A Study of Various Fractal Antenna Design Techniques for New Generation Wireless Network

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Abstract: The purpose of this paper is to introduce the concept of fractals and its use in antenna arrays for obtaining multiband property. Fractal antennas are presented in this paper which can be useful for next generation wireless network application. It is found that increase in number of fractal iterations, number of resonant frequencies also increase .further ,this paper focuses on unique features of fractal geometries along with its application in different fields .It will be shown that how to quantify the space –filling ability of fractal geometries, and how this correlates with miniaturization.

Keywords: Fractals; antenna arrays; antenna theory; antenna radiation patterns.

I. INTRODUCTION

In our modern society people need to be in touch with the world, for that technology is being developed in such way that anyone can communicate or be informed about everything just by using a small handset cellular device. This equipment needs to operate in a wide range of frequencies, allowing people to connect to the WEB (standards 802.11a, 802.11b or 802.11g), make phone calls (GSM), video conferences (UMTS) and other utilities. All these technologies operate in different frequencies demanding a high efficient multi-band antenna with a very compact size. Fractal geometry antennas may help answer these requirements.

The main problem of common antennas is that they only operate at one or two frequencies, restricting the number of bands that equipment is capable of supporting. Another issue is the size of a common antenna. Due to the very strict space that a handset has, setting up more than one antenna is very difficult. To help these problems, the use of fractal shaped antennas is being studied [1].

II. BACKGROUND

A fractal is a rough or fragmented geometric shape that can be subdivided in parts, each of which is a reduced – size copy of whole. There are many mathematical structures that are fractal; e.g. Sierpinski gasket, Cantor's comb, Koch curves.

Why fractal as antenna elements?

When antenna elements or array are designed with the concept of self similarity for most fractal, they can achieve multiple frequency bands because different parts of antenna are similar to each other at different scales. Application of the fractional dimension of fractal structure leads to the gain optimization of wire antenna and the self –similarity make it possible to design antenna with very wide-band performance.

a) Fractal as Space-filling Geometries

A fractal is mathematically defined to be infinite in intricacy, this is not desirable if antenna are to be fabricated using these geometries. For example, the complexity and repetition of a cloud does not extend to infinitely small or large scale ,but can be approximated as doing so for a certain band of scales. The Hilbert curve is an example of a space- filling fractal curve that is self voiding .The first four steps in the construction of the Hilbert curve are shown in Figure. 1.

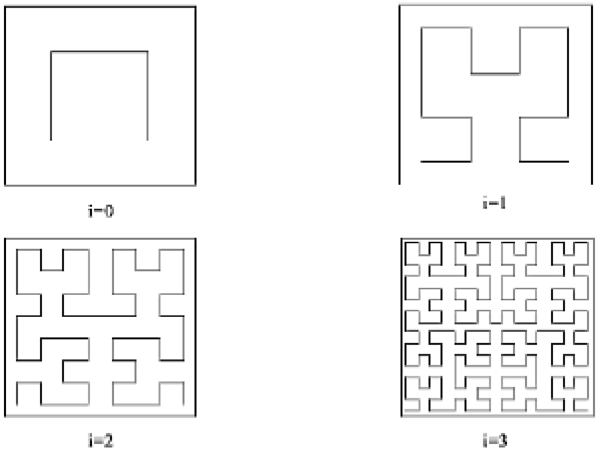

Figure 1.Generation of four iterations of Hilbert curves [4]

b) Fractals as Miniaturized Antennas

Fractal can fill the space occupied by the antenna in a more effective manner than the traditional Euclidean antenna .This leads to more effective coupling of energy from feeding transmission lines to free space in less volume. Fractal loop and fractal dipole antennas, fractals effectively fills the space and because of fractal dimension allows antenna miniaturization. Fractal antennas do not to be limited to only wire antennas.

c) Fractals as Multiband Antennas

Fractal antennas show multiband or log periodic behavior that has been attributed to self similar scale factor of the antenna geometry. In order to enable more operating bands within lower spectrum, a higher scaling factor is required. Fractal antenna represents a class of electromagnetic radiators where the overall structure is comprised of a series of repetition of a single geometry and where repetition is at different scale.

III. FRACTAL GEOMETRY

1. Sierpinski Carpet

The Sierpinski carpet [2] is constructed similar 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 [3].

Figure 2: Sierpinski Carpet Fractal [3]

2. Koch Curves

The geometric construction of the standard Koch curve [4] 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 [2].

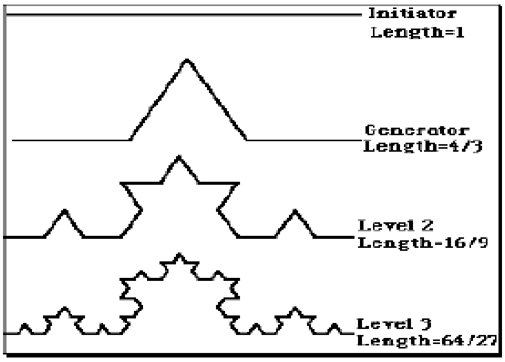

Figure 3: Koch Curve Fractal [4]

3. Sierpinski Gasket Geometry

Sierpinski gasket geometry [5] is the most widely studied fractal geometry for antenna applications. The steps for constructing this fractal are described.1st a triangle is taken in a plane. Then in next step a central triangle is removed with vertices that are located at the midpoint of the sides of the triangle as shown in the figure. The process is then repeated for remaining triangles as shown in figure. The Sierpinski gasket fractal is formed by doing this iterative process infinite number of times. Black triangular areas represent a metallic conductor and the white triangular areas represent the region from where metals are removed

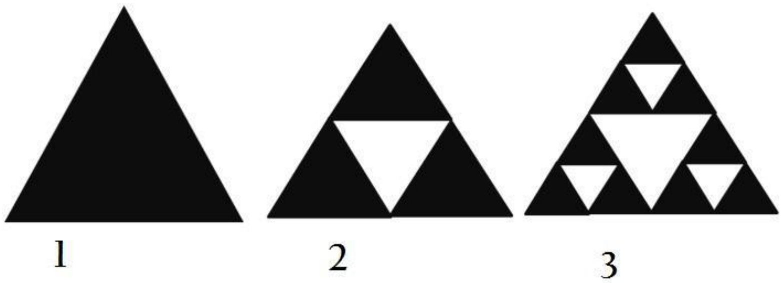

Figure 4: Sierpinski Gasket Fractal [5]

Table 1: Summary of Various Antenna Designs with Their Pros and Cons

S.No	Antenna Design	Frequency Band	Gain & Radiation Pattern	Application
1	**Square Carpet Fractal Antenna**	2.7-2.9 GHz 9.0-9.3 GHz	6.44- 12.02 (dB) Broadside pattern	Aeronautical radio navigation Aeronautical/Maritime radio navigation
2	**Koch Fractal Antenna**	IEEE 802.11 standard (2.41 to 2.49 GHz, 5.15 to 5.35 GHz and 5.725 to 5.825 GHz)	2.281 dBi - 3.85 dBi Omni directional pattern	Capable of covering the entire band of WLAN IEEE 802.11 a/b/g Standard. Designed for WLAN USB dongle.
3	**Sierpinski Fractal Antenna**	2.4 and 5.2 GHz ISM bands	3.0 – 5.9 (db) Omni directional	WLAN / Bluetooth systems application

IV. APPLICATIONS OF FRACTAL ANTENNAS

There are many applications that can benefit from fractal antennas. Discussed below are several ideas where fractal antennas can make an real impact. The sudden grow in the wireless communication area has sprung a need for compact integrated antennas. The space saving abilities of fractals to efficiently fill a limited amount of space create distinct advantage of using integrated fractal antennas over Euclidean geometry. Examples of these types of applications include personal hand-held wireless devices such as cell phones and other wireless mobile devices such as laptops on wireless LANs and networkable PDAs. Fractal antennas can also enrich applications that include multiband transmissions. This area has many possibilities ranging from dual-mode phones to devices integrating communication and location services such as GPS, the global positioning satellites. Fractal antennas also decrease the area of a resonant antenna, which could lower the radar cross-section (RCS). This benefit can be exploited in military applications where

V. ADVANTAGES AND DISADVANTAGES

Advantages of fractal

- minituratization
- better input impedance matching
- wideband/multiband (use one antenna instead of many)
- frequency independent (consistent performance over huge frequency range)
- reduced mutual coupling in fractal array

Disadvantages of fractal antenna

- gain loss
- complexity
- numerical limitations
- the benefit begin to diminish after first few iterations

VI. CONCLUSION

The basic theory of Fractal Antenna along with iteration has been discussed. From this we conclude that there are many Fractal techniques that used to design an antenna for wireless applications, each one has its own pros and cons. These approaches considered the different attributes related to performance parameters of an antenna such as; wide bandwidth, low VSWR, high gain, high radiation efficiency and small size etc. This paper also exposed a performance comparison table of different technique that was proposed earlier for wireless applications such as; Wireless video operation, WLAN USB dongle, Aeronautical radio navigation, Aeronautical/Maritime radio navigation, Bluetooth systems application. This antenna found application in next generation wireless network communication.

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