A Design of Star Shaped Fractal Antenna for Wireless Applications

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ABSTRACT
This paper presents a design of star shaped fractal antenna for wireless applications. The FR4 glass epoxy substrate is used to design the antenna with relative permittivity 4.4 and thickness 1.6mm. Different parameters of antenna such as return loss, gain, VSWR and bandwidth have been analyzed at the resonant frequency of 5GHz. The -10dB impedance bandwidth of proposed antenna is from 3.5GHz to 6.4GHz and the gain of antenna increases from 5.45dB to 8.09dB by increasing the iteration number. The antenna is designed and simulated by using HFSS (High Frequency Structure Simulator) version 13 software. Proposed antenna can be used for various wireless communication applications such as WLAN, satellite communication, long distance radar telecommunication etc.

Keywords
HFSS, WLAN, return loss, VSWR.

1. INTRODUCTION
The fractal antenna plays a most important role in the field of wireless communications due to its multiband and wideband characteristics. This is the reason, that the use of microstrip fractal antenna geometry has been a recent topic for the researchers in the world [1].The fractal means the irregular fragments, which are the set of complex geometries that possess the self-similarity structures [2]. Fractal geometries of antenna also reduce the overall size of antenna and produce the multiple resonant bands [3].Fractal antenna concept was given by Nathen Cohen in 1995. The self-similarity and space filling properties of fractal antennas make it possible to use for UWB applications [4]. To increase the radiation efficiency of antennas, discontinuities introduced in the patch of fractal antenna geometry [5]. Partial ground planes are used in antennas to increase the relative bandwidth of antennas [4]. Fractal antennas are designed by applying the infinite number of times an iterative algorithm such as Multiple Reduction Copy Machine (MRCM) [1].There are number of fractal shapes are designed like Minkowski [3], Koch Curves [6], Hilbert curves, I- shape fractals or E-shape fractals etc [2].

2. ANTENNA DESIGN
The geometry of proposed antenna is designed on FR4 epoxy substrate having thickness 1.6mm and dielectric constant 4.4, with resonant frequency of 5GHz. The side length of the triangular patch is calculated by using the equation 1 and is found to be 19.04mm. The 1st iteration of proposed antenna is designed by inverting another triangle of same dimensions to make the star shaped patch antenna. The geometry of 1st iteration of proposed antenna and its ground plane is shown in Figure 1 and its parametric values are given in Table 1.

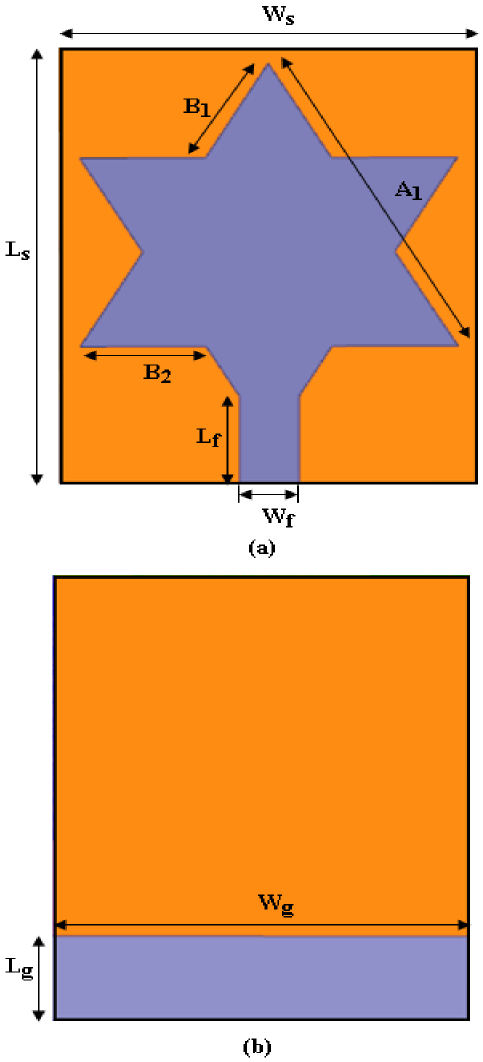

Figure 1: 1st iteration of proposed antenna (a) top view and (b) bottom view

The 2nd iteration of proposed antenna is designed by subtracting the sierpinski star shape of side length C_1=3.17mm which is then half of the side length of triangle and taking all the other dimensions same as that of the 1st iteration. The geometry of 2nd iteration of proposed antenna is shown in Figure 2.

$$W_t\,(mm) = \frac{2\ X\ c}{3\ X\ f_r\ X \sqrt{\mathcal{E}_r}} \qquad (1)$$

Where,

C = velocity of light in free space.

f_r = resonant frequency.

ε_r = dielectric constant of substrate.

W_t = side length of triangular patch.

Table 1. Parametric Values of Proposed Antenna

S. No.	Parameters	Descriptions	Values
1.	W_s	Width of substrate	21.06mm
2.	L_s	Length of substrate	25.5mm
3.	L_f	Length of feed line	5.09mm
4.	W_f	Width of feed line	3mm
5.	W_g	Width of ground plane	21.06mm
6.	L_g	Length of ground plane	4.8mm
7.	A_1	Side length of triangle	19.04mm
8.	$B_{1=}$ B_2	Side length of star	6.34mm

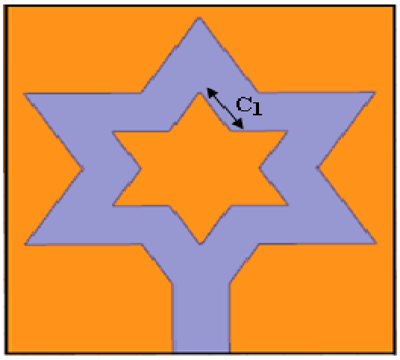

Figure 2: 2nd iteration of proposed antenna

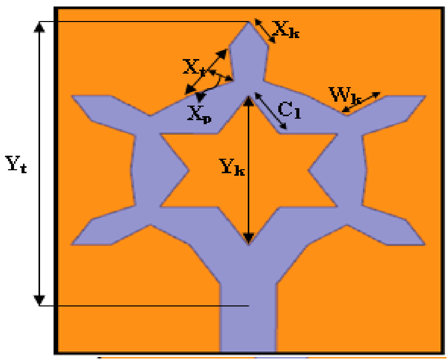

Figure 3: 3rd iteration of proposed antenna

The 3rd iteration of proposed antenna is designed by taking the structure of 2nd iteration as a base geometry. The star shaped sierpinski iterated structure having the dimensions $Y_t = Y_k/2$ = 11mm is cut out from the star shaped patch with a side length C_1 = 3.17 mm. The Koch curves cut out from each side of the star shaped patch having dimension $X_k = X_t/2$ = 1.58 mm, X_p = 1.5 mm and W_k = 2.58 mm. The geometry of 3rd iteration is shown in Figure 3.

3. RESULT AND DISCUSSIONS

3.1 Return loss

Return loss is the important parameter of antenna it is the difference between forward and reflected power in dB. The acceptable value of return loss is less than -10dB for the antenna to work efficiently. Figure 4 shows the simulated return loss v/s frequency plot of 1st, 2nd and 3rd iteration of proposed antenna. The curves shows that the 1st iteration has -20.47dB return loss at 5.44GHz frequency, 2nd iteration has -25.14dB return loss at 5.38GHz frequency and 3rd iteration has -26.91 at 5.53GHz frequency.

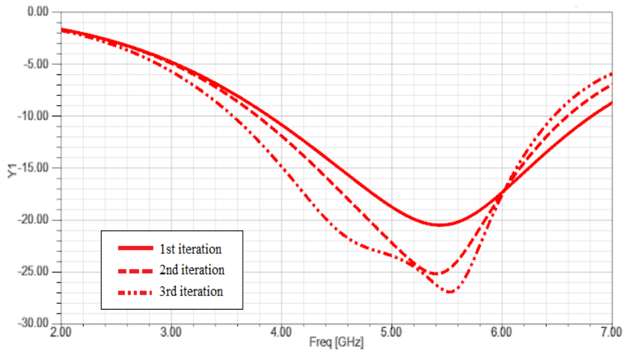

Figure 4: Return loss v/s frequency plot of 1st, 2nd and 3rd iteration of proposed antenna

3.2 VSWR

The VSWR is the measure of impedance mismatch between the feed line and the antenna. The mismatch increases the value of VSWR. The minimum value of VSWR is unity and the maximum VSWR is 2 for the perfect impedance matching. The simulated VSWR v/s frequency plot of 1st, 2nd and 3rd iteration of proposed antenna is shown in Figure 5. The 1st iteration of proposed antenna shows that the value of VSWR is 1.20 at 5.44GHz frequency and also has VSWR less than 2 for the frequency range from 3.89 to 6.80GHz, 2nd iteration of proposed antenna shows the value of VSWR is 1.11 at 5.38GHz frequency and also has VSWR less than 2 for the frequency range from 3.78 to 6.58 GHz and 3rd iteration of proposed antenna shows the value of VSWR is 1.09 at 5.53GHz and also has VSWR less than 2 for the frequency range from 3.55GHz to 6.46GHz.

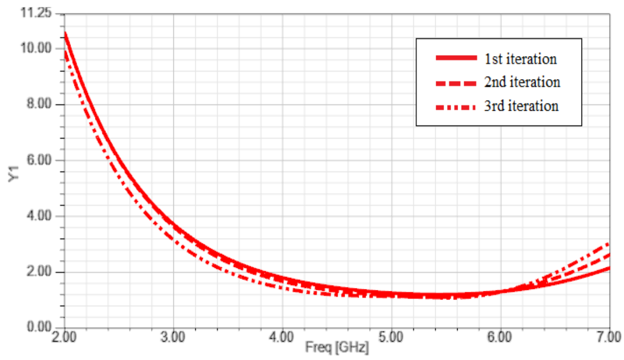

Figure 5: VSWR v/s frequency plot of 1st, 2nd and 3rd iteration of proposed antenna

3.3 Gain

The gain describes the efficiency and directional capabilities of antenna. The value of the gain should be greater than 3dB for the antenna to work efficiently. The 1st, 2nd and 3rd iteration of proposed antenna shows the gain of 5.45dB, 6.76dB and 8.09dB respectively. The 3D gain plot of 1st, 2nd and 3rd iteration of proposed antenna is shown in Figure 6, 7 and 8 respectively.

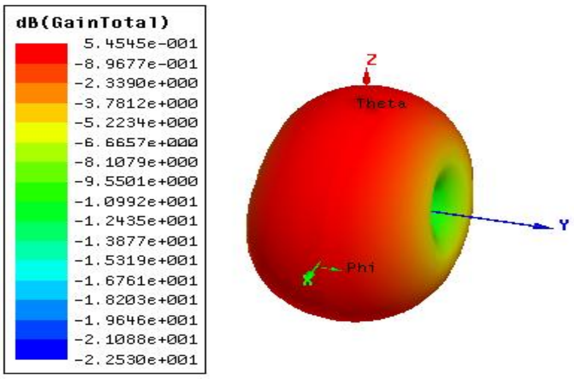

Figure 6: 3D gain plot of 1st iteration

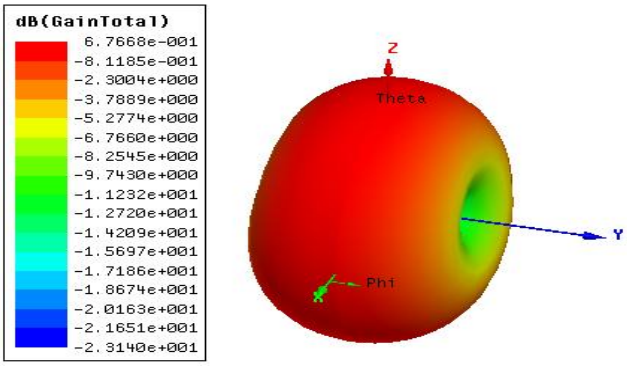

Figure 7: 3D gain plot of 2nd iteration

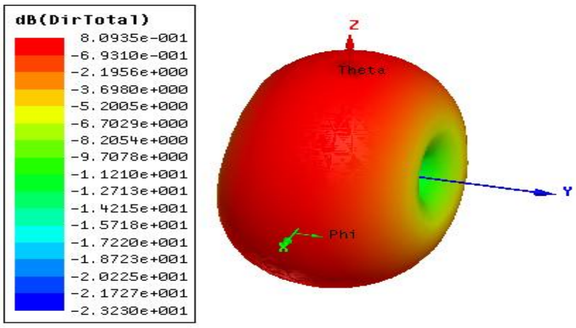

Figure 8: 3D gain plot of 3rd iteration

4. CONCLUSIONS

The aim of this paper is to design a star shaped fractal antenna for wireless applications and to analyze the different parameters of the same. An antenna has been designed by using FR4 epoxy substrate and the microstrip line feed is used to excite the antenna. By analysing the results, it is observed that the return loss of all the iterations of designed antennas has a negative value which shows that the losses are minimum during transmission. It also shows that the gain of antenna increases on increasing the iteration number. The gain of antenna increases from 5.45dB to 8.09dB. The designed antenna can be used for different wireless applications such as WLAN, satellite communication, long distance radar telecommunication etc.

5. REFERENCES

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