Performane Enhancement of Annular Ring Antenna using Photonic Band Gap Structures

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ABSTRACT
This paper presents a novel technique of gain enhancement of microstrip antennas which otherwise have a low gain. The annular ring antenna is selected as it has higher radiation efficiency than simple antennas because of two radiating edges. Annular ring antenna with Photonic bandgap (PBG) etched on a ground plane in the higher order mode of TM_{31} is simulated and experimentally demonstrated. Comparison is done between annular ring antenna with periodic lattice of circular and annular ring structure etched only on ground plane to find out an optimum design of high gain antenna. Details of experimental results are presented and discussed.

Keywords: annular ring antenna, Photonic bandgap, surface wave loss

1. INTRODUCTION
The Excitation of surface waves is one of the limitations of microstrip antennas. Using photonic band gap (PBG) structures an enhanced gain annular ring antenna is designed. Surface wave propagation reduces the antenna efficiency and gain [1]. Photonic Band Gap structures reduce the losses due to surface waves resulting in gain enhancement [2]. A PBG is a periodic structure that forbids the propagation of all electro-magnetic waves within a particular frequency band. PBG structures are used in several forms [3, 4].In this paper promising applications of PBG structure etched only on ground plane [5,6] of probe feed annular ring antenna operating in higher order mode for gain enhancement is shown. Using two different shapes of PBG lattice etched only on ground plane an optimum high gain antenna is obtained. The simulations are done using Ansoft HFSS software. Simulations and experimental investigations are in good agreement.

2. Antenna Design
Reference patch antenna designed on FR4 substrate with ε_r = 4.4 and a and b are the inner and outer radii which are calculated as 3.9 mm and 5.85 mm for a design frequency 14.5GHz. Feed Point is optimized for best matching at (x, y, z) = (24, 24, 1.6). Annular ring antenna with PBG structure has slightly different patch dimensions than the annular ring antenna without PBG structure, so that antenna with PBG also resonates at the operating frequency of annular ring antenna without PBG. Period of the PBG structure is obtained from the equation given below.

$$f_0 = \frac{c}{2s\sqrt{\varepsilon_{ef}}} \qquad (1)$$

f_0 is the operating frequency, s is the period of PBG lattice, c = speed of the light in free space and ε_{ef} is the effective dielectric constant. Radius of the circular and annular ring structure of figure I are calculated as 0.25Ssuch that optimizes PBG structure is obtained [7].

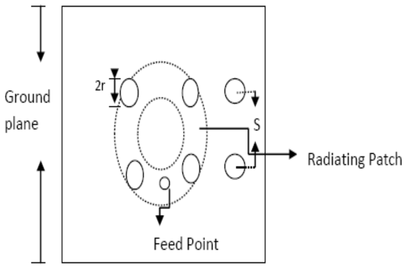

Fig I. Annular ring antenna with periodic lattice of circular structure etched only on ground Plane antenna1

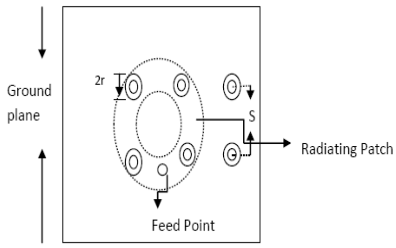

Fig II. Annular ring antenna with periodic lattice of annular ring structure etched only on ground Plane antenna2

3. Results
For experimental studies a reference patch antenna without PBG structure is also fabricated along with antennas with PBG.S_{11} of fabricated antennas are measured with the help of VNA and radiation patterns are obtained using spectrum analyzer and signal generator.

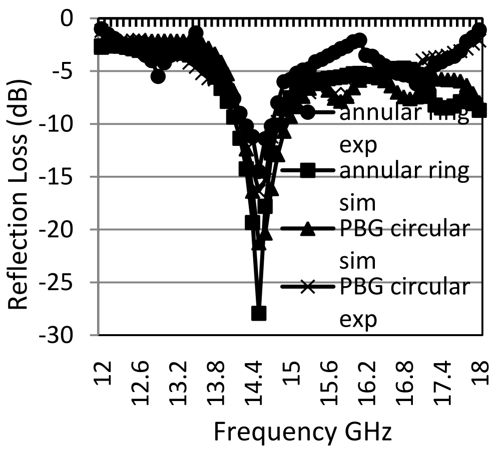

Fig III. Experimental and simulated reflection loss for the reference antenna and annular ring antenna with periodic lattice of circular structure etched only on ground Plane

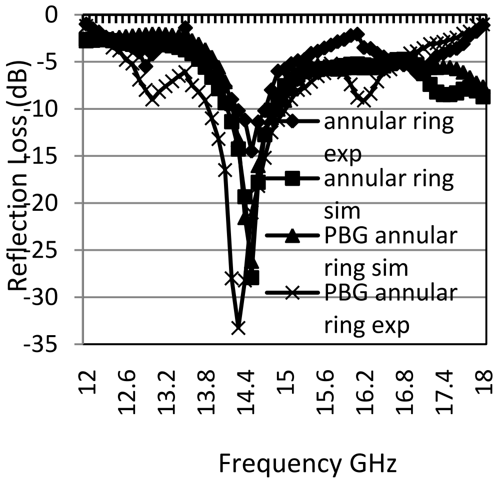

Fig IV. Experimental and simulated reflection loss for the reference antenna and annular ring antenna with periodic lattice of annular ring structure etched only on ground Plane

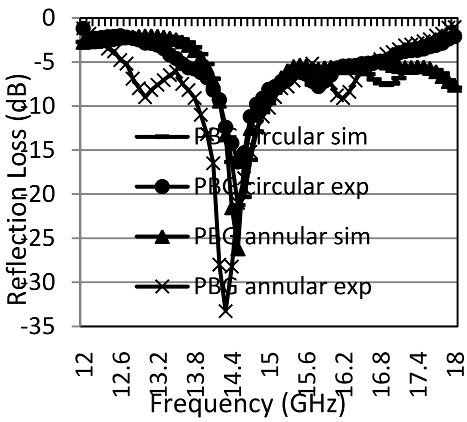

Fig V. Experimental and simulated reflection loss for annular ring antenna with periodic lattice of annular ring structure etched only on ground Plane and annular ring antenna with periodic lattice of annular ring structure etched only on ground Plane

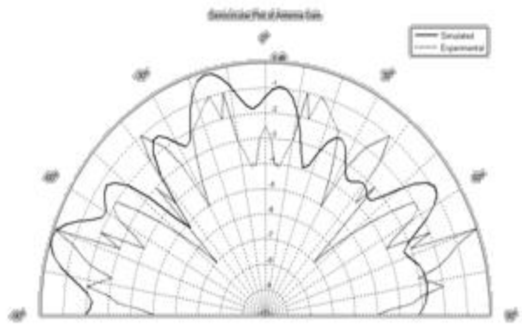

Fig VI. Experimental and simulated Radiation Pattern for reference antenna

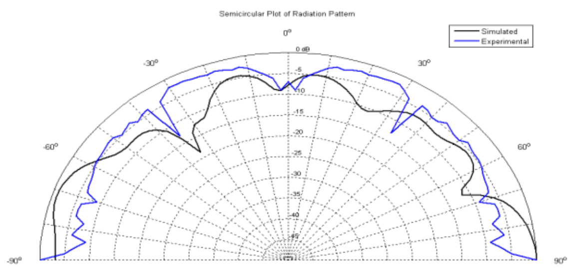

Fig VII. Experimental and simulated Radiation Pattern for annular ring antenna with periodic lattice of Circular structure etched only on ground Plane

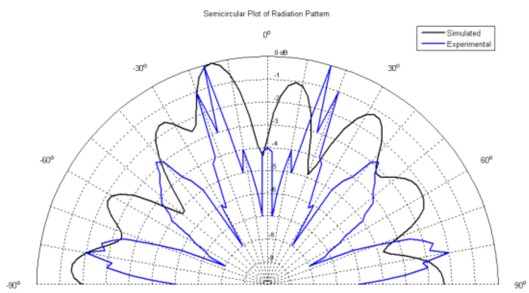

Fig VIII. Experimental and simulated Radiation Pattern for annular ring antenna with periodic lattice of annular ring structure etched only on ground Plane

4. Discussions of results

Figure III shows comparative experimental and simulated reflection loss of reference antenna and annular ring antenna with periodic lattice of Circular structure etched only on ground plane (antenna1). From this figure it is clear that antenna1 resonates at the operating frequency of reference antenna as the dimension of the patch is changed. Reference antenna resonates at 14.5 GHz with experimental and simulated reflection loss of -14.4 dB and -27.9dB respectively and antenna1 resonates at 14.5 GHz with simulated reflection loss of -27.9 dB and experimentally resonates at 14.5 GHz with reflection loss of -14.4 dB. Antenna2 resonates at 14.5 GHz with simulated reflection loss of -26.0 dB and experimentally resonates at 14.3 GHz with reflection loss of -33.27dB. The Matching improves with the both PBG structures but there is a slight shift in the resonant frequency of antenna2. Bandwidth of antenna1and antenna2 has increased by two and three times of the reference antenna respectively. Bandwidth of reference antenna is 2.75% antenna1 is 4.82% and antenna2 is 7.6%. Fabricated antenna gains are reduced slightly due to some losses occurring in fabrication and testing process.

Table I Comparison Table

Parameter		**Annular ring antenna without PBG**	**Annular ring antenna with periodic lattice of Circular structure etched only on ground Plane**	**Annular ring antenna with periodic lattice of annular structure etched only on ground Plane**
S_{11} (dB)	Simulated	-27.9 dB 14.5 GHz	-21.0 dB 14.5 GHz	-26.0 dB 14.5 GHz
	Experimental	-14.4 dB 14.5 GHz	-16 dB 14.5 GHz	-33.27 dB 14.3 GHz
Gain (dB)	Simulated	8.81 dB	12.92 dB	9.34 dB
	Experimental	5.105 dB	8.605 dB	7.60 dB

5. Conclusion

From the comprehensive analysis of the annular ring antenna for gain enhancement it can be concluded that annular ring antenna with periodic lattice of Circular structure etched only on ground plane (antenna1) gives good impedance matching and considerable gain enhancement to the antenna. There is some shift in direction of maximum radiation, which can be overcome by optimization, but still this technique can be very fruitful for gain enhancement of antennas.

6. Fabricated Antennas

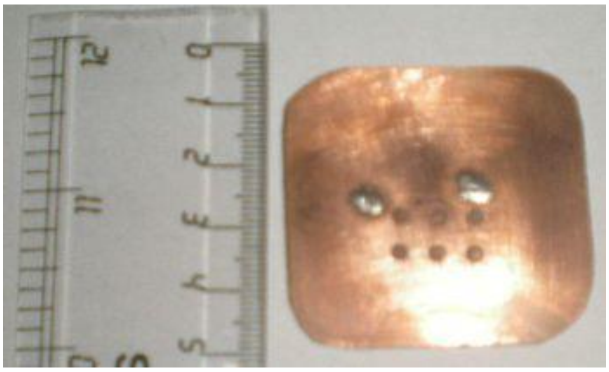

Fig IX. Annular ring antenna with periodic lattice of Circular structure etched only on ground Plane

Fig X. Annular ring antenna with periodic lattice of annular structure etched only on ground Plane

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