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INVESTIGATION OF MAGNETIC RESONANCES BETWEEN TWO RINGS AND THREE RINGS OF SRR FOR DIFFERENT GEOMETRICAL SHAPES

Thill A. Kadhum Al-Musawi, Shawki Khalaph Muhammad
Physics Department, Science College, Al-Muthanna University, Iraq
Electromechanical Systems Engineering Department, Thi-Qar Technical College, Southern Technical University, Iraq

Abstract

A comparative study of split ring resonator (SRRs) of different geometrical shape was presented in this paper. Printed the (SRRs) on similar dielectric substrates are study for same physical dimensions. Split form expressions for computing the resonance frequency of these shapes were also presented and compared which determines the region of negative permeability. The suggested multi-band structure was simulated and the S-parameters were studied using CST MS.

Introduction

Negative index materials (NIM) can be realized using periodic alignment of structures exhibiting negative permittivity and negative permeability [1-4]. Different researchers have worked with different arranging of SRR, as circular SRR (c-SRR), square SRR (s-SRR), circle-circle SRR (c-c-SRR) etc. for realizing artificial negative material the SRR. In this paper, a comparative study of (SRRs) having different geometrical configurations is presented. The resonance frequencies of the circle- square (c-sq), circle- square- circle (c-sq-c), square circle (sq-c) and square- circle- square (sq- c-sq) SRRs are computed using CST MS as in figure (1) [5]. All four geometrical configurations of the (SRR) printed on similar dielectric substrates are study for same physical dimensions, the comparison of their resonance frequency, which determines the region of negative permeability [6-8]. The negative permittivity is realized using conducting wires, and negative permeability can be realized using split ring resonators (SRR) (5). Complex transmission and reflection characteristics of the proposed (SRR) are obtain by CST MS, and then they are used to extract the effective medium parameters (ϵ_{eff}) and (μ_{eff}) of the designed metamaterials to verify the nature of resulting resonances [9-11].

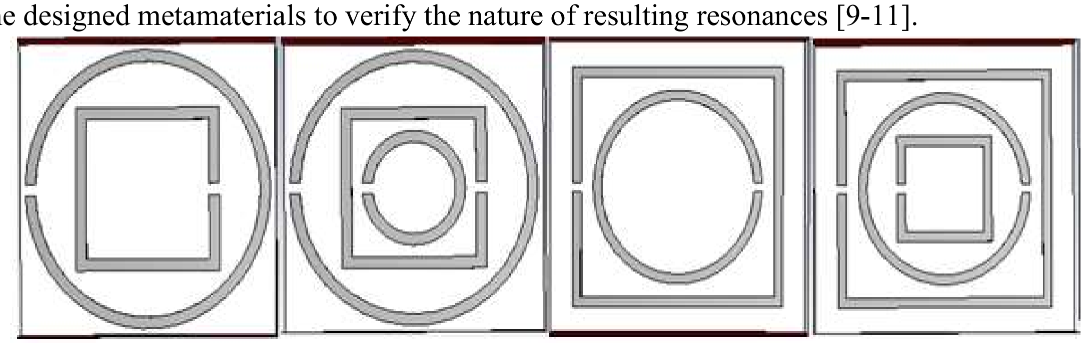

Fig. (1): A typical unit cell SRR with a metallic one rod placed on the dielectric board for
(c- sq) design, (c- sq- c) design, (sq- c) design and (sq- c- sq) design.

Design and Simulation

After the proper designs are completed, it concluded that the effective range of frequencies that contains the peaks and dips under interest is between (8- 12) GHz as in figures (2- 5). From the real parts of (S11) and (S21) parameters the effective resonance frequencies for all designs have been found as in table (1), and it is obvious that the resonant frequency proportional directly with decreasing number of rings for all four designs. This happens because of decreasing the capacitance that is proportional inversely with increasing of gap distance between the rings. It can be concluded that the largest value of resonant frequency is for the design (c- sq) and then (c- sq- c), (sq- c) and (sq- c- sq).

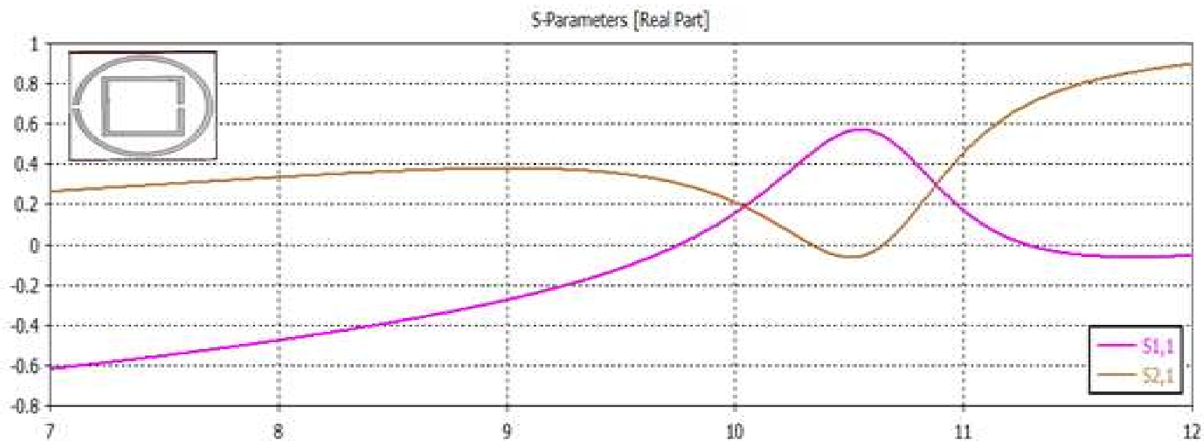

Fig. (2): Real parts of (S11) and (S21) parameters for (c- sq) design.

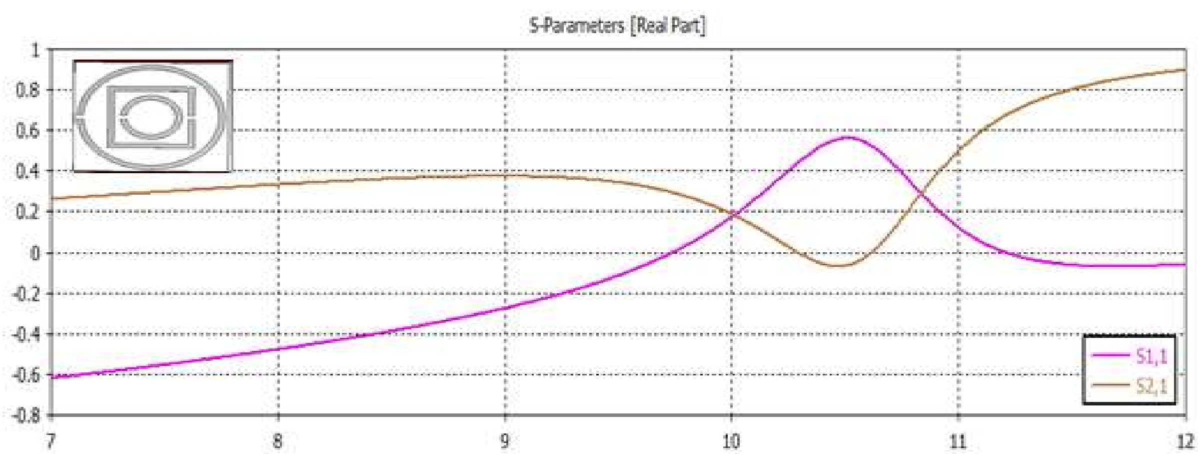

Fig. (3): Real parts of (S11) and (S21) parameters for (c- sq- c) design.

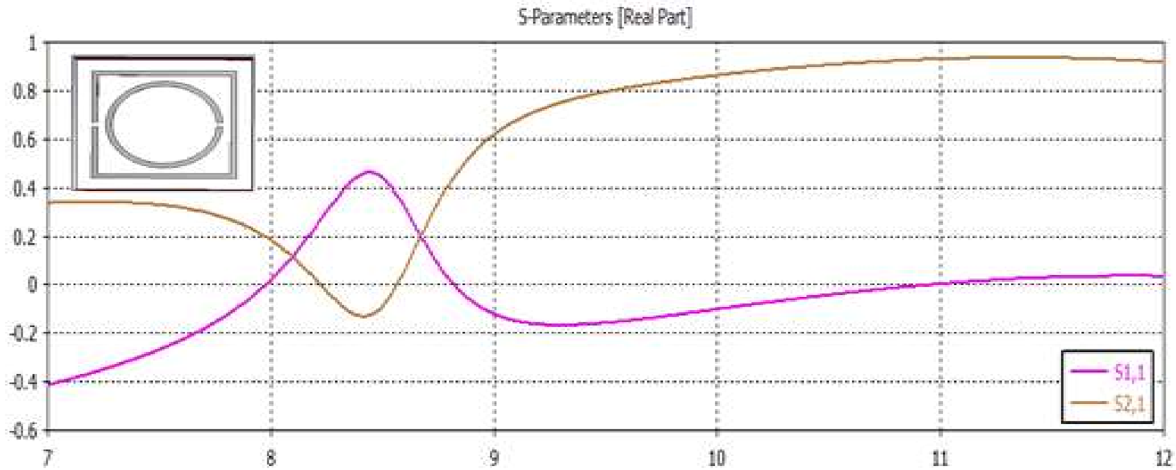

Fig. (4): Real parts of (S11) and (S21) parameters for (sq- c) design.

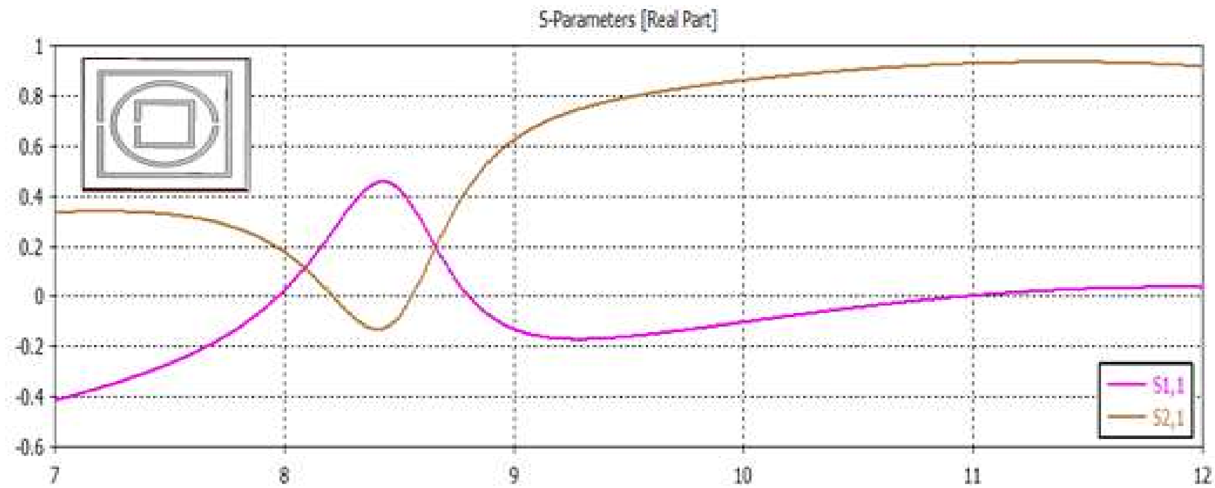

Fig. (5): Real parts of (S11) and (S21) parameters for (sq- c- sq) design.

Then, the values of real of (ϵ) of design have been extracted from S- parameters using post-processing of (CST). It is obvious that the negative values of (ϵ_{real}) were found in the frequencies below (12) GHz. Also, the negative values of (μ_{real}) have been estimated using the same manner and it seems that these values shifted to the right (higher frequency or shorter wavelength) as rings number decreasing, as exhibited in figure (6).

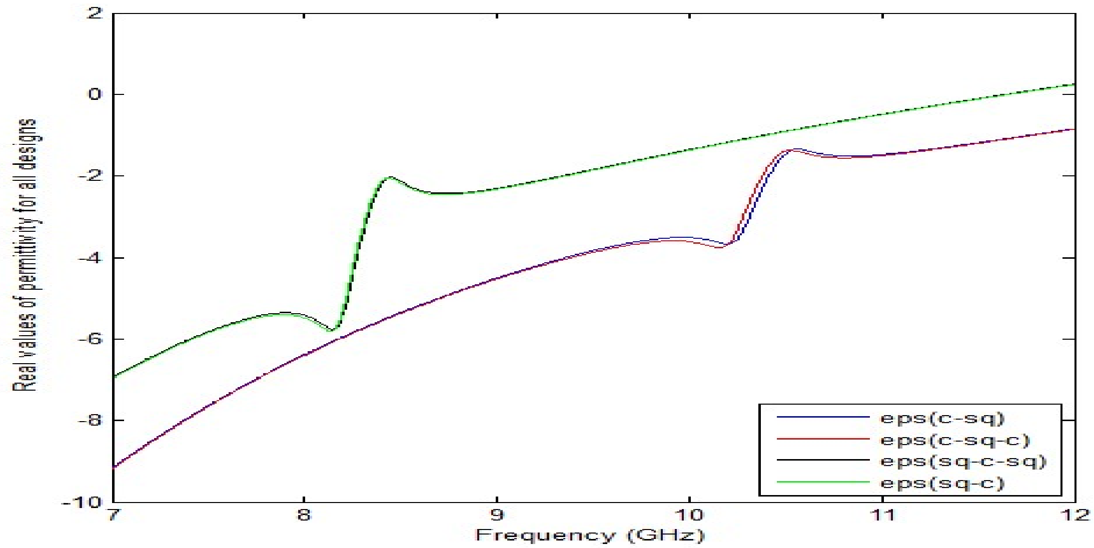

Fig. (6): Real parts of ermittivity (ϵ) parameters for all designs.

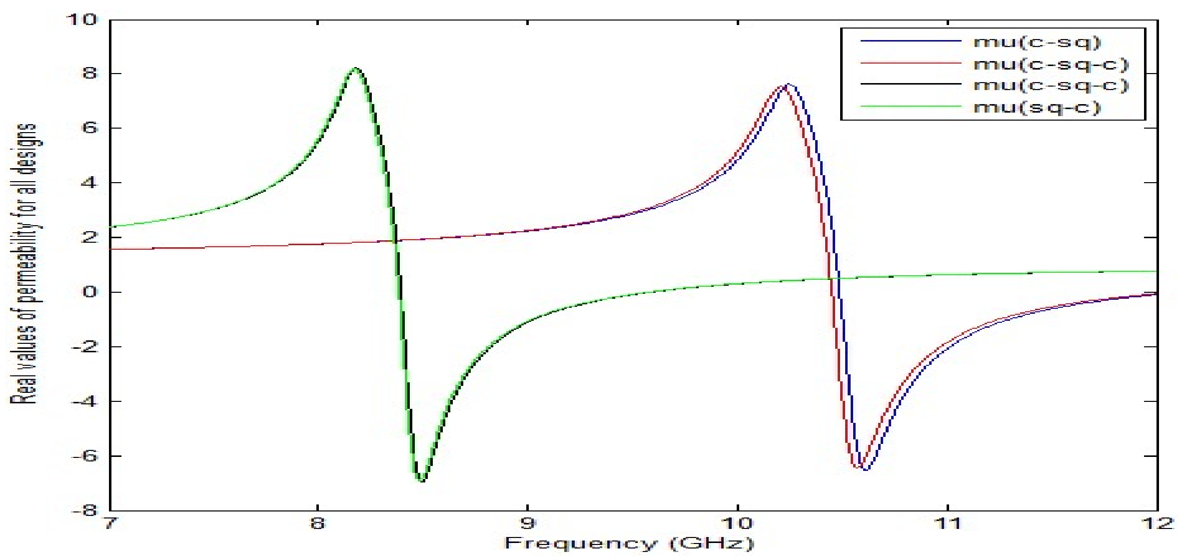

Fig. (7): Real parts of permeability (μ) parameters for all designs.

By looking to figure (8) it can be concluded that the largest value of effective refractive index is for the design (c- sq) and then (c- sq- c), (sq- c) and (sq- c- sq), and (neff) exhibits a negative values table (1).

Table (1): Comparison of computed and simulated resonance frequencies.

Type of SRR	SRR Resonance frequency (GHz)		Effective refractive index (n_{eff})
	f s11	f s22	
c-sq	**10.550**	**10.505**	**7- 12**
c-sq-c	**10.510**	**10.465**	**7- 12**
sq-c-sq	**8.440**	**8.415**	**7- 10.500**
sq-c	**8.430**	**8.405**	**7- 10.515**

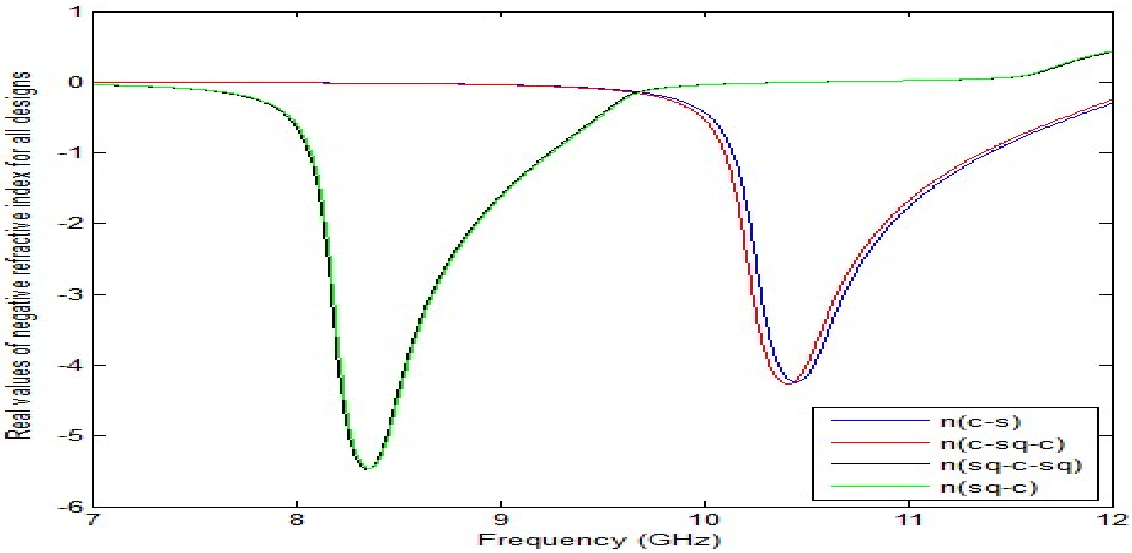

Fig. (8): Effective refractive index (n_{eff}) for all designs.

Results

The resonance frequency for SRR of different geometries is computed using equations (1) and (2) [11]:

$$L = \frac{\mu_0 b}{\sqrt{\pi}}\left[\log\left(\frac{32b}{a\sqrt{\pi}}\right) - 2\right] \quad (1)$$

$$C_s = \frac{\epsilon a t}{2g} \quad (2)$$

where (L) is equivalent induced inductance, (Cs) is the total series capacitance between the rings, (μ0) is the permeability of free space ($\mu_0 = 4\pi \times 10^{-7}\ N/A^{-2}$), (a) is the ring width, (g) is the split gap, (b) is the ring length, (ϵ) is the permittivity of the material and (t) is the thickness of the split ring. In this paper the dimensions are chosen to be: a=0.1mm, g=0.1mm, b=2.5mm, t=0.25mm. Capacitors and inductors in parallel act as a resonant circuit with resonance frequency ($f = \frac{1}{2\pi\sqrt{LC}}$).

These results demonstrate that a desired number of magnetic resonances can be realized by selecting the number of SRR rings within the limits of geometrical constraints. The simulated resonance frequency was extracted from the transmission coefficient curves. The (c-sq) SRR resonates at higher frequency compared to the others designs and at lower frequency compared to the (sq-c) SRR, having similar dimensional parameters, as in table (1) [12].

Conclusions

The possibility of multiple magnetic resonances with negative permeability bands are demonstrated for the suggested multi ring SRR, where the number of resonances is determined by the number of concentric rings. Also, It is also worth mentioning that resonance frequencies can also be adjusted by changing the design parameters such as the gap width, metal width, inter-ring distances and length of rod.

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