

# “Radio Frequency Measurement Technology for Future Power Amplifiers and Transmitters”

KKS Dnr 2006/0231

## 1

## Introduction

The project is in the field of radio frequency (RF) measurement technology applied on future power amplifiers (PAs) and transmitters. Despite the needs for modernizing the field of RF measurement technology, it is still mostly an area of traditional engineering. Our proposal of a research project is interdisciplinary in the way that it is focusing on RF measurement technologies, but is on the other hand strongly influenced by both digital signal processing (DSP) and microwave engineering to create new possibilities and solutions.

The price erosion on the products, e.g. cellular base stations, is very large, but the decrease in production test cost is much smaller and this will become an increasing problem. Decrease of test times and decrease of investment costs are key issues. There is a large focus on efficient design and efficient design tools, while much less attention has been given to efficient testing. Novel measurement technology can significantly contribute to solving these issues. Such a technology is the focus of the proposed project.

The emerging technologies for wireless communication to support the long term evolution of wireless systems, e.g. multiple-input-multiple-output (MIMO), orthogonal frequency division multiplexing (OFDM) and new efficiency enhancement techniques for RF PAs, require novel measurement techniques both for design and production. The trend for advanced RF communication products are increased bandwidth, more efficient modulation schemes, decreased size, power consumption and cost, and a transfer of the digital interface closer and closer to the antenna.

The RF PA continues to be one of the most important components in wireless communication systems due to the high linearity and efficiency requirements and its design and characteristics is, thus, of the highest importance. This calls for new RF measurement techniques, both for development of PAs, but also for efficient production testing of them. There is a large focus towards efficiency enhancement techniques (switched PAs, envelope elimination and restoration (EER) amplifiers and Doherty amplifiers and linearization techniques such as digital pre-distortion that puts new requirements on tests and measurements.

The requirements are changing on all levels from power devices, power amplifiers and at higher levels. Different measurement techniques, e.g. load pull, Large Signal Network Analyzer (LSNA) and modulation domain measurements, are used to characterize the different device under test (DUT), however the different measurements are seldom compared and there is a lack of traceability between the different techniques and within the different measurement methods. Comparison between different measurement systems will be an important area in the project.

There are no measurement standards in describing products performance especially in higher operational modes, i.e. transistors, amplifiers, etc; as a consequence it is very hard to compare products from different vendors. There is also a lack of understanding of what is a good component/module on lower levels and, thus, strong need for correct measurement/evaluation criteria. There is a need for measurement standards that really relates to performance at higher levels. *De facto* measurement standards will be a focus area in this project.

The area of measurement technology for high power RF devices, such as PAs, is a quite unexplored area from an academic standpoint and the approach to combine the two academic fields DSP and microwave engineering is of very large interest for the industry. This is common knowledge for the product design,

but is seldom done in the test and measurement community. The potential is however large. By tradition the measurement society is conservative, focusing towards a sinusoidal and a narrow band world while modern communication systems such as 3G WCDMA, LTE, WIMAX, WLAN, etc uses complex digital modulation schemes, large bandwidths and high peak-to-average power ratios (PAPR).

The trend of combining RF and DSP has been prevalent for some time for the case of radio products. For the case of measurement systems we choose to use the expression software driven measurements (SDM) which will be one of the focus areas of this project.

Behavioral models including nonlinearities and memory effects have attracted interest as a means for characterizing PAs. Typically, these models relate sampled input and output signals. An advantage is that realistic signals can be used for exciting the PA. Behavioral models are used for modeling the properties of subsystems of telecommunication systems, which are too complex for circuit level or transistor level simulations. Physical models are based on a physical description of the components of the PA and how they interact and are typically formulated as equivalent circuit models. When used for analyzing a PA, physical models can give insight into the cause of the nonlinear properties and memory effects.

Enhanced calibration algorithms, digital pre-distortion (DPD) and post-correction can be used to improve the performance of components, individual instruments, and also of the complete measurement system. Thereby shortcomings in the instruments in terms of e.g. bandwidth, dynamic range, distortion, phase accuracy, time resolution, test speed, etc ..., can be overcome. It shall here be noted that nonlinear measurements and the associated calibration algorithms are considerably more complex than linear measurements. There are large similarities between a transmitter and a vector signal generator, and between a receiver and a vector signal analyzer. These are the most important parts of a measurement system for modeling of radio components. Thus much of the work done on transmitters and receivers apply to the measurement instruments as well.

It is believed that the trend within the RF measurement area is that a general signal generation and signal capture architecture will form a hardware basis on which more or less all measurement capabilities are implemented in software. This gives truly “virtual” instruments. It is highly desired to use a system level architecture that is modular, flexible and scalable.

Work done within the current KKS project, Dnr 2003/0218, has built up a significant competence in RF measurement technology, PA characterization, PA modeling and model identification and analog-to-digital converter (ADC) performance enhancements at the University of Gävle (HiG).

## 2 Project Description

The project is a continuation and extension of the previous KKS project Dnr 2003/218.

The vision for the project is state-of-the-art RF Measurement technology as an enabler for efficient design, characterization, labeling and production testing of future power devices, power amplifiers and transmitters, that includes

- Define *de facto* measurement standards
- Develop efficient software driven measurements
- Comparison and traceability between different measurement technologies
- Modular, flexible and scalable system level measurement system architecture
- Production test methodology

State-of-the-art applied measurement technology requires a strong interaction with the customers and

their applications. A very deep knowledge about the requirements and their trade-offs are essential as depicted in Figure 1. Measurement requirements can come either from production, product research, product design or product modeling. Each of these must be served with answers to the specific kind of measurement requirements they have. For example, the production may require fast measurement methods for a few parameters while the product design wants measurement of more parameters but can wait longer for the answer.

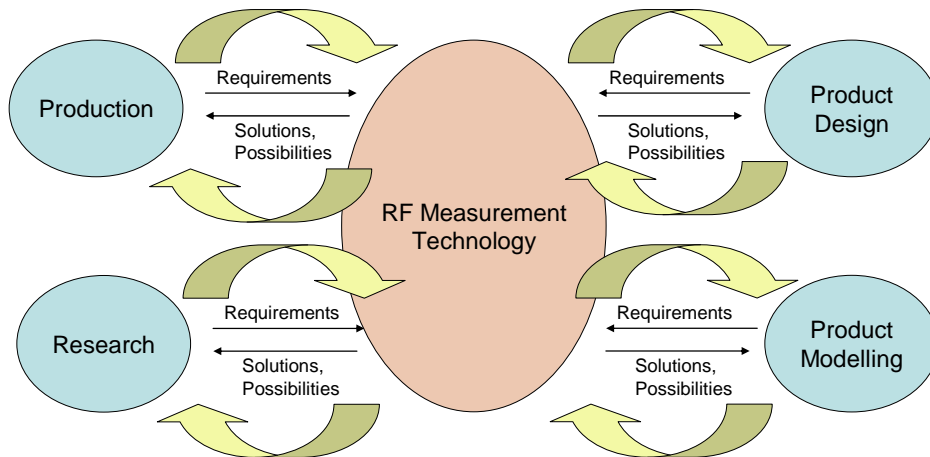


Figure 1. Interactions and connections to create world leading RF Measurement Technology, an enabler.

The project is divided into a number of work packages (WPs) and on the top level there are five, see Figure 2:

- Collaboration (WP 1), described in detailed in appendix “Project plan for collaboration”.
- Project Measurement system and RF measurement technology (WP 2).
- Product design, production, product modeling, product research and their requirements plus device under test (DUT) procurement (WP 3).
- University of Gävle/Center for RF measurement Technology, Measurement System (WP 4)
- Measurement Standards (WP 5)

The work packages are either directly related to project objectives or support the objectives. The objectives can be scientific, related to collaboration and/or related to communication.

The WPs are divided into one or more levels ending up in a well defined deliverable, which is limited in time and resources (from both university and the partner companies); see way of working in appendices “Project plan for collaboration”. Most of the deliverables of the different sub WPs in WP 2 shall be in the form of a journal paper or conference presentation and are in many cases an SDM.

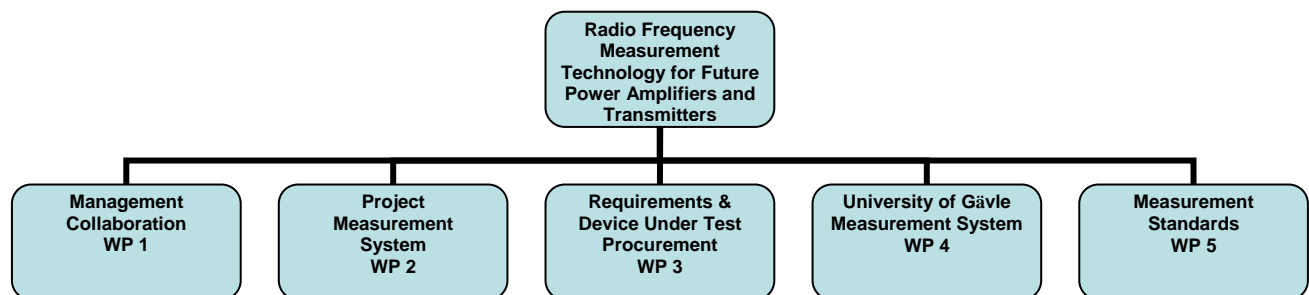


Figure 2. Work packages of the project, top level.

The WP 4 is not a part of the project but is closely related to the project. It is a measurement system scheduled to be bought and set up by the Center for RF Measurement Technology/HiG.

The project measurement system is shown in Figure 3. It essentially consists of a vector signal generator (VSG) and a vector signal analyzer (VSA). The test signal is generated in the PC and downloaded to the VSG that produces the desired modulated signal at the desired RF. This signal might be further amplified using a driver power amplifier (DPA). The output signal of the PA is measured using the VSA, returned to the PC and compared to a reference (input) signal. Alternatively the signal is measured using the ADC measurement set-up. In the case of ADC measurements, the ADC itself is the DUT. In that case the signal is passed directly, or through a filter, from the VSG to the ADC.

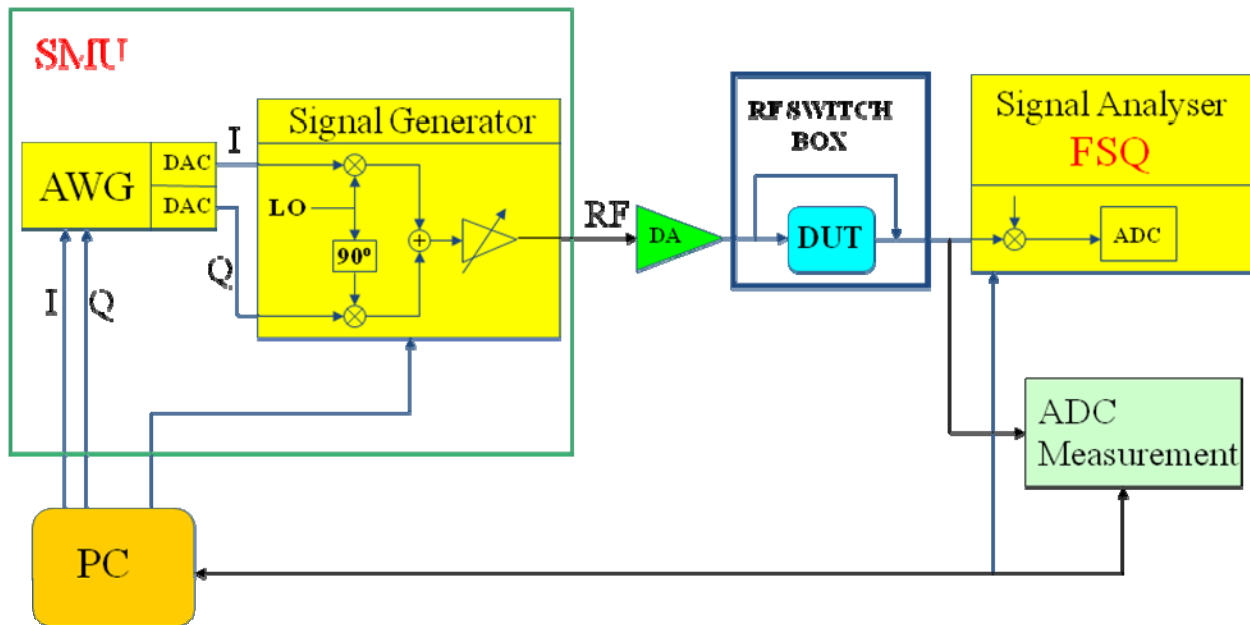


Figure 4. Project Measurement System. A vector signal generator, a vector signal analyzer and ADC testbed. Control and measurement functionality is located to the PC.

The measurement system (WP 2) is intended for general RF measurements, but the actual measurements that will be carried out are most likely to be done mostly on RF power devices, RF PAs and transmitters. This calls for new RF measurement techniques, both for development of PAs, but also for efficient production testing of them.

Production test cost is a key issue to stay competitive.

## 2.1 Scientific Publications objectives

3 Ph.D. Theses, 11 Journal articles, 20 conference papers to support the goals.