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Design of Fractal Antenna for Multiband Application

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Abstract- In this paper, A Multiband rectangular Fractal antenna designed And Analysis with Multiband Koch Fractal Monopole Antenna. This antenna is microstrip line fed and its structure is based on fractal geometrics. This antenna design with the help of dielectric constant, substrate height and resonant frequency. Antenna properties such as return loss, gain, VSWR, Directivity and Bandwidth are analyzed and discussed in this project. Design and Analysis of fractal antenna is done by using Software named HFSS (High Frequency Structure Simulator). Frequency bandwidth (0.8 GHz to 3 GHz) used in this project. We can use this antenna for mobile antenna and Wi-Fi antenna. Fractal antenna can meet the need antenna requirements of modern communication thin section, small size, being easy to manufacture and low price.

Keywords - Multiband antennas, fractal antennas, Microstrip patch antenna, Resonant Frequency, Microstrip line feeding.

I. INTRODUCTION

In modern wireless communication systems and of other wireless applications, wider bandwidth, multiband [1-2] and low profile antennas are in great demand for both commercial and military applications. It has initiated antenna research in numerous directions; at least one is applying fractal shaped antenna elements. [3] Traditionally, each antenna operates in a single or dual frequency bands [1-2], where different antenna is required for various applications. It will cause a limited space and place problem. In order to overcome this problem, multiband antenna can be used in which a single antenna can operate at many frequency bands. One technique to construct a multiband antenna is by applying fractal shape into antenna geometry [3].

This project presents the multiband rectangular fractal antenna where this famous shape, the antenna behaviours are investigated. As well as the theoretical design procedure, numerical simulation was performed using HFSS (High frequency structure Simulator) to obtain design parameters such as size of patch and feeding location. The antennas have been analyzed and designed by using the software HFSS.

Fractal technology has great potential in antenna miniaturization, multi-frequency, ultra-wideband application, and this paper are about fractal technology in the application of multi-frequency microstrip antenna. Based on the fractal structure design of Sierpinski, we studied the multirate characteristics of nested triangle fractal monopole antenna, using electromagnetic field simulation software Microwave Studio. The current communication system has been developed to the broadband and integration; meanwhile people’s needs for portable mobile communication are higher. This requires antenna development corresponding broadband technology, Multifrequency technology and miniaturization. Multifrequency antenna has been taken more and more attention, with its small volume, light weight, easy and active circuitry integration advantages, especially along with the rapid development of wireless communications. Antenna of Multifrequency, miniaturization, wideband and circular polarization such technology will be the domestic and foreign research hotspot. Future communications will put more serious technology challenges for antenna, demanding a miniaturized structure to complete antenna miscellaneous tasks. Fractal antenna can meet the need Antenna requirements of modern communication thin section, small size, being easy to manufacture and low price. Fractal is produced with the self-similarity of fractal dimension structure through iterative, not only realized the antenna of miniaturization, but also strengthened the directional antenna. The antennas produce low frequency resonant modes. Fractal antenna solved two limitations of the traditional antenna:

l) Commonly used antenna performance is highly dependent upon the antenna electricity size. This means that main antenna parameters (gain, input impedance, and orientation graph and side lobe electricity equality) will changes as working frequency for fixed antenna size. Fractal self-similarity make fractal antenna how frequency and broadband characteristics.

2) Fractal complex shapes make some antenna’s size get reduced. The research of fractal antenna in military and civilian have a widely application prospect.

Fractal Antennas Elements:-
There are many benefits when we applied these fractals to develop various antenna elements. By applying fractals to antenna elements:
• We can create smaller antenna size.
• Achieve resonance frequencies that are multiband.
• May be optimized for gain.
• Achieve wideband frequency band.

Most fractals have infinite complexity and detail that can be used to reduce antenna size and develop low profile antennas. For most fractals, self-similarity concept can achieve multiple frequency bands because of different parts of the antenna are similar to each other at different scales. The combination of infinite complexity and self similarity makes it possible to design antennas with various wideband performances.
We need fractal antenna due to the following facts:

- Very broadband and multiband frequency response that derives from the inherent properties of the fractal geometry of the antenna.
- Compact size compared to antennas of conventional designs, while maintaining good to excellent efficiencies and gains.
- Mechanical simplicity and robustness; the characteristics of the fractal antenna are obtained due to its geometry and not by the addition of discrete components.
- Design to particular multi frequency characteristics containing specified stop bands as well as specific multiple pass bands.

FRACTAL GEOMETRY:-
There are many fractal geometries that have been found to be useful in developing new and innovative design for antennas. Fig. [1] below shows some of these unique geometries.

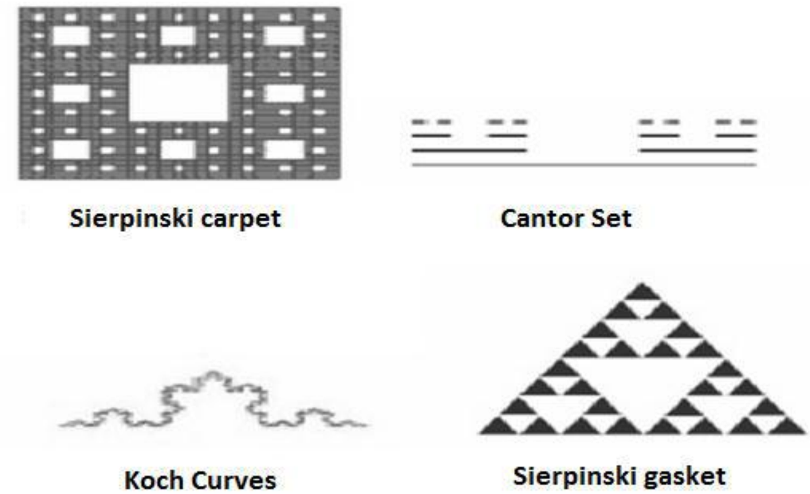

Fig.1. Types of fractal geometries

II. ANTENNA DESIGN

Microstrip antenna is a simple antenna that consists of radiated patch component, dielectric substrate, and ground plane. The radiated patch and ground plane is a thin layer of copper or gold which is a good conductor. Each dielectric substrate has their own dielectric permittivity values. This permittivity will influence the size of the Antenna. Microstrip antenna is a low profile antenna. They have several advantages like light weight, small dimension, cheap and easy to integrate with other circuits which make it chosen in many applications.[11]

ANTENNA PROPERTIES: - The performance of the antenna is determined by several factors. Properties of those factors are as follows:

Input Impedance:- Generally, input impedance is important to determine maximum power transfer between transmission line and the antenna. This transfer only happen when input impedance of antenna and input impedance of the transmission line matches. If they do not match, reflected wave will be generated at the antenna terminal and travel back towards the energy source. This reflection of energy results causes a reduction in the overall system efficiency. [11]
In the other sense "the impedance presented by an antenna at its terminals or the ratio of the voltage to current at a pair of terminals or the ratio of appropriate components of the electric to magnetic fields at a point."[5] The ratio of the voltage to current at these terminals, with no load attached, defines the impedance of the antenna as

$$Z_A = R_A + jX_A$$

Where

Z_A= Antenna impedance at terminals a-b (ohms)

R_A= Antenna resistance at terminals a-b (ohms)

X_A= Antenna reactance at terminals a-b (ohms)

Gain: - The gain of an antenna is basically a measure from the antenna's overall efficiency. If the antenna is 100% efficient, it could have a gain equal to its directivity. There are lots of factors that affect and minimizing at the overall efficiency of an antenna. Probably the most significant factors that impact antenna gain include impedance matching, network losses, material losses and random losses. By considering all factors, it would appear that the antenna must overcome a great deal of adversity in order to achieve acceptable gain performance.[11]

Gain of an antenna is defined as "the ratio of the intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically. The radiation intensity corresponding to the isotropically radiated power is equal to the power accepted (input) by the antenna divided by 4Π."[5] We can be expressed as:

$$\text{Gain} = 4\Pi * \frac{radiation\ \ intensity}{total\ \ input\ \ power} = 4\Pi * \frac{U(\theta,\emptyset)}{P_{in}}$$

Where

$U(\theta, \phi)$ = radiation intensity

P_{in} = Total input power

In most cases we deal with relative gain, which is defined as "the ratio of the power gain in a given direction to the power gain of a reference antenna in its referenced direction." The power input must be the same for both antennas. The reference antenna is usually a dipole, horn, or any other antenna whose gain can be calculated or it is known. In most cases, however, the reference antenna is a lossless isotropic source. [5] Thus

$$G = \frac{4\pi U\,(\theta,\emptyset)}{P_{in}}$$

Radiation Pattern: - The radiation patterns of the antenna provide the information that describes how an antenna directs the energy it radiates. All antennas if 100% efficient will radiate exactly the same total energy for equal input power whatever the pattern shape. Radiation patterns are usually presented on the relative power db scale.

An antenna radiation pattern or antenna pattern is defined as "a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates. In most cases, the radiation pattern is determined in the far-field region and is represented as a function of the directional coordinates. Radiation properties include power flux density, radiation intensity, field strength, directivity, phase or polarization." The radiation property of most concern is the two or three- dimensional spatial distribution of radiated energy as a function of the observer's position along a path or surface of constant radius.

Isotropic, Directional and Omnidirectional patterns radiation is defined as "a hypothetical lossless antenna having equal radiation in all directions."[5] Although it is ideal and not physically realizable, it is often taken as a reference for expressing the directive properties of actual antennas.

Principal patterns E- and H- plane patterns. The E-plane is defined as "the plane containing the electric-field vector and the direction of maximum radiation." And the H-plane as "the plane containing the magnetic-field vector and the direction of maximum radiation." .

Directivity: - Directivity, D is important parameter that shows the ability from the antenna focusing radiated energy. Directivity would the ratio of maximum radiated to radiate reference antenna. Reference antenna usually can be an isotropic radiator in which the radiated energy is same to all direction and has directivity of 1. [5] Directivity is described as the following equation:

$$D = \frac{\mathrm{F}_{\max}}{F_0}$$

Where

F_{max} = Maximum radiated energy.

F_0 = Isotropic radiator radiated energy

Directivity of an antenna defined as "the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged overall directions. The average radiation intensity is equal to the total power radiated by the antenna divided by 4Π. If the direction is not specified, the direction of maximum radiation intensity is implied." Stated more simply, the directivity of a nonisotropic source is equal to the ratio of its radiation intensity in a given direction over that of an isotropic source. We can describe in mathematical form:[11]

$$D = \frac{U}{U_0} = \frac{4\pi U}{P_{rad}}$$

Polarization: - The polarization of the antenna describes the orientation and sense from the radiated wave's electric field vector. There are three types of basic polarization:
• Linear polarization
• Elliptical polarization
• Circular polarization

Generally most antennas radiate with linear or circular polarization. Antennas with linear polarization radiate in the same plane with all the direction from the wave propagate. For circular polarization the antenna radiate in circular form.

In other word we can say polarization of an antenna in given direction is defined as "the polarization of the wave transmitted (radiated) by the antenna. When the direction is not stated, the polarization is taken to be the polarization in the direction of maximum gain." [11]

Bandwidth: - The term bandwidth simply defines the frequency range that an antenna meets a particular set of specification performance criteria. The important issue to consider regarding bandwidth would be the performance tradeoffs between each one of its performance properties described above. There are two methods for computing an antenna bandwidth. [11]

An antenna is considered broadband if $\frac{f_H}{f_L} \geq 2$.

Narrowband by % age

$$BWp = \frac{(f_h - f_l)}{f_0} \times 100\%$$

Broadband by ratio

$$BWb = \frac{f_h}{f_l}$$

Where
f_0 = Operating frequency.
f_h = Higher cut-off frequency.
f_l = Lower cut-off frequency.

In other words the bandwidth of an antenna is defined as "the range of frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard." The bandwidth can be considered to be the range of frequencies, on either side of a centre frequency (usually the resonance frequency for dipole), where the antenna characteristics (such as input impedance, pattern, beamwidth, polarization, side lobe level, gain, beam direction, radiation efficiency) are within an acceptable value of those at the centre frequency [5].

FEEDING TECHNIQUES:- Feeding techniques [4-5] are important in designing the antenna to make antenna structure so that it can operate at full power of transmission. Designing the feeding techniques for high frequency, need more difficult process. This is because the input loss of feeding increases depending on frequency and finally give huge effect on overall design. There are a few techniques that can be used.

1. Microstrip Line feeding
2. Coaxial Probe feeding
3. Aperture Coupled feeding
4. Proximate Coupled feeding
5. CPW feeding

III. METHODOLOGY

We will use HFSS (High Frequency Structure Stimulator). This software are given great flexibility in tackling a wide application range.Multi-frequency antenna has a low frequency operation also has a high frequency bandwidth and operating bandwidth. A fixed space often has many different communication systems, these wireless systems need to work on different operating frequency and pattern. If we can use one or very few antenna wireless systems that can meet these requirements, then no matter the cost size and weight of the system that are very meaningful. There are many methods of designing multi-frequency antenna. Resonant frequency of the antenna with the main unit placed near the resonant frequency of a parasitic element to another, you can get a dual-band antenna, which is to obtain dual-band antenna, the easiest method. The two works in different frequency antenna elements fed by a serial port work is also a way to achieve dual-band. Another way to obtain two resonant frequencies whiles the impedance matching.

The proposed model is designed using three iterative steps. Here the same radiating patch is used throughout the steps. But, the ground plane shape is modified in the consecutive steps. Starting from a triangle and superimposing another similar inverted triangle upon it and so on we have obtained the required geometry. The antenna is along XY plane. Along positive Y axis the antenna has rectangular geometry and that along negative Y axis has triangular geometry. The feed source point of this antenna is placed at origin (0,0,0) and this source set at 1 volt. The designed frequency has been chosen to be 0.8 GHz to 3 GHz.

IV. RESULTS

4.1 RETURN LOSS PLOT FOR MULTIBAND RECTANGULAR FRACTAL ANTENNA.

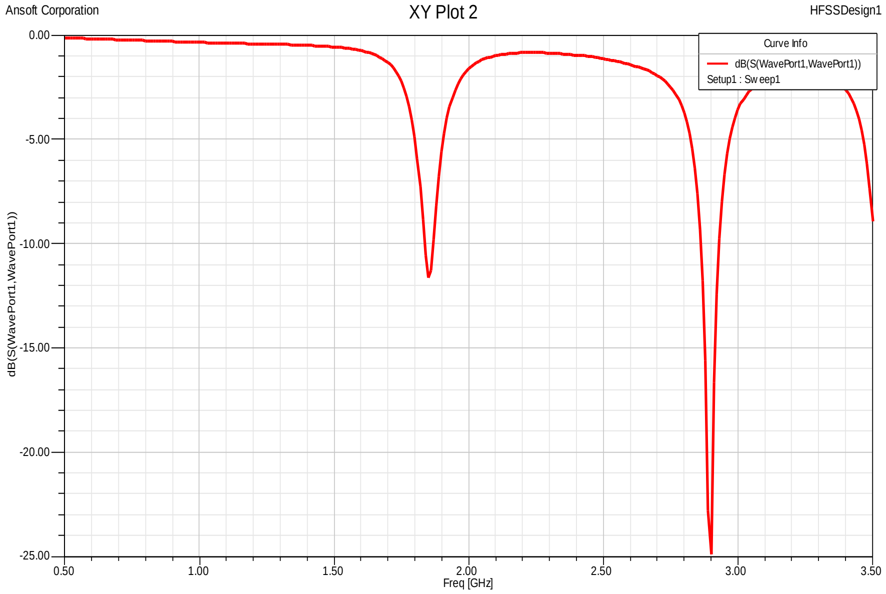

Fig. 4.1: Return Loss plot for multiband rectangular fractal antenna.

4.2 VSWR PLOT FOR MULTIBAND RECTANGULAR FRACTAL ANTENNA.

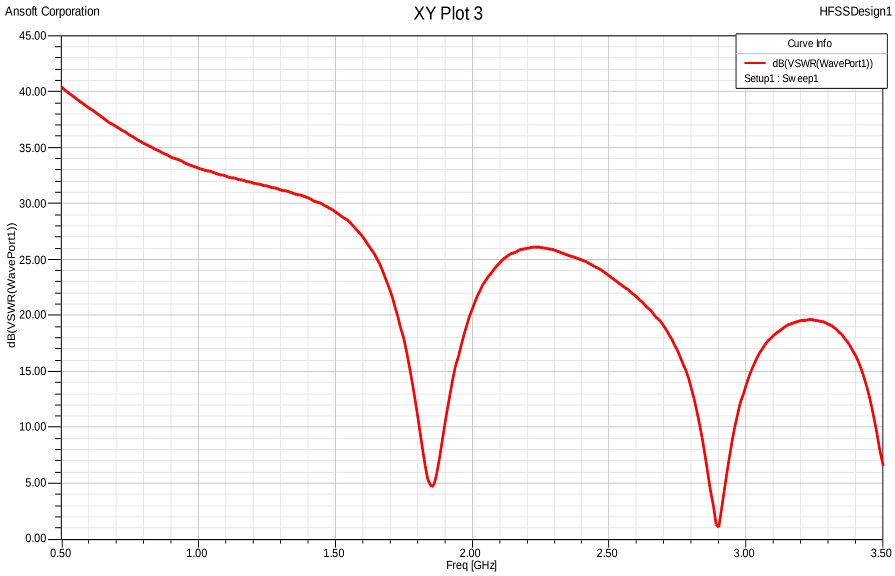

Fig. 4.2: VSWR plot for Multiband Rectangular fractal antenna.

Since there is a rapid development in wireless communication systems their applications are increasing every day. Accordingly antennas are designed to radiate in a relatively narrow range of frequencies. As opposed to traditional narrowband antennas, the Fractal antennas can transmit and receive electromagnetic waves in a wide range. The Fractal antennas are used to transmit the signal with minimum noise and distortion in the shape of the pulses. Much important is that the increasing demand for low profile and portable miniature wireless systems has increased interests in the compact antennas. It can be integrated with many electronics devices, chips, mobile phones etc. There are more advantages of low radiation loss, and dispersion.

V. CONCLUSION

Multiband Rectangular Fractal antenna is suitable for mobile and Wi- Fi network operation. This geometry is covered the frequency range from 0.8 to 3.0 GHz.
Return loss is -10 to -25 db and VSWR – 1-2 and impedance- 48 to 50 ohm.
Microstrip line feeding is provided to proposed antenna which is simple and suitable for this.

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