A Self-Similar Fractal Antenna with Square EBG Structure

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Abstract

Low profile antenna in communication is a new methodology. Fractal geometry is a methodology through which size reduction is achieved. In this paper, a self-similar fractal antenna with square EBG structure is proposed and studied. Plus shaped fractal antenna surrounded with periodic square EBG structures has designed on substrate with εr=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 2.71 GHz to 2.31 GHz and 2.28 GHz after first and second iterations respectively. With square EBG the antenna gives bandwidth of 240 MHz, size reduction of 34.3% and improved gain of 2.19dB. The Proposed antenna is simulated by using the method of moment based commercial software (IE3D) and simulated results are in good agreement with experimental results.

Keywords: Squared periodic EBG, size reduction, plus shaped fractal, multiband.

1. Introduction

With Advance of wireless communication systems and increasing importance of other wireless applications, wide band and low profile antennas are in great demand for both commercial and military applications [1].For antenna design that possess the following highly desirable attributes: i) Compact size ii) Low profile iii) Conformal iv) Multiband and broadband, there are a variety of approaches that have been developed over years, which can be utilized to achieve one or more of these design objectives. The use of fractal geometry is a solution to the design of multiband antennas. In recent years several fractal geometries have been introduced for antenna applications with varying degrees of success in improving antenna characteristics [2]. Fractal represents a class of geometry with very unique properties that are useful to antenna designers. The efficient packing of this electrically large element constitutes a miniaturization technique to produce small-size elements suitable for installation in portable telecommunication devices [3].The space filling property, when applied to an antenna element, leads to an increase of electrical length. The more convoluted and longer surface currents results in lowering the antenna resonant frequency for a given overall extension of resonator. Therefore given a desired resonance frequency, the physical size of the whole structure can be reduced [4]. Method to improve the antenna performance is by using the electromagnetic band gap(EBG) structure on microstrip antenna.EBG structure are periodic lattices, which can provide effective and flexible control over the propagation of the EM waves within a particular band. It has been shown that this structure can lower input return loss and widen the impedance bandwidth [5] of microstrip antenna by suppressing the unwanted surface waves [6]. The inclusion of EBG in microstrip antenna design allows gain enhancement, enhanced directivity [7-8], improved bandwidth and size miniaturization.

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

2. Plus Shape Fractal Antenna

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.

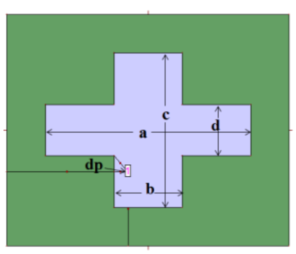


Fig 1(a): Geometry of base antenna

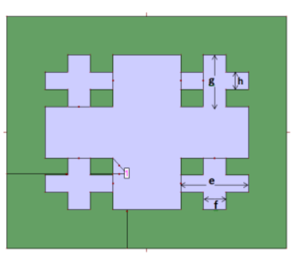


Fig 1(b): Geometry for first iteration

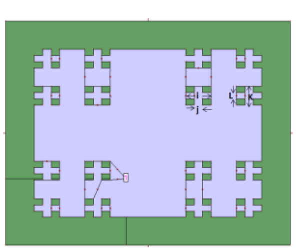


Fig 1(c): Geometry for second iteration

Fig 2(a) Fig 2(b)

Fig 2(a) & 2 (b): Fabricated antennas with top view and bottom view

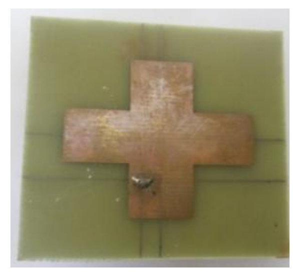
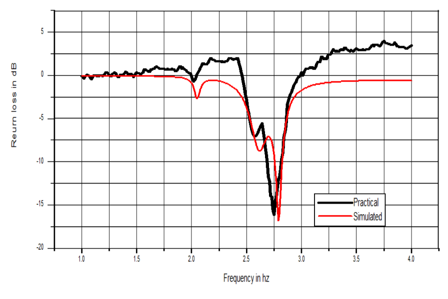


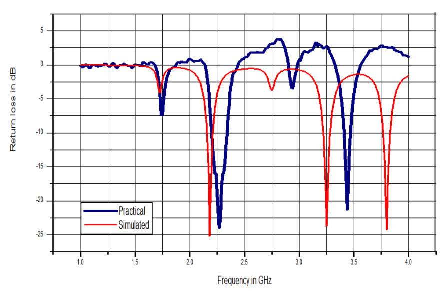
Fig 2(a): Fig 2(b)

Fig 2(c): Fabricated antenna with first iteration
Fig 2(d): Fabricated antenna with second iteration

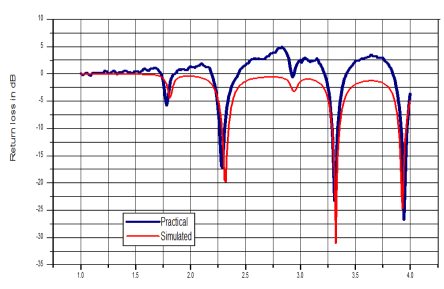
The characteristics of proposed antennas were simulated by using software IE3D and verified experimentally by using Vector network analyzer model No.8651. For all cases, the simulated results are obtained and are compared to the experimental results. They are shown in figure 3(a) to 3(c). From the results 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 multi-frequencies. 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.



3(a) Base Antenna



3(b) First iteration

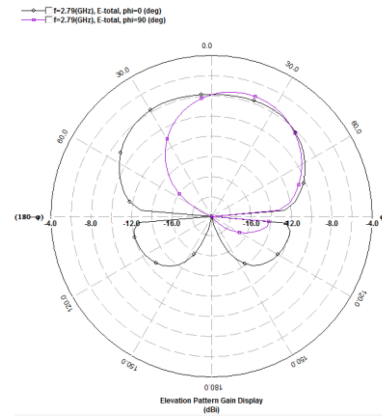


3(c) Second iteration

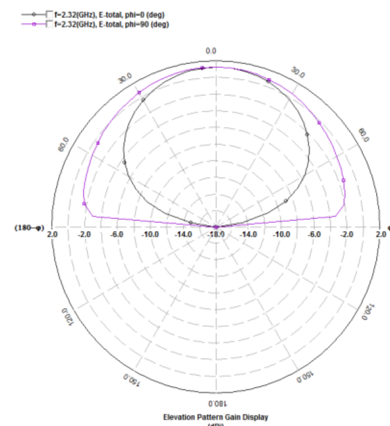
Fig 3: Return loss characteristics of proposed antennas without EBG structure.

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

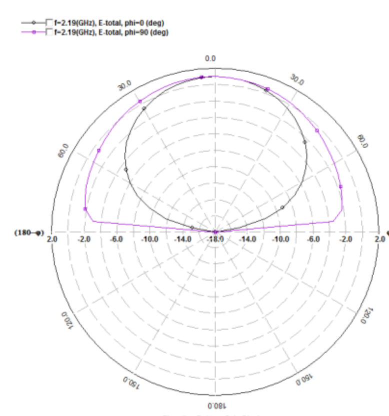
Table 1: Results of proposed antenna without EBG structure



4(a) Base antenna



4(b) First iteration



4(c) Second iteration

Fig 4: Radiation patterns of proposed antenna without EBG structure

3. Plus shape Fractal antenna with square Patch EBG structure

Fig5 (a) to 5(c) shows the geometry of a self-similar plus shaped fractal antenna with square EBG structure. Geometry of designed antenna with zero, First and Second iterations are surrounded by square shape EBG structure as indicated in the below figures. The total area occupied by the base shape patch is 40mm x 30mm. The Plus shaped patch with different iterations is placed at the center and it is surrounded by 6 square patch 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 square patch periodic EBG are shown in fig 6(a) to 6(d).

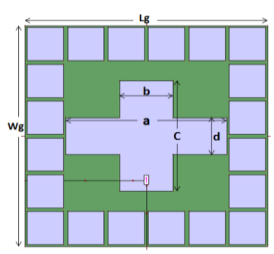


Fig 5(a): Geometry of base antenna with EBG

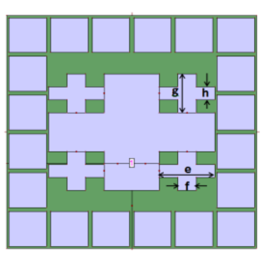


Fig 5(b): Geometry for first iteration with EBG

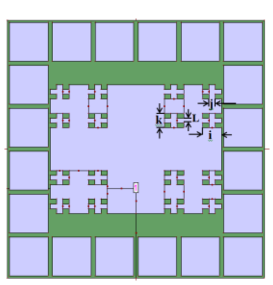


Fig 5(c): Geometry for second iteration with EBG

Fig 6(a)

Fig 6(b)

Fig 6(a) & 6 (b): Fabricated antennas with top view and bottom view with EBG

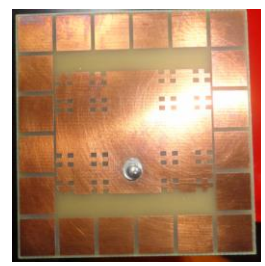
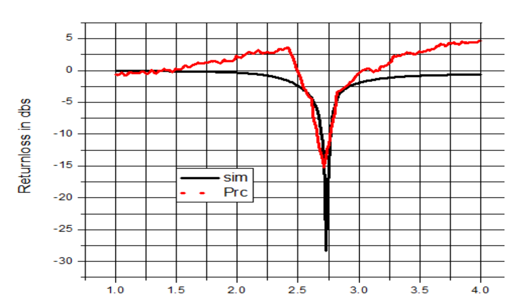


Fig 6(c):

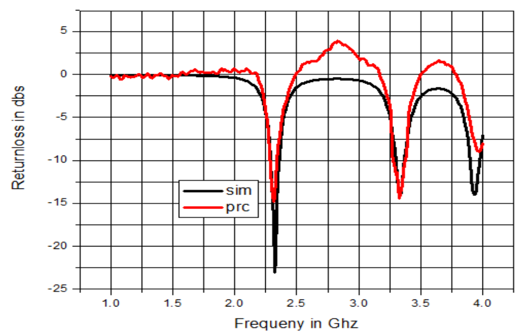
Fig 6(d)

Fig 6(c): Fabricated antenna with first iteration EBG
Fig 6(d): Fabricated antenna with second iteration EBG

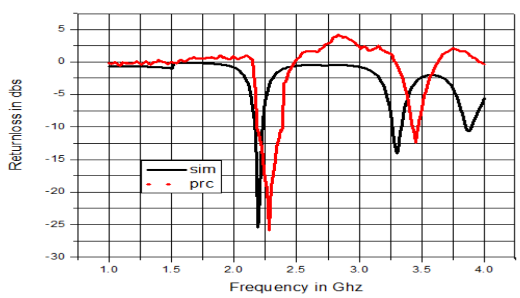
The Simulated and measured return loss characteristics of antenna are shown in fig 7(a) to 7(c). Agreement between measured and simulated results is good. The results are shown in table 2. The results indicate that the proposed antenna performance with periodic EBG structures is improved i.e., the bandwidth and gain are enhanced. The base antenna with zero iteration is resonating at 2.71 GHz. The antenna with first iteration gives resonance at 2.31 GHz, 3.33 GHz while the second iteration is resonating at 2.28 GHz and 3.45 GHz. The overall bandwidth is enhanced to 240MHz with second iteration.



7(a) Base antenna



7(b) First iteration



7(c) Second iteration

Fig 7: Return loss characteristics of proposed antenna with 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=2.73	f1=2.71	-28	-15.27	60	100	60	100
Fractal antenna with first iteration	f1=2.32 f2=3.33 f3=3.93	f1=2.31 f2=3.33 ----	-23 -14.1 -14	-14.83 -13.4 ---	60 70 70	50 100 ---	200	150
Fractal antenna with Second iteration	f1=2.19 f2=3.3	f1=2.28 f2=3.45	-25.4 -14	-25.87 -12.41	60 60	200 40	120	240

Table 2: Results of proposed antenna with EBG structure

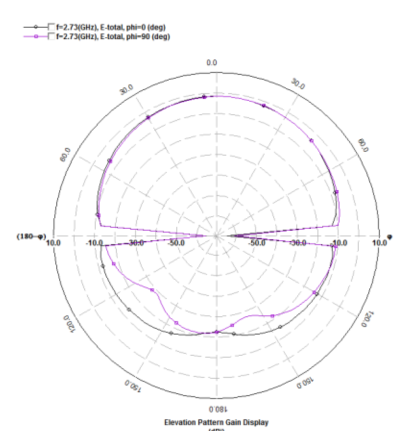
Also the radiation patterns have been studied for all the antennas with EBG structure and it is shown in fig 8(a) to 8(c). It is observed that the radiation patterns are broadside.

Further the table 3 shows overall bandwidth, gain and percentage of size reduction of proposed antennas without and with EBG structure. The bandwidth of the antenna with first iteration and EBG is 150 MHz and gain is 2.19 dBi. Further there is an increment in overall bandwidth of about 240 MHz with gain of 2.19 dBi after second iteration. In summary there is increment in overall bandwidth and gain of plus shaped antenna with periodic EBG structure in an comparison with plus shaped antenna without EBG structure.

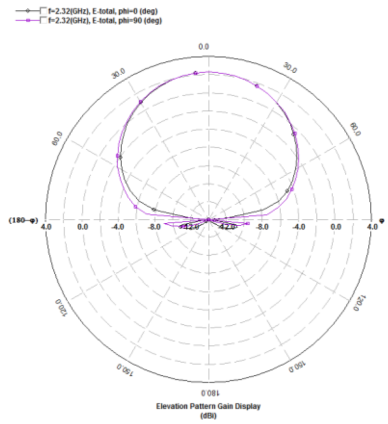
The directivity of proposed antennas are also studied, It has been observed that with EBG there is an improvement in directivity of all antennas. The base antenna gives directivity of 5.06 dBi without EBG and 6.5 with EBG. The first iteration Antenna gives directivity of 6.38 dBi without EBG & 6.8 with EBG. The second iteration antenna gives directivity 6.39 dBi without EBG & 6.82 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)	%age of size reduction		Overall Bandwidth (MHz)		Gain (dBi)	%age of size reduction	
	Sim	Prc	Sim	Sim	Prc	Sim	Prc	Sim	Sim	Prc
Base Antenna	70	110	0.1	----	----	60	100	0.1	----	----
I iteration	190	150	1.0	31.2	29.8	200	150	2.19	28	27.6
II iteration	180	200	1.2	38.7	32.2	120	240	2.19	36	34.3

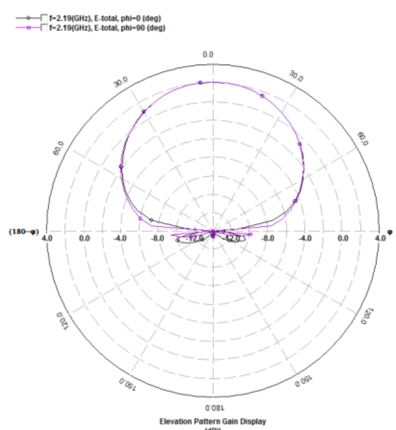
Table3: Results shown to compare proposed antennas without and with EBG



8(a) Base antenna



8(b) First iteration



8(C) Second iteration

Fig 8: Radiation patterns of proposed antennas With periodic structure

4. Conclusion

This paper outlines a new concept of plus shape fractal antenna with different iteration orders and square patch periodic 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 multi-frequency operation and reduced size. The size reduction of 34.3% is obtained. The overall bandwidth improvement is of 240 MHz after the second iteration. The Gain obtained is 2.19 dBi and broadside radiation patterns are achieved.

5. Acknowledgements

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