A Novel Broadband Dual-Polarized Dipole Antenna Element for 2G/3G/LTE Base Stations

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Abstract—**A novel broadband dual-polarized crossed-dipole antenna element with parasitic branches is designed for 2G/3G/LTE base stations. The proposed antenna mainly comprises a curved reflector, two crossed-dipoles, a pair of feeding strips, and two couples of balanced-unbalanced (BALUN) transformers. Compared to the traditional square-loop radiator dipole, the impedance bandwidth of the proposed antenna can be greatly improved after employing two parasitic metal stubs and two pairs of parasitic metal branches, and a better radiation performance of the proposed antenna can be obtained by optimizing the angle of the reflector. Simulation results show that the proposed antenna element can operate from 1.7 to 2.7 GHz with has an impedance bandwidth of VSWR $<$ 1.5, the port isolation of more than 30 dB, a stable radiation pattern with half-power beamwidth 65.2$^\circ \pm 5.6^\circ$ at H-plane and V-plane, and a relatively stable dipole antenna gain of 8.5 ± 0.4 (dBi). Furthermore, measured results have a good agreement with simulated ones.**

Index Terms—**Broadband; dual-polarized; crossed-dipole; parasitic branches; curved reflector; 2G/3G/LTE**

I. INTRODUCTION

ALTHOUGH great advancement of mobile communication systems has taken place over the past two decades, a variety of communication systems, such as existing 2G (1710-1920 MHz) and 3G (1880-2170 MHz), and emerging and popular LTE (2300-2400 MHz and 2570-2690 MHz) will coexist for a long time in the world. Hence, in order to avoid repetitive construction costs of telecommunication systems and other additional infrastructure, it is reasonably necessary to demand that base station antennas can cover much more and broader current frequency ranges simultaneously and meet the corresponding standards as well. In [1], a wideband dual-band antenna composed of an irregular shorted patch and three planar dipoles is introduced and a bandwidth of 49.5% (1.58-2.62 GHz) is obtained. However, it is single-polarized and has a very large lateral dimensions, uneasy to form base station antenna arrays. Moreover, with the great development of mobile communication systems, dual-polarized antennas, especially $\pm 45^\circ$slant polarized antennas, have been widely used to combat multipath fading and to increase capacity [2]. Some broadband and dual-polarized antennas have been studied [3], [4], [5], [6], but they can‘t operate in the whole frequency range from 1.7 to 2.7 GHz. In [5], a dual-band and dual-polarized antenna array is proposed for 2G/3G/LTE base stations, and it consists of two independent $\pm 45^\circ$dual-polarized arrays, one of which operates from 1.71 to 2.17 GHz, and the other of which is designed from 2.5 to 2.69 GHz unable to cover LTE 2300 frequency band. In [6], a compact multiband and dual-polarized mobile base station antenna is proposed for multiple communications services, among of which is band2: PCS, WCDMA, and WiFi in 1.92-2.17 GHz, band3: WiBro (Wireless Broadband access service) and Wimax in 2.300-2.400 GHz, unable to operate in LTE 2600 frequency band.

Therefore, the antennas with advantages of broadband and dual-polarized characteristics have aroused much attention in base station antennas, and some competitive literatures have been reported. In [7], the proposed antenna composed of a cross dipole, a square loop, a square plate, and a small-size reflector is presented and it can operate from 1.71 to 2.69 GHz with low VSWRs ($<$1.5) at both ports. Unfortunately, its port isolation is only more than 22 dB, and its half-power beamwidth is 70° ± 5° both of which can‘t satisfy the specifications of commercial base station antennas. In [9], a broadband $\pm 45^\circ$ dual-polarized base station antenna is proposed for 2G/3G/LTE bands and it has an impedance bandwidth of 45% (1.7-2.7 GHz). Nonetheless, its port isolation is just more than 25 dB, unable to meet the requirements of base station antennas.

The remainder of this paper is organized as follows. Section II proposes antenna design and configuration of a novel broadband $\pm 45^\circ$slant orthogonal dual-polarized crossed-dipole antenna element with parasitic branches. Section III gives analysis and optimization of some key parameters. Measured and simulation results are presented in Section IV and conclusions are drawn in Section V.

II. ANTENNA DESIGN AND CONFIGURATION

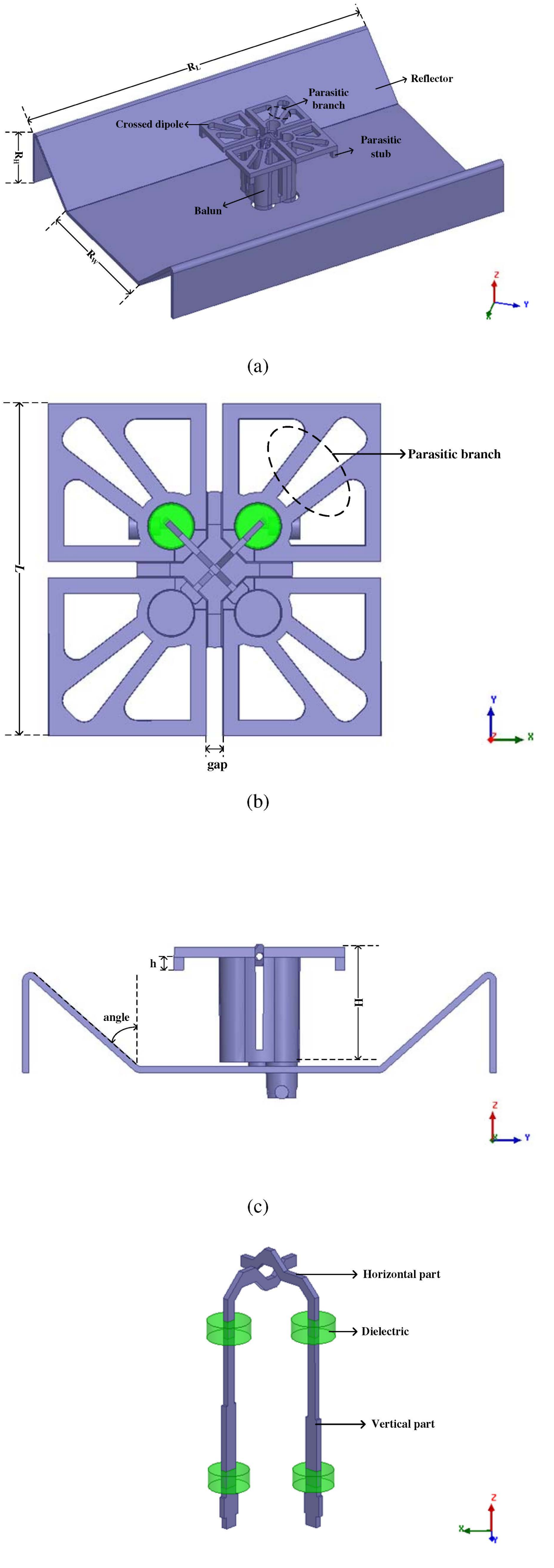
The configuration of the proposed antenna is illustrated in Fig. 1. The proposed antenna is mainly composed of a curved reflector, two crossed-dipoles, a pairs of feeding strips, and two couples of baluns [8]. As shown in Fig. 1(a), two crossed-dipoles are orthogonally located to get dual-polarization radiation characteristic, and two couples of baluns act as a quarter-wave impedance transformer and supporting structure. As shown in Fig. 1(b), one of the distinctive advantages of the proposed antenna is that each crossed-dipole consists of a pairs of square-loop radiator, two parasitic metal stubs and two pairs of parasitic metal branches. What is more, the impedance bandwidth of the proposed antenna can be greatly improved after introducing the two parasitic metal stub and two pairs of parasitic metal branches, compared to the traditional square-loop radiator dipole [10]. Furthermore, when one of the crossed-dipole is excited, the other can be treated as a parasitic element, which further extends its impedance bandwidth. As depicted in Fig. 1(c), the other distinctive advantage of the proposed antenna element is that the reflector is bent to some angle to achieve a better unidirectional radiation performance.

Fig. 1(d) shows a pair of feeding strips, and each of them has a pair of annular dielectrics, with a relative permittivity of 2.7 and a dielectric loss tangent of 0.0023. The feeding strip consists of the horizontal part and the vertical part. The end of the horizontal part is electrically connected to the opposite crossed-dipole, and the end of the vertical portion is soldered to the feeding cable beneath the reflector. And, it has to be mentioned that the balun, the feeding strip, and the corresponding dielectric act as a capacitor, which is beneficial to the VSWR operations of the proposed antenna. In addition, a pair of feeding strips is staggered up and down so as to avoid intersection between them. Therefore, we can safely draw a conclusion that highly symmetric performances can be obtained at two ports, since the two crossed-dipoles are almost same, except the location of the two feeding strips.

III. PARAMETERS STUDY AND ANALYSIS

To explore how the height of the parasitic metal stub influences the VSWR performance of the proposed element, parametric study is performed and the simulated result of different h is shown in Fig. 2. It can be seen obviously that the VSWR of the proposed antenna element in the upper band remains almost the same as before, while the lower band is affected significantly with the increase of h. When h=0 mm, it means that the parasitic metal stub is removed, leading to the resonant point of the antenna element far away from the lower band. After analyzing the simulation results, it may be due to the fact that the current paths of the crossed-dipoles are indirectly extended by the parasitic metal stub. Therefore, h=4 mm is chosen to achieve a better impedance matching over the overall frequency band.

For a better understanding of the influence of the numbers of parasitic metal branches on the VSWR performance of the proposed crossed-dipole, different numbers of parasitic metal branches are studied using simulation software HFSS16. As shown in Fig. 3, the middle band of the operating frequency band is notably improved, while both the lower band and the upper band are hardly affected by the numbers of parasitic metal branches. From Fig. 6, it can be easily observed that the VSWR of the proposed crossed-dipole antenna with two parasitic metal branches is much better than that of the square-loop dipole without any branches. In addition, the comparison of the surface current density at 2.2 GHz with different numbers of parasitic metal branches is presented in Fig. 4(a), Fig. 4(b), Fig. 4(c), Fig. 4(d). Arrows represent the direction of the current, and colors represent the strength of the current. As Fig. 4(a), Fig. 4(b), Fig. 4(c), Fig. 4(d) show, the currents on the crossed-dipole flow along the edges of the squares and the parasitic metal branches, thus the paths of currents increases, along with the numbers of parasitic metal branches. Therefore,



(a)

(b)

(c)

(d)

Fig. 1. Geometry of the proposed crossed-dipole antenna element, (a) 3D perspective view, (b) Top view, (c) Side view, (d)The feeding strips.

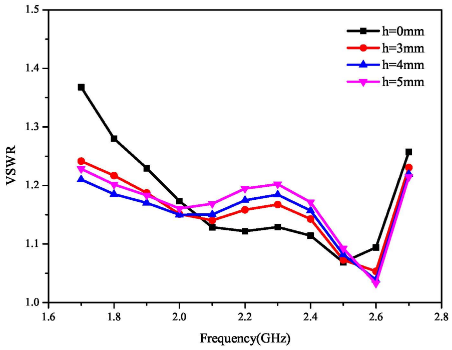


Fig. 2. Effects of h on VSWR of the proposed crossed-dipole antenna element.

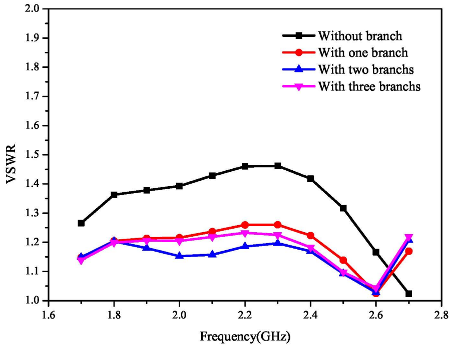


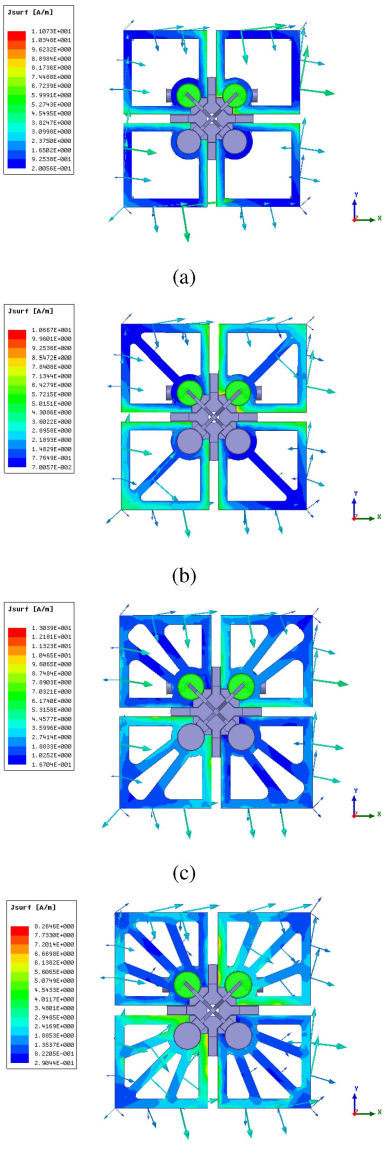
Fig. 3. Effects of numbers of parasitic branches on VSWR of the proposed crossed-dipole antenna element.

we can treat parasitic metal branches and square-loop radiator as parallel circuits and the numbers of parasitic metal branches can be applied to adjust the impedance bandwidth of the proposed crossed-dipole antenna element. From the simulation results, we can conclude that two additional branches is the best choice for the proposed crossed-dipole antenna.

The proposed crossed-dipole antenna element introduces a curved reflector, to obtain an unidirectional radiation pattern. As shown in Fig. 5, it can be evidently observed that when the angle is 60 degree, the half-power beamwidth is best, about $66° \pm 4°$. However, the cross polarization ratio and front-to-back ratio must be taken into consideration as well, except the half-power beamwidth, since both the performance of the cross polarization ratio, front-to-back ratio and the half-power beamwidth must meet the requirements of base station. Finally, 50 degree is chosen to obtain better radiation pattern, after balancing the cross polarization ratio, front-to-back ratio and the half-power beamwidth, as shown in Fig. 5, Fig. 6, Fig. 7.

IV. MEASURED AND SIMULATED RESULTS

In order to validate our design, the prototype of the proposed crossed-dipole antenna element is fabricated as shown in Fig. 8. And the optimal dimensions of the proposed crossed-dipole antenna element are listed in Table I.



(a)

(b)

(c)

(d)

Fig. 4. The surface current density of crossed-dipole (a) without branch, (b) with one branch, (c) with two branches, (d) with three branches.

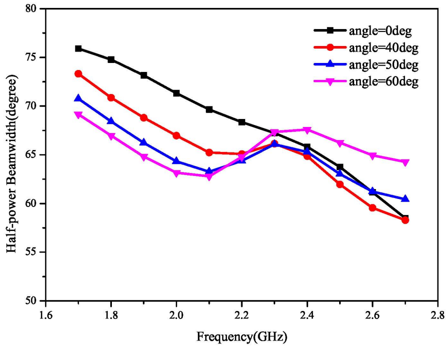


Fig. 5. Simulated half-power beamwidth for different angles.

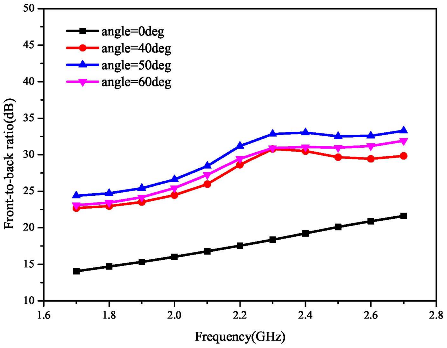


Fig. 6. Simulated front-to-back ratio for different angles.

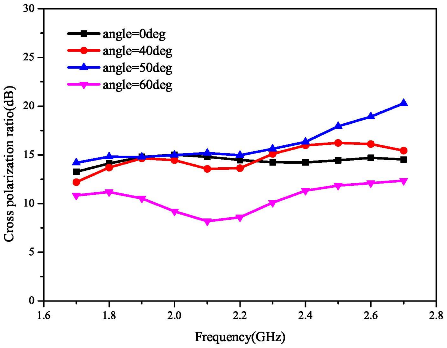


Fig. 7. Simulated cross polarization ratio for different angles.

TABLE I
OPTIMAL DIMENSIONS OF PROPOSED CROSSED-DIPOLE ANTENNA ELEMENT.

Parameters	Value	Parameters	Value
R_l	200mm	L	53mm
R_w	73mm	H	33mm
R_h	29mm	h	4.0mm
$angle$	50°	gap	2.7mm

The electrical performance is measured by E5061B network analyzer in the anechoic chamber, and the radiation performance is tested by far field test system in MOBI Antenna Technologies (Shenzhen) Co., Ltd. As shown in Fig. 9, it can be clearly seen that both the simulated and measured VSWRs are less than 1.5 from 1.7 to 2.7 GHz. Moreover, the simulated and measured VSWRs agree with each other very well. The measured gain is also shown in Fig. 9. Although the simulated gain varies around 9.3 dBi, while the measured one varies around 8.5dBi, a relatively stable dipole antenna gain of 8.5±0.4 dBi is obtained over the whole desired frequency band. The discrepancy may result from fabrication tolerance. It is known to all that high isolation between the two ports is required for dual-polarized base station antennas. Fig. 10 shows the measured port-to-port isolation is more than 30dB, which meets the requirement of base station antenna. The difference between the simulation and measurement results may be also caused by fabrication tolerance.

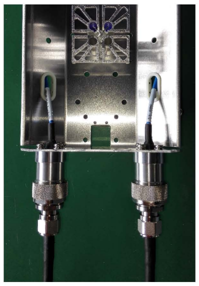


Fig. 8. Prototype of the proposed crossed-dipole antenna element.

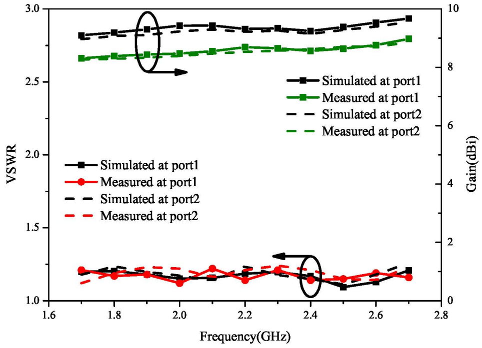


Fig. 9. Simulated and measured VSWRs and gains of the proposed antenna element at both ports.

Since the radiation patterns are highly symmetric at two ports, only the radiation patterns of the port1 in the horizontal plane at the frequencies of 1.7 GHz, 2.2 GHz and 2.7 GHz are depicted in Fig. 11(a)-Fig. 11(c). It can be observed that the measurement results agree with the simulation ones. The radiation patterns of the co-polarization are stable across the overall operating frequency band, and meanwhile, the radiation patterns of the cross-polarization get better as frequency increases. Finally, a stable radiation pattern with half-power beamwidth 65.2° $\pm$ 5.6° at H-plane and V-plane is obtained.

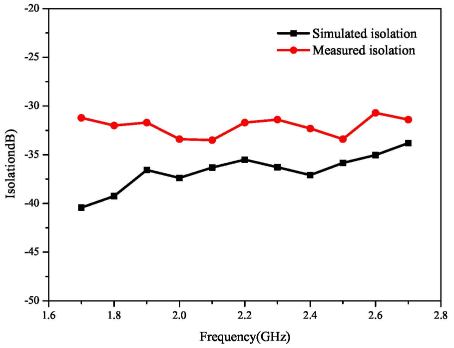
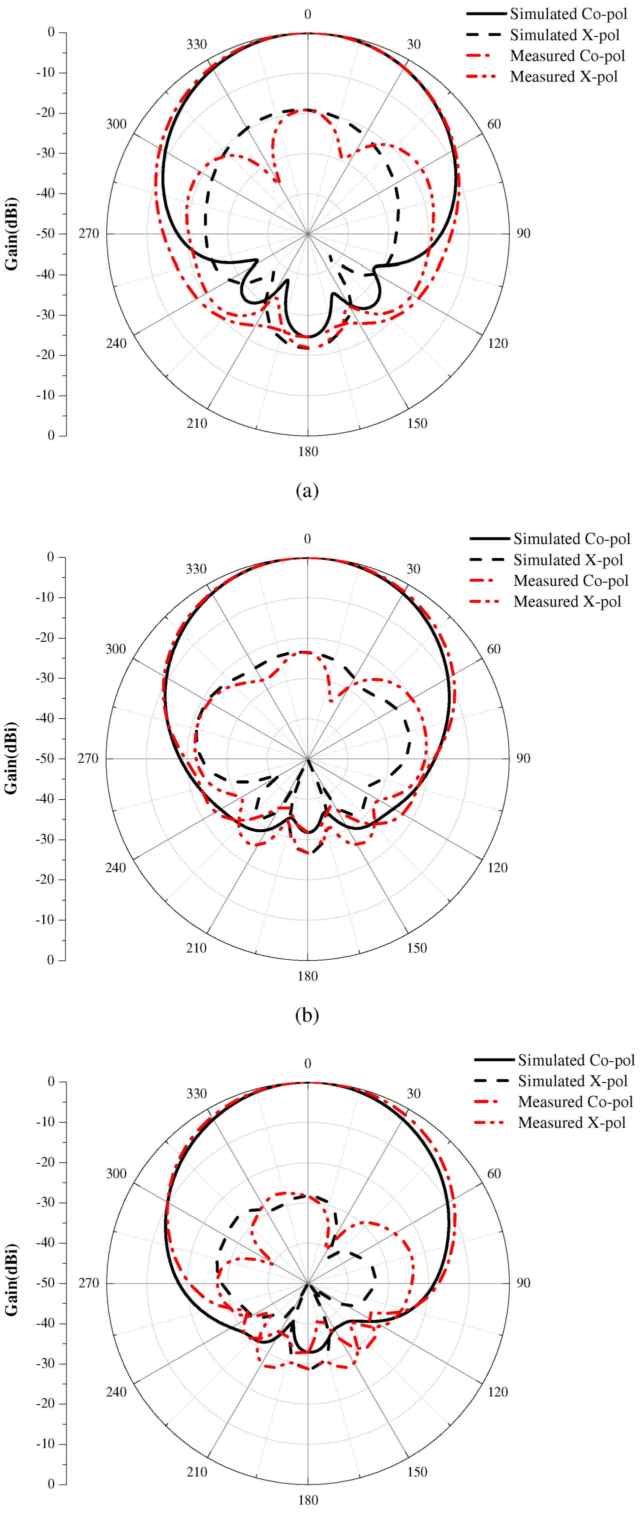


Fig. 10. Simulated and measured isolation of the proposed antenna element.



(a)

(b)

(c)

Fig. 11. Simulated and measured radiation patterns of the proposed antenna excited at Port 1, (a) f=1.7 GHz, (b) f=2.2 GHz, (c) f=2.7 GHz.

V. CONCLUSIONS

A novel broadband ±45°slant orthogonal dual-polarized crossed-dipole antenna element with parasitic branches is presented, and is sufficient to cover the whole frequency band of 2G/3G/LTE communication systems. Compared to the traditional square-loop radiator dipole, the impedance bandwidth of the proposed antenna can be greatly improved after employing two parasitic metal stub and two pairs of parasitic metal branches, and a better radiation performance of the proposed antenna can be obtained by optimizing the angle of the reflector. A wide impedance bandwidth, a stable antenna gain, and a relatively stable radiation pattern can be obtained. Moreover, it is easy to be manufactured on a large scale due to its simple and compact structure. Therefore, the proposed antenna is an ideal choice to modern mobile communication systems.

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