Comparative Analysis of Circular Fractal Antenna with Composite and Star Shaped Fractal Antennas for Wireless Applications

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Abstract- This paper presents the comparison of three different types of fractal antennas. All the antennas are designed by using low cost FR4 glass epoxy substrate with relative permittivity of 4.4 and a thickness of 1.6mm. The different antenna parameters has been observed and analyzed such as return loss, VSWR, gain etc. The results of existing antennas (composite and star shaped fractal antennas) are compared with the designed circular fractal antenna. It is observed that the designed circular fractal antenna has much better results as compared to the existing antennas. HFSS V13 software is used to design and simulate the proposed antenna. The designed antenna is fabricated and tested by using VNA (Vector Network Analyzer), which shows that the measured results are in good agreement with the simulated results. The proposed design of antenna can be used for the practical wireless applications such as WLAN (4.82 - 5.95GHz), bluetooth (2.12 – 2.95GHz) and C – band (4 – 8GHz).

Keywords – HFSS, VNA, Circular fractal, Composite fractal, Star fractal, Key shaped fractal

I. INTRODUCTION

The microstrip antenna with fractal geometries have been widely developed for wideband and multiband applications in wireless communication systems [1]. The fractal concept was first developed by Nathan Cohen in 1995 [2]. Fractal antennas are designed by applying the two unique properties such as space-filling and self-similarity [3]. The self-similarity of fractal antenna describes the multiband nature of antenna and space-filling property used to reduce the size of antenna [4] [9]. To overcome the limitations caused by simple microstrip patch antenna such as low gain and bandwidth the fractal antennas are used which provide the high gain, bandwidth and exhibit multiband characteristics [6]. The fractal antennas are also designed to transmit or receive the signals over the wide range of frequencies [1]. The fractal elements of antenna allow it to operate on different resonant frequencies and the discontinuities in the fractal geometry increases the radiation property and the directivity of antenna [5]. The low profile, less fabrication cost and light weight are the main advantages of fractal antennas. Fractal antennas are used in different wireless applications such as ISM, GPS, RFID, WLAN (2.4-2.48GHz), (5.15-5.35GHz), (5.725-5.825GHz); Wi-MAX (2.5-2.69GHz), (3.4-3.69GHz) [7] [8].

The rest of the paper is organized as follows. The design configurations of all the antennas are explained in section II. Simulated and experimental results are presented in section III. Concluding remarks for all the antennas are given in section IV.

II. ANTENNA DESIGN AND CONFIGURATION

The design of existing antennas such as composite fractal antenna [7] and star fractal antenna [8] are shown in Figure 1(a), (b) and (c) respectively. The composite antenna is designed on FR4 epoxy substrate with size of $96\times72\times1.5$ mm^3, including substrate thickness of 1.5 mm, and dielectric constant €r =4.9 with 0.025 loss tangent, whereas the star shaped fractal is printed on FR4 substrate with size of 33.5x28.5x 1.6mm^3, including substrate thickness (h) of 1.6mm, and dielectric constant of 4.4 with 0.025 loss tangent. The parametric values of existing antennas such as composite and star fractal antennas are shown in Table 1.

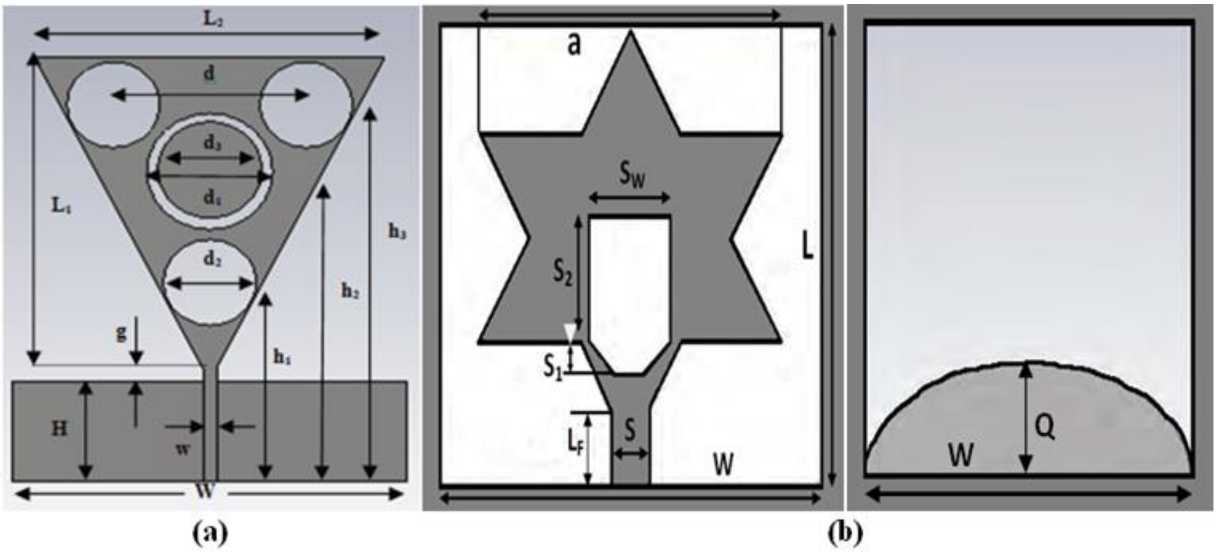

Figure1. (a) Composite fractal antenna [7] and (b) star fractal antenna [8]

Table-1 Parametric values of existing antennas

S. No.	Composite fractal antenna [7]		Star fractal antenna [8]	
	Parameters	**Values**	**Parameters**	**Values**
1.	**W**	**72**	**W**	**28.5**
2.	**L**	**96**	**L**	**33.5**
3.	**T**	**1.5**	**H**	**1.6**
4.	L_1	**61.4**	**S**	**2.9**
5.	**D**	**35.2**	**a**	**26**
6.	**H**	**20**	S_1	**2.5**
7.	L_2	**64**	S_2	**9.1**
8.	d_1	**23**	S_W	**6.2**
9.	d_2	**12**	L_F	**5.5**
10.	d_3	**19**	**Q**	**8.37**
11.	h_1	**38**	**-**	**-**
12.	h_2	**60**	**-**	**-**
13.	h_3	**73.2**	**-**	**-**
14.	**G**	**2.6**	**-**	**-**
15.	**W**	**3.5**	**-**	**-**

The proposed circular fractal antenna is designed on FR4 glass epoxy substrate with relative permittivity of 4.4 and thickness 1.6mm. The resonant frequency of designed antenna is taken as 3.2GHz and the radius of circular patch is calculated by using equation (1) and (2) which comes to be 12.6mm.

$$a = F\left\{1 + \frac{2h}{\pi F \varepsilon_r}\left[\ln\left(\frac{\pi F}{2h}\right) + 1.7726\right]\right\}^{\frac{-1}{2}} \quad (1)$$

$$F = \frac{8.791\, X\, 10^9}{f_r \sqrt{\varepsilon_r}} \quad (2)$$

Where,
a = Radius of circular patch.
c = Velocity of light in free space.

fr = Resonant frequency.
h = Substrate height.
ε_r= Dielectric constant of the substrate.

The geometry of proposed antenna is designed by applying the circular fractal elements of radius 2.52mm at the boundaries of circular patch of radius 12.6mm. The simulated geometry of proposed circular fractal antenna is shown in Figure 2 and the parametric values are shown in Table 2.

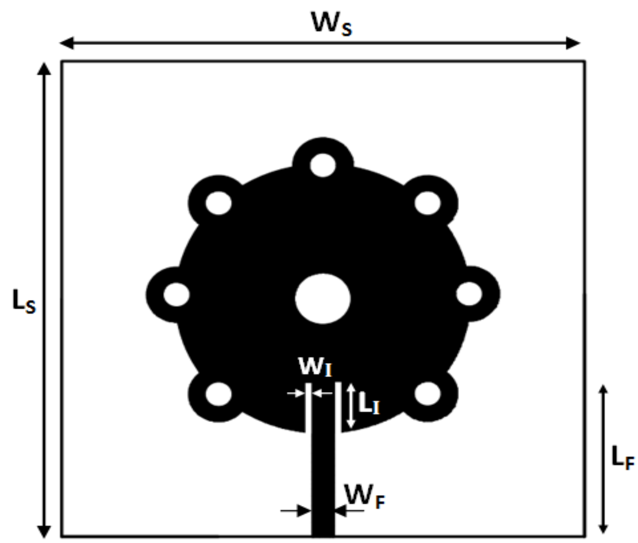

Figure 2. Simulated structure of proposed circular fractal antenna

Table 2: Parametric values of proposed antenna

S. No.	Parameters	Description	Values
1.	W_S	**Width of substrate**	**45mm**
2.	L_S	**Length of substrate**	**44.92mm**
3.	W_I	**Width of inset cut**	**0.4mm**
4.	L_I	**Length of inset cut**	**3.06mm**
5.	W_F	**Width of feed line**	**1.8mm**
6.	L_F	**Length of feed line**	**12.99mm**

III. Result and Discussion

The return loss is the most important parameters of an antenna, which shows the capability of an antenna to work for a practical application or not. The acceptable value of return loss is below -10dB for an antenna to work efficiently on a particular frequency bands. Return loss v/s frequency plots of composite fractal antenna [7] and star fractal antenna [8] are shown in Figure 3 and Figure 4 respectively. By observing these plots it has been concluded that the existing antennas works only on two resonant frequencies, but for an optimal design there is a need of more than two frequency bands to make it a multiband antenna. There is a need to fabricate the antenna for validating the simulated results with the measured results, but in the existing design the antenna is not fabricated. To remove this drawback the proposed circular antenna is designed and fabricated to validate the simulated results with the experimental results. The fabricated prototype of proposed fractal antenna is shown in Figure 6. Proposed fractal antenna works on five resonant frequency bands with a return loss below -10dB. Comparison of simulated and measured return loss of proposed fractal antenna is shown in Figure 5, which shows that the simulated and measured results are in good agreement with each other. The comparison of return loss and of existing antennas with a proposed fractal antenna is shown in Table 3.

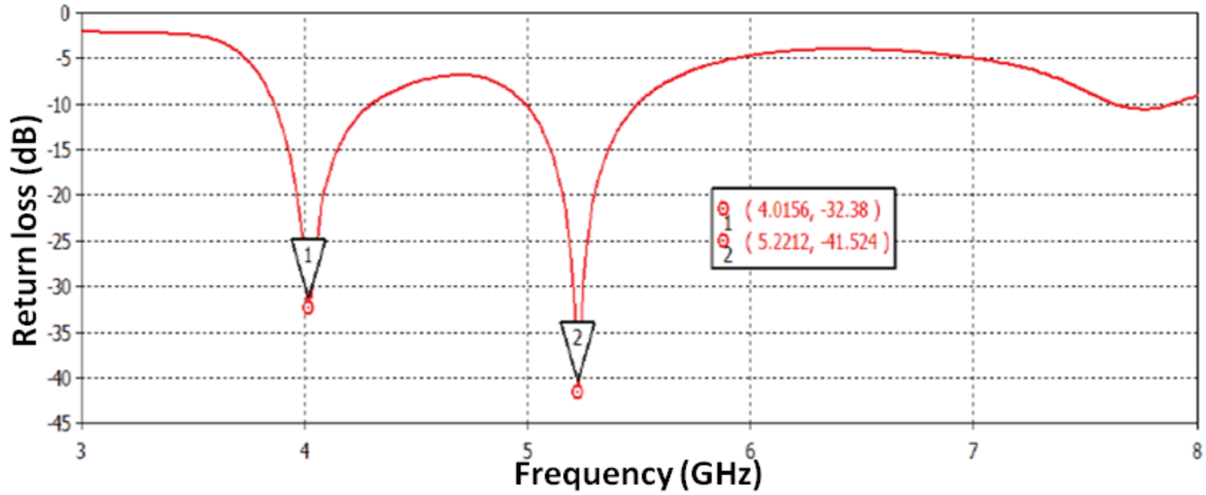

Figure 3. Return loss v/s frequency plot of composite fractal antenna [7]

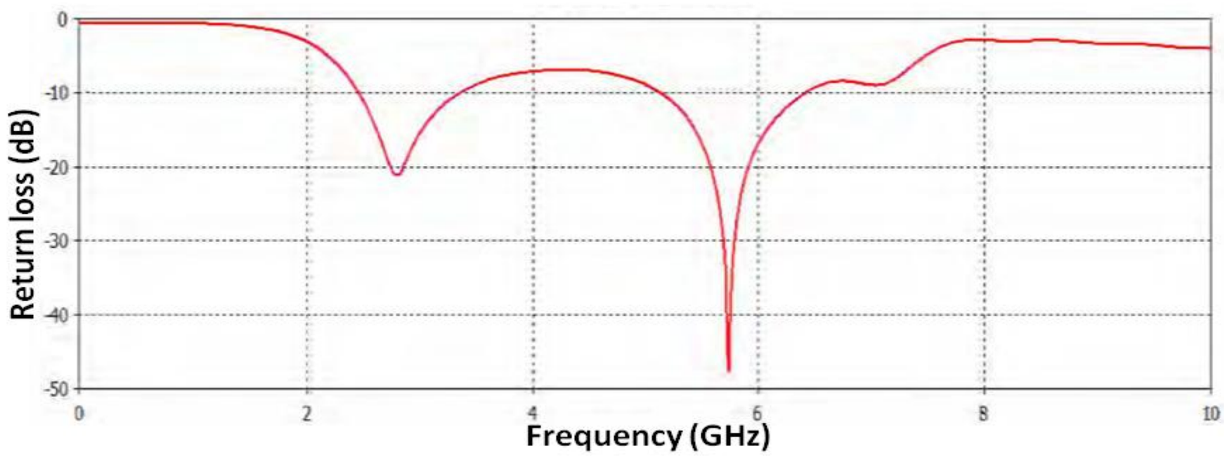

Figure 4. Return loss v/s frequency plot of star fractal antenna [8]

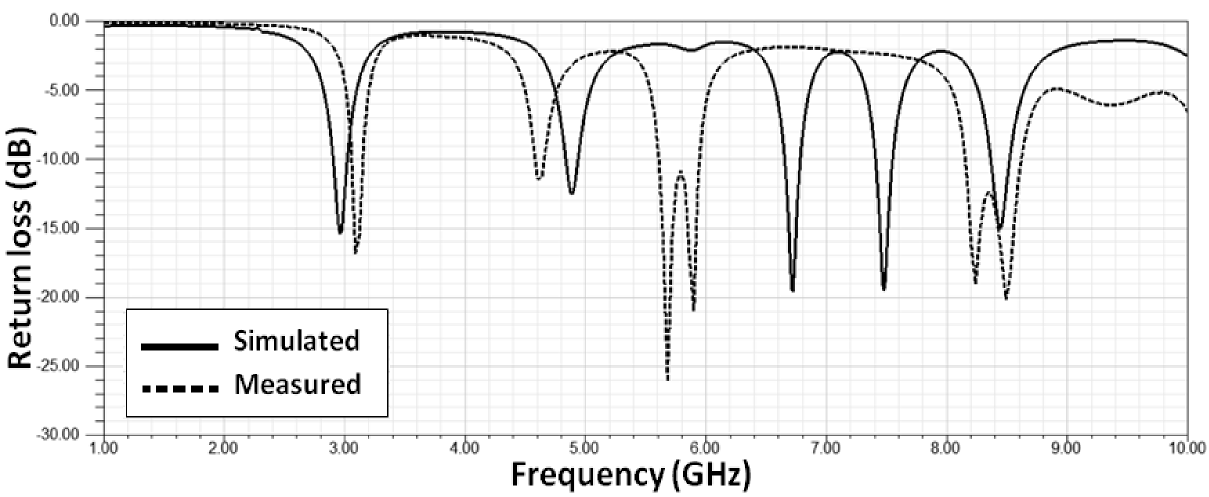

Figure 5. Return loss v/s frequency plot of proposed fractal antenna

Figure 5 shows that measured results of proposed antenna is much better than the simulated antenna. Because the measured result shows that the bandwidth of antenna is increasing at some frequency bands near 5.68-5.89GHz and 8.23-8.48GHz.

Figure 6. Fabricated prototype of proposed circular fractal antenna

Table 3: Comparison of designed antenna with existing antennas

Parameters	Composite fractal antenna [7]	Star fractal antenna [8]	Proposed circular fractal antenna	
			Simulated	Measured
Frequency (GHz)	4.01 and 5.22	2.8 and 5.7	2.96, 4.88, 6.71, 7.47 and 8.44	3.08, 4.60, 5.68, 5.89, 8.23 and 8.48
Return loss (dB)	-32.38 and -41.52	-20.8 and -49.5	-15.44, -12.55, -19.44, -19.44 and -15.06	-16.84, -11.43, -26.13, -21.00, -19.02 and -20.20

The acceptable value of gain for an antenna to work for practical applications is greater than 3dB. Gain of composite fractal antenna [7] and star shaped fractal antenna [8] is very less as compared to the proposed antenna. Composite antenna shows the value of gain less than 1.5dB at both the frequency bands. Similarly, the star shaped fractal antenna also shows the very less value of gain at both the frequency bands. To conquer this drawback the proposed antenna is designed which shows the high value of gain at the particular frequency bands. The value of gain is 9.57dB, -6.98dB, 2.40dB, 5.32dB and 7.59dB at the frequency bands of 2.96GHz, 4.88GHz, 6.71GHz, 7.47GHz and 8.44GHz respectively. The 3D gain plots at different frequency bands are shown in Figure 7.

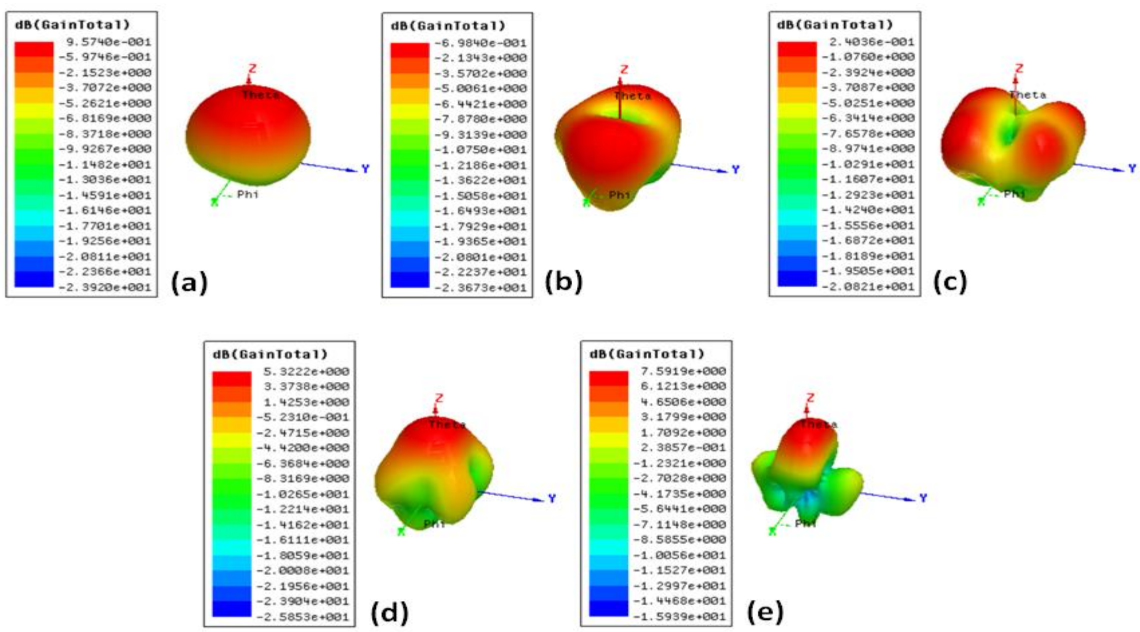

Figure 7: 3D gain plot at (a) 2.96GHz, (b) 4.88GHz, (c) 6.71GHz, (d) 7.47GHz and (e) 8.44GHz frequency band

IV.CONCLUSION

The main aim of this paper is to compare the existing antennas such as composite fractal antenna [7] and star fractal antenna [8] with the proposed circular fractal antenna. The results of different parameters such as return loss and gain of designed antenna is compared with the results of existing antennas. Comparison shows that the designed antenna has much better results as compared to the existing antennas. Proposed antenna works on five frequency bands with the maximum gain of 9.57dB at 2.96GHz frequency band; whereas the existing antennas works only on two resonant frequencies with a value of gain less than 1.5dB. Due to the better performance the proposed fractal antenna can be effectively used for wireless applications such as WLAN (4.82 - 5.95GHz), bluetooth (2.12 – 2.95GHz) and C – band (4 – 8GHz).

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