DESIGN AND DEVELOPMENT OF MINIATURIZED 2-ITERATION KOCH FRACTAL ANTENNA FOR Wi-Fi, C BAND AND X BAND WIRELESS COMMUNICATIONS

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Abstract:

This paper presents a multiband miniaturized fractal antenna designed and fabricated based on Koch Fractal geometry. The proposed antenna adopts 2-iteration Koch fractal structure fabricated on FR-4 epoxy substrate, with a overall size of 29.6x35.7x1.6mm^3 .The Koch fractal antennas (iteration -0,1,2) are simulated over the frequency range (1-12GHz) using ANSYS HFSS software to analyze the radiation characteristics in terms of Return loss, VSWR, Gain and Bandwidth .All the 3 antennas are exited using 50 ohms micro strip feed line. The simulation results of the 2-itration Koch MPA produces better radiation characteristics with 7.74% of Miniaturization. so it is fabricated ,which shows 4 resonances at at 2.7 GHz,6.6 GHz,8.4 GHz, and 11.3 GHz center frequencies.. The proposed antenna validated using VNA and the resonating bands covered by this antenna are (2.4-2.77 GHz), (6.5-6.682 GHz) (8.1-8.42 GHz), (10.8-11.4 GHz) which proves that it is suitable for Wi-Fi, C and X band wireless communications. More over the measured results of the proposed antenna found to be in very good matching with its numerical simulated results

Keywords: Fractal antenna, Miniaturization, Iteration, Koch geometry.

1.INTRODUCTION

The modern antenna designers concentrate on Multiband , Miniaturized antennas for mobile and wireless services. However a traditional monopole, dipole antennas cannot fulfill these features because of its limited bandwidth characteristics. Micro strip patch antennas are being used in each of the wireless system because of their features like compact, less weight, low profile, conformal and low cost. The methods preferred to reduce the size of the patch antennas are slotting, DGS, fractals. Fractal means self similar segment. There are different Fractal structures like Sierpinski Triangle, Carpet, Minkowski, Koch, Hilbert curve which are mostly used in antenna design for obtaining multi resonant behavior with shrinking dimensions. The Bandwidth of a single band Micro strip Triangular patch antenna is enhanced using a line slot [1].A compact patch antenna array designed for high frequency 60GHz applications with larger Bandwidth[2]. Compact slot antenna designed for Bandwidth enhancement and multi bands [3-5].The multi resonant fractal antennas with their multi resonant behavior presented with its dimensions [6-7]. A modified Sierpinski Fractal antenna with rectangular slots , CSRR and a SPK Bowtie antenna are developed and Analyzed for obtaining multiple resonances[8-10]. Koch fractal antennas are studied as small antennas and designed for multiband applications[11-14].A Koch fractal geometry is developed on a log periodic antenna to increase radiation performance characteristics[15].A stacked rectangular patch antenna with stacked pins presented for GPS, Cellular communications[16].A energy harvesting Koch fractal antenna presented for LTE,GSM, UMTS and WiFi bands [17].

2. PROPSED ANTENNA DESIGN METHODOLOGY:

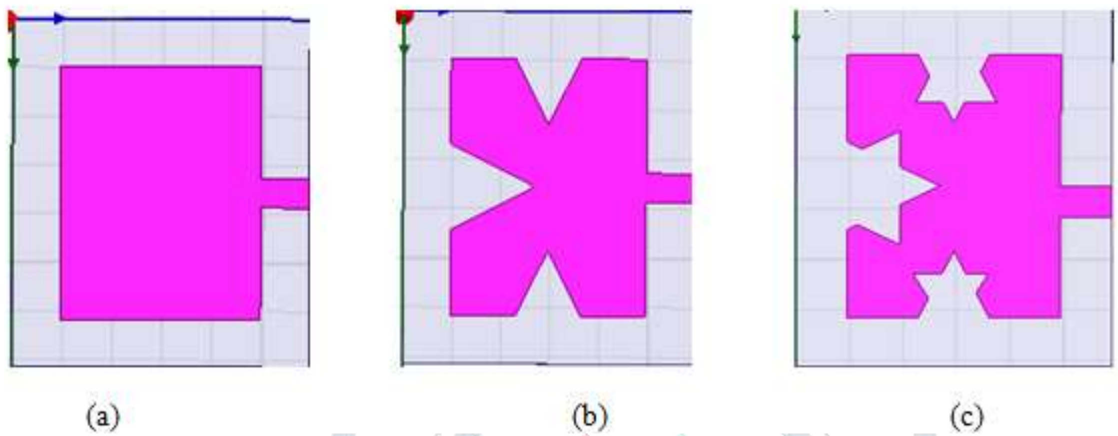


Fig.1.Koch Fractal antenna iterations (a) Iteration-0, (b) Iteration-1, (c) Iteration-2

Table1.Design parameters

Antenna parameter	Size(mm)
Substrate Name	FR4-epoxy
Di electric constant	4.4
ubstrate length L_S	29.6
Substrate width W_S	35.7
Substrate thickness	1.6
Ground length	29.6
Ground width	35.7
Patch length	19.98
Patch width	26.08

The designating of proposed antenna involves 3 stages as shown in the Fig.1. A Koch fractal structure is used to miniaturize the design. There are 4 sub sections in each iteration of the Koch. Curves Koch fractals provides longer electrical path length .After 'n' iterations the length of element becomes $(4/3)^n$. However the end to end length of each iteration should be kept same. The shape of Koch fractal is un even and highly rough .So it is highly recommended as a good radiator. The iterative Function system (IFS) used for generation of Koch Fractals. In this work the inclination angle Θ for the new subsection with respect to the previous subsection is considered as 60^0. The similarity dimension of Koch fractal geometry is defined as $D = \frac{\log(N)}{\log(\frac{1}{f})}$

$$D = \frac{4}{3} = 1.268$$

Where 'N' is the number of subsections in each additional iteration and 'f' is the scale factor which changes with the changing inclined angle.

Here $f = \frac{1}{1+2cos\theta}$

2. 1ITERATION-0 KOCH FRACTAL ANTENNA:

The design procedure of iteration-0 Koch Fractal antenna evolved from the designing of a rectangular micro strip patch antenna with dimensions as shown in the Table-1.For this the working frequency is chosen as 5.8GHz. The antenna is structured by picking up the substrate material as FR4-epoxy of dielectric constant 4.4 as high di electric constant reduces the size of the antenna. The length and width of Substrate, ground, patch are determined by using the below patch antenna formulas.

The patch width $W_P = \frac{c}{2f} \text{x} \sqrt{\frac{2}{\varepsilon r+1}}$

The patch Length $L_p = \frac{c}{2f}(\frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2} \sqrt{1+12h/w})^{-1/2} - 2\Delta L$

Here ε_r- is the relative permittivity or dielectric constant of the substrate

ΔL is the effective length subjected to the correction factor

The length and width of the ground plane are same as the substrate and are chosen as

$W_g = W+6h$

$L_g = L + 6h$

2.2 ITERATION-1 KOCH FRACTAL ANTENNA:

Koch fractal can be generated on a two dimensional plane by the following Algorithm.

$$w\begin{pmatrix} x_1 \\ x_2 \end{pmatrix} = \begin{pmatrix} a & b \\ c & d \end{pmatrix}\begin{pmatrix} x_1 \\ x_2 \end{pmatrix} + \begin{pmatrix} e \\ f \end{pmatrix} = Ax + t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

In the above equation x_1 , x_2 are two end to end points of a line segments, and a, b, c, d, e and f are real numbers

After mapping transformation the equation can be written as

$$W(x_1 \;\; x_2) = (ax_1 + bx_2 + e, \;\; cx_1 + dx_2 + f) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The displacement transformation matrix A can be written as $A = \begin{pmatrix} rcos\theta & -rcos\theta \\ rsin\theta & rcos\theta \end{pmatrix}$

The generation of iteration -1 starts on the rectangular MPA by dividing its side lengths and width in to three equal sections $L_1 = L_2 = L_3 = 6.66$mm, $W_1 = W_2 = W_3 = .8.693$ On the middle section of each side is an equilateral triangle of suitable size (S_W , S_L) created on the patch Later these 3 triangles were subtracted from the patch to get the required structure as shown in Fig.1(b)

2.3 ITERATION-2 KOCH FRACTAL ANTENNA:

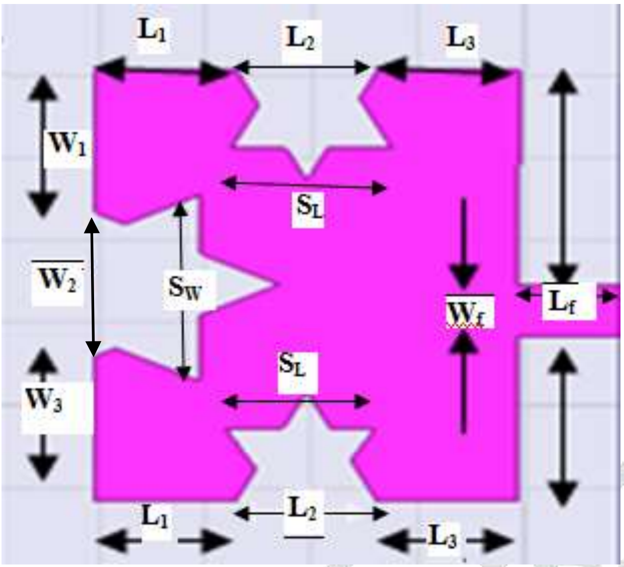


Fig.2 Proposed Iteration-2Koch Fractal antenna Geometry

Table2.Patch Dimensions

parameter	Length(mm)
$L_1 = L_2 = L_3$	6.66
$W_1 = W_2 = W_3$	8.693
L_f	4.81
W_f	3..0
S_L	6.66
S_W	8.693

To enhance the miniaturization and radiation characteristics, the iteration-1 is further modified such that each section is subdivided into subsections and each section should have 4 segments. The 3 triangles of iteration-1 are copied and rotated by 180^0 to crate a star like structure on three sides of the patch and later they etched away to form the geometry shown in Fig 2. After etching these triangles the % of miniaturization is increased to 7.74 .

3. SIMULATION & MEASURED RESULTS :

Fig.3 depicts the iteration wise simulation results of Koch Fractal antenna , in which Fig.3 (a),(b) are related to iteration-0 with 2 bands at center frequencies at 5.1 GHzz and 10.1GHz. similarly Fig.3.(c),(d) describes iteration-1 performance with 5 resonances centered at 2.9GHz, 6.8GHz, 9.1GHz, 10.6GHz and 11.7GH with reasonable Return loss ,VSWR values. Finally proposed iteration-2 Koch fractal antenna return loss, VSWR results described by Fig.2.(e),(f), which has 4 center frequencies 2.7 GHz, 6.7 GHz, 8.1 GHz, 11.6 GHz with minimum values of return losses are -10.27 dB, -12.2 dB, -11.5 dB, -34.7 dB respectively. The gain values at these resonant frequencies are 0.982 dB, 1.967 dB, 3.33 dB, 11.33 dB. The percentage of miniaturization is calculated by subtracting the area of 3 etched triangles formed during 1st iteration plus 6 small triangles formed during 2nd Iteration also increased to 7.74%.The simulation Results are compared for all the three iteration antennas in Fig.4 whih shows that proposed antenna has minimum value of S(1,1)dB parameter value of

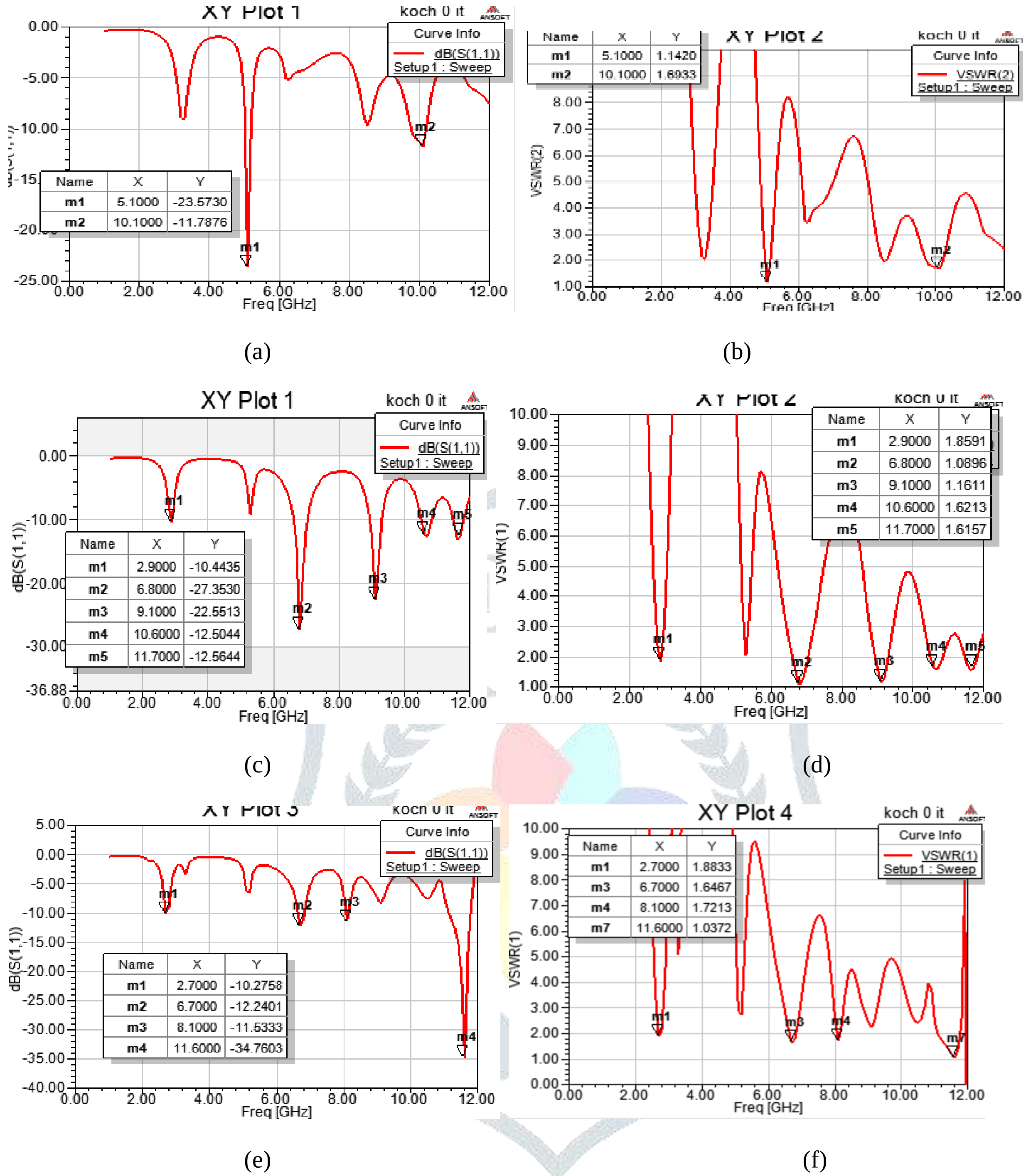


Fig.3.Simulation Results of Koch Fractal antennas (a) Return loss plot of Iteration-0, (b) VSWR plot of Iteration-0,(c)) Return loss plot of Iteration-1, (d) VSWR of Iteration-1, (e)) Return loss plot of Iteration-2, (f) VSWR of Iteration-2

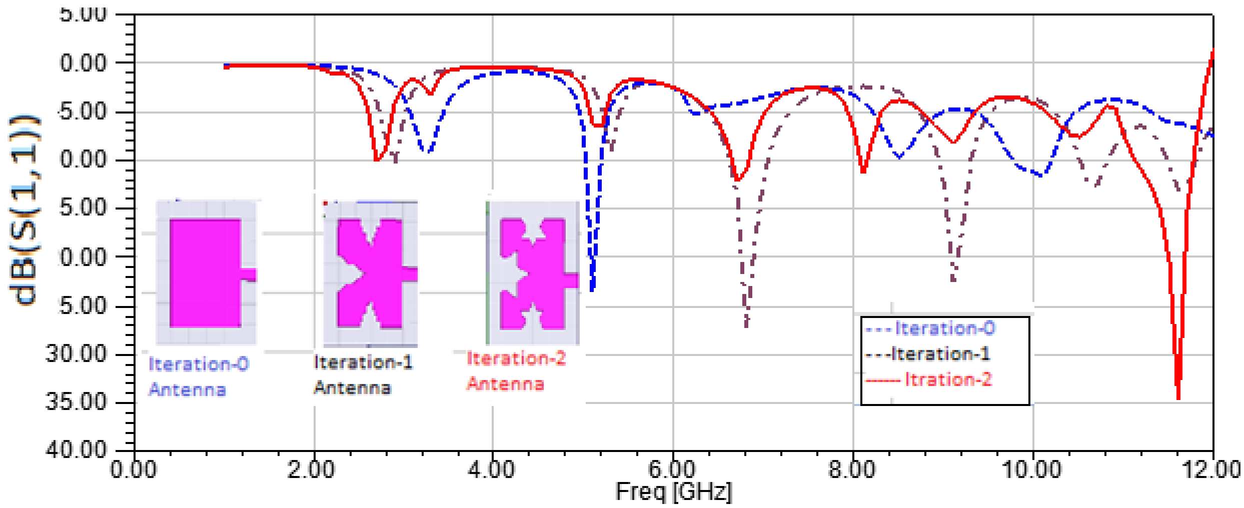


Fig.4. Comparison of Simulation Results of Koch Fractal antennas for iteration 0,1 and 2

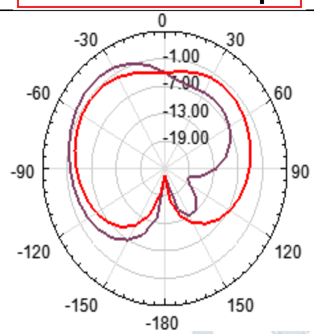
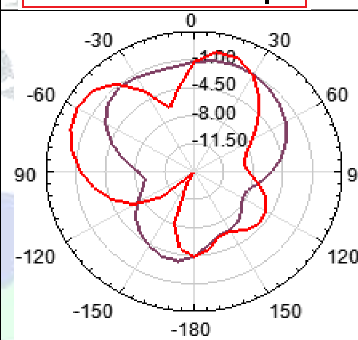
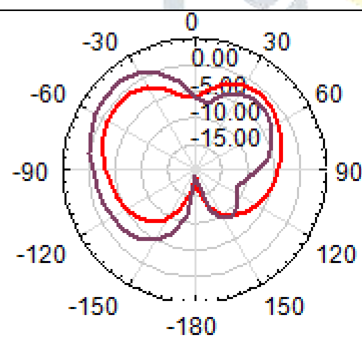
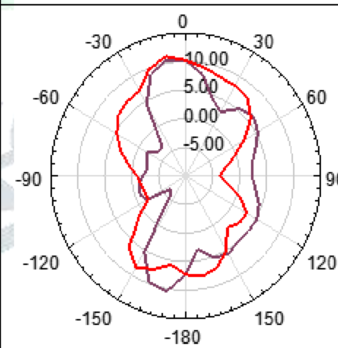
f_r(GHz)	E ,H Plane Radiation Patterns	f_r (GHz)	E ,H Plane Radiation Patterns
	E Plane Φ=0⁰ H Plane Φ=90⁰		E Plane Φ=0⁰ H Plane Φ=90⁰
2.7		8.1	
6.7		11.6	

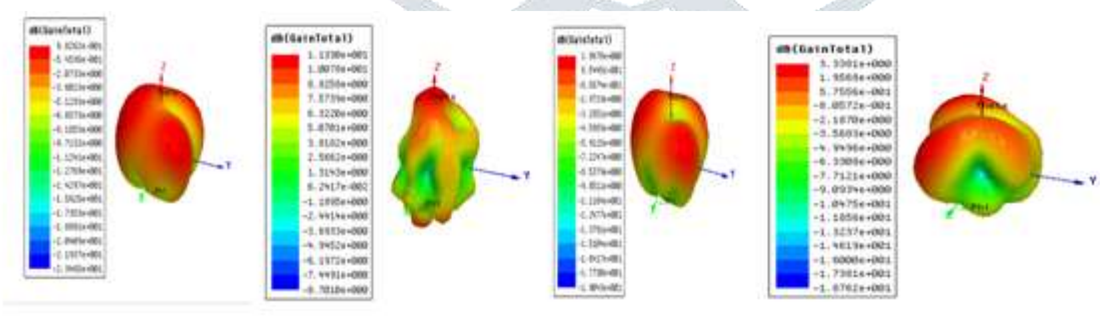
Fig5. Simulated Radiation Patterns of proposed 2- iteration Koch fractal antenna

Tanle.3 comparative study of Koch Fractal antenna's iterations using Simulation results

Table3. shows the comparative study of radiation parameters and influence of iterations on the number of

Iteration order No	f_r (GHz)	Bands(GHz)	S11(dB)	VSWR	Ga in (dB)	BW(MHz)	% impedance BW	% of Miniaturization
Koch ITERATION -0	5.1	5.01-5.193	-23.573	1.142	-9.9641	178	5.23	-
	10.1	9.8-10.2	-11.787	1.693	7.146	40	4	
Koch ITERATION -1	2.9	-	-10.443	1.859	-2.4738	-	-	6.57
	6.8	6.613-7.0427	-27.353	1.0896	2.6834	429	5.85	
	9.1	8.932-9.30	-22.551	1.161	5.2933	370	4.03	
	10.6	10.50-10.825	-12.504	1.621	5.4983	325	1.52	
	11.7	11.473-11.8	-12.564	1.6157	5.3876	327	2.8	
Koch ITERATION -2	2.7	-	-10.27	1.88	0.982	-	-	7.74
	6.7	6.63-6.83	-12.2	1.64	1.967	200	2.91	
	8.1	8.06-8.14	-11.5	1.72	3.33	80	0.98	
	11.6	11.1-11.7	-34.7	1.03	11.33	600	5.26	

resonant frequencies .In the evolution of the antenna, it is noticed that the lower resonant frequency value reduced from iteration- 0 to iteration-1 and the number of resonances are more in case of iteration-2. The reflection coefficient value is obtained better in iteration -2 antenna and the percentage of Miniaturization is also more. The radiated power in all directions can be viewed using radiation patters shown in Fig.5.The gains of proposed antenna at resonant frequencies are shown by using 3D Polar plots ahown in the Fig.6 and reported as shown in the Table3.



(a) (b) (c) (d)

Fig6. Simulated Gains of proposed 2- iteration Koch fractal antenna using 3D-Polar plots (a) at 2.7 GHz Gain is 0.982 dB (b) at 6.7 GHz Gain is1.967 dB (c) at 8.1 GHz Gain is 1.2 dB (d) at 11.6 GHz Gain is11.33 dB. The E plane, H-plane radiation patterns are shown in Fig5.The gain values are more at high frequencies rather than low frequencies in the Fig.7.

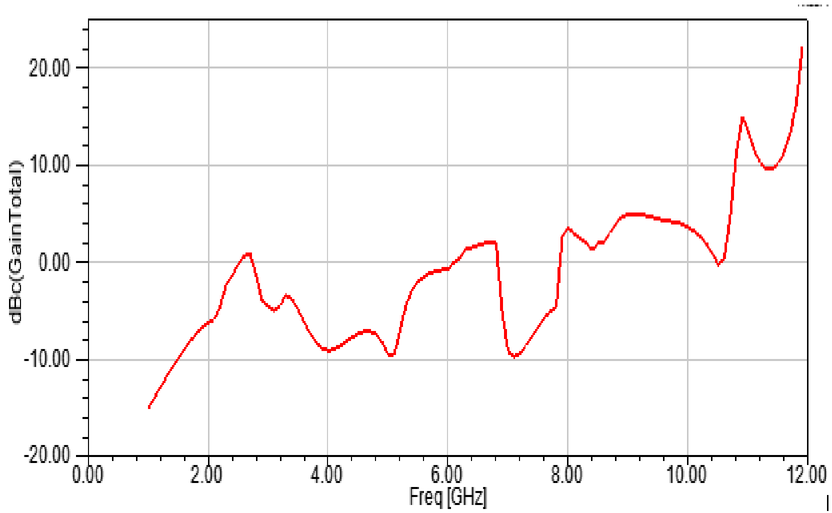


Fig.7.Gain Vs Frequency Plot of Proposed 2- iteration Koch fractal antenna

4.PROPOSED FABRICATED PROTOTYPE AND ITS VALIDATION USING VECTOR NETWORK ANALYZER:

(a) (b) (c)

Fig.8. Experiment set up of proposed 2- iteration Koch fractal antenna (a) patch top view (b) Ground plane (c) Antenna validation set up using VNA

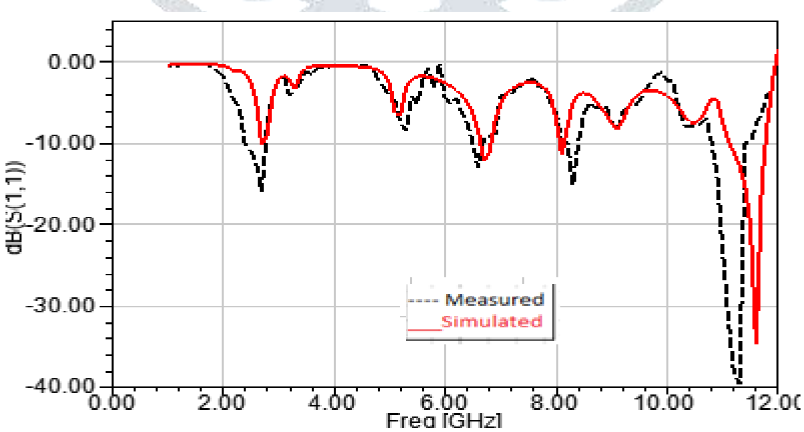


Fig.9. Comparison of simulation results with measured results of proposed antenna based on Return loss plot

Table4. Comparison of simulation results with measured results of proposed 2-iteration Koch Fractal Antenna

Simulation Results				Measured results			
f_r (GHz)	Bands(GHz)	BW(MHz)	S11(dB)	f_r (GHz)	Bands(GHz)	BW(MHz)	S11(dB)
2.7	-		-10.27	2.7	2.4-2.77	370	-15.9
6.7	6.63-6.83	200	-12.2	6.6	6.5-6.682	182	-13.12
8.1	8.06-8.14	80	-11.5	8.4	8.1-8.42	320	-10.0
11.6	11.1-11.7	600	-34.7	11.3	10.8-11.4	600	-39.61

Table 4. shows that the values of resonant frequencies obtained through simulation are nearly matches with the measured results.

Table5. Comparison of performance of proposedKoch Fractal antenna with alredy existing Koch Fractal antennas

Ref No	Iteration order, size(mm^2)	f_r (GHz)	Bands(GHz)	S11(dB)	Ga in (dB)	Application
[14]	2, 111x137	[4] 0.8249 1.8450 2.1020 2.4153	Not mentioned	-8.931 -7.255 -17.348 -49.456	1.227 0.617 1.909 5.112	LTE/GSM/UMTS/WiFi
[15]	2, 72x42	[3]1.75 3.2 4.25	1.47-4.52	-21.6 -45.3 -35.2	2.4dBi, 3.1dBi 2.3dBi	Wide band 2G/3G/4G/LTE/WLAN/Bluetooth
This work	2, 29.6x35	[4] 2.7 6.6 8.4 11.3	2.4-2.77 6.5-6.682 8.1-8.42 10.8-11.4	-15.9 -13.12 -10.0 -39.61	0.982 1.967 3.33 11.33	(Wi-Fi, C,X) Multiband wireless communication applications

Table5. shows the difference between proposed antenna and existing other reseacher's antennas,which proves that it is better interms of size and covers more bands.The design is also simple and compact with out any complexity in the feedstructure.

CONCLUSION:

A multiband 2-iteration Koch fractal antenna is designed in three stages using ANSYS HFSS software and fabricated .The Koch iteration-2 fractal structure proved better radiation capability than iteration-0,1 and helps in achieving multiple bands with decreased value of lower resonant frequency , without increasing the dimensions. The resonant frequencies are 2.7GHz, 6.6 GHz,8.4 GHz,113 GHz with gains 0.982dB,1.967 dB, 3.33 dB, 11.33 dB respectively. In the measured results the first band (2.4-2.77) covers Wi-Fi band, the second and third bands (6.5-6.682), (8.1-8.42) are in C band , the fourth band (10.8-11.4) lies in X band.Hence it is concluded that the proposed antenna is suitable for Wi-Fi, C and X band wireless communication applications with compact size as compared to the other existing antenna designs. In future the work can be extended by incorporating some other fractal structure along with Koch to increase Miniaturization..

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