Annular Ring Antenna on a Novel PBG Structure

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ABSTRACT

This paper presents a novel technique of gain enhancement of microstrip antennas which otherwise have a very low gain. The annular ring antenna is selected as it has higher radiation efficiency than simple antennas because of two radiating edges. A PBG is developed using periodic cylinders filled with different dielectrics. Maximum gain of 12.17 dB is achieved using this technique.

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

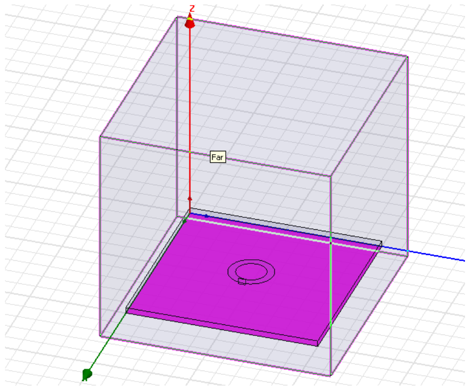
1. INTRODUCTION

High gain antenna is the demand of the time. Major drawback of a microstrip antenna is its low gain, which has been overcome using the proposed design. Annular ring antenna is chosen for its high radiation efficiency [1]. The lower frequency bands are very crowded and the stress is now on higher frequencies, Ku band is becoming very popular for different communication services. Because of higher frequency the size is also reduced which is very helpful. Photonic Band gap (PBG) technology is a novel approach for gain and bandwidth enhancement. PBG structures are artificially made structures with periodically loaded obstacles. PBG structures can have several different forms [2, 5].

1.1 In this paper, a periodic metal pads with periodic dielectric cylinders from the center of metal pads to the ground plane is used to enhance the gain of an annular ring antenna operating at higher frequency and excited at TM_{31} mode. The periodic metal pads with dielectric cylinder are used for introducing the band gaps. Two types of dielectric are used and comparison is done to obtain optimum results. An annular ring antenna without PBG is also constructed to show the enhancement in gain. The simulation results are obtained using the Ansoft HFSS software.

2. Antenna Design

The inner and outer radii of the ring are calculated as a = 3.9 mm and b= 5.85 mm, respectively. The fed patch is etched on a dielectric substrate of relative dielectric constant, ε_r =4.4. The feed Point location is optimized at (x, y, z) = (24, 24, 1.6). Fig. 1 shows the annular ring antenna excited at TM_{31} mode and operating at Ku band frequencies. 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.



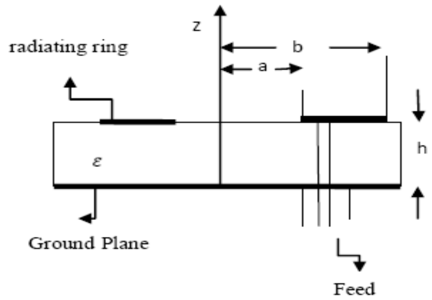


Fig I. Geometry of annular ring antenna without PBG

Fig. 1 shows an annular ring antenna on FR4 with periodically loaded metal pads with periodic dielectric cylinders. The period of metal pads with dielectric cylinder is obtained from the equation given below [6].

$$f_0 = \frac{c}{2s\sqrt{\varepsilon_{ef}}}$$

f_0 is the center frequency of the stop band for forbidding electromagnetic wave propagation in the substrate or 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. Using above equation s is calculated as 5.76 mm and r, the radius of circle which is 0.25 s to obtain the optimized PBG structure is 1.44 mm [7].

3. Theoretical Considerations

Fig. 2 shows the geometrical configuration of the annular ring antenna with small periodic circular metal pads on the layer of the antenna with periodic dielectric cylinders from the center of the metal pads to the ground. The radius, r_1 = 1.44 mm of the circular metal pads and r_2 = 0.72 mm is the radius of the dielectric cylinder. Initially, RT duroid of dielectric constant 10.2 is used and finally FR4 of dielectric constant 4.4 is used as cylinders. The comparison between the results of two conditions is carried out and compared with the simple annular ring antenna excited at TM_{31} mode.

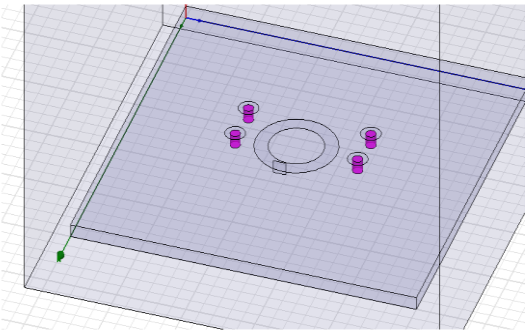


***Fig2.* Geometry annular ring antenna with small periodic circular metal pads and periodic cylinders of two different dielectric materials from the center of the metal pads to the ground**

4. Results

The antenna is designed for different substrate configurations and simulated on the HFSS simulation software. The results are given in the following graphs.

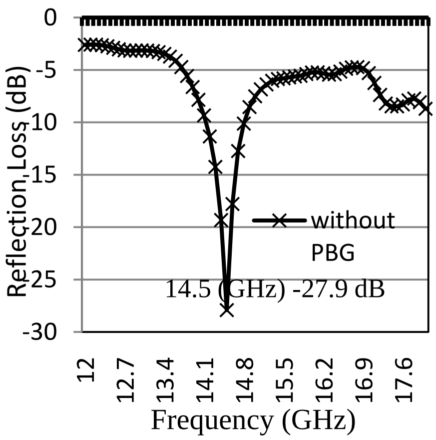


***Fig2.* Reflection Loss (dB) of annular ring antenna without PBG**

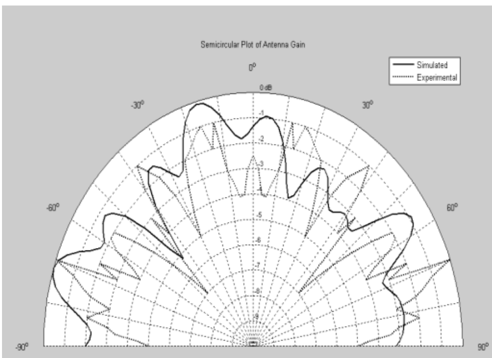


***Fig3.* Radiation Pattern of annular ring antenna without PBG**

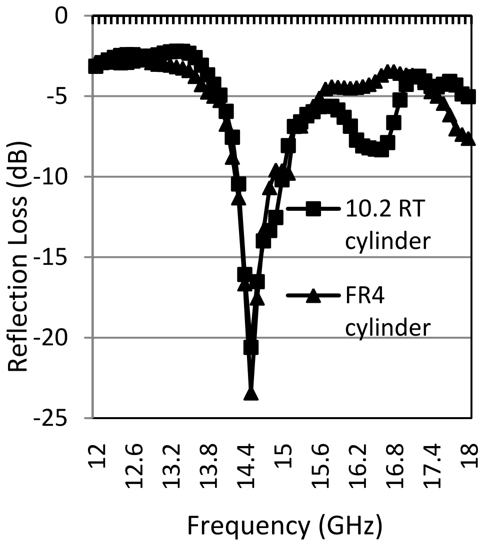


***Fig4.* Reflection Loss (dB) of annular ring antenna with small periodic circular metal pads and periodic cylinders of two different dielectric materials from the center of metal pads to the ground**

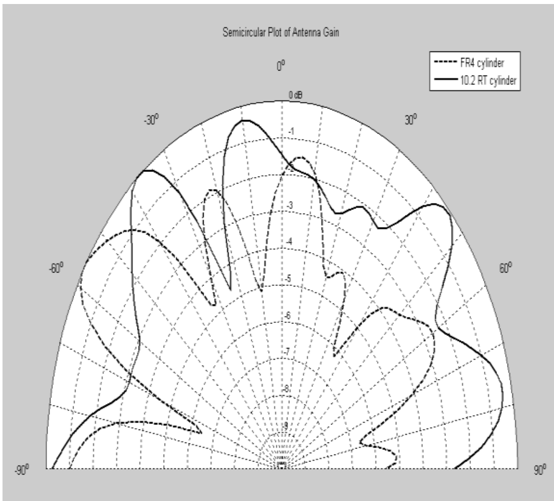


***Fig5.* Radiation Pattern of annular ring antenna with small periodic circular metal pads and periodic cylinders of two different dielectric materials from the center of metal pads to the ground**

5. Discussions of Results

Firstly, a simple annular ring antenna is designed on FR4 without PBG resonating at 14.5 GHz with simulated gain of 8.81 dB. The radiation pattern shows maxima at 35^0, which is due to the excitation of the antenna at higher modes (TM_{31}). Higher order mode is chosen for the design for obtaining good impedance match and higher gain. The antenna designed on FR4 with small metal pads and with RT duroid cylinder (dielectric constant 10.2) to the ground, shows a simulated gain of 11.45 dB at -90°. In addition, because of slightly different patch dimension antenna with Novel PBG structure resonates at 14.5 GHz with -20.6 dB. The enhancement in gain of the antenna is considerable. On introducing FR4 cylinder (dielectric constant 4.4) gain of an antenna increased to 12.17 dB and maxima is at -56°. Antenna with this PBG structure resonates at 14.5 GHz with -23.43 dB. Gain of antenna with this PBG structure has maximum gain. The experimental results for antenna 4 are not shown as it was difficult to fabricate.

Table I Comparison Table

Parameter	**Annular ring antenna without PBG**	**Annular ring antenna with periodically loaded metal pads and RT duroid cylinder from the center of the metal pads (dielectric constant 10.2) to the ground**	**Annular ring antenna with periodically loaded metal pads and FR4 cylinder from the center of the metal pads (dielectric constant 4.4) to the ground**
S_{11} (dB)	-27.9 dB (14.5 GHz)	-20.6 dB (14.5 GHz)	-23.43 dB (14.5 GHz)
Gain (dB)	8.81 dB	11.45 dB	12.17 dB

6. Conclusion

From the comprehensive analysis of the annular ring antenna for gain enhancement it can be concluded that annular ring antenna with Novel PBG structure gives good impedance matching and considerable gain enhancement to the antenna. There is some shift in resonance frequency and direction of maximum radiation, which can be overcome by optimization, but still this technique can be very fruitful for gain enhancement of antennas.

7. REFERENCES

[1] Garg.R.et.al "Microstrip Antenna Design Handbook" Artec House 2001

[2] T.H. Liu, W.X.zhang,and K.F.Tsang"Low profile spiral antennas with PBG substrate, Electronic Lett 36 (2000),779-780

[3]Y.Qian,R.Coccioli D.Sievenpiper,V.Radisic,E.Yablonvitch and T.itoh" A microstrip patch antenna using Photonic bandgap structures" Microwave J 42 (1999),66-76

[4] R.Coccioli, W.R. Deal and T.itoh "Radiation characteristic of patch antenna on a thin PBG substrate" 1998 IEEE Antenna and Propagation Soc Int symp Dig, pp 650-659

[5] Y.Horii and M.Tsutsumi "Harmonic control by photonic bandgap on microstrip patch antenna, IEEE Microwave Guided Wave Lett 9 (1999), 13-15

[6] Ramon Gonzalo, Beatriz Martinez, Peter de Maagt and Mario Sorolla " Improved Patch Antenna Performance by using Photonic Bandgap Substrates" Microwave and optical Technology Letters Vol.24, No. 4 February 2000.

[7] V.Radiasic, Y Qian, R. Coccioli and T. Itoh "Novel 2D Photonic Bandgap Structure for microstrip Lines" IEEE Microwave Guided Wave Lett 8 (1998), 69-71