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A Broadband Dual-Polarized Omnidirectional MIMO Antenna for 4G LTE Applications

Yiqiang Yu[1, 2, 3, 4], Hongmei Zhang[1, *], and Zhizhang Chen[3, 4, 5]

Abstract—A low-profile broadband omnidirectional MIMO antenna with dual-polarization is proposed for 4G LTE applications. It consists of two orthogonally polarized radiating elements with separate ports. The horizontally polarized element consists of four printed arc dipoles, a broadband balun feeding network, four arc parasitical strips and four double L-shaped parasitical strips. It exhibits a 48.9% fractional bandwidth (return loss $>$ 10 dB) from 1.70 GHz to 2.80 GHz with a cross-sectional size less than $100 \times 100\,\mathrm{mm}^2$. The vertically polarized element consists of a discone, a round sleeve, and a top-loading ring shorted to the ground-plane with three equally-spaced pins. It provides a 47.3% fractional bandwidth (return loss $>$ 10 dB) from 1.68 to 2.72 GHz with an overall volume less than $84 \times 84 \times 22\,\mathrm{mm}^3$. In addition, an isolation of 25 dB is achieved in the overlapping band of two elements and the cross-polarization levels for both radiating elements are lower than 20 dB.

1. INTRODUCTION

Recently, increasing demand for speed and stability of wireless communication systems has led to intensive research and development in antenna designs with polarization diversity in substitution for space diversity. Especially in a complex multipath environment, a dual-polarized MIMO antenna system with omnidirectional radiation patterns can significantly improve the communication performance of an indoor wireless network or a base station. A lot of typical dual-polarized MIMO antennas system consists of a vertically polarized (VP) antenna element and a horizontally polarized (HP) antenna element [1–4, 12, 13]. Although some of them have a good isolation, most of them is unable to meet the 4G Long Term Evolution (LTE) bandwidth requirements. Besides, the size of the antenna is relatively large, not suitable for interior decoration and installation. Many HP antennas have been proposed [5–9], however, they are unable to meet the 4G LTE bandwidth requirements. Several designs have been investigated as the potential candidates for the VP antenna element of a 4G LTE MIMO antenna system. In [10], a wideband monocone antenna with shorted top hat was presented, and it provides a fractional bandwidth of 99%. However, it requires a large ground-plane (diameter of 253 mm) to produce adequate impedance matching for the lower end of the operational bandwidth, which makes it unsuitable for the ceiling-mounted base stations.

In this paper, a new broadband omnidirectional 2-port MIMO antenna system is presented to provide polarization diversity for 4G LTE systems and networks, which refers to the previous work [11], but in this paper we do not cover the low frequency. The smaller bandwidth makes the antenna have a better omnidirectional radiation pattern. The return loss, impedance bandwidth, radiation patterns and gain of the proposed antenna are presented, and the isolation between the VP and the HP elements is also discussed.

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* Corresponding author: Hongmei Zhang (zhanghongmei2013@hotmail.com).
[1] School of Information Engineering, East China Jiaotong University, Nanchang 330013, China. [2] The State Key Laboratory of Millimeter Wave, Nanjing, China. [3] School of Dalhousie University, Halifax, NS, Canada. [4] ECE Department, Canada. [5] School of Electronic Engineering, University of Electronic Science and Technology, Chengdu, Sichuan, China.

2. HORIZONTAL POLARIZATION ELEMENT DESIGN

As shown in Figs. 1(a)–(b), the proposed HP antenna element consists of four printed arc dipoles, four arc parasitical strips and four double L-shaped parasitical strips on the top side of the substrate and a broadband balun feeding network on the bottom side. The element is fed by a 50-Ω coaxial cable with an SMA connector from the center of the top plane. It is coupling fed by the balun feeding network. The feed point is given in Fig. 1(d). Four parasitical strips and four double L-shaped parasitical strips are applied to the top plane of the substrate to suppress the reactance of the antenna for bandwidth enhancement. The step increments of the balun are optimized for broadband impedance matching. When excited, the symmetric layout of the radiators will yield a synchronous clockwise or counter clockwise current flow on the surface of the radiators, and it in turn generates omnidirectional radiation in azimuth plane. Fig. 2(a) depicts the return loss of the HP element with and without parasitical

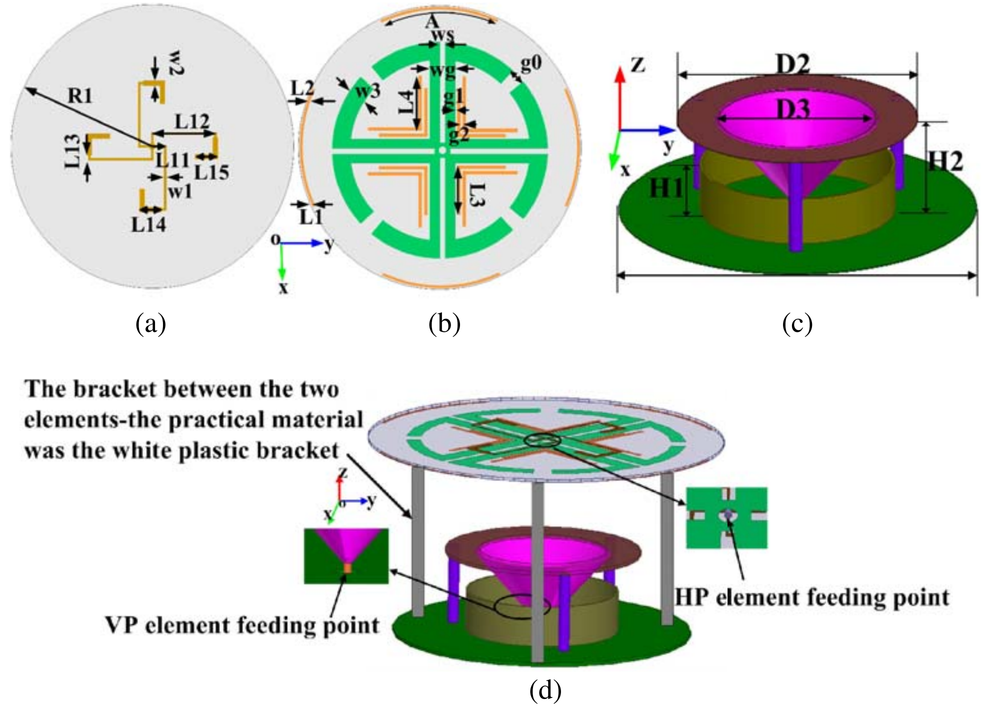


Figure 1. Geometry of the proposed MIMO antenna; (a) HP element, bottom plane; (b) HP element, top plane; (c) VP element; (d) The 3D view of the antenna.

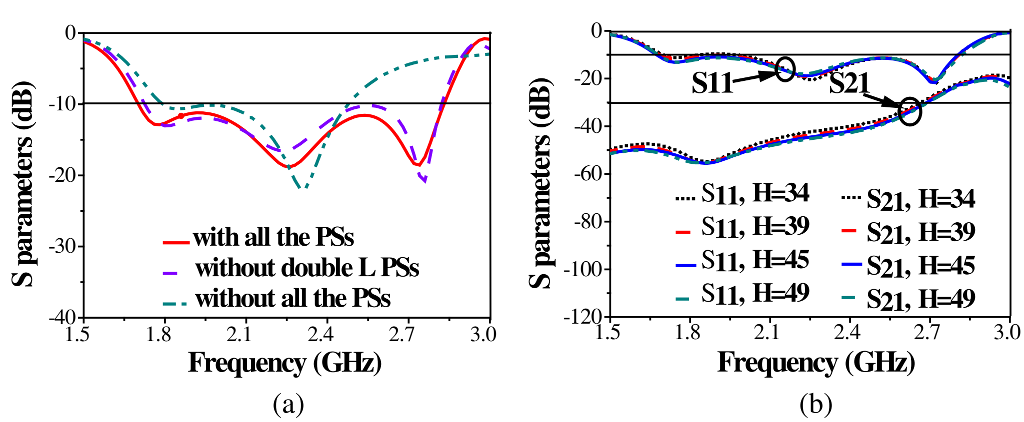


Figure 2. Effect of (a) parasitical strips on the return loss of the HP element, (b) height H between the VP and HP elements on S_{11} and S_{12}.

strips (PSs). As shown, with arc parasitical strips and L-shaped parasitical strips, the return loss of the antenna is significantly improved.

3. VERTICAL POLARIZATION ELEMENT DESIGN

The geometrical design of the VP antenna element is illustrated in Fig. 1(c). As shown, it mostly refers to our previous work. The main body of the VP antenna element is a discone antenna, where the diameter of ground plane is defined to be 84 mm, and the height of cone is then chosen accordingly to match with the 50-Ω feeding line. The gap between the cone and the ground plane is found to be 1 mm for best impedance matching. The feeding port was indicated in Fig. 1(d), and it is coaxial feed. To improve the impedance bandwidth of the antenna, a planar ring is applied to the top of the open-ended cone and shorted to the circular ground with three equally-spaced pins. The radius of the pin was chosen to be 1.58 mm corresponding to the thinnest off-the-shelf copper rod of 1/8 inch in diameter. In addition, a round sleeve with a radius of 21 mm and height of 11.3 mm is added to the ground plane of the discone for the further bandwidth enhancement. The dimensions and design parameters of both horizontally and vertically polarized antenna elements are listed in Table 1. The geometric parameters optimized using HFSS 13.0.

Table 1. Dimensions and design parameters. (Unit: millimeter).

D_1 (mm)	84	L_2 (mm)	0.7	L_{15} (mm)	8.8
D_2 (mm)	55.2	L_3 (mm)	16.8	w_1 (mm)	0.5
D_3 (mm)	36	L_4 (mm)	21.1	w_2 (mm)	1.8
H_1 (mm)	11.3	L_{11} (mm)	5.36	w_3 (mm)	4
H_2 (mm)	22	L_{12} (mm)	25.4	w_g (mm)	11.5
R_1 (mm)	50	L_{13} (mm)	2.1	w_s (mm)	2.1
L_1 (mm)	0.2	L_{14} (mm)	8.9	A (degree)	47
g_0 (degree)	7.9	g_1 (mm)	0.8	g_2 (mm)	0.53

The HP antenna element is placed above the VP antenna element to complete the proposed dual-polarized MIMO antenna assembly, Fig. 1(d) shows the 3D view. S_{11} and S_{12} parameters of the proposed antenna with different spacing (H) between the VP and HP elements are depicted in Fig. 2(b). As shown, both the return loss and the isolation of the antenna maintain stable while H varies between 34 and 49 mm. A spacing of 45 mm is selected in this work to yield optimum return loss and isolation without sacrificing the compactness of the design.

4. FABRICATION AND RESULTS

A prototype of the proposed MIMO antenna is displayed in Fig. 3. The HP antenna element is fabricated on a Rogers substrate with a thickness of 0.8 mm and a dielectric constant of 3.55,

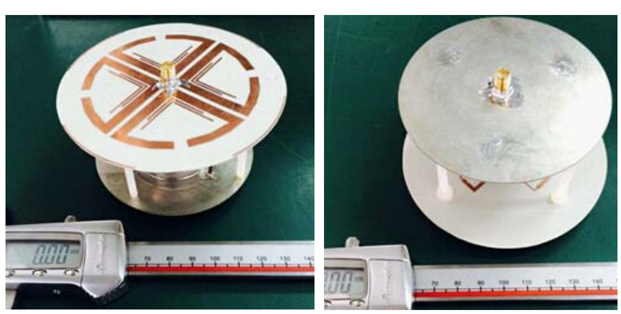


Figure 3. Photograph of the fabricated antenna.

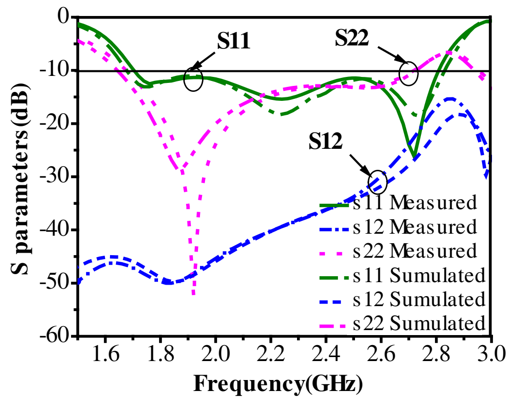
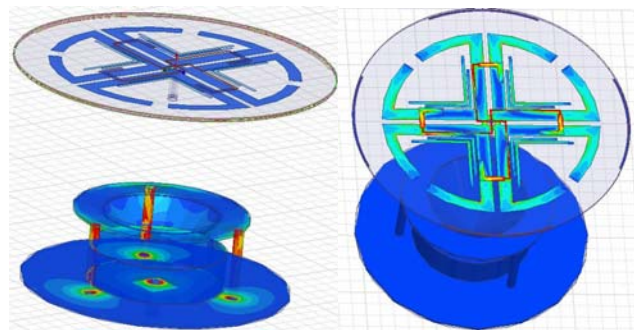


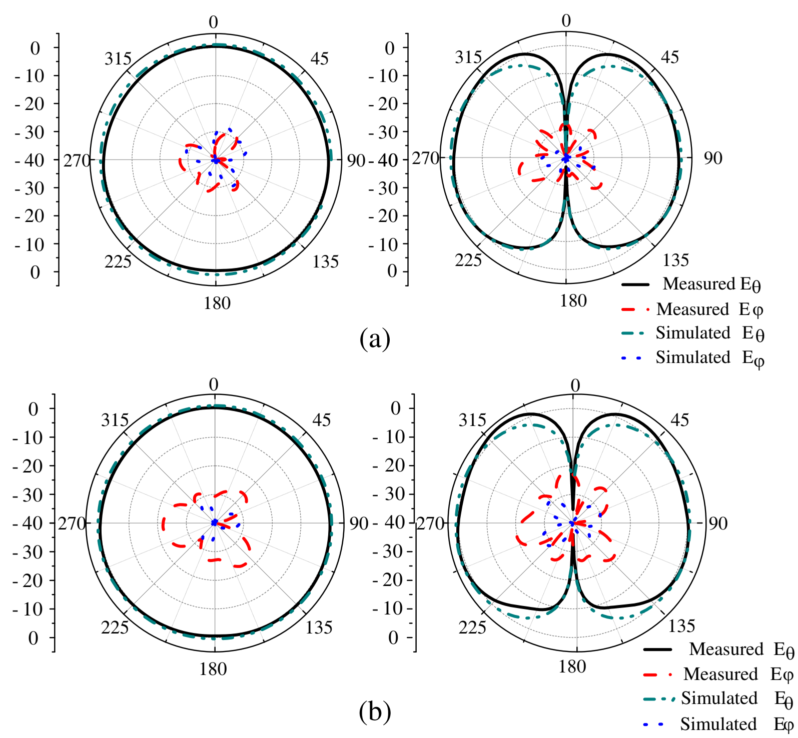
Figure 4. S-parameters of the proposed MIMO antenna.



(a) (b)

Figure 5. The surface current distributions of the antenna at 2 GHz. (a) When the VP element is excited, (b) when the HP element is excited.

whereas the VP antenna element is fabricated with a 0.5 mm-thick copper sheet. Fig. 4 shows S-parameters of the dual-polarized antenna at different ports. It is observed that the HP element exhibits an operational bandwidth of 1700–2800 MHz whereas the vertically polarized element provides an operational bandwidth of 1680–2720 MHz, both with return loss greater than 10 dB. The isolation between the VP and HP ports is higher than 25 dB over the overlapping band. To investigate the isolation of two element, the images of the surface current distributions when one antenna is excited while the other is terminated with a matched load were given in Fig. 5. As we can see, when one is excited, the other have little current on the surface shows it has a good isolation. Fig. 6 shows radiation patterns of the antenna at 1.8 GHz and 2.2 GHz, where high roundness and low cross-polarization are observed for both VP and HP elements. Fig. 7 illustrates that the VP element has a smooth gain of 2.0 to 3.5 dBi and the HP element exhibits a smooth gain of 2.0 to 2.35 dBi in their respective operational bands.



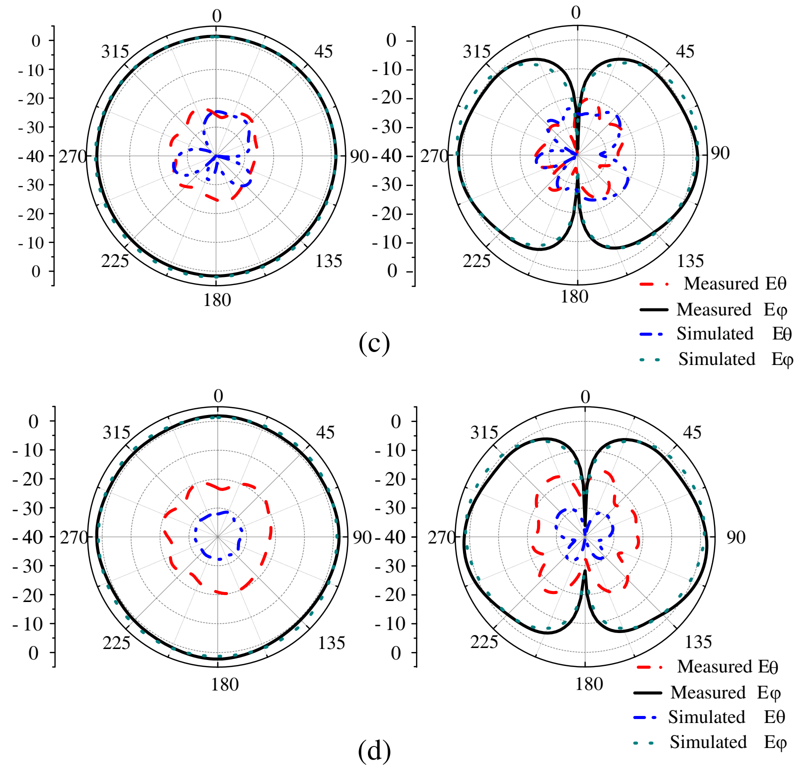


Figure 6. Radiation patterns of the proposed MIMO antenna: (a) VP at 1.78 GHz; (b) VP at 2.2 GHz; (c) HP at 1.78 GHz; (d) HP at 2.2 GHz.

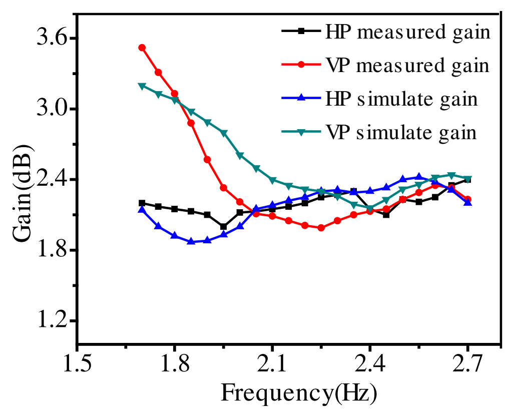


Figure 7. Gain for the proposed MIMO antenna.

5. CONCLUSION

A broadband omnidirectional dual-polarized MIMO antenna is proposed. The results reveal that both the HP and VP elements of the proposed MIMO antenna can cover the WCDMA, TD-SCDMA, GSM1800/1900, PCS, UMTS, Bluetooth, ISM, WLAN and all LTE bands above 1700 MHz. The sufficient impedance bandwidth, excellent isolation between two polarizations, omnidirectional radiation patterns, smooth gain, and compact design render the proposed antenna an ideal candidate for the orthogonally polarized MIMO antenna in 4G LTE wireless communication systems, networks and base stations.

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