17-22 January 2021
Virtual Conference

2021 IEEE Radio & Wireless Week
96th ARFTG Microwave Measurement Symposium

Tuesday, January 19, 2021
9:45 am – 11:15 am ET

Session A: Nonlinear Measurements and Modeling

Modulation Analysis – A Novel Way to Characterize Components under Modulated Operating Conditions (Invited Talk) 40 minutes

Jan Verspecht (Keysight Technologies)

This presentation describes “modulation analysis”, a new method to accurately and efficiently characterize modulation quality at the component level as well as at the system level. In contrast with existing methods of error-vector-magnitude and noise-power-ratio, modulation error analysis does not require demodulation and can be applied to any modulation format. As a result, the new method is universal and is well suited for metrological purposes in the context of applications like 5G, 6G and aerospace. Modulation analysis provides a unified approach to the concepts of error-vector-magnitude (EVM), noise-power-ratio (NPR) and effective-number-of-bits (ENOB). The method is based on Shannon`s theorem and uses channel capacity and channel capacity density as the fundamental measurands. The analysis is based on the concept of cross-spectral density between input and output signals, whereby these signals can be analog as well as digital. As a consequence the method can be used across a wide range of applications, from individual components like amplifiers, mixers and frequency convertors, to complete receiver and transmitter systems.

Linearity Measurement of 6G Receiver with One Transmission Frequency Extender Operating at 330 GHz

Marko E. Leinonen (University of Oulu); Klaus Nevala (University of Oulu); Nuutti Tervo (University of Oulu); Aarno Pärssinen (University of Oulu)*

The future sixth-generation (6G) is envisioned to support data rates up to 1 Tbps. The operational frequencies of the 6G system will be expanded towards the sub-mmW and THz regions. The 6G systems will utilize directive beams, as well, to compensate increased signal attenuation between link ends. The linearity of a receiver (Rx) is one of the most significant parameters for any radio system. Traditional Rx linearity measurement relies on a two-tone measurement technique, which requires two dedicated RF signals and combining them to the test signal. The generation of two independent RF signals at a 300 GHz frequency band leads to a costly and bulky solution.

This paper proposes a linearity measurement method for 6G Rx, which uses only one continuous wave transmission frequency extender. A method is proposed where the RF input signal of frequency extender is narrowband amplitude modulated (AM), generating side tones around continuous wave carrier. The carrier frequency and first side tones are used as test signals, and the linearity test is like a traditional two-tone test with unequal signals. It is shown that the carrier level can be modified by back-offing the RF input power in the frequency extender input. By varying the AM modulation index, the side tones' levels can be varied, enabling the sweep of the tone input power to perform Rx linearity measurements.

Surrogate Modeling-Based Acceleration of Multi-Harmonic Near-Field Measurements

Jonas Urbonas (Maury Microwave); Haris Votsi (University of Cyprus); Alexander Shakouri (Microsanj); Peter Aaen (Colorado School of Mines)*

In this paper, a surrogate modeling-based acceleration technique for multi-harmonic phase-coherent electrooptic near-field measurements is presented. The implementation uses an adaptive sampling and modeling algorithm instead of the conventional raster scanning approach, which reduces the measurement time by a factor of 9, from 7 hours to 45 minutes, and the number of samples by a factor of 23, from 10556 to 464, while maintaining the average measurement error under 5%. The reduction in measurement time helps to preserve the accuracy of the multi-harmonic near-field measurements, as the electro-optic measurement system response can drift over time, due to thermal fluctuations in the measurement environment.

Emulation of a Multi-Stage Differential Amplifier Using One Single-Ended Device-Under-Test

Koen Buisman (Chalmers University of Technology); Jose-Ramon Perez-Cisneros (Chalmers University of Technology); William Hallberg (Qamcom IPR); Dhecha Nopchinda (Chalmers University of Technology); Peter Zampardi (Qorvo, Inc.)*

A method to emulate multi-stage power amplifier (PA) architectures is presented. The technique predicts multistage PA performance. The method is based on an iterative procedure using transistor/branch PA active load-pull measurements to include inter-stage interaction. As a benefit, real world performance of a multi-stage PA can be evaluated early in the design process. Compared to previous published work, the method requires only a single representative device-undertest to embody multi-stage architectures. Thus, a compelling measurement method for PA designers is presented. The method is demonstrated by emulating a two-stage differential amplifier at 2.14 GHz using single-tone signals.

Estimation of the Coverage Probability of S-Parameters for Safety-Critical Systems with Hotelling's T2 Distribution

*Franz G. Aletsee (Augsburg University of Applied Sciences)**

Safety-critical systems, such as medical products, industrial safety functions, or autonomous driving systems, rely not only on the knowledge of the actual system parameters, but it is imperative to also take statistic properties into account. Besides measurement uncertainties, sample variation can play an extraordinary role in the evaluation of the overall variation of a certain parameter. S-parameters are used to describe the linear behavior of high-frequency devices, such as cables. This paper focuses on the quantification of sample variation to satisfy predefined safety margins. First, statistic relations are deduced and presented. Afterwards, these results are verified by means of Monte Carlo simulations. It can be shown, that even for moderate sample sizes of about 50 observations, the Hotelling's T2 distribution needs to be used to account for the uncertainty of the sample covariance matrix estimation. These general findings are adapted to S-parameter measurements and an application based on 9 cable measurements is presented.

Wednesday, January 20, 2021
9:45 am – 11:15 am ET

Session B: Over-the-Air and On-Wafer Characterization

Uncertainty in mmWave Over-the-Air Test (Panel Session) 60 minutes

Moderated by Dylan Williams (NIST) and Kate Remley (NIST)

This panel session will address the many difficulties in evaluating the uncertainty of Over-the-Air tests. Our panel of experts will address measurement uncertainty in OTA test, how important it is, where we can cut corners, and where the current practice will have to be modified. Questions will start with whether specifications on reflection coefficients are adequate or if measurement-based mismatch corrections must be performed and progress all the way to capturing correlations in errors, treatment of systematic bias and the practicality of performing Monte Carlo analyses in complex free-field measurements.

Anomalies in Multiline-TRL-Corrected Measurements of Short CPW Lines

Gia Ngoc Phung (Physikalische Technische Bundesanstalt); Uwe Arz (Physikalisch-Technische Bundesanstalt (PTB))*

Microwave probes in on-wafer measurements contribute to a number of parasitic effects deteriorating the accuracy of multiline Thru Reflect Line (mTRL) calibrations. The accuracy of mTRL calibration is especially sensitive in Devices under Test (DUTs) of shorter line length. It has been demonstrated in previous experimental studies that the calibrated results are often only reliable as long as the length of the line is at least 2 mm. However, the reasons behind this phenomenon have not yet been clarified. Therefore, this paper reports on a systematic analysis of the dependency of the mTRL calibration accuracy on probe effects with a focus on coplanar waveguides (CPW) of shorter line length. For the first time, investigations with regard to the probe effects in shorter CPWs are presented.

Electromagnetic Field Measurements Above On-Wafer Calibration Standards

Haris Votsi (University of Cyprus); Jonas Urbonas (Maury Microwave); Stavros Iezekiel (University of Cyprus); Peter Aaen (Colorado School of Mines)*

This paper presents electromagnetic field measurements obtained above on-wafer calibration standards. The results show the complexity of calibrating in an on-wafer environment, especially at high frequencies as the fields couple to adjacent devices, resulting in the standards behaving different than expected. A vector network analyzer and an electro-optic measurement system are integrated to enable the measurement of the electric-field components above a calibration wafer between 2–26 GHz. The measured tangential electric-field component is compared to electromagnetic simulations, verifying the validity of the measurements. Both the tangential and normal electric field components capture the electromagnetic fields present within an on-wafer environment, when a coplanar-waveguide offset short structure is excited.

RF-dc Converter Optimization using MIMO Antennas and OTA Multi-Sine Calibration Method

Marina Jordao (Instituto de Telecomunicacoes, University of Aveiro); Daniel Belo (Instituto de Telecomunicacoes); Rafael F. S. (University of South Wales, Cardiff, UK, Instituto de Telecomunicações (IT), Delegação de Leiria, ESTG, Polytechnic Institute of Leiria, Portugal); Arnaldo Oliveira (Instituto de Telecomunicações, Universidade de Aveiro); Nuno Borges Carvalho (Instituto de Telecomunicacoes)*

In this paper, the optimization of the power transmitted from several non-collocated antennas to an RF-dc converter circuit is performed using an Over-The-Air (OTA) multi-sine feedback method. An experimental system is tested in an indoor environment and the OTA multi-sine calibration method is applied to produce constructive interference at the RF-dc converter location. It is shown that its overall performance is improved for different indoor positions. Experimental results demonstrate the effectiveness of using the proposed method for Wireless Power Transfer (WPT) applications since the RF-dc converter presents higher efficiency when the method is applied even in worst scenarios, such as low input power or larger distance.

Automatic Probing System with Machine Learning Algorithm

Ryo Sakamaki (National institute of Advanced Industrial Science and Technology); Masahiro Horibe (AIST)*

This paper presents a novel probe alignment system that implements machine learning methods. The developed measurement system is demonstrated at frequencies ranging from 100 MHz to 125 GHz. The measurement system measures the S-parameter with slightly shifting the probe. The S-parameter is expressed by ten trigonometric function orders using the linear least mean square method. The coefficient of each function order is used to calculate the local outlier factor (LOF). Then, the calculated LOFs are used to detect the probe touchdown, and the LOF threshold is preliminarily determined using training data. The accuracy of probe positioning was compared with that of a conventional automatic probing technique, and the difference in the probe position between the two techniques was determined to be approximately 1 μm.

Numerically Stable Digital Predistortion Model for Over-the-Air MIMO transmission

Shipra (IIT Roorkee); Meenakshi Rawat (Indian Institute of Technology, Roorkee, India)*

Digital Predistortion technique is the most economical and reliable technique among all the linearization techniques available. This paper adduces the idea of linearization based on piecewise polynomial or essential spline functions as an integral solution to the MIMO nonlinearity and compares with the Crossover Memory polynomial model. MIMO nonlinearity is strongly coupled together due to the combined effect of PA nonlinearity and crosstalk. For the proof of concept, the method is implemented over the air on 2X2 MIMO, and simulation is performed for 4X4, 8X8, 16X16 MIMO System. Numerical evaluation of the technique is exhibited in terms of NMSE, BER, and EVM., while numerical stability is presented in terms of Condition number and Dispersion coefficient.

Thursday, January 21, 2021
9:45 am – 11:15 am ET

Session C: Traceability in Calibrations and Measurement Uncertainty

Traceability and Uncertainty – What Are They? And Why Do We Need Them? (Invited Talk) 40 minutes

Nick Ridler (National Physical Laboratory)

Traceability and Uncertainty are two terms that are often encountered when discussing and describing measurements and metrology. But what do these terms actually mean, and why are they important? This talk will provide answers to these two questions.

The talk will begin by exploring the origins of traceability from the early days of commercial trading, and how traceability has evolved to enable trading to be achieved on a global scale. At the same time, an equivalent need for traceability in science, engineering and technology will show how this has led to the development of a quantum-based international system of units.

The talk will also explore the meaning of the term uncertainty, as applied to measurements. It will do this by demonstrating that uncertainty is an integral part of all measurement results. In fact, a more general way to understand and interpret a measurement result is by way of a probability distribution describing the overall state of knowledge concerning the measurand – i.e. the quantity being measured. The uncertainty is then used to help summarise the information contained in the probability distribution.

Throughout the talk, examples will be given to illustrate the concepts that are used. These will be examples drawn from everyday life as well as from various RF and microwave measurement scenarios. The talk will conclude by identifying some of the current challenges involved in applying traceability and uncertainty concepts to contemporary RF and microwave measurement situations.

Improvement of Measurement Uncertainty of THz Waveguide Vector Network Analyzers

*Masahiro Horibe (AIST)**

Even if systematic error terms, i.e. directivity, matching and tracking, in vector network Analyzer (VNA) can be corrected by a calibration process, but it is difficult to ignore the other random error effects, i.e. connection repeatability and flexure effects of cables attached to test ports, etc. In the THz waveguide VNA using frequency extension modules, LO and RF cables making connection from frequency extension modules to microwave VNA produce a large impact on the uncertainty in the transmission phase measurements. This paper proposes minimization of cable flexure effects of RF and LO cables in the THz VNA using frequency extension modules. Then, VNA error model including the LO and RF cable flexure effects are discussed.

Investigation on PIFA and Folded-IFA for TPMS Receiver

Abdellatif Bouyedda (XLIM); Bruno Barelaud (XLIM); Laurent Gineste (EXOTIC-SYSTEMS)*

This paper presents a comparative study between a printed FIFA on PCB and a PIFA integrated in a TPMS Reader. The two antennas are modelled with the enclosure and all metallic parts of the reader, and simulated using a 3D EM simulator. The designed Folded IFA has dimensions of $0.1*\lambda0x0.1*\lambda0$. Compared with the dimension of the actual PIFA $0.1*\lambda0x0.1*\lambda0x0.014*\lambda0$, the proposed miniaturized antenna has better performance than the PIFA and can reduce the volume of the device up to 50%. The simulation results are validated by the measurements performed on the prototyped readers with the two antennas. The performances of the readers are evaluated with a developed test bench based on the ADALM-Pluto SDR platform and a Raspberry PI. The readers are also tested in a vehicle equipped with TPMS sensors.

Classification of Plastic Materials using a Microwave Negative-Order-Resonance Sensor and Support-Vector-Machine

Dania Covarrubias-Martinez (CICESE); Oscar Martinez-Rodriguez (CETYS Universidad); Humberto Lobato-Morales (CICESE); Jose Medina-Monroy (CICESE)*

A method for plastic material classification using a negative-order-resonance (NOR) sensor operating at the 2.5 GHz band and support-vector-machine (SVM) for pattern recognition is presented. The proposal experimentally demonstrates the correct classification of different plastic materials based on their dielectric properties, dealing with large sources of uncertainty introduced by pellet measurements such as air gaps and position/dimension of the pellets. The proposed technique results attractive for the plastic industry as it involves a fast and nondestructive process along with the use of small circuit elements.