A Self-Similar Plus shape Fractal antenna with Hexagonal slotted EBG Structure

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Abstract- In this paper, self-similar fractal antenna with electromagnetic band gap (EBG) is proposed and studied. Fractal geometry is a methodology through which size reduction is achieved. Plus shaped fractal antennas with base, first and second iteration of order 1/3 are surrounded with Hexagonal square slotted EBG structures. This is designed on substrate with ε_r=4.4 & h=1.6mm. The designed antenna resonates at multiple frequencies with improved return loss, bandwidth and gain. The resonant frequency of the antenna is reduced from 2.73 GHz to 2.32 GHz and 2.31 GHz after first and second iterations respectively. Hexagonal square slotted EBG with iterated antenna gives bandwidth of 155.23 MHz, size reduction of 28.12% and improved gain of 2.19dB. The Proposed antenna is simulated by using the method of moment based commercial software (IE3D) measured with Vector Network Analyzer. The simulated results are in good agreement with experimental results.

KEYWORDS – Hexagonal slotted EBG, size reduction, plus shaped fractal, multiband, wireless applications.

I. INTRODUCTION

Fractal is a recursively generated structure having self-similar shape, which means that some of the parts have the same shape as the whole object but at different scale. The self-similarity property of fractals makes them especially suitable for the design of multiband frequency antennas [1].The original inspiration for the development of fractal geometry came largely from in depth study of patterns of nature. This geometry, which has been used to model complex objects found in nature such as clouds and coastlines, has space filling properties that can be utilized to miniaturize antennas [2]. Each fractal is composed of multiple iterations of a single elementary shape. The iteration can continue infinitely, thus forming a shape within a finite boundary but of infinite length or area. The first application of fractals to the field of antenna theory was reported by Kim and Jaggard. They introduced a methodology for designing low side arrays that is based on the theory of random fractals. The fact that self-scaling arrays can produce fractal radiation pattern was first established in 1992. This is accomplished by studying the properties of special type of non-uniform linear array, called aweiertrass array, which has self-scalling element spacing and current distributions [3]. Another technique used is electromagnetic band gap (EBG) structure has been widely accepted today. The periodic EBG structures exhibit band-gap feature in suppression of surface wave propagations. This feature applied in field of antenna helps to improve performance of antenna, such as increasing the gain of antenna. In this paper, Hexagonal slotted electromagnetic bandgap structures are surrounding the plus shaped fractal antenna [4-8].

This paper evaluates the performance of a plus shaped fractal antenna integrated with electromagnetic bandgap EBG structure. It is observed that the proposed antenna with EBG improves the gain and bandwidth.

II. PLUS SHAPE FRACTAL ANTENNA

Fractal Geometry with base shape of Plus shaped patch is designed using IE3D simulated software which is shown in fig1 (a). First iteration of four plus shapes of order 1/3 of base shape are placed touching the base shape is as shown in fig1(b).Same procedure is repeated for second iterations which is as shown in fig 1(c). Each iteration is of order of $(1/3)^n$ of base shape, where n is the number of iterations. Geometry of designed antenna is implemented practically using fabricated technology by selecting material of type glass epoxy having dielectric substrate with €r=4.4 and height of substrate as 1.6mm.The Photographs of base, first and second iteration antennas are as shown in fig 2(a),2(b),2(c) &2(d). In our simulation a=40mm, c=30mm, d=10mm. The dimension of first iteration is taken as

e= (1/3) a & g= (1/3) c also f= (1/3) b & h= (1/3) d

i= (1/3) e & k= (1/3) g also j= (1/3) f & L= (1/3) h

which gives e=13.33mm, g=10mm gives f=4.443mm and h=3.33mm respectively. Probe feed is used to feed the antenna and the location of probe is dP= (-4mm,-8mm) from the origin.

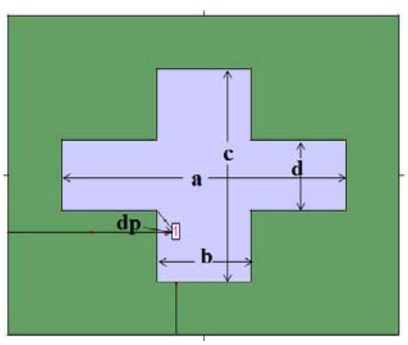

Fig 1(a) Geometry of base antenna

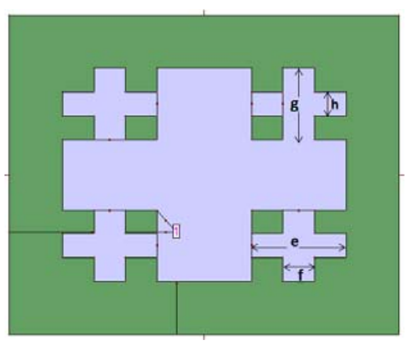

Fig 1(b) Geometry for first iteration

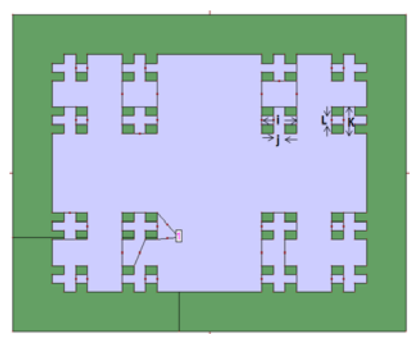

Fig 1(c) Geometry for second iteration

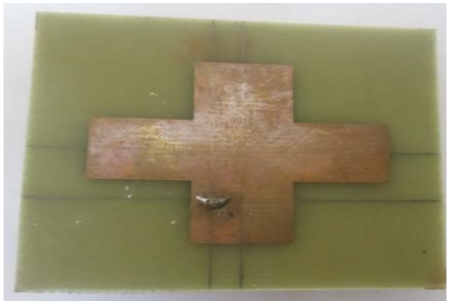

Fig 2(a) Fabricated antenna with top view without EBG structure

Fig 2 (b) Fabricated antenna with bottom view without EBG structure

Fig 2(c) Fabricated antenna with first iteration without EBG structure

Fig 2 (d) Fabricated antennas with Second Iteration without EBG structure

The characteristics of proposed antennas were simulated by using software IE3D and verified experimentally by using Vector network Analyzer model No.8651. For all cases, the simulated results are obtained and are compared to the experimental results. They are shown in figure 3(a) to 3(c). From the results it is clear that simulated results are in good agreement with measured results. The base antenna with zero iteration is resonating at 2.75 GHz. The antenna with first iteration gives resonances at 2.29 GHz, 3.31 GHz and 3.94 GHz which means it is operating at multifrequencies. Similarly antenna with second iteration is resonating at 2.27 GHz and 3.44 GHz. The results of the proposed fractal antenna without EBG structure with different iterations are shown in Table1. The overall bandwidth is enhanced to 200 MHz with second iterations. The radiation patterns of all iterations were studied though simulation and it is shown in fig 4(a) to 4(c) and all are broadside patterns.

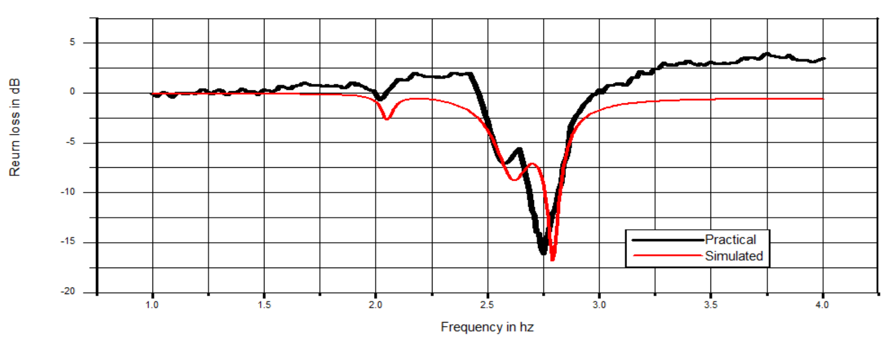

Fig 3(a) Base Antenna

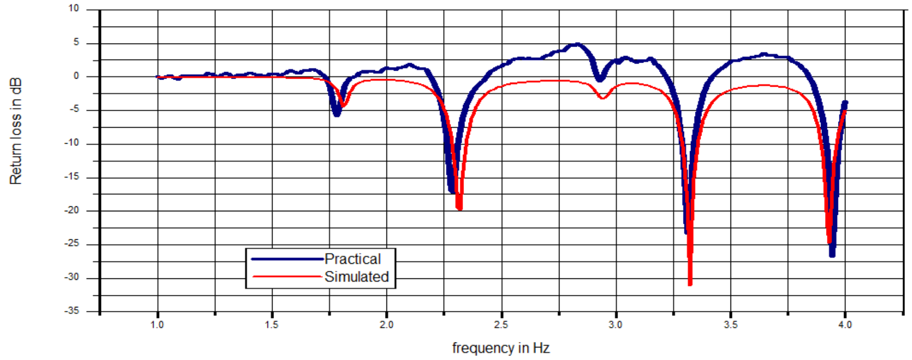

Fig 3(b) First iteration

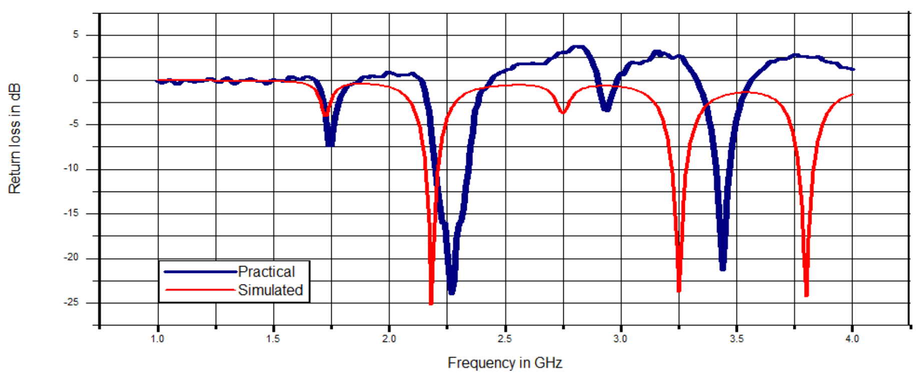

Fig 3(c) Second iteration

Fig 3: Return loss characteristics of proposed antenna without EBG Structure

Prototype Antenna	Resonant frequency Fr(GHz)		Return loss (db)		Bandwidth (MHz)		Overall Bandwidth (MHz)	
	Sim	Pract	Sim	Pract	Sim	Pract	Sim	Pract
Fractal base antenna	f1=2.79	f1=2.75	-16.8	-16.1	70	110	70	110
Fractal antenna with first iteration	f1=2.32 f2=3.32 f3=3.93	f1=2.29 f2=3.31 f3=3.94	-19.85 -31.09 -24.76	-17.14 -23.27 -26.73	60 70 60	50 50 50	190	150
Fractal antenna with Second iteration	f1=2.19 f2=3.25 f2=3.8	f1=2.27 f2=3.44 ----	-25.18 -23.72 -24.3	-23.98 -21.3 ----	60 60 60	140 60 ----	180	200

Table 1: Results of proposed antenna without EBG Structure

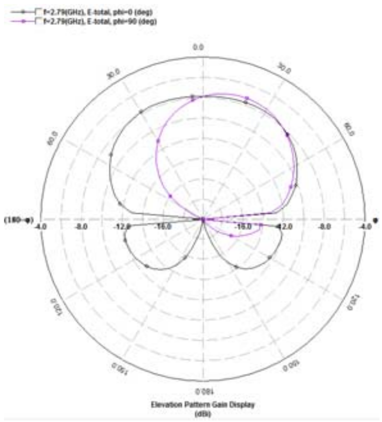

Fig 4(a) Base antenna

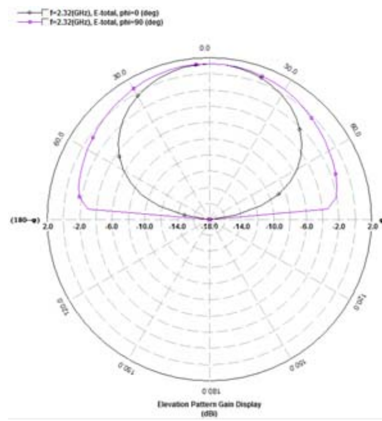

Fig 4(b) First iteration

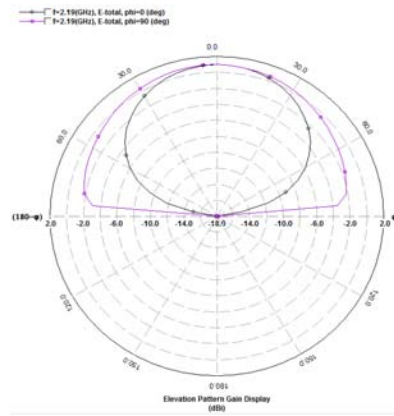

Fig 4(c) Second iteration

Fig 4: Radiation patterns of proposed antenna without EBG structures

III. Plus shape Fractal antenna with Hexagonal Square slotted EBG structure

Geometry of designed antenna with zero, First and Second iterations of order 1/3 are surrounded by hexagonal square slotted EBG structure as indicated in figures from 5(a) to 5(c). The total area occupied by the base shape patch is 40mm x 30mm. The Plus shaped patch with different iterations of order 1/3 is placed at the center and it is surrounded by 6 six hexagonal slotted patch UC-EBG structure with gap of 1mm between them. Optimized dimensions are a=40mm, b=6.66mm, c=30mm and d=10mm. The dimension of ground plane is 60mm x 60mm. The photograph of all designed antenna with hexagonal square slotted EBG structure are shown in fig 6(a) to 6(d).

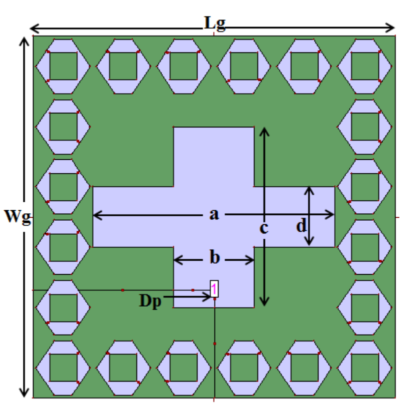

Fig 5(a) Geometry of base antenna

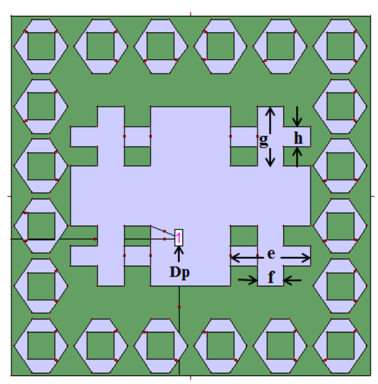

Fig 5(b) Geometry for first iterated antenna with EBG

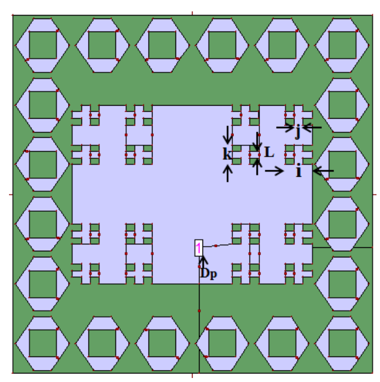

Fig 5(c) Geometry for 2^{nd} iterated antenna with EBG

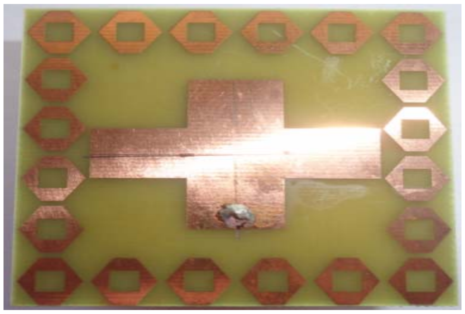

Fig 6(a) Photograph of base antenna with EBG showing top view.

Fig 6(b) Photograph of base antenna with EBG showing bottom view.

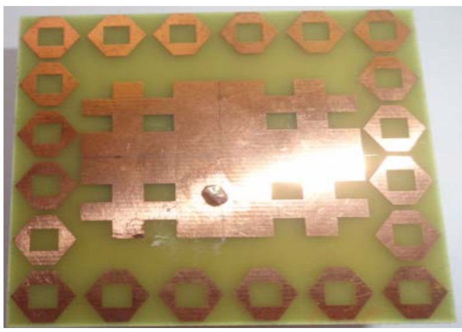

Fig 6(c) Fabricated antenna with first iteration with EBG structure.

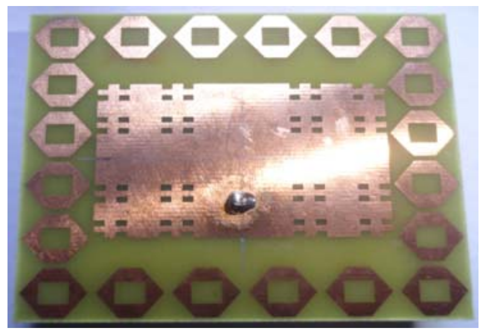

Fig 6(d) Fabricated antenna with second iteration with EBG structure

Simulated and measured return loss characteristics of antenna are shown in fig 7(a) to 7(c). Simulated results are in good agreement with experimental results whose results have been summarized in Table 2. From the tabular results the proposed antenna performance with UC-EBG structures is improve i.e interms of bandwidth, gain are enhanced. The base antenna with zero iteration is resonating at 2.73GHz. The antenna with first iteration gives resonance at 2.32GHz, 3.36 and3.98GHz while the second iteration is resonating at 2.31 GHz and 3.5 GHz. The overall bandwidth is enhanced to 155.23MHz with second iteration.

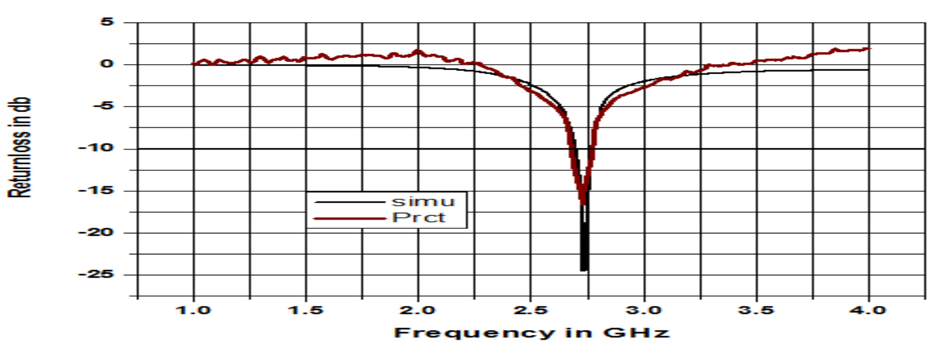

Fig 7(a) Base antenna

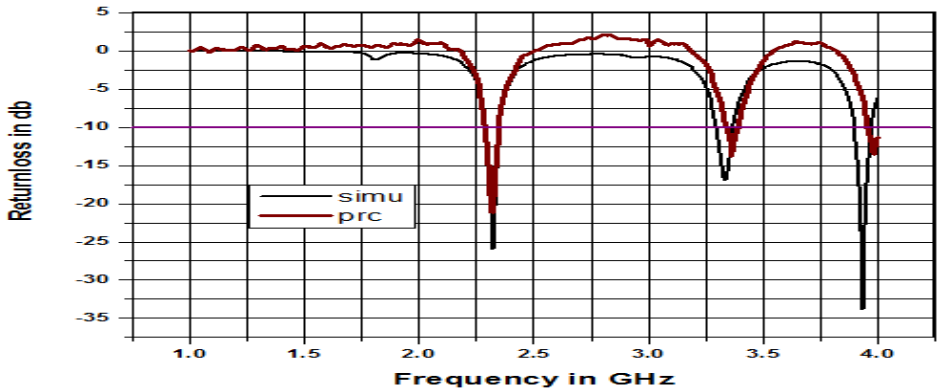

Fig 7(b) First iteration

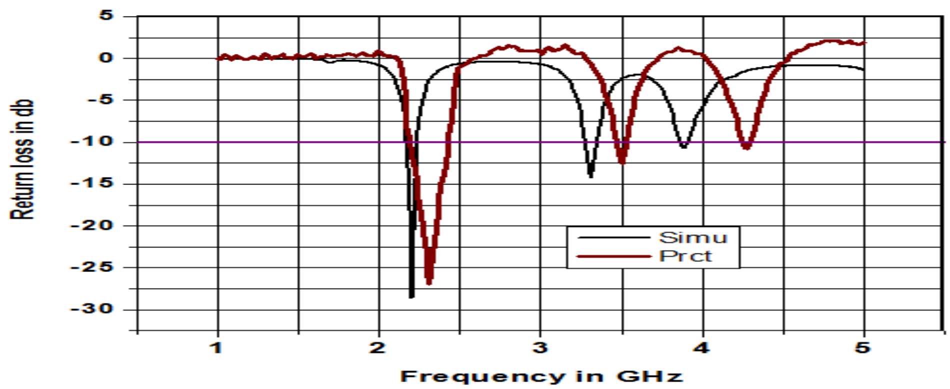

Fig 7(c) Second iteration

Fig 7 : Return loss characteristic of proposed antenna with EBG structure

Prototype Antenna	Resonant Frequency Fr(GHz)		Return loss (db)		Band width (MHz)		Overall Bandwidth (MHz)	
	Sim	Prct	Sim	Prct	Sim	Prct	Sim	Prct
Fractal base antenna	F_1=2.73	F_2=2.72	-24.5	-16.6	25.64	33.08	25.64	33.08
Fractal antenna with first iteration	F_1=2.32 F_2=3.33 F_3=3.93	F_1=2.32 F_2=3.36 F_3=3.98	-25.95 -16.88 -33.87	-21.16 -13.73 -13.48	25.86 18.01 17.81	21.55 13.39 62.81	61.68	97.75
Fractal antenna with second iteration	F_1=2.2 F_2=3.31	F_1=2.31 F_2=3.5	-28.5 -14.2	-26.8 -12.53	27.27 21.15	95.23 60	48.4	155.23

Table 2: Results of proposed antennas with EBG structure

Radiation patterns have been studied for iterated with EBG structure and it is shown in fig 8(a) to 8(c). It is observed that the radiation patterns are broadside. Further the table 3 shows the overall bandwidth, gain and percentage of size reduction without and with EBG structure. The bandwidth of antenna with first iteration gives 97.75 MHz and gain is 0.19dbi. Further there is an increment in overall bandwidth of about 155.23MHz with gain of 2.19dbi after second iteration. In summery there is increment in overall size reduction and gain of plus shaped iterated antenna with EBG structure in comparison with plus shaped iterated antenna without EBG structure.

The directivity of proposed antennas are also studied, It has been observed that with EBG there is an improvement in directivity of all antennas. The base antenna gives directivity of 5.06 dBi without EBG and 6.5 with EBG. The first iteration Antenna gives directivity of 6.38 dBi without EBG & 6.81 with EBG. The second iteration antenna gives directivity 6.39 dBi without EBG & 6.9 dBi with EBG. Also it is observed that there is an improvement in the radiation pattern with EBG for all proposed antennas.

Prototype Antenna	Without EBG					With EBG				
	Overall bandwidth (MHZ)		Gain (dBi)	% of Size reduction		Overall bandwidth (MHZ)		Gain (dBi)	% of Size reduction	
	Sim	Prct	Sim	Sim	Prct	Sim	Prct	Sim	Sim	Prct
Base Antenna	70	110	0.19	----	----	25.64	33.1	0.19	----	-----
I Iteration Antenna	190	150	1.0	31.2	29.8	61.68	97.8	2.19	28.06	27.5
II Iteration Antenna	180	200	1.2	38.7	32.2	48.4	155	2.19	35.36	28.12

Table 3: Results shown to compare proposed antennas without and with EBG

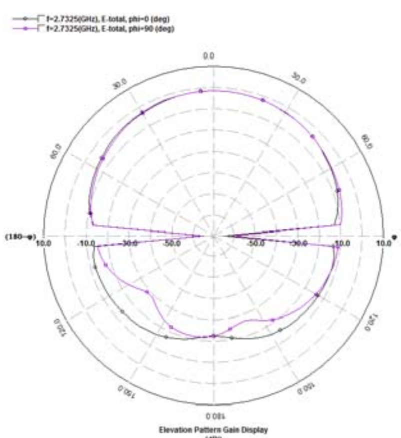

Fig 8(a) Base antenna

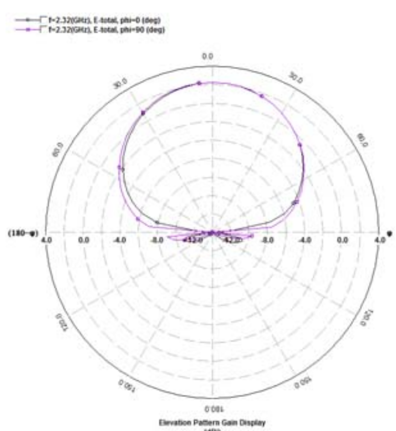

Fig 8(b) First iteration

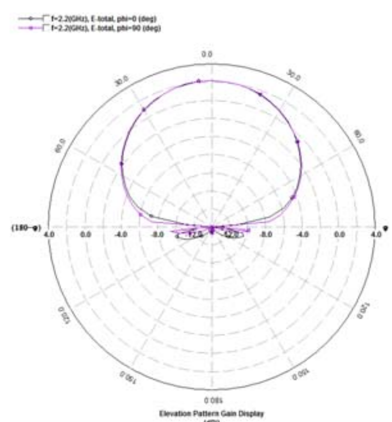

Fig 8(c) Second iteration

Fig 8(c): Radiation pattern of proposed antennas with EBG structure

IV.CONCLUSION

This paper outlines a new concept of plus shape fractal antenna with different iteration with 1/3rd orders and order one and two having hexagonal square slot patch EBG structure. Measured values of resonant frequencies and bandwidth for these antennas have been found to agree well with the simulated ones. The antenna gives multifrequency operation and reduced size. The size reduction of 28.12% is obtained. The Gain obtained is 2.19 dBi and broadside radiation patterns are achieved. The gain of the antenna is improved with EBG structure and reduces the backlobe radiations

V. ACKNOWLEDGEMENTS

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