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Overview of Fractal Tree Antenna for Wireless Application

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Abstract: *A fractal antenna [1] can be designed to receive and transmit over a wide range of frequencies. A fractal is a fragmented geometric shape that can be subdivided in parts, each of which is (at least approximately) a reduced-size copy of the whole. This property is called as self similarity. The fractals have second property that is the efficiency of space filling. The space filling nature of fractal antenna lead to significant reduction in antenna size, comparatively to that of classic antennas. shrinking the size of an antenna through the use of fractals result in miniaturized antenna design. A promising fractal geometry that ensures a successful design of multiband antenna is known as the fractal tree. A new design of fractal antenna for wireless application is proposed.*

Keywords: *Fractal antenna, fractal geometry, multiband, miniaturization, iteration.*

1. Introduction

The classic wired and patch antenna are intrinsically a narrow band devices. Their behavior is strongly dependent on the size of an antenna for working wavelength. As the antenna size changes, it will result in frequency disagreement. And hence gain and radiation pattern will be affected. So Fractal antennas can be used to find the best distribution of current within a given volume in order to meet a particular design goal . There are several advantages as in [2] of these fractal devices including reduction of resonant frequencies, smaller size and broadband width as well as low profile, low weight, conformal to the surface of objects and they have easy production. Hence aim is to design antenna which is compact in size and simple and which will provide the mentioned advantages.

2. Fractals as Antenna

B. Mandelbrot described fractal geometry in 1975. He did it with an iterative procedure. As fractals have property of space filling, now a days they have been widely used in antenna designs to obtain various kinds of small and multiband antenna. Tree-shaped fractal antennas have been broadly investigated in recent years. Fractal antennas are mainly divided [2] into four parts: fractal line antennas, fractal three dimensional antennas, fractal planar antennas and fractal antenna arrays. Tree-shaped fractal antennas are mainly researched as fractal three dimensional antennas or fractal planar antennas. Fractal tree antennas provide following advantages [3].

- Miniaturization
- Better input impedance matching
- Wideband/multiband(use one antenna instead of many)
- Frequency independent (consistent performance over huge frequency range)

Fractal antennas can be made in different shapes such as square, rectangle, triangle, elliptic, etc. In comparison to patch elements; the antennas with slot configurations demonstrate enhanced characteristics, including wider bandwidth, less conductor loss and better isolation. Particularly the multi-slot structure is a versatile approach for multi-band and broadband design.

Fractal antennas are multi-resonant and smaller in size. Qualitatively, multi-band characteristics have been associated with the self-similarity of the geometry. Research towards quantitative relation between antenna properties and fractal parameters is going on extensively. Any variation of fractal parameters has direct impact on the primary resonant frequency of the antenna, its input resistance at this frequency, and the ratio of the first two resonant frequencies. In other words, these antenna features can be quantitatively linked to the fractal dimension of the geometry. This finding can lead to increased flexibility in designing antennas using these geometries. 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. The fractal antenna can be an excellent design for wideband and multi-band applications[5].

Various fractal shapes are as below:

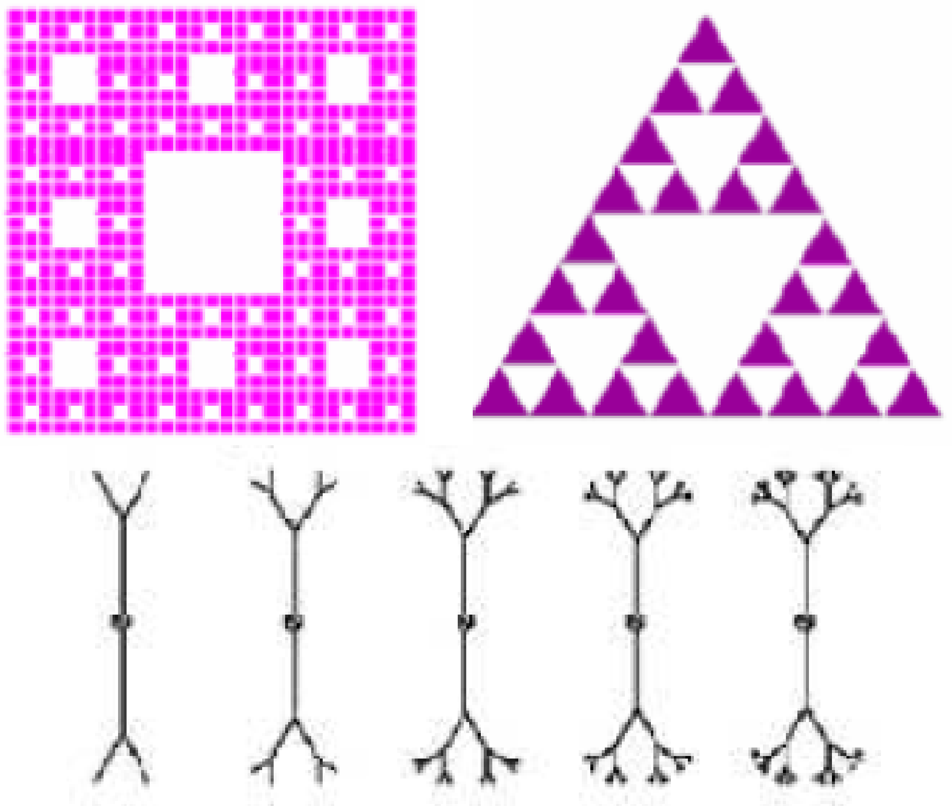

Fig1. *Various Types of Fractals Used As Antenna*

2.1. Fractal Geometry- Pythagorean Tree

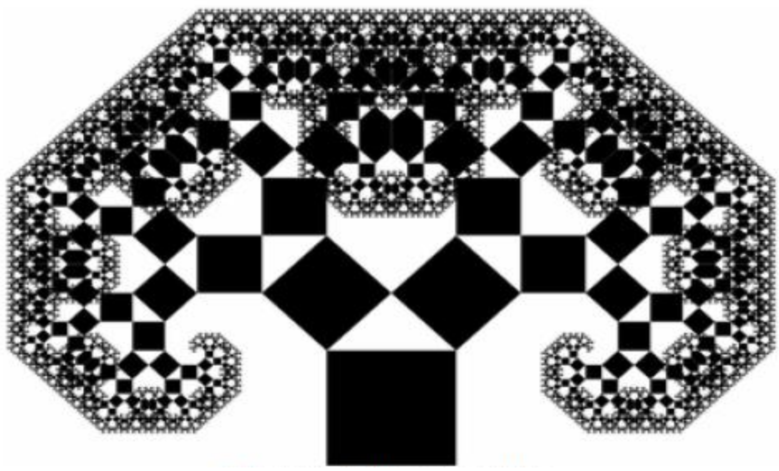

Fig 2: Pythagorean tree

The Pythagorean tree is a plane fractal constructed from squares. It is named as Pythagoras because each triple of touching squares encloses a right triangle, in configuration traditionally used to depict the Pythagorean Theorem.

3. Fractal Tree Antenna

The initial segment is divided by a scale factor, moved at an angle and placed at the top of the initial segment. The same pattern is repeated to construct the tree of any order.After some order, depending on the scale factor and angle, the branches start overlapping each other. This makes the antenna so that it has many different resonances which can be chosen and adjusted by choosing the proper fractal design. Here different variable parameters of the fractal are the size of the initial segment, scale factor, branching angle and number of iterations. Increasing the number of segments may increase the coupling between branches. Size of the first segment determines the one of the resonant frequency of the antenna. Scale factors may decide the ratio between the successive resonant frequencies. The branching angle also affects the coupling. However it does not affect the ratio of resonant frequency if the lengths and widths of the branches are not dependent on the angle. [9] Fractal geometry are generated in an iterative fashion, leading to self structure .The tree geometry start with a stem allow one of its ends to branch off in two directions .In the next stage of iteration ,each of these branches allowed to branch off again. The process is continued endlessly as shown in fig.3

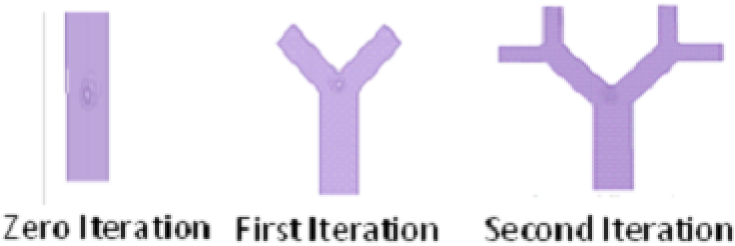

Fig3. *Process of making fractal tree antenna*

It is possible to vary the scale factor between the length of the stem and branches. The transformations required to obtain branches of the geometry in such case may be expressed as follows by equations,

$$W1\begin{pmatrix}x\\y\end{pmatrix} = \begin{bmatrix}\frac{1}{s}cos\theta & -\frac{1}{s}sin\theta\\ \frac{1}{s}sin\theta & \frac{1}{s}cos\theta\end{bmatrix}\begin{pmatrix}x\\y\end{pmatrix} + \begin{pmatrix}0\\1\end{pmatrix}$$

$$W2\begin{pmatrix}x\\y\end{pmatrix} = \begin{bmatrix}\frac{1}{s}cos\theta & \frac{1}{s}sin\theta\\ \frac{1}{s}sin\theta & \frac{1}{s}cos\theta\end{bmatrix}\begin{pmatrix}x\\y\end{pmatrix} + \begin{pmatrix}0\\1\end{pmatrix}$$

Where

S = scale factor

θ = Branching half angle

As the scale is changed, the fractal dimension is also changed. Length ratio x:1 between branches and the stem, the following expression may be satisfied for the fractal dimension.

$$\left(\frac{1}{1+x}\right)^{D} + 2\left(\frac{1}{1+x}\right)^{D} = 1$$

3.1. Wideband Fractal Antenna

It is intuitive that the self similarity property of fractals will result in multiple resonances. The multiple resonances can be converted into wide band characteristics by bringing the resonance frequencies closer and letting the bands overlap. If the fractal parameters are controlled properly, this can be achieved. In general, for any antenna to have wide band characteristics, the parameters discussed below have to be taken into account. The impedance bandwidth of a micro strip antenna can be determined from frequency response of its equivalent circuit. For parallel-type resonance,

The half power bandwidth for parallel type resonance is given by

$$\mathrm{BW} = \frac{2G}{W0\ \frac{dB}{dW}}$$

Where Y=G+jB is the input impedance at resonance frequency.

$$\mathrm{BW} = \frac{VSWR-1}{Q\sqrt{VSWR}}$$

Where Q is the quality factor of the structure.

As Q decreases, bandwidth increases.

4. Antenna Design

Because of their geometric complexity, it difficult to predict mathematically the fractal antenna radiation pattern properties. The wide availability of the powerful electromagnetic simulator makes possible of such problems, which would be otherwise impossible to solve. A first step in the utilization of fractal properties in antenna design should involve the dimension of the geometry. Many numerical methods are available that predict the performances of such antennas. All these techniques are based on solving a discrete form of Maxwell's equations. The most often used are the method of moments (MoM) and the Finite Difference Time Domain (FDTD) method. There exists many softwares such as IE3D, HFSS, Fidelity, CST, Feko, EMPro, SIMetric, SuperNEC etc. for the simulation of the RF component designs.

5. Conclusion

In today world of wireless communications, there has been an increasing need for more compact and portable communications systems.Fractal antennas can be implemented. to minimize the antenna size while keeping high radiation efficiency. The unique properties of fractals have been exploited to develop a new class of antenna element designs to possess several highly desirable properties, including multiband performance, low side lobe levels.Fractal antennas have scope in different areas.Examples of application include personal hand-held wireless devices such as cell phones and other wireless mobile devices such as laptops. Fractal antennas have scope in wireless LAN, GSM, PCS, wireless vehicular communication..

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