



T A R G E T
TOP AMPLIFIER RESEARCH GROUPS
IN A EUROPEAN TEAM

Course description: **Modelling for TX System Level Analysis**

Modules:

1. System Level Simulation Techniques - Introduction
2. Behavioural Modelling Technique: Power and Driver Amplifiers modelling
3. Behavioural Modelling Technique: Mixer modelling
4. Behavioural Modelling Technique: Voltage Controlled Oscillator modelling
5. System Level Analysis by using Behavioural Modelling Techniques

Audience:

This course is designed for engineers working with TX system architectures optimization and subsystem modelling.

Preliminary Knowledge:

Microwave characterization

Our presenters:

Alessandro Cidronali (University of Florence, Italy)
Dominique Schreurs (Katholieke Universiteit Leuven, Belgium)
Nuno Borges Carvalho (University of Aveiro, Portugal)
José Carlos Pedro (University of Aveiro, Portugal)
Giorgio Vannini (University of Ferrara, Italy)
Iacopo Magrini (University of Florence, Italy)
Matteo Camprini (University of Florence, Italy)



Module 1 - System Level Simulation Techniques

Simulating a complete wireless system, or even any of its sub-systems like the transmitter, in single electronic design automation, EDA, platform is not a trivial task. On one hand, such a system involves very disparate block types as the base-band digital processing circuits, low frequency analogue/mixed-mode VLSI cores and the conventional RF circuits, but also electromagnetic elements as the antenna and the air-interface medium. This poses tough difficulties in selecting appropriate model and signal representation formats.

On the other hand, even if it were possible to represent all these different blocks at their mostly detailed physical level, there was no guarantee to have a simulator capable of handling a problem of that size. In fact, we must realize that since each circuit node requires a KCL equation, the presence of any reactive element turns these possibly nonlinear algebraic equations into nonlinear ordinary differential equations, ODEs. Then, if we add the disparate signal formats present in any wireless system, we immediately conclude that such an attempt will have to remain fiction for the next several years.

This module discusses solutions to this problem by addressing three different levels of wireless system simulation – logic level, circuit level and envelope level – and the model requirements they impose on the representation format of each of the sub-system blocks or electronic circuits.

Presenter: José Carlos Pedro or Nuno Borges Carvalho
Duration: 2 hours

Module 2 – Behavioural Modelling techniques: Amplifiers

Amplifier behavioural models available in the commercial CAD suffer from the lack of description of the short and long terms memory effects. The latter manifest their presence as a dispersive behaviour in-band. Spectral asymmetries are a critical factor that hardly is considered in the available models, introducing inaccuracy similar to the linear distortion associated to linear time invariant system. Asymmetries in the spectral regrowth are even more involved arising from nonlinear short terms memories, again a critical feature for the subsystem model. Conventional models are refinements of old fashioned model techniques based on the a simple static nonlinearity embedded in frequency dependent blocks, originally developed for the single tone applications, they appear not suited for applications where the relative bandwidth increases. In particular for the case under investigation, the signals spectrum under consideration are continuous rather than discrete, involving a complex description of the nonlinear dispersive behaviour of both the frequency harmonic generation and the intermodulation production.

This module deals with the advanced amplifier modelling techniques based on vectorial large-signal measurements. The techniques allow characterizing, quickly, the physical component or the circuit-level model, and constructing the behavioural model in a repeatable, procedural, and automated way. Several techniques based on state-functions and frequency domain mode are introduced along with practical example on commercially available driver and power amplifier for WLAN.

Presenter: Alessandro Cidronali or Dominique Schreurs
Duration: 2 hours

Module 3 - Behavioural Modelling Technique: Mixer modelling

As for other subsystems behavioural models available in the commercial CAD, mixer behavioural models suffer from the lack of description of the short and long terms memory effects. This module considers an approach to the behavioural modelling of the conversion mechanism in a nonlinear device suitable for the analysis of RF/microwave mixers. The core of the model consists in the conversion matrix representation of the mixer, which represents its linearization around the large signal state. System level analysis is thus significantly reduced due the absence of nonlinear component to be analysed; the intermodulation products are calculated in relative amplitude and phase, and allocated in the spectrum on the basis of the conversion matrix coefficients. Input/output impedance are carefully modelled in order to evaluate the load effect of cascaded subsystem. Moreover the mixer behavioural model describes both the frequency-dependent nonlinear behaviour of the IMPs and describe properly the propagation of harmonic and intermodulation distortions through the system, to enable the designer to meet rigid specifications, while being simple enough to allow rapid simulation.

An extended version of the model consists in the cascade connection of the above mentioned Linear Time Invariant block and an ideal mixer box that provides the AM\AM and AM\PM distortion.

The module illustrates the technique to implement this model in a commercial CAD, the way in which it allows a dept insight in the conversion mechanism and, finally, the application to the characterization in of a sub-harmonic mixer prototype.

Presenter: Alessandro Cidronali
Duration: 2 hours

Module 4 – Behavioural Modelling Technique: Voltage Controlled Oscillator modelling

The VCO behavioural models for system/subsystem analysis available in commercial CAD environments and in the technical literature do not usually account for nonlinear dynamic effects. More precisely, they describe only a linear relationship between the oscillator instantaneous frequency and the tuning voltage, possibly with a delay. In such a way, only a linear time-varying VCO response is considered. However, nonlinear dynamic effects can play an important role when transient phenomena must be studied as for instance in the simulation of the settling behaviour of a VCO, the locking behaviour of a PLL or, in general, the communication system behaviour during a change of the LO frequency (as in UWB OFDM frequency hopping).

In the commercial EDA VCOs and dividers models are available. In the first model the frequency is controlled in a linear manner by the tuning voltage while the second model allows for the definition of a nonlinear tuning characteristic. Both of the models can account for dynamics only through a constant, ideal delay between the tuning voltage and the actual change in the oscillator frequency. The divider model enables a frequency divider to be incorporated in the same VCO model so that the time-step during a PLL analysis can be chosen to be larger and the simulation speed is improved; however, they do not account for dynamic effects.

The module describes the different approaches proposed to account for dynamic effects in behavioural VCO models. In some works a more accurate linear dynamic model is derived by defining a linear transfer function instead of a simple ideal delay emphasis is given on nonlinear dynamic approaches based on “finite memory models”, previously applied to electron devices.

Presenter: Giorgio Vannini
Duration: 2 hours

Module 5 – System Level Analysis by using Behavioural Modelling Techniques

Usually, the most of the TX corrupting effects are related to the PA while the remaining subsystems are considered mostly ideal. Here we consider the PA embedded in a complete non-ideal system, i.e. a system where analogue and digital sub-systems interact, introducing their corrupting effects during the transmission process. This module is aimed to highlight the effects of the TX's subsystems in the information processing for two cases of study: the 5.2GHz WLAN and the UWB applications.

The goal of the module is twofold. Firstly, to investigate in the particular applications the key subsystems and their most critic features to be accurately modelled. Secondly, to describe how to achieve to a proper subsystems specifications and constraints trade-off preventing severe and conservative specifications for the PA. This opens the door to new efficient simulation strategies of mixed-signal architectures with detailed behavioural models for the different subsystems. For effective system-level analysis, behavioural models have become a necessity to come to optimization of bit-error-rate (BER) or error-vector-magnitude (EVM) in acceptable CPU times.

The behavioural models should not hide too much detail, since otherwise important signal-degrading effects are not seen in the simulations. On the other hand they should be as easier as possible and with straightforward identification procedure. We select a preliminary step in the process of the selection of the best suited model approach for a given building block function and application; henceforth we'll refer to this as zero-order behavioural model. This class of model considers static nonlinearities embedded in dynamic linear blocks, the goal is the modelling of the subsystems' nominal behaviour. The use of such a model in a system level simulation allows the identification of the key sub-systems and their critical parameters.

We expect that higher-order effects seriously degrade BER and EVM, e.g., noise, nonlinear memory behaviour, phase noise, impedance loading and pulling, pass band linear distortion, etc., for that reason they will be the focus of advanced behavioural modelling capable to take into account them accurately. Behavioural modelling permits the inclusion of a measurement based model of physical subsystems allowing checking the system response with respect of real sub-systems and/or the selection between available blocks. It allows a closer insight of the system, considering the effects that in most cases are not available at simulation stage.

Presenter: Matteo Camprini or Iacopo Magrini
Duration: 2 hours
Please note: to be selected in conjunction with modules 1-4