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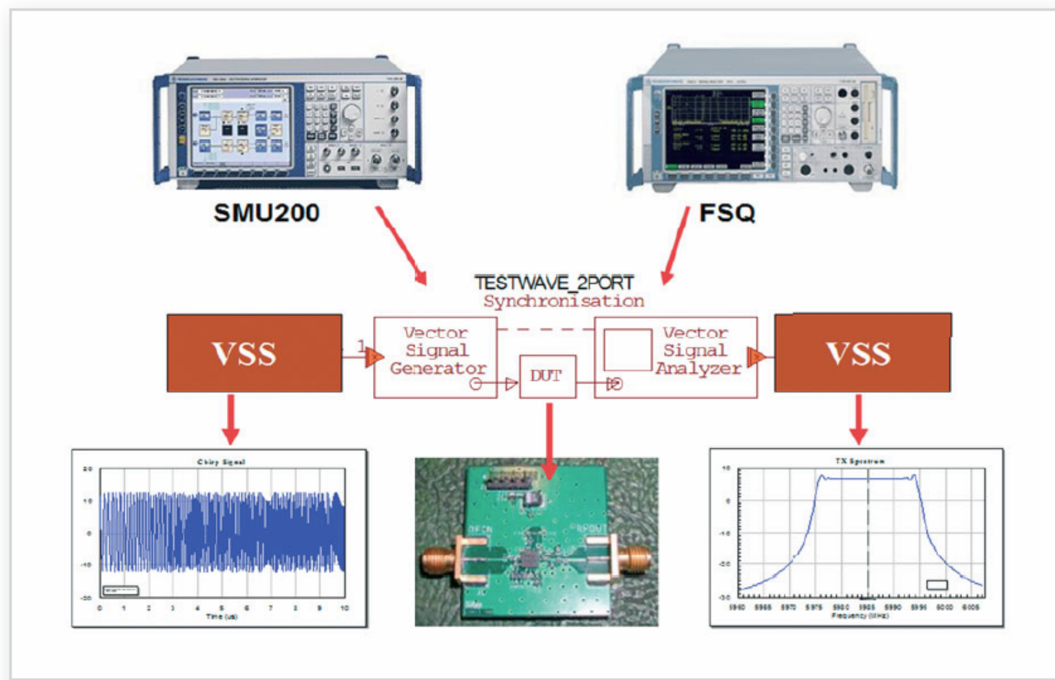

HIL implementation of a design process with LabVIEW and AWR

Examensarbete inom högskoleingenjörsprogrammet Elektroingenjör

CHRISTOFFER OLSSON

Institutionen för signaler och system
CHALMERS TEKNISKA HÖGSKOLA
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Preface

This written report is the result of a Bachelor's Thesis project performed by Christoffer Olsson at SAAB EDS Göteborg. It is the final examination of the study programme Elektroteknik 180 hp (högskoleingenjör) at Chalmers University of Technology (B.Sc. in Electrical Engineering). This project comprises of 15 högskolepoäng (hp) (College study credits) which is equivalent to 10 weeks full-time work (40 hours a week). The work was done during the spring of 2013.

I would like to thank Lennart Berlin for all support and help during the course of this project and thanks to Audun Tengs for taking time off his work to let me interview him for details about the workflow at his department.

I give a special thank you to all helpful co-workers at SAAB EDS for their support and for giving me the opportunity to do my thesis work there.

I highly appreciate being able to participate in a course in VSS at SAAB EDS held by Lars Van Der Klooster from AWR Corporation.

Abstract

SAAB EDS wants to evaluate and investigate the possibilites of utilizing a HIL-implementation in their design process for integrated circuits which operate at microwave frequencies, specifically MMIC and PCB design. The objective of this project is to find different methods for testing and verification steps in the design process that enhance and improve the time-to-market-value (TTM) of the product that is being designed. The evaluation also encompasses how the software programs AWR product suite and LabVIEW can be utilized to to a higher degree for testing purposes.

Sammanfattning

SAAB EDS vill utvärdera och undersöka möjligheterna att utnyttja ett HIL-implementering i sin designprocess för integrerade kretsar som arbetar på mikrovågsfrekvenser, speicifikt menas MMIC och PCB design. Syftet med detta projekt är att hitta olika metoder för testning och verifiering i alla steg av designprocessen och använda detta för att minska och förbättra tiden-till-marknads-värdet (TTM) av den produkt som håller på att utvecklas. Utvärderingen omfattar också hur programvaran AWR och LabVIEW kan utnyttjas i högre grad för att utföra dessa tester och verifieringar och på så vis förkorta produktionscykler.

Contents

1 Abbreviations/Glossary

API - Application Programming Interface
DRC - Design Rule Check
DUT - Device Under Test
EDA - Electronic Design Automation
EM - Electromagnetism
ERC - Electrical Rule Check
EVM - Error Vector Magnitude
FEM - Finite Element Method
FFT - Fast Fourier Transform
FPGA - Field Programmable Gate Array
HDL - Hardware Description Language
HIL - Hardware In the Loop
LVS - Layout Versus Schematic
MMIC - Monolithic Microwave Integrated Circuit
MWO - MicroWave Office
PA - Power Amplifier
PCB - Printed Circuit Board
RF - Radio Frequency
RFIC - Radio Frequency Integrated Circuit
TTM - Time To Market
VSS - Visual System Simulator
VSWR - Voltage Standing Wave Ratio
VHSIC - Very High Speed Integrated Circuit

2 Introduction

2.1 Background

Within the field of designing microwave hardware, there are breakthroughs and technological advances at regular intervals. New hardware iterations, e.g. MMIC or PCB, often provide better linearity, less loss, higher gain etc. etc. Circuits become more and more complex and at the same time getting smaller and smaller. The negative aspect to both these developments is that, the more complex a circuit becomes, it takes longer time to develop. Smaller circuits also bring another problem that presents itself in construction. Higher frequencies are being used more regularly because of bandwidth demands from the consumers in e.g. Smartphones. This applies to both 3G, 4G and especially Wi-Fi. Because of this, newly developed MMIC are so small that very expensive equipment is needed for construction and testing. Typically, MMIC sizes range from $1mm^2$ to $10mm^2$ [2]
SAAB EDS has asked for an investigation into how the design process can be streamlined with the addition of a HIL-implementation of the testing/verification process at their microwave department in Lackarebäck. HIL-implementations can take many forms, but the defined focus for this investigation is on the utilization of the software AWR in conjunction with a LabVIEW-oriented real-time measurement/testing system. The current setup for testing and verification is with traditional boxed instruments and measurements are written down in paper form. A partly automated form of measuring in this step could potentially save time and ultimately reduce time to market, which is the main goal.

2.2 Purpose

This project aims to find different solutions to HIL implementations for MMIC and PCB design. The focus is to find flaws in current design cycles and define ways to approach solutions for them. Most design cycles include many testing iterations which cost both time and money and anything that can help reduce iterations is good for economic reasons

2.3 Delimitations

Delimitations set upon the project include the actual design/construction of an example of HIL-implementation. This would have taken to much time to complete and also the VST was not available for testing.

2.4 Definition of task

These are the main questions that the aim is to answer during this project.

- What is HIL and why is it beneficial?
- Can AWR and LabVIEW be used to create a HIL testing environment?

- How does the design process work at SAAB and what are the steps involved in the design of an MMIC/PCB?
- Can HIL be implemented with both a VST and/or traditional boxed instruments?

3 Method

The method that will be used for the gathering of data for this investigation will partly include information research and partly involve experimentation with the software. A course in AWR:s software VSS will be providedd during the couurse of this task. Examples of HIL-implementation will be studied and interview will be held at the design process in Lackarebäck.

4 Technical background

4.1 Microwave and RF design

Microwave and RF design is a collected term for the design of systems/components which have high operating frequencies. In this context, high frequencies are usually between 100MHz and 300 GHz. The most common method of transmitting signals wirelessly uses electromagnetic waves. Depending on the frequency used for the application, the wavelength of the electromagnetic wave changes according to the following formula:

$$\lambda = \frac{v_p}{f} \left[\frac{\frac{m}{s}}{\frac{1}{s}} \right] = [m] \tag{1}$$

Here the wavelength is signified by the character λ and an increase in frequency results in decreased wavelength and vice versa. This presents a problem for developers of circuits/RF design. The shorter a wavelength of a signal is in relation to the length of the line it is transmitted on, affects the performance of the whole design. To solve these kinds of problems, a different mathematical theory must be used, instead of the lumped parameter model. The lumped parameter model simplifies a circuit's representation with discrete components. This is only valid when the wavelength is much longer than the circuit's length $l_c \ll \lambda$. Otherwise, the performance of the circuit can not be guaranteed. E.g. if a Power Amplifier (PA) is constructed and is operating in an environment with higher frequency than it has been constructed to handle, the amplificationn could be affected negatively by a decrease. Transmission line theory takes these affects into consideration with a new model of how electrical signals are transmitted and interpreted. E.g assume "normal" conditions inside the earth´s atmosphere, the phase velocity v_p of an electromagnetic wave is roughly the speed of light$\approx 300 \left[\frac{km}{s}\right]$. If a transmission line (overhead cable) is constructed with the aim to be operated at 3GHz, this would result in:$\lambda \approx \frac{c_0}{f} = \frac{3 \cdot 10^8}{3 \cdot 10^9} = \frac{1}{10}\,[m] = 10\,[cm]$. As a general thumb rule for construction, transmission line theory should be used when the length of the line is longer than 10% of the wavelength, $l_c > \frac{\lambda}{10}$, which in this case would result in:$l_c > \frac{\lambda}{10} = \frac{10}{10}\,[cm] = 1\,[cm] \implies l_c > 1\,[cm]$. If the transmission line in this example is longer than 1 cm, transmission line theory must be used to gain accurate results.

4.1.1 Electromagnetic Field Theory

To understand the reason behind why transmission line theory needs to be used, the basics of electromagnetic field theory is needed. The most fundamental mathematical expressions in EM theory is called Maxwell's equations. These equations form the basis and can describe, explain and predict all macroscopic electromagnetic phenomena. They are represented here in partial differential form:

Gauss' law for electricity[5]:

$$\nabla \cdot \mathbf{D} = \rho \tag{2}$$

Gauss' law for magnetism[5]:

$$\nabla \cdot \mathbf{B} = 0 \tag{3}$$

Faraday's law of induction[5]:

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t} \tag{4}$$

Ampere's Law[5]:

$$\nabla \times \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t} \tag{5}$$

These equations will not be derived here, as it is beyond the scope of this thesis[footnote people interested Cheng], but these equations are complex and the four field vectors **E, D, B, H** have three components each (x, y and z in carthesian coordinates) and therefore represent twelve unknowns. With the constitutive relations, $\mathbf{D} = \epsilon\mathbf{E}$ and $\mathbf{B} = \mu\mathbf{H}$, all of these equations can be solved with rigourous mathematical skill and time. With mathematical computer tools, these equations can be solved easier and much faster. AWR provides tools which can calculate and solve the equations in 3d with relative ease and provides threedimensional graphs of the results.

4.1.2 Transmission Line Theory

Transmission line theory takes into account the characteristics that the waveform presents on the transmission line by utilizing the spatial dimension in the equations. The mathematical expressions for this are called the telegraph equations and are results/derived from Maxwell´s equations.
The telegraph equations are practical and intuitive to use. The equations consist of several distributed components which can be easily explained with a figure:

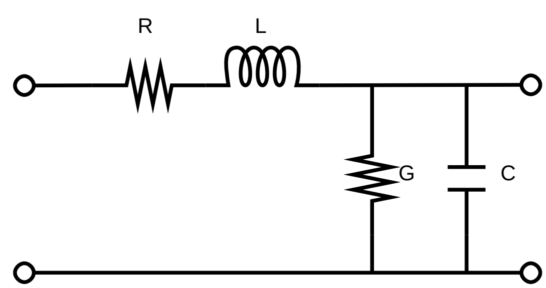

Figure 1: Telegraph equations elementary components

This two-port structure is infinitesimal and is part of an infinite series of these elements along a transmission line.

R represents the resistance per unit length of the conducting wire (usually $\frac{\Omega}{m}$).[4]
The inductance component per unit length, **L**, represents the magnetic field around wires and self inductance ($\frac{H}{m}$)[4]
Capacitance per unit length is represented by **C** ($\frac{F}{m}$)[4]
Conductance between the two conductors is represented by **G** ($\frac{S}{m}$)[4]

The ordinary differential equations to use these elements are as follows[4]:

$$-\frac{\partial V(z)}{\partial z} = (R + j\omega L)I(z) \tag{6}$$

$$-\frac{\partial I(z)}{\partial z} = (G + j\omega C)V(z) \tag{7}$$

This is the general equations that can always be used (lossy and lossless transmission lines). The ordinary use of this theory is to match networks and maximize the gain and/or characteristics needed for your application. This can be done by laborious usage of the formulas presented above or by simulation in a program like MWO.

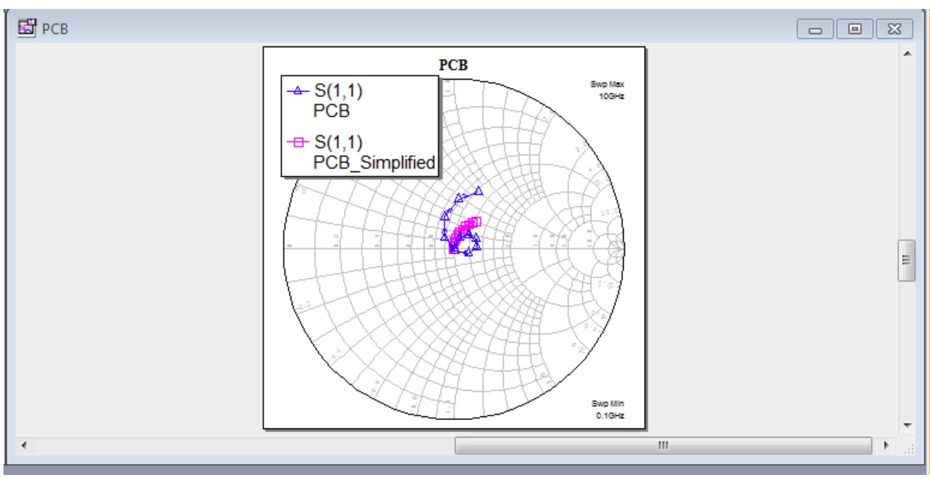

Figure 2: MWO smith chart example

With MWO you can simulate filters, power amplifiers, stubs et cetera. Before the time/frequency domain could easily be simulated with a computer, simplified graphical tools such as smith charts could be used to get all parameters needed.

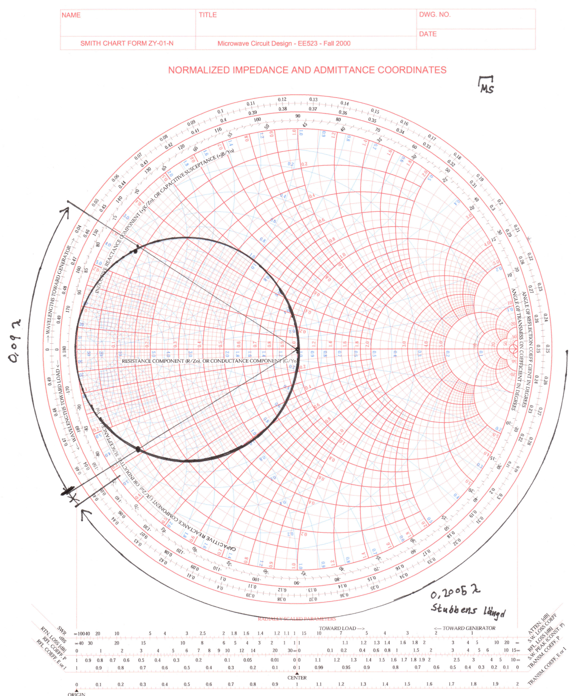

Figure 3: Example of a Smith chart being used to calculate the length of a stub

Smith charts, although useful, are not the most optimal way of performing calculations when computers can perform the calculations in microseconds. As a consequence off the higher frequency, the circuits/designs are getting smaller. The small design is beneficial to matching so that there is no more than a maximum of one wavelength in the design. This is generally done because it is cheaper and it maximizes the gain if there is as little reflection loss as possible. The main advantage with utilizing microwave frequencies for sending/receiving data is that the bandwidth is also higher. Antennas are proportional to the wavelength and are therefore also smaller and, in affect, cheaper to make. Even though lower frequency signals propagate farther and better in different mediums, they can not carry the same amount of data because of lower bandwidth. The antennas needed are bigger in size for lower frequency signals, but not as many are needed as with the higher frequency antennas because you can make one with high power that reaches a larger area.

4.1.3 MMIC

A MMIC (Monolithic Microwave Integrated Circuit) is basically an integrated circuit device that is designed to work at microwave frequency ranges (300MHz-300GHz). Typically it is used for power/low-noise amplification but it can be used for a variety of applications e.g. frequency mixing/switching. MMIC are often physically "small" (depending on the frequency it is dimensioned for). They range from about $1mm^2$ to $10mm^2$. At SAAB the most commonly used materials for manufacturing are GaAs and GaN which have different working conditions and costs of manufacturing attached to them. GaN power amplifiers can be used at much higher temperatures and can therefore provide higher voltages and gain. The downside is that it is more expensive than GaAs. GaAs is the traditional materials used for MMIC manufacturing and provide good characteristics. In MMIC design at SAAB, the program ADS (Advanced Design System) by Agilent is used most frequently.

4.1.4 PCB

A printed circuit board (PCB) is a circuit which can be mass produced with wires printed unto the board. The wires are etched unto the board by patterning out where the wires, which consist of copper, are supposed to be and removing the unwanted copper from the layer of the board. Components such as resistors, inductors and capacitors are added to complete the circuit. For PCB design, Microwave Office by AWR Corporation is most commonly used.

4.2 AWR Product Suite

AWR is a corporation owned by the National Instruments Corporation. AWR stands for Applied Wave Research and it is an Electronic Design Automation (EDA) software company and they have developed what is called the AWR Design Environment. This design environment consists of several products with different uses. The products are developed for computer-based environments and are used for designing hardware used at higher frequencies i.e. radio wave frequencies (3kHz-300GHz). The Design Environment provides easy access to all the different products developed by AWR Corporation.

4.2.1 Microwave Office

Microwave Office is a RF/Microwave Circuit Design Software. It is mainly used to design MIC, MMIC or PCB with a schematic layout design. The program can be used to simulate linear or non-linear circuits before implementation of the product.

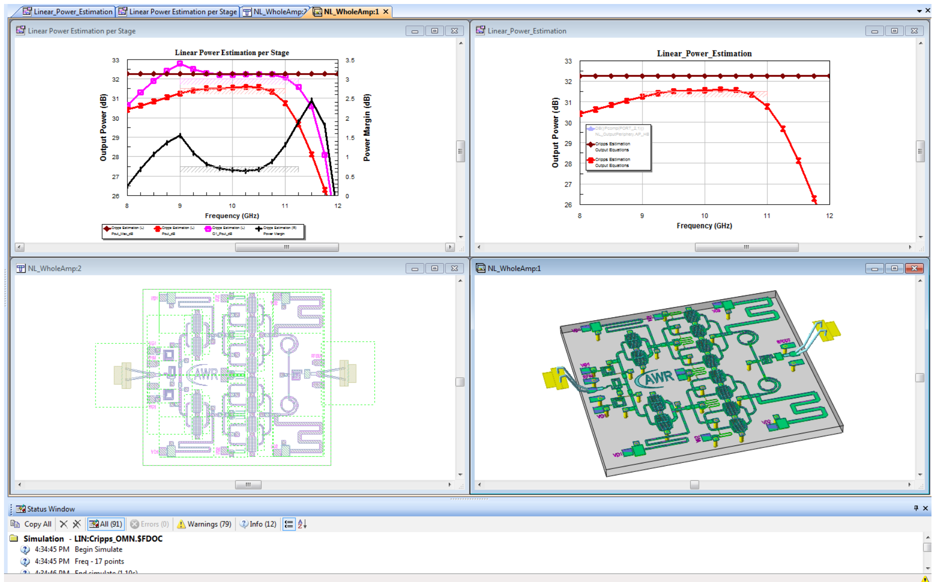

Figure 4: MMIC HPA design example

You can also perform a physical verification of the IC layout design to see if it meets the criteria needed in the form of ERC, DRC and LVS checks. APLAC can be used for harmonic balance time domain simulation and transient analysis. It can also be used to determine the DC operation point in biasing.

4.2.2 Visual System Simulator

The Visual System Simulator is primarily used for simulating systems under the conditions the user sets to it. The program has the capability to monitor the VSWR for impedance mismatching and the impact it has on the system. It includes test benches for a variety of wireless standards, e.g. GSM or LTE. It can also be used to create custom signals as a signal generator. VSS has an innate ability to integrate with National Instruments LabVIEW in a HIL-implementation.

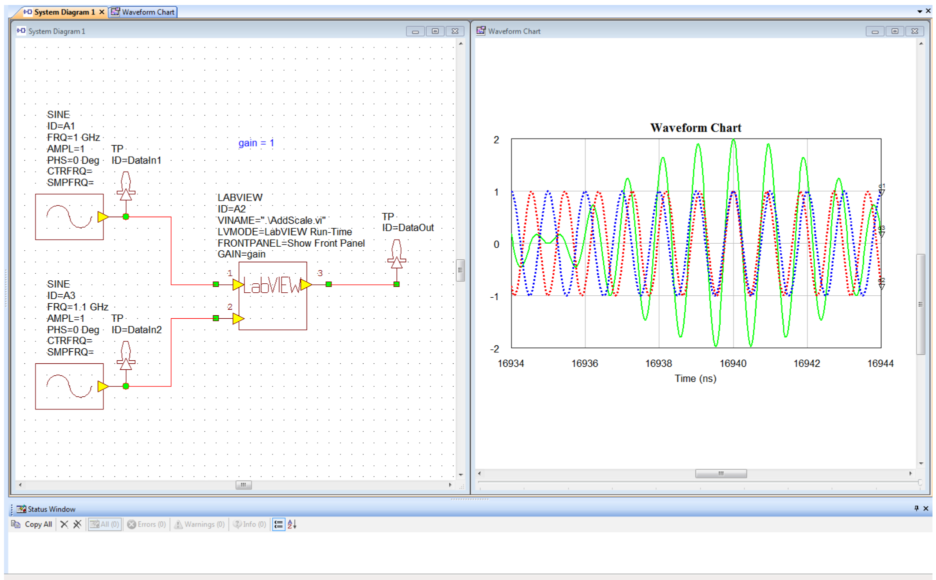

Figure 5: LabVIEW VI in VSS

A LabVIEW VI can be used in conjunction with AWR VSS to utilize the powerful signal processing that LabVIEW is capable of. LabVIEW contains a wide range of algorithms, including: Transforms (FFT, Laplace, Hilbert, etc. etc.) Demodulation/Modulation of signals (AM, FM, PSK, QAM, etc. etc.) Mathematical functions HIL-implementation with both LabVIEW and VSS is one of the strengths of this program. The data collected during HIL-tests can also be used to correlate between software simulations and hardware tests. The LabVIEW integration also enables construction of a more complex/advanced system design where many functions can be automated in a software environment instead of having to develop physical test equipment, which costs both money and time.

4.2.3 Analog Office

Analog Office has the capability to offer an accurate design environment for analog purposes. It is used for design of and to simulate, optimize, synthesize and verify RFIC and analog IC in general. Parasitic effects can be calculated with parasitic extraction which purpose is to give an accurate model of the analogue properties of the circuit. It can perform transient/time-domain, AC and noise analysis with APLAC or HSPICE.

4.2.4 AXIEM

AXIEM is a 3D Planar Electromagnetic (EM) analysis tool. It is used to characterize the EM properties of a schematic before manufacturing. This is an essential tool for any designer to shorten or eliminate design cycles and decrease Time-to-Market TTM. It can be run straight from the schematic in the program and it has a form of automatic adaptive meshing to discretize the continuous domain to values which can be stored and processed. These results can be visualised post-processing in the 3D model of the design and/or with animation. This tool is a full-wave 3D planar EM solver and is therefore very precise (although still an approximation) in the quantified values it solves according to all of Maxwell´s equations. This program can also be used to simulate antenna and antenna relay conditions and analyze the results post-processing.

4.2.5 Analyst

Analyst is a 3D FEM Electromagnetic (EM) Analysis tool and has much of the same capabilities as AXIEM. The core difference is that Analyst performs full 3D EM FEM analysis. It uses 3D volumetric meshing which is tetrahedron-based. This tool can also do parametric studies which can be used to optimize, tune and to streamline the yield of the design.

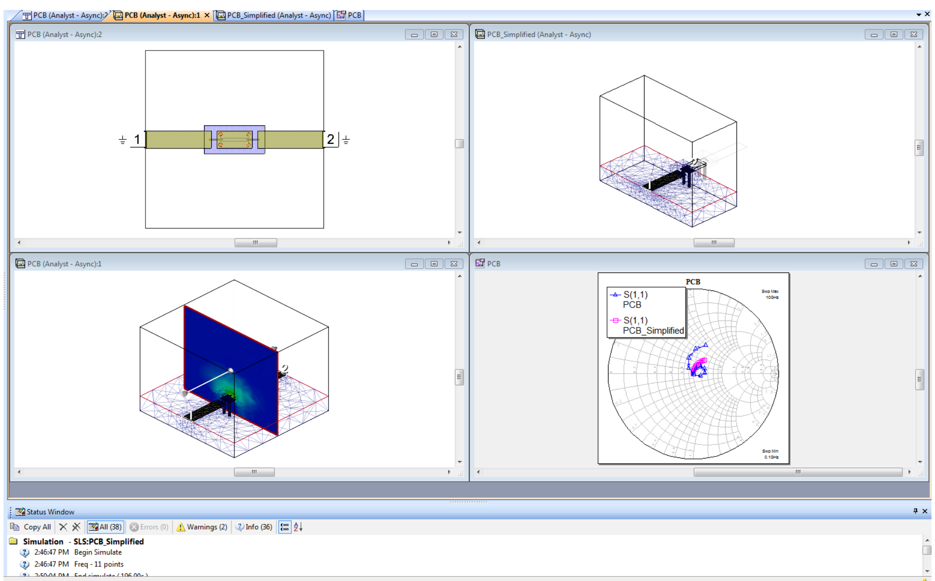

Figure 6: Simple PCB design tested in Analyst

4.3 ADS

ADS is short for Advanced Design System and it is a product that has basically the same functionality that AWR does, with the exception of LabVIEW integration.

4.4 LabVIEW

LabVIEW (Laboratory Virtual Instrumentation Engineering Workbench) is a program developed and maintained by National Instruments. It is essentially a design environment for programming. The programming is done in what is called a visual programming language named “G”.

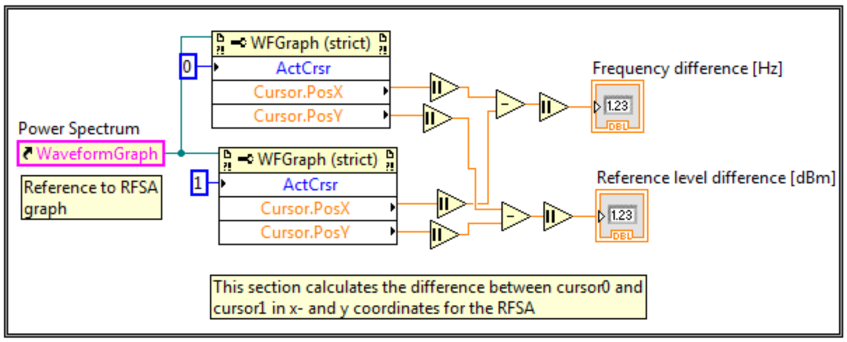

Figure 7: Example “G” code

This design environment is commonly used for purposes which include (but is not limited to) data acquisition, instrument control and industrial automation. Arguably, the most important part of LabVIEW is the capability to simulate different instruments functions before physical implementation and to be able to program physical instruments directly to fill the needs of the user. This is especially convenient when LabVIEW can be used with drivers and an API to directly control/program an instrument. An instrument in this context is either some form of measurement equipment or signal processing equipment. LabVIEW can also be used to program FPGA modules in instruments and therefore provide a faster access time. This saves a lot of development time also since the programming is usually done in VHDL (VHSIC Hardware Description Language), which is more time consuming since it is a low-level programming language.

```
begin
state_shift:process(CLK_50)
begin
        if rising_edge(CLK_50) then
        if (slow_clk = 0) then
                case state is
                when I =>
                        DOUT<='1';
                        if (NS = '0') then
                                state <= S3;
                                Q<="0111";
                                NCC<='1';
                        else
                                state <=I;
                        end if;
                when S3 => Q(3)<=DIN; Q(2)<='0';
                        state <=S2;
                        DOUT<= DIN;
                when S2 => Q(2)<=DIN; Q(1)<='0';
                        state <=S1;
                        DOUT<= DIN;
```

Figure 8: Example VHDL code

With a high-level programming language, such as LabVIEW, you can significantly reduce development time and, in so doing, reduce costs. Since National Instruments acquisition of AWR Corporation in 2011[3], the company has worked on integration with LabVIEW and AWR. The virtual instruments (VI´s) developed in LabVIEW can be used in the AWR design environment, as can be seen in figure **5**. This provides a unique opportunity for implementation in current systems involving construction, testing, verification et cetera.

4.5 VST, other equipment

A Vector Signal Tranciever is a software-defined RF test system that combines a Vector Signal Generator (VSG) and a Vector Signal Analyzer (VSA) into one small module, whereas before they where separate modules which could be interconnected to perform the same function.

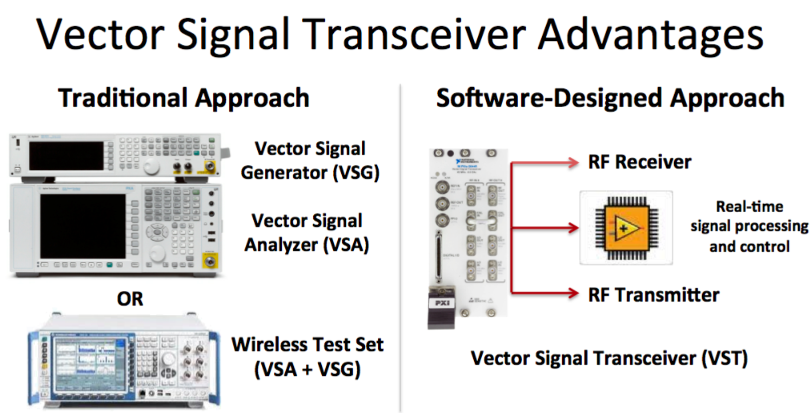

Figure 9: NI VST©traditional vs. software-designed approach

The VST has a FPGA-chip installed for real-time signal processing and control and this is significant in terms of the speed it provides. The VST can generate, process and analyze signals from 65MHz to 6GHz with 80 MHz instantaneous bandwidth. Comparing a similar VSA to a boxed instrument, with setup and test time included, it is 20x faster[1]. If a design is expected to work in conditions between 65 MHz to 6 GHz, the VST is ideal for both testing and verification of previously calculated and/or expected parameters. This device can be used for many applications, depending on the user´s preference. The FPGA-chip allows for reprogramming the unit to suit a specific application. The VST is ideal for Power level servoing and it can also be used to generate noise which can be run through a DUT and then analyze the results to see if they are within expected parameters.

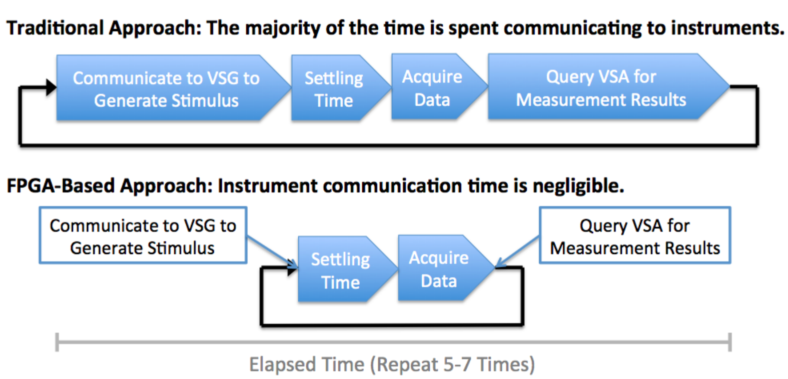

Figure 10: Settling time and acquisition

The VST can be used to control/test the DUT by interconnectivity and drastically decrease testing time by automation of testing procedures.

4.6 FPGA

A Field Programmable Gate Array, FPGA, is a integrated circuit that can be programmed by the end user. It consists of programmable logic mostly consisting of logical gates. This provides very high speed and is ideal for analogue systems operating at higher frequencies where more discrete measurement points are required for accurate measurement of a signal. Typically, a Hardware Description Language (HDL) is used for programming. Newer FPGA-IC's, provided by National Instruments, can be programmed in LabVIEW which is a higher level programming language. This makes programming much easier and more efficient.

4.7 HIL

HIL stands for Hardware In the Loop and it is a technique that is commonly used to simulate a newly developed system. This is primarily done to test real time events on a certain part of an embedded system that is completed and simulate the parts of the design that are missing/not completed. HIL simulation has obvious advantages to ordinary test benches which may only simulate and parameterize the specific part of the design that is connected and therefore not simulate the specific part's impact on the whole design. The HIL-testing is often the last step before implementation in the embedded system and it is advantageous to implement on a FPGA-chip due to the fast I/O speed. An FPGA-chip is also easily programmable with VHDL or even LabVIEW. HIL-testing is beneficial to have in a design project for several reasons:

- If the system has not been built, you can test completed parts of the design individually.
- Verifying parameters before implementation.
- The system does not allow for safe testing or 100% performance is not guaranteed in the testing environment because of safety reasons. Testing the whole system will create downtime, which is expensive, for the already implemented system and may cause problems due to the lack of prior testing.
- Testing conditions that are difficult to physically replicate. HIL-testing can replicate these conditions in software.

5 The process

5.1 SAAB Design process

The hierarchical structure at SAAB EDS is divided into two main branches called Avitronics Processes and Microwave Processes respectively.

Figure 11: SAAB Design process for PCB design

Under Microwave Processes R&D processes, the SAAB Design process for PCB design emerges under several subprocesses. As an example, an ordinary design process for a PCB/MMIC is used. This is a generalized model of a product cycle wherein each sub system can have multiple iterations until the process is completed.

- **Conceptual Design:** The designer takes into account and analyzes original requirements and refines them into a design specification.
- **Initial Physical Design:** In this part of the chain, the circuit diagram for board layout with components is completed.
- **PCB Physical Design**: Complete set of manufacturing data and documents.
- **Final Physical Design:** Finalize the circuit diagram, create the mounting drawing and pick and place information.

For a general ordinary process, these steps take about 500 hours to complete[2]. After these steps have been made, the product is shipped to a foundry/manufacturer. For MMIC manufacturing, the time at the foundry is about 10 weeks[2] after which you get a wafer (or substrate) with several MMIC. After the PCB/MMIC is done, the product is tested in the Design test step.
The programs used in these steps are MWO and ADS alternately depending on what is being designed. Usually, a MMIC is designed with ADS and a PCB with MWO. Because of the disparity between the programs, this can be a problem with efficiency in workgroups. To learn how to use two programs is inefficient use of design time, especially considering that the programs are so similar in function. MWO and ADS can basically perform the same measurements, although with different approaches, and for the designer it is a steep curve to learn both programs and use them at a proficient level.

- **Design test:** In this step, the product is tested to see if all requirements are being fulfilled. This is to verify that software tested parameters for reliance and performance are being actualized. If improvements can be made, these need to be identified and passed along to the next step in the design process. This step usually takes about 5 weeks to complete. The testing in this step is done with boxed instruments and measurements are written down with pen and paper.

5.2 HIL implementation of the design test phase

The design test phase have different forms of testing/verification.
The testing and verification of the design is not exclusively performed in the design test phase. It is important to be able to test out a design at an early stage in development. It is an important step in the development and should be performed in any stage of the development if appropriate conditions for testing are present. Testing the design/concept out early could potentially save time in development by reducing the chances of finding a critical flaw in the design at a late stage in development.
The prevalent way of testing a design during development is to perform simulations of frequency sweeps and see the results presented in either a smith chart and/or a Power vs. Frequency diagram. This can be used to validate/invalidate the design you are developing. Tweaking of the components of the design is necessary in most cases more than once.
MWO and ADS both also provide tools for doing EM calculations on the design in either MWO or ADS. Calculations for EM-field modelling are a trade-off between accuracy and computation time. The calculations require what is called a mesh which defines many small areas which are called finite elements. Within each of these finite elements, Maxwell´s equations are calculated. To gain the best accuracy, an infinite amount of finite elements is required which directly equates to infinite amount of time. That is highly impractical and therefore some trade-offs are necessary. With computers today, highly accurate 3D models of EM-fields can be calculated within minutes.

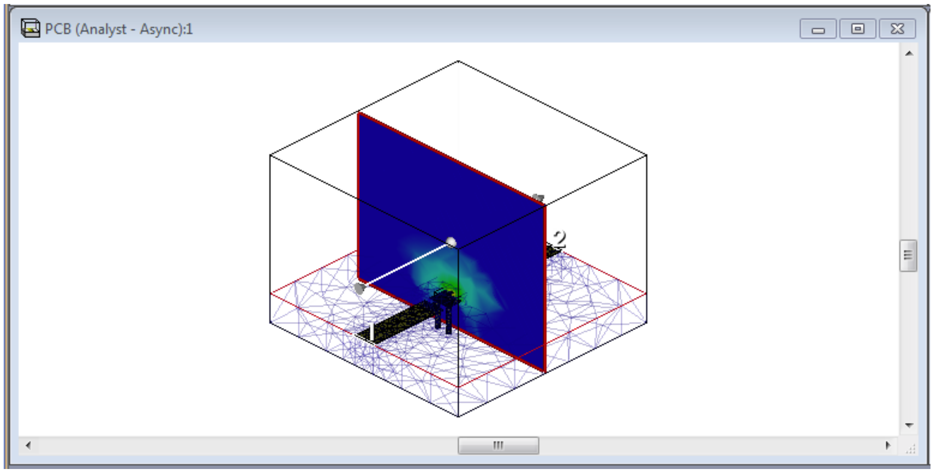

Figure 12: Example of mesh grid generated in AWR

VSS provides tools for testing and simulating a system and there are different ways of performing a test on a design. All the tests/simulations performed by VSS are highly accurate theoretical models and a design that has been programmed in MWO can be exported to VSS and be used in the simulations. External stimuli from e.g. a programmed VST with conditions resembling real world real time signals can be used to stimulate the virtual design. Examples of different signals which can be interesting to simulate include noise, deviations from expected values or disturbances. Ordinary situations can also be simulated by inclusion of the system in which the sub-system design is to be implemented. Signals can be sent through the simulated complete system and see if the measurements reach expected values.
If a hardware design has been constructed, e.g. a MMIC, it can be used as a DUT under the same conditions as previous example. But instead of using the Microwave Office design in VSS, the actual hardware is connected in a loop.

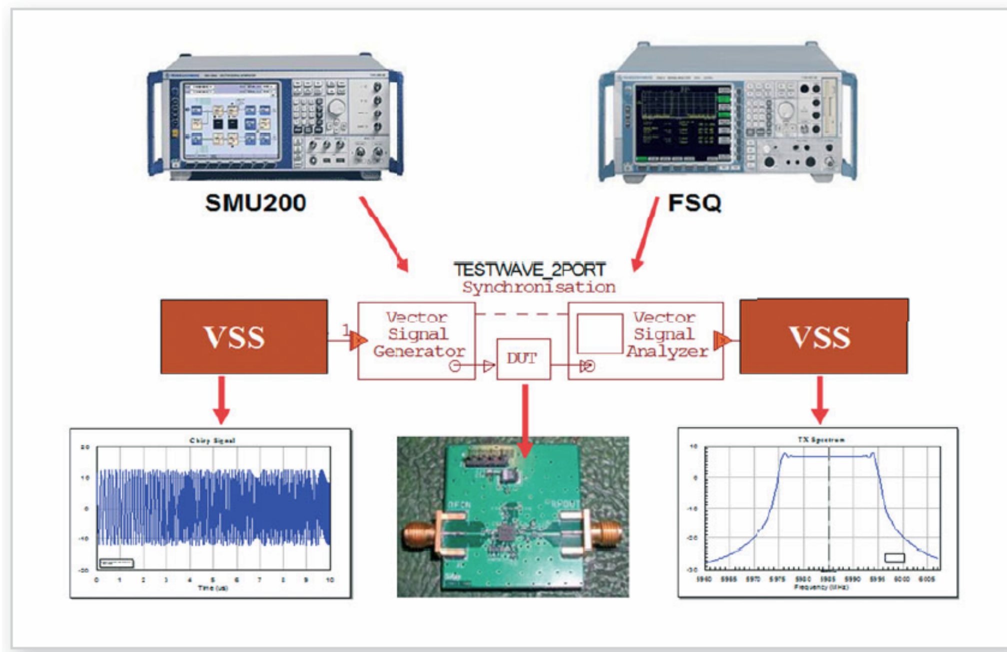

Figure 13: Example of HIL testing with traditional instruments

In figure 13 an example of HIL-testing has been implemented with traditional boxed instruments. This gives the advantage of being able to test the theoretical design before construction and after construction. The only change being that the part called DUT in the figure is either a physical object or a design schematic in AWR on a computer. This brings the advantage of subjecting the same measurements and/or conditions upon the product in two steps. Before construction and after construction and this is a really good way to correlate between expected design parameters and actual design parameters. Both manufacturer, the design and the design environment are being tested for accuracy of results.

6 Conclusion

The main reason for this investigation was to find different solutions for implementing HIL into the workflow. Several ways to accomplish this have been outlined in this document and can be summarized into three different approaches:

1. AWR and/or LabVIEW used in conjunction with traditional boxed instruments.
2. AWR and LabVIEW used with a Vector Signal Transciever
3. AWR and LabVIEW can be used as a HIL-implementation with the software design in the loop

The design can be tested with all these approaches with either the theoretical design within the AWR design environment or the actual constructed design. This provides a tremendous benefit in terms of testing. To be able to test the design before and after construction for verification purposes is very important, with both a software implementation and a hardware one. The MMIC design department at SAAB have many older instruments which can still be used with LabVIEW and/or AWR to design a test system with some automated testing features instead of manually handling all the equipment. With automation, some of the tests could be done quicker and reduces the time to market value for the specific product. This is somethinmg that can actually be implemented right now but with less flexible testing environment and with not as high speed as can be obtained with a VST from NI.
The VST can be programmed to test with more complex testing environments on the design and has the flexibility of taking up much less space.
Another different conclusion that has been made is that MMIC and PCB design utilize two different programs for no apparent benefit. To streamline this, one program should be used to reduce costs and increase benefits for the company. Both ADS and MWO can do basically the same of designs and measurements. The main benefits of using AWR is:

- Good integration with LabVIEW because of National Instruments acquistion of AWR Corporation in 2011.
- Easy to use and learn. The interface is more intuitive and tuning can be done in real-time
- The AWR product suite have cheaper licensing costs than ADS

7 References

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