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Design A Fractal Microstrip Printed Antenna For Wireless Applications

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Abstract: This article aims to introduce a new type of fractal patch antenna that is powered by a coaxial wire and placed on a FR4 substrate. To change the operating range to lower frequencies and enable the antenna to function at many frequencies, the first iteration employs a highly effective technique called the fractal methodology, specifically the Koch curve. By adhering to the principles of antenna design, it is feasible to create an antenna that can operate at a lower frequency without necessitating any enlargement of its dimensions. Consequently, this preserves the antenna's small dimensions, making it suitable for use in compact devices. Maintaining the antenna's physical dimensions will result in an increase in its overall efficiency.

Key words: *Microstrip Patch Antenna, Fractal antenna, FR4 epoxy , Fractal Geometry, wireless communication systems*

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I. Introduction.

The microstrip patch antenna consists of a metallic patch positioned on a ground ed substrate. Deschamps suggested the original Microstrip antenna in 1953, sparking a renewed interest in the Microstrip patch antenna in the early 1970s. [1].

One of the most common uses for microstrip antennas is in millimeter wave and microwave systems [2]. The Microstrip patch antenna plays a crucial role in reducing the size of technologies like mobile phones, wireless laptops, wireless universal serial bus (USB) dongles, and many other similar devices [3]. To accommodate the decreasing number of mobile devices, applications in modern mobile communication networks often require a smaller antenna. This is due to the fact that mobile devices are becoming smaller. As a result, miniaturization and multi-band augmentation are rapidly becoming the most important design priorities for Microstrip antennas in the real world. This is due to the reasons stated above. Many people are familiar with and adore Microstrip patch antennas because they function very well and are very robust. Although Microstrip antennas have some flaws, their impedance bandwidth is quite narrow [4]. The radiating patch can have several geometrical configurations, such as square, rectangle, circular, elliptical, triangular, E-shaped, H-shaped, L-shaped, U-shaped, or any other shape. In this case, we specifically chose a square shape. Any material with a dielectric constant ranging from 2.2 to 12, including both values, can compose a substrate [5]. By altering the patch form to a fractal shape, we can develop antennas that operate at multiple frequencies simultaneously, rather than being limited to a single frequency range. We conduct the design and simulations using the HFSS software suite [6].

II. Classical Antenna Design.

Before commencing the process of designing a Microstrip patch antenna, it is necessary to take into consideration a number of different criteria or elements. The characteristics being discussed here include the patch's length (L), width (W), and thickness (h), as well as the substrate's dielectric constant (r) and frequency of operation. There is a representation of the parameters in Figure 1.

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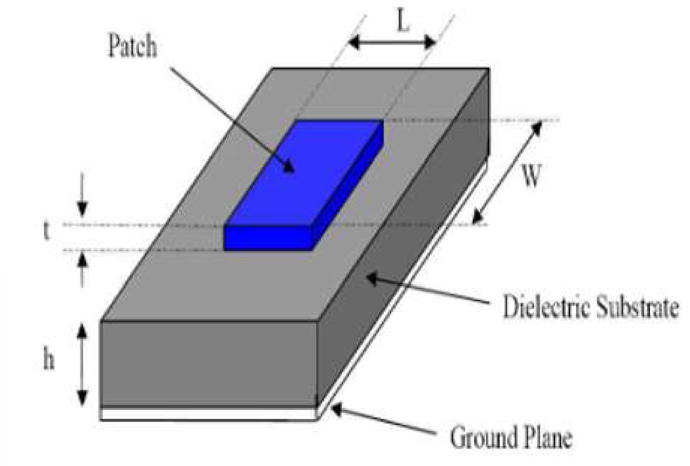

Figure (1) : Patch Antenna Parameters.

Firstly, it is crucial to determine two significant parameters in the design, namely the Width and Length of the patch. The width can be determined using equation (1) [7].

$$W = \frac{C}{2f\sqrt{\frac{\epsilon_r+1}{2}}} \ldots\ldots\ldots\ldots(1)$$

Then also must calculate the length, it can be found from the equation (2) [8].

$$L = \frac{C}{2f\sqrt{\epsilon_r(eff)}} - 2\Delta L \ldots\ldots\ldots\ldots(2)$$

As seen in the above equation it needs to find ΔL and ε_{reff} (Effective dielectric constant), and they can be found from equations (3) and (4) [9].

$$\Delta L = \frac{0.412h\,[\epsilon_{r(eff)}+0.3](\frac{W}{h}+0.264)}{[\epsilon_{r(eff)}-0.258](\frac{W}{h}+0.8)} \ldots\ldots\ldots\ldots(3)$$

$$\epsilon_{r(eff)} = \frac{(\epsilon_r+1)}{2} + \frac{(\epsilon r-1)}{2\sqrt{1+\frac{10W}{h}}} \ldots\ldots\ldots\ldots(4)$$

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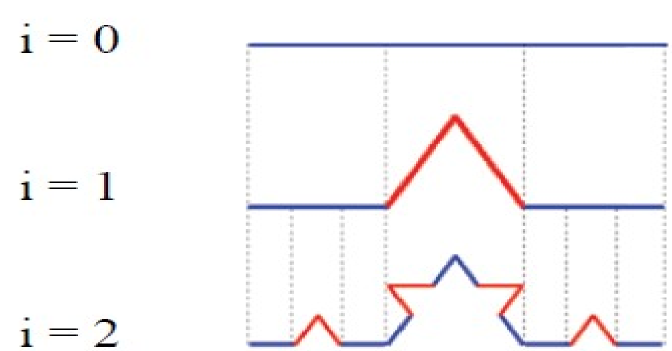
The antenna's initial configuration is square, with a side length of 28.5 mm. We fabricate the patch antenna on a FR4 substrate, measuring 65 mm x 65 mm x 1.5 mm. A coaxial probe at coordinates (3.25 mm, 0 mm) supplies power to the patch.

III. Fractal Antenna Design.

The Koch curve is a fractal characterized by a simple pattern consisting of a line divided into three parallel pieces of equal length. Eliminating the central section and substituting it with an inverted position resembling a V shape results in a complete design of four line segments. The next action entails duplicating the previous action. We substitute the middle part of each of the four lines with a "V," and then separately divide each line into three equal halves. Currently, there are two options available: either 4x4 or 16-line segments. Iterating the identical idea repeatedly leads to the emergence of fractals, or enduring patterns. We utilized the Koch curve, as illustrated in Figure 2 [10].



This fractal has a dimension of approximately 1.2618. Now, when we apply this principle to our square patch using the first iteration of the Koch curve, we can see the resulting shape of the fractal patch in figure 3b.

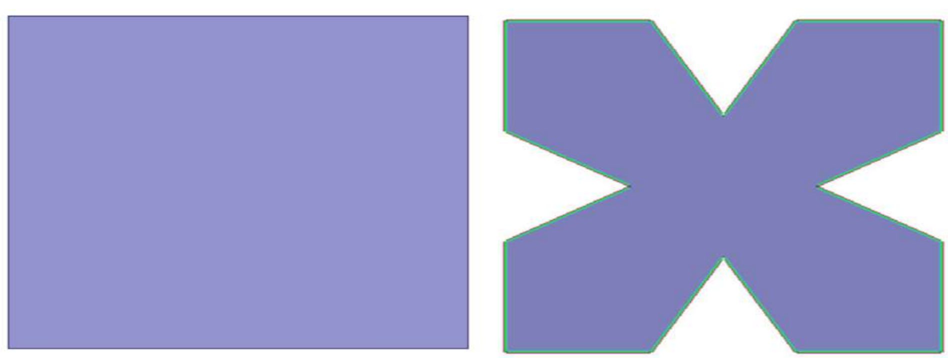


Figure (3): Patch Shape (a) Classical Patch (b) Fractal Patch.

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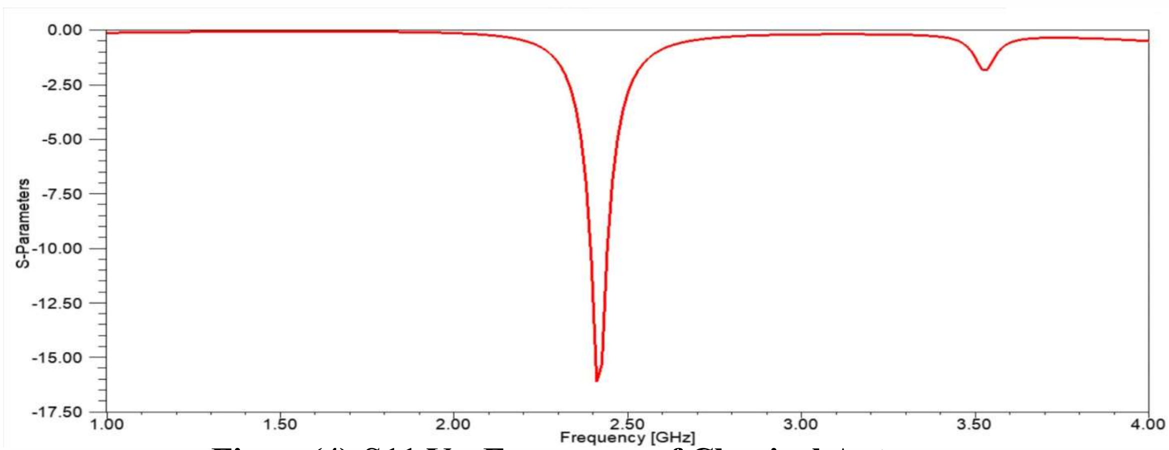
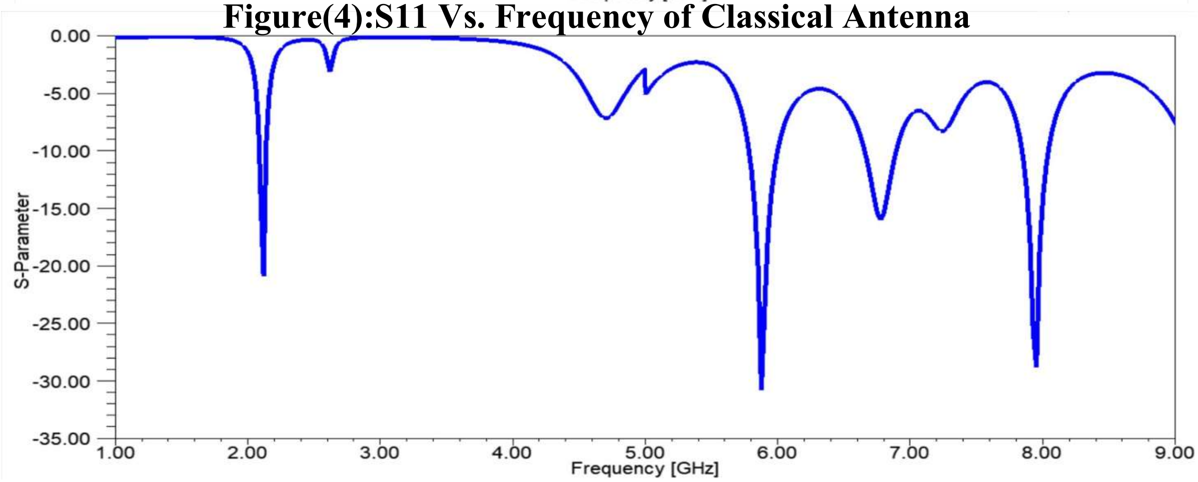
IV. Results And Discussion.

In this case, we use the Ansoft HFSS v13 code to create and simulate a model of classical and fractal antennas. The S-parameter calculations for the fractal antenna shape indicate that it exhibits multi-band behavior. Unlike the traditional antenna that operates at a single frequency band (2.4 GHz), as depicted in Figure 4, The fractal antenna resonates at different frequencies, including 5.76 GHz, 6.4 GHz, and 7.32 GHz. Additionally, a shift in the fundamental frequency from 2.4 GHz to 2.1 GHz has led to a reduction in size. Figure 5 illustrates this information. Table 1 contains the parameters for classical antennas. Figures (6) and (7) display the fractal's directivity, shapes of radiation patterns, and three-dimensional gain, respectively. We calculate the gain using the HFSS code.



Figure(4):S11 Vs. Frequency of Classical Antenna



Figure(5):S11 Vs. Frequency of Fractal Antenna

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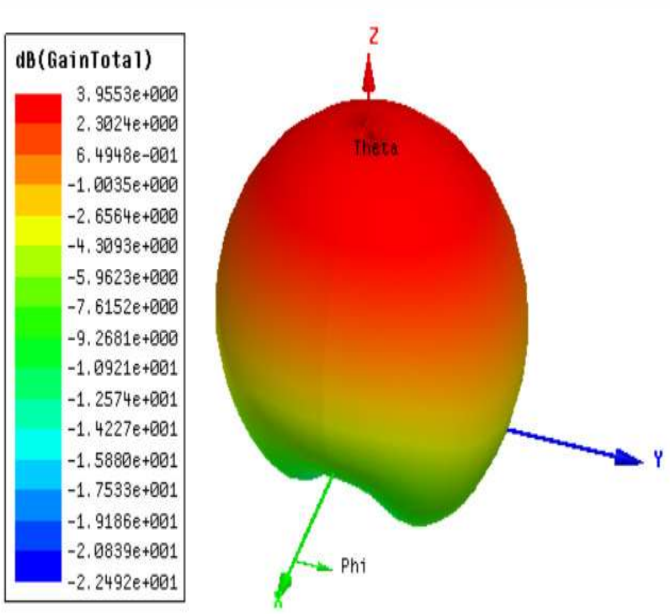
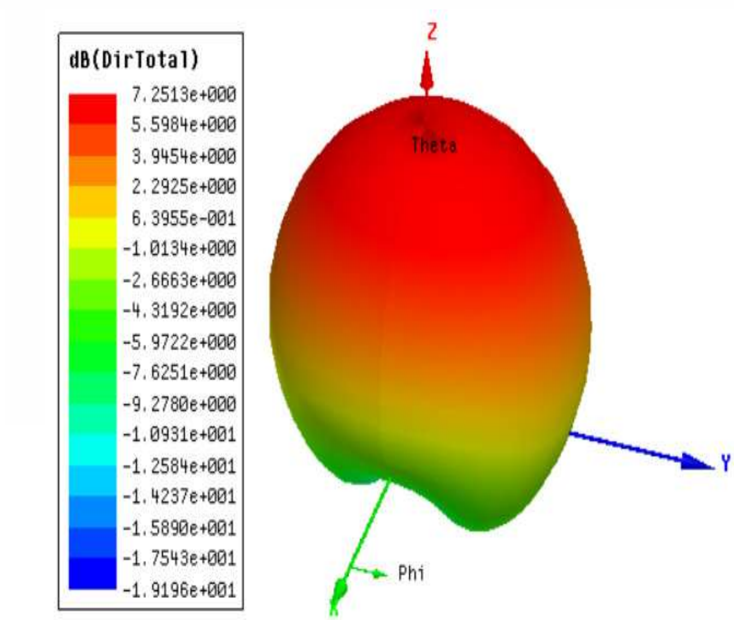
Table 1. Classical & Fractal Antenna Parameters.

	Frequency (GHz)	Gain (dB)	Directivity (dB)	S11 (dB)
Classical Antenna	2.4	3.9	7.2	-16.1
Fractal Antenna	2.1	3.9	6.2	-20.88
	5.8	18.4	20.5	-30.7
	6.8	22.3	25.4	-16.3
	7.9	22	26.3	-28.7



Figure(6a): Three Dimensional Far Field Antenna Gain



Figure(6b): Three Dimensional Far Field Antenna Directivity

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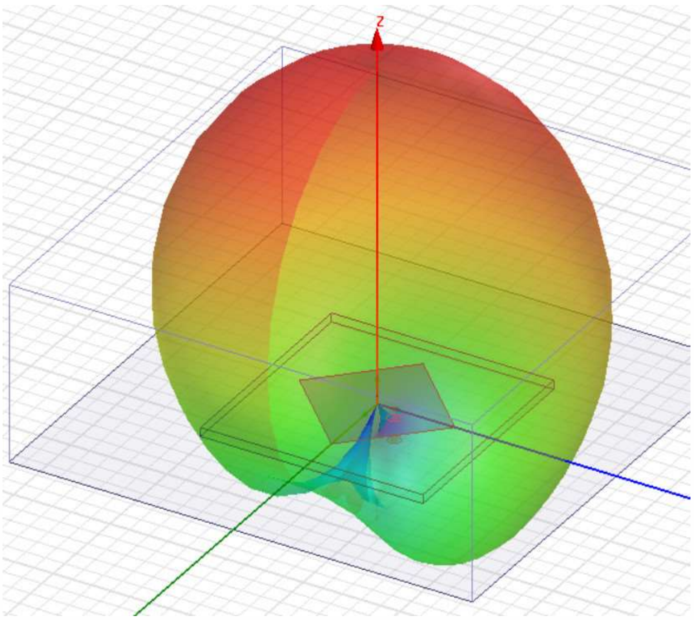
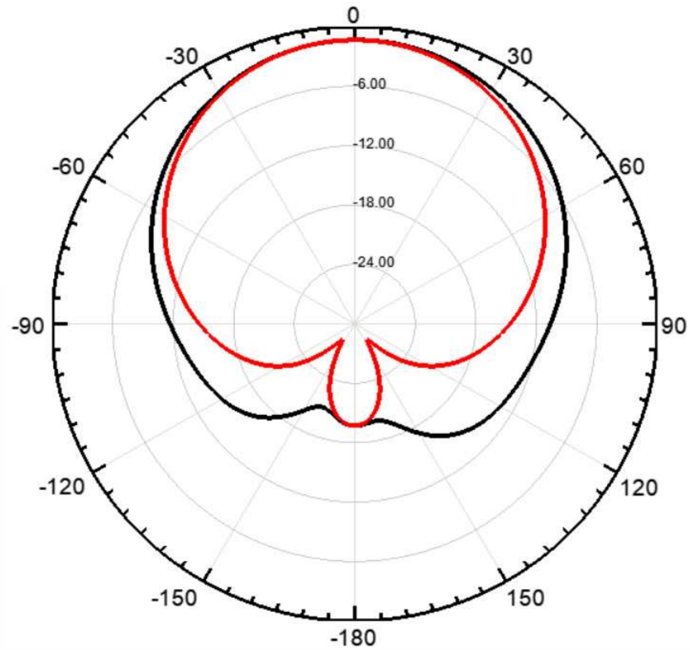


Figure(6c): Three Dimensional Far Field Antenna Pattern



Figure(6d): Two Dimensional Far Field Antenna Pattern

Figure (6): Classical Antenna Parameters.

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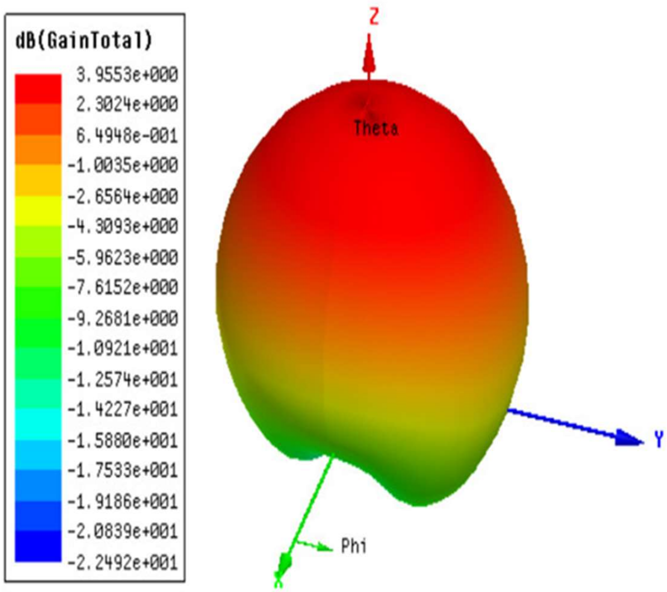
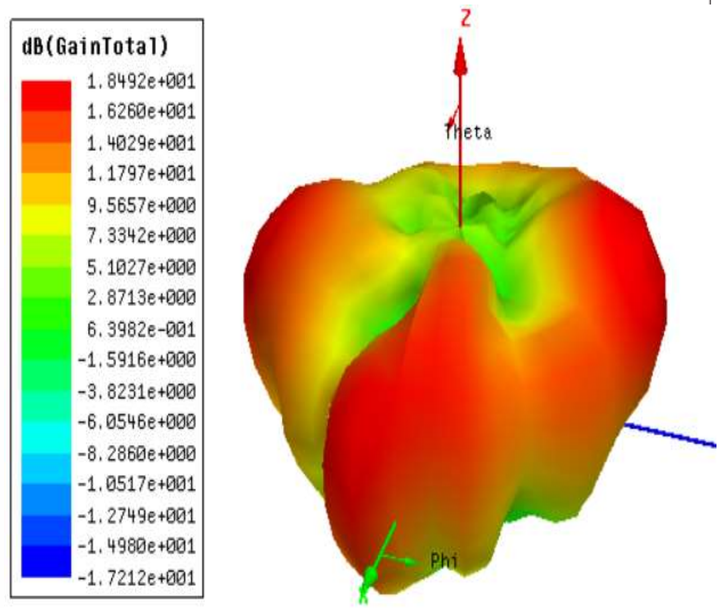
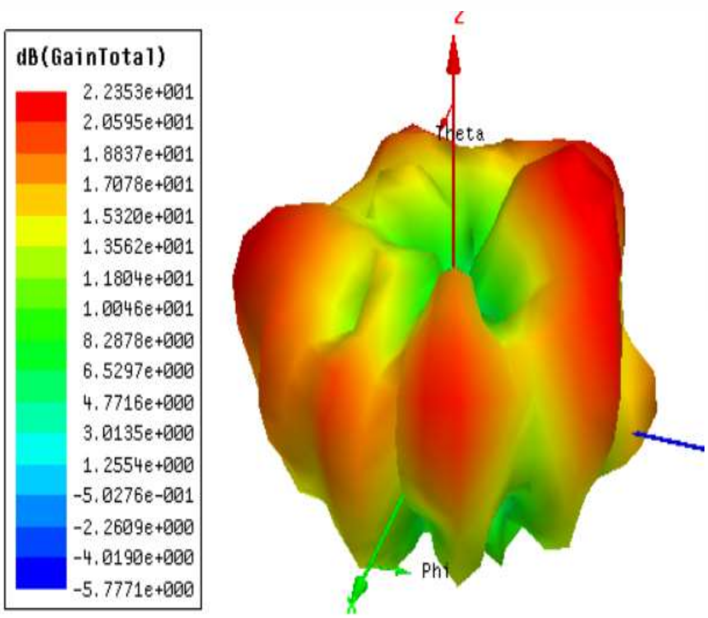


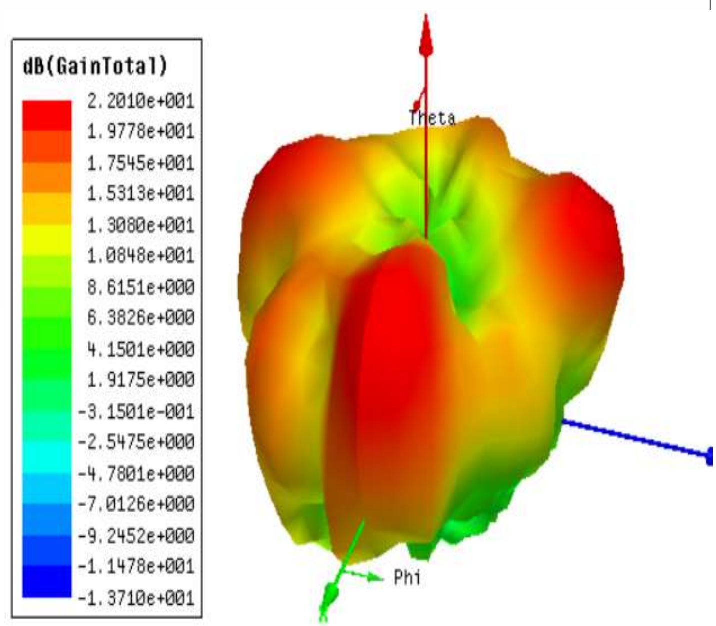
Figure(7a): Fractal Antenna Gain at 2.1 GHz



Figure(7b): Fractal Antenna Gain at 5.8 GHz



Figure(7c): Fractal Antenna Gain at 6.8 GHz



Figure(7d): Fractal Antenna Gain at 7.9 GHz

Figure (7): Fractal Antenna Parameters.

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V. Conclusion.

This paper describes the design and evaluation of a fractal antenna based on the first iteration of the Koch curve. We specifically intended the antenna for use in WLAN applications. A "fractal structure" is a self-repeating pattern that increases the overall length of the patch used for transmitting and receiving electromagnetic radiation. The suggested antenna consists of three layers: the patch dielectric material, the ground, and a probe feed coaxial wire. We do this to improve the input impedance performance. We utilize an HFSS platform for both the system's design and simulation. We have assessed the results from both the conventional and fractal forms generated on the radiating patch. We have also compared the differences in radiating frequency, return loss, bandwidth, VSWR, gain, and directivity. The results suggest that the proposed antenna is well-suited for WLAN applications.

The simulation results indicate that this antenna can effectively function as a multiband antenna. Furthermore, fractal geometry principles improve the antenna's bandwidth. Based on these frequencies, this antenna has the capacity to operate as a multiband antenna, enabling it to cover several applications, including GPS, WiMAX, and radar.

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