Simulation study of Split Ring Resonators for Electromagnetic Cloaking in X-band

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Introduction: In recent years cloaking techniques have been emerged as a promising counter measure to make target invisible. We report on preparation and evaluation of constitutive parameters for Ferro-Nano-Carbon (FNC) split ring resonators (SRRs) behaving as a bi-anisotropic left-handed material (LHM) that generates an electromagnetic cloak in sub-X-band region (8.5-10GHz). In this, the paths of electromagnetic waves are controlled within a material by introducing a specific spatial variations in constitutive parameters.

Computational Methods: The simulations were performed using RF module of COMSOL multi-physics and harmonic propagation analysis was used. The geometry has been shown in figure 1 and then parameters associated with FNC are added. Then boundary conditions were applied using Maxwell's theory across the waveguide.

$$\frac{1}{\mu_r}\nabla^2\bar{E} = \bar{\nabla}(\bar{\nabla}.\bar{E}) - k^2\left(\epsilon_r - \frac{j_T}{\omega\sigma}\right)\bar{E},$$

$$\frac{dS_r}{d\Omega} = \frac{\overline{E_{i,r}}.\overline{E_1} - |\bar{E}_1|^2}{|\bar{E}_1|^2} + \frac{\bar{E}_{i,r}.\bar{E}_2}{|\bar{E}_2|}.$$

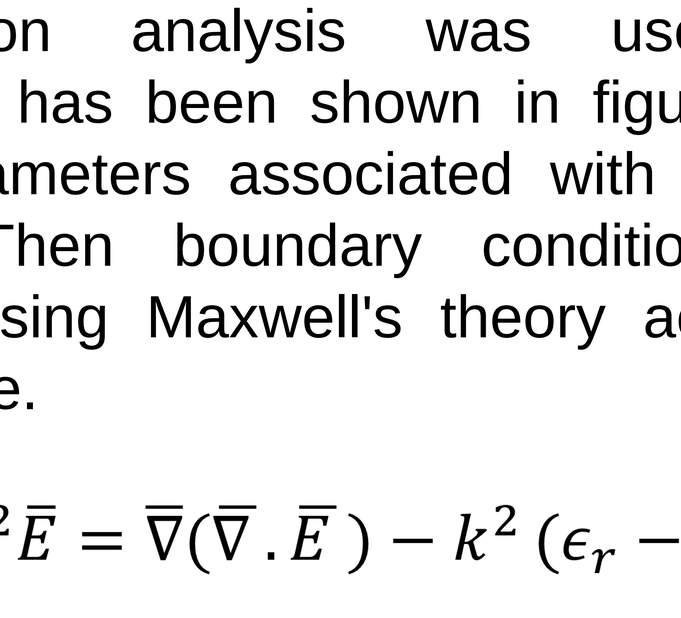

Figure 1.Configurations of principle axis and geometry of FNC SRR unit cell

Results: The electric field distribution, in x-y plane, is simulated for a typical FNC SRRs unit cell, that squeezing and localization of incident field around the cell, as shown in figure 2.

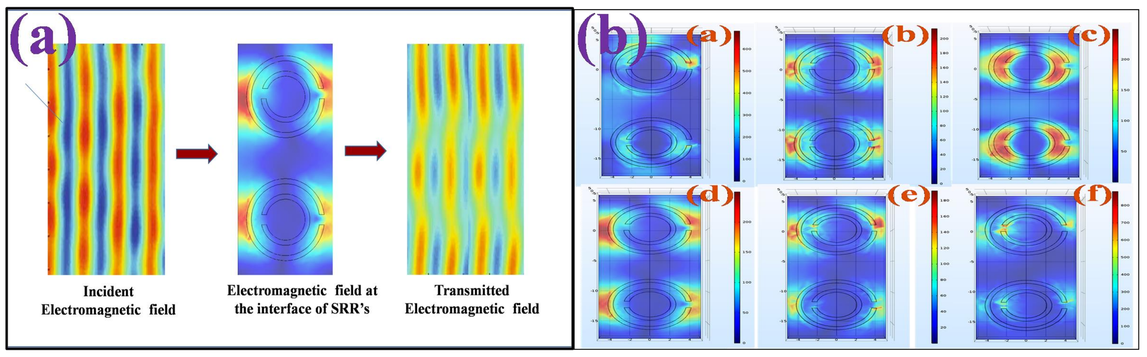

Figure 2: (a) Demonstration of Electromagnetic cloak using SRR's , (b) Response of SRR's at 8 to 12 GHz

The constitutive s-parameters, scattering losses are simulated & relative permittivity ,permeability is calculated using Ross-Nicolson formulation as shown in figure 3.

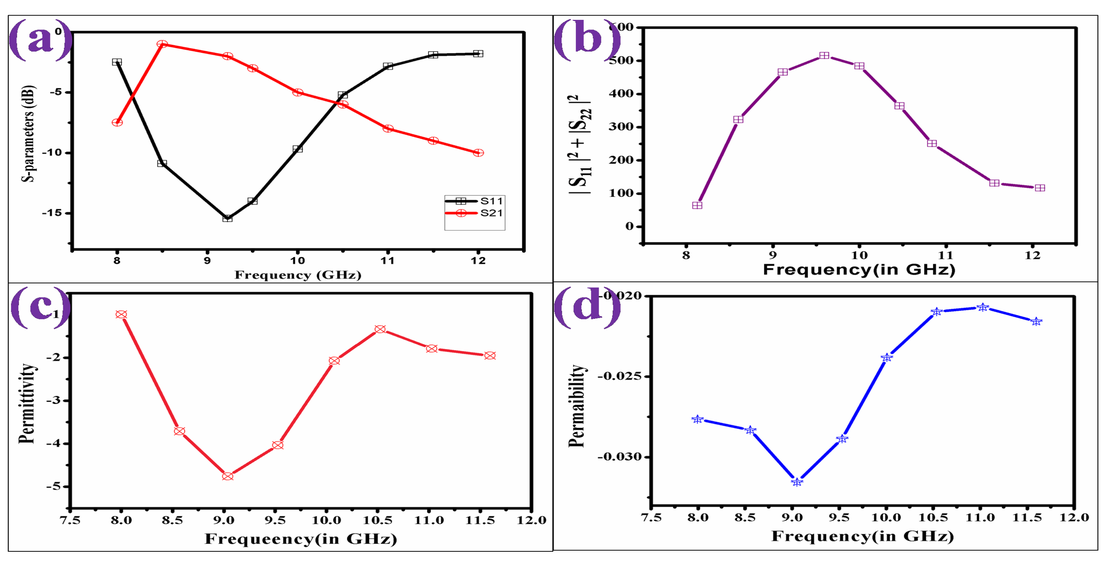

Figure 3: (a) S parameters (b) $|S_{11}|^2 + |S_{22}|^2$, (c) Permittivity (d) Permeability v/s Frequency (in GHz)

Conclusions: The simulated FNC SRR's acts as a bi-anisotropic left-handed meta-material (LHM) generates a cloak-like response in sub microwave X-band regime (8.5-12 GHz). The effective constitutive parameters obtained using COMSOL multi-physics and calculated using Ross-Nicolson formulation validates the same.

References:

1. U.C. Hasar, Boundary Effects on the Determination of Electromagnetic Properties of Bianisotropic Metamaterials from Scattering Parameters, IEEE Trans. Antennas Propag. 64 (2016)
2. R. Jagtap, Ferro-nano-carbon Split Ring Resonators a Bianisotropic Metamaterial in X-band: **Constitutive Parameters Analysis,** *Materials Chemistry and Physics (2017)*