

THREE-DIMENSIONAL NEGATIVE-REFRACTIVE-INDEX
META-MATERIALS COMPOSED OF SPHERICAL DIELECTRIC
RESONATORS

Tetsuya Ueda, Tatsuo Itoh
Dept. of Electrical Engineering, UCLA

Propagation characteristics have been numerically investigated in the three-dimensional lattice structures which are composed of dielectric spheres in a host dielectric medium in an attempt to obtain the negative-refractive index near the resonant frequency of the spheres. For simplicity, we have assumed that they have the periodicity in the calculation but it is not essential for the operation. The mechanisms to be considered here are classified into two schemes; the first is the one-sphere scheme that is based on the spatial coupling between neighboring homogeneous dielectric resonators, and the second is the two-sphere scheme that is made of a combination of heterogeneous spheres with spherical TE and TM resonant modes. The former is the extension to the three-dimensional structure of the concept that is well-known for designing the microwave bandpass filters using dielectric resonators [1]. Here, the magnetic coupling between the spheres with TE resonant mode can give rise to the left handed wave transmission along a series of the dielectric resonators. On the other hand, for the two-sphere scheme, the sphere with a TE dielectric resonant mode and the one with a TM mode behave like a split ring resonator and thin wire, respectively, so that the negative effective permeability and permittivity are realized simultaneously [2].

For the one-sphere scheme, we have investigated various types of lattice structures such as simple cubic, body-centered cubic, and face-centered cubic lattices, and so forth. The left handed characteristics are confirmed in the dispersion diagrams for the face-centered cubic lattice in any propagation directions near the spherical TE resonant frequencies. The behavior of the EM wave propagation is mainly governed by the resonant conditions of spheres, but not by Bragg scattering in the periodic structure that is used for designing band gaps in photonic crystals [3]. It is found that there are still some problems of anisotropy, polarization dependence of the EM wave, and undesired secondary scattering modes that show forward wave characteristics. In addition, we have also investigated the cases where additional spheres are doped in the unit cell of the lattice to attempt to improve the dependence of propagation direction and polarization.

For the two-sphere scheme, the dispersion diagrams for the periodic structure and the scattering parameters for finite unit cells are obtained that verify the left handed transmission characteristics when a plane wave is assumed to be normally incident to a specific direction.

[1] Y. Konishi, Microwave Integrated Circuits, Dekker, 1991.

[2] C. L. Holloway et al., IEEE Trans. Antennas Propagat., 51, 2596, 2003.

[3] M. Notomi, Phys. Rev. B, 62, 10696, 2000.

Abstract Submission Form
2006 National Radio Science Meeting

Abstract: ueda31178

Date Received: September 16, 2005

1. (a)
Tetsuya Ueda
Dept. of Electrical Engineering,
405 Hilgard Ave.
66-127B Engineering IV Bldg.
Los Angeles, CA
90095 USA
ueda@dj.kit.ac.jp
(b) 310-206-0557
(c) 310-206-4819
2. B - Fields and Waves
3. (a) S-B1
4. I - Invited Paper, Program chair:
J. L. Volakis
5. This paper is invited to be
presented in the Special Session
on S-B1 "Electromagnetic
Applications of Metamaterials".