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A DOUBLE-PRINTED TRAPEZOIDAL PATCH DIPOLE ANTENNA FOR UWB APPLICATIONS WITH BAND-NOTCHED CHARACTERISTIC

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Abstract—In this paper, a novel double-printed trapezoidal patch dipole antenna suitable for UWB applications with band-notched characteristic is presented and investigated. The band-notched characteristic is achieved by inserting T-shape slots on the trapezoidal radiating patches. The impedance characteristic, radiation patterns and the transfer function are studied. Experimental results show that the proposed antenna covers the entire UWB band (3.1–10.6 GHz) while it has a notched band for the IEEE 802.11a frequency band (5.15–5.825 GHz). Measured group delay, transmission characteristics and Time domain characteristics indicate that the proposed antenna satisfies the requirement of the current wireless communications systems.

1. INTRODUCTION

With the development of wideband wireless communication systems, various kinds of ultra wide band (UWB) antennas have been studied extensively and various feasible designs of ultra-wideband antennas are steadily growing [1–4]. It is a well-known fact that planar dipole antennas present really appealing features such as simple structure, compact size, low cost, omni-directional character, etc. Due to these interesting characteristics, many dipole antennas are studied widely [5–7].

Since the 5.15–5.825 GHz frequency band allocated for wireless local area network (WLAN) systems can interfere with the UWB communications systems, a band-notched filter in UWB systems is necessary. Compared with adding a filter to increase the complexity

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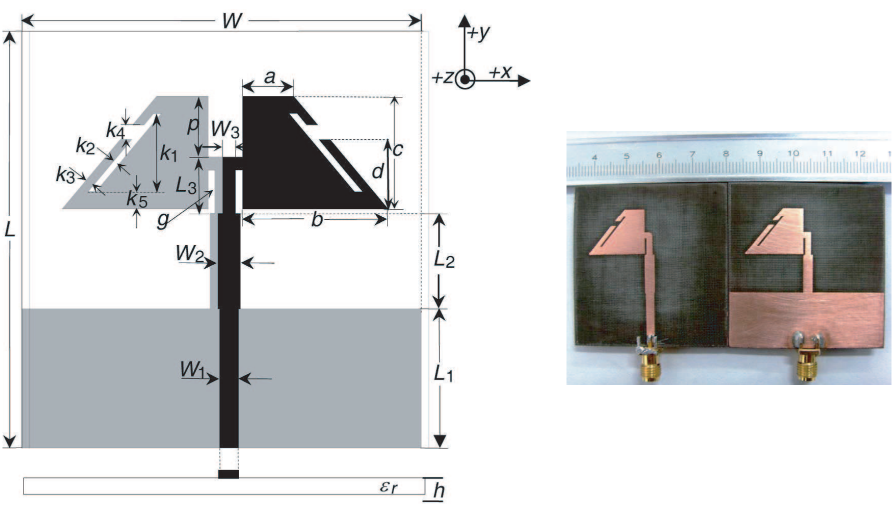
of the UWB system, using a UWB antenna having frequency band-notched function is the advisable choice. Various Planar antennas with band-notched performance have been proposed for UWB applications [8–17].

In this article, we propose a novel double-printed trapezoidal patch dipole antenna having a frequency band-notched function for UWB communication. The band-notched characteristic is obtained by inserting T-shape slots on the radiators. The band-width and the notched frequency band can be adjusted by changing the antenna parameters. Details of the design and experimental results are presented and discussed in the following sections.

2. DESIGN AND ANALYSIS OF THE ANTENNA

Figure 1 shows the proposed antenna. Two trapezoidal patches are printed on the opposite sides and fed by micro-strip lines. The ultra-wide band without notch band characteristics is obtained by optimizing the width of the feed line and the parameters of the patches. Two T-shape slots are inserted on the trapezoidal radiating patches to get the band-notched characteristic.

The antenna is printed on a substrate with relative permittivity of 2.78 and the thickness h of 0.8 mm. Designing sizes are as follows:



(a) Geometry (b) Photograph

Figure 1. The geometry and photograph of the proposed antenna.

$L = 48\,\text{mm}$, $L_1 = 16\,\text{mm}$, $L_2 = 11\,\text{mm}$, $L_3 = 6.3\,\text{mm}$, $W = 46\,\text{mm}$, $W_1 = 2.2\,\text{mm}$, W_2=2.6 mm, $W_3 = 1.5\,\text{mm}$, $a = 5.9\,\text{mm}$, $b = 16.8\,\text{mm}$, $c = 13\,\text{mm}$, $d = 8\,\text{mm}$, $g = 0.8\,\text{mm}$, $p = 7\,\text{mm}$, $k_1 = 1.7\,\text{mm}$, $k_2 = 9\,\text{mm}$, $k_3 = 0.7\,\text{mm}$, $k_4 = 1\,\text{mm}$, $k_5 = 2\,\text{mm}$.

The proposed antenna is simulated by CST software which is based on the method of finite integration technology. When the T-shape slots are not inserted to the antenna, the ultra-wideband characteristic is achieved without a band-notched characteristic. It can bee seen that the VSWR is strongly affected by parameter g. By optimizing the parameter g, the antenna can obtain an ultra-wideband impedance matching. Figure 2 shows that the simulated VSWR with various g. When g equals 0.8 mm, the antenna obtains the desired band.

Figure 3 shows the current distribution of the antenna without the T-shape slot simulated by CST software. We can see that the

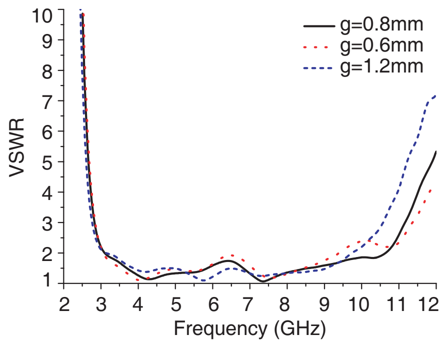


Figure 2. Simulated VSWR against frequency for antenna (no slot) with various g.

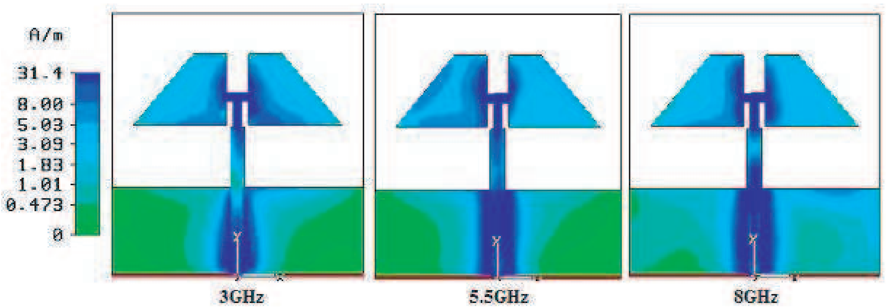


Figure 3. Simulated current distribution of the antenna without the T-shape slot.

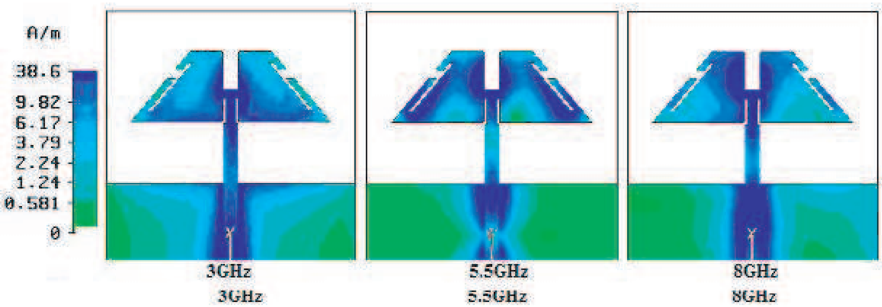


Figure 4. Simulated current distribution of the antenna.

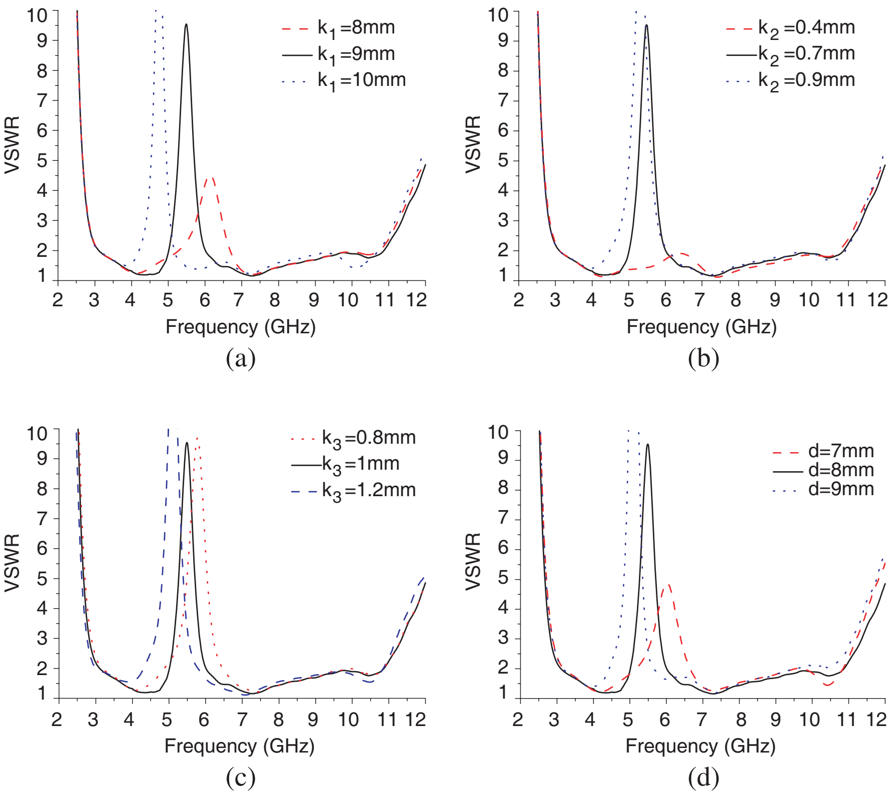


Figure 5. Simulated VSWR with varying parameters: (a) k_1, (b) k_2, (c) k_3, (d) d.

distribution of the antenna reaches the densest at the feeding gap. However, the distribution of the antenna reaches the densest at the hypotenuse at 5.5 GHz. So we can choose the appropriate position at the hypotenuse to insert a slot so as to obtain band-notched characteristic. As shown in Figure 4, the distribution of the proposed antenna reaches the densest at the T-shape slots at 5.5 GHz. The slots strongly affect the distribution of the antenna to achieve the band-notched characteristic.

Figure 5 shows the simulated VSWR varying by k_1, k_2, k_3 and d, which are more susceptible parameters for the band-notch function. As shown in Figures 5(a), 5(b) and 5(d), varying the value of k_1, k_2 and d, the center frequency of the notched band can be easily turned. As the value of k_1, k_2 and d increases, the center frequency of the notched band is decreasing while magnitude in the notched band is increasing. However, in Figure 5(b), if the value of k_2 are decreasing too much, the band-notched characteristic will be lost because geometry of the antenna will be destroyed. Figure 5(c) shows that the center frequency of the notched band is decreasing as the value of k_3 increases.

3. SIMULATION AND MEASUREMENT

The antenna is measured by Agilent E8363B vector network analyzer. The simulated and measured VSWR against frequency are shown in Figure 6. The measured impedance bandwidth for VSWR < 2 is from 3 to 11 GHz and the bandwidth of the frequency notched band (VSWR > 2) is from 4.9 to 6.3 GHz. It shows that the impedance bandwidth of the antenna satisfies the UWB system requirement while avoiding the interference of 5 GHz WLAN system. Although the two results are in good agreement, the measured notched band is a little

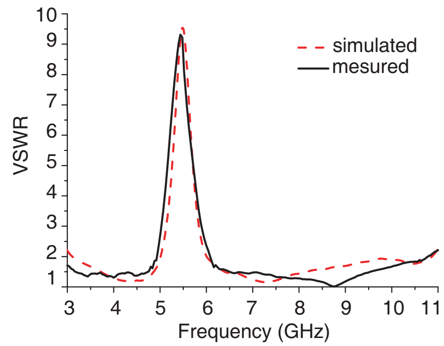
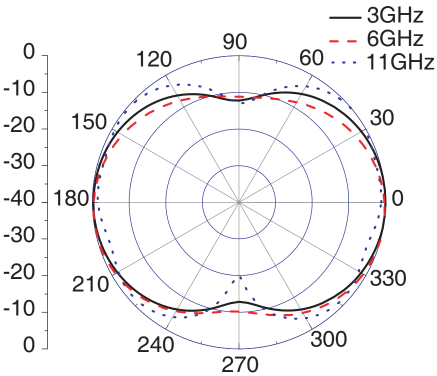


Figure 6. Measured and simulated VSWR for the proposed antenna.

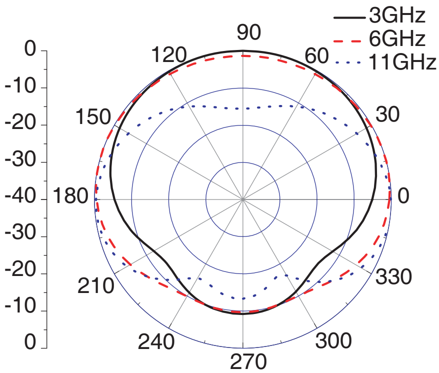
wider than the simulated one because of the fabrication error and the numerical error.

Figure 7 shows that the simulated radiation patterns of E-plane and H-plane at 3.6 and 11 GHz respectively. It is observed that the radiation pattern of E-plane and H-plane at 3 and 6 GHz are approximately omni-directional while those at 11 GHz are a little worse.

The peak gain of the proposed antenna against frequency is given in Figure 8. The peak gain in the operation frequency band ranges from 3.6 dBi to 5.9 dBi. The result presents that the proposed antenna is successfully performed with the rejection in the 5.1–5.9 GHz (WLAN band).



(a) x-y plane (E-plane)



(b) y-z plane (H-plane)

Figure 7. Simulated radiation patterns at different frequencies.

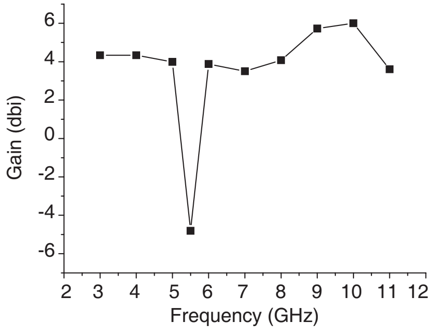


Figure 8. Peak gain at different frequencies.

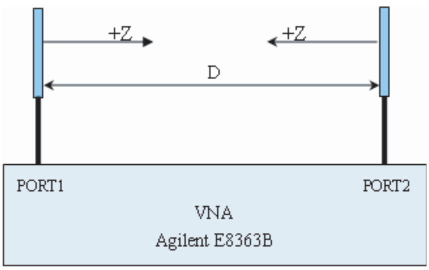


Figure 9. Transfer system set up.

4. TRANSFER FUNCTION AND TIME DOMAIN STUDY

In designing UWB antennas, it is crucial to evaluate the system transfer functions. In the operating band, the magnitude of the transfer functions should be as flat as possible and the phase is required to be linear. The group delay is able to show any nonlinearity and required to be constant over the entire band. As shown in Figure 9, a pair of proposed antennas is used as the transmitting and receiving antennas and the distance is 15 cm (D). By considering the system as a two-port network, it is measured by Agilent E8363B vector network analyzer and simulated by CST software.

The measured and simulated magnitude of S_{21} is shown in Figure 10. The simulate magnitude of S_{21} is relatively flat (variation less than 10 dB). The measured magnitude is relatively flat from 3 GHz to 8.5 GHz while the curve decreases rapidly when the frequency is more than 8.5 GHz. Two results both have an attenuation of about 30 dB in the notched band.

The measured and simulated phase of S_{21} is given respectively in Figures 10(a) and 10(b). The simulated result shows a linear result in the 3–11 GHz UWB band while it has a strong disturbance in the notched band, which agrees with the magnitude of S_{21}. The measured phase of S_{21} is in agreement with the simulated result.

Figure 10 shows the simulated and measured group delay of the antenna system. The variation of the group delay is within 2 ns across the whole band except the notched band, in which the maximum group delay is more than 5 ns. The group delay corresponds well to the magnitude and phase of S_{21}, so it proves that the antenna has a good time-domain characteristic.

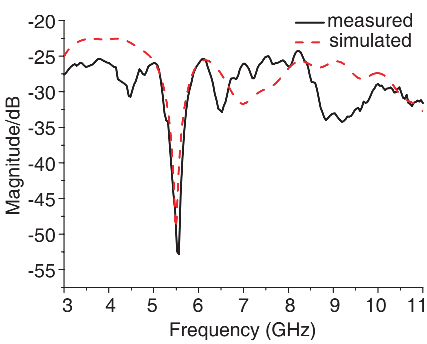
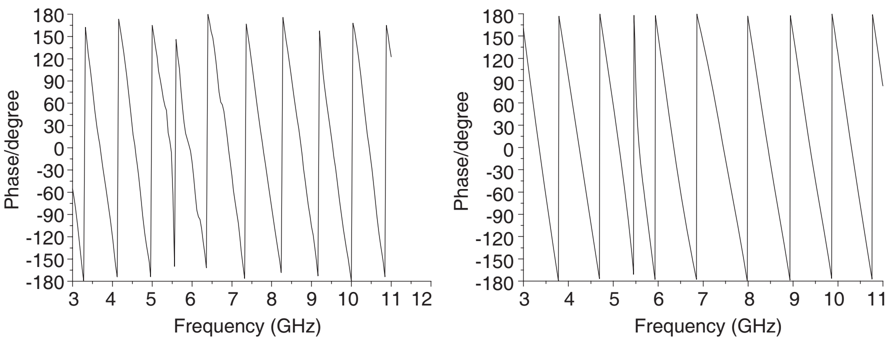


Figure 10. Simulated and measured amplitude of S_{21} for the antenna systems.

Time domain study based on the measurement set up as shown in Figure 9 and the pulse in x direction is evaluated. Figure 12 shows the excited pulse, radiated pulse and received pulse of the proposed antenna. The excited pulse is Gaussian function. Pulse signals are normalized and moved parallel along the abscissa in order to see clearly. We can see that the radiated pulse and received pulse are distorted as compared to excited pulse.

The fidelity is defined as

$$\rho = \max_{\tau} \left\{ \left| \frac{\int p(t)s(t-\tau)dt}{\sqrt{\int p^2(t)dt}\sqrt{\int s^2(t)dt}} \right| \right\} \tag{1}$$



(a) measured (b) simulated

Figure 11. Simulated and measured phase of S_{21} for the antenna systems.

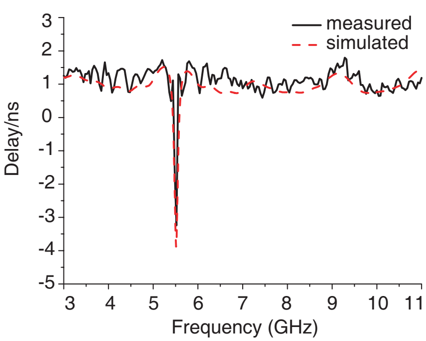


Figure 12. Simulated and measured group delay for the antenna systems.

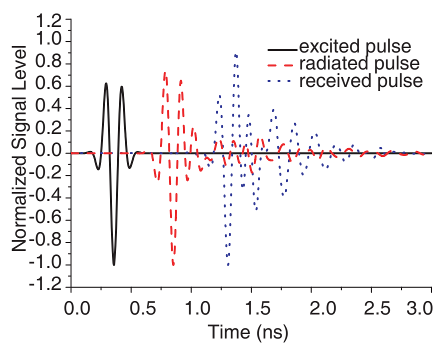


Figure 13. The pulse waveforms for the antenna system.

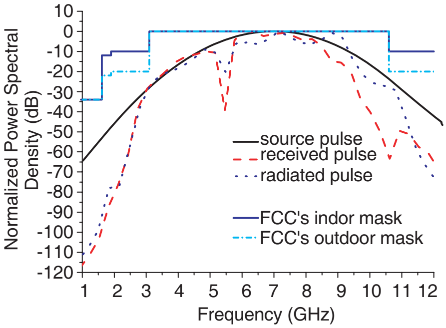


Figure 14. The normalized power spectrum density (PSD) of pulses for the antenna system.

where τ is a delay which is varied to make the numerator in Eq. (1) a maximum. It determines the correlation between the signals $s(t)$ and $p(t)$. The excited pulse is chosen as the reference signal $p(t)$, while the radiated pulse and received pulse as signal $s(t)$. The calculated fidelity between excited and received pulse is 0.7893 and the fidelity between excited and radiated pulse is 0.7173. It indicates that the radiated and received pulse have the similar waveform.

The normalized power spectrum density (PSD) of the excited, radiated and received pulse for the proposed antenna are calculated and shown in Figure 13 respectively. It is shown that all the pulses comply with FCC's emission mask. The PSD of radiated and receive pulse show a similar result and decreased in the notched band, which confirms the transfer function results.

5. CONCLUSION

A novel double-printed trapezoidal patch dipole antenna suitable for UWB applications with band-notched characteristic is studied. The band-notched function is achieved by inserting two T-shape slots on the antenna, and the demanded notched frequency band is achieved by adjusting the T-shape slots. The measured VSWR less than 2 completely covers the UWB range of 3.1–10.6 GHz and have a notch band (5.15–5.825 GHz). Transfer function and time domain study results correspond well to the VSWR.

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