Wednesday, January 24th

ARFTG Workshop “Traditional vs. Data and Artificial Intelligence Driven Modeling: Battle of the Ages”

7:50 – 8:00

Welcome

Mauro Marchetti (Anteverta-mw B.V.)

8:00 – 8:45

Evolution Toward Automatic Power Amplifier Design

Patrick Roblin (Ohio State University)

Abstract: In today’s highly competitive world, the capability of successfully realizing first-pass design for high-performance microwave power amplifiers has grown in importance. This presentation will review new design techniques and tools which streamline the PA design process for the GaN HEMT technology.

First, the availability of accurate nonlinear device models is critical for a successful model-base design of power amplifiers. Whether compact analytic model, table-based, artificial neural network or behavioral models are used, these models must provide a realistic response of GaN HEMTs for small and large RF excitations at various DC bias conditions while accounting for self-heating and trapping effects. The accuracy of these models in accounting for these memory effects can be verified at low and high frequencies using pulsed or modulated excitations.

The emergence of nonlinear embedding models has made possible the synthesis of amplifiers of various classes such as class B, F and E in a single simulation without performing multi-harmonic source and loadpull. Starting from a textbook PA model, the required optimal fundamental and harmonic source and load impedances at the package reference planes are obtained in a single harmonic balance simulation. Example of NVNA verification at X band of the prediction of ASMHEMT nonlinear embedding models will be presented for class F operation. Nonlinear embedding models have also been developed for Angelov and ANN models and are now becoming commercially available.

Multi-transistor amplifiers can further be designed using nonlinear embedding.

An algorithm for the automatic design of Doherty PA first demonstrated at RWW in 2019 will be reviewed. Further work on the accelerated synthesis of broadband dual-input PAs within the Chireix-Doherty continuum will be presented. Because nonlinear embedding projects the

operation at the current source reference planes to the extrinsic or package reference planes, the realistic performance of an amplifier can also be estimated even before designing and implementing the matching networks and combiners. We will review a 2023 PAWR paper which provides a comparison study of the broadband performance of various load-modulated architectures using Nonlinear Embedding at 20 GHz. This work demonstrated among other things, how at such high frequencies the manifold of the auxiliary PA undesirably dissipates power at backoff even when it is off. This highlights the advantage of the conventional LMBA which does not use an auxiliary PA but relies instead on an injection PA.

The talk will conclude with a review of areas where machine learning could be used to further streamline these novel broadband PA design techniques by assisting the PA designer in the synthesizing of the required passive combiner and matching networks.

Speakers Biography: Patrick Roblin received the Maîtrise de Physics degree from the Louis Pasteur University, Strasbourg, France, in 1980, and the D.Sc. degrees in Electrical Engineering from Washington University, St. Louis, MO, in 1984. In 1984, he joined the Department of Electrical Engineering at The Ohio State University, Columbus, OH where he is currently a Professor. His present research interests include the measurement, modeling, design and linearization of non-linear RF devices and circuits such as power-amplifiers and MIMO systems. He authored and co-authored three textbooks two published with Cambridge University Press and one by Springer. He is the founder of the Non-Linear RF research lab at OSU. He has also developed at OSU two educational RF/microwave laboratories and associated curriculum for training both undergraduate and graduate students. He served as a Distinguished Microwave Lecturer for IEEE-MTT in 2016, 2017 and 2018.

8:45 – 9:30

Unconventional Measurement Techniques for Nonlinear Modelling of Microwave GaN FETs

Valeria Vadalà[1], Antonio Raffo[2] ([1]University of Milano-Bicocca, [2]University of Ferrara, Italy)

Abstract: Nonlinear modeling of GaN HEMTs is a formidable challenge especially when accurate predictions are desired under nonlinear dynamic operations. This complexity primarily arises from the dispersion phenomena affecting state-of-the-art III-V based devices. The challenge get bigger and bigger with increasing frequency and power demands, driven by emerging telecommunication applications that require operation in the mm-wave range. Indeed, this produces tangible obstacles in characterizing transistors under nonlinear regime that inevitably leads to difficulties in gathering accurate nonlinear models.

In this talk, we delve into modeling-oriented characterization techniques which enable the accurate characterization of microwave GaN HEMTs under actual operating conditions showing how they can be fruitfully used into the extraction process of nonlinear compact models oriented to circuits design. The advantages of employing such nonlinear characterization techniques for modeling purposes are underscored, with practical examples illustrating the characterization and modeling of GaN devices.

Speakers Biography: Valeria Vadalà (S'07–M'11) was born in Reggio Calabria, Italy, in 1982. She received the M.S. degree cum laude in electronic engineering from the "Mediterranea" University of Reggio Calabria, Reggio Calabria, Italy, in 2006 and the Ph.D. degree in information engineering from the University of Ferrara, Ferrara, Italy, in 2010.

She is currently Assistant Professor at the Department of Physics, University of Milano-Bicocca, Milan, Italy, where she teaches the course of electronic instrumentation and measurement. Form 2010 to 2021 she was research assistant with the Department of Engineering, University of Ferrara. In 2013 she was Visiting Fellow at the Telecommunication and Microwave Laboratory (TELEMIC) KU Leuven. Her current research interests include nonlinear electron-device characterization and modelling and circuit-design techniques for nonlinear microwave and millimeter wave applications.

Dr. Vadalà is Associate Editor of the International Journal of Numerical Modelling: Electronic Networks, Devices and Fields (Wiley).

9:30 – 10:15

Cardiff Behavioral Model: Data Driven Modelling Solution

Paul J Tasker, James Bell and Roberto Quaglia (University of Cardiff, UK)

Abstract: The emergence of the large signal network analyzer - "A network analyzer equipped to measure both the magnitude and phase, with respect to a given time reference, of the large signal forward and backward waves at its ports. These waves most often include a distinct, commensurate set of spectral components." - triggered a development of behavioral model solutions formulated in terms of these spectral forward and backward waves components, Aph and Bph. (p – port, h – harmonic). Different formulations include X-parameters, S-functions, and the Cardiff Behavioral Model. All these formulations have a common origin and can be explained in terms of signal mixing. The Cardiff Behavioral Model provides a data driven, "look up table" CAD model for PA design. Its original formulations captured all information necessary to ensure fundamental and harmonic source-/load-pull measurement data could be used in CAD design. Alternative formulations, like admittance-parameters based, allow for transistor width scaling and frequency scaling. Recent Cardiff Behavioral Model advancements have included additional parameters such as gate bias, drain bias and temperature, while the extension to include multiport stimuli enables the Cardiff Behavioral Models to be used to model multi-transistor circuit topologies, such as Doherty or Load Modulated Balanced Amplifiers. Moreover, as a fundamental concern for any data driven modelling solution is the robustness of the coefficient extraction process, a tailoring of the experimental datasets that can address this issue has also been proposed.

Speakers Biography: Paul J Tasker has been working in the field of high frequency compound semiconductor microwave and millimetre wave devices and circuits > 40 years. In that time, he has been involved in their design, fabrication and characterization. After receiving his PhD in 1983 at Leeds University, he worked for six years as postdoctoral researcher at Cornell University with Lester Eastman involved in the design and development of high frequency transistors. In 1990 he moved to the IAF (Fraunhofer Institute for Applied Solid State Physics) in Freiburg Germany, to lead the development of millimetre wave GaAs pHEMT MMICs. He joined the School of Engineering at Cardiff University as Professor in the summer of 1995. While at Cardiff he has establish the Cardiff University Centre for High Frequency Engineering. The Centre's research objective is to pioneer the development and application of RF I-V Waveform and Engineering Systems, with a particular focus to addressing the Power Amplifier PA design problem for wireless communication applications. He has contributed to > 400 journal and conference publications, workshop presentations, was a Distinguished Microwave Lecturer (2008-2011) and is now a Member of IEEE MTT Speakers Bureau. He is a Fellow of the IEEE, IET and the Learned Society of Wales.

10:15 – 10:30

Break

10:30 – 11:15

Advanced Transistor Modeling - Neural Models versus Traditional Models

Zlatica Marinković (University of Nis, Serbia)

Abstract: During the last two decades artificial neural networks have found their place in modeling of microwave devices, owing to their capability to learn from data. This talk will be focused on applications of artificial neural networks for small signal modeling of microwave and mm-wave transistors and will give insights into modeling principles, model development, implementation of the models in standard circuit simulators, and model verification. A special emphasis will be on a discussion related to the measured data needed for development of the models valid in a wide range of operating conditions (i.e., biases, temperature, etc.) and for the development of the scalable models. After the neural models are contrasted to the traditional modeling approaches, models combining the advantages of neural and traditional approaches will be presented.

Speakers Biography: Zlatica Marinković (S'02–M'08-SM'13) received the diploma degree (Dipl.-Ing.) in Electronics and Telecomunications at the University of Niš, Faculty of Electronic Engineering Serbia in 1999, and magister and PhD degrees in Telecommunications at the same University in 2003 and 2007, respectively. After graduation she joined the University of Niš, where she is currently a Full Professor teaching several subjects in telecommunications, microwaves and machine learning for microwaves and telecommunications.

Her main research areas are neural modeling of microwave transistors and machine learning applications in the field of microwaves, telecommunications and electronics. She was a visiting researcher with the University of Messina, Italy and the University of L'Aquila, Italy. She authored/coauthored more than 150 scientific papers in international journals and conferences and three book chapters. She serves as the Associate Editor of International Journal of Numerical Modelling: Electronic Networks, Devices and Fields. She served as the Editor-in-Chief of the journal Microwave Review.

Dr. Marinković serves as the IEEE MTT-S EduCom Undergraduate Scholarship Chair, the Vice-Chair of IEEE Section of Serbia and Montenegro and the Vice-Chair of the IEEE Serbia and Montenegro WIE Affinity Group. She served as the Chair of IEEE MTT-S Chapter of Serbia and Montenegro.

11:15 – 12:00

Artificial Intelligence and Machine Learning for RF and Microwave Design: practical technologies for present and future applications

Jianjun Xu (Keysight Technologies, Santa Rosa)

Abstract: This talk reviews some powerful and practical Artificial Intelligence and Machine Learning (AI/ML) technologies for applications in traditional RF and Microwave design and beyond. After a very brief overview of the AI/ML landscape, we focus on Artificial Neural Networks (ANNs) and provide several key examples of modern ANN applications to electronic, electro-thermal, and electro-chemical device modeling, device characterization, and behavioral modeling to illustrate the substantial benefits and generality of present techniques. The talk concludes with a discussion of the potential of AI/ML technologies to address and solve future challenging and important RF and Microwave design problems, e.g., for 6G.

Speakers Biography: Dr. Jianjun Xu is recognized internationally as a leading innovator of advanced artificial neural network (ANN) technology and its practical applications to a wide range of microwave and RF engineering problems. He is presently Senior Machine Learning

Engineer at Keysight Laboratories, Keysight Technology, Inc., in Santa Rosa CA. His ANN research has been integrated into leading commercial simulators and measurement-based design flows, including transistor characterization and nonlinear modeling of GaAs and GaN FETs, cryogenic CMOS devices, lithium-ion battery models, TCAD-to-circuit links, and more. Dr. Xu received the Ph.D. Degree in Electrical Engineering from Carleton University, Ottawa, Canada, in 2004, and is a frequent technical reviewer for the IEEE on topics of AI/ML and ANNs.