



# Design and Simulation of sierpinski carpet stacked microstrip fractal antenna

**Sudhina HK<sup>1</sup>, Jagadeesha S<sup>2</sup>, Shetti NM<sup>3</sup>, Sandeep V<sup>4</sup>**

1. Associate Professor & Head, E & CE Dept., REC, Hulkoti, Gadag, India, Ph. D Scholar at St. Peter's University, Chennai, India, Email: sudhinahk@gmail.com
2. Professor, E & CE, S.D.M.I.T, Ujire, Karnataka (D.K), India, Email: jagadeesh.sd69@gmail.com
3. Professor, Physics, S.D.M College Ujire, Karnataka (D.K), India, Email: nmshetti2003@yahoo.co.in
4. Bangalore, Karnataka, India, Email: vedagarbhamsandeep@gmail.com

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## General Note



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## ABSTRACT

The finite-difference time-domain (FDTD) method is applied to the probe-fed square patch microstrip antenna and stacked with a parasitic patch to achieve higher gain. The input impedance, the directivity, the far field radiation patterns and the near field distributions are analysed. The relationship between various antenna structures and their respective gain values are been investigated. The calculated input impedance and radiation patterns agree well with the experimental values. When the size of parasitic patch is nearly equal to the fed patch and the distance between the fed patch and the parasitic patch is about a half wavelength, the maximum gain of 7dbi is obtained. In this case, the region between the fed patch and the parasitic patch forms a resonator. Then, the amplitude of current distribution on the parasitic patch becomes large and its phase is opposite to the current on the fed patch. The amplitude of electromagnetic fields of the space between the patches is increased.

**Keywords:** microstrip, carpet fractal, substrate, infinite ground plane, feed.

## 1. INTRODUCTION

Stacked rectangular microstrip fractal antenna is experimentally studied. It is a probe fed antenna for impedance matching with 50  $\Omega$  coaxial cable. This antenna works well in the frequency range 2 to 12 GHz. It is basically a low cost, light weight medium gain antenna, which is used for X band applications. The variations of the fractals for the stacked rectangular patch antenna have been analysed. And the resonances with increasing fractals of rectangular microstrip antenna are noted.

The advantages with the fractals are of multiple electric dimensions, self loaded to 50 ohm, auxiliary reactance and capacitance not needed, mutual coupling between array elements can be reduced substantially and many more. Several geometries are available like Helix, Koch curve, Hilbert curve and Sierpinski carpet etc (B.T.P.Madhav, D. Ujwala, and J. Ravindranath Chowdary, 2013). The input impedance and VSWR, return loss have been simulated with the help of IE3D software. The stacked microstrip antenna has a wide bandwidth (Egashira and Nishiyama, 1996). The stacked microstrip antenna has been analyzed numerically by using the spectral domain method (Araki et al., 1986 and Croq F, Pozar DM, 1991). Fractal geometries have found an intricate place in science as a representation of some of unique geometrical features occurring in nature. For most fractals, self-similarity concept can achieve multiple frequency bands because of different parts of the antenna are similar to each other at different scales (Amit V. Narad, et al., 2012). In this paper a stacking is carried out for a probe feeding of the sierpinski carpet microstrip fractal Antennas.

## 2. DESIGN OF FRACTAL ANTENNA

### 2.1. DESIGN CALCULATION

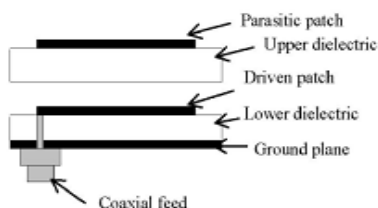
The feeding point is designed for lower patch to match the (50  $\Omega$ ) coaxial cable feed and the patch. The feeding point can be fabricated along the length of the patch. The input conductance of the patch fed on the edge slot will be twice the conductance of one of the edge slots as suggested by Harrington.

$$G = \frac{\Pi W}{\eta \lambda_0} \left[ 1 - \frac{(kh)^2}{24} \right] \quad [1]; \quad \text{Where } \eta = 120\pi, k = \frac{2\pi}{\lambda_0}, \lambda_0 = \text{wavelength of free space}$$

So the input impedance of the patch is given by

$R_1 = 1/2G$  ( $\Omega$ ), where  $G$  is radiation conductance.

So the upper patch is parasitic and the lower patch is fed with a co axial probe at the position ( $X_0, Y_0$ ) where  $X_0 = -5$  mm and  $Y_0 = -4$  mm. figure 1 shows the arrangement for stacking of an antenna.

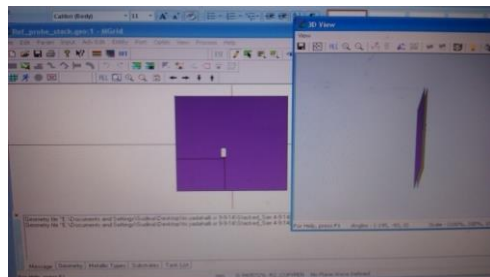


**Figure 1** Electromagnetically coupled stacked antenna

## 3. ANALYSIS

### 3.1. Reference stack

Figure 2 shows a pictorial view of the stacked sierpinski reference antenna for the probe feeding and table 1 shows the values observed from the simulation through IE3D simulator. Parameters such as resonant frequency, bandwidth, return Loss and gain of the particular iterations are noted.



**Figure 2** Picture of a ref. antenna stacking

**Table 1**  
Values of ref. iteration model

Freq (GHz)	Bandwidth (MHz)	Return loss $S_{11}$ (db)	Gain (dbi)
2.6	40	-16.5	-7.0
3.7	20	-13	2
6.6	50	-16.5	2

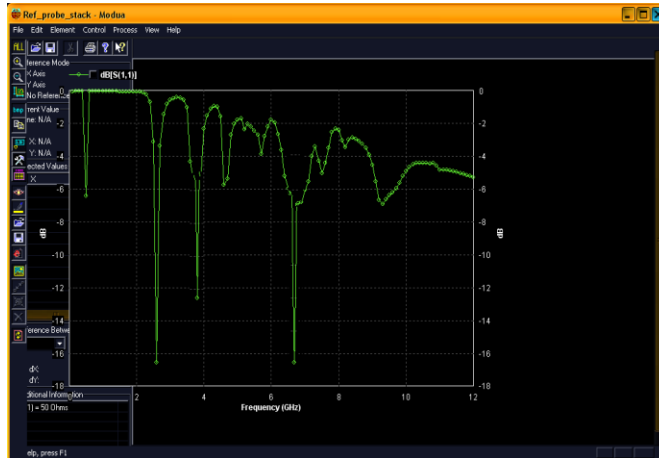


Figure 3 (a)  $S_{11}$  parameter for ref. stack

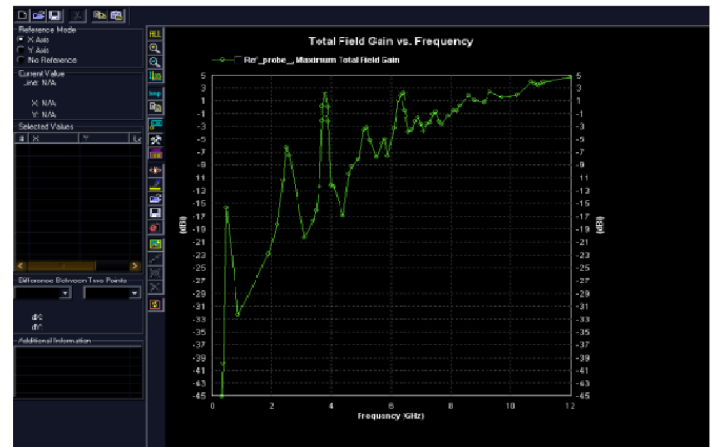


Figure 3 (b) Gain versus frequency

Figure 3(a) shows the IE3D simulated result and Figure 3(b) shows the graph of gain versus frequency. The reference antenna displays the resonant frequency of -16.5 db at 6.6 GHz With 2 db gain and a bandwidth of 50 MHz.

### 3.2. Stack Iteration 1

Figure 4 shows a pictorial view of the stacked sierpinski iteration1 antenna for the probe feeding and table 2 shows the values observed for the simulation through IE3D simulator. First a microstrip patch at the required operating frequency is designed, and then the first iteration of the sierpinski carpet fractal antenna proceeds by dividing the microstrip patch into nine equal squares and removing the center square. Since the length of the microstrip patch is  $L_0 = 54$  mm, the length of the side of the square is  $L_1 = 8$  mm here  $L_1$  is called the scale factor for length. Figure 4 also shows the location of the feed for stacking of two similar layers.

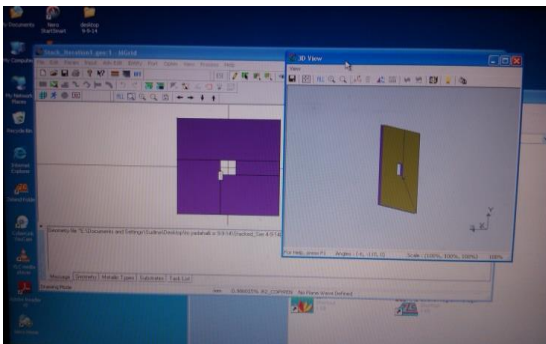


Figure 4 Picture of a ref. antenna stacking

Table 2

Values of 1<sup>st</sup> iteration model

Freq (GHz)	Bandwidth (MHz)	Return loss $S_{11}$ (db)	Gain (dbi)
2.6	50	-13.5	-7
3.7	75	-30	-15
4.6	50	-10.9	-10
6.6	250	-24	3
7.49	75	-21	5

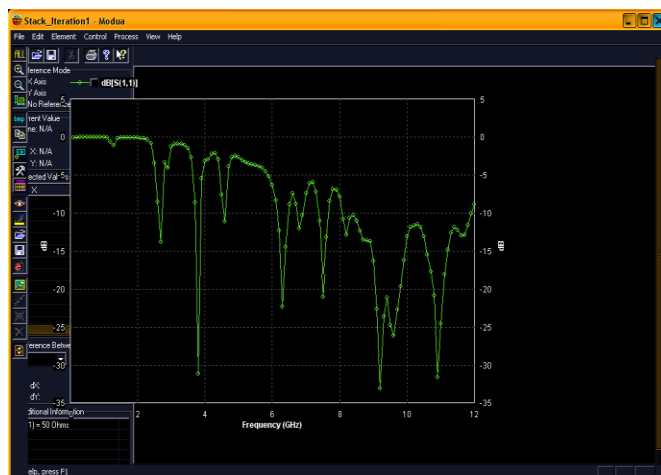


Figure 5 (a)  $S_{11}$  parameter for Stack Iteration 1

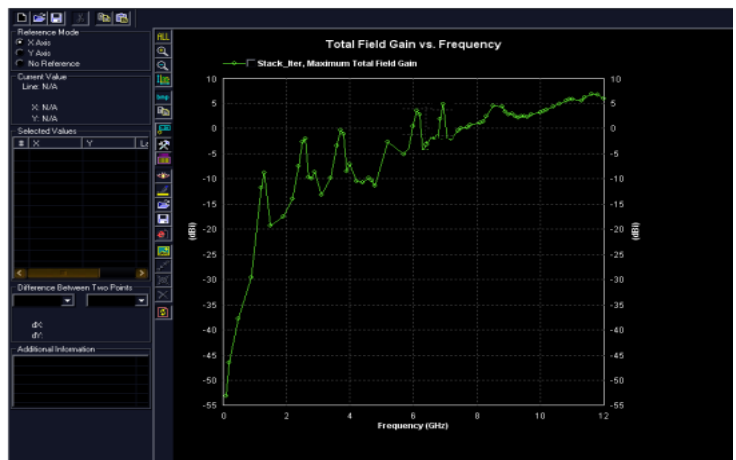


Figure 5 (b) Gain versus frequency

Figure 5(a) show the IE3D simulated result and figure 5(b) show the graph of gain versus frequency. The points for the probe feed are (x, y) = (-5, -4). From the simulation it is noted that the antenna has a magnitude of return loss nearby at designed

frequency of 6 GHz. It is displaying multiband behavior at 2.6 GHz, 3.7 GHz, 4.6 GHz, 6.6 GHz & 7.49 GHz, a positive gain at the designed operating frequency 6.6 GHz is observed.

### 3.3. Stack Iteration 2

Figure 6 shows a pictorial view of the stacked sierpinski stack iteration 2 antenna for the probe feeding and table 3 shows the values observed for the simulation through IE3D simulator.

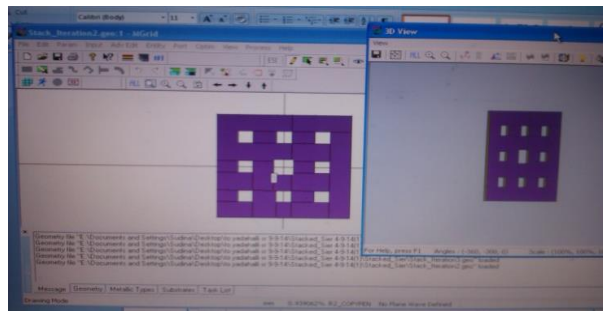


Figure 6 Picture of a ref. antenna stacking

Table 3

Values of 2<sup>nd</sup> iteration model

Freq (GHz)	Bandwidth (MHz)	Return loss $S_{11}(\text{db})$	Gain (db <sub>i</sub> )
2.6	0	-10	-3
3.7	125	-24.3	-2
4.5	10	-10	-10
6.6	200	-15	5.32
8.9	150	-12.5	3.16

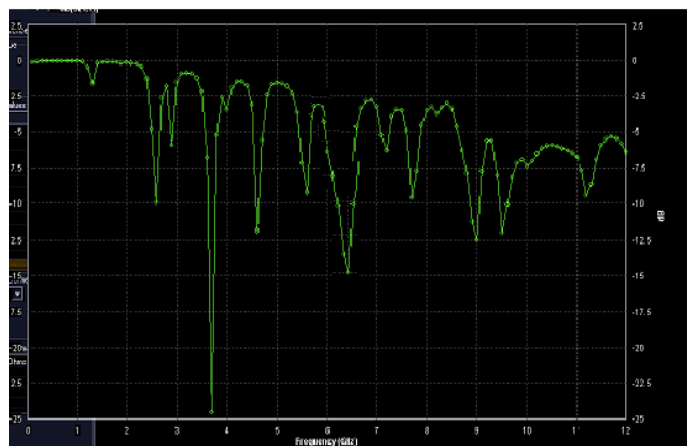


Figure 7 (a)  $S_{11}$  parameter for Stack Iteration 2

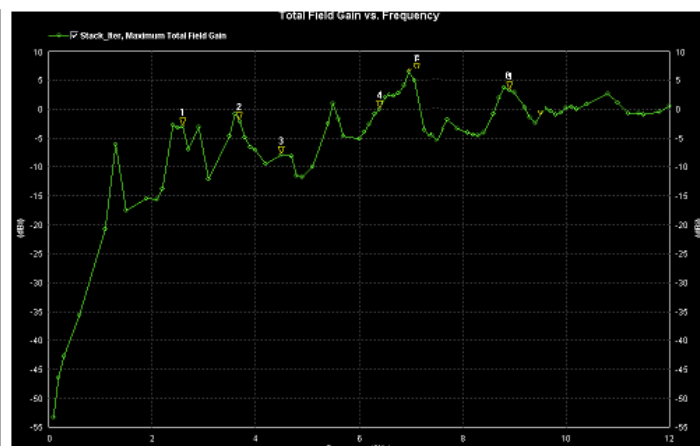


Figure 7 (b) Gain versus frequency

Figure 7(a) shows the IE3D simulated result and figure 7(b) shows the graph of gain versus frequency. The points for the probe feed are (x, y) = (-5, -4). From the simulation it is noted that the antenna has a magnitude of return loss of -13 db nearby at designed frequency of 6 GHz. It is displaying multiband behavior at 2.59 GHz, 3.69 GHz, 4.5 GHz, 6.8 GHz and 8.9 GHz, a positive gain at the designed operating frequency 6 GHz is observed.

### 3.4. Stack Iteration 3

Figure 8 shows a pictorial view of the stacked sierpinski stack iteration 3 antenna for the probe feeding and table 4 shows the values observed from the simulation through IE3D simulator.

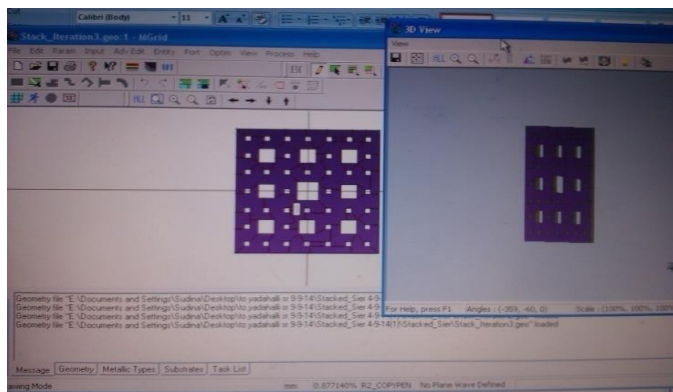


Figure 8 Picture of a ref. antenna stacking

Table 4

Values of 3<sup>rd</sup> iteration model

Freq (GHz)	Bandwidth (MHz)	Return loss $S_{11}(\text{db})$	Gain (db <sub>i</sub> )
3.7	50	-14	1.05
4.5	125	-15	-7.8
6.6	350	-16	7
7.9	200	-12	4

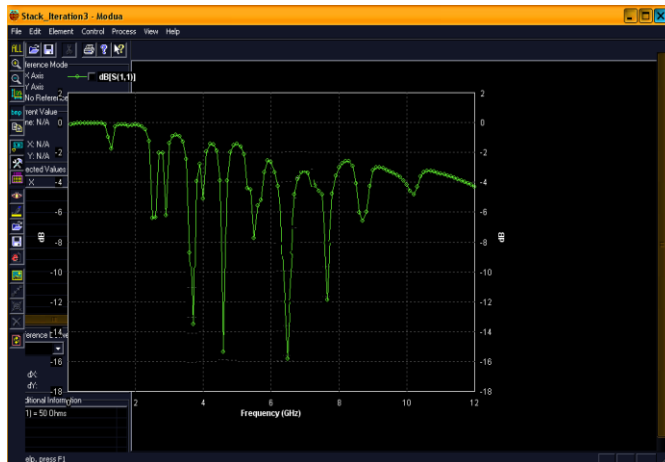


Figure 9 (a)  $S_{11}$  parameter for Stack Iteration 3

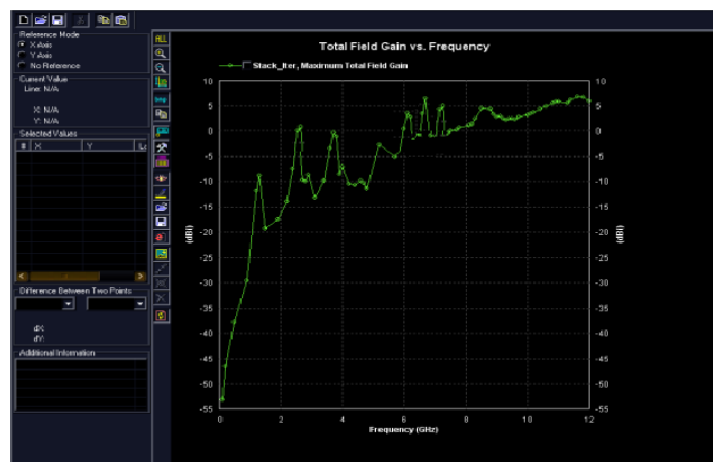


Figure 9 (b) Gain versus frequency

Figure 9(a) shows the IE3D simulated result and figure 9(b) shows the graph of gain versus frequency. The points for the probe feed are  $(x, y) = (-5, -4)$ . From the simulation it is noted that the antenna has a magnitude of return loss of -16 dB nearby at designed frequency of 6 GHz. It is displaying multiband behavior at 3.7 GHz, 4.5 GHz and 6.6 GHz and 7.9 GHz, a positive gain at the designed operating frequency 6 GHz is observed.

#### 4. CONCLUSION

Stacking of the patch is studied for the case of Sierpinski Carpet Fractal (SCF). The simple antenna with patch as second iteration sierpinski carpet is showing a maximum bandwidth of 200 MHz, but the same structure when stacked with simple rectangular patch as driven patch and the parasitic patch as the Sierpinski Carpet, which is electromagnetically coupled to the driven patch, is giving a total bandwidth of 350 MHz. Thus use of the antennas stacking is justified in this case. Also when the parasitic patch is fed, there is a change in the return loss characteristics. More harmonics are present, which is possibly due to the height of the air sandwiched layer between both the designs. It is observed that there is a increase in the bandwidth as the increase in the number of iterations i.e. in the simulated result it is increasing from 150 MHz for reference antenna at designed frequency to 400 MHz for the third iteration.

#### FUTURE ISSUES

- The proposed antenna will be fabricated and measured result will be compared with simulated results.
- After fabrication it will be operated in the given conditions and the radiation pattern will be analysed.

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