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A comparative study of split ring resonator (SRR) of different geometrical shape

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Abstract :

Metamaterials are structures that are purposefully constructed and have distinctive characteristics. They are designed to reach negative values of permittivity and permeability simultaneously in a certain frequency range. This results in negative values of the index of refraction. Because of how sensitive the resonant frequencies of these structures are to the geometry of the structure itself, they are often used in the functioning of the structures themselves. Cloaking, super lenses, sub-diffraction focusing, perfect absorption, and biosensing are only a few of the various frequency ranges in which metamaterials have been proven. Cloaking, super lenses, and perfect absorption have also been demonstrated. These range anywhere from gigahertz to optical frequencies. Split-ring resonators, also known as SRRs, are an essential construction block since they are one of the core components that are required to really create metamaterials. As SRRs, either thin metallic rings or split square loops are employed, and they are both positioned on top of a dielectric substrate. SRRs are some of the earliest metamaterial-based microwave resonators. This is due to the fact that their geometries are much smaller than the wavelength of the electromagnetic waves that are stimulating them.

A comparative study of split ring resonator (SRR) of different geometrical shape is presented in this paper.

Keywords-Split Ring Resonators; Double negative media

Introduction :

Circular and rectangular split-ring resonators have been shown to be the most prevalent forms of split-ring resonators presented so far in the field of metamaterials. Research is conducted on a variety of performance qualities, including sensing sensitivity. It's possible that rectangular forms will give enhanced sensitivity when they're put to use in sensing applications. In contrast to circular structures, rectangular resonators are more suited for downsizing and dense packing because of their square shape. In addition, several adjustments have been included into typical designs, such as the creation of multi-gap rectangular or circular split-ring resonators. These alterations have been made possible as a result of advancements in technology. It has been shown that the magnetic resonance that is brought about by the current that is created by the electric field disappears when the intervals that are present between the structures are lengthened. As a further consequence of this alteration, the resonant frequency has a propensity to get higher.

Double negative media, also known as negative index materials, may be made by periodically aligning structures that have a negative permittivity and a negative permeability. This process is known as double negative (DNG) media (NIM). As a result of the fact that conductors are capable of producing negative permittivity, Pendry proved that split ring resonators are also capable of producing negative permeability (SRR). Circular SRR (C-SRR), square SRR (S-SRR), and hexagonal SRR (H-SRR), amongst others, have all been the focus of research by a variety of academics who are interested in realising artificial magnetic materials or utilising the SRR as perturbations in the design of passive planar circuits. These researchers have denoted the SRR as circular SRR (C-SRR), square SRR (S-SRR), and hexagonal SRR (Both circular and square split ring resonators have been the focus of a significant amount of attention from academics over the course of many years. The use of C-SRR, S-SRR, and H-SRR in the design of passive planar circuits, such as filters, power dividers, duplexers, and phase shifters, has greatly risen over the course of the last few years. [C-SRR], [S-SRR], and [H-SRR] The findings of an analysis that compared SRRs with a variety of different geometrical configurations are presented in this article. In addition to this, the surface current density of the SRRs that were collected via the use of the EM simulator is analysed and compared.

THEORY

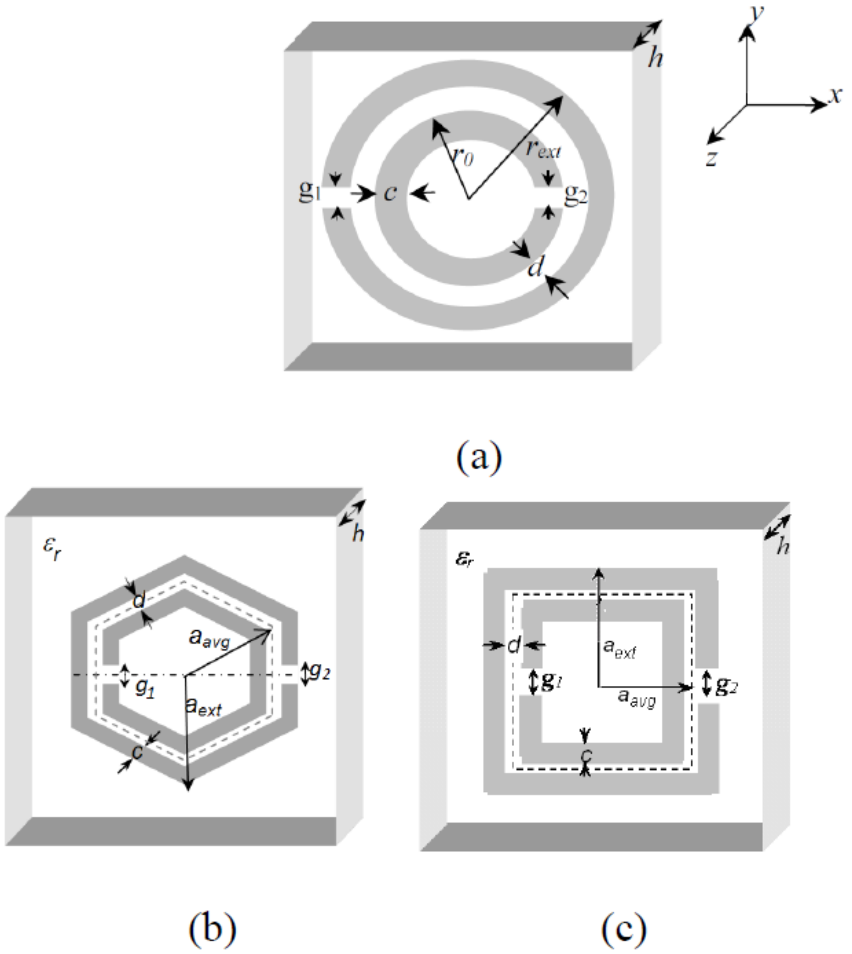


Figure 1. Schematic view of split ring resonators formed with metallic strips of width, c, dimension r_{ext} *(For Circular) and* a_{ext} *(For Square and Hexagonal), with inter ring spacing d and split gap dimensions, g1 = g2, printed on a dielectric substrate having thickness, h and dielectric constant* ε_r*. (a)Circular (b) square (c) Hexagonal*

Fig. 1 shows a schematic view of a C-SRR , S-SRR and H-SRR having strip width c and spacing *d* between the rings. *g1* and *g2* are gaps within the inner ring and outer ring, respectively. The structure is printed on a dielectric substrate with dielectric constant, ε_r and thickness h. The equivalent circuit model of these split ring resonators is shown in Fig.2. Under the exposure of external magnetic field the induced electromotive force around the SRR causes a currents which passes from one ring to the other through the inter ring spacing, d and the structure behaves as an oscillatory L-C circuit.

The resonance frequency of the SRR is given by,

$$\omega_0 = \sqrt{\frac{1}{L_T C_{eq}}} \tag{1}$$

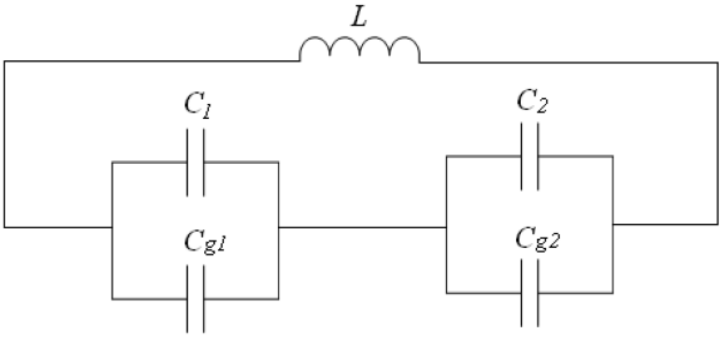


Figure 2. Equivalent circuit of the Split Ring Resonators shown in Fig. 1

The expression of the resonant frequency of different SRR is given as

$$\text{For C - SRR :}$$

$$f_{0C} = \frac{1}{2\pi\sqrt{LC_{eq}}} = \frac{1}{2\pi\sqrt{L_T\left[\frac{(\pi r_0 - g)C_{pul}}{2} + \frac{\varepsilon_0 ct}{2g}\right]}} \tag{2}$$

$$\text{For S - SRR :}$$

$$f_{0S} = \frac{1}{2\pi\sqrt{L_T C_{eq}}} = \frac{1}{2\pi\sqrt{L_T\left[\left(2a_{avg} - \frac{g}{2}\right)C_{pul} + \frac{\varepsilon_0 ch}{2g}\right]}} \tag{3}$$

For H- SRR :

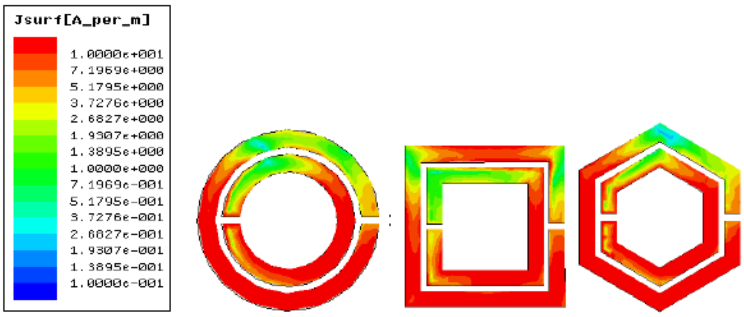
$$f_{0H} = \frac{1}{2\pi\sqrt{L_T C_{eq}}} = \frac{1}{2\pi\sqrt{L_T\left[\frac{(3a_{avg}-g_1)C_{pul}}{2} + \frac{\varepsilon_0 ch}{2g_1}\right]}} \qquad (4)$$

where L_T is the total inductance of the SRR and C_{eq} is the equivalent capacitance of the structure and is calculated from the equivalent circuit in Fig.2, as in [5]. C_{pul}, is the per unit length capacitance, between the rings and r0 (C-SRR) and a_{avg} (S-SRR and H-SRR) are the distance of the two constituent rings of the SRRs from the centre. C_{pul} is calculated as :

$$C_{pul} = \sqrt{\varepsilon_e} \Big/ c_0 Z_0 \qquad (5)$$

where c_0 = 3×10 m/s is the velocity of light in free space. e ε_e is the effective permittivity of the medium and Z_0 is the impedance of the medium.

Figure 3 shows the induced surface current density of the SRRs when excited with an incident EM signal. The figure shows higher current distribution in S-SRR which yields higher LT and hence lower resonance frequency.



(a) (b) (c)

Fig. 3. Simulated surface current distributions of (a)Circular (b) square (c) Hexagonal shaped Split Ring Resonators

CONCLUSIONS

Using a method known as the simple equivalent circuit technique, a comparative investigation of the SRR of various geometrical forms was carried out. The comparison research reveals that various geometrically designed SRRs with comparable footprints each have a frequency shift of around 36 percent.

REFERENCES :

1. J.B. Pendry, A.J. Holden, D.J. Ribbins, and W.J. Stewart, Magnetism from conductors and enhanced nonlinear phenomenon, IEEE Trans. Microwave Theory Tech., 47 (1999), 2075-2084.
2. R.Marquez, F. Medina and R. Rafii-El-Idrissi, Role of bianisotropy in negative permeability and left-handed metamaterials, Phys. Rev. B, 65 (2002), 144 440(1) – 144 440 (6).
3. R. W. Ziolkowski, Design, fabrication, and testing of double negative metamaterials, IEEE Trans. Antennas Propagat., 51(2003), 2572-2581
4. R.Marquez, F. Mesa, J. Martel, F. Medina, Comparative analysis of edge- and broadside- coupled split ring resonators for metamaterial design-theory and experiments, IEEE Trans. Antennas Propagat., 51(2003), 2572-2581.
5. C.Saha and J.Y.Siddiqui, Versatile CAD Formulation for Estimation of the Resonant Frequency and Magnetic Polarizability of Circular Split Ring Resonators, International Journal of RF and Microwave Computer Aided Engineering, 21(2011), No.4.
6. S. Lim, C. Caloz, and T. Itoh, Electronically scanned composite right/left handed microstrip leaky-wave antenna, IEEE Microwave Wireless Comp. Lett., 14(2004), 277–279.
7. C. Saha and J.Y. Siddiqui “Simplified CAD model for accurate estimation of the Resonant Frequency of Edge Coupled Hexagonal Split Ring Resonators” Proc. APSYM 10, Cochin, December 14-16, 2010 8. I. Arnedo, et.al, Forward and backward leaky wave radiation in split ring resonator based metamaterials, IET Microwaves, Antennas Propag., 1 (2007), 65-68
8. M. A. Antoniades and G. V. Eleftheriades, A broadband series power divider using zero degree metamaterial phase shifting lines, IEEE Microwave Wireless Comp. Lett., 15 (2005), 808–810.
9. F. Martin, et. al, Split ring resonator-based left-handed coplanar waveguide, Applied Phys. Lett., 83 (2003), 4652 – 4654.