General Lecture 4 (11:00–12:00, Friday, May 31, 2019)

Unimodularity and Magnetoelectric Coupling — Looking for Unconventional Taxonomy of Electromagnetic Materials

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Abstract

In electromagnetics, recent advances in complex media and metamaterials have revealed the incredible variety of responses that a medium can display under exposure to electric and magnetic fields. A simplest isotropic, homogeneous, lossless, achromatic dielectric medium can be represented in electromagnetic equations by a single real number, the permittivity, and in this special case the commonly-used term “dielectric constant” is in proper place. But in the real world, material response of course is much more interesting. Natural materials are more complicated, and in engineering applications, composites are designed in a manner which result in material response functions that surpass those of the constituent materials they are made of. The directions of going into more general responses are many: anisotropy, dissipation, gyrotropy, chirality, non-reciprocity, bi-anisotropy, non-linearity, coupling with non-electromagnetic excitations and responses, etc.

In this presentation I will focus on media with magnetoelectric coupling. In other words, the set of constitutive parameters of the medium has to extend beyond dielectric permittivity and magnetic permeability. In the domain of bi-isotropic magnetoelectric media, the classical way to parametrize the response is to add the chirality (Pasteur) and non-reciprocity (Tellegen) constituents to complement the permittivity and permeability functions. The talk will cover the ways of classifying such media. However, also an alternative taxonomy of bi-isotropic media will be presented which is rather unconventional. The new approach builds up logically from extreme materials that form natural boundary conditions, in particular PEC, PMC, and PEMC (perfect electromagnetic conductor [Lindell and Sihvola, Journal of Electromagnetic Waves and Applications, Vol. 19, No. 7, pp. 861-869, 2005]). From there, through concepts such as Gibbsian isotropic medium and simple-skewon medium, we arrive at the medium that can be characterized by the property of unimodularity.

Profile

Ari Sihvola was born in 1957, in Valkeala (Finland). He received the degrees of Diploma Engineer in 1981, Licentiate of Technology in 1984, and Doctor of Technology in 1987, all in Electrical Engineering, from the Helsinki University of Technology (TKK), Finland. Besides working for TKK and the Academy of Finland, he was visiting engineer in the Research Laboratory of Electronics of the Massachusetts Institute of Technology, Cambridge, in 1985–1986, and in 1990–1991, he worked as a visiting scientist at the Pennsylvania State University, State College. In 1996, he was visiting scientist at the Lund University, Sweden, and for the academic year 2000–2001 he was visiting professor at the Electromagnetics and Acoustics Laboratory of the Swiss Federal Institute of Technology, Lausanne. In the Summer of 2008, he was visiting professor at the University of Paris XI, France, and in the Summer 2015 in University of Rome La Sapienza. Ari Sihvola is professor of electromagnetics in Aalto University School of Electrical Engineering (Aalto University was created in 2010 as a merger of three universities: Helsinki University of Technology, Helsinki School of Economics, and the University of Art and Design). His scientific interests range from electromagnetic theory, complex media, materials modeling, remote sensing, and radar applications, into engineering education research and history engineering and technology. Ari Sihvola is Chairman of the Finnish National Committee of URSI (International Union of Radio Science), Former Chairman of the Commission B (Fields and Waves) of the international URSI, and presently Vice President of URSI. He is Fellow of IEEE, URSI, and the Electromagnetics Academy.