Asymmetric Single Split Resonator for RFID Applications

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Abstract

This paper presents a new Asymmetric Single Split Resonator (ASSR) structure for single negative and/or double negative metamaterial applications and its characteristics. The uniplanar structure is a modified split ring resonator with a single split and the prototype is analyzed based on reflection coefficient and unit cell simulations. It exhibits high field confinement as compared to SRR, so best suited for filter and RFID applications. The paper presents the constitutive parameters of ASSR for parallel polarization with supporting simulation and measurement results.

1 Introduction

The application of artificial metamaterials created a new era in the design of present-day electronic gadgets. The concept explained by Pendry et al [1] and experimented by Smith [2] provided the first novel structure with unusual properties. The different characteristics of Split Ring Resonators (SRRs) are reported widely such as equivalent circuit models [3], magnetic properties [4], spurious radiation suppression [5], nonlinearity [6], superdirectivity [7] etc. The applications of metamaterials include antenna miniaturization, bandwidth enhancement, directivity/gain enhancement etc. Even though the studies on Split Ring Resonator (SRR) are still going on, the new structures added to the category is very less in number. The authors present a new simple, planar and asymmetric structure to achieve the properties of metamaterials and its analysis results.

2 Unit Cell Structure

Split ring resonators are found to be most widely used metamaterial structure to achieve negative permeability. But the SRR is having a symmetric geometry which will reduce the nonlinear behavior. For filter and RFID applications, it needs more energy density which can be attained by increasing the nonlinear behavior [1]. The asymmetry in geometry can improve the nonlinear behavior. The geometry of the Asymmetric Single Split Resonator (ASSR) structure is derived from those reported in [1] and is shown in Figure 1. A prototype is fabricated on a substrate of dielectric constant 4.4, thickness of 1.6mm and a loss tangent of 0.01. The outer radius is 12mm and the width of the metallic disc is 2mm. The outer radius of the inner loop is taken to be 7mm and the center to center distance between the discs is 3.15mm. The dimensions are selected so as to operate in the lower frequency regime. The structure is devoid of any vias and additional metallic ground planes which makes it simple, uniplanar and easy for fabrication. The structure is analyzed with computational solver CST Microwave studio and the measurements are done using PNA E8362B Vector Network analyzer.

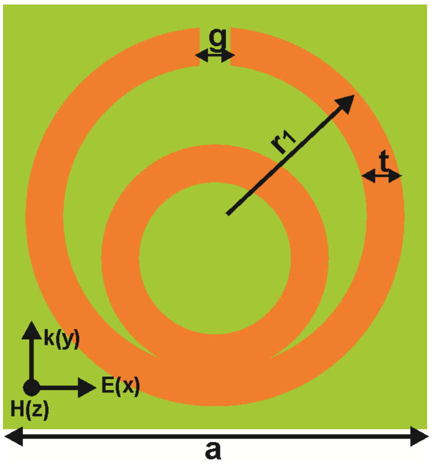

Figure 1. Structure of a unit cell with its dimensions and field vectors (r_1=12mm, g=1mm, t=2mm)

3 Characteristics of ASSR

The schematic view of the proposed unit cell structure together with the excitation details are shown in Figure 1. A uniform plane wave is made incident for parallel polarization that is propagation along Y axis where electric field and magnetic fields are oriented along X and Z axes respectively. A unit cell of 30mmx30mm dimension is simulated for infinite periodic arrangement of ASSR using CST Microwave Studio. In order to verify the characteristics of ASSR, the transmission coefficient of the structure is measured experimentally by PNA E8362 vector network analyzer using the microstrip line fixture method [9] and its simulated and measured reflection and transmission parameters are plotted in Figure 2. The change in resonant frequency is justified with the fabrication tolerance and additional capacitance coupling during the transmission line measurement. The measured response shows a transmission dip at 1.33GHz in the sub wavelength regime with very narrow band operation.

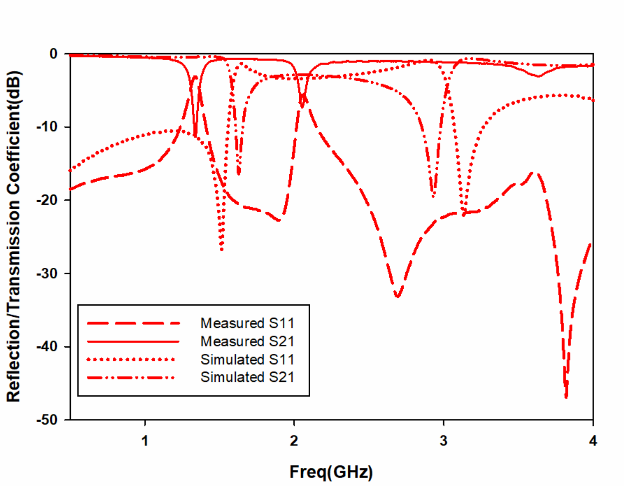

Figure 2. Simulated and measured Reflection and Transmission coefficients

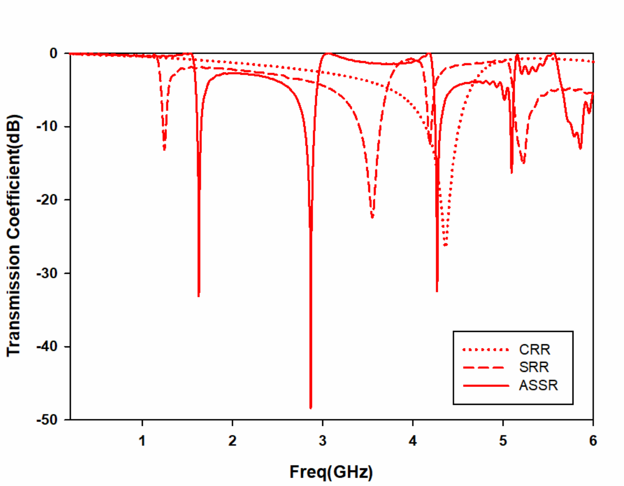

Figure 3. Simulated Transmission coefficients of (a)CRR (b)SRR (c)ASSR

The magnetic resonance of the structure is identified by comparing it with a closed ring resonator (CRR) of same dimensions as stated in [8] and is shown in Fig. 3. The fundamental resonance of CRR is found to be at 4.365GHz whereas the ASSR shows the first resonance which is the magnetic resonance of the resonator at 1.63GHz; attributed for the capacitance effect provided by the slit on the outer ring of the ASSR. But an SRR of same outer diameter and gap width and excited with same boundary conditions exhibits a lower resonance of 1.23GHz. The capacitance effect in SRR is more as compared to an ASSR since there exist two slits and a gap between inner and outer rings. The asymmetry in ASSR makes it less capacitive. The current distribution at the resonance is also shown in Figure 5 in which the anti-parallel loop currents through the inner and outer rings indicate the existence of negative permeability. But the second resonance of ASSR is less compared to SRR where it shows the electrical resonance of the metamaterial structure. It shows more electrical nature compared to SRR. The constitutive parameters and refractive index of the material are extracted using the 3D EM simulation tool CST microwave studio for the above incident polarization and is depicted in Figure 4.

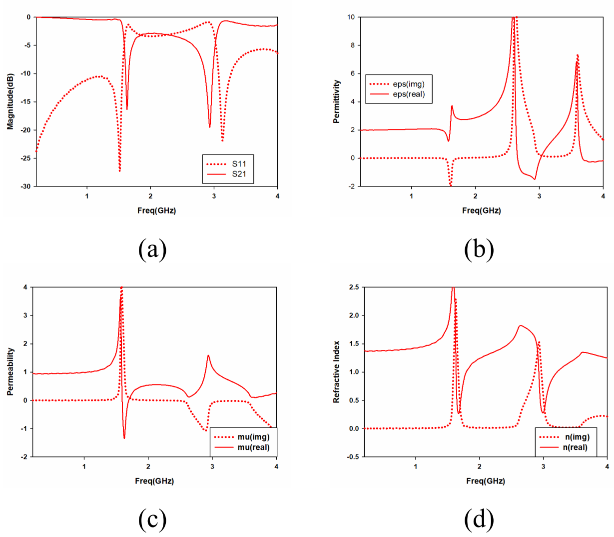

Figure 4. (a) Transmission and reflection coefficient (b) Permittivity (c) Permeability (d) Refractive Index

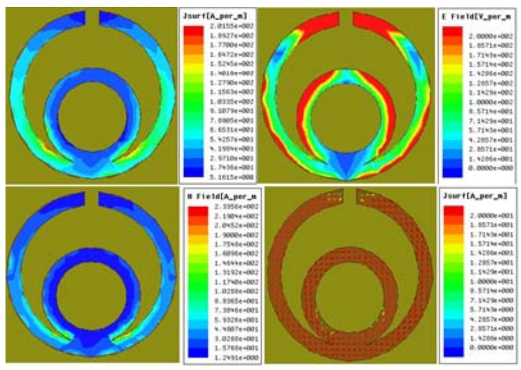

Figure 5. Microscopic properties of SSR: Magnitudes of Current, Electric field, Magnetic field and Current distribution with its phase

Understanding the field in Figure 5, the electric field is dominant at the vicinity of splits/gap between the rings whereas the magnetic field is maximum around the opposite region of splits contributed by the current induced by the element. The asymmetric distribution of current increases the energy density within the volume. Hence the field confinement is more for ASSR as compared to an SRR of same dimension. Thus, it may be well suited for filter and RFID applications rather than SRR.

4 Conclusion

A new metamaterial to achieve the negative permeability is proposed in this paper. The ASSR structure is a modified form of basic split ring resonator and is asymmetric. It exhibits high field confinement as compared to SRR, so it can be used for filter and RFID applications. The paper presents the constitutive parametrs of ASSR for parallel polarization with supporting simulation and measurement results. It can be used for single negative and/or double negative metamaterial applications with different polarization of incident wave.

6 Acknowledgements

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7 References

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