DISSERTATION FOR THE DEGREE OF DOCTOR OF ENGINEERING

Implementing spectrum commons: Implications for Thailand

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Abstract

Spectrum is a natural and limited resource that needs to be managed both internationally and nationally because of the unique propagation characteristics of radio waves. Once transmitted, a radio signal propagates until its power is depleted. Furthermore, electromagnetic energy does not recognize borders between countries. Spectrum is administered internationally by the International Telecommunication Union (ITU). The Radio Regulations (RR) is an international treaty that provides international guidelines on spectrum management to keep interference manageable by allocating spectrum to services internationally. Spectrum assignment for the provision of rights to use frequency is carried out nationally by the National Regulatory Authority (NRA). Three typical approaches to spectrum assignment are command-and-control, market-based, and spectrum commons.

The purpose of this thesis is to study the implementation of spectrum commons in Thailand, including the consequences of spectrum commons allocation on the RR at WRC, the transformation of international regulation into national regulation for spectrum commons in Thailand, and the implementation of spectrum commons as national regulation in Thailand.

The results of this study illustrate 1) the development of spectrum commons allocation in the RR via the decision-making process at WRC, including WRC agenda setting and the study process for WRC-12 Agenda Items 1.19 and 1.22; 2) the transformation of international regulation for spectrum commons in terms of the definition of industrial, scientific, and medical (ISM) application, footnotes 5.138 and 5.150, frequency bands in the table of frequency allocation (TFA) into national regulation as the NBTC regulation, including the Thai TFA, footnotes, and frequency bands; and 3) the implementation of spectrum commons in Thailand, including the authorization of spectrum commons and the exemption of radiocommunication devices as unlicensed.

The study uses the institutional analysis and development (IAD) framework to understand the decision-making process at WRC via the WRC agenda setting and study process for WRC-12 Agenda Items 1.19 and 1.22. However, the IAD framework only provides a list of questions that should be considered, not the detailed content regarding the implementation of spectrum commons. Moreover, the study illustrates the transformation of international regulation into national regulation in terms of a world of actions: constitution-choice, collective-choice, and operational level. Furthermore, the IAD framework assists in understanding the bundles of rights to use frequency for spectrum commons.

To implement spectrum commons regulation, an understanding of the RR at international level helps in local implementation at national level. The timely transfer of international to national regulation provides opportunities to benefit from device innovation and technological advancement. Once economies of scale are achieved, the general public benefits from the reasonable price of devices. As it is not a manufacturing country of such devices, Thailand should follow spectrum commons regulation and prepare national regulation changes in order to gain the benefits of spectrum commons by relaxing regulatory restrictions as much as possible.

Keywords: Radio Regulations (RR), World Radiocommunication Conference (WRC), institutional analysis and development (IAD) framework, spectrum commons, spectrum management, spectrum allocation, spectrum assignment

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APPENDED PAPERS

This dissertation is based on work in the following papers

Paper I — Ard-paru, N. (2012a). *Information and coordination in international spectrum policy: Implications for Thailand*. Retrieved from http://www.lib.chalmers.se (ISBN 978-91-980300-3-7).

Paper II — Ard-paru, N. (2012b). *Managing spectrum commons in Thailand: Allocation and assignment challenges.* Retrieved from http://www.lib.chalmers.se (ISBN 978-91-980300-3-7).

Paper III — Ard-paru, N. (2010). *Spectrum assignment policy: Towards an evaluation of spectrum commons in Thailand.* (Licentiate thesis). Retrieved from http://www.lib.chalmers.se (ISSN 1654-9732).

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Table of Contents

Chapter 1 Introduction ... 1
1.1 Background ... 1
1.2 Motivation ... 8
1.3 Purpose and limitation ... 9
1.4 Research question ... 10
1.5 Originality and contributions ... 11
1.6 Structure of the study ... 12
Chapter 2 Theoretical framework ... 13
2.1 Selection of IAD framework ... 13
2.2 The IAD framework ... 17
2.3 Three worlds of action in spectrum management ... 25
2.4 Bundle of rights to use frequency ... 27
2.5 Summary ... 29
Chapter 3 Methodology ... 33
3.1 Data and data collection method ... 33
3.2 Data analysis ... 35
3.3 Approach ... 35
3.4 Summary ... 38
Chapter 4 Summary of appended paper ... 39
4.1 Paper I ... 39
4.2 Paper II ... 44
4.3 Paper III ... 49
4.4 Connection between papers ... 52
Chapter 5 Discussion of IAD relevance ... 55
5.1 IAD framework and its connectivity ... 55
5.2 The bottom-up initiatives ... 62
5.3 IAD framework and its hypothetical outcome ... 63

5.4 Summary and discussion 64

Chapter 6 Conclusion, implications for Thailand, and future research 69

6.1 Conclusion 69

6.2 Implication for Thailand 70

6.3 Future research 74

References 75

List of abbreviations 83

Annex - Bibliography of spectrum management 85

List of figures

Figure 1. Regions in Radio Regulations 2012 2

Figure 2. Options for spectrum assignment 6

Figure 3. Summary of research problem 9

Figure 4. Framework for an institutional analysis 19

Figure 5. A rules-in-use and the action situation 22

Figure 6. Level of analysis and outcomes 24

Figure 7. Summary of research problem (cf. Figure 3, Chapter 1) 55

List of tables

Table 1. Table of Frequency Allocation, 1 710-2 170 MHz 3

Table 2. Frequency allocation literature 8

Table 3. Theoretical framework summary 13

Table 4. IAD literature 14

Table 5. Categories of goods 19

Table 6. Level of analysis and stakeholders 26

Table 7. Bundle of rights associated with telecommunication stakeholders 27

Table 8. Rights to use frequency 29

Table 9. Methodology summary 33

Table 10. IAD independent and dependent variables 36

Table 11. IAD variable map, missing data, and observer activities 56

Table 12. Spectrum management activities with IAD levels of analysis and outcomes 58

Table 13. IAD independent and dependent variables (cf. Table 10, Chapter 3) 65

Chapter 1 Introduction

This study is about the implementation of spectrum commons in Thailand, including the consequences of spectrum commons allocation on the Radio Regulations (RR) at the World Radiocommunication Conference (WRC), the transformation of international regulation into national regulation for spectrum commons in Thailand, and the implementation of spectrum commons as national regulation in Thailand.

1.1 Background

Spectrum is a natural and limited resource that requires both an international and national approach because of its characteristics of propagation. Once transmitted, it propagates until the power runs out and it does not recognize borders between countries.

For spectrum to be administered internationally by the International Telecommunication Union (ITU), the international treaty, the RR, provides the guidelines on spectrum management to keep interference manageable through service allocation and allotment of spectrum with the relevant constraints.

ITU uses the RR as a tool to manage spectrum internationally. The ITU allocates spectrum to radiocommunication services with particular frequency bands. Radiocommunication services, in short, services, represent the purpose of frequency uses. There are more than 40 services currently in use in RR2012. The individual frequency bands are defined by the start and stop frequencies. The start and stop frequencies represent the allowable edges of the frequency to be used for specified services.

The RR is revised every three to four years via the World Radiocommunication Conference (WRC). The current RR is RR2012, which was revised by WRC-12. RR2012 defines usable frequency up to 3,000 GHz and divides the frequency use into services, including terrestrial and space services such as broadcasting, mobile, satellite, maritime, aeronautical, fixed, and earth exploration. All the services can share frequency bands, although sharing requires services to be designated as primary or secondary. The table of frequency allocation (TFA) contains both primary (printed in “capitals,” e.g., FIXED) and secondary (printed in “normal characters,” e.g., Mobile) services. Secondary services must not interfere with primary services and cannot claim protection from interference by primary service transmission and reception.[1]

The RR divides the world into three regions. Region 1 covers the European and African continents, Region 2 covers North America and South America, and Region 3 covers Asia and Australasia. The RR2012 regions are shown in Figure 1.[2]

A frequency allocated in one region can be used in others: re-use of frequency. For example, frequency band A is allocated to Region 3 but can be re-used in Region 1 or 2 for the same or different services.

[1] 5.23-5.32, Article 5, Radio Regulations
[2] Information obtained from 5.2-5.9, Article 5, Radio Regulations (2012)

Re-use of frequency has an indirect relationship with coverage area. A large coverage area has a low re-use of frequency, while a small coverage area has a high re-use of frequency. Spectrum re-use characteristics vary by service, frequency, location, time, and transmitting power.

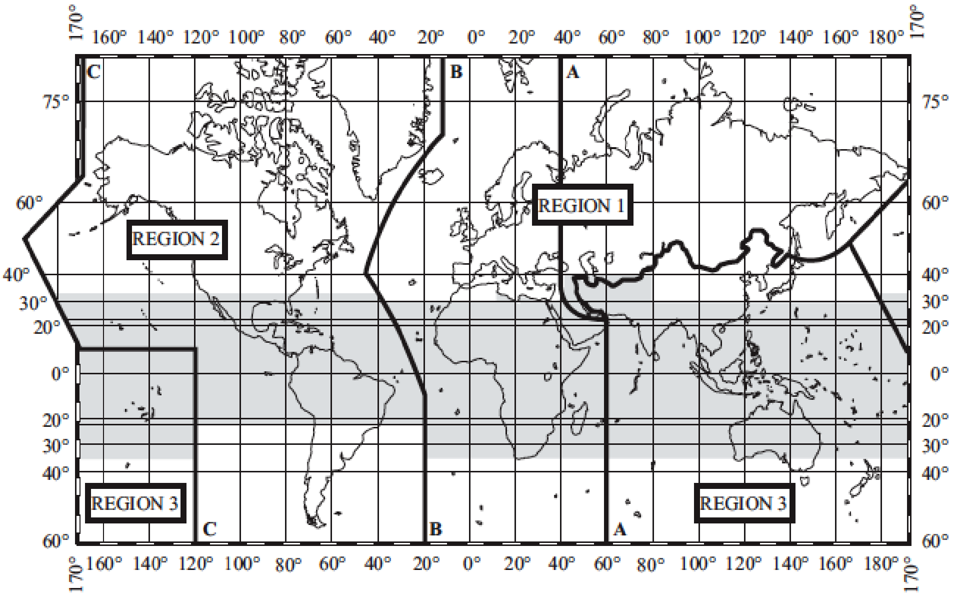

Figure 1. Regions in Radio Regulations 2012

Frequencies are further divided into bands. Their characteristics have an inverse relationship to wavelengths. A wavelength equals its speed of propagation (normally that of light) divided by its frequency ($\lambda = c/f$). Each frequency band has its own propagation characteristics, such as sea-surface communication, stratospheric scattering, and long-range communication.

Table 1 shows the TFA for the 1 710-2 170 MHz band, the global as well as the regional allocations captured from RR2012. The purpose of the TFA is to provide an overview of the use of frequency bands by service with the relevant regulations, including services, frequency bands, and footnotes. The functions of the TFA are similar to a map that provides an overview of the RR.

Regions and frequency bands

Within the TFA, the main components are regions, frequency bands, services, and footnotes. When a frequency allocation has the same frequency band (the same start and stop frequencies) for three regions, it is called a global or worldwide allocation. For example, Table 1 shows the frequency band 1 710-1 930 MHz, which is a global allocation. However, the frequency band 1 930-1 970 MHz is allocated differently to Regions 1, 2, and 3. These three allocations are regional allocations.

Services

Within each frequency band, services are allocated as either primary or secondary. For example, in the 1 970-1 980 MHz band, the fixed and mobile services are allocated as primary services.

Table 1. Table of Frequency Allocation, 1 710-2 170 MHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
1 710-1 930	FIXED MOBILE 5.384A 5.388A 5.388B 5.149 5.341 5.385 5.386 5.387 5.388	
1 930-1 970 FIXED MOBILE 5.388A 5.388B 5.388	**1 930-1 970** FIXED MOBILE 5.388A 5.388B Mobile-satellite (Earth-to-space) 5.388	**1 930-1 970** FIXED MOBILE 5.388A 5.388B 5.388
1 970-1 980	FIXED MOBILE 5.388A 5.388B 5.388	
1 980-2 010	FIXED MOBILE MOBILE-SATELLITE (Earth-to-space) 5.351A 5.388 5.389A 5.389B 5.389F	
2 010-2 025 FIXED MOBILE 5.388A 5.388B 5.388	**2 010-2 025** FIXED MOBILE MOBILE-SATELLITE (Earth-to-space) 5.388 5.389C 5.389E	**2 010-2 025** FIXED MOBILE 5.388A 5.388B 5.388
2 025-2 110	SPACE OPERATION (Earth-to-space) (space-to-space) EARTH EXPLORATION-SATELLITE (Earth-to-space) (space-to-space) FIXED MOBILE 5.391 SPACE RESEARCH (Earth-to-space) (space-to-space) 5.392	
2 110-2 120	FIXED MOBILE 5.388A 5.388B SPACE RESEARCH (deep space) (Earth-to-space) 5.388	
2 120-2 160 FIXED MOBILE 5.388A 5.388B 5.388	**2 120-2 160** FIXED MOBILE 5.388A 5.388B Mobile-satellite (space-to-Earth) 5.388	**2 120-2 160** FIXED MOBILE 5.388A 5.388B 5.388
2 160-2 170 FIXED MOBILE 5.388A 5.388B 5.388	**2 160-2 170** FIXED MOBILE MOBILE-SATELLITE (space-to-Earth) 5.388 5.389C 5.389E	**2 160-2 170** FIXED MOBILE 5.388A 5.388B 5.388

For the 2 120-2 160 MHz band in Regions 1 and 3, there are fixed and mobile services on a primary basis.

For the 2 120-2 160 MHz band in Region 2, there are fixed and mobile services on a primary basis and mobile-satellite (space-to-Earth) services on a secondary basis.

Footnotes

ITU Member States generally use footnotes to make their reservation for applying the provisions of the RR. The footnotes contained in the TFA can be used in several situations, including for the status of services (on a primary or secondary basis), additional allocation, alternative allocation, and miscellaneous provisions.

Apart from “capitals” and “normal characters” in the TFA, footnotes can indicate the priority of services. For example, footnote 5.385 indicates that the 1 718.8-1 722.2 MHz band is allocated for radio astronomy service on a secondary basis for spectral line observations.[3]

The additional allocation footnote has the same service as indicated in the TFA, but in an area smaller than the region. For instance, footnote 5.386 is allocated to the 1 750-1 850 band for space operation (Earth-to-space) and space research (Earth-to-space) services in Region 2, in Australia, Guam, India, Indonesia, and Japan on a primary basis.[4]

The alternative allocation footnote replaces the service indicated in the TFA, but in an area smaller than the region. For example, footnote 5.315 is allocated to the 790-838 MHz band for broadcasting service on a primary basis in Greece, Italy, and Tunisia.[5]

The miscellaneous provision footnote represents specific operational constraints, such as footnote 5.388 in the 1 885-2 025 MHz and 2 110-2 200 MHz bands, which provides International Mobile Telecommunications (IMT) on condition that these bands do not preclude use by other services to which they are allocated.[6]

Footnotes can also be used for a particular service, in which case they are located next to the service, or the entire frequency band, when they are placed at the bottom of the band, as indicated in the TFA. The band footnote is applied to all services allocated in this band. For example, in the 2 025-2 110 MHz band, the use of mobile service has the specific footnote 5.391. The band footnote is 5.392 and it applies to all services in this band, including space operation, Earth exploration-satellite, fixed, mobile, and space research services.

In Regions 1 and 3, the 2 120-2 160 MHz band has two specific footnotes for mobile service: 5.388A and 5.388B. The fixed service is allocated on a primary basis and does not have a specific footnote. Footnote 5.388 is applied to both fixed and mobile services as a band footnote.

In Region 2, the 2 120-2 160 MHz band has two specific footnotes for mobile service 5.388A and 5.388B. The fixed service is allocated on a primary basis but the mobile-satellite (space-

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[3] 5.385 *Additional allocation:* the band 1 718.8-1 722.2 MHz is also allocated to the radio astronomy service on a secondary basis for spectral line observations. (WRC-2000)

[4] 5.386 *Additional allocation:* the band 1 750-1 850 MHz is also allocated to the space operation (Earth-to-space) and space research (Earth-to-space) services in Region 2, in Australia, Guam, India, Indonesia and Japan on a primary basis, subject to agreement obtained under No. 9.21, having particular regard to troposcatter systems. (WRC-03)

[5] 5.315 *Alternative allocation*: in Greece, Italy and Tunisia, the band 790-838 MHz is allocated to the broadcasting service on a primary basis. (WRC-2000)

[6] 5.388 The bands 1 885-2 025 MHz and 2 110-2 200 MHz are intended for use, on a worldwide basis, by administrations wishing to implement International Mobile Telecommunications (IMT). Such use does not preclude the use of these bands by other services to which they are allocated. The bands should be made available for IMT in accordance with Resolution 212 (Rev.WRC-07) (see also Resolution 223 (Rev.WRC-07)[*]). (WRC-12)

to-Earth) service is allocated on a secondary basis. Footnote 5.388 is applied to fixed, mobile, and mobile-satellite (space-to-Earth) services as a band footnote.

The TFA represents the frequency allocation by WRC to allocate radiocommunication services by frequency bands. The services represent the purpose of frequency use that is defined in Article 1: Terms and Definitions.

Allocation, allotment, and assignment

Spectrum allocation means giving specific frequency bands to radiocommunication services, i.e., for the purpose of frequency use, with both regional and global scope.

The allocation is presented in the TFA, which shows the services that are allowed to be used by frequency band. The TFA is divided into three regions (Regions 1-3). The services can be either primary or secondary. In the TFA, primary services are given in "capitals" and secondary services in "normal characters." The reason for this division is to avoid harmful interference, with primary services always taking priority over secondary services by way of station (network and device) construction. This allocation is by WRC.

Spectrum allotment means designating specific frequency bands to at least one ITU Member State for a specified service (terrestrial or space). For example, Appendix 25 of the RR provides the allotment plan for coast radiotelephone stations in maritime mobile services between 4 000 kHz and 27 500 kHz (e.g., the 4 358.4 kHz band is allotted to South Africa, Australia, Chile, and Cuba). Appendix 30, Article 10 provides an allotment plan for broadcasting-satellite services in the 12.2-12.7 GHz band in Region 2, such as Beam SPMFRAN3 (channels 1, 5, 9, 13, and 17 are allotted to Germany, Denmark, Iceland, Norway, and Sweden).

Spectrum assignment means giving a specific frequency band to users: providers, operators, or end-users. For example, the 897.5-915 and 942.5-960 MHz bands are assigned to Operator A for mobile services. The use of radiocommunication devices is managed at national level by the national regulatory authority (NRA). The NRA assigns the frequency to the assignee, in other words, the NRA provides the right to use frequency to frequency users. This is called spectrum assignment. Typical spectrum assignment methods are command-and-control, market-based, and spectrum commons.

There are two principal approaches to licensing: command-and-control and market-based. These approaches grant the exclusive right to use frequency to licensees. Spectrum commons, however, is unlicensed. Brief details of each approach are described in Figure 2.

Property rights (maximize value)	Command and control (conserve state control)	Licence-free (avoid interference)
-Market knows best -Auctions/secondary trading -High flexibility -Pro big business	-Government knows best -First come, first served -Beauty contest -Low flexibility -Pro-government (and its friends)	-Nobody knows best -No legal protection -Technical protection -High flexibility -Pro-innovation -Optimistics

Source: Geiss (2004)

Figure 2. Options for spectrum assignment

As regards the command-and-control approach, the NRA assigns the frequency to users on a first-come, first-served basis, imposing the conditions for the use of the frequency. This process raises the issue of transparency. The command-and-control approach is an administrative approach in which the competent authority, usually the government, uses its power of discretion to grant an exclusive right of use of some frequency bands to assignees, with conditions. These conditions include power limitation, antenna specification, and other technical requirements in terms of radiocommunication equipment, mainly for the purpose of avoiding harmful interference. The flexibility of the use of frequency under this approach is limited. All frequency operations, including the location, working frequency, bandwidth, output power, antenna gain, modulation technique, and technology, are decided by the NRA. When users want to adopt new technology, they have to go through an administrative process to be approved before implementation.

As for the market-based method, the NRA uses a market mechanism to assign the frequency, such as a spectrum auction or secondary trading. This approach creates more flexibility for regulators and operators to manage the spectrum and makes the process more transparent than a command-and-control approach. Although the market-based approach can maximize spectrum efficiency in some cases, the outcome may be competition between strong financial parties to buy most of the available spectrum on the market. As a result, the market may become monopolized if the regulator does not have proper control or “spectrum caps” (limits on obtaining spectrum).

On the other hand, the non-exclusive right to use frequency unlicensed can be treated as spectrum commons. In this situation, no one has an exclusive right to use frequency. Everyone can use the same frequency under some constraints. Nevertheless, services under spectrum commons cannot claim protection, because spectrum commons is open to anyone with any application, under the given limitations.

Spectrum commons is widely used and part of day-to-day activities, ranging from garage openers, remote controls, toys, closed-circuit television (CCTV), navigation systems (land, air, and sea), earphones, cordless telephones, and card readers, to Internet connection (Wi-Fi) in smart phones. The main applications for spectrum commons are low-power and short-range devices (SRD). Most SRDs use the frequency in the industrial, scientific, and medical (ISM) application band (RR 5.138 and 5.150). The rapid development of technology renders the exclusive use of frequency unnecessary because smart devices can search, change, and occupy frequency whenever it becomes available. The main technologies for spectrum commons are software-defined radio (SDR) and cognitive radio system (CRS), which have been discussed at WRC-12, under Agenda Items 1.19 and 1.22, providing non-exclusive use of frequency. Spectrum commons increases spectrum efficiency and flexibility of use.

Spectrum commons has developed both allocation at WRC in the form of the RR and assignment via national regulation. It is interesting to understand the transformation of spectrum commons from allocation under international regulation into assignment under national regulation.

Spectrum commons regulations in the form of the RR, including the allocation in footnotes 5.138 and 5.150, the definition of the ISM application, and relevant frequency bands, have been transformed into the national regulation, in this case the TFA of Thailand. Spectrum commons has been developed alongside spectrum assignment development, including the transition from command-and-control to market-based economies; in other words, from authorization to licensing schemes. Spectrum commons has also developed alongside the allowed use of radiocommunication devices in Thailand without relevant licenses, since 2004. In line with the Thai NRA, the authority also changed over time from a government agency (the Post and Telegraph Department, PTD) to an independent agency (the National Broadcasting and Telecommunications Commission, NBTC).

At WRC, the spectrum commons regulations have been allocated through footnotes 5.138 and 5.150. An understanding of the WRC processes for frequency allocation for spectrum commons and the transformation of international regulation into national regulation are assisting Thailand with the proper implementation of the regulation.

Early research

There is much literature on spectrum assignment, especially spectrum auction and command-and-control, including Ostrom (2003), Faulhaber and Farber (2003), Cave, Doyle, and Webb (2007), Caicedo and Weiss (2011), Freyens, Loney, and Poole (2010), Madden and Ahmad (2013), and Madden and Morey (2013). There are few studies on spectrum allocation at WRC, however, especially the WRC processes (WRC agenda setting and study process). Literature on the transformation from international into national regulation is also rare. Table 2 presents the relevant literature and a summary regarding WRC.

Most of the literature is from before 1992 (the current WRC process is after the Additional Plenipotentiary Conference of 1992), except the last two from 2003 and 2011. All the literature in Table 2 deals with the specific issues at WRC. Most of the literature is relevant to national and international cooperation in terms of the implementation or consequences of the WRC decision. There are two pieces of literature regarding the transformation from international into national regulation; however, these are from before 1992.

Moreover, the study provides the bibliography of spectrum management in the annex, including the handbook and textbook on spectrum management, spectrum allocation, spectrum assignment, market-based or spectrum auction, and spectrum commons.

Table 2. Frequency allocation literature

Literature	Relevance to frequency allocation at WRC	Scope
Gould (1970)	US preparatory work for space service and radio astronomy for further frequency allocation at the World Administrative Radio Conference (WARC)	National and international
Tanaka (1979)	WARC-79 decision impact on Japan, Asia, and Oceania and problem regarding high-frequency broadcasting and space service	National
Katzenstein, Moore, and Kimball (1979)	WARC-79 decision impact on the TFA above 40 GHz with challenges to the frequency manager	National
Probst and Bradley (1979)	Revision of the TFA by WARC-79 with a suggestion by the US TFA	Transformation
Covitt and Neuman (1979)	US frequency sharing between radio navigation services and the Air Traffic Control Radar Beacon System	National
Fisher (1984)	UK frequency sharing between land mobile and broadcasting service in TV Band III as a result of WARC-79	National
Gould and Kelleher (1985)	Frequency sharing between broadcasting-satellite and other services	National and international
Blanc (1986)	New frequency allocation for land mobile-satellite service in Europe at WARC-MOB 87 (for mobile service)	National and international
Willmets (1986)	New frequency allocation for land mobile-satellite service in the band 1.5/1.6 GHz in Europe at WARC-MOB 87	National and international
Walton (1987)	Frequency usage for mobile services in fuel and power industries	National
Goddard (1988)	National and regional cooperation in Western Europe and the UK as a consequence of WARC	Transformation
Tycz (1990)	The impact of WARC for geo-stationary satellite orbit and planning of space service (ORB-88) to US fixed satellite service and orbit assignment by FCC	National
Fournier (2003)	New allocation for satellite radio navigation or new services in the band 108-118/MHz for WRC-03 for aeronautical communications	National and international
Lyall (2011)	ITU structure development	International

1.2 Motivation

The motivation for this study comes from the implementation of spectrum commons in Thailand. The study combines three previous studies: I) Information and coordination in international spectrum policy: Implications for Thailand, II) Managing spectrum commons in Thailand: Allocation and assignment challenges, and III) Spectrum assignment policy: Towards an evaluation of spectrum commons in Thailand.

Figure 3 gives a summary of the research problem with the connection between Papers I, II, and III. [7]

The development of the spectrum commons allocation applies the RR development from Paper I providing an overview of the WRC processes (WRC agenda setting and study process) and the RR development in terms of frequency band development. Paper I uses spectrum commons in WRC-12 Agenda Items 1.19 and 1.22 with regard to SDR, CRS, and SRD as the object of study.

[7] The bottom-up initiatives from national level are a feedback relationship. They represent the national interest to review or revise the international regulations (the RR). The national request for RR revision is part of the WRC preparatory process. The ITU Member States submit their contribution to WRC corresponding to defined WRC agenda items, i.e., point of RR revisions. When the national request does not comply with any existing WRC agenda items, such a request will be included in the WRC agenda-setting process either for the next or future WRC agenda items (see Chapter 4 for details).

Paper II applies the WRC process to explore the ITU archive for ISM application in terms of the definition and frequency allocation in the development of footnotes 5.138 and 5.150. The spectrum commons allocation development illustrates the international regulation for spectrum commons.

Paper I	Paper II	Paper III
Spectrum commons		Spectrum commons
Allocation At the WRC as RR revision	**Transformation**	Assignment Bundle of rights to use frequency
International regulations		National regulations

Figure 3. Summary of research problem

Paper II also transforms spectrum allocation into assignment for spectrum commons in Thailand by demonstrating how to implement international regulation into national regulation for spectrum commons in Thailand. The study applies the institutional analysis and development (IAD) framework to illustrate the interaction and relationship between levels of analysis and outcome: from the RR to the NBTC regulations. Moreover, the study highlights the challenges of spectrum commons (advantages and disadvantages of spectrum commons from Paper III) and IAD application for spectrum management.

Spectrum commons in Thailand is captured by the spectrum assignment development since 1875 in Paper III. This paper presents the history of spectrum assignment development in Thailand in terms of national regulation development with particular attention to spectrum commons.

1.3 Purpose and limitation

The purpose of this study is to illustrate the implementation of spectrum commons regulation in Thailand, including the allocation of spectrum commons in the RR as the international regulation (Paper I), transformation of international regulation into national regulation for spectrum commons in Thailand (Paper II), and the implementation of spectrum commons as national regulation in Thailand (Paper III).

The study limits its analysis of international spectrum policy to WRC-12. However, there are more than 30 agenda items at WRC-12. In order to understand the WRC process, the study focuses on spectrum commons in WRC-12 Agenda Items 1.19 and 1.22 using SDR, CRS, and SRD as objects of study. These two agenda items represent the WRC process, including the

WRC agenda setting and study process and the national and regional preparatory process for Thailand.

In order to demonstrate the transformation of international into national regulation, Thailand and spectrum commons regulation is selected as the object of study for the transformation of the spectrum commons regulation.

To illustrate the implementation of spectrum commons at national level, the development of spectrum assignment in Thailand is selected.

1.4 Research question

The overarching research question for this study is "**How should spectrum commons be implemented in Thailand?**". Connecting the three research questions from the three papers illustrates the implementation of spectrum commons in Thailand, starting with the allocation of spectrum commons via international regulation in the RR at WRC, transforming international into national regulation in Thailand, and concluding with the implementation of spectrum commons as national regulation in Thailand.

Paper I

The purpose of the study is to understand the information needs and coordination of international spectrum policy setting, including the processes and archives relevant to the ITU (WRC proceedings and RR versions). The study also proposes a possible way to alleviate the missing information in this policy setting.

In order to study international spectrum policy, the study focuses on WRC-12 Agenda Items 1.19 and 1.22 regarding SDR, CRS, and SRD, representing spectrum commons as an object of study in order to demonstrate the whole WRC process at the ITU.

The main research question of the study is "**How is international spectrum policy developed and affected by the lack of detailed documentation?**". In order to respond to the main research question, the study has four sub-research questions as follows:

1. How is international spectrum policy set in terms of ITU structure, WRC, and the RR, and how did they develop?
2. What information would be more useful for making decisions?
3. How does the missing information affect international spectrum policy?
4. How can the existing ITU archives be improved or added to?

Paper II

The purpose of this study is to demonstrate the relationship between international and national regulations in terms of how to implement spectrum commons in Thailand. The study also illustrates the development of frequency allocation for spectrum commons at international level and the transfer of the international regulation for spectrum commons into Thai national regulation.

To fulfill the purpose of the study, the main research question is "**How is the Radio Regulations transformed into National Broadcasting and Telecommunications Commission regulation for spectrum commons in Thailand?**". In order to answer this research question, the five sub-research questions are as follows:

1. What are the main applications and technologies for spectrum commons?
2. What are the spectrum allocations for spectrum commons and ISM applications, and how did they develop?
3. What is spectrum assignment, especially spectrum commons, in Thailand, and how did it develop?
4. How should spectrum commons regulation be transformed from the RR into the national NBTC regulation? What are the challenges?
5. How is the IAD framework relevant to spectrum management?

Paper III

The purpose of this licentiate thesis is to examine the spectrum commons approach to spectrum assignment. The thesis focuses on the case of Thailand.

The main research question is "**What are the consequences of using spectrum commons for frequency assignment in Thailand?**".

To approach the main research question – What are the consequences of using spectrum commons for spectrum assignment in Thailand? – this thesis addresses five sub-research questions:

1. What is a suitable framework for analyzing different types of spectrum commons?

2. What type of spectrum commons has been used in Thailand?

3. What are the advantages and disadvantages of spectrum commons in general?

4. How can the benefits and costs of spectrum commons be measured?

5. What are the implications of implementing spectrum commons in Thailand?

1.5 Originality and contributions

This study contributes a comprehensive view of the process from spectrum allocation to spectrum assignment, with the specific case study of spectrum commons and Thailand, in order to demonstrate how international regulation is transformed into national regulation in the current WRC process. One achievement of the study is the application of a multi-layer framework to explore spectrum commons issues at national and international level. Nobody has sought to integrate analyses of spectrum commons issues at these three interrelated levels.

This approach deepens our understanding of policy options for spectrum commons and their implementation, and it offers new insights into spectrum management in general and spectrum commons in particular.

The study contributes the whole process of implementing spectrum commons, from frequency allocation at WRC to national regulation in Thailand, including the WRC and RR development, especially the frequency band development, IAD framework application in the WRC context and spectrum management activities, transformation of international into national regulation, and history of spectrum assignment development in Thailand and the bundle of rights to use frequency.

1.6 Structure of the study

This study consists of six chapters, starting with an introduction in Chapter 1, which includes the background and research questions. Chapter 2 provides the theoretical framework for this study. Chapter 3 deals with the methodology. The summary of appended papers is provided in Chapter 4. The discussion of IAD relevance is presented in Chapter 5, and, finally, the conclusion, implications for Thailand, and future research of the study are presented in Chapter 6.

Chapter 2 Theoretical framework

This chapter provides the theoretical framework for this study, i.e., the IAD framework, three worlds of action in spectrum management, and the bundle of rights to use frequency. The justification for using the IAD framework is also presented. The chapter uses some parts of Chapter 2 of Ard-paru (2012a), an updated version of Ard-paru (2011), and Chapter 2 of Ard-paru (2010).

Table 3 gives a summary of the theoretical framework that has been used in Papers I, II, and III.

Table 3. Theoretical framework summary

Framework	Paper I	Paper II	Paper III
Kiser and Ostrom (1982)			x
Ostrom (2005a, 2005b, 2007 and 2011)	x	x	

Paper III used the old version of the IAD framework, originally developed in 1982. This framework has been developed over time by Ostrom and her colleagues. The current version of 2011 has been used in Papers I and II. The details of the framework are discussed below.

2.1 Selection of IAD framework

The IAD framework is part of the new institutional economics (NIE) that have been developed through economic thinking. Economic thinking ranges from classical to institutional: from commodities and individuals to transactions and working rules for collective actions. Its classical theories are based on the relationship of man to nature, while institutional theories are based on the relationship of man to man (Commons, 1931).

Commons (1931) also provides the definition of "institution" as collective actions in the control, liberation, and expansion of individual actions. Individual actions are transactions instead of either individual behavior or the exchange of commodities (Commons, 1931, pp. 651-652). The transaction serves as the smallest unit of activity with its participants. The major activities are bargaining, managerial, and rationing transactions (Commons, 1931).

However, the early development of institutional economics or old institutional economics (OIE) provides imaginative insights, perceptive description, and quantitative measurement, not a theory (North, 1992, p. 3). NIE builds on the assumption of scarcity and competition and attempts to incorporate an institution into economics. In the real world, human beings have incomplete information and a limited mental capacity to process information by imposing constraints on interaction with structural exchange. The information is costly and asymmetrical to exchange between parties. Institutions are formed to reduce uncertainty in human exchange (North, 1992).

Moreover, North (1992) provides the definition of institutions as society's rules of the game or humanly devised constraints structuring human interaction. Furthermore, he defines the organization as the player or groups of individuals bound by a common purpose to achieve objectives.

NIE has been developed in different areas, such as property rights economics, public choice, and the theory of the firm. The IAD framework has been developed by Ostrom and her colleagues at the Workshop in Political Theory and Policy Analysis in order to understand the institution, especially common-pool resources, which are part of property rights economics. The IAD framework has been developed since 1982, providing the world of actions with a systematic approach to the decision-making process.

The IAD framework provides a systematic approach to the decision-making process in terms of exogenous and endogenous variables as independent variables. The exogenous variables are biophysical conditions, attributes of community, and rules-in-use, representing the external parameters that influence the decision situation. Endogenous variables represent the connection between the action situation and the rules-in-use, and they are represented by seven rules: boundary, position, choice, information, payoff, aggregation, and scope. The dependent variable is the outcome of the decision situation.

Moreover, the interconnection between the world of actions or level of analysis and outcomes – operational, collective-choice, constitutional, and metaconstitutional situations – is presented in the interaction between level and feedback as influencing decision-making at the lower level. The four levels of analysis and outcome by Ostrom are similar to the four levels of the economics of institutions by Williamson (2000). However, Williamson does not provide the detail of the action situation at each level.

The IAD framework enhances the understanding of the decision-making process in several fields, especially agriculture, such as fisheries, forestry, farming, water, and river basins. Table 4 shows some of the IAD literature on applications in the fields. Most of it concentrates on common-pool resources, especially in the field of fisheries. However, there is no literature relevant to politicians bargaining and heads of state negotiating in Table 4.

Table 4. IAD literature

Literature	Introduction to the use of the IAD framework	Action situation
Imperial (1999a)	Examining the structure and performance of the institutional arrangement used to implement the Salt Ponds, a special area management (SAM) plan, Rhode Island	4-ecosystem-based management
Imperial (1999b)	Understanding the institutional arrangement used to implement an ecosystem-based management program	4-natural resource management
Piipponen (1999)	Examining the institutional setting for the forest sector in the Republic of Karelia, Russia	4-forest
Carlsson (2000)	Incorporating the policy network approach to an analytical framework, e.g., the IAD framework	Other-analytical framework
Leach and Pelkey (2001)	Reviewing the conflict resolution in watershed partnerships on collaborative resource management	4-water
Sekher (2001)	Analyzing the process of organized participatory resource management in community forestry practices in India	4-forest
Sobeck (2003)	Examining an early stage of policy development emphasizing group membership and participation	Other-collaboration
Flinkman (2004)	Evaluating the effectiveness and credibility of exchanges in the wood construction supply chain in Dar es Salaam and Mwanza	4-wood
Rudd (2004)	Facilitating critical examinations of important cross-cutting issues by a modified IAD framework providing a platform for ecosystem-based fisheries management policy, experiment, design, and monitoring	4-fishery

Literature	Introduction to the use of the IAD framework	Action situation
Imperial and Yandle (2005)	Examining competing institutional arrangements used to manage fisheries: bureaucracy, markets, community, and co-management, to understand critical issues related to institutional analysis	4-fishery
Koontz (2005)	Examining collective decision-making related to natural resources for farmland preservation planning in Ohio, USA.	4-farmland
Hill and Hupe (2006)	Illustrating how the IAD framework assists in highlighting the links between UK health and education policy analysis	2-health
Blackstock and Carter (2007)	Providing sufficient incentives to make the transition from traditional science to sustainability science for the implementation of the Water Framework Directive (WFD)	4-water
Clement and Amezaga (2008)	Examining land use changes in Vietnam that national policy interfered with, with local factors leading to a complex course of decision-making and action	4-forest, land
Klass (2008)	Identifying the institutional roots of the crisis in Côte d'lvoire, and suggestions for resolution	Other
Yandle (2008)	Examining the development, strengths, and weaknesses of New Zealand's fisheries co-management, commercial stakeholder organizations (CSOs)	4-fishery
Andersson (2009)	Analyzing the contextual factors that affect stakeholders' motivation to engage in collaborative learning activities for the Swedish International Development Cooperation Agency (SIDA)	Other-collaboration
Coleman and Steed (2009)	Examining theoretical determinants of monitoring and sanctioning at local community level and external government agents from the International Forestry Resources and Institutions (IFRI) research program	4-forest
Dong et al. (2009)	Examining the effectiveness of institutional development at local and national levels in mitigating the problems facing sustainable rangeland management in Nepal	4-rangelands
Hardy and Koontz (2009)	Illuminating how the operational rules produced by different types of partnerships result in outputs that impact three watershed management systems	4-water
Laing et al. (2009)	Understanding partnerships between protected area agencies and the tourism industry	Other-partnership success
Martinez (2009)	Identifying and examining the structure and relationships between the different stakeholders involved in tobacco control policies in health care organizations	2-tobacco policy in hospital
Schlager and Heikkila (2009)	Identifying the conditions under which interstate river compacts are likely to address conflict and solutions	4-water
Akinola (2010)	Providing polycentric planning, self-governance, and adaptive development strategies to resolve the socio-economic and political crisis in the Niger Delta	2-public sphere
Hardy and Koontz (2010)	Evaluating the transaction costs and environmental, social, and policy outputs of two watersheds: urban and rural	4-water
Mokhtar, Torman, and Hossain (2010); Mokhtar et al. (2011); and Toriman et al. (2012)	Identifying institutional challenges associated with Integrated River Basin Management (IRBM) implementation in Langat River Basin, Malaysia	4-water
Ostrom and Cox (2010)	Enabling a finer understanding of biodiversity loss, climate change, pollution, and natural resource degradation systems, and providing a basis for comparisons for policy prescriptions	2-environment
Asquer (2011)	Analyzing the liberalization and regulatory reforms of network industries in Italy	Other-regulatory
Beitl (2011)	Examining the relationship between collective action and environment to sustainable mangrove fisheries in coastal Ecuador	4-fishery
Bushouse (2011)	Identifying six governance structures in the commercial and non-profit sectors for childcare services	1-club goods

Literature	Introduction to the use of the IAD framework	Action situation
Heikkila, Schlager, and Davis (2011)	Identifying the 14 interstate river basin systems and applying common-pool resource (CPR) design principles	4-water CPR management
Henry and Diet (2011)	Understanding the trust in variables-belief system and networks-influence trust	Other-trust
Li and Li (2011)	Analyzing multifunctional agriculture (MFA) in Chongqing, China	4-agriculture
McGinnis (2011)	Providing a systematic approach to elaborating on a complex policy network with overlapping groups of stakeholders influencing the rules of interaction in Maine lobster fisheries, international development assistance, and faith-based organizations for USA welfare policy	4-fishery Other-coordination, welfare
Mehring et al. (2011)	Structuring forest management in Central Sulawesi, Indonesia, by considered rules, participants, and conservation outcomes	4-forest
Oakerson and Parks (2011)	Explaining local variations in public organizations as a function of the geo-physical diversity of localities in Yellowstone and Adirondack Park	4-forest
Thiele et al. (2011)	Understanding the multi-stakeholder platforms for potato-based value chains in Bolivia, Peru, and Ecuador	4-farmers
Wasike, Kahi, and Peters (2011)	Identifying the missing stakeholder in action situations for animal-recording activities	4-animal farm
Chadsey, Trainer, and Leschine (2012)	Identifying key success factors of the Olympic Region Harmful Algal Bloom (ORHAB) partnership with harmful algal blooms (HABs)	4-marine
Fidelman et al. (2012)	Highlighting the diverse contextual factors that challenge the governance of large-scale marine commons, using the Coral Triangle Initiative as an example	4, (2)-marine
Ghorbani, Dignum, and Dijkema (2012)	Modeling agent-based systems based on the IAD framework (MAID: Modeling Agent-based systems based on Institutional Analysis)	Other-modeling
Mulazzani et al. (2012)	Describing the anchovy fisheries of Croatia and Italy, and France and Spain	4-fishery
Reiners (2012)	Examining how and why on-the-ground decisions and outcomes differ	4-wildfires/forest
Ho and Gao (2013)	Analyzing collective action problems in building management	4-housing

Note: 1: Buyers and sellers exchanging goods (services) in a market
2: Legislators making legislative decisions about future laws
3: Powerful politicians bargaining over the allocation of public support
4: Users of a common-pool resource withdrawing resource units (such as fish, water, or timber)
5: Heads of state negotiating an international treaty
Other: excluded from five categories

Source: Ard-paru (2012a), Table 3

WRC as an action situation represents the negotiation of RR revisions as an international treaty. Ostrom (2005b) pointed out that this action situation can be described and analyzed using a common set of variables, that is, the variables of an action situation within the IAD framework. However, Ostrom did not provide the IAD application to the negotiation of an international treaty.

The author is familiar with the IAD framework from the previous work to understand the bundle of rights for frequency use on frequency assignment approaches: command-and-control, market-based, and spectrum commons (Ard-paru, 2010). The element of the IAD framework helps in understanding the different bundles of rights for frequency use in each frequency assignment approach in operational and collective-choice situations.

It is a challenge for the author to apply the IAD framework to a constitutional situation in which the regulations or rules for the collective-choice and operational situations are revised. In the field of spectrum management, WRC is the forum for international negotiations on RR revisions as the action situation at a constitutional situation. At WRC, the dynamic situation of international negotiations between Member States can be analyzed and described systematically by the element of the IAD framework. Discussions at WRC contain the rationale of the RR revisions that is missing from the ITU archives. The IAD framework therefore assists with identifying the limitations of the ITU archives and observations from meetings by its variables. The ITU archives enable responses to some of the IAD variables, including physical condition, boundary, position, scope rules, and potential outcome. The participant observations can respond to all IAD variables, however, it can provide only for the current situation. This applicability of the IAD framework to WRC as the forum for international negotiation is the original work of the author.

To conclude, the study selects the IAD framework because it has the ability to systematize the action situation and explain the dynamic situation of the decision-making process at WRC via international negotiations. This study also contributes to the first application of the IAD framework in the context of WRC international negotiations or an action situation. Moreover, the IAD framework helps in understanding the transformation of international into national regulation for spectrum commons in Thailand and the bundle of rights to use frequency for different frequency assignment approaches.

2.2 The IAD framework

Elinor Ostrom, among others, developed the IAD framework. The details of the IAD framework are discussed below.

The IAD framework has its roots in classic political economy, neoclassical microeconomic theory, institutional economics, public choice theory, transaction-cost economics, and non-cooperative game theory (Ostrom, Gardner, & Walker, 1994, p. 25). The IAD framework orients the analyst to ask particular questions. The questions generated by the IAD framework are the most important contributions. These questions are used to diagnose, explain, and prescribe action situations during the decision-making processes (Ostrom et al., 1994).

The IAD framework was originally developed by Kiser and Ostrom (1982) and provides three worlds of action: operational, collective choice, and constitutional choice levels. Kiser and Ostrom (1982) provide a metatheoretical framework to explain the relationships between institutional arrangements and the individual in terms of the transformation of rules into individual behavior. Institutional arrangements are rules used by individuals to determine who and what is included in decision situations, how information is structured, what actions can be taken and in what sequence, and how individual actions will be aggregated into a collective decision (Kiser & Ostrom, 1982, p. 179). Field (1992) has a similar level of analysis but with different names, i.e., three economic institutions: operational, institutional, and constitutional levels.

In other words, the IAD framework explains phenomena attributed to the aggregation of individual actions that decision makers have decided to take or strategies (plans of action) based on situations and the individual. The situation depends on rules, events, and the community. This framework also captures the dynamic situation through feedback from the phenomena that influence the community, situation, and individuals. Here is a brief explanation of the independent and dependent variables.

The inputs to the phenomena are the independent variables, including biophysical conditions, attributes of community, rules-in-use, action situations interaction, and evaluative criteria. The output of the phenomena is the dependent variables, i.e., outcomes.

When expanding the action situation with rules-in-use, the inputs to the action situation can be divided into exogenous and endogenous variables as the independent variables. The exogenous variables are biophysical conditions, attributes of community and rules-in-use. The endogenous variables are represented by boundary, position, choice, information, payoff, aggregation, and scope rules. The dependent variable is the potential outcomes.

According to Kiser and Ostrom (1982), each world of action has five working parts in an institutional structure: the decision-maker or individual, the community, the event (or goods and services), the institutional arrangement, and the decision situation. The results of the institutional structure are individual actions or strategies, and the aggregation of individual actions.

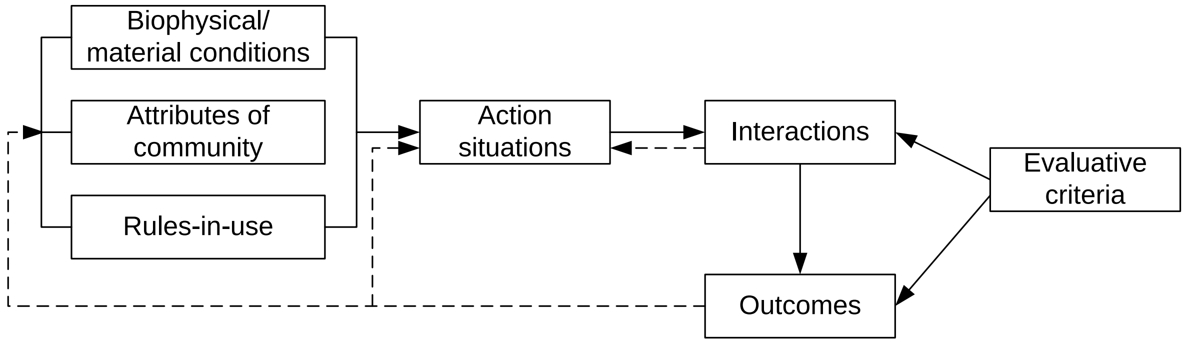
Each level or world of action: metaconstitutional, constitutional, collective-choice, and operational situations, comprises an IAD framework for an institutional analysis. The linkage between levels is in part the rules-in-use at each level as will be elaborated upon below.

The three worlds of action were developed by Ostrom from 1982 to 2011 (Kiser & Ostrom, 1982; Ostrom, 2005a; 2005b, 2007, 2011). The differences between the old version from 1982 and the current version from 2011 are the consideration layers, the names of the elements, and the details of the internal rules. The old version has three worlds of action, while the new version has four levels of analyses and outcomes.

The other difference is that the names of the elements in 1982 were changed in 2011: aggregated results to outcome; actions, activities, and strategies to interaction; attributes of decision situation to action situation; attributes of institutional arrangement to rules-in-use; and attributes of events to biophysical conditions. The attributes of the individual were merged into an action situation. The evaluative criteria were added in 2011.

The names of the rules-in-use in 1982 were changed in 2011 from authority rules to choice rules. The unchanged rules are boundary, scope, position, aggregation, and information rules. The procedural rules were removed. The payoff rules were added in 2011.

The IAD framework provides consideration levels, or worlds of action, for the decision-making process, i.e., operational, collective-choice, constitutional, and metaconstitutional situations. Moreover, the IAD framework provides exogenous variables and an internal action situation at each situation level. The exogenous variables include biophysical/material conditions, attributes of community, and rules-in-use. The internal action situation structure comprises boundary, position, choice, payoff, information, aggregation, and scope rules. Figure 4 shows the IAD framework.



Source Ostrom (2011, p. 10), Figure 1

Figure 4. Framework for an institutional analysis

Interaction (action and strategy)

When an individual wants to take action or implement a strategy, he/she must know the consequences of the action or strategy, or the outcome and value of the alternative actions or strategies. A tennis player makes a decision to charge at the net or wait for the ball to bounce and use a groundstroke: the outcomes of the actions differ. In order to predict actions, a minimum of the following assumptions must be made: the level of information about the decision situations, the valuation of the potential outcomes, the alternative actions within the situation, and the process of calculation to act from alternative actions or strategies.

Action situations (or decision situations)

According to Kiser and Ostrom (1982), the decision situation is determined from interdependent relationships. Interdependent relationships depend on more than one input from the exogenous variables. The IAD framework separates the exogenous variables from the action arena or action situation. The exogenous variables include biophysical/material conditions, attributes of community, and rules-in-use.

Biophysical/material conditions

The biophysical/material conditions describe the type of goods. Goods can be further refined into four groups: private goods, toll goods, common-pool goods, and public goods. Each group has different characteristics, defined by the level of subtractability and the cost of exclusion (Kiser & Ostrom, 1982). Table 5 shows four categories of goods.

Table 5. Categories of goods

Level of subtractability / Cost of exclusion	High	Low
Low	Private goods	Toll goods
High	Common-pool goods	Public goods

Source Kiser and Ostrom (1982, p. 198), Table 7.1

The level of subtractability and cost of exclusion can also be explained in terms of four attributes of biophysical conditions that individuals seek to produce and consume: jointness of use or consumption, exclusion, measurement, and degree of choice, in order to define private goods, tool goods, common-pool resources, and public goods.

Jointness of consumption explains separable and joint consumption goods. One individual consumes separable consumption goods, while several individuals consume joint consumption goods. Joint consumption goods are defined as public goods that are non-subtractable, while separable consumption goods are private goods.

The exclusion attributes explain the difference between private and public goods. Public goods are non-excludable goods that an individual can consume without exclusion. Private goods are excludable goods that the individual can consume with exclusion.

The measurement is the degree of packaging and unitization. Public goods are hard to package and unitize in contrast to private goods. The measurement of private goods is more precise than that of public goods.

The degree of choice for the consumer differs between public and private goods. Public goods are non-subtractable and non-excludable, so there is not much choice, while private goods can produce many choices from subtractable and excludable goods.

The level of subtractability is defined by the characteristics of the goods that can be separated. Private goods can be separated by individual consumption, but public goods cannot. For example, rice can be consumed from a bowl by taking a spoon, as private goods. Air in the park is a public good. People can breathe, but no one can separate air for individual consumption.

Ostrom and Ostrom (1997) use the level of subtractability and the cost of exclusion to classify private goods, tool goods, common-pool resources, and public goods. Private goods, such as bread, milk, automobiles, and haircuts have a low cost of exclusion and a high level of subtractability. Toll goods, for example, theaters, nightclubs, telephone services, cable TV, electric power, and libraries, have a low cost of exclusion and a low level of subtractability. World Cup football is toll goods at a low level of subtractability, because football players and spectators jointly benefit from football matches, whereas the cost of exclusion is low but managed by selling tickets to matches. Common-pool resources, e.g., water pumped from a ground basin, fish taken from an ocean, and crude oil extracted from an oil pool, have a high cost of exclusion and a high level of subtractability. Public goods, such as peace and security of a community, national defense, mosquito abatement, air pollution control, and weather forecasts, have a high cost of exclusion and a low level of subtractability.

Characteristics of spectrum and linkage to the IAD physical condition

Spectrum, or frequency, is a natural and limited resource serving as the carrier to convey information from one place to another regardless of borders between countries. Spectrum that uses high frequencies reaches shorter distances but has a larger carrying capacity. Conversely, spectrum using low frequencies reaches longer distances but has a lower carrying capacity. This propagation characteristic is attenuation according to losses such as free space, connection, coupling, and transmitter losses.

Most of the usable frequency is a man-made resource according to the electronic circuit (inductor and capacitor circuit) that generates the frequency. Therefore, frequency is non-depletable because it can be created all the time.

Moreover, frequency can be re-used by dividing it into frequencies, time, geography, angle of arrival, polarization, and uses. The maximum that is reused of a frequency depends on the level of harmful interference. The advancement of technology has reduced harmful interference and made exclusive use of frequency unnecessary.

Spectrum can have exclusive and non-exclusive rights to the use of frequency depending on the method of assignment: command-and-control, market-based, and spectrum commons.

The characteristic of spectrum can be categorized by the IAD biophysical condition-type of goods: public, private, and common-pool goods.

Normally, unassigned spectrum is public goods because everyone can use it without separation from others. However, it is costly to exclude others from its use. Therefore, unassigned spectrum has a low level of subtractability and high cost of exclusion. In Thailand, all uses of radiocommunication devices and frequencies are prohibited except those that have a grant from the authority (the NBTC). The unassigned frequency is the frequency allocated in the TFA that is not assigned to anyone.

Once the NRA gives the exclusive right to use frequency to licensees via command-and-control or market-based approaches (e.g., auction), spectrum is private goods. The licensees can use licensed spectrum to provide service to their customers. This spectrum has a high level of subtractability and low cost of exclusion as when the licensees obtain spectrum others cannot use it.

Moreover, the NRA gives the right to use frequency to the public, such as unlicensed spectrum. No one has exclusive right to use this frequency. Unlicensed frequency has non-exclusive rights of use. Everyone is able to use this frequency, and the cost is high to exclude others while using it. Unlicensed frequency is therefore common-pool goods.

The advancement of technology has changed the frequency exclusivity from becoming unnecessary because these technologies can use frequency while it is not occupied or use frequency underneath without causing harmful interference. The frequency assignment provision of the exclusive right to use frequency becomes blurred to the NRA if such technologies exist and are fully used.

Attributes of community

The attributes of community comprise levels of common understanding, common agreement, and distribution of resources. The common understanding between people in the action situation could be the norm, culture, or tradition in each community that has a direct influence on the decision situation.

After setting the rules, the individual or member of the community must have a common understanding of them, i.e., the allowable actions and outcomes. Without a common understanding of the rules, they cannot be exercised.

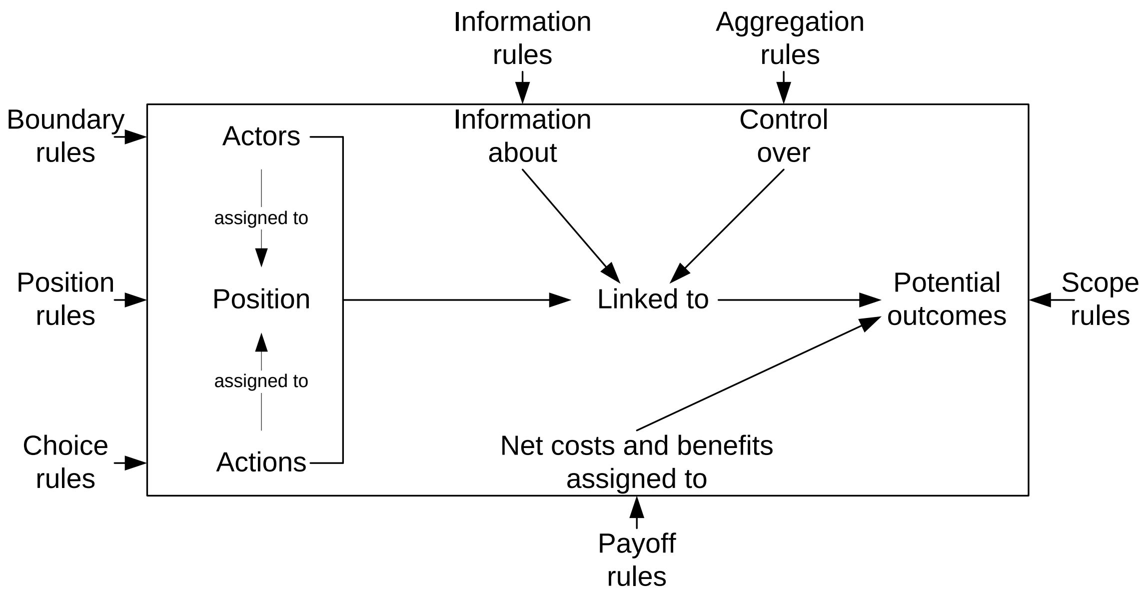
Real actions must be evaluated with a common understanding of the rules. If community members obey the rules, allowable actions, and outcomes, the need for rule enforcement is low. If, on the other hand, the individual disagrees, the need for enforcement is high.

The distribution of the resource represents a situation in the market or community. If resources are distributed equally, a competitive environment arises. Otherwise, oligopoly or monopoly may arise.

Rules-in-use

The rules-in-use provide an institutional arrangement in a decision-making situation, including boundary, position, choices, payoff, information, aggregation, and scope rules. In general, rules-in-use can be thought of in terms of “do and don’t” rules, for example, when a new member of staff arrives at the office on the first day, the first thing he/she should ask his/her colleagues about is the “dos and don’ts” in the office. This is more important than the rules-in-form that are written down (Ostrom, 2007, pp. 36-37).

A detailed discussion regarding the action situations is provided below. These rules help explain the action arena or action situation. Figure 5 shows the rules-in-use and the action situation.



Source: Ostrom (2011, p. 20), Figure 3

Figure 5. A rules-in-use and the action situation

Boundary rules: who is eligible to participate in a decision-making or action situation? These rules provide the list of participants or actors. For example, in the French Open, tennis players with a higher rank automatically go to the first round, while newcomers have to win qualifying matches to enter the first round.

Position rules: what role does each participant perform in his/her position or what authority is given to each position? In each match, there are referees, line-persons, ball boys or girls, and two or four tennis players. Each position has its own task or responsibility to perform.

Choice rules: what actions should be taken? During the game, after one game of serving, the opponent has to strike back. There are many choices, e.g., whether to wait and hit a groundstroke or to go forward to volley. Even for the server, there are many choices when it comes to hitting the ball, e.g., whether to direct it to the corner, to the right, to the left, or to go for an ace on the first serve.

Payoff rules: what is the cost and benefit of the choice that is taken? During the game, if player A plays a drop shot at the net, player A expects player B to rush to the net to get the ball back.

Information rules: what information is available when making the decision? In the game, the information about players, weather conditions, changing to new balls or a new racket, medical breaks, and player injury are available to both players.

Aggregation rules: what level of control does the participant have in his/her action situation? During the game, the player has the ability to control his/her action to move forward or backward, to serve, or to hit the ball in order to win a point. Moreover, the player should control his/her performance to win the match in a normal game or a tiebreak.

Scope rules: what is the rule to delimit the potential outcome that is linked to a specific outcome? During the match, the winner has to win two out of three sets or three out of five sets. Both players can play a point in the specified court, including the height of the net, and the type and size of the court.

Outcomes

The terms 'outcomes' in Figure 4 and 'potential outcomes' in Figure 5 describe the same concern. The outcomes are the result of actions or strategies by the decision-maker in a decision-making process. Moreover, the evaluative criteria in Figure 4 should be used to find the net costs and benefits of the outcomes in Figure 5.

Evaluative criteria

Ostrom (2011) also provides evaluative criteria, including economic efficiency, equity through fiscal equivalence, redistributional equity, accountability, conformance to the values of local actors, and sustainability.[8] The evaluative criteria are the possible outcomes under the alternative institutional arrangements (Ostrom, 2011, p. 15).

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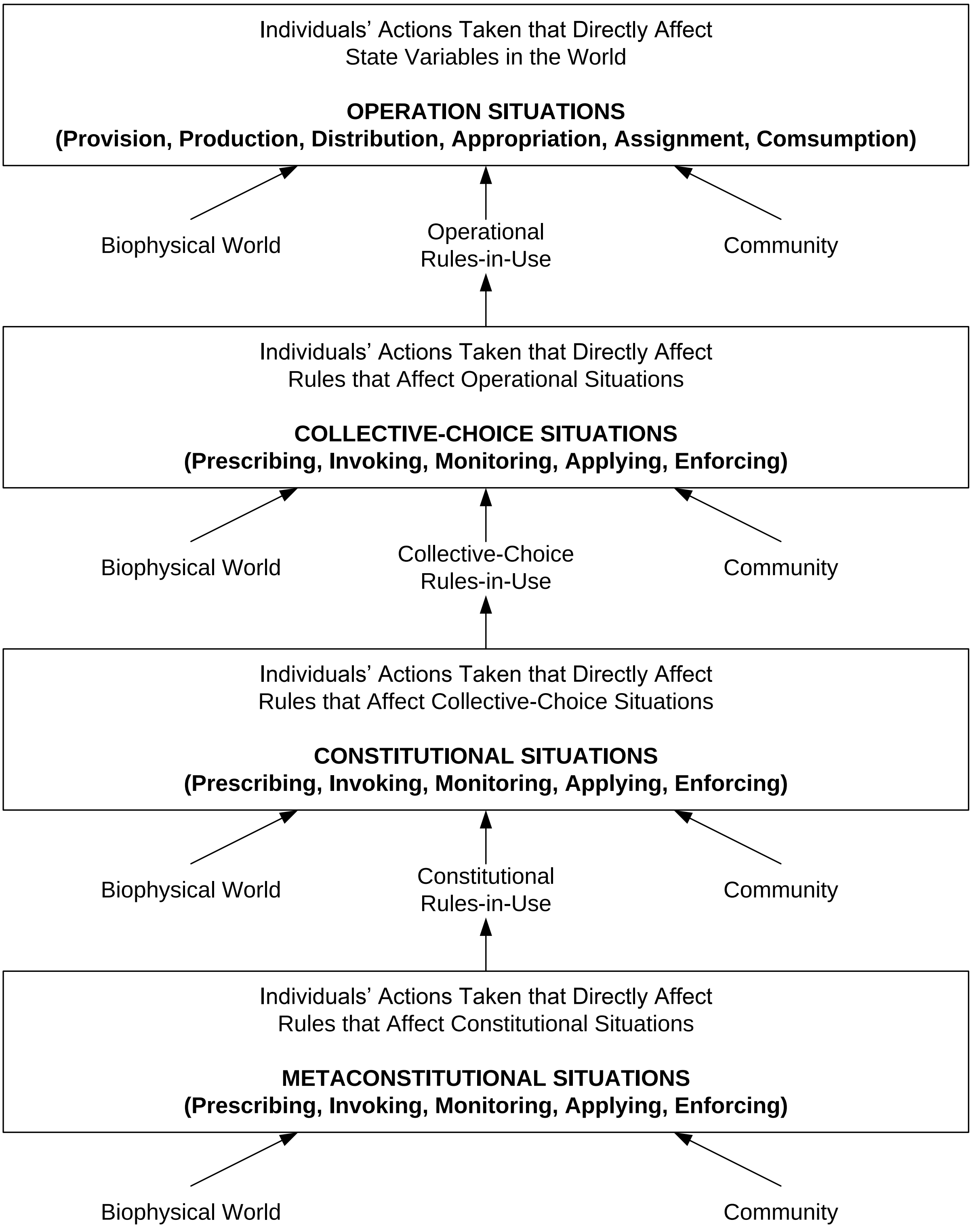
[8] For more information, see Ostrom (2011, pp. 16-17).

Levels, worlds of action, or situations

The IAD framework provides consideration levels, or worlds of action, for the decision-making process, i.e., operational, collective-choice, constitutional, and metaconstitutional situations. Figure 6 shows the level of analysis and outcomes in the IAD framework.



Source Ostrom (2007, p. 45), Figure 2.2

Figure 6. Level of analysis and outcomes

Each level or analysis comprises an internal action situation, as mentioned above. The seven parts of the IAD framework are contained in each level of the analysis. They are biophysical/material conditions, attributes of community, rules-in-use, action situations, interactions, evaluative criteria, and outcomes.

An operational situation is affected by the operational rules of day-to-day decision-making by the participant. The decision is made according to the operational rules, which are defined in the collective-choice situation. For example, in the State of Maine's lobster industry, the day-to-day work is to fish or obtain lobster from the inland shore. The fishermen have to fish with specified tools and a time slot.

A collective-choice situation is affected by the collective-choice rules to determine who is eligible, and it defines rules to change the operational rules. For example, if someone wants to change who can fish, and the tools and the time to fish lobster, he/she has to revise the operational rules in the collective-choice situation.

A constitutional situation is affected by the constitutional rule of who is eligible and can change collective-choice rules, and this has consequences for the operational rules. For example, in the telecommunication industry, the national regulatory agency defines the set of rules that allow the use of Wi-Fi devices. The rules specify a frequency of 2 400-2 500 MHz with transmitting power of up to 100 milliwatts. These rules work as constitutional rules with room for manufacturers or the standard-setting agency to produce its technology and standards to fit these rules. The standard for Wi-Fi devices is set in the collective-choice situation. After that, Wi-Fi devices are on the market and available to use. Users buy and use Wi-Fi devices according to the standard.

As a constitutional decision-maker, Fédération Internationale de Football Association **(**FIFA) determines the rules of football at a high level. European or national football associations use FIFA's rules for their tournaments, such as EUROPA and the Premier League. Football teams must obey the rules to participate in tournaments.

At a metaconstitutional level, the situation is the deepest layer of analysis, underlying all three of the above levels. The metaconstitutional level should contain the fundamental rules, such as customs, tradition, norms, and religion (Williamson, 2000).[9]

2.3 Three worlds of action in spectrum management

The concept of three worlds of action and the property rights regime mentioned above provide an understanding of the interaction between the decision-maker and the decision situation within and between the three levels.

An analysis of the decision-makers at each level of spectrum management reveals the relevant stakeholders shown in Table 6.

[9] Williamson explains this as Level 1 (embeddedness), which is taken as given. Institutions at this level change very slowly: 100-1000 years.

Table 6. Level of analysis and stakeholders

Stakeholders	Level of analysis
Administrator/Regulator/Authority	Constitutional situation
Operator/Provider/Standard-Setting Organization	Collective-choice situation
User	Operational situation

Source Ard-paru (2010), Table 7

Constitutional situation

A high level of regulation conducted directly will influence the collective-choice situation. In radiocommunication, the constitutional situation starts with the regulator, administrator, or authority in each country up to the ITU level. The constitutional situation gives the overall regulation and broadly influences the collective-choice situation (or institutional situation).

Collective-choice situation

After the administrator, authority, or regulator outlines the technical specifications, the operators, providers, or standard-setting units have to create technology according to the regulation (constitutional-choice situation). For example, in the 2 400-2 500 MHz band there are two popular technologies, Wi-Fi and Bluetooth. These technologies provide personal and local connectivity with a peer-to-peer connection for Bluetooth and a Wi-Fi infrastructure for Internet connection, respectively.

Wi-Fi technology has been developed by the Institute of Electrical and Electronics Engineers (IEEE), and the current standard is 802.11n. This standard provides many technical specifications on how to use this frequency, e.g., medium access control (MAC) and physical layer (PHY) specifications.

Bluetooth has been developed to replace cable connectivity for personal area networks (PANs). The Bluetooth standard uses the frequency-hopping spread spectrum for radio technology. PANs can connect mobile phones, faxes, printers, computers, laptops, GPS receivers, video recorders, and cameras.

In a collective-choice or institutional situation, technology or standard rules show how the frequency should be used by the provider, operator, or standard-setting unit and determine which devices can access its network.

Operational situation

At this level, users can choose to select devices and use them. After selecting the devices, however, users have collective-choice or institutional situation rules. For example, once the users access Wi-Fi hotspots in hotels, they must have devices with a specified Wi-Fi connection and an account to access the Internet defined by the operator. If, on the other hand, the user connects to the Wi-Fi router at home, the user specifies the access rule by password to determine who can connect to his/her router.

2.4 Bundle of rights to use frequency

With regard to the right to use a frequency, the access and withdrawal right depends on the devices (transceiver: transmitter and receiver). When users access a resource, they withdraw the product or consume the frequency. Thus, the access to frequency explains the access and withdrawal right of frequency. For example, the user makes a call from his/her mobile phone. The phone connects to the base station via a selected frequency. The selected frequency is occupied by the user. After hanging up, the selected frequency can be used by others.

The access right in an operational situation is defined by the network operator that defines the network rule to access the frequency in terms of the technical specification or standard. The network operator acts as both proprietor and claimant with the management and exclusion right to define how, when, where, and who can access the frequency. For example, when a user makes a call from his/her mobile phone, the operator specifies which standard and technology the phone and the SIM card will use.

An alienation right is defined as ownership that can be sold, leased, or transferred. For example, the frequency auction in the primary market and frequency trading in the secondary market provide ownership of frequency for the owner to trade. Normally, the alienation right is defined by the authority, regulator, or administrator.

In Table 6, stakeholders are divided into the three levels. Applying the idea from Table 6, the bundle of rights for each stakeholder reveals the rights to use frequency shown in Table 7.

Table 7. Bundle of rights associated with telecommunication stakeholders

Stakeholders / Rights	Regulator	Operator A	Operator B	Advanced user	General user
Access and withdrawal	x	x	x	x	x
Management	x	x	x		
Exclusion	x	x	x	x	
Alienation	x	x			
Assignment approach		Market-based	Command-and-control	Spectrum commons	Spectrum commons

Source Ard-paru (2010), Table 12

In a constitutional situation, the regulator, administrator, or authority holds all the rights to frequency use, including access, withdrawal, management, exclusion, and alienation rights. Once the regulator delegates authority, using the market mechanism to assign frequency, the alienation right passes to a collective choice or institutional situation, i.e., Operator A. Operator A is able to sell, lease, or transfer frequency to another party. Operator B, however, cannot sell because the regulator still holds the alienation right. Thus, frequency assignment using the command-and-control approach means that Operator B must ask the regulator for approval to transfer the frequency, e.g., 2G frequency assignment in Thailand. Operator A represents frequency assignment using the market-based approach, including primary trading (auction) and secondary trading (resale). Operator A has the freedom to transfer frequency without regulatory approval, e.g., 3G auctions in the UK and the USA.

In a collective-choice or institutional situation, the management and the exclusion rights are held by the providers, operators, or standard-setting units. They set up their network rules on how, when, and where to harvest frequency reflected by technology or device choices. For example, mobile phone operators set their standard of network and equipment to allow only their consumers to use the network. The advanced user (in the operational situation), however, sets his/her own rules that allow access to the frequency. For example, advanced users of Wi-Fi routers can set their own security code for network access.

In an operational situation, access and withdrawal rights are held by users. Users have to use devices according to the standard preset by the operators.

As for the right to use frequency, the assignees, and command-and-control and market-based approaches have the exclusive right to use frequency, but spectrum commons has a non-exclusive right. For the exclusive right, assignees have priority to use it free of interference. For the non-exclusive right, however, users have to share and accept interference. Exclusivity should be added to the property rights for the right to use frequency.

The level of deregulation of the right to use frequency from the regulator in the constitutional situation can be delegated to operators in the collective-choice or institutional situation, and users in the operational situation. The regulator can use the market-based approach to delegate alienation rights to operators. Thus, the operator can obtain the frequency from primary and secondary markets. The operator has the flexibility to sell, lease, or transfer frequency. In the operational situation, the regulator can delegate its authority of self-regulation after defining the necessary conditions, including frequency, power limitation, and standard of devices. Thus, users have to manage the use of frequency.

Relationship between the bundle of rights to use frequency and the IAD framework

The bundle of rights to use frequency in Table 7 can be categorized into two levels of analysis: operational and collective-choice situations. In the operational situation, there are access and withdrawal rights to use frequency to perform day-to-day activities to use the radiocommunication devices. In the collective-choice situation, there are management, exclusion, and alienation rights to use frequency to define the rules on abilities to access, withdraw, change, sell, and lease the frequency.

Comparing the IAD rules-in-use and action situation at each level with the bundle of rights to use frequency, the action situation uses the radiocommunication device.

In the operational situation, the boundary rules are defined by access and withdrawal rights indicating who can access and use the frequency. The position rules are the regulator, Operator A, Operator B, advanced user, and General user. The choice rules are the option to use frequency: access and withdrawal frequency. The interactions between user and radiocommunication devices have been predefined according to the rules in the collective-choice situation. The information, aggregation, payoff, and scope rules are the interactions of users and devices, i.e., to use or not use the devices.

In the collective-choice situation, the action situation changes the rules or revises the use of frequency, including how to access, withdraw, change, sell, and lease the frequency. The boundary rules are similar to those in the operational situation: access withdrawal rights.

However, the position rules are limited to the regulator, Operator A, Operator B, and the advanced user. As for the position rules, only the regulator and Operator A have a full choice of actions to access, withdraw, change, sell, or lease the frequency. Operator B has no right to sell or lease the frequency. The advanced user has the additional right to identify the person who can access and use the frequency. The interactions between actors on rule changing represent information, aggregate, payoff, and scope rules. The outcome is the possible rule changes for using frequency.

Table 8 shows the rights to use a frequency and the regulated level.

Table 8. Rights to use frequency

Property right / Regulated level	Exclusive use	Non-exclusive use
Centralized by regulator/state agency	Command–and-control	Public commons
Middleman/operator	Market-based	Private commons
Self-regulated/user	-	Unlicensed

Source: Ard-paru (2010), Table 13

The command-and-control assignment approach means that regulators hold all the rights to use frequency while assigning frequency to assignees. The assignee has the exclusive right to use the frequency with all the imposed conditions. Assignees have limited opportunities to change the use of frequency.

The market-based approach is the assignment method in which assignees can buy frequency from the primary and secondary market. The assignee has the exclusive right to use the frequency. The regulator gives away the alienation right to the assignee and this right can be sold, leased, and transferred. Thus, it is more flexible than the command-and-control approach. Some necessary conditions should be imposed on the use of frequency, however, such as the standard of devices.

The next three categories have non-exclusive rights to use frequency. This means that users have to share frequency. At the regulated level, it includes management and exclusion rights. When a state agency or government manages the frequency use, it is public commons. When the operator manages the frequency use, it is private commons. When users manage the frequency use, it is unlicensed.

2.5 Summary

This chapter presents the IAD framework, three worlds of action in spectrum management, and bundles of rights to use frequency.

This study describes the elements of the IAD framework, including exogenous and endogenous variables. The independent variables are exogenous and endogenous variables. Exogenous refers to the external variables that influence the action situation, including biophysical conditions, attributes of community, and rules-in-use. Endogenous refers to the internal variable that is directly connected to rules-in-use. There are seven rules, including boundary, position, choice, payoff, information, aggregation, and scope rules. The dependent variable is the potential outcomes.

The IAD physical condition explains the characteristic of spectrum as three types of goods, i.e., public, private, and common-pool goods depending on the method of spectrum assignment with the level of subtractability and cost of exclusion.

When the spectrum is allocated to services in the TFA, the unassigned spectrum is public goods because everyone can use it without separation from others. However, it is costly to exclude others from its use. Therefore, unassigned spectrum has a low level of subtractability and high cost of exclusion.

When the spectrum is assigned by command-and-control or market-based approaches, the assigned spectrum is private goods because the NRA gives the exclusive right to use frequency to licensees. This spectrum has a high level of subtractability and low cost of exclusion because when the licensees obtain spectrum others cannot use it.

When the spectrum is assigned by the spectrum commons approach, the NRA gives a right to use frequency to the public, such as unlicensed spectrum. No one has the exclusive right to use this frequency. Everyone has the ability to use this frequency (high level of subtractability) and the cost is high to exclude others while using it. The unlicensed frequency is therefore common-pool goods.

Moreover, three worlds of action provide the interrelation between levels of action: constitutional, collective-choice, and operational situation. These levels of action provide the link to how the rules-in-use at the higher level influence the lower level.

This study illustrates three worlds of action in spectrum management by mapping the levels of action and the stakeholders. For the constitutional situation, the administrator, regulator, and authority provide international and national regulation as the scope of spectrum management. In the collective-choice situation, the operator, provider, and standard-setting organization comply with the given regulation from the constitutional situation in order to create their collective-choice situation regulation such as the network rules or standard of equipment. For the operational situation, users buy the equipment and use it according to the specified standard and regulation.

This study demonstrates the bundle of rights to use a frequency as the application from the IAD framework in the collective-choice and operational situation. The bundle of rights to use a frequency can also be divided into five rights: access, withdrawal, management, exclusion, and alienation rights. The access and withdrawal rights to use a frequency can be combined, however, due to the technical characteristics of the transmitter, receiver, and transceiver. When the transceiver is switched on, it operates or accesses the specified frequency and uses the frequency for the specified service. This means that transceivers combine access and withdrawal rights to use the frequency at the same time.

In an operational situation, general users hold access and withdrawal rights to use frequency by selecting devices (transmitter, receiver, or transceiver) that follow specified conditions.

Advanced users hold an additional exclusion right to determine who can use the frequency by applying a username and password.

In a collective-choice or institutional situation, operators, providers, and standard-setting organizations hold additional management and exclusion rights that specify how, when, and where a frequency can be used in terms of the standard of device, technology, SIM card, etc.

In a constitutional choice situation, the authority, administrator, or regulator has all the rights to frequency use and to specifying regulations. When the regulator decentralizes the alienation right, however, by using the market mechanism, the operator at the collective choice level can obtain the frequency from primary and secondary markets.

The exclusive right to use frequency is a key point to separate the three spectrum assignment approaches: command-and-control, market-based, and spectrum commons. The command-and-control and market-based approaches have an exclusive right to use frequency, but spectrum commons has a non-exclusive right. The regulated level indicates the decentralization of regulators. Regulators may give away some rights to the operator or end-user. Thus, both the exclusive right and the regulated level help to explain the differences between these approaches. When the regulator holds the alienation right, the approach is command-and-control. When the regulator delegates the alienation right via primary and secondary markets, the approach is market-based.

In the category of non-exclusive rights to use frequency, the regulated levels range from regulator, operator, and end-users, i.e., public commons and private commons, to unlicensed. Public commons has a state agency to manage frequency, such as a municipality or local administrator, etc. Private commons has private entities to manage frequency, such as a Wi-Fi operator in a hotel, airport, department store, etc. Unlicensed spectrum is self-regulated.

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Chapter 3 Methodology

This chapter concerns the available data, the mode of data collection, and the methods used in data analysis.

Table 9 shows the summary of the methodology that has been used in Papers I, II, and III.

Table 9. Methodology summary

Methodology	Paper I	Paper II	Paper III
Data and data collection method	Primary/ Secondary data	Secondary data	Secondary data
Data analysis	IAD	IAD	IAD
Approach	Deductive/ Inductive	Deductive	Deductive/ Inductive

All papers use the IAD framework for data analysis, but the data and data collection methods are different. The details of the differences are discussed below.

3.1 Data and data collection method

Paper I uses both primary and secondary data. The primary data are sourced from observations made while attending the selected Project Team A (PT A), the European Conference of Postal and Telecommunications Administrations (CEPT) preparatory group (CPG), the Asia-Pacific Telecommunity (APT) preparatory group (APG), and the World Radiocommunication Conference 2012 (WRC-12) meetings. The primary data from participant observation help to analyze the rationale behind RR provision changes.

The primary data are obtained from participant observation and transcription of voice recordings from the meetings. Voice transcriptions provide the rationale for the argumentation and its resolution.

Such observations provide an internal view or meeting perspectives (Flick, 2009, pp. 226-233). However, Flick identifies the limitations of such observations, in particular, the difficulty of systematizing the status of meetings while maintaining distance. Moreover, observers must be limited to what can be observed. Additional interviews of situations can help in understanding processes.

The secondary data are sourced from the ITU, CEPT, and APT archives. The ITU archives include all the versions of the RR, including 1906, 1912, 1927, 1932, 1938, 1947, 1959, 1968, 1971, 1976, 1982, 1986, 1990, 1994, 1996, 1998, 2001, 2004, 2008, and 2012. All ITU documents can be accessed through the ITU History Portal (http://www.itu.int/en/history/Pages/default.aspx), including the PP (complete list of Plenipotentiary Conferences), Radiocommunications collection (complete list of Radiotelegraph & Radiocommunication conferences), and RR (complete list of Radio Regulations). Conversion of the TFA for alternative versions of the RR into Excel sheets provides a record of the frequency bands by services and band development. Moreover, the ITU structure development is based on the relevant literature and is cross-checked with the relevant Plenipotentiary Conferences (PP) document.

Paper II uses secondary data. Secondary data are sourced from the ITU, and NBTC archives. The ITU archives include all versions of the RR, including 1906, 1912, 1927, 1932, 1938, 1947, 1959, 1968, 1971, 1976, 1982, 1986, 1990, 1994, 1996, 1998, 2001, 2004, 2008, and 2012.

Paper III uses secondary data. The secondary data were sourced from the ITU and National Telecommunications Commission (NTC) archives. The NTC archives include the minutes of the National Frequency Management Board (NFMB), and the PTD and ministerial regulations. The relevant literature and public consultation of the Radio Spectrum Policy Group on “Aspects of a European Approach to Collective Use of Spectrum” was posted on June 10, 2008 and closed on September 29, 2008.´

The data are secondary and qualitative in nature. The secondary data archive approach is due to Rutkowski (2011). Rutkowski downloaded principal data from the ITU History Portal. The data allowed examination of versions of the regulations to enable the identification of key definitions and provisions by RR versions. Rutkowski’s analysis enabled the identification and links to detect any differences in the text. Rutkowski applied this method to cyber security and to find where such text amendments arose.

The benefit obtained from applying the Rutkowski approach is that mapping the archive over time improves the understanding of the context in which regulations developed.

In order to use documents as secondary data, Flick (2009) provides guidelines on how to select suitable analysis documents by the criteria: authenticity (applied to both primary and secondary data), credibility (official or personal), representativeness (typical or non-typical), and meaning (text clarity).

Document authenticity depends on the data source. If information is obtained from primary data sources and is documented by witnesses, then authenticity is “high.” When data are obtained from a secondary data source and documented from primary data, the authenticity of the document is “medium” or “low.” Document credibility depends on the type of document. For official documents, credibility is “high.” Naturally, for personal documents, credibility is “low.” Representativeness is measured by document type. When documents are recorded for specific purposes, representativeness is non-typical. If the document is for general purposes, representativeness is typical. The document’s meaning depends on its clarity.

To summarize, primary data obtained from meetings are considered “participant observations” of the PT A, CPG, APG, and WRC-12 meetings. These observations provide insight, interaction, and dynamic and current practice of regional preparatory groups and WRC. The constructed template standardizes the participant observation recording process.

Secondary data obtained from the ITU, CEPT, APT, NTC, PTD, NFMB, and NBTC archives provide a high degree of authenticity and credibility. Furthermore, documents’ representativeness depends on their purpose. The purpose may be general (typical) or specific (non-typical). In this study, the documents are specific. The representativeness of this study is also mainly non-typical. The meaning of documents is also measured by document clarity.

3.2 Data analysis

Paper I

Data analysis explains action situations, i.e., how decisions are made at the WRC meetings. This study starts from a list of IAD questions that should be considered as a basis on which to analyze the ITU, CEPT, and APT archives, and guide participant observations.

Paper II

Data analysis explains the level of analysis and outcomes, i.e., how international regulation is transformed into national regulation. This study starts from a level of analysis and outcomes that includes the constitutional, collective-choice, and operational situation, to understand the transformation from the RR into NBTC regulation.

Paper III

Data analysis explains the bundle of rights to use a frequency for spectrum commons in Thailand. This study applied three levels of action by Kiser and Ostrom (1982), providing a metatheoretical framework addressing the relationship between instructional arrangement, the individual, and the bundle of property rights regime.

The IAD framework provides seven elements of institutional analysis: biophysical conditions, attributes of community, rules-in-use, action situation, interactions, outcomes, and evaluative criteria. Moreover, the interaction between level of analysis and outcomes provides four levels: metaconstitutional, constitutional, collective-choice, and operational situation, to understand the influence of rules-in-use in the deeper layer on other layers. However, this study applies three levels of analysis, namely constitutional, collective-choice, and operational situation for the transformation of international regulation into national regulation.

3.3 Approach

All three papers use a deductive approach from the IAD framework in different contexts.

The study applies the IAD framework by using its variables, both exogenous and endogenous. Moreover, three levels of analysis and outcome, i.e., constitutional, collective-choice, and operational situation are applied. The independent variables of an action situation are biophysical condition, attribute of community, and rules-in-use. Inside an action situation, the independent variables are actors (position rules), positions (position rules), actions (choice rules), flow of information (information rules), control over action or stances (aggregate rules), cost and benefit of actions (payoff rules), and possible outcome (scope rules). The dependent variable is potential outcomes.

The IAD framework provides each variable as the list of concerned questions applying to the action situations. The study selects the object of study as an action situation in different circumstances. Table 10 presents the independent and dependent variables, level of analysis, and action situations of this study.

Table 10. IAD independent and dependent variables

IAD variables	Paper I	Paper II	Paper III
Independent			
Physical condition	Spectrum as public goods	Spectrum as public goods	Spectrum as public, private, and common-pool goods
Attribute of community	Norm, culture, and tradition of ITU and Member States	Norm, culture, and tradition of ITU and Thailand	Norm, culture, and tradition of Thailand
Rules-in-use		RR: definition of ISM application, footnotes 5.138 and 5.150, and relevant frequency bands (TFA)	
Boundary	ITU membership	Thai telecom industry	Access and withdrawal right
Position	HoD, regional rep., chair, secretary	NRA, operator, manufacture, standard-setting organization, users	NRA, Operator A, Operator B, advanced users, end-users
Choice	Support, oppose, neutral	Adopt or not adopt rules	Use or not use device/ Rule changes
Payoff	Cost and benefit	Link to action situation	Link to action situation
Information	Public or informal information flow	Link to action situation	Link to action situation
Aggregate	Control over choice	Link to action situation	Link to action situation
Scope	ADD, MOD, SUP, NOC	Link to action situation	Link to action situation
Interaction	Link to action situation	Link to action situation	Link to action situation
Evaluation criteria	Link payoff rules	Link payoff rules	Link payoff rules
Dependent			
Action situations	WRC-12 Agenda Items 1.19 and 1.22 (Negotiation)	Transformation of spectrum commons regulations (Adopt or not adopt rules)	Implementing spectrum commons (Use or not use device/ Rule changes)
Potential outcomes	RR revisions	NBTC regulations: Thai TFA and NBTC unlicensed regulations	Bundle of rights to use frequency

Note: HoD-Head of Delegation, Rep.-Representative, ADD-Addition, MOD-Modification, SUP-Suppression, NOC-No change

Paper I, the action situation in WRC-12 Agenda Items 1.19 and 1.22 is the study object, including the WRC preparatory process (agenda setting and study process). The independent variables of the exogenous variables are spectrum characteristics (biophysical condition), ITU and Member States culture and tradition (attribute of community), ITU and Member States regulations (rules-in-use). These variables directly influence the action situation at WRC-12.

In the action situation for WRC-12 Agenda Items 1.19 and 1.22, the independent variable of the exogenous variable is directly influenced by the endogenous variable, which is represented by seven rules: boundary, position, choice, information, aggregate, payoff, and scope. The dependent variable is a potential outcome.

The WRC-12 Agenda Items 1.19 and 1.22 action situations are conducted in the constitutional situation at international level.

In Paper II, the action situation is the transformation of spectrum commons regulation from the RR into the NBTC regulation. The relevant level of analysis and outcomes is in the constitutional situation between the international and national level. The transformation is part of the IAD rules-in-use between the international and national level.

The independent variable is the rules-in-use at international level as for the RR. The dependent variable is the NBTC regulations. The transformation of spectrum commons regulations in the RR is the definition of the ISM application, footnotes 5.138 and 5.150, and relevant frequency bands. The NBTC spectrum commons regulations are the Thai TFA and NBTC unlicensed regulations as dependent variables.

In Paper III, the action situation is the implementation of spectrum commons at national level in terms of the bundle of rights to use frequency including the constitutional, collective-choice, and operational situations.

The independent variables are spectrum characteristic, Thai culture and tradition, and Thai law and regulation as exogenous variables that are influenced by the international regulation transformation.

In the constitutional and collective-choice situations, the action situations are rule settings, including the NBTC Acts and regulations and Radiocommunication Act (constitutional situation), and standard of devices and network management rules (collective-choice situation). The use of radiocommunication devices with a bundle of rights to use frequency are included in collective-choice and operational situations.

Paper I uses the IAD framework to understand the decision-making process at WRC-12. Paper II uses the IAD framework to transform the international regulation into national regulation in terms of the rules-in-use in the constitutional situation from the RR to influence directly the NBTC regulation, as the national regulation in Thailand. Paper III uses the IAD framework to understand the bundle of rights to use a frequency for spectrum commons in Thailand together with the stakeholder at each level of analysis and outcomes.

To sum up, Paper I also applies the inductive approach from the participant observation at the meeting to induce the rationale of discussion as the reason behind the RR revisions.

Paper III applies the inductive approach from understanding the advantages and disadvantages of spectrum commons in the relevant literature and RSPG consultations.

To summarize, the study uses a deductive IAD framework to understand the decision-making process at WRC, the transformation of international into national regulation for spectrum commons in Thailand, and the bundle of rights to use a frequency for spectrum commons in Thailand. The study uses an inductive approach from the participant's observation to understand the rationale behind the RR provision changes and the advantages and disadvantages of spectrum commons from relevant literature and RSPG consultation.

3.4 Summary

This study uses both primary and secondary data. Primary data are from participant observation at PT A, CPG, APG, and WRC-12 meetings. Secondary data are from the ITU, CEPT, APT, NTC, PTD, NFMA and NBTC archives, relevant literature, and RSPG public consultations.

This study analyzes secondary data with questions provided by the IAD framework. The IAD framework provides the independent variable, including boundary, position, choice, information, aggregate, payoff, and scope rules. The dependent variable is the outcome of the action situation. The questions identify the limitations of the ITU, CEPT, and APT archives. These gaps can be closed with information obtained from the participant observations. However, the participant observations are limited to the current meetings (Paper I).

This study analyzes secondary data according to the IAD framework to understand the transformation of international into national regulation and the interaction between the level of analysis and outcomes for spectrum management activities and relevant stakeholders (Paper II).

This study analyzes secondary data for the bundle of rights to use a frequency for spectrum commons and identifies the advantages and disadvantages of spectrum commons from the author's perspectives (Paper III).

Chapter 4 Summary of appended paper

This chapter presents the main contributions from three papers, including the development of RR provisions, the transformation of international into national regulation for spectrum commons in Thailand, the development of spectrum assignment for commons in Thailand, and the bundle of rights to use spectrum commons.

4.1 Paper I

Paper I Ard-paru, N. (2012). *Information and coordination in international spectrum policy: Implication for Thailand*. Retrieved from http://www.lib.chalmers.se (ISBN 978-91-980300-3-7).

In order to study the international spectrum policy, the study focuses on WRC-12 Agenda Items 1.19 and 1.22 regarding SDR, CRS, and SRD representing spectrum commons as an object of study.

The study contains the main research, i.e., **How is international spectrum policy developed and affected by the lack of more detailed documentation?** To fulfill the main research question, four sub-research questions are posed.

Sub-research question 1: How is international spectrum policy set in terms of the ITU structure, WRC, and RR, and how did it develop?

The findings of this sub-research question identify the relevant stakeholder of the ITU and WRC that constitutes the main player to change the RR provisions. The study selects the issues relevant to spectrum commons to demonstrate the whole process of WRC, describing the critical procedure in the WRC agenda setting and study processes.

The study responds to the first sub-research question in four parts: (1) ITU structure development; (2) RR development; (3) WRC agenda setting; and (4) WRC study process.

ITU structure development (Chapter 4)

The study provides the ITU structure development since 1865, from the International Telegraph Union to ITU via the International Telegraph Conference, International Telecommunication Conference, and PP. The major change to the ITU structure is a result of the study by the High Level Committee during 1989-1992. The current ITU structure is the decision of the APP1992 and its amendments (1994, 1998, 2002, and 2006).

RR development (Chapter 5 and appendices)

The study further explores the ITU archives, including the input and output of the WRC proceedings and RR versions, to construct its own database. The keywords are used to keep track of the RR provisions, and the TFA provides the RR developments in Chapter 5 and Appendices A, B, C, D, E, F, G, H, I, and J. The results of the exploration also confirm that the ITU archives are incomplete: they lack the rationale behind the RR provisions.

This study provides a review of the WRC and RR developments in terms of: (1) key definitions (telecommunication, radiocommunication, and radio waves), (2) important provisions (choice of apparatus, frequency assignment provision, licenses, allocation, allotment and assignment, priority of services, radiocommunication services, and radiocommunication station), and (3) frequency band developments (maritime mobile service, MMS; maritime mobile-satellite service, MMSS; broadcasting service, BS; broadcasting-satellite service, BSS; fixed service, FS; fixed-satellite service, FSS; mobile service, MS; mobile-satellite service, MSS; space research service, SRS; and earth exploration-satellite service, EESS).

Furthermore, this study explores the ITU archives to explain the process of RR revision, including the WRC agenda setting and study processes. The study also illustrates the WRC-12 preparatory process as the WRC standard process. The results of the WRC agenda-setting process and WRC study process are presented in Chapters 6 and 7, respectively.

WRC agenda-setting process (Chapter 6)

The WRC agenda-setting process provides a standard for ITU to prepare the WRC agendas for the next and future WRCs in the conference preparatory meeting (CPM) report. The WRC agenda-setting process has two study cycles for preparation, i.e., the next and future WRC agendas in the CPM report. The whole WRC agenda-setting process takes eight years.

However, the last WRC is the crucial forum in which the next WRC agenda is approved before the Council approval. This means that the agenda items, including the CPM report, for the next and future WRCs are not guaranteed inclusion in the final version of the WRC agenda by the last WRC approval. Interested Member States with limited resources should pay attention to the last WRC that is finalized in the next WRC agenda.

WRC study process (Chapter 7)

The WRC study process for WRC-12 Agenda Items 1.19 and 1.22 provides the output of the discussion from the ITU study group (SG) and the issues of these agenda items that use one WRC study cycle. The output from the SG is presented in the CPM report as the options for Member States to decide on at WRC-12. Moreover, the output from the Radiocommunication Assembly-12 (RA-12) provides additional information for Member States to consider at WRC-12

Sub-research question 2: What information would be most useful for making the decision?

The findings of this sub-research question demonstrate the missing information during the decision-making process at WRC by applying the IAD framework to the WRC context. The study focuses on WRC-12 Agenda Items 1.19 and 1.22 in the national and regional preparatory meeting, and WRC-12 as the object of study for spectrum commons.

This study responds to the second sub-research question, which has three parts: (1) the IAD framework application in the WRC context, (2) the national and regional preparatory meetings for WRC, and (3) WRC-12 Agenda Item 1.19.

This study proposes the use of the IAD framework as the outline for a question within the action situation: WRC and relevant meetings. The justification for the IAD framework is also described and prescribed in Chapters 2 and 9. The results of the IAD framework application, indicating the limitation of the ITU archives, lack the dynamic situation or discussion in the meetings.

However, the IAD framework only provides a list of relevant questions, not the detailed content of the discussion. The participant observations by the author were pursued to capture the debate inside the meetings, as the missing information was left out of the ITU archives.

IAD application to the WRC context (Chapters 2 and 9)

The results of the IAD analysis show that the ITU archives are incomplete, because they lack the rationale underlying the RR provisions. The study further expands the element of the IAD framework to complete the missing information: the interaction or discussion comprising the attributes of community (common understanding between participants at the meetings), choice rules (the options that are available at the meetings), payoff rules and evaluative criteria (the evaluation of the option according to the choice rule), information rules (the information exchange in the meetings), aggregate rules (the control of the Member States' stance at the meetings), and action situation and interaction (discussion at the meeting).

This study also explains the limitations of the ITU archives that can be fulfilled by participant observation via attending meetings. However, the observation is only applicable to the situation in question.

This study also demonstrates the application of the IAD framework to the informal group (IG) IG6A2 1.19 at WRC-12 to show the missing information from the ITU archives.

National and regional preparatory meeting (Chapter 6)

The national and regional preparatory work assists the WRC preparatory process before WRC. The study elaborates on Thailand and Sweden as national preparatory processes and the APG and CPG as regional preparatory processes on WRC-12 Agenda Items 1.19 and 1.22.

During the discussion, the rationale on how this process changes, as well as the missing information, is available to attending Member States. The author participated in the national and regional preparatory meetings, providing the information that was missing from the archives.

This study also presents the missing information for WRC-12 Agenda Items 1.19 and 1.22 during the CPG, APG, and WRC-12 in Chapters 6, 8, and 9.

WRC-12 Agenda Items 1.19 and 1.22 (Chapters 7 and 8)

This study presents the details of WRC Agenda Items 1.19 and 1.22 from the ITU preparatory work, including the SG and RA. These two agenda items regarding SDR, CRS, and SRD represent spectrum commons at WRC-12.

This study also addresses the missing information during the discussion of WRC-12 Agenda Items 1.19 and 1.22. This missing information can be captured at sub-working group (SWG) and IG levels. The author attended the relevant meetings on WRC-12 Agenda Items 1.19 and 1.22 to illustrate the missing information from the ITU archives, which is the rationale underlying the discussion and is available only to attending participants.

The missing information during the discussions in informal meetings creates information asymmetry between attending and non-attending Member States. Moreover, the missing information at the SWG and IG meetings is not documented in the ITU archives. The information matters when the issue could change outcomes or propose new options. When such an issue continues to the next or future WRCs, the information matters to non-attending Member States that need it to prepare and develop their position at the relevant meetings if the issue has a strong effect on their interests.

The demonstration of WRC-12 Agenda Items 1.19 and 1.22 fulfills the ITU archives in terms of the Member States' discussions at the SWG and IG meetings. These discussions contain the rationale underlying the RR revisions. Moreover, the identification of the missing information for WRC-12 Agenda Item 1.19 also highlights the effects on the international spectrum policy at a higher level, such as at the WG, COM, and plenary.

Sub-research question 3: How does the missing information affect international spectrum policy?

The findings of this sub-research question demonstrate the importance of missing information during the decision-making process at WRC. The study focuses on WRC-12 Agenda Items 1.2, 1.19, and 1.22 in the national and regional preparatory meeting, and WRC-12 as the object of study for spectrum commons.

This study responds to the third sub-research question and has two parts: (1) the importance of WRC-12 Agenda Items 1.2, 1.19 and 1.22, and (2) a demonstration of the effects on international spectrum policy.

Importance of WRC-12 Agenda Items 1.2, 1.19, and 1.22

This study also presents the importance of the missing information with regard to the WRC-12 Agenda Item 1.2 from Thailand's perspective, in order to illustrate how the missing information affects Thailand's position in relation to further developing the argument for this agenda item in Chapters 1 and 8.

Moreover, the current situation of the FS and MS in Thailand is also provided as basic information to analyze the impact or consequences of FS and MS convergence. The background to the definition development of FS, fixed station, and mobile station for the ongoing issue to WRC-15 is also presented in Chapter 8.

This study presents the importance of WRC-12 Agenda Items 1.19 and 1.22 to Thailand as basic information to analyze the effects or consequences of the RR revisions in Chapter 7. It also considers the usefulness of the missing information in terms of WRC-12 Agenda Item

1.19 in demonstrating the valuable information to non-attending Member States that prioritize this agenda item in Chapter 9.

Effect on international spectrum policy

This study demonstrates the effects on Thailand of the missing information in WRC-12 Agenda Items 1.2 and 1.19 in terms of its importance as basic information to analyze its impact at the meeting and for ongoing issues for the next or future WRCs.

Moreover, the demonstration of the missing information in WRC-12 Agenda Item 1.19 at the SWG meeting influences non-attending Member States, as it is additional information to decide on at WRC-12.

The missing information represents the rationale of the RR revisions or the issues at the meeting and provides an understanding for Member States to develop further argumentation at the relevant meeting for ongoing debates or implementations, such as the RR provisions.

Sub-research question 4: How can the existing ITU archives be improved or completed?

The findings of this sub-research question propose policy recommendations to improve the ITU archive.

This study responds to the fourth sub-research question in the form of policy recommendations.

This study proposes four possibilities for completing the missing information in the ITU archives: (1) the meeting record together with the webcast archives, (2) minutes of the meeting below the level of the plenary session, (3) full utilization of the SharePoint Site during WRC, and (4) connection with a regional representative on each WRC agenda item, such as Member State networking. The study presents the results in Chapters 6 and 9.

Learning from IAD framework

The IAD framework helps in understanding the RR revision process by providing a list of relevant questions as independent and dependent variables in an action situation. The action situation is the decision in WRC-12 Agenda Items 1.19 and 1.22. The potential outcome is the RR revision as a dependent variable. The independent variables are representing by exogenous and endogenous variables. The exogenous variables are physical condition, attribute of community, and rules-in-use. The endogenous variables are directly connected with rules-in-use including boundary, position, choice, payoff, information, aggregation, and scope rules.

The IAD framework provides the systematic approach to explain the action situation of WRC, indicating the ITU archive limitation (lacking of rationale of RR revision). In other words, these variables explain the decision-making process at WRC-12 in terms of understanding the IAD variables as independent and dependent variables:

Independent variables

The physical condition represents the study object of the decision situation at WRC-12, i.e., the spectrum as the public goods, because the spectrum at WRC is allocated to services inside the TFA.

The attribute of community represents the common understanding at WRC, including the norm, culture, and tradition of the ITU and Member States.

The rules-in-use, represented by seven rules, explain the interaction at WRC, including actors (ITU membership), positions (head of delegation, delegate, regional representative, chairman, or secretary), and actions (support, oppose or neutral to meeting proposals), with direct connection to their cost and benefit of actions, information flow, and control over actions during negotiation. The possible outcomes of each proposal are addition, modification, suppression, or no change to the RR provision.

Dependent variables

The potential outcomes of the negotiation are RR revisions as the dependent variables of the action situation on each issue.

The IAD variables explain the decision-making situation at WRC-12 and indicate the limitation of ITU archive, which does include the rationale behind RR revision. These variables indicate the difference between the ITU archive and participant observation at WRC-12 and strengthen the understanding of the decision situation at WRC-12.

4.2 Paper II

Paper II Ard-paru, N. (2012). *Managing spectrum commons in Thailand: Allocation and assignment challenges.* Retrieved from http://www.lib.chalmers.se (ISBN 978-91-980300-3-7).

The main research question is "**How is the Radio Regulations transformed into National Broadcasting and Telecommunications Commission regulation for spectrum commons in Thailand?**". In order to answer this research question, the five sub-research questions are as follows:

Sub-research question 1: What are the main applications and technologies for spectrum commons?

The findings of this sub-research question present the main applications and technologies for spectrum commons, i.e., SRD, SDR, and CRS.

This study responds to the first sub-research question by providing the main applications and technologies for spectrum commons in terms of SRD, SDR, and CRS. The study concentrates on applications and technologies relating to ISM applications using the frequency band according to RR Nos. 5.138 and 5.150.

The main characteristics of the SRDs are non-interference and non-protection. Most SRDs use the ISM band, especially footnotes 5.138 and 5.150. Moreover, the power limitation in terms of magnetic and electric field strength and maximum power level varies from country to country. The allocation of frequency band to the ISM band is done at WRC. However, authorization of the use of SRDs is granted locally by the NRA. SRDs migrate national to international issues when unlicensed SRDs are transported from one country to another that does not allow the use of such SRDs. The use of unlicensed SRDs in countries where they are not permitted creates interference with existing services. However, regional and global harmonization of frequency bands may be possible.

The characteristics of CRS are obtained from the operational environment, changing the radio operational parameter simultaneously and automatically by software, and learning from experience to improve its performance. SDR is enabled technology for CRS because the characteristic of SDR is the ability to change the radio operational parameter simultaneously and automatically by software.

The characteristic of CRS provides the non-exclusive right to use a frequency that is the same as a spectrum commons characteristic. Therefore, SDR and CRS are the main technologies for spectrum commons.

Sub-research question 2: What is the spectrum allocation for spectrum commons and ISM applications, and how did they develop?

The findings of this sub-research question present spectrum commons allocation development in terms of ISM band development.

This study responds to the second sub-research question by elaborating on the result of international negotiations or the result of WRC in the form of the RR revision for spectrum allocation for radiocommunication services.

Spectrum commons are allocated in ISM application footnotes 5.150 and 5.138. Most of the short-range or low-power devices use the frequency under these provisions with non-exclusive use of frequency.

The current ISM bands are 6 765-6 795 kHz, 433.05-434.79 MHz, Region 2, 61-61.5 GHz, 122-123 GHz, 244-246 GHz, for 5.138; and 13 553-13 567 kHz, 26 957-27 283 kHz, 40.66-40.70 MHz, 902-928 MHz, Region 1, 2 400-2 500 MHz, 5 725-5 875 MHz, and 24-24.25 GHz for 5.150.

The first allocation was for low-power stations in the European region in RR1938 and ceased in RR1947. Most of the ISM bands were developed in RR1982 and continued to be used until RR2012.

This study shows the development of each ISM band and indicates the differences between them. Footnote 5.138 requires special authorization to operate, while footnote 5.150 allows other services to share the same frequency with acceptance of harmful interference from ISM applications. Neither 5.138 nor 5.150 provides the explicit ITU recommendation, however, the relevant ITU-R recommendation is Recommendation ITU-R SM.1056-1: Limitation of radiation from industrial, scientific and medical (ISM) equipment.

Sub-research question 3: *What is spectrum assignment, especially spectrum commons, in Thailand, and how did it develop?*

The findings of this sub-research question present spectrum commons assignment development in Thailand.

This study responds to the third sub-research question by exploring the NBTC archives, including the relevant NFMB minutes, and the PTD, NTC, NBTC, MOT, and MICT regulations.

The study demonstrates the development of spectrum assignment in Thailand. Thailand has developed spectrum assignment from a command-and-control to a market-based approach. Spectrum was initially for use by a limited number of parties, first only the government agency and then it was extended to the general public. The development of the spectrum assignment agency in Thailand included the PTD, NFMB, MICT, NTC, ONTC, NBTC, and ONBTC, in order to change the authorization to a licensing scheme or command-and-control to market-based economics.

The study also illustrates the development of spectrum commons in Thailand since the NFMB in terms of authorization of the use of 1-watt transmitters. The Ministerial Regulation allowed low-power devices with relevant licences. The PTD regulations allowed the use of WLAN indoor applications and extended this to outdoor applications. Finally, as the first unlicensed regulation in Thailand, the Ministerial Regulation of the Exemption of Radiocommunication Licences in 2004 allowed low-power devices without relevant licences.

Sub-research question 4: *How should spectrum commons regulation be transformed from the RR into national NBTC regulation? What are the challenges?*

The findings of this sub-research question demonstrate the transformation of the spectrum commons regulation from the RR into the NBTC regulations.

The study responds to the fourth sub-research question by exploring the current RR2012 and Thailand TFA 2012 for ISM definition, footnotes 5.138 and 5.150, and TFA. Moreover, the study demonstrates the transformation from international into national regulations:

There are two phases. Firstly, footnotes 5.138 and 5.150 are adopted in the Thai TFA, including the ISM definition, footnotes, and frequency bands. However, the definition of ISM applications is not explicitly shown in the Thai TFA. Both footnotes 5.138 and 5.150 are adopted, corresponding to frequency bands in Region 3 in the Thai TFA.

The RR TFA represents the IAD rules-in-use in the constitutional situation, which influences the Thai TFA, in the form of rules-in-use in national regulation at the constitutional level in Thailand. In addition to the RR TFA influencing the use of spectrum commons in Thailand, national regulation, i.e., the Radiocommunication Act B.E. 2498 (1955), also represents the rules-in-use in the constitutional situation in Thailand. The Radiocommunication Act prohibits the use of radiocommunication devices unless permission is granted by the authorities.

Secondly, the development of national regulation allows the use of spectrum commons with regard to lower power radiocommunication. In 1975, the first spectrum commons was granted by the NFMB to the PTD allowing 1-watt transmitters for pagers and anti-theft devices. However, the use of these devices required relevant radiocommunication licences. Several additional national regulations have been developed over time to allow more frequency bands for spectrum commons with maximum power and technical specification. Ten current relevant NBTC regulations are shown in the previous section and categorized into Thailand footnotes: T-Unlicensed 1, 2, and 3 in Tables 22-24 with relevant radiocommunication licenses. In addition to the frequency bands specified by footnotes 5.138 and 5.150, other frequency bands were allowed to be used as spectrum commons in Thailand, including the frequency band lower than 135 kHz, 1.6-1.8 MHz, 30-50 MHz, 54-74 MHz, 88-108 MHz, 165-210 MHz, 300-500 MHz, 920-925 MHz, 5.150-5.350 GHz, 5.470-5.725 GHz, 10-10.6 GHz, 76-81 GHz, 72-72.745 MHz, 78-79 MHz, 245-246 MHz, 510-790 MHz, 794-806 MHz, 925-920 MHz, 1 900-1 906 MHz, and 76-77 GHz.

The challenges of transforming international regulation into national regulation both in terms of allocation and assignment are reflected by the advantages and disadvantages of spectrum commons. The challenges of the advantages are to maintain them in a sustainable way. The challenges of the disadvantages are to reduce them as much as possible.

The study applies the IAD framework to understand the transformation from the RR into the NBTC regulation for spectrum commons in Thailand in terms of the definition of ISM applications, footnotes 5.138 and 5.150, and the frequency bands in the TFA.

Sub-research question 5: *How is the IAD framework relevant to spectrum management?*

The findings of this sub-research question illustrate the relevance of the IAD framework to spectrum management activities.

The study responds to the fifth sub-research question by applying the IAD framework in terms of the level of analysis and outcomes to demonstrate the relationship between spectrum management activities at different levels of analysis. The study uses three levels of analysis and outcome, namely constitutional, collective-choice, and operational situations.

The constitutional situation represents rule setting, review, and revision at international and national level that is directly influenced by the collective-choice and operational situation, including the RR (allocation and allotment of frequency), National Frequency Management Master Plan, TFA (planning and regulation), and international and regional cooperation.

The collective-choice situation represents the ability to review and revise operational rules, including how to assign or license frequency, authorize equipment, charge license fees, and coordinate if interference occurs. Moreover, standard setting, assignment and licensing, and international and regional cooperation on the setting of rules are done at this level. Spectrum monitoring and regulation enforcement are also performed to provide information back to spectrum planning.

The operational situation represents day-to-day or routine work corresponding to the rules that have been specified in the collective-choice situation. The spectrum management activities at this level are assignment and licensing, equipment authorization, international and regional cooperation, national liaison and consultation, and support functions.

The study also illustrates the IAD application to spectrum management activities by analyzing and describing the spectrum management activities according to aspects of the IAD framework, including physical condition (spectrum as public goods for allocation, spectrum as private and common-pool goods for assignment), attributes of community (a common understanding among stakeholders in spectrum management including ITU, Member States, manufacturers, operators, and end-users), rules-in-use (the RR, national regulation, network rules, standard of equipment), action situation and interaction (spectrum management activities between stakeholders: regulators, operators, manufacturers, standard-setting bodies, and end-users), outcome, and evaluative criteria (efficient use of spectrum and the balance of benefit between stakeholders).

Learning from the IAD framework

The IAD level of analysis and outcomes help in understanding the differences and relationship between international and national regulations in the constitutional situation. The international regulation, i.e., the RR, is the independent variables of the national regulations, i.e., the NBTC regulations (a dependent variable). The IAD framework helps to explain the RR as rules-in-use (exogenous variables) that are influencing the NBTC regulations, e.g., the Thai TFA.

In order to completely transform the RR into national regulation, the NBTC has to endorse the Thai TFA with changes according to the RR revisions. Consequently, the relevant NBTC regulations may be changed according to the Thai TFA revision.

Moreover, the IAD level of analysis and outcomes help in understanding the multi-level relationship and to categorize the spectrum management activities into three main levels according to constitutional, collective-choice, and operational situations. In the constitutional situation, the activities are relevant to rule setting, such as allocation and allotment of frequency, and planning and regulation, at both international and national levels. In the collective-choice situation, the activities represent the ability to review and revise operational rules, such as assigning and licensing frequency, and standard setting. In the operational situation, the activities are the day-to-day activities of spectrum management including frequency assignment and licensing.

The spectrum management activities that are categorized by the IAD level of analysis and outcome clearly show the relationship between main activities and level of analysis and outcome. Moreover, the relationship of rule setting between the international and national level is part of the rules-in-use. The main independent variables are the rule setting that influenced the assigning and licensing frequency as dependent variables for spectrum management activities.

4.3 Paper III

Paper III Ard-paru, N. (2010). *Spectrum assignment policy: Towards an evaluation of spectrum commons in Thailand.* (Licentiate thesis). Retrieved from http://www.lib.chalmers.se (ISSN 1654-9732).

The main research question is "**What are the consequences of using spectrum commons for frequency assignment in Thailand?**". In its approach to the main research question, the thesis addresses five sub-research questions:

Sub-research question 1: What is a suitable framework for analyzing different types of spectrum commons

The findings of this sub-research question provide a framework for analyzing spectrum commons.

The economics of institutions and three worlds of action from Schlager and Ostrom (1992) provide the level of analysis for the decision-maker and decision situation. The property rights regime and natural resources in the Maine lobster industry from Kiser and Ostrom (1982) also provide the rights to use the common-pool resource. These two concepts provide a framework for analyzing the right to use frequency in Thailand. The chronology of events for spectrum management in Thailand provides evidence of the rights to frequency use.

The market-based approach has all the rights to use frequency, including access and withdrawal, management, exclusion, and alienation rights (i.e., selling or leasing frequency). Command-and-control does not have an alienation right, however. The command-and-control and market-based approaches both grant the exclusive right to use frequency to licensees. Spectrum commons does not have an exclusive right to use frequency, however. There are two types of users in spectrum commons, i.e., general and advanced users. These users have access and withdrawal rights because of the characteristics of transceivers. The transceivers are specified to access and use the frequency at the same time. Only advanced users have the additional exclusion right to determine who can use their network by setting passwords or encryption codes.

Sub-research question 2: What type of spectrum commons has been used in Thailand?

The findings of this sub-research question demonstrate the development of spectrum commons in Thailand.

There are three types of spectrum commons, i.e., public commons, private commons, and unlicensed. Regulators delegate some rights to licensees to manage their network. These represent the regulated level. When the state agency is in charge of network management, it is called public commons. For example, local municipalities have their Wi-Fi network for their community. When private entities manage their network for commercial service, it is called private commons, such as the public Wi-Fi hotspots in hotels, airports, department stores, etc. When end-users have to manage the network by themselves, it is called unlicensed.

The history and development of the spectrum management institution in Thailand also constitutes an original source that documents important events concerning spectrum management, especially spectrum commons in Thailand. There are two steps to implementing spectrum commons in Thailand: 1) the authorization of the use of devices, and 2) the exemption of relevant radiocommunication licences.

Sub-research question 3: What are the advantages and disadvantages of spectrum commons in general?

The findings of this sub-research question illustrate the advantages and disadvantages of spectrum commons.

Advantages of spectrum commons include lowering barriers to entry, reducing administration costs, encouraging innovation, and stimulating demand. On the other hand, the main disadvantage of spectrum commons is irreversibility. After the NRA assigns frequency to users, it is hard to get the frequency back to the NRA to reassign or refarm such frequency to new users or services. A comparison of the advantages and disadvantages is required to determine the net benefit of spectrum commons. Most disadvantages can be resolved by the development of new technology and a relevant standard of devices, apart from irreversibility once spectrum commons has been assigned to public use.

Sub-research question 4: How can the benefits and costs of spectrum commons be measured?

The findings of this sub-research question present a benefits and cost analysis to measure the value of spectrum commons in Thailand.

The benefits and cost analysis provides the framework for evaluating the spectrum. The specified frequency for spectrum commons is the 2.4 GHz band. The applications of the 2.4 GHz bands include public Wi-Fi operators and home data networking. The evaluation of spectrum commons can be used as important information for regulators to decide whether to have licensed or unlicensed spectrum.

The 2.4 GHz band has been identified as the operating frequency. Public Wi-Fi routers and home data networking (home Wi-Fi routers) are the focus of the spectrum commons evaluation. The possible benefits for public Wi-Fi operators are revenue, cost saving from wiring, and license exemption. The possible costs for public Wi-Fi operators are wireless routers, installation and maintenance costs, Internet connection, and the ISP license fee. The possible benefits of home data networking are cost savings from wiring, license exemption, and increasing flexibility. The possible cost is the wireless router.

Sub-research question 5: What are the implications of implementing spectrum commons in Thailand?

The findings of this sub-research question present the implications of implementing spectrum commons in Thailand.

Three types of spectrum commons have been used in Thailand (public commons, private commons, and unlicensed). They provide the current status of spectrum commons in Thailand. These three types also appear in other countries that have a similar situation.

Regulators should use these findings for further consideration of using spectrum commons to increase spectrum efficiency in terms of utilization of frequency and distribution of frequency to users.

Regulators should conduct a similar public consultation to identify the advantages and disadvantages of spectrum commons in their context to adjust to their environment.

The regulator may consider adding spectrum commons to other frequency bands, imposing power limitation, and specifying frequency as necessary constraints. These constraints have a strong potential to attract innovation. The market will select services and applications freely under the constraint to respond to demand. The low entry barrier makes spectrum easier to access and encourages competition in the market. End-users will have better quality of service and lower prices.

Regulators should use the evaluation of spectrum commons as important information for deciding whether to have licensed or unlicensed spectrum. The spectrum evaluation will reflect the best utilization of spectrum. Greater use of spectrum commons for frequency assignment will increase spectrum efficiency in terms of the number of frequency users and spectrum utilization.

The regulator should consider the loss of the frequency usage fee through non-exclusive rights. On the other hand, operators and end-users gain the benefit of not paying the frequency usage fee. The benefits to society may be greater than the lost income for the regulator.

Learning from the IAD framework

The IAD framework helps in understanding the bundle of rights to use frequency after frequency assignment, including access, withdrawal, management, exclusion, and alienation rights at the two levels of analysis and outcome. In the operational situation, the action situations are to use or not to use frequency as turn on or off devices (access and withdrawal rights). In the collective-choice situation, the action situation is rule setting, including how to manage frequency, exclude non-users, and lease and rent frequency (management, exclusion, and alienation rights). The rule setting is the independent variables to use or not to use frequency (a dependent variable).

Regarding the action situation for assigning frequency, the dependent variable is whether to assign frequency with an exclusive or non-exclusive right to licensees. The independent variable is the method of frequency assignment, including command-and-control, market-based, and spectrum commons. Command-and-control and market-based approaches both provide an exclusive right to use frequency, but spectrum commons does not. The regulator (actor and position) has to make decisions on frequency assignment methods (choices) based on the cost and benefit of each method (payoff).

The advantages and disadvantages of spectrum commons are the cost and benefit when assigning frequency for spectrum commons. The advantages and disadvantages provide an overview of the use of spectrum commons as crucial information for the NRA to assign frequency, whether licensed or unlicensed.

Moreover, the value of frequency represents one of the key parameters as it is an indicator for the regulator to decide on a suitable method of spectrum assignment for such frequency bands.

The advantages, disadvantages and value of spectrum commons represent the information in the decision situation as the IAD payoff rules and evaluative criteria.

The additional independent variables are regulator, advantages and disadvantage, and value of frequency. The dependent variable is assigning frequency.

The IAD framework helps in the systematic understanding of assigning frequency through its variables inside the action situation, including boundary, position, choice, payoff, information, aggregation, and scope rules as independent variables. The potential outcome is frequency assignment as a dependent variable.

4.4 Connection between papers

The study demonstrates a comprehensive understanding of spectrum commons implementation in Thailand. Initially, spectrum commons allocation was carried out at international level via WRC in the form of the RR, especially footnotes 5.138 and 5.150 for the ISM band. These two footnotes represent the spectrum commons allocation. Paper I demonstrates the frequency allocation at WRC via the WRC processes: WRC agenda setting and study processes. The study focuses on WRC-12 Agenda Items 1.19 and 1.22 as an object of study to illustrate the WRC processes that are relevant to spectrum commons issues from national and regional preparatory meetings and WRC-12.

After understanding spectrum commons allocation at WRC in terms of the RR, the transformation of the spectrum commons regulation from international regulation into national regulation is demonstrated in Paper II. The study illustrates the development of spectrum commons regulation in terms of footnotes 5.138 and 5.150, together with the relevant frequency bands. The footnotes and frequency bands from the RR TFA are then both transformed into national regulation in Thailand. The footnotes and frequency bands have been converted into the Thai TFA in the form of the national regulation for spectrum commons.

After the transformation of spectrum commons from international into national regulation has been completed, the study describes the national implementation of spectrum commons in the form of spectrum assignment development in Paper III. All radiocommunication devices require relevant licenses. National regulation has been developed for spectrum commons in Thailand, including authorization and unlicensing in terms of the Ministerial Regulations for the NBTC regulations.

To conclude, the study demonstrates a comprehensive view on spectrum commons implementation in Thailand by using the IAD framework, including spectrum commons allocation at WRC, transformation of spectrum commons regulation from international into national regulation in terms of footnotes 5.138 and 5.150 within the Thai TFA, and finally implementing spectrum commons regulation in terms of unlicensed regulation as the NBTC regulations.

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Chapter 5 Discussion of IAD relevance

The study synthesizes the connection between Papers I, II, and III in terms of the relevance of IAD to spectrum commons.

The overarching research question for this study is "**How should spectrum commons be implemented in Thailand?**". Connecting three main research questions from three papers illustrates the implementation of spectrum commons in Thailand, starting with the allocation of spectrum commons through international regulation in the RR at WRC, transforming international regulation into national regulation in Thailand, and concluding with the implementation of spectrum commons as a national regulation in Thailand.

The study applies the IAD framework to connect the spectrum commons issues from each paper.

5.1 IAD framework and its connectivity

The overarching research question is "**How should spectrum commons be implemented in Thailand?**", as the common ground for connecting the main research from the three papers:

1) How is international spectrum policy developed and affected by the lack of more detailed documentation? (Allocation of spectrum commons)

2) How is the Radio Regulations transformed into the National Broadcasting and Telecommunications Commission regulation for spectrum commons in Thailand? (Transformation of international into national regulation for spectrum commons)

3) What are the consequences of using spectrum commons for frequency assignment in Thailand? (Implementation of national regulation for spectrum commons in Thailand)

The study illustrates Papers I, II, and III using the IAD framework to demonstrate the relationship and connections as shown in Figure 7.

Paper I	Paper II	Paper III
Spectrum commons		Spectrum commons
Allocation At the WRC as RR revision	**Transformation**	Assignment Bundle of rights to use frequency
International regulations		National regulations

Figure 7. Summary of research problem (cf. Figure 3, Chapter 1)

The overarching research question involves connecting the allocation (Paper 1) to the assignment (Paper III) of spectrum commons via transformation from allocation into assignment (Paper II).

Paper I: Information and coordination in international spectrum policy: Implications for Thailand

Paper I represents the development of spectrum commons allocation in the RR via the decision-making process at WRC by the WRC-12 preparatory process for Agenda Items 1.19 and 1.22.

This study applied the IAD framework to WRC in order to find the missing information as the rationale behind the RR revision, including the ITU archive and WRC-12. This paper used the IAD framework element to explain the decision-making process at WRC-12 as an IAD action situation.

Table 11 illustrates the IAD application for WRC, with differences between the ITU archive and participant observation at the WRC-12 meetings.

The "IAD variable" column represents the IAD variables: exogenous and endogenous. The "WRC" column shows the IAD application at WRC. The "RR/WRC Archive" and the "Participant observation" columns reveal the ability of documents in the ITU archive and information gathered from participant observations to correspond to the IAD variables.

Table 11. IAD variable map, missing data, and observer activities

IAD variable	WRC	RR/WRC Archive	Participant observation	
			PTA, CPG, APG	WRC-12
Physical condition	Spectrum as public good	X	X	X
Attribute of community	Norm, culture, and tradition		X	X
Rules-in-use				
Boundary	ITU membership	X	X	X
Position	HoD, regional rep., chair, secretary	X	X	X
Choice	Support, oppose, neutral		X	X
Payoff	Cost and benefit		X	X
Information	Public or informal information flow		X	X
Aggregate	Control over choice		X	X
Scope	ADD, MOD, SUP, NOC	X	X	X
Action situation	Negotiation		X	X
Interaction	Negotiation		X	X
Evaluation criteria	Link payoff rules		X	X
Outcome	Link RR revisions to scope rules	X	X	X

Source: Ard-paru (2012a), Table 10

The IAD exogenous and endogenous variables are independent variables of an action situation. In this case, the action situation is WRC-12 Agenda Items 1.19 and 1.22. The exogenous variables are physical conditions of the spectrum, attribute of community of ITU and Member States, and rules-in-use that are influencing endogenous variables. The endogenous variables are represented by seven rules, i.e., boundary, position, choice, payoff, information, aggregation, and scope rules. The dependent variable is the outcome of the action situation.

The ITU archive can respond to the physical condition, boundary, position, and scope rules that cannot capture the dynamic situation of the meeting. However, the participant observation can respond to all of the IAD variables but is limited to the current situation.

The outcome of the action situation depends on independent variables such as when the new information is expressed, and the position or stance of actors must be considered. The detailed discussion will be explained in a later section.

To summarize, the IAD framework provides a list of relevant questions in an action situation, not detailed contents. The participant observations can provide detailed discussions for the current situation. The archives cannot respond to or capture the dynamic of the meetings. The archive can only cover the physical IAD conditions, boundary, position, scope rules and outcome that are not covered by the rationale behind RR provision.

When using the ITU archive (RR and WRC proceedings), the limitations of the missing information should be taken into account.

Paper II: Managing spectrum commons in Thailand: Allocation and assignment challenges

Paper II represents a bridge between Paper I and Paper III, from allocation to assignment for spectrum commons in Thailand. By using the IAD framework levels of analysis and outcomes in a constitutional situation, the RR (definition of ISM application, footnotes 5.138 and 5.150, and frequency bands within the TFA), works as the IAD rules-in-use that influence the rules-in-use in a constitutional situation in Thailand. Thailand must transform the RR (international rules-in-use) into national regulation.

This transformation is part of the spectrum management activities in allocation frequency bands according to the RR and national TFA. Table 12 presents the spectrum management activities with IAD levels of analysis and outcome.

The spectrum management activities represent the action situation of making decisions. The rule setting activities in the constitutional and collective-choice situations provide the independent variables to rules-in-use in the operational situation. The outcomes of spectrum management are frequency assignment and licensing and its relevant activities (standard of equipment and cooperation of use), representing the dependent variable of spectrum management.

In the constitutional situation, the activities relate to creating, reviewing, and revising the RR, including allocation and allotment of frequency to services, international and regional coordination, the National Frequency Management Master Plan, and the TFA. These spectrum management activities provide rules in the constitutional situation that influence the rules for collective-choice and day-to-day activities in the operational situation.

In a constitutional situation in Thailand, not only the RR as an international regulation but also the Radiocommunication Act and NBTC Act must be taken into account for Thai regulation, or rules-in-use for Thailand.

Table 12. Spectrum management activities with IAD levels of analysis and outcomes

Spectrum Management activities	Constitutional	Collective-choice	Operational
Spectrum management planning and regulations	x		
Allocation and allotment of frequency bands	x		
Frequency assignment and licensing		x Rule setting	x Compliance
Spectrum management financing		x	
Standard, specifications, and equipment authorization		x Setting	x Compliance
Spectrum monitoring		x	
Spectrum regulation enforcement		x	
International and regional cooperation	x Rule setting	x Rule setting	x Compliance
National liaison and consultation			x
Support function			x

Source: Ard-paru (2012b), Table 27

In the collective-choice situation, the spectrum management activities that implement the rules from the constitutional situation create the rules for the operational situation such as how to assign the frequency: first-come first-serve or auction, rules on how to use a network or standard settings for permissible devices, and rules on how to coordinate between operators in neighboring countries when interference occurs. The fee calculation formula for spectrum management financing activities is also established at this level.

Furthermore, spectrum monitoring for the use of frequency and spectrum regulation enforcement: inspection and investigation of the use of radiocommunication devices is included at this level to supervise day-to-day activities for frequency assignment and licensing and to provide the information to spectrum planning.

In the operational situation, the day-to-day or routine activities of spectrum management comprise assignment, licensing, standard compliance, cooperative protocol compliance, consultation of rules, and supporting activities.

Assignment and licensing activities are carried out according to specified rules in the collective-choice situation, i.e., which frequency can be assigned with technical specification, which licenses are applied, and what fees are charged.

Radiocommunication equipment standard compliance is performed according to a predefined standard setting and procedures carried out in the collective-choice situation, i.e., which standard or equipment is allowed to be used in Thailand.

During frequency coordination between countries, when the interference is found, both the regulator and operator in the relevant countries must follow the rules as specified in the collective-choice situation to identify and eliminate such interference.

National liaison and consultation activities comprise day-to-day work to create a common understanding of the rules with regard to public consultation or focus groups. Output information would benefit from greater efficiency of rule implementation at higher levels.

The support activities aim to facilitate the main spectrum activities on a daily basis, including technical and administrative support.

This study classifies the spectrum management activities into the IAD level of analysis and outcomes to understand the interaction between each activity and relationships across levels. All spectrum management activities dealing with rule setting are carried out in the constitutional or collective-choice situations. Day-to-day activities performed according to specified rules are in the operational situation.

According to the IAD framework, spectrum management activities can be described as follows:

Biophysical conditions: This study deals with spectrum that can be public, private, or common-pool goods depending on the allocation and assignment approach. Spectrum allocation at international level can be treated as public goods. On the other hand, spectrum assignment at national level can be treated as private or common-pool goods, depending on the assignment approach used.

Attributes of community: Spectrum management involves many stakeholders from international to national level including the ITU, Member States, manufacturers, operators, and end-users. A common understanding between them is essential in order to understand the regulation and properly implement it in order to ensure frequency efficiency with or without minimal harmful interference.

Rules-in-use: The rules-in-use of spectrum management are represented by the RR, national regulation, the network rules of operators, and manufacturers' equipment standards. These rules directly influence the action situation and interaction between stakeholders in spectrum management activities.

Action situation and interaction: Spectrum management activities represent the action situation and interaction between stakeholders in each activity and the various aspects of the decision-making process. From rule setting to implementation of rules by the regulator, manufacturers, operators, and end-users, these represent the action situation and interaction in spectrum management.

Outcome: the ultimate outcome of spectrum management is the efficient use of spectrum with manageable harmful interference via frequency assignment and licensing. Moreover, the outcome is directly influenced by the evaluative criteria, which vary between countries and stakeholders. The challenge is to balance the benefit and outcome with the sustainable use of spectrum.

The independent variables are the physical condition, attribute of community, rules-in-use (with seven rules of the exogenous variable), and the action situation. The dependent variable has frequency assignment and licensing as the outcome.

To summarize, the study uses the IAD framework to demonstrate the transformation of international regulation into national regulation for spectrum commons in Thailand in terms of the definition of ISM application, footnotes 5.138 and 5.150, and frequency bands within the TFA.

Paper III: Spectrum assignment policy: Towards an evaluation of spectrum commons in Thailand.

Paper III applied the IAD framework to understand the bundle of rights to use frequency for spectrum assignment in Thailand, especially spectrum commons, in order to implement the spectrum commons regulation with the aspect of national regulation in Thailand, including authorization for the use of spectrum commons and exemption of radiocommunication licenses as unlicensed.

The study began by applying the level of analysis and outcomes to the Thai telecommunication industry and subjected the relevant stakeholders to various levels of analysis and outcomes.

The stakeholders who perform frequency planning, allocation, allotment, and coordination are the administrator, regulator or authority in the constitutional situation. The outcome of this level is the independent variable for rules-in-use in the collective-choice situation. The examples of constitutional rules are the Radiocommunication Act, NBTC and NTC Act, NBTC and NTC regulations, PTD regulations, TFA, and National Frequency Management Master Plan.

In a collective-choice situation, the activities are rule settings that are relevant to network rules and standard of equipment by operators, providers, and standard-setting organizations. They use the constitutional situation rules such as the NBTC regulation and the Thai TFA, as their independent variables and to create their own standard and network rules as the rules-in-use in the operational situation, such as the standard for Wi-Fi, mobile phones, smart card readers/writers.

In an operational situation, the users have to use and comply with the devices provided by their operator or manufacturer.

Moreover, the study applied the IAD framework to classify the bundles of rights to use frequency as licenses (outcome of spectrum management as a dependent variable) in different stakeholders including the regulator, Operators A and B, advanced users, and general users.

The boundary rules are defined by access and withdrawal rights, indicating who can access and use the frequency of devices. When a radio transmitter, receiver or transceiver is on, the access and withdrawal rights of frequency are engaged. General users only have access and withdrawal rights. The management right regards how to consume the frequency and which technique or equipment can be used. The exclusion right selects who can consume the frequency. The alienation right allows frequency to be sold or sub-leased.

The position rules are the regulator, Operator A, Operator B, advanced user, and general user. The choice rules are the option to use frequency: access and withdrawal frequency. The interactions between the user and radiocommunication devices have been predefined according to the rules in the collective-choice situation. The information, aggregation, payoff, and scope rules are the interactions of users and devices, i.e., to use or not to use the devices.

The seven rules represent the independent variable for the outcome of using or not using the devices as the dependent variable.

In the collective-choice situation, the action situation is rule changing or revising the use of frequency, including how to access, withdraw, change, sell, and lease the frequency. The boundary rules are similar to those in the operational situation: access withdrawal rights. However, the position rules are limited to the regulator, Operator A, Operator B, and advanced user. As for the position rules, only the regulator and Operator A have a full choice of actions to access, withdraw, change, sell, and lease the frequency. Operator B has no right to sell or lease the frequency. The advanced user has the additional right to identify the person who can access and use the frequency. The interactions between actors on rule changing represent information, aggregate, payoff, and scope rules. The outcome is possible rule changes on using frequency.

The right to use frequency can be divided into two categories: exclusive and non-exclusive, with the level of deregulation determined by the regulator (giving away an alienation right: right to sell, lease, or transfer the frequency) or network management right.

For exclusive use of frequency, the command-and-control approach is carried out by the centralized regulator or state agency. The market-based approach is carried out by the market mechanism.

For non-exclusive use of frequency, the spectrum commons approach has been introduced. When networks such as public Wi-Fi are managed by the state or a local municipality, they are called public commons. When the network is managed by a private company, it is called private commons, such as hotspot providers in hotels, supermarkets, and airports. When the network is managed by users or is self-regulated, it is unlicensed.

To summarize, Paper III applied the IAD framework to understand the bundle of rights to use frequency associated with stakeholders, including access, withdrawal, management, exclusion, and alienation rights. The stakeholders for the bundle of rights to use frequency are general users, advanced users, Operator B (without alienation right), Operator A (with alienation right), and regulators. Moreover, the IAD framework helps in understanding the different levels of analysis and outcomes between stakeholders, including administrators, regulators, or authorities in a constitutional situation; operators, providers, standard-setting organizations in a collective-choice situation; and users in an operational situation. Furthermore, the deregulated level provides differences between exclusive and non-exclusive use of frequency such as command-and-control for centralized agencies, market-based when regulators deregulate in order to use a market mechanism. For non-exclusive use of frequency, the regulated level depends on the ability to manage the network, including public commons, private commons, and unlicensed for the state agency, private companies, and end-users, respectively.

5.2 The bottom-up initiatives

The study explains the relationship between Papers I, II, and III in terms of spectrum commons implementation in Thailand including the spectrum commons allocation at WRC, transformation of spectrum commons regulations from international into national regulation, and implementing spectrum commons in Thailand at national level. Figure 7 depicts the top-down approach in the international to national direction.

However, the backward relationship, or bottom-up initiatives from national to international levels as a feedback loop, is already included in this study in part of the WRC preparatory process (see Chapter 6, Paper I for details).

The national initiatives originate from the Member States' concerns over the RR revision, representing the national demand or request for the use of radiocommunication services or equipment that require changes to the current RR. The request may be initiated by the local telecommunication industry, standard-setting organization, or general users regarding the difficulties of using radiocommunication equipment according to the current RR.

The NRA has to consolidate the request for RR changes into the Member State contributions in order to submit them to WRC for consideration. When the issues ally with other countries' contributions, such issues can form multi-country or common regional proposals to WRC.

However, the points or issues for RR revision must be defined in advance as part of the WRC preparatory process: the WRC agenda setting and study process, i.e., two WRC cycles for agenda setting and one WRC cycle for the study process. The ITU Member States submit their contribution concerning issues of RR revision to part of the WRC agenda item (WRC agenda setting). Once the WRC agenda items are approved at WRC, the WRC study process has to be conducted by the relevant ITU SG to study and gather possible solutions based on the ITU Membership submission. At the end of the process, the Member States make decisions based on the ITU SG study as part of the CPM report and the Member States' submission at the consequent WRC.

The bottom-up initiatives based on the national request are therefore incorporated in the WRC preparatory process (WRC agenda setting and study process) to raise the national issues to the international agenda via WRC.

5.3 IAD framework and its hypothetical outcome

In an action situation, there are many independent variables, including boundary, position, choice, information, aggregate, payoff, and scope rules. There is one dependent variable: the potential outcomes.

The boundary rules provide actors in the selected action situation. The position rules present the position of actors inside the action situation with the possible choices of actions as choice rules. The choices are directly connected to the payoff rules to analyze the net cost and benefit of such actions. The aggregate rules represent the control over the preferable outcomes to either keep the same or change to the new position. The information flows inside the action situation influence the choice of actions and consequently the payoff and aggregate rules. The possible outcomes of choices represent the scope rules. The potential outcomes are the output of the action situation as the taken decisions.

At WRC-12, the action situation is the revision of the RR according to the defined agenda items. The possible outcomes as scope rules depending on issues are no change to the RR (NOC), modification of the RR (MOD), adding new regulation (ADD), and deleting the provision of the RR (SUP). However, the potential outcomes can be reached via consensus or compromise between ITU Member States, depending on the level of coherence of the issues (information rules).

When there is coherence of input documents from Member States in terms of the individual, multi-country, or regional proposal, it is possible to reach a consensus between Member States with an agreeable potential outcome.

On the other hand, when there is incoherence in the input documents, consensus between Member States cannot be reached, and the compromised solution is preferable.

In the action situation, during the meetings, when there is a representative on behalf of the regional group (position rules), it is highly likely to reach either a consensus or compromised solution more easily than for individual Member States.

The available choices of actions for actors inside each action situation are support, abstain, and object (veto). Each Member State considers the choice of actions according to its interests (payoff rules). The Member States' stance represents the aggregate rules, remaining or changing from the previous position, which directly links the payoff rules and consequent potential outcomes.

When there is only one objection on each issue, the compromise solution between concerned Member States must be reached to maintain the ITU tradition without voting.

At the CPG-12, the EU regional preparatory meeting, one administration objected to the EU proposal on WRC-12 Agenda Item 1.19, and there was therefore no common EU proposal to WRC-12. However, the multi-country proposal on this agenda item was sent to WRC-12 instead.

5.4 Summary and discussion

Summary

Paper I is about spectrum allocation for spectrum commons. This paper applied the IAD framework to understand the international spectrum allocation process at WRC via the WRC preparatory process (WRC agenda setting and study process). Moreover, the IAD framework helps to identify the missing information as the rationale behind the RR provision. The IAD framework provides a list of relevant questions for the decision-making process, not detailed information. The participant observations provide the detailed content contained in the rationale behind such a provision. The ITU archive is incomplete and cannot capture the dynamic discussion at the meetings. The archive can only respond to the physical IAD condition, boundary, position, scope rules, and outcome. The use of ITU archives should take into consideration the limitations of the rationale behind such provision.

In Paper II, the study applies the IAD framework to understand the transformation from RR into NBTC regulation for spectrum commons in Thailand in terms of the definition of the ISM application, footnotes 5.138 and 5.150, and frequency band in the TFA.

Paper III is about spectrum assignment for spectrum commons. This paper applied the IAD framework to understand the bundle of rights to use frequency for frequency assignment in Thailand, including access, withdrawal, management, exclusion, and alienation rights. Together with the relevant stakeholder at each level of analysis and outcomes, there are regulators, administrators, or authorities in a constitutional situation; operators, providers, and standard-setting organizations in a collective-choice situation; and users in an operational situation. Moreover, the command-and-control and market-based approaches provide exclusive use of frequency. The spectrum commons approach, including public commons, private commons, and unlicensed frequency, provides non-exclusive use of frequency depending on the level of network management.

Finally, the study uses Paper II to link Paper I to Paper III, as the transformation from international into national regulation for spectrum commons in Thailand. Moreover, the study also applied the IAD framework to understand the bundle of rights to use frequency for spectrum assignment in Thailand in Paper III. Furthermore, to understand the WRC process for spectrum commons frequency allocation, the study applied the IAD framework to find the missing information as the rationale behind RR provision. The list of relevant questions provided by the IAD framework helps to identify the incomplete information from the ITU archive and the contribution from archives and participant observation in Paper I.

Discussion on IAD framework and decision situation

The study applies the IAD framework to address the implementation of spectrum commons regulation in Thailand via three papers in order to illustrate the connection between spectrum commons allocations, transformation of spectrum commons regulations from international into national regulations, and implementing spectrum commons regulation at national level.

The level of analysis and outcomes determines where action situations take place. The spectrum commons allocations are in the constitutional situation at international level. The transformation of spectrum commons regulations is in the constitutional situation between the international and national levels. The implementation of spectrum commons regulation in Thailand is in the constitutional situation at national level.

Table 13 summarizes the IAD variables in terms of the independent and dependent variables of the three papers.

Table 13. IAD independent and dependent variables (cf. Table 10, Chapter 3)

IAD variables	Paper I	Paper II	Paper III
Independent			
Physical condition	Spectrum as public goods	Spectrum as public goods	Spectrum as public, private, and common-pool goods
Attribute of community	Norm, culture, and tradition of ITU and Member States	Norm, culture, and tradition of ITU and Thailand	Norm, culture, and tradition of Thailand
Rules-in-use		RR: definition of ISM application, footnotes 5.138 and 5.150, and relevant frequency bands (TFA)	
Boundary	ITU membership	Thai telecom industry	Access and withdrawal right
Position	HoD, regional rep., chair, secretary	NRA, operator, manufacturer, standard-setting organization, users	NRA, Operators A and B, advanced users, end-users
Choice	Support, oppose, neutral	Adopting or not adopting rules	Using or not using device/ Rule changes
Payoff	Cost and benefit	Link to action situation	Link to action situation
Information	Public or informal information flow	Link to action situation	Link to action situation
Aggregate	Control over choice	Link to action situation	Link to action situation
Scope	ADD, MOD, SUP, NOC	Link to action situation	Link to action situation
Interaction	Link to action situation	Link to action situation	Link to action situation
Evaluation criteria	Link payoff rules	Link payoff rules	Link payoff rules
Dependent			
Action situations	WRC-12 Agenda Items 1.19 and 1.22 (Negotiation)	Transformation of spectrum commons regulations (Adopting or not adopting rules)	Implementing spectrum commons (Using or not using device/Rule changes)
Potential outcomes	RR revisions	NBTC regulations: Thai TFA and NBTC unlicensed regulations	Bundle of rights to use frequency

Note: HoD-Head of Delegation, Rep.-Representative, ADD-Addition, MOD-Modification, SUP-Suppression, NOC-No change

When viewing action situations as the unit of analysis, they are dependent variables of the IAD exogenous variables. The action situations in this study are relevant to the spectrum commons, i.e., allocation of spectrum commons in terms of WRC-12 Agenda Items 1.19 and 1.22, transformation of spectrum commons regulation (definition of ISM application, footnotes 5.138 and 5.150, and relevant frequency bands [TFA]), and implementing spectrum commons in terms of the NBTC regulations.

The IAD exogenous variables are independent variables that influence the structure of action situations, and they include the physical condition, attributes of community, and rules-in-use.

The physical condition is the characteristic of spectrum, including public, private, and common-pool goods. As for spectrum commons allocation and transformation, the spectrum is public goods, and as regards implementing spectrum commons, the spectrum is private and common-pool goods depending on the spectrum assignment methods.

The attribute of community is the common understanding between the actors in each situation. Some overlap situations, such as the norm, culture, and tradition of ITU and influence both spectrum commons allocation and transformation. Moreover, the norm, culture, and traditions in Thailand influence both the transformation and implementation of spectrum commons in Thailand.

Rules-in-use are directly connected to action situations representing “do and don’t” rules in terms of the seven rules as IAD internal variables.

The IAD framework provides multiple variables to explain how and why decisions have been taken. From a broad view, the exogenous variables (physical condition, attributes of community, and rules-in-use) are independent variables that influence the action situation (a dependent variable).

Inside the action situation, when viewing the potential outcomes as a dependent variable, the seven rules are independent variables. These rules explain the potential outcomes of the decision-making process including RR revisions, NBTC regulations, and bundle of rights to use frequency.

The boundary rules influence actors inside an action situation. The boundary rules are ITU membership and the Thai telecom industry for allocation and transformation of spectrum commons, respectively. However, the boundary rules for implementing spectrum commons in Thailand are the access and withdrawal rights to use frequency.

The position rules are the rules influencing roles of actors inside action situations, ranging from head of delegation, delegate, regional representative, and chairman to secretary for spectrum commons allocation at WRC-12. As for the transformation and implementation of spectrum commons in Thailand, the position rules are NRA, operator, manufacturer, standard-setting organization, and users.

The choice rules are the rules that influence possible actions that are different, i.e., support, oppose, neutral, adopting or not adopting, and using or not using.

The payoff, information, aggregation, and scope rules are the rules connecting the actions and evaluative criteria containing issues and dynamic situations of the decision-making process.

From a narrow view inside the action situations, the potential outcomes of the decision-making process are the dependent variable. The independent variables are seven rules (boundary, position, choice, payoff, information, aggregation, and scope rules) explaining a decision situation.

When analyzing Table 12 and Table 13 together, the IAD variables explain the connection between the three papers as parts of the spectrum management activities. Paper I deals with spectrum allocations at WRC. Paper II is about the transformation of regulation from international into national level. Papers I and II are both in the "Allocation and allotment of frequency band" and "Spectrum management planning and regulation" of spectrum management activities. Paper III's activity, on the other hand, is in the "Frequency assignment and licensing" of spectrum management activities.

Thus, the relationship between Papers I and II is that the spectrum commons allocation is an input to the transformation of spectrum commons regulation. The relationship between Papers II and III is that the transformation of spectrum commons regulation is an input to the implementation of spectrum commons in Thailand.

The study uses the IAD framework to explain the spectrum commons activities, from the allocation of spectrum commons and transformation of spectrum commons regulation to the implementation of spectrum commons in Thailand. Multi-level analysis and outcomes provide the study with appropriate levels of analysis, including constitutional, collective-choice, and operational situation. These levels help to separate and categorize action situations systematically. Moreover, the IAD variables as a list of concerned questions facilitate clarification of the decision situation in terms of independent and dependent variables. These elements helped to identify the limitations of the archives and the participant observations during the collection of the information for this study.

Finally, the IAD framework is appropriate for explaining the decision situation as negotiations at WRC-12 and for understanding the transformation and implementation of spectrum commons in Thailand.

Discussion on technical characteristic of spectrum commons

The study addresses the technical characteristics of spectrum or frequency that is a natural and limited resource serving as the carrier to convey information regardless of borders between countries and subjected to attenuation according to losses as a propagation characteristic. Frequency is a man-made and non-depletable resource because it can be created all the time. The frequency dividing into frequencies, time, geography, angle of arrival, polarization, and uses creates a reused frequency depending on the level of harmful interference. Harmful interference can be reduced by the technology advancement that made exclusive use of frequency unnecessary because these technologies can use frequency while it is not occupied or use frequency underneath without causing harmful interference.

Spectrum commons is one of the typical spectrum assignment approaches providing a non-exclusive use of frequency via the NRA by giving the right to use frequency to the public. No one has exclusive right to use this frequency. Everyone is able to use this frequency.

The advancement of technology has changed the frequency exclusivity from becoming unnecessary.

The frequency assignment provision of the exclusive right to use frequency becomes blurred to the NRA if such technologies exist and are fully used.

These spectrum commons characteristics are a common-pool goods (a high level of substractability and low cost of exclusion) that is categorized by the IAD biophysical condition.

The characteristics of spectrum commons directly influence the frequency assignment process. It should be reconsidered whether the exclusive right to use frequency via command-and-control and market-based approaches is necessary when the goal of frequency assignment is to maximize the utilization of frequency.

Consequently, the rules governing spectrum common should be relaxed as loose as possible. The minimal restriction of use is preferable such as the frequency band and maximum transmitting power. The enforcement should impose on the standardization and certification of conformity of devices.

The public society should be aware of the non-exclusive right to use frequency regime that requires the limitation to use spectrum subjecting to spectrum commons characteristics including shared use and non-protection basis.

In conclusion, the spectrum commons characteristics have potentially influenced the frequency assignment process in term of the nature of, rules governing, and common understanding on the use of spectrum commons as the IAD variables (physical condition, attribute of community, and rules-in-use).

Chapter 6 Conclusion, implications for Thailand, and future research

This chapter presents the conclusion of this study, implications for Thailand, and future research.

6.1 Conclusion

The study demonstrates the spectrum management activities regarding spectrum commons in Thailand, including the spectrum commons allocation at WRC, transformation of spectrum commons regulation in the form of the RR into NBTC regulations, and implementing spectrum commons in Thailand in part of the spectrum assignment development. The study uses the overarching research question "**How should spectrum commons be implemented in Thailand?**". Connecting three research questions from three papers illustrates the implementation of spectrum commons with the multi-layer IAD framework to explore spectrum commons issues at national and international levels.

Paper I: How is international spectrum policy developed and affected by the lack of detailed documentation?

The study demonstrates the spectrum allocation process at WRC via the spectrum commons issues of WRC-12 Agenda Items 1.19 and 1.22 in order to understand the international spectrum policy in part of the WRC preparatory process (WRC agenda setting and study process). By using the IAD framework, it provides a list of relevant questions to capture the international negotiation representing the rationale of RR revision that is available through participant observation, not included in ITU archive.

Paper II: How is the Radio Regulations transformed into National Broadcasting and Telecommunications Commission regulation for spectrum commons in Thailand?

The study presents the linkage between the international regulation in the form of the RR and national regulation in the form of NBTC regulation by using the IAD level of analysis and outcome. The study also illustrates the transformation of footnotes 5.138 and 5.150, frequency band allocation, and the RR TFA regarding spectrum commons into the national regulation in Thailand. The adoption of the RR TFA is transformed into the Thai TFA in terms of the definition of the ISM application, footnotes 5.138 and 5.150, frequency bands inside the footnotes, and the TFA. The transformation from international into national regulation is completed in the first phase in the form of the Thai TFA. However, national regulation, i.e., the Radiocommunication Act, prohibits the use of radiocommunication devices unless authorization is granted by the authority. The development of national regulation allowing the use of spectrum commons in Thailand must therefore be continued as the second phase via the unlicensed regulations.

Paper III: What are the consequences of using spectrum commons for frequency assignment in Thailand?

The study demonstrates the development of spectrum assignment for spectrum commons in Thailand. Using the IAD framework helps in understanding the bundle of rights to use frequency in Thailand. The result shows that spectrum commons is one approach to spectrum assignment in Thailand that has been developed alongside command-and-control and marked-based approaches. Spectrum commons has been initiated by the NFMA authorizing the PTD to allow radiocommunication devices of less than 1 watt to operate in Thailand. Such radiocommunication devices require the relevant radiocommunication licences. Additional authorization of spectrum commons has been developed over time until the MICT regulation on the exemption of the use of radiocommunication licences in 2004. This process shows that the use of spectrum commons belongs to national regulation in relation to the use of radiocommunication devices for end-users.

Cover paper: How should spectrum commons be implemented in Thailand?

Finally, the study demonstrates how the IAD framework assists in the understanding of spectrum commons from the allocation at international level at WRC in the form of the RR to the transformation into national regulation in the form of the NBTC in Thailand. Moreover, the development of spectrum commons regulation in Thailand also reveals the national rules-in-use in a constitutional situation, apart from the RR. The study attempts to connect these three elements in order to understand spectrum commons from both a practical and theoretical perspective viewed through the IAD framework in terms of the level of analysis and outcomes.

6.2 Implication for Thailand

Paper I – Information and coordination in international spectrum policy: Implications for Thailand.

Basic understanding of the RR development

Thailand could use the RR development from the study contributions to understand the basic concept of the RR, especially the way the RR is reviewed and revised by WRC.

The development of the RR for key definitions, important provisions, and frequency bands in specified services provides the basic information for Thailand to further investigate the relevant RR for detailed information. The study provides a starting point as a mind map to explore the ITU archives further.

Moreover, the database compiled by the author can serve as a resource for the TFA development since no one collects and compares all the TFA in the RR versions. The database could represent a starting point for further exploration of the TFA issues

RR implementation and caution

The study confirms that the ITU archives lack the rationale behind the RR provisions. The rationale can be captured during the meeting discussions. In order to implement the RR, Thailand should be aware of this limitation, and it may consider participating in the ITU activities to obtain missing information or rationale that matters to Thailand. Thailand may start to consider the priority of the WRC agenda items in the case of limitations of resources and identify the relevant ITU activities to attend the WRC preparatory process.

WRC preparatory process

The study illustrates the WRC preparatory process, the WRC agenda setting and the WRC study process. The WRC agenda setting takes two WRC cycles to complete for the next and future WRC agendas in the CPM report. However, the crucial forum is the last WRC, which finalizes the WRC agenda.

The study explores the WRC agenda-setting process from 1993 to 2012. The results of the approval of the WRC agenda items at the finalized WRC reveal that the majority of the WRC agenda items come from the contributions at the finalized WRC. Moreover, the WRC agenda prepared by the CPM in the CPM report for the next and future WRC agenda items is reducing over time.

Thailand should therefore concentrate on the finalized WRC by submitting contributions to and participating in this WRC to ensure inclusion of WRC agenda items if necessary.

With regard to the WRC study cycle by ITU SG, after the WRC agenda item prioritization, Thailand should participate in the relevant activities by the relevant SGs and submit contributions (if necessary) to ensure preferable options are included in the CPM report. ITU SG/WP will usually convene approximately three times a year (from the previous meetings of SG1, WP1A, and WP1B).

Regional preparatory meeting (APG)

The study also elaborates on the role of the regional preparatory meeting, especially the APG, as the regional preparatory meeting in the Asia-Pacific regions by the APT. Moreover, ITU recognizes the importance of the six regional preparatory meetings as the regional forum for consolidation and negotiation among Member States represented by the commons or regional proposal. Furthermore, the regional coordinator or representative represents its own region to negotiate and report back to their regional meeting during WRC. The commons proposal and regional representative both help to reduce the number of documents and discussions at WRC and encourage consensus or compromise between Member States.

The author was part of the Thai team preparing Thailand's position on WRC-12 Agenda Items 1.19 and 1.22. During the meeting discussions at the APG2012-5, the author observed the dynamic meeting situation between APT members in order to understand the issue of these two agenda items and the APG preparatory process for the APT common proposal to WRC-12. The discussions varied between agenda items depending on the APT members' standpoints (based on their interests). When a consensus or compromise was reached, the APT common proposal was submitted to WRC-12.

Thailand should create a connection between stakeholders at national and regional level through participation in national and regional preparatory meetings. The connection between stakeholders enables information exchange and improves understanding of the issues or situations of the WRC agenda items in order to prepare Thailand's position and protect its national interest.

The stakeholder connection, especially Member State networking, may help to relieve the issue of the missing information from the ITU archives and the information asymmetry between attending and non-attending Member States. The follow-up discussion with relevant Member States will enhance understanding of the issues, as the crucial information for improving Thailand's decision-making process at the relevant meetings.

WRC-12 Agenda Items 1.2, 1.19, and 1.22

The study demonstrates the effects of the missing information on the WRC-12 Agenda Items 1.2, 1.19, and 1.22 from Thailand's perspective. The demonstration shows the strong impact this has on Thailand. It is important for Thailand to prepare for the rapid growth of new technology, especially the spectrum commons and FS and MS convergence.

In order to prepare for the convergence technology, an evaluation of the current situation of both FS and MS is necessary: an up-to-date database. A review of the current status of FS and MS usage should be conducted and the existing database updated. The initial phase may begin with FS and MS and apply to all services at a later stage.

To prepare for the relevant issues on spectrum commons, Thailand may consider participating in all relevant meetings, including the ITU SG, WP, CPM, SC, RA, and WRC parts of the WRC preparatory process (WRC agenda setting and WRC study process) to update the information and prepare Thailand's position in order to take advantage of the advancement of technology.

Paper II – Managing spectrum commons in Thailand: Allocation and assignment challenges

This study provides an overview of the implementation of spectrum commons regulation in Thailand. This includes the development of spectrum allocation for spectrum commons in the RR, the main application and technology for spectrum commons, the development of spectrum assignment for spectrum commons in Thailand and the practical transformation from the RR into NBTC regulation.

The study demonstrates that the process of transformation from international into national regulation is a time-consuming process through spectrum allocation at WRC and implementation of the national NBTC regulation to allow the use of spectrum commons both with the relevant licences and unlicensed. Thailand should transform or update the Thai TFA according to the RR revision on a timely basis in order to gain advantages or benefit from the updated regulation.

Moreover, this study proposes looser regulation for spectrum commons in Thailand in order to gain advantages or benefit from the rapid change of technology, because the process of reviewing and revising both international and national regulation is time-consuming.

Paper III – Spectrum assignment policy: Towards an evaluation of spectrum commons in Thailand

The study applies the IAD framework to understand the bundle of rights to use the frequency including exclusive and non-exclusive right to use frequency. The exclusive use of frequency by command-and-control or market-based approaches has limited the use of spectrum to the assignees or winning bidders. They sometimes do not occupy the spectrum. The framework of non-exclusive use of frequency is introduced in spectrum commons, while no one owns the frequency or has an exclusive right to use frequency. Users must share frequency and accept interference. The non-exclusivity increases the number of users and the efficiency until the maximum capacity is reached.

Moreover, three types of spectrum commons have been used in Thailand (public commons, private commons, and unlicensed). Thailand should encourage more use of spectrum commons by additional unlicensed bands and allowing secondary users underneath primary users' noise floor to increase spectrum efficiency.

Thailand may consider adding spectrum commons to other frequency bands, imposing power limitation, and specifying frequency as necessary constraints. These constraints have a high potential to attract innovation. The market will select services and applications freely under the constraint to respond to demand. The low entry barrier makes spectrum easier to access and encourages competition in the market. The end-user will have better quality of service and lower prices.

Thailand should use the value of spectrum commons as important information on whether to license or unlicense spectrum. The value of spectrum will reflect the best utilization of spectrum. Greater use of spectrum commons of frequency assignment will increase spectrum efficiency in terms of the number of frequency users and the spectrum utilization.

The summary of implications for Thailand is as follows:

1) Using RR development and a database as basic information to further investigate the relevant RR in detail

2) Keeping in mind the limitation of ITU archives (lacking the rationale behind the RR provisions)

3) Sending NBTC staffs to attend relevant ITU activities after prioritizing WRC agenda items

4) Submitting contributions to the finalized WRC for WRC agenda setting

5) Creating connections between stakeholders and Member States at national and regional level by actively participating in national and regional preparatory meetings such as the APG and relevant ITU meetings

6) Transforming or updating the Thai TFA according to the RR revision on a timely basis in order to gain advantages or benefit from the updated regulation

7) Loosening regulation for spectrum commons in order to gain advantages or benefit from the rapid change of technology

8) Considering more spectrum commons to another frequency band by imposing power limitations and specifying frequency as necessary constraints

9) Valuing spectrum commons as important information on whether to license or unlicense spectrum

6.3 Future research

Further study on the transformation of international regulation into national regulation in other services, such as fixed or mobile services, may be interesting. Moreover, a comparative study between countries in different regions (Regions 1, 2, and 3) may be interesting to explore in order to understand the different rules-in-use in different contexts.

Further exploration of spectrum commons theory may be a possibility for future research. A deeper, metatheoretical exploration of spectrum commons would be possible to gain greater understanding of spectrum commons theory.

Further studies on the transformation of other services, such as mobile services, from the RR into national regulation would be interesting to explore.

Comparative studies on spectrum commons implementation between countries in different regions could also form the basis of other future studies to understand the differences and similarities between countries.

From a theoretical point of view, the IAD framework by Ostrom, and the complete or incomplete information assumption depends on an action situation. An action situation that has complete information reduces the complexity of modeling the outcome. The study does not reformulate the theoretical part of the IAD framework; however, the study demonstrates and applies the IAD framework in the real action situation at the WRC-12 meetings, which contain the elements of incomplete information situations, as shown in the study. From a theoretical point of view, it may be of interest to conduct future research on the IAD framework by modifying the assumption to model the outcome in the case of incomplete information in other fields.

Further feasibility studies on spectrum commons allocation in frequency bands other than those existing in footnotes 5.138 and 5.150 may be interesting to investigate in order to formulate the relevant technical characteristics and regulatory scheme at the national and regional, and WRC meetings in part of the WRC preparatory process (WRC agenda setting and study process) or regional process such as CEPT and APT.

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List of abbreviations

General

APG	Asia-Pacific Telecommunity conference preparatory group for WRC
CC	The Council
CRS	Cognitive radio system
CPG	CEPT conference preparatory group
CPM	Conference Preparatory Meeting
GHz	Giga Hertz
GPS	Global positioning system
HF	High frequency
IG	Informal group
ISM	Industrial science and medical application
kHz	Kilo Herth
MAC	Medium access control
MHz	Mega Hertz
MIFR	Master International Frequency Registration
PP	Plenipotentiary conference
PT A	Project team A
PANs	Personal area networks
PHY	Physical layer
RA	Radiocommunication Assembly
RR	Radio Regulations
SDR	Software defined-radio
SIM	Subscriber identification module
SG	Study group
SRD	Short-range devices
SWG	Sub-working group
TFA	Table of frequency allocation
Wi-Fi	Wireless fidelity
WRC	World Radiocommunication Conference

Administration and organization

APT	Asia-Pacific Telecommunity
BR	Radiocommunication Bureau
CPG	CEPT conference preparatory group
FIFA	Fédération Internationale de Football Association
IEEE	Institute of Electrical and Electronics Engineers
ITU	International Telecommunication Union
MICT	Ministry of Information and Communication Technology
MOT	Ministry of Transport
NBTC	National Broadcasting and Telecommunication Commission
NFMB	National Frequency Management Board
NRA	National regulatory authority
NTC	National Telecommunications Commission
PTD	Post and Telegraph Department
RSPG	Radio Spectrum Policy Group

Radiocommunication service

BS	Broadcasting service
BSS	Broadcasting-satellite service
EESS	Earth-exploration satellite service
FS	Fixed service

FSS	Fixed-satellite service
MMS	Maritime mobile service
MMSS	Maritime mobile-satellite service
MS	Mobile service
MSS	Mobile-satellite service
SRS	Space research service

Annex - Bibliography of spectrum management

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Paper I

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Information and coordination on international spectrum policy: Implications for Thailand

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Abstract

The Radio Regulations (RR) is an international treaty with which the International Telecommunication Union (ITU) Member States comply when managing the spectrum to avoid harmful interference. The RR is the outcome of the World Radiocommunication Conference (WRC) and is based on Member State contributions and negotiations.

Member States must implement the RR provisions carefully. However, national interpretations of the provisions are typically complex, leading to conflicts. Improved knowledge of the rationale behind the provisions would reduce tensions between Member States. Unfortunately, the ITU archives contain only the final input and output documents of the WRC proceedings and RR versions, nothing on the informal deliberations that form the rationale and missing information.

The purpose of this study is to understand the information needs of spectrum policy setting, including the relevant ITU processes and archives (WRC proceedings and RR versions). The study also proposes possible solutions to handling the missing information from the ITU archives in this policy setting.

To address the purpose, the study explores the contents of the ITU archives in terms of the WRC and RR developments. The author attended several meetings to document observations on meeting dynamics. Meeting observations were conducted through national and regional preparatory meetings and the WRC-12 on Agenda Items 1.19 and 1.22. The observations identify the particular form and nature of the information missing from the archives. An analysis of WRC-12 Agenda Items 1.2 and 1.19 from Thailand's perspective illustrates the gains that would accrue if this information were to be made available.

The main study results are the WRC and RR developments, including key definitions, important provisions, frequency bands in specified services, and the WRC preparatory process. These processes include the agenda-setting and study processes (national and regional activities). Many aspects of these processes are not documented. Using the institutional analysis and development (IAD) framework to understand the decision-making process inside the WRC activities yields a broad list of questions. This list includes questions about action situations. Much of the information that has not yet been documented could improve the resolutions.

To improve the archive resources, the study proposes that an information record form with webcast archives, minutes of meeting below the level of plenary session, and full use of a SharePoint website be completed and lodged with the archives. Member State networking would also provide an option to reduce the information deficit and compensate for Member States that do not attend the relevant meetings.

Enhanced archives and Member State networking would assist Low Income countries and Member States that are unable to participate in meetings due to resource constraints by providing argumentations and issue summaries. Augmented archives and networking would provide a stronger basis for understanding such RR provision changes. Moreover, for issues continuing to the next WRC, Member States would have a basis on which to develop further argumentations.

Keywords: Radio Regulations (RR), World Radiocommunication Conference (WRC), institutional analysis and development (IAD) framework, decision situation, participant observation, interaction

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Table of Contents

Chapter 1 Introduction 1

1.1 Background 1

1.2 Motivation and problem 6

1.3 Purpose and limitations 27

1.4 Research question(s) 27

1.5 Structure of study 30

Chapter 2 Theoretical framework 31

2.1 RR background 31

2.2 IAD framework 36

2.3 WRC-12 background 43

2.4 IAD framework in the WRC context 46

2.5 IAD framework and information matters 50

2.6 Summary 51

Chapter 3 Methodology 53

3.1 Data and data collection method 54

3.2 Data analysis 55

3.3 Approach 56

3.4 Summary 57

Chapter 4 History of the International Telecommunication Union 59

4.1 International Telegraph Conferences, 1865-1932 59

4.2 International Telecommunication Conference, 1947 61

4.3 Plenipotentiary Conferences, 1952-2012 61

4.4 ITU Constitution 63

4.5 Summary and discussion on research question 65

Chapter 5 History of the Radio Regulations 67

5.1 History of WRC 67

5.1.1 International Telegraph Conferences, 1865-1875 67

5.1.2 International Radiotelegraph Conferences, 1903-1947 67

5.1.3 Ordinary and Extraordinary Administrative Radio Conferences, 1959-1992 68

5.1.4 World Radiocommunication Conferences, 1993-2012 69

5.2 RR versions and WRC 69

5.3 RR definitions 70

5.3.1 Telecommunication 70

5.3.2 Radiocommunication 72

5.3.3 Radio waves 72

5.3.4 Radio 74

5.4 RR provisions 75

5.4.1 Choice of apparatus 75

5.4.2 Frequency assignment 77

5.4.3 Licences 79

5.4.4 Allocation, allotment, and assignment 81

5.4.5 Service priority 82

5.4.6 Radiocommunication service 84

5.4.7 Radiocommunication stations 87

5.5 Table of Frequency Allocation 89

5.5.1 Pre-TFA allocations 89

5.5.2 TFA Overview 90

5.5.3 Frequency band development and archived material 94

5.6 Summary and discussion on research question 95

Chapter 6 WRC preparatory process 97

6.1 Background 97

6.2 Agenda-setting 98

6.3 Assessment of the WRC agenda-setting process 103

6.4 Preparatory process 104

6.5 National preparatory process 105

6.6 Regional meetings and observer attendance 106

6.7 Summary and discussion on research questions 110

Chapter 7 Preparatory work on WRC-12 Agenda Items 1.19 and 1.22 113
7.1 Importance to Thailand 113
7.2 Background to WRC-12 Agenda Items 1.19 and 1.22 117
7.3 Challenges to CRS and SDR 118
7.4 Preparatory process 119
7.5 Assessment of the WRC agenda study process 120
7.6 Agenda item issues 121
7.7 RA-12 proposals for WRC-12 Agenda Items 1.19 and 1.22 123
7.8 Summary and discussion on research questions 124
Chapter 8 Participation in the WRC-12 meetings and the issue of the WRC-15 127
8.1 WRC-12 organization 127
8.2 WRC-12 documents 127
8.3 WRC-12 observation documentation 128
8.4 Observed interaction 130
8.5 Actual dynamic situation of the CRS issue 133
8.6 Informal channel at WRC-12 135
8.7 Role of Sector Members 136
8.8 Importance of missing information 136
8.9 WRC-12 Agenda Item 1.2 ongoing to WRC-15 137
8.10 Preparatory work on the definitions of FS, fixed station, and mobile station for the WRC-15 140
8.11 Summary and discussion on research questions 143
Chapter 9 Analysis and policy recommendation 147
9.1 Statement of problem 147
9.2 Application of the IAD framework to the WRC negotiations 147
9.3 Agenda Item 1.19 missing information cost 149
9.4 Policy recommendation 151
9.5 Summary and discussion on research questions 154
Chapter 10 Summary and findings 157

10.1 Synthesis 157
10.2 Result 158
10.3 Responses to research questions 162
10.4 General policy implications and recommendations 164
10.5 Implications for Thailand 164
10.6 Recommendations for future research 166
Reference 169
List of abbreviations 177
Appendix A Maritime mobile service geographic frequency allocations 181
Appendix B Maritime mobile-satellite service geographic frequency allocations 185
Appendix C Broadcasting service geographic frequency allocations 187
Appendix D Broadcasting-satellite service geographic frequency allocations 195
Appendix E Fixed service geographic frequency allocations 197
Appendix F Fixed-satellite service geographic frequency allocations 225
Appendix G Mobile service geographic frequency allocations 231
Appendix H Mobile-satellite service geographic frequency allocations 257
Appendix I Space research service geographic frequency allocations 261
Appendix J Earth exploration-satellite service geographic frequency allocations 269

List of figures

Figure 1. Overview of the RR processes 8

Figure 2. Agenda Item 1.2 meetings and document flow 25

Figure 3. Structure of the study 30

Figure 4. Regions in Radio Regulations 2012 32

Figure 5. Framework for an institutional analysis 37

Figure 6. A rules-in-use and action situation 40

Figure 7. Level of analysis and outcomes 42

Figure 8. WRC-12 meeting hierarchy 44

Figure 9. COM6 work program 44

Figure 10. ITU’s structure 64

Figure 11. Global bandwidth allocations, 1971-2012 92

Figure 12. Region 1 bandwidth allocations, 1947-2012 93

Figure 13. Region 2 bandwidth allocations, 1947-2012 93

Figure 14. Region 3 bandwidth allocations, 1947-2012 94

Figure 15. WRC-12 preparatory process 98

Figure 16. Specified WRC agenda items, 1993-2015 101

Figure 17. Regional preparatory and WRC-12 meeting processes 105

Figure 18. Thailand’s spectrum management profile 114

Figure 19. Agenda Items 1.19 and 1.22 and related issues 118

Figure 20. WRC-12 process for Agenda Item 1.19 119

Figure 21. WRC-12 process for Agenda Item 1.22 119

Figure 22. Meeting template 129

Figure 23. Agenda Item 1.19 meeting and document flow 130

Figure 24. Agenda Item 1.19 issue development 131

Figure 25. Agenda Item 1.22 meeting and document flow 132

Figure 26. Agenda Item 1.2 meetings and document flow (c.f. Figure 2, Chapter 1) 137

Figure 27. Agenda Item 1.19 issue development (c.f. Figure 24, Chapter 8) 150

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List of tables

Table 1. ITU nomenclature ... 6

Table 2. WRC-12 agenda items for this study ... 9

Table 3. IAD literature ... 11

Table 4. WRC-12, national delegates by World Bank income classification ... 20

Table 5. Timeline of RR provisions implementation ... 21

Table 6. Timeline of WRC issues ... 21

Table 7. Radio frequency propagation ... 32

Table 8. Table of Frequency Allocation, 460-890 MHz ... 34

Table 9. Categories of goods ... 38

Table 10. IAD variable map, missing data, and observer activities ... 49

Table 11. Meeting participation ... 53

Table 12. List of Ordinary and Extraordinary Administrative Radio Conferences 1959-1992 ... 68

Table 13. RR versions and WRC, 1906-1994 ... 69

Table 14. RR versions and WRC, 1993-2012 ... 69

Table 15. Telecommunication definition ... 71

Table 16. Radio wave definition ... 74

Table 17. Choice of apparatus provision ... 77

Table 18. Frequency assignment provisions ... 78

Table 19. Licence provisions ... 81

Table 20. Category of service and allocation provision ... 84

Table 21. RR2012 services ... 85

Table 22. Terminated services, 1927-1976 ... 86

Table 23. Service category, 1906-1994 ... 86

Table 24. Station classification added 1906-1998 ... 87

Table 25. Terminated station classification since 1932 ... 87

Table 26. RR2012 station classification ... 88

Table 27. Wavelength from the Annex to the Berlin 1906 Convention ... 89

Table 28. Wavelength of Detailed Service Regulation appended to the London 1912 Convention ... 90

Table 29. TFA frequency limits ... 91

Table 30. Global and regional frequency bands ... 91

Table 31. Broadcasting service 550-1705 kHz frequency band development ... 94

Table 32. WRC agenda items, 1993-2015 ... 100

Table 33. Specified WRC agenda items by service, 1993-2015 ... 102

Table 34. Thailand’s frequency assignment profile ... 115

Table 35. WRC-12 attendance 23 January-3 February 2012 ... 128

Table 36. WRC-12 attendance 6-17 February 2012 ... 128

Table 37. Agenda Item 1.19 meeting organization ... 132

Table 38. WRC-12 Agenda Item 1.22 meeting organization ... 133

Table 39. WRC Agenda Item 1.19 document positioning ... 134

Table 40. List of tables for Thailand TFA on FS, FSS, MS, and MSS ... 138

Table 41. Number of frequency band on FS, FSS, MS, and MSS for Thailand ... 138

Table 42. Occupied bandwidth (kHz) with percentages for FS, FSS, MS, and MSS ... 139

Table 43. Thailand’s 2012 utilization bandwidth for FS, FSS, MS, and MSS ... 139

Table 44. Fixed service definition ... 141

Table 45. Fixed station definition ... 142

Table 46. Mobile station definition ... 142

Table 47. IAD variable map, missing data, and observer activities (c.f. Table 10, Chapter 2) ... 148

Table 48. WRC Agenda Item 1.19 document positioning (c.f. Table 39, Chapter 8) ... 149

Table 49. Information recording form ... 152

Table 50. Responses to the sub-research questions related to the chapters of the study ... 162

Table 51. MMS Global allocation for exclusive/primary services ... 181

Table 52. MMS Global allocation for shared/secondary services ... 181

Table 53. MMS EU region/Region 1 allocation for exclusive/primary services ... 182

Table 54. MMS EU region/Region 1 allocation for shared/secondary services ... 182

Table 55. MMS American region/Region 2 allocation for exclusive/primary services ... 183

Table 56. MMS American region/Region 2 allocation for shared/secondary services ... 183

Table 57. MMS Other regions/Region 3 allocation for exclusive/primary services 184
Table 58. MMS Other regions/Region 3 allocation for shared/secondary services 184
Table 59. MMSS Global allocation for primary service 185
Table 60. MMSS Region 1 allocation for primary service 185
Table 61. MMSS Region 2 and 3 allocations for primary service 185
Table 62. BS Global allocation for exclusive/primary services 187
Table 63. BS Global allocation for share/secondary services 188
Table 64. BS EU region/Region 1 allocation for exclusive/primary services 189
Table 65. BS EU region/Region 1 allocation for shared/secondary services 190
Table 66. BS American region/Region 2 allocation for exclusive/primary services 191
Table 67. BS American region/Region 2 allocation for shared/secondary services 192
Table 68. BS Other regions/Region 3 allocation for exclusive/primary services 192
Table 69. BS Other regions/Region 3 allocation for shared/secondary services 193
Table 70. BSS Global allocation for primary service 195
Table 71. BSS Region 1 allocation for primary service 195
Table 72. BSS Region 2 allocation for primary service 195
Table 73. BSS Region 3 allocation for primary service 196
Table 74. FS Global allocation for exclusive/primary services-1 197
Table 75. FS Global allocation for primary service-2 198
Table 76. FS Global allocation for primary service-3 199
Table 77. FS Global allocation for primary service-4 200
Table 78. FS Global allocation for primary service-5 202
Table 79. FS Global allocation for primary service-6 204
Table 80. FS Global allocation for shared/secondary services-1 206
Table 81. FS Global allocation for shared/secondary services-2 207
Table 82. FS EU region/Region 1 allocation for exclusive/primary services-1 208
Table 83. FS Region 1 allocation for primary service-2 209
Table 84. FS Region 1 allocation for primary service-3 210
Table 85. FS Region 1 allocation primary service-4 211

Table 86. FS EU region/Region 1 allocation for shared/secondary services-1 212
Table 87. FS Region 1 allocation for shared/secondary services-2 212
Table 88. FS Region 2 allocation for exclusive/primary services-1 213
Table 89. FS Region 2 allocation for primary service-2 214
Table 90. FS Region 2 allocation for primary service-3 215
Table 91. FS Region 2 allocation for primary service-4 216
Table 92. FS American region/Region 2 allocation for shared/secondary services-1 217
Table 93. FS Region 2 allocation shared/secondary services-2 218
Table 94. FS Region 3 allocation for primary service-1 219
Table 95. FS Region 3 allocation for primary service-2 220
Table 96. FS Region 3 allocation for primary service-3 221
Table 97. FS Region 3 allocation for primary service-4 222
Table 98. FS Other regions/Region 3 allocation for shared/secondary services-1 223
Table 99. FS Region 3 allocation for secondary service-2 224
Table 100. FSS Global allocation for primary service-1 225
Table 101. FSS Global allocation for primary service-2 226
Table 102. FSS Global allocation for primary service-3 227
Table 103. FSS Region 1 allocation for primary service 228
Table 104. FSS Region 2 allocation for primary service 229
Table 105. FSS Region 3 allocation for primary service 230
Table 106. MS Global allocation for exclusive/primary services-1 231
Table 107. MS Global allocation for primary service-2 231
Table 108. MS Global allocation for primary service-3 232
Table 109. MS Global allocation for primary service-4 233
Table 110. MS Global allocation for primary service-5 235
Table 111. MS Global allocation for primary service-6 237
Table 112. MS Global allocation for share/secondary services-1 239
Table 113. MS Global allocation for share/secondary services-2 240
Table 114. MS EU region/Region 1 allocation for exclusive/primary services-1 241

Table 115. MS Region 1 allocation for primary service-2 ... 242
Table 116. MS Region 1 allocation for primary service-3 ... 244
Table 117. MS EU region/Region 1 allocation for share/secondary services-1 ... 244
Table 118. MS Region 1 allocation for share/secondary services-2 ... 245
Table 119. MS Region 2 allocation for exclusive/primary services-1 ... 246
Table 120. MS Region 2 allocation for primary service-2 ... 247
Table 121. MS Region 2 allocation for primary service-3 ... 248
Table 122. MS Region 2 allocation for primary service-4 ... 249
Table 123. American Region/MS Region 2 allocation for share/secondary services-1 ... 249
Table 124. MS Region 2 allocation for share/secondary services-2 ... 250
Table 125. MS Other regions/Region 3 allocation for exclusive/primary services-1 ... 251
Table 126. MS Region 3 allocation for primary service-2 ... 252
Table 127. MS Region 3 allocation for primary service-3 ... 253
Table 128. MS Region 3 allocation for primary service-4 ... 254
Table 129. MS Other regions/Region 3 allocation for share/secondary services-1 ... 255
Table 130. MS Region 3 allocation for share/secondary services-2 ... 256
Table 131. MSS Global allocation for primary service ... 257
Table 132. MSS Global allocation for secondary service ... 258
Table 133. MSS Region 1 allocation for primary service ... 258
Table 134. MSS Region 1 allocation for secondary service ... 258
Table 135. MSS Region 2 allocation for primary service ... 259
Table 136. MSS Region 2 allocation for secondary service ... 259
Table 137. MSS Region 3 allocation for primary service ... 260
Table 138. MSS Region 3 allocation for secondary service ... 260
Table 139. SRS Global allocation for primary service-1 ... 261
Table 140. SRS Global allocation for primary service-2 ... 262
Table 141. SRS Global allocation for secondary service ... 264
Table 142. SRS Region 1 allocation for primary service ... 265
Table 143. SRS Region 1 allocation for secondary service ... 265

Table 144. SRS Region 2 allocation for primary service ... 266
Table 145. SRS Region 2 allocation for secondary service ... 266
Table 146. SRS Region 3 allocation for primary service ... 267
Table 147. SRS Region 3 allocation for secondary service ... 267
Table 148. EESS Global allocation for primary service ... 269
Table 149. EESS Global allocation for primary service ... 270
Table 150. EESS Global allocation for secondary service ... 271
Table 151. EESS Region 1 allocation for primary service ... 272
Table 152. EESS Region 1 allocation for secondary service ... 272
Table 153. EESS Region 2 allocation for primary service ... 273
Table 154. EESS Region 2 allocation for secondary service ... 273
Table 155. EESS Region 3 allocation for primary service ... 274
Table 156. EESS Region 3 allocation for secondary service ... 274

Chapter 1 Introduction

This study is about the nature of information needs and coordination in the telecommunication sector between stakeholders: administrators, regulators, operators, manufactures, and end-users. However, the study only focuses on the information needs and coordination within the decision-making process of the International Telecommunication Union (ITU) Member States via the World Radiocommunication Conference (WRC).

1.1 Background

Communication has the purpose of connecting people. Basic communication begins with talking with each other at the same venue. When one party is distanced from others, telecommunication technology is introduced.

Telecommunication technology has developed from telegraph to radiotelegraph, from fixed telephone to mobile telephone, and from terrestrial services to satellite services. The transmission mediums are wire and wireless. Wire is developed from copper (twisted pair) and coaxial to fiber optics. Messages or information is converted into electric or light signals before being sent from transmitters via a transmission line to receivers.

What is spectrum?

Conversely, wireless uses radio (spectrum, radio waves, radio frequency, or frequency) as the medium. An electromagnetic wave up to 3,000 GHz (RR2012) carries messages through the air or free space without artificial guides. The radio propagation characteristics vary by frequency. Higher frequencies have a greater carrying capacity but a shorter communication range. Lower frequencies have a lower carrying capacity but a longer communication range.

Spectrum is a non-depletable resource. It can be reused by dividing it into frequencies, time, angle of arrival, polarization, geography, and uses. Due to its nature, transmissions will propagate across country borders until the power runs out.

Why manage spectrum?

In terms of technical aspects, the spectrum is similar to roads carrying traffic. It needs rules or regulations to control the use of each application and prevent disorder and harmful interference. Proper spectrum management can maximize its use by allowing for the maximum number of users, while keeping interference and congestion manageable.

In terms of social aspects, in some countries, such as Thailand, spectrum is a national resource of public interest. As stated in the Constitution of Thailand (2007), there must be an independent regulatory body with the duty of distributing frequency and supervising its use. There shall be regard for maximum public benefit at national and local levels in education, culture, state security, other public interests, and fair and free competition, including encouraging the public to participate in the management of public mass communication.

One of the WTO's declarations is to urge WTO members to liberalize basic telecommunication service. This requires the establishment of a regulatory authority. Such an

authority is denoted by law, i.e., administrator, national regulatory authority (NRA), or regulator.

In terms of economics, spectrum is a scarce resource and limited by its frequency band, time, and place. The spectrum can be used for different purposes or services. The different services of the spectrum make it similar to other goods that follow supply and demand. Demand for spectrum is created by the users, and supply of spectrum is provided by the regulator. A particular aspect of spectrum, from an economic point of view, is that it is non-excludable, non-depletable, and subject to congestion problems. It therefore has some properties that are similar to public goods, though it is not purely public goods.

How is spectrum managed?

With regard to the propagation of spectrum, there are three levels of spectrum management: allocation, allotment, and assignment. Allocation and allotment are designed at international level, while assignment is the responsibility of national agencies. Management at international level is by ITU, a United Nations specialized agency, through the issuing of the Radio Regulations (RR) via WRC to harmonize the allocation of frequency bands with radiocommunication services. The RR is the international treaty for radiocommunication managing the spectrum internationally without causing harmful interference.

Harmonization can also be regional. Active regional organizations are the African Telecommunications Union (ATU), Arab Spectrum Management Group (ASMG), Asia Pacific Telecommunity (APT), European Conference of Postal and Telecommunications Administrations (CEPT), Inter-American Telecommunication Commission (CITEL), and Regional Commonwealth in the Field of Communications (RCC). They help to consolidate and compromise on different ideas within and across regions.

National assignment and modes of assignment vary by country. Spectrum may be assigned by an administrator, NRA, or relevant ministry, depending on the laws of the country. Before the spectrum is assigned, the NRA normally checks the availability of spectrum, existing users, related regulations (national and international), and suitable technical characteristics imposed on the use of spectrum and radiocommunication equipment.

All obligations imposed by the authority must comply with the RR to avoid harmful interference between countries and maintain priority on claims to use the spectrum. The regulators have the right to manage the spectrum within their territories but not to interfere with neighboring countries. They set up coordination and cooperation with neighboring countries to help manage interference. For example, Thailand and Malaysia established the Joint Technical Committee (JTC) for frequency coordination on the Thailand-Malaysia border to avoid harmful interference. The coordination includes frequency planning and technical specifications for several services, such as mobile phone, television, and sound broadcasting.

What is spectrum allocation?

Spectrum allocation means giving specific frequency bands to radiocommunication services, i.e., for the purpose of frequency use, with both regional and global scope.

The allocation is presented in a so-called Table of Frequency Allocation (TFA), which shows the services that are allowed to be used by frequency band. The TFA is divided into three regions (Regions 1-3). The services can be either so-called primary or secondary. In the TFA, primary services are spelled out in capital letters while secondary services are in lower case. The reason for this division is to avoid harmful interference, with primary services always taking priority over secondary services by way of station (network and device) construction. This allocation is by WRC.

For example, the TFA of the RR2012, 472-479 kHz, is a global allocation to maritime mobile service on a primary basis, and amateur and aeronautical radionavigation services on a secondary basis. The 38.25-39 MHz band is allocated to fixed and mobile services in Region 1 on a primary basis. The 38.25-39.986 MHz band is allocated to fixed and mobile services in Region 2 on a primary basis. The 38.25-39.5 MHz band is allocated to fixed and mobile services in Region 3 on a primary basis. The 41.015-42 MHz band is allocated to fixed and mobile services on a global and primary basis.

What is spectrum allotment?

Spectrum allotment means designating specific frequency bands to at least one ITU Member State in a specified service (terrestrial or space). For example, Appendix 25 of the RR provides the allotment plan for coast radiotelephone stations in maritime mobile service between 4 000 kHz and 27 500 kHz (e.g., the 4 358.4 kHz band is allotted for South Africa, Australia, Chile, and Cuba). Appendix 30, Article 10 provides an allotment plan for broadcasting-satellite service in the 12.2-12.7 GHz band in Region 2, such as Beam SPMFRAN3 (channels 1, 5, 9, 13, and 17 are allotted to Germany, Denmark, Iceland, Norway, and Sweden).

What is spectrum assignment?

Spectrum assignment means giving a specific frequency band to users: providers, operators, or end-users. For example, the 897.5-915 and 942.5-960 MHz bands are assigned to Operator A for mobile service.

Spectrum assignment policy is limited to wireless or radiocommunication in a national territory. Each country has its own sovereignty. Spectrum assignment is a subset of spectrum management. Spectrum assignment is one of most important functions of spectrum management, beside other functions such as planning and regulation, financing, allocation and allotment, national liaison and consultation, international and regional cooperation, standards, specifications and equipment authorization, monitoring, and enforcement (ITU, 2005).

Spectrum management policy is a subset of telecommunications policy. Telecommunications policy includes technical, economic, and social aspects. It overlaps the natural sciences (technical) and social science (economics and society). Telecommunications policy often, but not always, deals with an institutional analysis. This is an analysis of an institutional arrangement or set of rules governing the number of decision-makers, allowable actions or strategies, authorized results, transformation from internal to decision situations, and linkages

between decision situations (Kiser & Ostrom, 1982). Telecommunications policy also includes economic analysis of, for example, the social value or value to private players of the spectrum. The regulator may impose conditions on spectrum to make it excludable, which in turn makes frequency use a specific right for a designated entity or person.

In the language of telecommunication planning, the regulator has the right to assign frequency to assignees. If the frequency is assigned to specific entities, i.e., individuals and legal persons, it is called licensed frequency, in short, licensed. The entities that obtain this assigned frequency are named licensees. If the frequency is not assigned to specific entities, in other words, assigned to the general public, it is called unlicensed frequency or, in short, unlicensed. A characteristic of licensees is that they have the exclusive right to use frequency. The unlicensed frequency does not carry this right however.

International relationship

Thailand became an ITU Member State in 1883 (formerly the International Telegraph Union and Siam). Thailand complied with the 1906 and 1912 International Telegraph Convention as its national regulation. Thailand’s first Table of Frequency Allocation was brought into force in 1999 according to the RR1997. The Thailand’s current Table of Frequency Allocation is the 2011 version according to the RR2008.

WRC is the forum for the decision-making process among Member States that reviews and revises the RR. The RR and WRC are administered by ITU. However, the ITU archives only contain the input and output documents of the WRC proceedings and the RR versions; they exclude the rationale underlying any such RR changes.

International differences

Member States have different income levels: High, Upper Middle, Lower Middle, and Low (World Bank income classification). This difference limits opportunities to participate in the ITU activities, including meetings and proposal preparation for the relevant conferences such as WRC (Hudson, 1997). As a consequence, the Member States that do not participate in the archival meetings may have a different understanding of the RR implementation.

Furthermore, Member States have different concerns and benefits with regard to the RR and ITU meetings. The concerns and benefits depend on their national interests and priorities. For example, manufacturing-based countries have concerns about global frequency allocations. They can produce and sell products globally. Conversely, the non-manufacturing-based or importing countries have concerns about standard compatibilities. They can use compatible standards with which interference is manageable.

The Member States’ concerns and interests directly influence the WRC agenda items, including the number of delegates and relevant issues. For example, when issues directly connect to their benefit or interest, Member States might send several delegates to ensure outcomes that are favorable to them and protect their interest. On the other hand, when there is no issue on a specific agenda item, Member States might send a delegate to follow the argument or not attend such meetings.

ITU administers WRC to revise the RR and facilitate the meetings. One concern for ITU is to balance the benefit between developed and developing Member States. Each Member State has a different background and concerns regarding the RR, in both regulatory and technical respects. The developed countries revise the RR to correspond with the rapid growth in technological development. Conversely, the developing countries might focus on technology and standard compatibilities due to the different technological adoption rates.

For example, in the maritime mobile service, a new technology, i.e., Global Maritime Distress and Safety System (GMDSS), is introduced by developed countries. Ships at sea are required to install GMDSS equipment under the Safety of Life at Sea (SOALS) Convention of the International Maritime Organization (IMO). Consequently, the relevant RR provisions must be revised for GMDSS, especially the deletion of Appendix 13 of the RR. Appendix 13 is about distress and safety communications, including the use of distress signals, calls, and messages when distress incidents happen at sea.

Conversely, in developing countries, there are many fishing boats (non-GMDSS vessels) that continue to use distress communication. The developing countries propose retaining the use of distress communication under the RR to safeguard their fishing boats. A compromise is therefore reached between Member States to keep the distress communication for non-GMDSS vessels and to implement GMDSS equipment for ships under the SOLAS Convention.

The other concern for ITU is the consequences of the rapid growth of technology necessitating changes in the ITU structure and RR provisions. In the beginning, ITU was in charge of the international telegraph and developed telecommunication, including wire and wireless technology, in both terrestrial and space services. Importantly, the RR was developed from a specific scope of regulation for maritime service and expanded to a general scope of regulation to govern several services.

Specific scope of regulation means that one regulation governs one application, technology, or service. Generic scope of regulation means that one regulation governs more than one application, technology, or service.

For example, in the space service, there are both generic and specific scopes of regulations, namely, unplanned and planned bands, respectively (Hudson, 1990, 1997). Unplanned bands originate from a first come, first served basis by the notification and coordination process to the Master of International Frequency Registration (MIFR) administered by ITU in order to provide satellite services, both domestic and international. Planned bands began after an unplanned plan to allot the frequency bands with an orbital slot for all Member States to have equal access to the resources for broadcasting-satellite service (BSS). However, coordination between these two schemes must be implemented in order to keep harmful interference manageable, not burden the development of satellite technology, and ensure equal access to the resources (a frequency and satellite orbit). Unplanned bands are supported by developed countries that have funding and technology to develop and operate satellite services. Planned

bands are supported by developing countries that seek support for funding and technology to deploy their domestic satellite services.

1.2 Motivation and problem

The motivation for this study originated from observing ITU members (Members States and Sector Members) using the RR as spectrum management guidelines to avoid interference between country transmission and reception.

Table 1 shows the ITU nomenclature used throughout the study. The "Term" column represents frequently used text used in the RR and mentioned in this study. The "Meaning" column provides a short definition of the relevant text.

Table 1. ITU nomenclature

Term	Meaning	Enforceability
Provisions	General term for all regulations in the RR, such as articles, appendices, WRC resolution and recommendation, ITU-R recommendation incorporated by reference	Binding/ Not binding
Final Act	Outcome of WRC containing the RR revisions	Binding
WRC resolution, e.g., Resolution xxx (WRC-xx)	Resolution approved by WRC	Binding
Resolution xxx (Rev. WRC-xx)	Resolution revised and approved by WRC	Binding
WRC recommendation, e.g., Recommendation xxx (WRC-xx)	Recommendation approved by WRC	Not binding
Recommendation xxx (Rev. WRC-xx)	Recommendation revised and approved by WRC	Not binding
ITU-R resolution	Resolution approved by the Radiocommunication Assembly (RA)	Not binding
ITU-R recommendation	Recommendation approved by the RA	Not binding
ITU-R recommendation incorporated by reference	Recommendation approved by the RA and adopted by WRC to be included in the RR	Binding
Recommendation ITU-R SM	ITU-R recommendation in spectrum management	Not binding
Recommendation ITU-R M	ITU-R recommendation in mobile, radiodeterminations, amateur, and related satellite services	Not binding
Recommendation ITU-R F	ITU-R recommendation in fixed service	Not binding
CPM report	Report prepared by the ITU-R study group for the Conference Preparatory Meeting (CPM) to be included as information for Member States to decide on at WRC	Not binding
ADD	Add or create new provisions	-
SUP	Delete the provisions	-
MOD	Modify, revise, or change the existing provisions	-
NOC	No change to the existing provisions	-

The "Enforceability" column represents the level of the RR implementation. "Binding" means that Member States must comply with this provision and that its implementation is mandatory. “Not binding” means that Member States may implement this provision on a voluntary basis.

The RR2012 contains provisions that can be divided into four volumes, i.e., Volume 1 – Articles, Volume 2 – Appendices, Volume 3 – Resolutions and Recommendations, and Volume 4 – ITU-R Recommendations incorporated by reference.

Volume 1 – Articles contains nine chapters that include terminology and technical characteristics; frequencies; coordination, notification, and recording of frequency assignment and plan modifications; interferences; administrative provisions, provisions for services and stations; distress and safety communications; aeronautical services; and maritime services.

Volume 2 – Appendices provides 23 appendices, for example, Appendix 1 – Classification of emissions and necessary bandwidth, Appendix 9 – Report of an irregularity or infringement, and Appendix 18 – Table of transmitting frequencies in the VHF maritime mobile band.

Volume 3 – Resolutions and Recommendations comprises 148 resolutions and 23 recommendations, for example, Resolution 729 (Rev. WRC-07) – Use of frequency adaptive systems in the MF and HF bands, and Recommendation 7 (Rev. WRC-97) – Adoption of standard forms for ship station and ship earth station licences and aircraft station and aircraft earth station licences.

Volume 4 – ITU-R Recommendations incorporated by reference includes 38 recommendations, such as Recommendation ITU-R SM. 1138-1 – Determination of necessary bandwidths including examples for their calculation and associated examples for the designation of emissions, Recommendation ITU-R M.1583 – Interference calculations between non-geostationary mobile-satellite service or radionavigation-satellite service systems and radio astronomy telescope sites, and Recommendation ITU-R F.1613 – Operational and deployment requirements for fixed wireless access systems in the fixed service in Region 3 to ensure the protection of systems in the Earth exploration-satellite service (active) and the space research service (active) in the band 5 250-5 350 MHz.

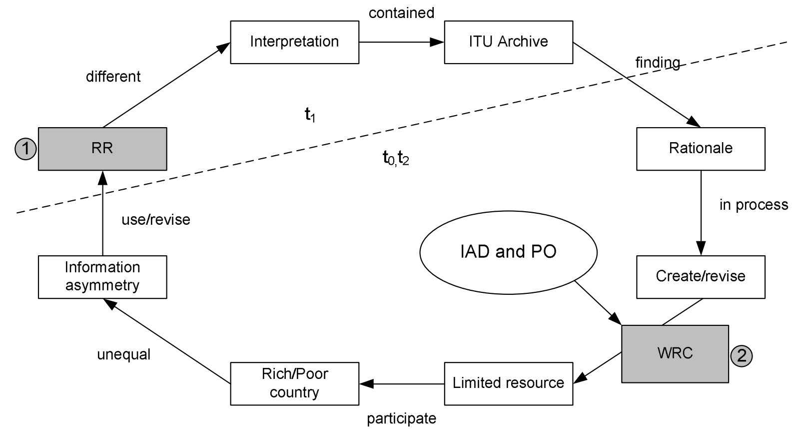


Figure 1. Overview of the RR processes

Figure 1 presents an overview of the main steps of the RR processes. The time t_1 represents when the RR becomes available in the ITU archives. The time t_0 represents when the RR is reviewed and revised during WRC. The time t_2 represents the next WRC.

In Figure 1, circle 1 denotes the starting point for the RR to be revised or implemented. Different actors: Member States and Sector Members have different interpretations of the reason for the RR changes or implementations, with some countries relying primarily on the ITU archives. The archives only provide the final input and output of the WRC proceedings or RR revisions and do not have the rationale of RR changes. The rationale for changing the RR is contained in the RR revision process at WRC (see circle 2). For this study, the institutional analysis and development (IAD) framework and participant observation (PO) are used to analyze WRC in order to capture the rationale behind it. However, since countries have varying resources in terms of participating in WRC, there is information asymmetry between attending and non-attending countries, or rich and poor countries. This information asymmetry influences the use and revision of the RR for the next round of RR revisions (circle 1).

The study uses the missing information and information asymmetry in the following:

When Member States or Sector Members implement the RR provisions, some of the provisions are not self-explanatory or have ambiguities. Such provisions need further interpretation. The interpretation varies and depends on who makes it. To understand the rationale of such provisions, further exploration of the ITU archives is required. However, the ITU archives only contain the final input and output documents of the WRC proceedings and RR versions. The rationale can be captured during the discussion at the relevant WRC. Only attending Member States have this information, which is missing for non-attending Member States.

This missing information is not documented in the archives. Member States that use the ITU archives therefore have incomplete information, because the archives lack the rationale underlying the RR provisions, as it is left out. The study shares the view of incomplete information with institutional economics that, in the real world, the decision-maker has incomplete information, which imposes constraints on human interaction (North, 1992), such as buyers having incomplete information about the product compared with the information that sellers have. In the WRC context, Member States and Sector Members that only rely on the ITU archives have incomplete information regarding the missing information.

Consequently, the difference in availability of information between attending and non-attending Member States at the relevant meetings represents information asymmetry. The study shares the idea of information asymmetry with the principal-agent approach that the principal delegates responsibility for selecting and implementing an action to the agent (Thompson & McKee, 2011, p. 160). The level of understanding of information therefore differs between the principal and the agent and becomes information asymmetry. However, the study only applies the information asymmetry to the case between attending and non-attending Member States at the relevant meetings. Only the attending Member States have information on the underlying discussion and rationale.

At WRC, the Conference represents action situations for reviewing and revising the RR. The review is conducted through a formalized agenda with carefully numbered items. One agenda item may have several issues. Table 2 provides an overview of the main formal agenda items in this study for the WRC-2012.

Table 2. WRC-12 agenda items for this study

Agenda item	Detail
1.2	taking into account the ITU-R studies carried out in accordance with Resolution 951 (Rev. WRC-07), to take appropriate action with a view to enhancing the international regulatory framework
1.19	to consider regulatory measures and their relevance, in order to enable the introduction of software-defined radio and cognitive radio systems, based on the results of ITU-R studies, in accordance with Resolution 956 (WRC-07)
1.22	to examine the effect of emissions from short-range devices on radiocommunication services, in accordance with Resolution 953 (WRC-07)

Source Resolution 805 (WRC-07) – Agenda for the 2011 World Radiocommunication Conference adopted by the CC08 Resolution 1291 (MOD) – Place, dates and agenda of the World Radiocommunication Conference (WRC-12).

The reason why these agenda items are of interest because agenda items 1.19 and 1.22 study technologies and application regarding spectrum commons providing non-exclusive use of frequency. Spectrum commons increases the spectrum efficiency and flexibility of use. Moreover, agenda item 1.2 introduces the studies for convergence technologies between fixed

and mobile services, and fixed-satellite and mobile-satellite services allowing the RR responses to the rapid change of technology.

Selection from the IAD framework

The school of economic thinking shifts from classical to institutional: from commodities and individuals to transactions and working rules of collective actions. Its classical theories are a relation of man to nature, but institutional theories are a relation of man to man (Commons, 1931).

Commons (1931) also provides the definition of “institution” as collective actions in control, liberation, and expansion of individual actions. The individual actions are transactions instead of either individual behavior or the exchange of commodities (Commons, 1931, pp. 651-652). The transaction serves as the smallest unit of activity with its participants. The major activities are bargaining, managerial, and rationing transactions (Commons, 1931).

However, the early development of institutional economics or old institutional economics (OIE) provides imaginative insights, perceptive description, quantitative measurement, not a theory (North, 1992, p. 3). The new institutional economics (NIE) builds on the assumption of scarcity and competition and attempts to incorporate an institution into economics. In the real world, human beings have incomplete information and limited mental capacity to process information by imposing constraints on interaction with structural exchange. The information is costly and asymmetrical to exchange between parties. Institutions are formed to reduce uncertainty in human exchange (North, 1992).

Moreover, North (1992) provides the definition of institutions as the rules of the games of society or humanly devised constraints structuring human interaction. Furthermore, he defines the organization as the player or groups of individuals bounded by a common purpose to achieve objectives.

NIE has been developed in different areas, such as property rights economics, public choice, and the theory of the firm. The IAD framework has been developed by Ostrom and her colleagues at the workshop in political theory and policy analysis in order to understand the institution, especially the common-pool resources, which are part of the property rights economics. The IAD framework has been developed since 1982, providing the world of actions with a systematic approach to the decision-making process.

The IAD framework provides a systematic approach to the decision-making process in terms of exogenous and endogenous variables. The exogenous variables are bio/physical condition, attribute of community, and rules-in-use, representing the external parameter that influences the decision situation. Endogenous variables represent the connection between the action situation and the rules-in-use, and they are represented by seven rules: boundary, position, choice, information, payoff, aggregation, and scope.

Moreover, the interconnection between the world of actions or level of analysis and outcome: operational, collective-choice, constitutional, and metaconstitutional situations, is presented in the interaction between level and feedback as influencing the decision-making at the lower level. The four levels of analysis and outcome by Ostrom are similar to the four levels of the economics of institutions by Williamson (2000). However, Williamson does not provide the detail of the action situation at each level.

The IAD framework enhances the understanding of the decision-making process in several fields, especially agriculture such as fishery, forestry, farming, water, and river basin. Table 3 shows some of the IAD literature on applications in the field. Most of them concentrate on common-pool resources, especially in the fishery field.

Table 3. IAD literature

Literature	Introduction to the use of the IAD framework	Action situation
Ho and Gao (2013)	Analyzing collective action problems in building management	4-housing
Chadsey, Trainer, and Leschine (2012)	Identifying key success factors of the Olympic Region Harmful Algal Bloom (ORHAB) partnership with harmful algal blooms (HABs)	4-marine
Fidelman et al. (2012)	Highlighting the diverse contextual factors that challenge the governance of large-scale marine commons, using the Coral Triangle Initiative as an example	4, (2)-marine
Ghorbani, Dignum, and Dijkema (2012)	Modeling agent-based systems based on the IAD framework (MAID: Modeling Agent-based systems based on Institutional Analysis)	Other-modeling
Mulazzani et al. (2012)	Describing the anchovy fisheries of Croatia and Italy, and France and Spain	4-fishery
Reiners (2012)	Examining how and why on-the-ground decisions and outcomes differ	4-wildfires/forest
Asquer (2011)	Analyzing the liberalization and regulatory reforms of network industries in Italy	Other-regulatory
Beitl (2011)	Examining the relationship between collective action and environment to sustainable mangrove fisheries in coastal Ecuador	4-fishery
Bushouse (2011)	Identifying six governance structures in the for-profit and nonprofit sectors for childcare service	1-club goods
Heikkila, Schlager, and Davis (2011)	Identifying the 14 interstate river basin systems and applying common-pool resource (CPR) design principles	4-water CPR management
Henry and Diet (2011)	Understanding the trust in variables-belief system and networks-influence trust	Other-trust
Li and Li (2011)	Analyzing the multifunctional agriculture (MFA) in Chongqing, China	4-agriculture
McGinnis (2011)	Providing a systematic approach to elaborating on a complex policy network with overlapping sets of actors influencing the rules of interactions in Maine lobster fisheries, international development assistance, and faith-based organizations for USA welfare policy	4-fishery Other-coordination, welfare
Mehring et al. (2011)	Structuring the forest management in Central Sulawesi, Indonesia, by considered rules, participants, and conservation outcomes	4-forest
Mokhtar, Torman, and Hossain (2010); Mokhtar et al. (2011); and Toriman et al. (2012)	Identifying institutional challenges associated with Integrated River Basin Management (IRBM) implementation in Langat River basin, Malaysia	4-water
Oakerson and Parks (2011)	Explaining local variations in public organizations as a function of the geo-physical diversity of localities in Yellowstone and Adirondack Park	4-forest
Thiele et al. (2011)	Understanding the multi-stakeholder platforms for potato-based value chains in Bolivia, Peru, and Ecuador	4-farmers

Literature	Introduction to the use of the IAD framework	Action situation
Wasike, Kahi, and Peters (2011)	Identifying the missing actor in action situations for animal-recording activities	4-animal farm
Akinola (2010)	Providing polycentric planning, self-governance, and adaptive development strategies to resolve the socio-economic and political crisis in the Niger Delta	2-public sphere
Hardy and Koontz (2010)	Evaluating the transaction costs and environmental, social, and policy outputs of two watersheds: urban and rural	4-water
Ostrom and Cox (2010)	Enabling a finer understanding of biodiversity loss, climate change, pollution, and natural resource degradation systems, and providing a basis for comparisons for policy prescriptions	2-environment
Andersson (2009)	Analyzing the contextual factors that affect the actors' motivation to engage in collaborative learning activities for SIDA	Other-collaboration
Coleman and Steed (2009)	Examining theoretical determinants of monitoring and sanctioning at local community level and external government agents from the International Forestry Resources and Institutions (IFRI) research program	4-forest
Dong et al. (2009)	Examining the effectiveness of institutional development at the local and national levels in mitigating the problems facing sustainable rangeland management in Nepal	4-rangelands
Hardy and Koontz (2009)	Illuminating how the operational rules produced by different types of partnerships result in outputs that impact three watershed management systems	4-water
Laing et al. (2009)	Understanding partnerships between protected area agencies and the tourism industry	Other-partnership success
Martinez (2009)	Identifying and examining the structure and relationships between the different actors involved in the tobacco control policies in health care organizations	2-tobacco policy in hospital
Schlager and Heikkila (2009)	Identifying the conditions under which interstate river compacts are likely to address conflict and solutions	4-water
Clement and Amezaga (2008)	Examining land use changes in Vietnam that national policy interfered with, with local factors leading to a complex course of decision-making and action	4-forest, land
Klass (2008)	Identifying the institutional roots of the crisis in Côte d'Ivoire, and suggestions	Other
Yandle (2008)	Examining the development, strengths, and weaknesses of New Zealand's fisheries co-management, commercial stakeholder organizations (CSOs)	4-fishery
Blackstock and Carter (2007)	Providing sufficient incentives to make the transition from traditional science to sustainability science for the implementation of the Water Framework Directive (WFD)	4-water
Hill and Hupe (2006)	Illustrating the IAD framework assisting the English health and education policy analysis that are inter-related or nested	2-health
Imperial and Yandle (2005)	Examining competing institutional arrangements used to manage fisheries: bureaucracy, markets, community, and co-management to understand critical issues related to institutional analysis	4-fishery
Koontz (2005)	Examining collective decision-making related to natural resources for farmland preservation planning in Ohio, USA.	4-farmland
Flinkman (2004)	Evaluating the effectiveness and credibility of exchanges in the wood construction supply chain in Dar es Salaam and Mwanza	4-wood
Rudd (2004)	Facilitating critical examinations of important cross-cutting issues by a modified IAD framework providing a platform for ecosystem-based fisheries management policy, experiment, design, and monitoring	4-fishery
Sobeck (2003)	Examining an early stage of policy development emphasizing group membership and participation	Other-collaboration

Literature	Introduction to the use of the IAD framework	Action situation
Leach and Pelkey (2001)	Reviewing the conflict resolution in watershed partnerships on collaborative resource management	4-water
Sekher (2001)	Analyzing the process of organized participatory resource management in community forestry practices in India	4-forest
Carlsson (2000)	Incorporating the policy network approach to an analytical framework, e.g., the IAD framework	Other-analytical framework
Imprerial (1999a)	Examining the structure and performance of the institutional arrangement used to implement the Salt Ponds, a special area management (SAM) plan, Rhode Island	4-ecosystem-based management
Imperial(1999b)	Understanding the institutional arrangement used to implement an ecosystem-based management program	4-natural resource management
Piipponen (1999)	Examining the institutional setting for the forest sector in the Republic of Karelia, Russia	4-forest

Note: 1: Buyers and sellers exchanging goods (services) in a market
2: Legislators making legislative decisions about future laws
3: Powerful politicians bargaining over the allocation of public support
4: Users of a common-pool resource withdrawing resource units (such as fish, water, or timber)
5: Heads of state negotiating an international treaty
Other: excluded from five categories

WRC as an action situation represents the negotiation of RR revisions as an international treaty. Ostrom (2005b) pointed out that this action situation can be described and analyzed using a common set of variables, that is, the variables of an action situation inside the IAD framework. However, Ostrom did not provide the IAD application on a negotiation of an international treaty.

The author is familiar with the IAD framework from the previous work to understand the bundle rights of frequency use on frequency assignment approaches: command-and-control, market-based, and spectrum commons (Ard-paru, 2010). The element of the IAD framework helps in understanding the different bundles of rights for frequency use in each frequency assignment approach at the operational and collective-choice level.

It is a challenge to the author to apply the IAD framework at the constitutional level where the regulations or rules for collective-choice and operational level are revised. In the field of spectrum management, WRC is the forum for international negotiations of the RR revisions as the action situation at the constitutional level. At WRC, the dynamic situation of international negotiations between Member States can be analyzed and described systematically by the element of the IAD framework. The discussion at WRC contains the rationale of the RR revisions that is missing from the ITU archives. The IAD framework therefore allows the limitation of the ITU archives and meeting observation to be identified. This IAD framework applicability to WRC as the international negotiation is the original work of the author.

To conclude, the study selects the IAD framework, because the IAD framework has the ability to systematize the action situation and explain the dynamic situation of the decision-making process at WRC as the international negotiations. This study also contributes to the

first application of the IAD framework in the context of WRC as the international negotiations or an action situation.

Furthermore, in order to understand the rationale behind such discussions, the IAD framework provides a list of questions that should be asked during the decision-making process (WRC). However, the IAD framework does not provide the content or a detailed discussion. Participant observation (PO) or attending such relevant meetings captures the argument that represents the rationale behind it. This information is only available for attending the delegation and is never documented. This missing information from the ITU archives becomes crucial when the particular revision of the RR is not finished at the relevant WRC. The missing information then becomes critical input to influence the decision-making process at the next WRC, since the archives are incomplete. The attending Member States benefit from the information gathered by participant observations. This information enables them to develop further arguments or options during WRC or fully develop contributions for the next or future WRCs.

At WRC, Member States also have their own priority for each WRC agenda item, depending on their national interests. There are many meeting forms running in parallel after the plenary session. Member States that have limited resources (number of delegations, time, and budget) cannot attend all meetings.

The number of delegates among the Member States shows the gap between High, Upper Middle, Lower Middle, and Low Income countries. Moreover, the number of delegates illustrates the unequal access to the WRC meetings as information asymmetry. This number of delegates highlights the information asymmetry between them. It is highly likely that the High and Upper Middle Income countries, which have more delegates, will allow full (or almost full) participation at all relevant meetings, compared with the Lower Middle and Low Income countries. The study attempts to fill in the missing information as a contribution. A detailed discussion follows.

Problem with RR interpretation

Member States must understand the RR in order to operate national and international markets under the constraints of the provisions. Occasionally, when implementing RR provisions, the ambiguity of text can cause interpretation problems among Member States.

For instance, the text considering b) and c) of Resolution ITU-R 58 – Studies on the implementation and use of cognitive radio system (CRS) is the issue in Agenda Item 1.19 of the WRC-12. [1,2,3] The text is as follows:

"b) that studies on regulatory measures related to the implementation of CRS are outside the

[1] The Resolution ITU-R 58 is approved by the Radiocommunication Assembly (RA) to facilitate further studies on CRS implementation.
[2] The CRS is an enabling technology allowing the operating parameters to be changed automatically by software to obtain knowledge from the environment and improve performance.
[3] The ITU-R resolution is the resolution adopted by the RA. The RA is convened prior to WRC. The RA also approves recommendations and reports from the ITU-R study group (SG).

scope of this ITU-R Resolution;

"c) that any radio system implementing CRS technology needs to operate in accordance with provisions of the Radio Regulations;"

The issue of WRC-12 Agenda Item 1.19 is whether regulatory measures are outside the scope of Resolution ITU-R 58. Some Member States interpret the above provisions as a need to have regulation in place. Another interpretation is that there is no need to have an additional regulation as "c)" already indicated that CRS technology should be operated under the relevant RR provisions.

Generally, when there is a problem of interpretation, Member States submit requests for an official interpretation to the Radiocommunication Bureau (BR) for clarification. The BR prepares relevant documents for submission to the Radio Regulations Board (RRB) for approval. After the RRB ruling, the resulting interpretation is published as the Rules of Procedure.[4]

To understand the RR provisions, the rationale of the provisions is required. Unfortunately, the rationale for RR provisions is not clearly stated in the RR. Member States must search relevant documents in the ITU archives. The WRC proceedings are also available in the ITU archives for this purpose.

To understand how and why such changes to the RR occurred, this study explored the ITU archives, as the RR development is contained in them.

ITU archives

The ITU archives contain the input and output documents of the WRC proceedings in the form of the RR revisions. However, the archives do not contain the rationale of the decision. The WRC proceedings only contain input documents (written documents from Member States) and output documents (RR revisions). The WRC proceedings also include only minutes of plenary meetings, not all meetings containing the rationale of RR revision. Verbal comments made during WRC meetings are not documented and discussions outside the meetings are completely unrecorded. Such argumentations contain the underlying rationale for RR revisions. Importantly, only participating Member States have this information, which is missing from the archives.

RR revisions

When there are new radio technologies, applications, and services, Member States may need to change the RR provisions to accommodate them. Moreover, any RR ambiguity should be corrected, and new national and regional concerns about the RR provisions addressed. These requirements necessitate RR revisions, which are performed during WRCs every three to four years, an important process for international and domestic policies concerning spectrum management.

[4] See Chapter 4 for details on the ITU structure development.

In order to review and revise the RR, the WRC agenda must be prepared four to six years in advance and approved by the Council (CC) according to the ITU Convention.[5]

Underlying issues of RR revisions

The underlying issues of RR revisions are conflict between existing services or current users and new technologies, applications, and services. Existing services and current users are normally always aware of the introduction of new services, technologies, or applications when they share (use the same or adjacent) frequencies. The main concern is the risk of interference to their existing users. When the new WRC agenda items propose a new or additional allocation for new services in the TFA, the issues of possible interference with the existing service and compatibility studies for sharing the same frequency are raised by the existing service to ensure that the new allocation does not cause harmful interference to existing users. Some examples of conflicts between existing services and new technologies follow:

(1) At the WRC-03, there was conflict between GMDSS and non-GMDSS vessels (Agenda Item 1.14). GMDSS is the new technology to replace the old technology for distress communication in the 2 182 kHz band. The non-GMDSS vessels, such as small local fishing boats in the developing countries, insisted on retaining the use of the 2 182 kHz band. Member States compromised by revising WRC Resolution 331 for non-GMDSS vessels for distress communication.

(2) At the WRC-03, there was conflict between ARS, amateur-satellite (ARSS), and broadcasting service (BS) in the 7 MHz band (Agenda Item 1.23). The conflict was about a global reallocation of ARS in the 7 MHz band. This conflict occurred after the World Administrative Radio Conference 1992 (WARC-92). Member States compromised by removing BS in Region 1 and Region 3 in the 7 100-7 200 kHz band and adding the new ARS global allocation in the 7 100-7 200 kHz band.

(3) At the WRC-12, there was conflict between existing services and the new applications or technologies addressed in Agenda 1.2 on whether the current RR has any flexibility to govern the rapid development of technology. This issue has been ongoing since the WRC-03 (Louis, 2011). However, the outcome of the WRC-12 on this issue needs further study on reviewing the definitions of fixed service, fixed station, and mobile station (during the WRC-15 study period) and further action will be taken at the WRC-15.

(4) At the WRC-12, there was conflict between maritime mobile service (MMS) and amateur service (ARS) for a frequency allocation in the 495-505 kHz band (Agenda Items 1.10 and 1.23).[6]

[5] See Chapters 4 and 3 for details on the ITU structure development and the WRC preparatory process.

[6] Council Resolution 1291 (MOD), Place, dates, and agenda of the World Radiocommunication Conference (WRC-12), provides Agenda Items 1.10 and 1.23 as follows:
1.10 to examine the frequency allocation requirements with regard to operation of safety systems for ships and ports and associated regulatory provisions, in accordance with Resolution 357 (WRC-07); and
1.23 to consider an allocation of about 15 kHz in parts of the band 415-526.5 kHz to the amateur service on a secondary basis, taking into account the need to protect existing services.

The proposal for MMS was for a primary allocation in the 495-505 kHz band on a global basis. However, the proposal for ARS was for a secondary global allocation of a 15 kHz bandwidth. The original proposal was to allocate ARS in the 415-526.5 kHz band. During the discussion, the proposal was reduced to the 495-510 kHz band (The National Association of Amateur Radio, 2012).

The conflict between the MMS and ARS proposals was in the 495-505 kHz and 495-510 kHz bands. During the Member State discussion, a compromise was reached, i.e., MMS was given a global allocation in the 495-505 kHz band on a primary basis and ARS an allocation in the 472-479 kHz band on a secondary basis.

(5) WRC-12 Agenda Item 1.22 is about the use of short-range devices (SRD), especially Radio Frequency Identification (RFID) devices, in the extended C-band that may interfere with satellite receivers. The existing satellite operator conducted the studies and found that RFID devices caused harmful interference to its satellite receivers. Consequently, the satellite operators proposed recognizing the use of SRD in the satellite bands as an option for WRC Agenda Item 1.22, in order to make a clear discussion and decision regarding the SRD, in the view of the potential harmful interference.

Harmful interference from SRD also raised concerns from international organizations: the International Civil Aviation Organization (ICAO), International Maritime Organization (IMO), and World Meteorological Organization (WMO). They expressed their objections to sharing frequency with SRDs within their current frequency bands.

Form of RR revisions

The form of the RR revisions represents the scope of the RR provisions to be applied to a particular area: application, technology, or service, namely, a specific regulation, or to be applied to a broad or more than one area, namely, a generic regulation.

The specific and generic regulations are similar to the posterior and priori approaches explained by Codding and Rutkowski (1982). The posterior approach uses a case-by-case method that relies on coordination between interested parties or on a notice and recordation procedure (Codding & Rutkowski, 1982, p. 252). The posterior approach is likely to be a first-come, first-served method to allocate the right to use radio resources. Compared with this study, the generic regulation is similar to a posterior approach.

The priori approach is a principled approach, usually relying on a negotiated plan based on a general formula or criteria for seeking equity among all the parties (Codding & Rutkowski, 1982, p. 252). Compared with this study, the specific regulation is similar to a priori approach.

Examples of posterior and priori approaches include unplanned and planned bands for orbital satellite filling, respectively. The posterior approach uses existing rules to register the use of satellite orbits and frequencies at the MIFR. The registration record helps to notify and coordinate interested parties administered by the BR on a case-by-case basis. The existing rules are applied as a generic regulation. The posterior approach has greater flexibility to capture the rapid change of telecommunication technology than a priori approach (Codding & Rutkowski, 1982).

Conversely, the priori approach provides equality to access the satellite orbit and frequency with an allotment for each Member State, such as the BSS planned band. However, the detailed specifications and inflexible constraints unnecessarily impede the implementation of new technology (Codding & Rutkowski, 1982, p. 253). The priori approach provides a specific regulation by service.

In 1906, the RR was part of the Berlin Convention (International Radiotelegaph Convention). The Convention was regulated only by communication between the ship and coast stations in MMS. However, over time, the development of radiocommunication technology necessitated additional services. The Berlin Convention had to expand its scope to cover additional services, such as definitions for stations and services. The mix between a generic and specific regulation was unavoidable. Some additional examples of the regulation form follow:

(1) The RR2012 contains both generic and specific regulations. The generic regulation governs more than one service. The specific regulation provides practical guidelines for such technologies or applications, within either a specified frequency band or service. For example, Article 1 of the RR provides terms and definitions that can be used for all services. Article 5 of the RR provides the TFA by frequency band. The TFA specifies the services in each frequency band with footnotes (containing the specific constraint of use).

(2) In WRC-12 Agenda Item 1.19, the issue of CRS and SDR technologies raised the question of the form of the regulation. Some Member States viewed the current RR as allowing the use of these two technologies to be governed and that there was therefore no need to have a specific regulation (WRC resolution). Some Member States argued that the current RR did not provide a practical guidance when there was harmful interference. Thus, a specific regulation was required to provide Member States with practical guidelines.

Member States that consider the current RR to be sufficient to govern the SDR and CRS technologies are concerned about specific practical guidelines for new technologies. If WRC agrees with the specific guidelines for new technologies, every new technology will need to have its own guidelines or regulations in the future. There would then be many specific regulations in the future.

The debate was settled by a compromise between the Member States, and the WRC recommendation to encourage Member States to participate in the further CRS study and decision on regulatory matters, if necessary, will be taken at the WRC-15.

Limitations of the ITU archives

The ITU archives provide official but incomplete documentation on the RR and WRC proceedings. Member States that do not attend WRC meetings must rely on the ITU archives as their primary information source. The following examples demonstrate the limitations of the ITU archives.

The definition of “telecommunication” has developed over time. The ITU archives capture changes in meanings via the RR versions, i.e., 1932, 1947, and 1982. The ITU archives also capture changes from the codified input documents submitted by the Member States, however, non-codified verbal comments are not recorded. The rationale as to why changes have occurred is therefore not documented. This “missing” information would be valuable if changes to the “telecommunication” definition are proposed at future WRCs.

Another crucial construct is the notion of frequency band. Frequency bands for MMS were first allocated in 1927. The first frequency band was 125-150 kHz. However, at the International Radiotelegraph Conference in Atlantic City in 1947, this band was terminated. The ITU archives are mute on the reason for this decision.

The study covers the development of selected RR provisions and frequency bands for specified services by identifying differences across the RRs, but the archives only contain the output documents, i.e., how and what they change.

Relevance and limitations of the IAD framework

The IAD framework is a valuable tool as it guides identification of the likely form of any missing information. The output obtained by applying the IAD framework to a decision-making process is the list of issues that would have been addressed during the meetings as an institutional arrangement. The missing information would vary by the WRC meeting forms. The IAD framework proposes a general form for missing information by posing the questions: What issues are debated?; Who raised the issues?; Who starts, who supports, who opposes the issues (position rules)?; How do issues flow inside meetings (information rules)?; How do Member States control their stances (aggregation rules)?; What are Member States’ stances (support, oppose, neutral) (choice rules)?; What are the costs and benefits of choice (evaluative criteria and payoff rules)?; and What are the consequences of individual choice (outcome and scope rules)?

Clearly, the IAD approach only provides the questions, not their detailed content. Importantly, the detailed content varies with the form of the meetings, while the issues are case specific. To obtain details of the negotiations, participant observations by attending meetings are required.

Limitations of participant observations

Potentially, participant observation or attending meetings could provide the information missing from the archives. However, such information can only be provided for current situations.

At the WRC meetings, the number of delegates varies by the agenda item. Moreover, there are many meeting forms[7] (plenary, committee [COM], working group [WG], sub-working group [SWG], informal group [IG], and drafting group [DG]). To be specific, the maximum number of parallel sessions at the WRC-12 is twelve. However, as there are 32 agenda items for the WRC-12, this would require a delegation of 32 persons to allow full coverage of all the WRC meetings.

[7] The various meeting forms will be further explained in Chapter 2.

Table 4 lists the delegates attending the WRC-12, grouped by the World Bank income classification. Table 4 also indicates that Low Income countries have fewer delegates and therefore depend more on archived material for their future decision-making on issues that continue to the next WRC.

Table 4. WRC-12, national delegates by World Bank income classification

High	**No.**	**Upper Middle**	**No.**	**Lower Middle**	**No.**	**Low**	**No.**
Andorra	2	Albania	9	Angola	18	Afghanistan	5
Australia	38	Algeria	47	Armenia	9	Bangladesh	6
Austria	10	Argentina	18	Bhutan	2	Benin	13
Bahrain	4	Azerbaijan	5	Cameroon	18	Burkina Faso	7
Barbados	3	Belarus	22	Congo, Rep.	6	Burundi	4
Belgium	6	Bosnia and Herzegovina	15	Côte d’Ivoire	29	Cambodia	1
Brunei Darussalam	4	Botswana	9	Djibouti	9	Central African Rep.	4
Canada	43	Brazil	29	Egypt	11	Chad	14
Croatia	9	Bulgaria	16	El Salvador	6	Congo, Dem. Rep.	9
Cyprus	9	Chile	7	Georgia	2	Gambia, The	6
Czech Republic	9	China	116	Ghana	22	Guinea	9
Denmark	9	Colombia	21	Guatemala	3	Guinea-Bissau	2
Estonia	6	Costa Rica	14	Guyana	1	Haiti	1
Finland	16	Cuba	9	Honduras	5	Kenya	17
France	103	Dominican Rep.	4	India	36	Korea, Dem. Rep.	4
Germany	45	Ecuador	7	Indonesia	55	Kyrgyz Rep.	4
Greece	19	Gabon	11	Iraq	13	Liberia	2
Hungary	13	Grenada	1	Lao PDR	4	Madagascar	8
Iceland	2	Iran, Islamic Rep.	41	Lesotho	5	Malawi	4
Ireland	6	Jamaica	6	Mauritania	5	Mali	11
Israel	20	Jordan	9	Moldova	9	Mozambique	12
Italy	52	Kazakhstan	15	Mongolia	7	Myanmar	7
Japan	71	Latvia	11	Morocco	22	Niger	6
Korea, Rep.	60	Lebanon	12	Nicaragua	1	Rwanda	9
Kuwait	14	Libya	19	Nigeria	68	Sierra Leone	6
Liechtenstein	4	Lithuania	12	Pakistan	21	Somalia	1
Luxembourg	14	Macedonia, FYR	9	PNG	11	Tajikistan	2
Malta	3	Malaysia	30	Paraguay	13	Tanzania	14
Monaco	6	Mauritius	7	Philippines	8	Togo	14
Netherlands	19	Mexico	31	Senegal	16	Uganda	14
New Zealand	7	Montenegro	9	South Sudan	3	Zimbabwe	13
Norway	12	Namibia	12	Sri Lanka	9		
Oman	23	Panama	4	Sudan	15		
Poland	24	Romania	28	Swaziland	3		
Portugal	7	Russian Fed.	74	Syrian Rep.	7		
Qatar	13	Serbia	13	Ukraine	43		
San Marino	2	South Africa	35	Uzbekistan	7		
Saudi Arabia	51	Suriname	3	Vietnam	19		
Singapore	13	Thailand	22	Yemen, Rep.	3		
Slovak Rep.	11	Tunisia	16	Zambia	8		
Slovenia	9	Turkey	84				
Spain	36	Uruguay	7				
Sweden	27	Venezuela, RB	8				
Switzerland	11						
Trinidad and Tobago	7						
UAE	48						
United Kingdom	50						
United States	138						
Mean	**23.08**		**20.4**		**13.8**		**7.39**

Information asymmetry thus exists between High Income and Upper Middle Income countries, which have enough delegates attending all (or most) meetings, and Lower Middle Income and Low Income countries.

Event timeline

Table 5 presents the RR provision implementation at times t_0 and t_1. WRC is held at t_0. t_1 is the time when the archives are "completed."

Table 5. Timeline of RR provisions implementation

Provisions	**WRC at t_0 (past)**	**Archives at t_1 (current time)**
No ambiguous text	Not attending	Self-contained
	PO	No additional information
With ambiguous text	Not attending	Not self-contained and rationale is needed
	PO	Additional rationale apart from archives

When Member States implement the RR provisions, these provisions are understandable within the RR itself (no ambiguous text). The RR, as part of the ITU archives, is then self-contained. Attendance of the relevant WRCs or participant observations (PO) are therefore not necessary. In other words, meeting attendance does not provide additional information other than the archives.

Conversely, when such provisions contain ambiguous text, interpretations of the texts will vary between Member States. Further exploration of the ITU archives is then required to obtain the underlying rationales. Unfortunately, the ITU archives do not document such rationales. Participation in the relevant WRCs is therefore crucial to understanding such provisions. Only attending Member States have the information that is behind such provisions. Consequently, the ambiguous text may render issues for the RR revisions.

The possibilities for the RR revisions are represented by the WRC agenda items. Each agenda item contains at least one issue. For example, WRC-12 Agenda Item 1.19 contains two issues: software-defined radio (SDR) and CRS.

Table 6 shows the timeline of WRC issues. WRC is held at t_0. t_1 is the time when the archives are "completed." t_2 is the time when the next WRC meeting will be held.

Table 6. Timeline of WRC issues

Issues	**WRC at t_0 (past)**	**Archives at t_1 (current time)**	**Next WRC at t_2 (future)**
Settled	Not attending	Self-contained	No issues carried forward
	PO	No additional information	
Ongoing	Not attending	Lack rationale	Issues brought forward
	PO	Provide rationale	

At WRC, when the WRC agenda items have been solved or settled, the Final Act is the output of the discussions contained in the ITU archives as the WRC proceedings. In other words, the issues have been settled during the Member State negotiations at WRC. Only resolved issues move forward for approval as possible RR revisions. Other information, including the discussion of issues during the debates, is lost. The Final Act only contains the discussion settlement, not the details of the discussion of such issues. Non-attending Member States will

be better off because the issues are settled and no remaining issues are carried forward to the next WRC.

Conversely, when the issues are controversial or debatable and cannot be settled in that WRC, they are carried forward to the next WRC for further consideration. Only Member States attending the relevant WRC meetings will then have a clear understanding of these issues. The discussion is not documented anywhere. Unfortunately, Member States not attending the meetings will not know the rationale behind these issues, which is crucial information to develop further argumentation.

To sum up, in cases without ambiguous text or settled issues, participation in the meeting does not provide non-attending Member States with any additional information. The archives are therefore self-contained, providing an understanding of the RR provisions and settled issues as RR revisions.

However, in the case of RR with ambiguous text, the archives are not self-contained, because they lack the rationale behind the provisions. Only attending Member States will have this information to complement the archives. This information provides the full understanding of these ambiguous texts.

In the case of ongoing issues, the archives are not self-contained and, as such, do not provide an understanding of the rationale behind the issues. It is therefore vital for the Member State to attend the relevant meetings to capture these arguments, as they provide a strong basis on which the attending Member State can develop further documents for the next WRC or relevant meetings.

Incomplete information

Member States that only rely on the ITU archives have incomplete information, because the ITU archives do not document the rationale or missing information. Only Member States that attend the relevant meetings have this information. There is therefore information asymmetry between attending and non-attending Member States.

The following example demonstrates the practical importance of "missing" archive information to a developing country.

Thailand is an Upper Middle Income country (see Table 4) that sent 22 delegates to the WRC-12. However, only six delegates attended for the entire period of the WRC-12 (four weeks). Each delegate was required to contribute to several agenda items. The maximum number of parallel meetings at the WRC-12 was twelve. It was therefore impossible for the Thai delegates to attend all the meetings. Each delegate prioritized his/her agenda items and meetings. When issues outside the scope of the agenda continued to the next or future WRCs, Thailand did not have a strong basis on which to develop further argumentation. Moreover, if the issues are part of the RR provisions, Thailand has limited understanding of the provisions because of the missing information.

Does the missing information matter?

The missing information matters to Member States that would benefit from it. Not all Member States give WRC agenda items the same priority. Missing information from an agenda item may be valuable to some Member States and not to others.

The priority of WRC agenda items varies by country and depends on the benefit to the country. For example, countries that have a manufacturing, standard setting, or research and development base benefit from a global allocation of services. However, countries that only import radiocommunication equipment benefit from standard compatibility. They therefore have a choice of many compatible standards.

For example, for WRC-07 Agenda Item 1.14 regarding GMDSS, Thailand has many small fishing boats that are non-GMDSS vessels. The local fishermen cannot afford GMDSS equipment but still use the 2 182 kHz for distress communication. This evidence as background information renders concerns about this agenda item. Thailand must therefore protect its interest (local fishermen) by supporting the retention of the 2 182 kHz for non-GMDSS vessels for distress communication in WRC Resolution 331.

For WRC-12 Agenda Item 1.22 regarding the emission of SRD, Thailand has an existing satellite service with potential interference from SRD emissions to satellite receivers. Thailand must therefore protect its existing satellite service. Thailand submitted a proposal to the APG2012-4, indicating that the satellite receiver needed protection criteria from SRD emissions (Method C or D). However, at the APG2012-5, the satellite operator changed its views and did not submit Thailand's proposal further. Only a verbal statement in a drafting group mentioned that Thailand retained its previous position. The result of the APG2012-5 was a compromise with APT member countries that preferred to modify the existing ITU-R resolution to study harmonization of SRD further with adequate constraints to ensure there was no harmful interference to existing services.

For WRC-12 Agenda Item 1.2 regarding the enhancement of the international regulatory framework for fixed and mobile convergence, Thailand did not have a delegate to attend at drafting group level, as this may not have had any effect on Thailand at the end of the WRC-12. Thailand therefore lacked argumentation on the possibilities of changing the definitions of "fixed service" (FS), "fixed station," and "mobile station." Unfortunately, this issue will continue to the next WRC-15, and it may raise the impact on the existing fixed and mobile services, because they are the main services in Thailand. Thailand must therefore prepare itself by following the activities on this matter and evaluate the current situation on whether the change will be made at the WRC-15 or a Thai reservation as a country footnote will be necessary.[8]

The following example illustrates the importance of missing information on WRC-12 Agenda Item 1.2 to Thailand.

[8] The use and role of footnotes will be further explained in Chapter 2.

Agenda Item 1.2 concerns, in particular, the technological convergence of FS and mobile service (MS), and fixed-satellite service (FSS) and mobile-satellite service (MSS).[9] While there is general acceptance that the technology is converging, technological convergence allows the merger between FS and MS, allowing FS and MS to share the same frequency. One service can have at least one application. An example of an FS application is a microwave link between point-to-point and point-to-multipoint. Examples of MS applications include mobile phones, trunk radios, and walkie-talkies (push to talk). The implication of technological convergence for the implementation of the RR is whether the current RR will be able to govern the convergence or will need to be reviewed and revised.

Two main approaches were captured from the CPM report to revise the RR in terms of the scope of the RR implementation, namely: (1) specific scope and (2) general scope.

The specific scope is to implement the RR in a limited way, i.e., a particular service or application. The goal is to have a specific regulation for a service, such as a resolution or footnotes. In this case, the specific regulation is for fixed and mobile convergence service.

The general scope is to implement the RR over several services. In this case, the general scope approach is for the possibility of convergence between FSS and MSS, but the consequences apply to all allocations of frequency bands of the TFA.

The specific scope was proposed by the ITU-R study group (SG) that studied FS and MS (terrestrial service) convergence. The study proposed four options: (1) no change being made to the RR; (2) modifying the FS, fixed, mobile, and land station definitions contained in Article 1 and modifying Appendix 4; (3) modifying the FS and fixed station definitions, and modifying Article 11 and Appendix 4; or (4) modifying Appendix 4.

Alternatively, the general scope was to study FSS and MSS (space service) convergence. This study proposed two options: (1) no change being made to the RR and (2) adding FSS and MSS to the WRC resolution (Principle Allocation of Frequency Bands).

The Member States made some 25 submissions on Agenda Item 1.2 at the WRC-12, while Sector Members submitted 7 documents. The WRC-12 outcomes are contained in the Final Act: WRC Resolution 957 [PLEN/1] (WRC-12) – Studies Towards Review of the Definition of Fixed Service, Fixed Station and Mobile Station. Another WRC-12 output concerning this agenda item is the modified WRC Recommendation 34 – Principle for the Allocation of Frequency Bands. Figure 2 shows the Agenda Item 1.2 meetings and the document flow.

[9] Council Resolution 1291 (MOD), Place, dates and agenda of the World Radiocommunication Conference (WRC-12), provides Agenda item 1.2 as follows:
1.2 taking into account the ITU-R studies carried out in accordance with Resolution 951 (Rev.WRC-07), to take appropriate action with a view to enhancing the international regulatory framework.

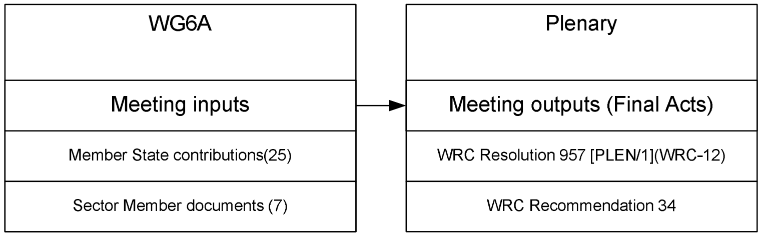


Figure 2. Agenda Item 1.2 meetings and document flow

The input (CPM report and submissions by Member States and Sector Members) and output documents (the Final Act) of WRC are contained in the ITU archives. However, the development of issues from four proposed options of the CPM report (FS and MS) to the WRC resolution and from two options (FSS and MSS) to the WRC recommendation are not documented in the archives. Only Member States that attended the meetings have knowledge of how and why the change occurred. Thailand did not have enough delegates to be able to attend the SWG and IG on Agenda Item 1.2. The ongoing Agenda Item 1.2 argumentation is therefore not available for Thailand to consider when developing further proposals on the matter.

WRC Recommendation 34, as a WRC-12 outcome in the form of an implementation guideline, is not mandatory for Thailand to implement because it is not binding. The recommendation suggests that a service allocation be a broadly defined service, provide on a global basis, require minimum footnotes, and take into account the relevant CPM report, and ITU-R recommendations and reports.[10]

However, WRC Resolution 957 mandates further study of the FS, fixed station, and mobile station definitions. Should the new definitions merge FS and MS into a single service, other provisions such as notification and coordination will need to be revised. This potential revision is important to Thailand because FS and MS are the two most allocated services in terms of the number of frequency bands used and the volume of their bandwidths. The majority of radiocommunication usage in Thailand is FS and MS applications. For example, FS and MS are used to provide a fixed microwave link and mobile phone. In terms of subscriber numbers and transmission, these are the dominating services in Thailand.

The ITU-R SG will study the possibility of modifications to the FS, fixed station, and mobile station definitions. The results of the study will be reported as information to Member States to make further decisions at the WRC-15.

Importantly, the change in these definitions, especially the merger between FS and MS, may influence a (almost entirely) national telecommunications regulation review. It includes a global as well as Thai TFA, FS and MS regulations, National Frequency Master Plan, frequency assignment scheme and criteria, licensing conditions, national law (radiocommunication, telecommunication and broadcasting), station technical characteristics, and the notification and coordination process (national and international).

[10] Footnotes inside the TFA can represent the different categories of additional or alternative allocation apart from the TFA. Moreover, Member States can use the footnotes to reserve their rights to use different services or not comply with such provisions.

For example, when the modification of the definitions for FS, fixed station, and mobile station allows the merger between FS and MS (allowing the FS and MS to use the same frequency), the entire TFA must be reviewed and revised by the relevant frequency bands with priority. For example, MS can operate in the frequency bands that have FS allocation. The TFA must review and make the required changes for FS and MS convergence.

Furthermore, irrespective of the band allocation, a compatibility study must be conducted to ensure there is no harmful interference between the existing FS and MS, and new services. Moreover, the existing notification and coordination record must be reviewed to accommodate the RR revisions.

In the border area, Thailand and its neighboring countries have set up the JTC to coordinate the use of frequencies, e.g., mobile phone and broadcasting service. The JTC helps to set up the channel allocation plan and relieve harmful interference across the border.

Consequently, the existing FS and MS registry of station characteristics must be reviewed for the FS and MS convergence, especially stations that require international recognition (such as stations located on the country border). The JTC Thailand-Laos, Thailand-Cambodia, and Thailand-Malaysia must review the notification procedures.

The review of the FS, fixed station, and mobile station definitions is continuing during the WRC-15 study period. The goal is to allow convergence between FS and MS under the definition revisions. This review of definitions provides Thailand with a forum in which to develop proposals to protect its national interests. The possible merging of FS and MS, in particular, requires a sufficient period to allow existing services to gradually migrate to fixed and mobile convergence services, where appropriate. In the RR, a worst case scenario is that Member States reserve the right to use different services, apart from the services indicated in the TFA, by adding a country footnote. In the case of FS and MS convergence, Thailand may submit a country footnote for reservation to exempt it from being bound by the FS and MS convergence. This is the worst case scenario, because Thailand would not comply with this provision of the RR by having the Thai footnote exemption. Consequently, Thailand would not have the benefit of global harmonization in terms of economy of scale (low price of equipment) and this would delay the benefits of innovations.

Moreover, the review of the definitions for convergence between FS and MS provides Thailand with an opportunity to evaluate the current use of FS and MS and measure the impact of the RR revisions.

Finally, the missing information matters to non-attending Member States (i.e., Thailand) in the case of WRC-12 Agenda Item 1.2 for further study on the FS, fixed station, and mobile station definitions. This missing information provides a strong basis for Thailand to evaluate its own situation and prepare further argumentation for relevant meetings.

The archives should be complete in order to create information equality between Member States, providing equal opportunities during the decision-making process.

1.3 Purpose and limitations

The purpose of the study is to understand the information needs and coordination in the international spectrum policy setting, including the relevant ITU processes and archives (WRC proceedings and RR versions). The study also proposes the possibility of alleviating the problem of missing information in this policy setting.

The study limits the international spectrum policy setting as a decision-making process for international spectrum management to only inside WRC and its relevant ITU and regional group preparatory works. The stakeholders of WRC are defined as the ITU memberships, e.g., Member States and Sector Members.

1.4 Research question(s)

To fulfill the purpose of the study, the main research question is: **How is the international spectrum policy developed and affected by the lack of detailed documentation?** In order to answer this research question, the four sub-research questions are as follows:

1. How is international spectrum policy set in terms of ITU structure, WRC, and the RR, and how did they develop?
2. What information would be more useful for making decision?
3. How does the missing information affect international spectrum policy?
4. How can the existing ITU archives be improved or added to?

Sub-research question 1: How is international spectrum policy set in terms of ITU structure, WRC, and the RR, and how did they develop?

The relevant literature and ITU archives have been explored to understand the development of ITU, WRC, and the RR.

The results of the exploration present the development of ITU, WRC, and the RR in terms of the ITU structure, RR provisions, and WRC process. The RR provisions include key definitions, important provisions, and the TFA in specified services. The key definitions comprise telecommunication, radiocommunication, radio waves, and radio. The important provisions are choice of apparatus, frequency assignment, licences, allocation, allotment and assignment, priority of services, radiocommunication services, and radiocommunication stations. The specified services for the development of TFA are maritime mobile service (MMS), maritime mobile-satellite service (MMSS), broadcasting service (BS), broadcasting-satellite service (BSS), fixed service (FS), fixed-satellite service (FSS), mobile service (MS), mobile-satellite service (MSS), space research service (SRS), and earth exploration-satellite service (EESS). The key definitions are selected based on the foundation of the RR. Important provisions are selected on the basis of usage. The TFA is selected because it contains an

overview of how to use each frequency band. The TFA works as a map and links relevant provisions. The specified services and their satellite part are selected according to the first allocated service (MMS), most influential service for the public (BS), two most allocated services in terms of number of usage bandwidths and frequency bands (FS and MS), and space science service (SRS and EESS).

Hence, the first sub-research question addresses how the existing ITU archives have developed. However, the rationale behind the RR provision is missing as the reason they changed, and this is the topic of the second sub-research question.

Sub-research question 2: What information would be more useful for making decision?

In order to identify useful information for making the decision or the missing information, the study selects the WRC-12 as the study object for the standard process of WRC, including the WRC agenda-setting and preparatory work by ITU (WRC study process). The WRC standard process uses WRC-12 agenda-setting and the preparatory work for WRC-12 Agenda Items 1.19 and 1.22. WRC agenda-setting is the process for including the issues of RR revisions into the WRC agenda items. ITU's preparatory work process is used to study and provide decision options on each agenda item. The output of the preparatory work is the CPM report, as information for Member States to decide on at WRC. WRC-12 Agenda Item 1.19 is about the implementation of SDR and CRS. WRC-12 Agenda Item 1.22 is about the consequences of short-range device (SRD) emission.[11] These two agenda items are interesting to investigate, because they are relevant to the spectrum commons scheme. Spectrum commons increases spectrum use and encourages innovations. These two agenda items also contain controversial issues at both regional and international level.

To explore the WRC process, the IAD framework provides a list of questions to be considered during negotiations at relevant meetings. The meeting discussions represent the missing information that is not documented. Only the results of the discussions are carried forward to the next or higher meetings. However, the IAD framework only provides a broad view, not a detailed document. By attending the meetings, the author was able to capture the dynamic discussions inside them.

In order to capture these discussions, the author attended the relevant meetings, including Project Team A (PT A-9), the CEPT Conference Preparatory Group (CPG-12), the Asia-Pacific Telecommunity (APT) Conference Preparatory Group for the WRC 2012-5 (APG-2012-5), and the WRC-12.

The missing information is the detailed discussions during the negotiations inside the WRC meetings. This information provides the rationale behind the change in the RR provision and

[11] Council Resolution 1291 (MOD), Place, dates and agenda of the World Radiocommunication Conference (WRC-12), provides the relevant agenda items as follows:
1.19 to consider regulatory measures and their relevance, in order to enable the introduction of software-defined radio and cognitive radio systems, based on the results of ITU-R studies, in accordance with Resolution 956 (WRC-07);
1.22 to examine the effect of emissions from short-range devices on radiocommunication services, in accordance with Resolution 953 (WRC-07).

serves as a strong basis on which Member States can develop fully the argumentation to protect their interests in the relevant WRC meetings.

Sub-research question 3: How does the missing information affect international spectrum policy?

The study responds by illustrating the importance of the missing information for WRC-12 Agenda Item 1.2 in the case of Thailand. As a consequence of its limited resources, Thailand did not have sufficient delegates to follow the whole discussion at the SWG and IG levels. Thailand has no information regarding its argumentation. At the WRC-12, the unsettled issue of Agenda Item 1.2, including the possibility of a revision of FS, fixed station, and mobile station, is continuing to the WRC-15.

WRC-12 Agenda 1.2 is about the convergence between FS and MS, and FSS and MSS. The remaining issues carried forward to the WRC-15 are possibilities of modifying the FS, fixed station, and mobile station definitions.

The study also demonstrates the missing information regarding WRC-12 Agenda Item 1.19 during the discussion at the SWG and IG levels. The output from the SWG and IG levels is the results of the discussions, excluding all available options at the meetings. Only the agreed options are forwarded to the next or higher level of meetings, the rest of the information is omitted and not documented in the ITU archives.

The study therefore demonstrates how important WRC-12 Agenda Items 1.2 and 1.19 are to Thailand, in the response to this sub-research question.

Sub-research question 4: How can the existing ITU archives be improved or added to?

In order to add the missing information to the incomplete ITU archives, the study proposes the meeting record form with webcast archives, full utilization of the SharePoint website, and Member State networking, as policy suggestions. The study also provides the potential costs and benefits, in terms of advantages and disadvantages, for each option, as information for policymakers.

Finally, the main research question is answered by the four sub-research questions that the missing information from the ITU archives has affected the international spectrum policy at WRC. Member States attending relevant meetings understand the rationale and benefit from it. The improved or added to ITU archives would benefit the non-attending Member States, especially the Low Income countries.

The study contributes original work on the IAD application to the international negotiations between the Member States at WRC. The study also contributes original work on spectrum policy setting at the spectrum allocation level, especially the development of the TFA by specified services in Appendices A, B, C, D, E, F, G, H, I, and J. These appendices provide the starting point to further explore why they change over time.

The contribution by this study also highlights the information missing from the ITU archives, i.e., the lack of rationale behind the provisions, by demonstrating WRC-12 Agenda Items 1.2 and 1.19. Use of the ITU archives (RR versions and WRC proceedings) should therefore bear this limitation in mind.

1.5 Structure of study

The study consists of ten chapters, starting with an introduction in Chapter 1, which includes the background and research questions. Chapter 2 provides the theoretical framework for this study. Chapter 3 deals with the methodology. The ITU history is provided in Chapter 4. The RR history and frequency band development are presented in Chapter 5 and Appendices A, B, C, D, E, F, G, H, I, and J. Chapter 6 describes the WRC preparatory process. Chapter 7 reports on the preparatory work or WRC study process on WRC-12 Agenda Items 1.19 and 1.22, including observations on national and regional preparatory work. The participant observations of the WRC-12 meetings are illustrated in Chapter 8. The study analyses and policy recommendation are provided in Chapter 9. Finally, the summary and findings are presented in Chapter 10. Figure 3 shows an overview of the study, including the contents in brief of each chapter.

Chapter 1 Introduction	Study background, motivation and problem, purpose and limitation, and research questions
Chapter 2 Theoretical framework	A theoretical framework, including the background to the RR, the IAD framework, background to WRC, and application of the IAD framework to the WRC context
Chapter 3 Methodology	Available data, mode of data collection, and methods used in data analysis
Chapter 4 History of ITU	History of ITU as the development of ITU's structure
Chapter 5 RR history	History of WRC as the RR provisions development: key definitions, important provisions, the TFA, and Appendices A, B, C, D, E, F, G, H, I, and J.
Chapter 6 WRC preparatory process	The WRC-12 preparatory work as the WRC agenda-setting and its assessment, and the national (Sweden and Thailand) and regional preparatory works (CPG and APG) for WRC
Chapter 7 Preparatory work on WRC-12 Agenda Items 1.19 and .122	The WRC study process and Thailand's spectrum management development as well as the importance of WRC-12 Agenda Items 1.19 and 1.22
Chapter 8 Participation in the WRC-12 and the issue of WRC-15	Reviews of the WRC preparatory materials based on WRC-12 Agenda Items 1.19 and 1.22, as a demonstration of the missing information and the importance of WRC-12 Agenda Item 1.2 to Thailand and the preparatory work toward the WRC-15.
Chapter 9 Analysis and policy recommendation	Analyses: the IAD framework applied to the justification of the WRC-12 IG6A2-1.19 and an illustration of the missing information for WRC-12 Agenda Item 1.19 with the policy recommendation
Chapter 10 Summary and findings	The study synthesis, results, responses to research question(s), general policy implications and recommendations, recommendations for Thailand, and recommendations for future research

Figure 3. Structure of the study

Chapter 2 Theoretical framework

This chapter provides a theoretical framework for the study, including the background to the RR, the IAD framework, background to WRC, and application of the IAD framework to the WRC context.

2.1 RR background

The RR has been developed in stages since 1865, initially as part of the International Telegraph Convention, Annex to the International Radiotelegraph Convention, and the RR. The forum for revision of the RR has included the International Telegraph Conference, the International Radiotelegraph Conference, the World Administrative Radio Conference, and WRC.

Following the Additional Plenipotentiary Conference 1992 (APP1992), each WRC has its own agenda, i.e., points or issues of the RR to be reviewed and revised. The agenda comprises several items, each of which contains issues that will become the RR revisions when adopted. All the agenda items deal with spectrum allocation and relevant technical and regulatory aspects on efficient use and interference.

ITU uses the RR as a tool to manage spectrum internationally. ITU allocates spectrum to radiocommunication services with particular frequency bands. Radiocommunication services, in short, services, represent the purpose of frequency uses. There are more than 40 services currently in use in the RR2012. The individual frequency bands are defined by the start and stop frequencies. The start and stop frequencies represent the allowable edges of the frequency to be used for specified services. Details of the development of the services and frequency bands are elaborated on in Chapter 5 and Appendices A, B, C, D, E, F, G, H, and I.

The RR is revised every three to four years via WRC. The current RR is the RR2012, which was revised by the WRC-12. The RR2012 defines usable frequency up to 3,000 GHz and divides the frequency use into services, including terrestrial and space services such as broadcasting, mobile, satellite, maritime, aeronautical, fixed, and earth exploration. All the services can share frequency bands; however, sharing requires services to be designated as primary or secondary. The TFA contains both primary (capitalized) and secondary (lower case) services. Secondary services must not interfere with primary services and cannot claim protection from interference by primary service transmission and reception.[12]

The RR divides the world into three regions. Region 1 covers the European and African continents, Region 2 covers North America and South America, and Region 3 covers Asia and Australasia. The RR2012 regions are shown in Figure 4.[13]

The frequency allocated in one region can be used in others: reuse of frequency. For example, frequency band A is allocated to Region 3 but can be reused in Region 1 or 2 for the same or different services.

[12] 5.23-5.32, Article 5, Radio Regulations
[13] Information obtained from 5.2-5.9, Article 5, Radio Regulations (2012)

Reuse of frequency has an indirect relationship with coverage area. A large coverage area has a low reuse of frequency, while a small coverage area has a high reuse of frequency. Spectrum reuse characteristics vary by service, frequency, location, time, and transmitting power.

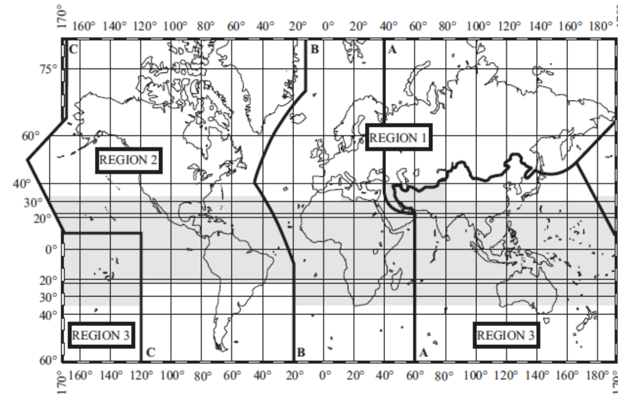


Figure 4. Regions in Radio Regulations 2012

The frequencies are further divided into bands. A wavelength equals its speed of propagation (normally that of light) divided by its frequency (λ = c/f). Each frequency band has its own propagation characteristics, such as sea-surface communication, stratospheric scattering, and long-range communication. Table 7 shows propagations by frequency band.

Table 7. Radio frequency propagation

Band	Frequency	Range	Uses	Bandwidth	Interference
VLF	3-30 kHz	to 1000 km	Long-range radio navigation	Very narrow	Widespread
LF	30-300 kHz	to 1000 km	VLF strategic communications	Very narrow	Widespread
MF	0.3-3 MHz	2000-3000 km	VLF strategic communications	Moderate	Widespread
HF	3-30 MHz	to 1000 km	Global broadcast and point-to-point	Wide	Widespread
VHF	30-300 MHz	200-300 km	Broadcast, PCS, Mobile, WAN	Very wide	Confined
UHF	0.3-3 GHz	to 100 km	Broadcast, PCS, Mobile, WAN	Very wide	Confined
SHF	3-30 GHz	30-2000 km	Broadcast, PCS, Mobile, WAN, satellite communications	Very wide to 1 GHz	Confined
EHF	30-300 GHz	20-2000 km	Microcell, point-to-point, PCS, and satellite communications	Very wide to 10 GHz	Confined

Notes: Table obtained from http://www.ictregulationtoolkit.org/en/Section.2658.html. WAN is wide area network. PCS is personal communication services.

The “Band” column in Table 7 represents the short form of frequency bands, i.e., very low frequency (VLF), low frequency (LF), medium frequency (MF), high frequency (HF), very high frequency (VHF), ultra high frequency (UHF), super high frequency (SHF), and extremely high frequency (EHF).

The “Frequency” column represents the range of frequency (the start and stop frequencies) in each frequency band. These short forms with frequency bands and start and stop frequencies correspond to RR Article 2.1.

The “Range” column represents communication distances between transmitters and receivers. This range is directly relevant to the applications or “Uses” column. For example, the VHF band provides the suitable distance between transmitters and receivers for broadcasting and mobile services. The EHF band is suitable for very long distance service for satellite communications.

The “Bandwidth” column represents the amount of carrying capacity. As mentioned before, the higher frequency band has a larger carrying capacity. The lower frequency band has a lower carrying capacity. For example, the VHF and LF bands have very narrow bandwidths. Conversely, the UHF, SHF, and EHF bands have very wide or large bandwidths.

The last column “Interference” represents the level of interference in the case of operating in those bands. For example, interference from the VLF, LF, MF, and HF bands is widespread. This means that the interference affects a very wide area due to the propagation characteristics of these bands. On the other hand, the interference from the VHF, UHF, SHF, and EHF bands is confined. This means that the interference from these bands is contained in a limited area.

Table 7 shows the TFA for the 460-890 MHz band, the global as well as the regional allocations captured from the RR2012. The purpose of the TFA is to provide an overview of the use of frequency bands by service, with the relevant regulations, including services, frequency bands, and footnotes. The functions of the TFA are similar to a map that provides an overview of the RR.

Regions and frequency bands

Inside the TFA, the main components are regions, frequency bands, services, and footnotes. When a frequency allocation has the same frequency band (the same start and stop frequencies) for three regions, it is called a global or worldwide allocation. For example, Table 8 shows the frequency band 460-470 MHz, which is a global allocation. On the other hand, the frequency band 470-790 MHz is allocated to Region 1. The frequency band of 470-512 MHz is allocated to Region 2. The frequency band of 470-585 MHz is allocated to Region 3. These three allocations are regional allocations.

Services

Inside each frequency band, services are allocated as either primary or secondary. For example, in the band 460-470 MHz, the fixed and mobile services are allocated as primary

services. Conversely, the meteorological-satellite service is allocated as a secondary service. These three services are allocated on a global basis.

Table 8. Table of Frequency Allocation, 460-890 MHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
460-470	FIXED MOBILE 5.286AA Meteorological-satellite (space-to-Earth) 5.287 5.288 5.289 5.290	
470-790 BROADCASTING 5.149 5.291A 5.294 5.296 5.300 5.302 5.304 5.306 5.311A 5.312 5.312A	**470-512** BROADCASTING Fixed Mobile 5.292 5.293	**470-585** FIXED MOBILE BROADCASTING 5.291 5.298
	512-608 BROADCASTING 5.297	
	608-614 RADIO ASTRONOMY Mobile-satellite except aeronautical mobile-satellite (Earth-to-space)	**585-610** FIXED MOBILE BROADCASTING RADIONAVIGATION 5.149 5.305 5.306 5.307
	614-698 BROADCASTING Fixed Mobile 5.293 5.309 5.311A	**610-890** FIXED MOBILE 5.313A 5.317A BROADCASTING 5.149 5.305 5.306 5.307 5.311A 5.320
790-862 FIXED MOBILE except aeronautical mobile 5.316B 5.317A BROADCASTING 5.312 5.314 5.315 5.316 5.316A 5.319	**698-806** MOBILE 5.313B 5.317A BROADCASTING Fixed 5.293 5.309 5.311A	
862-890 FIXED MOBILE except aeronautical mobile 5.317A BROADCASTING 5.322 5.319 5.323	**806-890** FIXED MOBILE .317A BROADCASTING 5.317 5.318	

For the 470-890 MHz band in Region 1, there are three frequency bands: 470-790 (broadcasting), 790-862 (fixed, mobile except aeronautical mobile, and broadcasting), and 862-890 MHz (fixed, mobile, and broadcasting).

For the 470-890 MHz band in Region 2, there are six frequency bands: 470-512 (broadcasting, fixed, and mobile), 512-608 (broadcasting), 608-614 MHz (radio astronomy, and mobile-satellite except aeronautical mobile-satellite [Earth-to-space]), 614-698 (broadcasting, fixed, and mobile), 698-806 (mobile, broadcasting, and fixed), and 806-890 MHz (fixed, mobile, and broadcasting).

For the 470-890 MHz band in Region 3, there are three frequency bands: 470-585 (fixed, mobile, and broadcasting), 585-610 (fixed, mobile, broadcasting, and radionavigation), and 610-890 MHz (fixed, mobile, and broadcasting).

Footnotes

The footnotes contained in the TFA can be used in several situations, including for the status of services (on a primary or secondary basis), additional allocation, alternative allocation, and miscellaneous provisions.

Apart from capital and lower case letter inside the TFA, footnotes can indicate the priority of services. For example, footnote 5.290 indicates the use of meteorological-satellite service in the 460-470 MHz band on a primary basis in Afghanistan, Azerbaijan, Belarus, China, the Russian Federation, Japan, Mongolia, Kyrgyzstan, Slovakia, Tajikistan, Turkmenistan, and Ukraine.[14]

The additional allocation footnote has the same service as indicated in the TFA, but in an area smaller than the region. For instance, footnote 5.291 is allocated the 470-485 MHz band for space research and space operation services in China.[15]

The alternative allocation footnote replaces the service indicated in the TFA, but in an area smaller than the Region. For example, footnote 5.315 is allocated the 790-838 MHz band for broadcasting service on a primary basis in Greece, Italy, and Tunisia.[16]

The miscellaneous provision footnote represents specific operation constraints such as footnote 5.287 in the 460-470 MHz band that provides the condition of maritime mobile service operations in the relevant bands.[17]

[14] 5.290 Different category of service: in Afghanistan, Azerbaijan, Belarus, China, the Russian Federation, Japan, Mongolia, Kyrgyzstan, Slovakia, Tajikistan, Turkmenistan and Ukraine, the allocation of the band 460-470 MHz to the meteorological-satellite service (space-to-Earth) is on a primary basis (see No. 5.33), subject to agreement obtained under No. 9.21. (WRC-07)

[15] 5.291 *Additional allocation:* in China, the band 470-485 MHz is also allocated to the space research (space-to-Earth) and the space operation (space-to-Earth) services on a primary basis subject to agreement obtained under No. 9.21 and subject to not causing harmful interference to existing and planned broadcasting stations.

[16] 5.315 *Alternative allocation*: in Greece, Italy and Tunisia, the band 790-838 MHz is allocated to the broadcasting service on a primary basis. (WRC-2000)

[17] 5.287 In the maritime mobile service, the frequencies 457.525 MHz, 457.550 MHz, 457.575 MHz, 467.525 MHz, 467.550 MHz, and 467.575 MHz may be used by on-board communication stations. Where needed,

Footnotes can also be used for a particular service, in which case it is located next to the service, or the entire frequency band, when it is placed at the bottom of the band, as indicated in the TFA. The band footnote is applied to all services allocated in this band. For example, in the 460-470 MHz band, the use of mobile service has the specific footnote 5.286AA. The band footnotes are 5.287, 5.288, 5.289, and 5.290, and they apply to all services in this band, including fixed, mobile, and meteorological-satellite services.

In Region 1, the 790-862 MHz band has two specific footnotes for mobile, except aeronautical mobile service 5.316B and 5.317A (These two footnotes are modified by the WRC-12). However, in the 862-890 MHz band, 5.317A is a specific footnote for mobile service. The broadcasting service in the 862-890 MHz band has 5.322 as a specific footnote. In the 790-862 MHz band, six footnotes, 5.312, 5.314, 5.315, 5.316, 5.316A, and 5.319, are band footnotes. In the 470-790 MHz band, footnote 5.312A indicates the band footnote. This footnote was added at the WRC-12.

In Region 2, the 470-512 MHz band has two band footnotes: 5.292 and 5.293. In the 806-890 MHz band, the mobile service has 5.317A as a specific footnote.

In Region 3, the 610-890 MHz band has two particular footnotes for mobile service (5.313A and 5.317A). The band footnotes are 5.149, 5.305, 5.306, 5.307, 5.311A, and 5.320.

2.2 IAD framework

Ostrom, among others, developed the IAD framework. The details of the IAD framework are discussed below.

The IAD framework has its roots in classic political economy, neoclassical microeconomic theory, institutional economics, public choice theory, transaction-cost economics, and non-cooperative game theory (Ostrom, Gardner, & Walker, 1994, p. 25). The IAD framework orients the analyst to ask particular questions. The questions generated by the IAD framework are the most important contributions. These question are used to diagnose, explain, and prescribe (Ostrom et al., 1994).

The literature of the IAD framework was developed by Kiser and Ostrom (1982) and provides three worlds of action: the operational, collective choice, and constitutional choice levels. Field (1992) has a similar level of analysis but with different names, i.e., three economic institutions: the operational, institutional, and constitutional levels. Kiser and Ostrom (1982) provide a metatheoretical framework to explain the relationships between institutional arrangements and the individual in terms of the transformation of rules into individual behavior.

equipment designed for 12.5 kHz channel spacing using also the additional frequencies 457.5375 MHz, 457.5625 MHz, 467.5375 MHz, and 467.5625 MHz may be introduced for on-board communications. The use of these frequencies in territorial waters may be subject to the national regulations of the administration concerned. The characteristics of the equipment used shall conform to those specified in Recommendation ITU-R M.1174-2 (WRC-07).

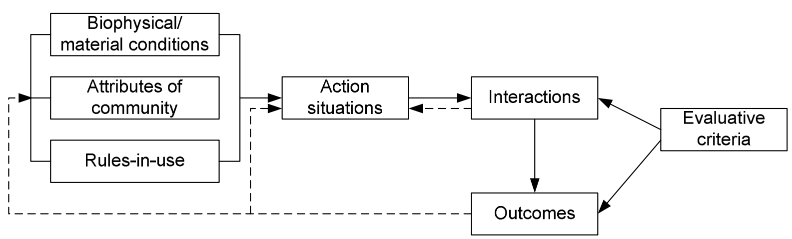
Institutional arrangements are rules used by individuals to determine who and what is included in decision situations, how information is structured, what actions can be taken and in what sequence, and how individual actions will be aggregated into a collective decision (Kiser & Ostrom, 1982, p. 179). In other words, this framework explains phenomena attributed to the aggregation of individual actions that they have decided to take or strategies (plans of action) based on situations and the individual. The situation depends on rules, events, and the community. This framework also captures the dynamic situation through feedback from the phenomena that influence the community, situation, and individuals.

According to Kiser and Ostrom (1982), each world of action has five working parts in an institutional structure: the decision-maker or individual, the community, the event (or goods and services), the institutional arrangement, and the decision situation. The results of the institutional structure are individual actions or strategies, and the aggregation of individual actions.

Each level or world of action: metaconstitutional, constitutional, collective, and operation situations, comprises an IAD framework for an institutional analysis. The linkage between levels is in part the rules-in-use at each level (see Figure 7).

The three worlds of action were developed by Ostrom from 1982 to 2011 (Kiser & Ostrom, 1982; Ostrom, 2005a, 2005b, 2007, 2011). The differences between the old version from 1982 and the current version from 2011 are the consideration layers, the names of the elements, and the details of the internal rules.

The IAD framework provides consideration levels, or worlds of action, for the decision-making process, i.e., operational, collective-choice, constitutional, and metaconstitutional situations. Moreover, the IAD framework provides exogenous variables and an internal action situation at each situation level. The exogenous variables include biophysical/material condition, attributes of community, and rules-in-use. The internal action situation structure comprises boundary, position, choice, payoff, information, aggregation, and scope rules. Figure 5 shows the IAD framework.



Source Ostrom (2011, p. 10), Figure 1

Figure 5. Framework for an institutional analysis

Interaction (action and strategy)

When an individual wants to take action or implement a strategy, he or she must know the

consequences of the action or strategy, or the outcome and value of the alternative actions or strategies. A tennis player makes a decision to charge at the net or wait for the ball to bounce and use a groundstroke: the outcome of the actions differs. In order to predict actions, a minimum of the following assumptions must be made: the level of information about the decision situations, the valuation of the potential outcomes, the alternative actions within the situation, and the process of calculation to act from alternative actions or strategies.

Action situations (or decision situation)

According to Kiser and Ostrom (1982), the decision situation is determined from interdependent relationships. Interdependent relationships depend on more than one input from the exogenous variables. The IAD framework separates the exogenous variables from the action arena or action situation. The exogenous variables include biophysical/material conditions, attributes of community, and rules-in-use.

Biophysical/material conditions

The biophysical/material conditions describe the type of goods. Goods can be further refined into four groups: private goods, toll goods, common-pool goods, and public goods. Each group has different characteristics, defined by the level of subtractability and the cost of exclusion (Kiser & Ostrom, 1982). Table 9 shows four categories of goods.

Table 9. Categories of goods

Level of subtractability / Cost of exclusion	High	Low
Low	Private goods	Toll goods
High	Common-pool goods	Public goods

Source Kiser and Ostrom (1982, p. 198), Table 7.1

The level of subtractability and cost of exclusion can also be explained in terms of four attributes of biophysical condition that individuals seek to produce and consume: jointness of use or consumption, exclusion, measurement, and degree of choice, in order to define private goods, tool goods, common-pool resources, and public goods.

Jointness of consumption explains separable and joint consumption goods. One individual consumes separable consumption goods, while more than one individual consume joint consumption goods. Joint consumption goods are defined as public goods that are non-subtractable, while separable consumption goods are private goods.

The exclusion attributes explain the difference between private and public goods. Public goods are non-excludable goods that an individual can consume without exclusion. Private goods are excludable goods that the individual can consume with exclusion.

The measurement is the degree of packaging and unitization. Public goods are hard to package and unitize in contrast to private goods. The calculation of private goods is more precise than that of public goods.

The degree of choice for the consumer differs between public and private goods. Public goods are non-subtractable and non-excludable, so there is not much choice, while private goods can produce many choices from subtractable and excludable goods.

The level of subtractability is defined by the characteristics of the goods that can be separated. Private goods can be separated by individual consumption, but public goods cannot. For example, rice can be consumed from a bowl by taking a spoon, as private goods. Air in the park is a public good. People can breathe, but no one can separate air for individual consumption.

Ostrom and Ostrom (1997) use the level of subtractability and the cost of exclusion to classify private goods, tool goods, common-pool resources, and public goods. Private goods, such as bread, milk, automobiles, and haircuts, have a low cost of exclusion and a high level of subtractability. Toll goods, for example, theaters, nightclubs, telephone service, cable TV, electric power, and libraries, have a low cost of exclusion and a low level of subtractability. World Cup football is tool goods at a low level of subtractability, because football players and spectators jointly benefit from football matches, whereas the cost of exclusion is low but managed by selling tickets to matches. Common-pool resources, e.g., water pumped from a ground basin, fish taken from an ocean, and crude oil extracted from an oil pool, have a high cost of exclusion and a high level of subtractability. Public goods, such as peace and security of a community, national defense, mosquito abatement, air pollution control, and weather forecasts, have a high cost of exclusion and a low level of subtractability.

Attributes of community

The attributes of community comprise levels of common understanding, common agreement, and distribution of resources. The common understanding between people in the action situation could be the norm, culture, or tradition in each community that has direct influence on the decision situation.

After setting the rules, the individual or member of the community must have a common understanding of them, i.e., the allowable actions and outcomes. Without a common understanding of the rules, they cannot be exercised.

Real actions must be evaluated with a common understanding of the rules. If community members obey the rules, allowable actions, and outcomes, the need for rule enforcement is low. If, on the other hand, the individual disagrees, the need for enforcement is high.

The distribution of the resource represents a situation in the market or community. If resources are distributed equally, a competitive environment arises. Otherwise, oligopoly or monopoly may arise.

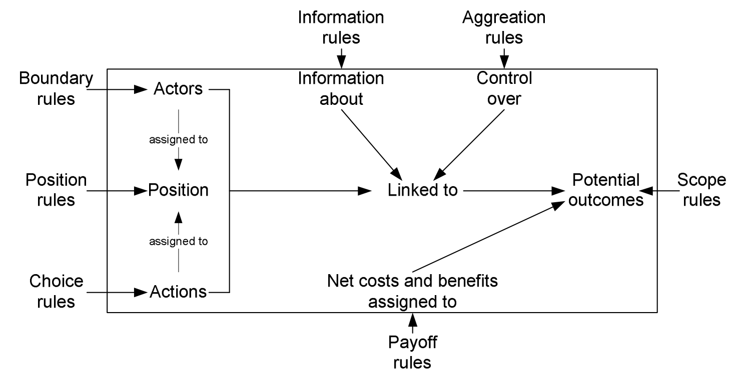
Rules-in-use

The rules-in-use provide an institutional arrangement in a decision-making situation, including boundary, position, choices, payoff, information, aggregation, and scope rules. Generally, rules-in-use can be thought of in terms of "do and don't" rules, for example, when a new member of staff arrives at the office on the first day, the first thing he/she should ask

his/her colleagues about is the "dos and don'ts" in the office. This is more important than the rules-in-form that are written down (Ostrom, 2007, pp. 36-37).

A detailed discussion with a connection to the action situations is provided below. These rules help to explain the action arena or action situation. Figure 6 shows the rules-in-use and the action situation.

Boundary rules: who is eligible to participate in a decision-making or action situation? These rules provide the list of participants or actors. For example, in the French Open, tennis players with a higher rank automatically go to the first round, while newcomers have to win qualifying matches to enter the first round.



Source Ostrom (2011, p. 20), Figure 3

Figure 6. A rules-in-use and action situation

Position rules: what role does each participant perform in his/her position or what authority is given to each position? In each match, there are referees, line-persons, ball boys or girls, and two or four tennis players. Each position has its own task or responsibility to perform.

Choice rules: what actions should be taken? During the game, after one game of serving, the opponent has to strike back. There are many choices, e.g., whether to wait and hit a groundstroke or to go forward to volley. Even for the server, there are many choices when it comes to hitting the ball, e.g., to direct it to the corner, to the right, to the left, or to go for an ace on the first serve.

Payoff rules: what is the cost and benefit of the choice that is taken? During the game, if player A plays a drop shot at the net, player A expects player B to rush to the net to get the ball back.

Information rules: what information is available when making the decision? In the game, the information about players, weather conditions, changing to new balls or a new racket, medical breaks, and player injury are available to both players.

Aggregation rules: what level of control does the participant have in his/her action situation? During the game, the player has the ability to control his/her action to move forward, backward, to serve, or to hit the ball in order to win a point. Moreover, the player should control his/her performance to win the match in a normal game or a tiebreak.

Scope rules: what is the rule to delimit the potential outcome that is linked to a specific outcome? During the match, the winner has to win two out of three sets or three out of five sets. Both players can play a point in the specified court, including the height of the net, and the type and size of the court.

Outcomes

The term outcomes in Figure 5 and potential outcomes in Figure 6 describe the same concern. The outcomes are the result of actions or strategies by the decision-maker in a decision-making process. Moreover, the evaluative criteria in Figure 5 should be used to find the net costs and benefits of the outcomes in Figure 6.

Evaluative criteria

Ostrom (2011) also provides evaluative criteria, including economic efficiency, equity through fiscal equivalence, redistributional equity, accountability, conformance to the values of local actors, and sustainability.[18] The evaluative criteria are the possible outcomes under the alternative institutional arrangements (Ostrom, 2011, p. 15).

Levels or worlds of action

The IAD framework provides consideration levels, or worlds of action, for the decision-making process, i.e., operation, collective-choice, constitutional, and metaconstitutional situations. Figure 7 shows the level of analysis in the IAD framework.

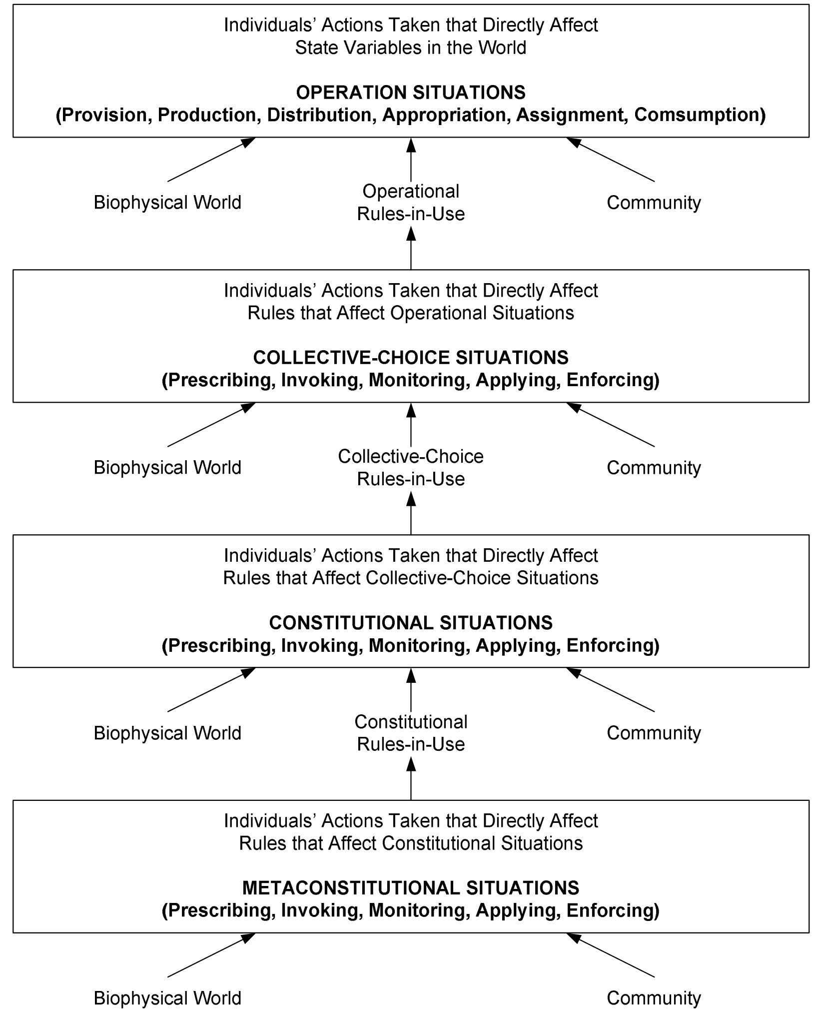
Each level or analysis comprises an internal action situation, as mentioned above. The seven parts of the IAD framework are contained in each level of the analysis. They are biophysical/material condition, attributes of community, rules-in-use, action situations, interactions, evaluative criteria, and outcomes.

At the operation level, the situation is affected by the operational rules of day-to-day decision-making by the participant. The decision is made according to the operational rules, which are defined at the collective-choice level. For example, in the State of Maine's lobster industry, the day-to-day work is to fish or obtain lobster from the inland shore. The fishermen have to fish with specified tools and a time slot.

At the collective-choice level, the collective-choice situation is affected by the operational rules to determine who is eligible, and it defines rules to change the operational rules. For example, if someone wants to change who can fish, and the tools and the time to fish lobster,

[18] For more information, see Ostrom (2011, pp. 16-17).

they have to revise the operational rules at the collective-choice level.



Source Ostrom (2007, p. 45), Figure 2.2

Figure 7. Level of analysis and outcomes

At the constitutional-choice level, the situation is affected by the collective-choice rule of who is eligible and can change collective-choice rules, and it has consequences for the operational rules. For example, in the telecommunication industry, the national regulatory agency defines the set of rules allowing the use of Wi-Fi devices. The rules specify a frequency of 2.4-2.5 GHz with transmitting power up to 100 milliWatts. These rules work as constitutional-choice rules with room for the manufacturer or standard-setting agency to produce its technology and standards to fit these rules. The standard for Wi-Fi devices is set at the collective-choice level. After that, Wi-Fi devices are in the market and available to use. The user buys and uses Wi-Fi devices according to the standard.

As a constitutional decision-maker, Fédération Internationale de Football Association (FIFA) determines the rules of football at a high level. European or national football associations use FIFA's rules for their tournaments, such as EUROPA and the Premier League. Football teams must obey the rules to participate in tournaments.

At the metaconstitutional level, the situation is the deepest layer of analysis, underlying all three of the above levels. The metaconstitutional level should contain the fundamental rules like customs, tradition, norms, and religion (Williamson, 2000).[19]

2.3 WRC-12 background

At WRC, the meeting forms that consider the RR revisions include the plenary, COM, WG, SWG, IG, DG, and ad hoc group.

At the WRC-12, there was a single plenary, seven COMs, nine WGs, and many SWGs, IGs, and DGs. The RR revision process starts by the plenary allocating selected input documents to particular COMs. Each COM forms WGs, and each WG forms SWGs to further consider individual input documents (documents submitted by Member States) and comments made at meetings. Each SWG can form IGs or DGs as required. Figure 8 shows the WRC meeting hierarchy.

COMs 1, 2, 3, and 7 are steering, credentials, budget control, and editorial committees, respectively. These committees facilitate the WRC meetings as administrative works. On the other hand, COMs 4, 5, and 6, are allocated specified agenda items in order to achieve the solution for WRC-12.

The arrows in Figure 8 show the direction of the document flows. The input documents flow from plenary to COMs, to WGs, to SWGs, to IGs or DGs by agenda item. The arrow on the right-hand side presents the flow of approval documents from the bottom to the top of the pyramid.

[19] Williamson explains this as Level 1 (social theory), which is taken as given. Institutions at this level change very slowly: 100-1000 years.

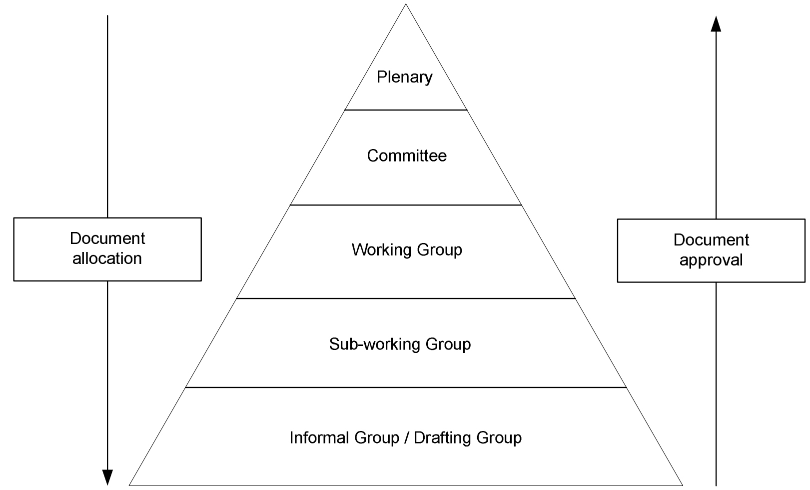


Figure 8. WRC-12 meeting hierarchy

At the WRC-12, Figure 9 shows, for example, the COM6 work program as an illustration of the process, including document allocations and approval.

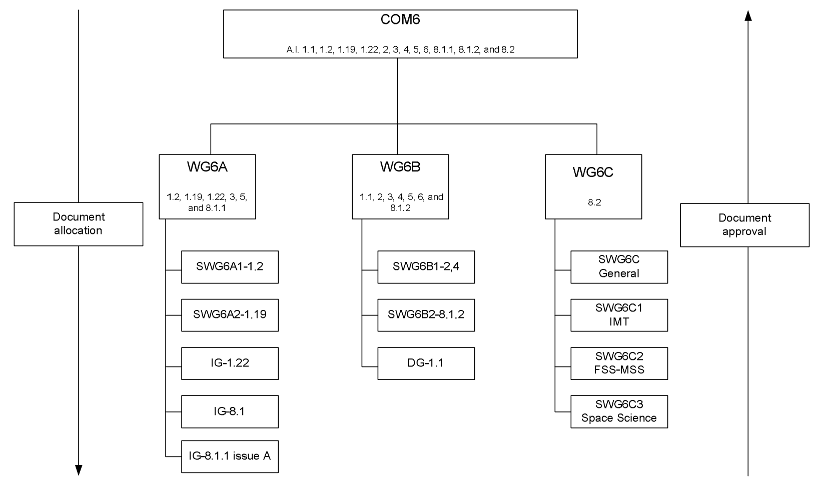


Figure 9. COM6 work program

COM6 is allocated Agenda Items 1.1, 1.2, 1.19, 1.22, 2, 3, 4, 5, 6, 8.1.1, 8.1.2, and 8.2 by the plenary. The items concern the related areas of fixed, mobile, and broadcasting issues, and future work programs.

The COM6 Chairman established three WGs, i.e., WG6A, WG6B, and WG6C. The WG6A is allocated Agenda Items 1.2, 1.19, 1.22, 3, 5, and 8.1.1. The WG6B is allocated Agenda Items 1.1, 2, 3, 4, 5, 6, and 8.1.2. The WG6C is allocated Agenda Item 8.2.

Furthermore, the WGs established their own SWGs, IGs, or DGs by agenda item. For example, the WG6A Chairman established two SWGs (SWG6A1-1.2 and SWG6A2-1.19), and three IGs (Agenda Items 1.22, 8.1, and 8.1.1 issue A). The WG6B formed two SWGs (SWG6B1-2. 4 and SWG6B2-8.1.2), and one DG (DG-1.1). The WG6C formed four SWGs (SWG6C-General, SWG6C-IMT, SWG6C-FSS-MSS, and SWG6C-Space Science).

COM4 and COM5 have similar structures to COM6, but they have different agenda items and the corresponding number of SWGs, IGs, or DGs.

At the SWG, IG, or DG level, detailed debates relating to the input documents are discussed to obtain consensus between the Member States. In terms of the IAD framework, this consensus approach is an attributes of community or common understanding between Member States (see Figure 5). The SWG, IG, or DG Chairman leads the discussions and attempts to achieve consensus on the issues.

When Member States reach consensus, the issue is resolved. However, only the result of the consensus moves forward (with possible forms of revision of relevant parts of the RR) to the next level for approval (e.g., SWG to WG), that is, all other information concerning the principles by which the matter is resolved is “left behind.” This becomes the problem of the missing information.

Conversely, when consensus cannot be reached, a compromise solution may be achieved, the results of which “move forward” to the next meetings, that is, higher level meetings such as from SWG to WG, WG to COM, or COM to the plenary.

For example, on WRC-12 Agenda Item 1.22, the WG6A Chairman also presided over the IG 1.22. With no issue on the agenda item, the RA-12 approved ITU-R Resolution 54-1 to allow the study of a harmonized band for short-range devices (SRD) to proceed for further study in the WRC-15 study period (between the WRC-12 and WRC-15, and the results of the study to be presented at the WRC-15). The clarification required for ITU-R Resolution 54-1 concerned whether Member States needed to discuss the necessity of implementing the WRC resolution for SRD. Moreover, the RA-12 took place one week prior to the WRC-12, and the WRC-12 submission deadline was two weeks before the Conference. On the WRC-12 submission deadline, Member States submitting documents to the WRC-12 therefore had no information on the RA-12 approval. Further discussion on the approval of ITU-R Resolution 54-1 among Member States that had the WRC-12 submission for a WRC resolution was conducted. Accordingly, only confirmation from regional representatives was required for the IG

Chairman to draft the IG output to the WG6A for approval: no change to the current RR was required.

The information on the IG subsequently moved to the WG without the missing information.

Conversely, the SWG6A2 was established at the WRC-12 in Agenda Item 1.19. The issue concerned whether a WRC resolution was required to use CRS. Both sides (the Member States who did and those who did not prefer to have a WRC resolution) provided arguments. The SWG6A2 created the IG to settle issues for a WRC resolution.

The IG meeting discussed issues about harmful interference, dynamic spectrum access, notification and coordination, and regulatory concerns for dynamic spectrum access. Details of these discussions are not included in the IG output. Accordingly, these unresolved issues now move forward to the SWG6A2, WG6A, and COM6. This is an example of the information loss that occurs during the process for IG Agenda Item 1.19, with seven possible options disappearing. Importantly, the omitted arguments are not documented, with only the three final options moving forward. Hence, this information is missing for those who did not participate.

The COM6 Chairman established an ad hoc group to consider the three options with the WG6A President. Ultimately, the SWG6A2 Chairman proposed a single option that Member States accepted.

Thus, valuable information was “lost” to Member States that did not participate at the meetings. This is because the debates below WG level are not documented. These arguments are only available to delegates in attendance at such meetings.

2.4 IAD framework in the WRC context

Occasionally, agenda items cannot be concluded within a WRC and must be carried forward to the next WRC. The discussions relating to the unsettled issues are not recorded, that is the abridged, not the final, output of the Final Act or the RR.

The RR and WRC archives provide a list of input (documents submitted by Member States) and output documents (RR revisions). However, the archives do not include the argumentations of the meetings. When issues are carried forward to the next WRC, only the delegates at the meetings know the arguments. This information, which may contain options for decision-makers, is missing from the archives of the RR and the WRC.

Accordingly, the archives do not provide a sound basis of arguments for decision-making on the issues. The administrations have no information regarding the arguments for the actions, limiting their understanding of the discussion and thereby their basis for developing full arguments for the next WRC.

This study contributes to the list of questions that should be considered during the action situation (decision-making process) inside the WRC meeting. A useful framework to address this information is the IAD framework developed by Ostrom (Kiser & Ostrom, 1982; Ostrom, 2005b, 2011). However, Ostrom has not applied the framework to international negotiations within WRC. This study will apply the IAD framework to identify questions that should be considered to show limitations of the archives. Moreover, this study uses three levels of analysis, i.e., operational, collective-choice, and constitutional choice.

Participant observation provides the information that is gained by delegates when they attend a meeting. Such information captures the dynamics of the meeting, i.e., arguments and rationale of the decision-making process. Attendance at a meeting corresponds to a list of questions obtained from the IAD framework. As such, attendance is an indicator of the limitations of the archives as an intrinsic area. However, participations at meetings from past event are not observed.

IAD application to WRC

The IAD framework provides a list of questions that should be considered during the decision-making process. The framework defines an action situation and decision-maker. An action situation is a situation in which decisions are made. The decision-maker is the person who makes the decision. The list of questions can be grouped into exogenous and endogenous variables.

Exogenous variables represent external influences on the action situation, which is comprised of biophysical/material conditions, attributes of community, and rules-in-use.

Biophysical/material conditions are the objects of the study. Normally, the study objectives can be categorized into four groups according to the level of subtractability and cost of exclusion, i.e., private, toll, common-pool, and public goods.

In this study, the biophysical/material condition inside WRC is a global spectrum, which has a low level of subtractability – it is easy to obtain, but the global spectrum has a high cost of exclusion. A global spectrum is therefore a public good.

Attributes of community are the common understanding of WRC, i.e., ITU and ITU members' cultures, traditions, and norms. This common understanding within a community or country directly influences the action situation of the meeting in terms of information constraints, e.g., it is common for Arab and European delegates to be outspoken during meetings.

Rules-in-use represent both a written and tacit form of rules, including "do" and "don't" rules during the action situations. Rules-in-use are comprised of boundary, position, choice, payoff, information, aggregation, and scope rules. The rules-in-use directly connect to the endogenous internal variables.

Endogenous variables are the action situations, such as interaction, outcome, and evaluative criteria, that can be linked by the rules-in-use. They provide actors, position, actions, net cost and benefit, and information about control and potential outcomes. The details of the rules-in-use of exogenous and endogenous variables are provided below.

The boundary rule defines who can participate in WRC (ITU membership). The ITU membership is clearly defined by the ITU Constitution (CS), the boundary rule for the regional preparatory meeting, i.e., PT A, CPG, and APG, and in its regulation. Participants have to be members of CEPT or APT or obtain endorsement from a member to receive observer status.

Inside the WRC-12, the boundary rule also includes access and withdrawal rights for the WRC documents, including the Wi-Fi access code, and a Telecommunication Information Exchange Service (TIES) account (defined by the BR as the WRC Secretariat).[20] Archive and participant observation can both capture this rule.

The position rule defines the delegate roles within the meeting. Formal roles are Head of Delegate (HoD), Deputy Head (DH), and Delegate (D). The original credentials need to be submitted to WRC for the right to vote and to sign the Final Act. However, the right to express views and information is available to all participants, including observers from the Sector Members. The Chairman and Secretary of each meeting also provide an extra role to conduct and facilitate the meetings, including the plenary, COM, WG, SWG, DG, and IG.

This rule can be captured from the archives and participant observations at the plenary and COM level. Below COM level, only participant observation can capture this role.

The regional preparatory meeting plays a major role in consolidating and coordinating the regional view during the WRC-12. Regional representatives from each regional preparatory meeting negotiate on behalf of their regional administrations. This process reduces lengthy discussion. This position rule for regional representatives can be only captured by participant observation.

The choice rule represents possible action that can be taken according to the position rule. The choice rule has direct influence on the interactions, including information, aggregation, payoff, scope rules, and evaluation criteria and outcomes.

For example, the final compromise recommendation was reached at the WRC-12-IG6A2 on Agenda Item 1.19. Delegates represent regional or individual administrations on whether to accept the final outcome. The choice of WRC recommendation influences the delegates' stance, including information, aggregation, payoff, scope rules, and evaluation criteria and outcomes of the negotiations. This choice is new information that is conveyed to their regional group to inform it of future decisions based on these evaluation criteria (or payoff rule) for their national or regional benefit. It also influences the stance of individual administrations, which either maintain or change their position (as the position and aggregate rules). The final decision can influence the scope rules as outcomes of the negotiation or interaction process.

According to the choice rule, this interaction can only be captured by delegate observation. The archives have no capacity to capture negotiations.

[20] In order to participate in WRC, registration is done electronically by the designated focal point (DFP).

The payoff rule uses evaluation criteria and provides costs and benefits in the selection of actions based on national interests. The payoff rule and the evaluation criteria can both be derived from interactions between delegates. Interaction cannot be recorded even in the minutes of the meetings.

The information rule represents the flow of information inside the meeting, including written and verbal forms. Inside WRC, written and verbal contribution can be presented in terms of the information rule, which always happens inside and outside the meetings.

The archives can capture the input and output from previous documents. Current written and verbal communication can only be captured by participant observation.

The aggregation rule shows how to impose control on decision-making through the choice rule on outcome. The aggregation rule reflects the delegates' stance after making decisions by selecting a specific choice at the end of the discussions. The rule is only captured from delegate observations.

The scope rule is an outcome of the decision situation and provides the possibility for revision of the RR through no change, modification, addition, and suppression provisions. The rule is influenced by action situations and interactions. The scope rule provides an overview of possible revisions but lacks information from the detailed discussions and interactions.

The archives can capture this scope rule information from the previous event. However, WRC's current practices only allow participant observation to be made.

Table 10 shows the relationship between the IAD and the approaches of this study.

Table 10. IAD variable map, missing data, and observer activities

IAD variable	WRC	RR/WRC Archive	Participant observation	
			PTA, CPG, APG	WRC-12
Physical condition	Spectrum as public good	X	X	X
Community attribute	Norm, culture, and tradition		X	X
Rules-in-use				
Boundary	ITU membership	X	X	X
Position	HoD, Regional Rep., Chair, Secretary	X	X	X
Choice	Support, oppose, neutral		X	X
Payoff	Cost and benefit		X	X
Information	Public or informal information flow		X	X
Aggregate	Control over choice		X	X
Scope	ADD, MOD, SUP, NOC	X	X	X
Action situation	Negotiation		X	X
Interaction	Negotiation		X	X
Evaluation criteria	Link payoff rules		X	X
Outcome	Link RR revisions to scope rules	X	X	X

The list of questions that should be considered within the action situation (WRC meetings) is provided by the IAD framework and appears in the "IAD variable" column of Table 9. The "WRC" column identifies the corresponding IAD elements.

The "RR/WRC archives" column shows the IAD question that can be addressed from the RR and WRC archives. Cleary, only selected IAD questions can be considered with archived material. The RR and WRC archives therefore only provide partial information, lacking the dynamic interactions that occur inside meetings.

Conversely, participant observations can address all the IAD questions in the current situation. The interactions within meetings can be captured by the participant observations, which are only available to attending delegates. Such negotiations provide the argument and rationale concerning agenda items. When an issue is continued to the next WRC, it becomes important that information of this sort is not available to absent delegates. As it stands, the administration has no access to this information. There is therefore limited understanding of the debate and no basis on which to develop full arguments toward the next WRC.

However, the RR and WRC archives only provide incomplete records of proceedings, as demonstrated above. Therefore, the archives cannot be relied upon as a basis for understanding the past decision-making or basis on which to plan for future decisions when the issues continue to the next WRC. The information on the dynamics of the meeting will be valuable for an administration that has no representative at such meetings.

For example, the issue of WRC-12 Agenda Item 1.2 has continued to the next WRC-15, at which administrations are not represented. They have no basis for understanding the current debate on this issue. There is therefore no strong basis on which to develop a full argument for the WRC-15.

Finally, this study identifies the limitations of the RR and WRC archives by implementing the IAD framework.

2.5 IAD framework and information matters

Ostrom (2005b) provides the perspective of complete and incomplete information in an action situation as follows. The complete information is an assumption that each participant could know the full structure of an action situation. When a participant has perfect information, he or she can know all other parties' actions before they take any further action. Incomplete information makes the action situation more complicated to model. Ostrom (2010) also points out that incomplete and imperfect information may influence the participant to make a mistake during the decision-making process. A couple of examples of the IAD framework with information asymmetry or imperfect information follows:

(1) Bushouse (2011) uses the information asymmetry to classify three categories of club goods: for-profit, nonprofit, and public providers. Bushouse also uses the information asymmetry to further explain the bio/physical condition as an exogenous variable in the IAD framework to identify six governance structures in the for-profit and nonprofit sectors.

(2) Wasike, Kahi, and Peters (2011) use the IAD framework with imperfect price information: input and output of the system to identify missing actors in the action arena, poor rule conformance and absence of rules in the animal recording system.

The study uses the IAD framework to identify the rationale behind the RR provisions as the missing information from the ITU archives. Consequently, Member States that only reply to the ITU archives have incomplete information. This missing information in the ITU archives renders the information asymmetry between attending and not-attending Member States at the relevant meetings. The missing information at SWG and IG influences the Member States' decision-making process at the higher level meetings, including the WG, COM, and plenary to make further decision on the RR.

The study demonstrates the missing information and its consequences in WRC-12 Agenda Items 1.2, 1.19, and 1.22, which will be discussed in a later chapter.

2.6 Summary

This chapter presents the background to the RR and WRC, including the spectrum propagation characteristics, TFA, WRC-12 work programs, and meeting forms. Moreover, the IAD framework is described together with the application of the IAD in the WRC context.

The study describes the background to the RR in terms of the technical characteristics of frequency propagation, which vary by frequency band, e.g., low frequencies can propagate above a sea surface and are suitable for maritime communication. Furthermore, the RR divides the Earth's geographic area into three regions: Region 1 (European, African, and Arab countries, and Russia), Region 2 (North and South American countries), and Region 3 (Asian and Australasian countries). These regions construct the possibilities of frequency reuse, such as frequency band A allocated in Region 1 also being able to be reused or reallocated in Region 2 or Region 3.

The study also provides an overview of frequency use by explaining the TFA. The TFA works as a map. It usually divides a frequency allocation into global or regional. Inside the TFA, the services are allocated with either primary or secondary service. Moreover, the footnotes can be used for an additional or alternative allocation, or miscellaneous provisions for a particular service or entire frequency bands.

The study describes and prescribes the IAD framework in the WRC context. This is original work for the IAD framework application in the context of international negotiations.

The IAD framework helps to explain the action situation inside the international negotiations at WRC by posting a list of questions representing the institutional arrangements in terms of the exogenous and endogenous variables. The exogenous variables are the bio/physical material, the attribute of community, and rules-in-use. The endogenous variables are directly connected to the rules-in-use and comprise the seven rules: boundary, position, choice, payoff, information, aggregation, and scope.

At WRC, the world of action is in a constitutional situation, which represents the reviewing and revising of the international treaty: the RR via WRC.

The bio/physical material is the spectrum allocation that is treated as public goods. The attribute of community represents the common understanding between the ITU Member States, including ITU's and the Member States' cultures, traditions, and norms. The rules-in-use are represented in the endogenous variable by the seven rules.

At WRC, the boundary rule represents the ability to access the meetings, i.e., ITU membership. Each delegate performs in different roles at the meetings, including HoD, DH, D, or observer (as the position rule). However, only the Member States have a right to vote that is directly connected to the choice rule, which allows the action to be performed inside the meetings. The action to be taken is influenced by the information flow inside the meeting (as the information rule). Member States may change or retain their stances according to the availability of information (the aggregate rule). Member States have their own criteria to evaluate their action or decision in terms of cost and benefit analysis (the payoff rule and evaluative criteria) and consequences or outcomes of the action (the scope rule and outcome).

The missing information is contained in the rationale underlying the RR provisions and is not documented in the ITU archives. This missing information is only available to the attending Member States. The missing information may be treated as part of the information flow between Member States inside the meeting (the information rule), which directly influences the decision-making process and outcome.

Finally, the IAD framework provides the list of relevant questions as an institutional arrangement inside the decision-making process at WRC. However, the IAD framework does not provide the detailed content of the meeting decision. Instead, participant observation captures the meeting argumentation inside the current event, not in past events.

Chapter 3 Methodology

This chapter concerns the available data, mode of data collection, and methods used in data analysis.

The primary data are sourced from observations made during the attendances at the selected PT A, CPG, APG, and WRC-12 meetings. Participating in meetings provides the rationale by which the complete archives should be understood.

Moreover, attending the PT A, CPG, APG, and WRC-12 meetings provides an enhanced understanding of the history of the differences between the current practice of the WRC-12 and previous practice from the archived document. Table 11 shows the details of the author's participation in the meetings.

Table 11. Meeting participation

Meeting	Date	Days	Venue	Participants
PT A-9	29-30 Mar 2011	2	Copenhagen, Denmark	53
CPG-12-7	27 Jun-1Jul 2011	5	Oxford, United Kingdom	181
APG2012-5	29 Aug-3 Sep 2011	6	Busan, Rep of Korea	385
WRC-12	23 Jan-17 Feb 2012	25	Geneva, Switzerland	>3000

The data are secondary and qualitative in nature. The secondary data are sourced from the ITU, CEPT, and APT archives. The secondary data archive approach is due to Rutkowski (2011). Rutkowski downloaded the principal data from the ITU History Portal. The data allowed examination of versions of the regulations to enable identification of key definitions and provisions by the RR versions. The analysis by Rutkoski enabled identification and links to detect any differences in the text. Rutkoski applied this method to cyber security and to find where such text amendments arose.

The benefit obtained from applying the Rutkowski approach is that the mapping of the WRC archives though time improves understanding of the context in which the regulations developed. However, the current study recognizes that the archives are only a record of the final input and output documents for particular regulations. That is, certain information is not recorded, i.e., argumentations during meetings.

To address this shortcoming the study employs the IAD framework to construct a list of questions that are probably considered in comprehensive meetings.

Complete archives would provide information on the context in which the final documents (archives) were developed and help to identify the shortcomings of the official archives.

Accordingly, the study is based on data obtained from archived documents and information derived from meeting attendance. The ITU archives include all the versions of the RR including 1906, 1912, 1927, 1932, 1938, 1947, 1959, 1968, 1971, 1976, 1982, 1986, 1990, 1994, 1996, 1998, 2001, 2004, 2008, and 2012. Conversion of the TFA for alternative versions of the RR into Excel sheets provides a record of the frequency bands by services and

band development. Moreover, the ITU structure development is based on the relevant literature and is cross-checked with the relevant Plenipotentiary Conferences (PP) document.

The WRC standard process is further explored through meeting documents from the WRC-12 agenda-setting and WRC-12 Agenda Items 1.19 and 1.22.

3.1 Data and data collection method

The primary data are obtained from participant observation and transcription of voice recordings from the meetings. Voice transcriptions provide the rationale of the argumentation and its resolution.

Such observations provide an internal view or meeting perspectives (Flick, 2009, pp. 226-233). However, Flick identifies the limitations of such observations, in particular, the difficulty of systematizing the status of meetings while maintaining distance. Moreover, observers must be limited only to what can be observed. Additional interviews of situations can help in understanding processes.

The secondary data are obtained from the ITU, CEPT, and APT archives outlining the timeline of RR changes by agenda item. In order to use documents as secondary data, Flick (2009) provides guidelines on how to select suitable analysis documents by the criteria: authenticity (applied to both primary and secondary data), credibility (official or personal), representativeness (typical or non-typical), and meaning (text clarity).

Document authenticity depends on the data source. If information is obtained from primary data sources and is documented by witnesses, then the authenticity is "high." When the data are obtained from a secondary data source and are documented from primary data, the authenticity of the document is "medium" or "low." Document credibility depends on the type of document. For official documents, credibility is "high." Naturally, for personal documents, credibility is "low." Representativeness is measured by document type. When documents are recorded for specific purposes, representativeness is non-typical. If the document is for general purposes, representativeness is typical. The documents' meaning depends on its clarity.

Here, a brief summary of the data collection methods follow. To gain an appreciation of how the RR and WRC have developed over time, the ITU archives are the principal source of input and output documentation for all RR versions. These data are used to construct a database of the TFA to track changes to key definitions and the WRC process to alter the RR.

All ITU documents can be accessed through the ITU History Portal (http://www.itu.int/en/history/Pages/default.aspx) including the PP (Complete List of Plenipotentiary Conferences), Radiocommunications Collection (Complete List of Radiotelegraph & Radiocommunication Conferences), and RR (Complete List of Radio Regulations).

The ITU history in Chapter 4 is described from the relevant literature and double-checked against the PP documents. Each PP provides conference outcomes, a list of participants, and conference documents.

The RR history in Chapter 5 is described from the RR versions as final outcomes from WRC. The Radiotelegraph & Radiocommunication Conferences did not provide complete sets of conference outcomes (only a list of participants and conference documents). The study therefore uses the complete list of RRs to track the changes through the RR versions.

The keywords from the selected RR provisions help to identify the change from each RR version. However, each frequency band of the TFA must be converted into an Excel sheet in order to identify the change by service of how each frequency band developed over time. Each RR version has four tables, i.e., global, Region 1, Region 2, and Region 3. Each table is categorized by service, priority (primary and secondary services), and frequency band.

Finally, the manual comparison by service (MMS, MMSS, BS, BSS, FS, FSS, MS, MSS, SRS, and EESS) summarizes the frequency band development across RR versions and is described in Appendices A, B, C, D, E, F, G, H, I, and J. Each appendix is composed of eight allocation tables, including global, Region 1, Region 2, and Region 3 with primary and secondary services.

To sum up, primary data obtained from meetings are considered "participant observations" of the PT A, CPG, APG, and WRC-12 meetings. These observations provide insight, interaction, and dynamic and current practice of regional preparatory groups and WRC. The template constructed in Chapter 8 standardizes the participant observation recording process.

Secondary data obtained from the ITU, CEPT, and APT archives provide a high degree of authenticity and credibility. Furthermore, the representativeness of the documents depends on their purpose. The purpose may be general (typical) or specific (non-typical). In this study, the documents are specific. The representativeness of this study is also mainly non-typical. Furthermore, the meaning of the documents is measured by document clarity.

3.2 Data analysis

Data analysis explains action situations, i.e., how decisions are made at the WRC meetings. This study starts from a list of IAD questions that should be considered as a basis on which to analyze the ITU, CEPT, and APT archives, and guide participant observations.

The IAD framework provides three questions on exogenous variables and seven questions on endogenous variables. There are three exogenous questions: what is the study object (physical condition-spectrum)?; what are the community characteristics (community attribute)?; and what are the "do" and "don't" rules (rules-in-use)? In essence, the exogenous variables help define the institutional framework within which the RR is considered. The seven endogenous questions relate to the operation of the "do" and "don't" rules, in particular, a micro relationship such as who can participate; which roles participants can perform; in each role which action can be selected; which action can be decided on based on the criteria; how to

control action; how the information flows inside the action; and what the possible outcomes are of an action.

The ITU, CEPT, and APT archives provide input and output documentation from previous RR and WRCs. However, the archives cannot answer all the questions. For example, the WRC-07 archives can provide the study object, i.e., spectrum as a public good (physical condition), the details of ITU membership indicating who can join the WRC-07 (boundary rule) in which position (HoD, DH, and D) (position rule). The possible outcome is RR revisions, i.e., modification, addition, suppression, or no change to the RR (scope rule).

The archives also provide the development of input and output documentation since 1865. The use of keywords helps in tracking the development of provisions over time. However, the rationale for changes is not recorded in the archives.

Participant observations capture meeting interactions (action situations). For example, at the IG 1.19 (CRS), the information constraints were treated as attributes of community (which country speaks out or avoids speaking). The available options proposed by a Member State potentially influenced others (information rules). Options discussed by Member States were based on their criteria of whether to support, oppose, or keep neutral positions (choice, payoff, and aggregate rules). During debates, rationales were revealed but not documented. Only resolved issues moved forward to higher-level meetings for RR revision. If issues continued to the next or future WRCs, this rationale of arguments was more valuable to Member States that did not attend to fully develop such arguments for the next or future WRC.

Conversely, participation observations are limited to selected current meetings. For example, the discussion on issues of WRC-12 Agenda Items 1.2 and 1.19 convened at the same time in different meetings. If Member States have teams available to attend such meetings, they can exchange meeting notes. For Member States with limited resources, informal discussion can provide some understanding of the missing information.

3.3 Approach

The empirical work of the study is the exploration of the ITU, CPG, and APG archives. Together with relevant literature, the study presents the ITU structure development. Moreover, the exploration of the ITU archives provides the empirical work for the RR (key definitions, important provisions, and TFA) and WRC (agenda-setting process and preparatory work) development. The exploration of the CPG and APG archives, as the regional preparatory work, assists the ITU preparatory process.

The results of the empirical findings deduced from the exploration of the archives show that the ITU archives only contain the final input and output of the WRC proceedings and RR versions. The archives are incomplete because of the lack of rationale behind the RR provisions.

In order to obtain the rationale behind such provisions, the IAD framework by Ostrom (2011), as a key framework, provides a list of relevant questions during the interactions between the stakeholders. The study applied the IAD framework to the WRC context as an action situation during the international negotiations. The list of relevant questions is deduced from the IAD framework, not the detailed content of the discussion.

The author's attendance or participant observations from the relevant meetings for WRC-12 Agenda Items 1.19 and 1.22 capture discussions that are missing from the archives. The study provides the missing information in the case of WRC-12 Agenda Item 1.19 as the result induced from the meetings.

To sum up, the study uses both the deductive IAD framework and the inductive participant observation approaches. The list of questions deduced from the IAD framework are probably considered during meetings. The results of the missing information are induced from the participant observations. As such, they provide a basis on which to analyze the archives and guide participant observations.

3.4 Summary

The study uses both primary and secondary data. Primary data come from the participant observations by attending the PT A, CPG, APG, and WRC-12 meetings. The secondary data come from the ITU, CEPT, and APT archives.

The study analyzes secondary data with questions provided by the IAD framework. The questions identify limitations of the ITU, CEPT, and APT archives. These gaps can be closed with information obtained from the participant observations. However, the participant observations are limited to the current meetings.

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Chapter 4 History of the International Telecommunication Union

This chapter presents the history of ITU (formerly, International Telegraph Union) since its establishment, in terms of the development of ITU's structure.[21]

ITU's structure has been established through a sequence of conferences, namely the International Telegraph Conference (1865-1932), International Telecommunication Conference (1947), and Plenipotentiary Conference (PP, 1952-2012). Administrative conferences, namely, the International Radiotelegraph Conference (Berlin, 1906), International Telegraph Conference (Paris, 1925), and International Radiotelegraph Conference (Washington, 1927), also focus on ITU's structure.

4.1 International Telegraph Conferences, 1865-1932

The first international telegraph activity occurred in 1849. Prussia and Austria-Hungary created the Austro-German Telegraph Union (Allison, 1993; Huurdeman, 2003). In 1850, Prussia, Austria-Hungary, Saxony, and Bavaria created the Austrian-German Telegraph Union in Dresden (Huurdeman, 2003; Rutkowski, 2011; Smith, 1976). The Dresden Treaty served as the first international telegraph convention.

Paris, 1865

The International Telegraph Conference was first held in Paris in 1865. The Conference created the international telegraph regulations (Rutkowski, 2011; White & Lauria, 1995). The Paris Convention had the signatory countries of France, Switzerland, Austria (Hungary), Bavaria, Belgium, Denmark, Spain, Greece, Hamburg, Hanover, Italy, Holland, Portugal, Prussia, Russia, Saxe, Sweden, Norway, Turkey, and Wurtenburg. The Convention contained the main text relating to the international telegraph operations with uniform transmission charges.[22]

Importantly, Mr. Kern (Swiss delegate) proposed that each country have one vote, irrespective of delegate numbers (Allison, 1993; ITU, 1965). This proposal had been approved by the Conference.

Vienna, 1868

The International Telegraph Conference had 23 signatory nations. The permanent secretariat was founded, namely, the International Bureau of Telegraph Administration in Berne, Switzerland (nee Berne Bureau). The Berne Bureau carried out administrative work and published a telegraphy journal (now *ITU news*), which was first published on 25 November 1869 (Codding, 1991; Glazer, 1962; Huurdeman, 2003; Lyall, 1997; Smith, 1976).

[21] This chapter is based on the History of the International Telecommunication Union (ITU), http://www.itu.int/en/history/Pages/default.aspx, accessed in May 2012, and relevant literature, but it is written in the author's own words.
[22] The Convention used French as the official language (Huurdeman, 2003; Lyall & Larsen, 2009).

Rome, 1871-1872

The International Telegraph Conferences included 19 countries and allowed private companies to attend as observers (as most telegraph cable is laid by private companies).

St. Petersburg, 1875

The Conference created the PP and Administrative Conferences. The PP produced the Convention text (principle), while the Administrative Conference provided the Annex (regulations) (Allison, 1993; Huurdeman, 2003).

Berlin, 1906

The International Radiotelegraph Conference transformed the International Telegraph Union into the International Radiotelegraph Union (Codding, 1991). This conference is an administrative conference with 30 delegate countries. The Conference amended the Annex (the RR) and appointed the Berne Bureau as the central registration office (Huurdeman, 2003; Smith, 1976).

Paris, 1925

In 1924, the International Telephone Consultative Committee (CCIF) was established for technical telephone study (Bellchamers, Francis, Hummel, & Nickelson, 1984).

The Conference founded the International Telegraph Consultative Committee (CCIT) to study technical aspect of telegraphy (Codding, 1991; Huurdeman, 2003; Lyall & Larsen, 2009). In 1956, the CCIF and CCIT were merged to form the International Telegraph and Telephone Consultative Committee (CCITT) (Codding, 1991; Huurdeman, 2003), which became the ITU-T in 1992 at the APP1992.

Washington D.C., 1927

Eighty countries attended the Conference. French was once again the official language, but the Conference allowed non-French speaking country delegates to converse in English (Smith, 1976).

Moreover, the Conference created the International Radio Consultative Committee (CCIR) as the technical committee for radio matters (Allison, 1993; Bellchamers et al., 1984; Codding, 1991; Glazer, 1962; Huurdeman, 2003; Lyall & Larsen, 2009). In 1992, the CCIR became the RA by the APP1992.

The Conference also established the Administrative Council to perform the tasks of the PP between conferences. Finally, private companies were given permission to contact the Berne Bureau directly (Allison, 1993).

Madrid, 1932

The PP merged the telegraph, telephone, and radio sectors into a single international union, ITU. The Madrid Convention developed the ITU Treaty as well as the Telegraph, Telephone, and Radio Regulations. ITU became effective on 1 January 1934 (Allison, 1993; Codding, 1991, 1995).

4.2 International Telecommunication Conference, 1947

USSR, 1946

The Union of Soviet Socialist Republics (USSR) invited China, France, the UK, and the USA to attend a Moscow meeting on June 25. The USA viewed telecommunication as a private sector activity and declined the invitation. Accordingly, the USSR invited attendance from private enterprise (Glazer, 1962). The meeting proposed housing ITU within the United Nations (UN) and forming a permanent administrative council (Codding, 1991; Huurdeman, 2003; Smith, 1976).

Atlantic City, 1947

The PP adopted proposals from the Moscow meeting for ITU to become a UN special agency (Allison, 1993; Lyall & Larsen, 2009; Smith, 1976) and an administrative council to be established to supervise the Union (Allison, 1993; Codding, 1991, 1995; Huurdeman, 2003; Lyall & Larsen, 2009; Smith, 1976).[23] The PP also established the General Secretariat to replace the Berne Bureau, and moved the administration to Geneva (Allison, 1993; Codding, 1991; Huurdeman, 2003; Smith, 1976).

Moreover, the PP established the International Frequency Registration Board (IFRB) to operate between the International Radiotelegraph Conference meetings. The IFRB updated the Master of Frequency list and solved several international interference issues (Allison, 1993; Codding, 1991, 1995; Huurdeman, 2003; Lyall & Larsen, 2009; Smith, 1976). In 1992, the IFRB became the RRB by the APP1992.

The official ITU languages increased to five to include Chinese, English, French, Russian, and Spanish (Huurdeman, 2003).

4.3 Plenipotentiary Conferences, 1952-2012

Geneva, 1959

The launch of Sputnik in 1957 influenced the Geneva Conference to change the TFA (Glazer, 1962). The PP also separated the Administrative Conference into the Ordinary Administrative Conference (broad regulation) and Extraordinary Administrative Conference (specified agenda) (Smith, 1976).

Moreover, because of the technology change, the PP reviewed ITU's purpose (White & Lauria, 1995).

[23] There were initially 18 members of the Administrative Council.

Montreux, 1965

The PP reviewed the future of the IFRB after establishing the General Secretariat (Codding, 1991) and prepared a draft ITU Constitution for the next meeting (White & Lauria, 1995).

Malaga-Torremolinos, 1973

This PP divided the Convention into the Constitutional Charter (basic provision, purpose, and structure) and the Convention (general regulation) (White & Lauria, 1995).

Nairobi, 1982

During this meeting, the use of the Voluntary Fund and the International Commission (world-wide telecommunication development) were discussed (Codding, 1991, 1995). The PP prepared the text, or ITU's purpose, to be included in the Constitution (White & Lauria, 1995). A schedule of world and regional administrative conferences was also developed for 1983-1988 (Bellchamers et al., 1984).

Nice, 1989

The year 1989 saw the merger of telecommunications and information technology (computing) (Codding, 1991; White & Lauria, 1995), which required a reorganization of ITU's structure (Allison, 1993; Codding, 1995; Goddard, 1994; Lyall, 1997; Lyall & Larsen, 2009; Noll, 2001).

The PP also established the Telecom Development Bureau to replace the Technical Cooperation Department, which operated under the auspices of the General Secretariat (Codding, 1995). The PP also changed the IFRB from a full-time to a part-time working scheme (Codding, 1991, 1995) and reduced the number of CCs conducted (Allison, 1993).

Furthermore, the PP accelerated the speed of standard-making by the CCITT (Codding, 1991) and increased ITU membership (White & Lauria, 1995) by introducing the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC), regional standards organizations, and the European Telecommunications Standards Institute (ETSI) in the CCITT and CCIR to the organization (Codding, 1991).

Finally, the PP completed the ITU CS and Convention (CV) (White & Lauria, 1995), and created the High Level Committee (HLC) to reorganize ITU's structure (Allison, 1993; Codding, 1991, 1995; Goddard, 1994; Lyall & Larsen, 2009; White & Lauria, 1995).

Additional Plenipotentiary, 1992

In Geneva, the HLC presented the new ITU structure. (Codding, 1995; Goddard, 1994; Huurdeman, 2003; Lyall, 1997; Lyall & Larsen, 2009; White & Lauria, 1995). The current ITU structure is the result of the APP1992 and its amendments. The amendments to this structure were made at Kyoto 1994, Minneapolis 1998, Marrakesh 2002, and Antalya 2006.

4.4 ITU Constitution

The result of this sequence of reorganizations is the current ITU structure, that is, ITU, an intergovernmental organization comprising Member States and Sector Members (Article 2, CS20). ITU promotes the extension of the benefits of new telecommunication technologies to the world's inhabitants (Article 1, CS6), harmonizes the actions of the Member States, and promotes fruitful and constructive cooperation and partnership between Member States and Sector Members in the attainment of these ends (Article 1, CS8).

The radio functions contained in Article 1 of the CS give ITU the power to: a) allocate radio-frequency spectrum band, allot radio frequencies, and register radiofrequency assignments for space services (any orbital position in geostationary-satellite orbit or any satellites in other orbits); b) coordinate efforts to eliminate intentional interference between radio stations and improve the use of radio-frequency spectrum (for radiocommunication services and of the geostationary-satellite and other satellite orbits); and c) facilitate the global standardization of telecommunications with a satisfactory quality of service.

The ITU Members' rights and obligations are contained in Article 3 of the CS. Furthermore, ITU activity is regulated by the CS, CV, International Telecommunication Regulations, and RR (Article 4 of the CS).

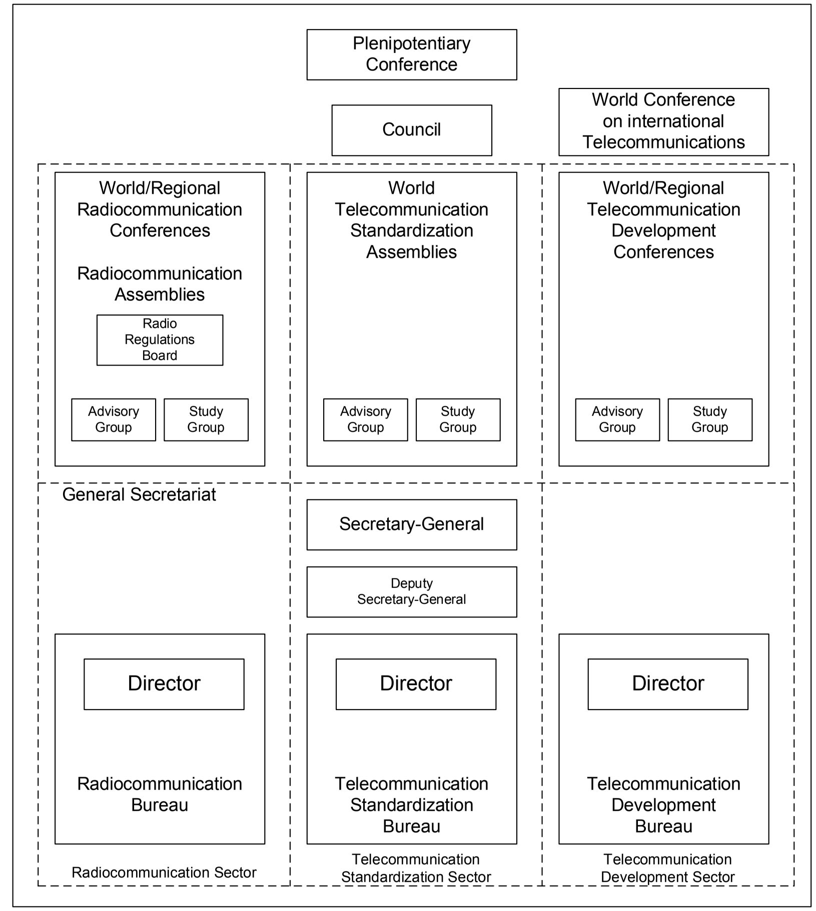
ITU's structure is contained in Article 7 of the CS and includes the PP; CC; World Conference on International Telecommunication; the Radiocommunication Sector: ITU-R (WRC and Regional Radiocommunication Conference, RA and RRB); the Telecommunication Standardization Sector: ITU-T (World Telecommunication Standardization Assemblies); the Telecommunication Development Sector: ITU-D (World and Regional Telecommunication Development Conferences); and the General Secretariat (CS-Article 7 a-g).

Figure 10 shows the internal structure of ITU, based on the *Collection of the Basic Texts of the International Telecommunication Union adopted by the Plenipotentiary Conference* (ITU, 2007a).

The PP is composed of Member States, and it convenes every four years to consider ITU matters, including policy and strategic plans, and budgetary matters, and it elects the members to the CC (Secretary-General, Deputy Secretary-General, Directors of the Sector Bureaux, and the RRB).

The CC is comprised of 48 Member States (25% of the Member States). The CC acts between PP meetings, but with limited power. The CC convenes annually and supervises the ITU Secretary-General.

The ITU-R is comprised of WRC and the Regional Radiocommunication Conferences, RA, RRB, Radio Advisory Group (RAG), and SG. The ITU-R office is the BR and is headed by an elected director.



Source: http://www.itu.int/aboutitu/structure/, Lee, K. (1996), and Hudson, H. E. (1997)

Figure 10. ITU's structure

The ITU-T includes the World Telecommunication Standardization Assemblies, Telecommunication Standardization Advisory Group, and SG. The ITU-T office is the Telecommunication Standardization Bureau and is headed by an elected director.

The ITU-D includes the World and Regional Telecommunication Development Conferences, Telecommunication Development Advisory Group, and SG. The ITU-D office is the Telecommunication Development Bureau and is headed by an elected director.

The APP1992 also changed the World Administrative Radio Conference (WARC to the WRC), CCIR (to the RA), IFRB (to the RRB), and CCITT (to the ITU-T), and required ITU to prepare the work for WRC.

4.5 Summary and discussion on research question

This chapter responds to sub-research question 1: *How is international spectrum policy set in terms of ITU structure, WRC, and the RR, and how did they develop?* The study illustrates the development of ITU's structure from 1865 to 1992 in terms of the International Telegraph Conference, International Telecommunication Conference, and Plenipotentiary Conference. The ITU Constitution (after the APP1992) also presents the current ITU structure.

The study explores the relevant literature regarding the ITU structure from available databases and websites. The keyword of the ITU structure and its timeline helps to illustrate the development of the ITU structure. The relevant literature provides the event of the ITU structure change and cross-checks it with the relevant convention. This output of the ITU structure is included in the Convention of the International Telegraph Conference, International Telecommunication Conference, and Plenipotentiary Conference. However, the reasons for the ITU structure change are not included. Some of the literature can complete this missing information from the ITU archives.

The ITU structure was developed from the International Telegraph Conference into the International Telecommunication Conference because of the development of technology from telegraph and radiotelegraph to telecommunication. The structure of ITU had to expand its scope to govern the growth of technology.

Most of the structure change concentrates on the supreme conference, i.e., the International Telegraph Conference, International Telecommunication Conference, and Plenipotentiary Conference. Changes are based on the input document from the Member States and discussions at the conferences.

During the initial stage, both the International Telegraph Conference and the International Telecommunication Conference responded to all matters (the Convention and Annex). The PP and administrative conferences were then separated. The PP now responds to the ITU structure as a main duty of the supreme body, and the administrative conferences take care of the regulations. Moreover, the PP separates the traditional International Telecommunication Convention into the ITU Constitution and the Convention. Here are the milestones of ITU's structure development:

(1) the Secretariat Unit developed from the Berne Bureau (1868) into the ITU General Secretariat (1934)

(2) the Administrative Council (1927) developed into the Councils (1992)

(3) the CCIF (1924) merged with the CCIT (1924) into the CCITT (1956) and developed into the ITU-T (1992)

(4) the CCIR (1927) developed into the ITU-R (1992)

(5) the IFRB (1947) developed into the RRB (1992)

(6) the Technical Cooperation Department developed into the Telecom Development Bureau (1989) and further into the ITU-D (1992)

The major reorganization of the ITU structure is the result of the HLC study (1989-1992). The APP1992 followed the result and approved the ITU structure. The current ITU structure is the result of the APP1992 and its amendments (1994, 1998, 2002, and 2006).

However, the reasons for the ITU structure change are not included in the ITU archives. Only the input and output of the conferences are provided.

This chapter illustrates the ITU structure development over time in order to respond to the first sub-research question: *What is the international spectrum policy setting in terms of the ITU structure, and how did it develop?*

Moreover, interesting changes to the ITU structure highlight the consequences of the rapid growth of telecommunication technologies. The rigid structure of the former ITU structure (before APP 1992) was not suitable for governing the dynamic situation of the rapid development in the telecommunication industry. However, the reason for the ITU structure changes did not explicitly show in the ITU archives. Only the Member States that attended have this missing information. Member States who rely on the ITU archives have incomplete information on the ITU structure change. The first sub-research question, *What is the international spectrum policy setting in terms of the ITU structure, and how did it develop?*, is therefore essential in terms of the ITU structure development to show that the ITU archives cannot capture the rationale underlying the ITU structure changes over time. This sub-research question is important to highlight the missing information as the conclusion of this chapter.

Chapter 5 History of the Radio Regulations

This chapter presents the history of WRC in terms of the RR development since the establishment of ITU (formerly the International Telegraph Union) in 1865. The study illustrates the RR development in terms of the RR provisions development, including key definitions, important provisions, the TFA, and Appendices A, B, C, D, E, F, G, H, I, and J. [24]

5.1 History of WRC

The study reviews the development of WRC, including the PP (International Telegraph Conference, 1865-1875), administrative conferences (International Radiotelegraph Conference, 1903-1947), Ordinary and Extraordinary World Administrative Radio Conference (1959-1992), and WRC (1993-2012).

5.1.1 International Telegraph Conferences, 1865-1875

The International Telegraph Conferences were convened in Paris (1865), Vienna (1868), Rome (1871-1872), and St. Petersburg (1875) to develop the ITU structure. WRC was embedded in the PP. The PP revised the Convention based on the contributions submitted by the Member States. The International Telegraph Conference output is the Convention.

Paris, 1865

The Convention developed general provisions, regulations, and effective dates. These elements are continuing (Codding, 1991; Smith, 1976). However, the Convention did not separate the general provisions (permanent text) from the operating manual (annex).

5.1.2 International Radiotelegraph Conferences, 1903-1947

In 1901, Marconi established coast stations in Belgium, Great Britain, Canada, Ireland, Italy, and Newfoundland. Operators were instructed only to exchange wireless signals between stations that had Marconi's equipment (Codding, 1991; Huurdeman, 2003).

Berlin, 1903

At the Berlin Conference, Wilhelm II called for the removal of Marconi's monopoly power on the radiotelegraph networks to allow distress communications with all ships. Austria, France, Germany, Great Britain, Hungary, Italy, Russia, Spain, and the United States made preliminary arrangements to cancel Marconi's monopoly (Allison, 1993; Glazer, 1962; Huurdeman, 2003; Smith, 1976).

Berlin, 1906

The Conference produced the document as the International Radiotelegraph Convention and the Annex. The Annex included frequency bands (wavelengths), service length of coast

[24] This chapter is based on the History of the International Telecommunication Union (ITU), http://www.itu.int/en/history/Pages/default.aspx, accessed in May 2012, and relevant literature, but it is written in the author's own words.

station, fees, telegram transmissions (Morse code and SOS distress signals), and the International Bureau.

London, 1912

After the Titanic disaster (14 April 1912), the Conference mandated that SOS distress signals between coast stations and ships be allowed regardless of the brand of the equipment. This was the end of Marconi's monopoly (Huurdeman, 2003).

Washington D.C., 1927

The Conference canceled the use of high-power spark transmitters (greater than 150 Watts) and included the right to be protected from interference (Allison, 1993; Huurdeman, 2003).

Atlantic City, 1947

The Conference reviewed the entire TFA to meet World War II requirements (Glazer, 1962).

5.1.3 Ordinary and Extraordinary Administrative Radio Conferences, 1959-1992

In 1959, the Conference reviewed the entire RR provisions, including the TFA (including the allocation for space services), provisions, and footnotes (Glazer, 1962).

Table 12. List of Ordinary and Extraordinary Administrative Radio Conferences 1959-1992

Ordinary	Title	
	Administrative Radio Conference, Geneva, 1959	ARC-59
	World Administrative Radio Conference, Geneva, 1979	WARC-79
Extraordinary	**Topic**	
	Allocate frequency bands for space radiocommunication purposes, Geneva, 1963	Spa-63
	Prepare a revised allotment plan for the aeronautical mobile (R) service, Geneva, 1966	Aer-66
	Maritime mobile service, Geneva, 1967	Mar-67
	Space telecommunications, Geneva, 1971	WARC-71
	Maritime, Geneva, 1974	Mar-74
	Broadcasting-satellite, Geneva, 1977	HFBC-77
	Aeronautical mobile (R) service, Geneva, 1978	Aer-78
	Mobile services (1st session), Geneva, 1983	Mob-83
	Planning of HF bands allocated to broadcasting service (1st session), Geneva, 1984	HFBC-84
	Use of geostationary-satellite orbit and planning of space services utilizing it (1st session), Geneva, 1985	Orb-85
	Planning of HF bands allocated to broadcasting service (2nd session), Geneva, 1987	HFBC-87
	Mobile services (2nd Session), Geneva, 1987	Mob-87
	Use of geostationary-satellite orbit and planning of space services utilizing it (2nd session), Geneva, 1988	Orb-88
	Frequency allocations in certain parts of the spectrum, Málaga-Torremolinos, 1992	WARC-92

However, the fourteenth Extraordinary Administrative Conference only reviewed the RR according to a specified agenda. Table 12 shows the list of Ordinary and Extraordinary Administrative Conferences (1959-1992).

5.1.4 World Radiocommunication Conferences, 1993-2012

The APP1992 mandated the WRC-93 to prepare the WRC-95 and WRC-97 agendas. Initially, two years (WRC-95 and WRC-97) were used. After 1997, the WRC convened between the PPs (Article 3, CV24). The WRC preparatory work was done by the CPM as part of the ITU-R SG.

5.2 RR versions and WRC

The development of WRC can be captured through the RR revisions. Table 13 and Table 14 show the relation between WRCs and the RRs.

Table 13. RR versions and WRC, 1906-1994

Conference	RR versions by years																		
	06	12	27	32	38	47	59	68	71	76	78	79	81	82	85	86	88	90	94
Berlin, 1903																			
Berlin, 1906	x																		
London, 1912		x																	
Washington D.C., 1927			x																
Madrid, 1932				x															
Cairo, 1938					x														
Atlantic City, 1947						x													
ARC-59							x												
Spa-63								x	x	x		x	x	x					
Aer-66								x	x	x		x	x						
Mar-67								x	x	x		x	x						
WARC-71									x	x		x	x						
Mar-74										x		x	x						
HFBC-77												x	x						
Aer-78												x	x						
WARC-79													x	x					
Mob-83															x	x	x	x	x
HFBC-84																			
Orb-85																x	x	x	x
HFBC-87																	x	x	x
Mob-87																		x	x
Orb-88																		x	x
WARC-92																			x

Table 14. RR versions and WRC, 1993-2012

RR / Conferences	1996	1998	2001	2004	2008	2012
WRC-93						
WRC-95	x					
WRC-97		x				
WRC-2000			x			
WRC-03				X		
WRC-07					x	
WRC-12						x

5.3 RR definitions

5.3.1 Telecommunication

The definition of "telecommunication" first appeared at the Madrid Convention. The Conference merged telegraph, telephone, and radio into telecommunication. The definition appears in the Annex of "Definition of Terms," Madrid 1932 Convention, p. 25:

"Telecommunication: Any telegraphic or telephonic communication of signs, signals, writing, facsimiles and sounds of any kind, by wire, wireless or other systems or processes of electric signalling or visual signalling (semaphores)" (ITU, 1932b, p. 25). This definition was also used in Cairo (ITU, 1938, p. 1).

In 1947, the definition included "any transmission, emission, or reception" and is found in Chapter 1, Article 1, the RR, p. 1:

"Telecommunication: Any transmission, emission or reception of signs, signals, writing, images and sounds or intelligence of any nature by wire, radio, visual or other electromagnetic systems" (ITU, 1947, p. 1).[25]

The PP Malaga-Torremolinos changed the definition found in Chapter 1 (Article 1, RR, p. RR1-1):

"Telecommunication: Any transmission, emission or reception of signs, signals, writing, images and sounds or intelligence of any nature by wire, radio, optical or other electromagnetic systems" (ITU, 1982, pp. RR1-1).[26]

[25] This definition was used at the following nine conferences:
1) The ARC-59 according to Chapter 1, Article 1, the RR, p. 3. (ITU, 1959)
2) The Spa-63 according to Chapter 1, Article 1, the RR, p. 5 (ITU, 1968)
3) The Aer-66 according to Chapter 1, Article 1, the RR, p. 5 (ITU, 1968)
4) The Mar-67 according to Chapter 1, Article 1, the RR, p. 5 (ITU, 1968)
5) The WARC-71 according to Chapter 1, Article 1, the RR, p. RR1-1 (ITU, 1971)
6) The Mar-74 according to Chapter 1, Article 1, the RR, p. RR1-1 (ITU, 1976)
7) The HFBC-77. There was no change in the RR edition of 1979 regarding the definition of "telecommunication" (ITU, 1979)
8) The Aer-78. There was no change in the RR edition of 1979 regarding the definition of "telecommunication" (ITU, 1979)
9) The WARC-79. There was no change in the RR edition of 1981 regarding the definition of "telecommunication" (ITU, 1981)

[26] This definition was used at the following 12 conferences and continues effectively until 2012:
1) The Mob-83. There was no change in the RR edition of 1985 regarding the definition of "telecommunication" (ITU, 1985)
2) The Orb-85 according to Chapter 1, Article 1, the RR, p. RR1-1 (ITU, 1986)
3) The HFBC-87. There was no change in the RR edition of 1988 regarding the definition of "telecommunication" (ITU, 1988)
4) The Mob-87 according to Chapter 1, Article 1, the RR, p. RR1-1 and 2 (ITU, 1990)
5) The Orb-88 according to Chapter 1, Article 1, the RR, p. RR1-1 and 2 (ITU, 1990)
6) The WARC-92 according to Chapter 1, Article 1, the RR, p. RR1-2 (ITU, 1994)
7) The WRC-95. There was no change in the RR edition of 1996 regarding the definition of "telecommunication" (ITU, 1996)
8) The WRC-97 according to Article S1.3, p. 7 of the RR edition of 1998 (ITU, 1998) and the Constitution (CS1012)

Table 15 shows the analysis of the "Telecommunication" definition of RR1932, RR1947 and RR1982 categorized by communication type, transmission object, and medium type.

Table 15. Telecommunication definition

Version	Communication	Transmission object	Medium
1932	Telegraphic or telephonic	Signs, signals, writing, facsimiles and sounds of any kind	Wire, wireless, or other systems or processes of electric signaling or visual signaling (semaphores)
1947	Transmission, emission, or reception	Signs, signals, writing, images, and sounds or intelligence of any nature	Wire, radio, visual, or other electromagnetic systems
1982	Transmission, emission, or reception	Signs, signals, writing, images, and sounds or intelligence of any nature	Wire, radio, optical, or other electromagnetic systems

Communication

The meaning of communication changed between the RR1932 and RR1947 (1982) because of the technology differences. The RR1932 provided telegraph and telephone. The RR1947 and RR1982 expanded into the general communication types: transmission, reception, and emission.

Transmission object

The RR1932 had "facsimiles," but the RR1947 and RR1982 replaced "facsimiles" by "image" and extended the definition to "intelligence of any nature."

Medium type

The RR1932 provided wireless, electric signaling, or visual signaling (semaphores). However, the RR1947 replaced "wireless" with "radio," "electric signaling" with "electromagnetic system," and "visual signaling (semaphores)" (the arm attached to a tower that sends visual signals between stations) with "visual." However, visual is not the medium. The medium is the light that enables the sighting of an object.

The RR1982 replaced "visual" with "optical." The optical communication includes optical cables and links.

The current "telecommunication" definition should be sufficient for future development because it expands "transmission" and "medium" to cover possible telecommunication technology.

9) The WRC-2000 according to Article 1.3, p. 7 of the RR edition of 2001 (ITU, 2001) and the Constitution (CS1012)
10) The WRC-03 according to Article 1.3, p. 7 of the RR edition of 2004 (ITU, 2004) and the Constitution (CS1012)
11) The WRC-07 according to Article 1.3, p. 7 of the RR edition of 2008 (ITU, 2008) and the Constitution (CS1012)
12) The WRC-12 according to Article 1.3 of the RR edition of 2012 (ITU, 2012b)

5.3.2 Radiocommunication

The RR1932 provided the definition "radiocommunication" in the Annex of "Definition of Terms" on p. 25 of the Madrid Convention:

"Radiocommunication: Any telecommunication by means of Hertzian waves" (ITU, 1932b, p. 25).

This definition was used in Cairo (ITU, 1938, p. 1) and Atlantic City (ITU, 1947, p. 1).

The ARC-59 replaced "Hertzian waves" with "radio waves," and it is found in Chapter 1 (Article 1, RR, p. 4):

"Radiocommunication: Telecommunication by means of radio waves" (ITU, 1959, p. 4).[27]

The differences between the RR1932 and RR1959 were "Hertzian" and "radio."

5.3.3 Radio waves

The definition of "Hertzian Waves" first appeared in Atlantic City and is found in the Annex to Chapter 1, Article 1, p. 1:

[27] This definition was used at the following 21 conferences and continues effectively until 2012:
1) The Spa-63 according to Chapter 1, Article 1, the RR, p. 6 (ITU, 1968)
2) The Aer-66 according to Chapter 1, Article 1, the RR, p. 6 (ITU, 1968)
3) The Mar-67 according to Chapter 1, Article 1, the RR, p. 6 (ITU, 1968)
4) The WARC-71 according to Chapter 1, Article 1, the RR, p. RR1-2 (ITU, 1971)
5) The Mar-74 according to Chapter 1, Article 1, the RR, p. RR1-2 (ITU, 1976)
6) The HFBC-77. There was no change in the RR edition of 1979 regarding the definition of "radiocommunication" (ITU, 1979)
7) The Aer-78. There was no change in the RR edition of 1979 regarding the definition of "radiocommunication" (ITU, 1979)
8) The WARC-79. There was no change in the RR edition of 1981 regarding the definition of "radiocommunication" (ITU, 1981)
9) The PP Malaga-Torremolinos 1973 Convention used the same definition as ARC-59 (ITU, 1982, pp. RR1-1 and 2)
10) The Mob-83. There was no change in the RR edition of 1985 regarding the definition of "radiocommunication" (ITU, 1985)
11) The Orb-85 according to Chapter 1, Article 1, the RR, p. RR1-1 and 2 (ITU, 1986)
12) The HFBC-87. There was no change in the RR edition of 1988 regarding the definition of "radiocommunication" (ITU, 1988)
13) The Mob-87 according to Chapter 1, Article 1, the RR, p. RR1-1 and 2 (ITU, 1990)
14) The Orb-88 according to Chapter 1, Article 1, the RR, p. RR1-1 and 2 (ITU, 1990)
15) The WARC-92 according to Chapter 1, Article 1, the RR, p. RR1-2 (ITU, 1994)
16) The WRC-95. There was no change in the RR edition of 1996 regarding the definition of "radiocommunication" (ITU, 1996)
17) The WRC-97 according to Article S1.6, p. 7 of the RR edition of 1998 (ITU, 1998), the Constitution (CS1009), and the Convention (1005)
18) The WRC-2000 according to Article 1.6, p. 7 of the RR edition of 2001 (ITU, 2001) and the Constitution (CS1009), and the Convention (1005)
19) The WRC-03 according to Article 1.6, p. 7 of the RR edition of 2004 (ITU, 2004) and the Constitution (CS1009), and the Convention (1005)
20) The WRC-07 was also the same as the RR of the ARC-59 according to Article 1.6, p. 7 of the RR edition of 2008 (ITU, 2008), the Constitution (CS1009), and the Convention (1005)
21) The WRC-12 according to Article 1.3 of the RR edition of 2012 (ITU, 2012b)

"Hertzian Waves: Electromagnetic waves of frequencies between 10 kc/s and 3 000 000 Mc/s" (ITU, 1947, p. 1).

The ARC-59 changed the definition found in Chapter 1, Article 1, the RR, p. 4:

"Radio Waves (or Hertzian Waves): Electromagnetic waves of frequencies lower than 3 000 Gc/s, propagated in space without artificial guide" (ITU, 1959, p. 4).[28]

The differences were "radio waves" and "propagated in space without artificial guide."

The Mar-74 changed the definition found in Chapter 1 (Article 1, RR, p. RR1-2 from c/s to Hz):

"Radio Waves (or Hertzian Waves): Electromagnetic waves of frequencies lower than 3 000 GHz, propagated in space without artificial guide" (ITU, 1976, pp. RR1-2).[29]

PP Malaga-Torremolinos changed the definition, which is found in Chapter 1 (Article 1, RR, p. RR1-1):

"Radio Waves or Hertzian Waves: Electromagnetic waves of frequencies arbitrarily lower than 3 000 GHz, propagated in space without artificial guide" (ITU, 1982, pp. RR1-1).[30]

The differences were the deletion of parenthesis "()" and the addition of "arbitrarily." The "arbitrarily" represents unspecified frequency lower than 3 000 GHz.

[28] This definition was used at the four following conferences:
1) The Spa-63 according to Chapter 1, Article 1, the RR, p. 6 (ITU, 1968)
2) The Aer-66 according to Chapter 1, Article 1, the RR, p. 6 (ITU, 1968)
3) The Mar-67 according to Chapter 1, Article 1, the RR, p. 6 (ITU, 1968)
4) The WARC-71 according to Chapter 1, Article 1, the RR, p. RR1-2 (ITU, 1971)

[29] This definition was used at the three following conferences:
1) The HFBC-77. There was no change in the RR edition of 1979 regarding the definition of "radio waves" (ITU, 1979)
2) The Aer-78. There was no change in the RR edition of 1979 regarding the definition of "radio waves" (ITU, 1979)
3) The definition of "radio waves" in WARC-79 was also the same as the RR of the Mar-74, edition of 1976. There was no change in the RR edition of 1981 regarding definition of "radio waves" (ITU, 1981)

[30] This definition was used in the following 12 conferences and continues effectively until 2012:
1) The Mob-83. There was no change in the RR edition of 1985 regarding the definition of "radio waves" (ITU, 1985)
2) The Orb-85 according to Chapter 1, Article 1, the RR, p. RR1-1 (ITU, 1986)
3) The HFBC-87. There was no change in the RR edition of 1988 regarding the definition of "radio waves" (ITU, 1988)
4) The Mob-87 according to Chapter 1, Article 1, the RR, p. RR1-1 and 2 (ITU, 1990)
5) The Orb-88 according to Chapter 1, Article 1, the RR, p. RR1-1 and 2 (ITU, 1990)
6) The WARC-92 according to Chapter 1, Article 1, the RR, p. RR1-2 (ITU, 1994)
7) The WRC-95. There was no change in the RR edition of 1996 regarding the definition of "radio waves" (ITU, 1996)
8) The WRC-97 according to Article S1.5, p. 7 of the RR edition of 1998 (ITU, 1998)
9) The WRC-2000 according to Article 1.5, p. 7 of the RR edition of 2001 (ITU, 2001)
10) The WRC-03 according to Article 1.5, p. 7 of the RR edition of 2004 (ITU, 2004)
11) The WRC-07 according to Article 1.5, p. 7 of the RR edition of 2008 (ITU, 2008)
12) The WRC-12 according to Article 1.3 of the RR edition of 2012(ITU, 2012b)

Table 16 presents the analysis of "radio waves" of the RR1947, RR1959, RR1976, and RR1982.

Table 16. Radio wave definition

Version	Heading	Medium	Text	Frequency unit	Propagation mode
1947	Hertzian Waves	Electromagnetic waves of frequencies	Between 10 kc/s and 3 000 000	Mc/s	None
1959	Radio Waves (or Hertzian Waves)	Electromagnetic waves of frequencies	Lower than 3 000	Gc/s	Propagated in space without any artificial guide
1976	Radio Waves (or Hertzian Waves)	Electromagnetic waves of frequencies	Lower than 3 000	GHz	Propagated in space without any artificial guide
1982	Radio Waves or Hertzian Waves	Electromagnetic waves of frequencies	Arbitrarily lower than 3 000	GHz	Propagated in space without any artificial guide

The RR1947 introduced "Hertzian waves" and replaced it with "Radio waves or Hertzian wave" in the RR1959, RR1976, and RR1982.

The propagation mode is inserted to differentiate between waves travelling in free space and with a waveguide. Only waves that travel in free space without any artificial guide need to be regulated.

The RR1982 added "arbitrarily" to include all unspecified frequency.

5.3.4 Radio

The definition of "Radio" first appeared in Atlantic City and is found in the Annex, Chapter 1, Article 1, p. 2:

"Radio: A general term applied to the use of Hertzian waves" (ITU, 1947, p. 2).

The ARC-59 changed the definitions and again they are found in Chapter 1, Article 1, the RR, p. 4:

"Radio: A general term applied to the use of radio waves" (ITU, 1959, p. 4).[31]

[31] This definition was used in the following 21 conferences and continues effectively until 2012:
1) The Spa-63 according to Chapter 1, Article 1, the RR, p. 6 (ITU, 1968)
2) The Aer-66 according to Chapter 1, Article 1, the RR, p. 6 (ITU, 1968)
3) The Mar-67 according to Chapter 1, Article 1, the RR, p. 6 (ITU, 1968)
4) The WARC-71 according to Chapter 1, Article 1, the RR, p. RR1-2 (ITU, 1971)
5) The Mar-74 according to Chapter 1, Article 1, the RR, p. RR1-2 (ITU, 1976)
6) The HFBC-77. There was no change in the RR edition of 1979 regarding the definition of "radio" (ITU, 1979)
7) The Aer-78. There was no change in the RR edition of 1979 regarding the definition of "radio" (ITU, 1979)
8) The WARC-79. There was no change in the RR edition of 1981 regarding the definition of "radio" (ITU, 1981)
9) The PP Malaga-Torremolinos 1973 Convention also used the same definition as ARC-59 (ITU, 1982, pp. RR1-1 and 2)
10) The Mob-83. There was no change in the RR edition of 1985 regarding the definition of "radio" (ITU, 1985)

The RR1959 replaced "Hertzian" with "Radio" in line with the "Radio Wave" definition.

5.4 RR provisions

The development of selected RR provisions, including choice of apparatus, services, stations, licenses, frequency assignment in general, and allocation, allotment, and assignment definition, are examined below.

5.4.1 Choice of apparatus

The Berlin 1906 Conference first revised the Choice of Apparatus provision to allow all communication between coast stations and ships at sea, regardless of the brand of equipment. The provision is contained in Article I of the Rule of Services of the Annex to the Berlin 1906 Convention:

"Le choix des appareils et des dispositifs radiotélégraphiques à employer par les stations côtières et les stations de' bord est libre. L'installation de ces stations doit répondre, autant que possible, aux progrès scientifiques et techniques" (ITU, 1906b, p. 361).

The choice of radiotelegraphy apparatus and devices to be used by the coastal stations and on-board stations is free. The installation of these stations must, as far as possible, match scientific and technical progress (English translation).

Marconi thus did not follow the Convention until the tragedy of the Titanic. Only then did Marconi allow his coast stations to communicate with all ships at sea.

The London Conference did not change the provision. Article 1 of the Detailed Service Regulations appended to the London 1912 Convention state that:

"The choice of radiotelegraph apparatus and devices to be used by coast stations and ship stations is free. The installation of these stations must, as far as possible, be in keeping with scientific and technical progress" (ITU, 1912a, p. 187).

The Washington D.C. Conference revised the provisions. In Article 3, Choice of Calibration of Apparatus, General Regulations Annexed to the Washington D.C. 1927 Convention:

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11) The Orb-85 according to Chapter 1, Article 1, the RR, p. RR1-1 and 2 (ITU, 1986)
12) The HFBC-87. There was no change in the RR edition of 1988 regarding the definition of "radio" (ITU, 1988)
13) The Mob-87 according to Chapter 1, Article 1, the RR, p. RR1-1 and 2 (ITU, 1990)
14) The Orb-88 according to Chapter 1, Article 1, the RR, p. RR1-1 and 2 (ITU, 1990)
15) The WARC-92 according to Chapter 1, Article 1, the RR, p. RR1-2 (ITU, 1994)
16) The WRC-95. There was no change in the RR edition of 1996 regarding the definition of "radio" (ITU, 1996)
17) The WRC-97 according to Article S1.4, p. 7 of the RR edition of 1998 (ITU, 1998)
18) The WRC-2000 according to Article 1.4, p. 7 of the RR edition of 2001 (ITU, 2001)
19) The WRC-03 according to Article 1.4, p. 7 of the RR edition of 2004 (ITU, 2004)
20) The WRC-07 according to Article 1.4, p. 7 of the RR edition of 2008 (ITU, 2008)
21) The WRC-12 according to Article 1.3 of the RR edition of 2012 (ITU, 2012b)

"The choice of the radioelectric apparatus and devices to be used by a station is free, provided that the waves emitted are in conformity with the provisions of these Regulations" (ITU, 1927, p. 32).[32]

The Conference clarified "scientific and technical progress" by adding "conformity with the provision of these Regulations."

The Atlantic City Conference deleted "radioelectric, free" and added "unrestricted." In Article 16, Choice of Apparatus, 395 § 1 of the RR, which is annexed to the Atlantic City 1947 Convention:

"The choice of apparatus and devices to be used in a station shall be unrestricted, provided that the performance thereof and the emissions therefrom satisfy the provisions of these Regulations" (ITU, 1947, p. 87).

In Geneva, the Conference changed "choice of apparatus" to "technical characteristics of station" in Article 12 (Technical characteristic of equipment and emission, 667 § 1, RR1959):

"The choice and performance of equipment to be used in a station and any emissions therefrom shall satisfy the provisions of these Regulations" (ITU, 1959, p. 144).[33]

Table 17 shows the "Choice of apparatus" provisions.

Choices

The RR1906-1947 uses "choice of apparatus" as equipment and devices. The RR1959 changed "apparatus and devices" to "performance of equipment."

Location

The RR1906 and RR1912 limit the location of apparatus to coast and ship stations. The RR1927 revised the provision to be able to use "choice of apparatus" by any station.

General Provision

The RR1906 and RR1912 did not define the scope of "choice of apparatus;" however, the RR1927 limited the scope of "choice of apparatus" to the RR provisions.

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[32] This provision was used in the two following RR:
1) General Radiocommunication Regulations annexed to the International Telecommunication Convention, Madrid 1932, Article 4, the RR, p. 8, [37] §1 of the RR (ITU, 1932a) . The difference was "these" and "present"
2) General Radiocommunication Regulations annexed to the International Telecommunication Convention, Cairo 1938, Article 4, the RR, p. 6, 52§1 of the RR (ITU, 1938)

[33] This provision was used in the ten following RR and has continued until 2012:
1) Article 12, Technical Characteristics of Equipment and Emission, 667 § 1. (1) of the RR (ITU, 1968, 1976)
2) Article 5, Technical Characteristics of Stations, 299 § 1. (1) of the RR (ITU, 1982, 1990, 1994)
3) Article S3, Technical Characteristics of Stations, S3.1, of the RR (ITU, 1998)
4) Article 3, Technical Characteristics of Stations, 3.1 of the RR (ITU, 2001, 2004, 2008, 2012b)

Table 17. Choice of apparatus provision

Version	Choice	Location	General provision
1906	Apparatus and radio departments	Coast stations and the stations and ship station	Installations should respond, if possible, to scientific and technical progress
1912	Radiotelegraph apparatus and devices	Coast stations and ship stations	Installations must, as far as possible, be in keeping with scientific and technical progress
1927	Radioelectric apparatus and devices	Any station	Waves emitted conform to the provisions of the Regulations
1947	Apparatus and devices	Any station	Performance thereof and emissions therefrom satisfy the provisions of the Regulations
1959	Equipment and its performance	Any station and emission therefrom	Satisfy the provisions of the Regulations

5.4.2 Frequency assignment

The frequency assignment provision is initiated at the Washington D.C. Convention, Article 5 (Distribution and use of frequencies [wave lengths] and types of emission, §1):

"The administrations of the contracting governments may assign any frequency and any type of wave to any radioelectric station under their authority upon the sole condition that no interference with any service of another country results therefrom" (ITU, 1927, p. 35).

The Madrid Conference revised the provision (see General Radiocommunication Regulation, Article 7, Distribution and use of frequencies [wavelengths] and type of emission, ["] § 1):

"Subject to the provisions of section (5) of § 5 below, the Administrations of the contracting countries may assign any frequency and any type of wave to any radioelectric station under their authority, upon the sole condition that no interference with any service of another country results therefrom" (ITU, 1932a, p. 11).[34]

The Atlantic City Conference revised the provision. The provision is contained in the Annex to the Atlantic City 1947 Convention, Article 3, General rules for the assignment and use of frequencies, 86§1:

"The countries, members of the Union, adhering to these Regulations, agree that in assigning frequencies to stations which, by their very nature, are capable of causing harmful interference to the services rendered by the stations of another country, they will make such assignments in accordance with the table of frequency allocations and other provisions of this chapter" (ITU, 1947, p. 16).

The RR1959, RR1968, and RR1976, revised the provision (Article 3 General rules for the assignment and use of frequencies, 113 §1):

[34] This provision was used in Cairo 1938 with slight changes to the relevant provision in the General Radiocommunication Regulation, Article 7, Distribution and use of frequencies (wavelengths) and type of emission, 79§1, p. 8 of the RR (ITU, 1938).

"The Members and Associate Members of the Union agree that in assigning frequencies to stations, which are capable of causing harmful interference to the services rendered by the stations of another country, such assignments are to be made in accordance with the Table of Frequency Allocations and other provisions of these Regulations" (ITU, 1959, p. 21, 1968, pp. RR3-1, 1976, pp. RR3-1).

The RR1982 revised the provision in Article 6 General rules for the assignment and use of frequencies, 340 § 2 of the RR:

"Members undertake that in assigning frequencies to stations which are capable of causing harmful interference to the services rendered by the stations of another country, such assignments are to be made in accordance with the Table of Frequency allocation and other provisions of these Regulations" (ITU, 1982, pp. RR6-1).[35]

Table 18. Frequency assignment provisions

Version	Authority	Harmful interference	General provision
1927	Administration of contracting governments	Assign any frequency and wave to any radioelectric station under their authority on the condition that there is no interference with other country services	None
1932	Administration of contracting countries	Assign any frequency and wave to any radioelectric station under their authority on the condition that there is no interference with other country services	Section (5) of § 5
1947	Countries, ITU Members, adhering to the Regulations	Recognize that assigning frequencies to stations can cause harmful interference to other country services	Assignments accord with the Table of Frequency Allocations and other provisions
1976	ITU Members and Associate Members of the Union	Recognize that assigning frequencies to stations can cause harmful interference to other country services	Assignments accord with the Table of Frequency Allocations and other provisions of the Regulations
1982	Members	Recognize that assigning frequencies to stations can cause harmful interference to other country services	Assignments accord with the Table of Frequency Allocations and other provisions of the Regulations

Table 18 shows the development of the "frequency assignment" provision. Three concepts have been developed: authority, harmful interference, and general provision.

[35] This provision was used in seven of the following RR and continued to be in use until 2012:
1) Article 6 General rules for the assignment and use of frequencies, 340 § 2 of the RR (ITU, 1990, 1994)
2) Article S4, Assignment and use of frequencies, Section I General rules, S4.2 of the RR (ITU, 1998)
3) Article 4, Assignment and use of frequencies, Section I General rules, 4.2 of the RR (ITU, 2001, 2004, 2008, 2012b)

Authority

The provision developed from "Administration of the Contracting Government or Countries," "Countries, members of Union," "Members and Associated Members," to "Members." The "Members" is defined as the ITU Members.

Harmful interference

While RR1927, RR1932, RR1947, RR1976, and RR1982 revised the provision, the concept of "not causing harmful interference" remained.

General provisions

The RR1932 established the specific provision (Section (5) of § 5). However, the RR1947, RR1976, and RR1982 revised the provision by referring to the TFA and RR provisions.

5.4.3 Licences

Licenses are tools that control devices and frequencies. The Berlin Conference established the provision contained in Article 6 (§ 1 of the Rule of Services Annexed to the Berlin 1906 Convention):

"Aucune station de bord ne peut être établie ou exploitée par une entreprise privée sans autorisation du Gouvernement dont dépend le navire. Cette autorisation fait l'objet d'une licence délivrée par ce Gouvernement" (ITU, 1906b, p. 362).

No on-board station may be established or operated by a private enterprise without authorisation from the government to which the ship belongs. This authorisation is the subject of a licence issued by this government (English translation).

The London Conference revised the provision via Article 9 (1 of Detailed Service Regulations appended to the London 1912 Convention):

"No ship station may be established or worked by private enterprise without licence issued by the Government to which ship is subject" (ITU, 1912a, p. 190).

Later, the Washington Conference further revised the provision via Article 2§1 (General Regulations, Annexed to Washington 1927 Convention):

"No radioelectric sending station shall be established or worked by an individual person or by a private enterprise without a special licence issued by the Government of the country to which the station in question is subject" (ITU, 1927, p. 31).

A Madrid revision is in Article 3, ["] § 1- (1) (General Radiocommunication Regulation, Madrid 1932 Convention):

"No sending station shall be established or worked by an individual person, or by any enterprise, without a special licence issued by the Government to which the station in question is subject" (ITU, 1932a, p. 7).

The differences between the RR1927 and RR1932 are in the deletion of "radioelectric" and "private," but the "private" was reinserted at the RR1938.

Additionally, the Cairo Conference added "of the country" in Article 3 (47 § 1. (l), General Radiocommunication Regulation, Cairo 1938 Convention):

"No sending station may be established or worked by a private person, or by any enterprise, without a special licence issued by the Government of the country to which the station in question is subject" (ITU, 1938, p. 5).

Furthermore, the Atlantic City Conference changed from "sending" to "transmitting" in Article 22 (Choice of Apparatus, 488 § 1 (1) of RR annexed to the Atlantic City 1947 Convention):

"No transmitting station may be established or operated by a private person or by any enterprise without a licence issued by the government of the country to which the station in question is subject" (ITU, 1947, p. 105).[36]

The RR1982 revised the provision by also adding "conformity with the provision" in Article 24 (Licences, § 1. (1) of RR1982):

"No transmitting station may be established or operated by a private person or by any enterprise without a licence issued in an appropriate form and in conformity with the provision of these Regulation by the government of the country to which the station in question is subject" (However, see Nos. 2021, 2027 and 2030)" (ITU, 1982, pp. RR24-21).[37]

Finally, the WRC-98 added "or on behalf of" in order to include other parties that act on behalf of the administration. The revision is found in Article S18 (Licences, S18.1 § 1, 1) of RR1998):

"No transmitting station may be established or operated by a private person or by any enterprise without a licence issued in an appropriate form and in conformity with the provisions of these Regulations by or on behalf of the government of the country to which the station in question is subject (however, see Nos. S18.2, S18.8 and S18.11)" (ITU, 1998, p. 202).[38]

Table 19 shows the development of the "Licences" provision.

[36] This provision was used in four of the following RR with a slightly changed relevant provision in RR:
1) Article 18, Licences, 725§1 of the RR (ITU, 1959)
2) Article 18, Licences, 18§1 (1) of the RR (ITU, 1968, 1971, 1976)

[37] This provision was used in two of the following RR in Article 24, Licences, §1(1) of the RR (ITU, 1990, 1994).

[38] This provision was used in four consequent RRs with slight changes to the relevant provision in RR, Article 18, Licences, 18.1§1 (1) of the RR (ITU, 2001, 2004, 2008, 2012b).

Table 19. Licence provisions

Version	Station	Operator	Licences	Authority
1906	Ship	Private company	Government permission	Government
1912	Ship	Private enterprise	Licence issue	Government
1927	Radioelectric sending station	Individual person or private enterprise	Special licence issue	Government
1932	Sending station	Individual person or private enterprise	Special licence issue	Government
1938	Sending station	Private person or enterprise	Special licence issue	Government
1947	Transmitting station	Private person or enterprise	Licence issue	Government
1982	Transmitting station	Private person or enterprise	Licence issue that conforms with regulations	Government
1998	Transmitting station	Private person or enterprise	Licence issue that conforms with regulations	By or on behalf of the Government

Station

The concept of stations developed from “ship stations,” “radioelectric sending station” to “transmitting station.”

Operator

Operators that control the use of radiocommunication stations developed from “private company,” “private enterprise,” “individual person,” to “private person and any enterprise.”

Licenses

Permission to use radiocommunication stations developed from “ship station,” “special licences” to “licences.” The RR1982 provision limited the use of licenses to those specified by the Regulations.

Authority

The concept of authority initially focused on the Government (RR1906, RR1912, RR1927, RR1932, RR1938, RR1947, and RR1982), but is later extended to those acts on behalf of the Government (RR1998).

5.4.4 Allocation, allotment, and assignment

The initial definition of allocation, allotment, and assignment is provided in the RR1982 and remains unchanged.

The definitions are contained in Section II – Specific terms related to frequency management (2.1, 2.2, and 2.3 of the RR1982):

“allocation (of a frequency band): Entry in the Table of Frequency Allocations of a given frequency band for the purpose of its use by one or more terrestrial or space radiocommunication services or the radio astronomy service under specified conditions. This term shall also be applied to the frequency band concerned.

“allotment (of a radio frequency or radio frequency channel): Entry of a designated frequency channel in an agreed plan, adopted by a competent conference, for use by one or more administrations for a terrestrial or space radiocommunication service in one or more identified countries or geographical areas and under specified conditions.

“assignment (of a radio frequency or radio frequency channel): Authorization given by an administration for a radio station to use a radio frequency or radio frequency channel under specified conditions” (ITU, 1982, pp. RR1-3).

These definitions are also found in the RR1990 and RR1994 (ITU, 1990, 1994). The provision numbers were changed to S1.16, S1.17, and S1.18 at the RR1998 (ITU, 1998). However, the provision numbers reverted to 1.16, 1.17, and 1.18, respectively in the RR2001, RR2004, RR2008, and RR2012 (ITU, 2001, 2004, 2008, 2012b).

5.4.5 Service priority

The service priority indicates an ability to claim protection from interference.

In 1906 and 1912, services were allocated through a paragraph describing the use of frequency or wavelength.

The RR1927 provides the initial TFA. However, RR1927, RR1938, and RR1947 do not indicate any service priority, namely, all services have the same priority.

In Geneva in 1959, the service priority was officially established, i.e., primary, permitted, and secondary services. However, primary and permitted services have the same priority. Importantly, permitted services have a lower priority than primary services in the allocation of frequency bands.

The secondary services are not permitted to cause any interference. Nor can a secondary service claim protection from primary and permitted services.

Primary, permitted, and secondary services are found in Article 5 (Section II. Categories of Services and Allocations, Primary Services, Permitted Services, and Secondary Services, 137-141, of the RR1959) (ITU, 1959, pp. 26-27).[39]

[39] This provision was used in the RR editions of 1968, 1971, and 1976 (ITU, 1968, 1971, 1976),
“137 Where, in a box of the Table in Section IV of this Article, a band is indicated as allocated to more than one service, either on a world-wide or Regional basis, such services are listed in the following order:
a) services, the names of which are printed in ‘small capitals’ (example: FIXED); these services are called ‘primary’ services ;
b) services, the names of which are printed in ‘grotesque light’ (example: Radiolocation); these are ‘permitted’ services (see No. 138);

In the TFA, the font formats “grotesque light” and “italics” indicate permitted and secondary services, respectively. A new format was proposed in the RR1982.

The RR1982 revision added remarks in Article 8 (Section II – Categories of Services and Allocations, primary, permitted and secondary services, 413-425 of RR1982) (ITU, 1982, pp. RR8-5 to 6).[40]

Primary and permitted services are given the same priority. RR1996 revised the priority by removing permitted services from the TFA in Article S5 (Section II – Categories of services and allocations, primary and secondary services, S5.23-S5.33 of the RR1996) (ITU, 1996, pp. RRS5-5 to 7).[41] The RR2001 removed the prefix “S” from the provision numbers used in the

c) services, the names of which are printed in ‘italics’ (example: *Mobile)*; these are ‘secondary’ services (see No. 139).
138 Permitted and primary services have equal rights, except that, in the preparation of frequency plans, the primary service, as compared with the permitted service, shall have prior choice of frequencies.
139 Stations of a secondary service:
a) shall not cause harmful interference to stations of primary or permitted services to which frequencies are already assigned or to which frequencies may be assigned at a later date;
b) cannot claim protection from harmful interference from stations of a primary or permitted service to which frequencies are already assigned or may be assigned at a later date;
c) can claim protection, however, from harmful interference from stations of the same or other secondary service(s) to which frequencies may be assigned at a later date.
140 Where a band is indicated in a footnote to the Table as allocated to a service ‘on a secondary basis’ in an area smaller than a Region, or in a particular country, this is a secondary service (see No. 139).
141 Where a band is indicated in a footnote to the Table as allocated to a service ‘on a primary basis’, or ‘on a permitted basis’ in an area smaller than a Region, or in a particular country, this is a primary service or a permitted service only in that area or country (see No. 138).”

[40] This provision was used in the RR editions of 1990 and 1994, (ITU, 1990, 1994):
“413 Primary, Permitted and Secondary Services
414 § 8. (1) Where, in a box of the Table in Section IV of this Article, a band is indicated as allocated to more than one service, either on a worldwide or Regional basis, such services are listed in the following order:
415 a) services the names of which are printed in ‘capitals’ (example: FIXED); these are called ‘primary’ services;
416 b) services the names of which are printed in ‘capitals between oblique strokes’ (example: /RADIOLOCATION/); these are called ‘permitted’ services (see No. 419);
417 c) services the names of which are printed in ‘normal characters’ (example: Mobile); these are called ‘secondary’ services (see Nos. 420 to 423).
418 (2) Additional remarks shall be printed in normal characters (example: MOBILE except aeronautical mobile).
419 (3) Permitted and primary services have equal rights, except that, in the preparation of frequency plans, the primary service, as compared with the permitted service, shall have prior choice of frequencies.
420 (4) Stations of a secondary service:
421 a) shall not cause harmful interference to stations of primary or permitted services to which frequencies are already assigned or to which frequencies may be assigned at a later date;
422 b) cannot claim protection from harmful interference from stations of a primary or permitted service to which frequencies are already assigned or may be assigned at a later date;
423 c) can claim protection, however, from harmful interference from stations of the same or other secondary service(s) to which frequencies may be assigned at a later date.
424 (5) Where a band is indicated in a footnote of the Table as allocated to a service ‘on a secondary basis’ in an area smaller than a Region, or in a particular country, this is a secondary service (see Nos. 420 to 423).
425 (6) Where a band is indicated in a footnote of the Table as allocated to a service ‘on a primary basis’, or ‘on a permitted basis’ in an area smaller than a Region, or in a particular country, this is a primary service or a permitted service only in that area or country (see No. 419).”

[41] This provision was used in the RR edition of 1998 (ITU, 1998):
“S5.23 Primary and Secondary Services

four RR editions of 2001, 2004, 2008, and 2012 in Article 5, Section II – Categories of services and allocations, 5.23-5.33 (ITU, 2001, 2004, 2008, 2012b).

Table 20 shows the evolution of the “Categories of service and allocation” provision.

Table 20. Category of service and allocation provision

Version	Primary	Permitted	Secondary	Additional remarks
1959	Small capitals, e.g., FIXED	Grotesque light, e.g., Radiolocation	Italic, e.g., *Mobile*	None
1982	Capitals, e.g., FIXED	Capitals between oblique strokes, e.g., /RADIOLOCATION/	Normal characters, e.g., Mobile	Normal characters, e.g., MOBILE except aeronautical mobile
1996	Capitals, e.g., FIXED	None	Normal characters, e.g., Mobile	Normal characters, e.g., MOBILE except aeronautical mobile

5.4.6 Radiocommunication service

The frequency is allocated within the TFA to enable the provision of services.[42] The definition of “Services” has developed over time. The initial service was considered “Maritime Mobile Service” (formerly “Maritime Service”) in 1906. From 1906 to 2012, 41 services were added and 20 services removed from the TFA.

Table 21 shows the current service designation at the RR2012. Table 22 provides a list of terminated services. Table 23 shows the development of the “Service” category from 1906 to 1990.

S5.24 (1) Where, in a box of the Table in Section IV of this Article, a band is indicated as allocated to more than one service, either on a worldwide or Regional basis, such services are listed in the following order:
S5.25 a) services the names of which are printed in ‘capitals’ (example: FIXED); these are called ‘primary’ services;
S5.26 b) services the names of which are printed in ‘normal characters’ (example: Mobile); these are called ‘secondary’ services (see Nos. S5.28 to S5.31).
S5.27 (2) Additional remarks shall be printed in normal characters (example: MOBILE except aeronautical mobile).
S5.28 (3) Stations of a secondary service:
S5.29 a) shall not cause harmful interference to stations of primary services to which frequencies are already assigned or to which frequencies may be assigned at a later date;
S5.30 b) cannot claim protection from harmful interference from stations of a primary service to which frequencies are already assigned or may be assigned at a later date;
S5.31 c) can claim protection, however, from harmful interference from stations of the same or other secondary service(s) to which frequencies may be assigned at a later date.
S5.32 (4) Where a band is indicated in a footnote of the Table as allocated to a service ‘on a secondary basis’ in an area smaller than a Region, or in a particular country, this is a secondary service (see Nos. S5.28 to S5.31).
S5.33 (5) Where a band is indicated in a footnote of the Table as allocated to a service ‘on a primary basis’, in an area smaller than a Region, or in a particular country, this is a primary service only in that area or country.”

[42] *Radiocommunication service:* A service as defined in this section involving the transmission, *emission* and/or reception of *radio waves* for specific *telecommunication* purposes. This definition is captured from Article 1. Section III–Radio services, 1.19 of the RR edition 2012 (ITU, 2012b).

Table 21. RR2012 services

Service	Abbreviation	Provision	RR
Fixed	FS	1.20	1927
Fixed-satellite	FSS	1.21	1971
Inter-satellite	ISS	1.22	1971
Space operation	SOS	1.23	1971
Mobile	MS	1.24	1927
Mobile-satellite	MSS	1.25	1971
Land mobile	LMS	1.26	1947
Land mobile-satellite	LMSS	1.27	1971
Maritime mobile	MMS	1.28	1906
Maritime mobile-satellite	MMSS	1.29	1971
Port operation	POS	1.30	1959
Ship movement	SMS	1.31	1976
Aeronautical mobile, route, off-route	AMS	1.32, 1.33, 1.34	1932
Aeronautical mobile-satellite, route, off-route	AMSS	1.35, 1.36, 1.37	1971
Broadcasting	BS	1.38	1927
Broadcasting-satellite	BSS	1.39	1968
Radiodetermination	RDS	1.40	1959
Radiodetermination-satellite	RDSS	1.41	1971
Radionavigation	RNS	1.42	1947
Radionavigation-satellite	RNSS	1.43	1968
Maritime radionavigation	MRNS	1.44	1947
Maritime radionavigation-satellite	MRNSS	1.45	1971
Aeronautical radionavigation	ARNS	1.46	1947
Aeronautical radionavigation-satellite	ARNSS	1.47	1971
Radiolocation	RLS	1.48	1947
Radiolocation-satellite	RLSS	1.49	1994
Meteorological aids	MetAids	1.50	1938
Earth exploration-satellite	EESS	1.51	1971
Meteorological-satellite	MetSat	1.52	1968
Standard frequency and time signal	SFTSS	1.53	1982
Standard frequency and time signal-satellite	SFTSSS	1.54	1982
Space research	SRS	1.55	1968
Amateur	ARS	1.56	1927
Amateur-satellite	ARSS	1.57	1971
Radioastronomy	RAS	1.58	1959
Safety	Safety	1.59	1959
Special	Special	1.60	1927

Most terminated services are merged with existing services. However, "Low-power Station" is merged with the industrial science and medical application (ISM) footnote. "Space," "Earth," "Terrestrial," and "Communication-satellite" services have been moved to specific terrestrial or satellite services such as BS, FSS, MSS, and BSS. "Facsimile" has also been removed because it is an application not a service.

Radiobeacon and experiment services have been transferred to the radiocommunication "Stations" category.

Table 22. Terminated services, 1927-1976

Services	RR version		Note
	First	Last	
Air	1927	1927	Merged with AMS (communication to airplane)
Radiobeacon	1927	1938	Moved to station
Experiment	1927	1938	Moved to station
Telephone broadcasting	1932	1932	Merged with BS
Visual broadcasting	1932	1932	Merged with BS
Not open to public	1932	1938	Merged with AM(OR)S
Sound broadcasting	1938	1938	Merged with BS
Television	1938	1938	Merged with BS
Facsimile	1938	1938	Disappeared because it is an application*
Radiosounding	1938	1938	Merged with MetAids
Ionosphere measurement	1938	1938	Merged with MetAids
Low power station	1938	1938	Merged with an ISM applications
Standard frequency	1947	1976	Merged with SFTSS
Time signal	1959	1976	Merged with SFTSS
Space	1959	1968	Transformed into other satellite service
Earth	1959	1959	Transformed into other satellite service
Terrestrial	1968	1976	Transformed into other terrestrial service
Communication-satellite	1968	1968	Transformed into other satellite service
Standard frequency-satellite	1971	1976	Merged with SFTSSS
Time signal-satellite	1971	1976	Merged with SFTSSS

*Normally, one service can have at least one application using the frequency.

Table 23. Service category, 1906-1994

Year	Additional services
1906	MMS
1927	FS, MS, BS, ARS, Special
1932	AMS
1947	LMS, RNS, MRNS, ARNS, RLS, MetAids
1959	POS, RDS, RAS, Safety
1968	BSS, RNSS, MetSats, SRS
1971	FSS, ISS, SOS, MSS, LMSS, MMSS, AMSS, RDSS, MRNSS, ARNSS, EESS, ARSS
1976	SMS
1982	SFTSS, SFTSSS
1990	AM(R)S, AM(OR)S, AMS(R)S, AMS(OR)S
1994	RLSS

5.4.7 Radiocommunication stations

A radiocommunication "Station" has at least one transmitter or receiver.[43] Several "Station" classifications were developed from 1906 to 2012. Thirty-eight "Station" classifications are currently used, while seventeen "Station" classifications have been removed since 1932. Table 24 shows "Station" classifications added during the period 1906 to 1990. Table 25 shows a list of removed "Station" classifications.

Table 24. Station classification added 1906-1998

Year	Station
1906	Coast, ship
1927	Mobile, land, aeronautical, aircraft, broadcasting, radiodirection-finding, radiobeacon
1932	Fixed, amateur
1947	Base, land mobile, radionavigation mobile, radionavigation land, experiment
1959	Earth, space, survival craft, radiodetermination, radiolocation mobile, radiolocation land
1968	Terrestrial, port, emergency position-indicating radiobeacon, radio astronomy
1976	Ship Earth, on-board communication
1982	Mobile Earth, coast Earth, aeronautical Earth, aircraft Earth, standard frequency and time signal
1990	Land Earth, base Earth, land mobile, satellite-emergency position-indicating radiobeacon
1998	High-altitude platform

Table 25. Terminated station classification since 1932

Station	RR version		Changed/Merged station classification
	First	Last	
Aeronautical fixed	1947	1994	Merged with "Fixed"
Standard frequency	1947	1976	Merged with "Standard frequency and time signal"
Private experimental	1927	1938	Merged with "Experiment"
Station on board	1932	1938	Merged with "On-board communication"
Telephone broadcasting	1932	1932	Merged with "Broadcasting"
Visual broadcasting	1932	1932	Merged with "Broadcasting"
Private radiocommunication	1932	1938	Changed with specified station
Portable	1938	1938	Merged with "Mobile"
Communication-satellite Earth	1968	1968	Merged with "Earth"
Communication-satellite space	1968	1968	Merged with "Space"
Radiolocation	1947	1947	Changed with specified station
Radionavigation	1947	1947	Changed with specified station
SRS Earth	1968	1968	Merged with "Earth"
SRS space	1968	1968	Merged with "Space"
RNSS Earth	1968	1968	Merged with "Earth"
RNSS space	1968	1968	Merged with "Space"
MetSat Earth	1968	1968	Merged with "Earth"

[43] *Station:* One or more transmitters or receivers or a combination of transmitters and receivers, including the accessory equipment, necessary at one location for carrying on a *radiocommunication service*, or the *radio astronomy service*. This definition is captured from Article 1. Section IV – Radio stations and systems, 1.61 of the RR edition 2012 (ITU, 2012b).

Table 26 shows the current stations in the RR2012.[44]

Table 26. RR2012 station classification

Station	Provision	RR
Terrestrial	1.62	1968
Earth	1.63	1959
Space	1.64	1959
Survival craft	1.65	1959
Fixed	1.66	1932
HAP	1.66A	1998
Mobile	1.67	1927
Mobile Earth	1.68	1982
Land	1.69	1927
Land Earth	1.70	1990
Base	1.71	1947
Base Earth	1.72	1990
Land mobile	1.73	1947
Land mobile Earth	1.74	1990
Coast	1.75	1906
Coast Earth	1.76	1982
Ship	1.77	1906
Ship Earth	1.78	1976
On-board communication	1.79	1976
Port	1.80	1968
Aeronautical	1.81	1927
Aeronautical Earth	1.82	1982
Aircraft	1.83	1927
Aircraft Earth	1.84	1982
Broadcasting	1.85	1927
Radiodetermination	1.86	1959
Radionavigation mobile	1.87	1947
Radionavigation land	1.88	1947
Radiolocation mobile	1.89	1959
Radiolocation land	1.90	1959
Radio direction-finding	1.91	1927
Radiobeacon	1.92	1927
Emergency position-indicating radiobeacon	1.93	1968
Satellite emergency position-indicating radiobeacon	1.94	1990
Standard frequency and time signal	1.95	1982
Amateur	1.96	1932
Radio astronomy	1.97	1968
Experiment	1.98	1947

[44] The definition of radiocommunication services was not changed in the Provisional Final Act, World Radiocommunication Conference (WRC-12) (ITU, 2012a) and RR2012 (ITU, 2012b).

5.5 Table of Frequency Allocation

The TFA is a function map that relates frequency bands to services and footnotes. Footnotes refer to constraints on frequency use.

Frequency bands inside the TFA are explored to explain the evolution of frequency band allocation within the TFA.[45]

Service allocation developments are considered next. In particular, the analysis considers the early allocations prior to the establishment of the TFA; an overview of the TFA developments from 1927 to 2012; and a detailed analysis of the MMS, MMSS, BS, BSS, FS, FSS MS, MSS, SRS, and EESS classification from the RR1927-2012. The service level analysis is contained in Appendices A, B, C, D, E, F, G, H, I, and J to the chapter.

5.5.1 Pre-TFA allocations

The RR1906 and RR1912 are part of the Annex of International Radiotelegraph Convention (Annex to the Berlin Convention 1906 and Detailed Service Regulation appended to the London 1912 Convention). These provide the wavelengths allowed between ships and coast stations.

In the RR1906 and RR1912, global allocations are provided for maritime service communications between ships and coast stations.

Annex to the 1906 Berlin Convention

The frequencies 188 kHz, 500 kHz, and 1000 kHz are allocated to the maritime service. However, in the Berlin Annex, they are defined as the corresponding aerial lengths of wavelengths of 1600, 600, and 300 meters, respectively.

Table 27 shows the wavelengths contained in the Annex to the Berlin 1906 Convention (ITU, 1906b, p. 361).

Table 27. Wavelength from the Annex to the Berlin 1906 Convention

Frequency (kHz)	Wavelength (meters)	Maritime service	Purpose
1000	300	Ship, coast station	General public
500	600	Ship, coast station	General public
to 188, >500	to 600, > 1600	Coast station	Long-range or other
> 1000	to 300	Ship station	Small vessel

The 500 kHz and 1000 kHz frequencies (wavelength 300 meters and 600 meters, respectively) are allocated to public services. Frequencies below 188 kHz (wavelength greater than 1600 meters) or higher than 500 kHz (wavelength shorter than 600 meters) are allocated

[45] The analysis of footnotes is not considered in this study.

to long-distance communications from ship to coast station and other services. The non-public services are military and naval (Huurdeman, 2003; Lyall & Larsen, 2009).

Detailed Service Regulation appended to the London 1912 Convention

The London Conference cancelled the allocations for wavelengths of less than 300 meters for small vessels. The Conference also added two frequencies of 167 kHz and above 2 MHz for radiotelegrams and radiobeacons (Huurdeman, 2003). Meteorological information (time signal and weather report) is included in a radiotelegram service (Huurdeman, 2003; Lyall & Larsen, 2009).

Table 28. Wavelength of Detailed Service Regulation appended to the London 1912 Convention

Frequency (kHz)	Wavelength (meters)	Maritime service	Purpose
1000	300	Ship, coast station	General public
500	600	Ship, coast station	General public
167	1800	Ship, coast station	Radiotelegrams
to 188 >500	to 600 > 1600	Coast station	Long-range or other service
> 2000	to 150	Ship, coast station	Ship positioning

Table 28 shows the wavelength of the Detailed Service Regulation appended to the London 1912 Convention (Article 2 and 3) (ITU, 1912a).

5.5.2 TFA Overview

The Washington 1927 Conference provided the initial TFA global allocation. Both frequency bands and wavelengths are allocated to specific services. Particular services received an exclusive right to use a specified frequency band.

In Madrid 1932, the TFA was allocated to the European and other geographic regions. The TFA therefore made global allocations and allocations to the EU and other regions.

The Cairo 1938 Conference added an American region (Appendix 4 of the General Radiocommunication Regulation) (ITU, 1938).

The other regions were spitted to America and Asia-Pacific at the Atlantic City Conference. The Conference introduced the A, B, and C lines to separate Region 1 (EU Region), Region 2 (American Region), and Region 3 (Asia-Pacific Region) (Article 5, TFA of Atlantic City 1947 Convention) (ITU, 1947, pp. 18-20). The lines are still in effect (Article 5, Section I-Regions and areas, 5.2-5.22 of the RR) (ITU, 2012b, pp. 37-39).

TFA frequency limits

Table 29 reports the TFA frequency limits for the period 1927 to 2012.

An example of the TFA lower limit change to the global allocation occurs separately from 10 to 9 kHz and 9 to 8.3 kHz. The upper limit change occurs from 60 to 30 MHz, 30MHz to 10.5

GHz, 10 to 40 GHz, 40 to 275 GHz, 275 to 400 GHz, 400 to 1000 GHz, and 1000 to 3000 GHz.

The lower limit changes are less frequent because the minimum sampling frequency of human voice is 8 kHz (digital modulation). The upper limit changes are more frequent because of the need for new services.

Table 29. TFA frequency limits

RR	Global		Region 1		Region 2		Region 3	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
1927	10 kHz	60 MHz						
1932	10 kHz	60 MHz	160 kHz	2 MHz			160 kHz	2 MHz
1938	10 kHz	30 MHz	160 kHz	200 MHz	25 MHz	300 MHz	160 kHz	60 MHz
1947	10 kHz	10.5 GHz	70 kHz	10.5 GHz	70 kHz	5.925 GHz	70 kHz	5.925 GHz
1959	10 kHz	40 GHz	70 kHz	10.55 GHz	70 kHz	10.55 GHz	70 kHz	10.55 GHz
1968	10 kHz	40 GHz	70 kHz	33.4 GHz	70 kHz	33.4 GHz	70 kHz	33.4 GHz
1971	10 kHz	275 GHz	70 kHz	33.4 GHz	70 kHz	33.4 GHz	70 kHz	33.4 GHz
1976	10 kHz	275 GHz	70 kHz	33.4 GHz	70 kHz	33.4 GHz	70 kHz	33.4 GHz
1982	9 kHz	400 GHz	70 kHz	31.8 GHz	70 kHz	31.8 GHz	70 kHz	31.8 GHz
1986	9 kHz	400 GHz	70 kHz	31.8 GHz	70 kHz	31.8 GHz	70 kHz	31.8 GHz
1990	9 kHz	400 GHz	70 kHz	31.8 GHz	70 kHz	31.8 GHz	70 kHz	31.8 GHz
1994	9 kHz	400 GHz	70 kHz	31.8 GHz	70 kHz	31.8 GHz	70 kHz	31.8 GHz
1996	9 kHz	400 GHz	70 kHz	31.8 GHz	70 kHz	31.8 GHz	70 kHz	31.8 GHz
1998	9 kHz	400 GHz	70 kHz	42.5 GHz	70 kHz	42.5 GHz	70 kHz	42.5 GHz
2001	9 kHz	400 GHz	70 kHz	41 GHz	70 kHz	41 GHz	70 kHz	41 GHz
2004	9 kHz	1000 GHz	70 kHz	50.2 GHz	70 kHz	50.2 GHz	70 kHz	50.2 GHz
2008	9 kHz	1000 GHz	70 kHz	50.2 GHz	70 kHz	50.2 GHz	70 kHz	50.2 GHz
2012	8.3 kHz	3000 GHz	70 kHz	50.2 GHz	70 kHz	50.2 GHz	70 kHz	50.2 GHz

TFA number of frequency bands

Table 30. Global and regional frequency bands

RR	Global	Region 1	Region 2	Region 3
1906	5			
1912	6			
1927	59			
1932	51	16		10
1938	52	71	34	24
1947	102	57	47	50
1959	146	75	62	68
1968	181	88	76	82
1971	237	95	84	90
1976	237	95	84	90
1982	304	98	103	96
1985	304	98	103	96
1986	304	98	103	96
1990	307	101	106	99
1994	337	119	124	116
1996	343	123	128	120
1998	350	118	123	115
2001	360	118	123	115
2004	369	125	128	120
2008	372	128	132	124
2012	375	151	152	147

Table 30 shows global and regional frequency bands for the period 1906 to 2012.

After the RR1938, the number of frequency bands, global and regional allocation, increased steadily. This growth in frequency bands was driven by the introduction of new services. However, more frequency bands added complexity to the management of the TFA. Furthermore, the underlying growth in the demand for services meant increased use of the frequencies.

Regional allocations lead to increased frequency utilization. To avoid interference, a set of complex coordination provisions must be addressed. In particular, frequency band harmonization (regional to global) aims to reduce interference, but it reduces frequency use.

TFA bandwidth

The bandwidth is the quantity of frequency allocated to a service. A frequency band can be allocated to several services (either on a primary or secondary basis), increasing frequency utilization.

The RR1927, RR1938, and RR1947 introduced the practice of allocation between exclusive and shared bandwidth. However, the quantities were not substantial.

From the RR1947 to RR1968, the total bandwidth increased from 13 to 63 GHz. This period coincided with the relabeling of "exclusive" as "primary", and "shared" as "secondary" services. From the RR1971 (410 GHz) to RR2012 (1062 GHz), allocations increased threefold (see Figure 11).

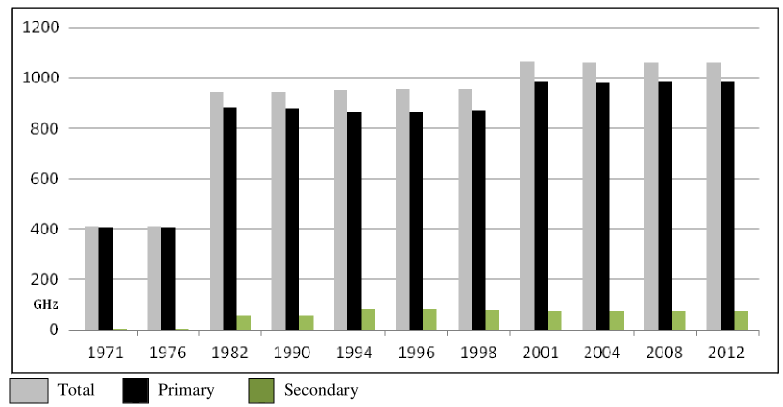

Figure 11. Global bandwidth allocations, 1971-2012

Figure 12 shows the bandwidth allocation for Region 1 (1932-2012). Prior to the RR1938, allocations were made to the EU Region. Figure 13 depicts Region 1 allocations for primary and secondary services.

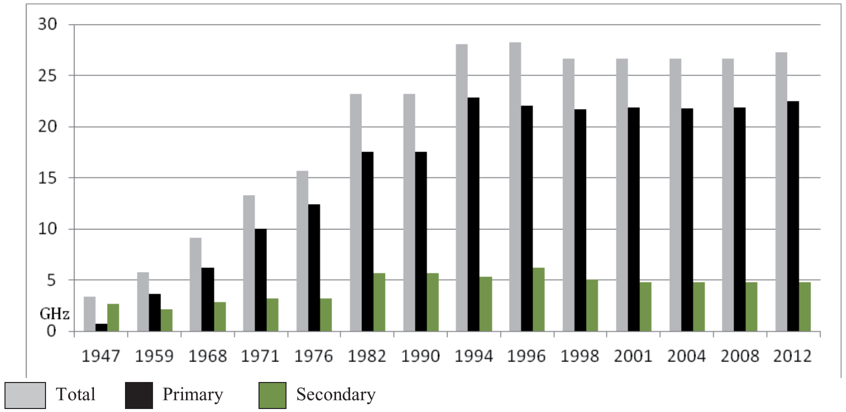

Figure 12. Region 1 bandwidth allocations, 1947-2012

Similarly, Figure 13 depicts Region 2 bandwidth allocations since 1947.

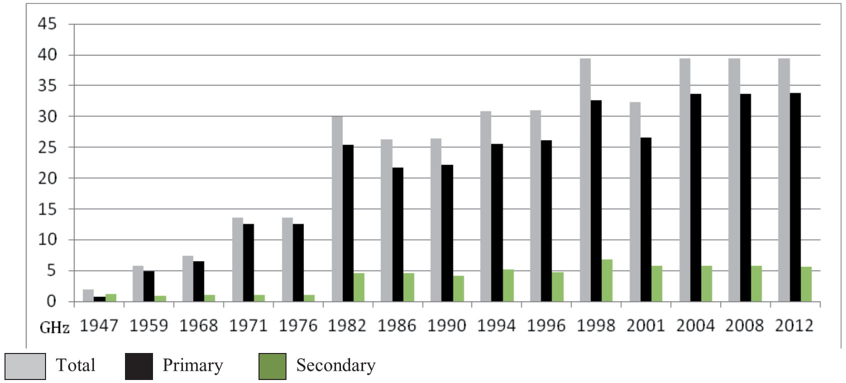

Figure 13. Region 2 bandwidth allocations, 1947-2012

Finally, Figure 14 shows Region 3 bandwidth allocations since 1947.

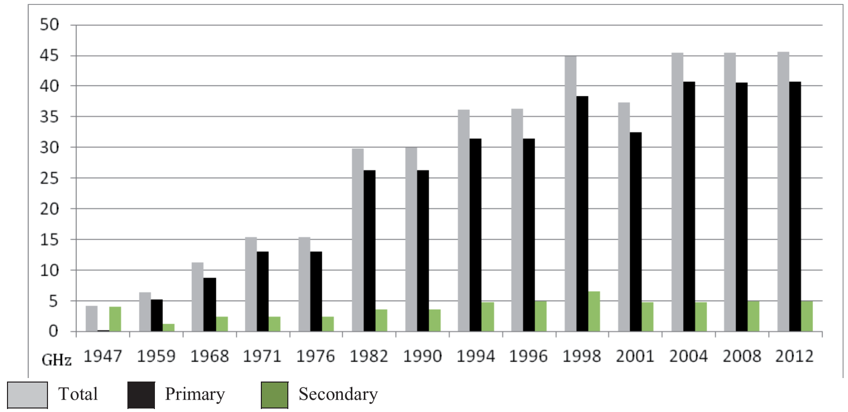

Figure 14. Region 3 bandwidth allocations, 1947-2012

5.5.3 Frequency band development and archived material

Appendices A, B, C, D, E, F, G, H, I, and J illustrate frequency band developments for MMS, MMSS, BS, BSS, FS, FSS, MS, MSS, SRS, and EESS. The following example of the BS in the 550-1705 kHz band is extracted from the relevant tables in Appendix C to show how to use the appendices.

The BS frequency band developments are illustrated in Appendix C. From Appendix C, the BS allocations in the 550-1705 kHz band are listed in Table 31.

Table 31. Broadcasting service 550-1705 kHz frequency band development

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	RR removal	Allocation/priority
1927	550	1300	1932	Global/Primary
1959	535	1605	1982	Global/Primary
1932	550	1500	1947	Global/Secondary
1947	525	535	1982	Region 1/Primary
1982-2012	526.5	1606.5		Region 1/Primary
1959-2012	525	535		Region 2/Primary
1982-2012	535	1605		Region 2/Primary
1982-2012	1605	1625		Region 2/Primary
1982-2012	1625	1705		Region 2/Primary
1959	525	535	1982	Region 3/Primary
1982-2012	526.5	535		Region 3/Primary
1982-2012	535	1606.5		Region 3/Primary

From 1927 to 1932, the BS global allocation was on a primary basis for the 550-1300 kHz band. In 1959, the global allocation (on a primary basis) expanded to spectrum to cover the 535-1605 kHz band. However, this allocation band was terminated in 1982.

The treatment of the BS was altered during the period 1932-1947, and the 550-1500 kHz band was allocated on a secondary basis.

From 1947, some allocations were based on a regional table. For instance, in 1947, the 525-535 kHz band was allocated to BS Region 1 on a primary basis but it was terminated in 1982.

By 1982, there were regional allocations (on a primary basis) for Region 1, Region 2, and Region 3. The 526.5-1606.5 kHz band was allocated to Region 1. The three frequency bands 535-1605, 1605-1625, and 1625-1705 kHz were allocated to Region 2. Finally, the two frequency bands 526.5-535 and 535-1606.5 kHz were allocated to Region 3.

The above information is obtained from the RR versions housed in the ITU archives. However, the reasons for the changes are not illustrated in the archives. Importantly, the rationale underneath the document is not documented. Only delegates that attended the meetings have this (missing) information.

5.6 Summary and discussion on research question

This chapter responds to sub-research question 1: *How is international spectrum policy set in terms of ITU structure, WRC, and the RR, and how did they develop?*

The study illustrates the development of WRC (International Telegraph Conference, International Radiotelegraph Conference, Ordinary/Extraordinary Administrative Radio Conference and WRC), the evolving relationship between WRC and the RR, and changes to the RR definitions (telecommunication, radiocommunication, radio waves and radio) and the RR provisions (choice of apparatus, frequency assignment, licenses, allocation, allotment and assignment, priority of services, services, and stations). Alterations to the TFA (MMS, MMSS, BS, BSS, FS, FSS, MS, MSS, SRS, and EESS in Appendices A, B, C, D, E, F, G, H, I, and J) are also reviewed.

The study explored the relevant literature and found that no literature was relevant to the RR development, especially the TFA development in terms of frequency band development. The study limits the exploration and explanation of the RR to several interesting RR provisions. The selection of the RR provision is based on the importance of such provisions. Some of the literature provides interesting keywords such as the definition of "telecommunication."

The study applies Rutkoski's approach to download all RR versions, including the Convention, Annex to the Convention, and the RR from the ITU History Portal. The study further explores each RR in depth by the keywords to trace the relevant provision and constructs in the personal database in an Excel file.

The keywords are key definitions, important provisions, and frequency bands by services. These keywords represent the sampling point of the RR development.

Key definitions and important provisions provide a starting point by searching each version of the RR and building up the personal database containing the changes to such provisions. The exploration will end when the changes match the current version (RR2012). The study analyzes the differences between versions by explaining different elements or concepts that have been developed over time. However, the RR versions provide the output from the WRC discussions, not the reasons why and how it changes.

Frequency band development is the output from the conversion of the TFA for each RR version into the Excel file. The study converted each frequency allocation, including for global, Region 1, Region 2, and Region 3, of each RR version into the table of the Excel sheet. The study sorts the TFA by service and manually keeps track of each frequency band across RR versions until it meets the current frequency band (RR2012). The table presents the output of the manual sorting that is illustrated in Appendices A, B, C, D, E, F, G, H, I, and J. Each appendix contains the global, Region 1, Region 2, and Region 3 allocations with separated primary and secondary services.

The table provides the starting point to further investigate the rationale underlying the frequency band development of RR versions.

The frequency band development is original work that the study contributes to the international spectrum policy setting as a mind map to further explore the rationale underlying the change to the TFA. The TFA is sorted by frequency band up to 3 000 GHz. The study changes the view of the TFA into the service-oriented one that has provided the additional information to the TFA on the service perspective. Appendices A, B, C, D, E, F, G, H, I, and J cover the majority of services in terms of bandwidth allocation and number of frequency bands.

However, the empirical findings from the exploration of the ITU archives only provide what they have developed over time in terms of the output of WRC as the RR revisions. The RR revisions are the consequences of the WRC agenda-setting and WRC study process and will be discussed in a later chapter.

The study illustrates the RR development by presenting the key definitions, important provisions, and frequency band development responding to one part of the first sub-research question: *What is the international spectrum policy setting in terms of the WRC and RR development?*

Furthermore, this part of the first sub-research question strengthens the fact that Member States that rely on the ITU archives have incomplete information that lack the reason changes occur. The study results provide RR development over time as the output for analyzing the personal database with manual sorting. The sub-research question *What is the international spectrum policy setting in terms of the WRC and RR development?* is therefore important in terms of the exploration of the existing situation of the ITU archives that lack the reason behind it. This sub-research question reflects on and supports the argument of incomplete information in the international policy setting in the summary of this chapter.

Chapter 6 WRC preparatory process

This chapter illustrates the WRC-12 preparatory work by ITU, including the agenda-setting and its assessment. The national (Sweden and Thailand) and regional preparatory works (CPG and APG) for WRC are also included. The WRC preparatory processes by ITU, regional, and national preparatory meetings are part of the RR development to prepare possible RR revision options for Member States to decide on at WRC.

6.1 Background

The study focuses on the preparatory work after the APP 1992, because there was a mandate from the APP 1992 requesting the preparatory work for WRC. Before the APP1992, the revision of the RR was based purely on Member State contributions with no advance preparatory WRC agenda. The Chairman conducted the meeting with consideration for the existing RR from the beginning to the end together with the Member State contributions.

After the APP 1992, the systematic structure of the preparatory work was introduced. The RA-93 began the process to establish an SG to undertake preparatory work for the WRC-95 and WRC-97. The WRC-95 agenda was finalized at the WRC-93 and approved by the CC. The initial preparatory process has continued to be used until now, with some modifications, such as the WRC cycle. Figure 15 presents the current WRC preparatory process for the WRC-12.[46]

The CPM-1 begins when the current WRC finalizes the next WRC agenda. The agenda is an input to the CPM-1 (according to Resolution ITU-R 2-5).

The CPM-1 distributes work programs according to the WRC agenda to the SGs. Currently, there are six SGs, i.e., SG1-spectrum management, SG3-radiowave propagation, SG4-satellite service, SG5-terrestrial services, SG6-broadcasting service, and SG7-science services. Each SG has a duty to prepare a draft CPM text after studying the assigned issue from the WRC agenda (according to Resolution ITU-R 4-5). To complete their tasks, the SGs can form working parties (WPs).

Moreover, the issues relating to regulatory and procedural study must pass to the Special Committee on regulatory/procedural matters (SC) (see Resolution ITU-R 38-3).

The CPM-1 is held immediately after WRC. Based on documents submitted by ITU Members, this CPM-1 produces the input for the SGs and SC through the distribution of work programs, including a chapter outline for the CPM report.[47]

Based on the documents submitted by the ITU Members, the SGs produce a draft CPM text along the lines specified in the WRC agenda to the CPM chapter rapporteurs. Rapporteurs consolidate the text from the SGs into the chapter contained in the draft CPM report. This report is published on the ITU-R website prior to the second CPM session. At the same time,

[46] Source: The figure is adapted from Figure I-1 Organization of the ITU-R conference preparatory work, CPM report to WRC-12
[47] The ITU membership comprises Member States, Sector Members, Associates, and Academia.

the SGs submit the draft CPM text to the SC on issues relevant to regulatory and procedural matters.

At the CPM-2, a final report based on the draft CPM text, SC output, and ITU Members' document, the CPM report, is finalized.

Member States and Sector Members can submit documents to the RA. However, only Member States can submit documents (including joint, multiple, and common proposals) to WRC.

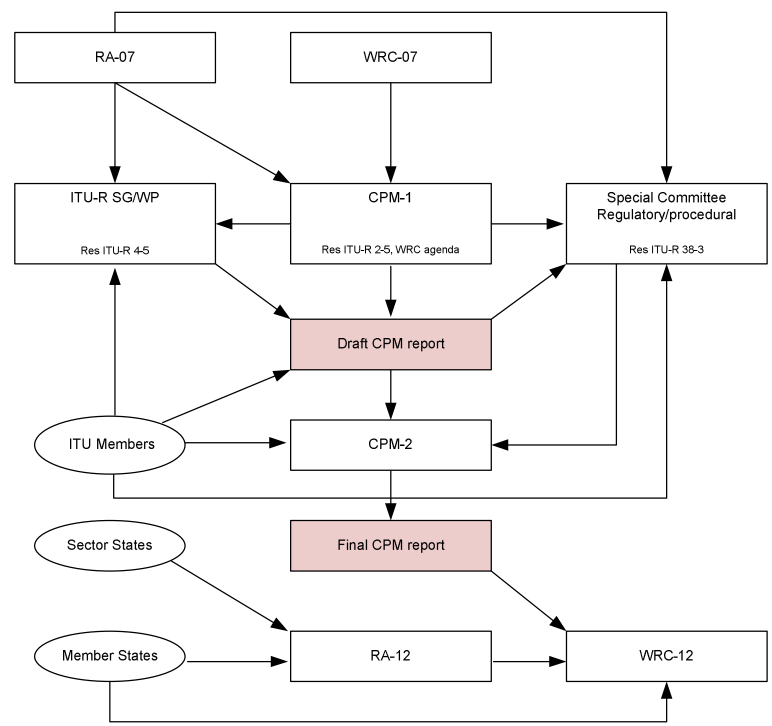

Figure 15. WRC-12 preparatory process

6.2 Agenda-setting

The WRC agenda contains issues that arise when new radio technologies, applications, or services are introduced and are of concern to Member States. Such concerns identify the need to revise the current RR. Consequently, conflict between existing services and new technologies is often unavoidable.

RR revisions to the TFA (frequency bands, services, and footnotes), or elsewhere, may be required. Frequency bands include both the "start" and "stop" frequencies. The service provision is the objective of frequency allocation (see Article 1 of the RR). Footnotes contain constraints on both frequency bands and services in terms of their technical characteristics, specific band allocations, and duration.

For instance, WRC-03 Agenda Item 1.23 considered the need to reallocate ARS to the global allocation table across three regions within the 7 MHz band. This agenda item moved the 7000-7100 kHz and 7100-7200 kHz band TFA allocation to an ARS global allocation (with relevant footnotes).

During the period in which new radio technologies and applications are developed, the developers must identify both the radio frequency and check the TFA (see Article 5 of the RR) to determine whether a new frequency or regulation is required.

For example, at the WRC-07, the replacement of analog by digital television occurred in the European countries (or digital dividend). The consequence of this transition is that the 790-862 MHz band is now available for new services and applications, especially MS (system beyond IMT-2000). In the RR2004, the Region 1 TFA has no 790-862 MHz band or footnote for MS allocation. Thus, an MS allocation in the 790-862 MHz band in Region 1 is required.

Consequently, developers must evaluate whether a change in the current RR within the WRC agenda is needed. To change the current RR within the WRC agenda, developers must request their Member States submit contributions to WRC at least 14 days before the Conference.

For example, to change the RR2008 provisions contained within the WRC-12 agenda, developers request their Member States to submit documents (within the specified WRC-12 agenda) at least 14 days prior to the WRC-12 (9 January 2012). Moreover, the WRC-12 attendance is required to ensure the change is accepted.

Accordingly, to prepare the WRC agenda, WRC and the SG must prepare a report. The WRC process spans four weeks while the SG process requires four years to complete.

The WRC agenda has both permanent and specified agenda items. Future RR provision changes are specified by agenda item for the next WRC agenda (contained in the permanent agenda). For example, in the WRC-12 agenda, the next WRC agenda (WRC-15) and future WRC agenda (WRC-18) are included within the permanent Agenda Item 8.2:

"8.2 recommend to the Council items for inclusion in the agenda for the next WRC, and to give its views on the preliminary agenda for the subsequent conference and on possible agenda items for future conferences" (WRC-12 agenda).

However, ITU Members can submit proposals directly to the SGs via the CPM reports for the next and future WRC agendas. This process requires eight years (two WRC cycles for inclusion of the WRC agenda in the CPM report). For example, the WRC-15 agenda will be included in "the future WRC agenda" in the CPM report from the WRC-07 and the "next WRC agenda" in the CPM report from WRC-12.

WRC agenda-setting, 1993 to 2015

During the period 1993-1997, WRC had a two-year cycle (WRC-93, WRC-95, and WRC-97) of preparatory activities. After 1997, the average WRC cycle increased to a four-year period. Table 32 shows the number of WRC agenda items specified from 1993 to 2015.

Table 32. WRC agenda items, 1993-2015

Conference	CC	Agenda		Dropped	Merged	F to N (%)	N to C (%)
		Next	Future				
WRC-93	0	0	0	0	0	0	0
WRC-95	9	9	0	0	0	0	100.0
WRC-97	20	11	12	1	0	91.7	55.0
WRC-2000	25	1	4	3	0	25.0	4.0
WRC-03	42	11	19	8	0	57.9	26.2
WRC-07	20	5	15	7	3	33.3	25.0
WRC-12	24	3	7	3	1	42.9	12.5
WRC-15	20	2	1	0	0	100	10
Total	**160**	**42**	**58**	**22**	**4**	**72.4**	**26.3**

The column "CC" indicates the WRC agenda items finalized by WRC and approved by the CC. The columns labeled "Next" and "Future" show the next and future WRC agenda items in the CPM report. The column "Dropped" reports differences in the future and next WRC agendas. The next column shows the number of next and future agenda items that are merged. The column "F to N" shows the percentage of the future to next WRC agenda items. The column "N to C" indicates the percentage of the next approved agenda items.

The percentages of "F to N" and "N to C" fell over time. Only the WRC-15 agenda in row "WRC-15," column "F to N" shows that the future WRC agenda was included in the next WRC agenda. These agenda items, in the future and next WRC agendas, prepared by the CPM, are not guaranteed to be contained in the final WRC agenda.

In Figure 16, the "non-service" category includes uncategorized service and general provisions such as the new radio applications, SDR, CRS, SRD, unmanned aircraft systems, and regulatory issues (transition from a broad international regulatory framework to a national framework).

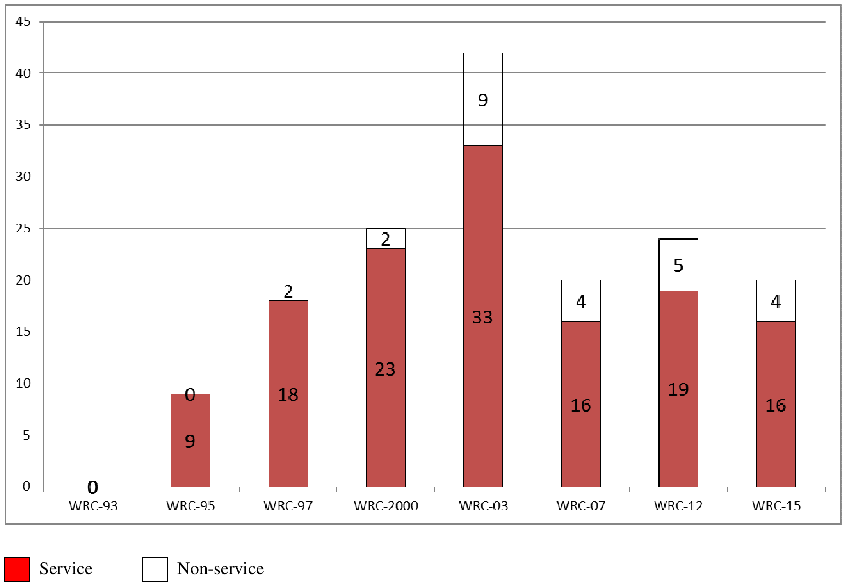

Figure 16. Specified WRC agenda items, 1993-2015

The "service" category represents the WRC agenda item with specified services. It varies over time. For example, from WRC-95 to WRC-03, the trend of WRC agenda items with specified services increases, however, it is dropped at the WRC-07 and fluctuates until the WRC-15.

Table 33 shows the distribution of specified WRC agenda items by service from 1993 to 2015. The service abbreviations are found in Table 21, except TS (terrestrial service) and SS (space service).

Table 33. Specified WRC agenda items by service, 1993-2015

Service	WRC								Total
	1993	1995	1997	2000	2003	2007	2012	2015	
Non-service	0	0	2	2	9	4	5	4	**26**
FSS	0	1	1	6	6	2	0	5	**21**
MSS	0	4	1	5	5	2	1	1	**19**
EESS	0	1	4	2	3	3	0	2	**15**
MMS	0	0	4	2	3	1	2	2	**14**
BSS	0	0	1	5	4	2	1	0	**13**
FS	0	0	1	3	3	0	3	0	**10**
SS	0	2	2	2	2	2	0	0	**10**
MS	0	0	1	2	1	1	3	2	**10**
BS	0	1	2	0	3	2	1	0	**9**
SRS	0	1	1	1	1	3	1	1	**9**
MMSS	0	0	4	0	1	1	0	1	**7**
RLS	0	0	0	0	2	1	3	1	**7**
RNSS	0	0	0	3	2	0	1	0	**6**
AM(R)S	0	0	1	1	1	1	1	0	**5**
AMS	0	0	0	0	3	1	1	0	**5**
TS	0	0	1	2	0	1	1	0	**5**
ARS	0	0	0	0	1	1	1	1	**4**
RAS	0	0	0	2	1	1	0	0	**4**
AMSS	0	0	0	0	3	0	0	0	**3**
MetSat	0	0	1	0	0	1	1	0	**3**
MetAids	0	0	1	0	0	0	1	0	**2**
AMS(R)S	0	0	0	0	0	0	1	0	**1**
ARSS	0	0	0	0	1	0	0	0	**1**
ARNS	0	0	0	0	1	0	0	0	**1**
SOS	0	1	0	0	0	0	0	0	**1**
Total	**0**	**11**	**28**	**38**	**56**	**30**	**28**	**20**	**211**

From 1993 to 2012, the most specified WRC agenda items are non-service (26), followed by FSS (21). The non-service may lead to revised service definitions to ensure service neutrality.

The number of specified WRC agenda items and services differs because a specified agenda may evolve through a single or several services. For example, WRC-12 Agenda Item 1.5 relates to FS, BS, and MS. The majority of specified WRC agenda items concerns MS: MSS, MMS, MMSS, AM(R)S, AMS(R)S, ARNS, and ARNSS.

6.3 Assessment of the WRC agenda-setting process

The ITU Convention (CV118) mandates preparation of the WRC agenda items or WRC agenda-setting four to six years in advance. The WRC agenda-setting process takes two WRC cycles to prepare the future and next WRC agendas. In order to assess the lengthy process of WRC agenda-setting, the IAD framework is discussed as follows.

In this case, the physical condition or study object is the WRC agenda-setting, and the issue is the RR revisions, both the technical and regulatory aspects.

The attribute of community is ITU and its membership environment, including its membership culture and traditions, with a common understanding of why the issues should be included in the WRC agenda and how to precede this matter in the ITU context.

The rules-in-use, as an action situation, reflect the discussions within the relevant meetings, including the relevant CPM, SG, and WRC.

The boundary rule, which determines who is allowed to participate in the relevant meetings, is ITU membership during the CPM and SG. However, only Member States can vote during WRC.

The position rule is directly relevant to the boundary rule: which role each delegate should perform during the discussions in an action situation and which option they have as the choice rule.

The actions to be taken will have been evaluated with consequences and possible outcomes (scope rule) by criteria such as the payoff rule. The dynamic discussion provides the information exchange within the meetings (information rule) and directly influences the choice and payoff rules in the meeting. The stances of the Member States represent their choices and how they control their decisions as the aggregate rule.

Table 31 shows the trend of agenda items prepared in the CPM report for the next and future WRCs decreasing over time. It may be that the Member States realize the importance of each forum for drafting and finalizing WRC agenda items. For example, the agenda items included in the future WRC in the CPM report are not guaranteed inclusion in the final version of the WRC agenda.

Conversely, the meeting to finalize the next WRC agenda items is crucial. For example, at the WRC-12, the WRC-15 agenda items were finalized under COM6 by the WG6C. Seventy-two documents were submitted by Member States containing 210 proposals for possible WRC-15 agenda items. The final version of the WRC-15 agenda included 20 issues. There were many discussions and compromises between the Member States to reach consensus.

During the discussion, the WG6C Chairman attempted to find similar issues among the possible WRC-15 agenda items to be grouped and nominated by the DG Chairman. The DG Chairman consolidated the views of the Member States' documents and discussions to

provide either a consensus or compromise text, if applicable. Once consensus was reached on the text, the final approval at the plenary of WRC-12 was quick.

Conversely, when conflict between Member States arises during discussions, either at the DG, WG, COM, or plenary level, a lengthy approval time is expected. The debate among the Member States represents information exchange, choices, consequences of decisions, and control over their stances as a decision situation captured by the IAD framework.

Finally, compromise must be reached on the Member State conflicts over the WRC agenda items for selection in order for them to be finalized and approved by the plenary.

The study therefore reveals that the WRC agenda-setting is lengthy in the preparatory process by ITU via the CPM, SG, and WRC, as it takes two WRC cycles or eight years. It provides several forums for discussing possible WRC agenda items; however, it does not guarantee inclusion of the outcome in the WRC agenda at the final stage of approval. Member States that have limited resources should pay attention to the final WRC in order to finalize the WRC agenda items for the next conference, such as the WRC-12, which was finalized in the WRC-15 agenda. When Member States realize the importance of having issues as agenda items to be included at the next WRC, they must submit documents to and actively participate in the relevant meetings at such WRCs in order to ensure inclusion of their proposed agenda items.

6.4 Preparatory process

WRC-12 Agenda Items 1.19 and 1.22 are identified as subjects of study, following the national, regional preparatory, and WRC-12 processes. The review leads to an identification of differences between submission processes and outcomes (relationship between them).

National preparatory meeting process

Sweden and Thailand are interesting to review, as they have different preparatory processes for their regional and WRC meetings. Both countries can submit to the regional and WRC-12 meetings.

Regional preparatory meeting process

The PT A, CPG, and APG are observed, as the processes and outcomes concern Agenda Items 1.19 and 1.22. The regional meeting is a forum that obtains a common view from its members on selected issues. The outcomes of regional meetings are regional proposals for the WRC-12.

Figure 17 presents the relationship between individual country delegations, regional meetings, and WRC processes. For example, Thailand can submit proposals directly to the WRC-12 or the APG-2012 to form common proposals (PACPs) prior to submission to the WRC-12.

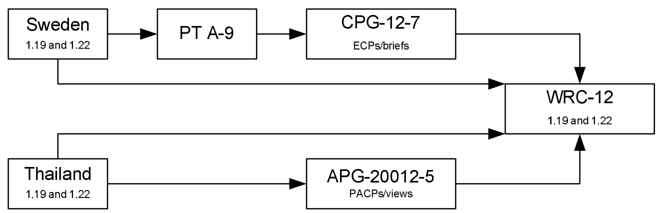

Figure 17. Regional preparatory and WRC-12 meeting processes

Differences between Sweden's and Thailand's preparatory processes are observed in an examination of preparatory material before the regional meetings, during the meetings, and in the meeting outputs.

The regional meetings help to reduce the number of issues as well as the proposals submitted to WRC. Countries with few delegates may use the regional meetings to protect their interests via common proposals and regional coordinators.

Participation at meetings provides an insight into the tabled issues and delegate position on Agenda Items 1.19 and 1.22 in a European and an Asia-Pacific context. Moreover, the ongoing discussion at the WRC-12 is observed to identify the issues that may potentially be missing from the archives.

6.5 National preparatory process

Sweden

The Swedish Post and Telecom Authority (PTS), as the Swedish national regulatory authority, prepared the Swedish position for meetings, including the PT, CPG, ITU-R SG/CPM, RA, and WRC.

The PTS has a mailing to distribute information to stakeholders, including meeting and venue, and submission and participant confirmation dates. E-mails are normally sent out the week prior to an activity. For example, for the CPG-12-7, the Swedish preparatory meeting was conducted in the week prior to the CPG-12-7.

During the preparatory meeting, the discussion on input documents from stakeholders helps to shape the Swedish position and prepare the document for submission to the relevant meetings.

Thailand

The Ministry of Information and Communication Technology (MICT) arranged a meeting prior to the APG2012-5 to establish a preparatory committee. The National Broadcasting and Telecommunications Commission (NBTC) (broadcasting and telecommunication regulator) is

a member of the committee. Dedicated staff prepared responses to the agenda items. These responses to the MICT process are in parts.

There were no proposals from Thailand for WRC-12 Agenda Items 1.19 and 1.22 at the APG2012-5. However, Thailand maintained its previous position (Method C or D) on WRC-12 Agenda Item 1.22 at the DG meeting. However, the change in position was discussed with the Head of the Thai delegation during the APG2012-5.

At the APG2012-5 and WRC-12, the Thai delegation's meeting between the staff responsible and the Head of the Thai Delegation depended on new information and possibilities to retain or change Thailand's position. The update status on each agenda item must be communicated directly via e-mail or discussion.

6.6 Regional meetings and observer attendance

At the WRC-12, there were 24 specified and 8 permanent agenda items to be reviewed. If all the Member States submitted only one document per issue for an agenda item, the minimum contribution to the WRC-12 would be more than 5,000 documents. However, Member States can submit many documents to the WRC-12.

To reduce this potentially large flow of documentation, the regional preparatory meetings act as a forum to discuss and negotiate common regional interests on the WRC agenda items. This forum helps to consolidate member views and develop common proposals for WRC.

ITU recognizes six regional preparatory meetings, i.e., APT, ASMG, ATU, CEPT, CITEL, and RCC.[48]

To be able to attend a regional preparatory meeting (boundary rules), a delegate observer requires permission from a regional preparatory meeting member.

The CEPT had CPG prepare a common proposal for WRC. As Sweden is a CEPT member country, the PTS allowed the author to be a CPG-PT A-9 and CPG-12-7 meeting observer.

The APT had APG as a regional forum to negotiate and prepare common proposals for submission to WRC. The NBTC, Thailand, allowed the author to be included in a preparatory team for the WRC-12 and attendance at the APG2012-5 and WRC-12 meeting as a Thai delegate.

The CPG process

The CPG is a forum for CEPT members to prepare common views for submission to WRC, the RA, and relevant ITU-R meetings, e.g., the SG and CC. The outputs of the CPG are the European Common Proposals (ECPs) and CEPT briefs (summary of discussion) for submission to WRC and the RA.

The CPG-12 has five PTs, i.e., PT A, B, C, D, and E. Each PT has several WRC-12 agenda items. WRC-12 Agenda Items 1.19 and 1.22 are included under the PT A.

[48] Some RCC member countries are also members of CEPT (e.g., the Russian Federation, Ukraine, and Belarus).

The PT and CPG meet separately. The PT is a function, as a WP provides a common view in the form of ECPs and briefs based on the documents submitted by CEPT members (including member countries and companies).

The CEPT Coordinator, as Chairman of the WG, drafts ECPs and briefs by agenda item. The WG can run two parallel meetings. The CEPT coordinator finalizes the draft ECPs and briefs for submission to the PT for approval. Each PT can have several meetings. The PT outputs are ECPs and briefs for CPG approval.

The CPG is an approval forum for the ECPs and briefs by agenda item. The CPG convenes meetings in a plenary manner (without parallel sessions). The CPG Chairman requests approval of the ECPs and briefs by agenda item. The right to vote on ECPs belongs to the CEPT Member Countries. The available positions are support, abstain, or oppose. Individual Members have a right to veto ECP proposals. After voting, formal signatory arrangements are conducted before submission to WRC.

The CPG met eight times and the PT A ten times to complete the ECPs and briefs for the WRC-12 and RA-12.

The APG process

The APG is a regional forum for APT members to formulate common views for submission to WRC, the RA, CPM, and SC to promote common benefits for the Asia-Pacific Region. The APG output takes the form of a common proposal submitted to WRC, the RA, CPM, and SC.

The APG-2012 has six WPs according to the CPM report. Each WP has several agenda items. WRC-12 Agenda Item 1.19 was included in the WP6, and Agenda Item 1.22 was contained in WP3.

The WP and APG convene at the same time. The APG conducts the plenary session chaired by the APG Chairman. Normally, the plenary is conducted on the first and last day of the APG. The first meeting introduces the working method, and the second meeting is intended to approve the WP output document.

The WP is conducted in two parallel sessions. Each WP has several agenda items. Each agenda item has a DG Chairman. The DG Chairman is the coordinator at WRC. Based on the document submitted by the APT Members and the discussion at the DG meeting, the DG Chairman drafts a preliminary view and the Asia-Pacific Common Proposal (PACP) by agenda item. The document is subsequently discussed at the DG and WP meetings.

The DGs are conducted via seven parallel sessions (from APG2012-5), each one lasting 90 minutes. If APT Members have insufficient delegate members attending a DG, the WP is the last forum to review and revise the draft preliminary view and PACP, prior to approval by the APG plenary. After finalizing the draft preliminary view and PACP on an agenda item, they are submitted to the WP for approval.

At the WP, the draft preliminary view and PACP are discussed and concluded for final approval by the APG plenary. Sometimes the debate at the WP is rigorous and the WP Chairman splits the meeting into smaller groups for discussion and compromises.

At the APG plenary session, all the draft preliminary views and PACPs are approved.

The APG2012 met five times to prepare the preliminary views and PACPs for the WRC-12. The last APG2012-5 meeting was held 29 September-3 August 2011, in Busan, the Republic of Korea.

CPG and APG comparisons

The processes

The CPG and APG have similar hierarchical work allocation structures to prepare common proposals for WRC. The plenary meetings approve the ECPs/PACPs and briefs/preliminary views on agenda items. The CPG and APG have the PT and WP, respectively, as DG pre-approval outputs. Similarly, the CPG and APG have the CEPT Coordinators and DG Chairmen to prepare the draft briefs/preliminary views and ECPs/PACPs on agenda items. Moreover, the CEPT Coordinators and DG Chairmen negotiate with other regional representatives at WRC.

The APG and CPG processes differ in the number of meetings held. The PT can arrange meetings until the work program is complete. However, the APG and WP have limited time to provide the preliminary views and PACPs.

The institutions

The IAD bio/physical condition indicates the nature of regional preparatory meetings. The CPG and APG have a similar objective, namely to formulate the common proposals for the WRC-12.

The IAD attributes of community concern the culture between the EU and Asia-Pacific Regions, for example, the ways in which views are presented in the plenary session. Most Asian countries are reluctant to express their views in English, when not mandated to do so, and prefer to converse in a small group.

The APG and CPG have similar IAD boundary rules (who can join the meeting), i.e., CEPT Members and APT Members. Members must endorse meeting delegates and their stated delegate or observer. These conditions indicate the position rules. There is a written rule for both APG and CPG.

The APG and CPG must approve common proposals via voting rules. Only the APT and CEPT Member Countries are able to vote. However, the CPG has a formal procedure with the options: support, abstain, or oppose.

There is no voting at the APG, but the WP Chairman seeks APG members' approval. The official support is indicated by an official signatory. When there is more than 25% APT Member support, a common proposal is made on behalf of the APT.

Conversely, in the CPG, when any CEPT member opposes the propositions, no common proposal is obtained for the agenda item.

The APG and CPG both use English as the common language to communicate. However, the local discussions are in their national languages.

The position of the APT and CEPT Members at the DG (WG) meeting is crucial when taking a new decision and position. For example, at APG2012-5, the DG meeting on Agenda Item 1.22 of WRC-12, when the DG Chairman sought the option to be drafted as the PACP, the majority indicated Method A. A decision was determined within the first five minutes of the meeting.

The draft PACP identified Method A with the WRC resolution (including an emission mask for SRD and modification of ITU-R Resolution 54).

The APG2012-5 meeting preferred the ITU Resolution for the CRS. The PACPs therefore made the following contributions: (1) draft ITU Resolution to the RA-12, and (2) no RR change with the suppression of Resolution 956 and the WRC resolution to the WRC-12. When the RA-12 approved the modified ITU-R 54, the APT withdrew the WRC resolution from the WRC-12.

Interactions

At the PT A-9, WRC-12 Agenda Item 1.19, one view expressed was that the WRC resolution was preferable. This concern was raised during a WG meeting chaired by a CEPT coordinator. This proposal was included in the PT A-9 minutes. However, the majority supported the ITU-R resolution.

The same view was repeated at the CPG-12-7. Due to this continued opposition, there was no ECP on this agenda item. Other solutions must be considered via multi-country proposals for the ITU-R resolution.

At the APG2012-5, with regard to WRC-12 Agenda Item 1.22, an APT Member proposed that the list of recommendations be included in the WRC resolution (SRD harmonization band and emission mask) at the DG meeting.

At the DG meeting, the majority supported the draft PACP Method A with no RR change. After the argument concerning whether the WRC resolution should be modified by adding the list of recommendations, the meeting decided that the ITU-R Resolution 54 modification be accepted as a compromise.

Finally, the DG meeting could not agree whether the list to ITU-R Resolution 54 should be kept or deleted, and the DG Chairman placed it in square brackets and moved the issues forward to the WP3 for further consideration.

At the WP3, further arguments considered the removal of the square brackets, however, no support for the proposition was received. The WP3 Chairman's final resolution was to remove this text from the resolution.

The APG and CPG discussions both show, via the aggregate rule, that the stances were held to the end of the process.

6.7 Summary and discussion on research questions

This chapter responds to one part of sub-research question 1: *How did they develop?;* sub-research question 2: *What information would be more useful for making decision?;* and sub-research question 4: *How can the existing ITU archives be improved or added to?*

The study provides an illustrated WRC preparatory process for agenda-setting by ITU to respond to how to review and revise the RR in terms of the WRC agenda-setting process. The WRC agenda-setting process is used to identify which issues should be considered at WRC as possible RR revisions.

The WRC agenda-setting process provides a standard procedure for ITU to prepare the WRC agenda for the next and future WRCs in the CPM report. The study explores the CPM reports contained in the preparatory work for the next and future WRC agenda after the APP1992. The study also constructs a table to show the number of the next and future agenda items on each CPM report in order to understand the WRC agenda-setting process and identify the critical point in the process.

The empirical finding of the study showed that the WRC agenda-setting process carried out by ITU has two study cycles for the preparation in terms of the next and future WRC agenda in the CPM report. It takes eight years for the whole WRC agenda-setting process.

However, the study also reveals that the last WRC is a crucial forum for approving the next WRC agenda before the CC approval. The numbers "F to N" and "N to C" in Table 32 are falling over time. This evidence supports the last WRC being the crucial forum, which means that the agenda items, including those in the CPM report, for the next and the future WRC agendas are not guaranteed inclusion in the final version of the WRC agenda by the last WRC approval. Interested Member States with limited resources should pay attention to the last WRC that is finalized in the next WRC agenda.

The results of the exploration of the WRC agenda-setting process respond to one part of the first sub-research question, *How did they change?,* in terms of the creation of agenda items, as the point or issues will be discussed in the RR revisions. This sub-research question is important to show the process of RR revision, and it confirms that the ITU archives lack the rationale behind the RR revision, because the CPM report contains only the output of the discussion, not the underlying issues.

Moreover, the study provides the national and regional preparatory works that assist in the WRC preparatory process before WRC. The study elaborates on the national and regional preparatory processes in terms of Thailand and Sweden, as a national preparatory process, and the APG and CPG, as a regional preparatory process. The exploration of the APT and CEPT archives helps provide an understanding of the issues and clarify the regional preparatory processes.

With regard to the second sub-research question, the study provides an inside view of the PT A, CPG, and APG on WRC-12 Agenda Items 1.19 and 1.22 via the attendance of the author. The record of the meeting discussions reveals the rationale behind the ultimate resolutions not contained in the archives. This information provides a more complete basis for understanding the state the issue has revealed and for the development of further arguments at relevant meetings.

During the discussion, the rationale of how it changes, as the missing information, is available to an attending Member State. The author's participation in both national and regional preparatory meetings provides the missing information apart from the archives.

The CPG and APG, as the regional forums, allow discussions on regional interests and preparation of common proposals for WRC. The process reduces the volume of submitted documents. Moreover, regional coordinators act as regional representatives and negotiate and report to regional coordination meetings. Highlights of the agenda items in the regional preparatory meeting include the following:

At the CPG, WRC-12 Agenda Item 1.19, the ITU-R and WRC resolutions on the CRS discussion rendered no ECP for the WRC-12 because of an objection from one Member State.

At the APG, WRC-12 Agenda Item 1.22, a resolution on the SRD issue is achieved through APT Member compromise. The proposal is submitted to the RA-12 and WRC-12. When the RA-12 approves the ITU-R resolution, the WRC-12 contribution is withdrawn.

The author's attendances at the national and regional preparatory meetings (PT A, CPG, and APG) illustrate the preparatory process and capture the missing information during the discussion inside the meetings. The second sub-research question highlights the importance of the missing information in the regional preparatory meetings by providing the rationale for the discussion of the meeting as the insight view missing from the archives.

Furthermore, national and regional preparatory meetings represent a forum for negotiation between stakeholder at national and regional level. The connection between stakeholders is formed during networking to exchange information before, during, and after the meeting. This networking also helps in understanding the rationale of the discussion, which is omitted from the archives. The networking is another possible solution to improve the ITU archives as the fourth sub-research question.

The fourth sub-research question is important for the study to identify the possibility to fulfill the limitation of the archives that lack the rationale underlying the RR provision. This rationale is not documented in the archives.

Finally, the study provides the RR development in terms of the WRC agenda-setting process to respond to one part of the first sub-research question. Furthermore, the study elaborates on

the national and regional preparatory meeting process, as the preparatory work before WRC. The study also demonstrates the missing information in the national and regional preparatory meeting and addresses the rationale underlying the preparatory process of WRC. In addition, the study highlights the appointment of national and regional stakeholders representing the networking for information exchange before, after, and during the meeting. This may be a possible solution to improve the limitation of the archives.

This chapter responds to the first sub-research question: *How did they develop?*; the second sub-research question: *What information would be more useful for making decision?*; and the fourth sub-research question: *How can the existing ITU archives be improved or added to?* as a conclusion.

Chapter 7 Preparatory work on WRC-12 Agenda Items 1.19 and 1.22

The chapter provides preparatory work for WRC-12 Agenda Items 1.19 and 1.22 as the WRC study process and its assessment, including agenda item background, process, issues, and results from the SG, CPM, and RA-12. The study also covers the importance of WRC-12 Agenda Items 1.19 and 1.22 to Thailand as the basic information for analyzing how the missing information affects international spectrum policy.

7.1 Importance to Thailand

The study uses Thailand to illustrate spectrum management development and the importance of WRC-12 Agenda Items 1.19 and 1.22.

Thai regulatory profile

Thailand has a long history of spectrum management, dating back to 1875. Telecommunications developed from wire to wireless communication: from telegraph, telephone over a telegraph infrastructure, and radiotelegraph for ship-to-shore communication, to radiocommunication for both broadcasting and telecommunication. At the initial stage (without regulations), the use of radiocommunication devices was limited to government agencies, especially the Navy and the Army. Frequency assignment was initially made by His Majesty the King of Thailand. After 10 December 1932, this authority was transferred to the Prime Minister. The King delegated his authority to the responsible ministry. The ministry used the command-and-control approach on a first come, first served basis to authorize the use of radiocommunication devices. Thailand also endorsed the International Telegraph Convention 1906 and 1912 (ITU, 1906a, 1912b) as a national regulation. Most of the users were government agencies. There was little other usage and low demand, so there was no congestion of the use of radiocommunication.

After the Radio Act was enacted in 1914, all radiocommunication activities were prohibited, except with authorization granted by the authority, in terms of radiocommunication licenses. The authority was the Post and Telegraph Department (PTD), and it still used the command-and-control approach on a first come, first served basis to authorize the use of radiocommunication devices. However, the PTD functioned only for radiocommunication licences in technical respects and did not take into consideration the growing demand for the use of radiocommunication devices until congestion led to harmful interference.

The government realized that "good" spectrum management of frequencies would provide efficient national allocations. On 26 March 1974, the National Frequency Management Board (NFMB) was established to determine the national technical standard; control, assign, and register frequency; examine the standard of radiocommunication devices; create an efficient procedure; evaluate radiocommunication stations; and coordinate all radiocommunication users. The NFMB comprised several representatives from government agencies, and it was chaired by the Minister of Transport (the NFMB came into force in 1975). The NFMB acted as the approval board before the PTD issued radiocommunication licenses. The NFMB

operated until 2002, while the PTD was transferred and became part of the Ministry of Information and Communication Technology (MICT).

After the Act on Establishment of the National Broadcasting Commission (NBC) and the National Telecommunications Commission (NTC) were enacted in 2000, the NTC was established on 1 October 2004, and the PTD was dissolved by law to become the Office of the NTC on 1 January 2005. A new era of telecommunication with an independent regulator, the NTC, was founded in order to change the authorization process into a licensing process. Not only the technical aspects, but also social and economic aspects, were included in the licensing process.

On 7 October 2011, the National Broadcasting and Telecommunications Commission (NBTC) was established, according to the Thai Constitution 2007 and the Act on Organization to Assign Radio Frequency and to Regulate the Broadcasting and Telecommunications Service 2010. The Office of the NTC (ONTC) was transferred to the Office of the NBTC (ONBTC) from 20 December 2010. The NBTC responds to the broadcasting and telecommunication industry and ensures the transition from authorization to the licensing process.

Figure 18 shows the Thai spectrum management development profile: administrator, regulator, secretariat (an administrative unit), and operator.

	Administrator	Regulator	Secretariat	Operator
Before 1975	PTD			
1975-2002	PTD	NFMB	PTD	PTD/TOT/CAT
2002-2004	PTD		PTD	TOT/CAT
2004-2011	MICT	NTC	ONTC	TOT/CAT +licensees
2011-now	MICT	NBTC	ONBTC	TOT/CAT +licensees

Figure 18. Thailand's spectrum management profile

The administrator represents the Thai government as the Thai delegation to international activities, such as international conferences, conventions, treaties, negotiations, and cooperations. The regulator acts as the NRA for frequency management. The secretariat is the regulator's administrative office. The operator provides the services after obtaining the frequency and licenses from the regulator (TOT and CAT are state-owned companies).

Before 1975, the 1914 Radio Act authorized only the PTD to assign frequency to users. The PTD acted as the administrator, regulator, and operator.

To separate it from the PTD, the NFMB worked as regulator to assign frequency to users until 2002 and was dissolved by the MICT.

During 2002-2004, there was no regulator to assign new frequency (according to the provision of the Act on Establishment of the NBC and NTC 2000).

The transition period from the monopoly by state enterprise (or currently state-owned company) to market economies by licensees started with the NTC.

The NTC was founded in 2004 with the establishment of the licensing scheme for the Thai telecom sector. The NBC was never founded however. The NTC did not have full authority to form the Joint Committee between the NTC and the NBC to approve the National Table of Frequency Allocation or National Master Plan. The reason for the Supreme Administrative Court on 23 September 2010 was not to provide the NTC with any right to pursue the 3G auction until the establishment of the NBTC.

The NBTC was established on 7 October 2011 to combine broadcasting and telecommunication into a single regulator with full authority to assign new frequency. The 3G frequency assignment or auction will be able to be carried out after approval of the National Table of Frequency Allocation or National Master Plan.

Table 34 summarizes the important events in Thailand's spectrum assignment profile.

Table 34. Thailand's frequency assignment profile

Frequency transfer (alienation right)	NFMB in 1998 NTC in 2009
Auction	NFMB initiated in 1997 NTC attempted in 2010 NBTC in 2012
Spectrum commons	Authorization since 1974 Unlicensed since 2004

Thai telecommunication industry

The telecommunication industry in Thailand began with command-and-control and developed for the market economy that originated from the government-provided telecommunication service, state enterprise, and state-owned company to licensees.

The right to use frequency by command-and-control assignment has shifted to auction in order to provide licensees with exclusive rights to use frequency during a defined period of time. Two auction attempts were made by the NTC and NBTC during 2010-2012.

Thailand is not a telecommunication-manufacturing-based or research development country. Most telecommunication devices are imported, including telecommunication network infrastructure and end-user terminals. In order to take advantage of telecommunication development, Thailand must ensure that the regulatory regime facilitates the growth of the telecommunication industry by allowing frequencies to be used with compatible standards. For example, Thailand allows the 1900-1906 MHz to be used for personal cordless telephones, Digital Enhanced Cordless Telecommunication (DECT) as well as Personal

Handyphone System (PHS) technologies. The right to select standards and technologies should belong to the operators.

Importance of spectrum commons

Spectrum commons provides non-ownership of spectrum by sharing the use of frequency equally and having non-exclusive rights to use frequency. This increases spectrum efficiency. It was initiated in 1974 and became unlicensed for the general public in 2004.

The success story of Wi-Fi-enabled devices in Thailand confirms the appropriated regulatory regime. For example, Thailand has allowed the 2.4 GHz band to be used for Wireless LAN with relevant radiocommunication licenses since 1996, and it became unlicensed for all Wi-Fi-enables devices in 2004.

The global allocation of the 2.4 GHz band for spectrum commons is in accordance with the 5.150 ISM footnote of the RR. It allows manufacturers to reach mass production. When economy of scale is achieved, the price of devices becomes affordable to users.

In order to benefit from spectrum commons, the global frequency must be allocated either in the footnotes or in the relevant services of the RR. Thailand must therefore follow the relevant agenda items in terms of Thailand's position preparation and to evaluate the consequences of the RR revisions.

Importance of WRC-12 Agenda Items 1.19 and 1.22

At the WRC-12, there are two agenda items that are relevant to spectrum commons, i.e., Agenda Items 1.19 and 1.22. Agenda Item 1.19 is about the use of SDR and CRS. Agenda Item 1.22 is about the emission of SRD.

SDR and CRS are enabling technologies for spectrum commons. SDR is the technology that allows the operating parameter to be changed automatically via software. CRS is the technology that enables the operating parameter to be changed automatically via software, learning the environment from previous operations, and improving operating performance.

With these two enabling technologies, the use of spectrum commons can be shared with existing services, avoid harmful interference, and increase spectrum efficiency.

SRD is an example of a spectrum commons application or device that is mostly used under the ISM footnotes, for example, Wi-Fi-enabled devices in mobile phones, cameras, printers, Wi-Fi access points, garage door openers, RFID tags, and credit cards.

Thailand's situation

Comparing three frequency assignment approaches: command-and-control, market-based (auction), and spectrum commons, command-and-control still dominates in terms of legacy or existing assignments. However, the auction and unlicensed devices are introduced in different processes. For example, the 3G frequency auction is expected to be completed in 2012, but unlicensed devices have been initiated since 2004.

The development of radiocommunication technology enables sharing between radiocommunication services. An exclusive right to use frequency may not be necessary when the advancement of technology enables communication in any frequency without causing harmful interference between services. Consequently, a spectrum commons regime may be appropriated to prepare for future situations.

It is important for Thailand, as an importing country, to follow spectrum commons issues at the WRC-12 on Agenda Items 1.19 and 1.22 for its position on preparation and to evaluate the consequences for Thailand.

7.2 Background to WRC-12 Agenda Items 1.19 and 1.22

The WRC-12 agenda first appeared in the future WRC agenda contained in the CPM report for the WRC-03. The second appearance of the agenda was in the next WRC agenda contained in the CPM report for the WRC-07. The CPM-06-2 added the new proposals from the ITU Member documents and removed previous text when no support was received for the proposals.

WRC-12 Agenda Items 1.19 and 1.22 are not contained in the CPM reports of the future WRC or the next WRC agendas. These issues were introduced by the WRC-07 Member State documents. This treatment is consistent with the argument in Chapter 6 that most WRC agenda items are introduced by the last WRC.

Twenty-six documents concerning 80 issues were sent to the WRC-07 as WRC-12 agenda items. Seven remaining issues from the CPM report were not finalized or sent to the WRC-07. The WRC-07 established an ad hoc plenary 7.2 to finalize 24 issues through Member State negotiation. The WRC-12 agenda was approved by the plenary meeting. The plenary approved the first and second reading at the same time. The duration of the preparatory process for the WRC-12 agenda is therefore eight years (two CPM reports), and three plenary meetings (two ad hoc and one plenary meeting) during the WRC-07.

Of the 24 issues, WRC-12 Agenda Items 1.19 and 1.22 concern spectrum commons issues. Spectrum commons allows non-exclusive use of frequency, that is, when the frequency is being used, it is temporarily occupied, but later released. The shared used of frequency is intended to increase spectrum utilization.

WRC-12 Agenda Item 1.19 is about the use of SDR and CRS, and whether RR revisions are required. SDR is an enabling technology that allows radio-operation parameters to vary dynamically and autonomously by software. The CRS technology is comprised of obtaining knowledge about frequency use, dynamically changing radio-operating parameters via software, and learning from operational experiences to improve performance.[49]

[49] This section is based on the 2nd session of the Conference preparatory meeting for the WRC-12-CPM report on technical, operational, and regulatory/procedural matters to be considered by the 2012 World Radiocommunication Conference (ITU, 2011). The document is available on http://www.itu.int/md/R07-CPM11.02-R-0001/en
SDR is based on a working document towards a preliminary new draft Report ITU-R [LMS.CRS](ITU, 2010).

Issues related to these agenda items concern the definition, regulations, and technical matters. The main concern is whether SDR and CRS are classified as technologies or services. As there are several ITU definitions, a single definition is needed for clarity.

WRC-12 Agenda Item 1.22 examines the effect of SRD emissions on existing services. SRDs use an ISM frequency band, but SRDs are not ISM applications, as they contain a transceiver to send and receive information.

The issue is whether the SRD should be handled nationally or internationally. While SRD is local, SRD circulation renders it an international issue. Most SRD is unlicensed and transportable between countries. However, SRD authorization is local (national) by Member States. When one country allows SRD but another does not, the emissions can interfere with existing services.

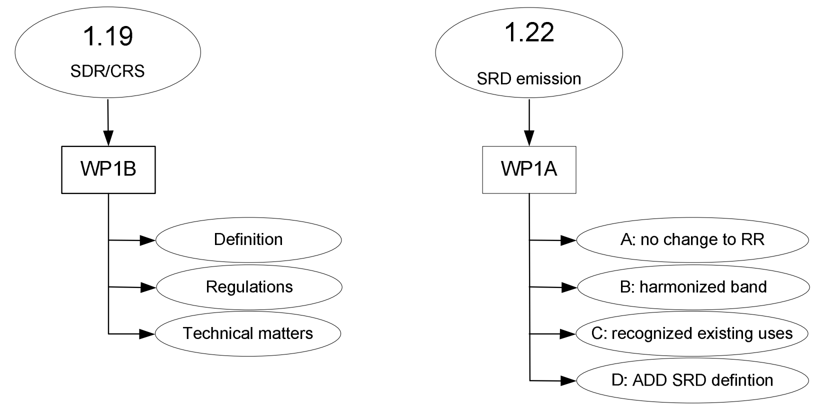

Figure 19. Agenda Items 1.19 and 1.22 and related issues

Figure 19 relates Agenda Items 1.19 and 1.22 to particular issues.

SDR and CRS are spectrum commons-enabling technologies that allow users to occupy spectrum frequencies temporarily, then later release them.

SRDs are local unlicensed applications. There are therefore no exclusive rights to use SRD frequency. SDR and CRS are both enabling technologies for SRD applications, such as Wi-Fi-enabled devices contained in computers, mobile phones, printers, and cameras.

7.3 Challenges to CRS and SDR

CRS and SDR are enabling technologies. SDR is an enabling technology for CRS that is able to change operating parameters automatically and dynamically via software.

CRS is based on Report ITU-R M.2117 (ITU, 2007b).

CRS and SDR can be deployed in any services and applications, such as satellite and mobile services. These two technologies help to avoid harmful interference during transmission. Importantly, CRS and SDR abilities, i.e., to change operating parameters dynamically and automatically via software, to learn from experiences and the environment, and to improve system performance, enable the transmission frequencies to be changed between the transmitter and receiver to avoid harmful interference.

The challenges faced by the Member States are how to facilitate and reduce the burden of the use of technologies, for example, the Member States may consider whether the existing regulatory scheme is appropriate or if there is a need for new regulation. Consequently, the impact of using this technology for portable devices may migrate national to international matter such as SRDs.

The telecommunication providers are challenged on how to introduce the new devices under the existing regulation, especially the use of new devices, which must not cause harmful interference.

7.4 Preparatory process

After finalization of the WRC-12 agenda by the WRC-07 (and approval by the CC2008), the CPM-11-1 organized and distributed preparatory work to relevant SGs/WPs. In particular, WRC-12 Agenda Items 1.19 and 1.22 are allocated to the SG1/WP1B and SG1/WP1A, respectively.

The SG1 meeting is a forum to approve the WP1B and WP1A report, prior to submission to the RA-12. The SG1 convenes annually. Figure 20 and Figure 21 show the preparatory process for Agenda Items 1.19 and 1.22.

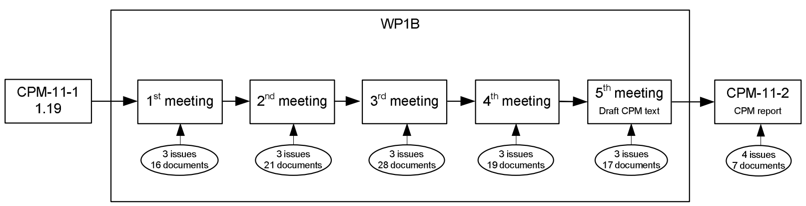

Figure 20. WRC-12 process for Agenda Item 1.19

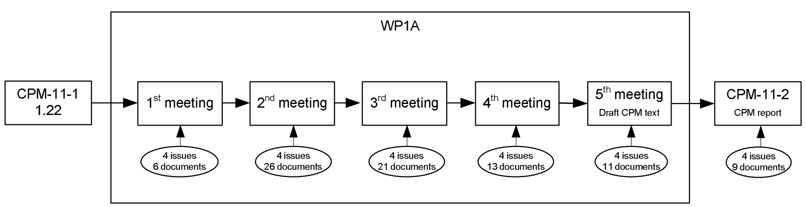

Figure 21. WRC-12 process for Agenda Item 1.22

The WP1B and WP1A met five times between the first and second session of the CPM. They studied and prepared the draft CPM text for inclusion in the CPM report, as the possible RR revision options for Member States to make a decision at WRC.

7.5 Assessment of the WRC agenda study process

The WRC study process is similar to the WRC preparatory process (WRC agenda-setting process), Chapter 6. The study process is only one WRC study cycle, but the WRC agenda-setting is two WRC cycles.

The study process is mandated by the RA and the relevant ITU-R resolution as mentioned in Figure 16 in Chapter 6. The study is conducted by the relevant SGs. The objective of the study process is to prepare the possible options for RR revisions on each agenda item as the CPM report. The CPM report provides the information required by Member States to consider the RR revisions during WRC.

The study by SGs takes time between WRCs. This is normally about four years. However, the study must be finished and be ready as the draft CPM text to be included as the CPM report at the CPM-2. For example, the draft CPM report for the WRC-12 was available on 5 August 2010. The SGs must study and prepare the text to be included around June 2010. The study time is around two years and seven months (after CPM-11-1 in November 2007 to the last meeting of the SGs in June 2010 before the draft CPM report was available). At the WRC-15, the study time is shorter. In order to assess the study process, the IAD framework is discussed as follows.

The study object is the study of each agenda item. The results of the study provide the options with the advantages and disadvantages of each agenda item for possible RR revisions.

The attribute of community is the same as the WRC agenda-setting environment because the study is conducted under ITU and its membership environment.

The rules-in-use as an action situation reflects the discussion within the relevant meetings, including the relevant CPMs and SGs.

The boundary rule that determines who is allowed to participate in the relevant meetings is ITU membership during the CPMs and SGs, including Member States, Sector Members, and Academia.

The position rule is directly relevant to the boundary rule, which role each participant will perform during the discussion in an action situation, and which options each has as the choice rule.

The actions to be taken have been evaluated with consequences and possible outcomes (scope rule) using evaluative criteria as the payoff rule. The dynamic discussion provides the information exchange in the meetings (information rule) and directly influences the choice and payoff rules of the meeting. Participant stances represent their choice and how to control their decision as the aggregate rule.

Figures 20 and 21 show the study process of the WP1B and WP1A for WRC-12 Agenda Items 1.19 and 1.22. There were five meetings on each agenda item to study and prepare the text to be included in the draft CPM report. The results of the study are based on the document from the ITU members and the relevant results of the ITU-R study group in terms of the report, recommendations, and handbook.

The discussion, as an action situation inside the SGs, is less controversial when compared with WRC. The main discussion concentrates on the possible options to revise the RR according to the results of the relevant study and documents submitted by the ITU members. However, not all of the Member States attend and submit document to the SGs.

The results of the study, as stated in the CPM report, therefore represent the view of the relevant SGs and participants concerned. It may not include all possible concerns on each agenda item. The report serves as the basic text and possible options for Member States to consider the RR revisions on each agenda item.

7.6 Agenda item issues

WRC-12 Agenda Item 1.19

The principal concerns are issues related to the SDR and CRS. According to the RR, the status of SDR and CRS is unclear with regard to whether they should be treated as a service or technology. If they are a designated as a service, the SDR and CRS definitions should be added to Article 1. Consequently, their service priority would need to be identified as either primary or secondary within the TFA (Article 5). However, this treatment is not appropriate, as the WP1B identified the SDR and CRS as techniques to communicate and, as such, they are best treated as a technology.

Next, the WP1B Chairman sends a liaison statement to the relevant ITU/SG/WPs, where other current ITU definitions are in place; the Recommendation ITU-R M.1797 is identified.

Based on the definition contained in Recommendation ITU-R M.1797, a WP1B subgroup (corresponding group) is charged with developing a final definition.

ITU Members submit documents, including information concerning liaison statements, working methods, SDR and CRS definitions, and views on a proposed service or technology classification.

The SDR and CRS definitions were concluded in the CPM draft at the second meeting. The SDR and CRS are both determined technologies.

Other issues to be resolved concerning regulatory and technical matters were identified and inserted in the background of the CPM draft.

The SDR technology, in particular, is used to provide many services, especially in the LMS. The SDR is already subjected to an ITU recommendation and report. There is no need for new SDR regulation or RR revisions.

The CRS technology has three main functions: (1) the ability to change radio operating parameters dynamically and automatically via software (SDR is the enabling technology), (2) the ability to use knowledge of the working environment, and (3) the ability to improve performance based on this knowledge.

As for CRS environmental knowledge and performance, the adjustment functions are in their infancy. However, unlike SDR technology, there is insufficient knowledge to make any decision on regulatory and technical matters on CSR. The RR revision is therefore not necessary at this stage, and further study of CRS matters is required.

At the final WP1B meeting, the draft CPM text (covering the background and issues considered) was submitted to the CPM chapter rapporteur. The CPM chapter rapporteur consolidated the draft CPM text into the draft CPM report, which is to be finalized at the CPM-11-2.

CPM report to the WRC-12 on Agenda Item 1.19

The CPM report contains two responses to the SDR and CRS issues. The response to the SDR issue is that there is no change to the RR. With respect to the CRS issues, there are three options: (1) no change to the RR (Method B1 option 1); (2) no change to the RR, with the ITU-R resolution for CRS requiring further study (Method B1 option 2); (3) no change to the RR, with the WRC resolution for CRS requiring further study (Method B2). The RA approved the ITU-R resolution, whereas the WRC resolution was approved by WRC. Importantly, the WRC resolution is mandatory for Member States, but the ITU-R resolution is voluntary.

WRC-12 Agenda Item 1.22

The prospect of SRD emissions interfering with existing services lies at the heart of the conflict between existing and new users. Providers of existing services do not want new services or applications to interfere with service transmission, especially satellites with highly sensitive receivers.

The reason SRD technology has created international interference, in particular, is that SRD encompasses the low-power devices (normally unlicensed) that are transportable internationally. Local SRD authorization by Member States is covered by national regulations. However, because of international circulation, there may be a need for international SRD regulations. For example, if Country A allows unlicensed SRD use in Band A but it is not allowed in Country B, then cross-border travel can lead to interference with existing services in Country B, thus requiring RR revisions.

In addressing emission issues, the WP1A is unable to consider a wide range of SRD applications; it therefore focuses specifically on Radio Frequency Identification (RFID) applications such as tags, barcodes, access cards, and credit cards.

The WP1A Chairman submitted liaison statements, establishing a subgroup (correspondence group) to consider documents from ITU Members to prepare the draft CPM text.

The report considered two main issues concerning whether the RR revisions were required: (1) if SRD was a truly national issue, there would be no need to revise the current RR; and (2) if global interference from SRD was considered a serious problem. It provided three options, depending on the severity of the problem.

The first proposal was that an SRD harmonization band be introduced to reduce interference from emissions. This band would not be restrictive to service transmission and would allow sufficient growth for the economy of scale to be raised (a lower price). TheWP1A therefore proposed the WRC resolution for further study of SRD to be accepted.

The second proposal recognized that existing SRD use could be constrained (emission mask) to ensure there was no further interference to existing services, especially satellite receivers. An SRD footnote providing for proper constraints was therefore proposed. This footnote was drafted in a similar manner to the ISM footnote.

The final proposal was that the new SRD definition be strengthened by inclusion in Article 1 and that SRD be a priority service. SRD could then claim protection from existing services.

At the last WP1A meeting, the draft CPM text (covering the background and the issues considered) was submitted to the CPM chapter rapporteur. The CPM chapter rapporteur consolidated the draft CPM text into the draft CPM report, which is due to be finalized at the CPM-11-2.

CPM report to WRC-12 on Agenda Item 1.22

The CPM report contains four options: (1) no RR change (existing RR and ITU recommendations and reports can govern SRD) (Method A), (2) a WRC resolution (further study on global and regional harmonized frequency bands for SRD) (Method B), (3) a footnote similar to the ISM footnote (recognize existing SRD use, ensuring no harmful interference to existing services) (Method C),and (4) a new SRD definition under Article 1 (Method D).

7.7 RA-12 proposals for WRC-12 Agenda Items 1.19 and 1.22

For WRC-12 Agenda Items 1.19 and 1.22, the ITU-R resolutions developed were Resolution 58 and Resolution 54-1, respectively. Resolution 58 deals with proposed further study of technical CRS issues, whereas Resolution 54-1 is concerned with the study of the harmonization of short-range devices.

Based on the ITU Members' submitted documents, contributions were introduced in Resolution 58 (five proposals) and Resolution 54-1 (four proposals).

The RA-12 also resolved, through ITU-R Resolution 58, to conduct further study of technical CRS issues for WRC-12 Agenda Item 1.19.

The RA-12 modified ITU-R Resolution 54 to require further study of the harmonization of short-range devices. This RA-12 output is contained in ITU-R Resolution 54-1 for WRC-12 Agenda Item 1.22.

7.8 Summary and discussion on research questions

This chapter responds to one part of sub-research question 1: *How did they develop?* and sub-research question 3: *How does the missing information affect international spectrum policy?*

The study explores the ITU archives for the WRC study process for WRC-12 Agenda Items 1.19 and 1.22. The WRC study process provides the output of the discussion from the ITU SG and the issues of these agenda items. The WP1B and WP1A of SG1 are in charge of WRC-12 Agenda Items 1.19 and 1.22, respectively. The study explores the input and output documents of the ITU members' contributions to both study groups. The illustration of study output is presented as follows.

The output from the WP1B provides one option for SDR and three options for CRS in the CPM report for WRC-12 Agenda Item 1.19. The SDR issue is that there is no change to the RR. For the CRS issues, there are three options: (1) no change to the RR (Method B1 option 1), (2) no change to the RR with the ITU-R resolution for CRS requiring further study (Method B1 option 2), and (3) no change to the RR with the WRC resolution for CRS requiring further study (Method B2).

The output from the WP1A provides four options in the CPM report for WRC-12 Agenda Item 1.22: (1) no RR change (existing RR and ITU recommendations and reports can govern the SRD) (Method A), (2) a WRC resolution (further study of a global and regional harmonized SRD frequency band) (Method B), (3) a footnote similar to the ISM footnote (recognize existing SRD use ensuring no harmful interference to existing services) (Method C), and (4) a new SRD definition in Article 1 (Method D).

Moreover, the output from the RA-12 provides two ITU-R resolutions for WRC-12 Agenda Items 1.19 and 1.22: ITU-R Resolution 54-1 and ITU-R Resolution 58, respectively.

The output of the SG is presented in the CPM report as the options for Member States to decide on at the WRC-12. Moreover, the output from the RA-12 provides additional information regarding these two agenda items (ITU-R Resolutions 58 and 54-1). However, the missing information in terms of the reasons for such options being developed has been omitted from the ITU archives.

The study illustrates the WRC study process as the preparatory work for WRC, which is contained in the CPM report and the RA report to WRC. This chapter responds to one part of the first sub-research question, *How did they develop?*, in terms of the issue content that is the output from the ITU-SG study to provide possible options for Member States to decide on at WRC.

This sub-research question is important to the study in order to understand the content of WRC-12 Agenda Items 1.19 and 1.22 in depth. The information forms the decision options for Member States, including the background to issues and possible options, with the advantages and disadvantages in the CPM report. This information includes the output from the ITU SG study and the RA report to WRC. However, the rationale of the issues is not included in the ITU archives, only the conclusion of the study is presented. The results of this sub-research also strengthens the missing information from the archives.

Furthermore, the study explores the history of Thailand's spectrum management from the relevant literature, including the development from the monarchy to the democracy era and from the PTD, MICT, and NTC to the NBTC.

The study also analyzes the development of the Thai telecommunication industry that has gradually developed from a command-and-control to a market economy, as the transition from authorization to licensing scheme.

The study also illustrates challenges of CRS and SDR facing Thailand's perspective: how do these technologies influence Thailand's spectrum management? Thailand's spectrum management profile and background are also presented as Thailand's environment.

The importance of WRC-12 Agenda Items 1.19 and 1.22 influences Thailand's priority on the WRC agenda items. The priority can either be an amplifier or attenuator of the missing information during the decision-making process at WRC. The importance of WRC-12 Agenda Items 1.19 and 1.22 therefore forms the basis of the information to analyze the effects of the missing information on international spectrum policy.

CRS and SDR are enabling technologies for frequency sharing between radiocommunication services. The exclusive right to use frequency may not be necessary when the advancement of technology enables communication in any frequency without causing harmful interference between services. Consequently, a spectrum commons regime may be appropriated to prepare for future situations.

Thailand is an importing country in the telecommunication sector. It is important for Thailand to follow spectrum commons issues at WRC-12 on Agenda Items 1.19 and 1.22 in terms of Thailand's position on the preparation and its evaluation.

The study looks at the challenges and importance of WRC-12 Agenda Items 1.19 and 1.22 from Thailand's perspective, responding to one part of the third sub-research question, *How does the missing information affect international spectrum policy?*, in terms of the existing situation in Thailand as an impact background for further analysis of the impact level when Thailand faces the missing information on this matter.

The third sub-research question is crucial to preparing the impact background for the analysis of the missing information affecting the international spectrum policy from Thailand's perspective.

To conclude, this chapter illustrates the RR development as part of the WRC study process by ITU in the CPM report and the RA-12 output for WRC-12 Agenda Items 1.19 and 1.22. The study also underlines the limitations of the archives, which lack the underlying rationale, corresponding to one part of the first sub-research question: *How did they develop?*

Moreover, the study also illustrates the challenge and importance of WRC-12 Agenda Items 1.19 and 1.22 from the perspective of Thailand as the basic information to analyze the effects of the missing information on Thailand's spectrum management policy, responding to the third sub-research question: *How does the missing information affect international spectrum policy?*

Chapter 8 Participation in the WRC-12 meetings and the issue of the WRC-15

This chapter reviews the WRC preparatory materials based on the observations and outcomes of WRC-12 Agenda Items 1.19 and 1.22. The WRC-12 organization, documents, and observations are also provided. The informal channel of communication during the WRC-12 is acknowledged, and the importance of the missing information is restated. This chapter also presents the ongoing issues of the WRC-12 Agenda Item 1.2, including the existing situation in Thailand and the preparatory work toward the WRC-15.

8.1 WRC-12 organization

The WRC-12 was convened at the Centre International de Conférences Genève (CICG) and the ITU buildings, Geneva, Switzerland, 23 January-17 February 2012.

More than 3,000 participants from 165 Member States and Sector Members attended. A hard copy of the Conference documentation was provided to Member States on request.[50] The electronic means facilitated meetings: website, webcast, SharePoint (working document), and mobile applications (e.g., meeting schedules) were employed.[51]

Six languages (i.e., Arabic, Chinese, English, French, Russian, and Spanish) were officially supported by simultaneous interpretations. Documentation was also available during the plenary, COMs, and WGs for all the supported languages. However, SWGs, DGs, and IGs were only conducted in English.

Six meeting sessions were scheduled: two in the morning, afternoon, and evening. No offer meetings could take place when the plenary was in session. At all other times, at least two parallel COM, WG, SWG, and IG meetings must be held.

The official Conference session times were 9.00-12.00, 14.00-17.00, and 17.00-22.00 (Monday to Thursday), and 9.00-12.00, 14.30-17.30, and 17.30-22.00 on Friday. Weekend time slots were also available on request.

The Chairman and Secretary scheduled the meeting rooms. Room sizes varied from a capacity of 12 to 2,200 delegates at the CICG and ITU buildings (Tower and Monbrillant). For example, at the plenary, Rooms 1+2+3+4 of the CICG accommodated more than 3,000 delegates. When there was no vacant seating, webcast was available during the plenary, COM, and WG. Moreover, Rooms 1, 2, 3, 4 at CICG, and Popov at the ITU Tower, had webcast archives, which were available through the TIES system.

8.2 WRC-12 documents

Delegates obtained Conference information though the TIES (temporary TIES) system. Documents could be uploaded via a SharePoint website. The LAN and Wi-Fi connections

[50] The hard copy is provided at the WRC before each session begins.
[51] The WRC document is only available for participants because of its confidentiality. The conference provides press release for public. Webcasting is a voice streaming delivering the conference live broadcasting. SharePoint is a website providing the space for delegates to upload and download working document. There is no presentation on screen during the plenary session because there are six languages document.

were the Conference Internet access mediums. For their Wi-Fi connections, the delegates were provided with passwords obtained at the registration desk.

The Conference access rules (Internet and TIES systems) were an IAD boundary rule determining resource access (Internet and documentation).

The submission deadline to the WRC-12 was two weeks prior to the Conference and in a defined format. The submission deadline and formatting requirement were also an IAD boundary rule.

8.3 WRC-12 observation documentation

The author attended 79 sessions of the Conference; only 37 of these were relevant to WRC-12 Agenda Items 1.19 and 1.22.[52] Table 35 and Table 36 report the sessions relevant to the WRC-12 during the period 23 January-17 February 2012. The "1.19" and "1.22" show meetings that were relevant to the agenda items.

Table 35. WRC-12 attendance 23 January-3 February 2012

Meeting	Jan 24	Jan 25	Jan 26	Jan 27	Jan 30	Jan 31	Feb 1	Feb 2	Feb 3
APT			1.19						
APT			1.22						
Plenary									1.19
COM6						1.19		1.19	
COM6						1.22		1.22	
WG6A	1.19	1.22		1.22			1.19		1.19
WG6A	1.22						1.22		
SWG6A2		1.19	1.19			1.19		1.19	
Informal6A2				1.19	1.19				
Informal6A2					1.19				
Informal6A			1.22						
Total	**2**	**2**	**4**	**2**	**2**	**3**	**2**	**3**	**2**

Table 36. WRC-12 attendance 6-17 February 2012

Meeting	Feb 6	Feb 7	Feb 8	Feb 9	Feb 10	Feb 13	Feb 14	Feb17
APT				1.19				
Plenary			1.22		1.22		1.19	1.19
Plenary							1.22	1.22
Plenary							1.19	
COM6		1.19	1.19	1.19		1.19		
WG6A	1.19							
Informal6A2					1.19			
AdHocCOM6-1.19			1.19					
Total	**1**	**1**	**3**	**2**	**2**	**1**	**3**	**2**

[52] The author did not participate in the meetings for agenda item 1.2 because it was known at the time that this agenda item would not be resolved until WRC-15, and the focus of the participant observation related to the agenda items related to spectrum commons, 1.19 and 1.22.

A template or meeting summary recorded the author's observations in the development for the WRC-12 meetings. The template that was developed allowed issues concerning Agenda Items 1.19 and 1.22 to be captured. The core elements of the document were Item 4 (Arguments) and Item 5 (Solving the argument). These Items correspond to "interaction" with the IAD framework. It was these data that were not recorded, and therefore not lodged in the ITU archives. Figure 22 shows the WRC-12 meeting summary document (observation template).[53]

Observation Report
Meeting: **Date:** **Time:** **Room**

Opening	Plenary	Committee	WG	SWG	HoD	APT	Lobby

Chairman (Head) Chairman

Objectives (agenda in focus/documents) ___

Was the aim achieved (following the schedule until): YES NO (_______YES___________________)

Number of participants: ________________ Involved:

1	2	3 - 7	8-12	more

Check (for PhD-related documents, recordings, etc.) _________________

1. Comments on what the meeting was like (Rank 1 to 5: 3 is normal, 1 is very bad, 5 is very good)
   climate
   chairman mastery
   breadth
   depth
   attention
   openness
   responsiveness
   difficulties
2. Comments on objectives
3. Method(s) of dealing with the objectives (per issue, e.g., how the Chairman and party achieve the objectives. Voting?)
4. Arguments (in relation to)?
5. Solving the arguments?
6. Involved (form and extent of participation, country, etc.):
7. Other (on the next page):

Figure 22. Meeting template

[53] However, some IGs allowed the non-voice recording of meeting notes. The author took note in an electronic form.

The ITU meetings had an agenda to meet pre-determined objectives. Before commencement of the meeting, the agenda was approved. The approval of the agenda provided clear guidelines for the way the Chairman could best conduct the meeting. In forming a draft resolution from the meeting or conclusion concerning an issue, the Chairman requested any observations from the delegates. In closing the meeting, any final conclusion could only be adopted when any objection had been resolved.

Summary notes were recorded by the authors on a daily basis to keep track of WRC-12 Agenda Items 1.19 and 1.22 developments at the relevant meetings, details of any arguments, and mapping of Item 4 and Item 5 into the IAD framework process.

8.4 Observed interaction

During the WRC-12, all discussion concerning the agenda items had to be conducted through a parallel session. During the first week of the Conference, the plenary considers documents submitted by Member States. After reviewing these documents, work programs were allocated to the COMs. The directions to the COMs included a list of agenda items to be considered with the durations for such deliberations, in particular, WRC-12 Agenda Item 1.1 on a country footnote deletion, which was allocated to COM6.

Moreover, during the first two weeks, most SWGs and WGs must submit recommendations for approval to the COMs. In the final week, the COMs submitted a proposal to the plenary for approval (first and second reading prior to inclusion in the Final Act). The WRC Chairman could arrange the plenary night sessions on 15-16 February to consider any unresolved issues by the COMs.

At the WRC-03 and WRC-07, the overnight sessions were held on Thursday night and Friday morning. However, at the WRC-12, the overnight sessions were held on a Wednesday. The meeting schedules were therefore acted on by the WRC Chairman.

Agenda Item 1.19

Figure 23 illustrates the document flow of WRC-12 Agenda Item 1.22. The process of advancement required 26 meetings: COM6 (6), plenary (5), IG6A2 (4), SWG6A2 (4), WG6A (4), APT (2), and ad hoc COM6 (1) meetings.

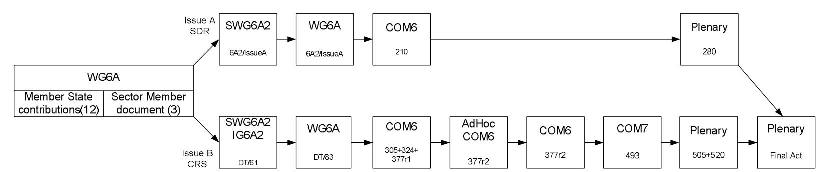

Figure 23. Agenda Item 1.19 meeting and document flow

Figure 24 shows the issues involving the nature of the CRS (Agenda Item 1.19).

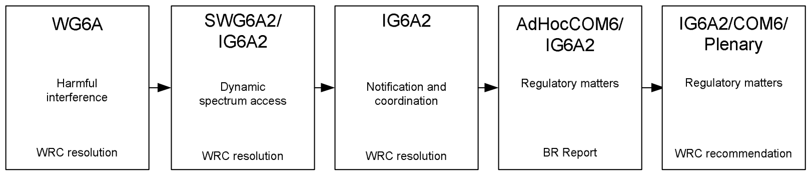

Figure 24. Agenda Item 1.19 issue development

Two views on the CRS issues were presented at the first WG6A meeting. The meeting discussed whether a WRC resolution should be made. The meeting proposed that to avoid harmful interference with the CRS system, a WRC resolution was required. Subsequently, the SWG6A2/IG6A2 changed the topic to dynamic spectrum access. The IG6A2 meeting progressed the resolution further by notifying the MIFR database of an international recognition and coordination between neighboring countries (bilateral and multi-lateral) for the CRS station's operating characteristic, e.g., location, transmitted power, and frequency bands. Furthermore, the issue moved on to regulatory matters (during ITU-R Resolution 58 on the CRS study) that will be reported at the next WRC via the BR Directors' report. The final outcome of the process was a WRC recommendation (a compromise solution between Member States).

The lengthy discussion process through several meetings provides an example of the Chairman's leadership and ability to facilitate a consensus outcome.

Table 37 shows approximate delegate numbers and discussion themes for Agenda Item 1.19. The corresponding meeting dates and locations are provided.

Table 37. Agenda Item 1.19 meeting organization

Meeting	Date	Room	Delegates	Discussion themes
WG6A	24 January	1, CICG	200	> 12
SWG6A2	25 January	A, ITU Tower	70	> 12
SWG6A2	26 January	A, ITU Tower	80	> 12
APT	26 January	5+6, CICG	120	> 12
Informal 6A2	27 January	T103, ITU Tower	16	> 12
Informal 6A2	30 January	T103, ITU Tower	24	> 12
Informal 6A2	30 January	T103, ITU Tower	8	3-7
COM6	31 January	1, CICG	300	> 12
SWG6A2	31 January	C1, ITU Tower	80	8-12
WG6A	1 February	1, CICG	200	> 12
COM6	2 February	1, CICG	300	> 12
SWG6A2	2 February	H, Monbrillant	50	8-12
WG6A	3 February	3+4, CICG	200	8-12
Plenary	3 February	1, CICG	500	> 12
WG6A	6 February	2, CICG	300	> 12
COM6	7 February	1, CICG	500	> 12
COM6	8 February	1, CICG	500	> 12
AdHocCOM6	8 February	A, ITU Tower	50	> 12
COM6	9 February	1, CICG	500	> 12
APT	9 February	3+4, CICG	200	> 12
Informal 6A2	10 February	17, CICG	8	3-7
COM6	13 February	1, CICG	500	> 12
Plenary	14 February	1+2+3+4, CICG	1500	> 12
Plenary	14 February	1+2+3+4, CICG	1500	> 12
Plenary	15 February	1+2+3+4, CICG	1500	> 12
Plenary	17 February	1+2+3+4, CICG	1000	> 12

Agenda Item 1.22

Figure 25 illustrates the document flow of theWRC-12 for Agenda Item 1.22. The process of advancement required 12 meetings: plenary (4), COM6 (2), WG6A (4), APT (1), and IG6A (1).

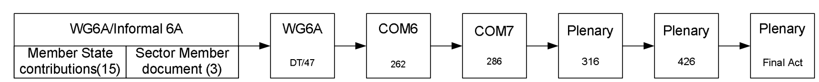

Figure 25. Agenda Item 1.22 meeting and document flow

Table 38 shows the approximate numbers of delegates and discussion themes for WRC-12 Agenda Item 1.22. The corresponding dates and locations are also recorded.

Table 38. WRC-12 Agenda Item 1.22 meeting organization

Meeting	Date	Room	Delegates	Discussion themes
WG6A	24 January	1, CICG	200	> 12
WG6A	25 January	Popov, ITU Tower	200	3-7
APT	26 January	5+6, CICG	120	> 12
Informal 6A	26 January	15, CICG	40	> 12
WG6A	27 January	1, CICG	200	> 12
COM6	31 January	1, CICG	300	> 12
WG6A	1 February	1, CICG	200	> 12
COM6	2 February	1, CICG	300	> 12
Plenary	8 February	1, CICG	500	> 12
Plenary	10 February	1, CICG	400	> 12
Plenary	14 February	1+2+3+4, CICG	1500	> 12
Plenary	17 February	1+2+3+4, CICG	1000	> 12

The discussions among the delegates were information exchanges. Within the meetings, these exchanges included a particular stance on agenda items, Member State justifications for that stance, alternative positions in the face of resistance to a particular stance, the form of the proposed recommendation, and the cost/benefit for the proposing Member States. Such interactions represented the position, choice, aggregation, payoff, scope, and information rules contained within the IAD framework.

For example, the Country A delegation saw that ITU-R Resolution 54-1 covered the content of the WRC resolution and that there was therefore no need for a new WRC resolution. This view showed Country A's position with regard to the IAD payoff (cost/benefit), choice, aggregate (control of the stance), information (flow of information exchange), and scope (possible outcome) rules. Consequently, the Country A delegation's statement influenced other parties at the meeting (representing information exchange). Each Member State reacted to Country A's stance by considering its own position.

8.5 Actual dynamic situation of the CRS issue

WRC-12 Agenda Item 1.19 concerns SDR and CRS technologies (see Chapter 7). Here, the focus is on the CRS, because there are currently subject proposals and counter-proposals.

The "Document" column in Table 39 identifies the Member States' positions on the CRS issues. For example, "5 A19" refers to document number 5 Annex 19. "SUP" means suppression of Resolution 956 (i.e., it is an instruction to delete the resolution from the RR). "ADD" means the addition of a WRC resolution (i.e., it is an instruction to add the WRC resolution to the RR). "WRC rec" is a WRC recommendation.

Table 39. WRC Agenda Item 1.19 document positioning

Member States	Input				Output
	Document	RR change	Resolution 956	WRC resolution	Final Act
CEPT	5 A19	No	SUP		WRC rec [COM6/1]
RCC	6 A19	No	SUP	ADD	
USA	9 A19	No	SUP		
CITEL	10 A19	No	SUP		
Cameroon	15 A15	No	SUP	ADD	
ATU	17 A19	No	SUP	ADD	
Multi-country*	19	No	SUP	ADD	
ASMG	25 A19	No	SUP		
APT	26 A19	No	SUP		
China	45 A19	No	SUP		
Colombia	90				
Multi-country*	97 A19	No	SUP	ADD	

*Angola (Republic of), Botswana (Republic of), Democratic Republic of the Congo, Lesotho (Kingdom of), Madagascar (Republic of), Malawi, Mauritius (Republic of), Mozambique (Republic of), Namibia (Republic of), Seychelles (Republic of), South Africa (Republic of), Swaziland (Kingdom of), Tanzania (United Republic of), Zambia (Republic of), Zimbabwe (Republic of)

While Table 39 records all relevant input and output documents for Agenda Item 1.19 contained in the ITU archives, the development issue that led from a WRC resolution to a WRC recommendation has been omitted.

Table 39 provides Member State positions captured from their documents submitted to the WRC-12. There are two groups: with and without a WRC resolution.[54] The Member States that do not support a WRC resolution are CEPT, the USA, CITEL, ASMG, APT, China, and Colombia. The Member States that support a WRC resolution are RCC, Cameroon, ATU, and a multi-country proposal from the South African countries.

The actual dynamic situation was captured from the meetings on Agenda Item 1.19. The summary of the debate is presented anonymously below.

ITU-R Resolution 58 on CRS was adopted at the RA-12 after the Member States submitted their documents to the WRC-12. ITU-R Resolution 58 is new information that Member States should consider with a view to whether to review their positions.

Group A represents countries that do not support a WRC resolution. Group A expressed its concern that the current RR could govern the use of CRS. There was therefore no need for a WRC resolution. If the use of CRS requires a WRC resolution, when the new application or technology emerges, there will be a WRC resolution for every single new application or technology. This would be unacceptable for Group A.

Group B represents countries supporting a WRC resolution, considering the new information for ITU-R Resolution 58. Group B compared ITU-R Resolution 58 with its proposal for a WRC resolution. The result was that ITU-R Resolution 58 included all the concerns from a WRC resolution. Consequently, Group B developed its new position to support Group A,

[54] WRC resolution is a practical guidance to implement the CRS which Member States are obliged to implement. However, some Member States argue that the current RR can govern the use of CRS. Thus, the WRC resolution is not necessary in their opinion.

because there was no need for a WRC resolution regarding the adoption of ITU-R Resolution 58 at the RA-12.

Group C represented countries supported a WRC resolution. Group C insisted on having a WRC resolution with its views that ITU-R Resolution 58 does not include the regulatory aspect while using the CRS. Moreover, its concern over the possibility of harmful CRS interference may need the provisional regulatory framework as a WRC resolution.

Group A and Group B asked Group C to clarify the real issues or concerns regarding harmful interference. Group C expressed its concerns in more detail during the discussion. Consequently, Group A and Group B pointed out that each concern could be governed by the current RR.

Group C's issue developed from harmful interference, dynamic spectrum access, notification and coordination to regulatory matters (see Figure 24).[55]

However, Group C insisted on having a WRC resolution at the end. Two Member States from Groups A and B formally opposed a WRC resolution at the COM6 meeting. The COM6 Chairman therefore established the ad hoc group to find a compromise between Group A, Group B, and Group C.

During the ad hoc group meeting, the Chairman of the COM6 ad hoc group proposed the compromised text as the minutes of the plenary. However, Group C proposed a WRC recommendation as an alternative.

After the meeting, one Member State from Group A arranged an informal meeting between the regional representatives of Group A, Group B, and Group C. The purpose of this meeting was to compromise on all the concerns as a WRC recommendation with agreed text between the Member States. Finally, a compromise was reached at the COM6 with a WRC recommendation.[56]

It was a lengthy debate from the first day of the WRC-12, however, the spirit of consensus and compromise encouraged Member States to find an acceptable solution as the ITU tradition.

8.6 Informal channel at WRC-12

Besides the formal meetings in Tables 36 and 37, there were some informal channels for delegates to communicate during the WRC-12. The informal channels increased the participation level between the Member States in terms of the stakeholders on such issues.

The informal channel serves as an important way to encourage the discussion to be settled either as a compromise or consensus.

[55] Group C is concerned about the possibilities of harmful interference from the use of CRS, however, there is no ITU evidence or study that supports these concerns.
[56] This WRC recommendation encourages Member States to participate in further studies on CRS by the ITU SG. Member States are not mandated to implement this WRC recommendation but it is voluntary.

The informal channel forms that could be observed during the WRC-12 were a discussion and e-mail. The informal discussion was almost observed in parallel with formal meetings. For example, while the Chairman conducted the meetings, the informal discussions between the delegation and the regional groups always happened to exchange the information and prepare to express their positions. This conversation sometimes continued outside the meeting room, during break, lunch, or dinner. When the Chairman experienced a lengthy discussion, the meeting intermission took place with a small group discussion on issues.

Secondly, the informal e-mails between the stakeholders expressed their concerns, clarified issues, and updated a status or stance. These e-mails mostly originated from the meeting chairmen. Only notified Member States were included on this mailing list. This mailing list also notified remaining issues, further discussion issues, and details of meeting discussions.

8.7 Role of Sector Members

The sector Members include recognized operating agencies (e.g., Algérie Télécom SPA, China Mobile Communications Corporation [CMCC], and SOFTBANK MOBILE Corp.), scientific and industrial organizations (e.g., Free TV Australia Ltd., ZTE Corporation, and Nokia Corporation), other entities dealing with telecommunication matters (e.g., Autorité de Régulation de la Poste et des Télécommunications [ARPT], and the Telecommunications Authority of Trinidad and Tobago [TATT]), and regional and other international organizations (e.g., the Arab States Broadcasting Union, Broadcast Networks Europe, and the International Amateur Radio Union). Some of the Sector Members are part of the Member States delegation. They can perform both roles inside WRC.

Sector Members are allowed to attend WRC as observers. They are allowed to express their views and clarify their document to the meeting. However, they do not have the right to vote.

For example, at the plenary, the Chairman allowed the Sector Members to present their document and clarify their concerns. During the WRC-12 Agenda Item 1.19 discussions, one of the Sector Members expressed its view on the meeting discussions that issues went back and forth and proposed a new option to settle this debate.

8.8 Importance of missing information

The rationale underlying the RR provision was contained during the discussion, which is missing from the ITU archives. The discussion of issues and information inside an informal e-mail is only available to attending Member States. This information is missing for non-attending Member States and not documented in the ITU archives. When such issues affect the interests of the non-attending Member States, they become a matter for them to follow and seek missing information on for their understanding. This missing information is essential to them to develop further proposals to protect their interest when the issues continue to the next or future WRCs.

For example, WRC-12 Agenda Item 1.2, at which no Thai delegation attended the discussion, is crucial to Thailand to evaluate and prepare its position regarding possible consequences of the RR revisions on this agenda item at the WRC-15.

8.9 WRC-12 Agenda Item 1.2 ongoing to WRC-15

At WRC-12 Agenda Item 1.2, Thailand did not have a delegate to attend the SWG and IG meetings. Thailand therefore has no information regarding the discussion at the SWG and IG meeting, which covered the underlying issues or rationale of the discussion. The ITU archives only contain the final input and output of the WRC proceedings and RR version. The input document is from the contributions by the Member States and Sector Members. The Member States made some 25 submissions on Agenda Item 1.2 at the WRC-12, while Sector Members submitted 7 documents. During the discussion, the underlying issue of FS and MS convergence under WRC-12 Agenda Item 1.2 is missing from the archives. The outputs of the discussion are found in the Final Act WRC-12, including WRC Resolution 957 [PLEN/1] (WRC-12) – Studies Towards Review of the Definition of Fixed Service, Fixed Station and Mobile Station, and the modified WRC Recommendation 34 – Principle for the Allocation of Frequency Bands. Figure 26 shows the Agenda Item 1.2 meeting and document flow.

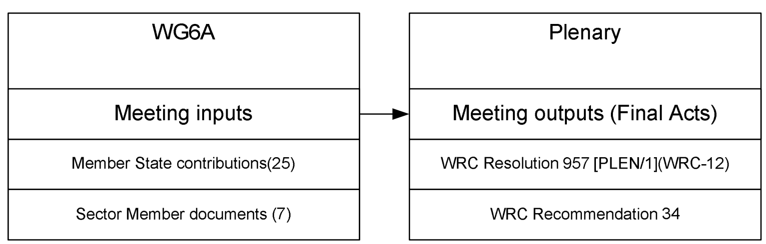

Figure 26. Agenda Item 1.2 meetings and document flow (c.f. Figure 2, Chapter 1)

Normally, the input (CPM report and submission by Member States and Sector Members) and output documents (the Final Act) of WRC are contained in the ITU archives. However, the development of issues from the four proposed options of the CPM report (FS and MS)[57] to the WRC resolution, and from two options (FSS and MSS)[58] to the WRC recommendation are not documented in the archives. Only Member States that attended the meetings have knowledge of how and why the change occurred. Thailand did not have enough delegates to be able to attend the SWG and IG on Agenda Item 1.2. The ongoing Agenda Item 1.2 argumentation is therefore not available to Thailand to consider when developing a further proposal on the matter.

[57] The CPM report proposed four options for WRC-12 Agenda Item 1.2 for FS and MS: (1) no change be made to the RR; (2) modify the FS, fixed, mobile, and land station definitions contained in Article 1 and modify Appendix 4; (3) modify the FS and fixed station definition and modify Article 11 and Appendix 4; or (4) modify Appendix 4.

[58] The CPM report proposed two options for WRC-12 Agenda Item 1.2 for FSS and MSS: (1) no change to be made to the RR and (2) to add FSS and MSS to the WRC resolution (Principle Allocation of Frequency Bands).

Only WRC Resolution 957 is going on to WRC-15 for further decision on the possibilities of definition of the revision of the FS, fixed station, and mobile station.

Thailand's concern is the ongoing issue to the WRC-15 that Thailand has no information regarding the underlying issues of the FS and MS convergence. The only available information is WRC Resolution 957 that allows further study on the possibility of a revision of the definition.

In order to prepare Thailand's position for the WRC-15 and understand how the missing information on WRC-12 Agenda Item 1.2 impacts Thailand, the existing situation, both allocation and assignment, for the FS, MS, FSS, and MSS are explored.

Current allocation FS, MS, FSS, and MSS

Thailand can use the TFA for FS, MS, FSS, and MSS, both a global and Region 3 allocation. Table 40 shows the summary of the relevant appendices and tables from this study for Thailand.

Table 40. List of tables for Thailand TFA on FS, FSS, MS, and MSS

Service	Appendix	Global allocation		Region3 allocation	
		Primary	Secondary	Primary	Secondary
FS	E	74, 76, 78	79, 80	93, 95, 96	97, 98
FSS	F	99, 101	-	104	-
MS	G	106, 108, 110	111, 112	124, 126, 127	128, 129
MSS	H	130	131	136	137

Table 40 represents the IAD scope rule for Thailand to allocate a frequency for the FS, FSS, MS, and MSS captured from the RR2012.

Table 41 and Table 42 show the number of frequency bands, bandwidth, and percentage of occupied bandwidth for the FS, FSS, MS, and MSS for a global and Region 3 allocation.

Table 41. Number of frequency band on FS, FSS, MS, and MSS for Thailand

Service	Global allocation		Region 3 allocation		Total	
	Primary	Secondary	Primary	Secondary	Primary	Secondary
FS	175	12	105	6	280	18
FSS	53	0	24	0	77	0
MS	148	19	81	9	229	28
MSS	28	9	10	8	38	17

Comparing the total frequency band in Table 28, Chapter 5, the total numbers of frequency bands for a global and Region 3 allocation are 375 and 147, respectively.

Almost 50% of the frequency band belongs to the FS for global allocation. Moreover, 75% of the frequency bands in Region 3 are allocated for the FS.

As for the MS, 45% of the frequency bands are allocated for the MS for a global allocation. In addition, 61% of the frequency bands are allocated for the MS in Region 3.

The majority of frequency bands available for Thailand to allocate are therefore FS and MS. The figure for the frequency band in Table 40 provides the scope of allocation for Thailand.

Table 42 presents the occupied bandwidth with percentages for FS, FSS, MS, and MSS for global and Region 3 allocation.

Table 42. Occupied bandwidth (kHz) with percentages for FS, FSS, MS, and MSS

Service	Global allocation		Region 3 allocation	
	Primary	Secondary	Primary	Secondary
FS	151168442.9	213920	11567937	305012.6
	(15.36)	(0.27)	(28.44)	(6.27)
FSS	83600000	0	9095000	0
	(8.50)	(0)	(22.36)	(0)
MS	157016553	1517657	10861500	1010279
	(15.96)	(1.92)	(26.70)	(20.78)
MSS	53226925	1406325	91900	912800
	(5.41)	(1.78)	(0.23)	(2.24)

In terms of the occupied bandwidth, FS and MS are the most occupied bandwidths for both global and regional allocation.

Table 41 and Table 42 provide the upper limit or scope for Thailand to allocate frequency bands to the FS and MS.

Table 43 illustrates the utilization bandwidth captured from Thailand's utilization chart in 2012.

Table 43. Thailand's 2012 utilization bandwidth for FS, FSS, MS, and MSS

Service	Bandwidth (kHz)	Occupied percentage
FS	12203456	13.56
FSS	6600000	7.33
MS	321975	0.36
MSS	144500	0.16

The percentage of occupied bandwidth is calculated from the total amount of bandwidth of 90 GHz. In Thailand, the FS is the most occupied bandwidth.

The impact of the RR revisions on FS and MS convergence will therefore affect the existing use of FS and MS in Thailand due to the majority use in terms of frequency bands, occupied bandwidths, and number of subscribers. Furthermore, consideration must be given to changing or merging the existing database that separates the FS and MS.

Consequently, the change in FS and MS convergence may influence a (almost entirely) national telecommunications regulation review. The review includes the allocation of global and Thai TFA, FS and MS regulations, the National Frequency Master Plan, frequency assignment scheme and criteria, licensing conditions, national laws (radiocommunication, telecommunication, and broadcasting), station technical characteristics, and notification and coordination process (national and international).

The possibility of the RR revision of the definition of FS, fixed station, and mobile station is conducted under the SG during the WRC-15 study cycle. The study output will be available in the CPM report for the WRC-15 to make a further decision on the RR revisions.

8.10 Preparatory work on the definitions of FS, fixed station, and mobile station for the WRC-15

The study demonstrates that the ITU archives are incomplete and cannot provide the rationale behind the RR provisions. The following example illustrates the use of this study as the starting point or basic information to further explore the ITU archives in depth.

The issue of WRC-12 Agenda Item 1.2 left over for consideration by the WRC-15 was the possibility of reviewing and revising the definition of FS, fixed station, and mobile station. Further study of WRC-12 Agenda Item 1.2 is continuing to the WRC-15 under the WP1B. The study takes into account the convergence between the FS and MS by these three definitions.

The result of this study provides the starting point to further explore Table 19, Table 22, and Table 23, Chapter 5. The specified version of the RR has shown the original point of exploration for further exploration of the relevant RR versions. The exploration is finished when the definition is matched with the current version (RR2012).

Fixed service

The definition of "fixed service" first appeared in the General Regulations annexed to the Washington D.C. 1927 Convention, Article 1, Definition, p. 30:

"A service effecting radioelectric communications of any kind between fixed points, but does not include the broadcasting service or special services"(ITU, 1927, p. 30).

In 1932, the Madrid Convention changed the definition slightly by deleting "effecting," changing "any" to "all," and "not include" to "with the exception of":

"A service of radioelectric communications of all kinds between fixed points, with the exception of broadcasting services and special services" (ITU, 1932a, p. 6).

In Cairo 1938, the definition changed "radioelectic communication" to "radiocommunication":

"A radiocommunication service of any kind between fixed points, with the exception of broadcasting services and special services" (ITU, 1938, p. 2).

The RR1947 changed the definition to "service of radiocommunication":

"A service of radiocommunication between specified fixed points" (ITU, 1947, pp. 3-E) and continued to use it in the RR1959, RR1968, and RR1976.

In the RR1982, the definition changed back to "radiocommunication service":

"A radiocommunication service between specified fixed points" (ITU, 1982, pp. RR1-3), which continued being used in the RR2008, Provisional of Final Act WRC-12, and RR2012.

Table 44 shows the development of the "fixed service" definition.

Table 44. Fixed service definition

RR	Service	Medium	Location	Exception
1927	Service	Radioelectric	Fixed points	Broadcasting or special services
1932	Service	Radioelectric	Fixed points	Broadcasting or special services
1938	Radiocommunication service	-	Fixed points	Broadcasting or special services
1947	Service of radiocommunication	-	Specified fixed points	-
1982	Radiocommunication service	-	Specified fixed points	-

The development of the "fixed service" definition does not have a significant change through time. The main concept of radiocommunication service between specified fixed points represents the main characteristic of the FS.

Fixed station

The development of the "fixed station" definition started in Madrid 1932, General Radiocommunication Regulation Annexed to the Madrid 1932 Convention:

"A station not capable of moving which communicates, by means of radiocommunication, with one or more stations similarly established" (ITU, 1932a, p. 6).

In the RR1947, the final development was shortened and appeared as follows:

"A station in the fixed service" (ITU, 1947, pp. 4-E). This definition continued being used in the RR2008, Provisional of Final Act WRC-12, and RR2012.

Table 45 shows the development of the "fixed station" definition.

Table 45. Fixed station definition

RR	Characteristics	Means	Location	Scope
1932	not capable of moving	radiocommunication	one or more stations	-
1947	-	-	-	A station in the fixed service

The concept changes from a specific detail of station and narrows to the scope of station that is already mentioned in the FS definition.

Mobile station

The definition of "mobile station" first appeared in the General Regulations annexed to the Washington D.C. 1927 Convention, Article 1, Definition:

"Any mobile station whatever; all mobile stations wherever they are" (ITU, 1927, p. 29).

The new definition was developed and contained in the General Radiocommunication Regulation Annexed to the Madrid 1932 Convention, Article 1, definition:

"A station capable of moving which ordinarily does move" (ITU, 1932a, p. 5).

In Cairo 1938, the definition changed slightly from "ordinarily" to "usually":

"A station capable of moving which is usually moving" (ITU, 1938, p. 4).

The final version of the definition was adopted in Atlantic City 1947 with an explanatory clause for location both in motion and during halts:

"A station in a mobile service intended to be used while in motion or during halts at unspecified points" (ITU, 1947, pp. 5-E) and continued being used in RR2008, Provisional of Final Act WRC-12, and RR2012.

Table 46 shows the development of the "mobile service" definition.

Table 46. Mobile station definition

RR	Characteristics	Location	Scope
1927	whatever	wherever	-
1932	moving which ordinarily does move	-	-
1938	moving which is usually moving	-	-
1947	in motion or during halts	at unspecified points	A station in a mobile service

The concept of the mobile station definition gradually changes from "any mobile station" to "moving station" to "station in motion or during halts." The location of the mobile station is unspecified by nature. Finally, the scope of the mobile station is specified according to the MS.

8.11 Summary and discussion on research questions

This chapter responds to sub-research question 2: *What information would be more useful for making decision?* and sub-research question 3: *How does the missing information affect international spectrum policy?*

The study describes the WRC-12 environment in terms of the organization and document. Moreover, at the WRC-12, the study illustrates WRC-12 Agenda Items 1.19 and 1.22 activities by participant observations. The observation demonstrates the document flow from the plenary to the SWG or IG, the approval process from the SWG or IG to the plenary, the negotiation among Member States on the issues, and the issue development on WRC-12 Agenda Items 1.19 and 1.22.

The study explores the WRC-12 meeting documents: the input from the Member States and the Sector Members as well as the administrative document by the ITU BR for preparation and facilitation at the WRC-12 meetings.

The study also addresses the missing information during the discussion of WRC-12 Agenda Items 1.19 and 1.22. This missing information can be captured at the SWG and IG levels. The author attended the relevant WRC-12 Agenda Items 1.19 and 1.22 meetings to illustrate the missing information from the ITU archives, which is the rationale underlying the discussion and available only to attending participants.

The study illustrates how the missing information affects the decision-making during the Member States' negotiations in the case of WRC-12 Agenda Item 1.19. The summary of WRC-12 Agenda Items 1.19 and 1.22 follows.

The CRS or WRC-12 Agenda Item 1.19 is a controversial issue. The issue is gradually developed at several IG meetings. The development of the argument is from the harmful interference to dynamic spectrum access issue. Consequently, the argument moves to MIFR notification and coordination. Finally, regulatory matters (during ITU-R Resolution 58 on CRS study) are reported to the next WRC via the BR Director's report. The final outcome is the WRC recommendation as a compromise solution between the Member States.

Additionally, the SRD or WRC-12 Agenda Item 1.22 is solved at the RA-12 with ITU-R Resolution 54-1 (further studies on harmonization of short-range devices). Consequently, there are no more issues for discussion: only the documentation of the approval process is required to complete the matters.

The missing information during the discussion in an informal meeting creates an information asymmetry between the attending and non-attending Member States. Moreover, the missing information at the SWG and IG meetings is not documented in the ITU archives, and Member States that use the ITU archives have incomplete information. The information is a matter when the issue may change outcomes or propose new options. When such an issue continues to the next or future WRC, the information is a matter for non-attending Member States to prepare and develop their position on relevant meetings if the issue has a strong effect on their interest.

The demonstration of WRC-12 Agenda Items 1.19 and 1.22 fulfills the second and third sub-research question to identify the missing information from the ITU archives in terms of the discussion by the Member States at the SWG and IG meetings. This discussion contains the rationale underlying the RR revisions. Moreover, the demonstration of the missing information on WRC-12 Agenda Item 1.19 provides the effects of the international spectrum policy at the higher level, such as at the WG, COM, and plenary.

Sub-research questions 2 and 3 are important for the study to investigate the missing information and the effect of the missing information in the context of WRC-12 Agenda Items 1.19 and 1.22. The result displays the missing information, leaving the Member States that use the ITU archives with incomplete information. The missing information cannot be documented during the negotiations by the Member States at the SWG and IG meetings. Moreover, the missing information is only available to attending Member States. The missing information therefore creates an information asymmetry between attending and non-attending Member States.

Moreover, the study provides the background to the definition of the FS, fixed station, and mobile station for the ongoing WRC-12 Agenda Item 1.2 to the WRC-15.

The study also explores the ITU archives with the relevant RR provisions, including the development of the FS, fixed station, and mobile station definition.

Moreover, the study elaborates on how Thailand is affected by the missing information on WRC-12 Agenda Item 1.2 in terms of reviewing the current situation on the FS and MS and the preparatory work toward the WRC-15.

The review of the current status of the FS and MS in Thailand provides the basic information to analyze the effect of the FS and MS convergence. The availability of frequency allocation and occupied bandwidth is presented. The preparatory work for the WRC-12 on reviewing the FS, fixed station, and mobile station is also reported.

The exploration of the ITU archives provides the background to the FS, fixed station, and mobile station definition development. The existing situation of frequency allocation and frequency utilization for FS and MS in Thailand also provides critical information to analyze the impact or consequences of the RR revisions. This information serves as the basis to analyze the effect of Thailand's spectrum management policy corresponding to the third sub-research question: *How does the missing information affect international spectrum policy?*

The third sub-research question is crucial to the study to reflect on the consequences of the missing information for the international spectrum policy. Moreover, it helps to understand how the missing information affects attending as well as non-attending Member States in their decision-making process at WRC.

To conclude, this chapter illustrates the useful information as the missing WRC-12 Agenda Items 1.19 and 1.22 responding to the second sub-research question. Moreover, the study also demonstrates how this missing information affects the decision-making process at the WRC-12, corresponding to the third sub-research question. Furthermore, the importance of WRC-12

Agenda Item 1.2 raises concern for Thailand's response to the FS and MS situation and preparatory work for the WRC-15 corresponding to the third sub-research question.

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Chapter 9 Analysis and policy recommendation

This chapter provides analyses on the IAD framework applied to the justification of the WRC-12 IG6A2-1.19. WRC-12 Agenda Item 1.19 is used to illustrate the nature of the missing information from the ITU archives and potential usefulness of the data. Finally, the policy recommendation to relieve the missing information at WRC is presented with advantages and disadvantages.

9.1 Statement of problem

The study addresses problems of missing information in an international spectrum policy setting within WRC in terms of the RR provision interpretation by observing Member States and Sector Members implementing the RR. Interpretations vary because stakeholders have views that are linked to their own conflicting interests. With this context in mind, the ITU archives are explored to isolate the rationales behind such RR provisions. Unfortunately, the ITU archives are incomplete. Only the input and output documents of the WRC proceedings and RR versions are included in the archives.

Accordingly, this study proposes the IAD framework as a vehicle to capture delegate interactions during meetings, including the position, payoff, choice, information, and aggregate rules. However, the IAD framework provides only the general list of missing data, not detailed content of the discussion.

Consequently, observations by the author from attending the meetings are a means to obtain interaction details from the discussions. The observations provide the insight views expressed at meetings. Importantly, such observations can only be obtained for the current situations, not past events, that is, the information for past events is permanently lost.

Member States that are unable to attend meetings have no information about the nature of the discussions. This missing information (from the ITU archives) becomes an issue or serious matter for Member States that prioritize issues based on their interest. When issues carry over to the next or future WRCs, these Member States are in a weak position to develop further arguments. Most Low Income countries cannot attend all the meetings. This income difference has led to the information asymmetry arising between High and Low Income countries. Thus, poor countries can only rely on the ITU archives as a source of information.

The study proposes that the reporting of interaction information is recorded. Such information would benefit everyone, especially poor countries (see Chapter 1 and Chapter 2). This study also proposes that Member States network as an alternative solution, especially, in connection with a regional representative in charge of the WRC agenda items.

9.2 Application of the IAD framework to the WRC negotiations

The study applies the IAD framework to analyze WRC negotiations conducted at various meetings addressing potential RR revisions. The framework elements are presented in Table 47.

Table 47. IAD variable map, missing data, and observer activities (c.f. Table 10, Chapter 2)

IAD variable	WRC	RR/WRC Archive	Participant observation PTA, CPG, APG	Participant observation WRC-12
Physical condition	Spectrum as public good	X	X	X
Community attribute	Norm, culture, and tradition		X	X
Rules-in-use				
Boundary	ITU membership	X	X	X
Position	HoD, Regional Rep., Chair, Secretary	X	X	X
Choice	Support, oppose, neutral		X	X
Payoff	Cost and benefit		X	X
Information	Public or informal information flow		X	X
Aggregate	Control over choice		X	X
Scope	ADD, MOD, SUP, NOC	X	X	X
Action situation	Negotiation		X	X
Interaction	Negotiation		X	X
Evaluation criteria	Link payoff rules		X	X
Outcome	Link RR revisions to scope rules	X	X	X

Table 47 records the mapping of IAD variables to the WRC context. In doing so, the broad classes of missing data are also identified, as in an observer activity.

The above IAD-WRC mappings are next applied to the particular IG6A2-1.19 meeting for a WRC recommendation.

Physical conditions are the object of the study. In the context of Agenda Item 1.19, consider whether a WRC recommendation is required for CRS spectrum use as a non-exclusive scheme (public goods).

Community attributes or attributes of community is a basic understanding of the IG6A2-1.19 issue within the meeting. At the meeting, delegates clearly require an understanding of the meetings' objective for the issue to progress. The Chairman's role is to encourage compromise between Member States to accept a WRC recommendation. Meeting compromises and consensus are a tradition within the ITU process.

Rules-in-use can be represented by the following rules:

At the meeting, a delegate's role is as an individual or regional representative (boundary and position rules) to provide views. Individual and regional representatives have different contexts in which their views are formed and expressed.

When a chairman calls for any further modification to a WRC recommendation, the representatives offer their opinions. Subsequently, other delegates review any proposal change (based on their national or regional interest – the payoff rule and associated criteria) and consider whether to support, oppose, or remain in a neutral position on the issues (choice rules). Information exchange flows from proposals and counter-proposals (information rule), the role of the chairman is to distil the debate and suggest compromise propositions for consideration. The information rule also influences individual and regional stances (aggregate rule), and meeting outcomes (scope rule and outcomes). Finally, the IG6A2-1.19 output document containing the WRC recommendation is agreed between the Member States.

This process illustrates the IAD framework applied to the IG6A2-1.19 meeting. However, the IAD framework only provides a general guideline for the source of missing data, not the detailed discussion elements. Only an observer has the ability to obtain detailed information or meeting negotiations. The current ITU archive procedure cannot be documented meeting interactions. That is, only input documents submitted by Member States and output of a WRC recommendation are recorded.

9.3 Agenda Item 1.19 missing information cost

WRC-12 Agenda Item 1.19 is not contained in the WRC-03 and WRC-07 CPM reports. However, this agenda item is introduced through documents submitted by Member States for the WRC-07. At the WRC-07, it was finalized and included in WRC-12 agenda items.

WRC-12 Agenda Item 1.19 concerns SDR and CRS technologies (see Chapter 8). Here, the focus is on CRS, because there are currently subject proposals and counter-proposals.

The “Document” column in Table 48 identifies the Member States’ positions on the CRS issues. For example, “5 A19” refers to document number 5 Annex 19. “SUP” means suppression of Resolution 956 (i.e., it is an instruction to delete the resolution from the RR). “ADD” means the addition of the WRC resolution (i.e., it is an instruction to add a WRC resolution to the RR). “WRC rec” is a WRC recommendation.

Table 48. WRC Agenda Item 1.19 document positioning (c.f. Table 39, Chapter 8)

Member States	Input				Output
	Document	RR change	Resolution 956	WRC resolution	Final Act
CEPT	5 A19	No	SUP		WRC rec [COM6/1]
RCC	6 A19	No	SUP	ADD	
USA	9 A19	No	SUP		
CITEL	10 A19	No	SUP		
Cameroon	15 A15	No	SUP	ADD	
ATU	17 A19	No	SUP	ADD	
Multi-country*	19	No	SUP	ADD	
ASMG	25 A19	No	SUP		
APT	26 A19	No	SUP		
China	45 A19	No	SUP		
Colombia	90				
Multi-country*	97 A19	No	SUP	ADD	

*Angola (Republic of), Botswana (Republic of), Democratic Republic of the Congo, Lesotho (Kingdom of), Madagascar (Republic of), Malawi, Mauritius (Republic of), Mozambique (Republic of), Namibia (Republic of), Seychelles (Republic of), South Africa (Republic of), Swaziland (Kingdom of), Tanzania (United Republic of), Zambia (Republic of), Zimbabwe (Republic of).

While Table 48 records all relevant input and output documents for Agenda Item 1.19 contained in the ITU archives, the development issue that led from a WRC resolution to a WRC recommendation has been omitted.

The Member States that do not attend meetings have no access to information on how and why issues developed as they did. When final documents are submitted to the plenary for approval, such Member States must accept negotiated outcomes with limited clarity.

Missing information

With regard to the plenary through the IG, WRC-12 Agenda Item 1.19 is considered via 26 meetings. The CRS issues were initially developed at the SWG and IG meetings. The WRC resolution proposal is developed from the impact of CRS considering harmful interference to other services and, in particular, issues related to dynamic spectrum access. With dynamic access deemed not to be the core problem, the focus of the alternative moved to notification and coordination and, finally, to regulatory matters. The final format of the regulation developed from a WRC resolution, a BR Directors’ report, to a WRC recommendation. This final recommendation is contained in the Final Act. The Final Act is an archived document.

Figure 27 depicts the CRS issue development.

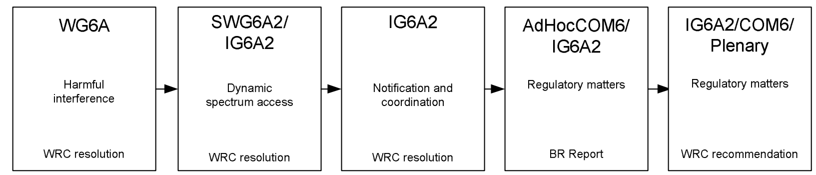

Figure 27. Agenda Item 1.19 issue development (c.f. Figure 24, Chapter 8)

Information not contained in the archives includes the options proposed at the IG meetings by the SWG6A2 Chairman, in particular, because the IG6A2 meeting was deadlocked on whether CRS required an additional regulation and the form of that regulation. At the IG6A2, the Chairman proposed the following compromise proposals: (1) that no RR change be made and that WRC Resolution 956 be suppressed; (2) that no RR change be made and WRC Resolution 956 be suppressed with additional text with no additional regulation required; (3) that no RR change be made and that WRC Resolution 956 be suppressed with an additional text included in the BR Directors’ report to the next WRC to explain the RR difficulties or inconsistencies; 4) that no RR change be made and WRC Resolution 956 be suppressed with an additional text included in the RA report to the WRC via the BR Directors’ report; (5) that a cross-border coordination handbook be developed in the WP5A and WP5C; (6) that a list of questions be submitted to ITU-R for further study on issues related to the sharing of MS and FSS in the 3400-4200 MHz band; and (7) that no RR change be made, the WRC Resolution 956 be suppressed, and an additional WRC resolution be made.

The SWG6A2 discussed the Chairman’s seven proposals. The meeting agreed that Proposal (1), Proposal (3), and Proposal (7) move forward for further consideration at the WG6A.

The final outcome was contained in a WRC recommendation of the Final Act with Proposal (3) (see Chapter 8).

Usefulness of missing information

Member States that did not have delegates in attendance at the SWG and IG meetings have no information in relation to the "lost" proposal, namely, Proposal (2), Proposal (4), Proposal (5), and Proposal (6).

Consequently, when WRC-12 Agenda Item 1.19 CRS issues are studies further via ITU-R Resolution 58, the focus of the study is Proposal (3). The SGs report to the RA-15, which sends an approval to the WRC-15.

The WRC-15 will consider the report on the CRS agenda item. The input document includes the study report form SG concerning Proposal (3). The report is housed in the ITU archives, which give all Member States an equal opportunity to review the status quo of the issues.

However, the deliberations concerning Proposal 2, 4, 5, and 6 are effectively "lost" to Member States that did not send delegates to the WRC-12. The practical importance of this state is that the trajectory of future debates and resolution is path-dependent on the information received from the archives.

The nature and form of these data are effectively framed by delegates in attendance at the WRC-12. That is, they frame future debates.

9.4 Policy recommendation

The ITU archives are incomplete (see the illustration of the development of the WRC and RR provisions contained in Chapter 5 and Appendices A, B, C, D, E, F, G, H, I, and J). The archives only provide the WRC proceedings and RR versions, excluding the rationale issue development that underlies RR provisions and their changes.

The IAD questions provide an outline that enables the capture of interactions between Member States at meetings, but not the detailed discussions.

The study proposes three possibilities to solve the missing information as follows:

1) An information record form developed for implementation by the BR. The form would be completed by a BR officer designated by the Chair. The records would form part of the ITU archives for inclusion together with the ITU webcast archives.

Table 49 shows the format of the proposed document.

Table 49 presents an example of a completion of Agenda Item 1.19 CRS concerning the otherwise missing information. This information shows issue developments with the parties concerned: initiating, supporting, and opposing. When this information becomes available, all Member States have information equality, and information asymmetry between the attending and non-attending Member States is minimized.

Table 49. Information recording form

Meeting:	Room:	Date:	Time:
Issues	Party with reason		
	Initiating	Supporting	Opposing
e.g., CRS 1.19			
Dynamic spectrum access	Country A	Country B	Country C, D, E
Notification and coordination	Country A	Country B	Country C, D, E
Regulatory matters during the ITU-R study	Country A	Country B	Country C, D, E

The form would act as a guide to propose the ITU webcasts also contained in the archives. The form should be completed for all meetings, especially the SWG and IG meetings, with the corresponding webcast.

Advantages

-The missing information is available to all Member States.

Disadvantages

-The extra budget for the recording system in every room should be implemented.

-As the meeting secretary, the BR officer should fill in the form (same as the log book). It may impose some extra work on the meeting secretary.

2) Minutes of meeting, at WRC only plenary session has the minutes of meeting. Most of plenary minutes summarize the approval of document. The COM, WG, SWG, DG, IG meeting do not have minutes of meeting. The minutes of meeting below the level of plenary session contain the rationale of RR revision. Such minutes of meeting can be summarized the discussion or debate by meeting chairman or secretary. The implementation of minutes of meeting at all meeting forms will capture the reason behind RR revision.

Advantages

-The missing information is available to all Member States.

Disadvantages

-The extra work for the meeting secretary and chairman summarizing meeting discussion should be considered.

3) Discussion forum during WRC, at the WRC-12 the SharePoint site is introduced to facilitate shared folders for Member States to exchange informal documents during meetings.[59] The WRC-12 SharePoint site requires a TIES system for access. Moreover, inside

[59] The SharePoint Site is the website provided by the BR during the WRC-12. This website is used for Member States to upload and download the working document during the WRC-12. To access this website, the TIES user is required.

the SharePoint, the functions "Announcement" and "Tags & Notes" provide an additional communication channel. However, no one is interesting in using it. It is an opportunity to fully use the SharePoint site as a discussion forum during WRC. The BR should inform Member States of this function. More information could be added from the existing "SharePoint Sites Information" regarding the discussion forum.

Advantages

-Additional channel to communicate, obtain the missing information and follow up the discussion

-No extra cost for implementing the software development

Disadvantages

-Additional work on guidelines on using the discussion forum (BR officers).

-Additional work for the meeting between the Chairman and secretary, and stakeholders who post the files and comments must be aware of a response time (need immediate response)

4) Member States Networking (regional representatives): The connection between Member States and Sector Members becomes more important before, during, and after WRC. In order to exchange information, including the position and rationale behind it, and a formal or informal discussion establishes the connection. However, the content of the issues varies for each agenda item.

For Low Income countries, it is difficult to send a delegate to the relevant meetings, apart from WRC. Even for WRC, there are limited resources. Member States should prioritize the WRC agenda items based on their national interest or benefit.

During the national preparatory work for WRC, Member States should identify the coordinator on each agenda item to be a contact or focal point and follow the relevant activities at both national and international meetings. The preliminary views on each agenda item should be prepared in order to initiate the discussion in the meeting.

Consequently, the contact point should follow the relevant activities in order to find the regional representative or coordinator on each agenda item at the regional preparatory meeting either from participation or electronic communication. The coordinators prepare the common views as a regional position to WRC. The discussion or communication with coordinators provides the information and rationale between stakeholders.

When the national position is in line with the regional positions, the regional proposals can be supported. The communication with the coordinator will update the discussion on this issue.

When the national and regional positions are in conflict, the regional proposals cannot be supported. Frequent communication with the coordinator will provide an insight position between the Member States that can be used to form the multi-countries proposal, if necessary.

Advantages

Obtain information from a regional representative when Member States cannot participate in the meetings.

Disadvantages

Take time and money to build up Member States networking, i.e., attending relevant meetings (local, regional, and global).

9.5 Summary and discussion on research questions

This chapter responds to sub-research question 2: *What information would be more useful for making decision?*; sub-research question 3: *How does the missing information affect international spectrum policy?;* and sub-research question 4: *How can the existing ITU archives be improved or added to?*

The study describes and prescribes the IAD framework in order to understand and apply the framework to the WRC context. The IAD framework helps to differentiate the capability between the ITU archives and observation, and to identify the limitation of the ITU archives and the observations.

The results of the IAD analysis identifies the ITU archives as incomplete because they lack the rationale underlying the RR provisions. The study further expands the element of the IAD framework to fulfill the missing information: the interaction or discussion comprising the attribute of community (common understanding between participants at the meetings), choice rule (the options that are available at the meetings), payoff rule and evaluative criteria (the evaluation of the option according to the choice rule), information rule (the information exchange inside the meetings), aggregate rule (the control of the Member States' stance at the meetings), action situation and interaction (discussion at the meeting).

The study also explains the limitation of the ITU archives that can be fulfilled by the participant observation via the meeting attendances. However, the observation is only available in the current situations.

Moreover, the study demonstrates the application of the IAD framework to the IG6A2 1.19 at the WRC-12 to show the missing information from the ITU archives.

The analysis of the IAD framework in the WRC context reveals the type of the missing information as the IAD element responding to the second sub-research question: *What information would be more useful for making decision?*

The second sub-research question is crucial to identifying the type of missing information or rationale that is not documented in the ITU archives. Moreover, the second sub-research question reveals the fact that the ITU archives are incomplete, and it raises awareness of the Member States that use these ITU archives with caution that the ITU archives do not contain the rationale of the RR provision, only the input and output of the WRC proceeding and RR version are available.

The study uses the observation of WRC-12 Agenda Item 1.19 at the SWG meeting to demonstrate the missing information. Furthermore, the effects or consequences of the missing information on the decision-making process at the higher-level meetings and the usefulness of the missing information are prescribed.

At the SWG6A2 1.19, the seven proposals from the Chairman were put forward, however, the meeting decided to select only three options to forward to the next meetings. This meant that the other four options were left out. These options were not documented. Only the attending participants have this missing information. When this information becomes available to other Member States, especially non-attending Member States, the missing information becomes a possible option for Member States to make a decision.

The study demonstrates the usefulness of the missing information in the case of SWG6A2 to respond to the third sub-research question: *How does missing information affect the international spectrum policy?* The third sub-research question is important to enlighten the cruciality of the missing information in the international spectrum policy as WRC to the Member States that do not attend such meetings. When the missing information is available, the Member States can have additional information to decide on at WRC.

In order to improve the missing information in the ITU archives, the study also proposes three possible methods as policy recommendations to improve them: (1) a meeting record form with webcast archives, (2) minutes of meeting below the level of plenary session, (3) the enhancement of the SharePoint Site in the discussion forum, and (4) Member States networking for a regional representative connection. Moreover, the study also provides the advantages and disadvantages of each option, responding to the fourth sub-research question: *How can the existing ITU archives be improved or added to?*

The fourth sub-research question is the final output of this study to manage the missing information in the ITU archives. This sub-research question is crucial to the study to complete the whole process from the exploration of the ITU archives, identification of the missing information, analysis of the effects of the missing information, and improvement of the ITU archives.

To conclude, the study applies the IAD framework as the guidelines to identify the missing information from the ITU archives. Moreover, the study demonstrates how the missing information affects the international policy setting in the case of WRC-12 Agenda Item 1.19. Finally, possible solutions to reduce the missing information are proposed: (1) a meeting summary record form with the webcast archives, (2) minutes of meeting below the level of plenary session containing a meeting discussion summary, (3) full utilization of the SharePoint Site, and (4) Member States networking, especially a regional representative on the WRC agenda items.

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Chapter 10 Summary and findings

This chapter provides an overview and findings of the study. The explicit answer to the research question is also illustrated.

10.1 Synthesis

Looking back at the complex issues associated with the RR processes, the author provides a summary below.

Problem

An RR interpretation problem always arises when Member States and Sector Members implement changes to the RR provisions. Interpretations can vary because stakeholders have very different views about the RR that are linked to their own interests, leading to conflict. The ITU archives are explored by the Member States to obtain a rationale that underlies such provision changes. However, the ITU archives only contain the final form of the input and output documents of the WRC proceedings, along with the RR versions (Chapter 1).

The study has the main research question: *How is international spectrum policy developed and affected by the lack of detailed documentation?* In order to respond to the main research question, the study has four sub-research questions as follows:

1. How is international spectrum policy set in terms of ITU structure, WRC, and the RR, and how did they develop?
2. What information would be more useful for making decision?
3. How does the missing information affect international spectrum policy?
4. How can the existing ITU archives be improved or added to?

Purpose

The purpose of the study is to understand the information needs and coordination in the international spectrum policy setting, including the processes and archives relevant to the ITU (WRC proceedings and RR versions). The study also proposes a possible way to alleviate the missing information in this policy setting.

The study attempts to explore and explain the WRC and RR developments. Moreover, the author observed the PT A, CPG, APG, and WRC-12 meetings with a view to obtaining insights into the nature of and substance information lost through adequate archiving. In particular, the study illustrates the preparatory processes of the WRC-12 Agenda Items 1.19 and 1.22 at both national and regional meetings. WRC-12 Agenda Item 1.19 is the focus for demonstrating the valuable nature of the lost information. Furthermore, the importance of WRC-12 Agenda Item 1.2 to Thailand is illustrated. The study proposes that the missing information (corresponding to the IAD framework analysis) be completed along with webcasts. Together, these initiations would directly address the situations of information asymmetry between rich and poor countries. The full utilization of the SharePoint Site

provides an additional opportunity for communication between the Member States during WRC. Furthermore, Member State networking in terms of connection with the regional representatives on the WRC agenda items helps the non-participating Member States fill in the missing information.

Method

The study uses both inductive and deductive approaches, and primary and secondary data. The primary data are obtained from observations made during the meeting negotiations at the PT A, CPG, APG, and WRC-12. The secondary data are obtained from the ITU, CEPT, and APT archives. The keyword mapping helps to track the relevant provisions across the RR versions.

The IAD framework provides a "concerned question" list to capture the rationale driving the negotiations.

Participant observations at meetings allow for more complete meeting documentation. A limitation of such observations is that they can only be conducted for current situations, not past events. Accordingly, the process is one of demonstration, with full implementation requiring complete documentation at meetings, which is subsequently included.

10.2 Result

The results of the study are as follows:

(1) ITU structure development (Chapter 4)

The study provides the ITU structure development since 1865, from the International Telegraph Union to ITU via the International Telegraph Conference, International Telecommunication Conference, and Plenipotentiary Conference. The major change to the ITU structure is a result of the study by the High Level Committee during 1989-1992. The current ITU structure is the decision of the APP1992 and its amendments (1994, 1998, 2002, and 2006).

(2) RR development (Chapter 5) and Appendices A, B, C, D, E, F, G, H, I, and J

The study provides a review of the WRC and RR developments in terms of: (1) key definitions (telecommunication, radiocommunication, and radio waves), (2) important provisions (choice of apparatus, frequency assignment provision, licenses, allocation, allotment and assignment, priority of services, radiocommunication services, and radiocommunication station), and (3) frequency band developments (MMS, MMSS, BS, BSS, FS, FSS, MS, MSS, SRS, and EESS).

(3) WRC preparatory work

3.1) WRC agenda-setting process (Chapter 6)

The WRC agenda-setting process provides a standard for ITU to prepare the WRC agendas for the next and future WRC in the CPM report. The WRC agenda-setting has two study cycles for preparation, i.e., the next and future WRC agendas in the CPM report. The whole WRC agenda-setting process takes eight years.

However, the last WRC is a crucial forum in which to approve the next WRC agenda before CC approval. This means that the agenda items, including the CPM report, for the next and future WRCs are not guaranteed inclusion in the final version of the WRC agenda by the last WRC approval. Interested Member States with limited resources should pay attention to the last WRC that is finalized in the next WRC agenda.

3.2) WRC study process (Chapter 7)

The WRC study process for WRC-12 Agenda Items 1.19 and 1.22 provides the output of the discussion from the ITU SG and the issues of these agenda items that use one WRC study cycle. The output from the SG is presented in the CPM report as the options for Member States to decide on at the WRC-12. Moreover, the output from the RA-12 provides additional information for Member States to consider at the WRC-12

3.3) National and regional preparatory meeting (Chapter 6)

The national and regional preparatory work assists the WRC preparatory process before WRC. The study elaborates on Thailand and Sweden as national preparatory processes and the APG and CPG as regional preparatory processes.

The study provides an inside view of the PT A, CPG, and APG on WRC-12 Agenda Items 1.19 and 1.22 via attendance by the author. The record of the meeting discussions reveals the rationale behind the ultimate resolutions not contained in the archives. This information provides a more complete basis for understanding the state of the issue and the development of further arguments at the relevant meetings.

During the discussion, the rationale on how it changes, as the missing information, is available to an attending Member State. The author participated in the national and regional preparatory meetings, providing the missing information apart from the archives.

The CPG and APG, as the regional forums, allow discussion of regional interests and preparation of common proposals for WRC. The process reduces the volume of submitted documents. Moreover, regional coordinators, as regional representatives, negotiate and report to the regional coordination meetings.

Furthermore, national and regional preparatory meetings represent the forums in which the stakeholders can negotiate at national and regional level. The connections between the stakeholders form the networking to exchange information before, during, and after the meeting. This networking also helps them understand the rationale of the discussion, which is omitted from the archives. Networking is also a possible solution to improve the ITU archives as the fourth sub-research question.

(4) WRC-12 Agenda Items 1.19 and 1.22 (Chapters 7 and 8)

The WP1B and WP1A of SG1 are in charge of WRC-12 Agenda Items 1.19 and 1.22, respectively. The study explores the input and output documents of the ITU members' contribution for both WPs. The illustration of the study output is presented as follows.

The output of the WP1B provides one option for the SDR and three options for the CRS in the CPM report for WRC-12 Agenda Item 1.19. The SDR issue is that there is no change to the RR. There are three options for the CRS issues: (1) no change to the RR (Method B1 option 1), (2) no change to the RR with the ITU-R resolution for CRS requiring further study (Method B1 option 2), (3) and no change to the RR with the WRC resolution for CRS requiring further study (Method B2).

The output of the WP1A provides four options in the CPM report for WRC-12 Agenda Item 1.22: (1) no RR change (existing RR and ITU recommendations and reports can govern the SRD) (Method A), (2) a WRC resolution (further study on SRD global and regional harmonized frequency bands) (Method B), (3) a footnote similar to the ISM footnote (recognize existing SRD use ensuring no harmful interference to existing services) (Method C), and (4) a new SRD definition under in the Article 1 (Method D).

Moreover, the output from the RA-12 provides two ITU-R resolutions for WRC-12 Agenda Items 1.19 and 1.22: ITU-R Resolution 54-1 and ITU-R Resolution 58, respectively.

The study also addresses the missing information during the discussion of WRC-12 Agenda Items 1.19 and 1.22. This missing information can be captured at the SWG and IG levels. The author attended the relevant meetings on WRC-12 Agenda Items 1.19 and 1.22 to illustrate the missing information from the ITU archives, which is the rationale underlying the discussion and is available only to attending participants.

The study illustrates how the missing information affects the decision-making during the negotiations by the Member States in the case of WRC-12 Agenda Item 1.19. A summary of WRC-12 Agenda Items 1.19 and 1.22 follows.

The CRS or WRC-12 Agenda Item 1.19 is a controversial issue. The issue is gradually developed at several IG meetings. The development of the argument stems from the issue of harmful interference to dynamic spectrum access. Consequently, the argument moves to MIFR notification and coordination. Finally, regulatory matters (during ITU-R Resolution 58 in the CRS study) are then reported to the next WRC via the BR Director's report. The final outcome is the WRC recommendation, as a compromise solution between the Member States.

The SRD or WRC-12 Agenda Item 1.22 is solved at the RA-12 with ITU-R Resolution 54-1 (further studies on the harmonization of short-range devices). Consequently, there are no more issues for discussion; only the documentation on the approval process is required to complete the matter.

The missing information during the discussion in an informal meeting creates information asymmetry between attending and non-attending Member States. Moreover, the missing information at the SWG and IG meetings is not documented in the ITU archives. The information matters when the issue could change outcomes or propose new options. When such an issue continues to the next or future WRCs, the information matters to non-attending Member States that need it to prepare and develop their position at the relevant meetings if the issue has a strong effect on their interests.

The demonstration of WRC-12 Agenda Items 1.19 and 1.22 fulfills the ITU archives in terms of the Member States' discussions at the SWG and IG meetings. These discussions contain the rationale underlying the RR revisions. Moreover, the demonstration of the missing information for WRC-12 Agenda Item 1.19 also provides the effects to the international spectrum policy at a higher level, such as at the WG, COM, and plenary.

(5) IAD application to the WRC context (Chapters 2 and 9)

The results of the IAD analysis identify that the ITU archives are incomplete, because they lack the rationale underlying the RR provisions. The study further expands the element of the IAD framework to complete the missing information: the interaction or discussion comprising the attribute of community (common understanding between participants at the meetings), choice rule (the options that are available at the meetings), payoff rule and evaluative criteria (the evaluation of the option according to the choice rule), information rule (the information exchange inside the meetings), aggregate rule (the control of the Member States' stance at the meetings), and action situation and interaction (discussion at the meeting).

The study also explains the limitation of the ITU archives that can be fulfilled by participant observation via meeting attendances. However, the observation is only available in the current situations.

The study also demonstrates the application of the IAD framework to the IG6A2 1.19 at the WRC-12 to show the missing information from the ITU archives.

(6) Demonstration of the missing information effects on Thailand (Chapters 1, 7, 8, and 9)

The study demonstrates the effects on Thailand of the missing information on WRC-12 Agenda Items 1.2 and 1.19 in terms of its importance as basic information to analyze its impact at the meeting and for ongoing issues to the next or future WRC.

Moreover, the demonstration of the missing information on WRC-12 Agenda Item 1.19 at the SWG meeting influences non-attending Member States, as it is additional information to decide on at the WRC-12.

The missing information represents the rationale of the RR revisions or the issues at the meeting and provides an understanding for Member States to develop further argumentation at the relevant meeting for ongoing debates or implementations, such as the RR provisions.

(7) Policy recommendation (Chapter 9)

The study also proposes three possible methods as a policy recommendation to improve the ITU archives: 1) a meeting record form with webcast archives, 2) minutes of meeting below

the level of plenary session, 3) enhancement of the SharePoint Site in a discussion forum, and 4) Member State networking for a regional representative connection. The study also provides the advantages and disadvantages of each option.

10.3 Responses to research questions

The study summarizes the responses to the sub-research questions in Table 50. Table 50 presents the responses to the sub-research questions related to the content of the study.

Table 50. Responses to the sub-research questions related to the chapters of the study

RQ		Chapter								
		4	5	6	6	7	7	8	8	9
1	ITU structure development	X								
1	RR development		X							
1	How did they develop			X		X				
2	Missing information				X			X		X
3	Effects on international policy setting						X	X	X	X
4	Improvement of the ITU archives				X					X
Detailed content		Appendices A, B, C, D, E, F, G, H, I, and J		WRC agenda-setting	National, APG& CPG	WRC study process	Importance 1.19 & 1.22	Missing info 1.19 & 1.22	Importance 1.2	Analysis, missing info 1.19

The study contains the main research, i.e., *How is international spectrum policy developed and affected by the lack of more detailed documentation?* To fulfill the main research question, four sub-research questions are posed.

Sub-research question 1: *How is international spectrum policy set in terms of ITU structure, WRC, and the RR, and how did they develop?*

The study responds to the first sub-research question in four parts: (1) ITU structure development; (2) RR development; (3) WRC agenda-setting; and (4) WRC study process.

The study explores the relevant literature and cross-checks it with the ITU Convention to provide the ITU structure development in Chapter 4. The revision of the ITU structure is based on the Member States' contributions.

The study further explores the ITU archives, including the input and output of the WRC proceedings and RR versions, to construct its own database. The keywords are used to keep track of the RR provisions, and the TFA provides the RR developments in Chapter 5 and

Appendices A, B, C, D, E, F, G, H, I, and J. The results of the exploration also confirm that the ITU archives are incomplete: lack the rationale behind the RR provisions.

Furthermore, the study explores the ITU archives to explain the process of RR revision, including the WRC agenda-setting and WRC study process. The study also illustrates the WRC-12 preparatory process as the WRC standard process. The results of the WRC agenda-setting process and WRC study process are presented in Chapters 6 and 7, respectively.

Sub-research question 2: *What information would be more useful for making decision?*

The study responds to the second sub-research question, which has three parts: (1) the IAD framework application in the WRC context, (2) the national and regional preparatory meeting for WRC, and (3) WRC-12 Agenda Item 1.19.

The study proposes the use of the IAD framework as the outline for a question inside the action situation: WRC and relevant meetings. The justification for the IAD framework is also described and prescribed in Chapters 2 and 9. The results of the IAD framework application, indicating the limitation of the ITU archives, lacks the dynamic situation or discussion inside the meetings.

However, the IAD framework provides only a list of relevant questions, not the detailed contents of the discussion. The participant observations by the author are pursued to capture the debate inside the meetings, as the missing information was left out of the ITU archives.

The study also presents the missing information for WRC-12 Agenda Items 1.19 and 1.22 during the regional preparatory meetings: the CPG, APG, and WRC-12 in Chapters 6, 8, and 9.

Sub-research question 3: *How does the missing information affect international spectrum policy?*

The study responds to the third sub-research question and has two parts: (1) the importance of WRC-12 Agenda Items 1.2, 1.19 and 1.22 and (2) a demonstration of the effects on international spectrum policy.

The study also presents the importance of the missing information on WRC-12 Agenda Item 1.2 from Thailand's perspective in order to illustrate how the missing information affects Thailand's position to further develop the argument for this agenda item in Chapters 1 and 8.

Moreover, the current situation of the FS and MS in Thailand is also provided as basic information to analyze the impacts or consequences on the FS and MS convergence. The background to the definition development of FS, fixed station, and mobile station for the ongoing issue to the WRC-15 is also presented in Chapter 8.

The study presents the importance of WRC-12 Agenda Items 1.19 and 1.22 to Thailand as basic information to analyze the effects or consequences of the RR revisions in Chapter 7. It also considers the usefulness of the missing information in terms of WRC-12 Agenda Item

1.19 to demonstrate the valuable information to non-attending Member States that prioritize this agenda item in Chapter 9.

Sub-research question 4: *How can the existing ITU archives be improved or added to?*

The study responds to the fourth sub-research question and has two parts: (1) national and regional preparatory networking and (2) policy recommendations.

The study proposes three possibilities to complete the missing information in the ITU archives: (1) the meeting record form together with the webcast archives, (2) minutes of meeting below the level of plenary session, (3) full utilization of the SharePoint Site during WRC, and (4) connection with a regional representative on each WRC agenda item as Member State networking.

The proposals do not complete the ITU archives; however, they offer possible ways to reduce the missing information in the ITU archives and the information asymmetry between High and Low Income countries, or attending and non-attending Member States. The study presents the results in Chapters 6 and 9.

10.4 General policy implications and recommendations

The study proposes three possible solutions to reduce the amount of missing information in the ITU archives: (1) completing and lodging an information record form in the ITU archives along with corresponding webcast archives of all meetings, (2) implementing minutes of meeting below the level of plenary session by summarizing meeting discussion (3) making full use of the SharePoint Site to provide an additional opportunity for communication between Member States during WRC, and (4) Member State networking in terms of connections with regional representatives on the WRC agenda items to help non-attending Member States fill in the missing information.

The study illustrates that the ITU archives are incomplete because they lack the rationale underlying the RR provisions. The Member States and Sector Members must therefore implement the RR provisions carefully and be aware of the missing information from the ITU archives.

10.5 Implications for Thailand

The study contributes original work on the RR development including key definitions, important provisions, frequency bands in specified services, and the WRC preparatory process.

Basic understanding of the RR development

Thailand could use the RR development from the study contributions to understand the basic concept of the RR, especially the way the RR is reviewed and revised by WRC.

The development of the RR for key definitions, important provisions, and frequency bands in specified services provides the basic information for Thailand to further investigate the relevant RR for detailed information. The study provides a starting point as a mind map to further explore the ITU archives.

Moreover, the database compiled by the author can serve as a resource for the TFA development since no one collects and compares all the TFA in the RR versions. The database could represent a starting point for further exploration of the TFA issues

RR implementation and caution

The study confirms that the ITU archives lack the rationale behind the RR provisions. The rationale can be captured during the meeting discussions. In order to implement the RR, Thailand should be aware of this limitation, and it may consider participating in the ITU activities to obtain missing information or rationale that matters to Thailand. Thailand may start to consider the priority of the WRC agenda items in the case of limitation of resources and identify the relevant ITU activities to attend in the WRC preparatory process.

WRC preparatory process

The study illustrates the WRC preparatory process, the WRC agenda-setting and the WRC study process. The WRC agenda-setting takes two WRC cycles to complete for the next and future WRC agendas in the CPM report. However, the crucial forum is the final WRC, which finalizes the WRC agenda.

The study explores the WRC agenda-setting process from 1993 to 2012. The results of the approval of the WRC agenda items at the finalized WRC reveal that the majority of WRC agenda items comes from the contributions at the finalized WRC. Moreover, the WRC agenda prepared by the CPM in the CPM report for next and future WRC agenda items is reducing over time.

Thailand should therefore concentrate on the finalized WRC by submitting contributions to and participating in this WRC to ensure the inclusion of WRC agenda items if necessary.

With regard to the WRC study cycle by ITU SG, after the WRC agenda item prioritization, Thailand should participate in the relevant activities by the relevant SGs and submit contributions (if necessary) to ensure preferable options are included in the CPM report. ITU SG/WP will usually convene approximately three times each year (from the previous meetings of SG1, WP1A, and WP1B).

Regional preparatory meeting (APG)

The study also elaborates on the role of the regional preparatory meeting, especially the APG, as the regional preparatory meeting in the Asia-Pacific regions by the APT. Moreover, ITU recognizes the importance of the six regional preparatory meetings as the regional forum for consolidation and negotiation among Member States represented by the commons or regional proposal. Furthermore, the regional coordinator or representative represents its own region to negotiate and report back to their regional meeting during WRC. The commons proposal and

regional representative both help to reduce the number of documents and discussions at WRC and encourage consensus or compromise between Member States.

The author was part of the Thai team preparing Thailand's position on WRC-12 Agenda Items 1.19 and 1.22. During the meeting discussions at the APG2012-5, the author observed the dynamic meeting situation between APT members in order to understand the issue of these two agenda items and the APG preparatory process for the APT common proposal to the WRC-12. The discussions varied between agenda items depending on the APT members' standpoints (based on their interests). When a consensus or compromise was reached, the APT common proposal was submitted to the WRC-12.

Thailand should create a connection between stakeholders at national and regional level through participation in national and regional preparatory meetings. The connection between stakeholders enables information exchange and improves understanding of the issues or situations of the WRC agenda items in order to prepare Thailand's position and protect its national interest.

The stakeholder connection, especially Member State networking, may help to relieve the issue of the missing information from the ITU archives and the information asymmetry between attending and non-attending Member States. The follow-up discussion with relevant Member States will enhance understanding of the issues, as the crucial information for improving Thailand's decision-making process at the relevant meetings.

WRC-12 Agenda Items 1.2, 1.19, and 1.22

The study demonstrates the effects of the missing information on WRC-12 Agenda Items 1.2, 1.19, and 1.22 from Thailand's perspective. The demonstration shows the strong impact this has on Thailand. It is important for Thailand to prepare for the rapid growth of new technology, especially the spectrum commons and FS and MS convergence.

In order to prepare for the convergence technology, an evaluation of the current situation of both FS and MS is necessary: an up-to-date database. A review of the current status of FS and MS usage should be conducted and the existing database updated. The initial phase may begin with FS and MS and apply to all services at a later stage.

To prepare for the relevant issues on spectrum commons, Thailand might consider participating in all relevant meetings, including the ITU SG, WP, CPM, SC, RA, and WRC parts of the WRC preparatory processes (WRC agenda-setting and WRC study process) to update the information and prepare Thailand's position in order to take advantage of the advancement of technology.

10.6 Recommendations for future research

Further studies on FS and MS convergence following the ITU activities for reviewing and revising the definition of FS, fixed station, and mobile station during the WRC-15 study cycle may be considered. It is a long process for WRC to make the RR more flexible to govern the new technology.

Further studies relevant to spectrum commons may be encouraged to follow: (1) the study on frequency harmonization of SRD according to ITU-R Resolution 54-1 and (2) further study on the CRS according to ITU-R Resolution 58. Both of these studies are conducted by the ITU SG in the WRC-15 study cycle.

From a theoretical point of view, the IAD framework by Ostrom, the complete or incomplete information assumption depends on an action situation. An action situation that has complete information is to reduce complexity to model the outcome. The study does not reformulate the theoretical part of the IAD framework; however, the study demonstrates and applies the IAD framework to the real action situation at the WRC-12 meetings, which contains the elements of incomplete information situation, as shown in the thesis. From a theoretical point of view, it may be of interest to conduct future research on the IAD framework by modifying the assumption to model the outcome in the case of incomplete information.

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List of abbreviations

General

ADD	Addition
APG	Asia-Pacific Telecommunity conference preparatory group for WRC
APP1992	Additional Plenipotentiary conference 1992
ARC	Administrative Radio Conference
CC	The Council
CICG	Centre International de Conférences Genève
CRS	Cognitive radio system
CPG	CEPT conference preparatory group
COM	Committee
CPM	Conference Preparatory Meeting
CS	The ITU Constitution
CV	The ITU Convention
D	Delegate
DECT	Digital enhanced cordless telecommunication
DFP	Designated focal point
DH	Deputy head
DG	Drafting group
DT	Temporary document
ECP	European common proposal
GHz	Giga Hertz
HF	High frequency
HoD	Head of delegate
Hz	Hertz
IAD	Institutional Analysis and Development
IFIC	International Frequency Information Circular
IG	Informal group
IMT-2000	International Mobile Telecommunication-2000
ISM	Industrial science and medical application
LAN	Local area network
LF	Low frequency
MF	Medium frequency
MHz	Mega Hertz
MIFR	Master International Frequency Registration
MOD	Modification
NOC	No change
PACP	Asia-Pacific common proposal
PCS	Personal communication system
PHS	Personal handyphone system
PO	Participant observation
PP	Plenipotentiary conference
PT A	Project team A
RA	Radiocommunication Assembly
Rev	Revision
RFID	Radio-frequency identification
RR	Radio Regulations
SDR	Software defined-radio
SC	Special Committee on regulatory and procedural matter
SG	Study group
SHF	Super high frequency
SRD	Short-range devices
SUP	Suppression
SWG	Sub-working group

TFA	Table of frequency allocation
TIES	Telecommunication Information Exchange Service
UHF	Ultra high frequency
VLF	Very low frequency
VHF	Very high frequency
WAN	Wide area network
WARC	World Administrative Radio Conference
Wi-Fi	Wireless fidelity
WG	Working group
WP	Working party
WRC	World Radiocommunication Conference

Administration and organization

APT	Asia-Pacific Telecommunity
ASMG	Arab Spectrum Management Group
ATU	African Telecommunications Union
BR	Radiocommunication Bureau
CCIF	International Telephone Consultative Committee
CCIR	International Radio Consultative Committee
CCIT	International Telegraph Consultative Committee
CCITT	International Telegraph and Telephone Consultative
CEPT	European Conference of Postal and Telecommunications administrations
CISPR	Special committee of the international electrotechnical commission for interference
CITEL	Inter-American Telecommunication Commission
CPG	CEPT conference preparatory group
ETSI	European Telecommunications Standards Institute
HLC	High level committee
ICAO	International Civil Aviation Organization
IEC	International Electrotechnical Commission
IFRB	International Frequency Registration Board
IMO	International Maritime Organization
ISO	International Organization for Standard
ITU	International Telecommunication Union
ITU-D	Telecommunication development sector
ITU-R	Radiocommunication sector
ITU-T	Telecommunication standardization sector
MICT	Ministry of Information and Communication Technology
NBC	National Broadcasting Commission
NBTC	National Broadcasting and Telecommunications Commission
NFMB	National Frequency Management Board
NRA	National regulatory authority
NTC	National Telecommunications Commission
ONBTC	Office of the NBTC
ONTC	Office of the NTC
PTD	Post and Telegraph Department
PTS	Swedish Post and Telecom Authority
RAG	Radiocommunication Advisory Group
RCC	Regional Commonwealth in the Field of Communications
RRB	Radio Regulations Board
UK	United Kingdom
UN	United Nations
USA	United States of America
USSR	Union of Soviet Socialist Republic
WMO	World Meteorological Organization

Radiocommunication service

ARNS	Aeronautical radionavigation service
ARNSS	Aeronautical radionavigation-satellite service
AMSS	Aeronautical mobile-satellite service
AM(R)S	Aeronautical mobile (route) service
AM(OR)S	Aeronautical mobile (off-route) service
AMS(R)S	Aeronautical mobile-satellite (route) service
AMS(OR)S	Aeronautical mobile-satellite (off-route) service
ARS	Amateur service
ARSS	Amateur-satellite service
BS	Broadcasting service
BSS	Broadcasting-satellite service
EESS	Earth-exploration satellite service
FS	Fixed service
FSS	Fixed-satellite service
LMS	Land mobile service
LMSS	Land mobile-satellite service
ISS	Inter-satellite service
MetAids	Meteorological aids services
MetSat	Meteorological-satellite service
MMS	Maritime mobile service
MMSS	Maritime mobile-satellite service
MRNS	Maritime radionavigation service
MRNSS	Maritime radionavigation-satellite service
MS	Mobile service
MSS	Mobile-satellite service
POS	Port operation service
RAS	Radio astronomy service
RDS	Radiodeterminatio service
RDSS	Radiodetermination-satellite service
RLS	Radiolocation service
RLSS	Radiolocation-satellite service
RNS	Radionavigation service
RNSS	Radionaviation-satellite service
SOS	Space operation service
SRS	Space research service
SFTSS	Standard frequency and time signal service
SFTSSS	Standard frequency and time signal-satellite service
SS	Space service
TS	Terrestrial service

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Appendix A Maritime mobile service geographic frequency allocations

Table 51. MMS Global allocation for exclusive/primary services

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1927	125	150	25	1947
1947	16460	17360	900	1982
1947	22000	22720	720	1982
1947	12330	13200	870	1982
1959	415	490	75	1982
1959	25070	25110	40	1982
1959-2012	14	19.95	5.95	
1959-2012	20.05	70	49.95	
2012	472	479	7	
1982-2012	2170	2173.5	3.5	
1982-2012	2190.5	2194	3.5	
1982-2012	4000	4063	63	
1947-2012	4063	4438	375	
1947-2012	6200	6525	325	
1982-2012	8100	8195	95	
1947-2012	8195	8815	620	
1982-2012	12230	13200	970	
1982-2012	16360	17410	1050	
1982-2012	18780	18900	120	
1982-2012	19680	19800	120	
1982-2012	22000	22855	855	
1982-2012	25070	25210	140	
1982-2012	26100	26175	75	
Initial RR	**Lower frequency (MHz)**	**Upper frequency (MHz)**	**Bandwidth (MHz)**	**RR removal**
1982	156.7625	156.8375	75	2012
2008-2012	156.4875	156.5625	75	
2012	156.7875	156.8125	25	

Table 52. MMS Global allocation for shared/secondary services

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1927	1300	1500	200	1947
1947	14	70	56	1959
1947	90	110	20	1959
1982	90	110	20	2012

Table 53. MMS EU region/Region 1 allocation for exclusive/primary services

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1932	1670	1715	45	1938
1932	290	315	25	1947
1932	315	320	5	1947
1932	1630	1670	40	1947
1938	1600	1630	30	1947
1938	2900	2925	25	1947
1938	32000	32500	500	1947
1947	130	150	20	1982
1959	90	110	20	1982
1959	115	126	11	1982
1959	150	160	10	1982
1959	255	285	30	1982
1959	510	525	15	1982
1982	130	148.5	18.5	2008
1982	435	495	60	2012
1959-2012	72	84	12	
1959-2012	86	90	4	
1959-2012	110	112	2	
1982-2012	117.6	126	8.4	
1959-2012	129	130	1	
2008-2012	130	135.7	5.7	
2008-2012	135.7	137.8	2.1	
2008-2012	137.8	148.5	10.7	
1982-2012	415	435	20	
2012	435	472	37	
2012	479	495	16	
1982-2012	505	526.5	21.5	
1982-2012	1606.5	1625	18.5	
1982-2012	1635	1800	165	
1982-2012	2045	2160	115	
1959-2012	2625	2650	25	
Initial RR	**Lower frequency (MHz)**	**Upper frequency (MHz)**	**Bandwidth (MHz)**	**RR removal**
2012	156.7625	156.7875	25	
2012	156.8125	156.8375	25	

Table 54. MMS EU region/Region 1 allocation for shared/secondary services

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1932	1925	2000	75	1959
1938	1715	1925	210	1959
1938	2000	2050	50	1959
1938	2070	2330	260	1959
1938	2360	2635	275	1959
1947	70	90	20	1959
1947	110	130	20	1959
1947	150	160	10	1959
1947	255	285	30	1959
1947	510	525	15	1959
1947	2625	2650	25	1959
1982-2012	115	117.6	2.6	

Table 55. MMS American region/Region 2 allocation for exclusive/primary services

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1947	2065	2105	40	1959
1959	130	150	20	1982
1959	150	160	10	1982
1982	130	160	30	2008
1982	415	495	80	2012
1959-2012	70	90	20	
1959-2012	110	130	20	
2008-2012	130	135.7	5.7	
2008-2012	135.7	137.8	2.1	
2008-2012	137.8	160	22.2	
2012	415	472	57	
2012	479	495	16	
1982-2008	505	510	5	
2012	510	525	15	
1959-2012	2065	2107	42	
Initial RR	**Lower frequency (MHz)**	**Upper frequency (MHz)**	**Bandwidth (MHz)**	**RR removal**
2012	156.7625	156.7875	25	
2012	156.8125	156.8375	25	
2012	161.9625	161.9875	25	
2012	162.0125	162.0375	25	
1982-2012	21.6	22	4000	

Table 56. MMS American region/Region 2 allocation for shared/secondary services

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1947	70	90	20	1959
1947	110	130	20	1959
1947	130	150	20	1959
1947	150	160	10	1959
1959	90	110	20	1982

Table 57. MMS Other regions/Region 3 allocation for exclusive/primary services

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1938	290	315	25	1947
1947	2065	2105	40	1959
1959	70	90	20	1982
1959	90	110	20	1982
1959	110	130	20	1982
1959	130	150	20	1982
1959	150	160	10	1982
1959	510	525	15	1982
1982	130	160	30	2008
1982	415	495	80	2012
1982-2012	72	84	12	
1982-2012	86	90	4	
1982-2012	110	112	2	
1982-2012	117.6	126	8.4	
1982-2012	129	130	1	
2008-2012	130	135.7	5.7	
2008-2012	135.7	137.8	2.1	
2008-2012	137.8	160	22.2	
2012	415	472	57	
2012	479	495	16	
1982-2012	505	526.5	21.5	
1959-2012	2065	2107	42	
Initial RR	**Lower frequency (MHz)**	**Upper frequency (MHz)**	**Bandwidth (MHz)**	**RR removal**
2012	156.7625	156.7875	25	
2012	156.8125	156.8375	25	
2012	161.9625	161.9875	25	
2012	162.0125	162.0375	25	

Table 58. MMS Other regions/Region 3 allocation for shared/secondary services

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1938	285	290	5	1947
1947	70	90	20	1959
1947	110	130	20	1959
1947	130	150	20	1959
1947	150	160	10	1959
1982-2012	70	72	2	
1982-2012	84	86	2	
1982-2012	112	117.6	5.6	
1982-2012	126	129	3	

Appendix B Maritime mobile-satellite service geographic frequency allocations

Table 59. MMSS Global allocation for primary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1971	1535	1542.5	7.5	1982
1971	1542.5	1543.5	1	1982
1971	1636.5	1644	7.5	1982
1971	1644	1645	1	1982
1982	1626.5	1645.5	19	1994
1982	1535	1544	9	1998
1994	1631.5	1634.5	3	1998
1994	1634.5	1645.5	11	1998
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1971	43	48	5	1982
1971	66	71	5	1982
1971	95	101	6	1982
1971	142	150	8	1982
1971	190	200	10	1982
1971	250	265	15	1982

Table 60. MMSS Region 1 allocation for primary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1982	1530	1535	5	1994
1994	1525	1530	5	1998
1994	1530	1533	3	1998
1994	1533	1535	2	1998
1994	1626.5	1631.5	5	1998

Table 61. MMSS Region 2 and 3 allocations for primary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1982	1530	1535	5	1998

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Appendix C Broadcasting service geographic frequency allocations

Table 62. BS Global allocation for exclusive/primary services

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1927	550	1300	750	1932
1927	6000	6150	150	1938
1927	9500	9600	100	1938
1927	17750	17800	50	1938
1927	21450	21550	100	1938
1938	6000	6200	200	1947
1938	9500	9700	200	1947
1927	11700	11900	200	1947
1927	15100	15350	250	1947
1938	17750	17850	100	1947
1932	25600	26600	1000	1947
1947	9500	9775	275	1982
1947	11700	11975	275	1982
1947	15100	15450	350	1982
1947	17700	17900	200	1982
1938	21450	21750	300	1982
1947	25600	26100	500	1982
1959	535	1605	1070	1982
1994	7300	7350	50	2004
1959-2012	3200	3230	30	
1959-2012	3230	3400	170	
1959-2012	4850	4995	145	
1959-2012	5005	5060	55	
1994-2012	5900	5950	50	
1947-2012	5950	6200	250	
2004-2012	7300	7400	100	
1994-2012	9400	9500	100	
1982-2012	9500	9900	400	
1994-2012	11600	11650	50	
1982-2012	11650	12050	400	
1994-2012	12050	12100	50	
1994-2012	13570	13600	30	
1982-2012	13600	13800	200	
1994-2012	13800	13870	70	
1982-2012	15100	15600	500	
1994-2012	15600	15800	200	
1994-2012	17480	17550	70	
1982-2012	17550	17900	350	
1994-2012	18900	19020	120	
1982-2012	21450	21850	400	
1982-2012	25670	26100	430	
Initial RR	**Lower frequency (MHz)**	**Upper frequency (MHz)**	**Bandwidth (MHz)**	**RR removal**
1947	88	100	12	1959
1947	470	585	115	1959
1947	610	940	330	1959
1982-2012	100	108	8	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1959	11.7	12.7	1	1971
1982	40.5	42.5	2	1998
1982	84	86	2	2001
2001-2012	41	42.5	1.5	
2001-2012	74	76	2	

Table 63. BS Global allocation for share/secondary services

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1927	160	194	34	1932
1927	194	285	91	1932
1927	1300	1500	200	1932
1932	550	1500	950	1947
1938	7200	7300	100	1947
1947	3200	3230	30	1959
1947	3230	3400	170	1959
1947	4850	4995	145	1959
1947	5005	5060	55	1959

Table 64. BS EU region/Region 1 allocation for exclusive/primary services

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1932	160	240	80	1947
1938	415	460	45	1947
1938	1500	1560	60	1947
1938	64000	70500	6500	1947
1938	85000	94000	9000	1947
1938	170000	200000	30000	1947
1947	7150	7300	150	1959
1959	150	160	10	1982
1947	160	255	95	1982
1959	255	285	30	1982
1947	525	535	10	1982
1959	7100	7300	200	2004
1982-2012	148.5	255	106.5	
1982-2012	255	283.5	28.5	
1982-2012	526.5	1606.5	1080	
1959-2012	2300	2498	198	
1959-2012	3950	4000	50	
1959-2012	4750	4850	100	
2004-2012	7200	7300	100	
2004-2012	7400	7450	50	

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1947	41	68	27	1959
1947	87.5	88	0.5	1959
1947	940	960	20	1959
1947	10000	10500	500	1959
1959	41	47	6	1982
1947	174	216	42	1982
1959	216	223	7	1982
1959	470	582	112	1982
1959	582	606	24	1982
1959	606	790	184	1982
1959	790	890	100	1982
1959-2012	47	68	21	
1959-2012	87.5	100	12.5	
1982-2012	174	223	49	
1982-2012	223	230	7	
1982-2012	470	790	320	
1982-2012	790	862	72	
1982-2012	862	890	28	
1959-2012	890	942	52	
1959-2012	942	960	18	
1994-2012	1452	1492	40	

Initial RR	Lower frequency (GHz)	Upper frequency (GHz)	Bandwidth (GHz)	RR removal
1998	40.5	42.5	2	2001
1976-2012	11.7	12.5	0.8	
2001-2012	40.5	41	0.5	

Table 65. BS EU region/Region 1 allocation for shared/secondary services

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1932	240	255	15	1947
1932	255	265	10	1947
1938	40500	56000	15500	1947
1938	56000	58500	2500	1947
1938	58500	60000	1500	1947
1947	150	160	10	1959
1947	255	285	30	1959
1947	2300	2498	198	1959
1947	3950	4000	50	1959
1947	4750	4850	100	1959
1947	7100	7150	50	1959

Table 66. BS American region/Region 2 allocation for exclusive/primary services

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1938	25000	25600	600	1947
1938	26600	27000	400	1947
1938	41000	44000	3000	1947
1938	44000	56000	12000	1947
1938	66000	72000	6000	1947
1938	78000	90000	12000	1947
1938	96000	108000	12000	1947
1938	156000	168000	12000	1947
1938	180000	192000	12000	1947
1938	204000	216000	12000	1947
1938	234000	246000	12000	1947
1938	258000	270000	12000	1947
1938	282000	294000	12000	1947
1959-2012	525	535	10	
1982-2012	535	1605	1070	
1982-2012	1605	1625	20	
1982-2012	1625	1705	80	
1959-2012	2300	2495	195	
1959-2012	4750	4850	100	
Initial RR	**Lower frequency (MHz)**	**Upper frequency (MHz)**	**Bandwidth (MHz)**	**RR removal**
1947	585	610	25	1959
1959	68	74.6	6.6	1968
1968	68	73	5	1982
1959	75.4	88	12.6	1982
1947	100	108	8	1982
1968	470	890	420	1982
1959-2012	54	68	14	
1982-2012	68	72	4	
1982-2012	76	88	12	
1959-2012	88	100	12	
1959-2012	174	216	42	
1982-2012	470	512	42	
1982-2012	512	608	96	
1982-2012	614	806	192	
1982-2012	806	890	84	
1994-2012	1452	1492	40	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1971	11.7	12.2	0.5	1982
1971	12.2	12.5	0.3	1982
1982	12.1	12.3	0.2	1986
1982	12.3	12.7	0.4	1990
1998	40.5	42.5	2	2001
1990-2012	12.2	12.7	0.5	
2001-2012	40.5	41	0.5	

Table 67. BS American region/Region 2 allocation for shared/secondary services

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1947	2300	2495	195	1959
1947	4750	4850	100	1959
Initial RR	**Lower frequency (MHz)**	**Upper frequency (MHz)**	**Bandwidth (MHz)**	**RR removal**
1947	44	50	6	1959
1947	54	72	18	1959
1947	76	88	12	1959
1947	174	216	42	1959

Table 68. BS Other regions/Region 3 allocation for exclusive/primary services

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1947	7150	7300	150	1959
1959	525	535	10	1982
1959	7100	7300	200	2004
1982-2012	526.5	535	8.5	
1982-2012	535	1606.5	1071.5	
1959-2012	2300	2495	195	
1959-2012	3900	3950	50	
1959-2012	3950	4000	50	
1959-2012	4750	4850	100	
2004-2012	7200	7300	100	
2004-2012	7400	7450	50	
Initial RR	**Lower frequency (MHz)**	**Upper frequency (MHz)**	**Bandwidth (MHz)**	**RR removal**
1947	87	88	1	1959
1947	940	960	20	1959
1959	44	50	6	1982
1947	100	108	8	1982
1959	170	174	4	1982
1959	174	216	42	1982
1982-2012	47	50	3	
1959-2012	54	68	14	
1959-2012	87	100	13	
1982-2012	174	223	49	
1982-2012	223	230	7	
1982-2012	470	585	115	
1982-2012	585	610	25	
1959-2012	610	890	280	
1959-2012	890	942	52	
1959-2012	942	960	18	
1994-2012	1452	1492	40	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1998	40.5	42.5	2	2001
1971-2012	11.7	12.2	0.5	
1971-2012	12.2	12.5	0.3	
2001-2012	40.5	41	0.5	

Table 69. BS Other regions/Region 3 allocation for shared/secondary services

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1938	1500	1600	100	1947
1938	2300	2500	200	1947
1938	3300	3500	200	1947
1938	4770	4965	195	1947
1947	2300	2495	195	1959
1947	3900	3950	50	1959
1947	3950	4000	50	1959
1947	4750	4850	100	1959
1947	7100	7150	50	1959
Initial RR	**Lower frequency (MHz)**	**Upper frequency (MHz)**	**Bandwidth (MHz)**	**RR removal**
1947	44	50	6	1959
1947	54	68	14	1959
1947	170	200	30	1959

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Appendix D Broadcasting-satellite service geographic frequency allocations

Table 70. BSS Global allocation for primary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1971	2550	2655	105	1982
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1971	41	43	2	1982
1982	40.5	42.5	2	1998
1971	84	86	2	2001
2001-2012	41	42.5	1.5	
2001-2012	74	76	2	

Table 71. BSS Region 1 allocation for primary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1971	2500	2550	50	1990
1990	2500	2655	155	1994
1971	2655	2690	35	1994
1994-2012	1452	1492	40	
1994-2012	2520	2655	135	
1994-2012	2655	2670	15	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1998	40.5	42.5	2	2001
1971-2012	11.7	12.5	0.8	
1994-2012	21.4	22	0.6	
2001-2012	40.5	41	0.5	

Table 72. BSS Region 2 allocation for primary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1971	2500	2535	35	1982
1971	2535	2550	15	1982
1982	2500	2655	155	1994
1971	2655	2690	35	1994
1994-2012	1452	1492	40	
1994-2012	2520	2655	135	
1994-2012	2655	2670	15	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1971	11.7	12.2	0.5	1982
1982	12.1	12.3	0.2	1986
1982	12.3	12.7	0.4	1986
1982	22.5	22.55	0.5	1994
1982	22.55	23	0.45	1994
1998	40.5	42.5	2	2001
1986-2012	12.2	12.7	0.5	
1994-2012	17.3	17.7	0.4	
1994-2012	17.7	17.8	0.1	
2001-2012	40.5	41	0.5	

Table 73. BSS Region 3 allocation for primary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1971	2500	2535	35	1994
1971	2535	2550	15	1994
1971	2655	2690	35	1994
1994-2012	1452	1492	40	
1994-2012	2520	2535	15	
1994-2012	2535	2655	120	
1994-2012	2655	2670	15	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1971	22.5	23	0.5	1982
1982	22.5	22.55	0.05	1994
1982	22.55	23	0.45	1994
1998	40.5	42.5	2	2001
1971-2012	11.7	12.2	0.5	
1982-2012	12.5	12.75	0.25	
1994-2012	21.4	22	0.6	
2001-2012	40.5	41	0.5	

Appendix E Fixed service geographic frequency allocations

Table 74. FS Global allocation for exclusive/primary services-1

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1927	2750	2850	100	1932
1927	9600	11000	1400	1938
1927	17800	21450	3650	1938
1932	26600	28000	1400	1938
1927	10	100	90	1947
1927	5700	6000	300	1947
1927	6675	7000	325	1947
1927	7300	8200	900	1947
1927	8900	9500	600	1947
1938	9700	11000	1300	1947
1927	11900	12300	400	1947
1927	13350	14000	650	1947
1927	14400	15100	700	1947
1927	15350	16400	1050	1947
1938	17850	21450	3600	1947
1938	26600	27500	900	1947
1947	15450	16460	1010	1968
1947	18030	19990	1960	1968
1968	18030	18036	6	1971
1968	18036	19990	1954	1971
1947	5730	5950	220	1982
1947	7300	8195	895	1982
1947	9775	9995	220	1982
1947	10100	11175	1075	1982
1927	11400	11700	300	1982
1947	11975	12330	355	1982
1947	13360	14000	640	1982
1968	15450	15762	312	1982
1968	15762	15768	6	1982
1968	15768	16460	692	1982
1947	17360	17700	340	1982
1971	18068	19990	1922	1982
1947	21750	21850	100	1982
1947	22720	23200	480	1982
1959	23350	24990	1640	1982
1968	25110	25600	490	1982
1968	26100	27500	1400	1982
1982	7300	8100	800	1994
1947	9040	9500	460	1994
1982	11400	11650	250	1994
1982	12050	12230	180	1994
1982	13410	13600	190	1994
1982	13800	14000	200	1994
1982	15600	16360	760	1994
1982	17410	17550	140	1994
1982	18900	19680	780	1994
1994	7350	8100	750	2004
1982	5250	5450	200	2012
1994	13410	13570	160	2012
1994	15800	16360	560	2012
1982	24000	24890	890	2012
1982	26175	27500	1325	2012

Table 75. FS Global allocation for primary service-2

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1959-2012	14	19.95	5.95	
1959-2012	20.05	70	49.95	
1959-2012	3155	3200	45	
1959-2012	3200	3230	30	
1959-2012	3230	3400	170	
1959-2012	4000	4063	63	
1959-2012	4850	4995	145	
1959-2012	5005	5060	55	
1947-2012	5060	5250	190	
2012	5275	5450	175	
1947-2012	6765	7000	235	
2004-2012	7450	8100	650	
1982-2012	8100	8195	95	
1994-2012	9040	9400	360	
1982-2012	9900	9995	95	
1982-2012	10100	10150	50	
1982-2012	10150	11175	1025	
1994-2012	11400	11600	200	
1994-2012	12100	12230	130	
1982-2012	13360	13410	50	
2012	13410	13450	40	
2012	13550	13570	20	
1994-2012	13870	14000	130	
1947-2012	14350	14990	640	
2012	15800	16100	300	
2012	16200	16360	160	
1994-2012	17410	17480	70	
1971-2012	18030	18052	22	
1971-2012	18052	18068	16	
1982-2012	18168	18780	612	
1994-2012	19020	19680	660	
1982-2012	19800	19990	190	
1947-2012	20010	21000	990	
1982-2012	21850	21870	20	
1996-2012	21870	21924	54	
1982-2012	22855	23000	145	
1982-2012	23000	23200	200	
1996-2012	23200	23350	150	
1982-2012	23350	24000	650	
2012	24000	24450	450	
1968-2012	25010	25070	60	
1982-2012	25210	25550	340	
2012	26175	26200	25	

Table 76. FS Global allocation for primary service-3

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1959	29.7	41	11.3	1968
1959	136	137	1	1968
1959	235	328.6	93.6	1968
1959	335.4	400	64.6	1968
1959	450	470	20	1968
1959	1660	1700	40	1968
1959	2550	2700	150	1968
1959	4400	5000	600	1968
1959	5925	8400	2475	1968
1959	8400	8500	100	1968
1959	406	420	14	1971
1968	2550	2690	140	1971
1968	7300	7750	450	1971
1968	8025	8400	375	1971
1968	30.01	37.75	7.74	1982
1968	37.75	38.25	0.5	1982
1968	38.25	41	2.75	1982
1968	273	328.6	55.6	1982
1971	2550	2655	105	1982
1968	4400	4700	300	1982
1968	4700	4990	290	1982
1968	5925	6425	500	1982
1968	6425	7250	825	1982
1982	273	322	49	1994
1968	335.4	399.9	64.5	1994
1968	1670	1690	20	1994
1968	7900	7975	75	1994
1982	7975	8025	50	1994
1968	450	460	10	1996
1982	5925	7075	1150	1996
1968	7750	7900	150	1998
1994	2010	2025	15	2004
1982	7075	7250	175	2004
1982	41.015	44	2.985	2012
1998	7750	7850	100	2012
1998	7850	7900	50	2012

Table 77. FS Global allocation for primary service-4

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1982-2012	27.5	28	0.5	
1968-2012	29.7	30.005	0.305	
1968-2012	30.005	30.01	0.005	
1982-2012	30.01	37.5	7.49	
1982-2012	37.5	38.25	0.75	
1982-2012	38.25	39.986	1.736	
1982-2012	39.986	40.02	0.034	
1982-2012	40.02	40.98	0.96	
1982-2012	40.98	41.015	0.035	
2012	41.015	42	0.985	
2012	42.5	44	1.5	
1982-2012	44	47	3	
1968-2012	235	267	32	
1968-2012	267	272	5	
1968-2012	272	273	1	
1994-2012	273	312	39	
1994-2012	312	315	3	
1994-2012	315	322	7	
1982-2012	322	328.6	6.6	
1994-2012	335.4	387	51.6	
1994-2012	387	390	3	
1994-2012	390	399.9	9.9	
1971-2012	406.1	410	3.9	
1971-2012	410	420	10	
1982-2012	420	430	10	
1982-2012	440	450	10	
1996-2012	450	455	5	
1996-2012	456	459	3	
1968-2012	460	470	10	
1959-2012	1427	1429	2	
1982-2012	1668.4	1670	1.6	
1994-2012	1670	1675	5	
2004-2012	1675	1690	15	
1994-2012	1710	1930	220	
1998-2012	1970	1980	10	
1994-2012	1980	2010	30	
1994-2012	2025	2110	85	
1994-2012	2110	2120	10	
1994-2012	2170	2200	30	
1994-2012	2200	2290	90	
1994-2012	2290	2300	10	
1982-2012	4400	4500	100	
1982-2012	4500	4800	300	
1982-2012	4800	4990	190	
1982-2012	4990	5000	10	
1996-2012	5925	6700	775	
1996-2012	6700	7075	375	
2004-2012	7075	7145	70	
2004-2012	7145	7235	90	
2004-2012	7235	7250	15	
1982-2012	7250	7300	50	
1971-2012	7300	7450	150	
1971-2012	7450	7550	100	
1971-2012	7550	7750	200	
2012	7750	7900	150	
1994-2012	7900	8025	125	

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1998-2012	8025	8175	150	
1998-2012	8175	8215	40	
1998-2012	8215	8400	185	
1971-2012	8400	8500	100	

Table 78. FS Global allocation for primary service-5

Initial RR	Lower frequency (GHz)	Upper frequency (GHz)	Bandwidth (GHz)	RR removal
1959	10.55	10.7	0.15	1968
1959	14.4	15.15	0.75	1968
1959	15.25	15.4	0.15	1968
1959	17.7	21	3.3	1968
1959	25.25	31.5	6.25	1968
1968	10.55	10.68	0.13	1971
1959	10.7	11.7	1	1971
1959	11.7	12.7	1	1971
1959	12.7	13.25	0.55	1971
1968	14.4	15.25	0.85	1971
1968	17.7	19.3	0.16	1971
1968	19.4	21	0.16	1971
1959	22	23	1	1971
1968	25.25	31	5.75	1971
1971	10.7	10.95	0.25	1982
1971	11.2	11.45	0.25	1982
1971	11.45	11.7	0.25	1982
1971	14.4	14.5	0.1	1982
1971	14.5	15.35	0.85	1982
1971	17.7	19.7	2	1982
1971	21.2	22	0.8	1982
1971	22	22.5	0.5	1982
1971	23	23.6	0.6	1982
1971	25.25	27.5	2.25	1982
1959	36	40	4	1982
1982	18.1	18.6	0.5	1994
1982	21.4	22	0.6	1994
1982	25.25	27	0.175	1994
1971	27.5	29.5	2	1994
1982	37.5	39.5	2	1994
1982	39.5	40.5	1	1994
1982	151	164	13	1994
1982	17.7	18.1	0.40	1994
1982	18.8	19.7	0.9	1996
1994	28.5	29.5	1	1996
1982	116	126	10	1996
1994	22.55	23	0.45	1998
1982	23	23.55	0.55	1998
1982	54.25	58.2	3.95	1998
1982	59	64	5	1998
1982	92	95	3	1998
1982	74	75.5	1.5	2001
1982	100	102	2	2001
1996	116	119.98	3.98	2001
1996	119.98	120.02	0.04	2001
1996	120.02	126	5.98	2001
1982	126	134	8	2001
1982	149	150	1	2001
1982	150	151	1	2001
1994	151	156	5	2001
1994	156	158	2	2001
1994	158	164	6	2001
1982	168	170	2	2001
1982	170	174.5	4.5	2001
1982	174.5	176.5	2	2001
1982	176.5	182	5.5	2001

Initial RR	Lower frequency (GHz)	Upper frequency (GHz)	Bandwidth (GHz)	RR removal
1982	185	190	5	2001
1982	200	202	2	2001
1982	202	217	15	2001
1982	231	235	4	2001
1982	235	238	3	2001
1982	238	241	3	2001
1982	47.2	50.2	3	2004
1982	50.2	50.4	0.2	2004
1998	22.55	23.55	1	2012

Table 79. FS Global allocation for primary service-6

Initial RR	Lower frequency (GHz)	Upper frequency (GHz)	Bandwidth (GHz)	RR removal
1971-2012	10.55	10.6	0.05	
1971-2012	10.6	10.68	0.08	
1971-2012	12.75	13.25	0.5	
1982-2012	14.4	14.47	0.07	
1982-2012	14.47	14.5	0.03	
1982-2012	14.5	14.8	0.3	
1982-2012	14.8	15.35	0.55	
1994-2012	18.1	18.4	0.3	
1994-2012	18.4	18.6	0.2	
1996-2012	18.8	19.3	0.5	
1996-2012	19.3	19.7	0.4	
1982-2012	21.2	21.4	0.2	
1982-2012	22	22.21	0.21	
1982-2012	22.21	22.5	0.29	
1994-2012	22.5	22.55	0.05	
2012	22.55	23.15	0.6	
2012	23.15	23.55	0.4	
1982-2012	23.55	23.6	0.05	
1994-2012	25.25	25.5	0.25	
1994-2012	25.5	27	1.5	
1994-2012	27.5	28.5	1	
1996-2012	28.5	29.1	0.6	
1996-2012	29.1	29.5	0.4	
1998-2012	31	31.3	0.3	
1998-2012	31.8	32	0.2	
1998-2012	32	32.3	0.3	
1998-2012	32.3	33	0.7	
1998-2012	33	33.4	0.4	
1982-2012	36	37	1	
1982-2012	37	37.5	0.5	
1994-2012	37.5	38	0.5	
1994-2012	38	39.5	1.5	
1994-2012	39.5	40	0.5	
1994-2012	40	40.5	0.5	
2001-2012	41	42.5	1.5	
1982-2012	42.5	43.5	1	
2004-2012	47.2	47.5	0.3	
2004-2012	47.9	48.2	0.3	
1982-2012	50.4	51.4	1	
1998-2012	51.4	52.6	1.2	
1998-2012	55.78	56.9	1.12	
1998-2012	56.9	57	0.1	
1998-2012	57	58.2	1.2	
1998-2012	58.2	59	0.8	
1998-2012	59	59.3	0.3	
1998-2012	59.3	64	4.7	
1998-2012	64	65	1	
1998-2012	65	66	1	
1982-2012	71	74	3	
2001-2012	74	76	2	
1982-2012	81	84	3	
1982-2012	84	86	2	
1998-2012	92	94	2	
1998-2012	94.1	95	0.9	
2001-2012	95	100	5	
1982-2012	102	105	3	

Initial RR	Lower frequency (GHz)	Upper frequency (GHz)	Bandwidth (GHz)	RR removal
2001-2012	105	109.5	4.5	
2001-2012	111.8	114.25	2.45	
2001-2012	122.25	123	0.75	
2001-2012	130	134	4	
2001-2012	141	148.5	7.5	
2001-2012	151.5	155.5	4	
2001-2012	155.5	158.5	3	
2001-2012	158.5	164	5.5	
2001-2012	167	174.5	7.5	
2001-2012	174.5	174.8	0.3	
2001-2012	191.8	200	8.2	
2001-2012	209	217	8	
2001-2012	217	226	9	
2001-2012	231.5	232	0.5	
2001-2012	232	235	3	
2001-2012	238	240	2	
2001-2012	240	241	1	
2004-2012	252	265	13	
1982-2012	265	275	10	

Table 80. FS Global allocation for shared/secondary services-1

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1927	160	194	34	1932
1927	194	285	91	1932
1927	1715	2000	285	1932
1927	2000	2250	250	1932
1927	2850	3500	650	1932
1927	22300	23000	700	1932
1932	2000	3500	1500	1938
1927	3500	4000	500	1938
1927	100	110	10	1947
1927	4000	5500	1500	1947
1927	8550	8900	350	1947
1927	12825	13350	525	1947
1927	17100	17750	650	1947
1932	22300	24600	2300	1947
1947	14	70	56	1959
1947	90	110	20	1959
1947	3155	3200	45	1959
1947	3200	3230	30	1959
1947	3230	3400	170	1959
1947	4000	4063	63	1959
1947	4850	4995	145	1959
1947	5005	5060	55	1959
1947	21850	22000	150	1959
1947	23200	23350	150	1959
1947	23350	24990	1640	1959
1947	25010	25600	590	1959
1947	26100	27500	1400	1959
1982-2012	90	110	20	

Table 81. FS Global allocation for shared/secondary services-2

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1947	235	328.6	93.6	1959
1947	335.4	420	84.6	1959
1947	460	470	10	1959
1947	1700	2300	600	1959
1947	2450	2700	250	1959
1947	3900	4200	300	1959
1947	4400	5000	600	1959
1947	5925	8500	2575	1959
1959	401	406	5	1968
1968	402	406	4	1971
1982	137	138	1	1994
1982	136	137	1	1998
1982	1660.5	1668.4	7.9	2004
1947	9800	10000	200	2008
1994-2012	137	137.025	0.025	
1994-2012	137.025	137.175	0.0150	
1994-2012	137.175	137.825	0.0650	
1994-2012	137.825	138	0.0175	
1968-2012	401	402	1	
1971-2012	402	403	1	
1971-2012	403	406	3	
2004-2012	1660.5	1668	7.5	
2004-2012	1668	1668.4	0.4	
2008-2012	9800	9900	100	
2008-2012	9900	10000	100	

Initial RR	Lower frequency (GHz)	Upper frequency (GHz)	Bandwidth (GHz)	RR removal
1959	15.15	15.25	0.1	1968
1959	31.5	31.8	0.3	1968
1982	40.5	42.5	2	1998
1982	65	66	1	1998

Table 82. FS EU region/Region 1 allocation for exclusive/primary services-1

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1938	26600	27500	900	1947
1959	115	126	11	1982
1959	130	150	20	1982
1959	1605	2000	395	1982
1959	2000	2045	45	1982
1959	2045	2065	20	1982
1959	2065	2170	105	1982
1959	5250	5430	180	1982
1959	5430	5480	50	1982
1982	5730	5950	220	1994
1982	130	148.5	18.5	2008
1959	90	110	20	2012
1947	4438	4650	212	2012
1959-2012	72	84	12	
1959-2012	86	90	4	
1959-2012	110	112	2	
1982-2012	117.6	126	8.4	
1959-2012	129	130	1	
2008-2012	130	135.7	5.7	
2008-2012	135.7	137.8	2.1	
2008-2012	137.8	148.5	10.7	
1982-2012	1606.5	1625	18,5	
1982-2012	1635	1800	165	
1982-2012	1850	2000	150	
1982-2012	2000	2025	25	
1982-2012	2025	2045	20	
1982-2012	2045	2160	115	
1959-2012	2194	2300	106	
1959-2012	2300	2498	198	
1959-2012	2502	2625	123	
1959-2012	2650	2850	200	
1959-2012	3500	3800	300	
1959-2012	3800	3900	100	
1959-2012	3950	4000	50	
2012	4438	4488	50	
2012	4488	4650	162	
1959-2012	4750	4850	100	
2012	5250	5275	25	
1982-2012	5450	5480	30	
1994-2012	5730	5900	170	
2012	9040	9305	265	
2012	9305	9355	50	
2012	9355	9400	45	
2012	13450	13550	100	
2012	16100	16200	100	
2012	24450	24600	150	
2012	24600	24890	290	
2012	26200	26350	150	
2012	26350	27500	1150	

Table 83. FS Region 1 allocation for primary service-2

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1959	146	151	5	1968
1959	1429	1535	106	1968
1959	1710	2290	580	1968
1959	151	154	3	1971
1959	2450	2550	100	1971
1968	8400	8500	100	1971
1968	150.05	151	0.95	1982
1971	151	153	2	1982
1959	154	156	2	1982
1959	156	174	18	1982
1959	420	430	10	1982
1959	440	450	10	1982
1959	790	890	100	1982
1968	1525	1535	10	1982
1968	1710	1770	60	1982
1968	1770	1790	20	1982
1968	1790	2290	500	1982
1971	2500	2550	50	1982
1971	4990	5000	10	1982
1971	2450	2500	50	1990
1968	146	149.9	3.9	1994
1968	136	137	1	1994
1968	1429	1525	96	1994
1982	1710	2290	580	1994
1959	2290	2300	10	1994
1982	2500	2655	155	1994
1971	2655	2690	35	1994
1994	2120	2160	40	1996
1971	8025	8175	150	1998
1971	8175	8215	40	1998
1971	8215	8400	185	1998
1994	1492	1525	33	2004
1994	1675	1690	15	2004
1994	1970	1980	10	2004
1982	154	156.7625	2.7625	2008
1982	156.8375	174	17.1625	2012

Table 84. FS Region 1 allocation for primary service-3

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
2012	38.25	39	0.75	
2012	39	39.5	0.5	
2012	39.5	39.986	0.486	
2012	39.986	40.02	0.034	
2012	42	42.5	0.5	
1959-2012	68	74.8	6.8	
1959-2012	75.2	87.5	12.3	
1994-2012	146	148	2	
1994-2012	148	149.9	1.9	
1982-2012	150.05	153	2.95	
1971-2012	153	154	1	
2008-2012	154	156.4875	2.4875	
2008-2012	156.5625	156.7625	0.2	
2012	156.8375	161.9625	5.125	
2012	161.9625	161.9875	0.025	
2012	161.9875	162.0125	0.025	
2012	162.0125	162.0375	0.025	
2012	162.0375	174	11.9625	
1982-2012	230	235	5	
1996-2012	455	456	1	
1996-2012	459	460	1	
1982-2012	790	862	72	
1982-2012	862	890	28	
1959-2012	890	942	52	
1959-2012	942	960	18	
1959-2012	1350	1400	50	
1994-2012	1429	1452	23	
1994-2012	1452	1492	40	
2004-2012	1492	1518	26	
2004-2012	1518	1525	7	
1982-2012	1525	1530	5	
1959-2012	1700	1710	10	
1994-2012	1930	1970	40	
1996-2012	2010	2025	15	
1996-2012	2120	2160	40	
1994-2012	2160	2170	10	
1959-2012	2300	2450	150	
1990-2012	2450	2483.5	33.5	
1990-2012	2483.5	2500	16.5	
1994-2012	2500	2520	20	
1994-2012	2520	2655	135	
1994-2012	2655	2670	15	
1994-2012	2670	2690	20	
1959-2012	3400	3600	200	
1959-2012	3600	4200	600	
1959-2012	5850	5925	75	

Table 85. FS Region 1 allocation primary service-4

Initial RR	Lower frequency (GHz)	Upper frequency (GHz)	Bandwidth (GHz)	RR removal
1959	10.5	10.55	0.05	1982
1971	10.95	11.2	0.25	1982
1971	22.5	23	0.5	1982
1982	22.5	22.55	0.05	1994
1982	22.55	23	0.45	1994
1998	40.5	42.5	2	2001
1982-2012	10	10.45	0.45	
1982-2012	10.5	10.55	0.05	
1982-2012	10.7	11.7	1	
1976-2012	11.7	12.5	0.8	
1982-2012	14.3	14.4	0.1	
1994-2012	17.7	18.1	0.4	
1982-2012	18.6	18.8	0.2	
1994-2012	21.4	22	0.6	
1994-2012	24.25	24.45	0.2	
1994-2012	24.45	24.65	0.2	
1994-2012	24.65	24.75	0.1	
1994-2012	24.75	25.25	0.5	
1982-2012	27	27.5	0.5	
2001-2012	40.5	41	0.5	
2004-2012	47.5	47.9	0.4	
2004-2012	48.2	48.54	0.34	
2004-2012	48.54	49.44	0.9	
2004-2012	49.44	50.2	0.76	

Table 86. FS EU region/Region 1 allocation for shared/secondary services-1

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1932	1500	1530	30	1938
1938	1600	1630	30	1947
1932	1715	1925	210	1947
1938	2000	2050	50	1947
1938	2070	2330	260	1947
1938	2360	2635	275	1947
1938	2660	2810	150	1947
1938	2860	2900	40	1947
1938	2930	3065	135	1947
1938	3095	3245	150	1947
1938	3305	3500	195	1947
1938	3500	3635	135	1947
1938	3685	3950	265	1947
1938	4000	4480	480	1947
1938	4530	5500	970	1947
1938	40000	40500	500	1947
1947	70	90	20	1959
1947	110	130	20	1959
1947	1605	2000	395	1959
1947	2000	2045	45	1959
1947	2065	2300	235	1959
1947	2300	2498	198	1959
1947	2502	2625	123	1959
1947	2650	2850	200	1959
1947	3500	3800	300	1959
1947	3800	3900	100	1959
1947	3950	4000	50	1959
1947	4750	4850	100	1959
1947	5250	5430	180	1959
1947	5430	5480	50	1959
1982-2012	115	117.6	2.6	

Table 87. FS Region 1 allocation for shared/secondary services-2

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1947	31.7	41	9.3	1959
1947	70	72.8	2.8	1959
1947	75.2	78	2.8	1959
1947	80	83	3	1959
1947	85	87.5	2.5	1959
1947	156	174	18	1959
1947	1300	1600	300	1959
1947	3300	3900	600	1959
1947	5850	5925	75	1959
1959	41	47	6	1982
1959	223	235	12	1990
1982	1530	1535	5	1990
1990	1530	1533	3	1998
1990	1533	1535	2	1998
1990-2012	223	230	7	
1998-2012	1530	1535	5	
1968-2012	1690	1700	10	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1968-2012	31.5	31.8	0.3	

Table 88. FS Region 2 allocation for exclusive/primary services-1

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1947	940	960	20000	1959
1959	130	150	20	1982
1959	150	160	10	1982
1947	160	200	40	1982
1959	1605	1800	195	1982
1959	1800	2000	200	1982
1959	2505	2625	120	1982
1959	2625	2850	225	1982
1959	3500	4000	500	1982
1959	5250	5450	200	1994
1982	130	160	30	2008
1959	4438	4650	212	2012
1959-2012	70	90	20	
1959-2012	110	130	20	
2008-2012	130	135.7	5.7	
2008-2012	135.7	137.8	2.1	
2008-2012	137.8	160	22.2	
1982-2012	160	190	30	
1982-2012	1625	1705	80	
1982-2012	1705	1800	95	
1982-2012	1850	2000	150	
1959-2012	2000	2065	65	
1959-2012	2107	2170	63	
1959-2012	2194	2300	106	
1959-2012	2300	2495	195	
1982-2012	2505	2850	345	
1982-2012	3750	4000	250	
2012	4438	4488	50	
2012	4488	4650	162	
1959-2012	4750	4850	100	
2012	5250	5275	25	
1994-2012	5730	5900	170	
2004-2012	7400	7450	50	
2012	9040	9400	360	
2012	13450	13550	100	
2012	16100	16200	100	
2012	24450	24650	200	
2012	24650	24890	240	
2012	26200	26420	220	
2012	26420	27500	1080	

Table 89. FS Region 2 allocation for primary service-2

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1959	68	74.6	6.6	1968
1959	137	144	7	1968
1959	148	174	26	1968
1959	1700	1710	10	1968
1959	1710	2290	580	1968
1959	2290	2300	10	1968
1959	2450	2550	100	1971
1959	132	136	4	1971
1959	27.5	28	0.5	1982
1959	41	50	9	1982
1959	54	68	14	1982
1968	68	73	5	1982
1959	75.4	88	12.6	1982
1968	150.05	174	23.95	1982
1959	174	216	42	1982
1959	225	235	10	1982
1959	890	942	52	1982
1968	1710	1770	60	1982
1968	1770	1790	20	1982
1968	1790	2290	500	1982
1971	2500	2535	35	1982
1971	2535	2550	15	1982
1959	1429	1435	6	1990
1971	2450	2500	50	1990
1990	1429	1525	96	1994
1982	1710	2290	580	1994
1971	2290	2300	10	1994
1982	2500	2655	155	1994
1971	2655	2690	35	1994
1994	2120	2160	40	1996
1994	1970	1980	10	1998
1971	8025	8175	150	1998
1971	8175	8215	40	1998
1971	8215	8400	185	1998
1994	1492	1525	33	2004
1994	1675	1690	15	2004
1982	150.05	156.7625	6.7125	2008
2008	150.05	156.4875	6.4375	2012
1982	156.8375	174	1.71625	2012

Table 90. FS Region 2 allocation for primary service-3

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
2012	38.25	39.986	1.736	
2012	39.986	40.02	0.034	
2012	42	42.5	0.5	
1982-2012	47	50	3	
1982-2012	72	73	1	
1982-2012	74.6	74.8	0.2	
1982-2012	75.2	75.4	0.2	
1982-2012	75.4	76	0.6	
1968-2012	138	143.6	5.6	
1968-2012	143.6	143.65	0.05	
1968-2012	143.65	144	0.35	
1968-2012	148	149.9	1.9	
2012	150.05	154	3.95	
2012	154	156.4875	2.4875	
2008-2012	156.5625	156.7625	0.2	
2012	156.8375	161.9625	5.125	
2012	161.9875	162.0125	0.025	
2012	162.0375	174	11.962.	
1959-2012	216	220	4	
1982-2012	220	225	5	
1982-2012	225	235	10	
1996-2012	455	456	1	
1996-2012	459	460	1	
1982-2012	806	890	84	
1982-2012	890	902	12	
1982-2012	902	928	26	
1982-2012	928	942	14	
1959-2012	942	960	18	
1994-2012	1429	1452	23	
1994-2012	1452	1492	40	
2004-2012	1492	1518	26	
2004-2012	1518	1525	7	
1971-2012	1700	1710	10	
1994-2012	1930	1970	40	
1996-2012	2010	2025	15	
1996-2012	2120	2160	40	
1994-2012	2160	2170	10	
1990-2012	2300	2450	150	
1990-2012	2450	2483.5	33.5	
1990-2012	2483.5	2500	16.5	
1994-2012	2500	2520	20	
1994-2012	2520	2655	135	
1994-2012	2655	2670	15	
1994-2012	2670	2690	20	
1982-2012	3400	3500	100	
1959-2012	3500	3700	200	
1959-2012	3700	4200	500	
1982-2012	5850	5925	75	

Table 91. FS Region 2 allocation for primary service-4

Initial RR	Lower frequency (GHz)	Upper frequency (GHz)	Bandwidth (GHz)	RR removal
1971	10.95	11.2	0.25	1982
1971	11.7	12.2	0.5	1982
1971	12.2	12.5	0.3	1982
1971	12.5	12.75	0.25	1982
1971	22.5	23	0.5	1982
1982	12.1	12.3	0.2	1986
1982	12.3	12.7	0.4	1986
1982	22.5	22.55	0.05	1994
1982	22.55	23	0.45	1994
1998	40.5	42.5	2	2001
1982-2012	10.5	10.55	0.05	
1982-2012	10.7	11.7	1	
1982-2012	11.7	12.1	0.4	
1986-2012	12.2	12.7	0.5	
1986-2012	12.7	12.75	0.05	
1994-2012	17.7	17.8	0.1	
1994-2012	17.8	18.1	0.3	
1994-2012	18.6	18.8	0.2	
1994-2012	21.4	22	0.6	
1982-2012	27	27.5	0.5	
2001-2012	40.5	41	0.5	
2004-2012	47.5	47.9	0.4	
2004-2012	48.2	50.2	2	

Table 92. FS American region/Region 2 allocation for shared/secondary services-1

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1938	27000	27500	500	1947
1938	30000	41000	11000	1947
1938	60000	66000	6000	1947
1938	72000	78000	6000	1947
1938	90000	96000	6000	1947
1938	108000	112000	4000	1947
1938	118000	123000	5000	1947
1938	132000	156000	24000	1947
1938	168000	180000	12000	1947
1938	192000	204000	12000	1947
1938	216000	224000	8000	1947
1938	230000	234000	4000	1947
1938	246000	258000	12000	1947
1938	270000	282000	12000	1947
1938	294000	300000	6000	1947
1947	70	90	20	1959
1947	110	130	20	1959
1947	130	150	20	1959
1947	150	160	10	1959
1947	1605	1800	195	1959
1947	1800	2000	200	1959
1947	2000	2065	65	1959
1947	2105	2300	195	1959
1947	2300	2495	195	1959
1947	2505	2850	345	1959
1947	3500	4000	500	1959
1947	4438	4650	212	1959
1947	4750	4850	100	1959
1947	5250	5450	200	1959
1938	27500	28000	500	1959
1959	90	110	20	1982

Table 93. FS Region 2 allocation shared/secondary services-2

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1947	29.7	44	14.3	1959
1947	44	50	6	1959
1947	54	72	18	1959
1947	72	76	4	1959
1947	76	88	12	1959
1947	132	144	12	1959
1947	148	174	26	1959
1947	174	216	42	1959
1947	216	220	4	1959
1947	225	235	10	1959
1947	450	460	10	1959
1947	3500	3900	400	1959
1959	1435	1535	100	1968
1968	1525	1535	10	1982
1982	1530	1535	5	1990
1959	2300	2450	150	1990
1968	1435	1525	90	1990
1990	1530	1533	3	1998
1990	1533	1535	2	1998
1982	614	806	192	2012
1982-2012	54	68	14	
1982-2012	68	72	4	
1982-2012	76	88	12	
1982-2012	174	216	42	
1982-2012	470	512	42	
2012	614	698	84	
2012	698	806	108	
1982-2012	1525	1530	5	
1982-2012	1530	1535	5	
1982-2012	3300	3400	100	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1994	21.4	22	0.6	1996

Table 94. FS Region 3 allocation for primary service-1

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1959	70	90	20	1982
1959	90	110	20	1982
1959	110	130	20	1982
1959	130	150	20	1982
1959	150	160	10	1982
1947	160	200	40	1982
1959	1605	1800	195	1982
1959	2505	2625	120	1982
1959	2625	2850	225	1982
1959	5250	5430	180	1982
1959	5430	5480	50	1982
1982	5730	5950	220	1994
1982	130	160	30	2008
1959	4438	4650	212	2012
1982-2012	72	84	12	
1982-2012	86	90	4	
1982-2012	110	112	2	
1982-2012	117.6	126	8.4	
1982-2012	129	130	1	
2008-2012	130	135.7	5.7	
2008-2012	135.7	137.8	2,1	
2008-2012	137.8	160	22.2	
1982-2012	160	190	30	
1982-2012	1606.5	1800	193.5	
1959-2012	1800	2000	200	
1959-2012	2000	2065	65	
1959-2012	2107	2170	63	
1959-2012	2194	2300	106	
1959-2012	2300	2495	195	
1982-2012	2505	2850	345	
1959-2012	3500	3900	400	
1959-2012	3950	4000	50	
2012	4438	4488	50	
2012	4488	4650	162	
1959-2012	4750	4850	100	
2012	5250	5275	25	
1982-2012	5450	5480	30	
1994-2012	5730	5900	170	
2012	9040	9305	265	
2012	9305	9355	50	
2012	9355	9400	45	
2012	13450	13550	100	
2012	16100	16200	100	
2012	24450	24600	150	
2012	24600	24890	290	
2012	26200	26350	150	
2012	26350	27500	1150	

Table 95. FS Region 3 allocation for primary service-2

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1959	137	144	7	1968
1959	148	170	22	1968
1959	1429	1535	106	1968
1959	1710	2290	580	1968
1959	5850	5925	75	1968
1959	132	136	4	1971
1968	136	137	1	1971
1959	2450	2550	100	1971
1968	5850	6425	575	1971
1968	8400	8500	0.1	1971
1959	27.5	28	0.5	1982
1959	41	44	3	1982
1959	44	50	6	1982
1959	68	70	2	1982
1959	70	74.6	4.6	1982
1959	75.4	78	2.6	1982
1959	78	80	2	1982
1959	80	87	7	1982
1968	150.05	170	19.95	1982
1959	170	174	4	1982
1959	174	216	42	1982
1959	225	235	10	1982
1968	1525	1535	10	1982
1968	1710	1770	60	1982
1968	1770	1790	20	1982
1968	1790	2290	500	1982
1971	2535	2550	15	1982
1968	4990	5000	10	1982
1971	2450	2500	50	1990
1968	1429	1525	96	1994
1982	1710	2290	580	1994
1959	2290	2300	10	1994
1971	2500	2535	35	1994
1971	2655	2690	35	1994
1994	2120	2160	40	1996
1994	1970	1980	10	1998
1971	8025	8175	150	1998
1971	8175	8215	40	1998
1971	8215	8400	185	1998
1994	1492	1525	33	2004
1994	1675	1690	15	2004
1982	150.05	156.7625	6.7125	2008
1982	3500	3700	200	2008
2008	150.05	156.4875	6.4375	2012
1982	156.8375	174	17.1625	2012

Table 96. FS Region 3 allocation for primary service-3

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
2012	38.25	39.5	1.25	
2012	39.5	39.986	0.486	
2012	39.986	40	0.014	
2012	40	40.02	0.02	
2012	42	42.5	0.5	
1982-2012	47	50	3	
1959-2012	54	68	14	
1982-2012	68	74.8	6.8	
1982-2012	75.2	75.4	0.2	
1982-2012	75.4	87	11.6	
1959-2012	87	100	13	
1968-2012	138	143.6	5.6	
1968-2012	143.6	143.65	0.05	
1968-2012	143.65	144	0.35	
1982-2012	146	148	2	
1968-2012	148	149.9	1.9	
2012	150.05	154	3.95	
2012	154	156.4875	2.4875	
2008-2012	156.5625	156.7625	0.2	
2012	161.9875	162.0125	25	
2012	162.0375	174	11.9625	
1982-2012	174	223	49	
1982-2012	223	230	7	
1982-2012	230	235	5	
1996-2012	455	456	1	
1996-2012	459	460	1	
1982-2012	470	585	115	
1982-2012	585	610	25	
1959-2012	610	890	280	
1959-2012	890	942	52	
1959-2012	942	960	18	
1994-2012	1429	1452	23	
1994-2012	1452	1492	40	
2004-2012	1492	1518	26	
2004-2012	1518	1525	7	
1982-2012	1525	1530	5	
1959-2012	1700	1710	10	
1994-2012	1930	1970	40	
1996-2012	2010	2025	15	
1996-2012	2120	2160	40	
1994-2012	2160	2170	10	
1982-2012	2300	2450	150	
1990-2012	2450	2483.5	33.5	
1990-2012	2483.5	2500	16.5	
1994-2012	2500	2520	20	
1994-2012	2520	2535	15	
1982-2012	2535	2655	120	
1994-2012	2655	2670	15	
1994-2012	2670	2690	20	
1982-2012	3400	3500	100	
2008-2012	3500	3600	100	
2008-2012	3600	3700	100	
1959-2012	3700	4200	500	
1971-2012	5850	5925	75	

Table 97. FS Region 3 allocation for primary service-4

Initial RR	Lower frequency (GHz)	Upper frequency (GHz)	Bandwidth (GHz)	RR removal
1971	10.95	11.2	0.25	1982
1971	22.5	23	0.5	1982
1982	22.5	22.55	0.05	1994
1982	22.55	23	0.45	1994
1998	40.5	42.5	2	2001
1982-2012	10	10.45	0.45	
1982-2012	10.5	10.55	0.05	
1982-2012	10.7	11.7	1	
1971-2012	11.7	12.2	0.5	
1971-2012	12.2	12.5	0.3	
1971-2012	12.5	12.75	0.25	
1982-2012	14.3	14.4	0.1	
1994-2012	17.7	18.1	0.4	
1982-2012	18.6	18.8	0.2	
1994-2012	21.4	22	0.6	
1994-2012	24.25	24.45	0.2	
1994-2012	24.45	24.65	0.2	
1994-2012	24.65	24.75	0.1	
1994-2012	24.75	25.25	0.5	
1982-2012	27	27.5	0.5	
2001-2012	40.5	41	0.5	
2004-2012	47.5	47.9	0.4	
2004-2012	48.2	50.2	2	

Table 98. FS Other regions/Region 3 allocation for shared/secondary services-1

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1932	160	194	34	1938
1932	194	285	91	1938
1932	1500	1715	215	1938
1938	160	200	40	1947
1938	1500	1600	100	1947
1938	1600	1715	115	1947
1932	1715	2000	285	1947
1938	2000	2300	300	1947
1938	2300	2500	200	1947
1938	2500	3300	800	1947
1938	3300	3500	200	1947
1938	3500	4000	500	1947
1938	4000	4770	770	1947
1938	4770	4965	195	1947
1938	4965	5500	535	1947
1947	70	90	20	1959
1947	110	130	20	1959
1947	130	150	20	1959
1947	150	160	10	1959
1947	1605	1800	195	1959
1947	1800	2000	200	1959
1947	2000	2065	65	1959
1947	2105	2300	195	1959
1947	2300	2495	195	1959
1947	2505	2850	345	1959
1947	3500	3900	400	1959
1947	3950	4000	50	1959
1947	4438	4650	212	1959
1947	4750	4850	100	1959
1947	5250	5430	180	1959
1947	5430	5480	50	1959
1947	27500	28000	500	1959
1982-2012	70	72	2	
1982-2012	84	86	2	
1982-2012	112	117.6	5.6	
1982-2012	126	129	3	

Table 99. FS Region 3 allocation for secondary service-2

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1947	29.7	31.7	2	1959
1947	31.7	44	12.3	1959
1947	44	50	6	1959
1947	54	68	14	1959
1947	70	78	8	1959
1947	80	87	7	1959
1947	132	144	12	1959
1947	148	170	22	1959
1947	170	200	30	1959
1947	1300	1700	400	1959
1947	3300	3900	600	1959
1947	5850	5925	75	1959
1959	2300	2450	150	1982
1959	3500	3700	200	1982
1982	1530	1535	5	1990
1990	1530	1533	3	1998
1990	1533	1535	2	1998
1998-2012	1530	1535	5	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1968-2012	31.5	31.8	0.3	

Appendix F Fixed-satellite service geographic frequency allocations

Table 100. FSS Global allocation for primary service-1

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1971	4400	4700	300	1982
1971	5925	6425	500	1982
1982	5925	7075	1150	1996
1976	7900	7975	75	2001
1971	7975	8025	50	2001
1982-2012	4500	4800	300	
1996-2012	5150	5250	100	
1996-2012	5925	6700	775	
1996-2012	6700	7075	375	
1971-2012	7250	7300	50	
1971-2012	7300	7450	150	
1971-2012	7450	7550	100	
1971-2012	7550	7750	200	
2001-2012	7900	8025	125	
1998-2012	8025	8175	150	
1998-2012	8175	8215	40	
1998-2012	8215	8400	185	

Table 101. FSS Global allocation for primary service-2

Initial RR	Lower frequency (GHz)	Upper frequency (GHz)	Bandwidth (GHz)	RR removal
1971	11.45	11.7	0.25	1982
1971	14	14.3	0.3	1982
1971	14.3	14.4	0.1	1982
1971	14.4	14.5	0.1	1982
1971	17.7	19.7	2	1982
1971	19.7	21.2	1.5	1982
1971	29.5	31	1.5	1982
1971	40	41	1	1982
1971	50	51	1	1982
1971	140	142	2	1982
1971	150	152	2	1982
1971	220	230	10	1982
1982	17.3	17.7	0.4	1994
1982	18.1	18.6	0.5	1994
1982	19.7	20.2	0.5	1994
1971	27.5	29.5	2	1994
1982	29.5	30	0.5	1994
1982	37.5	39.5	2	1994
1982	39.5	40.5	1	1994
1982	151	164	13	1994
1982	17.7	18.1	0.4	1996
1982	18.8	19.7	0.9	1996
1994	28.5	29.5	1	1996
1996	15.4	15.7	0.3	1998
1982	74	75.5	1.5	2001
1971	92	95	3	2001
1971	102	105	3	2001
1982	149	150	1	2001
1982	150	151	1	2001
1994	151	156	5	2001
1994	156	158	2	2001
1994	158	164	6	2001
1982	202	217	15	2001
1982	231	235	4	2001
1982	238	241	3	2001
1982	47.2	50.2	3	2004

Table 102. FSS Global allocation for primary service-3

Initial RR	Lower frequency (GHz)	Upper frequency (GHz)	Bandwidth (GHz)	RR removal
1982-2012	12.75	13.25	0.5	
1994-2012	13.75	14	0.25	
1982-2012	14	14.25	0.25	
1982-2012	14.25	14.3	0.05	
1982-2012	14.4	14.47	0.07	
1982-2012	14.47	14.5	0.03	
1982-2012	14.5	14.8	0.3	
2001-2012	15.43	15.63	0.2	
1994-2012	18.1	18.4	0.3	
1994-2012	18.4	18.6	0.2	
1996-2012	18.8	19.3	0.5	
1996-2012	19.3	19.7	0.4	
1994-2012	20.1	20.2	0.1	
1982-2012	20.2	21.2	0.1	
1994-2012	27.5	28.5	1	
1996-2012	28.5	29.1	0.6	
1996-2012	29.1	29.5	0.4	
1994-2012	29.9	30	0.1	
1982-2012	30	31	1	
1994-2012	37.5	38	0.5	
1994-2012	38	39.5	1.5	
1994-2012	39.5	40	0.5	
1996-2012	40	40.5	0.5	
2004-2012	41	42.5	0.15	
1982-2012	42.5	43.5	1	
2004-2012	47.2	47.5	0.3	
2004-2012	47.9	48.2	0.3	
1982-2012	50.4	51.4	1	
1982-2012	71	74	3	
2001-2012	74	76	2	
1982-2012	81	84	3	
2001-2012	84	86	2	
2001-2012	123	130	7	
2001-2012	158.5	164	5.5	
2001-2012	167	174.5	7.5	
2001-2012	209	217	8	
2001-2012	217	226	9	
2001-2012	232	235	3	
1982-2012	235	238	3	
2001-2012	238	240	2	
1971-2012	265	275	10	

Table 103. FSS Region 1 allocation for primary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1971	5725	5850	125	1996
1971	8025	8175	150	1996
1971	8175	8215	40	1996
1971	8215	8400	185	1996
1971-2012	3400	3600	200	
1971-2012	3600	4200	600	
1996-2012	5725	5830	105	
1996-2012	5830	5850	20	
1971-2012	5850	5925	75	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1971	10.95	11.2	0.25	1982
1982-2012	10.7	11.7	1	
1971-2012	12.5	12.75	0.25	
1982-2012	14.3	14.4	0.1	
1994-2012	17.3	17.7	0.4	
1994-2012	17.7	18.1	0.4	
1982-2012	18.6	18.8	0.2	
1994-2012	19.7	20.1	0.4	
2012	24.65	24.75	0.1	
2012	24.75	25.25	0.5	
1994-2012	29.5	29.9	0.4	
2001-2012	40.5	41	0.5	
2004-2012	47.5	47.9	0.4	
2004-2012	48.2	48.54	0.34	
2004-2012	48.54	49.44	0.9	
2004-2012	49.44	50.2	0.76	

Table 104. FSS Region 2 allocation for primary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1971	2500	2535	35	1982
1971	2655	2690	35	1994
1971	8025	8175	150	1998
1971	8175	8215	40	1998
1971	8215	8400	185	1998
1994-2012	2500	2520	20	
1982-2012	2500	2655	155	
1994-2012	2655	2670	15	
1994-2012	2670	2690	20	
1994-2012	3400	3500	100	
1971-2012	3500	3700	200	
1971-2012	3700	4200	500	
1982-2012	5850	5925	75	

Initial RR	Lower frequency (GHz)	Upper frequency (GHz)	Bandwidth (GHz)	RR removal
1971	10.95	11.2	0.25	1982
1971	11.7	12.2	0.5	1982
1971	12.5	12.75	0.25	1982
1982	12.1	12.3	0.2	1986
1998	40.5	42.5	0.2	2001
1982-2012	10.7	11.7	1	
1982-2012	11.7	12.1	0.4	
1986-2012	12.1	12.2	0.1	
1982-2012	12.7	12.75	0.05	
1982-2012	14.3	14.4	0.1	
1994-2012	17.3	17.7	0.4	
1994-2012	17.7	17.8	0.1	
1994-2012	17.8	18.1	0.3	
1982-2012	18.6	18.8	0.2	
1994-2012	19.7	20.1	0.4	
1994-2012	24.75	25.25	0.5	
1982-2012	27	27.5	0.5	
1994-2012	29.5	29.9	0.4	
2001-2012	40.5	41	0.5	
2004-2012	47.5	47.9	0.4	
2004-2012	48.2	50.2	2	

Table 105. FSS Region 3 allocation for primary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1971	2500	2535	35	1994
1971	2655	2690	35	1994
1971	8025	8175	150	1998
1971	8175	8215	40	1998
1971	8215	8400	185	1998
1971	3500	3700	200	2008
1994-2012	2500	2520	20	
1994-2012	2520	2535	15	
1994-2012	2655	2670	15	
1994-2012	2670	2690	20	
1971-2012	3400	3500	100	
2008-2012	3500	3600	100	
2008-2012	3600	3700	100	
1971-2012	3700	4200	500	
1971-2012	5850	5925	75	

Initial RR	Lower frequency (GHz)	Upper frequency (GHz)	Bandwidth (GHz)	RR removal
1971	10.95	11.2	0.25	1982
1998	40.5	42.5	2	2001
1982-2012	10.7	11.7	1	
2004-2012	12.2	12.5	0.3	
1971-2012	12.5	12.75	0.25	
1982-2012	14.3	14.4	0.1	
1994-2012	17.3	17.7	0.4	
1994-2012	17.7	18.1	0.4	
1982-2012	18.6	18.8	0.2	
1994-2012	19.7	20.1	0.4	
2012	24.65	24.75	0.1	
1994-2012	24.75	25.25	0.5	
1982-2012	27	27.5	0.5	
1994-2012	29.5	29.9	0.4	
2001-2012	40.5	41	0.5	
2004-2012	47.5	47.9	0.4	
2004-2012	48.2	50.2	2	

Appendix G Mobile service geographic frequency allocations

Table 106. MS Global allocation for exclusive/primary services-1

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1927	315	350	35	1932
1927	350	360	10	1932
1927	390	460	70	1932
1927	485	515	30	1932
1927	515	550	35	1932
1927	1500	1715	215	1932
1927	2250	2750	500	1932
1927	5500	5700	200	1938
1927	6150	6675	525	1938
1932	24600	25600	1000	1938
1927	110	125	15	1947
1927	150	160	10	1947
1932	400	460	60	1947
1927	460	485	25	1947
1932	485	515	30	1947
1938	5500	5640	140	1947
1938	6200	6675	475	1947
1927	8200	8550	350	1947
1927	11000	11400	400	1947
1927	12300	12825	525	1947
1927	16400	17100	700	1947
1927	21550	22300	750	1947
1938	24600	25000	400	1947
1938	25000	25600	600	1947
1947	490	510	20	1982
1959	2170	2194	24	1982
1959	25110	25600	490	1990
1959	26100	27500	1400	1990
1982	495	505	10	2012
1982	5250	5450	200	2012
1990	26175	27500	1325	2012

Table 107. MS Global allocation for primary service-2

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
2012	479	505	26	
1982-2012	2173.5	2190.5	17	
1959-2012	3155	3200	45	
1959-2012	3200	3230	30	
1959-2012	3230	3400	170	
2012	5275	5450	175	
2004-2012	6765	7000	235	
1982-2012	23350	24000	650	
2004-2012	23350	24000	650	
1959-2012	25010	25070	60	
1990-2012	25210	25550	340	
2012	26175	26200	25	

Table 108. MS Global allocation for primary service-3

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1959	29.7	41	11.3	1968
1959	136	137	1	1968
1959	235	328.6	93.6	1968
1959	335.4	400	64.6	1968
1959	450	470	20	1968
1959	1660	1700	40	1968
1959	2550	2700	150	1968
1959	4400	5000	600	1968
1959	5925	8400	2475	1968
1959	8400	8500	100	1968
1959	406	420	14	1971
1968	2550	2690	140	1971
1968	7300	7750	450	1971
1968	7750	7900	150	1971
1968	8025	8400	375	1971
1968	30.01	37.75	7.74	1982
1968	38,25	41	2.75	1982
1968	273	328.6	55.6	1982
1971	2550	2655	105	1982
1968	4400	4700	300	1982
1968	4700	4990	290	1982
1968	5925	6425	500	1982
1968	6425	7250	825	1982
1968	37.75	38.25	0.5	1990
1982	273	322	49	1994
1968	335.4	399.9	64.5	1994
1968	1670	1690	20	1994
1968	7900	7975	75	1994
1982	7975	8025	50	1994
1968	450	460	10	1996
1994	2010	2025	15	1996
1982	5925	7075	1150	1996
1971	7750	7900	150	1998
1982	7075	7250	175	2004
1982	41.015	44	2.985	2012
1998	7750	7850	100	2012
1998	7850	7900	50	2012

Table 109. MS Global allocation for primary service-4

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1982-2012	27.5	28	0.5	
1968-2012	29.7	30.005	0.305	
1968-2012	30.005	30.01	0.05	
1982-2012	30.01	37.5	7.49	
1990-2012	37.5	38.25	0.75	
1982-2012	38.25	39.986	1.736	
1982-2012	39.986	40.02	0.034	
1982-2012	40.02	40.98	0.96	
1982-2012	40.98	41.015	0.035	
2012	41.015	42	0.985	
2012	42.5	44	1.5	
1982-2012	44	47	3	
1968-2012	235	267	32	
1968-2012	267	272	5	
1968-2012	272	273	1	
1994-2012	273	312	39	
1994-2012	312	315	3	
1994-2012	315	322	7	
1982-2012	322	328.6	6.6	
1994-2012	335.4	387	51.6	
1994-2012	387	390	3	
1994-2012	390	399.9	9.9	
1971-2012	406.1	410	3.9	
1971-2012	410	420	10	
1982-2012	420	430	10	
1982-2012	440	450	10	
1996-2012	450	455	5	
1996-2012	456	459	3	
1968-2012	460	470	10	
1959-2012	1427	1429	2	
1982-2012	1668.4	1670	1.6	
1994-2012	1670	1675	5	
2004-2012	1675	1690	15	
1994-2012	1710	1930	220	
1998-2012	1970	1980	10	
1994-2012	1980	2010	30	
1994-2012	2025	2110	85	
1994-2012	2110	2120	10	
1994-2012	2170	2200	30	
1994-2012	2200	2290	90	
1994-2012	2290	2300	10	
1982-2012	4400	4500	100	
1982-2012	4500	4800	300	
1982-2012	4800	4990	190	
1982-2012	4990	5000	10	
2004-2012	5150	5250	100	
2004-2012	5250	5255	5	
2004-2012	5255	5350	95	
2004-2012	5470	5570	100	
2004-2012	5570	5650	80	
2004-2012	5650	5725	75	
1996-2012	5925	6700	775	
1996-2012	6700	7075	375	
2004-2012	7075	7145	70	
2004-2012	7145	7235	90	
2004-2012	7235	7250	15	
1982-2012	7250	7300	50	
1971-2012	7300	7450	150	
1971-2012	7450	7550	100	
1971-2012	7550	7750	200	
2012	7750	7900	150	
1994-2012	7900	8025	125	
2001-2012	8025	8175	150	
2001-2012	8175	8215	40	
2001-2012	8215	8400	185	
1971-2012	8400	8500	100	

Table 110. MS Global allocation for primary service-5

Initial RR	Lower frequency (GHz)	Upper frequency (GHz)	Bandwidth (GHz)	RR removal
1959	10.55	10.7	0.15	1968
1959	14.4	15.15	0.75	1968
1959	15.25	15.4	0.15	1968
1959	17.7	21	3.3	1968
1959	25.25	31.5	6.25	1968
1968	10.55	10.68	0.13	1971
1959	10.7	11.7	1	1971
1959	11.7	12.7	1	1971
1959	12.7	13.25	0.55	1971
1968	14.4	15.25	0.85	1971
1968	17.7	19.3	1.6	1971
1968	19.4	21	1.6	1971
1959	22	23	1	1971
1968	25.25	31	5.75	1971
1971	10.7	10.95	0.25	1982
1971	11.2	11.45	0.25	1982
1971	11.45	11.7	0.25	1982
1971	14.4	14.5	0.1	1982
1971	14.5	15.35	0.85	1982
1971	17.7	19.7	2	1982
1971	21.2	22	0.8	1982
1971	22	22.5	0.5	1982
1971	23	23.6	0.6	1982
1971	25.25	27.5	2.25	1982
1959	36	40	4	1982
1982	17.7	18.1	0.4	1994
1982	18.1	18.6	0.5	1994
1982	21.4	22	0.6	1994
1982	25.25	27	1.75	1994
1971	27.5	29.5	2	1994
1982	37.5	39.5	2	1994
1982	151	164	13	1994
1982	18.8	19.7	0.9	1996
1994	28.5	29.5	1	1996
1982	116	126	10	1996
1994	22.55	23	0.45	1998
1982	23	23.55	0.55	1998
1982	50.2	50.4	0.2	1998
1982	54.25	58.2	3.95	1998
1982	59	64	5	1998
1982	92	95	3	1998
1982	74	75.5	1.5	2001
1996	116	119.98	3.98	2001
1996	119.98	120.02	0.04	2001
1996	120.02	126	5.98	2001
1982	126	134	8	2001
1982	134	142	8	2001
1982	149	150	1	2001
1982	150	151	1	2001
1994	151	156	5	2001
1994	156	158	2	2001
1994	158	164	6	2001
1982	168	170	2	2001
1982	170	174.5	4.5	2001
1982	174.5	176.5	2	2001
1982	176.5	182	5.5	2001

Initial RR	Lower frequency (GHz)	Upper frequency (GHz)	Bandwidth (GHz)	RR removal
1982	185	190	5	2001
1982	190	200	10	2001
1982	200	202	2	2001
1982	202	217	15	2001
1982	231	235	4	2001
1982	235	238	3	2001
1982	238	241	3	2001
1982	100	102	2	2001
1982	47.2	50.2	3	2004
1998	22.55	23.55	1	2012

Table 111. MS Global allocation for primary service-6

Initial RR	Lower frequency (GHz)	Upper frequency (GHz)	Bandwidth (GHz)	RR removal
1971-2012	10.55	10.6	0.05	
1971-2012	10.6	10.68	0.08	
1971-2012	12.75	13.25	0.5	
1982-2012	14.4	14.47	0.07	
1982-2012	14.47	14.5	0.03	
1982-2012	14.5	14.8	0.3	
1982-2012	14.8	15.35	0.55	
1994-2012	18.1	18.4	0.3	
1994-2012	18.4	18.6	0.2	
1996-2012	18.8	19.3	0.5	
1996-2012	19.3	19.7	0.4	
1982-2012	21.2	21.4	0.2	
1982-2012	22	22.21	0.21	
1982-2012	22.21	22.5	0.29	
1994-2012	22.5	22.55	0.05	
2012	22.55	23.15	0.6	
2012	23.15	23.55	0.4	
1982-2012	23.55	23.6	0.05	
1994-2012	25.25	25.5	0.25	
1994-2012	25.5	27	1.5	
1994-2012	27.5	28.5	1	
1996-2012	28.5	29.1	0.6	
1996-2012	29.1	29.5	0.4	
1968-2012	31	31.3	0.3	
1982-2012	36	37	1	
1982-2012	37	37.5	0.5	
1994-2012	37.5	38	0.5	
1994-2012	38	39.5	1.5	
1994-2012	39.5	40	0.5	
1982-2012	40	40.5	0.5	
1982-2012	42.5	43.5	1	
1982-2012	43.5	47	3.5	
2004-2012	47.2	47.5	0.3	
2004-2012	47.9	48.2	0.3	
1982-2012	50.4	51.4	1	
1998-2012	51.4	52.6	1.2	
1998-2012	55.78	56.9	1.12	
1998-2012	56.9	57	0.1	
1998-2012	57	58.2	1.2	
1998-2012	58.2	59	0.80	
1998-2012	59	59.3	0.3	
1998-2012	59.3	64	4.7	
1998-2012	64	65	1	
1998-2012	65	66	1	
1982-2012	66	71	5	
1982-2012	71	74	3	
2001-2012	74	76	2	
1982-2012	81	84	3	
1982-2012	84	86	2	
1998-2012	92	94	2	
1998-2012	94.1	95	0.9	
1982-2012	95	100	5	
1982-2012	102	105	3	
2001-2012	105	109.5	4.5	
2001-2012	111.8	114.25	2.45	
2001-2012	122.25	123	0.75	
2001-2012	130	134	4	
2001-2012	141	148.5	7.5	
2001-2012	151.5	155.5	4	
2001-2012	155.5	158.5	3	
2001-2012	158.5	164	5.5	
2001-2012	167	174.5	7.5	
2001-2012	174.5	174.8	0.3	
2001-2012	191.8	200	8.2	
2001-2012	209	217	8	
2001-2012	217	226	9	
2001-2012	231.5	232	0.5	
2001-2012	232	235	3	
2001-2012	238	240	2	
2001-2012	240	241	1	
1982-2012	252	265	13	
1982-2012	265	275	10	

Table 112. MS Global allocation for share/secondary services-1

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1927	160	194	34	1932
1927	194	285	91	1932
1927	360	390	30	1932
1927	1715	2000	285	1932
1927	2000	2250	250	1932
1927	2850	3500	650	1932
1927	22300	23000	700	1932
1932	365	385	20	1938
1932	2000	3500	1500	1938
1927	3500	4000	500	1938
1927	100	110	10	1947
1938	365	380	15	1947
1932	550	1500	950	1947
1927	4000	5500	1500	1947
1927	8550	8900	350	1947
1927	12825	13350	525	1947
1927	17100	17750	650	1947
1932	22300	24600	2300	1947
1947	3155	3200	45	1959
1947	3200	3230	30	1959
1947	3230	3400	170	1959
1947	4850	4995	145	1959
1947	23350	24990	1640	1959
1947	25010	25600	590	1959
1947	26100	27500	1400	1959
1982	13410	13600	190	1994
1982	13800	14000	200	1994
1994	13410	13570	160	2012
1982-2012	5060	5250	190	
1982-2012	10150	11175	1025	
2012	13410	13450	40	
2012	13550	13570	20	
1994-2012	13870	14000	130	
1982-2012	14350	14990	640	
1994-2012	18168	18780	612	
1982-2012	20010	21000	990	
1982-2012	23000	23200	200	

Table 113. MS Global allocation for share/secondary services-2

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1947	235	328.6	93.6	1959
1947	335.4	420	84.6	1959
1947	460	470	10	1959
1947	1700	2300	600	1959
1947	2450	2700	250	1959
1947	3900	4200	300	1959
1947	4400	5000	600	1959
1947	5925	8500	2575	1959
1959	401	406	5	1968
1968	402	406	4	1971
1982	137	138	1	1994
1982	136	137	1	2001
1982	1660.5	1668.4	7.9	2004
1994-2012	137	137.025	0.025	
1994-2012	137.025	137.175	0.015	
1994-2012	137.175	137.825	0.65	
1994-2012	137.825	138	0.175	
1968-2012	401	402	1	
1971-2012	402	403	1	
1971-2012	403	406	3	
2004-2012	1660.5	1668	7.5	
2004-2012	1668	1668.4	0.4	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1959	15.15	15.25	0.1	1968
1959	31.5	31.8	0.3	1968
1982	40.5	42.5	0.2	1998
1982	65	66	1	1998
2001-2012	41	42.5	1.5	

Table 114. MS EU region/Region 1 allocation for exclusive/primary services-1

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1932	1530	1630	100	1938
1938	1560	1600	40	1947
1938	1670	1715	45	1947
1938	25000	25600	600	1947
1938	157000	162000	5000	1947
1959	405	415	10	1982
1959	1605	2000	395	1982
1959	2000	2045	45	1982
1959	2045	2065	20	1982
1959	2065	2170	105	1982
1959	4438	4650	212	2012
1982-2012	1850	2000	150	
1982-2012	2000	2025	25	
1982-2012	2025	2045	20	
1959-2012	2194	2300	106	
1959-2012	2300	2498	198	
1959-2012	2502	2625	123	
1959-2012	2650	2850	200	
1959-2012	3500	3800	300	
2012	4438	4488	50	
2012	4488	4650	162	
2012	5250	5275	25	
2012	26200	26350	150	
2012	26350	27500	1150	

Table 115. MS Region 1 allocation for primary service-2

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1959	146	151	5	1968
1959	1429	1535	106	1968
1968	136	137	1	1971
1959	2450	2550	100	1971
1968	8400	8500	100	1971
1959	151	154	3	1976
1947	100	108	8	1982
1968	150.05	151	0.95	1982
1976	151	153	2	1982
1976	153	154	1	1982
1959	154	156	2	1982
1959	156	174	18	1982
1959	420	430	10	1982
1959	440	450	10	1982
1971	2500	2550	50	1982
1959	3400	3600	200	1982
1968	4990	5000	10	1982
1971	2450	2500	50	1990
1968	146	149.9	3.9	1994
1968	1429	1525	96	1994
1982	2500	2655	155	1994
1971	2655	2690	35	1994
1994	1970	1980	10	1998
1971	8025	8175	150	1998
1971	8175	8215	40	1998
1971	8215	8400	185	1998
1994	1492	1525	33	2004
1994	1675	1690	15	2004
1982	154	156.7625	2.7625	2008
1982	156.8375	174	17.1625	2012
2012	38.25	39	0.75	
2012	39	39.5	0.5	
2012	39.5	39.986	0.486	
2012	39.986	40.02	0.034	
2012	42	42.5	0.5	
1959-2012	68	74.8	6.8	
1959-2012	75.2	87.5	12.3	
1994-2012	146	148	2	
1994-2012	148	149.9	1.9	
1982-2012	150.05	153	2.95	
1982-2012	153	154	1	
2008-2012	154	156.4875	2.4875	
2008-2012	156.5625	156.7625	0.2	
2012	156.8375	161.9625	5.125	
2012	161.9625	161.9875	0.025	
2012	161.9875	162.0125	0.025	
2012	162.0125	162.0375	0.025	
2012	162.0375	174	11.9625	
1982-2012	230	235	5	
1996-2012	455	456	1	
1996-2012	459	460	1	
2008-2012	790	862	72	
1982-2012	862	890	28	
1982-2012	890	942	52	
1982-2012	942	960	18	
1959-2012	1350	1400	50	
1994-2012	1429	1452	23	

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1994-2012	1452	1492	40	
2004-2012	1492	1518	26	
2004-2012	1518	1525	7	
1994-2012	1700	1710	10	
1994-2012	1930	1970	40	
1996-2012	2010	2025	15	
1994-2012	2120	2160	40	
1994-2012	2160	2170	10	
1994-2012	2300	2450	150	
1990-2012	2450	2483.5	33.5	
1990-2012	2483.5	2500	16.5	
1994-2012	2500	2520	20	
1994-2012	2520	2655	135	
1994-2012	2655	2670	15	
1994-2012	2670	2690	20	
1959-2012	5850	5925	75	

Table 116. MS Region 1 allocation for primary service-3

Initial RR	Lower frequency (GHz)	Upper frequency (GHz)	Bandwidth (GHz)	RR removal
1971	10.95	11.2	0.25	1982
1976	11.7	12.5	0.8	1982
1971	22.5	23	0.5	1982
1982	22.5	22.55	0.05	1994
1982	22.55	23	0.45	1994
1994	11.7	12.5	0.8	1996
1982-2012	10	10.45	0.45	
1959-2012	10.5	10.55	0.05	
1982-2012	10.7	11.7	1	
1998-2012	11.7	12.5	0.8	
1982-2012	14.3	14.4	0.1	
1994-2012	17.7	18.1	0.4	
1982-2012	18.6	18.8	0.2	
1994-2012	21.4	22	0.6	
1982-2012	27	27.5	0.5	
2004-2012	47.5	47.9	0.4	
2004-2012	48.2	48.54	0.34	
2004-2012	48.54	49.44	0.9	
2004-2012	49.44	50.2	0.76	

Table 117. MS EU region/Region 1 allocation for share/secondary services-1

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1932	1500	1530	30	1938
1932	1715	1925	210	1938
1938	2660	2810	150	1947
1938	2860	2900	40	1947
1938	2930	3065	135	1947
1938	3095	3245	150	1947
1938	3305	3500	195	1947
1938	3500	3635	135	1947
1938	3685	3950	265	1947
1938	4000	4480	480	1947
1938	4530	5500	970	1947
1938	40000	40500	500	1947
1947	1605	2000	395	1959
1947	2000	2045	45	1959
1947	2065	2300	235	1959
1947	2300	2498	198	1959
1947	2502	2625	123	1959
1947	2650	2850	200	1959
1947	3500	3800	300	1959
1947	3800	3900	100	1959
1947	4750	4850	100	1959
1947	5250	5430	180	1959
1947	5430	5480	50	1959
2012	13450	13550	100	

Table 118. MS Region 1 allocation for share/secondary services-2

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1947	31.7	41	9.3	1959
1947	70	72.8	2.8	1959
1947	75.2	78	2.8	1959
1947	80	83	3	1959
1947	85	87.5	2.5	1959
1947	156	174	18	1959
1947	1300	1600	300	1959
1947	3300	3900	600	1959
1947	5850	5925	75	1959
1959	1710	2290	580	1968
1959	41	47	6	1982
1959	223	235	12	1982
1968	1525	1535	10	1982
1968	1710	1770	60	1982
1968	1770	1790	20	1982
1968	1790	2290	500	1982
1982	1530	1535	5	1990
1959	1700	1710	10	1994
1982	1710	2290	580	1994
1959	2290	2300	10	1994
1959	2300	2450	150	1994
1990	1530	1533	3	2001
1990	1533	1535	2	2001
1982-2012	223	230	7	
1982-2012	1525	1530	5	
2001-2012	1530	1535	5	
1968-2012	1690	1700	10	
1982-2012	3400	3600	200	
1959-2012	3600	4200	600	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1982	11.7	12.5	0.8	1994
1996	11.7	12.5	0.8	1998
1998	40.5	42.5	2	2001
1968-2012	31.5	31.8	0.3	
2001-2012	40.5	41	0.5	

Table 119. MS Region 2 allocation for exclusive/primary services-1

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1947	525	535	10	1982
1959	1605	1800	195	1982
1959	1800	2000	200	1982
1959	2505	2625	120	1982
1959	2625	2850	225	1982
1959	3500	4000	500	1982
1982	5730	5950	220	1994
1947	510	525	15	2012
1959	4438	4650	212	2012
1982-2012	1625	1705	80	
1982-2012	1705	1800	95	
1982-2012	1850	2000	150	
1959-2012	2000	2065	65	
1959-2012	2107	2170	63	
1959-2012	2194	2300	106	
1959-2012	2300	2495	195	
1982-2012	2505	2850	345	
1982-2012	3750	4000	250	
2012	4438	4488	50	
2012	4488	4650	162	
1982-2012	4750	4850	100	
2012	5250	5275	25	
1994-2012	5730	5900	170	
2004-2012	7400	7450	50	
2012	26200	26420	220	
2012	26420	27500	1080	

Table 120. MS Region 2 allocation for primary service-2

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1959	68	74.6	6.6	1968
1959	137	144	7	1968
1959	148	174	26	1968
1959	1435	1535	100	1968
1959	1700	1710	10	1968
1959	1710	2290	580	1968
1959	2290	2300	10	1968
1959	132	136	4	1971
1959	2450	2550	100	1971
1959	27.5	28	0.5	1982
1959	41	50	9	1982
1959	54	68	14	1982
1968	68	73	5	1982
1959	75.4	88	12.6	1982
1968	150.05	174	23.95	1982
1959	174	216	42	1982
1959	216	220	4	1982
1968	1710	1770	60	1982
1968	1770	1790	20	1982
1968	1790	2290	500	1982
1971	2500	2535	35	1982
1971	2535	2550	15	1982
1959	1429	1435	6	1990
1968	1435	1525	90	1990
1971	2450	2500	50	1990
1990	1429	1525	96	1994
1982	1710	2290	580	1994
1971	2290	2300	10	1994
1982	2500	2655	155	1994
1971	2655	2690	35	1994
1994	1970	1980	10	1998
1971	8025	8175	150	1998
1971	8175	8215	40	1998
1971	8215	8400	185	1998
1994	1492	1525	33	2004
1994	1675	1690	15	2004
1982	150.05	156.7625	6.7125	2008
2008	150.05	156.4875	6.4375	2012
1982	156.8375	174	17.1625	2012

Table 121. MS Region 2 allocation for primary service-3

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
2012	38.25	39.986	1.736	
2012	39.986	40.02	0.034	
2012	42	42.5	0.5	
1982-2012	47	50	3	
1982-2012	72	73	1	
1982-2012	74.6	74.8	0.2	
1982-2012	75.2	75.4	0.2	
1982-2012	75.4	76	0.6	
1968-2012	138	143.6	5.6	
1968-2012	143.6	143.65	0.05	
1968-2012	143.65	144	0.35	
1968-2012	148	149.9	1.9	
2012	150.05	154	3.95	
2012	154	156.4875	2.4875	
2008-2012	156.5625	156.7625	0.2	
2012	156.8375	161.9625	5.125	
2012	161.9875	162.0125	0.25	
2012	162.0375	174	11.9625	
1982-2012	220	225	5	
1959-2012	225	235	10	
1996-2012	455	456	1	
1996-2012	459	460	1	
2012	698	806	108	
1982-2012	806	890	84	
1982-2012	890	902	12	
1982-2012	928	942	14	
1994-2012	942	960	18	
1994-2012	1429	1452	23	
1994-2012	1452	1492	40	
2004-2012	1492	1518	26	
2004-2012	1518	1525	7	
1971-2012	1700	1710	10	
1994-2012	1930	1970	40	
1996-2012	2010	2025	15	
1994-2012	2120	2160	40	
1994-2012	2160	2170	10	
1990-2012	2300	2450	150	
1990-2012	2450	2483.5	33.5	
1990-2012	2483.5	2500	16.5	
1994-2012	2500	2520	20	
1994-2012	2520	2655	135	
1994-2012	2655	2670	15	
1994-2012	2670	2690	20	
1959-2012	3500	3700	200	
1959-2012	3700	4200	500	
1982-2012	5850	5925	75	

Table 122. MS Region 2 allocation for primary service-4

Initial RR	Lower frequency (GHz)	Upper frequency (GHz)	Bandwidth (GHz)	RR removal
1971	10.95	11.2	0.25	1982
1971	11.7	12.2	0.5	1982
1971	12.2	12.5	0.3	1982
1971	12.5	12.75	0.25	1982
1971	22.5	23	0.5	1982
1982	12.1	12.3	0.2	1986
1982	12.3	12.7	0.4	1986
1982	22.5	22.55	0.05	1994
1982	22.55	23	0.45	1994
1982-2012	10.5	10.55	0.05	
1982-2012	10.7	11.7	1	
1986-2012	12.2	12.7	0.5	
1982-2012	12.7	12.75	0.05	
1994-2012	17.8	18.1	0.3	
1982-2012	18.6	18.8	0.2	
1996-2012	21.4	22	0.6	
1982-2012	27	27.5	0.5	
2004-2012	47.5	47.9	0.4	
2004-2012	48.2	50.2	2	

Table 123. American Region/MS Region 2 allocation for share/secondary services-1

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1938	27000	27500	500	1947
1938	30000	41000	11000	1947
1938	60000	66000	6000	1947
1938	72000	78000	6000	1947
1938	90000	96000	6000	1947
1938	108000	112000	4000	1947
1938	118000	123000	5000	1947
1938	132000	156000	24000	1947
1938	168000	180000	12000	1947
1938	192000	204000	12000	1947
1938	216000	224000	8000	1947
1938	230000	234000	4000	1947
1938	246000	258000	12000	1947
1938	270000	282000	12000	1947
1938	294000	300000	6000	1947
1947	2505	2850	345	1959
1947	3500	4000	500	1959
1947	4438	4650	212	1959
1947	5250	5450	200	1959
1938	27500	28000	500	1959
2012	13450	13550	100	

Table 124. MS Region 2 allocation for share/secondary services-2

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1947	29.7	44	14.3	1959
1947	44	50	6	1959
1947	54	72	18	1959
1947	72	76	4	1959
1947	76	88	12	1959
1947	132	144	12	1959
1947	148	174	26	1959
1947	174	216	42	1959
1947	216	220	4	1959
1947	225	235	10	1959
1947	450	460	10	1959
1947	3500	3900	400	1959
1968	1525	1535	10	1982
1982	1530	1535	5	1990
1959	2300	2450	150	1990
1982	942	960	18	1994
1990	1530	1533	3	1998
1990	1533	1535	2	1998
1982	614	806	192	2008
2008	698	806	108	2012
1982-2012	54	68	14	
1982-2012	68	72	4	
1982-2012	76	88	12	
1982-2012	174	216	42	
1982-2012	470	512	42	
2008-2012	614	698	84	
1982-2012	902	928	26	
1982-2012	1525	1530	5	
1998-2012	1530	1535	5	
1982-2012	3300	3400	100	
1982-2012	3400	3500	100	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1998	40.5	42.5	2	2001
1982-2012	11.7	12.1	0.4	
1994-2012	17.7	17.8	0.1	
2001-2012	40.5	41	0.5	

Table 125. MS Other regions/Region 3 allocation for exclusive/primary services-1

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1932	385	400	15	1938
1938	400	415	15	1947
1947	405	415	10	1959
1947	510	525	15	1959
1947	525	535	10	1982
1959	1605	1800	195	1982
1959	2505	2625	120	1982
1959	2625	2850	225	1982
1959	4438	4650	212	2012
1982-2012	1606.5	1800	193.5	
1959-2012	1800	2000	200	
1959-2012	2000	2065	65	
1959-2012	2107	2170	63	
1959-2012	2194	2300	106	
1959-2012	2300	2495	195	
1982-2012	2505	2850	345	
1959-2012	3500	3900	400	
2012	4438	4488	50	
2012	4488	4650	162	
2012	5250	5275	25	
2012	26200	26350	150	
2012	26350	27500	1150	

Table 126. MS Region 3 allocation for primary service-2

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1959	137	144	7	1968
1959	148	170	22	1968
1959	1429	1535	106	1968
1959	1710	2290	580	1968
1959	5850	5925	75	1968
1959	132	136	4	1971
1968	136	137	1	1971
1959	2450	2550	100	1971
1968	5850	6425	575	1971
1968	8400	8500	100	1971
1959	27.5	28	0.5	1982
1959	41	44	3	1982
1959	44	50	6	1982
1959	68	70	2	1982
1959	70	74.6	4.6	1982
1959	75.4	78	2.6	1982
1959	78	80	2	1982
1959	80	87	7	1982
1968	150.05	170	19.95	1982
1959	170	174	4	1982
1959	174	216	42	1982
1959	225	235	10	1982
1968	1710	1770	60	1982
1968	1770	1790	20	1982
1968	1790	2290	500	1982
1971	2535	2550	15	1982
1968	4990	5000	10	1982
1971	2450	2500	50	1990
1968	1429	1525	96	1994
1982	1710	2290	580	1994
1959	2290	2300	10	1994
1971	2500	2535	35	1994
1971	2655	2690	35	1994
1994	1970	1980	10	1998
1971	8025	8175	150	1998
1971	8175	8215	40	1998
1971	8215	8400	185	1998
1994	1492	1525	33	2004
1994	1675	1690	15	2004
1982	150.05	156.7625	6.7125	2008
2008	150.05	156.4875	6.4375	2012
1982	156.8375	174	17.1625	2012

Table 127. MS Region 3 allocation for primary service-3

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
2012	38.25	39.5	1.25	
2012	39.5	39.986	0.486	
2012	39.986	40	0.014	
2012	40	40.02	0.02	
2012	42	42.5	0.5	
1982-2012	47	50	3	
1959-2012	54	68	14	
1982-2012	68	74.8	6.8	
1982-2012	75.2	75.4	0.2	
1982-2012	75.4	87	11.6	
1959-2012	87	100	13	
1968-2012	138	143.6	5.6	
1968-2012	143.6	143.65	0.05	
1968-2012	143.65	144	0.35	
1982-2012	146	148	2	
1968-2012	148	149.9	1.9	
2012	150.05	154	3.95	
2012	154	156.4875	2.4875	
2008-2012	156.5625	156.7625	0.2	
2012	161.9875	162.0125	0.025	
2012	162.0375	174	11.9625	
1982-2012	174	223	49	
1982-2012	223	230	7	
1982-2012	230	235	5	
1996-2012	455	456	1	
1996-2012	459	460	1	
1982-2012	470	585	115	
1982-2012	585	610	25	
1959-2012	610	890	280	
1959-2012	890	942	52	
1959-2012	942	960	18	
1994-2012	1429	1452	23	
1994-2012	1452	1492	40	
2004-2012	1492	1518	26	
2004-2012	1518	1525	7	
1959-2012	1700	1710	10	
1994-2012	1930	1970	40	
1996-2012	2010	2025	15	
1994-2012	2120	2160	40	
1994-2012	2160	2170	10	
1982-2012	2300	2450	150	
1990-2012	2450	2483.5	33.5	
1990-2012	2483.5	2500	16.5	
1994-2012	2500	2520	20	
1994-2012	2520	2535	15	
1982-2012	2535	2655	120	
1994-2012	2655	2670	15	
1994-2012	2670	2690	20	
1982-2012	3500	3700	200	
1959-2012	3700	4200	500	
1971-2012	5850	5925	75	

Table 128. MS Region 3 allocation for primary service-4

Initial RR	Lower frequency (GHz)	Upper frequency (GHz)	Bandwidth (GHz)	RR removal
1971	10.95	11.2	0.25	1982
1971	22.5	23	0.5	1982
1982	22.5	22.55	0.05	1994
1982	22.55	23	0.45	1994
1982-2012	10	10.45	0.45	
1982-2012	10.5	10.55	0.05	
1982-2012	10.7	11.7	1	
1971-2012	11.7	12.2	0.5	
1971-2012	12.2	12.5	0.3	
1971-2012	12.5	12.75	0.25	
1982-2012	14.3	14.4	0.1	
1994-2012	17.7	18.1	0.4	
1982-2012	18.6	18.8	0.2	
1994-2012	21.4	22	0.6	
1994-2012	24.25	24.45	0.2	
1994-2012	24.45	24.65	0.2	
1994-2012	24.65	24.75	0.1	
1994-2012	24.75	25.25	0.5	
1982-2012	27	27.5	0.5	
2004-2012	47.5	47.9	0.4	
2004-2012	48.2	50.2	2	

Table 129. MS Other regions/Region 3 allocation for share/secondary services-1

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1932	160	194	34	1938
1932	194	285	91	1938
1932	1500	1715	215	1938
1938	160	200	40	1947
1938	200	285	85	1947
1932	320	325	5	1947
1932	345	365	20	1947
1938	380	385	5	1947
1938	385	395	10	1947
1938	395	400	5	1947
1938	1500	1600	100	1947
1938	1600	1715	115	1947
1932	1715	2000	285	1947
1938	2000	2300	300	1947
1938	2300	2500	200	1947
1938	2500	3300	800	1947
1938	3300	3500	200	1947
1938	3500	4000	500	1947
1938	4000	4770	770	1947
1938	4770	4965	195	1947
1938	4965	5500	535	1947
1947	1605	1800	195	1959
1947	1800	2000	200	1959
1947	2000	2065	65	1959
1947	2105	2300	195	1959
1947	2300	2495	195	1959
1947	2505	2850	345	1959
1947	3500	3900	400	1959
1947	4438	4650	212	1959
1947	5250	5430	180	1959
1947	5430	5480	50	1959
1947	27500	28000	500	1959
1982	5730	5950	220	1994
1982-2012	526.5	535	8.5	
1994-2012	5730	5900	170	
2012-2012	13450	13550	100	

Table 130. MS Region 3 allocation for share/secondary services-2

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1947	29.7	31.7	2	1959
1947	31.7	44	12.3	1959
1947	44	50	6	1959
1947	54	68	14	1959
1947	70	78	8	1959
1947	80	87	7	1959
1947	132	144	12	1959
1947	148	170	22	1959
1947	170	200	30	1959
1947	1300	1700	400	1959
1947	3300	3900	600	1959
1947	5850	5925	75	1959
1968	1525	1535	10	1982
1959	2300	2450	150	1982
1959	3500	3700	200	1982
1982	1530	1535	5	1990
1990	1530	1533	3	2001
1990	1533	1535	2	2001
1982-2012	1525	1530	5	
2001-2012	1530	1535	5	
1982-2012	3400	3500	100	
2012	3500	3600	100	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1998	40.5	42.5	2	2001
1968-2012	31.5	31.8	0.3	
2001-2012	40.5	41	0.5	

Appendix H Mobile-satellite service geographic frequency allocations

Table 131. MSS Global allocation for primary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1982	1544	1545	1	1998
1982	1645.5	1646.5	1	1998
1994-2012	137	137.025	0.025	
1994-2012	137.175	137.825	0.65	
1998-2012	149.9	150.05	0.15	
1998-2012	399.9	400.05	0.15	
1994-2012	400.15	401	0.85	
1971-2012	406	406.1	0.1	
1998-2012	1535	1559	24	
1998-2012	1626.5	1660	33.5	
1998-2012	1660	1660.5	0.5	
2004-2012	1668	1668.4	0.4	
2004-2012	1668.4	1670	1.6	
2004-2012	1670	1675	5	
1994-2012	1980	2010	30	
1994-2012	2170	2200	30	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1982	39.5	40.5	1	1994
1982	95	100	5	2001
1982	134	142	8	2001
1982	190	200	10	2001
1994-2012	20.1	20.2	0.1	
1982-2012	20.2	21.2	1	
1994-2012	29.9	30	0.1	
1982-2012	30	31	1	
1994-2012	39.5	40	0.5	
1994-2012	40	40.5	0.5	
1982-2012	43.5	47	3.5	
1982-2012	66	71	5	
1982-2012	71	74	3	
1982-2012	81	84	3	
2001-2012	123	130	7	
2001-2012	158.5	164	5.5	
2001-2012	191.8	200	8.2	
1982-2012	252	265	13	

Table 132. MSS Global allocation for secondary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1994-2012	137.025	137.175	0.15	
1994-2012	137.825	138	0.175	
1994-2012	312	315	3	
1994-2012	387	390	3	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1982-2012	19.7	20.2	0.5	1994
1982-2012	29.5	30	0.5	1994
1998-2012	14	14.25	0.25	
1998-2012	14.25	14.3	0.05	
1998-2012	14.4	14.47	0.07	
1998-2012	14.47	14.5	0.03	
1982-2012	50.4	51.4	1	

Table 133. MSS Region 1 allocation for primary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1994	2500	2520	20	2008
1994	2670	2690	20	2008
1994-2012	148	149.9	1.9	
2004-2012	1518	1525	7	
1998-2012	1525	1530	5	
1998-2012	1530	1535	5	
1994-2012	1610	1610.6	0.6	
1994-2012	1610.6	1613.8	3.2	
1994-2012	1613.8	1626.5	12.7	
1994-2012	2483.5	2500	16.5	

Table 134. MSS Region 1 allocation for secondary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
2012	156.7625	156.7875	0.025	
2012	156.8125	156.8375	0.025	
2012	161.9625	161.9875	0.025	
2012	162.0125	162.0375	0.025	
1994-2012	1613.8	1626.5	12.7	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1998-2012	14.3	14.4	0.1	
1994-2012	19.7	20.1	0.4	
1994-2012	29.5	29.9	0.4	

Table 135. MSS Region 2 allocation for primary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1994	1970	1980	10	1996
1994	1626.5	1631.5	5	1998
1994	1675	1690	15	2004
1994	1690	1700	10	2004
1994	1700	1710	10	2004
1994	2500	2520	20	2008
1994	2670	2690	20	2008
1996-2012	148	149.9	1.9	
2012	156.7625	156.7875	0.025	
2012	156.8125	156.8375	0.025	
2012	161.9625	161.9875	0.025	
2012	162.0125	162.0375	0.025	
1996-2012	455	456	1	
1996-2012	459	460	1	
1994-2012	1492	1525	33	
1994-2012	1525	1530	5	
1998-2012	1530	1535	5	
1994-2012	1610	1610.6	0.6	
1994-2012	1610.6	1613.8	3.2	
1994-2012	1613.8	1626.5	12.7	
1996-2012	2010	2025	15	
1994-2012	2160	2170	10	
1994-2012	2483.5	2500	16.5	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1994-2012	19.7	20.1	0.4	
1994-2012	29.5	29.9	0.4	

Table 136. MSS Region 2 allocation for secondary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1982-2012	608	614	6	
1994-2012	1613.8	1626.5	12.7	
1994-2012	1930	1970	40	
1994-2012	2120	2160	40	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1998-2012	14.3	14.4	0.1	
2001-2012	40.5	41	0.5	

Table 137. MSS Region 3 allocation for primary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1994	1626.5	1631.5	5	1998
1996-2012	148	149.9	1.9	
2004-2012	1518	1525	7	
1994-2012	1525	1530	5	
1998-2012	1530	1535	5	
1994-2012	1610	1610.6	0.6	
1994-2012	1610.6	1613.8	3.2	
1994-2012	1613.8	1626.5	12.7	
1994-2012	2483.5	2500	16.5	
1994-2012	2500	2520	20	
1994-2012	2670	2690	20	

Table 138. MSS Region 3 allocation for secondary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
2012	156.7625	156.7875	0.025	
2012	156.8125	156.8375	0.025	
2012	161.9625	161.9875	0.025	
2012	162.0125	162.0375	0.025	
1994-2012	1613.8	1626.5	12.7	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1998-2012	14.3	14.4	0.1	
1994-2012	19.7	20.1	0.4	
1994-2012	29.5	29.9	0.4	

Appendix I Space research service geographic frequency allocations

Table 139. SRS Global allocation for primary service-1

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1968	400.05	401	0.95	1971
1968	5250	5255	5	1971
1971	136	137	1	1982
1968	137	138	1	1994
1982	1660.5	1668.4	7.9	2004
1998	1240	1260	20	2008
1998	1260	1300	40	2008
1968-2012	30.005	30.01	0.005	
1994-2012	137	137.025	0.025	
1994-2012	137.025	137.175	0.15	
1994-2012	137.175	137.825	0.65	
1994-2012	137.825	138	0.175	
1971-2012	400.15	401	0.85	
1998-2012	410	420	10	
1998-2012	1215	1240	25	
2008-2012	1240	1300	60	
1982-2012	1400	1427	27	
2004-2012	1660.5	1668	7.5	
2004-2012	1668	1668.4	0.4	
1994-2012	2025	2110	85	
1994-2012	2110	2120	10	
1994-2012	2200	2290	90	
1994-2012	2290	2300	10	
1982-2001	2690	2700	10	
1998-2001	5250	5255	5	
1998-2001	5255	5350	95	
2004-2012	5350	5460	110	
2004-2012	5460	5470	10	
2004-2012	5470	5570	100	
2004-2012	7145	7235	90	
1971-2012	8400	8500	100	
1998-2012	8550	8650	100	
2008-2012	9300	9500	200	
1998-2012	9500	9800	300	

Table 140. SRS Global allocation for primary service-2

Initial RR	Lower frequency (GHz)	Upper frequency (GHz)	Bandwidth (GHz)	RR removal
1968	15.25	15.35	0.1	1971
1971	51	52	1	1982
1971	52	54.25	2.25	1982
1971	130	140	10	1982
1971	182	185	3	1982
1971	230	240	10	1982
1982	116	126	10	1996
1982	51.4	54.25	2.85	1998
1982	54.25	58.2	3.95	1998
1971	64	65	1	1998
1982	105	116	11	2001
1996	119.98	120.02	0.04	2001
1996	120.02	126	5.98	2001
1982	150	151	1	2001
1982	164	168	4	2001
1982	174.5	176.5	2	2001
1982	217	231	14	2001
1982-2012	10.6	10.68	0.08	
1982-2012	10.68	10.7	0.02	
1998-2012	13.25	13.4	0.15	
1998-2012	13.4	13.75	0.35	
1982-2012	15.35	15.4	0.05	
1998-2012	17.2	17.3	0.1	
1982-2012	21.2	21.4	0.02	
1982-2012	22.21	22.5	0.29	
2012	22.55	23.15	0.60	
1982-2012	23.6	24	0.4	
2004-2012	25.5	27	1.5	
1982-2012	31.3	31.5	0.2	
1994-2012	31.8	32	0.2	
1994-2012	32	32.3	0.3	
1994-2012	34.2	34.7	0.5	
1998-2012	35.5	36	0.5	
1982-2012	36	37	1	
1996-2012	37	37.5	0.5	
1994-2012	37.5	38	0.5	
1994-2012	40	40.5	0.5	
1982-2012	50.2	50.4	0.2	
1998-2012	52.6	54.25	1.65	
1998-2012	54.25	55.78	1.53	
1998-2012	55.78	56.9	1.12	
1998-2012	56.9	57	0.1	
1998-2012	57	58.2	1.2	
1971-2012	58.2	59	0.8	
1998-2012	59	59.3	0.3	
1971-2012	65	66	1	
1971-2012	86	92	6	
1998-2012	94	94.1	0.1	
1971-2012	101	102	1	
2001-2012	105	109.5	4.5	
2001-2012	109.5	111.8	2.3	
2001-2012	111.8	114.25	2.45	
2001-2012	114.25	116	1.75	
1996-2012	116	119.98	3.98	
2001-2012	119.98	122.25	2.27	
2001-2012	148.5	151.5	3	

Initial RR	Lower frequency (GHz)	Upper frequency (GHz)	Bandwidth (GHz)	RR removal
2001-2012	155.5	158.5	3	
2001-2012	164	167	3	
2001-2012	174.8	182	7.2	
1982-2012	182	185	3	
2001-2012	185	190	5	
2001-2012	190	191.8	1.8	
1982-2012	200	202	2	
2001-2012	202	209	7	
2001-2012	217	226	9	
2001-2012	226	231.5	5.5	
1982-2012	235	238	3	
1982-2012	250	252	2	

Table 141. SRS Global allocation for secondary service

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	RR removal
1968	15762	15768	6	1971
1968	18030	18036	6	1971
1982-2012	2501	2502	1	
1994-2012	5003	5005	2	
1982-2012	10003	10005	2	
1982-2012	15005	15010	5	
1971-2012	18052	18068	16	
1982-2012	19990	19995	5	
1982-2012	25005	25010	5	

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1994	410	420	10	1998
1971	5250	5255	5	1998
1982	39.986	40.02	0.034	2012
1982-2012	40.98	41.015	0.035	
1998-2012	3100	3300	200	
1982-2012	4990	5000	10	
1968-2012	5670	5725	55	
2008-2012	9800	9900	100	

Initial RR	Lower frequency (GHz)	Upper frequency (GHz)	Bandwidth (GHz)	RR removal
1968	31.8	32.3	0.5	1982
1982	13.4	14	0.6	1994
1982	31.8	32	0.2	1994
1982	32	32.3	0.3	1994
1968	34.2	35.2	1	1994
1994	13.4	13.75	0.35	1998
1982	17.2	17.3	0.1	2001
1994	74	75.5	1.5	2001
1994	75.5	76	0.5	2001
1994	76	81	5	2001
1982-2012	12.75	13.25	0.5	
1994-2012	13.75	14	0.25	
1982-2012	14	14.25	0.25	
1982-2012	14.25	14.3	0.05	
1982-2012	14.4	14.47	0.07	
1982-2012	14.5	14.8	0.3	
1982-2012	14.8	15.35	0.55	
1982-2012	16.6	17.1	0.5	
1968-2012	31	31.3	0.3	
1994-2012	34.7	35.2	0.5	
2001-2012	74	76	2	
2001-2012	76	77.5	1.5	
2001-2012	77.5	78	0.5	
2001-2012	78	79	1	
2001-2012	79	81	2	
1994-2012	81	84	3	

Table 142. SRS Region 1 allocation for primary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1968	136	137	1	1971
1968	8400	8500	100	1971
1968	1700	1710	10	1982
1968	2290	2300	10	1994
1968-2012	143.6	143.65	0.05	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1968-2012	31.5	31.8	0.3	

Table 143. SRS Region 1 allocation for secondary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1982	2655	2690	35	1994
2012	39.986	40.02	0.034	
1994-2012	2655	2670	15	
1994-2012	2670	2690	20	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1982-2012	18.6	18.8	0.2	

Table 144. SRS Region 2 allocation for primary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1968	136	137	1	1971
1968	8400	8500	100	1971
1968	1700	1710	10	1982
1968	2290	2300	10	1994
1968-2012	143.6	143.65	0.05	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1982-2012	18.6	18.8	0.2	
1968-2012	31.5	31.8	0.3	

Table 145. SRS Region 2 allocation for secondary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1986	2655	2690	35	1994
2012	39.986	40.02	0.034	
1971-2012	138	143.6	5.6	
1971-2012	143.65	144	0.35	
1994-2012	2655	2670	15	
1994-2012	2670	2690	20	

Table 146. SRS Region 3 allocation for primary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1968	136	137	1	1971
1968	8400	8500	100	1971
1968	1700	1710	10	1982
1968	2290	2300	10	1994
1968-2012	143.6	143.65	0.05	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1968-2012	31.5	31.8	0.3	

Table 147. SRS Region 3 allocation for secondary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1982	2655	2690	35	1994
2012	39.986	40	0.014	
2012	40	40.02	0.02	
1971-2012	138	143.6	5.6	
1971-2012	143.65	144	0.35	
1994-2012	2655	2670	15	
1994-2012	2670	2690	20	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1982-2012	18.6	18.8	0.2	

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Appendix J Earth exploration-satellite service geographic frequency allocations

Table 148. EESS Global allocation for primary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1998	1240	1260	20	2004
1998	1260	1300	40	2004
1998-2012	401	402	1	
1998-2012	402	403	1	
1998-2012	1215	1240	25	
2004-2012	1240	1300	60	
1982-2012	1400	1427	27	
1994-2012	2025	2110	85	
1994-2012	2200	2290	90	
1982-2012	2690	2700	10	
1998-2012	5250	5255	5	
1998-2012	5255	5350	95	
1998-2012	5350	5460	110	
2004-2012	5460	5470	10	
2004-2012	5470	5570	100	
1998-2012	8025	8175	150	
1998-2012	8175	8215	40	
1998-2012	8215	8400	185	
1998-2012	8550	8650	100	
2008-2012	9300	9500	200	
1998-2012	9500	9800	300	

Table 149. EESS Global allocation for primary service

Initial RR	Lower frequency (GHz)	Upper frequency (GHz)	Bandwidth (GHz)	RR removal
1971	21.2	22	0.8	1982
1971	51	52	1	1982
1982	231	235	4	1990
1982	116	126	10	1996
1982	54.25	58.2	3.95	1998
1982	64	65	1	1998
1982	105	116	11	2001
1996	119.98	120.02	0.04	2001
1996	120.02	126	5.98	2001
1982	150	151	1	2001
1994	156	158	2	2001
1982	164	168	4	2001
1982	174.5	176.5	2	2001
1982	217	231	14	2001
1982-2012	10.6	10.68	0.8	
1982-2012	10.68	10.7	0.02	
1998-2012	13.25	13.4	0.15	
1998-2012	13.4	13.75	0.35	
1982-2012	15.35	15.4	0.05	
1998-2012	17.2	17.3	0.1	
1982-2012	21.2	21.4	0.2	
1982-2012	22.21	22.5	0.29	
1982-2012	23.6	24	0.4	
1998-2012	25.5	27	1.5	
1982-2012	31.3	31.5	0.2	
1998-2012	35.5	36	0.5	
1982-2012	36	37	1	
1994-2012	40	40.5	0.5	
1982-2012	50.2	50.4	0.2	
1982-2012	51.4	54.25	2.85	
1998-2012	54.25	55.78	1.53	
1998-2012	55.78	56.9	1.12	
1998-2012	56.9	57	0.1	
1998-2012	57	58.2	1.2	
1982-2012	58.2	59	0.8	
1998-2012	59	59.3	0.3	
1971-2012	65	66	1	
1982-2012	86	92	6	
1998-2012	94	94.1	0.1	
1982-2012	100	102	2	
2001-2012	109.5	111.8	2.3	
2001-2012	114.25	116	1.75	
1996-2012	116	119.98	3.98	
2001-2012	119.98	122.25	2.27	
2001-2012	130	134	4	
2001-2012	148.5	151.5	3	
2001-2012	155.5	158.5	3	
2001-2012	164	167	3	
2001-2012	174.8	182	7.2	
1982-2012	182	185	3	
2001-2012	185	190	5	
2001-2012	190	191.8	1.8	
1982-2012	200	202	2	
2001-2012	202	209	7	
2001-2012	226	231.5	5.5	
1982-2012	235	238	3	
1982-2012	250	252	2	

Table 150. EESS Global allocation for secondary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1982	401	402	1	1998
1982	402	403	1	1998
1998-2012	3100	3300	200	
2008-2012	9800	9900	100	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1994	28.5	29.5	1	1996
1982	17.2	17.3	0.1	1998
1982	25.25	27	1.75	1998
2004-2012	13.75	14	0.25	
1982-20112	24.05	24.25	0.2	
1996-2012	28.5	29.1	0.6	
1996-2012	29.1	29.5	0.4	
1994-2012	29.9	30	0.1	
1994-2012	37.5	38	0.5	
1994-2012	38	39.5	1.5	
1994-2012	39.5	40	0.5	
1994-2012	40	40.5	0.5	

Table 151. EESS Region 1 allocation for primary service

Initial RR	Lower frequency (GHz)	Upper frequency (GHz)	Bandwidth (GHz)	RR removal
2001-2012	18.6	18.8	0.2	
1982-2012	31.5	31.8	0.3	

Table 152. EESS Region 1 allocation for secondary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1971	1525	1535	10	1982
1982	1530	1535	5	1990
1982	2655	2690	35	1994
1990	1530	1533	3	1998
1990	1533	1535	2	1998
1971	8025	8175	150	1998
1971	8175	8215	40	1998
1971	8215	8400	185	1998
2004-2012	432	438	6	
1982-2012	1525	1530	5	
1998-2012	1530	1535	5	
1994-2012	2655	2670	15	
1994-2012	2670	2690	20	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1982	27	27.5	0.5	1994
1982	18.6	18.8	0.2	2001
1994-2012	29.5	29.9	0.4	

Table 153. EESS Region 2 allocation for primary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1971	8025	8175	150	1998
1971	8175	8215	40	1998
1971	8215	8400	185	1998
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1982-2012	18.6	18.8	0.2	
1982-2012	31.5	31.8	0.3	

Table 154. EESS Region 2 allocation for secondary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1971	1525	1535	10	1982
1982	1530	1535	5	1990
1982	2655	2690	35	1994
1990	1530	1533	3	1998
1990	1533	1535	2	1998
2004-2012	432	438	6	
1982-2012	1525	1530	5	
1998-2012	1530	1535	5	
1994-2012	2655	2670	15	
1994-2012	2670	2690	20	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1982	27	27.5	0.5	1994
1994-2012	29.5	29.9	0.4	

Table 155. EESS Region 3 allocation for primary service

Initial RR	Lower frequency (GHz)	Upper frequency (GHz)	Bandwidth (GHz)	RR removal
2001-2012	18.6	18.8	0.2	
1982-2012	31.5	31.8	0.3	

Table 156. EESS Region 3 allocation for secondary service

Initial RR	Lower frequency (MHz)	Upper frequency (MHz)	Bandwidth (MHz)	RR removal
1971	1525	1535	10	1982
1982	1530	1535	5	1990
1982	2655	2690	35	1994
1990	1530	1533	3	1998
1990	1533	1535	2	1998
1971	8025	8175	150	1998
1971	8175	8215	40	1998
1971	8215	8400	185	1998
2004-2012	432	438	6	
1982-2012	1525	1530	5	
1998-2012	1530	1535	5	
1994-2012	2655	2670	15	
1994-2012	2670	2690	20	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**RR removal**
1982	27	27.5	0.5	1994
1982	18.6	18.8	0.2	2001
1994-2012	29.5	29.9	0.4	

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REPORT IN PART OF THE DISSERTATION FOR THE DEGREE OF DOCTOR OF ENGINEERING

Managing spectrum commons in Thailand: Allocation and assignment challenges

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Abstract

Spectrum is a natural and limited resource that needs to be handled both internationally and nationally because of its characteristic of propagation. Once transmitted, it propagates until the power runs out, and it does not recognize borders between countries. Spectrum is administered internationally by the International Telecommunication Union (ITU). The Radio Regulations (RR) is an international treaty that provides international guidelines on spectrum management to keep interference manageable by allocating spectrum to services internationally. Further, spectrum assignment for the provision of rights to use frequency is carried out nationally by the National Regulatory Authority (NRA). Three typical approaches of spectrum assignment are common-and-control, market-based, and spectrum commons.

The purpose of this study is to demonstrate the relationship between international and national regulations on how to implement spectrum commons in Thailand. It also illustrates the development of frequency allocation for spectrum commons at the international level and the transfer of international regulation for spectrum commons to Thai national regulation.

The results of this study present the connection between international regulation in the form of the RR and national regulation in the form of the National Broadcasting and Telecommunications Commission (NBTC) regulation in Thailand with regard to spectrum commons. The study also highlights challenges for Thailand in implementing spectrum commons in order to respond to the rapid growth of technology.

Spectrum commons is one of three typical assignment approaches providing non-exclusive rights to use frequency, i.e. no one owns the frequency. Spectrum commons regulation was established internationally by the RR during the international negotiations at the World Radiocommunication Conference (WRC) by allocating spectrum to industrial, scientific and medical (ISM) applications. The majority of applications are in low-power devices or short-range devices. The relevant technologies concerning spectrum commons at the WRC-12 were software-defined radio (SDR) and cognitive radio systems (CRS) which encourage the sharing of spectrum with existing services and increase spectrum utilization. However, the transfer of international regulation of spectrum commons belongs to the NRA at national level.

The study uses the institutional analysis and development (IAD) framework to illustrate the relationship between international and national regulations in terms of world of actions: constitution, collective-choice, and operational level. However, the IAD framework only provides a list of questions that should be considered, not the detailed content regarding the implementation of spectrum commons.

To implement spectrum commons regulation, an understanding of the RR at international level assists local implementation at national level. The timely transfer of international regulation to national regulation provides opportunities to benefit from device innovation and technological advancement. Once economies of scale are achieved, the general public benefits from the reasonable price of devices. As it is not a manufacturing country for such devices, Thailand should follow spectrum commons regulation and prepare national regulation changes in order to gain the benefits of spectrum commons.

Keywords: Radio Regulations (RR), World Radiocommunication Conference (WRC), institutional analysis and development (IAD) framework, spectrum commons, spectrum management, spectrum allocation

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Table of Contents

Chapter 1 Introduction 1

1.1 Background 1

1.2 Motivation 5

1.3 Purpose 6

1.4 Research question 6

1.5 Structure of the study 8

Chapter 2 Theoretical framework 9

2.1 The IAD framework 9

2.2 Three worlds of action in spectrum management 16

2.3 Bundle of rights to use frequency 17

2.4 Summary 19

Chapter 3 Methodology 21

3.1 Data and data collection method 21

3.2 Data analysis 22

3.3 Approach 23

3.4 Summary 23

Chapter 4 Spectrum commons application and technology 25

4.1 Short-range devices 25

4.2 Software-defined radio and cognitive radio system 30

4.3 Summary and discussion of research question 33

Chapter 5 Spectrum allocation for spectrum commons 35

5.1 Spectrum allocation 35

5.2 Allocation of spectrum commons 37

5.3 Development of industrial, scientific and medical application band 37

5.3 Similarities and differences between 5.138 and 5.150 47

5.4 Summary and discussion of research question 48

Chapter 6 Frequency assignment for spectrum commons in Thailand 51

6.1 Background 51

6.2 Frequency assignment development in Thailand 53

6.3 Spectrum commons development in Thailand 57

6.4 Summary and discussion of the research question 64

Chapter 7 International to national regulations 67

7.1 From the RR to the Thai TFA 67

7.2 Spectrum commons in NBTC regulations 76

7.3 Allocation and assignment challenges 81

7.4 Summary and discussion of research question 83

Chapter 8 Relevance of IAD framework to spectrum management 85

8.1 IAD framework level of analysis and outcomes 85

8.2 Spectrum management activities 86

8.3 Applying IAD framework to spectrum management activities 91

8.4 Summary and discussion of research question 93

Chapter 9 Summary and findings 95

9.1 Synthesis 95

9.2 Findings to the research questions 96

9.3 Benefit for Thailand 101

9.4 Recommendations for future research 101

References 103

List of abbreviations 109

List of figures

Figure 1. Regions in Radio Regulations 2012 2

Figure 2. Structure of the study 8

Figure 3. Framework for an institutional analysis 10

Figure 4. A rules-in-use and action situation 13

Figure 5. Level of analysis and outcomes 15

Figure 6. General cognitive cycle 31

Figure 7. Options for spectrum assignment 52

Figure 8. Thailand spectrum management profile 55

Figure 9. Stakeholders of spectrum commons 81

List of tables

Table 1. Table of Frequency Allocation, 1 710-2 170 MHz 3

Table 2. Categories of goods 11

Table 3. Level of analysis and stakeholders 16

Table 4. Bundle of rights associated with telecommunication stakeholders 17

Table 5. The rights to use frequency 18

Table 6. SRD applications 27

Table 7. Example of SRD technologies 27

Table 8. Common frequency bands for SRDs 28

Table 9. Common frequency bands for SRD 29

Table 10. Table of Frequency Allocation, 2 300 – 2 483.5 MHz 36

Table 11. Frequencies of ISM bands 5.138 and 5.150 39

Table 12. ISM frequency bands development 40

Table 13. Similarities and differences between 5.138 and 5.150 48

Table 14. Important events for Thailand spectrum management 56

Table 15. Spectrum commons events in Thailand 63

Table 16. RR TFA for 5.138 70

Table 17. Thailand TFA for 5.138 71

Table 18. RR TFA for 5.150 72

Table 19. Thailand TFA for 5.150 73

Table 20. RR TFA for 5.150 74

Table 21. Thailand TFA for 5.150 75

Table 22. Thailand footnote T-Unlicensed 1 77

Table 23. Thailand footnote T-Unlicensed 2 78

Table 24. Thailand footnote T-Unlicensed 3 78

Table 25. Spectrum commons allocation and assignment challenges 82

Table 26. Spectrum commons allocation and assignment challenges 85

Table 27. Spectrum management activities with IAD levels of analysis and outcomes 91

Chapter 1 Introduction

This study is about the transformation of international regulation as the Radio Regulations (RR) into national regulation for spectrum commons in Thailand. However, the study only focuses on the development of spectrum commons in RR in ISM footnotes, the application for short-range devices, and technology for software-defined radio and cognitive radio systems. The challenges of the transformation of spectrum commons regulation are only presented in the context of Thailand.

1.1 Background

Spectrum is a natural and limited resource that requires both an international and national approach because of its characteristic of propagation. Once transmitted, it propagates until the power runs out and it does not recognize borders between countries.

For spectrum to be administered internationally by the International Telecommunication Union (ITU), the international treaty the RR provides the guidelines on spectrum management to keep interference manageable through service allocation and allotment of spectrum with the relevant constraints.

ITU uses the RR as a tool to manage spectrum internationally. The ITU allocates spectrum to radiocommunication services with particular frequency bands. Radiocommunication services, in short, services, represent the purpose of frequency uses. There are more than 40 services currently in use in the RR2012. The individual frequency bands are defined by the start and stop frequencies. The start and stop frequencies represent the allowable edges of the frequency to be used for specified services.

The RR is revised every three to four years via the WRC. The current RR is the RR2012, which was revised by the WRC-12. The RR2012 defines usable frequency up to 3,000 GHz and divides the frequency use into services, including terrestrial and space services such as broadcasting, mobile, satellite, maritime, aeronautical, fixed, and earth exploration. All the services can share frequency bands, although sharing requires services to be designated as primary or secondary. The table of frequency allocation (TFA) contains both primary (capitalized) and secondary (lower case) services. Secondary services must not interfere with primary services and cannot claim protection from interference by primary service transmission and reception.[1]

The RR divides the world into three regions. Region 1 covers the European and African continents, Region 2 covers North America and South America, and Region 3 covers Asia and Australasia. The RR2012 regions are shown in Figure 1.[2]

The frequency allocated in one region can be used in others: reuse of frequency. For example, frequency band A is allocated to Region 3 but can be reused in Region 1 or 2 for the same or different services.

[1] 5.23-5.32, Article 5, Radio Regulations
[2] Information obtained from 5.2-5.9, Article 5, Radio Regulations (2012)

Reuse of frequency has an indirect relationship with coverage area. A large coverage area has a low reuse of frequency, while a small coverage area has a high reuse of frequency. Spectrum reuse characteristics vary by service, frequency, location, time, and transmitting power.

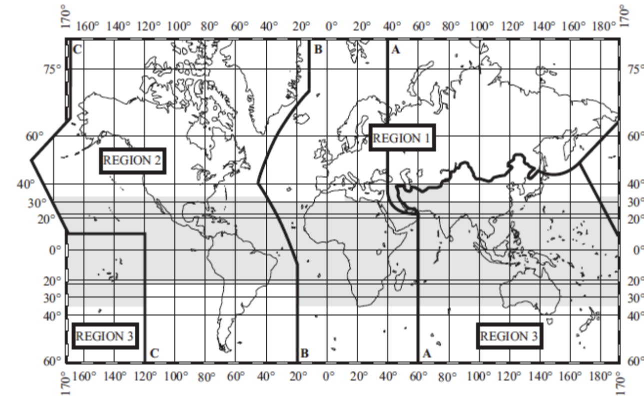


Figure 1. Regions in Radio Regulations 2012

Frequencies are further divided into bands. A wavelength equals its speed of propagation (normally that of light) divided by its frequency (λ = c/f). Each frequency band has its own propagation characteristics, such as sea-surface communication, stratospheric scattering, and long-range communication.

Table 1 shows the TFA for the 1 710-2 170 MHz band, the global as well as the regional allocations captured from the RR2012. The purpose of the TFA is to provide an overview of the use of frequency bands by service, with the relevant regulations, including services, frequency bands, and footnotes. The functions of the TFA are similar to a map that provides an overview of the RR.

Regions and frequency bands

Within the TFA, the main components are regions, frequency bands, services, and footnotes. When a frequency allocation has the same frequency band (the same start and stop frequencies) for three regions, it is called a global or worldwide allocation. For example, Table 1 shows the frequency band 1 710-1 930 MHz, which is a global allocation. However, the frequency band 1 930-1 970 MHz is allocated to Regions 1, 2, and 3. These three allocations are regional allocations.

Services

Within each frequency band, services are allocated as either primary or secondary. For example, in the 1 970-1 980 MHz band, the fixed and mobile services are allocated as primary services.

Table 1. Table of Frequency Allocation, 1 710-2 170 MHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
1 710-1 930	FIXED MOBILE 5.384A 5.388A 5.388B 5.149 5.341 5.385 5.386 5.387 5.388	
1 930-1 970 FIXED MOBILE 5.388A 5.388B 5.388	**1 930-1 970** FIXED MOBILE 5.388A 5.388B Mobile-satellite (Earth-to-space) 5.388	**1 930-1 970** FIXED MOBILE 5.388A 5.388B 5.388
1 970-1 980	FIXED MOBILE 5.388A 5.388B 5.388	
1 980-2 010	FIXED MOBILE MOBILE-SATELLITE (Earth-to-space) 5.351A 5.388 5.389A 5.389B 5.389F	
2 010-2 025 FIXED MOBILE 5.388A 5.388B 5.388	**2 010-2 025** FIXED MOBILE MOBILE-SATELLITE (Earth-to-space) 5.388 5.389C 5.389E	**2 010-2 025** FIXED MOBILE 5.388A 5.388B 5.388
2 025-2 110	SPACE OPERATION (Earth-to-space) (space-to-space) EARTH EXPLORATION-SATELLITE (Earth-to-space) (space-to-space) FIXED MOBILE 5.391 SPACE RESEARCH (Earth-to-space) (space-to-space) 5.392	
2 110-2 120	FIXED MOBILE 5.388A 5.388B SPACE RESEARCH (deep space) (Earth-to-space) 5.388	
2 120-2 160 FIXED MOBILE 5.388A 5.388B 5.388	**2 120-2 160** FIXED MOBILE 5.388A 5.388B Mobile-satellite (space-to-Earth) 5.388	**2 120-2 160** FIXED MOBILE 5.388A 5.388B 5.388
2 160-2 170 FIXED MOBILE 5.388A 5.388B 5.388	**2 160-2 170** FIXED MOBILE MOBILE-SATELLITE (space-to-Earth) 5.388 5.389C 5.389E	**2 160-2 170** FIXED MOBILE 5.388A 5.388B 5.388

For the 2 120-2 160 MHz band in Regions 1 and 3, there are fixed and mobile services on a primary basis.

For the 2 120-2 160 MHz band in Region 2, there are fixed and mobile services on a primary basis and mobile-satellite (space-to-Earth) services on a secondary basis.

Footnotes

The footnotes contained in the TFA can be used in several situations, including for the status of services (on a primary or secondary basis), additional allocation, alternative allocation, and miscellaneous provisions.

Apart from capital and lower-case letters in the TFA, footnotes can indicate the priority of services. For example, footnote 5.385 indicates that the 1 718.8-1 722.2 MHz band is allocated for radio astronomy service on a secondary basis for spectral line observations.[3]

The additional allocation footnote has the same service as indicated in the TFA, but in an area smaller than the region. For instance, footnote 5.386 is allocated to the 1 750-1 850 band for space operation (Earth-to-space) and space research (Earth-to-space) services in Region 2, in Australia, Guam, India, Indonesia, and Japan on a primary basis.[4]

The alternative allocation footnote replaces the service indicated in the TFA, but in an area smaller than the Region. For example, footnote 5.315 is allocated to the 790-838 MHz band for broadcasting service on a primary basis in Greece, Italy, and Tunisia.[5]

The miscellaneous provision footnote represents specific operation constraints, such as footnote 5.388 in the 1 885-2 025 MHz and 2 110-2 200 MHz band that provides International Mobile Telecommunications (IMT), on condition that these bands do not preclude the use by other services to which they are allocated.[6]

Footnotes can also be used for a particular service, in which case they are located next to the service, or the entire frequency band, when they are placed at the bottom of the band, as indicated in the TFA. The band footnote is applied to all services allocated in this band. For example, in the 2 025-2 110 MHz band, the use of mobile service has the specific footnote 5.391. The band footnote is 5.392 and it applies to all services in this band, including space operation, Earth exploration-satellite, fixed, mobile, and space research services.

In Regions 1 and 3, the 2 120-2 160 MHz band has two specific footnotes for mobile service; 5.388A and 5.388B. The fixed service is allocated on a primary basis and does not have a specific footnote. Footnote 5.388 is applied to both fixed and mobile services as a band footnote.

---

[3] 5.385 *Additional allocation:* the band 1 718.8-1 722.2 MHz is also allocated to the radio astronomy service on a secondary basis for spectral line observations. (WRC-2000)

[4] 5.386 *Additional allocation:* the band 1 750-1 850 MHz is also allocated to space operation (Earth-to-space) and space research (Earth-to-space) services in Region 2, in Australia, Guam, India, Indonesia and Japan on a primary basis, subject to agreement obtained under No. 9.21, having particular regard to troposcatter systems. (WRC-03)

[5] 5.315 *Alternative allocation*: in Greece, Italy and Tunisia, the band 790-838 MHz is allocated to the broadcasting service on a primary basis. (WRC-2000)

[6] 5.388 The bands 1 885-2 025 MHz and 2 110-2 200 MHz are intended for use, on a worldwide basis, by administrations wishing to implement International Mobile Telecommunications (IMT). Such use does not preclude the use of these bands by other services to which they are allocated. The bands should be made available for IMT in accordance with Resolution 212 (Rev.WRC-07) (See also Resolution 223 (Rev.WRC-07)*). (WRC-12)

In Region 2, the 2 120-2 160 MHz band has two specific footnotes for mobile service 5.388A and 5.388B. The fixed service is allocated on a primary basis but the mobile-satellite (space-to-Earth) service is allocated on a secondary basis. Footnote 5.388 is applied to fixed, mobile, and mobile-satellite (space-to-Earth) services as a band footnote.

The TFA represents the frequency allocation at the WRC to allocate radiocommunication services by frequency bands. The services represent the purpose of frequency use that is defined in Article 1: Terms and Definitions.

However, the use of radiocommunication devices is managed at national level by the national regulatory authority (NRA). The NRA assigns the frequency to the assignee, in other words, the NRA provides the right to use frequency to frequency users. This is known as spectrum assignment. The typical spectrum assignment methods are command-and-control, market-based, and spectrum commons. The NRA assigns the frequency to the user on a first-come first-serve basis, imposing the technical specification for the use of frequency in the form of command-and-control. As for the market-based method, the NRA uses a market mechanism to assign the frequency, such as spectrum auction or secondary trading. Both command-and-control and market-based methods provide the exclusive right to use a frequency to users, whereas spectrum commons provides non-exclusive rights to use a frequency. With spectrum commons, the NRA assigns the frequency for public use. No one owns the frequency. Everyone shares the frequency and the risk of harmful interference.

Spectrum commons has developed both allocation at the WRC as part of the RR and assignment under national regulations. It is interesting to understand the transformation of spectrum commons from allocation under international regulation to assignment under national regulation.

1.2 Motivation

The motivation of this study comes from the implementation of international regulation in the form of the RR in national regulation in the form of the National Broadcasting and Telecommunications Commission (NBTC) regulation for spectrum commons in Thailand. Moreover, the study attempts to combine two previous studies: I) Spectrum Assignment Policy: Towards an Evaluation of Spectrum Commons in Thailand, and II) Information and Coordination in International Spectrum Policy: Implication for Thailand.

The development of spectrum commons allocation applies the development of RR from Paper II to explore the ITU archive for industrial, scientific, and medical (ISM) applications in terms of the development of definition and frequency allocation in footnotes 5.138 and 5.150. The development of spectrum commons allocation illustrates international regulation for spectrum commons.

The spectrum assignment for spectrum commons in Thailand captures the development of spectrum assignment for spectrum commons in Thailand since 1875 in Paper I, which provides the history of spectrum commons development in Thailand in terms of the development of national regulation for spectrum commons.

This study combines spectrum allocation and assignment for spectrum commons in Thailand by demonstrating how to implement international regulation into national regulation for spectrum commons in Thailand. The study applies the Institutional Analysis and Development (IAD) framework to illustrate the interaction and relationship between levels of analysis and outcome: from the RR to NBTC regulations. Moreover, the study also highlights the challenges for spectrum commons (advantages and disadvantages for spectrum commons from Paper I) and IAD application for spectrum management.

1.3 Purpose

The purpose of this study is to demonstrate the relationship between international and national regulations on how to implement spectrum commons in Thailand. It also illustrates the development of frequency allocation for spectrum commons at international level and the transfer of international regulation for spectrum commons to Thai national regulation.

This study is limited to spectrum commons in footnotes 5.138 and 5.150 for the development of spectrum commons. The main application of spectrum commons for the purposes of this study is short-range devices. The main technologies focused on are software-defined radio (SDR) and cognitive radio systems (CRS). The study focuses on the transfer of spectrum commons regulation for Thailand.

1.4 Research question

To fulfill the purpose of this study, the main research question is: **How is the Radio Regulations transformed into National Broadcasting and Telecommunications Commission regulation for spectrum commons in Thailand?** In order to answer this research question, the five sub-research questions are as follows:

Sub-research question 1: *What are the main applications and technologies for spectrum commons?*

The relevant literature in the SCOPUS database and ITU archives has been explored to understand the main applications and technologies for spectrum commons. The main applications are short-range or low-power devices such as garage-door openers, baby monitors, remote controls, cordless telephones, wireless microphones, wireless earphones, Wi-Fi, RFID tags, and smart cards. The main technologies are SDR and CRS. These technologies provide the ability to use spectrum non-exclusively. No one owns the spectrum. This is the main characteristic of spectrum commons.

Sub-research question 2: *What are the spectrum allocations for spectrum commons and ISM applications, and how did they develop?*

The ITU archives have been explored to understand the development of spectrum commons allocation in terms of ISM application: definition and frequency allocation.

The results of the exploration illustrate the development of spectrum commons regulation in terms of ISM application development and frequency allocation for the development of footnotes 5.138 and 5.150. The first allocation for low-power stations was in 1938 for the European region only, although it was terminated in 1947. The current ISM bands are: 6 765-6 795 kHz, 433.05-434.79 MHz, Region 2, 61-61.5 GHz, 122-123 GHz, 244-246 GHz, for 5.138; and 13 553-13 567 kHz, 26 957-27 283 kHz, 40.66-40.70 MHz, 902-928 MHz, Region 1, 2 400-2 500 MHz, 5 725-5 875 MHz, and 24-24.25 GHz for 5.150.

Sub-research question 3: *What is spectrum assignment, especially spectrum commons, in Thailand, and how did it develop?*

This study explores the NBTC regulations in terms of the National Frequency Management Board (NFMB), Post and Telegraph Department (PTD), National Telecommunications Commission (NTC) and NBTC regulations since 1875 in order to demonstrate the development of spectrum assignment for spectrum commons in Thailand.

The development of spectrum commons in Thailand was initiated by the NFMB to authorize the PTD to allow the use of 1-watt transmitters for pagers and anti-theft equipment. However, the use of such radiocommunication equipment required relevant radiocommunication licenses. The current unlicensed regulation for spectrum commons was developed in 2004, i.e. the Ministerial Regulation of the Exemption of Radiocommunication Licenses – Ministry of Information and Communication Technology. This regulation was adopted by the NTC as its regulation in 2007 and is still valid today.

Sub-research question 4: *How should spectrum commons regulation be transformed from the RR into the national NBTC regulation? What are the challenges?*

In order to understand the relationship between the RR and the NBTC regulation, the study applies the IAD framework that was used in Paper II to understand the interaction during the decision-making process at the WRC. Moreover, the IAD framework has the ability to understand the relationship between rules-in-use at different levels of analysis and outcome represented at international level by the RR and at national level by the NBTC.

This study demonstrates the transformation of international regulation into national regulation in terms of the ISM definition, footnotes 5.138 and 5.150, and frequency allocation for spectrum commons in the Table of Frequency Allocation (TFA). The results are the adoption of ISM definition implicitly in the Thai TFA and the adoption of footnotes 5.138 and 5.150 explicitly in the Thai TFA with additional Thailand footnotes in the form of the NBTC regulation for spectrum commons. Apart from footnotes 5.138 and 5.150, Thailand allows several frequencies for spectrum commons, including the frequency band lower than 135 kHz, 1.6-1.8 MHz, 30-50 MHz, 54-74 MHz, 88-108 MHz, 165-210 MHz, 300-500 MHz, 920-925 MHz, 5.150-5.350 GHz, 5.470-5.725 GHz, 10-10.6 GHz, 76-81 GHz, 72-72.745 MHz, 78-79 MHz, 245-246 MHz, 510-790 MHz, and 794-806 MHz.

This study also examines the advantages and disadvantages of spectrum commons in Paper I in terms of the challenges for managing spectrum commons: allocation and assignment. The challenges are grouped in terms of allocation and assignment with relevant stakeholders. The study also examines the long process at the WRC for the allocation of spectrum commons,

and the loss of revenue for the assignment of spectrum commons at national level. The main challenge is to keep the advantages and reduce the disadvantages of spectrum commons.

Sub-research question 5: *How is the IAD framework relevant to spectrum management?*

To understand the relevance of the IAD framework to spectrum management, the study applies the IAD framework to spectrum management activities.

The result illustrates that the IAD framework enables categorization of spectrum management activities into three levels of analysis and outcome: constitutional, collective-choice, and operational situation. Moreover, the IAD framework also explains the relationship between spectrum management activities in terms of the elements of the IAD framework.

1.5 Structure of the study

This study consists of nine chapters, starting with an introduction in Chapter 1, which includes the background and research questions. Chapter 2 provides the theoretical framework for this study. Chapter 3 deals with the methodology. The application and technology for spectrum commons are provided in Chapter 4. The allocation of spectrum commons is presented in Chapter 5. Chapter 6 describes the frequency assignment for spectrum commons in Thailand. Chapter 7 demonstrates how spectrum commons of the RR is transformed into national regulation in Thailand and the challenges involved. The relevance of the IAD framework to spectrum management is illustrated in Chapter 8. Finally, the conclusion of the study is presented in Chapter 9. Figure 2 gives an overview of the study, including the contents of each chapter in brief.

Chapter 1 Introduction	The study background, motivation and problem, purpose and limitation, and research questions
Chapter 2 Theoretical framework	A theoretical framework including the IAD framework, three worlds of action in spectrum management, and bundles of rights to use frequency
Chapter 3 Methodology	The available data, the mode of data collection, and methods used in data analysis
Chapter 4 Application & technology	Main application and technology for spectrum commons
Chapter 5 Allocation of spectrum commons	Spectrum allocation for spectrum commons from the RR in ISM footnotes
Chapter 6 Assignment of spectrum commons in Thailand	Spectrum assignment for spectrum commons in Thailand in terms of unlicensed regulation and its development
Chapter 7 International to national	The transformation of international regulation in the form of the RR into the national regulation in the form of the NBTC for spectrum commons in Thailand
Chapter 8 Relevance of IAD framework	The IAD application for spectrum management activities
Chapter 9 Conclusion	Conclusion of the study, challenges of spectrum commons allocation and assignment for Thailand

Figure 2. Structure of the study

Chapter 2 Theoretical framework

This chapter provides a theoretical framework for this study, i.e. the institutional analysis and development (IAD) framework, three worlds of action in spectrum management, and bundle of rights for frequency use. This chapter uses some parts of Chapter 2 of Ard-paru (2012), an updated version of Ard-paru (2011), and Chapter 2 of Ard-paru (2010).

2.1 The IAD framework

Elinor Ostrom, among others, developed the IAD framework. The details of the IAD framework are discussed below.

The IAD framework has its roots in classical political economy, neoclassical microeconomic theory, institutional economics, public choice theory, transaction-cost economics, and non-cooperative game theory (Ostrom, Gardner, & Walker, 1994, p. 25). The IAD framework orients the analyst to ask particular questions. The questions generated by the IAD framework are the most important contributions. These questions are used to diagnose, explain, and prescribe action situations during decision-making processes (Ostrom et al., 1994).

The IAD framework was originally developed by Kiser and Ostrom (1982) and provides three worlds of action: the operational, collective choice, and constitutional choice levels. Kiser and Ostrom (1982) provide a metatheoretical framework to explain the relationships between institutional arrangements and the individual in terms of the transformation of rules into individual behavior. Institutional arrangements are rules used by individuals to determine who and what is included in decision situations, how information is structured, what actions can be taken and in what sequence, and how individual actions will be aggregated into a collective decision (Kiser & Ostrom, 1982, p. 179). Field (1992) has a similar level of analysis but with different names, i.e. three economic institutions: the operational, institutional, and constitutional levels.

In other words, the IAD framework explains phenomena attributed to the aggregation of individual actions that they have decided to take or strategies (plans of action) based on situations and the individual. The situation depends on rules, events, and the community. This framework also captures the dynamic situation through feedback from the phenomena that influence the community, situation, and individuals.

According to Kiser and Ostrom (1982), each world of action has five working parts in an institutional structure: the decision-maker or individual, the community, the event (or goods and services), the institutional arrangement, and the decision situation. The results of the institutional structure are individual actions or strategies, and the aggregation of individual actions.

Each level or world of action: metaconstitutional, constitutional, collective, and operation situations, comprises an IAD framework for an institutional analysis. The linkage between levels is, in part, the rules-in-use at each level (see Figure 7).

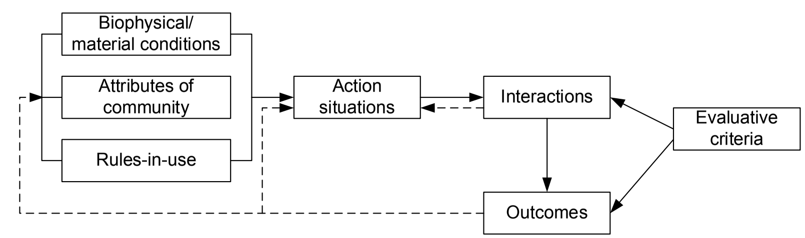
The three worlds of action were developed by Ostrom from 1982 to 2011 (Kiser & Ostrom,

1982; Ostrom, 2005a; 2005b, 2007, 2011). The differences between the old version from 1982 and the current version from 2011 are the consideration layers, the names of the elements, and the details of the internal rules. The old version has three worlds of action, but the new version has four levels of analysis and outcomes.

The names of the elements in 1982 were changed in 2011: aggregated results to outcome; actions, activities, and strategies to interaction; attributes of decision situation to action situation; attributes of institutional arrangement to rules-in-use; and attributes of events to biophysical conditions. The attributes of the individual were merged into an action situation. The evaluative criteria were added in 2011.

The names of rules-in-use in 1982 were changed in 2011: authority rules to choice rules. The unchanged rules are boundary, scope, position, aggregation, and information rules. The procedural rules were removed. The payoff rules were added in 2011.

The IAD framework provides consideration levels, or worlds of action, for the decision-making process, i.e. operational, collective-choice, constitutional, and metaconstitutional situations. Moreover, the IAD framework provides exogenous variables and an internal action situation at each situation level. The exogenous variables include biophysical/material conditions, attributes of community, and rules-in-use. The internal action situation structure comprises boundary, position, choice, payoff, information, aggregation, and scope rules. Figure 3 shows the IAD framework.



Source Ostrom (2011, p. 10), Figure 1

Figure 3. Framework for an institutional analysis

Interaction (action and strategy)

When an individual wants to take action or implement a strategy, he or she must know the consequences of the action or strategy, or the outcome and value of the alternative actions or strategies. A tennis player makes a decision to charge at the net or wait for the ball to bounce and use a groundstroke: the outcome of the actions differs. In order to predict actions, a minimum of the following assumptions must be made: the level of information about the decision situations, the valuation of the potential outcomes, the alternative actions within the situation, and the process of calculation to act from alternative actions or strategies.

Action situations (or decision situations)

According to Kiser and Ostrom (1982), the decision situation is determined from interdependent relationships. Interdependent relationships depend on more than one input from the exogenous variables. The IAD framework separates the exogenous variables from the action arena or action situation. The exogenous variables include biophysical/material conditions, attributes of community, and rules-in-use.

Biophysical/material conditions

The biophysical/material conditions describe the type of goods. Goods can be further refined into four groups: private goods, toll goods, common-pool goods, and public goods. Each group has different characteristics, defined by the level of subtractability and the cost of exclusion (Kiser & Ostrom, 1982). Table 2 shows four categories of goods.

Table 2. Categories of goods

Level of subtractability / Cost of exclusion	High	Low
Low	Private goods	Toll goods
High	Common-pool goods	Public goods

Source Kiser and Ostrom (1982, p. 198), Table 7.1

The level of subtractability and cost of exclusion can also be explained in terms of four attributes of biophysical conditions that individuals seek to produce and consume: jointness of use or consumption, exclusion, measurement, and degree of choice, in order to define private goods, tool goods, common-pool resources, and public goods.

Jointness of consumption explains separable and joint consumption goods. One individual consumes separable consumption goods, while several individuals consume joint consumption goods. Joint consumption goods are defined as public goods that are non-subtractable, while separable consumption goods are private goods.

The exclusion attributes explain the difference between private and public goods. Public goods are non-excludable goods that an individual can consume without exclusion. Private goods are excludable goods that the individual can consume with exclusion.

The measurement is the degree of packaging and unitization. Public goods are hard to package and unitize in contrast to private goods. The calculation of private goods is more precise than that of public goods.

The degree of choice for the consumer differs between public and private goods. Public goods are non-subtractable and non-excludable, so there is not much choice, while private goods can produce many choices from subtractable and excludable goods.

The level of subtractability is defined by the characteristics of the goods that can be separated. Private goods can be separated by individual consumption, but public goods cannot. For example, rice can be consumed from a bowl by taking a spoon, as private goods. Air in the park is a public good. People can breathe, but no one can separate air for individual consumption.

Ostrom and Ostrom (1997) use the level of subtractability and the cost of exclusion to classify private goods, tool goods, common-pool resources, and public goods. Private goods, such as bread, milk, automobiles, and haircuts, have a low cost of exclusion and a high level of subtractability. Toll goods, for example, theaters, nightclubs, telephone services, cable TV, electric power, and libraries, have a low cost of exclusion and a low level of subtractability. World Cup football is tool goods at a low level of subtractability, because football players and spectators jointly benefit from football matches, whereas the cost of exclusion is low but managed by selling tickets to matches. Common-pool resources, e.g. water pumped from a ground basin, fish taken from an ocean, and crude oil extracted from an oil pool, have a high cost of exclusion and a high level of subtractability. Public goods, such as peace and security of a community, national defense, mosquito abatement, air pollution control, and weather forecasts have a high cost of exclusion and a low level of subtractability.

Attributes of community

The attributes of community comprise levels of common understanding, common agreement, and distribution of resources. The common understanding between people in the action situation could be the norm, culture, or tradition in each community that has a direct influence on the decision situation.

After setting the rules, the individual or member of the community must have a common understanding of them, i.e. the allowable actions and outcomes. Without a common understanding of the rules, they cannot be exercised.

Real actions must be evaluated with a common understanding of the rules. If community members obey the rules, allowable actions, and outcomes, the need for rule enforcement is low. If, on the other hand, the individual disagrees, the need for enforcement is high.

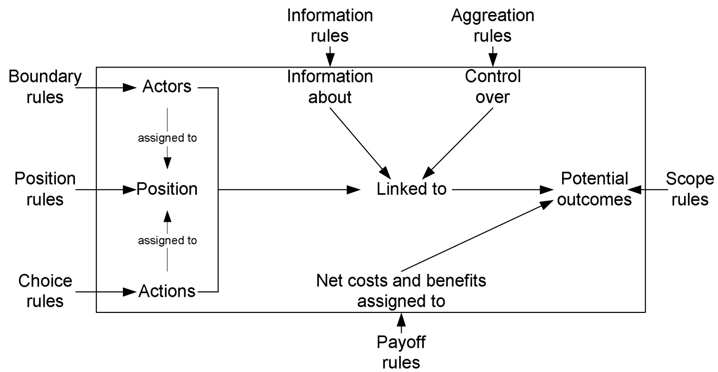
The distribution of the resource represents a situation in the market or community. If resources are distributed equally, a competitive environment arises. Otherwise, oligopoly or monopoly may arise.

Rules-in-use

The rules-in-use provide an institutional arrangement in a decision-making situation, including boundary, position, choices, payoff, information, aggregation, and scope rules. Generally, rules-in-use can be thought of in terms of “do and don’t” rules, for example, when a new member of staff arrives at the office on the first day, the first thing he/she should ask his/her colleagues about is the “dos and don’ts” in the office. This is more important than the rules-in-form that are written down (Ostrom, 2007, pp. 36-37).

A detailed discussion regarding the action situations is provided below. These rules help to explain the action arena or action situation. Figure 4 shows the rules-in-use and the action situation.

Boundary rules: who is eligible to participate in a decision-making or action situation? These rules provide the list of participants or actors. For example, in the French Open, tennis players with a higher rank automatically go to the first round, while newcomers have to win qualifying matches to enter the first round.



Source Ostrom (2011, p. 20), Figure 3

Figure 4. A rules-in-use and action situation

Position rules: what role does each participant perform in his/her position or what authority is given to each position? In each match, there are referees, line-persons, ball boys or girls, and two or four tennis players. Each position has its own task or responsibility to perform.

Choice rules: what actions should be taken? During the game, after one game of serving, the opponent has to strike back. There are many choices, e.g. whether to wait and hit a groundstroke or to go forward to volley. Even for the server, there are many choices when it comes to hitting the ball, e.g. whether to direct it to the corner, to the right, to the left, or to go for an ace on the first serve.

Payoff rules: what is the cost and benefit of the choice that is taken? During the game, if player A plays a drop shot at the net, player A expects player B to rush to the net to get the ball back.

Information rules: what information is available when making the decision? In the game, the information about players, weather conditions, changing to new balls or a new racket, medical breaks, and player injury are available to both players.

Aggregation rules: what level of control does the participant have in his/her action situation? During the game, the player has the ability to control his/her action to move forward, backward, to serve, or to hit the ball in order to win a point. Moreover, the player should control his/her performance to win the match in a normal game or a tiebreak.

Scope rules: what is the rule to delimit the potential outcome that is linked to a specific outcome? During the match, the winner has to win two out of three sets or three out of five sets. Both players can play a point in the specified court, including the height of the net, and the type and size of the court.

Outcomes

The terms 'outcomes' in Figure 3 and 'potential outcomes' in Figure 4 describe the same concern. The outcomes are the result of actions or strategies by the decision-maker in a decision-making process. Moreover, the evaluative criteria in Figure 3 should be used to find the net costs and benefits of the outcomes in Figure 4.

Evaluative criteria

Ostrom (2011) also provides evaluative criteria, including economic efficiency, equity through fiscal equivalence, redistributional equity, accountability, conformance to the values of local actors, and sustainability.[7] The evaluative criteria are the possible outcomes under the alternative institutional arrangements (Ostrom, 2011, p. 15).

Levels or worlds of action

The IAD framework provides consideration levels, or worlds of action, for the decision-making process, i.e. operation, collective-choice, constitutional, and metaconstitutional situations. Figure 5 shows the level of analysis in the IAD framework.

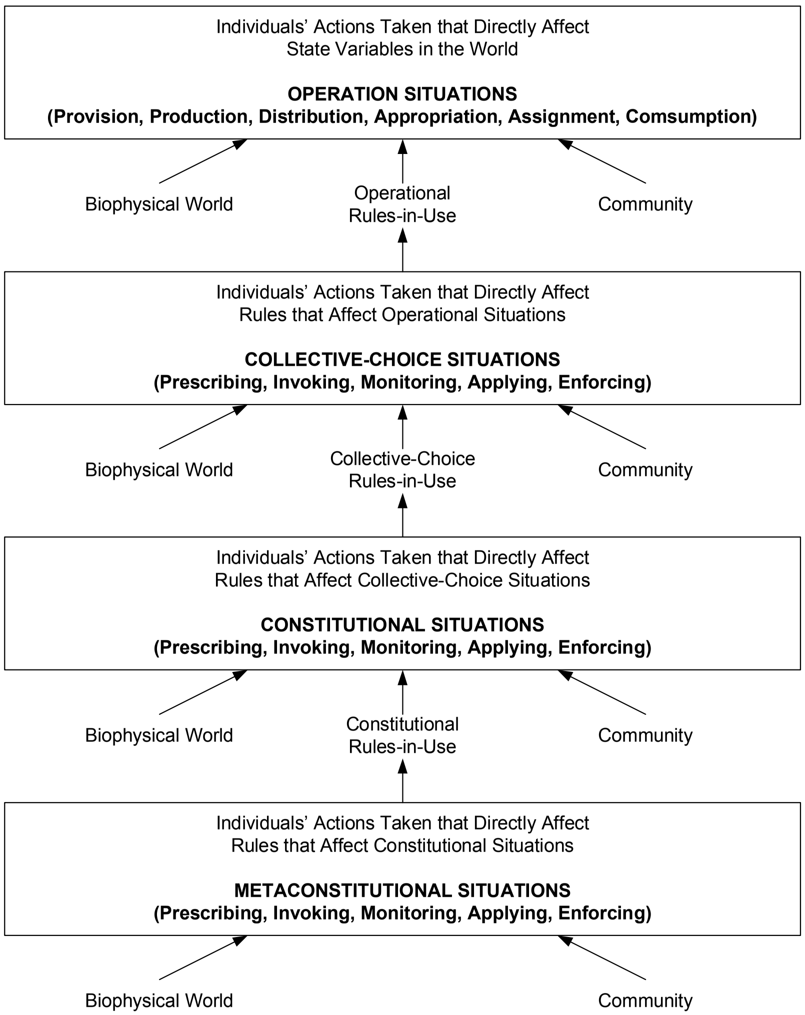
Each level or analysis comprises an internal action situation, as mentioned above. The seven parts of the IAD framework are contained in each level of the analysis. They are biophysical/material conditions, attributes of community, rules-in-use, action situations, interactions, evaluative criteria, and outcomes.

At an operational level, the situation is affected by the operational rules of day-to-day decision-making by the participant. The decision is made according to the operational rules, which are defined at the collective-choice level. For example, in the State of Maine's lobster industry, the day-to-day work is to fish or obtain lobster from the inland shore. The fishermen have to fish with specified tools and a time slot.

In a collective-choice situation, the collective-choice situation is affected by the operational rules to determine who is eligible, and it defines rules to change the operational rules. For example, if someone wants to change who can fish, and the tools and the time to fish lobster, they have to revise the operational rules at the collective-choice level.

In a constitutional situation, the situation is affected by the collective-choice rule of who is eligible and can change collective-choice rules, and it has consequences for the operational rules. For example, in the telecommunication industry, the national regulatory agency defines the set of rules allowing the use of Wi-Fi devices. The rules specify a frequency of 2.4-2.5 GHz with transmitting power of up to 100 milliwatts. These rules work as constitutional-choice rules with room for manufacturers or standard-setting agency to produce technology and standards to fit these rules. The standard for Wi-Fi devices is set at the collective-choice level. After that, Wi-Fi devices are on the market and available to use. Users buy and use Wi-Fi devices according to the standard.

[7] For more information, see Ostrom (2011, pp. 16-17).



Source Ostrom (2007, p. 45), Figure 2.2

Figure 5. Level of analysis and outcomes

As a constitutional decision-maker, Fédération Internationale de Football Association (FIFA) determines the rules of football at a high level. European or national football associations use FIFA's rules for their tournaments, such as EUROPA and the Premier League. Football teams must obey the rules to participate in tournaments.

At a metaconstitutional level, the situation is the deepest layer of analysis, underlying all three of the above levels. The metaconstitutional level should contain the fundamental rules like customs, tradition, norms, and religion (Williamson, 2000).[8]

2.2 Three worlds of action in spectrum management

The concept of three worlds of action and the property rights regime mentioned above provide an understanding of the interaction between the decision-maker and the decision situation within and between three levels.

An analysis of decision-makers at each level of spectrum management reveals the relevant stakeholders shown in Table 3.

Table 3. Level of analysis and stakeholders

Stakeholders	Level of analysis
Administrator / Regulator / Authority	Constitutional situation
Operator / Provider / Standard-setting Organization	Collective-choice situation
User	Operational situation

Source Ard-paru (2010), Table 7

Constitutional situation level

A high level of regulation conducted directly will influence the collective-choice level. In radiocommunication, the constitutional level starts with the regulator, administrator, or authority in each country up to the ITU level. The constitutional level gives the overall regulation and broadly influences the collective choice (or institutional level).

Collective-choice situation level

After the administrator, authority, or regulator outlines technical specifications, the operators, providers, or standard-setting units have to create technology according to the regulation (constitutional-choice level). For example, in the 2 400-2 500 MHz band there are two popular technologies, Wi-Fi and Bluetooth. These technologies provide personal and local connectivity with a peer-to-peer connection for Bluetooth and a Wi-Fi infrastructure for Internet connection, respectively.

Wi-Fi technology has been developed by the Institute of Electrical and Electronics Engineers (IEEE), and the current standard is 802.11n. This standard provides many technical specifications on how to use this frequency, e.g. medium access control (MAC) and physical layer (PHY) specifications.

Bluetooth has been developed to replace cable connectivity for personal area networks (PANs). The Bluetooth standard uses the frequency hopping spread spectrum for radio technology. PANs can connect mobile phones, faxes, printers, computers, laptops, GPS receivers, video recorders, and cameras.

At a collective-choice or institutional level, technology or standard rules show how the

[8] Williamson explains this as Level 1 (social theory), which is taken as given. Institutions at this level change very slowly: 100-1000 years.

frequency should be used by the provider, operator, or standard-setting unit and determine which devices can access their network.

Operational situation level

At this level, users can choose to select devices and use them. After selecting the devices, however, users have collective-choice or institutional level rules. For example, once the users access Wi-Fi hotspots in hotels, they must have devices with a specified Wi-Fi connection and an account to access the Internet defined by the operator. If, on the other hand, the user connects to the Wi-Fi router at home, the user specifies the access rule by password to determine who can connect to his or her router.

2.3 Bundle of rights to use frequency

With regard to the right to use a frequency, the access and withdrawal right depends on the devices (transceiver: transmitter and receiver), which are similar and cover access as in the fishing ground example. When users access a resource, they withdraw the product or consume the frequency. Frequency is a non-depletable resource, however. Thus, the access right is sufficient to explain the access to frequency. For example, the user makes a call from his or her mobile phone. The phone connects to the base station via a selected frequency. The selected frequency is occupied by the user. After hanging up, the selected frequency can be used by others.

The access right at operational level is defined by the network operator that defines the network rule to access the frequency in terms of the technical specification or standard. The network operator acts as both proprietor and claimant with regard to the management and exclusion right to define how, when, where, and who can access the frequency. For example, when a user makes a call from his or her mobile phone, the operator specifies which standard and technology the phone and the SIM card will use.

An alienation right is defined as ownership that can be sold, leased, or transferred. For example, the frequency auction in the primary market and frequency trading in the secondary market provide ownership of frequency for the owner to trade. Normally, the alienation right is defined by the authority, regulator, or administrator.

In Table 3, stakeholders are divided into the three levels. Applying the idea from Table 3, the bundle of rights for each stakeholder reveals the rights to use frequency shown in Table 4.

Table 4. Bundle of rights associated with telecommunication stakeholders

Stakeholders / Rights	Regulator	Operator A	Operator B	Advanced user	General user
Access and withdrawal	x	x	x	x	x
Management	x	x	x		
Exclusion	x	x	x	x	
Alienation	x	x			
Assignment approach		Market-based	Command-and-control	Spectrum commons	Spectrum commons

Source Ard-paru (2010), Table 12

At a constitutional level, the regulator, administrator, or authority holds all the rights to frequency use, including access, withdrawal, management, exclusion, and alienation rights. Once the regulator delegates authority, using the market mechanism to assign frequency, the alienation right passes to a collective-choice or institutional level, i.e. Operator A. Operator A is able to sell, lease, or transfer frequency to another party. Operator B, however, cannot sell because the regulator still holds the alienation right. Thus, frequency assignment using the command-and-control approach means that Operator B must ask the regulator for approval to transfer the frequency, e.g. 2G frequency assignment in Thailand. Operator A represents frequency assignment using the market-based approach, including primary trading (auction) and secondary trading (resale). Operator A has the freedom to transfer frequency without regulatory approval, e.g. 3G auction in the UK and the USA.

At a collective-choice or institutional level, the management and the exclusion rights are held by the providers, operators, or standard-setting units. They set up their network rules on how, when, and where to harvest frequency reflected by technology or device choices. For example, mobile phone operators set their standard of network and equipment to allow only their consumers to use the network. The advanced user (at the operational level), however, sets his or her own rules that allow access to the frequency. For example, advanced users of Wi-Fi routers can set their own security code for network access.

At an operational level, access and withdrawal rights are held by users. Users have to use devices according to the standard preset by the operators.

As for the right to use frequency, the assignees, and command-and-control and market-based approaches have the exclusive right to use frequency, but spectrum commons have a non-exclusive right. For the exclusive right, assignees have priority to use it free of interference. For the non-exclusive right, however, users have to share and accept interference. Exclusivity should be added to the property rights for the right to use frequency.

The level of deregulation of the right to use frequency from the regulator at the constitutional level can be delegated to operators at the collective-choice or institutional level, and users at operational level. The regulator can use the market-based approach to delegate alienation rights to operators. Thus, the operator can obtain the frequency from primary and secondary markets. The operator has the flexibility to sell, lease, or transfer frequency. At the operational level, the regulator can delegate its authority of self-regulation after defining the necessary conditions, including frequency, power limitation, and standard of devices. Thus, users have to manage the use of frequency. Table 5 shows the rights to use a frequency and the regulated level.

Table 5. The rights to use frequency

Property right / Regulated level	Exclusive use	Non-exclusive use
Centralized by regulator / state agency	Command–and-control	Public commons
Middleman/Operator	Market-based	Private commons
Self-regulated/User	-	Unlicensed

Source Ard-paru (2010), Table 13

The command-and-control assignment approach means that regulators hold all the rights to use frequency while assigning frequency to assignees. The assignee has the exclusive right to use the frequency with all the imposed conditions. Assignees have limited opportunities to change the use of frequency.

The market-based approach is the assignment method in which assignees can buy frequency from the primary and secondary market. The assignee has the exclusive right to use the frequency. The regulator gives away the alienation right to the assignee and this right can be sold, leased, and transferred. Thus, it is more flexible than the command–and-control approach. Some necessary conditions should be imposed on the use of frequency, however, such as the standard of devices.

The next three categories have non-exclusive rights to use frequency. This means that users have to share frequency. At the regulated level, it includes management and exclusion rights. If a state agency or government manages the frequency use, it is public commons. If the operator manages the frequency use, it is private commons. If users manage the frequency use, it is unlicensed.

2.4 Summary

This chapter presents the IAD framework, three worlds of action in spectrum management, and bundles of rights to use a frequency.

This study describes the elements of the IAD framework, including exogenous and endogenous variables. Exogenous refers to the external variables that influence the action situation, including biophysical conditions, attributes of community, and rules-in-use. Endogenous refers to the internal variable that is directly connected to rules-in-use. There are seven rules, including boundary, position, choice, payoff, information, aggregation, and scope rules.

Moreover, three worlds of action provide the interrelation between levels of action: constitutional, collective-choice, and operation situation. These levels of action provide the link as to how the rules-in-use in the higher level influence the lower level.

This study illustrates three worlds of action in spectrum management by mapping the levels of action and stakeholders. For the constitutional situation, the administrator, regulator, and authority provide international and national regulation as the scope of spectrum management. In the collective-choice situation, the operator, provider, and standard-setting organization comply with the given regulation from the constitutional situation in order to create their collective-choice situation regulation such as the network rules or standard of equipment. For the operational situation, users buy the equipment and use it according to the specified standard and regulation.

This study demonstrates the bundle of rights to use a frequency as the application from the IAD framework in the collective-choice and operational situation. The bundled rights to use a frequency can also be divided into five rights: access, withdrawal, management, exclusion, and alienation rights. The access and withdrawal rights to use a frequency can be combined,

however, due to the technical characteristics of the transmitter, receiver, and transceiver. When the transceiver is switched on, the transceiver operates or accesses the specified frequency and uses the frequency for the specified service. This means that transceivers combine access and withdrawal rights to use the frequency at the same time.

At an operational level, general users hold access and withdrawal rights to use frequency by selecting devices (transmitter, receiver, or transceiver) that follow specified conditions. Advanced users hold an additional exclusion right to determine who can use the frequency by applying a specified username and password.

At a collective-choice or institutional level, operators, providers, and standard-setting organizations hold additional management and exclusion rights that specify how, when, and where a frequency can be used in terms of the standard of device, technology, SIM card, etc.

At a constitutional choice level, the authority, administrator, or regulator has all the rights to the frequency use and to specifying regulations. If, however, the regulator decentralizes the alienation right by using the market mechanism, the operator at the collective choice level can obtain the frequency from primary and secondary markets.

The exclusive right to use frequency is a key point to separate the three spectrum assignment approaches: command-and-control, market-based and spectrum commons. The command-and-control and market-based approaches have an exclusive right to use frequency, but spectrum commons has a non-exclusive right. The regulated level indicates the decentralization of regulators. Regulators may give away some rights to the operator or end-user. Thus, both the exclusive right and the regulated level help to explain the differences between these approaches.

In the exclusive right to use frequency, the regulated level depends on the degree to which the alienation right is decentralized. If the regulator holds the alienation right, the approach is command-and-control. If the regulator delegates the alienation right via primary and secondary markets, the approach is market-based.

In the category of non-exclusive rights to use frequency, the regulated levels range from regulator, operator, and end-users, i.e. public commons and private commons, to unlicensed. Public commons have a state agency to manage frequency, such as a municipality or local administrator, etc. Private commons have private entities to manage frequency, such as a Wi-Fi operator in a hotel, airport, department store, etc. Unlicensed spectrum is self-regulated.

Chapter 3 Methodology

This chapter concerns the available data, the mode of data collection, and methods used in data analysis.

The data are secondary and qualitative in nature. Secondary data are sourced from the ITU, and NBTC archives. The secondary data archive approach was developed by Rutkowski (2011). Rutkowski downloaded principal data from the ITU History Portal. The data allowed examination of versions of the regulations to enable the identification of key definitions and provisions by RR versions. Rutkowski's analysis enabled the identification and links to detect any differences in the text. Rutkowski applied this method to cyber security, and to find where such text amendments arose.

The benefit obtained from applying the Rutkowski approach is that mapping the archive over time improves the understanding of the context in which regulations developed.

Accordingly, the study is based on data obtained from archived documents and information derived from meeting attendance. The ITU archives include all versions of the RR, including 1906, 1912, 1927, 1932, 1938, 1947, 1959, 1968, 1971, 1976, 1982, 1986, 1990, 1994, 1996, 1998, 2001, 2004, 2008, and 2012.

3.1 Data and data collection method

Secondary data are obtained from the ITU and NBTC archives outlining the timeline of RR changes by agenda item. In order to use documents as secondary data, Flick (2009) provides guidelines on how to select suitable analysis documents by the criteria: authenticity (applied to both primary and secondary data), credibility (official or personal), representativeness (typical or non-typical), and meaning (text clarity).

Document authenticity depends on the data source. If information is obtained from primary data sources and is documented by witnesses, then authenticity is 'high'. When data are obtained from a secondary data source and documented from primary data, the authenticity of the document is 'medium' or 'low'. Document credibility depends on the type of document. For official documents, credibility is 'high'. Naturally, for personal documents, credibility is 'low'. Representativeness is measured by document type. When documents are recorded for specific purposes, representativeness is non-typical. If the document is for general purposes, representativeness is typical. The document's meaning depends on its clarity.

There follows a brief summary of data collection methods. To gain an appreciation of how the RR and WRC developed over time, the archive of the ITU is the principal source of input and output documentation for all RR versions. These data are used to construct a database of TFA to track changes of key definitions and the WRC process to alter the RR.

All ITU documents can be accessed through the ITU History Portal (http://www.itu.int/en/history/Pages/default.aspx), including the PP (complete list of Plenipotentiary Conferences), Radiocommunications collection (complete list of

Radiotelegraph & Radiocommunication conferences), and the RR (complete list of the Radio Regulations).

The application and technology for spectrum commons in Chapter 4 is described from the relevant literature, including the ITU-R report and SCOPUS database.

The allocation of spectrum commons in Chapter 5 is illustrated by relevant ISM provisions in the RR, including definition, footnotes 5.138 and 5.150, and relevant frequency bands. Keyword mapping for ISM applications helps to identify the change and how changes developed over time.

The frequency assignment for spectrum commons in Thailand in Chapter 6 is described based on the relevant regulations in the NBTC archive, including the Radiocommunication Act, NTC and the NBTC established Act, PTD, NTC, and NBTC regulation.

The transformation of spectrum commons from international to national regulation in Chapter 7 applies the IAD framework to understand the relationship between the RR and NBTC regulation in terms of the RR and Thai TFA, footnotes, relevant frequency band, and national regulations.

To summarize, secondary data obtained from the ITU and NBTC archives provide a high degree of authenticity and credibility. Further, documents' representativeness depends on their purpose. The purpose may be general (typical) or specific (non-typical). In this study, the documents are specific. The representativeness of this study is also mainly non-typical. Furthermore, the meaning of documents is measured by document clarity.

3.2 Data analysis

Data analysis explains the level of analysis and outcomes, i.e. how international regulation is transformed into national regulation. This study starts from a level of analysis and outcomes that includes the constitutional, collective-choice, and operational situation, to understand the transformation from the RR into NBTC regulation.

The IAD framework provides seven elements of institutional analysis: biophysical conditions, attributes of community, rules-in-use, action situation, interactions, outcomes, and evaluative criteria. Moreover, the interaction between level of analysis and outcomes provides four levels: metaconstitutional, constitutional, collective-choice, and operational situation to understand the influence of rules-in-use in the deeper layer for other layers. However, this study applies three levels of analysis, namely constitutional, collective-choice, and operational situation for the transformation of international regulation into national regulation.

Moreover, the IAD framework assists in understanding spectrum management activities in terms of the interaction between stakeholders at each level of analysis and outcome.

3.3 Approach

The empirical work of the study consists of the exploration of the ITU and NBTC archives. Together with relevant literature, the study presents spectrum commons allocation development in terms of ISM application definition and footnotes 5.138 and 5.150. Moreover, the study also demonstrates the development of spectrum assignment for spectrum commons in Thailand. The results of empirical findings are deduced from the exploration of ITU and NBTC archives.

In order to understand the transformation from international to national regulation, the author applies the level of analysis and outcomes of the IAD framework to understand the relationship between international and national regulation in terms of the RR and the Thai TFA, footnotes, and frequency bands. The analysis is deduced from the IAD framework.

To summarize, the study uses deductive IAD framework and the results of the empirical findings to understand the transformation of international into national regulation and the development of spectrum commons, both allocation and assignment, in Thailand.

3.4 Summary

This study uses secondary data. Secondary data are from the ITU and NBTC archives.

This study analyzes secondary data according to the IAD framework to understand the transformation of international into national regulation and the interaction between the level of analysis and outcome for spectrum management activities and relevant stakeholders.

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Chapter 4 Spectrum commons application and technology

This chapter presents the main application and technology for spectrum commons in terms of short-range devices and software defined radio and cognitive radio system. The study concentrates on the application and technology relating to the industrial, scientific and medical (ISM) application, which use the frequency band according to RR No. 5.138 and 5.150.

4.1 Short-range devices

Short-range devices (SRDs) are used in many aspects of human daily life such as in the home, in offices, factories, on roads, airplanes, ships and so on. The study uses the definition of SRDs from the Report ITU-R SM.2153, including purpose of use, permitted operation, antenna, standard, and license. This definition covers the overall characteristics of SRDs.

Definition

"The short-range radio device is intended to cover radio transmitters which provide either unidirectional or bidirectional communication and which have low capability of causing interference to other radio equipment.

Such devices are permitted to operate on a non-interference and non-protected basis.

SRDs use either integral, dedicated or external antennas and all types of modulation and channel pattern can be permitted subject to relevant standards or national regulations.

Simple licensing requirements may be applied, e.g. general licences or general frequency assignments or even licence exemption, however, information about the regulatory requirements for placing short-range radiocommunication equipment on the market and for their use should be obtained by contacting individual national administrations" (ITU, 2009b, p. 2).

Technical characteristics

From the definition, the first characteristic is either transmitter or transceiver. The transmitter provides one-way communication or broadcasting signals, such as remote controls and garage door openers. The transceiver, comprising transmitter and receiver, provides two-way communication, such as a radio data transfer between routers and computers.

The second characteristic is a low interference or non-interference with other radio equipment. Moreover, the SRD cannot claim any protection from other radio equipment on a non-protected basis.

The third characteristic is an antenna, either an integral, dedicated, or external antenna. The integral antenna is built into SRDs, such as smart cards and keyless cars. The dedicated antenna has a special piece of equipment dedicated as an antenna, such as Wi-Fi router antenna. An external antenna is a separate antenna that can connect with SRDs, such as an

antenna that is connected to a walkie-talkie, which increases the communication range. However, the permitted type of antenna depends on the standard and national regulations.

Licensing

Whether the use of SRDs requires a specified licence or is unlicensed depends on the country and varies between countries. The licensing could be a general license, frequency authorization, or license exemption.

Noticeably, the overall definition of SRD does not specify communication ranges because the range depends on frequencies and transmitting powers. Generally, at the same transmitting power, a lower frequency can propagate longer than a higher frequency. Moreover, the ranges also depend on the purpose of SRDs, which reflects on the applications. For example, a smart card with a RFID tag requires a few centimeters between a card and reader. Conversely, inventory in a warehouse requires high transmitting power and an antenna to broadcast the signal and receive the data from the tag.

Application

There are several applications for SRDs, which vary according to the purpose of use. Table 6 shows the categories of SRD application by function and samples of applications from Report ITU-R SM.2153 (ITU, 2009b, pp. 2-5).

The applications for SRDs presented in Table 6 use both ISM band and other frequency bands. SRDs are mostly concentrated on the personal area network (PAN) or local area network (LAN). The approximate distance is a few meters between transceivers.

For example, household applications for SRDs include telecommand, voice and video, broadband radio local area network, model control, and wireless audio applications such as remote controls, baby monitors, walkie-talkies, Wi-Fi, computers, home entertainment, and toys.

Transportation applications are included in railway applications, road transport and traffic telematics, equipment for detecting movement and equipment for alerts, and inductive applications such as the intelligent transport system (ITS), millimeter radar while driving, and keyless car access.

Factory and warehouse applications include telemetry, inductive application, RFID, and RF (radar) level gauges, such as inventory management, barcode replacement, and monitoring at power plants.

The safety of life applications include equipment for detecting avalanche victims, alarms, and ultra-low-power active medical implants, as well as search and rescue beacons for victims, crime surveillance and monitoring, medical equipment at hospitals and implant devices for patients.

Table 6. SRD applications

Categories	Application
Telecommand	Remote controls or remote access
Telemetry	Distance recording
Voice and video	Walkie-talkies, baby monitors, citizen band (CB)
Equipment for detecting avalanche victims	Search and rescue for avalanche victims
Broadband radio local area network	RLANs, Wi-Fi devices, Bluetooth devices
Railway application – train and track communication	Automatic vehicle identification (AVI) Balise system Loop system
Road transport and traffic telematics	ITS, navigation, automatic toll-collection, route and parking guidance, collision avoidance
Equipment for detecting movement and equipment for alerts	Determination of position, velocity
Alarms	Home or office security, calling doctor or fire department
Model control	Toys: cars, airplanes, and boats with remote control
Inductive application	Car immobilizers, car access systems or car detectors, animal identification, alarm systems, item management and logistic systems, cable detection, waste management, personal identification, wireless voice links, access control, proximity sensors, anti-theft systems including RF anti-theft induction systems, data transfer to handheld devices, automatic article identification, wireless control systems and automatic road tolling
Radio microphone	Wireless microphone
RFID	Tags, smart cards, credit cards, barcode replacement
Ultra-low-power active medical implants	Medical implant communication system (MICS)
Wireless audio applications	Portable compact disc players, cassette decks or radio receivers carried on a person, cordless headphones for use in a vehicle, for example for use with a radio or mobile telephone, etc. in-ear monitoring, for use in concerts or other stage productions
RF (radar) level gauges	Level measurement gauges in refineries, chemical plants, pharmaceutical plants, pulp and paper mills, food and beverage plants, and power plants

Source Report ITU-R SM.2153 (ITU, 2009b, pp. 2-5)

Technology

This study explores the relevant literature regarding SRD in the ISM bands. Table 7 presents some of the technologies that are used for SRD. However, no description can be exhaustive. There are, for example, also Bluetooth, SAW filter, frequency hopping (FH), ZigBee, 802.11 a/b/g/n (Wi-Fi), 802.15.3 and 4: high data rate (HDR) and low data rate (LDR), ultra wide band (UWB), complementary metal oxide semiconductor (CMOS), near field communication (NFC), cognitive radio system (CRS) and software defined radio (SDR).

Table 7. Example of SRD technologies

Technology	Literature
802.11 a,b,g,n	Hao and Yoo (2011)
802.15.3, 4 (HDR and LDR)	Hao and Yoo (2009)
Bluetooth	Valenzuela, Hermandes and Valdovinos (2005)
CMOS and NFC	Cenger (2009), Teo and Yeoh (2008)
CRS and SDR	Fadda, Murroni, and Popescu (2012)
FH	Popovski, Yomo and Prasad (2006)
SAW filter	Alexander (2004)
UWB	ITU (2006)
ZigBee	De Francisco, Huang, Dolmans, and De Groot (2009), Ling (2007)

These technologies enable SRDs to perform on a non-interference and non-protection basis. The nature of SRDs is to share the frequency between other services and cannot cause harmful interference to other services. The frequency sharing represents the non-exclusive right to use the frequency. It is an important characteristic of spectrum commons. Therefore, SRDs are deemed to be an example of spectrum commons devices.

This study focuses on CRS and SDR for further explanation because they are included in the WRC-12 agenda item 1.19 that is relevant to spectrum commons.

Frequency band

Most SRDs use the frequency band under the ISM band. However, there are other frequency bands commonly used for SRD. Table 8 presents the frequency bands for SRDs that are taken from Table 1 of Report ITU-R SM. 2153 (ITU, 2009b, p. 7).

Table 8. Common frequency bands for SRDs

5.138	5.150
6 765-6 795 kHz 61-61.5 GHz 122-123 GHz 244-246 GHz	13 553-13 567 kHz 26 957-27 283 kHz 40.66-40.70 MHz 2 400-2 483.5 MHz 5 725-5 875 MHz 24-24.25 GHz
Other commonly used frequency ranges	
9-135 kHz:	Commonly used for inductive short-range radiocommunication applications
3 155-3 195 kHz:	Wireless hearing aids (RR No. 5.116)
402-405 MHz:	Ultra-low-power active medical implants Recommendation ITU-R RS.1346
5 795-5 805 MHz:	Transport information and control systems Recommendation ITU-R M.1453
5 805-5 815 MHz:	Transport information and control systems Recommendation ITU-R M.1453
76-77 GHz:	Transport information and control system (radar) Recommendation ITU-R M.1452

Source Table 1 of Report ITU-R SM. 2153 (ITU, 2009b, p. 7)

The ISM band in Table 8 excludes the 433.05-434.79 MHz in Region 1 for 5.138 and 902-928 MHz in Region 2 for 5.150. Other commonly used frequency ranges are 9-135 kHz, 3 155-3 195 kHz, 402-405 MHz, 5 795-5 805 MHz, 5 805-5 815 MHz, and 76-77 GHz. Two frequency bands are used for medical purposes: hearing aids and active medical implants. Three frequency bands are used in transportation.

The frequency bands for SRD may not be permitted for radio astronomy, aeronautical mobile, radionavigation and safety of life service (ITU, 2009b, p. 6)

Power

Power limitation for SRD depends on national regulation, which varies between countries. Power limitation can be defined as radiated power, magnetic field, or electric field strength. Table 9 shows the example of power limitation in European countries and the United States, which is taken from Table 2, Table 3 and Table 4 of Report ITU-R SM.2153 (ITU, 2009b, pp. 8-11).

Table 9. Common frequency bands for SRD

European countries	
Magnetic field strength	**Frequency bands**
42 dB(µA/m) at 10 m	59.750-60.250 kHz 9070-119 kHz 135-140 kHz 6 765-6 795 kHz 13.553-13.567 MHz 26.957-27.283 MHz
Maximum power level	**Frequency bands**
100 mW (Levels are either effective radiated power (e.r.p.) (below 1 000 MHz) or equivalent isotropically radiated power (e.i.r.p.) (above 1 000 MHz) or maximum mean e.i.r.p.)	26.990-27.000 MHz 27.040-27.050 MHz 27.090-27.100 MHz 27.140-27.150 MHz 27.190-27.200 MHz 34.995-35.225 MHz (for flying models only) 40.660-40.700 MHz 865.0-865.6 MHz(2) 2 400-2 483.5 MHz (for RLANs only) 17.1-17.3 GHz 24.050-24.250 GHz 61.0-61.5 GHz 122-123 GHz 244-246 GHz

USA		
Frequency (MHz)	**Electric field strength (µV/m)**	**Measurement distance (m)**
0.009-0.490	2 400/*f* (kHz)	300
0.490-1.705	24 000/*f* (kHz)	30
1.705-30.0	30	30
30-88	100	3
88-216	150	3
216-960	200	3
Above 960	500	3

Source Table 2, Table 3 and Table 4 of Report ITU-R SM.2153 (ITU, 2009b, pp. 8-11)

Table 9 presents power limitation in terms of the magnetic field strength and maximum power level for EU countries, for example the 13.553-13.567 MHz band has a magnetic field strength of 42 dB(µA/m) at 10 meters, and the 2 400-2 483.5 MHz band has a maximum power level of 100 mW (e.i.r.p.) for RLANs only. In the United States, the band above 960 MHz has maximum electric field strength of 500 (µV/m) at 3 meters' measurement distance, for example.

Health issue

Most SRD use involves sharing the frequency with ISM equipment. There are some concerns from Bozec, Robinson, Pearce and Marshman (2004) and Krishnamoorthy et al. (2003) regarding the fact that electromagnetic interference from SRDs might interfere with ISM or medical equipment in healthcare facilities, especially near emergency rooms, operating

rooms, and intensive care units in hospitals. One concern relates to head absorption from Anguera et al. (2012), regarding the radiation from handheld equipment near the head.

These issues are relevant to the use of SRDs in the healthcare environment, which is raising the awareness of limiting SRD use so that SRDs cannot cause any harmful interference to ISM equipment.

Migration from national to international issue

The use of SRDs alternates between the international and national level in terms of the allocation of frequency bands into ISM footnotes, and between national and international level in terms of the circulation of SRD between countries. The allocation of frequency bands to the ISM footnotes is coordinated at the WRC, the international negotiations are between Member States, however, authorization or permission to use SRD is managed locally by the NRA of each country. When permission is granted to use a SRD without licences or unlicensed in one country, Country A, it can be transported to other countries: Country B. When Country B does not allow use of Country A's SRD, the operation of Country A's SRD will interfere with the existing service of Country B.

This situation migrates from a national to an international issue because the unlicensed SRD can be transportable between countries. There is no single solution for this issue. However, the possibility of harmonization for SRD frequency bands at regional and global level might be considered.

To summarize, two main characteristics of SRDs, i.e. non-interference and non-protection basis, are at the heart of using SRDs in order to share the frequency with other services, especially ISM equipment. Most SRD use involves sharing the ISM band, however, the use of SRDs cannot interfere with ISM equipment. Enabled technologies such as SDR and CRS are facilitating the use of SRDs. Shared use provides the non-exclusive right to use a frequency as the main characteristic of spectrum commons. Therefore, the main applications of spectrum commons are SRDs.

4.2 Software-defined radio and cognitive radio system

Two of several technologies that can be used for SRD are SDR and CRS. These two technologies are included in the WRC-12 agenda item 1.19, which is directly relevant to spectrum commons. The WRC provides the forum for Member States to negotiate possibilities to revise the RR. The study selects SDR and CRS for further explanation because they are relevant to spectrum commons and included in the WRC-12 agenda item 1.19, which has the possibility of reviewing and revising the spectrum allocation for spectrum commons.

Definition

The development of the definition of these two technologies has been conducted in the ITU-R SG WP1B in the study period of WRC-12: after WRC-07 and before WRC-12. The study adopts the definition of SDR and CRS from Report ITU-R SM. 2152:

"Software-defined radio (SDR): A radio transmitter and/or receiver employing a technology that allows the RF operating parameters including, but not limited to, frequency range, modulation type, or output power to be set or altered by software, excluding changes to operating parameters which occur during the normal pre-installed and predetermined operation of a radio according to a system specification or standard.

Cognitive radio system (CRS): A radio system employing technology that allows the system to obtain knowledge of its operational and geographical environment, established policies and its internal state; to dynamically and autonomously adjust its operational parameters and protocols according to its obtained knowledge in order to achieve predefined objectives; and to learn from the results obtained"(ITU, 2009a, p. 1).

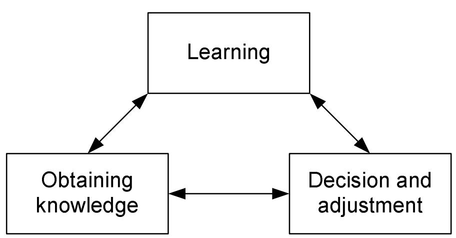
Technical characteristics

SDR is a technology that has the ability to change the RF operating parameters of the transmitter, receiver, or transceiver using software, such as frequency bands, modulation type and output power.

CRS is a combination of technologies that have the ability to obtain knowledge from the operational environment, learn from experience to establish the internal protocol, and adjust the operating parameters dynamically and automatically using software to improve performance.

Therefore, SDR is enabling technology for one function of CRS to change radio operating parameters using software. However, the remaining functions of CRS are still in their infancy: obtaining knowledge from the operational environment and learning from experience to establish the internal protocol for making decisions.

Figure 6 shows the cycle of CRS that displays the main functions: obtaining knowledge from the operational environment, adjusting the radio operational parameters simultaneously and automatically, and learning from the results.



Source Figure 1 of Matinmikko and Bräysy (2011, p. 18)

Figure 6. General cognitive cycle

Application

There are a number of applications using SDR, such as selection of frequency in Global Positioning System (GPS) receivers, noise cancellation in low noise amplifier (LNA) mixers,

mobile dynamic channel selection in mobile phones, vehicular dynamic spectrum access in vehicles, and 5G terminals (Bajaj, Kim, Oh, & Gerla, 2011; Elyasi, Jannesari, & Nabavi, 2012; Li, Kaur, & Andersen, 2011; Raju et al., 2012; Rzayev, Shi, Vafeiadis, Pagadarai, & Wyglinski, 2011). These applications use SDR to change the operational frequency both to avoid interference and increase spectrum efficiency.

Moreover, there are several applications applying CRS, especially for interference reduction and increasing spectrum efficiency. When interference is reduced, spectrum efficiency increases.

There are several applications for interference reduction, such as sharing the spectrum between primary and secondary users by interference constraint time slots, reducing a narrowband interference of orthogonal frequency division multiplexing (OFDM) by interference estimation and decoding (IED), and introducing spectrum sensing in Bluetooth and Wi-Fi (Dikmese & Renfors, 2012; Qu, Yi, Jiang, & Zhu, 2012; Sun et al., 2012; Xia, Ding, & Chen, 2012).

Further, Matinmikko and Bräysy (2011) provide four deployment scenarios for increasing spectrum efficiency using CRS: licensed spectrum, unlicensed spectrum, primary-secondary setting, and dedicated band for CRS.

For licensed spectrum, the licensee can utilize its licensed spectrum by introducing the CRS at the same frequency in different locations, for example frequency for mobile base stations can be introduced to home base stations without the need for additional regulation.

For unlicensed spectrum, i.e. ISM band, the CRS can be utilized while using the same frequency bands with other applications.

In a primary-secondary setting, the secondary users can implement the CRS as opportunistic spectrum access, while primary users do not use the frequency, such as the white space frequency in the US.

For CRS bands, it is similar to the ISM band but the equipment implementing CRS must share this band.

Generic and specific regulation issue

During the WRC-12 agenda item 1.19 regarding the use of SDR and CRS, there was the issue of regulation governing the use of SDR and CRS. The SDR issue was settled because this technology is at a mature stage and has been used in several services. There is no need for additional regulation. However, the CRS is in the process of development, and is not a mature technology. The CRS issue was debated, with two opposing views: whether the existing regulation is enough to govern the use of CRS, or whether new regulation is required. At the end of the WRC-12, the compromise result was that CRS required further study.

Benefit

These technologies increase spectrum access and efficiency in both licensed and unlicensed frequency bands. Moreover, interference while sharing between primary and secondary users is reduced. Not only is there sharing between primary and secondary users, but co-primary users also benefit from CRS. Further, network implementation has improved flexibility to provide capabilities for self-organization and self-healing (Matinmikko & Bräysy, 2011, pp. 19-20)

CRS can entirely change the exclusive right to a frequency scheme because it is unnecessary to have dedicated or licensed frequency bands to provide radiocommunication services. Therefore, CRS is the main technology for providing non-exclusive rights to use frequency as the main characteristic of spectrum commons.

In conclusion, the characteristics of CRS are obtaining knowledge from the operational environment, changing the radio operational parameters simultaneously and automatically using software, and learning from experiences to improve the performance. SDR is one of the main characteristics of CRS. The benefit of CRS is reducing interference, creating spectrum access opportunities, and increasing spectrum efficiency. The characteristic of CRS renders the exclusive right to use frequency unnecessary. Therefore, these technologies provide non-exclusive rights to use frequency schemes as spectrum commons.

4.3 Summary and discussion of research question

This chapter responds to sub-research question 1: *What are the main applications and technologies for spectrum commons?*

This study explores the relevant literature, including the report and recommendation of the ITU-R to illustrate the characteristics of the SRD, SDR and CRS.

The main characteristics of SRDs are use on a non-interference and non-protected basis. Most SRDs use the ISM band, especially 5.138 and 5.150. Moreover, power limitations in terms of magnetic and electric field strength and maximum power level vary from country to country. The allocation of frequency band to the ISM band is coordinated by the WRC. However, authorization of the use of SRDs is managed locally by the NRA. SRDs migrate national to international issues when unlicensed SRDs are transported from one country to other countries that do not allow the use of such SRDs. The use of unlicensed SRDs in countries that do not allow it creates interference with the existing services. There may be a solution through regional and global harmonization of frequency bands.

SRDs are the main application for spectrum commons, because the characteristic of non-interference and non-protection provides the non-exclusive use of frequency that is similar to spectrum commons.

SDR and CRS are enabled technologies for SRD. This study focuses on these two technologies because they are relevant to WRC-12 agenda item 1.19 and might present opportunities to review and revise the RR.

The characteristics of CRS are obtaining the operational environment, changing the radio operational parameters simultaneously and automatically using software, and learning from the experience to improve its performance. SDR is enabled technology for CRS because SDR can change the radio operational parameters simultaneously and automatically using software.

The development of SDR is at a mature stage that has already been implemented into several services, however the CRS is in its infancy and needs to further develop. The main benefits of CRS are providing spectrum access opportunities, increasing spectrum efficiency, and reducing interferences.

The characteristic of CRS provides the non-exclusive right to use frequency as the same as spectrum commons characteristic. Therefore, the SDR and CRS are the main technologies for spectrum commons.

This study presents the characteristics of SRD, SDR, and CRS in order to illustrate the non-exclusive right of use that is the same characteristic of spectrum commons. This chapter responds to the first sub-research question: what is the main application and technology for spectrum commons? The answer to this sub-research question provides fundamental information such as the main characteristics of SRDs, SDR, and CRS for spectrum in order to relate the spectrum allocation for spectrum commons at international level to spectrum assignment for SRDs at national level.

Chapter 5 Spectrum allocation for spectrum commons

This chapter presents the overview of frequency allocation within the RR and also describes the development of frequency allocation for spectrum commons in terms of the frequency allocation for ISM bands and its definition.

5.1 Spectrum allocation

Spectrum shows its characteristics when it is transmitted from a transmitter; it will propagate until the power runs out and does not recognize borders between countries. In order to manage spectrum internationally, the ITU, via the WRC, manages the spectrum according to the RR as the international treaty providing the guidelines on spectrum management internationally.

In order to manage the use of frequency, the WRC allocates radiocommunication services (purpose of frequency usage) to frequency bands with footnotes to the RR.[9] This activity is called spectrum allocation. Allocation can be either regional or global.

The allocation is presented in a Table of Frequency Allocation (TFA) contained in Volume 1 - Articles, sorted by frequency band with the services that are allowed to be used. The TFA is divided into three regions (Regions 1-3) and currently defines the usable frequency up to 3,000 GHz. The services can be either primary or secondary services. In the TFA, primary services are presented in upper case, while secondary services are in lower case. The reason for this division is to avoid harmful interference, with primary services always having priority over secondary services by way of station (network and device) construction.

For example, in the TFA of RR2012, the 2 300-2 483.5 MHz band in Table 10 shows the regional allocation. In Region 1, in the 2 300-2 450 MHz band, there are two primary services – fixed and mobile services, and two secondary services – amateur and radiolocation services. In Regions 2 and 3, in the band 2 450-2 483.5 MHz, there are three primary services – fixed, mobile, radiolocation services.

Apart from capitalized and lower-case letters in the TFA, the footnotes can also indicate the priority of services. For example, footnote 5.397 indicates the use of radiolocation services in the band of 2 450-2 500 MHz on a primary basis in France.[10]

The additional allocation footnote is the footnote that has the same service as indicated in the TFA, but in an area smaller than the Region. For instance, footnote 5.393 allocates the 2 400-2 450 MHz band to broadcasting-satellite services (sound) on a primary basis in Canada, the United States, India, and Mexico.[11]

Table 10. Table of Frequency Allocation, 2 300 – 2 483.5 MHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
2 300-2 450 FIXED MOBILE 5.384A Amateur Radiolocation 5.150 5.282 5.395	**2 300-2 450** FIXED MOBILE 5.384A RADIOLOCATION Amateur 5.150 5.282 5.393 5.394 5.396	
2 450-2 483.5 FIXED MOBILE Radiolocation 5.150 5.397	**2 450-2 483.5** FIXED MOBILE RADIOLOCATION 5.150	

The alternative allocation footnote is the footnote that replaces the service indicated in the TFA, but in an area smaller than the Region. For example, footnote 5.315 (not in Table 10) allocates the band 790-838 MHz for broadcasting services on a primary basis in Greece, Italy, and Tunisia.[12]

The miscellaneous provision footnote is the footnote that represents the specific operation constraints, such as footnote 5.396 in the 2 310-2 360 MHz band that provides the conditions for broadcasting-satellite services by a space station.[13]

Moreover, footnotes can be used for a particular service: the footnote is located next to the service, or entire frequency bands: the footnote is placed at the bottom of the band as indicated in the TFA. The band footnote is applied to all services allocated in this band. For example, in Region 1, in the 2 300-2 450 MHz band, the use of mobile services has a particular footnote, 5.384A. The band footnotes are 5.150, 5.282, and 5.395, which apply to all services in this band, including fixed, mobile, amateur, and radiolocation services.

In Regions 2 and 3, the 2 300-2 450 MHz band has a particular footnote for the mobile service: 5.384A. However, the band footnotes are 5.150, 5.282, 5.393, 5.394, and 5.395 which apply to all services in this band, including fixed, mobile, radiolocation, and amateur services.

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[9] *Radiocommunication service:* A service as defined in this Section involving the transmission, *emission* and/or reception of *radio waves* for specific *telecommunication* purposes. This definition is taken from Article 1. Section III–Radio services, 1.19 of the RR edition 2012 (ITU, 2012).

[10] 5.397 *Different category of service:* in France, the band 2 450-2 500 MHz is allocated on a primary basis to the radiolocation service (see No. 5.33). Such use is subject to agreement with administrations having services operating or planned to operate in accordance with the Table of Frequency Allocations which may be affected.

[11] 5.393 *Additional allocation:* in Canada, the United States, India and Mexico, the band 2 310-2 360 MHz is also allocated to the broadcasting-satellite service (sound) and complementary terrestrial sound broadcasting service on a primary basis. Such use is limited to digital audio broadcasting and is subject to the provisions of Resolution 528 (Rev.WRC-03), with the exception of *resolves* 3 in regard to the limitation on broadcasting-satellite systems in the upper 25 MHz. (WRC-07)

[12] 5.315 *Alternative allocation*: in Greece, Italy and Tunisia, the band 790-838 MHz is allocated to the broadcasting service on a primary basis. (WRC-2000)

[13] 5.396 Space stations of the broadcasting-satellite service in the band 2 310-2 360 MHz operating in accordance with No. 5.393 that may affect the services to which this band is allocated in other countries shall be coordinated and notified in accordance with Resolution 33 (Rev.WRC-97)*. Complementary terrestrial broadcasting stations shall be subject to bilateral coordination with neighboring countries prior to their bringing into use.

All allocations at the WRC are based on Member States' contributions. The successful allocations are the outcome of international negotiations based on consensus or compromise among Member States.

The allocations, both services and footnotes, belong to Member States, which are the authority representing the government of each country. This implies that the allocation at the WRC reflects the command-and-control approach at international level among representatives from governments around the world. When allocations are in line with all government benefits, consensus is achieved. However, when allocation raises controversial and debatable issues, a compromise solution is reached.

5.2 Allocation of spectrum commons

Normally, the service allocation by the WRC provides both primary and secondary services by frequency bands. Among primary services, there are co-primary services, which need operating criteria when they are co-located in order to keep harmful interference manageable. Conversely, the secondary services cannot cause any harmful interference with the primary service.

The use of spectrum commons is neither allocated to primary nor secondary services in the TFA. Spectrum commons are allocated in the footnotes for industrial, scientific and medical (ISM) applications without priority. ISM footnotes provide the non-exclusive right to use frequency. ISM applications are locally operated with short-range devices. There are two footnotes regarding ISM applications, namely 5.138 and 5.150. The development of these two footnotes is presented in the next section.

5.3 Development of industrial, scientific and medical application band

Industrial, scientific and medical (ISM) applications have been defined in Article 1 – Terms and Definitions since RR1982 and remain unchanged up until the RR2012. Before 1982, ISM applications used different wording, such as purpose and equipment in the RR1947 and RR1959.

5.3.1 Definition

The current definition of ISM applications is found in RR2012, page RR1-2:

"1.15 industrial, scientific and medical (ISM) applications (of radio frequency energy): Operation of equipment or appliances designed to generate and use locally radio frequency energy for industrial, scientific, medical, domestic or similar purposes, excluding applications in the field of telecommunications" (ITU, 2012, pp. RR1-2).[14]

The use of the ISM equipment is local, especially for industrial, scientific, medical, or domestic purposes, apart from telecommunication applications. Usually, the use of telecommunication applications via radio is allocated by services. However, most ISM

[14] This provision was used under provision No. 1.14 in RR1982 (ITU, 1982, pp. RR1-2), RR1990 and RR1994 (ITU, 1990; 1994, pp. RR1-3). Moreover, this provision was also used under provision No. S1.15 in RR1998 (ITU, 1998, p. 8) and No. 1.15 in RR2001, RR2004, and RR2008 (ITU, 2001, 2004; 2008, pp. RR1-2).

applications are used locally, i.e. by short-range or low-power devices. The footnote allocating ISM frequency bands provides additional conditions of use.

5.3.2 ISM frequency bands

The current frequency bands with corresponding footnotes for ISM applications are provided in Table 11. The current provisions of ISM applications are in RR2012: 5.138 and 5.150 with relevant footnotes (ITU, 2012).[15, 16]

Table 11 presents a summary of frequency bands for ISM applications in footnotes 5.138 and 5.150, together with the allowable regions and main applications. There are five frequency bands for 5.138: 6,765-6,795 kHz, 433.05-434.79 MHz, 61-61.5 GHz, 122-123 GHz, and 244-246 GHz. There are six frequency bands for 5.150: 13 553-13 567 kHz, 26 957-27 283 kHz, 40.66-40.70 MHz, 902-928 MHz, 2 400-2 500 MHz, and 5 25-5 875 MHz. The total bandwidth of 5.138 and 5.150 is 3,778.15 MHz. This is only 0.126% of the whole usable spectrum of 3,000 GHz, however.

[15] These provisions were used in RR2001, RR2004, and RR2008 (ITU, 2001, 2004, 2008).

[16] 5.138 The following bands:
6765-6 795 kHz (center frequency 6 780 kHz),
433.05-434.79 MHz (center frequency 433.92 MHz) in Region 1 except in the countries mentioned in No. 5.280,
61-61.5 GHz (center frequency 61.25 GHz),
122-123 GHz (center frequency 122.5 GHz), and
244-246 GHz (center frequency 245 GHz)
are designated for industrial, scientific and medical (ISM) applications. The use of these frequency bands for ISM applications shall be subject to special authorization by the administration concerned, in agreement with other administrations whose radiocommunication services might be affected. In applying this provision, administrations shall have due regard to the latest relevant ITU-R Recommendations.

5.280 In Germany, Austria, Bosnia and Herzegovina, Croatia, The Former Yugoslav Republic of Macedonia, Liechtenstein, Montenegro, Portugal, Serbia, Slovenia and Switzerland, the band 433.05-434.79 MHz (center frequency 433.92 MHz) is designated for industrial, scientific and medical (ISM) applications. Radiocommunication services of these countries operating within this band must accept harmful interference which may be caused by these applications. ISM equipment operating in this band is subject to the provisions of No. 15.13. (WRC-07)

5.150 The following bands:
13 553-13 567 kHz (center frequency 13 560 kHz),
26 957-27 283 kHz (center frequency 27 120 kHz),
40.66-40.70 MHz (center frequency 40.68 MHz),
902-928 MHz in Region 2 (center frequency 915 MHz),
2400-2 500 MHz (center frequency 2 450 MHz),
5725-5 875 MHz (center frequency 5 800 MHz), and
24-24.25 GHz (center frequency 24.125 GHz)
are also designated for industrial, scientific and medical (ISM) applications. Radiocommunication services operating within these bands must accept harmful interference which may be caused by these applications. ISM equipment operating in these bands is subject to the provisions of No. 15.13.

15.13 § 9 Administrations shall take all practicable and necessary steps to ensure that radiation from equipment used for industrial, scientific and medical applications is minimal and that, outside the bands designated for use by this equipment, radiation from such equipment is at a level that does not cause harmful interference to a radiocommunication service and, in particular, to a radionavigation or any other safety service operating in accordance with the provisions of these Regulations[1].

[1] 15.12.1 and 15.13.1 In this matter, administrations should be guided by the latest relevant ITU-R Recommendations.

Table 11. Frequencies of ISM bands 5.138 and 5.150

Frequency	Footnote	Bandwidth	Region 1	Region 2	Region 3	Main application
6 765-6 795 kHz	5.138	30 kHz	✓	✓	✓	Inductive application
13 553-13 567 kHz	5.150	14 kHz	✓	✓	✓	RFID
26 957-27 283 kHz	5.150	326 kHz	✓	✓	✓	Railway application – Eurobalise
40.66-40.70 MHz	5.150	0.04 MHz	✓	✓	✓	Control signal
433.05-434.79 MHz	5.138	1.74 MHz	✓			Control signal
902-928 MHz	5.150	26 MHz		✓		Spread spectrum transmitter
2 400-2 500 MHz	5.150	100 MHz	✓	✓	✓	WLAN
5 725-5 875 MHz	5.150	150 MHz	✓	✓	✓	WLAN
24-24.25 GHz	5.150	250 MHz	✓	✓	✓	RF level gauge
61-61.5 GHz	5.138	0.5 GHz	✓	✓	✓	Millimeter-wave radar
122-123 GHz	5.138	1 GHz	✓	✓	✓	Non-specific SRDs
244-246 GHz	5.138	2 GHz	✓	✓	✓	Non-specific SRDs

Source: ITU (2009b) and (2012)

Most of the applications are short-range devices and have various applications, ranging from an inductive application to a millimeter-wave radar. Only two frequency bands of 433.05-434.79 MHz and 902-928 MHz are allocated to Region 1 and Region 2, respectively. The rest of the ISM bands are global allocations.

The development of ISM bands is illustrated in Table 12. Table 12 provides three sections of ISM band development: kHz, MHz, and GHz. The relevant RR provisions and versions are also included.

kHz band

The *60-80 kHz band* was allocated in the U.S.S.R. for industrial, scientific and medical purposes in the RR1959 and was used in the RR1968, RR1971 and RR1976. Unfortunately, this band was stopped in the RR1982.[17]

The *6 765-6 795 kHz band* was allocated initially in the RR1982 and continued to be used without changing the substance of the RR1990 and RR1994 under provision No. 524.[18]

[17] 161 In the U.S.S.R., frequencies in the band 60-80 kHz may be used for industrial, scientific and medical purposes subject to the condition that interference is not caused to stations of services to which this band is allocated (ITU, 1959, 1968, 1971, 1976).

[18] 524 The band 6 765 - 6 795 kHz (center frequency 6 780 kHz) is designated for industrial, scientific and medical (ISM) applications. The use of this frequency band for ISM applications shall be subject to special authorization by the administration concerned, in agreement with other administrations whose radiocommunication services might be affected. In applying this provision, administrations shall have due regard to the latest relevant CCIR Recommendations (ITU, 1982, 1990, 1994).

Table 12. ISM frequency bands development

Initial RR	Lower frequency (kHz)	Upper frequency (kHz)	Bandwidth (kHz)	Footnote/Provision	RR removal
1959	60	80	20	161	1982
1947	13 553.22	13 566.78	13.56	164,217	1982
1947	26 957.28	27 282.72	325.44	171,225	1982
1982-2012	6 765	6 795	30	524,S5.138,5.138	
1982-2012	13 553	13 567	14	534,S5.150,5.150	
1982-2012	26 957	27 283	326	546,S5.150,5.150	
Initial RR	**Lower frequency (MHz)**	**Upper frequency (MHz)**	**Bandwidth (MHz)**	**Footnote/Provision**	**RR removal**
1938	30	32	2	Lower-power station	1947
1938	40.5	56	15.5	Lower-power station	1947
1947	40.65966	40.70034	0.04068	176,236	1982
1938	56	58.5	2.5	Lower-power station	1947
1938	58.5	60	1.5	Lower-power station	1947
1938	60	64	4	Lower-power station	1947
1938	70.5	74.5	4	Lower-power station	1947
1938	75.5	85	9.5	Lower-power station	1947
1938	95.5	110	14.5	Lower-power station	1947
1938	110.5	112	1.5	Lower-power station	1947
1938	112	120	8	Lower-power station	1947
1938	120	150	30	Lower-power station	1947
1938	162	170	8	Lower-power station	1947
1959	433.05216	434.787884	1.73568	321	1982
1947	890	940	50	212,340	1971
1947	5775	5925	150	228	1959
1982-2012	40.66	40.70	0.04	548, S5.150,5.150	
1982-2012	433.05	434.79	1.74	661,662,S5.138,S5.280, 5.138,5.280	
1971-2012	902	928	26	340,707,S5.150,5.150	
1947-2012	2 400	2 500	100	220,357,752,S5.150,5.150	
1959-2012	5 725	5 875	150	391,806,S5.150,5.150	
Initial RR	**Lower frequency (GHz)**	**Upper frequency (GHz)**	**Bandwidth (GHz)**	**Footnote/Provision**	**RR removal**
1959	22	22.250	0.25	410	1971
1971-2012	24	24.25	0.25	410C,881,S5.150,5.150	
1982-2012	61	61.5	0.5	911,S5138,5.138	
1982-2012	122	123	1	916,S5138,5.138	
1982-2012	244	246	2	922,S5138,5.138	

Later on, this frequency band was consolidated in footnote S5.138 in the RR 1996 and also used in the RR1998.[19] In the RR2001, the provision number was changed to 5.138 and

[19] S5.138 The following bands:
6 765- 6795 kHz (center frequency 6780kHz),
433.05-434.79 MHz (center frequency 433.92 MHz) in Region 1 except in the countries mentioned in No. S5.280,
61 - 61.5 GHz (center frequency 61.25 GHz),
122- 123 GHz (center frequency·122.5 GHz), and
244-246 GHz (center frequency 245 GHz)
are designated for industrial, scientific and medical (ISM) applications. The use of these frequency bands for ISM applications shall be subject to special authorization by the administration concerned, in agreement with other administrations whose radiocommunication services might be affected. In applying this provision, administrations shall have due regard to the latest relevant ITU-R Recommendations.

continued to be used in the RR2004, RR2008, and RR2012. The provision includes the frequency band for ISM applications and their conditions of use, i.e. obtaining special authorization by its administration and administrations concerned with relevant CCIR Recommendations.

The *13 553-13 567 kHz band* was allocated initially in the RR1947 under provision No. 164 by center frequency of 13 560 kc/s with the bandwidth ± 0.05% of this frequency. [20] The content of this provision continued to the RR1959 under provision No. 217. This provision was used in the RR1968, RR1971, and RR1976.[21] The provision includes the frequency band, the purpose of frequency use, and the conditions of use for other radiocommunication services that must accept harmful interference from ISM applications.

In 1982, the format of the frequency band was changed to provide an upper and lower frequency in order to define the frequency band. Further, the provision number was changed to 534 in the RR1982, RR1990, and RR1994.[22] This provision, which adds the condition of use for ISM equipment, is subject to provision No. 1815. Provision No. 1815 mandated the administration to keep radiation from ISM applications to a minimum and not to cause harmful interference to radionavigation or other safety services by following the latest relevant CCIR Recommendation.[23] This provision was used in the RR1982, RR1990, RR1994, and RR1996. The number of the provision was changed to S15.13 in the RR1998, and changed to 15.13 in the RR2001 and continued to be used up until the RR2012.[24]

S5.280 In Germany, Austria, Bosnia and Herzegovina, Croatia, The Former Yugoslav Republic of Macedonia, Liechtenstein, Portugal, Slovenia, Switzerland and Yugoslavia, the band 433.05-434.79 MHz (center frequency 433.92 MHz) is designated for industrial, scientific and medical (ISM) applications. Radiocommunication services of these countries operating within this band must accept harmful interference which may be caused by these applications. ISM equipment operating in this band is subject to the provisions of No. 1815/S15.13 (ITU, 1996, 1998).

[20] 164 [50)] The frequency 13 560 kc/s is designated for industrial, scientific and medical purposes. Emissions must be confined within the limits of ± 0.05% of this frequency. Radiocommunication services operating within those limits must accept any harmful interference that may be experienced from the operation of industrial, scientific and medical equipment (ITU, 1947).

[21] 217 The frequency 13 560 kc/s is designated for industrial, scientific and medical purposes. Emissions must be confined within the limits of ±0.05% of that frequency. Radiocommunication services operating within those limits must accept any harmful interference that may be experienced from the operation of industrial, scientific and medical equipment (ITU, 1959, 1968, 1971, 1976).

[22] 534 The band 13 553-13 567 kHz (center frequency 13 560 kHz) is designated for industrial, scientific and medical (ISM) applications. Radiocommunication services operating within this band must accept harmful interference which may be caused by these applications. ISM equipment operating in this band is subject to the provisions of No. 1815 (ITU, 1982, 1990, 1994).

[23] 1815 § 10. Administrations shall take all practicable and necessary steps to ensure that radiation from equipment used for industrial, scientific and medical applications is minimal and that, outside the bands designated for use by this equipment, radiation from such equipment is at a level that does not cause harmful interference to a radiocommunication service and, in particular, to a radionavigation or any other safety service operating in accordance with the provisions of these Regulations[1].
1815.1 [1] In this matter, administrations should be guided by the latest relevant CCIR Recommendations (ITU, 1982, 1990, 1994, 1996).

[24] S15.13 § 9 Administrations shall take all practicable and necessary steps to ensure that radiation from equipment used for industrial, scientific and medical applications is minimal and that, outside the bands designated for use by this equipment, radiation from such equipment is at a level that does not cause harmful interference to a radiocommunication service and, in particular, to a radionavigation or any other safety service operating in accordance with the provisions of these Regulations[1].

In 1996, the consolidated ISM band was initiated and the 13 553-13 567 kHz band was in footnote S5.150 in the RR1996 and RR1998.[25] After the RR2001, the provision was changed to 5.150 and continued to the RR2012.

The *26 957-27 283 kHz band* was allocated initially in the RR1947 under provision No. 171 by center frequency of 27 120 kc/s with the bandwidth ± 0.6% of this frequency.[26] The content of this provision continued to the RR1959 under provision No. 225. This provision was used in the RR1968, RR1971, and RR1976.[27] The provision includes the frequency band, the purpose of frequency use, and the condition of use for other radiocommunication services that must accept harmful interferences from ISM applications.

In 1982, the format of the frequency band was changed to provide an upper and lower frequency in order to define the frequency band. Further, the provision number was changed to 546 in the RR1982, RR1990, and RR1994.[28] This provision adds the condition of use for ISM equipment subject to provision No. 1815, which is similar to the 13 553-13 567 kHz band.

In 1996, the consolidated ISM band was initiated and the 26 957-27 283 kHz was in footnote S5.150 in RR1996 and RR1998. After RR2001, the provision was changed to 5.150 and continued to RR2012.

MHz band

The development of the lower-power station was initiated in the European region in RR1938 with twelve frequency bands: 30-32, 40.5-56, 56-58.5, 58.5-60, 60-64, 70.5-74.5, 75.5-85, 95.5-110, 110.5-112, 112-120, 120-150, and 162-170 MHz for both primary and secondary

[1] S15.12.1 and S15.13.1 In this matter, administrations should be guided by the latest relevant ITU-R Recommendation (ITU, 1998).

[25] S5.150 The following bands:

13 553- 13 567kHz	(center frequency 13 560kHz),
26 957 - 27 283 kHz	(center frequency 27 120 kHz),
40.66-40.70 MHz	(center frequency 40.68 MHz),
902- 928 MHz	in Region 2 (center·frequency 915 MHz),
2400-2500 MHz	(center frequency 2450 MHz),
5 725 -5875 MHz	(center frequency 5 800 MHz), and
24-24.25 GHz	(center frequency 24.125 GHz)

are also designated for industrial, scientific and medical (ISM) applications. Radiocommunication services operating within these bands must accept harmful interference which may be caused by these applications. ISM equipment operating in these bands is subject to the provisions of No. 1815/S15.13 (ITU, 1996, 1998).

[26] 171 [67)] The frequency 27 120 kc/s is designated for industrial, scientific and medical purposes. Emissions must be confined within the limits of ±0.6% of that frequency. Radiocommunication services operating within those limits must accept any harmful interference that may be experienced from the operation of industrial, scientific and medical equipment (ITU, 1947).

[27] 225 The frequency 27 120 kc/s is designated for industrial, scientific and medical purposes. Emissions must be confined within the limits of ±0.6% of that frequency. Radiocommunication services operating within those limits must accept any harmful interference that may be experienced from the operation of industrial, scientific and medical equipment (ITU, 1959, 1968, 1971, 1976).

[28] 546 The band 26 957 - 27 283 kHz (center frequency 27 120 kHz) is designated for industrial, scientific and medical (ISM) applications. Radiocommunication services operating within this band must accept harmful interference which may be caused by these applications. ISM equipment operating in this band is subject to the provisions of No. 1815 (ITU, 1982, 1990, 1994).

services. Unfortunately, these frequency bands were discontinued at the RR1947. None of them were developed to the current frequency for ISM applications.

The *40.66-40.70 MHz band* was allocated initially in the RR1947 under provision No. 176 by center frequency 40.68 Mc/s with the bandwidth ± 0.05% of this frequency.[29] The content of this provision was continued to the RR1959 under provision No. 236. This provision was used in RR1968, RR1971, and RR1976.[30] The provision includes the frequency band, the purpose of frequency use, and the conditions of use for other radiocommunication services that must accept harmful interferences from ISM applications.

In 1982, the format of the frequency band was changed to provide an upper and lower frequency in order to define the frequency band. Further, the provision number was changed to 548 in RR1982, RR1990, and RR1994.[31] This provision adds the condition of use for ISM equipment subject to provision No. 1815, which is similar to the 13 553-13 567 kHz band.

In 1996, the consolidated ISM band was initiated and 40.66-40.70 MHz was in footnote S5.150 in the RR1996 and RR1998. After RR2001, the provision was changed to 5.150 and continued to RR2012.

The *433.05-434.79 MHz band* was allocated initially in RR1959 only in Austria, Portugal, the Federal Republic of Germany, Yugoslavia, and Switzerland under provision No. 321 by center frequency 433.92 Mc/s with bandwidth of ± 0.2% of this frequency. This provision was used in RR1968, RR1971, and RR1976.[32]

In RR1982, 433.05-434.79 MHz band coverage was extended to Region 1 except for the countries in provision No. 662. This frequency band was under provision No. 661 with similar conditions to the 6 765-6 795 kHz band with regard to obtaining special authorization by its administration and administrations concerned, with relevant CCIR Recommendations.

Provision No. 662 allowed the Federal Republic of Germany, Austria, Liechtenstein, Portugal, Switzerland, and Yugoslavia to use other radiocommunication services in this band, subject to provision No. 1815 that the use of other radiocommunication services must accept harmful interference by ISM applications. These two provisions were also used in RR1990

[29] 176 [62)] The frequency 40.68 Mc/s is designated for industrial, scientific and medical purposes. Emissions must be confined within the limits of ±0.05% of that frequency. Radiocommunication services operating within those limits must accept any harmful interference that may be experienced from the operation of industrial, scientific and medical equipment (ITU, 1947).

[30] 236 The frequency 40.68 Mc/s is designated for industrial, scientific and medical purposes. Emissions must be confined within the limits of ± 005% of that frequency. Radiocommunication services operating within those limits must accept any harmful interference that may be experienced from the operation of industrial, scientific and medical equipment (ITU, 1959, 1968, 1971, 1976).

[31] 548 The band 40.66 - 40.70 MHz (center frequency 40.68 MHz) is designated for industrial, scientific and medical (ISM) applications. Radiocommunication services operating within this band must accept harmful interference which may be caused by these applications. ISM equipment operating in this band is subject to the provisions of No. 1815 (ITU, 1982, 1990, 1994).

[32] 321 In Austria, Portugal, the F. R. of Germany, Yugoslavia and Switzerland, the frequency 433.92 Mc/s is designated for industrial, scientific and medical purposes. Emissions must be confined within the limits of ± 0.2% of that frequency (ITU, 1959, 1968, 1971, 1976).

and 1994.[33]

Later on, the 433.05-434.79 MHz band was consolidated into footnote S5.138 in RR1996 and also used in RR1998. In the RR2001, the provision number was changed to 5.138 and continued to be used in the RR2004, RR2008, and RR2012. The provision includes the frequency band for ISM applications and their conditions of use, i.e. obtaining special authorization by its administration and administrations concerned, with relevant CCIR Recommendations.

The *902-928 MHz band* was allocated initially in RR1947 for Region 2 under provision No. 212 by center frequency 915 Mc/s with the bandwidth ± 25 Mc/s of this frequency.[34] The content of this provision was continued to RR1959 and RR1968 under provision No. 340.[35] However, in RR1971 the bandwidth of this provision was changed to ± 13 MHz and continued to be used in the RR1976.[36] The provision includes the frequency band, the purpose of frequency use, and the conditions of use for other radiocommunication services that must accept harmful interferences from ISM applications.

In 1982, the format of the frequency band was changed to provide an upper and lower frequency in order to define the frequency band. Further, the provision number was changed to 707 in RR1982, RR1990, and RR1994.[37] This provision adds the condition of use for ISM equipment subject to provision No. 1815, which is similar to the 13 553-13 567 kHz band.

In 1996, the consolidated ISM band was initiated and 902-928 MHz was in footnote S5.150 in RR1996 and RR1998. After the RR2001, the provision was changed to 5.150 and continued to RR2012.

[33] 661 In Region 1, except in the countries mentioned in No. 662, the band 433.05-434.79 MHz (center frequency 433.92 MHz) is designated for industrial, scientific and medical (ISM) applications. The use of this frequency band for ISM applications shall be subject to special authorization by the administration concerned, in agreement with other administrations whose radiocommunication services might be affected. In applying this provision, administrations shall have due regard to the latest relevant CCIR Recommendations.
662 In the Federal Republic of Germany, Austria, Liechtenstein, Portugal, Switzerland and Yugoslavia, the band 433.05-434.79 MHz (center frequency 433.92 MHz) is designated for industrial, scientific and medical (ISM) applications. Radiocommunication services of these countries operating within this band must accept harmful interference which may be caused by these applications. ISM equipment operating in this band is subject to the provisions of No. 1815 (ITU, 1982, 1990, 1994).

[34] 212 [98)] In Region 2, the frequency 915 Mc/s is designated for industrial, scientific and medical purposes. Emissions must be confined within the limits of ±25 Me/s of that frequency. Radiocommunication services operating within those limits must accept any harmful interference that may be experienced from the operation of industrial, scientific and medical equipment (ITU, 1947).

[35] 340 In Region 2, the frequency 915 Mc/s is designated for industrial, scientific and medical purposes. Emissions must be confined within the limits of ± 25 Mc/s of that frequency. Radiocommunication services operating within those limits must accept any harmful interference that may be experienced from the operation of industrial, scientific and medical equipment (ITU, 1959, 1968).

[36] 340 In Region 2, the frequency 915 MHz is designated for industrial, scientific and medical purposes. Emissions must be confined within the limits of ± 13 MHz of that frequency. Radiocommunication services operating within these limits must accept any harmful interference that may be experienced from the operation of industrial, scientific and medical equipment (ITU, 1971, 1976).

[37] 707 In Region 2, the band 902 - 928 MHz (center frequency 915 MHz) is designated for industrial, scientific and medical (ISM) applications. Radiocommunication services operating within this band must accept harmful interference which may be caused by these applications. ISM equipment operating in this band is subject to the provisions of No. 1815 (ITU, 1982, 1990, 1994).

The *2 400-2 500 MHz band* was allocated initially in RR1947 for Region 2, Australia, New Zealand, Northern Rhodesia, Southern Rhodesia, the Union of South Africa, the territory under the mandate of Southwest Africa, and the United Kingdom, under provision No. 220 by center frequency 2 450 Mc/s with the bandwidth ± 50 Mc/s of this frequency.[38] The provision was changed to cover global coverage and continued to RR1959 under provision No. 357, except in Albania, Bulgaria, Hungary, Poland, Romania, Czechoslovakia, and the U.S.S.R. This provision was used in RR1968, RR1971, and RR1976.[39] The provision includes the frequency band, the purpose of frequency use, and the condition of use for other radiocommunication services that must accept harmful interferences from ISM applications.

Finally, in 1982, the format of the frequency band was changed to provide an upper and lower frequency in order to define the frequency band. Further, the provision number was changed to 752 in RR1982, RR1990, and RR1994 without any exception of Member States and provided global allocation in this band.[40] This provision adds the condition of use for ISM equipment subject to provision No. 1815, which is similar to the 13 553-13 567 kHz band.

In 1996, the consolidated ISM band was initiated and 2 400-2 500 MHz was in footnote S5.150 in RR1996 and RR1998. After RR2001, the provision was changed to 5.150 and continued to RR2012.

The *5 725 - 5 875 MHz band* was allocated initially in RR1947 under provision No. 228 by center frequency 5 850 Mc/s with the bandwidth ± 75 Mc/s of this frequency.[41] The initial frequency band was 5 725-5 925 MHz. Moreover, this initial frequency band was allocated in Region 2, Australia, New Zealand, Northern Rhodesia, Southern Rhodesia, the Union of South Africa, the territory under the mandate of Southwest Africa, and the United Kingdom. This provision was stopped at RR1959.

In RR1959, the center frequency was changed to 5 800 Mc/s and coverage was expanded to global allocation. The updated provision number was 391. This provision was used in

[38] 220 [106)] In Region 2, Australia, New Zealand, Northern Rhodesia, Southern Rhodesia, the Union of South Africa, the territory under mandate of Southwest Africa, and the United Kingdom, the frequency 2 450 Mc/s is designated for industrial, scientific and medical purposes. Emissions must be confined within the limits of ±50 Mc/s of that frequency. Radiocommunication services operating within those limits must accept any harmful interference that may be experienced from the operation of industrial, scientific and medical equipment (ITU, 1947).

[39] 357 The frequency 2 450 Mc/s is designated for industrial, scientific and medical purposes except in Albania, Bulgaria, Hungary, Poland, Romania, Czechoslovakia and the U.S.S.R., where the frequency 2 375 Mc/s is used. Emissions must be confined within ± 50 Mc/s of the frequencies designated. Radiocommunication services operating within these limits must accept any harmful interference that may be experienced from the operation of industrial, scientific and medical equipment (ITU, 1959, 1968, 1971, 1976).

[40] 752 The band 2 400 - 2 500 MHz (center frequency 2 450 MHz) is designated for industrial, scientific and medical (ISM) applications. Radio services operating within this band must accept harmful interference which may be caused by these applications. ISM equipment operating in this band is subject to the provisions of No. 1815 (ITU, 1982, 1990, 1994).

[41] 228[114)] In Region 2, Australia, New Zealand, Northern Rhodesia, Southern Rhodesia, the Union of South Africa, the territory under mandate of Southwest Africa, and the United Kingdom, the frequency 5 850 Mc/s is designated for industrial, scientific and medical purposes. Emissions must be confined within the limits of ±75 Mc/s of that frequency. Radiocommunication services operating within those limits must accept any harmful interference that may be experienced from the operation of industrial, scientific and medical equipment (ITU, 1947).

RR1968, RR1971, and RR1976.[42] The provision includes the frequency band, the purpose of frequency use, and the condition of use for other radiocommunication services that must accept harmful interferences from ISM applications.

In 1982, the format of the frequency band was changed to provide an upper and lower frequency in order to define the frequency band. Further, the provision number was changed to 806 in RR1982, RR1990, and RR1994.[43] This provision adds the condition of use for ISM equipment subject to provision No. 1815, which is similar to the 13 553-13 567 kHz band.

In 1996, the consolidated ISM band was initiated and 5 725 - 5 875 MHz was in footnote S5.150 in RR1996 and RR1998. After RR2001, the provision was changed to 5.150 and continued to RR2012.

GHz band

The *22-22.25 GHz band* was allocated in RR1959 under provision No. 410 by center frequency 22.125 Gc/s with the bandwidth ± 125 Mc/s of this frequency.[44] Unfortunately, this frequency was stopped in RR1968.

The *24-24.25 GHz band* was allocated in RR1971 under provision No. 410C by center frequency 24.125 Gc/s with the bandwidth ± 125 Mc/s of this frequency, which shifted from the previous allocation of 22-22.25 Gc/s by 2 GHz. This provision was also used in RR1976.[45] The provision includes the frequency band, the purpose of frequency use, and the conditions of use for other radiocommunication services that must accept harmful interferences from ISM applications.

In 1982, the format of the frequency band was changed to provide an upper and lower frequency in order to define the frequency band. Further, the provision number was changed to 881 in RR1982, RR1990, and RR1994.[46] This provision adds the condition of use for ISM equipment subject to provision No. 1815, which is similar to the 13 553-13 567 kHz band.

[42] 391 The frequency 5 800 Mc/s is designated for industrial, scientific and medical purposes. Emissions must be confined within the limits of ± 75 Mc/s of that frequency. Radiocommunication services operating within those limits must accept any harmful interference that may be experienced from the operation of industrial, scientific and medical equipment (ITU, 1959, 1968, 1971, 1976).

[43] 806 The band 5 725 - 5 875 MHz (center frequency 5 800 MHz) is designated for industrial, scientific and medical (ISM) applications. Radiocommunication services operating within this band must accept harmful interference which may be caused by these applications. ISM equipment operating in this band is subject to the provisions of No. 1815 (ITU, 1982, 1990, 1994).

[44] 410 The frequency 22.125 Gc/s is designated for industrial, scientific and medical purposes. Emissions must be confined within the limits of ± 125 Mc/s of that frequency. Radiocommunication services operating within those limits must accept any harmful interference that may be experienced from the operation of industrial, scientific and medical equipment (ITU, 1959, 1968)

[45] 410C (Spa2) The frequency 24.125 GHz is designated for industrial, scientific and medical purposes. Emissions must be confined within the limits of ±125 MHz of that frequency. Radiocommunication services operating within those limits must accept any harmful interference that may be experienced from the operation of industrial, scientific and medical equipment (ITU, 1971, 1976).

[46] 881 The band 24 - 24.25 GHz (center frequency 24.125 GHz) is designated for industrial, scientific and medical (ISM) applications. Radiocommunication services operating within this band must accept harmful interference which may be caused by these applications. ISM equipment operating in this band is subject to the provisions of No. 1815 (ITU, 1982, 1990, 1994).

In 1996, the consolidated ISM band was initiated and 24-24.25 GHz was in footnote S5.150 in RR1996 and RR1998. After RR2001, the provision was changed to 5.150 and continued to RR2012.

The *61-61.5 GHz band* was allocated initially in RR1982 under provision No. 911 by center frequency 61.25 GHz. This provision was used in RR1990 and RR 1994.[47]

Later on, the 61-61.5 GHz band was consolidated to footnote S5.138 in RR1996 and also used in RR1998. In RR2001, the provision number was changed to 5.138 and continued to be used in RR2004, RR2008, and RR2012. The provision includes the frequency band for ISM applications and their conditions of use, i.e. obtaining special authorization by its administration and administrations concerned, with relevant CCIR Recommendations.

The *122-123 GHz band* was allocated initially in RR1982 under provision No. 916 by center frequency 122.5 GHz. This provision was used in RR1990 and RR 1994.[48]

Later on, the 122-123 GHz band was consolidated into footnote S5.138 in RR 1996 and also used in RR1998. In RR2001, the provision number was changed to 5.138 and continued to be used in RR2004, RR2008, and RR2012. The provision includes the frequency band for ISM applications and their conditions of use, i.e. obtaining special authorization by its administration and administrations concerned, with relevant CCIR Recommendations.

The *244-246 GHz band* was allocated initially in RR1982 under provision No. 922 by center frequency of 245 GHz. This provision was used in RR1990 and RR 1994.[49]

Later on, the 244-246 GHz band was consolidated to footnote S5.138 in RR1996 and also used in RR1998. In RR2001, the provision number was changed to 5.138 and continued to be used in RR2004, RR2008, and RR2012. The provision includes the frequency band for ISM applications and their conditions of use, i.e. obtaining special authorization by its administration and administrations concerned, with relevant CCIR Recommendations.

5.3 Similarities and differences between 5.138 and 5.150

The development of both definition and frequency bands allocation for ISM applications in footnotes 5.138 and 5.150 is illustrated in the previous section. Table 13 shows the assessment

[47]911 The band 61 - 61.5 GHz (center frequency 61.25 GHz) is designated for industrial, scientific and medical (ISM) applications. The use of this frequency band for ISM applications shall be subject to special authorization by the administration concerned in agreement with other administrations whose radiocommunication services might be affected. In applying this provision administrations shall have due regard to the latest relevant CCIR Recommendations (ITU, 1982, 1990, 1994).

[48]916 The band 122 - 123 GHz (center frequency 122.5 GHz) is designated for industrial, scientific and medical (ISM) applications. The use of this frequency band for ISM applications shall be subject to special authorization by the administration concerned in agreement with other administrations whose radiocommunication services might be affected. In applying this provision administrations shall have due regard to the latest relevant CCIR Recommendations (ITU, 1982, 1990, 1994).

[49]922 The band 244 - 246 GHz (center frequency 245 GHz) is designated for industrial, scientific and medical (ISM) applications. The use of this frequency band for ISM applications shall be subject to special authorization by the administration concerned in agreement with other administrations whose radiocommunication services might be affected. In applying this provision administrations shall have due regard to the latest relevant CCIR Recommendations (ITU, 1982, 1990, 1994).

of these two footnotes in terms of frequency bands, authorization requirement, sharing with other radiocommunication services abilities, and relevant ITU-R recommendations.

The "Frequency bands" column in Table 13 shows the differences between 5.138 and 5.150 in the number of frequency bands that are allowed to be used for ISM applications. Most frequency bands are allocated on a global basis, except the 433.05-434.79 MHz band in Region 2 and 902-928 MHz band in Region 1.

Table 13. Similarities and differences between 5.138 and 5.150

Footnote	Frequency bands	Authorization	Sharing	ITU-R recommendation
5.138	6 765-6 795 kHz 433.05-434.79 MHz, Region 2 61-61.5 GHz 122-123 GHz 244-246 GHz	Required	-	SM.1056-1: Limitation of radiation from industrial, scientific and medical (ISM) equipment
5.150	13 553-13 567 kHz 26 957-27 283 kHz 40.66-40.70 MHz 902-928 MHz, Region 1 2 400-2 500 MHz 5 725-5 875 MHz 24-24.25 GHz	-	Allow	

Special authorization from its administration and administrations concerned is required for using ISM applications only for 5.138. However, only footnote 5.150 allows other radiocommunication services to share the same frequency on condition that other radiocommunication services must accept harmful interferences from ISM applications.

Neither 5.138 nor 5.150 provide the implicit ITU-R recommendation in their footnotes for the use of ISM applications. Moreover, there is no ITU-R recommendation that is relevant to the ISM applications in Volume 4 of RR2012, ITU-R Recommendations incorporated by reference. That means the use of the relevant ITU-R recommendations for ISM applications is voluntary for Member States to implement. There is one recommendation that is relevant to the use of ISM applications, i.e. ITU-R SM.1056-1: Limitation of radiation from industrial, scientific and medical (ISM) equipment.

5.4 Summary and discussion of research question

This chapter responds to sub-research question 2: *What are the spectrum allocations for spectrum commons and ISM applications, and how did they develop?*

This study elaborates on the results of international negotiations or the results of the WRC in the form of the RR for spectrum allocation in terms of radiocommunication services. The WRC allocates services by frequency bands inside the TFA based on the Member States' contributions. The TFA is divided into three Regions: Regions 1, 2, and 3. Each service is either a primary or secondary service, with primary services in upper case and secondary services in lower case. Moreover, the footnotes indicate the primary and secondary services with the word "on a primary basis" or "on a secondary basis", respectively.

The spectrum allocation represents the result of negotiations at international level because the final allocation is the output of government representative negotiations among Member States.

Spectrum commons are allocated in the footnotes 5.138 and 5.150 of ISM applications. Most of the short-range or low-power devices use the frequency under these provisions with non-exclusive use of frequency.

This study illustrates the development of ISM applications, including definition and frequency bands allocated to ISM applications. The official definition of ISM applications has been developed in RR1982 and remains unchanged up until RR2012. Long before that, ISM applications used different wording: purpose and equipment in RR1947 and RR1959.

The current ISM bands are: 6 765-6 795 kHz, 433.05-434.79 MHz, Region 2, 61-61.5 GHz, 122-123 GHz, 244-246 GHz, for 5.138; and 13 553-13 567 kHz, 26 957-27 283 kHz, 40.66-40.70 MHz, 902-928 MHz, Region 1, 2 400-2 500 MHz, 5 725-5 875 MHz, and 24-24.25 GHz for 5.150.

For example, a popular ISM band is 2 400-2 500 MHz that can be used for Wi-Fi-enabled devices and Bluetooth devices. This 2 400-2 500 was originated in RR1947 and provided for Region 2 and some countries in Regions 1 and 3. Until RR1982, this band was allocated worldwide and continued to be used up to RR2012.

The first allocation was for low-power stations in the European region in RR1938 and was discontinued in RR1947. Most of the ISM bands were developed in RR1982 and continued to be used up to RR2012.

This study shows the development of each ISM band and indicates the differences between them. Footnote 5.138 requires special authorization to operate, while footnote 5.150 allows the other services to share the same frequency with acceptance of harmful interference from ISM applications. Neither 5.138 nor 5.150 provide the explicit ITU recommendation, however, the relevant ITU-R recommendation is Recommendation ITU-R SM.1056-1: Limitation of radiation from industrial, scientific and medical (ISM) equipment.

This chapter responds to the second sub-research question: What are the spectrum allocations for spectrum commons and ISM applications, and how did they develop? This provides an overview of spectrum allocation and the development of spectrum commons in terms of ISM band. The second sub-research question fulfills the main research question: How is international regulation – the RR – transformed into national NBTC regulation for spectrum commons in Thailand. As part of international regulation for spectrum commons, it is important to understand the scope of spectrum commons in international regulation – the RR – prior to implementation of such regulations in national NBTC regulation for Thailand.

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Chapter 6 Frequency assignment for spectrum commons in Thailand

This chapter illustrates the overall spectrum assignment and approaches. The study also describes the development of spectrum assignment for spectrum commons in Thailand. The study uses and updates some parts of Ard-paru (2010) and (2012).

6.1 Background

Spectrum assignment is about giving a specific frequency band to users: providers, operator, or end-users. For example, the 1 920-1 935 and 2 110-2 125 MHz bands are assigned to Operator A for mobile services.

Spectrum assignment policy is limited to wireless or radiocommunication within a national territory. Each country has its own sovereignty. Spectrum assignment is a subset of spectrum management. Spectrum assignment is one of most important functions of spectrum management, besides other functions, such as planning and regulation, financing, allocation and allotment, national liaison and consultation, international and regional cooperation, standards, specifications and equipment authorization, monitoring, and enforcement (ITU, 2005).

Spectrum management policy is a subset of telecommunications policy. Telecommunications policy includes technical, economic, and social aspects. It overlaps with the natural sciences (technical) and social science (economics and society). Telecommunications policy often, but not always, deals with an institutional analysis. An institutional analysis is the analysis of an institutional arrangement or set of rules governing the number of decision-makers, allowable actions or strategies, authorized results, transformation from internal to decision situations, and linkages between decision situations (Kiser & Ostrom, 1982). Telecommunications policy also includes economic analysis of, for example, the social value or value to private players of the spectrum. The regulator may impose conditions on spectrum to make it excludable, which in turn makes frequency use a specific right for a designated entity or person.

In the language of telecommunication planning, the regulator has the right to assign frequency to assignees. If the frequency is assigned to specific entities, i.e. individuals and legal persons, it is called licensed frequency, in short, licensed. The entities that obtain this assigned frequency are called licensees. If the frequency is not assigned to specific entities, in other words, assigned to the general public, it is called unlicensed frequency or unlicensed. A characteristic of licensees is that they have the exclusive right to use a frequency. The unlicensed frequency, however, does not carry this right.

The typical approaches of spectrum assignment include command-and-control, market-based, and spectrum commons. There are two approaches to licensed frequency: the command-and-control and the market-based approach. These approaches grant the exclusive right to use frequency to licensees. Spectrum commons, however, is unlicensed. Brief details of each approach are described in Figure 7.

Property rights (maximize value)	Command and control (conserve state control)	Licence-free (avoid interference)
-Market knows best -Auctions/secondary trading -High flexibility -Pro big business	-Government knows best -First come, first served -Beauty contest -Low flexibility -Pro government (and its friends)	-Nobody knows best -No legal protection -Technical protection -High flexibility -Pro innovation -Optimistics
Economist	Regulators	Regulators

Source Geiss (2004)

Figure 7. Options for spectrum assignment

Historically, spectrum has been assigned by a command-and-control approach, an administrative approach in which the competent authority, usually government, uses its power of discretion to grant an exclusive right of use of some frequency bands to assignees, with conditions. These conditions include power limitation, antenna specification, and other technical requirements in terms of radiocommunication equipment, mainly for the purpose of avoiding harmful interference. Under this approach, spectrum is assigned on a first come, first served basis. This process raises the issue of transparency. If spectrum usage is requested by government agencies, it is usually assigned.

There is consensus among economists, lawyers, and engineers, however, that the command-and-control approach is inefficient (Wang, 2009). The flexibility of the use of frequency under this approach is limited. All frequency operations, including the location, working frequency, bandwidth, output power, antenna gain, modulation technique, and technology, are decided by the NRA. When users want to adopt new technology, they have to go through an administrative process to be approved before implementation.

Technological development, together with increased spectrum demand, makes spectrum scarce. Hence, a market-based approach has been introduced in many countries, because, under this approach it is believed that the market knows best. Here, spectrum is mostly assigned using an auction or secondary trading scheme. This approach creates more flexibility for regulators and operators to manage the spectrum and makes the process more transparent than a command-and-control approach.

The 3G auction in the UK in April 2000 was the largest auction to date. After BT won the spectrum auction, however, the business was not commercially viable and the spectrum was sold to O2. Although the market-based approach can maximize spectrum efficiency in some cases, the outcome may be competition between strong financial parties to buy most of the available spectrum on the market. As a result, the market may become monopolized if the regulator does not have proper control or “spectrum caps” (limit to obtaining spectrum).

On the other hand, the non-exclusive right to use frequency unlicensed can be treated as spectrum commons. In this situation, no one has an exclusive right to use frequency. Everyone can use the same frequency under some constraints. Nevertheless, services under spectrum commons cannot claim protection, because spectrum commons is open to anyone with any application, under the given limitations.

The characteristics of spectrum as goods depend on the approach to spectrum assignment, with the market-based approach treating spectrum as goods that can be owned and the commons approach treating spectrum as being without ownership rights. In general, goods can be classified into two groups: private and public goods. Public goods are non-excludable goods that an individual can consume without prohibiting others from consuming. Private goods are excludable goods that an individual can consume while prohibiting others from consuming. The cost of exclusion for public goods is therefore higher than the cost of exclusion for private goods.

Goods can be further refined into four groups: private goods, toll goods, common-pool goods, and public goods. Each group has different characteristics defined by the level of subtractability and the cost of exclusion (Kiser & Ostrom, 1982).

The level of subtractability is defined by the characteristics of the goods that can be separated. Private goods can be separated by individual consumption, but public goods cannot. For example, rice can be consumed from a bowl by taking a spoon as private goods. Air in the park is a public good. People can breathe, but no one can separate air for individual consumption.

Private goods, such as bread, milk, automobiles, and haircuts, have a low cost of exclusion and a high level of subtractability. Toll goods, such as, theaters, nightclubs, telephone service, cable TV, electric power, and libraries, have a low cost of exclusion and a low level of subtractability. Common-pool goods have a high cost of exclusion and a high level of subtractability. Examples of common-pool goods include water pumped from a ground basin, fish taken from an ocean, and crude oil extracted from an oil pool. Public goods, such as peace and security of a community, national defense, mosquito abatement, air pollution control, and weather forecasts, have a high cost of exclusion and a low level of subtractability (Kiser & Ostrom, 1982).

Spectrum assignment can change the spectrum from public goods to private or common-pool goods. For command-and-control and market-based approaches, the spectrum has been treated as private goods with exclusive rights to use frequency. The spectrum can be transferred or sold to others by the regulator or the market. On the other hand, spectrum commons can be treated as common-pool goods that have non-exclusive rights to use frequency. No one owns the spectrum.

6.2 Frequency assignment development in Thailand

Thailand has a long history of spectrum management since 1875. Telecommunications developed from wired to wireless communication: from telegraph, telephone over telegraph infrastructure, and radiotelegraph for ship-to-shore communication, to radiocommunication for both broadcasting and telecommunication. At the initial stage (without regulations), the use of radiocommunication devices was limited to government agencies, particularly the

Navy and the Army. Frequency assignment was initially made by His Majesty the King of Thailand. After December 10, 1932, this authority was transferred to the Prime Minister. The King delegated his authority to the responsible ministry. The ministry used the command-and-control approach on a first come, first served basis to authorize the use of radiocommunication devices. Thailand also endorsed the International Telegraph Convention in 1906 and 1912 (ITU, 1906, 1912) as national regulation. Most of the users were government agencies. Otherwise there was little usage and low demand, so there was no congestion of the use of radiocommunication.

After the Radio Act was enacted in 1914, all radiocommunication activities were prohibited, except with authorization granted by the authority in terms of radiocommunication licences. The authority was the Post and Telegraph Department (PTD) and it still used the command-and-control approach on a first come, first served basis to authorize the use of radiocommunication devices. However, the PTD functioned only for radiocommunication licences in technical respects, and did not take into consideration the growing demand for the use of radiocommunication devices until congestion led to harmful interference.

The government realized that “good” spectrum management of frequencies would provide efficient national allocations. On March 26, 1974, the National Frequency Management Board (NFMB) was established to determine the national technical standard; control, assign, and register frequency; examine the standard of radiocommunication devices; create efficient procedures; evaluate radiocommunication stations; and coordinate all radiocommunication users. The NFMB comprised several representatives from government agencies and it was chaired by the Minister of Transport (the NFMB came into force in 1975). The NFMB acted as the approval board before the PTD issued radiocommunication licences. The NFMB operated until 2002, when the PTD became part of the Ministry of Information and Communication Technology (MICT).

After the Act on Establishment of the National Broadcasting Commission (NBC) and the National Telecommunications Commission (NTC) was enacted in 2000, the NTC was established on 1 October 2004, and the PTD was dissolved by law to become the Office of the NTC on 1 January 2005. A new era of telecommunication with an independent regulator, the NTC, was founded in order to change the authorization process into a licensing process. It was not only the technical aspects, but also social and economic aspects that were included in the licensing process.

On 7 October 2011, the National Broadcasting and Telecommunications Commission (NBTC) was established, according to the Thai Constitution 2007 and the Act on Organization to Assign Radio Frequency and to Regulate the Broadcasting and Telecommunications Service 2010. The Office of the NTC (ONTC) was transferred to the Office of the NBTC (ONBTC) on 20 December 2010. The NBTC is responsible for both broadcasting and telecommunication industry and ensures transition from authorization to the licensing process.

The NBTC comprises eleven commissioners: one chairman, two vice chairman, and eight commissioners. The NBTC has two commissions: broadcasting and telecommunications. The broadcasting commission comprises a chairman (one of the vice chairman of the NBTC) and four commissioners. The telecommunications commission comprises a chairman (one of vice chairman of the NBTC) and four commissioners. Each group has its own authority on behalf of the NBTC such as licensing broadcasting or telecommunications licences. However, some tasks, such as frequency management master plan and table of frequency allocation, are managed by the NBTC.

Figure 8 shows the Thai spectrum management development profile: administrator, regulator, secretariat (an administrative unit), and operator.

	Administrator	Regulator	Secretariat	Operator
Before 1975	PTD			
1975-2002	PTD	NFMB	PTD	PTD/TOT/CAT
2002-2004	PTD		PTD	TOT/CAT
2004-2011	MICT	NTC	ONTC	TOT/CAT +licensees
2011-now	MICT	NBTC	ONBTC	TOT/CAT +licensees

Figure 8. Thailand spectrum management profile

The administrator represents the Thai government as the Thai delegation to international activities, such as international conferences, conventions, treaties, negotiations, and cooperation. The regulator acts as the NRA for frequency management. The secretariat is the regulator administrative office. The operator provides the services after obtaining the frequency and licenses from the regulator (TOT and CAT are state-owned companies).

Before 1975, the 1914 Radio Act only authorized the PTD to assign frequency to users. The PTD acted as the administrator, regulator, and operator.

To separate from the PTD, the NFMB worked as regulator to assign frequency to users until 2002, when it was dissolved by the MICT.

During 2002-2004, there was no regulator to assign new frequencies (according to the provision of the Act on Establishment of the NBC and NTC 2000).

The transition period from the monopoly by a state enterprise (or currently state-owned company) to market economies by licensees started with the NTC.

The NTC was founded in 2004 and established the licensing scheme for the Thai telecom sector. However, the NBC was never founded. The NTC did not have full authority to form the Joint Committee between the NTC and the NBC to approve the National Table of Frequency Allocation or National Master Plan. The Supreme Administrative Court decided on

23 September 2010 not to provide the NTC with any right to pursue the 3G auction until the establishment of the NBTC.

The NBTC was established on October 7, 2011 to combine both broadcasting and telecommunication into a single regulator with full authority to assign new frequencies. The 3G frequency assignment or auction can be done after the approval of the National Table of Frequency Allocation or National Master Plan.

Table 14 summarizes the important events of the Thailand spectrum assignment profile.

Table 14. Important events for Thailand spectrum management

Frequency transfer (alienation right)	NFMB in 1998 NTC in 2009
Auction	NFMB initiated in 1997 NTC attempted in 2010 NBTC in 2012
Spectrum commons	Authorization since 1974 Unlicensed since 2004

The frequency transfer representing the alienation right – the right to sell or sub-lease frequency – was initiated by the NFMB and the frequency transfer between CAT concessionaires in the 1800 MHz band was approved in 1998. In 2009, the NTC approved the frequency transfer between CAT and TOT in the 1900 MHz band.

The frequency auction was initiated by the NFMB in 1997, however, the first auction was attempted by the NTC in 2010. Unfortunately, the Administrative Court cancelled the auction. In 2012, the NBTC auctioned the 45 MHz in 2.1 GHz frequency for mobile services. Three companies qualified and entered the auctions. These companies are subsidiaries of the top three mobile operators in Thailand. Each company received 15 MHz each and the Telecommunications Commission approved the auction. However, it is debatable whether the auction process was anti-competitive. The Ombudsman filed a complaint with the Administrative Court in order to have an order to cancel the 3G auction. Finally, the court withdrew the case, allowing the NBTC to grant the 3G licences.

Frequency assignment for spectrum commons in Thailand has developed from authorization to unlicensed. The use of radiocommunication equipment required permission under the Radio Act. The use of spectrum commons was granted individually with authorization and relevant radiocommunication licences in 1974. In 2004, regulation changed, in order to increase flexibility for the general public to use the frequency and equipment without any relevant licences. Unlicensed regulation exempts the relevant licences such as import, usage, and installation licences.

6.3 Spectrum commons development in Thailand

This study explores the relevant regulations including the minutes of NFMB, ministerial regulations, NTC and NBTC regulation.[50]

The NFMB first attempted to delegate authority to the PTD to assign the use of frequency under one watt. The regulated level was transferred from the NFMB to the PTD. The decision-maker for frequency assignment under the power of one watt was therefore the PTD.

Using low-power devices in Thailand

The PTD authorized the use of low-power devices, depending on the technical characteristics, as a first priority to avoid harmful interference. Users had to obtain authorization from the PTD. The use of low-power devices still requires the relevant radiocommunication licences, however. The PTD realized the benefit to the general public and the initiation of the exemption of relevant radiocommunication licences pushed forward as the Ministerial Regulations. The exemption of licenses facilitated the use of low-power devices such as spectrum commons.

The stakeholders for low-power devices were the authority, users, and manufacturers or importers. The NTC also allowed the Internet service provider to use spectrum commons. The stakeholders were extended to the service provider as well.

In Thailand, there are two separate steps for unlicensed devices. Firstly, the devices must receive authorization under the Radio Act, according to the Table Frequency Allocation and related regulations in terms of technical specification or standard of devices. Secondly, when the use of these devices increases over time, the authority may consider exempting the related licences imposed on the use of these devices to reduce the burden for the general public by issuing a regulation to exempt the related licences in terms of the ministerial or NTC regulations. The authorization of the use of radiocommunication devices by command-and-control for frequency assignment and technical standard approval of devices was centralized by the authority.

Use of low-power devices before 1974

[50] This section is mainly based on the minutes of meetings of the National Frequency Management Board (1974-2000) (PTD, 1974 - 2000) and a summary of the minutes of meetings of the National Frequency Management Board (2001)(PTD, 2001) , the Ministerial Regulation of the Ministry of Transport No.24 (1993) (MOT, 1993), the Ministerial Regulation of the Ministry of Transport No.28 (1998) (MOT, 1998), the Ministerial Regulation of the Ministry of Transport No.30 (2001) (MOT, 2001), the Ministerial Regulation of the Ministry of Information and Communications Technology on the exemption of radiocommunication licences (2004)(MICT, 2004) , the National Telecommunications Commission Regulation of nature and categories of telecommunication business (2005) (NTC, 2005b), the National Telecommunications Commission Regulation of criteria and procedures for Internet service licence application (2005) (NTC, 2005a), the National Telecommunications Commission Regulation of exemption of radiocommunication licences (2007) (NTC, 2007b), the National Telecommunications Commission Regulation on the standard of telecommunication devices for radio local area network (RLAN) (2007) (NTC, 2007a), the National Telecommunications Commission Regulation on the standard of telecommunication devices (2008) (NTC, 2008a), and the National Telecommunications Commission Regulation on the standard of telecommunication devices – procedures and standards (2008) (NTC, 2008b).

During the period when there was no regulation – without the Radio Act – there was no use of radiocommunication devices for the general public, only by government agencies. With the Radio Act enacted, all radiocommunication usage was prohibited, except for the authorization granted by the PTD since 1914. On March 26, 1974, the cabinet authorized the Ministry of Transport to set up the NFMB with the Ministry Order of 78/1974 on April 19, 1974, to double-check the work of the PTD. Thus, all the radiocommunication activities of the PTD had to ask the NFMB for approval. This was the centralized management style of the NFMB at the initial stage.

Use of low-power devices in 1975-1986

In 1975, the NFMB delegated some authority to the PTD at the first meeting in 1975 on January 8, 1975. The NFMB authorized the PTD to allow the private sector to install transmitters for paging services in the 26.92-27.23 MHz band in limited areas. The power of the transmitters could not exceed one watt. That was the starting point of decentralization in spectrum management and the initiation of allowing the general public to use low-power devices.

On January 22, 1975, at the second meeting in 1975, the NFMB authorized one company to make an anti-theft device with the frequency of 27.060 MHz and authorized the PTD to allow the use of anti-theft devices in cars and motorcycles for the general public.

At the first meeting in 1978 on January 25, 1978, the NFMB authorized the PTD to allow the private sector to use UHF transceivers in the 461.150-461.250 MHz band, with power of up to one watt. The UHF transceiver was the walkie-talkie application service.

On June 25, 1982, at the second meeting in 1982, the NFMB re-authorized the PTD to allow the use of radiocommunication devices with power of up to one watt for all applications and anti-theft devices in cars and motorcycles for any frequency.

At the third meeting in 1982 on July 8, 1982, the NFMB authorized the PTD to allow the use of the citizen band (26.96-27.23 MHz) for transceivers, cordless telephones, wireless microphones, wireless remote controls, such as model plane remote controls, anti-theft devices, garage-door openers, and radiocommunication devices in industrial science services that were not used for communication purposes such as microwave ovens.

The minutes of the NFMB's fourth meeting in 1982 on August 18, 1982, authorized the PTD to allow the installation of base stations for wireless telephones for one-to-one (one transmitter and one receiver) operation only. Wireless telephones used frequencies of 1.7/49, 27/49 MHz with power of up to 500 milliwatts for short-range communication (around 500 meters). Moreover, wireless telephones used frequencies of 27/49 MHz with power of up to five watts for long-range communication (around 10 kilometers).

Additional low-power devices introduced in 1986

On April 17, 1986, at the fifth meeting in 1986, the NFMB authorized the PTD to allow the use of radio warning devices with power of up to one watt and a 16 kHz bandwidth.

After the NFMB delegated authorization of all radiocommunication devices with power of up to one watt, the PTD allowed the use of transceivers in medical instruments with power of up to 10 milliwatts, and electronic and telecommunication measurement equipment.

Previous events concerned the authorization of the use of radiocommunication devices. Their use required related licences, however. The story of the exemption of licences was different because the power to waive licences belonged to the Ministry of Transport, which had to issue Ministerial Regulations according to the Radio Act of 1955 and its amendments.

Increased number of low-power devices after 1986

The PTD realized that the use of low-power devices had increased over time and wanted to facilitate the use of low-power devices for the general public. The PTD proposed that radiocommunication licences be exempt from Ministry of Transport Ministerial regulations. There were lengthy procedures from drafting to announcement, however. Firstly, the PTD drafted the Ministerial Regulations Then the draft of the Ministerial Regulations was sent to the Council of State in order to check the format and content and then sent back to the PTD for revision. Next the draft of the Ministerial Regulations, including revisions by the Council of State, was sent to the Ministry of Transport for consideration and signing. Then the final version of the Ministerial Regulations was sent to the *Royal Gazette* for formal publication. The process took almost two years.

Ministerial Regulations for radiocommunication license exemptions 1993-2004

Ministerial Regulation No. 24

Ministerial Regulation No. 24 – the first Ministerial Regulation for radiocommunication licence exemption – was published on March 12, 1993. It comprised five sections. Section 1 was an exemption on making, possessing, using, importing, exporting, and trading radiocommunication licences. Section 2 was an exemption on possessing, using, and exporting radiocommunication licences. Section 3 was an exemption on importing radiocommunication licences. Section 4 was an exemption on parts of radiocommunication devices when assembled with devices that already had a licence. Section 5 was an exemption on installing radiocommunication licences.

The unlicensed devices were in Section 1, which exempted all radiocommunication licences. They included: 1) wireless microphones with power of up to 10 milliwatts in the 33-50, 88-108, 165-210, and 470-490 MHz bands and with power of up to 30 milliwatts in the 902-960 MHz band; 2) wireless telephones with power of up to 10 milliwatts in the 1.6-1.8, 30-50, and 54-74 MHz bands; 3) radio-control models with power of up to 100 milliwatts in the 26.964-27.405 MHz band; 4) long-range radio control with power of up to 100 milliwatts in the 26.964-27.405 MHz band and with power of up to 10 milliwatts in the 300-500 MHz band; 5) transceivers of the citizen band with power of up to 100 milliwatts in the 26.964-27.405 MHz band, and warning devices with power of up to 10 milliwatts in the 300-500 MHz band; 6) transceivers in medical instruments with power of up to 10 milliwatts in the 300-500 MHz band; and 7) electronic and telecommunication measurement equipment.

Section 1 of Ministerial Regulation No. 24 exempted all radiocommunication with specified applications, power limitation, and operating frequency that were not flexible for use with the new applications.

On October 15, 1996, the PTD allowed the general public to use radiocommunication devices in the 2 400-2 500 MHz band with effected radiated power (E.R.P.) up to 100 milliwatts for indoor use only. These devices had to hold either licences for the possession, use or installation of radiocommunications. The devices had to be type-approved by the PTD.

Ministerial Regulation No. 28

On December 21, 1998, Ministerial Regulation No. 28 was published, as well as two additional items in Ministerial Regulation No. 24, one in Section 2 and one in Section 5. These allowed the use of cordless telephones for personal use with power of up to 10 milliwatts in the 1 900-1 906 MHz band and they could be used with digital enhanced cordless telecommunications (DECT) and personal handy-phone systems (PHS) technology, with a slight modification of frequency arrangements.

Ministerial Regulation No. 30

On January 17, 2001, Ministerial Regulation No. 30 was published and Section 3 of Ministerial Regulation No. 24 revised to allow cellular phone and radio paging that already had type approval from the PTD and international roaming agreements for device circulation.

After October 1, 2003, the PTD was transferred to the Ministry of Information Communications and Technology. On November 28, 2003, the PTD amended the regulation that allowed the general public to use radiocommunication devices in the 2 400-2 500 MHz band by deleting "for indoor use only." The limitation of power, the related radiocommunication licenses, and the type approval remained in place, however.

Change in Ministerial Regulation [2004]

There was a change in the format of the Ministerial Regulations that amended the substance of the regulation. Ministerial Regulations Nos. 24, 28, and 30 have been revised and called the Ministerial Regulations of the Exemption of Radiocommunication Licences, and were published on March 25, 2004.

The Ministerial Regulation on the Exemption of Radiocommunication Licences in 2004 consisted of ten sections. Section 1 revoked Ministerial Regulations Nos. 24, 25, 28, 29, and 30. Section 2 exempted the making, possession, use, import, export, and trade of radiocommunication licences. Section 3 exempted the possession, use, and export of radiocommunication licences. Section 4 exempted the possession, import, export, and trade of radiocommunication licences for cellular telephones, radio paging, and radiocommunication devices in global mobile personal communication by satellite (GMPCS), which had been type-approved by the PTD. Section 5 exempted the import and export of radiocommunication licences for cellular telephones, radio paging, and radiocommunication devices in GMPCS that had international roaming agreements. Section 6 exempted the possession and use of radiocommunication licences for transceivers of the citizen bands 78 and 245 MHz. These already had licences and they were transferred. Thus, the transferees did not require the possession and use of radiocommunication licences. This did not include the transfer of ownership of the radiocommunication device, however, which required a relevant licence. Section 7 exempted the possession and use of radiocommunication licences for transceivers of amateur radios that already had licences and been transferred. Thus, the transferees did not require the possession and use of radiocommunication licences. The operation of amateur radios required a separate amateur radio certificate, however, and it did not include transfer of ownership of the radiocommunication device, which had to be done legally with the relevant licence. Section 8 exempted the parts of the radiocommunication devices when assembled with other such devices. Section 9 and Section 10 exempted the installation of radiocommunication licences.

In the Ministerial Regulation of the Exemption of Radiocommunication Licences in 2004, Section 2 and Section 10 related to unlicensed devices. When comparing Ministerial Regulation No. 24 and the Ministerial Regulation of the Exemption of Radiocommunication Licences in 2004, there were several differences. Firstly, the Ministerial Regulation of 2004 added an exemption on installing radiocommunication licences from Ministerial Regulation No. 24 (the exemption of making, possessing, using, importing, exporting, and trading radiocommunication licences). Secondly, the Ministerial Regulation of 2004 added five items in Section 2. These were 8) the receiver in radio navigation services, radio navigation satellite services, radio location services and radio location satellite services, 9) the radar application in the 5.725-5.875, 10.0-10.6, 24.05-24.25, and 76-81 GHz bands with equivalent isotropically radiated power (E.I.R.P.) of up to 10 milliwatts, 10) devices in the band lower than 135 kHz with E.I.R.P. of up to 150 milliwatts, 11) devices in the 13.533-13.567 MHz band with E.I.R.P. of up to 5 milliwatts, and 12) devices in the 2 400-2 500 MHz band with E.I.R.P. of up to 100 milliwatts.

In the Ministerial Regulation of 2004, there was flexibility or neutrality of technology for radiocommunication devices in Section 2, Items 10, 11, and 12, which allowed all applications using the specified frequency band and the power limitation, including radio frequency identification (RFID), Tag, e-SEAL, Bluetooth, and Wi-Fi devices.

Establishing the National Telecommunications Commission and its regulations [2004-2007]

On October 1, 2004, the NTC was established and the PTD was dissolved by law to be transformed into the Office of the NTC from January 1, 2005.

The NTC regulation has the same rank as the Ministerial Regulations.[51] The procedure for publishing the regulation is much shorter than the previous procedure. The Office of the NTC drafts the new NTC regulation and prepares an agenda for NTC meetings in order to obtain

[51] The hierarchy of Thai law is Constitution, Act, Ministerial Regulations, Ministerial Announcements, Department Regulations, and Department Announcements. The NTC regulations have the same rank as Ministerial Regulations.

approval from the NTC. After NTC approval, the Chairman of the NTC signs and sends it to the *Royal Gazette* for publication. The whole new procedure takes around six months.

On June 22, 2005, the NTC Regulations of Nature and Categories of Telecommunication Business (2005) and Criteria and Procedures for Internet Service Licence Applications (2005) were published to determine the nature and categories of telecommunication business, and provide clear and unambiguous criteria and conditions for Internet service licence applications, respectively. Wi-Fi service (public hotspots) falls into the "Type 1" Internet licence.

Adapting the Ministerial Regulation for exemptions by the NTC [2007]

On August 29, 2007, the NTC Regulation of the Exemption of Radiocommunication Licenses was published, adapting the Ministerial Regulation for the Exemption of Radiocommunication Licences in 2004 and indicating which radiocommunication licences were and were not exempt.

The NTC Regulation on the Exemption of Radiocommunication Licences in 2007 comprises eleven sections. Section 1 revokes all prior regulations against this regulation. Section 2 is similar to Section 2 and Section 10 of the Ministerial Regulation for the Exemption of Radiocommunication Licences in 2004. The differences are: 1) the deletion of wireless microphones in the 902-960 MHz band, which is the same band as cellular phones (GSM 900 MHz); 2) the deletion of wireless telephones in the 54-74 MHz band, because the technology is obsolete; 3) open applications in the 26.965-27.405 MHz band with power of up to 100 milliwatts; 4) open applications in the 30-50 MHz band with power of up to 10 milliwatts; 5) open applications in the 300-500 MHz band with power of up to 10 milliwatts; 6) receivers in the meteorological aid service, meteorological satellite service, Earth exploration-satellite services, standard frequency and time signal services, standard frequency and time signal satellite services, space research services, radio astronomy services, and safety services. Section 3 has the exemption of possessing, using and exporting radiocommunication licences but still includes the production, import, and trading of radiocommunication licences. Sections 4, 5, 6, 7, 8, and 9 of the NTC Regulation on the Exemption of Radiocommunication Licences 2007 are the same as Sections 4, 5, 6, 7, 8, and 9 of the Ministerial Regulation for the Exemption of Radiocommunication Licences in 2004. Section 10 is the exemption of the import and export of radiocommunication licences for radiocommunication devices for experiments and research and is also used by United Nations specialists, the Red Cross, and foreign embassies. The use of these radiocommunication devices exempted the possession, use, and installation of radiocommunication licences for temporary use up to a period of three months. Section 11 is the enforcement date after publication in the *Royal Gazette*.

On January 26 and August 3, 2007, the NTC regulation of standard telecommunication devices for radio local area network (RLAN) allowed the use of RLAN in the 5 150-5 350 MHz band with E.I.R.P. of up to 200 milliwatts for indoor use only, and in the 5 470-5 725 and 5 725-5 850 MHz bands with E.I.R.P. of up to one watt.

On January 18, 2008, all short-range devices (according to the NTC regulation) were certified by suppliers according to the NTC Regulation of Standard of Telecommunication Devices (both procedure and standard). Suppliers must certify that the equipment has technical specifications according to the NTC Regulation, in the form of a Supplier's Declaration of Conformity.

Since the establishment of the NBTC on October 7, 2011, there has been no new regulation for spectrum commons or additional unlicensed regulation. However, the NTC regulations are valid until they are replaced by the NBTC regulations.

To summarize this period, after the NFMB delegated power to the PTD, the development of short-range devices was gradually introduced. This proceeded from specific applications. Power limitation and specified frequency were still enforced, however, to avoid harmful interference in this limited area. The use of short-range devices was non-exclusive, i.e. no one had an exclusive right to use this frequency. The management of the use of short-range devices, or managerial right also started from self-regulation: users have to manage, with middleman management, service providers, or private commons, with the provider managing the use of commons, such as the Wi-Fi hotspot or public commons managed by the state agency.

Table 15 shows a summary of significant events for spectrum commons in Thailand.

Table 15. Spectrum commons events in Thailand

Time	Event
1955	The Radiocommunication Act enacted
1974	The National Frequency Management Board (NFMB) founded by ministry order
1975	The NFMB authorized the PTD to allow 1-watt transmitters (paging + anti-theft)
1978	The NFMB authorized the PTD to allow walkie-talkies
1982	The NFMB authorized the PTD to allow 1-watt transmitters for all applications, including Citizen Band (26.96-27.23 MHz) transceivers, cordless telephones, wireless microphones, wireless remote controls, such as model plane remote controls, anti-theft devices, garage doors
1986	The NFMB authorized the PTD to allow radio warning devices
1993	Ministerial Regulation No. 24 came into force – Ministry of Transport
1996	The PTD allowed WLAN on 2400-2500 MHz, indoor only
1998	Ministerial Regulation No. 28 came into force – Ministry of Transport
2001	Ministerial Regulation No. 30 came into force – Ministry of Transport
2003	The PTD allowed WLAN on 2400-2500 MHz, indoor and outdoor
2004	Ministerial Regulation of the Exemption of Radiocommunication Licences – Ministry of Information and Communications Technology
2005	Wi-Fi service provider – hotspot
2007	The NTC Regulation of the Exemption of Radiocommunication Licences RLAN 5150-5350/5470-5725/5725-5850 MHz allowed
2008	Supplier's Declaration of Conformity (SoD) for unlicensed devices

Source Ard-paru (2010),Table 19

In 1955, the Radiocommunication Act came into force and all radiocommunication equipment had to obtain permission before being used. In 1974, the NFMB was founded and began to act as the regulator for frequency assignment in Thailand. In 1975, the first initiative by the NFMB was to authorize 1-watt transmitters for paging services and anti-theft equipment, and

walkie-talkies in 1978. In 1982, the NFMB allowed 1-watt transmitters for all applications, including Citizen band transceivers, cordless telephones, wireless microphones and wireless remote controls, and radio warning devices in 1986.

In 1993–2003, the authorization for spectrum commons in terms of low-power devices was changed to the Ministerial Regulation. In 1996, the PTD was first allowed using WLAN 2 400-2 500 MHz for indoor application only, extending to outdoor application in 2003.

The new era of unlicensed regulation in Thailand began in 2004 with the Ministerial Regulation of the Exemption of Radiocommunication Licences allowing low-power devices without relevant licences.

In 2005, the NTC allowed internet service providers to use WLAN, providing hotspots. In 2007 and 2008, the NTC added the RLAN in 5 GHz and supplier's declaration of conformity (SoD) for unlicensed devices.

In 2011, the NBTC established and allowed continuation of unlicensed regulation. There is no additional unlicensed regulation by the NBTC as of 2012.

6.4 Summary and discussion of the research question

This chapter responds to sub-research question 3: *What is spectrum assignment, especially spectrum commons, in Thailand, and how did it develop?*

This study illustrates the overall approach of spectrum assignment, which has three typical approaches: command-and-control, market-based, and spectrum commons. Spectrum assignment is managed by the national regulatory authority. Of the three typical approaches, only command-and-control and market-based provide exclusive rights to use frequency, but spectrum commons does not. However, the command-and-control approach is inefficient, i.e. lacking the flexibility of frequency use. The market-based and spectrum commons approaches are introduced to overcome such inefficiency. The market-based or spectrum auction in the UK in 2000 is an example of the largest auction where the winning bidder was not commercially viable and sold the spectrum at a later stage.

The spectrum can be treated as goods depending on the method of assignment. For command-and-control and market-based approaches, the spectrum has been treated as private goods that have exclusive rights to use frequency. The spectrum can be transferred or sold to others by regulator or market. On the other hand, spectrum commons can be treated as common-pool goods that have non-exclusive rights to use frequency. The general public own spectrum commons.

This study demonstrates the development of spectrum assignment in Thailand. Thailand has developed spectrum assignment from command-and-control to a market-based approach. Spectrum was initially for use by a limited group, only government agencies, and then extended to the general public. The development of spectrum assignment agencies in Thailand included the PTD, NFMB, MICT, NTC, ONTC, NBTC, and ONBTC in order to change authorization to a licensing scheme, or command-and-control to market-based economics.

The study also illustrates the development of spectrum commons in Thailand since the NFMB in terms of authorization of the use of 1-watt transmitters. The Ministerial Regulation allowed low-power devices with relevant licences. The PTD regulations allowed the use of WLAN indoor applications and extended this to outdoor applications. Finally, the Ministerial Regulation of the Exemption of Radiocommunication Licences as the first unlicensed regulation in Thailand in 2004 allowed low-power devices without relevant licences.

This chapter responds to sub-research question 3 “What is spectrum assignment, especially spectrum commons, in Thailand, and how did it develop?” on the development of spectrum assignment, and illustrates the development of spectrum commons in Thailand. This sub-research question provides useful information to understand the context of spectrum commons in Thailand and how it has developed. It helps to fulfill the main research issue of how to implement international regulation into national regulation for spectrum commons in Thailand.

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Chapter 7 International to national regulations

This chapter demonstrates the transformation of international regulation in the form of the RR into national regulation in the form of NBTC regulation for spectrum commons in Thailand. Moreover, the challenges of allocation and assignment of spectrum commons are also included.

The RR is the international regulation of spectrum management for Member States as a guideline for managing the use of frequency without causing international harmful interference. The first phase of transforming the RR into national regulation, especially in Thailand, regards the adoption of spectrum commons regulation from the RR into the national TFA. The second phase is to have a national regulation that permits the use of radiocommunication devices for spectrum commons in Thailand.

7.1 From the RR to the Thai TFA

The spectrum commons regulations in RR2012 include a definition of ISM applications, frequency allocations in footnotes 5.138 and 5.150, and TFA.

ISM definition

The definition of ISM applications is found in RR No. 1.15 Terms and definition:

"1.15 *industrial, scientific and medical (ISM) applications* (of radio frequency energy)*:* Operation of equipment or appliances designed to generate and use locally radio frequency energy for industrial, scientific, medical, domestic or similar purposes, excluding applications in the field of *telecommunications*" (ITU, 2012, pp. RR1-2).

However, the Thai TFA does not explicitly include the definition of ISM. The Thai TFA only includes footnotes 5.138 and 5.150 in the TFA.

Footnotes 5.138 and 5.150

The RR footnotes 5.138 and 5.150 for ISM applications are found in RR No. 5.138 and 5.150:

"5.138 The following bands:

6 765-6 795 kHz	(centre frequency 6 780 kHz),
433.05-434.79 MHz	(centre frequency 433.92 MHz) in Region 1 except in the countries mentioned in No. 5.280,
61-61.5 GHz	(centre frequency 61.25 GHz),
122-123 GHz	(centre frequency 122.5 GHz), and
244-246 GHz	(centre frequency 245 GHz)

are designated for industrial, scientific and medical (ISM) applications. The use of these frequency bands for ISM applications shall be subject to special authorization by the administration concerned, in agreement with other administrations whose radiocommunication services might be affected. In applying this provision, administrations shall have due regard to the latest relevant ITU-R Recommendations.

5.150 The following bands:

13 553-13 567 kHz	(centre frequency 13 560 kHz),
26 957-27 283 kHz	(centre frequency 27 120 kHz),
40.66-40.70 MHz	(centre frequency 40.68 MHz),
902-928 MHz	in Region 2 (center frequency 915 MHz),
2 400-2 500 MHz	(centre frequency 2 450 MHz),
5 725-5 875 MHz	(centre frequency 5 800 MHz), and
24-24.25 GHz	(centre frequency 24.125 GHz)

are also designated for industrial, scientific and medical (ISM) applications. Radiocommunication services operating within these bands must accept harmful interference that may be caused by these applications. ISM equipment operating in these bands is subject to provisions No. 15.13" (ITU, 2012, pp. RR 5-24 and 29).

Thailand has also adopted these two footnotes into the Thai TFA, but it is translated into the Thai language (NBTC, 2012, pp. 142,146).

TFA frequency allocation for spectrum commons

The frequency allocations for spectrum commons in ISM applications are shown in footnotes 5.138 and 5.150 corresponding to the relevant frequency bands in the TFA. Tables 16, 18, and 20 show the relevant TFA containing footnotes 5.138 and 5.150.

Thailand has also adopted the frequency allocations for ISM applications and footnotes into the Thai TFA. Tables 17, 19, and 21 show the relevant Thai TFA containing footnotes 5.138 and 5.150.

Comparing frequency allocation for footnote 5.138 between the RR TFA in Table 16 and Thai TFA in Table 17, the frequency bands allocating footnote 5.138 are the same. However, the 432-438 MHz band is only allocated in Region 1. Thailand is in Region 3; therefore, the Thai TFA does not have this band for footnote 5.138. Moreover, Thailand does not have its own national footnote for the use of footnote 5.138.

When comparing frequency allocation for footnote 5.150 between the RR TFA in Table 18 and Thai TFA in Table 19, it is noted that the frequency bands allocating footnote 5.150 are not the same.

The 13 553-13 567 kHz band is contained in different bands between the RR and Thai TFA. The RR TFA is 13 550 – 13 570 kHz but the Thai TFA is 13 410 – 13 570 kHz. The starting frequency of this frequency band is different, however; they cover the 13 553-13 567 kHz band for footnote 5.150.

The 26 957-27 283 kHz band is contained in different bands between the RR and Thai TFA. The RR TFA is 26 350 – 27 500 kHz but the Thai TFA is 26 175 – 27 500 kHz. The starting frequency of this frequency band is different, however; they cover the 26 957-27 283 kHz band for footnote 5.150.

The 40.66-40.70 MHz band is contained in the same band both for the RR and Thai TFA. However, the 902-928 MHz band is only available in Region 2. Therefore, the Thai TFA does not have this band for footnote 5.150.

The 2 400-2 500 MHz band is contained in the same three bands both for the RR and Thai TFA, including 2 300-2 450, 2 450-2 483.5, and 2 483.5-2 500 MHz for footnote 5.150.

When comparing frequency allocation for footnote 5.150 between the RR TFA in Table 20 and Thai TFA in Table 21, it is noted that the frequency bands allocated to footnote 5.150 are the same.

The 5 725-5 875 MHz band is contained in the same three bands both for the RR and Thai TFA, including 5 725-5 830, 5 830-5 850, and 5 850-5 925 MHz for footnote 5.150.

The 24-24.25 GHz band is contained in the same two bands both for the RR and Thai TFA, including 24-24.05 and 24.05-24.25 GHz for footnote 5.150.

Spectrum commons of RR TFA in terms of ISM bands in footnotes 5.138 and 5.150 represent the IAD rules-in-use in the constitutional situation as the outcome of the international negotiations at the WRC. This RR TFA or rules-in-use in the constitutional situation directly influences the rules-in-use in the constitutional situation in Thailand in terms of the Thai TFA. Thailand adopts all frequency band allocations for footnotes 5.138 and 5.150 on ISM applications. The RR TFA for spectrum commons in terms of footnotes 5.138 and 5.150 represent one of the rules-in-use for Thailand. Moreover, Thailand also has its own rules-in-use in terms of the national regulation, such as the Radiocommunication Act and the NBTC Establishment Act.

The Radiocommunication Act does not permit the use of radiocommunication devices freely. The use of radiocommunication requires relevant licenses. In order to allow the use of ISM applications in Thailand, the national regulation has been implemented by the NBTC.

In the Thai TFA, Thailand has Thailand footnotes as national footnotes for the use of ISM band for footnote 5.150, i.e. T-unlicensed 1 and 2. The details of the Thailand footnotes will be described in the next section.

Table 16. RR TFA for 5.138

Allocation to services		
Region 1	**Region 2**	**Region 3**
5 003-7 450 kHz		
6 765-7 000 FIXED MOBILE except aeronautical mobile (R) 5.138		
410-460 MHz		
432-438 AMATEUR RADIOLOCATION Earth exploration-satellite (active) 5.279A 5.138 5.271 5.272 5.276 5.277 5.280 5.281 5.282	**432-438** RADIOLOCATION Amateur Earth exploration-satellite (active) 5.279A 5.271 5.276 5.278 5.279 5.281 5.282	
55.78-66 GHz		
59.3-64 FIXED INTER-SATELLITE MOBILE 5.558 RADIOLOCATION 5.559 5.138		
119.98-151.5 GHz		
119.98-122.25 EARTH EXPLORATION-SATELLITE (passive) INTER-SATELLITE 5.562C SPACE RESEARCH (passive) 5.138 5.341		
122.25-123 FIXED INTER-SATELLITE MOBILE 5.558 Amateur 5.138		
200-248 GHz		
241-248 RADIO ASTRONOMY RADIOLOCATION Amateur Amateur-satellite 5.138 5.149		

Table 17. Thailand TFA for 5.138

Allocation to services		
Thailand		**Thailand footnotes**
5 003-7 450 kHz		
6 765-7 000	FIXED MOBILE except aeronautical mobile (R) 5.138	
55.78-66 GHz		
59.3-64	FIXED INTER-SATELLITE MOBILE 5.558 RADIOLOCATION 5.559 5.138	
100-123 GHz		
119.98-122.25	EARTH EXPLORATION-SATELLITE (passive) INTER-SATELLITE 5.562C SPACE RESEARCH (passive) 5.138	
122.25-123	FIXED INTER-SATELLITE MOBILE 5.558 Amateur 5.138	
202-248 GHz		
241-248	RADIO ASTRONOMY RADIOLOCATION Amateur Amateur-satellite 5.138 5.149	

Table 18. RR TFA for 5.150

Allocation to services		
Region 1	**Region 2**	**Region 3**
13 360-18 030 kHz		
13 550-13 570	FIXED Mobile except aeronautical mobile (R) 5.150	
23 350-27 500 kHz		
26 350-27 500 FIXED MOBILE except aeronautical mobile 5.150	**26 420-27 500** FIXED MOBILE except aeronautical mobile 5.150	**26 350-27 500** FIXED MOBILE except aeronautical mobile 5.150
27.5-47 MHz		
40.02-40.98	FIXED MOBILE 5.150	
890-1 300 MHz		
	902-928 FIXED Amateur Mobile except aeronautical mobile 5.325A Radiolocation 5.150 5.325 5.326	
2 170-2 520 MHz		
2 300-2 450 FIXED MOBILE 5.384A Amateur Radiolocation 5.150 5.282 5.395	**2 300-2 450** FIXED MOBILE 5.384A RADIOLOCATION Amateur 5.150 5.282 5.393 5.394 5.396	
2 450-2 483.5 FIXED MOBILE Radiolocation 5.150 5.397	**2 450-2 483.5** FIXED MOBILE RADIOLOCATION 5.150	
2 483.5-2 500 FIXED MOBILE MOBILE-SATELLITE (space-to-Earth) 5.351A RADIODETERMINATION-SATELLITE (space-to-Earth) 5.398 Radiolocation 5.398A 5.150 5.399 5.401 5.402	**2 483.5-2 500** FIXED MOBILE MOBILE-SATELLITE (space-to-Earth) 5.351A RADIOLOCATION RADIODETERMINATION-SATELLITE (space-to-Earth) 5.398 5.150 5.402	**2 483.5-2 500** FIXED MOBILE MOBILE-SATELLITE (space-to-Earth) 5.351A RADIOLOCATION RADIODETERMINATION-SATELLITE (space-to-Earth) 5.398 5.150 5.401 5.402

Table 19. Thailand TFA for 5.150

Allocation to services		
Thailand		**Thailand footnotes**
13 360-18 030 kHz		
13 410-13 570	FIXED Mobile except aeronautical mobile (R) 5.150	T-unlicensed1
23 350-40 020 kHz		
26 175-27 500	FIXED MOBILE except aeronautical mobile 5.150	T-unlicensed1 T-unlicensed2 T-PPDR
40.02-75.2 MHz		
40.02-40.98	FIXED MOBILE 5.150	T-unlicensed1 T-JTC2
2 170-2 520 MHz		
2 300-2 450	FIXED MOBILE 5.384A RADIOLOCATION Amateur 5.150 5.282 5.396	T-unlicensed1 T-BWA T-JTC2
2 450-2 483.5	FIXED MOBILE RADIOLOCATION 5.150	T-unlicensed1 T-JTC2
2 483.5-2 500	FIXED MOBILE MOBILE-SATELLITE (space-to-Earth) 5.351A RADIOLOCATION Radiodetermination-satellite (space-to-Earth) 5.398 5.150 5.402	T-unlicensed1

Table 20. RR TFA for 5.150

Allocation to services		
Region 1	**Region 2**	**Region 3**
5 570-7 250 MHz		
5 725-5 830 FIXED-SATELLITE (Earth-to-space) RADIOLOCATION Amateur 5.150 5.451 5.453 5.455 5.456	**5 725-5 830** RADIOLOCATION Amateur 5.150 5.453 5.455	
5 830-5 850 FIXED-SATELLITE (Earth-to-space) RADIOLOCATION Amateur Amateur-satellite (space-to-Earth) 5.150 5.451 5.453 5.455 5.456	**5 830-5 850** RADIOLOCATION Amateur Amateur-satellite (space-to-Earth) 5.150 5.453 5.455	
5 850-5 925 FIXED FIXED-SATELLITE (Earth-to-space) MOBILE 5.150	**5 850-5 925** FIXED FIXED-SATELLITE (Earth-to-space) MOBILE Amateur Radiolocation 5.150	**5 850-5 925** FIXED FIXED-SATELLITE (Earth-to-space) MOBILE Radiolocation 5.150
22-24.75 GHz		
24-24.05	AMATEUR AMATEUR-SATELLITE 5.150	
24.05-24.25	RADIOLOCATION Amateur Earth exploration-satellite (active) 5.150	

Table 21. Thailand TFA for 5.150

Allocation to services		
Thailand		**Thailand footnotes**
5 570-7 250 MHz		
5 725-5 830	FIXED 5.453 MOBILE 5.453 RADIOLOCATION Amateur 5.150	T-unlicensed1
5 830-5 850	FIXED 5.453 MOBILE 5.453 RADIOLOCATION Amateur Amateur-satellite (space-to-Earth) 5.150	T-unlicensed1
5 850-5 925	FIXED FIXED-SATELLITE (Earth-to-space) MOBILE Radiolocation 5.150	T-unlicensed1
22-24.75 GHz		
24-24.05	AMATEUR AMATEUR-SATELLITE 5.150	
24.05-24.25	RADIOLOCATION Amateur Earth exploration-satellite (active) 5.150	T-unlicensed1

7.2 Spectrum commons in NBTC regulations

Thailand has a long history of the spectrum commons development that is illustrated in Chapter 6. The explicit transformation of the RR to Thai TFA was first shown in Thai TFA in 1999.

Before 1999, the transformation was implicit in terms of preparation of national regulation by the PTD official. The PTD official checked the relevant provision of the RR, frequency band, and technical characteristics before processing the application for radiocommunication equipment approval.

The Radiocommunication Act B.E. 2498 (1955) and its amendments prohibit the use of all radiocommunication equipment, unless permission for use is obtained from the authority. In 1955, the authority was the PTD, however, the use of spectrum commons was initiated by the NFMB in 1975. The NFMB authorized the PTD to allow 1-watt transmitters for pagers and anti-theft devices. This was the first time that low-power devices were allowed as spectrum commons in Thailand, however, users of such devices had to have the relevant radiocommunication licences.

The development of spectrum commons in Thailand comprises two categories: technical characteristics and radiocommunication licences. The technical characteristics have included both heavy- and light-handed development. These characteristics still remain in the current regulation.

The heavy-handed technical characteristics are a specified frequency, maximum power, technology, and applications such as the RFID transponder in the 900 MHz band. The light-handed technical characteristics are a specified frequency and maximum power such as the use of 2 400-2 500 MHz with 100 miliwatts e.i.r.p. for all technologies and applications, such as Wi-Fi, Bluetooth, cordless earphones, and cordless printers. The technical characteristics in between heavy- and light-handed are a specified frequency, maximum power, and applications such as cordless telephones in the 54-74 MHz band and wireless microphones in the 88-108 MHz band.

Radiocommunication licences are tools for an authority to control the use of radiocommunication, not only radiocommunication licences for spectrum commons, but also radiocommunication licences for command-and-control and market-based assignment approaches, apart from the broadcasting and telecommunications business licences.

The radiocommunication licences for spectrum commons are mostly for low-power devices. The development of radiocommunication licences ranges from imposing to exempting all licences. The radiocommunication licences cover the licence to make, possess, use, import, export, trade, and install a radiocommunication station, radio operator's licence, and a licence to receive news from abroad.

The current regulation can be categorized into three categories: unlicensed 1, 2, and 3.

Unlicensed 1: the use of spectrum commons with licence exemption is shown in Table 22.

Table 22. Thailand footnote T-Unlicensed 1

Frequency Band	Maximum Output Power	Applications	Related NTC Notification(s)
<135 kHz	150 mW e.i.r.p.	Radio equipment	1. NTC Notification dated Aug. 29, 2007 2. NTC TS 1010-2550
1.6-1.8 MHz	10 mW	Cordless telephones	NTC Notification dated Aug. 29, 2007
13.553-13.567 MHz	10 mW e.i.r.p.	Radio equipment	1. NTC Notification dated Aug. 29, 2007 2. NTC TS 1010-2550
26.965-27.405 MHz	100 mW	Radio equipment	NTC Notification dated Aug. 29, 2007
30-50 MHz	10 mW	Radio equipment	NTC Notification dated Aug 29, 2007
54-74 MHz	10 mW	Cordless telephones	NTC Notification dated Aug. 29, 2007
88-108 MHz	10 mW	Wireless microphones	NTC Notification dated Aug. 29, 2007
165-210 MHz	10 mW	Wireless microphones	NTC Notification dated Aug. 29, 2007
300-500 MHz	10 mW	Radio equipment	NTC TS 1010-2550
920-925 MHz	4 W e.i.r.p.	RFID (Transponder/Tag)	1. NTC Notification dated Jan. 24, 2006 2. NTC TS 1010-2550
2 400-2 500 MHz	100 mW e.i.r.p.	Radio equipment	1. NTC Notification dated Aug. 29, 2007 2. NTC TS 1010-2550 3. NTC TS 1012-2551
5.150-5.350 GHz	0.2 W e.i.r.p.	SRD	1. NTC BP 101-2550 2. NTC TS 1010-2550 3. NTC TS 1012-2551
5.470-5.725 GHz	1 W e.i.r.p.	SRD	1. NTC BP 101-2550 2. NTC TS 1010-2550 3. NTC TS 1012-2551
5.725-5.850 GHz	1 W e.i.r.p.	SRD	1. NTC BP 101-2550 2. NTC TS 1010-2550 3. NTC TS 1012-2551
5.725-5.875 GHz	10 mW e.i.r.p.	Radar	NTC Notification dated Aug. 29, 2007
10-10.6 GHz	10 mW e.i.r.p.	Radar	NTC Notification dated Aug. 29, 2007
24.05-24.25 GHz	10 mW e.i.r.p.	Radar	NTC Notification dated Aug. 29, 2007
76-81 GHz	10 mW e.i.r.p.	Radar	NTC Notification dated Aug. 29, 2007

Source: Thailand Table of Frequency Allocation, T-Unlicensed 1, (NBTC, 2012, pp. 241-242)

Unlicensed 2: the use of spectrum commons exempted from applying for 1) licence to possess, 2) licence to use, and 3) licence to export radio equipment is shown in Table 23.

Table 23. Thailand footnote T-Unlicensed 2

Frequency Band	Maximum Output Power	Applications	Related NTC Notification(s)
26.965-27.405 MHz	>100 mW < 500 mW	Radio equipment	NTC Notification dated Aug. 29, 2007
72-72.745 MHz	750 mW	Model control	1. NTC Notification dated Aug. 29, 2007 2. NTC TS 007-2548
78-79 MHz	500 mW	Citizen band	1. NTC Notification dated Aug. 29, 2007 2. NTC TS 002-2548
245-246 MHz	500 mW	Citizen band	1. NTC Notification dated Aug. 29, 2007 2. NTC TS 002-2548
510-790 MHz	10 mW	Wireless audio/video transmitters	NTC Notification dated Aug. 29, 2007
794-806 MHz	50 mW	Wireless microphones	1. NTC Notification dated Aug. 29, 2007 2. NTC TS 006-2548

Source: Thailand Table of Frequency Allocation, T-Unlicensed 2,(NBTC, 2012, p. 242)

Unlicensed 3: the use of spectrum commons exempted from applying for 1) licence to possess 2) licence to use 3) licence to export radio equipment and 4) licence to install a radio station is shown in Table 24.

Table 24. Thailand footnote T-Unlicensed 3

Frequency Band	Maximum Output Power	Applications	Related NTC Notification(s)
925-920 MHz	0.5 W e.i.r.p.	RFID (Interrogator/ Reader)	1. NTC Notification dated Jan. 24, 2006 2. NTC TS 1010-2550
1900-1906 MHz	10 mW	Cordless telephone systems (private applications)	NTC Notification dated Aug. 29, 2007
76-77 GHz	10 W e.i.r.p.	Vehicle radar	1. NTC Notification dated Aug. 30, 2006 2. NTC TS 1011-2549

Source: Thailand Table of Frequency Allocation, T-Unlicensed 3,(NBTC, 2012, p. 243)

Tables 22 – 24 provide several national regulations for spectrum commons:

1. NTC Notification dated Jan. 24, 2006,
2. NTC Notification dated Aug. 30, 2006,
3. NTC Notification dated Aug. 30, 2007,
4. NTC TS 002-2548,
5. NTC TS 006-2548,

6. NTC TS 007-2548,
7. NTC TS 1011-2549,
8. NTC TS 1010-2550,
9. NTC BP 101-2550, and
10. NTC TS 1012-2551.

These national regulations provide for the use of spectrum commons, including specified frequency, maximum power, and relevant technical specification.

Tables 22-24 show the spectrum commons regulation in Thailand, including in the Thai TFA as T-Unlicensed 1, 2, and 3. The frequency bands in Table 24 are not in footnotes 5.138 and 5.150. Moreover, there are frequency bands in Table 22 and 23 that are not in footnotes 5.150, i.e. the frequency band lower than 135 kHz, 1.6-1.8 MHz, 30-50 MHz, 54-74 MHz, 88-108 MHz, 165-210 MHz, 300-500 MHz, 920-925 MHz, 5.150-5.350 GHz, 5.470-5.725 GHz, 10-10.6 GHz, 76-81 GHz, 72-72.745 MHz, 78-79 MHz, 245-246 MHz, 510-790 MHz, 794-806 MHz, 925-920 MHz, 1 900-1 906 MHz, and 76-77 GHz.

The fact that the national authority uses the RR as its guideline and implements its own regulation within its territory reflects the independence of the national regulation. Thailand has a disadvantage with regard to globally transportable devices in using local frequency as these frequencies are only used in Thailand. The devices must be tailor-made for the Thai market. When these frequencies cause harmful interference to neighboring countries, Thailand does not have the international right to claim protection because these frequencies are allocated outside the RR. However, there are also certain advantages in responding to national needs.

Tables 22-24 summarize the list of frequency bands with maximum power and application that can be used in Thailand. The column "Application" includes the technology and application for the use of radiocommunication devices such as cordless telephones, wireless microphones, RFID, SRD, Radar, model control, citizen band, and wireless audio/video transmitters. The radio equipment in this column represents all technologies and applications that can be used in these frequency bands with a specified maximum power. The last column shows the relevant national regulations.

The use of frequencies listed in Tables 22-24 as spectrum commons does not require the payment of the frequency usage fee and no one has the exclusive right to use these frequencies.

The transformation for spectrum commons in footnotes 5.138 and 5.150 from the RR TFA to the Thai TFA are mentioned in the previous section. This transformation has been done in the constitutional situation from international to national regulation. The RR TFA representing the rules-in-use influences the Thai TFA as the national regulation. The Thai TFA adopted the spectrum commons in footnotes 5.138 and 5.150 by establishing this in the Thai TFA. The transformation from the RR TFA to Thai TFA is complete.

However, the use of spectrum commons in Thailand must correspond to national regulation, i.e. the Radiocommunication Act B.E. 2498 (1955). The use of radiocommunication devices is prohibited unless authorization is given by the authority. The Radiocommunication Act represents the rules-in-use for national regulation in the constitutional situation.

The use of spectrum commons in Thailand was granted by the authority in terms of the Ministerial Regulation, NTC, or NBTC regulation allowing the use of radiocommunication devices with specified frequency bands and specifying the maximum power, technology, and application. These regulations have been decided by the national regulatory authority in the constitutional situation to provide the rules-in-use for the collective-choice situation so that operators, manufacturers, or innovators implement these rules in terms of the network rules for building radiocommunication devices according to the rules specified by the authority.

In the collective-choice situation, manufacturers or innovators create and produce any radiocommunication devices according to given specifications under national regulation. However, Thailand is not where the manufacturing is based, and most of the radiocommunication devices are imported. The importer must be aware of the specifications of national regulation that only permit the import of radiocommunication devices that meet the specifications stated by the national regulation.

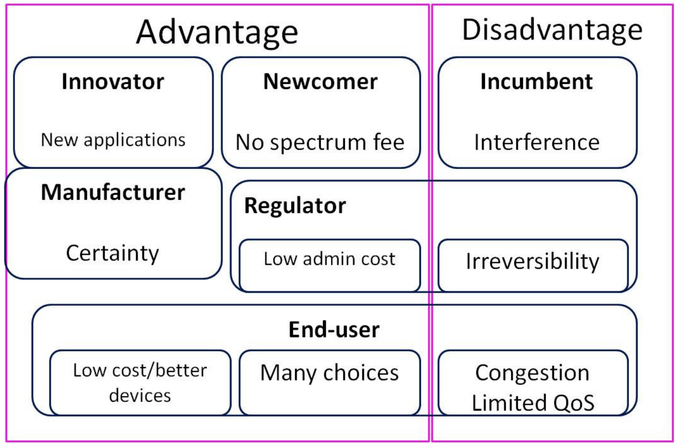
In the operational situation, users buy or select radiocommunication devices and use the devices according to the standard specified by the manufacturer at the collective-choice level. In Thailand, the users might need extra radiocommunication licences, however, as set out in Table 23 and 24.

Most of the spectrum commons regulations in Thailand adopt a bottom-up approach. Importers or users make a request of the authority to use new radiocommunication devices. The official in charge refers to the existing regulation in considering whether the new devices can be allowed to be used in Thailand. If the new devices are not allowed by the current regulation, the official must check whether the requested frequency is in line with the RR or Thai TFA as well as technical specifications and possible radiocommunication licences if necessary.

For example, if the requested frequency is used in other regions or countries but not in Thailand, the official must check whether existing users are on such a frequency and must refer to other countries' regulations in order to consider the possible use of such a frequency with the specified technical characteristics in Thailand. Once the requested frequencies and technical characteristics have been checked, regulatory approval according to the national regulatory process will be conducted. This process takes less time than the Ministerial Regulation process. Finally, the new national regulation will allow the use of new radiocommunication devices on the Thai market. The process time for new regulation always lags behind the rapid changes in technology for radiocommunication devices. The national regulatory authority has to deal with this challenge.

7.3 Allocation and assignment challenges

This study uses the advantages and disadvantages of spectrum commons from Ard-paru (2010). The challenges of spectrum commons are set out in Figure 9.



Source Ard-paru (2010),Figure 9

Figure 9. Stakeholders of spectrum commons

Figure 9 shows the advantages and disadvantages of spectrum commons with the relevant stakeholders.

There are three disadvantages of spectrum commons: harmful interference with existing service (incumbent), irreversibility once the frequency is given for spectrum commons (regulator), and congestion and limited quality of service when sharing with licensed application (end-user). The harmful interference, congestion and limited quality of service can be reduced by the advancement of technology such as the cognitive radio system. However, the irreversibility of spectrum commons is hard to eliminate because when the regulator gives such a frequency band for spectrum commons and it has been used widely by the public it is difficult to return such a frequency for spectrum refarming for new allocation or assignment. Moreover, it would not be worth it to get the spectrum back by collecting all the relevant radiocommunication devices as the cost of recollecting might be higher than the value of the frequency, for example, the 2 400-2 500 MHz frequency for Wi-Fi. Reducing irreversibility will be a challenge for both the allocation and assignment of spectrum commons by the regulator.

Figure 9 also shows the advantages of spectrum commons, including the low administrative cost for the regulator, no frequency usage fee for new-comers compared to spectrum auctions, new applications for innovators for all technologies and applications, global allocation and assignment for spectrum commons which creates certainty for manufacturers producing the

devices, and a range of choices, low cost and better devices for end-users to buy. The challenges are to maintain the advantages of spectrum commons in a sustainable way.

Table 25 shows the relevant advantages and disadvantages of spectrum commons allocation and assignment.

Table 25. Spectrum commons allocation and assignment challenges

	Allocation	
Irreversibility	Regulator	Disadvantage
Long process at the WRC	Regulator	Disadvantage
New application	Innovator	Advantage
Certainty	Manufacturer	Advantage
	Assignment	
Irreversibility	Regulator	Disadvantage
Loss of revenue	Regulator	Disadvantage
Long process for national regulation	Regulator	Disadvantage
Low administrative cost	Regulator	Advantage
Interference	Incumbent	Disadvantage
No spectrum fee	Newcomer	Advantage
Many choices	End-user	Advantage
Low cost and better devices	End-user	Advantage
Congestion, limited QoS	End-user	Disadvantage

The challenges of spectrum commons allocation includes the irreversibility once it is allocated and the long allocation process at the WRC for the regulator and administrator, the creation of new applications by innovators, and creating certainty for manufacturers to produce the devices.

The long process for spectrum commons allocation has been illustrated in Ard-paru (2012), Chapter 7. It can take up to eight years for preparation and four years for study prior to a new allocation. The correct submission of agenda items must be prepared and submitted to the WRC, which then finalizes the next WRC agenda item. Moreover, active participation and contribution submission in the relevant ITU SG and WRC meetings are necessary to ensure that the preferred outcome is included in the Final Act or the RR at a later stage.

The challenges of spectrum commons assignment include spectrum irreversibility, loss of revenue in the event of frequency usage fee, a long process for the adoption of new national regulation, and a low administrative cost for the regulator, harmful interference with existing services for incumbents, no burden for newcomers to pay for a spectrum auction, diversity of choice, low cost, better devices, congestion and limited service quality while sharing license applications for end-users.

The challenges for spectrum commons assignment for the regulator are loss of revenue and a timely process for new regulation. There is a trade-off between the loss of a frequency usage fee and the benefit to society from using spectrum commons. It is difficult to measure both the direct and indirect value of spectrum commons.

The long process involved in adopting new regulation can be managed by keeping constraints, such as only specified frequency bands and maximum power, to a minimum to ensure that rapid technological change is sufficient, and does not specify applications and technology.

7.4 Summary and discussion of research question

This chapter responds to sub-research question 4: *How should spectrum commons regulation be transformed from the RR into the national NBTC regulation? What are the challenges?*

This study explores the current RR2012 and the Thailand Table of Frequency Allocations 2012 for ISM definition, footnotes 5.138 and 5.150, and the TFA. Moreover, the study demonstrates the transformation from international into national regulations:

There are two phases. Firstly, the footnotes 5.138 and 5.150 are adopted in the Thai TFA including ISM definition, footnotes, and frequency bands. However, the definition of ISM applications is not explicitly shown in the Thai TFA. Both footnotes 5.138 and 5.150 are adopted corresponding to frequency bands in Region 3 within the Thai TFA.

The RR TFA represents the IAD rules-in-use in the constitutional situation that influences the Thai TFA as rules-in-use in national regulation in the constitutional situation in Thailand. In addition to the RR TFA influencing the use of spectrum commons in Thailand, national regulation, i.e. the Radiocommunication Act B.E. 2498 (1955), also represents the rules-in-use in the constitutional situation in Thailand. The Radiocommunication Act prohibits the use of radiocommunication devices unless permission is granted by the authority.

Secondly, the development of national regulation allows the use of spectrum commons with regard to lower-power radiocommunication. In 1975, the first spectrum commons was granted by the NFMB to the PTD allowing 1-watt transmitters for pagers and anti-theft devices. However, the use of these devices required relevant radiocommunication licences. Several additional national regulations have been developed over time to allow more frequency bands for spectrum commons with a maximum power and technical specification. Ten current relevant NBTC regulations are shown in the previous section and categorized by Thailand footnotes: T-Unlicensed 1, 2, and 3 in Table 22-24 with relevant radiocommunication licences. In addition to the frequency bands specified by footnotes 5.138 and 5.150, additional frequency bands are allowed for use as spectrum commons in Thailand, including frequency bands lower than 135 kHz, 1.6-1.8 MHz, 30-50 MHz, 54-74 MHz, 88-108 MHz, 165-210 MHz, 300-500 MHz, 920-925 MHz, 5.150-5.350 GHz, 5.470-5.725 GHz, 10-10.6 GHz, 76-81 GHz, 72-72.745 MHz, 78-79 MHz, 245-246 MHz, 510-790 MHz, 794-806 MHz, 925-920 MHz, 1 900-1 906 MHz, and 76-77 GHz.

The challenges of transforming international regulation into national regulation for both allocation and assignment are reflected by the advantages and disadvantages of spectrum commons. The challenges for the advantages are to maintain these in a sustainable way. The challenges for the disadvantages are to reduce these as much as possible.

Allocation challenges: the challenges for the regulator are the irreversibility once a frequency has been allocated for spectrum commons (it is hard to return such a frequency for new

allocation or assignment), and the long process for new allocation for spectrum commons at the WRC. For innovators, there is an opportunity to create new applications. For manufacturers, there is a certainty of mass production for global allocation.

Assignment challenges: the challenges for the regulator are the irreversibility of such frequency when assigning to spectrum commons and it is used widely (it is costly to recall such radiocommunication devices to refarm the frequency for new assignment), the loss of a frequency usage fee compared with the social benefit of spectrum commons, the long process of adopting national regulation, and the low administrative cost for spectrum commons. For an incumbent, there is harmful interference with its existing users or services. For new-comers, there is no spectrum fee to use spectrum commons. For end-users, there is a wide range of choices, low cost, and better devices to use on the market. However, harmful interference, congestion and limiting of service quality are manageable through the advancement of technology such as the cognitive radio system.

This chapter responds to sub-research question 4: How should spectrum commons regulations be transformed from the RR into the national NBTC regulation? What are the challenges? This study illustrates the transformation of international regulation into national regulation for spectrum commons in Thailand and demonstrates the challenges of the allocation and assignment of spectrum commons in terms of the advantages and disadvantages of spectrum commons for stakeholders. This sub-research question refers to the transformation of spectrum commons in the RR TFA to Thai TFA and the adoption of national regulation for the use of spectrum commons according to the Radiocommunication Act. This helps to answer the main research question of how to implement international regulation in national regulation for spectrum commons in Thailand.

Chapter 8 Relevance of IAD framework to spectrum management

This chapter discusses the IAD framework, especially the level of analysis outcomes for spectrum management activities in understanding the relevance of the IAD framework to spectrum management. This chapter combines spectrum assignment and allocation for spectrum commons in Thailand from Ard-paru (2010) and (2012) with regard to the activities of spectrum management and the IAD framework.

8.1 IAD framework level of analysis and outcomes

The IAD level of analysis and outcomes was presented in Chapter 2, describing the relationship and interaction between levels of analysis: operational, collective-choice, constitutional, and metaconstitutional. This study uses only three levels of analysis, i.e. operational, collective-choice, and constitutional to describe spectrum management activities.

Table 26 shows the activities at each level of analysis.

Table 26. Spectrum commons allocation and assignment challenges

Level of analysis and outcomes	Activities-action situation
Operational situations	Provision, production, distribution, appropriation, assignment, consumption
Collective-choice situations	Prescribing, invoking, monitoring, applying, enforcing
Constitutional situations	Prescribing, invoking, monitoring, applying, enforcing
Metaconstitutional situations	Prescribing, invoking, monitoring, applying, enforcing

Source Ostrom (2007, p. 45), Figure 2.2

In operational situations, day-to-day activities are conducted including provision, production, distribution, appropriation, assignment and consumption. For example, the use of radiocommunication devices by end-users is included in this level because the devices access and use the frequency.

In collective-choice situations, activities relate to managing and revising the rules for operational situations. For example, the rules on how to use devices, technical characteristics of devices, rules on who can use the frequency, and the ability to lease or sell the frequency are defined at this level.

In constitutional situations, activities include reviewing and revising the rules on the collective-choice situation, such as the revision of the Thailand Frequency Management Master Plan, the Table of Frequency Allocation, and the NBTC regulations.

The IAD framework suggests similar activities in both collective-choice and constitutional situations, including prescribing, invoking, monitoring, applying, and enforcing.

The same person can act differently at each level of analysis depending on the activities they perform or the action situations for which they are responsible.

8.2 Spectrum management activities

The handbook, National Spectrum Management, has been developed by ITU Study Group 1: spectrum management, based on contributions from ITU Member States and Sector Members and discussion at the meetings. There are two editions: 1995 and 2005. The current edition is from 2005. Although this handbook is not mandatory for Member States to implement, it describes the key elements of spectrum management, including spectrum management fundamentals, spectrum planning, frequency assignment and licensing, spectrum monitoring, spectrum inspection and investigation, spectrum engineering, spectrum economics, automation of spectrum management activities and measures of spectrum utilization and spectrum utilization efficiency.

The author has selected these spectrum management activities from the handbook because the activities described in the handbook reflect the practical activities of spectrum management in Thailand. The author has direct experience of how the Thai regulator has managed frequency since 1997 from the PTD, NTC, and NBTC. The key elements of spectrum management remain important, but the priority between activities varies over time. For example, at the PTD, spectrum management financing took responsibility for radiocommunication licences and frequency usage fee. After the NTC was established, this task was extended to business licenses and spectrum auction fees such as reserved price. At the PTD, national liaison and consultation was minimal due to budget constraints and the lack of requirements by law. After the NTC, public consultation became mandatory for new regulation.

Therefore, the author follows spectrum management activities from the ITU handbook, and follows national spectrum management according to experience of spectrum management in Thailand.

The handbook, National Spectrum Management (2005) (ITU, 2005), also provides activities such as functional responsibilities and requirements of spectrum management, as follows;[52]

a) Spectrum management planning and regulations;

b) Allocation and allotment of frequency bands;

c) Frequency assignment and licensing (including non-licensing allocations);

d) Spectrum management financing, including fees;

e) Standard, specifications, and equipment authorization;

f) Spectrum monitoring;

g) Spectrum regulation enforcement: inspections and investigations;

h) International and regional cooperation including frequency coordination and notification;

[52] This study uses text from Chapter 2, Ard-paru (2010)

i) National liaison and consultation; and

j) Spectrum management support functions including administrative and legal, computer automation, spectrum engineering, and training.

Spectrum management planning and regulations

The spectrum management organization should take account of the advancement of technology as well as the social, economic, and political realties when developing implementation plans, regulation, and policies. The Table of Frequency Allocation is the output of planning and policy-making efforts, reflecting the various radio services or uses. In the event of competing uses or interests, the spectrum management organization should determine the use or uses that would best serve public and government interests and how the spectrum should be shared.

In order to allocate frequency, the following factors should be taken into account: public and government needs, technical considerations, and apparatus limitations. Public and government needs and benefit considerations are a requirement of the service for radio frequencies, as are considerations regarding the probable number of people who will benefit from the service, the relative social and economic importance of the service, the probability of establishment of the service, the degree of public support expected for the service, the impact of the new applications on existing investment in the proposed frequency band, and government requirements for security, aeronautical, maritime, and science services. Technical considerations comprise the need for the service to use the frequency with particular propagation characteristics and compatibility within and outside the selected frequency band, the amount of frequency required, the signal strength required for reliable service, the amount of interference that is likely to be encountered, and the viability of the technology. Apparatus limitations comprise the upper useful or higher limit of radio frequency, operating characteristics of transmitters, types of antenna availability and practical limitations, receiver availability, and characteristics.

Allocation and allotment of frequency bands

The national allocation table should represent the current national frequency assignment as well as the national plan for future use. The national allocation table provides details of current national uses, including all data on terrestrial and space services and their applications. Each country uses the ITU allocation table as guidance for the region allocation to which the particular country belongs. It is not necessary for every country to follow exactly the ITU table, which deviates to a limited degree to satisfy national requirements, as long as this does not cause harmful interference and protection is not required. Reasons for following the ITU table include availability of equipment in the region according to the agreement of the allocation table, minimized interference from neighboring countries, conformity of equipment in the regional table, and global service such as aeronautical, maritime, and satellite service.

Normally, existing spectrum users oppose changes to frequency allocation tables because of the many costs incurred, including equipment costs, learning costs, and loss of customers. In

order to develop national table frequency allocation, the spectrum management organization should follow the ITU Table of Allocation as closely as possible, develop the plan based on current use, not impede the advancement of future technology, allow efficient allocation for government and security, and align with other countries' allocation.

Frequency assignment and licensing (including non-licensing allocations)

Frequency assignment is routine work for spectrum management organizations. Analyses select the most suitable frequencies for radiocommunication systems and coordinate proposed assignments with existing ones.

The frequency assignment function includes the licensing function, national legislation, and regulations and related procedures to control the operation of stations by: 1) examining licence applications and related documents to determine the licensing eligibility of the application and the technical acceptability of the radio equipment proposed; 2) assigning the radio call signs to individual stations; 3) issuing licences and collecting fees, if appropriate; 4) establishing methods for administering system or network licences, as appropriate; 5) renewing, suspending, and canceling licences, as appropriate; and 6) conducting examinations of operators.

The related procedures should specify information to be supplied with frequency applications to allow spectrum managers to perform better. Unnecessary or difficult procedures may discourage radiocommunication development.

Spectrum management financing

Spectrum is a natural resource that is a valuable national asset and typically controlled by government. The primary objective of the spectrum management fee policy should be to: 1) improve the telecommunication infrastructure through the efficient and effective use of radio spectrum; 2) support spectrum management infrastructure via administrative fees for all users; 3) encourage spectrum efficiency by providing appropriate incentives, assessing the fees according to the amount of bandwidth usage and the number of transmitters in the network; 4) reflect economic principles and radio standards required in the RR and ITU-R Recommendations; and 5) release inefficient and ineffective use of spectrum.

Licence fees include application fees, construction permit fees (installation fee), spectrum usage or regulatory fees, operator certificate fees, and administrative fees.

Standard, specifications, and equipment authorization

In general, the spectrum management organization should follow the technical characteristics of the station in Article 3 of the RR, the maximum value for frequency tolerance and spurious domain emission, and other technical standards in Appendices 2 and 3 of the RR in order to avoid interference. Thus, administrators ensure that all the equipment characteristics within their territory conform to these regulations.

There are two main functions of the standard: standard setting and standard compliance. The standard setting can be national or international, depending on interests. Standard compliance spectrum management organization, however, can be by the administration itself or another party and comprises the compliance testing requirement and other administrative procedures related to compliance.

Administrative procedures, such as national acceptance of equipment test results from other administrations, self-certification, or private sector testing laboratories, help to reduce paperwork and cost, but spectrum management organization ensures that radiocommunication equipment meets standard requirements.

As for self-certification, the spectrum management organization should have its own test laboratory to perform spot checks, including transmitting and receiving equipment, laboratory testing according to type approval procedures, maintenance and calibration of laboratory test equipment, and other inspection and monitoring equipment, acceptance evaluation of equipment for inspection and monitoring, and outfitting special/purpose monitoring vehicles, and calibration of equipment to be fitted in such vehicles.

Equipment authorization is part of the global standard setting that helps avoid fragmentation of the market for the benefit of both consumers and industry. The ITU maintains principles of consensus, transparency, openness, impartiality, maintenance, public access to deliverables, consistent rules, efficiency, accountability, and coherence in order to maintain successful development of the global standard.

Spectrum monitoring

Spectrum monitoring feeds back to spectrum management, i.e., good frequency planning and assignment reduce the possibility of harmful interference. Spectrum monitoring responsibilities include routine monitoring of a wide range of frequency and special tasks to find illegal frequency uses or harmful interference. Monitoring provides actual use of spectrum as information for frequency assignment in order to compare spectrum planning with reality. The consequences are the adjustment of spectrum planning.

Information from monitoring also supports the enforcement approach to the ideal of interference-free, properly authorized, and harmonized use of the spectrum. Monitoring can also be used to identify and measure interfering signals, verify technical and operational characteristics of radiated signals, and detect illegal transmitters.

Spectrum regulation enforcement: inspections and investigations

The purpose of the enforcement inspection is to strengthen spectrum management processes to reflect the effective management of the spectrum, depending on the ability to control its use through the enforcement of relevant regulations. The authority should grant appropriate authority to the spectrum management organization in order to enforce regulation and set appropriate penalties.

Enforcement, inspection, and investigation should work closely with monitoring, assignment, and licensing units to collect information to investigate interference complaints, illegal

operation, and operations not in accordance with the radio station licence, collect information for legal prosecution and law enforcement, ensure that the radio station complies with national and international regulations, and take technical measurements.

International and regional cooperation including frequency coordination and notification

When interference cannot be contained nationally, international and regional cooperation, in terms of activities within international bodies, and bilateral and multilateral discussions should be conducted. The cooperation is conducted by ITU world and regional radiocommunication conferences (WRCs and RRCs), together with the three ITU Sectors (Radiocommunication, Telecommunication Standardization, and Telecommunication Development). Moreover, the notifications from Member States to the Radiocommunication Bureau help to coordinate frequency authorization via the Bureau's International Frequency Information Circular (BR IFIC).

Moreover, discussions in other international organizations, such as the International Civil Aviation Organization (ICAO), the International Maritime Organization (IMO), the World Meteorological Organization (WMO), and the Special Committee of the International Electrotechnical Commission for Interference (CISPR), help to settle interference issues via negotiation. The administration must therefore also give consideration to participating in these organizations.

Bilateral cooperation between countries, especially neighboring countries, in terms of a joint committee, helps to relieve interference at operational level.

National liaison and consultation

The spectrum management organization should set up liaison units for communication and consultation with users, including businesses, telecommunication industries, the government and the general public to disseminate information on policy, rules and regulations, and practices and provide mechanisms for feedback to evaluate consequences. A liaison unit, as a focal point of spectrum management organization, maintains media relations, issues public notices, conducts meetings, and acts as a mediator to resolve interference problems. The form of the liaison unit ranges from informal to formal contact and depends on the tradeoff between efficient dialogue and quick results, and transparent administrative procedures that ensure fair and impartial treatment.

Spectrum management organizations are encouraged to establish procedures for individuals and organizations to revise spectrum regulations and assignment or allocation to meet the needs of the national constituency.

The spectrum management support function includes administrative and legal support, computer automation, spectrum engineering, and training

Spectrum engineering support provides adequate evaluation information, capabilities, and choices in the field of technology and engineering analysis of technical factors. Administrative, legal, and computer support provides an efficient facility for the spectrum management organization.

8.3 Applying IAD framework to spectrum management activities

Analyzing the layers of the IAD framework classifies the spectrum management activities into each level of analysis to understand the relevance of the IAD framework to spectrum management activities. Table 27 illustrates the outcome of the spectrum management activities at each level of analysis.

Table 27. Spectrum management activities with IAD levels of analysis and outcomes

Spectrum Management activities	Constitutional	Collective-choice	Operational
Spectrum management planning and regulations	x		
Allocation and allotment of frequency bands	x		
Frequency assignment and licensing		x Rule setting	x Compliance
Spectrum management financing		x	
Standard, specifications, and equipment authorization		x Setting	x Compliance
Spectrum monitoring		x	
Spectrum regulation enforcement		x	
International and regional cooperation	x Rule setting	x Rule setting	x Compliance
National liaison and consultation			x
Support function			x

In constitutional situations, the activities relate to creating, reviewing, and revising the RR, including allocation and allotment of frequency to services, international and regional coordination, National Frequency Management Master Plan, and the Table of Frequency Allocation. These spectrum management activities provide rules at the constitutional level that influence the rules for collective-choice and day-to-day activities at the operational situation.

In the collective-choice situation, the spectrum management activities that implement the rules from the constitutional situation create the rules for operational situation such as rules on how to assign the frequency: first-come first-serve or auction, rules on how to use a network or standard settings for permissible devices, and rules on how to coordinate between operators in neighboring countries when interference occurs. Moreover, the fee calculation formula for spectrum management financing activities is also established at this level.

Furthermore, spectrum monitoring for the use of frequency and spectrum regulation enforcement: inspection and investigation of the use of radiocommunication devices are included at this level to supervise day-to-day activities for frequency assignment and licensing and provide the information back for spectrum-planning activities.

In the operational situation, the day-to-day or routine activities of spectrum management comprise assignment, licensing, standard compliance, cooperative protocol compliance, consultation of rules, and supporting activities.

Assignment and licensing activities are carried out according to specified rules in the collective-choice situation, i.e. which frequency can be assigned with technical specification, which licences are applied, what fees are charged.

Radiocommunication equipment standard compliance is performed according to predefined standard setting and procedures carried out in the collective-choice situation, i.e. which standard or equipment is allowed to be used in Thailand.

During frequency coordination between countries, when the interference is found, the both the regulator and operator in the relevant countries must follow the rules as specified in the collective-choice situation to identify and eliminate such interference.

National liaison and consultation activities comprise day-to-day work to create a common understanding of the rules with regard to public consultation or focus groups. Output information would benefit from greater efficiency of rule implementation at higher levels.

The support activities aim to facilitate the main spectrum activities on a daily basis, including technical and administrative support.

This study classifies the spectrum management activities into the IAD level of analysis and outcomes to understand the interaction of each activity and relationships across levels. All spectrum management activities dealing with rule-setting are carried out in the constitutional or collective-choice situation. Day-to-day activities performed according to specified rules are in the operational situation.

According to the IAD framework set out in Figure 2, Chapter 2, spectrum management activities can be described as follows:

Biophysical conditions: This study deals with spectrum that can be public, private, or common-pool goods depending on the allocation and assignment approach. Spectrum allocation at the international level can be treated as public goods. On the other hand, spectrum assignment at the national level can be treated as private or common-pool goods, depending on the assignment approach used.

Attributes of community: Spectrum management involves many stakeholders from the international to national level including the ITU, Member States, manufacturers, operators, and end-users. Common understanding among them is essential in order to understand the regulation and properly implement it in order to ensure frequency efficiency without or with minimal harmful interference.

Rules-in-use: The rules-in-use of spectrum management are represented by the RR, national regulation, the network rules of operators, and manufacturers' equipment standards. These rules directly influence the action situation and interaction between stakeholders in spectrum management activities.

Action situation and interaction: Spectrum management activities represent the action situation and interaction between stakeholders in each activity representing various aspects of the decision-making process. From rule-setting to implementation of rules by the regulator, manufacturers, operators, and end-users, these represent the action situation and interaction in spectrum management.

Outcome: the ultimate outcome of spectrum management is the efficient use of spectrum with manageable harmful interference. Moreover, the outcome is directly influenced by the evaluative criteria that vary between countries and stakeholders. The challenge is to balance the benefit and outcome with the sustainable use of spectrum.

8.4 Summary and discussion of research question

This chapter answers the sub-research question 5: *How is the IAD framework relevant to spectrum management?*

This study applies the IAD framework in terms of the level of analysis and outcomes to demonstrate the relationship between levels of analysis in spectrum management activities. The study uses three levels of analysis and outcome, i.e. the constitutional, collective-choice, and operational situation.

The operational situation represents day-to-day or routine work corresponding to the rules that have been specified in the collective-choice situation. The spectrum management activities at this level comprise assignment and licensing, equipment authorization, international and regional cooperation, national liaison and consultation, and support functions.

The collective-choice situation represents the ability to review and revise operational rules, including how to assign or license frequency, authorize equipment, how to charge for licence fees, and how to coordinate when interference occurs. Moreover, standard-setting, assignment and licensing, and international and regional cooperation rule-setting have been carried out at this level. Furthermore, spectrum monitoring and regulation enforcement have been performed to provide information back to spectrum planning.

The constitutional situation consists of rule-setting, reviewing, and revising at the international and national level that is directly influenced to the collective-choice and operational situation, including the RR (allocation and allotment of frequency), the National Frequency Management Master Plan, the Table of Frequency Allocation (planning and regulation), and international and regional cooperation.

The study also illustrates the application of the IAD to the spectrum management activities by analyzing and describing spectrum management activities according to aspects of the IAD framework including biophysical condition (spectrum as public goods for allocation, spectrum as private and common-pool good for assignment), attributes of community (common understanding between stakeholders in spectrum management including ITU, Member States,

manufacturers, operators and end-users), rules-in-use (the RR, national regulation, network rules, standard of equipment), action situation and interaction (spectrum management activities between stakeholders: regulator, operators, manufacturers, standard-setting body, and end-users), outcome, and evaluative criteria (efficient use of spectrum and balancing of the benefit between stakeholders).

This study applies the IAD framework to understand the transformation from the RR to NBTC regulation for spectrum commons in Thailand in terms of the definition of ISM applications, footnotes 5.138 and 5.150, and frequency bands in the TFA.

This chapter answers sub-research question 5: How is the IAD framework relevant to spectrum management? This study applies the IAD framework to describe and categorize spectrum management activities into three levels of analysis and outcome in order to demonstrate the relationship between stakeholders in spectrum management in each level of analysis. Moreover, spectrum management can be described by the IAD framework to understand the activities according to aspects of the framework. This sub-research question highlights the relevance of the IAD framework to the spectrum management activities. It also helps to fulfill the main aim of this research, namely how to implement international regulation in national regulation for spectrum commons in Thailand.

Chapter 9 Summary and findings

This chapter provides an overview of the findings of this study. It also provides an explicit answer to the research question.

9.1 Synthesis

There follows a summary of the complex issues associated with the transformation of international regulation into national regulation in terms of transforming the RR into NBTC regulation.

Purpose

The purpose of this study is to demonstrate the relationship between international and national regulations with regard to implementing spectrum commons in Thailand. It also illustrates the development of frequency allocation for spectrum commons at the international level and the international regulation transfer for spectrum commons to Thai national regulation.

Motivation

The study attempts to understand the relationship between the RR as the international regulation and the NBTC regulation as the national regulation for spectrum commons at the IAD constitutional situation.

The main research question of this study is: **How is the Radio Regulations transformed into National Broadcasting and Telecommunications Commission regulation for spectrum commons in Thailand?** In order to answer this research question, the five sub-research questions are as follows:

1. What are the main applications and technologies for spectrum commons?
2. What is the spectrum allocation for spectrum commons and ISM applications, and how was it developed?
3. What is spectrum assignment, especially spectrum commons, in Thailand, and how did it develop?
4. How should spectrum commons regulation be transformed from the RR into the national NBTC regulation? What are the challenges?
5. How is the IAD framework relevant to spectrum management?

Method

The study uses deductive approaches and secondary data. The secondary data are obtained from the ITU and NBTC archives. Keyword mapping helps to track the relevant provisions across the RR versions.

The IAD framework provides a layer of analysis and outcomes to explain the connection between international regulations at the ITU, in the form of the RR, and national regulation in the form of the NBTC.

9.2 Findings to the research questions

The study's findings corresponding to the relevant research questions are as follows:

(1) Spectrum commons application and technology (Chapter 4) corresponding to the first sub-research question: What are the main applications and technologies for spectrum commons?

This study responds to the first sub-research question by providing the main application and technology for spectrum commons in terms of short-range devices and software-defined radio and cognitive radio system. The study concentrates on applications and technology relating to industrial, scientific and medical (ISM) applications using the frequency band according to RR No. 5.138 and 5.150.

The study explores the relevant literature, including the report and recommendations of the ITU-R to illustrate the characteristics of SRDs, and SDR and CRS.

The main characteristics of the SRDs are non-interference and non-protection. Most SRDs use the ISM band, especially 5.138 and 5.150. Moreover, power limitation in terms of magnetic and electric field strength and maximum power level vary from country to country. Allocation of frequency band to the ISM band is done at the WRC. However, authorization of the use of SRDs is granted locally by the NRA. SRDs migrate the national to international issues when unlicensed SRDs are transported from one country to other countries that do not allow the use of such SRD. The use of unlicensed SRDs in countries where it is not permitted creates interference with existing services. However, regional and global harmonization of frequency bands might be possible.

SRDs are the main application for spectrum commons because the characteristic of non-interference and non-protection provide the non-exclusive use of frequency that is similar to spectrum commons.

SDR and CRS are enabled technologies for SRD. The study focuses on these two technologies because they are relevant to WRC-12 agenda item 1.19 and might offer possibilities to review and revise the RR.

The characteristics of CRS are obtaining the operational environment, changing the radio operational parameter simultaneously and automatically by software, and learning from experience to improve its performance. SDR is enabled technology for CRS because the characteristic of SDR is the ability to change the radio operational parameter simultaneously and automatically by software.

The development of SDR is at a mature stage that has already been implemented for several services, however CRS is in its infancy and needs further development. The main benefit of CRS is that it provides spectrum access opportunities, increasing spectrum efficiency and reducing interference.

The characteristic of CRS provides the non-exclusive right to use a frequency that is the same as a spectrum commons characteristic. Therefore, SDR and CRS are the main technologies for spectrum commons.

(2) Spectrum allocation for spectrum commons (Chapter 5) corresponding to the second sub-research question: What are the spectrum allocations for spectrum commons and ISM applications, and how did they develop?

The study responds to the second sub-research question by elaborating on the result of international negotiations or the result of the WRC in the form of the RR revision for spectrum allocation for radiocommunication services. The WRC allocates service by frequency bands inside the TFA based on Member State contributions. The TFA is divided into three Regions: Regions 1, 2, and 3. Each service consists of either primary or secondary services, which can be written in capital letters for primary services while secondary services are lower case. Moreover, the footnotes can indicate the primary and secondary services with the words "on a primary basis" or "on a secondary basis", respectively.

The study explores the ITU archive with relevant RR and WRC proceedings to capture the development of the allocation of spectrum commons in the RR.

Spectrum allocation represents the result of negotiations at international level because the final allocation is the output of governmental negotiations between Member States.

Spectrum commons are allocated in ISM application footnotes 5.150 and 5.138. Most of the short-range or low-power devices use the frequency under these provisions with non-exclusive use of frequency.

This study illustrates the development of ISM applications, both in terms of definition and frequency bands allocated for ISM applications. The official definition of ISM applications has been developed in RR1982 and remained unchanged until RR2012. Long before that, ISM applications used different words: purpose and equipment in RR1947 and RR1959.

The current ISM bands are: 6 765-6 795 kHz, 433.05-434.79 MHz, Region 2, 61-61.5 GHz, 122-123 GHz, 244-246 GHz, for 5.138; and 13 553-13 567 kHz, 26 957-27 283 kHz, 40.66-40.70 MHz, 902-928 MHz, Region 1, 2 400-2 500 MHz, 5 725-5 875 MHz, and 24-24.25 GHz for 5.150.

The first allocation was for low-power stations in the European region in RR1938 and ceased in RR1947. Most of the ISM bands were developed in RR1982 and continued to be used until RR2012.

This study shows the development of each ISM band and indicates the differences between them. Footnote 5.138 requires special authorization to operate, while footnote 5.150 allows other services to share the same frequency with acceptance of harmful interference from ISM applications. Neither 5.138 nor 5.150 provide the explicit ITU recommendation, however the relevant ITU-R recommendation is Recommendation ITU-R SM.1056-1: Limitation of radiation from industrial, scientific and medical (ISM) equipment.

(3) Frequency assignment for spectrum commons in Thailand (Chapter 6) in response to the third sub-research question: What is spectrum assignment especially spectrum commons in Thailand, how did it develop?

This study responds to the third sub-research question by exploring the NBTC archives, including the relevant NFMB minutes, and PTD, NTC, NBTC, MOT, and MICT regulation.

The study illustrates overall spectrum assignment which has three typical approaches: command-and-control, market-based, and spectrum commons. Spectrum assignment is managed by the national regulatory authority. Among the three typical approaches, only command-and-control and market-based provide an exclusive right to use a frequency, whereas spectrum commons does not. However, the command-and-control approach is inefficient as it lacks the flexibility of frequency use. The market-based and spectrum commons approaches were introduced to overcome such inefficiency. The market-based or spectrum auction in the UK in 2000 was an example of the largest auction in which the winning bidder was not commercially viable and later sold the spectrum.

The spectrum can be treated as goods, depending on the method of assignment. For command-and-control and market-based approaches, the spectrum is treated as private goods with an exclusive right to use a frequency. The spectrum can be transferred or sold to others by the regulator or the market. On the other hand, spectrum commons can be treated as common-pool goods with a non-exclusive right to use a frequency. The ownership of spectrum commons belongs to the general public.

The study demonstrates the development of spectrum assignment in Thailand. Thailand has developed spectrum assignment from a command-and-control to a market-based approach. Spectrum was initially for use by a limited number of parties, first only the government agency and then extended to the general public. The development of the spectrum assignment agency in Thailand included the PTD, NFMB, MICT, NTC, ONTC, NBTC, and ONBTC in order to change the authorization to a licensing scheme or command-and-control to market-based economics.

The study also illustrates the development of spectrum commons in Thailand since the NFMB in terms of authorization of the use of 1-watt transmitters. The Ministerial Regulation allowed low-power devices with relevant licences. The PTD regulations allowed the use of WLAN indoor applications and extended this to outdoor applications. Finally, as the first unlicensed regulation in Thailand, the Ministerial Regulation of the Exemption of Radiocommunication Licences in 2004 allowed low-power devices without relevant licences.

(4) International to national regulation (Chapter 7) in response to the fourth sub-research question: How should spectrum commons regulation be transformed from the RR into the national NBTC regulation? What are the challenges?

The study responds to the fourth sub-research question by exploring the current RR2012 and Thailand Table of Frequency Allocations 2012 for ISM definition, footnotes 5.138 and 5.150, and TFA. Moreover, the study demonstrates the transformation from international to national regulations:

There are two phases. First, the footnotes 5.138 and 5.150 are adopted in the Thai TFA, including ISM definition, footnotes, and frequency bands. However, the definition of ISM applications is not explicitly shown in the Thai TFA. Both footnotes 5.138 and 5.150 are adopted corresponding to frequency bands in Region 3 within the Thai TFA.

The RR TFA represents the IAD rules-in-use in the constitutional situation that influences the Thai TFA as rules-in-use in national regulation at the constitutional level in Thailand. In addition to the RR TFA influencing the use of spectrum commons in Thailand, national regulation, i.e. the Radiocommunication Act B.E. 2498 (1955), also represents the rules-in-use in the constitutional situation in Thailand. The Radiocommunication Act prohibits the use of radiocommunication devices unless permission is granted by the authorities.

Second, the development of national regulation allows the use of spectrum commons with regard to lower-power radiocommunication. In 1975, the first spectrum commons was granted by the NFMB to the PTD allowing 1-watt transmitters for pagers and anti-theft devices. However, the use of these devices required relevant radiocommunication licenses. Several additional national regulations have been developed over time to allow more frequency bands for spectrum commons with maximum power and technical specification. Ten current relevant NBTC regulations are shown in the previous section and categorized into Thailand footnotes: T-Unlicensed 1, 2, and 3 in Table 22-24 with relevant radiocommunication licenses. In addition to the frequency bands specified by footnotes 5.138 and 5.150, other frequency bands were allowed to be used as spectrum commons in Thailand, including the frequency band lower than 135 kHz, 1.6-1.8 MHz, 30-50 MHz, 54-74 MHz, 88-108 MHz, 165-210 MHz, 300-500 MHz, 920-925 MHz, 5.150-5.350 GHz, 5.470-5.725 GHz, 10-10.6 GHz, 76-81 GHz, 72-72.745 MHz, 78-79 MHz, 245-246 MHz, 510-790 MHz, 794-806 MHz, 925-920 MHz, 1 900-1 906 MHz, and 76-77 GHz.

The challenges of transforming international into national regulation both in terms of allocation and assignment are reflected by the advantages and disadvantages of spectrum commons. The challenges of the advantages are to maintain them in a sustainable way. The challenges of the disadvantages are to reduce them as much as possible.

Allocation challenges: the challenges for the regulator are irreversibility once such frequency has been allocated for spectrum commons (it is hard to return such frequency for new allocation or assignment), and the long process for new allocation for spectrum commons at the WRC. For innovators, this is an opportunity to create a new application. For manufacturers, this offers the certainty of mass production for global allocation.

Assignment challenges: the challenges for the regulator are the irreversibility of such frequency when assigning to spectrum commons, and the fact that it is widely used (it is costly to recall such radiocommunication devices to refarm the frequency for new assignment), the loss of a frequency usage fee compared with the social benefit of spectrum commons, the long process of adopting national regulation, and the low administrative cost

for spectrum commons. For an incumbent, the challenge is the harmful interference with its existing users or services. For a new-comer, there is no spectrum fee to use spectrum commons. For end-users, there is a wide choice, low cost, and better devices to use on the market. However, harmful interference, congestion and limited quality of service are manageable through advancements in technology such as the cognitive radio system.

(5) International to national regulation (Chapter 8) in response to the fifth sub-research question: How is the IAD framework relevant to spectrum management?

The study responds to the fifth sub-research question by applying the IAD framework in terms of the level of analysis and outcomes to demonstrate the relationship between spectrum management activities at different levels of analysis. The study uses three level of analysis and outcome, namely constitutional, collective-choice, and operational situation.

The operational situation represents day-to-day or routine work corresponding to the rules that have been specified in the collective-choice situation. The spectrum management activities at this level are assignment and licensing, equipment authorization, international and regional cooperation, national liaison and consultation, and support functions.

The collective-choice situation represents the ability to review and revise operational rules, including how to assign or license frequency, authorize equipment, how to charge licence fees, and how to coordinate if interference occurs. Moreover, standard-setting, assignment and licensing, and international and regional cooperation on the setting of rules are done at this level. Furthermore, spectrum monitoring and regulation enforcement are performed to provide information back to spectrum planning.

The constitutional situation represents rule-setting, reviewing, and revising at the international and national level that is directly influenced to the collective-choice and operational situation including the RR (allocation and allotment of frequency), National Frequency Management Master Plan, Table of Frequency Allocation (planning and regulation), and international and regional cooperation.

The study also illustrates the IAD application to spectrum management activities by analyzing and describing the spectrum management activities according to aspects of the IAD framework, including biophysical condition (spectrum as public goods for allocation, spectrum as private and common-pool goods for assignment), attributes of community (a common understanding among stakeholders in spectrum management including ITU, Member States, manufacturers, operators, and end-users), rules-in-use (the RR, national regulation, network rules, standard of equipment), action situation and interaction (spectrum management activities between stakeholders: regulators, operators, manufacturers, standard-setting bodies, and end-users), outcome, and evaluative criteria (efficient use of spectrum and the balance of benefit between stakeholders).

The study applies the IAD framework to understand the transformation from the RR into the NBTC regulation for spectrum commons in Thailand in terms of definition of ISM applications, footnotes 5.138 and 5.150, and frequency bands in the TFA.

9.3 Benefit for Thailand

This study provides an overall view on the implementation of spectrum commons regulation in Thailand. This includes the development of spectrum allocation for spectrum commons in the RR, the main application and technology for spectrum commons, the development of spectrum assignment for spectrum commons in Thailand, and the practical transformation from the RR into NBTC regulation.

The study helps us understand that the process of transformation from international into national regulation is a time-consuming process through spectrum allocation at the WRC and implementation of the national NBTC regulation to allow the use of spectrum commons both with the relevant licences and unlicensed.

This study proposes looser regulation for spectrum commons in order to gain advantages or benefit from the rapid change in technology because the process of reviewing and revising both international and national regulation is a time-consuming process.

9.4 Recommendations for future research

Further studies on the transformation of other services such as mobile services from the RR into national regulation would be interesting to explore.

Comparative studies between countries in different region could also form the basis for other future studies to understand the differences and similarities between countries.

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List of abbreviations

General

AVI	Automatic vehicle identification
CB	Citizen band
CMOS	Complementary metal oxide semiconductor
CRS	Cognitive radio system
DECT	Digital enhanced cordless telecommunications
e.i.r.p.	Equivalent isotropically radiated power
e.r.p.	Effective radiated power
FH	Frequency hopping
GHz	Giga Hertz
GPS	Global positioning system
HDR	High data rate
Hz	Hertz
IAD	Institutional Analysis and Development
IFIC	International Frequency Information Circular
IED	Interference estimation and decoding
IMT	International Mobile Telecommunication
ISM	Industrial science and medical application
ITS	Intelligent transport system
kHz	Kilo Hertz
LDR	Low data rate
LNA	Low noise amplifier
MAC	Medium access control
MHz	Mega Hertz
MICS	Medical implant communication system
NFC	Near field communication
OFDM	Orthogonal frequency division multiplexing
PANs	Personal area networks
PHS	Personal handy-phone system
PHY	Physical layer
PP	Plenipotentiary conference
RF	Radio frequency
RFID	Radio-frequency identification
RLAN	Radio local area network
RR	Radio Regulations
RRC	Regional radiocommunication conference
SDR	Software defined-radio
SG	Study group
SIM	Subscriber identification module
SoD	Supplier's declaration of conformity
SRD	Short-range devices
TFA	Table of frequency allocation
UWB	Ultra wide band
WLAN	Wireless local area network
Wi-Fi	Wireless fidelity
WRC	World Radiocommunication Conference

Administration and organization

BR	Radiocommunication Bureau
CCIR	International Radio Consultative Committee
CISPR	Special committee of the international electrotechnical commission for interference
FIFA	Fédération Internationale de Football Association
ICAO	International Civil Aviation Organization

IEEE	Institute of Electrical and Electronics Engineers
IMO	International Maritime Organization
ITU	International Telecommunication Union
MICT	Ministry of Information and Communication Technology
NBTC	National Broadcasting and Telecommunication Commission
NFMB	National Frequency Management Board
NRA	National regulatory authority
NTC	National Telecommunications Commission
ONBTC	Office of the NBTC
ONTC	Office of the NTC
PTD	Post and Telegraph Department
WMO	World Meteorological Organization

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THESIS FOR THE DEGREE OF LICENTIATE OF ENGINEERING

Spectrum assignment policy: Towards an evaluation of spectrum commons in Thailand

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Abstract

There is consensus among economists, engineers, and lawyers that a traditional command-and-control approach to spectrum assignment is inefficient and that a market-based or commons approach can be more efficient. The purpose of this thesis is to find the benefits of using spectrum commons for frequency assignment in Thailand. To satisfy this purpose, four main contributions are provided: 1) a framework to understand the institution of spectrum commons and its application to Thailand, 2) an approach to explain the advantages and disadvantages of spectrum commons, 3) an exploration of the use of a framework for a benefit and cost analysis to valuate the spectrum commons, and 4) possible implications of using spectrum commons in Thailand. These contributions will serve as information for a regulator to make better-grounded decisions on frequency assignment and on whether to license or unlicense spectrum.

The thesis uses history, content analysis, and literature critique as its main sources. The content analysis and literature critique are based on the public consultation in 2008 by the European Radio Spectrum Policy Group. It addresses the aspects of a European approach to the collective use of spectrum and identifies the advantages and disadvantages of spectrum commons. To describe the institution of spectrum commons, the property rights regimes by Schlager and Ostrom (1982) are used. This is based on three economic institutions originally described by Kiser and Ostrom (1982) and later adopted by Field (1992). This information is examined, together with the benefit and cost analysis based on the research by Campbell and Brown (2003), Indepen (2006), and Sweet et al. (2002). Data from this examination contribute to defining a framework that can be used to valuate spectrum commons in Thailand.

The institution of spectrum commons in Thailand comprises technical and non-technical aspects. The technical aspects are power limitation and use of the specified frequency band, and the non-technical ones are frequency sharing among users and no endowed rights to request compensation from interfering parties.

The advantages of spectrum commons are lower entry barriers for new entrants, a reduction in administration work (such as defining property rights to use frequency, auction process, etc.), and enhancing social benefits. These attributes contribute to increasing the potential for innovation and stimulating further demand for new technologies. The main disadvantage of spectrum commons is irreversibility after spectrum assignment, congestion, and limited quality of service. Even these eventual limitations can be solved with the advancement of technology, while the threats, e.g., lack of innovation while sharing with licensed services, are questionable.

The thesis argues that spectrum commons has more strengths and opportunities than weaknesses and threats. In order to implement the spectrum commons and valuate the usefulness of this approach in practice, a framework of benefits and costs is defined. The output of this thesis can be used as information for regulators to decide whether the frequency should be licensed or unlicensed and to evaluate the consequences of implementing spectrum commons.

Keywords: spectrum management, spectrum assignment, spectrum commons, collective use of spectrum, benefit and cost analysis

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"We only know the time we were born but we do not know the time we will die.

Life is too short, if you would like to do a good thing, please DO it."

"Happiness is here and now
I have dropped my worries
Nowhere to go, Nothing to do
No longer in a hurry"
Song from "Plum village," France

Table of Contents

Chapter 1 Introduction ... 1
- 1.1 What is spectrum? ... 1
- 1.2 Why manage spectrum? ... 1
- 1.3 How is spectrum managed? ... 2
- 1.4 What is spectrum assignment? ... 2
- 1.5 Spectrum commons ... 5
- 1.6 Motivation ... 6
- 1.7 Aim and research question ... 7
- 1.8 Structure of thesis ... 8

Chapter 2 Spectrum management: Perspective from practice and literature ... 9
- 2.1 Spectrum management by the ITU ... 9
- 2.2 Functional responsibilities and requirements for spectrum management ... 11
- 2.3 The rights to use frequency ... 15
- 2.4 Summary ... 31

Chapter 3 Methodology ... 33
- 3.1 Type of data and data collection method ... 33
- 3.2 Research design ... 35
- 3.3 Approach ... 36
- 3.4 Summary ... 37

Chapter 4 The history of spectrum assignment in Thailand ... 39
- 4.1 The context of examining the history of spectrum management in Thailand ... 39
- 4.2 No Radio Act ... 40
- 4.3 The Radio Act –command-and-control ... 41
- 4.4 The National Frequency Management Board –command-and-control ... 44
- 4.5 The National Telecommunications Commission ... 49
- 4.6 Self-regulated – spectrum commons ... 51
- 4.7 Discussion ... 60

- 4.8 Summary ... 63

Chapter 5 Advantages and disadvantages of spectrum commons in Europe ... 65
- 5.1 Examining literature and consultation ... 65
- 5.2 Disadvantages of using spectrum commons ... 66
- 5.3 Advantages of using spectrum commons ... 67
- 5.4 Examining advantages and disadvantages ... 68
- 5.5 Issues for spectrum commons implementation ... 69
- 5.6 Interpreting the results of the main stakeholders and discussion ... 70
- 5.7 Summary ... 71

Chapter 6 Conceptual benefit and cost analysis ... 73
- 6.1 Benefit and cost analysis ... 73
- 6.2 Valuation of unlicensed applications ... 74
- 6.3 Engineering value ... 76
- 6.4 Outline of the valuation of spectrum commons for Thailand ... 77
- 6.5 Summary ... 81

Chapter 7 Findings and future research ... 83
- 7.1 Findings ... 84
- 7.2 Generalizability: Can spectrum commons be applied in other countries? ... 88
- 7.3 Future research ... 88

References ... 89

List of abbreviation ... 94

List of figures

Figure 1. Options for spectrum assignment ... 3
Figure 2. Wi-Fi-enabled, application-specific devices shipment forecast ... 6
Figure 3. Regions in Radio Regulations 2008 ... 10
Figure 4. The working parts of an institutional analysis ... 16
Figure 5. Three levels of institutional analysis ... 19
Figure 6. Number of WLAN routers 1996-2004 ... 58
Figure 7. Number of WLAN routers 2001-2010 ... 59
Figure 8. Role of actors in spectrum assignment in Thailand ... 60
Figure 9. Stakeholders of spectrum commons ... 70
Figure 10. Relationship between the project and the private, efficiency, and reference group net benefits ... 73
Figure 11. Approach to projecting the economic value of license-exempt applications ... 75
Figure 12. Value of spectrum commons (co-location with existing service) ... 78
Figure 13. Value of frequency in the case of trade-off between licensed and unlicensed spectrum ... 79
Figure 14. Stakeholder of spectrum commons (cf. Figure 9) ... 86

List of tables

Table 1. Categories of goods ... 4
Table 2. Research question ... 7
Table 3. Radio frequency propagation ... 10
Table 4. Example of table of frequency allocation ... 11
Table 5. Property rights of common-pool resources ... 20
Table 6. Bundles of rights associated with position ... 21
Table 7. Level of action and stakeholders ... 23
Table 8. Frequencies of ISM bands 5.138 and 5.150 ... 24
Table 9. Example of Thailand's Table of Frequency Allocation ... 25
Table 10. CEPT power level ... 25
Table 11. FCC general limits for any intentional transmitter ... 26
Table 12. Bundles of rights associated with telecommunication stakeholders ... 28
Table 13. The rights to use frequency ... 29
Table 14. Period before the Radio Act ... 41
Table 15. Period of Radio Act ... 44
Table 16. National Frequency Management Board meetings ... 46
Table 17. Period of National Frequency Management Board ... 48
Table 18. Period of the National Telecommunications Commission ... 51
Table 19. Period of self-regulated spectrum commons ... 60
Table 20. Thailand's frequency assignment profile ... 61
Table 21. Advantages and disadvantages of using spectrum commons ... 65
Table 22. SWOT analysis of advantages and disadvantages of using spectrum commons ... 68
Table 23. Spectrum value of unlicensed applications in the United Kingdom ... 75
Table 24. Benefit and cost of public access Wi-Fi and home data networking ... 80
Table 25. Bundles of rights associated with telecommunication stakeholders (cf. Table 12) ... 85
Table 26. The rights to use frequency (cf. Table 13) ... 85

Chapter 1 Introduction

Nowadays, telecommunication devices and services are mandatory tools in both business and the household. Wireless technology, in particular, with its increasing mobility, is the key. Wireless devices using radiocommunication are part of day-to-day activities, ranging from garage openers, remote controls, toys, closed circuit television (CCTV), navigation systems (land, air, and sea), earphones, cordless telephones, and card readers, to Internet connection (Wi-Fi) in smart phones. Most of these are low-power, unlicensed devices whose uses are increasing. The unlicensed devices use frequency or spectrum as a carrier of communication and share frequency or spectrum with other devices or uses. Spectrum is a limited resource. Understanding the nature of spectrum will therefore help to use it efficiently.

1.1 What is spectrum?

Spectrum is an electromagnetic wave comprising electric and magnetic fields that can be characterized as properties of light and particles. It can also be referred to as radio, radio wave, radio frequency, or frequency. Spectrum refers to the subset of the electromagnetic wave spectrum that is below 3,000 GHz (ITU, 2008). According to the propagation characteristic, spectrum using higher frequencies reaches shorter distances but has a larger carrying capacity. Conversely, spectrum using lower frequencies reaches longer distances but has a lower carrying capacity. This characteristic limits the application of spectrum. The spectrum is a non-depletable resource. It can be reused by dividing it into frequencies, time, angle of arrival, polarization, geography, and uses. Spectrum cannot be controlled for transmission. Due to its nature, transmission will propagate across country borders until the power runs out. The spectrum services are not only useful in telecommunications, fixed and mobile services, but also in broadcasting, satellite, maritime, and aeronautical services.

1.2 Why manage spectrum?

In terms of technical aspects, the spectrum is similar to roads carrying traffic. It needs rules or regulations to control the use of each application to prevent disorder and harmful interference. In addition, proper spectrum management can maximize spectrum use by allowing for the maximum number of users, while keeping interference and congestion manageable.

In terms of social aspects, in some countries, such as Thailand, spectrum is a national resource of public interest. As stated in the Thai Constitution 2550, there must be an independent regulatory body with the duty of distributing frequency and supervising its use. There shall be regard for maximum public benefit at national and local levels in education, culture, State security, other public interests, and fair and free competition, including encouraging the public to participate in the management of public mass communication. A country typically has a regulatory authority. Such an authority is denoted by law, i.e., administrator, national regulatory authority, or regulator.

In terms of economics, spectrum is a scare resource and limited by its frequency band, time, and place. The spectrum can be used for different purposes or services. The different services of spectrum make it similar to other goods that follow supply and demand. Demand for spectrum is created by the users, and supply of spectrum is provided by the regulator. A particular aspect of spectrum, from an economic point of view, is that it is non-excludable, non-depletable, and subject to congestion problems. It therefore has some properties that are similar to public goods, although it is not purely public goods, as will be explained below.

1.3 How is spectrum managed?

With regard to the propagation of spectrum, there are three levels of spectrum management: allocation, allotment, and assignment. Allocation[1] and allotment[2] are designed at international level, while assignment is the responsibility of national agencies. Management at international level is by the International Telecommunication Union (ITU), a United Nations specialized agency, through issuing Radio Regulations (RR) via the World Radiocommunication Conference (WRC) to harmonize the allocation of frequency bands with radiocommunication services.

Harmonization can also be regional. Active regional organizations are the Asia Pacific Telecommunity (APT), the European Conference of Postal and Telecommunications Administrations (CEPT), the Inter-American Telecommunication Commission (CITEL), the African Group, and the Arabic Group. They help to consolidate and compromise different ideas within and across regions.

The national assignment[3] and the modes of assignment vary by country. Spectrum may be assigned by an administrator, national regulatory authority (NRA), or relevant ministry, depending on the laws of the country. Before the spectrum is assigned, the NRA normally checks the availability of spectrum, existing users, related regulations (national and international), and suitable technical characteristics imposed on the use of spectrum and radiocommunication equipment.

All obligations imposed by the authority must comply with the ITU RR, however, to avoid harmful interference between countries and maintain priority on claims on using this spectrum. Within their territory, the regulators have the right to manage the spectrum by their own authority but not to interfere with neighboring countries. They set up coordination and cooperation with neighboring countries to help manage interference.

1.4 What is spectrum assignment?

Spectrum assignment policy is limited to wireless or radiocommunication in a national territory. Each country has its own sovereignty. Spectrum assignment is a subset of spectrum management. Spectrum assignment is one of most important functions of spectrum management, beside other functions, such as planning and regulation, financing, allocation and allotment, national liaison and consultation, international and regional cooperation, standards, specifications and equipment authorization, monitoring, and enforcement (ITU, 2005).

Spectrum management policy is a subset of telecommunications policy. Telecommunications policy includes technical, economic, and social aspects. It overlaps the natural sciences (technic) and social science (economics and society). Telecommunications policy often, but not always, deals with institutional analysis. An institutional analysis is the analysis of an institutional arrangement or set of rules governing the number of decision-makers, allowable actions or strategies, authorized results, transformation from internal to decision situations, and linkages between decision situations (Kiser & Ostrom, 1982). Telecommunications policy also includes economic analysis of, for example, the social

[1] *Allocation* (of a frequency band)*:* Entry in the Table of Frequency Allocations of a given frequency band for the purpose of being used by one or more terrestrial or space *radiocommunication services* or the *radio astronomy service* under specified conditions. This term shall also be applied to the frequency band concerned. (International Telecommunication Union – Radio Regulations 2008)

[2] *Allotment* (of a radio frequency or radio frequency channel)*:* Entry of a designated frequency channel in an agreed plan, adopted by a competent conference, for use by one or more administrations for a terrestrial or space *radiocommunication service* in one or more identified countries or geographical areas and under specified conditions. (International Telecommunication Union – Radio Regulations 2008)

[3] *Assignment* (of a radio frequency or radio frequency channel)*:* Authorization given by an administration for a radio *station* to use a radio frequency or radio frequency channel under specified conditions. (International Telecommunication Union – Radio Regulations 2008)

value or value to private players of the spectrum. The regulator may impose conditions on spectrum to make it excludable, which in turn makes frequency use a specific right for a designated entity or person.

In the language of telecommunication planning, the regulator has the right to assign frequency to assignees. If the frequency is assigned to the specific entities, i.e., individuals and legal persons, it is called licensed frequency, in short, licensed. The entities that obtain this assigned frequency are named as licensees. If the frequency is not assigned to specific entities, in other words, assigned to the general public, it is called unlicensed frequency or, in short, unlicensed. A characteristic of licensees is that they have the exclusive right to use frequency. The unlicensed frequency does not carry this right however.

The typical approaches of spectrum assignment include command-and-control, market-based, and spectrum commons. There are two approaches to licensed frequency: the command-and-control and the market-based approach. These approaches grant the exclusive right to use frequency to licensees. Spectrum commons, however, is unlicensed. Brief details of each approach are described below.

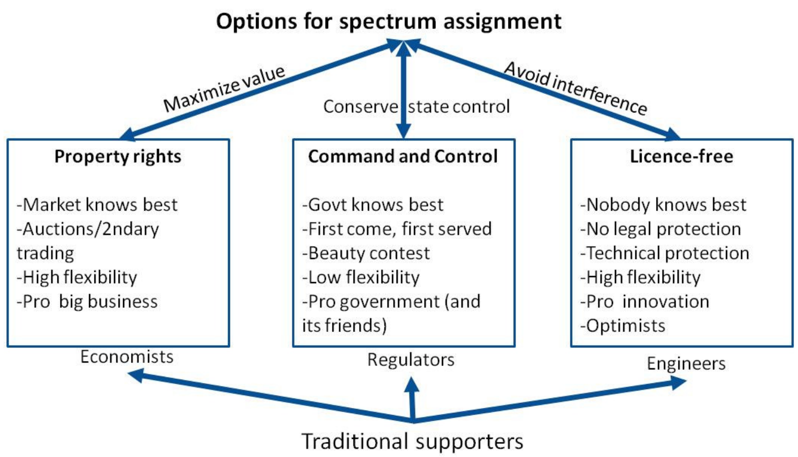

Figure 1. Options for spectrum assignment [4]

Historically, spectrum has been assigned by a command-and-control approach, an administrative approach in which the competent authority, mostly government, uses its power of discretion to grant an exclusive right of use of some frequency bands to assignees with conditions. These conditions include power limitation, antenna specification, and other technical requirements of radiocommunication equipment, mainly for the purpose of avoiding harmful interference. Under this approach, spectrum is assigned on a first come, first served basis. This process raises the issue of transparency. If spectrum usage is requested by government agencies, it is usually assigned.

There is consensus among economists, lawyers, and engineers, however, that the command-and-control approach is inefficient (Wang, 2009). The flexibility of the use of frequency under this

[4] Source: Geiss (2004)

approach is limited. All frequency operations, including the location, working frequency, bandwidth, output power, antenna gain, modulation technique, and technology, are decided by the NRA. When users want to adopt new technology, they have to go through an administrative process to be approved before implementation.

Technological development, together with increased spectrum demand, makes spectrum scarce. Hence, a market-based approach has been introduced in many countries, because, under this approach, it is believed that the market knows best. Here, spectrum is mostly assigned using an auction or secondary trading scheme. This approach creates more flexibility for regulators and operators to manage the spectrum and makes the process more transparent than a command-and-control approach.

The 3G auction in the UK in April 2000 was the largest auction so far. After BT had won the spectrum auction, however, the business was not commercially viable and the spectrum was sold to O2. Although the market-based approach can maximize spectrum efficiency in some cases, the outcome may be competition among strong financial parties to buy most of the available spectrum on the market. As a result, the market may become monopolized if the regulator does not have proper control - spectrum caps (limit to obtaining spectrum).

The characteristics of spectrum as goods depend on the approach to spectrum assignment, with the market-based approach treating spectrum as goods that can be owned and the commons approach treating spectrum as being without ownership rights. In general, goods can be classified into two groups: private and public goods. Public goods are non-excludable goods that an individual can consume without prohibiting others from consuming. Private goods are excludable goods that an individual can consume while prohibiting others from consuming. The cost of exclusion for public goods is therefore higher than the cost of exclusion for private goods.

Goods can be further refined into four groups: private goods, toll goods, common-pool goods, and public goods. Each group has different characteristics defined by the level of subtractability and the cost of exclusion (Kiser & Ostrom, 1982). Table 1 shows four categories of goods.

Table 1. Categories of goods[5]

Level of subtractability / Cost of exclusion	High	Low
Low	Private goods	Toll goods
High	Common-pool goods	Public goods

The level of subtractability is defined by the characteristics of the goods that can be separated. Private goods can be separated by individual consumption, but public goods cannot. For example, rice can be consumed from a bowl by taking a spoon as private goods. Air in the park is a public good. People can breathe, but no one can separate air for individual consumption.

Private goods, such as bread, milk, automobiles, and haircuts, have a low cost of exclusion and a high level of subtractability. Toll goods, such as, theaters, nightclubs, telephone service, cable TV, electric power, and libraries, have a low cost of exclusion and a low level of subtractability. Common-pool goods have a high cost of exclusion and a high level of subtractability. Examples of common-pool goods include water pumped from a ground basin, fish taken from an ocean, and crude oil extracted form an oil pool. Public goods, such as peace and security of a community, national defense, mosquito

[5] Source: Kiser and Ostrom (1982, p. 198), Table 7.1

abatement, air pollution control, and weather forecasts, have a high cost of exclusion and a low level of subtractability (Kiser & Ostrom, 1982).

1.5 Spectrum commons

The exclusive right to use frequency granted by a regulator, with a command-and-control or market-based approach, transforms spectrum into private goods. The regulator therefore limits the use of frequency to licensees who can access the frequency. In the command-and-control approach, the regulator holds all the rights to the use of the frequency. The regulator has full control over licensees, creating inflexibility in terms of changing to new technology. Under the market-based approach, the regulator allows licensees to transfer frequency to other parties by a market mechanism that will be discussed in terms of the institution of spectrum commons and the bundle of rights to use frequency in Chapter 2. The market mechanism may also raise an unexpected auction fee and affect long-term investment.

On the other hand, the non-exclusive right to use frequency unlicensed can be treated as common-pool goods. In this situation, no one has an exclusive right to use frequency. Everyone can use the same frequency under some constraints. Nevertheless, services under spectrum commons cannot claim protection, because spectrum commons is open to anyone with any application, under the given limitations. For example, in the use of a Wi-Fi hotspot in a conference room, anyone who has a Wi-Fi device can access the Wi-Fi hotspot for conference material. It is hard to prohibit or exclude other participants from accessing the Wi-Fi hotspot. When the use of the Wi-Fi reaches its maximum capacity, however, there is no more access to the Wi-Fi hotspot, because all of the frequencies are occupied.

In the Radiocommunication Act of Thailand, no one can use any radiocommunication device without permission from the regulator. For example, prior to 1996, there was no use of Wireless Local Area Networks (WLANs) in Thailand, because the regulator did not authorize the use of WLANs. In 1996, the regulator granted authorization of WLANs with relevant radiocommunication licences. The use of WLANs in Thailand began in a limited area, because it required relevant radiocommunication licences. Once the WLAN was included in the portable computer and mobile phone chipset, mass production of WLAN devices rendered the price of WLAN devices cheaper. The use of WLAN devices then increased. The regulator realized that relevant radiocommunication licences limited the use of WLANs. In 2004, the regulator declared that the use of radiocommunication devices in the 2400-2500 MHz band with power up to 100 milliwatts (equivalent isotropibcally radiated power, e.i.r.p.) was exempted from all radiocommunication licences.

Here, the regulator assigns specific frequency as spectrum commons, also known as unlicensed band, collective use or license-exempted. Regulators impose constraints on devices in terms of power limitation, frequency, and necessary technical specification to avoid harmful interference.

Most short-range devices (SRDs) use the industrial, scientific, and medical (ISM) applications band, but not all applications become widely used. The phenomenon of the expansion of Wi-Fi devices is growing around the world, with examples such as the laptop, personal device accessories (PDAs), mobile phones, and printers. Moreover, there is ongoing growth in Wi-Fi-enabled devices, which will reach almost 300 million in 2010, according to forecasts by Celine (2008). Figure 2, obtained from Celine (2008), shows the growth in Wi-Fi-enabled devices.

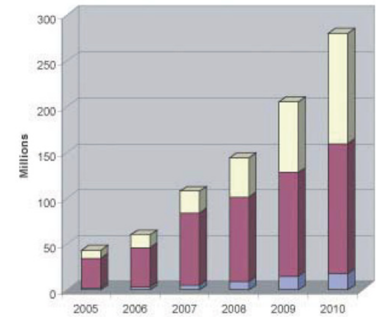

Figure 2. Wi-Fi-enabled, application-specific devices shipment forecast[6]

In general, spectrum commons has its advantages and disadvantages. Spectrum commons has many advantages compared with other approaches, including lowering the entry barrier for new entrants, lowering the administration cost, increasing social benefit, creating innovation, and stimulating demand. Spectrum commons also has several disadvantages, however, e.g., irreversibility of frequency, overuse, and difficulty estimating demand.

The value of spectrum commons can help regulators determine the optimal time to implement spectrum commons. The concept of the benefit and cost analysis helps find the value of spectrum commons. The projection of benefits and costs in the future predicts the value of spectrum commons in the future and discounts it to the current value of spectrum commons.

1.6 Motivation

The traditional command-and-control approach is inefficient because it is inflexible and unable to cope with emerging technologies. The market-based approach limits the number of frequency users to those who pay most. The characteristic of the exclusive right to use frequency limits the number of people who can access the frequency. Spectrum commons grants a non-exclusive right to use frequency however. This increases the number of people who can access the frequency.

In Thailand, most frequency assignments use a command-and-control approach, which is inefficient in terms of the frequency licensee distribution. Most frequency licensees are government agencies or state-owned enterprises. It is interesting to explore the Thai case, because the development of spectrum commons policy involves two separate processes: an authorization of the use of radiocommunication devices and an exemption of relevant radiocommunication licensed or unlicensed.

An exploration of the spectrum management institution provides a starting point for understanding the current situation in Thailand. The history of spectrum management in Thailand is explored to provide an understanding of the development of spectrum assignment. Three worlds of action, a property rights regime and natural resource concepts help to explain the interaction between stakeholders. An understanding of the current situation in Thailand offers potential for frequency assignment for spectrum commons.

[6] Source: Celine (2008)

The investigation into the public consultation of the Radio Spectrum Policy Group (RSPG) in 2008 helps to understand the situation of spectrum commons in European countries. The advantages and disadvantages of spectrum commons are reflected in the stakeholder's interest. It is a European example that will be adjusted for use in Thailand, in terms of a suitable time to implement spectrum commons.

The indicator of spectrum commons implementation is the valuation of the spectrum commons. The benefit and cost analysis is the concept to measure the valuation of the spectrum commons. Moreover, the example valuation of spectrum commons in the UK in 2006 provides a practical procedure to measure spectrum commons.

To measure the value of spectrum commons in Thailand, the adjusted framework and method will be applied to suitable and available information. The output from the valuation of spectrum commons will provide important information for the regulator on whether to license or unlicense a specific frequency band.

1.7 Aim and research question

The purpose of this licentiate thesis is to examine the spectrum commons approach to spectrum assignment. The examined case is Thailand. The main research question is: **"What are the consequences of using spectrum commons for frequency assignment in Thailand?"**

The research problem is divided into three parts: conceptual, empirical, and analytical. The conceptual part deals with the right to use frequency and examines the framework associated with spectrum commons. The empirical part gathers information from history of spectrum management in Thailand and public consultation on spectrum commons in the context of European countries to explore the type of spectrum commons in Thailand and the advantages and disadvantages of spectrum commons. The analytical part uses the benefit and cost analysis concept on spectrum commons in Thailand.

In its approach to the main research question: "What are the consequences of using spectrum commons for spectrum assignment in Thailand?" the thesis addresses five research sub-questions; see Table 2.

Table 2. Research question

Main research question	**What are the consequences of using spectrum commons for spectrum assignment in Thailand?**
RQ.1	*What is a suitable framework for analyzing different types of spectrum commons?*
RQ.2	*What type of spectrum commons has been used in Thailand?*
RQ.3	*What are the advantages and disadvantages of spectrum commons in general?*
RQ.4	*How can the benefits and costs of spectrum commons be measured?*
RQ.5	*What are the implications of implementing spectrum commons in Thailand?*

RQ.1 looks at finding a framework to analyze different types of spectrum commons. Kiser and Ostrom (1982), and Field (1992) provide the three worlds of action as a framework to analyze spectrum commons. The five rights of the property regime by Schlager and Ostrom (1992) are also adopted in

order to find the interaction between the layer of the decision-maker and the right to use frequency. The comparison between property rights regimes and natural resources in the Maine lobster industry (Schlager & Ostrom, 1992) addresses the right to use frequency.

RQ.2 looks at the use of the framework developed in RQ.1 to understand the institution of spectrum commons and its application to Thailand so far. The exploration of the history of spectrum assignment also helps the understanding of spectrum commons and the right to use frequency in Thailand. These are important premises for identifying possibilities for implementing spectrum commons.

RQ.3 looks at the advantages and disadvantages of spectrum commons from the public consultation of the Radio Spectrum Policy Group (RSPG) in November 2008 in the European Union to obtain the current thoughts of stakeholders that built up a general understanding regarding the use of spectrum commons.

RQ.4 is the benefit and cost analysis of the spectrum commons concept from Campbell and Brown (2003), Indepen (2006), and Sweet et al. (2002) to build a framework that can be used to measure spectrum commons in Thailand. Campbell and Brown (2003) provide the framework of the benefit and cost analysis in terms of the undertaken project. The framework applies mostly to whether a company intends to undertake a specific project. The comparison between the current values of whether to undertake the project provides the decision-makers with important information. The values without undertaking the project are obtained from the same allocation resources for alternative uses. Indepen (2006) provides a practical method to measure the unlicensed application in the United Kingdom in 2006, based on the ten most important applications among a hundred applications of unlicensed devices. Sweet et al. (2002) provide the valuation of the spectrum using the engineering value – cost saving in the infrastructure of the network operator.

RQ.5 covers the implications of implementing spectrum commons in Thailand.

The five research questions are intended to contribute to increased understanding of using spectrum commons and to the effectiveness of using spectrum commons in Thailand.

The scope of this thesis focuses on understanding the institution of spectrum assignment, including the decision-maker and decision situation – the institutional arrangement, events, and community – in order to find possibilities for implementing spectrum commons for spectrum assignment in practical ways in Thailand. It also covers the advantages and disadvantages of implementing spectrum commons in the context of Europe. This thesis also has an economic perspective on the value of the spectrum. By using the concept of the benefit and cost analysis, the value of spectrum commons has been identified as important information for the regulator to decide whether to license or unlicensed the specified frequency band.

1.8 Structure of thesis

The licentiate consists of seven chapters, starting with the Introduction in Chapter 1, which includes the background, and research question of this research. Chapter 2 provides spectrum management from both the ITU and the rights to use frequency from academic papers, addressing a suitable framework for spectrum commons in RQ.1. Chapter 3 deals with the methodology of the thesis. Chapter 4 presents the development of spectrum management in Thailand, corresponding to RQ.2. Chapter 5 is about the advantages and disadvantages of spectrum commons, corresponding to RQ.3. Chapter 6 concerns the benefit and cost analysis concept, corresponding to RQ.4. Chapter 7 addresses the findings, corresponding to RQ.5, and the conclusion of this thesis.

Chapter 2 Spectrum management: Perspective from practice and literature

This chapter addresses a suitable framework for analyzing the spectrum commons and elaborates on the first research question. Exploring the perspective from the ITU and relevant literature, in practice, helps to address the appropriate framework for understanding spectrum commons.

Background

Electromagnetic waves consisting of electric and magnetic components were first explained by James Clerk Maxwell in the 19th century. Their dualistic properties relating to light and particle motion were discovered in the early 20th century, when such waves also began to be used for communication. Radio waves are now also referred to as frequency, radio frequency, radio spectrum, or simply spectrum. This thesis only discusses the wave properties of frequency and wavelength.

An important characteristic of spectrum is that higher frequencies reach shorter distances but have larger carrying capacity. Once frequency is transmitted, it will propagate until its power has dissipated. Physical boundaries cannot stop spectrum at the border of a country. Spectrum management activities have therefore been performed internationally by the United Nations agency ITU.

2.1 Spectrum management by the ITU[7]

The ITU uses the RR as a tool to manage spectrum internationally. The RR is revised every three to four years by WRC. The current RR is RR 2008, which was revised by WRC2007. RR 2008 defines the usable frequency up to 3,000 GHz and divides the uses of frequency into services. There are about 40 services in RR 2008, including terrestrial and space services such as broadcasting, mobile, satellite, maritime, aeronautical, fixed, and earth exploration services. Each service can be shared as primary and secondary services. The primary service uses the capital letter and secondary service uses the lower case letter in the Table of Frequency Allocation in Article 5, RR. Moreover, the secondary service must not cause harmful interference to the primary service and cannot claim protection from harmful interference by the primary service and other secondary service[8].

The RR also divides the world into regions. The regions are defined by lines A, B, and C. Region 1 covers all the European and African countries, Region 2 covers North and South America, and Region 3 covers Asia and Australasia. For example, Sweden is in Region 1, the USA is in Region 2, and Thailand is in Region 3. The regions in RR 2008 are shown in Figure 3.

Reuse of frequency has an indirect relationship with coverage area. A large coverage area has low reuse of frequency, and a small coverage area has high reuse of frequency.

[7] This section is based on the ITU handbook of spectrum management 2005, but it is written in the author's own words.
[8] 5.23-5.32, Article 5, Radio Regulations (2008).

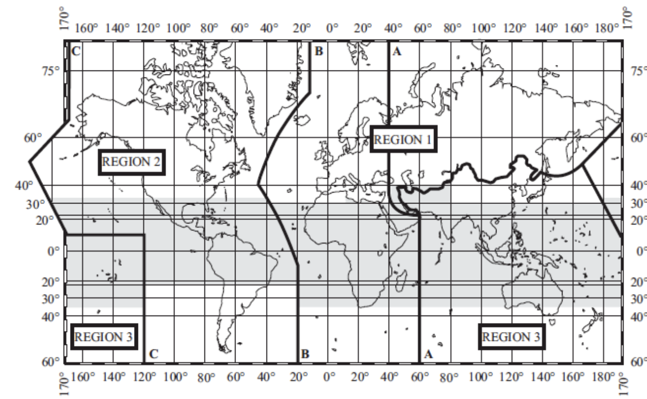

Figure 3. Regions in Radio Regulations 2008[9]

The frequencies are divided into ranges or bands. A wavelength equals its speed of propagation (normally that of light) divided by its frequency ($\lambda = c/f$). Each range of frequency has its own propagation characteristics, as in cases like sea-surface communication, stratospheric scattering, and long-range communication. Table 3 shows the propagation in different frequency bands.

Table 3. Radio frequency propagation[10]

Band	Frequency	Range	Uses	Bandwidth	Interference
VLF	3-30 kHz	1000s of km	Long-range radio navigation	Very narrow	Widespread
LF	30-300 kHz	1000s of km	Same as VLF strategic communications	Very narrow	Widespread
MF	0.3-3 MHz	2000-3000 km	Same as VLF strategic communications	Moderate	Widespread
HF	3-30 MHz	up to 1000 km	Global broadcast and Point–to-Point	Wide	Widespread
VHF	30-300 MHz	200-300 km	Broadcast, PCS, Mobile, Wan	Very wide	Confined
UHF	0.3-3 GHz	< 100 km	Broadcast, PCS, Mobile, Wan	Very wide	Confined
SHF	3-30 GHz	Ranges from 30 km to 2000 km	Broadcast, PCS, Mobile, Wan, Satellite Communication	Very wide up to 1 GHz	Confined
EHF	30-300 GHz	Ranges from 20 km to 2000 km	Microcell, Point-to-Point, PCS, and Satellite, (Personal Communication Services: PCS)	Very wide up to 10 GHz	Confined

[9] Information obtained from 5.2-5.9, Article 5, Radio Regulations (2008)
[10] Table obtained from http://www.ictregulationtoolkit.org/en/Section.2658.html

Spectrum-reusable characteristics vary with service, frequency, location, time, and transmitter power. The following section explains the Table of Frequency Allocation in RR 2008 and represents the allocation of frequency.

Table 4. Example of table of frequency allocation

410-460 MHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
420-430	FIXED MOBILE except aeronautical mobile Radiolocation 5.269 5.270 5.271	
...	...	
432-438 AMATEUR RADIOLOCATION Earth exploration-satellite (active) 5.279A 5.138 5.271 5.272 5.276 5.277 5.280 5.281 5.282	**432-438** RADIOLOCATION Amateur Earth exploration-satellite (active) 5.279A 5.271 5.276 5.277 5.278 5.279 5.281 5.282	

Table 4 shows the frequency allocation in the 410-460 MHz band. It consists of sub-bands 420-430 and 432-438 MHz. The 420-430 MHz band is worldwide allocation, i.e., the same allocation for all three regions. There are two primary services, indicated by capital letters: fixed and mobile except for aeronautical mobile. There is a secondary service indicated by a lower case letter: radiolocation. There are three footnotes for all the services: 5.269, 5.270, and 5.271.

In the other band, 432-438 MHz, frequency is divided into two sections. The first section is on the left, with frequency uses only in Region 1. There are two primary services: amateur and radio location. There is a secondary service: earth exploration-satellite (active) and it has 5.279A as a specific footnote. There are eight footnotes for all the services, e.g., 5.138 and 5.271. The second section is on the right, with frequency uses in Regions 2 and 3. There is one primary service: radiolocation. There are two secondary services: amateur and earth exploration-satellite (active). Only earth exploration-satellite (active) has 5.279A as a specific footnote. There are seven footnotes for all the services, e.g., 5.138 and 5.271.

Furthermore, the RR works as an international treaty that all ITU Member States are obliged to follow. It is essential to understand the Table of Frequency Allocation in the RR to implement the correct spectrum assignment.

Allocation and allotment are assigned by the ITU, but spectrum is assigned by the NRAs. Besides allocation and allotment, the ITU also regulates by adding footnotes to encourage the use of spectrum commons and improve the efficiency of frequency usage.

2.2 Functional responsibilities and requirements for spectrum management

The handbook, National Spectrum Management (ITU, 2005), also provides functional responsibilities and requirements of spectrum management, as follows;

a) Spectrum management planning and regulations;

b) Allocation and allotment of frequency bands;

c) Frequency assignment and licensing (including non-licensing allocations);

d) Spectrum management financing, including fees;

e) Standard, specifications, and equipment authorization;

f) Spectrum monitoring;

g) Spectrum regulation enforcement: inspections and investigations;

h) International and regional cooperation including frequency coordination and notification;

i) National liaison and consultation; and

j) Spectrum management support function including administrative and legal, computer automation, spectrum engineering, and training.

Spectrum management planning and regulations

The spectrum management organization should take the advancement of technology as well as the social, economic, and political realties into the development of the implementation plans, regulation, and policies. The Table of Frequency Allocation is the output of the planning and policy-making effort, which reflects the various radio services or uses. In the event of competing uses or interests, the spectrum management organization should determine the use or uses that would best serve the public and government interest and how to share the spectrum.

In order to allocate frequency, the following factors should be taken into account: public and government needs, technical considerations, and apparatus limitations. Public and government needs and benefit considerations are a requirement of the service for radio frequencies, the probable number of people who will benefit from the service, the relative social and economic importance of the service, the probability of establishment of the service, the degree of public support expected for the service, the impact of the new applications on existing investment in the proposed frequency band, and government requirements for security, aeronautical, maritime, and science services. Technical considerations are the need for the service to use the frequency with particular propagation characteristics and compatibility within and outside the selected frequency band, the amount of frequency required, the signal strength required for reliable service, the amount of interference that is likely to be encountered, and the viability of the technology. Apparatus limitations are the upper useful or higher limit of radio frequency, operating characteristics of transmitters, types of antenna availability and practical limitations, receiver availability, and characteristics.

Allocation and allotment of frequency bands

The national allocation table should represent the current national frequency assignment as well as the national plan for future use. The national allocation table provides details of current national uses, including all data on terrestrial and space services and their applications. Each country uses the ITU allocation table as guidance for the region allocation to which the particular country belongs. It is not necessary for every country to follow exactly the ITU table, which deviates to a limited degree to satisfy national requirements, if it does not cause harmful interference and protection is not required. Reasons to follow the ITU table are availability of equipment in the region according to the agreement of the allocation table, minimized interference from neighboring countries, conformity of equipment in the regional table, and global service such as aeronautical, maritime, and satellite service.

Normally, existing spectrum users oppose changes to frequency allocation tables because of the many costs incurred, including equipment costs, learning costs, and loss of customers. In order to develop national table frequency allocation, the spectrum management organization should follow the ITU Table of Allocation as closely as possible, develop the plan based on current use, not impede the advancement of future technology, allow efficient allocation for government and security, and align with other countries' allocation.

Frequency assignment and licensing (including non-licensing allocations)

Frequency assignment is routine work for spectrum management organizations. Analyses select the most suitable frequencies for radiocommunication systems and coordinate proposed assignments with existing ones.

The frequency assignment function includes the licensing function, national legislation, and regulations and related procedures to control the operation of stations by: 1) examining license applications and related documents to determine the licensing eligibility of the application and the technical acceptability of the radio equipment proposed; 2) assigning the radio call signs to individual stations; 3) issuing licences and collecting fees, if appropriate; 4) establishing methods for administering system or network licences, as appropriate; 5) renewing, suspending, and canceling licenses, as appropriate; and 6) conducting examinations of operators.

The related procedures should specify information to be supplied with frequency applications to allow spectrum managers to perform better. Unnecessary or difficult procedures may discourage radiocommunication development.

Spectrum management financing

Spectrum is a natural resource that is a valuable national asset and typically controlled by government. The primary objective of the spectrum management fee policy should be to: 1) improve the telecommunication infrastructure through the efficient and effective use of radio spectrum; 2) support spectrum management infrastructure via administrative fees for all users; 3) encourage spectrum efficiency by providing appropriate incentives, assessing the fees according to the amount of bandwidth usage and the number of transmitters in the network; 4) reflect economic principles and radio standards required in the RR and ITU-R Recommendations; and 5) release inefficient and ineffective use of spectrum.

License fees include application fees, construction permit fees (installation fee), spectrum usage or regulatory fees, operator certificate fees, and administrative fees.

Standard, specifications, and equipment authorization

In general, the spectrum management organization should follow the technical characteristics of the station in Article 3 of the RR, the maximum value for frequency tolerance and spurious domain emission, and other technical standards in Appendices 2 and 3 of the RR in order to avoid interference. Thus, administrators ensure that all the equipment characteristics within their territory conform to these regulations.

There are two main functions of the standard: standard setting and standard compliance. The standard setting can be national or international depending on interests. Standard compliance spectrum management organization, however, can be by the administration itself or another party and comprises the compliance testing requirement and other administrative procedures related to compliance.

Administrative procedures, such as national acceptance of equipment test results from other administrations, self-certification, or private sector testing laboratories, help to reduce paperwork and cost, but spectrum management organization ensures that radiocommunication equipment meets standard requirements.

As for self-certification, the spectrum management organization should have its own test laboratory to perform spot checks, including transmitting and receiving equipment, laboratory testing according to type approval procedures, maintenance and calibration of laboratory test equipment, and other inspection and monitoring equipment, acceptance evaluation of equipment for inspection and monitoring, and outfitting special/purpose monitoring vehicles, and calibration of equipment to be fitted in such vehicles.

Equipment authorization is part of the global standard setting that helps avoid fragmentation of the market for the benefit of both consumers and industry. The ITU maintains principles of consensus, transparency, openness, impartiality, maintenance, public access to deliverables, consistent rules, efficiency, accountability, and coherence in order to maintain successful development of the global standard.

Spectrum monitoring

Spectrum monitoring feeds back to spectrum management, i.e., good frequency planning and assignment reduce the possibility of harmful interference. Spectrum monitoring responsibilities include routine monitoring of a wide range of frequency and special tasks to find illegal frequency uses or harmful interference. Monitoring provides actual use of spectrum as information for frequency assignment in order to compare spectrum planning with reality. The consequences are the adjustment of spectrum planning.

Information from monitoring also supports the enforcement approach to the ideal of interference-free, properly authorized, and harmonized use of the spectrum. Monitoring can also be used to identify and measure interfering signals, verify technical and operational characteristics of radiated signals, and detect illegal transmitters.

Spectrum regulation enforcement: inspections and investigations

The purpose of the enforcement inspection is to strengthen spectrum management processes to reflect the effective management of the spectrum, depending on the ability to control its use through the enforcement of relevant regulations. The authority should grant appropriate authority to the spectrum management organization in order to enforce regulation and set appropriate penalties.

Enforcement, inspection, and investigation should work closely with monitoring, assignment, and licensing units to collect information to investigate interference complaints, illegal operation, and operations not in accordance with the radio station license, collect information for legal prosecution and law enforcement, ensure that the radio station complies with national and international regulations, and take technical measurements.

International and regional cooperation including frequency coordination and notification

When interference cannot be contained nationally, international and regional cooperation, in terms of activities within international bodies, and bilateral and multilateral discussions should be conducted. The cooperation is conducted by ITU world and regional radiocommunication conferences (WRCs and RRCs), together with the three ITU Sectors (Radiocommunication, Telecommunication

Standardization, and Telecommunication Development). Moreover, the notifications from Member States to the Radiocommunication Bureau help to coordinate frequency authorization via the Bureau's International Frequency Information Circular (BR IFIC).

Moreover, discussions in other international organizations, such as the International Civil Aviation Organization (ICAO), the International Maritime Organization (IMO), the World Meteorological Organization (WMO), and the Special Committee of the International Electrotechnical Commission for Interference (CISPR), help to settle interference issues via negotiation. The administration must therefore also give consideration to participating in these organizations.

Bilateral cooperation between countries, especially neighboring countries, in terms of a joint committee, help to relieve interference at operational level.

National liaison and consultation

The spectrum management organization should set up liaison units for communication and consultation with users, including businesses, telecommunication industries, the government and the general public to disseminate information on policy, rules and regulations, and practices and provide mechanisms for feedback to evaluate consequences. A liaison unit, as a focal point of spectrum management organization, maintains the media relations, issues public notices, conducts meetings, and acts as a mediator to resolve interference problems. The form of the liaison unit ranges from informal to formal contact and depends on the tradeoff between efficient dialogue and quick results, and transparent administrative procedures that ensure fair and impartial treatment.

Spectrum management organizations are encouraged to establish procedures for individuals and organizations to revise spectrum regulations and assignment or allocation to meet the needs of the national constituency.

The spectrum management support function includes administrative and legal support, computer automation, spectrum engineering, and training

Spectrum engineering support provides adequate evaluation information, capabilities, and choices in the field of technology and engineering analysis of technical factors. Administrative, legal, and computer support provides an efficient facility for the spectrum management organization.

To conclude this section, the ITU provides the overall functional responsibility and requirements for spectrum management organizations, ranging from planning, assignment, monitoring, enforcement, and the supporting unit. The next section concentrates on the rights to use frequency in each spectrum assignment approach, including command-and-control, market-based and spectrum commons, which can be divided into three levels: constitutional choice, collective choice, and operational level.

2.3 The rights to use frequency

As mention in Section 1.4, Chapter 1, an overview of spectrum assignment is given, including three typical approaches: command-and-control, market-based, and spectrum commons. Each approach has a different set of rights – the particular actions that are authorized (V. Ostrom, 1976) – to use the frequency, depending on the rules that refer to the prescriptions that create authorizations (Schlager & Ostrom, 1992).

The adoption of three economic institutions: the operational, institutional, and constitutional level from Field (1992), or the three worlds of action by Kiser and Ostrom (1982): the operational,

collective choice, and constitutional choice level of action, are considered below as a framework to address spectrum commons. Kiser and Ostrom (1982) provide the metatheoretical framework to explain the relationship between institutional arrangements and the individual in terms of the transformation of rules into individual behavior.

Institutional arrangements are rules used by individuals to determine who and what are included in decision situations, how information is structured, what actions can be taken and in what sequence, and how individual actions will be aggregated into a collective decision (Kiser & Ostrom, 1982, p. 179). In other words, this framework explains phenomena attributed by the aggregation of individual actions that an individual decides to take or strategies (plans of action) based on situations and the individual. The situation depends on rules, events, and community. This framework also captures the dynamic situation by feedback from the phenomena that influence the community, situation, and individuals.

Five working parts of the institutional structure

There are five working parts in an institutional structure: the decision-maker or individual, the community, the event (or goods and services), the institutional arrangement, and the decision situation. The results of the institutional structure are individual actions or strategies, and the aggregation of individual actions. The figure shows the interactions, which are explained below:

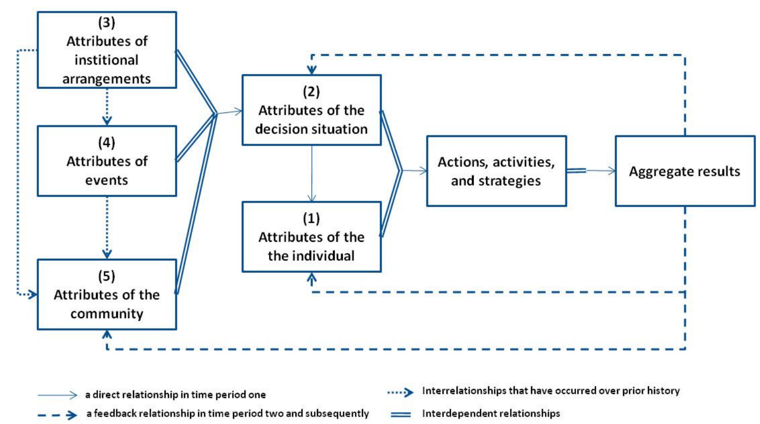

Figure 4. The working parts of an institutional analysis[11]

Attributes of an individual or decision-maker

When an individual wants to take an action or strategy, he or she must know the consequence of the action or strategy, or the outcome and value of the alternative actions or strategies. A tennis player makes a decision to charge at the net or wait for the ball bounce and use a groundstroke: the outcome of the action is different. In order to predict actions, a minimum of the following assumptions must be made: the level of information about decision situations, the valuation of potential outcomes, the alternative actions within the situation, and the process of calculation to act from alternative actions or strategies.

[11] Source: Kiser and Ostrom (1982, p. 187) Figure 7.1

Attributes of decision situations

The decision situation is determined from interdependent relationships. Relationships depend on more than one input from institutional arrangements, events, and the community. If the environment changes during the game, e.g., a new ball or racket, the decision situations change and influence the player's actions and strategies.

Institutional arrangement

An institutional arrangement is a set of rules to: 1) allow entry and exit conditions for participation; 2) determine allowable actions and outcome from interaction; 3) distribute authority among positions; 4) aggregate joint action; 5) provide procedural rules in complex situation; and 6) identify information constraints.

In order to implement rules, they should be enforced in parallel, depending on the attributes of the community.

The types of rule mentioned above are: 1) boundary rules, 2) scope rules, 3) position and authority rules, 4) aggregation rules, 5) procedural rules, and 6) information rules.

The rules of World Cup football provide an example of institution arrangements, as follows:

1) Boundary rules: which teams can enter the tournament, i.e., qualifying rounds for countries on continents and number of teams on each continent;
2) Scope rules: the size of the football field, ball, and goal area that allow actions and outcomes, and the number of players, the number of player changes, and the number of faults;
3) Position and authority rules: the rights and duties assigned to players, referees, linemen, and coaches;
4) Aggregation rules: how to score, wins, and losses;
5) Procedural rules: how teams proceed through the tournament competition in the first round, second round, third round, quarterfinal, semi-final, and final; and
6) Information rules: how information about the tournament rules, the opponent's strategies, and other matters are conveyed to players.

Attributes of events (public and private goods)

There are four attributes of events that individuals seek to produce and consume: jointness of use or consumption, exclusion, measurement, and degree of choice, in order to define private goods, tool goods, common-pool resources, and public goods.

Jointness of consumption explains separable and joint consumption goods. An individual consumes separable consumption goods, while more than one individual consume joint consumption goods. Joint consumption goods are defined as public goods that are non-subtractable, while separable consumption goods are private goods.

Exclusion attributes explain the difference between private and public goods. Public goods are non-excludable goods that an individual can consume without exclusion. Private goods are excludable goods that individual can consume with exclusion.

Measurement is the degree of packaging and unitization. Public goods are hard to package and unitize, while private goods are easy to package and unitize. The calculation of private goods is more precise than of public goods.

The degree of choice indicates the consumers' choices between public and private goods. Public goods are non-subtractable and non-excludable, so there is not much choice, while private goods can produce many choices from subtractable and excludable goods.

V. Ostrom and E. Ostrom (1997) use the level of subtractability and the cost of exclusion to classify private goods, tool goods, common-pool resources, and public goods. Private goods, such as bread, milk, automobiles, and haircuts, have a low cost of exclusion and a high level of subtractability. Toll goods, for example, theaters, night clubs, telephone service, cable TV, electric power, and libraries, have a low cost of exclusion and low level of subtractability. Common-pool resources, i.e., water pumped from a ground basin, fish taken from an ocean, and crude oil extracted from an oil pool, have a high cost of exclusion and a high level of subtractability. Public goods, such as peace and security of a community, national defense, mosquito abatement, air pollution control, and weather forecasts, have a high cost of exclusion and a low level of subtractability.

World Cup football is tool goods at a low level of subtractability because football players and spectators jointly benefit from football matches, whereas the cost of exclusion is low but managed by selling tickets to matches.

The community

The community includes all stakeholders that directly or indirectly affect the decision situation. The attributes of the community comprise levels of common understanding, common agreement, and distribution of resources.

After rules setting, the individual or member of the community must have a common understanding of the rules, i.e. the allowable actions and outcomes. Without a common understanding of the rules, the rules cannot be exercised.

With a common understanding of the rules, real actions must be evaluated. If community members obey the rules, allowable actions, and outcomes, the need for rules enforcement is low. If, on the other hand, the individual disagrees, the need for enforcement is high.

The distribution of the resource represents a situation on the market or in the community. If resources are distributed equally, a competitive environment arises. Otherwise, oligopoly or monopoly may occur.

Three worlds of action and three levels of analysis

Five working parts explain the relationships of individuals (decision-makers), the decision situation, the institutional arrangement, the events, and the community, as mentioned in Figure 4. The aggregated result not only influences or feeds back to the institutional arrangement in the same world of actions, but also influences the next world of actions. Kiser and Ostrom (1982) suggest that there are three worlds of action: constitutional choice, collective choice, and operational world. The top level is the constitutional choice world. The middle level is the collective choice world. The low level is the operational world. The following figure shows the interaction of the three worlds of action over time.

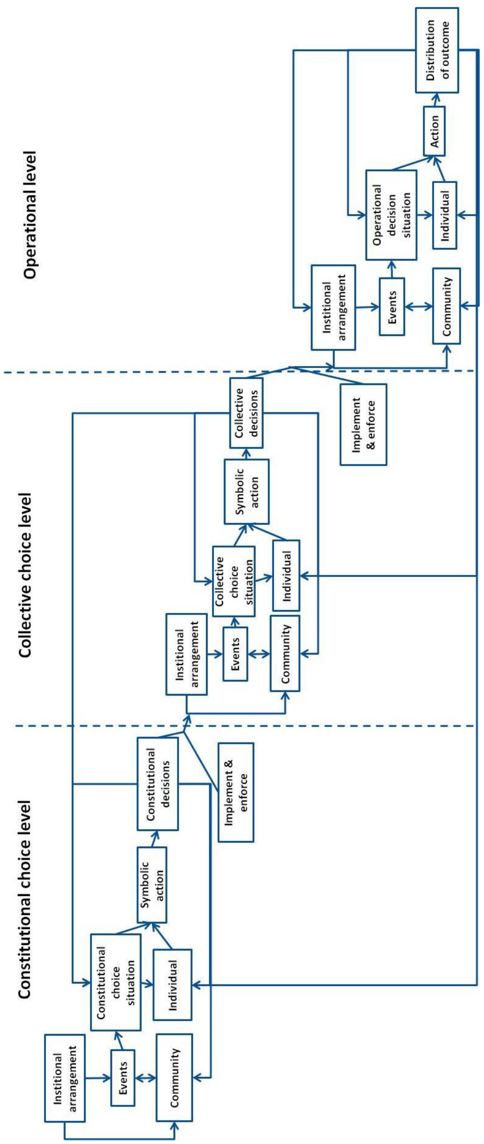

Figure 5. Three levels of institutional analysis[12]

[12] Source: Kiser and Ostrom (1982, p. 207), Figure 7.2

The constitutional choice level also comprises five working parts, with additional feedback from the aggregate result from the collective choice level. At this top level, the decision-maker makes a high-level decision in terms of constitution, e.g., constitution, law, or regulation. This decision is given to the collective choice level.

The collective choice level also comprises five working parts, with additional feedback from the aggregate result from the operational level. At this middle level, the decision-maker makes the operational rule, such as determining, enforcing, continuing, or changing the actions authorized by the constitutional rules from the constitutional choice level.

The operational level also comprises five working parts with the feedback from the aggregate result from its level. At this low level, the actions or strategies of individuals happen according to determined rules from the above level.

Constitutional decisions establish rules as institutional arrangements and their enforcement for the collective choice level. Collective decisions establish institutional arrangements and their enforcement for individual action at an operational level.

As a constitutional decision-maker, FIFA determines the rules of football at a high level. European or national football associations use FIFA's rules for their tournaments, such as EUROPA and the Premier League. Football teams must obey the rules to join tournaments.

An example of the Maine lobster industry

The three levels of action are applied to the Maine lobster industry by Schlager and Ostrom (1992). The purpose is to explain a conceptual scheme to distinguish a bundle of property rights from the authorized user, proprietor, claimant, and owner of the Maine lobster industry.

The Maine lobster industry comprises the fishing ground, state authority, and fishermen. The fishing ground is the area in the sea that contains the scare resource, in this case, the lobster. There are two types of fishing ground. First, inland, it is the sea associated with the harbor. Second, the open water ground, the sea that is outside the inland area. The state authority is the State of Maine, the community owner. The fishing ground is a common property resource or common pool resource. Fishermen are people who fish in the fishing ground.

There are two types of property rights: *de jure* and *de facto*. *De jure* rights are given by law or regulation and are formal and legalized. *De facto* rights originate from resource users who manage their resources among themselves as *de jure* rights.

Moreover, there are five rights for common pool resources: access, withdrawal, management, exclusion, and alienation. At an operational level, there are access and withdrawal rights. At the collective choice level, there are management, exclusion, and alienation rights. The following table shows the summary of rights at each level.

Table 5. Property rights of common-pool resources[13]

Level of action / Economic	Rights
Constitutional	-
Collective choice / Institutional	Management, Exclusion, Alienation
Operational	Access, Withdrawal

[13] Source: Kiser and Ostrom (1982, pp. 250-251)

Schlager and Ostrom (1992) provide the definition for each right. Access right is the right to enter a defined physical property. Withdrawal right is the right to obtain the products of a resource (e.g., lobster in the fishing ground). Management right is the right to regulate internal use patterns and transform the resource by making improvements. Exclusion right is the right to determine who will have an access right and how that right may be transferred. Alienation right is the right to sell or lease either or both of the above collective choice rights (Schlager & Ostrom, 1992, pp. 250-251).

The State of Maine issues the right to fish, including access and withdrawal rights for authorized users, as *de jure rights* and leaves other rights for the community to decide as *de facto* rights.

Authorized users are fishermen who have rights to access the fishing ground, access right, and obtain lobsters from the fishing ground, withdrawal right, as day-to-day activities. At operational level, fishermen go to the fishing ground and use the fishing equipment at a particular location specified by the claimant in a collective choice.

The claimants determine management rights in terms of which fishing equipment is allowed or prohibited. Where fishermen can fish is set for authorized users at the operational level. This management right is not given by the State of Maine. The claimant has a management right as a *de facto* right.

The proprietor has an exclusion right for who can fish in the fishing ground. This exclusion right is not given by the State of Maine. The proprietor has an exclusion as a *de facto* right.

If, however, no one intends to use the fishing ground, the exclusion right is not practicable. The difference between claimant and proprietor disappears.

Owners have all the rights to use the resource, including an alienation right to rent, lease, sell, or transfer their right to others. In the Maine lobster industry, the State of Maine owns the fishing ground, and fishermen cannot sell or lease their fishing ground. Thus, a *de jure* and a *de facto* right of alienation are not different, because the fishermen do not have an alienation right. A summary of the bundles of rights is shown in the following table.

Table 6. Bundles of rights associated with position[14]

Position / Rights	Owner	Proprietor	Claimant	Authorized User
Access and withdrawal	x	x	x	x
Management	x	x	x	
Exclusion	x	x		
Alienation	x			

Schlager and Ostrom (1992) also refer to the study of the Maine lobster industry by Acheson (1975), Grossinger (1975), and Wilson (1977). The State of Maine has owned the fishing ground since the establishment of the state. It is a *de jure* right. The fishermen have to obtain a license to fish in the fishing ground.

Prior to 1920, the fishing ground was separate from the owners of the harbor along the coast. The fishermen in the harbor determined who could enter the fishing ground, and how, when, and where to fish. The fishermen obtained the management and exclusion rights as *de facto* rights. The fishermen

[14] Source: Schlager and Ostrom (1992, p. 252), Table 1

cannot lease, sell, or transfer the right, however, because the alienation right is owned by the State of Maine.

Enforcement within the fishing ground was also down to the fishermen. The sanction for persons violating the communal rules was gear destruction. The fishermen used wooden traps on the sea floor and tied up buoys. If anyone violated the communal rules, the rope was cut. The cutting rope represents the exclusion right to determine who can access the fishing ground.

After 1920, new technology emerged. Motors were installed on boats instead of buoys. Fishermen could harvest lobster in a large area all year long. The traditional wooden trap and buoys could only operate in summer. The fishermen who installed the motors gained more benefit from fishing lobster both inland and on the open water. The traditional inland fishermen could only fish on inland fishing ground.

The new motor technology changed the mode of how to fish. The enforcement of exclusion turned into a lobster war between the inland and open water fishermen. The *de facto* rights for management and exclusion became blurred and were reduced to *de jure* rights – only access and withdrawal rights. In order to solve the problem, the inland and open water fishermen agreed to have a mixture of traditional wooden trap and buoys, and motors. Moreover, the separation between the fishing grounds allowed traditional communal rules, such as cutting the rope, as exclusion rights – *de facto* right and did not allow enforcement, free access as an authorized user – *de jure* right was established.

The enforcement of communal rules that remain in the fishing ground helps fishermen limit the harvest. This exclusion right has encouraged fishermen to invest in institutional arrangements. Fishing grounds that have no communal rules, however, harvest all year long without a limit. Thus, over-harvesting represents as tragedy of commons. Wilson (1977) also reports that controlled fishing gains average 22,929 USD per year, with fishermen in uncontrolled fishing grounds gaining on average 16,449 USD per year.

The Maine lobster industry example proposes property rights for decision-makers, ranging from authorized users, claimants, proprietors, and owners, to understand better the bundle of rights at different institutional levels. Exploring the institution and decision-makers interaction helps to understand the bundle of rights (access, withdrawal, management, exclusion, and alienation right) in a property rights regime.

The economic institution: constitution, institution, and operation, therefore provides a decision-making context. Moreover, the bundle of rights in the property regime also clarifies the differences between decision-making positions.

Three worlds of action in spectrum management

The concept of three worlds of action and the property rights regime mentioned above provide an understanding of the interaction between the decision-maker and the decision situation within and between three levels. Moreover, the property rights regime from the Maine lobster industry provides the bundle rights to resources, especially the common pool resources.

An analysis of decision-maker at each level of spectrum management reveals the relevant stakeholders shown in the following table.

Table 7. Level of action and stakeholders

Stakeholders	Level of action / Economic institution
Administrator / Regulator / Authority	Constitutional choice
Operator / Provider / Standard Setting Organization	Collective choice / Institutional
User	Operational choice

Constitutional choice level

A high level of regulation conducted directly will influence the collective choice level. In radiocommunication, the constitutional level starts from the regulator, administrator, or authority in each country up to the ITU level. The constitutional level gives the overall regulation and broadly influences the collective choice (or institutional level).

The following sample is at constitutional level and includes the allocation of spectrum commons and relevant recommendations, which have been to allocate the spectrum commons frequencies that have been decided to the ITU-RR 2008. There are two main footnotes i.e. 5.138 and 5.150 allocated for industrial, scientific, and medical (ISM) applications. The use of ISM applications is according to ITU-RR No. 1.15. These applications are used to generate and use radio-frequency energy locally for ISM, domestic, or similar purposes, excluding applications in the field of telecommunications. Short-range radiocommunication devices in this band must accept harmful interference (ITU, 2009) however.

Report ITU-R SM.2153 also provides a definition for short-range radio communication devices (SRDs), covering radio transmitters that provide either unidirectional or bidirectional use with low capacity, causing interference with other radio equipment.

Examples of short-range device applications are telecommand, telemetry, voice and video, equipment for detecting avalanche victims, broadband radio local area networks (RLANs), railway applications, road transport, and traffic telematics (RTTTs) equipment for detecting movement and for alerts, alarms, model control, inductive applications, radio microphones, RF identification (RFID) systems, ultra-low power active medical implants (ULP-AMI), wireless audio applications, and RF- (radar) level gauges (ITU, 2009).

Footnotes 5.138 and 5.150 contain five and seven sub-bands, respectively. In 5.138, there are 6,765-6,795 kHz, 433.05-434.79 MHz in Region 1, 61-61.5 GHz, 122-123 GHz, and 244-246 GHz. These bands are designated for ISM applications. The use of these frequency bands for ISM applications is subject to special authorization by the administration concerned, in agreement with other administrations whose radiocommunication services may be affected. In applying this provision, administrations shall have due regard for the latest relevant ITU-R Recommendations.

In 5.150, there are 13,553-13,567 kHz, 26,957-27,283 kHz, 40.66-40.70 MHz and 902-928 MHz, and in Region 2, 2,400-2,500 MHz, 5,725-5,875 MHz, and 24-24.25 GHz. These bands are also designated for ISM applications. Radiocommunication services operating within these bands must accept harmful interference that may be caused by these applications. The ISM equipment operating in these bands is subject to the provisions of No. 15.13.

A summary of ISM frequencies and the main applications is shown in the following table.

Table 8. Frequencies of ISM bands 5.138 and 5.150[15]

Frequency	Footnote	Bandwidth	Region 1	Region 2	Regions 3	Main application
6,765-6,795 kHz	5.138	30 kHz	✓	✓	✓	Inductive application
13,553-13,567 kHz	5.150	14 kHz	✓	✓	✓	RFID
26,957-27,283 kHz	5.150	326 kHz	✓	✓	✓	Railway application – Eurobalizing
40.66-40.70 MHz	5.150	0.04 MHz	✓	✓	✓	Control signal
433.05-434.79 MHz	5.138	1.74 MHz	✓			Control signal
902-928 MHz	5.150	26 MHz		✓		Cordless telephone
2,400-2,500 MHz	5.150	100 MHz	✓	✓	✓	WLAN
5,725-5,875 MHz	5.150	150 MHz	✓	✓	✓	WLAN
61-61.5 GHz	5.138	0.5 GHz	✓	✓	✓	Millimeter-wave radar
122-123 GHz	5.138	1 GHz	✓	✓	✓	Non-generic SRDs
244-246 GHz	5.138	2 GHz	✓	✓	✓	Non-generic SRDs

Note: The total bandwidth of 5.138 and 5.150 is 3,778.15 MHz. This is only 0.126% of the whole usable spectrum of 3,000 GHz however.

Report ITU-R SM.2153 also suggests the other six bands commonly used for SRDs. These are 9-135 kHz, 3,155-3,195 kHz, 402-405 MHz, 5,795-5,805 MHz, 5,805-5,815 MHz and 76-77 GHz. The use of these bands is subject to specific regulation, such as the 402-405 MHz band used for ultra-low, power-active medical implants subject to Recommendation ITU-R RS.1346, the 5,795-5,805 MHz bands, and the 5,805-5,815 MHz band used for transport information and control systems subject to Recommendation ITU-R M.1453.

The use of SRDs depends on national administration regulations. In general, SRDs cannot claim protection from other radio communication services, although some NRAs specify protection due to the nature of the application. SRDs are used on a worldwide basis. The technical and operating parameters, and the spectrum requirement are also found in Report ITU-R SM.2153. The SDR regulations should not be more restrictive than necessary.

As in every country, in order to adopt ITU regulations, Thailand puts these footnotes into the National Frequency Allocation. The following table is an example of the Thailand Table of Frequency Allocation in the 2,400-2,500 MHz band.

[15] Source: Radio Regulation (2008), Articles No. 5.138 and 5.150

Table 9. Example of Thailand's Table of Frequency Allocation[16]

Allocation to services		
Thailand		Remark
2,300-2,450	FIXED T17 T21 MOBILE RADIOLOCATION Amateur S5.150 S5.282 S5.396	
2,450-2,483.5	FIXED T21 MOBILE RADIOLOCATION S5.150	
2,483.5-2,500	FIXED T22 MOBILE MOBILE-SATELLITE (space-to-Earth) RADIOLOCATION Radiodetermination-satellite (space-to-Earth) S5.398 S5.150 S5.402	

Countries should also specify domestic regulations for the use of these footnotes. For example, in the USA, the Federal Communication Commission (FCC) specifies rules in Part 15 of the Communication Act. In the European Conference of Postal and Telecommunications Administrations (CEPT), countries adopt recommendation CEPT/ERC/REC 70-03 "Relating to the use of short-range devices (SRD)" for use in these footnotes. In Thailand, the National Telecommunications Commission (NTC) issues the National Telecommunications Commission Regulation of Exemption of Radiocommunication Licences (NTC, 2007c) for use by short-range devices. Most of these regulations specify the frequency, power limitation, and necessary technical specification for use by these footnotes. The following table shows an example of the technical specification by the FCC and CEPT.

Table 10. CEPT power level[17]

Maximum power level	Frequency bands
100 mW[(1)]	2,400-2,483.5 MHz (for RLANs only) 17.1-17.3 GHz 24.00-24.25 GHz 61.0-61.5 GHz 122-123 GHz 244-246 GHz

(1) Levels are either effective radiated power (e.r.p.) (below 1,000 MHz) or equivalent isotropically radiated power (e.i.r.p.) (above 1,000 MHz).

[16] Source: http://www.ntc.or.th/index.php?option=com_content&task=view&id=3368&Itemid=191 (accessed on May 26, 2010)
[17] Source: Report ITU-R SM.2153 (ITU, 2009, p. 9), Table 3

Table 11. FCC general limits for any intentional transmitter[18]

Frequency (MHz)	Electric field strength (µV/m)	Measurement distance (m)
0.009-0.490	2,400/*f* (kHz)	300
0.490-1.705	24,000/*f* (kHz)	30
1.705-30.0	30	30
30-88	100	3
88-216	150	3
216-960	200	3
Above 960	500	3

The ITU regulations and the national regulation are both at the constitutional level, providing a broad guideline for collective-choice or the institutional level.

Collective choice or institutional level

After the administrator, authority, or regulator outlines technical specifications, the operators, providers, or standard setting units have to create technology according to the regulation (constitutional choice level). For example, in the 2,400-2,500 MHz band, there are two popular technologies, i.e., Wi-Fi and Bluetooth. These technologies provide personal and local connectivity with a peer-to-peer connection for Bluetooth and a Wi-Fi infrastructure for Internet connection, respectively.

Wi-Fi technology has been developed by the Institute of Electrical and Electronics Engineers (IEEE), and the current standard is 802.11n. The standard provides many technical specifications on how to use this frequency, e.g., medium access control (MAC) and physical layer (PHY) specifications.

Bluetooth has been developed to replace cable connectivity for personal area networks (PANs). The Bluetooth standard uses the frequency hopping spread spectrum for radio technology. PAN can connect mobile phones, faxes, printers, computers, laptops, GPS receivers, video recorders, and cameras.

At the collective choice or institutional level, technology or standard rules show how the frequency should be used by the provider, operator, or standard setting unit and determine which devices can access their network.

Operational level

At this level, the users have choices to select devices and use them. After selecting the devices, however, users have collective choice or institutional level rules. For example, once the users access Wi-Fi hotspots in hotels, they must have devices with a specified Wi-Fi connection and an account to access the Internet defined by the operator. If, on the other hand, the user connects to the Wi-Fi router at home, the user specifies the access rule by password to determine who can connect to his or her router.

After understanding the three worlds of action from the decision-maker at each level: constitutional choice, collective choice, and operational levels, the following discussion considers the right to use frequency. It is related to the right to use the frequency from relevant literature.

[18] Source: Report ITU-R SM.2153 (ITU, 2009, p. 9), Table 4

The difference between market-based approach (which assignee has property rights over the spectrum) and spectrum commons approach is explained by Benkler (2006). Benkler explains these two schemes as "I can buy an easement from my neighbor to reach a nearby river, or I can walk around her property using the public road that makes up our transportation commons."

According to the observations by Hardin (1968), spectrum commons allows use of the resource until it is overused or overpopulated, i.e., the tragedy of the commons. Hardin (1968) also suggested that this problem cannot be solved by technical means, except by implementing the concept: "freedom is the recognition of necessity." This means that there should be constraints to control resource use. This reflects the basic characteristic of spectrum commons, i.e., unlimited access to resources but with constraints. The proposal of eight design principles by E. Ostrom (1990) is another way of solving the tragedy of commons. There is an opposing view from Heller (1998), however, of an underused resource with multiple owners with exclusive rights, as a new property right defined by the government. Heller (1998) also suggested managing this underused resource by concentrating on the content of a property bundle rather than on the clarification of rights.

If frequency (or spectrum) is regarded as property, there are two main kinds of property: public and private. Heller (1999) defined the boundaries of private property that lie between the commons and the anti-commons. The public also claimed property when the property could physically be monopolized by private persons, and the properties themselves were most valuable when used by indefinite and unlimited numbers of persons (Rose, 1986). In terms of property, the spectrum commons have no exclusivity, alienation, or management (Wang, 2009). Another idea by Werbach (2004) regards "Supercommons." It has open entry and open boundaries, a white space which encouraged different business models to use spectrum with impermissible interference. The concept of Supercommons is hard to implement and goes far beyond the spectrum commons.

Another interesting concept by Faulhaber (2006), and Faulhaber and Farber (2002) proposed a mix of market- and commons-based regimes to meet future needs. E. Noam (1995) and (1998) suggests a similar mix with full openness to entry for all users and a dynamic access fee payment, which is automatic by a clearing house. The access fee depends on the demand and supply conditions at the time of access. This idea is opposed by Brennan (1998) and Hazlett (1998) who argue that it would take a long time to prove the open-access concept and that the mechanism would duplicate the efficiencies of the market and make the spectrum resource under-utilized.

The practical discussion on how to implement spectrum commons is also interesting. Benkler (1998) proposes a model based on non-owned components and an information infrastructure based on unlicensed wireless devices, such as commons, and suggests that the computer hardware and software market is necessary to operate in an unlicensed environment that will drive the innovation and deployment of the infrastructure. Werbach (2003) suggests that regulators should make more unlicensed spectrum available through a dedicated open-access band with low-power underlay and opportunistic sharing to overcome spectrum scarcity. Lehr and Crowcroft (2005) provide a concept to manage spectrum commons by implementing an appropriate protocol that includes liquidity and is decentralized/distributed, adaptive, and flexible. Peha (2005) suggests that a licensing scheme works better with a QoS requirement and that an unlicensed one works better for a wireless connection between a computer and cable modems.

Bundle of rights to use frequency

The example of the Maine lobster industry provides an understanding of property rights regimes, including access, withdrawal, management, exclusion, and alienation rights such as authorized users, claimants, proprietors, and owners.

Considering the right to use frequency, the access and withdrawal right depends on the devices (transceiver: transmitter and receiver), which are similar and cover access as in the fishing ground example. When users access a resource, they withdraw the product or consume the frequency. Frequency is a non-depletable resource however. Thus, the access right is sufficient to explain the access to frequency. For example, the user makes a call from his or her mobile phones. The phone connects to the base station via a selected frequency. The selected frequency is occupied by users. After hanging up, the selected frequency can be used by others.

The access right at operational level is defined by the network operator that defines the network rule to access the frequency in terms of the technical specification or standard. The network operator acts as both proprietor and claimant with the management and exclusion right to define how, when, where, and who can access the frequency. For example, when the user makes a call from his or her mobile phone, the operator specifies which standard and technology the phone and the SIM card will use.

An alienation right is defined as ownership that can be sold, leased, or transferred. For example, the frequency auction in the primary market and frequency trading in the secondary market provide ownership of frequency for the owner to trade. Normally, the alienation right is defined by the authority, regulator, or administrator.

In Table 7, stakeholders are divided into the three levels. Applying the idea from Table 6, the bundle of rights of each stakeholder reveals the rights to use frequency shown in Table 12.

Table 12. Bundles of rights associated with telecommunication stakeholders

Stakeholders / Rights	Regulator	Operator A	Operator B	Advanced user	General user
Access and withdrawal	x	x	x	x	x
Management	x	x	x		
Exclusion	x	x	x	x	
Alienation	x	x			
Assignment approach		Market-based	Command-and-control	Spectrum commons	Spectrum commons

At the constitutional level, the regulator, administrator, or authority holds all the rights to frequency use, including access, withdrawal, management, exclusion, and alienation rights. Once the regulator delegates authority, using the market mechanism to assign frequency, the alienation right passes to a collective choice or institutional level, i.e., Operator A. Operator A is able to sell, lease, or transfer frequency to another party. Operator B, however, cannot sell because the regulator still holds the alienation right. Thus, the frequency assignment by the command-and-control approach means that Operator B must ask the regulator for approval to transfer the frequency, e.g., 2G frequency assignment in Thailand. Operator A represents frequency assignment by the market-based approach including primary trading (auction) and secondary trading (resale). Operator A has the freedom to transfer frequency without regulatory approval, e.g., 3G auction in the UK and the USA.

At the collective choice or institutional level, the management and the exclusion right are held by the providers, operators, or standard setting units. They set-up their network rules on how, when, and where to harvest frequency reflected by technology or device choices. For example, mobile phone operators set their standard of network and equipment to allow only their consumers to use the network. The advanced user (at the operational level), however, sets his or her own rules that allow access to the frequency. For example, advanced users of Wi-Fi routers can set their own security code for network access.

At the operational level, the access and withdrawal right are held by users. Users have to use devices according to the standard preset by the operators.

As for the right to use frequency, the assignees, and command-and-control and market-based approaches have the exclusive right to use frequency, but spectrum commons have a non-exclusive right. For the exclusive right, assignees have priority to use it free of interference. For the non-exclusive right, however, users have to share and accept interference. Exclusivity should be added to the property rights for the right to use frequency.

The level of deregulation of the right to use frequency from the regulator, at the constitutional level, can be delegated to operators at the collective choice or institutional level and users at operational level. The regulator can use the market-based approach to delegate alienation rights to operators. Thus, the operator can obtain the frequency from primary and secondary markets. The operator has the flexibility to sell, lease, or transfer frequency. At the operational level, the regulator can delegate its authority of self-regulation after defining the necessary conditions, including frequency, power limitation, and standard of devices. Thus, users have to manage the use of frequency. Table 13 shows the rights to use frequency and the regulated level.

Table 13. The rights to use frequency

Property right / Regulated level	Exclusive use	Non-exclusive use
Centralized by regulator / state agency	Command–and-control	Public commons
Middleman/Operator	Market-based	Private commons
Self-regulated/User	-	Unlicensed

The command-and-control assignment approach means that regulators hold all the rights to use frequency while assigning frequency to assignees. The assignee has the exclusive right to use the frequency with all the imposed conditions. Assignee has inflexibility to change the use of frequency.

The market-based approach is the assignment method in which assignees can buy frequency from the primary and secondary market. The assignee has the exclusive right to use frequency. The regulator gives away the alienation right to the assignee and this right can be sold, leased, and transferred. Thus, it is more flexible than the command–and-control approach. Some necessary conditions should be imposed on the use of frequency, however, such as the standard of devices.

The next three categories have non-exclusive rights to use frequency. This means that users have to share frequency. At the regulated level, it includes management and exclusion rights. If a state agency or government manages the frequency use, it is public commons. If the operator manages the frequency use, it is private commons. If users manage the frequency use, it is unlicensed.

In conclusion, the economic institution or level of action, and the property rights regime from the Maine lobster industry provide a starting point for the discussion. The economic institution or level of action has three levels: constitutional, institutional or collective choice, and operational levels that

define and divide the decision-making positions. The property rights regime explains the bundle of rights, including access, withdrawal, management, exclusion, and alienation rights. The economic institution and property rights regime both explain the Maine lobster industry, for which the common pool resource is the fishing ground.

In the Maine lobster industry, the decision-making positions are authorized user, claimant, and proprietor and owner. Property rights vary from access and withdrawal, management and exclusion to alienation right.

By analogy, frequency is a scarce resource similar to the fishing ground. The economic institution comprises the stakeholder at each level. The authority, administrator, or regulator is at the constitutional choice level that provides the law and regulations. The operators, providers, or standard setting organizations are at the collective choice level. They provide network rules, namely, how, when, and where to use the frequency, and determine who can use the frequency. The user is at the operational level, which follows the rules from the collective choice level.

The bundled rights to use frequency can also be divided into five rights, as mention in the property rights regime in the Maine lobster industry. These are access, withdrawal, management, exclusion, and alienation rights. The access and withdrawal rights to use frequency can be combined, however, due to the technical characteristics of the transmitter, receiver, and transceiver. When the transceiver is switched on, the transceiver operates or accesses the specified frequency and uses the frequency for the specified service. This means that the transceivers combine access and withdrawal rights to use the frequency at the same time.

At the operational level, general users hold access and withdrawal rights to use frequency by selecting devices (transmitter, receiver, or transceiver) that follow specified conditions. Advanced users hold an additional exclusion right to determine who can use the frequency by specified username and password.

At the collective choice or institutional level, operators, providers, and standard-setting organizations hold additional management and exclusion rights that specify how, when, and where frequency can be used in terms of the standard of device, technology, SIM card, etc.

At the constitutional choice level, the authority, administrator, or regulator has all the rights to the frequency use and to specifying regulations. If, however, the regulator decentralizes the alienation right by using the market mechanism, the operator at the collective choice level can obtain the frequency from primary and secondary markets.

The exclusive right to use frequency is a key point to separate the three spectrum assignment approaches: command-and-control, market-based and spectrum commons. The command-and-control and market-based approaches have an exclusive right to use frequency, but spectrum commons has a non-exclusive right. The regulated level indicates the decentralization of regulators. Regulators may give away some rights to the operator or end-user. Thus, both the exclusive right and the regulated level help to explain the differences between these approaches.

In the exclusive right to use frequency, the regulated level depends on the degree on which the alienation right is decentralized. If the regulator holds the alienation right, the approach iscommand-and-control. If the regulator delegates the alienation right via primary and secondary markets, the approach is market-based.

In the category of non-exclusive right to use frequency, the regulated levels range from regulator, operator, and end-users, i.e., public commons and private commons, to unlicensed. Public commons have a state agency to manage frequency, such as a municipality or local administrator, etc. Private commons have private entities to manage frequency, such as a Wi-Fi operator in a hotel, airport, department store, etc. Unlicensed spectrum is self-regulated.

2.4 Summary

This chapter addresses a suitable framework, derived from the three worlds of action and property rights regime, to understand the institution of spectrum commons. The analysis of the decision-maker and decision situation at each level helps us to understand the interaction between stakeholders. The property rights regime provides the right to use frequency from the study of the Maine lobster industry. These findings address a suitable framework for analyzing different types of spectrum commons (RQ.1).

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Chapter 3 Methodology

The discussion of method considers specific methods that concern the type of data and the data collection method, research design, method of data analysis, and methodology. This thesis uses mostly non-numeric data and archival research design. It also uses deductive and inductive approaches.

3.1 Type of data and data collection method

In this thesis, the problem is on the conceptual level of telecommunications policy. Suitable data should contain the rationale and clearly describe the interactions between the regulator and other stakeholders involved in considering spectrum commons in the Thai context. Non-numeric data may be appropriate, because numeric data may not elaborate on the institution of spectrum commons, especially, the way it is. Moreover, it is hard to quantify policy matters in terms of numeric data. The conceptual part of the thesis relates to policy decisions by exploring the available documents containing policy decision-making.

In order to use documents as data in this thesis, Flick (2009) provides guidelines on how to select suitable documents with criteria: authenticity (primary or secondary data), credibility (official or personal), representativeness (typical or non-typical), and meaning (clarity of text).

The authenticity of documents depends on the source of the data. If the data come from a primary data source and they are documented by a first witness, then the authenticity is high. If the data come from a secondary data source and they are documented from primary data, the authenticity of the document is medium or low. The level of credibility of a document depends on the type of document. If the data are from an official document, the credibility is high. If the data are from a personal document, the credibility is low. The degree of representativeness is measured by the type of document. If the document was drawn up for a specific purpose, the representativeness is non-typical. If the document was drawn up for a general purpose, the representativeness is typical. The level of meaning of the document depends on the clarity of the document. For example, primary data should be clearer than secondary data. These concepts are applied to this thesis and through each research questions as shown below.

Research question 1 – What is a suitable framework for analyzing different types of spectrum commons? The primary source is obtained from Kiser and Ostrom (1982) and Schlager and Ostrom (1992). The three levels of action by Kiser and Ostrom (1982) also contribute to a metatheoretical framework that explains the relationship between an institutional arrangement and individuals in terms of transformation of rules for individual behavior. The article by Schlager and Ostrom (1992) explains the conceptual scheme to distinguish a bundle of property rights from the view of the decision-makers. These two main pieces of literature help to explain and describe the institution of spectrum commons. They are original works intended to generalize the framework for many fields and typical representativeness.

Research question 2 – What type of spectrum commons has been used in Thailand? The necessary document includes the history of the institution and how it developed. The research presented here is original and unique and is based on personal archival research. The primary data come from the minutes and summary of minutes of the National Frequency Management Board, the archive of the International Telecommunication Union in part of Thailand (Siam), the history of the Post and Telegraph Department (PTD) at its 100-year anniversary (PTD, 1983), the regulations including the Radiotelegraph Convention, the Radiotelegraph Act, the Radiocommunication Act, Sound and

Broadcasting, the Ministerial Regulations, the National Telecommunications Commission Regulations, the Constitution of Thailand, the Act of Establishment of the National Broadcasting Commission and the National Telecommunications Commission, the Telecommunication Business Act, and the PTD's Regulations. Additional interviews were conducted with people who helped to find the right documents and confirm the requested incidents.

The number of the WLAN devices collected from the PTD is the old archive of type approval of radiocommunication devices. There was a manual count, item by item, of all radiocommunication devices that were submitted for the type approval process. Each record of a type-approved radiocommunication device was from the PTD's official issue by issue. Each issue can contain one item or a thousand items, depending on the applicant's requirement. The record of type-approved radiocommunication devices was made manually and was contained in several big logbooks. First, only the 2,400-2,500 MHz band was filtered from the whole logbook, from 1996 to 2004, item by item. This involved a large amount of work. The second filtering from all the radiocommunication devices operating in the 2,400-2,500 MHz band was done by counting only WLAN devices. It includes the access point, portable unit, circuit board, and PCMCIA or USB module that enables the creation of an access point. The data exclude the Wi-Fi module in the mobile phone. The result of the second filtering was put into an Excel file for the database.

The number of the WLAN collected from the Customs Department of Thailand has been available from 2001 to now. The item code of the WLAN has been requested by formal letter from the Customs Department via the Customs Customer Service. After obtaining the item code, the manual count from the online database at the Customs Department was done month by month in order to construct the Excel file as a database.

The history of spectrum management in Thailand is an original work that collects the important events from the above-mentioned sources. Exploring the laws and regulations, double-checking the minutes of board meetings, and interviewing the relevant persons help to confirm the crucial moment of history of spectrum management in Thailand.

Research question 3 – What are the advantages and disadvantages of spectrum commons in general? The primary and secondary data come from literature, including Cave (2007), Chaduc and Pogorel (2008), Mark and Williams (2007), Tonge and Vries (2007), and from the public consultations of the Radio Spectrum Policy Group on "Aspect of a European Approach to Collective Use of Spectrum" posted on June 10, 2008 and closed on September 29, 2008. There are nine respondents, including the ARD-ZDF, Deutsche Telecom/T-Mobile, the EICTA, GSMA Europe, Metil Telecom consultants, Microsoft, Telefónica, PWMS Manufacturer Group, and Delft University of Technology. The result of this public consultation was posted on November 19, 2008.

Data from the public consultation contain the advantages and disadvantages of spectrum commons in European countries. Finding important dimensions for the public in Europe may also be relevant to other countries. The literature also helps to categorize the most important issues associated with the consideration of spectrum commons and the consequences of applying it.

Research question 4 – How can the benefits and costs of spectrum commons be measured? The data come from the work by Campbell and Brown (2003) and provide a benefit and cost analysis with and without a project for the decision-maker. If the decision-maker undertakes the project, how much of the scarce resource will be allocated to this project and what the value of the project will be. If the decision-maker does not undertake the project, the same amount of the scare resource can be allocated to alternative uses.

Data also come from the study of Indepen (2006). This work provides details on the use of a benefit and cost analysis for spectrum assignment and, within this, exploits the consequences of applying spectrum commons. Indepen (2006) is measuring the valuation of unlicensed applications in the UK from 2006 to 2026.

The view of using the engineering value from Sweet et al. (2002) also provides the valuation of spectrum as a cost saving in the infrastructure of the network operator.

These three pieces of literature indicate practical ways of measuring the benefits, costs, and consequences of spectrum commons. Practical possibilities of introducing spectrum commons in Thailand will be discussed and a similar approach considered and applied to Thailand.

Research question 5 – What are the implications of implementing spectrum commons in Thailand? The information comes from the results of the four previous research questions. Combining these provides suggestions and implications for implementing spectrum commons in Thailand and describes the consequences and expected outcomes of certain implementation strategies.

To conclude this section, the primary data from the International Telecommunication Union, the Post and Telegraph Department, and the National Telecommunications Commission provide a high degree of authenticity. Moreover, most of the information comes from official documents from the International Telecommunication Union, the Post and Telegraph Department, and the National Telecommunications Commission. It has a high level of credibility. The representativeness of the documents depends on the purpose of creating them. The purpose may have been general (typical) or specific (non-typical). In this thesis, the documents are specific. The representativeness of this thesis is also mainly non-typical. Furthermore, the meaning of the document is measured by the clarity of the document. It is reflected in the level of understanding of the document that communicated the message from authors.

3.2 Research design

The main research strategy is archival analysis, including history, content analysis, and literature critique (Lee, 1999; Miles & Huberman, 1994). In order to fulfill the research questions, data will be gathered from the archive of the Thai regulator, including the regulations and the minutes of meetings, and relevant literature, including journals and books.

The first research question provides a suitable framework for analyzing different types of spectrum commons. Analyzing the conceptual analysis of the three levels of action model by Kiser and Ostrom (1982), and the property rights regime and natural resources by Schlager and Ostrom (1992) provides a metatheoretical framework. This framework addresses the relationship between the institutional arrangement, the individual, and the bundle of property rights regime. The benefit of discriminating between the three levels of actions includes important data on the relationship between the constitutional choice, collective choice, and operational levels. This describes the relationship between the decision-maker and the decision situation for each of the levels. This interaction helps to describe the institution that needs to be considered in this thesis. The bundle of property rights regime addresses the rights that are relevant to the resources and stakeholders. This helps to describe the right to use frequency.

The second research question uses the framework from the first research question to understand the institution of spectrum commons in Thailand. The thesis uses the deductive approach of two theories: the property rights regime and three levels of action and applies them to the rights to use frequency of

spectrum commons in Thailand. The possible forms of spectrum commons in Thailand are induced from the rights to use frequency of spectrum commons, indicating three forms of spectrum commons, including public commons, private commons, and unlicensed.

The third research question uses relevant literature (Cave (2007), Chaduc and Pogorel (2008), Mark and Williams (2007), and Tonge and Vries (2007)) and the Radio Spectrum Policy Group's (RSPG) public consultation on aspects of the European Approach to "Collective Use of Spectrum," 2008, as sources of data to analyze many aspects of the advantages and disadvantages of spectrum commons, including the relevant stakeholders' viewpoint and summing up the framework to analyze a suitable time to implement spectrum commons. The method of data analysis is document analysis, especially content and hermeneutics analysis. The methodology has been adopted by Bryman and Bell (2007) and has been used successfully to analyze information generated from the social factor, as stakeholders in public consultations on spectrum commons.

The fourth research question deals with conceptual benefit and cost analysis (Campbell & Brown, 2003; Indepen, 2006; Sweet et al., 2002). This shows how the overall concept of valuating spectrum commons is applicable. Using the existing framework, the thesis uses the deductive approach of benefit and cost analysis. In the case of Thailand, however the adjusted framework can be treated as constructive.

The fifth research question uses the output from the previous research questions to indicate the impact of spectrum commons applied to the case of Thailand.

3.3 Approach

The three levels of action by Kiser and Ostrom (1982), and the property rights regime and natural resources by Schalger and Ostrom (1992) use the existing theory in the first research question. Moreover, the concept can be applied to analyze the institution of spectrum commons in Thailand with a deductive approach. Furthermore, the empirical results from the history of spectrum commons are used to induce the type of spectrum commons in Thailand.

The advantages and disadvantages of spectrum commons have been drawn from the public consultation of the Radio Spectrum Policy Group on spectrum commons in European countries in 2008. The research into each contribution by nine respondents from academia, manufacturers, end-users, operators, and consultants has been investigated in order to categorize the common view or idea of spectrum commons in consultation. Moreover, the Radio Spectrum Policy Group has also summarized the main ideas and responded to the public consultation in a final report. The final report and relevant literature have been explored to create a point of discussion on the view of advantages and disadvantages of spectrum commons and further issues to be considered when implementing spectrum commons. The output of a discussion on advantages and disadvantages induced from public consultation and relevant literature is categorized by stakeholders.

Furthermore, the concept of the benefit and cost analysis from Campbell and Brown (2003), Indepen (2006), and Sweet et al. (2002) is used for the valuation of spectrum commons in Thailand by a deductive approach from this literature and a constructive approach to Thailand.

The methodology of the thesis is therefore both deductive and inductive. It is deductive because the right to use frequency and the valuation of spectrum commons are deduced from existing theory, including three layers of action, the property rights regime and natural resources, and a benefit and cost analysis. It is inductive because the type of spectrum commons, and the advantages and disadvantages are induced from the history of spectrum commons in Thailand and a public consultation in Europe. The possible forms of spectrum commons in Thailand are induced from the rights to use frequency.

3.4 Summary

The type of data used in this thesis consists of documents (non-numeric) collected from the International Telecommunication Union, the National Telecommunications Commission, and the Post and Telegraph Department, as well as academic literature, which has a high degree of authenticity and credibility. The thesis uses documents as data for the data collection method.

This thesis uses archival analysis for data analysis, including history, content analysis, and literature critique. Non-numeric data and archival analysis are both used in the qualitative method.

The methodology of this thesis is both deductive and inductive, as it uses existing theories: layers of action, property rights regime and natural resources, and a benefit and cost analysis to deduce the results. The type of spectrum commons, and the advantages and disadvantages of spectrum commons are induced the from author's perspective.

Finally, the thesis uses mixed methods, with quantitative methods as the primary method and archival research design as the qualitative method, which uses deductive methodology, archival analysis, and non-numeric data as document.

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Chapter 4 The history of spectrum assignment in Thailand[19]

This chapter elaborates on the second research question: What type of spectrum commons has been used in Thailand? From the understanding of the framework for the right to use frequency and the interaction by the stakeholder in frequency management activities in Chapter 2, the concepts provide a framework to explore the history of spectrum management in Thailand. This chapter provides a chronological account of how spectrum assignment, especially spectrum commons, developed in Thailand with regard to the regulated level of the decision-maker for spectrum assignment.

4.1 The context of examining the history of spectrum management in Thailand

By understanding the history of spectrum assignment in Thailand, the development of right to use frequency originates from the regulator for command-and-control approach with full rights to use frequency as exclusive right to use frequency. On the other hand, the spectrum commons is also developed with two stages: authorization and unlicensed.

In Thailand, telecommunications developed from wireline to wireless communication: from telegraph, telephone over a telegraph infrastructure, and radiotelegraph for ship-to-shore communication, to radiocommunication for both broadcasting and telecommunication. At the initial stage (without regulations), the use of radiocommunication devices was limited to government agencies, especially the Navy and the Army. Frequency assignment was initially made by His Majesty the King of Thailand. After December 10, 1932, this authority was transferred to the Prime Minister. The King delegated his authority to the responsible ministry. The ministry used the command-and-control approach on a first come, first served basis to authorize the use of radiocommunication devices according to the international treaty (ITU, 1906, 1912). Most of the users were government agencies. There was otherwise little usage and low demand, so there was no congestion of the use of radiocommunication.

After the Radio Act was enacted, all radiocommunication activities were prohibited, except with authorization granted by the authority in terms of radiocommunication licences. The authority was the PTD and it still used the command-and-control approach on a first come, first served basis to authorize the use of radiocommunication devices. However, the PTD functioned only for radiocommunication licences in technical respects, and did not take into consideration the growing demand for the use of radiocommunication devices until congestion led to harmful interference.

The government realized that "good" spectrum management of frequencies would provide efficient national allocation. Thus, on March 26, 1974, the National Frequency Management Board (NFMB) was established to determine the national technical standard, and control, assign, and register frequency, examine the standard of radiocommunication devices, create an efficient procedure, evaluate radiocommunication stations, and coordinate all radiocommunication users. The NFMB comprised several representatives from government agencies and it was chaired by the Minister of Transport. The NFMB acted as the approval board before the PTD issued radiocommunication licences. The NFMB operated until 2002, while the PTD was transferred to the Ministry of Information and Communication Technology.

On October 1, 2004, the National Telecommunications Commission (NTC) was established, and the PTD was dissolved by law to become the Office of the NTC on January 1, 2005. A new era of

[19] This chapter is a revision of Ard-paru (2010).

telecommunication with an independent regulator, the NTC, was founded in order to change the authorization process into a licensing process. Not only the technical aspects, but also social and economic aspects were included in the licensing process.

The development of spectrum assignment started from command-and-control, though the spectrum commons (unlicensed devices) initiated by the NFMB delegated some authorities to the PTD and issued the Ministerial Regulation for Exemption of Radiocommunication Licences. The use of a market-based approach for frequency assignment was mentioned at the NFMB. Unfortunately, it was not a success.

4.2 No Radio Act[20]

At the initial stage, before the establishment of the Radio Act, decision-making for frequency assignment belonged to His Majesty the King of Thailand, according to the monarchy system before December 10, 1932. His Majesty the King transferred the authority to a government agency to provide radiocommunication services. Without domestic regulations, His Majesty the King used the international treaty, the International Telegraph Convention, as an institutional arrangement. The use of frequency during this period was infrequent. The radiocommunication service was primarily a wireline replacement, i.e., a radiotelegraph service. The radiotelegraph was used within the government agency and extended to the general public at a later stage.

The first attempt to build a telegraph infrastructure was made during the reign of King Rama X in 1869 by English telegraph technicians. It failed to meet the deadline however. In 1875, the Thai government's Ministry of Defence built the first telegraph infrastructure from Bangkok to Samuth Pragran, with a range of 45 kilometers. Moreover, the first telephone using the telegraph infrastructure was established between Bangkok and Samuth Pragran to report on boat traffic at the seafront. At the early stage, communication was limited to within government agencies. The general public had telegraph service provided on July 16, 1883. The building of a telegraph infrastructure with zinc-coated iron wires was extended through the main provinces in Thailand and connected to those of neighboring countries.

On August 4, 1883, the Post Department and the Telegraph Department were established. On April 21, 1883, however, Siam (now Thailand) filed an application for membership of the International Telegraph Union (which changed its name to International Telecommunication Union, ITU, in 1932), and this obliged Thailand to adopt its conventions and constitution.

In 1886, the Ministry of Defence transferred the telephone and its related tasks to the Telegraph Department to provide telephone service for the general public.

On July 19, 1898, the Post Department and the Telegraph Department merged to form the Post and Telegraph Department (PTD) under the Ministry of Interior and provided mainly postal and telegraph services.

In April 1903, the first attempt to use radiotelegraph communication took place between Koh Sri Chang, Chol Buri and Phu Khao Thong, Wat Sa Ket, and Bangkok and it was granted by the Ministry of Interior. It failed however.

[20] This section is mainly based on PTD (1983), ITU (1883), and ITU (1906, 1912).

In 1906, Thailand participated in the First Radiotelegraph Conference and signed the radiotelegraph convention in Berlin, Germany. In 1907, the first successful radiotelegraph communication in Thailand was conducted by the Army and the Navy.

In 1912, Thailand participated in the Second Radiotelegraph Conference, London, which revised the First Radiotelegraph Convention to strengthen measures relating to the improvement of safety at sea by means of radiotelegraphy, after the tragedy of the Titanic. Thailand also adopted the word "radio" for use in Thailand and translated it into the Thai language in 1914.

To summarize this period, radiotelegraphy as radiocommunication was only used in government agencies and was strongly restricted. The use of the radiotelegraph was adopted at the International Radiotelegraph Conventions in both Berlin and London in 1906 and 1912, respectively, however. Frequency assignment was made by the authority, using the international treaty as guidance on a first-come first, served basis. The use of radiotelegraphy was limited for the general public, because of the lack of equipment and supporting regulations.

A summary of significant events is shown in following table.

Table 14. Period before the Radio Act

Time	Event
1875	The first telegraph infrastructure from Bangkok to Samuth Pragran was built.
1883	The first telegraph service for the public was launched.
1883	Siam became an ITU member. The Post Department and the Telegraph Department were founded.
1898	The Post and Telegraph Department was founded.
1906	Thailand signed the first radiotelegraph convention in Berlin, Germany.
1907	The first radiotelegraph communication in Thailand was established.
1912	Thailand signed the Second Radiotelegraph Convention in London, UK.
1914	Thailand adopted "radio" for use in the Thai language.

4.3 The Radio Act –command-and-control[21]

At this stage, His Majesty the King delegated his authority to the government agency, as stated in the Radio Act. The decision-maker for frequency assignment changed from time to time depending on the amendments to the Radio Act. The Radio Act empowered the PTD as the decision-maker. The PTD also endorsed the international treaties, such as the International Radiotelegraph Convention, as domestic regulations. The use of radiocommunication was prohibited, unless the users obtained approval from the authority. The use of radiocommunication services was highly regulated by the authority in terms of the conditions of use and inflexibility in terms of change. Only government agencies were allowed to access frequency. The government agency still provided radiocommunication service directly to the general public. The government agency had the role of administrator and operator at the same time.

The Radio Act in Thailand was enacted on April 28, 1914, in the Radiotelegraph Act. The Act empowered the PTD, under the Ministry of Transport, to control the use of telephony over radiotelegraphy on ships on the Thai seas, ashore, and inland in Thailand. The use of radiotelegraphy endorsed the International Radiotelegraph Convention, London, 1912, as a necessary regulation. All

[21] This section is mainly based on the *Radiotelegraph Act 1914*, *Radiocommunication Act 1935*, *Radiocommunication Act 1955*, and *Sound and Broadcasting Act 1955*.

radio stations had to be approved by the Minister of Transport prior to installation, except for use by the Army and the Navy. The use of radiotelegraphy on commercial ships was only for distress and safety. The second amendment of the Radiotelegraph Act was in 1921 in order to allow ships on Thai seas, including the Koh Si Chang area, to use radiotelegraph communication temporarily with approval of the Minister of Transport. On September 14, 1930, the third amendment of the Radiotelegraph Act was enacted in order to decentralize power from the government to the Minister of Commerce and Transport to allow the general public to have radiotelegraph receivers, including trading, possessing, using, and installing licenses.

During World War I (WWI), all uses of radiotelegraph communication within Thai territory were prohibited, while Thailand declared a neutral position on August 17, 1914 until May 22, 1919, when cancellation of the prohibition on the use of radiotelegraph communication was enacted because Thailand joined the Allies in WWI. Radiotelegraphy on board Allied and neutral ships could be operated over Thai territory.

In 1927, the Navy transferred two radiotelegraph stations, Sa La Daeng and Songkhla, to the PTD. Fifty radiotelegraph stations were also built in provinces and districts throughout Thailand.

In the same year, the Minister of the Ministry of Commerce and Transport conducted a pilot broadcasting station and arranged a national radiocommunication meeting in Thailand in order to allocate frequency between the PTD, under the Ministry of Commerce and Transport; the Ministry of Navy; the Ministry of Army; and the Department of Aircraft.

On January 15, 1928, international radiotelegraphy was conducted by the PTD with a 20,000-watt vacuum tube transmitter and high frequency (HF) between Bangkok and Berlin.

On February 15, 1930, a permanent broadcasting-sound station was established at Phayathai Palace (Radio Bangkok at Phayathai) with 2,500 watts of transmitting power, 350-meter wavelength or 826.44 kHz, 41-meter wavelength or short wave radio, and a 40-meter antenna tower. The call signs[22] of this station were HSP1 and HSP2.

In 1930, the PTD established two aeronautical radio stations at Phisanulok and Don Muang to facilitate aeronautical activity, including weather news broadcasting, and direction and location finding. In 1934, the PTD established three additional aeronautical radio stations at Nakhon Ratchasima, Udon Thani, and Surat Thani. In 1938, the PTD established the last aeronautical radio station at Koh Samui. In 1940, the PTD established the radio beacon station north of Don Muang for navigation systems and transferred all aeronautical activities to the Department of Civil Aviation and Aerothai Company Limited in 1948.

On February 1, 1935, a new Radiocommunication Act was enacted to replace the Radiotelegraph Act in order to update the regulation and cope with the change of technology in radiocommunication. The Act empowered the PTD, the Ministry of Commerce, to control the use of broadcasting receivers, including trading, importing, possessing, using, making licences, and the use of radio stations on board ships and aircraft. The majority of this Act related to broadcasting service. There were five amendments to this Act in 1938, 1940, 1942, 1948, and 1954. In 1938, additional power was given to

[22] The call sign is the identifier of the radiocommunication station that supplies a territory or geographic area. All stations open to international public correspondence, all amateur stations, and other stations that are capable of causing harmful interference beyond the boundaries of the territory or the geographical area in which they are located shall have call signs from the international series allocated to its administration, as given in the Table of Allocation of International Call Sign Series in Appendix **42** (Nos.19.28A and 29 -RR2008).

the Prime Minister, apart from the Minister of the Ministry of Commerce. In 1940, the definition of repair was included in the licence. In 1942, there was an extension to the date line from March 31 to December 31, and a change in responsibility for the Minister of Transport. In 1948, additional power was given to the Minister of Transport to issue special licenses for safety for civil aviation. In 1954, a legal person was added by the Cabinet approval, for exemption from the Radiocommunication Act in order to promote broadcasting service in Thailand.

On April 1, 1939, the PTD transferred the broadcasting activities to the Public Relations Department.

In 1945, during World War II, the power plant in Bangkok was bombed, so the Minister of Transport requested that the PTD prepare a spare broadcasting transmitter for temporary use and experimental purposes. It was named HS1PN. On June 5, 1946, the HS1PN extended its frequencies to 4755, 7022, 920, and 5955 kHz.

On February 8, 1955, two important acts were enacted: first, the new Radiocommunication Act and, second, the Sound and Television Broadcasting Act.

The Radiocommunication Act of 1955 revoked all previous acts regarding radiocommunication and prohibited the use of radiocommunication equipment, the operation of radios, and the reception of international news for commercial purposes except with authorization granted by officials. According to this Act, the licences were for making, importing, possessing, using, exporting, and installing. Moreover, the radio operator and international news reception for commercial purpose licence was also included. This Act empowered the Minister of Transport to authorize the aeronautical radio stations and empowered the PTD to control and assign frequency to stations. The Act limited the use of frequency to the PTD, the Public Relations Department[23], the Ministry of Defence, and other specified government agencies in the Ministerial Regulations. There were two amendments to the Act, in 1961 and 1992. In the 1961 amendment, permission was granted to all government agencies to use radiocommunication equipment. In the 1992 amendment, further additions were made: a new trading licence, the empowerment of the PTD to authorize the installation of radio stations, and the empowerment of the Minister of Transport to exempt radiocommunication licences for some services and charge the licensee a frequency usage fee.

The Sound and Television Broadcasting Act 1955 allowed the general public to use broadcasting receivers with a one-time registration for the lifetime of the receiver, and separated the Broadcasting Act from the Radiocommunication Act. This Act prohibited transmission of sound and television broadcasting services, as well as making, possessing, importing, exporting, and trading receivers of sound and television broadcasting, and using radiocommunication equipment, except with authorization granted by officials or specified in the Ministerial Regulations. The licences according to this act were for transmitting sound or a television broadcasting service, making, possessing, importing, exporting, and trading. This act empowered the Prime Minister and appointed the Public Relations Department to administer the act. The act was not enforced, however, for the Public Relations Department, the PTD, the Ministry of Defence, and other specified government agencies in the Ministerial Regulations. Thus, the Act controlled only the use of sound and television broadcasting receivers. Transmitters of sound and television broadcasting fell under the Radiocommunication Act and its amendments. There were three amendments, in 1959, 1978 and 1987. In the 1959 amendment, permission was given for the general public to possess, import, export, and trade sound and broadcasting receivers without related licences. In the 1978 amendment, there was a revision of

[23] The Public Relations Department is the government broadcasting agency with both regulator and operator roles.

licence fees according to the current economic situation. In the 1987 amendment, there was an addition of media in sound and television broadcasting services including cable TV.

On June 24, 1955, a television broadcasting station was established at Pang Khun Prom Palace with the National Television System Committee (NTSC) system of Radio Corporation of America (RCA) from the USA. It used Channel 4 for this station. On June 14, 1959, the second television broadcasting station was established and used Channel 7 with NTSC system.

To summarize this period, both the Radiocommunication and Broadcasting Acts were developed. With regard to the Radiocommunication Act, there were three acts, including the Radiotelegraph Act 1914, the Radiocommunication Act 1935, and the Radiocommunication Act 1955. The purpose of the Radio Act is to cover the areas that wireline communication cannot reach in the initial stage. The need for distress and safety communication at sea and in the air also makes the implementation of radiocommunication mandatory. The first radiocommunication was ship-to-shore, which developed into aeronautical radio stations for aircraft and grew into the mass communication of the sound and television broadcasting service. With regard to the Sound and Television Broadcasting Act, only the use of broadcasting receivers and content management was controlled, leaving the installation of transmitting stations to the Radiocommunication Act. The majority of radiocommunication usage only occurred in the government agencies. The priority was national security, distress and safety at sea and in the air, followed by broadcasting.

A summary of significant events is shown in following table.

Table 15. Period of Radio Act

Time	Event
1914	First radio act – the Radiotelegraph Act
1928	First international radiotelegraph – Bangkok and Berlin
1930	First permanent sound broadcasting station – Phayathai Palace Two aeronautical radio stations – Phisanulok and Don Muang
1935	The Radiocommunication Act enacted
1955	The Radiocommunication Act and the Sound and Television Broadcasting Act were enacted. The first television broadcasting station – Channel 4 Pang Khun Prom Palace

4.4 The National Frequency Management Board –command-and-control[24]

After the government delegated decision-making for frequency assignment to the PTD via the Radio Act, the government decided to change its positions on the telecommunication industry. The government decided to separate the role from a solely integrated government agency, including the decision-maker for frequency assignment, and provide service to the general public, to have separate functions: a decision-maker for frequency assignment and providers. The decision-maker was the PTD, which had its responsibilities reduced to frequency management only. Government-established state enterprises were to provide service to the general public, such as Telephone Organization of Thailand (TOT) and the Communication Authority of Thailand (CAT).

All of the frequency assignees were government agencies and state enterprises however. The Radio Act only empowered the PTD as decision-maker for frequency assignment. There was much political intervention by government agencies. Using cabinet approval, the government therefore set up the

[24] This section is mainly based on PTD (1974 - 2000, 1983, 2001).

NFMB to decide on frequency assignment over the PTD. The authority centralized the regulated level however.

The Radiocommunication Act and the Sound and Television Broadcasting Act were enacted on February 8, 1955. These acts empowered the PTD and the Public Relations Department to control the use of frequency of radiocommunication stations and issue sound and television broadcasting licences, respectively. No technical characteristic were imposed on the use of such radiocommunication stations however. Moreover, these two acts did not encroach on government agencies, which had control over radiocommunication stations. Thus, the Thai government received experts from the United States Operations Mission (USOM) to investigate and report with recommendations to the Thai government.

In the USOM report of 1966, there was a crucial recommendation to set up a radio regulatory office at the same level as the department[25] in order to determine the technical specifications of radiocommunication devices, assign frequency, register the use of frequency to the ITU, enforce the regulations, solve interference problems, monitor the use of frequency, and research and develop radiocommunication services. This office could be under any government agency.

On October 24, 1967, the Cabinet agreed not to implement the radio regulatory office and to set up the Frequency Management Board instead. Most of the work of this board concentrated on broadcasting, especially drafting its governmental broadcasting regulations.

On February 8, 1972, the government agreed to set up the National Frequency Management Board (1972), after a suggestion by the Ministry of Defence, in order to strengthen the PTD in terms of staff and instruments. The National Frequency Management Board (1972) supported the creation of the radio regulatory office inside the PTD. The radio regulatory office was succeeded in 1973 and called the Frequency Management Bureau. The Frequency Management Bureau has the same rank as the division within the PTD. After that, the National Frequency Management Board (1972) was dissolved.

Until March 26, 1974, the Thai cabinet approved and ordered the Ministry of Transport to establish the NFMB by the Ministry Order of 78/1974 on April 19, 1974, to examine and coordinate radiocommunication activities before licenses were granted by the PTD.

In the beginning, the NFMB comprised representatives from the Security Council, the Military Communication Department, the PTD, the Prime Minister's Office, the Ministry of Internal Affairs, the Office of the National Economics and the Social Development Board, and the Budget Bureau, and was chaired by the Minister of Transport. In 1991, two specialists were added to the NFMB.

The NFMB had responsibility for determining the national technical standard, and control, assign, and register frequency, examine the standard of radiocommunication devices, create efficient procedures, evaluate the radiocommunication stations, and coordinate all radiocommunication users.

The NFMB convened meetings from 1974 to 1979 and from 1982 to 2002[26]. The NFMB met on a monthly basis. The total number of meetings was 164. The total number of issues considered was 2,003. The number and issues of the meetings are shown in Table 16. The NFMB worked as the

[25] In Thailand, the bureaucracy of government comprises the ministries. Each ministry has several departments under supervision. Each department has several divisions under supervision. Each division has several sections under supervision.

[26] From 1980 to 1982, the Director General of the PTD dissolved the NFMB using direct power from the *Radio Act 1955*, but strong political intervention re-established the NFMB.

approval board for all the radiocommunication activities in Thailand and had the PTD to work as the secretary of the NFMB to implement board decisions.

Table 16. National Frequency Management Board meetings

Year	1974	1975	1976	1977	1978	1979	1982	1983	1984	1985	1986	1987	1988	1989
Times	9	5	5	11	13	8	7	5	11	10	10	11	9	6
Issues	26	76	63	106	190	143	68	64	112	100	112	164	152	119
Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**Total**
Times	5	6	5	5	5	3	2	4	2	2	2	2	1	**164**
Issues	132	90	53	48	41	30	14	36	23	16	10	11	4	**2045**

The NFMB gave guidelines or procedures for frequency management of several services, including broadcasting service, fixed service or microwave link, land mobile service, satellite service, and low-power devices. The highlights were the guidelines of amateur radio service, the sound and television broadcasting plan, the citizen band for the general public, the fixed microwave link plan, the trunk radio plan, the National Table Frequency Allocation 1999, etc.

The NFMB drafted the National Frequency Management Regulation, which came into force on January 9, 1975. This regulation was under the Office of the Prime Minister and signed by the Prime Minister, but the Minister of Transport was the person in charge.

The National Frequency Management Regulation of 1975 empowered the NFMB to authorize all radiocommunication stations before they could obtain radiocommunication licences from the PTD. There were five sections in this regulation. Section 1 – Radiocommunication Station: all radiocommunication stations belonged to the government agency or to private sectors that had contracts with government agencies. Section 2 – Transmitting Power: no transmitters should operate over the given limit. Section 3 – Antennas and propagation: all antennas should use the given specification. Section 4 – Frequency assignment: only assigned frequencies should be operated and followed under the Radio Regulations and ITU Recommendations. Section 5 – Others: all transferred radiocommunication stations should be approved by the NFMB prior to transfer.

From 1974 to 1979, the NFMB had several important issues ranging from drafting the relevant regulation to assigning frequency to specific users. The majority of licensees are government agencies (national security and civil service) such as the military, the police, and the Royal Bureau, the Ministry of Public Health, the Department of Provincial Administration, the Royal Forest Department, and the Princess Mother's Medical Volunteer Foundation. The private companies that had contracts with a government agency, such as mining, road construction, sugar factories, were the second group of licensees. The objective of frequency assignment during this period ranged from national security and national interest to specific uses by private companies. The majority of uses or services of frequency assignment was fixed service and land mobile service. Fixed service included fixed link point-to-point and point-to-multipoint. Land mobile service included walkie-talkie and trunk radio. The NFMB used the first come, first served basis for frequency assignment.

From 1982 to 2002, the second period after the re-establishment of the NFMB, due to the strong political intervention, the NFMB still used the first come, first served basis. The most important frequency assignment by the NFMB was the frequency assignment to TOT and CAT for cellular service, especially the concession under both TOT and CAT.

In the sixth meeting of the NFMB in 1989, the NFMB assigned the frequency of the 900 MHz band for cellular service to TOT. TOT has Advanced Info Service PLC (AIS) as a concessionaire. The AIS uses GSM 900 for its service.

In the first and third meetings of the NFMB in 1990, the NFMB assigned the frequency of 1800 MHz for cellular service to CAT. CAT has Total Access Communication PLC (DTAC) as a concessionaire. The DTAC uses GSM1800 for its service.

On November 4, 1997, the NFMB issued guidelines on frequency assignment to provide clear criteria and transparent processes. There were four sections in this regulation. Section 1 gave the characteristics of the frequency assignees, which were the government agencies, state enterprises, or private sectors that had contracts with government agencies. Section 2 covered the assignment criteria including 1) the purpose of frequency usage, 2) efficient use of frequency, 3) block allocation for flexibility of users, 4) National Frequency Allocation Table, Radio Regulations, and ITU-R Recommendation, 5) primary and secondary service, 6) neighboring country, 7) the duration of frequency assignment was five years, and 8) auction possibility. Section 3 dealt with the right of frequency assignees that cannot be transferred to others, partially or wholly, before NFMB approval. Section 4 was ex-post regulation after frequency assignment, including 1) utilization report after one year, 2) recall of unused frequency after two years, 3) enforcement for the missed use of frequency assignment, 4) compensation to the existing assignees if there has been harmful interference, 5) partial recall if frequency utilization was inefficient, and 6) the right to change the frequency assignment, if necessary.

On February 20, 1998, at the first meeting of the NFMB, the NFMB approved a frequency transfer within the CAT concession (now CAT Telecom PLC). CAT proposed the transfer of 1710-1722.6/1805-1817.6 MHz to Wireless Communication Service Company Limited (now True Move) and 1747.9-1760.5/1842.9-1855.5 MHz to Digital Phone Company Limited (now belongs to the AIS), additionally from the DTAC, which was the existing concessionaire on 1800 MHz of CAT. The NFMB approved CAT's proposal to limit the duration of frequency transfer to that of CAT-DTAC's contract. The whole process was conducted from January 31, 1997 to February 20, 1998.

The frequency transfer reflected the property right of frequency, which gives ownership or individual right to use. The whole frequency transfer process was with the NFMB via the command-and-control approach however.

The main purpose of establishing the NFMB was to reduce political intervention by government agencies, because the Radio Act 1955 did not enforce it[27]. Thus, there was much political intervention in the PTD. The emergence of the NFMB acted as a buffer for the PTD. From 1980 to 1982, the Director General of the PTD dissolved the NFMB using the direct power of the Radio Act of 1955, but strong political intervention re-established it.

On October 11, 1997, the Constitution 1997 of Thailand was enacted. Article 40 gave guidelines to an independent agency to regulate frequency as a national resource. This constitution did not affect the working of the NFMB until the Act on Establishment of the National Broadcasting Commission (NBC) and the National Telecommunications Commission (NTC) were enacted on March 7, 2000. There was a provision in Article 80 that prohibited additional frequency assignment and business

[27]The Post and Telegraph Department, the Public Relations Department, the Ministry of Defence, and other government agencies in Ministerial Regulations shall not be enforced under the *Radio Act 1955*. This means that these government agencies do not require a radiocommunication licence. Prior authorization from the NFMB shall be sought however.

licenses, so the NFMB could not assign new frequency. The NTC was ultimately formed on October 1, 2004. During almost four years, from March 7, 2000 to October 1, 2004, there were no new frequency assignments or business licences for telecommunication or broadcasting service. Furthermore, the NBC could not be established because of the extremely strong political intervention.

On October 1, 2002, the PTD was transferred to the Ministry of Information and Communications Technology and the PTD proposed the continuation of the NFMB, but the Ministry of Information and Communications Technology dissolved it.

On November 16, 2002, the Telecommunications Business Act was enacted and it removed all monopoly rights from the government agencies or state enterprises, including TOT and CAT, which monopolized domestic and international telecommunication services, respectively, by revoking the Telegraph and Telephone Act of 1934 and 1974.The opposite situation arose, however, because there was no regulator NTC to exercise the power of this act. The existing operator under the state-owned enterprises became stronger because it faced no new entrants or regulator.

During the period of the NFMB, all radiocommunication services were monopolized by government agencies or the private sector that had contracts with government agencies. In the beginning, the general public was only allowed to use low-power devices, which will be discussed in Section 4.6, first with relevant licences and then unlicensed. The frequency assignment used the command-and-control approach on a first come, first served basis. At this stage, the technical aspects in terms of harmful interference were the main concern of the assignment process.

To summarize this section, the NFMB was set up to separate the roles of the PTD. Before the NFMB, the PTD had sole authority as administrator, regulator, and operator of frequency assignment in Thailand. After the NFMB, the PTD only had an administrator and operator role. The NFMB had the regulator role instead.

The NFMB used command-and-control on a first come, first served basis for frequency assignment. Until the end of 1997, the NFMB set the broad scope of a market-based approach for auction, if necessary, and allowed the transfer of the right to use frequency to other parties after NFMB approval. The frequency transfer showed that the NFMB frequency assignment guidelines of 1997 gave property rights to frequency. Unfortunately, there were no auctions during the NFMB period.

A summary of significant events is shown in following table.

Table 17. Period of National Frequency Management Board

Time	Event
1955	The Radiocommunication Act and the Sound and Television Broadcasting Act enacted
1972	The first National Frequency Management Board is dissolved
1974	The National Frequency Management Board (NFMB) founded by ministry order
1975	The National Frequency Management Regulation came into force
1997	The first guidelines for frequency assignment came into force The Constitution of Thailand enacted
2000	The Act on Establishment of the NBC and NTC – Article 80 enacted
2002	The PTD transferred to the Ministry of Information and Communication Technology The Telecommunications Business Act enacted The NFMB dissolved

4.5 The National Telecommunications Commission[28]

After the separation of the decision-maker for frequency assignment from the providers during the NFMB period, the decision-maker was still under the direct control of the government. The Constitution of 1997 initiated an independent regulatory agency to regulate the use of frequency as national interest. The constitution changed the decision-maker to an independent agency. Consequently, the relevant acts and regulations changed the old scheme of authorization or permission to have a licensing scheme that allowed all qualified parties to obtain frequency. The authority still held highly regulated power imposed on radiocommunication use however. The telecommunication industry comprised an independent agency, a provider (state enterprise and private entity), and users.

The NTC was established on October 1, 2004, after a long delay of almost four years from the Act on Establishment of the NBC and NTC was enacted in 2000, and three years after the Telecommunication Business Act was enacted in 2001. The PTD was dissolved by law and transferred to the Office of the NTC on January 1, 2005.

The Act on Establishment of the NBC and NTC 2000 separated the role of authority for frequency assignment. The NTC comprised seven commissioners acting in the regulator role. The office of the NTC acts as the secretary office of the NTC. The MICT acts as administrator on behalf of the Thai government in international activities.

For almost six years, the NTC issued regulations to change the scheme of authorization of frequency, which was monopolized by government agencies, state enterprises, or private sectors that had contracts with government agencies, into a licensing scheme for all parties, including both government and non-government organizations in order to optimize the benefits of frequency, which is a national resource, at all levels (local, regional, and national).

The NTC issued almost 112 regulations, which were published in the *Royal Gazette*[29] from October 1, 2004 to March 30, 2010, to ensure the transition from the monopoly to a liberalized market. There are two NTC sets of regulations concerning the frequency assignment published in the *Royal Gazette*, but one regulation on frequency assignment was never published.

The NTC regulations that were not published concerned the interim provision on frequency assignment on January 7, 2005 and were not published in the *Royal Gazette*. There were three phases: short, medium, and long term. The short term ran from January 7 to March 31, 2005, and did not allow new assignment except for national security and disaster relief. The medium term ran from April 1 to July 31, 2005, and allowed new assignment, if necessary, apart from national security, disaster relief, and international treaty or state contract. The long term was after July 31, 2005, and was subjected to the NTC regulation of the frequency assignment criterion.

The NTC regulation of the frequency assignment criterion that was published in the *Royal Gazette* on September 28, 2005, consisted of ten sections. Section 1 revokes the NFMB guidelines for frequency assignment from 1997. Section 2 is the definition of non-commercial and commercial use. Section 3 states the purposes of frequency assignment. Section 4 concerns necessary frequency assignment, including government agencies, one-year renewal of commercial and non-commercial use, the urgency of non-commercial use, and harmful interference to existing services. Section 5 gives the frequency

[28] This section is mainly based on NTC (2005b, 2005c, 2005d, 2007a) and the *Act of Establishment of the National Broadcasting Commission and the National Telecommunications Commission 2000*.

[29] The regulations published in the *Royal Gazette* came into force. No one has the right to claim that he/she/it does not know the regulations.

assignment criteria including characteristics of frequency assignees, technical characteristics, social impact, financial aspects, and compatibilities with the Telecommunications Master Plan and Frequency Master Plan. Section 6 is the process of application. Section 7 states the frequency usage fees according to the Ministry of Information and Communication Technology Regulation on March 10, 2003. Section 8 gives the right for the NTC to exempt this regulation. Section 9 is the enforcement date. Section 10 deals with the cancellation of all regulations that conflict with this regulation.

The second NTC regulation of frequency assignment that was published in the *Royal Gazette* on November 17, 2005, concerned experimenting with temporary use and was intended to facilitate the development of new technology. Currently, there are 18 licensees to test the WiMax technology. Each licensee had to pay a frequency usage fee and had 90 days for experimenting.

The NTC regulations on September 28 and November 17, 2005, do not mention the right of frequency assignees, which had been mentioned in the NFMB guidelines for frequency assignment in 1997. Article 53 of the Act of Establishment of the NBC and the NTC in 2000, however, clearly states that the frequency licence is an individual right that cannot be transferred prior to NTC approval. On July 31, 2007, the NTC issued the regulation according to Article 53 as the guidance and process for frequency transfer.

The frequency transfer was addressed in 2007, however, by the NTC regulation on frequency transfer in 2007 and provided the process and details of frequency transfer, including the rights of transferor and transferee, and the frequency transfer fee. Moreover, this regulation provided the concepts of frequency sharing, frequency substitution, and refarming. After the licensees obtained the frequency assignments from the NTC, they had to proceed as stated in the NTC regulation of frequency transfer if they wanted to transfer the frequency to other parties.

The highlight of the frequency transfer was the transfer of 1900 MHz between the TOT Public Limited Company and CAT Telecom Public Limited Company. Both companies are state-owned and incumbents in the telecommunications market. The process began on October 22, 2008, and finished at the NTC meeting on March 13, 2009. The frequency transfer fee – five percent of the frequency value – was 262 million baht (around 8 million USD).

This frequency transfer showed the property right of frequency, especially the exclusive right to use the frequency – an individual right. The mechanism is by the command-and-control approach, which followed the NTC regulation of frequency transfer in 2007.

Four new NTC[30] commissioners were appointed on February 18, 2010. The NTC has introduced a market-based approach – an auction for 3G frequency in the 2 GHz band. The process of the 3G auction was ended by the Supreme Administrative Court Order on September 23, 2010.

To summarize this section, the NTC issues regulations to change the authorization scheme to a licensing scheme in order to shift from a command-and-control economy to a market economy. Frequency transfer that represents the property right of frequency can also be carried out by the NTC, by both a command-and-control and a market-based approach.

A summary of significant events is shown in following table.

[30] The NTC comprises seven commissioners – one chairman and six commissioners. The term of the NTC is six years. In the first three years, three commissioners had to withdraw. In this case, one commissioner resigned before withdrawing. There are therefore four new commissioners of the NTC.

Table 18. Period of the National Telecommunications Commission

Time	Event
1997	The Constitution of Thailand enacted – Article 40 gave birth to the independent regulator
2000	The Act on Establishment of the NBC and NTC – Article 80
2002	The Telecommunications Business Act enacted
2004	The National Telecommunications Commission (NTC) founded
2005	NTC frequency assignment criterion came into force
2007	NTC frequency transfer came into force
2009	1900 MHz frequency transfer – TOT and CAT telecom
2010	Four new NTC commissioners appointed 3G auction ended by the Supreme Administrative Court Order on September 23, 2010

4.6 Self-regulated – spectrum commons[31]

The exclusive right to use frequency was awarded to the frequency assignees to ensure there was no harmful interference in the use of radiocommunication services. The new technology developments made the use of exclusivity of frequency unnecessary however. The non-exclusive use of frequency was initiated in the low-power devices, especially in the ISM band. The users shared the frequency with others and accepted the interference from the other users or devices. The constraints of such uses included the specified frequency and power limitations.

The NFMB fist attempted to delegate the authority to the PTD to assign the use of frequency under one watt. The regulated level was transferred from the NFMB to the PTD. The decision-maker for frequency assignment under the power of one watt was therefore the PTD.

Using low-power devices in Thailand

The PTD authorized the use of low-power devices, depending on the technical characteristics, as a first priority to avoid harmful interference. The users had to obtain authorization from the PTD. The use of low-power devices still require the relevant radiocommunication licences however. The PTD realized the benefit of the general public and the initiation of the exemption of relevant radiocommunication licences pushed forward as the Ministerial Regulations. The exemption of licenses facilitated the use of low-power devices such as spectrum commons.

The stakeholders for low-power devices were the authority, users, and manufacturer or importers. The NTC also allowed the Internet service provider to use the spectrum commons. The stakeholders were extended to the service provider as well.

In Thailand, there are two separate steps for unlicensed devices. First, the devices must receive authorization under the Radio Act, according to the Table Frequency Allocation and related regulations in terms of technical specification or standard of devices. Second, when the use of these devices increases over time, the authority may consider exempting the related licences imposed on the use of these devices to reduce the burden for the general public by issuing a regulation to exempt the related licenses in terms of the ministerial or NTC regulations. The authorization of the use of radiocommunication devices by command-and-control for frequency assignment and technical standard approval of devices was centralized by the authority.

[31] This section is mainly based on MICT(2004), MOT(1993, 1998, 2001), NTC(2005a, 2005e, 2007b, 2007c, 2008a, 2008b), and PTD (1974 - 2000, 2001) .

Use of low-power devices before 1974

During the time of no regulation – without the Radio Act – there was no use of radiocommunication devices for the general public except by government agencies. With the Radio Act enacted, all radiocommunication usages were prohibited except the authorization granted by PTD since 1914. On March 26, 1974, the cabinet approved for the Ministry of Transport to set up the NFMB with the Ministry Order of 78/1974 on April 19, 1974, to double-check the work of the PTD. Thus, all the radiocommunication activities of the PTD had to ask the NFMB for approval. This was the centralized management style of the NFMB at the initial stage.

Use of low-power devices in 1975-1986

In 1975, the NFMB delegated some authority to the PTD at the first meeting in 1975 on January 8, 1975. The NFMB authorized the PTD to allow the private sector to install transmitters for paging service in the 26.92-27.23 MHz band in limited areas. The power of the transmitters must not exceed one watt. That was the starting point of decentralization in spectrum management and the initiation of allowing the general public to use low-power devices.

On January 22, 1975, in the second meeting in 1975, the NFMB authorized one company to make an anti-theft device with the frequency of 27.060 MHz and authorized the PTD to allow the use of the anti-theft device in cars and motorcycles for the general public.

In the first meeting in 1978 on January 25, 1978, the NFMB authorized the PTD to allow the private sector to use UHF transceivers in the 461.150-461.250 MHz band with power up to one watt. The UHF transceiver was the walkie-talkie application service.

On June 25, 1982, in the second meeting in 1982, the NFMB re-authorized the PTD to allow the use of radiocommunication devices with power up to one watt for all applications and anti-theft devices in cars and motorcycles for any frequency.

In the third meeting in 1982 on July 8, 1982, the NFMB authorized the PTD to allow the use of the citizen band (26.96-27.23 MHz) transceivers, cordless telephones, wireless microphones, wireless remote controls, such as small plane remote controls, anti-theft devices, garage door openers, and radiocommunication devices in the industrial science service that were not used for communication purposes such as microwave ovens.

The minutes of the NFMB for the fourth meeting in 1982 on August 18, 1982, authorized the PTD to allow installation of base stations for wireless telephone for one-to-one (one transmitter and one receiver) only. The wireless telephone used frequencies of 1.7/49, 27/49 MHz with power up to 500 milliwatts for short-range communication (around 500 meters). Moreover, the wireless telephone used frequencies of 27/49 MHz with power up to five watts for long-range communication (around 10 kilometers).

Additional low-power devices introduced in 1986

On April 17, 1986, in the fifth meeting in 1986, the NFMB authorized the PTD to allow use of radio warning devices with power up to one watt and a 16 kHz bandwidth.

After the NFMB delegated authorization of all radiocommunication devices with power up to one watt, the PTD allowed the use of transceivers in medical instruments with power up to 10 milliwatts, and electronic and telecommunication measurement equipment.

Previous events concerned the authorization of the use of radiocommunication devices. Their use required related licences however. The story of the exemption of licenses was different because the power to waive licences belonged to the Ministry of Transport, which had to issue the Ministerial Regulations according to the Radio Act of 1955 and its amendment.

Increased number of low-power devices after 1986

The PTD realized that the use of low-power devices had increased over time and wanted to facilitate the use of low-power devices for the general public. The PTD proposed the exemption of radiocommunication licences to the Ministry of Transport to issue the Ministerial Regulations. There were lengthy procedures from drafting to announcement however. First, the PTD drafted the Ministerial Regulations. Second, the draft of the Ministerial Regulations was sent to the Council of State in order to check the format and content and send it back to the PTD for revision. Third, the draft of the Ministerial Regulations included revision by the Council of State to be sent to the Ministry of Transport for consideration and signing. Fourth, the final version of the Ministerial Regulations was sent to the *Royal Gazette* for formal publication. The process took almost two years.

Ministerial Regulations for radiocommunication licence exemptions 1993-2004

Ministerial Regulation No. 24

Ministerial Regulation No. 24 – the first Ministerial Regulation for radiocommunication licence exemption – was published on March 12, 1993. It comprised five sections. Section 1 was an exemption on making, possessing, using, importing, exporting, and trading radiocommunication licences. Section 2 was an exemption on possessing, using, and exporting radiocommunication licences. Section 3 was an exemption on importing radiocommunication licences. Section 4 was an exemption of parts of radiocommunication devices when assembled with devices that already had a licence. Section 5 was an exemption on installing radiocommunication licences.

The unlicensed devices were in Section 1, which exempted all radiocommunication licences. There were: 1) wireless microphones with power up to 10 milliwatts in the 33-50, 88-108, 165-210, and 470-490 MHz bands and with power up to 30 milliwatts in the 902-960 MHz band; 2) wireless telephones with power up to 10 milliwatts in the 1.6-1.8, 30-50, and 54-74 MHz bands; 3) radio-control models with power up to 100 milliwatts in the 26.964-27.405 MHz band; 4) long-range radio control with power up to 100 milliwatts in the 26.964-27.405 MHz band and with power up to 10 milliwatts in the 300-500 MHz band; 5) transceivers of the citizen band with power up to 100 milliwatts in the 26.964-27.405 MHz band, and warning devices with power up to 10 milliwatts in the 300-500 MHz band; 6) transceivers in medical instruments with power up to 10 milliwatts in the 300-500 MHz band; and 7) electronic and telecommunication measurement equipment.

Section 1 of Ministerial Regulation No. 24 exempted all radiocommunication with specified applications, power limitation, and operating frequency that were not flexible for the new applications.

On October 15, 1996, the PTD allowed the general public to use radiocommunication devices in the 2400-2500 MHz band with Effected Radiated Power (E.R.P.) up to 100 milliwatts for indoor use only. These devices had to hold either the possessing, using or installing radiocommunication licences. The devices had to be type-approved by the PTD.

Ministerial Regulation No. 28

On December 21, 1998, Ministerial Regulation No. 28 was published, as well as two additional items in Ministerial Regulation No. 24, one in Section 2 and one in Section 5. These allowed the use of cordless telephones for personal use with power up to 10 milliwatts in the 1900-1906 MHz band and they could be used with DECT and PHS technology with slight modification of frequency arrangements.

Ministerial Regulation No. 30

On January 17, 2001, Ministerial Regulation No. 30 was published and Section 3 of the Ministerial Regulation No. 24 revised to allow cellular phone and radio paging that already had type approval from the PTD and international roaming agreements for device circulation.

After October 1, 2003, the PTD was transferred to the Ministry of Information Communications and Technology. On November 28, 2003, the PTD amended the regulation that allowed the general public to use radiocommunication devices in the 2400-2500 MHz band by deleting "of indoor use only." The limitation of power, the related radiocommunication licences, and the type approval remained imposed however.

Change in Ministerial Regulation [2004]

There was a change in the format of the Ministerial Regulations that called on the substance of the regulation. The Ministerial Regulations Nos. 24, 28, and 30 have been revised and called the Ministerial Regulations of the Exemption of Radiocommunication Licences, and were published on March 25, 2004.

The Ministerial Regulation of the Exemption of Radiocommunication Licences in 2004 consisted of ten sections. Section 1 revoked Ministerial Regulations Nos. 24, 25, 28, 29, and 30. Section 2 exempted the making, possession, use, importing, exporting, and trading of radiocommunication licences. Section 3 exempted the possession, use, and exporting of radiocommunication licences. Section 4 exempted the possession, importing, exporting, and trading of radiocommunication licences for cellular telephone, radio paging, and radiocommunication devices in Global Mobile Personal Communication by Satellite (GMPCS), which had been type-approved by the PTD. Section 5 exempted importing and exporting of radiocommunication licences for cellular telephone, radio paging, and radiocommunication devices in GMPCS that had international roaming agreements. Section 6 exempted the possession and use of radiocommunication licences for transceivers of the citizen bands 78 and 245 MHz. These already had licences and they were transferred. Thus, the transferees did not require the possession and use of radiocommunication licences. This did not include the transfer of ownership of the radiocommunication device, however, which required a relevant licence. Section 7 exempted the possession and use of radiocommunication licences for transceivers of amateur radio that already had licences and been transferred. Thus, the transferees did not require the possession and use of radiocommunication licences. The operation of amateur radio required the amateur radio certificate separately, however, and it did not include transfer of ownership of the radiocommunication device, which had to be done legally with the relevant licence. Section 8 exempted the parts of the radiocommunication devices when assembled with other such devices. Section 9 and Section 10 exempted the installation of radiocommunication licences.

In the Ministerial Regulation of the Exemption of Radiocommunication Licences in 2004, Section 2 and Section 10 related to unlicensed devices. When comparing Ministerial Regulation No. 24 and the

Ministerial Regulation of the Exemption of Radiocommunication Licences in 2004, there were several differences. First, the Ministerial Regulation of 2004 added an exemption on installing radiocommunication licences from Ministerial Regulation No. 24 (the exemption of making, possessing, using, importing, exporting, and trading radiocommunication licences). Second, the Ministerial Regulation of 2004 added five items in Section 2. These were 8) the receiver in radio navigation service, radio navigation satellite service, radio location service and radio location satellite service, 9) the radar application in the 5.725-5.875, 10.0 10.6, 24.05-24.25, and 76-81 GHz bands with Equivalent Isotropically Radiated Power (E.I.R.P.) up to 10 milliwatts, 10) devices in the band lower than 135 kHz with E.I.R.P. up to 150 milliwatts, 11) devices in the 13.533-13.567 MHz band with E.I.R.P. up to 5 milliwatts, and 12) devices in the 2400-2500 MHz band with E.I.R.P. up to 100 milliwatts.

In the Ministerial Regulation of 2004, there was flexibility or neutrality of technology for radiocommunication devices in Section 2, Items 10, 11, and 12, which allowed all applications using the specified frequency band and the power limitation, including Radio Frequency Identification (RFID), Tag, e-SEAL, Bluetooth, and Wi-Fi devices.

Establishing the National Telecommunications Commission and its regulations [2004-2007]

On October 1, 2004, the NTC was established and the PTD was dissolved by law to be transformed into the Office of the NTC from January 1, 2005.

The NTC regulation has the same rank as the Ministerial Regulations[32]. The procedure to publish the regulation is much shorter than the previous procedure. The Office of the NTC drafts the new NTC regulation and prepares an agenda for NTC meetings in order to obtain approval from the NTC. After the NTC approval, the Chairman of the NTC signs and sends it to the *Royal Gazette* for publication. The whole new procedure takes around six months.

On June 22, 2005, the NTC Regulations of Nature and Categories of Telecommunication Business (2005) and Criteria and Procedure for Internet Service Licence Applications (2005) were published to determine the nature and categories of telecommunication business, and provide clear and unambiguous criteria and conditions for Internet service licence application, respectively. Wi-Fi service (public hotspots) falls into the "Type 1" Internet licence.

Adapting the Ministerial Regulation for exemptions by the NTC [2007]

On August 29, 2007, the NTC Regulation of the Exemption of Radiocommunication Licences was published, adapting the Ministerial Regulation for the Exemption of Radiocommunication Licences in 2004 and indicating which radiocommunication licences were and were not exempted.

The NTC Regulation on the Exemption of Radiocommunication Licences in 2007 comprises eleven sections. Section 1 revokes all prior regulations against this regulation. Section 2 is similar to Section 2 and Section 10 of the Ministerial Regulation for the Exemption of Radiocommunication Licences in 2004. The differences are: 1) the deletion of the wireless microphone in the 902-960 MHz band, which is the same band as cellular phone (GSM 900 MHz); 2) the deletion of wireless telephone in the 54-74 MHz band, because the technology is obsolete; 3) open applications in the 26.965-27.405 MHz band with power up to 100 milliwatts; 4) open applications in the 30-50 MHz band with power up to 10

[32] The hierarchy of Thai law is Constitution, Act, Ministerial Regulations, Ministerial Announcements, Department Regulations, and Department Announcements. The NTC regulations have the same rank as Ministerial Regulations.

milliwatts; 5) open applications in the 300-500 MHz band with power up to 10 milliwatts; 6) receivers in the meteorological aid service, meteorological satellite service, Earth exploration-satellite service, standard frequency and time signal service, standard frequency and time signal satellite service, space research service, radio astronomy service, and safety service. Section 3 has the exemption of possessing, using and exporting radiocommunication licences but still holds the making, importing, and trading radiocommunication licences. Sections 4, 5, 6, 7, 8, and 9 of the NTC Regulation on the Exemption of Radiocommunication Licences 2007 are the same as Sections 4, 5, 6, 7, 8, and 9 of the Ministerial Regulation for the Exemption of Radiocommunication Licences in 2004. Section 10 is the exemption of importing and exporting of radiocommunication licences for radiocommunication devices for experiment and research and is also used by the United Nations specialists, the Red Cross, and foreign embassies. The use of these radiocommunication devices exempted the possession, use, and installation of radiocommunication licences for temporary use up to a period of three months. Section 11 is the enforcement date after publication in the *Royal Gazette*.

On January 26 and August 3, 2007, the NTC regulation of standard telecommunication devices for radio local area network (RLAN) allowed the use of RLAN in the 5150-5350 MHz band with E.I.R.P. up to 200 milliwatts for indoor use only, and in the 5470-5725 and 5725-5850 MHz bands with E.I.R.P. up to one watt.

On January 18, 2008, all short-range devices (according to the NTC regulation) were certified by suppliers according to the NTC Regulation of Standard of Telecommunication Devices (both procedure and standard). The suppliers must certify that the equipment has technical specifications according to the NTC Regulation, as a Supplier's Declaration of Conformity.

Remarks on collected data on WLAN in Thailand

Before this time, there were three regulations regarding the type approval test by the Post Telegraph Department. On July 21, 1992, the PTD imposed the regulation of a type approval test for amateur radio equipment, because there was much illegal equipment in use in amateur radio service that could be tuned to other frequency bands. On December 7, 1995, the PTD revised the regulation of 1992, and on April 7, 1998, it extended the type approval test to other services, including land mobile, maritime mobile, and aeronautical mobile service. On June 7, 2001, the PTD revised the regulation of 1995 to accept test reports from accredited test laboratories other than the PTD.

In 1996, the PTD allowed the use of WLAN in Thailand with the relevant radiocommunication licences including the type approved for radiocommunication devices. The number of WLANs on type approval, possessing and importing licences are available in the archive of the PTD and the NTC FMS database. They are not publicly available on the website however. The manual access to the PTD has been conducted to gather the information from 1996 up to 2004. After the Ministerial Regulation of the Exemption of Radiocommunication Licences – the Ministry of Information and Communication Technology came into force; the information regarding the unlicensed devices at the PTD was not collected.

Fortunately, the Customs Department has an online database on the importation of radiocommunication devices, including WLAN routers. The information is available from 2001. Figures 6 and 7 show the number of WLAN routers that were type-approved by the PTD from 1996 to 2004 and the imported number of WLAN routers by the Customs Department from 2001 to 2010.

The number of WLAN routers in Figure 6 depicts the gradual growth of the use of WLANs in Thailand from 1996 to 2000. At that time, WLANs were used little and in a limited area. The increased growth in WLANs occurred from 2000 to 2004, in parallel with the big demand from warehouse management in big supply distribution.

The number of WLANs collected from the PTD was a subset of the number of WLANs collected from the Customs Department. The PTD's number had been collected since 1996 and ceased in 2004, however, after unlicensed regulations came into force (Figure 6). The Customs Department's number is available from 2001 to now (Figure 7). Figures 6 and 7 show the number of WLANs at two important points. The first point is after 1996 (the first time that WLAN was allowed to be used in Thailand). The second point is after 2004 (after the unlicensed regulations came into force). In order to compare the two stages of implementing unlicensed regulation – before and after – the growth of WLAN routers can be observed from Figures 6 and 7.

The number of WLAN routers in Figure 7 addresses the continued growth since 2001. The big growth started after the Ministerial Regulation of the Exemption of Radiocommunication Licences in 2004. This growth was in parallel with the event of WLAN being put into in the chipset of the smart phone and laptop. Mass production may also reach economy of scale, rendering the low price of the Wi-Fi chipset.

Figures 6 and 7 display differences in the number of WLAN routers before and after the implementation of unlicensed regulations in Thailand. This unlicensed regulation is one of many factors that encouraged wide use of WLAN routers in Thailand.

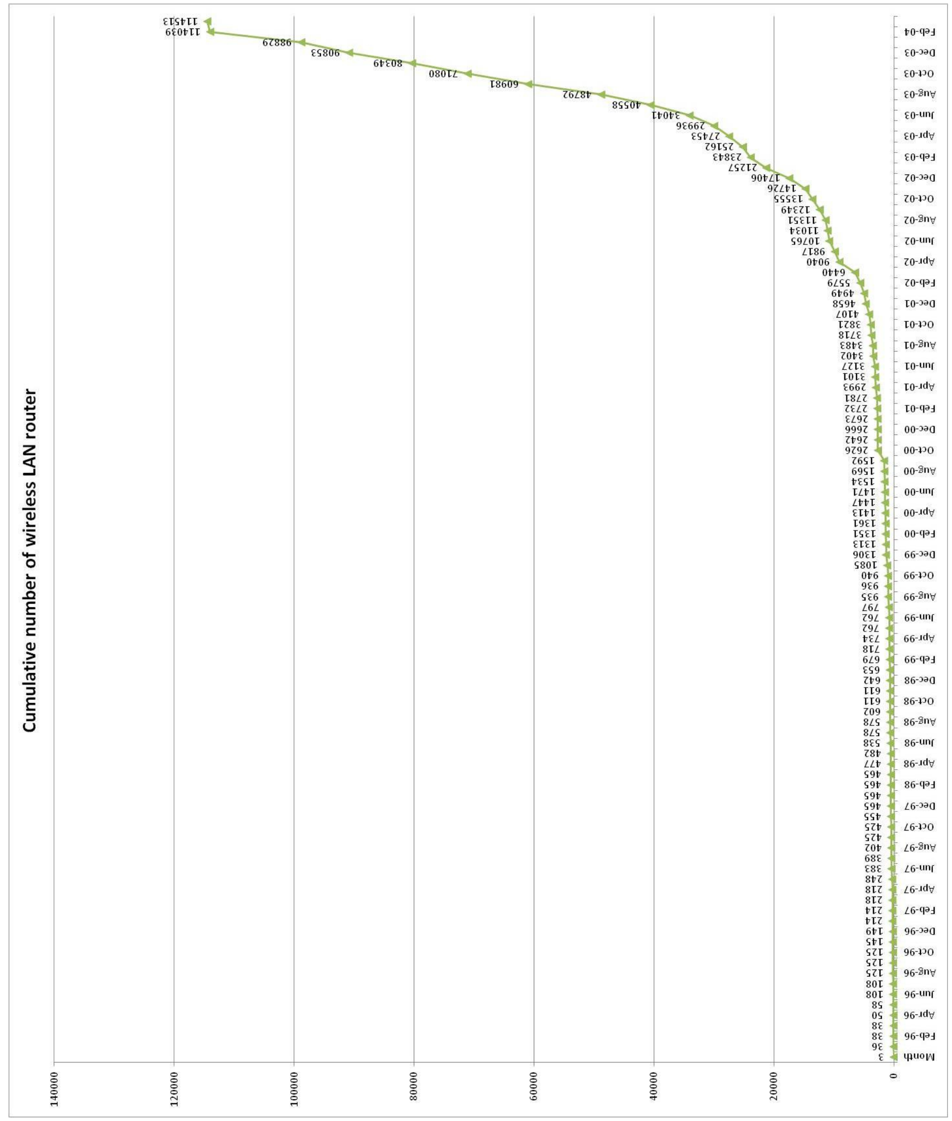

Figure 6. Number of WLAN routers 1996-2004[33]

[33] Source: Post and Telegraph Department, Thailand

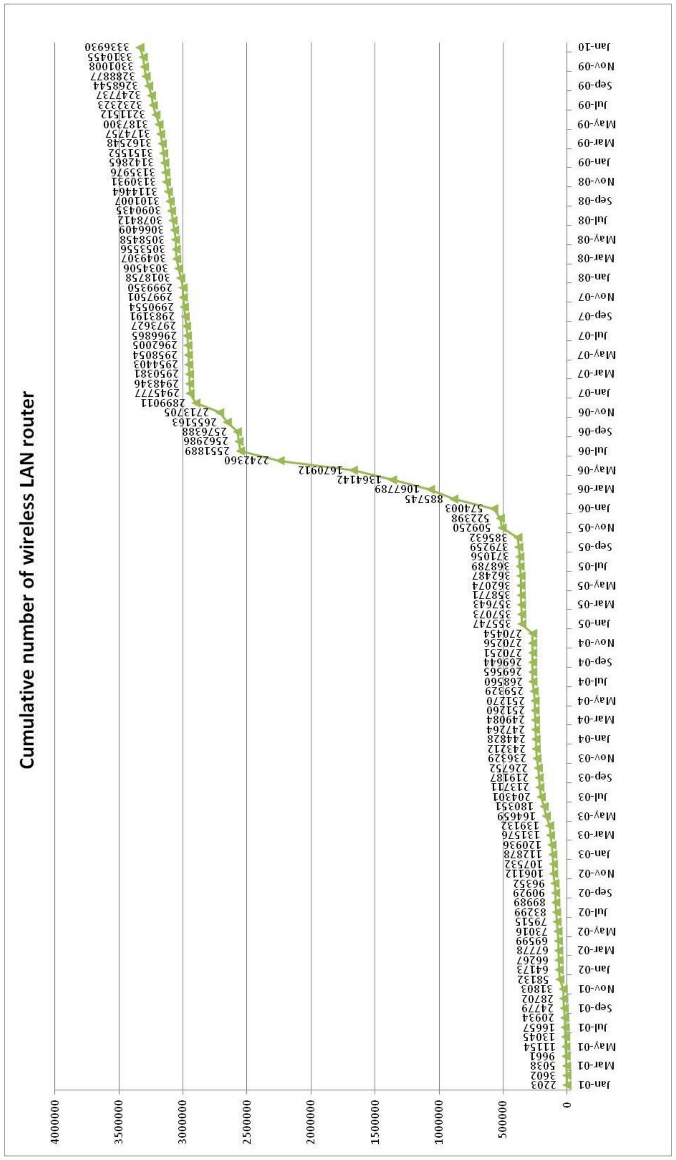

Figure 7. Number of WLAN routers 2001-2010[34]

[34] Source: Customs Department, Thailand

Summary

To summarize this period, after the NFMB delegated power to the PTD, development of short-range devices was gradually introduced. It proceeded from specific applications. Power limitation and specified frequency were still enforced, however, to avoid harmful interference in this limited area. The use of short-range devices was non-exclusive, i.e., no one had an exclusive right to use this frequency. The management of the use of short-range devices, or managerial right also started from self-regulation: users have to manage, with middleman management, service providers, or private commons, with the provider managing the use of commons, such as the Wi-Fi hotspot or public commons managed by the state agency.

A summary of significant events is shown in the following table.

Table 19. Period of self-regulated spectrum commons

Time	Event
1955	The Radiocommunication Act enacted
1974	The National Frequency Management Board (NFMB) founded by ministry order
1975	The NFMB authorized the PTD to allow 1-watt transmitters (paging + anti-theft)
1978	The NFMB authorized the PTD to allow walkie-talkies
1982	The NFMB authorized the PTD to allow 1-watt transmitters for all applications, including the Citizen Band (26.96-27.23 MHz) transceivers, cordless telephones, wireless microphones, wireless remote controls, such as small plane remote controls, anti-theft devices, garage doors
1986	The NFMB authorized the PTD to allow radio warning devices
1993	Ministerial Regulation No. 24 came into force – Ministry of Transport
1996	The PTD allowed WLAN on 2400-2500 MHz, indoor only
1998	Ministerial Regulation No. 28 came into force – Ministry of Transport
2001	Ministerial Regulation No. 30 came into force – Ministry of Transport
2003	The PTD allowed WLAN on 2400-2500 MHz, indoor and outdoor
2004	Ministerial Regulation of the Exemption of Radiocommunication Licences – Ministry of Information and Communications Technology
2005	Wi-Fi service provider – hotspot
2007	The NTC Regulation of the Exemption of Radiocommunication Licences RLAN 5150-5350/5470-5725/5725-5850 MHz allowed
2008	Supplier's Declaration of Conformity (SoD) for unlicensed devices

4.7 Discussion

In Thailand, the development of spectrum assignment has several roles. There are four important roles related to spectrum assignment: administrator, regulator, secretary office[35], and operator. Figure 8 shows the different actors in each period and the role of the actors.

	Administrator	Regulator	Secretary office	Operator
Before 1975	Post and Telegraph Department (PTD)			
1975 - 2002	PTD	NFMB	PTD	PTD/TOT/CAT
2002 - 2004	PTD		PTD	TOT/CAT
2004 - now	MICT	NTC	ONTC	TOT/CAT+ licensees

Figure 8. Role of actors in spectrum assignment in Thailand

[35] The Secretary Office is the secretary unit of the regulator. The secretary office works as the administrative unit of regulators.

Figure 8 shows the actors, including the administrator, regulator, secretary, and operator. The administrator represents the Thai government as the Thai delegate to international activities, such as international conferences, conventions, treaties, negotiations, and cooperation. The regulator acts as the national authority to assign frequency and issue the relevant regulations. The secretary works as the regulator's office and does all the administrative works for the regulator. The operator provides the services to the end-users after obtaining the frequency from the regulator.

Before 1975, the Radio Act had been enacted since 1914 and it gave sole authority to the PTD to assign frequency to users. At same time, the PTD acted as the administrator, regulator, and operator.

The NFMB was founded in 1975 by cabinet approval. The NFMB's role is as regulator to separate the authority from the PTD. The NFMB worked as regulator to assign frequency to users until 2002 and it was dissolved by the Ministry of Information and Communication Technology. The PTD was transferred under the Ministry of Information and Communication Technology in 2002.

After the Act on Establishment of the National Broadcasting Commission (NBC) and the National Telecommunications Commission (NTC) was enacted in 2000, the NTC was founded in 2004. During 2002-2004, there was no regulator to assign new frequency to users, according to the provision of the Act on Establishment of the NBC and NTC 2000. There was uncertainty in the Thai telecommunication industry.

The NTC was founded in 2004. The NBC was never founded however. So far, the NTC has only acted as regulator to assign frequency in telecom matters. The NTC does not have full authority to form the Joint committee between the NTC and the NBC to approve the National Table Allocation or National Master Plan. The reason of the Supreme Administrative Court on September 23, 2010, was not to provide the NTC with any right to pursue the 3G auction until the establishment of the National Broadcasting and Telecommunications Commission.

Table 20 presents Thailand's frequency assignment profile and the development of frequency assignment.

Table 20. Thailand's frequency assignment profile

Issue \ Country	Thailand
Type of economy	Command–and-control economy (beginning) and becoming a market economy
Frequency transfer (alienation right)	The NFMB in 1998 The NTC in 2009
Auction	The NFMB initiated in 1997 The NTC attempted in 2010
Spectrum commons	Authorization since 1974 and unlicensed since 2004

In order to elaborate on Table 20, Table 7 in Chapter 2 provides the stakeholders at each level of actions. At the constitutional choice level, there is an administrator and a regulator. At the collective choice level, there are operators. At the operational level, there are users.

At constitutional level, the decision-makers range from His Majesty the King or an authority appointed by the King during the monarchy period to the authority appointed by the Radio Act and the government. At constitutional level, the decision-maker produces rules and regulations to govern the

use of frequency. The decision-maker changes from time to time, starting from His Majesty the King, the authority appointed by the King, the authority appointed by the Radio Act, and the authority appointed by the Cabinet to the independent regulatory agency.

At the collective choice or institutional level, the operator or provider appears in terms of state enterprises as 100% owned by the Ministry of Finance. State enterprises, at the collective choice level, follow the rules and regulation from the constitutional level and create their own rules as network rules for users at operational level to follow. In Thailand, the state enterprises can have a private company as a partner to provide service to users.

During the authorization period, before the NTC, only state enterprises and their private companies can obtain frequency to provide telecommunication service to the general public, until the NTC changes to a licensing scheme to allow all qualified entities to obtain the frequency. At the collective choice level, there were therefore only state enterprises at the initial stage and many more private companies after the NTC period.

At the operational level, users always follow rules from both the operators at the collective choice level and the regulator at the constitutional choice level.

In Thailand, the rights to frequency use – access, withdrawal, management, exclusion, and alienation – vary by the regulated level and position in the telecommunication industry.

Before the Radio Act, all rights to frequency use belonged to the authority – His Majesty the King. There was a high degree of regulation because only the government agency could access frequency that was strictly controlled by His Majesty the King or an authority appointed by the King. The use of frequency had followed international treaties such as the International Radiotelegraph Convention.

Through the Radio Act, all rights to frequency use belonged to the stated authority: the PTD. Regulation was high because the PTD imposed conditions on the use of radiocommunication devices in terms of the installation of a radiocommunication station to provide the exclusive right to use frequency without interference. Conditions on use, including frequency, duration, area, and technical characteristic are rights to access, withdrawal, management, and exclusion. The alienation right belongs to the authority however.

After the NFMB was set up with Cabinet approval, the decision-maker of the frequency assignment changed from the PTD to the NFMB. Moreover, the NFMB exercised the alienation right (frequency-transfer of DTAC in 1998) and initiated auction of frequency in 1997. There was no case for holding auctions at that time however. The regulation was therefore slightly reduced because of the auction initiative to use the market mechanism to assign frequency.

In 2004, the NTC changed the authorization scheme to a licensing scheme and opened the telecommunication industry to qualified entities. The decision-maker for frequency assignment changed to the NTC. Regulation remains at a high level, however, according to the conditions imposed on the use of radiocommunication devices. In 2009, the NTC approved the frequency-transfer between TOT and CAT, in the case of the 1900 MHz band. This event reflects that the NTC holds the alienation right of frequency. The licensees have access, withdrawal, management, and exclusion rights. Now, the NTC aims to hold a 3G auction by 2010 but be ceased by the Supreme Administrative Court Order. Therefore, the degree of regulation may change due to the use of a market mechanism – an auction to assign frequency. The alienation right will be passed on to the winner during the auction.

While regulations from the regulator give exclusive rights to use frequency without harmful interference, a degree of self-regulated or spectrum commons allows for a non-exclusive right to use frequency. No one owns frequency. Everyone has to share frequency. In order to avoid harmful interference, the regulator assigns specific frequency, power limitation, and application as constraints. In Thailand, the spectrum commons as an unlicensed device was stated in 2004. The Thai experience shows that two steps are required for the spectrum commons approach, however: authorization of the use of spectrum commons and the exemption of radiocommunication licences allowing open access.

Moreover, the regulated level of network for spectrum commons is provided by the Internet service provider type 1 according to the NTC Regulation of Criteria and Procedure for Internet Service Licence Application (2005). The providers have the ability to manage Wi-Fi hotspots for their service.

Furthermore, spectrum commons can be divided into three groups, depending on the level of management rights: public commons, private commons, and unlicensed. If there is someone – a service provider or state agency – to manage access to the frequency, it is private commons or public commons, respectively. An example of private or public commons is access to the Internet via a Wi-Fi hotspot provided by the Wi-Fi operator or state agency to manage the frequency to access the Internet.

An example of unlicensed use is access to the Internet via a wireless router or Wi-Fi at home or in the office. Importantly, users do not pay for frequency access via a wireless router or Wi-Fi, but have to connect to the Internet by other means.

4.8 Summary

To summarize this chapter, the discussion on Thailand's history confirms the rights to use frequency in Table 13 in Chapter 2, provided the exclusive right to use frequency by using a command-and-control and market-based approach. The level of regulation depends on the alienation right the regulator delegates to the assignee. Spectrum commons is a non-exclusive right to use frequency and can be divided into three types: public commons, private commons, and unlicensed, responding to RQ.2.

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Chapter 5 Advantages and disadvantages of spectrum commons in Europe[36]

This chapter elaborates on the third research question: What are the advantages and disadvantages of spectrum commons? The chapter reflects on the advantages and disadvantages of spectrum commons from the author's perspective by blending the perspectives of stakeholders in the consultation with relevant literature.

The views of different stakeholders in European countries provide issues to be considered when implementing spectrum commons. The chapter starts by collecting views of stakeholders in the public consultation[37] of the Radio Spectrum Policy Group (RSPG) on commons on the "Aspect of a European Approach to Collective Use of Spectrum." There are nine respondents including the ARD-ZDF, Deutsche Telecom/T-Mobile, the EICTA, GSMA Europe, Metil Telecom consultants, Microsoft, Telefónica, PWMS Manufacturer Group, and the Delft University of Technology. These contributions, together with the results of the RSPG public consultation, provide input data for this chapter.

The main literature comes from Cave (2007), Chaduc and Pogorel (2008), Mark and Williams (2007), and Tonge and Vries (2007). They provide additional ideas in parallel with the RSPG consultation. These include suggestions for discussion on the appropriate time to implement a frequency, choosing a suitable frequency and an amount, and the technical aspects.

5.1 Examining literature and consultation

This section discusses the views of Cave (2007), Chaduc and Pogorel (2008), Mark and Williams (2007), Tonge and Vries (2007), and the RSPG public consultation in November 2008 in terms of the advantages and disadvantage of spectrum commons. Finding similarities and differences in the examined data motivates the identification of issues for spectrum commons. Table 21 summarizes the main advantages and disadvantages commonly recognized by the different input data.

Table 21. Advantages and disadvantages of using spectrum commons

Disadvantages	Advantages
Irreversibility	Reduce the barrier to entry
Lack of innovation if sharing with licensed services	Lower administrative cost
No legal right to complain of interference	Greater social benefit
Congestion and limited quality of service	Create innovation and stimulate demand for new service
	Suitable for small user and low-density area

These advantages and disadvantages of spectrum commons are discussed in more detail in the following paragraphs.

[36] This chapter is a revision of Ard-paru and Bohlin (2009).
[37] The public consultation on the draft RSPG opinion on "Aspect of a European Approach to Collective Use of Spectrum" was posted on June 10, 2008, and closed on September 29, 2008. The results of this public consultation was posted on November 19, 2008 (RSPG, 2008).

5.2 Disadvantages of using spectrum commons

Irreversibility
Once the regulator or administrator assigns a frequency band with certain conditions for licensed exemption or unlicensed spectrum, anyone can use the band as a public good. An example is Wi-Fi devices. Most laptops include a Wi-Fi chip set, and the Wi-Fi access point can be used anywhere from the home to public areas such as airports, train stations, and universities. Wi-Fi hot spots are also located in hotels and department stores.

If the regulator regained frequency and refarmed it for other users or services, it would be more difficult, because the equipment could be everywhere, and it would take a long time to clear this band. If, for example, the 2400-2500 MHz band, which is already used for Wi-Fi, Bluetooth, and other short-range devices, were considered for refarming for new services, i.e., a cellular mobile network. All these devices would have to stop transmission to ensure a new service would not receive interference.

Lack of innovation when sharing licensed services
Normally, when regulators assign frequency to licensees, an appropriate constraint is imposed, such as the technical specification of transmitters and receivers, the height of the transmitting station, the modulation type, and the level of transmitter power. After that, the regulator sometimes identifies spectrum commons to share with the licensed services. The regulator places more constrains on spectrum commons to ensure that use will not interfere with licensed services. Sharing obstructs innovative applications, because new applications are limited to prior constraints. It is more likely that an extension of spectrum commons of less than 30 GHz will reduce sharing between licensed services.

Solutions to interference between licensed services and spectrum commons are available by implementing an appropriate framework that addresses distance, level of power, part of spectrum, type of usage, and technology (especially cognitive technology) constraints.

No legal right to complain about interference
In general, after the regulator grants a specific frequency band to the spectrum commons for public use. All applications can be used with constraints. Users cannot complain when interference occurs. This means that users must bear their own risk when using equipment under spectrum commons.

For example, many people use a Bluetooth earphone to communicate on their mobile phone. When capacity is fully occupied, the mobile phone cannot connect to the Bluetooth earphones because there are no vacant channels. The more users there are, the more congestion there will be. Another example is garage door openers. If the neighbor has the same model, when the device is pressed, the nearby garage door will open.

Congestion and limited quality of service
The use of devices under spectrum commons is generally limited in terms of the service area, because they are low-power devices. A common problem of congestion usually happens when all users use their applications at the same time. The quality of service will vary from high, when few people use the service at the same time, to poor quality of service when there is heavy concurrent usage. For instance, at the beginning of the ITS conference in Japan, a few participants logged on to the Wi-Fi network and the system worked smoothly. When all the participants tried to access the Wi-Fi network, however, they system became overloaded and collapsed.

The use of spectrum commons in the band below 30 GHz with other services may create congestion of the existing spectrum use and cause poorer quality of service.

On the other hand, quality of service can be improved by combining licensed services and spectrum commons, which may improve the utilization of spectrum (make it more efficient) by introducing cognitive devices in the guard band or interleaving channels – spacing between the transmitting or receiving channel. The development of a relevant standard of spectrum commons will also reduce congestion and improve the quality of service through improved spectrum efficiency.

5.3 Advantages of using spectrum commons

Reducing barriers to entry
When regulators assign frequency under spectrum commons, the frequency can be used equally. There is no license or frequency usage fee (unlicensed). Users only pay for their devices. This is a crucial advantage of spectrum commons. Moreover, new entrants or players can enter the market more easily and launch services to compete with incumbent operators. This means that the barrier to entry is reduced. The market under spectrum commons will have many more providers and applications.

Furthermore, after the regulator announces a specific frequency band with certain constraints, the manufacturer who produces the equipment will have certainty over the introduction of its new products to the market. This announcement will reduce the manufacturing risk of creating the equipment. If the specific frequency band can be used in other countries – regional or worldwide – the manufacture will have an economy of scale to produce the devices more cheaply. For example, the price of Wi-Fi products has fallen dramatically.

Lower administrative costs
Under spectrum commons, the regulator only defines the frequency band, amount of bandwidth, and usage constraints (in terms of standardization of the equipment).

In contrast, if the regulator uses the command-and-control or market-based approaches for frequency assignment, the regulator must define property rights, coordinate existing users, and settle disputes. Thus, administration costs under spectrum commons are lower.

Greater social benefit
Society benefits from the use of spectrum under spectrum commons in many ways. First, without paying spectrum access or usage fees, the operators will enter the market more readily. After the regulator assigns the band, under spectrum commons, manufacturers have certainty of producing equipment. Moreover, if the band is regional or worldwide, manufacturers are able to provide cheaper devices to the market.

Furthermore, these devices will be circulated globally, i.e., GSM mobile phone roaming. Besides this, the compatible standards eliminate harmful interference. If, however, the devices cannot be used globally, global circulation will not occur. For example, the low-power FM micro transmitter and the ultra-wide band equipment (UWB) are widely used in the USA but are illegal in the EU.

Innovation and stimulating demand for new services
Rapid adoption of and demand for new applications increase under spectrum commons. This new demand drives innovators that create products. Competition innovation under spectrum commons will lead to new applications.

To make this happen, regulators should remove all unnecessary constraints and only maintain rules for safety and prioritized services. Restrictions on spectrum commons should be more flexible, generic, and only be applied to broad categories of devices.

Suitability for smaller users and low-density areas
Spectrum commons is suitable for use by small users. More users create more congestion. Furthermore, pilot projects under spectrum commons for the new frequency should be in low-density areas to avoid harmful interference to existing neighborhood services.

Developments in wireless technology – cognitive radio, software define radio, and smart antenna – will improve sharing between existing services however.

5.4 Examining advantages and disadvantages

The discussion on the advantages and disadvantages of spectrum commons is categorized into a SWOT analysis and the results are interpreted for major stakeholders, according to their interest.

Table 22. SWOT analysis of advantages and disadvantages of using spectrum commons

Strength	**Weakness**
- create innovation	- congestion and limited quality of service
Opportunity	**Threat**
- reduce barrier to entry - lower administrative cost - greater social benefit - stimulate demand	- irreversibility - lack of innovation when sharing with licensed services

Spectrum commons has a major strength in encouraging innovators to create, because spectrum commons allows the space to be shared by all technologies, services, and applications. This strength creates an ideal test bed for innovative activity.

Furthermore, spectrum commons creates certainty for manufacturers and stimulates user demand. Once manufacturers have certainty[38], they will develop and supply devices to the market more readily. From the newcomers' viewpoints, spectrum commons reduces barriers to entry (licensed or access fee). Spectrum commons offers end-users more choices. Moreover, if the market is competitive, users will have access to better and cheaper devices. Spectrum commons also lowers the costs of administration and regulation. The regulator has to set the standard of the devices in terms of *ex ante* regulation. The standard of devices could be just the frequency, maximum power, and the general safety standard.

When spectrum is already assigned to public use, it is harder to refarm[39]. For instance, if the regulator wants to refarm the 2.4 GHz band – the Wi-Fi band – the regulator has to recall all devices. Another threat of spectrum commons is lack of innovation while sharing with a licensed service. As spectrum commons and licensed services have constrained the use of devices to avoid interference, they also provide less opportunity to develop their spectrum use. Fortunately, this threat, congestion, and the

[38] The manufacturer and the innovator could be the same person.
[39] Refarming of spectrum is the process of recalling spectrum from existing services or users and re-assigning it to new services or users.

limited quality of service can be solved by new technology and relevant standards, including software-defined radio and cognitive radio.

From the SWOT analysis, it is apparent that spectrum commons has more strengths than weaknesses. Most threats can be solved by the development of new technology and relevant standards. There are some risks, however, concerning the maturity of new technology that the regulator should consider.

When the objective of spectrum use is safety and prioritized services, spectrum commons is not the appropriate solution. If there is no specific objective, however, spectrum commons should be selected. Furthermore, if the objective of spectrum assignment is to encourage innovation and stimulate new demand, spectrum commons may be appropriate.

5.5 Issues for spectrum commons implementation

Suitable time
A possible indicator is the assessment of costs and benefits to find the net benefit of spectrum commons. A comparison of economic value between spectrum assignment approaches and economic value could possibly be measured from auction.

Suitable frequency
Existing users have paid for spectrum and do not want to share, but newcomers will want frequency band.

Possible frequencies for spectrum commons are the remaining bands from the transition to Digital Television (white space in the US), the interleave channel in TV broadcasting (broadband wireless access), and the vacant frequency above 40 GHz.

Suitable frequencies for spectrum commons have minimum use, are vacant or expected to be vacant in the future, or are inefficient or under-utilized. They will depend on the different situations, from country to country, which have no single solution for this topic.

Amount of frequency
The top-down approach determines the overall bandwidth required for spectrum commons across the frequency band. For example, if mostly low-power devices are used, the estimation of the amount of frequency for low-power device usage in the next ten years will be measured. After that, the regulator must identify the frequency and release it for spectrum commons. It will then review spectrum commons use periodically.

In the bottom-up approach (band-by-band basis), the regulator selects the frequency band that is determined to be the most likely use of band under spectrum commons and licensed. Next, the regulator estimates the economic value of the use of that band under spectrum commons and licensed. The regulator selects the approach that maximizes economic value. If it is spectrum commons, the regulator should determine the restrictions to be applied.

Technical aspects
After the selection of frequency and amount of spectrum under spectrum commons, the technical specification for devices should be imposed. In order to control the use of spectrum commons, the technical standardization of the devices set by the regulator depends on the assigned frequency. Furthermore, the greater the risk of interference, the more restrictions on usage should be imposed.

The implementation of band segmentation can also mean multiple classes of spectrum commons applications. The low level of power of UWB devices means that they can be used across the entire frequency band.

Spectrum commons has many advantages, including the creation of an innovative environment and no spectrum usage fee because of the non-exclusive right to use frequency, lower administrative and social costs. The main disadvantages is irreversibility. To implement the spectrum commons scheme, the regulator should use a benefit and cost analysis as an indicator of the potential net social benefit of the introduction of a spectrum commons scheme.

5.6 Interpreting the results of the main stakeholders and discussion

Figure 9 provides a synthesis of the stakeholders' view based on close readings of the stakeholders' consultation document by the ARD-ZDF, Deutsche Telecom/T-Mobile, the EICTA, GSMA Europe, Metil Telecom consultants, Microsoft, Telefónica, PWMS Manufacturer Group, and Delft University of Technology, and the final report from the RSPG consultation.

The interpretations are made by examining stakeholders as decision-makers, the decision situation according to Figure 4 in Chapter 2, and the level of actions according to Table 7 in Chapter 2.

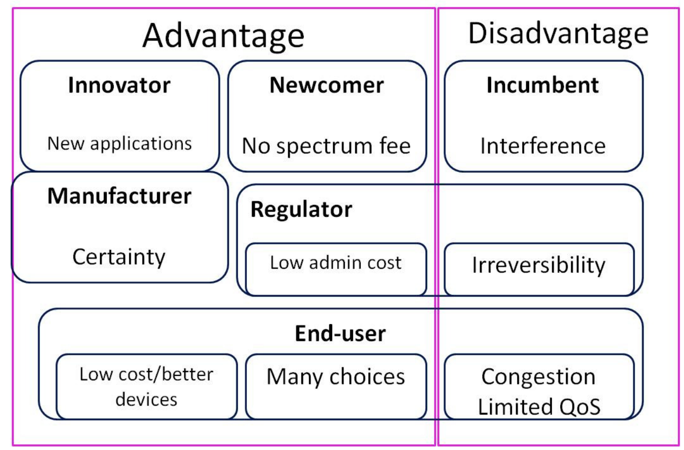

Figure 9. Stakeholders of spectrum commons

At the constitutional choice level, the decision-maker is the regulator. The decision situation comprises the institution arrangement, events, and the community. At this level, the regulator has an international agreement as the institution arrangement, such as the Radio Regulations as an international treaty. The feedback from the event is also a characteristic of spectrum commons. Spectrum commons has a non-exclusive right to use frequency. Spectrum commons therefore has a high cost of exclusion and is highly subtractable, like common-pool goods such as the fishing ground in the Maine lobster industry. The community is the common understanding of the international regulation.

The regulator provides the law and regulations for spectrum commons. The regulator has the advantage of low administrative costs to manage spectrum commons compared with other spectrum assignment approaches. Spectrum commons has the disadvantage of irreversibility however.

At the collective choice level, the decision-makers are manufacturers, innovators, incumbents, and newcomers. They use law and regulations of spectrum commons from the regulator as an institutional arrangement to create their own rules for users at the operational level. These rules, namely network rules, are standards for devices for manufacturers and innovators, and network management for incumbents (existing operators) and newcomers (new operators).

If the regulations are technology and service neutrality, innovators can create new applications. If the regulator allocates frequency worldwide, the manufacturer gains economies of scale from mass production. The price of the device then becomes cheaper.

The operator or provider will also set up the access rules for users to access frequency. This could be via a username/password. The access rule determines who qualifies to access the network.

The event is the characteristic of spectrum commons that is similar to the constitutional choice level. The community is the common understanding of the national law and regulations from the regulator.

Manufacturers have the certainty to produce spectrum commons devices as an advantage. Innovators have the potential to create any applications under spectrum commons that are specified by the frequency and power limitation as advantages. Newcomers have low-cost entry to the market, because spectrum commons is on a non-exclusive use basis. No one owns the spectrum or pays a spectrum fee, which are advantages. The incumbents worry about interference from sharing spectrum commons with their existing service, which are disadvantages.

At the operational level, the decision-maker is the end-user. The end-user has to use the devices according to the rules set at the collective choice level for spectrum commons. The institution arrangement is a network rule from the collective choice level. The event is the characteristic of spectrum commons that is similar at the constitutional choice level. The community is the common understanding of network rules including how to use the devices.

The end-users have many choices of devices and application as advantages. Spectrum commons have the potential to create competition among devices, applications, and operators. This competition provides cheaper prices, better devices, as advantages. Unlimited use of spectrum commons devices may, however, create congestion and limit the quality of the service, which are disadvantages.

5.7 Summary

This chapter discussed the advantages and disadvantages of spectrum commons corresponding to the third research question.

Advantages of spectrum commons include a lower entry barrier and improved administration costs, the creation of innovation, and the stimulation of demand. On the other hand, a disadvantage of this approach is irreversibility after spectrum assignment. This problem can be solved by the development of new technology and relevant standards of devices. A SWOT analysis also shows that spectrum commons has more strengths and opportunities than weaknesses and threats. The riskiness of the new technology should be taken into account however.

Finally, it is difficult for the regulator to select an appropriate frequency. A benefit and cost analysis will be used to compare the economic value of spectrum usage under spectrum commons with other approaches. The result will be information to help regulators select the spectrum assignment approaches. The challenge of the activity for the regulator is to balance the benefit of spectrum usage for all users.

Chapter 6 Conceptual benefit and cost analysis

The chapter addresses the fourth research question: How can the benefits and costs of spectrum commons be measured? The purpose is to measure the benefits and costs of spectrum commons to find its value.

The value of spectrum commons depends on its applications. The applications of spectrum commons are mostly short-range devices. Short-range devices have many applications and frequencies. For example, the Wi-Fi routers can operate at both the 2.4 and 5.7 GHz band. The Bluetooth wireless headset operates at 2.4 GHz. If the regulator provides the technology and service neutrality for spectrum commons regulations, there will be great potential for many new applications to emerge. Thus, the applications of spectrum commons have been identified, in the first place, to value spectrum commons.

The value of spectrum commons can be viewed from different perspectives. From the perspective of firms that use spectrum commons for their businesses, the value of spectrum commons derives from the financial benefits and costs at firm level. From the perspective of the national economy, however, the value of spectrum commons derives from economic benefits and costs. The financial benefit and cost analysis at firm level is therefore part of the economic benefit and cost analysis. The value of spectrum commons to the national economy will be important information for the regulator to decide whether to license or unlicense spectrum.

This chapter elaborates on the benefit and cost analysis at the conceptual level. The concepts are benefit and cost analysis (Campbell & Brown, 2003), valuation of unlicensed applications (Indepen, 2006), and engineering value (Sweet et al., 2002). A possible framework for valuation of spectrum commons in Thailand is provided at the end.

6.1 Benefit and cost analysis

Campbell and Brown (2003) provide a benefit and cost analysis to appraise the project: with and without projects. If the decision-maker undertakes the project, there is a need to know how much of the scarce resource will be allocated to it and what the value of the project will be. If the decision-maker does not undertake the project, the same amount of scare resource can be allocated to alternative uses.

Campbell and Brown (2003) also provide a conceptual scheme view for appraisal of the project. Figure 10 provides both a firm and whole economy (social) point of view.

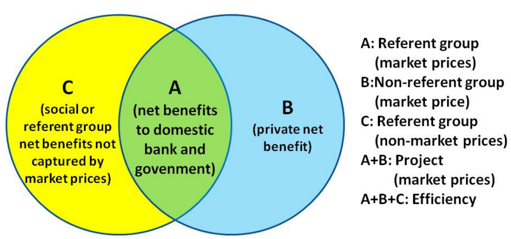

Figure 10. Relationship between the project and the private, efficiency, and reference group net benefits[40]

[40] Source: Campbell and Brown (2003, p. 7), Figure 1.3

Figure 10 shows the overlap between circle A+B (project) and circle A+C (social or referent group[41]) from the appraisal of the project. The A+B area represents the project benefit and cost analysis at the firm level (financial benefit and cost analysis). This A+B area can be obtained from the value of the project at private market prices. The B area represents the private benefit and cost analysis for the firm by subtracting tax, interest, and debt from the project. The A+B+C area represents the efficiency benefit and cost analysis that is used to shadow prices instead of market prices[42]. The A+C area represents the benefit and cost analysis of the referent or social group. The A+C area can be obtained directly from the value of all members in society. Alternatively, the analyst can obtain the whole A+B+C and subtract B.

With regard to suitable information for the regulator to license or unlicense spectrum, the efficiency benefit and cost analysis will be selected. The process should begin with the financial benefit and cost analysis at the firm level and, as far as possible, the added value of all members in society.

To appraise the project (implementing spectrum commons), the benefits are measured as revenues from the project. The costs are measured as all the expenses. Forecasts are made for both the revenues and the costs through the duration of the project. For simplicity, the demand forecast may be set to be the same for the whole project. After identifying all the benefits and costs, the calculation of the net present value (NPV) of the project is made by using an appropriate discount rate. The discount rate is calculated from the Weighted Average Cost of Capital (WACC) of the firm. A positive NPV throughout the project duration indicates a profitable project. The value of spectrum commons is represented by the net present value of the project.

Moreover, the value of all the members in society should be identified as the stakeholders. The details of finding the value of all the stakeholders should be further investigated.

6.2 Valuation of unlicensed applications

Indepen (2006) provides details of the benefit and cost analysis: how the valuation of unlicensed applications can be measured in the UK from 2006 to 2026. There are a number of unlicensed applications in the UK. It is hard to project all applications however. Ten unlicensed applications were selected: road user charging in the 5.8 GHz band; automotive short-range radar in the 24, 77/79 GHz band; blood glucose sensor in the 401-406, 600, and 1400 MHz bands; RFID in the retail market in the 860-960 MHz band; public access Wi-Fi in the 2.4 and 5 GHz bands; home data networking, especially home entertainment, in the 2.4 and 5 GHz bands; wireless building automation in the 2.4 and 5 GHz bands; fixed wireless link in the higher 70 GHz band; telemetry in the utilities in several bands; and wireless home alarms in several bands. These applications are the most important unlicensed application in the UK. Table 23 shows the value of spectrum commons of ten unlicensed applications.

[41] The referent group is defined as a group of individuals deemed by the decision-maker to be relevant in the relatively narrow interpretation in the context of the social benefit and cost analysis (Campbell & Brown, 2003, p. 6).
[42] In certain instances, the accounting prices can replace the shadow price (Campbell & Brown (2003), Chapters 5 and 12).

Table 23. Spectrum value of unlicensed applications in the United Kingdom[43]

Application*	Value in 2026 (£m)*	Frequency (GHz)*	Relevant to Thailand
road user charging	53	5.8	similar use, initial phase
automotive short-range radar	1776	24, 77/79	76-77 radar 24-79 not used
blood glucose sensor	0	0.4	less use
RFID in retail market	2478	0.860-0.960	warehouse register board
public access Wi-Fi	5270	2.4	similar use and continued growth
home data networking	395	2.4	similar use and continued growth
wireless building automation	96	2.4	pilot project
fixed wireless link	50	70	not used
telemetry in the utilities	600	0.4	not used
wireless home alarms	143	0.9+0.4	not used

As mentioned in Section 1.6, most of the frequency assignments use a command-and-control approach that is inefficient in terms of the frequency licensee's distribution. Most frequency licensees are government agencies or state-owned enterprises. The development of a spectrum commons policy in Thailand has two separated processes: authorization of the use of radio communication devices and exemption of relevant radiocommunication licences or unlicensed.

The unlicensed regulation was imposed in 2004. The application in the 2400-2500 MHz band, especially WLAN, was authorized for use in 1996 with the relevant radiocommunication licences. Until 2004, the 2400-2500 MHz band was open for any applications with power up to 100 milliwatts (e.i.r.p.). The consequent growth in the number of WLANs from the Customs Department is displayed in Figure 7.

From Table 23, the biggest value unlicensed application in the UK is public access Wi-Fi. It is used in the 2.4 GHz band. In the study by Indepen (2006), there are three applications in the 2.4 GHz band, i.e., public access Wi-Fi, home networking, and wireless building automation. Wireless building automation is not widely implemented in Thailand. Public access Wi-Fi and home networking are interesting to explore however.

The framework of Indepen (2006) is shown in the following figure.

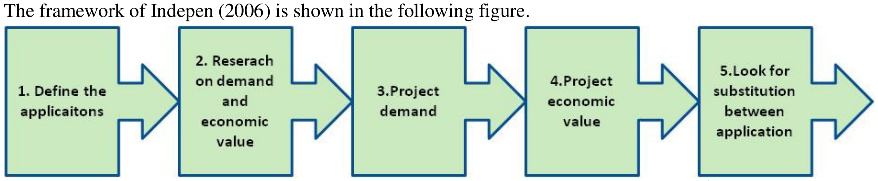

Figure 11. Approach to projecting the economic value of license-exempt applications[44]

First, the framework begins by defining the application to provide a definition of an application that makes unambiguous projections of economic value. Second, research into the demand for and economic value of the application helps analysts understand the application, the technical characteristics of the application, the demand for the application, and the sources of economic value from the application.

[43] (*) Source: Indepen (2006, p. 53) Figure 6.2
[44] Source: Indepen (2006, p. 2), Figure S1

Third, by making demand projections, analysts project future application demand, which reflects market demand, excluding any congestion and cross-application interference. Future demand projections involve four tasks: 1) defining the basic measure of demand for public access Wi-Fi and home networking using the volume of traffic and number of households with wireless access, respectively; 2) constructing demand scenarios, i.e., low, medium, high, reflecting the range of likely outcomes and associated probabilities of each scenario; 3) considering the drivers of demand and constructing a basic demand model; and 4) using a spreadsheet to generate high, medium, and low demand projections.

Fourth, the economic value from the demand projection of future cost and benefit estimates is obtained. There are three projections reflecting high, medium, and low demand scenarios. Fifth, looking for the substitution effect to avoid over-estimating the economic value of an application. For example, the Wimax will be the substitution service for public Wi-Fi hotspots to provide access to the Internet. Indepen (2006) selected 10 out of 100 unlicensed applications, however, and given that, there is no substitution effect of the study.

Indepen (2006) provides the number of access point per square kilometer subject to the empirical test and assumptions, i.e., 8.7 and 19.5 per square kilometer outdoors and indoors (public access Wi-Fi). The number of access points is the output of the interference testing scenario at 50 test points. Moreover, the maximum volume of the capacity that an access point can handle is also assumed. During a busy hour, the access point activity ratio is 30%, the workable carrier is 11 Mbps, and the interference protection of the test point is 90%, and three non-overlapping channels at 2.4 GHz are assumed. The maximum handling volume is 87,000 and 39,000 Mbytes/square kilometer indoors and outdoors during a busy hour, respectively. The population penetration can be used to calculate the traffic volume per year including dense areas, urban areas, and rural areas.

6.3 Engineering value

Sweet et al. (2002) provide the concept of valuation of the spectrum by using the engineering value. The engineering value is determined by the cost saving in the infrastructure of the operators' network, obtained when the additional spectrum is used (Sweet et al., 2002). This is one way to value B stated in Section 6.1.

Wireless communication can replace wire communication. For example, the copper wire telephone line from the local exchange to the customer premises can be replaced by the wireless local loop. The cost saving from implementing a wireless connection instead of a wire connection is the value of the spectrum.

In the other case, the use of WLAN or Wi-Fi in the office replaces the LAN connection to all personal computers. The cost saving for wiring the LAN connection is the value of the Wi-Fi or spectrum commons.

The value of spectrum commons depends on its application and operating frequencies. For example, Internet access from xDSL, cable modem, Fiber to the X (FTTx) (home, building, and curb, etc.), and mobile telephone networks can be replaced by spectrum commons via Wi-Fi or WiMax (if the regulator allows WiMax as spectrum commons). The value of spectrum commons depends on which part of the network is replaced as a cost saving. At the least, the copper wire local loop to the customer premises can be replaced by a Wi-Fi hotspot. The WiMax can also be replaced by FTTx in rural areas.

The cost savings are all relevant costs, including investment, installation, operation, and maintenance costs. The engineering value is the cost saving that can be used as the value of spectrum commons.

6.4 Outline of the valuation of spectrum commons for Thailand

In Thailand, spectrum commons has been implemented since 2004, according to the Ministerial Regulation of the Ministry of Transport No. 24, and the updated regulation of spectrum commons is the National Telecommunications Commission Regulation of Exemption of Radiocommunication Licences. The regulator did not account for the valuation of spectrum commons when selecting a specified frequency for unlicensed devices.

The process originates from importers or operators who want to market low-power devices. They send applications to import devices to the regulator for import radiocommunication licences. The regulator checks with the existing regulation, including the National Table Frequency Allocation, ITU regulations, and recommendations. The regulators check the technical specifications of the devices: frequency, power limitation, application, and standard to ensure there is no harmful interference with the existing services. After that, the regulators grant the authorization and the import radiocommunication licence. The authorization includes the relevant radiocommunication licences. If regulators want to facilitate the use of devices and deregulate them, they should support unlicensed regulation. Once devices are unlicensed, all relevant radiocommunication licences are exempted.

The case of WLAN

In Thailand, the PTD allowed WLAN use in 1996 under the PTD regulation and users had to obtain relevant radiocommunication licences. At the time, the use of WLAN was limited to indoor use only. In 2003, the PTD amended the regulation to allow both indoor and outdoor use with relevant radiocommunication licences.

The WLAN devices became unlicensed in 2004 in terms of the Ministerial Regulation of Exemption of Radiocommunication Licences, the Ministry of Information and Communication Technology including WLAN in the 2400-2500 MHz band. Moreover, the NTC has granted licensed Wi-Fi hotspots to the Internet service providers since 2005. In 2007, the NTC updated the unlicensed regulation and allowed 5150-5350/5470-5725/5725-5850 MHz for WLAN.

Two scenarios for spectrum commons in Thailand

In Thailand, Wi-Fi devices co-locate with a fixed microwave link in the 2.4 GHz band. Wi-Fi devices operate with low-power output of 100 milliwatts (e.i.r.p.). The fixed microwave link operates at higher power output, however, for example, output power of 3 watts and antenna gain of 17 dBi. The Wi-Fi devices can operate with a fixed microwave link without causing harmful interference.

From the case of Thailand, spectrum commons can be implemented into two scenarios. The first scenario, as mentioned above, is co-location with an existing service. The second scenario is the trade-off between licensed and unlicensed for new frequency.

Co-location with existing services

In Thailand, the decision-makers or regulators must decide whether to implement spectrum commons with the existing services. If the regulator decides to allow spectrum commons to be co-located with existing services, the value of frequency use can be obtained from both existing services (Z) and spectrum commons (X), in the case of implementing spectrum commons and the externality of

spectrum commons in terms of social benefit (Y). On the other hand, the value of frequency use can only be obtained from existing service in the case of not implementing spectrum commons. The value of implementing spectrum commons can be obtained directly from the value of the frequency use of spectrum commons and its externality. Figure 12 depicts the value of spectrum commons and whether it should be implemented.

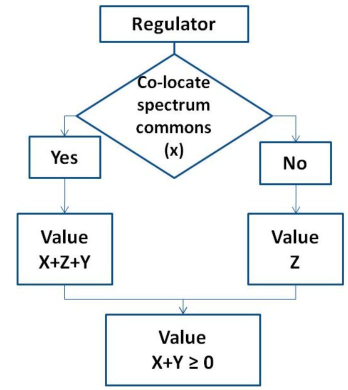

Figure 12. Value of spectrum commons (co-location with existing service)

The spectrum commons can be co-located with existing service. The value of spectrum commons can be derived directly from the spectrum commons itself and its externality.

Trade-off between licensed and unlicensed for new frequency allocation

If the regulator has to trade off between licensed and unlicensed application, the value of the spectrum has to be determined for both licensed and unlicensed. The value of licensed spectrum can be obtained from the financial benefit and cost analysis at firm level. On the other hand, the value of spectrum commons can be determined from an efficiency benefit and cost analysis at the economy level. The value of spectrum commons has been obtained from the financial benefit and cost analysis of its applications and the benefit of all the members of society.

The regulator has to take the value of licensed and unlicensed spectrum into consideration. The regulator selects the higher value of the spectrum. Figure 13 describes the trade-off between licensed and unlicensed spectrum.

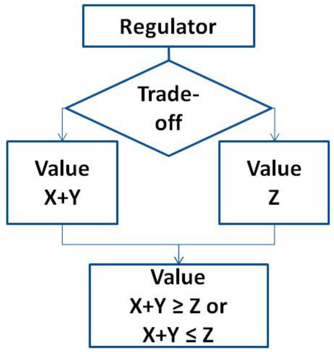

Figure 13. Value of frequency in the case of trade-off between licensed and unlicensed spectrum

This helps to reflect the decision-maker's choices to implement spectrum commons co-located or trade-off options.

Suggestion for a valuation of spectrum commons in Thailand

Spectrum commons was introduced into Thailand in 1993, according to the Ministerial Regulation of Ministry of Transport No. 24. At the time, only technical aspects had been taken into account, especially the harmful interference with other services or applications. The specific usage, frequencies, and power limitation have been addressed by the regulation. Until 2004, the Ministerial Regulation of the Ministry of Information and Communications Technology of the Exemption of Radiocommunication Licences, the unlicensed application had been more service and technology neutrality. Only specified frequency and power limitation remains in the regulation.

The regulator does not take the valuation of spectrum commons in Thailand into account as important information on whether to allow usage of unlicensed applications. There are many unlicensed applications in any frequency band in Thailand. The focus on the operating application and frequency band should be identified. This thesis provides an initial suggestion to value spectrum commons.

From the value of unlicensed applications from Indepen (2006) in Table 23, the highest value is public Wi-Fi that operates in the 2.4 GHz band. In the 2.4 GHz band, Thailand has allowed WLAN to be used since 1996 and unlicensed since 2004. It is interesting to explore WLAN, because there are two timelines: 1996-2004 and after 2004. Moreover, the Internet service provider has been able to use Wi-Fi to provide hotspots for Internet access since 2005. The use of the 2.4 GHz band for Wi-Fi in Thailand also increases from time to time.

At the initial stage, the operating frequency is identified as the 2.4 GHz band in this thesis. The application of unlicensed applications is Wi-Fi routers that can be used as public Wi-Fi hotspots and home Wi-Fi routers.

The important stakeholders that are relevant to Wi-Fi routers have also been identified. At the constitutional choice level, it is the regulator (NTC). At the collective choice level, there are manufacturers, importers, dealers, retailers, Wi-Fi operators, Internet service providers, and telecom operators. At the operational level, it is the end-users.

The stakeholders are the public Wi-Fi operator and the end-users. Table 24 shows the possible benefits and costs of the public Wi-Fi operator and end-users (home data networking). The Wi-Fi operator will use public Wi-Fi access as its project, as B in Section 6.1. The end-users use the Wi-Fi router at home as the benefit of the referent group, as C in Section 6.1.

Table 24. Benefit and cost of public access Wi-Fi and home data networking

Public Wi-Fi operator		Home data networking	
Benefit	**Cost**	**Benefit**	**Cost**
Revenue	Wireless router installation+maintenance	Wiring cost reduction	Wireless router
Wiring cost reduction	Internet connection fee	Increased flexibility	
Licence exemption	ISP licensed fee	Licence exemption	

Public Wi-Fi operator

Revenue: The Wi-Fi operators receive income by charging the users in several packages, pre-paid and post-paid service. The possible packages are charged per volume or duration of usage. The stream of income can be forecast from the user demand deriving from the network capacity utilization.

The forecast of demand is from 2010 to 2030. The volume of traffic varied from area to area. The three types of population density are business, urban, and rural area. The assumption of high, medium, and low demand can be applied. The portion, as a percentage of the maximum volume of traffic, can be adjusted as 100%, 85%, and 20%, respectively. The business, urban, and rural area can be calculated as a percentage of the overall area such as 3%, 6%, and 91%, respectively. These two assumptions are obtained from an NTC project in 2010 on comprehensive spectrum valuation wireless performance and demand assessment for the Kingdom of Thailand: towards and optimized spectrum master plan.

The demand forecast for public access Wi-Fi can be captured as a portion of Internet traffic. The interpolation of the growth of that traffic can infer demand for public access Wi-Fi from 2010 to 2030 as a top-down approach.

Cost saving: The Wi-Fi connection can be replaced with a traditional local loop such as copper wire. The Wi-Fi as an access medium can save the cost for wiring the local loop to customer premises or line rental from a telecom operator. The local loop in Thailand is copper wired. Moreover, the Wi-Fi connection can provide higher bandwidth than xDSL and in areas without any wired network.

Licence exemption: The Wi-Fi operators are exempted from paying for importation, installation, and using Wi-Fi routers, because of the unlicensed regulation. Moreover, the frequency usage fee is exempted.

Cost: The public Wi-Fi operators have to pay for the Wi-Fi router and installation cost – a one-time charge. Moreover, they have to pay the maintenance cost after implementation to the end of business. The cost of connection from the public Wi-Fi router to the Internet gateway is the operating cost. The ISP license is the administrative cost payable yearly.

Home data networking

Cost saving: The Wi-Fi connection can replace the wire inside the home. The Wi-Fi as an access medium can save the cost of wiring cable to customer devices such as LAN connection, printer, speakers, and home entertainment.

Other benefit: The flexibility of the customer to move around the home will be the added as a consumer surplus.

Licence exemption: The end-users are exempted from paying for installation, and using Wi-Fi routers because of the unlicensed regulation. Moreover, the frequency usage fee is exempted.

Cost: The users have to pay for their Wi-Fi routers once.

The number of Wi-Fi routers at home can be calculated from the number of households with a wireless router, which can be obtained from the number of xDSL subscribers. Most providers offer wireless routers to new subscriber for free or at a deductible price. A portion of the growth of xDSL will be used to project the demand for home data networking.

6.5 Summary

The conceptual benefit and cost analysis provides the framework for valuing the project (implementing spectrum commons) at the first and the whole economy level. The financial benefit and cost analysis is used to find the value at firm level, which is one part of the economic benefits and costs in the whole economy. The engineering value can also be used to value the cost reduction at firm level. The study of the valuation of unlicensed application in the United Kingdom provides the practical procedures to find the valuation of unlicensed application.

The suggestion of a valuation of spectrum commons has been identified in the public access Wi-Fi and Wi-Fi routers at home as the initial stage. The possible benefits and costs of Wi-Fi operators and home data networking are specified in Table 24, responding to RQ.4.

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Chapter 7 Findings and future research

The purpose of this licentiate thesis is to examine the spectrum commons approach to spectrum assignment. The examined case is Thailand. The main research question is: **"What are the consequences of using spectrum commons for frequency assignment in Thailand?"**

To approach the main research question – What are the consequences of using spectrum commons for spectrum assignment in Thailand? – this thesis addresses five research questions:

RQ.1 *What is a suitable framework for analyzing different types of spectrum commons?*

RQ.2 *What type of spectrum commons has been used in Thailand?*

RQ.3 *What are the advantages and disadvantages of spectrum commons in general?*

RQ.4 *How can benefits and costs of spectrum commons be measured?*

RQ.5 *What are the implications of implementing spectrum commons in Thailand?*

RQ.1 looks at finding a framework to analyze different types of spectrum commons. Three economic institutions from Kiser and Ostrom (1982) and Field (1992) are adopted. The five rights of the property regime by Schlager and Ostrom (1992) is also adopted in this thesis to find the interaction between the layer of the decision-maker and the right to use frequency. The comparison between property rights regimes and natural resources in the Maine lobster industry addresses the right to use frequency.

RQ.2 looks at the use of the framework developed in RQ.1 to understand the institution of spectrum commons and its application to Thailand. The exploration of the history of spectrum assignment also helps the understanding of spectrum commons and the right to use frequency in Thailand.

RQ.3 looks at the advantages and disadvantages of spectrum commons from the public consultation of the Radio Spectrum Policy Group (RSPG) in November 2008 in the European Union to obtain the current thoughts of stakeholders regarding the use of spectrum commons.

RQ.4 is the benefit and cost analysis of the spectrum commons concept from Campbell and Brown (2003), Indepen (2006), and Sweet et al. (2002) as the framework to measure spectrum commons in Thailand. Campbell and Brown (2003) provide the framework of the benefit and cost analysis in terms of the undertaken project or not. The comparison between the current values of whether to undertake the project or not provides the decision-maker with important information. The values without undertaking project measures are obtained from the same allocation resource to alternative uses. Indepen (2006) provides a practical method to measure the unlicensed application in the United Kingdom in 2006. Indepen (2006) selected the ten most important applications among a hundred applications of unlicensed devices. Sweet et al. (2002) provide the valuation of the spectrum using the engineering value – cost saving in the infrastructure of the network operator. The adjusted framework of Campbell and Brown (2003), Indepen (2006), and Sweet et al. (2002) addresses how to value spectrum commons in Thailand. The finding is a framework to evaluate spectrum commons in Thailand in terms of the benefit and cost analysis.

RQ.5 covers the implications of implementing spectrum commons in Thailand.

The five research questions are intended to contribute to increased understanding of using spectrum commons and contribute to the effectiveness of using spectrum commons in Thailand. The summary of these findings are as follows:

1) The economic institution or three worlds of action provide three layers of analysis: constitutional choice, collective choice, and operational level. This framework provides an understanding of the decision-maker and the decision situation within and between layers. Moreover, the property rights regime and natural resource of the Main lobster industry provides the right to use frequency: access, withdrawal, management, exclusion, and alienation rights.

2) The frameworks from RQ.1 provide rights to use frequency in Thailand. Three types of spectrum commons have been used in Thailand: public commons, private commons, and unlicensed. The spectrum commons has non-exclusive right to use frequency. The regulated level of the network provides the different types of spectrum commons. If the state agency manages the network, it is public commons. If the private entities manage the network, it is private commons. If the end-users manage the network by themselves, it is unlicensed. The thesis provides an overview of the spectrum assignment institution in Thailand.

3) The advantages of spectrum commons are lowering barriers to entry for newcomers, lowering the administration costs for the regulator, creating innovation for the innovator, and stimulating demand. The disadvantage of spectrum commons is irreversibility after spectrum assignment.

4) The benefit and cost analysis provides the framework to value the spectrum. The 2.4 GHz band is the specified frequency for the spectrum commons. The applications of the 2.4 GHz bands are public Wi-Fi operators and home data networking. The valuation of spectrum commons can be used as important information for regulators to decide whether to license or unlicense spectrum.

5) The spectrum commons has potential to increase spectrum usage more efficiently by allowing spectrum commons to be co-located with existing services.

The research problem is divided into three parts: conceptual, empirical, and analytical parts. The conceptual part deals with the right to use frequency and examines the framework associated with spectrum commons. The empirical part gathers from history and public consultation to explore the type of spectrum commons in Thailand and the advantages and disadvantages of spectrum commons from the public consultation on spectrum commons in the context of European countries. The analytical part is to use the benefit and cost analysis concept on spectrum commons in Thailand.

7.1 Findings

RQ.1 What is a suitable framework for analyzing different types of spectrum commons?

The economics institution and three worlds of action from Schlager and Ostrom (1992) provide the level of analysis for the decision-maker and decision situation. The property rights regime and natural resource in the Maine lobster industry from Kiser and Ostrom (1982) also provides the right to use the common pool resource. These two concepts provide a framework to analyze the right to use frequency in Thailand. The chronology of events of spectrum management in Thailand provides evidence of the rights to frequency use. The result is provided in Table 25.

Table 25. Bundles of rights associated with telecommunication stakeholders (cf. Table 12)

Stakeholders / Rights	Regulator	Operator A	Operator B	Advanced user	General user
Access and Withdrawal	x	x	x	x	x
Management	x	x	x		
Exclusion	x	x	x	x	
Alienation	x	x			
Assignment approach		Market-based	Command-and-control	Spectrum commons	Spectrum commons

The market-based approach has all the rights to use frequency, including access and withdrawal, management, exclusion, and alienation rights (i.e., selling or leasing frequency). Command-and-control does not have an alienation right however. The command-and-control and market-based approaches both grant the exclusive right to use frequency to licensees. Spectrum commons does not have an exclusive right to use frequency however. There are two types of users in spectrum commons, i.e., general and advanced users. These users have access and withdrawal rights because of the characteristics of transceivers. The transceivers are specified to access and use the frequency at the same time. Only the advanced users have the additional exclusion right to determine who can use their network by setting passwords or encryption code.

RQ.2 What type of spectrum commons has been used in Thailand?

The type of spectrum commons that has been used in Thailand is addressed. Using the category of the right to use frequency from Table 25 provides the regulated level of the regulator. Moreover, the exclusivity of using frequency provides exclusive and non-exclusive use in order to separate the spectrum commons from the command-and-control and market-based approach. The type of spectrum commons is provided in Table 26.

Table 26. The rights to use frequency (cf. Table 13)

Property right / Regulated level	Exclusive use	Non-exclusive use
Centralized by regulator / state agency	Command-and-control	Public commons
Middleman/operator	Market-based	Private commons
Self-regulated/user	-	Unlicensed

There are three types of spectrum commons, i.e., public commons, private commons, and unlicensed. Regulators delegate some rights to licensees to manage their network. These represent the regulated level. If the state agency is in charge of network management, it is called public commons. For example, the local municipalities have their Wi-Fi network for their community. If the private entities manage their network for commercial service, it is called private commons, such as the public Wi-Fi hotspots in hotels, airports, department stores, etc. If the end-users have to manage by themselves, it is called unlicensed.

The history and development of the spectrum management institution in Thailand also provides an original work that narrates important events concerning spectrum management, especially spectrum commons in Thailand. There are two steps to implementing spectrum commons in Thailand: 1) the authorization of the use of devices and 2) the exemption of relevant radiocommunication licences.

RQ.3 What are the advantages and disadvantages of spectrum commons in general?

The advantages and disadvantages of spectrum commons are provided from the analysis of public consultation in Europe by the RSPG and relevant literature. Figure 14 shows the advantages and disadvantages of spectrum commons with the relevant stakeholders.

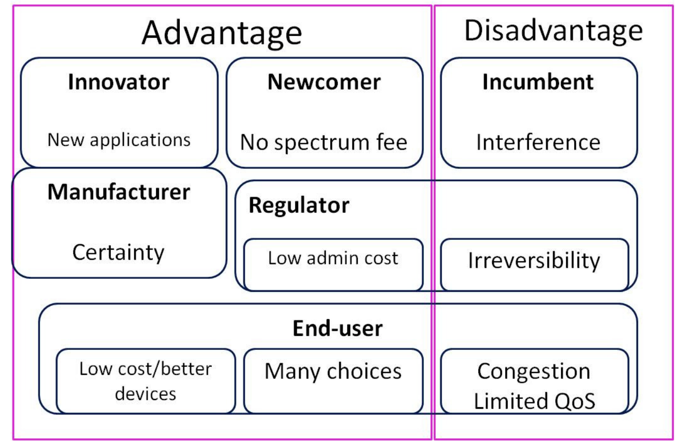

Figure 14. Stakeholder of spectrum commons (cf. Figure 9)

Advantages of spectrum commons include lowering barriers to entry, lowering the administration costs, creating innovation, and stimulating demand. On the other hand, the main disadvantage of spectrum commons is irreversibility after spectrum assignment. To determine the net benefit of spectrum commons, a comparison of the advantages and disadvantages is required. Most disadvantages can be solved by the development of new technology and a relevant standard of devices, except irreversibility, once the spectrum commons has been assigned to public use.

RQ.4 How can the benefits and costs of spectrum commons be measured?

The concept of the benefit and cost analysis for the appraisal project to undertake or not is the outline to value the spectrum commons. The efficiency benefit and cost analysis captures the financial benefits and costs at firm level plus the value or benefits and costs of all members in society from implementing the spectrum commons. The cost saving from the engineering value contributes to the value of spectrum commons as benefits for both the firm and society.

The procedure to measure the benefits and costs of spectrum commons begins with the identification of the operating frequency and application of spectrum commons. The stakeholders of specified applications of spectrum commons have been explored. The limitation of stakeholders at the initial stage should be considered in order to limit the scope of valuation of spectrum commons. The categories of benefits and costs of the application of spectrum commons have been identified. Data collection from the identified benefits and costs should be pursued in order to calculate the value of spectrum commons.

In this thesis, the 2.4 GHz band has been identified as the operating frequency. The public Wi-Fi routers and home data working (home Wi-Fi routers) are the target of the valuation of the spectrum commons. The possible benefits of the public Wi-Fi operator are revenue, cost saving from wiring, and license exemption. The possible costs of the public Wi-Fi operator are wireless routers, installation and maintenance costs, Internet connection, and the ISP license fee. The possible benefits of home data networking are cost savings form wiring, licence exemption, and increasing flexibility. The possible cost is the wireless router.

RQ.5 What are the implications of implementing spectrum commons in Thailand?

The frameworks in Chapter 2 and RQ.1 (three worlds of action, and property rights regime and natural resource) provide the analysis of exclusive and non-exclusive right to use frequency. The exclusive use of frequency by a command-and-control or market-based approach has limited the use of spectrum to the assignees or winning bidders. They sometimes do not occupy the spectrum. The framework of non-exclusive use of frequency is introduced in spectrum commons, while no one owns the frequency or has an exclusive right to use frequency. Users must share frequency and accept interference. The non-exclusivity increases the number of users and the efficiency until the maximum capacity is reached.

Moreover, three types of spectrum commons have been used in Thailand in Chapter 4 or RQ.2 (public commons, private commons, and unlicensed). They provide the current status of spectrum commons in Thailand. These three types also appear in other countries that have a similar situation.

Regulators should use these findings for further consideration of using spectrum commons to increase spectrum efficiency in terms of utilization of frequency and distribution of frequency users.

The public consultation of RSPG in November 2008 in Chapter 5 or RQ.3 provides the advantages and disadvantages in a European context. Most of the spectrum commons frequency is worldwide allocation however. The stakeholders are also most probably the same. The findings of advantages and disadvantages at high level should not be different. There may be a slight deviation in the local context.

Regulators should conduct a similar public consultation to identify the advantages and disadvantages of spectrum commons in their context to adjust to their environment.

The regulator may consider adding spectrum commons to other frequency bands, impose power limitation, and specify frequency as necessary constraints. These constraints have a high potential to attract innovation. The market will select services and applications freely under the constraint to respond to demand. The low entry barrier makes spectrum easier to access and encourages competition in the market. The end-user will have better quality of service and lower prices.

The benefit and cost analysis to value spectrum commons in Chapter 6 or RQ.4 provides the framework to measure the value of spectrum commons. The result of the valuation of spectrum commons depends on the availability of data collection and varies from country to country.

Regulators should use the value of spectrum commons as important information on whether to license or unlicensed spectrum. The value of spectrum will reflect the best utilization of spectrum. Greater use of spectrum commons of frequency assignment will increase spectrum efficiency in terms of the number of frequency users and the spectrum utilization.

The regulator should consider the loss of the frequency usage fee through non-exclusive right as income loss. On the other hand, the operator and end-users gain the benefit of not paying the frequency usage fee. The benefits to society may be greater than the lost income of the regulator.

7.2 Generalizability: Can spectrum commons be applied in other countries?

Learning to use spectrum commons in Thailand provides information to regulators in other countries that have a similar use of spectrum in the same or other regions. The use of the ISM band in footnotes 5.138 and 5.150 is the starting point to considering the use of spectrum commons in their countries. The worldwide frequency allocation will support the use of spectrum commons in terms of the available standard and devices.

The benefit and cost analysis offers the valuation of spectrum commons as an indicator for the regulator to decide whether to license or unlicensed spectrum. The value of spectrum commons depends on the number of applications. This study of the valuation of spectrum commons may serve as an example to considering the use spectrum commons in other countries.

The RSPG public consultation in the European countries provides the perspective of relevant stakeholders. The context can be generalized if the behavior of stakeholders is similar to other contexts, such as the behavior of incumbents, manufacturers, end-users, and regulators in Thailand. There may be some extent of similarity. The public consultation in Thailand will help adjust and form a precise perspective on spectrum commons in the Thai context however.

7.3 Future research

The possible outcome of implementing spectrum commons in Thailand can be measured in terms of the valuation of spectrum commons from the perspective of the regulator. The valuation of spectrum commons provides important information on whether to license or unlicensed spectrum. The other possible outcomes for implementing spectrum commons should be investigated further for other stakeholders, applications, and frequencies. The suggestion in this thesis is limited to public access Wi-Fi and home Wi-Fi routers in the 2.4 GHz band. There are only two stakeholders in this thesis, i.e., public Wi-Fi operators and end-users. The possible extensions of other frequencies, such as WiMax or other stakeholders such as manufacturers or innovators, should be considered in future research.

Further exploration of spectrum commons theory may be a possibility for future research. A deeper, metatheoretical exploration of spectrum commons would be possible to gain a deeper understanding of spectrum commons theory.

Deeper or wider exploration of the social benefits of spectrum commons should be considered as future research to find the contribution of spectrum commons to other areas in society. For example: Could spectrum commons contribute to the wealth of a country? Could spectrum commons improve the overall efficiency of spectrum? Could spectrum commons help to improve society?

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List of abbreviation

AIS	Advanced Info Service Public Company Limited
APT	Asia Pacific Telecommunity
ARD-ZDF	ARD-Verbindungsbüro and ZDF-Europabüro
BT	BT Public Company Limited
CAT	Communication Authority of Thailand
CCTV	Closed Circuit Television
CEPT	European Conference of Postal and Telecommunications
CISPR	Special Committee of the International Electrotechnical Commission for Interference
CITEL	Inter-American Telecommunication Commission
DSL	Digital Subscriber Line
DTAC	Total Access Communication Public Company Limited
EHF	Extra High Frequency
EICTA	European Information & Communications Technology Industry Association
E.I.R.P.	Equivalent Isotropically Radiated Power
FCC	Federal Communication Commission
FTTx	Fiber to the X
GHz	Gigahertz
GMPCS	Global Mobile Personal Communication by Satellite
GPS	Global Positioning System
GSMA	GSM Association
HF	High Frequency
ICAO	International Civil Aviation Organization
IEEE	Institute of Electrical and Electronics Engineers
IMO	International Maritime Organization
ISM	Industrial, Scientific and Medical
ITU	International Telecommunication Union
ITU-R	International Telecommunication Union – Radiocommunication
kHz	Kilohertz
LAN	Local Area Network
LF	Low Frequency
MAC	Medium Access Control
MF	Medium Frequency
MHz	Megahertz
MICT	Ministry of Information and Communications Technology
MoT	Ministry of Transport

mW	Milliwatt
NBC	National Broadcasting Commission
NFMB	National Frequency Management Board
NPV	Net Present Value
NRA	National Regulatory Authority
NTSC	National Television System Committee
NTC	National Telecommunications Commission
O2	Telefónica O2 UK Limited
ONTC	Office of the National Telecommunications Commission
PAN	Personal Area Network
PCMCIA	**P**ersonal **C**omputer **M**emory **C**ard **I**nternational **A**ssociation
PCS	Personal Communication Services
PDA	Personal Device Accessories
PHY	Physical layer
PTD	Post and Telegraph Department
PWMS	Professional Wireless Microphones Systems
QoS	Quality of Service
RCA	Radio Corporation of America
RF	Radio Frequency
RFID	Radio Frequency Identification
RLAN	Radio Local Area Network
RQ	Research question
RR	Radio Regulations
RSPG	Radio Spectrum Policy Group
RTTTs	Railway applications, road Transport and Traffic Telematics
SHF	Super High Frequency
SIM	Subscriber Identity Module
SoD	Supplier's Declaration of Conformity
SRD	Short-Range Device
SWOT	Strength Weakness Opportunity Threat
TOT	Telephone Organization of Thailand
True Move	Truemove Company Limited
UHF	Ultra High Frequency
ULP-AMI	Ultra Low Power Active Medical Implant
USB	Universal Serial Bus
USOM	United States Operations Mission
UWB	Ultra Wide Band

VLF	Very Low Frequency
VHF	Very High Frequency
WACC	Weighted Average Cost of Capital
Wi-Fi	Wide Fidelity
WiMax	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network
WMO	World Meteorological Organization
WRC	World Radiocommunication Conference
WWI	World War I
2G	Second Generation mobile telephone
3G	Third Generation mobile telephone