


**Antenna Research at CHASE – Chalmers Antenna Systems Excellence Centre**

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## 1. Introduction

Chase is one of a total of eighteen "VINN Excellence Centres" that are funded by VINNOVA, the Swedish Governmental Agency for Innovation Systems. The aim of these centres is to provide a forum for collaboration between the private and public sectors, universities and colleges, research institutes and other organisations that conduct research. The Chase centre was started in 2007 and has a budget of at least 23 million Euro over ten years with cash and in kind contributions. The research activities in Chase cover antennas and antenna system aspects, and the industrial interests are mainly in Wireless Communications, Remote Sensing and Medical Applications of Microwaves. The projects are chosen based on industrial needs, usefulness for society and global sustainability.

## 2. Centre Operation

Chase is hosted by Chalmers University of Technology (Chalmers) and has attracted 15 industrial partners, some of them world leading in the technology development for communication and medical applications. The partners offer Chase access to unique experience, competence in particular on market needs, and test facilities. The close cooperation with SP Technical Research Institute of Sweden is also important for the research environment and the possibilities to mobilize the skill and facilities needed to solve upcoming questions. Associated to the centre is also the University of Uppsala and KTH Royal Institute of Technology in Stockholm. The combined resources from industry and academia give the centre a position as one of the strongest research environments in the field of antenna systems in the world.

During stage 2 (2009-2011) seven projects have been conducted within Chase:

1. MIMO Systems
2. Test Environment for Cellular Radio Systems – OTA
3. Antenna System Simulator
4. MIMO Terminals 2
5. Antenna Systems for Biomedical Applications
   - Electromagnetic Optimization of Medical Implants and Devices
   - Microwave Tomography
6. Gap Waveguide Frontend Demonstrator
7. Microwave Hyperthermia

## 3. Impact on Partners

The industrial partners in Chase represent a wide spectrum of companies, ranging from small start-ups to large multinational companies, developing products and services within wireless

communication, wireless access, medical technology, measurements, satellite communication and security/safety. Some of the companies are main suppliers, and some of them are subcontractors.

The requirements and expectations from the companies on their membership in Chase therefore demonstrate large variations in terms of applicability of the research results (immediate access vs. long term perspective) and in terms of interaction and cooperation between the academic researchers and the companies (direct collaboration vs. long term knowledge transfer). It has been a challenge to satisfy these needs, and at the same time keep a high standard of the academic research. It is therefore very satisfying to experience the very positive comments and attitudes from the companies regarding their membership in Chase. There are a number of ways how research results in an academic environment may come to use in companies. One very important path is master thesis works, and within the framework of the Chase research projects a number of master thesis works have been performed. In several cases the master students have been employed by the companies after receiving their MSc degree.

In the project **"MIMO systems"**, Ericsson has increased their knowledge when it comes to network MIMO, MIMO repeaters and the repeater related wave propagation campaigns. Ericsson has together with researchers from Chalmers and other partner companies published several papers in these areas and also two patent applications related to repeaters and relays have been filed. Other successful research work has been on what is called Line-Of-Sight MIMO (LOS-MIMO) for microwave radio links. Traditionally MIMO techniques have been developed for multi-path propagation and rich scattering which is associated with non-LOS propagation. However, MIMO can also be used in LOS scenarios like point-to-point microwave communications. In fact, the LOS-MIMO concept for microwave links has been analytically analyzed and published at an international conference and, maybe more importantly, been demonstrated at the annual mobile world congress (MWC 2011) in Barcelona where it gained a lot of interest since the highest spectral efficiency ever demonstrated for microwave links was achieved. Gigabit microwave is an important building stone in future high-rate telecommunications standards such as 3GPP LTE and its evolution.

The project **"Test environments for cellular radio systems (OTA)"** addresses an area of importance for Sony Ericsson AB, Bluetest AB and Ericsson AB, although from different perspectives. Several papers from Sony Ericsson, SP Technical Research Institute of Sweden (SP), Bluetest AB and Chalmers have been presented at EU COST conferences which aim at defining OTA testing principles for the 3GPP and CTIA standards. A functional OTA testing tool ("Multi-Path Simulator", MPS) is in operation at Sony Ericsson and several terminals are now being tested for system level performance evaluations and data throughput in semi realistic environments. Chase researchers at Chalmers and SP have focused on research related to the use of reverberation chambers (RC) and also developed simulation tools for both the RC and the MPS. The outcome of the OTA project will serve as valuable input to Sony Ericsson when deciding on what testing principles to adopt for efficient MIMO antenna design and optimization for mobile handsets. Bluetest is a leading provider of Over-The-Air measurement technology for the telecom area, specifically targeting mobile phones and other wireless devices. To stay in the leading position, there is a constant need to further explore the ins-and-outs of antenna measurement technology in general and the RC technology in particular. Bluetest has during stage 2 of Chase participated actively in the "Test Environment for Cellular Radio Systems" project. In addition, Bluetest has closely followed the progress in the "MIMO Terminals 2" project. Both of these projects have provided an excellent forum for networking and discussions about possible ideas for product development. The combination of academia and industry is the key to the usefulness of the Chase research center for a smaller company like Bluetest. The implementation of research results from Chase in the Bluetest products is straightforward. First of all, with an active participation in projects, the research directions can be influenced to make the research relevant for Bluetest products. Secondly, Bluetest is an engineering company, with a large share of employees with university education, which makes it natural to constantly strive forward and implement new research results.

In the project **"Antenna System Simulator"** one has been able to integrate LTE functionality into the simulator. It is now a tool that may facilitate even deeper collaboration between industry and university on different antenna system evaluations to better understand

fundamental behaviour and effects in the link between receiver and transmitter of a wireless system. With the capability to detail different parts in the link chain there is also a possibility for Ericsson to evaluate concept and product ideas. Worth noticing is also the attention the simulator has received from organizations outside Chase. Another output from the collaboration is that contacts have been established for proposed future Chase studies on array antenna technologies.

Also RUAG Space has participated in the project, and considers that the general knowledge obtained and the good contacts with other industries and with Chalmers have been of great value. Specifically, RUAG has used the approach from the project for their satellite arrays for L- and S-band mobile communication. With the developed methods, one can predict system performance impact of any minor errors in the components. Thus one can more easily set tolerances and trade performance requirements between the components of the antenna system.

Part of the work within the System simulator project has been focused on Radar signal processing, a very important issue for Saab AB. Within this subtask, Saab and Chalmers have had a prosperous cooperation within the field of MIMO-radar. The ideas and the basis of the work were established by extensive work at Saab and were later introduced to Chalmers, as a Saab in kind contribution. The results presented by Saab were interesting, but the algorithms required too extensive computational resources to be feasible in realistic scenarios. Within this Chase project, Chalmers have reformulated the problem using matrix formalism and continued to study aspects to simplify the implementation and improve the performance. The progress has been good and the results are promising. As Saab, as well as Chalmers, finds this area of research interesting, an application for grants for an industrial PhD was submitted to the Swedish Research Council. This application is considered a very positive output from the studies performed within Chase.

The intention of the **"MIMO Terminals 2"** project is to study and evaluate new advanced antenna solutions and system technologies for future mobile terminals from a systems perspective in which the full system performance is considered. The aim of the research is to develop tools and methods for efficient MIMO antenna design rather than developing new products. For this purpose a user friendly simulation tool called the Multiport Antenna Evaluator (MPA) has been developed. This tool has the potential to drastically reduce the time for designing feeding networks for multi-port antennas for use in mobile terminals, and has been used at Sony Ericsson as well as Perlos when comparing different ways of developing MIMO antennas. The MPA has so far been applied to "theoretical" antennas only and because of the multi dimensional optimization demands when implementing practical terminal antennas no good example of a practical realization can be given at this point. Several master thesis studies supervised by Sony Ericsson and Perlos performed by students from both Chalmers and Lund University have utilized the tool as part of their studies. One of the master students was employed by Ericsson Research partly thanks to the master thesis project she did in the project. The work with the MPA has also resulted in a PhD thesis. The Chase researchers at Chalmers have focused on theoretical studies of the effects of mutual coupling, embedded element efficiencies and correlations on diversity gain and MIMO performances. This has resulted in a better understanding and new simple formulas for diversity gain and efficient measurement methods. This research has been done in close cooperation with the Chase project "Test environment for cellular radio system – OTA", a collaboration that has been very fruitful and beneficial for the partners of both projects.

The project **"Antenna Systems for Biomedical Applications"** is closely linked to the two start-ups Medfield Diagnostics AB and Micropos Medical AB, and to the major medical device company St. Jude Medical AB. Medfield has gained knowledge about time domain measurement and frequency domain measurements. For Medfield, the membership in Chase is of profound importance, and it offers an exciting environment where one has the opportunity to interact and collaborate with researchers at Chalmers, and also with other companies sharing their interest in antenna systems technologies. Micropos Medical AB is a Swedish medical device start-up. The company was founded in 2003 as a result of four physician's long clinical experience in the therapeutic radiation oncology field (cancer treatment). The company develops technologies that enhance the precision in radiotherapy of cancer. The first product, RayPilot®, is an electromagnetic positioning system that enables real time information of the position of the prostate for a fast and objective set-up and for continuous positioning during the treatment. The RayPilot® system has the

potential for future use in other tumor areas. The research in Chase serves as an input to the development and design of the current and the next generation of the RayPilot® system.

For St. Jude Medical AB, the results from Chase so far have been on a ground work level which has deepened the understanding of some results from own measurements and thus allowed for a move forward with more confidence. The results have been feed into the pool of knowledge in the MRI area and will together with own research be part of the foundation for future MRI compatible pacemaker systems from St. Jude.

The project **"Gap Waveguide Frontend Demonstrator"** started in spring 2011 and is thus in an early investigating phase and no results have yet been utilized by partners to establish new products and services. The plan is to test practical assembly and to do measurement of key building blocks of the front-end regarding packaging and isolation of active microwave circuits using gap waveguide technology and to verify the expected performance of a transition between a ridge gap waveguide and a PCB. The project started initially with a focus on 38 GHz components, but the focus has now been changed to the commercially more interesting 60 GHz band, and to develop the first gap waveguide antennas for this band. 60 GHz is a less regulated frequency band, and some novel so-called WiGig systems have been proposed for short range Gigabit transmission. The Chase partner Gapwaves is following these markets and related technologies, and have contacts with Huawei Technologies Sweden AB as well as Ericsson AB to find the right upcoming market for a joint venture.

The recently started project "**Microwave Hyperthermia"** is another example of medical applications of microwaves, which is a relatively new and rapidly developing field. During the last decade clinical studies have demonstrated the ability of hyperthermia to dramatically enhance the response to radiation therapy and chemotherapy, leading to increased cancer patient survival. Despite these positive clinical studies and a solid biological basis, there are challenges in the ability to deliver uniform target levels of hyperthermia under strict spatial and temporal parameters. The present project focuses on research with the goal to introduce a new generation of hyperthermia system into clinics. The industrial partner in the project is Elekta AB, a human care company pioneering significant innovations and clinical solutions for treating cancer and brain disorders. Elekta provides intelligent and resource-efficient technologies that improve, prolong and save patient lives. The reason for Elekta to join Chase and participate in this project is the potential for the company to widen their present offer of equipments for cancer treatments. The Region Västra Götaland is the regional provider of healthcare and is also a key actor in the support of regional sustainable growth and development.

# 4. Summary

The research projects in Chase are performed in close collaboration between academic and industrial researchers, in an environment that stimulates and encourages knowledge transfer to the companies for the benefit of their product development. The support from the society is crucial for establishing this framework, since the overall priorities in the academic world is quite different from those in a commercial environment.

It is thus of profound importance that the Chase environment stimulates the interest and ambitions among the researchers to have close links to companies and also to be engaged in efforts to commercialize their research results. This has resulted in successful collaborations with several established companies and by remarkable start-up successes like Bluetest AB and Medfield AB.

The research in Chase is of great benefit also for the academic participants, and the scientific output is impressive: more than one hundred journal papers and close to three hundred conference papers during the first five years, i.e. an average of twenty journal papers and sixty conference papers per year.