

Characteristics of Microstrip Fractal Antenna Shape Covered by Modified Split Ring Resonator

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Abstract: Metamaterials exhibiting negative index of refraction has attracted a great amount of attention in recent years. These materials are artificial structures that exhibit characteristics not found in nature. Microstrip antennas covered by metamaterial are one of the interesting areas of study. In this paper fractal shape antenna is proposed and covered by two layers of modified split ring resonator. The results shows an enhancement in Reflection Coefficients, gain, directivity and far field shapes.

Keywords: Fractal Antenna, left handed materials, metamaterials, negative refractive index, split ring resonators

I. Introduction

Few years ago, there has been an interest in the study of Metamaterials. It is a class of composite materials, that is artificially constructed to exhibit properties not found in nature. Simultaneously negative permeability and permittivity over certain frequency range are the most important properties of interest. Veselago has studied this type of materials in 1968 [1]. He termed such media as left handed material (LHM) according to the direction of poynting vector and K vector. He mentioned to some unique properties like negative refractive index and backward waves.

Microstrip patch antennas have become one of the most popular antennas because they have many advantages such as low-profile, light weight, low cost of fabrication. The addition of a superstrate layer over microstrip patch antenna (MPA) has been reported to enhance antenna gain and radiation efficiency [2]–[5]. In addition, superstrate layers are often used to protect microstrip patch antenna from its environment hazards, especially when mounted on aircrafts and missiles. Several configurations of superstrates were used to improve antenna radiation properties, such as dielectric slabs [6], electromagnetic bandgap (EBG) structures [7], highly-reflective surfaces [8], and the most recently artificial magnetic superstrates [9].

In this paper we introduce modified split ring resonator by adding more spaces to the open side that acts as capacitors, and use this design as a superstrate of two layers over fractal Quadruple Koch antenna shape. This configuration is shown in Fig.1. Ansoft's HFSS software was used to make simulation which is based on finite element method to solve S - parameters. Notable enhancement of gain and directivity obtained of this model of fractal shape metamaterial antenna.

II. Split Ring Design

Dimensions of the unit cell of split ring are 6 mm side length, 0.4 mm width of side, 0.4 mm width of the middle space and 0.2 mm width of extra spaces. We use three and five extra spaces in our design as shown in Fig.2. Arrangement of three different unit cells are simulate in a waveguide to calculate scattering parameters, meta-cover configuration is shown in Fig.3. Unit cells are etched on FR4 substrate of $\epsilon_r = 4.4$ and 0.25 mm thickness. Relative permittivity, relative permeability and refractive index are determined using Nicolson-Ross-Weir approach [10].

$$\epsilon_r = \frac{2}{jkd} \frac{1-v_1}{1+v_1} \dots \dots (1)$$

$$\mu_r = \frac{2}{jkd} \frac{1-v_2}{1+v_2} \dots \dots (2)$$

$$n = \pm \sqrt{\epsilon_r \mu_r} \dots \dots (3)$$

Where:

$$v_1 = S_{21} + S_{11}$$

$$v_2 = S_{21} - S_{11}$$

$k = \omega/c$, ω = Radian frequency

d = Substrate thickness, n = refractive index

III. Fractal Antenna Design

In this section we will describe the fractal shape generation of the antenna and its meta-cover. The starting shape of the antenna is a square of 28.5 mm side length. The generator is a second iteration of Koch curve applied to each side as shown in Fig.4. Details of Koch curve generating can be found in [11]. Patch antenna etched on substrate of dimensions 58 mm x 58 mm x 2 mm. Material of substrate is FR4 with relative permittivity $\epsilon_r = 4.4$.

IV. Results And Discussion

Ansoft HFSS code is used here to design and simulate fractal antenna model covered by two layers of split ring metamaterial. We introduce different shapes of split ring, having three and five extra spaces. The resonance of each model is shown in Fig. 5, and the relation of each of relative permittivity, relative permeability and refractive index with the frequency is shown in Fig. 6. The refractive index can have negative values without the simultaneous negative values of μ' and ϵ' if the condition, $\mu''\epsilon' + \mu'\epsilon'' < 0$ is satisfied [12]. This condition is plotted with frequency in Fig.7. Fig.5 shows that adding more spaces to the split ring will increase the bandwidth; where refractive index negative is increased too.

Calculations of S-parameters of fractal antenna shape shows that this model has multi band behavior. It resonates at 5.76 GHz, 6.4 GHz and 7.32 GHz. This is shown in Fig.8. Gain and directivity of these three frequencies are listed in Table1. Shapes of radiation patterns are shown in Fig.9. By adding the two layers meta-cover to the antenna, we obtain enhancement of gain and directivity. Results are listed in Table 2. Fig.10 and Fig.11 shows S_{11} and radiation pattern shape respectively of fractal antenna with meta-cover. Fig.12 shows three dimensional far field of the antenna with and without meta-cover.

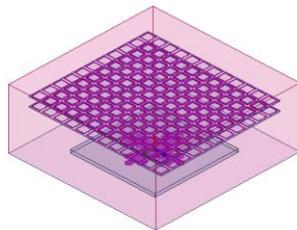


figure1. Configuration of Superstrate Over fractal Antenna Shape

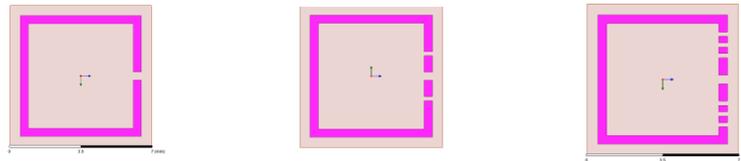


figure2. Modified Split Ring Resonator

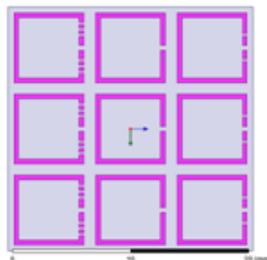


Figure3. Meta-Cover Configuration



figure 4. Fractal Antenna Shape

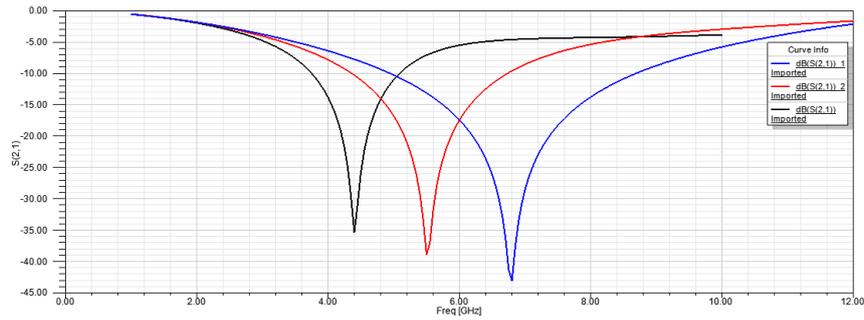


figure 5. S_{21} Vs. Frequency of Split Ring of one, three and five spaces

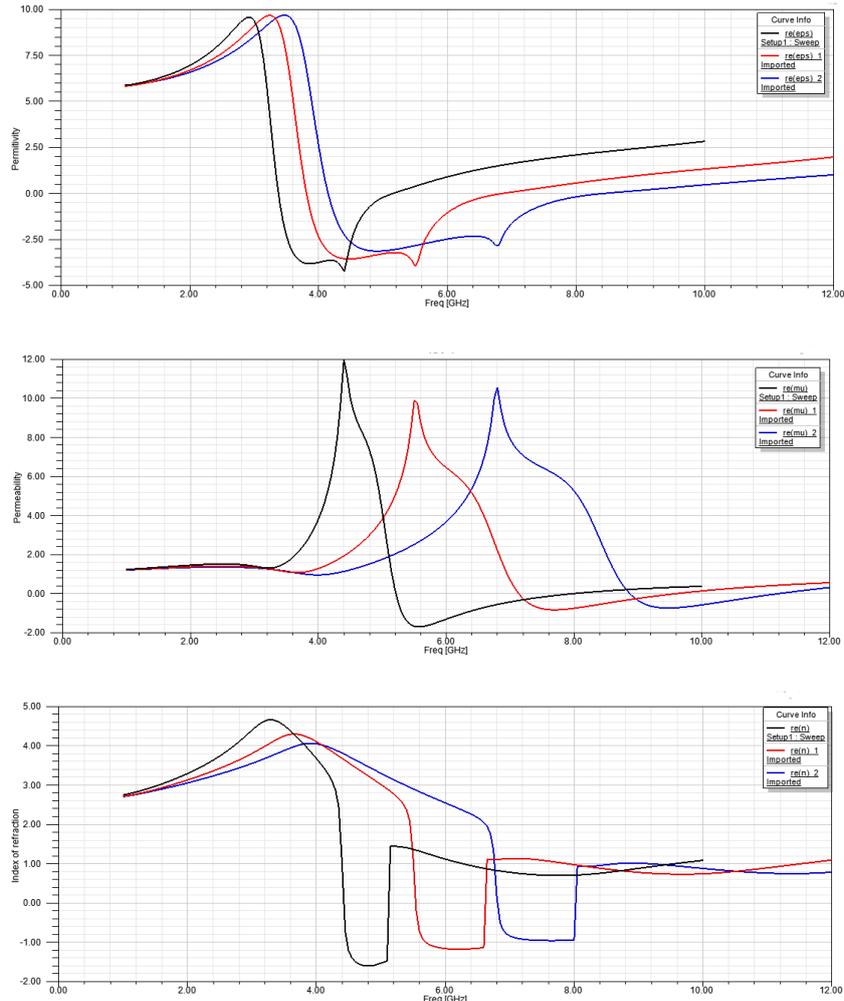


figure 6. Relative permittivity, Permeability, and Refractive index Vs. Freq.

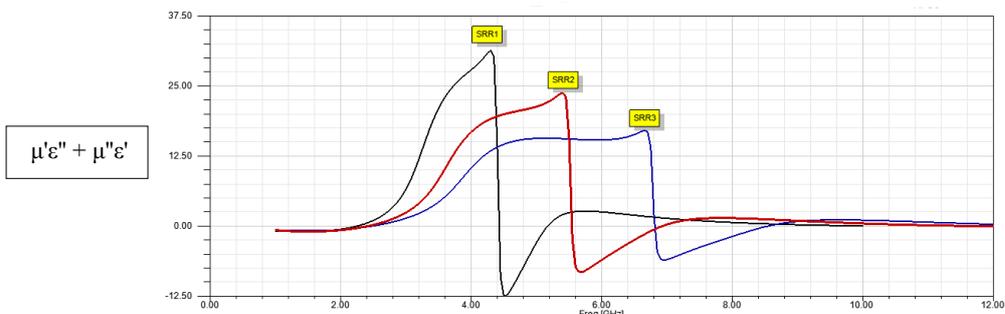


figure 7. $\mu'\epsilon'' + \mu''\epsilon'$ Vs. frequency

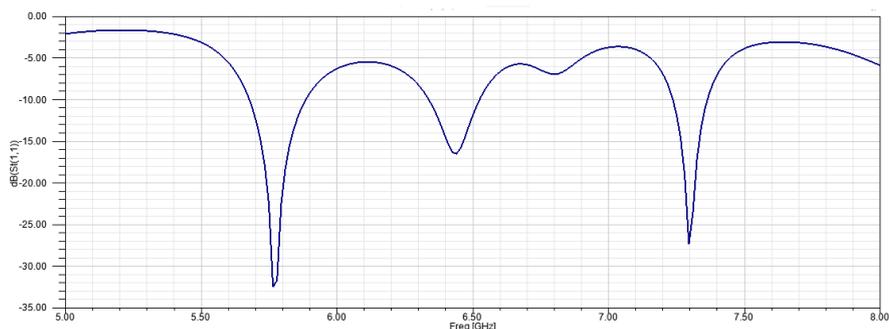


figure 8. S_{11} Vs. Frequency of Fractal Antenna without meta-cover

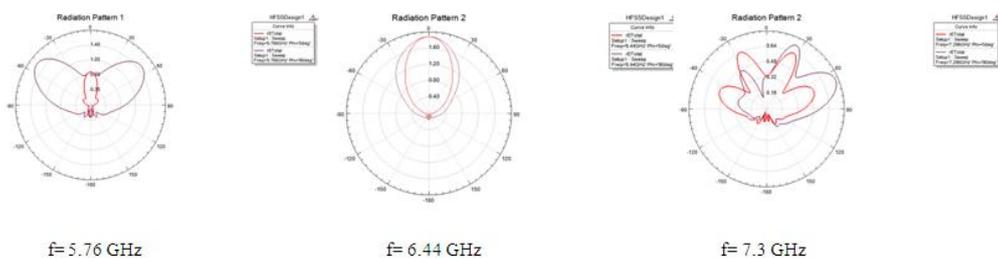


figure 9. Radiation Pattern of Fractal Antenna without meta-cover

Table 1. Fractal Antenna Parameters without meta-cover

| Frequency (GHz) | Gain (dB) | Directivity (dB) | S11 (dB) |
|-----------------|-----------|------------------|----------|
| 5.76 | 6.1 | 8.9 | -32.4 |
| 6.4 | 7.7 | 10.4 | -16.4 |
| 7.29 | 2.1 | 8.1 | -27 |

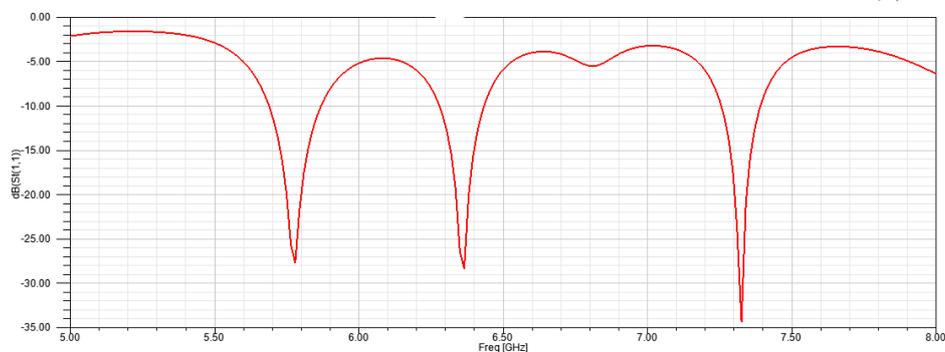


figure 10. S_{11} Vs. Frequency of Fractal Antenna with meta-cover

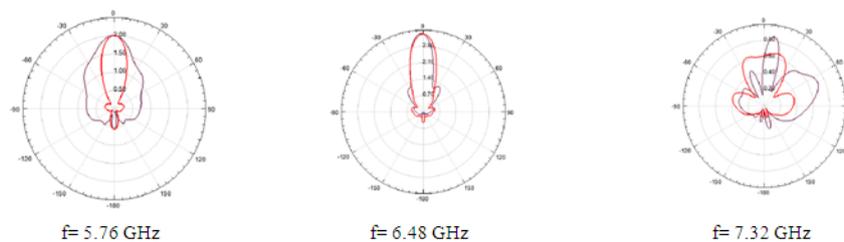


figure 11. Radiation Pattern of Fractal Antenna with meta-cover

Table 2. Fractal Antenna Parameters with meta-cover

| Frequency (GHz) | Gain (dB) | Directivity (dB) | S11 (dB) |
|-----------------|-----------|------------------|----------|
| 5.76 | 8.24 | 11.1 | -27 |
| 6.48 | 12.9 | 15.3 | -29 |
| 7.32 | 2.4 | 8.3 | -34 |

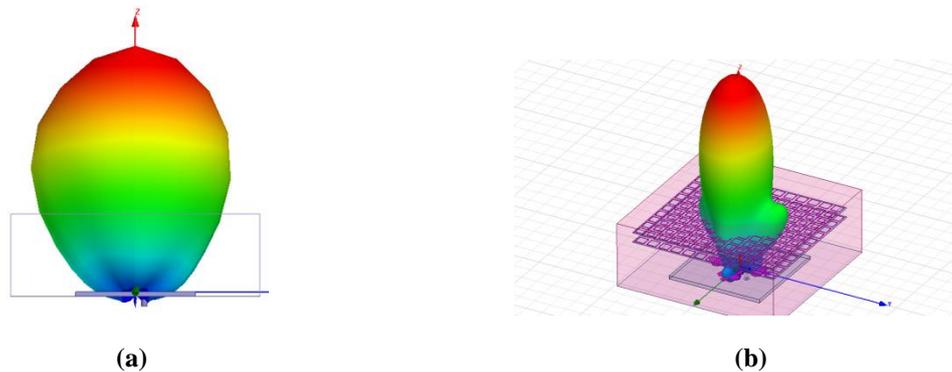


figure12. Three Dimensional Far Field Antenna (a) without meta-cover (b) with meta-cover

V. Conclusion

In this paper we use modified split ring resonator as two layers meta-cover over fractal quadruple Koch shape antenna. Distance between antenna and cover is 25mm. The two layers are separated by 4 mm. Results shows best enhancement in gain and directivity at 25 mm distance between antenna and meta-cover. There is an enhancement and smoothen in far field shape of the antenna. This enhancement of antenna parameters is related to the extra spaces added to the unit cell of meta-cover.

This model is very useful in point to point communication and meta-cover can protect the antenna from environment hazards in addition to enhance antenna parameters.

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