A Review of Various Fractal Geometries for Wireless Applications

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Abstract: With the advancement in antenna technology, there is a great need of a low profile, multiband and wideband antennas for wireless communication. Fractal antennas are different from others because of their self similarity and self repetitive properties. Fractal microstrip patch antennas have small size, light weight and support multiple frequencies. In this paper, we have discussed various fractal geometries so as to understand the multiband behavior of microstrip patch antenna. We have also explained fractal antennas for various wireless communication applications such as in WiMAX technology.

Keywords: Fractal microstrip patch antenna, Fractal geometries, wireless communication.

I. INTRODUCTION

Microstrip patch antenna was developed by Bob Munson in 1972. It consists of radiating patches that are placed on the top of the dielectric substrate and a conductive layer is present on the bottom surface of the substrate, forming a ground for the antenna. The shape and dimensions of the patch are the important features of the antenna. Microstrip patch antennas are light in weight because of absence of machined parts and are simpler, compact and easy to manufacture with printed circuit technology [1].

In 1988, first Fractal antenna was built by Dr. Nathan Cohen. Fractal antennas have self similar and self repetitive characteristics. The idea behind fractal antennas came from patterns existing in nature. They have space filling properties that are well utilized in designing antennas for wideband behavior. Fractal antennas are the combination of antennas that are operating at different frequencies with a small size.

In wireless communication, military communication and navigation communication, we require an antenna that provides multiband support, compact size, higher gain and optimal performance. To meet these requirements fractal antennas are needed. Fractal antennas do not have any deterministic size [2]. These antennas are smaller in size and support multiband frequencies. Therefore such antennas require less space which is highly desirable for wireless communication and advanced military communication where space is a major issue. Self similar property in fractal antennas shows wideband behavior. This property is used to expand the length of the material by keeping the total area same. Space filling property reduces the size of the antenna and hence helps in making a low profile antenna required in most of the communication systems [3]. Therefore using fractal geometries a compact and wideband antenna can be designed. A single fractal antenna can be used to operate on many resonant frequencies. These antennas provide same radiation patterns and gain as conventional antennas but occupy less space. Multiple iterations exist in single basic shape. These iterations can continue infinitely but occupying finite space. Therefore Fractal antennas are compact in size and supports multiband frequencies [4].

II. FRACTAL GEOMETRIES FOR PATCH ANTENNA

Fractal designs offer better parameters and controlled designs. Fractal antennas not only provide multiband characteristics but also have self similarity of the geometry. A Fractal antenna provides excellent performance at many different frequencies simultaneously. These antennas are nature inspired antennas. There are four commonly used geometries.

(1) Sierpinski Gasket
Sierpinski gasket is named after the mathematician Sierpinski. In this the central triangle is subtracted from the main triangle shape. After subtraction three equal triangles appear on the structure, each being half the size of original triangle. Iterations can occur infinite number of times and hence sierpinski gasket is obtained [5, 6].

Fig.1 Sierpinski Gasket [5]

(2) Sierpinski Carpet
This geometry is similar to sierpinski gasket, but it uses squares in place of triangles. It starts with a square at first, and divides itself in nine smaller squares while dropping the central square. The same process is again repeated with smaller squares. The Sierpinski Gasket shape is widely used because by using this shape a single antenna can be operated on multiple frequencies [5, 7].

Fig. 2 Sierpinski Carpet [5]

(3) Koch Curve
This geometry starts with a straight line. This line is then again divided into three equal parts. The middle segment is substituted with two other segments of approximately same length. This is known as first iteration [5, 8].
III. APPLICATIONS OF FRACTAL ANTENNA

A large number of fractal antenna designs have been proposed. The purpose of this paper is to show various applications and remarkable growth of fractal antenna in the fields of wireless communication.

A. Fractal Antenna for UWB Devices

The presented antenna is an ultra wideband inscribed triangular circular antenna. This antenna has been designed for UWB devices. The antenna shows ultra bandwidth from 2.25 GHz to 15 GHz. These characteristics have been achieved by using CPW fed and fractal geometries. It is seen that the fourth iteration shows wideband characteristics which is suitable for designing UWB devices. The antenna is rested on FR4 substrate with dielectric constant 4.3. The thickness of substrate is 1.53mm with initial dimensions of 30mm diameter. In order to achieve UWB characteristics the gap between patch and ground is set to h= 0.4mm. The length of the ground plane is 28mm and the width is 25mm. The radiation patterns of the antenna are omni-directional in H plane and bidirectional in E plane. Fractal antenna is designed by using High Frequency Structure Simulator (HFSS) software. It is observed that wideband characteristics improve as the number of iterations increases. The antenna can be used for various military and commercial applications. The design of the antenna is shown in figure 5 [10, 11].

B. Fractal Antenna for Aerospace Navigation

The presented antenna is a square patch antenna based on Koch geometry. The antenna is designed for Aeronautical radio navigation. The antenna shows multiband behavior at 2.7-2.9GHz for aeronautical radio navigation and 9.0-9.3GHz for Maritime radio navigation. In this a square patch is taken whose design changes according to the variations in the fractal geometries. The material of the substrate is Roger RT/Duroid 5880™ having permittivity 2.2 and thickness 0.32cm. The dimensions of the substrate are A+2 cm Side Square. A coaxial cable is used as feed in the center of the patch. It is seen that the third iteration shows multiband nature used for aeronautical radio navigation. The antenna is designed using High Frequency Structure Simulator (HFSS) software. It is observed that as the number of iterations increases, perimeter of patch also increases and hence the effective area of antenna decreases. This antenna gives effective directivity than multiband antenna. This antenna can be used for various commercial applications. The design of the antenna is shown in figure 6 [12, 13].

C. Fractal Antenna for Wireless Power Transmission Systems

The presented antenna is a rectangular patch antenna that is iterated up to 3rd level. The antenna is designed for multiband applications and Wireless Power Transmission (WPT) System. The main application of WPT system is in Solar Power Satellites (SPS). The antenna resonates at four frequencies i.e., 1.86, 2.29, 3.02 and 4.05 GHz. The material of the substrate is FR4 with permittivity 4.4 and thickness h = 1.52mm. The length of the ground and the substrate is 54.36mm and width is 46.72mm. The length and width of the patch is 37mm and 28mm respectively. The final results of the antenna can be obtained from third iteration of microstrip patch antenna. The antenna is designed using High Frequency Structure Simulator (HFSS) software. The wideband characteristics increase as the number of iterations increases. The antenna can also be used for short range satellite applications. The design of the antenna is shown in figure 7 [14, 15].
IV. CONCLUSION
The present review paper exhibits the performance of microstrip patch antenna using various fractal geometries. In this paper, we have discussed various designs and applications of fractal patch antenna. From this paper we have concluded that Sierpinski Gasket shape is widely used because in this shape a single antenna can be operated on multiple frequencies. Here a square patch fractal antenna covers a large frequency band. The paper also provides a Literature Review table for different applications.

REFERENCES

TABLE 1: LITERATURE REVIEW TABLE

<table>
<thead>
<tr>
<th>S. No.</th>
<th>ANTENNA DESIGN</th>
<th>FREQUENCY BAND</th>
<th>RETURN LOSS</th>
<th>GAIN</th>
<th>APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Circular Patch Fractal Antenna</td>
<td>3.0 GHz, 4.275 GHz, 6.3 GHz, 10.2 GHz, 11.2 GHz</td>
<td>-15.5 db, -20.2 db, -20.4 db, -20.8 db, -25.5 db, -25 db</td>
<td>&gt;5 dbi</td>
<td>UWB Devices</td>
</tr>
<tr>
<td>2.</td>
<td>Square Patch Fractal Antenna</td>
<td>3.0 GHz, 0.74 GHz, 09.68 GHz, 11.21 GHz</td>
<td>-22.2 db, -18.7 db, -30.96 db, -23.5 db</td>
<td>12.02 db</td>
<td>Aeronautical radio navigation, Aeronautical/Maritime radio navigation</td>
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