EDITORIAL:

Special Section Proposal Tunable Devices for Modern Communications: Materials, Integration, Modeling, and Applications

I. INTRODUCTION

The tunability of devices is a prerequisite for modern communications: the next generation of systems operating at RF, microwave, millimeter-wave, THz, and optical frequencies requires operation over ultra-wide bands, fast switching between channels, and low noise, along with easy integration and low cost. With the advent of novel applications related to 5G and the Internet of Things (IoT), different technologies are being developed for answering these needs in the various frequency bands. In particular, new materials have been proposed, which allow device tunability at high frequencies, such as liquid crystals, ferroelectrics, atomically thin materials, and metamaterials. Novel tunable components and properties have been recently developed, in particular in the field of tunable filters and reconfigurable antennas. Furthermore, innovative integration technologies for the complete integration of millimeter-wave systems are gaining increasing interest, including substrate integrated waveguide (SIW) and circuit (SIC) technologies. In addition to the scientific and technological developments, new and efficient modeling & CAD techniques are required to design such components and systems, which guarantee reliable modeling, design flexibility, and fast time-to-market.

For developing a successful tunable device operating in the RF, microwave, or terahertz frequency ranges, there is an intense need for interdisciplinary efforts to achieve accurate and cost-effective modeling (by means of advanced mathematics & CAD tools, optimization, …). Advanced fabrication techniques involving a variety of new and smart materials that are capable of dealing with the new trends in 5G and IoT systems, and experimental characterization of all elements of the devices and systems and their performance characteristics is needed. 5G technologies are meant to enhance a user's experience because they will provide better information transference. However, to achieve this goal with the next generation of smaller mobile platforms, reconfigurable devices and systems must be developed.

A review of tunable metasurfaces is presented by Aobo Li and Daniel Sievenpiper *et al.*, in the invited article "Nonlinear, active, and tunable metasurfaces for advanced electromagnetics applications." This article provides a review of recent advances in nonlinear and active metamaterial surfaces as well as a wide range of related applications. In each case, the surface impedance is tuned by active electronics such as diodes, transistors, varactors, etc. and other devices can be controlled manually, actively, or self-adaptively. The reconfigurable and self-tuning metamaterial surfaces can be implemented to support a broadband reconfigurable antenna system or to adapt to a wide range of incoming frequencies. The concepts of nonlinear and active tunable metasurfaces are discussed, including results of full-wave simulation analysis, EM/circuit co-simulation, and experimental results in waveguides, using a near-field scanner, as well as far-field measurements in an anechoic chamber. Unlike classical and conventional electromagnetic surfaces, the nonlinear, active and tunable metasurfaces proposed in this article provide new ways of manipulating the interaction between electromagnetic waves and materials, enabling unique properties like broad bandwidth, power or waveform dependency and reconfigurability. Based on the techniques introduced here, more flexible metasurface designs for applications in absorbers, conformal antennas, leaky wave structures, and control of surface waves may be achieved in the future.

In a second article by Y. J. Guo *et al.* (co-authored by Richard Ziolkowski, Guest Editor of the Special Section), "Advances in reconfigurable antenna systems facilitated by innovative technologies," advances in reconfigurable antenna for future fifth generation 5G wireless platforms are presented. Several classes of reconfigurable antennas (RAs) enabled by new technologies were reviewed. Examples of reconfigurable partially reflective surface antennas, reconfigurable filtennas, reconfigurable Huygens dipole antennas, and reconfigurable feeding network-enabled antennas are presented and discussed. They represent novel classes of frequency, pattern, polarization, and beam direction reconfigurable systems realized by the innovative combinations of radiating structures and circuit components. These RAs and future extensions have the great potential to provide many performance characteristics desired to enhance current wireless platforms and to enable future cognitive radio and other 5G and beyond wireless systems.

T. Hongnara *et al.*, propose in their work, "Design of compact beam-steering antennas using a metasurface formed by uniform square rings," two original designs of slot-fed metasurface antenna for beam steering applications. Both designs have the same two-layer stacked configuration consisting of either a single-slot or a double-slot radiator and a metasurface superstrate. In contrast to existing phase-gradient metasurfaces with varying unit elements for beam steering, the proposed metasurface is formed by uniform square rings. Measurement results show excellent agreement with simulations, and demonstrate that a beam steering angle range of -35 to 35 degrees can be achieved for the single-slot design, and -30 to 30 degrees can be realized for the double-slot configuration.

Filters tunability based on smart materials, new geometrical models and CAD design tools is presented by E. A. Casu *et al.* (co-authored by the Associate Editor, Andrei Muller) in the article "Vanadium oxide bandstop tunable filter for Ka frequency bands based on a novel reconfigurable spiral shape defected ground plane CPW." The article presents original filter geometries for reducing the defected ground plane bandstop devices area by exploiting smart materials (Vanadium Oxide) phase transitions. The innovative 3D Smith chart tool (v.1) launched in 2017 is also used in the fabricated filters modelings, which operate between 28 GHz−35GHz frequency range. The paper presents developments of the ongoing HORIZON2020 PHASE-CHANGE SWITCH Project.

The receiver architecture and fast switching required in modern communications systems are treated in the article by (Guest Editor) J. Kim *et al.*, in "The evolution of channelization receiver architecture: Principles and design challenges.'" This article presents a broadband channelization receiver architecture along with its design challenges and system analysis. The proposed channelization receiver architecture adopts the parallel band partition at the front-end and the series channelization at the back-end. The parallel band partition at the front-end relaxes the signal condition due to the interferences and eases the optimization per sub-band.

In “A concept of synchronous ADPLL networks in application to small-scale antenna arrays,” E. Koskin, D. Galayko, and the Guest Editor, E. Blokhina introduce a reconfigurable oscillatory network that generates a synchronous and distributed clocking signal. The article proposes an accurate model of the network to facilitate the study of its design space and ensure that it operates in its optimal, synchronous mode. The network is designed and implemented in a fully integrated 65nm CMOS system-on-chip that utilises coupled all-digital phase locked loops interconnected as a Cartesian grid. The synchronisation of the network was investigated in particular with application to drive an antenna array.

In the article by E. E. Hernandez-Orallo *et al.*, “An analytical model based on population processes to characterize data dissemination in 5G opportunistic networks,” a mathematical approach is presented to challenge the scarcity of bandwidth due to the explosive growth of mobile devices in 5G. Communications in mobile opportunistic networks take place upon the establishment of ephemeral contacts among mobile nodes using direct communication. In this article, an analytical model based on population processes to evaluate data dissemination is presented, considering several parameters, such as user density, contact rate, and the number of fixed nodes. From this model, a closed-form expression for determining the diffusion time, the network coverage, and the waiting time is obtained. In this article, the combination of opportunistic communications and the new 5G wireless technologies like WiGig high-speed links to achieve faster content dissemination among nearby devices is considered.

Advances in analytical methods for the design power amplifiers for microwave frequency ranges are presented in the article by V. Camarchia *et al.*, “A design strategy for AM/PM compensation in GaN doherty power amplifiers.” This article presents the theoretical analysis of phase distortion (AM/PM) mechanisms in Gallium Nitride (GaN) Doherty power amplifiers (DPAs) and a novel approach to optimize the tradeoff between linearity and efficiency. In particular, it is demonstrated how it is possible to mitigate the AM/PM by designing a suitable mismatch at the input of the active devices, based on the identification of constant AM/PM and gain contour circles.

In “Broadband GaN Class-E power ampli_er for load modulated delta sigma and 5G transmitter applications,” T. Sharma *et al.* present a design of a broadband, high efficiency class-E power amplifier (PA) for the advanced efficiency enhancement architectures applications. A sequential load pull methodology to design broadband class-E power amplifiers using a packaged gallium nitride power transistor is presented. Two different broadband matching synthesis techniques have been proposed using lumped elements that have been presented and implemented in the manuscript. A fourth-order, low-pass impedance transformation topology is designed as the output matching network to provide the optimum load reflection coefficients in the targeted bandwidth (1.8-2.7 GHz).

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He launched the first 3-D Smith chart tool in 2017. Since 2017, he has been a Scientist with the Nano Electronic Devices Laboratory (Nanolab), Swiss Federal Institute of Technology, Lausanne. His main research areas are based on vanadium oxide applications in microwave design, while his current research interests include applications of differential geometry in circuit theory and design. He is an Associate Editor of IEEE ACCESS.

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RICHARD W. ZIOLKOWSKI (F'94) received the B.Sc. degree *(magna cum laude)* in physics from Brown University, Providence, RI, USA, in 1974, and the M.S. and Ph.D. degrees in physics from the University of Illinois at Urbana-Champaign, Urbana, IL, USA, in 1975 and 1980, respectively. He was a member of the Lawrence Livermore National Laboratory, Engineering Research Division, from 1981 to 1990, where he served as the Leader of the Computational Electronics and Electromagnetics Thrust Area for the Engineering Directorate. He joined the Department of Electrical and Computer Engineering, The University of Arizona, in 1990, as an Associate Professor, where he was promoted to Full Professor in 1996. He was selected by the Faculty to serve as the _rst Kenneth Von Behren Chaired Professor from 2003 to 2005. He is currently serving as a Litton Industries John M. Leonis

Distinguished Professor. He holds a joint appointment with the College of Optical Sciences. He is also a Distinguished Professor with the Global Big Data Technologies Centre, University of Technology Sydney, Ultimo,NSW, Australia. His research interests include the application of new mathematical and numerical methods to linear and nonlinear problems dealing with the interaction of acoustic and electromagnetic waves with complex media, metamaterials, and realistic structures. He was a recipient of the honorary Doctor Technish Honoris Causa from the Technical University of Denmark in 2012. He was the Australian Defense Science and Technology Organization Fulbright Distinguished Chair in Advanced Science and Technology from 2014 to 2015. He was a 2014 Thomas-Reuters Highly Cited Researcher. Dr. Ziolkowski has been a fellow of the Optical Society of America (OSA) since 2006 and the American Physical Society (APS) since 2016. He was the President of the IEEE Antennas and Propagation Society (AP-S) in 2005, where he served as the Vice President in 2004. He served as a member of the IEEE AP-S Administrative Committee for nine years, and as a member and the Chair of the IEEE Electromagnetics (Technical Field) Award Committee. He has been a member of the International Advisory Committee of the IEEE AP-S, technically co-sponsored iWAT, ISAP, ISAPE, and MAPE meetings. He is also a member of APS and the Tau Beta Pi, Eta Kappa Nu, Sigma Xi, and Phi Kappa Phi honor societies. He was the Vice Chairman of the 1989 (San Jose, CA, USA) and was the Co-Chair of the 2016 (Fajardo, Puerto Rico) IEEE International Symposium on Antennas and Propagation/U.S. National Committee (USNC)-International Union of Radio Science (URSI) National Radio Science meeting, the Technical Program Chairperson of the 1998 IEEE Conference on Electromagnetic Field Computation (Tucson, AZ, USA) , and the General Co-Chair of iWAT2012 (Tucson). He has served as the U.S. URSI Secretary of Commission B (Fields and Waves), the Chairperson of the Commission B Technical Activities Committee, and the Secretary for Commission D (Electronics and Photonics). He was a Member-at-Large of USNC of URSI, where he is currently serving as a member of the International Commission B Technical Activities Board. He was a Co-Organizer of the Photonics Nanostructures Special Symposia at the 1998_2000 OSA Integrated Photonics Research Topical Meetings. He was the Chair of the resulting 2001 IPR sub-committee IV, Nanostructure Photonics. He has served as the Co-Chair of the 2008, 2010, and 2012 SPIE Europe Conferences on Metamaterials. He was the Technical Program Committee Chair of the 2008 Metamaterials Congress and member of the Steering Committees for the 2009_2016 Metamaterials Congresses. He was a Co-Guest Editor of the 1998 Feature Issue of *JOSA A* on Mathematics and Modeling in Modern Optics. He was an Associate Editor of the IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION and a Co-Guest Editor of the IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION Special Issue on Metamaterials in 2003. He served on the Editorial Board of *Metamaterials* (Elsevier). He is serving on the Editorial Board of *EPJ Applied Metamaterials*. He has been a plenary, keynote, and invited speaker at numerous professional society events.

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Dr. Bozzi received several awards, including the MECSA Prize of the Italian Conference on Electromagnetics (XIII RiNEm), in 2000, the Best Young Scientist Paper Award of the XXVII General Assembly, URSI, in 2002, the 2014 Premium Award for the Best Paper in Electronics Letters, and the 2015 Premium Award for Best Paper in *IET Microwaves, Antennas and Propagation*.