Course Description

Course name	**#007 - Behavioral Modeling and Digital Predistortion of RF Power Amplifiers**
Duration	**3 days**
Format	**Public Classroom or Inhouse Event. Not suitable Online**

Overview

Dr. John Wood, Owner and Technical Consultant, Obsidian Microwave, LLC, USA is teaching this 3-day course that explains nonlinear behavior of **RF power amplifiers** and developing general modeling techniques to describe the nonlinearities & memory effects.

Linearization of **power amplifiers** has become an essential requirement since the introduction of 3G wireless communications systems. With **5G** about to make its mark with massive **MIMO**, multi-band, and millimetre-wave systems, bringing a number of new challenges for PA linearization. Come and find out about the fundamentals of these techniques and what is required for the next generation.

Technical Focus

The goals of **RF power amplifier design** are high efficiency and linearity. With modern cellular communications modulation formats such as LTE and WCDMA these goals are difficult to achieve simultaneously with traditional RF PAs, and high-efficiency architectures such as Doherty, Envelope Tracking, and so forth are becoming more commonplace.

These PAs require an additional linearization system to achieve the mandated linearity specifications.

The emergence of high-speed digital signal processing techniques has enabled the linearization to be accomplished in the digital signal domain, and digital pre-distortion (DPD) is now the preferred linearization technique.

Course Content

This course explains the nonlinear behavior of **RF power amplifiers**, developing general modeling techniques to describe the nonlinearities and memory effects. A system-level approach to the modeling and linearization of the PA is adopted, and techniques for implementation of **DPD** in practical situations are described.

Upon completing the course, the participant will be able to:

- Understand and describe the nonlinear behavior and memory effects found in RF power amplifiers
- Use and understand the mathematical algorithms for behavioral modeling and digital pre-distortion
- Use and implement digital pre-distortion methods for linearization of RF Pas
- Evaluate and compare modeling and DPD techniques

Mathworks MATLAB is used for all of the mathematical modeling, and Keysight ADS for any circuit simulations for verification, presented in the course. The course is intended to use these tools as a way of showing strategies and examples during the course. It is not mandatory that participants have previous knowledge of using these specific tools.

Who should attend?

This course is suitable for:

- **RF PA designers**
- **DSP designers**
- **System-Level engineers**

who are involved in the specification, design, and implementation of linearized RF PAs and transmitter systems, or who are developing pre-distortion methods, software and algorithms for linearization of RF PAs.

Electrical Engineering degree or equivalent and at least two years' applicable practical experience is recommended.

Course Daily Schedule

Day 1

RF Power Amplifiers in Modern Wireless Communications Systems

- Modern Wireless Communications modulations formats: LTE, WCDMA
- Signal Metrics: Peak-to-Average Power Ratio
- High-efficiency PA architectures: Doherty, Envelope Tracking
- PA metrics: AM-AM, AM-PM, ACLR, EVM

Introduction to Models and Modeling

- Compact models, Behavioral models
- Introduction to System Identification methods

Day 2

Behavioral Modeling Methods

- Linear System review
- Nonlinear modeling
- Memory effects

- Nonlinear dynamical models: Volterra Series formulations and practical implementations
- Artificial Neural Networks
- Frequency-domain models and methods: X-parameters

Day 3

Digital Pre-Distortion Methods

- Typical architectures and approaches using digital control techniques; 'indirect learning'; LUT and algorithmic approaches
- Adaption techniques: convergence, optimization
- DPD implementations: hardware, system components, power and cost
- Practical and commercial DPD systems overview

Future Developments

- Carrier aggregation
- Wide bandwidths
- SDR
- etc

Instructor Biography

Dr. John Wood, PhD, Owner and Technical Consultant, Obsidian Microwave, LLC, USA.

Dr. Wood earned B.Sc. and Ph.D. degrees in Electrical and Electronic Engineering from the University of Leeds, in 1976 and 1980, respectively.

He is currently owner and technical consultant with Obsidian Microwave, LLC. He was with Maxim Integrated from 2011-2015, where he was responsible for RFIC system architecture and DPD developments. Dr. Wood was a Distinguished Member of the Technical Staff in the RF Division of Freescale Semiconductor, from 2005-2011, responsible for nonlinear behavioral modelling and development of digital predistortion techniques for the linearization of high-power amplifiers. From 1997-2005 he worked in the Microwave Technology Center of Agilent Technologies, developing large-signal and bias-dependent linear FET models for mm-wave applications, and nonlinear behavioral models using LSNA measurements and nonlinear system identification techniques.

Dr. Wood is author or co-author of over 150 papers and articles, and three books, including a recent book on “Behavioral Modeling and Linearization of RF Power Amplifiers” (Artech House, 2014). He is a Fellow of the IEEE, and a member of the Microwave Theory and Techniques, and Electron Devices Societies.

Dr. Wood has been a member of the Continuing Education Institute-Europe faculty since 2009.

Publications:

1. J. Wood, "System-level design considerations for digital pre-distortion of wireless base station transmitters," IEEE Transactions on Microwave Theory & Techniques, MTT-65 (5), 1880-90 (2017) (**Invited**)
2. J. Wood, "Digital pre-distortion of RF power amplifiers," IEEE Topical Conference on RF/Microwave Power Amplifiers for Radio and Wireless Applications (PAWR), Phoenix, AZ, 15-18 January 2017 (**Invited**)
3. A. Katz, J. Wood, D. Chokola, "The evolution of PA linearization," IEEE Microwave Magazine, 17(2), pp 32-40 Feb 2016
4. J. Wood, "Digital pre-distortion of RF power amplifiers: progress to date and future challenges," International Microwave Symposium Digest, Phoenix, AZ, 17-22 May 2015 (**Invited**)
5. J. Wood, "Behavioral Modeling and Linearization of RF Power Amplifiers," Norwood, MA: Artech House, 2014