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A Novel Metamaterial Inspired Star shape Fractal Antenna

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Abstract: A metamaterial-based novel compact microstrip antenna is presented for ultra-wideband (UWB) applications. The antenna consists of a layer of metamaterial made by etching a crossed-shaped slots, on the ground plane,respectively. The shunt inductance developed due to the patterned ground plane lead to the left-handed behaviour of the metamaterial. The proposed antenna hasa compact size of 45.4 × 31.6 × 1.6mm^3 and is fed by a 50 Ω microstripline. Radiating patch is fractal antenna of star shape with 6mm side length. The impedance bandwidth (−10 dB) is from 3 GHz to more than 14 GHz with maximum radiation in the horizontal plane and tends towards a directional pattern as the frequency increases. Maximum gain 15.8533db obtained from fractal antenna. The scattering parameter is obtain from fabricated antenna is -24.98.

Keywords: HFSS, Fractal, Metamaterial, Return Loss, Gain

I. INTRODUCTION

The wireless industry is witnessing an volatile emergence today in present era.Today's antenna systems demand versatility and unobtrusiveness. Operators are looking for systems that can perform over several frequency bands or are reconfigurable as the demands on the system changes. Some applications require the antenna to be as miniaturized as possible. Fractal plays a prominent role for these requirements. Fractals have non-integral dimensions and their space filling capability could be used for miniaturizing antenna size and their property of being self-similarityin the geometry leads to have antennas which have a large number of resonantfrequencies. Fractal antennas also have Multiband performance is at non-harmonicfrequencies. Fractal antennas have improved Impedance, improved SWR(standingwave ratio) performance on a reduced physical area when compared to non fractalEuclidean geometries. Fractal antennas show Compressed Resonant behavior. At higher frequencies the Fractal antennas are naturally broadband. Polarization and phasing of Fractal antenna is possible. In many cases, the use of fractal elementantennas can simplify circuit design. Often fractal antenna do not require any matching components to achieve multiband or broadband performance. Perturbationcould be applied to shape of fractal antenna to make it to resonate at different frequency.

In this paper Star fractal with different iterations have been generated using HFSS tool. fractal of Star length6 mm with different iterations as a monopole antenna have been simulated using HFSS software and show the desirableadvantages of fractal antennas. Different three iteration star fractal monopoles havebeen studied for GSM900 and GSM1800 bands .The Koch monopole exhibitsexcellent performance at 925 MHz and 1800Mhz and has radiation properties nearlyidentical to that of traditional, straight-wire monopoles at that frequency. The greatest advantage of the star monopole design is compactness. A size reduction of nearly50% was achieved over the straight-wire, ,λ/ 4 free-space monopole. This is highly significant for applications such as GSM cellular phones. Since it is half the size of the traditional monopole, it could easily be completely integrated within the case ofthe phone, eliminating the protruding monopoles commonly seen on many cellularphones. Since the radiation pattern is highly uniform and identical to that of a

Traditional λ/ 4 monopole, it could be used in nearly any type of wirelesscommunications receiver. The very similar gain to the traditional λ/ 4 monopole is

another benefit of the design. Another beneficial of fractal antennas is fractal antennasare in form of a PCB. Thus the Koch monopole presents an excellent, compactsolution to the traditional straight-wire monopole.

The non-integral dimensions, recursive irregularity, andspace filling capability of fractal antennas make it useful forvarious applications in wireless communication includingminiaturized antenna designs [1]. Their property of beingself-similar in the geometry leads to antennas of compact sizewith simplified circuit designs. Antennas, which have fractalgeometry, are self-iterative, exhibiting multiband operation.

Fractal antennas are frequency independent and have schemes for realizing low sidelobe designs. An antenna withfractal geometry is preferred to conventional antenna designsdue to the iterative behavior of the structure,which is believedto improve the performance factors like gain, bandwidth,return loss and frequency of operation [2].
Metamaterials are artificial structures designed by placing electromagnetic (EM) resonators, such as split ring resonators(SRRs), at regular intervals. The metamaterials havefrequency selective response and exhibit unique EM propertiessuch as negative permittivity and permeability, artificial magnetism and negative refractive index, which can be used to improve the performance of antenna [3]. Themedia composed of metamaterials have tunable effectivematerial parameters, and their electromagnetic responsecan be adjusted in real time. By using metamaterials as substratesor superstrates for antenna, significant improvements have been observed in the properties of the fractal antenna.
The rest of the paper is organized as follows. Section II outlines the complete design of zero iteration star patch antenna. Measured and simulated results of the proposed antenna are discussed in Section V. The conclusions are given in Section VI.

II. Zero Iteration star patch Antenna Design

An FR-4 substrate with 4.4 and thickness 1.6 mm was used in this design. The dimensions of the patch antenna were chosen in such way that when octagon stars fractal radiate energy.
A patch of area 36 ×36 mm was selected. Such a patch resonatedat 3.45 GHz in normal operating mode. To reduce theresonant frequency of the patch antenna, zero iteration wasetched out from its radiating patch at its center. After that it is compare with second iteration which was etched out from its radiating patch as in star form.
In the design of the zero iterationpatch, the dimension of the star lengthwas varied and the antenna was tuned to resonate at 3.45GHz using the commercial software HFSS. The final design obtainedis shown in Fig. 1. The length of each side was 6 mm.The feedline width was 9.7 mm, which givesa characteristic impedance of 50 Ω. The top view of Zero iteration patch antenna is as shown in the fig 1.

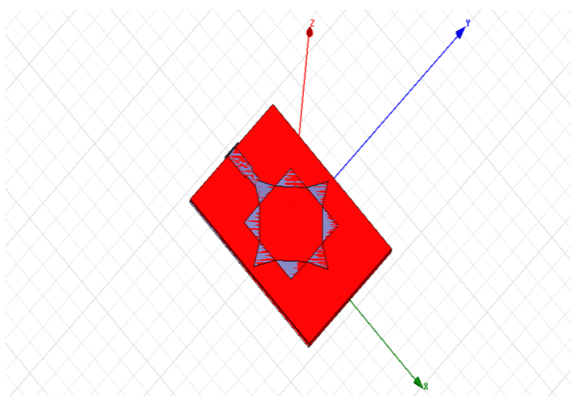

Fig 1. Top View of Zero Iteration Antenna

The proposed antenna is compare with metamaterial patch antenna as shown in fig 2. Square rings are cut into the ground plane with 0.2mm distance apart. On the other hand for making star shape cut in ground give 0.3mm star shape antenna. Another ground is designed with 2mm gap to metamaterial. Dimension of ground is 20.6 × 31.6.
The configurations of metamaterial cell are given in figure 2. Metamaterial cell side 3.6 mm.& No of EBG Cell: 4× 7.

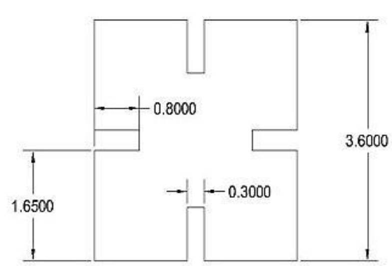

Figure 2. Metamaterial Structure

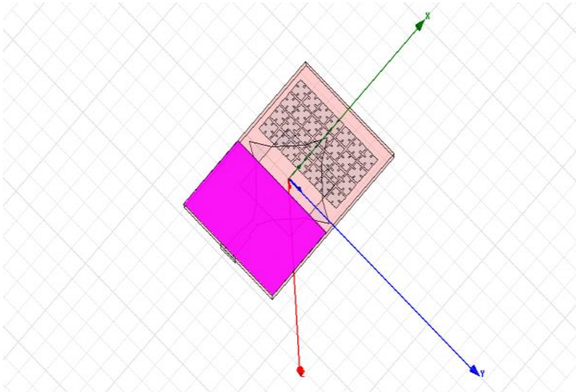

Fig 3. Bottom View of Zero Iteration Antenna

Return Loss is important parameter for an antenna design. The ideal return loss is assumed to be -10db. Return loss should be minimum. The antenna is simulated in HFSS tool and return loss is measure. In case of zero iteration antenna return loss is -13.220 db. The return loss of zero iteration is given by fig 3. This graphs shows that impedance matching of port to the antenna

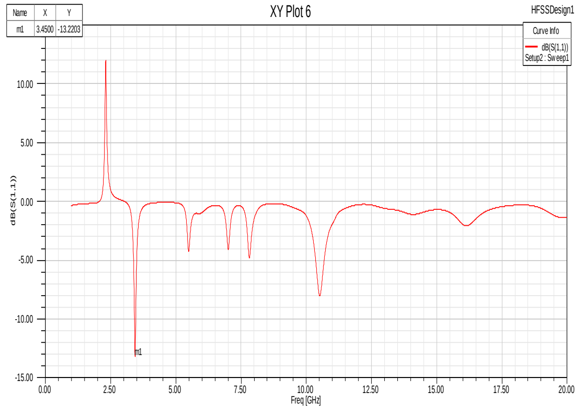

Fig 4. Return Loss of Zero Iteration Antenna

The current distribution gives an idea to distribute a charge to the whole surface. The distributed current is gives in ampere per meter. In case of zero iteration current distribution is given as $1.110 \times e^{+002}$ ampere per m^2.Current distribution of CSRR is shown in fig 5

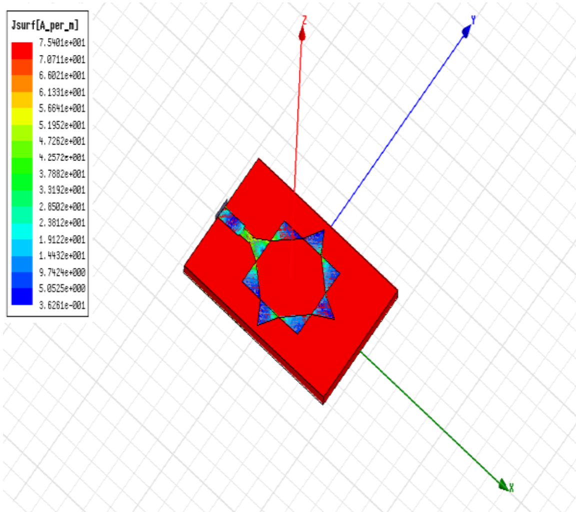

Fig 5. Current Distribution of Zero Iteration Antenna

Gain is also an important parameter to design an antenna. The Gain enhanced by drawing different slots. Radiation pattern of gain given in fig 6. Gain of zeroth iteration antenna is 7.6309 db

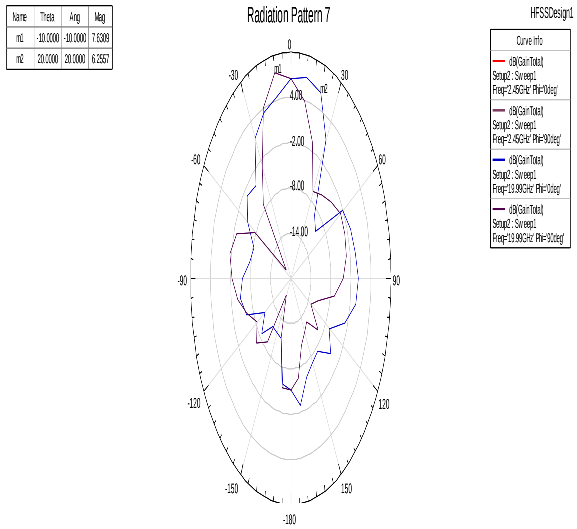

Fig 6. Radiation Pattern of Gain of Zero Iteration Antenna

III. First Iteration star patch Antenna Design

The First iteration antenna is compare with zeroth patch antenna as shown in fig 7. Same shape as previous antenna is designed.Side of iterative star antenna is reducingto 4mm. On the other hand air gap in two iteration is 1 mm.

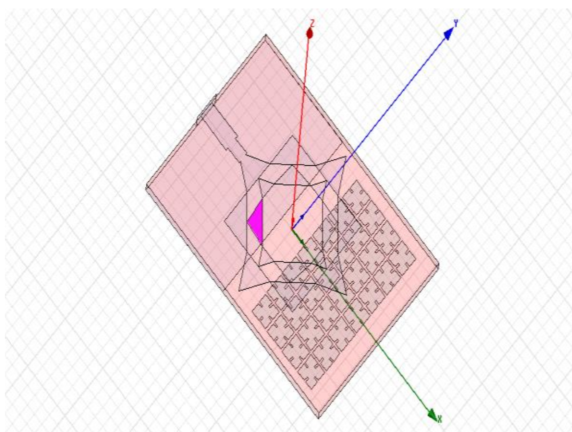
Fig 7. Top View of First Iteration Antenna

In case of 1st iteration return loss is -15.7035 db. The return loss of 1st iteration is given by fig 8. This graphs shows that return loss becomes more negative as compared to zeroth iterrative antenna.

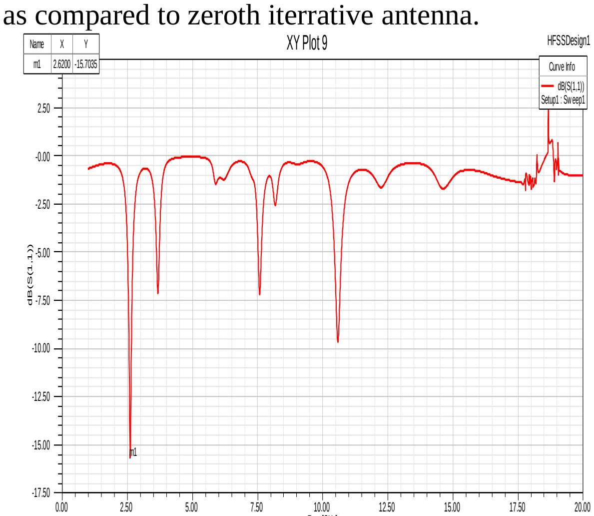

Fig 8. Return Loss of First Iteration Antenna

The currentdistribution is improved in 1st iteration. The distributed current is gives in ampere per meter. In case of 1st iteration current distribution is given as $1.11e^{+002}$ ampere per m^2.Current distribution of 1st iteration is shown in fig 9.

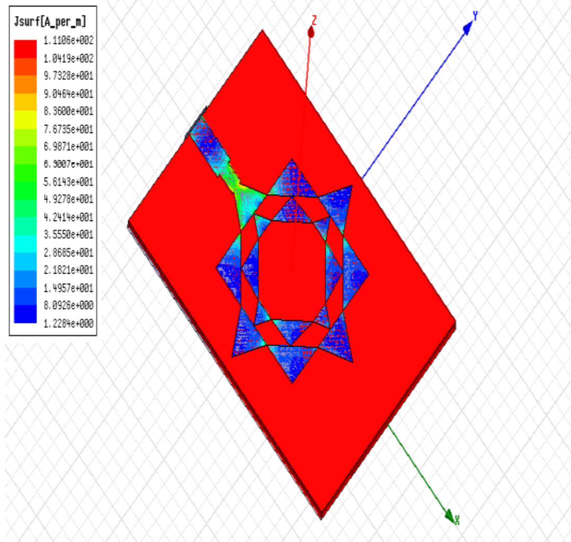

Fig 9. Current Distribution of First Iteration Antenna

Gain is improved with repeating shape. Radiation pattern of gain given in fig 10. Gain of 1st iteration antenna is 10.0762 db.

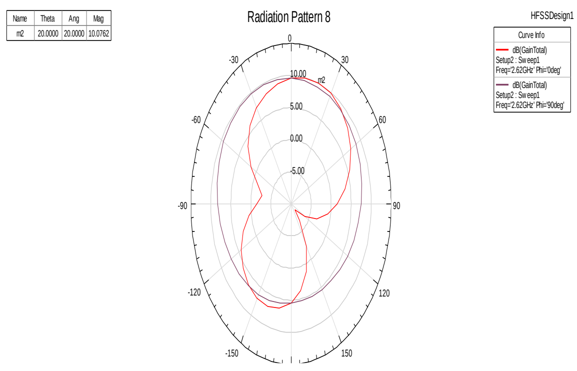

Fig 10. Radiation Pattern of Gain of First Iteration Antenna

IV. Second Iteration star patch Antenna Design

Second iteration is designed with repeating of 0th& 1st iteration antenna. This shape provides identical results of an antenna. The fractal having side of 6mm and gap between them is 2mm. Bottom view of 2nditeration is shown in fig 11.

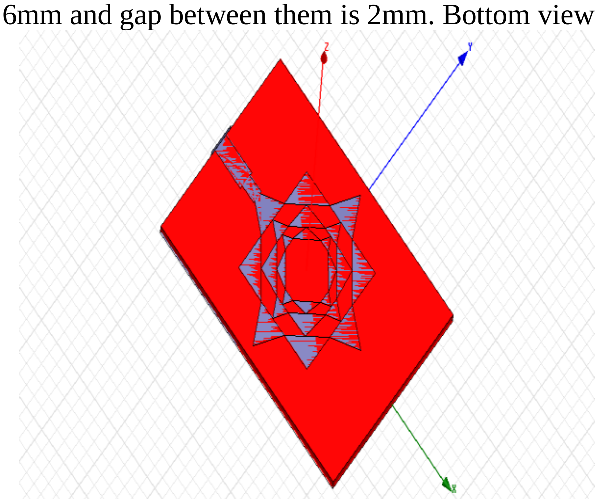

Fig 11.Top View of Second Iteration Antenna

In case of 2nd iteration return loss is -17.4276 db. The return loss of 2nd iteration is given by fig 12. This graphs shows that return loss becomes more negative as compared to zeroth iterative & 1st iterative antenna.

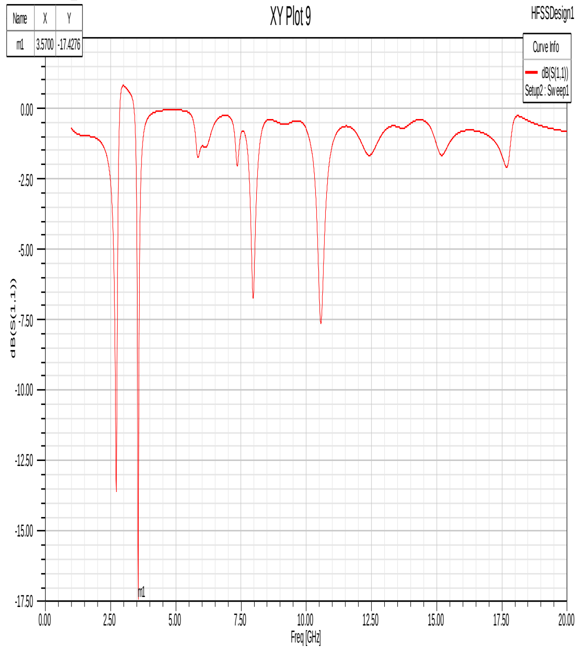

Fig 12. Return Loss of Second Iteration Antenna

The current distribution is improved in 2nd iteration. The distributed current is gives in ampere per meter. In case of 2nd iteration current distribution is given as 1.437 e^{+002} ampere per m^2.Current distribution of 2nd iteration is shown in fig 13.

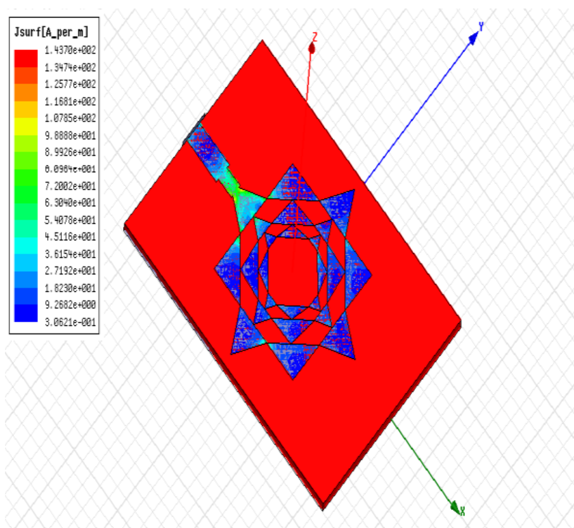

Fig 13. Current Distribution of Second Iteration Antenna

Gain is improved with repeating shape. Radiation pattern of gain given in fig 14. Gain of 2nd iteration antenna is 15.8533 db.

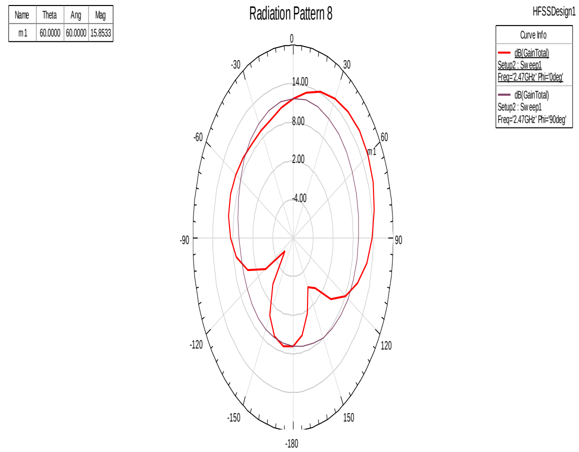

Fig 14. Radiation Pattern of Gain of Second Iteration Antenna

V. Fabrication of Antenna

The proposed antenna is fabricated in Microwave Imaging &Space Technology Application Lab , IIT Roodkee.

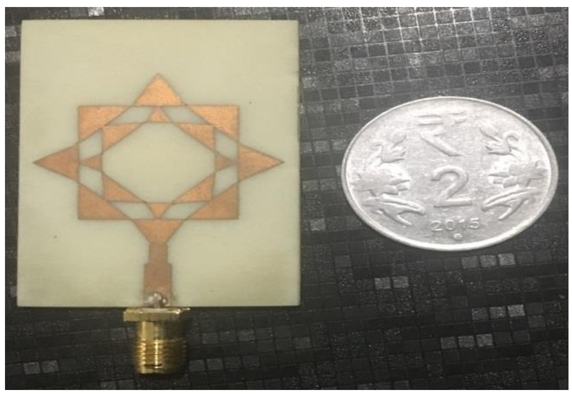

Fig 15 Front View of Fabricated Prototype of Fractal Antenna

Fabricated prototype of fractal antenna is shown in fig 15. The proposed antenna is fabricated in IIT, Delhi. 1st iteration of antenna is as shown in the figure.

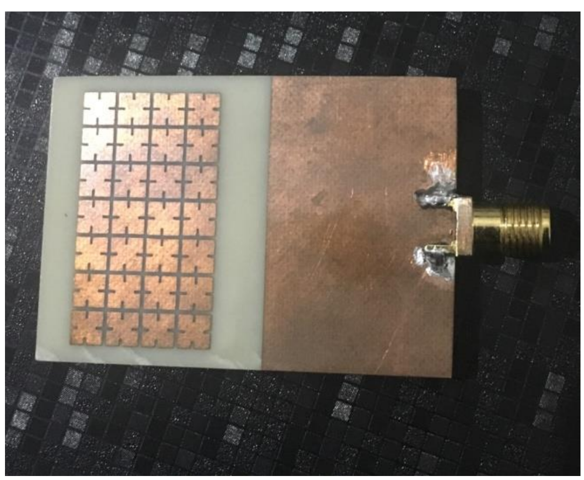

Fig 16 Back view of Fabricated Prototype of Fractal Antenna.

The back view of fabricated prototype of fractal antenna is shown in fig 16. The metamaterial is placed in the back of the proposed antenna. Metamaterial is used to enhance the bandwidth. The narrow bandwidth is obtained from the fractal antenna.

Front View of Fractal Antenna in Anionic Chamber is shown in fig 17. The radiation absorber is provided in anionic chamber so that radiation pattern should be measured. .

Fig 17 Front View of Fractal Antenna in Anionic Chamber

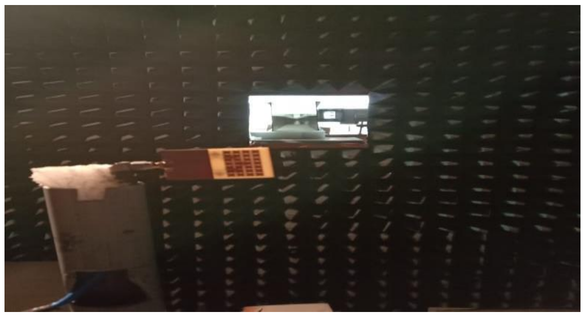

Fig 18 Back View of Fractal Antenna with Metamaterial in Anionic Chamber.

Similarly back view of fractal antenna with metamaterial is shown in fig 18.

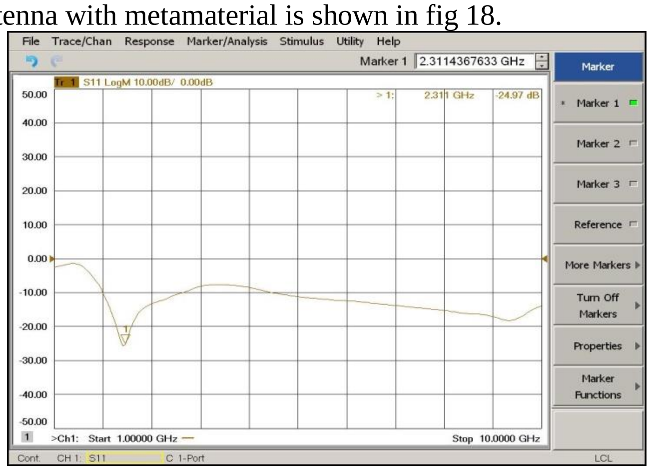

Fig 19 Measured Return loss of Fractal Antenna

The measured result of return loss of fractal antenna is -24.98 db

VI. Comparative Analysis

In this section, comparative of two configurations is shown in tabular form. Return loss and bandwidth is compared in table 1.

Table 1.Comparative analysis of different iteration of Antenna

	Simulated Result				Measured Result
Sr. No	Parameter	0^{th} Iteration Antenna	1^{st} Iteration Antenna	2^{nd} Iteration Antenna	Fabricated Prototype
1.	F_L	3.12	3.06	2.97	2.96
2.	F_H	3.68	3.92	4.12	3.84
3.	F_0	3.45	3.45	3.45	3.41
4.	% B.W	16.23	24.9	33.33	25.8
5.	Return Loss	-13.220	-15.7035	-17.4276	-24.98
6.	Gain	7.6309	10.0762	15.8533	9.893

VI. Conclusion

After Simulation, it is found that zero iteration fractalpatchantenna has low return loss with high gain andbandwidth. Simulated return loss is -17.4276 with gain 15.8533 db and bandwidth 33.33% is obtained from multi iteration patch antenna

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