

**WSC (RFIC) Sunday 08:00 – 17:00 BCEC Room 153AB**  
**Advances in PA and Tx architectures**  
**Full-day workshop reviewed by RFIC.**

**Organizer(s):**

Patrick Reynaert, K.U.Leuven, Belgium.

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Although most PA and TX architectures (Doherty, Polar, outphasing, LINC, ...) have been envisioned several decades ago, there is not a clear winner today. Technology considerations (GaN, CMOS, SiGe,...), system level considerations (output power, bandwidth,...), implementation and packaging issues and the specific cost or business model (basestations, terminals,...), make the optimal choice less obvious. This workshop will cover the different solutions that exist today for PA and TX architectures. It will discuss the different trade-offs and implementation issues of the various architectures, crucial information when selecting the architecture of choice. All speakers will also give an outlook of new PA architectures that are being developed in their field.

**Speakers:**

1. Steve C. Cripps, Cardiff University, United Kingdom

“Old Dogs and New Tricks in the Pursuit of Higher RFPA Efficiency”

This opening talk will review the various classical techniques for enhancing the efficiency of RF power amplifiers under amplitude modulated signal conditions. The Doherty PA, Chireix Outphasing PA, Polar Transmitter and Envelope Tracking will be introduced, along with some attempts to compare their strengths and weaknesses, taking account of both RF and baseband bandwidth requirements. In particular, the tradeoffs between RF and baseband circuit design challenges will be shown to be remarkably polarized, and a more novel intermediate approach will be proposed.

2. John Gajadharsing, NXP, Netherlands

“Recent Advances in Doherty Amplifiers for Wireless Infrastructure”

Two-way Doherty amplifiers are widely deployed in the wireless infrastructure market since they offer high efficiency in combination with low complexity and low cost. The continued demand for higher efficiency and the trends towards higher peak-to-average ratios associated with 3G-LTE and WiMAX systems drive the development of more advanced Doherty concepts and LDMOS technology. In this presentation recent progress will be provided on the development of next generation Doherty amplifiers like the two-way and three-way Doherty based on state-of-the-art LDMOS technology. The different trade-offs and implementation issues of these architectures will be discussed. Also the Integrated Doherty Amplifier in LDMOS MMIC technology will be addressed which will enable miniaturized low cost designs. Finally a mixed signal approach for a three-way Doherty will be addressed to further enhance efficiency.

3. Leo de Vreede, T.U.Delft, The Netherlands  
“Enhanced LINC/Chireix Power Amplifiers”

Although, originally introduced to enhance linearity, LINC amplifiers when utilizing a Chireix power combiner, can also offer high-efficiency operation in power back-off conditions. A feature that is very important when dealing with complex modulated signals like (W)CDMA. In spite of its long history, practical LINC / Chireix implementations are still rare. Reasons for this lack in popularity are the difficulties found in creating the appropriate drive conditions, the extreme loading conditions of the output stages at large outphasing angles and the often disappointing PAE performance in back-off when considering practical implementations. In this talk measures will be given to overcome these difficulties and create truly efficient LINC / Chireix amplifier implementations.

4. Thomas Johnson, PulseWave RF, USA  
“Carrier Frequency Switch Mode Amplification and Linearization”

Spectral efficiency is a fundamental system design consideration that conflicts with other requirements, namely cost and power added efficiency associated with linear transmitter design. The theoretical promise of exceptional power added efficiency points one toward switch mode amplifier design but there are numerous other challenges associated with switching architectures that are difficult to overcome. The fundamental problem is the high spectral efficiency requirement implies complex modulation schemes with very high peak to average power ratios. Amplitude modulation is necessary to preserve high spectral efficiency but this directly conflicts with highly nonlinear switch mode amplifier design. This work addresses one possible scheme that directly addresses how to construct a modulation friendly signal suitable for switch mode amplification. It also explores methods to further improve the linear dynamic range and power added efficiency of a practical commercial implementation.

5. Georg Fischer, University of Erlangen / Alcatel-Lucent, Germany  
“Practical Design and Implementation Challenges of the Class-S PA”

There is increasing interest in the Class-S PA architecture as it promises addressing the needs for increased efficiency, increased linearity, frequency agility and higher level of digitization conforming to SDR principles. However a balanced view has to be taken in order to weight the promises against the challenges with implementation. The Class-S concept belongs to the family of switch mode PA classes, however over classical switch modes it also supports large amplitude variations. By that the Class-S architecture is well suited for modulation formats with high Crest factor like LTE and W-CDMA multicarrier processing. The contribution focuses on the selection of a proper modulator to provide the needed switching sequence, the imperfections introduced by using Gallium Nitride transistors as switches and the necessary termination requirements the reconstruction filter has to ensure to properly terminate the switching stage.

6. Earl McCune, RF Communications Consulting, Santa Clara, CA, USA  
“Polar Modulation and Power Amplifiers”

As the wireless communications industry continues to look for ways to achieve high fidelity multimode signal generation simultaneously with high energy efficiency, polar modulation techniques continue to be attractive. The significant differences between polar technology and conventional quadrature linear technologies continue to be better understood and managed. This presentation is a report on this continued progress.

7. Patrick Reynaert, K.U.Leuven ESAT-MICAS, Belgium  
“CMOS RF Power Amplifiers”

It is a challenge to achieve a high output power from a low-voltage CMOS technology. Furthermore, the high dynamic range requirements of wireless standards emphasize the need for efficient power control, whereas the battery lifetime requirements put a challenge on the peak and average efficiency performance. This talk will focus on power combining and linearization as key enablers for high-linearity, high efficiency, fully integrated and reconfigurable CMOS power amplifiers. The use of CMOS technology also allows for a higher PA and TX complexity, since processing power is available at a relative low cost. This enables reconfigurable PA architectures to be designed with the digital and analog TX frontend. Several examples and case-studies of integrated CMOS RF PAs will be addressed and some of the major challenges with these topologies will be discussed in more detail.

8. Gottfried Magerl, TU Vienna, Austria  
“Class F Amplifiers”

The presentation starts with explaining the main ideas of optimizing power added efficiency of microwave power amplifiers. Class F operation is presented as one solution for achieving high efficiency together with high output power, however, at rather moderate gain. In a second step a more realistic picture of Class F operation is drawn leading to third harmonic peaking amplifiers. Furthermore, bandwidth and linearity achievements in realistic Class F operation are treated. Finally, Class F amplifiers with substantially increased gain are presented. Class A gain in Class F operation can be achieved by driving the amplifier with non-sinusoidal signals. This leads to the concept of harmonic controlled amplifiers with even better power added efficiency than pure Class F. Again, examples of amplifiers are shown and their performance with respect to operational frequency, gain, and efficiency is discussed.

9. Panel discussion with speakers and attendees