METAMATERIALS LENS GAIN ENHANCEMENT AND POWER APPLICATIONS

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ABSTRACT

Metamaterials are man-made structures, usually designed by placing electromagnetic resonators, such as split ring resonators (SRRs), in a periodic array. Metamaterials also exhibit lensing properties, and, when placed next to antennas, are known to improve the gain of the antenna. For high power antennas, the placement of metamaterials with embedded metallic resonators, however, may lead to excessive heating effects and alternative solutions need to be developed.

In this research work, a metamaterial lens constructed from cubic high dielectric resonators (CHDR) embedded in a low dielectric slab was placed in front of a circular patch and a fractal patch antenna respectively, in order to characterize the effects on the antenna parameters, specifically the gain, as a result of the antenna and lens coupling. The CHDR based metamaterial lens was designed to have a negative refractive index at 10.4 GHz, which was determined through the extraction of the constitutive parameters from the s-parameters. The optimum distance of lens placement was then determined in order to maximize the antenna gain for both cases. Heating effects at high power were also demonstrated through a comparison of the CHDR based metamaterial with a SRR based structure.

A methodology for optimizing the metamaterial lens design is also presented, which is based on the Drude dispersion model applied to a homogeneous metamaterial. The model determines the optimum placement and geometry of the metamaterial lens in order to maximize

antenna gain for a source radiating spherical electromagnetic waves. Finally, in order to demonstrate the advantages of a CHDR based metamaterial lens over a metallic split-ring resonator (SRR) based lens, for high power applications, the structures were subjected to electromagnetic radiation and their thermal properties were studied. All simulations were performed using CST microwave studio (a commercially available electromagnetic software suite).

The optimum placement of the metamaterial slab in front of the circular patch antenna and the fractal patch antenna for maximum gain enhancement was determined to be 14 mm, and 18 mm respectively. The gain improvement for the circular patch antenna was from 7.380 dB to 11.75 dB, and the gain improvement for the fractal patch antenna was from 8.980 dB to 12.28 dB.

In a separate but related study, a metamaterial lens was designed and analyzed through the Drude formulation and a concept to improve the directivity of an antenna through a special metamaterial lens design was presented. The main purpose of using the Drude model is to allow a user of CST Microwave Studio to indirectly set the values of the permittivity and permeability (i.e. the refractive index and absorption) at a given frequency, which are then used by the program to calculate the electromagnetic fields in time and space.

A homogenous metamaterial lens was analyzed through the Drude formulation, it was shown that if the source is radiating a spherical wave, the geometry of the metamaterial lens should be flat on the side in which the wave is entering and parabolic on the side of the lens that the wave is exiting. In addition, the optimum distance away from the source was determined to be equal to the thickness of the rectangular portion of the metamaterial lens.

Finally, in the lens heating study using SRR and CHDR resonators, it was found that for a power factor of 65W and a background temperature of 300 K, an SRR based lens has a maximum temperature of 1676.0 K, while the CHDR lens has a maximum temperature of 300.16 K, demonstrating that the CHDR based lens is the preferred metamaterial type for high power applications. For compact high power applications requiring high gain antennas without significant heating problems, a coupling of CHDR based metamaterials and a fractal or patch antenna is a preferable and a viable candidate.