A Compact Wide slot antenna with dual band-notch characteristic for Ultra Wideband Applications

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***Abstract*— A compact CPW-fed ultra-wideband antenna with dual band-notch characteristic is presented. Two notched frequency bands are obtained by embedding two U-shaped slots in the radiation patch and a rectangle slot in the ground plane. The two notched bands can be controlled by adjusting the length of the responding slots. The proposed antenna is successfully simulated, fabricated and tested. Experimental and numerical antenna shows that the proposed antenna with compact size of 21×28mm2, has an impedance bandwidth range from 3.1GHz to more than 11.0GHz for voltage standing-wave ratio less than 2, expect two notch band frequency 5GHz-6GHz for WLAN and 7.7GHz-8.5GHz for X-band for satellite communications in China.**

Index Terms—CPW-fed; ultra-wideband (UWB) antenna; dual band-notch; omni-directional antenna.

I. INTRODUCTION

With the development of the modern wireless communications, the ultra-wideband (UWB) systems have attached much attention recently because of its advantages including high speed data, small size, low cost, low complexity [1-4]. As the important part of the UWB systems, the antenna has received increased attention due to its impedance bandwidth, simple structure and omni-directional radiation pattern. Recently, a lot of UWB antennas have been realized for 3.1GHz-10.6GHz applications [1-8], such as spline-shaped antenna[1], diamond antennas [2-3], annual ring antenna [4], bow-tie antennas [5-6],triangular patch antennas [7], square monopole antenna with inverted T-Shaped notch in the ground plane [8]. However, several narrow bandwidth systems have been used for a long time, such as WLAN (5-6GHz) and X-band (7.7-8.5GHz). Therefore, plenty of UWB antennas with band notch antennas have been proposed for reducing the potential interference between UWB and narrow band

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systems. But most of the proposed antenna only has one band-notch characteristics [9-13], such as pie slot antenna [9], U-slot antennas [10], parasitic elements[11], slots [12-14]. Three UWB antennas using SSRs [15], C-shaped parasitic strip and slots [16] and E-shaped slots have been realized [17]. But the allocation shapes have intensive influence to band notch characteristics. It is difficult to fabricate and adjust the central frequency of the notch band.

In this paper, a compact CPW-fed UWB antenna with dual band notch characteristic is investigated numerically and experimentally. By using two U-shaped slots in the radiation patch and an rectangle slot in the CPW ground, two band-notched frequency will be appeared, which reduce the potential interference. The antenna was successfully optimized by Ansoft high frequency structure simulator (HFSS) 10, fabricated and tested. It is found that the designed antenna satisfies all the requirements in the UWB frequency band except 5-6GHz for WLAN and 7.7-8.5GHz for X-band. Details of the antenna design are presented herein and the measured voltage standing-wave ratio, radiation pattern and the gain are given.

The article is divided as follows: Section II discusses the antenna model and the configuration; Section III gives the studies on the key parameters; Section IV shows the measured results of the VSWR, radiation pattern and the gain. Section V concludes the article.

II. ANTENA DESIGN

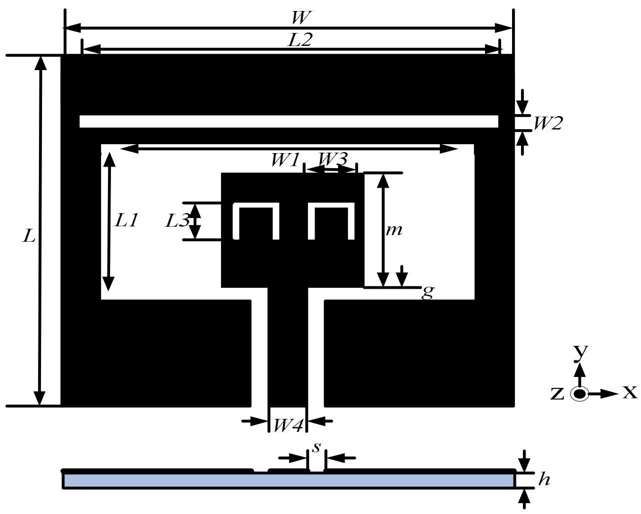

Fig.1 Geometry of the antenna.

Fig.1 illustrates the geometry of the proposed CPW-fed UWB antenna with dual band notch characteristic. The antenna is printed on a substrate with relative permittivity 2.65, a loss tangent of 0.002 and a thickness of 1.6mm. The size of the antenna is $21\times28mm^2$, and a 50Ω CPW feeding structure is employed. The notch bands of the proposed antenna are caused by a rectangle slot with width 0.8mm in the CPW ground and a simple square patch with two U-shaped slots with width 0.2mm. Two U-shaped slots which determine the notch band 7.7GHz-8.5GHz are etched in the radiation patch. The rectangle slot embedded in the CPW ground plays an important role in 5-6GHz.

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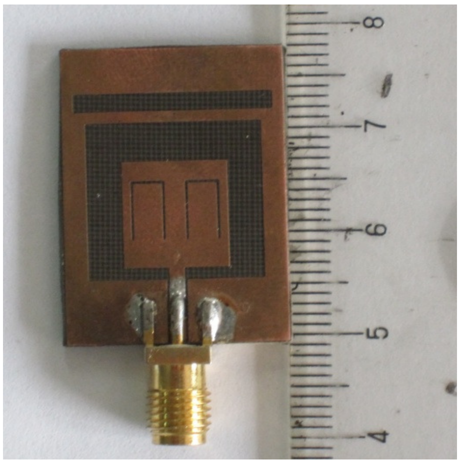


Fig.2 The photograph of the proposed antenna.

The photograph of the fabricated antenna is shown in Fig.2. In order to obtain the characteristic of the antenna, the current distributions of the proposed antenna have been investigated by using the Ansoft HFSS 10.

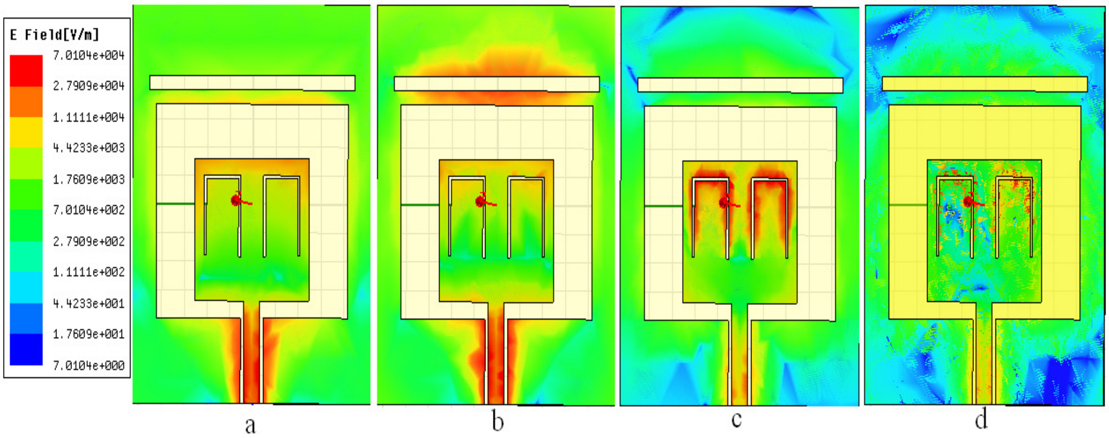
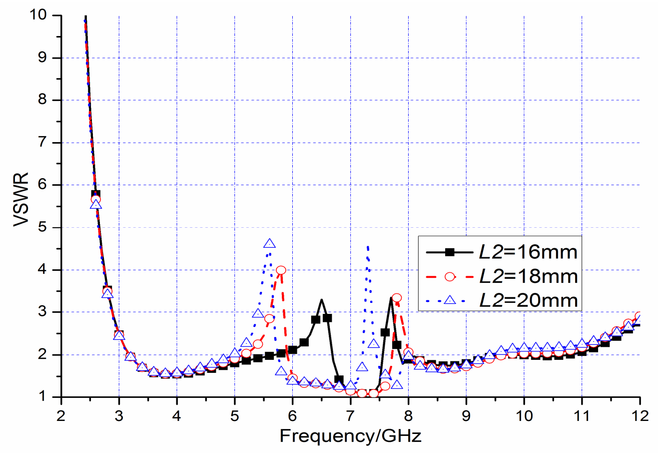


Fig.3 Simulated current of the proposed antenna.

Fig.3 (a) and (d) show the current distributions at 3.5GHz and 9.0GHz, respectively. The current distributions mainly flow along the CPW ground and the patch, while around the slots the current are small. On the contrary, in Fig.3 (b) and (c) the current distributions around slots are obtained at 5.5GHz and 8GHz. The current distributions are mainly flow though along the rectangle slot and the two U-shaped slots. Therefore, the surface current produced by the slots can excite the notch band frequencies.

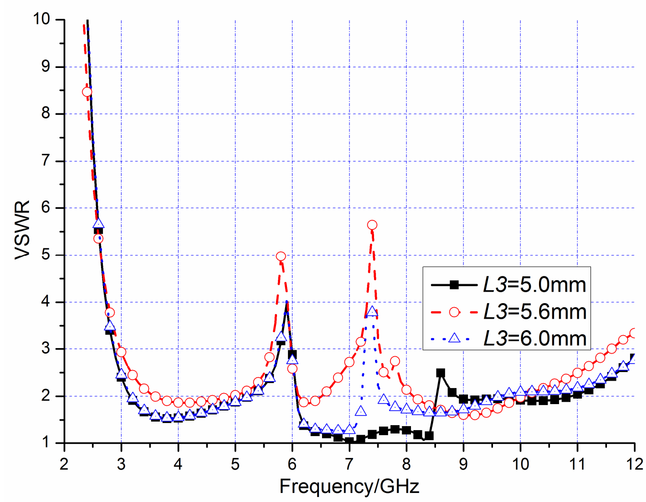
III. PARAMETERS STUDIES

The length of the embedded rectangle slot *L2*, the length of the U-shaped slots *L3*, the distance *g* between the radiation and the CPW ground and the dimension *m* of the square radiation patch have large effects on the proposed antenna. So they are selected to obtain the optimized results. In the investigated process, only one parameter is changed with other parameters fixed at one time. The effects of the parameters *L2*, *L3*, g and m on the VSWR vs. frequency are plotted in Fig.4.



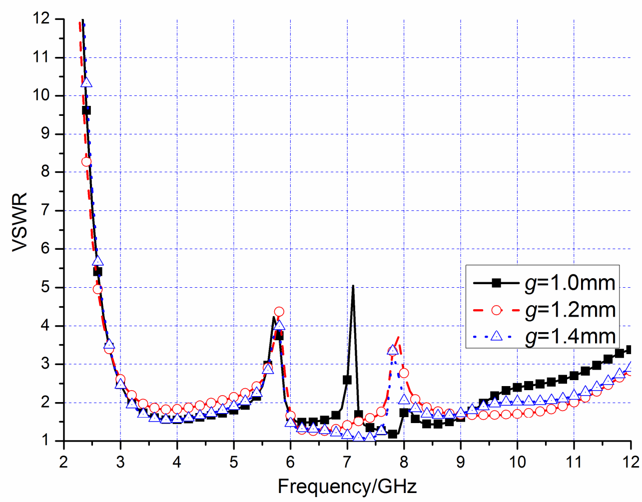
VSWR
Frequency/GHz
L2=16mm
L2=18mm
L2=20mm

(a)



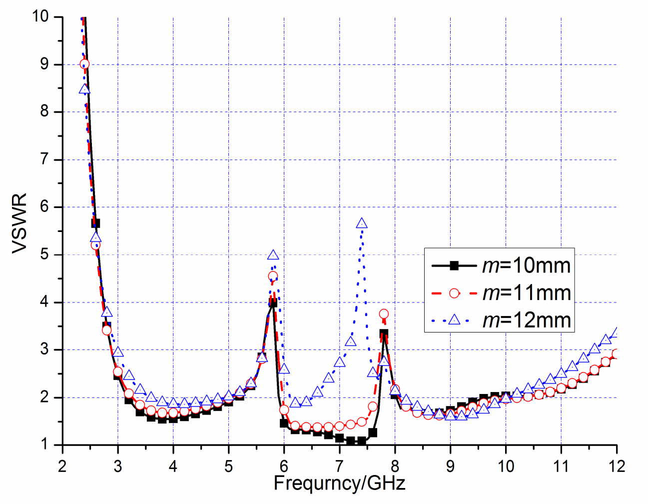
VSWR
Frequency/GHz
L3=5.0mm
L3=5.6mm
L3=6.0mm

(b)



VSWR
Frequency/GHz
g=1.0mm
g=1.2mm
g=1.4mm

(c)



(d)

Fig.4 simulated VSWRs Vs. frequency with various parameters.

It can be seen from the Fig.4 (a), the rejection frequency can be changed from 5GHz to 6GHz by increasing length *L2* of the rectangle slot. At the same time, the other rejection frequency at X-band is also changed. Form the Fig.3; we can see that changing current distribution at the X-band could alter rejection frequency. Therefore the length of the rectangle is the key parameter, then, it should be selected carefully in the design. Fig.4 (b) shows that with the increasing in the length of *L3*, the higher rejection frequency produced by U-shaped would moves to the lower level, while lower the rejection frequency only changed slightly at 5-6GHz. Fig.4 (c) indicates that the width *g* is a crucial factor for the rejection frequency at X-band. The higher rejection frequency can changed rapidly with the increasing of *g*. The changed current distributions between the radiation and the CPW ground cause this situation. Fig.4 (d) describes the influence of the dimension of the square radiation patch m. With the increasing of the dimension of the radiation patch, the higher rejection frequency at X-band removes to the lower band. While the lower rejection frequency at 5-6GHz for WLAN changed slightly. The entire above can implies that the proposed antenna has two rejection frequencies .The lower at 5-6GHz for WLAN is mainly determined by the rectangle slot and the higher at 7.7-8.5GHz for X-band is caused by the U-shaped slots and the distance between radiation patch and CPW ground (g). As the electrical size has more effect on impedance bandwidth, they need optimized by tradeoff in this design.

For the length of the slots have great influence on the notch band. The length of the embedded rectangle slot and the two U-shaped slots can be postulated as [16]

$$f_{notch} = \frac{c}{2L\sqrt{\varepsilon_{re}}} \qquad (1)$$

where L is the total length of the U-shaped slots and rectangle slot, ε_{re} is the effective dielectric constant, and c is the speed of light. We take (1) and the parameters studies above into consideration in achieving the dimensions of the rectangle slot and the U-shaped slots at the beginning of the design and then adjust the geometry for the final design. Based on the parameters study above, the proposed antenna with dual band notch characteristics is optimized and manufactured after several adjustments of different parameters. The antenna is also optimized by using Ansoft HFSS 10. The optimized parameters of the antenna are as follow: *L*=28mm, *W*=21mm, *L1*=15 mm, *W1*=16.8 mm, *L2*=19mm, *W2*=0.8mm, *L3*=5.6mm, *W3*=2.8mm, *m*=10.8mm, *S*=0.3 mm, *W4*=1.4mm, *g*=1.2mm.

IV. RESULTS AND DISCUSSIONS

To evaluate the performance of the optimized antenna, the proposed antenna was implemented and tested. The VSWR of the antenna is obtained by using the HP8757D vector network analyzer. In order to compare the simulation results of the antenna, the proposed antennas with rectangle slot and U-shaped slots and without all the slots are manufactured and measured. The VSWRs of the antennas are shown in Fig.5.

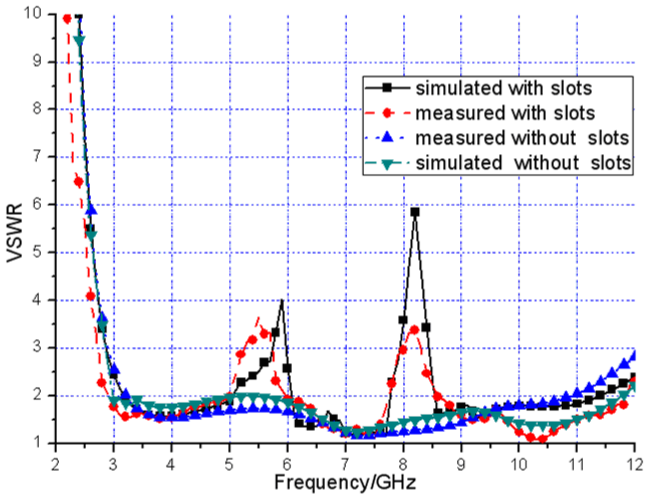
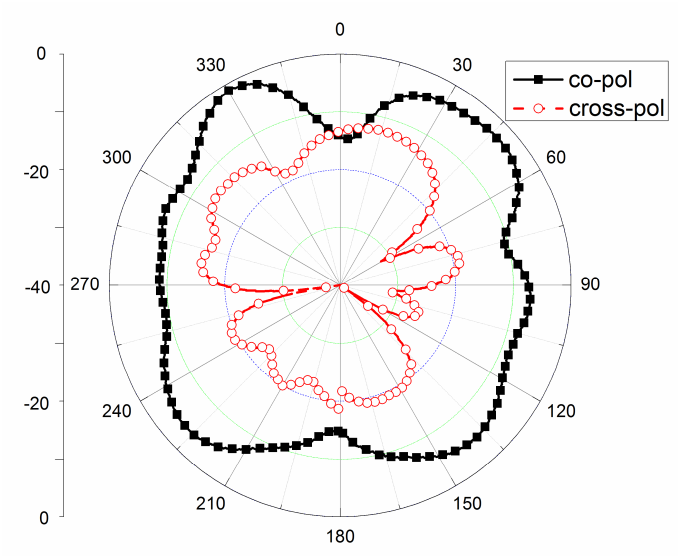
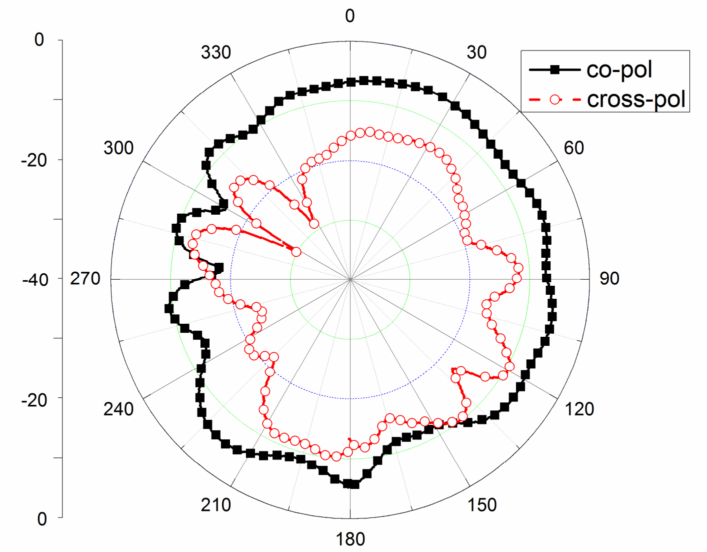


Fig.5 the VSWR of the antenna with and without the slots.

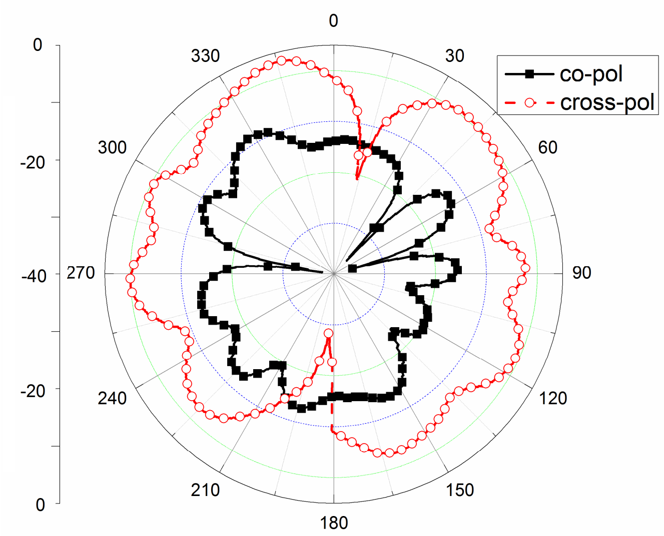
From the Fig.5, the measured result is seen well agreed with the simulated result which helps to verify the design accuracy. The differences between the simulated and measured values may be due to the errors of the manufactured antenna and the SMA connector to CPW-fed transition, which is included in the measurements but not taken into account in the calculated results. Two notch bands characteristic are found from Fig.5. The radiation patters were measured in an anechoic chamber. The measured radiation patterns mainly at 3.5GHz, 6.5GHz and 9.5GHz are shown in Fig.6. It shows that the antenna can give a nearly omni-directional characteristic in the x-y plane and quasi omni-directional pattern in the x-z plane. As can be seen in Fig.6, the radiation patterns in the x-y plane deteriorate more or less with the frequency increasing, but the radiation patterns are still nearly omni-directional. The peak gains of the proposed antenna at these frequencies are achieved by compared to a wire dipole antenna. A stable gain can be obtained throughout the operation band expect the two notched frequencies. In order to compare, the proposed antenna without slots is also measured.



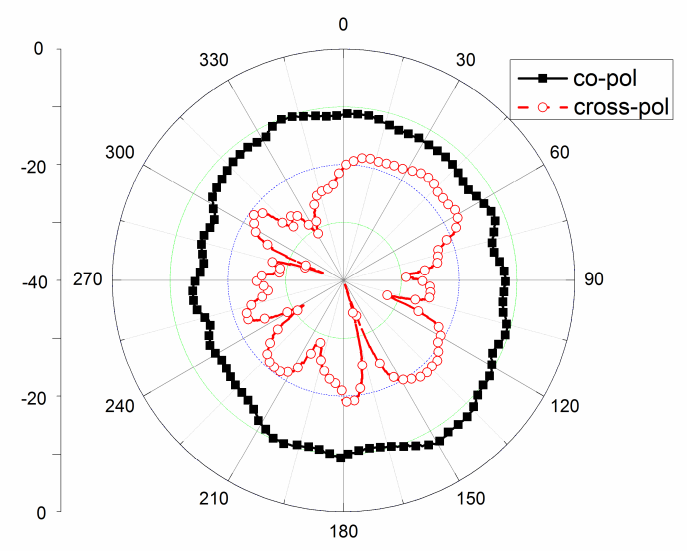
3.5GHz (x-z plane)



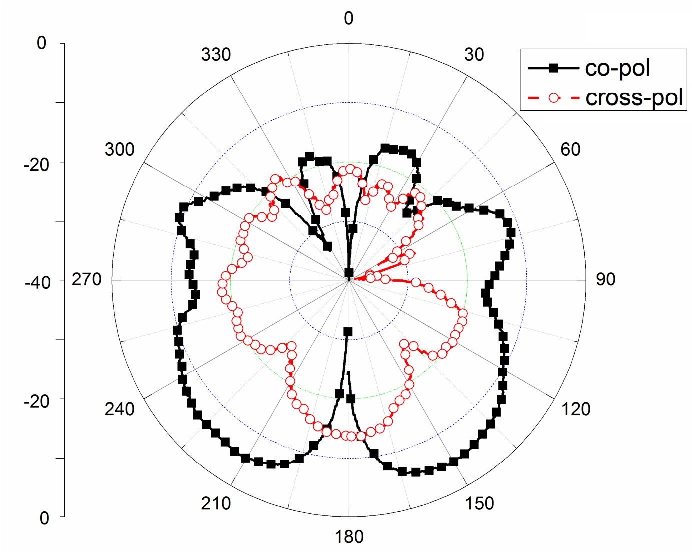
3.5GHz(x-y plane)



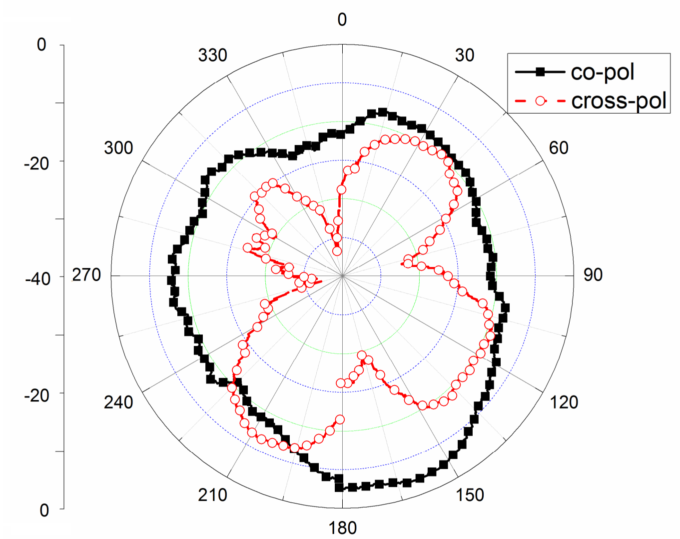
6.5GHz (x-z plane)



6.5GHz(x-y plane)



9.5GHz (x-z plane)



9.5GHz(x-y plane)

Fig.6 Measured radiation pattern of the proposed antenna.

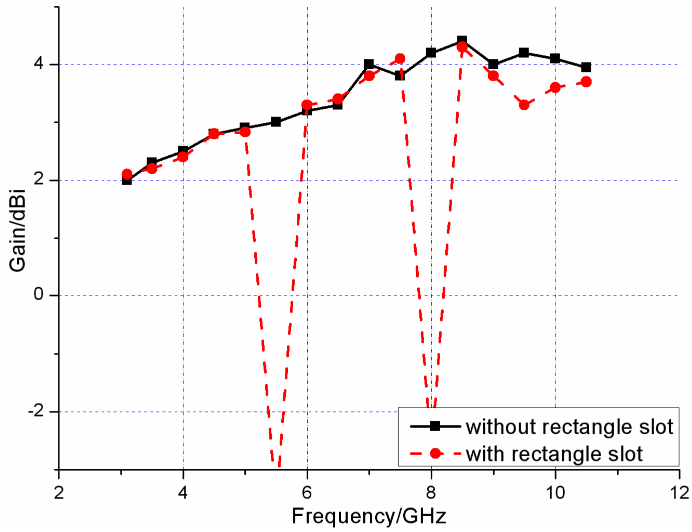


Fig.7 The gain of the antenna with and without slots.

The gain of the proposed antenna with and without slot is shown in Fig.7. In the operation band, two sharp gains decreased in the vicinity of 5.5GHz and 8.0GHz. The gain drops to -3.6dBi and -2.4dBi at the notch band, respectively.

V. CONCLUSIONS

A CPW-fed ultra-wideband antenna with dual band-notch characteristic is proposed for UWB applications. Dual stop band is achieved by cutting two U-shaped slots in the radiation patch and a rectangle in the CPW ground. The antenna is successfully optimized, fabricated, tested. The results show that the antenna not only has dual band notch characteristics but also has good radiation pattern.

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REFERENCES

[1] Lizzi,L.,Viani,F.,Azaro,R.,Massa,A., "A PSO-Driven Spline-Based Shaping Approach for Ultrawideband (UWB) Antenna Synthesis", IEEE Trans. Antennas Propag,56(8):2613-2621, 2008.

[2] Lu, G., vonder Mark, S., Korisch, I., Greenstein, L. J. and Spasojevic, P., "Diamond and rounded diamond antennas for ultrawide-band communications", IEEE Antennas Wireless Propagation Lett., 3(1): 249-252, 2004.

[3] Koohestani M., and Golpour M., "Compact rectangular slot antenna with a novel coplanar waveguide fed dimond patch for ultra wideband applications", Microw. Opt. Technol. Lett., 52(1):331-334, 2010.

[4] Ren, Y.J.,Chang,K., "An annual ring antenna for UWB communications", IEEE Antennas Wireless Propag Lett, 5(1):274-276, 2006.

[5] Karacolak, T.,Topsakal,E., "A double-sided rounded bow-tie antenna (DSRBA) for UWB communication", IEEE Antennas Wireless Propag Lett, 5(1):446-449, 2006.

[6] Kiminami, K., Hirata, A., Shiozawa, T., "Double-sided printed bow-tie antenna for UWB communications", IEEE Antennas Wireless Propag. Lett., 3(1):152-153, 2004.

[7] Choi, S. T., Hamaguchi, K., and Kohno, R., "Small printed CPW-fed triangular monopole antenna for ultra-wideband applications", Microw. Opt. Technol. Lett., 51(1):1180-1182, 2009.

[8] Mohammad Ojaroudi, Changiz Ghobadi, Javad Nourinia , "Small Square Monopole Antenna With Inverted T-Shaped Notch in the Ground Plane for UWB Application" , IEEE Antennas And Wireless Propagation Letters, 8(1):728-731, 2009.

[9] Chin-Ju Pan, Chungnan Lee,,Chih-Yu Huang, Hsiao-Cheng Lin, “band-notched ultra-wideband slot antenna”, Microwave And Optical Technology Letters , 48(12):2444-2446, 2006.
[10] Yuan, T., Qiu, C.W., Li L. W., Leong M. S.,and Zhang,Q., “Elliptically shaped ultra wideband patch antenna with band-notch features”, Microw. Opt. Technol. Lett. 50(1):736-738, 2008.
[11] A. M. Abbosh and M. E. Bialkowski, “Design of UWB Planar Band-Notched Antenna Using Parasitic Elements”, IEEE Transactions On Antennas And Propagation, 57(3):796-799, 2009.
[12] Carla R. Medeiros, Jorge R. Costa, Carlos A. Fernandes, “Compact Tapered Slot UWB Antenna with WLAN Band Rejection”, IEEE Antennas and Wireless Propagation Letters, 8(1):661-664, 2009.
[13] L.-H. Ye and Q.-X. Chu, “Improved band-notched UWB slot antenna”, Electronics Letters, 45(25): 1283-1285, 2009.
[14] Joon-Won Jang and Hee-Yong Hwang, “An Improved Band-Rejection UWB Antenna with Resonant Patches and a Slot”, IEEE Antennas and Wireless Propagation Letters, 8(1): 299-302, 2009.
[15] Zha, F. T., Gong S. X., Liu G., Yang H. Y., and Lin S. G., “compact slot antenna for 2.4GHz/UWB with dual band-notched characteristic”, Microw. Opt. Technol. Lett., 48(1):1859-1862, 2009.
[16] Chu, Q. X., and Yang, Y. Y., “A compact ultra wideband antenna with 3.4/5.5GHz dual band-notched characteristics”, IEEE Trans. Antennas Propag., 56(12):3637-3644, 2008.
[17] Luo, L., Cui, Z.,Xiong J. P., Zhang, X. M., and Jiao, Y. C., “Compact printed ultra-wideband monopole antenna with dual band-notch characteristic”, Electron. Lett., 44(1):1106-1107, 2008.