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Triangular shaped Sirpinski fractal patch antenna used in GPS, 4th generation and 5th generation

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ABSTRACT

Recent efforts by several researchers around the world to combine fractal geometry with electromagnetic theory have led to a large number of novel and innovative antenna designs. In this research work, we provide a comprehensive overview of the latest advances in the rapid development of fractal antenna engineering. Fractal antenna engineering research focuses on two aspects: the first is the analysis and design of fractal antenna elements and the second is the application of fractal theory in antenna array design. Fractals do not have feature sizes and are usually replicated by themselves at different scales. These unique properties of fractal have been developed for the development of new types of antenna element designs in multi-band or compact size. On the other hand, fractal arrays are a subset of sparse arrays and have been shown to have many very desirable properties, including multi-band performance. Low side lobe level, and the ability to develop fast beam forming algorithms based on the fractal, recursive nature. In this research work, we are presenting four band fractal antenna used for GPS, 4G and 5G applications. The antenna is simulated in HFSS (High-Frequency Structure Simulator) software tool. For the optimization of the proposed work parametric analysis is performed at various dimensions of the fractal antenna.

Keywords: *Monopole, Fractal antenna, Multi-band antenna, HFSS, GPS, 4G, 5G.*

1. INTRODUCTION

The research in wireless communications are increasing day by day and antennas are a key factor in their success. Antennas cannot be dropped in any wireless technology because it is the only medium for receiving and transmitting signals [1]. The rapid growth of wireless applications requires low cost, miniaturized and small antennas. Microstrip patch antenna is comprised of many advantages such as low weight, small size, and simple integration by using PCB (printed circuit board). Thus to reduce the structure of antenna become an n important t area of research. A number of methods are used to decrease the size of the antenna. In the proposed work fractal geometry is considered to reduce the size of the antenna [2]. Fractal electrodynamics is one of the main applications of fractal, in which fractal is the combination of electromagnetic theory, radiation, transmission, and levels scattering problems. Antenna theory and design become one of the most promising areas of fractal Electro kinetic research. The fractal antenna consists of repeated geometry that can be designed in many shapes, such as the Sierpinski rug, Sierpinski Washer, Minkowski ring, Koch and many more. These antennas have been used mostly, because of their advantages like multi-band, wide bandwidth and Compact size etc. Fractal geometry has two common characteristics, Self-similarity and space-filling geometry [3]. Fractal self-similarity Geometry can be described as geometry Similar to the observer's all possible views. Self-similarity provided extra flexibility of antenna design and also allows to reduce antenna with the same factor or different factor level And vertical. This property can be successful applied to multi-band fractal antenna design Such as the Sierpinski gasket antenna. According to observation, this space-filled property can result in Miniaturization of the antenna. Various designs already put this property to reduce the size [4, 5].

2. RELATED WORK

In this section, the research work done on Sierpinski fractal antenna, Kotch fractal shapes by various researchers has been explained along with the feeding techniques, simulator tool used advantages and their outcomes.

Table -1: Comparison of existing techniques

References	Feeding technique/ Antenna Design	Simulator	advantages	Outcomes
[6]	2nd order Sierpinski fractal geometry has been used. The triangular shape has been used of the patch. FR4 substrate has been used. Microstrip feed line is used.	HFSS	Factorization reduces the size of the antenna.	The designed antenna has been used in WI-max and WLAn application. Antenna resonates at two frequencies.
[7]	4th order Sierpinski gastek geometry has been used. Coaxial feeding is used. 'Taconic' substrate with 0.7874 mm thickness and relative permittivity of εr¼ 3.32.	HFSS	Better impedance matching up to 50ohm has been obtained at the 1st resonant frequency.	Mulatiband resonant characteristic has been obtained.
[8].	Proposed a Minkowski based fractal patch antenna with square shape slot at the center of the patch. FR4 substrate has been used with a height of 1.6mm.	Computer simulation technology (CTS)	The proposed antenna find application in wireless personal area application, X band and Ku band ranges from 12 GHz to 18 GHz.	The performance parameters like return loss, gain, smith chart, and bandwidth has been evaluated. The maximum gain obtained is 1.86dB. For first order iteration antenna resonates at two frequencies whereas for the 2nd order of iterations antenna resonates at four frequencies.
[9]	T shaped fractal patch antenna along with DGS shape has been proposed. The dimensions of patch and ground are 36mm *36mm and 50mm * 50 mm has been considered. FR4 substrate has been used.	HFSS	The antenna finds applications in WIMAX , WLAN, satellite & RADAR, and 4G applications	The designed antenna has worked on four frequencies such as 3.51GHz, 4.5 GHz, 6.11 GHz, 8.1 GHz and 9.41 GHz. The maximum gain of 7.7 dBi has been obtained at 4.5 GHz.

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[10]	Proposed a Koch island and Sierpinski carpets. Three fractal iterations have been applied on the patch. The size of the antenna is taken as 130*100*0.5mm^3	HFSS	The small-sized antenna finds application in a wireless communication system.	The size reduction up to 77% has been achieved. Higher quality factor has been achieved. Wider bandwidth has been obtained.

3. ANTENNA DESIGN

Multiband fractal patch antenna has been designed using Sierpinski fractal geometry. Sierpinski fractal antenna has been designed by applying six iterations of fractal geometry to form self-similar structures. The design of the proposed antenna is shown in the figure below.

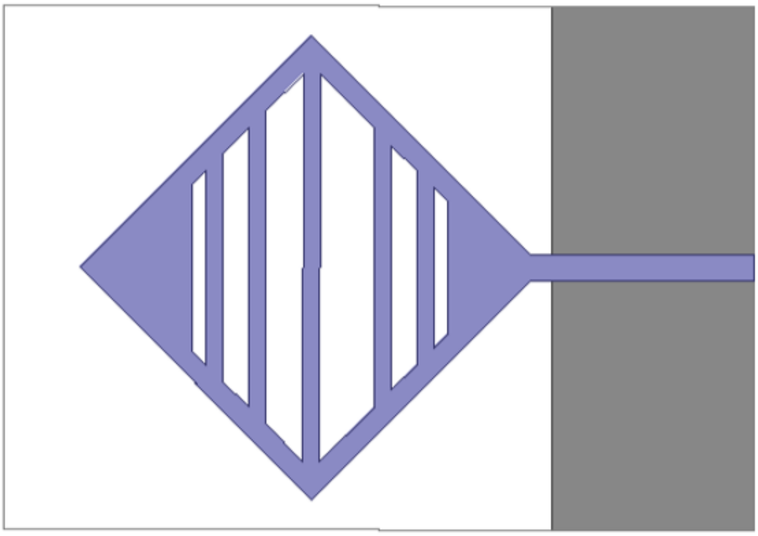


Figure1: Proposed antenna

The basic cell of the Sierpinski geometry is embedded with the diamond configuration for size reduction purposes as shown in Figure 1. It is found that good bandwidth is obtained by applying microstrip feeding technique. Parametric analysis can be obtained by varying substrate thickness, feed point, and other parameters. Design and simulation have been carried out using HFSS.

Table -2: Dimension of triangular Sierpinski fractal patch antenna

Variable	Value
Length of ground	62
Width of ground	24
Thickness of substrate	0.8
Feeding technique used	Microstrip patch antenna
Substrate used	FR4
Feed Point	29.5,0.0.8
Length of the feed line	27.2
The width of the feed line	3

Sierpinski fractal geometry algorithm has been applied to triangular patch and final fractal geometry is shown in figure1. In this geometries length of the ground is reduced. Here triangular patch with polyhedron shape of 4 sides has been taken with a center position of (31, 52.5 ,0.8) and start position of (31, 80 ,0.8). Microstrip line feed has been given at (29,0,0.8)). Feed point has been chosen in such a way that impedance matching takes place. Triangular Shaped patch as shown in figure1 is made by using the concept of fractal geometry.

4. SIMULATED RESULTS

In this section, the results obtained after the simulation of the antenna has been shown below. The observation parameters such as return loss, VSWR, gain, and radiation pattern are discussed in detail.

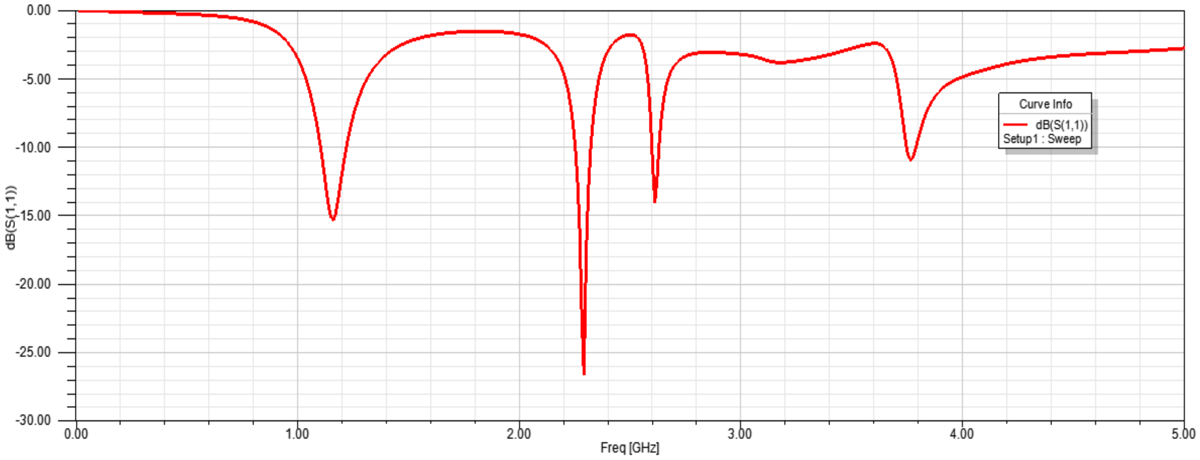


Figure 2: Return loss

From the above figure, it is clear that antenna resonates at four resonant frequencies the return loss values along with frequency is listed in the table below.

Table -3: Return loss values along with resonant frequencies

Frequency (GHz)	Return loss(dB)
1.15	-15.21
2.28	-26.61
2.60	-14.02
3.76	-10.90

The antenna resonates at four frequencies 1.15GHz, 2.28 GHz, 2.60 GHz, 3.76 GHz with return loss values -15.21,-26.61, -14.02,-10.90 respectively. Maximum return loss is obtained at 2.28 GHz.

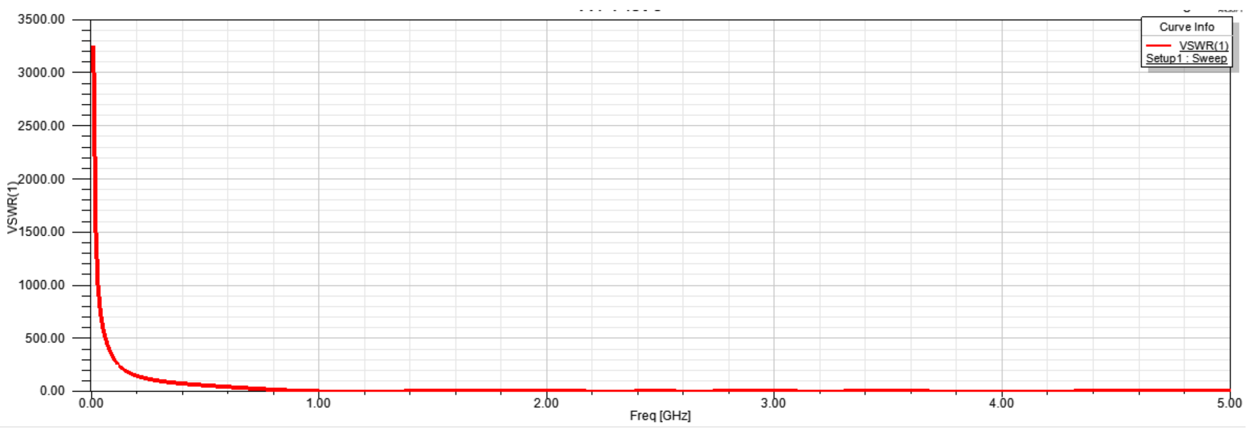


Figure 3: VSWR at solution frequency=1.16GHz

The above figure represents the VSWR value obtained for the proposed antenna when solution frequency is set at 1.16GHz. It is clear from the above graph that the value of VSWR obtained for the proposed antenna is 0 which means that all the power transmitted from the source is received by the load with no power loss.

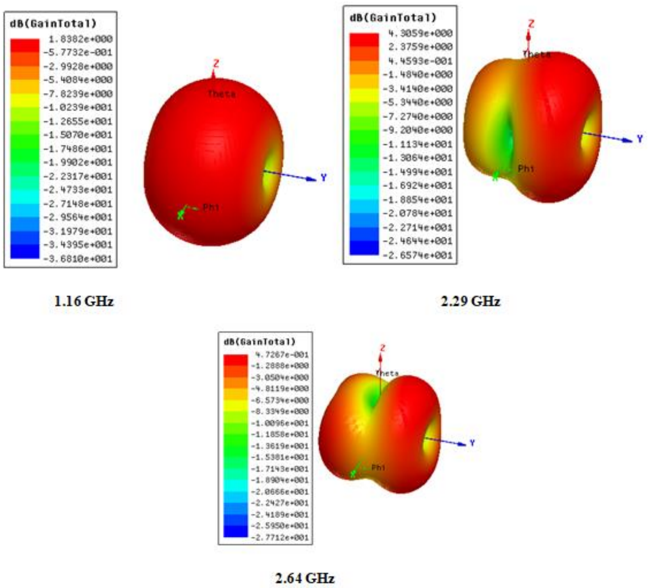
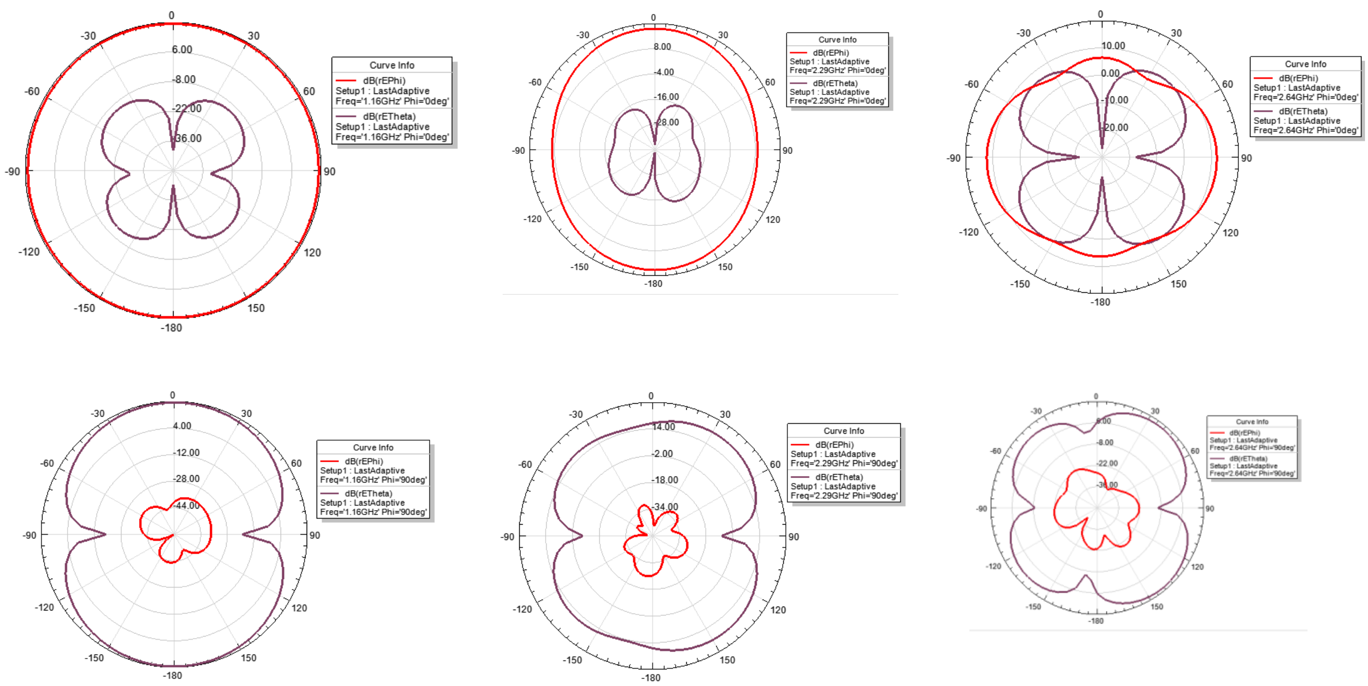


Figure 4: Gain

The above figure represents the gain obtained at 1.16GHz, 229GHz, and 2.64 GHz. The gain obtained for the proposed antenna is 1.83dB, 4.30 dB, and 472dB respectively. The positive value of gain represents that the antenna radiates with high power in a particular direction.



F=1.16 GHz **F=2.29GHz** **F=2.64GHz**

Figure 5: radiation pattern of proposed antenna

The above figure represents the radiation of proposed antenna at three resonant frequencies 1.16 GHz, 2.29 GHz and 2.64 GHz respectively. The radiation pattern is measure at phi=0 degree and phi=90 degree that represents the co and cross-polar component. Here, E phi is the co-polar component and E theta is the cross-polar component.

5. CONCLUSION

The field of fractal antenna engineering is still in the relatively early stages of development, with the anticipation of much more innovative advancement to come over the months and years ahead. In this research work, a triangular shape fractal Sierpinski antenna has been designed by using HFSS 13.0 simulator tool. Initially, a triangular shape patch antenna is considered and then fractal geometry has been applied up to 5 numbers of iterations. A modified Sierpinski monopole fractal antenna is proposed operating at 1.16GHz, 2.28GHz, and 2.64 GHz. The optimization of the resonant frequency points and there impedance matching is done through parametric analysis of the different dimensions of the ground plane and feed line of the antenna. The proposed

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antenna finds application in GPS (Global positioning system), 4G LTE and 5th generation (5G). The gain of the proposed antenna obtained are 1.83dB, 4.30 dB and 4.72dB obtained at three solution frequencies at 1.16GHz, 2.28GHz, and 2.64 GHz. The VSWR obtained for the proposed antenna is less than 2 which indicates that antenna radiates properly without any back propagation or loss.

In future, DGS (Defected ground structure) geometry can be used to reduce the size and to increase the bandwidth of the proposed antenna.

6. REFERENCES

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