TARGET
TOP AMPLIFIER RESEARCH GROUPS IN A EUROPEAN TEAM

Course description: **Device-Level Linearization Techniques**

Modules:

1. Fundamentals of Device Small and Large signal IMD behaviour
2. Small and Large Signal Sweet Spots and PA operating class
3. Techniques for Understanding Large-Signal IMD behaviour
4. IMD Evolution: Load Line and Bias
5. Operating Condition Optimization for Improved Linearity
6. Nonlinear Measurement Techniques for Accurate Device IMD control
7. Specific Device-Based Linearization Techniques: Part I
8. Specific Device-Based Linearization Techniques: Part II
9. On the CAD "Measurement" of the Device's High Order Derivatives and dynamics

Audience:

This course is designed for engineers (process engineers or circuit designers) and PhD students wishing to have an in-depth knowledge of Device-Level IMD control.

Preliminary Knowledge:

Solid State Devices and microwave electronic/measurement fundamentals

Our presenters:

José Carlos Pedro (Professor at the University of Aveiro, Portugal)
Christian Fager (Assistant Professor at the University of Chalmers, Sweden)
Nuno Borges Carvalho (Associate Professor at the University of Aveiro, Portugal)
José Angel García (Associate Professor at the University of Cantabria, Spain)
Angel Mediavilla (Professor at the University of Cantabria, Spain)

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Introduction

In the last years, device-level linearization techniques have been standing as a promising area in the solution of the power amplifier, PA, linearity versus efficiency trade-off, thanks to recent advances on the understanding of the device's large-signal distortion behaviour.

Indeed, it has been shown that the appropriate selection of the bias and load conditions may result in controlled transistor linearity with two possible applications on the field of highly linear and efficient PA design. First, this knowledge may lead to the optimization of the PA linearity - given the PA operating class and terminations - when the transistor is used as the main active device. Second, it may also serve to shape the distortion generation process when, in the PA linearization context, the transistor is used as an auxiliary nonlinear distortion source for cancelling the intermodulation distortion of the main amplifying device.

This course addresses the main nonlinear characteristics responsible for the transistor's intermodulation distortion behaviour. These characteristics will be employed for optimizing the device operating conditions, namely bias voltages, fundamental frequency load termination, as well as envelope and harmonic impedance conditions. A review of device-level proposed topologies will be finally presented, including details of its particular extrapolation to other circuit functions (the mixer case), and its integration with the radiating structures.

Module 1 - Fundamentals of Device Small and Large Signal IMD Behaviour

This module gives an introduction to the course. It starts by comparing the nonlinear transistor characteristics of the main devices: FET's and BJT's through a simple description of the device physics. Then, it discusses the origin of the IMD associated to the device.

Presenter: José Carlos Pedro
Duration: 1.5 hours
Please note: As this module is a general introduction to Device-Level Linearization, it is recommended to always book it.

Module 2 – Small and Large Signal Sweet Spots and PA operating class

Following the introduction and generalities given in Module 1, the critical distortion generation points: "Small and Large Signal Sweet-Spots" are discussed. Following these ideas, Power amplifier nonlinearity and Operating Classes are derived. Finally, a Systematic Power Amplifier Classification related to the IMD behaviour is presented.

Presenter: José Carlos Pedro
Duration: 1.5 hours
Please note: It is recommended to book Module 2 in combination with Module 1

Module 3 - Techniques for Understanding Large-Signal IMD behaviour

One of the most important issues for accurate IMD prediction is the nonlinear device model's ability in simulating not only two-tone tests but also ACPR or NPR under excitations of complex modulation formats. This module will cover the topics related to intelligent model construction with improved IMD prediction, along with a piecewise approximation of the device characteristics for improved qualitative understanding of the various factors determining the complex IMD versus input power patterns experienced in practice.

Presenter: Christian Fager
Duration: 1.5 hours
Please note: Module 2 is a prerequisite for Module 3.

Module 4 – IMD Evolution: Load Line and Bias

With respect to the design of high efficiency and highly linear PAs, a very important aspect is the IMD influence of the different zones of the transistor along a given load line. This knowledge will allow us to define appropriate operating points to optimise the trade-off between output power, efficiency and linearity. The analysis of the IMD Sweet-Spot dependence with bias will help in clarifying Specific Device-Based Linearization Techniques, but can also provide insight to device manufacturers on how to optimize the characteristics for a specific application.

Presenter: Christian Fager
Duration: 1.5 hours
Please note: It is recommended to book Module 4 in combination with Module 3.

Module 5 – Operating Condition Optimization for Improved Linearity

This Module focuses on the sensitivity of the IMD Sweet-Spots on various issues of the amplifier circuit, in particular to its dependence on the Output Termination Impedances and the Excitation Signal Statistics. That is the basis of an accurate prediction of load-pull behaviour of the active device's IMD and for the extrapolation of the standard two-tone characterization to the actual PA performance when driven by real telecommunication signals. In addition, the dependence of these critical IMD points on the PA Long-Term Memory Effects, either caused by the bias circuitry and intrinsic dispersion phenomena, will also be addressed.

Presenter: Nuno Borges Carvalho
Duration: 1.5 hours
Please note: Module 4 is a prerequisite for Module 5.

Module 6 – Nonlinear Measurement Techniques for Accurate Device IMD control

This module addresses various measurement issues related to the PA's IMD prediction and control. So, it focuses on the laboratory set-ups required for carrying on Measurements for IMD Model Extraction and for IMD Phase Evaluation. While the former has a recognized role on CAD assisted PA designs, the latter is a topic that has recently received an increased attention due to its paramount importance on the characterization of the PA's long-term memory effects and on the design of PA linearizers. Then, some hints will be given on the ability of certain signals to excite the device's, or PA's, nonlinearity and memory, specially on what the Excitation Statistics are concerned, as these can be determinant for a successful Model Extraction or Model Evaluation.

Presenter: Nuno Borges Carvalho
Duration: 1.5 hours
Please note: It is recommended to book Module 6 in combination with Module 5.

Module 7 – Specific Device-Based Linearization Techniques: Part I

In this module, the main nonlinear characteristics determining the transistor behaviour in terms of IMD will be employed for optimizing the device operating conditions in order to define several Device-Based Linearization Techniques. The concept of derivative superposition, pre-distortion and Bias/Load adaptation topologies will be discussed from a device-level point of view. The particular aspect of envelope-tracking will be treated in depth. Several practical examples will be examined and validated from the previous knowledge.

Presenter: Jose Angel García
Duration: 1.5 hours
Please note: Module 5 is a prerequisite for Module 7.

Module 8 – Specific Device-Based Linearization Techniques: Part II

This module shows how it is possible to design wireless PAs and their associated radiating antennas in an integrated way. For this, the electrical properties of single antennas and arrays, along with the transistor IMD behaviour, will be used to achieve some specific spatial combining effects. Indeed, it will be explained how these techniques are able to cancel the IMD distortion in a given direction (and maximize it in another direction), thus giving a higher security level to the transmission. Practical examples and applications will be described.

Presenter: José Angel García
Duration: 1.5 hours
Please note: It is recommended to book Module 8 in combination with Module 7.

Module 9 – On the CAD “Measurement” of the Device’s High Order Derivatives and dynamics

Most of the times the circuit designer uses nonlinear models supplied by a given foundry and useful on a specific CAD tool. Furthermore, in most of the cases these Transistor Models are compiled and the circuit designer does not have any access to the internal equations. This module will help the designer to easily “measure” and extract the Higher Order Derivatives and the Pulsed I/V dynamics of the device by using commercially available CAD simulators. With this information, the designer will be able to control the IMD behaviour of the device, as well as the true RF dynamics defined by the Pulsed I/V curves. Examples of CAD implementation will be carefully discussed.

Presenter: Angel Mediavilla
Duration: 1 hours
Please note: It is recommended to have a minimum of knowledge on ADS, MwOffice, APLAC, ...