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# Multi-Band Microstrip Rectangular Fractal Antenna for Wireless Applications

**Wael Shalan, and Kuldip Pahwa**

*Department of Electronics and Communication Engineering, Maharishi Markandeshwer Engineering College, Maharishi Markandeshwer University, Mullana, Ambala, E-mail: salamnyairaq@yahoo.com and kpahwa2002@yahoo.com*

***Abstract:*** Modern telecommunication systems require antennas with wider bandwidth and smaller dimensions. Various antennas for wide band operation have been studied for communication and radar systems. The fractal antennas are preferred due to small size, light weight and easy installation. A rectangular fractal microstrip antenna is described in this paper. The use of fractal pattern in this paper provides a simple and efficient method for obtaining the compactness. A sierpinski carpet based fractal antenna is designed for 4.31 GHz, 4.99 GHz,6.16 GHz ,8.55 GHz,9.09 GHz, and 9.99 GHz. The gain of the antenna at resonant frequencies respectively are 5.81 dBi, 5.24dBi, 8.54 dBi, 4.91dBi,4.54 dBi and 4.32 dBi for 2nd iteration. the VSWR is between 1 and 2. The bandwidth of the antenna are 55 MHz, 27 MH,z 73 MHz, 50 MHz, 40 MHz and 25 MHz for 4.31 GHz, 4.99 GHz, 6.16 GHz, 8.55 GHz, 9.09 GHz and 9.99 GHz respectively. In term of wavelength ($\lambda$) the length of the antenna is .42$\lambda$ and the dimension of antenna is 33 mm × 25 mm.

***Keywords:*** Fractal, Multiband patch antenna, Sierpinski

## 1. INTRODUCTION

The term fractal was coined by the French mathematician B.B. Mandelbrot during 1970's after his pioneering research on several naturally occurring irregular and fragmented geometries not contained within the realms of conventional Euclidian geometry. The use of fractal geometries has significantly impacted many areas of science and engineering; one of which is antennas. Antennas using some of these geometries for various telecommunications applications are already available commercially. The use of fractal geometries has been shown to improve several antenna features to varying extents.Microstrip patch antenna (MPA) has attracted wide interest due to its important features, such as light weight, low profile, low cost, simple to manufacture and easy to integrate with RF devices. For reducing the size of antenna, fractal geometries have been introduced. The main objective is to design a square shaped fractal antenna which will be small in size and multiband performance. A fractal is "a rough or fragmented geometric shape that can be split into parts, each of which is a reduced size copy of the whole. Roots of mathematical interest in fractals can be traced back to the late 19th century; however mathematical fractal is based on an equation that undergoes iteration, a form of feed based on recursion.

Fractals are a class of shapes which have not characteristic size. Each fractal is composed of multiple iterations of a single elementary shape. The iteration can continue infinitely, thus forming a shape within a finite boundary but of infinite length or area.

Fractal has the following features

It has a fine structure at arbitrarily small scales.

(2) It is too irregular to be easily described in traditional Euclidean geometric.

It is self-similar.

(4) Simple and recursive.

A fractal is "a rough or fragmented geometric shape" that is generated by starting with a very simple pattern that grows through the application of rules. In many cases the rules to make the figure grow from one stage to next involve taking the original figure and modifying it or adding to it. The process can be repeated recursively an infinite number of times.

The first application of fractals to the field of antenna theory was reported by Kim and Jaggard. They introduced a methodology for designing low side lobe arrays that is based on the theory of random fractals. The fact that self-scaling arrays can produce fractal radiation pattern was first established in 1992 .This is accomplished by studying the properties of a special type of non uniform linear array, called aweiertrass array, which has self-scaling element spacing and current distributions.

For reducing the size of antenna, fractal geometries have been introduced in the design of antenna. Fractal geometries have two common properties: Self-similar property, Space filling property. The self-similarity property of certain fractals results in a multiband behaviour. Using the self-similarity properties a fractal antenna can be designed to receive and transmit over a wide range of frequencies. While using space filling properties, a fractal make reduce antenna size.

Fractal antenna engineering is the field, which utilizes fractal geometries for antenna design. It has become one of the growing fields of antenna engineering due to its advantages over conventional antenna design.

## 2. ANTENNA DESIGN

When including a subsection you must use, for its heading, small letters, 12pt, left justified, bold, Times New Roman as here.

The transmission line model represents the microstrip antenna by two slots each of width $W$ and hight $h$ separated by low-impedance $Zc$ transmission line of length $L$. The essential parameters for the design an antenna according the transmission line method are; dielectric constant of the substrate ($\varepsilon_r$), resonant frequency ($f_r$) and the height of substrate $h$. The conventional microstrip rectangular patch antenna is designed by following the standard procedures:

(1) Calculation of the width $W$ of antenna, which is given by:

$$W = \frac{v_o}{2 f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \quad (1)$$

where $v_o$ is the free-space velocity of light.

(2) Calculation of effective dielectric constant, $\varepsilon_{reff}$ , which is given by:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-\frac{1}{2}} \quad (2)$$

(3) Calculation of the effective length, $L_{eff}$ , which is given by:

$$L_{eff} = \frac{v_o}{2 fr\sqrt{\varepsilon_{reff}}} \quad (3)$$

(4) Calculation of the length extension, $\Delta L$, which is given by:

$$\Delta L = 0.412h\frac{(\varepsilon_{reff} + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{w}{h} + 0.8\right)} \quad (4)$$

(5) Calculation of actual length of patch, $L$ which is given by:

$$L = L_{eff} - 2\Delta L \quad (5)$$

(6) Calculation of the ground plane dimensions $L_s$ and $W_S$, which are given by:

$$L_s = 6h + L \quad (6)$$

$$W_s = 6h + W \quad (7)$$

(7) Determination of feed point location :

A coaxial probe type is to be used in this design. The feed point must be located at that point on the patch, where the input impedance is 50 ohms for the resonant frequency. Hence, a trial and error method is used to locate the feed point.

The parameters taken into account for the design are the resonant frequency ($\varepsilon_r$ = 2.77GHz), dielectric constant ($\varepsilon_r$ = 4.3) and thickness of the Substrate ($h$ = 1.575 mm). The conventional patch antenna is shown in Figure1 with dimensions.

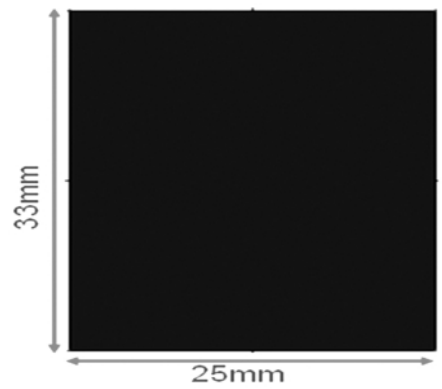


**Fig.1:** Conventional Rectangular Microstrip Patch Antenna

The rectangular microstrip patch antenna is based on Sierpinski carpet. For designing this fractal antenna IE3D software is used. The FR-4 epoxy material is used as substrate. The thickness of the substrate is 1.575 mm. The dielectric constant ($\varepsilon_r$) of the antenna is 4.3. The Sierpinski carpet fractal shape is used in this paper with single iteration. In decomposition algorithm for rectangular shape is cut down from the centre of the rectangular patch antenna which shows the 1st iteration and gives one resonance frequency. For second iteration, again rectangular shape is cut down from the some portion of 1st iteration. Finally resonant frequencies found at 2nd iteration. Fig. 1 shows the rectangular patch antenna without iteration and Fig. 2 shows the fractal with 1st iteration of the rectangular patch antenna. Fig. 3 shows the rectangular patch antenna with 2nd iteration. The size of rectangular patch fractal antenna is 25 mm × 33 mm (without iteration) and after 1st iteration ‘indentation’ size is 8 mm × 11 mm. This rectangular patch fractal antenna has scale factor equal to 1/3.

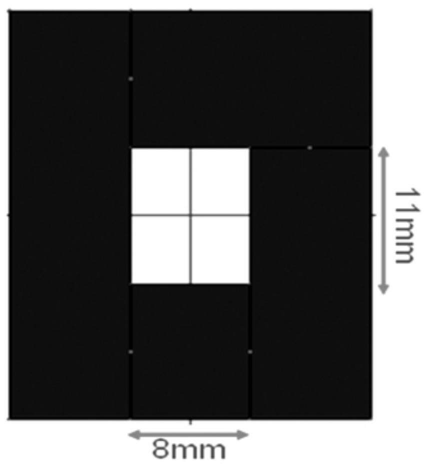


**Fig. 2:** Geometry of First Iteration

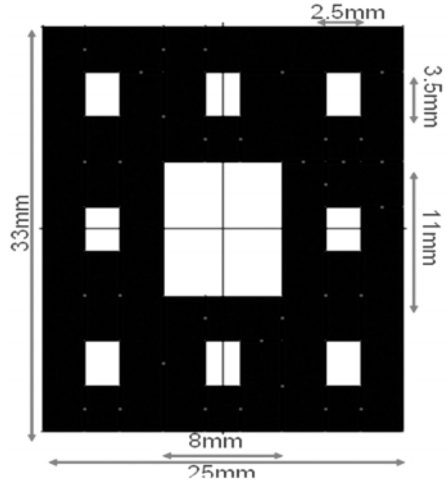


**Fig. 3:** Geometry of Second Iteration

## 3. SIMULATION RESULTS AND DISCUSSION

Simulation of the proposed antenna is carried out by Zeland Inc's IE3D software based on method of Moment (MoM). The simulated return loss of second iteration is shown in Fig. 4.

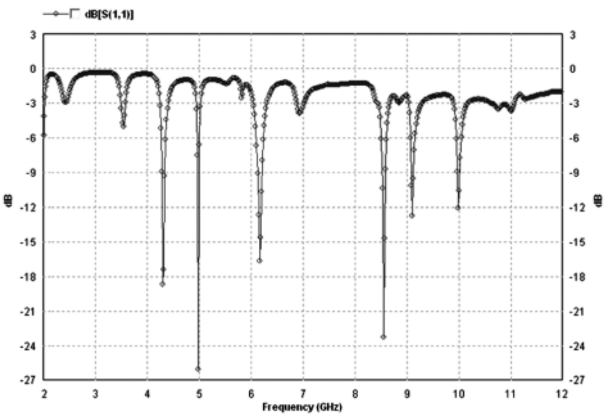


**Fig. 4:** Simulated Return Loss (s11) of Rectangular Fractal Antenna

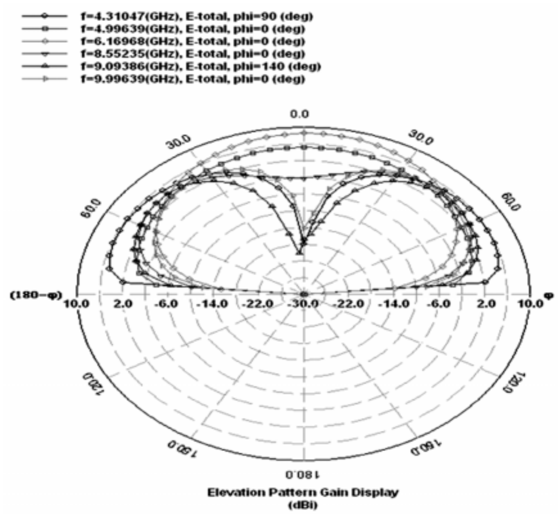


**Fig. 5:** Elevation Pattern Gains Display (dBi)

The gain of the antenna should be positive. In this paper the proposed antenna resonates at (4.31, 4.99, 6.16, 8.55, 9.09 and 9.99) GHz with the gain of (5.81, 5.24, 8.54, 4.91, 4.53 and 4.32) dBi respectively. These results shown in Fig. 5

The table below will show the values of resonant frequencies, bandwidths and gains:

**Table 1**
**Simulation Results**

| *S. No.* | *Resonant Frequency (GHz)* | *Return Loss (dBi)* | *Band width (MHz)* | *Gain (dBi)* |
|---|---|---|---|---|
| 1 | 4.310 | –18.7 | 55 | 5.81 |
| 2 | 4.996 | –26.06 | 27 | 5.24 |
| 3 | 6.169 | –16.66 | 73 | 8.54 |
| 4 | 8.552 | –23.32 | 50 | 4.91 |
| 5 | 9.093 | –12.79 | 40 | 4.53 |
| 6 | 9.996 | –12.09 | 25 | 4.32 |

The azimuth Pattern Gain Display shown in Fig. 6

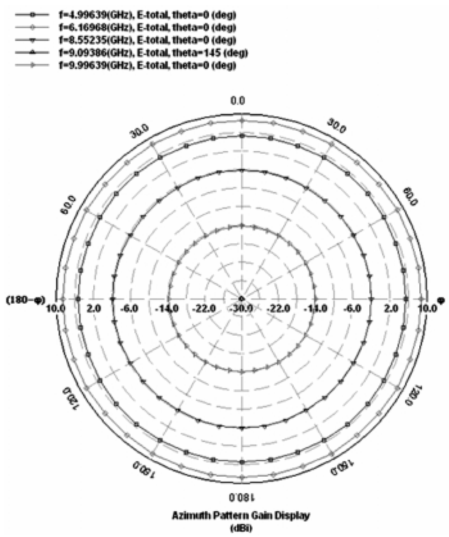


**Fig. 6:** Azimuth Pattern Gains Display (dBi)

The total Field Gain v/s Frequency characteristics shown in Fig. 7

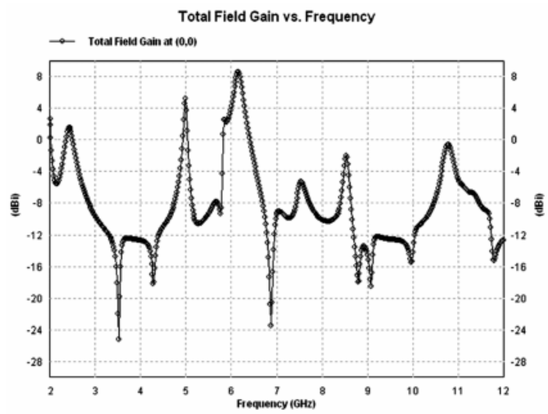


**Fig. 7:** Total Field Gain v/s Frequency Characteristics

The total Directivity v/s Frequency characteristics shown in Fig. 8

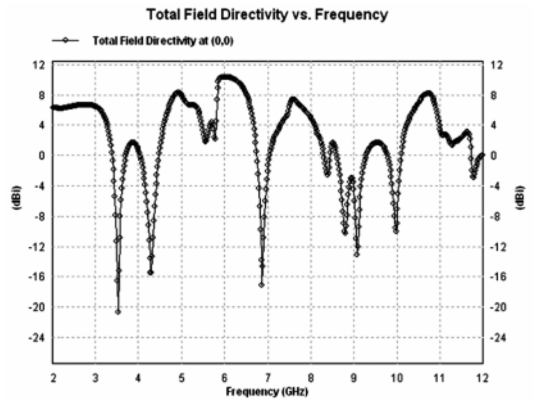


**Fig. 8:** Total Directivity v/s Frequency Characteristics

The smith charts are presented in Fig. 9

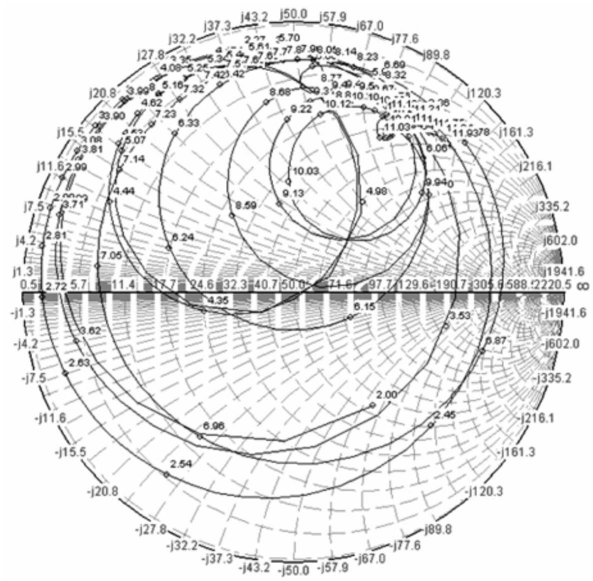

**Fig. 9:** Smith Chart of the Antenna

And the VSWR characteristics shown in Fig. 10

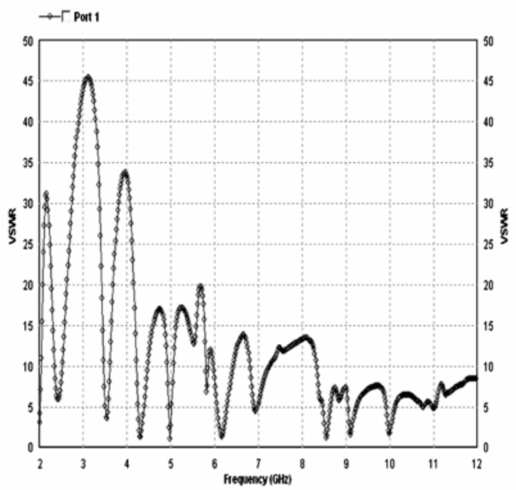


**Fig. 10:** VSWR v/s Frequency Characteristics

## 4. CONCLUSION AND FUTURE WORK

The aspects of microstrip antennas have been studied in this paper. The aspect is the design of typical rectangular microstrip antenna. A simple and efficient technique of design has been introduced for an impedance matching improvement of antennasIn this paper; the microstrip fractal patch antenna is proposed for the wireless various applications. The antenna is designed for multi-band frequencies (4.31, 4.99, 6.16, 8.55, 9.09 and 9.99) GHz and the simulation results are obtained up to second iteration. The proposed antenna show a significant size reduction compared to the conventional microstrip patch antenna. The size of antenna is reduced to 20.212% at second iteration from the conventional patch. A conventional rectangular microstirp patch antenna has been successfully designed having a central frequency of 2.77 GHz. The patch dimensions are 33 mm by 25 mm. Hence, the designed antenna is compact enough to be placed in typical wireless devices.

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