Behavioural Modelling of Microwave Transistors for Wideband High Efficiency Power Amplifier Design

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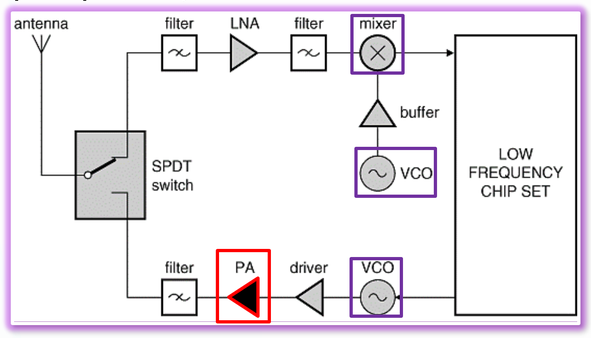
Motivation of the Work

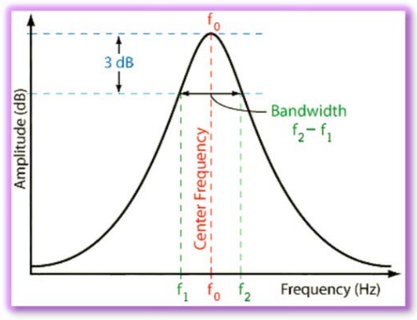
Power amplifier (PA) design for modern wireless communications systems is a complex process, since the **transceiver PA** module must accomplish strict specs in:



- Output Power
- Bandwidth
- Efficiency
- Linearity
- …

But accurate & efficient broadband PA design in this context, specially at C-band and beyond and under high PAPR signals, relies on the **quality of the FET nonlinear (NL) model**. Behavioral meas.-based NL models are a promising tool (like X-params, Cardiff [1],[2]), but they have limited bandwidth.

Thesis Objectives



1.- Bandwidth improvement of NL behavioural models for broadband PA design.

2.- Development of large-signal characterization/extraction tools for NL **model generation and validation.**

3.- Application in the design of high efficiency **broadband GaN PAs** for complex signals in C-band.

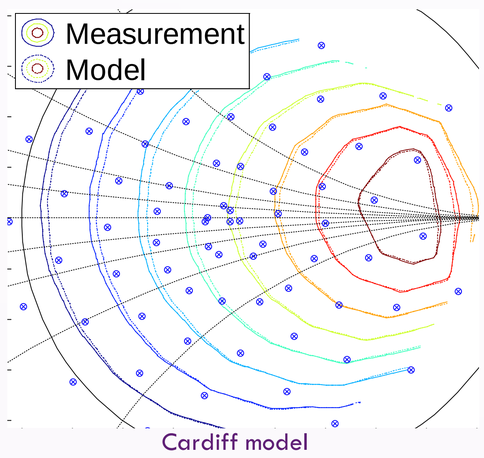
Related Task:

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

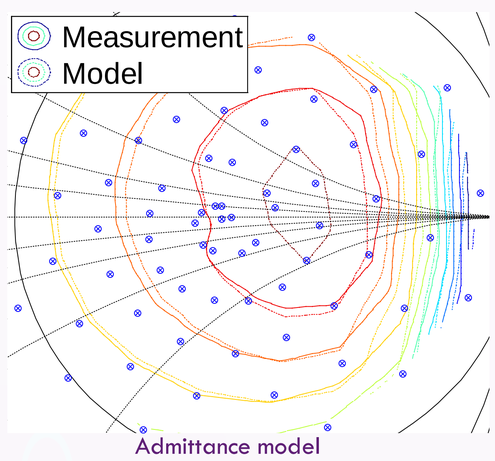
Results & Discussions

Main developments/improvements in the thesis:

- High order Cardiff model vs. low order X-parameters model [1]-[6],[8].
  Improved robustness in model extraction and load-pull prediction.
- Improvement on behavioural models direct extraction from NVNA Load-pull measurements .
  a) First time, systematic analysis of Cardiff model complexity required for accurate extraction/ prediction [9], [future journal].
  b) Improvement, higher order Admittance model direct extraction from NVNA measurements [7],[10].



Cardiff model



Admittance model

Terms in AB Higher order Cardiff model as result of harmonic mixing theory

		b				
		-2	-1	0	1	2
r	0	$\|A_{21}\|^2Q^{-2}$	$\|A_{21}\|^1Q^{-1}$	$\|A_{21}\|^0Q^0$	$\|A_{21}\|^1Q^1$	$\|A_{21}\|^2Q^2$
	1	$\|A_{21}\|^4Q^{-2}$	$\|A_{21}\|^3Q^{-1}$	$\|A_{21}\|^2Q^0$	$\|A_{21}\|^3Q^1$	$\|A_{21}\|^4Q^2$
	2	$\|A_{21}\|^6Q^{-2}$	$\|A_{21}\|^5Q^{-1}$	$\|A_{21}\|^4Q^0$	$\|A_{21}\|^5Q^1$	$\|A_{21}\|^6Q^2$

- Stay in Cardiff School of Engineering. Cardiff University, UK. 3 months.
- Extended formulation of Cardiff/Admittance model in order to enhance models extraction from meas.:

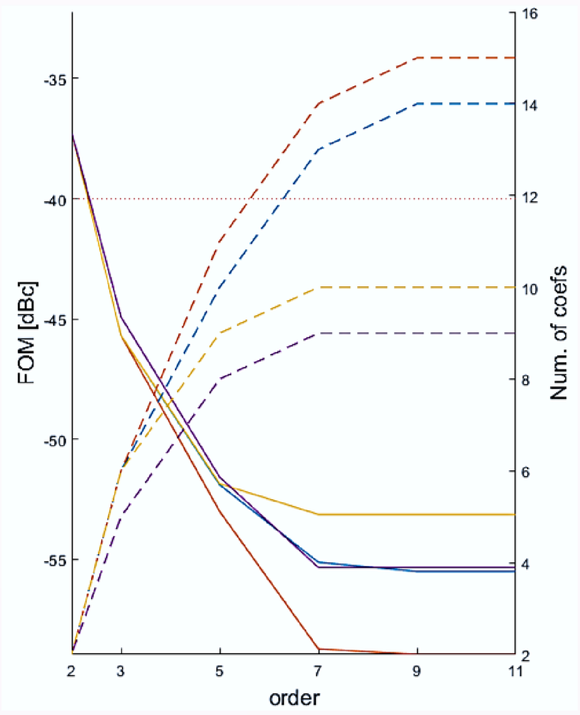
AB domain: $B_{p,h} = \sum_{t=0}^{V}\sum_{i=0}^{W} K_{p,h.i,t}|A_{2,1}|^{a_i}\angle A_{2,1}^{b_i}|A_{2,2}|^{c_i}\angle A_{2,2}^{d_i}|A_{1,1}|^{e_{i,t}}$, $M_{p,h.i}(|A_{1,1}|) = \sum_{t=0}^{V} K_{p,h.i,t}|A_{1,1}|^{e_{i,t}}$

IV domain: $I_{p,h} = \sum_{t=0}^{V}\sum_{i=0}^{W} L_{p,h.i,t}|V_{2,1}|^{a_i}\angle V_{2,1}^{b_i}|V_{2,2}|^{c_i}\angle V_{2,2}^{d_i}|V_{1,1}|^{e_{i,t}}$, $N_{p,h.i}(|V_{1,1}|) = \sum_{t=0}^{V} L_{p,h.i,t}|V_{1,1}|^{e_{i,t}}$

- Study of the origin of model terms from harmonic mixing theory [journal paper in preparation].
- Exhaustive comparison between Cardiff and Admittance model predictions with NVNA meas.
- Model validation in Power Amplifier design (in progress).

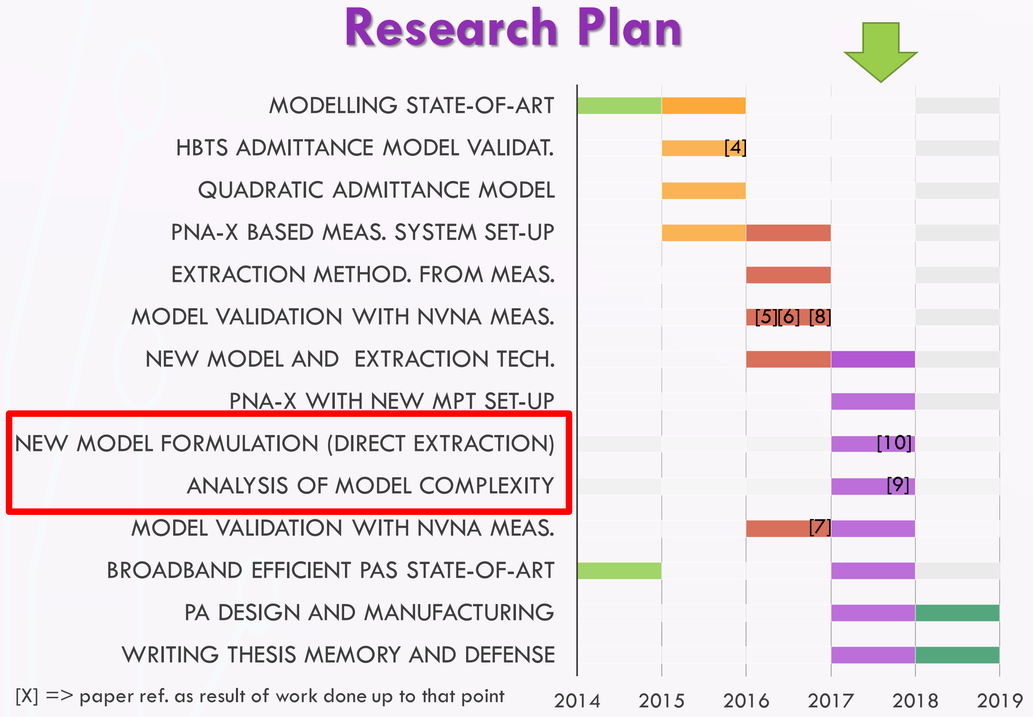
FOM for LP up to 3dB compression for meas.

Order	b	r	Coefs DC	Coefs fund	Coefs 2nd	FOM DC	FOM fund	FOM 2nd
5	3	0	5	6	5	-30	-42	-22
	2	1	8	9	7	-36	-51	-26
	2	0	5	5	4	-30	-41	-21
	1	1	6	6	5	-36	-47	-23
	1	0	3	3	3	-30	-41	-19
7	3	0	7	7	6	-31	-42	-22
	2	1	10	10	9	-42	-53	-32
	2	0	5	5	5	-30	-41	-22
	1	1	6	6	6	-36	-47	-26
	1	0	3	3	3	-30	-41	-19



Comparison of Cardiff model predictions in f_0 for different model complexities.

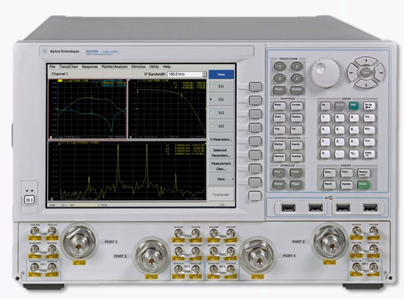
Research Plan



[X] => paper ref. as result of work done up to that point

Next Year Planning

1. **a.-** Broadband Admittance model extraction & validation with the same GaN FET and the LS meas. system.
   b.- Design broadband GaN PA prototype with this model.
2. **2.-** Finishing writing the thesis memory and thesis defense.



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