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A NOVEL MONOPOLE DUAL BAND-NOTCHED ANTENNA WITH TAPERED SLOT FOR UWB APPLICATIONS

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Abstract—In this article, a novel microstrip-line fed monopole dual band-notched antenna with tapered slot for UWB applications is presented. The tapered slot, making the antenna have a scissors-like shape, is utilized to enhance the wideband characteristics. In addition, the dual notched bands, from 3.3 to 3.7 GHz and from 5.15 to 5.85 GHz, are achieved by inserting slots on the ground plane and adding circle arc stubs on the radiating patch. Details of the antenna design are described, a theoretical and experimental investigation of the antenna is given as well.

1. INTRODUCTION

For Ultra Wide-band (UWB) applications, a suitable UWB antenna is required to provide satisfactory performance over the whole FCC defined frequency band from 3.1 GHz to 10.6 GHz, including return loss less than -10 dB or VSWR below 2. Additionally, to prevent the potential interference between the existing operating bands applied to UWB radio systems ($3.1 \sim 10.6$ GHz), WiMAX ($3.3 \sim 3.7$ GHz) and WLAN ($5.15 \sim 5.35$ and $5.725 \sim 5.825$ GHz), band-notched function is appreciable and necessary for a good candidate UWB antenna [1–4]. Many UWB antennas with band-notched function have been reported in recent years, which mainly use partial ground and feed gap to yield wide working band [5–10].

In this article, a microstrip-line fed monopole dual band-stop UWB antenna with tapered slot is presented. A tapered slot is proposed to enhance the wideband characteristics, which makes this

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antenna have a scissors-like shape. Slots inserted on the ground plane are used to realize one notched band (5.725 $\sim$ 5.825 GHz), and circle arc stubs are added on the radiator to obtain the other rejected frequency band (3.3 $\sim$ 3.7 GHz). Meanwhile, Stable omnidirectional radiation patterns and good gains except in the rejected frequency bands, have also been obtained. Details of the antenna design and the measured results are presented and discussed, too.

2. ANTENNA DESIGN

Figure 1 shows the geometry of the proposed antenna. This antenna is fabricated on a dielectric substrate with the size of 36 mm $\times$ 27 mm, the thickness h = 1 mm and the relative permittivity ε_r = 2.65. A partial ground plane with the size of L_0 = 11 mm $\times$ W_0 = 27 mm is printed on one side of the dielectric substrate. The dimensions of the slots on the ground plane are determined by the parameters $s_1 = s_3 = 0.8$ mm, $s_2 = 1$ mm and $L_m = 19.5$ mm. The design concept of the notch function is to adjust the length of the embedded slots to be about half-wavelength at the desired notched frequency making the input impedance singular [11]. In this design, unlike the other reported UWB antennas, the width of the slots is not constant, and the parameters s_1, s_2, s_3 have been optimized to realize the suitable notched band. It is also found that the width of the slots can also alter the rejected band slightly, especially the ones closed to the microstrip

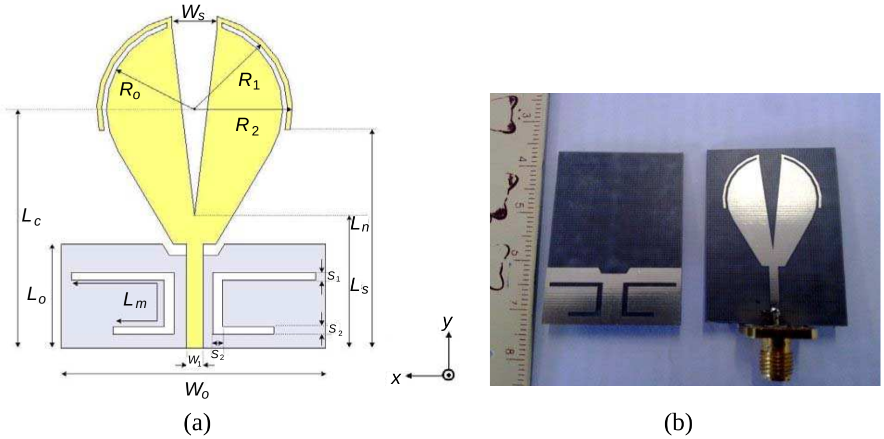

Figure 1. Configuration of the proposed antenna: (a) Geometry; (b) fabrication antenna.

line. On the other side of the substrate, a scissors-shaped patch with a radius of $R_0 = 9$ mm and a 50 Ω microstrip feed line with the width $w_1 = 1.7$ mm are printed. The dimensions of the tapered slot are $w_s = 4.6$ mm, $Ls = 14$ mm, which have been adjusted to realize the ultra wide-band impedance matching. The circle arc stubs are fixed at the radiuses of $R_1 = 9.5$ mm, $R_2 = 10$ mm, $L_n = 23$ mm, and their length adjusted by the parameter L_n controls the corresponding resonant frequency, which makes it possible for the proposed antenna to yield a band-notched function at $3.3 \sim 3.7$ GHz when the length of circle arc stubs is around half-wavelength at the center frequency of the notched band.

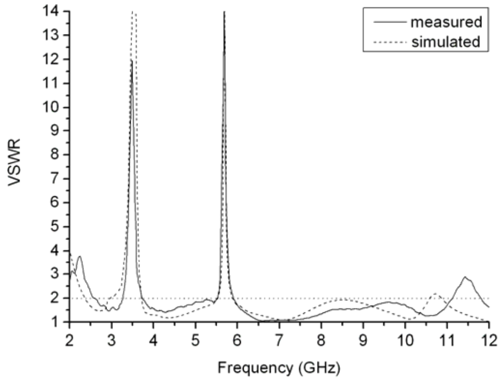

Figure 2. The comparision of the measured and simulated VSWR results.

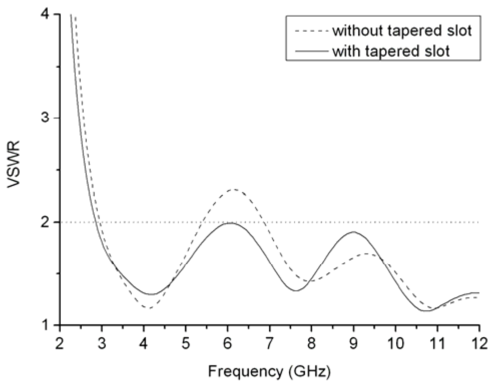

Figure 3. The comparisons of simulated VSWR results for the antennas with and without tapered slot.

3. SIMULATION AND EXPERIMENTAL RESULTS

The proposed antenna is simulated with Ansoft **HFSS** v11 and measured with a **WILTRON37269A** vector network analyzer after fabricated. Figure 2 depicts the simulated and measured VSWR performance of this antenna. As seen from the measured results, the proposed antenna satisfies the VSWR (≤ 2) requirement through the UWB band with dual band rejection characteristics from 3.3 to 3.7 GHz and from 5.5 to 5.9 GHz, covering the bands WiMAX ($3.3 \sim 3.7$ GHz) and WLAN ($5.725 \sim 5.825$ GHz). There is a good agreement shown between the measured result and the simulation.

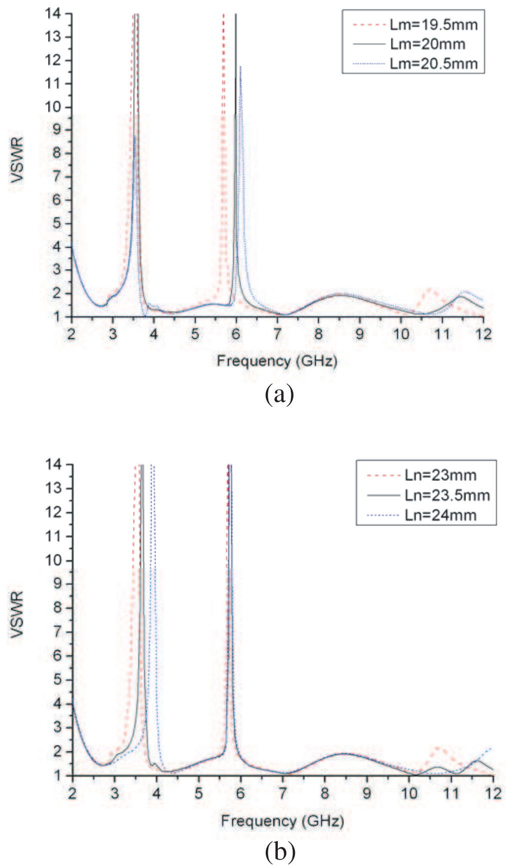

Figure 4. (a) Simulated VSWR for the proposed antenna in terms of L_m ($L_n = 23$ mm); (b) simulated VSWR for the proposed antenna in terms of L_n ($L_m = 19.5$ mm).

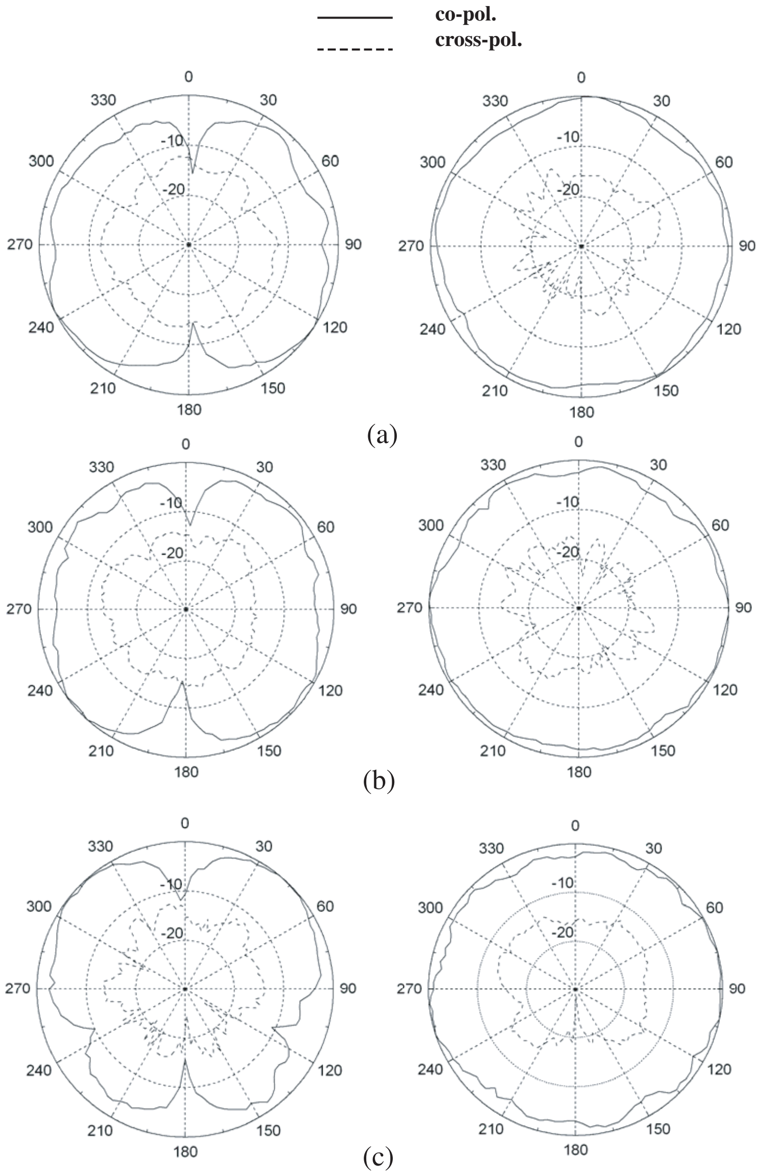

Figure 5. Measured E plane (left) and H plane (right) radiation pattern of the proposed antenna (-10 dB/div) at (a) 3.1 GHz, (b) 4.5 GHz, (c) 7.5 GHz.

Figure 3 indicates the wideband enhancement effect from the tapered slot inserted on the radiating patch, by comparing the VSWR of two antennas with and without the tapered slot. To prevent the influence of the notched bands, the involved structures of the two antennas, the slots on the ground plane and circle arc stubs on the radiating patch, are neglected. The other dimensions of both antennas keep the same. The tapered symmetrical structures of the radiating element produce a smooth transition from one resonant mode to another and ensure good impedance match over abroad frequency range.

Figures 4(a) and (b) display the simulated VSWR results for the proposed antenna in terms of diverse values L_m and L_n respectively. It can be concluded from the results that the notched frequency band can be easily adjusted by tuning the values of L_m and L_n. The measured radiation patterns at 3.1 GHz, 4.5 GHz and 7.5 GHz are presented in Figure 5, which indicates the radiation patterns of the proposed antenna at frequencies out of the rejected band are stable and omnidirectional in the E-plane (xy plane) and similar in the H-plane (yz plane).

Pairs of proposed antennas are used as the transmitting and receiving antennas. The transmitter and receiver are positioned face to face with a distance of 15 cm [13]. By considering the antenna system as a two-port network, the transmission scattering parameter S_{21}, indicating the transfer function, is measured and shown in Figure 6. It should be noted that the measurement was performed in a real environment with reflecting objects in the surrounding area. Figure 7

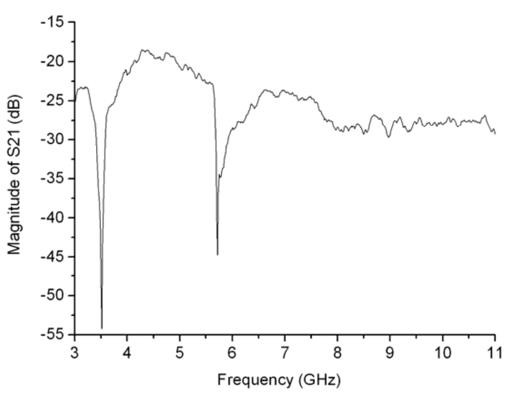

Figure 6. Measured magnitude of S_{21}.

displays the measured group delay of the proposed antenna system. The variation of the group delay is within 1.0 ns across the whole UWB band except the notched bands, in which the maximum group delay is more than 3 ns. The group delay corresponds well to the magnitude of S_{21}, which proves that the antenna has a good time-domain characteristic as well as a small pulse distortion. Furthermore, the antenna peak gain in part of the operating band is shown in Figure 8, where two sharp gains decrease around 3.5 and 5.7 GHz, reflecting the dual band-notched characteristics.

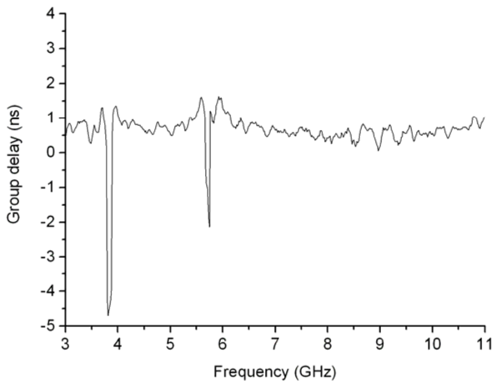

Figure 7. Measured group delay of the transfer system.

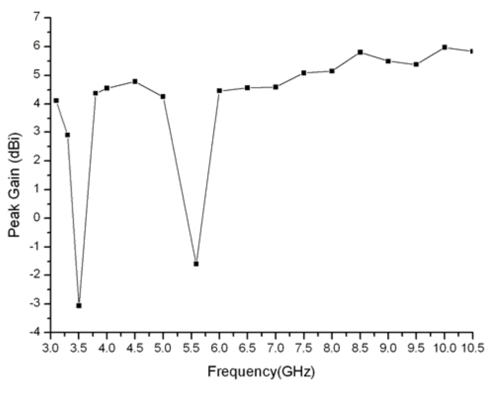

Figure 8. Measured peak gain of the proposed UWB antenna.

4. CONCLUSION

A novel dual band-notched antenna of scissors-like shape using microstrip feed has been demonstrated to exhibit UWB characteristics. A tapered slot is utilized to obtain sufficient matching band, and it hardly affects the radiation patterns of this antenna. Via inserting the slots on the ground plane and adding circle arc stubs on the radiating patch, suitable dual band-rejected characteristics can be realized. The measured results indicate that the proposed UWB antenna not only owns stable good radiation patterns and good gains with its small size, but also prevents interference from other communication systems.

REFERENCES

1. Zhou, H.-J., Q.-Z. Liu, Y.-Z. Yin, and W. B. Wei, "Study of the band-notch function for swallow-tailed planar monopole antennas," *Progress In Electromagnetics Research*, PIER 77, 55–65, 2007.
2. Kim, K.-H. and S.-O. Park, "Analysis of the small band-rejected antenna with the parasitic strip for UWB," *IEEE Transactions on Antennas and Propagation*, Vol. 54, No. 6, 1688–1692, Jun. 2006.
3. Chung, K., J. Kim, and J. Choi, "Wideband microstrip-fed monopole antenna having frequency band-notched function," *IEEE Microwave and Wireless Components Letters*, Vol. 15, No. 11, 766–768, Nov. 2005.
4. Kim, K.-H., Y.-J. Cho, S.-H. Hwang, and S.-O. Park, "Bandnotched UWB planar monopole antenna with two parasitic patches," *Electronics Letters*, Vol. 41, No. 14, 783–785, Jul. 7, 2005.
5. Alshehri, A. A., A. R. Sebak, and T. A. Denidni, "Printed ultra-wideband elliptical antenna with a frequency-band notch function," *Microwave Opt. Technol. Letters*, Vol. 51, 860–864, 2009.
6. Gao, G.-P., J.-S. Zhang, and T. Jin, "Printed ultra-wide band microstrip-line fed slot antenna with a band-notched function," *Microwave Opt. Technol. Letters*, Vol. 51, 1573–1576, 2009.
7. Krishna, D. D., M. Gopikrishna, C. K. Aanandan, P. Mohanan, and K. Vasudevan, "Ultra-wideband slot antenna with band-notch characteristics for wireless USB dongle applications," *Microwave Opt. Technol. Letters*, Vol. 51, 1500–1504, 2009.
8. Ren, W., Z. G. Shi, and K. S. Chen, "Novel planar monopole UWB antenna with 5-GHz band-notched characteristic," *Journal*

of Electromagnetic Waves and Application, Vol. 21, No. 12, 1645–1652, 2007.

9. Zhang, G.-M., J.-S. Hong, and B.-Z. Wang, "Two novel band-notched UWB slot antennas FED by microstrip line," *Progress In Electromagnetics Research*, PIER 78, 209–218, 2008.
10. Fallahi, R., A. A. Kalteh, and M. G. Roozbahani, "A novel UWB elliptical slot antenna with band-notched characteristics," *Progress In Electromagnetics Research*, PIER 82, 127–136, 2008.
11. Chu, Q.-X. and Y.-Y. Yang, "3.5/5.5 GHz dual band-notch ultra-wideband antenna," *Electronics Letters*, Vol. 44, 172–174, 2008.
12. Powell, J., "Antenna design for ultra wideband radio," MSc Thesis, Massachusetts Institute of Thechnology, Cambridge, MA, 2004.
13. Cho, Y. J., K. H. Kim, D. H. Choi, S. S. Lee, and S.-O. Park, "A miniature UWB planar monopole antenna with 5-GHz band-rejection filter and the time-domain characteristics," *IEEE Transactions on Antennas and Propagation*, Vol. 54, No. 5, 1453–1460, May 2006.