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Wideband Dual-Polarized Crossed-Dipole Antenna with Parasitical Crossed-Strip for Base Station Applications

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Abstract—A wideband dual-polarized crossed-dipole antenna with parasitical crossed-strip for base-station applications is presented. By using a pair of orthogonal crossed-dipoles, two linear polarizations ($\pm 45^\circ$) are obtained. A parasitical crossed-strip is introduced to improve the impendence bandwidth and enhance the isolation (S_{12}) between the two orthogonal polarizations of the upper band. The antenna shows a wideband impedance characteristic about 34.9% for $S_{11} \leq -10\,\text{dB}$ ($+45^\circ$ polarization) and $S_{22} \leq -10\,\text{dB}$ (-45° polarization). High isolation ($S_{12} \leq -32\,\text{dB}$) between the two polarizations in the required band are obtained. The stable peak gain, unidirectional radiation patterns and low cross-polarization over the whole operating band are also achieved. Due to its good performance, simple fabrication technique and low cost, the antenna is very suitable for potential base station applications in mobile communication such as DCS, PCS and UMTS.

1. INTRODUCTION

Dual-polarized wideband antennas are widely needed in both radar and communication systems which need polarization diversity, and many dual-polarized antennas have been reported in literatures. For base station systems, the antenna has at least one cruciform radiating element module which is aligned using dipoles radiators, patch radiators or slot radiators as primary radiators, at angles of $+45^\circ$ and -45° with respect to vertical. Signals on two orthogonal polarizations help to reduce fading caused by multiple reflections at buildings, trees, etc. With the rapid development of base-station communications, antennas with wide impedance bandwidth become a necessary component in these systems. Many technologies were reported to broaden the bandwidth. The stacked patch antennas with aperture coupled feed [1–3] can provide wider bandwidth, but they involve structures with several layers resulting in high cost and difficulty in adjustment. Microstrip stacked patches for dual-polarization have been proposed to cover GSM1800 and UMTS in [4]. Patch elements fed with two probes with a relatively broad bandwidth [5, 6] have been introduced, but the bandwidth is not wide enough to cover both the GSM1800 and UMTS bands. Genetic algorithm has been used to design microstrip patches operating at GSM1800 up to UMTS in [7]. In [8–10], wideband dual-polarized printed dipole antennas are also designed. For simple structure and stable performance requirement, crossed metal dipole antenna is an usual choice. However, the impedance bandwidth performance of a traditional dipole antenna may not be good enough for some applications.

In this paper, we propose a design of a dual-polarized crossed-dipole antenna with a parasitical crossed-strip for bandwidth enhancement. Using the parasitical crossed-strip to effectively improve the impendence matching and the isolation between the two orthogonal polarizations of the upper band, the proposed antenna can achieve an operating bandwidth about 34.9% for $S_{11} \leq -10\,\text{dB}$ ($+45^\circ$ polarization) and $S_{22} \leq -10\,\text{dB}$ (-45° polarization) and high isolation ($S_{12} \leq -32\,\text{dB}$) between the two

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polarizations in the required band. Moreover, the stable peak gain, unidirectional radiation patterns, and low cross-polarization over the whole operating band are also achieved. With the simple fabrication technique, low cost and stable performance, the antenna is an excellent candidate for base-station applications in mobile communication such as DCS, PCS and UMTS. Details of the antenna design and results are presented and discussed.

2. ANTENNA DESIGN AND DISCUSSION

The configuration of the dual-polarized crossed-dipole antenna and coordinate system are shown in Figure 1(a). The antenna mainly comprises a pair of crossed-dipoles with dimension of $L_3 \times W_1$, parasitical crossed-strip with dimension of $L_4 \times W_2$, two inverted L-shaped feed strips and a ground plane with dimension of $L_1 \times L_2$. With the large ground plane, the unidirectional radiation pattern of the antenna is obtained. The side view and the detail structures of the crossed-dipole and parasitical crossed-strip are shown in Figures 1(b) and (c). The crossed-dipole is composed of two dipoles whose axes are orthogonal and the parasitical crossed-strip is located on the top of the crossed-dipole, and the distance between the crossed-dipole and the parasitical crossed-strip is H_4, which can affect the impedance matching of the upper band.

The feed mechanism as shown in Figure 1(d) is two inverted L-shaped strips, which is designed into two parts: a vertical strip and a horizontal strip. The vertical strip with the hollow metal cylinder acts as a coaxial line that feeds to an arm of the dipole directly. One end of the coaxial line is connected to an SMA connector and another end joined to the edge of the horizontal strip which feeds to another

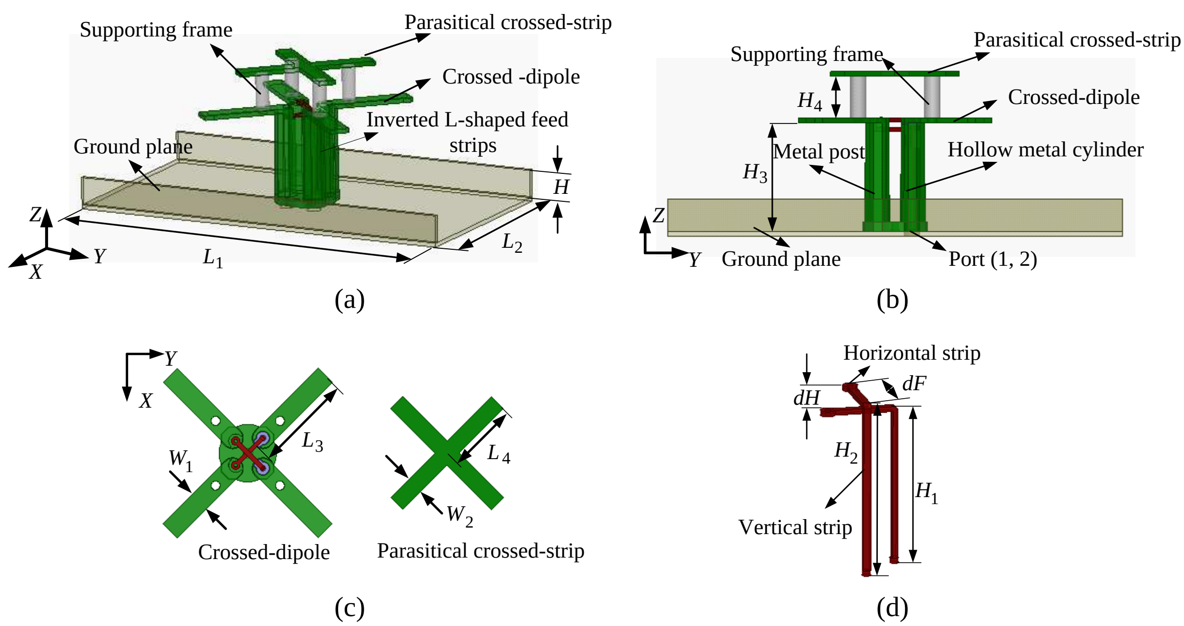

Figure 1. Geometry of the proposed design. (a) 3D view; (b) side view; (c) detail view of the crossed-dipole and the parasitical crossed-strip; (d) detail view of the inverted L-shaped feed strips.

Table 1. Dimensions of the proposed antenna.

Parameters	L_1	L_2	L_3	L_4	H_1	H_2	dH
Values(mm)	200	130	34.5	25	32	35	3
Parameters	W_1	W_2	H_3	H_4	H	dF	
Values(mm)	7	6	33.5	13	10	13	

arm for the dipole. The distance between the crossed-dipole and ground plane (H_3) is about a quarter of wavelength at the center frequency, thus, the outer part of the coaxial line and the shorting metal post will produce a balun, which is used to improve the impedance matching of the antenna. This kind of balun is used in some antenna arrays for base stations [11]. With the uncomplicated structure, a simple fabrication technique and low cost are also obtained. The final optimal antenna parameters are shown in Table 1.

In the following, details of the operating principle of the proposed antenna are discussed. The antenna performance was computed with the commercial software Ansoft High Frequency Structure Simulator (HFSS 13.0). Figure 2 shows the simulated reflection coefficients against frequency for the designed antenna. It can be observed that for $S_{11} \leq -10\,\text{dB}$ (Port 1, $+45°$ polarization) the impedance bandwidths are from 1.63 to 2.35 GHz, and for $S_{22} \leq -10\,\text{dB}$ (Port 2, $-45°$ polarization) the impedance bandwidths are from 1.63 to 2.3 GHz, which clearly cover the required bandwidths of the DCS, PCS and UMTS applications. Meanwhile, to examine the effects of the parasitical crossed-strip on the antenna's matching condition, the simulated results of reflection coefficients for the case without the parasitical crossed-strip are also studied and plotted in Figure 2. Obviously, without the parasitical crossed-strip, it is seen that a resonant mode is excited at the lower band only, which is far from covering the whole band. With the parasitical crossed-strip, a new resonant point in the upper band is produced for bandwidth enhancement. Figure 2 also presents the simulated isolation (S_{12}) between the two orthogonal ports. It can be observed that the isolation between the two orthogonal polarizations at the upper band is also enhanced with the parasitical crossed-strip. These results clearly indicate that existence of the

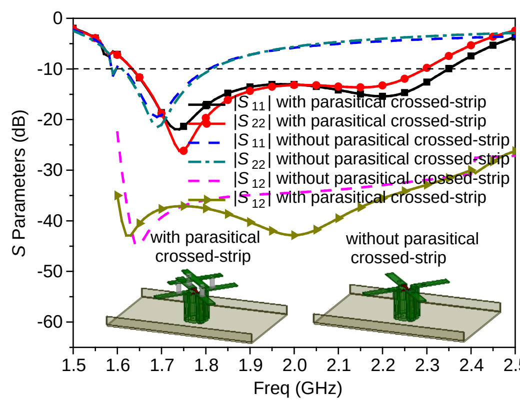

Figure 2. Simulated reflection coefficients and the isolation between without the parasitical crossed-strip and the proposed antenna.

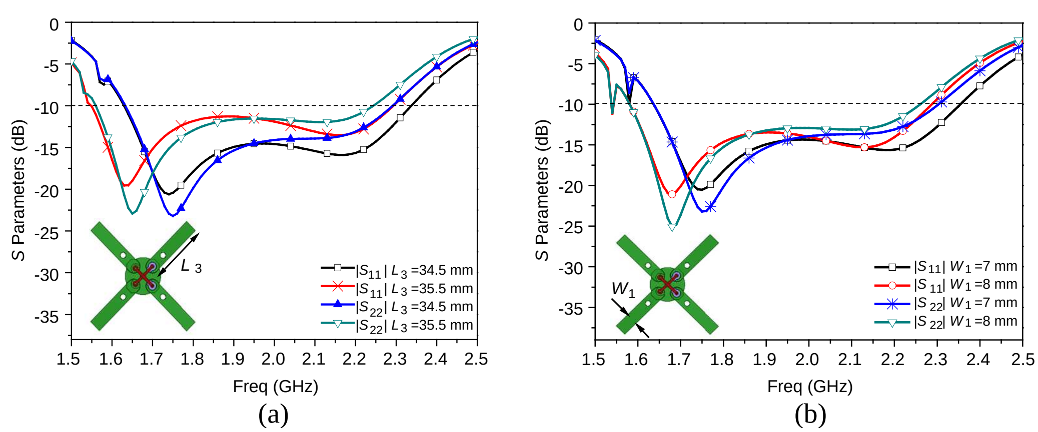

Figure 3. Simulated reflection coefficients for different values of L_3 and W_1.

parasitical crossed-strip can significantly improve the impedance bandwidth and the isolation of the upper band.

The parametric study of the dimension of the dipole arm on the antenna's impedance characteristics is also conducted. Figures 3(a), (b) show the simulated reflection coefficients for the length of the arm (L_3) varied from 34.5 to 35.5 mm and the width of the arm (W_1) varied from 7 to 8 mm. In the figures, it can be seen that the two parameters both have very small effects on the antenna's upper band; on the other hand, there are significant effects on the lower band, in which the excited resonant mode is shifted to lower frequencies with increases of the parameters.

The effects of the parasitical crossed-strip on the impedance bandwidth are also shown in Figure 4. Figures 4(a), (b) present the simulated reflection coefficient by varying the length (L_4) and width (W_2) of the parasitical crossed-strip. It can be seen that with decrease in L_4 and W_2, the resonant point of the upper band is shifted to upper band whereas that of the lower band is almost unchanged. Figure 4(c) presents the tuning effect of the distance (H_4) between the crossed-dipole and the parasitical crossed-strip for the proposed antenna with selected values from 13 to 14 mm on reflection coefficient. With the increase of H_4, the coupling between the crossed dipole and the parasitical crossed-strip becomes weak, the impedance matching of the upper band is deteriorated, whereas that of the lower band is almost unchanged. This confirms that the resonant mode of the upper band is mainly related to the dimensions of the parasitical crossed-strip, and hence the variations in the three parameters will cause the shifting of the upper band. With $L_4 = 25$ mm, $W_2 = 6$ mm and $H_4 = 13$ mm, the optimal results are obtained for the proposed antenna.

These results clearly indicate that all these parameters have great effects on the impedance matching of the antenna. In order to have more indications on the contribution of the individual parts of this

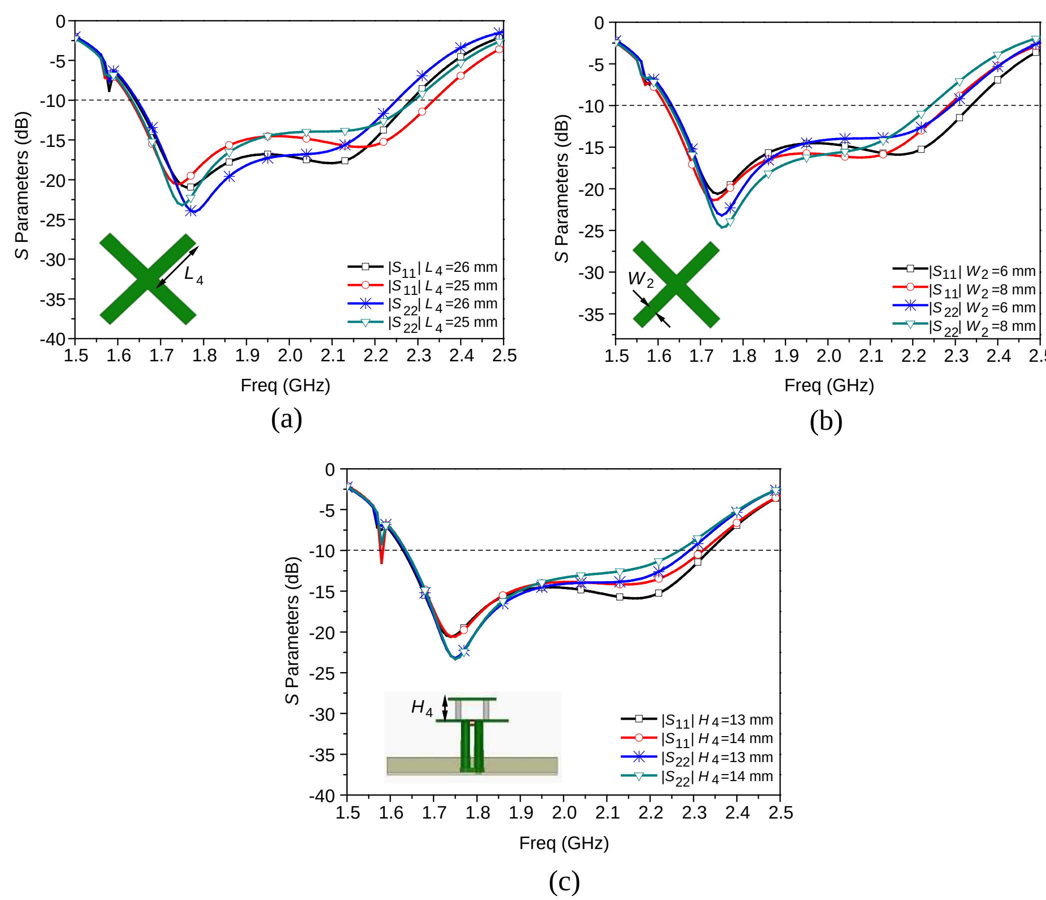

Figure 4. Simulated reflection coefficients for different values of L_4, W_2 and H_4.

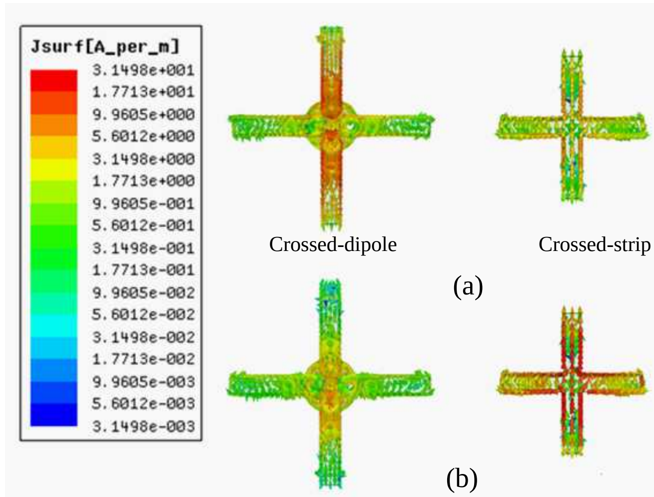

Figure 5. Simulated surface current distributions at (a) 1.74 GHz, (b) 2.18 GHz.

antenna, the surface current distributions at 1.74 GHz and 2.18 GHz are investigated in Figure 5. From the figure, it can be seen that at lower frequency (1.74 GHz), high current density can be observed along the crossed-dipole, which can confirm that the lower band is mainly determined by the dipole. On the other hand, at upper frequency (2.18 GHz), the current distribution around the crossed-dipole is relatively weak, but in the parasitical crossed-strip is strong.

3. EXPERIMENTAL RESULTS

A prototype of the proposed antenna was fabricated according to these design parameters, as shown in Figure 6. The measured results are obtained with Agilent E8363B network analyzer and an anechoic chamber. Figure 7 presents the measured and simulated S parameters against the frequency for the proposed antenna. Obviously, wideband operations are obtained. For $S_{11} \leq -10$ dB (Port 1, $+45^\circ$ polarization) the measured impedance bandwidths are from 1.61 to 2.42 GHz and for $S_{22} \leq -10$ dB (Port 2, -45° polarization) the measured impedance bandwidths are from 1.63 to 2.32 GHz. In the figure, the measured and simulated isolations between the two polarizations are also given, which are higher than -32 dB over the entire bandwidth. The measured and simulated reflection coefficients agree

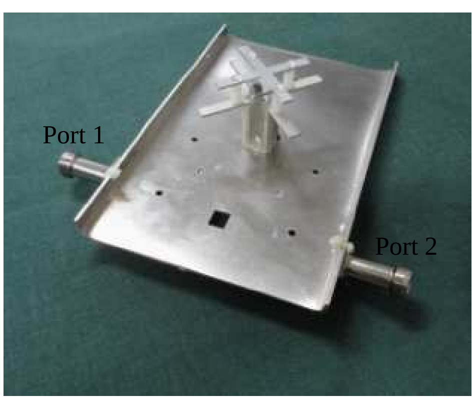

Figure 6. Photograph of the proposed antenna.

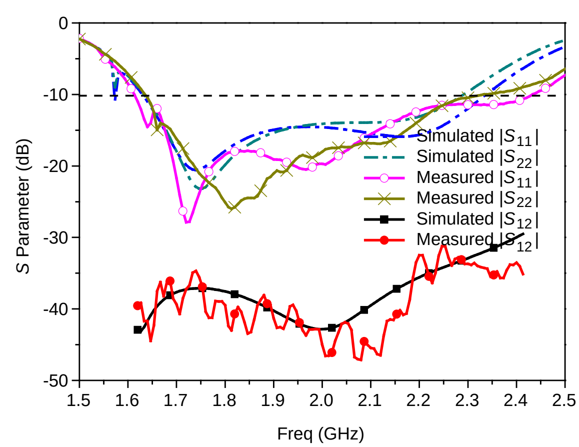

Figure 7. Simulated and measured S-parameters of the proposed antenna.

very well with each other. However, for isolation results, the agreement is not so good, but the trend is similar. The discrepancies may be due to the fabrication tolerance, especially because the horizontal strips of the inverted L-shaped feed strips at the feeding points for orthogonal polarizations cannot be placed exactly orthogonally and the distance cannot be exact.

The measured radiation patterns of the co-polarization and the cross-polarization for the proposed antenna for port 1 in the XOZ-plane and YOZ-plane at 1.71, 1.92 and 2.17 GHz are plotted in Figure 8, whereas that of port 2 is almost the same. The half-power beamwidths in the XOZ-plane (the horizontal plane) are about $65^\circ \pm 5^\circ$ over the whole band. For the operating bands, it can be observed that the measured results have maximum normal cross-polarization level about -20 dB in XOZ- and YOZ-

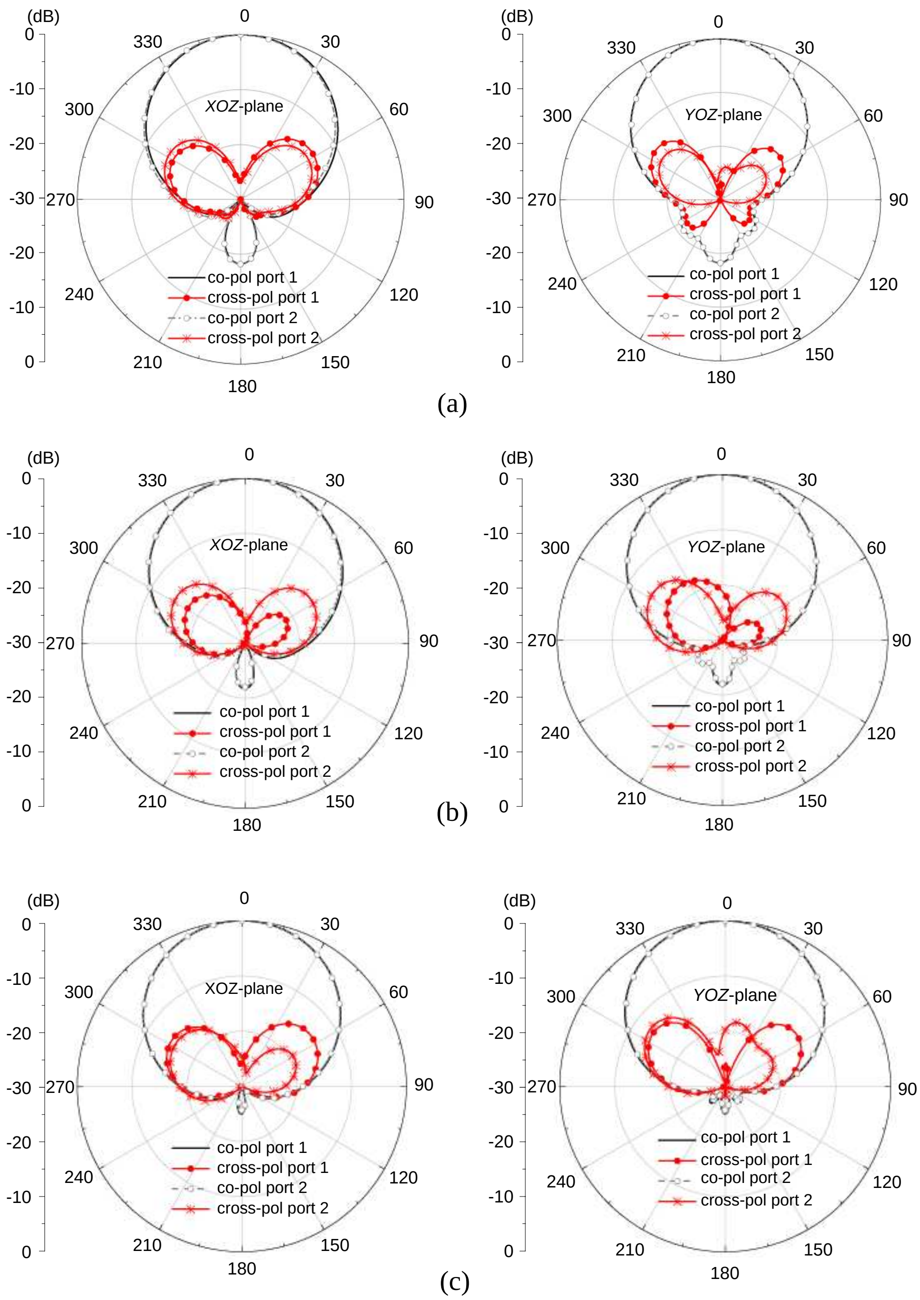

Figure 8. Measured radiation patterns for the proposed antenna at (a) 1.71 GHz, (b) 1.92 GHz, (c) 2.17 GHz.

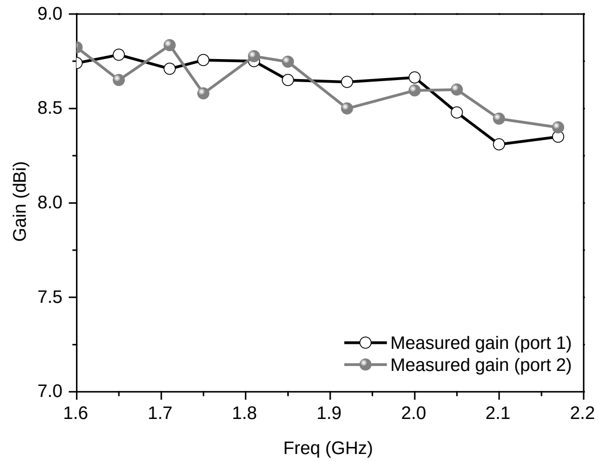

Figure 9. Measured gain of the proposed antenna.

Table 2. Summary of antenna performances for the proposed and reference antennas.

	This work	**[6]**	**[8]**
Bandwidth (S_{11})	1.61–2.42 GHz ($S_{11} < -10$ dB)	1.68–2.06 GHz ($S_{11} < -14$ dB)	1.71–2.17 GHz ($S_{11} < -14$ dB)
Bandwidth (S_{22})	1.63–2.32 GHz ($S_{22} < -10$ dB)	1.59–2.03 GHz ($S_{22} < -14$ dB)	1.71–2.17 GHz ($S_{22} < -14$ dB)
Isolation (S_{12})	≤ -32 dB	≤ -25 dB	≤ -30 dB
Gain	≥ 8.4 dBi	> 6.0 dBi	9.6 dBi

planes, and the front-to-back ratio is better than -18 dB. Figure 9 shows the peak antenna gain for the proposed antenna. Over the whole band, the antenna gain is varied from about 8.4 to 8.8 dBi.

Table 2 summarizes the antenna performances of this work and the reference antennas [6, 8] in terms of the bandwidth, isolation (S_{12}) and gain. Comparison shows that the proposed antenna significantly outperforms the references in terms of isolation ($S_{12} \leq -32$ dB). In addition, it demonstrates a slightly increased impedance bandwidth and better gain (≥ 8.4 dBi).

4. CONCLUSION

The wideband dual-polarized crossed-dipole antenna with the parasitical crossed-strip is presented and investigated. Using the parasitical crossed-strip to achieve another resonate point and effectively improve the impendence bandwidth and the isolation between the two orthogonal polarizations of the upper band, the proposed antenna can achieve a wideband operating impendence characteristics about 34.9% for $S_{11} \leq -10$ dB ($+45°$ polarization) and $S_{22} \leq -10$ dB ($-45°$ polarization) and high isolation ($S_{12} \leq -32$ dB) between the two polarizations in the required band. Stable unidirectional radiation patterns and low cross-polarization over the whole operating band are also provided. Due to these good performances, simple fabrication technique and low cost, the antenna has wide and potential applications for wireless communication system.

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