Education News

IEEE MTT-S 2018 Webinar Series: Speaker Biographies and Webinar Abstracts

■ **Ramesh K. Gupta and Michael C. Hamilton**

©ISTOCKPHOTO.COM/GUZALIIA FILIMANOVA

Education is what remains after one has forgotten everything he learned in school.

— Albert Einstein

The IEEE Microwave Theory and Techniques Society (MTT-S) Education Committee continues to offer high-quality webinars from experts in their respective fields, a series that started in 2016 [1], [2]. These webinars continued in 2017 and 2018 and have provided collaborative learning opportunities to our MTT-S membership as well as the global microwave/RF community. The MTT-S Education Committee is grateful to our webinar speakers for their efforts in preparing and delivering cutting-edge educational content through our popular MTT-S webinar series.

This month's "Education News" column presents the speaker biographies and webinar abstracts for our 2018 webinar series. Our class of 2018 webinar speakers represents a diverse group of leading subject-matter experts from around the globe, including current or emeritus Distinguished Microwave Lecturers as well as industry experts with in-depth knowledge and understanding of the webinar topics. The addition of industry-sponsored speakers has been a new feature, introduced in the 2018 webinar series in an effort to provide webinar content inclusive of academia and industry.

All the 2018 webinar presentations have been archived together with the 2016 and 2017 webinar content on the MTT-S website: https://mtt.org/webinar-library. Here you'll find 36 h of valuable content from the 2016–2018 webinar series available to everyone for educational purposes.

Ramesh K. Gupta (ramesh.gupta@ieee.org) served on the MTT-S Administrative Committee as Education Committee chair from 2014 to 2018. He is with Ligado Networks, Reston, Virginia, United States. Michael C. Hamilton (mchamilton@auburn.edu) serves as a moderator for the IEEE MTT-S webinar series. He is with Auburn University, Alabama, United States.

Digital Object Identifier 10.1109/MMM.2018.2885672
Date of publication: 7 February 2019

If you would like to be considered as a webinar speaker and present a topic of current interest to the MTT-S community in the 2019 webinar series, please send an email to webinars.ieeemttsedu@gmail.com outlining your topic and providing a brief abstract, biography, and sample slides.

References

[1] R. Gupta and M. Hamilton, "MTT-S Education Committee launches successful 2016 webinar series" [Education News], *IEEE Microw. Mag.*, vol. 17, no. 11, pp. 84–91, 2016.

[2] R. Gupta and M. Hamilton, "MTT-S 2017 webinar series–Another successful year of collaborative learning" [Education News], *IEEE Microw. Mag.*, vol. 19, no. 2, pp. 88–101, 2018.

Seminar Topics and Their Presenters

9 January 2018

Switchable and Tunable Ferroelectric Devices for Adaptive and Reconfigurable RF Circuits

Amir Mortazawi, University of Michigan, Ann Arbor, United States.

Amir Mortazawi received his Ph.D. degree in electrical engineering from the University of Texas at Austin in 1990. He is currently a professor of electrical engineering with the University of Michigan, Ann Arbor. His research interests include microwave and millimeter-wave (mm-wave) circuits, phased arrays, power amplifiers (PAs), ferroelectric thin-film-based devices, and frequency-agile microwave circuits. He served as an associate editor (2005) and editor-in-chief (2006–2010) of *IEEE Transactions on Microwave Theory and Techniques*. He also served as associate editor of *IEEE Transactions on Antennas and Propagation* (1998–2001). He was a member of the IEEE MTT-S Administrative Committee for eight years. Dr. Mortazawi is a Fellow of the IEEE.

Webinar Abstract

The exponential increase in the number of wireless devices as well as the limited wireless spectrum pose significant challenges in the design of future wireless communication systems. Adaptive and reconfigurable radios that can change their frequency and mode of operation based on the unused/available wireless spectrum have been proposed to address such challenges. Frequency-agile RF circuits play a key role in the realization of these radios.

This webinar focuses on applications of ferroelectric thin-film barium strontium-titanite (BST) for the design of frequency-agile radios. BST is a low-loss, high-dielectric constant, field-dependent multifunctional material. The electric field dependence of BST has been employed to design tunable RF and microwave devices and components. Another important property of BST is its dc electric field-induced piezoelectric or electrostrictive effect. These properties are utilized to design intrinsically switchable film bulk acoustic wave resonators and filters.

Switchable ferroelectric-based filter banks can significantly reduce the size and power consumption of conventional filter banks employed in frequency-agile radios. The designs of several BST-based adaptive and reconfigurable RF circuits are presented.

13 February 2018

5G Enabling Technologies—Multiple Input/Multiple Output (MIMO), Multiuser MIMO, and Massive MIMO

Abbas Omar, University of Magdeburg, Germany.

Abbas Omar received his B.Sc., M.Sc., and Doktor-Ing. degrees in electrical engineering in 1978, 1982, and 1986, respectively. He has been professor of electrical engineering since 1990 and chair of the Microwave and Communication Engineering Department at the University of Magdeburg since 1998. He joined the Petroleum Institute in Abu Dhabi as a distinguished professor in 2012 and in 2013 became an organizer of the research activities for the Abu Dhabi oil and gas industry. From 2014 to 2015, he chaired the Department of Electrical and Computer Engineering Department at the University of Akron, Ohio, United States. Dr. Omar has authored and/or coauthored more than 450 technical papers extending over a broad spectrum of research areas. His current research fields cover microwave, magnetic-resonance, and acoustic imaging; microwave and mm-wave material characterization; phased arrays and beamforming; massive MIMO; indoor positioning; subsurface tomography and ground-penetrating radar; and field-theoretical modeling of microwave systems and components. He is a Fellow of the IEEE.

Webinar Abstract

In this webinar, the fundamentals underlying the MIMO concept are explained, showing how multiple reflections in indoor and urban environments can effectively be used to create additional independent channels that can serve the purposes of diversity and/or spatial multiplexing. Extending this concept for a base station to serve multiple users gives rise to multiuser MIMO, in which both the number of served users and that of the array elements are very moderate. Massive MIMO, on the other hand, uses large antenna arrays to produce multiple very narrow beams capable of simultaneously establishing independent channels between the base station and a number of mobile or stationary users. The commonly used deterministic and stochastic models for representing mobile wireless channels (linear time-varying systems) are explained, emphasizing the massive MIMO aspects. Recently developed sample massive MIMO systems are presented.

A comparison among various alternatives in terms of hardware/software complexity, power consumption in the RF front end and digital signal processing, PA linearity and efficiency, signal distortion, and others are also provided.

28 March 2018

The Art of Effectively Communicating Complex, Highly Technical Work in Three Minutes

John Bandler, McMaster University, Hamilton, Ontario, Canada.

John Bandler is professor emeritus with the Department of Electrical and Computer Engineering, McMaster University, as well as an engineer, entrepreneur, innovator, researcher, artist, speaker, and author of fiction, including stage plays. He has published 500 technical papers, pioneered space mapping, and won several awards, including both the Microwave Application and Microwave Career Awards from the IEEE MTT-S. In 1997, Hewlett-Packard acquired his company, Optimization Systems Associates Inc.

A Fellow of several societies, including the IEEE and the Royal Society of Canada, he has been honored by a Queen Elizabeth II Diamond Jubilee Medal. In 2016, he was appointed Officer of the Order of Canada, with a citation beginning, "John Bandler has helped to put Canada at the forefront of microwave technology," and ending, "He has been a mentor to numerous highly successful students and a strong advocate for the inclusion of more women in the field of engineering." He mentors individuals preparing presentations and has been coorganizing the Three Minute Thesis (3MT) Competition for the IEEE MTT-S International Microwave Symposium (IMS) since 2017.

Erin Kiley, Massachusetts College of Liberal Arts, North Adams, United States.

Erin Kiley is an assistant professor of mathematics at the Massachusetts College of Liberal Arts. She is an applied mathematician whose research specializes in modeling and computational electromagnetics, including problems in microwave sintering. She received her B.Sc. degree in mathematics and statistics and her B.A. degree in Russian from the University of New Hampshire, Durham, and her M.Sc. degree in applied mathematics and Ph.D. degree in mathematics from Worcester Polytechnic Institute, Massachusetts. She has been coorganizing the 3MT Competition at the IMS since 2017.

Daniel Tajik, McMaster University, Hamilton, Ontario, Canada.

Daniel Tajik received his B.S. degree in electrical and biomedical engineering and M.S. degree in electrical and computer engineering from McMaster University in 2015 and 2017, respectively. His Ph.D. research is focused on developing microwave image processing algorithms for use in medical diagnostics. His research interests include applications of microwave engineering in breast cancer imaging, stroke detection, concealed weapon detection, and through-the-wall imaging as well as antenna design for satellite communications. At IMS2017, he won both the First Place and Audience Choice awards in the first-ever 3MT Competition for his presentation "Microwave Holography: The Future of Medical Imaging."

Webinar Abstract

Given 3 min, you have to present your complex, highly technical work to an audience that is educated but has specialized neither in your personal niche nor in your broad field of endeavor. Is it even possible? Can you capture the imagination of nonspecialists and inspire them to ask for more? Sheer enthusiasm is not enough to hold people's attention for any length of time. Engaging an audience takes practice and empathy. The first challenge is to kill the jargon.

In this webinar, we address the art of brief, effective live communication of complex technical material in language suited to a nonspecialist audience. We draw on actual 3MT experiences, including organizing, mentoring, and hands-on competing. Much of what we discuss is applicable to regular technical presentations: the importance of first impressions, subtext, authenticity, articulation, stage presence, slide composition, metaphor, storytelling, authenticity, articulation, and much more.

10 April 2018

Microwave Near-Field Imaging in Real Time

Natalia K. Nikolova, McMaster University, Hamilton, Ontario, Canada.

Natalia K. Nikolova received her Dipl.Eng. degree in radioelectronics from the Technical University of Varna, Bulgaria, in 1989 and her Ph.D. degree from the University of Electro-Communications, Tokyo, Japan, in 1997. From 1998 to 1999, she held a postdoctoral fellowship with the Natural Sciences and Engineering Research Council of Canada at Dalhousie University in Halifax and McMaster University in Hamilton. In 1999, she joined the Department of Electrical and Computer Engineering at McMaster University, where she is currently a professor. Her research interests include inverse scattering and microwave imaging as well as computer-aided analysis and design of high-frequency structures and antennas.

Prof. Nikolova has authored more than 250 refereed manuscripts, five book chapters, and the text *Introduction to Microwave Imaging* (Cambridge University Press, 2017). She has delivered 37 invited lectures around the world on microwave imaging and computer-aided electromagnetic analysis and design. She served as an IEEE Distinguished Microwave Lecturer from 2010 to 2013. Prof. Nikolova is a Canada Research chair in high-frequency electromagnetics and a Fellow of the IEEE and the Canadian Academy of Engineering.

Webinar Abstract

In the last decade, we have witnessed a dramatic decrease in the price and size of microwave electronics along with the advent of radio-on-a-chip, software-defined radio, and single-chip radars. This has spurred unprecedented growth in applications, such as imaging, sensing, and detection. From automotive radar to medical diagnostics and concealed-weapon detection, microwave imaging and detection define the next wireless revolution. We introduce the methods of microwave imaging that allow interior viewing of optically opaque objects. A brief summary of the models used to describe the wave propagation inside the imaged object is presented. We also discuss how these properties can be deduced from measurements and presented in the form of 3D images. The inner working of one prominent imaging method, microwave holography, is presented.

8 May 2018

Enabling the Third Wireless Revolution: Transformative RF/mm-Wave Circuits, Wireless Systems and Sensing Paradigms

Harish Krishnaswamy, Columbia University, New York, United States.

Harish Krishnaswamy received his B.Tech. degree in electrical engineering from the Indian Institute of Technology Madras, Chennai, in 2001 and his M.S. and Ph.D. degrees in electrical engineering from the University of Southern California (USC), Los Angeles, in 2003 and 2009, respectively. In 2009, he joined the Electrical Engineering Department at Columbia University, where he is currently an associate professor and director of the Columbia High-Speed and Millimeter-Wave Integrated Circuits (IC) Laboratory.

Prof. Krishnaswamy was a recipient of the IEEE International Solid-State Circuits Conference (ISSCC) Lewis Winner Award for Outstanding Paper in 2007, the Best Thesis in Experimental Research Award from the USC Viterbi School of Engineering in 2009, the Defense Advanced Research Projects Agency (DARPA) Young Faculty Award in 2011, the 2014 IBM Faculty Award, the 2015 the IEEE RFIC Symposium Best Student Paper Award, and the 2017 the IEEE ISSCC Demonstration Session Certificate of Recognition. He has been a member of Technical Program Committees for several conferences, including the IEEE ISSCC since 2015 and the IEEE RFIC Symposium since 2013. He currently serves as a Distinguished Lecturer for the IEEE Solid-State Circuits Society (SSCS) and as a member of the DARPA Microelectronics Exploratory Council.

Webinar Abstract

Over the past 30 years, we have reaped the benefits of two wireless communication revolutions that have had significant social and economic impacts. The period 1990–2000 witnessed the mobile wireless communication revolution, with the emergence of cellular mobile telephony enabling instant global connectivity. The period 2000–present has been marked by the mobile wireless data revolution as 3G and 4G networks have brought the Internet to our fingertips. The next wireless revolution will be the mobile wireless–reality revolution, which will bring the physical world to our fingertips.

RF, mm-wave, and terahertz (THz) communication imaging and sensing devices will enable us to interrogate the physical world and create virtual or augmented worlds in ways that exceed and enhance human sensory situational awareness. The wireless–reality revolution will require a quantum leap forward in our ability to control and manipulate the RF-to-THz electromagnetic spectrum and to transmit, acquire, aggregate, and process the associated data.

This webinar focuses on recent research on high-power and energy-efficient mm-wave PAs, transmitters, and large-scale phased arrays that have drawn interest for next-generation 5G cellular networks and also extreme bandwidth (>20 Gb/s) communication links at mm-waves for applications like virtual and augmented reality. Other novel wireless communication paradigms, including massive MIMO and full-duplex wireless, that enable extremely high spectral efficiencies and data rates are presented. Finally, we consider the realization of city-scale testbeds that deploy advanced wireless hardware supporting mm-wave, massive MIMO, and full-duplex operation to enable higher-layer systems research at city scales.

19 June 2018

Automotive Radar—An Overview on State-of-the-Art Technology

Markus Gardill, InnoSenT GmbH, Donnersdorf, Germany.

Markus Gardill received his Dipl.-Ing. and Dr.-Ing. degrees in systems of information and multimedia technology/electrical engineering from Friedrich-Alexander University Erlangen-Nürnberg, Germany, in 2010 and 2015, respectively. In 2010, he joined the Institute for Electronics Engineering at Friedrich-Alexander University Erlangen-Nürnberg as a research assistant and teaching fellow. From 2014 to 2015, he was head of the Radio Communication Technology team. In 2015, he joined Robert Bosch GmbH as an R&D engineer for optical imaging. In 2016, he joined InnoSenT GmbH as a senior software developer for automotive radar signal processing algorithms. His main research interests include radar and communication systems, antenna (array) design, and signal processing algorithms. His particular interest is spatiotemporal processing, such as beamforming and direction-of-arrival estimation with a focus on combining the worlds of signal processing and microwave/electromagnetics.

Dr. Gardill is an IEEE Young Professional, a member of the IEEE MTT-S Technical Committee on Digital Signal Processing, and a reviewer for several journals and conferences. He is a Distinguished Microwave Lecturer on automotive radar systems for 2018–2020.

Webinar Abstract

Radar systems are a key technology for modern vehicle safety and comfort systems. Only the symbiosis of radar, lidar, and camera-based sensor systems can enable advanced autonomous driving functions. Several next-generation car models could have up to 10 radar sensors per vehicle, allowing a radar-based 360° surround view. Hence, the industry demand for high-precision, multifunctional radar systems is greater than ever before, leading to increased R&D activities in the field on functionality and sensor capabilities.

Current automotive radar technology is based almost exclusively on the principle of frequency-modulated continuous-wave (FMCW) radar. However, new degrees of freedom have been added to traditional FMCW radar system designs in terms of hardware capabilities, along with the simultaneous use of advanced signal processing and transmit and receive channels with independent modulation features and bandwidths. This webinar focuses on the fundamentals of FMCW radar and sensors. Insights into distributed or centralized processing concepts and sensor data fusion are discussed. The presentation dives into the details of current fast-chirp FMCW processing. The fundamentals of target range and velocity estimation based on the radar data matrix and the spatial dimension available using modern single-input/multiple-output and MIMO radar systems are presented.

Of particular interest is angular resolution. Traditional and modern methods for direction-of-arrival estimation in FMCW radar systems are presented. The presentation then introduces the great challenge of FMCW radar system interference. While FMCW radar interference can be handled using adaptive signal processing in today's systems, it will become a severe problem with the increasing number of radar sensor-equipped vehicles in dense traffic situations in the near future. Alternative radar waveforms such as pseudorandom or orthogonal-frequency division multiplexing for automotive radar systems are presented.

11 July 2018

The Role of Uncertainty for Today's Microwave and mm-Wave Measurements

Andrea Ferrero, Keysight Technologies, Santa Rosa, California, United States.

Andrea Ferrero received his laurea and Ph.D. degrees in electronics from the Politecnico di Torino, Italy, in 1987 and 1992, respectively. He joined the Hewlett-Packard Microwave Technology Division in Santa Rosa as a visiting scientist and began his career at Politecnico di Torino as an assistant professor. In 1988, he worked for Aeritalia (Gruppo Sistemi Avionici) as a microwave measurement system consultant on electromagnetic compatibility problems for avionics. In 1994, he won the Canadian National Scientist fellowship and spent a year at the Ecole Polytechnique of Montréal. He became an associate professor in 1997 and later a full professor at Politecnico di Torino, teaching electronic instrumentation and measurements and microwave instrumentation courses until 2012. In 2013, he joined Agilent (now Keysight Technologies) as a principal research engineer.

Dr. Ferrero is the author or coauthor of more than 100 papers on microwave technologies and measurement techniques. His current research interests are focused on device characterization, calibration techniques, and vector network analyzer metrology. He won the IEEE ARFTG Technology Award in 2006 for advances in network analyzer calibration and nonlinear microwave measurements. He has served as a Distinguished Microwave Lecturer for the MTT-S since 2011. In 2017, he became an associate editor for *IEEE Transactions on Microwave Theory and Techniques*. He is a Fellow of the IEEE.

Webinar Abstract

Modern communications and multimedia growth around the world demand more and more bandwidth and channel capabilities. These requirements translate into higher frequencies and more stringent specifications for devices and systems. Thus, the role of more accurate measurement is becoming increasingly mandatory and complex. To improve the quality of the measurements, the proper traceability chain and uncertainty evaluation tools are fundamental not only at the research level but also in the production environment. From modeling verification to yield analysis and from component specifications to production measurements, knowledge of how measurement uncertainty can change the entire ecosystem provides a better understanding of the device under test and of the measurement system.

This webinar addresses the modern tools and techniques used to improve accuracy and compute the uncertainty rate for microwave measurements. The presentation spans from advanced calibration techniques to the most recent tools for real-time uncertainty evaluation. Examples are provided for *S*-parameters and other microwave measurements.

14 August 2018

mm-Wave Power Amplifiers: State of the Art and Future Technology Trends

Hua Wang, Georgia Institute of Technology (Georgia Tech), Atlanta, United States.

Hua Wang received his M.S. and Ph.D. degrees in electrical engineering from the California Institute of Technology, Pasadena, in 2007 and 2009, respectively. He has worked at Intel Corporation and Skyworks Solutions and is currently an associate professor with tenure in the School of Electrical and Computer Engineering at Georgia Tech. Dr. Wang is interested in innovating mixed-signal, RF, and mm-wave ICs and hybrid systems for wireless communication, radar, imaging, and bioelectronics applications.

Dr. Wang received the DARPA Young Faculty Award in 2018, the National Science Foundation CAREER Award in 2015, the MTT-S Outstanding Young Engineer Award in 2017, the Georgia Tech Sigma Xi Young Faculty Award in 2016, the Georgia Tech Electrical and Computer Engineering Outstanding Junior Faculty Member Award in 2015, and the Lockheed Dean's Excellence in Teaching Award in 2015. He holds the Demetrius T. Paris professorship at the Georgia Tech School of Electrical and Computer Engineering. His research group has won multiple best paper awards.

Dr. Wang is an associate editor of *IEEE Microwave and Wireless Components Letters* and a guest editor of *IEEE Journal of Solid-State Circuits*. He is a Technical Program Committee member for the ISSCC, IEEE RFIC Conference, IEEE Custom IC Conference (CICC), and IEEE BiCMOS and Compound Semiconductor IC and Technology Symposia. He is a Steering Committee member for the RFIC and CICC. He serves as the chair of Atlanta's IEEE Circuits and Systems/SSCS Joint Chapter, which won the IEEE SSCS Outstanding Chapter Award in 2014.

Webinar Abstract

With 5G communication just around the corner, there is a rapidly increasing need for high-performance mm-wave PAs. However, these next-generation PAs are often expected to deliver nearly perfect performance: they should offer large output power to ensure a sufficient link budget, broad bandwidth to support multistandard communication or frequency reconfigurability/agility, high peak and back-off efficiency for energy saving, and inherent linearity for gigabits-per-second complex modulations with minimal or even no digital predistortion. It is noteworthy that, conventionally, a given PA design should make tradeoffs among these performance aspects. Interestingly, this essentially unreasonable quest for perfect mm-wave PAs has recently stimulated a new focus on mm-wave PA innovations at both the circuit and architecture levels.

In this webinar, we first review the state of the art for mm-wave PA technologies and identify trends based on "Power Amplifiers Performance Survey 2000 to Present" by a Georgia Tech research group. Next, we present several recent mm-wave PA designs that feature various innovations at both the circuit and architecture levels. We also showcase several mm-wave PA/antenna codesign examples that exploit this new paradigm to further enhance mm-wave PA output power and efficiency.

11 September 2018

One Promise of 5G: Everyday Millimeter Waves—What This Means for Standards and Measurements

Roger Nichols, Keysight Technologies, Santa Rosa, California, United States.

Roger Nichols has directed Keysight's 5G programs for more than four years. His 33 years of engineering and management experience in wireless testing and measurement at Hewlett-Packard, Agilent Technologies, and Keysight span roles in manufacturing, R&D, and marketing. He has worked on programs starting with analog cellular radio, evolving to 5G, and on every standard in between. He spent seven years as the senior marketing director for Keysight's (Agilent's) Mobile Broadband Division, responsible for the wireless test sets and systems used in all major design and certification labs as well as manufacturing facilities worldwide. He received his B.S.E.E. degree from the University of Colorado, Boulder.

Webinar Abstract

It appears that the arrival of 5G is upon us. In June 2018, the 3rd Generation Partnership Project (3GPP) announced completion of the release 15 standard—the first version of which was announced in December 2018. Multiple mobile operators around the world have announced commercialization timetables, and the industry is struggling to address the mix of hype, new technology, and very aggressive schedules. Release 15 includes radio capabilities in the sub-6-GHz range (FR1) as well as for mm-wave frequencies 24–52 GHz (FR2). The addition of the mm-wave spectrum to commercial wireless technology has pulled a new and wider audience into the arena of highly directional radio propagation.

5G commercial wireless industries will have scale, cadence, and cost pressures that the aerospace and defense and satellite industries have yet to confront. These new cost and time pressures impact designs, materials, and lifecycles, and, of course, quantitatively measuring their performance and functionality is no small part of that impact. The testing and measurement of these systems require using expensive equipment, time-consuming procedures, over-the-air techniques, and new end-to-end validation processes based on an unprecedented mobile-use model. The fact that FR2 is relatively new means that the standard still has a long way to go. The list of exceptions in release 15 and the number of items deferred to release 16 are good indicators of what is yet to be done. As of July 2018, 3GPP Radio Access Network (RAN)4 and RAN5 are still engaged in discussions (and not yet decisions) about over-the-air test methods (and their dramatic impact on measurement uncertainty) for such mundane measurements as power, spurious emissions, spectral emissions, and error-vector magnitude. Much work is still to be done for receiver measurements. This webinar covers the status of the 3GPP NR (New Radio) specification and some of its impacts on hardware and system design. It also covers some examples of the tough measurement challenges confronting the industry as well as what to expect as the standard and the industry evolve.

23 October 2018

The Load-Modulated, Balanced Amplifier

Steve C. Cripps, Cardiff University, Wales, United Kingdom.

Steve C. Cripps received his M.S. and Ph.D. degrees from Cambridge University, United Kingdom, in the 1970s. After working for several years with the pioneering gallium arsenide (GaAs) group at Plessey Research, he immigrated to the United States, where he worked for 15 years in various engineering and management positions at Watkins Johnson, Loral, and Celeritek. In 1996, Dr. Cripps returned to the United Kingdom, working as an independent consultant before taking an academic post at Cardiff University, where he is currently a distinguished research professor. Dr. Cripps has authored several bestselling books on RF PA design and is a regular contributor to *IEEE Microwave Magazine* with his popular "Microwave Bytes" column. He is an IEEE Fellow and was the 2008 recipient of the IEEE Microwave Application Award.

Webinar Abstract

Quadrature-balanced amplifiers hold a revered position in the historical development of broadband microwave amplifiers up to 20 GHz and beyond because they replaced unreliable traveling-wave tubes with solid-state equivalents. After declining in popularity when monolithic microwave ICs entered the market, they are now becoming useful again because of research at Cardiff University and the University of Colorado, Boulder, showing a surprising and counterintuitive property that allows active load modulation of the output match presented to the balanced transistors. This has enabled broadband matching network design to break away from conventional constraints and opened up application avenues in high-efficiency RF PA design in both telecommunication and electronic countermeasure bands.

13 November 2018

Terahertz Imaging for Margin Assessment of Excised Breast Cancer Tumors

Magda El-Shenawee, University of Arkansas, Fayetteville, United States.

Magda El-Shenawee received her Ph.D. degree in 1991 from the University of Nebraska–Lincoln and is currently a professor of electrical engineering at the University of Arkansas. Her background is in electromagnetics theory, measurements, and computation. She was a research associate at the Center for Electro-Optics, University of Nebraska–Lincoln, 1992–1994; there, she conducted research on the enhanced backscatter from random rough surfaces. She spent two years at the National Research Center in Cairo, Egypt (1994–1996), and at the University of Illinois, Urbana-Champaign (1997–1999). From 1999 to 2001, she was a member of the multidisciplinary University Research Initiative team at Northeastern University, Boston, Massachusetts, where she conducted research on antipersonnel landmine detection.

Prof. El-Shenawee's research interests include experimental THz imaging and spectroscopy, breast cancer imaging, image reconstruction algorithms, antenna design and measurements, computational electromagnetics, and biopotentials and biomagnetics of breast cancerous cells. Her current research, funded by the National Science Foundation, National Institutes of Health, and the state of Arkansas, focuses on the THz imaging of breast cancer tumors. Her education goals are represented in her online antenna courses for industry and the open electromagnetic laboratory for undergraduate students, funded by the IEEE Antennas and Propagation Society. She has published more than 228 papers in refereed journals and conference proceedings and has been invited to present her research at several universities internationally.

Webinar Abstract

Breast cancer is a serious disease, with almost one out of eight women in the United States expected to have a diagnosis of breast cancer in her lifetime. The American Cancer Society is the leader in the fight to end breast cancer, having invested more in breast cancer research than any other cancer type to detect, prevent, treat, and cure the disease. This research is focused on investigating the capability of THz imaging and spectroscopy to differentiate between types of tumor tissues in lumpectomy surgery. Breast-conserving surgery, i.e., lumpectomy, reduces breast disfigurement compared with radical mastectomy. However, the margins of excised tumor tissue need to be analyzed by pathologists to judge whether any traces of cancerous tissue remain. This can take several days, and, in the case of positive margin detection, a second surgery is needed to remove more tissue. Unfortunately, clinical studies indicate that in roughly 20–40% of cases, excised malignant breast tumors contain positive margins.

THz technology offers several favorable features, including high submillimeter resolution, minimal scattering, and sensitivity to water content. Experimental data in the literature have demonstrated image contrast enhancement when using THz waves compared with using near-infrared and optical radiation. The novelty of this research lies in imaging 3D tumors instead of processed 2D sections. Using whole excised tumor tissues, we demonstrate that THz imaging has the potential to be directly incorporated into the operating room for real-time margin assessment.

This research demonstrates THz transmission and reflection imaging of freshly excised and formalin-fixed, paraffin-embedded breast cancer tumors. THz imaging is shown to be capable of defining the 3D boundaries of tumors embedded in paraffin blocks. This procedure produces cross-section images of the tumor borders at any depth and enables direct correlation with histopathology sections. Tumors obtained from mice models and the human breast are investigated. An unsupervised classifier is implemented to evaluate the THz image correlation with pathology. This research is a collaboration among electrical engineering, biomedical engineering, and pathology staff at the University of Arkansas and Oklahoma State University.

11 December 2018
Design of GaN Power Amplifiers
Edward Niehenke, Niehenke Consulting, Baltimore, Maryland, United States.

Edward C. Niehenke pioneered the development of state-of-the-art RF, microwave, and mm-wave components at Westinghouse/Northrop Grumman for 34 years. Circuits he has worked on include low-noise amplifiers, low-noise oscillators, mixers, PAs, phase shifters, attenuators, limiters, frequency multipliers, low-phase-noise mm-wave fiber optical links, and miniature integrated assemblies and subsystems. He also worked in cryogenic electronics research at Martin-Marietta. He now consults and lectures on linear/nonlinear and wireless transmit/receive circuits and systems. Since 1983, he has lectured to more than 3,000 professionals throughout the world for Besser Associates. He holds nine patents as well as the George Westinghouse Innovation award and has authored and presented numerous papers on RF, microwave, and mm-wave circuits.

Webinar Abstract

This webinar introduces attendees to the gallium nitride (GaN) transistor, its properties, and various structures that include the latest GaN PA design techniques. The properties of GaN are presented, demonstrating the advantage of these devices over GaAs and silicone. A GaN high-electron mobility transistor (HEMT) delineating various geometries, semiconductor processes, and structures with associated performance is presented. Guidelines for reliable operation are suggested, considering device junction temperature including thermal management techniques. Nonlinear models of GaN HEMT devices necessary for the computer-aided design of PAs are presented. Design considerations for both constant amplitude envelope signals and nonconstant amplitude envelope signals are presented. Step-by-step design procedures are shown for various GaN PA examples, including different classes of operation and the popular Doherty PA.

Application Note *(continued from page 23)*

[13] Z. Lin et al., "Research of dual-polarized monopulse microstrip antenna array," in *Proc. 2013 IEEE Int. Conf. Microwave Technology Computational Electromagnetics*, Qingdao, China, 2013, pp. 216–219.

[14] T. Kawai et al., "A branch-line-type eight-port comparator circuit," in *Proc. IEEE MTT-S Int. Microwave Symp. Dig.*, vol. 2. Boston, MA, 1991, pp. 869–872.

[15] H. Wang, D.-G. Fang, and X. G. Chen, "A compact single layer monopulse microstrip antenna array," *IEEE Trans. Antennas Propag.*, vol. 54, no. 2, pp. 503–509, Feb. 2006.

[16] O. Colak and D. S. A. Sahinkaya, "SLL suppressed monopulse microstrip antenna design," in *Proc. 2014 IEEE Antennas and Propagation Society Int. Symp.*, Memphis, TN, 2014, pp. 1855–1856.

[17] M. Fartookzadeh and S. H. Mohseni Armaki, "Dual-band circularly-polarized monopulse antenna system with single layer patches and separated feed networks," *Prog. Electromag. Res. C*, vol. 55, pp. 43–52, 2014. doi:10.2528/PIERC14100601.

[18] J. Aliasgari and Z. Atlasbaf, "A novel compact monopulse parallel-plate slot array antenna," *IEEE Antennas Wireless Propag. Lett.*, vol. 15, pp. 762–765, Sept. 2016.

[19] D. R. Jahagirdar and V. G. Borkar, "A high efficiency Ku-band printed monopulse array," in *Proc. 2010 IEEE Antennas and Propagation Society Int. Symp.*, Toronto, ON, Canada, 2010, pp. 1–4.

[20] H. Wang, D.-G. Fang, X.-G. Chen, and W.-X. Sheng, "Investigation on the performance of a compact microstrip monopulse antenna array," in *Proc. IEEE 6th Int. Symp. Antennas, Propagation EM Theory*, Beijing, 2003.

[21] Q. Xu, H. Sun, H. Yang, and X. Lu, "A digital sum-difference millimeter wave monopulse system based on microstrip array antenna," in *Proc. IEEE 2008 Asia-Pacific Microwave Conf.*, Macau, 2008, pp. 1–4.

[22] S. Bhilegaonkar and A. Dhande, "Mono-pulse comparator network system with hybrid rings," in *Proc. IEEE 2013 19th Asia-Pacific Conf. Communications*, Denpasar, Indonesia, 2013, pp. 556–560.

[23] H. Kumar and G. Kumar, "Microstrip antenna array with ratrace comparator at X-band for monopulse tracking radar," in *Proc. IEEE APS/URSI Int. Symp. Antenna Propagation*, pp. 513–514, 2016.

[24] W. Kolosowski, E. Sedek, A. Jeziorski, and P. Lukawski, "Dielectric substrate monopulse antenna," in *Proc. IEEE 2006 Int. Conf. Microwaves, Radar Wireless Communications*, Krakow, Poland, 2006, pp. 767–770.

[25] A. W. Kolosowski, E. Sedek, A. P. Gajewski, and A. Jeziorski, "Microstrip monopulse array antenna," in *Proc. IEEE 2010 18th Int. Conf. Microwave Radar Wireless Communications,* Vilnius, Lithuania, 2010, pp. 1–3.

[26] D. Bonefacic and J. Jancula, "Laboratory model of a monopulse radar tracking system," *Proc. IEEE ELMAR 2006*, Zadar, 2006, pp. 227–230.

[27] D. Biswas and R. Vulapalli, "A two-layer microstrip antenna to generate cosecant-squared fan beam for monopulse tracking," in *Proc. IEEE Int. Conf. Recent Advances Microwave Theory Applications,* Jaipur, India, 2008, pp. 89–91.

[28] S.-G. Kim and K. Chang, "Low-cost monopulse antenna using bi-directionally-fed microstrip patch array," *Electron. Lett.*, vol. 39, no. 20, pp. 1428–1429, Oct. 2003.

[29] H. Huang, B. Wang, F. Li, and L. Zhao, "A Ka-Band monopulse microstrip antenna array," in *Proc. IEEE 2008 MTT-S Int. Microwave Workshop Series Art Miniaturizing RF Microwave Passive Components*, Chengdu, China, 2008, pp. 124–127.

[30] F. Yu, Y. Xie, and L. Zhang, "Single patch antenna with monopulse patterns," in *IEEE Microw. Compon. Lett.*, vol. 26, no. 10, pp. 762–764, Oct. 2016.

[31] G. Kumar and K. P. Ray, *Broadband Microstrip Antennas*. Norwood, MA: Artech House, 2003.

[32] Mentor Graphics Corporation, "IE3D software version 15.3." [Online]. Available: www.mentor.com

[33] D. M. Pozar, *Microwave Engineering*, 3rd ed. New York: Wiley, 2005.

[34] S. N. Reddy, N. C. E. Reddy, and K. K. Reddy, "Performance evaluation and error analysis of monopulse radar comparator," in *Proc. IEEE Joint Conf. Instrumentation Measurement Technology Conf.*, 1996, pp. 1382–1384.

[35] S. Cornbleet, "Use for the fourth output of a monopulse network," *Electron. Lett.*, vol. 2, no. 3, pp. 83, Mar. 1966.