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An Overview of Fractal Geometries and 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.). In development of antenna design, the size reduction of antenna is becoming important consideration. Here we introduce the compact size as well as multiband antenna "The Fractal Antenna" which meet up with all ideal characteristics of an antenna (i.e. Directivity, Gain, Efficiency, Return loss, etc.) In this paper we introduce the types of fractal geometries, how it can be use to make an antenna and fractal geometries' iteration functions which reduce the size of an antenna by next to next iterations.*

I. INTRODUCTION

In the study of antennas, fractal antenna theory is a new area in antenna design technology. 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 [1]. Multiband and wideband antennas are compatible with personal communication systems, small satellite communication systems and other wireless applications. The development of an antenna with the using of fractal concepts reduces the antenna size without reducing the performance [2]. The fractal geometries have two common properties: (1) space filling and (2) self similarity [2]. The self similarity property of fractal shapes is used to design of multiband fractal antennas [3]. In literature review, we have found advantages of the fractal geometries which are compact in size, and multi-band frequency operations. Recently, the antenna design Sierpinski triangle fractal antenna is created by iterating the initial triangle through a monopole antenna.

II. FRACTAL GEOMETRIES

The term 'fractal' was found by the French mathematician B.B. Mandelbrot in 1970. 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. [4] 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. 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. [4]
Fractal divided in many types, Fig. 1 and Fig. 2 shows some examples.

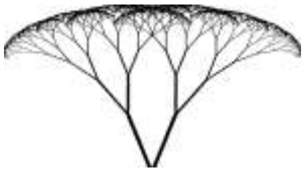


Figure 1. Fractal Tree Figure 2. Fractal leaf (Fern)

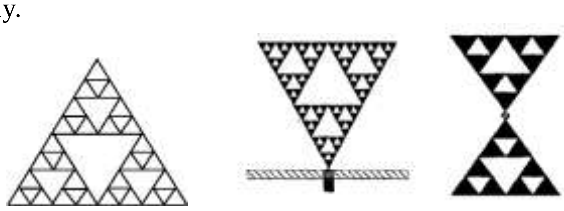
III. FRACTAL SHAPES USED AS ANTENNA

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. [5]

The commonly used fractal shapes are:

3.1 *Sierpinski* Gasket

Sierpinski gasket geometry is the most widely studied fractal geometry for antenna applications. Sierpinski gaskets have been investigated extensively for monopole and dipole antenna configurations. The self-similar 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.



(a) (b) (c)

Figure 3. (a) Sierpinski gasket (b) Sierpinski monopole (c) Sierpinski dipole

3.2 Sierpinski Carpet

The Sierpinski carpet is constructed analogously to the Sierpinski gasket, but it use squares instead of triangles. 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.

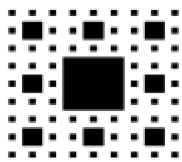


Figure.4. Sierpinski Carpet

3.3 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.

(a) (b) (c)

Figure 5. (a) Koch Curve (b) Koch curve Monopole (c) Koch curve Dipole

3.4 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.

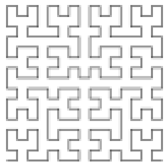


Figure 6. Hilbert Curve

From all above fractal shape, the sierpisnki gasket shape is widely used to make an antenna. Because it acts as a multi band, so we don't have to accommodate more than one antenna for multiple frequencies.

IV. Sierpinski Tirangle Iteration Function

We can formalize the construction of the Sierpinski triangle by using iterated function systems. If K is the Sierpinski triangle, then it is made up of 3 smaller copies of itself.

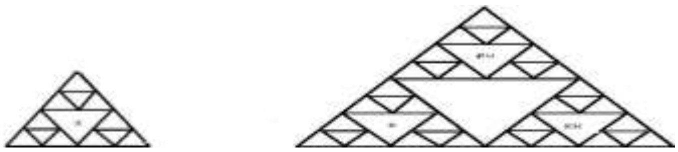


Figure 7. (a) Sierpinski triange K (b) Sierpinski triangle With Iteration

By putting the triangle in the coordinate plane, giving the base length 1 and setting the height equal to 1, we see the lower left triangle

$$KU = \frac{1}{2}K \tag{1}$$

Then, the lower right Klr and upper Ku triangles can be defined similarly as

$$Klr = \frac{1}{2}K + \left(\frac{1}{2}, 0\right) \tag{2}$$

$$Ku = \frac{1}{2}K + \left(\frac{1}{4}, \frac{1}{2}\right) \tag{3}$$

The union $KU \cup Klr \cup Ku$ of these three scaled copies of K again gives K. If we had started with a solid triangle, then by repeatedly applying these transformations infinitely many times, we would recover the Sierpinski Triangle. The fractal then is the fixed point set of this transformation.

This procedure can be generalized to allow all plane transformations, which are combinations of the following:

1. Scaling - Changing the dimensions of K by a fixed scale factor.
2. Reaction - Taking the mirror image of K across a line.
3. Rotation - Rotating K through some angle.
4. Translation - Shifting K left, right, up, down, or some combination, in the plane.

If T is a plane transformation, then we call it a contraction if the scale factor is less than 1. An iterated function system is given by a collection of contractions T1, T2,……, Tn. If K is some object in the plane, let

$$K1 = T1(K) \cup T2(K) \cup ... \cup Tn(K) \tag{4}$$

We can further define Km iteratively as the union of Ti (Km-1). The limit set for the Km as m goes to infinitely will be a fractal and the fractal will be invariant under this procedure. That is, by applying the Ti to the fractal and taking the union, we will again obtain the fractal. [6]

V. Applications Of The Fractal Antenna

There are many applications of the fractal antennas. Fractal antennas can make a real impact. The recent growth in the wireless communication needs the compact integrated antennas. So the fractals antenna has efficiently to fill a limited amount of space. Examples of these types of application include personal hand-held wireless devices such as cell phones and other wireless mobile devices such as laptops on wireless LANs and network able PDAs. Fractal antennas can also have applications that include multiband transmissions. Fractal antennas also decrease the area of a resonant antenna, which could lower the radar cross-section. This benefit can be used in military applications.

VI. Advantages And Disadvantages Of Fractal Antenna

Advantages of fractal antenna

1. Wideband or multiband- we can use one antenna instead of many antennas.
2. Miniaturization techniques.
3. We can get good input impedance matching.
4. It can operate in huge frequency.

Disadvantages of fractal Antenna:

1. Loss in the Gain.
2. It has numerical limitation.
3. It is very complex.
4. After few more iterations, it degrades the antenna parameters.

VII. Conclusion

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. By fractal antenna engineering, we can make the evolution in the antenna designing. We can reduce the size of antenna and as well as get the better performance by fractal antenna engineering.

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