Bandwidth and Gain Enhancement of Ultra-Wideband Monopole Antenna Using MEBG Structure

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Abstract: Two designed of Ultra-Wide Band (UWB) monopole antenna with/without Electromagnetic Band Gap (MEBG) mushroom structure has been designed and analyzed. EBG structure is used in UWB monopole antenna to enhance the gain and the bandwidth as well, several main parameters of the proposed antenna are discussed such as return loos, gain, radiation pattern. First design of monopole antenna gave the bandwidth without EBG of 8.069 GHz (2.77-10.84 Ghz) while the maximum gain is 4.4 dB. Whereas second design with EBG gives wide huge bandwidth of 23.33 GHz (2.67-26 GHz) and higher maximum gain 5.8 dB. The highest impedance bandwidth attained is 161% considers VSWR 2:1. The proposed antenna will serve different applications such as Bluetooth, cellular systems and satellite communication and 5 G. The greater bandwidth also offers the antenna low mutual coupling rather than the antenna without EBG. FR4 substrate is used here with comparative permittivity 4.4. At the end of this study, physical model and measured results are presented and the measured results well match with the simulations.

Key words: EBG, ultra-wide-band, monopole antenna, physical mode, UWB, MEBG

INTRODUCTION

With the startling request for miniaturization of the wireless communication system, antenna design becomes more challenging. Recently monopole antennas have been widely used in satellite communications, aerospace, radars, biomedical Due to its inherent characteristics such as light weight, applications and reflector feeds, low profile, low cost, mechanically robust, integrated circuit compatibility and a highly reliable resonant frequency. Polarization, impedance and pattern. Despite its many advantages, they suffer from disadvantages such as narrow bandwidth, low gain and surface wave excitation., etc. (Liang and Yang, 2007; Islam *et al.*, 2008; Wong, 2002). These inconveniences limit their use in other fields. To overcome the constraints of monopole patch antennas such as narrow bandwidth and low gain, the bandwidth of this antenna can either be improved by optimizing the patch geometry or by using larger substratum thicknesses. Several techniques for such antenna has been initiated to improve performance. One of them, the optimized values for feed and shorting plates are chosen to achieve wideband for a Planar Inverted-F Antenna (PIFA) (Chattha *et al.*, 2009). Another

technique for improving bandwidth is the design of a printed monopole antenna with L-shaped slot. With a patch shaped fork (Emadian *et al.*, 2012). However, due to reduced permittivity and thickness of the substrate, the surface wave increases, leading to efficiency, The lower antenna gain and the radiated pattern of the field are also warped. To enhance the antenna performance.

Fairly recently, microstrip antenna and Electromagnetic Band Gap (EBG) structures have attracted Further attention, to high bandwidth with surface doubling. EBG sporadic provisions of dielectric and translucent materials, they have very high impedance and show a band gap to stifle the surface wave current (Zaker and Abdipour, 2011). This will be of various shapes such as fork, fractal, F, sprial, etc. and can be designed even without vias (Verma, 2012).

Various EBG structure (s) techniques are introduced to improve bandwidth such as the use of reversed F-L microstrip patches on the ground with slotted structures. (Verma, 2012), Semi-circular patch and mushroom type ground EBG (Chauhan and Singhal, 2014). Design of a semicircular planar monopole radiator and ground plane together with metamaterial Structures and Artificial Magnetic spiral Conductors (SAMC) (Yang *et al.*, 2005),

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2×2 patch array locate on EBG spiral type and ground plane spiral type (Madany, 2013). Use of EBG 1-D multilayer structure with large capacity and ground through (Elsheakh *et al.*, 2009). Designing slot monopole antenna with EBG structures. The structures of EBG could be used to improve the gain (Nashaat *et al.*, 2009) and eliminate the interconnection between the array elements (Nashaat *et al.*, 2011; Shen *et al.*, 2014).

In this study, partial ground planes are used as a technique for improving the bandwidth in the monopoly antenna. The bandwidth can extend from 8.069-23.33 GHz. In addition, a higher bandwidth increase from 8.069-23.33 GHz can be obtained by inserting the Electromagnetic Band-Gap (EBG) mushroom type into the original UWB antenna monopoly slot and that's available for most services of wireless communication. The novelty of the methods suggested could be indicated that the bandwidth can be improved without damaging the previous UWB performance and the largest bandwidth of impedance of 156% can be obtained.

MATERIALS AND METHODS

Design considerations of the antenna: Figure 1a represents the UWB monopole antenna without EBG. This using CST microwave studio antenna was designed, the material that used for FR-4 substrate board with double side copper conductor. The dielectric constant of substrate is 4.3 with 1.6 mm of thicknesses and double side copper thicknesses of 0.035 mm as shown in Fig. 1a the dimensions of rectangular patch with length 20 mm and width10 mm, beside it another rectangular patch with length of 18 mm and width of 5 mm. The ground plane of the original antenna is partial ground with length of 16 mm. This patch is connected by microstrip feed line with length of 17 mm and width of 3.6 mm. Which is suitable for 50 Ω SMA connector port.

In order to improve bandwidth, the UWB monopole antenna modified with EBG mushroom structure as illustrated in Fig. 1b, consists of the first design antenna monopole antenna modified with EBG mushroom structure which is 32 rectangular EBG mushroom structure that located broadside the microstrip feed line all rectangular EBGs with same dimensions feed line, the width of the EBG (Web g) is 2.7 mm and the length (Leb g) is 1.3 mm, the Gap Between the EBGs (GBeb g) is 0.4 mm with Gap Between Feed line and EBG (GBFeb g) is 0.7 mm and the Gap inside the EBG cell (Geb g) is 0.8.

Figure 2 illustrates the fabricated version of UWB monopole antenna with/without EBG mushroom structure. The fabrication process using photoresist method and the antenna soldering with SMA connector.
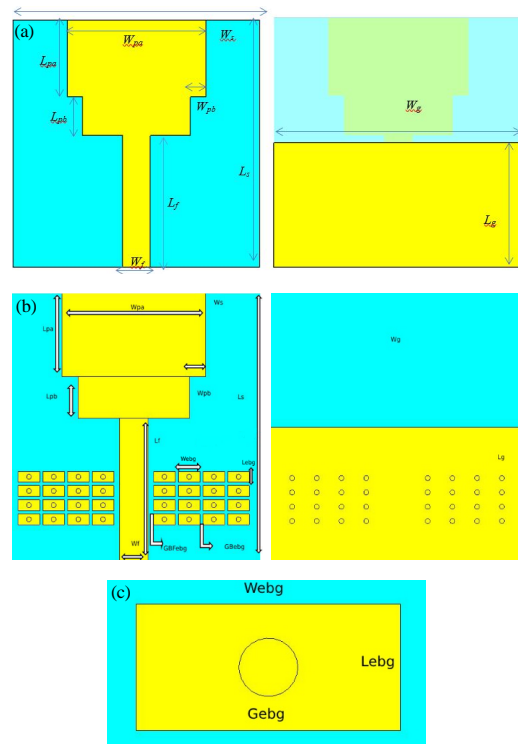

Fig. 1: a) The UWB monopole antenna without EBG mushroom structure $L_s = W_g = 32$, $L_g = 16$, $W_{pa} = 18$, $L_{pa} = 10$, $W_{pb} = 2$ and $L_{pa} = 5$; b) With EBG mushroom structure Web g = 2.7, Leb g = 1.3, Gbeb g = 0.4, GBFeb g = 0.7, Geb g = 0.8 and e) Unit cell EBG
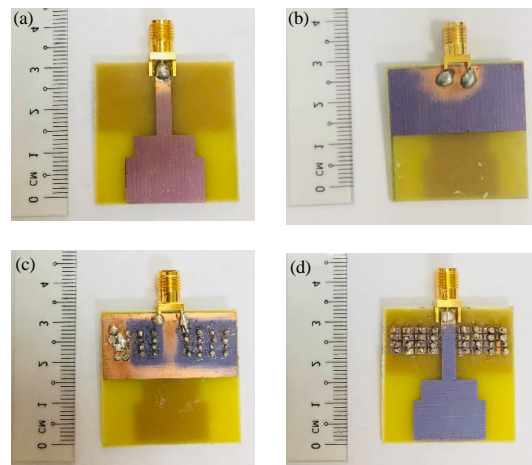

Fig. 2: Fabricated design of the UWB monopole antenna: a) Front view without EBG; b) Back view without EBG; c) Front view with EBG mushroom structure and d) Back view with EBG mushroom structure
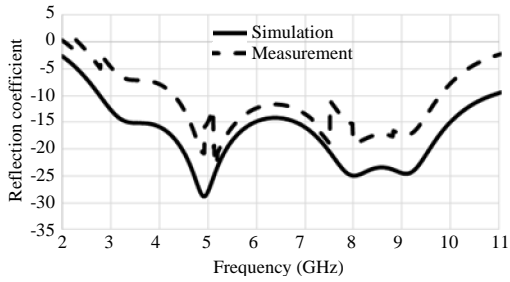
Fig. 3: Simulation and measurement return loss of the UWB monopole antenna without EBG
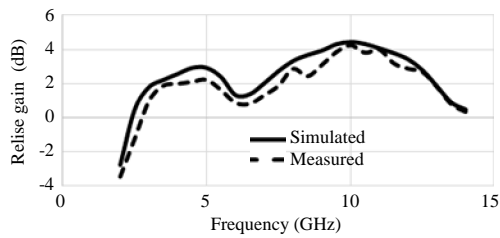

Fig. 4: Antenna gain performance result of UWB monopole antenna without EBG mushroom structure
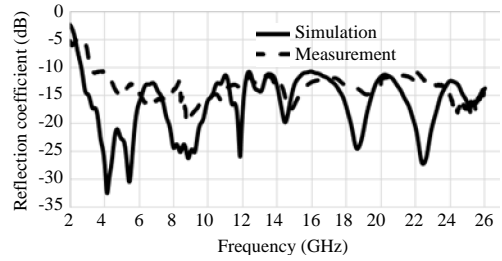

Fig. 5: Simulating and measuring return loss of the UWB monopole antenna with EBG mushroom structure
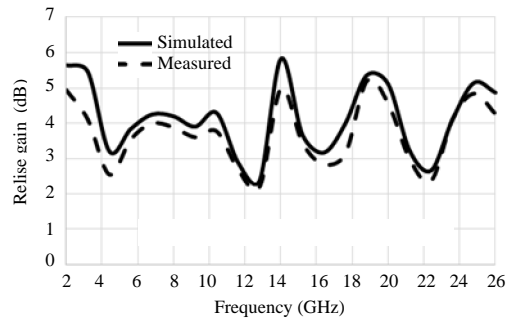
Fig. 6: Antenna gain performance result of the EBG mushroom structure UWB monopole antenna

RESULTS AND DISCUSSION

In this study by using optimized parameter to obtained better results. The results were carried out using CST microwave studio. Some significant performance outcomes considered for this proposed monopole antenna. These performance outcomes are resonant frequency (GHz), return loss (dB), antenna gain (in dBi), 2D radiation pattern and bandwidth (in GHz).

Figure 3 demonstrates the simulated and measured return loss for the UWB monopole antenna without EBG, the antenna operates at range between to 2.77-10.84 GHz and the maximum return loss is -30 dB. It has the bandwidth of 8.069 GHz, the measurement operates at range between 2.81-9.8 GHz and the maximum return loss is -24 dB. The maximum gain of this antenna is only 4.4 and the measurement gain is about 4.2 dB as shown in Fig. 4.

Figure 5 shows, the simulated and measured return loss for the EBG mushroom structure UWB monopole antenna. the antenna operates at range between to GHz (2.67-26 GHz) GHz and the maximum return loss is below -30 dB. It has the bandwidth of 23.33 GHz, the measurement operates at range between (3.24-26) GHz has the bandwidth of 19.76 GHz and the maximum gain of this antenna is only 5.8 dB and the measurement gain is 5 dB as shown in Fig. 6.

Table 1: Comparison performance of the UWB monopole antenna without EBG and with EBG

	Without EBG		With EBG	
Variables	BW (%) (f_2-f_1) (GHz)	Max gain (dB)	BW (%) (f_2-f_1) (GHz)	Max gain (dB)
Simulation	124 (2.77-10.84)	4.4	161 (2.67-26)	5.8
Measurement	110 (2.81-9.8)	4.2	155 (3.24-26)	5

Table 2: The comparison between this work with published regarding to UWB monopole antenna using EBG structure technique

References	BW% (F_1-F_2) (GHz)	Size (mm)	Max gain
Guo *et al.*	151% (1.53-11)	115×60×0.8	3 dBi
Li *et al.*	66.6% (3-6)	60×50×1.5	--
Peng *et al.*	120% (2.74-11)	50×48×1	2.38 dBi
This research	155% (3.24-26)	32×32×1.6	5 dBi

Table 1 and 2 comparison between this research work with other UWB antenna publications that used EBG structure, this research work shows small antenna size, large bandwidth ranges with higher gain.

CONCLUSION

In this study UWB monopole antenna with EBG mushroom structure to achieve higher gain and bandwidth without via. two designs simulated and fabricated and they were compared, UWB monopole antenna with EBG mushroom structure applied in various applications such as Bluetooth, mobile and satellite communication systems and 5G, the mushroom monopole

antenna without EBG cover the range 2.77-10.84 GHz with gain 4.4 dB, give impedance bandwidth of 124%. This specific antenna could be used for some part of UWB application by inserting EBG mushroom structure to increase the bandwidth to higher of 161% that covers the entire frequency range of 2.67-26 GHz with maximum gain 5.8 dB that can be used together with satellite communications for Bluetooth, WiMAX, UWB frequency range.

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