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Improved Performance of Sierpinski Carpet Based Mushroom Shaped Fractal Microstrip Antenna with DGS

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Abstract: The combination of electromagnetic theory and fractal geometry has led to many innovative and useful antenna designs. Sierpinski Carpet fractal technique has been applied on the patch antenna with a square patch of $25\times25mm^2$. Co-axial feed has been applied to the patch antenna and the substrate used is FR4 with dielectric constant of 4.4. The multiband properties and the improvement in bandwidth have been observed, allowing a single antenna to be used in integrated application devices. The proposed antenna has a bandwidth of 3.5GHz with the minimum return loss of -24dB. Based on this it has applications in long distance radio communication, microwave relays, satellite communications and RADAR. The antenna has been analyzed in terms of various parameters such as return loss, gain, bandwidth, directivity etc. Design and simulation has been carried out using IE3D Simulation software.

Keywords: Patch antenna, Sierpinski fractal, IE3D software, co-axial feed.

I. INTRODUCTION

Wireless technology has become a necessity during the past few decades. Nowadays, wireless technology requires antennas which are having smaller dimensions and wider bandwidth [1]. Microstrip antennas are widely used in such applications because of their features such as low weight, less cost, simplicity of manufacture and high efficiency. However, they have the major disadvantage of microstrip antenna is narrow bandwidth and poor polarization [2]. Fractal geometry allowed us to design miniature antennas and to integrate multiple bands into a single device. Fractal was first defined by Benoit Madelbrot in 1975 and snowflakes were the first example of fractal given by him. Due to the geometric properties of fractals they have different features. Antenna with characteristics such as multiband behavior, higher bandwidth and miniaturization can be achieved by the self similar and space filling features of the fractal geometry [3]. Using these properties of fractal, a single antenna can be used for a number of applications thus saving the space and time. Fractals have different shapes such as Minkowski fractal, Koch Fractal, Sierpinski carpet fractal Hilbert curve and fractal arrays.

II. SIERPINSKI CARPET ANTENNA

The Sierpinski gasket is named after the mathematician Sierpinski who described some of the main properties of this fractal shape in 1916. Sierpinski carpet follows iteration function of squares which can have n iterations. In order to start this type of fractal antenna, it begins with a square in the plane, and then divides it into nine congruent squares where the middle square is dropped. The remaining eight squares are divided into nine smaller congruent squares where each middle square is dropped which is decomposition approach which is shown in the figure 1. The scaling factor is also very important and that is because the second iteration is made in accordance with the first iteration.

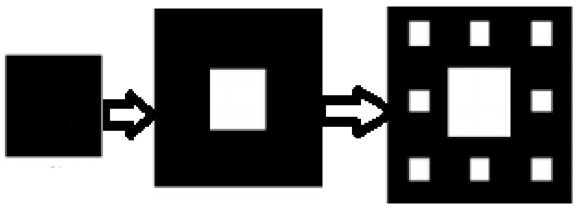

Figure 1(a) Multiple copy approach

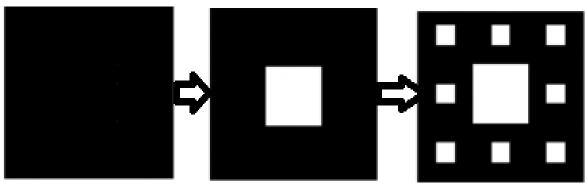

Figure 1(b) Decomposition approach

III. DESIGN AND IMPLIMENTATION

In order to use same antenna for different applications the antenna which is required should be a multiband antenna and miniaturized to suite different wireless applications. Before we design an antenna the frequency of operation of the antenna should be known. By the use of fractal geometry a single antenna can be made to work at different frequencies. This makes the device in which the antenna is used, to work at different frequencies and hence can be used at different applications. There are a number of techniques which can be used to make a multiband antenna. Sierpinski carpet technique has been used to design a mushroom shaped antenna. Three iterations have been done and the parametric analysis has been carried out The designing starts with a Sierpinski carpet fractal monopole antenna. At first a square patch is analyzed. The square patch has dimensions of L×B= 25mm×25mm. The substrate used is FR4 and has a relative permittivity of €sub=4.4. Coaxial field has been used to provide feed to the antenna. Feeding is done at a point where the impedance matching is maximum. Design and simulation has been carried out using IE3D software.

TABLE 1: Dimensions of mushroom shaped FMPA

Variable	Value
Length of patch	25mm
Width of patch	25mm
Length of ground	30mm
Width of ground	30mm
Thickness of substrate	2.4mm
Feeding technique used	Coaxial Feeding Technique
Substrate used	FR-4
Dielectric constant	4.4
Loss Tangent	0.02
Feed point	X=-11, y=-11, z=0
First iteration cut	8mm
Second iteration cut	3mm

The different geometries corresponding to 0^{th}, 1^{st}, and 2^{nd} iterations has been shown in figure 1(a), 1(b) and 1(c). the square has a dimensions of 25mm×25mm and the ground dimensions are 30mm×30mm. the coaxial feed has been applied at (-11, -11, 0). The feed point is selected in such a way that impedance matching takes place.

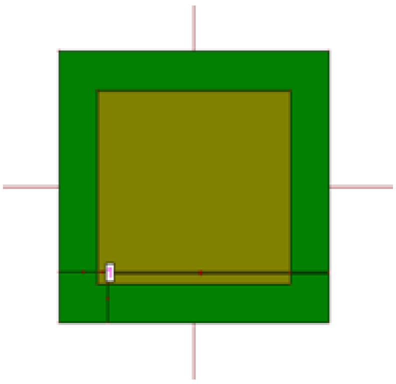

Figure 1(a)

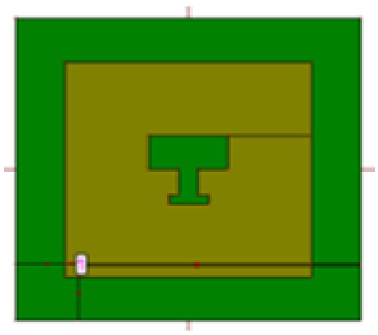

Figure 1(b)

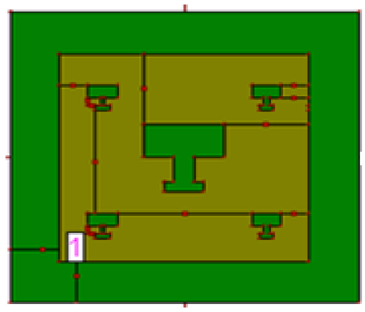

Figure 1(c)

1^{st} iteration of Sierpinski carpet technique has been applied to the patch as shown in figure 1(b). A mushroom shaped cut is made in the center of the patch. Now in the 2^{nd} iteration the same mushroom is made on all four sides of the mushroom made in the 1^{st} iteration. For carrying out this operation 3mm cuts are made on all four sides of the center mushroom as shown in figure1(c). IE3D software has been used hence the one has to consider the center of the square for making cuts. These geometries show self repeated structures. It can be seen from the figures that as the number of iterations keep on increasing, the size of mushroom keeps decreasing and the area also decreases.

IV. RESULTS AND DISCUSSIONS

In this section result of different iterations of cantor fractal geometry applied n square patch are discussed. Dimensions of proposed antenna are optimized by IE3D simulation software and the final dimensions are listed in table II. The antenna characteristics are defined on the basis of resonant frequency, return loss, gain, Bandwidth, directivity etc.

From figure 2 it is clear that fractal geometry helps in improving the characteristics of an antenna. At 0^{th} iteration the antenna resonates 5.4GHz, 8.1 GHz, and 10.2GHzwith return loss of -30 dB, -18db and -20dB, gain at these frequencies is 0.9dBi, 3.1dBi and 0.7dBi. With directivity of 4.3dBi, 9.1dBi and 8.9dBi. With a bandwidth of 450Mb. On applying first iteration the antenna resonates at5.9GHz, 8.3GHz, 8.7GHz and 0.7GHz with return loss of -10.3dB, -11.6dB, -15.76dB and -39.9dB, with gain of2.5dBi, 2.3dBi. 1.7dBi and 2.2dBi and directivity of 7.3dBi, 8.4dBi, 7.87dBi and 7.6dBi a bandwidth of1GHz.

Table II: Comparison of the results of different iterations

Iter No	Resonance Freq. (GHz)	Return Loss (dB)	Gain (dBi)	Directivity (dBi)	Band Width (MHz)
0^{th}	5.4	-30	0.936	4.348	
	8.1	-18	3.111	9.136	
	10.2	-20	0.072	8.945	450MHz
1^{st}	5.94	-10.34	2.558	7.37	50MHz
	8.3	-11.66	2.324	8.4	
	8.7	-15.76	1.777	7.87	
	9.7	-39.9	2.283	7.6	1800Mhz
2^{nd}	5.5		2.29	5.82	
	8.2	-13	1.33	7.62	200MHz
	9.4		2.65	8	
	9.7	-28.26	1.93	6.8	2GHz

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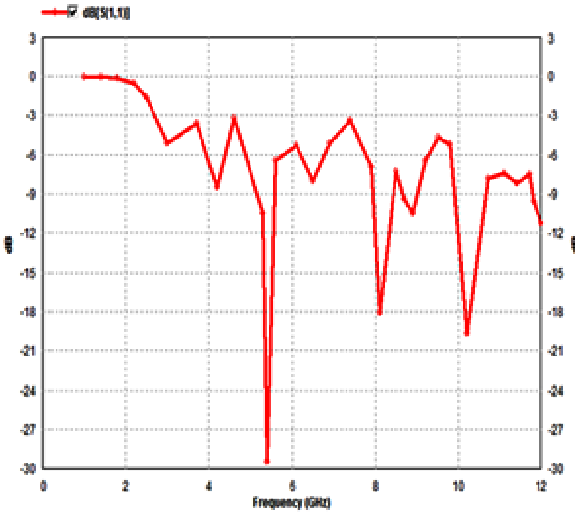

Figure 2(a)

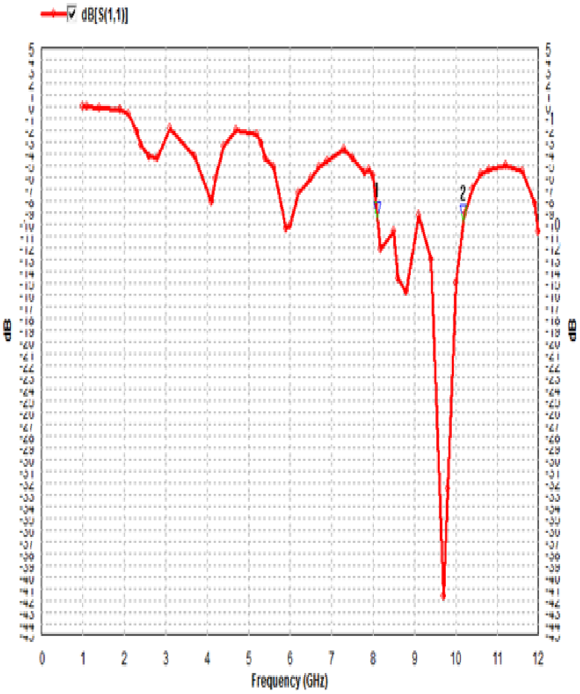

Figure 2(b)

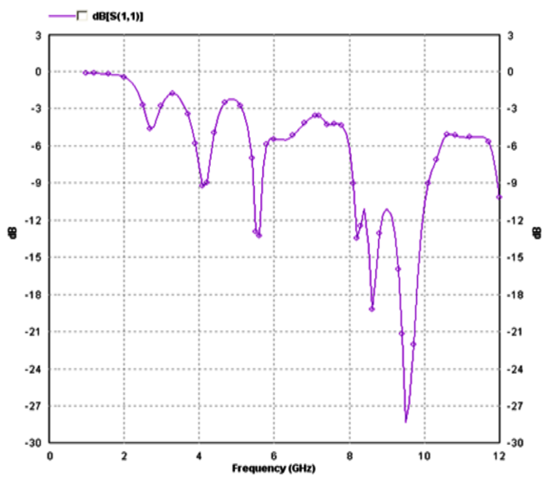

Figure 2(c)

With the 2nd iteration there are certain improvements in the characteristics. with the antenna resonating at 5.5GHz, 8.2GHz, 9.4GHz and 9.7GHz and the return loss of -13db and -28.26dB, with the gain of 2.29dBi, 1.33dBi, 2,65dBi and 1.93dBi, directivity of 5.82dBi, 7.62dBi, 8dBi and 6.8dBi with a bandwidth of 2Ghz. The radiation pattern corresponding to the frequencies 5.5GHz, 8.2GHz and 9.4GHz is shown in figure 3.

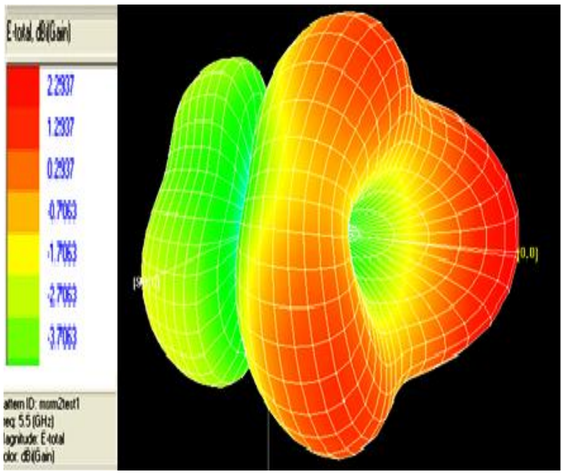

Figure 3(a)

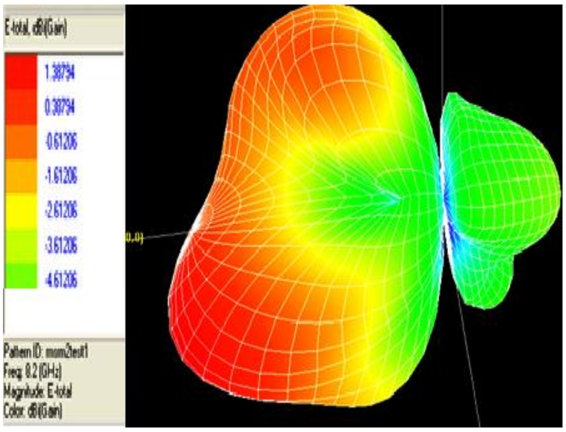

Figure 3(b)

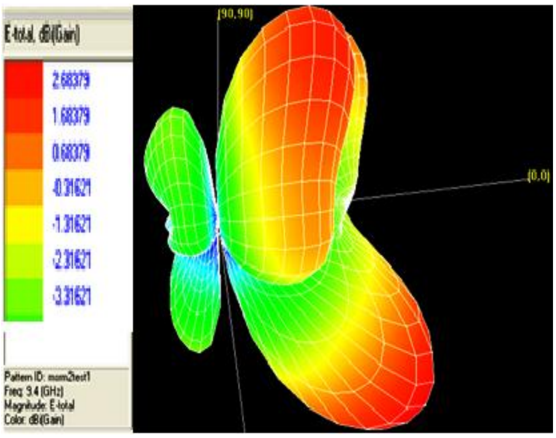

Figure 3(c)

Figure 3: Radiation patterns of reference antenna at (a) 5.5 GHz (b) 8.2 GHz (c) 9.4 GHz

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V. EFFECTS OF APPLYING DGS

By applying fractal geometry, multiband characteristics of the antenna are obtained. In order to further improve the characteristics of an antenna DGS is applied on the ground plane. Two U-slot DGS have been applied to the ground plane of the mushroom shaped patch antenna. There are many other configurations of DGS which can be applied. We use the configuration which produces the best results for our design. The DGS is made on the ground plane of the antenna. A u shaped slot is cut on the ground plane having a width of 1mm. By applying DGS, area of the ground plane decreases and the flow of current changes its direction. The main advantage of using DGS is that it produces wide bands and reduces the surface waves.

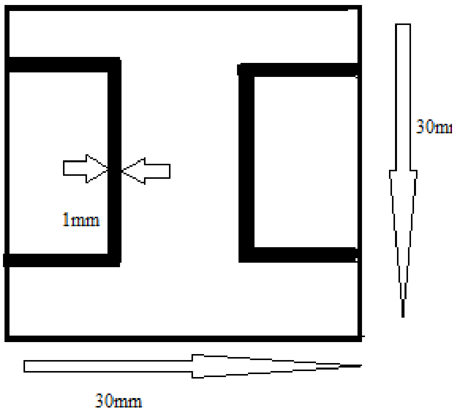

Figure 4: Two U shaped DGS on horizontal plane

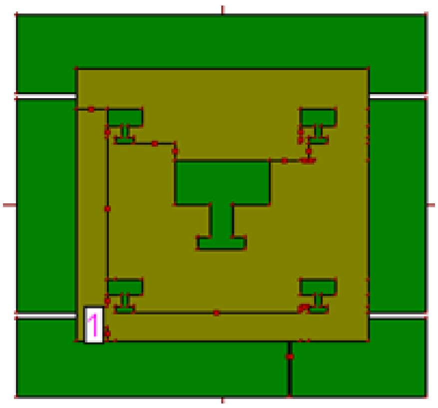

Figure 5(a)

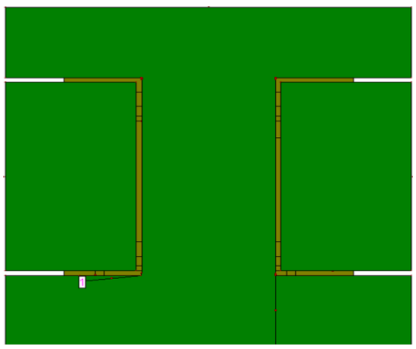

Figure 5(b)

Figure 5: antenna with DGS (a) top view (b) bottom view

The geometry of U shaped DGS is shown in the figure 4 above, the U shaped cut in the ground helps in reducing the area of the ground and improving bandwidth at different frequencies. The DGS is made on the ground plane of the mushroom shaped antenna. It consists of two U shaped slots of 1mm width. Top and bottom view of the DGS is shown in figure 5(a) and 5(b).

VI. SIMULATION RESULTS OF MUSHROOM SHAPED FRACTAL PATCH ANTENNA USING DGS

As we have seen in figure 2(c) that after applying 2nd iteration the antenna resonates at 5.5GHz, 8.2GHz and 9.7GHz with return loss of -13dB, -28.26dB, with a gain of 2.29dBi, 1.33dBi, 2.65dBi and 1.93dBi, directivity of 5.82dBi, 7.62dBi, 8dBi and 6.8dBi with a bandwidth of 2GHz. By applying DGS the characteristics of the antenna improves. The return loss vs frequency graph of antenna after applying DGS is shown below.

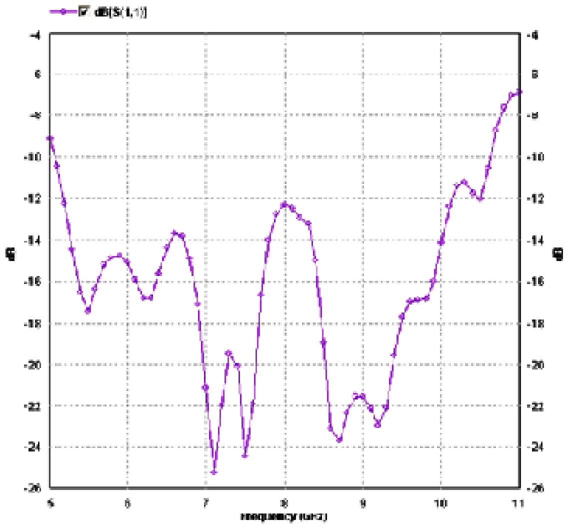

Figure 6: Return loss vs. frequency graph after applying DGS

The antenna with DGS resonates at 5.3GHz, 7.8GHz, 10.3GHz and 11GHz having a maximum return loss of -24dB. The bandwidth produced is 3500MHz. the gain at different frequencies is 1.17dBi, 2.26dBi, 1.62dBi, 1.87dBi. The directivity produced is 5.86dBi, 7.885dBi and 8.6dBi respectively
The radiation patterns at different frequencies have been shown in figure 7.

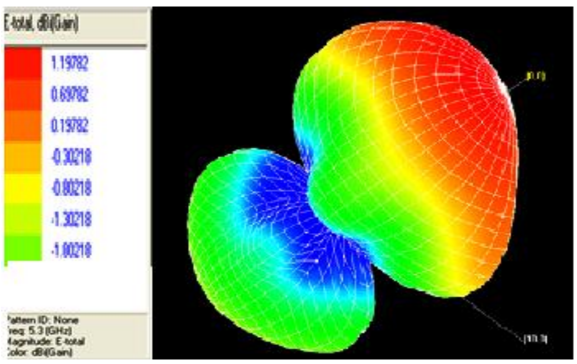

Figure 7(a)

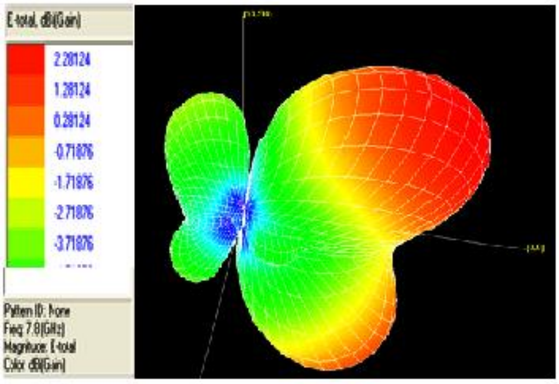

Figure 7(b)

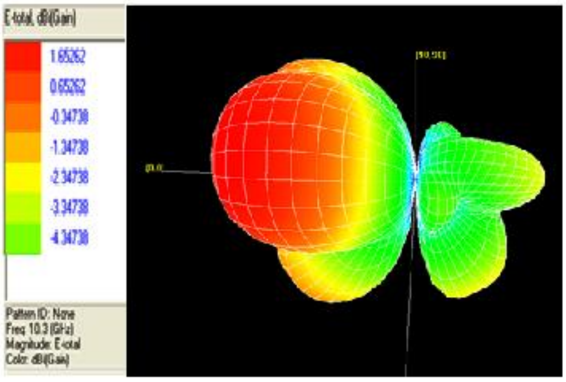

Figure 7(c)

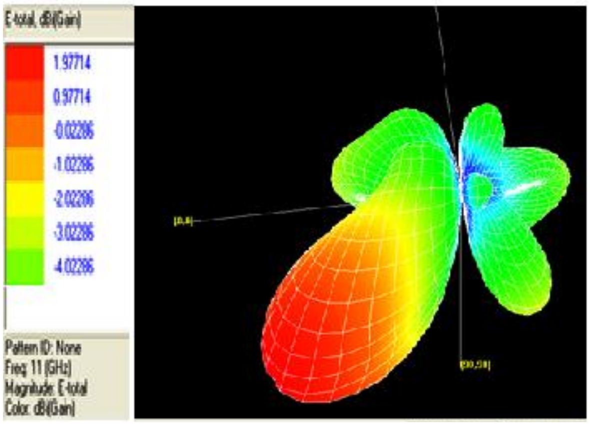

Figure 7(d)

Figure 7: radiation pattern of U shaped DGS at (a) 5.3GHz (b) 7.8GHz (c) 10.3GHz (d) 11GHz

The results show that there is an improvement in bandwidth from 2Gb to 3Gb but there is a slight increase in the value of return loss. Hence DGS provides wide bands. This antenna produces a band between 6GHz to 12 GHz. The comparison of the result of 2nd iteration and the results using DGS are shown in the table III.

Now the table III above shows that the band produced using DGS is 3.5GHz and that of without DGS is 2GHz. So the bandwidth range has been improved but there is slight degradation in the value of return loss. There is always a trade-off between antenna parameters. The proposed antenna using DGS is applicable for C (4-12) GHz and X(8-12)GHz microwave frequency bands.

Table III: Comparison of the results of antenna design with and without DGS.

Iteration no.	Resonance Freq (GHz)	Return Loss (dB)	Gain (dBi)	Directi-vity	Band-width
2^{nd} iteration	5.5	-13	2.29	5.82	200MHZ
	8.2	-28.26	1.33	7.62	2Ghz
	9.4		2.65	8	
	9.7		1.93	6.8	
	10		2.18	7	
U-slot DGS	5.3	-24	1.17	5.86	3GHz
	7.8		2.26	7.885	
	10.3		1.62	7.17	
	11		1.87	8.6	

So based on these values this antenna is applicable to long distance radio communication, microwave relays satellite communication and RADAR.

VII. CONCLUSION

In this work mushroom shaped antenna has been designed using Sierpinski carpet fractal geometry. Initially a square patch of side 25mm×25mm has been analyzed. Then two iterations have been applied on the patch using Sierpinski carpet geometry. The second iteration resonates at 8.2GHz, 9.4GHz and 10 GHz frequencies and produces a bandwidth of 2 GHz having a return loss of -28.26dB. the feed points are taken at (-11.-11) co-ordinates using coaxial feed. After applying U slot DGS the bandwidth is improved. The 2^{nd} iteration using DGS resonates at 5.3GHz, 7.8GHz, 10.3GHz, and 11GHz frequencies. This antenna design resonates between 6GHz to 12GHz frequency range. It produces a band of 3.5Ghz. So this shows that the bandwidth has been improved using DGS. the proposed antenna can be used for long distance radio telecommunication, microwave relays, satellite communications and RADAR.

REFERENCES

[1]. Rowdra Ghatak, Anirban Karmakar, D. R. Podder, 2012. "Hexagonal Boundary Sierpinski Carpet Fractal Shaped Compact Ultra-wideband Antenna with Band Rejection Functionality," International Journal for Electronics and Communication, Vol 67, pp 250-255.
[2]. Howell, J.Q._ Microstrip Antennas IEEE Trans. Antenna Propagation, Vol. AP-23", January 1975, pp.90–93.
[3]. Improved performance of Sierpinski Carpet Based Fractal Antenna using Stacked Configuration Anuj Attri, Ankush Kansal
[4]. "Design of Sierpinski Carpet Fractal Antenna for Multiband Applications" Ashish Dhankhar1, Dr.Jaswinder Kaur.
[5]. Parthsarthi Namdeo, Navneet Agrawal, Pankaj Yadav, Rahul Vishwakarma, and Gaurav Chaitanya, 2015. "Design and Analysis of Sierpinski Carpet Fractal Antenna", International journal of innovative research in electrical, electronic, instrumentation and control engineering, Vol. 3, Issue 5.
[6]. D.H. Werner and S. Ganguly, 2003, " an overview of fractal antenna engineering research", IEEE antennas and propagation magazine, vol 45, No1, pp 38-57.
[7]. Feng Wai Yao, Xiao-Bo Xuan, Yuan-Yun Liu, Yuan-Bo Shang, 2012, " A novel compact microstrip slot antenna with spirals".
[8] C.A. Balanis, Antenna Theory, second edition, New York: John Wiley and sons, Inc 1997
[9]. Sangjun Ha and Chang Won Jung, "single patch beam steering with U-slot for wearable applications
[10] Antenna engineering handbook, third edition, by Richard C. Johnson.