SSRG International Journal of Electrical and Electronics Engineering
ISSN: 2348-8379/ https://doi.org/10.14445/23488379/IJEEE-V12I2P102

Volume 12 Issue 2, 12-17, February 2025

Original Article

Design and Performance of Three Stages Rectangular Multiband Microstrip Fractal Antenna

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Received: 04 December 2024 Revised: 03 January 2025 Accepted: 01 February 2025 Published: 22 February 2025

Abstract - *The antennas with features that modern wireless communication trans-receivers can be benefitted. Currently, a single antenna is working on one frequency band with one application. The novel antennas have been demonstrated in three stages that patch forms have a number of benefits over traditional antenna types, such as multiband, attractive design features and good electromagnetic energy radiation. A variety of frequencies are used by wireless communication technologies, which are becoming widespread. The proposed antenna designs with the highly desired qualities of multi-band, multi frequencies, low profile, and limited size have become necessary with high dielectric substrates and large electrical lengths. Due to their ability to transmit and receive a wide range of multi-frequencies, square-cut fractal antennas are ideal for multiband applications. When it comes to decreasing patch antenna cross-sectional area, fractal antenna works better than the methods outlined below. The antenna electrical length is increased by the shorting posts' procedures by improving its design, etching periodic slow wave structures on the ground plane, adding inductive components of the patch antenna-like edges with rotating and scale down to 54% and placing the slots inside the patch having structure of rectangular patch 27 mm x 27 mm. The simulated results with two frequency bands achieved bandwidth are 1.7143 GHz and 2.1714 GHz under VSWR and Return loss.*

Keywords - *Square cut, Rectangular, Multiband, Fractal.*

1. Introduction

This research paper's goal is to explain and expand on the idea of antennas that provide beneficial features for modern wireless communication receivers, currently with many antennas that are available for single frequency bands. Consumption of power and utilization of space are not addressed in any of the current antenna structures. The proposed antenna is designed to cater for the above requirements. The conceptual study of this antenna has features that are advantageous to contemporary wireless communication receivers [1].

In recent years, researchers have focused more on low-profile systems due to the growing need for portable devices. Antenna size is crucial when constructing low-profile communication systems. Consequently, a variety of shrinking techniques for microstrip patch antennas have been proposed and implemented. These tactics include resistive or reactive loading, the use of high dielectric substrates, and optimizing the short-point technique and form to increase the electrical length of the antenna. When coupled with production and material constraints, the bandwidth reduction could result in a major production issue for very narrow-band components, such as Microstrip patches. Therefore, it would be advantageous to use a broadband element that needs little or no dielectric loading. The patch antenna's multiband operation is often believed to be a result of either its self-similar or space-filling construction, and there is evidence to support this theory.

2. Literature survey

One common way to reduce the size of an antenna element is to fill it with a material that has a high permittivity or dielectric constant [7]. This dielectric "loading" increases the effective electrical length of the loaded element by slowing the velocity of propagation of a wave in that medium. Although dielectric loading can effectively reduce the size of an element, it comes at a cost [5].

The differences in electrical properties associated with a particular degree of dielectric loading must be considered. In addition to making an antenna heavier and more expensive, dielectric loading reduces its bandwidth and efficiency. The bandwidth and efficiency loss will depend on the degree of drop and the material properties of the selected dielectric [11].

The application of the fractal notion has increased the potential for creating antenna design elements. Mandelbrot was the first to develop the fractal geometry [8]. Experimental studies indicate that when the fractal form iteration order grows, the patch's resonance frequency may be significantly reduced [1]. Because fractal shapes are Centro symmetry and self-similar, the emission patterns of the fractal-shaped antennas were preserved [9]. There is a lot of evidence and a strong belief that the self-similar structure and/or space-filling capabilities of the fractal antenna are what give it its multiband functioning capability [10]. The flow of antenna design processes as follow-

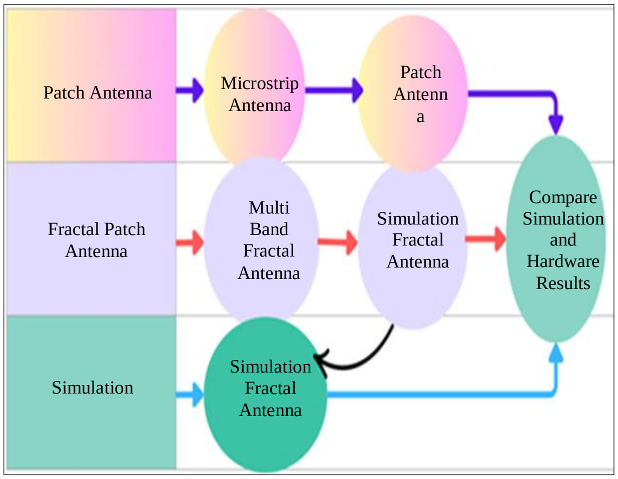

Fig. 1 Atenna design process

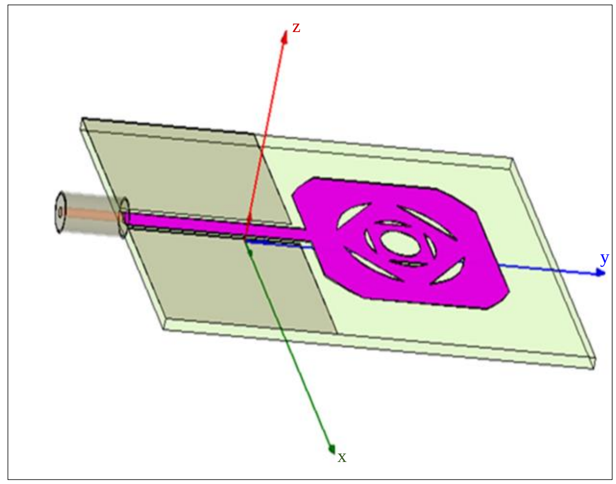

Fig. 2 Dielectric substrate of fractal Antenna

Table 1. Comparison between different feeding techniques

Characteristics	Microstrip Line Feed	Coaxial Feed	Aperture coupled Feed	Novelty of the Research
Spurious feed radiation	More	More	Less	**Minimum**
Reliability	Better	Poor due to soldering	Good	**Good**
Ease of fabrication	Easy	Soldering and drilling are needed	Alignment required	**Alignment required**
Impedance matching	Easy	Easy	Easy	**Easy**
Bandwidth	2-5% [1, 2]	2-5% [7, 12]	2-5% [6, 15]	**9%**

3. Theory of Fractal Antenna

A microstrip square-cut rectangular patch antenna, as shown in Figure 2, consists of a radiating patch on one side of a dielectric substrate and a ground plane on the other. The patch is frequently made of a conducting material, such as copper or gold, and can have any shape. The dielectric substrate, feed, and two-stage square-cut rectangular patch are typically used.

3.1. Multiband Frequency

The antenna can operate at a range of frequencies due to its geometry and construction. The main disadvantage of a generic patch antenna that only supports one frequency is that it is ineffective when working on many frequencies despite offering respectable gain and directivity. To overcome this problem, we use fractal antennas [20].

3.2. Small Size

It's pretty little. The main advantage of this antenna is that it may be affixed to the surface on which it will be used, saving room and giving it a visually pleasing appearance due to its self-similarity. The efficiency and gain will depend on the size with respect to the antennas [19].

3.3. Space Filling Property

Because the system can operate in several bands with the same size of antenna, it makes efficient use of the available area. It boasts outstanding improvements and efficiency and is quite small.

3.4. Mechanical Simplicity and Robustness

The discrete components' shape determines the antenna's properties. It is excellent for applications such as space satellite applications since it can be adhered to any surface.

Above is a demonstration of the self-similar property of the antenna. The same basic rectangular shape is repeated each time, as shown in Figure 2.

4. Methods of Fractal Antenna Design

The different type of fractal patches is designed on the same substrate and with the same dimensions. A detailed description of each is given below.

Step 1 : Antenna: a metallic apparatus commonly referred to as an aerial or radiator for radio waves [2].

Step 2 : Microstrip Antennas are commonly available, inexpensive, lightweight, and conformable. These are active devices and printed strip-line feed networks. Due to their tiny size, low profile, ease of manufacture, ease of attachment to both planar and non-planar surfaces, simplicity, affordability, and mechanical robustness, which is made of grounded substrate with a metallic patch, which can be square, circular, triangular, or rectangular, having adaptability for impedance bandwidth, radiation pattern, polarization, and resonant frequency. A radiating patch on one side of a dielectric substrate with a ground plane makes up a microstrip patch antenna [8, 21].

Step 3 : Fractal Antennas are low-profile portable systems available in small sizes for creating low-profile communication systems [12].

Step 4 : Properties of Fractal Antennas over conventional antenna types, emitting electromagnetic energy, are found important for Fractal shapes by utilizing the fractal geometry for traditional antenna configuration, decreasing antennas' size and optimizing shape to enhance their electrical length. With two primary characteristics of fractal geometries-space-filling and self-similar properties-fractal shape antenna elements offer a number of benefits, including multiband, broad bandwidth, and smaller antenna sizes [10, 13].

Step 5 : Geometry Fractal antennas are more effective than patch antenna size reduction. By optimizing the geometry, filling the patch's edges with inductive components, etching periodic slow wave patterns on the ground plane, and inserting slots into the patch, the shorting posts procedures increase the electrical length of the antenna.

Step 6 : Optimization of Fractals antennas are self-similar geometrical structures, and by being repeated for specific simple geometries, they can produce nearly any complex structure found in nature. Extending the antenna's overall electrical length increases the area of material utilized in the antenna [14].

Step 7 : Scaled Down Fractal antennas recurrence of a motif over two or more scale sizes, or "iterations.", known as multilevel and space-filled curves. These are incredibly small, multiband or wideband, and have practical uses in microwave and cellular phone communications [16].

Step 8 : Simulation Results Fractal antennas: the antenna exhibits discrete bands between given frequencies. Additionally, its reflection coefficient gains VSWR to indicate superior performance for the specified application.

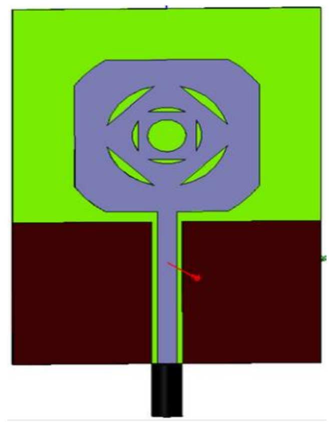

Fig. 3 Multiband property explanation of fractal antenna

Table 2. Dimension of fractal antenna

Name	Dimension
Rectangular patch	27 mm x 27 mm
Substrate	46 mm x 66 mm
Cylinder of radius	18 mm
width	3.1 mm
Height	1.53 mm
The gap between ground and feed	0.95 mm

As seen in Figure 3, a rectangular patch measuring 27 mm by 27 mm is used to build the radiating antenna on a rectangle FR4 substrate measuring 46 mm by 66 mm. Permittivity = 4.4 and height = 1.53 mm. This fundamental structure (square cut) is then curved at the corners by crossing with an 18 mm cylinder, the centroid of which is the square's center. A curved edge facilitates better bandwidth operation. The central portion is etched out in a 10 mm cylindrical form. For the previous fractal level, this is the fundamental structure that is then reduced to 52% of its original size. Three of these fractals are joined together, and a feed line with a width of 3.1 mm is attached to it. Both sides of the feed have coplanar ground with dimensions with size 21.5 mm x 27 mm. The gap between ground and feed is 0.95mm. And ground to patch 2mm.

5. Simulated Results

The antenna design focuses on two bands, i.e. S-band and C-band. With different bands, the antenna is simulated and designed using HFSS. The software is based on the FEM method; in this technique, large structures are converted into multiple fractal shape structures for ease of analysis.

5.1. VSWR

VSWR must be less than two for the antenna to be in the operational band. The simulation results below show that each type of antenna, or antenna, has two different bands.

Table 3. VSWR range

Starting Frequency in GHz	Ending Frequency in GHz	Frequency Band in GHz
2.2571	3.9714	1.7143
5.0000	7.1714	2.1714

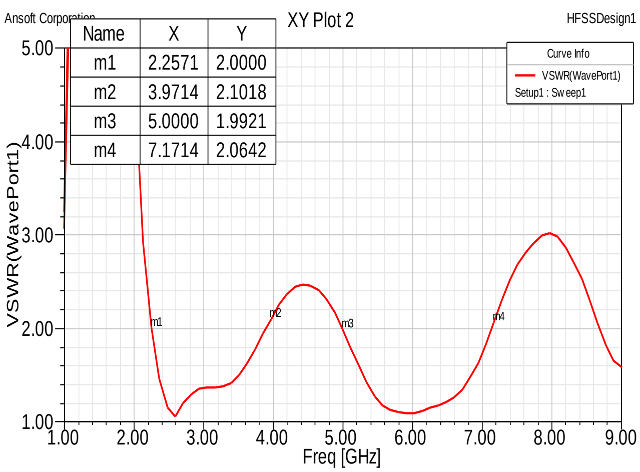

Fig. 4 VSWR for fractal antenna

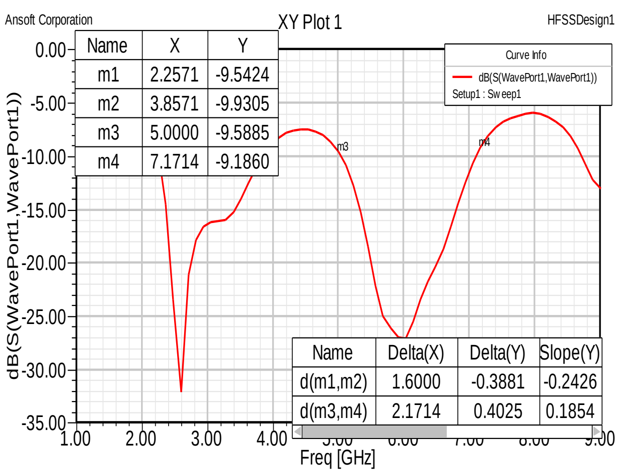

Fig. 5 Reflection coefficient for fractal antenna

5.2. Reflection Coefficient

The reflection coefficient measures electromagnetic wave reflection in the transmission channel caused by an impedance discontinuity. This is the proportion between the incident wave's and the reflected wave's amplitudes at the intersection. The return loss bandwidth is obtained by deducing frequencies below -10dB. The return loss graph in Figure 5 is consistent with the VSWR results.

5.3. Radiation Pattern

Figure 6 illustrates the bi-directional pattern of Antenna A. For our project, we plotted gain as a function of directive angles ranging from 0^0 to 360^0. The pattern can be plotted as a function of radiated energy, directivity, electric field intensity, magnetic field dispersion, gain, etc. Gain in antennas reduces as the angle moves away from the original plane. This results in a figure of eight-like bidirectional patterns (8).

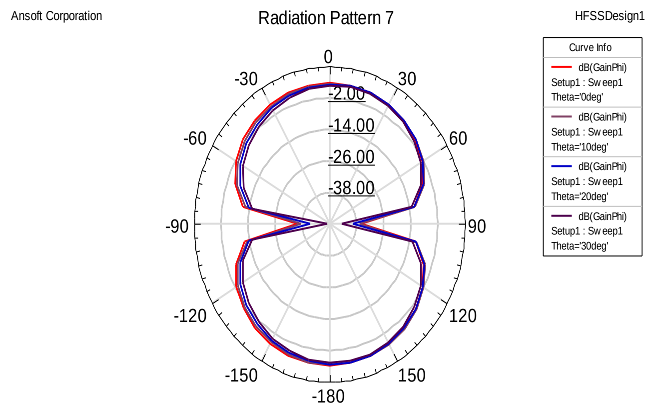

Fig. 6 Radiation pattern for fractal antenna

5.4. Peak Gain

The antenna Gain was found to be uniform, around 6 dB for the entire operating band of 2-4 GHz and uniform, around 7.5 dB for an entire operating band of 6-8 GHz. It is observed that the overall nature of the graph is increasing from a lower to a higher band for all Antennas. Further graph exponentially increases for 0-2 GHz and linearly increases after 2GHz, as shown in Figure 7. A gain less than 0 indicates non-radiating frequencies.

5.5. Smith Chart

Figure 8 shows that at 1.95GHz, the impedance is 51Ω. Both the results are in almost the same agreement, minor deviations occurred due to manual errors during fabrication, soldering and or testing of the antenna.

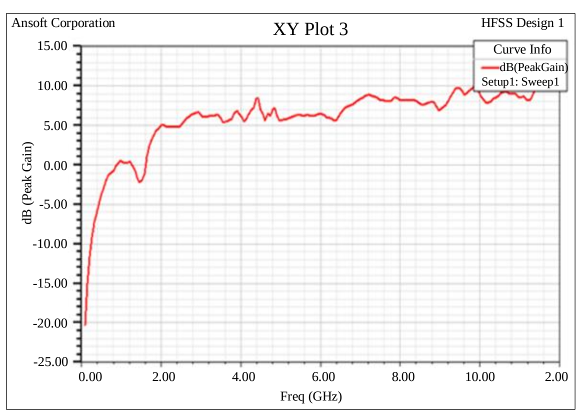

Fig. 7 Peak gain for fractal antenna

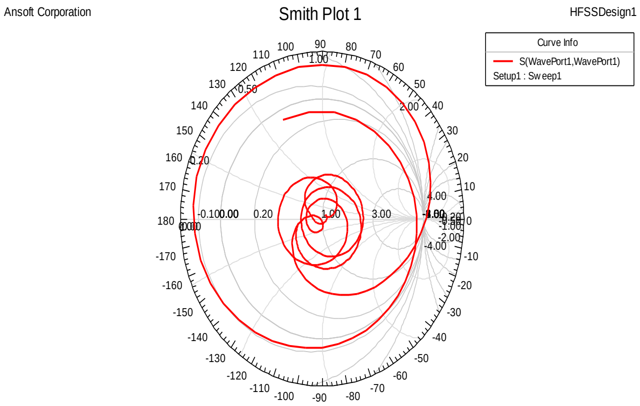

Fig. 8 Smith chart of fractal antenna

6. Conclusion

The above design and simulation work carried out is the original contribution of wireless communication technology, which was carried out personally for technical advancement in the field for better communication, achieving more than 95% peak gain in the experimented frequency band. When creating an antenna, the Patch property is added to get the results for a multiband frequency antenna. When two distinct bands with VSWRs less than two are joined, two broad bands of 2.1714 GHz and 1.6000 GHz are produced, demonstrating that our antenna is effective for the specified application frequencies. Antenna performance is higher for the specified application when the frequency bands 2.2571 GHz to 3.8571 GHz and 5.000 GHz to 7.1714 GHz are distinct, and the reflection coefficient is less than -10 dB. Figure 5 shows the 8 patterns, indicating that the antenna is bidirectional. Figure 6 illustrates that a high gain is achieved for the operational frequency band.

6.1. Highlights

- In the S-band and C-band, the achieved bandwidth is 1.7143 GHz and 2.1714 GHz under VSWR.
- The Return loss is maintained at less than -10dB. For getting distinct bands in antenna with 2.2571 GHz to 3.8571 GHz and 5.000 GHz to 7.1714 GHz.

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