Dual Band Electromagnetic Band Gap Structure with wideband antenna

Muhammad Abdul Hamid, Mohamad Kamal A Rahim, Umar Mussa
Advanced RF and Microwave Research group
Faculty of Electrical Engineering
Universiti Teknologi Malaysia
81310 UTM JB Johor, Malaysia

Abstract - **This paper describes the design, simulation and measurement of a slotted electromagnetic band gap (EBG) structure incorporated with wideband antenna. The design is carried out on FR4 substrate of dielectric constant, $\mathcal{E}_r$=4.6 and thickness, h=1.6mm. The result from the simulation and measurement of electromagnetic band gap (EBG) structure is presented in term of transmission coefficient S_{21} and in term of reflection coefficient, S_{11}(dB). Two bands of frequencies have been achieved in this design. The wideband monopole antenna is designed using circular patch with half ground plane. The EBG structure is incorporated with the wideband antenna to suppress the wave from propagating through the transmission line. It shows that two band of frequencies has been suppressed when incorporated with the EBG structure**

Index Terms — **Wideband Antenna, Electromagnetic band gap, stop band, transmission coefficient**

1. Introduction

Electromagnetic band gap (EBG) structures are presently one of the most rapidly advancing sectors in the electromagnetic field. The structures allowed the propagation of electromagnetic waves at certain band of frequency and stop the propagation of electromagnetic waves at certain band of frequency. The rapid advances in both theory and experiment together with substantial technological potential have driven the development of electromagnetic band gap technology [1, 2].

Because of its unique properties, it is widely used in various research fields especially in RF design. Many exciting phenomena appear when periodic structures interact with electromagnetic waves, which include band pass, band stop and also frequency band gap. The periodic structure reviewed previously revealed that varieties of applications like guiding wave, reflector, photonic crystals and photonic band gap are the typical advantages derived. Others include wave propagation, noise reduction for high speed electronic devices and mutual coupling effect reduction [3-6].

In the field of antenna and microwave engineering, EBG structures play an important role by improving their performances. From previous work done by many researchers in this field, the usage of EBG structures can be divided into four main areas which includes;

i. EBG structures for suppressing surface wave effect in planar antenna and also for increasing the antenna efficiency [7].
ii. EBG structures as Artificial Magnetic Conductor or High Impedance surface(reflectors for antenna)
iii. EBG structures to create tapered walls for directive horn antennas [8].
iv. EBG structures to create a resonating antenna that create high directivity via the angle dependent properties of the EBG material [9].

In this paper, four slots are introduced on a conventional (mushroom) EBG structures. The design offers a dual band and after incorporating with wideband antenna the structure is successfully suppressed the surface wave. The structure allowed the manipulation of the propagation of electromagnetic waves to an extent that was previously not possible. The rapid advances in both theory and experiment together with substantial technological potential have driven the development of electromagnetic bandgap technology [1, 2].

2. Design consideration of dual band EBG

Figure 1 shows the slotted EBG with dual band operation. The parameter L (inductance) results from the current that flow through the vias and the C (capacitance) is due to the gap effect between the neighboring patches. The patch width W, substrate thickness h, gap width g, length of the via d, dielectric constant $\mathcal{E}_r$, the inductance, L and capacitance, C are determine by the following expressions [10-15].

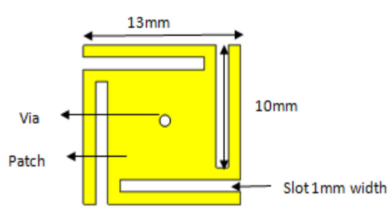

Figure 1: slotted EBG structure

3. Wideband Antenna design with EBG

The conventional circular patch antenna in figure 2 was designed using FR-4 substrate of dielectric constant $\mathcal{E}_r$= 4.6 and height h=1.6mm. The antenna was designed using a double layer substrate which is 3.2mm (2x1.6mm) that is incorporated later with the slotted EBG structure. Figure 2(a) gives the overall dimensions of the antenna. Figure 2(b) shows the antenna with the EBG structure

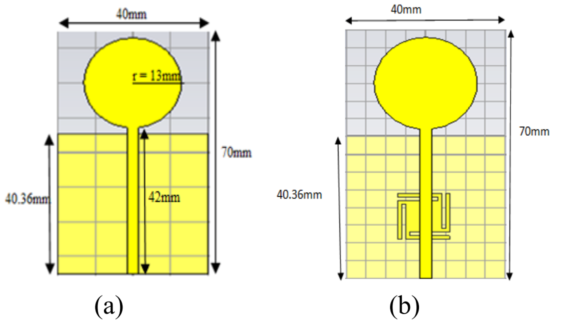

Figure 2: (a) The final antenna dimension (b) the antenna with EBG structure

4. Result and Discussion

Figure 3 shows the simulated and measured transmission coefficient of the slotted EBG structure. The fractional bandwidth from the simulation is found to be 10.8% at 1.71GHz to 1.91GHz and 5.4% at 4.05GHz to 4.27GHz, while 6.5% at 1.89GHz to 2.02GHz and 7.3% at 4.15GHz to 4.47GHz was found from the measurement after the fabrication process, which shows the operational frequency shifts to higher frequency for the measurement.

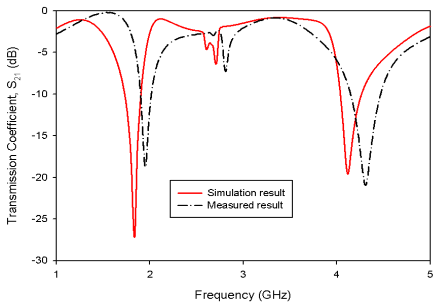

Figure 3: simulation and measured transmission Coefficient of the slotted EBG structure

Figure 4 shows the simulated and measured reflection coefficient, S_{11}(dB) of the wideband antenna incorporated with the slotted EBG structure.

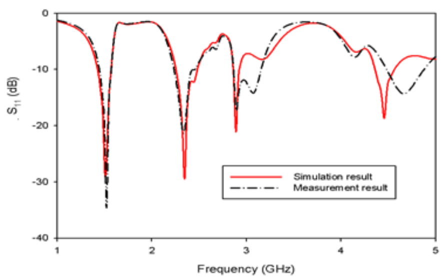

Figure 4: Simulation and measured return loss of the wideband antenna with slotted EBG structure

From the simulations the fractional bandwidth are 9.6%, 9.3%, 2.5% and 5% while from the measurement the fractional bandwidth are 9.4%, 9.3%, 9.5% and 8.5%. The measured results for the wideband microstrip antenna incorporated with EBG after fabrication process shows the operational frequency shifts to higher frequency. It can be seen that the frequency band at 2GHz, 3GHz to 4.2GHz are all suppressed by the slotted EBG structure.

5. Conclusion

A slotted Electromagnetic band gap (EBG) structure incorporated with an antenna has been discussed in this paper. The structure successfully suppressed the surface wave after incorporating it with antenna which makes it possible for other antenna applications other than wave suppression.

Acknowledgment

This work was supported by Ministry of Higher education (MOHE), Research Management Centre (RMC), Faculty of Electrical Engineering, Universiti Teknologi Malaysia (UTMJB) Johor Bahru, under research grant no 4L811 and 12H09.

References

[1] M. S. Alam, N. Misran, B. Yatim, and M. T. Islam, "Development of electromagnetic band gap structures in the perspective of microstrip antenna design," *International Journal of Antennas and Propagation,* vol. 2013, 2013.

[2] P. De Maagt, R. Gonzalo, J. Vardaxoglou, and J. Baracco, "Review of electromagnetic-bandgap technology and applications," *Radio Science Bulletin,* vol. 309, pp. 11-24, 2004.

[3] O. Ayop, M. K.A. Rahim, M. Kamarudin, M. Aziz, and M. Abu, "Dual band electromagnetic band gap structure incorporated with ultra-wideband antenna," in *Antennas and Propagation (EuCAP), 2010 Proceedings of the Fourth European Conference on*, 2010, pp. 1-4.

[4] Liu, Y., Hao, Y. W., Jia, Y. T., & Gong, S. X. (2014, August). Wideband RCS Reduction of Microstrip Antenna by Frequency Reconfigurable Electromagnetic Band Gap. In *PIERS Proceedings*.

[5] Y. Rahmat-Samii and H. Mosallaei, "Electromagnetic band-gap structures: Classification, characterization, and applications," in *Antennas and Propagation, 2001. Eleventh International Conference on (IEE Conf. Publ. No. 480)*, 2001, pp. 560-564.

[6] R. Kumar and J. P. Shinde, "On the Effect of Fractal Electromagnetic Band Gap on Antenna Performance," *IETE Journal of Research,* vol. 56, pp. 333-339, 2010.

[7] A. R. Weily, K. P. Esselle, and B. C. Sanders, "Layer-by-layer photonic crystal horn antenna," *Physical Review E,* vol. 70, p. 037602, 2004.

[8] E. Brown, E. Yablonovitch, and C. Parker, "Radiation properties of a planar antenna on a photonic- crystal substrate," *JOSA B,* vol. 10, pp. 404-407, 1993.

[9] A. Sharma and G. Singh, "Design of single pin shorted three-dielectric-layered substrates rectangular patch microstrip antenna for communication systems," *Progress In Electromagnetics Research Letters,* vol. 2, pp. 157-165, 2008.

[10] D. Zhang, T. Jiang, and Y. Kong, "A novel compact EBG structure for multiband wireless communication," 2014.

[11] T. Masri and M.K.A.Rahim, 'Dual Band Microstrip Antenna Array with a Combination of Mushroom, Modified Minkowski and Sierpenski EBG', IET Microwave Antenna and Propagation, volume 4, pp 1756-1763, 2010 .

[12] F. Yang and Y. Rahmat-Samii, "Reflection phase characterizations of the EBG ground plane for low profile wire antenna applications," *Antennas and Propagation, IEEE Transactions on,* vol. 51, pp. 2691-2703, 2003.