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Research Article

Dual-Polarized Cross Bowtie Dipole for 3G and LTE Applications

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A dual-polarized cross bowtie dipole element with parasitical circular patch and vertical metal cylinders for base station antennas is presented. A pair of orthogonal cross bowtie dipoles, with a reflector ground plane, is used to obtain the two linear polarizations. Besides two inverted L-shaped feed strips and two shorted feed baluns, parasitical circular patch is introduced to improve the impendence bandwidth and vertical metal cylinders are employed to decrease the lateral dimensions of the antenna. A wideband impedance characteristic of about 45.6% for VSWR $\leq$ 1.5 (+45° polarization) and VSWR $\leq$ 1.5 (−45° polarization) ranging from 1.76 to 2.80 GHz is obtained. Moreover, the stable peak gain, unidirectional radiation patterns, high isolation between the two orthogonal polarizations, and low cross-polarization over the whole operating band are also achieved. The proposed antenna is very suitable for potential base station applications in mobile communication such as TD-SCDMA, WCDMA, and CDMA2000 and LTE applications.

1. Introduction

For base station systems, the antenna has at least one cruciform radiating element module, that is, aligned using dipoles radiators, patch radiators, or slot radiators as primary radiators, at angles of +45° and −45° with respect to vertical or horizontal. Signals on two orthogonal polarizations help to reduce the fading caused by multiple reflections at buildings, trees, and so forth. With the rapid development of base station communications, antennas with wide impedance bandwidth become a necessary component in the 3G systems, such as TD-SCDMA, WCDMA, and CDMA2000 (1880–2170 MHz) [1] and the LTE (4G) systems, which operate in the 2.3 GHz (2300–2400 MHz) and the 2.6 GHz (2570–2690 MHz) bands [2]. Many technologies were reported to broaden the bandwidth. The stacked patch antennas with aperture coupled feed [3–5] can provide wider bandwidth; however, layer structures are involved, which lead to the high cost and the difficulty in adjustment. Broadband patch elements fed with two probes [6, 7] were introduced, but the bandwidth is not wide enough to cover both the 3G and the LTE bands. In [8–10], wideband dual-polarized printed dipole antennas were proposed. The cross metal dipole antenna is usually used to achieve the simple structure and the stable performance. However, the impedance bandwidth performance of a traditional dipole antenna may not be good enough for some other applications.

In this paper, we propose a dual-polarized cross bowtie dipole antenna with inverted L-shaped feed strips and parasitical circular patch for bandwidth enhancement. Using the parasitical circular patch to effectively improve the impendence matching and the vertical metal cylinders to decrease the lateral dimensions of the antenna, the proposed antenna can achieve an operating bandwidth of about 45.6% for VSWR $\leq$ 1.5 (+45° polarization) and VSWR $\leq$ 1.5 (−45° polarization) ranging from 1.76 to 2.80 GHz and better than 28 dB for the isolation between the two polarizations. Moreover, the stable peak gain, the unidirectional radiation patterns, and the low cross-polarization over the whole operating band are also achieved. With simple structure and stable performance, it is an excellent candidate for the base station antennas in mobile communication. Details of the antenna design and both numerical and experimental results are presented and discussed.

2. Antenna Design and Discussion

The configuration of the dual-polarized cross bowtie dipole and coordinate system are shown in Figure 1(a). The antenna is mainly composed of a pair of cross bowtie dipole, inverted L-shaped feed strips, a parasitical circular patch, vertical metal cylinders, and a ground plane with dimension of $L1 \times L2 \times H$. The unidirectional radiation pattern of the antenna is obtained via the large ground plane. The side view and the detailed structures of the cross bowtie dipole are shown in Figures 1(b) and 1(c). The cross bowtie dipole is a pair of dipoles whose centers are colocated and whose axes are orthogonal. Each bowtie dipole has a pair of square arms. Each arm is notched by a square hole at the center. The distance between the cross bowtie dipole and the ground plane is about a quarter of wavelength at the center frequency. The parasitical circular patch is employed on the top of the cross bowtie dipole to improve the impedance matching; on the other hand, it can enhance the impedance bandwidth by achieving the other resonant mode at the upper band. The distance between the cross dipole and the parasitical circular patch is $H3$. The diameter of the parasitical circular patch is D.

The feed mechanism, as shown in Figure 1(d), is an inverted L-shaped strip. The strip is divided into two parts: a vertical strip and a horizontal strip. The vertical line with the hollow metal cylinder acts like a coaxial feeder, whose outer part is connected to one arm of the dipole, while the inner part is connected to the other arm. The outer part of the coaxial feeder is also connected to the ground, which will connect one arm of the dipole to the ground. There is another metal post at the symmetrical place with the coaxial feeder connecting the other arm of the dipole to the ground. The outer part of the coaxial feeder and the shorting metal post will produce a balun, which will improve the feed of the antenna. The two orthogonal and horizontal feed strips are staggered up and down. The distance between the two orthogonal feed strips is dH. It is noted that the distance (dH) can adjust the isolation between the two orthogonal polarizations. Moreover, the stubs are employed to adjust the port impedance matching. The final optimal antenna parameters are listed in Table 1.

The parametric study is conducted to characterize the relationship between the length of the vertical cylinder and the impedance characteristics of the proposed antenna. Figure 2(a) shows the simulated VSWR where the length of vertical metal cylinder is changing from 8 to 12 cm; in Figure 2(b), the range for the diameter of vertical metal cylinder is from 1 mm to 2 cm. From these figures, it can be seen that the two parameters hardly affect the upper band of the antenna, while the lower band of the antenna is badly affected. The matching point moves with the changing of parameters. It should be noted that the size of the antenna is significantly reduced due to the existence of the vertical metal cylinders. With $H2 = 10$ mm and $dd = 1.5$ mm, the optimal results are obtained for the proposed antenna.

The effect of the parasitical circular patch on the impedance bandwidth is shown in Figure 3. Figure 3(a) presents the simulated VSWR, where the diameter (D) of the parasitical circular patch is changing. It can be seen that with a decrease in D, the resonant point of the upper band is shifted to lower band, whereas that of the lower band is almost unchanged. Figure 3(b) presents the tuning effect of the distance ($H3$) between the cross bowtie dipole and the parasitical circular patch on VSWR. With the increase of $H3$, the coupling between the cross bowtie dipole and the parasitical circular patch is becoming weak, and the resonant point of the upper band is shifted to upper band, 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 circular patch, and hence the variations in the two parameters will cause the shifting of the upper band. With $D = 32$ mm and $H3 = 7$ mm, the optimal results are obtained for the proposed antenna.

Table 1: Dimensions of the proposed antenna.

Parameters	Values (mm)
$L1$	200
$L2$	117
L	48
D	32
$H1$	29.5
$H2$	10
dH	3
$P1$	29
$P2$	26
B	1
S	6.5
H	10
g	3
dd	1.5
$q1$	6.2
$b1$	9.5
$b3$	7
$q2$	7
$b2$	3.6
$b4$	4
$T1$	17.6

3. Experimental Results

A prototype of the proposed antenna was fabricated and is shown in Figure 4. Agilent E8363B network analyzer was used to do the measurement, and the measurement was performed in the anechoic chamber. Figure 5 also presents the measured and simulated VSWR against the frequency for the proposed antenna. Obviously, wideband characteristic is obtained. For VSWR $\leq$ 1.5 (port1, $+45^\circ$ polarization), the measured impedance bandwidths are from 1.76 to 2.81 GHz, and for VSWR $\leq$ 1.5 (port2, -45° polarization), the measured impedance bandwidths are from 1.76 to 2.80 GHz. In Figure 6, the measured and simulated isolation between the two polarizations are also given, both better than 28 dB over the entire bandwidth. The discrepancy between the simulated

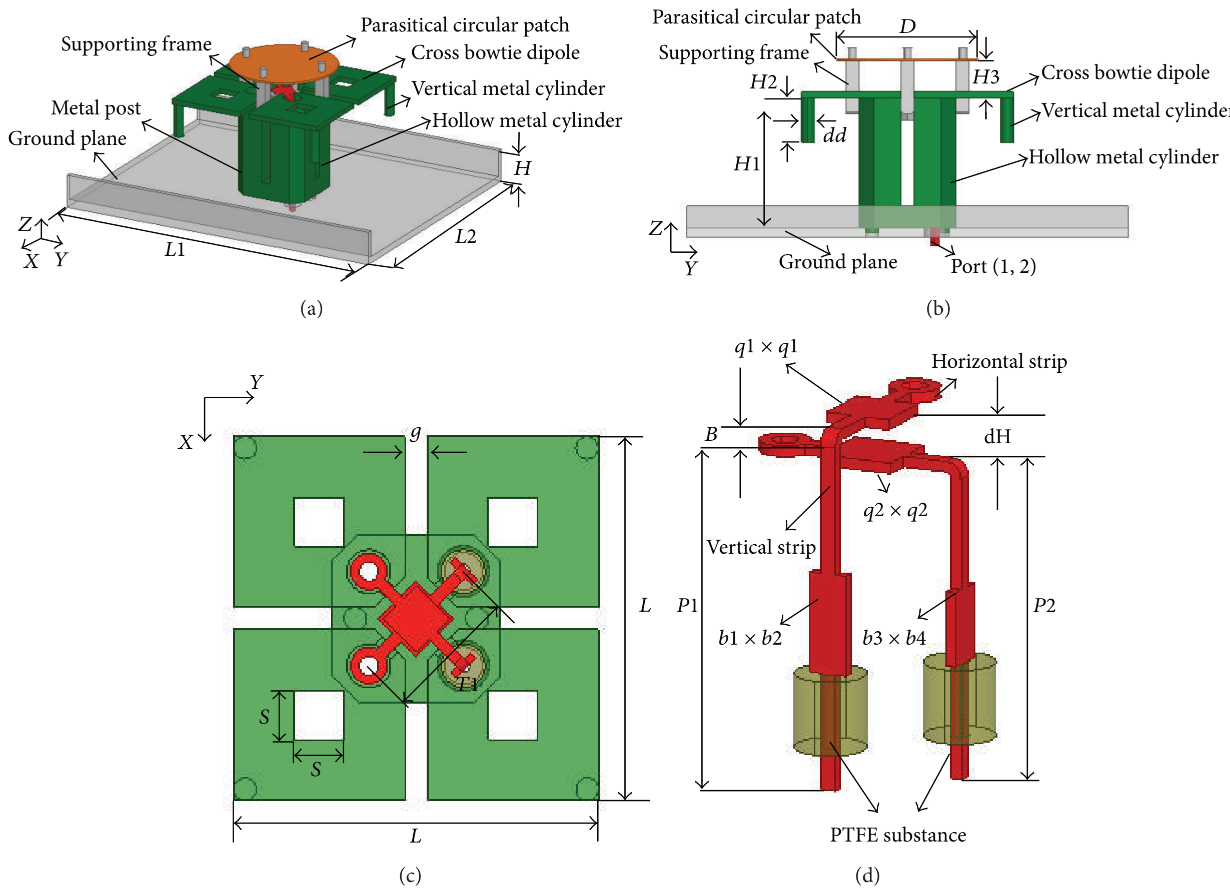


Figure 1: Geometry of the proposed design: (a) 3D view; (b) side view; (c) detailed view of the cross bowtie dipole; (d) detailed view of the feed strips.

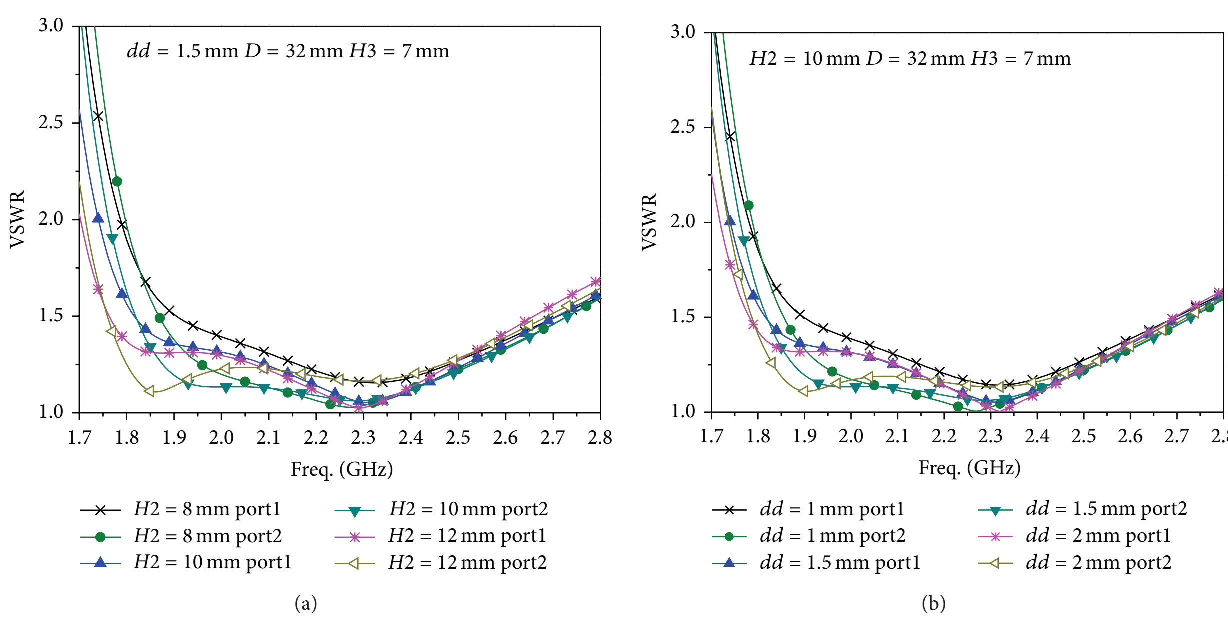
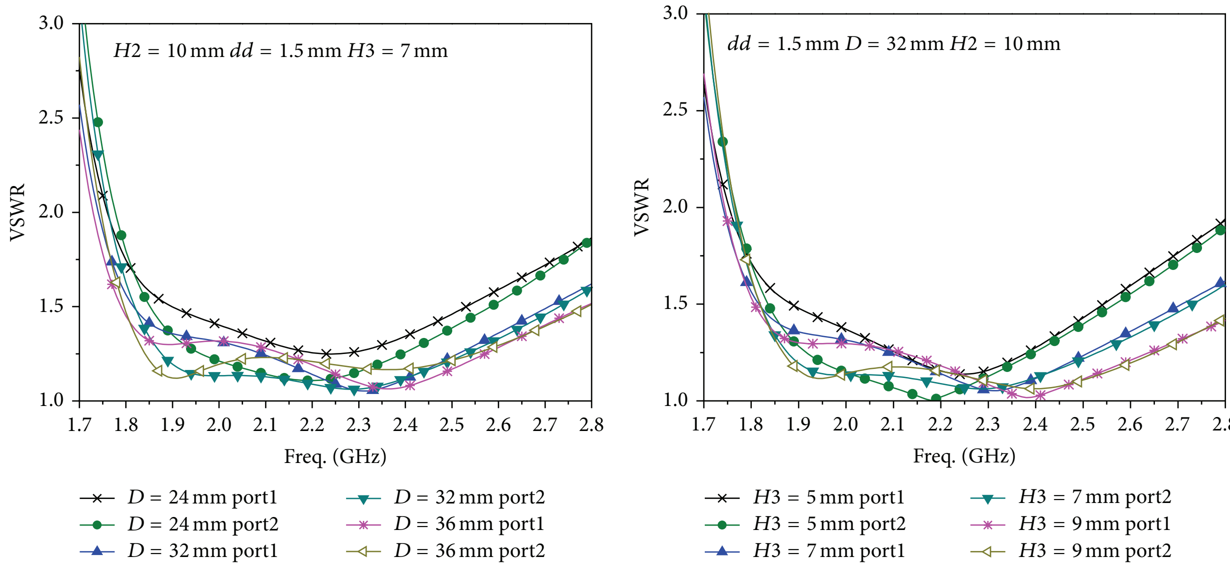


Figure 2: Simulated VSWR for different values of $H2$ and dd.



(a) (b)

FIGURE 3: Simulated VSWR for different values of D and $H3$.

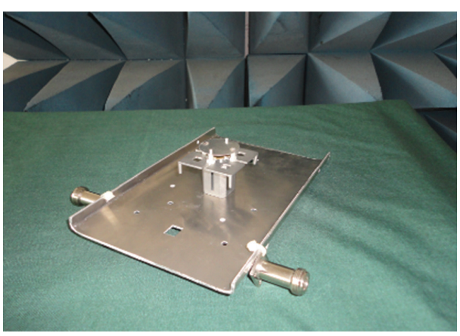


FIGURE 4: Photograph of the proposed antenna.

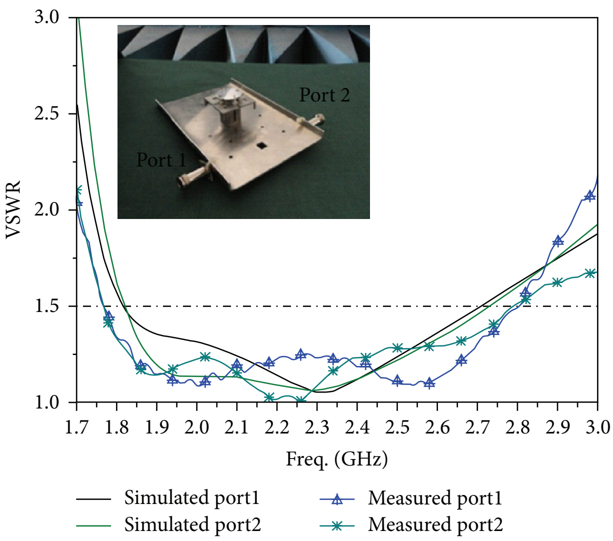


FIGURE 5: Simulated and measured VSWR against frequency.

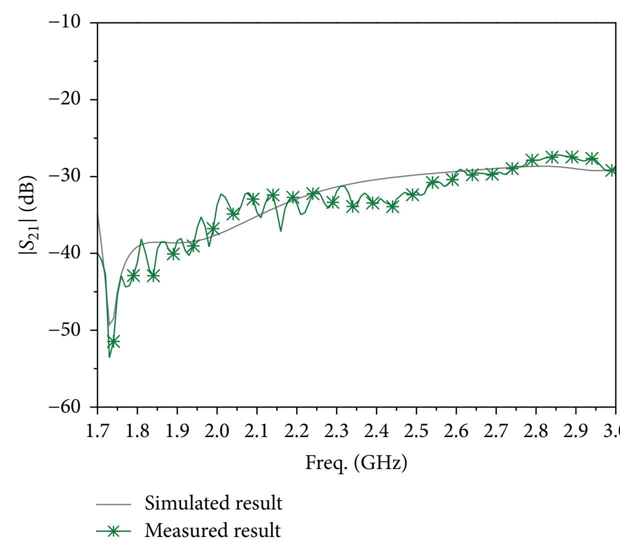


FIGURE 6: Simulated and measured |S21| of the proposed antenna.

and measured results is probably caused by fabrication tolerance.

The measured radiation patterns of the copolarization and the cross-polarization for the proposed antenna in the *XOZ*- and *YOZ*-plane at 1.8, 2.2, and 2.6 GHz are plotted in Figure 7. The half-power beam widths 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 of about −21 dB in the *XOZ*-plane and the front-to-back ratio is better than −22 dB. Figure 8 shows the peak gain for the proposed antenna. Over the whole band, the antenna gain ranges from 8.5 to 9 dBi. The loss of the proposed antenna (dielectric loss, conductor loss, and surface wave loss) is so

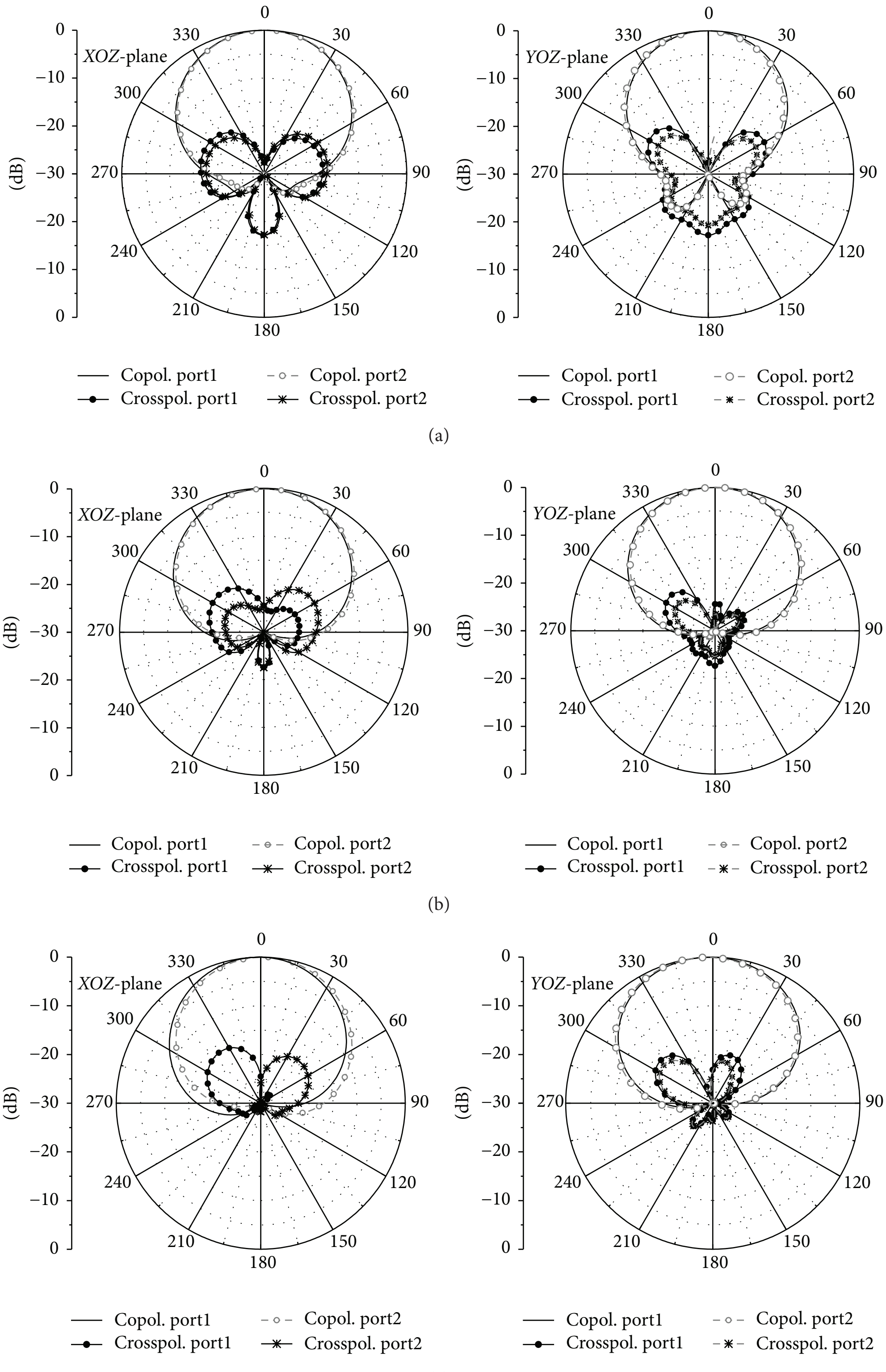


Figure 7: Measured radiation patterns for the proposed antenna at (a) 1.8 GHz; (b) 2.2 GHz; (c) 2.6 GHz.

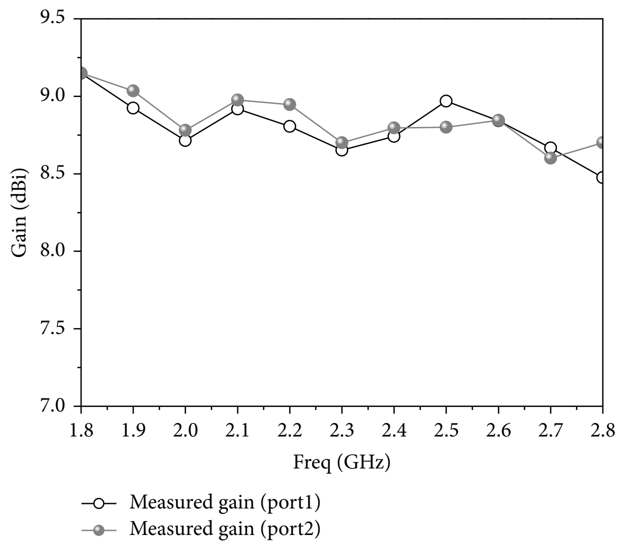


Figure 8: Measured gain of the proposed antenna.

small that the radiation efficiency is close to one hundred percent.

4. Conclusion

A wideband dual-polarized cross bowtie dipole antenna with inverted L-shaped strip feed, vertical metal cylinder, and parasitical circular patch is presented and investigated. Using the parasitical circular patch to improve the impendence bandwidth, the proposed antenna can achieve a wideband operating impendence characteristic. Stable unidirectional radiation patterns, high isolation between the two orthogonal polarizations, and low cross-polarization over the whole operating band are also realized. Based on the performance presented above, this novel antenna has wide and potential applications for wireless communication system.

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