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MODIFIED SIERPINSKI CARPET FRACTAL ANTENNA FOR WIRELESS COMMUNICATION

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***Abstract---*A compact fractal antenna based on the Sierpinski Carpet is proposed and designed in this paper. The paper illustrates the design optimization of the modified fractal antenna up to second order iteration for multiband characteristics. The antenna is fed by coaxial feed. The design is obtained at the center frequency 2GHz. The designs are simulated for various locations of coaxial feed. Moreover the effect of cutting slots in modified Sierpinski Carpet is observed. The enhancement in the operating bands is observed in the proposed design. Operating frequency bands are adjusted by variations in design parameters. Multiband functionality is observed in first and the second order iteration of the design presented in this paper. By alterations in the design parameters of this antenna various operating frequencies are achieved which are applicable to more than one application. Gain and Directivity are stabilized to large extent. Improvement in the return loss and VSWR is observed .These antenna designs are thoroughly simulated on FR-4 substrate with loss tangent 0.025 and dielectric constant 4.3 and analyzed using Computer Simulation Technology Microwave Studio-2012. These designs are applicable to Personal communication System, Satellite Communication and Navigation System, Mobile, WLAN, Wi-Max, Wi-Fi, Bluetooth ,Radio Navigation i.e. L-band, S-band and C-band applications.**

Index Terms: fractal antenna, Sierpinski Carpet, multiband, rectangular patch antenna

I. INTRODUCTION

In contemporary world of wireless communication there is high demand of multi-functional, compact, conformal and discreet antenna that is versatile [1]. In order to accomplish this requirement a multiband and miniaturized antenna is proposed. There are number of fractal antennas introduced and designed to obtain multiband characteristics. Fractal is consequent from the Latin word “fractus” which means irregular and iterative and was coined by Mandelbrot [2].A different and also useful attribute of some fractal element antennas is their self-scaling aspect [3]. Fractals have self-similarity and space-filling property which make them iterative in nature. The self-similar shapes were first created by Nathan Cohen. Due to this property the electrical length of antenna increases [4]. Fractal antenna technology has come to the rescue for designers in military and defense applications. It is used for UWB applications, RFID, mobile communication, satellite communication, WLAN, Wi-MAX, ISM, Wi-Fi applications [5]. The standard geometries that follow self-similarity property are Sierpinski Carpet and Sierpinski Gasket [6]. Sierpinski Gasket has n iterations which results into number of operations bands [7]. Here the height of triangle of first iteration is twice that of the triangle in second iteration. Hence the scaling factor is of great significance. Sierpinski Gasket can operate as a quasi-single-mode laser [8].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 smaller congruent squares where the middle square is dropped. The remaining eight squares are divided into nine smaller congruent squares where each middle are dropped which is decomposition approach which is shown in figure 1 up to 2nd iteration.

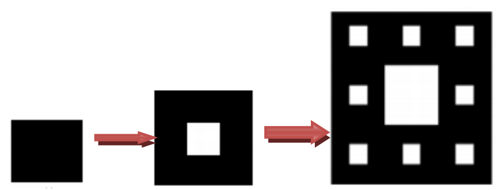

Fig:1(a) Multiple Copy Approach[9]

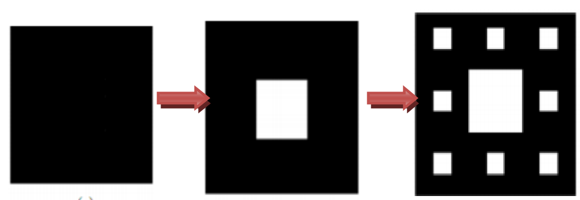

Fig:1(b) Decomposition Approach[9]

The scaling factor here is also important as the second iteration element is scaled with respect to the first iteration element. The other examples are Koch fractal loop and contor set that reflects similarity in structure. Geometric construction of Koch curve starts with the straight line as an initiator. This is partitioned into three equal parts, and the segment at the middle is replaced with two others of the same length .This is the first iterated version of geometry and is called generator. Fractals includes the geometry that fall between the distinctions, it can be a line that approaches the sheet. The space-filling properties lead to the curves that are electrically very long, but fit into compact physical space and

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lead to miniaturization of antennas elements [10].Hilbert curves follows the property of space-filling. This property hence increases the number of operating frequencies. Peano curves can be used for space filling property. [11]

(A)DESIGN 1 (B) DESIGN 2 (C) DESIGN 3

Fig.2. Modified Sierpinski Carpet at various iterations

II MATHEMATICAL SUPPORT:

Step 1: Calculation of the Width (W):

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_{r+1})}{2}}}$$

Step 2: Calculation of Effective dielectric constant (ε_{reff}):

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}}$$

Step 3: Calculation of the Effective length (L_{eff}):

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}}$$

Step 4: Calculation of the length extension (ΔL):

$$\Delta L = 0.412h\,\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

Step 5: Calculation of actual length of patch :

$$L = L_{eff} - 2\Delta L$$

Step 6**:** Calculation of the ground plane dimensions (Lg and Wg) : The transmission line model is applicable to infinite ground planes only. However, for practical considerations, it is essential to have a finite ground plane. It has been shown by that similar results for finite and infinite ground plane can be obtained if the size of the ground plane is greater than the patch dimensions by approximately six times the substrate thickness all around the periphery. Hence, for this design, the ground plane dimensions would be given as:[C.A.BALANIS]

Lg=6h+L

Wg= 6h+W

III DESIGN GEOMETRIES FOR VARIOUS ITERATIONS:

*A) Design 1 (**Zero Order Iteration**):*

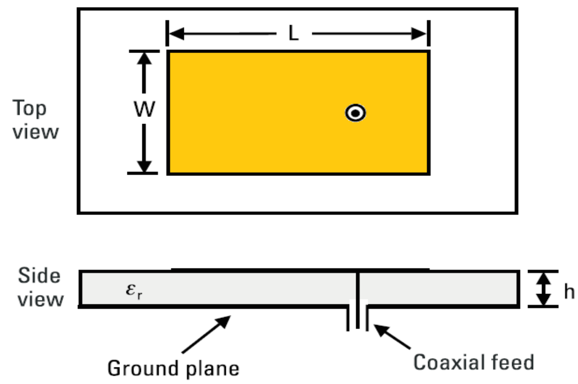

Fig.3 (a) Basic structure of rectangular patch

Table 1

Parametric Study:

Length of Patch(L) (mm)	Width of Patch(W) (mm)	Substrate height(h) (mm)	Dielectric constant (εr)	Design Frequency (fr) (GHz)
46	34	2.4	4.3	2

Parameteric Dimensions of Zero Order Iteration

*B) Design 2 (**First Order Iteration**):*

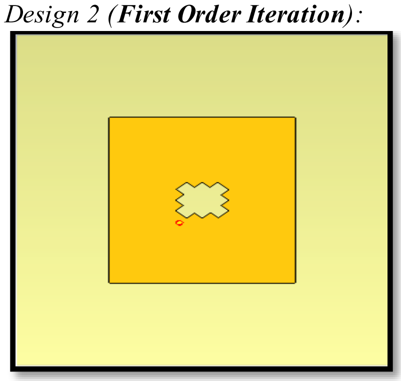

Fig 3(b): 1st order iteration of Modified Sierpinski Carpet

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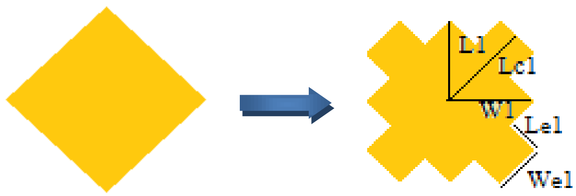

(45^o rotation of square shape) (extruded shape for first iteration)

Fig.3(c) Design Procedure of modified Sierpinski Carpet at 1[st] order iteration

Table 2
Parameters Of First Order Iteration Of Modified Sierpinski Carpet :

Dimensions of first iteration		Dimensions of extended rectangle		
Length of slot(L1) (mm)	Width of slot(W1) (mm)	Length Of slot (Le1) (mm)	Width Of slot (We1) (mm)	Diagonal From centre (Lc1) (mm)
3.5	3.5	2.12	2.82	5.65

Parameteric Dimensions of First Order Iteration

*C) Design 3 (**Second Order Iteration**):*

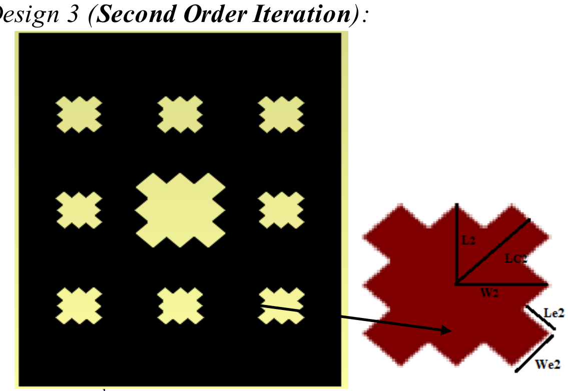

Fig.3(d). 2[nd] order iteration of modified Sierpinski Carpet

Table 3
Parameters Of Second Order Iteration Of Modified Sierpinski Carpet :

Dimensions of second iteration		Dimensions of extended rectangle		
Length of slot (L2) (mm)	Width Of slot (W2) (mm)	Length Of slot (Le2) (mm)	Width Of slot (We2) (mm)	Diagonal From centre (Lc2) (mm)
2.48	2.48	1.13	1.41	2.89

Parameteric Dimensions of Second Order Iteration

IV PARAMETRIC STUDY

1) *Effect Of Variation In The Scaling Factor:*
By changing the geometrical scale factor of the Sierpinski Fractal, the band positions are changed accordingly, which confirms that the band positions correspond to the geometrical scale factor of the Sierpinski fractal, but it results in poor input matching. The scaling factor is given by

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

Where, δ is the scaling factor. [12]

2) *Effect Of Increase In The Number Of Iterations:*
It was observed that as the iterations go on increasing the Loading causes multiple resonances and a shift down in Frequency .Also with increase in the number of elements there is reduction in gain.[13]

3) *Effect Of Change In The Position Of The Feed Location:*
By changing the feed probe or coaxial feed location we can see the variations in the impedance on smith chart. It also varies the return loss of the antenna which affects the bandwidth of the antenna.[14]

V .DESIGN AND METHODOLOGY

The focus of this paper is to enhance the multi-frequency applications retaining the other parameters of antenna (beam-width, directivity, gain, radiation pattern). Design modifications are obtained by cutting slots in the Standard Sierpinski Carpet and its effect is analyzed through simulations using CST MICROWAVE STUDIO-2012.

The design is obtained by considering the inputs $\boldsymbol{f_r}$ (resonant frequency),h (height of the triangle) ,$\in_r$(dielectric constant) to the models which are simulated to obtain optimum results.

VI COMPARATIVE ANALYSIS OF THE PROPOSED ANTENNA DESIGN:

1) ***Zero Order Iteration of Rectangular Microstrip Antenna*:**

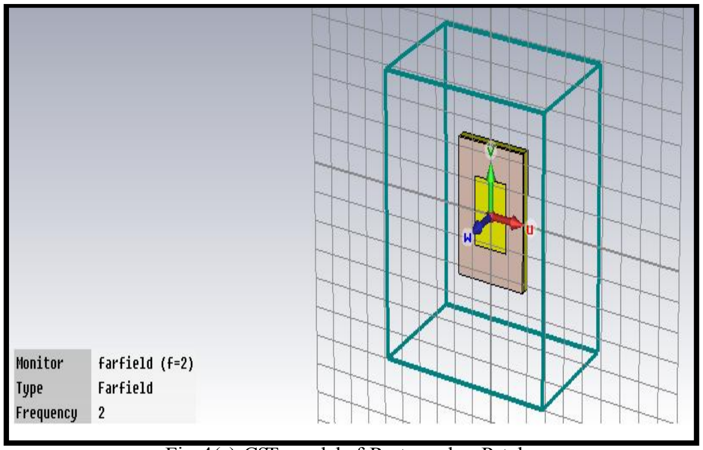

Fig-4(a) CST model of Rectangular Patch

Simulated Results:

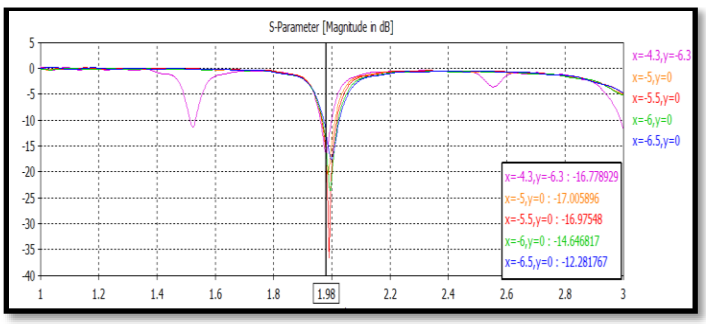

Fig-4 (b) Return loss plot

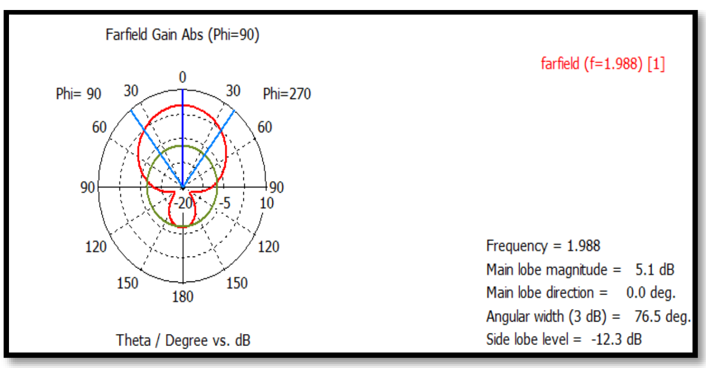

Fig-4(c) Polar plot (gain)

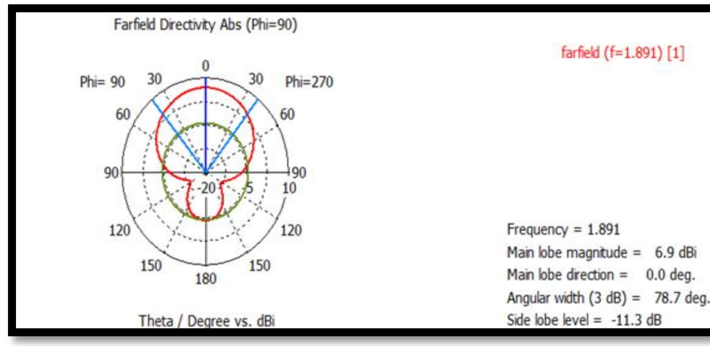

Fig-4(d) Polar plot (directivity)

Table 4

Optimum Results For RMSA

Fr (GHz)	S_{11} (dB)	Gain (dB)	Directivity (dBi)	Efficiency	VSWR
1.522	**-11.316**	**3.761**	**5.973**	**0.629**	**1.746**
1.980	**-16.778**	**5.244**	**6.938**	**0.755**	**1.338**

Simulated Results for Zero order Iteration

Result Analysis:

The results are simulated at 2GHz.The results for gain and directivity at resonating frequency 1.988 GHz are shown above along with return loss plot for different coaxial variations on patch. The efficiency is about 75% at the resonating frequency. Moreover VSWR is less than 2 which is appreciable. The sidelobe level is highly suppressed which is -12.2 dB. Angular

width(3dB) is about 76^{o}.Main lobe magnitude is 5.244 dB and Directivity is given as 6.938 dBi

2) First Order Iteration of Modified Sierpinski Carpet:

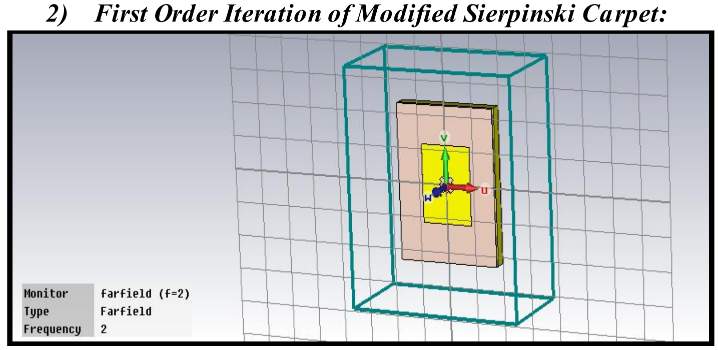

Fig-5(a)CST model First Order Iteration of Modified Sierpinski Carpet

Simulated Results

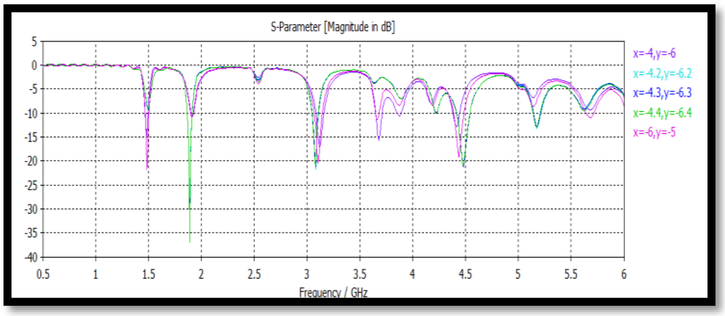

Fig-5(b) Return Loss plot

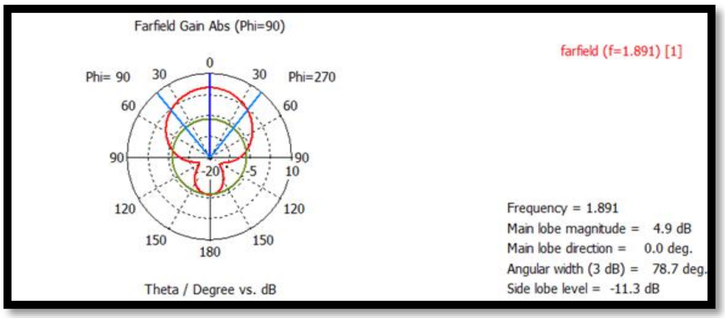

Fig-5(c) Polar Plot (gain)

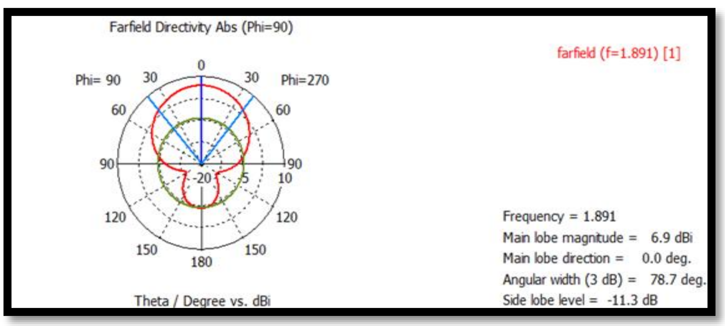

Fig-5(d) Polar Plot (directivity)

Table 5
Optimum Simulated Results For First Order Iteration Of Modified Sierpinski Carpet

Fr (GHz)	S11 (dB)	Gain (dB)	Directivity (dBi)	Efficiency	VSWR
1.8915	**-34.937**	**4.901**	**6.880**	**0.712**	**1.036**
3.0795	**-21.256**	**4.910**	**7.502**	**0.654**	**1.191**
4.223	**-10.000**	**2.225**	**6.396**	**0.347**	**1.938**
4.482	**-21.200**	**6.753**	**10.390**	**0.649**	**1.190**
5.175	**-12.995**	**1.494**	**6.461**	**0.231**	**1.577**

Simulated Results for First order Iteration

***Result Analysis**:*

The design for 1st order Sierpinski Carpet is implemented and simulated for resonating frequency 2 GHz.The gain and directivity results are almost same as the standard Sierpinski Carpet.The return loss results are highly improved at 1.891GHz.The results are otained for various positions of feed location.The efficiency is about 71.20% which is better compared to standard Sierpinski Carpet. Angular Beamwidth (3dB) is 78.7°. The side lobe level is -11.3dB which is substantial.

3)*Second Order Iteration of Modified Sierpinski Carpet:*

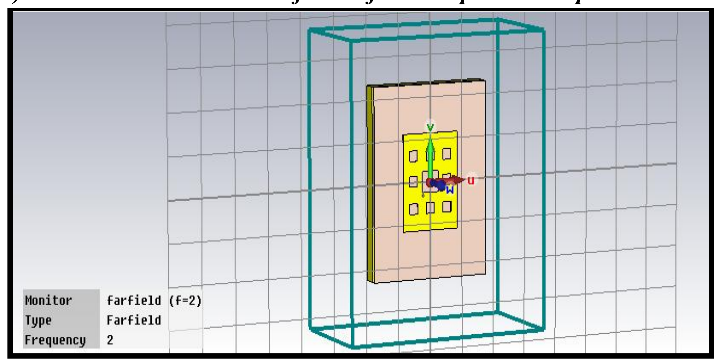

Fig-6(a)CST model Second Order Iteration of Modified Sierpinski Carpet

Simulated Results:

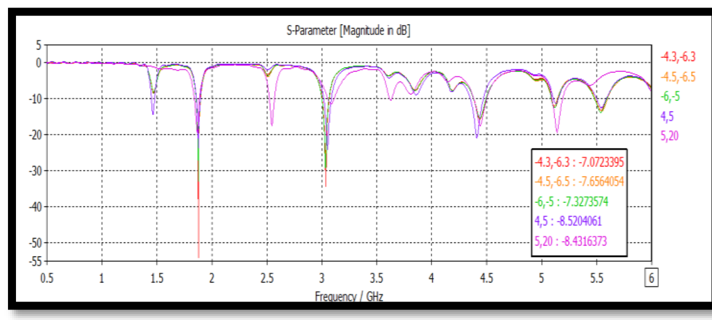

Fig-6(b) Return Loss Plot

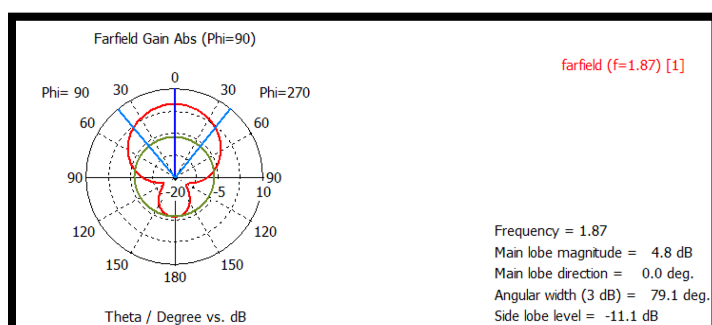

Fig-6(c) Polar Plot(gain)

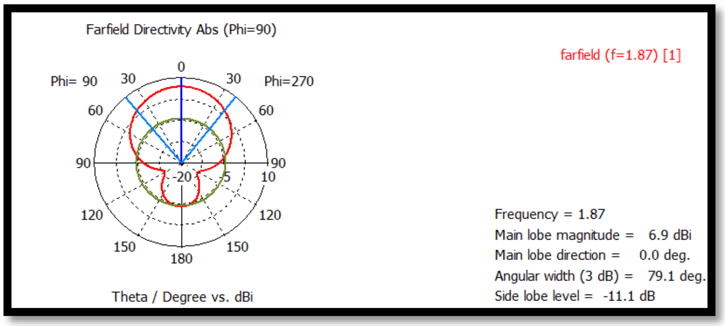

Fig-6(d) Polar Plot(directivty)

Table 6

Optimum Results For Second Order Iteration Of Modified Sierpinski Carpet

Fr (GHz)	S11 (dB)	Gain (dB)	Directivity (dBi)	Efficiency	VSWR
1.875	**-54.214**	**4.798**	**6.863**	**0.699**	**1.003**
3.035	**-34.278**	**4.691**	**7.478**	**0.627**	**1.039**
4.438	**-15.653**	**6.390**	**10.380**	**0.615**	**1.395**
5.125	**-12.416**	**1.908**	**7.328**	**0.260**	**1.629**
5.538	**-13.375**	**7.701**	**11.200**	**0.687**	**1.545**

Simulated Results for Second order Iteration

Result Analysis:

The model of second order modified Sierpinski Carpet is designed and simulated in CST MICROWAVE STUDIO-2012.The results of return loss for different coaxial variations are obtained. The gain and directivity results for all the resonating frequencies are obtained. The return loss at 1.875 GHz is -54.214dB which is very significant. Moreover gain and directivity results are far better. The efficiency is about 70%. Also VSWR =1.003 ≅ 1 which is highly considerable.

Table 7

Comparative Analysis

Design with various configuration	Fr (GHz)	S11 (dB)	Gain (dB)	Directivity (dBi)	Efficiency	VSWR
0th order iteration	1.522	-11.316	3.761	5.973	0.629	1.746
	1.980	-16.778	5.244	6.938	0.755	1.338
1st order iteration	1.891	-34.937	4.901	6.880	0.712	1.036
	3.079	-21.256	4.910	7.502	0.654	1.191
	4.223	-10.000	2.225	6.396	0.347	1.938
	4.482	-21.200	6.753	10.390	0.649	1.190
	5.175	-12.995	1.494	6.461	0.231	1.577
2nd order iteration	1.875	-54.214	4.798	6.863	0.699	1.003
	3.035	-34.278	4.691	7.478	0.627	1.039
	4.438	-15.653	6.390	10.380	0.615	1.395
	5.125	-12.416	1.908	7.328	0.260	1.629
	5.538	-13.375	7.701	11.200	0.687	1.545

Comparative Analysis of Modified Sierpinski Carpet

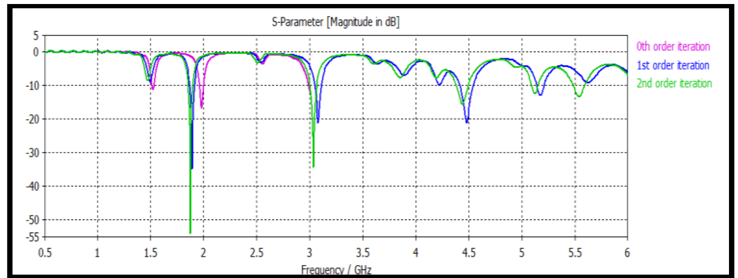

Fig7.Comparative analysis of return loss at 0th, 1st &2nd order iterations of Modified Sierpinski Carpet

Result Analysis:

From the comparative study of various iterations in modified Sierpinski Carpet and its analysis it can be said that the results are highly improved in terms of return loss, gain, directivity, VSWR and multiple operating frequencies for 2nd order modified Sierpinski Carpet.

The results here show that the return loss results are outstanding i.e -54.214 far better than 0th and 1st order iteration at 1.9GHz (-16.778dB & -34.937dB respectively). Gain, Efficiency and Directivity are not much affected. They are stabilized.

There is significant improvement in the VSWR results for both 1st and the 2nd order iteration where 2nd order iteration result is 1.003≅1.

Thus with this design it is possible to gratify multiple applications

VII FUTURE SCOPE:

Bandwidth and Gain optimization of the results obtained for Modified Sierpinski Carpet Antenna is possible by stacking and array respectively with second layer.[15]

VIII CONCLUSION

This paper presents three designs which reflect Zero, First and Second order iterations designs respectively for Modified Sierpinski Carpet. Simulated results for all the three designs showed successive increase in the number of operating frequencies and improvement in the return loss and VSWR. The gain and directivity results are stabilized.

The comparative study of all the three design showed that best results are obtained in Second Order Iteration. The return loss and VSWR are -54.214 and 1.003≅1 which is highly appreciable. The antenna is efficient about 70%.

The most important aspect is the miniaturization of antenna which is achieved through various designs simulated in the paper.

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