Automatic RF Techniques Group

69th ARFTG Microwave Measurement Conference

Hilton Hawaiian Village, Honolulu, HI U.S.A. June 8, 2007

TECHNICAL AGENDA WITH ABSTRACTS

8:05 to 8:45 AM

Keynote Speech

"Characterization Challenges for Future Base-Station Power Amplifiers"

Wolfgang Heinrich, FBH Berlin

The field of base-station power amplifiers is facing fundamental changes. The number of wireless standards is growing, new services such as WiMAX have entered the scene. This demands for PAs with multi-standard multi-band capabilities. On the technology side, GaN devices offer unprecedented power-bandwidth potential and make highly efficient switch-mode architectures feasible. These developments towards multi-band and digital concepts require advances in measurement techniques. The talk will start with an overview on the trends and highlight the challenges for characterization.

8:45 to 9:45AM

Session 1: Active Device Characterization

Jean-Pierre Teyssier, Session Chair

Negative Input Resistance and Real-time Active Load-pull Measurements of a 2.5GHz Oscillator Using a LSNA,

Inwon Suh (1), Seok Joo Doo (1), Patrick Roblin (1), Xian Cui (1), Young Gi Kim (1), Jeffrey Strahler (2), Marc Vanden Bossche (3), Roberto Rojas (1), and Hyo Dal Park (1), 1 Ohio State University, Columbus, OH, 2 Andrew Corporation, 3 NMDG Engineering

A large-signal measurement-based methodology to design oscillators using the Kurokawa theory is presented in this paper. Measurements of the negative input resistance and device line of a 2.5GHz HEMT oscillator versus frequency and power, and its optimization using real-time active load-pull (RTALP) for the 2nd and 3rd harmonics are performed with a large signal network analyzer (LSNA). As a result, the maximum output power of the oscillator is increased from 31.0mW to 38.8mW. Finally self-oscillation is verified using a load tuner to yield an output power and frequency of oscillation in reasonable agreement with the Kurokawa analysis.

Inter-Laboratory Comparison of CMOS Distortion Measurements,

Kate A. Remley (1), Joe Gering 2), Susan Sweeney (3), C. Michael Olsen (4), Cliff Xie (2), Dave Walker (1), Tom McKay (4), Jack Pekarik (5), 1 NIST, Boulder, CO, 2 RF Micro Devices, Greensboro, NC, 3 IBM SRDC, Essex Junction, VT,4 IBM SRDC Hopewell Junction, NY, 5 RF Micro Devices, Scotts Valley, CA

We describe a measurement comparison of distortion in a complementary metal-oxide semiconductor low-noise device operating under weakly nonlinear conditions. Issues that commonly arise in performing and interpreting nonlinear measurements are discussed, such as power and wavebased representations and the effects of terminating impedance on intermodulation distortion. We demonstrate that the increased confidence provided by a measurement comparison can help to diagnose issues with a device model that was initially derived from DC I/V curves and their derivatives and then compared to RF measurement.

Optimum Tuning Range Analysis of Load Pull Measurement Systems and Impedance Transforming Networks,

Jérôme Sirois and Basim Noori, Freescale Semiconductor, Tempe AZ

This paper studies, by mean of a mapping between the Smith chart and impedance plot, the different aspects that impact the tunable range at the DUT reference plane in a passive load pull measurement system. The utilization of an impedance transforming fixture is considered and the technique to choose the right transformation ratio is presented. Finally, a method to encircle the absolute tunable region of a load pull system is explained, considering the use of any impedance transforming network.

10:30 to 11:50 PM

Session 2: Multiport and Differential Measurements

Jon Martens, Session Chair

True Differential Stimulus Gives Additional Insight into Nonlinear Amplifier Behavior,
Jochen Simon, Rohde & Schwarz, Germany

Known n-port VNA calibration procedures in conjunction with consistent wave normalization and power calibration provide a and b waves at the calibration plane with correct absolute amplitude and relative phases. VNAs with two sources that are adjustable in amplitude and relative phase can be used for the generation of true error-corrected differential and common-mode stimulus signals. A special correction procedure has been developed that takes source crosstalk via the DUT into account. Applying these stimulating signals, single-ended or mixed-mode n-port-S-parameters can be determined.

Optimization for Multiport VNA Vector Error Correction,
David Blackham, Agilent Technologies

Multiport vector error correction leverages the techniques that apply to two-port error correction. In some testset configurations the load match at any particular port may take on multiple distinct values that must be characterized. As the number of ports increases it becomes important to find ways to minimize the number of connections required to calibrate the VNA. This paper presents techniques for optimizing the calibration both from the point of view of minimizing the number of calibration steps as well as utilizing TRL, Unknown Thru and QSOLT calibration without requiring dual reflectometers at each testport.

VNA Error Model Conversion for N-Port Calibration Comparison,
Leonard Hayden, Cascade Microtech, Inc., Beaverton, OR

This paper examines the extended 12-term error model commonly used in commercial multiport vector network analyzers, introduces a generalized multiport error model, and applies this error model for the purposes of general N-port comparison of calibrations. These tools have been implemented in a commercially available calibration and measurement software product [1]. Previous work demonstrated the utility of these tools in the estimation of calibration error associated with ignoring coupling [2] and for evaluating measurement system repeatability [3]. Equations are presented for bidirectional conversion between an extended 16-termlike error model and the extended 12-term model as well as for calculation of DUT-specific and worst-case multiport calibration comparison error bounds.

A Robust Broadband Calibration Method for Wafer-Level Characterization of Multiport Devices,
Andrej Rumiantsev (1), Holger Heuermann (2), and Steffen Schott (1), 1 SUSS MicroTec Test Systems GmbH, Sacka, Germany, 2 University of Applied Sciences Aachen, Germany

This paper describes the theory and practical results of the new multiport calibration procedure especially suited for wafer-level device characterization over a wide frequency range. An analysis of the currently available multiport calibration approaches was carried out. The advantages and drawbacks of each approach are demonstrated. It is shown that a robust wafer-level multiport calibration procedure should combine the strengths of both 7-term and 10-term based algorithms. It should also provide reference-match measurements on each VNA measurement port and be insensitive to the behavior of highly-reflective standards and the design of transmission standards. Corresponding to these requirements, the definition of the advanced multiport RRMT+ algorithm is given. The results of a practical experiment proved the theory and demonstrated the advantages of the new multiport RRMT+ calibration procedure.

1:00 to 2:40 PM

Session 3: On-Wafer Microwave Measurements

Dylan Williams, Session Chair

Highly Accurate Frequency/Time Domain Characterization of Transmission Lines and Passives for SiP Applications up to 65 GHz,

M. Wojnowski (1), M. Engl (1), R. Weigel (2), 1 Infineon Technologies AG, Neubiberg, Germany, 2 University of Erlangen-Nuremberg, Erlangen, Germany

Accurate determination of the characteristic impedance determines the accuracy of the characterization of transmission lines and passive devices. In this paper, we present a novel, time-domain based procedure for the complex characteristic impedance determination. The method is insensitive to changes in the reference plane and the parasitic shunt admittance at the probe tips. For highly accurate passives characterization, a modification of the Thru-Reflect-Line (TRL) calibration algorithm is proposed. It enables the use of the TRL method to deembed components having the ports on different metallization levels. Additionally, a comprehensive overview and evaluation of both frequency and time-domain methods for characteristic impedance determination is included for completeness. We present measurement results of transmission lines and spiral inductors fabricated in MCM-D technology on low- and high resistivity substrates up to 65 GHz.

A bilateral comparison of on-wafer S-parameter measurements at millimeter wavelengths,

Roland G. Clarke (1) and Nick M. Ridler (2), 1 University of Leeds, UK,2 National Physical Laboratory, UK

This paper reports on a comparison of measurements that has taken place recently between two UK-based measurement facilities – the University of Leeds and the National Physical Laboratory. The comparison involved making complex S-parameter measurements of a commercially available co-planar waveguide calibration substrate. Most measurements were made at frequencies up to 65 GHz, although some measurement data was obtained up to 110 GHz. Subsidiary investigations also looked at measurement repeatability and the effects of using different VNA calibration schemes. A breakdown of the likely error processes affecting these measurements as a function of frequency is also given leading to rudimentary uncertainty estimates for such measurements.

Experimental Analysis of On-Wafer Deembedding Techniques for RF Modeling of Advanced RFCMOS and BiCMOS Technologies,

Jing Wang, Robert Groves, Basanth Jagannathan and Lawrence Wagner, IBM Semiconductor Research and Development Center, Hopewell Junction, NY

Based on hardware measurement of 45nm RFCMOS and 130nm SiGe BiCMOS wafers, we present the first experimental investigation of the accuracy of various de-embedding techniques for high-frequency (up to 110GHz) on-wafer s-parameter characterization. The results clearly show that 4-port COMPLETE deembedding offers accurate results only if the non-ideality of resistor standards is properly taken into account by using a newly developed technique. The industry-standard open-short (OS) de-embedding causes error at frequencies above 30GHz, and the pad-open-short technique significantly improves de-embedding accuracy over OS and, therefore, becomes an attractive approach since it only requires one more test structure than OS. The effects of gate electrostatic-discharge protection diodes on deembedding accuracy for RFCMOS FETs are also presented and a technique is proposed that minimizes the associated errors.

Design and analysis of inductors for 60 GHz applications in a digital CMOS technology,

Karen Scheir (1,3), Piet Wambacq (2,3), Yves Rolain (1), Gerd Vandersteen (1,3), 1 Vrije Universiteit Brussel (VUB), ELEC, Brussels, 2 VUB, ETRO, Brussels, 3 IMEC, Heverlee, Belgium

RFIC designers of on-chip transceivers for 60 GHz applications face the trade-off between lumped and distributed design techniques, due to the on-chip wavelength of approximately 3 mm. This paper demonstrates that the lumped approach is favorable for realizing 60 GHz inductive components in digital CMOS technologies. Advantages in area consumption, Q-factor and the range of achievable component values are shown using simulations and measurements. Simulations of lumped inductors using the electromagnetic field solver HFSS are compared with measurements and different topologies for the lumped inductor are investigated and compared. The measurement results reveal that a planar unshielded topology yields the best inductor quality for 60 GHz circuits in a digital CMOS technology.

Evaluation of Wafer-Level LRRM and LRM+ Calibration Techniques,

Ralf Doerner, Ferdinand-Braun-Institut fuer Hoechstfrequenztechnik (FBH), Berlin, Germany

This paper presents a comparison of two well-known two-port wafer-level calibration methods, the enhanced linereflect-reflect-match (eLRRM) and the advanced line-reflect-match (LRM+) approach. Both methods are based on the seven term error model and involve self-calibration techniques. The reference impedance is established by the match standard. Therefore, accuracy is strongly influenced by the description ofthis standard. Experimental results for calibration accuracy up to 110 GHz are given.

3:20 to 4:20 PM

Session 4: Accuracy of Linear Vector Network Analysis

Nick Ridler, Session Chair

Computing Uncertainties of S-Parameters by Means of Monte Carlo Simulation,
Johannes Paul Hoffmann, Pascal Leuchtmann, Juerg Schaub, and Ruediger Vahldieck,
ETH Zurich, IFH, Zurich, Switzerland

The uncertainty of a Vector Network Analyzer (VNA) measurement is a consequence of the uncertainties both of calibration standards and the VNA. How the latter uncertainties move forward to the final measurement uncertainties is a complicated multistage process. The first stage (calibration of the VNA) essentially results in the error box terms. The nonlinear relationship between the parameters of the standards and the error box terms poses in this stage a problem. In the second stage (measurement of Device Under Test (DUT)) the uncertain error box terms are used to calculate the S-parameters of the DUT and again mix up with uncertainties of the VNA and the connectors. In this stage the correlation of error box terms amongst each other poses a second problem. It is important to note that only uncertainty distribution functions (with assumed parameters such as shape and variance) of the VNA and the standards are used to obtain predictions about the final measurement uncertainties.

One common simplification of conventional approaches in VNA uncertainty computations is that stage one formulas (which express error box terms as a function of the standards' S-parameters) are replaced by their respective Taylor expansions. Another commonly applied approximation is that computed distributions of error terms are subsequently applied to the DUT without accounting for correlation of error terms among themselves.

The goal of a good approach must be that the effects of different types of input uncertainties (e.g., transmission phase or reflection coefficient of standards) can be studied separately. Unfortunately, as a consequence of the above approximations and in contradiction to more rigorous approaches nearly the same measurement uncertainty is calculated for different types of uncertainties in the standards. Unlike traditional approaches the method presented in this paper is (1) based on Monte Carlo Simulation (MCS) and (2) does not use any simplifying assumptions to compute the measurement uncertainty. Essentially the whole calibration and subsequent measurement process is simulated a couple of ten thousand times by starting with random input values for the standards. The resulting distribution of the S-parameters of a given DUT is then analyzed using a statistics software.

This approach was particularly useful for studying different calibration techniques in conjunction with snap on connectors which show large phase and small reflection coefficient variances. The MCS makes it possible to clearly distinguish between effects of transmission phase deviations and reflection coefficient deviations.

We found that MCS is a well suited method for the computation of uncertainties in VNA calibration. In particular we make comparisons between different calibration strategies in conjunction with snap on connectors. The main outcome of the study is that it is favorable to use a calibration for 1.85 mm connectors and de-embed the used 1.85 mm to snap on connector adapters, rather than making a calibration using snap on standards.

Experienced measurement engineers mostly would have proposed this kind of calibration for a snap on connector. Our results do not only confirm these heuristic approaches but give additional hard facts and quantify the differences between selected calibration strategies.

Determination of Complex Residual Error Parameters of a Calibrated Vector Network Analyzer,
Gerd Wuebbeler (1), Clemens Elster (1), Thomas Reichel (2), and Rolf Judaschke (3), 1 Physikalisch-Technische Bundesanstalt (PTB), Berlin, 2 Rohde & Schwarz, Munich, 3 Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany

A novel technique for the determination of the residual directivity and the residual source match of a calibrated one-port vector network analyzer is investigated. The method corresponds to the "ripple extraction" schemes and is based on a single reflection measurement employing a high precision airline terminated by a short. The complexvalued residual system errors are not directly measured, but will be extracted over the entire measured frequency range by a sophisticated data analyzing scheme utilizing, among other things, bandpass filtering and linear prediction. By modeling the utilized short, also the residual reflection tracking can be estimated. Thus, in comparison with a standard SOL calibration (performed with sliding load), a VNA accuracy enhancement can be achieved by second-order error correction.

LRM: A quantitative look at reference impedance contradictions and other uncertainty impacts,
Jon Martens, Anritsu Company, Morgan Hill, CA

LRM and its derivatives have been popular VNA calibration techniques, particularly on-wafer, for many years. The quantitative effects of standards problems (line impedance issues, match issues, reflect asymmetries) have not always been well-understood including the cases where the standards present internal contradictions to the calibration. These effects will be studied here through the use of constructed measurements and simulations based on a parameter space consistent with commercial VNAs and common test situations.

4:20 to 5:00 PM

Session 5: Complex Waveform Analysis

Jan Verspecht, Session Chair

Complex Signal Measurement Bench Based on a Special Spectrum Super-Resolution Algorithm,
João Paulo Martins (1), Paulo J. S. G. Ferreira (2), and Nuno B. Carvalho (1), 1 Instituto de Telecomunicações, 2 IEETA, Universidade de Aveiro, Portugal

This paper presents a new algorithm that allows the use of non-uniform multi-sines for CAD/CAE modeling and characterization procedures. The new measurement procedure explores the narrow bandwidth of the signals used to obtain a sparsely, possibly NON-uniformly sampled representation, from which the spectral coefficients can nevertheless be accurately estimated.

A General Evaluation Criteria For Behavioral Power Amplifier Models,
David Wisell (1,2,3), Magnus Isaksson (1,2), Niclas Keskitalo (1,3), 1 University of Gävle, Dept. of Electronics, Gävle, Sweden, 2 Royal Institute of Technology, Signal Processing Lab, Stockholm, Sweden

In this paper a new goodness measure for behavioral complex envelope power amplifier models is defined in the frequency domain. The measure can be calculated for any input signal using the same formulas, which makes it general and easy to use. The results will however be dependent on the input signal. The total model error, or normalized mean-square error, for power amplifier models are normally dominated by the in-band error, often mainly caused by the linear distortion. The new measure is aimed at capturing the nonlinear modeling performance of the amplifier model. This is of interest since it is most often the nonlinear, rather than the linear, distortion that causes most harm in real-life power amplifier applications.
I.

Interactive Forum

Characterization of Low Dielectric Constant Materials,
Dietmar Köther, Uwe Gollor, IMST GmbH, Kamp-Lintfort, Germany

Materials with low dielectric constants offer great chances for applications were losses, low thermal influences and phase stability are important. One of these applications is earth observation by SAR's. Syntactic foams is a promising material but its properties with respect to homogeneity are not well investigated. A new method provides qualitative characterization with good geometrical resolution.

ANN Modeling of Synthetic Cold Loads,
Diego Langoni and Mark H. Weatherspoon, Department of Electrical and Computer Engineering Florida A&M University-Florida State University College of Engineering, Tallahassee, FL

Preliminary results are presented for artificial neural network (ANN) models of the available output noise temperature of a FET-based synthetic cold load. Two different ANNs were studied for this application: the radial basis function (RBF) and the Levenberg-Marquardt (LM) backpropagation (BP). The best average relative error (ARE) and maximum local relative error (MLRE) results for the model of incident noise temperature versus load impedance were 0.1439% and 1.1544% respectively. The best ARE and MLRE results for the model of incident noise temperature versus load reflection coefficient were 0.1810% and 1.5044% respectively.

A new technique for measuring the resonant behavior of power amplifier bias circuits,
Scott Rumery (1) and Basim Noori (2),1 Skyworks Inc. Cedar Rapids, IA,2 Freescale Semiconductor Inc. Tempe, AZ

In this paper, a new and simple technique for measuring the magnitude and phase of low frequency components of bias circuits of power amplifiers is described. The Low-Frequency probe technique is implemented to determine modulation bandwidth and low frequency behaviors of power amplifiers and is also useful in determining the resonant frequencies of peripheral components causing potential instability and oscillations. The construction, set-up and calibration of the probe are discussed and supported by simulation and measurement results.

A Study of a Variable-Capacitance Drain Network's Influence on Dynamic Behavioral Modeling of an RF PA,
Magnus Isaksson (1,2), David Wisell (1,2,3), Anders Eng (4), and Daniel Rönnow (5), 1 University of Gävle, Gävle, Sweden, 2 Royal Institute of Technology, Stockholm, Sweden, 3 Ericsson AB, Stockholm, Sweden, 4 Syntronic AB, Gävle, Sweden, 5 WesternGeco AS Asker, Norway

An investigation of the complex-valued parameters of two different dynamic behavioral models due to changes in the drain decoupling network of a PA has been performed. The study is based on complex-envelope measurements on a real PA. The complex coefficients of the parallel Hammerstein (PH) and the optimal pole placements of the Kautz-Volterra (KV) models are analyzed. It is concluded that the parameters follow smooth, predictable functions and that the KV poles give a robust description of the PA's memory effects compared with the PH model.

HiCUM and Bsim3V3.2.4 Nonlinear Behavior Validation in RF BiCMOS SiGeC 0.25µm Process for Bipolar and CMOS Transistors,
Raphael Paulin, Hélène Beckrich-Ros, Samuel Boret, Patrick Scheer, Didier Céli, Daniel Gloria, STMicroelectronics, Crolles Cedex, France

This paper deals with HiCUM [1] and BSIM3V3.2.4 [2] large signal validation. On contrary with traditional approach that deals with output signal at fundamental and harmonics frequencies [3], this study focuses on IIP1 and IIP3 figures of merit (FoM). In this way, two input power tones are injected at 2 GHz and 2.1 GHz in respect with the W-CDMA receive band. Thus, not only IIP1 could be compared between simulations and measurements, but also IIP3 due to intermodulations. This analysis is based on BiCMOS SiGeC 0.25µm process for RF bipolar and CMOS transistors measurements. On the one hand, an in-house load pull system based on Maury microwaves tuners is described. This bench is used to measure the DUTs at various bias points with source and load impedances close to 50 W. These impedances are characterized at fundamental and at carefully chosen out-of-band frequencies. On the other hand, HiCUM and BSIM3V3.2.4 simulations are compared to measurements. DC parameters and out-of-band impedances importance is highlighted. Accurate DC parameters enable obviously a right gain simulation but above all it leads to a suitable IM3 level, and thus to a precise IIP3. Moreover, it is demonstrated that H2, H3, IM2 and IM3 out-of-band impedances characterization is a necessary and

sufficient criterion to validate IIP3 FoM. Finally, it will be shown that HiCUM and BSIM3V3.2.4 models allow an accurate distortion phenomena description in terms of IIP1 and IIP3.

Noncontacting measurement of reflection coefficient and power in planar circuits up to 40 GHz,
K. Yhland, J. Stenarson, and C. Wingqvist, SP Technical Research Institute of Sweden, Boras, Sweden

This paper describes the use of loop-coupler probes for noncontacting measurement of power and reflection coefficient in microstrip circuits up to 40 GHz. The inherent directivity of the loop-coupler probe makes it suitable for use with scalar measuring instruments such as power meters and spectrum analyzers. The probe coupling and directivity and their sensitivity to probe positioning errors are investigated. The results are summarized in a simple uncertainty budget. Measurements of reflection coefficient with a vector network analyzer are also presented and verified by coaxially contacting measurements.

Analytical expression of error propagation from OSL calibration standards for RF reflection measurement,
Yufeng Han, MKS Instruments, ENI, Rochester, NY

OSL (Open-Short-Load) calibration is the commonly used technique for one-port RF reflection/impedance measurement. Generally, the calibration standards are assumed to be “perfect” or traceable to “perfect standards”. With no doubts, the imperfections on calibration standards or process of traceability will create a second-level error for measurement. Recent attempts focus on predicting the second-level error with numerical simulations. However, direct analytical expression and experimental validation have not been demonstrated yet. In this paper, analytical solution to error propagation from OSL calibration standards is derived with introducing small perturbations to these standards and using first-order approximations. It leads to sensitivity analysis for OSL calibration with imperfect standards. In order to validate the analysis, a female-to-male adapter is adopted as an error source for OSL calibration standards. By comparing the reflection measurements for the cases of calibration with/without the adapter, the analytical solution is validated experimentally.

Residual error models for the SOLT and SOLR VNA calibration algorithms,
J.Stenarson, K. Yhland, SP Technical Research Institute of Sweden, Boras, Sweden

Uncertainty calculation of vector network analyzers (VNAs) using the SOLT or SOLR calibration algorithms is often performed using residual directivity, match and tracking. In the literature the uncertainty equations are often stated without a derivation from a proper model equation. In this paper we derive the model equations for both the SOLT and SOLR calibration, the two cases do not result in the same model equation. The results are also compared to the commonly used expressions for uncertainty in the EA guidelines for VNA evaluation. For one-port measurements our results confirm the expressions in the EA guide but for two-ports there are significant differences. The symbolically derived model equations are verified using numerical simulations.

A new assessment method for the residual errors in SOLT and SOLR calibrated VNAs,
J. Stenarson, K. Yhland, SP Technical Research Institute of Sweden, Boras, Sweden

The traditional residual error assessment methods for the vector network analyzer (VNA) are improved by using measurements from both SOLT and SOLR calibrations. The difference in sensitivity to residual errors for the SOLT and SOLR algorithms is utilized to assess the residual directivity, match, and tracking of both VNA ports. A two-port measurement on an airline is used in the assessment. Even though two-port measurements are used the resulting residual errors are applicable to one-port SOL measurements as well. Compared to earlier methods, which use oneport airline measurements, the number of airline connections is reduced to one fourth. Yet the quality of the assessment is improved. The residual match is now assessed independent of the residual directivity giving a better accuracy. The residual transmission tracking, which was earlier unavailable, is also obtained. For hermaphroditic connectors such as APC-7, waveguides or probed MMIC measurements, the method will also provide the residual reflection tracking, which the traditional ripple methods fails to provide at all. The method is compared to earlier assessment methods with measurements on a calibration in type-N connectors.

Characterization of MOS varactor with Large Signal Network Analyser (LSNA) in CMOS 65nm bulk and SOI technologies,
Y. Morandini (1,2), D. Ducateau (2), J.-F. Larchanche (1), C. Gaquière (2), and Daniel Gloria (1), 1 STMicroelectronics, Crolles Cedex, France, 2 IEMN, Villeneuve d’Ascq Cedex, France

Here we report for the first time the non linear characterization and modeling of MOS varactor with a LSNA in bulk and SOI process. The comparison between large signal measurements and Harmonic Balance simulation using an electrical equivalent scheme based on small signal measurements validates the accuracy of the proposed model in this large signal conditions. Nevertheless, the capacitance behavior versus biasing voltage is depending on signal power. From this, we develop a method for capacitance extraction. We

highlight the difference of LSNA and small signal capacitance versus voltage revealing the deepth depletion with large signal conditions. Lastly, the parallel study between bulk and SOI process shows a difference on the capacitance induced by non-linearities of the substrate capacitance with large signal analysis.

Optimization of the substrate parameters for EM simulators,
F. Korndoerfer (1), F. Sischka (2), 1 IHP, Frankfurt(Oder), Germany, 2 Agilent Technologies, Böblingen, Germany

A technique for extraction and optimization of silicon substrate parameters is presented. The parameters are optimized to get the best fit between measured and simulated Sparameters for passive elements. Test structures were fabricated in a SiGe:C process with 5 metallization layers. The measurements were performed on-wafer. Loss and relative permittivity ε_r of each insulation layer is extracted and optimized separately.

The Modified Ripple Test for On-Wafer S-Parameter Measurements,
Holger Heuermann (1) and Andrej Rumiantsev (2), (1) Univ. of Applied Sciences Aachen, Germany, (2) SUSS MicroTec Test Systems, Sacka, Germany

This paper addresses the background, implementation, and the on-wafer measurement results of an automatic analysis of the accuracy of S-parameters. The classic ripple-test is automated and expanded to the use of a dispersive transmission line as a reference. Consequently, it was the first time a dispersive coplanar line was used for the ripple-test. The novel technique is illustrated through a number of examples. Numerical and measurement results have verified the proposed method. 1

An Automated LNA/PPA Characterization System,
Jean-François Nowakowski, STMicroelectronics, Crolles Cedex, France

In the competitive market of RFICs, components test plays a key role. In order to reduce the critical factor time to market, the main objective is to test the most products possible in the least amount of time, for the lowest cost and the highest accuracy. Automated tests help reaching this goal, for example for LNA/PPA measurements.

A fully automated modular test system in industrial environment has been developed for RF and I/O products. This paper presents a part of this global test system and focuses on LNA/PPA measurements capabilities. Automatic LNA/PPA setup switching, multiple die testing, automatic RF generators calibration, temperature control, automatic report generation, traceability, large modularity, enhanced accuracy, multiple instruments choice, friendly interface, re-use strategy are ones of the main features of this system.

Using this solution, the measured improvement in terms of characterization time is a factor of 5 (Noise Figure measurements), 8 (Adjacent Power Channel Ratio measurements), 16 (S-Parameters measurements), 32 (Intermodulation measurements). Increasing traceability, avoiding errors and inaccuracies, the quality of the results has been deeply increased by the way. In the future, this system will be extended to other types of RF/PLL/mixed measurements to provide complete characterization solutions in a wide spectrum of applications.

Using a Mismatch Transmission Line to Verify Accuracy of a High Performance Noise Figure Measurement System,
Ken Wong (1), Roger Pollard (1,2), Bob Shoulders (1), Lynn Rhymes (1), 1 Agilent Technologies, Inc., Santa Rosa, CA, 2 School of Electronic and Electrical Engineering, University of Leeds, Leeds, UK

To verify noise figure measurement accuracy, an amplifier fully characterized by a reference laboratory may be used. The uncertainty of such a method is quite large because amplifier noise characteristics drift with temperature and time and quite sensitive to DC bias conditions. Since the noise characteristics of a passive 2-port network are directly related to its S-parameters, its measured noise figure can be directly traceable to S-parameter measurements. Passive 2-port devices such as matched through devices, isolators and 2-port networks that simulate the mismatch characteristics of an amplifier had been proposed. It had been demonstrated that no passive devices can fully verify the wide range of noise figure measurement conditions. More recently, the preferred verification method is to use a passive two port network cascaded with an amplifier. These passive 2-port networks typically provide a limited range of mismatch conditions that the amplifier interacts with and therefore do not fully quantify the operating range of a high performance noise figure measurement system. A mismatch transmission line (Beatty Line) provides a wide range of match conditions over a very wide bandwidth. This paper demonstrates how such a device can be used to verify a high performance noise figure measurement system.

On-Wafer Time Domain Load-Pull Optimization of Transistor Load Cycle with the New Multi-Harmonic MPT Tuner,
Fabien De Groote (1), Olivier Jardel (1), Jean-Pierre Teyssier (1), Tony Gasseling (2), Jan Verspecht (3), Vince Mallette (4), Christos Tsironis (4), (1) XLIM CNRS, University of Limoges, France, (2) AMCAD Engineering, Limoges, France, (3) Jan Verspecht BVBA, Belgium, (4) Focus Microwaves, Canada

This paper describes an on-wafer measurement setup based on several state of the art features: the LSNA time domain measurement system; the new Multi-Purpose Tuner from Focus Microwaves with fundamental F0 and harmonic 2F0 and 3F0 tuning capabilities from 1.8 to 18GHz; and the so-called 'wave probe' coupling method. The combination of all these equipments allows extensive load-pull investigations with the direct view of the transistor output port load lines. The result of the 2F0 and 3F0 tuning on load lines is demonstrated on a power GaN FET up to 3.4Watts at 2.4GHz. It is also shown that different load impedances can provide the same efficiency, but with dramatically different load cycles resulting in a reduced transistor reliability.

A New Multiline TRL Calibration Technique Implemented with a Variable Phase Shifter,
J. E. Zúñiga-Juárez, J. A. Reynoso-Hernández, CICESE, Ensenada, México

By using artificial coaxial lines, synthesized with a variable phase shifter, a new multiline Thru-Reflect-Line (TRL) calibration technique for vector a network analyzer (VNA) is introduced in this paper. The main advantages of the new multiline TRL is the enhancement of the calibration frequency band for lower frequencies and the use of a phase shifter rather than different coaxial air lines.

Characterizing the 2.92 mm-Connector Airline using the Time-domain Gating Methods,
Yeou-Song (Brian) Lee, Anritsu Company, Morgan Hill, CA

Historically the performance of Anritsu precision airlines was characterized using the swept reflectometer. The worst error or uncertainty of the airline was determined based on the ripple techniques. This usually includes the effect of the connectors or defects at the interface of the connections. As the ISO Guide to the expression of uncertainty in measurement (GUM) and ISO 17025 have become popular in recent years, customers are demanding more accurate uncertainty statements for the precision airlines. Therefore, we have investigated the time-domain gating methods of vector network analyzers (VNA) to determine the performance of the precision airlines and sources of their defects. In this paper, the author will discuss the time-domain gating method setup. The experimental results will also be presented.

45 Degrees Loaded-Line Phase Shifter using Switchable Slow Wave Transmission Lines,
S. Brebels (1,2), X. Rottenberg (1,2), P. Ekkels (1,2), R. P. Mertens (1,2), and W. De Raedt (1), 1 IMEC Leuven, Belgium, 2 K.U.LEUVEN, ESAT, Leuven, Belgium

This paper presents a 45 degrees loaded-line phase shifter at 5.25 GHz using switchable slow-wave transmission lines as loading elements.

Dynamic Time-Frequency Waveforms for VSA Characterization of PA Long-term Memory Effects,
Jie Hu (1), Kevin G. Gard (1), Nuno Borges Carvalho (2) and Michael B. Steer (1), 1 North Carolina State University, Raleigh, USA, 2 Instituto de Telecomunicações, Campo Universitário, Aveiro, Portugal

This paper presents a new two-tone measurement signal with dynamic frequency characteristics for PA memory evaluation using a Vector Signal Analyser, VSA, as the instrumentation measurement tool. This new dynamic frequency waveform enables nonlinear PA characterization over frequency with a single measurement similar to what is done for sequential two-tone measurements when the tone spacing is varied over multiple different frequencies. Measurements are conducted in order to characterize a PA with memory effects manifestation. Moreover all the previous measurements capabilities that were made with a Transition Analyser are expanded here with use of a VSA. This will impose synchronization problems that will also be described on the paper.

An Innovative Waveguide Interface for Millimeter Wave and Sub-millimeter Wave Applications,
Yuenie S. Lau and Anthony Denning, OML Inc., Morgan Hill, CA

An inherent problem with waveguide interface above 110 GHz is waveguide flange misalignment. This misalignment occurs as the result of machining tolerances. Under the current MIL SPECS specified tolerances and the standard alignment pins to alignment holes method, the smaller the waveguide, the greater the relative misalignment and the greater the impact to the system electrical performance. At 680 GHz, the flange and the waveguide can be misaligned as much as a quarter (¼) wavelength - that is, half (1/2) the physical waveguide dimension.

The XML File Format as a General Solution for Measurement Data Storage and Exchange,
Jean-Pierre Teyssier (1), Fabien de Groote (1), Markus Mayer (2), Peter Schlemko (2), Andrej Rumantsev (3), Viktar Khutko (3), Roland Gesche (4), Ralf Doerner (4), 1 XLIM-IRCOM, CNRS, University of Limoges, Brive, France, 2 Technische Universität Wien, Vienna, Austria, 3 SUSS MicroTec Test Systems GmbH, Thiendorf OT Sacka, Germany, 4 Ferdinand-Braun-Institut für Höchstfrequenztechnik (FBH), Berlin, Germany

Based on the open-standard XML language, a file format devoted to measurement data is described. A draft of the file format scheme is established and a set of general rules are proposed for its sanity and its evolutions. A plan for the future in terms of support and moderation of the file format is given. Finally, we expose our ideas about some generic applications for data plotting and processing, and about the links with a database engine for the storage of huge quantities of data.

Modeling of Multi-Port Inductor Considering Mutual Components,
Takeshi Ito, Kenichi Okada, and Kazuya Masu, Integrated Research Institute, Tokyo Institute of Technology, Yokohama, Japan

This paper proposes a modeling method of multi-port onchip inductors considering mutual components. Mutual inductances in a multi-port inductor influence each other. In this paper, self and mutual inductances are derived from Sparameters by using a matrix decomposition technique. An equivalent circuit model for multi-port inductors is presented, and extracted results using measured S parameters are demonstrated. The average errors of L and Q are 2.1% and 10.0%, respectively.

An Automated 1-kHz Null-Balance Receiver for Precision RF and Microwave Attenuation Measurements and Standards,
Anton Widarta, Hitoshi Iida and Tomoteru Kawakami, National Metrology Institute of Japan (NMIJ), National Institute of Advanced Industrial Science and Technology (AIST)

An automated 1-kHz null-balance receiver for the RF attenuation measurement system based on the dual-channel intermediate frequency substitution method was constructed and examined. A commercial programmable inductive voltage divider (IVD) was applied as its attenuation reference; however, highly accurate voltage ratios were ensured by the developed voltage ratio standard system. It is shown that the uncertainties caused by the imperfect voltage ratio of the IVD were less than 0.001 dB for attenuation measurements up to 60 dB. Comparison on attenuation measurements between the proposed automated receiver and the manual accurate one, were carried out in some microwave frequencies and good agreements were obtained.

Noise Temperature Measurement Uncertainty Analysis Using Monte Carlo Simulations,
R. Joe Smith and Mark H. Weatherspoon, Department of Electrical and Computer Engineering, Florida A&M University–Florida State University College of Engineering, Tallahassee, FL

Noise temperature measurement uncertainty is analyzed for a commercial noise measurement system. The system noise equation is used with measured data sets to develop a program to determine the receiver parameter uncertainties through the use of a Monte Carlo (MC) simulation, a non-linear fitting routine, and an uncertainty extraction routine. Noise temperature uncertainty results are presented for both correlated and uncorrelated underlying uncertainties. In addition, the dependence of the noise temperature uncertainty on receiver parameter uncertainties is also explored and the most significant results are presented.