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A Review on Fractal Antenna

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Abstract

Now days, there is highly demand of antenna with these characteristics (1) Compact size (2) Low profile and (3) Multiband or broad band. As well as it have to maintain antenna parameters (i.e. Gain, Efficiency, Return loss, Directivity etc.). With advancement in communication technology over the past decade, there is an increasing demand for miniaturization, cost effective, multiband and wideband antennas. Fractal antenna designs can support in meeting these requirements. Though these antennas provide several advantages but at the same time miniaturization and performance of the fractal antennas can be further enhanced using reconfiguration concept. Fractal antenna theory is built, as is the case with conventional antenna theory, on classic electromagnetic theory. Fractal antenna theory uses a modern (fractal) geometry that is a natural extension of Euclidian geometry. Fractal antenna have valuable application in cellular telephony and in microwave engineering .But as size of antenna decreases bandwidth support also decreases. New fractal geometry for microstrip antennas is presented in this paper. In this paper fractal antenna is designed using triangular Koch curve and Sierpinski gasket fractal geometries. In this work two designs of fractal antennas have been studied.

Keywords: *Fractral antenna, Sierpinski Gasket, iteration factor, Koch curve.*

I. Introduction

In the study of antennas, fractal antenna[1] theory is a new area in antenna design technology. The emergence of antennas with fractal geometries has given an answer to two of the main limitations stated by Werner (1999) of the classical antennas, which are the single band performance and the dependence between size and operating frequency. In the advance of wireless communication systems and Increasing importance to make small size and multiband application antennas a great demand for both commercial as well as military applications[5]. The concept of fractal antenna came from fractals existing in nature [6][10]. Fractal antenna is one such category that provides miniaturization and have multi-band characteristic. These are composed of multiple iterations of a single elementary shape and are used to describe a family of complex shapes that possess an inherent self-similarity and self-affinity in their geometrical structure. Dr. B Mandelbrot[6] invented the term fractal .Fractal represents broken or irregular fragments. He investigated the relationship between fractals and nature using finding made by Gaston Julia, Pierce Fatou and Felix Hausdoff[5]. 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.

A fractal is a rough or fragmented geometric shape that can be subdivided in parts, each of which is (at least approximately) a reduced-size copy of the whole. Fractals are generally self-similar and independent of scale. There are many mathematical structures that are fractals; e.g. Sierpinski's gasket[8], Cantor's comb, von Koch's[4] snowflake, the Mandelbrot set, the Lorenz attractor, et al. Fractals also describe many real-world objects, such as clouds, mountains, turbulence, and coastlines that do not correspond to simple geometric shapes. The terms fractal and fractal dimension are due to Mandelbrot, who is the person most often associated with the mathematics of fractals. The geometry of fractal antenna[10] can be defined and verified on the basis of iterative process and which is self symmetrical structure.

These can be categorized in two type: deterministic and random such as Sierpinski gasket[8] and the Von Koch Snowflake[3]. Random fractals also have element of randomness that permits the simulation of natural phenomena. Many fractals exist in nature and have various properties like recursive, infinite, space filling and self-symmetry. Recently, the antenna design Sierpinski triangle fractal antenna is created by iterating the initial triangle through a monopole antenna.

We need fractal antenna for following reasons:

1. They have broadband and multi-band frequency response
2. Compact size compared to conventional antennas.
3. Mechanical simplicity and robustness.
4. Characteristics of the fractal antennas are due to its geometry and not because of the addition of discrete components.

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5. Design to suit particular multi-frequency characteristics containing specified stop bands as well as specific multiple pass bands as required.

II. Fractal Geometries

Fractal was originally coined by French mathematician Mandelbrot[6] (1975) to describe a family of complex shapes that possess an inherent self-similarity or self-affinity in their geometrical structure. Jaggard (1990) defined fractal electrodynamics as an area in which fractal geometry[9] was combined with electromagnetic theory for the purpose of investigating a new class of radiation, propagation, and scattering problems. One of the most promising areas of fractal electrodynamics research is in its application to antenna theory and design. There are a variety of approaches that have been developed over the years, which can be utilized to achieve one or more of these design objectives. The development of fractal geometry came largely from an in depth study of the patterns of nature. A “fractal” is a geometrical shape that can be split into parts, each of which is a reduced size copy of the whole infinitely. Fractals are a class of shapes which have not characteristic size. Each fractal is composed of multiple iterations of a single shape. The iteration can continue infinitely, thus forming a shape within a finite boundary but of infinite length or area. The use of fractal geometries are used in many areas of science and engineering; one of which is antennas. Antennas use some of these geometries for various communication applications. The use of fractal geometries has been shown to improve several antenna features to varying extents. For reducing the size of antenna, fractal geometries have been introduced.

Fractal Geometries have the following features:

1. Self similarity
2. It is simple
3. Compact size by iteration
4. It forms irregular and fragmented shape

Fractal geometries have two common properties: Self-similar property, Space filling property[7]. The self similarity property of fractals gives results in a multiband behavior of an antenna. Using the self-similarity properties a fractal antenna can be designed to receive and transmit over a wide range of frequencies because it acts as a multiband. While using space filling properties, a fractal make reduce antenna size. Hilbert curve fractal geometry has a space filling property.

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Properties of Fractal Geometries:

1. Space Filling Properties: Space filling property is based on space filling curves.
2. Self-Similarity: A self-similar object is exactly or approximately similar to a part of itself.

Fractal Geometric Types: Fractal geometry involves a recursive generating methodology that results in contours with infinitely intricate fine structures. These geometries are modern discovery even though fractals in nature have been around forever. These are based on shapes being self similar. These are usually based on a building process that gets repeated and repeated.
There are two geometric types (as shown in Fig 2) for fractal defined:
Random: Random fractals are quite familiar and many look like random walks (Brownian motion); dendrites;or lightning bolts.
Deterministic (chaotic): They take a 'motif' or 'generator' and apply it on successive size scales.

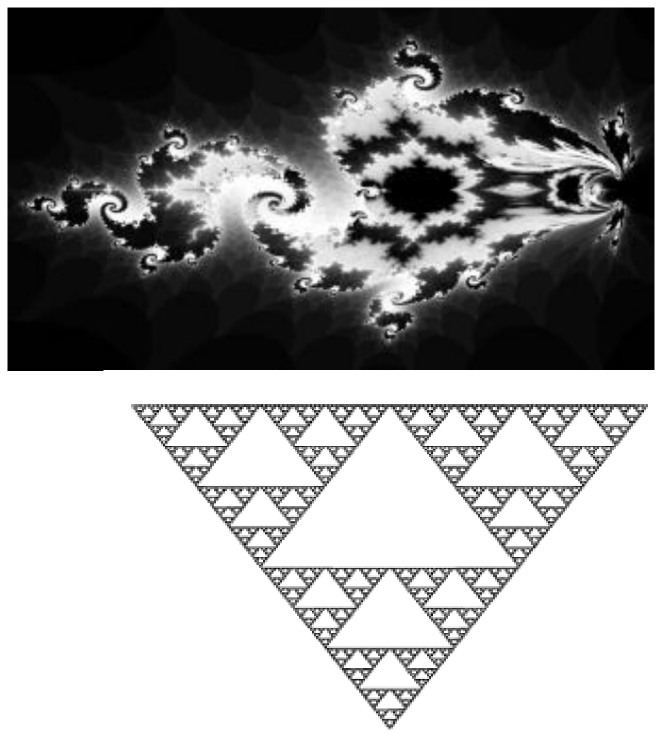
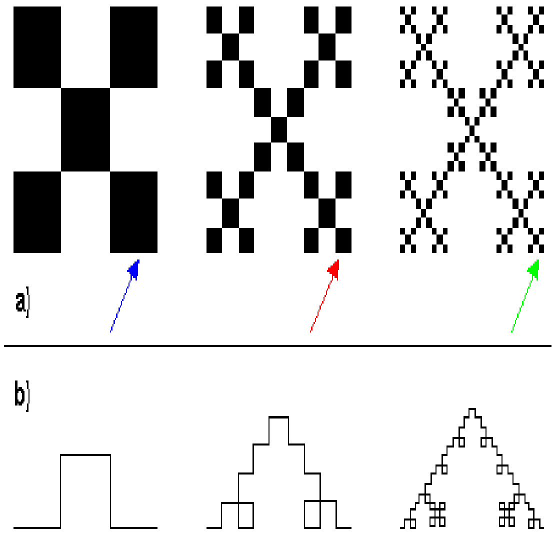
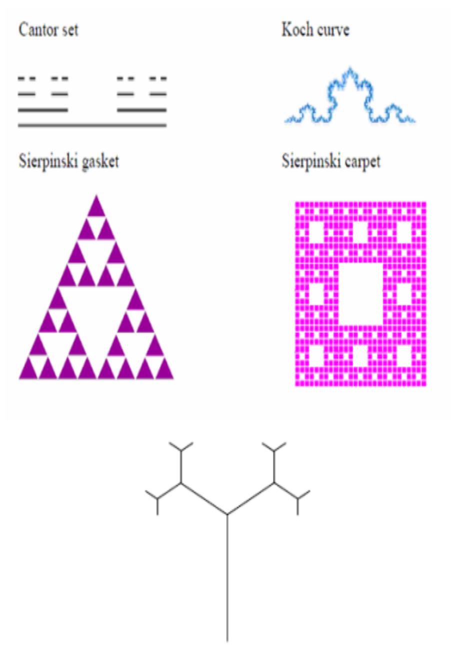


Figure 1: Random and deterministic fractals

Two examples of naturally occurring fractal geometries are snow-flakes[3] and boundary of geographic continents. Several naturally occurring phenomena such as lightning are better analyzed with the aid of fractals. One significant property of all these fractals is indeed their irregular nature. Some examples of fractals are given in Fig. 2. Most of these geometries are infinitely sub-divisible, with each division a copy of the parent. This special nature of these geometries has led to several interesting features uncommon with Euclidean geometry.



(a)



(b)

Figure 2: (a) and (b) Some common examples of Fractal Geometries

III. Fractal Shapes used as Antenna

There are many fractal shapes which can be used in antenna designing. The fractal shape gives iteration one by one, so by this property antenna size can be reduce. And by space filling property, the antenna size can be reducing also.

The commonly used fractal shapes are:

Sierpinski Gasket: Sierpinski gasket[8] geometry is the most widely studied fractal geometry for antenna applications. Sierpinski gaskets have been investigated extensively for monopole and dipole antenna configurations. The selfsimilar current distribution on these antennas is expected to cause its multi-band characteristics. Sierpinski gasket shape also used to make monopole and dipole antenna. Fig. 3(b) and Fig. 3(c) shows monopole antenna and dipole antenna respectively.

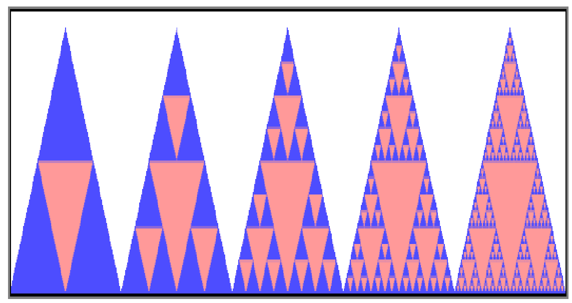


Figure 3: Sierpinski Gasket

Sierpinski Carpet: The Sierpinski carpet is constructed analogously to the Sierpinski gasket, but it use squares instead oftriangles. In order to start this type of fractal antenna, it begins with a square in the plane, and then divides it into nine smaller congruent squares where the open central square is dropped. The remaining eight squares are divided into nine smaller congruent squares which each central are dropped.

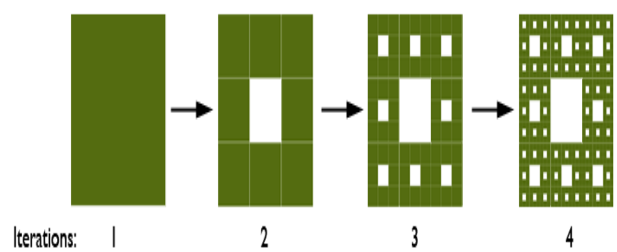


Figure 4: Sierpinski Carpet

Koch Curve: The geometric construction of the standard Koch curve is fairly simple. It starts with a straight line as an initiator. This is partitioned into three equal parts, and the segment at the middle is replaced with two others of the same length. This is the first iterated version of the geometry and is called the generator. The process is reused in the generation of higher iterations. By this fractal shape, we can construct monopole as well as dipole antenna. Fig. 5(B) and Fig. (C) Shows monopole and dipole respectively.

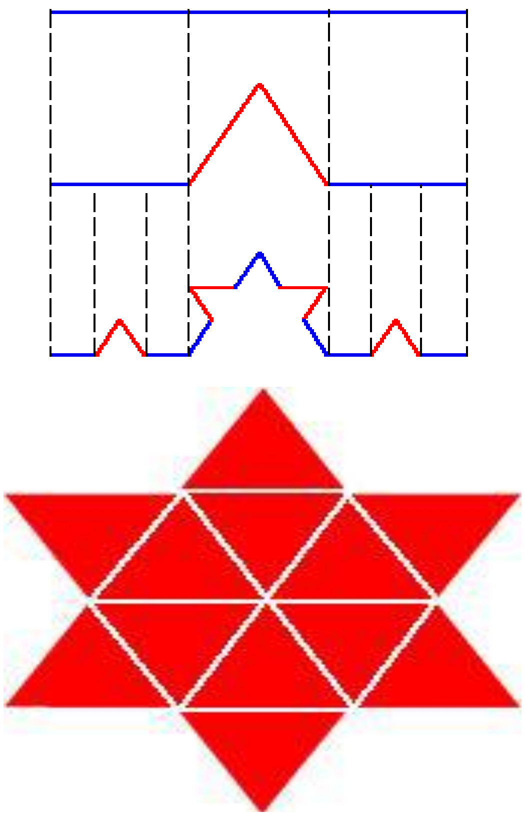


Figure 5: Koch Curve

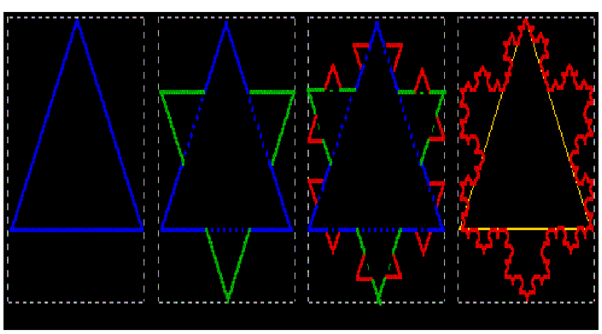


Figure 6: Steps for construction of the Koch curve geometry

Hilbert Curve: This geometry is a space-Filling curve, since with a larger iteration, one may think of it as trying to fill the area it occupies. Additionally the geometry also has the following properties: self-Avoidance (as the line segments do not intersect each other), simplicity (since the curve can be drawn with a single stroke of a pen) and self-similarity.

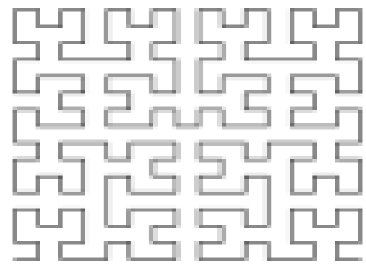


Figure 7: Hilbert Curve

IV. Merits and Demerits of Fractal Antenna

Merits

1 Small in size
2 Better input impedance
3 Wideband/multiband support (one antenna can be used instead of many)
4 Consistence performance over huge frequency range.
5 Added inductance and capacitance without components.

Demerits

1 Fabrication and design is little complicated.
2 Lower gain in some cases
3 Numerical limitations.
4 Performance starts to decrease after first little iteration.

V. Applications

1 In Building Communication: Fractal antenna provides universal wideband antenna technology that is ideal for in – building communication applications. Operating over 150MHz to 6GHz, fractal antennas deliver excellent Omni directional coverage in a compact form factor.
2 Wireless Networks: Fractal Antenna Systems provide excellent advanced antenna technology that enables emerging wireless protocols, such as

ZigBee[11], WiMAX and MIMO, to deliver their maximum potential.

3 Universal Tactic Communication: Future communications systems will use cognitive radios that require vast bandwidths, with one antenna.

4 Mobile Devices: From PDAs to cellular phones to mobile computing, today's wireless devices require compact, high performance multiband antennas. At the same time, packaging constraints demand that each component, especially the antenna, be inherently versatile.

5 Telematics: Today's automobile can have dozens of antennas that provide everything from emergency notification and navigational services to satellites radio and TV. Multiple antennas create performance and form factor challenges, as well as aesthetic design issues.

6 RFID[12] (Radio frequency identification): Fractal antenna system provides a compact, low cost solution for multitude of RFID applications. Because fractal antennas are small and versatile, they are ideal for more compact RFID equipment.

VI. Conclusion

Through characterizing the fractal geometries and the performance of the antennas, it can be summarized that increasing the fractal dimension of the antenna leads to a higher degree of miniaturization. Also it is possible to use fractal structure to design small size, low profile, and low weight antennas. Applications of fractal geometry are increasing in the fields of science and engineering. This overview of fractal antenna presented a comprehensive overview of the research area we call fractal antenna engineering. Triangular Koch Curve antenna geometry shows multiband behavior thus it can be used as multiband antenna while the Sierpinski gasket design, after iteration resonates at single frequency. We can reduce the size of antenna and as well as get the better performance by fractal antenna engineering.

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