DESIGN OF HIGH GAIN FRACTAL ANTENNA

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ABSTRACT: *In this paper, a high gain and efficient suspended minkowski fractal antenna is proposed. Recent efforts by several researchers around the world to combine fractal geometry with electromagnetic theory have led to a plethora of new and innovative antenna designs fractal antenna engineering research has been primarily focused in two areas: the first deals with the analysis and design of fractal antenna elements, and the second concerns the application of fractal concepts to the design of antenna arrays. Fractals have been exploited in order to develop a new class of antenna-element designs that are multi-band and/or compact in size. In this paper a compact microstrip antenna suspended at the height of 1.5mm is designed and implemented. Total height of the structure is increased to 3.09mm with the gain of 2 dBi and bandwidth of 116 MHZ with the 36% reduction in size. The antenna is simulated using IE3D and fabricated on FR4 substrate. The results are measured with Agilent Technologies: N9916A,SN:MY53102947. The measurement results are found to agree well with simulation results.*

Key Words: *Minkowski, fractal, antenna, suspended, high gain, bandwidth, multiband antenna.*

I. INTRODUCTION

The explosive growth in wireless broadband services demands new standards to provide high degree of mobility and enhanced data transmission. Advance communication requires antenna with wide bandwidth and smaller dimension. The use of Fractal geometry in designing antenna has been a recent topic of interest. It has already proved that fractal shaped have their own unique characteristics that improved antenna achievement without degrading antenna properties. Fractal antenna theory uses a modern (fractal) geometry that is a natural extension of Euclidian geometry. The term fractal, which means broken or irregular fragments, was originally coined by Mandelbrot. Fractal antennas have been shown to demonstrate repetitive multi-band, frequency independent or log- periodic behaviour that has been attributed to the self-similar antenna geometry.

Minkowski fractal geometry has received lot of attention in respect of reduction in the size of the conventional loop antenna leading to compactness and miniaturization. Tight packing of Minkowski Island loop antenna elements in the array and reduced mutual coupling was achieved without affecting the bandwidth much. Recent studies have shown that the application of printed Koch curve fractal shapes in MIMO antenna design allows reduced mutual coupling between antenna elements in (MIMO) system for multiband applications besides providing miniaturization [15] [16].

In this paper due to minkowiski fractal antenna design to resonate at 5.8GHZ has made to resonate at 4.3GHZ. So miniaturization is achieved. As we cut the slots ,the conducting surface area reduces so there is reduction in gain is observed. So we go for suspended combination. Simulation is done using IE3D. For fabrication purpose the low cost FR4 is chosen as the substrate. Although the loss tangent of FR4 is high the radiation efficiency is improved significantly compared to the conventional patch antenna. The improvement of maximum antenna gain is because of suspended combination as explained in [6].

II. TYPES OF FRACTALS

Koch curve:

The Koch fractal curve is one of the most well-known fractal shapes. It consists of repeated application of the IFS. The Koch curve is shown in Figure 1. Each iteration adds length to the total curve which results in a total length that is 4/3 the length of Koch curve and is given by:[9] [10].

$$L= \left(\frac{4}{3}\right)k$$

k=iteration stage

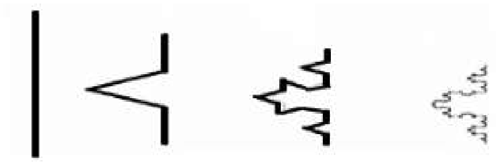


Fig.1

Sierpinski gasket:

The Sierpinski gasket or triangle is generated by using triangle as the basic function shape. The Sierpinski Gasket fractal is generated by the IFS method and the following figure 2 shows the step generation of Sierpinski gasket.[11] [12].

Fig.2

Minkowski fractal antenna:

Minkowski fractals were first introduced by Hermann Minkowski in the form of representation and definition of geometries in the year 1885 (Strobl 1985, Schwermer 1991). The basic square patch geometry is compressed five smaller squares to form the Minkowski fractal geometry as shown below in Figure 3. This is explained in terms of affine transformation shown in Figure 4.

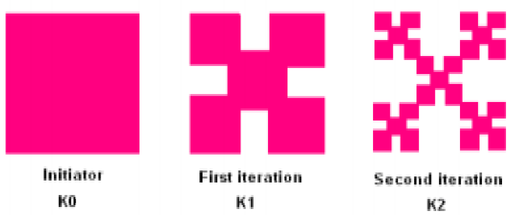


Fig.3

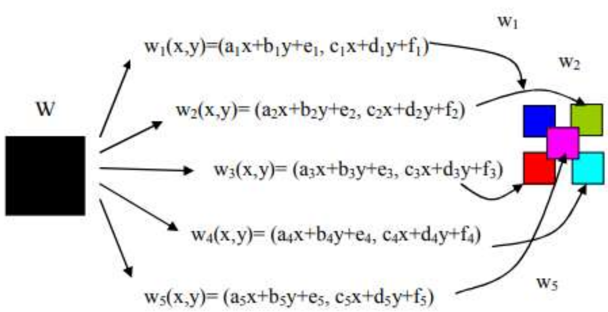


Fig.4

Iterated function systems (IFS) represent an extremely versatile method for conveniently generating a wide variety of useful fractal structures (Michael Barnsley 1993). These iterated function systems are based on the application of a series of fine transformations, w, defined by

$$w\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} e \\ f \end{bmatrix}$$

where a, b, c, d, e, and f are real numbers. In affine transformation, w, is represented by six parameters.[2][3].

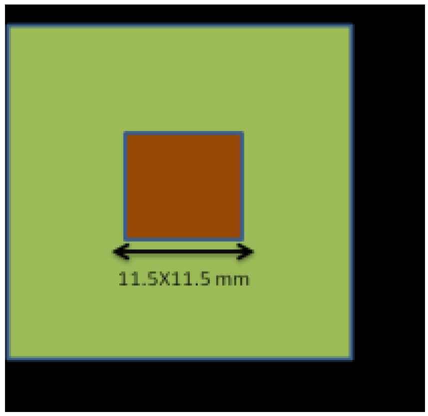
III. ANTENNA DESIGN

A. Design Of MSA:

Basic MSA is designed at the frequency 5.8GHzas a square patch of length

$$L=0.47\lambda$$

with the dimensions as shown in Fig .5



B. Design of Minkowski fractal antenna

The basic square patch geometry as shown in Fig.5 is compressed into five smaller squares to form minkowski fractal geometry as shown in Fig.6. Inside this five squares; five squares are etched which is as shown in Fig.7 to achieve the parameter enhancement like increase in bandwidth and reduction in size.

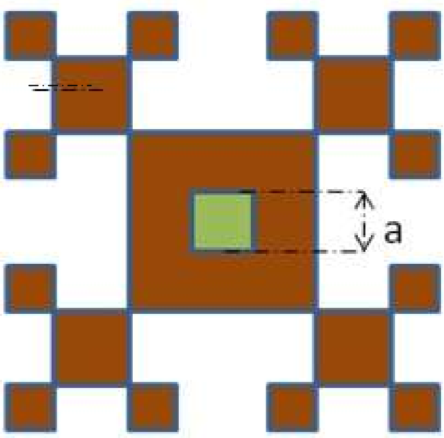


Fig.6 With centre slot (a = 1.033mm)

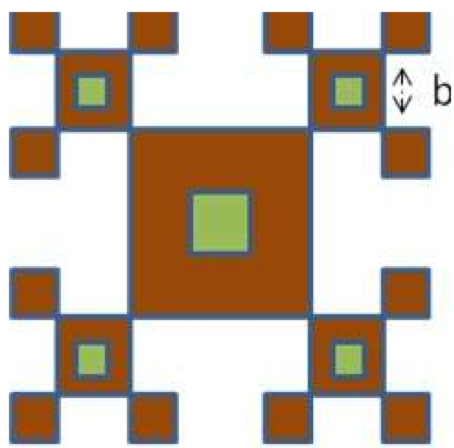


Fig.7 With five slots (b = 0.46mm)

The fractal similarity dimensions of this geometry is given by

$$D = \frac{\log 5}{\log 3} = 1.465$$

This implies that there are five copies of squares are generated in the successive iteration having dimension scaled down to one third.

IV. RESULTS AND DISCUSSION

Simulated results:

The proposed antenna is simulated by IE3D a conventional patch antenna which also operates at 5.8GHz is also simulated for comparison.

A. Simulated results of MSA

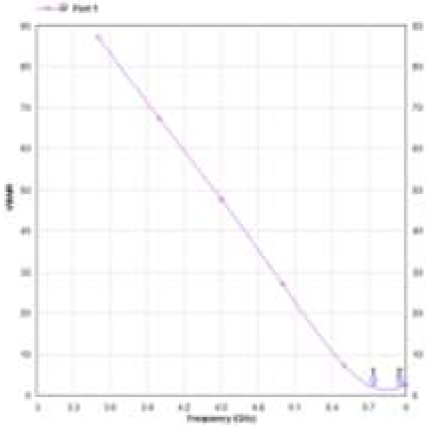


Fig.8 VSWR vs frequency graph

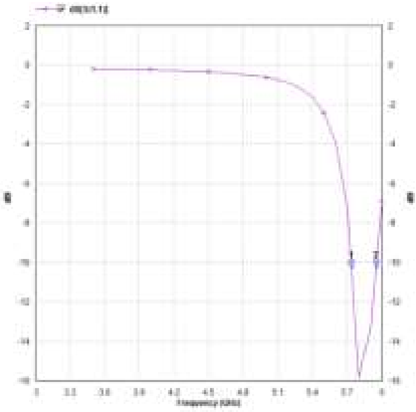


Fig.9 Return loss vs frequency graph

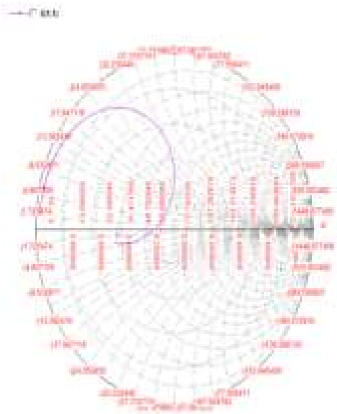


Fig.10 Smith chart

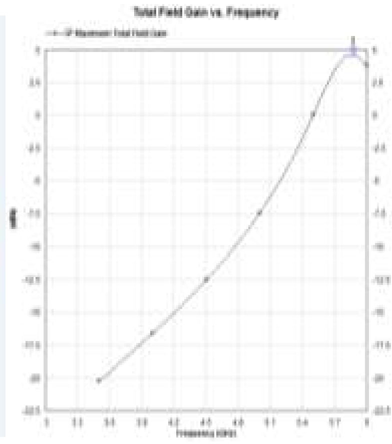


Fig.11 Gain vs frequency graph

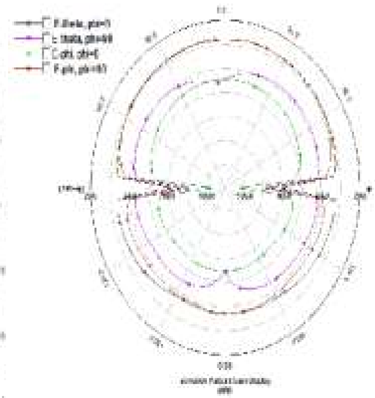


Fig.12 Radiation pattern

Antenna is resonating at 5.8GHz with return loss bandwidth of 0.21GHz and gain 4.5dBi.

B. Comparison graphs of fractal antenna with centre slots and suspended fractal antenna:

Proposed fractal antenna and its suspended form at the height of 1.5mm is also simulated in IE3D.

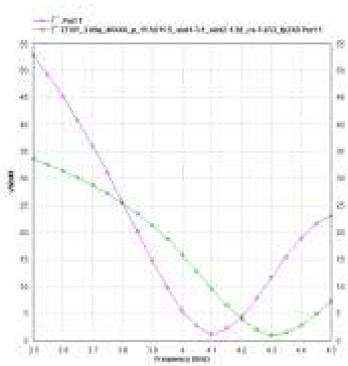


Fig.13 VSWR vs frequency graph

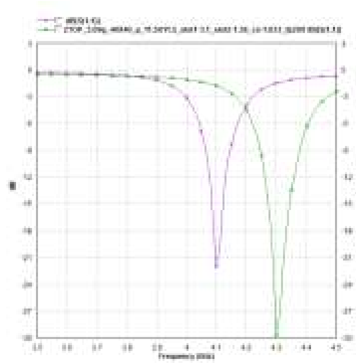


Fig.14 Return loss vs frequency graph

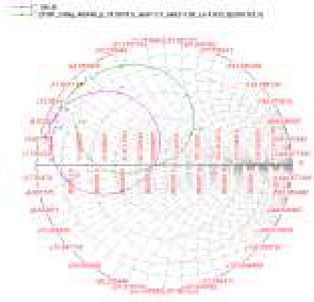


Fig.15 Smith chart

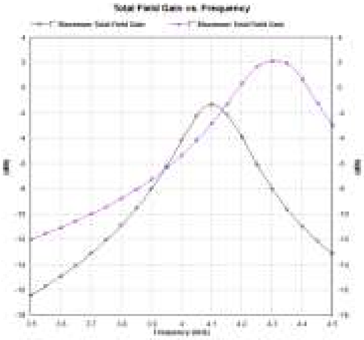


Fig.16 Gain vs frequency graph

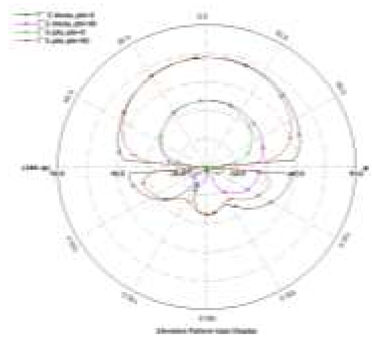


Fig.17 Radiation pattern of fractal antenna with centre slot

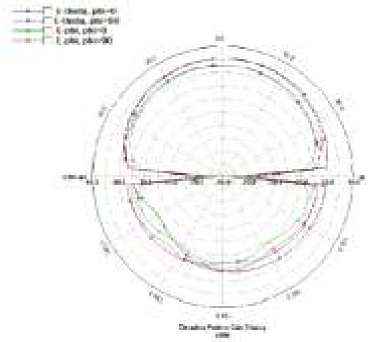


Fig.18 Radiation pattern Suspended antenna with centre slot

Resonating frequency of fractal antenna is reduced to 4.1GHz so 44% miniaturisation is achieved with return loss bandwidth of 110MHz but gain is reduced to -1.95dBi. With suspended form these parameters are improved . The resonating frequency is changed to 4.3GHz that reduces in miniaturisation but return loss bandwidth is 116MHz and gain is improved to 2dBi

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PARAMETER	MSA	FRACTAL ANTENNA	SUSPENDED FRACTAL ANTENNA
Frequency	5.8GHz	4GHz	4.3GHz
VSWR	0.21	0.036	0.12
RETURN LOSS	0.21	0.106	0.11
GAIN	4.5dBi	-1.95dBi	2dBi

Table 1. Comparison of all above parameters including resonating frequency for MSA, Fractal and Suspended Antenna

C. Fabrication and Measured results

The antenna with minkowski fractal is fabricated. This one layer antenna is very easy to fabricate and can be done using common PCB mailing machine. The image is shown in Fig. 19.

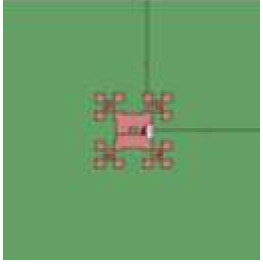

Fig. 19. Geometry of proposed Suspended antenna structure

The top view and side view of fabricated antenna is shown in Fig. 20 and Fig. 21 respectively. To increase the gain same antenna is suspended at the height of 1.5mm. The proposed antenna is compared to conventional antenna. The proposed antenna can achieve significant reduction in size, increase in gain and bandwidth.

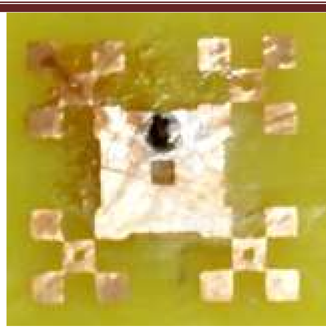
Fig.20 Top view


Fig.21 Side view

Hardwear results are shown in Fig.22, Fig. 23 and Fig. 24.The measured results are found to agree well with simulated results. Antenna is resonating at frequency of 4.236GHz with returnloss bandwidth of 81.62MHz.

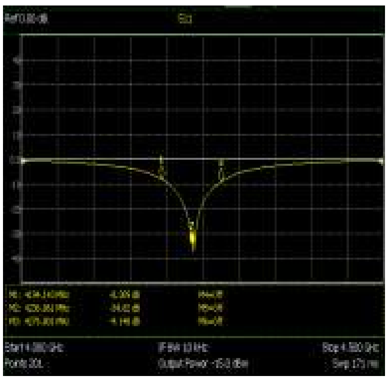
Fig.22 Return loss vs frequency graph.

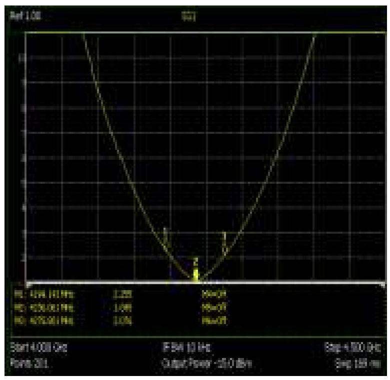
Fig.23 VSWR vs frequency graph.


Fig.24 Smith chart.

V .CONCLUSION

In this paper a simple Minkowski fractal antenna suspended at the height of 1.5mm using FR4 dielectric is designed and optimized to operate at the lower frequency of 4.3GHz. Parametric study shows that the gain is increased to 2dBi and bandwidth is 116MHz.with 36 % reduction in size.

VI .REFERENCES

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