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Frequency Reconfigurable Metamaterial Inspired High Gain Antenna

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Abstract: In this paper, we present a design of frequency reconfigurable metamaterial inspired high gain antenna. In this we use an equilateral triangular shaped split ring resonator (ETSRR) with rotated rings. The rings are virtually rotated with the help of Microelectro-mechanical system (MEMS) switches. The ETSRR structure exhibits negative refractive index material (NRIM) property and at the same time ETSRR structure behaves like high gain antenna. When the inner ring of ETSRR is rotated the antenna resonant frequency shits from 8.07 GHz to 8.05 GHz; while by rotation of outer ring the antenna resonant frequency shifts from 8.07 GHz to 8.04 GHz or to 8.08 GHz. Thus we get frequency reconfigurability.

Keywords: Equilateral triangular shaped split ring resonator (ETSRR), MEMS, Metamaterial, Reconfigurable.

1. Introduction

Metamaterials gain tremendous attraction among the research community from the time it was physically implemented by using split ring resonators (SRRs) and metal rod by smith et al. [1]. It has simultaneously negative value of permittivity (ε_{eff}) and permeability (μ_{eff}) over a common frequency band. Metamaterials are also regarded as Double negative medium (DNG) material, Single negative medium (SNG) materials, Left handed materials (LHMs) or negative refractive index material (NRIMs). These materials exhibit the properties not found in natural materials like back propagation, reverse Doppler Effect. The negative values of effective permittivity (ε_{eff}) can be obtained by using metal rod and effective permeability (μ_{eff}) can be obtained by Split ring [2]. Various types of ring type structures like circular, square, U- shaped, S- shaped, Ω- shaped, elliptical shaped [3], phi-shaped [4] have been proposed till now. Triangular shaped metamaterial resonator was first studied by Sabah [5], although now few studies are there in

literature [6-7].Metamaterials were widely used in antenna field to enhance the antenna's performance and in miniaturization of an antenna [8-10]. In this paper, authors present a design of frequency reconfigurable metamaterial inspired high gain antenna based on an equilateral triangular shaped split ring resonator (ETSRR) with rotated outer and inner rings. The rotation of outer and inner rings is achieved by putting splits in each arm of rings and then the position of splits can be made ON/OFF by using RF MEMS switches. By this the resonant frequency gets shifted and thus getting tunability[11]. Compared to PIN diodes and FET transistors, RF MEMS switches have better performance in terms of isolation, insertion loss, power consumption and linearity [12-13].

2. Design

The proposed design of frequency reconfigurable metamaterial inspired high gain antenna is shown in Figure 1. Physical parameters of proposed antenna are: Rogers RT/duriod5880 (Relative permittivity =2.2) with a thickness of 0.8 mm is used as substrate.

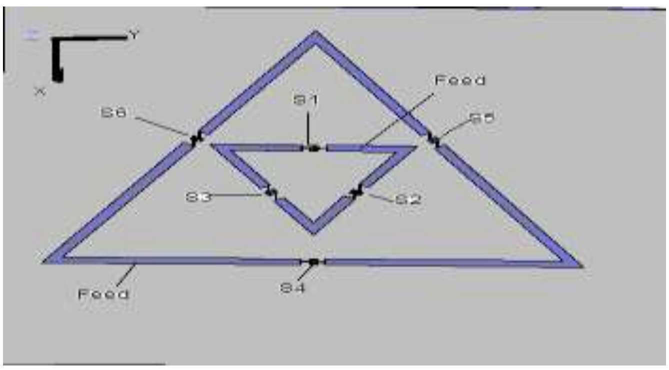


Figure 1: Microstrip ETSRR antenna.

The dimensions of ETSRR are: The dimensions of outer ETSRR base length are 22.52 mm and height is 19.5 mm; 8.66 and 7.52 mm for inner ETSRR. The separation between outer and inner ETSRR is 9.5 mm from vertex of outer ETSRR to base of inner ETSRR. The width of each strip is 0.5 mm. The split gap in each ETSRR is 1.0 mm. Splits are made at each arm of inner and outer ETSRR along with RF MEMS switches placed in each split. Switches S1, S2, S3 are placed in inner ETSRR and switches S4, S5, S6 are placed in outer ETSRR. The structure of RF MEMS shunt switch (Figure 2) consist of thin metal (gold in this case) membrane bridge that is suspended over the central conductor of coplanar waveguide (CPW) and fixed on the ground conductor. The dimensions of shunt switch are: length of the bridge = 200 µm, width of the bridge = 90 µm, thickness of the bridge = 2 µm, silicon nitrate (relative permittivity = 7) is used as the dielectric having a thickness of 0.2 µm, air gap between lower conductor and upper conductor is 0.9 µm.

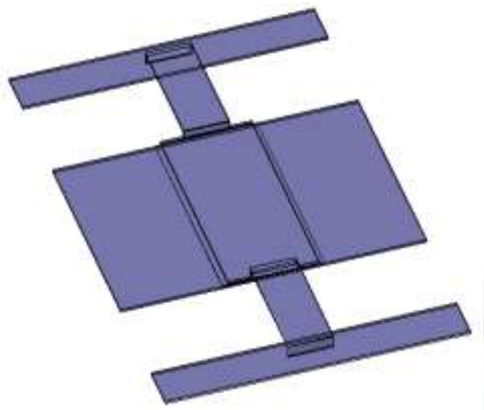


Figure 2: The structure of RF MEMS shunt switch.

When a switch is in ON position in a particular arm, that means there is no split in that particular arm; whereas, when the switch is in OFF position, then it means there is presents of a split in that arm. The rings of ETSRR are coaxial probe fed. The structure is designed and simulated by using Ansoft HFSS simulator, finite element based electro-magnetic mode solver. To show the physical properties of the designed structure, S parameters are obtained by HFSS and real value of refractive index is extracted by using effective parameter retrieval method [14].

3. Analysis And Discussion

F basic configuration of ETSRR (When the switch S4 was OFF in outer ETSRR and switch S1 was OFF in inner ETSRR, while rest of switches were ON), the ETSRR structure exhibiting NRIM property in the frequency regime 2.7 – 4.7 GHz and 5.5 – 8.6 GHz (Figure 3) . Also the structure behaves as a high gain antenna which resonant at a frequency of 8.07 GHz (Figure 4) with a gain of 3.91 dB (Figure 5).

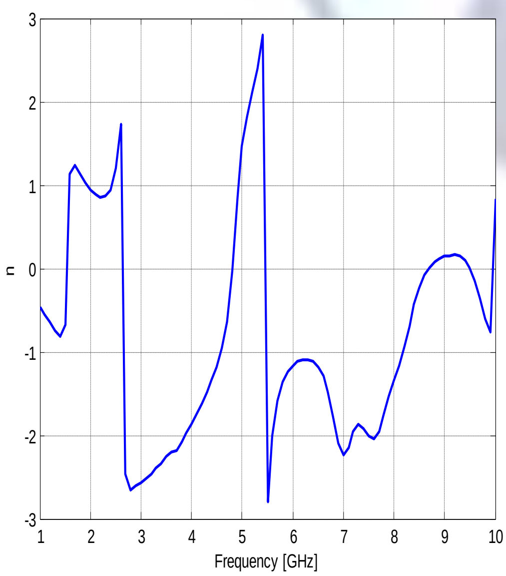


Figure 3: Real value of refractive index of basic configuration of ETSRR.

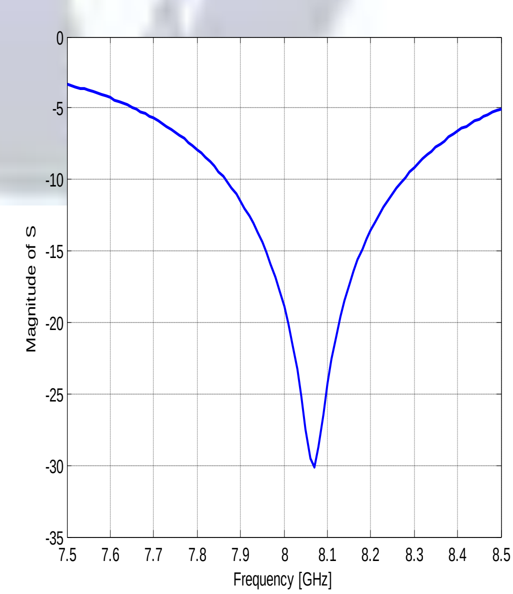


Figure 4: Return Loss of basic configuration of ETSRR

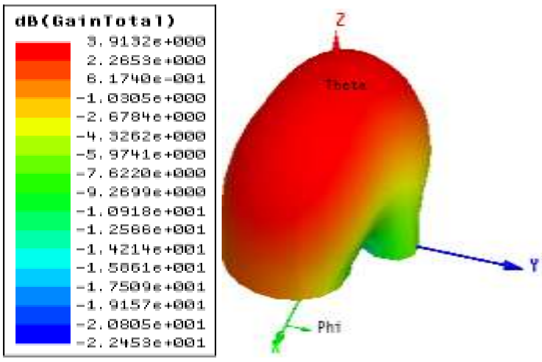


Figure 5: Gain of basic configuration of ETSRR.

When the inner ring of ETSRR is rotated towards left (by making switch S3 and S4 OFF, while rest of switches in ON position); the antenna resonant frequency shifts from 8.07 GHz to 8.05 GHz (Figure 6 Red curve) with a gain of 3.99 dB (Figure 7a). By rotating the inner ring of ETSRR towards right (by making switch S2 and S4 OFF, while rest of switches in ON position); the antenna resonant frequency shifts from 8.07 GHz to 8.05 GHz (Figure 6 Green curve) with a gain of 3.94 dB (Figure 7b).

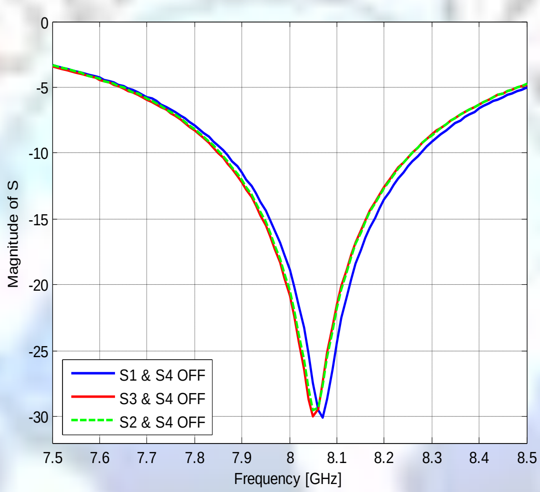
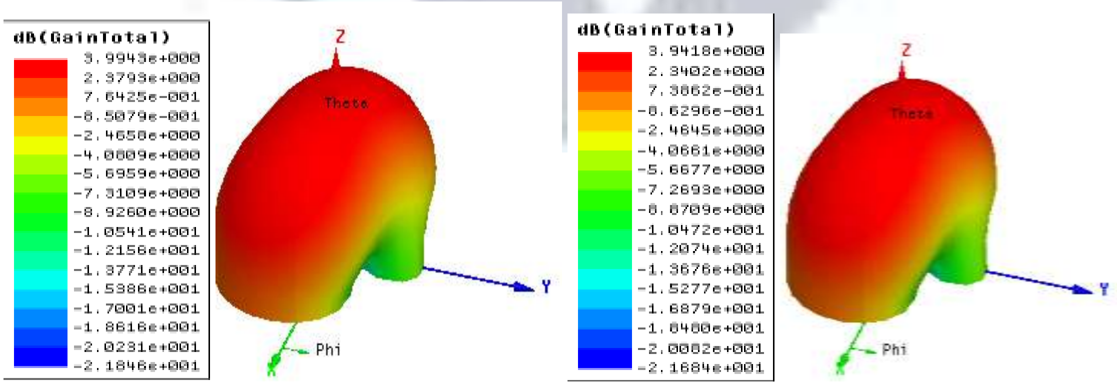


Figure 6: Return Loss of antenna when inner ring of ETSRR is rotated either left or right.



(a) (b)

Figure 7: Gain of antenna when inner ring of ETSRR is rotated (a) left, (b) right.

When the outer ring of ETSRR is rotated towards left (by making switch S1 and S6 OFF, while rest of switches in ON position); the antenna resonant frequency shifts from 8.07 GHz to 8.04 GHz (Figure 8 Red curve) with a gain of 3.99 dB (Figure 9a).

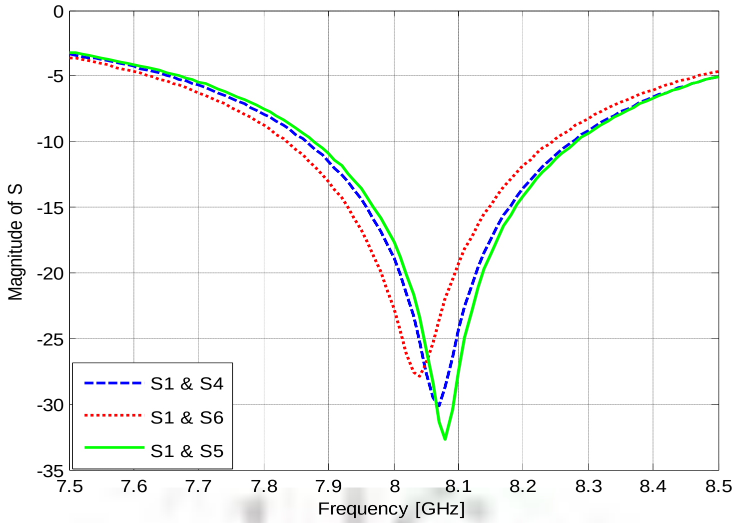
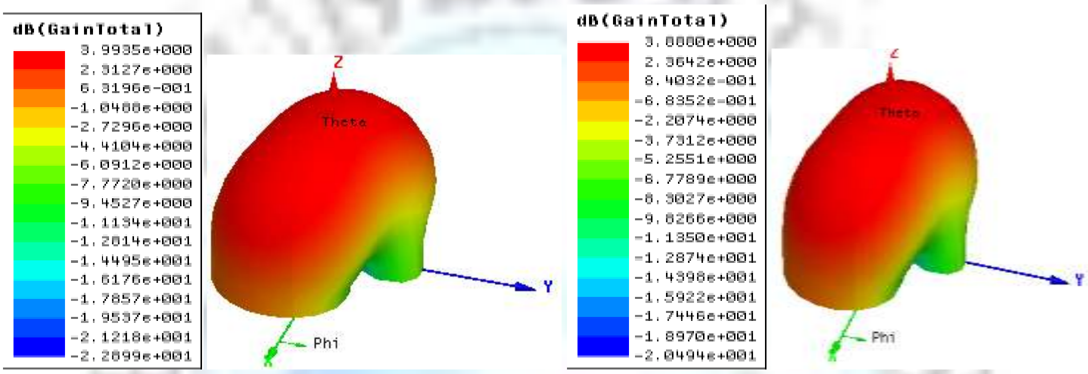


Figure 8: Return Loss of antenna when outer ring of ETSRR is rotated either left or right.



(a) (b)

Figure 9: Gain of antenna when outer ring of ETSRR is rotated (a) left, (b) right.

By rotating the outer ring of ETSRR towards right (by making switch S1 and S5 OFF, while rest of switches in ON position); the antenna resonant frequency shifted from 8.07 GHz to 8.08 GHz (Figure 9 Green curve) with a gain of 3.89 dB (Figure 9b).Thus by rotating the rings of ETSRR by using MEMS switches the resonant frequency of antenna shifts. Thus we get tunability.

Conclusion

In this paper, we present a frequency reconfigurable metamaterial inspired high gain antenna. In this we got frequency reconfigurability by rotating the inner and outer ring of ETSRR. The resonant frequency shifts from 8.07 GHz to 8.05 GHz either by rotation of inner ring towards left or right; whereas by rotation of outer ring either towards left or right, the resonant frequency shifts from 8.07 GHz to 8.04 GHz and from 8.07 GHz to 8.08 GHz respectively. So we get frequency reconfigurability. However the shift in frequency is not much but by optimizes the design we can get much shift.

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