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UWB PRINTED SLOT ANTENNA WITH DUAL BAND-NOTCHED CHARACTERISTIC

W.-M. Li*, T. Ni, S.-M. Zhang, J. Huang, and Y.-C. Jiao

National Laboratory of Antennas and Microwave Technology, Xidian University, Xi'an, Shaanxi 710071, China

Abstract—This article presents a compact dual band-notched UWB antenna with a pair of L-shaped and modified L-shaped slots on either side of the ground plane for the 3.5/5.5 GHz dual band-notched characteristics. The radiating patch of the proposed antenna has a ladderlike structure symmetrically and fed by a 50-Ω microstrip transmission line. By etching two sets of L-shaped slots on the ground plane, dual band-notched properties in the WiMAX/WLAN bands are achieved, respectively. The proposed antenna has the promising performance including matched impedance, consistent radiation pattern and stable gain.

1. INTRODUCTION

Owing to its high data transmission rate, large bandwidth, and short-range characteristics, ultra-wideband (UWB) technology has completely revolutionized the wireless and high speed data communication world since the Federal Communication Commission (FCC) first approved in 2002 the rules for the 3.1–10.6 GHz unlicensed band for commercial UWB communications utilization [1]. However, there still exist several narrow bands for other communication systems over the designated frequency band, such as: world interoperability for microwave access (WiMAX) service from 3.3 to 3.7 GHz; the wireless local area network (WLAN) for IEEE 802.11a in the USA (5.15 to 5.35 GHz, 5.725 to 5.825 GHz) and HIPERLAN/2 in Europe (5.15 to 5.35 GHz, 5.47 to 5.725 GHz). To avoid the electromagnetic interference with the existing WLAN and WiMAX systems, many UWB antennas with band-notched characteristic are designed [2–8].

In this letter, we thus propose a printed monopole antenna that simply employs a pair of L-shaped and modified L-shaped coupling

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* Corresponding author: Weimei Li (li_weimei@163.com).

slots to flexibly control the rejection frequency band for UWB system operation. The reference antenna consists of a ladder-like exciting stub on the front side and a modified rectangular aperture on the back ground plane [9]. Usually L-shaped stubs and slots are embedded in the radiation patch [5] or at the bottom of the ground plane [10], generally only single notched band is obtained. This letter presents a new method to achieve the characteristics of L-shaped slots for dual band-notched UWB antenna. The modified L-shaped slots on the bottom layer deal with the lower notched band while the L-shaped slots aim at the higher one. The simulation software HFSS is used in the design and simulation processes of the proposed antenna. Good agreement between simulations and measurements is obtained, which shows that the antenna is a promising candidate for UWB applications.

2. ANTENNA DESCRIPTION

A new design of band notched UWB antenna is presented in this letter, which has a compact profile of $31 \times 31 \times 1$ mm. The configuration of the proposed antenna is shown in Figure 1. The antenna is fabricated on a substrate with a dielectric constant of $\varepsilon_r = 2.55$ and a thickness of 1 mm. On one side of the substrate, a rectangular and two triangular slots are etched to create a relatively wide frequency band since the rectangular slot affects the middle frequency mode, while the two triangular slots influence the higher frequency mode. On the opposite side, a 50-Ω microstrip feed line with a width of 2.8 mm is adopted for centrally feeding the antenna. Moreover, at the end of the feed line, a ladder-like conducting patch is applied

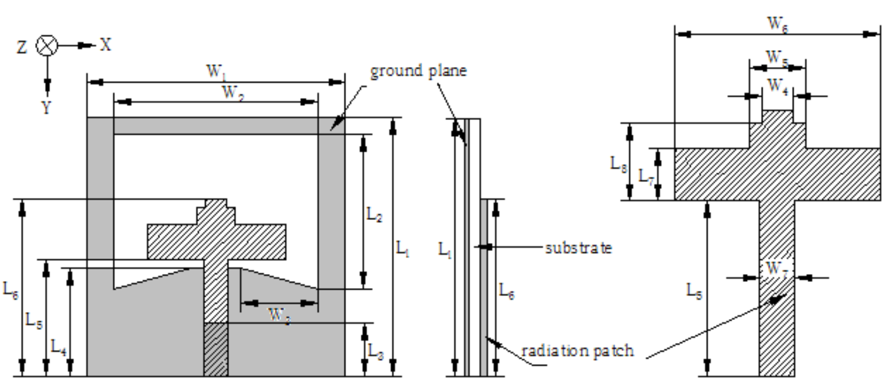


Figure 1. Geometry and dimensions of proposed antenna.

to create a good impedance matching for the proposed antenna to attain the bandwidth enhancement for the UWB applications. The electromagnetic software Ansoft HFSS is employed to perform the design and optimization process. Listed below are the optimal design parameters of the antenna for us to investigate the performance of the proposed antenna: $W_1 = 31\,\text{mm}$, $W_2 = 24.4\,\text{mm}$, $W_3 = 9.3\,\text{mm}$, $W_4 = 3.8\,\text{mm}$, $W_5 = 4.5\,\text{mm}$, $W_6 = 2.5\,\text{mm}$, $W_7 = 2.8\,\text{mm}$, $L_1 = 31\,\text{mm}$, $L_2 = 18.6\,\text{mm}$, $L_3 = 6.4\,\text{mm}$, $L_4 = 13\,\text{mm}$, $L_5 = 14\,\text{mm}$, $L_6 = 21.2\,\text{mm}$, $L_7 = 4.2\,\text{mm}$, $L_8 = 6.2\,\text{mm}$, $H = 1\,\text{mm}$.

In order to create a band notched behavior within the UWB over which the patch antenna is active, one needs to short out the radiation of the patch at the required notch center frequency. Two similar resonating structures are embedded in the reference UWB antenna as shown in Figure 2. To decrease the potential interferences between UWB systems and these narrowband systems, the dual-band notched characteristics are created by inserting a pair of L-shaped and modified L-shaped slots, and the notched centre frequencies can be easily adjusted by the parameters of the slots and the dielectric.

The first notch at 3.5 GHz is produced by a pair of L-shaped slots as shown in Figure 2. The length of the L-shaped slot ($W_8 + L_9$) is about a quarter of the wavelength of the notch frequency at 3.5 GHz. The wavelength can be approximately calculated by the formula as follows.

$$\lambda_g \approx \frac{c}{f\sqrt{\frac{\varepsilon_r+1}{2}}}$$

where ε_r, c, and f are dielectric constant, the velocity of light in free space, and the center frequency of the desired bands respectively.

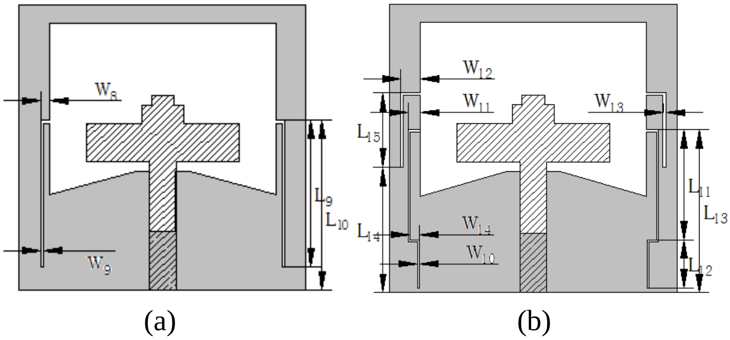


Figure 2. Geometry and dimensions of the (a) single and (b) dual band-notched antenna.

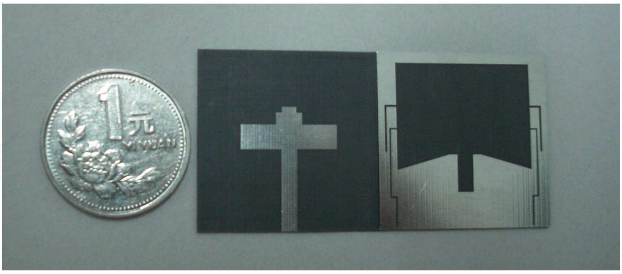


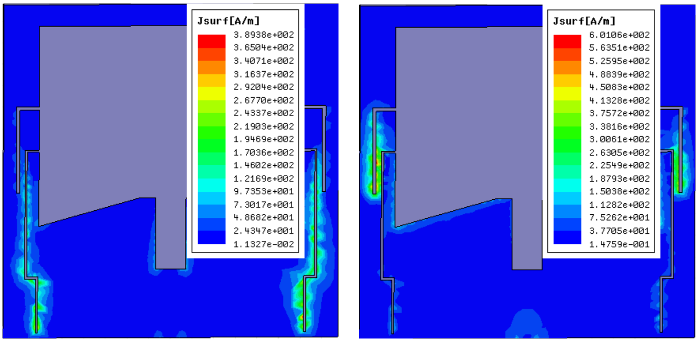
Figure 3. Photograph of the manufactured dual band-notched antenna.

Another pair of L-shaped slots ($W_{12}+L_{15}$) is also introduced to achieve the notch at 5.5 GHz by employing the same theory. Because of the compact configuration and relative position of the slots, a little change is made by bending the first slots. The length of the new first slots ($W_{11}+L_{11}+W_{14}+L_{12}$) remains about a quarter of the wavelength of the notch frequency at 3.5 GHz. By tuning the length of the slots, the following parameters of the band-notched antenna can be got: $W_8 = 1$ mm, $W_9 = 0.3$ mm, $W_{10} = 0.2$ mm, $W_{11} = 1.3$ mm, $W_{12} = 2.1$ mm, $W_{13} = 0.3$ mm, $W_{14} = 1$ mm, $L_9 = 16$ mm, $L_{10} = 18.5$ mm, $L_{11} = 11.8$ mm, $L_{11} = 11.8$ mm, $L_{12} = 5.2$ mm, $L_{13} = 17.5$ mm, $L_{14} = 13.5$ mm, $L_{15} = 8$ mm. The appearance of two slots will change the surface current and electric field distribution on the antenna. Then it will create a strong impedance mismatch at the desired bands. The photograph of manufactured dual band-notched antenna is shown in Figure 3.

3. ANTENNA PERFORMANCES

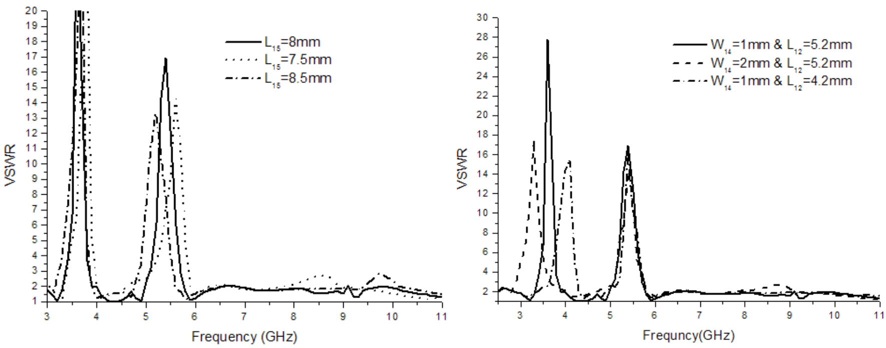
For better understanding of the proposed antenna behavior, the simulated current distribution on the antenna at the frequencies of 3.5 GHz and 5.5 GHz is presented in Figure 4. It can be seen that at the desired frequency, only are the corresponding slots active while the others are inactive, confirming the independence of the frequency bands.

The simulated VSWR for different values of L_{15}, L_{12} and W_{14} are displayed in Figure 5 and the simulated results show that wanted notched bands can be easily obtained by tuning these parameters. As it is seen in Figure 5(a), upon increasing L_{15} from 7.5 to 8.5 mm with other parameters constant, the upper notched band moves to a lower frequency.The parameters L_{12} and W_{14} mainly determine the lower



(a) (b)

Figure 4. Surface current distributions at (a) 3.5 GHz and (b) 5.5 GHz.



(a) (b)

Figure 5. (a) Simulated VSWR of proposed antenna with different L_{15} values. (b) Simulated VSWR of proposed antenna with different L_{12} and W_{14} values.

notched band. Figure 5(b) shows the effect of varying the length of the modified L-shaped slots on the ground plane. Besides, it is found out that by adjusting one of these parameters, only the corresponding notched frequency band changes without disturbing the other notched band, which reveals that the proposed antenna has stable notched bands characteristics.

The proposed dual band-notched antenna is measured by a network analyzer Agilent N5230A (10 MHz–50 GHz). Results of the reference antenna without notched characteristics are also shown for comparison. It can be seen from Figure 6 that the measured

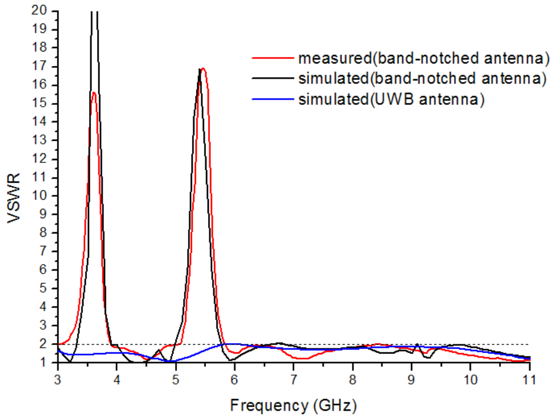


Figure 6. Simulated and measured VSWR of the dual band-notched antenna.

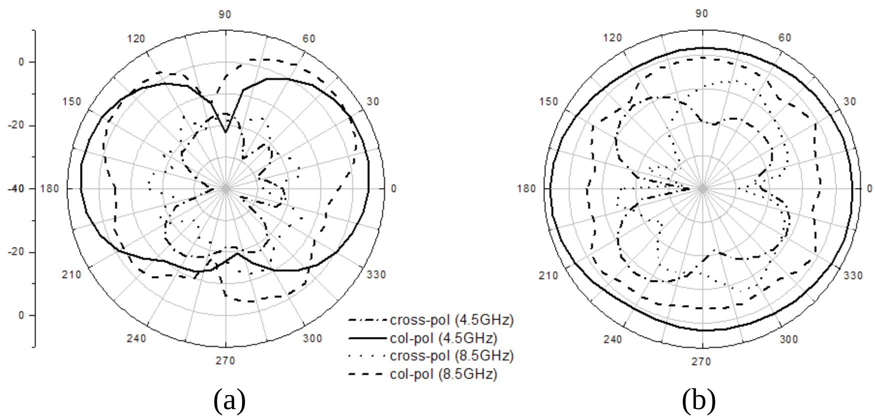


Figure 7. Measured (a) E plane and (b) H plane radiation patterns (in dB).

VSWR reasonably agrees with the simulated results with an acceptable frequency discrepancy, which may be referred to the difference between the simulated and the measured environments.

The far-field radiation characteristics of the proposed dual band-notched antenna are also investigated. Figure 7 presents the measured co- and cross-polarized patterns in the E- and H-planes at 4.5 and 8.5 GHz. Nearly omnidirectional radiation patterns in the x-y plane and dipole-like radiation patterns in the x-z plane are obtained at these frequencies. The results show that there is an increase in the cross-polarized pattern in both planes for higher frequency of operation. The results also reveal the fact that the radiation patterns of the antenna are stable in both planes.

Figure 8 reveals the measured transfer function and group delay by using two identical fabricated prototypes for the proposed antenna with a distance of 50 cm. the group delay and the magnitude transfer function are flat in the whole band except in the notched bands, which indicates far-field phase linearity and a quality of a pulse distortion and derived from the first differential coefficient of the phase [11], and it also proves that the antenna has a good time-domain characteristic and a small pulse distortion as well. Figure 9 represents the gain in dBi verses frequency. The gain increases with the frequency and the measured peak gains within the operation frequency bands range from 1.5 dBi to 3.2 dBi. It is clear that there are two sharp dips in the gain around 3.5 GHz and 5.5 GHz, which confirms the effective operation of the UWB dual band-notched antenna in the two-narrow band systems. As observed in the figure the gain in rejection bands is expected to be sharply reduced as low as −4.6 dBi. For other frequencies outside the rejected bands, the gains remain good and stable in performance. All of these show that the proposed antenna has good band-notched characteristics and effectively minimize the potential interferences between UWB system and the narrowband wireless systems.

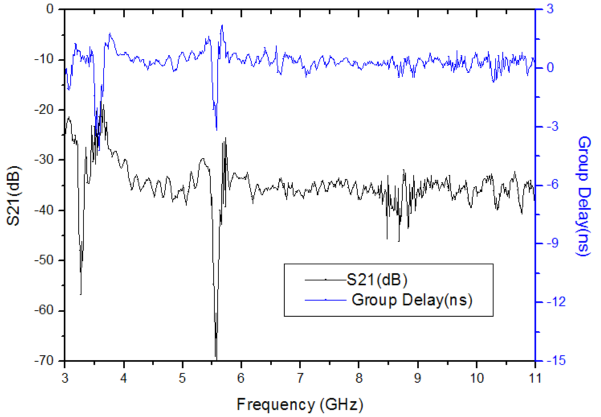


Figure 8. Measured group delay and transfer function for the proposed antenna.

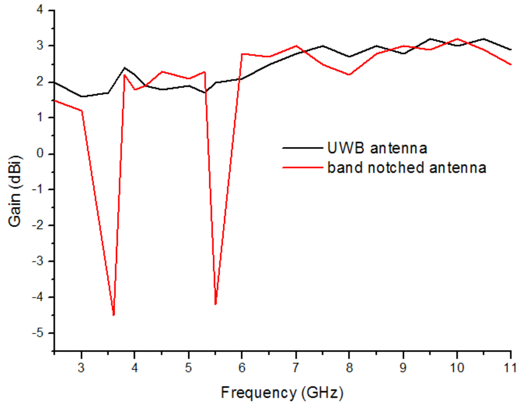


Figure 9. The measured peak gain of the proposed antenna.

4. CONCLUSION

A novel compact UWB antenna with dual band-notched characteristics at WiMAX/WLAN frequencies has been proposed and discussed. The modified ground plane with triangular and rectangular shaped slots helps to increase the impedance bandwidth. By employing two sets of symmetrical L-shaped slots of quarter-wavelength of the ground plane, two notched bands centered at 3.5 GHz (WiMAX) and 5.5 GHz (WLAN) are created. It is observed from measurement that the slots act independently, and their addition to the slot antenna does not change the behavior of the original UWB slot antenna. The measured results confirm with the simulated ones. Such superior frequency characteristics and electrical performance make the proposed antenna suitable for integration into UWB portable devices.

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