Sierpinski Carpet Fractal Antenna for Multiband Applications

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ABSTRACT
A Planar antenna with Microstrip feed Sierpinski carpet fractal geometry for multiband applications is presented. The multiband behavior is analyzed through two fractal iterations. Self similarity property of fractal technology is applied in the antenna design to reduce the physical size, increase bandwidth and gain. The proposed antenna covers multi bands such as 1.8/5.59/5.78/6.4/6.63/7.84 GHz. The parameters of the antenna such as radiation pattern, return loss and Gain are simulated using the method of moments (IE3D) software.

General Terms
Fractal, radiation pattern, gain

Keywords
Multiband, Self-similarity, Space filling

1. INTRODUCTION
Fractal is a new class of geometry that was proposed by 'Mandelbrote' [1]. Fractal concepts are employed in the field of antenna engineering to develop new types of antennas with prolific characteristics. Fractal shaped antennas exhibits some interesting features due to their geometrical properties [2]. Surface mounted antennas in cars, trains, aircrafts, satellite etc., needs to be smaller in size, light weight so that it consumes less fuel. Here space filling property of fractal antenna plays a vital role in the miniaturization [3] of antennas. This property is exploited through higher order [4] fractal concept.
Self similarity and space filling properties of fractal antennas is utilized in the design of antennas with notable characteristics like multiband behavior and miniaturization. Self similarity means that an object is build of sub units and subunits on multiple levels which tries to figure out the structure of entire object [5].
Sierpinski carpet antenna[6] based on fractal geometry are low profile antennas, moderate gain and can be operated at multiband of frequencies leads to a multi functional structure. This type of wideband [7] antenna displays high self similarity and symmetry [8].

2. ANTENNA DESIGN
The basic structure of Sierpinski antenna is built from a regular Microstrip patch and runs through several iterations to generate multiband characteristics[9][10].
The width of the microstrip patch antenna is given by [11],

$$Width(W) = \frac{c}{2 f_0} \sqrt{\frac{2}{(\varepsilon_r + 1)}} \tag{1}$$

$$\varepsilon_{reff} = \frac{(\varepsilon_r + 1)}{2} + \frac{(\varepsilon_r - 1)}{2} (1 + 12\frac{h}{W})^{-1/2} \tag{2}$$

$$L_{eff} = \frac{c}{2 f_0 \sqrt{\varepsilon_{reff}}} \tag{3}$$

$$\Delta L = 0.412h \frac{(\varepsilon_{reff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{reff} - 0.258)(\frac{W}{h} + 0.8)} \tag{4}$$

$$Length(L) = L_{eff} - 2\Delta L \tag{5}$$

Where

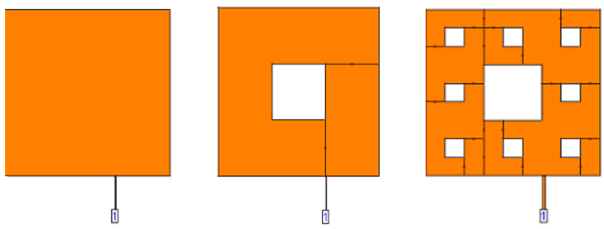
c = Velocity of light in free space.

f_0 = Operating resonant frequency.

ε_r = Dielectric constant of the substrate used.

ε_{reff} = Effective dielectric constant.

h = Height of the substrate.



(a) (b) (c)

Figure 1: Antenna Layout (a) Zero iteration (b) First iteration (c) Second iteration

The Substrate chosen for implementing this antenna is FR4 of thikness 1.59 mm and tan δ =0.012. The length of the square patch is found to be 37 mm.

Let Nn be the number of black boxes, Ln is the scale factor for length of a side of white boxes, An is the scale factor for fractional area of black boxes after the nth iteration[12].

$$N_n = 8^n \quad (6)$$

$$L_n = (1/3)^n \quad (7)$$

$$A_n = L_n^2 N_n = (8/9)^n \quad (8)$$

First iteration of Microstrip carpet structure is designed by dividing a square into nine smaller squares. Then the square at the center is eliminated which results in 8 squares.

$$L_n = (1/3)^1 = 0.33 \quad (9)$$

L_1 is the scale factor for first iteration. The length of the small square is determined by taking the product of L_1 and actual size of a square i.e 36.875mm. Length of small square is 12.3. The A_1 is the scaling factor for the fractional area after performing first iteration. For basic square patch antenna, the area (A_0) is 37x37 mm^2. The area of the small square at the center is 12.3x12.3= 151.29 mm^2.This smaller square is removed and hence the effective area becomes

$$Area_1 = 1369 - 151.29 = 1217.77 mm^2 .$$

$$A1 = \frac{Area_1}{A_0} = 0.889 \quad (10)$$

Hence the antenna area is reduced by 11.1%.

Similarly after second iteration size is further reduced by 20.8%.[13]

3. RESULTS AND DISCUSSION

Initially the square was designed and simulated. Then Sierpinski carpet fractal geometry is used and two iterations were performed and simulated using IE3D software [14]. For optimization, simulation have been repeated at various feed positions.

3.1 Zero Iteration

The figures 2, 3 and 4 show the simulation results of zero iteration. The square patch resonates at the frequency of 1.8 GHz with a return loss of -33 dB.

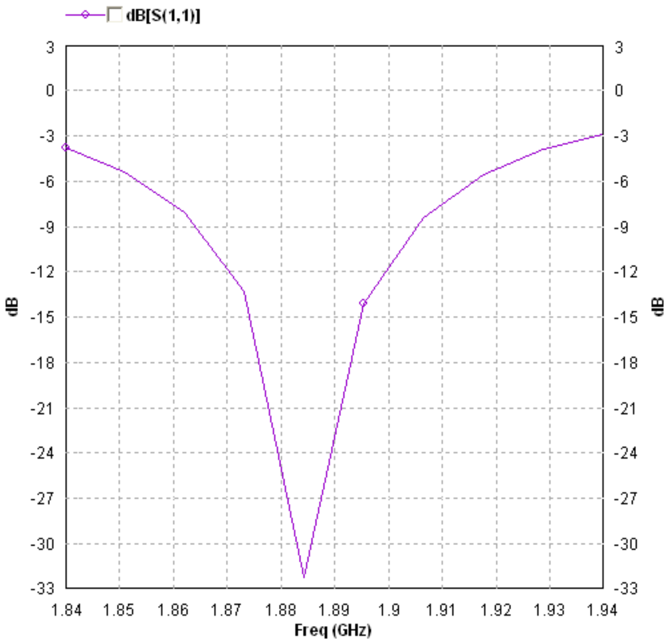


Fig 2 : Return Loss for iteration 0

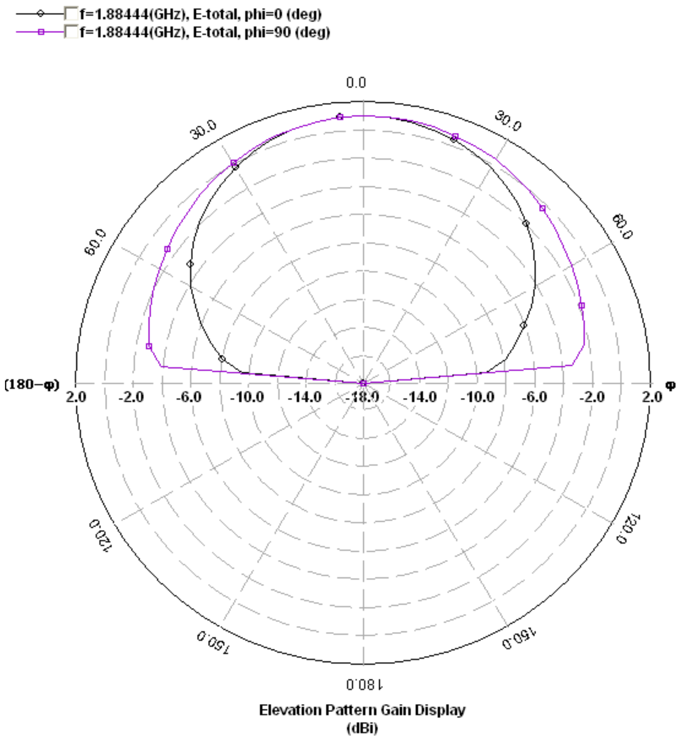


Fig 3 : Elevation Pattern for iteration 0

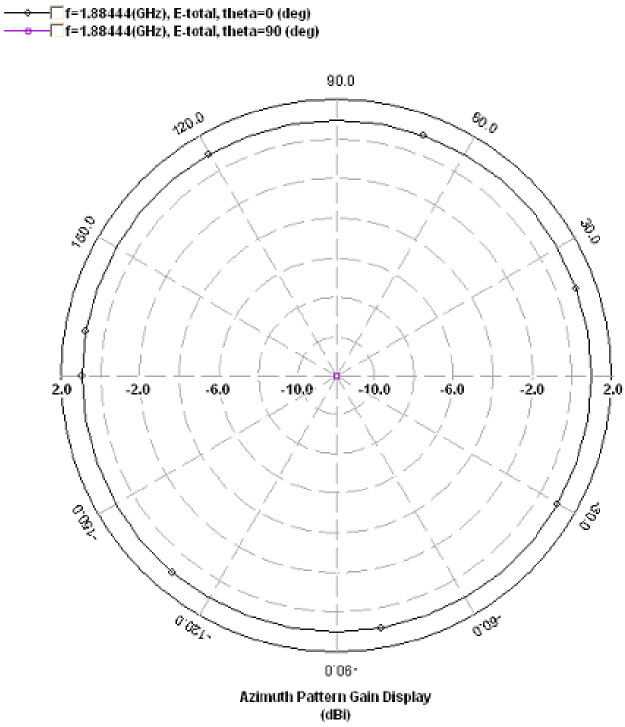


Fig 4 : Azimuth Pattern for iteration 0

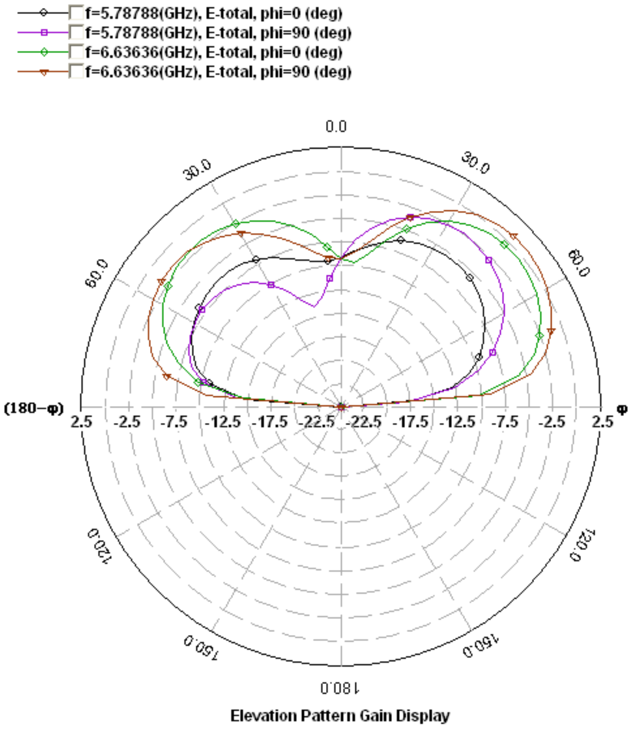


Fig 6 : Elevation Pattern for iteration 1

3.2 First Iteration

The first iteration of the fractal antenna is performed and its simulated results are shown in figure 5, 6 and 7. After first iteration the Sierpinski carpet antenna resonates at two different frequencies namely 5.78 GHz and 6.63 GHz with the better return loss of -14.09 dB and -22.63 dB respectively.

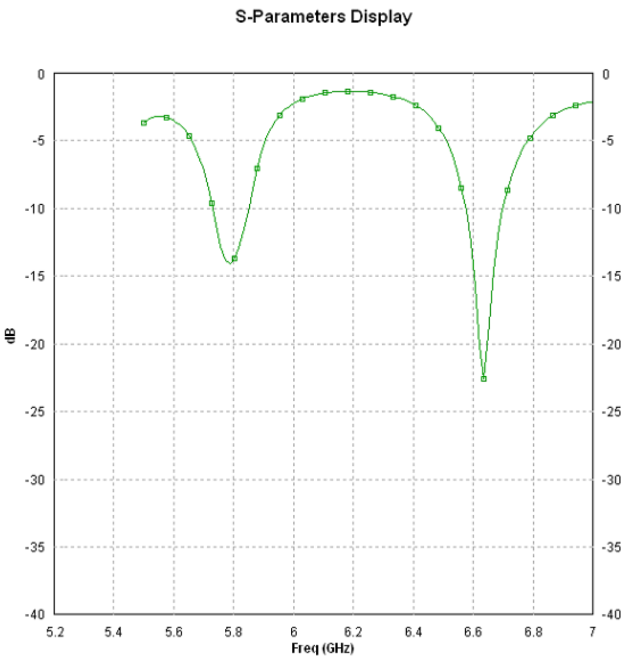


Fig 5 : Return Loss for iteration 1

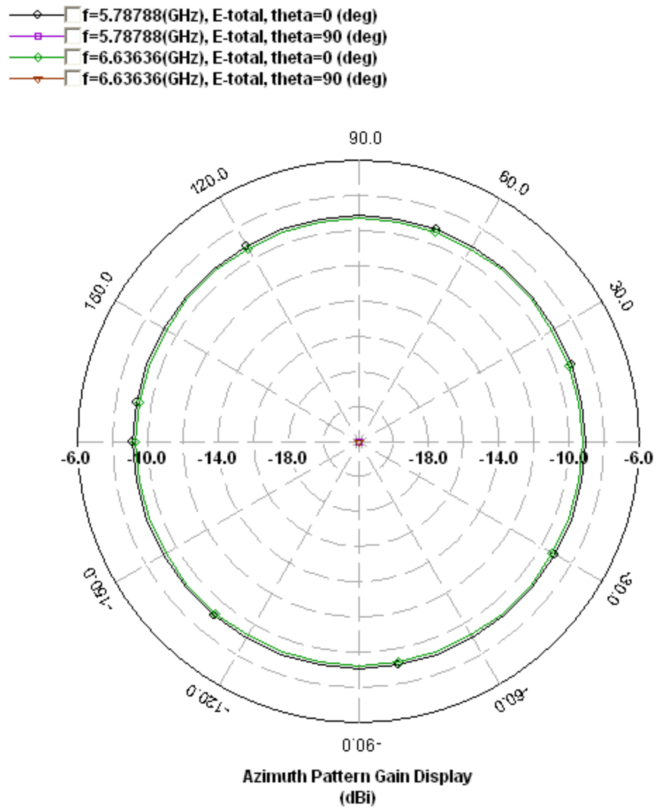


Fig 7 : Azimuth Pattern for iteration 1

3.3 Second Iteration

Sierpinski carpet antenna has gone through the second iteration to exhibit the multiband characteristics at 5.59 GHz, 6.4 GHz and 7.84 GHz with the return loss of -16.86 dB, -15.15 dB and -18.87 dB respectively. The simulation results are shown in figure 8, 9 & 10.

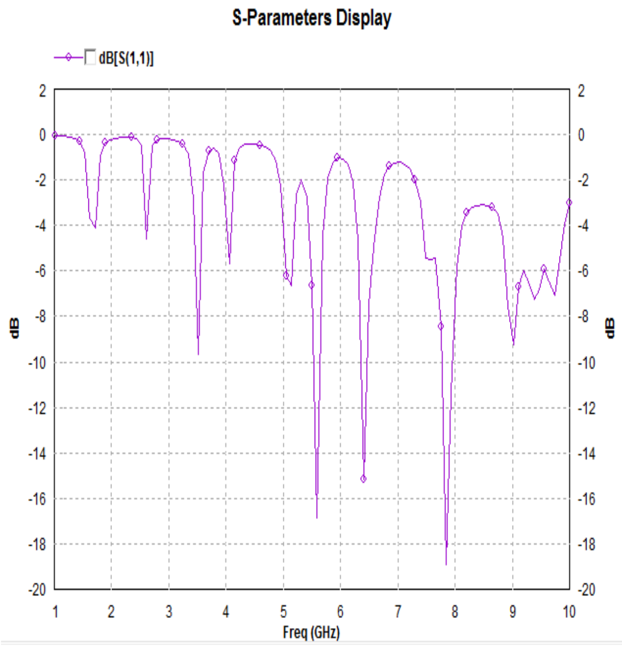


Fig 8 : Return Loss for iteration 2

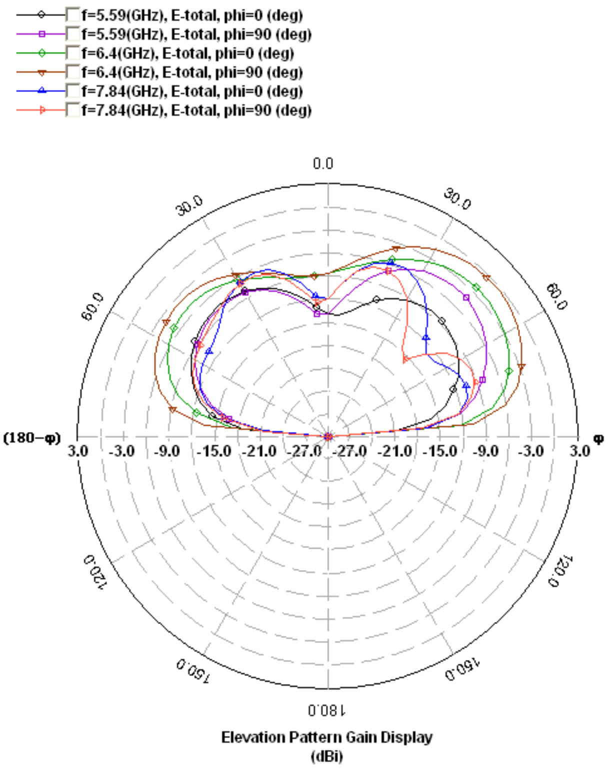


Fig 9 : Elevation Pattern for iteration 2

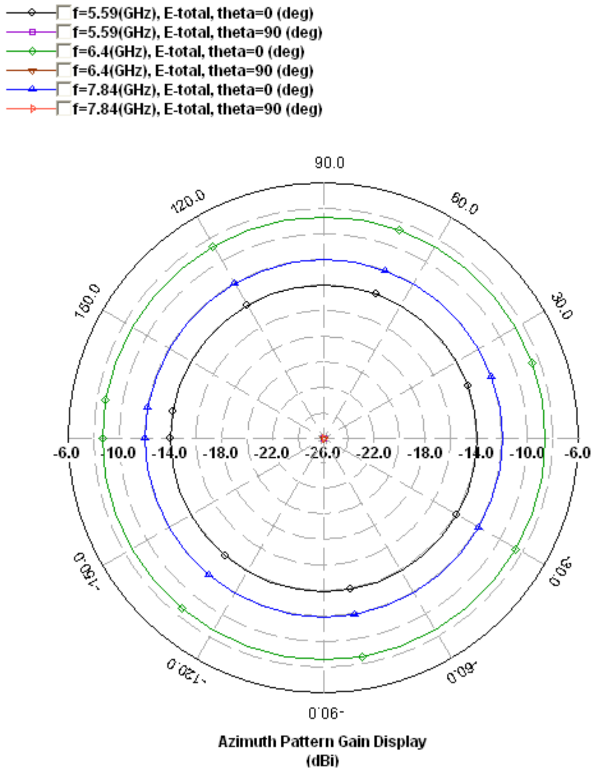


Fig 10 : Azimuth Pattern for iteration 2

4. CONCLUSION

The Microstrip Sierpinski carpet fractal shape antenna is designed for multiband operation has been presented. The simulated result shows that the antenna is suitable for 1.8/5.59/5.78/6.4/6.63/7.84 GHz wideband applications. Microstrip Sierpinski carpet antenna is designed and iterated up to second iteration to exhibit multiband behavior. To overcome the problem in the positioning of antenna feed for higher iterations, Aperture coupling can be employed.

5. ACKNOWLEDGMENTS

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