Ultra-Wideband Slot Antenna with Notched Band for World Interoperability for Microwave Access

Rezaul Azim, A. Toaha Mobashsher, and M. Tariqul Islam

Abstract**—**In this paper a novel ultra-wideband (UWB) slot antenna with band notch characteristics for world interoperability for microwave access (WiMAX) is proposed. The designed antenna consists of a rectangular radiating patch and a ground plane with tapered shape slot. To realize a notch band, a curved parasitic element has been etched out along with the radiating patch. It is observed that by adjusting the length, thickness and position of the parasitic element, the proposed antenna can achieved an impedance bandwidth of 8.01GHz (2.84 to 10.85GHz) with a notched band of 3.28-3.85GHz. Compared to the recently reported band notch antennas, the proposed antenna has a simple configuration to realize band notch characteristics in order to mitigate the potential interference between WiMAX and UWB system. Furthermore, a stable radiation pattern and moderate gain except at the notched band makes the proposed antenna suitable for various UWB applications.

Keywords**—**Band notch, Filter element, Ultra-wideband (UWB), WiMAX.

I. Introduction

BEING a high speed short distance wireless communication technology ultra-wideband (UWB) has recently attracted the attention of researchers both in academia and industries. In 2002, Federal Communications Commission (FCC) of US declares the frequencies between 3.1 to 10.6GHz as an unlicensed band for wireless radio communication. UWB technology is characteristics with high data transmission rate, low complexity, low cost, low spectral power density and require simple hardware configuration over the conventional wireless systems. As a key component of the communication system, antenna plays a vital role in the proper utilization UWB technology. Different types of antennas have already been proposed for UWB applications. The 3D antennas require a perpendicular ground plane resulting in increased antenna size, and therefore, it is difficult for integration with microwave-integrated circuitries. Compared to these 3D types of antennas planar UWB antenna, printed on a piece of printed circuit board is a good option for many applications, because it can be easily embedded into wireless devices or integrated with other RF circuitry. Moreover, planar antennas have attracted the most attention due to its attractive features, such as low cost, low profile, wide bandwidth and omnidirectional radiation pattern.

Rectangular, square and disc monopole planar antennas are widely investigated by many researchers since they exhibit the basic performance of UWB antennas [1]-[5]. Compared to the rectangular and disc monopole antennas, slot antennas have relatively large magnetic fields that tend not to couple strongly with nearby objects which make them suitable for applications wherein near-field coupling is required to be minimized [6], [7].

Though the FCC allocates UWB to work within the frequency band of 3.1 to 10.6GHz, there is existing narrow band such as IEEE 802.16 worldwide interoperability of microwave access (WiMAX) operating in the 3.3-3.8GHz band. As a consequence, there is a potential danger that the UWB system will interfere with WiMAX band. A common technique to suppress the interfering signals is to use several band-stop filters such as a frequency selective surface connected to the antenna. But this filtering technique will increase the system complexity and requires more space when integrated with other microwave devices. A more useful and dimension method is to employ the antenna element with band-notched characteristics. Therefore, it is desirable to design antennas that are capable of filtering the frequency band of 3.3 to 3.8GHz to mitigate the potential interference between UWB and existing WiMAX system.

There are numerous methods to realize the band-notched characteristics. One main method is to plant different types of slots on the radiating patch, such as a large slot on the patch, U-slot, square slot, pi-slot; attaching bar, the U-shaped bar, or in the ground plane [8]-[13]. Alternate way is placing parasitic elements near the antenna structure as filters to reject the undesired band [14]-[18], or by etching an I-shaped parasitic element on the rear side of the substrate [19]. Nevertheless, some of the proposed designs utilize complex filter structures with large volumetric size which cannot satisfy the demand of portable communication devices nowadays. Moreover, some designed antennas filtered out the necessary band/s resulting in degradation of the received signal quality.

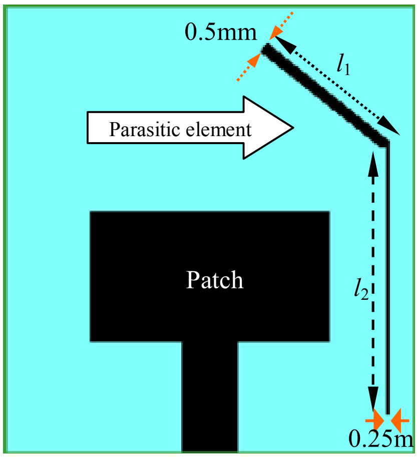
In this paper, a simple and compact planar printed slot antenna covering the UWB band with a notched band centered at 3.5 GHz is presented. The antenna consists of a microstrip line fed rectangular radiating patch and a conducting ground plane with a wide slot; and is printed on an inexpensive printed circuit board (PCB) substrate material. To achieve notched band of 3.3 to 3.8GHz, a curved parasitic element is

Rezaul Azim and M. T. Islam are with the Institute of Space Science (ANGKASA), Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia (e-mail: razim71@ gmail.com).
A. Toaha Mobashsher is with the School of Information Technology and Electrical Engineering, The University of Queensland, Brisbane St Lucia, QLD 4072, Australia.

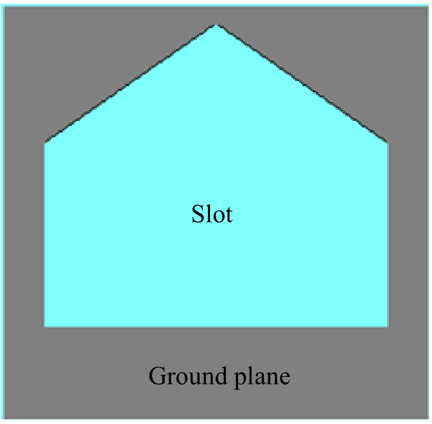
etched out at the same side of the radiating patch. By adjusting the placement and size of the parasitic element, a notched band centered at 3.5GHz can be achieved with stable radiation patterns.

II. Antenna Design

The design layout of the proposed antenna is depicted in Fig. 1. The basic antenna consists of a rectangular radiating patch and a conducting ground plane, and is printed on an inexpensive standard FR4 PCB substrate with a thickness of 1.6 and dielectric constant of 4.6. The radiating element with a dimension of 13mm×7mm, fed by a microstrip line along the major axis is printed on the front side of the substrate while the conducting ground plane with a tapered slot is printed on the other side. To achieve 50Ω characteristics impedance, the width and length of the microstrip feed line are fixed at 3mm and 6mm respectively. An SMA is connected to the port of the feeding microstrip line.



(a) Top view



(b) Bottom view

Fig. 1 Schematic diagram of the proposed antenna

To create a notch band for WiMAX, one curved shape parasitic element is etched in the same side of the piece as shown in Fig 1 (a). It has two parts; one vertical portion with length l_2 and width 0.25mm, and one inclined portion with length l_1 and width 0.5mm. The etched parasitic element has a strong couple to the radiating patch which leads to high impedance at the notch frequency band. At the notch frequencies, the current flows are dominating around the parasitic element and they are oppositely directed between the parasitic element and the radiating patch as well the ground plane as depicted in Fig. 2. Hence, the resultant radiation fields cancel out and high attenuation near the notch frequency is proposed. Therefore, the antenna at that frequency does not radiate efficiently resulting in creation of notch frequency band [15], [17].

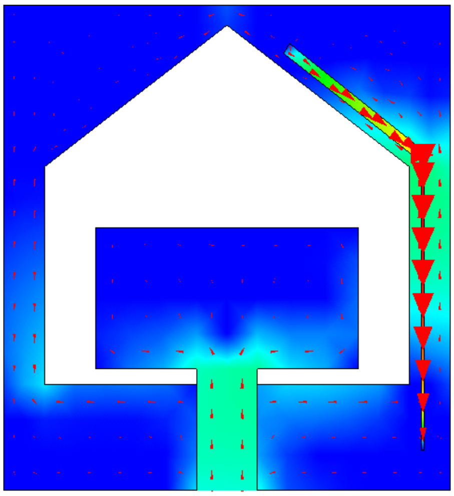


Fig. 2 Surface current distribution at 3.5 GHz

In order to investigate the effects of parasitic elements on band-notch characteristics as well on antenna's impedance characteristics, a parametric study has been carried out. The commercial full-wave electromagnetic field solver is applied to execute the design and optimization process. Since the curved parasitic element is the main filtering element in achieving notched band, its parameters l_1 and l_2 are selected to analyze the sensitivity test. The effects of l_1 and l_2 on antenna performance as well as band notch characteristics are simulated and depicted in Figs. 3 and 4.

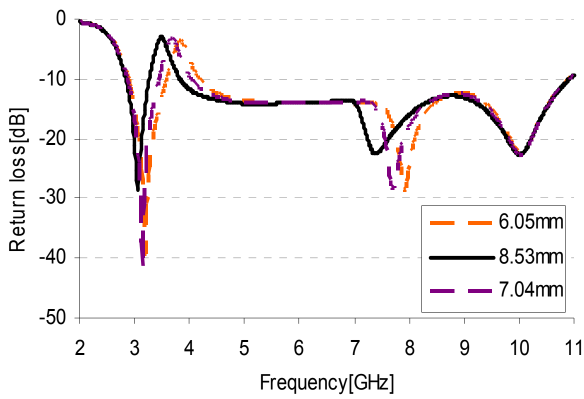


Fig. 3 Simulated return loss for different values of l_1

Fig. 3 depicts the return loss characteristics for different values of l_1 while the other parameters are kept constant. It is observed from the plot that the center frequency of the notch band for shifting towards the lower frequency band as the values of l_1 varied from 6.05mm to 8.53mm. It is also noted that the bandwidth of the notched band decreases with increasing l_1 and a value of 8.53 mm is optimized to exhibit a notched band perfect for WiMAX.

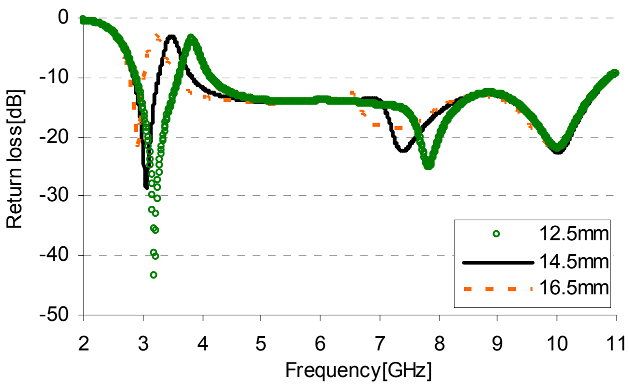


Fig. 4 Simulated return loss for different values of l_2

The return loss plot of the designed antenna for different values of l_2 is illustrated in Fig. 4. It is seen from the plot that the centre frequency as well as the bandwidth of the notched band is strongly dependent on l_2. As the values of l_2 increases the center frequency of the notch band moves towards the lower frequency band and the bandwidth is increased.

Therefore, from Figs. 3 & 4 it can be concluded that, the notched band for WiMAX is controlled by the curved parasitic element. It is also revealed from the figures that when the values of l_1 and l_2 are changed, the return loss values over the entire UWB band almost remains unchanged except at the notched band which offer a great freedom to choose the band notch characteristics and operating bandwidth for the antenna.

III. Results and Discussion

Full-wave electromagnetic field solver IE3D from Zeland was employed to perform the antenna design. The return loss characteristics of the proposed antenna against frequency are described in Fig. 5. It is observed from the plot that the proposed antenna able to achieve an operating bandwidth ($S_{11} \geq$ -10dB) ranging from 2.84GHz to 10.85GHz. This achieved bandwidth is sufficient to encompass the entire UWB band as allocated by the FCC. It is also noted that the proposed antenna with filter structure exhibits a notched band of 3.28 - 3.85GHz which cover the entire WiMAX band. Therefore the potential inference caused from WiMAX can completely be avoided using the proposed antenna.

Figs. 6 and 7 depict the peak gain and radiation efficiency of the proposed antenna respectively. It is observed that the gain and efficiency decreases significantly at around 3.5GHz which clearly indicated the effect of filter element. Other than the notched frequency band, the proposed antenna achieved a good gain and radiation efficiency, and is about the same of the antenna without filter element.

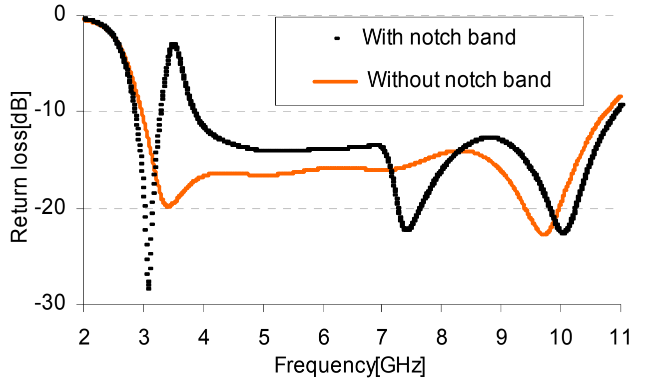


Fig. 5 Performance of the proposed antenna against frequency

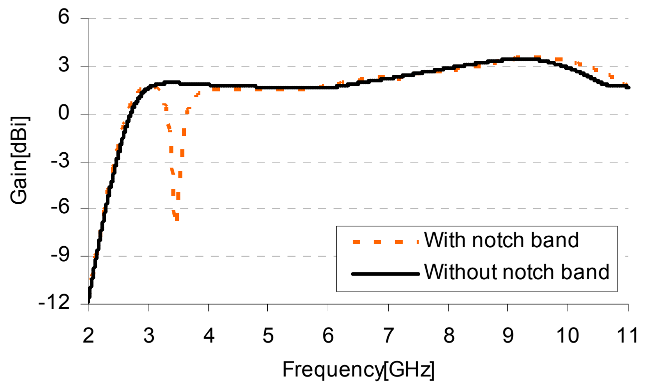


Fig. 6 Peak gain of the proposed antenna

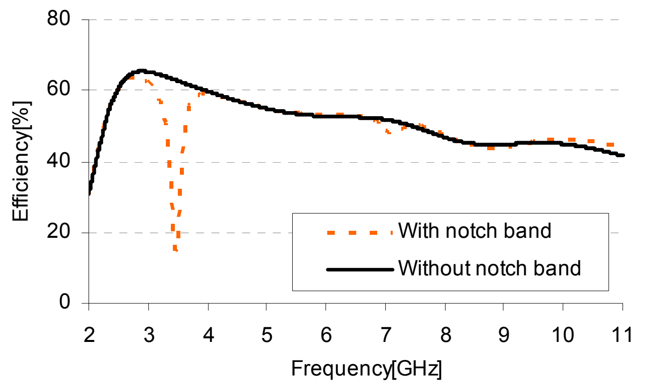


Fig. 7 Radiation efficiency of the proposed antenna

Fig. 8 shows the radiation patterns of the proposed antenna in two principal planes-namely *E*- and *H*-plane at 3GHz, 5GHz and 7.5GHz. It can be observed that at low frequencies both the *E*- and *H*-plane radiation patterns are almost omnidirectional and the antenna has a main beam in the broadside direction. At lower frequencies the cross-polarization field is remarkably smaller in both the *E*- and *H*-plane and the radiation patterns are approximately the same as that of monopole antennas. As the frequency increases the

World Academy of Science, Engineering and Technology
International Journal of Electronics and Communication Engineering
Vol:7, No:7, 2013

radiation patterns becomes slightly directional due to excitation of the higher order current modes. However, a stable and symmetric radiation pattern is observed over the entire operating band of the antenna.

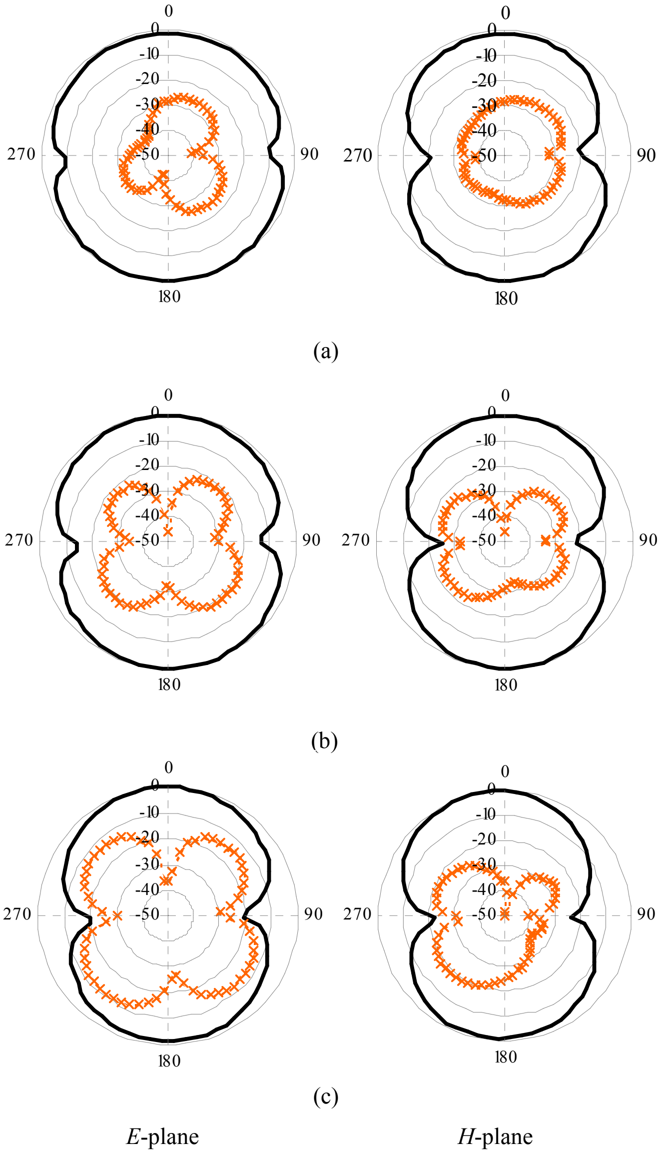


Fig. 8 Radiation patterns at (a) 3 GHz, (b) 5 GHz and (c) 7.5 GHz [Solid line: Co-polarized field; Crossed line: Cross-polarized field]

IV. Conclusion

A novel planar slot antenna with the band notch characteristics has been proposed for UWB applications. The antenna consists of a rectangular radiating patch and slotted ground plane and has an overall size of 22mm × 24mm. By etching one parasitic element along with the radiating patch, a notched band centred at 3.5GHz is realized, which helps to mitigate the potential interference caused from the existing WiMAX band. It is found that the proposed antenna revealed good UWB performance, accompanied with a notched band of 3.28-3.85GHz. The characteristics of simple structure, inexpensive and low profile with symmetric radiation patterns make the proposed antenna suitable for different UWB applications.

References

[1] R. Azim, M. T. Islam, and N. Misran, “Design of a planar UWB antenna with new band enhancement technique,” *ACES Journal*, vol. 26, no. 10, pp. 856-862, 2011.

[2] L. Liu, S. W. Cheung, R. Azim, and M. T. Islam, “A compact circular-ring antenna for ultra-wideband applications,” *Microwave and Optical Technology Letters*, vol. 53, no. 10, pp. 2283-2288, 2011.

[3] R. Azim, M. T. Islam, N. Misran, S. W. Cheung, and Y. Yamada, “Planar UWB antenna with multi-slotted ground plane,” *Microwave and Optical Technology Letters*, vol. 53, no. 5, pp. 966-968, 2011.

[4] R. Azim, M. T. Islam, and N. Misran, “Printed Circular Disc Compact Planar Antenna for UWB Applications,” *Telecommunication Systems*, pp. 1-7, DOI: 10.1007/s11235-011-9632-z.

[5] R. Azim, M. T. Islam, N. Misran and A. T. Mobashsher, “Compact UWB Planar Antenna for Broadband Applications,” *Informacije MIDEM*, vol. 41, no.1, pp. 37-40, 2011.

[6] H. G. Schantz, “UWB Magnetic Antennas,” Proceedings of the IEEE Antennas and Propagation Society International Symposium, USA, 604-607, 2003.

[7] R. Azim, M. T. Islam, and N. Misran, “Compact tapered shape slot antenna for UWB applications,” *IEEE Antennas and Wireless Propagation Letters*, vol. 10, no.1, pp. 1190-1193, 2011.

[8] Y. Gao, B. L. Ooi, and A. P. Popov, “Band-notched ultrawideband ring monopole antenna,” *Microwave and Optical Technology Letters*, vol. 48, no. 1, pp. 125-126, 2006.

[9] W. S. Lee, D. Z. Kim, K. J. Kim, and J. W. Yu, “Wideband planar monopole antennas with dual band-notched characteristics,” *IEEE Transactions on Microwave Theory and Techniques*, vol. 54, no. 6, pp. 2800-2806, 2006.

[10] Y. L. Zhao, Y. C. Jiao, G. Zhao, L. Zhang, Y. Song, and Z. B. Wong, “Compact planar monopole UWB antenna with band-notched characteristic,” *Microwave and Optical Technology Letters*, vol. 50, no. 10, pp. 2656-2658, 2008.

[11] R. Azim, M. T. Islam, J. S. Mandeep Singh and A. T. Mobashsher, “A planar circular ring ultra-wideband antenna with dual band-notched characteristics,” *Journal of Electromagnetic Waves and Applications*, vol. 26, nos. 14–15, pp. 2022–2032, 2012.

[12] W. C. Liu and S. M. Chen, “Ultra-wideband printed fork-shaped monopole antenna with a band-rejection characteristic,” *Microwave and Optical Technology Letters*, vol. 49, no. 7, pp. 1536–1538, 2007.

[13] R. Azim and M. T. Islam, “Compact planar UWB antenna with band notch characteristics for WLAN and DSRC,” *Progress In Electromagnetics Research*, vol. 133, pp. 391-406, 2013.

[14] S. J. Hong, J. W. Shin, H. Park, and J. H. Choi, “Analysis of the band-stop techniques for ultrawideband antenna,” *Microwave and Optical Technology Letters*, vol. 49, no. 5, pp. 1058–1062, 2007.

[15] M. T. Islam, R. Azim, and A. T. Mobashsher, “Triple band-notched planar UWB antenna using parasitic strips,” *Progress In Electromagnetics Research*, vol. 129, pp. 161-179, 2012.

[16] K. H. Kim, Y. J. Cho, S. H. Hwang, and S. O. Park, “Band-notched UWB planar monopole antenna with two parasitic patches,” *Electronic Letters*, vol. 41, no. 14, pp. 783-785, 2005.

[17] R. Azim, M. T. Islam, J. S. Mandeep, N. Misran and A. T. Mobashsher, “UWB Antenna adds two notches,” *Microwave and RF Journal*, vol. 51, no. 12, pp. 56-64, 2012.

[18] R. Azim, M. T. Islam, and A. T. Mobashsher, “Ultra-wideband Antenna with Band-notches for Lower and Upper WLAN,” *Przegląd Elektrotechniczny*, vol. R. 89 NR 1a, pp. 266-270, 2013.

[19] N. Choi, C. Jung, J. Byun, F. J. Harackiewicz, M. J. Park, Y. S. Chung, T. Kim, and B. Lee, “Compact UWB antenna with I-shaped band-notch parasitic element for laptop applications,” *IEEE Antennas and Wireless Propagation Letters*, vol. 8, pp. 580- 582, 2009.