Design And Analysis of Uniplanar Compact Electromagnetic Bandgap Structures

Shivam Gautam[1], **Komalbir Kaur**[1], **N. S. Raghava**[1], **and Asok De**[2]

[1]Delhi Technological University, India
[2]NIT Patna, India

Abstract— A uniplanar compact electromagnetic bandgap (UCEBG) antenna and its performance analysis is presented in this paper. The antenna consists of a rectangular patch element on a dielectric substrate, micromachined with a layer of periodic unit electromagnetic bandgap (EBG) structures below the dielectric. This EBG improves the antenna's efficiency and increases its compactness, enabling it to perform better at a lower frequency. The whole structure is backed by a ground plane with an air gap of 9 mm.

1. INTRODUCTION

Microstrip Antennas are one of the most widely used type of antennas owing to their low cost and compactness. However, their low gain, efficiency and bandwidth lead to their poor performance [1]. By etching EBG structures on one side of the substrate, the performance parameters like gain, efficiency and bandwidth can be improved, in turn, leading to better operation of the antenna [2].

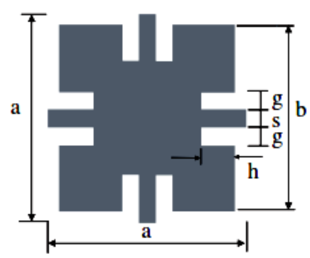

Figure 1: Unit EBG structure.

EBG structures are 3-D periodic objects that prevent the propagation of the electromagnetic waves in a specified band of frequency for all angles and for all polarization states [3]. Initial interest in the development of EBG structures was in the sphere of optics [4], but as these structures are readily scaleable and applicable to a wide range of frequencies, over the years there has been an increasing interest in the applications of these structures in microwave and millimeter wave regions. Applications of the EBG phenomena in microwave region improves the radiation pattern of antennas [5], increase the output power and efficiency of power amplifiers [6]. Apart from this, EBG structures are easy to fabricate, low cost and compatible with prevalent planar circuit technology [7]. The shape of a unit of the EBG structure may be hexagonal as in [8] or cross shaped as in [9]. The shape presented in this paper is a square pad with connecting branches [10].

2. ANTENNA DESIGN

The EBG plane is formed by periodic repetitions of a unit EBG structure depicted in Figure 1. The dimensions of the unit EBG structure, depicted in Figure 1, are as follows: $a = 11.2$ mm, $b = 10.5$ mm, $s = 1$ mm and $g = 0.9$ mm.

The antenna is composed of a reflector, an EBG plane, a dielectric substrate and a radiating patch. Figure 2(a) depicts the top view of the antenna. The length of each side of the ground plane is L which is equal to 191.2 mm. The antenna consists of a 17×17 matrix of unit UCEBG structure. The side view of the antenna is depicted in Figure 2(b). The substrate between the UCEBG layer and the radiating patch is of 0.7 mm thickness and a dielectric constant of 6.15. The reflector is introduced at the back end of the antenna to reduce the back lobe. The air gap between the reflector and the UCEBG layer is 9 mm, which has been determined by varying its position with respect to the substrate [2]. The radiating patch element is of dimension $70\,\text{mm} \times 54\,\text{mm}$.

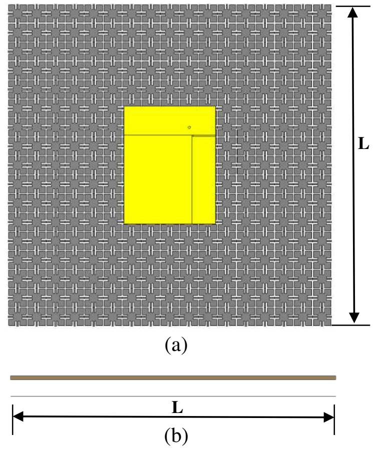

Figure 2: (a) Top view of UCEBG. (b) Side view of UCEBG.

3. RESULTS AND DISCUSSIONS

The antenna is simulated using the software Computer Simulation Technology (CST) Microwave Studio. The results obtained from the simulation show that the central frequency of operation of the antenna is 1.556 GHz. The antenna has a Voltage Standing Wave Ratio (VSWR) of 1.06 at the operating frequency. The graphical representation of reflection coefficients are shown in Figure 3 whereas the VSWR is depicted in Figure 4.

The polar plot representation of the antenna is depicted in Figure 5(a). The three dimensional depiction of radiation pattern of the antenna is shown in Figure 5(b). The antenna has a gain of 5.58 dB at $\theta = 1°$, $\phi = 0°$.

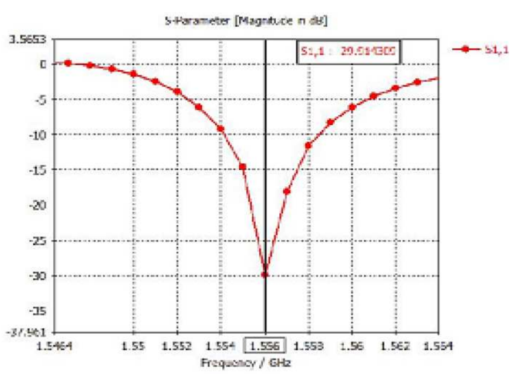

Figure 3: Reflection coefficient parameters.

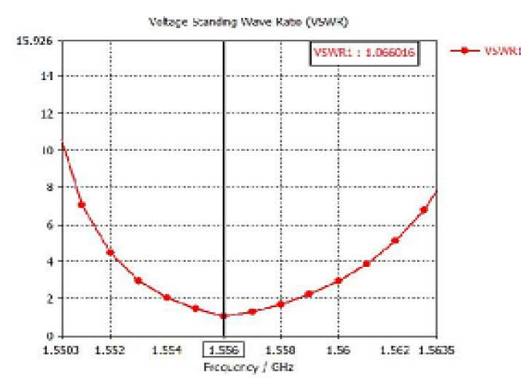

Figure 4: VSWR parameters.

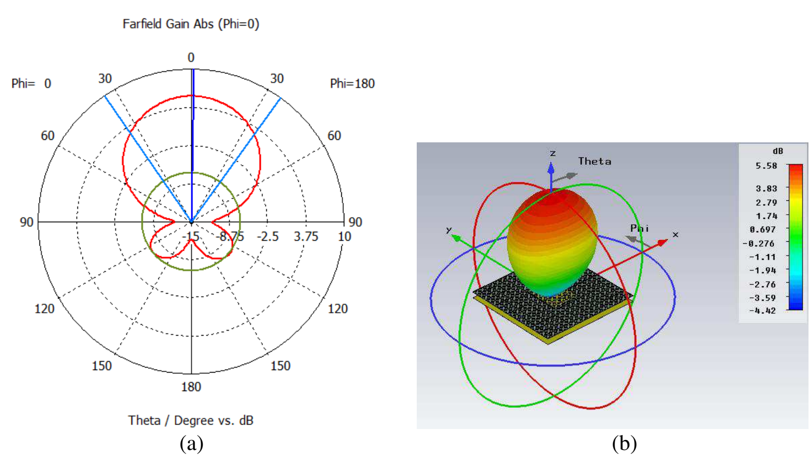

Figure 5: (a) Polar plot at $\phi = 0°$. (b) Three dimensional depiction of radiation pattern.

4. CONCLUSION

The Uniplanar Compact Electromagnetic Bandgap Antenna was presented in this paper. The introduction of the EBG layer increases the compactness of the antenna and makes it possible to integrate with a wide range of applications. The structure is compact and the operational parameters of the antenna such as reflection coefficient, gain and VSWR are optimal to be integrated with suitable applications such as road vehicle communication systems [11].

REFERENCES

1. Balanis, C. A., *Antenna Theory: Analysis and Design*, John Wiley & Sons, Inc., 1997
2. Raghava, N. S. and A. De, "Effect of air gap width on the performance of a stacked square electronic band gap antenna," *IJMOT*, Vol. 4, No. 5, 315–317, Sep. 2009.
3. Rahmat-Samii, Y. and H. Mosallaei, "Electromagnetic band-gap structures: Classification, characterization and applications" *Proc. Inst. Elect-Eng. — ICAP Symp.*, 560–564, Apr. 2001.
4. Yablonovitch, E., "Inhibited spontaneous emission in solid-state physics and electronics," *Phys. Rev. Lett.*, Vol. 58, No. 20, 2059–2062, May 1987.
5. Ellis, T. J. and G. M. Rebeiz, "MM-wave tapered slot antennas on micromachined photonic bandgap dielectrics," *Proc. IEEE MTT-S Int. Microwave Symp. Dig.*, 1157–1160, Jun. 1996.
6. Radisic, V., Y. Qian, and T. Itoh, "Broadband power amplifiers using di- electric photonic band gap structure," *IEEE Microw. Guided Wave Lett.*, Vol. 8, 13–14, Jan. 1998.
7. Chang, C. C., Y. Qian, and T. Itoh, "Analysis and applications of uniplanar compact photonic bandgap structures," *Progress In Electromagnetic Research*, Vol. 41, 211–235, 2003.
8. Choudhary, A., N. S. Raghava, A. Biswas, and A. De, "A highly efficient rectangular microstrip antenna with hexagonal holes as an electromagnetic bandgap structure in the ground plane," *Proc. of InternationalConference on Microwave*, 152–153, 2008.
9. Raghava, N. S., A. De, N. Kataria, and S. Chatterjee, "Stacked patch antenna with cross slot electronic band gap structure," *International Journal of Information and Computation Technology*, Vol. 3, No. 5, 1–4, 2013.
10. Yang, F. R., K. P. Ma, Y. Qian, and T. Itoh, "A uniplanar compact photonic-bandgap (UC-PBG) structure and its applications for microwavecircuits," *IEEE Trans. Microwave Theory Tech.*, Vol. 47, 1509–1514, Aug. 1999.
11. Raghava, N. S. and A. De, "Photonic bandgap stacked rectangular microstrip antenna for road vehicle communication," *IEEE Trans. Antennas and Wireless Propagation Letters*, Vol. 5, 421–423, Dec. 2006.