

Research Article

Design of Two Novel Dual Band-Notched UWB Antennas

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Two novel dual band-notched ultra-wideband (UWB) printed monopole antennas with simple structure and small size are presented. The size of both antennas is $25 \times 25 \times 0.8 \text{ mm}^3$. The bandwidth of one of the proposed antenna can be from 2.7 GHz to 36.8 GHz, except the bandwidth of 3.2–3.9 GHz for WiMAX applications and 5.14–5.94 GHz for WLAN applications. The bandwidth of the other is ranging from 2.7 to 41.1 GHz, except the bandwidth of 3.2–3.9 GHz for WiMAX applications and 4.8–5.9 GHz for WLAN applications. Bandwidths of the antennas are about 512% and 455% wider than those of conventional band-notched UWB antennas, respectively. In addition, the time-domain characteristics of the two antennas are investigated to show the difference between both antennas.

1. Introduction

There has been more and more attention in ultrawideband (UWB) antennas ever since the Federal Communications Commission (FCC)'s allocation of the frequency band 3.1–10.6 GHz for commercial use [1]. Over the designated bandwidth of UWB system, there are some other existing narrowband services that already occupy frequencies in the UWB band, such as wireless local-area network (WLAN) operating in the 5.15–5.875 GHz band and world interoperability for microwave access (WiMAX) service from 3.3 to 3.6 GHz. However, the uses of filters increase the complexity and cost. It is desirable to design the UWB antenna with dual band notches. The printed planar monopole antenna is a good candidate for the band-notched UWB system because of its low cost, low profile, light weight, omnidirectional radiation patterns, easy realization, and convenience for integrating with microwave monolithic integrated circuit (MMIC) technologies. Various kinds of printed monopole antennas with notched band have been reported in the literature. The band-notched UWB antennas in [2–5] are not able to satisfy the compact property, the antennas reported in [5–7] have high profile, the antennas mentioned in [4–8] have only single band-notches. Challenges of the feasible dual-notched UWB antenna design contain proper notched bandwidths and the above advantages which belong to printed planar monopole antennas.

Based on the background of the researches above, two novel, simple and compact ultra-wideband printed monopole antennas with dual band-notched characteristics are proposed in this paper. By cutting a wide slot on the patch and a narrow slot on the ground plane, dual frequency band notches can be obtained. The desired notched band frequencies can be easily achieved by adjusting the total lengths of the slots. By changing the widths and locations of the slots, the notched bandwidths can be efficiently controlled. The bandwidth of one antenna is from 2.7 GHz to 41.1 GHz, except the bandwidth of 3.2–3.9 GHz for WiMAX applications and 4.8–5.9 GHz for WLAN applications. The other has an impedance bandwidth ranging from 2.7 GHz to 36.8 GHz, eliminating the bandwidth of 3.2–3.9 GHz for WiMAX applications and 5.14–5.94 GHz for WLAN applications. The size of both the novel antennas is just $25 \times 25 \times 0.8 \text{ mm}^3$.

2. The Proposed Antenna Structure and Design

2.1. UWB Antenna Design. In this section, we will develop a novel UWB antenna which can be used to design the dual band-notched antennas. Figure 1(a) shows the geometry and configuration of the proposed antenna without slots that is UWB antenna fed by a 50Ω microstrip feed line. L ($L = 25 \text{ mm}$) and W ($W = 25 \text{ mm}$) denote the length

and width of the dielectric substrate, respectively. L_1 is the length of the patch which is equal to 10.4 mm. The most important parameter effect on the performance of the proposed antenna is the apex angle α which is given by [9]

$$\alpha = \frac{3}{4}\pi - \arctan\left(\frac{L - 2L_1}{W}\right). \quad (1)$$

The tapered microstrip line at the connection between the feeding line and the patch is employed for broadband matching of the antenna to the $50\ \Omega$ microstrip line. The width and length of the $50\ \Omega$ microstrip line are 1.5 mm and 10.9 mm, respectively. The arcs at edges of the patch and the ground plane are employed for reducing the radiation loss and the difficulties of fabricating. The proposed antenna is printed on the FR4 substrate with the thickness of 0.8 mm, relative permittivity 4.4 and loss tangent $\tan\delta = 0.02$. Shown in Figure 1(b) is the simulated VSWR result of the proposed UWB antenna; it can be seen that the impedance bandwidth (VSWR < 2) is from 2.9 GHz to 41 GHz.

2.2. Single Band-Notched UWB Antenna Design. Before developing the dual band-notched UWB antennas, we need to investigate the method generating the single notched band. Several novel antennas with filtering property operating in the 3.2–3.9 GHz band, 5.2–5.9 GHz and 5.14–5.94 GHz are designed to reduce the interference from the WiMAX or WLAN applications. Those band-notched functions are desirable in the UWB system. Figure 2 shows the geometry and configuration of those novel antennas. By etching a straight slot in the patch or the ground plane of UWB antenna, a frequency band notch is created. Note that when the band-notched design applied to UWB antenna, there is no retuning work required for the previously determined dimensions, since the filtering ability is generated by integrating filtering structures in the antenna. In addition, the design concept of the notch function is to adjust the total length of the straight slots to accord with Formula (2).

In single band-notched antenna 1, the wide slot etched in the patch shown in Figure 2(a) whose length and width are 13.8 mm and 0.8 mm, respectively, is employed to obtain the desired notched band which is from 3.2 GHz to 3.9 GHz and which is shown in Figure 3 so that the proposed antenna cannot interfere with WiMAX applications.

In single band-notched antenna 2, a narrow slot etched in the ground plane shown in Figure 2(b) whose length and width are 8.4 mm and 0.2 mm, respectively, is employed to obtain the desired notched band which is from 5.2–5.9 GHz (as shown in Figure 3). In addition, the narrow slot etched in the patch shown in Figure 2(c) whose length and width are 9.6 mm and 0.25 mm, respectively, is employed to obtain the desired notched band which is from 5.14–5.94 GHz (as shown in Figure 3) so that the proposed antenna cannot interfere with WLAN applications. Note that the bandwidth is shorted by adding a narrow slot on the patch; the reason is the narrow slot and the wide slot is so near that they interfere with each other. The notched frequency, given the

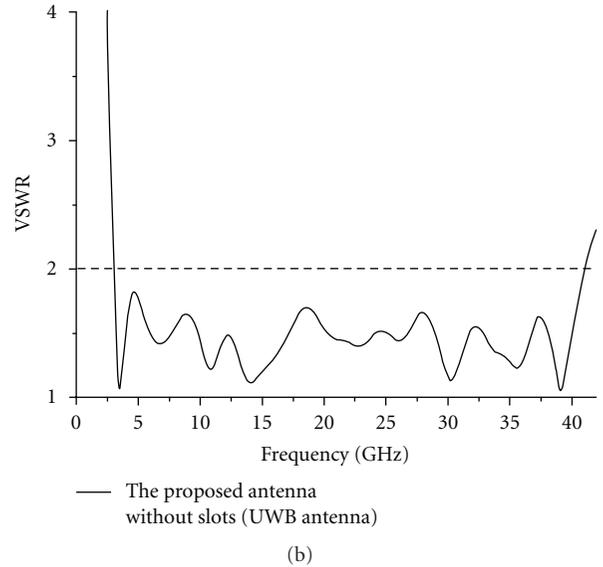
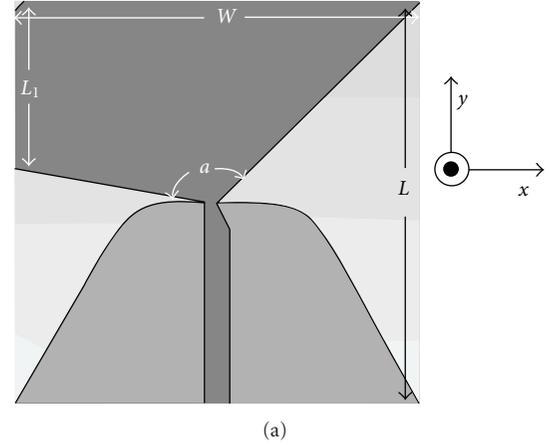


FIGURE 1: The geometry and the simulated VSWR result of the proposed antenna without slots (UWB antenna): (a) the geometry, (b) the simulated VSWR result.

dimensions of the band-notched feature, can be postulated as [10]

$$f_{\text{notch}} = \frac{c}{4L\sqrt{(\epsilon_r + 1)/2}}. \quad (2)$$

2.3. Dual Band-Notched Antenna Design. Based on single band-notched antennas aforementioned, the dual band-notched antennas will be investigated to reduce the interferences from the existing bands.

Figure 4 shows the geometries of two dual band-notched antennas. Their VSWR results are shown in Figure 5, respectively; it can be seen that the bandwidth of the UWB system is hardly affected by the slots, and the bandwidth of the low frequency band-notched antenna formed by only a wide slot and the bandwidth of the high frequency band-notched antenna formed by only a narrow slot do not interfere with each other.

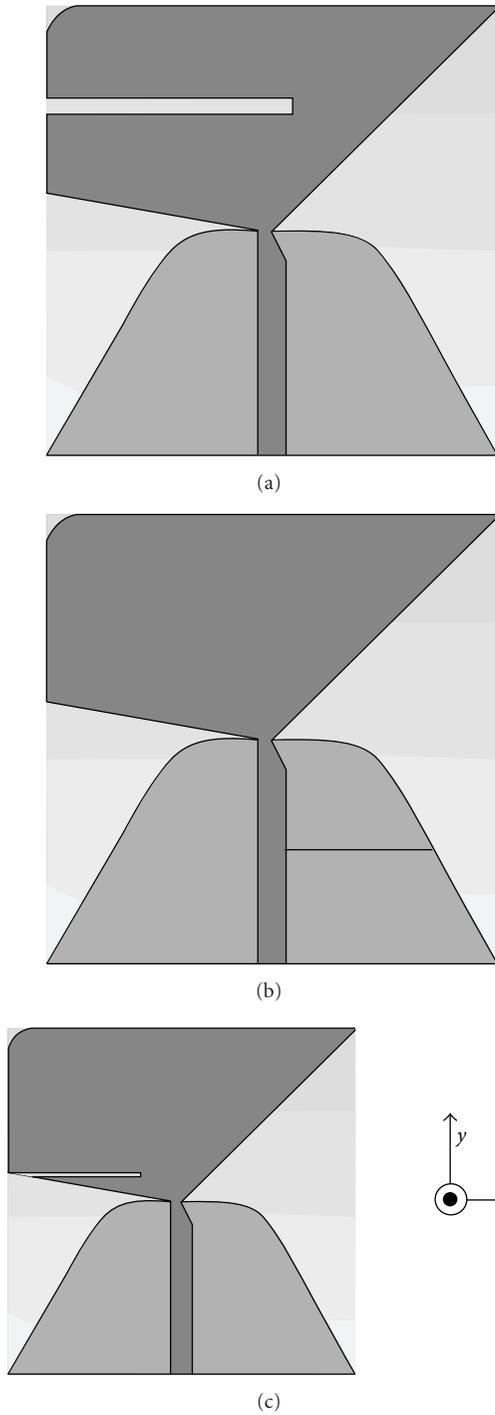


FIGURE 2: The geometry of the single band-notched antennas: (a) single band-notched antenna 1, (b) single band-notched antenna 2, (c) single band-notched antenna 3.

3. Results and Discussions

3.1. *Frequency-Domain Performances.* The dual band-notched UWB antennas were simulated and optimised using the business software CST. Shown in Figure 6 are prototypes of the antennas.

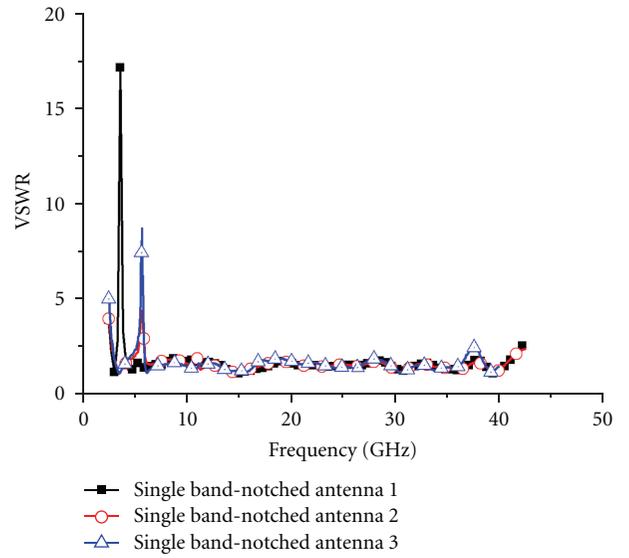


FIGURE 3: The simulated VSWR results of the single band-notched antennas.

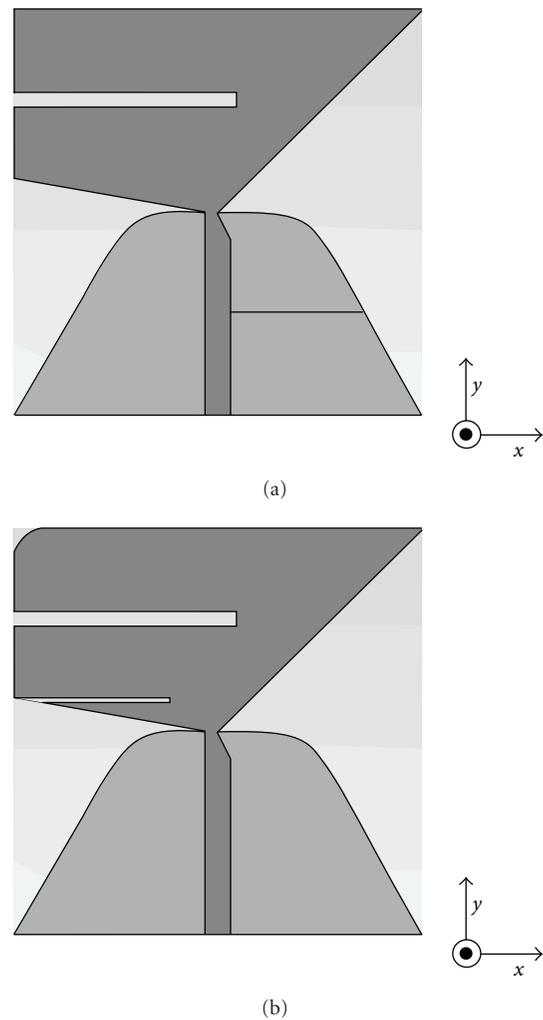


FIGURE 4: The geometries of the proposed antennas: (a) dual band-notched antenna 1, (b) dual band-notched antenna 2.

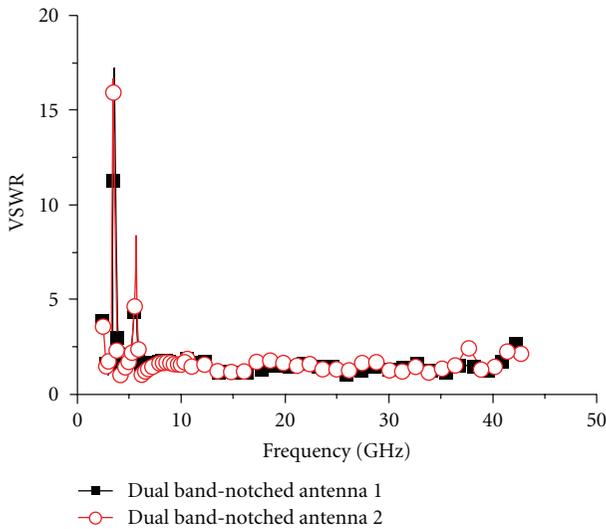
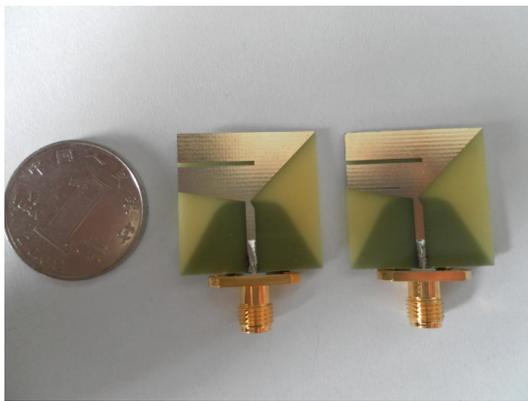
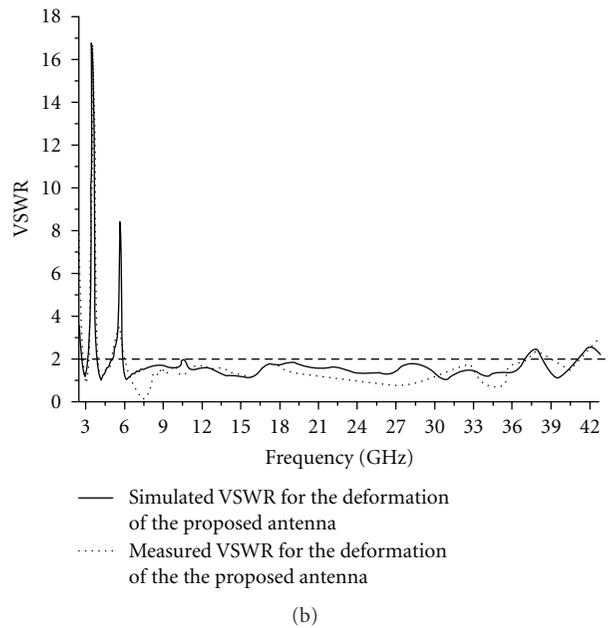
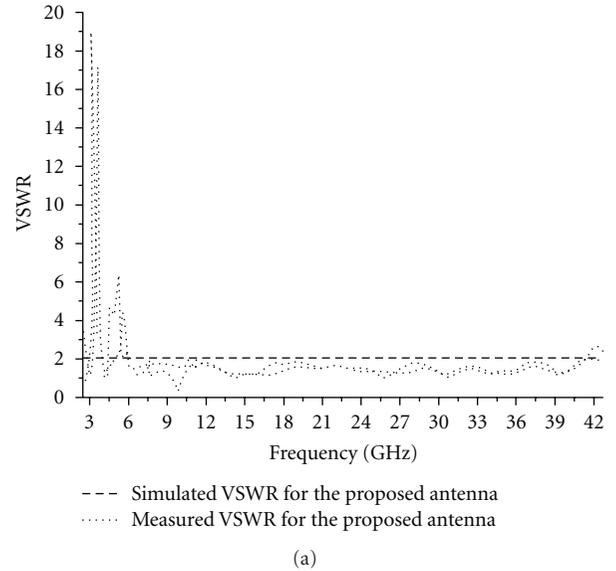
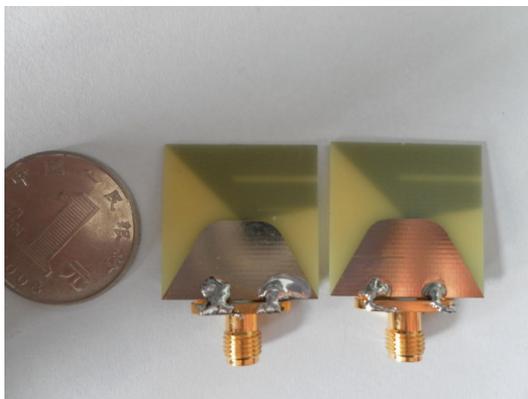


FIGURE 5: The simulated VSWR results of the dual band-notched antennas.



(a)



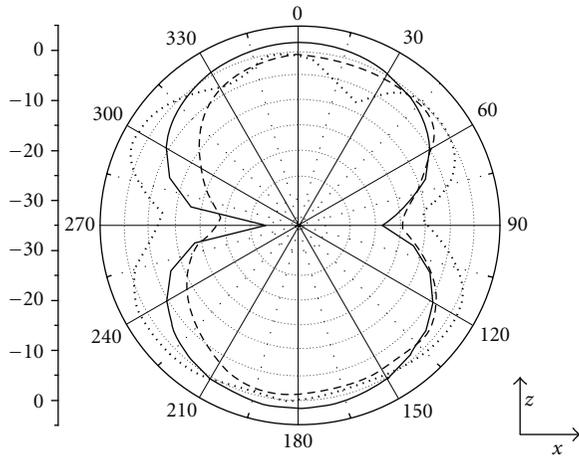
(b)

FIGURE 6: The photos of the proposed antenna: (a) the front of dual band-notched antennas, (b) the back of dual band-notched antennas.

FIGURE 7: Simulated and measured VSWR results of the proposed antennas: (a) dual band-notched antenna 1, (b) dual band-notched antenna 2.

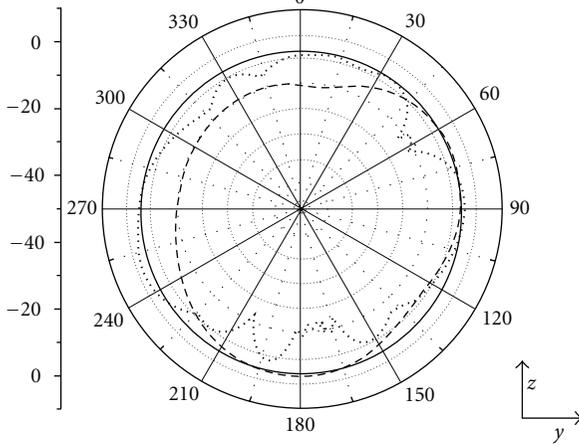
Shown in Figure 7, it can be seen that the simulated and measured results show relatively good agreement. As shown in Figure 7(a), the dual band-notched antenna 1 has two notched bands which can cover the WiMAX band (3.2–3.9 GHz) and the 4.8–5.9 GHz band. In addition, the dual band-notched antenna 2 can eliminate the 3.2–3.9 GHz band and the 5.14–5.94 GHz band, as Figure 7(b) shows.

The radiation patterns of the proposed antennas at 3.1 GHz, 10.6 GHz and 36 GHz are shown in Figures 8 and 9, respectively. The antennas give a nearly omnidirectional radiation patterns in the *H*-plane. The antennas gain in the entire operating band is presented in Figure 10. As desired,



— 3.1 GHz
 - - - 10.6 GHz
 36 GHz

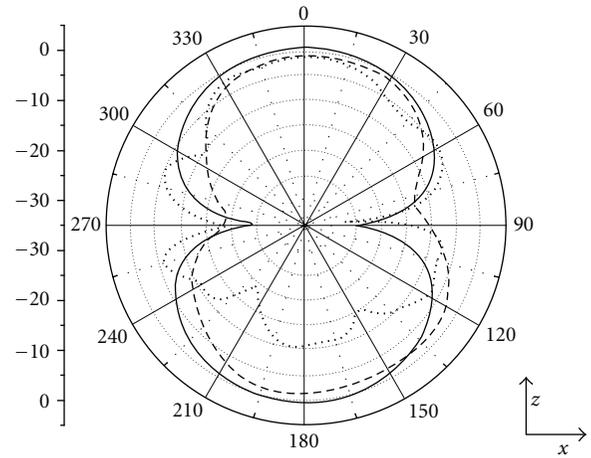
(a)



— 3.1 GHz
 - - - 10.6 GHz
 36 GHz

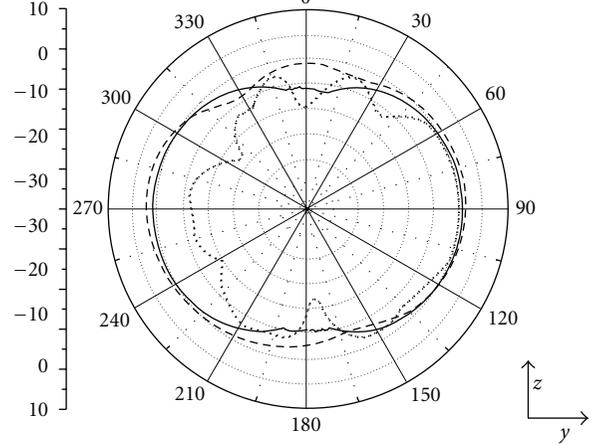
(b)

FIGURE 8: Radiation patterns on *E*-plane (*x-z* plane) and *H*-plane (*y-z* plane) for the dual band-notched antenna 1 at 3.1 GHz, 10.6 GHz, and 36 GHz: (a) *E*-plane (b) *H*-plane.



— 3.1 GHz
 - - - 10.6 GHz
 36 GHz

(a)



— 3.1 GHz
 - - - 10.6 GHz
 36 GHz

(b)

FIGURE 9: Radiation patterns on *E*-plane (*x-z* plane) and *H*-plane (*y-z* plane) for the dual band-notched antenna 2 at 3.1 GHz, 10.6 GHz, and 36 GHz: (a) *E*-plane (b) *H*-plane.

two sharp gains decrease in the vicinity of 3.55 GHz and 5.6 GHz, and the gains are stable in the entire operating band.

3.2. Time-Domain Behaviors. As shown in the previous section, the proposed antennas present the very wide band. However, as far as an UWB antenna is concerned, the good frequency-domain performances cannot necessarily ensure that the antenna also behaves well in time domain. Some multiresonant antennas, such as the Yagi-Uda and the log-periodic antennas [11], due to its multiple reflections in their structures, seriously widen the narrow pulse in time domain. Therefore, in order to ensure the usefulness of the

proposed antenna for time-domain applications, its time-domain responses must be investigated.

The transmit characteristic in time domain is measured in a manner shown in the inserted figure in Figure 11. The two identical proposed antennas are put face to face in a distance of 20 cm. The measured group delay of S21, given in Figure 11, indicates far-field phase linearity and a quality of a pulse distortion and is derived from the first differential coefficient of the phase.

Group delays of the proposed antennas are shown in Figure 12. The variation of the group delay of the dual band-notched antenna 1 is about 1 ns across the whole UWB except the notched bands, in which the maximum group delay is

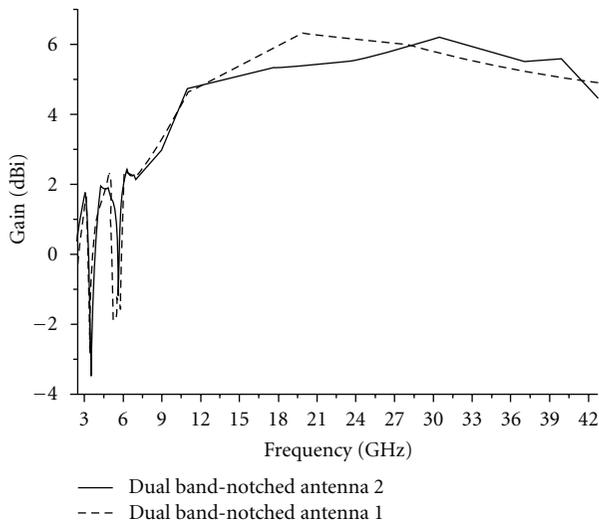


FIGURE 10: Gains of the proposed antennas.

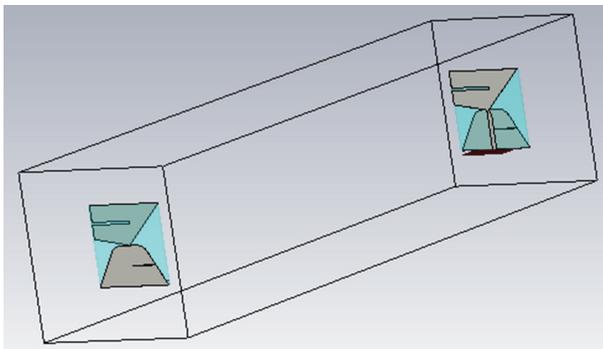


FIGURE 11: The setup of the group delay experiment.

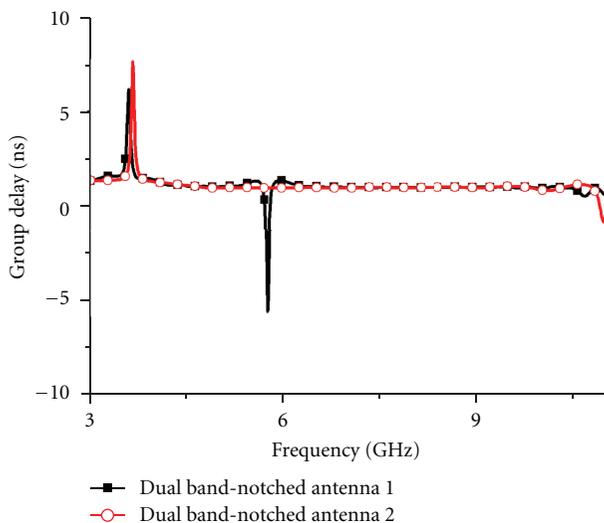


FIGURE 12: Group delays of the proposed antennas.

6 ns. On the other hand, the variation of the group delay of dual band-notched antenna 2 is about 1 ns across the whole UWB except the notched band, in which the maximum group delay is 7 ns. It is worthwhile to mention that the maximum group delay of dual band-notched antenna 2 only appears in the first notched band, but those of dual band-notched antenna 1 exist in the two notched bands. The monopole patch is the main element which transmits the pulse; when the slots etched outside the monopole patch, like dual band-notched antenna 2, the slots cannot effectively suppress the signals of the notched bands. As a result, there is a huge difference between the group delays of the two antennas.

In general, dual band-notched antenna 1 has a good time-domain characteristic and a small pulse distortion as well.

4. Conclusion

Two simple and compact ultra-wideband printed monopole antennas with dual band-notches are proposed in this paper. Using a monopole configuration, the antenna dimensions were optimised to gain the best VSWR response throughout the UWB frequency band. By embedding two slots in the antennas, dual band-notches will be created, which exempts from interference with existing WiMAX and WLAN operating bands, and measurement results show that the designed antennas satisfy the UWB design goals very well.

Acknowledgments

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