Comparative Study of Rectangular, Circular SRR and SRR Array Metamaterials

Prahlad Kumar Rahul[1] Garima Tiwari[2]
[2]Assistant Professor
[1,2]Department of Electronics & Telecommunications Engineering
[1,2]Jabalpur Engineering College, Jabalpur, Madhya Pradesh India

Abstract— In this paper, we discuss the comparative study of rectangular SRR, circular SRR and SRR Array for multi-band metamaterial applications. The value of each resonance frequency can be adapted by changing design parameters such as metal widths and gap distances for each ring as well as ring-to-ring separations. The suggested SRR and SRR Array structure is simulated using CST Microwave Studio. The material parameters of the resulting rectangular, circular SRR and SRR Array type metamaterials are estimated by a Nicolson- Ross-Weir (NRW) retrieval algorithm. Since a metamaterial is a manmade material which is having negative permittivity and permeability, it can be regarded as an artificial medium with negative index of refraction. Negative refraction was determined by a Snell's Law. The split ring resonator acts as an artificial magnetic dipole. The gap between inner and outer ring acts as a capacitor while the rings themselves act as an inductor, resulting in an LC resonant circuit and SRR Array gives the fine resonance frequency.

Key words: Circular SRR, Nicolson- Ross-Weir, Rectangular SRR, SRR Array

I. INTRODUCTION

Metamaterials are specially designed for periodic structures which can show unique properties such as having negative values of permeability and/or negative values of permittivity over finite frequency bands. Theoretical aspects and many important applications of metamaterials in microwave, tera hertz and optic regions have been investigated in detail in a vast amount of publications for the last decade [1-6].

Split ring resonator (SRR) type magnetic resonators are among the most popular metamaterial structures having negative permeability over narrow frequency bands. Although various forms of SRR structures have been found useful in narrowband applications, research on metamaterials has also been focused recently on the design of multiband and/or frequency tunable metamaterials. In this study, a SRR unit cell and SRR Array design is introduced for multi-band metamaterial applications. For a given substrate FR-4 epoxy material, design parameters are the side lengths and widths of metal strips, gap distances for each ring and the separation distances between the rings. As a proof of concept, several multi-band SRR arrays are designed and simulated in this paper for rectangular SRR, circular SRR and SRR Array by using CST Microwave Studio. Complex transmission and refection characteristics (i.e. the complex S-parameters S21 and S11) of the proposed SRR arrays are obtained by CST, and then they are used to extract the effective medium parameters μ and ϵ of the designed metamaterials to verify the nature of resulting resonances. The basic retrieval procedure given in [7] is used for parameters estimation.

II. SIMULATION & ANALYSIS

This experimental setup is simulated in CST (computer simulation technology) modeling. Therefore, planner faces of waveguide port which are left and right to rectangular and circular SRR are modeled to be perfect electric (PE) boundaries in Y-axis as they coincide with the metallic walls of the waveguide. The perpendicular faces to the X-axis are typical to be the input/output ports. By analysis the rectangular SRR, circular SRR and SRR Array shape metamaterial shown in Fig. 1, Fig. 2, Fig. 3, the simulated S11 and S21 for different structures. Fig. 4(a), Fig. 5(a), Fig. 6(a). Fig. 4(b-c), Fig. 5(b-c) and Fig. 6(b-c) shows retrieved the dielectric permittivity and magnetic permeability respectively. We can see that the given circular SRR resonates near 2 GHz, but SRR Array shape metamaterial structure gives resonance near 1.9 GHz as shown in Fig. 5(b) and Fig. 6(b). We can observe the effect of SRR Array shows resonance frequency is decrease (resonance near 1.9 GHz) for the SRR Array structure.

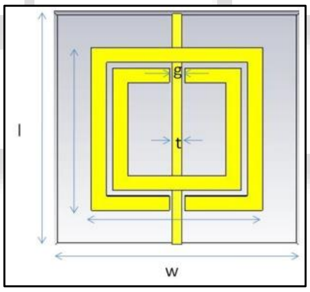

Fig. 1: Rectangular SRR unit cell structure

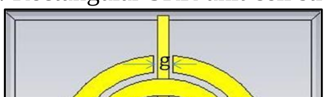

Fig. 2: Circular SRR unit cell structure

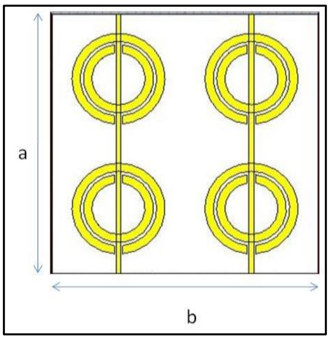

Fig. 3: Circular SRR Array Metamaterial

Symbols	Dimensions(mm)	Description
a	32	Length of SRR Array
b	32	Width of SRR Array
l	16	Length of SRR unit cell
w	16	Width of SRR unit cell
g	1	Cut
t	0.6	Thickness of wire

Table 1 Dimensions of SRR Metamaterial

III. RESULTS

Complex *S*-parameters *S*21 and *S*11 computed for the rectangular SRR, circular SRR and SRR Array topologies revealed magnetic resonance frequencies at 1.5 GHz, 2 GHz, and 1.9 GHz, respectively. The magnitude plots for these transmission and reflection spectra of rectangular SRR and circular SRR shown in Figure 4(a) and 5(a). Increase in the side length (overall length) of the metal ring results in an increase of the self-inductance leading to a decrease in the LC resonance frequency of the resonator [8], as expected. Next, the magnitude spectra of the *S*21 and *S*11 parameters are computed for SRR Array topology of Figure 3. Resulting plots are given in Figure 6(a), the plots for the real parts of the retrieved parameters, effective permittivity and effective permeability. As seen in Figure 6(b-c), the rectangular SRR array structure has three distinct resonances over the range from 1 GHz to 10 GHz. Two of those frequencies at 1.5 GHz and 6 GHz are magnetic resonances and the last one at 8.2 GHz is an electric resonance .As shown in Figure 4(a-c), on the other hand, the circular SRR has three distinct resonances. Three of them (at 2 GHz, 6.5 GHz and 8.45 GHz) are magnetic resonances and the one at 8.45 GHz is an electric resonance. These results demonstrate that a desired number of magnetic resonances can be realized by selecting various types of SRR rings within the limits of geometrical constraints. It is also worth mentioning that resonance frequencies can also be adjusted by changing the design parameters *r1*, *r2* and *g*.

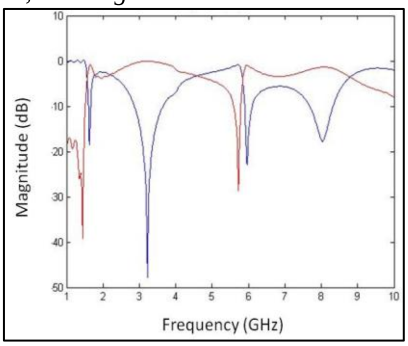

Fig. 4(a): S-Parameters of rectangular SRR Metamaterial

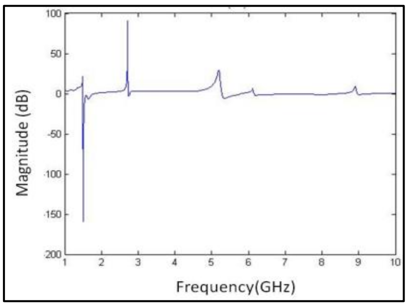

Fig. 4(b): Electrical Permeability of Rectangular SRR Metamaterial

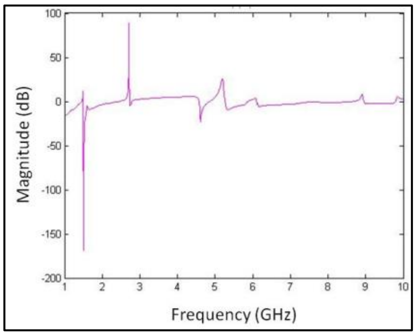

Fig. 4(c): Electrical Permittivity of Rectangular SRR Metamaterial

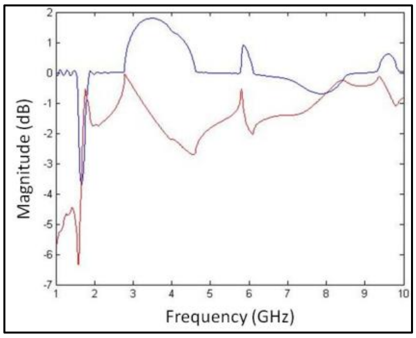

Fig. 4(d): Refractive index of Rectangular SRR Metamaterial

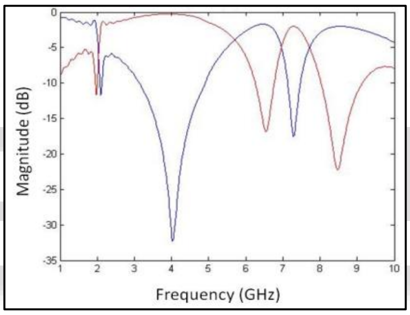

Fig. 5(a): S-Parameters of Circular SRR Metamaterial

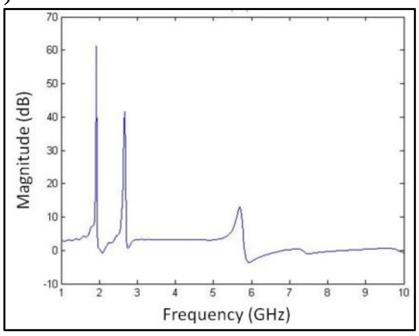

Fig. 5(b): Electrical Permeability of Circular SRR Metamaterial

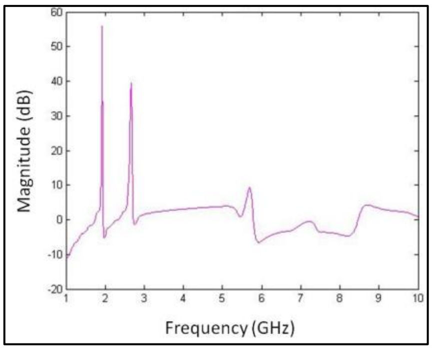

Fig. 5(c): Electrical Permittivity of Circular SRR Metamaterial

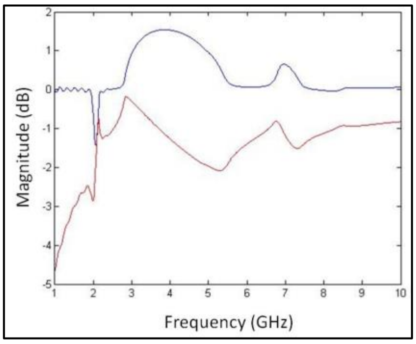

Fig. 5(d): Refractive Index of Circular SRR Metamaterial

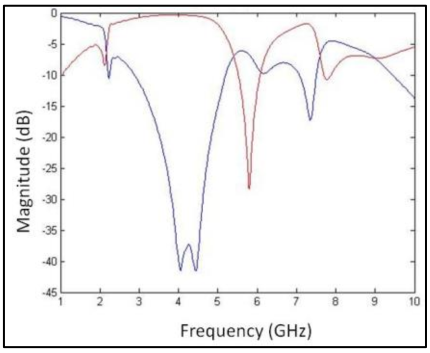

Fig. 6(a): S-Parameters of SRR Array Metamaterial

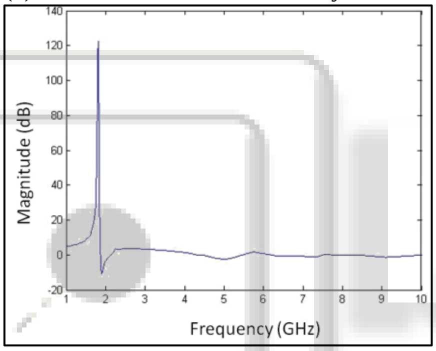

Fig. 6(b): Electrical Permeability of SRR Array Metamaterial

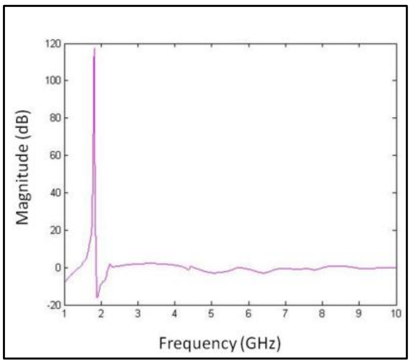

Fig. 6(c): Electrical Permittivity of SRR Array Material

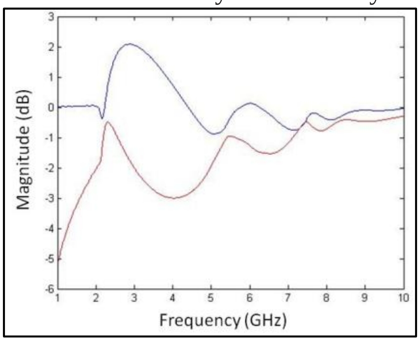

Fig. 6(d): Refractive Index of SRR Array Metamaterial

IV. CONCLUSION

We have simulated different structure of metamaterial which can give left handed effect. From the simulated results, we can conclude that rectangular SRR, circular SRR and SRR Array metamaterial structure resonates at higher frequency. When we use SRR Array metamaterial structure then simulation results shows that the resonating frequency is decrease but provided a sharp frequency ranges at which negative permittivity and permeability are obtained. So by this analysis we observe that the SRR Array structure reduces the resonating frequency, it will work more efficient as compare to other frequency which is useful in the designing of antenna.

REFERENCES

[1] Veselago, V. G., “The electrodynamics of substances with simultaneously negative values of □ and μ," Sov. Phys. Usp., Vol. 10, 509-514, 1968.

[2] Pendry, J. B., A. J. Holden, D. J. Robbins, and W. J. Stewart, Low-frequency plasmons in thin wire structures," J. Phys., Condens. Matter, Vol. 10, 4785-4809, 1998.

[3] Pendry, J. B., A. J. Holden, D. J. Robbins, and W. J. Stewart, \Magnetism from conductors and enhanced nonlinear phenomena," IEEE Trans. Microw. Theory Tech., Vol. 47, No. 11, 2075-2084, 1999.

[4] Smith, D. R, W. J. Padilla, D. C. Vier, S. C. Nemat-Nasser, and S. Schultz, Composite medium with simultaneously negative permeability and permittivity," Phys. Rev. Lett., Vol. 84, No. 18, 4184{4187, 2000.

[5] Ekmekci, E. and G. Turhan-Sayan, Comparative investigation of resonance characteristics and electrical size of the double-sided SRR, BC-SRR and conventional SRR type metamaterials for varying substrate parameters," Progress In Electromagnetic Research B, Vol. 12, 35-62, 2009.

[6] Soukoulis, C. M., T. Koschny, J. Zhou, M.Kafesaki, and E. N. Economou, \Magnetic response of split ring resonators at terahertz frequencies," Phys. Stat. Sol. B, Vol. 244, 1181-1187, 2007.

[7] Ghodgaonkar, D. K., V. V. Varadan, and V. K. Varadan, Free-space measurement of complex permittivity and complex permeability of magnetic materials at microwave frequencies," IEEE Trans. Instrum. Meas., Vol. 39, No. 2, 387-394, 1990.

[8] Kafesaki, M., T. Koschny, R. S. Penciu, T. F. Gundogdu, E. N. Economou, and C.M. Souk-oulis, Left-handed metamaterials: Detailed numerical studies of the transmission properties, J. Opt. A: Pure Appl. Opt., Vol. 7, 12-22, 2005.

