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Full Length Research Paper

A microstrip metamaterial split ring resonator

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This paper introduces a new low cost, robust microstrip structure, exhibiting metamaterial property, as a replacement of conventional bulky metamaterials structures. These types of planar microstrip structures are very useful for applications where space of equipment is a constraint. Although, the structure is inspired by Split-Ring resonator (SRR), it does not incorporate additional metallic rod for electrical resonance, as used with conventional SRRs. The rings are elliptical in shape and coaxial dual feeding has been used that are offset in phase. Simulations of the elliptical split ring resonator (ESRR) have been carried out in microwave regime. S-parameter simulation results of the resonator show metamaterial property at multiple frequency bands.

Key words: Metamaterial, microstrip structures, split ring resonator, negative refractive index material, microwave.

INTRODUCTION

In recent years, there has been growing interest of the research fraternity in study of metamaterials. The metamaterials are defined as artificial materials having ability to exhibit an electromagnetic response not readily found in naturally occurring material, such as, negative refractive index and artificial magnetism (Zilkowski et al., 2003; Si et al., 2008; Zharov et al., 2003; Weng et al., 2007; Erentok et al., 2005). Metamaterials are often characterized in terms of their effective material parameters, such as electric permittivity and magnetic permeability (Shalaev et al., 2005). These parameters can either be both negative, and only one of them may be negative. The former is referred to as left-handed metamaterials (LHM), double negative (DNG), or negative refractive index material (NRIM) (Zharov et al., 2003; Weng et al., 2007; Shalaev et al., 2005; Hao et al., 2009). The latter is known as single negative material (SNG) (Hao et al., 2009; Cui et al., 2010).

Effective negative permittivity can be obtained in the artificial plasmas for all frequencies smaller than plasma frequency of the Plasmon medium (Si et al., 2008; Pendry et al., 1996; Pendry et al., 1998). Effective negative permeability can be obtained in the well known Split-ring-resonator structure, but only for a narrow magnetic resonant frequency band (Pendry et al. 1999). New innovative structures are being reported showing performance improvement in terms of size bandwidth, ease of fabrication etc. (Sabah, 2010). Most of the structures incorporate metallic strip or rod along with split ring resonator for electrical resonance. This paper presents design and simulation of a new planar microstrip elliptical split-ring resonator (ESRR) exhibiting negative index of refraction at multiple bands while no metallic strip or rod used for electrical resonance. The split rings are off-set fed. The structure has been simulated on HFSS and s-parameter values (S_{11} and S_{21}) thus obtained were used to calculate index of refraction.

The formula used for the calculation of refractive index is (Sabah, 2010; Ali et al., 2008, Smith et al., 2002; Smith et al., 2005):

$$n = \frac{1}{kdj}\cosh^{-1}\left[\frac{1-S_{11}^2+S_{21}^2}{2S_{21}}\right] \quad (1)$$

Where n is index of refraction, kd the electrical path length, S_{11} the reflection coefficient and S_{21} the

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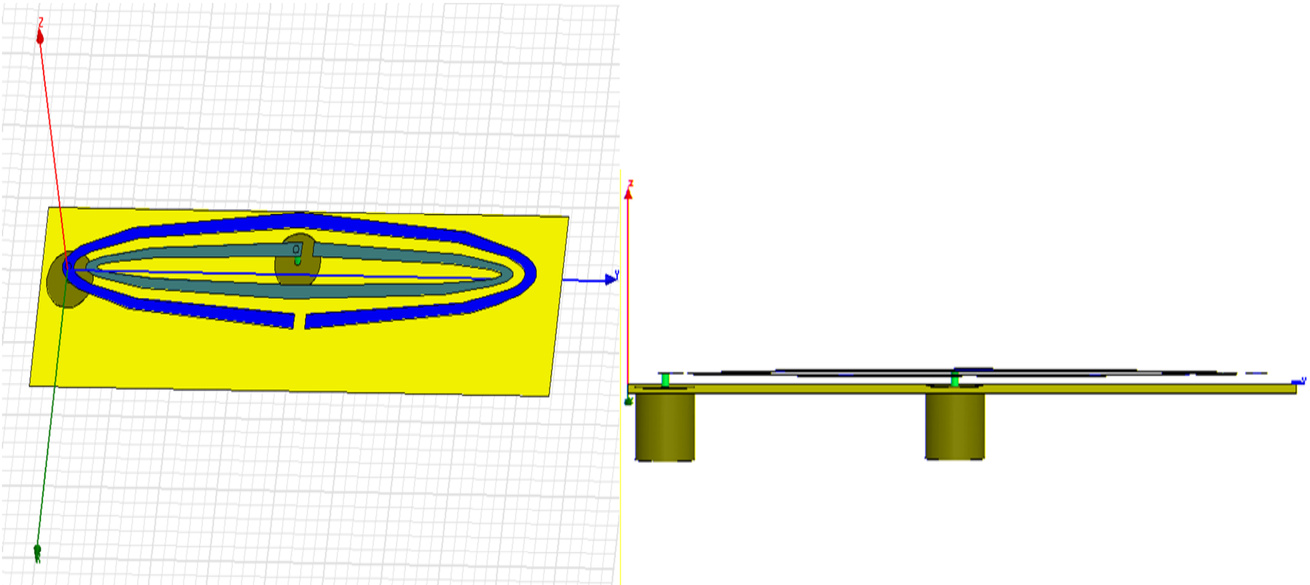

a b

Figure 1. (a) The schematic top view of ESRR, (b) The schematic side view of ESRR.

transmission coefficient.

THE STRUCTURE

The structural top view and side view of ESRR is shown in Figures 1(a) and (b) respectively. The RF signal ranging from 1 to 10 GHz is fed to each of the rings through 50 ohm coaxial cables as shown in Figure 1. The property of negative refractive index is obtained when both feeds are in phase offset as can be seen in Figure 1. The physical parameters of the ESSR are as follows:

Substrate (RT Duroid 5880)
Thickness = 2 mm
Relative dielectric constant = 2.2
Major axis of outer ellipse (inner side end to end) =78 mm
Major axis of inner ellipse (inner side end to end) =70 mm
Axial ratio= 5.125
Width of strip (each ellipse) =2 mm
Slot cut in each ellipse= 2 mm

RESULTS

The ESSR structure was simulated on HFSS (Ansoft) platform, a commercial finite element based electromagnetic mode solver. With S_{11} and S_{21} thus obtained, values of refractive index, normalized with $1/k_d$ is calculated using equation (1). The $S_{11}$and S_{21}versus frequency curves are shown in Figure 2. Normalized refractive index (obtained from equation (1)) versus frequency curve is shown in Figure 3. It is evident from Figure 3 that the ESRR structure is exhibiting NRIM property (negative real part of refractive index) at multiple bands such as: 1 to 1.22, 1.33 to 1.36, 1.65 to 1.87, 2.12 to 2.50, 2.87 to 3.43, 4.23 to 4.63, 4.95 to 5.23, 5.37 to 5.57, 5.99 to 6.66, 7.21 to 7.96, 8.14 to 8.30, 8.66 to 8.85 and 9.32 to 9.84 GHz, respectively.

The dip in transmission coefficient S_{21}(magnitude) at these frequencies accompanied with zero crossing in phase of S_{21} gives indication of the presence of NRIM property at these frequencies (Sabah, 2010) which was further elaborated by calculating value of refractive index using equation(1).

Conclusion

A new multiband metamaterial resonator using elliptical split rings (ESRR) is demonstrated that exhibits property of negative index of refraction. The conventional SRR shows negative permeability at a narrow magnetic frequency resonant band and to obtain LHM, an additional metallic rod is to be incorporated with the SRR for electrical resonance (negative permittivity) while the ESRR structure gives LHM response (Figure 3) without using any additional metallic rod. This type of ESRR can be easily incorporated with microstrip antennas to get highly directional beam patterns because of NRIM properties of ESRR.

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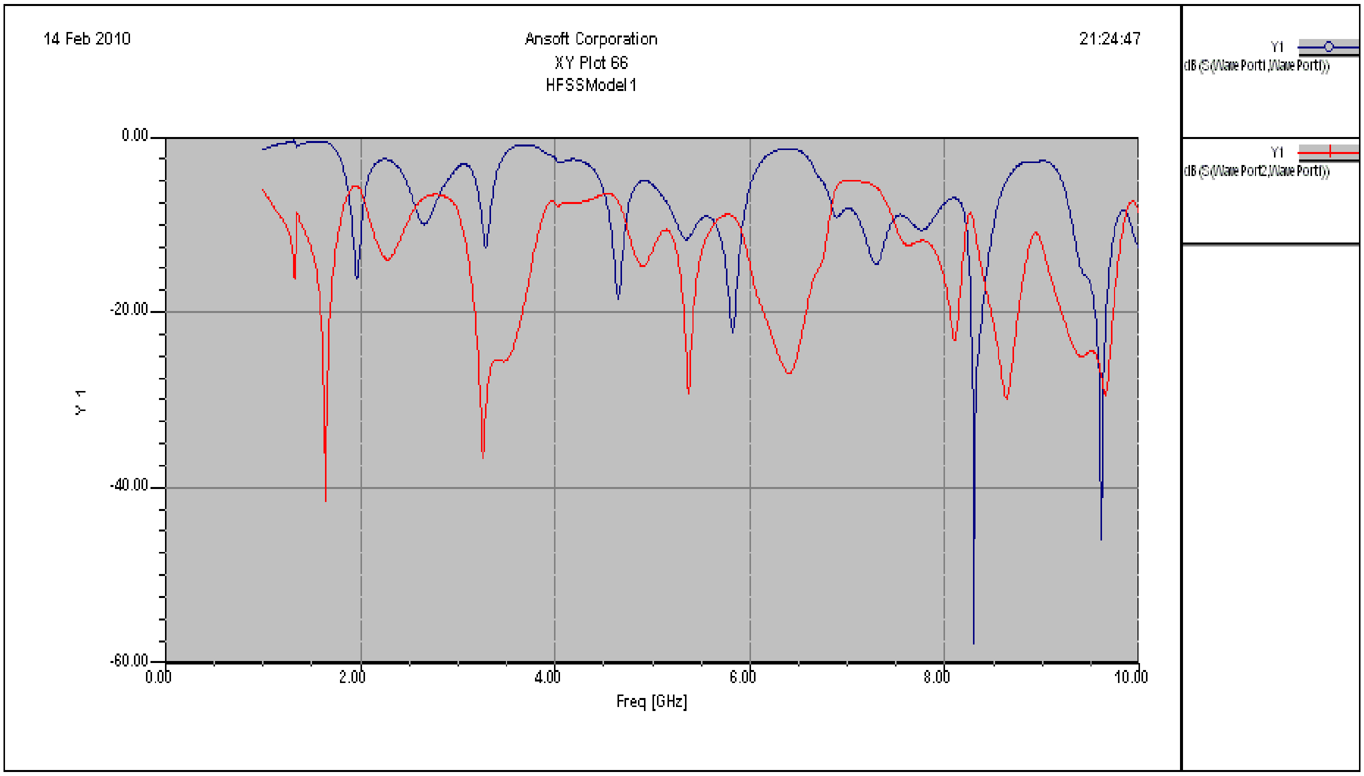
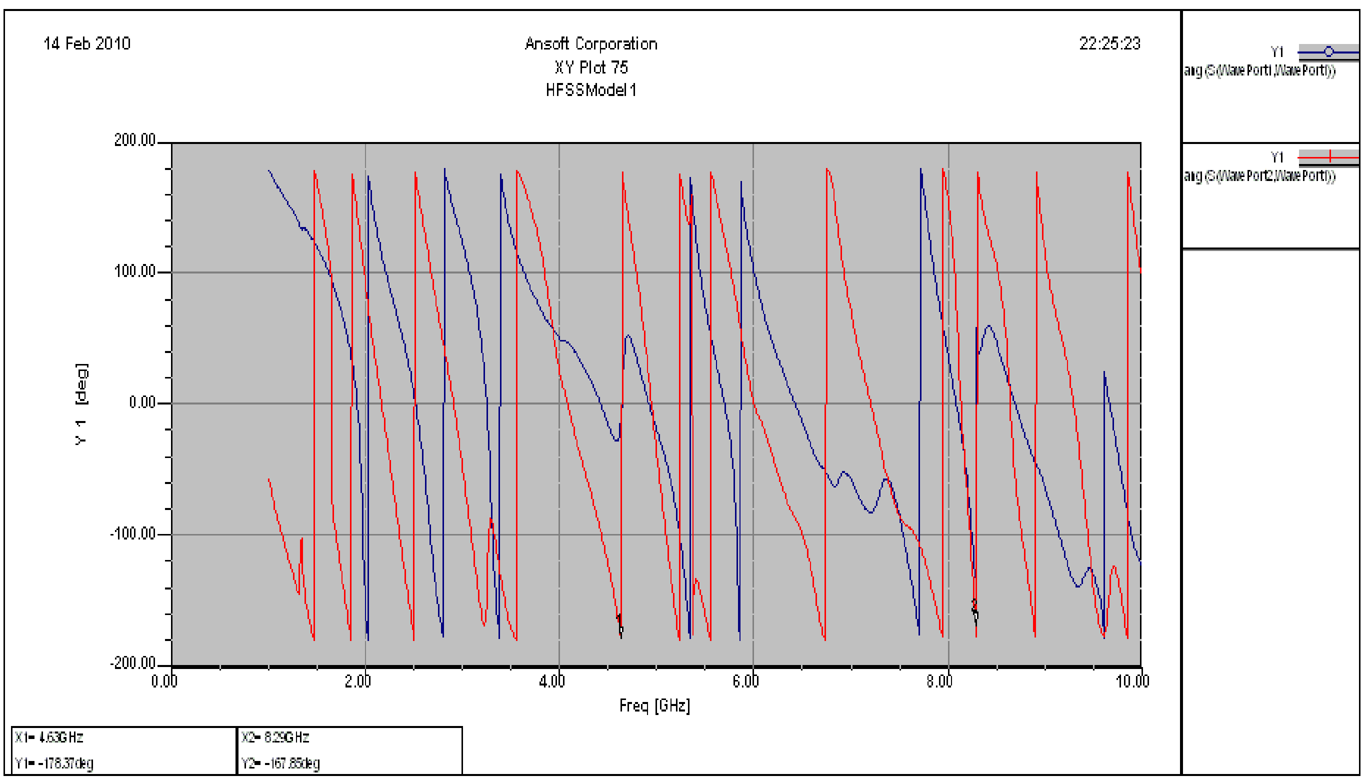


(a)



(b)

Figure 2. a) Magnitude response (red-S_{11}, blue -S_{21}), b) Magnitude Response (red-S_{21}, blue -S_{11}).

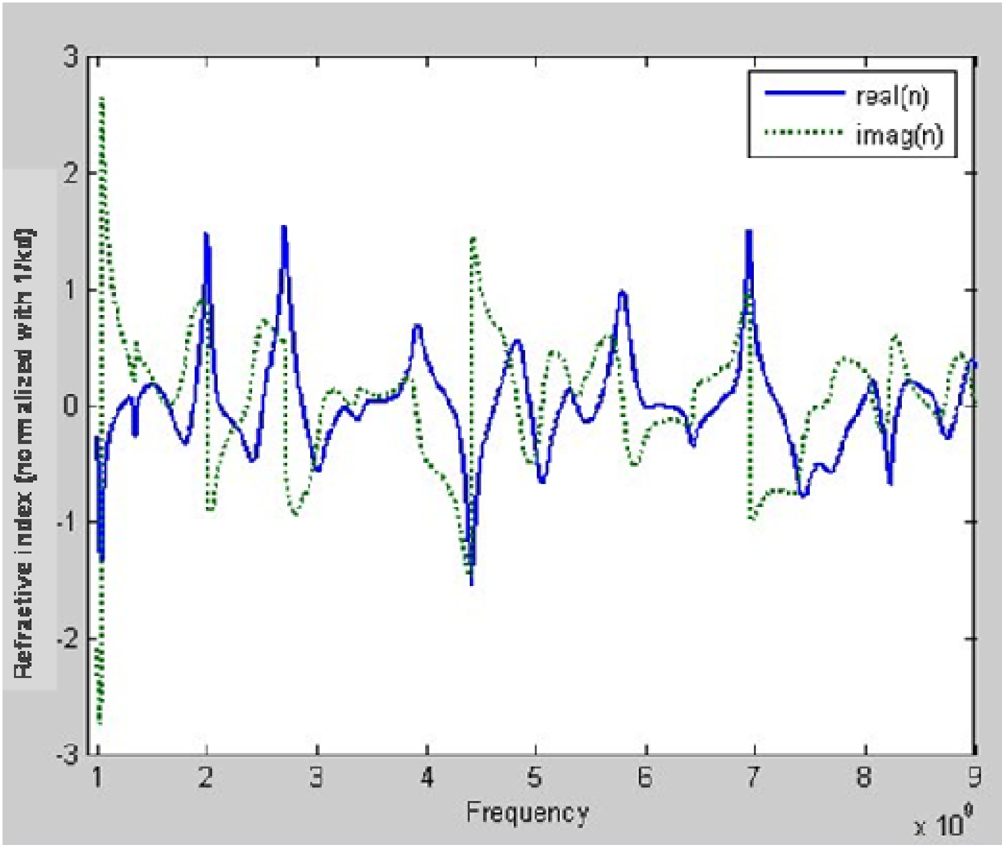


Figure 3. Refractive index versus frequency curve obtained from calculation using Equation (1).

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