On the Possibility of Constructing Negative-Refraction Metamaterials with Closely-Spaced Bilayered Frequency Selective Surfaces

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Metamaterials with double-negative (DNG) properties, which exhibit negative refraction, have been the subject of interest in recent years. The idea dates back to 1967 when Veselago theoretically analyzed electromagnetic plane wave propagation in such media. The first experimental verification of negative refraction in such media at microwave frequencies was achieved by Smith, Schultz and coworkers (A. Shelby, D. R. Smith, and S. Schultz, "Experimental verification of a negative index of refraction," Science 292, pp. 77-79, April 2001.). Most of the metamaterials considered so far have been 3-D structures consisting of coupled resonant unit cells. However, having planar inclusions for obtaining 3-D bulk media has certain advantages. Here, we address the idea for synthesis of negative-refraction metamaterials using planar closely-spaced bilayered frequency selective surfaces (FSS). This design procedure is inspired and stems from the well known configuration for negative refractive index transmission lines, where the negative refractive index is obtained by embedding shunt inductors and series capacitors in an ordinary transmission line (see e.g., G. V. Eleftheriades and K. G. Balmain (eds.), *Negative-Refraction Metamaterials: Fundamental Principles and Applications*, IEEE Press, Wiley-Interscience, 2005; and C. Caloz and T. Itoh, *Electromagnetic Metamaterials: Transmission-Line Theory and Microwave Applications*, Wiley, 2005). By employing an equivalence existing between Frequency Selective Surfaces (FSS) and shunt loadings in transmission lines, we therefore substitute the shunt inductances with properly designed FSS. To obtain an effect similar to that of the series capacitance, we resort to the mutual coupling between the two closely spaced inductive FSSs through their evanescent modes. The two coupled FSSs can be therefore interpreted as the building component (elementary block) of the artificial medium. We therefore obtain a structure with an arguably more simplified design than the well known combination of Split Ring Resonators (SRRs) and arrays of wires. Furthermore, due to the compact profile (i.e., compact in the direction of propagation) of the elementary bi-layered resonating inclusions, it is possible to model such bi-layered structure as a single lumped element in a transmission line model for the resulting bulk negative-refraction medium. In Fig. 1, we show the dispersion diagram for the bi-layer structure proposed as such materials. The continuous line represents the real part of the wave vector, the dashed line shows the imaginary part of the wave vector. In this talk, we will present our theoretical results and numerical simulations.