# Engineering Passive and Active Metamaterial-inspired Electrically Small Radiating Systems

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The introduction of metamaterials and metamaterial-inspired structures into the tool set of RF engineers has led to a wide variety of advances in discovery within the antennas and propagation research areas. The enhanced awareness of complex media, both naturally occurring and artificially constructed, which has been stimulated by the debut of metamaterials, has enabled paradigm shifts in terms of our understanding of how devices and systems operate and our expectations of their performance characteristics. These shifts include the trends of miniaturization, enhanced performance, and multi-functionality of antenna systems for wireless platforms; dispersion engineering to modify the properties, for example, of transmission lines and antennas; scattering mitigation (cloaking, active jamming, perfect absorbers) and enhancements (sensors, detectors); and the tailoring output beams (leaky wave broadside radiators, sub-diffraction limit resolution in remote sensing and highly directive beams for energy transfer and low probability of intercept systems).

A number of advances in the use of metamaterial-inspired constructs to improve the overall efficiency, directivity and bandwidth performance of electrically small antennas (ESAs) in the VHF, UHF and microwave regimes will be reviewed. Several metamaterial-inspired ESA designs have been fabricated and tested; these measurement results are in nice agreement with predictions. While initial efforts emphasized simply high overall efficiencies without using any external matching networks, more recent resonant near-field parasitic (NFRP) designs have also explored the ability to exhibit multi-functional performance, higher directivity and enhanced bandwidths. Multi-functionality is achieved by combining multiple NFRP elements in an electrically small package. Higher directivity from an electrically small system is obtained by augmenting the NFRP antenna with structured ground planes. Enhanced bandwidths are achieved in an electrically small system by augmenting the NFRP antenna internally with non-Foster (active) elements, which are implemented as negative impedance convertor (NIC)-based inductors and capacitors. The possibility to develop an electrically small system sharing all of these interesting characteristics will be discussed. Connections to similar enhanced radiation and scattering performance characteristics at higher frequencies, i.e., millimeter wave, terahertz and optical systems, will also be discussed.

**Speaker:** Richard W. Ziolkowski (ScB with Honors 1974, Brown University; MS'75 and PhD'80 from the University of Illinois at Urbana-Champaign, all in Physics) is the Litton Industries John M. Leonis Distinguished Professor in the Department of Electrical and Computer Engineering at the University of Arizona. He is a Distinguished Adjunct Professor to King Abdulaziz University (KAU), Jeddah, Saudi Arabia. He was awarded an honorary doctoral degree (*Doctor Technish Honoris Causa*) from the Technical University of Denmark in 2012. He is also a Professor in the College of Optical Sciences at the University of Arizona. He was the Computational Electronics and Electromagnetics Thrust Area Leader in the Engineering Research Division at the Lawrence Livermore National Laboratory before joining the University of Arizona in 1990. Professor Ziolkowski is a Fellow of both the Institute of Electrical and Electronics Engineers (IEEE) and the Optical Society of America (OSA). He was President of the IEEE Antennas and Propagation Society in 2005. He is currently the 2014-2015 Australian DSTO Fulbright Distinguished Chair in Advanced Science and Technology. He and Prof. Nader Engheta, University of Pennsylvania, are Co-Editors of the best-selling 2006 IEEE-Wiley book, *Metamaterials: Physics and Engineering Explorations*.

**The talk will be held at CSIRO theatre, Marsfield, from 1:30-3:30 on 30 April (Thursday).**

The address of CSIRO is Cnr Pembroke and Vimiera Rds, Marsfield, 2122. For GPS purpose, it is opposite to "27 Pembroke Rd, Marsfield, NSW."