Design & Fabrication of Sierpinski Fractal Antenna for Multiband Wireless Application

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Abstract*— The Sierpinski (SPK) geometry has a paramount application in multiband antennas. The multi frequency characteristics of the SPK are characterized by its scaling factor and successive iterations. Here I propose a modified fractal Sierpinski patch antenna capable to work with multiband wireless application is proposed. Various heights of a triangle component in Sierpinski antenna are compared to achieve the desired resonant frequencies and then a coplanar wave guide feed is used to achieve more multiband resonant frequencies within 0-7 GHz frequency range. The characteristics for Return loss clearly shows that the antenna can be utilized for WLAN and also GSM bands for VSWR<2.

Index Terms— **Fractal, Sierpinski, Multiband, VSWR, Bandwidth, Return loss, Radiation pattern**

I. INTRODUCTION

In today's communication era there is no space for wire. For this we need a multiband antenna design which can cover various frequency bands for the wireless applications such as Wireless Local Area Network (WLAN) and WiMAX.

In last decade several methods of an antenna design to meet a multiband characteristics has been researched. One of them is by applying a fractal geometry in antenna. This fractal's self-similarity characteristics, can be used to produce multi band radiators. One of the most famous fractal geometry is the Gasket Sierpinski. A Gasket Sierpinski has a base shape of an equilateral triangle. Because of this shape, a gasket Sierpinski antenna has a similar characteristic with a bowtie antenna. The multiband behavior of this Sierpinski shaped antenna has been studied [1]. Because of the multiband characteristics, fractal shaped antenna has been used in multi band applications such as in dual band GSM [2], multi band radar [3], multilevel antenna [4], mobile communications [5], dual band wireless devices[6], and LTE[7] .

Further modifications has also been delivered by researchers to improve the multiband characteristics of this fractal antenna. For example: stacked Sierpinski patched antenna [8], and a stub addition in piano curve [9].

II. FREQUENCY INDEPENDENCY & SELF-SIMILARITY CHARACTERISTICS OF FRACTALS

Researchers from the field of electromagnetics works a lot on self-similarity characteristics & structure of the fractals, which is recursive in nature [10-13]. Element's quality of shape retaining for multiple iterations result in frequency independency [14]. But earlier then this structure proposed by Mandelbrot, similar structure were proposed named Log periodic and Spiral etc [15] & they also provide constant impedance characteristics. Scientist Rumsey V.H, suggest a new definition for frequency independent antennas and says that "If the dimensions of an antenna are taken in terms of angles only then the curve for radiation pattern of antenna and impedance curve of that antenna will be independent from frequency".

III. DESIGN ASPECTS

A) Dielectric constant [16]:

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-0.5} \qquad (1)$$

where,
W = Width of patch &
h = height of substrate

B) Fringes factor [16]:

$$\Delta L = 0.412h\,\frac{(\epsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\epsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \qquad (2)$$

where,
W = Width of patch &
h = height of substrate

C) Length [16]:

$$L = Le - 2\,\Delta L \qquad (3)$$

with

$$Le = \frac{c}{2f_r\sqrt{\epsilon_{eff}}}$$

where,
L = Length of patch &
ΔL = Change in length due to fringing

D) Width [17]:

$$W = \frac{c}{2\sqrt{\left(\frac{\epsilon_r + 1}{2}\right)}} \qquad (4)$$

where,
c = Light speed
f_r = Resonant frequency

E) Ground plane dimensions [17]:

$$Lg = L + 6h\,,\; Wg = W + 6h \qquad (5)$$

where
h = Substrate height,
L = Patch length &
W = Patch width.

F) Equilateral triangular patch arm [17]:

$$a = \frac{2c}{3f_r\sqrt{\epsilon_{eff}}} \qquad (6)$$

where,
c = Speed of light in free space,

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f_r = Resonant frequency &
ϵ_{eff} = Effective dielectric constant.

IV. DESIGN DIMENSIONS FOR PROPOSED SIERPINSKI FRACTAL ANTENNA

The Sierpinski arrowhead is designed on Glass Epoxy sheet with a slab height of 1.6 mm. The dielectric constant of this metal is 0.5. This is an equilateral triangle of 6 cm side length i.e. the outer dimension for all the three iteration remains the same.

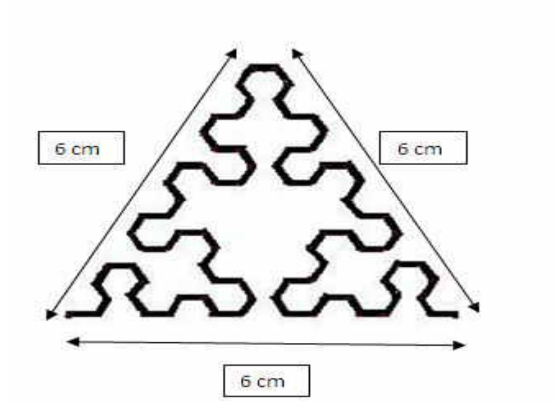

Fig 1: Basic design of Sierpinski arrowhead Antenna

V. SIMULATION

To access the reliability and effectiveness of the design, the results validation of proposed Sierpinski antenna design must be verified by both software as well as hardware. This will show the performance overview of the design. The software simulation is done with the help of Zeland (IE3D). This will provide output in terms of 3D graphs. The hardware design of the same antenna is analyzed with Vector Network analyzer. So the analysis provides both type of results.

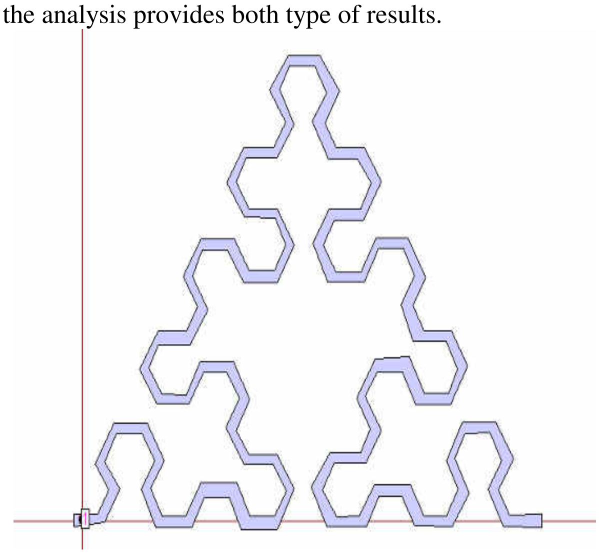

Fig 2: Sierpinski Arrowhead shaped fractal antenna geometry for 2nd iteration

The figure 2 shows the planner view of second iteration. The dimensions obtained from mathematical analysis are used to design the geometry of proposed Sierpinski antenna. The geometry is obtained with the use of IE3D software. In figure 2, a probe feed is applied at the corner of the obtained geometry. Figure 3 shows the 3D pattern of antenna obtained from IE3D software. Similarly figure 4 shows the current distribution curve for deep understanding of the designed geometry.

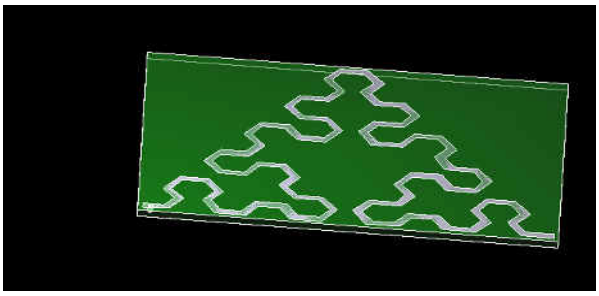

Fig 3: 3 D geometry of Sierpinski Arrowhead fractal antenna for 2nd iteration

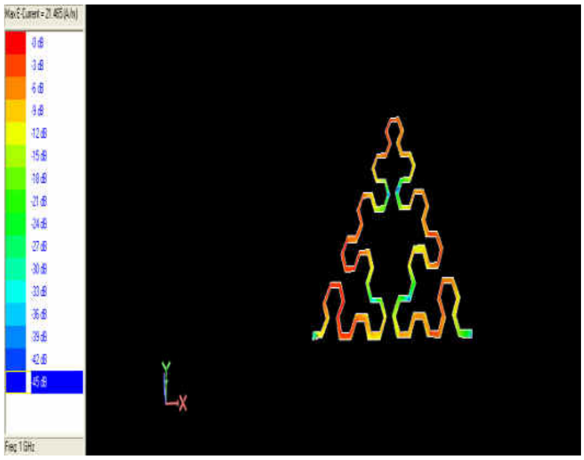

Fig 4: Current distribution curve of Sierpinski Arrowhead fractal antenna for 2nd iteration

A. *Return loss:*

The response of the return loss is represented in Figure 5. It can be noticed that Sierpinski antenna is indeed resonating at 4.943 GHz and 5.623 GHz with a return loss of 16.439 dB and 16.316 dB respectively.

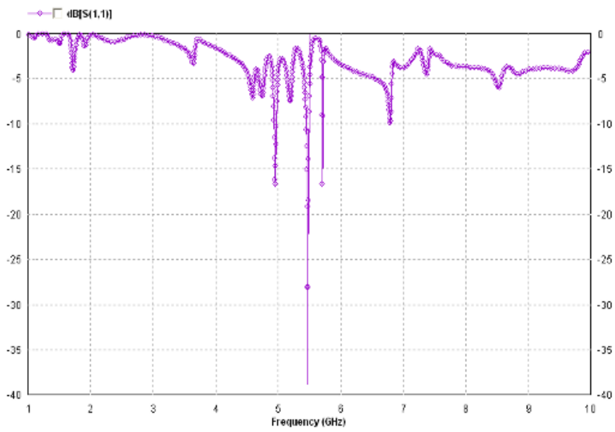

Fig 5: Return loss characteristics of Sierpinski Arrowhead fractal antenna for 2nd iteration

B. *VSWR:*

VSWR (Voltage Standing Wave Ratio) is a quantity, which deals with the impedance matching of antenna. It describes the power reflected from the antenna. From Fig 6 it is clear that VSWR for two operational frequencies is a real and positive number and nearly to 1, where VSWR = 1 implies a matched load.

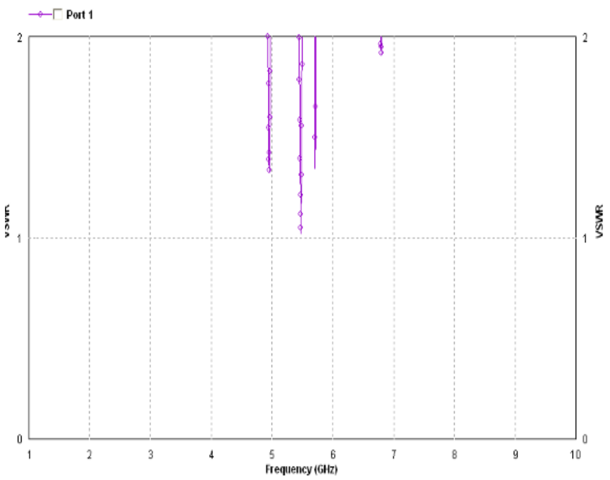

Fig 6: VSWR curve of Sierpinski Arrowhead shaped fractal antenna for 2nd iteration

We simulate the antenna using IE3D and obtain the various antenna parameters, as user graphics format of IE3D is accessible for analysis. The figure 5 shows the simulation characteristics for Return Loss. The S parameters of the antenna should satisfy the condition that S11 ≤ -10 dB. Under this condition the designed Sierpinski arrowhead fractal antenna geometry will provide multiple frequency sample points. Similar information can be obtained from VSWR curve as shown in figure 6 (VSWR ≤ 2).

C. Input Impudence:

The input impedance of this antenna design is found extremely sensitive to the width of the microstrip feed line (Fig. 7) and thus the matching requirements at these frequencies are also fulfilled as indicated by the simulated results of return loss .

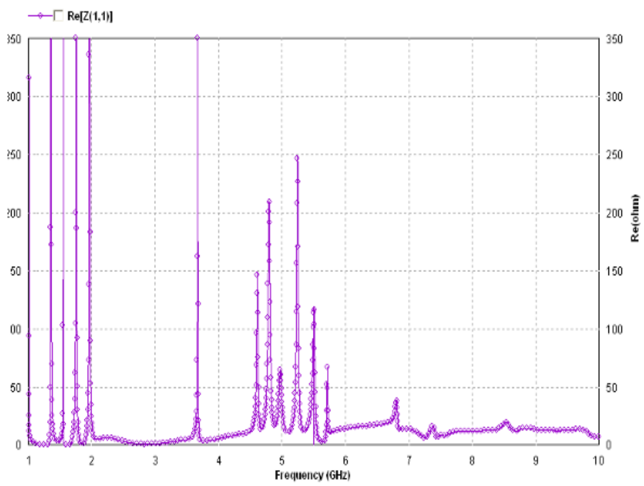

Fig 7: Impedance curve of Sierpinski Arrowhead fractal antenna for 2nd iteration

It also provides closer look on antenna impedance (plot consist of curves for real impedance). The magnitude of impedance found to be 50Ω at the resonant frequency points.

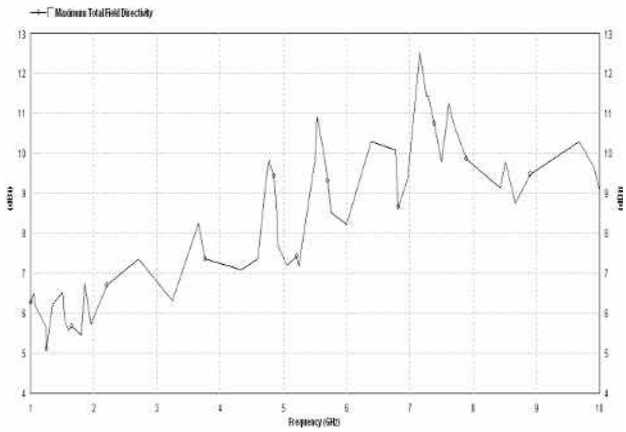

Fig 8: Directivity curve of Sierpinski Arrowhead fractal antenna geometry for 2nd iteration

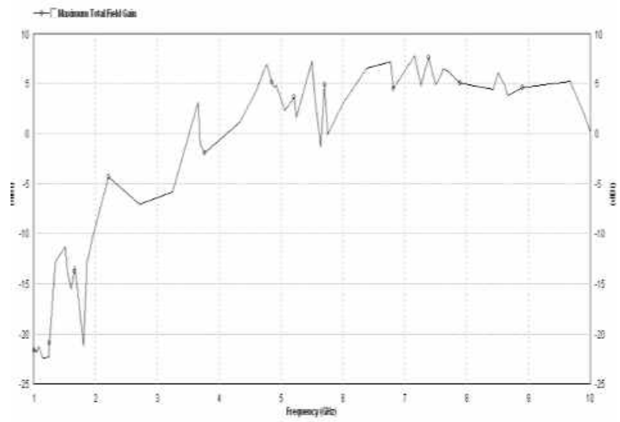

Fig 9: Gain curve of Sierpinski Arrowhead fractal antenna geometry for 2nd iteration

Some other important parameters of the designed Sierpinski antenna geometry are also considered during the designing. Figure 8 represents the curve between Directivity & frequency. After analyzing the graph we can say that the designed Sierpinski antenna peruse notable Directivity ranges from 7 dBi to 12.65 dBi for various frequencies. Likely figure 9 shows the graph between Gain & Frequency. As from the graph it can be noted that total gain reaches up to 7.7 dB.

D. Radiation pattern:

The radiation pattern is obtained for far field (Fig 10), for both frequencies width two angles Phi = 0 and Phi

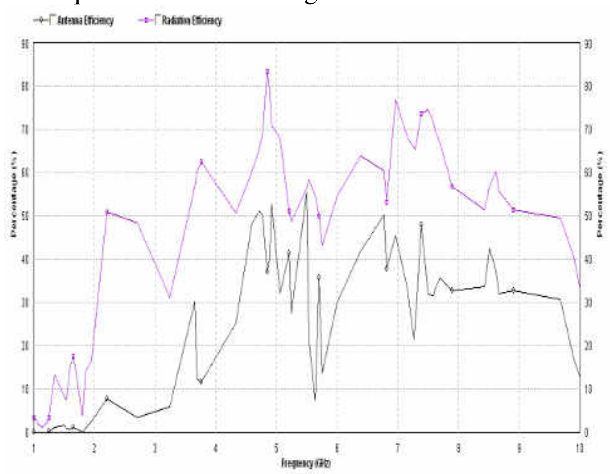

Fig 10: Radiation Efficiency of Sierpinski Arrowhead fractal antenna for 2nd iteration

= 90, the radiation patter is quite similar to a monopole antenna. It is omnidirectional for the first resonant frequency & in the second resonant frequency, two small beams appear and radiation pattern is quasi omni directional.

Other area of consideration for designed Sierpinski antenna are its efficiency & impedance. Figure 10 shows the curve between radiation efficiency & frequency.

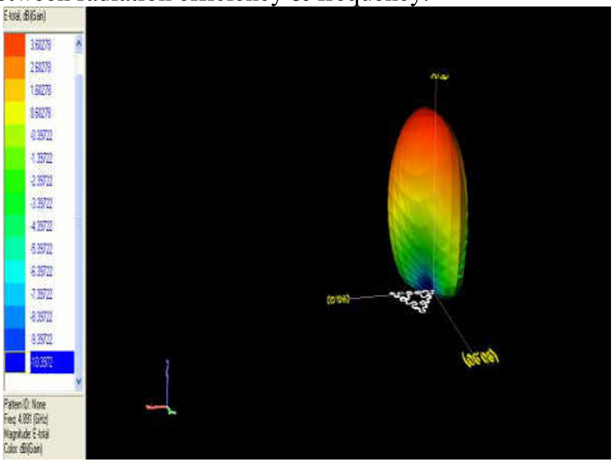

Fig 11: Radiation Pattern at a frequency of 0.81 GHz for Sierpinski Arrowhead fractal antenna for 2nd iteration

The designed antenna possess encouraging radiation patterns. The 3D radiation pattern for designed Sierpinski arrowhead fractal antenna at different frequencies are represented in figures 11 and figure 12.

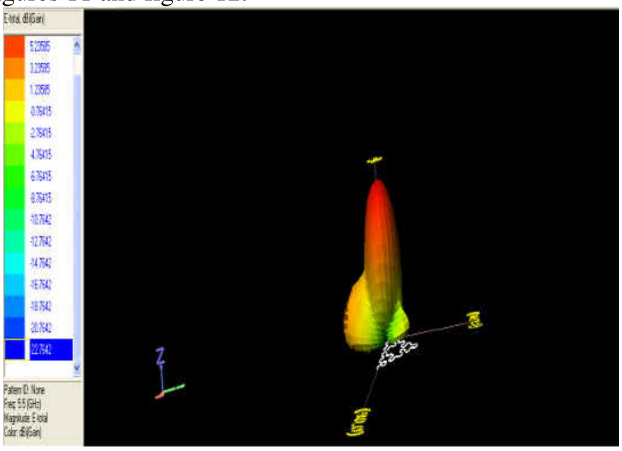

Fig 12: Radiation Pattern at a frequency of 5.5 GHz for Sierpinski Arrowhead fractal antenna for 2nd iteration

The figure 13 shows the fabricated antenna proposed by us. It is tested in the lab and analyzed with Network analyzer (VNA) for finding antenna parameters like Return Loss parameter (S_{11}).

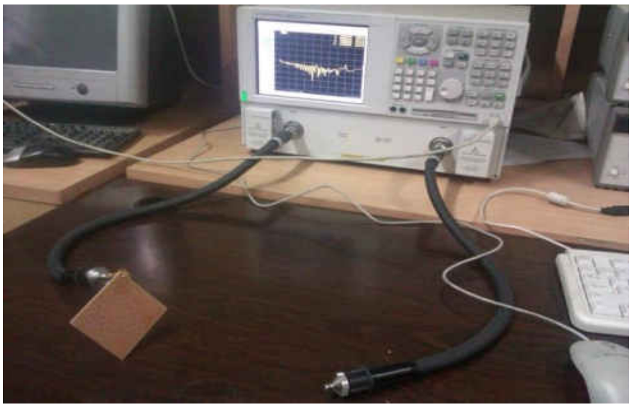

Fig 13: Return Loss curve for designed Sierpinski Arrowhead antenna at VNA screen

VI. RESULT

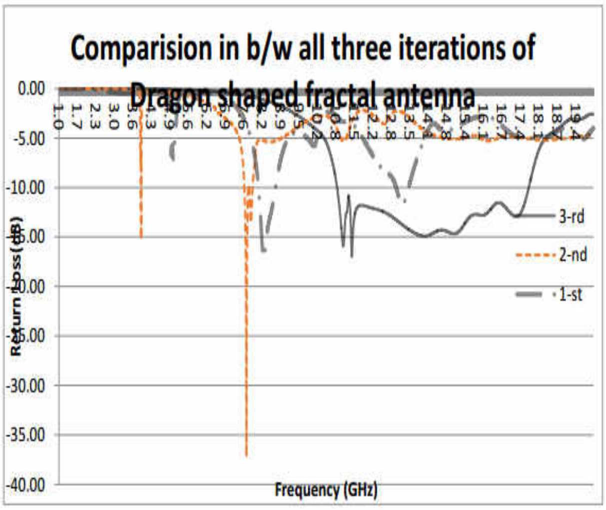

Fig 14: Simulation curve of return loss for 1st, 2nd & 3rd iteration of Sierpinski Arrowhead geometry

Sierpinski Arrowhead (Dragon Shaped) shaped fractal antenna has been fabricated. After fabrication this antenna was tested for wireless environment. The designed antenna has simple geometry. It can be noted from the developed antenna that it represents flexibility for different frequencies starts from 2 GHz to 10 GHz. It also brings curve for 90% radiation efficiency. This curve also shows highly acceptable gain of 7.7 dBi with directivity of 12.65 dB. The designed Sierpinski fractal antenna exhibit wonderful radiation curve. Apart from this the third iteration provides very wide band ranging from 10.7 GHz to 17.6 GHz for Ka and Ku band application.

More we have drawn is comaparision curve of all the three iteration of Sierpinski arrowhead fractal antenna as shown in figure 14. From this curve it is clearly observed that the resonsnce frequency is decrementing in lograthemic ratio when we move from first iteration to third iteration. The same is represented in the form of a table (Table .1). These observations verified the fractal characterstics of the designed antenna.

Table .1 Collective study of Return loss for 1st , 2nd & 3rd iteration of Sierpinski Arrowhead geometry

Freq.	S_{11}- 3rd Iter.	Freq.	S_{11}- 2nd Iter.	Freq.	S_{11}- 1st Iter.
10.7	-10	3.9	-15	8.3	-17
11	-16	4.0	-14		
11.2	-15	7.8	-37		
11.6	-17				
15	-14				
17.2	-12.2				
17.6	-11.1				

CONCLUSION

Here a fractal antenna is designed which is capable to work at different frequencies. The simulation of antenna is done using IE3D software. The hardware testing is performed with the help of network analyzer. Various antenna characteristics has been taken into consideration during the designing like VSWR, input impedance, return loss, radiation pattern etc. With this work we can conclude that the effective length, space filling characteristics & scale factor are the important factors that effects the behavior of antenna while studying different iterations. The feed location and size of patch are also some parameters of concern.

We use IE3D for simulation, which is sufficient to simulate at higher frequencies. The designed geometry have efficient characteristics like high gain, efficiency & input impedance etc.

FUTURE SCOPE

Here in this paper, I have done compelling analysis of Sierpinski arrowhead fractal geometry for wireless communication at different frequencies. Further area of development is antenna element minimization without degradation in efficiency. Now a days the size of all electronic equipment's is getting reduced day by day. So the antenna size may be the key area of future research.

The absorption of electromagnetic energy can also be minimized at user's head. Surrounding of users by a strong electromagnetic energy for a long time may create health issues. Degradation due to ground plane measurement can be minimized to improve the antenna characteristics.

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