

Electromagnetic Metamaterials and their Microwave Applications

After ten years of intense research activities, metamaterials have become one of the most vibrant and promising fields of radio science and technology. Following the discovery of novel electromagnetic concepts, such as negative refraction, super-resolution imaging and cloaking, an impressive number of novel metamaterial component, antenna and system concepts and applications have been developed over the past few years. This tutorial will present an up-to-date overview of metamaterial science and technology. It will first introduce the fundamentals of metamaterials, including basic definitions, historical milestones, an intuitive description of the main metamaterial properties, and the genesis of modern metamaterials. Next, it will present the two classes of "conventional" metamaterials, the resonant-particle and the transmission-line metamaterials, showing their fundamental differences and similarities, and establishing their theoretical foundations, with a particular emphasis on composite right/left-handed (CRLH) transmission line metamaterials, which have lead to the most significant microwave applications of the field. Upon this basis, a suite of applications will be overviewed, including enhanced-bandwidth and multi-band components, tight broadband couplers, agile power combiners, real-time Fourier devices, smart leaky-wave and resonant antennas, active beam-shaping systems, refractors, meta-substrates and non-reciprocal radomes. Finally, the novel concept of multi-scale metamaterials, believed by the author to prelude the next generation of metamaterials, will be discussed. Such materials are structured at different scales - the micro, nano and atomic scales, and their simultaneous exploitation of several of these scales leads to unprecedented opportunities for new microwave devices based on material dispersion, anisotropy and quantum engineering. The next-generation metamaterials will be illustrated by the example of ferromagnetic nanowire metamaterials, whose unique properties of double ferromagnetic resonance, self-biasing, spin-torque and related novel applications will be briefly presented. Concluding remarks will summarize the tutorial and discuss future directions of the field.

Christophe Caloz – Biography



Christophe Caloz received the Diplôme d'Ingénieur en Électricité and the Ph.D. degree from École Polytechnique Fédérale de Lausanne (EPFL), Switzerland, in 1995 and 2000, respectively. From 2001 to 2004, he was a Postdoctoral Research Engineer at the Microwave Electronics Laboratory of University of California at Los Angeles (UCLA). In June 2004, Dr. Caloz joined École Polytechnique of Montréal, where he is now a Full Professor, a member of the Poly-Grames Microwave Research Center, and the holder of a Canada Research Chair (CRC). He

has authored and co-authored over 360 technical conference, letter and journal papers, 3 books and 8 book chapters, and he holds several patents. He is a Member of the Microwave Theory and Techniques Society (MTT-S) Technical Committees MTT-15 (Microwave Field Theory) and MTT-25 (RF Nanotechnology), a Speaker of the MTT-15 Speaker Bureau, and the Chair of the Commission D (Electronics and Photonics) of the Canadian Union de Radio Science Internationale (URSI). He is a member of the Editorial Board of the International Journal of Numerical Modelling (IJNM), of the International Journal of RF and Microwave Computer-Aided Engineering (RFMiCAE), of the

International Journal of Antennas and Propagation (IJAP), and of the journal "Metamaterials" of the Metamorphose Network of Excellence. He received several awards, including UCLA Chancellor's Award for Post-doctoral Research in 2004 and the MTT-S Outstanding Young Engineer Award in 2007. He is an IEEE Fellow. His research interests include all fields of theoretical, computational and technological electromagnetics engineering, with strong emphasis on emergent and multidisciplinary topics.