Special Session Proposal NEWCAS 2015

"On-chip measurements for characterization, testing, and calibration of analog front-ends and mmW devices "

- **Short biography of the organizers:**

Jean-Daniel Arnould was born in Chevreuse, France, on July 1974. He received the Engineer's degree in electronics and radioelectricity and the M. Sc. degree in optics and radiofrequency in 1998, and the Ph.D. degree from the Grenoble Institute of Technology (Grenoble-INP), Grenoble, France, in 2002. Since October 2004, he has been working as an associate professor at Grenoble-INP-IMEP-LAHC. His research interests include the design of passive devices, such as filters, matching networks, de-embedding structures and now on chip mmW device characterization.

Haralampos-G. Stratigopoulos received the Diploma in electrical and computer engineering from the National Technical University of Athens, Greece, in 2001 and the Ph.D. in electrical engineering from Yale University, USA, in 2006. He is currently a Researcher with the French National Center for Scientific Research (CNRS) at TIMA Laboratory, Grenoble, France. His main research interests are in the areas of design-for-test and built-in test for analog, mixed-signal, RF circuits and systems, computer-aided design, and machine learning. He has served on the Technical Program Committees of Design, Automation, and Test in Europe Conference (DATE), IEEE International Conference on Computer-Aided Design (ICCAD), IEEE VLSI Test Symposium (VTS), IEEE European Test Symposium (ETS), and several others international conferences. He is an Associate Editor of Springer Journal of Electronic Testing: Theory & Applications, IEEE Design & Test Magazine, and IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems. He received the Best Paper Award in the 2009 and 2012 IEEE European Test Symposium.

Rationale of the need for the special session:

The purpose of the special session is to discuss state-of-the-art on-chip measurement methods in the context of characterization of mmW devices and testing and calibration of analog, mixed-signal, and RF integrated circuits. The need for low-overhead, non-intrusive, and reliable on-chip measurement methods is dictated by (a) the heterogeneity and complexity of modern mixed analog-digital systems-on-chip and systems-in-package that offer very limited controllability and observability from the output pins in order to perform testing; (b) the increased process variations in advance technology nodes (e.g. 65nm and beyond) that make post-manufacturing calibration of outmost importance in order to correct yield loss; (c) safety-critical and mission-critical systems that need to be equipped with on-chip self-calibration mechanisms for detecting early reliability hazards and applying self-corrective actions (e.g. fault tolerance, self-repair, etc.); and (d) the numerous modern applications of high-frequency devices (e.g. RF, mmW) whose accurate characterization and post-silicon verification requires to rely on on-chip test structures, since extracting signals off-chip for processing seriously degrades the measurement accuracy. This special session will gather together worldwide experts on the above research fields to share with the conference attendees the most recent and state-of-the-art solutions proposed to date.

1) Title: **Self-healing of RF circuits using built-in non-intrusive sensors**

Authors: Martin Andraud, **Haralampos-G. Stratigopoulos**, and Emmanuel Simeu
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Abstract: Integrated systems in nanometer technologies are highly susceptible to process parameter variations, power supply and temperature variations, environmental disturbances, and ageing effects. To account for these non-idealities it is required to equip systems with efficient self-healing capabilities both at post-manufacturing and during their lifetime in the field of operation. Self-healing at post-manufacturing aims at correcting yield loss while self-healing in the field of operation aims at maintaining an expected level of performances in a power-efficient manner to account for unexpected applications, harsh environments, and ageing. In this talk, we will present a generic self-healing paradigm for RF transceivers that is based on tuning knobs judiciously inserted into the design to add several degrees of freedom, built-in non-intrusive sensors, and a statistical learning algorithm. In particular, we will focus on post-manufacturing self-healing, where the statistical learning algorithm maps the output of non-intrusive sensors that offer an "image" of process variations to an optimal tuning knob setting in one-shot, that is, without needing to enter into a time-consuming self-test/self-healing loop.

Speaker's Biography: **Haralampos-G. Stratigopoulos** received the Diploma in electrical and computer engineering from the National Technical University of Athens, Greece, in 2001 and the Ph.D. in electrical engineering from Yale University, USA, in 2006. He is currently a Researcher with the French National Center for Scientific Research (CNRS) at TIMA Laboratory, Grenoble, France. His main research interests are in the areas of design-for-test and built-in test for analog, mixed-signal, RF circuits and systems, computer-aided design, and machine learning. He has served on the Technical Program Committees of Design, Automation, and Test in Europe Conference (DATE), IEEE International Conference on Computer-Aided Design (ICCAD), IEEE VLSI Test Symposium (VTS), IEEE European Test Symposium (ETS), and several others international conferences. He is an Associate Editor of Springer Journal of Electronic Testing: Theory & Applications, IEEE Design & Test Magazine, and IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems. He received the Best Paper Award in the 2009 and 2012 IEEE European Test Symposium.

2) Title: **150 GHz load pull measurements on BiCMOS 55nm SiGe:C HBT using in situ tuner**

Authors: **Alice Bossuet[1,2]**, Thomas Quemerais[2], Estelle Lauga-Larroze[1], Jean-Michel Fournier[1], Christophe Gaquière[3]

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Abstract : In this paper we report load-pull measurements on a heterojunction bipolar transistor at 150 GHz with a variation of load impedance using an integrated tuner. These power measurements are done on a SiGe:C HBT from the BiCMOS 55nm technology featuring 320/370 GHz Ft/Fmax, from STMicroelectronics. Integrated impedance tuner is specially designed in order to characterize the device for various load impedance. After ensuring the linearity of the integrated tuner, bipolar transistor is characterized in a non-linear region in order to extract the large signal characteristics such as maximum power gain and output power at 150 GHz.

Speaker's Biography : **Alice Bossuet** received the M.S. degree in Integrated Electronic Systems from the Grenoble Institute of Technology (INPG), France in 2013. She is currently working toward the Ph.D degree at STMicroelectronics, as part of the Microwaves and Electrical Characterization Team, Crolles, France, and at the IMEP-LAHC Institute, the Microelectronics, Electromagnetism and Photonic laboratory, Grenoble, France, and the IEMN Institute, the Electronics, Microelectronics and Nanotechnologies laboratory, Lille, France. Her principal research interests are in the design of integrated circuit at millimeter-waves frequencies in advanced SiGe BiCMOS technologies dedicated to active device modelling and electrical characterization.

3) Title: **Integrated Test Concepts for In-Situ Millimeter-Wave Device Characterization**

Authors: **D. Kissinger[1,2]**, J. Nehring[3], A. Oborovski[3], K. Borutta[3], I. Nasr[4], B. Lämmle[5], and R. Weigel[3]

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Abstract : This paper presents state-of-the-art integrated test concepts for the in-situ characterization of silicon-integrated millimeter-wave devices and transceiver components for radar and communication applications. Narrowband as well as ultra-broadband integrated network analysis solutions for a variety of frequency bands ranging from 50 to 120 GHz are outlined. Furthermore, extended characterization approaches for noise and linearity analysis are discussed.

Speaker's Biography: **Dietmar Kissinger** was born in Leipzig, Germany, in 1980. He received the Dipl.-Ing. degree and the Dr.-Ing. degree in electrical engineering from the University of Erlangen-Nuremberg, Erlangen, Germany, in 2007 and 2011, respectively. In 2007, he joined the Institute for Electronics Engineering, Erlangen, Germany as a Research Assistant. From 2007 to 2010, he was with Danube Integrated Circuit Engineering, Linz, Austria, where he worked as a System and Application Engineer in the automotive radar group. Since 2010, he holds a position as Lecturer and Head of the RF Integrated Sensors Group at the Institute for Electronics Engineering. His research interests include silicon-based microwave and millimeter-wave integrated circuits as well as wireless sensors and communication systems for ultra-low power, automotive, industrial, security, and medical applications. In these areas he has authored or co-authored more than 50 technical publications and holds 3 patents.

4) Title: **Embedded Instruments for Dependability of Analogue and Mixed-Signal IPs**

Authors: Jinbo Wan and **Hans G. Kerkhoff**

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Abstract : The idea of embedded instrument (EI) is to embedding some form of test and measurement into silicon to characterise, debug and test chips. The concept of the EI is different from the build in self test (BIST) and other kinds of monitors by the fact that embedded instrument can provide user with rich and detailed information about performances of the target, not just true/false indication. In this paper, a few embedded instruments for analogue and mixed-signal IPs focusing on dependability applications are introduced. they are the EI for measuring MOS transistors' threshold voltage, the EI for testing Opamps' gain and offset, and the EI for detecting active filters' cut-off frequencies. Measurements and simulation results are provided to validate these EIs and show their efficiency in monitoring the ageing of analogue and mixed-signal IPs in their life time.

Speaker's Biography: **Hans G. Kerkhoff** is an associate professor and head of the Testable Design and Testing of Integrated Systems Group at the Centre of Telematics and Information Technology (CTIT), a subsidiary of the University of Twente, the Netherlands. He is the founder of the test consultancy company TwenTest. Kerkhoff has an M.Sc. degree in telecommunication from the Technical University of Delft and a PhD in technical science from the University of Twente.

5) Title: **Substrate coupling effect in BiCMOS technology for millimeter wave application**

Authors: **Sebastien Fregonese**, Rosario D'Esposito, Cristell Maneux, Thomas Zimmer

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Abstract : The down-scaling of SiGe HBT has pushed its electrical performances to the sub-THz and THz range. THz electronic technology is an emerging area that has shown a great potential. It opens up new applications such as security applications, THz imaging for healthcare, medical and biology. In this frequency range, new physical effects are no longer negligible, such as the electrical coupling through the substrate between two neighboring transistors. This effect must be taken into account in process design kits for an efficient high frequency circuit design. SiGe HBTs are isolated from neighbouring devices by means of shallow and deep trenches. In addition, a substrate guard ring is surrounding the device in order to reduce the electrical coupling with other devices. To assess the substrate coupling effect, specific test structures have been designed for mmW characterization (see Fig. 1). They consist in various device configurations (with different dimensions and distances between adjacent devices). In addition, the associated de-embedding structures such as an open, short, open pad and short pad have also been designed. Finally, S parameters measurements have been performed up to 110 GHz and the coupling has been investigated.

For further investigation and validation of the observed coupling effect, Sentaurus TCAD simulations devices are used. This type of simulation is dedicated to semiconductor physics and considers only the electrostatic effect. Thus, a (EM) electromagnetic simulator was used to validate the hypothesis that the electrostatic model is sufficient in this case. A comparison between the S-parameter measurements and results of TCAD simulation will be given. The importance of the substrate guard ring and the impact of the distance of the transistors will be highlighted.

Finally, a scalable compact model based on lumped elements will be proposed dedicated to circuit design and modelling in the sub-THz range.

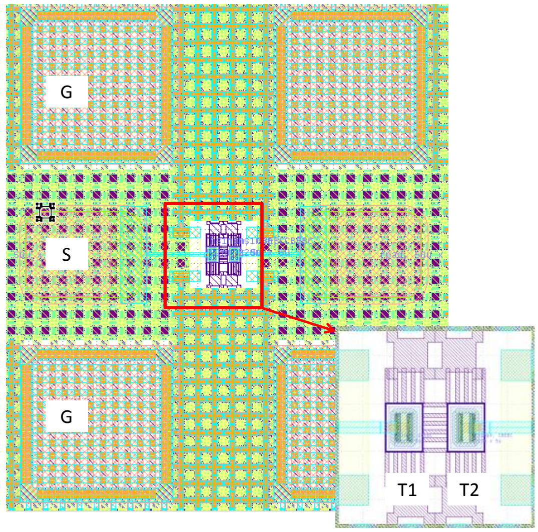

Fig. 1: Test structure for the evaluation of substrate coupling between two neighboring devices.

Speaker's Biography: **S. Frégonèse** was born in Bordeaux, France, in 1979. He received the Ph.D. degrees in electronics from the Université Bordeaux, Talence, France, in 2005, respectively. During his Ph.D. research, he investigated bulk and thin film SOI SiGe HBTs, with emphasis on compact modeling. From 2005 to 2006, he was with the Technical University of Delft, Delft, The Netherlands, with a postdoctoral position, where his research activities dealt with the Si strain FET emerging devices. In 2007, he joined the "Centre National de la Recherche Scientifique" (CNRS) as a Researcher at the IMS Laboratory, UMR 5218, in Bordeaux, France. His research interests are focused on electrical compact modeling and characterization of HF devices such as the SiGe HBTs and carbon based transistors. From 2011 to 2012, he was visiting researcher at the IEMN laboratory in Lille, France, in order to focus his work on the graphene FET device modelling. He is involved in a couple of National and European research projects like the European FP7 IP Dot5 and Dot7 Project, FP7 GRADE. Dr. Frégonèse has served as a reviewer for Scientif Reports, Physica Status Solidi, the IEEE Transactions, Solid State Electronics and some IEEE conferences.

6) Title: **Calibration and characterization techniques for on-wafer device characterization.**

Authors: L. Galatro and **M. Spirito**

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Abstract : Device and component characterization at mm-wave and sub-mm-wave pose various challenges that need to be accounted for. The paper will review the problems and state-of-the art solutions related to calibration substrate and methodologies, small signal device characterization (with a required power level stimulus) and large signal response of mm-wave and sub-mm-wave devices.

Experimental data on the substrate selection and the design of calibration artifacts will be given. Moreover the impact and procedure to achieve absolute power levelling of S-parameters at the probe tips of frequency extended VNAs will be presented and experimental results will be shown.

Speaker's Biography: **Marco Spirito** (S'01-M'08) received the M.Sc. degree (cum laude) in electrical engineering from the University of Naples "Federico II," Naples, Italy, in 2000, and the Ph.D. degree from the Delft University of Technology, Delft, The Netherlands, in 2006. In April 2008 he joined the Electronics Research Laboratory at the Delft University of Technology as an Assistant Professor, where he is an Associate Professor since April 2013. His research interests include the characterization of highly efficient and linear power amplifiers, the development of advanced characterization setups for millimeter and sub-millimeter waves, and the integration of mm-wave sensing systems.

Dr. Spirito was the recipient in 2002 of the Best Student Paper Award for his contribution BCTM contribution, the IEEE MTT Society Microwave Prize in 2008, was a co-recipient of the best student paper award at SiRF topical meeting 2011 and at the IEEE RFIC 2011.