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MultibandCircular Fractal Antenna for Wireless Applications

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Abstract--- *A circular fractal antenna is presented in this paper for wireless applications. Sierpinski fractal geometry is used to make circular fractals of scaled dimensions. The fractal antenna has the multiband operation due to the self-similar property in fractal geometry. Fractal geometry leads to improved bandwidth, radiation efficiency and reduced size. This antenna is designed using HFSS V15 simulator with finite element method. The proposed antenna resonant frequencies are centered at 2.4GHz, 4.8 GHz, 5.8 GHz, 6.3 GHz, 7 GHz, 8 GHz, 8.8 GHz and 9.2 GHz with at Least 200 MHz bandwidth. Circular patch antenna is used as the basic geometry and 3 stages of iterations produced the proposed design. Radius of the base antenna is 24 mm.Thickness of substrate is 1.6mm.*

Keywords*--*Circular antenna, HFSS simulator,Sierpinski fractal,Multiband Applications.

I.INTRODUCTION

The fact that a fractal object is in some sense composed of smaller copies of itself. It has interesting implications. Fractal shapes demonstrates symmetry under three transformations of Reflection, Rotation and Translation [1]. The fourth type of symmetry is self-similarity. Self-similarity objects appear the same under magnification. They are in the same fashion composed of smaller copies of themselves. This is called scaling symmetry [5]. Mathematical fractals can possess an infinite range of scaling symmetry. Fractal building is started with a base geometry called pre-fractals. Fractals with same shape and some properties altered are cut from the base shape repetitively. Each round of this process is known as iteration [3]. Fractal geometries are used for development of micro-strip antennas with improved characteristics like multiband, miniature and high directive elements [4]. The proposed circular antenna can be used for multiple applications. For example, GPS, Wi-Fi, Bluetooth, satellite based communications, terrestrial cellular, and many other applications. Fractal antennas are used indifferent 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]. Single circular fractal antenna can be used for multiple applications with different frequencies. The proposed antenna works efficiently at 2.4 GHz, 4.8 GHz, 5.8 GHz, 6.3 GHz, 7 GHz, 8 GHz, 8.8 GHz and 9.2 GHz. All the listed frequencies are useful for today's communication technology. Many designs of fractal antenna were reference during this work.[3] And [4] used multi-fractal type of designs that increases the bandwidth of antenna in a fixed single operating frequency. [5] And [6] also used a multi-fractal antenna, but the smallest dimension there is of the order of 0.5 mm which is very difficult to fabricate without special arrangements. As compared to the above works our design is working very well in ISM band of frequencies (2.4 GHz and 5.8 GHz). There are more similar designs that are inspired from Sierpinski fractal like [12], [13] and [14] but either their designs are too complex or the approach is using genetic algorithm that requires sophisticated means

and methods for execution. On the other hand the design proposed in this paper is a single layer antenna using easily available FR4 epoxy dielectric sheet.

II. ANTENNA DESIGN AND CONFIGURATION

The proposed design of circular fractal antenna is based on Sierpinski fractal geometry. The antenna is designed on FR4 epoxy substrate with size of 85x60x1.6 mm3, including substrate thickness of 1.6 mm with loss tangent 0.025 and dielectric constant Ɛr=4.4. The resonant frequency is 2.4GHz and radius of circular patch is calculated using following equation which comes to be 24mm [4].

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

$$F = \frac{8.791 \times 10^9}{f_r \sqrt{\epsilon_r}}$$

Where,
a = Radius of circular patch.
c = Velocity of light in free space.
fr =Resonant frequency.
h = Substrate height.
Ɛr= Dielectric constant of the substrate.

Width of the feed line is 3 mm and height of substrate is 1.6 mm resulting W/H ratio of 1.875 (>1). To obtain the characteristic impedance of 50 ohms following equation is used [10].

$$Z_0 = \frac{120\pi}{\sqrt{\varepsilon_{eff}} \times \left[\frac{W}{h} + 1.393 + \frac{2}{3}\ln\left(\frac{W}{h} + 1.444\right)\right]}$$

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

Where,
Ɛeff = Effective dielectric constant. W = Width of feed line.

Base circular antenna is of the diameter 48 mm. This length is calculated keeping in mind the resonant frequency of 2.4 GHz. Since the shape of the antenna is circular there is only one parameter that can be changed (radius of the patch). Thischanges the resonant frequency of the antenna [4]. A circular antenna inherently works on more than one frequency because it supports higher order modes in TMmnp. In the first iteration shown by S1, two circular patches are cut along the axis of the feed line (D1=20 mm). In the second iteration (S2), two more circles are subtracted from the base shape perpendicular to the feed axis (D2=12 mm). In the third and final iteration (S3) four circles of diameter D3=4 mm are cut from the remaining diagonal spaces in the base circular patch. Every iteration shows better response in terms of bandwidth, current distribution and radiation properties. The simulated geometry of proposed circular fractal antenna is shown in Figure 1. All the dimensions are shown in Table 1. Figure 2 shows the progressive process of cutting fractals in each stage to get the final result.

Table 1. Antenna Dimensions

Sr.No	Parameters	Description	Value (mm)
1	Lg	Length of substrate	86
2	Wg	Width of substrate	60
3	Lz	Length of feed line	27
4	Wz	Width of feed line	3
5	D0	Diameter of base patch	48.01

6	D1	Diameter of 1st inner cut	20
7	D2	Diameter of 2nd inner cut	12
8	D3	Diameter of 3rd inner cut	4

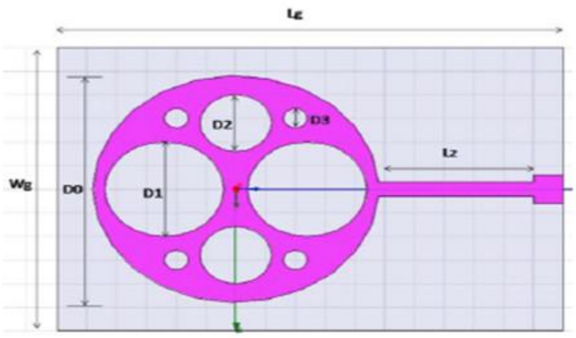

Figure 1. Antenna Geometry

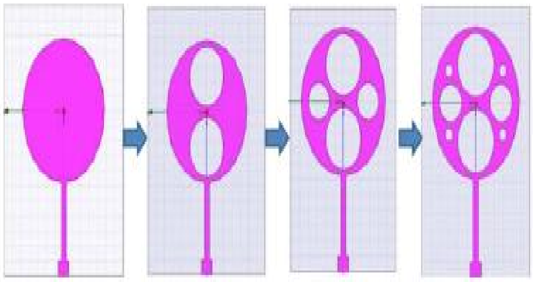

Figure 2. Recursive procedure of forming fractals

III. RESULT AND DISCUSSION

A.Return Loss

The circular antenna return loss at multiple frequencies at 3.5 GHz (-25 dB), 3.88 GHz (-16 dB), 5.4 GHz (-18 dB), 7.7GHz (-27 dB) and 8.8 GHz (-33 dB). Very less return losses are observed at 7GHz (-25.33 dB), 8 GHz (-23.15 dB), 8.8 GHz and 9.25GHz (-16 dB each).After the third and final iteration return loss at 2.4 GHz (22.72 dB). The bandwidth centered at this frequency is 330 MHz

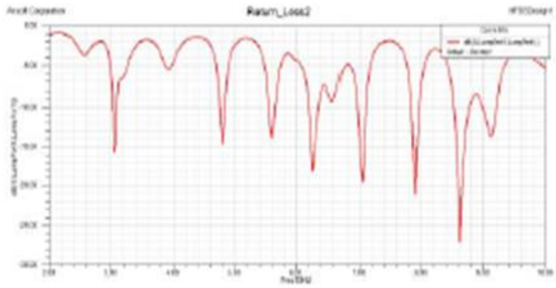

Figure 3.Simulated return loss of basic geometry

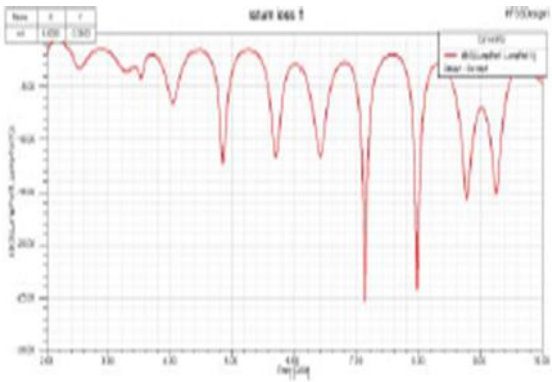

Figure 4. Simulated return loss after 1st iteration

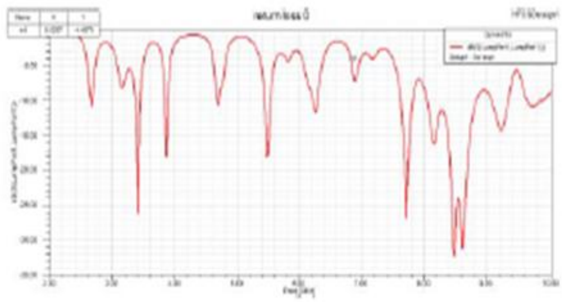

Figure 5. Simulated return loss after 2nditeration

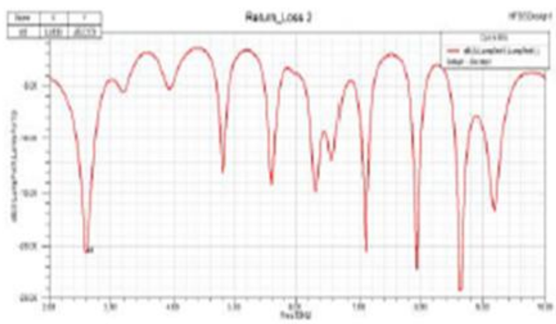

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Figure 6.Simulated return loss after 3rd iteration

B. Current Distribution

As shown in figure current distribution is impressive at the edges of the geometry at 2.4 GHz. So the radiation efficiency and bandwidth is increased.

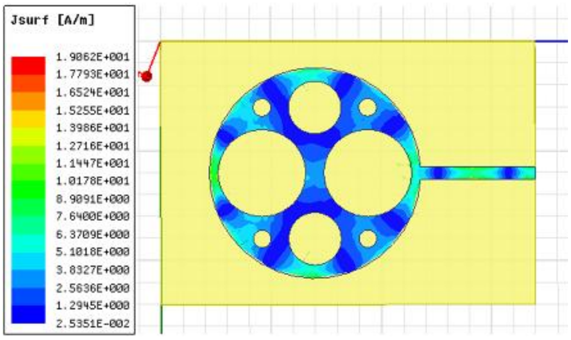
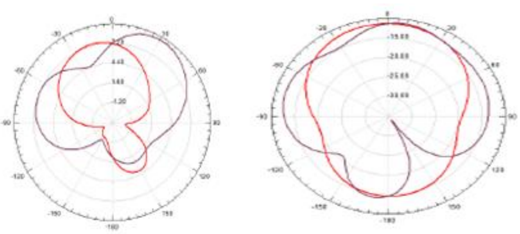


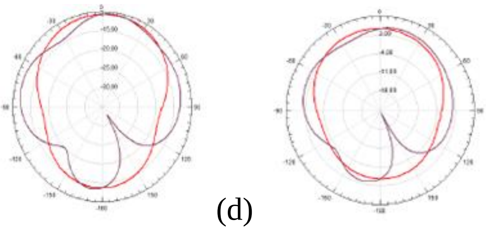
Figure 7. Current Distribution at 2.4 GHz

C. Radiation Pattern

Radiation patterns are usually studied in azimuthal plane and polar plane. Figure 8 shows the plots of the simulated radiationpatterns in the E-plane and H-plane at resonant frequencies. With increase in frequency, the number of lobes also increases. This type of behavior is seen in multiband fractal antenna. Major lobe covers most of the part of the radiation pattern which makes the antenna useful. There are some minor lobes but not that decrease the performance of the antenna.



(a) (b)



(c) (d)

Figure 8. Radiation pattern of different antennas in E-plane (blue) and H-plane(red) (a)Radiation pattern S0 (b) Radiation pattern S1 (c) Radiation pattern S2 (d) Radiation pattern S3

D. 3-D Gain Plot

The value of gain is 9.8 dB, -6.96dB, 2.44dB, 5.35dB and 7.6 dB at the frequency bands of 2.4 GHz, 4.88GHz, 6.3 GHz, 7 GHz and 8.8 GHz respectively. The 3D gain plots at different frequency bands are shown in Figure 9.

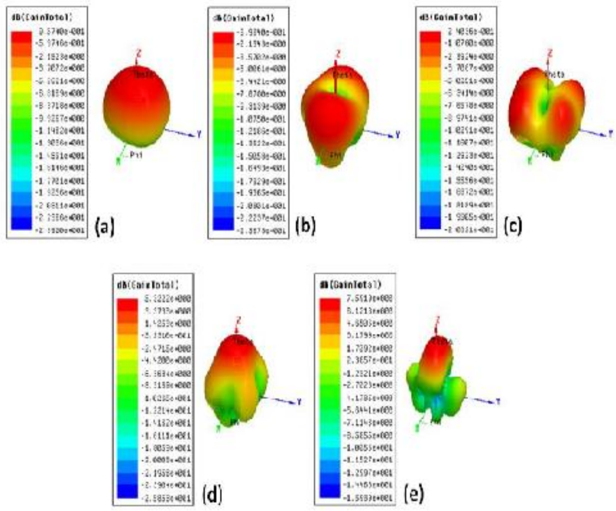


Figure 9. 3D gain plot at (a) 2.4GHz, (b) 4.88GHz, (c) 6.3 GHz, (d) 7 GHz and (e) 8.84GHz frequency band

IV.CONCLUSION

The main aim of this paper is to design a circular Sierpinski fractal antenna for multiband wireless communication with large bandwidth and better radiation efficiency. The result of different parameters like return loss,

gain, radiation efficiency and current distribution are observed.Proposed antenna works on frequencies 2.4 GHz, 4.8 GHz, 5.8 GHz, 6.3 GHz,7 GHz, 8 GHz, 8.8 GHz and 9.2 GHz. The maximum gain 0f 9.8 dB is observed at 2.4 GHz. 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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