A Dual Band Antenna Utilizing Sierpinski Fractal Geometry for X/Ku Band Applications

N. Srikanta, M. Pachiyannan

ABSTRACT--- This proposed research letter reported the different Iterations of Fractal antenna for X/Ku Band applications. The standard rectangular patch modified with different Iterations to achieve this dual band characteristics. In this research work the fractal structure is applied to attain the required resonance frequencies of 11.85/12.77/13.83 GHz with wideband behaviour. The overall dimensions of the patch is 38.04x29.44 mm utilizing high frequency supporting material Rogers RT/Duroid 5880 with dialectic constant of 2.2. This projected work is evaluated by ANSYS 3D High frequency structure simulator which uses a finite element approach solver for EM structures. The suggested work exhibits VSWR < 2, gain of 6.6 dBi with good radiation efficiency satisfying X/Ku Band applications, also it is suitable for remote sensing, surface movement radar applications.

Keywords: Fractal Structure, Iterations, Rectangular Patch, Remote Sensing, X/Ku Band.

I. INTRODUCTION

From past few decades the wireless applications are very much essential because of its advantages. These wireless technologies require antennas with large bandwidth, small dimensions and accordingly the researchers are turning their sights onto fractal structures. In current wireless communication systems antennas with multiple bands play an important role. The antenna that is designed should be able to cover multiple bands of frequencies and should possess low profile, high impedance matching along with being compact in size [1]. The microstrip patch antenna is desirable answer for these wireless communication systems, because of its worthwhile features like conformal nature, less manufacturing cost, less weight, and simple printed circuit fabrication mechanism during past two to three decades [2].

But, unfortunately there are certain limitations including narrow bandwidth, low power handling capability and less efficiency. By overcoming the limitations specified, fractal antenna became popular in the field of communications. Keeping these constraints in view, the Fractal antenna's geometry is utilised to attain multiband features [3]. The term "fractal" has its roots in the Latin word "fractus" which means untethered lines. Through a process that is recursive, self-similarity and self-affinity are brought out and the required geometry is attained for the structure [4]. The fractal geometry is obtained by re-dividing the entire antenna into different parts with each part a copy of the shape of original antenna [5]. Sierpinski Gasket which is important in the fractal antenna set was introduced by Waclaw Sierpinski in 1915.

These Fractals exhibit multi-band characteristics, a result of self-similarity properties, which enables optimization for Ultra-Wideband applications. The different UWB fractal antennas being reported recently with this concept [6]. The main use of fractal is its multiband functionality, high efficiency and smaller size as compared to the orthodox antenna.

From the above discussions the basic fractal antenna structure and design were studied. Many authors reported that the fractal antenna gain has less than 5 dBi and to improve the gain along with multi band characteristics the proposed antenna has been developed in this research work. In below section 2 discuss about antenna modelling and design, section 3 describe about the Iteration methods of the proposed antenna with results.

II. ANTENNA MODELING AND DESIGN

In this letter the standard Roger family Duroid 5880 material with relative permittivity of 2.2 and height 1.6 mm is approached. Basic antenna structure is exposed below in fig. 1.

The designed antenna's dimensions are as shown in table I.

To design an antenna with good impedance matching is necessary to achieve required frequency without any losses. In this way the 50 ohm line feeding technique introduced in this work which is easy to calibrate and measure the result. In this work 23.66x2 mm size microstrip line fed is used with centre of the patch to attain the maximum impedance.

Table I: Antenna Dimensions (in mm)

l	w	a	b	c	d
60	60	29.44	38.04	23.66	2
e	f	h	i	j	k
10.68	9.81	3.8	3.27	1.409	1.099

Parameters of the antenna like radiation pattern, return loss characteristics, voltage standing wave ratio (VSWR) are most needed for determining its performance.

Below mentioned are the design equations for the designed antenna, to calculate its dimensions [7].

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The RMSA width is computed by using equation (1) as given below

$$w = \frac{c}{2f_r\sqrt{\frac{(\varepsilon_r+1)}{2}}} \quad (1)$$

An effective relative permittivity is determined by equation (2)

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+\frac{12h}{w}\right]^{-\frac{1}{2}} \quad (2)$$

Extending the patch dimensions by Δl on both sides, due to fringing effect with respect to equation (3)

$$\Delta l = 0.412h\frac{(\varepsilon_{eff}+0.3)(\frac{w}{h}+0.264)}{(\varepsilon_{eff}-0.258)(\frac{w}{h}+0.8)} \quad (3)$$

The microstrip's length is as follows in equation (4)

$$l = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} - 2\Delta l \quad (4)$$

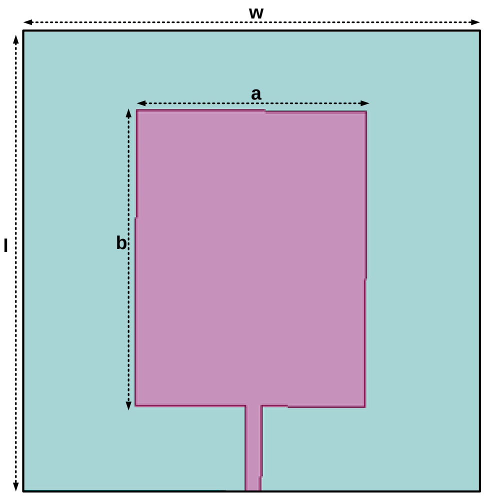

Fig. 1. Zeroth Iteration for designed antenna

The HFSS software simulates S_{11} Parameters, Gain, Radiation Pattern and VSWR. Fig. 2 shows S_{11} parameters of zeroth Iteration and this exhibits resonance frequency of 13.88 GHz with return loss of -10.62 dB which shows that more loss also the corresponding VSWR curve is shown in Fig. 3 which has 1.83.

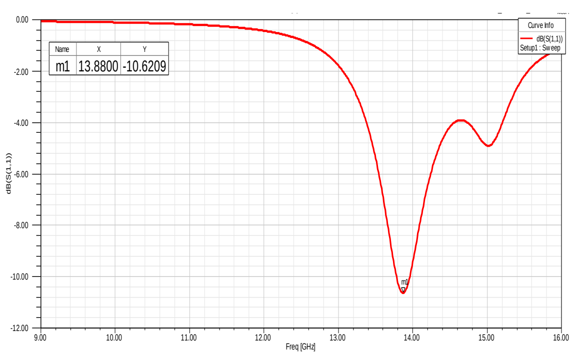

Fig. 2. Frequency vs Return loss curve for Zeroth Iteration

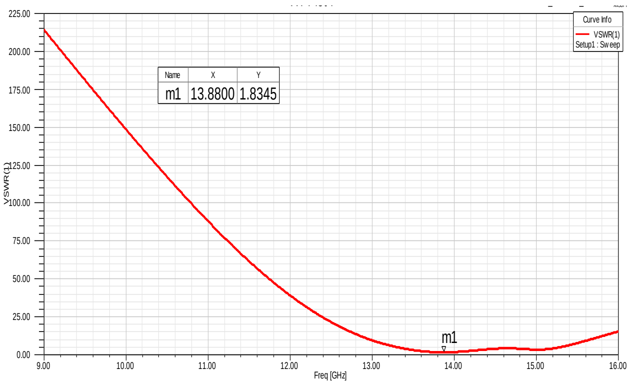

Fig. 3. Frequency vs VSWR curve for Zeroth Iteration

III. ITERATION METHODS, RESULT AND DISCUSSIONS

In this section to discuss various Iteration methods with different fractal structure to achieve the required resonance frequency. The overall Iteration 1, 2 and 3 structure is shown in Fig. 4.

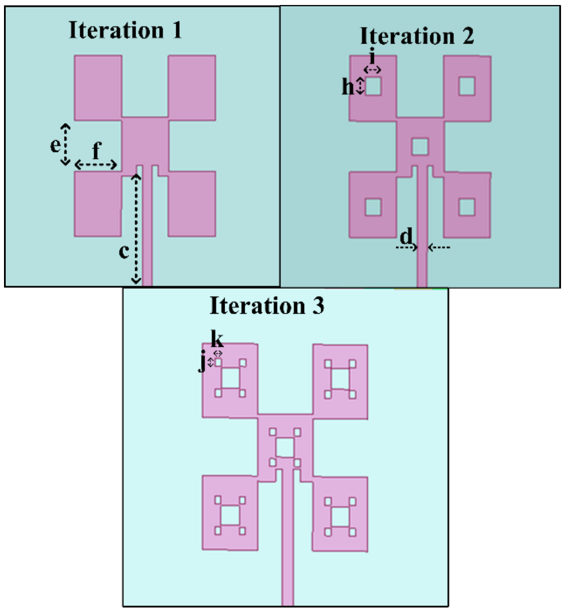

Fig. 4. Fractal Iterations for designed antenna

In Iteration 1, the regular rectangular patch modified with four slot structure with the dimensions of 10.68x9.81 mm, likewise the Iteration 2, 3 the corresponding dimension of 3.8x3.27 mm and 1.409x1.099 mm evaluated by ANSYS 3D High frequency structure simulator which uses a finite element approach solver for EM structures.

This Iterations tuned the required frequency of 11.85/12.77/13.83 GHz providing the maximum gain of 6.6 dBi. The corresponding VSWR, gain, Radiation pattern and return loss curve are shown below Fig. 5, 6, 7 and 8 respectively.

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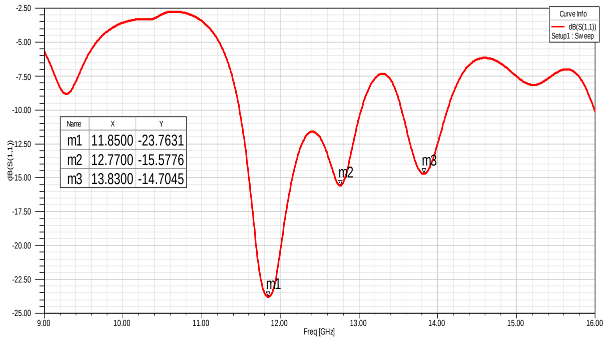


Fig. 5. Frequency vs Return loss curve of designed antenna (Iteration3)

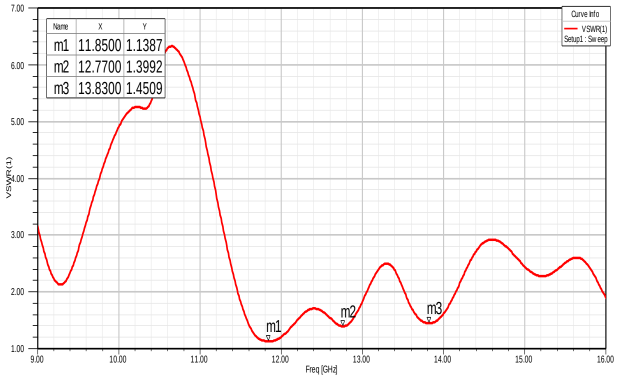
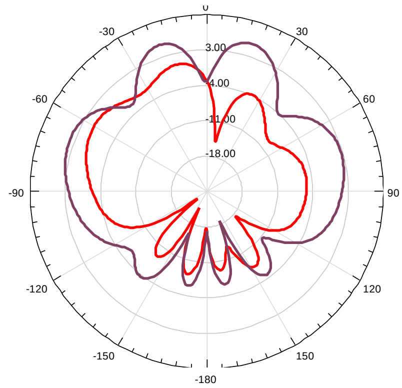
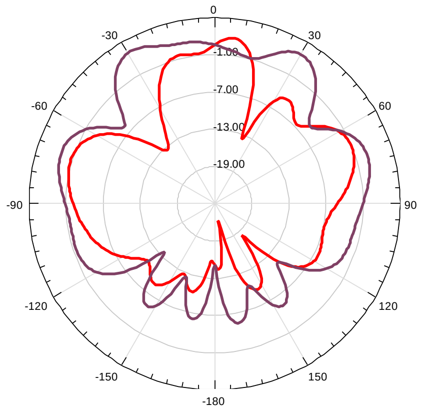


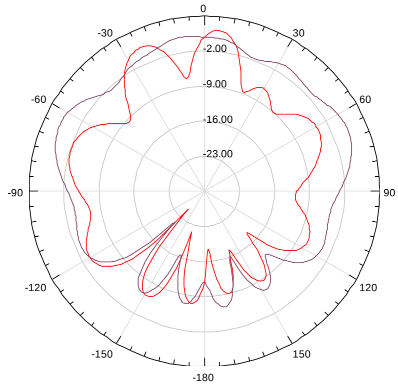
Fig. 6. Frequency vs Return loss curve of designed antenna



11.85 GHz

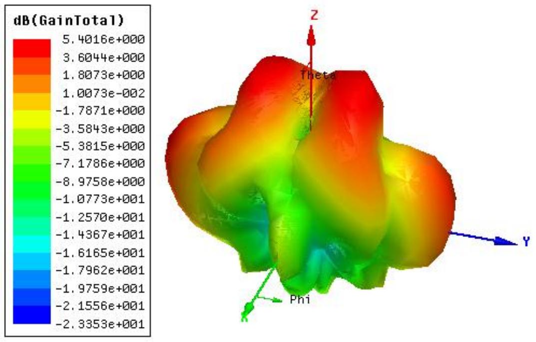


12.77 GHz

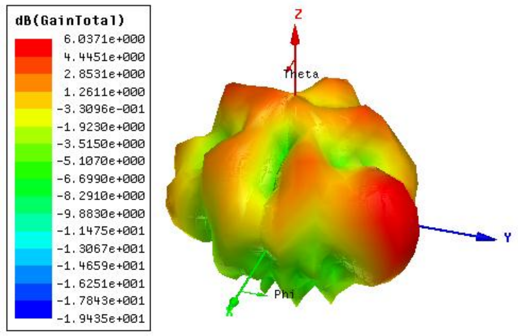


(c) 13.83 GHz

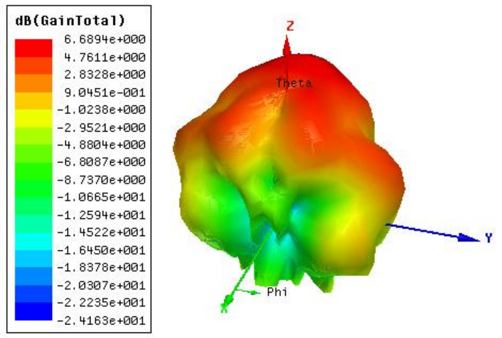
Fig. 7. Designed antenna's simulated radiation pattern



11.85 GHz



12.77 GHz



13.83 GHz

Fig. 8. Simulated Gain of designed antenna

From the above analysis the proposed work has compared with different iterations. In this way the below Fig. 9 shows that the comparative analysis with return loss curve with different Iterations. The figure show that the Iteration 3 has better result compared to existing work.

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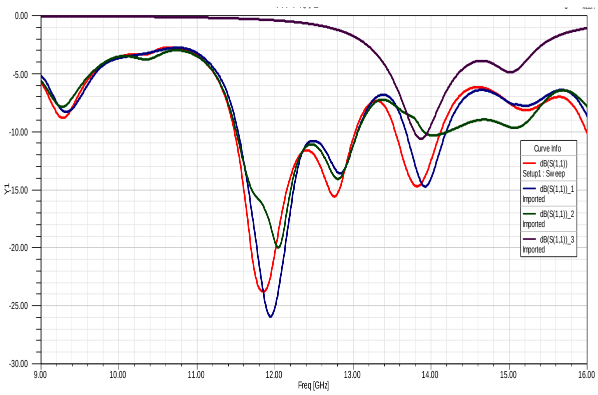

Fig. 9. Frequency vs Reflection coefficient characteristics of antenna for Iteration 0-3

Table II: Results comparison of different fractal Iterations

Iteration	Frequency (GHz)	Return Loss (dB)	VSWR	Gain (dBi)
0	13.88	-10.62	1.8345	2.8960
1	12.06	-19.88	1.2256	5.6438
	12.81	-14.04	1.4935	5.5519
	14.03	-10.33	1.8748	5.8346
2	11.94	-25.89	1.1067	5.6310
	12.84	-13.56	1.5286	6.1424
	13.96	-14.68	1.4614	6.1094
3	11.85	-23.76	1.1387	5.4016
	12.77	-15.57	1.3992	6.0371
	13.83	-14.70	1.4509	6.6894

From the above table conclude that the characteristic analysis of different Iterations and state that the Iteration 3 has better gain compared to the Iteration 0-2. This result recommend that the antenna can be operate at X/Ku band applications.

IV. CONCLUSION

By modifying the rectangular shape with different Iterations the fractal structure antenna studied and designed with the help of finite element structural simulator in this letter. The overall gain of 6.6dBi has been achieved with the dimension of 38.04x29.44 mm microstrip patch with different Iterations. Finally conclude that this structure is very much essential and highly recommended for X/Ku band applications and also it is suitable for the emerging sector of remote sensing, radar surveillance applications because this antenna operated at omnidirectional radiation pattern.

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