

# Distortion in Doherty Amplifiers

## Background and challenges

### Efficiency Challenge

The most challenging part in a **wireless communication** base station, in terms of energy consumption, is the RF power amplification.

**Higher Efficiency PAs, as Doherty PA,** are required to reduce the wasted power, reducing also the power consumption of the cooling system.

vs

### Linearity Challenge

However, to fulfill the **very strict spectral masks**, the PA designer can no longer focus solely on efficiency maximization, but has to look also onto **linearity**.

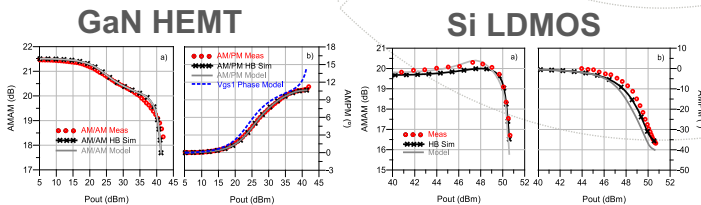
So, it is necessary to fully understand the **nonlinear distortion** of the Doherty to improve the digital **predistortion** models.

## Description and main innovation

### Nonlinear distortion of a single-ended PA

It was developed a physical model for the current-mode PA AM/AM and AM/PM distortion mechanisms:

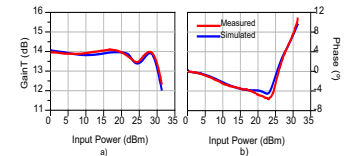
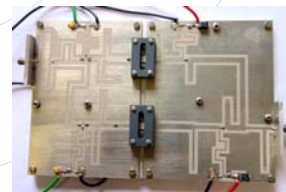
$$V_{gs1} \approx \frac{V_s(\omega_0) + j\omega_0 Z_s(\omega_0) \left[ \frac{1}{2} C_{gs2} \cdot V_{gs1}^* - C_{gs1} \cdot V_{gs2} \right]}{1 + j\omega_0 Z_s(\omega_0) [C_{gs0} + C_{gs1} (1 - A_{v1})]} \quad V_{ds1} \approx \left\{ j\omega_0 Z_L(\omega_0) \left[ \frac{C_{ds2}}{2} V_{ds1}^* - C_{ds1} V_{ds2} \right] - Z_L(\omega_0) I_{ds1} \right\} \times \left\{ 1 + j\omega_0 Z_L(\omega_0) \left[ C_{ds0} + C_{gs1} \left( \frac{A_{v1} - 1}{A_{v1}} \right) \right] \right\}^{-1}$$



### Nonlinear distortion of 2-way Doherty

It was addressed the impact of the input capacitance variation on the AM/PM distortion characteristic of a GaN HEMT based Doherty PA:

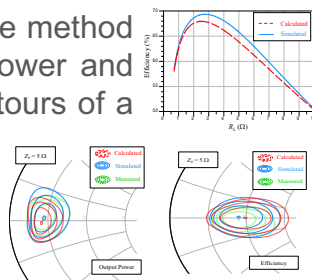
$$V_{gs1}(A) = \frac{V_s(\omega)}{1 + j\omega Z_s(\omega) [C_{gs}(A) + C_{gs}(1 - A_v(A))]}$$



### Efficiency Load-Pull Contours

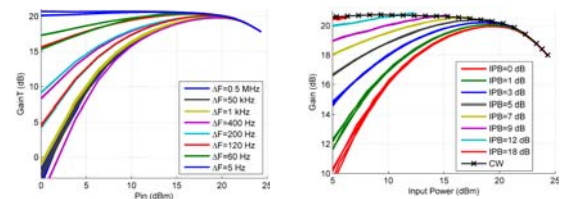
It was developed a simple method to estimate the output power and Efficiency Load-Pull Contours of a Class-B PA:

$$\eta(Z_L) = \frac{\pi R_L}{4 |Z_L| + 2R_{on}} \frac{V_{DD}}{V_{DD} + \frac{\pi}{2} \chi(I_{dq})(|Z_L| + 2R_{on})}$$



### Long-term memory effects on GaN HEMTs

It was explained the soft compression observed in GaN-HEMT devices when measured with static CW excitations.



## Achievements

### Prizes

**Winner** of the International Microwave Symposium 2014 Digital Predistortion Student Design Contest.

### International conferences

Authored **three** and co-authored **five** papers

### Journals and Magazines

Authored **one** paper in *IEEE Transactions on Microwave Theory and Techniques*

Co-authored **one** paper in *IEEE Microwave Magazine*.