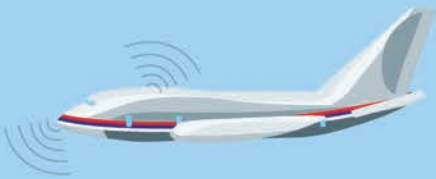


# CONFERENCE GUIDE



Electronic Design **Innovation** Conference  
Workshops & Exhibition

RF/MICROWAVE • EMC • SI



September 20-22, 2016  
Hynes Convention Center ■ Boston, MA

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## Event At A Glance

### Tuesday, September 20, 2016

- 9:30 a.m.- 12:00 p.m. .... Technical Sessions
- 12:00 - 6:00 p.m. .... Exhibition Open
- 12:30 - 6:00 p.m. .... Frequency Matters Theater Sessions (Exhibition Floor)
- 12:00 - 1:30 p.m. .... Lunch (Concessions in the Exhibit Hall open until 2 p.m.)
- 1:30 - 4:20 p.m. .... Workshops, Panels & Sponsored Talks
- 3:00 - 4:00 p.m. .... Poster Session (Exhibition Floor)
- 3:00 - 3:30 p.m. .... Coffee Break (Exhibition Floor)
- 4:30 - 6:00 p.m. .... Plenary Session, Room 302/304
- 7:00 - 10:00 p.m. .... Welcome reception for conference attendees (badge & ticket required); Fenway Park

### Wednesday, September 21, 2016

- 9:00 a.m. - 12:00 p.m. .... Technical Sessions
- 10:00 a.m. - 5:00 p.m. .... Exhibition Open
- 10:20 - 10:50 a.m. .... Coffee Break (Exhibition Floor)
- 10:30 a.m. - 5:00 p.m. .... Frequency Matters Theater Sessions (Exhibition Floor)
- 11:30 a.m. - 1:00 p.m. .... Lunch (Concessions in the Exhibit Hall open until 2 p.m.)
- 1:00 - 3:20 p.m. .... Workshops, Panels & Sponsored Talks
- 4:00 - 5:00 p.m. .... Happy Hour (Exhibition Floor)

### Thursday, September 22, 2016

- 9:00 - 11:30 a.m. .... Technical Sessions
- 9:00 a.m. - 5:00 p.m. .... RF Back to Basics Course
- 10:00 a.m. - 3:00 p.m. .... Exhibition Open
- 10:20 - 10:50 a.m. .... Coffee Break (Exhibition Floor)
- 10:30 a.m. - 2:00 p.m. .... Frequency Matters Theater Sessions (Exhibition Floor)
- 11:30 a.m. - 1:00 p.m. .... Lunch (Concessions in the Exhibit Hall open until 2 p.m.)
- 1:00 - 2:30 p.m. .... Workshops
- 2:40 - 5:00 p.m. .... Short Courses

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Tuesday, September 20, 2016

Room	201	202	203	207	208	209		
8:00 - 5:00	<b>On-Site Registration</b>							
	<b>General Technical Sessions</b>							
	<b>Signal Integrity/ Power Integrity Track</b>	<b>Modeling Track</b>	<b>RF/MW: Amplifiers Track</b>	<b>Measurement Track</b>	<b>5G/Advanced Communications Track</b>	<b>RF/Microwave Design Track</b>		
9:30 - 10:00	TU_101: Signal Integrity Characterization of 40 GHz Bulk Cable Clamp Test Fixtures (16) M. Witte, Harting KGaA	TU_102: Which Model is Best? Comparing DPD Models for Mobile Handset PA Linearization (96) B. Glass, NI	FEATURED KEYNOTE: Microwave and Millimeter Wave Power Amplifiers: Technology, Applications, Benchmarks and Future Trends (31) James Komiak, BAE Systems	TU_104: Testing Global Navigation Satellite Systems (GNSS) Devices (59) L. Wilson, R&S	TU_105: 5G Modulation Scheme Candidates - Spectrum and Modulation Measurements (47) K. Sander, R&S	TU_106: Optimizing the Analog Interface for Multi-GSPS ADC System (22) B. Sam, ADI		
10:10 - 10:40	TU_201: Practical Model of Conductor Surface Roughness Using Cubic Close-Packing of Equal Spheres (64) B. Simonovich, Lamsim Enterprises Inc.	TU_202: High-Speed and Wideband On-Wafer Load Pull for Model Extraction, Validation and Design (70) R. Hilton, Maury Microwave Corp.	TU_203: A 1-Kilowatt Power Amplifier for SAR Remote Sensing in P-Band (68) J. Walker, Integra Technologies Inc.	TU_204: Calibration and Measurement of Terahertz Applications up to 500 GHz (53) A. Paula, R&S	TU_205: Simulation of Beamforming by Massive MIMO Antennas in Dense Urban Environments (90) G. Skidmore, Remcom	TU_206: Multimode Extractor and Converter for Monopulse Tracking System for mmWave Satellite Tracking (73) A. Pandey, Keysight Technologies		
10:50 - 11:20	TU_301: Building an Algorithm in FPGA to Detect Abnormal Events in Electrical Signals (32) R. Azevedo, NI	TU_302: Conductor Profile Structure Effects on Propagation in Transmission Lines on Extremely Low Loss Circuit Laminates (82) A. Horn, Rogers Corp.	TU_303: 50 nm MHEMT Technology for Ultra-Sensitive Low Noise Amplifiers (102) P. Smith, BAE Systems	TU_304 Atomic Microwave Receiver (79) D. Stack, MITRE	TU_305: Co-Designed CMOS Based Antenna Modules for 5G Radio Nodes (55) C. Scholz, R&S	TU_306: An Introduction to Patch Antennas (39) D. Orban, Orban Microwave		
11:30 - 12:00	TU_401: A Novel Approach for Modeling and Co-Simulation of FPGA Base Package and Board (86) S. Surender, Cadence	TU_402: Easy and Effective Methods to Generate Substrate Stack-Up Files for Accurate EM Simulation (103) C. Kalluru, Keysight Technologies	TU_403: Amplifier Measurements Using Non-CW Stimulus (62) F. Ramian, R&S	TU_404: Broadband Sensing and Measurement of RF Power (23) E. Nash, ADI	TU_405: Overview of 5G: Addressing the Requirements of Next Generation Wireless Communications Systems (85) D. Hall, NI	TU_406: AlGaAs mmW PIN Diode Switch: A New Benchmark for Power Handling (15) T. Boles, MACOM		
12:00 - 2:30	<b>Lunch Break &amp; Dedicated Exhibit Time - Exhibition Floor</b>							
			<b>Workshops and Panels</b>		<b>Sponsored Talks</b>			
1:30 - 2:10			WS_TU103: GaN Power Amplifiers in Mobile Communication Systems (117) ADI	WS_TU104: Spectrally Agile RF Subsystems: Utilizing OpenRFM, a Scalable, Modular, and Interoperable Open RF Architecture (138) Mercury Systems	WS_TU105: 5G Vision and Enabling Technologies (7) Keysight Technologies	CT_TU106 (2 papers): Designing of Wideband High-Efficiency PAs Through Advanced Load-Pull Simulation (42), NI, Three Technologies That Can Make or Break Your Spectrum Monitoring System (145)		
2:20 - 3:00		WS_TU202: 3D Electromagnetics and the Validation Continuum (109) Mentor Graphics	WS_TU203: Techniques and Challenges in Designing Wideband Power Amplifiers Using GaN vs. LDMOS (122) NXP	WS_TU204: Fundamentals of Wideband Signal Generation: Going Beyond the Banner Specs (133) R&S	WS_TU205: Massive MIMO Technology Insights and Challenges (8) Keysight Technologies	CT_TU206 (2 papers): Advances in RF Design Enablement for Wireless and Wireline ICs (40), Tower Jazz & RF Technical Innovations that Improve System Signal to Noise Ratio and Reduce Intermodulation Distortion (105), IDT	<b>Exhibit Hall open 12 - 6 p.m.</b>	
3:00 - 3:30	<b>Coffee Break: Exhibition Floor</b>							
3:40 - 4:20			WS_TU303: Hybrid Beamforming for Wireless Communication Systems (129) MathWorks	WS_TU304: PCB Material Design Choices and Their Impact on Thermal Management (140) Rogers Corp.	PA_TU305: PANEL: How Will 5G Ride the mmWave? NI	CT_TU306 (2 papers): Get Ready for mmWave in Production Test (89), NI & Techniques for Extending Microwave Frequency Instruments for mmWave Measurements (136), NI		<b>Poster Session: Exhibition Floor 3 - 4 p.m.</b>
4:30 - 6:00	<b>Plenary Session: Room 302/304</b>							
7:00 - 10:00	<b>Welcome Reception for Conference Attendees (Badge &amp; Ticket Required)</b>							



Wednesday, September 21, 2016

Room	201	202	203	207	208	209
8:00 - 5:00	<b>On-Site Registration</b>					
	<b>General Technical Sessions</b>					
	<b>IoT Track</b>	<b>Signal Integrity/ Power Integrity Track</b>	<b>RF/MW Design Track</b>	<b>Modeling Track</b>	<b>Systems Track</b>	<b>Measurement Track</b>
9:00 - 9:30	WE_101: Maximizing Wireless Communications Energy Efficiency (45) E. McCune, Eridan Communications	WE_102: High-Speed Signal Integrity Measurements (52) A. Paula, R&S	WE_103: State-of-the-Art RF Design Technique for RF Switches to Maintain Near Constant Impedance When Switching RF Ports (101) M. Schrepferman, IDT	WE_104: In-Situ Antenna/Circuit Simulation for Scanned Antenna Arrays (41) J. Dunn, NI	WE_105: Planar Active Antennas: Approaches to Scaling to Higher Frequency (88) D. Carlson, MACOM	WE_106: Amplifier Testing with Envelope Tracking Technology (60) L. Wilson, R&S
9:40 - 10:10	WE_201: The IoT for Connected Soldiers & Battlefield Security (38) L. Salman, ANSYS	WE_202: DDR4 and LPDDR4 Bus Level Signal Integrity Insight (24) A. Gosselin, Keysight Technologies	WE_203: The MATRICs RF-FPGA in 180nm SiGe-on-SOI BiCMOS (97) G. Flwelling, BAE Systems	WE_204: Hierarchical Chip/System/Board Modeling With Circuit/EM Co-Simulation (43) J. Dunn, NI	TU_205: Design & Implementation of Visible Light Wireless Communication System for Audio Applications (1) A. Aboussaada, Suk Ajourmaa Higher Institute	WE_206: Wideband Satellite Component Test Challenges (21) M. Lombardi, Keysight Technologies
10:20 - 10:50	<b>Coffee Break - Exhibition Floor</b>					
	<b>IoT Track</b>	<b>Signal Integrity/ Power Integrity Track</b>	<b>RF/MW Design Track</b>	<b>RF/MW: Amplifiers Track</b>	<b>Systems &amp; SI Tracks</b>	<b>Measurement Track</b>
10:50 - 11:20	WE_301: Coexistence Testing in the World of IoT (57) L. Wilson, R&S	WE_302: Chip, Package and PCB Co-Design (111) R. Myers, Mentor Graphics	WE_303: Time Domain Gating of Microwave Component Responses Using Analog Techniques (77) T. Reeves, MathWorks	WE_304: 12 W, 2 to 18 GHz GaN on Diamond, MMIC with Embedded Cooling (99) C. Creamer, BAE Systems	WE_305: Evaluating Waveform Coexistence for 5G, Wireless and Radar Applications (11) G. Jue, Keysight Technologies	WE_306: Phase-Coherent Vector Signal Analyzer Systems for MIMO Applications (81) V. Fernandez, NI
11:30 - 12:00	WE_401: Multi Physics Simulations of an Energy Efficient IoT-Based Smart Home (37) C. Blair, ANSYS	WE_402: Leveraging SerDes Design Flows for AMI Model Development (114) T. Westerhoff, SiSoft	WE_403: Characterization and Modeling of High Q Dielectric Resonator Loaded Cavity Design for RF/Microwave Oscillators (107) E. Liang, MCV Microwave	WE_404: Designing for Maximum PA Efficiency Using CAD Transistor Waveform Optimization (118) R. Pengelly, Prism Consulting NC	WE_405: Probe Loading Effects on Common High Speed Signals (63) J. Bartlett, Tektronix	
11:30 - 1:00	<b>Lunch Break &amp; Dedicated Exhibit Time - Exhibition Floor</b>					
		<b>Workshops and Panels</b>				<b>Sponsored Talks</b>
1:00 - 1:40			WS_WE103: Practical Antenna Design for Advanced Wireless Products (44) NI	FEATURED KEYNOTE: Invisibility Cloaks and Deflector Shields: Disappearing at Microwave's Frontiers (135) Nathan Cohen, Fractal Antenna	WS_WE105: The Communication System Architect's Guide to 5G Physical Layer Modeling (9) Keysight Technologies	CT_WE106 (2 papers): Next Generation Interconnect Cabling (95), Southwest Microwave & Simulation Apps Provide Unlimited Ways to Optimize Numerical Models (139), COMSOL
1:50 - 2:30		WS_WE202: Overcoming the Evolving Test and Measurement Requirements of IoT Devices (143) Copper Mountain	WS_WE203: Fundamentals of Vector Network Analyzers (126) R&S	WS_WE204: From Wave-Based Load-Pull to Behavioral Nonlinear Models (123) ElectroRent	WS_WE205: A Flexible Testbed for 5G Waveform Generation & Analysis (10) Keysight Technologies	CT_WE206 (2 papers): A Programmable Delay Line? What's That? (127), Colby Instruments & Non-Linear and Noise Modeling of a 0.15um GaN Die Family (20) Modelithics Inc.
2:40 - 3:20		WS_WE302: Test Solutions (141) Mini-Circuits	WS_WE303: Minimizing Uncertainty in Noise Figure Measurements (80) NI	PA_WE103: Panel: Not Your Father's Oldsmobile: The Connected Car (144)	WS_WE305: 5G mmWave MIMO Channel Sounding (12) Keysight Technologies	CT_WE306 (2 papers): Crest Factor as a Figure of Merit for Communication Amplifiers (150), Wireless Telecom Group and Additive Manufacturing Techniques for the Production of RF Components (151) Microwave Development Labs
3:30 - 4:10	<b>Dedicated Exhibition Time</b>					
4:00 - 5:00	<b>Happy Hour - Exhibition floor</b>					
5:00 - 8:00	<b>Geek A Palooza Reception (separate registration required) <a href="http://www.ediconusa.com/registration.asp">www.ediconusa.com/registration.asp</a></b>					

Exhibition 10:00 a.m. - 5:00 p.m.



Thursday, September 22, 2016							
Room	200	202	203	207	208		
8:00 - 3:00	<b>On-Site Registration</b>						
	<b>All Day Seminar</b>	<b>RF/Microwave Design Track</b>	<b>Measurement Track</b>	<b>Radar/Defense Track</b>	<b>Signal Integrity/Power Integrity Track</b>		
9:00 - 9:30	RF BACK TO BASICS Seminar, Keysight Technologies (Separate Registration Required)	TH_102: Reaching New Heights in Mixer Linearity with GaN MMIC Technology (115) C. Trantaniella, Custom MMIC	TH_103: Impact of Test Equipment Calibration on Power Amplifier Characterization (34) D. Chheda, Keysight Technologies	TH_104: Advances in Kilowatt UHF Radar Power Amplifiers With RF GaN Transistors Operating at 150 V (17) J. Walker, Integra Technologies	TH_105: How to Evaluate the Signal Integrity Performance for Your High Bandwidth Real-Time Oscilloscopes (30) A. Gosselin, Keysight Technologies		
9:40 - 10:10		TH_202: Software Controlled Narrowband Tunable Bandpass Filters for UHF Receivers (74) Y. Yigit, ASELSAN Inc.	TH_203: Simplifying Phase Coherent Signal Generation (58) L. Wilson, R&S	TH_204: 24 GHz Radar Technology Enable Next Generation Sensors (18) P. Walsh, ADI	TH_205: Using VNAs as a Tool for Signal Integrity in High Speed Digital Systems (35) J. Mallon, Anritsu		
10:20 - 10:50		<b>Coffee Break - Exhibition Floor</b>					
11:00 - 11:30			TH_303: Considerations for ADC Testing (61) L. Wilson, R&S	TH_304: Automotive Radar Systems - Radio Testing in the E-Band (50) K. Sander, R&S	TH_305: Modeling Ferromagnetic Components in Voltage Regulation Modules (VRM) (3) C. Warwick, Keysight Technologies		
11:30 - 1:00	<b>Lunch Break &amp; Dedicated Exhibition time - Exhibition Floor</b>						
		<b>Workshops &amp; Short Courses</b>					
1:00 - 1:40	RF BACK TO BASICS Seminar, Keysight Technologies (Separate Registration Required)	WS_TH102: Introduction to 802.11ax: High Efficiency Wi-Fi (83) NI	WS_TH403: A Single EM Simulation Tool for Integrating the Many Aspects of New Electronics Product Design (125) CST	WS_TH404: Highly Integrated Antenna Front-End Design for Radar, SATCOM and 5G (116) ElectroRent		<b>Exhibition 10:00 a.m. - 3:00 p.m.</b>	
1:50 - 2:30		WS_TH202: From VHF to Ka-Band: LTCC, A Suitable Yet Challenging Technology for Both Passive and Active Components (142) Mini-Circuits	WS_TH503: Electromagnetic System Modeling - Concept and Reality (66) ANSYS	WS_TH204: Analyzing Wideband Signals in mmWave Bands (134) R&S			
2:40 - 3:20		SC_TH602: Intuitive Microwave Filter Design With EM Simulation (36) D. Swanson	SC_TH603: Radiated Emissions - Product Evaluation and Pre-Compliance Testing (67) K. Wyatt	SC_TH604: Basics, Advances & Breakthroughs in Phased-Arrays, Radar and MIMO (121) E. Brookner	SC_TH605: Fundamentals of Power Integrity (106) S. Sandler & H. Barnes		

Details in this conference matrix were correct at the time of going to press. They are subject to change. For up-to-date information visit [www.ediconusa.com](http://www.ediconusa.com).



▼ Tuesday, September 20, 2016 ■ 9:30 - 10:00 ▼

## Technical Sessions

**Signal Integrity/Power Integrity Track****Room: 201****Signal Integrity Characterization of 40 GHz Bulk Cable Clamp Test Fixtures****Markus Witte, HARTING KGaA**

High quality digital channels require the passive copper media to be high performance in order to realize the data rates of next generation standards. At today's signal speeds this can only be achieved using high quality pre-production simulation and optimization which demands high quality models of each part of the channel. Cable models should be based on measurements for best accuracy, but de-embedding cables from a measurement including connectors or fixtures is very challenging. However, the authors would like to propose a new method of directly measuring the raw bulk cable signal integrity properties with the use of a detachable fixation of the wires on a high performance PCB.

**Modeling Track****Room: 202****Which Model is Best? Comparing DPD Models for Mobile Handset PA Linearization****Brian Glass, National Instruments**

With the increasing peak-to-average power ratio (PAPR) of modern communications signals like LTE-Advanced and 802.11ac, engineers face an increasing need to linearize handset power amplifiers (PAs) using digital predistortion (DPD). Some of the most common DPD models for PA linearization include the memoryless lookup table (LUT), memory polynomial model (MPM), and generalized memory polynomial model (GMP). When considering each of these models, engineers must make careful tradeoffs between computational complexity, test time, and resulting performance for a particular PA. In this paper, we will compare and contrast each implementation and evaluate these trade-offs for PA characterization and production test.

**RF/MW: Amplifiers Track****Room: 203****Featured Keynote: Microwave and Millimeter Wave Power Amplifiers: Technology, Applications, Benchmarks, and Future Trends****James Komiak, BAE Systems Electronic Systems**

Solid state transistor device technology is ubiquitous in communications, radar, electronic warfare, and instrumentation applications. This presentation will cover Si LDMOS, PHEMT, InP HEMT/MHEMT and GaN HEMT. Content includes principles of operation, structures, characteristics, classes of operation, and device state-of-the-art benchmarks. The art of power amplifier design is approached from a historical perspective. Power amplifiers utilizing these device technologies covering UHF through sub-millimeter wave are described. Future trends are highlighted and summarized.



**Measurement Track****Room: 207****Testing Global Navigation Satellite Systems (GNSS) Devices****Lawrence Wilson, Rohde & Schwarz Inc. USA**

Devices enabled with Global Positioning System (GPS) are becoming increasingly more common, and the range of applications is mind-blowing, from aircraft, to tractors to wearable technology. These devices are meant to be on the move, resulting in operational environments that are hard to predict. For the engineers responsible for getting these products to market, this means developing test scenarios that include many of the real world conditions that the receiver will face, such as multi-path effects, fast moving trajectories, etc. This paper will discuss these different testing models and how they vary between R&D and Production.

**5G Advanced Communications Track****Room: 208****5G Modulation Scheme Candidates - Spectrum and Modulation Measurements****Kay-Uwe Sander, Rohde & Schwarz GmbH & Co. KG, Munich**

While LTE has been established as the number one global cellular standard, many international research projects have started on the fifth generation (5G) wireless communications technology. A key topic under discussion are new modulation schemes for the radio interface which are more agile and provide a higher spectral efficiency than existing standards. The modulation schemes under investigation include universal filtered multi-carrier (UFMC), generalized frequency division multiplexing (GFDM) and filter bank multi carrier (FBMC). As part of the research process, the spectral behavior and modulation quality of these modulation schemes must be tested over the air interface and through radio frequency components such as mixers, filters or amplifiers to validate theoretical emulations. This paper gives an overview of some 5G modulation scheme candidates and introduces a possible test solution consisting of a signal generator and a spectrum analyzer to investigate the modulation scheme candidates in terms of spectrum and modulation quality.

**RF & Microwave Design Track****Room: 209****Optimizing the Analog Interface for Multi-GSPS ADC System****Benjamin Sam, Analog Devices**

In traditional receiver signal chains, the downconverted signal is typically digitized by an ADC at a low IF or at baseband. As carrier bandwidths continue to increase, the IF bandwidth goes up accordingly, and often the signal is being sampled directly at RF. In order to maximize the signal-to-noise-and-distortion ratio (SINAD) of the digitized signal, utmost attention must be paid to the design of the amplifiers and interface circuits between the ADC and the RF signal source. This paper describes techniques in optimizing a number of parameters, including system gain, common-mode level, AC vs. DC coupling, impedance matching and filtering, to achieve the best possible dynamic range for the data acquisition system. These aspects are illustrated through the design of a Giga-sample per second ADC System, and the resulting performance is presented.

**▼ Tuesday, September 20, 2016 · 10:10 - 10:40 ▼****Signal Integrity/Power Integrity Track****Room: 201****Practical Model of Conductor Surface Roughness Using Cubic Close-packing of Equal Spheres****Bert Simonovich, Lamsim Enterprises Inc.**

In the GB/s regime, accurate modeling of conductor losses is a precursor to successful high-speed serial link designs. In this paper, a practical method for modeling conductor surface roughness is presented. Obtaining the roughness parameters solely from manufacturers' data sheets, conductor loss can now be accurately predicted from first principles. By using a cubic close-packing of equal spheres model, the radius of the spheres and area of the multi-sphere tiled base are determined then applied to the Huray "snowball" model. A case study using FR408HR material with reverse treated copper foil is used to validate the model's accuracy to 50 GHz.

**Modeling Track****Room: 202****High-Speed and Wideband On-Wafer Load Pull for Model Extraction, Validation and Design****Richard Hilton, Maury Microwave Corp.**

Load pull is an essential tool in the large-signal characterization of high-frequency devices, in that it can be used to determine the optimal loading conditions of the device under test (DUT) for common large-signal parameters (e.g. gain, output power, power added efficiency). However, common passive and active load pull techniques are highly demanding in measurement time, especially when it is desired to monitor and control multiple parameters simultaneously (fundamental and harmonic terminations, multiple input power levels, multiple biases). This is usually reflected in extremely long measurement times and slows-down the PA design/optimization process. In addition, consumer demand for streaming content, video conferencing and nonstop cellular usage has led to the development of complex modulation schemes with progressively higher operating bandwidths. The latest technologies utilize handsets and base stations requiring tens or hundreds of MHz of instantaneous bandwidth. This bandwidth requirement puts a heavy stress on the power amplifiers which lie at the heart of both handsets and base stations. Amplifier designers must take special care when designing matching networks, shifting their design from CW or two-tone device characterization to realistic mobile communications (such as LTE) device characterization. Amplifiers must be simultaneously optimized for power, efficiency, ACPR and EVM. In this paper, we demonstrate a mixed-signal active load pull approach that reduces hours of measurements to just minutes in single-tone CW and pulsed-CW operation, and enables instantaneous wideband impedance control up to 240 MHz for modulated load pull operation.

**Modeling Track****Room: 202****A 1-Kilowatt Power Amplifier for SAR Remote Sensing in P-Band****John Walker, Integra Technologies**

A 2-stage 40dB gain 1 kilowatt transmitter pallet for remote sensing synthetic aperture radar (SAR) applications in P-band from 420 MHz to 450 MHz is presented. The unique feature of this paper is the use of GaN transistors operating from a 75V drain bias. All commercially-available GaN transistors operate from 60V or less drain supply, but using 75V increases the load impedance at the fundamental and reduces the output capacitance which enables the optimum impedance to be presented to the FET at the harmonics even at kW power levels. As a consequence, we report 75% minimum power-added efficiency from a two-stage amplifier across the entire 420-450 MHz bandwidth under 100 $\mu$ s with 10% duty cycle conditions. This is 15% higher efficiency than is typically achieved with traditional TWT implementations.

**Measurement Track****Room: 207****Calibration and Measurement of Terahertz Applications Up to 500 GHz****Anja Paula, Rohde & Schwarz GmbH & Co. KG**

A challenge in characterizing mm-wave components and systems is to perform precise S-parameter measurements – despite the effect of the movement of test cables and frequency converter modules during calibration and measurement, in particular for multiport DUTs. This paper focuses on fundamental methods to reduce these effects by choosing the appropriate calibration and measurement solution for frequencies beyond 170 GHz. The impact of the chosen parameter description of the calibration standards will also be shown.

**5G Advanced Communications Track****Room: 208****Simulation of Beamforming by Massive MIMO Antennas in Dense Urban Environments****Greg Skidmore, Remcom, Inc.**

This paper presents a new predictive capability for simulating massive MIMO antennas and beamforming in dense urban propagation environments. 5G Advanced Communication includes massive MIMO, a term for large antenna arrays that allow base stations to use beamforming techniques to provide data streams to multiple users within the same frequency band in a small cell. However, applying these techniques successfully in urban environments is complex due to the large amount of multipath, and traditional tools and methods for channel modeling and network planning are simply unable to predict many of the key channel characteristics for MIMO antennas. To overcome these shortfalls, we present an approach for efficiently simulating the detailed multipath of large numbers of MIMO channels using ray-tracing, while overcoming the limitations and computational complexity of traditional ray-tracing methods. Our study uses this new model to predict the complex channel characteristics between a massive MIMO base station and several mobile devices within an urban small cell with significant multipath. This is followed by analysis using techniques such as maximum ratio transmission (MRT) and zero-forcing (ZF) beamforming to predict the ability of beamforming to transmit data to multiple users, including a scenario to predict the impact of pilot contamination from a mobile device in a neighboring cell. The capabilities of this unique approach allow us to not only predict the signal-to-interference-plus-noise ratio (SINR) at specific device locations, but also the actual physical beams formed using these techniques, including unintentional distortions caused by pilot contamination. The results provide new insight into some of the key problems and complexities faced by massive MIMO systems, and demonstrate a new simulation approach that can be used for channel modeling studies and virtual assessment of new concepts.

**RF & Microwave Design Track****Room: 209****Multimode Extractor and Converter for Monopulse Tracking System for mmWave Satellite Tracking****Anil Pandey, Keysight Technologies**

This paper presents the design of a unique multimode extractor and converter of higher order modes of a circular waveguide. The multi-mode extractor couples first five circular waveguide propagation modes TE<sub>11</sub>, orthogonal TE<sub>11</sub>(o), TM<sub>01</sub>, TE<sub>21</sub>, and TE<sub>21</sub>(o) that includes the three tracking signals (i.e. sum signal, elevation signal, and azimuth signal) used in a high-frequency monopulse tracking system and two communication channels for transmitting and receiving signal at Ka band. This design is based on amplitude and phase characteristics of the higher-order modes TM<sub>01</sub>, TE<sub>21</sub>, and TE<sub>21</sub>(o) excited in circular waveguide. TE<sub>21</sub> and TE<sub>21</sub>(o) modes are extracted from circular waveguide to TE<sub>10</sub> mode in rectangular waveguide by two longitudinal slots milled in the circular waveguide. TE<sub>11</sub> mode is coupled using two coupling slots and H-plane power combiner. A turnstile junction is used to extract TM<sub>01</sub> and TE<sub>11</sub>(o) mode. This multimode tracking system is designed both for linear or circular polarized ground earth station antennas to track orbiting satellites.

▼ Tuesday, September 20, 2016 · 10:50 - 11:20 ▼

**Signal Integrity/Power Integrity Track****Room: 201****Building an Algorithm in FPGA to Detect Abnormal Events in Electrical Signals****Renan Azevedo, Engineer at National Instruments | Researcher at Instituto Federal de São Paulo**

This paper presents the development of an algorithm in FPGA based on a statistical correlation technique to create an automatic system to detect abnormal events in electrical signals. The implementation of this technique can be considered a first step in the development of high-performance digital oscilloscopes with the possibility of expanding its functionality. This research was chosen due to the increasing occurrence of unwanted events in electrical signals, mainly due to the high integration of transistors on integrated circuits. These occurrences can cause failures in products after its market launch due to oscilloscopes which do not have an architecture that allows it to capture one hundred percent of the events during the phase of validation and testing. This is because all oscilloscopes have a time slot known as dead time, in which the instrument is unable to detect any signal due to the performance of tasks related to the processing and display of data on the screen. Based on these challenges, this work presents an alternative for dealing with a signal integrity test through an algorithm implemented in FPGA, which resulted in the detection of random events during the laboratory tests. In the end of the paper the challenges encountered during the development stage are presented, particularly in relation to the difficulty in scheduling a sufficient optimized code for this type of application, in order to ensure that the FPGA chip has hardware resources necessary to reproduce the expected operation of the system. Finally, some limitations of the work are explained for the development of future research.

**RF/MW: Amplifiers Track****Room: 203****Conductor Profile Structure Effects on Propagation in Transmission Lines on Extremely Low Loss Circuit Laminates****Allen F. Horn, Rogers Corporation**

Designers of high frequency electrical devices have long known that conductor surface roughness affects loss. Earlier correlations such as those of Morgan and Hammerstand & Jensen under predict insertion loss by a large margin at higher frequencies and on narrower transmission lines where conductor effects dominate. The present work experimentally demonstrates that the recent Hall-Huray “snowball” model and the Sonnet conductor loss correlation correctly predict the shape of the insertion loss versus frequency curve up to 110 GHz over a wide range of copper profiles. Quantitative agreement, however, requires empirical adjustment of the SA ratio, snowball radius or RMS roughness. “Rolled” copper foil, as well as some experimental ED foils exhibits conductor loss that approaches that of theoretically smooth foil. We also demonstrate that the “nodular roughness” characteristic of the treated side of copper foil has a much larger effect on loss and propagation constant than the roughness of the untreated side of reverse-treated foils. The effect of several circuit finishes is also measured.

**RF/MW: Amplifiers Track****Room: 203****50nm MHEMT Technology for Ultra-Sensitive Low Noise Amplifiers****Phillip Smith, BAE Systems**

Metamorphic high electron mobility transistors (MHEMTs) with short gates and high indium mole fraction channels have demonstrated the lowest noise figures of any room-temperature technology at millimeter-wave frequencies. 50nm gate-length MHEMT MMIC low noise amplifiers (LNAs) with state-of-the-art performance are reported. A 3-stage LNA exhibits noise figure (NF) as low as 1.6 dB with 25 dB gain at 80 GHz, and also shows unprecedented wideband performance, covering the 45-90 GHz band with NF of 2 dB average, 2.4 dB max and  $25 \pm 1$  dB gain. Similarly, a 4-stage 50 nm MHEMT LNA designed for G-Band operation has demonstrated record noise figure of 3 dB at 183 GHz. Other important characteristics of these MMIC LNAs will be presented, including integration into waveguide modules (performed by Millitech, Inc. and Virginia Diodes, Inc.) as well as input power survivability and the behavior of gain and NF over temperatures ranging from  $-20^{\circ}$  to  $+50^{\circ}\text{C}$ .

**Measurement Track****Room: 207****Atomic Microwave Receiver****Daniel Stack, MITRE**

Weak microwave frequency electromagnetic fields can be difficult to detect and fully characterize with traditional methods. However, it is possible to transduce the measurement of these fields from the microwave domain to the optical domain via resonant transitions in atomic systems probed by lasers. This technique allows for very sensitive and accurate measurements of the microwave field amplitude, polarization, and spatial waveform with laser precision as compared to measurements performed with dipole antennas. An atomic system can make millions of independent and coherent measurements of microwave frequency signals at specific atomic resonances, thereby increasing signal sensitivity. Atomic sensors have already demonstrated tremendous accuracy and precision for measuring important quantities: time, acceleration, rotation, magnetic field, etc. Highly-excited (Rydberg) neutral atoms have very large electric-dipole moments and many dipole-allowed transitions from RF to THz frequencies. It is possible to sensitively probe the electric field in this range using the combination of two quantum interference phenomena: electromagnetically induced transparency and the Autler-Townes effect. This technique allows for very sensitive field amplitude, polarization, and subwavelength imaging measurements. These quantities can be extracted by measuring properties of a probe laser beam as it passes through a warm rubidium vapor cell. Thus far, Rydberg microwave electrometry has relied upon the absorption of the probe laser. We report on our use of polarization rotation, which corresponds to the real part of the susceptibility, for measuring the properties of microwave frequency electric fields. Our simulations show that when a magnetic field is present and directed along the optical propagation direction a polarization rotation signal exists and can be used for microwave electrometry. The central advantage in using the polarization rotation rather than absorption is that common mode laser noise is eliminated leading to a potentially dramatic increase in signal-to-noise ratio.

**5G Advanced Communications Track****Room: 208****Co-Designed CMOS Based Antenna Modules for 5G Radio Nodes****Chris Scholz, Rohde & Schwarz Inc. USA**

Millimeter-wave digital remote radio units (RRU) will be essential for the future of 5G networks. In this session, we will demonstrate compact co-designed modules using CMOS, PCB, antenna and a standard manufacturing and verification flow. A full duplex, 2 Gbps bistatic link has been developed, and the following parameters will be reviewed: transmitter chain, received power, spectral measurements, half-power beamwidth and complete link budget. The digital mm-wave radio platform supports point-to-point and point-to-multipoint RRU architectures that enable complete gigabit wireless links at 1/meter.

**RF & Microwave Design Track****Room: 209****An introduction to Patch Antennas****Dan Orban, Orban Microwave Inc.**

With its low planar profile, versatility and ease of production, it is no surprise that the patch antenna is one of the most widely used radiating structures used in the industry. For this reason, it is advantageous for technologists of all stripes to have a basic knowledge of this important class of antennas. Therefore, by means of an illustrative, qualitative description, we present the basic functionality and design rules for patch antennas for radiating linear or circularly polarized waves. We give insight on example antenna structures, oscillating modes, feed methods as well as methods for tuning the antenna gain and feedpoint impedance. To enhance understanding, we present these discussions using a minimum of cumbersome mathematics and a maximum of compact intuitive physical illustrations. In this manner, we hope that attendees will come away with an understanding that permits them to confidently discuss antenna design requirements as well as possibly to attempt basic designs themselves, should the need arise.

**▼ Tuesday, September 20, 2016 · 11:30 - 12:00 ▼****Signal Integrity/Power Integrity Track****Room: 201****A Novel Approach for Modeling and Co-Simulation of FPGA Based Package and Board****Surender Singh, Cadence Design System**

Field programmable gate array (FPGA) circuits play a significant role in most major embedded process control designs of recent times. FPGA based organizations do not provide an IC package and models files to the customers; instead, they typically provide only the pin delay report in a comma-separated file format. Most simulation tools do not consider this file format while performing analysis and simulation. If IC package layout and model files are missing, simulation tools do not consider the package delay in package board co-simulation. In this paper a methodology is proposed that considers package delay in the absence of real package models in board, package co-simulation. Spice model of the package is created which is close to the real model of the package and tested in a high-speed FPGA base board. The real package model results are compared with the proposed model results.

**Modeling Track****Room: 202****Easy and Effective Methods to Generate Substrate Stack-up Files for Accurate EM Simulation****Chan Basha Kalluru, Keysight Technologies**

This presentation describes the use of an electromagnetic (EM) simulator for passive circuit modelling and analysis. Accurate EM simulation enables RF/MMIC designers to improve design performance and increase confidence that the manufactured product will meet specifications. One of the key inputs for EM simulator is the substrate stack-up file. The designers usually spend their time to manually create stack-up files. This manual creation of stack-up files is time consuming, increase the chances of errors creeping in and thus has impact on the overall design cycle. We discuss how the automated solution helps to create an accurate substrate stack-up files in Keysight Momentum-Virtuoso flow and comparison of various passive devices (spiral inductors, MIM & MOM capacitors) we show EM results against foundry measurement data.

**RF/MW: Amplifiers Track****Room: 203****Amplifier Measurements using non-CW Stimulus****F. Ramian, Rohde & Schwarz**

Typical amplifier measurements include gain, compression, and distortion as well as further standard specific measurements such as ACLR, or EVM. In this paper, we show a method that performs most amplifier measurements by just using a vector signal analyzer (VSA) along with a vector signal generator (VSG) combination. By knowing exactly the transmitted signal, i.e. the signal being transmitted from the VSG, the analysis part can exactly determine the characteristics of the DUT. This method does not only allow a fast and easy measurement of gain and distortion parameters, but also unveils how the amplifier behaves under real world conditions. AM/AM conversion plots of the same device taken with a CW stimulus will look completely different than the one taken with an LTE signal as stimulus. If your amplifier was designed for LTE – the differences might be of interest. In addition, deriving all relevant parameters from a single measurement saves a significant amount of test time.

**Measurement Track****Room: 207****Broadband Sensing and Measurement of RF Power****Eamon Nash, Analog Devices**

RF detectors are functionally simple devices that are typically used to measure RF power. For example, by combining an RF detector with a directional coupler and an ADC, the output power of an RF transmitter or signal generator can be measured. Dual RF detectors can be used to measure gain or return loss. Because of their logarithmic transfer function, the output signals from log amps or linear-in-dB RMS detectors can be simply subtracted from one another to measure return loss (where one detector is sensing forward power and the other is sensing reverse power. However careful level planning is needed to ensure the forward and reflected signals are within the range of the detector). A broadband 1 W surface-mount dual detector with an integrated broadband directional bridge circuit will be presented along with the challenges and considerations for using such a device (S11, S22, insertion loss, directivity). Circuits and results will be presented which demonstrate a fast response time (<20 ns) and good flatness vs frequency over a wide frequency range.

**5G Advanced Communications Track****Room: 208****Overview of 5G: Addressing the Requirements of Next Generation Wireless Communications Systems****David Hall, National Instruments**

From 1G to 4G, requirements such as better voice coverage and mobile broadband significantly pushed the technical capabilities of mobile communications systems. Going forward, 5G is evolving based on a new set of requirements. Megatrend realities (such as the IoT and mobile broadband) are pushing 5G requirements into an increasingly diverse set of requirements. In this presentation, we explain the technical requirements driving 5G, and show how technologies such as massive MIMO, millimeter wave communications, and multi-RAT systems will address them. In addition, we provide an update on the 5G standardization process – providing an overview of the physical layer characteristics of the first and second of 5G deployments.

**RF & Microwave Design Track****Room: 209****AlGaAs mmW PIN Diode Switch: A New Benchmark for Power Handling****Timothy Boles, MACOM Technology Solutions**

Monolithic microwave integrated circuits (MMICs) based on high power PIN diodes are increasingly used for many transmit/receive systems in advanced defense electronics and telecommunications applications. Examples of such systems include radar, half-duplex data links, Internet-protocol-based (IP-based) wireless LANs, and millimeter-wave imagers. For such applications, switches are required to have high power handling, low insertion loss, good matching, fast switching, and, for non-reflective switches, good return loss in off state. This power handling requirement becomes especially challenging as the frequency of operation of the various systems moves from microwave bands into the realm of millimeter waves. While the use of bandgap engineering has been widely applied to bipolar transistors fabricated in elemental silicon and group IV materials, i.e. SiGe, SiC, SiGeC, etc.; and III V compounds, i.e. GaAs, AlGaAs, InGaAs, InGaP, InP, etc., the application of this technology to high frequency, microwave, and mmW diode structures was largely ignored. The development of the heterojunction AlGaAs/GaAs PIN diode is one of those rare improvements. It is the first reported application of a wide bandgap heterojunction used in place of a conventional p n junction, contained in a PIN diode structure that not only enhances the diode RF and microwave performance, but with no trade-off in any other characteristic. The heterojunction AlGaAs/GaAs PIN diode structure was first introduced in 2001 and has found applications in control functions from RF to microwave and continuing up to high mmW frequencies, i.e. 50 MHz to 110 GHz. Prior to this work, the power handling limit for this basic technology ranged from 250 milliwatts to a few watts of RF energy with the maximum being constrained by the functionality and design of the specific MMIC circuit and the frequency of operation. This paper discusses approaches and modeling techniques using AlGaAs/GaAs PIN diodes that demonstrate the possibility of a switch to reliably handle >40 watts of RF power at mmW frequencies. This work will set a new benchmark for loss, isolation, power handling and operational frequency capability.

**▼ Tuesday, September 20, 2016 · 1:30 - 2:00 ▼****Frequency Matters Theater Session****Room: Frequency Matters Theater****Forensic Analysis of Closed Eyes: Debug Techniques****Eric Bogatin, Teledyne LeCroy Signal Integrity Academy**

If you design your product correctly, it's supposed to work the first time. But what if it doesn't? That's when debugging and troubleshooting skills come in. The first step is to find the root cause of the problem and then fix it at the source. But in an Ethernet, high speed serial link, operating at 10 Gbps, for example, if your eye is completely closed, what can you do? In this session, we'll look at some tried and true debug techniques to quickly find the root cause of common problems in high speed serial links when the eye is closed. What are the clues you look for to identify problems with the measurement set up or problems with the clock source? We'll round up the usual suspects and show examples of how to interrogate them to find the guilty party.



▼ Tuesday, September 20, 2016 · 1:30 - 2:10 ▼

## Workshops and Panels

**Workshop****Room: 203****GaN Power Amplifiers in Mobile Communication Systems****Kagan Kaya, Analog Devices**

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The requirement for higher output power and longer operation time in mobile communication systems, drives up the demand for more efficient products. Designing systems with increased efficiency and higher output power is a never ending process in the RF world. With its process inherent high power density and increased power added efficiency (PAE), GaN amplifiers can bring the operating time of mobile communication systems into the next level. Analog Devices has developed a selection of GaN power amplifiers to address the requirements of various communication systems. GaN amplifiers providing higher output power levels with increased efficiency and reduced size, require higher bias voltage levels than what mobile communication systems usually have readily available. This workshop provides an example study of how to build practical biasing circuits, with existing power management products from ADI, to meet the biasing requirements for GaN power amplifiers.

**Workshop****Room: 207****Spectrally Agile RF Subsystems: Utilizing OpenRFM, a Scalable, Modular, and Interoperable Open RF Architecture****Alton "Lorne" Graves, Mercury Systems**

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Today's smartphones and tablets have provided users with "fused data" or information for just about any purpose. We have voice communications, navigation, and video at our fingertips. The new generation of DoD systems will be required to provide the same level of actionable information to the warfighter. The reliability and ruggedness for the systems must remain extremely high. However, the lessons from the commercial world must be applied to achieve the demands of the government's Better Buying Power 3.0 initiative and respond to constantly evolving threats. To achieve systems that are multi-function we have to scale from large platforms such as maritime platforms like the Arleigh Burke class destroyers to ground based vehicles like the Joint Light Tactical Vehicle. We must have a modular approach to allow seamless retrofits to systems as technology advances and matures. Lastly, we must have interoperable sensors across the various platforms to provide a true "plug and play" environment not a "plug and pray" environment. Mercury Systems will describe how the OpenRFM RF Architecture meets all of these demands from the HW to the SW. The brief demonstration will show an Intelligence Surveillance and Reconnaissance asset rapidly reconfigured via software to an electronic warfare asset.

**Workshop****Room: 208****5G Vision and Enabling Technologies****Roger Nichols, Keysight Technologies**

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The exact definition of 5G cellular technology is not yet clear, but it is envisioned to address the demands of a fully mobile and connected society. The market outlook is based on some aggressive projections including massive growth in demand for mobile data; exploding diversity of wireless applications; and exponential increase in the number of connected devices, resulting in very diverse and sometimes extreme requirements on the network. This workshop will provide an overview of the 5G vision and discuss key differences from 4G, some of the new candidate technologies - both evolutionary and revolutionary, the latest 5G market activities, and deployment timeline. It will conclude with a summary of design and measurement challenges and solutions.



▼ Tuesday, September 20, 2016 · 1:50 - 2:10 ▼

**Sponsored Talk****Room: 209****Designing of Wideband High-Efficiency PAs through Advanced Load-pull Simulation****David Vye, National Instruments/AWR**

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Load-pull simulation is one of the most valuable tools for high-efficiency switch-mode PA design. For these modes of operation (Classes E, F, inverse F, and others), the class of operation is determined by the behavior of input and output matching networks at harmonic frequencies. The PA designer must simultaneously find the most efficient impedance match at the fundamental while properly terminating each harmonic with the necessary short or open circuit. The ability to use load-pull simulation to determine device characteristic impedances at harmonic frequencies greatly speeds and simplifies the design process. This paper explores the design of power amplifiers using the load-pull scripts that are available in NI AWR Design Environment Microwave Office circuit design software. Using the example of a Cree CGH40010F gallium nitride (GaN) high-electron mobility transistor (HEMT) in a Class F PA at 2000 MHz, this paper demonstrates how power-added efficiency (PAE) is maximized by optimizing source and load pull at the fundamental frequency, plus second and third harmonics (2f<sub>0</sub> and 3f<sub>0</sub>).

▼ Tuesday, September 20, 2016 · 2:10 - 2:30 ▼

**Sponsored Talk****Room: 209****Three Technologies that Can Make or Break your Spectrum Monitoring System****Abhay Samant, National Instruments**

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Spectrum monitoring is increasingly being recognized as a vital component to enable dynamic spectrum access in wireless communication. Spectrum sharing can be broadly classified along the vectors of level of coupling and goals of sharing between the users. Traditionally, SwaP (size, weight, and power) have been the metrics used to classify spectral monitoring systems. As requirements evolve, onboard signal processing, latency, and bandwidth are the three key requirements that can potentially make or break your next generation spectral monitoring systems. This technical session discusses these trends and how a platform based approach helps you meet these challenging requirements.

▼ Tuesday, September 20, 2016 · 2:15 - 2:45 ▼

**Frequency Matters Theater Session****Room: Frequency Matters Theater****Forensic Analysis of Closed Eyes: Evaluate Suspect Channels****Eric Bogatin, Teledyne LeCroy Signal Integrity Academy**

Before you try to hunt and peck your way troubleshooting a broken channel, it helps if you already know the signatures of specific failure modes and if you use all the tools at your disposal to search for clues. But if your eye is already closed, what do you have to look at? We'll leverage two important tools to evaluate suspect channels, the single bit response and the S-parameters of the channel as diagnostic tools to search for known failure modes. These should be the first steps when searching for the root cause of channel problems. The results from these measurements will be used to identify the root cause of the problem which is the first step in getting it right the second time.



▼ Tuesday, September 20, 2016 · 2:20 - 3:00 ▼

**Workshop****Room: 202****3D Electromagnetics and the Validation Continuum****Daniel DeAraujo, Mentor Graphics**

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Efficiency is crucial to successfully verify the electrical performance of modern systems, especially those of great size. The complexity of a chip-package-board co-design requires that any system-level simulations performed be done so with fast simulators that do not compromise on accuracy, as well as checking that goes beyond simulation. Being able to find and eliminate problems on nets without running a simulation helps speed the board verification process, as does automating the process of the manual checking that gets performed on the layouts at release time. Add to that the ability to do signal integrity and power integrity simulations across all the nets in hours versus days, and you have a very fast, efficient, and repeatable verification process that gets products to market faster and products that are designed for performance and reliability. Design solutions for complex systems require a new level of depth and integration. Solutions within the HyperLynx product line combine the power of world class EM solvers, simulators, and geometry processing engines to efficiently achieve system design closure and electrical sign-off. Leveraging the strengths of each solution, HyperLynx enables a unique methodology for design, analysis and signoff validation supporting hybrid analysis flows and pattern recognition techniques to reduce simulation time by orders of magnitude. In this session, we will discuss a more efficient RDL-package-board verification methodology using the HyperLynx suite of tools, which integrates DRCs that encapsulate existing rules of thumb, engineer know-how, and design guidelines, with industry-leading pattern matching verification and 3D electromagnetic extraction and simulation technology.

**Workshop****Room: 203****Techniques and Challenges in Designing Wideband Power Amplifiers Using GaN versus LDMOS****Jeffrey Ho, NXP Semiconductors**

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GaN and LDMOS RF power transistors have the great potential to enable wideband power amplifier designs due to their excellent power and efficiency characteristics at RF and Microwave frequencies. With recent advancement in GaN process technology, these transistors can provide greater operating bandwidth, higher power density, better efficiency, and smaller device packaging than the comparable LDMOS technology. This workshop will present the benefits and challenges in designing wideband Class AB power amplifiers using GaN versus LDMOS technologies. A comparison of device characteristics and power amplifier performance, for a 500-2500 MHz, 100 Watt, 50 V GaN device (MMRF5014H) to a 400-1000 MHz, 100 Watt, 50 V LDMOS device (MMRF1305HR5) will be covered. Additionally performance in both CW and pulsed applications and material characteristic and how it may dictate system level tradeoffs, will be discussed. Wideband impedance matching techniques and design topologies are demonstrated through S-parameters and large-signal simulation using the GaN and LDMOS nonlinear device models. Simulated versus measured performance results for both wideband amplifier circuits will be presented.

**Workshop****Room: 207****Fundamentals of Wideband Signal Generation: Going Beyond the Banner Specs****Lawrence Wilson, Rohde & Schwarz Inc. USA**

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Signal generation plays a key role in electrical test and measurement. It is becoming even more important and challenging with increasing design complexity and signal speeds. Selecting the right tool for the test at hand can become very confusing and often requires to look beyond the advertised banner specs. Based on practical examples, this workshop addresses the fundamentals of signal generation and beyond. We'll look at analog and vector signal generators, and what to look for when looking at a datasheet. We will go beyond the basic specs and discuss possibilities and limitations. You will also learn about complex modulated mm-wave signal generation and multi-channel outputs, phase coherence and the generation of envelopes and data signals for amplifier characterization.

**Workshop****Room: 208****Massive MIMO Technology Insights and Challenges****Robin Wang, Keysight Technologies**

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Massive MIMO is one of the new technologies that is expected to be deployed in 5G. However, there are many questions about what massive MIMO really means: Is massive MIMO just MIMO with more antennas? Can massive MIMO be added to existing communications standards? Will massive MIMO only be used at millimeter frequencies? This workshop will begin with a review of different multi-antenna techniques building up to the definition of massive MIMO and how it could be deployed in 5G communications systems. Simulation data will be shown that highlights the improvements in capacity that can be expected from massive MIMO. Next, some of the issues that will impact the performance of massive MIMO will be discussed, leading to proposed solutions for how massive MIMO systems can be tested.

**▼ Tuesday, September 20, 2016 · 2:20 - 2:40 ▼****Sponsored Talk****Room: 209****Advances in RF Design Enablement for Wireless and Wireline ICs****Samir Chaudhry, TowerJazz**

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Advancements in foundry RF SOI and SiGe BiCMOS technologies have enabled specialty silicon foundries to become dominant suppliers for several classes of wireless and wireline ICs. These include, but are not limited to, switches, LNAs and PAs in front end modules (FEM) of wireless systems and optical networking ICs in wireline systems. Concurrently, design teams must reduce development costs and design cycle times to stay competitive. This is driving a need for design enablement platforms to accurately predict figures-of-merit such as noise figure, gain, and linearity in LNAs, power added efficiency in PAs, insertion and return loss, isolation and harmonics in RF switches. A emerging requirement, particularly for infrastructure products is verification of safe operating area (SOA). In this paper, we review novel design enablement tools and advanced modeling available from the Specialty foundry that leverage the tight interaction between EDA, models, and process technology to maximize the performance and yield while minimizing the time to market of these ICs.



▼ Tuesday, September 20, 2016 · 2:40 - 3:00 ▼

**Sponsored Talk****Room: 209****RF Technical Innovations that improve System Signal to Noise Ratio and Reduce Intermodulation Distortion****Baljit Chandhoke, IDT**

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In this paper we will discuss the RF innovations that improve system signal to noise ratio and reduce intermodulation distortion, helping system designers to enhance quality of service, improving coverage by freeing up under-utilized spectrum. Zero-Distortion technology practically eliminates intermodulation distortion in RF mixers and amplifiers enhancing the system's quality of service. This is also achieved with extremely low power consumption. Using zero distortion technology in mixers in a base station, we will show that the total intermodulation energy at the system level is reduced by 83%. This frees up that spectrum for the 3G user thus improving coverage and quality of service. FlatNoise technology improves overall system signal-to-noise performance by keeping the noise figure of the variable gain amplifiers (VGA) constant as gain is reduced. This enables system designers to adjust gain in the signal path without degrading the signal to noise ratio of the system. Glitch-free technology protects costly down-stream components by minimizing the voltage transient that results when changing device gain from one state to another. We will show plots illustrating envelope power as a function of time for a standard quarter-dB step attenuator during a MSB transition. With GlitchFree Technology, the glitch is eliminated resulting in improved PA reliability in transmitters, faster settling times in TDD systems, and overall improved quality of service in receivers. We will also look at applications of these technical innovations in base stations, CATV, distributed antenna systems.

▼ Tuesday, September 20, 2016 · 3:00 - 3:30 ▼

**Frequency Matters Theater Session****Room: Frequency Matters Theater****Best Practices for Signal Integrity During PAM4 Functional Test****Gordon Vinther, Ardent Concepts**

The push towards PAM4 signaling imposes challenges to engineers to ensure their system is tuned to perform as expected. Numerous pitfalls along the way can inevitably lead to compromised functional test. This session looks at what mistakes to avoid in modeling and measuring when designing a functional test of PAM4, and the best practices engineers can implement to safeguard against high bit error rates.

▼ Tuesday, September 20, 2016 · 3:40 - 4:20 ▼

**Workshop****Room: 203****Hybrid Beamforming for Wireless Communication Systems****Rick Gentile, MathWorks**

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Increased data rates and expanded bandwidth requirements have moved the operating frequency bands up into the millimeter wave range for next generation wireless communication systems. The wavelengths at these frequencies enable many more antenna elements within very small form factors. The resulting signal path and propagation challenges from operating at such high frequencies can be offset with smart array design and the use of spatial signal processing techniques including beamforming. With more channels per array and more arrays fielded to increase coverage, hardware and energy consumption design budgets can be difficult to meet. In this presentation, we will introduce techniques to design and evaluate complex antenna arrays which can be used in wireless communication systems. We will look at ways to model and design the array geometry, element spacing, subarrays, tapering and the effects of mutual coupling. We will also demonstrate techniques to explore architectural trade-offs for beamforming that span the RF and digital domains. These techniques can be used to help achieve the desired system level performance with an optimal partitioning between the RF and digital domains.

**Workshop****Room: 207****PCB Material Design Choices and their Impact on Thermal Management****Scott Kennedy, Rogers Corporation**

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Global data demand through mobile infrastructure networks continues to increase as users become more accustomed to accessing video wirelessly. Operators have been evolving their networks from WCDMA to LTE and now LTE-Advanced and with that we are seeing implementation of carrier aggregation techniques to maximize spectrum efficiencies and data rate speeds. In order to meet data demand, amplifier design has been moving up in power levels, increasing operating frequencies and reducing size in order to have lesser visual impact. All of these changes are of course driving operating temperatures higher, leading designers to search for improved thermal management approaches when using high performance PCB material solutions. This workshop will cover not just thermal conductivity properties, but also the impact of dielectric constant, loss tangent and thickness on temperature rise. In addition, selection of copper types and plating options can have impact on thermal management. These will also be discussed, giving designers a better understanding of all material/circuit considerations when selecting the best solution for their temperature sensitive designs.

**Panel****Room: 208****PANEL: How Will 5G Ride the mmWave?****Patrick Hindle, Microwave Journal****Panelists:**Michael Griffin, Planning Manager, WDO Wireless Devices and Operators, *Keysight Technologies*Bill Kardine, Application Engineer, *Rohde and Schwarz North America*Jin Bains, Vice President of R&D, *National Instruments*Dr. Thomas Cameron, Chief Technology Officer, Communications Business Unit, *Analog Devices*Robert Donahue, Chief Executive Officer, *Anokiwave*Ken Karnofsky, Senior Strategist, Signal Processing and Communications, *MathWorks*

This panel of experts from modeling, device and measurement companies will debate how to design, manufacture and test 5G mmWave components/systems today as trials are already underway well ahead of the 2020 standards development schedule. Although the standards are not determined, what mmWave technologies will likely be used first and how can we design devices and system that will meet these requirements today and verify their performance? See what the experts have to say and come with your questions about how to make 5G mmWave communications happen today.



▼ Tuesday, September 20, 2016 · 3:40 - 4:00 ▼

**Sponsored Talk****Room: 209****Get Ready for mmWave in Production Test****Raajit Lall, National Instruments**

Sponsored by:



While mmWave is catching on for standards such as 5G and 802.11ad, it brings new challenges to production test. Calibration, DUT connectivity and measurement accuracy are few of these challenges. This presentation focuses on questions that test engineers should be asking while designing and choosing test set ups.

▼ Tuesday, September 20, 2016 · 4:00 - 4:20 ▼

**Sponsored Talk****Room: 209****Techniques for Extending Microwave Frequency Instruments for mmWave Measurements****Raajit Lall, National Instruments**

Sponsored by:



The need for millimeter wave (mmWave) measurements is rapidly evolving in application spaces such as 5G, 802.11ad, automotive radar, and material characterization. This presentation discusses how traditional microwave frequency instruments (in the K- or Ka-band) can be extended to perform measurements in the mmWave frequency band. These techniques include concepts such as a complete downconversion, external harmonic waveguide mixing, and block downconversion. Each technique has its pros and cons, ranging from dynamic range, noise floor specifications and frequency range. In this presentation, we will discuss these pros and cons and present experimental results using the block downconversion and waveguide mixing techniques.

▼ Tuesday, September 20, 2016 · 3:45 - 4:15 ▼

**Frequency Matters Theater Session****Room: Frequency Matters Theater****Past, Present and Future of the RF Compound Semiconductor Industry****Eric Higham, Strategy Analytics**

From humble beginnings more than 35 years ago, the RF compound semiconductor industry has grown to more than \$9 billion in revenue. Compound semiconductor technology has expanded beyond GaAs (gallium arsenide) to include GaN (gallium nitride), InP (indium phosphide) and SiGe (silicon germanium), while the applications have evolved from high-speed digital circuits to encompass just about every commercial and military RF opportunity. This presentation will look at the trends, drivers and results that have shaped the RF compound semiconductor industry to this point, along with some thoughts and forecasts about how wireless and cellular communications and emerging applications like 5G and the Internet of Things (IoT) will influence the future direction of the industry.



▼ Tuesday, September 20, 2016 · 4:30 - 6:00 ▼

**EDI CON Plenary Session: Room 302/304**  
**With Introductions by Honorary Chair, Eli Brookner and**  
**Horizon House President, Ivar Bazzzy**

**Plenary/Keynote Speech**

**Room: 302/304**

**The High-Frequency, High-Speed Design Revolution Ahead:  
Why Your Design and Test Flow Will Soon Be Obsolete**  
**Todd Cutler, Keysight Technologies**



*Todd Cutler*

Without a doubt, electronic design has evolved through the years from something that was once performed on the back of an envelope to a process that now requires many different types of engineers using a range of different electronic design automation (EDA) tools. Today, that design process and the test flow that accompanies it is once again on the cusp of another evolution—one that is being driven by current and emerging trends in high-frequency and high-speed design. In his keynote, Todd Cutler, vice president and general manager of Keysight Design & Test Software, will discuss these trends and explain how, when coupled with market pressures, they are driving a revolution in the design and measurement industry. Cutler will also detail what this means for next-generation chip/package/board/system design, and paint a picture for what a typical design and test flow will look like in 3, 5, and 10 years. Is your existing flow on the road to becoming obsolete?

**Plenary/Keynote Speech**

**Room: 302/304**

**Innovation in Phased Arrays; Past, Present, and Future**  
**Thomas Sikina, Raytheon**



*Thomas Sikina*

Innovation in phased arrays has followed a number of different directions since its origins, but has consistently offered new insights and an expanded the vision of the power of human capabilities and understanding in this arena. It is useful to consider the trends and discoveries it has produced; it traces a pathway of human discovery, often with amusing and amazing stories. The first wave of phased array innovation introduced basic principles, developed by pioneers such as Maxwell, Hertz, Huygens, and Schelkunoff. These giants and their contemporaries established fundamentals that provided a vision for engineers and scientists of their time and continuing today. They established concepts such as the wave equation and its solutions, wave propagation, superposition, wave expansion, and the basics of the first arrays. At the same time, they set up the challenges and problem sets for the next generation of explorers in this field. A very practical series of discoveries followed in a second wave, including the development of the MIT RadLab series of publications, the origins of contemporary published works, such as the IEEE Antennas and Propagation, and Microwave Journal, and many others. Many industry giants found their footing and expanded their markets and capabilities, including what is now Lockheed Martin, Raytheon, Northrop Grumman, Boeing, ITT and others. Pioneering systems such as AWACS, multiple military systems, FAA airport systems, etc., just to name a few emerged. Advanced simulation codes emerged, such as the Method of Moments, GTD, Physical Optics, HFSS, CST, and started their modern expansions. Much of this work lead to published works, such as Theory and Analysis of Phased Array Antennas, Practical Phased-Array Systems, and the Radar Handbook stood out as monuments of our comprehension of advanced phased array capabilities. This vast set of developments lead to the current or third wave, where new expansions into the degrees of freedom have emerged. Adaptive arrays, MIMO, distributed receiver and low phase noise arrays, multiple simultaneous beam arrays, polarization diverse, and digital beamformed arrays are all expanding their capabilities. These innovations are leading to phased array systems with greatly expanded sensitivity in the form of advanced tracking and surveillance radars, remote sensing, telemetry, and multichannel communications systems. They are now found on land, sea, aircraft, near-earth and deep space, and in cyber-space. Innovation has consistently expanded our frontiers, and it has done so by providing a simple and clear vision of phased array capabilities. Many developers have contributed to this expansion, coming from our universities, industry, and a wide range of experimenters. It is difficult to see an end to this progression, other than still new frontiers, simply awaiting our recognition.



**Plenary/Keynote Speech**
**Room: 302/304**
**Continue the Innovation Towards Next-Generation Technologies**
**Faride Akretch, Rohde & Schwarz**

*Faride Akretch*

It is no news to anyone that the electronics industry is developing at an astounding pace. Be it for communication standards such as 5G or 802.11 with its various amendments, for automotive radar, or for any other leading application, test & measurement generally finds itself at the forefront of that development. Innovations, often with higher speeds, bandwidths, and more complex technologies have to be tested. In this plenary talk we'll take a look behind the scenes and explore some of the technologies enabling precise measurements. For one of the examples, we'll have a closer look at resolution, and how to achieve adequate resolution to measure and distinguish small signals in the presence of large ones. A typical application is for switched mode power supplies (SMPS), or when analyzing AM modulated signals. In a different example, we will discuss a new method of measuring phase noise, and where the traditional approach of an analog phase locked loop (PLL) to recover the phase difference between a reference oscillator and the device under test has its limitation.

**Plenary/Keynote Speech**
**Room: 302/304**
**Tomorrow's Wireless: How 5G, 802.11ad, and the IoT is Shaping the Future of Wireless Technology**
**Jin Bains, National Instruments**

*Jin Bains*

For an entire decade until about 2015, the volume of teenagers downloading goofy cat videos was likely a bigger driver of Wi-Fi and mobile networks than the IoT. In 2016, this is no longer the case. Wireless technology is being shaped by an entirely different set of use cases and market forces. Analysts predict that within the next decade, the number of connected things will outnumber people by about 10x. Connected things have different needs than connected people – and these needs will dramatically shape the future of wireless technology. In this presentation, we will investigate a handful of the hottest wireless technologies including LTE-M, LTE-Advanced Pro, 5G, 802.11ad, and 802.11ay. In addition to explaining the target use cases and features of these standards – we will also investigate how they change engineering design and test practices. As a result of attending, you will be better equipped to evolve your organization to address the future of wireless design and test.

**▼ Wednesday, September 21, 2016 · 9:00 - 9:30 ▼**
**Technical Sessions**
**IoT Track**
**Room: 201**
**Maximizing Wireless Communications Energy Efficiency**
**Earl McCune, Eridan Communications**

To maximize the operating energy efficiency of any wireless communication link requires a global optimization not only across the entire block diagram, but also including the selected signal modulation and aspects of the link operating protocol. Achieving this global optimization is first examined for the transmitter, receiver, and baseband circuitry. Then the important aspects of signal modulation necessary to access these circuit optimizations, with examples, are presented, followed by the correspondingly important protocol aspects needed. A realization of this global energy efficiency optimization in actual circuitry with measurements completes this paper.

**Signal Integrity/Power Integrity Track****Room: 202****High-speed Signal Integrity measurements****Anja Paula, Rohde & Schwarz GmbH & Co. KG**

In recent years, data rates for digital applications have continuously increased. Unlike previous generations, where channel tests were optional, today's digital cables require compliance tests to achieve certification acceptance. An example of this is the evolving USB Type C standard. Previously, most of the compliance parameters were measured with an oscilloscope, whereas now the vector network analyzer is becoming the tool of choice. One of the driving factors in this development is the need for multiport device tests. In this session we will talk about the need for precise multiport S-parameter measurements (e.g. crosstalk measurements such as FEXT, NEXT) and the steps involved in performing them. These measurements are the basis of a proper signal integrity analysis and are required for proper eye-diagram and jitter analysis. We will also present different de-embedding methods that counteract the impairments to the measurement results caused by the test fixture.

**RF & Microwave Design Track****Room: 203****State of the Art RF Design Technique for RF Switches to Maintain Near Constant Impedance when Switching RF Ports****Mark Schrepferman, Integrated Device Technology (IDT), Inc.**

RF switches play an increasingly important role in most high performance communication systems. Evolving standards to increase system data rates and reduce latency are driving the need for better RF switches to achieve improved system performance. Over the past 5 years there have been significant improvements in semiconductor technology, design techniques and circuit blocks used in RF switches, but one could argue that there has been much less advancements in basic MOSFET RF switch circuit design topology. A new RF switch circuit design topology called Constant Impedance, or  $K_z$ , has been developed to give equipment design engineers a way to meet these new system requirements by improving aspects of RF switch performance. Standard switches create a large voltage standing wave ratio (VSWR) and transient voltage stress on the MOSFETs when switching RF paths because the impedance of the switch is not well controlled during the switching event. These VSWR transients can potentially reduce the reliability of the switch itself (hot switching) and can also subject downstream components to large voltage stresses reducing reliability and degrading overall performance.  $K_z$  controls the impedance during the switching process minimizing the VSWR transient thereby improving hot switching reliability, reducing voltage stresses on downstream components and improving system performance. Case study results will be presented showing how design decisions were made to overcome challenges in achieving near constant impedance when switching between RF ports by preserving a high RF port return loss. Measurement results comparing key performance attributes of a  $K_z$  RF switch to a standard RF switch will show how the overall system benefits from improved switch performance.

**Modeling Track****Room: 207****In-situ Antenna/Circuit Simulation for Scanned Antenna Arrays****John Dunn, NI**

In a phased-array antenna, the impedance of each radiating elements at the feed port will vary considerably with scan angle, which in turn will impact the match (and delivered power) of the power amplifier. For this reason, designers need to simulate the interaction between the array and the RF circuit controlling the amplitude and phase of the signal feeding individual antenna elements. This session examines in-situ antenna simulation within the circuit network, discussing how the designer identifies the antenna data source and the circuit schematic driving the antenna to more accurately simulate metrics such as power radiated over scan angle. Several antenna types will be studied using both 3D planar and 3D finite-element (for arbitrary geometries) electromagnetic simulators.

**Systems Engineering Track****Room: 208****Planar Active Antennas: Approaches to Scaling to Higher Frequency****Douglas Carlson, MACOM**

Active or phased array antennas provide significant performance advantages and flexibility for both sensing and communications when compared with conventional antenna technology. The cost of implementing active antennas has restricted their use to high performance defense application. Recently, a major advance in active antenna manufacturing has enabled the implementation of array technologies at significantly reduced cost. This is allowing the expansion of this technology beyond critical defense applications to civil sensing and communications applications. The underlying aspects and approach to the implementation of an affordable planar tile based active antenna will be presented. The multifunction phased array radar (MPAR) will be used as the demonstration vehicle. This dual polarization S-Band array will be used to explore the requirements and trade-offs encountered in realizing a planar approach to active antennas. Emerging civil requirements demand the extension of array technology to the millimeter wave domain. Issues and approaches to facilitate the implementation of millimeter wave arrays will be presented including high levels for semiconductor integration and wafer level arrays.

**Measurement Track****Room: 209****Amplifier Testing with Envelope Tracking Technology****Lawrence Wilson, Rohde & Schwarz Inc. USA**

Typical power amplifiers (PA) are most efficient when operating the amplifier near their maximum output power (close to saturation). However modern communication signals, such as LTE show a high peak-to-average ratio. Due to the power density function (PDF) of such a signal, the amplifier is operated in low-efficiency regions most of the time. Envelope tracking is a technique to improve power-added efficiency (PAE) of PAs by varying the PA supply voltage in synchronicity with the envelope of the RF signal. As a result, the PA is working in the efficient regions most of the time and DC power consumption is reduced without effecting RF output power which results in lower power consumption. By applying shaping curves, the PA can be optimized for linearity (equal gain over the complete input range) which improves the performance (ACLR, EVM). This paper will discuss the impact this technology has on testing in both the design lab and the production line.



▼ Wednesday, September 21, 2016 · 9:40 - 10:10 ▼

**IoT Track****Room: 201****The IoT for Connected Soldiers & Battlefield Security****Laila Salman, ANSYS**

Today, the Internet of things (IoT) is considered to be the future of smart technologies, not only the integration of wide variety of commercial applications/devices but the intelligence data/information exchange among these applications over the web. The utilization of IoT-related technologies in military applications will be of great impact on protecting our soldiers in these harsh environments, especially in battlefields. The idea of the “connected soldier” relies on multiple radios for communications, navigation, data and video links etc. In order to maintain safety and insure mission success, critical real-time situational awareness must be available to the soldier on the battlefield. The battlefield itself represents a harsh RF environment with numerous radio systems and other sources of RF emissions spread out over the entire electromagnetic spectrum leading to the potential for serious radio frequency interference (RFI) issues. In this work, ANSYS simulation tools (HFSS and EMIT) are used to analyze the RFI experienced by the connected soldier for a scenario that involves an RF link from the soldier to a hovering UAV providing a radio relay. The impact of other sources of RF signals on the soldier's RF link is analyzed, as well as the potential RFI between systems on a nearby vehicle with multiple radio systems in simultaneous operation. Having identified the sources of interference, appropriate interference mitigation techniques are implemented. On the other hand, connected soldiers are usually protected by increasingly effective high technology body armor. Additional safety is provided by connectivity to equipment, such as a Humvee, a drone or a satellite. Having continuous communication as with IoT in the commercial world is critical. Bomb fragments or bullets may miss the soldier but disable the antenna's communication. ANSYS Explicit Dynamics is used to examine the response of the antenna on a Humvee to determine whether it will survive an impact. The impact velocity is a little bit over 100 m/s, which is in the lower range of a typical fragment velocity from near-field bomb explosions. Simulation results show that the antenna has been deformed severely but has not necessarily broken. The deformed geometry can be exported back for further electromagnetics analysis to check if the antenna is still working or needs to be replaced.

**Signal Integrity/Power Integrity Track****Room: 202****DDR4 and LPDDR4 Bus Level Signal Integrity Insight****A. Gosselin, Keysight Technologies**

Access to high speed digital signals such as DDR4 and LPDDR4 memory signals for signal integrity characterization is beyond challenging. Explore a paradigm shift in DDR memory test techniques, learn about time saving bus level signal integrity insight, and see case study examples showing how to use this insight to speed up your debug efforts on high speed memory systems. Bus level signal integrity insight provides qualitative eye scans for up to hundreds of signals in a system all relative to each other, captured under the same probing conditions. This presentation will cover the basic theory and techniques used to provide qualitative bus level signal integrity insight from eye scans created on a logic analyzer. The differences between qualitative and quantitative results will be explained and examples provided. The principles of eye scans apply broadly across high speed digital designs with clocked signals. For this presentation, multiple detailed real world examples of eye scans from DDR3, DDR4, LPDDR3, and LPDDR4 will be explored to help the audience understand the benefits and speed of using bus level signal integrity insight. Real system scans will be used so that the audience can experience the power and benefits first hand of being able to scroll through eye scans of all the DQS and DQ signals from a DDR4 DIMM, DDR4 BGA interposer, or LPDDR3/4 PoP probe scanned relative to each other when scanned as only READ bursts or only Write bursts. Different modes of operation resulting in different types of eye scans, overlaid and signal trace (burst scan), will be explained. Attendees should leave understanding how to use bus level signal integrity insight to decrease their debug time by knowing which signals they must probe with a scope and why they are probing before taking the time to solder on their scope probes.

**RF & Microwave Design Track****Room: 203****The MATRICs RF-FPGA in 180 nm SiGe-on-SOI BiCMOS****Gregory Flewelling, BAE Systems**

This paper explains MATRICs (Microwave Array Technology for Reconfigurable Integrated Circuits), a DC-to-20 GHz general purpose reconfigurable array of RF circuits embedded in a flexible switch fabric. Fabricated in a commercial SiGe-on-SOI BiCMOS process, the MATRICs IC employs SiGe HBTs for high-linearity ( $> +10$  dBm IIP3) amplification and low phase-noise frequency generation, and SOI FETs for low-loss switching. It achieves high on-chip RF isolation ( $>80$  dB at 16 GHz) due to the high-resistivity SOI substrate, differential signalling, and chip-scale flip-chip bump packaging. MATRICs will allow fixed-function RF systems to have the size, weight, and power benefits of a custom RF ASIC without the associated long development cycle and high NRE, and enable future RF subsystems to be dynamically reconfigured on-the-fly, adapting to changing environments.

**Modeling Track****Room: 207****Hierarchical Chip/System/Board Modeling with Circuit/EM Co-Simulation****John Dunn, NI**

Advanced RF front end integration through the adoption of various multi-technology chip/package/module/board architectures is placing higher demands on 3D full-wave electromagnetic modeling within the overall circuit simulation/optimization effort. As these designs grow in computational size and complexity, EM simulators must address larger problems and the supporting design automation will need to manage numerous EM simulations representing structures of diverse technologies that are hierarchically interconnected through 100's of ports. While EM simulators have been able to address these modeling challenges through advanced meshing techniques and high-performance computing, the automation required to dynamically control structure geometries and embed the resulting electrical performance within nonlinear RF circuit simulations is also advancing. This talk will look at both the EM modeling technologies and design automation required to successfully address multi-technology chip/package/module/board co-design through circuit/EM interoperability.

**Systems Engineering Track****Room: 208****Design & Implementation of Visible Light Wireless Communication System for Audio Applications****Anis Abousaada, Suk Ajoumaa Higher Institute**

Visible light communications VLC systems through light emitting diodes (LEDs) have gained much attention in recent years. In this paper, a wireless VLC system has been designed, realized/simulated and tested using LED and photo-transistor system. For the purpose of demonstration, audio signals have been transmitted and received over this wireless VLC circuit. Satisfactory results were obtained and audio signals were transmitted and received for a distance up to 1.7 meters. This basic system will be the building block to provide many optical wireless communication systems.

**Measurement Track****Room: 209****Wideband Satellite Component Test Challenges****Mark Lombardi, Keysight Technologies**

With the increasing demand of communications over satellite, Ka-band and wider bandwidths become the choice for many satellite manufacturers and operators. This makes it challenging to characterize satellite components, like amplifiers, BUC (block up converters), modulators/demodulators. Participants will have a better understanding of how to characterize wideband satellite components commonly used in Ka-band, high throughput satellite (HTS).



▼ Wednesday, September 21, 2016 · 10:30 - 12:30 ▼

### **Frequency Matters Theater Session**

**Room: Frequency Matters Theater**

**From Bits to Waves: Building a Modern Digital Radio in 1 Day**

**David Ricketts**

In this fun and interactive experience, participants will learn the basic theory of modern digital radios as well as the RF circuits and system used to build them. After an introductory session on digital radios, participants will select an RF building block to design and build. There will be short mini-classes (run in parallel) on each component: double balanced mixer, microstrip filters, low noise amplifiers, power amplifiers, baluns, etc. The radios will operate in the ISM 920 MHz band. After the mini-classes, each participant will design his or her RF component using NI AWR software. Then, the designs will be transferred to PCB via a simple "PCB in a bag" method and each component built and tested using a simple VNA. The workshop will conclude with a full radio test of at transmitter and receiver. Participants need only a basic background in RF circuits, such as S-parameters and basic transmission line theory. Example designs will be available to ensure that everyone, from the most advanced RF designer, to the student can build a successful RF component. A prize will be given to the best performing system. The workshop will be taught by Prof. David S. Ricketts, who has taught this hands on Radio System Design course at Carnegie Mellon University and NCSU as part of a senior design course. Radio System Design is an open, online course that teaches students the basics of digital communication, RF system design, RF circuit design and finally fabrication and testing. **Free but seating is limited to 30 participants; first come, first served. Course Equipment/Hardware: Bringing your own laptop running windows operating system.** Special note: 64-bit PCs are required to run V12 NI AWR Design Environment. Software, licenses, and required training materials will be provided.

▼ Wednesday, September 21, 2016 · 10:50 - 11:20 ▼

### **IoT Track**

**Room: 201**

**Coexistence Testing in the World of 'Internet of Things'**

**Lawrence Wilson, Rohde & Schwarz Inc. USA**

In a world where thousands of similar devices are in close proximity to each other and are using similar technology, how do you ensure that your device plays nicely with others? Understanding how your device coexists in a world with so many RF signals is key to having a reliable, successful product. This paper will discuss techniques for characterizing how your device, board or chip performs in the presence of all these other RF signals.

### **Signal Integrity/Power Integrity Track**

**Room: 202**

**Chip, Package, and PCB Co-Design**

**Randall Myers, Mentor Graphics**

Modern IC packaging techniques combined with specialized signal requirements push a signal's performance constraints through the whole system path and require a system wide co-design. While each of three disciplines have well developed design approaches, IC packaging and PCB, what is developing out of necessity is a method to allow these different design efforts to interact. Packaging is the bridge between chip and system, and the best opportunity for codesign. Designing correctly, with pre-optimized signal paths through the whole system sets up much fewer signal path issues to fix after simulation. With a co-design approach, simulation also becomes feasible from the chip's buffer block, through package routing, and system PCB implementation.

**RF & Microwave Design Track****Room: 203****Time Domain Gating of Microwave Component Responses Using Analog Techniques****Timothy Reeves, MathWorks Inc.**

This paper describes an analytical technique for time domain gating of RF/microwave components. Vector fitted rational function approximations will be used to describe S-parameters in the time domain. Properties of the Laplace Transform will be taken advantage of in order to perform gating on both the time domain reflection and transmission responses. Following the development of the gating technique, theoretical and measured examples will be presented to show the applicability of the technique described. This novel approach allows for time gating of measured and synthesized data. Additionally, gated time and frequency response data can be retained and used as a design input for development of microwave assemblies.

**RF/MW: Amplifiers Track****Room: 207****12 W, 2-18 GHz GaN on Diamond, MMIC with Embedded Cooling****Carlton Creamer, BAE Systems Technology Solutions**

Under the DARPA-sponsored NJTT and ICECool Applications programs, high power GaN on diamond transistors have been demonstrated >3.5X the RF power density relative to GaN on SiC. GaN on diamond monolithic microwave integrated circuit (MMIC) power amplifiers are now under development that achieve commensurate increases in power and will provide enabling technology for future advanced RF systems. These device and circuit breakthroughs place greater demands on the thermal management system. To address the associated increased heat challenges, complementary cooling technologies that incorporate embedded micro channels to handle the highly localized heat loads with capacity to transport waste heat away from the active electronics have been designed, fabricated and tested. A liquid phase, microchannel cooling system integral to the RF ground plane uses a 50-50 ethylene glycol-water mixture, and has been optimized for cooling in the range of dissipation of the MMIC amplifier (1kW/cm<sup>2</sup>) at inlet temperatures up to 65°C while maintaining transistor junction temperatures below 240°C required for 10<sup>6</sup> hour mean-time-between-failure. The high performance level is achieved by establishing a robust co-simulation process that provides cross domain hand-offs between electrical, electromagnetic, thermal and fluid simulation engines. Under the ICECool Applications program, detailed electrical and thermal models have been developed for MMIC circuits and microfluidic coolers that achieve computational efficiency that supports rapid development.

**Systems Engineering Track****Room: 208****Evaluating Waveform Coexistence for 5G, Wireless, and Radar Applications****Greg Jue, Keysight Technologies**

There is increasing interest in utilizing sub 6 GHz spectrum for new and emerging 5G applications, as well as potentially sharing spectrum between radar and LTE applications. Operating in the crowded sub 6 GHz spectrum poses questions as to how waveforms will interact and potentially interfere with each other, and how their co-existence might impact system performance. Researchers and engineers need flexibility in the R&D lab environment to evaluate many different potential co-existence scenarios before testing in the field with actual hardware. This paper will discuss a flexible testbed which can be used to evaluate many potential co-existence scenarios for 5G, wireless, and radar applications. Several different scenarios will be examined. The first scenario will examine a 5G candidate waveform filter bank multicarrier (FBMC) co-existence with a 4G LTE waveform. The second scenario will examine multiple 5G candidate waveforms including FBMC, generalized frequency division multiplexing (GFDM), custom orthogonal frequency division multiplexing (OFDM), and universal filtered multicarrier (UFMC) co-existence with multiple 3G, 4G, and PAN waveforms (LTE, EDGE, GSM, WCDMA, WLAN, and Zigbee). The last scenario will examine LTE and S-Band radar co-existence.

**Measurement Track****Room: 209****Phase-Coherent Vector Signal Analyzer Systems for MIMO Applications****Vimal Fernandez, NI**

The principle of beam forming to feed phase-shifted signals through an array of antennas to intensify or suppress the radiation pattern in a given direction is one of the key benefits of MIMO. However, if the transmitter or the receiver adds amplitude, time, and phase errors, the channel will not be accurately modeled and the symbols will not be resolved effectively. MIMO systems have to overcome key technical challenges related to phase, time and frequency synchronization in order to coherently transmit and process the data received from each element. In this paper, a robust calibration method is presented for aligning the phase and magnitude across multiple channels; to counter the effects like uncorrelated LO phase noise, ADC sample clock phase noise and quantization noise. Advanced concepts such as sharing reference signals, daisy chaining, and implementing star configuration with local oscillators are described. Accurate MIMO measurement results are provided with a super heterodyne receiver platform to show that the hardware has good phase coherence performance at various frequencies and signal bandwidths over significant periods of time. The results show that the phase drift variation is limited to  $\pm 1$  degrees variation across a 500 MHz to 26.5 GHz frequency range at  $23^{\circ}\text{C} \pm 5^{\circ}\text{C}$  for a multi-channel system. Ideally, a phase error of less than a degree and a nanosecond of timing alignment will yield an accurate result. These techniques can be used in real-world applications such as distributed radar and MIMO radar systems.

▼ Wednesday, September 21, 2016 · 11:30 - 12:00 ▼

**IoT Track****Room: 201****Multi physics Simulations of an Energy Efficient IOT-based Smart Home****Charlotte Blair, ANSYS**

The concept of “automated home/smart home” was first introduced over 80 years ago and has been facing different technical limitations. Recently, service providers and home appliance manufacturers have launched a new initiative to bring the concept of smart homes to reality. This initiative allows subscribers to remotely manage and monitor different home devices from anywhere via smart phones or over the web. Within the core concept of Smart Homes is the idea that all devices are integrated and interconnected via through the wireless network. Hence, smart home technology has become part of Internet of things (IoT). The future of smart homes is coupled with energy efficiency to yield an energy effect IoT-based Smart Home. In this work, a house model is analyzed to demonstrate the comprehensive simulation studies on consumed energy reduction for lighting as well as home cooling and heating. Various multiphysics simulations were carried out on the kitchen room portion of the house. Camera/motion sensors were used as part of the home security system and were coupled with the home light and HVAC control systems to remotely switch on/off the lights and turn on/off the heating/cooling system when a person entered or left the room. The camera/motion sensor sends signals to the home security system and energy control unit when motion is detected within the room or movement throughout the house. Full Wave Finite Element Method (FEM) based ElectroMagnetic simulation software is used to visualize the electromagnetic fields generated from the different antennas located in the home energy control unit, security/motion sensors/cameras, LED light bulbs, and the actuator for HVAC duct dampers. A 4mm accurate full human body model is used to fully characterize in body field penetration. The coupling/RF interference between these antennas within their RF circuitries are simulated using Radio Frequency Interference (RFI) Calculator. Signal integrity is examined to ensure IoT-enabled devices can communicate seamlessly to execute an energy saving protocol. A detailed Computational Fluid Dynamics (CFD) simulation is utilized to perform an analysis of the transient flow after opening the HVAC damper plate along with the flow and temperature distributions in the area. The CFD results show how the energy saving protocol manages temperature in the area and inside the critical components for cooling and lighting. Such computational methodologies can be extended to other home parts and buildings such as warehouses, commercial buildings, stadiums, and shopping malls.



**Signal Integrity/Power Integrity Track****Room: 202****Leveraging SerDes Design Flows for AMI Model Development****Todd Westerhoff, SiSoft**

Systems designers using the latest SerDes technologies need to make architectural tradeoffs and key design decisions long before silicon is available. For high-speed serial links, IBIS-AMI models are preferred - but model development often occurs "after the fact," in a different group from the one actually designing the SerDes, and only once detailed implementation (as in SPICE) or lab measurement data is available. This means that system designers can't get the design-in models they need when they actually need them. This happens because most SerDes designers approach the creation of IBIS-AMI models with a mixture of reluctance, procrastination, and dread. When IBIS-AMI model creation requires rewriting or changing key parts of the SerDes design code, engineers naturally put that task off for as long as possible. The gap between SerDes design and AMI model creation is large and won't close unless the fundamental model creation process can be changed. Finding a way to incorporate IBIS-AMI modeling as part of the SerDes design flow can help ensure that a SerDes design meets real-world customer needs. Allowing internal and external customers early access to SerDes models while detailed implementation is still in process helps ensure the design is fine-tuned to the final application, thereby providing SerDes designers with the insights that broad system level analysis brings. This paper presents the results of a collaborative effort between MathWorks, SiSoft and a major semiconductor vendor to leverage the SerDes design process for IBIS-AMI model generation. Simulink models created during the SerDes design process require minimal modification to generate IBIS-AMI models for distribution to system customers. The overall IBIS-AMI generation and validation flow is presented, along with techniques that ensure the generated models are fully compliant with the finer points of the IBIS-AMI specification, including correct analog/algorithmic partitioning and support for multiple oversampling ratios.

**RF & Microwave Design Track****Room: 203****Characterization and Modeling of High Q Dielectric Resonator Loaded Cavity Design for RF/Microwave Oscillator****Edward Liang, MCV Microwave**

Dielectric resonator (DR) loaded cavity found important RF/microwave filter and oscillator applications due to its high quality factor (Q), and smaller size. It offers similar Q in 1/8 to 1/12 the size of a waveguide cavity. It provides excellent temperature stability when designed with a proper choice of dielectric material. However, characteristics of a DR loaded cavity are not always straight forward. For example, in practical applications, cavity Q can be degraded from tuning, support and coupling structures. Interference from higher order modes in RF/microwave oscillator design and development commonly causes delays in prototyping and compromised optimal performance. This paper addresses the issues of practical applications in high Q DR cavity design for RF/microwave Oscillator. Dielectric resonator materials and basic cavity structures are described along with characterization and measurement of cavity Q. The complex resonant modes and coupling structures are detailed with special emphasis relating to the impact of the coupling and tuning structures on various resonant modes. Electro-magnetic (EM) simulation and its equivalent circuit that can be incorporated into linear and nonlinear circuit simulation are demonstrated with examples.

**RF/MW: Amplifiers Track****Room: 207****Designing for Maximum PA Efficiency using CAD Transistor Waveform Optimization****Ray Pengelly, Prism Consulting**

This paper concentrates on a novel technique to maximize the power and efficiency of GaN HEMT-based power amplifiers employing the principals of time domain waveform optimization ONLY. The paper demonstrates that design concentration at the application frequency is insufficient and that an equal amount of time needs to be spent on inspection of transistor  $f_1$  and the gains of the transistors at harmonic frequencies – transistor harmonic frequency performance is critical to optimum waveform engineering. To this end, accurate linear and non-linear models are required so that accurate evaluation of the effects of gate and drain harmonic terminations can be made. The paper concentrates on the inspection and utilization of intrinsic transistor waveforms i.e. the waveforms that the actual transistor “sees” rather than the effects of package parasitics etc. In the presentation the NI/AWR’s Microwave Office Simulator is used together with intrinsic large-signal models for relatively low-power Wolfspeed (Cree) GaN transistors. Several examples will be given of pure time domain waveform optimization for maximum output power and efficiency for Class F and inverse Class F power amplifiers including 100 MHz low frequency “near perfect” PA examples and 700 MHz “more practical” PA optimization. Peak drain efficiencies, for example, were improved from 69% to 85% by the optimization of harmonic terminations on both transistor gate and drain terminals. The frequency domain performance of those resulting optimized designs is shown together with the fact that the same approach can be used for much higher power transistors (up to several hundred watts). The design implications for compact hybrid and MMIC PAs are also covered.

**Signal Integrity/Power Integrity Track****Room: 208****Probe Loading Effects on Common High Speed Signals****Josiah Bartlett, Tektronix**

Whether it is characterization, troubleshooting, or compliance testing, probing of high speed signals can be a challenge. Whether the circuit is digital, analog, or RF, probe loading can change the behavior of a circuit, and also affect the integrity of the signal to the instrumentation. Also, probes often require user-supplied wire or soldering joints that affect the system in unspecified ways. In addition, differential signaling can be degraded by non-differential behaviors of probes. This paper presents some of the common issues with probe loading and demystifies the process of specifying and attaching a probe to a sensitive device under test.



▼ Wednesday, September 21, 2016 · 1:00 - 1:40 ▼

## Workshops and Panels

**Workshop****Room: 203****Practical Antenna Design for Advanced Wireless Products****Derek Linden, NI**

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Part 1: Antenna Design Fundamentals-Antenna performance plays a critical role in determining the communication range and quality of service for wireless devices. As devices must increasingly support challenging spectral performance (i.e. wideband or multi-band) and densely integrated packaging, design becomes crucial to the success of new wireless products. Competence in advanced antenna design strengthens the competitive edge of such products for their manufacturers. This workshop offers participants technical insights on the vital aspects of antenna design from an industrial and practical perspective. It covers fundamental theory, concepts and definitions to the features, specifications and performance of different types of commonly-used and advanced antennas found in wireless products. Practical implementation strategies on overall product design for optimum antenna performance will also be presented. Part 2: Antenna Synthesis-Growing demand for wireless connectivity will rely on integrated antenna solutions customized for optimal system performance, cost and size. Achieving multiple performance metrics such as impedance matching, gain, radiation efficiency and operating bandwidth is a time consuming process involving numerous iterative simulations and a significant amount of design knowledge. With the expected demand for design experience greatly exceeding the current supply of antenna engineers, an alternative approach is warranted. Fortunately, research into the use of evolutionary algorithms (EA), a programmatic method to explore the design space and automatically locate novel antenna designs, has matured into a viable technology. EA is proving to be more effective at generating antenna structures with greater performance than would otherwise be developed by traditional methods. This workshop will examine several examples of novel antenna design via antenna synthesis using a new commercial software product called AntSyn from National Instruments that combines EA with EM simulation.

**Plenary/Keynote Speech****Room: 207****Featured Keynote: Invisibility Cloaks and Deflector Shields: Disappearing at Microwave's Frontiers****Nathan Cohen, Fractal Antenna Systems, Inc.***Dr. Nathan Cohen*

Over the last decade, diversion of electromagnetic waves around objects has been realized in a way that allows for practical implementation. Specifically, cloaking has been perfected to allow for electrically thin cloaks, on electrically large objects, at wide bandwidths, and without requirements of specific angular orientations nor symmetric cloak geometries. In addition, tunneling approaches have also been devised (to allow objects to 'see' outside), as well as the use of cloaks to not only make the objects invisible, but deflectively immune to electromagnetic attack. In this talk I will present an introduction to this fractal-based approach and showcase a microwave demonstration as motivation for awareness of this exciting technology.

**Workshop****Room: 208****The Communication System Architect's Guide to 5G Physical Layer Modeling****Sangkyo Shin, Keysight Technologies**

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5G researchers face a number of critical challenges, especially when it comes to physical layer (PHY) modeling and simulation. Issues exist across the entire communication chain—from the baseband to the RF/antenna to the channel—in end-to-end link level simulation. This workshop demonstrates an integrated cross-domain, model based simulation approach with which a system architect can execute realistic technical research and easily migrate from one concept to another. We will examine multi-antenna system architectures, advanced modem technology and millimeter wave wireless channel models with realistic system model examples and a new simulation methodology.



▼ Wednesday, September 21, 2016 · 1:00 - 1:20 ▼

**Sponsored Talk****Room: 209****Next-Generation Interconnect Cabling****Donald Bradfield, Southwest Microwave, Inc.**

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As electronic systems expand in capability and shrink in size, there is a distinct need for multifunctional microwave interconnect solutions that support higher RF frequencies, greater bandwidth, improved survivability, easier servicing and a more compact footprint. This presentation will introduce systems integrators and design engineers to system performance improvements and total-project-cost reductions through innovative interconnect packaging alternatives that reduce weight, increase density, improve reliability and enhance RF/microwave performance using microwave coax contacts that seat in off-the shelf multiport connector cavities that accept M39029 contacts.

▼ Wednesday, September 21, 2016 · 1:20 - 1:40 ▼

**Sponsored Talk****Room: 209****Simulation Apps Provide Unlimited Ways to Optimize Numerical Models****Jiyoun Munn, COMSOL**

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In electromagnetic simulations, the ultimate goal is to boost the efficiency and productivity of your device by closely mimicking the effects observed in reality. This process requires an understanding of the reality you are trying to describe, as well as the details that should be included. This seminar will examine best practices in electromagnetic modeling through conventional and multiphysics simulation using COMSOL Multiphysics and its RF Module to improve your understanding of RF and antenna applications, and enhance your design process. We will also introduce the Application Builder, available with COMSOL Multiphysics software, which streamlines an organization's simulation, design, and manufacturing workflow. The Application Builder allows simulation experts to create easy-to-use applications based on their detailed models. The traditional computational modeling workflow involves creating geometry, defining all of the necessary materials and physics, meshing and solving the model, and postprocessing the results. Making any changes thereafter requires going back to previous steps and redoing them, which demands intimate knowledge of the original model. Now, engineers can instead wrap their model in a user-friendly interface that allows them or someone else to test out the necessary changes without requiring foreknowledge of the underlying model. A short live demo will present several antenna simulation apps: Slot-Coupled LTCC Microstrip Patch Antenna Synthesizer and Corrugated Horn Antenna Simulator. These will give you an idea of how simulation apps can be built and used.

▼ Wednesday, September 21, 2016 · 1:30 - 2:00 ▼

**Frequency Matters Theater Session****Room: Frequency Matters Theater****Designing for the Road to 5G****Ken Karnofsky, MathWorks**

Research and development of 5G technology is well under way. New modulation schemes, MIMO configurations and frequency bands are all candidates to form part of the new generation of mobile communication systems. Joint simulation of digital, RF, and antenna behavior is needed to assess and develop these candidate technologies. This talk will illustrate techniques for modeling and evaluating the performance of multi-antenna and multiuser-MIMO technologies at the core of LTE, WLAN, and emerging 5G systems.



▼ Wednesday, September 21, 2016 · 1:50 - 2:30 ▼

**Workshop****Room: 202****Overcoming the Evolving Test and Measurement Requirements of IoT Devices****Ben Maxson, Copper Mountain**

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The rapidly expanding number of connected devices means more products than ever are utilizing RF and microwave components. This burgeoning Internet of Things (IoT) world allows for RF engineers to extend their reach into industries and provides opportunities not possible even five years ago. However, these opportunities present a unique set of challenges. How can engineers who are responsible for the integrity of these RF components guarantee the manufacturers of IoT devices that they will perform accurately? How can they optimize existing test and measurement bottlenecks in throughput? And finally, how can they do all this in the most economical manner without sacrificing the performance and accuracy required? Engineers at Copper Mountain Technologies have produced compact, highly accurate, and fully programmable vector network analyzers (VNA) that function seamlessly in the most innovative and challenging test and measurement applications. This interactive workshop will demonstrate the advantages of compact high performance USB VNAs through an in depth look at real world scenarios and hands-on software tutorials.

**Workshop****Room: 203****Fundamentals of Vector Network Analyzers****Chris Scholz, Rohde & Schwarz Inc. USA**

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From chip design to circuit design and everything in between, one of the most common measuring tasks in RF engineering involves analysis of circuits (networks). And the higher signal speeds have become, the more important it is. A network analyzer is an instrument that is designed to handle this job with great precision and efficiency. Circuits that can be analyzed using network analyzers range from simple devices such as filters and amplifiers to complex modules used in communications satellites. But a network analyzer also is the most complex and versatile piece of test equipment in the field of RF engineering. It is used in applications in research and development and also for test purposes in production. We will discuss VNA measurements, including pulse width/risetimes, pulse repetition rate, transmitter peak power, frequency dependent loss, phase stability, filter characteristics, amplifier gain/efficiency/power, material testing and more.

**Workshop****Room: 207****From Wave-based Load-Pull to Behavioral Nonlinear Models****Vincent Mallette, Focus Microwaves**

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Recent trends in load-pull data acquisition technology include the use of a VNA for capturing complex traveling wave to and from- the device under test (DUT). When compared to a scalar load-pull bench, such a system has a very high through-put and a very good dynamic range. Focus Microwaves and Mesuro have developed a technique to transform data from swept load-pull measurements into a behavioral model ("Cardiff Model+" and "Load-dependent X-parameters"). This approach adds value for users of existing and future "wave-based" load-pull, because the models can be directly used within the CAD environment for amplifier design. During this workshop, we will explain how to optimize your load pull measurement setup; perform a one pass measurement to obtain contours for different parameters and link the results to the behavioral model extraction algorithm and export it in CAD software for simulation.

**Workshop****Room: 208****A Flexible Testbed for 5G Waveform Generation & Analysis****Greg Jue, Keysight Technologies**

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TECHNOLOGIES

A challenge of today's 5G research is the plethora of waveforms, frequencies, and bandwidths being investigated. This includes waveforms at wireless frequencies below 6 GHz, as well as waveforms at microwave and millimeter-wave frequencies. In addition some of the waveforms being investigated may include wideband waveforms, with possibly up to 2 GHz of modulation bandwidths. All of these introduce new test challenges for 5G signal generation and analysis—flexibility is key for today's 5G research. This paper discusses a new flexible testbed for 5G waveform generation and analysis which can be used to investigate and to perform “what-if” scenarios for new emerging 5G waveform applications. Co-existence scenarios between emerging 5G waveforms and legacy waveforms such as LTE are investigated. Wideband signal generation and analysis case studies are shown, both at microwave and millimeter-wave frequencies, with modulation bandwidths up to 2 GHz. Amplitude and phase corrections of wideband waveforms are considered and examined.

**▼ Wednesday, September 21, 2016 · 1:50 - 2:10 ▼****Sponsored Talk****Room: 209****A Programmable Delay Line? What's that?****Victor Chinn, Colby Instruments**

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**Colby Instruments**

This talk includes a brief explanation of what a programmable delay line is (or a variable length signal transmission line). Then, we will detail some uses and applications relevant to the microwave/RF and the digital electronics segments of the industry. By way of example, we will talk about a new instrument that is designed to enable new applications or uses in the signal integrity and test and measurement marketplace.

**▼ Wednesday, September 21, 2016 · 2:10 - 2:30 ▼****Sponsored Talk****Room: 209****Non-Linear and Noise Modeling of a 0.15um GaN Die Family****Larry Dunleavy, Modelithics, Inc.**

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A new set of models will be discussed for a family of six 0.15  $\mu\text{m}$  GaN die geometries capable of high frequency power amplifier and low-noise amplifier design. The devices, addressed range in size from 0.8mm to 3.2 mm gate periphery, with typical noise figures of < 0.8 dB at 10 GHz and output powers ranging from 4 W to 15 W. Both small signal noise and large signal models will be discussed with S-parameter validations through 40 GHz, noise parameter validations through 26 GHz and load-pull validations at 10 and 18 GHz. The large-signal models use a modified Angelov topology that accounts for ambient and self-heating effects as well as scaling of operating voltage from 20 to 28 V. The presentation will discuss measurement and modeling methods, data quality assurance checks, and examples of measured to modeled comparison results. Also to be discussed are a set of proposed measurement “goodness of fit” fidelity metrics for assessing linear and non-linear model quality.



▼ Wednesday, September 21, 2016 · 2:15 - 2:45 ▼

**Frequency Matters Theater Session**  
**Room: Frequency Matters Theater**  
**Radar Testing for Snow Pack Measurement System**  
**Joe Mazzochette, Eastern OptX, Inc.**

This presentation describes the development of the NASA Airborne and Satellite-based Snowpack Measurement capability (ASSM), which uses Eastern OptX bench-top radar test systems. The ASSM system is dedicated to the task of measuring and calculating the accumulated snow pack over an entire winter season, as well as the subsequent spring snow melt rate. This data is then used to estimate the fresh water availability for the post-melt period. Including details from the NASA Air Campaign Results for the Wideband Instrument for Snow Measurements (WISM) report, the presentation will describe the ASSM system along with the development and qualification test requirements. Test results will be given as well as a summary of the program status and projected outcomes.

▼ Wednesday, September 21, 2016 · 2:40 - 3:20 ▼

**Workshop**  
**Room: 202**  
**Test Solutions**  
**Chi Man Shum, Mini-Circuits**

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Mini-Circuits has developed a full catalog of software controlled RF test products to greatly reduce the cost and complexity of test system development. The product range stretches from the low cost component building blocks (USB and Ethernet controlled switches, programmable attenuators, signal sources and power/frequency sensors) to complete rack-mounted test systems. Central to the rack mount developments is an innovative, modular platform, that allows a custom requirement to be quoted within 24 hours of a new request, then built and shipped within two weeks of an order. This is achieved by leveraging Mini-Circuits' wide range of in-stock stock components with common techniques, controllers and modules, including our full range of high reliability mechanical switches and industry leading programmable attenuators, which provide up to 120 dB of attenuation range in 0.25 dB steps. This flexible approach also provides systems which can be easily re-purposed to cover future test scenarios, significantly reducing recurring engineering and software development costs.

**Workshop**  
**Room: 203**  
**Minimizing Uncertainty in Noise Figure Measurements**  
**Vimal Fernandez, NI**

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Like most RF measurements, the mechanics of making a noise figure measurement is the easy part. However, determining the measurement uncertainty can be challenging. Whether you are using either the popular Y-factor or cold-source technique – not understanding measurement uncertainty can result in inaccurate measurements. This presentation reviews the more important contributors to measurement uncertainty when measuring noise figure. In addition to explaining the sources of uncertainty and their relative importance, we then share common mistakes in the noise figure measurement process that can potentially lead to accuracy issues.

**Panel****Room: 207****Not Your Father's Oldsmobile: The Connected Car****Moderator: Gary Lerude, Technical Editor, Microwave Journal****Participating Companies:**

Analog Devices

Autoliv

NXP

Rohde &amp; Schwarz

It used to be you bought a car because of the engine under the hood, the styling of the body, and the luxurious, heated leather seats. Now, the electronics technology in the car plays a significant role in your buying decision: integration with your smartphone, wireless connectivity, navigation and driving aids. This panel from the automotive supply chain will discuss how sensors, wireless links, and the cloud are improving the driving experience, from navigation to safety — even perhaps autonomous driving.

**Workshop****Room: 208****5G mmWave MIMO Channel Sounding****Robin Wang, Keysight Technologies**

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The wireless industry is preparing for the impending 5G wireless technology in order to meet 1000 times projected growth in user demand. And unlike previous technologies 5G will likely use the mmWave frequency band, which means there is a need for accurate and comprehensive channel models at millimeter wave frequencies. This has made the mmWave channel sounding system, which is used to characterize the various mmWave wireless channel models a very hot topic for 5G. In this presentation, the channel sounding concept is discussed along with the requirements and challenges that 5G brings. The main focus is on how to setup a mmWave MIMO channel sounding system with commercial instruments that address six major technical challenges that we foresee in 5G, as well as being aware of the main channel measurement requirements. A look at considerations on how to best address these technical challenges based on the latest generation of mmWave/microwave instrumentation, measurement techniques and capabilities follows. Lastly, a proposed reference prototype system design for 5G mmWave MIMO channel sounding system, including a discussion of its functionalities and performance is presented.

▼ Wednesday, September 21, 2016 · 2:40 - 3:00 ▼

**Sponsored Talk****Room: 209****Crest Factor as a Figure of Merit for Communication Amplifiers****Matthew Diessner, Wireless Telecom Group**

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Today's rapidly evolving OFDM communications signals provide challenges for the broadband amplifier industry. Modern Wi-Fi and LTE signals, as well as the new 5G mobile communications devices use high video bandwidth signals that have to be amplified. Recent advances in RF power measurements enable fast and accurate time and statistical domain power measurements of these types of complex OFDM modulated RF signals. We will discuss how "crest factor measurements" can be used as a figure of merit for testing the broadband amplifier and how wideband USB power sensors can be used for product development, performance verification and production test.





▼ Wednesday, September 21, 2016 · 3:00 - 3:20 ▼

**Sponsored Talk****Room: 209****Additive Manufacturing Techniques for the Production of RF Components****Tom McWalters, Microwave Development Laboratories (MDL)**

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Additive manufacturing (AM) refers to a class of manufacturing processes based on the building of a solid object from three-dimensional (3D) model data by joining materials, usually layer upon layer. Microwave Development Labs has implemented several techniques for the production of passive RF components. These techniques are replacing traditional “tooling production” for investment casting. Eliminating “tooling” cost and build time can save customers production cost and increase deliverability, while maintaining good accuracy and reproducibility of RF components. This presentation gives an extensive overview of different AM techniques (i.e. stereolithography, laser sintering, 3D printing, and melt-extrusion techniques, used in the production of passive RF components.

▼ Wednesday, September 21, 2016 · 3:45 - 4:15 ▼

**Frequency Matters Theater Session****Room: Frequency Matters Theater****Antenna designs for Internet of Things (IoT)****C.J. Reddy, Altair**

With proliferation of miniature wireless sensors, every device (however low-tech it may be) is expected to have internet connectivity and there is widespread machine to machine (M2M) and machine to human (M2H) and human to machine (H2M) interaction wirelessly. This is referred to popularly as Internet of Things (IoT), which will span roughly 200 billion devices worldwide in the near future. It is expected to be a challenge to have reliability and performance of wireless connectivity, which is mainly dependent on not only efficient antenna designs, but also flawless function of these antennas in very complicated environments. One of the key aspects of IoT is requirement of key components to enable communications between devices and objects. Objects need to be augmented with an Auto-ID technology, typically an RFID tag, so that the object is uniquely identifiable. In this talk, various modeling techniques, such as MoM, MLFMM, FEM, FDTD etc, will be presented. Also asymptotic, ray-based method such as the uniform theory of diffraction or Ray Launching geometrical optics (shooting and bouncing rays) will be presented for electrically extremely large RFID problems such as long distance indoor propagation. Also aiding IoT are mobile broadband networks specifically focusing on the next generation of standards, namely 5G. This talk also addresses some of these futuristic technologies that are laying the foundation for the 5G standards, highlighting the concept of massive MIMO that employs antenna arrays and beamforming techniques to address the high data rate demands for IoT.



▼ Thursday, September 22, 2016 · 9:00 - 9:30 ▼

## Technical Sessions

**RF & Microwave Design Track****Room: 202****Reaching New Heights in Mixer Linearity with GaN MMIC Technology****Charles Trantanella, Custom MMIC**

One limiting factor in modern day microwave systems is the linearity of the mixer. Commonly expressed as the third order intercept point (IP3), mixer linearity is all too often lower than desired, which directly degrades the sensitivity of the system. Over the years, various MMIC technologies such as MESFET, PHEMT, and even GaAs HBT have been used to address the problem of poor mixer linearity, but these approaches have had limited success at best. Newer technologies such as Gallium Nitride (GaN) have delivered high linearity in other circuit functions such as low noise and power amplifiers. However, the use of GaN to create high linearity mixers has received scant attention, until now. At Custom MMIC, we have recently developed a family of GaN-based mixers in the 2 to 20 GHz range with superior linearity performance, and are currently in the process of commercializing a number of these designs. Using a variety of two-terminal (diode) and three-terminal (FET) mixer topologies, we have achieved input IP3 intercept points exceeding +40 dBm, while still maintaining a conversion loss of -7 to -8 dB and an LO to RF isolation of greater than 25 dB. In our work, we will discuss the approaches used and the performance levels achieved within our designs.

**Measurement Track****Room: 203****Impact of Test Equipment Calibration On Power Amplifier Characterization****Dipti Chheda, Keysight Technologies**

The demand for increased data throughput and better spectral efficiency leads to technological shifts such as the need for wider bandwidth, use of higher band frequencies, multi-channel design, to name a few. This in turn puts increased demand on the component design and test. Depending on the intended application, low power characterization, modulated signal characterization, and non-linear distortion characterization are three of the few key measurements made on power amplifiers. Calibration of test equipment and tools that you rely on are often times overlooked as means to optimize amplifier design or your production throughput. With the use of these power amplifier measurement examples, we will examine how the calibration process and consistency of the test equipment you rely on can impact your design tolerance margins, the risk of unexpected failures of your components, or your throughput in manufacturing. In some very limited circumstances, calibration may be treated as a commodity, but one should know a lot about your needs and measurements to ensure the risks resulting from limited calibration are acceptable to your design and business goals. The ultimate goal is to bring the overall cost of your program down, saving you both time and money while ensuring your amplifiers are operating reliably and accurately, giving you the needed competitive edge.

**Radar/Defense Track****Room: 207****Advances in Kilowatt UHF Radar Power Amplifiers With RF GaN Transistors Operating at 150V  
John Walker, Integra Technologies**

This paper explores the advantages in high power RF amplifiers that employ a high voltage GaN RF technology operating above the industry standard of 50 V. Our analysis is based on a 1 kilowatt amplifier for radar applications in the UHF frequency band from 420 MHz to 450 MHz, also within the so-called P-band, with a signal pulse of 100  $\mu$ s and 10% duty cycle. The power amplifier design is based on an RF GaN technology that operates at 150 V bias. The single-ended 150 V RF GaN transistor utilizes three dice of 15 mm gate periphery each assembled in a standard ceramic package. It achieves 1 kW output power across the band, with >70% drain efficiency without pulse gating during radar transmitter receive mode. The results reported are significant because power amplifier operation at 150 V offer several advantages among which are: 1) higher power density translates into fewer GaN chips and potentially lower \$/W; 2) higher impedance at fundamental and harmonic frequencies and therefore easier to broadband, 3) potential for achieving higher efficiency through proper harmonic terminations due to higher impedance at harmonic frequencies

**Signal Integrity/Power Integrity Track****Room: 208****How to Evaluate the Signal Integrity Performance for Your High Bandwidth Real-Time Oscilloscopes?****A. Gosselin, Keysight Technologies**

The term "signal integrity" surfaces regularly in electronic test. Signal integrity is the primary measure of signal quality, and signal integrity importance increases with bandwidth, the need to view small signals, or the need to see small changes on larger signals. Why does oscilloscope signal integrity matter? Signal integrity impacts all scope measurements. The amount of impact signal integrity can make on signal shape and measurement values might surprise you. Oscilloscopes themselves are subject to the signal integrity challenges of distortion, noise, and loss. Scopes with superior signal integrity attributes provide a better representation of signals under test, while scopes with poor signal integrity attributes show a poorer representation of signals under test. This difference impacts engineers' ability to gain insight, understand, debug, and characterize designs. Results from oscilloscopes with poor signal integrity can increase risk in development cycles times, production quality, and components chosen. To minimize this risk, it is a good idea to evaluate and choose an oscilloscope that has high signal integrity attributes.

**▼ Thursday, September 22, 2016 · 9:40 - 10:10 ▼****RF & Microwave Design Track****Room: 202****Software Controlled Narrowband Tunable Bandpass Filters for UHF Receivers  
Yarkin Yigit, ASELSAN INC.**

Numerous frequency bands are used in microwave and wireless communication equipment, and filter technologies are major contributors of performances of these devices. Tunable filters make receivers adaptable to multiple bands. Additionally they provide noise reduction and lowering the power consumption of ADC (analog to digital converters). In this paper, GaAs varactor and BST capacitors are evaluated as tuning elements for narrowband lumped bandpass tunable filters. Simulation results and outputs of fabricated hardware are assessed. In theoretical analysis, parameters which affect the bandwidth and center frequency of filters are indicated. Since BST capacitors do not have Spice models, S parameters of tunable capacitors have been derived from evaluation board which was designed for this work. Center frequencies of filters vary from 424 MHz to 710 MHz with approximately 90 MHz constant bandwidth. Insertion loss alters from 2.4 dB to 7.1 dB. This filter was controlled by 12 bit resolution DAC (Digital to Analog Converters) to drive these capacitors.

**Measurement Track****Room: 203****Simplifying Phase Coherent Signal Generation****Lawrence Wilson, Rohde & Schwarz Inc. USA**

Phase coherent RF and microwave signals are required in many different applications; however being able to create them in a reliable and repeatable manner has long been a challenge. This paper will discuss the basics of phase coherent signals, techniques to greatly simplify the process of generating phase coherent signals and the external factors that can influence the long term stability of these signals.

**Radar/Defense Track****Room: 207****24 GHz Radar Technology Enable Next Generation Sensors****Patrick Walsh, Analog Devices**

24 GHz Radar based millimeter wave sensors are increasingly being used in automotive, industrial and consumer applications to provide users critical real time information such as presence, movement, velocity and distance. This paper will review radar principles and the building blocks and design tradeoffs for various radar applications from system tradeoffs associated with configuration options from simple Doppler range to the more complex multi-channel configurations where there is need to resolve range, speed and angle of objects. The paper will review the options of the signal generation from open loop DAC control to closed PLL and the effect on these on the overall system. This will include a review of the various waveform option such as FMCW based systems and look at the flexibility offered by ramping PLLs allowing flexible sweep times, ramp bandwidths and ramp profiles to be generated. The key parameters for both for transmit and receive signal chains will be explored and how key parameters such as noise and transmit power affect the system. By way of example, we will discuss Analog Devices series of single channel and multi-channel transceiver chips that are designed to meet these various configurations needs.

**Signal Integrity/Power Integrity Track****Room: 208****Using VNAs as a Tool for Signal Integrity in High Speed Digital Systems****Joe Mallon, Anritsu**

As bit rates in serial communications systems increase, the signal paths that carry these signals must be treated as high frequency transmission lines. These signal paths can include chip packages, PCB traces, connectors, cables and backplanes and will be referred to as channels in this paper. The fact that these channels must now be treated as transmission lines means that engineers might need a new set of tools to use to design, simulate and characterize them. VNAs make measurements in the frequency domain and can be used to supplant the information that native time domain instruments, like fast oscilloscopes, signal quality analyzers (BERTs) and time domain reflectometers/transmission instruments (TDR/TDTs) already provide. This paper is intended to introduce vector network analyzers (VNAs) to engineers working on high speed digital designs that are using fast oscilloscopes and bit error rate testers (BERTS). These time domain based instruments can show you if you have issues with signal integrity or if your eye diagram is open or closed but they do not show you the reason for the problems. VNAs make measurements in the frequency domain and are a useful tool to understand the reasons for issues effecting signal integrity.



▼ Thursday, September 22, 2016 · 11:00 - 11:30 ▼

**Measurement Track****Room: 203****Considerations for ADC Testing****Lawrence Wilson, Rohde & Schwarz Inc. USA**

Analog-to-digital converters (ADCs) have taken giant steps in speed over the past decade. Such devices are widely used in a wide range of applications across all industries. When testing these ADCs, either as part of the design process, or as part of the device evaluation process, requires the use of test equipment that can drive the device to its limits without impacting the performance of the device. The end goal is always to evaluate the ADC, not the test equipment. This paper will explain the important performance characteristics that must be considered when testing an ADC.

**Radar/Defense Track****Room: 207****Automotive Radar Systems - Radio Testing in the E-Band****Kay-Uwe Sander, Rohde & Schwarz GmbH & Co. KG, Munich**

The progress of Advanced Driver Assistance Systems (ADAS) leads to an increasing number of radar systems in the automotive industry. Radar based ADAS features include adaptive cruise control, pre-crash protection and collision warning systems. The global trend for automotive radars are E-band systems operating at center frequencies between 77 and 79 GHz depending on the geographical region, with wideband modulation using FM chirp waveforms to reach good target resolution. This paper gives a survey of recent trends in the development of automotive radar systems. We present a test solution, which is suitable to generate and analyze continuous wave (FMCW) radar signals in the E band, using ultra-wideband chirp sequence modulation with up to 2 GHz bandwidth, and demonstrate radar signal analysis and how glitches in the signal can be identified.

**Signal Integrity/Power Integrity Track****Room: 208****Modeling Ferromagnetic Components in Voltage Regulation Modules (VRMs)****Colin Warwick, Keysight Technologies**

For power integrity and power-aware signal integrity, it is essential to model not only the IC load, power distribution network (PDN), and decoupling capacitors (decaps), but also the voltage regulation module (VRM). The switching converter in the VRM usually contains integrated magnetics with ferroelectric cores that exhibit complicated non-linearity and hysteresis. In this paper we show how to implement an efficient but powerful modeling methodology using the physics-based Jiles-Atherton model. We implemented it as coupled electric and magnetic circuits using the multi-discipline Verilog-A method developed by Williams, Vogelsong, and Kundert. From three basic components (cores, windings, and gaps), it is possible to build arbitrarily complex inductors, mutual inductors, transformers, etc. These run in any SPICE-like simulator that supports the industry-standard Verilog-A language. They can be combined with active and passive lumped SPICE elements and distributed element models extracted from layout artwork via an EM field solver or from measured data. Having a complete simulation or "virtual prototype" enables insightful "what if" design space exploration without expensive and time-consuming "cut and try" physical prototyping.



▼ Thursday, September 22, 2016 · 11:15 - 11:45 ▼

**Frequency Matters Theater Session**  
**Room: Frequency Matters Theater**  
**Ham Radio – the Original Social Network**  
**Doug Grant**

Amateur (also known as “ham”) radio has been around for more than 100 years and is still growing, with over 700,000 licensees in the U.S. and over 2 million worldwide. A very diverse activity, it includes experimenting, public service, emergency communications, and even competitions. Radio amateurs continue to be in the forefront of communications technology and science while promoting international goodwill and friendship through direct person-to-person communications using only the ionosphere as infrastructure. This talk will explore how amateur radio has evolved and adapted in the 21st century.

▼ Thursday, September 22, 2016 · 12:00 - 12:30 ▼

**Frequency Matters Theater Session**  
**Room: Frequency Matters Theater**  
**Vivaldi Antennas for Ground Penetrating Radar**  
**Skander Chaouch-Bouraoui, Howard University**

This research is a part of a project for the forward-looking SIRE radar system with application in IED and landmine detection. The antenna subsystem is an important component of the SIRE radar. The material permittivity effects on Vivaldi antennas is a fundamental since it is related to the radiation efficiency. The Vivaldi antenna is used as a receiver here. The software FEKO is used to simulate the Vivaldi antenna and characterize its radiation pattern and how it varies with the relative permittivity. Varying the relative permittivity gives interesting variation of the radiation pattern. The radiation pattern has been calculated at different frequencies. For the far field the relative permittivity of the substrate of the Vivaldi antenna for a higher permittivity has higher absorption than the one with the lower relative permittivity. Also, the power for the former is greater than the latter. This paper investigates the permittivity effect of the substrate for planar printed Vivaldi antennas. Using the methodology of parametric study with electromagnetic simulation, the antenna has been characterized. The results are to be applied to the understanding of the radiation mechanism of the Vivaldi antennas in the SIRE transceiver subsystem.

▼ Thursday, September 22, 2016 · 12:45 - 1:15 ▼

**Frequency Matters Theater Session**  
**Room: Frequency Matters Theater**  
**Design and Verification of X-Band Anechoic Chamber**  
**Brittany Decker**

The Raytheon UMass Lowell Research Institute is a new research facility at University of Massachusetts Lowell focused on the advancement of innovative technologies, including flexible and printed electronics. In order to properly test and characterize developed technologies, the laboratory requires a test facility free of electromagnetic interference. A group of undergraduate students was tasked with creating a far-field anechoic chamber using an existing 8' x 8' Faraday cage for testing devices exposed to microwave frequencies. The project involved selecting appropriate materials, designing the layout, and installing equipment to balance the limited chamber size while maximizing allowable bandwidth and performance for testing. Upon completion of construction, industry-standard validation tests were used to measure and qualify chamber performance. An overview of design expectations are compared to the measured performance of the chamber; demonstrating the capabilities and limitations of the chamber constructed.

▼ Thursday, September 22, 2016 · 1:00 - 1:40 ▼

**Workshops and Panels**
**Workshop**
**Room: 202**
**Introduction to 802.11ax: High Efficiency Wi-Fi**
**Alejandro Buritica, National Instruments**

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Although the creation of new wireless standards promises many benefits to us as consumers – they introduce new design and test challenges. One exciting new technology is 802.11ax, also known as High-Efficiency Wi-Fi (HEW). HEW is an evolution to 802.11ac, and is expected to become a mainstream Wi-Fi technology by 2017. This presentation, we will introduce several of the new physical layer characteristics of 802.11ax, including features such as clear channel assessment (CCA), narrow sub-carriers, 1024 QAM, and orthogonal frequency division multiple access (OFDMA). As a result of this presentation, attendees will have a better understanding of the new technology and how it will affect their current RF design and test practices.

**Workshop**
**Room: 203**
**A Single EM Simulation Tool for Integrating the Many Aspects of New Electronics Product Design**
**James Willhite, CST of America**

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**CST**


Electronic design innovations in communication devices often involve a multitude of challenges which should be addressed before fabrication begins. Can the signal move from the digital to analog portions of the boards with little loss or distortion? Can the radiating structure be made to fit into increasingly limited space? Will the signal be radiated efficiently without coupling back into the device? Will power components introduce excessive temperatures? Can we safely get the design into fabrication before getting “scooped” by competition? Each of these problems might introduce an iterative looping through rings of simulations with different technologies. Using a simulation tool which can address all of these issues can help shorten design time. A simple handheld communication device will be studied using the complete technology of a FEM, time domain, & thermal solvers in one integrated package. By doing this high quality results can be obtained in modest time without resorting to magic.

**Workshop**
**Room: 207**
**Highly integrated antenna frontend design for Radar, SATCOM and 5G**
**Zacharia Ouardirhi, Electro Rent Corporation**

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G L O B A L

Highly integrated RF frontends are key components for K/Ka-band satellite communication on-the-move, including multimedia entertainment systems, radar systems, 5G mobile communication as well as 60 GHz broadband home access equipment and backbone networks. Designing such complex modules is a real challenge. This workshop will demonstrate how to use EMPIRE from IMST GmbH, a full wave 3D EM-field solver based on FDTD. Topics covered include: different RF frontend designs composed of not only a large number of antenna elements but also of complex multilayer feeds, RF-transitions, and power combiners. Workshop attendees will also learn how to merge RF- and thermal characteristics of active RF-components in the 3D EM-simulation process. The modelling technique as well as different designs will be presented including a live simulation of a complete antenna front end.



▼ Thursday, September 22, 2016 · 1:50 - 2:30 ▼

**Workshop****Room: 202****From VHF to Ka-Band: LTCC, a Suitable Yet Challenging Technology for Both Passive and Active Components****Aaron Vaisman, Mini-Circuits**

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Since its inception back in the 1950s, LTCCs have become one of the most sought after technologies available for implementing miniature RF and microwave components. These have been intended to be high performing, reliable and low cost while at the same time, offer the possibility to be mass produced in low, medium and high quantities. As decades have passed by, the technology has matured a great deal. New developments both in LTCC technology and the supporting EM simulation software, are creating opportunities to realize circuits and modules at even lower and higher frequencies than ever, bringing on densely packed circuits in smaller case styles. This has required the technology to become very flexible, opening the doors for highly customized designs to be realized within shorter design cycles while setting more demanding specification goals. This workshop will discuss the LTCC state of the art in regards to current capabilities and applications. Also, it will point out the most relevant tradeoffs and challenges currently being faced by the design community. In that order of ideas, an insight into the design flow geared to mitigate some of these constraints will be presented. Finally, we will include some remarks on the foreseeable future of the technology.

**Workshop****Room: 203****Electromagnetic System Modeling - Concept AND Reality****Mark Ravenstahl, ANSYS**

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As signal frequencies push higher in the GHz regime and digital signals cross into the analog realm, electromagnetic coupling is a fact of life. Highly integrated assemblies contain coupling paths which cannot be identified through traditional circuit simulation. As much of the system needs to be modeled together without requiring significant computing investment. Our workshop will examine realistic system models combining PCBs and vendor 3D components. These 3D Components are fully encapsulated and (optionally) encrypted 3D representations of supplier products. They include all the physical descriptions of the model, including materials, boundary conditions, and excitations, yet allow the supplier to hide information from the end user to protect their intellectual property. This allows full electromagnetic coupling without giving away sensitive designs. We will show how the systems are assembled, simulated, and evaluate the compute resources required. Additionally, we will show a similar system combining antennas and nonlinear components to explore non-uniform thermal effects. As part of this workshop, we will also discuss ways to access on-demand computation resources.

**Workshop****Room: 207****Fundamentals of Spectrum Analysis: Analyzing Wideband Signal in mm-Wave Bands****Rich Pieciak, Rohde & Schwarz Inc.**

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The IEEE 802.11ad standard makes use of approximately 2 GHz bandwidth in the 60 GHz frequency domain. Developers of automotive radar are talking about the 79 GHz frequency band with an available bandwidth of up to 4 GHz, and designers for 5G for cellular networks are discussing the use of up to 2GHz signals in the cm and mm-wave frequency bands. Verification of the spectrum allocation and in depth analysis of the transmitted signals is becoming more and more important. But where to start? This workshop looks at where you can begin when analyzing wideband signals in millimeter wave bands.





▼ Thursday, September 22, 2016 · 2:40 - 3:20 ▼

**Short Course****Room: 202****Intuitive Microwave Filter Design With EM Simulation****Dan Swanson, SW Filter Design**

Microwave filters are a critical component in low cost, high volume commercial systems as well as in higher performance, lower volume military systems. Examples include high Q cavity filters for cellular base stations and planar, thin-film filters for electronic warfare or surveillance systems. There are many other filter technologies and applications we could add to this list. In this short course we will present a brief introduction to both high Q cavity filters and planar thin-film filters. We will outline a common design flow for both filter types and highlight the design tools that make the design process as intuitive and efficient as possible. EM simulation is an integral part of these design flows and we will offer some useful tips on how to use these tools most effectively.

**Short Course****Room: 203****Radiated Emissions - Product Evaluation and Pre-Compliance testing****Kenneth Wyatt, Interference Technology**

Radiated emissions is usually the number one failure when it comes to EMC compliance testing. This, plus the fact few universities or colleges teach how to design products for compliance often necessitate repeated testing, cost overruns, and project release delays. This short course will explain the most common reasons for product failure, describe a straightforward process for troubleshooting radiated emissions, and demonstrate how to perform simple pre-compliance testing on a budget. This will help you "know before you go"!

**Short Course****Room: 207****Basics, Advances, & Breakthroughs in Phased-Arrays, Radar, and MIMO****Eli Brookner**

Array Basics: array phase scanning, embedded element gain, array factor, sub-array time delay steering, thinned arrays, array blindness and grating lobes, error sidelobes, limited scan and hemispherical scan arrays, array feeds and phase shifters, sidelobe cancelling and adaptive array processing (made easy). Recent Technology Advances: (1) Metamaterials: For low cost \$1k satellite electronically steered array (ESA) at 30 GHz; for stealthing, for low profile 250-505 MHz antenna; focusing beyond the diffraction limit, isolation, wide angle impedance matching (WAIM); (2) Digital Beam Forming (DBF): at element and its advantages; (3) Potential Advances for Moore's Law Via: Graphene (transistors with 1 GHz clock speed), Spintronics, Memristors and Quantum Computing; (4) Low Cost Arrays: using COTS; (5) DARPA Arrays at Commercial Timescales (ACT) Program: whose goal is development of low cost commercial reconfigurable building blocks for phased arrays; (6) Extreme MMIC: 32 element 60 GHz T/R array on chip costing just few dollars in future; (7) MIMO Radar: in simple physical terms without heavy math, we show how conventional radar arrays can do as well as MIMO radar arrays re: (1) angle accuracy and resolution, (2) minimum detectable velocity for airborne radars, (3) barrage, repeater and hot-clutter jammers, all without the severe signal processing load and waveform design problem of MIMO radars, and finally we show where MIMO radar makes sense.

**Short Course****Room: 208****Fundamentals of Power Integrity****Steve Sandler, Picotest**

Power integrity is important to the entire system performance and consists of much more than power distribution noise. This session provides an understanding of power integrity, why it is important, how to design for it, and it teaches techniques for high-fidelity simulation, analysis and measurement. The goal is to enable you to better isolate, troubleshoot, and optimize power related issues.



Level 2 Floor Plan

