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A Single-Layer Wideband Dual-Polarized Antenna with High Isolation

Ruina Lian*, Shufeng Zheng, Ying-Zeng Yin, Jianjun Wu, Shaoshuai Zhang, and Guan-Xi Zhang

Abstract—A single-layer wideband printed antenna for dual-polarized applications is proposed in this paper. Two orthogonal linear polarizations are achieved by adopting a hybrid feeding technique. The horizontal polarization is excited by an aperture-coupled microstrip feed line while the coplanar waveguide (CPW) feed line is responsible for the vertical polarization. Measurements demonstrate a fairly wide common impedance bandwidth of 56.3% (1.61–2.87 GHz) with SWR ≤ 2 could be achieved. By loading a rectangular patch in the narrow rectangular slot, the isolation between two ports can be improved to better than 40 dB over the entire bandwidth. Moreover, the average gains of the proposed antenna are about 5.8 dBi and 5 dBi for port 1 and port 2, respectively.

1. INTRODUCTION

Antenna with polarization diversity nowadays has aroused much attention in modern mobile communication systems, due to its prominent abilities to provide high channel capacity, effectively deal with the multipath fading problem and offer transmit-receive channels at the same frequency, etc.. Meanwhile, the demand for a wideband antenna has become increasingly apparent owing to the explosive growth of wireless communication services like GSM, PCS, UMTS and WLAN/WiMAX. It is natural that the wideband dual-polarized antennas win the favor of amounts of researchers who devote themselves to design better antennas. In the process of designing a dual-polarized antenna, besides the bandwidth and port isolation, the simplicity and compactness of the structure is another key consideration.

In previous works, to enhance the bandwidth, a representative type of dual-polarized antennas is the stacked patch antenna in which one or more parasitic elements are placed above a lower patch [1, 2]. This technique can improve the bandwidth up to the order of 30–35% [3]. On the other hand, an antenna with a meandering probe in recent published literature [4] shows a bandwidth of 26% because of introducing some capacitance to cancel out the inductance caused by the probe, thus lowering Q-factor. Moreover, as is presented in [5], an electromagnetic-fed patch antenna could achieve a common bandwidth of 34.9%. However, all these antennas either occupy a huge three-dimensional space or have a complex feeding structure. Inevitably, these antennas will encounter some trouble and inconvenience when the space is limited and also confront difficulty in fabrication.

On the contrary, the printed slot antennas, which have the characteristics of low cost, low profile and easy conformity, become attractive and exhibit enormous study value. There appear some dual-polarized slot antennas, such as antennas in [6–8], achieving dual polarizations by exploiting the even and odd modes of a CPW feeding structure. However, the antennas above still suffer narrow bandwidth and the isolation also needs some improvement.

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* Corresponding author: Ruina Lian (rnlian@163.com).
The authors are with the National Laboratory of Science and Technology on Antennas and Microwave, Xidian University, Xi'an, Shaanxi 710071, China.

In this letter, a low-profile wideband dual-polarized antenna with high isolation for bidirectional radiation applications is proposed, which is based on the fact that a circular slot could support two orthogonal degenerate TE_{11} modes [9], as illustrated in Fig. 2. Here, a hybrid feeding structure, consisting of an aperture-coupled microstrip line and a coplanar waveguide line, is adopted to achieve dual polarizations. By elaborately adjusting the hybrid feeding structure, a common bandwidth ($|S_{11}| \leq -10$ and $|S_{22}| \leq -10\,\text{dB}$) for the two ports of 56.3% (1.61–2.87 GHz) could be achieved and the isolation could be improved up to around 40 dB over the entire operating band.

2. ANTENNA CONFIGURATION AND DESIGN

The proposed antenna is printed on a 1-mm-thick FR4 substrate with permittivity 4.4 and loss tangent 0.02. As shown in Fig. 1, a circular slot with radius R_1 and an E-shaped slot lie on the top of the substrate, serving as the radiation aperture while the part remaining of the substrate is occupied by copper, acting as the ground of the microstrip line sitting on the bottom of the substrate. Moreover, the E-shaped slot can be regarded as a rectangular slot loaded with a rectangular patch which is benefit for a better isolation. And the circular patch connected with a stepped microstrip line, thus forming an impedance transformer, has a significant effect on the wide bandwidth. The ground plane is selected as $125 \times 175\,\text{mm}^2$. In the design, a 50-ohm open-ended microstrip line is utilized to excite the antenna for horizontal polarization, while the antenna could operate at a vertical polarization mode by using the coplanar waveguide line.

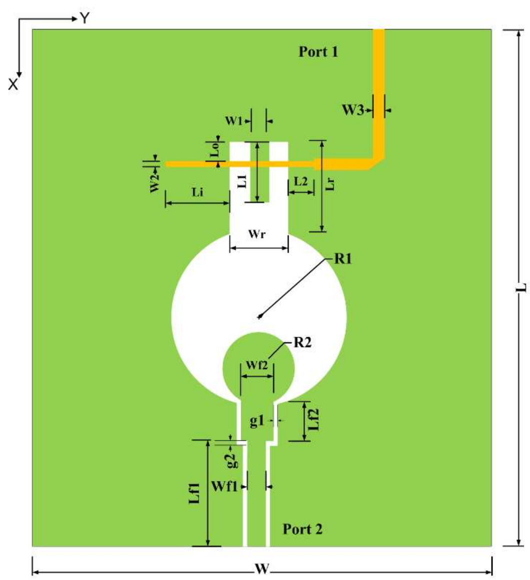
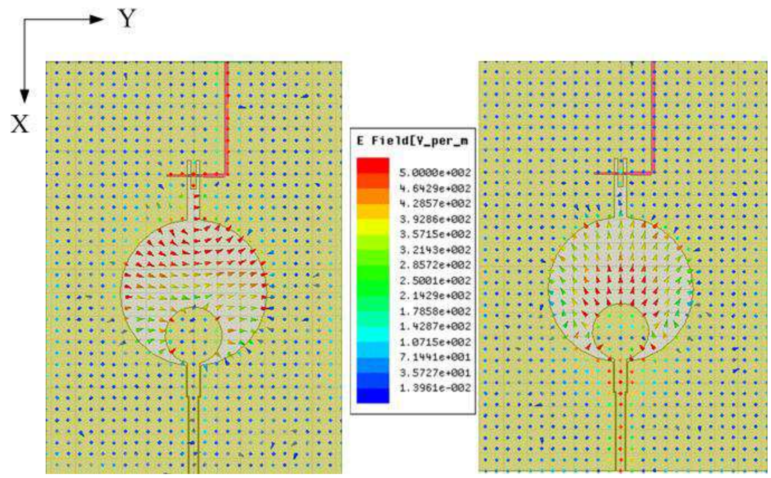


Figure 1. Geometry of the proposed antenna. Some of the optimized key parameters are listed as follows: $L = 175$, $W = 125$, $L_{f1} = 34$, $L_{f2} = 13.8$, $W_{f1} = 3.8$, $W_{f2} = 5.4$, $g_1 = 0.3$, $g_2 = 0.5$, $R_1 = 31$, $R_2 = 12$, $W_1 = 2.4$, $W_r = 5.2$, $W_2 = 1$, $W_3 = 1.5$, $L_1 = 12$, $L_2 = 2$, $L_i = 8.8$, $L_r = 25$, $L_o = 6$ (Units: mm).

The electric field distribution at 2.3 GHz fed by two ports is shown in Fig. 2. Obviously, when port 1 is excited and port 2 is terminated to 50-ohm load, the electric field in the slot is along y-direction, which demonstrates the horizontal polarization is generated. Similarly, vertical polarization could be achieved when another port is excited. According to the electric field distribution, it can be seen the proposed antenna has two resonant modes. One depends on the monopole and another one relies on the aperture.

In order to have an insight into the influence of different parameters on the antenna, amounts of simulations have been conducted by Ansoft HFSS 13.0. The slot width W_r and the circular radius R_2



(a) (b)

Figure 2. Electric fields in circular slot at 2.3 GHz: fed by (a) Port 1 and (b) Port 2.

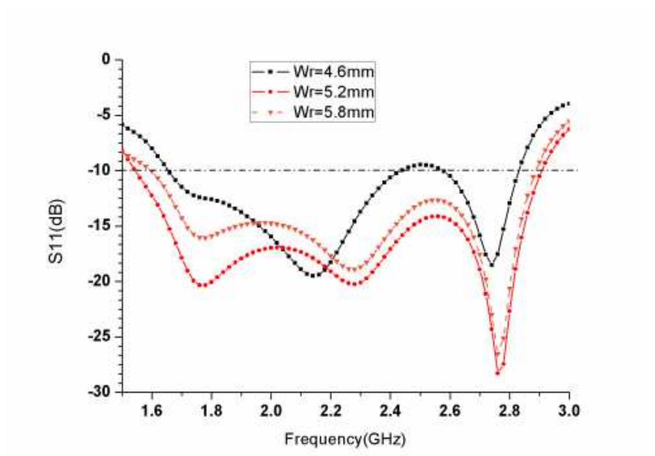


Figure 3. Simulated $|S_{11}|$ of the proposed antenna with different W_r.

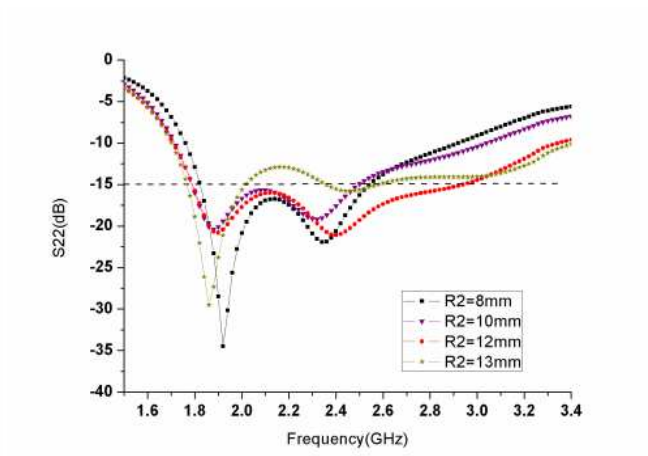


Figure 4. Simulated $|S_{22}|$ of the proposed antenna with different R_2.

are found important to enhance the bandwidth and the rectangular patch width W_1 plays an important role in improving the isolation. Therefore, we will focus on these three parameters. In the following discussion, when one parameter varies, the others will stay invariable.

Figure 3 shows the simulated $|S_{11}|$ of the antenna with different slot widths W_r. As illustrated, for $W_r = 5.2$ mm case, the bandwidth could arrive at its best condition. As for $|S_{22}|$, see Fig. 4, the effects of the circular patch with different R_2 on the bandwidth are given out. The larger the R_2 is, the wider bandwidth could be achieved. However, when R_2 equals 13 mm, the antenna is not matched so well. Based on the consideration above, R_2 is selected as 12 mm.

The simulated isolation of the antenna with different rectangular patch widths W_1 is plotted in Fig. 5. As shown, the isolation could be improved better than 48 dB across the entire operating bandwidth when W_1 equals 2.4 mm.

3. SIMULATION AND MEASUREMENT RESULTS

To verify the design, a prototype of the proposed antenna with the finally optimized parameters was fabricated and measured. The top and bottom views of the prototype are displayed in Figs. 6(a) and (b).

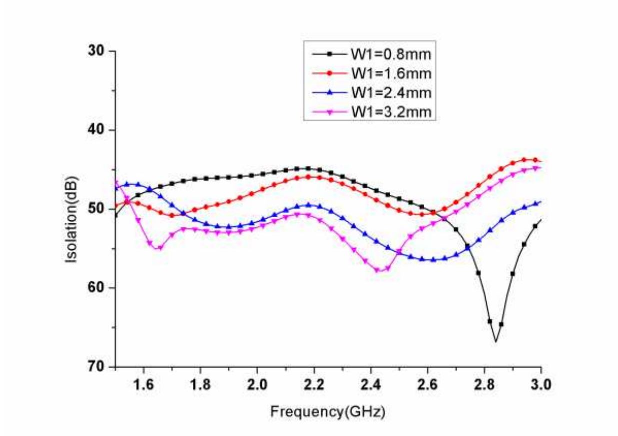
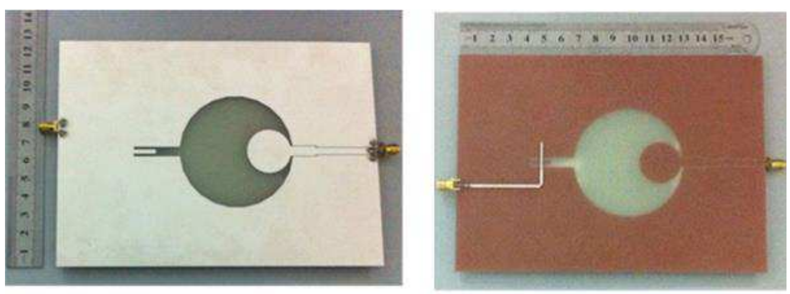


Figure 5. Simulated isolation of the proposed antenna with different W_1.



(a) (b)

Figure 6. Photographs of the proposed antenna (a) top and (b) bottom view.

3.1. Return Losses

Simulated and measured return losses for two ports are shown in Fig. 7. The simulated impedance bandwidths with SWR ≤ 2 are 61.3% (1.54–2.9 GHz) and 65.1% (1.70–3.34 GHz) while the measured impedance bandwidths are 61.5% (1.52–2.87 GHz) and 64.4% (1.61–3.14 GHz) for port 1 and port 2, respectively. Both of the two ports can cover DCS (1710–1880 MHz), PCS (1850–1990 MHz), UMTS (1920–2170 MHz), and WLAN/WiMAX (2400–2700 MHz) bands. As illustrated in Fig. 7, good agreement lies between the simulated and measured S-parameters. The slight discrepancy is mainly due to the material losses and the error in fabrication. It can also be observed several resonances are generated at the same time which result in such a wide bandwidth. Also, a detailed comparison between the proposed antenna and previous work in reference [9] is given out in Table 1.

Table 1. Comparison between the proposed antenna and antenna in [9].

	Port 1 (GHz)	Port 2 (GHz)	Common Bandwidth	Isolation (dB)	Size (mm^2)
Antenna in Reference [9]	51.8% 1.70–2.89	46.9% 1.68–2.71	45.8% 1.70–2.71	Better than 33 dB	150×150
Proposed Antenna	61.5% 1.52–2.87	64.4% 1.61–3.14	56.3% 1.61–2.87	Better than 40 dB	125×175

3.2. Isolation

Simulated and measured $|S_{21}|$ of the proposed antenna are also plotted in Fig. 7. Both results demonstrate the port-to-port isolation is higher than 40 dB over the entire operating bandwidth. Such an excellent isolation is attributed to the hybrid feeding technique and the rectangular patch with the size of $1.2 \times 2.4\,\text{mm}^2$.

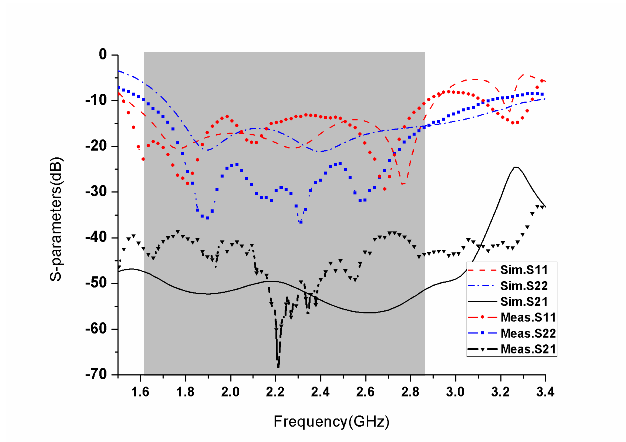


Figure 7. Simulated and measured S-parameters of the proposed antenna.

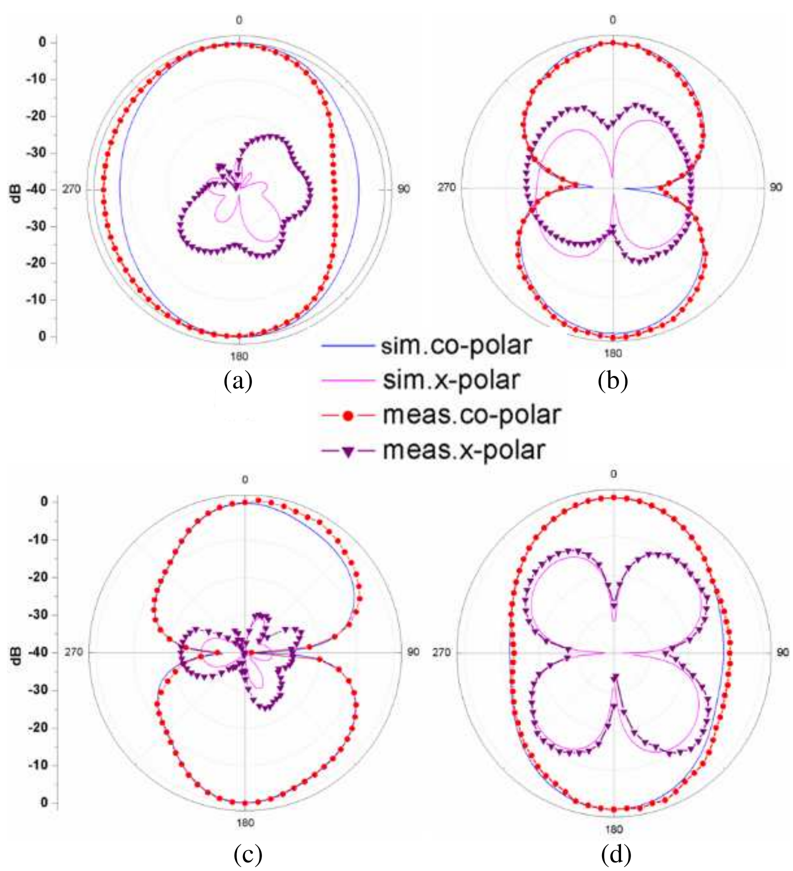


Figure 8. Measured and simulated radiation patterns at 1.9 GHz for port 1 (a) XZ-plane and (b) YZ-plane and port 2 (c) XZ-plane and (d) YZ-plane.

3.3. Radiation Patterns

Radiation patterns of the proposed antenna at frequencies of 1.9, 2.3, and 2.6 GHz for both polarization modes are measured in an anechoic chamber. The measured and simulated radiation patterns for both ports at these three frequencies are shown in Figs. 8–10, respectively. As expected, nearly omnidirectional radiation patterns could be found in H-plane compared with bidirectional radiation patterns in E-plane for both polarization at these three frequencies. It can be observed in E-plane there exist deep nulls in the region near $\theta = 90^\circ$ and 270°, which are caused by the cancellation of the fields radiated from two opposite magnetic current [10]. What is more, as the frequency increases, there is some distortion in H-plane for horizontal polarization shown in Fig. 10(a) because in part of the strip perpendicular to the E-shaped slot. Also, it deserves to be noted the cross polarization in H-plane is much higher than that in E-plane which can be explained by the asymmetrical structure of the antenna. Especially, when the antenna is excited from port 2, the cross polarization in H-plane becomes larger and larger with an increase in frequency which makes the antenna impossible to find its application. However, it can be observed from these radiation patterns that the signals of co-and cross polarizations are almost uncorrelated [6] and the cross polarization level lower than -20 dB in E-plane is small enough to be ignored. As discussed above, we can conclude this antenna can provide two independent channels in the mobile communication system. In addition, the size of ground should be properly selected as one side along x-axis larger than y-axis. Otherwise, the radiation patterns would become poor.

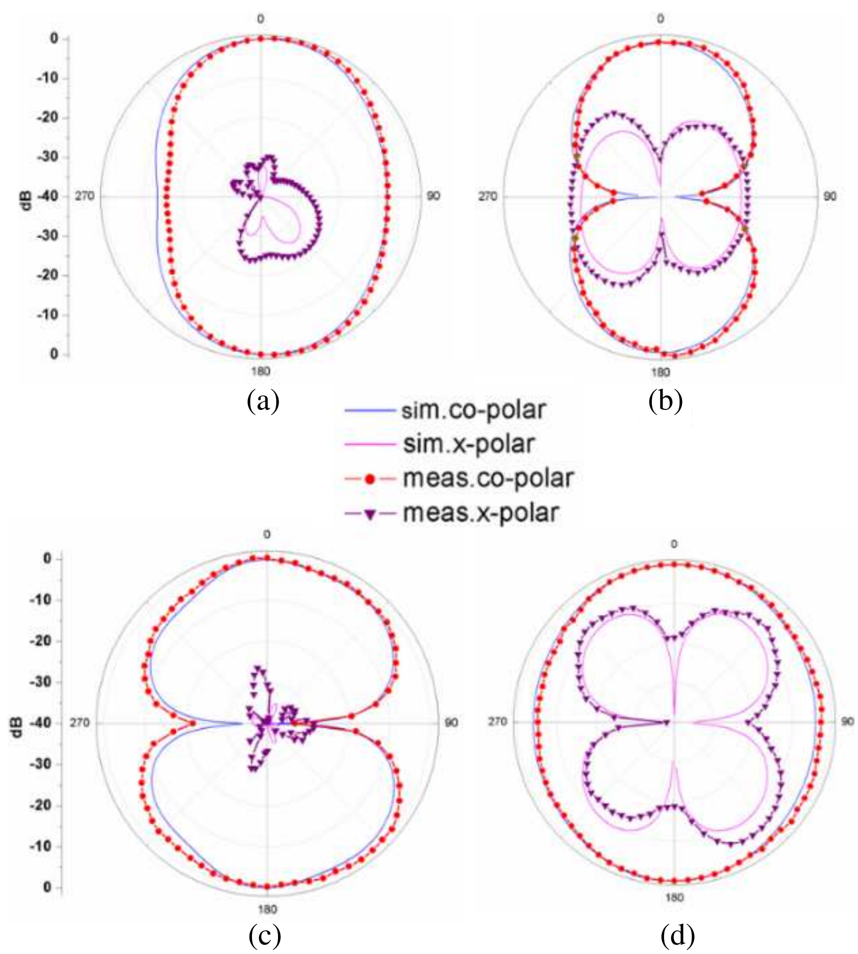


Figure 9. Measured and simulated radiation patterns at 2.3 GHz for port 1 (a) XZ-plane and (b) YZ-plane and port 2 (c) XZ-plane and (d) YZ-plane.

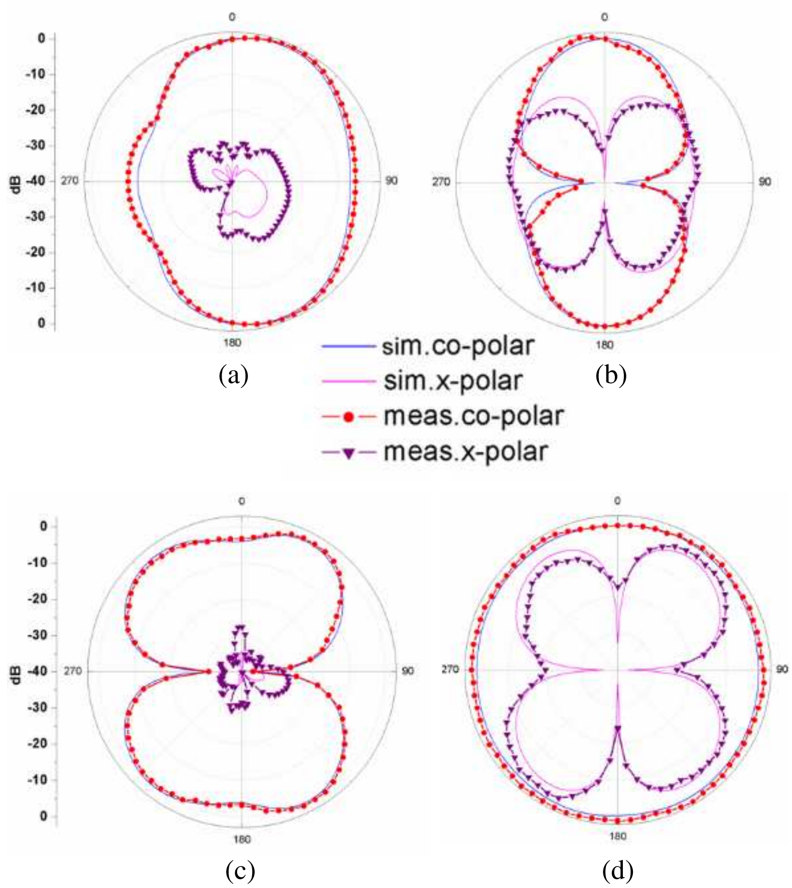


Figure 10. Measured and simulated radiation patterns at 2.6 GHz for port 1 (a) XZ-plane and (b) YZ-plane and port 2 (c) XZ-plane and (d) YZ-plane.

3.4. Antenna Gains

The measured and simulated gains of the proposed antenna against frequency excited from two ports are plotted in Fig. 11. The measured results are close to the simulated results. The gains vary in the range of 5.5 ± 1.5 dBi and 5 ± 1 dBi within the operating frequency, respectively. Since the proposed antenna has a large slot, the gains are relatively high, which makes it a good candidate for dual polarization application.

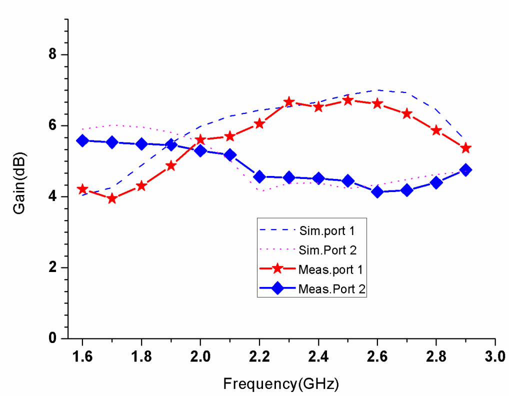


Figure 11. Measured and simulated gains for the proposed antenna.

4. CONCLUSION

A single-layer wideband dual-polarized antenna with high isolation is designed by adopting a hybrid feeding technique. The antenna achieves a wide common bandwidth of 56.3% (1.61–2.87 GHz) for both ports with reflection coefficient better than −10 dB. By loading the rectangular patch in the narrow rectangular slot, the isolation better than 40 dB can be obtained across the entire bandwidth. Moreover, the maximum gains of the proposed antenna are about 7 dBi and 6 dBi for port 1 and port 2, respectively. With these good features, the proposed antenna can be developed into an array, which will be a promising candidate for small base-station antenna applications in the picrocells and microcells.

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