WFA 08:00-17:00

RF Design and Packaging for Wireless Wearable and Implants
Sponsor: IMS

Organizer: J.-C. Chiao, *University of Texas at Arlington,* Jessi Johnson, *Advanced Cardiac Therapeutics,* Kamal Samanta, *Milmega*

Abstract: Recently a lot of research efforts have been dedicated towards the development of sophisticated wearable and implantable devices. The market growth has been substantially fast in a global scale. The driving forces are owing to the needs for continuous surveillance, monitoring, sensing, locating, tracking and conditioning of human conditions with ubiquitous computation and intelligence in networks. RF/microwave wireless sensors, identification tags and communication devices are emerging quickly in wide ranges of these applications in medicine, consumer electronics, fitness, athletic performance, safety and security. Examples include non-invasive vital-signal measurements, robust wireless positioning procedures, novel implants in brain, heart, joint and GI tracts, smart watches and fitness wearables. Due to the fast growing interest in private sectors, governments and academia, related investment in these fields to satisfy future needs have been increasing steadily and more research activities are expected . These factors encompass new enabling technologies for microwaves and miniaturization of systems for their wearability and mobility to make possible novel applications. These devices often integrate with physical and chemical sensors, wireless communication functions, wireless powering capability, and microprocessors. Due to the facts that the devices are closely in contact with or surrounded by human tissues, the macro and micro environments for electromagnetic wave propagation are very different from the ones in air. Furthermore, wearables and implants typically have physical and material constraints for packaging in order to match dimension, form factors, biocompatibility and FDA requirements. These constraints present tremendous challenges to RF designs and packaging issues for RF performance. The aim of this workshop is to report recent research findings in the very promising area of wearable and implantable electronics utilizing microwave techniques by world-wide experts. General requirements, circuit design, antenna, wave propagation, RF energy and protocols, flexible electronics, tissue issues and multi-physics simulation, and packaging considerations will be discussed.

1. Challenges for the design of RF antennas in pacemakers and the benefits of improved packaging.
   Perri Li; St. Jude Medical
2. RF contact/non-contact vital sensors and their packaging and human body effects
   Jong-Gwan Yook; *Yonsei University, Seoul, Korea*
3. Novel Flexible Antenna Technology for Miniature Near-field Radar Sensing Applications
4. Hongdun Lin; *Industrial Technology Research Institute (ITRI), Taiwan*
   Wireless Design for Wearable Devices: an Integrated Design Approach
   Larry Arne; *Proteus Digital Health*
5. Wireless in Medical Implantable Products
   Eric Chow; *Cyberonics*
6. 3D/Inkjet-Printed Packaging and Antenna Structures for Wearable and Implantable RF Modules
   Manos Tentzeris; *Georgia Tech*
7. Wearable Device RF Packaging and Prototyping using 3D Simulation
   Marc Horner; ANSYS; *Sara Louie; ANSYS, Inc.*
8. Flexible adhesive-integrated antenna systems for biomedical applications
   Todd Coleman; *University of California, San Diego*
9. Ultra-Wideband 60 GHz Wireless System for Biomedical Applications
   Kamal Samanta; *Milmega, UK*

WFB 08:00-12:00

Advanced Millimeter-Wave 3D/Multilayer MCM/SoP and Printing Technologies
Sponsor: IMS

Organizer: Apostolos Georgiadis, *CTTC Spain*, Kamal Samanta, *Milmega*, Manos Tentzeris, *Georgia Institute of Technology*, Maurizio Bozzi, *University of Pavia*

Abstract: This workshop will discuss the design challenges and recent advancement in 3D/multilayer MCM/SoP technologies, including using additive manufacturing (e.g. 3D, inkjet, aerosol, gravure), for realizing advanced microwave and mmW high quality embedded passive components, circuits and vertically stacked and multilayer/3D MCM/SoPs. At the same time, will cover important progresses in highly integrated multilayer/3D components and systems (like complete Ka-band satellite and 60 GHz receivers) using conventional /subtractive printing technologies (like LTCC and photoimageable TF). The workshop will also provide various examples in the area of multifunction packaging, high-Q passives and energy harvesting/transfer techniques, Internet of Things, flexible platform and morphing/origami-based shape changing modules, wearable electronics, wireless sensor networks and 4G/5G systems.

1. LTCC Modules for Future Communication Satellites in Ka-Band
   Ingo Wolff; *IMST*, *Germany*; P Uhlig;*I MST Germany*; R Kulke; *IMST*; C Günner; *IMST*; J Kassner; *IMST*
2. Aerosol Jet 3D Printing for mmW SOP RF Front Ends
   John Papapolymerou; *Michigan State University*
3. Millimeter-wave 3D MCM/SoP Using Multilayer Screen Printed Technology
   Kamal Samanta; *Milmega*
4. Additively Manufactured Flexible and Origami-Shaped RF Modules
   Manos Tentzeris; *Georgia Institute of Technology*
5. Inkjet-Printed Energy Harvesting and Autonomous Wireless Sensor Nodes
   Apostolos Georgiadis; *CTTC, Spain*;Nuno Carvalho; *University of Aveiro*
6. Inkjet and 3D printed Conductive RF Structures
   Luca Roselli; *University of Perugia, Italy*
7. Additive manufacturing of ceramics using Stereolithographyns
   Dominique Baillargeat; *XLIM, France*

WFC 13:00-17:00

Antenna and Packaging Integration Technologies for mmWave and Terahertz-Wave Applications
Sponsor: IMS

Organizer: Xiaoxiong (Kevin) Gu, *IBM Research*

Abstract: This half-day workshop extends from the previous-year packaging workshop and covers important additional integration technologies for mmWave and Terahertz-wave modules with embedded antennas. The applications include 60GHz and 5G wireless communications, W-band/THz passive imaging, as well as THz waveguide integration at wafer-level. Five industrial experts and renowned faculty members will present their recent mmWave and THz packaging and integration work with focus on different substrate technologies as well as design and characterization approaches. Specifically, the presentations include silicon interposer technology and antenna solutions for highly-integrated mmWave transceiver modules; a study of analytical and empirical investigation of antenna and system integration for a 5G mmWave cellular device prototype; the cross-THz antenna and packaging development for passive imaging applications; and the most recent advances of multilayer organic technology and wafer-level THz waveguide design, fabrication and characterization.

1. Silicon Interposer Technology and Antenna Solutions for Highly-Integrated mmW Transceiver Modules
   Laurent Dussopt; *CEA-LETI*
2. Analytical and Empirical Investigation of a 5G mmWave Cellular Device Prototype
   Wonbin Hong; *Samsung Electronics Co., Ltd.*
3. Multilayer Organic Packaging for Microwave and mm-wave Front Ends
   John Papapolymerou; *Michigan State University*
4. Cross-THz Antenna and Packaging Development for Passive Imaging Applications
   Danny Elad; *IBM Research - Haifa*
5. Design Study of Wafer-level Compatible Terahertz Planar Waveguides and Their Characterization
   Prem Chahal; *Michigan State University*

WFD 13:00-17:00

MM-Waves Measurement Needs for 5G
Sponsor: IMS

Organizer: Nuno Carvalho, *Instituto de Telecomunicacoes,* Jon Martens, *Anritsu*

Abstract: 5G is the next big step on wireless communications. Several proposals are moving this technology to millimeter wave solutions, which will allow to increase significantly the bandwidth and bitrate levels. Nevertheless not only several transceiver design strategies should be discussed but also new characterization techniques should be adapted for this frequency band. In this workshop several strategies for 5G transceiver design will be addressed first with a group of industry and academic groups presenting their new designs, and will be followed by a strong discussion on characterization, instrumentation and measurement techniques, specially focused on millimeter wave signals that would be used on 5G applications. In this scenario industry and R&D laboratories will discuss this issue carefully.

1. Metrology Issues for 5G
   Kate Remley; *NIST*
2. Millimeter-waves for 5G and Evolving Measurement Needs
   Debabani Choudhury; *Intel Corporation*
3. Practical Aspects and Considerations for High Instantaneous Bandwidth, High Data Rate, Millimeter Wave Wireless Characterization and Test Systems
   Justin Magers; *National Instruments Corporation*
4. Linearity topics in wideband modulated mm-wave measurements
   Jon Martens; *Anritsu*
5. 5G communication systems at mm-wave frequencies and their consequences for hardware design
   Rik Jos; *Ampleon*
6. Mmwave Antenna and 5G Testbed characterization
   Ilja Ocket; *KU Leuven*; Sofie Pollin; *KU Leuven*
7. Toward 5G Measurement: How the Modern VNA will help
   Andrea Ferrero; *Keysight Technologies*

WFE 13:00-17:00

Phase Change Material Switches for a New Class of Microwave Control Components
Sponsor: IMS

Organizer: Harvey Newman, *Naval Research Laboratory*, Tony Ivanov, *US Army Research Laboratory*

Abstract: Phase change materials (PCMs) based on the chalcogenides are a class of solids that can be transitioned by thermal actuation between a crystalline phase, which is highly electrically conductive, and an amorphous phase, which is highly electrically insulating. In particular, germanium telluride (GeTe)-based PCMs have demonstrated a very high amorphous-to-crystalline resistance ratio and a very low crystalline-state resistance. This resistance state is non-volatile and is naturally applicable for latching RF/microwave switches. A PCM device has an actuation mechanism that is fundamentally different from traditional semiconductor switch technologies. Switches have been reported that show a switch figure of merit (i.e., cutoff frequency fc = 1/(2*pi*Ron*Coff)) equal to 12.5 THz. Latching RF Switches made from PCMs offer the promise for realizing IC-integrable components that can enable new classes of adaptive, reconfigurable and tunable networks. In addition to RF devices, PCMs could be used to create reconfigurable metallic surfaces, transmission lines, and antennas. This workshop will showcase presentations by leading researchers from industry, academia, and government who are currently developing RF switching devices based on PCMs. The first presentation will be tutorial, to help orient the attendee to this new topic. The following presentations will discuss materials development, device design, device modeling, thermal actuation techniques, and explore the application space for these devices. Discussions will include system insertion benchmarks such as RF loss, bandwidth, power consumption, power handling, and linearity. At the conclusion of the speakers’ presentation, a moderated session will be held to summarize the findings of the workshop and discuss, with inputs solicited from the speakers and the attendees, the state of the art of what may become the enabling technology for new adaptive RF systems.

1. Inline Phase Change Switches: The Future of Reconfigurable RF Systems
   Nabil El-Hinnawy; *Northrop Grumman Electronic Systems*
2. Phase-Change Materials for RF applications
   Jeong-Sun Moon; *Hughes Research Laboratories*
3. Phase Change RF Switch Technology
   James Bain; *Carnegie Mellon University*
4. Modeling of Phase Transformation Behavior at the Atomic and the Mesoscales
   Avinash Dongare; *University of Connecticut*
5. Exploring Materials Evolution in Phase Change RF Switches using Raman Imaging
   Glen Birdwell; *US Army Research Laboratory*
6. Analysis of Failure in PCM RF Switches
   James Champlain; *Naval Research Laboratory*
7. Compact Modeling of Directly and Indirectly Heated Phase Change RF Switches
   Mina Rais-Zadeh; *University of Michigan*

WFF 08:00-17:00

Beyond Graphene and Emerging Devices for Microwave Circuits and Systems
Sponsor: IMS

Organizer: David Ricketts, *North Carolina State University*, Dimitris Pavlidis, *National Science Foundation*, James Hwang, *Lehigh University*

Abstract: Graphene, a single sheet of carbon atoms arranged in a two-dimensional (2D) honeycomb crystal lattice has been the subject of numerous studies covering fundamental physics and material aspects but also device applications. Work in this area paves the way to related developments that utilize other 2D materials such as chalcogenides, germananes, silicenes, metal oxides and hexagonal boron nitrides. Possibilities exist for designing devices that utilize a combination of materials rather than isolated 2D crystals to satisfy diverse requirements ranging from insulator to direct bandgap properties. Their heterostructures provide further enhancement in device properties and design flexibility. The well-known limitations of opening the bandgap in graphene and its rather limited application in switching applications may consequently be overcome. Exceptionally good performance is expected from graphene and 2D materials in terms of carrier mobility, transconductance and stability. This could lead to a new generation of high frequency devices with much higher operation frequencies and multifunctional features. Aspects of interest for new generations of such devices include their fabrication technology using various approaches. Their non-linear properties arising from the Dirac cone bandstructure and use in circuits such as frequency multipliers is also of interest. 2D-2D tunneling devices may lead to novel low-power electronic applications. Negative Differential Resistance may also offer the possibility of developing new signal sources. Reconfigurable terahertz plasmonics and metamaterials can be envisaged. Minimizing parasitics and enhancing gate modulation is important for high frequency device applications. The workshop will focus on Beyond Graphene and Graphene-based Electronic Devices and Components and their Potential for High-Frequency Applications by covering a wide range of aspects from materials, to devices and their applications. Emphasis will be placed on high-frequency frequency applications but aspects such as switching, thermal management and integration possibilities with other device types such as sensors and Micro-Electro-Mechanical-Systems (MEMS) will also be considered.

1. Electronics and Optoelectronics with Transition Metal di-Chalcogenides
   Huili Grace Xing; *Cornell University*
2. 2D Materials and Devices for Smart Life
   Kaustav Banerjee; *University of California, Santa Barbara*
3. Graphene and Graphene Heterostructures for Linear and Ultra-low-power RF/MW/MMW Applications
   Jeong-Sun Moon; *Hughes Research Laboratories*
4. High Frequency Electronic Devices using 2D Materials: some issues to overcome the fmax limitation.
   Henri Happy; *University of Lille*
5. Graphene field-effect transistors, their processes and MMIC prospective
   Herbert Zirath; *Chalmers University of Technology*;Omid Habibpour;*Chalmers University of Technology*
6. Spin Torque Oscillators and Diodes
   Hiroshi Kubata; *AIST Japan*
7. Nanoscale III-V FETs and NW Devices
   Erik Lind; *Lund University*
8. Panel Session on Graphene, 2D and Emerging Devices
   Dimitris Pavlidis; *Boston University*; James Hwang; *Lehigh University*; David Ricketts; *North Carolina State University*

WFG 08:00-17:00

Digital Signal Generation With Focus on Direct Digital Synthesis DDS
Sponsor: IMS

Organizer: Bert Henderson, *Cobham*, Scott Wetenkamp, *SCEAN*

Abstract: Digital signal generation is a critical function in modern RF systems for both commercial and military applications. Direct Digital Synthesis (DDS), All Digital Phase Locked Loop (ADPLL), and Arbitrary Waveform Generation (AWG) are important aspects of digital signal generation that will be discussed in this workshop, with emphasis on DDS. The presenters are some of the top researchers and practitioners from universities and industry. They will present an overview of digital signal generation that includes basic concepts and extends up through new and emerging technologies and approaches. Important considerations such as word length and D/A resolution, timing skew, minimizing power dissipation, reducing and cancelling spurious products, reducing phase noise, and more will be discussed. Additionally, the tradeoffs between DDS, ADPLL, and AWG will be discussed. And application of DDS to frequency synthesis of RF up through millimeter-wave will also be covered.

1. How to Make a Good Direct Digital Frequency Synthesizer (DDFS)
   Alan Willson; *University of California, Los Angeles*
2. All Digital Frequency Synthesis Based on New Sigma Delta Architectures
   Paul Sotiriadis; *National Technical University of Athens, Greece*
3. Low Power High Performance Direct Digital Frequency Synthesis
   Fa Foster Dai; *Auburn University*
4. Advances in Digitally Intensive mm-Wave Frequency Synthesis
   Wanghua Wu; *Marvell Semiconductor, Inc.*
5. DDS Performance and Implementation Considerations
   Peter Delos; *Lockheed Martin Corp.*
6. DDS in Microwave Signal Generation
   David Williams; *Teledyne*
7. Getting the Most Out of Your DDS Device
   Jeffry Keip; *Analog Devices, Inc.*
8. Direct Digital Synthesis of RF Frequencies with DDS and AWG
   Neng-Huang Sheng; *Euvis*

WFH 08:00-17:00

Microwave and Photonics Techniques for Terahertz Applications in Science and Technology
Sponsor: IMS

Organizer: Iwao Hosako, *National Institute of Information and Communications Technology (NICT)*, Masayoshi Tonouchi, *Osaka University*, Peter Siegel, *California Institute of Technology*, Tadao Nagatsuma, *Osaka University*

Abstract: A lot of interest exists for basic science applications, such as space and planetary observation based on gas spectroscopy in the Terahertz (THz) frequency range. In addition, a variety of techniques and applications, such as non-destructive testing, material mapping, remote sensing, and wireless-communication applications are expected to realize in near future. In this introductory presentation, mapping of generation and detection techniques of THz signals (both the photonics based and the electronics based) and its applications will be shown to support an understandings of audience of the work shop. Based on the several mappings of the THz techniques, prospective views of THz technology and applications will be discussed to attract interests of novice and experts by developing an understanding of the entire picture of the THz techniques including scientific or engineering results.

1. Introduction to Terahertz frequencies and its importance in science and technology
   Iwao Hosako; *National Institute of Information and Communications Technology*
2. Coherent strong-field THz interaction on the sub-cycle scale
   Christoph Lange; University of Regensburg; Rupert Huber; *University of Regensburg*; Stephan Koch; *Philipps-Universität Marburg*; Mackillo Kira; *Philipps-Universität Marburg*
3. Antennae and circuits for THz quantum detectors
   Carlo Sirtori; *Université Paris Diderot*
4. Recent advances in room temperature, CW, monolithic tunable terahertz quantum cascade laser sources
   Manijeh Razeghi; *Northwestern University*
5. Terahertz Metamaterial Science and Technology
   Richard Averitt; *University of California at San Diego*
6. Scanning laser THz emission spectroscopic Imaging system to industrial applications
   Masayoshi Tonouchi; *Osaka University*
7. Spectroscopic Polarimetry of Archimedean Spiral Arrays: Experiments and Simulations
   Charles Schmuttenmaer; *Yale University*
8. Terahertz Cancer Imaging: Challenges and Opportunities
   Joo-Hiuk Son; *University of Seoul*
9. Prospects for Multi-THz III-V Transistors
   Mark Rodwell; *University of California, Santa Barbara*
10. Telecom-based Photonics Technologies for Terahertz Applications: From Discrete Devices to Integration
    Tadao Nagatsuma; *Osaka University*

WFI 08:00-17:00

Theory and Applications of Wireless Power Transfer

Sponsor: IMS

Organizer: Costas Sarris, *University of Toronto*, Alessandra Costanzo, *University of Bologna*, Jan Machac, *Czech Technical University in Prague, Czech Republic*

Abstract: The ubiquitous presence of wireless devices enabling an “internet of things” creates an urgent need for effective solutions to remotely charge these devices. To address this need, intensive research and development efforts are underway in the area of wireless power transfer. As a result of these efforts, major research advances and successful commercial products have emerged in the last few years, with more to come in the years ahead. The proposed workshop is aimed at bringing together researchers in academia and industry with proven track record of innovative research and state-of-the-art product development for near and far-field wireless power transfer. It is envisioned that the interaction between the two groups of speakers and the audience will lead to a comprehensive review of the current state of the art, the existing challenges and the future outlook of this very promising area. As a workshop that is jointly proposed by MTT-15 and MTT-26 (for the first time), it will feature recent advances in the theory along with new technologies for near and far field wireless power transfer and associated developments in power electronics.

1. Enabling Wireless Power Transfer Through a Metal Body
   Nathan Jeong; *Qualcomm, Inc.*; Francesco Carobolante; *Qualcomm, Inc.*
2. Wireless Power in the Reactive and Radiative Near Field
   Jason Heebl; *University of Michigan;* Anthony Grbic; *University of Michigan*
3. Solutions for Far-Field WPT
   Nuno Borges Carvalho; *Institute of Telecommunications, University of Aveiro*
4. Rectenna challenges and optimization for wireless power transfer systems
   Apostolos Georgiadis; *CCTC, Barcelona*
5. Analysis of Information and Power Transfer in Wireless Communications for a Matched Antenna System
   Tapan Sarkar; *Syracuse University;* Magdalena Salazar Palma; *Universidad Carlos III de Madrid*; Miguel Angel Lagunas; *Universidad Carlos III de Madrid;* Ana Perez-Neira; *Universidad Carlos III de Madrid*
6. ENERGY OUT OF THIN AIR - Theory of radiative, far-field wireless power transfer and applications
   Hubregt Visser; *IMEC*
7. Circuit level design of systems for simultaneous data and power transfer
   Alessandra Costanzo; *University of Bologna*; Riccardo Trevisan; *DEI "Guglielmo Marconi"/IMA Industries Srl*
8. Convex Optimization-Driven Design of Multi-Transmitter Wireless Power Transfer Systems
   Costas Sarris; *University of Toronto*; Hans-Dieter Lang; *University of Toronto*
9. High frequency power electronics for inductive power transfer
   Paul Mitcheson; *Imperial College London*
10. Ambient RF energy harvester synthesis
    Simon Hemour; *University of Bordeaux*; Carlos Lorentz; *École Polytechnique de Montréal*; Ke Wu; *École Polytechnique de Montréal*

WFJ 08:00-17:00

Power Amplifiers with Variable Loads

Sponsor: IMS

Organizer: Zoya Popovic, *University of Colorado*

Abstract: This workshop focuses on approaches to power amplifier (PA) design for applications where the output load is not a constant 50-ohm resistive load, but a time-variable complex load. Such load conditions can happen in many situations, and the contributions covered in this workshop include time-varying mismatch due to antenna position in handsets, RF tissue ablation, solid-state cooking, near-field wireless power transfer with variable distance, active scan reflection coefficient in phased arrays, and industrial heating. The power levels in these applications vary from sub-watt to kilowatts, and various techniques are used to prevent PA damage and/or improve efficiency and output power under varying load conditions. The selected speakers are well-established internationally in the field of power amplifiers, MEMS tuners and bio-medical and industrial applications of RF/microwaves. The speaker list includes researchers from industry, academia and private consultants. Several of the speakers are pioneers in the field of microwave power amplifiers, and authors of well-respected textbooks. Others have published highly-sighted papers and won prestigious awards for their work in this field. The goal of the workshop is to provide high-level instruction in various types of PAs with variable loads, beyond a basic introduction and glossary. For example, (add here some concrete things based on submitted abstracts).

1. Introduction to PAs with variable loads: Problems, cures, and opportunities
   Frederick Raab; *Green Mountain Engineering*
2. Reconfigurable TX Solutions for Mobile Device RF Front-ends
   Art Morris; *Wispry*
3. Tuning as a performance enhancement for front-ends in smartphones
   Denis Masliah; *ACCO Semiconductor*
4. Maintaining PA efficiency under variable load using impedance tuners, supply variation and load modulation
   Zoya Popovic; *University of Colorado*
5. Highly variable amplifier load: microwave tissue ablation probe
   Joseph Brannan; *Medtronic, Inc.*
6. Adaptive PAs for heating electroporation of cells for DNA sequencing
   Steve Cripps; *Cardiff University*
7. Phased array antenna scanning impedance effects on transmit PAs
   Brian Kormanyos; *Boeing*
8. SiC varactor-based impedance tuners for high-power applications
   Christian Fager; *Chalmers University of Technology*; Cesar Sanchez; *Qamcom*
9. Solid state improvements in microwave cooking
   Gregory Durnan; *Freescale Semiconductor, Inc.*
10. Power amplifier load variation in high-efficiency near-field variable-distance inductive resonant wireless power transfer links
    Alessandra Costanzo; *University of Bologna*; Corrado Florian; *University of Bologna*

SFA 08:00-12:00

Fundamental Advances on 2D Nano-Materials and Devices

Sponsor: MTT-S TC 25

Organizer: Davide Mencarelli, *Universita Politecnica delle Marche,* Luca Pierantoni, *Universita Politecnica delle Marche*

Abstract: The presentation deals with the analysis and characterization of nano-scale devices based on carbon nano-materials, and new low dimensional materials, for microwave and THz applications. The recent discover nano-materials, e.g., graphene related materials, carbon nanotubes, transition metal dichalcogenize monolayers, phosphorene, silicene, and many others, offer, by proper combination or functionalization, unlimited possibilities to the applied research. In this framework, potential scientific breakthrough in the roadmap of high-performance/highly-scaled digital technology and flexible electronics, from microwave up to THz frequency, can be provided by ballistic devices, where interference, tunnelling, filtering, and self-induced non-linearities can play a crucial role. Typical examples are given by field effect transistors (FET), RF detectors, Ratchet-effect devices, ballistic switches. At larger scales, modelling is extended to surface plasmonic devices, waveguides, tunable microwave attenuators, interconnects, graphene varactor-tunable antenna surfaces, and infrared metasurfaces. Since the electromagnetic properties of low-dimensional systems may depend sensitively on localized defects and interfaces, there is a specific need for spatially-resolved measurements of these systems. The near-field scanning microwave microscope (NSMM), in particular, provides a platform to bring RF and microwave metrology down to the atomic scale. Here, we will review the instrumentation, measurement techniques, and approaches to calibration for the NSMM and related tools.

SFB 08:00-17:00

Principles of RF and Microwave Imaging Technology: From Radar to MRI

Sponsor: MTT TC 1, TC 10, TC 15, and TC 17

Organizer: Fauzia Ahmad, *Villanova University,* Jürgen Sachs, *Technische Universität Ilmenau,* Natalia Nikolova, *McMaster University,* Robert Caverly, *Villanova University*

Abstract: The last decade marked the advent of close-range microwave imaging and detection. Microwaves penetrate most of the optically opaque materials enabling the detection of obscured targets such as hidden weapons and buried objects. In addition, magnetic resonance imaging (MRI) is evolving fast toward high-field scanners. This pushes its acquisition bandwidths into the microwave range. The microwave and the MR imaging technologies need engineers who understand the methods of image reconstruction and the technology of radar, ultra-wide band (UWB), and frequency-sweep data acquisitions. However, the educational literature on the subject is scarce while the research publications are scattered. As a result, microwave engineers struggle to make sense of these new developments. This is intended as a crash course for microwave engineers on the topic of RF/microwave imaging technologies. The basic principles are illustrated with examples from microwave holography, UWB radar, through-the-wall imaging, and MR coil design.