Design Evolution of Planar Slot Antennas for Ultra-wideband Wireless Communication

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***Abstract*—The design evolution of planar ultra-wideband slot antennas is presented in this paper. The basic antenna with a T-shaped radiator and ground plane with wide slot is able to exhibit UWB characteristics. Insertion of a curve slit in the front side of the basic antenna helps to generate a stop band at around 3.5GHz while etching of a pair of symmetric slits in the rear side helps to produce a stop band for WLAN. Dual stop band centered at 3.5GHz and 5.5GHz can be obtained by putting both types of slits together. The insertion of slits does not alter the size and shape of basic antenna which gives us an upper hand in the designing of UWB antenna with notch band/s.**

Keywords—Antenna; ultra-wideband(UWB); wireless communication; WiMAX; WLAN.

I. Introduction

Ultra-wideband (UWB), being a communication technology with distinctive characteristics is widely used in numerous wireless communication. The effectiveness of this technology is completely depends upon the performance of antenna, a vital component of any communication system. A suitable UWB antenna must have to an operating frequency band ranges from 3.1 - 10.6 GHz. At the same time UWB antenna have to have the capability to filter out narrow bands of WiMAX and WLAN.

Good number of antennas with UWB operating band are reported in open literature. When compared with other types of antennas, slot antennas possesses large magnetic field and appropriate for UWB communications where minimum near field coupling is necessary [1]. Recently, different UWB slots antennas with narrow and wide slot are reported. Different methods are employed to achieve UWB impedance bandwidth.

Despite of FCC allocation, UWB (3.1-10.6GHz) may electromagnetically interfere with WiMAX (3.3 - 3.8GHz) and WLAN (5.15 - 5.825GHz) which may degrade the system performance. Therefore it is necessary to notch these narrow bands within UWB. Different techniques are already employed to design band notch UWB antennas. Insertion of different shapes of slot/s in the patch or in the ground plane is commonly used to generate notch band/s. For example to produce two notch bands for WiMAX and WLAN, in [2] a concentric partial annular slot and a semi-circular slot were inserted in the ring shaped radiator. To notch a frequency band centered at 5.5GHz, a partial annular slot was embedded in the design reported in [3]. Another technique of notch is to use different types of slit/s along with patch or ground plane. For example, to notch dual frequency band centered at 3.5GHz and 5.5GHz a single tri-arm parasitic element was etched beneath the patch [4]. In [5], a pair of U-shaped strip was inserted in the radiator to produce two notch bands. The design proposed in [6] use three parasitic strips above the ground to produce triple stop bands for WiMAX, lower and upper WLAN. Defection of ground plane is also observed to produce stop band/s. For example in [7] three notches centered at 3.5, 5.68 and 7.48GHz were achieved by defected ground structure and fork-shaped stub. In [8] two pairs of meandered ground stubs were used to notch lower and upper WLAN band. To filter out undesired frequency spectrum, some reported design uses complex filter element/s which may create fabrication difficulties.

In this paper the design evolution of UWB slot antennas without and with band notch characteristics is presented. The basic design comprises a T-shaped patch and a wide slotted ground plane, and is able to exhibits UWB characteristics. To generate a notch band for WiMAX, a curve slit is placed in the front side while to generate a stop band for WLAN a pair of slits is etched in the rear side. Insertion of both these types of slits together can produce dual notch bands at around 3.5GHz and 5.5GHz and can effectively suppress the interference between WiMAX, WLAN and UWB systems.

II. Antenna Layout

A. Basic slot antenna with UWB operating band

The layout of the basic wideband slot antenna is displayed in Fig. 1(a). It consists of a T-shaped radiating stub and a ground plane, and is etched on the both sides of an inexpensive standard epoxy resin reinforced woven glass substrate of 1.6mm thick. The relative permittivity of the substrate material is 4.6 and its loss tangent is 0.02. The radiating stub has a dimension of 13×7 mm^2 and for signal transmission it is fed by a microstrip feed line of 50Ω characteristic impedance. The antenna occupies a very small area of 22×24 mm^2.

It is found using method of moment based full wave EM simulator IE3D that T-shaped radiating stub coupled strongly with the ground plane with tapered slot and a tapered-shape slot matched with a T-shaped tuning stub can exhibit an impedance bandwidth (S11≤-10dB) of 2.97 to 10.77 GHz as

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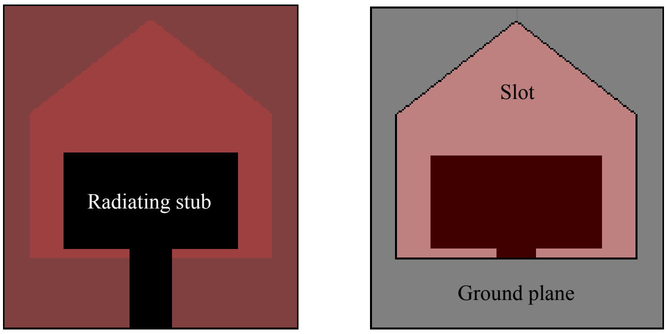
shown in Fig. 2. This achieved band covers the entire UWB frequency spectrum and that is why the designed antenna is very suitable for ubiquitous UWB wireless communication.



(a) Front view (b) Rear view

Fig. 1. Design layout of the basic UWB slot antenna.

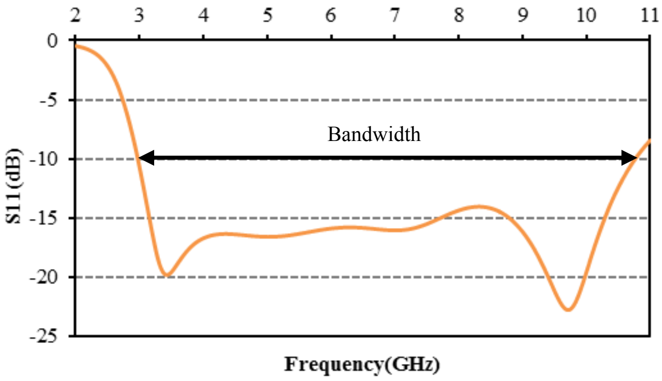
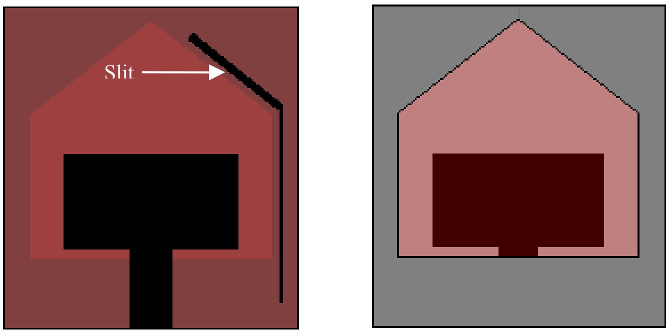


Fig. 2. Performance of the basic UWB slot antenna.



(a) Front view (b) Rear view

Fig. 3. Geometry of the antenna with notch band for WiMAX.

B. UWB antenna with notch band for WiMAX

In order to lessen the electromagnetic interference (EMI) between WiMAX and UWB, it is necessary to notch the frequency band of 3.3 - 3.8GHz. To generate a notch band at 3.5GHz, a slit has symmetrically been placed in the front side of the substrate as shown in Fig. 3. Other than the inclusion of this slit, all other parameters are as same as the basic design of Fig. 1.

The etched slit strongly couple with the radiating stub which leads to high impedance at around 3.5GHz. At the notch frequency band, the current concetrates srtongly at around the slit. The flows of current in the slit are oppositely directed to the radiator and ground structure as depicted in Fig. 4. Thus, the overall radiation fields canceled out each other. Therefore at 3.5GHz, the antenna with a slit (filter element) does not radiate effectively resulting in generation of a notch band ranging from 3.27 - 3.83GHz as displayed in Fig. 5.

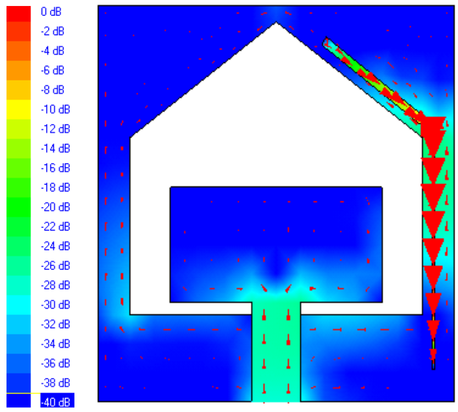


Fig. 4. Current distribution on the raditor and ground plane at 3.5GHz.

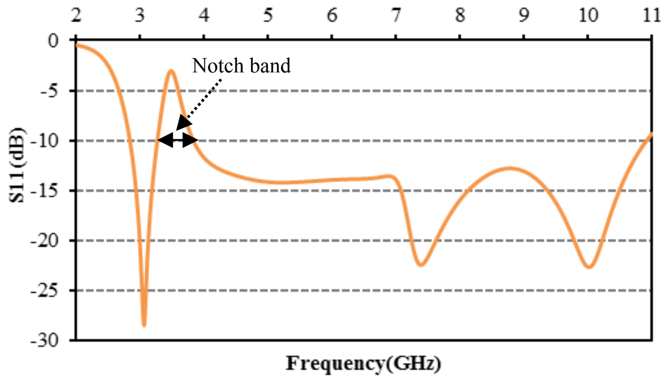
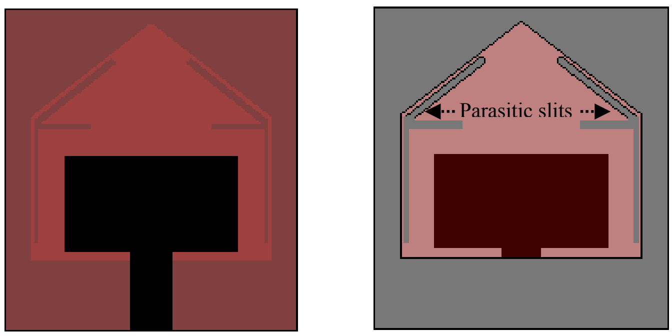


Fig. 5. S-parameter of the antenna with notch band for WiMAX.

C. UWB antenna with notch band for WLAN

To create a notch band with an aim to eliminate the EMI between UWB and WLAN, a pair of parasitic slits has been inserted in the ground plane (rear side) as shown in Fig. 6. This slits are symmetrical to the inner edges of the tapered slot and placed in the rear side of the substrate.



(a) Front view (b) Rear view

Fig. 6. Layout of the antenna with notch band for WLAN.

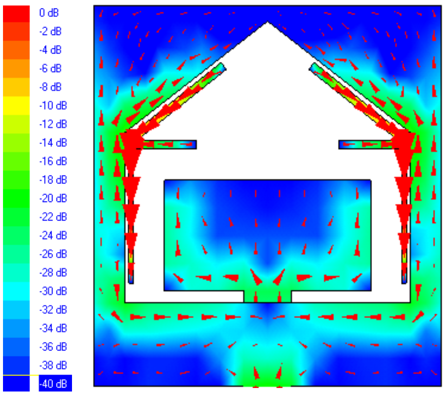


Fig. 7. Current distribution in the ground plane and raditor at 5.5GHz.

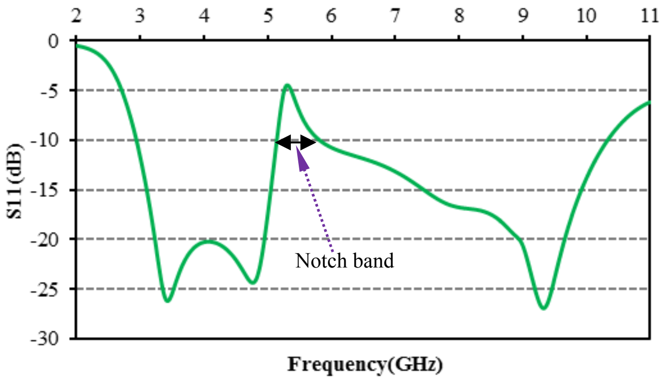


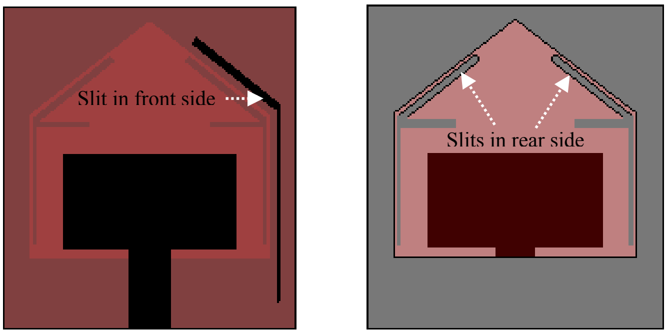
Fig. 8. S-parameter of the antenna with notch band for WLAN.

To understand the phenomenon of the creation of the notch band at around 5.5GHz, the surface current on the radiator and ground is shown in Fig. 7. It is observed from the plot that the current concentration around the parasitic slits is higher than the current on the other parts of the antenna. It is also seen that the current in the parasitic slits are oppositely directed to the currents in the ground plane and radiator. Thus the resultant radiation at around 5.5GHz is very weak and a notch band covering frequency band of 5.14 - 5.81GHz is produced as shown in Fig. 8. Except the exhibition of notch band characteristics, the operating bandwidth of this design is almost similar to that of basic UWB antenna.

D. UWB antenna with dual notch band for WiMAX and WLAN

The geometry of the UWB antenna with two notch band is depicted in Fig. 9. The antenna structure is similar to the design presented in Fig. 1. To filter out WiMAX band, a curve parasitic slit is placed in the front side of the antenna along with the radiator as shown in Fig. 9(a). To generate another notch band for WLAN, a pair of slits is symmetrically etched on the rear side of the antenna as depicted in Fig. 9(b).

From the simulated vector current distribution it can be reavealed that at 3.5GHz, the currents are strongly concentrated around the slit that has been etched in the front side of the antenna whereas at 5.5GHz, the currents are stronger near the slits that are placed in the rear side of the antenna. At both these frequencies, the directions of the currents in the slits are opposite to the currents in the radiator and ground plane. As a result, the effective radiation fields eliminate each other and dual notch bands at around 3.5GHz and 5.5GHz are produces as displayed in Fig. 10.



(a) Front view (b) Rear view

Fig. 9. Geometry of the antenna with dual notch band.

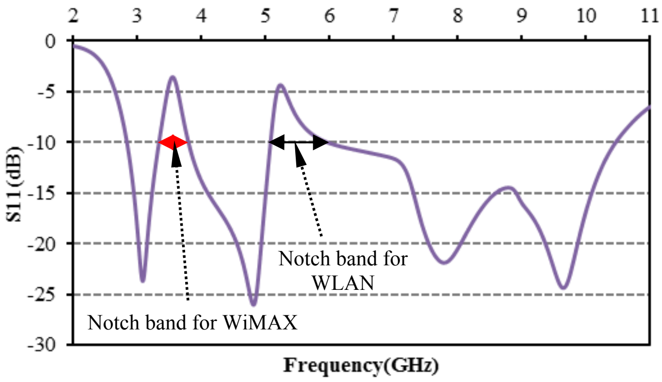


Fig. 10. S_{11} of the antenna with dual notch band for WiMAX and WLAN.

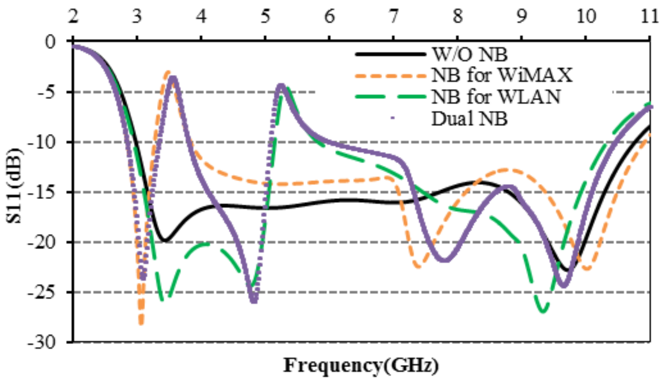


Fig. 11. S-parameter responses of the designed antennas.

III. COMPARISON OF THE PERFORMANCE OF DESIGN ANTENNAS

The performances of the designed antennas are plotted in Fig. 11. It can be revealed that without any slit (W/O NB), the basic slot antenna achieved an operating band (S11≤-10dB) of 2.97 to 10.77GHz which can cover the entire UWB. The insertion of a curved slit in the front side of the basic antenna produces a notch band of 3.27 - 3.83GHz while the etching of a pair of slits in the rear side notched a band ranging from 5.14 - 5.81GHz. By adding these two types of slits in the front and rear sides, dual notch bands centered at 3.5GHz and 5.5GHz can be created. Despite the inclusion of parasitic slits, the overall dimension of the basic antenna is remaining same.

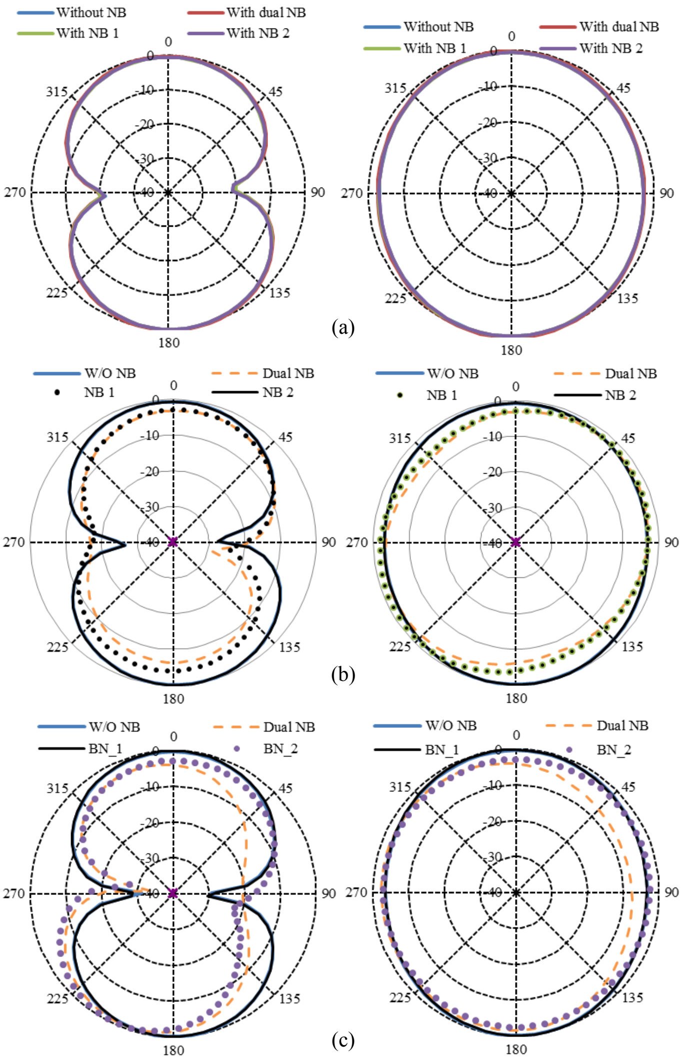


Fig. 12. Radiation patterns at (a) 3GHz, (b) 3.5GHz and (c) 5.5GHz.

The radiation patterns plotted in Fig. 12 shows that at passband frequency of 3GHz, the *E*-field pattern is similar to "8" shape while the *H*-field pattern is omnidirectional as in Fig. 12(a). It remarkable to mention that at pass band frequency of 3GHz, the gain for all the antennas are almost same. At notch frequencies of 3.5GHz and 5.5GHz, the radiation patterns are similar to that of passband frequencies as shown in Fig. 12(b) and 12(c). However, there is decrement in the gain for the antenna with slit/s i.e. inclusion of slit/s decreases the gain by filtering the desired portion of the signal.

The peak gain the designed antennas is plotted in Fig. 13 from where it can be commented that all the antennas achieved good gain. Without the exhibition of sharp decrement in the respective notch band, the peak gain of all the antennas almost similar. However, at frequencies more than 9GHz, there is fall of the gain and gain of the basic antenna (W/O NB) is much lower than that of antennas with parasitic slit/s. This may be due to fact at higher frequencies the parasitic slit/s act as a radiator as explained in [9].

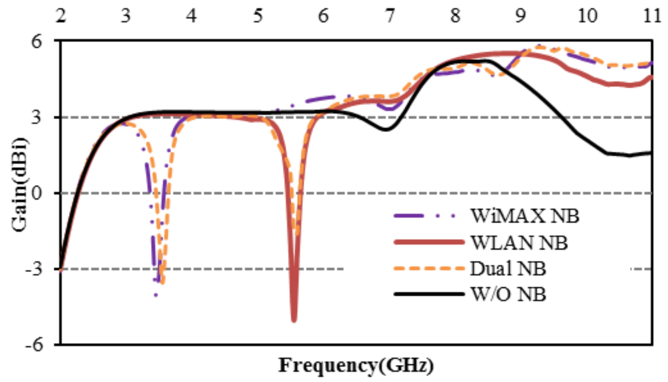


Fig. 13. Peak gain of the designed antennas.

IV. Conclusion

In this paper small size slot antennas are proposed for UWB applications. The ways to create notch band/s without sacrificing the UWB performance and without altering the size of the basic antenna are presented. It is demonstrated that a curve parasitic slit in the front side of basic antenna can produce a notch band for WiMAX while insertion of a pair of symmetrical slits in the rear side can notch WLAN band. The design with these two types of slits can exhibits UWB characteristics with dual notch bands at 3.5GHz and 5.5GHz.

References

[1] H. G. Schantz, "UWB Magnetic Antennas," *in Proc. of the IEEE Antennas Prop. Soc. Int. Symp.*, 22 - 27 June 2003, USA, pp. 604 - 607.

[2] R. Azim, M. T. Islam, J. S. Mandeep, and A. T. Mobashsher, "A planar circular ring ultra-wideband antenna with dual band-notched characteristics," *J. Electromagnet. Wave.*, vol. 26, nos. 14 - 15, pp. 2022 - 2032, 2012.

[3] R. Azim and M. T. Islam, "Compact planar UWB antenna with band notch characteristics for WLAN and DSRC," *Prog. Electromagn. Res.*, vol. 133, pp. 391 - 406, 2013.

[4] R. Azim, M. T. Islam, and A. T. Mobashsher, "Dual band-notch UWB antenna with single tri-arm resonator," *IEEE Antennas Wirel. Propag. Lett.*, vol. 13, pp. 670 - 673, 2014.

[5] M. Ojaroudi, N. Ojaroudi, and N. Ghadimi, "Dual band-notched small monopole antenna with novel coupled inverted U-ring strip and novel fork-shaped slit for UWB applications," *IEEE Antennas Wirel. Propag. Lett.*, vol. 12, pp. 182 - 185, 2013.

[6] M. T. Islam, R. Azim and A. T. Mobashsher, "Triple band-notched planar UWB antenna using parasitic strips", *Prog. Electromagn. Res.*, vol. 129, pp. 161 - 179, 2012.

[7] C. Zhang, J. Zhang, and L. Li, "Triple band-notched UWB antenna based on SIR-DGS and fork-shaped stubs," *Electron. Lett.*, vol. 50, no. 2, pp. 67 - 69, 2014.

[8] Y. F. Weng, W. J. Lu, S. W. Cheung, and T. I. Yuk, "UWB antenna with single or dual band-notched characteristic for WLAN band using meandered ground stubs," *in Proc. of the Loughborough Antennas Prop. Conf.*, 16 - 17 November 2009, Loughborough, UK, pp. 557 - 560.

[9] R. Azim, M. T. Islam, and A. T. Mobashsher, "Design of a dual band-notch UWB slot antenna by means of simple parasitic slits," *IEEE Antennas and Wireless Propagation Letters*, vol. 12, pp. 1412-1415, 2013.