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Design & Simulation of Fractal Microstrip Antenna for Satellite Communication

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Abstract: This paper presents the Koch fractal with bow tie patch antenna with microstrip feed is proposed. This proposed antenna has been developed with patch dimension 2mm x 5mm (WxL). Copper has been preferred as a conducting material for patch and ground. FR4 and silicon dioxide substrate material has been used. The operating frequency range is 4GHz – 8GHz. This antenna finds application for defense and secure communication, C band (4GHz – 8GHz) applications where antenna can be used for satellite communication and Radar communication. ADS software is used to design the proposed antenna.

Keywords: Koch Curve, Bow Tie Antenna, ADS (Advanced Design System)

1. Introduction

With the huge advancement in wireless communication systems and increasing its applications, multiband antenna with various shapes and design have become a great demand and desirable for various wireless applications, which gives raise to different shapes and types of antenna for the variations in antenna characteristic. There are different shapes and types of antennas designed for the variations in antenna characteristics. There are various shapes such as sierpinski, gasket, minskowsi, Hilbert curve; Koch curve, tree structure, etc are considered for the design of Fractal technique has got numerous applications in the field of science which includes fractal electro dynamics where the fractal concepts are combined with electromagnetic theory. Fractal antenna engineering focuses on two areas one is the design and analysis of fractal elements and other concerns to the application of the fractal theory to the design of antenna arrays. Both the antenna types are highly desired in various commercial and military sectors. Most of the fractal antenna elements possess compact size, low profile, cost effective, multi-band operations, easy feeding and their shape can be modified for better optimization. The fractal geometries feature two properties self-similarity and space filling properties. Both these properties become a reason attractive to consider fractal geometry. Similarity of antenna holds the duplication of itself at several scales and can operate at several wavelengths in similar fashion, which reduces the antenna size and occupies lesser space. The space filling property fill the area occupied by the fractal antenna as the number of iteration is increased. Higher the order of fractal antenna, lesser the antenna size. This reason makes the fractal antennas compact, multiband and use full for cellular applications and microwave applications.

In this paper I shaped fractal antenna is considered. This antenna finds applications for defense and secures communication, C band (4 GHz to 8 GHz) and X band (8 GHz to 12 GHz) applications where antenna can be used for satellite communication and RADAR application The length and width of the patch antenna are calculated by the following equations [4]. Where c is the velocity of light and εr dielectric constant of the substrate. In this context, the use of fractals in antenna array synthesis and fractal shaped antenna elements have been studied. Obtaining special antenna characteristics by using a fractal distribution of elements is the main objective of the study on fractal antenna arrays. It is widely known that properties of antenna arrays are determined by their distribution rather than the properties of individual elements. Since the array spacing (distance between elements) depends on the frequency of operation, most of the conventional antenna array designs are band-limited. Self-similar arrays have frequency independent multi-band characteristics. Fractal and random fractal arrays have been found to have several novel features. Variation in fractal dimension of the array distribution has been found to have effects on radiation characteristics of such antenna arrays. The use of Random fractals reduce the fractal dimension, which leads to a better control of side lobes. Synthesizing fractal radiation patterns has also been explored. It has been found that the current distribution on the array affects the fractal dimension of the radiation pattern. It may be concluded that fractal properties such as self-similarity and dimension play a key role in the design of such arrays.

2. Fractal Antennas

Since fractals show up in the real world of nature (snail shells, leaves on a tree, pine cones), why not see if they perform well as antennas? It turns out that if you make antennas with fractal shapes, they will radiate, and often have multiband properties. A Koch curve is generated by replacing the middle third of each straight section with a bent section of wire that spans the original third. Each iterations adds length to the total curve which results in a total length that is 4/3 the original geometry:

$$\text{Lenght}_{Koch} = h \cdot (\frac{4}{3})^n$$

The miniaturization of the fractal antenna is exhibited by scaling each iteration to be resonant at the same frequency. The miniaturization of the antennas shows a greater degree of effectiveness for the first several iterations. The amount of scaling that is required for each iteration diminishes as the number of iterations increase. The total length of the fractals at resonance is increasing, while the height reduction is reaching an asymptote. Therefore, it can be concluded that itcan be increased complexity of the higher iterations are not advantageous. The miniaturization benefits are achieved in the first several iterations.

Advantages and Disadvantages The various advantages of fractal antennas can be listed as: Smaller cross sectional area No impedance matching network required Multiple resonances Higher gain in some cases Though in the early stage of their development these antenna designs suffer form two man disadvantages. These are: Fabrication and design is little complicated Lower gain in some cases Further investigations and new developments in this field may be helpful in overcoming these disadvantages.

Fractal Antennas- Koch Fractal

Fractals are a class of shapes which have no characteristic size. Each fractal is composed of multiple iterations of a single elementary shape. The iterations can continue infinitely, thus forming a shape within a finite boundary but of infinite length or area. This compactness property is highly desirable in mobile wireless communication applications because smaller receivers could be produced. The expected benefit of using a fractal as a dipole antenna is to miniaturize the total height of the antenna at resonance, where resonance means having no imaginary component in the input impedance. KOCH LOOP The starting pattern for the Koch loop that is used as a fractal antenna is a triangle. From this starting pattern, every segment of the starting pattern is replaced by the generators. The first four iterations are shown in Fig. 5. The starting pattern is Euclidan and, therefore, the process of replacing the segment with the generator constitutes the first iteration.

3. Patch Antenna Design

1. Calculation of width: The width of the microstrip patch antenna is given by the equation as,

$$W = \frac{C}{2f\left[\frac{\varepsilon r+1}{2}\right]^{\frac{1}{2}}}$$

2. Calculation of effective dielectric constants

$$\varepsilon_{reff} = \left(\frac{\varepsilon_{r+1}}{2}\right) + \left(\frac{\varepsilon_{r-1}}{2}\right)\left[1 + {}^{10h}/_{w}\right]^{\frac{1}{2}}$$

3. Calculation of effective length:

$$L_{eff} = \frac{c}{2f_{o(\varepsilon_{reff})^{\frac{1}{2}}}}$$

4. Calculation of length extension:

$$\frac{\Delta l}{h} = 0.412\frac{\left(\varepsilon_{reff} + 0.300\right)\left(\frac{W}{h} + 0.262\right)}{\left(\varepsilon_{reff-0.258}\right)\left(\frac{W}{h} + 0.813\right)}$$

5. Calculation of actual lenth of the patch:

$$L = L_{eff} - 2\Delta L$$

6. Calculation of ground plane dimensions (L_g andW_g): Ideally the ground plane is assumed to be infinite size in length and width but practically it is impossible to make such infinite size ground plane. So to calculate the length and width dimensions of the ground plane following equations are used.

$$L_g = L + 6h, W_g = W + 6h$$

4. Geometry of Koch Snowflake

The Koch Curve is mathematical curve and is a mathematical curve. The construcation of the Koch fractal starts with a straight segment having length L (Intiator), then this line segment is divided into three parts of the equal length i.e. L/3 each. And next middle segment is replaced with two segments of the same length, with 60degree as a angle of triangle. This is called Generator and is the first iterated version of geometry by using this process further higher iteration are generated.

Design of Basic Triangular Patch

Here ADS 2011 software is used to design koch curve antenna. The Koch snowflake is constructed first by starting with a simple equilater triangular patch as shown in Fig. 1.

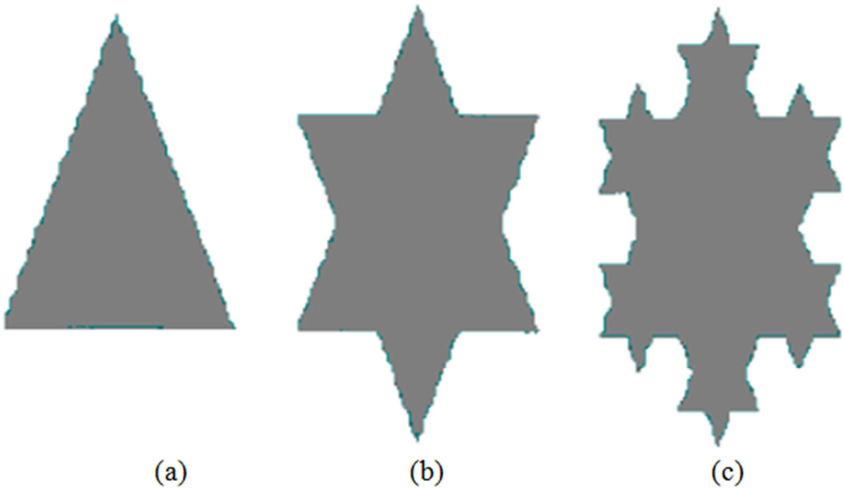

Figure 2. *Basic Steps Construction of Koch snowflake fractal (a) Basic triangular patch (b) 1st iteration (b) 2nd iteration.*

For the design of triangular patch antenna there are 3 important parameter i.e. resonant freq(fr), Dielectric material of the substrate, and the thickness of the substrate. The FR4 and silicon dioxide materials selected for this design.

The fundamental model resonant frequency of such antenna is given as follows

Where,

C-speed of light

Er – Relative permittivity of substrate

The patch side length(a) of triangle is given as follows:

5. Design Methodology

The design is carried out by the ADS tool. Design is carried out by FR4 and silicon dioxide substrate materials with ε_r=4.4 and ε_r=3.9 and thickness of substrate as 25mm and overall the dimensions of patch is

(2mmx5mm). Figure 3 is shown basic structure of Koch fractal antenna design. Figure 4 is basic Koch fractal antenna with bowtie. Figure 5 shows Koch fractal antenna with bowtie using microstrip feed method

(1) Basic Koch fractal antenna

Figure 3. *Design of Koch fractal antennas.*

(2) Koch snow flake fractal with bowtie antenna

Figure 4. *Design of Koch fractal with bowtie antenna.*

(3) Koch fractal patch bow tie antenna with microstrip feed

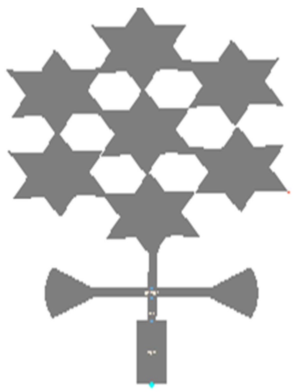

Figure 5. *Koch fractal patch bow tie antenna with feed.*

6. Simulation Results

Koch fractal patch bow tie antenna with microstrip feed are using two types of substrate

(1) FR4

(2) Silicon Dioxide

Return Loss

In telecommunications, return loss is the loss of power in the signal returned/reflected by a discontinuity in a transmission line or optical fiber. This discontinuity can be a mismatch with the terminating load or with a device inserted in the line. The return loss for Koch fractal patch array antenna using FR4 substrate with microstrip feed is -16dB at frequency 2.2GHZ. silicon dioxide substrate with microstrip feed is -16dB at frequency 5.5GHZ.

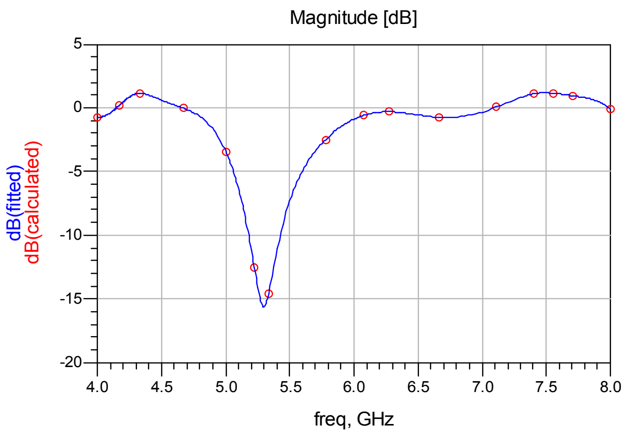

Figure 6. *FR4 material Return loss.*

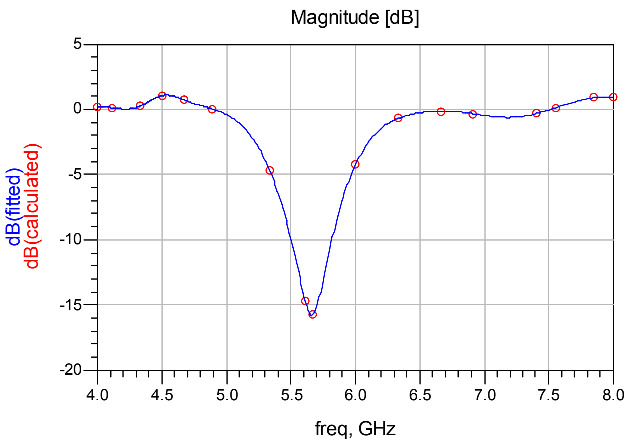

Figure 7. *Silicon Dioxide material Return loss.*

Table 1. *Comparison table of dielectric material performance.*

Parameter	FR4 material	Silicon dioxide material
Resonance frequency	5.3 GHz	5.6 GHz
Return loss	-16 dB	-16 dB
Gain(dBi)	7 dB	9 dB
Directivity	68 dB	79 dB
Efficiency(dB)	73	99

7. Conclusion

The Koch fractal patch antenna arrays are designed and simulated at 4GHz to 8GHz. The Koch fractal with bowtie patch antenna using microstrip feed with various substrates FR4 and Silicon Dioxide are analyzed from the analysis array antenna with FR4 and Silicon Dioxide substrate gives good performance characteristics. In this paper, discussed about the compact fractal antennas are studied for wideband operation. Based on this, future work may be carried out such as The effect of material properties on Fractal antenna performance such as gain, efficiency, radiation patterns, etc. can be studied. Study of new techniques to reduce the size and enhance the bandwidth of fractal wideband antennas for use in mobile and portable devices. Fabrication of the proposed Fractal antennas and comparison of simulated Results with the measured Results.

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