

Design Analysis of An Electromagnetic Band Gap Microstrip Antenna

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Abstract: Problem statement: Wideband compact antenna is highly demandable due to the dynamic development in the wireless technology. **Approach:** A simple, compact EBG microstrip antenna is proposed in this study that covers a wideband of 250 GHz and the design is conformal with the 2.45 GHz ISM band (WLAN, IEEE 802.11b and g)/Bluetooth/RFID applications. **Results:** A 6×6 array of square unit cell formed the EBG structure which is incorporated with the radiating patch to enhance the antenna performances. This design achieved an impedance bandwidth of 10.14% (2.34-2.59 GHz) at -10 dB return loss and VSWR ≤ 2. Simulated radiation pattern is almost omnidirectional. **Conclusion/Recommendations:** The simulated results prove the compatibility of the EBG antenna with the 2.45 GHz ISM band applications. Further enhancement of the antenna performance with improved design is under consideration.

Key words: Wireless technology, electromagnetic modes, periodical structure, wide bandwidth, wireless communications, space programs, short range radio

INTRODUCTION

Recent advances in wireless communications, radar, satellite and space programs have introduced tremendous demands in the antenna technology (Mobashsher *et al.*, 2010; Shakib *et al.*, 2010a; 2010b; Azim *et al.*, 2011; Islam *et al.*, 2009a; 2010b). Among the various type of antenna, microstrip antennas are of special interest because of their light weight, low profile, compactness and compatibility with integrated circuits, though they suffer from some drawbacks e.g., narrow bandwidth, low gain and excitation of surface waves (Garg *et al.*, 2001; Azim *et al.*, 2010). To overcome these limitations, new methods are still being explored and the interesting features of Electromagnetic Band Gap (EBG) materials have attracted the antenna researchers.

Usually, the Electromagnetic Band Gap (EBG) materials are periodical structures composed of metallic or dielectric elements. Addition of defects into the periodical structure, exhibits the ability to reject the propagation of the electromagnetic waves whose frequency is included within their frequency band gap and to open localized electromagnetic modes inside the forbidden frequency band (Yablonovitch, 1987). EBG always referred as high impedance surface that increase

antenna surface efficiency by suppressing the unwanted surface wave current. Suppression of surface waves excitation helps to improve antenna's performance such as reduces backward radiation and increase antenna gain (Gonzalo *et al.*, 1999).

In the recent past, the communication devices had been emerged rapidly (Alam *et al.*, 2009; Azim *et al.*, 2011). To cope with this fast development in wireless technology, miniaturization of antenna with wideband and good radiation characteristics is very much desirable (Faruque *et al.*, 2010; Islam *et al.*, 2009b; 2010a). In this regard, design of an antenna with reduced size while maintaining good performance in the Industrial Scientific and Medical (ISM) band of 2.4-2.5 GHz is in our concentration. This frequency allocation complies with the IEEE 802.11b Wireless Local Area Network (WLAN), Bluetooth and RF Identification Devices (RFID) applications. Bluetooth is a Wireless Personal Area Networking (WPAN) technology which is well suited for short range radio links between portable devices. Similarly, WLAN is efficient for medium range wireless communication environment where as RFID is widely used in tagging, tracking, monitoring and detection of objects (Ali *et al.*, 2002; Finkenzeller, 2003). Different type of microstrip antenna satisfies the dual-band operation for the ISM band 2.45/5.8 GHz have been

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investigated and published with good results. But still there are many applications in wireless communication greatly demand the operation of single-band antenna (Mobashsher *et al.*, 2010; Chen *et al.*, 2009; Zhang *et al.*, 2009; Pan *et al.*, 2005).

In this study, a simple and compact EBG microstrip antenna is proposed that is conformal with the short range and medium range wireless network operation. It covers the frequency band of 2.34-2.59 GHz and this design could be adopted for single band WLAN/PAN applications. Some parametric studies have been realized on the EBG structure and the radiating patch to achieve a high performance antenna. A rectangular patch over an array of EBG unit cell is designed and optimized for better performance. Considerable improvement in terms of bandwidth and radiation pattern is obtained which confirmed the suitability of the compact design for ISM band (WLAN, IEEE 802.11b/g)/Bluetooth/RFID applications.

Antenna design geometry: The schematic diagram of the coaxial probe fed EBG antenna with a finite ground plane is shown in Fig. 1. It consists of two layers and the radiating element is printed on the upper surface of the top layer. The bottom layer carries an array of square metallic patch printed on the dielectric substrate. The gray parts represent the metallic periodic structure and the black part is the radiator. This structure has a compact dimension of 34.5×34.5 mm. From the theoretical approach, the dimensions of a microstrip patch radiator can be modeled by using the following formulas (Bahl and Bhartia, 1980). For an efficient radiator, the practical width that leads to good radiation efficiencies is Eq. 1a:

$$W = \frac{c}{2f_0} \sqrt{\frac{\epsilon_r + 1}{2}} \quad (1a)$$

Where:

c = The free space speed of light

ϵ_r = The relative permittivity of dielectric substrate

The microstrip patch lies between air and dielectric material and thus, the effective dielectric constant can be found by Eq. 1b:

$$\epsilon_e = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[1 + \frac{12h}{W} \right]^{-1/2} \quad (1b)$$

where, h is the thickness of the substrate. The actual length of the patch can be determined by Eq. 1c:

$$L = \frac{c}{2f_0 \sqrt{\epsilon_e}} - 2\Delta l \quad (1c)$$

where, Δl is the extension in L and is given by Eq. 1d:

$$\Delta l = 0.412h \frac{(\epsilon_r + 0.3) \left(\frac{W}{h} + 0.264 \right)}{(\epsilon_e - 0.258) \left(\frac{W}{h} + 0.8 \right)} \quad (1d)$$

The EBG structure has 6×6 unit cells and an overall dimension of 32.5×32.5 mm, printed on a very inexpensive 1.6 mm thick (h_1) FR-4 dielectric substrate with relative permittivity (ϵ_{r1}) of 4.4 and loss tangent (δ) of 0.02. The antenna designed on a finite ground plane with a dimension of 34.5×34.5 mm. The length ($L_u = W_u$) of the square EBG metallic patch is 5mm and their spacing with adjacent patches is 0.5 mm. Thus the period of the lattice is 5.5 mm.

A rectangular radiating patch of (L_p) 13.6× (W_p) 14.5 mm with an extended microstrip line of 2.5 mm width (W_m) and 3.1718 mm length (L_m) is printed on the top layer. An air-filled substrate of thickness (h_2) 6.4 mm is sandwiched between the rectangular patch and the EBG structure. The patch is directly fed by a coaxial probe of radius 0.5 mm on the microstrip line and the feeding position is at the midpoint along X-axis and 8.5 mm away along the Y-axis.

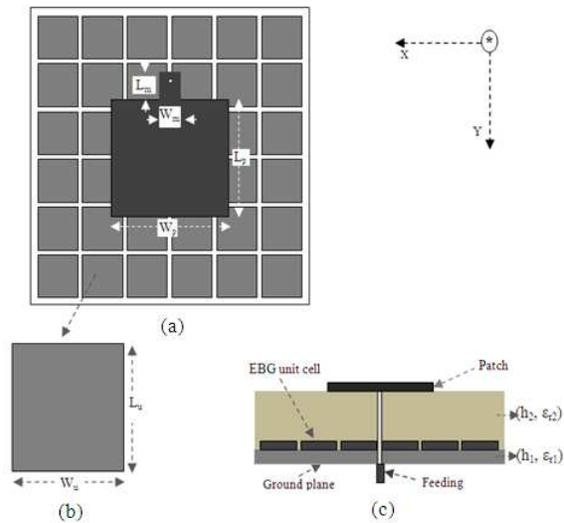


Fig. 1: Geometry of the proposed EBG antenna (a) top view (b) EBG unit cell (c) side view

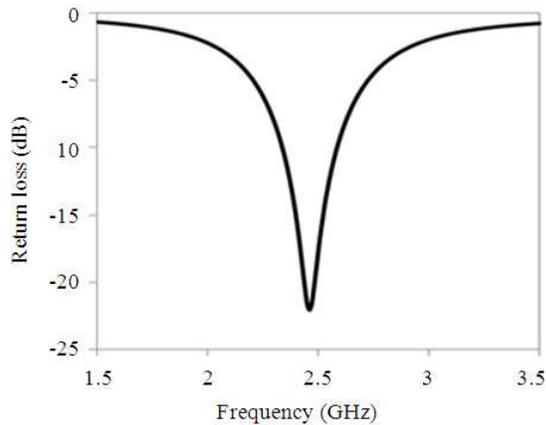


Fig. 2: Return loss of the proposed EBG antenna

MATERIALS AND METHODS

Finite Element Method (FEM) based full wave electromagnetic simulator Ansoft's HFSS v.10 is utilized to design and study the proposed EBG antenna performances. This design is aimed to be a simple construction with smaller size. First, the EBG structure is designed to have a wide band gap and then the rectangular radiating patch is optimized to meet the 2.45GHz ISM band WLAN applications requirement. The antenna is directly fed by a coaxial probe and some parametric studies are performed to obtain the feeding position to avoid impedance mismatch.

RESULTS

The study of return loss and radiation characteristics is the vital for the microstrip patch antenna design. Figure 2 shows the simulated return loss behavior of the EBG antenna. For return loss < -10 dB, the proposed antenna achieved an impedance bandwidth of 250 MHz (2.34-2.59 GHz). The return loss curve reached down to -22.15 dB at the resonant frequency of 2.46 GHz. The wideband of the design can also be seen from Fig. 3, at VSWR ≤ 2 is (2.34-2.59) GHz.

The simulated radiation patterns for the E-plane and H-plane of the proposed EBG antenna at frequency 2.46 GHz is shown in Fig. 4a and b, respectively. The pure black and dotted curves in the figures respectively represent the co-polarization and the cross-polarization characteristics.

In the E-plane the pattern is likely to be directional and the co-polar component is higher than the cross-polar component. The radiation in the H-plane is almost omni-directional and the cross-polar component is very lower than the other one.

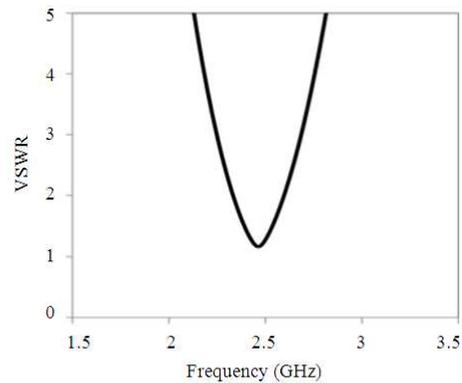


Fig. 3: VSWR of the EBG antenna

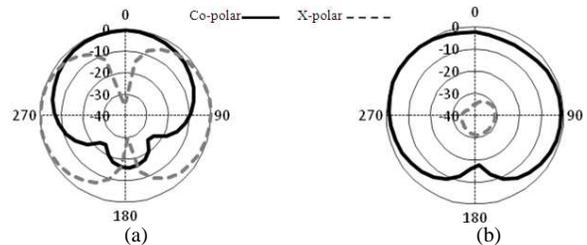


Fig. 4: A E-plane b H-plane Radiation patterns for the proposed EBG antenna at 2.46 GHz

DISCUSSION

In spite of the compactness, the proposed antenna achieved a wideband with a resonant frequency of 2.46 GHz. As depicted in the Fig. 2 and 3 in the result section, the operating frequency band (2.34-2.59 GHz) obtained by the EBG microstrip antenna makes it appropriate for (2.4-2.5) GHz ISM band WLAN applications. From the E and H-plane radiation curves it is observed that, throughout the bandwidth the designed EBG antenna achieved almost omni-directional radiation pattern.

CONCLUSION

The design and simulated characteristics of a compact EBG rectangular patch antenna is presented here for wireless short range and medium range operation. With the optimized antenna configuration, the proposed antenna offers an impedance bandwidth of 10.14% (2.34 -2.59 GHz), which is sufficient enough for 2.45 GHz ISM band (WLAN, IEEE 802.11b and g)/ Bluetooth/RFID applications. The radiation patterns are almost omni-directional and stable throughout the bandwidth. Utilization of the EBG structure shows improvement of the antenna performance significantly.

In terms of return loss and radiation pattern behavior, the proposed antenna with smaller size, exhibits its suitability with the aforementioned wireless communication technology.

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