Center for

Wireless and Microwave Information Systems

http://wami.eng.usf.edu/

Department of Electrical Engineering
University of South Florida

Annual Report 2015

Members: Dr. Huseyin Arslan, Dr. Lawrence Dunleavy, Dr. Richard Gitlin, Dr. Gokhan Mumcu, Dr. Ismail Uysal, Dr. Jing Wang (Co-Director), Dr. Tom Weller (Co-Director)

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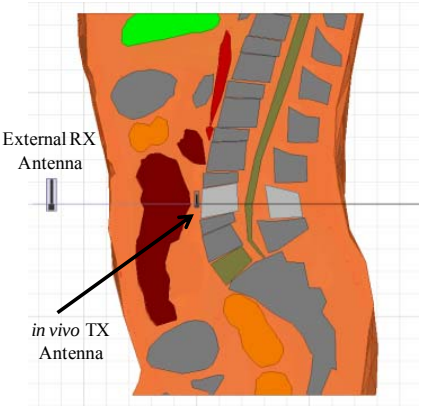
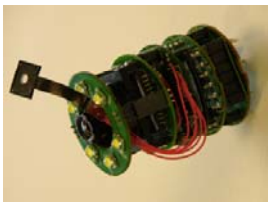
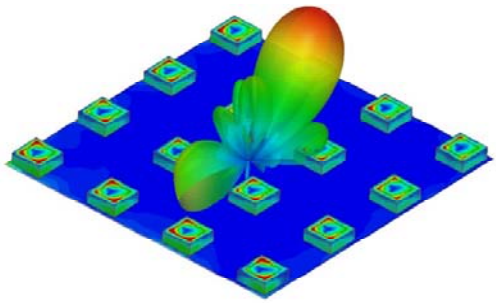
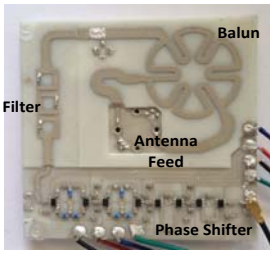
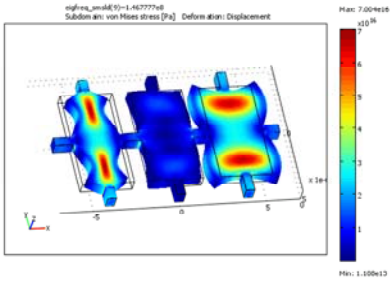










The Center for Wireless and Microwave Information Systems conducts research across a broad range of technical areas that include device modeling and characterization, RF micro electromechanical systems, advanced materials and nanoscale devices, active antennas, cognitive radio, next generation wireless architectures and RF identification (RFID). Research projects focus on basic scientific development as well as applications such as biomedical sensing, communications, robotics and transportation. Active collaborations are pursued with multiple industry and university partners as well as several centers at the University of South Florida.

In 2014/15 the Center supported 45 MS and PhD students, 2 post-doctoral fellows and 7 undergraduate students. Center faculty submitted over 40 research proposals in the past year; of these 17 proposals were funded. The WAMI faculty had more than 82 publications in journals, conferences and book chapters, 13 patents and gave 11 invited talks. The students and faculty received 11 awards and distinctions including best paper/poster awards and recognition for professional achievement.

Newsworthy Notes

- The **2015 Rudolf E. Henning Distinguished Mentoring Award** was presented to Dr. Zoya Popovic at WAMICON 2015. Zoya Popović received her Dipl. Ing. degree from the University of Belgrade, Serbia, in 1985, and the M.S. and Ph.D. degrees from Caltech, Pasadena, California, in 1986 and 1990, respectively. Her doctoral thesis was on large-scale quasi-optical microwave power combining. She joined the faculty of the University of Colorado in Boulder in 1990, where she became a full professor in 1998, and received an endowed professorship in 2006. She has developed five undergraduate and graduate electromagnetics and microwave laboratory courses and co-authored (with her late father) Introductory Electromagnetics for the junior-level core course for electrical and computer engineering students, translated to several foreign languages. Her research interests include high-efficiency linear microwave power amplifiers, low-loss broadband microwave and millimeter-wave circuits, millimeter-wave and THz quasi-optical techniques, intelligent RF circuits, active antenna arrays, cryogenic circuits, microwave radiometry, and wireless powering for low-power sensors. She was a Visiting Professor at the Technische Universitat Muenchen, Munich, Germany, in 2001 and 2003. She has authored over 300 technical papers, 3 books and contributed to 8 others. She is the wife of physics professor Dana Anderson and mother of three daughters who can all solder! The oldest is an electrical engineer and currently in graduate school.

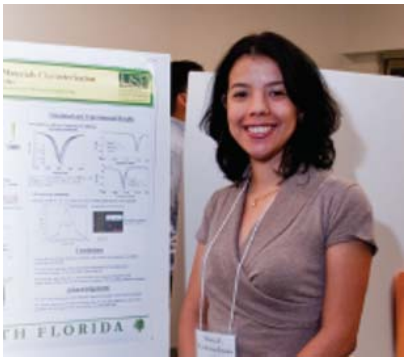
- **The 16th annual IEEE Wireless and Microwave Technology (WAMI) Conference** was held in Melbourne, FL on April 13-15, 2015. The theme for WAMICON 2015 was "Emerging RF and Microwave Technologies" where authors presented papers on biomedical applications, wireless sensing, energy harvesting, wireless power transfer, terahertz technologies, nanodevices and circuits. A total of 14 invited papers from universities and industry together with 65 other presentations were given in two parallel sessions during the 3-day event. Consistent with WAMICON tradition, there was also an interactive Student Poster Session held in conjunction with a reception that preceded the conference banquet.

- Special thanks to Raytheon for their continued financial support, which is used to provide supplemental funds for our students, support conference travel, and allow the WAMI Center to maintain its equipment. Mini Circuits continues to be a strong supporter of the WAMI teaching laboratory by contributing microwave components. The Center also acknowledges

the continuing strong support of Keysight Technologies, Applied Wave Research, and Modelithics for providing our students with no-cost access to their exceptional software tools.

- Masters and Ph.D. graduates from the WAMI Center in 2014/2015 are now working for Dow Corning, Intel, Lockheed Martin, Modelithics, Qorvo, Sandia National Lab, SRI International, and TDK.

Student Recognition



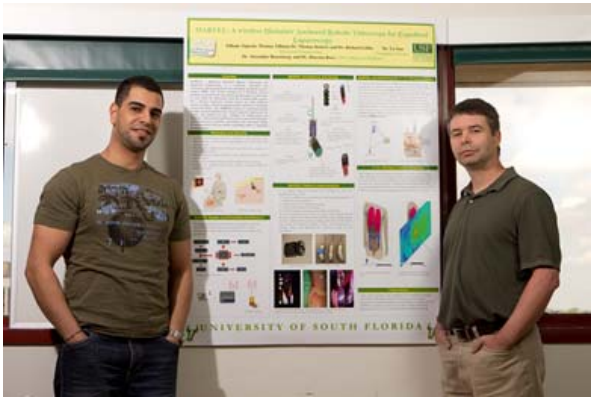
- **Maria Cordoba,** a WAMI Ph.D. student, received an IEEE Microwave Theory and Techniques Society Graduate Student Fellowship. Maria also received the 2014 ARFTG Roger Pollard Memorial Student Fellowship in Microwave Measurement.

- **Juan Castro,** a WAMI Ph.D. student received the Best of Track and Best of Session Paper Award at the 2015 International Microelectronics and Packaging Society Symposium.

- **Eduardo Rojas, a** WAMI Ph.D. student, received the Best Student Poster Award at the 2015 International Microelectronics and Packaging Society Symposium.

- **Di Lan, Juan Castro, Eduardo Rojas, Maria Cordoba and Derar Hawatmeh**, WAMI Ph.D. students, all received awards at the 2015 USF College of Engineering Poster Competition.

Research Highlights – Current & Recent Projects



- **Collaborative Research: A Systems-Centric Foundation for Electrical and Computer Engineering Education,** P.I. S. Thomas, Co-P.I. T. Weller, Granting Agency: National Science Foundation. Development of systems-centric, hands-on learning modules for the introductory circuits course. This is a joint project with U. Hawaii, U. Minnesota, U. Vermont and Northern Arizona U.

- **GOALI Collaborative Research: 3D RF Microsystems using Direct Digital Manufacturing Technology,** P.I. T. Weller, Co-P.I. C. Lusk (Mechanical Engineering) and K. Church (Sciperio), Granting Agency: The National Science Foundation. Investigate new 3D microwave systems using digital manufacturing techniques. This is a collaborative project with Georgia Tech (J. Papapolymerou).

- **Integrated Antenna System Design for High Clutter and High Bandwidth Channels Using Advanced Propagation Models,** P.I. P.I. T. Weller, Granting Agency: National Science Foundation. The objective is to investigate adaptive antenna systems for modeling for high clutter environments in machine-to-machine applications.

- **Rapid Design of Optimal Digitally-Manufactured 3D Electrically-Small Antennas,** P.I. T. Weller, Granting Agency: Central Intelligence Agency. Investigate design and optimization tools for digitally manufactured small antennas.

- **3D Formable RF Materials,** P.I. T. Weller, Granting Agency: Army Research Office. Microwave characterization of materials used in 3D printed RF electronics.

- **80-100 GHz Communications System**, PI T. Weller, Sponsor: Harris. The purpose of this project is to design and demonstrate a 80-100 GHz wideband communications system.

- **3D Fabricated Low Cost Phased Array Technology,** P.I. T. Weller, Granting Agency: Office of Naval Research. Develop a 2-18 GHz current sheet array unit cell using 3D direct digital manufacturing.

- **Three-Dimensional (3D) Structural Radio Frequency (RF) Electronics,** P.I. T. Weller, Granting Agency: Air Force Research Lab. Investigate a 2.45 GHz phased array module using direct print additive manufacturing techniques.

- **Improving the Communications Performance and Reliability of *In Vivo* Wireless Medical Devices** –Gitlin. Initially funded by the NSF and with continued funding from Innovatia Medical Systems, this project has the goal of advancing novel wireless communications technologies that enable high performance, reliable communications, and the ability to overcome link and/or power failures among networked *in vivo* medical devices. A prototypical *MARVEL* robotic camera is being designed with high-definition video and OFDM digital communications to replace the earlier VGA video and analog communications device.

- **Channel Modeling and Optimized Radio Access Design for *In Vivo* Wireless Communication**---Arslan and Gitlin. Funded by QNRF. This project is directed towards developing reliable signal processing and wireless communications technologies and methodologies to address the major challenges of the i*n* vivo communication channel that will be faced by emerging wireless body area networks. Channel models have been derived to describe the *in vivo* channel and reported on in many publications including a recently accepted survey paper in an IEEE publication and an invited book chapter is being finalized.

- **Holistically Application-Aware Multi-dimensional Cognitive Radio (HAMCR)** ---Arslan and Gitlin [and Haas (Cornell). Funded by NSF. HAMCR is an application-aware cognitive radio with new technology that enables substantial growth in the capacity of wireless networks, with support for diverse applications, without additional spectrum. HAMCR maximizes spectrum utilization by trading off the spectral resource allocations of connections for the application-level QoS, while still maintaining acceptable levels of QoS for the users of the underlying applications, thus satisfying an increased number of users in times of shortage of spectral resources. This work led to several papers and conference presentations and was the subject of Chao He's PhD dissertation.

- **Vectorcardiogram (VCG)** system. Funded by Jabil Circuit and Florida High Tech Corridor. The Vectorcardiogram presents a three dimensional (3D) view of the depolarization (depolarization cycle) of the heart by calculating the magnitude and direction of the electrical signals emanated from the heart and provides the same information as the "gold standard" Electrocardiogram (ECG). From the 3-lead VCG the 12-lead ECG may be created via a 3x12 matrix transformation. The principal advantage of the VCG is that it provides the same information as the 12-lead ECG but with a smaller number of leads. The project goal is to enable real-time 24x7 diagnostic-quality monitoring of the heart's electrical with a small form factor VCG that can be worn on the body of the patient. This breakthrough capability can revolutionize the field of cardiac rhythm management. Progress has been made in dramatically reducing the size of the research model, introduction of "dry" electrodes (replacing the wet electrodes), and

compensation for rotational and translational offsets in repositioning of the VCG device. Work has begun on deep machine learning with the goal of predicting cardiac events.

- **Application of Photosynthetic Proteins in a Field-Effect Transistor for Low Light Intensity Detection,** P.I. A. Takshi, Co-P.I. J. Wang, Granting Agency: National Science Foundation. The goal is to employ proteins from photosynthetic cells to develop a field effect phototransistor. Due to the unique properties of photon absorption and charge separation in photosynthetic proteins, theoretically the proteins are more sensitive to photons than conventional semiconductors.

- **Acoustic Emission Technology on a Chip**, PI J. Wang, Co-PI R. Guldiken, WavesinSolids, LLC through National Science Foundation (NSF) SBIR Phase I and Phase IB Program. The goal of this work is to thoroughly investigate the folded-beam MEMS resonator with interdigitated capacitive transducers to address the current limitations of MEMS acoustic emission sensors such as low sensitivity.

- **Development and evaluation at the laboratory level of biosensors for the diagnosis of all dengue virus serotypes based on the Non-Structural protein- 1 (NS-1)**, PI J. Wang, Granting Agency: the Administrative Department of Science, Technology and Innovation–COLCIENCIAS, Colombia. The aim of this work is to develop lab-on-a-chip devices that can be used as immunoassays for all dengue virus serotypes based on the Non-Structural protein-1 (NS-1) for accurate and early diagnosis of dengue infection.

- **Research and Training Internship for Enhanced Microwave and Millimeter-Wave Circuit Design, Characterization and Modeling,** PI: J. Wang, Granting Agency: Modelithics, Inc. and Florida High Tech Corridor. Research and training grant for development and verification of improved models as well as modeling and characterization techniques for high frequency transistors.

- **Pathways to Market of Piezoelectric Elastomer Composites for Additive Manufacturing of Flexible 3D Conformal Acoustic Emission and Ultrasonic Transducer Arrays,** P.I. J. Wang, Grant Agency: National Science Foundation. This program will conduct a thorough market analysis and assessment of piezoelectric-nanocomposite elastomer materials that enable customized design, injection molding or additive manufacturing and ease of deployment of a new class of flexible and 3D conformal ultrasonic transducer arrays. Due to the use of lightweight, low-cost, and piezoelectric composites, enhanced piezoelectric coupling efficiency, improved signal to noise ratio, and tailored frequency responses can be readily achieved for non-destructive structural health monitoring, wearable and point-of-care health diagnosis, and so on.

- **RF Nanomaterials and Transducers Fund,** PI: J. Wang, Granting Agency: USF Research Foundation, Inc. The objective is to support research in RF functional nanomaterials and transducers technologies with initial focus towards development of

novel soft magnetic nanomaterials for radio frequency and microwave devices such as near field communication (NFC), near-field and far-field wireless power transfer..

- **CAREER: Microfluidically Loaded Highly Reconfigurable Compact RF Devices,** PI: G. Mumcu, Granting Agency: National Science Foundation (NSF). This CAREER effort investigates the novel interdisciplinary concept of microfluidically loaded reconfigurability within the context of RF antennas, filters, and imaging systems. The project proposes unique RF device and imaging array implementations that provide unprecedented reconfigurability, high power handling capability, lower circuit complexity and cost-reductions as compared to the existing technologies.

- **EAGER: Reconfigurable Textile Antennas and RF Electronics Using Microfluidic Techniques,** PI: G. Mumcu, Granting Agency: National Science Foundation (NSF). This project focuses on a novel direction for efficient spectrum utilization of body worn RF front-ends by integration of highly functional textile antennas with microfluidics for reconfiguration.

- **Remote Environmental Monitoring and Diagnostics in the Perishable Supply Chain** P.I. C. Nunes, Co-P.I. I. Uysal, Granting Agency: US Army Natick Soldier RD&E Center. Using RFID sensor technology to monitor freshness of army rations and develop smart distribution systems. This is a joint project with University of Florida.

- **Testing and Calibration of RF Temperature Sensors** P.I. I. Uysal, Granting Agency: RFID Innovative Solutions LLC. Testing and calibration of ISO18000-7 Temperature Sensors developed by RFID IS LLC.

- **Reducing Strawberry Waste and Losses in the Postharvest Supply Chain via Intelligent Distribution Management** P.I. I. Uysal, Co-P.I. C. Nunes, Granting Agency: Walmart Foundation. Temperature mapping of the cold chain with wireless sensors to enable smart distribution practices

- **Increasing Consumption of Specialty Crops by Enhancing their Quality and Safety** P.I. C. Nunes, Co-P.I. I. Uysal, Granting Agency: US Department of Agriculture. Algorithmic modeling of the effects of environmental variables like temperature and humidity on specialty crops.

- **Calibration and Validation of DeltaTrak's Product Emulation Model** P.I. I. Uysal, Granting Agency: DeltaTrak Inc. Testing a product temperature emulation model developed by DeltaTrak to predict product temperatures by measuring ambient temperatures. This is a joint project with University of Florida.

- **Time-temperature Indicator Characterization** P.I. I. Uysal, Granting Agency: DeltaTrak Inc. Characterizing environmental behavior of TTI labels to construct a temperature-stage curve for response analysis and time prediction.

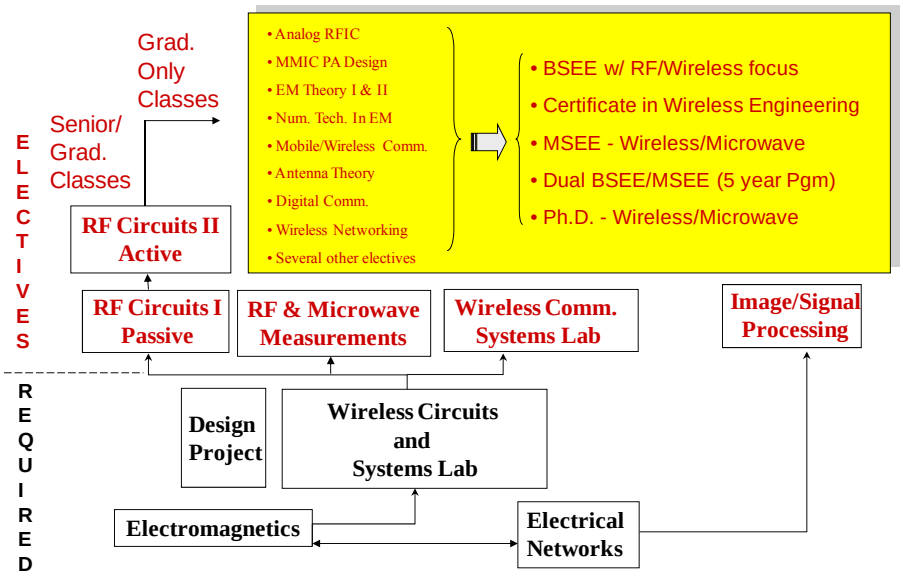
- **Algoithmic prediction and recognition of human activity and falls from wireless accelerometer data** P.I. I. Uysal, Granting Agency: RFID Innovative Solutions LLC. To develop a machine learning algorithm which would automatically recognize falls and other human activity based on measured RFID accelerometer data.

- **Algorithmic estimation of product temperatures using wireless sensors** P.I. I. Uysal, Granting Agency: Deltatrack Inc. To develop and assess an algorithm to correlate ambient air temperatures with the product temperature for more accurate wireless monitoring.

Selected Curriculum Activities

The WAMI faculty was engaged in several on-going and new activities in 2014/2015 aimed at improving the RF/microwave/wireless curriculum. These activities include:

- Dr. Gokhan Mumcu is developing innovative 3D visualization tools, first geared toward the undergraduate electromagnetics course, as part of his NSF CAREER Award. The aim of these tools is to help students grasp abstract concepts such as electromagnetic field propagation along transmission lines.
- A new, multi-university collaboration that will develop hands-on laboratories for the introductory circuits course, emphasizing systems-centric learning and the broad applications of electrical engineering. This project, called ENFUSE (Engaging Fundamentals & Systems Engineering) is sponsored by the National Science Foundation and involves the University of Hawaii, University of Vermont, University of Minnesota and Northern Arizona University.
- New teaching methods, such as the 'inverted classroom' that involve significant hands-on problem solving in the classroom, are being implemented across the courses in the WAMI curriculum.
- Modelithics and Qorvo are partnering in supporting real-world high power GaN power amplifier design/fab/test projects as part of the RF & Microwave PA Design class which was offered in Fall 2014 and will be offered again in Fall 2016.
- Through a partnership with Qorvo, the WAMI faculty has integrated the use of their GaAs process design kit into several of the RF/microwave courses. Students now have the opportunity to design, layout and test circuits fabricated by Qorvo.



Professional Activities

- **2016 International Workshop on Antenna Technology (IWAT) –** Dr. Mumcu is serving as the Technical Program Chair for this conference, to be held in Orlando, FL in February 2016.

- **2016 Wireless and Microwave Technology Conference –** Dr. Weller is serving as the Awards Chair and Student Paper Competition Chair for this conference, to be held in Cocoa Beach, FL in April 2016.

- **IMS 2016 Project Connect** – Dr. Weller is serving on the organizing committee for this NSF-sponsored project which brings undergraduate and first-year graduate students from under-represented groups to the International Microwave Symposium (San Francisco, May 2016) for professional development training.

- **International Journal of RF Technologies: Research and Applications** – Dr. Uysal was selected to the editorial board.

- **Dr. Gitlin** was appointed a faculty member of USF's Institute for Advanced Discovery & Innovation and gave keynotes on *in vivo* wireless networking at WCNC 2015 and WTSI 2015, and he will be giving a keynote on 5G at WAMICON 2016.

- **IEEE Transactions on Cognitive Communications and Networking-** Dr. Arslan was selected to the editorial board

- **IEEE Communications Surveys and Tutorials (COMST) -** Dr. Arslan was selected to the editorial board

- **Internet-of-Things (IoT) Showcase @ Washington D.C. Capitol Hill** – Dr. Uysal presented some of his research projects on RFID and IoT to the Energy and Commerce representatives of the U.S. Congress in March 2015.

Publications

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2. Deffenbaugh, P.I.; Weller, T.M.; Church, K.H., "Fabrication and Microwave Characterization of 3-D Printed Transmission Lines," in Microwave and Wireless Components Letters, IEEE , vol.25, no.12, pp.823-825, Dec. 2015.
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9. Nassar, I.; Tsang, H.; Weller, T., "3D printed wideband harmonic transceiver for embedded passive wireless monitoring," Electronics Letters, vol.50, no.22, pp.1609,1611, 10 23 2014.
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11. Eduardo A. Rojas-Nastrucci, Ramiro A. Ramirez, Sean T. Murphy, Mike Newton, and Thomas M. Weller, “A Direct Digital Manufactured RFID System Applied to Teaching Antenna Theory to Pre-College Students,” 2015 IMAPS, October 2015.
12. J. Castro, E .Rojas, T. Weller and J. Wang, “Advanced Functional Materials for Additive Manufacturing of 3D Microwave Electronics,” 2015 HENAAC, August 2015.
13. Juan Castro, Eduardo Rojas, Thomas Weller and Jing Wang, “Engineered Nanocomposites for Additive Manufacturing of Microwave Electronics,” 2015 IMAPS, October 2015.
14. Abdin, Mohamed M.; Castro, Juan; Wang, Jing; Weller, Thomas, "Miniaturized 3D printed balun using high-k composites," Wireless and Microwave Technology Conference (WAMICON), 2015 IEEE 16th Annual , vol., no., pp.1,3, 13-15 April 2015.

15. O'Brien, Jonathan M.; Weller, Thomas M.; Grandfield, John E., "Periodic spherical loop antenna," Wireless and Microwave Technology Conference (WAMICON), 2015 IEEE 16th Annual , vol., no., pp.1,4, 13-15 April 2015.
16. Ketterl, Thomas P.; Ramirez, Ramiro A.; Weller, Thomas M., "Reduced-size circular polarized antenna for 434MHz RFID systems using meandered bowtie elements with a novel quadrifilar feed," Wireless and Microwave Technology Conference (WAMICON), 2015 IEEE 16th Annual , vol., no., pp.1,3, 13-15 April 2015.
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18. Ramirez, Ramiro A.; Rojas-Nastrucci, Eduardo A.; Weller, Thomas M., "3D tag with improved read range for UHF RFID applications using Additive Manufacturing," Wireless and Microwave Technology Conference (WAMICON), 2015 IEEE 16th Annual , vol., no., pp.1,4, 13-15 April 2015.
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27. Castro, J.; Cure, D.;Wang,J.; Weller, T., “Development and Characterization of High-Permittivity and Low-Loss Polymer-Ceramic Composite Substrates for RF and Microwave Applications”, Hispanic

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