

## A BAND-NOTCHED UWB PRINTED HALF ELLIPTICAL RING MONOPOLE ANTENNA

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**Abstract**—In this paper, a compact ultra wideband (UWB) monopole antenna with a band-notched characteristic is presented. The band-notched characteristic is achieved by inserting a U-shaped slot in the half elliptical ring radiating patch. The measured bandwidth of the designed antenna for  $|S_{11}| \leq -10$  dB spans 3.1 GHz to 9.3 GHz with a notched band ( $|S_{11}| > -10$  dB) spanning 5.12 GHz to 5.99 GHz. A quasi-omnidirectional radiation pattern in the  $x$ - $z$  plane and quasi-symmetrical radiation patterns in the  $x$ - $y$  and  $y$ - $z$  planes are obtained throughout the operating band. The antenna is suitable for UWB communication applications and also reduces the interference with wireless local area network (WLAN) systems. The parameters which affect the performance of the antenna in terms of its frequency domain characteristics are investigated in this paper.

### 1. INTRODUCTION

Ultra wideband (UWB) antennas have drawn great attention in recent years for enabling high data rates, increased communication security, low power consumption and simple hardware configuration in practical applications [1]. The frequency band from 3.1 GHz to 10.6 GHz was allocated by the Federal Communications Commission (FCC) for commercial use. To satisfy such a requirement, various feasible

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wideband antennas have been studied [2–9]. Additionally, to avoid interference with existing wireless networks with the IEEE 802.11a standard (5.15 GHz–5.825 GHz), the design of antennas also requires a band-reject filter. The band-reject filter can reduce electromagnetic interference between UWB systems and WLAN systems. To address this problem, various antennas with band-notched functionality have been presented [10–19].

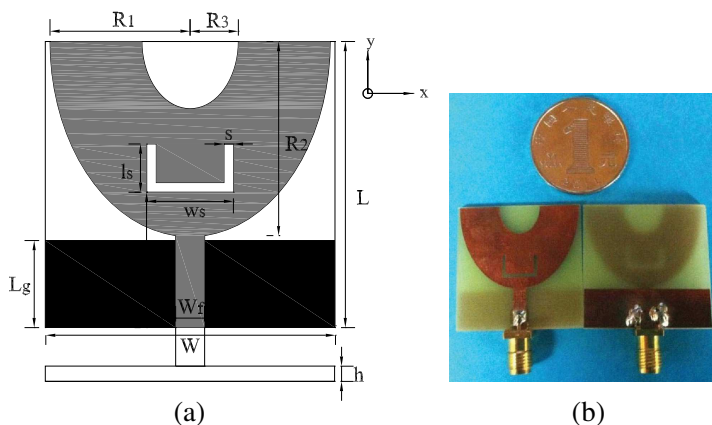
Among the previously presented UWB antenna designs, the printed monopole antenna [20–25] showed advantages due to its compact size, simple structure, wideband realizable characteristic, omnidirectional radiation patterns, high radiation efficiency and low cost. Different structures have been used to meet band-notched functionality for  $|S_{11}|$  by inserting a thin slot of different shapes in the radiation patch [26, 27], using parasitic patches [28, 29] or embedding a slot on the ground plane [30]. However, the structures of the antennas are relatively complex.

In this paper, a printed half elliptical ring monopole antenna with a band-notched performance for UWB application is proposed. To achieve the band-notched characteristic, a U-shaped slot was inserted in the half elliptical ring radiation patch. The measured frequency bandwidth for  $|S_{11}|$  of less than  $-10$  dB spans 3.1 GHz–9.3 GHz while the notched band from 5.12 GHz to 5.99 GHz, which mainly satisfies the UWB system requirement. The desired bandwidth and the notched frequency band can be easily adjusted by changing the antenna parameters. Details of the design are described, and experimental results of the proposed antenna are presented and discussed in the following sections.

## 2. ANTENNA DESIGN

### 2.1. Antenna Structure

Figure 1 shows the geometry and the photograph of the proposed printed half elliptical ring monopole antenna. The half elliptical ring patch can broaden the bandwidth through widening the width of the antenna element. The antenna is fed with a  $50\ \Omega$  microstrip feed line and is printed on an FR4 substrate ( $W \times L$ ) with a height ( $h$ ) of 1.6 mm and a relative permittivity 4.4. The ultra-wide band character is obtained by optimizing the parameters (i.e.,  $R_1$ ,  $R_2$  and  $R_3$ ) of the patch and the height ( $L_g$ ) of the ground plane. The total length of the U-shaped slot ( $l_s + l_s + w_s$ ) is equal to about a quarter of the wavelength of the desired notched frequency [31]. The U-shaped slot with optimized dimensions is inserted on the half elliptical ring radiating patch to achieve the band-notched characteristic. The proposed



**Figure 1.** Geometry and photograph of the proposed antenna. (a) Geometry. (b) Photograph.

**Table 1.** Parameters of the proposed antenna.

Parameters	$W$	$L$	$R_1$	$R_2$	$R_3$	$L_g$	$W_f$	$H$	$l_s$	$w_s$	$s$
Values/mm	32	32.6	15.5	21.2	5	11	3	15	4.1	4.5	1

antenna was optimized and finally fabricated with the parameters indicated in Table 1.

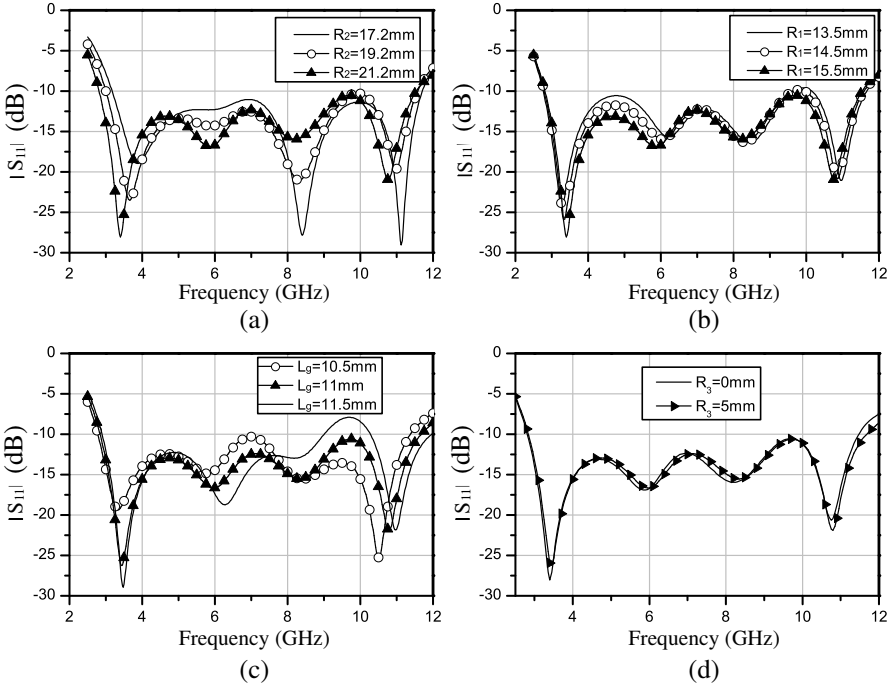
### 2.2. Analysis of the Parameters

In theory, all of the geometrical parameters have an effect on the function of the presented antenna, however, some of them may have more significant effects than others. Specifically, the size of the half elliptical ring and the height ( $L_g$ ) of the ground plane have bigger effects on the bandwidth. The band-notched characteristic is mainly controlled by the location ( $H$ ), width ( $w_s$ ) and height ( $l_s$ ) of the U-shaped slot. These parameters are investigated thoroughly to achieve the best performance. The numerical method we used is based on the finite element method (FEM) [32, 33].

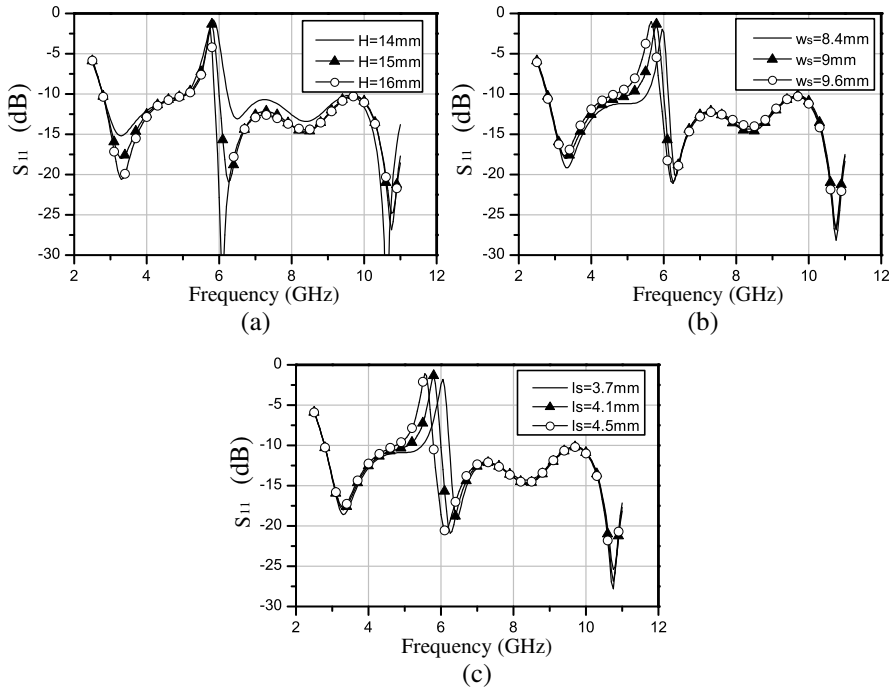
When the U-shaped slot is not used, the ultra-wideband characteristic is obtained without the band-notched performance. Fig. 2(a) shows the simulated  $|S_{11}|$  with various values of  $R_2$ . We can see that the major axis of the radiation patch, namely parameter  $R_2$ , has a strong effect on  $|S_{11}|$ . Within limits, the frequency band constantly moves down with enlargement of  $R_2$ . The main reason is the increase of  $R_2$  which is equivalent to increasing the height of the monopole antenna. In Fig. 2(b), it is shown that parameter  $R_1$ , the

minor axis of the radiator, has almost no effect on bandwidth. In Fig. 2(c), we can see the ground plane height  $L_g$ , which determines the width of the gap between the ground patch and the radiation patch, has a strong effect on bandwidth. In Fig. 2(d), it is shown that parameter  $R_3$ , the major axis of the inner half ellipse, has an effect on bandwidth. By optimizing the parameter  $R_3$ , the bandwidth could be improved. When  $R_3$  equals to 0 mm, which means that the radiation patch is a half ellipse, the bandwidth becomes a little narrower than the half elliptical ring patch.

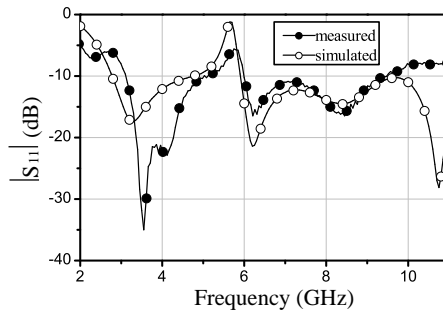
Furthermore, Fig. 3 shows the simulated  $|S_{11}|$  when varying  $H$ ,  $l_s$  and  $w_s$ , which are parameters that have a strong effect on band-notched performance. As is shown in Fig. 3(a), varying  $H$  affects the bandwidth of notched-band. As the value of  $H$  increases, the upper-edge frequency of the rejected-band decreases. Fig. 3(b) shows that as the value of  $w_s$  increases, the lower-edge frequency of the rejected-band decreases. Fig. 3(c) shows that the center frequency of the notched-band decreases as the value of  $l_s$  increases.



**Figure 2.** Simulated  $|S_{11}|$  with varying parameters for antenna (without slot, other parameters are given in Table 1). (a)  $R_2$ . (b)  $R_1$ . (c)  $L_g$ . (d)  $R_3$ .



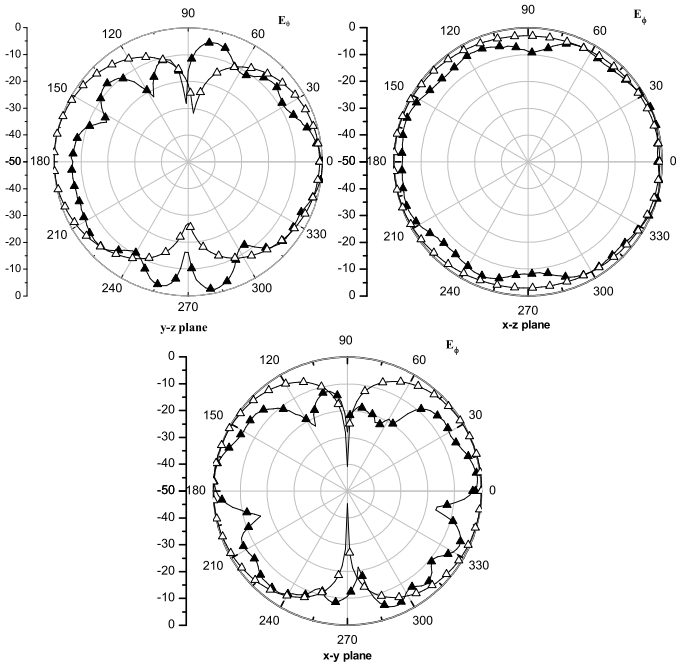
**Figure 3.** Simulated  $|S_{11}|$  with varying parameters for antenna (other parameters are given in Table 1). (a)  $H$ . (b)  $w_s$ . (c)  $l_s$ .



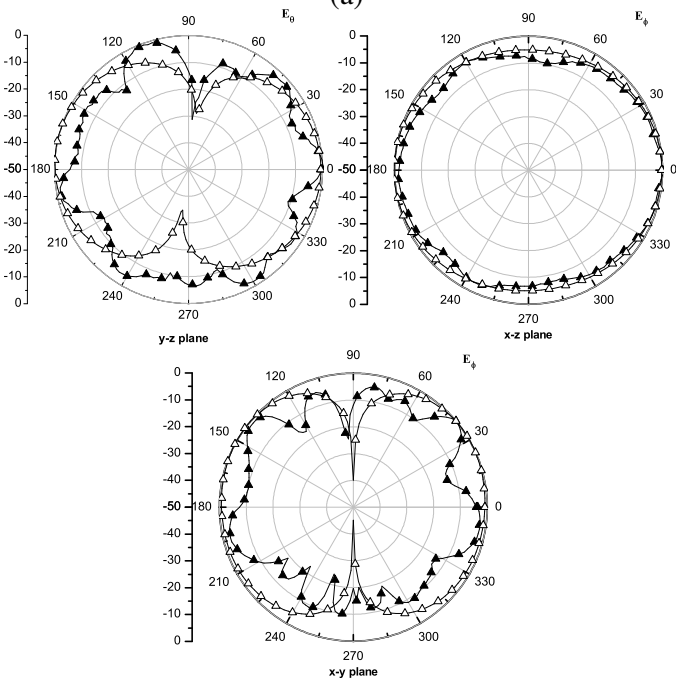
**Figure 4.** Measured and simulated  $|S_{11}|$  for the proposed antenna.

### 3. SIMULATION AND MEASUREMENT RESULTS

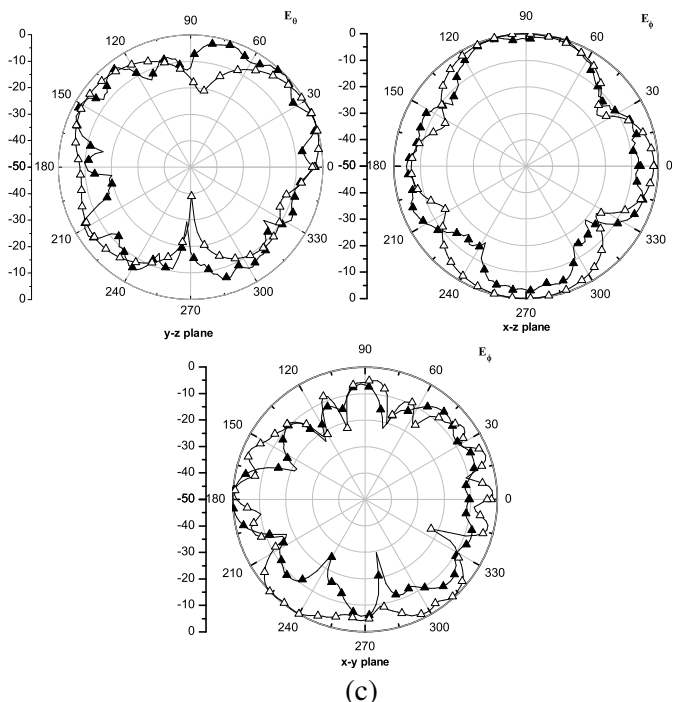
Simulation and measurement results of  $|S_{11}|$  and radiation patterns are investigated in this section. The antenna was measured by an Agilent E5071C Vector Network Analyzer in an anechoic chamber in Communication University of China.



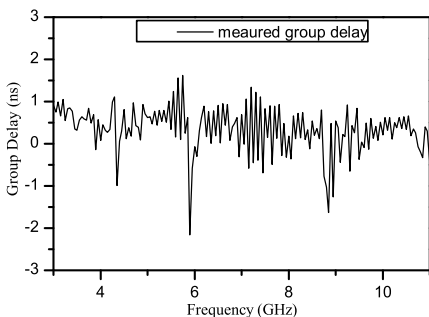
(a)



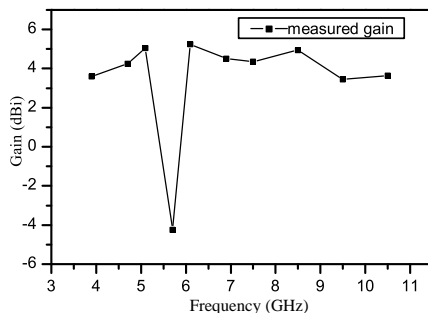
(b)



**Figure 5.** Radiation patterns in the  $y$ - $z$ ,  $x$ - $z$  and  $x$ - $y$  planes. -▲-: Measurement. -△-: Simulation. (a) 4.1 GHz. (b) 5.0 GHz. (c) 8.2 GHz.



**Figure 6.** Measured group delay for the antenna systems.



**Figure 7.** Measured gain of the proposed antenna.

### 3.1. Impedance Bandwidth

The simulated and measured  $|S_{11}|$  versus frequency are shown in Fig. 4. Essential agreement between the measured and simulated results can be seen from this figure. The measured impedance bandwidth for  $|S_{11}|$  of less than  $-10$  dB is from 3.1 GHz to 9.3 GHz and the bandwidth

of the frequency notched band ( $|S_{11}| > -10$  dB) is from 5.12 GHz to 5.99 GHz. It is evident that there is some discrepancy between the simulated result and the measured one. The deviation is probably caused by the tolerance of manufacture and the effect of the SMA connector. Basically, the impedance bandwidth of the antenna satisfies the UWB system requirement while reducing the interference of the 5.2 GHz and 5.8 GHz WLAN system.

### 3.2. Radiation Patterns

The simulated and measured radiation patterns for the  $y$ - $z$ ,  $x$ - $z$  and  $x$ - $y$  planes of the proposed antenna at 4.1 GHz, 5.0 GHz and 8.2 GHz are shown in Fig. 5. These figures demonstrate the simulated results are essentially in agreement with experimental results. It is observed that the proposed antenna radiates quasi-omnidirectionally in the  $x$ - $z$  plane and symmetrically in the  $x$ - $y$  and  $y$ - $z$  planes throughout the wide frequency band.

### 3.3. Measured Group Delay

The measured group delay of two antennas with a distance of 20 cm is shown in Fig. 6. It can be seen from the figure that the variation of the group delay is within 2 ns across the almost whole band except the notched band, where the maximum variation of the group delay is about 4 ns. Thus the proposed antenna has a good time-domain characteristic.

### 3.4. Measured Gain

Figure 7 shows the measured gain of the proposed antenna versus frequency. The measured gain in the operation frequency band ranges from 3.6 dBi to 5.25 dBi, except for the notched band (5.12–5.99 GHz) where the gain decreases to  $-4.25$  dBi at 5.7 GHz.

## 4. CONCLUSIONS

A compact ultra wideband microstrip-fed monopole antenna with band-notched filter suitable for UWB applications has been proposed. The antenna has advantages of low cost, compact size and easy design. To achieve wideband and band-notched characteristics, the antenna consists of a half elliptical ring with a U-shaped slot. The band-notched UWB antenna is designed, simulated, measured and analyzed in detail in this paper. The simulation and measurement results prove that the antenna satisfies the requirements of UWB communications.



## ACKNOWLEDGMENT

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