BEHAVIOURAL MODELLING OF MICROWAVE TRANSISTORS FOR WIDEBAND HIGH EFFICIENCY POWER AMPLIFIER DESIGN

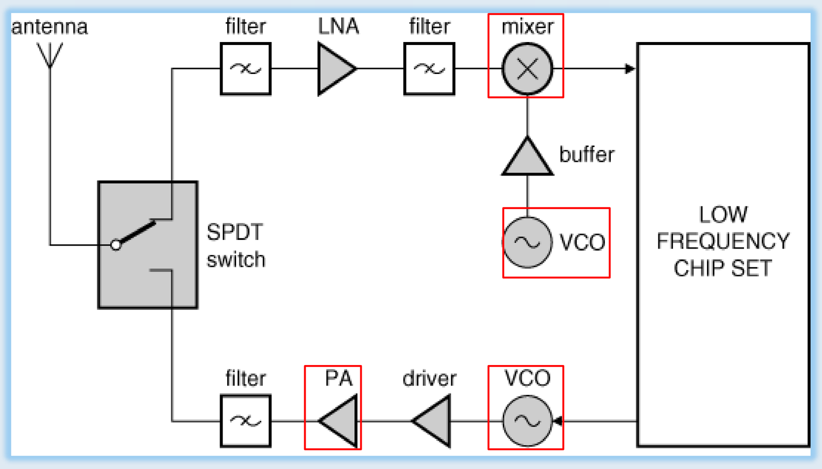
AUTHOR: Mª DEL ROCÍO MOURE FERNÁNDEZ

ADVISOR: MÓNICA FERNÁNDEZ BARCIELA

Motivation of the Work

Power amplifier (PA) design for modern wireless communications systems is a complex process, since the **transceiver PA** module must accomplish strict specs in terms of:

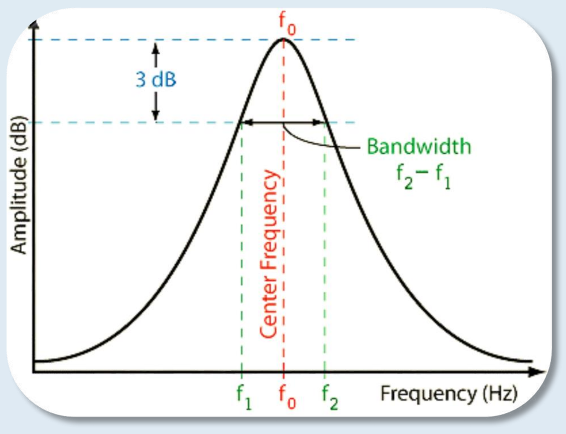
- Output Power
- Bandwidth
- Efficiency
- Reduced weight and size
- Gain
- Linearity
- Low cost



There have been proposed efficient PA configurations to achieve this goal, and accurate nonlinear meas-based device modelling tools, like X-parameters.

But PA bandwidth improvements, at C-band and above, for complex high PAPR signals is still a challenge.

Thesis Objectives



1.- Bandwidth improvement of nonlinear (frequency domain) behavioural models for broadband PA design.

2.- Development of large-signal characterization tools for nonlinear model **extraction and GaN PA prototype validation.**

3.- Determining the most appropriate high efficiency broadband **PA configuration** for complex signals in C-band. Dual-band, reconfigurable/concurrent, PAs also considered.

UAV

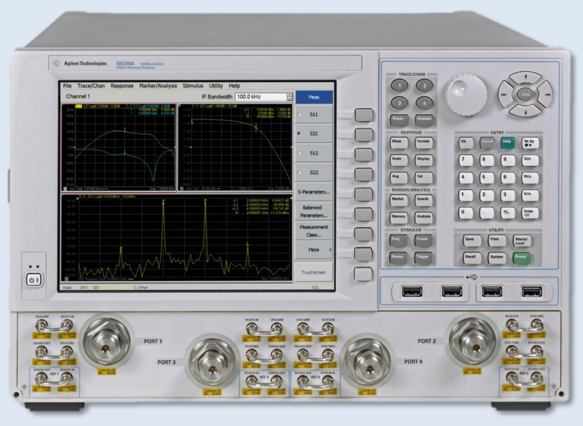
Related Task:

- Setting-up a 25 W 20 GHz large-signal meas. system (**PNA-X** based) HW/SW with harmonic load-pull and multi-tone characterization.

Research Plan

1.- **State-of-the-art** in behavioural modelling and broad-band efficient PA design. ✓
2.- Extension of **behavioural models** for **broadband PA design.** ✓
3.- **25 W** LS meas. system set-up for model **extraction and prototype validation.** ✓
4.- Development of behavioural model extraction **methodologies.** ⟵
5.- GaN transistor **characterization.** ⟵
6.- PA **architecture selection** and **design methodologies** development.
7.- PA Prototypes design and **manufacturing.** Performance evaluation.

Next Year Planning



PNA-X

1.- Optimize the **PNA-X** set-up for X/Y param meas.
2.- Study the appropriate wideband efficient GaN **PA architecture** for complex signals in C-band. Focused on **Continuous Class B/J.**
3.- **Develop an appropriate PA design methodology**

Results & Discussions

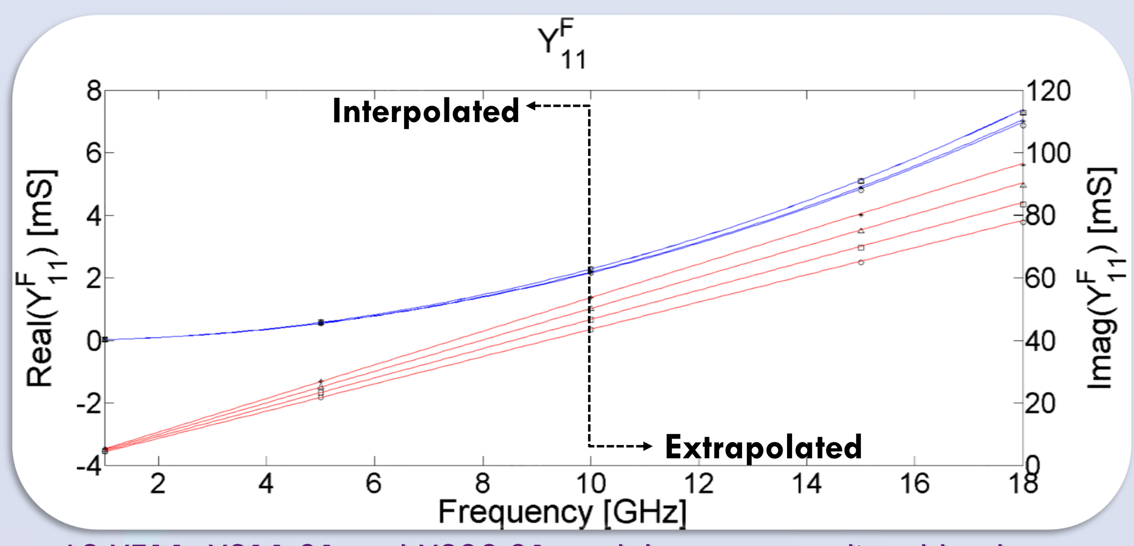
$$S-param \;\Rightarrow\; X-param \;\Rightarrow\; Y^{LS}-param \;\Rightarrow\; broadband\ FET\ Y^{LS} model$$

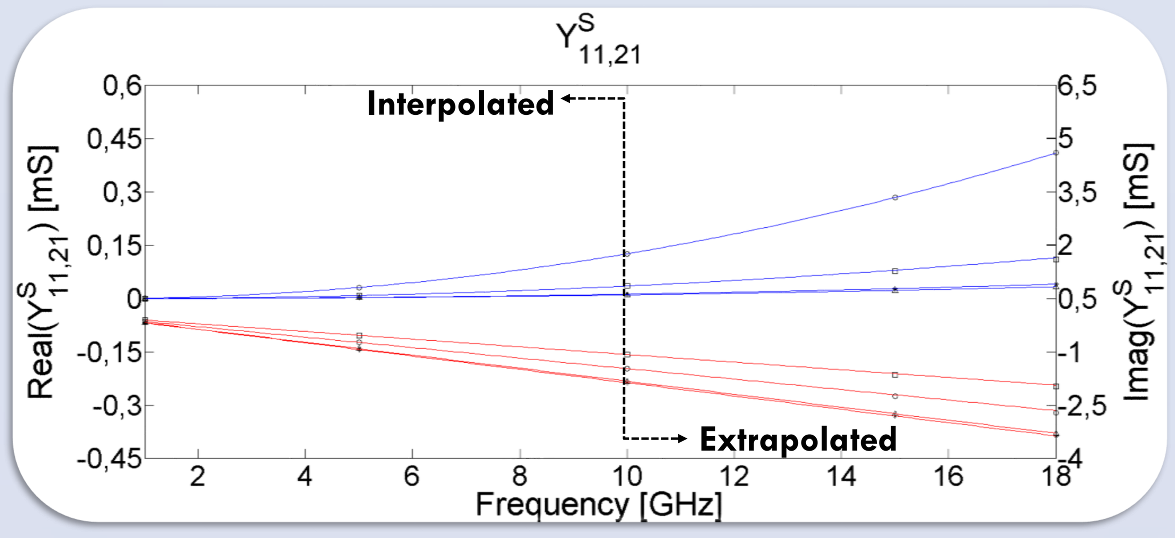
This year 2015/2016:

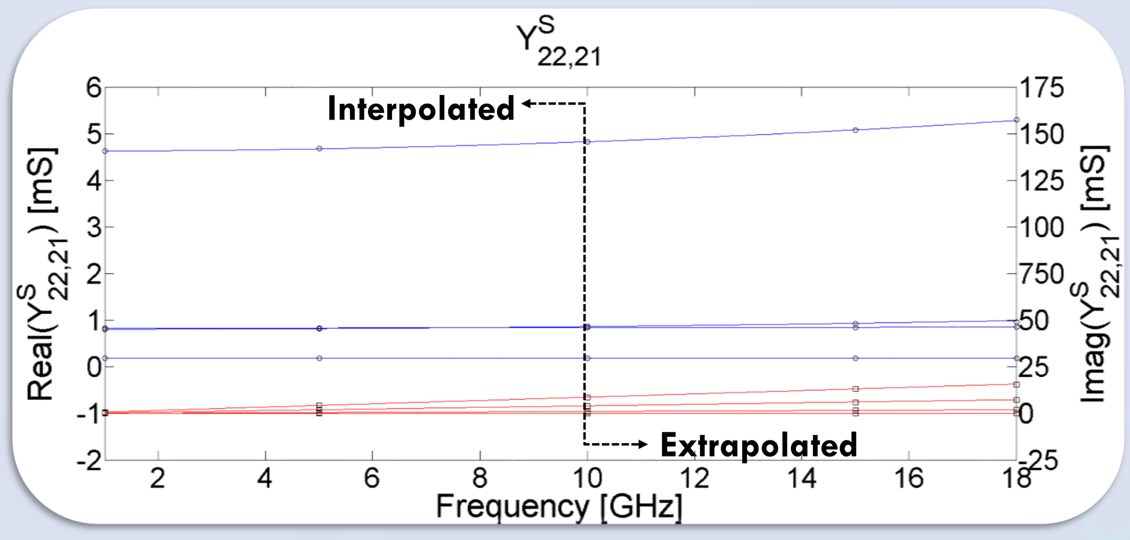
1.- Extraction, implementation in ADS and validation of the LS Y-param. FET model with linear freq. extrapolation. From Simulations.
2.- Extraction, implementation and validation of the LS Y-param. FET model with **quadratic** real Y extrapolation. From Simulations.
3.- **GaN FET characterization** for LS Y-model extraction and validation.
→ Stay in Cardiff School of Engineering. Cardiff Univ., UK. 5weeks. **Objectives:** WIN GaN HEMT characterization using a LS PNA-X based meas. system with active harmonic load-pull at different freqs.
4.- LS 50 GHz PNA-X based meas. system set-up for model extraction and validation in **small-** and **large-signal (25 W). Uvigo.**

Model extraction / Matlab:

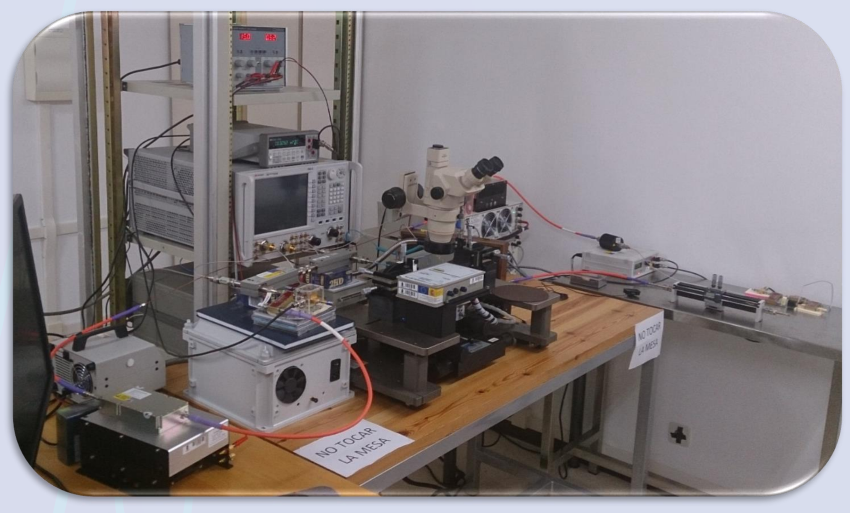
- LSNA FET/HBT Load-pull meas./simulation
- ↓ fixture & parasitics de-embedding
- ↓ Extraction Y^{LS} intrinsic G, C, (linear) and τ (quadratic)
- ↓ ADS Simulation Model implementation & simulation



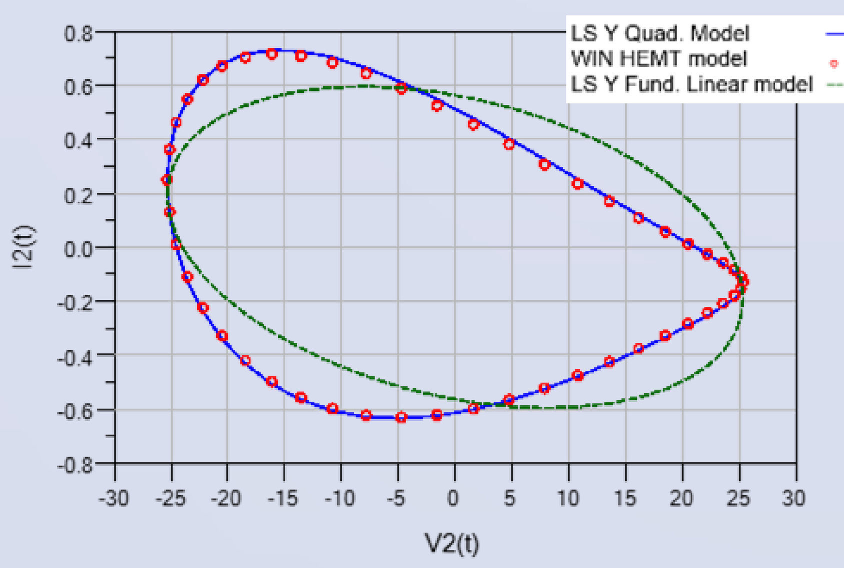




LS YF11, YS11,21 and YS22,21 model param. predicted by the proposed behavioral model (lines) and obtained from a compact CAD model (dots) compared vs. fund. freq and vs. V11. Behavioral model was extracted from compact CAD model "measurements" at fund. frequencies 1, 5 and 10 GHz. In the plot, the behavioral model (lines) is extrapolating beyond 10 GHz, up to frequencies close to the FET fT. Behavioral real (Y) show a quadratic freq. dependence, while Imag(Y) show a linear one. Device: 6x75µm GaN HEMT. Bias point: Vgs= -2.9 V, Vds= 28 V.



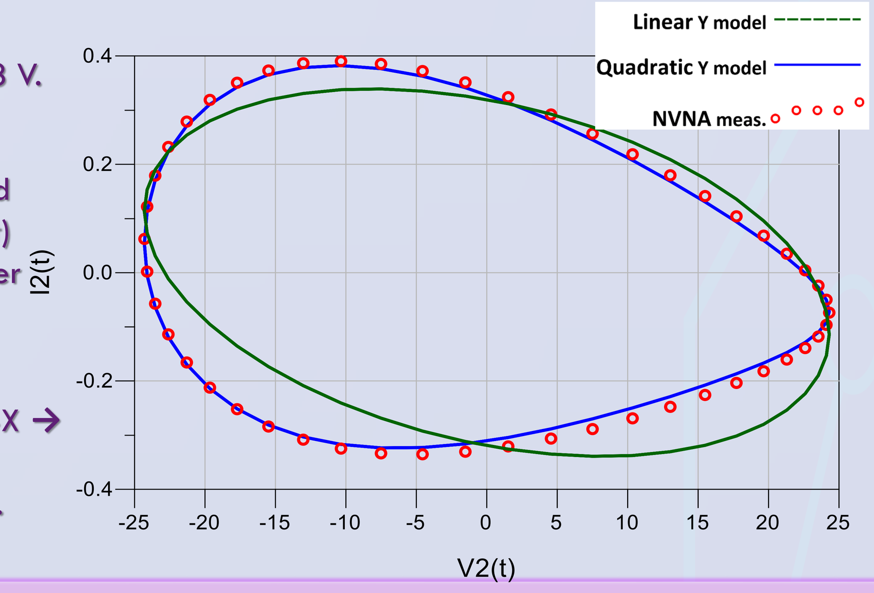
Meas. System PNA-X based set-up for 25W large-signal measurements at Uvigo



Device 6x75µm GaN HEMT. Bias point: Vgs= -2.9 V, Vds= 28 V.

← Quadratic and linear model predictions, extracted from compact CAD model "measurements" at fund. freq. of 1, 5 and 10 GHz, and simulations with the compact CAD model for Ids(t) vs. Vds(t). Dynamic load-line at a fund. freq. 18 GHz and power level at P3dB. In the figure, the model is extrapolating with frequency, close to the HEMT fT.

Quadratic and linear model predictions, extracted from PNA-X meas. at 2.4, 3, 5.4 and 9 GHz, and PNA-X meas. Dynamic load-line at a fund. freq. of 9 GHz and power level at P1dB. →



References:

[1] D. E. Root and J. Verspecht, "Polyharmonic distortion modeling," IEEE Microw. Mag., vol. 7, no. 3, pp. 44–57, Jun. 2006.
[2] M. del R. Moure Fernández, "PFC - Diseño de software para la caracterización de dispositivos y circuitos no lineales de microondas mediante parámetros X," Universidad de Vigo, 2014.
[3] M. Fernández-Barciela, A. M. Peláez Pérez, S. P. Woodington, J. I. Alonso, and P. J. Tasker, "Stretching the Design," IEEE Microw. Mag., no. October, pp. 106–120, 2014.
[4] Koh, M. , Bell, J.J. , Williams, D. , Patterson, A. , Lees, J. , Root, D.E. , Tasker, P.J., "Frequency scalable large signal transistor behavioral model based on admittance domain formulation", 2014 IEEE MTT-S (IMS), Page(s): 1 – 3, 2014

Publications from this work:

- "Broadband Non-Linear FET Behavioral Model Defined in the Admittance Domain". Oral communication. European Microwave Integrated Circuits Conference (EuMIC). European Microwave Week (EuMW). London, Oct 2016.
- "Modelos Comportamentales No Lineales para el Diseño de Amplificadores de Potencia". XXXI Simposium Nacional de la Unión Científica Internacional de Radio (URSI). Madrid, Sept. 2016.

UniversidadeVigo · Escola de Enxeñaría de Telecomunicación · AtlanTIC · GDAF

PHD PROGRAM ON INFORMATION AND COMMUNICATIONS TECHNOLOGY OF THE UNIVERSITY OF VIGO