

Electromagnetic Analysis of Concentric Split Ring Resonators in Conjunction to Microstrip Lines

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Abstract

In this paper, split-ring resonator coupled with microstrip line is presented. Split-ring resonators are sub wavelength resonators typically used to design metamaterial circuits. Here analysis of SRRs is carried out to obtain the characteristics of s-parameter behavior when such resonators are placed near microstrip lines. Apart from the stop band behavior the phase variation for different orientations are also visited with electromagnetic analysis which reveals that the phase varies drastically under certain orientations that lead to increased dispersive nature of the commonly called metamaterial loaded transmission line.

Keywords

Split-Ring Resonator, Microstrip Line, Metamaterial

1. Introduction

Metamaterials have been the source of interest for engineers for more than a decade [1]. It is artificially engineered homogeneous material not found naturally. It inherits properties like negative refractive index, negative permittivity and permeability at certain frequencies [2]. Due to this negative permittivity and permeability the wave vector k and the vector E and H form a left-handed triplet with the result of anti-parallel phase and group velocities, or backward wave propagation [1]. In fact metamaterial based structures have been minutely scrutinized in past decades for enhancing the operational capabilities of passive and active components in antennas and microwave circuits [2].

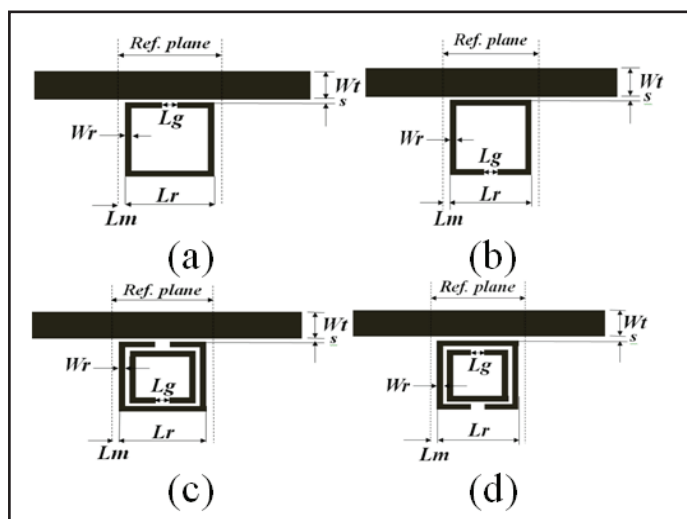


Fig. 1 (a) Single SRR with gap oriented near the host line horizontally to the microstrip line axis. (b) Single SRR with gap oriented away from the host line. (c) Outer SRR gap near the line and inner SRR gap oriented far from the host line. (d) Outer SRR gap away far from the line and inner SRR gap is near the host line.

Metamaterial fundamental particles like split ring resonators, that are basically sub wavelength resonators, have been also analyzed in conjunction to transmission lines. Metamaterial

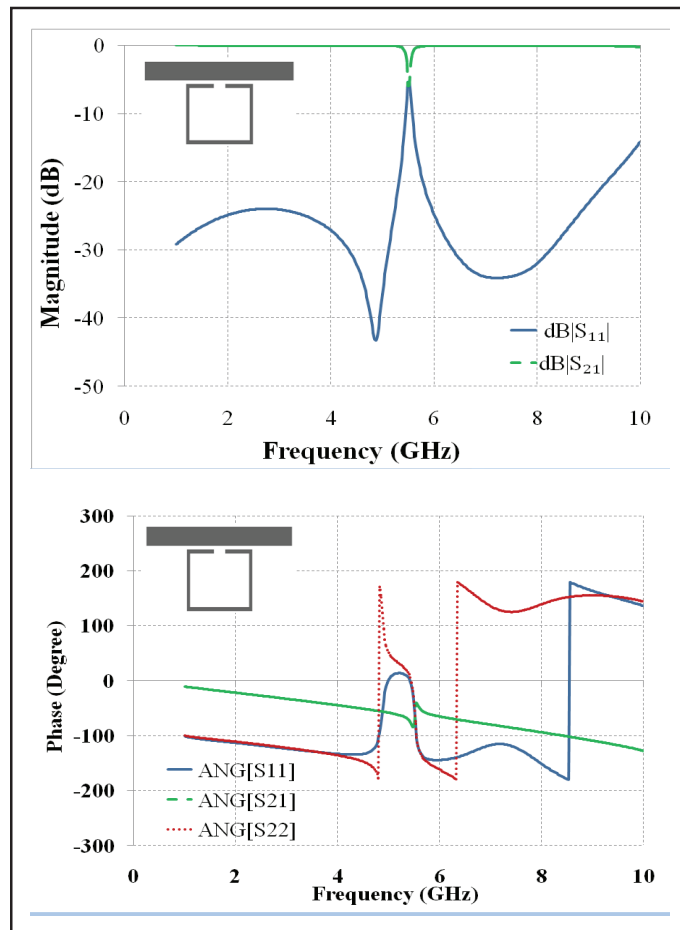


Fig. 2: Comparison of S-parameters magnitude and phase for the configuration as given in Fig. 1(a).

transmission lines have found wide applications in planar microwave circuits [3] and reconfigurable delay lines [4]. These resonant metamaterial transmission lines have been explored where split ring resonators (SRRs) and complementary SRRs (CSRR) are coupled to planar transmission lines like coplanar waveguide (CPW) [5] [6]. Recently the effect of orientation of gaps in case of loaded transmission lines have been analyzed [7]. SRR and CSRR composed of single split rings coupled to microstrip lines have been modeled in [8]. Miniaturized complementary spiral resonators using fractal geometry have also been studied in [9] which exhibit similar electrical behavior of placing a SRR in close proximity to a microstrip line or underneath a CPW line. However, the effect of orientation of gaps in concentric SRR arrangement coupled to microstrip lines have not been analyzed so far. This has been the problem formulation reported in this work. Rest of the paper is arranged as follows. Section II presents the detailed problem formulation regarding concentric dual SRR coupled to host transmission line. Results and discussion are given in Section III followed by concluding remarks in Section IV.

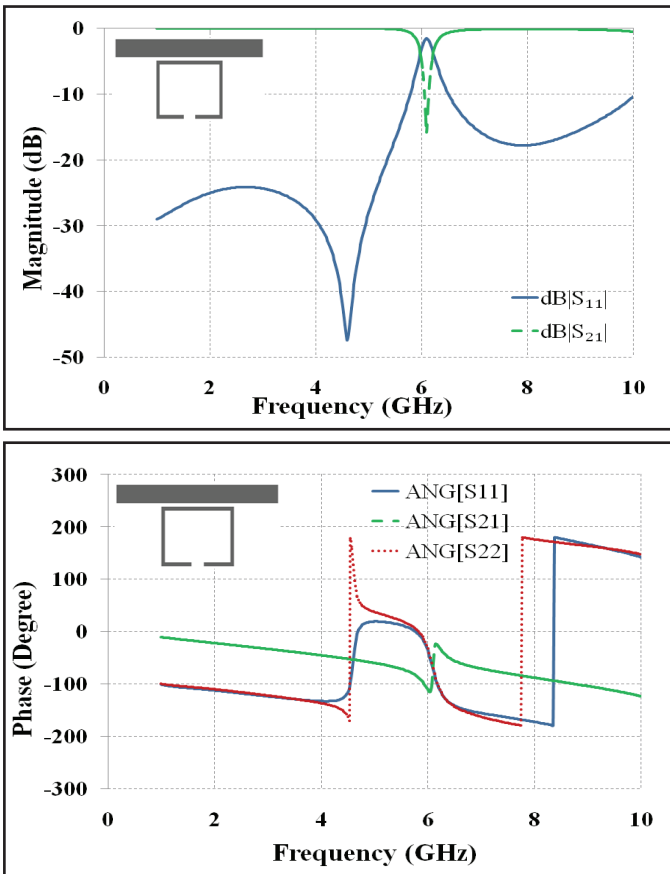


Fig. 3: Comparison of S-parameters Magnitude and Phase for the Configuration Illustrated in Fig. 1(b).

II. Problem Formulation

The problem formulation consists of electromagnetic analysis of single SRR as well as concentric dual SRR in proximity to host microstrip line. The SRRs are realized on dielectric substrate of $\epsilon_r = 10.2$ and thickness of 1.27mm. The combinations dealt with and reported in this paper are illustrated in Fig. 1. Referring to Fig. 1 all the outer rings and the single split ring resonators are of identical dimensions. The widths of the rings for outer as well as inner are same. This is of 0.2mm. The gap of slits denoted by L_g is of 0.5 mm is also same for both inner and outer rings. The SRR is placed at a distance of 0.1 mm from the host microstrip line of width 1.2 mm denoted by W_t in the Fig. 1. The length of the outer ring ' L_r ' resonating at 6 GHz is 3.0 mm. For Fig. 1 (c) and (d) the spacing between outer and inner ring is 0.2 mm. The combination of single as well as dual SRR in conjunction with microstrip line is analyzed using em Sonnet Lite of version 14.53. The single resonators have been studied in [8].

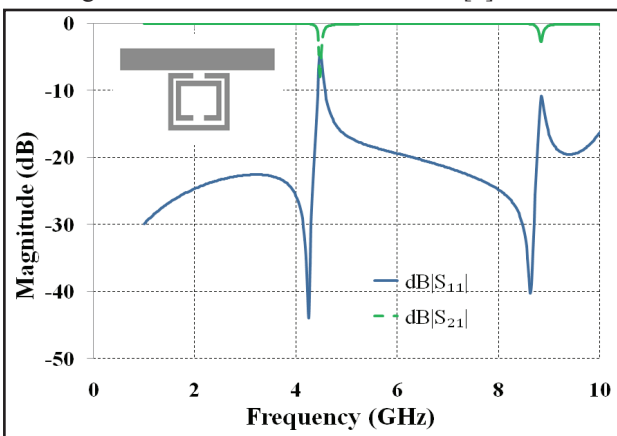
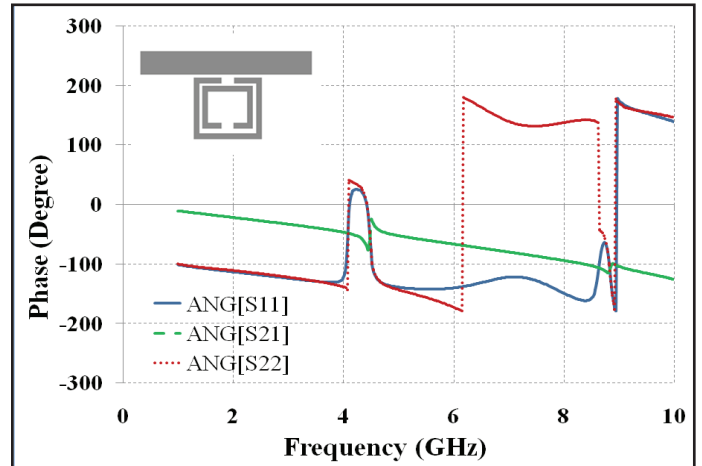


Fig. 4: Comparison of S-parameters magnitude and phase for the configuration shown in fig. 1 (c).

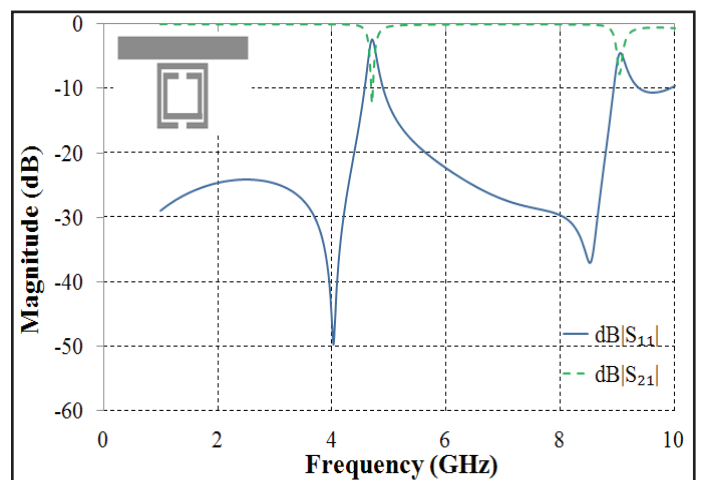
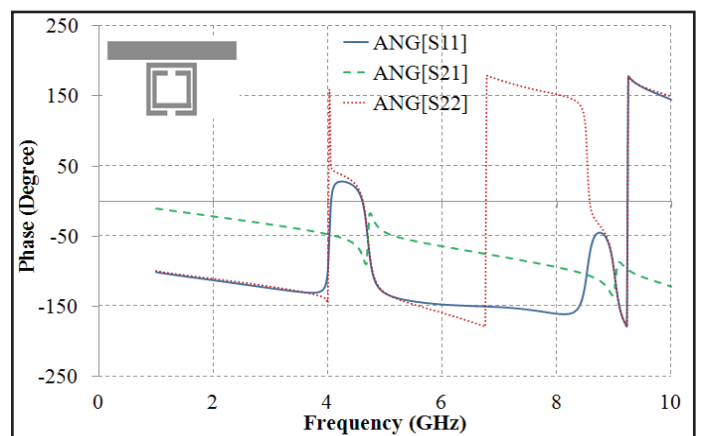


Fig. 5: Comparison of S-parameters magnitude and phase for the configuration shown in Fig. 1 (d).

and illustrations in Fig. 1 (a) and (b) are for highlighting the distinction from the problem formulation dealt here as illustrated in Fig. 1 (c) and (d), respectively. The different combinations of SRR shown in Fig. 1 are coupled to the host line and get excited by the electric and magnetic fields associated this transmission line.

III. Results and Discussion

The results for Fig. 1 (a) and (b) are provided from comparison view point as it has been analysed in [8]. We obtain with Sonnet Lite electromagnetic analysis similar results as reported in measured results given in [8]. These are given in Fig. 2 and 3, respectively. It can be noted that if we compare the effect of orientation then

the stop band shifts from 5.5 GHz to 6 GHz as the SRR slit is far from the host line. The case where the slit in SRR is near to microstrip line is also less effective in creating suitable attenuation at the stop band frequency. The S_{11} and S_{22} magnitude and phase are quite similar but the non-linear phase variation makes the line dispersive. This proves the fact that metamaterial transmission lines are dispersive.

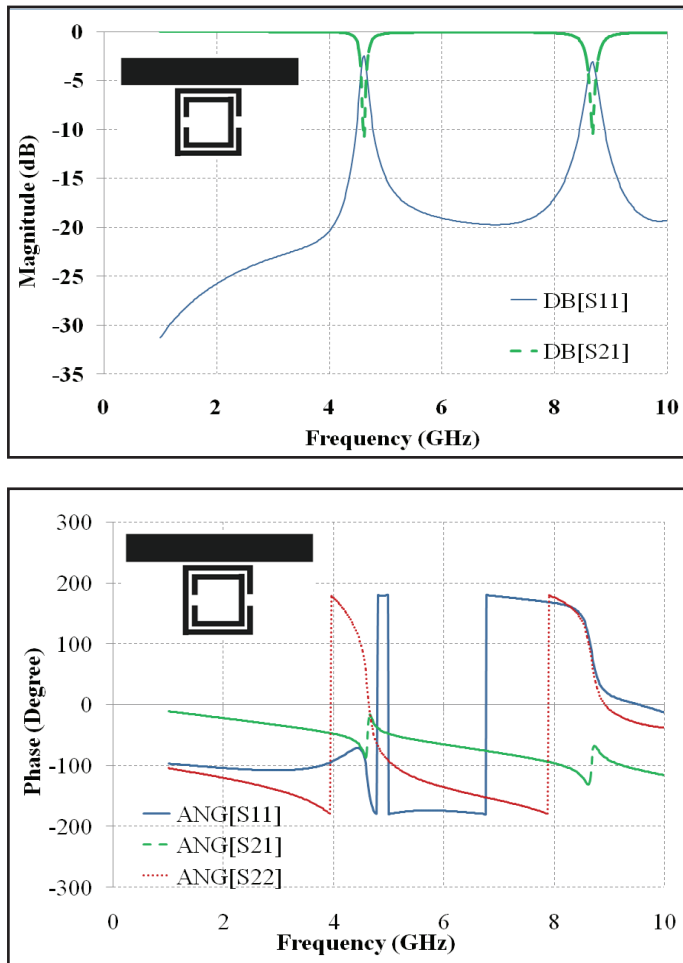


Fig. 6: Comparison of magnitudes phase of S-parameters obtained by rotating the dual SRRs in Fig. 1 (c) by 90 degree clockwise.

The electromagnetic analysis of concentric split ring resonators as shown in Fig. 1 (c) and (d) are presented in Fig. 4 and 5, respectively. The first and second transmission zeros are at 4.7 GHz and 9.035 GHz, respectively. The attenuation improves marginally with rotation by 180 degree clockwise. The phase variation also remains similar and indicates dispersion. The behaviour is similar to that when a single SRR was placed.

When the dual ring SRRs as shown in Fig. 1 (c) were rotated by 90 degree clockwise or when the SRR as shown in Fig. 1 (d) are rotated by 90 degree clockwise, the direct implication is improvement in attenuation as observed from S_{21} magnitude plot in Fig. 6 and 7, respectively. Another observation reported in [7] was for a CSRR loaded microstrip line where it is observed that the phase of S_{11} and S_{22} differ drastically when the SRR are oriented in 90 degree rotated format.

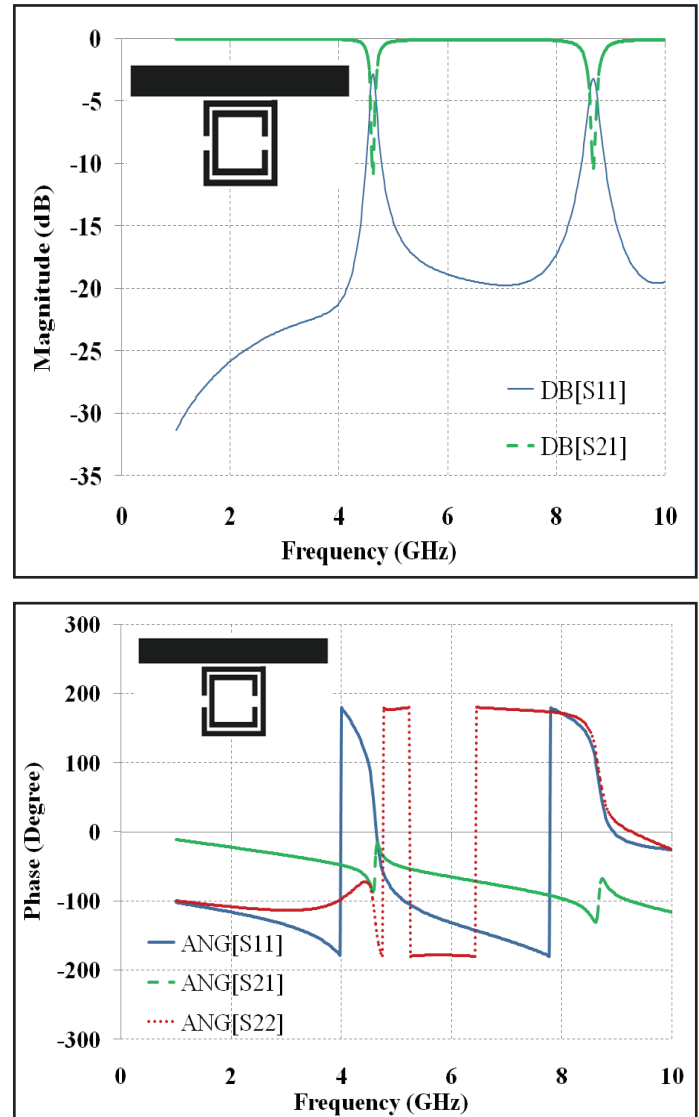


Fig. 7: Comparison of magnitudes phase of S-parameters obtained by rotating the dual SRRs in Fig. 1 (d) by 90 degree clockwise.

Similar observation is seen in case of dual SRR. The phase of S_{11} and S_{22} gets interchanged indicating different phase characteristics upon change in orientation of the SRRs.

IV. Conclusion

This paper presents an electromagnetic analysis of dual SRR for various orientations of inner and outer rings. The common observation is that the phase of S_{11} and S_{22} are same when the gaps are horizontally placed, in reference to microstrip line axis, and differ drastically when the gaps are vertically inserted. This is persistent for dual SRR and the other observation is that when the gaps are vertically placed the attenuation created by SRRs are improved as compared to when the gaps are horizontally placed.

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