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Design of a UWB Filtering Antenna with Defected Ground Structure

Rong Li and Peng Gao*

Abstract—In this paper, a band-notched UWB filtering antenna with defected ground structure (DGS) is presented. This defected ground structure as a lowpass filter (LPF) plays a role in filtering unwanted band. The DGS is applied to suppress the upper passband spectrum of the proposed antenna. A U-shaped slot line etched in the feeding line creates a single band-notched characteristic in 3.3–3.83 GHz for WiMAX to avoid potential interference with the existing system. The measured return loss has a wide fractional bandwidth up to 127.6%, which covers a range of 2.43–11 GHz, with the return loss higher than 10 dB except notch band and less than 2 dB up to 16 GHz. The measured and simulated results reveal that the antenna has good upper stopband performance and consistent quasi-omnidirectional radiation pattern within the UWB frequency range.

1. INTRODUCTION

With the development of wireless communication technology, ultra-wideband (UWB) technology is being reinvented with many promising modern applications since the Federal Commission (FCC) released the spectrum from 3.1 to 10.6 GHz for commercial communication application in 2002. UWB technology has lots of advantages, such as low power dissipation, low cost and high data transmission rate, which attracts huge attention of researchers, especially in the study of UWB antenna [1–3]. However, the antennas mentioned above cannot achieve a good performance in the passband and restrain the radiation in the upper frequency higher than 10.6 GHz very well at the same time. In [4], they integrate the UWB antenna and UWB filter to improve the upper stopband performance. In [5], four shoring pins are used to improve the selectivity of the UWB antenna performance. In [6, 7], although these antennas are integrated with simple filter structures, the edge-band selectivity and upper out-of band performance are not very good. In [8], the antenna integrated with a relatively complex multi-mode resonator improves the edge-band selectivity, but the lower cutoff frequency shifts up to 3.65 GHz, and the value of S11 is greater than -10 dB at 10.16 GHz, resulting in bad in-band performance and narrow bandwidth. The research of the UWB antenna with filtering characteristic that suppresses the upper passband and improves edge-band selectivity is a significant field.

Because the UWB antenna service operates in a wide frequency band, it will cause electromagnetic interference on the existing wireless communication systems, such as the worldwide interoperability for microwave access (WiMAX) systems for IEEE 802.16 operating in the 2.5 GHz (2.5–2.69 GHz), 3.5 GHz (3.4–3.69 GHz) and 5.8 GHz (5.725–5.8 GHz) bands and the wireless local area networks (WLAN). To overcome this problem, quite a few measures have been presented to filter these frequency bands, such as using different types of slot etching on the radiating patch or on the feeding line, EBG structure and a ring-shaped parasitic patch on the ground [9–11].

In this paper, a UWB antenna with good upper stopband performance and band-notched characteristic is proposed. Utilized as a LPF, DGS plays an important role in suppressing the upper passband radiation. A rectangle split and a pair of triangle corner cuts on the ground plane are applied to increase the impedance bandwidth. Furthermore, the single band-notched characteristic has been achieved by using one curving U-shaped slot etched on the feeding line.

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* Corresponding author: Peng Gao (penggao@uestc.edu.cn).
The authors are with the Research Institute of Electronic Science and Technology, University of Electronic Science and Technology of China, Chengdu, China.

2. ANTENNA DESIGN AND PERFORMANCE

The geometry of the proposed antenna and its prototype are shown in Fig. 1. The proposed antenna is fabricated on an FR4 epoxy substrate with a thickness of 1.6 mm and relative dielectric constant of 4.4. The circle radiator is fed by 50 Ω microstrip line, which is terminated with SMA connector for measurement.

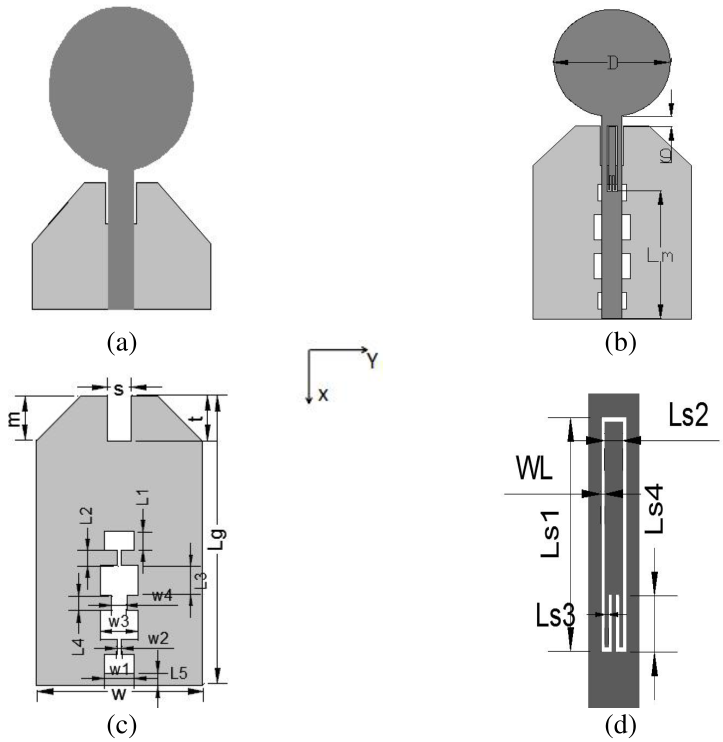


Figure 1. Geometry of: (a) prototype of the proposed antenna, (b) the proposed antenna, (c) the ground of the proposed antenna, (d) close view of the U-shaped slot. ($L1 = 2.5$ mm, $L2 = 2$ mm, $L3 = 3.8$ mm, $L4 = 2$ mm, $L5 = 1.5$ mm, $W1 = 4$ mm, $W2 = 0.6$ mm, $W3 = 5$ mm, $W4 = 2$ mm, $D = 16$ mm, $g = 1.2$ mm, $m = 5.9$ mm, $s = 3.2$ mm, $t = 6$ mm, $Lm = 19$ mm, $Ls1 = 9.8$ mm, $Ls2 = 1$ mm, $Ls3 = 0.2$ mm, $Ls4 = 2.4$ mm, $WL = 0.2$ mm, $Lg = 37.8$ mm).

To suppress the upper passband radiation while retaining the quasi-omnidirectional radiation pattern on H-plane and avoid interference with 3.5 GHz (WiMAX), the filtering antenna is proposed. As shown in Fig. 2, the bandwidth of the UWB antenna without DGS is from 3.14 to 13.66 GHz, which has bad edge-band selectivity, while the UWB antenna with DGS provides a shape roll-off at the higher cutoff frequency (11 GHz) than that in the UWB antenna without DGS. This is mainly caused by the DGS, which acts as a lowpass filter, suppressing the radiation of the upper passband ($>$ 11.2 GHz). The DGS etched on the ground has little effect on the radiation pattern of the antenna in the operating band, hence it is applied to enhance the upper stopband performance.

Furthermore, U-shaped slot length is approximately half the waveguide wavelength of the required notch frequency, and it plays a role as a filter to reject the limited band from 3.3 to 3.83 GHz. Fig. 3 shows that the length of a U-shaped slot will deeply affect the location of notched band whose peak value is -2.6 dB at 3.5 GHz when $Ls4 = 2.4$ mm and $Ls1 = 9.8$ mm, is -3.2 dB at 3.96 GHz when $Ls4 = 2.4$ mm and $Ls1 = 8$ mm, and is -4 dB at 4.55 GHz when $Ls4 = 0.2$ mm and $Ls1 = 9$ mm, respectively. As shown in Fig. 4, the impedance bandwidth increases, and the low cutoff frequency shifts to low frequency, because the physical structure of the slot increases the electrical length at the lower frequency band.

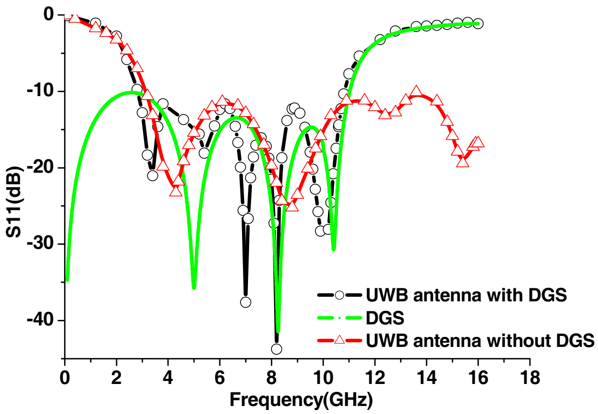


Figure 2. Simulated return loss of the UWB antenna with and without DGS.

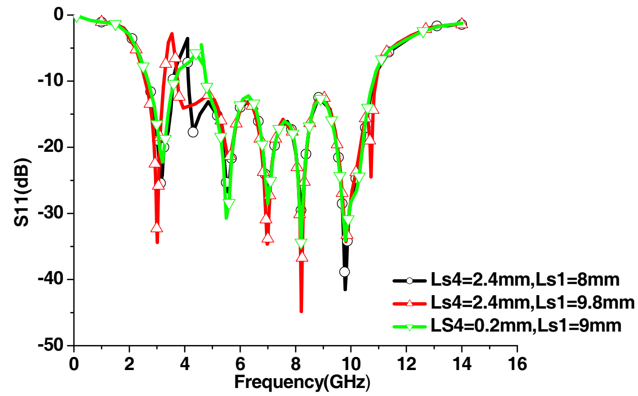


Figure 3. Simulated return loss of various lengths of slot.

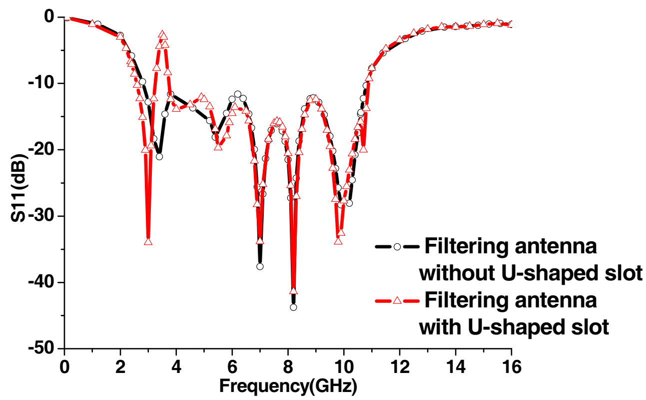
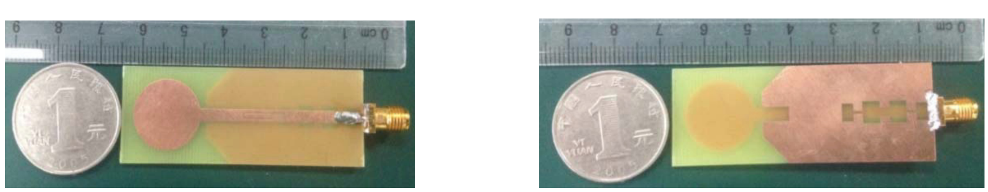


Figure 4. Simulated return losses of filtering antenna with and without U-shaped slot.

3. RESULTS AND DISCUSSION

To verify the predicted performance of this proposed antenna, the filtering antenna is fabricated and measured. Photographs of the proposed antenna are shown in Fig. 5. The measurement of S-parameters is performed with Agilent E8363B vector network analyzer (VNA) and simulation performed using ANSYS HFSS 15.0. Fig. 6 plots the simulated and measured return losses of the proposed antenna. According to the measured results, the UWB antenna covers the band (2.43–11 GHz) for $S11 < -10$ dB with rejecting band from 3.3 GHz to 3.83 GHz. The measurement shows that the proposed antenna has good upper stopband performance for $S11 > -2$ dB up to 16 GHz.

The simulated and measured normalized radiation patterns in E- and H-planes at the frequencies



(a) top-view (b) bottom-view

Figure 5. Photographs of the proposed antenna.

of 2.43 GHz, 6 GHz, 8 GHz, and 11 GHz are depicted in Fig. 7, respectively. The measured radiation patterns of H-planes are approximately omnidirectional over the operational frequency, and there is a great agreement with simulations, and the small discrepancy is due to the dispersion of the connectors and fabrication errors. As shown in Fig. 8, the maximum simulated gain of the proposed antenna is up to 4.18 dBi. It is obviously observed that a sharp decrease of antenna grain is in the notched frequency band at 3.5 GHz.

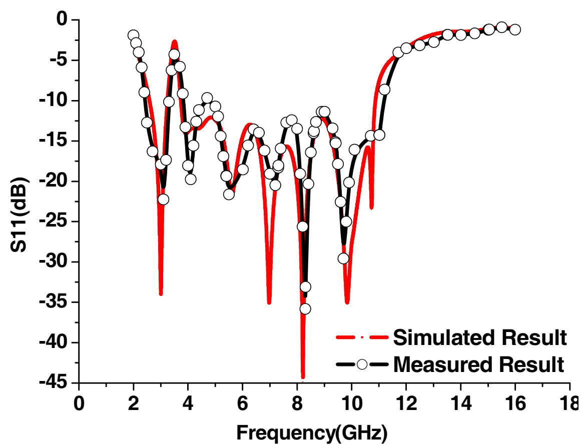
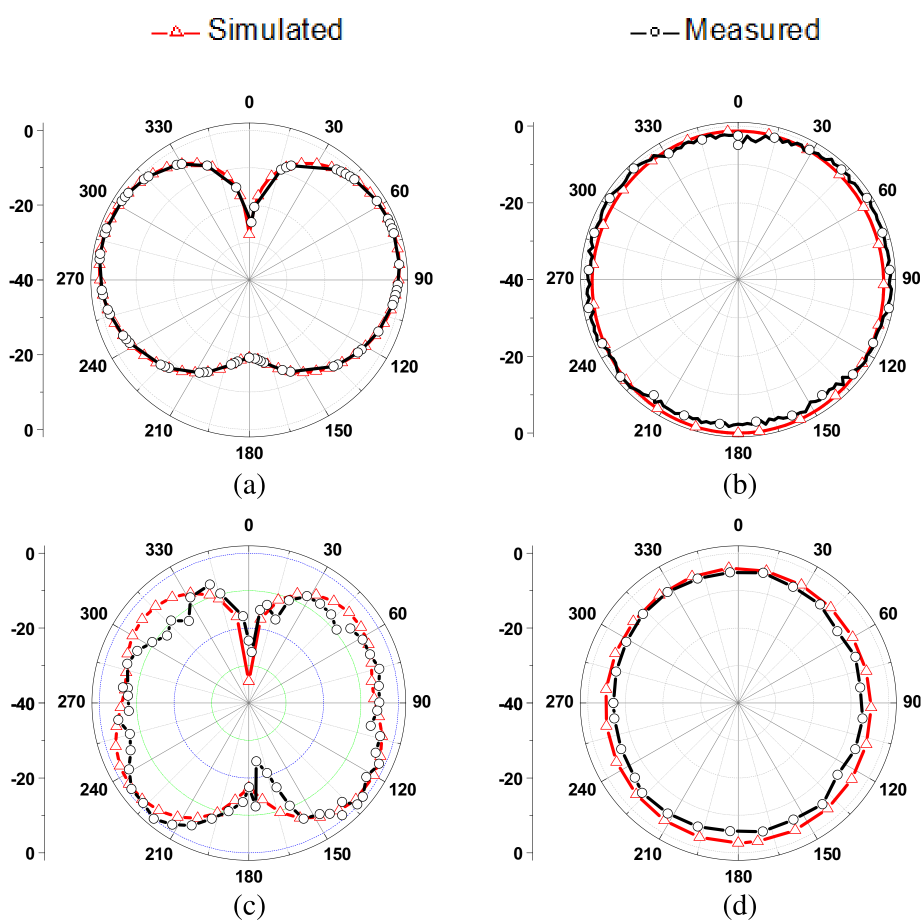


Figure 6. Simulated and measured return loss of the proposed antenna.



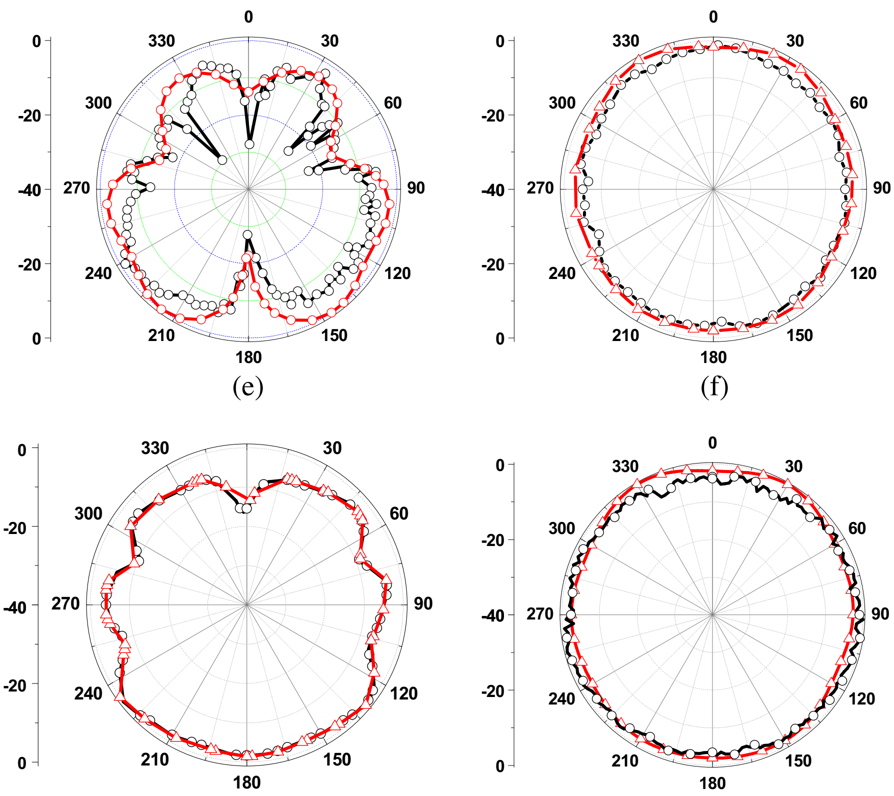


Figure 7. Simulated and measured radiation patterns of the proposed antenna: (a) 2.43 GHz E-plane. (b) 2.43 GHz H-plane. (c) 6 GHz E-plane. (d) 6 GHz H-plane. (e) 8 GHz E-plane. (f) 8 GHz H-plane. (g) 11 GHz E-plane. (h) 11 GHz H-plane.

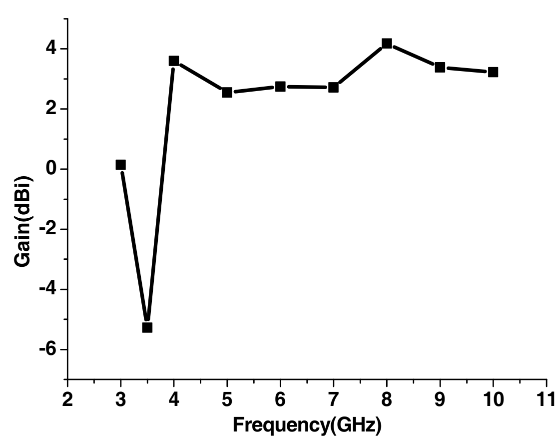


Figure 8. Measured gain of the proposed antenna.

4. CONCLUSION

A UWB filtering antenna with good upper stopband performance and band-rejected characteristic has been implemented. The DGS suppresses the radiation of the UWB antenna at upper frequency (> 11 GHz) and makes the UWB antenna have a great in-band selectivity. Furthermore, a U-shaped slot line is located in the feeding line of the antenna to generate the notched-band without additional circuit size. These features are very attractive for UWB application.

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