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Design of Coplanar-Waveguide-Feed Antenna

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***Abstract*—Design of dual-band and ultra-wide band (UWB) with band-notched antennas have been discussed in this paper. These antennas are fed by coplanar waveguide. Structure of dual-band antenna has been proposed with corner-free rectangle and isosceles trapezoid; it can work efficiency in 2.32GHz ~ 2.57GHz and 5.2GHz ~ 5.8GHz. The planar UWB antenna has a band-notched characteristic for the interference between the UWB applications and WLAN, which can be used to reject the frequency 5.1GHz ~ 5.9 GHz by inserting a thin slot on the radiation element. The results in simulation and measurement showed that both of them have wonderful impedance bandwidth and radiation efficiency that it is a kind of good performance, easy integration antenna with practical value.**

Keywords—CPW; UWB antenna; band-notched characteristic; planar antenna

I. INTRODUCTION

Printed antennas have attracted much attention due to the advantages of wide bandwidth and ease to integrate with monolithic microwave integrated circuits [1]-[7]. Coplanar waveguide is a kind of planar transmission line structure [8]-[16], whose ground and radiation patch are on the same layer of medium plate. Various types of coplanar waveguide feed antenna have been reported to achieve the goal of multiband, broad band and miniaturization [17] - [23]. In [24], [25], the antenna fed by coplanar waveguide, can obtain good impedance matching between the radiation patch and feeder, and can realize 52% impedance bandwidth, by adjusting the distance between microstrip patch and ground plate, but it is a single working frequency band, can not meet the requirement of current WLAN. In [26], the antenna has been proposed with symmetrical double trapezoid microstrip structure, which have advantage of uniplanar geometry and easier to fabricate than the design fed by microstrip line, however, the working frequency just in 5.6GHz ~ 11.3 GHz.

This paper presented two kinds of antenna fed by coplanar waveguide, which has very wide impedance bandwidth and good omnidirectional radiation characteristics. Combining these two kinds of antenna, it can basically meet the requirements of various kinds of commonly used frequencies. The ultra-wideband antenna has a very wide bandwidth and wide application, while it has so many WLAN frequency of signals used in the space, therefore the ultra-wideband antenna have a notch in the 5.1 GHz ~ 5.1 GHz frequency to avoid the interference of the WLAN. To make up the shortfall, the dual-band antenna specially be designed for the application of WLAN. Both of the dual-band and ultra-wideband antennas could integrate with RF/microwave circuits easily, enabling a miniature hybrid or monolithic microwave integrated circuit.

II. ANTENNA DESIGN

A. Principle of coplanar waveguide feed

As shown in Figure 1, the coplanar waveguide composed of dielectric substrate and three conduction band. Three metal etching conduction bands are in the same side of the dielectric substrate. The signal is in the between of the two ground part on the one side of the dielectric substrate, the other side is nothing. Coplanar waveguide structure generally adopts the high dielectric constant substrate, and the wavelength is less than λ_0 inside the waveguide, therefore the electromagnetic field is concentrated in the medium and the air interface. Alternating electromagnetic field generated between the metal conduction bands and the ground conduction band, can produce longitudinal and transverse alternating electromagnetic field. For traditional metal waveguide, only TE and TM mode are transmuted. Coplanar waveguide is used as transmission line to conduction TEM wave, as constraint conditions:

$$d < \lambda_0 /(40\varepsilon^{1/2})$$

in the formula, $d = 2w_f + s_0$

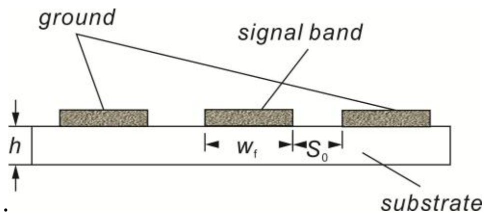


Fig. 1. the structure of coplanar waveguide

B. Design of dual-band antenna

The Dual-band antenna contains two resonant paths, one of then corresponding to the length (w_1) of corner-free rectangle at the top of the radiation patch, which makes the antenna working at high frequencies, another one corresponding to the high (w_4) of isosceles trapezoid at the bottom of the radiation patch, which makes the antenna working in low frequency band. By adjusting w1 and w4, the expected work frequency can be easily obtained in antenna. The valuables w_1 and w_4 are referred to as formula .

$$w_{1,4} = \frac{c}{f_{l,h}\sqrt{\varepsilon_e}}$$

The structure of dual-band antenna is shown in Figure 2, the radiation part and ground plane were etched on coplanar sides of the FR-4 (r_ε = 4.4 and h = 1.6mm). The width of the antenna (W_1) is 26mm, and the length of the antenna (L_1) is

35mm. The antenna fed with coplanar waveguide, makes the antenna working frequency band has a good impedance matching by adjust the width of the feeder (w_f) and the gap (s_0).

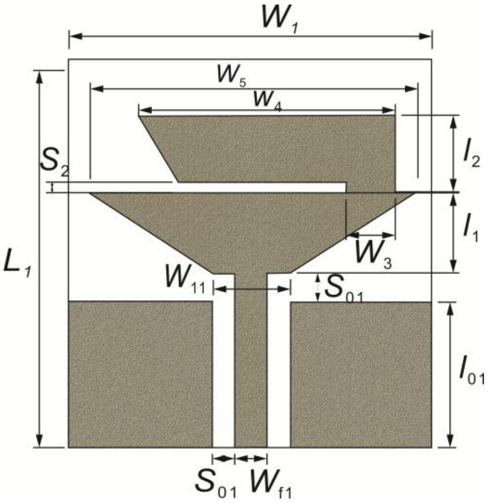


Fig. 2. configuration of dual-band antenna

It is found that the impedance bandwidth of the proposed design can be improved by adjusting the bottom side of trapezoidal. As show in figure 3, the center of high frequency shift up as the increase of s_0, while the center of low frequency be stay, Adjust the value of w_1, the change of reflection coefficient S_{11} of antenna is shown in Figure 4. The Figure 4 shows that the changing of w_1 affects on S_{11} a lot. With increasing of w_1, the center of high frequency shift to the right, but it has less impact on the low frequency band. The figure 5 shows that l_1 has a certain influence on both frequency bands, it can improving the bandwidth of the high frequency band with the increase of l_1. The corner-free rectangle patch make antenna works at 2.32GHz ~ 2.57GHz frequency band. Changing the long side w_4 of rectangular, it can be known by Figure 6 that w_4 mainly affects the center part of the low frequency band, and the center part of the low frequency shift to the left with the increase of w_4. When w_4 = 21.5 mm, the antenna gets the optimal resonance at 2.32GHz ~ 2.57GHz frequency band.

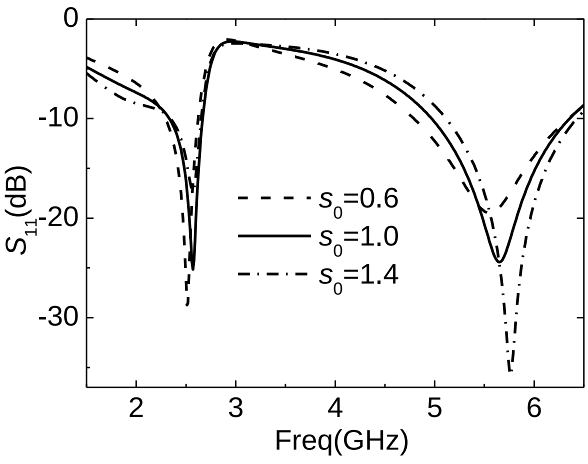


Fig. 3. S_{11} for different length of s_0

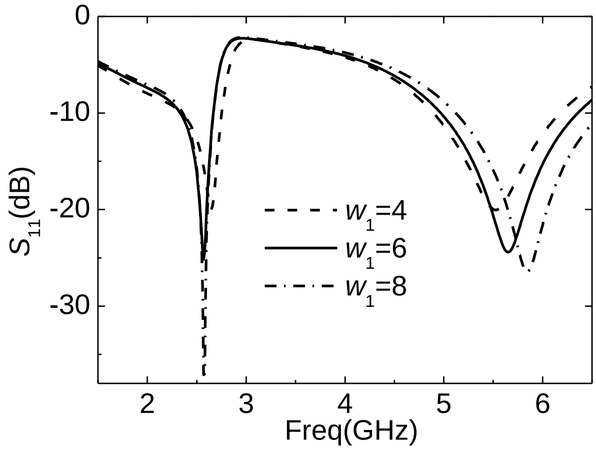


Fig. 4. S_{11} for different length of w_1

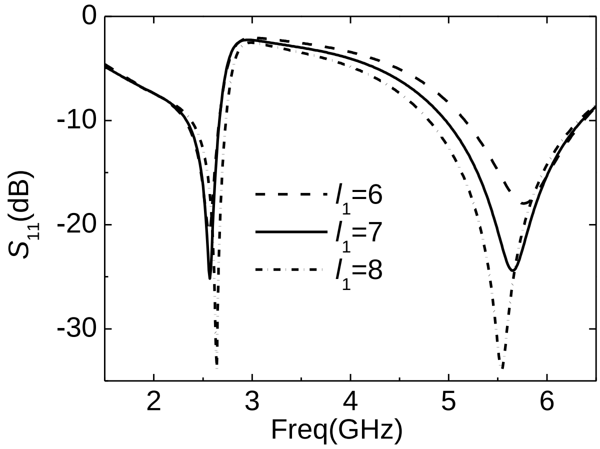


Fig. 5. S_{11} for different length of l_1

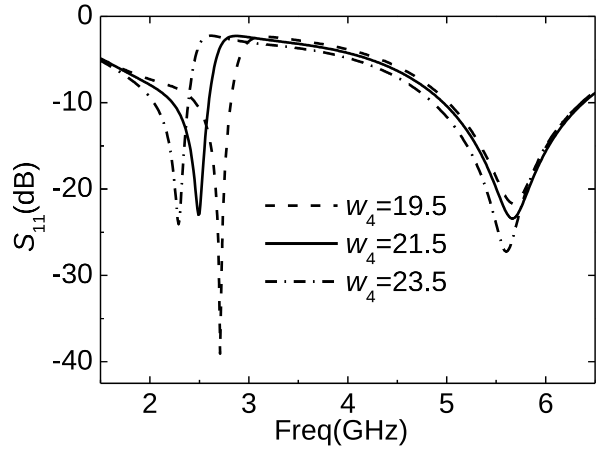


Fig. 6. S_{11} for different length of w_4

C. Design of Band-Notched UWB Antenna

The radiation patch of band-notched UWB antenna is composed of circular structure and semi-circular structures. Through adjusting the two center position and radius size to make antenna work in ultra wideband spectrum, at the same time, opening a slit in the middle of the patch to change the current distribution on antenna, which can realize band-notched feature on 5.1GHz ~ 5.9 GHz frequency band.

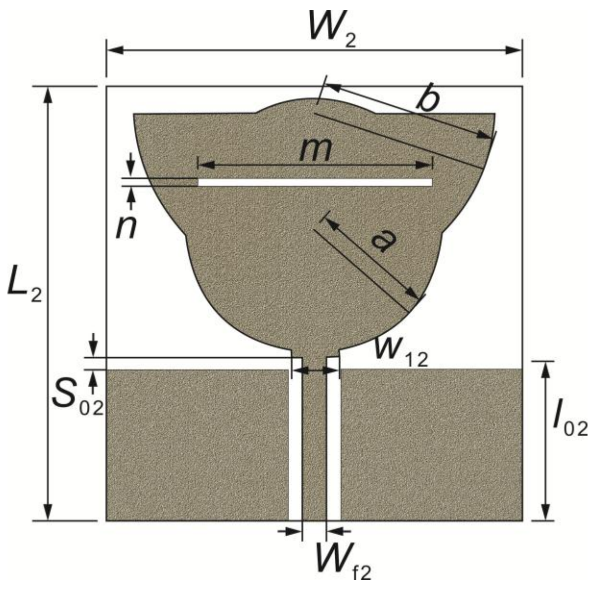


Fig. 7. configuration of Band-Notched UWB antenna

In order to get the prefect match, the distance of the coplanar waveguide (s_{02}) must be adjusted to the appropriate value. As the figure 6 shows that when s_{02} = 0.2mm, the antenna gets the optimal resonance. The radiation patch consists of a semicircular and circular which overlap each other. To make the antenna works in ultra wide band by adjust the radius of circle (*a*) and the radius of semicircular (*b*). Figure 7 shows that with the increases of *a*, the reflection coefficient of 5.9GHz ~ 11.8GHz frequency band move down significantly. When *a* = 8.2mm, the antenna gets the optimal resonance. As show in Figure 8, the value of *b* also could be the important factors. Opening slit in the middle of the radiation patch can change the current distribution, at last achieving notch function. The band-notched are mainly affected by the length of gap *m*, as the increases of *m* in Figure 8, the band-notched obviously move to left. By adjusting the size of *m* to avoid the interference WLAN band, when *m*=15mm, the band-notched is in 5.1GHz~5.9GHz frequency band.

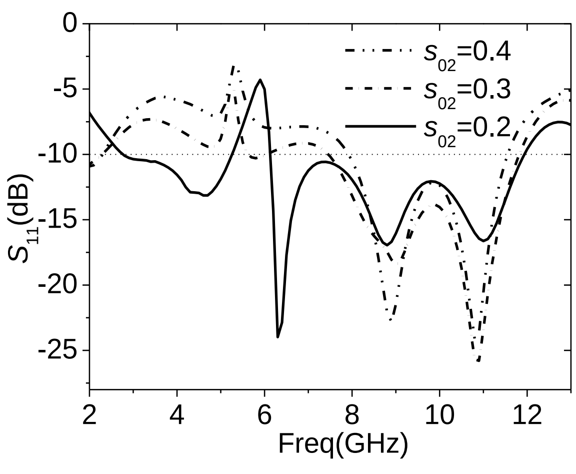


Fig. 8. S_{11} for different length of s_{02}

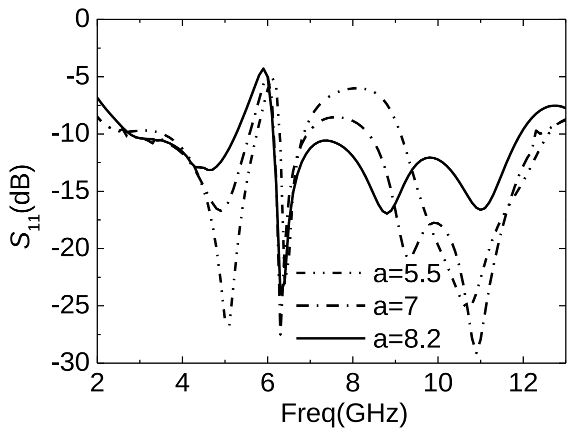


Fig. 9. S_{11} for different length of *a*

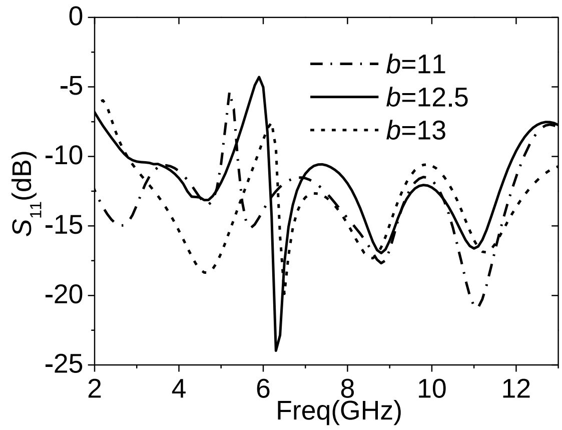


Fig. 10. S_{11} for different length of *b*

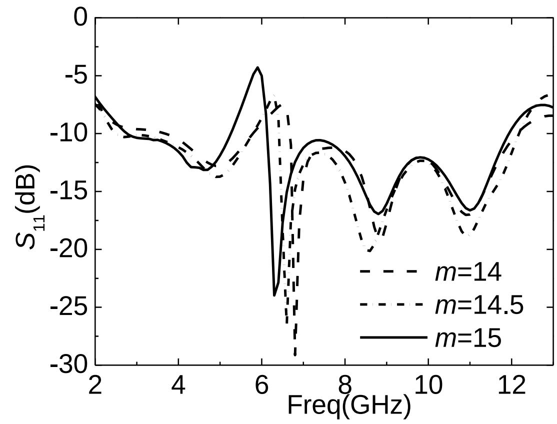


Fig. 11. S_{11} for different length of *m*

III. EXPERIMENTAL RESULTS AND DISCUSSION

By optimization of the antenna structure, the dimensions of the dual-band antenna and band-notched UWB antenna are showed in Table 1 and Table 2. According to the optimization parameters, the actual processing of the two antennas are shown in Figure 8 and Figure 9. Using high-performance RF integration AV3629 vector network analyzer to measure reflection coefficient S_{11} and *VSWR* of antenna, the measured results coincide with the simulation results.

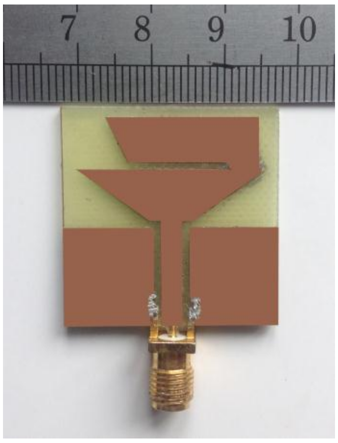


Fig. 12. photograph of dual-band antenna

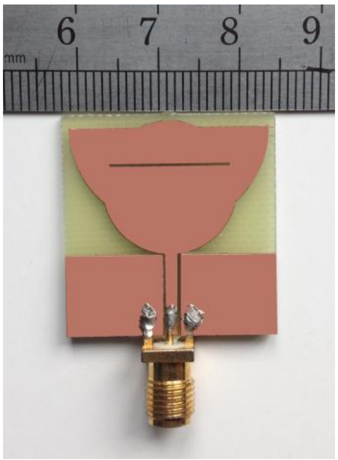


Fig. 13. photograph of band-notched UWB antenna

TABLE I. PARAMETERS OF THE DUAL-BAND ANTENNA (MM)

W_1	L_1	w_{f1}	w_{11}	w_2	w_3	w_4
30	30	2.91	6	26	4	20.9
l_{01}	l_1	l_2	s_{01}	s_2	h	
14.6	7	6	1	1	1.6	

TABLE II. PARAMETERS OF BAND-NOTCHED UWB ANTENNA (MM)

W_2	L_2	w_{f2}	w_{12}	a	b	m
28	26	1.5	3	8.2	12.2	15
n	L_{02}	s_{02}	h			
0.2	10.3	0.2	1.6			

As shown in Figure 10, the S_{11} parameter of dual-band antenna in 2.32GHz ~ 2.57GHz and 5.15GHz ~ 5.80GHz two bands are less than -10dB and the minimum values of S_{11} of the center frequency are below -20dB, which reached good transmission characteristics outwardly. As shown in Figure 11, the antenna *VSWR* is less than 1.5 in the above band.

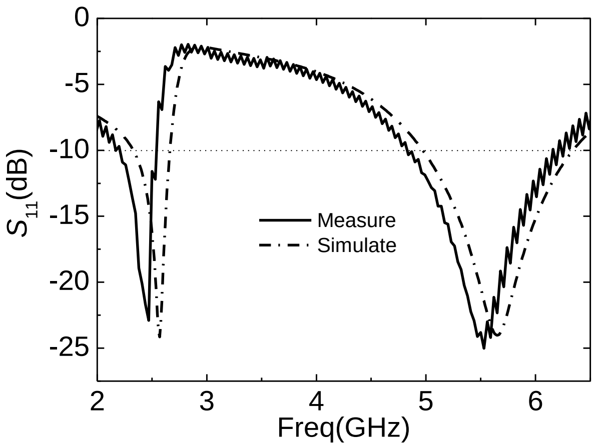


Fig. 14. comparison between measured and simulated S_{11} for the proposed antenna

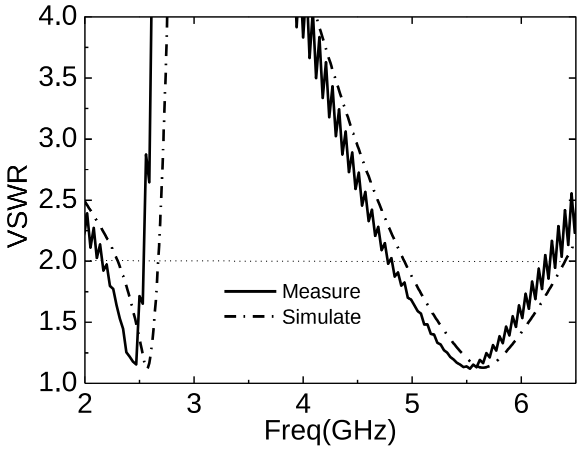
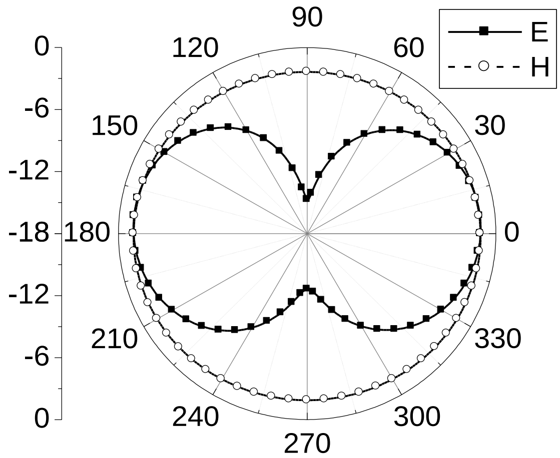
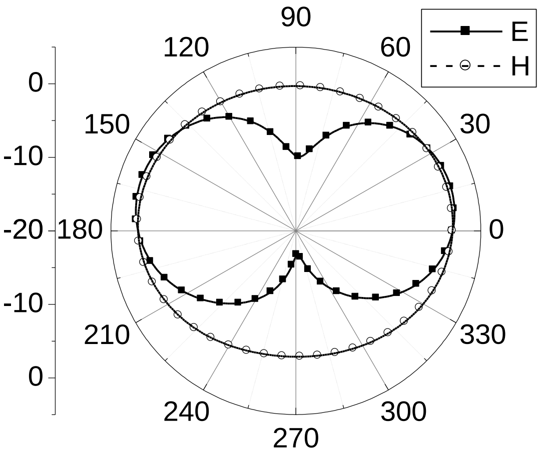


Fig. 15. comparison between measured and simulated *VSWR* for the proposed antenna

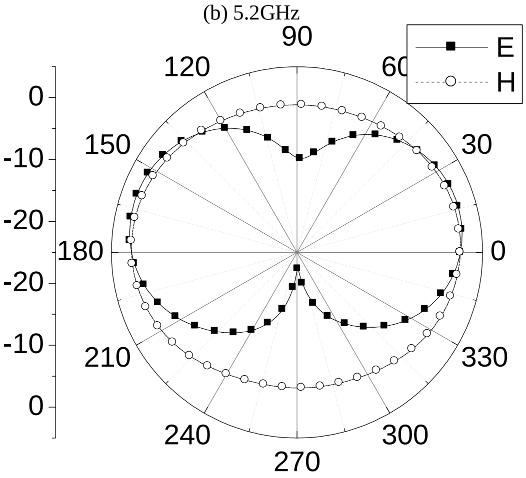
As shown in Figure 12, the radiation patterns were measured at frequencies of the three working frequency bands. H-plane patterns are round, which can send and receive signals in all directions. E-plane patterns similar to dumbbell shape, which shows that the antenna has good omnidirectional radiation characteristics.



(a) 2.4GHz



(b) 5.2GHz



(c) 5.8GHz

Fig. 16. radiation patterns of dual-band antenna at required frequencies.

As shown in Figure 15 and Figure 16, the impedance bandwidth is 9.1GHz within the frequency band of 2.7GHz-11.8GHz, and the antenna has obvious band-notched characteristics in the frequency 5.1GHz-5.9GHz band which can effectively prevent the interference of WLAN.

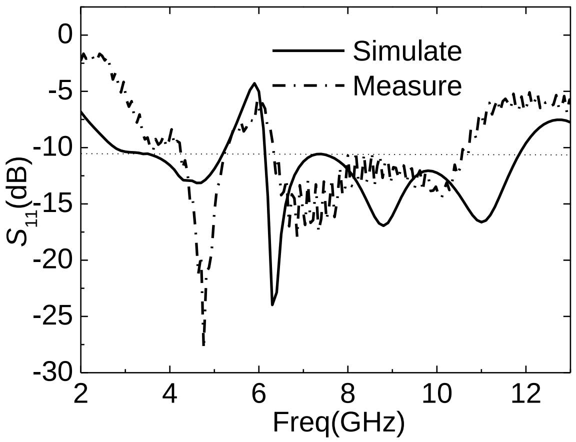


Fig. 17. comparison between measured and simulated S_{11} for the proposed antenna

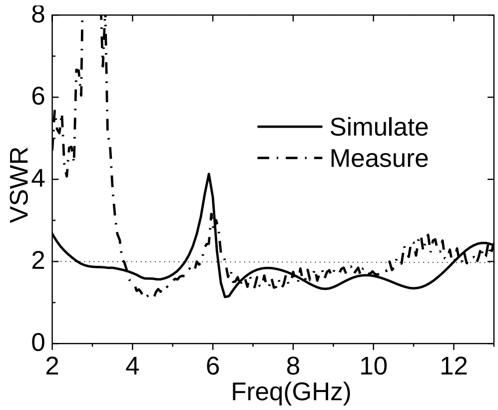
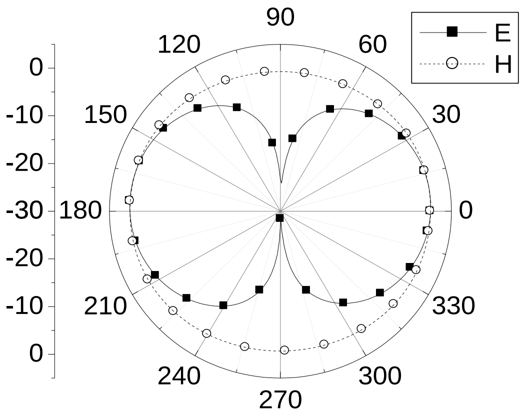
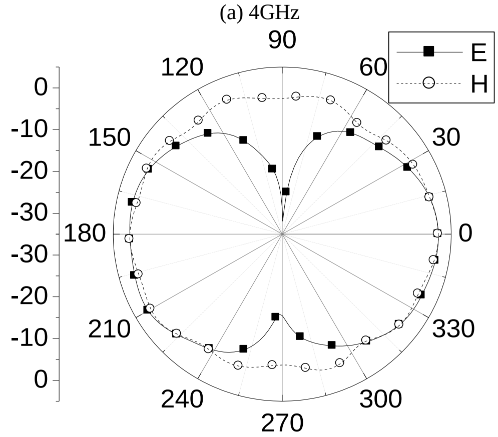


Fig. 18. comparison between measured and simulated *VSWR* for the proposed antenna

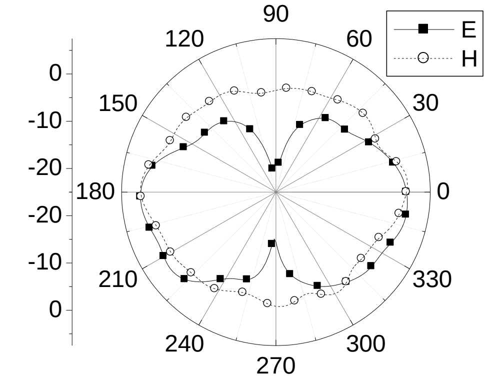
The radiation patterns were measured at frequencies of 4, 7, 8, 9 and 10GHz in the principal E-plane and H-plane. For brevity, the radiation patterns are shown in Figure 17. The H plane pattern of antenna is performance for amplitude omni-directional in the 4 GHZ band. When the frequency is greater than 7 GHz, the direction graph edge no longer keep the maximum value and have small sag. The E plane pattern of antenna is an approximation of "8" glyph, which cross polarization amplitude is less than -20 dB in the whole band. The results show that the antenna satisfies the radiation condition in the whole work band.



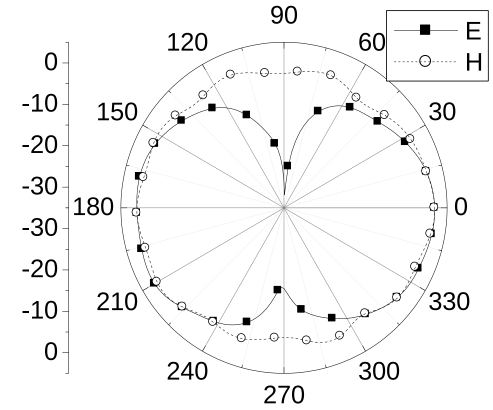
(a) 4GHz



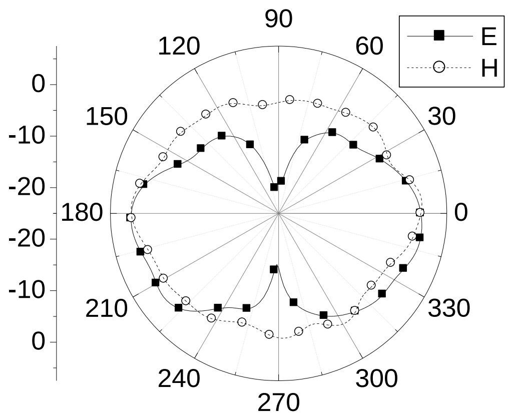
(b) 7GHz



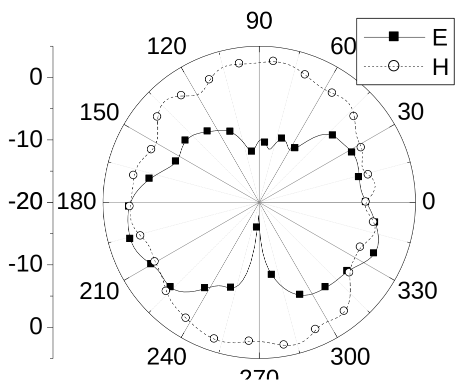
(c) 8GHz



(d) 9GHz



(e) 10GHz



(f) 11GHz

Fig. 19. radiation patterns of Band-Notched UWB antenna at required frequencies

IV. CONCLUSION

The radiation patterns were measured at frequencies of 4, 7, 8, 9 and 10GHz in the principal E-plane and H-plane. For brevity, the radiation patterns are shown in Figure 17. The H plane pattern of antenna is performance for amplitude omni-directional in the 4 GHZ band. When the frequency is greater than 7 GHz, the direction graph edge no longer keep the maximum value and have small sag. The E plane pattern of antenna is an approximation of "8" glyph, which cross polarization amplitude is less than -20 dB in the whole band. The results show that the antenna satisfies the radiation condition in the whole work band.

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