Study of Effect of Variations in slot dimensions on Fractal Patch antenna Performance

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ABSTRACT

An antenna is a device that is made to efficiently radiate and receive radiated Electromagnetic waves. Microstrip antennas are attractive due to their light weight, conformability and low cost. These antennas can be integrated with printed strip-line feed networks and active devices. This is a relatively new area of antenna engineering. For reducing the size of antenna, fractal geometries have been introduced in the design of patch antenna. Fractal antennas also called as space filling curves are very compact, multiband or wideband, and have useful applications in cellular telephone and microwave communications. In our research work, we have used IE3D software for designing the antenna. We study the effect of variations of slot dimensions on antenna performance so as to obtain good results. In this research work, four different fractal patch antennas are designed. The rectangular base geometry is same for the all four antennas but the elliptical slot dimensions differ. In simulation, S parameters of all four antennas are analyzed. From the S parameter displays, comparison of all four antennas is done on the basis of three parameters that are: Lowest frequency, Multiband and S_{11} values. The simulation results shows that as the elliptical slot dimension decreases on rectangular patch antenna, the performance of fractal patch antenna improves on the basis of three factors that are lowest frequency, multiband and s_{11} values.

KEYWORDS

Microstrip antenna, Fractal antenna, S parameters, Lowest frequency, Multiband and S_{11} values.

INTRODUCTION

An antenna is a device that is made to efficiently radiate and receive radiated Electromagnetic waves. Wireless communication plays a great role in our daily existence, with antennas being of continuously increasing significance. Microstrip patch antenna is becoming most popular in wireless communication applications. Microstrip patch antennas have various advantages such as low profile, light weight, easy fabrication and conformability to mounting hosts in addition size reduction and bandwidth enhancement are major design considerations for practical applications of microstrip antennas [1].

However, the size of a conventional microstrip antenna is typically large when designed in microwave frequency regime causing problems for mounting on transmitter/receiver and repeater systems. These antenna types also have limitations in terms of their narrow bandwidth, low gain, and weak radiating patterns. The gain reduction is caused by the overall reduction in the antenna size. It can also be attributed to the substrate characteristics which may lead to surface wave excitation and hence a reduction in gain. Therefore, it is challenging to design microstrip antennas to have better radiating properties and in the same time have a smaller size [2]. These antennas can be integrated with printed strip-line feed networks and active devices. A very important contributing factor for recent advances of microstrip antennas is the current revolution in electronic circuit miniaturization brought about by developments in large scale integration. The size of MPA is basically determined by its resonance length and width [3]. A microstrip antenna is characterized by its Length, Width, Input impedance, and Gain and radiation patterns. A microstrip antenna consists of conducting patch on a ground plane separated by dielectric substrate as shown in Figure 1.
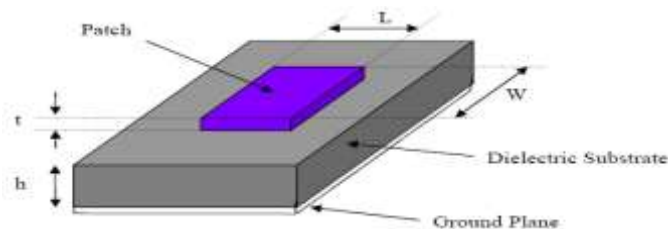

Fig 1: Structure of a Microstrip Patch Antenna.

Microstrip patch antennas can be fed by a variety of methods. The four most popular feed techniques used are the microstrip line, coaxial probe (both contacting schemes), aperture coupling and proximity coupling (both non-contacting schemes). For reducing the size of antenna, fractal geometries have been introduced in the design of patch antenna. 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. Fractal geometries have two common properties: Self-similar property, Space filling property. The self-similarity property of certain fractals results in a multiband behavior. 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 [4].The existence of infinite fractal geometries and their advantages opens the door to endless possibilities to accomplish the task at hand. The use of fractals provides us with a bigger set of parameters to control the antenna characteristics [5]. Figure 2 shows the properties of fractals.
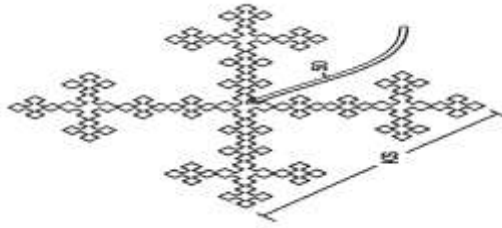

Fig 2: Space filling curve with self similar design.

A fractal antenna's response differs markedly from traditional antenna designs, in that it is capable of operating with good-to-excellent performance at many different frequencies simultaneously. Generally standard antennas have to be "cut" for the frequency for which they are to be used and thus the standard antennas only can work well at that frequency. This makes the fractal antenna an excellent design for wideband and multiband applications. The key features of fractal antenna technology are reduced antenna size, Multi-band functionality, improved antenna performance etc. Robust communications links are achieved with fractal-shaped antennas by not only using repeating and self-similar shapes, but also with irregular shapes that may not be immediately recognised as fractal. To perform Simulation of Fractal patch Antenna different software's are available [6].

IE3D is used in this work because of its multi-threaded and distributed simulation architecture and high design capacity. In this paper we study the effect of variations of slot dimensions on fractal patch antenna performance so as to obtain good results. In this paper further four different fractal patch antennas are designed [7]. The rectangular base geometry is same for the all four antennas but the elliptical slot dimensions differ. In simulation, S parameters of all four antennas are analyzed. The S parameter graph shows the relationship between return loss (S_{11}) and frequency. From the S parameter displays, comparison of all four antennas is done on the basis of three parameters that are:

1. Lowest frequency
2. Multiband
3. S_{11} values

In the next sections the Fractal Antenna Design Procedure, Design Parameters, simulation results and conclusions based on the simulations are explained.

FRACTAL ANTENNA DESIGN

In this section, the procedure for designing a Fractal Patch Antenna in IE3D software is explained. The design parameters are also explained in this section.

Design Parameters

The following specifications are taken into account for the design of Fractal Patch Antenna:

1. Practical Length (L) = 40.3 mm.

2. Practical width (w) =49.4mm.

3. Frequency (f_r) = 2.4 GHz.

4. Height (h) = 3.175 mm.

5. Velocity of light (c) = 3×10^8 m/s = 3×10^{11} mm/s.

6. Dielectric constant (ε_r) = 2.2

7. Loss Tangent (tan δ) = 0.0009

8. Radius of co-axial cable = 0.5mm.

Feed point is located where input impedance is matched to 50 ohms and where return loss is most negative. Low dielectric constant substrates are generally preferred for maximum radiation. The conducting patch can take any shape but rectangular and circular configurations are the most commonly used configuration.

In this work, four different fractal patch antennas are designed. The rectangular base geometry is same for the all four antennas but the elliptical slot dimensions differ.

The rectangular base geometry dimensions are:

1. Practical Length (L) of rectangle = 40.3 mm.

2. Practical width (w) of rectangle =49.4mm.

The elliptical slot dimensions for the antenna are shown in Table 1. The various antenna design based on elliptical slot dimension is given in Figure 3a, 3b, 3c, 3d.

Table 1. Fractal patch Antenna elliptical slot dimensions

Elliptical slot dimensions	Antenna 1	Antenna 2	Antenna 3	Antenna 4
Primary axis(mm)	20	16	10	5
Secondary axis(mm)	24.5	22.62	16	8
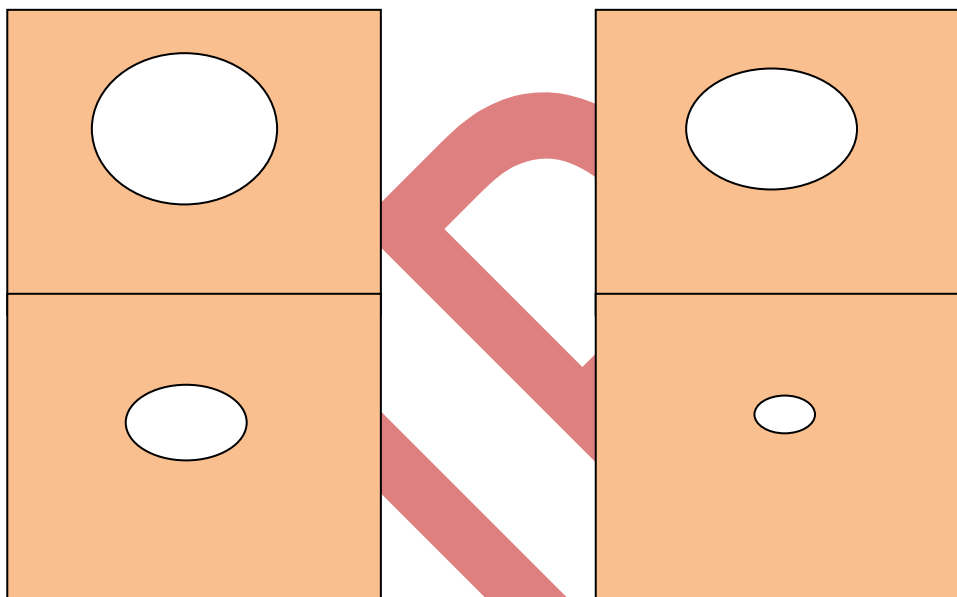
SIMULATION AND RESULTS

In simulation, S parameters of all four antennas are analyzed [8-10]. From the S parameter displays, comparison of all four antennas is done on the basis of three parameters that are:

1. Lowest frequency
2. Multiband
3. S_{11} values

Lowest frequency: The lowest frequency means the minimum operating frequency of an antenna on which antenna can work satisfactory. Under this, we observe the minimum operating frequency of all the four designed antennas from the S parameter displays [11]. The S parameter of all four designed antennas showing the lowest frequency of all the designed antennas are shown in Figure 4, 5, 6, 7 as follows [12]. Figure 4 shows the S parameter display of antenna 1 for the observation of lowest frequency operation.
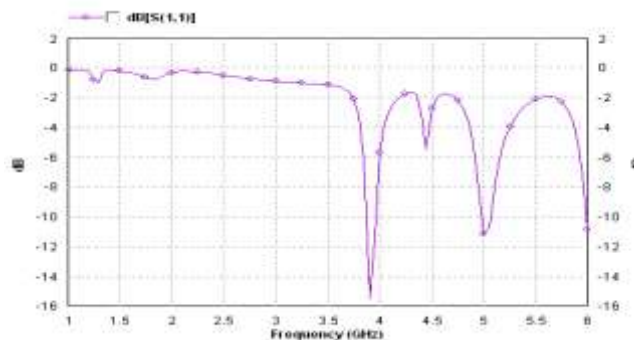

Fig 4: S parameter display of antenna 1 showing lowest frequency.

Figure 5 shows the S parameter display of antenna 2 for the observation of lowest frequency operation.
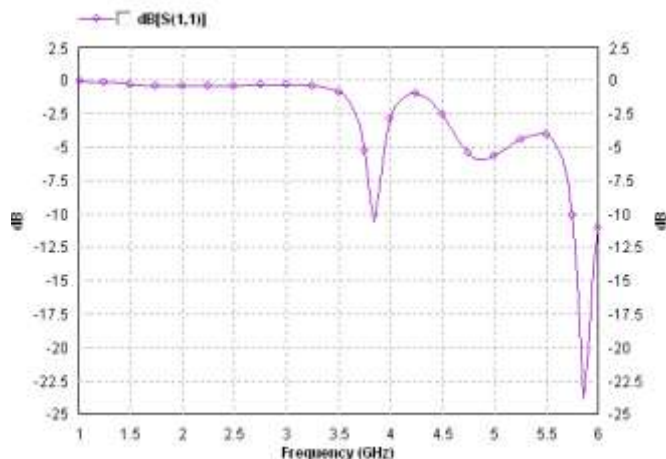
Fig 5: S parameter display of antenna 2 showing lowest frequency.

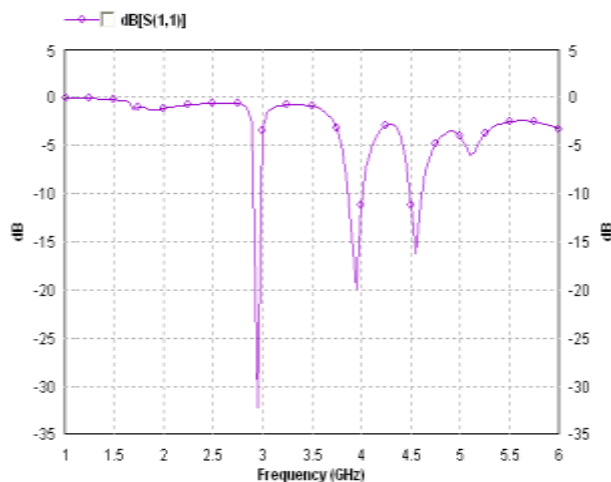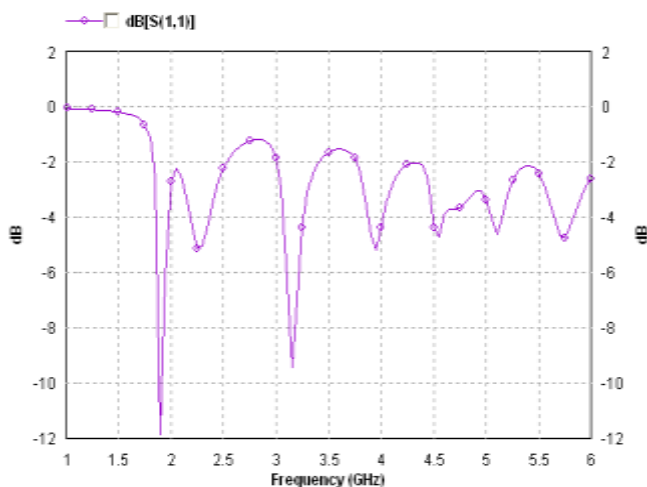Figure 6 shows the S parameter display of antenna 3 for the observation of lowest frequency operation.

Fig 6: S parameter display of antenna 3 showing lowest frequency.

Figure 7 shows the S parameter display of antenna 4 for the observation of lowest frequency operation.

Fig 7: S parameter display of antenna 4 showing lowest frequency.

From the above S parameter displays of the four designed antennas,it is clear that with the reduction in elliptical slot dimensions the lowest frequency of operation on which antenna can work satisfactory, decreases.

Multiband: Under this, the multiband operation is observed from S parameters displays for all four designed antennas. The S parameter display showing the number of frequencies on which antenna can operate satisfactory is shown in Figure 8, 9, 10, 11 as follows.

Figure 8 shows the S parameter display of antenna 1 for the observation of multiband frequency operation.
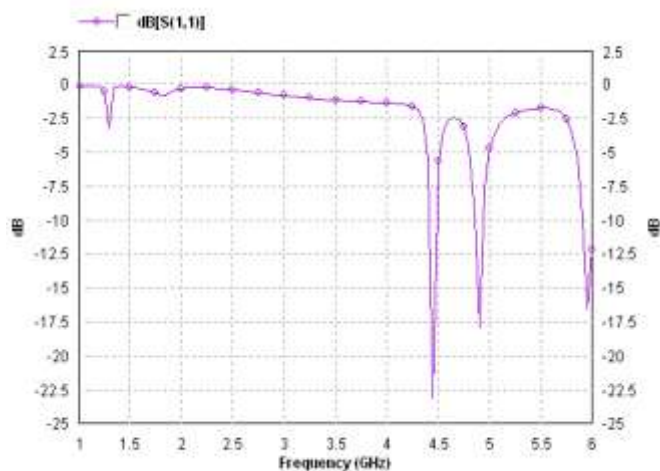

Fig 8: S parameter display of antenna 1 showing multiband frequency operation.

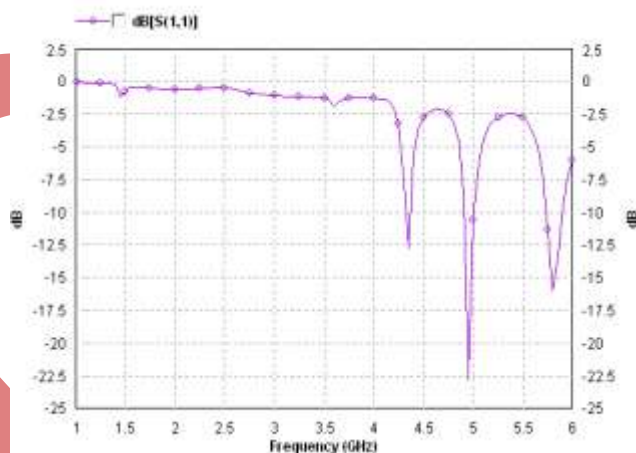Figure 9 shows the S parameter display of antenna 2 for the observation of multiband frequency operation.

Fig 9: S parameter display of antenna 2 showing multiband frequency operation.

Figure 10 shows the S parameter display of antenna 3 for the observation of multiband frequency operation.
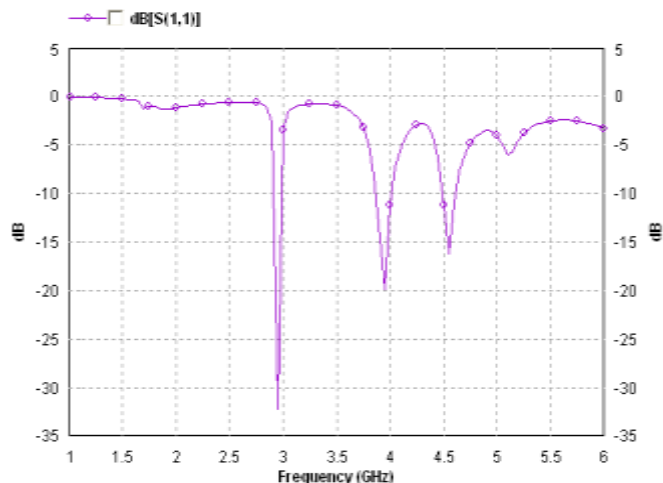
Fig 10: S parameter display of antenna 3 showing multiband frequency operation.

Figure 11 shows the S parameter display of antenna 4 for the observation of multiband frequency operation.
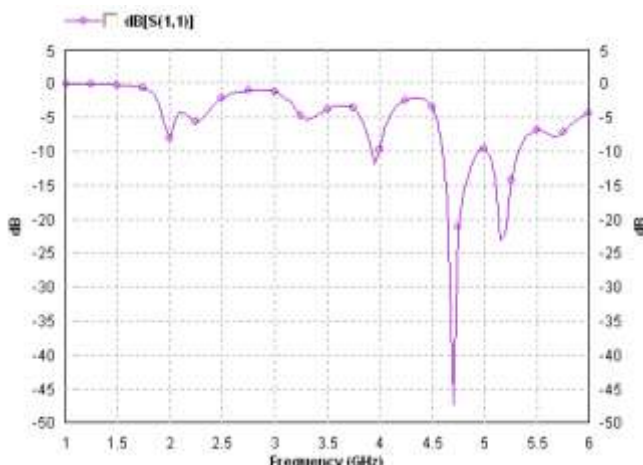

Fig 11: S parameter display of antenna 4 showing multiband frequency operation.

From the above S parameter displays of the four designed antennas,it is clear that with the reduction in elliptical slot dimensions there is not much effect on multiband frequency operation.

S_{11} value: It is also called return loss. It is defined as the ratio of the reflected back power to the incident power. For good antenna its value should be more negative then -10dB.Under this from the S parameter displays of all the four designed antennas minimum return loss for all the four antennas is observed and shown in Figure 12, 13, 14, and 15 as follows.

Figure 12 shows the S parameter display of antenna 1 for the observation of S_{11} value.
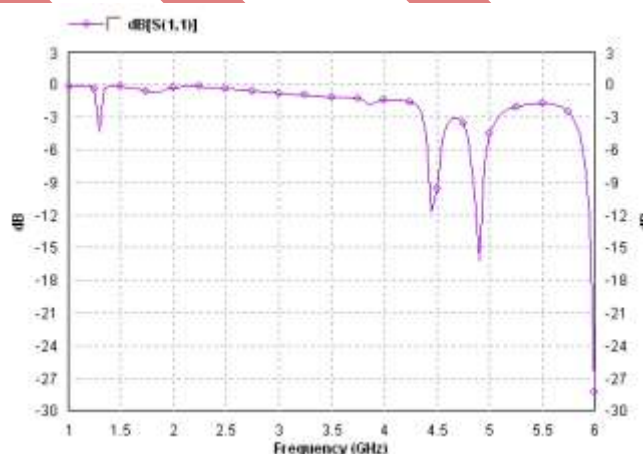

Fig 12: S parameter display of antenna 1 showing the S_{11} value.

Figure 13 shows the S parameter display of antenna 2 for the observation of S_{11} value.
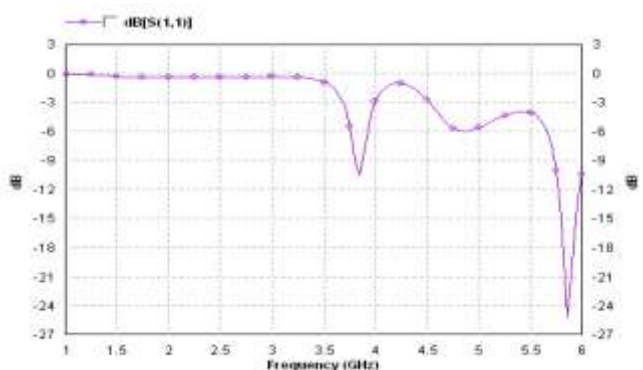

Fig 13: S parameter display of antenna 2 showing the S_{11} value.

Figure 14 shows the S parameter display of antenna 3 for the observation of S_{11} value.
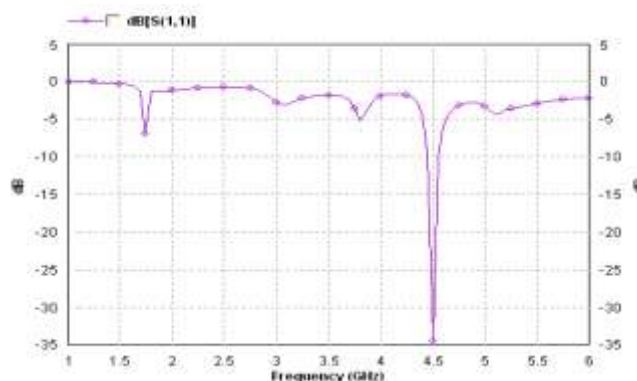

Fig 14: S parameter display of antenna 3 showing the S_{11} value.

Figure 15 shows the S parameter display of antenna 4 for the observation of S_{11} value.
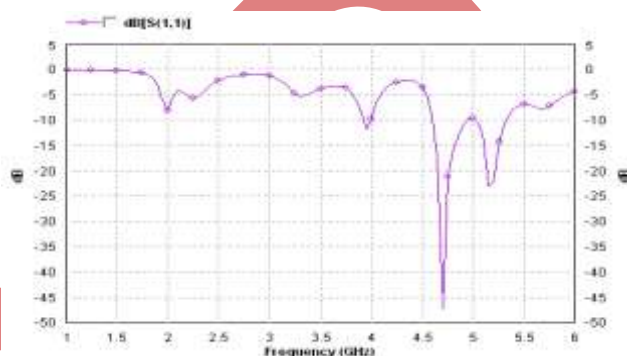

Fig 15: S parameter display of antenna 4 showing the S_{11} value.

From the above S parameter displays of the four designed antennas,it is clear that with the reduction in elliptical slot dimensions the S_{11} value also reduces. The lowest frequency, Multiband and S_{11} values of all the four fractal patch antennas are shown in Table 2.

Table 2: Comparison of antennas on the basis of lowest frequency, multiband and S_{11} values.

S parameter	Antenna 1	Antenna 2	Antenna 3	Antenna 4
Lowest frequency (GHz)	3.899	3.837	2.948	1.892
Multiband (GHz)	4.4507	4.3450	2.9483	4.4507
	4.8967	4.9436	3.9460	4.8964
	5.9530	5.8004	4.5446	5.9882
S_{11} values	-24.506	-24.701	-33.348	-45.651

The all four fractal patch antennas are compared in the above Table 2. The four designed antennas have been analyzed from the S parameter displays. The performance of the four designed antennas is observed on the basis of three parameters that are lowest frequency, multiband operation and S_{11} values. It is clear from the table that with reduction in the elliptical slot dimensions on the rectangular patch antenna, the return loss decreases, also the lowest frequency, on which antenna can work satisfactory, decreases.

CONCLUSION

The design of fractal (Probe Feed) antenna has been completed using IE3D software. The four fractal antennas are designed having same rectangular base geometry with different elliptical slots. The S parameter displays of all four antennas are compared. The simulation results shows that as the elliptical slot dimension decreases on rectangular patch antenna, the performance of fractal patch antenna improves on the basis of three factors that are lowest frequency, multiband and s_{11} values. Before going for fabrication we can optimize the parameters of antenna using a soft computing technique. Thus, use of fractal geometry results in a multi frequency and ultra-wide bandwidth operation of the antenna without employing any further modification. We can use fractal antenna for a multi band operation.

ACKNOWLEDGMENTS

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