Modeling Microwave Chiral Material Based on Crank Resonators Arrays Using COMSOL Multiphysics

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Abstract

Electromagnetic metamaterials are characterized for presenting exotic and unusual properties hardly to be found in nature with many potential applications. They are usually built by distributing small resonant structures in periodical lattices. If the structure has chiral symmetry, the medium is called chiral metamaterial. A chiral medium constituted by a two-dimensional array of four same handedness three-dimensional metallic cranks patterned on a FR4 dielectric board (Figure 1) has been reported [1,2] by authors to present large electromagnetic activity, circular dichroism, and negative refractive index in the X-band frequency range. By using our experimental free wave technique [3] for characterization of non-chiral materials adapted to chiral ones [4], the transmission and reflection coefficients were measured and effective values for the refractive index, permittivity and permeability and also for the chirality parameter were calculated. Here the electrodynamics behavior of chiral structures is modeled by making use of COMSOL's RF Module and successfully compared to the experiment. Three-dimension time harmonic propagation option and parametric frequency domain for the solver were chosen in order to model the normal incidence of TEM plane. The sample is formed by a two-dimension distribution of unit cells and an infinite slab is simulated by applying Floquet boundary periodic conditions at both pair of sidewalls of the computational domain. Geometry, subdomains and boundary conditions are shown in Figure 2. Figure 3 shows arrows volume distribution of the E-field along the axis of the sample at the resonance frequency. The linearly polarized incident wave is distorted after transmission and transformed into left-handed elliptically polarized. In order to illustrate the observations, alternatively, the phenomenon is also studied by simulating right-handed circularly polarized (RCP) and left-handed circularly polarized (LCP) waves, where a remarkable difference in the transmitted power for each mode was observed. At the resonance, the transmitted wave is perpendicular to the incident one, with a non zero ellipticity, as was deduced from the values of the transmitted electric field components provided by a "cut point probe" placed at nearly the end of the computational domain (Figure 3). Far from the resonance, the transmitted wave remains linearly polarized after transmission but rotates a certain angle θ. Finally, the simulation shows a strong enhancement of the electric field confined inside the sample, which it was also reported for non-chiral plasmonic nanostructures at optical frequencies [5,6]. Two models have been implemented to extract reflection and transmission coefficients for the electromagnetic characterization of the sample: one with the whole computational domain set to air as a reference and one with the proper sample. More details on all performed simulations and experimental results for comparison will be given later in the paper.

Reference

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Figures used in the abstract

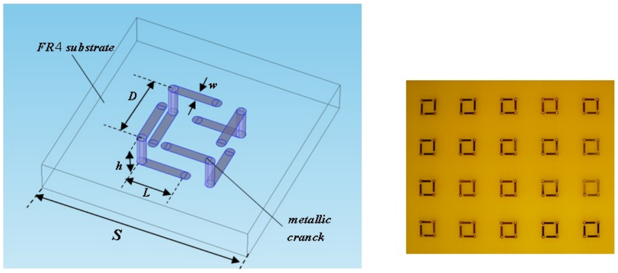

Figure 1: The four cranks resonator (left) and a picture of the experimental sample (right). The geometric parameters are given by S=13.5 mm, D=4.5 mm, L=2.9 mm, h=2.4 mm, and w=0.6 mm. The metal structures are built with copper 30 μm thick.

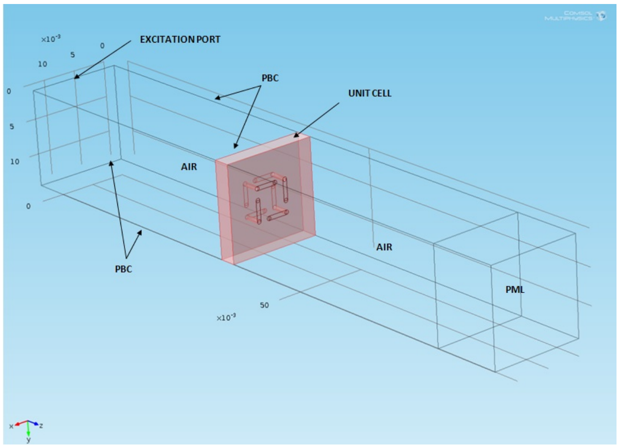

Figure 2: The COMSOL model. PBC: Periodic Boundary Condition. PML: Perfectly matched layer.

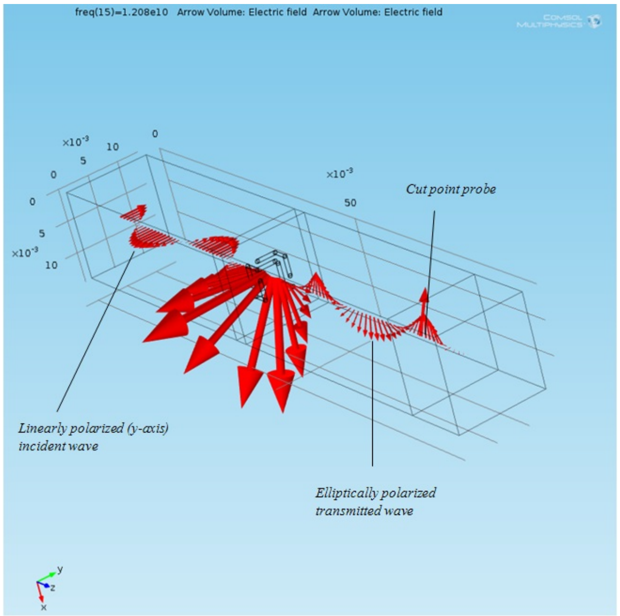

Figure 3: The simulated wave traveling along the axis of the sample (z-axis) at the resonance frequency of 12.08 GHz. Arrows represent the electric field.