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Plus Shape Fractal Antenna with EBG Structure for Wireless Communication

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ABSTRACT: 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 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 2.71 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 1.59dB. 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: Plus Antenna, Wireless communication, Improved Gain, Square EBG.

I. INTRODUCTION

Modern and future wireless systems are placing greater demands on antenna designs. Many systems now operate in two or more frequency bands, requiring dual –or triple band operation of fundamentally narrow band antennas. A verity of technique has been used to crate Multiband antennas. Several fractal geometry have been introduced for antenna application with different degrees of success in improving antenna characteristics. Some of these geometries have been particularly useful in reducing the size of the antenna. These are low profile antennas with moderate gain and can be operate at multiple frequency bands [1].

There are varieties of approaches that have been developed over the years for designing compact and multiband microstrip antennas. Recently the possibility of developing microstrip antenna design that exploit in some way the properties of fractal to achieve these goals has attracted a lot of attentions [2]. The term fractal, which means broken or irregular fragments. Fractal represents a class of geometry with very unique properties including :(i) Self –similarity (ii) Fractional dimension (iii) Formation by iteration (iv) Space-filling. These properties can further be exploited to design antennas which are miniaturized, have improved input matching ability and are multiband/wideband. Various fractal shapes that possess self-similarity have been applied to multiband or miniaturized antenna design [3]. The self-similarity property of fractal means that parts of figure or small copies of whole figure .This fractal property can be used to realize antenna designs over a large band of frequencies.

Also in modern wireless communications more and more systems are introduced which integrate many technologies and are often required to operate at multiple frequency bands. For such Applications use of fractal self-similar pattern is one of the solutions for designing antennas [4].

Method of improving the antenna performance is by using the electromagnetic band gap (EBG) structure on microstrip antenna. EBG structures 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 by suppressing the unwanted surface waves [5].This feature applied in field of antennas helps improve performance of antenna, such as increasing the gain of antenna[6].

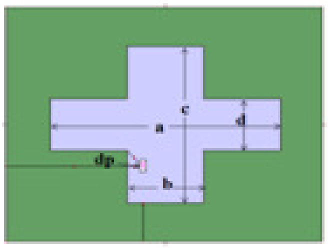
II. DESIGN CONSIDERATION

Fractal Geometry with base shape of plus shaped with EBG structure 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.



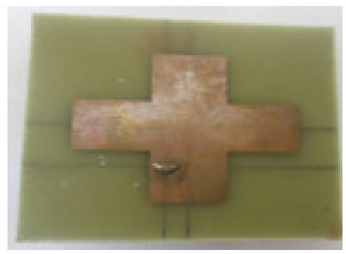
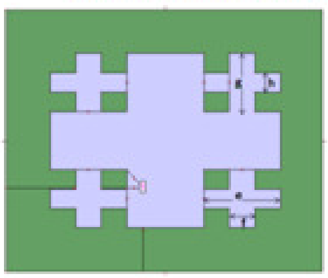


Fig. 1(a) Fig. 2(a)

Fig. 1(a) Geometry of base antenna

Fig. 2(a) Fabricated base antenna



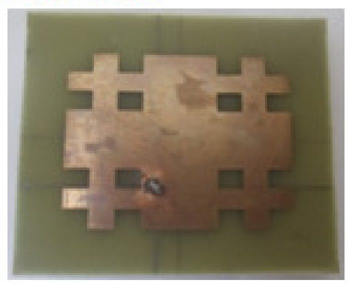
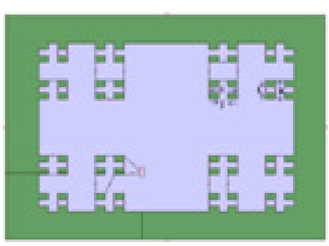


Fig. 1(b) Fig. 2(b)

Fig. 1(b) Geometry for first iteration

Fig. 2(b) Fabricated first iteration antenna



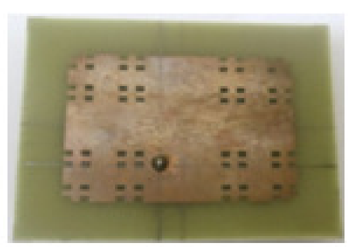


Fig. 1(c) Fig. 2(c)

Fig. 1(c) Geometry for second iteration

Fig. 2(c) Fabricated second iteration antenna

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.

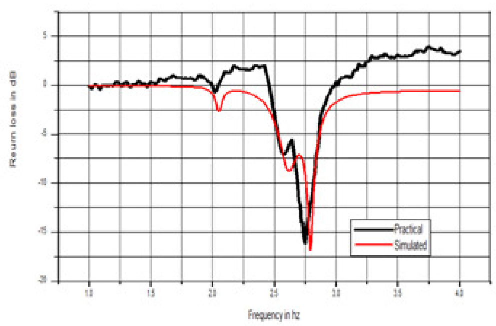


Fig. 3(a) Base antenna

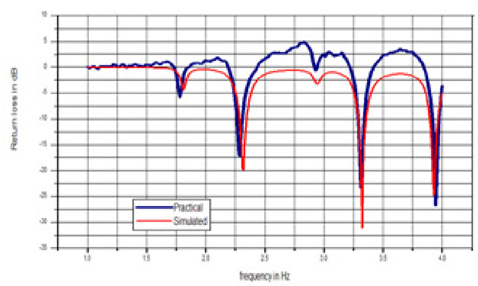


Fig. 3(b) First iteration

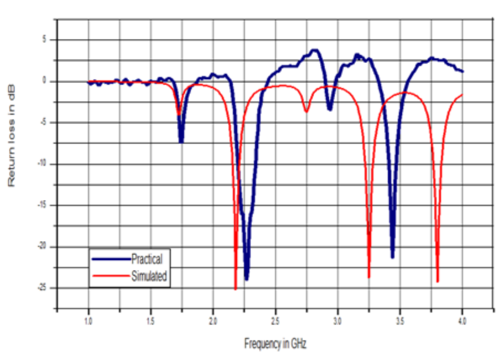


Fig. 3(c) Second iteration

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 Table 1. 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.

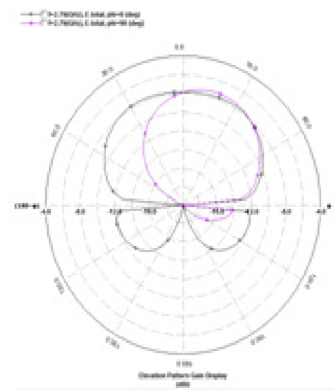


Fig 4(a) Base Antenna

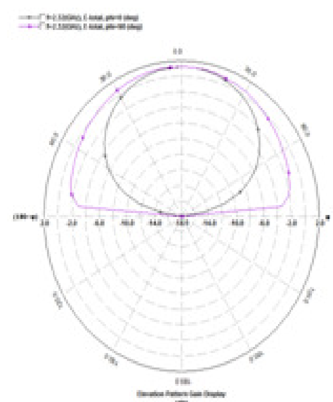


Fig 4(b) First iteration

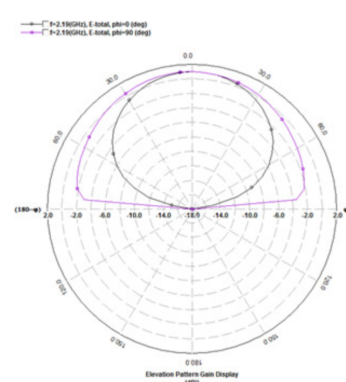


Fig. 4(c) Second iteration

Table 1: Results 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

III. PLUS SHAPE FRACTAL ANTENNA WITH SQUARE PATCH EBG STRUCTURE

Fig. 5 (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 centre 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).

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.

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.

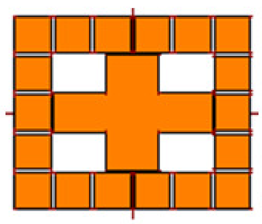



Fig 5(a) Fig 6(a)

Fig 5(a): Geometry of base antenna

Fig 6(a) Fabricated antenna of first iteration

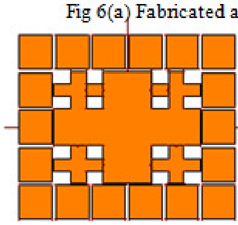



Fig 5(b) Fig 6(b)

Fig 5(b) Geometry for first iteration

Fig 6(b) Fabricated antenna of first iteration

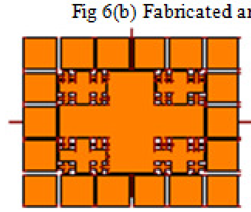
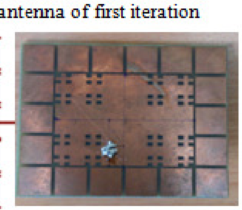



Fig 5(c) Geometry for second iteration

Fig. 6(c) Fabricated antenna of second iteration

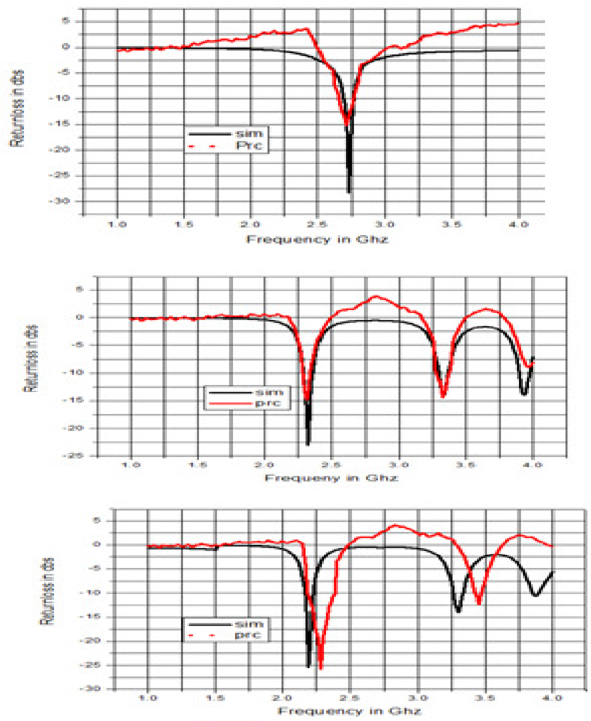


Fig. 7. Return loss characteristics of proposed antenna.

Table 2: Results 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

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.

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

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	1.53	28	27.6
II iteration	180	200	1.2	38.7	32.2	120	240	1.59	36	34.3

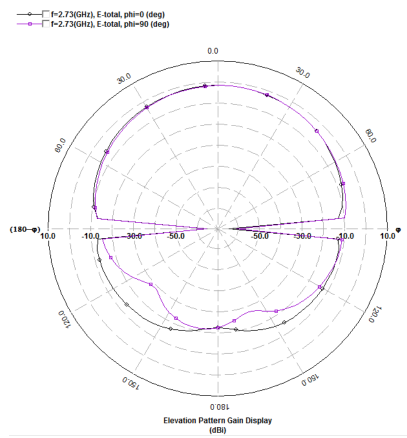


Fig. 8(a) Base Antenna

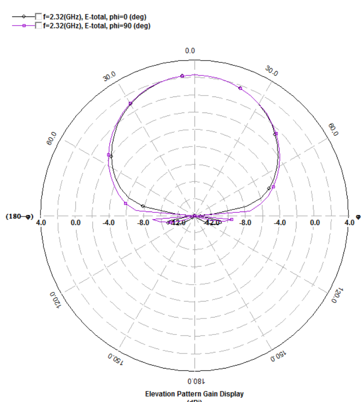


Fig. 8(b) First iteration

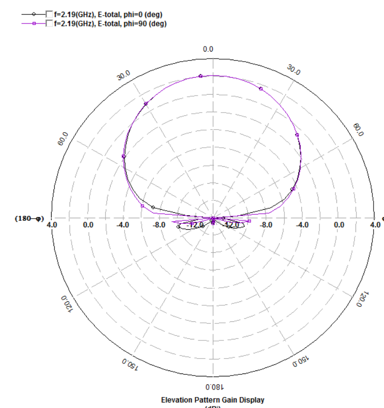


Fig. 8(C) Second iteration

Fig. 8. Radiation patterns of proposed antennas with periodic structure.

IV. 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 1.59 dBi and broadside radiation patterns are achieved.

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