Coaxial Probe Fed Modified Sierpinski Fractal Antenna for Wireless Applications

Yadwinder Kumar

Abstract: ***A modified Sierpinski fractal antenna has been designed for wireless applications. The designed antenna exhibits multiple resonance behavior due to the basic attributes of the fractal shapes. The proposed antenna has planar, compact in size and is suitable for various wireless applications. It is designed on the Flame Retardant epoxy board substrate (FR4), which is very easily available, light in weight and has less cost. IFS (Iterated Function System) methodology is accustomed to generate the complex fractal layout using the scripting methodology (.vbs) in the HFSS simulator. Scripting method provides a straight forward solution to generate complicated fractal structures by generating code in MATLAB. The proposed antenna resonates at five different frequencies 1.859 GHz, 3.623 GHz, 5.929 GHz, 9.095 GHz and 9.547 GHz with smart values of return loss up to -26 dB. It additionally demonstrates good radiation properties and has VSWR values less than two for all resonating frequencies. Radiation characteristics are displayed by 2D and 3D radiation patterns. It also has an low profile value of Gain of 3 dB.***

Keywords : Sierpinski Gasket, Fractal Antenna, Multiband, IFS, Return Loss, FR4, VSWR.

I. INTRODUCTION

There has been widespread use of wireless communication through recent years. This has opened new doors for researchers to explore bigger prospects of exploit multi-band antennas using fractal shapes. Planar microstrip antennas are the foremost vital choice by researchers to use multiple resonance properties of fractal shapes [1] as radiation structures. Self Similarity, space-filling and miniaturization are some vital properties transmissible by fractal shapes that may be accustomed to obtain compact and multiband antennas [2]. Many fractal geometries like Koch curve, Cantor set, Hilbert curve, Sierpinski gasket and Minkowski fractal [3] are usually utilized in designing fractal antennas that are accustomed acquire antennas that are compact in size and has multiband characteristics [4][5]. These are helpful in developing new and innovative antenna structures . Multiple resonant frequencies among a single compact device have given researchers a daring task to design and develop a multiband antenna capable of exhibiting multiband behavior [6]. Fractal geometries and shapes can offer an exposition to the present drawback. Benoit Mandelbrot [7] proposed fractal geometries in 1951, that were later used extensively to notice and design numerous antenna structures. Fractal structures boast distinctive options like self-similarity that facilitate to attain compactness and multiband/wideband behavior [8].

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Self-similarity can be consummate by applying an outsized range of iterations utilizing multiple cuts of reference shapes. The Koch curve and the Sierpinski curve [10] are some usually used geometry in fractal antenna design. Using these popular fractal shapes, varied items of researches are developed by varied ways to get multiple resonances, combining 2 or a lot of fractal geometries and modification of existing geometry are a number of the ways in which to attain this. [4] Fractals provides massive surface areas, separation, edges, segments, etc. during a restricted area. They are formed by periodic processes which results in lot of compactness and multiple resonances is consummated by availing broken framework as collated to other patch layouts [10].

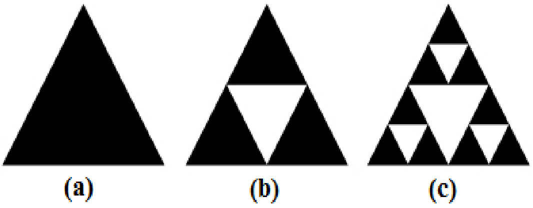

Figure 1. Sierpinski Gasket fractal with various iterations.

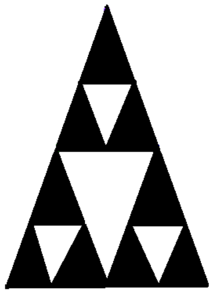

Figure 2. Proposed modified Sierpinski gasket fractal

Sierpinski fractal is a widely used fractal structure in planar as well as non-planar antennas configurations[5][11].

II. ANTENNA LAYOUT

In this analysis, the suggested fractal antenna is intended by modifying the standard Sierpinski gasket with all equal sides and a widening angle of 60 °. As shown in Figure 1. Figure 2 shows the modified Sierpinski with a flare angle of 50 ° and therefore the different two angles at 65° each. It has only two equal sides leading to isosceles triangle design. The Sierpinski gasket is one of the wide used fractal shapes used as antenna in several wireless applications [12]. Some vital factors needed to design the Sierpinski gasket fractal are the iteration range, scaling factor, triangle height and widening angle consisting of concatenation of scaled triangles with a scale factor of $\zeta = 0.5$ [13].

The proposed modified Sierpinski fractal structure has been obtained from the Iterated function system (IFS) [14], a very worthwhile calculation instrument used to narrate scaling, rotation, and translation of fractal layouts [15]. Various such operations can be performed by the following function:

$$W\begin{pmatrix}x\\y\end{pmatrix} = \begin{pmatrix}a & b\\c & d\end{pmatrix}\begin{pmatrix}x\\y\end{pmatrix}+\begin{pmatrix}e\\f\end{pmatrix} \quad (1)$$

Here *a, b, c* and *d* control the rotation and scaling while *e* and *f* control linear shift [14].

$$W_1\begin{pmatrix}x\\y\end{pmatrix} = \begin{pmatrix}-1.0/2.0 & 0\\0 & 1.0/2.0\end{pmatrix}\begin{pmatrix}x\\y\end{pmatrix}+\begin{pmatrix}1/2\\0\end{pmatrix} \quad (2)$$

$$W_2\begin{pmatrix}x\\y\end{pmatrix} = \begin{pmatrix}1.0/4.0 & 7/20\\67/125 & -1.0/4.0\end{pmatrix}\begin{pmatrix}x\\y\end{pmatrix}+\begin{pmatrix}1/2\\0\end{pmatrix} \quad (3)$$

$$W_3\begin{pmatrix}x\\y\end{pmatrix} = \begin{pmatrix}1/4 & -7/20\\-67/125 & -1.0/4.0\end{pmatrix}\begin{pmatrix}x\\y\end{pmatrix}+\begin{pmatrix}1/2\\1.072\end{pmatrix} \quad (4)$$

If *A* be the starting structure. Various transformations on *A*, can be revealed as follows:

$$W(A) = \cup_{n=1}^{N} W\,n(A) \quad (5)$$

The Sierpinski fractal geometry can be obtained from the Hutchinson operator ' *W* ' . Figure 3 is the final structure obtained by using scripting method in the HFSS electromagnetic simulator. The proposed antenna layout is sketched on the FR4 substrate having values of $\mathcal{E}_r$ =4.4, tan δ=0.02, h = 1.6 mm and area of 54 × 46 mm^2. Values of $\mathcal{E}_{reff}$ and impedance Z_0 can be calculated using equations (6) and (7) [4].

$$\mathcal{E}_{reff} = \frac{\mathcal{E}_r+1}{2} + \frac{\mathcal{E}_r-1}{2}\left[1\Big/\sqrt{1+12h/w}\right] \quad (6)$$

$$Z_0 = \frac{120\pi}{\sqrt{\mathcal{E}reff}\left[\frac{w}{h}+1.393+0.667\ln\left(\frac{w}{h}+1.444\right)\right]} \quad (7)$$

Figure 3 shows the final antenna geometry on FR4 substrate along with dimensions and feed point. Pink area shows the radiating layout and green area shows the substrate region.

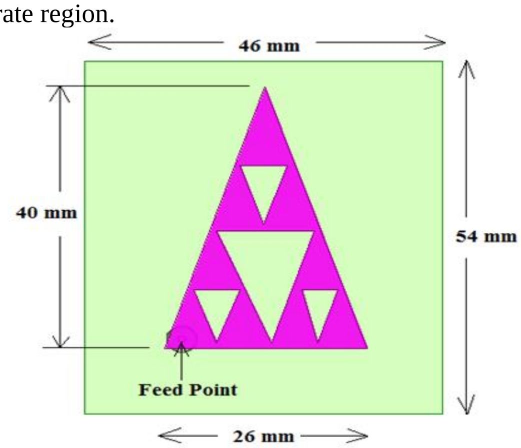

Fig 3. Geometry description of the proposed fractal antenna.

Side view of complete antenna layout is shown in Figure 4. It clearly shows an entire assembly together with fractal radiator, ground, substrate and coaxial connector. Compactness of this planar antenna will be calculable from this figure. Dimensional details of the designed antenna is given in Table 1, units used in the dimensional calculations are in millimeters

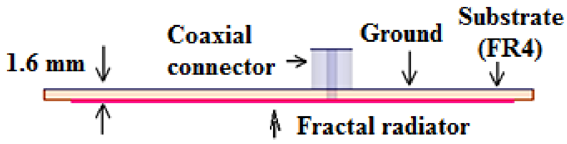

Fig 4. Complete structural details including connector placement and both sides.

Table 1 Layout details of the designed antenna.

Antenna Design Parameters	Values (mm)
Height & Width of FR4	54 × 46
Thickness	1.6
H & W of ground	54 × 46
Width of Sierpinski Patch	26
Height of Sierpinski Patch	40

III. OUTCOME AND CONVERSE

The proposed antenna was first designed on varied substrates like Arlon (6.15), Bakelite (4.8), Polyester (3.2) however the most effective results are obtained on FR4 epoxy (4.4) substrate only. The Simulated S_{11} graph is shown in Figure 5. Voltage standing wave ratio for all resonating frequencies lies in admissible range ≤ 2 [4].

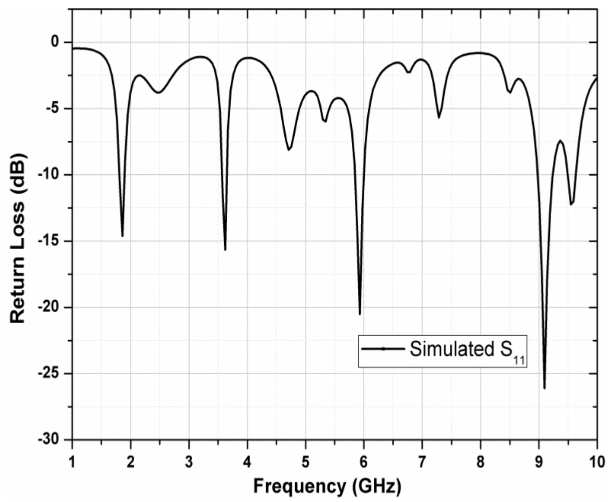

Fig 5. Simulated return loss (S_{11}) of proposed antenna for FR4 substrate.

Suggested antenna resonates at five different frequencies 1.859 GHz, 3.623 GHz, 5.929 GHz, 9.095 GHz and 9.547 GHz. Figure 6 (a to e) shows the simulated 2-Dimensional radiation diagrams for all the resonating frequencies. All these patterns depicts directional behavior of the antenna in the far-field region which is found to be almost omnidirectional in *H*-plane and bidirectional in *E*-plane. Fluctuation within the pattern observed in the radiation pattern as we tend to elevate frequency limit.

The reason behind this is found to be reflection of the radiated signal at the edges and divergence in the flow of current from standing wave patterns [15].

3-Dimensional radiation diagram along with gain legend is revealed in fig. 7. A low profile gain of 3 dB (max) is also observed. Table 2 shows the detailed allocation of all the resonating frequencies 'Fr' along with their respective VSWR values and associated bandwidth for each frequency band.

Table 2. Distribution of resonating frequencies.

Sr. No	Fr (GHz)	S_{11}(db)$_{max}$	B.W (MHz)	VSWR
1	1.859	-14.6	86.5	1.45
2	3.623	-15.64	84.1	1.39
3	5.929	-20.5	154	1.2
4	9.095	-26.09	253	1.1
5	9.547	-12.24	14	1.64

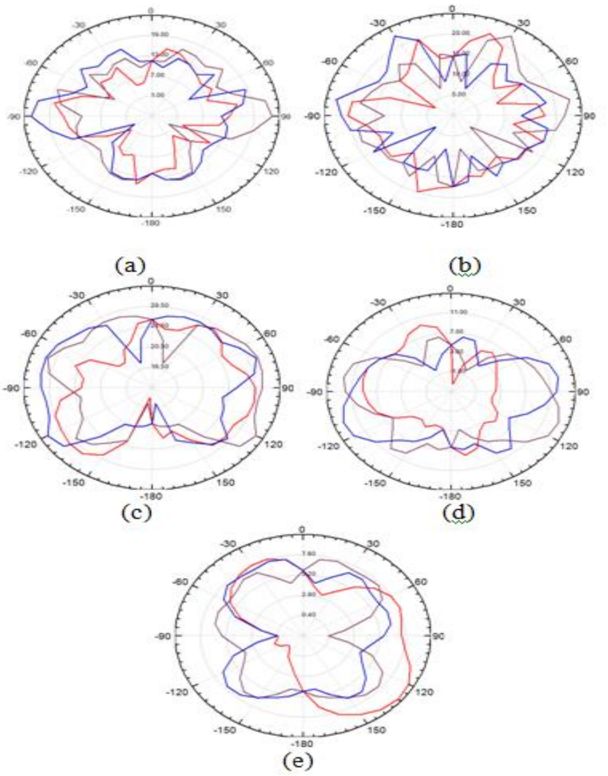

Fig 6. 2-Dimensional radiation diagrams for all 5 resonating frequencies.

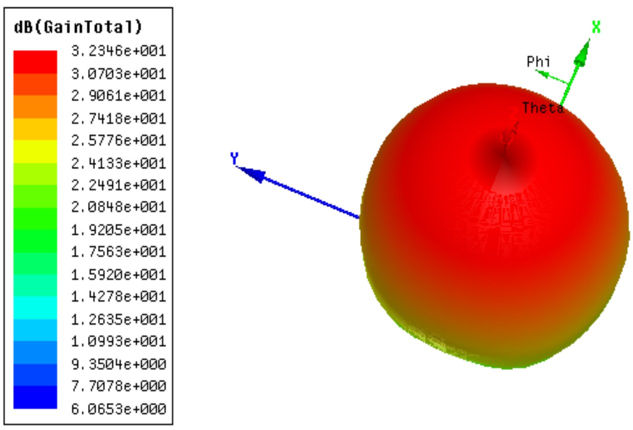

Fig 7. Three dimensional radiation distribution in free space along with gain legend.

IV. CONCLUSION

A redesigned Sierpinski fractal antenna based on Sierpinski gasket is intended and imitated on the FR4 epoxy substrate and the findings are scrutinized. Multiple resonance situations are determined by fractal layouts observed and are brought into play to procure additional resonance situations. The complete antenna layout has compact geometry of 54 mm × 46 mm × 1.6 mm and exhibits penta-band of operation by resonating at five different frequencies 1.859 GHz, 3.623 GHz, 5.929 GHz, 9.095 GHz, and 9.547 GHz along with acceptable values of reflection coefficient, gain, voltage standing wave ratio, and bandwidth. It finds its utility in compact wireless devices due to its lightweight, compact size and planar geometry.

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