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New compact UWB microstrip-fed printed planar antenna for wireless applications

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Abstract A proposed circular patch antenna with notch-cut fed by a simple microstrip line is described in this paper. It is designed for ultra-wideband (UWB) wireless communications and applications over the band 3.1–10.6 GHz. This antenna consists of a circular patch with notch-cut fed by a microstrip line, one transition step, and a partial ground plane. The 2:1 voltage standing wave ratio (VSWR) bandwidth ($S_{11} < -10$ dB) of the proposed antenna covers the entire UWB application range specified by Federal Communications Commission (FCC) that is from 3.1 to 10.6 GHz. The proposed antenna is able to achieve an impedance bandwidth about 8.6 GHz (2.4–11 GHz). The return loss, VSWR, radiation pattern, radiation efficiency, gain, group delay, and current distribution of the proposed antenna are included in this paper. The simulation results and proposed antenna design details are presented by CST Microwave Studio.

Keywords ultra-wideband antennas, patch antenna, current distribution, microstrip feed line, group delay

1 Introduction

In 2002, the Federal Communications Commission (FCC) allowed ultra-wideband (UWB) communications operating in the band of 3.1–10.6 GHz with a -10 dB bandwidth greater than 500 MHz. One of the key issues in UWB communications is the design of a compact antenna while providing wideband characteristics over the whole operating band. Due to the rapid development of such UWB system, a great deal of attention is being given for the designing of the UWB antennas. This is quite challenging in satisfying the requirement of the UWB, such as ultra-wide impedance bandwidth, omni-directional radiation

pattern, constant gain, high radiation efficiency, constant group delay, low profile, and easy manufacturing [1]. Various antenna configurations include planar monopole antenna, slot antennas and dipoles have been used. Among several antennas, the planar slot antennas are more interesting and promising for their simple structure, easy fabrication, and wide impedance bandwidth. In recent time, the coplanar waveguide fed slot antenna attracted great deal of attention due to its advantages, such as lower profile wide-bandwidth and easy fabrication [2].

Printed antennas offer low cost, light weight, and ease of implementation. These features are desirable for both indoor and outdoor handheld UWB antennas and many microwave applications. Several shapes and designs of UWB antennas, such as square, circular, pentagonal, hexagonal, elliptical, and trapezoidal shape, have been proposed to satisfy UWB specifications [3,4]. In these antennas, several bandwidth enhancement techniques are used to have a continuous UWB bandwidth. These techniques include adjusting the gap between radiating element and ground plane [5], a double feed [6], a beveling radiating element [7], and a beveling ground plane [8].

2 Antenna configuration

Figure 1 shows the configuration of the proposed UWB antenna, which consists of a circular patch with notch-cut fed by a microstrip line, one transition step, and a partial ground plane. The patch antenna, which has radius (r) of 10 mm is printed in the front of substrate FR4 of thickness of 1.5 mm, relative permittivity of 4.43, and loss tangent of 0.02. The dimension of the substrate is 42 mm \times 50 mm and the dimension of the ground plane is chosen to be 42 mm \times 19.6 mm in this work. The parameters of the proposed antenna structure are illustrated in Table 1.

The design dimensions of the proposed antenna are obtained using CST Microwave Studio. To design the UWB antenna, three techniques have been applied to the proposed antenna: i) a partial ground plane, ii) a notch-cut on the patch, and iii) a transition step. By selecting these

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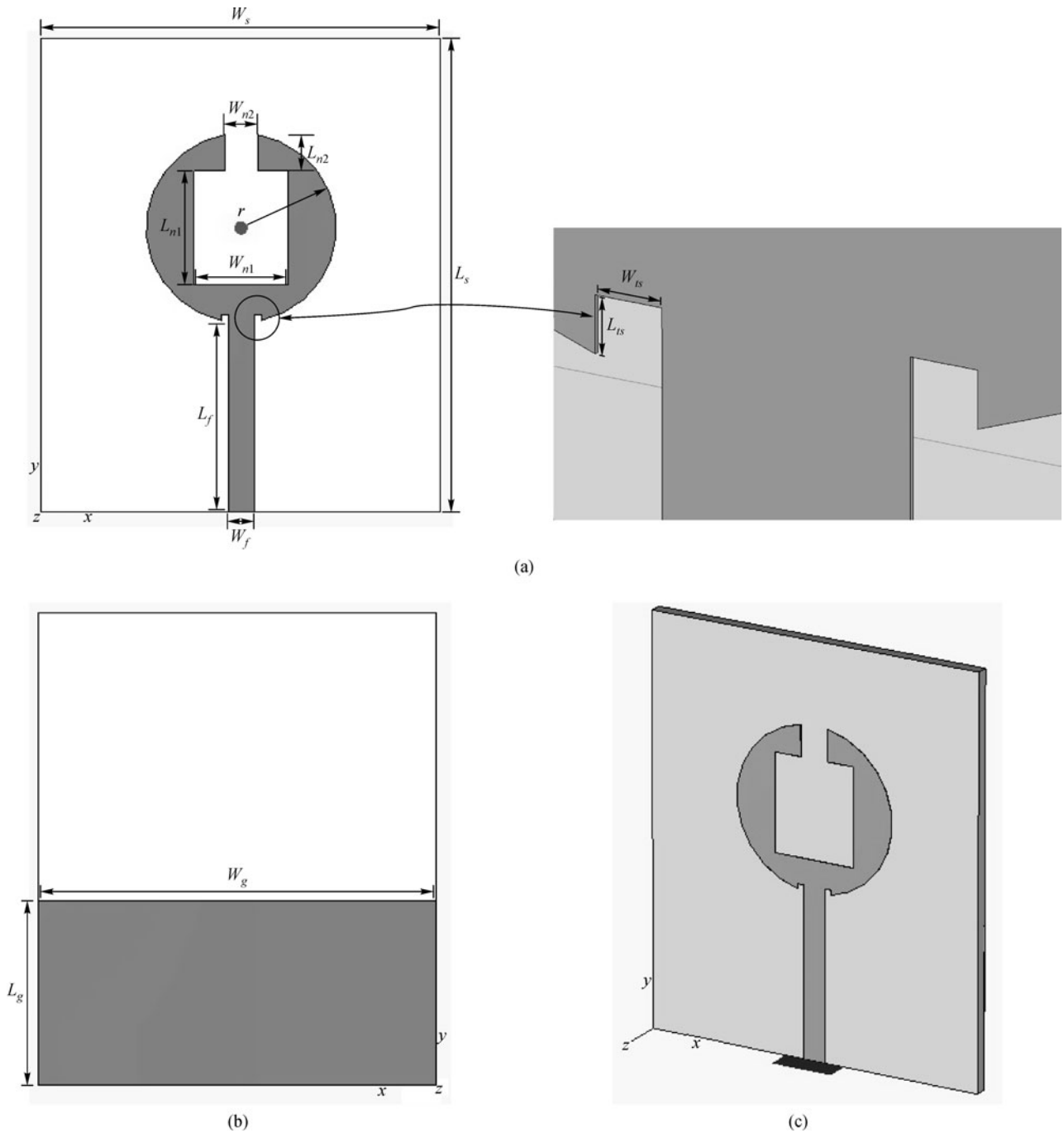


Fig. 1 Geometry of the proposed antenna. (a) Front view; (b) back view; (c) 3D view

parameters, the proposed antenna can be tuned to operate in the 2.4–11 GHz frequency range.

3 Simulation results and discussion

The proposed antenna was simulated in CST Microwave Studio which is based on finite integration technique (FIT) (<http://www.cst.com/content/products/mws/FIT.aspx>).

The simulated return loss and voltage standing wave

ratio (VSWR) of the proposed antenna are shown in Figs. 2 and 3, respectively, which clearly indicate that the impedance bandwidth of the antenna is 8.6 GHz (2.4–11 GHz) for a return loss (S_{11}) less than -10 dB (VSWR < 2).

The fractional bandwidth of the proposed antenna (BW) has been found by using the following equation [9]:

$$BW = \frac{f_2 - f_1}{\sqrt{f_2 f_1}} \times 100\%$$

Table 1 Structure parameters of the antenna

parameter	value/mm
W_s	42
L_s	50
W_g	42
L_g	19.6
W_f	2.8
L_f	20
r	10
W_{n1}	10
L_{n1}	12
W_{n2}	3.5
L_{n2}	4
W_{ts}	0.75
L_{ts}	0.75

where f_1 and f_2 are the lowest and highest frequencies at which the S_{11} is under 10 dB level. From the equation above, the fractional bandwidth of the proposed antenna is 167.4%.

Figure 4 shows the amplitude surface current distributions of the proposed antenna at 4, 6, 9, and 11 GHz, and from these figures, it can be seen that the current distributions on the surface of the antenna at 4, 6, 9, and 11 GHz equal to 35.4, 46.8, 51.1, and 35.8 A/m, respectively.

The computed radiation characteristics of the proposed antenna at 4, 6, 9, and 11 GHz within the impedance bandwidth obtained have also been studied. Figures 5, 6, and 7 show the power pattern of the proposed antenna in xz -plane, yz -plane, and xy -plane, respectively, where the antenna is placed in the xy -plane. Good omni-directional patterns in xy -plane, yz -plane, and xz -plane have been obtained. For achieving the pattern of xy -plane, θ has been set as 90° for all values of ϕ . Similarly, to show the trend of radiations in yz -plane, ϕ has been set as 90° for all values of θ ; and to have radiation trend in xz -plane, all values of θ are focused for $\phi = 0^\circ$.

Figure 8 shows the peak gain of the proposed antenna in a frequency range (2.4–11 GHz) and the gain variations are less than about 6.477 dBi.

Figure 9 shows the radiation efficiency of the proposed antenna in a frequency range (2.4–11 GHz). Good

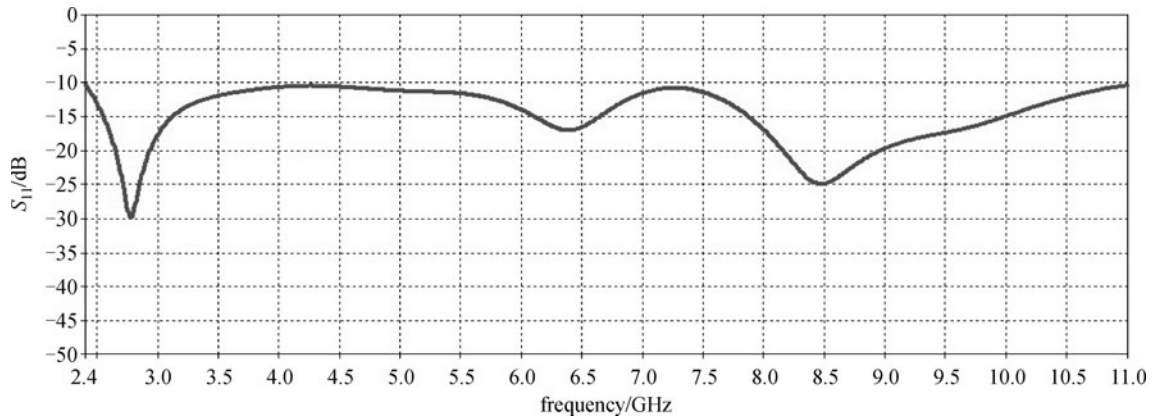


Fig. 2 Simulated return loss (S_{11}) of the proposed UWB antenna

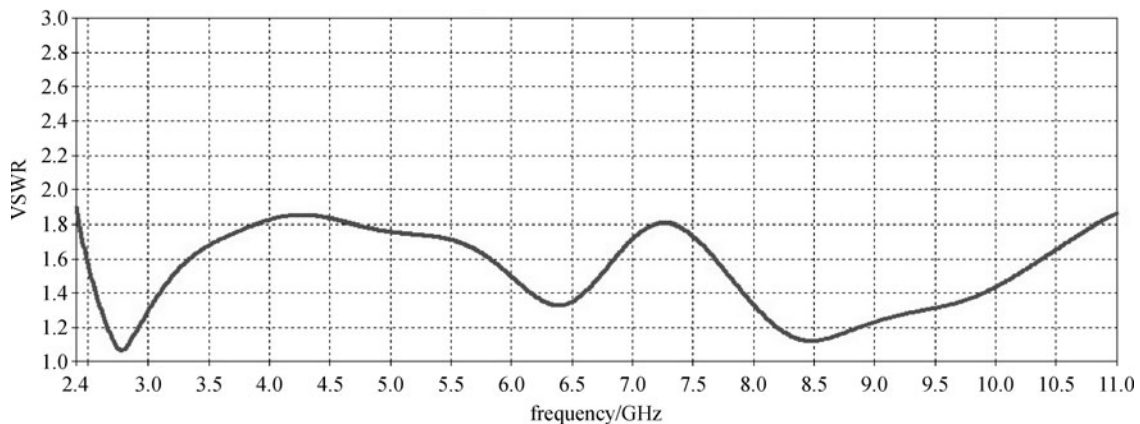


Fig. 3 Simulated VSWR of the proposed UWB antenna

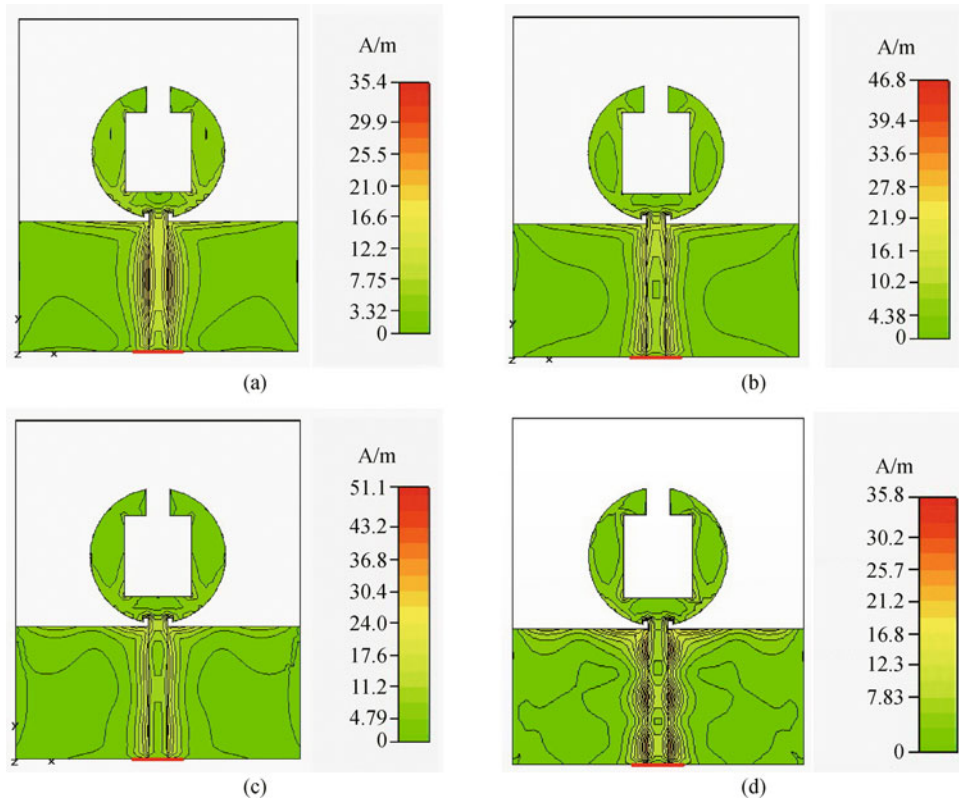


Fig. 4 Simulated amplitude surface current distribution of the proposed UWB antenna at (a) 4 GHz; (b) 6 GHz; (c) 9 GHz; and (d) 11 GHz

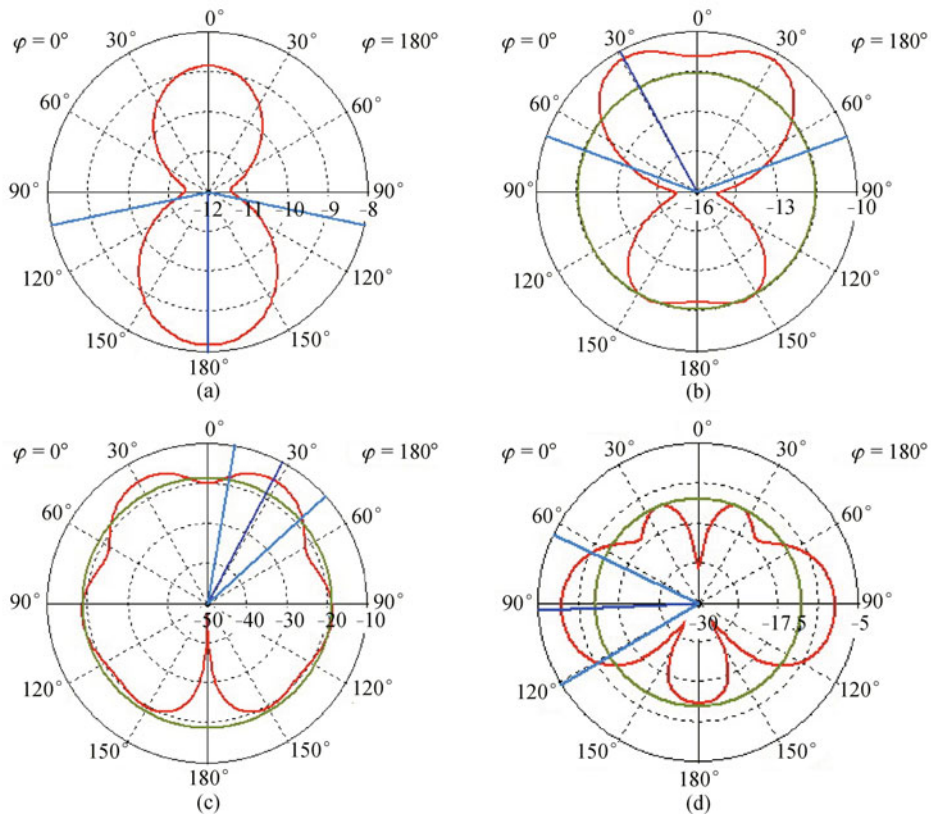


Fig. 5 Power pattern of the proposed antenna in xz -plane at (a) 4 GHz; (b) 6 GHz; (c) 9 GHz; and (d) 11 GHz

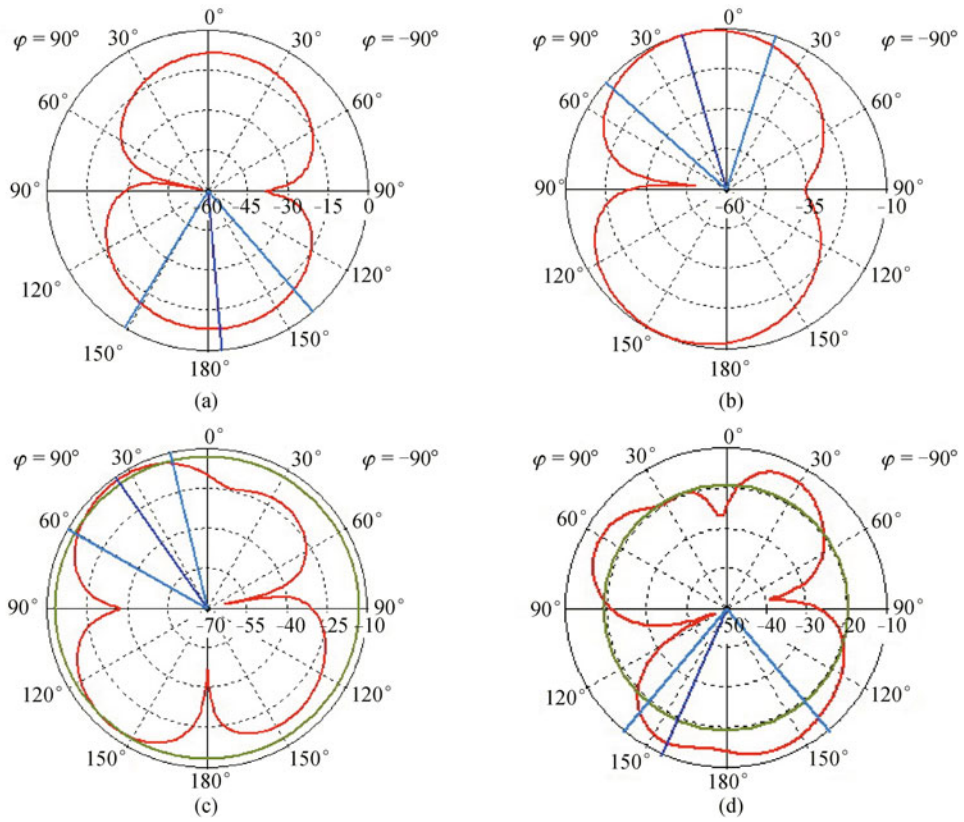


Fig. 6 Power pattern of the proposed antenna in yz -plane at (a) 4 GHz; (b) 6 GHz; (c) 9 GHz; and (d) 11 GHz

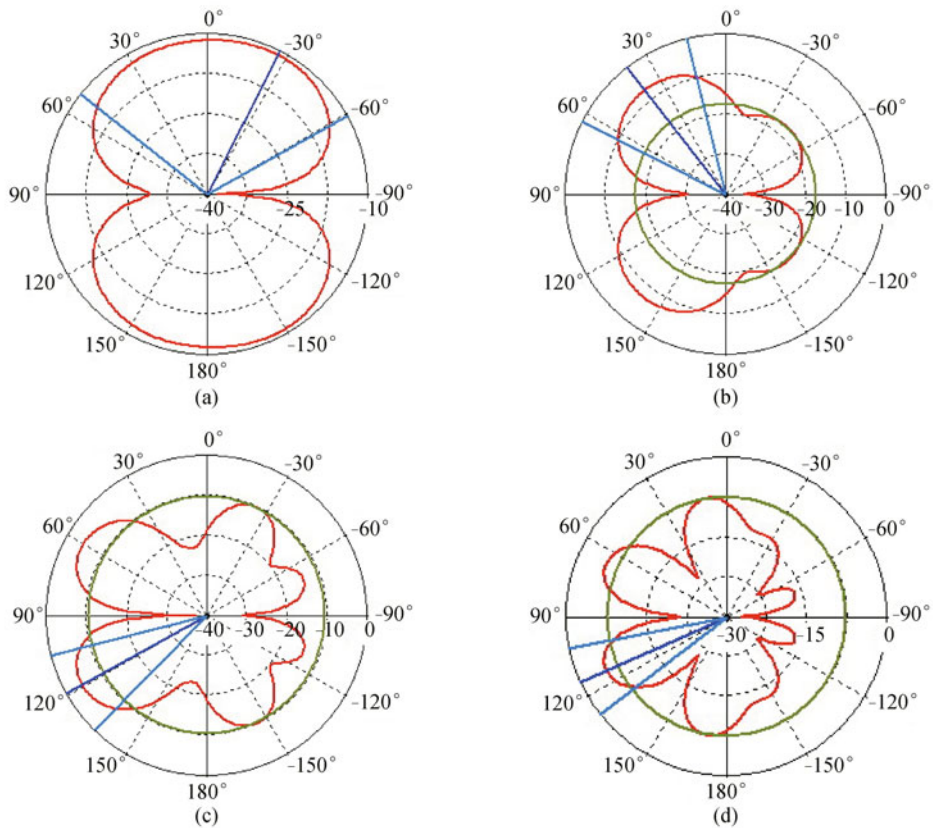


Fig. 7 Power pattern of the proposed antenna in xy -plane at (a) 4 GHz; (b) 6 GHz; (c) 9 GHz; and (d) 11 GHz

radiation efficiency has been obtained for the proposed antenna and it is more than 70%.

Group delay is another important criterion to determine the performance of UWB antenna. The antenna should be able to transmit the electrical pulse with minimal

distortion. The calculated group delay of the proposed antenna is portrayed in Fig. 10. The variation is less than 1 ns over the frequency band from 3.1 to 10.6 GHz. It shows that the antenna has low-impulse distortion and is suitable for UWB applications.

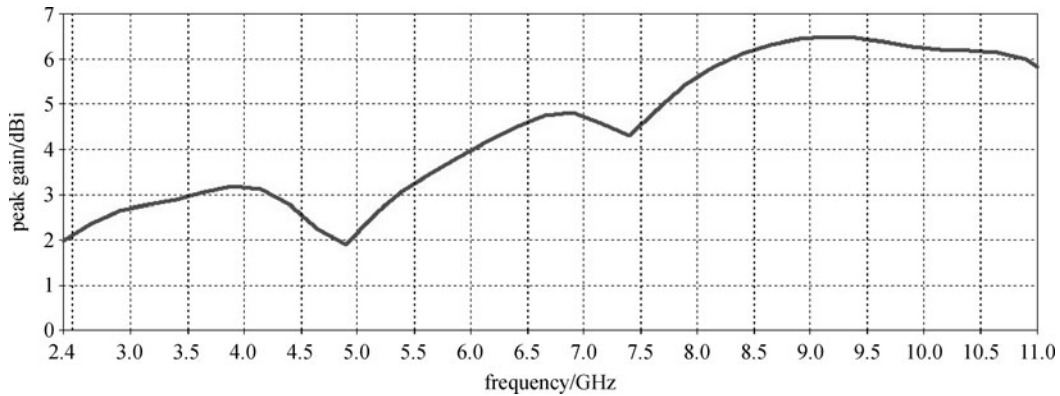


Fig. 8 Simulated gain of the proposed UWB antenna

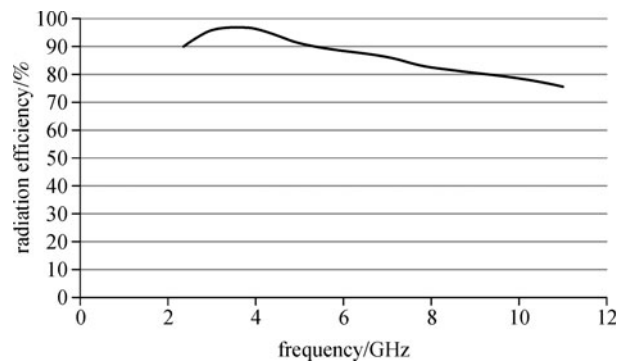


Fig. 9 Simulated radiation efficiency of the proposed UWB antenna

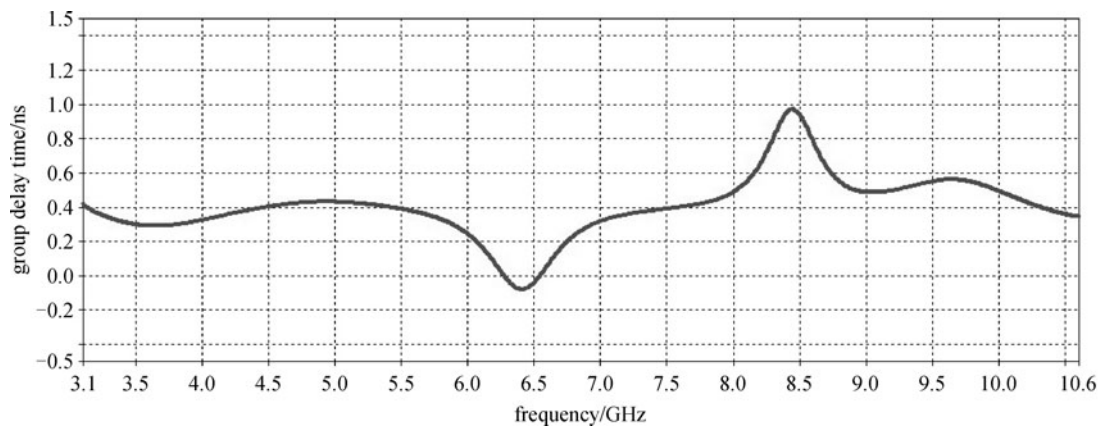


Fig. 10 Simulated group delay of the proposed UWB antenna

4 Conclusion

The design of the proposed UWB antenna based on a circular patch with notch-cut, one transition step, and a partial ground plane is presented. The obtained results show good performance in terms of radiation patterns, gain, radiation efficiency, and size. The antenna has a frequency band of 2.4 to 11 GHz for VSWR less than 2.0 ($S_{11} < -10$ dB). The proposed antenna also has a maximum gain equal to 6.477 dBi and a group delay time less than 1 ns. Thus, it can be concluded that the achieved bandwidth meets the UWB requirements.

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