Modelling and microwave properties of artificial materials with negative parameters

S.A. Tretyakov[1], I.S. Nefedov[1], S.I. Maslovski[1]
C.R. Simovski[1], and B. Sauviac[2]

[1]Radio Laboratory, Helsinki University of Technology
[2]DIOM Laboratory (Devices and Instrumentation for Optoelectronics and Microwaves), ISTASE,
Université Jean Monnet, Saint Etienne, France

In this review presentation we will present analytical models for basic elements used in the design of composites with negative parameters *(Veselago media)*. In the known experimental realization, arrays of parallel thin conducting wires are used to create effective negative permittivity, and arrays of double split-ring resonators are used to provide required magnetic response. Here we will explain the physics of these composite media and present simple and clear analytical models for estimation of the design parameters.

Furthermore, we will consider simple electromagnetic systems which include Veselago materials, especially waveguides and periodical media. Unique properties of eigenwaves in waveguides with negative slabs will be discussed. Possible applications will be mentioned.

We have considered the eigenmodes in a layered waveguide containing a layer of a Veselago medium, which has negative and real material parameters. We have found important differences between the eigenmode spectra. Both TE and TM modes can change the dispersion sign. This is possible because the energy transport directions are opposite in the two material layers, so there exists a spectral point, where the power flows in the two layers compensate each other. Under certain relations between the permeabilities and thicknesses of the layers there exists a non-dispersive TE mode without a low-frequency cutoff. Its slow-wave factor is constant and does not depend on the layer thicknesses. Furthermore, there exist both TE and TM super-slow waves, whose slow-wave factor is not restricted by the values of the permittivities and permeabilities of the layers. The fields of these waves decay exponentially in both layers from their interface in case of large propagation constants.

We have also considered new possibilities which can bring novel metamaterials with negative parameters when included in one-dimensional PBG structures. The main conclusion is that these materials offer a possibility to design PBG structures with extremely wide stop bands. The theoretical study of reflection and transmission in finite-period structure shows, for specific relations between the layer parameters, that the structure acts as a nearly omnidirectional reflector. The formation of extermely wide stop bands has been analysed by calculation of transmission through stacks with increasing number of layers.