A CPW-Fed Band-Notched UWB Antenna with T-shape Construct and Matching Branches

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Abstract **─** A compact coplanar waveguide (CPW) fed ultra-wideband (UWB) antenna with a band-notched performance is presented in this paper. The band-notched UWB antenna is designed on a $26 \times 34 \times 1.6$ mm^3 substrate. It consists of a circle ring with a T-shape construct, three rectangular matching branches, a rectangular transition branch, and a CPW feed line. The antenna is simulated and the geometrical parameters of the antenna selected with Ansoft HFSS. The simulated results show the impedance bandwidth covers from 3.0 GHz to 11.0 GHz with the notched rejection band of 5.1 GHz - 5.8 GHz. A prototype was fabricated and tested. The measured and simulated results show that the proposed antenna gives bidirectional radiation pattern in the E-plane and omnidirectional radiation pattern in the H-plane with relatively flat gains in the pass-band. Due to its compact configuration, the antenna can find good UWB applications.

Index Terms - Antenna, band notching, coplanar waveguide (CPW), impedance matching, and ultra-wideband (UWB).

I. INTRODUCTION

In February 2002, the Federal Communication Commission (FCC) allocated a frequency band 3.1 GHz-10.6 GHz for ultra-wideband (UWB) applications [1]. Since then, designs of the ultra-wideband (UWB) wireless systems have garnered great attention. The UWB systems have many advantages, such as excellent immunity to multipath interference, large bandwidth and high speed data rate. One of the most important components in an UWB wireless system is the antenna. Designing such an antenna faces many challenges, because the antenna has to have the special properties such as omni-directional pattern, ultra-wideband impedance bandwidth, constant gain, low profile, and easiness for manufacture [2].

Many antennas have been explored and developed for UWB wireless systems, such as monopole patch antenna [3], slot antenna [4], and fractal antenna [5]. By using optimization method, good characteristics of radiation, transmission, and impedance bandwidth can be achieved [6].

Many existing wireless communication and radio systems operate in a frequency band that overlaps with the UWB band, such as IEEE 802.11a in USA (5.15 GHz-5.35 GHz and 5.725 GHz-5.825 GHz), HIPERLAN/2 in Europe (5.15 GHz-5.35 GHz and 5.47 GHz -5.725 GHz) [7]. As a result, an existing system should not cause any interference to an UWB system and vice versa. One of the approaches to achieve the objective is to embed filters into UWB circuits, but it will increase the UWB system complexities. A much better way is to design UWB antennas with band-notched characteristics. To this end, many band-notched antennas have been designed and developed.

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Among the band-notched UWB antennas reported so far, the most popular are those with resonance structures added on radiators or feeding structures; they include U-shape slots [8-11], T-shape construct [12-14], π-shape strip [13], SRR and CSRR structures [15], stepped impedance stub [16]. All of them can have good performance in rejection or notched bands, and some of them even have multiple notched bands [8-10, 15-17].

On the other hand, planar monopole antennas have many advantages for UWB applications because of their compact size and stable radiation [18]. An UWB antenna fed by a coplanar waveguide (CPW) has the properties of low profile, wide bandwidth, low loss, and easy integration with electronic circuits; therefore, it is widely used in communication systems.

In this paper, a planar monopole band-notched UWB antenna fed by CPW is proposed. The band-notched characteristic is achieved by embedding a T-shape structure in the antenna's radiator and using three matching branches to adjust high frequency characteristic of the antenna.

The remainder of the paper is organized as follows. First, the geometry of the proposed antenna is described in section II. Analysis and simulation of the effects of the antenna parameters on impedance bandwidth are presented in section III. After that, the experimental results are presented to compare with the simulation results in section IV. Finally, in section V, conclusions are drawn.

II. THE PROPOSED ANTENNA

Figure 1 shows the geometry of the proposed antenna with a band-noched characteristic. The antenna is symmetrical about the *x*-axis. It consists of a circle ring radiation patch, three rectangular matching branches, a rectangular transition branch and a CPW. The band rejetion characteristic is mainly achieved by embedding a T-shape construct in the cirlcle ring radiation patch. The width of the T-shape construct is W_5 and W_6. The length is L_5 and L_6. The width and length of the two matching branches on the left side and on the top side are W_2 and L_2, W_4 and L_4, respectively. The thickness of the antenna is h. The physical dimensions of the antenna are shown in Table I.

III. ANTENNA DESIGN AND ANALYSIS

In this section, analysis and simulation results are presented. The Ansoft HFSS was used to carry out all the simulations.

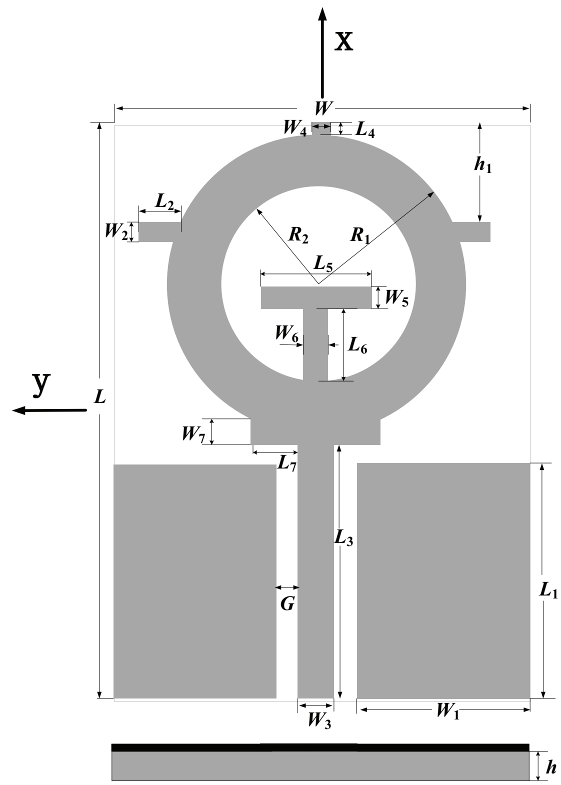


Fig. 1. Geometry of the proposed antenna.

Table I: Physical dimensions of the proposed UWB antenna (unit: millimeters).

Parameter	Value	Parameter	Value
L	34.00	W	26.00
L_1	13.46	W_1	11.15
L_2	3.31	W_2	1.00
L_3	14.55	W_3	2.00
L_4	0.58	W_4	1.00
L_5	5.00	W_5	0.50
L_6	3.54	W_6	0.50
L_7	3.00	W_7	0.82
h	1.60	h_1	6.00
R_1	9.50	R_2	5.91
G	0.85		

In the proposed antenna, the circular ring patch and the T-shape construct are equivalent to an inductor and a capacitor. The T-shape construct as a band-notched structure was analyzed in [12, 13]. At the resonant frequency, the construct can cause an impedance change that leads to impedance mismatching near the notched band. The matching branches and the circle ring are then introduced to compensate for the change as well as to adjust the width of the notched band. As a result, L_5, L_6, R_2, and L_2 are considered as main design variables that determine the performances of the antenna.

In general, the T-shape construct mainly affect the notched band, and have a slight influence on the pass band. Considering possible coupling between the T-shape construct and the circle ring patch, length L_5 and L_6 should not be too large. Because the length of the T-shape is measured collectively by L_5 and L_6, $L_5 + L_6$ is chosen as the analysis parameter. Figure 2 shows the simulated VSWR with various lengths of the T-shape construct. It is clearly seen from the figure that length $L_5 + L_6$ has a significant effect on the notched frequency. The rejection or notched frequency band shifts from around 5.6 GHz to 4.3 GHz when the length $L_5 + L_6$ increases from 7.9 mm to 9.9 mm, while the pass band is only affected slightly.

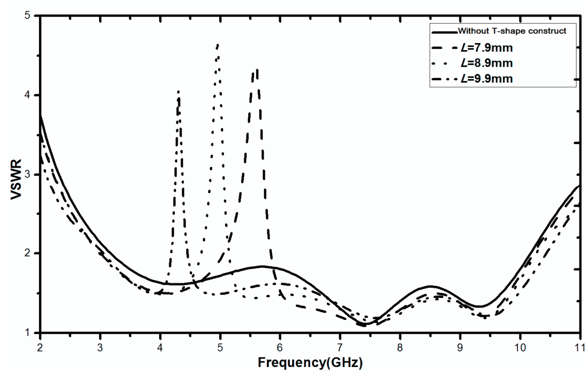


Fig. 2. Simulated frequency response of VSWRs with various $L_5 + L_6$.

Figure 3 shows the variations of the notched band with respect to R_2. It is obvious that the longer R_2, the wider nothed bandwidth. VSWR increases from 4.3 to 8.0 as R_2 increases from 5.2 mm to 7.2 mm, while the notched frequency only decreases slightly with the R_2.

Figure 4 shows the simulated VSWRs with L_2 varying from 1.9 mm to 3.5 mm. It can be seen that the upper-end frequency decreases as L_2 increases. When L_2 changes from 1.9 mm to 3.5 mm, the upper frequency decreases to 10.5 GHz, while the lower frequency hardly changes. This is because increasing the branches L_2 is equal to increasing the equivalent current length and decrease the resonant frequency [13]. After a detailed simulation analysis, the phsical parameters are set as shown in Table I.

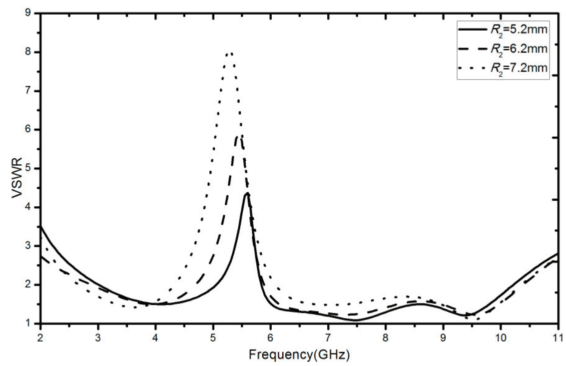


Fig. 3. Simulated frequency response of VSWRs with various R_2.

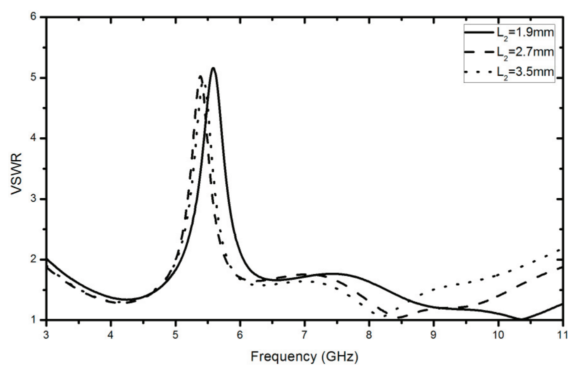
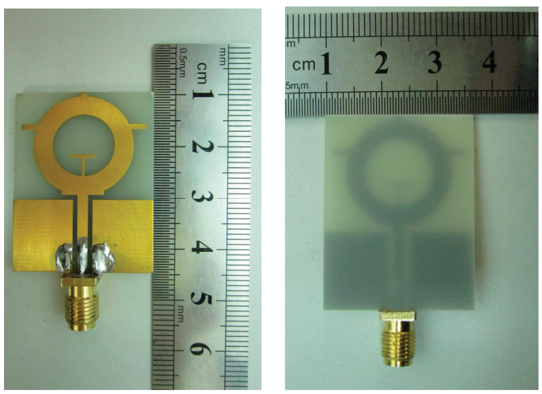


Fig. 4. Simulated frequency response of VSWRs with various L_2.

IV. EXPERIMENTAL RESULTS

The proposed antenna was fabricated and tested. Its photographs are shown in Fig. 5. The dielectric substrate used in the antenna was FR-4 with dielectric constant of 4.4, loss tangent of 0.02, and substrate thickness of 1.6 mm. SMA connector was used for transition between the CPW and coaxial cable for the measurement purpose.

VSWR was measured using Agilent E8362B PNA. The measured and simulated VSWRs are shown in Fig. 6. It can be seen that the simulated VSWR is less than 2.0 from 3.0 GHz to 11 GHz with a notched rejection band of 5.1 GHz-5.8 GHz, while the measused antenna bandwith covers the range of 3.5 GHz - 10.6 GHz with a noteched rejection band of 4.8 GHz - 5.8 GHz. The discrepancy between the simulated and measured VSWR can be attributed to fabrication errors and differences between the electrical properties used in the simulations and those of the actual materials.



(a) (b)

Fig. 5. Photographs of the proposed antenna; (a) front view and (b) rear view.

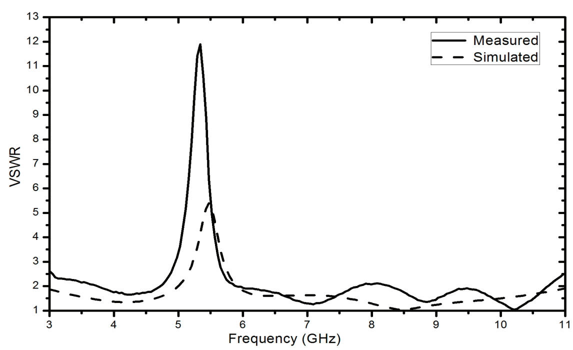
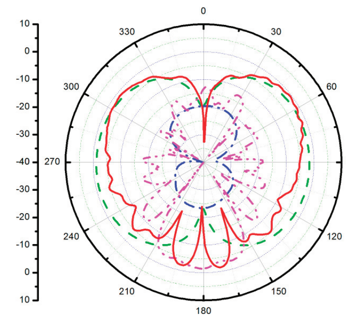
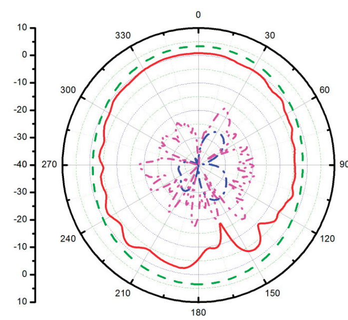


Fig. 6. Measured and simulated VSWR.

Figure 7 shows the far-field radiation patterns of the E-plane and H-plane at 5 GHz, 5.4 GHz, 6 GHz, and 7 GHz, respectively. 5.4 GHz is within the notched band. It can be seen that the patterns of the antenna at these frequencies are roughly omnidirectional in the H-plane. In the E-plane, they remain roughly bidirectional patterns. Figure 7 (b) indicates that the antenna has much lower gains in the notched band than those at other passband frequencies. The cross-polarization in the negative *x*-direction is much higher than that in other directions, which could be mainly due to the SMA connector that alters the distribution of the current.

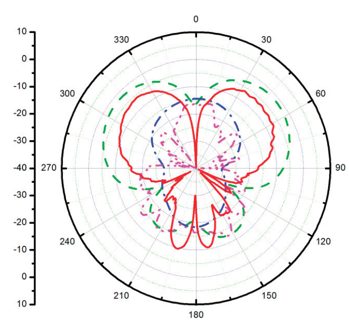


E-plane

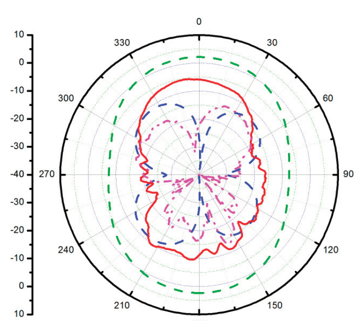


H-plane

(a)



E-plane



H-plane

(b)

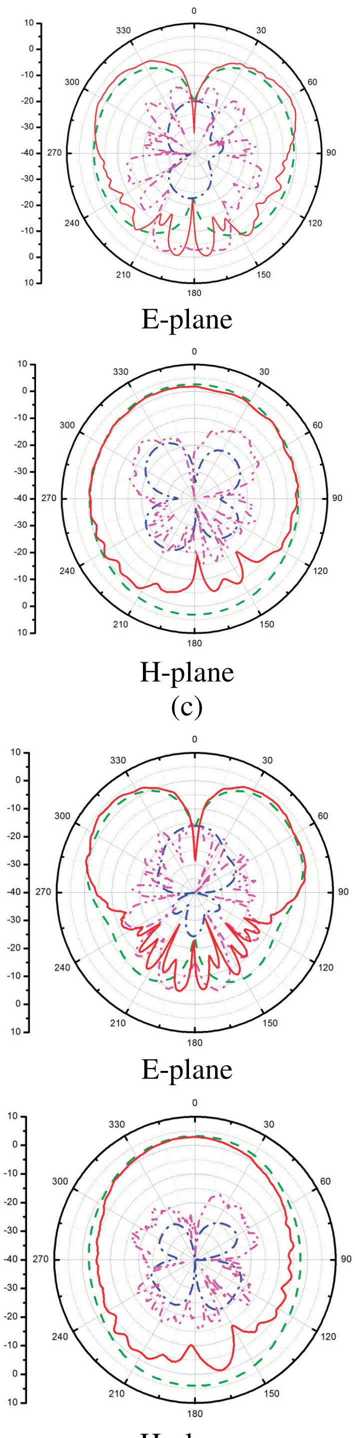


Fig. 7. Measured and simulated radiation patterns of the proposed antenna at (a) 5 GHz, (b) 5.4 GHz, (c) 6 GHz, and (d) 7 GHz (——Measured Co-polarization; - - - - Simulated Co-polarization; -·-·-Measured Cross-polarization; -·-·- Simulated Cross-polarization).

Figure 8 shows the measured and simulated gains of the proposed antenna from 3 GHz to 11 GHz. The figure indicates that the proposed antenna has good gain flatness except that in the notched band. Sharp gain decresases occur in the vicinity of 5.4 GHz, thus clearly indicating the band-notched effect of the T-shape construct.

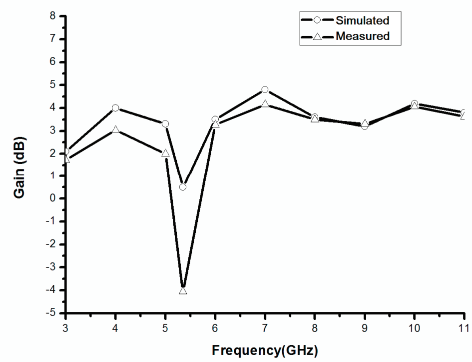


Fig. 8. The measured and simulated gains of the proposed antenna.

V. CONCLUSION

In this paper, a CPW-fed band-notched UWB antenna is presented. The circle ring radiation patch is used to give a wide bandwidth for UWB applications while three rectangular branches are employed to improve impedance conditions at high frequencies. The notched band, covering the WLAN band, is achieved by a T-shaped construct embedded inside the circle ring patch. The measured VSWR shows that the proposed antenna achieves a bandwidth ranging from 3.5 GHz-10.6 GHz with the notched band of 4.8 GHz-5.8 GHz. The proposed antenna has simple structure and presents omnidirectional patterns across the whole operating band in H-plane. The antenna has a compact size of $26\times34\times1.6$ mm^3. Measurement results show that the antenna is suitable for UWB applications.

ACKNOWLEDGMENT

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