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Fractal Peano Antenna Covered by Two Layers of Modified Ring Resonator

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Abstract

Negative index of refraction has attracted a great attention in literatures. These materials are artificial structures named metamaterials has characteristics not found in nature. Microstrip antennas covered by metamaterial are very interesting areas of study. In this paper fractal Peano shape antenna is proposed and covered by two layers of modified ring resonator. The results show an enhancement in Reflection Coefficients, gain, and directivity.

Index Terms: Metamaterials, left handed materials, split ring resonators, negative refractive index, fractal antennas.

1. Introduction

Few years ago, there is an interest among electromagnetic research groups in the study of Metamaterials as they provide electromagnetic properties not find in natural materials [1]. Simultaneously negative permeability and permittivity over certain frequency range are the most important properties of interest. Veselago while studying this type of materials in 1968 [2], he mentioned to some unique properties like negative refractive index and backward waves. Split ring resonator is regarded as the most known designs to get negative permeability. Several different shapes of split rings are published in literatures to achieve the requirement of negative permeability [3-5].

Classical microstrip patch antennas are the most popular antennas because of several advantages such as low profile, light weight and 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 [6-9]. Several configurations of superstrates were used to improve antenna radiation properties, such as dielectric slabs [10], electromagnetic band gap (EBG) structures [11], highly-reflective surfaces [12], and the most recently artificial magnetic superstrates [13].

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Fractal shapes are utilized in antenna design to improve its parameters. In this paper, we introduce modified ring design by adding more spaces to the open side and use it as a superstrate of two layers over fractal antenna shape. This configuration is shown in Fig.1. HFSS software code which is based on finite element modeling was used to calculate S - parameters. Notable enhancement of gain and directivity obtained from this model of fractal antenna shape.

This paper is containing five sections. First section is representing the introduction of the work. Ring design is discussed in section two. Section three explain the fractal antenna design. Results and discussion are presented in section four. Finally, conclusion of this work is presented in section five.

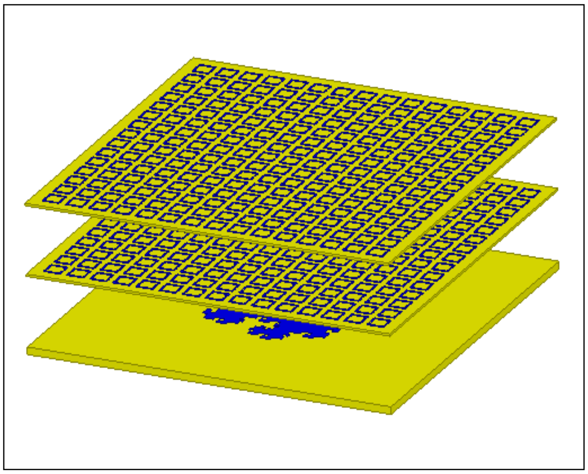


Fig. 1. Configuration of Superstrate Over fractal Antenna Shape

2. Ring Design

Dimensions of single unit cell are 4 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 (SRR1, SRR2, SRR3). Three different unit cells are simulated in a waveguide to calculate scattering parameters. Meta-cover (MTM) configuration is shown in Fig.2.

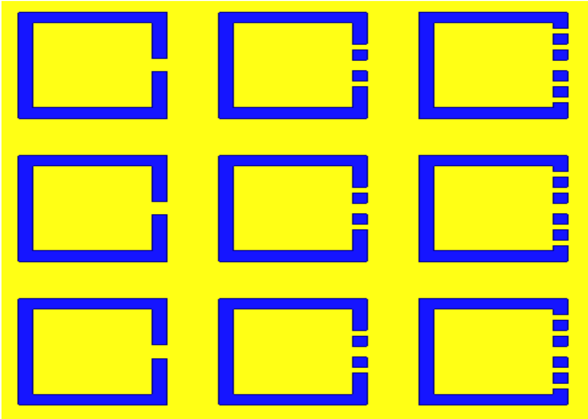


Fig.2. Meta-Cover configuration and unit cell design (SRR1, SRR2, SRR3)

Unit cells are etched on FR4 substrate ($\varepsilon_r = 4.4$) of 0.25 mm thickness. Separation distance between cells is 1.4 mm. 225 cells are distributed to cover the area above Peano antenna. Relative permittivity, relative permeability and refractive index are determined using Nicolson-Ross-Weir approach [14].

$$\varepsilon_r = \frac{2}{jkd}\frac{1-v_1}{1+v_1} \quad (1)$$

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

$$n = \pm\sqrt{\varepsilon_r \mu_r} \quad (3)$$

Where

$$v_1 = S_{21} + S_{11} \quad (4)$$

$$v_2 = S_{21} - S_{11} \quad (5)$$

$$k = {}^{\omega}/_{c} \quad (6)$$

Where ω is the radian frequency, *d* is Substrate thickness, and *n* is the refractive index

3. Fractal Antenna Design

In this section, description of fractal shape generation is presented. The starting shape of the antenna is a square has side length equals to 28.5 mm. The generator is a second iteration of Peano curve. The generator is applied to each side of the square to get the final fractal shape of the antenna as shown in Fig.3. The generator is a straight line divided into three segments, the middle one also divided into three segments. Keeping the middle one and removing its neighbors, and then connecting the middle segment with others by using tuning length called indentation width [15]. The shape we get from this process is the generator as shown in Fig.4. Patch antenna etched on substrate of dimensions 60 mm x 60 mm x 1.6 mm. Substrate material is FR4 with relative permittivity ($\varepsilon_r = 4.4$).

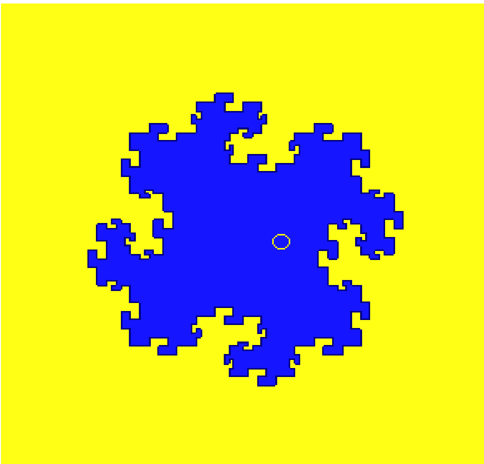
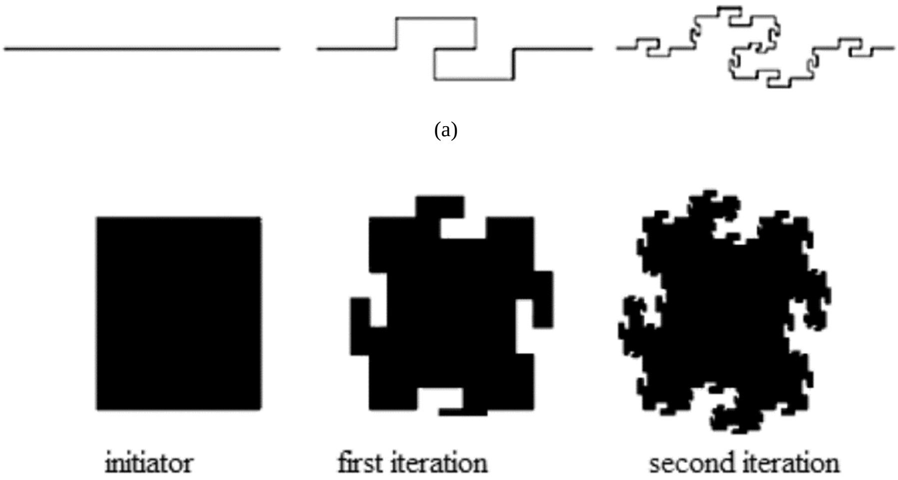


Fig.3. Fractal Peano Antenna Shape



(b)

Fig.4. Generator of Fractal Peano Antenna

4. Results and Discussion

Two layers of modified rings are designed to be superstrate cover over peano patch antenna. We introduce different shapes of rings. The rings have three and five extra spaces. Calculations shows that the best distance of separation between first cover and the patch is 15 mm. The second cover is placed at 15 mm above the first one. Fig. 5 shows the resonance frequency of each model of the rings. Fig. 6 shows relative permittivity, relative permeability and refractive index versus the frequency. From these figures, we can see the resonances and negative refractive index lies in the same range of frequency. The bandwidth of negative refractive index is increased when extra spaces are used in the design. Another way to prove left-handed behavior of the material is dispersion diagram. Fig.7 shows the dispersion diagram of SRR1, SRR2, and SRR3 designs. From this figure, we can see the backward radiation of the rings, which is started at the resonant frequency of each ring. The refractive index may has negative values without the simultaneous negative values of real permeability and permittivity (μ' and ε'). The condition in [16] is utilized to get negative refractive index as seen in (7).

$$\mu'\varepsilon'' + \mu''\varepsilon' < 0 \qquad (7)$$

Where μ',ε' are real part of permeability and permittivity and μ'',ε'' are imaginary part of permeability and permittivity. This condition is plotted versus frequency in Fig.8. Calculations of S-parameters of fractal antenna shape shows a multi band behaviour of this antenna model. It resonates at 7.6 GHz, 8.2 GHz, 10 GHz, and 11.17 GHz. Fig.9 shows the multiband behaviour of the antenna with meta-cover and without it. Gain and directivity of Peano antenna without meta-cover are listed in Table1. Shapes of radiation patterns are shown in Fig.10. By adding the two layers of meta-cover above the antenna, we obtain enhancement of gain and directivity. Enhancement of gain reach to 11.7 dB at 8.2 GHz. Results of gain and directivity are listed in Table 2. Fig.11 shows radiation pattern shapes of fractal antenna with meta-cover. Fig.12 shows three-dimensional far field of the antenna.

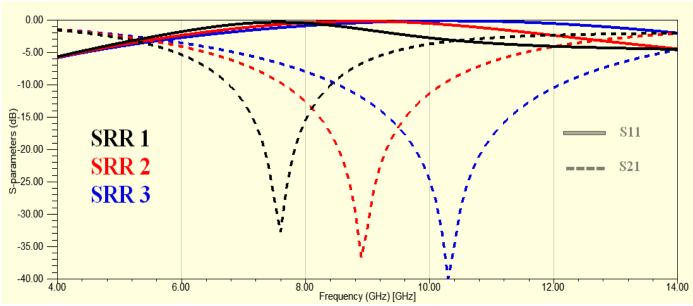
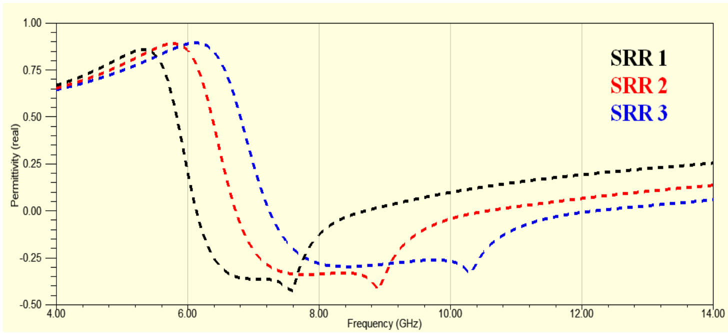
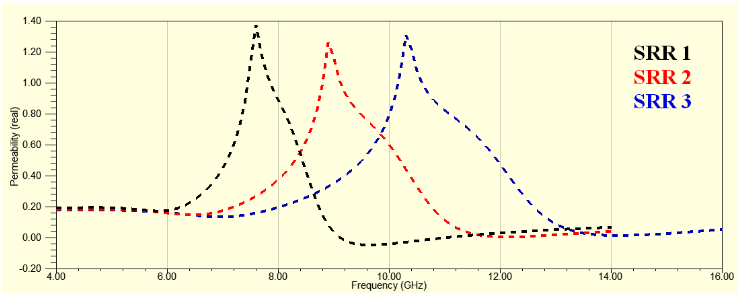


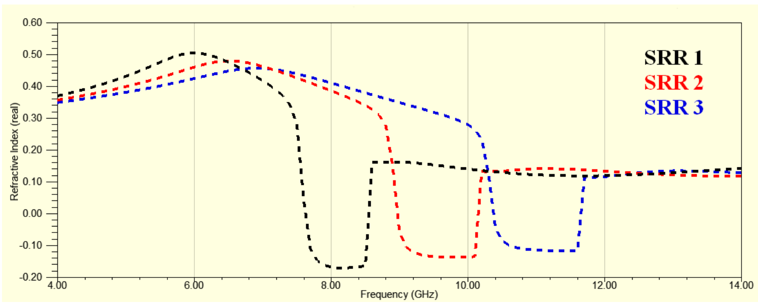
Fig.5. Resonance frequency of SRR1, SRR2, SRR3



(a). Permittivity



(b). Permeability



(c). Refractive Index

Fig.6. (a) Relative Permittivity (b) Relative Permeability (c) Refractive index versus Frequency

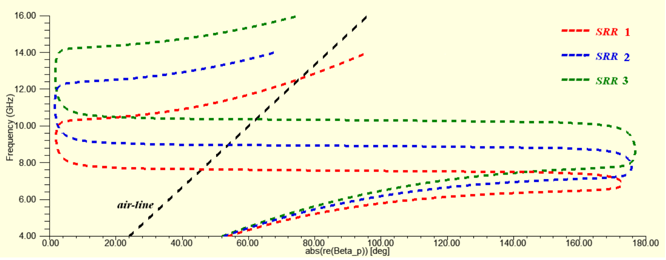


Fig.7. Dispersion diagram

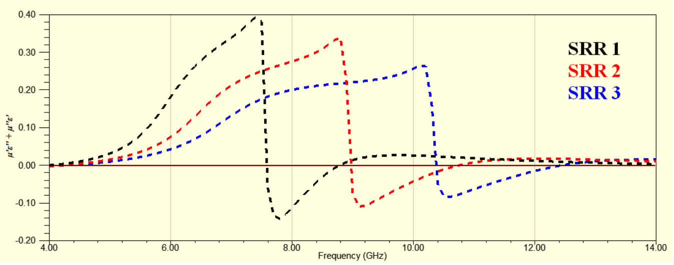


Fig.8. μ'ε'' + μ''ε' versus frequency

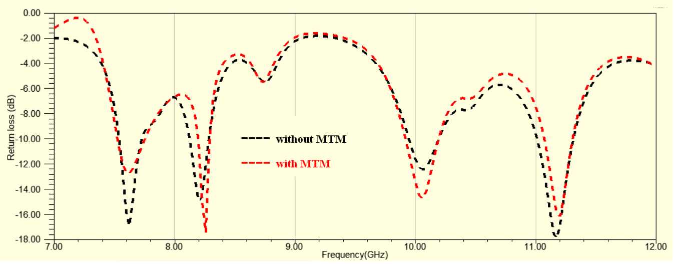
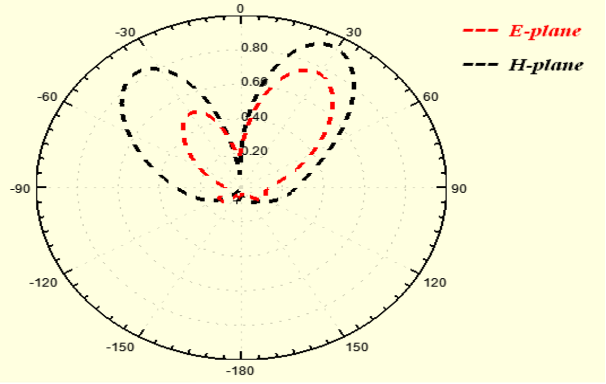
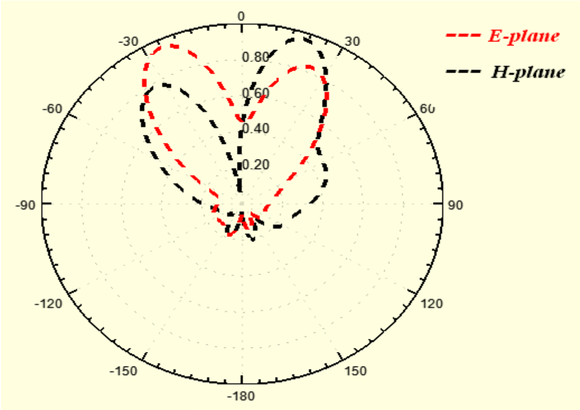


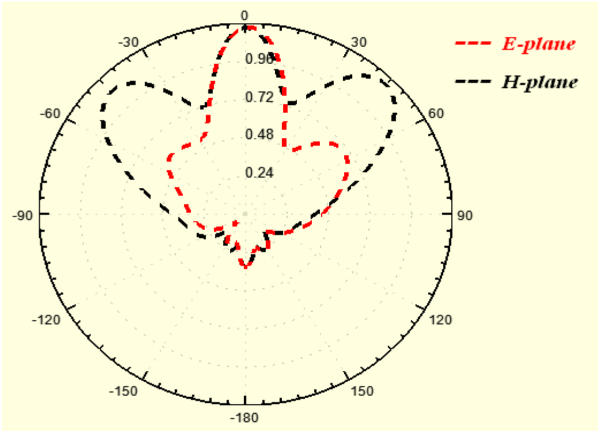
Fig.9. S11versu Frequency of Fractal Antenna without and with meta-cover



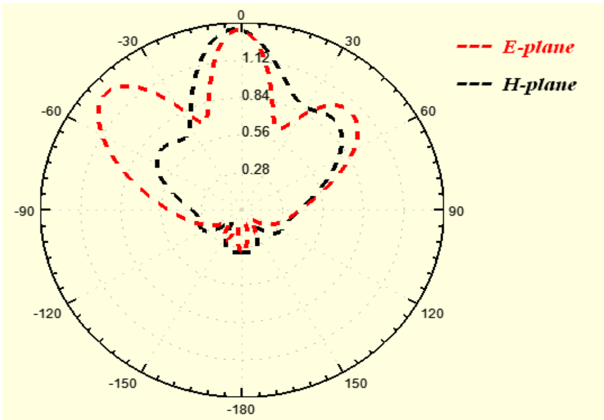
(a)



(b)

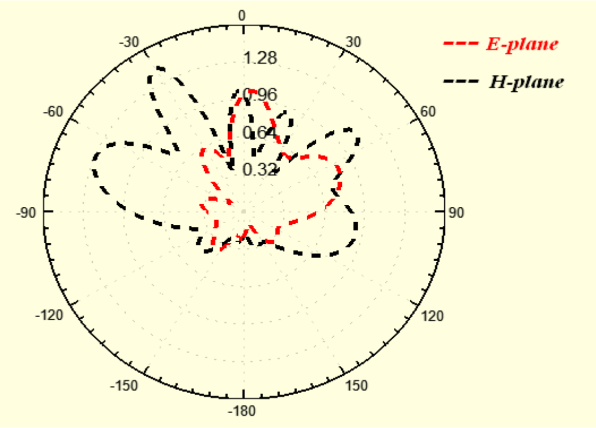


(c)



(d)

Fig.10. Radiation Pattern of Fractal Antenna without meta-cover (a) frequency = 7.6 GHz (b) frequency = 8.2 GHz (c) frequency = 10 GHz (d) frequency = 11.17 GHz


E-plane
H-plane
1.28
0.96
0.64
0.32
0
30
60
90
120
150
-180
-150
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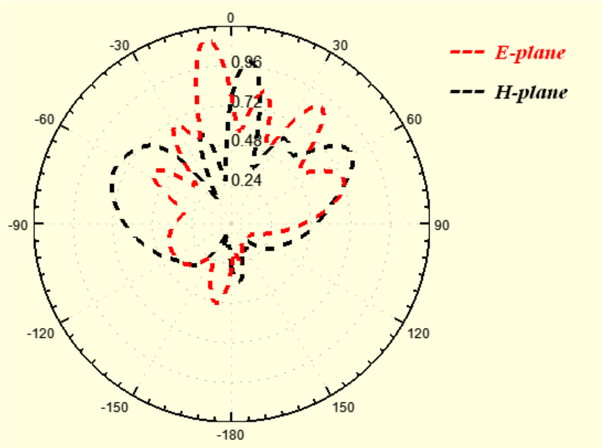
-90
-60
-30

(a)


E-plane
H-plane
0.96
0.72
0.48
0.24
0
30
60
90
120
150
-180
-150
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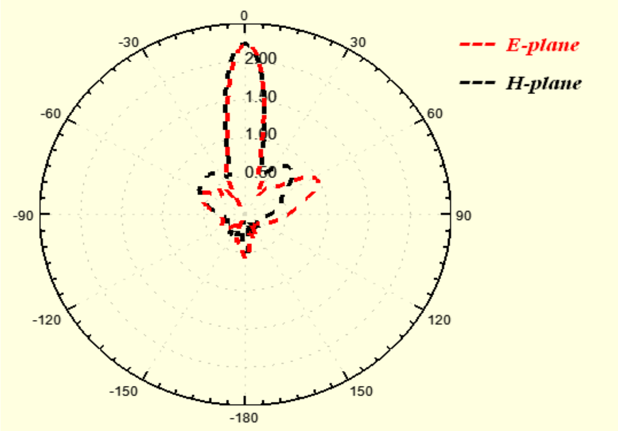
-90
-60
-30

(b)


E-plane
H-plane
2.00
1.50
1.00
0.50
0
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-180
-150
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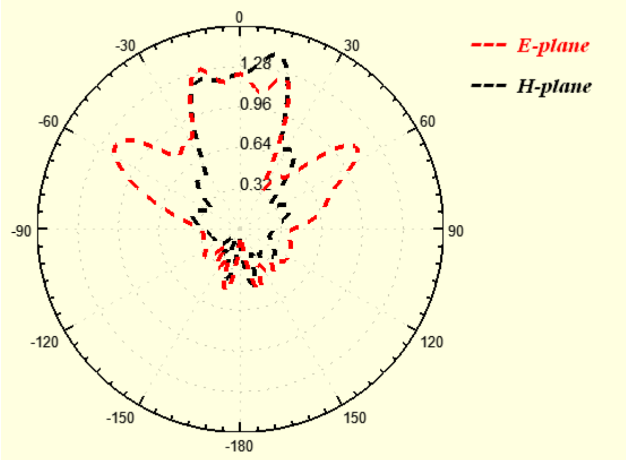
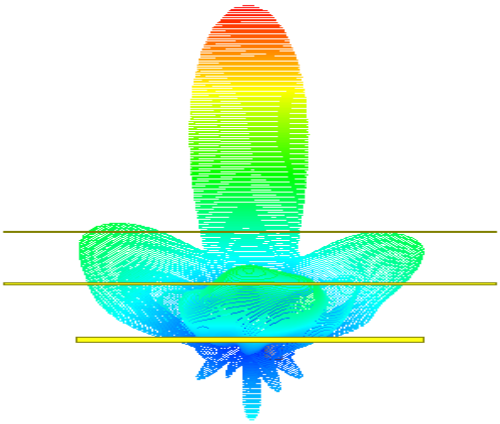
-90
-60
-30

(c)

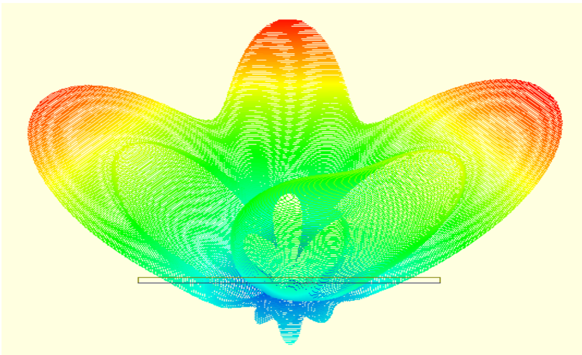


(d)

Fig.11. Radiation Pattern of Fractal Antenna with meta-cover (a) frequency = 7.6 GHz (b) frequency = 8.2 GHz (c) frequency = 10 GHz (d) frequency = 11.17 GHz



(a)



(b)

Fig.12. Three-dimensional far field antenna (a) with mtm (b) without mtm

Table 1. Fractal Antenna Parameters without meta-cover

Frequency (GHz)	Gain (dB)	Directivity (dB)	S_{11} (dB)
7.6	2.3	7.9	-13.9
8.2	3.3	8.6	-13
10	4.1	8	-15.2
11.17	5.7	8.5	-14.5

Table 2. Fractal Antenna Parameters with meta-cover

Frequency (GHz)	Gain (dB)	Directivity (dB)	S_{11} (dB)
7.6	6.7	9.2	-12.7
8.2	11.7	9.2	-17.3
10	9.3	13.7	-14.7
11.17	5.7	9.2	-15.8

5. Conclusions

In this paper we use modified rings as two layers of meta-cover over fractal Peano shape antenna. Distance between antenna and first cover is 15mm. The two layers are separated by 15 mm. Results shows best enhancement in gain and directivity at these distances. 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 enhancing antenna parameters. This model is currently under fabrication. Two other models are currently under investigation and will be discussed in future publications.

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