Design of a Rectangular Sierpinski Carpet Fractal Antenna for Multiband

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ABSTRACT

Fractals have the property of self-similarity, generated by iterations, which means that various copies of an object can be found in the original object at smaller size scales. A fractal is a rough or fragmented geometric shape that can be subdivided into parts, each of which is (at least approximately) a reduced size copy of the whole. Fractal antenna is capable of operating with good-to-excellent performance at many different frequencies simultaneously. Normally standard antennas have to be "cut" for the frequency for which they are to be used and thus the standard antennas only work well at that frequency. This paper represents a basic study of a simple fractal patch antenna with sierpinski carpet design for multiband operation which covers two frequency bands 1.8GHz and 2.29 GHz.

Key words: *Fractal, Iteration, Multiband.*

I. INTRODUCTION

Modern telecommunication systems require antennas with wider bandwidths and smaller dimensions as compared to the conventional antennas. This was beginning of antenna research in various directions; use of fractal shaped antenna elements was one of them. Some of these geometries have been particularly useful in reducing the size of the antenna, while others exhibit multi-band characteristics. Several antenna configurations based on fractal geometries have been reported in recent years [1] – [4]. These are low profile antennas with moderate gain and can be made operative at multiple frequency bands and hence are multi-functional.

According to Webster's dictionary, a fractal is defined as being "derived from the latin fractus" which means broken, irrespective of various extremely irregular curves or shapes that repeat themselves at any scale on which they are examined.

The term "Fractal" means linguistically "broken" or "fractured" from the Latin "fractus." The term was coined by Benoit Mandelbrot, a French mathematician about 20 years ago in his book "The fractal geometry of Nature" [5]. Names like G. Cantor (1872), G. Peano (1890), D. Hilbert (1891), Helge von Koch (1904), W. Sierpinski (1916) Gaston Julia (1918) and other personalities played an important role in Mandelbrot's concepts of a new geometry. Nathan Cohen, professor at Boston University built the first known fractal antenna in 1988. Cohen's efforts were first published the first scientific publication about fractal antennas in 1995, since then a number of patents have been issued.

Fractal is a geometrical shape that has the property of self-similarity, which means, each part of the shape is a smaller version of the parent shape or original shape. Fractals can be classified as natural and mathematical fractals.

II. ANTENNA CONFIGURATION

A. Working Principle

In fractal antenna coupling between sharp angles produce different current paths achieving multi band operation. Most of the miniaturization benefits of the Fractal Antenna occur within the first five iterations with very little changes in the characteristics. In the fractal antenna higher iterative geometries exhibits lower resonant frequencies. The graph of resonant frequency versus fractal iteration is given below.

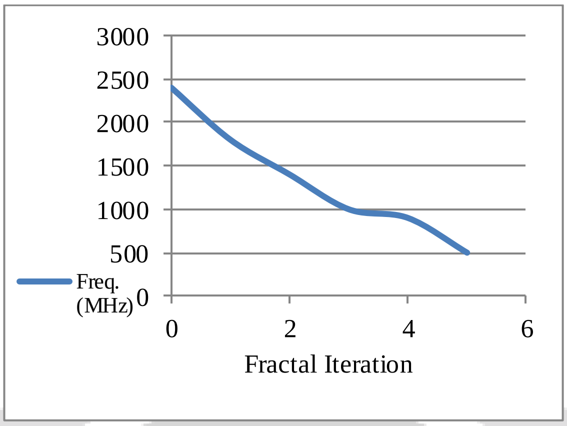

Fig. 1 Fractal Iteration versus Resonant Frequency

B. Design Steps of Rectangle Patch Antenna Co-ax feed

Since we know that the length of the patch and operating frequency has a direct relation, any of them has to be defined in the very beginning. We will try to design an Antenna for S band navigation applications i.e. 2.4GHz of operating frequency. In this project, High Frequency Structure Simulator (HFSS) Version 13.0 of Ansoft Corporation is used for design, simulations and results extraction of antennas.

Step 1: Designing a Rectangle of Length 38mm, Width of 28mm and applying feed point.

Step 2: Adding substrate having thickness 1.6mm and permittivity 4.4mm.conductor used is copper.

Step 3: Frequency Plan of 0.5 to 3.5GHz.

For calculating width and length of Patch Antenna following equations are used.

f_0 = 2.4 GHz

$\lambda_0 = \frac{c}{f_0} = 125\ mm$

For Material FR4, $\varepsilon_r = 4.4$

Height of substrate, h = 1.6 mm

Width of Patch,

$$W = \frac{c}{2 f_0 \sqrt{\frac{\varepsilon_r + 1}{2}}} \quad (2.1)$$

$$= \frac{3 \times 10^8}{2 \times 2.4 \times 10^9 \times 1.64} \quad (2.2)$$

$$W = 38.03\ mm \quad (2.3)$$

Length of Patch,

$$L = 29.44\ mm \quad (2.4)$$

C. Rectangle Patch

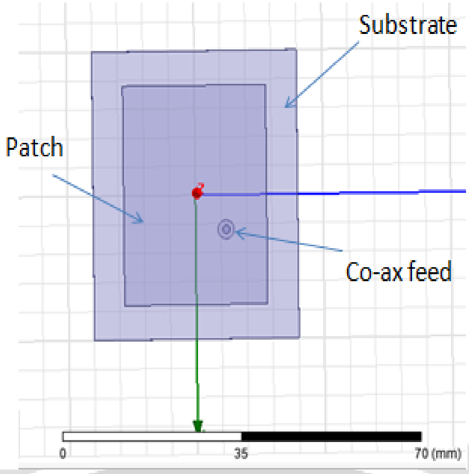

Fig. 2 Rectangular Patch Design

Object	Height(mm)	Width(mm)	Length(mm)
Patch	0.035	38	28
Ground plane	-	50	40
Substrate	1.6	50	40

Table 1 Dimension of patch

Feed Location is (6,6,0)

Level 1 (Design 1)

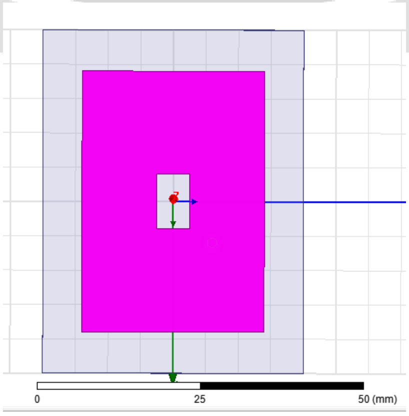

Fig. 3 1st Iteration Design

Object	**Height (mm)**	**Width (mm)**	**Length (mm)**
1st Iteration	0.035	8	5

Table 2 Dimension of 1st iteration

Level 2 (Design 1)

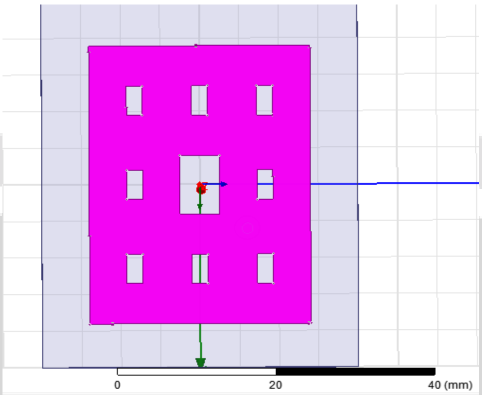

Fig. 4 2nd iteration Design

Object	Height (mm)	Width (mm)	Length (mm)
2nd Iteration	0.035	4	2

Table 3 Dimension of 2nd iteration

III. SIMULATION AND MEASURED RESULTS

A. Simulated Results

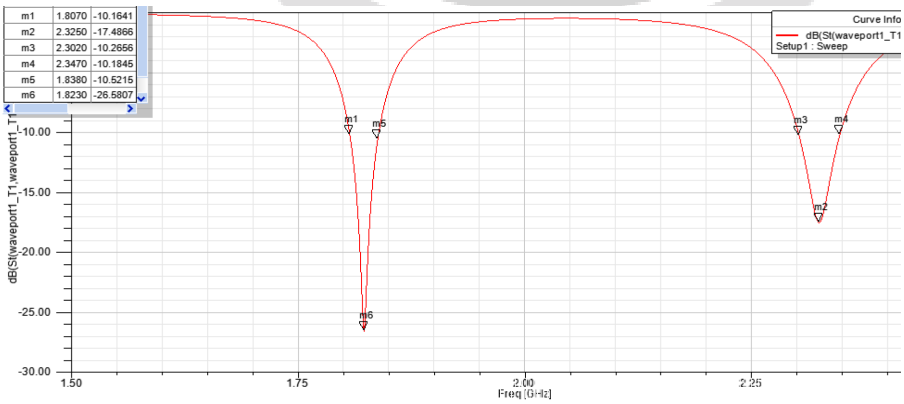

Fig. 5 graph of Return loss vs frequency

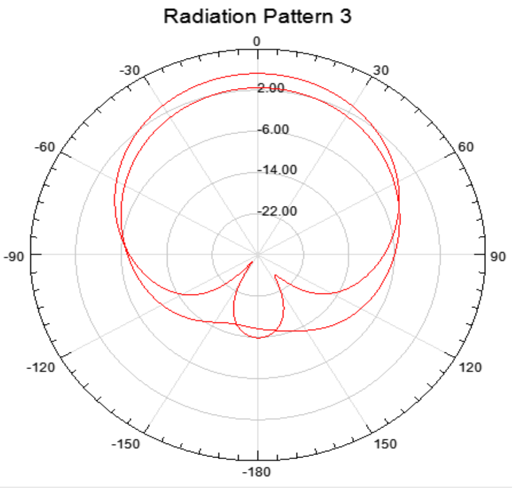

Fig. 6 Radiation pattern of gain

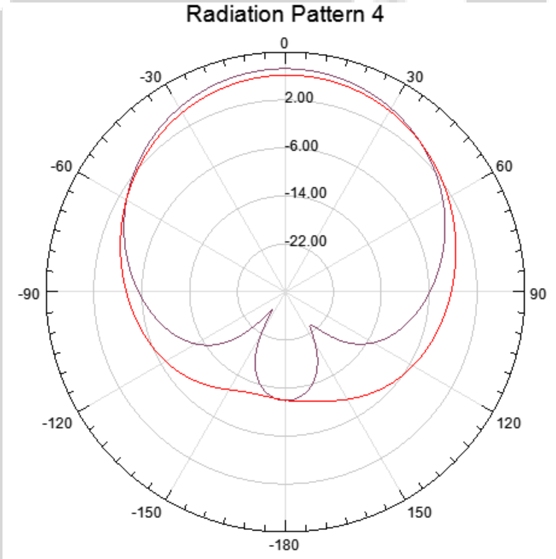

Fig. 7 Radiation pattern of Directivity

Substrate Height	Frequency (GHz)	Return Loss	Gain (dB)
1.6	2.36	-17.94	3.89
	1.83	-19.71	0.24
3.2	2.3	-15.63	5.28
	1.81	-24.39	2.52

Table 4 Comparison of results with substrate height

B. Measured Results

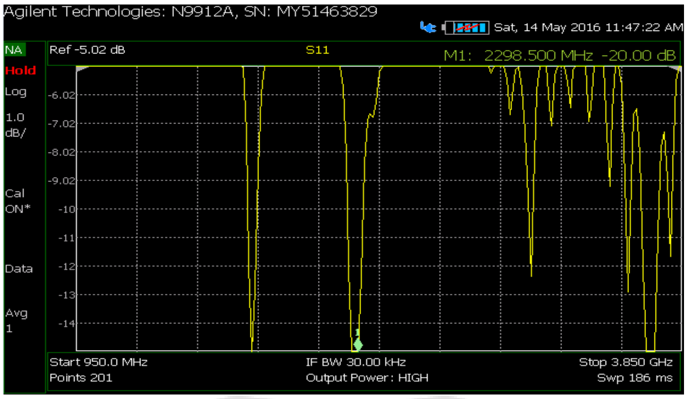

Fig. 8 Graph of return loss Return loss

Substrate Height	Frequency (GHz)	Return Loss
1.6	2.29	-20
	1.79	-23.05

Table 5 Measured Results

Fig. 9 Fabricated Fractal antenna with 2nd Iteration

IV. CONCLUSION

For given proposed Fractal Antenna using rectangle shape patch antenna with co-axial feed. Fractal antennas have the property for design the multiband antenna which can be used for various applications. Various shapes such as rectangular, triangular and circular shapes have been studied. Sierpinski carpet shape has been used for designing the 2.3GHz to 1.8GHz dual band antenna. Simulation results are in agreement with the specifications. Measured results for return loss (>-20dB) also exceed with simulation results. We can also design Fractal Antenna for various different shapes. We can get more frequency bands by increasing the iteration. By varying the substrate height we can also increase the gain.

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