A Novel Dual Narrow Band-Notched CPW-Fed UWB Slot Antenna with Parasitic Strips

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Abstract **─** A novel and compact 5.2/5.8GHz dual narrow band-notched ultra wideband (UWB) slot antenna with inverted U-shaped parasitic strips is presented. The band notches of this antenna fed by a coplanar waveguide (CPW) are realized by two pairs of inverted U-shaped parasitic strips. Each pair consists of two separate strips which are similar and close to each other. And dual narrow rejected properties in the lower WLAN band (5.15-5.35GHz) and upper WLAN band (5.725-5.825GHz) are obtained. The size of the proposed antenna is 24 × 24 × 1 mm^3. The simulated and measured results show that the antenna design exhibits an operating bandwidth (VSWR < 2) from 2.8 to 12 GHz excluding the rejected bands.

Index Terms **─** Coplanar waveguide fed, dual band notches, microstrip slot antenna, ultra wideband.

I. INTRODUCTION

Since the Federal Communications Commission (FCC) approved the frequency band from 3.1 to 10.6 GHz for the commercial use of ultra wideband (UWB) systems, much attention has been paid to the UWB technology [1-3]. It is reported that there are many practical applications in UWB communication, UWB pulse radar [4], UWB imaging [5], UWB electromagnetic pulse weapon and so on.

However, there are some other existing narrow band services in the UWB band, such as the WiMAX band (3.3-3.7GHz) and WLAN band (5.15-5.35GHz and 5.725-5.825GHz). Most band-notched designs only use a rejected band to notch the whole WLAN band [6]. Therefore, the resource of the band (5.35-5.725GHz) is wasted, and the useful information contained in the band is also lost.

In recent years, some UWB antennas with 5.2/5.8GHz narrow band notches are proposed. In [7], the authors embed a slot in the ground and etch another slot in the radiation patch to get 5.2/5.8GHz notched bands. In [8], by adding a pair of open-circuit stubs at the edge of the slot and etching one complementary split-ring resonator (CSRR) inside a circular exciting stub on the front side, dual notched band characteristic is realized. In [9-10], by embedding two split ring resonators (SRRs) close to each other, dual narrow band notches are obtained. However, it is often difficult to carry out the antenna design works.

In this paper, a new and simple method is proposed to get two adjacent narrow stopbands. With two pairs of parasitic strips on the backside of the antenna, two narrow band notches can be obtained. Because of the mutual coupling of the two notched structures, the reject characteristic between the two stopbands becomes weakened, and a passband between the two stop bands is realized. A novel and compact CPW-fed UWB slot antenna with 5.2/5.8GHz dual band notches obtained by adding two pairs of inverted U-shaped parasitic strips is designed.

The proposed antenna has a symmetrical structure which improves the antenna radiation pattern characteristics. Because of the simple reject structure, it is easy to tune for the notched antenna. And the simulated and measured results verify the proposed method.

II. ANTENNA DESIGN

Figures 1 and 2 show the geometry and the fabrication of the proposed antenna, respectively.

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The antenna, which occupies a compact area of $W \times L$, is built on an FR4 substrate with a relative permittivity of 4.4, a thickness of h and a loss tangent of 0.02, and is fed by a 50Ω CPW transmission line with a strip width of W_1 and gap width of d_1. An SMA connector is connected to the port of the feeding line. The original antenna structure without band-notched structures consists of a circle-like exciting stub and a slotted CPW ground.

In order to obtain two narrow stopbands and not to take up too much space, two similar pairs of inverted U-shaped parasitic strips are introduced on the backside of the antenna. The total length of each parasitic strip is the corresponding half wavelength to the center frequency of each notched band.

The required notched bands are 5.15-5.35GHz and 5.725-5.825GHz, therefore, the designed resonant frequencies are set to be about 5.25 and 5.8GHz. The wavelengths can be calculated by [11]

$$\lambda = \frac{c}{f\sqrt{\varepsilon_{\text{eff}}}} \tag{1}$$

$$\varepsilon_{\text{eff}} = \frac{1+\varepsilon_{\text{r}}}{2} \tag{2}$$

where c is the speed of the light, ε_{eff} is the effective dielectric constant, ε_{r} is the relative permittivity of the antenna substrate, and f is the designed resonant frequency. The corresponding length of the parasitic strips can be obtained by

$$L_{\text{strip\_outer}} = 2\times L_6 + W_3 \approx \frac{\lambda_{\text{low}}}{2} \tag{3}$$

$$L_{\text{strip\_inner}} = 2\times L_5 + W_2 \approx \frac{\lambda_{\text{high}}}{2} \tag{4}$$

where $L_{\text{strip\_outer}}$ and $L_{\text{strip\_inner}}$ are the total length of the outer and inner inverted U-shaped parasitic strips, respectively. And λ_{low} and λ_{high} are the wavelengths corresponding to the center frequency of the low and high notched band, respectively.

Through electromagnetic simulations, it can be found that the edge of slot is related to broadband impedance matching. Thus, the rejecting structures are away from the edge of the slot, and the dual narrow band-notched properties are obtained. The optimized parameters are listed as follows: R_1 = 11.4 mm, R_2 = 6.8 mm, L = 24 mm, L_1 = 4 mm, L_2 = 3.5 mm, L_3 = 1.5 mm, L_4 = 4 mm, L_5 = 7 mm, L_6 = 7.4 mm, L_7 = 7.4 mm, L_8 = 7.6 mm, W = 24 mm, W_1 = 3.6 mm, W_2 = 1.9 mm, W_3 = 3.3 mm, W_4 = 7.55 mm, d = 1 mm, d_1 = 0.4 mm, d_2 = 0.2 mm, and h = 1 mm.

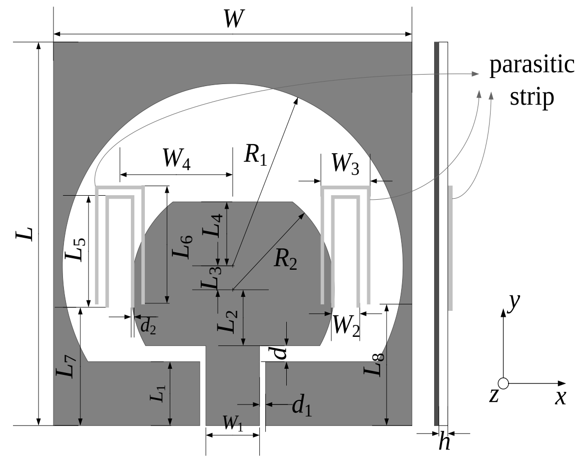


Fig. 1. Geometry of the proposed antenna.

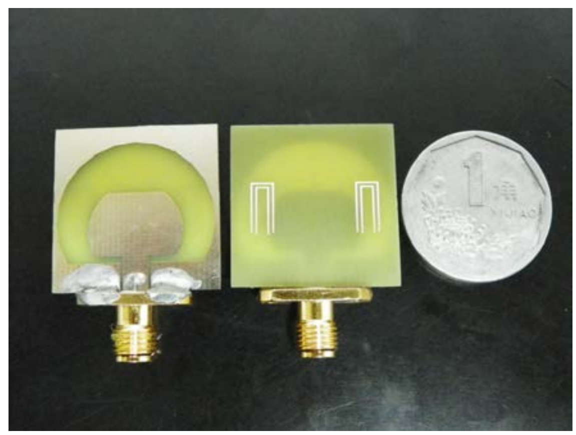


Fig. 2. Photograph of the proposed antenna.

III. RESULTS AND DISCUSSION

The VSWR results of the proposed antenna are simulated with HFSS software and measured with an Agilent E8363 network analyzer, respectively, as shown in Fig. 3. For comparison, the simulation VSWR result of the original UWB antenna without parasitic strips is also provided in Fig. 3.

The proposed antenna exhibits a bandwidth (VSWR < 2) from 2.8 to 12GHz, rejecting the 4.8-5.36GHz and 5.68-6.2GHz bands. The measured result of the proposed antenna is almost in accord with the simulated one except a little frequency offset. The difference between simulation and measurement is mostly due to the influences of manufactured precision and feeding cable. Obviously, it can be found that a wider passband between the two notched bands is obtained both in the simulated and measured results, which verify the proposed theory that a passband between two adjacent stopbands can be obtained because of the mutual coupling of the two notched structures.

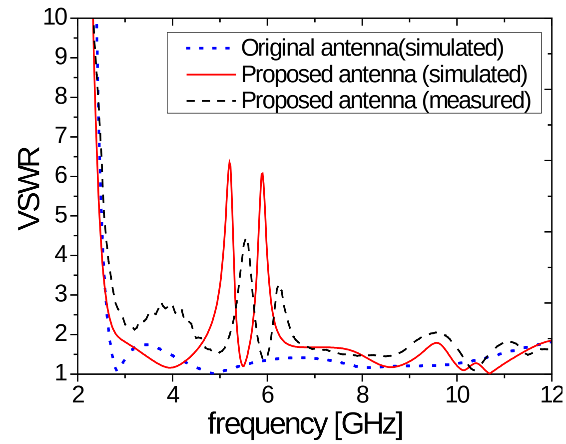


Fig. 3. Simulated and measured VSWR of the two antennas.

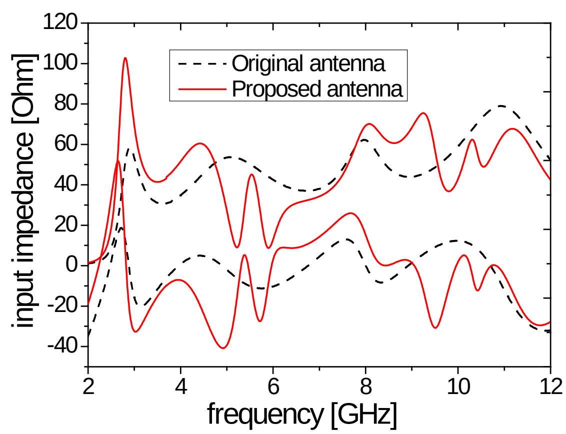


Fig. 4. Simulated input impedance of the two antennas.

Figure 4 shows the simulated input impedance of the two antennas. We can see that when the reject structures are added in the original antenna, the input impedance of the proposed antenna mismatches in the designed reject bands, but it matches in the other bands, especially the band between the two reject bands. Therefore, the proposed antenna cannot work well in the reject bands, and it does not disturb the reject band communication.

It is known that the frequency of the notched band is determined by the length of the notched structure. With the change of the parameters L_5 and L_6, the total lengths of the two notched structures are also changed. Therefore, the frequency responses with the various parameters L_5 and L_6 are simulated, respectively, shown in Figs. 5 and 6.

In Figs. 5 and 6, we can see that L_5 and L_6 mainly affect the central frequency of the higher band notch at 5.8GHz and the lower band notch at 5.2GHz, respectively. It is seen that the larger L_5 or L_6 becomes, the smaller the corresponding central frequency of the band notch becomes. Besides, it is also suggested that the two band notches should be independent of each other.

Surely, the range in which the notched frequencies are adjusted cannot exceed the working band of the original antenna.

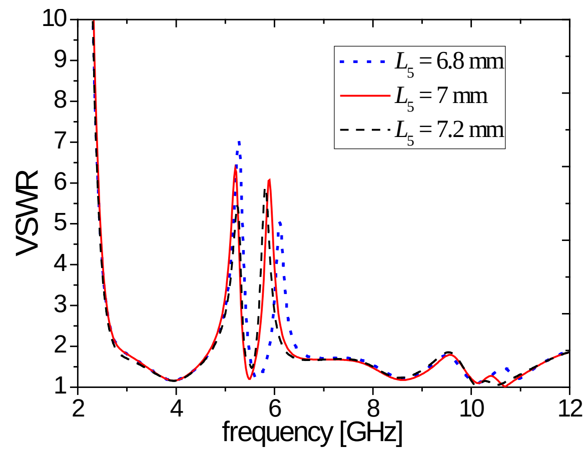


Fig. 5. Simulated VSWR with various L_5.

The parasitic strips can also change the surface current distributions. The current direction on the reject structures is opposite to that on the nearby antenna structure, so the far fields produced by the currents on the reject structures and nearby antenna structure cancel out each other in the reject band. Fig. 7 shows the simulated current distributions at 5.2, 5.8 and 5.6GHz on the antenna backside. In Fig. 7(a), the current mainly flows around the outer inverted U-shaped strips, which destructs the radiation of the original antenna at this band and results in the lower stopband. On the contrary, the current mainly flows around the inner inverted U-shaped strips in Fig. 7(b). In Fig.7(c), the current distribution at 5.6GHz is even on the outer and inner inverted U-shaped strips, but the current direction on the inner strips is opposite to that on the outer ones. It is suggested that two band notches should be mutually interfered with and the notched property does not have any influence on the antenna radiation at 5.6GHz. Then, a passband between two adjacent stopbands can be obtained because of the mutual interference of the two notched structures.

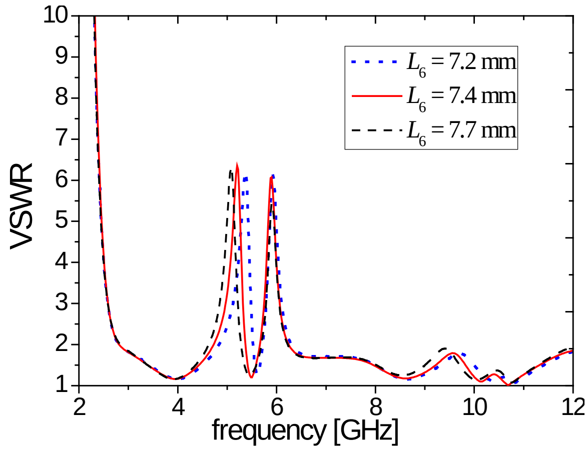


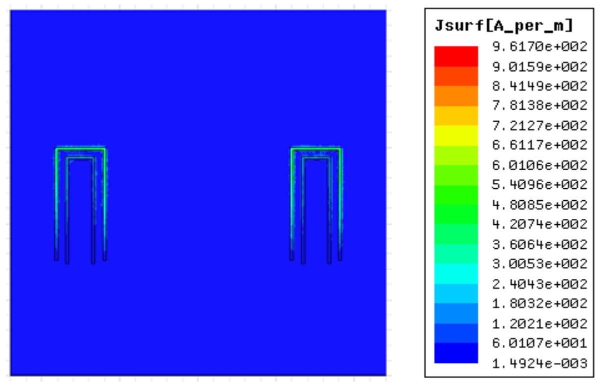
Fig. 6. Simulated VSWR with various L_6.

Figure 8 depicts simulated radiation patterns at 2.8, 3.5, 7, 9 and 12GHz on *yoz*-plane and *xoz*-plane. A nearly omnidirectional radiation pattern can be observed on xoz-plane over the whole UWB frequency range, especially at the low frequencies. The radiation patterns on the yoz-plane are like a small electric dipole leading to bidirectional patterns in a very wide frequency band. With the increase of frequency, the radiation patterns become worse because of the increasing effects of the cross polarization.

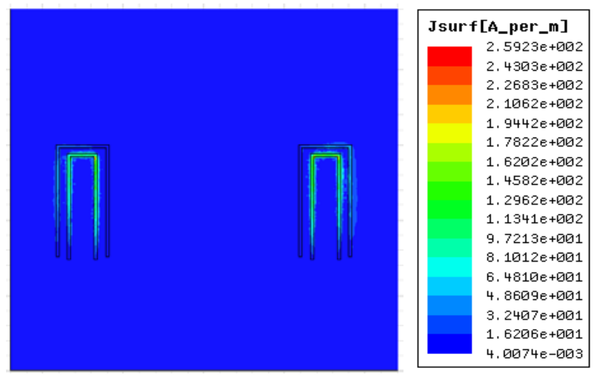
Simulated peak gain and radiation efficiency of antennas with strips and without strips are shown in Figs. 9 and 10, respectively. The sharp decreses of the gain and radiation efficiency of the proposed antenna occur in the lower and upper WLAN bands. It is suggested from the two figures that the radiation of the proposed antenna be bad at the reject bands. At the same time, the high radiation efficiency in the band between the two reject bands leads to a passband.

IV. CONCLUSION

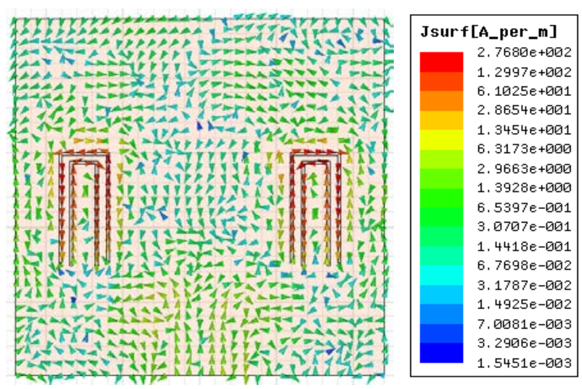
A novel and compact CPW-fed UWB slot antenna with 5.2/5.8GHz dual band notches obtained by adding inverted U-shaped parasitic strips is proposed and discussed in detail in this paper. A good dual narrow band-notched characteristic is obtained with two pairs of similar inverted U-shaped parasitic strips in the symmetric position of the antenna. The proposed antenna has stable gain and good omnidirectional radiation patterns in the H-plane over the whole frequency band of interest.



(a) 5.2 GHz

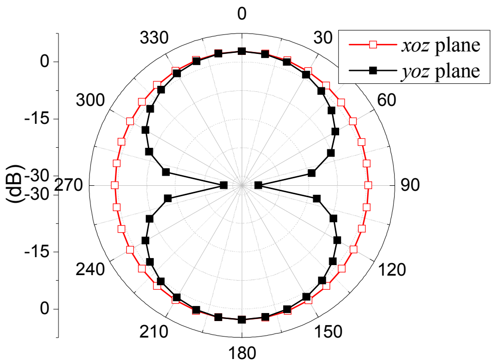


(b) 5.8 GHz

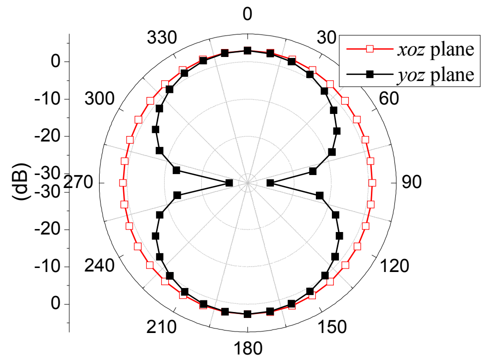


(c)5.6 GHz

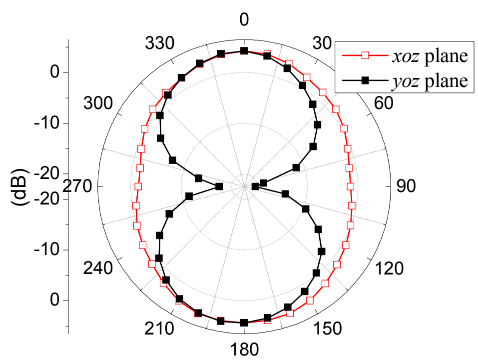
Fig. 7. Simulated current distributions.



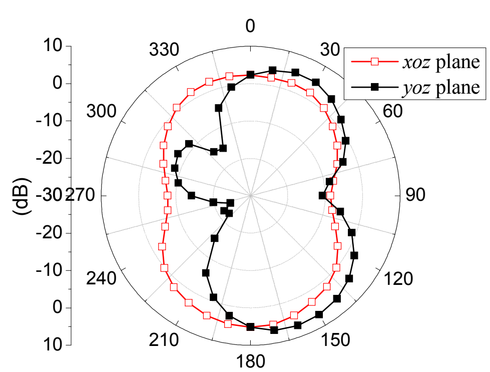
(a) 2.8GHz



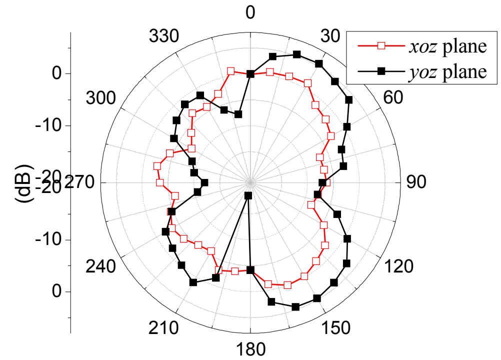
(b) 3.5GHz



(c) 7GHz



(d) 9GHz



(e) 12GHz

Fig. 8. Simulated radiation patterns on *yoz*-plane and *xoz*-plane for the proposed antenna.

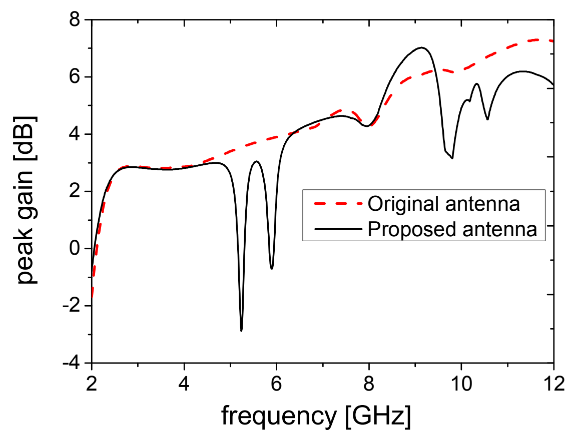


Fig. 9. Simulated peak gain of the two antennas.

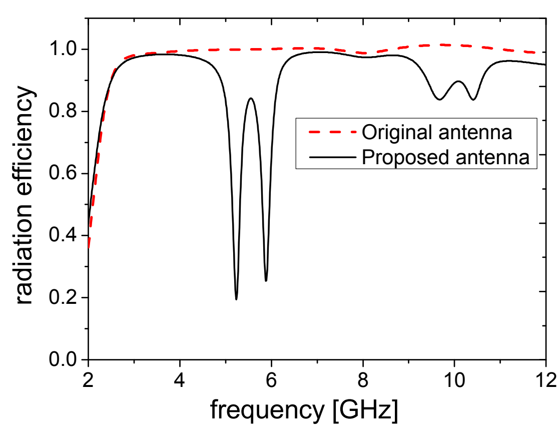


Fig. 10. Simulated radiation efficiency of the two antennas.

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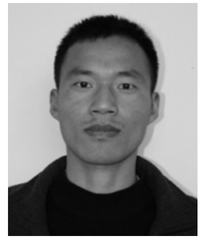

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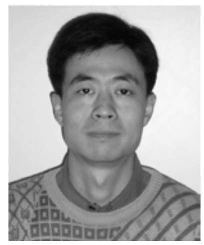

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