Hindawi Publishing Corporation
International Journal of Antennas and Propagation
Volume 2013, Article ID 956898, 6 pages
http://dx.doi.org/10.1155/2013/956898

Application Article

A Compact Printed Quadruple Band-Notched UWB Antenna

Xiaoyin Li, Lianshan Yan, Wei Pan, and Bin Luo

School of Information Science & Technology, Southwest Jiaotong University, Chengdu, Sichuan 610031, China

Correspondence should be addressed to Lianshan Yan; lsyan@home.swjtu.edu.cn

Received 10 December 2012; Accepted 18 February 2013

Academic Editor: Alfonso Muñoz-Acevedo

A novel compact coplanar waveguide- (CPW-) fed ultrawideband (UWB) printed planar volcano-smoke antenna (PVSA) with four band-notches for various wireless applications is proposed and demonstrated. The low-profile antenna consists of a C-shaped parasitic strip to generate a notched band at 8.01~8.55 GHz for the ITU band, two C-shaped slots, and an inverted U-shaped slot etched in the radiator patch to create three notched bands at 5.15~5.35 GHz, 5.75~5.85 GHz, and 7.25~7.75 GHz for filtering the WLAN and X-band satellite signals. Simulated and measured results both confirm that the proposed antenna has a broad bandwidth of 3.1~12 GHz with VSWR < 2 and good omnidirectional radiation patterns with four notched-bands.

1. Introduction

Ultrawideband (UWB) technology has received considerable attention due to its high speed data rates, low power consumption, resistant to severe multipath and jamming, and so on. The UWB antenna as a key part of UWB communication systems is also being investigated increasingly in recent years [1, 2]. Various types of UWB antennas with wide band and simple fabrication have developed. However, there are several existing frequency bands, that is, IEEE 802.11a (5.15–5.35 and 5.725–5.825 GHz), downlink of X-band satellite communication systems (7.25~7.75 GHz), and ITU band (8.01~8.5 GHz), which may cause mutual interference with UWB signals [2–5].

In order to avoid interferences with these existing frequency bands, one way is to add band-stop filters to UWB antennas, which may lead to high cost and large size to UWB transceivers. The emerging of the band-notched antenna makes it possible for integrating the filter into the antenna. There are many approaches demonstrated to create band-notches in UWB antennas [2–13]. Generally, the existing techniques widely used to achieve band-notch can be classified into the following two categories: adding and etching resonator units to the antenna [3, 6, 12]. The first method focuses on adding diverse parasitic elements on the antenna, such as strip near radiator patch in [3, 4] and split ring resonators (SRRs) near feed line in [5]. Another effective method is etching various slots in the antenna, such as arc-shaped slot [8, 9], U-shaped slot [10], square-shaped slot [11], and SRR-shaped slot [12]. By employing parasitic strips and etching slots at the same time [11, 14], multiple band-notched functions could be achieved. However, most of the examples can only provide two or three notched bands because of the space restrictions and coupling between band-notched structures; nevertheless, only limited ones can achieve four notched bands [3, 15].

In this paper, a modified planar volcano-smoke antenna (PVSA) is considered to cover the UWB range. The design parameters of the resonator units that affect the resonator frequency based on both of the parasitic elements method and etching slots method are discussed. Subsequently a four band-notched UWB antenna for filtering the WLAN, downlink of X-band satellite communication systems, and ITU band signals is proposed and demonstrated. Band-notch characteristics are achieved by embedding a C-shaped parasitic strip, two C-shaped slots, and a U-shaped slot on the patch. Details of designing the proposed antenna with simulations and measurements are carried out. The configuration of the proposed antenna is shown in Section 2. Both of the simulated and measured results including voltage-standing wave ratio (VSWR), radiation patterns, and peak gain are shown in Section 3. A conclusion will be drawn in Section 4.

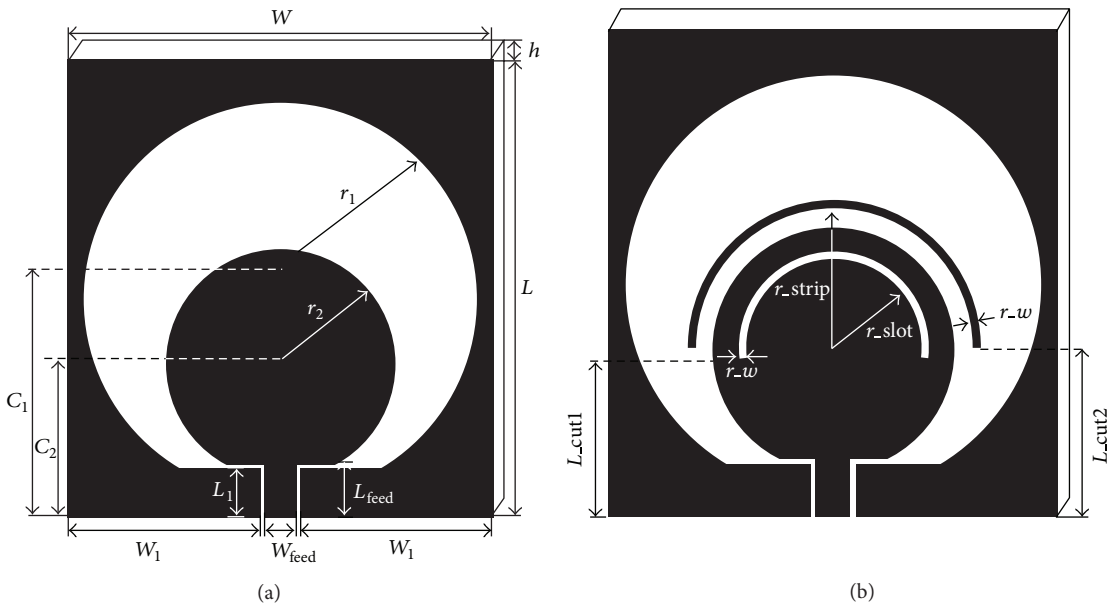


Figure 1: Structure of the antenna.

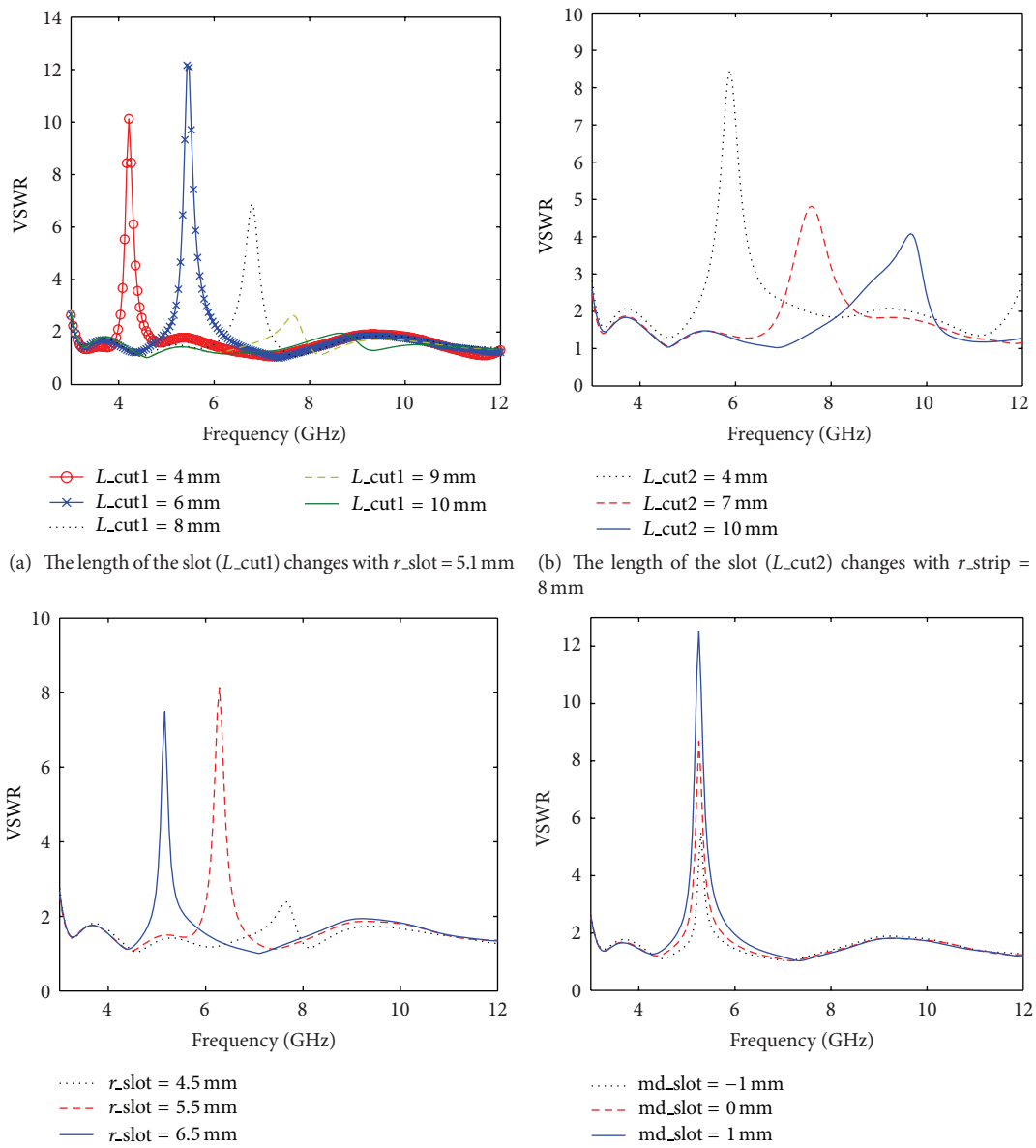
2. Antenna Design

The proposed quadruple band-notched antenna is based on a planar volcano-smoke antenna that covers the UWB frequency range, whose structure is shown in Figure 1(a) [4, 16, 17]. The based antenna uses FR4 substrate with the dimensions of $26 \times 28 \times 0.4\ \text{mm}^3$, relative permittivity $\varepsilon_r = 4.4$, and a loss tangent of 0.02. The antenna is fed by a CPW line which is designed for 50 Ω characteristic impedance with 1.8 mm feed line width (W_{feed}) and 0.2 mm ground gap. Through simulations with the software Ansoft High Frequency Structure Simulator (HFSS), the optimal dimensions of the designed PVSA are listed as follows: $W = 26$ mm, $L = 28$ mm, $h = 0.4$ mm, $r_1 = 12$ mm, $r_2 = 7$ mm, $C_1 = 13$ mm, $C_2 = 8$ mm, $W_{\text{feed}} = 1.8$ mm, $L_{\text{feed}} = 2$ mm, and $L_1 = 1.8$ mm. In order to eliminate interferences from WLAN, downlink of X-band satellite communication systems, and ITU band, antenna-filtering techniques by etching slots and employing parasitic strips on the PVSA are discussed.

To compare the frequency response characteristics of etching slots on the patch and adding parasitic elements, we investigate and simulate the two methods for creating band notched in the proposed UWB antenna, respectively. The structure of the two methods is shown in Figure 1(b), where the L_cut1 (L_cut2) means the distance between the end of the slot (strip) and the bottom edge of the substrate. Simulation results are shown in Figure 2. It is proved that the length of the slot (affected by the radius of the slot r-slot and the end position L_cut1) determines the resonant frequency, while the position of the slot (affected by md-slot that means the shift about the center of the slot) has relatively slight effect. The length of slots corresponds to half of the wavelength of the designed notch frequency, which can be used to estimate the notched frequency of the slots [8, 10, 11]. The length of the strip also determines the resonant frequency like the slot.

In theory, both the two methods can create any band-notch in the entire band of UWB. However, the size of the antenna and coupling of the band-notched structure make it difficult to create the band-notch in practical applications. For the proposed antenna, circle-like strip/slot aimed at reducing the strip/slot area. From Figure 2(a), it can be seen that the parasitic elements method can only create a band-notch with an upper limit of 8 GHz. As for higher notched band, when the length of the strip gets shorter, its rejection frequency goes higher but with a lower peak rejection ratio. Meanwhile, the shape of the parasitic strip might be too small to perform as a resonator. It also can be seen that the slot method cannot create a band-notch lower than 5 GHz from Figure 2(b), as the length of the slot cannot become longer because of the size restriction of the patch. From both methods, we propose a new antenna design to implement the requirements of any band-notches in the entire UWB band.

A four band-notches UWB antenna has been presented in [3] by feed-line with holes, which is not suitable for printable technology. Here, a novel CPW-fed UWB antenna with a parasitic strip and three slots is proposed, as shown in Figure 3. Slots with different shapes, such as rectangular, circular, and elliptical or any other shapes, can be arbitrarily etched on the patch to generate notched bands. However, a slot/strip with the same shape of the antenna patch can generate a stronger resonance than any other shape because the current distribution is concentrated at the edge of the patch. Meanwhile, the strips/slots with the same structures are useful for saving space [4, 5, 9, 17]. Therefore two C-shape, slots and one C-shape, strip are incorporated. It can be seen from Figure 2(d) that the position of the slot (means the shift of the center of the slot, indicated by md-slot) has little effect on the resonant frequency, but has effect on the bandwidth of the notched band. To obtain the narrow notched band, the slot S_2 is moved up 0.7 mm to decrease its bandwidth. With



(a) The length of the slot (L_cut1) changes with r_slot = 5.1 mm

(b) The length of the slot (L_cut2) changes with r_strip = 8 mm

(c) The radius of the slot (r_slot) changes with L_cut = 8 mm

(d) The position of the slot (md_slot) changes with r_slot = 5.1 mm and L_cut = 5.7 mm

Figure 2: VSWR of the antenna with different lengths of slots and strips (C_1 = 13 mm, C_2 = 8 mm, and r_w = 0.5 mm).

the restriction of the patch size and the coupling between the nearby slots, a U-shape, slot instead of the C-shape, slot is further added for reducing the coupling with other slots. The optimized parameters of the antenna geometry are listed in Table 1. For convenience, the reference point is considered to be the top left corner.

Table 1: Optimized parameters of the quad band-notched antenna.

Parameters	L_cut	L_cut1	L_cut2	r_w	md_slot
Value (mm)	5.7	9.2	8	0.5	0.7
Parameters	r_slot1	r_slot2	r_strip	L_U	W_U
Value (mm)	6.5	5.1	8	6	4.6
Parameters	L_{feed}	W_{feed}	$L1$	$L2$	$W1$
Value (mm)	2	1.8	1.8	9.6	11.9

3. Results and Discussion

To verify the design concept, a prototype of the quad band-notched antenna is fabricated and measured. The photograph of the fabricated quad band-notched antenna is given in Figure 4. And Figure 5 shows the simulated and measured VSWR of the proposed antenna. The measurement is performed with an Agilent 8719A vector network analyzer. It can be observed that the measurement and simulation results agree with each other well. There is a little discrepancy

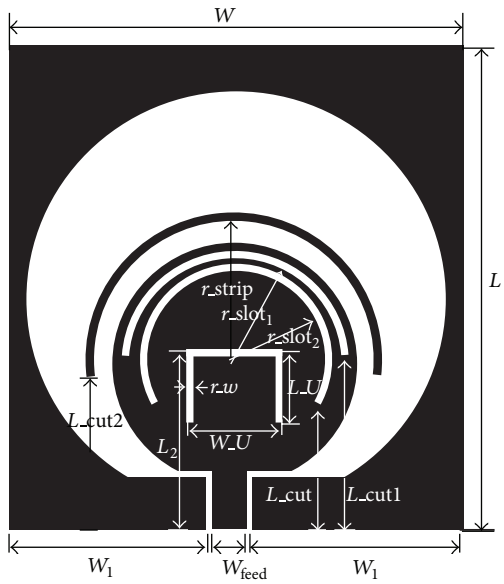


Figure 3: Schematics of the proposed quadruple band-notched UWB antenna.

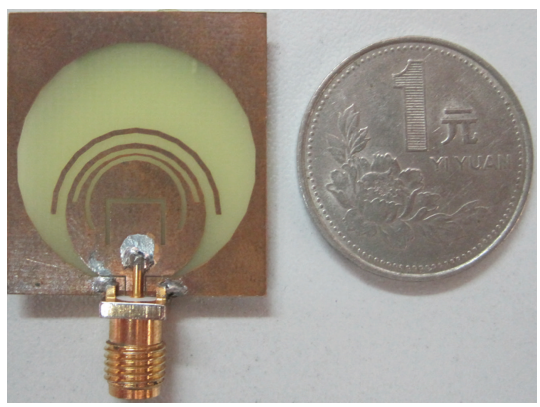


Figure 4: Photograph of the proposed quadruple band-notched UWB antenna.

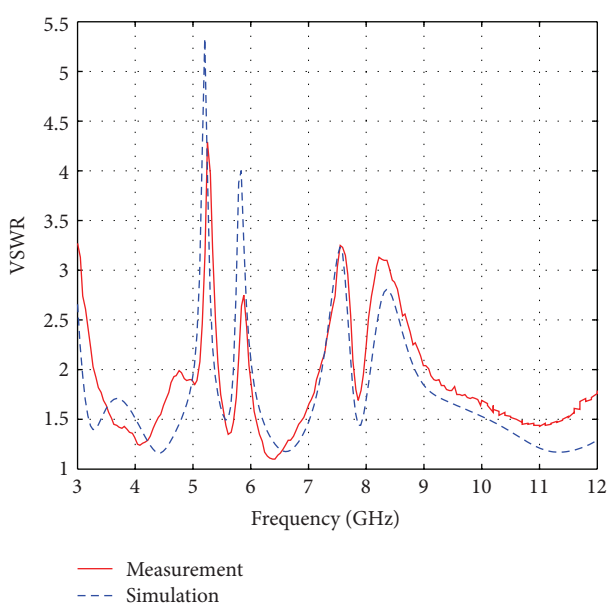


Figure 5: Simulated and measured VSWR of the quadruple band-notched UWB antenna.

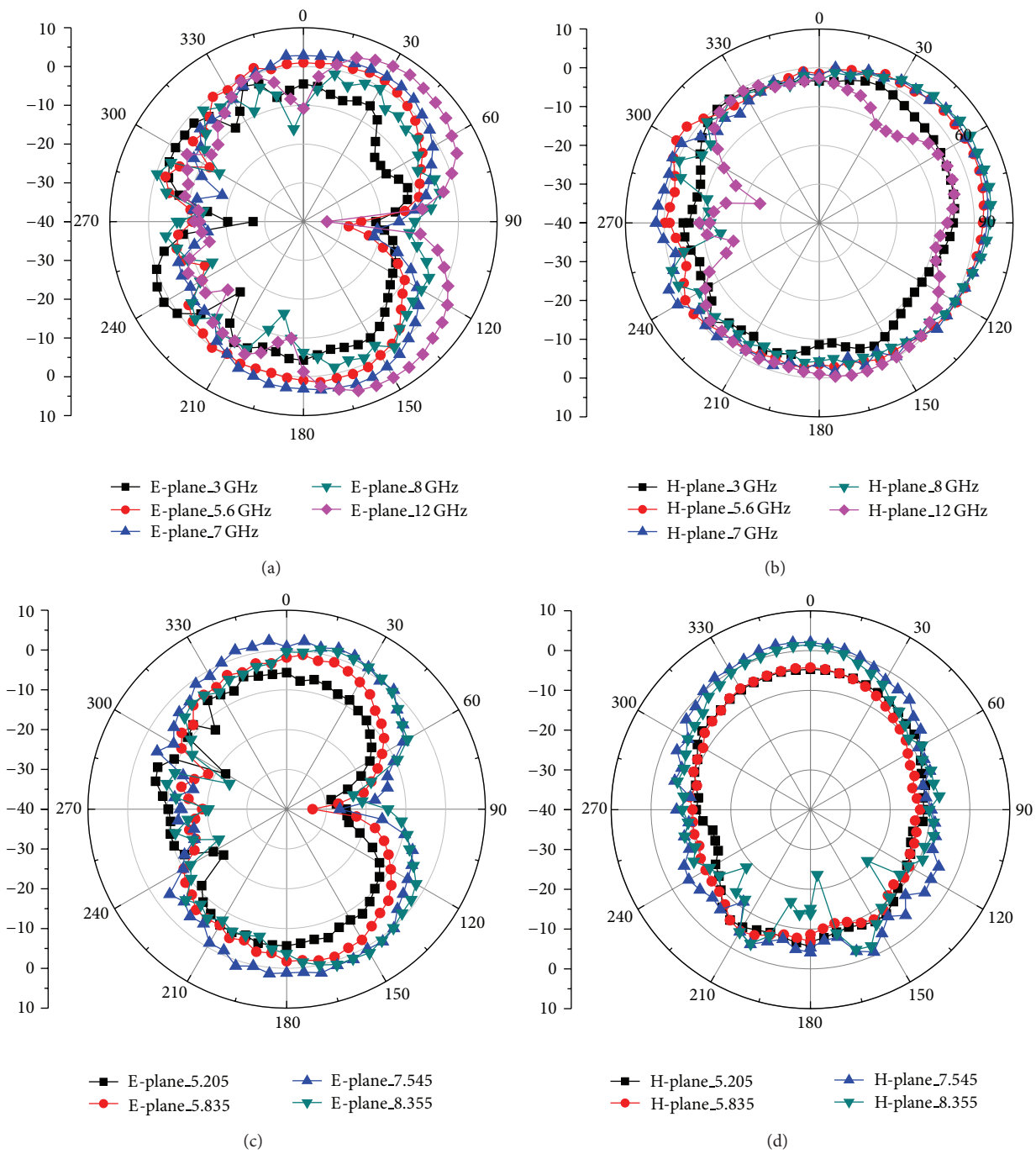


Figure 6: Radiation patterns of the quadruple band-notched UWB antenna.

between the measurement and the simulation results, which may be caused by the interference of the connector and feeding cable in the measurement. The proposed antenna exhibits good wideband performance from 3.1 to 12 GHz with VSWR less than 2, except for the designed four notched bands of 5.1–5.43, 5.78–5.98, 7.2–7.79, and 8.03–8.83 GHz.

The radiation characteristics of the proposed quad band-notched antenna are also measured. The measured far-field radiation patterns of the E-plane and H-plane at the four notched frequencies about 5.205, 5.835, 7.545, and 8.355 GHz and the passband frequencies at 3, 5.6, 7, 8, and 12 GHz are shown in Figures 6(a)–6(d), respectively. At the passband frequencies out of the notched bands, it can be seen from Figures 6(a) and 6(b) that the antenna has good omnidirectional radiation pattern in H-plane, while the antenna E-plane radiation pattern is almost bidirectional. Meanwhile, at the notched-band frequencies, as shown in Figures 6(c) and 6(d), it is noted that the antenna radiation gains reduction due to the slot in the direction of maximum gain.

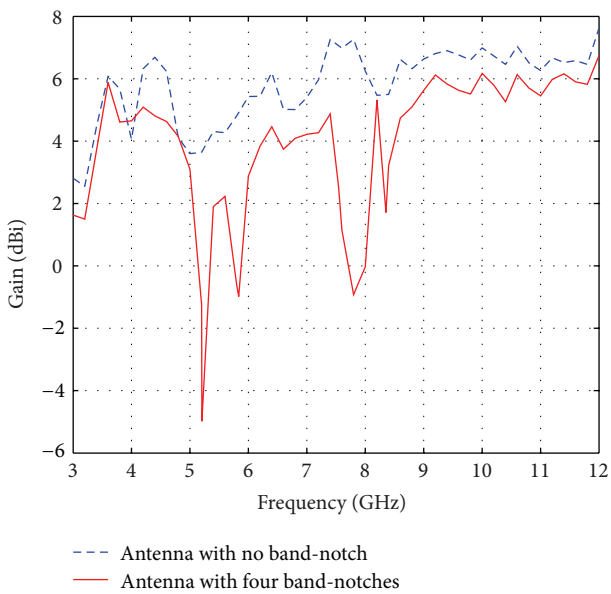


Figure 7: Measured peak gain over the frequency band.

Figure 7 shows the measured peak gains of the proposed antenna with and without the band-notches. It can be seen that there are four sharp decreases of the gain in the antenna at the vicinity of four notched bands. The energy at the notched frequency bands is not radiated so that the radiation efficiency drops at the notched frequency bands. Thus, the peak gain decreases sharply at the four notched bands, which clearly indicates the quad band rejection functions of the proposed antenna.

4. Conclusion

A novel and compact four band-notched UWB antenna is proposed and demonstrated. The proposed antenna exhibits good band rejection in the designed bands and has wideband performance from 3.1 to 12 GHz with VSWR less than 2, covering the entire band of UWB. The fabricated antenna shows good agreement with the simulation and keeps omnidirectional radiation performance successfully, which proves it is suitable for UWB applications.

Acknowledgments

The paper is supported by the National Basic Research Program of China (2012CB315704), the National Natural Science Foundation of China (no. 60972003), and the Key Grant Project of the Chinese Ministry of Education under Grant 313049.

References

[1] G. Adamiuk, T. Zwick, and W. Wiesbeck, "UWB antennas for communication systems," *Proceedings of the IEEE*, vol. 100, no. 7, pp. 2308–2321, 2012.

[2] K. S. Ryu and A. A. Kishk, "UWB antenna with single or dual band-notches for lower WLAN band and upper WLAN band," *IEEE Transactions on Antennas and Propagation*, vol. 57, no. 12, pp. 3942–3950, 2009.

[3] L. Li, Z.-L. Zhou, and J. S. Hong, "Compact UWB antenna with four band-notches for UWB applications," *Electronics Letters*, vol. 47, no. 22, pp. 1387–1388, 2011.

[4] C.-Y. Huang, S. A. Huang, and C. F. Yang, "Band-notched ultra-wideband circular slot antenna with inverted C-shaped parasitic strip," *Electronics Letters*, vol. 44, no. 15, pp. 891–892, 2008.

[5] Y. Zhang, W. Hong, C. Yu, Z. Q. Kuai, Y. D. Don, and J. Y. Zhou, "Planar ultrawideband antennas with multiple notched bands based on etched slots on the patch and/or split ring resonators on the feed line," *IEEE Transactions on Antennas and Propagation*, vol. 56, no. 9, pp. 3063–3068, 2008.

[6] J. Xu, D.-Y. Shen, G. T. Wang, X. H. Zhang, X. P. Zhang, and K. Wu, "A small UWB antenna with dual band-notched characteristics," *International Journal of Antennas and Propagation*, vol. 2012, Article ID 656858, 7 pages, 2012.

[7] X. L. Bao and M. J. Ammann, "Printed UWB antenna with coupled slotted element for notch-frequency function," *International Journal of Antennas and Propagation*, vol. 2008, Article ID 713921, 7 pages, 2008.

[8] F. Zhu, S. Gao, A. T. S. Ho et al., "Miniaturized tapered slot antenna with signal rejection in 5-6 GHz band using a balun," *IEEE Antennas and Wireless Propagation Letters*, vol. 11, pp. 507–510, 2012.

[9] G.-M. Zhang, J. S. Hong, and B.-Z. Wang, "Two novel band-notched UWB slot antennas fed by microstrip line," *Progress in Electromagnetics Research*, vol. 78, pp. 209–218, 2008.

[10] 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. 2800–2805, 2006.

[11] C. M. Li and L. H. Ye, "Improved dual band-notched uwb slot an-tenna with controllable notched band-widths," *Progress in Electromagnetics Research*, vol. 115, pp. 477–493, 2011.

[12] M. C. Tang, S. Xiao, T. Deng et al., "Compact UWB antenna with multiple band-notches for WiMAX and WLAN," *IEEE Transactions on Antennas and Propagation*, vol. 59, no. 4, pp. 1372–1376, 2011.

[13] T. D. Nguyen, D. H. Lee, and H. C. Park, "Design and analysis of compact printed triple band-notched UWB antenna," *IEEE Antennas and Wireless Propagation Letters*, vol. 10, pp. 403–406, 2011.

[14] W.-T. Li, X.-W. Shi, T.-L. Zhang, and Y. Song, "Novel UWB planar monopole antenna with dual band-notched characteristics," *Microwave and Optical Technology Letters*, vol. 52, no. 1, pp. 48–51, 2010.

[15] A. Foudazi, H. R. Hassani, and S. M. Ali Nezhad, "Small UWB planar monopole antenna with added GPS/GSM/WLAN bands," *IEEE Transactions on Antennas and Propagation*, vol. 60, no. 6, pp. 2987–2992, 2012.

[16] J. Yeo, Y. Lee, and R. Mittra, "Wideband slot antennas for wireless communications," *IEE Proceedings-Microwaves, Antennas and Propagation*, vol. 151, no. 4, pp. 351–355, 2004.

[17] M. A. Habib, A. Bostani, A. Djaiz, M. Nedil, M. C. E. Yagoub, and T. A. Denidni, "Ultra wideband cpw-fed aperture antenna with wlan band rejection," *Progress in Electromagnetics Research*, vol. 106, pp. 17–31, 2010.