THE CIRCULAR SRR AND CSR LOADED WITH TRANSMISSION LINE FOR WIRELESS APPLICATIONS

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***Abstract** - This paper presents investigation of frequency switching of Circular SRR and CSR loaded microstrip line. We loaded the microstrip line with planar circular split ring resonator and CSR structure of a copper on Rogers RO3010 a substrate. The electric and magnetic interaction of Circular SRR and CSR with microstrip line is presented by simulating microstrip line loaded ring inside a waveguide with 'High Frequency Structure Simulator' software. In this paper, the reduction of magnetic resonance is observed at changing of the shape of ring from circular SRR to CSR loaded with microstrip line.*

Key words**: **Metamaterials (MTM), Split Ring Resonator (SRR), Spiral Circular Resonator (CSR), Microstrip line, Double Negative Metamaterials (DNG).

1. INTRODUCTION

Metamaterials are artificially materials, exhibiting exotic unnatural features, engineered by metallic inclusions in the host media like substrate. The shape, dimensions, alignment, arrangement of the inclusions and electromagnetic features of the host medium determine the nature of the interaction between the metamaterial and an electromagnetic field. These materials gain their effective properties from its structures rather than inheriting them directly from its constituents. The phase velocity and group velocity in these materials are anti-parallel to each other. Metamaterials created an indelible sign in microwave engineering applications like waveguides, antennas, filters, phase shifters, delay lines etc.

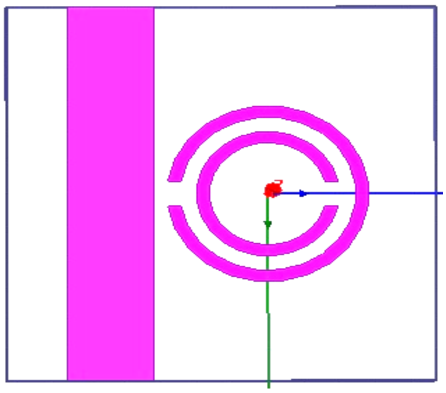
The novel idea of metamaterials was given by Victor Veselago in 1968 when he analyzed incident uniform plane-wave propagation in a media considering both permittivity and permeability to be negative [1]. He named these materials as Left Handed Metamaterials (LHM) or Double Negative Metamaterials (DNG). If only permeability (μ) is negative or permittivity (ε) is negative is termed as Mu Negative (MNG) and Epsilon (ENG) metamaterials respectively and termed as single negative (SNG) metamaterials. Pendry proposed SRR to achieve negative permeability [2] and thin wire to achieve negative permittivity [3] and a combined structure of SRR and thin wire to realize LHM [4]. Later then, Smith and his colleagues demonstrated metamaterials to show negative permittivity and permeability simultaneously and carried out microwave experiments to test its unusual properties in 2000. In 2001, Smith et al showed negative refraction experimentally, using a metamaterials with repeated unit cells of SRR and copper strips [5-7]. Marques et al investigated bianisotropic behaviour of the SRR unit cell structure in 2002. A modified version of SRR i.e. broadside coupled (BC-SRR) suggested in the same paper to avoid bianisotropy. A comparative analysis of the conventional (or edge-coupled) SRR and BC-SRR is shown with printed metallic rings of the BC-SRR on both sides of the dielectric substrate and aligned in such a way that their splits were displaced by 180 degrees [8]. Bilotti et al in 2007 suggested and analyzed SRR unit cells with multiple rings. Filiberto Bilotti et al proposed a model with multiple split ring resonator (MSRR) and spiral ring (SR) to increase the miniaturized rate and in the same structure when the number of turns and rings of SRs and MSRRs respectively, increases the saturation of the resonant frequency is occurred [9]. In 2010, Joshi et al proposed a micro strip patch antenna loaded with SRR and proved that loading the patch antenna with SRR can shift resonant frequency to lower frequency side [10]. In 2011, pattnaik et al also obtained that by changing the distance between patch antenna and SRR the resonant frequency shifts and decreases as the distance increases [11]. In 2012, Joshi et al worked on a rectangular slotted microstrip patch antenna with partially loaded metamaterial multiple-split ring resonator (MSRR) ground plane and shown that in unloaded condition, the resonant frequency of rectangular patch antenna higher but it decreases when loaded with MSRR [12]. In 2014, Radovan Bojanic et al presented an enhanced equivalent circuit approach for the magnetic/electric interaction of single split-ring resonators (SRRs) with printed lines and extract the different parameters of microstrip line with parallel and perpendicular gap to line [13].

In this paper, a microstrip line is loaded with Circular SRR and Circular Spiral Resonator (CSR) in the same plane. The loaded strip line is analyzed to compare the electromagnetic behavior of microstrip line with gap of resonators parallel and perpendicular to the microstrip line. This paper is planned in four sections. Section 1 gives a brief summary previous work done. Section 2 presents Circular SRR and CSR loaded microstrip line. Results have been presented and discussed in Section 3. Conclusion of the work done is presented in Section 4.

2. PROPOSED DESIGN OF MICROSTRIP LINE LOADED WITH SPIRAL RESONATOR

In the proposed model, a conventional microstrip line is loaded with planar Circular SRR and CSR. The circular shape SRR is coupled to microstrip line by placing it at distance's', in the same plane and gap is parallel to the microstrip line as depicted in Figure 1. Circular SRR coupled to microstrip line is in the same plane and gap is parallel to the microstrip line. This coupled line is modeled on Rogers RO3010 substrate of thickness (h) 1.27mm, dielectric permittivity εr=10.2 and tangent loss.0.035.

Fig. 3 shows the equivalent circuit of microstrip line coupled to CSR where Ls and Cs is inductance and capacitance of CSR respectively and LC is inductance and capacitance of microstrip line respectively.



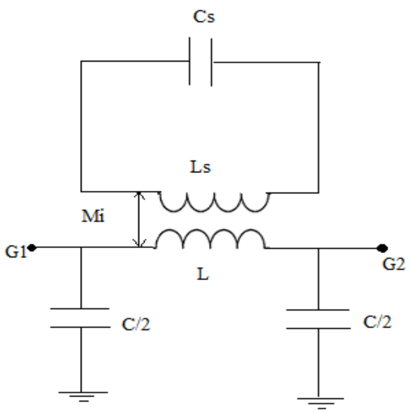


Fig.1 Equivalent circuit of the microstrip line loaded with Circular SRR

The G1 and G2 are two ports and Mi is mutual inductance. The capacitance Cs is obtained from the SRR resonance frequency as follows:

$$f_r = \frac{1}{2\pi\sqrt{LsCs}} \quad (1)$$

Where resonance frequency is also calculated as:

$$f_r = \frac{w_r}{2\pi} \quad (2)$$

The coupling coefficient M_i is then obtained as a function of f_{min} , the resonance frequency f_r , and the line parameters L and C as follows:

$$M_i^2 = \left(1 - \frac{w_r^2}{w_{min}^2}\right)(1 - a_1)$$

(3)

The term mutual inductance M_i is also varied by variation of the distance 'S' between the microstrip line and CSR. Where a_1 correspond to the circuit with one cell and $f_{min} = \frac{w_{min}}{2\pi}$. These coefficients are given by

$$a_1 = \left[\frac{L}{C} Y_0^2 + 2b\right] \quad (4)$$

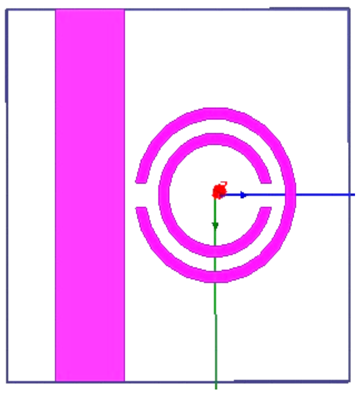
Where Y_0 is the characteristic admittance of the microstrip line and

$$b = \left(\frac{w_{min}}{w_0}\right) ; \; w_0^2 = \frac{8}{LC} \quad (5)$$

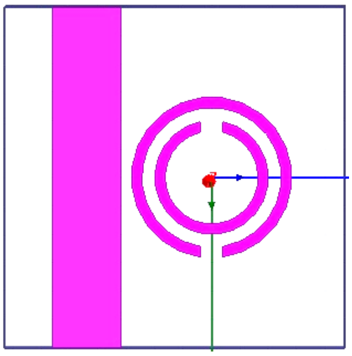
When microstrip line is loaded with Circular SRR and CSR, due to the magnetic coupling, the field gets induced in the Circular SRR and CSR, which excites it and makes it to exhibit metamaterials behavior. In loading condition, the resonant frequency of Circular SRR and CSR coupled microstrip line shift the frequency by change of the gap of Circular SRR and CSR. This is due to decrease of mutual inductance with changiing of gap parallel and perpendicular to the lone. Thus the proposed circuit can be used for design of filters.

2.1CIRCULAR SRR WITH GAP PARALLEL/ PERPENDICULAR TO THE LINE

We loaded microstrip line with Circular SRR in the same plane with gap parallel to the line as shown in Figure 2(a) and gap perpendicular to the line as presented in Figure 2(b).



3(a) SRR with gap parallel to the line .

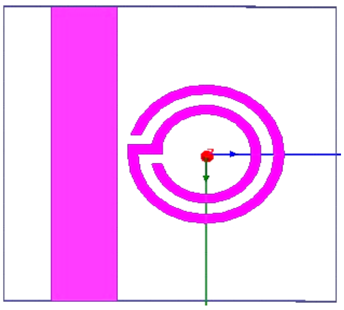


3(b) SRR with the gap perpendicular the line.

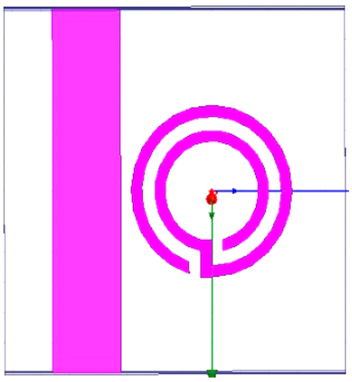
Figure 2 Layout of microstrip line loaded with Circular SRR .

2.2 CIRCULAR SPIRAL RESONATOR (CSR) WITH GAP PARALLEL/PERPENDICULAR TO THE LINE

We loaded microstrip line with CSR in the same plane with gap parallel to the line as shown in Figure 3(a) and gap perpendicular to the line as presented in Figure 3(b).



3(a) CSR with gap parallel to the line .



3(b) CSR with the gap perpendicular the line.

Figure 3 Layout of microstrip line loaded with CSR .

3.RESULTS & DISCUSSION

Circular SRR/CSR loaded microstrip line is numerically explored inside a waveguide with Ansoft software 'High Frequency Structure Simulator (HFSS)' to get the resonating frequency region. The perfect electric conductor (PEC) boundary conditions and the perfect magnetic conductor (PMC) boundary conditions are applied on the appropriate faces of the unit cell. The two wave ports 1 and 2 are assigned to the rest of the sides of unit cell so as to excite negative permeability characteristics.

The Magnitude and Phase of Circular SRR loaded microstrip line with the gap parallel to the line in Figure 4. The figure shows that the resonant frequency is 6.3GHz with acceptable return loss.

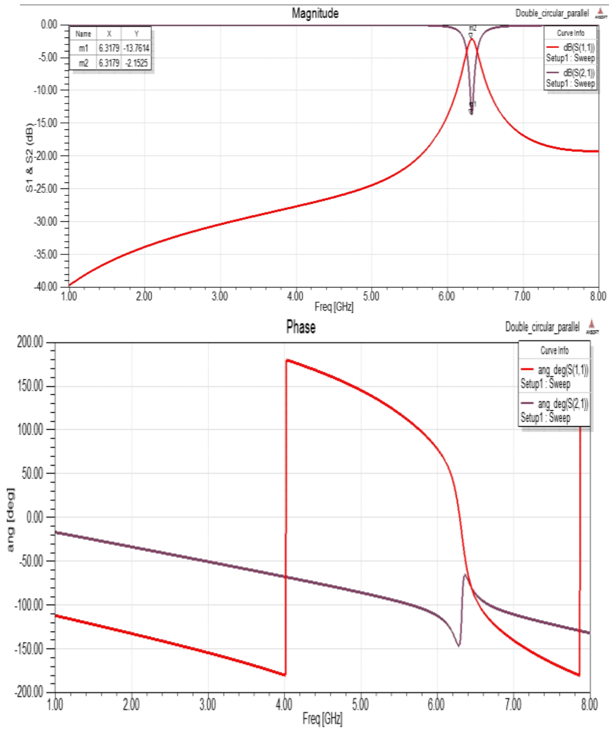
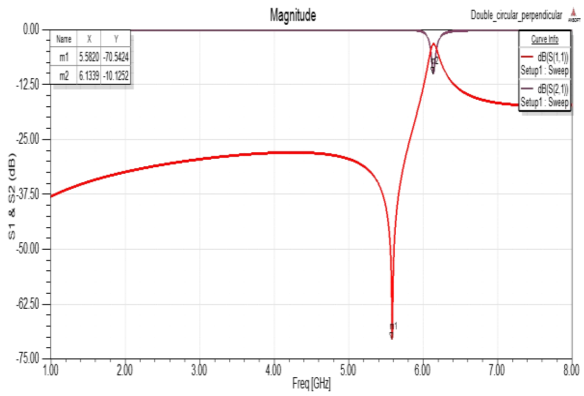


Figure 4 Magnitude and Phase of Circular SRR loaded microstrip line with the gap parallel to the line.

The Magnitude and Phase of Circular SRR loaded microstrip line with the gap perpendicular to the line in Figure 5. The figure shows that the resonant frequency is 5.8GHz and 6.1 GHz with acceptable return loss. 1



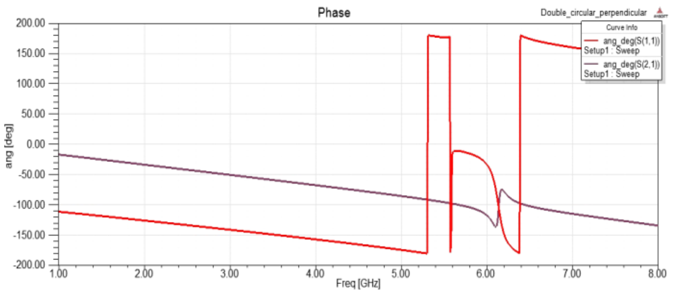


Figure 5 Magnitude and Phase of Circular SRR loaded microstrip line with the gap perpendicular to the line.

The Magnitude and Phase of CSR loaded microstrip line with the gap parallel to the line in Figure 6. The figure shows that the resonant frequency is 3GHz and 3.5GHz with acceptable return loss. The resonant frequency is too less as compared to the Circular SRR, that shows that the frequency is reduces as change the shape of the ring.

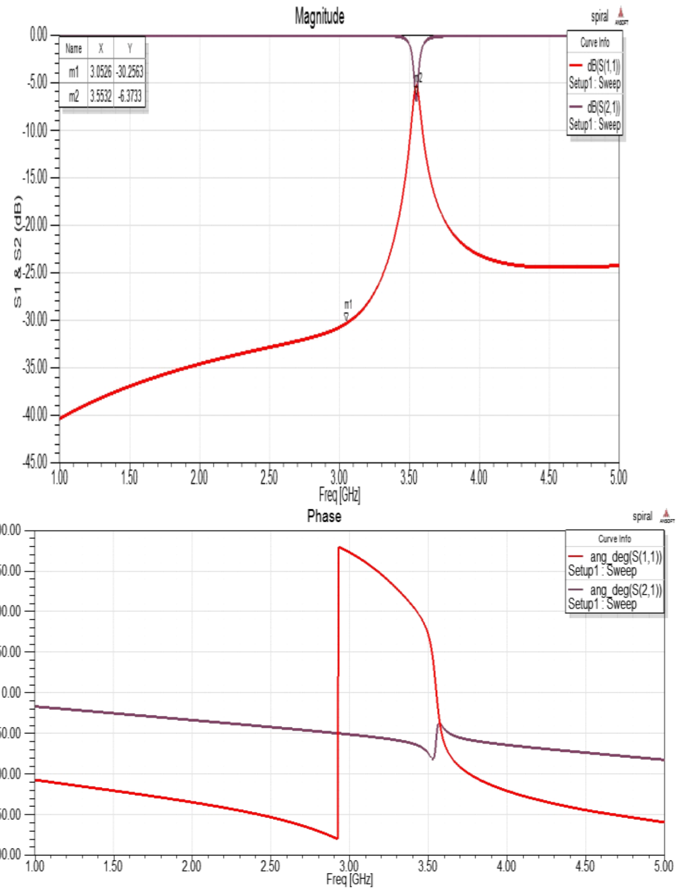


Figure 6 Magnitude and Phase of CSR loaded microstrip line with the gap parallel to the line.

The Magnitude and Phase of CSR loaded microstrip line with the gap parallel to the line in Figure 7. The figure shows that the resonant frequency is 3.1GHz and 3.4GHz with acceptable return loss

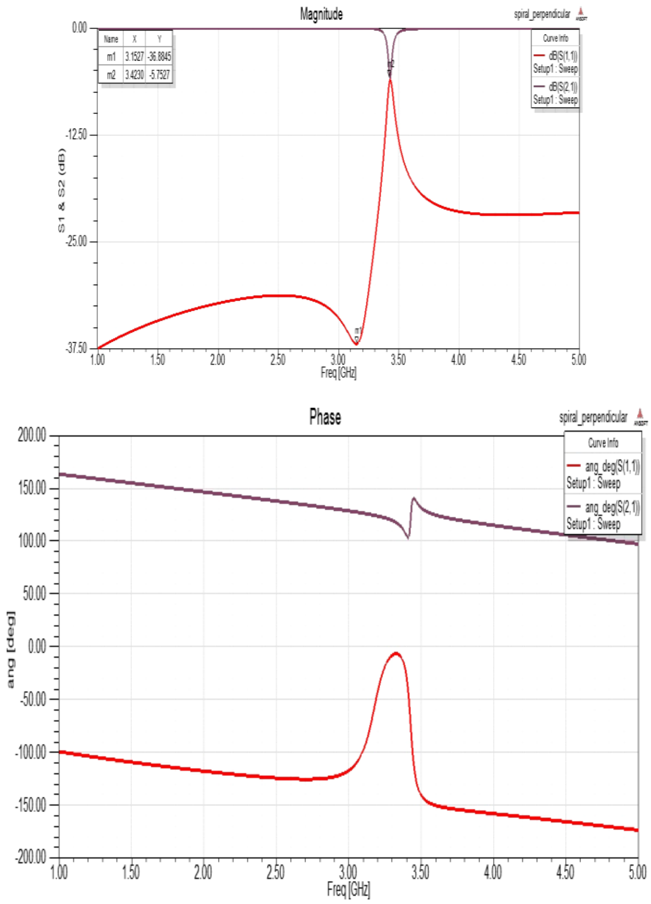


Figure 7 Magnitude and Phase of CSR loaded microstrip line with the gap perpendicular to the line

4. CONCLUSION

In this paper, the magnetic resonance of Circular SRR and CSR loaded microstrip lines is presented with gap parallel and perpendicular. It is clear from the results that the resonant frequency small shifts to higher region as gap of Circular SRR changes from parallel to perpendicular to the line with same dimension parameters. The same sized CSR exhibits almost half reduction in resonant frequency with acceptable return loss. So, it can be surmised that the same sized CSR resonate at comparatively lower resonating frequency as compared to Circular SRR. Hence it is proposed that CSR loading can be preferred to design an electrically small antenna by miniaturizing the dimensions to high scale.

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