Iterative Study of Different Shapes of Fractal Antenna

Rutuja R. Chopade[1], Deepak M. Shinde[2]
Department of E&TC
[1, 2]Pune Institute of Computer Technology , Pune – 411043, India

Abstract-*Fractal structures are used for the antenna designed so as to obtain the compactness with better efficiency. This paper proposed introduction of fractal, types of fractal and when we design the fractal antenna what are tha effect of iterations. here fractal antenna is designed based on Sierpinski model. The number of iterations carried out are two. With the increase in iterations the performance parameters obtained were enhanced. The antenna has been developed to target the application as of mobile phones. The antenna is designed on frequency 2.1GHz and FR4 substrate is used which have dielectric constant of value 4.4.Here we used microstrip feed line in triangular shape and in circular shaped fractal antenna the position of coaxial feed is optimized to get proper impedance which is nearly about 50 ohm. The designed fractal antenna is low profile, compact in size and it can be used in cellular communication.*

Keywords-cellular communication, return loss, antenna, sierpinski

I. INTRODUCTION

Antenna is one of the most important part in communication technology world. It is used for various applications like mobile phones, satellite communication, laptop, television, etc. In today's world around one thousand billion antennas are used for many applications.

In mobile communication we need antenna of various sizes, i.e. from microstrip patch antenna for mobile phones to large horn antennae for towers. For cell phone communication we need to have cell tower. In India roughly, there are about five lakh cell towers. A few years ago, monopole antenna was used for mobile phones, which was large in size as it's height was about 9cm and operated at a single frequency only. Hence, there was increase in need of multiband operational compact antenna. To serve these needs people came up with different solutions. One of them was, a normal mode helical antenna having the height of 2cm, which was compact as compared to earlier monopole antenna. But, world is moving towards miniaturization. So, there was still the demand of compactness. As a solution, printed antennas came into existence. As there were further developments, class of printed antennas got wider and today, fractal antenna is one of its sub category.

Today, the fractal antennas are used in mobile phone and they are placed such that they are hidden inside the mobile phone itself. But as compared to other patch antennas, fractal antennas are even more smaller in size and effective in nature.

Most of the cell phones already have built in fractal antenna. Few years earlier, cell phones had antenna on the outside. But, due to the development in printed patch antenna, it was possible to embed antenna inside the mobile itself. Antenna used in mobile is fractal antenna, categorized under printed patch antenna, that is etched on circuit board which allows them to get a better reception and pick up more frequency.

II. FRACTAL

Fractal antenna is an antenna made up of self-similar structure, so that it increases length or perimeter of material which transmits or receives EM signals in a particular volume or total surface area.

The term 'Fractal' is from Latin word 'franger' which means to be 'broken' or 'fractured' to create irregular fragments. Nathan Cohen discovered fractals early in 1988 also patented in 1995. Mandelbrod, a french mathematician coined the term 'Fractal' about 20 years ago wrote his book "The fractal geometry of nature".

Basically, fractal is a geometrical shape that has the property of self similarity, which means, each part of the shape is a smaller version of the parent shape or original shape. Fractals can be classified as:-

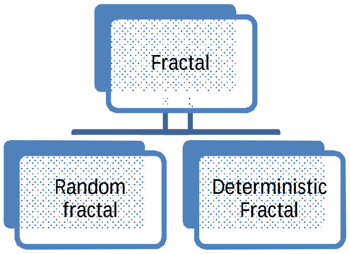

Fig. 1.Classification of fractals

A. Random fractal (Natural Antenna)

The fractals which are found in nature all around us are random fractals. These are also termed as Natural Antennas. These geometries are difficult to explain. For example branches of trees and plants, rivers, galaxies etc.

Fig. 2.Fractals in nature

B. Mathematical Antenna

The antenna which undergo iteration based on equations are called as Mathematical antenna. They are also called as Deterministic fractals. The example of mathematical antennas are Koch, Sierpinski gasket, Mendelbrot sets etc.

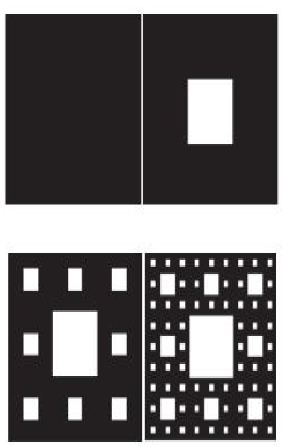

Fig. 3.Sierpinski Caropet

All the shapes which are present in regular geometry are used in mathematical antenna like rectangular, triangular, circular. In this paper we see triangular and circular shape fractal antenna and effect of the iteration.

III. DESIGN OF FRATCTAL ANTENNA

For Triangular shaped fractal antenna:-

- Effective dielectric constant :-

$$\varepsilon eff = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h_0}{w_0}\right]^{-0.5} \qquad (1)$$

Where,
W_0 is the width of patch
h_0 is the height of substrate.

- Fringes factor :-

$$\Delta L_0 = 0.412 h_0 \frac{\left(\varepsilon_{eff} + 0.3\right)\left(\frac{W_0}{h_0} + 0.264\right)}{\left(\varepsilon_{eff} - 0.258\right)\left(\frac{W_0}{h_0} + 0.8\right)} \qquad (2)$$

- Calculate the length of patch *(L)*:-

$$L_1 = L_0 - 2\Delta L_0 \qquad (3)$$

Where,

$$L_e = \frac{c_1}{2 f_{r0}\sqrt{\varepsilon_{eff}}} \qquad (4)$$

Where,
L_1:- Length of patch
ΔL :- extension in length due to fringing

- Calculate the width (W_1) :-

$$W_1 = \frac{C_1}{2\sqrt{\frac{\varepsilon_r + 1}{2}}} \qquad (5)$$

Where,
C_1 :- is the speed of light in free space
f_{ro} :- is resonant frequency

- Calculation of ground plane :-

$$L = 6h + 2L \qquad (6)$$
$$W = 6h + 2W \qquad (7)$$

Where,
h :- is height of substrate

L:- is length of patch
W :- is width of patch

- Side of equilateral triangular patch :-

$$a_0 = \frac{2C_1}{3 f_{r0} \sqrt{\varepsilon_{eff}}} \quad (8)$$

Where,
C_1 :- is speed of light in free space
f_{r0} :- resonant frequency
ε_{eff} :- is dielectric constant

For Circular shaped fractal antenna :-

- Radius of circular patch antenna:

$$a = \frac{F}{\left[1 + \frac{2h}{\pi \varepsilon_r F}\left(\ln\left(\frac{\pi F}{h}\right) + 1.7726\right)\right]^{\frac{1}{2}}} \quad (9)$$

Where,

$$F = \left[\frac{\left(8.791*10^9\right)}{\left(f_r \sqrt{\varepsilon_r}\right)}\right] \quad (10)$$

- Length of substrate *(L)*:-

$$L = 6h + 2a \quad (11)$$

- Width of substrate *(W)*:-

$$W = 6h + 2a \quad (12)$$

For all shapes we calculate some parameters by using formulae:-

- In terms of input reflection coefficient VSWR (Voltage Standing Wave Ratio) is defined as :-

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|} \quad (13)$$

Where,
Γ :- reflection coefficient

- The bandwidth of antenna is :-

$$BW = f_H - f_L \quad (14)$$

Where,
f_H :- Upper edge of the antenna bandwidth
f_L :- Lower edge of the antenna bandwidth
To measure bandwidth return loss is always below -10dB

- The iteration scale of the fractal antenna is :-

$$Iteration = \frac{a}{6} \quad (15)$$

Using above all above formulae triangle and circular patch antenna is implemented for the frequency f_r = 2.1 GHz. Then we are doing iterations on simple triangular and circular patch and observe the effect of iteration.

Calculated Parameters for triangular Antenna Designing

Table Head	**Parameters**	**Values**
1	Length of substrate	56.6364mm
2	Width of substrate	49.29mm
3	Height of substrate	1.6mm
4	Side of triangular Patch	42.968mm
5	Length of microstrip feed line	17.86mm
6	Width of microstrip feed line	5.05mm
7	Length of radiation box	56.6364mm
8	Width of radiation box	49.29mm
9	Height of radiation box	70mm
10	Side of triangle at 1st Iteration	7.1613mm
11	Side of triangle at 2nd Iteration	1.1935mm
12	Length of ground plane	56.6364mm
13	Width of ground plane	49.29mm
14	Dielectric constant	4.4

Calculated Parameters for circular Antenna Designing

Table Head	Parameters	Values
1	Factor *(F)*	1.7833
2	Diameter of circular patch *(a)*	38.856mm
3	Length of substrate	48.456mm
4	Width of substrate	48.456mm
5	Height of substrate	1.6mm
6	Length of radiation box	48.456mm
7	Width of radiation box	48.456mm
8	Height of radiation box	70mm
9	Length of ground plane	48.456mm
10	Width of ground plane	48.456mm
11	Dielectric constant	4.4
12	Diameter of circle at 1^{st} Iteration	6.4776mm
13	Diameter of at 2^{nd} Iteration	1.1793mm

IV. SIMULTION RESULTS

The triangular and circular shaped fractal antenna is an antenna which was designed to achieve frequency band of 3G. For simulation, used parametric values are given as in table I and table II respectively.

The design of circular shaped fractal antenna was carried out using the HFSS (High-Frequency Structure Simulator) tool vesion 13.0

Triangular shaped fractal antenna:-

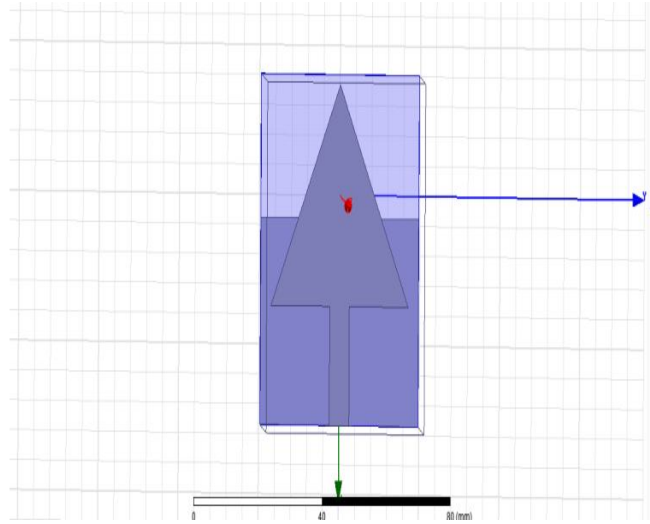

Fig. 4.Design of triangular shaped fractal antenna at 0^{th} iteration

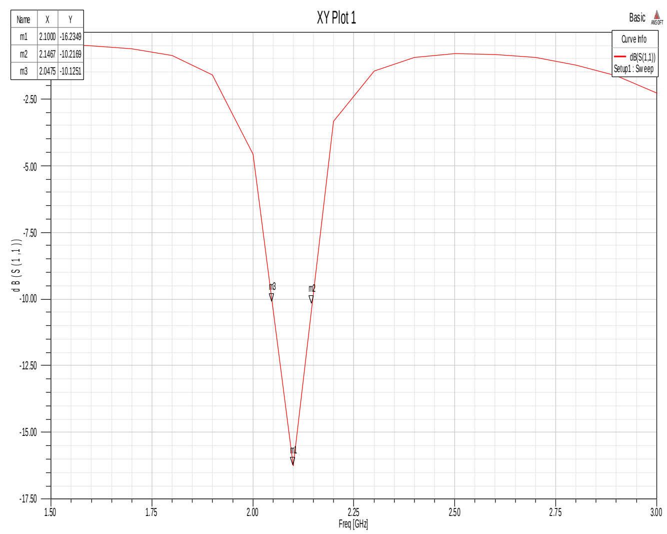

Fig. 5.Return loss of triangular shaped fractal antenna at 0^{th} iteration

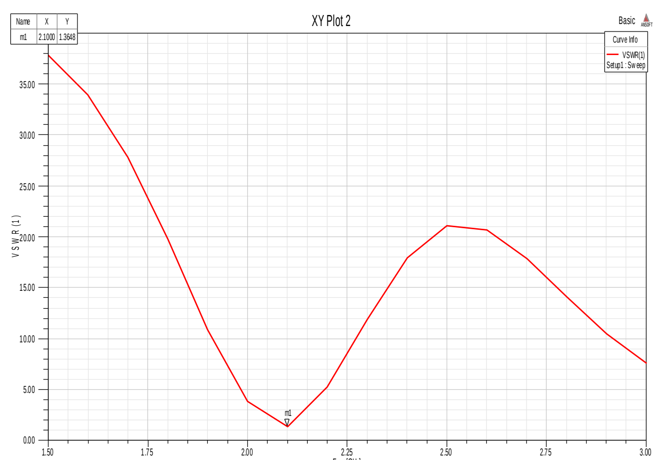

Fig. 6.VSWR of triangular shaped fractal antenna at 0^{th} iteration

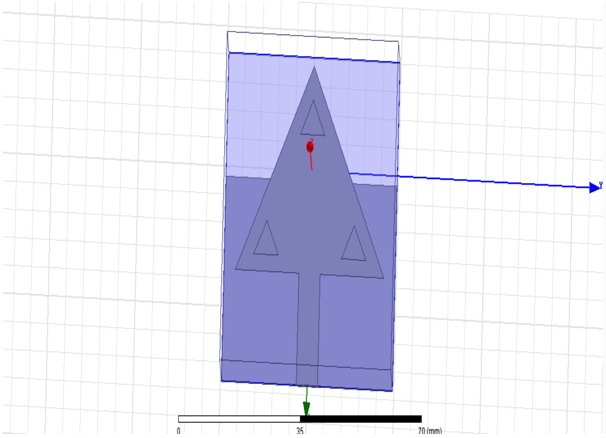

Fig. 7.Design of triangular shaped fractal antenna at 1st iteration

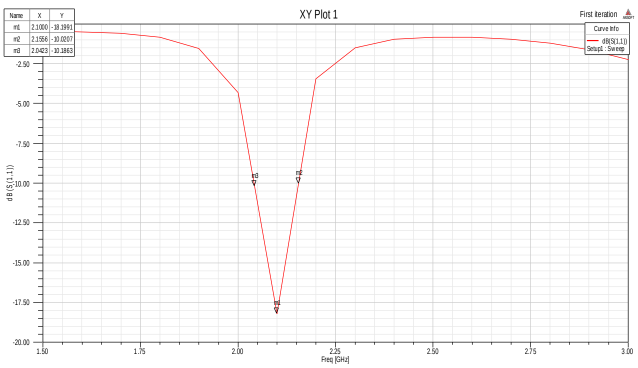

Fig. 8.Return loss of triangular shaped fractal antenna at 1st iteration

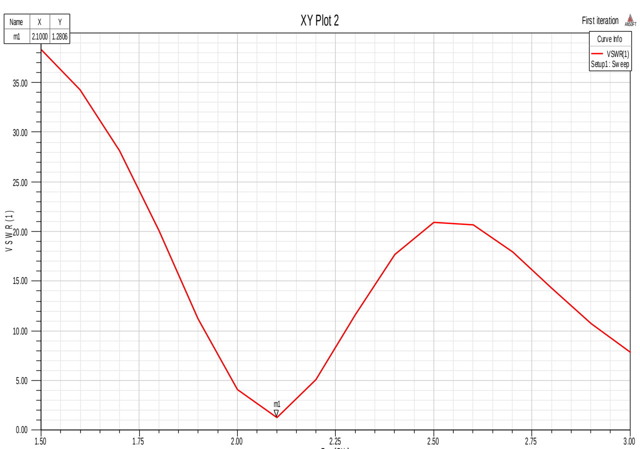

Fig. 9.VSWR of triangular shaped fractal antenna at 1st iteration

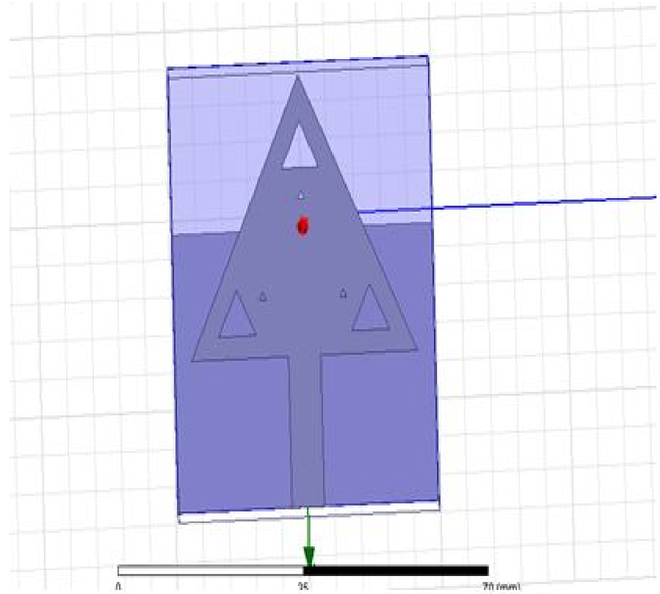

Fig. 10. Design of triangular shaped fractal antenna at 2nd iteration

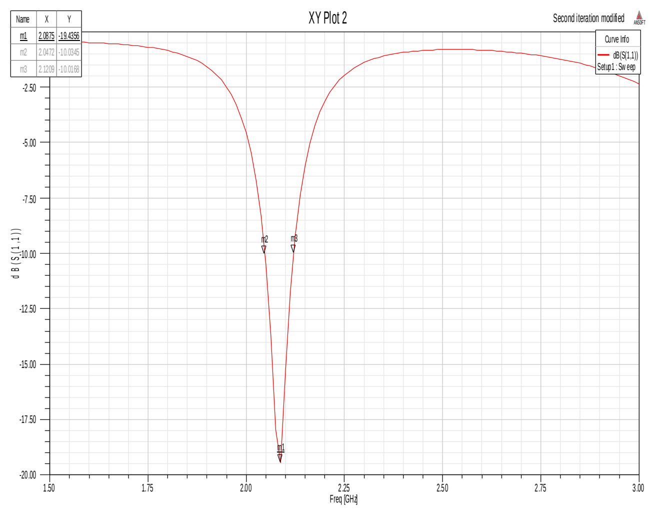

Fig. 11. Return loss of triangular shaped fractal antenna at 2nd iteration

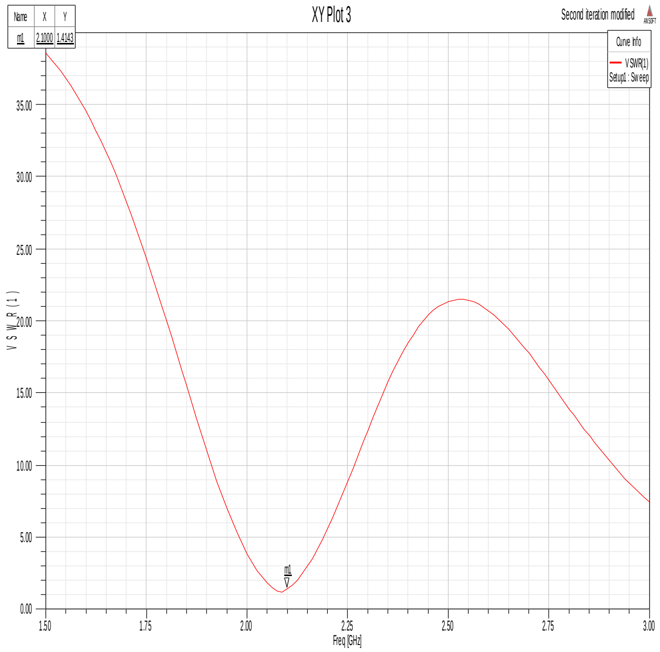

Fig. 12. VSWR of triangular shaped fractal antenna at 2nd iteration

Results Of Triangular Shaped Fractal Antenna

Sr. No.	Parameters	0th Iteration	1st Iteration	2nd Iteration
1	Resonant Frequency (GHz)	2.1	2.1	2.1
2	Return Loss (dB)	-16.2349	-18.1991	-19.4356
3	VSWR	1.3648	1.2806	1.4143

Circular shaped fractal antenna:-

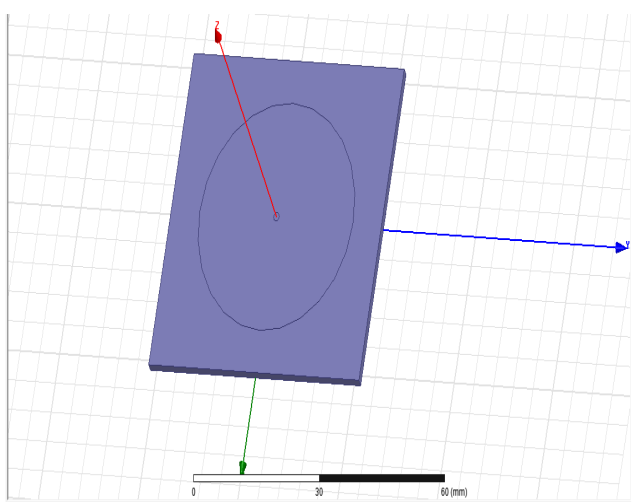

Fig. 13. Design of circular shaped fractal antenna at 0th iteration

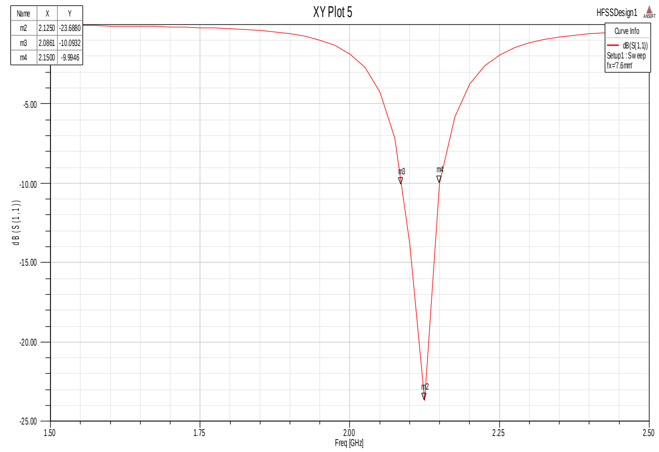

Fig. 14. Return loss ofcircular shaped fractal antenna at 0th iteration

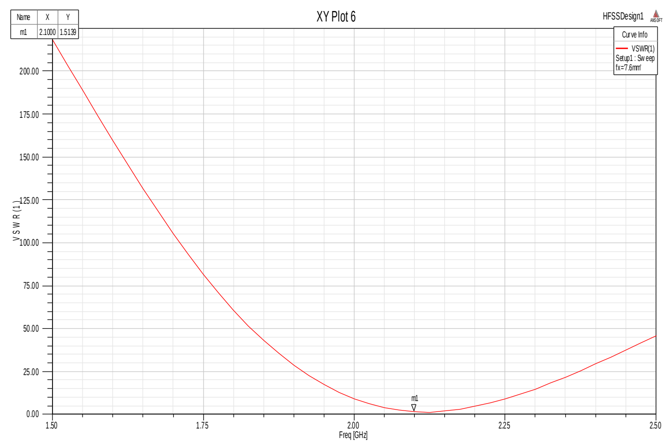

Fig. 15. VSWR of circular shaped fractal antenna at 0th iteration

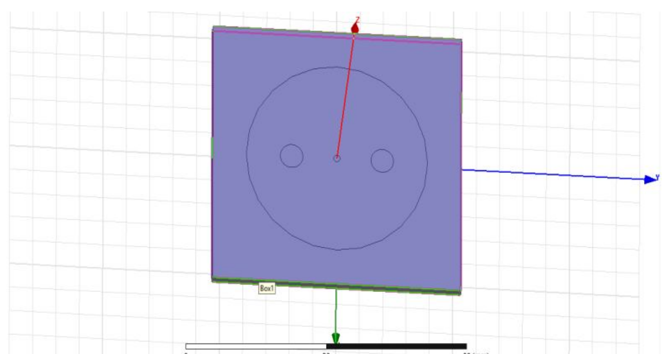

Fig. 16. Design of circular shaped fractal antenna at 1st iteration

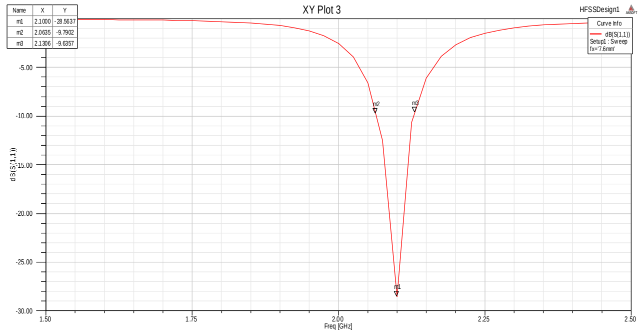

Fig. 17. Return loss of circular shaped fractal antenna at 1st iteration

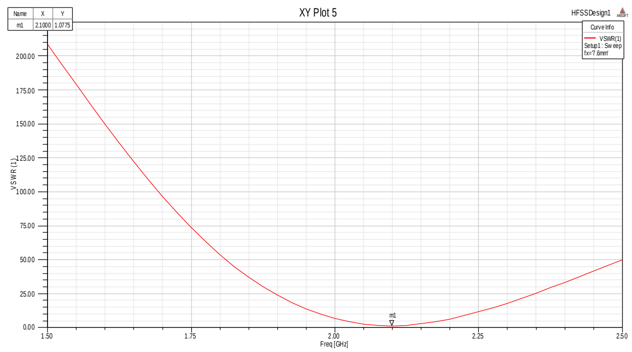

Fig. 18. VSWR of circular shaped fractal antenna at 1st iteration

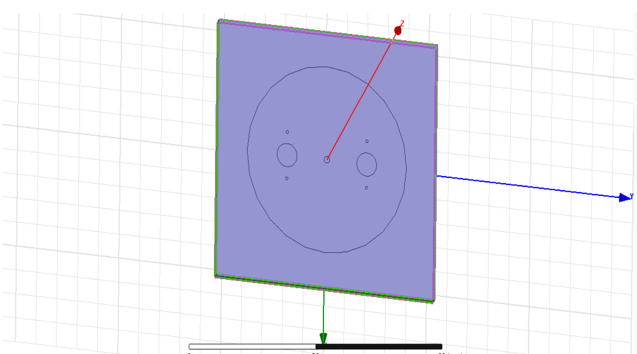

Fig. 19. Design of circular shaped fractal antenna at 2nd iteration

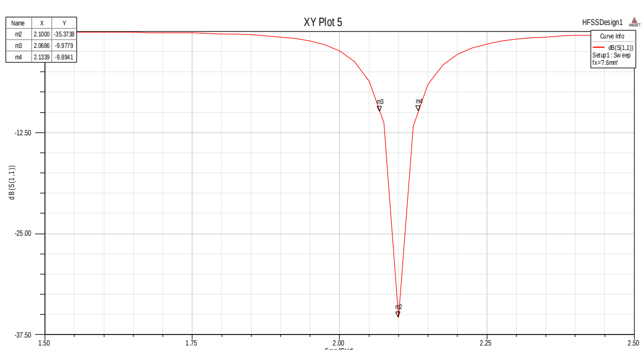

Fig. 20. Return loss of circular shaped fractal antenna at 2nd iteration

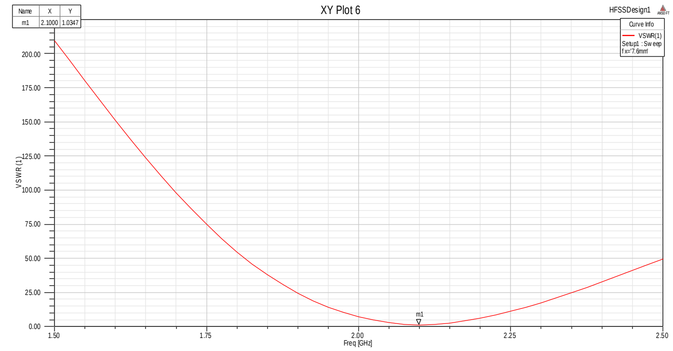

Fig. 21. VSWR of triangular shaped fractal antenna at 2nd iteration

Results Of Circular Shaped Fractal Antenna

Sr. No.	**Parameters**	**0th Iteration**	**1st Iteration**	**2nd Iteration**
1	Resonant Frequency (GHz)	2.1	2.1	2.1
2	Return Loss (dB)	-23.6880	-28.5637	-35.3738
3	Bandwidth (MHz)	38.9	64.1	65.3
4	VSWR	1.5139	1.0775	1.0347

From the above Table III and IV, we observe that, by increasing the iteration we get maximum possible bandwidth, minimum value of VSWR and efficient return loss.

V.CONCLUSION

The applications of designed circular shaped fractal antenna is in 3G cellular communication. To increase the bandwidth or to improve the other parameters we have done the iterations on triangular and circular shaped patch antenna. By performing iterations we have achieved efficient values of return loss, maximum bandwidth achieved of and VSWR is also in between 1 & 2.

REFERENCES

[1] Constantine A. Balanis, ―Antenna Theory: Analysis and Design,‖ 3rd Edition; John Wiley Sons Inc. New York, 2005.

[2] J.Guterman, A.A.Moreira and C.Peixeiro, ―Dual-Band Miniaturized Microstrip Fractal Antenna for a Small GSM 1800+UMTS Mobile Handset,‖ IEEE MELECON, May 12-15,2004, Dubrovnik Croatia.

[3] C. Puenfe, J. Romeu, A. Cardama, ―Fractal-Shaped Antennas, in Frontiers in Electromagnetics,‖ IEEE PRESS, 2000.

[4] M. A. Dorostkar, Z. H. Firouzeh, ―Design of Novel Multi and Wided Triangular-Circular Fractal Antenna for Mobile Communication and Upper UWB Applications,‖,IEEE 2014 7th Interanational Symposium on Telecommunications (IST 2014).

[5] Ravi Prakash Dwivedi and Divyanshu Upadhyay, ―High Gain Dual Band Antenna Using Fractal Geometry for Mobile Communication,‖ IEEE 2015 2nd International Conference on Signal Processing and Integrated Networks (SPIN).