Design and Analysis of Sierpinski Gasket Patch and Monopole Fractal Antenna

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Abstract- *The paper deals with the design and various analyses of Sierpinski Gasket Patch and Monopole antenna are presented and discussed in great detail. The Sierpinski Gasket Fractal geometry describes a multiband behavior of the fractal antenna. The Sierpinski Gasket Patch antennas describe multiband frequency but the frequency band cannot be predicted. Maximum iteration that applies to these is three. The behavior patterns of both type of antennas are investigated as radiation pattern, number of iterations and return loss. The entire antenna design comprehensively shows multiband in resonant frequencies. The Sierpinski monopole shows a pattern in return loss but not for Sierpinski patch. The monopole type demonstrates the frequency band log-periodically spaced by two same as the scale factor among the structure. The self-similarity properties of fractal structure are also translated into its electromagnetic (EM) behavior.*

Keywords- Sierpinski Gasket Patch, Monopole, antenna, multiband, radiation pattern, number of iterations and return loss and electromagnetic (EM)

I. INTRODUCTION

The use of fractal geometry in designing antenna has been a recent topic of research and interest. It has already been proved that fractal shaped have their own unique characteristics that improved antenna achievement without degrading antenna properties. The fractal geometry has been known to mathematics for a century. Fractal antenna engineering research is a relatively very recent development because considerable computing speed id required to complete their design [1].It has been found that fractal shapes radiate electromagnetic energy well and have several properties that are advantageous over traditional antenna types. They can be used as multi-band antennas which can radiate signals at multiple frequency bands. Another desirable property is that they are compact meaning that they can occupy a portion of space more efficiently than other antenna types. Such antennas could be used to improve the functionality of modern wireless communication receivers such as cellular handheld sets [2].

Most of the fractal geometries have the characteristics features like; infinite complexity, fractional dimension and self-similarity.Wider bandwidth, multiband and low profile antennas in modern wireless communication systems are ingreat demand for commercial purposes.

This phenomenon has initiated antenna elements [3].Traditionally, each antenna operates at a single or dual frequency bands where different antenna is neededfor different applications. This will cause a limited space and place problem. In order to overcome this problem, multiband antenna can be used where a single antenna can operate at many frequency bands. One of the techniques to construct a multiband antenna is by applying fractal shape into antenna geometry.

II. SIERPINSKI GASKET PATCH ANTENNA

The Sierpinski gasket geometry is the most widely researched and studied fractal geometry for antenna applications. The same have been investigated extensively for monopole and dipole antenna configurations [4]. The self-similar current distribution on these antennas is expected to cause its multiband characteristics. It has also been found that by perturbing the geometry the multiband nature of these antennas can be controlled [5]. The variations of the flare angle of these geometries have also been explored to change the band characteristics of the antenna [6].

The Sierpinski fractal has been generated through three iterations using the decomposition algorithm. An equilateral triangle is removed from the parent triangle is taken and adjoining the midpoints of each side of the triangle in the decomposition algorithm. A central inverted triangle is removed from the parent triangle. Three half scaled triangles are obtained, the same procedure is repeated on each of these triangles and so on this process is carried out upto three iterations as shown in fig. 1.

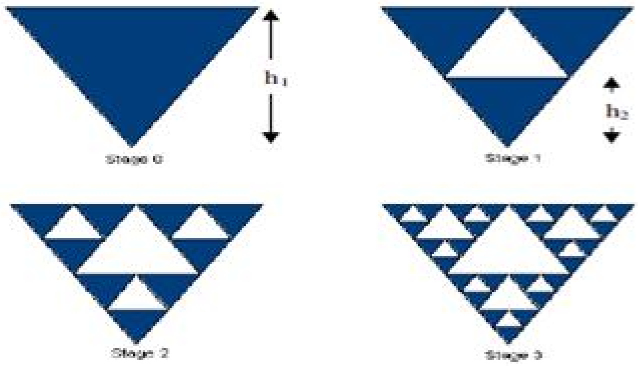

Fig. 1 Generation of Sierpinski Gasket patch Fractal

This Sierpinski fractal has geometrical scale factor,

$$\delta = \frac{h_n}{h_{n+1}} =$$

where;
h = height of sub gaskets
n = natural numberrepresenting the number of iterations

The antenna has been fabricated on 1 mm thick FR4 substrate when one edge of the antenna is direct feed to SMB connector a s shown in fig. 2

Fig. 2 Fabricated Sierpinski Gasket Patch Antenna

A. Simulated and Measured Results

1) Input Return Loss: The simulated and measured return loss of the antenna is shown in fig. 3.

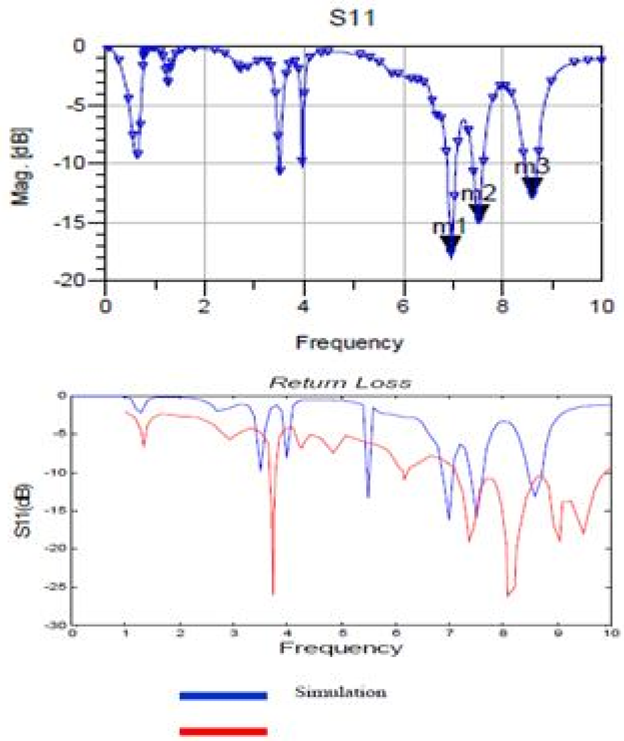

Fig. 3 Input Return Loss of Sierpinski Gasket patch (a) Simulated (b) Measured

The measured return loss is shown in fig. 3 (b). The S response for measurement result is slightly lower compared to simulation but it follows the pattern at the beginning frequency (0-3 GHz). At nearly 4 GHz, the response for measurement appear another frequency reach -26 dB where in simulation only reach -10 dB.The Sierpinskigasket patch antennas describe multiband frequency but the frequency band cannot be predicted.

2) Radiation Patterns: The main cuts of the simulated as well as measured radiation patterns of the antenna at three log periodic bands are shown in fig. 4. The solid line shows the measured result whereas dotted line shows the simulated result.

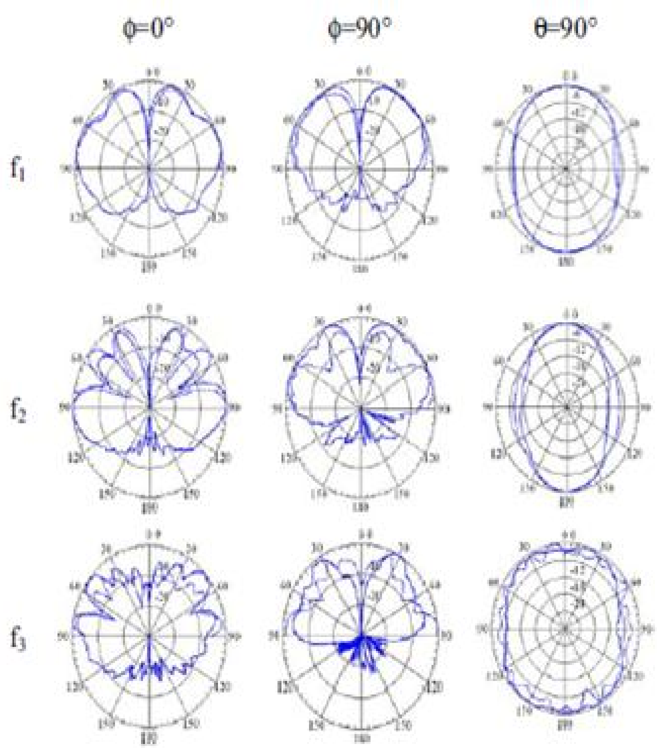

Fig. 4 Radiation patterns of Sierpinski gasket patch antenna

III. SIERPINSKI MONOPOLE ANTENNA DESIGN

The monopole antenna based on the Sierpinski gasket has been designed based on the literature [4]. Most of the antenna designs are highly frequency dependent where the size of the antenna relative to the operating wavelength. Carles Puente [8] first describe the multiband behaviour of Sierpinski gasket monopole geometry. Such behaviour is based on the self similarity properties of the fractal shape of antenna which open alternative antennas (FIA)

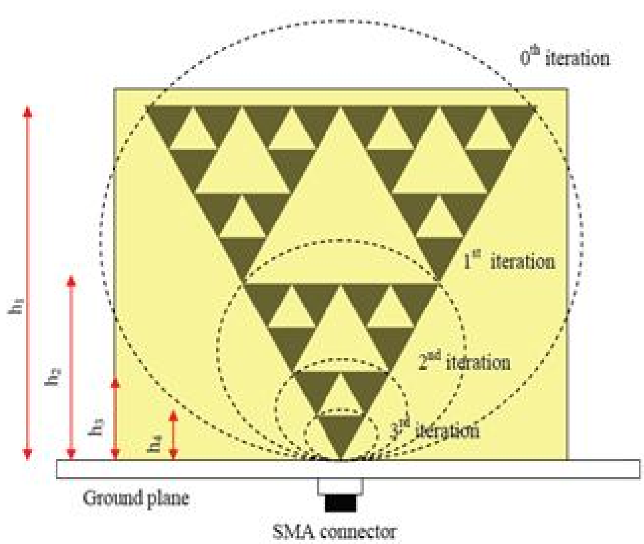

Fig. 5.Sierpinski gasket monopole antenna

The scale factor will determine the high of each sub gasket ans given by

$$\delta = \frac{h_n}{h_{n+1}} =$$

Figure 5 shows a third iteration of the fractal Sierpinski gasket. The high of each sub-gasket will determine resonant frequency of antenna. This means that we will get four different bands because of four different high of sub-gasket. We will get different high of each sub-gasket, thus different frequency band by changing the scale factor. The monopole Sierpinski gasket antenna is determined From [9], the simplified equation is given by as follows:

$$= k \quad \frac{c}{h} \cos\left(\frac{\alpha}{2}\right) (\delta$$

The flare angle is the angle of the inside of the triangle. In this very project, the flare angle was chosen to be 60 degree as a starting point. The constant k as given in [9] as 0.15, depends on the dielectric substrate type and thickness used. It is only used as a first guess for this paper and final parameters are fully confirmed through simulation.

A. Simulated and Measured Results

1) **Input Return Loss:**The simulation software used in this paper is ADS. The simulated and measured return loss of the antenna is shown in fig. 6.

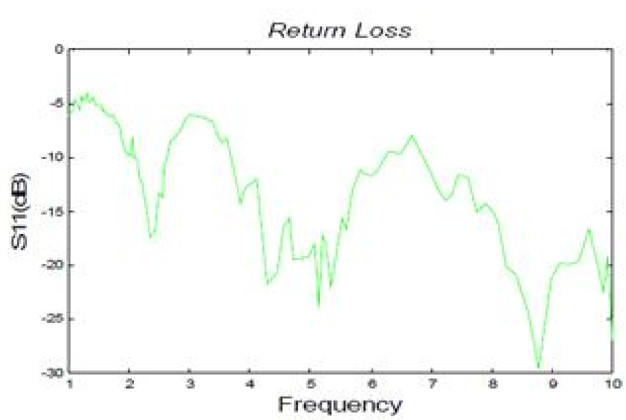

Fig.6 Input Return Loss of Sierpinski Gasket patch

The antennas is designed at 2.4 GHz and 5.0 GHz afore- mentioned. The measurement results are in good agreement with operating frequencies that are in good agreement with operating frequencies that are desired. A major improvement in bandwidth for each resonance frequency due to this antenna was designed with third iteration, there is four band od resonance frequency around < 1

GHz, 2.4 GHz, 5 GHz and 9 GHz. Thus, each band is multiple of ≈2 and it agrees with the scale factor that is used for this antenna. The input impedance for each band supposedly matched near 50 Ω [4]. It cannot be shown here due to tools and equipment issues.

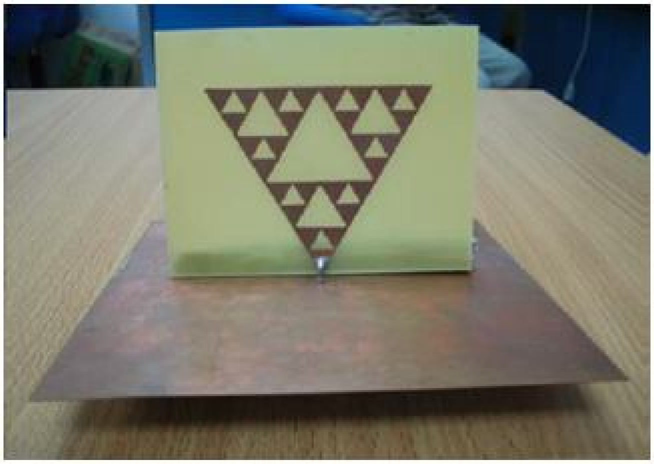

Fig. 7Fabricated Sierpinski Gasket Patch Antenna

Table II. Frequency Band, Return Loss and Bandwidth for Measurement

Band	F (GHz)	S_{11} (dB)	BW	f_0/f_{n+1}
m_1	2.44	-16.88	19.67	-
m_2	5.1	-23.91	49.42	2.09
m_3	8.8	-29.66	34.09	1.73

2) Radiation Patterns: The main cuts of the simulated as well as measured radiation patterns of the antenna at three log periodic bands are shown in fig.8. The solid line shows the measured result whereas dotted line shows the simulated result.

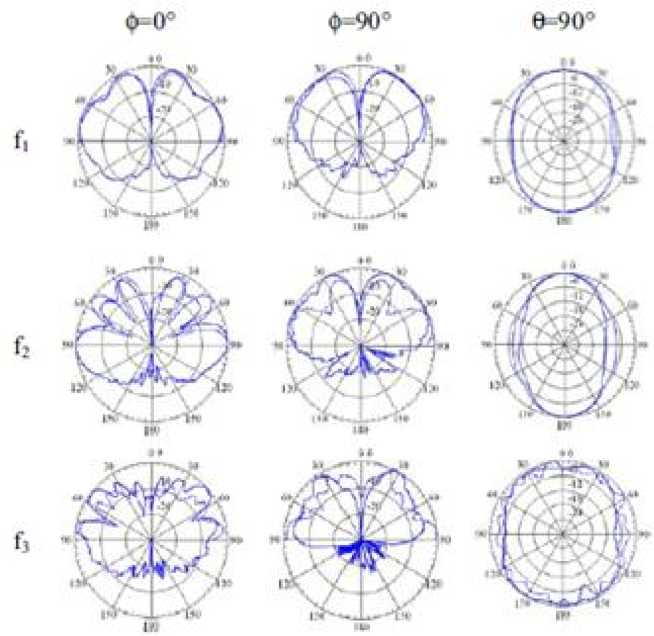

Fig. 8 Radiation patterns of Sierpinski monopole antenna

The radiation patterns at the three log periodic bands are almost similar to each other. The azimuth cut (θ=90°) shows that antenna radiates strongly in x- direction. Back lobes in the elevation patterns (φ=0° and φ=90°) increase as compared to those given in fig. 5 because of the planar ground plane used in the case of Sierpinski monopole antenna. It has been shown that Sierpinski gasket patch has a multiple band of resonant frequency (multiband). The band for patch type cannot be predicted from the results. The frequencies bands for patch type cannot be predicted. The band is highly influenced by the geometry of Sierpinski gasket itself especially the high of each sub-gasket for the monopole type. The high of each sub-gasket depends on scale factor and resonant frequency. It can be seen that the co-polar and cross-polar introduced more side lobe at the upper band. The upper band also show characteristic ripple. This is probably the high of resonance triangle is to close to the ground plane.

IV. CONCLUSION

The paper presents the design and various analyses of Sierpinski Gasket Patch and Monopole antenna are presented and discussed in great detail. The Sierpinski Gasket Fractal geometry describes a multiband behavior of the fractal antenna. The Sierpinski Gasket Patch antennas describe multiband frequency but the frequency band cannot be predicted. All the bands of Sierpinski Gasket Patch are narrowband but the wider bandwidth can be obtained with monopole. The Sierpinski Fractal monopole antenna design exhibits multiband behavior with three log-periodic bands and spaced with a log-period of 2. Changing the height of each sub-gasket of Sierpinski monopole will control the frequency band spacing and input impedance. Since, the Sierpinski fractal in this case is constructed through three iterations and the number log-periodic bands is also three thus, it can be concluded that the number of fractal iterations.

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