APPLICATION OF DOUBLE NEGATIVE MATERIALS TO MODIFY THE PERFORMANCE OF ELECTRICALLY SMALL ANTENNAS

Richard W. Ziolkowski and Allison D. Kipple*

Department of Electrical and Computer Engineering
The University of Arizona
1230 E. Speedway Blvd.
Tucson, AZ 85721-0104

Tel: (520) 621-6173
Fax: (520) 621-8076
E-mails: ziolkowski@ece.arizona.edu, kipplea@ece.arizona.edu

In the past few years, there has been a renewed interest in using structures to develop artificial materials that mimic known material responses or that qualitatively have new response functions that do not occur in nature. The effective response functions of these "metamaterials" are often generated by artificially fabricated, extrinsic, low dimensional inhomogeneities that are electrically small and are loaded into a substrate in a periodic fashion. A number of electromagnetic structures that exhibit both effective negative permittivity and permeability properties have been designed. Experiments on these so-called double negative (DNG) metamaterials have been performed and have confirmed their expected properties. We have begun a study of how these DNG metamaterials may impact the performance of various antenna systems.

The effect of surrounding an electrically small dipole antenna with a shell of double negative (DNG) material ($\varepsilon_r < 0$ and $\mu_r < 0$) has been investigated both analytically and numerically. The results of these investigations will be reported. The problem of an infinitesimal electric dipole embedded in a homogeneous DNG medium will be treated; its analytical solution shows that this electrically small antenna acts inductively rather than capacitively as it would in free space. We will then show that a properly designed dipole-DNG shell combination increases the real power radiated by more than an order of magnitude over the corresponding free space case. The reactance of the antenna will be shown to have a corresponding decrease. Analysis of the reactive power within this dipole-DNG shell system indicates that the DNG shell acts as a natural matching network for the dipole. An equivalent circuit model that confirms this explanation will be introduced and discussed. The results obtained from several parameter studies of the dipole-DNG shell system will be used to illustrate its performance. The difficult problem of interpreting the energy stored in the dipole-DNG shell system and, hence, of calculating the radiation Q when the DNG medium is frequency independent will be discussed from several points of view.