

Fall 2009 ARFTG Symposium

"Non-Linear Measurements for Power Amplifiers Design and Verification" Workshop

Wednesday December 2nd - 1:00pm – 5:00pm

Organizers:

Denis BARATAUD, XLIM – University of Limoges - e-mail: denis.barataud@xlim.fr

After a general introduction, specific topics will be addressed that are of relevance to the needs of industrial engineers and researcher workers. The workshop will conclude with a roundtable discussion to establish a consensus on future directions for work in this area.

Scheduled Speakers

13:00 – 13:15: Welcome Note - Workshop organizers

13:15 – 13:50

System Modeling and Measurement for High Accuracy Verification

T. Reveyrand – XLIM, T. Gasseling - AMCAD Engineering

13:55 – 14:30

Modeling and Characterization of the field-plate bias effects in Si LDMOSFETs

Marvin Marbell, James Hwang - Lehigh University, Infineon Technologies

14:35 – 15:00: Coffee break

15:00 – 15:35

Measuring and Engineering RF Waveforms

Jonathan Lees, P. Tasker and J. Benedikt - Cardiff University

15:40 – 16:15

Broadband Modulated Measurement with a Large Signal Network Analyzer

Patrick Roblin and YoungSeo Ko - ECE Department, The Ohio State University

16:20 – 16:55

Behavioral Modeling and Predistortion for Power Amplifiers

Paul Draxler - Qualcomm, Inc. and UCSD

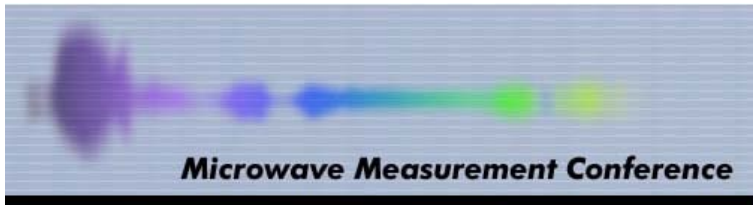
17:00 – 17:30

LSNA Calibration-Comparison Method and Software Package

Dylan F. Williams, Kate A. Remley, Joseph M. Gering, Gregory S. Lyons, Corey Lineberry, and Grant S. Aivazian - National Institute of Standards and Technology

Roundtable discussion:

Future Directions



Abstracts,

13:00 – 13:15

Welcome Note

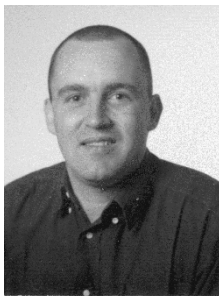
(Workshop organizers)

This workshop deals with improvements in non linear device characterization and modeling due to modern RF measurements techniques. This workshop aims to provide useful tools for power amplifier designers: for them, it is of great importance to dispose of as much information as possible about the non linear devices.

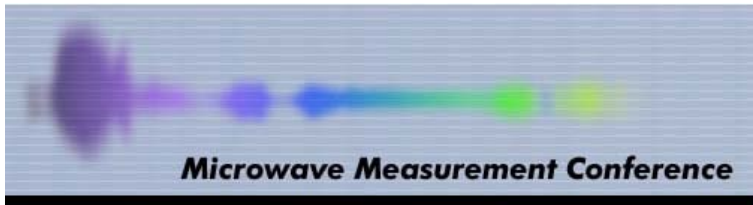
There are several levels to perform amplifier design: component, circuit or subsystem. The main objectives of this workshop are to scan and review the current and future measurements techniques to characterize non linear devices at the different levels.

This workshop will also focus on how to take benefits from these characterizations to evaluate the performances of the non linear devices and to extract or verify faithful models. It will also be an opportunity to answer questions about the CAD implementation techniques of these measurements depending on the purpose (modeling, model verification, performances evaluation,...) and depending on the level of the non-linear device characterization (component, circuit or subsystem).

Biography



Denis Barataud was born in Saint-Junien, France, in 1970. He graduated from "Ecole Nationale Supérieure de Télécommunications de Bretagne" in 1994. He received the PhD. Degree in Electronics from the University of Limoges in 1998. He was a postdoctoral scientist for Microwave Laboratory of the CNES of Toulouse, France, from 1998 TO 1999. Since 2000, he has been with the XLIM (formerly IRCOM) Laboratory at the University of Limoges where he became an assistant professor in 2001. He has defended in 2009 his habilitation thesis in order to become a full university professor His research interests include the development of time-domain equipment and techniques for the characterization of nonlinear devices.



13:15 – 13:50

System Modeling and Measurement for High Accuracy Verification

Authors : T. Reveyrand, T. Gasseling

Organization : XLIM, University of Limoges – AMCAD Engineering

e-mail : tibault.reveyrand@xlim.fr

Abstract :

This presentation will present, in two parts, two measurements setups for microwave power transistors or amplifiers and their applications for modeling. The benches are the pulsed IV S parameters measurement setup for circuit level model extraction and the load-pull setup for compact model validation or behavioral model extraction (at system level).

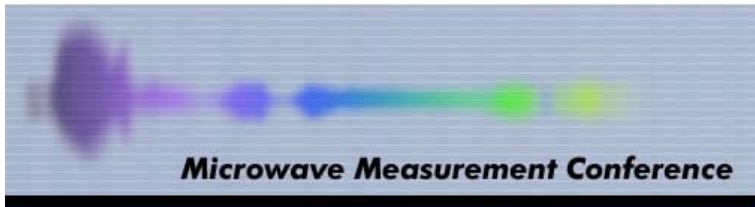
In the first part, the pulsed measurement setup will be presented. Then measurement based compact modeling of GaN HEMTs transistor will be detailed. We will present classical nonlinear models, electro-thermal models and models including trapping effect such as gate and drain lag essential for GaN transistor modeling. A new model for GaN transistor dedicated for SPDT application will be also described.

In the second part, source-pull and load-pull measurement setups will be presented. This setup is used for nonlinear model verification or test on final designs. In this part, different load-pull techniques and the importance of source-pull will be discussed.

Biography



Tibault Reveyrand was born in Paris, France, on September 20, 1974. He received the Ph.D. degree from the University of Limoges, France, in 2002. From 2002 to 2004, he was a post doctoral scientist with the CNES (French Space Agency). In 2005, he became CNRS engineer at XLIM (formerly IRCOM), Limoges. His research interests include the characterization and modeling of RF and microwave nonlinear components. He was the recipient of the European GAAS-2002 Best Paper Award.



13:55 – 14:30

Modeling and Characterization of the field-plate bias effects in Si LDMOSFETs

Authors : Marvin Marbell, James Hwang

Organization : Lehigh University, Infineon Technologies.

e-mail : marvin@marvinmarbell.com

Abstract :

The effects of the field-plate bias on drain current, drain resistance, capacitance, quasi-saturation and breakdown of Si LDMOSFET are modeled and characterized. 2D numerical simulations are used to explain experimental data, as well as to extract functional dependence of the channel potential on field-plate bias. The results are incorporated into the first 5-terminal LDMOSFET model that accounts for field-plate bias. Temperature dependence of transconductance, threshold voltage, drain resistance and breakdown voltage is also extracted and modeled, and a thermal sub-circuit is incorporated into the model to accurately account for dynamic self-heating effects. The model is a modification of the BSIM4 model and is implemented in the Verilog-A code.

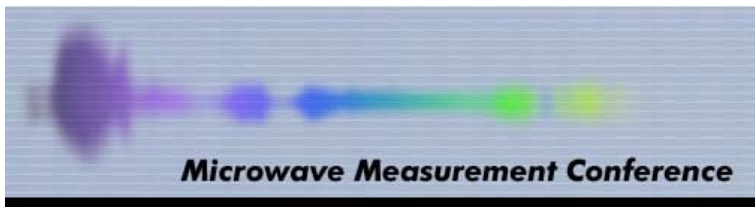
This contribution will present the steps used in model extraction, as well as model validation with measured data including pulsed I-V, DC I-V, C-V, S-parameters, swept power and Load-pull measurements. The model correctly predicts the effect of the field-plate bias on RF power, PAE and linearity, and the results suggest that adaptive field-plate bias can be used in conjunction with adaptive drain bias to improve power and efficiency of LDMOS Power Amplifiers in envelope tracking systems.

Biography



Marvin N. Marbell was born in Accra, Ghana in 1979. He received the B. S. Degree in Electrical and Computer Engineering from Lafayette College, Easton, PA in 2002, and the Ph.D. degree in electrical engineering from Lehigh University, Bethlehem, PA in 2007. He worked previously for RF Micro Devices as a Device Modeling Engineer with focus on CMOS and RFIC characterization and modeling, and later joined Modelithics Inc.

where he was involved with modeling various devices including Si LDMOS, GaAs and GaN HEMTs/pHEMTs. In 2009, he joined Infineon Technologies as a RFPA Design Engineer and is currently working on device and circuit optimization for improved PA performance. His current research interest include modeling and characterization of Si LDMOS, and advanced architecture PA design.



15:00 – 15:35

Measuring and Engineering RF Waveforms

Authors : Jonathan Lees, P. Tasker and J. Benedikt

Organization : Cardiff University
e-mail : leesj2@cardiff.ac.uk

Abstract :

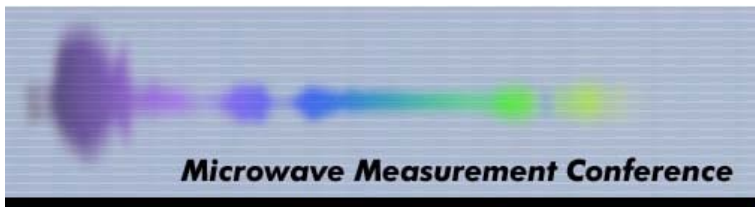
RF Waveforms can be considered as the unifying link between communication system performance, circuit design and transistor technology. This talk discusses how appropriately engineered RF waveforms can help PA designers meet telecommunication system goals such as power, efficiency, and linearity. It is well known that the performance of transistors in power amplifiers is linked to their mode of operation (Class A, A/B, C, etc.). A number of measurement systems now allow for the direct measurement of RF waveforms, either at RF or in the envelope domain, and the coupling of such systems with impedance control hardware enables the engineering of these terminal RF waveforms. Because these measurement systems operate in the time domain they allow for a more natural integration of measurement and CAD simulation based design approaches. This talk touches on several topics of interest to microwave engineers including modelling and measurement of power amplifier transistors and circuits; design and pre-distortion correction of nonlinear telecommunication systems; and circuit design methods that incorporate new transistor technology. Examples will demonstrate measurement feedback to support and link both the design of high power amplifier transistor technology and the circuit environment.

Biography



After obtaining his first degree from Swansea University, UK, Jonathan Lees spent 10 years working with QinetiQ on GPS technology integration. He went on to obtain MSc. and PhD. degrees from Cardiff University in 2002 and 2006 respectively, and has been a chartered Engineer since 1999. He is currently employed as a Senior Research Associate within Cardiff University's centre for High Frequency Engineering where his key research areas are linear-efficient PA design, the characterisation, design and optimisation of

Doherty Power Amplifiers and the study of device non-linearity and linearisation using time-domain and envelope domain techniques. His work in this area culminated in the first published GaN Doherty amplifier, and his more recent activities consider the development of novel high-power, broad-band time-domain measurement and load-pull techniques that directly address the current and future needs of modern communication systems. In June 2009 he took on an additional role as a senior design engineer supporting Mesuro Ltd, leading the commercial introduction of new measurement solutions that enable systematic waveform engineering at RF and microwave frequencies.



15:40 – 16:15

Broadband Modulated Measurement with a Large Signal Network Analyzer

Authors : Patrick Roblin and YoungSeo Ko

Organization : ECE Department, The Ohio State University

e-mail : roblin@ece.osu.edu

Abstract :

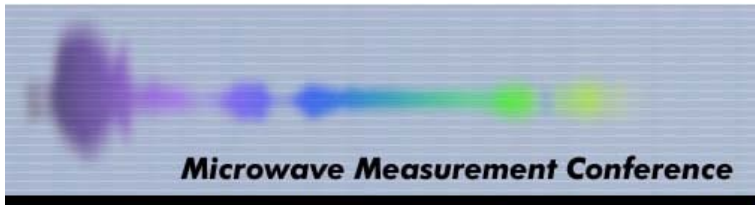
Traditionally vector measurements of digitally modulated RF signals are performed using a vector signal analyzer. Such broadband measurements are centered around the RF fundamental frequency. The use of a large signal network analyzer offers some interesting possibilities for characterizing both the modulated fundamental and harmonic RF response of nonlinear circuits excited with broadband periodically modulated RF signals. Indeed the LSNA relies on an analog implementation of sub-sampling down conversion which enables it to compress a very large RF bandwidth into a small IF bandwidth. In commercialized LSNA's the IF bandwidth usually sets a limit on the bandwidth of the modulated signals to be characterized. However, with an appropriate selection of the sampling frequency to avoid any tone collision, the receiver IF bandwidth does not place any fundamental limitation. The feasibility of the acquisition of signals with Giga-Hertz modulation bandwidth has already been experimentally demonstrated for uncalibrated signals using a 10 MHz IF bandwidth receiver by Jan Verspecht in a presentation at the LSNA user's group at ARFTG62 in 2003. Finally recently a methodology for calibrating such wideband signals has been reported [1]. In this presentation, the IF calibration for such broad measurements is revisited. It is demonstrated that the comparison of successive measurements for calibration verification relies on the extraction of two relative group delays: (1) the first one is associated with the RF source and (2) the second one with the LO sampling oscillator. A methodology for extracting these group delays is presented and applied to experimentally demonstrate the possibility of achieving highly reproducible measurements at 8 times the IF bandwidth. A theory for the stitching of the calibrations is also presented in the case a single harmonic phase reference (HPR) is not available for the full modulation bandwidth. The methodology requires however the use of two HPRs which have been calibrated relative to the same phase standard. Finally the presentation will conclude with an analysis of the fundamental measurement limitation associated with the LSNA dynamic range for such broadband measurements.

[1] M. Yaagoubi, G. Neveux, D. Barataud, T. Reveyard, J.M Nebus, F. Verbeyst, F. Gizard & J. Puech, "Time-Domain Calibrated Measurements of Wideband Multisine Using a Large Signal Network Analyzer," IEEE Trans. MTT, Vol. 56, No. 5, 2008.



Biography

Patrick Roblin was born in Paris, France, in September 1958. He received the Maitrise de Physics degree from the Louis Pasteur University, Strasbourg, France, in 1980, and the M.S. and D.Sc. degrees in electrical engineering from Washington University, St. Louis, MO, in 1982 and 1984, respectively. In 1984, he joined the Department of Electrical Engineering, at The Ohio State University (OSU), Columbus, OH, as an Assistant Professor and is currently a Professor. His present research interests include the measurement, modeling, design and linearization of non-linear RF devices and circuits such as oscillators, mixers, and power-amplifiers. He is the first author of a textbook on High-Speed Heterostructure Devices published by Cambridge University Press. He is the founder of the Non-Linear RF research lab at OSU. He has developed at OSU two educational RF/microwave laboratories and associated curriculum for training both undergraduate and graduate students.



16:20 – 16:55

Behavioral Modeling and Predistortion for Power Amplifiers

Authors : Paul Draxler

Organization : : Qualcomm, Inc. and UCSD

e-mail : pdraxler@ieee.org

Abstract :

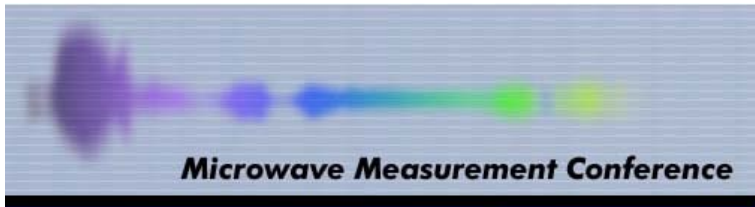
With complex modulation standards evolving to wide bandwidths and higher peak to average ratios, the need for transmitter chains to output a clean signal is ever increasing. One way to achieve the desired output signal is to compensate or pre distort the waveform for the Tx chain distortion effects. By performing behavioral modeling of power amplifiers we can establish targets as to how complex the predistortion must be to achieve a specific ACLR or NRMSE target. We will examine memoryless, signal and piecewise DDR Volterra based behavioral models and the associated predistortion. The next problem for power amplifiers is efficiency and heat dissipation. The conclusion of this talk will focus on applying these models and predistortion to envelope tracking power amplifiers

Biography



Paul J. Draxler (S'81–M'84) received the B.S.E.E. and M.S.E.E. degrees (with a special focus on electromagnetics, RF and microwave circuits, antennas, and plasma physics) from the University of Wisconsin–Madison, in 1984 and 1986, respectively, and is currently working toward the Ph.D. degree at the University of California at San Diego (UCSD), La Jolla focused on behavioral modeling of nonlinear and memory effects in power amplifiers.

Following graduation in 1986, he designed GaAs monolithic microwave integrated circuit (MMIC) and hybrid PA circuits with Hughes Aircraft Company and Avantek. From 1988 to 1995, he held various positions with EEsof and HP-EEsof, where he focused on RF and microwave computer-aided engineering: custom design environments, nonlinear modeling, and electromagnetic simulation. In 1995, he joined Qualcomm, Inc., San Diego, CA, to lead a team focused on RF computer-aided engineering. In this role, he has provided consulting to many design teams on system and circuit simulation, electromagnetic modeling, and board- and chip-level design methodologies. He is currently a Senior Staff Engineer in corporate research and development with Qualcomm, Inc. He has authored or coauthored numerous symposium, trade journal and transaction papers on electromagnetic simulation, circuit simulation, and system simulation. He holds two patents with others pending.



17:00 – 17:30

LSNA Calibration-Comparison Method and Software Package

Authors : Dylan F. Williams, Kate A. Remley, Joseph M. Gering, Gregory S. Lyons, Corey Lineberry, and Grant S. Aivazian

Organization : National Institute of Standards and Technology
e-mail : dylan@boulder.nist.gov

Abstract : We describe a procedure and metrics for comparing large-signal-network-analyzer calibrations. The metrics we develop provide a bound on differences between measurements obtained from large-signal-network-analyzer calibrations, as well as more specific information on how the power, phase, and scattering-parameter portions of the calibrations differ. The presentation will end with a demonstration of a freeware package for calculating the metrics.

Biography



Dylan F. Williams (M'80-SM'90-F'02) received a Ph.D. in Electrical Engineering from the University of California, Berkeley in 1986. He joined the Electromagnetic Fields Division of the National Institute of Standards and Technology in 1989 where he develops electrical waveform and microwave metrology. He has published over 80 technical papers and is a Fellow of the IEEE. He is the recipient of the Department of Commerce Bronze and Silver Medals, the Astin Measurement Science Award, two Electrical Engineering Laboratory's Outstanding Paper Awards, two Automatic RF Techniques Group (ARFTG) Best Paper Awards, the ARFTG Automated Measurements Technology Award, and the IEEE Morris E. Leeds Award. Dylan is now Editor of the IEEE Transactions on Microwave Theory and Techniques.

Roundtable discussion:
Future Directions