Investigation of Fractal Reconfigurable Antenna based on Fractal Geometries

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***Abstract*—A different antenna structure is suggested by combining the concept of a reconfigurable and fractal with the parasitic elements technique to attain the multiband frequency reconfigurable antenna. Fractal antenna with triangular slot is designed for operating at multiple frequencies. It has been originate that designing an antenna using the properties of fractal geometry results in an antenna that resonates at multiple frequencies. In this work two designs of fractal antennas have been studied. Fractal geometry has been applied on patch to obtain multiband characteristics to obtain wideband characteristics**

***Index Terms*—Fractal Antenna, Multiband Antenna, HFSS, Cognitive radio**

I. INTRODUCTION

A CR is a Software Defined Radio (SDR) that additionally senses its environment, tracks changes, and reacts upon its findings [1],[2]. A CR is an independent unit in a communications environment that frequently exchanges information with the networks it is able to access as well as with other CRs. The antenna for CR should be able to sense wide band spectrum and operate at various available frequencies, it is the combination of both wideband and frequency reconfigurable antennas [3], [4]. Many researchers have been concentrating on designing antennas for cognitive radio in recent times. It has been reported that the reconfigurable antennas with multiple switches are able to operate at multiple frequencies and are suitable for cognitive radio secondary user which requires switching over to various available frequencies. Secondary user also requires a wideband antenna for searching a wider band for available primary user unused frequency band [5], [6]. Fractal shaped reconfigurable antennas have been suggested for such applications with suitable slots to achieve such multi frequency operations [7]. Fractal antenna [8] provides miniaturization and has multi-band characteristics. These are composed of multiple iterations of a single elementary shape and are used to describe a family of complex shapes that possess an inherent self-similarity and self-affinity in their geometrical structure. Though these antennas reduce the size and cost, but in case of communication system many applications are used that works at different frequency band hence a single fractal antenna cannot be used to serve the purpose of the whole communication system. We are of the opinion that reconfiguration concept can be applied to fractal and it will be a great advantage for wireless communication system since it provides enhanced miniaturization in size of the overall communication system as well as provides frequency selectivity.

Fractal geometry is advantageous since by applying fractal geometry size of antenna decreases, resonant frequency reduces and number of bands increases. There are different fractal geometries that can be applied to antenna so as to obtain better results but any self-similar structure can be made using these fractal geometries. Different fractal geometries are discussed follow.

a) Minkowski Fractal Geometry
b) Koch Curve
c) Giuseppe Peano fractal geometry
d) Hilbert curve fractal geometry

Minkowski Fractal Geometry: Geometric construction of fractal Minkowski curve is shown in fig.1 in which each side of basic patch is divided into three equal parts and middle part of each side is replaced by a projection inwards with two vertical and two horizontal segments of equal length.

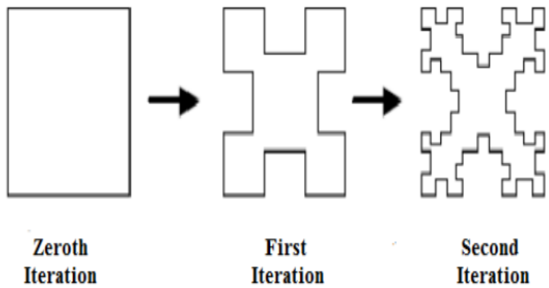

Fig.1: Minkowski Fractal Geometry

From fig.1, it is clear that by applying fractal geometry, area of antenna decreases but number of bands at which antenna resonates increases.

Koch Curve: The geometric construction of Koch curve is very simple. It starts with a straight line. In this length is divided into equal three parts, and middle is replaced with two others of the same length which joined at angle of 60 degree.

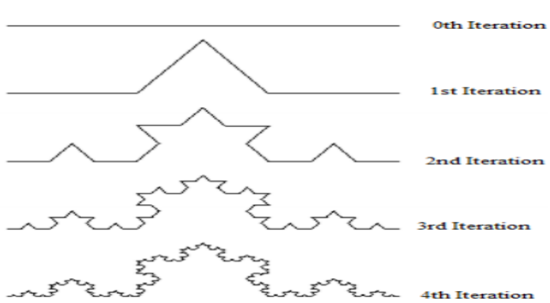

Fig.2: Koch Curve Fractal Geometry

By applying different iterations, self-similar structures represented as shown in fig.2.

Giuseppe Peano Fractal Geometry: The procedure of Giuseppe Peano fractal geometry is shown in fig.3, which applied on the edges of square patch. In this geometry as increase in iterations, the resonance frequency decreases.

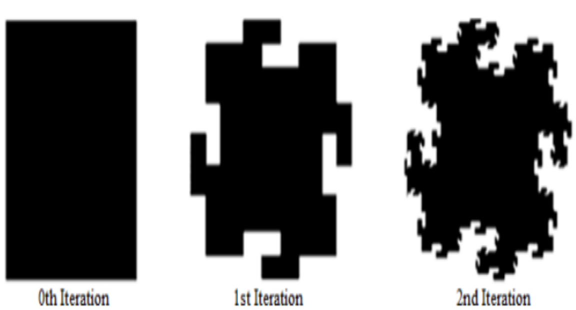

Fig.3: Giuseppe Peano Fractal Geometry

Hilbert Curve Fractal Geometry: This geometry is a space-filling curve. In this geometry as increase in iterations, the resonant length increases. Hilbert curve fractal geometry shown in fig.4. It may be noticed that each successive stage consists of four copies of the previous, iteration lines.

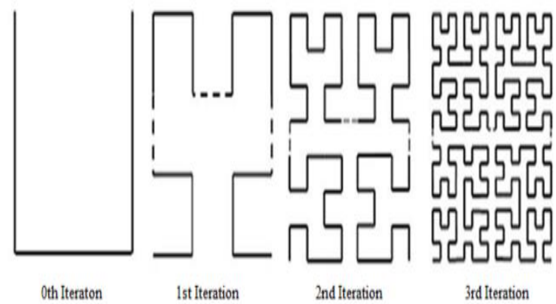

Fig.4: Hilbert Curve Fractal Geometry

Fractal geometry is composed of self-similar structure. By applying fractal geometry to microstrip patch antenna, area of patch decreases and characteristics of antenna in terms of bandwidth, return loss and gain show improvement.

II. LITERATURE SURVEY

Khidre et al. [9] presented U slot microstrip antenna for higher mode applications. This antenna resonated in a band from 5.17 GHz to 5.81 GHz hence useful for number of applications. This antenna was having dual radiation beams with both beams were directed at centre frequency. This antenna was having a gain of 7.92 dBi. This antenna found its applications for different wireless applications. This antenna exhibit impedance bandwidth of 11 % at VSWR less than two. This antenna was having dimensions of 64X 74 mm2. Substrate was having a dielectric constant of 2.2 and thickness of 3.1 mm. Design and simulation had been carried out using HFSS.

Gupta et al. [10] designed multiple band microstrip patch antenna. This antenna had been useful for c band and x band applications. This microstrip antenna was having a patch with different slots so as to have good antenna characteristics. These slots were four U slots, two small and two large and one I shaped slots. This antenna was having compact size of 25 X 23 mm2. Feed to this antenna is given by coaxial feeding technique and feed point is chosen properly. Design and simulation had been carried out using HFSS simulation software. This antenna was having bandwidth of 140 MHz from 5.85 GHz to 6 GHz and 1.21 GHz from 7.87 to 9 GHz. This antenna can be used for WLAN, C band and X band applications.

Janani.A et al. [11] designed E-shaped fractal patch antenna for multiband applications. For obtaining multiple bands, fractal geometry had been used. First of all, entire length was divided to form E shape patch by cutting two slots. On each section, fractal geometry was applied so as to make fractal antenna. . The proposed antenna had dimensions of 150 mm by 130 mm using two FR-4 having thickness of h=0.8 mm and h=1.6 mm and an air gap having thickness h= 4 mm between two FR-4 as substrate. The design and simulation had been carried out using HFSS simulation software. The main parameters at operating bands such as return loss, impedance, gain had been studied. This antenna found its application for different applications for mobile communication.

Waladi et al. [12] designed fractal microstrip patch antenna using star triangular shape. Fractal geometry had been applied on triangle to obtain star shape antenna. This antenna was fed by microstrip feeding technique which was having width of 4.8 mm and length of 1.9mm. This antenna was having large bandwidth of 30 GHz from one to 30 GHz at VSWR less than two. This antenna had been used for ultra-wideband and short wideband applications. This antenna had wideband characteristics because of presence of notch with dimensions of 4.8 X1.9 mm2.

Ghorpade et al. [13] made a comparison between E-shape antenna and E-shaped fractal microstrip patch antenna. From this analysis it was found that fractal antenna gave multiband characteristics. This antenna had large size of order of 150X130 mm2. The design and simulation has been carried out using a software HFSS. Characteristics of antenna were compared in terms of VSWR, return loss, gain and bandwidth. Because of fractal geometry, E-shaped fractal antenna resonated at 1.93 GHz, 2.4 GHz, and 3.52 GHz to cover GSM frequency bands, UMTS, Bluetooth and Wi-Max applications. By increasing number of iterations beyond limit, results began to degrade.

Kumar Raj et al. [14] proposed an ultra-wideband inscribed triangle circular fractal antenna. This antenna had a circular patch with dimensions of 30 mm. In order to design such antenna, substrate used was FR-4. This antenna had ultra-wideband characteristics from 2.25 GHz to 15 GHz at VSWR less than two. The antenna was fed by coplanar waveguide. By applying fractal geometry CPW, wideband characteristics were obtained. The results of simulated antenna were compared with that of tested antenna and both offered same characteristics. Because of such a large bandwidth, these antennas were useful for UWB applications.

Problem statement

In order to transmit or receive data in communication system, it is essential to have compact system, Transmission and reception system requires transmitting or receiving antenna to transmit/receive information. There are dissimilar factors which govern antenna selection. These are size, weight, complexity, bandwidth, gain and applications. One of best antenna that can optimize all parameters is microstrip antenna. This antenna is having small size and less weight but suffers from disadvantages like low bandwidth, high return loss and less gain and efficiency. By applying DGS (Defected Ground Structure), only bandwidth of antenna increases, hence in order to increase bandwidth of antenna and multiband characteristics, fractal antenna would be required.

III. SUGGESTED APPROACH

There are different steps that have been followed in order to achieve the objective of proposal:

- Fractal antenna dimensions calculated before design using HFSS software.
- Design, simulation and analysis are carried out using HFSS software.
- Application of different iterations of fractal geometry so as to obtain wideband characteristics

1) Fractal Geometries Used in Designing Proposed Antenna

Fractal geometries composed of self-similar structures, there are different fractal geometries which include Minkowski fractal geometry, Sierpinski fractal geometry, cantor and many other self-similar structures.

1) Design Procedure of Fractal Microstrip Patch Antenna:

Step 1: Selection of resonant frequency for desired application (f_r): Different wireless band applications use different frequency of operation. Entire frequency band is divided into different bands. Each band has a frequency range with different application as shown in table.1. Hence frequency is decided first.

Step 2: Substrate selection: It is important parameter that decides dimensions of patch. There are two most commonly substrate used which are FR-4 epoxy with dielectric constant of 4.4, loss tangent of 0.02 and Rogers RT Duroid 5880 with dielectric constant of 2.2 and loss tangent of 0.0009. It was found that as dielectric constant increases, dimensions of antenna decreases and efficiency and gain also decreases. Hence for selection, these factors are taken into account.

Table.1: Various Frequency Bands of Wireless Communication

Microwave Band	**Frequency range**	**Applications**
L Band	1 to 2 GHz	Military telemetry, GPS, Mobile phones (GSM), Amateur radio
S Band	2 to 4 GHz	WLAN, Bluetooth, cellular phones, Wi-Fi
C Band	4 to 8 GHz	Long distance radio telecommunications, Satellite, Microwave relay
X Band	8 to 12 GHz	RADAR

Step 3: Substrate thickness (h): It is find that increase in thickness of substrate causes efficiency and bandwidth to increase but this makes antenna more bulky.

Step 4: Choosing square dimensions: After selecting all three parameters, dimensions can be obtained. Optometric analysis has been carried out in order to select that dimensions that give best results.

Step 5: Selection of feed point: There are five different feeding techniques but most commonly used are microstrip and coaxial feeding technique.

Step 6: Applying fractal geometry iterations: Fractal geometry has biggest advantage of providing multiband characteristics. There are different fractal geometries like Koch,Minkowski, Sierpinski carpet, cantor shape.

Step 7: Calculation of ground dimensions: It is essential to have finite ground plane for practical considerations.

2) Design Considerations for Fractal Antenna:
It is necessary to design antenna in such a way that desired characteristics are obtained. Fractal geometry is applied to antenna so as to obtain multiband characteristics. Dimensions of antenna depend on desired frequency of application. If antenna is designed for small frequencies size would be large. Size of antenna also depends on dielectric substrate. If substrate has large dielectric constant, size would be small but efficiency and bandwidth decreases.

3) Design of Fractal Microstrip Patch Antenna:
Design of T-shaped fractal microstrip patch antenna has been obtained by applying fractal geometry. Patch is taken is known to be square whose dimensions has been calculated as per antenna specifications.

4) Parametric Analysis of Proposed Antenna:
It has been analyzed that by applying two iterations of fractal geometry, characteristics of antenna improves a lot. It is found with help of parametric analysis, one may obtain best configuration that has better result.

5) Effect of Changing Feed:
It is found that coaxial feed is easy method for feeding antenna. Feed point is chosen such that antenna impedance matching takes place.

IV. CONCLUSION

From above consequences it is found that parametric analysis had been carried out in terms of substrate thickness, feed point and number of iterations. It is found that by making use of fractal geometry, characteristics of antenna improve a lot.

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