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Multi-mode (Radar-Radiometer) Sensing for Security Applications: Improved Characterization of Hidden Dielectric Layers

Increasing threats of terrorism and contraband smuggling have led to a growing interest in high-frequency security sensors. Recently, systems combining active and passive microwave sensing into one unit have been proposed to improve reliability in the detection of contraband. However, the capability to measure material properties in real-time at stand-off distances of a few meters would greatly enhance the ability of security sensors to classify concealed items. This tutorial talk discusses a non-invasive approach to extract the complex permittivity and thickness of hidden or embedded dielectrics using multi-mode (active-passive) sensing. The design and operation of two types of microwave sensors are discussed – radar (active) and radiometer (passive) both operating in the K-band (18-26 GHz). Critical factors that degrade the performance of both systems often involve imperfections in the RF front-end as well as background clutter. To mitigate these issues, the following calibration techniques are presented to: (i) correct RF front-end distortion in frequency modulated continuous wave radars, (ii) correct mismatch and temperature dependent insertion loss contributions in the RF front-end of radiometers, and (iii) correct background noise for radiometers in indoor applications. The talk will conclude with a discussion on closed form models to predict the radar and radiometric responses of multi-layer dielectric targets. While presented from a security standpoint, the techniques presented in this talk may also be used in other applications like remote sensing, detection of buried fires, and food safety inspections.

Arya Menon is an Assistant Professor in the Department of Electrical and Computer Engineering at Texas A&M University (TAMU). Dr. Menon received the Bachelor of Engineering degree in electronics and communication from Manipal Institute of Technology, India in 2014, M.S. in electrical engineering from the University of South Florida in 2016, and Ph.D. in electrical and computer engineering from Oregon State University in 2021. She completed her postdoctoral fellowship at Texas A&M University in 2023. Her current research focuses on investigating bio-inspired intelligence in radar design. Her group focuses on three thrusts - hardware-software co-design for cognitive radars, creation of sharable wireless datasets, and sensor fusion with radar. Her other research interests include design of radiometers, sensor calibration techniques, and dielectric characterization methods. Her research has earned multiple awards and recognition including selection as a 2025 MTT-S Outstanding YP Lecturer, 2022 DARPA Riser for “*Bioinspired Hardware-Software Co-Design for Intelligent High-Frequency Active Sensors*,” the 2020 ARTFG Roger Pollard Student Fellowship (Silver), and the 2019 IEEE Microwave Theory and Techniques Society Graduate Fellowship, among others. Dr. Menon is also a passionate educator and was the recipient of the University of South Florida’s Provost’s Award for Outstanding Teaching in STEM by a Graduate Teaching Assistant in 2018 for her contributions towards developing laboratory experiments for a new undergraduate course in electromagnetics.



Shahid Ahmed
Principal Engineer,
TE Connectivity

Novel Features of Short-Pulse Ultrawideband Electromagnetics

Transient electromagnetic waves that exist for extremely short durations and rapidly decay are commonly classified as short-pulse electromagnetic phenomena. Owing to their inherent ultrawideband (UWB) nature, these pulses are capable of conveying exceptionally high information content. Because the area under the impulse waveform is very small, short-pulse signals contain minimal energy and therefore cause negligible interference with conventional radio-frequency communication systems. Their transient, burst-based transmission further enhances immunity to noise, enabling secure and reliable information transfer.

These distinctive features make short-pulse UWB technology attractive for a wide range of applications, including smart homes, advanced driver-assistance systems, keyless secure entry, healthcare, banking, security, peer-to-peer localization, and emerging social network platforms.

Beyond communications, recent investigations into the interaction of UWB pulses with biological systems have revealed another promising application domain. Experimental studies on human cells demonstrate that the biological response to UWB exposure depends strongly on pulse duration and field intensity. Notably, intense sub-microsecond pulses have been shown to induce programmed cell death, offering a potential non-invasive approach for reducing tumor growth.

Short-pulse electromagnetics can also be engineered to emulate extreme electromagnetic environments, such as nuclear electromagnetic pulses (NEMP) and lightning discharges. These capabilities are particularly valuable for aerospace and defense applications, including system hardening, survivability analysis, and electromagnetic compatibility testing.

This invited lecture will provide an overview of transient electromagnetics and its real-world applications across consumer electronics, medical technologies, aerospace, and defense. The presentation will also highlight recent advances in computational modeling, simulation, and visualization techniques used to address complex challenges in short-pulse electromagnetic analysis.

Shahid Ahmed is a Principal Engineer at TE Connectivity with extensive expertise in high-speed interface design, microwave engineering, and electromagnetics. His work spans both theoretical and experimental domains, including hardware development, measurements, and advanced computational modeling. Dr. Ahmed has played a key role in solving complex engineering and multiphysics problems, reflecting a broad and integrated understanding of electrical and electronics engineering.

As a leading author, Dr. Ahmed has published more than fifty papers in national and international journals and conference proceedings. He is also the author of the authoritative book *Electromagnetic Pulse Simulations Using Finite-Difference Time-Domain Method* (ISBN: 978-1-119-52617-9), which has become a significant reference in the field of short-pulse electromagnetics.

Dr. Ahmed is an active contributor to the engineering community through invited talks, workshops, and tutorials, underscoring his commitment to knowledge dissemination. He serves as a reviewer for leading journals, magazines, and U.S. Department of Energy SBIR/STTR proposals, and has chaired technical sessions and organized workshops at major international conferences.

A Senior Member of the IEEE with over a decade of membership, Dr. Ahmed is also affiliated with the IEEE Antennas and Propagation Society. In recognition of his professional achievements and technical leadership, he received the IEEE Hampton Roads Section Outstanding Engineer Award in 2013.



David R. Jackson
Professor,
University of Houston

Analysis and Design of Leaky-Wave Antennas

A leaky-wave antenna (LWA) is a type of traveling-wave antenna where a guiding structure supports a wave that radiates (leaks power) as it propagates down the structure, forming a directive beam. The beam is conical in shape (or semi-conical, if there is a ground plane), becoming a fan beam at broadside. An array of LWAs can be used to create a pencil beam. Leaky-wave antennas come in three general categories: uniform, quasi-uniform, and periodic. A uniform LWA has a uniform (constant) cross section and supports a guided wave with a single complex wavenumber. An example would be an air-filled rectangular waveguide with a long longitudinal slot in one of its walls. This type of structure is usually designed to support a fast phase (phase velocity greater than that of light in free space) to enable efficient radiation. A periodic LWA radiates by virtue of a periodic set of perturbations along the guiding structure, which introduces a finite set of space harmonics (Floquet modes), where usually the $n = -1$ space harmonic is chosen to radiate. A quasi-uniform structure is one that is periodic, but the period is small compared to a wavelength so that it acts as a uniform structure with the fundamental ($n = 0$) space harmonic radiating. In all cases a load is typically used at the end of the LWA to absorb the residual power left in the leaky wave.

For uniform and quasi-uniform LWAs the beam is limited to the forward direction, between broadside and endfire, assuming that the antenna is fed at one end, which is the usual case. However, broadside beams can be achieved by feeding the LWA in the center, creating a bidirectional leaky wave. For a periodic LWA a beam can be created in either the forward or backward directions. Furthermore, the beam scans with frequency, which can be advantageous for some applications. However, there is usually an open stopband at broadside that causes beam degradation as the beam is scanned through broadside, though techniques can be used to overcome this problem.

Simple design formulas can be obtained for LWAs to characterize the properties of beam angle, beamwidth, directivity, and pattern bandwidth. These formulas allow for a prediction of the optimum load efficiency to maximize the antenna gain, with the optimum load efficiency being close to 92% for relatively long LWAs.

A two-dimensional (2-D) LWA is one where a structure supports a radially-propagating leaky wave, excited by a central source. The Fabry-Pérot resonant cavity antenna is the most common example of such a LWA, where a partially reflecting surface (PRS) is placed above a grounded substrate (which may be air). This type of LWA can produce a symmetrical pencil beam at broadside, or a conical beam that is scanned to some angle from the vertical axis.

David R. Jackson obtained the B.S.E.E. and M.S.E.E. degrees from the University of Missouri, Columbia, in 1979 and 1981, respectively, and the Ph.D. degree in electrical engineering from the University of California, Los Angeles, in 1985. He is a Professor in the Department of Electrical and Computer Engineering at the University of Houston, where he has been since 1985. He has been a Fellow of the IEEE since 1999. His present research interests include microstrip antennas and circuits, leaky-wave antennas, wave propagation effects including surface waves and leaky waves, leakage and radiation effects in microwave integrated circuits, periodic structures, and electromagnetic compatibility and interference.

He presently serves on the IEEE Antennas and Propagation Society (AP-S) Committee on Promoting Equality (COPE), the AP-S Technical Committee 5 (Electromagnetics and Fundamentals), and on the MTT-1 (Microwave Field Theory) Technical Committee of the Microwave Theory and Technology Society. He is also serving as the Chair of the IEEE AP-S Constitution and Bylaws Committee.

Previously, he has served as the chair of USNC-URSI (The United States National Committee for the International Union of Radio Science), and as chair of Commission B of USNC-URSI. He has also been the chair of the Distinguished Lecturer Committee of the IEEE AP-S, the chair of the Transnational Committee of the IEEE AP-S, the chair of the Chapter Activities Committee of the AP-S, a Distinguished Lecturer for the AP-S, a member of the AdCom for the AP-S, and an Associate Editor for the IEEE Transactions on Antennas and Propagation.



Challenges and Opportunities for Development of Ultra-Low Power Scaled Quantum Computing Systems

This talk will cover practical challenges for the development of integrated system designs for next generation quantum computing which includes a combination of integrated circuits, systems and microwave engineering. Starting from system level, it will detail the design considerations for non-multiplexed, semi-autonomous, transmon qubit state controllers (QSC) implemented in 14nm CMOS FinFET technology. The QSC includes an augmented general-purpose digital processor that supports waveform generation and phase rotation operations combined with a low power current-mode single sideband upconversion I/Q mixer-based RF arbitrary waveform generator (AWG). Implemented in 14nm CMOS FinFET technology, the QSC generates control signals in its target 4.5GHz to 5.5 GHz frequency range, achieving an SFDR > 50dB for a signal bandwidth of 500MHz. With the controller operating in the 4K stage of a cryostat and connected to a transmon qubit in the cryostat's millikelvin stage, measured transmon T1 and T2 coherence times were 75.5 μ S and 73 μ S, respectively, in each case comparable to results achieved using conventional room temperature controls. In further tests with transmons, a qubit-limited error rate of 7.76 \times 10⁻⁴ per Clifford gate is achieved, again comparable to results achieved using room temperature controls. The QSC's maximum RF output power is -18 dBm, and power dissipation per qubit under active control is 23mW. An improved, low-power design version that achieves half of this power will also be presented, including some clocking solutions for large arrays.

Sudipto Chakraborty
Silicon Photonics Lead,
Omni Design Technologies

Sudipto Chakraborty (B. Tech, IIT, Kharagpur, 1998, Ph.D from GaTech, 2002) was with Texas Instruments till 2016 where he designed low power IC for >10 product families in automotive/wireless/medical/microcontrollers. From 2017-2025 he led the low power circuit design for next generation quantum computing applications in IBM research using nanometer CMOS. Since 2025, he has been leading the high speed and Silicon photonics IP developments at Omni Design Technologies. He has authored or co-authored >90 papers, two books and 98 US patents. He has served in the TPC including ISSCC, CICC, RFIC, IMS, and has been an IBM master inventor. He served as an AE of the (TCAS – I) and distinguished lecturer in the IEEE MTT-S, CASS and SSCS. He is an IEEE fellow.



Damla Dimlioglu
Research Scholar,
Cornell University

VSWR Sensitivity of the mmWave PA Performance in Integrated Transmit Phased Arrays

The abundance of bandwidth positions millimeter-wave (mmWave) communications as the most promising candidate to realize fifth generation (5G) and future networks for cellular and backhaul applications, as well as point-to-point links. To support the demand for high data rates in multi-user systems across large distances and to overcome the path loss, 5G communication systems and beyond require sharp beams with high directivity and power. mmWave beamforming technology is, therefore, the key enabler of future communications and sensing systems, and it is crucial to build compact, efficient, and low-cost mmWave phased arrays. This leads to the co-design of mmWave power amplifier (PA) and antenna (ANT), eliminating the bulky isolators at the interface. However, the antenna impedance changes due to beam steering and mutual coupling. This creates a non-ideal voltage standing-wave ratio (VSWR) at the PA-ANT interface, implying PA load modulation, and results in nonlinear distortions in the PA characteristics.

This talk presents a systematic approach based on active S-parameters, a forgotten yet powerful microwave engineering concept, to model the element- and array-level VSWR sensitivity of mmWave integrated transmit phased arrays, with a focus on power amplifier (PA) performance. Experimental results, as well as antenna, RF circuit, and system parameters from an example E-band (71-77 GHz) integrated phased-array transceiver on 22nm FinFET technology, have been studied to demonstrate the algorithmic methodology developed in this framework. The element-level analysis showed non-negligible variation in the VSWR and, therefore, the key performance indicators (KPI) of the E-band PA, such as output power (Pout) and power added efficiency (PAE) across scan angles for 16QAM modulation at the practical EVM metrics required in the modern communication channels, such -20 dB, -25 dB, and -27 dB, compared to the ideal-VSWR conditions. The array-level analysis, on the other hand, has revealed aggregate EVM degradation of multiple dBs and a reduction in efficiency, resulting in more than 1 W of extra power dissipation to compensate for transmitting the same amount of RF power despite averaging effects and the advantages of larger antenna arrays. The non-ideal VSWR environment also causes elements to radiate unequal amounts of power, which creates distortions in the beam pattern. As such, the VSWR sensitivity of nulls and side lobes will be reviewed, and its implications on the open-loop (TX-only) systems, where beam-tracking algorithms cannot be exploited, will be discussed. Finally, the potential on-chip mitigation techniques will be proposed towards future implementations.

Damla Dimlioglu (Member, IEEE) received the B.S. degree in Electrical and Electronics Engineering with a minor in Solid-State Physics from Middle East Technical University, Turkey, in 2012, and the M.S. degree in Electrical Engineering with a minor in Semiconductor Devices and Physics from the University of California, Davis, CA, in 2015. She has been a Research Scholar at Cornell University, NY, since 2020, focusing on Out-of-Band Interference-Tolerant mmWave Receivers on CMOS, SiGe, and GaN technologies for high-data-rate wireless communications and sensing.

In 2023, she demonstrated the first GaN N-path passive mixer ever reported to date in a mixer-first downconverter prototype and presented it to the Director of NIST, who oversees the CHIPS Act under the U.S. Secretary of Commerce. Before joining Cornell in 2020, she was an R&D mmWave IC design intern at Next Generation Radio Integration Lab at Intel Labs, OR, working on Nonlinear Distortions in mmWave Phased Array Transceivers. She worked on tunable PLLs at Analog Devices, CA (2015), high-speed optical modulator drivers at Bell Laboratories, NJ (2016), and bandwidth extension techniques for broadband amplifiers at Intel Labs, OR (2017).

Damla is a reviewer for the IEEE Journal of Solid-State Circuits (JSSC), IEEE Solid-State Circuits Letters (SSC-L), IEEE Transactions on Circuits and Systems-I (TCAS-I), IEEE Journal of Microwaves (JMW), IEEE Microwave Magazine, and IEEE Transactions on Microwave Theory and Techniques (T-MTT). She has been an editor for the IEEE Microwave Magazine since 2025. She is an Associate Editor of the IEEE Journal of Microwaves (JMW) for the technical tracks Microwave and mmWave Integrated Circuits, and RF/Mixed-Signal Integrated Circuits and Signal Processing. She has been a member of the IEEE MTT-S TC-14 Microwave and Millimeter-Wave Integrated Circuits Committee and the IEEE International Microwave Symposium Technical Program Review Committee (IMS TPRC) since 2021. She served on the 2023 IEEE IMS Early Career Paper Competition Review Committee. Since 2025, she has served on the technical review committees of the European Microwave Integrated Circuits (EuMIC), European Microwave Conference (EuMC), German Microwave Conference (GeMic), IEEE Space, Aerospace and Defense (IEEE SPACE), IEEE Microwaves, Antennas, and Propagation (IEEE MAPCON), and IEEE BiCMOS and Compound Semiconductor Integrated Circuits and Technology Symposium (IEEE BCICTS) conferences. She is the TPC Co-chair for the 2026 IEEE Texas Symposium on Microwave and Wireless Circuits and Systems (IEEE MWCS). Damla is the recipient of the 2024 IEEE Solid-State Circuits Society Rising Stars Award. She has been selected as one of the 2026 IEEE MTT-S Outstanding YP Lecturers in the global cohort of eight new speakers.

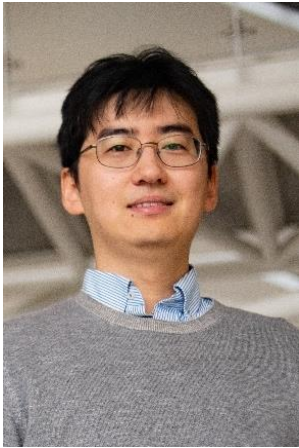


Sunhwan Jang
mmWave Package
Design Engineer,
Texas Instruments

CMOS mmWave Radar: Industry Perspectives

Radar systems operating at mmWave frequencies have traditionally relied on III/V compound semiconductor technologies, such as GaAs or InP. However, with the commercial success of CMOS RF ICs in the late 1990s and early 2000s, and the promising research outcomes in mmWave ICs using CMOS technology, the industry began to explore the possibility of building mmWave radar systems using standard CMOS processes. A pioneering work in this area was the development of a fully integrated 160GHz pulsed radar transceiver with an antenna in a standard silicon process at Texas Instruments' Kilby Lab. This breakthrough demonstration proved the feasibility of mmWave radar in silicon, paving the way for the commercialization of CMOS-based radar systems at mmWave frequencies. Although compound semiconductor-based radar chips may still be preferred for certain applications requiring extremely high performance or specialized functionality, CMOS radar offers numerous advantages that make it an attractive solution for the commercial market, including low cost, high yield, high integration levels, and high scalability. This presentation will provide an industry perspective on the design of CMOS mmWave radar systems, highlighting the evolution and improvement of CMOS radar designs at Texas Instruments to meet the needs of the market.

Sunhwan Jang (Ph.D., Texas A&M University, 2016) is a Member Group Technical Staff at Texas Instruments, where he designs integrated circuits (ICs) and packages for mmWave radar products. With expertise in TX/RX RF front-ends, including power amplifiers, low-noise amplifiers, mixers, and local oscillator distribution, etc., he has contributed to the development of over 10 successful radar products across 60 and 77GHz and various package technologies, such as FCCSP, WCSP, LoP, and AoP, for both automotive and industrial applications. He has authored or co-authored 10+ IEEE publications and holds 15+ US patents (granted or pending) in the areas of integrated circuits, systems, and semiconductor packaging. His current research focuses on optimizing IC and package co-design to minimize cost and loss, as well as developing area-efficient and low-loss passive components at mmWave and sub-THz frequencies.



Sensen Li

Assistant Professor,
University of Texas,
Austin

Adaptive Linearity Enhancement for LNA using Doherty Active Load Modulation

Modern wireless communication systems operate in increasingly dynamic and congested electromagnetic environments. Applications such as massive MIMO and automotive radar must manage multiple concurrent signal paths while detecting weak signals in the presence of strong interferers. Likewise, emerging platforms, including SATCOM-on-the-move, mmWave drone links, and high-definition wireless AR/VR systems, must contend with unknown, high-power interferers arriving across varying angles, frequencies, and modulation schemes. These challenges impose increasingly stringent linearity requirements, a performance metric that has traditionally received less emphasis in receiver and LNA design. As a result, receiver and LNA architectures with inherently high or reconfigurable linearity are becoming essential for preserving signal integrity in congested spectral environments. However, a fundamental challenge lies in the tightly coupled trade-offs between linearity and other key performance metrics, including NF, gain, bandwidth, and power consumption. Conventional approaches to improving linearity often degrade one or more of these parameters. To address these limitations, this talk introduces the concept of Doherty active load modulation, originally developed for PA architectures, into the LNA domain. The proposed Doherty LNAs achieve up to a 10× improvement in linearity without compromising other key performance metrics.

Sensen Li received the B.Eng. (Hons.) from Zhejiang University and the Ph.D. from the Georgia Institute of Technology. He is currently an Assistant Professor in the Department of Electrical and Computer Engineering at The University of Texas at Austin, where he directs the UT-Austin Circuits and Electromagnetics (UT-ACE) Lab. Previously, he was with Samsung Research, working on next-generation wireless systems. His research focuses on analog, RF, and mm-wave integrated circuits and systems for wireless communication and sensing, as well as AI-enabled RFIC design automation.

Dr. Li's research group received the 2025 ISSCC Jack Kilby Award for Outstanding Student Paper and the 2025 IEEE Microwave Prize, along with multiple other recognitions, including IEEE IMS Best Paper Finalist and First and Second Place in the Texas Wireless Symposium Student Research Competition. He is also a recipient of the 2018 IEEE RFIC Best Paper Award, with additional best paper recognitions at IEEE RFIC, IMS, and CICC. Dr. Li serves on the Technical Program Committees of IEEE IMS, CICC, and RFIC, and is an Associate Editor for the IEEE Transactions on Microwave Theory and Techniques (T-MTT).