

A CPW-FED ULTRA-WIDEBAND PLANAR INVERTED CONE ANTENNA

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Abstract—This paper presents a CPW-fed planar inverted cone antenna (PICA) for ultra-wideband (UWB) communication applications. The proposed PICA provides a conventional monopole type omnidirectional radiation pattern, and it utilizes the advantages of the coplanar-waveguide (CPW) to simplify the structure of the antenna into a single metallic level. To improve radiation characteristics, a tapered and corrugated ground plane is used. In addition, the PICA's radiating element with three self-similarity holes is attempted to enhance performance of the antenna. The simulated and measured results demonstrate that the proposed PICA achieves a broad impedance bandwidth from 1.3 GHz to 11 GHz within the magnitude of S_{11} (dB) less than -10 dB and maintains nearly omnidirectional radiation characteristics.

1. INTRODUCTION

Ultra-wideband (UWB) radio is an emerging and promising technology with uniquely attractive features inviting major advances in wireless communications, networking, radar, imaging, and positioning systems [1]. In the U.S., the Federal Communications Commission (FCC) allocated the frequency band 3.1–10.6 GHz for UWB applications in 2002 [2]. In either conventional communication systems or UWB communication systems, an antenna plays a very crucial role. Nevertheless, there are more challenges in designing an UWB antennas than a narrow band one [3].

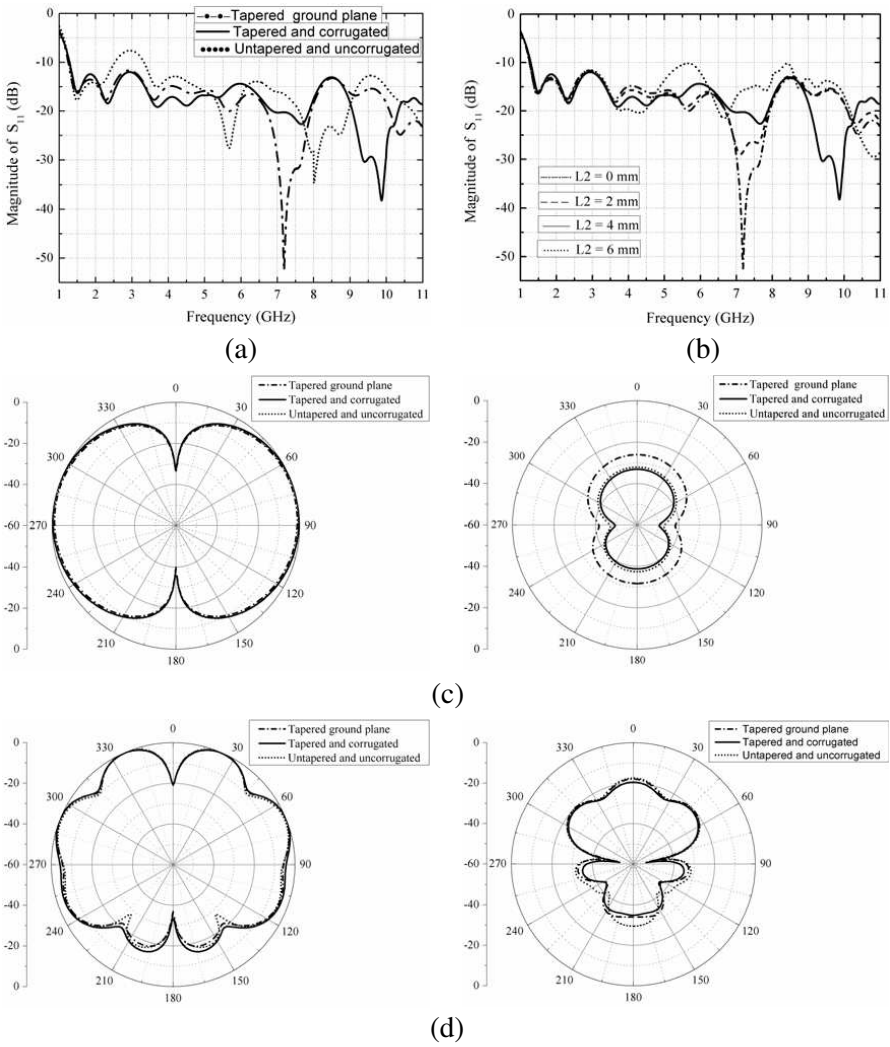
Recently, there are various types of UWB antennas which have been designed to achieve the requirement for different applications [4–12]. The planar inverted cone antenna is proposed by Suh and variants of the PICA concept have been investigated by others [13–17]. A typical PICA is composed of single flat element vertically mounted above a large ground plane and likes a wide monopole antenna. Its bandwidth is impressive in view of its small size and mechanical simplicity. However, it is not the most suitable for portable communication systems due to the protruding part of planar inverted cone antenna.

Planar UWB antennas have been realized by using either microstrip line or CPW feeds [18–20]. The CPW feeding has many attractive features, such as no soldering point, easy fabrication, and a simplified configuration with a single metallic layer. The monopole antenna with a tapered ground plane arises from the discone antenna first developed by Kandoian in 1945 [21], which offers satisfactory impedance performance over a wide frequency range and maintains nearly omnidirectional radiation characteristics. A new tapered and corrugated ground plane is investigated [22, 23]. In this paper, a CPW-fed PICA with tapered and corrugated ground plane is used to improve radiation characteristics, and the PICA's radiating element with three self-similarity holes is attempted to enhance performance of the antenna.

2. ANTENNA STRUCTURE AND DESCRIPTION

The geometry and dimensions of the PICA are shown in Figure 1. The antenna is based on the conventional planar monopole circular-disc antenna [24]. The top part of the circular disc antenna is trimmed to the shape of a planar inverted cone. The radiating element is backed with a finite ground plane, and its total height is about $\lambda_L/4$, where λ_L denotes a wavelength at the lowest operating frequency. The cone

bottom parts are trimmed to the shape of planar cone is attempted to enhance performance of the antenna. R_1 , R_2 , and R_3 represent radii of the three circular discs respectively. L_2 and h_2 represent the length and the width of the slot respectively, and L_1 is the height of the ground as shown in Figure 1. In order to obtain the desired characteristics, the cone angle α is chosen as 90° , tilt angle $\alpha_1 = 45^\circ$, and $R = R' = 37.5$ mm. Other parameters of the PICA are all shown in Figure 1. In addition, the antenna size can be easily changed to any specific frequency band of interest such as UWB band of 3.1–10.6 GHz.



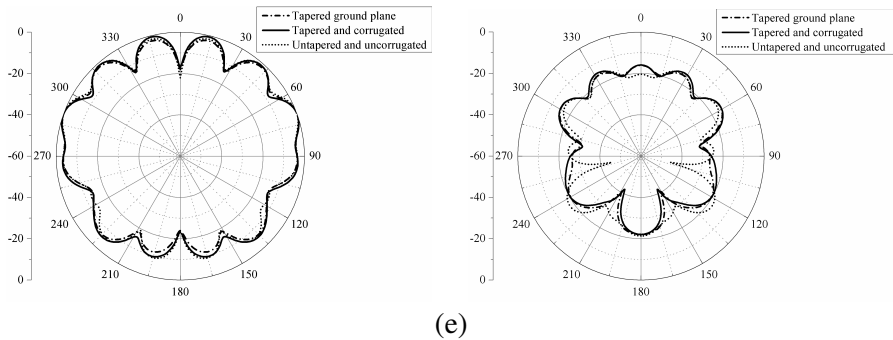


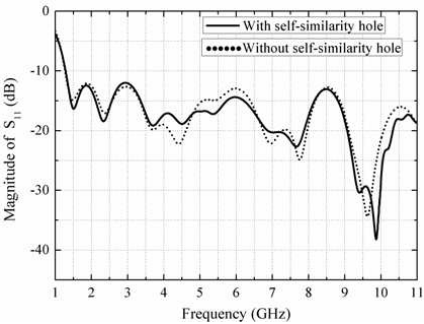
Figure 2. The effect of tapered and corrugated ground plane. (Other parameters are shown in Figure 1). (a) Simulated $|S_{11}|$ (dB) for the three ground planes. (b) Simulated $|S_{11}|$ (dB) for different slot length L_2 . (c) Simulated co-polar patterns (left) and cross-polar (right) patterns for the three ground planes at 1.5 GHz. (d) Simulated co-polar patterns (left) and cross-polar (right) patterns for the three ground planes at 5.0 GHz. (e) Simulated co-polar patterns (left) and cross-polar (right) patterns for the three ground planes at 8.0 GHz.

3. SIMULATION AND MEASUREMENT

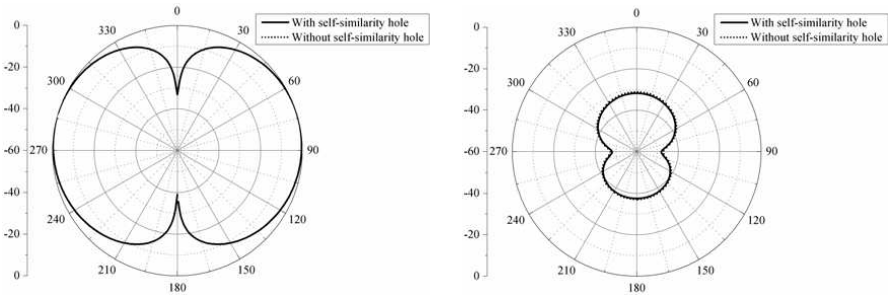
The proposed PICA is successfully implemented via using the simulation software CST Microwave Studio (MWS), which is based on the finite integration technique for electromagnetic computation. It is noticed in simulations that the operating bandwidth of the antenna is heavily depended on the diameter of the disc R , the slot size and the feed gap h . These parameters are optimized in the antenna design to obtain the desired characteristics. Here, the effect of the tapered corrugated ground plane and the three self-similarity holes are analyzed and some simulated results are shown in Figure 2 and Figure 3 respectively.

The advantages of the tapered corrugated ground plane over untapered, uncorrugated ground plane are demonstrated in Figure 2 and Figure 3. If the untapered and uncorrugated ground plane is used, the magnitude of S_{11} (dB) is more than -10 dB from 2.5 GHz to 3.3 GHz as shown in Figure 2(a). Thus, the tapered ground plane is applied, which is an effective method to improve the impedance bandwidth in this antenna design. The co-polarization patterns maintain nearly the same radiation characteristics, but the cross-polarization patterns deteriorate at low frequencies (such as at

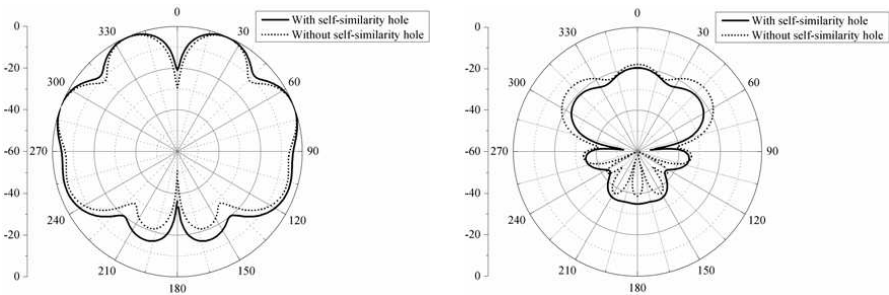
1.5 GHz) as shown in Figure 2(c). In order to improve the cross-polarization pattern at low frequencies, the tapered and corrugated ground plane is attempted. It is noticed that the slot can change the impedance of the antenna, especially at high frequencies. For instance, reflection coefficient deteriorates as the slot length L_2 increases as shown in Figure 2(b). Other results at some frequencies are shown in Figure 2. Here, the patterns of H -plane are not demonstrated in that the effect on H -plane is similar that of E -plane in the antenna.



(a)



(b)



(c)

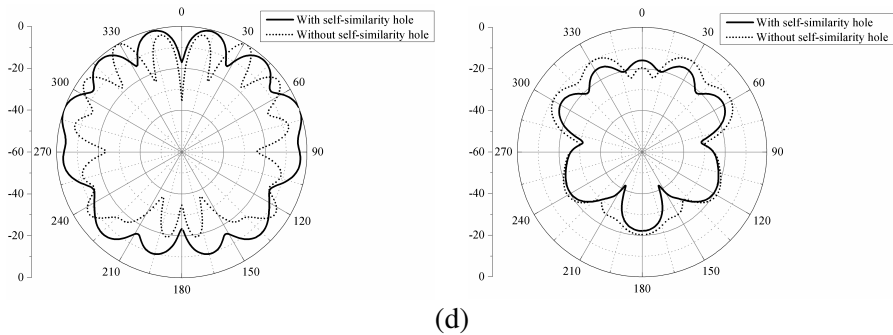


Figure 3. The effect of the three self-similarity holes. (Other parameters are shown in Figure 1). (a) Effect on S_{11} of the three self-similarity holes. (b) Simulated co-polar patterns (left) and cross-polar (right) patterns at 1.5 GHz. (c) Simulated co-polar patterns (left) and cross-polar (right) patterns at 5.0 GHz. (d) Simulated co-polar patterns (left) and cross-polar (right) patterns at 8.0 GHz.

Because the radiation patterns of the antenna distort as frequency increases, the PICA's radiating element with three self-similarity holes is attempted to enhance radiation pattern. The antenna with three self-similarity holes can provide broad impedance bandwidth as shown in Figure 3(a). The co-polarization pattern patterns are improved at high frequencies by using the method, and their respective cross-polarization patterns are also slightly improved as shown in Figures 3(b)–(d). Here, the patterns of H -plane are not given either because the effect on H -plane is similar that of E -plane in the antenna.

All parameters of the PICA are finally obtained via using CST Microwave Studio. The measures are carried out in the Antenna Measurement Laboratory of Sichuan University. The reflection coefficient and the radiation Patterns of the PICA are shown below.

3.1. Reflection Coefficient Measurement and Simulation

The reflection coefficient is measured by the Vector Network Analyzer (Agilent N5230A). The simulated and measured reflection coefficient of the antenna are shown in Figure 4, which are matched and exhibit broadband impedance characteristics for $|S_{11}|$ (dB) less than -10 dB.

3.2. Radiation Pattern Characteristics

The simulated and measured radiation patterns are shown in Figure 5 and Figure 6 corresponding to a number of relevant frequencies

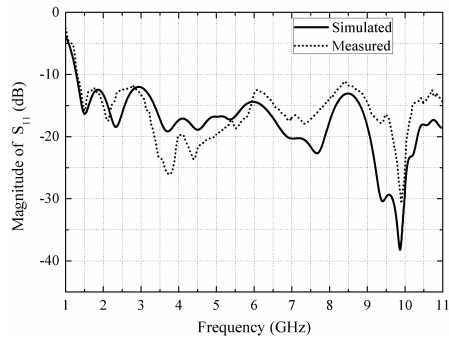
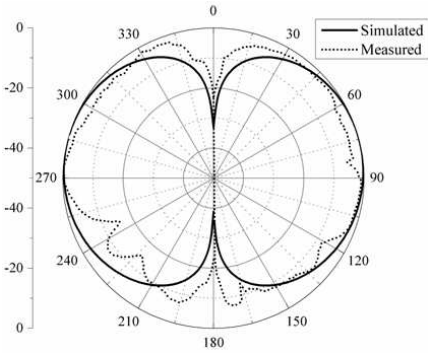
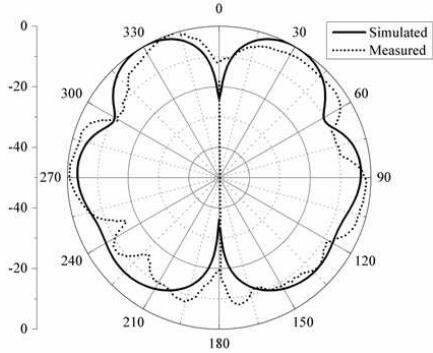


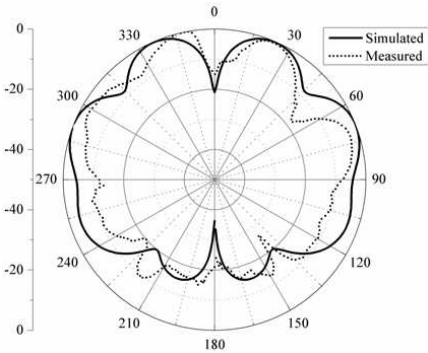
Figure 4. Simulated (solid line) and measured (dotted line) $|S_{11}|$ (dB) of the antenna.



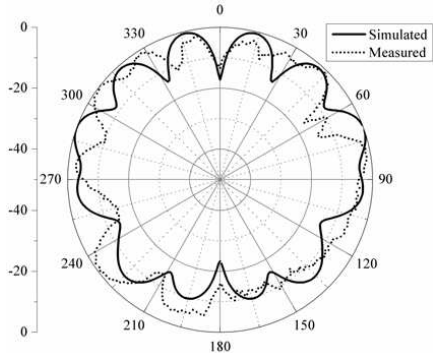
(a) 1.5 GHz



(b) 3.5 GHz



(c) 5.0 GHz



(d) 8.0 GHz

Figure 5. Simulated (solid line) and measured (dotted line) E -plane radiation patterns.

respectively. Figure 5 shows the E -plane radiation patterns of the proposed PICA at different frequencies and their respective H -plane radiation patterns are given in Figure 6.

In the E -plane, the number of side lobe increases with frequency, and the H -plane patterns are omnidirectional at lower frequencies and distort slightly at higher frequencies. Thus, the radiation patterns are generally omnidirectional over the frequency band of the interest, like a conventional monopole antenna.

The antenna maximum gain (dBi) in CST Microwave Studio is depicted in Figure 7. It reveals that the maximum gain gradually increases with frequency. A picture of fabricated PICA is shown in Figure 8.

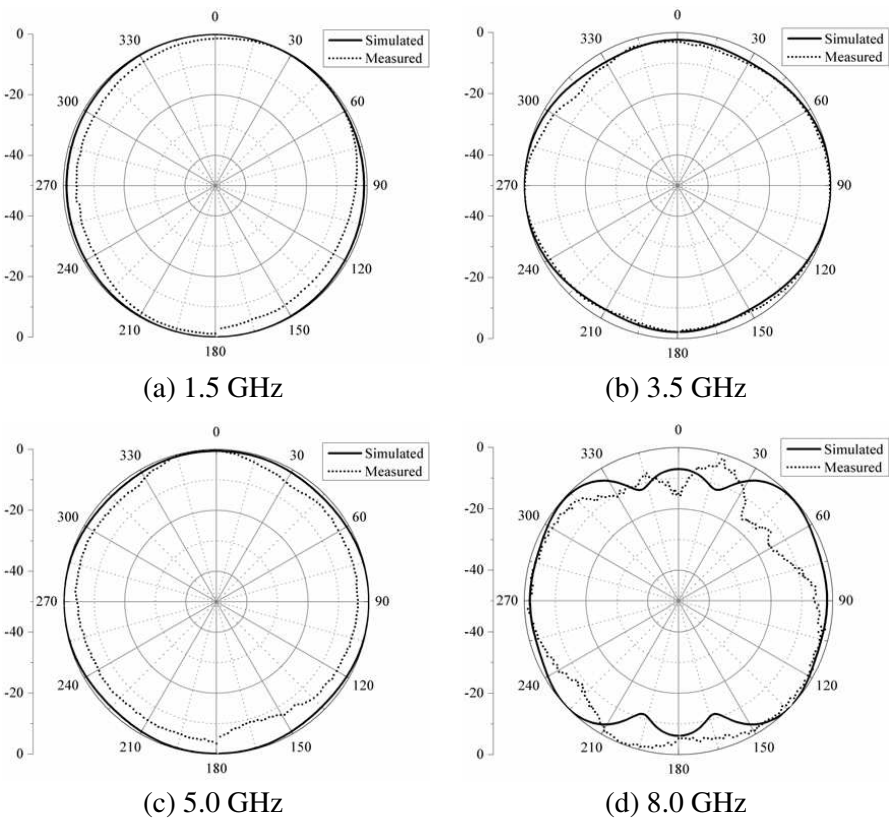


Figure 6. Simulated (solid line) and measured (dotted line) H -plane radiation patterns.

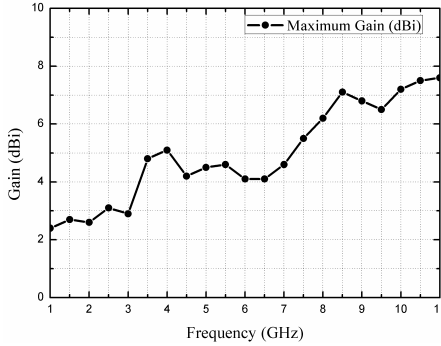


Figure 7. Computed maximum gain of the proposed PICA.

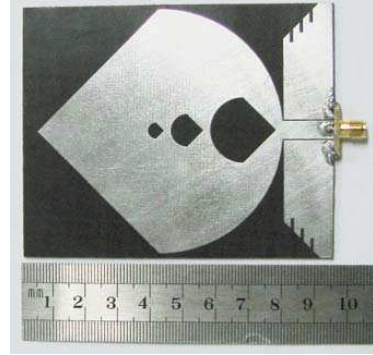


Figure 8. Picture of fabricated antenna.

4. CONCLUSION

In this paper, a CPW-fed ultra-wideband planar inverted cone antenna is designed, fabricated and tested. This antenna has thin profile, easy fabrication and low cost. The experimental results show that the PICA achieves an impedance bandwidth from 1.3 GHz to 11 GHz within $|S_{11}|$ (dB) less than -10 dB and maintains nearly omnidirectional radiation characteristics.

The concept of using tapered and corrugated ground plane is successfully applied to the proposed PICA to enhance its performance. The self-similarity holes application is proved to be an effective method to enhance radiation pattern in the PICA design. The proposed PICA provides wide impedance bandwidth and radiation pattern bandwidth, and is very suitable for UWB communication applications.

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