SIMULATION AND ANALYSIS OF NON-PERIODIC AND RANDOM METAMATERIAL STRUCTURES

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The concept of using negative refractive media for a perfect lens was theorized by Veselago in 1968 (Sov. Phys. Usp., 10, 509–514). Recent developments in metamaterials (Shelby *et al.*, Science 292, 77, 2001) allowed researchers to physically demonstrate that artificial composite media can be engineered to exhibit exotic properties, including negative refractive index, by exploiting features in arrays of sub-wavelength unit cells. These unconventional electromagnetic properties are realized through the couplings of the microscopic unit cells, which govern the macroscopic properties of the structure. Our study focuses on electromagnetic propagation in media in which the effective relative permittivity and permeability exhibit negative values, resulting in negative index of refraction over a given frequency range. These composite structures are engineered to act as a medium supporting electromagnetic wave propagation in which the direction of phase velocity is opposite to the direction of energy flow (Depine and Lakhtakia, Microw. Opt. Technol. Lett., 41, 315–316, 2004). Generally, metamaterial structures are comprised of resonant inserts, such as split ring resonators (SRRs), that are periodically arranged (Singh et al., J. Opt., 12, 015101, 2010). However, these structures have been limited by their narrow operational bandwidth, high loss, and isotropic limitations (Caloz, Materials Today, 12(3), 12-20, 2009).

While most studies have focused on perfecting the microscopic unit cell in periodic structures, our study seeks to exploit greater bandwidth and greater isotropic properties through assembling non-periodic and randomized metamaterial structures (Fig. 1). This emphasis on greater bandwidth and isotropic response aims at making metamaterials more suitable for practical engineering applications. With antenna and communication related applications in mind, our study focuses on operational frequencies in the X, Ku, and Ka bands. We also seek to gain a greater understanding of the effects of disorder and non-periodicity on conventional metamaterial structures. In this analysis, we develop algorithms to assemble large customizable structures comprising of unit cells that are arranged in non-periodic or random patterns in both position. Our structures utilize the SRR and capacitively coupled loop with probe (CCL-P) cells (Fig. 2) to perform parametric analyses using full-wave simulation tools. The effective properties were determined by a standard retrieval approach (Chen *et al.*, Phys. Rev. E, 70, 016608, 2004) using a computer code to characterize a finite length of metamaterial structure from its transmission and reflections coefficients. Future plans are to extend our work to measured data to validate results obtained using simulations.

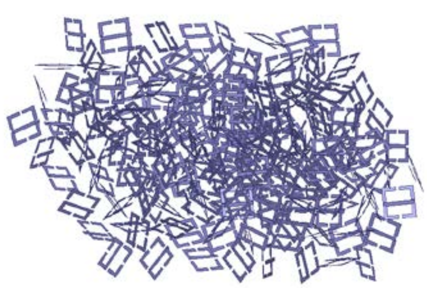

Figure 1. Random metamaterial structure

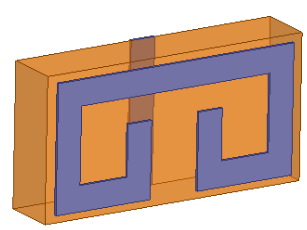

Figure 2. Unit cell with CCL-P