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Design of Microstrip Patch Antenna with Koch Snowflake Geometry for Multiband Applications

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ABSTRACT: This paper presents the design and simulation of Koch Snowflake Fractal antenna up to second iteration. The Koch snowflake antenna is used for size reduction. Due to the self similar and space-filling property of fractal geometry, antenna operates at lower resonant frequency. From the results it is observed that, as the iteration and the iteration factor increases, the resonant frequency of the antenna shifted to lower frequency. For design and simulation of antenna CAD-FEKO - 6.3 software is used. Koch Snowflake Fractal antenna helps in fitting large electrical lengths into small volume. FR4 substrate having dielectric constant - 4.4 is used for designing the antenna and is fed with 50 ohms coaxial line. By optimizing the coaxial feed and its location the antenna has been optimized to operate at multiple frequencies 1.24 GHz for GPS application, 1.42 for L-band applications and 2.92 GHz for S-band applications.

KEYWORDS: CAD FEKO -6.3, Co-axial feed, Koch Snowflake Fractal antenna, **.**

I.INTRODUCTION

Nowadays due to tremendous development in both the military as well as the commercial area, there is great demand for antenna design that possesses some highly desirable features such as compact size, low profile, conformal and multiband or broadband. There are a variety of approaches that have been developed over that year, which can be utilized to achieve one or more of these design objectives. The fractal geometry plays an important role for achieving these requirements. Basically fractal means, broken or irregular fragment. Fractal was first defined by Benoit Mandelbrot in 1975 as a way of classifying structures whose dimensions were not whole numbers. A fractal is a rough or fragmented geometric shape that can be subdivided in parts, each of which is (at least approximately) a reduced-size copy of the whole. In nature there are many mathematical structures that are fractals; such as clouds, mountains, turbulence, and coastlines that do not correspond to simple geometric shapes. The use of fractal geometry is a very good solution to reduce the size of antenna. Fractal shaped antennas show some interesting features which results from their geometrical properties. Self similarity and space filling properties are the unique features of fractals which enable the realization of antennas having some interesting characteristics such as multi-band operation and miniaturization.

We know that, traditionally antenna can operate on single or dual frequency bands so different antenna is needed for different applications. In Order to overcome this problem there is need to design multiband antenna which can operate at many frequency bands. One technique to construct a multiband antenna is by applying fractal shape into antenna geometry. This paper proposes the design and simulation of simple triangular microstrip patch antenna at 1.6 GHz. Further by applying fractal geometry the Koch snowflake fractal antenna is formed. Using Koch snowflake fractal geometry it is possible to achieve the directional pattern with multiple frequency bands. The objective of this paper is to design antenna which can covers a large number of wireless communication applications including GPS (1.24 GHz), L-band applications (1.42 GHz) & S-band applications (2.92 GHz).

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II. GEOMETRY OF KOCH SNOWFLAKE

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

III. ANTENNA DESIGN

A. Design of Basic Triangular Patch

Here CAD FEKO-6.3 software is used to design the Koch antenna. The Koch snowflake is constructed first by starting with a simple equilateral triangular patch as shown in Fig 1(a) .

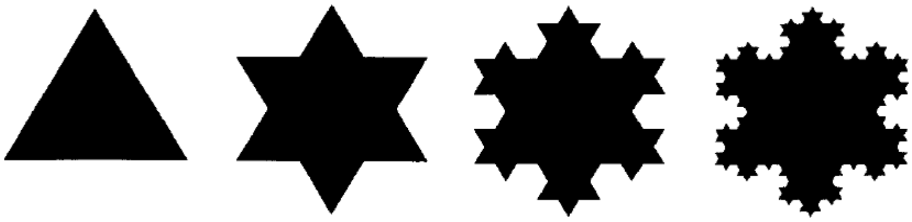

Fig.1. Basic Steps construction of a Koch snowflake fractal
(a) Basic Triangular Patch geometry, (b) First iteration, (c) Second iteration (d) Third iteration

For the design of triangular patch antenna there are three important parameters i.e. resonant frequency (fr), dielectric material of the substrate (ϵ_r), and the thickness of the substrate (D). The resonant frequency chosen here is 1.6 GHz. FR-4 is the dielectric material selected for this design having a dielectric constant (ϵ_r) of 4.4.
The fundamental mode resonant frequency of such antenna is given as follows:

$$Fr = \frac{2c}{3a\sqrt{\epsilon_r}} \qquad (1)$$

Where,
C = Speed of light
ϵ_r= Relative permittivity of substrate

$$a = \frac{2c}{3Fr\sqrt{\epsilon_r}} \qquad (2)$$

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

$$Lambda = \frac{c}{f}$$

Where,
Fr = 1.6 GHz
ϵ_r = 4.4 Ground length = **Lambda/2**

B. Design of a First Iteration of Koch Fractal

Koch fractal geometry is one of the well known fractal shapes. The first iteration of Koch fractal is obtained by replacing the sides of an equilateral triangle by a Koch curve. After first iteration of the Koch Fractal, the resulting shape is a star shape patch as shown in Fig. 1(b)

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C. Design of Second Iteration of Koch Fractal

After second iteration of the Koch fractal antenna, the resulting shape is as shown in Fig. 1 (c) .It is observe that in each new iteration the area of the geometry increases .Let be the area at iteration ,then the area of the next iteration can be computed as:

Where a is the side

$$A_{k+1} = A_K + \frac{\sqrt{3}}{12}\left(\frac{4}{9}\right)^{K-1} * a^2$$

length of initial triangle that has an area of ,

$$A_0 = \frac{\sqrt{3}}{4} * a^2$$

IV. SIMULATION RESULTS AND DISCUSSION

The simulation tool used for evaluating the performance of the Koch fractal antenna is CAD-FEKO 6.3 software, which is based on the method of moment's technique and used for computing VSWR, Return Loss and Gain.

A. Simulation Result for Basic TMSA (Iteration -0)

The structure of basic TMSA (Iteration-0) is shown in Fig. 2 and on simulating the structure with the help of CAD FEKO -6.3; the following results were obtained,

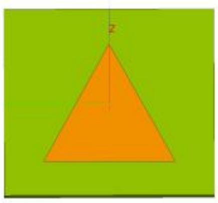

Fig. 2 Structure of basic TMSA (Iteration – 0)

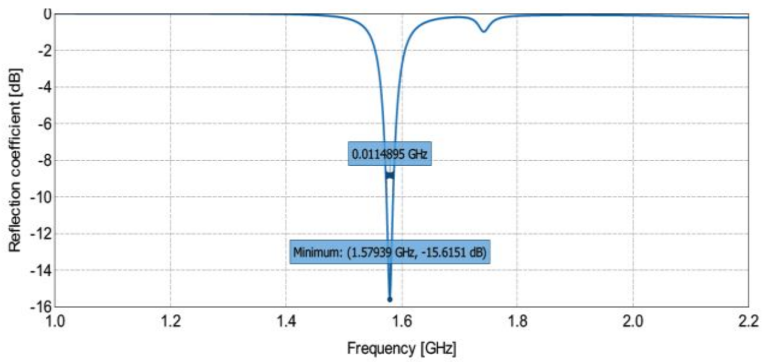

Fig. 3 Return loss of basic TMSA (Iteration – 0)

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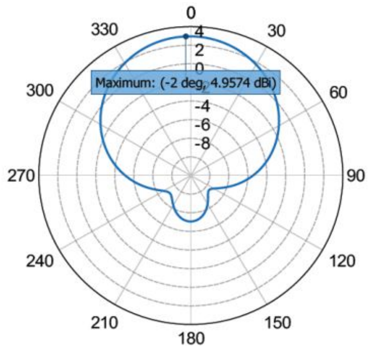

Fig. 4 E-plane radiation pattern of basic TMSA (Iteration – 0)

Above fig. 3 shows return loss of basic TMSA. The triangular patch resonates at the frequency 1.57 GHz having bandwidth 25.25 MHz with a return loss of -15.61 dB and fig.4 shows the directional radiation pattern of the basic TMSA with 3.42 db gain.

B. Simulation Result for Iteration -1

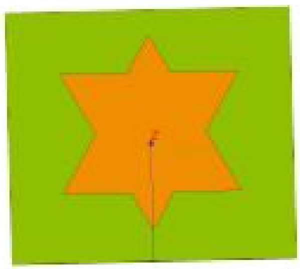

Fig. 5 Iteration -1 of Koch snowflake Fractal Antenna

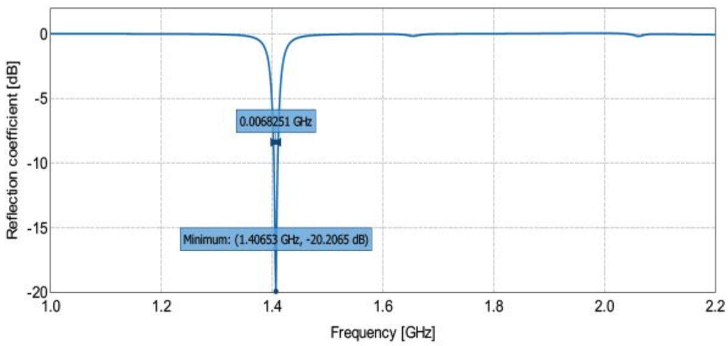

Fig. 6 Iteration – 1 of Koch snowflake fractal antenna return loss

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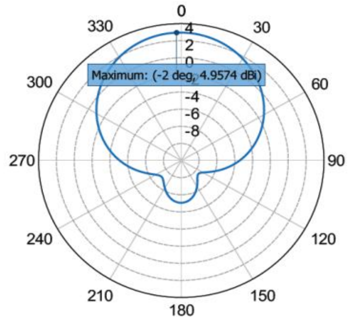

Fig. 7 Iteration – 1 of Koch snowflake fractal antenna E-plane radiation pattern

Above Fig. 5 shows the structure of Koch snowflake fractal antenna with first iteration and on simulating the above structure with the help of CAD FEKO software we get return loss as shown in fig 6. In which antenna resonate at 1.4 GHz frequency with 20.04 MHz bandwidth and -20.2 db return loss. Fig. 7 shows E-plane directional radiation pattern of iteration-1 with improved gain of 4.95 db.

C. Simulation Result for Iteration -2

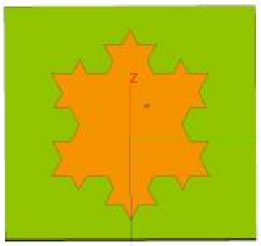

Fig. 8 Iteration -2 of Koch snowflake Fractal Antenna

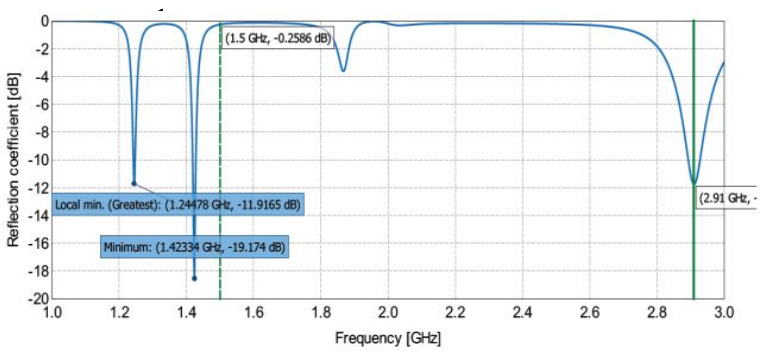

Fig.9 Return Loss of Iteration - 2 of Koch snowflake Fractal Antenna

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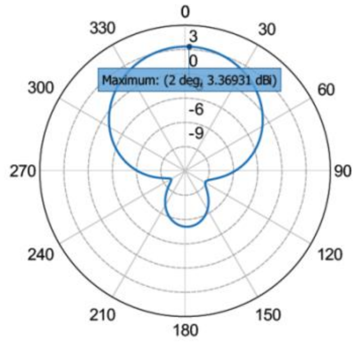

Fig. 10 Iteration -1 of Koch snowflake Fractal Antenna E-plane radiation pattern

After simulating the structure of iteration -2 of Koch snowflake fractal antenna we get simulated return loss and E-plane radiation pattern as shown in fig 8 & fig. 9 respectively. This shows that antenna can resonate at three different resonant frequencies 1.24 GHz, 1.42 GHz and 2.91 GHz with 7.88 MHz, 10.43 MHz and 41.22 MHz bandwidth respectively. E-plane radiation pattern as shown in fig.10 shows decrease in gain of the antenna due to addition of multiple frequencies.

The Table1 gives all the summarized results of the three proposed antennas.

Table 1: Iteration wise results of Koch Fractal Antenna

Types of Microstrip Antenna	Frequency (GHz)	Bandwidth (MHz)	Return Loss(dB)	VSWR	Gain(dB)	Impedance (Ohm)
Triangular Microstrip Antenna	1.57	25.25	-15.61	1.39	3.42	47.12
Iteration - 1 of koch snowflake fractal antenna	1.4	20.04	-20.2	1.27	4.95	42.54
Iteration – 2 of koch snowflake fractal antenna	1.24	7.88	-11.91	1.67	3.36	53.9
	1.42	10.43	-19.17	1.24		47.83
	2.91	41.22	-11.9	1.68		53.12

From above table it is clear that when iteration increases, the resonant frequency of this triangular patch antenna shifted to lower side and in second iteration we triple frequency band with large bandwidth.

VI .CONCLUSION

This paper presented the design and simulation of Koch Snowflake antenna up to second iteration. Three resonant bands have been obtained by simulation the simulated result shows that as the number iteration increases, the antenna becomes multiband, with different resonant frequencies. This conclude that t he resonant frequency increases with increase in the number of iterations. The bandwidth of the antenna gets increased with increase in the number of iterations. Improvement in VSWR is also observed with increase in iterations. The multiband effect of fractal geometry on patch antenna has been analyzed. This Koch snowflake antenna is a good example of the properties of fractal incremental boundary patch antennas. As the fractal iteration increases, perimeter of patch increases and effective area of antenna increases with improve multiband application. The antenna is now resonant at more frequencies. It gives multiband properties to fractal geometry antenna with directive patterns. The designed antenna have some favourable characteristics such as; compact size, directional radiation pattern, multiband , satisfactory return loss less than -10 db

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and operate at desired frequency 1.24 GHz for GPS (Global Position Systems) applications, 1.42GHz for L-band applications & 2.92 GHz for S-band applications.

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