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A Novel Broadband Dual-Polarized Antenna Element for LTE700 MHz/GSM850 MHz/GSM900 MHz Applications

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ABSTRACT This paper presents a novel broadband and $\pm 45^\circ$ slant orthogonal dual-polarized antenna element designed for LTE700 MHz/GSM850 MHz/GSM900 MHz applications. The proposed antenna element consists of an annular base, four couples of baluns, three kinds of parasitic plastic fasteners ($3 \times 4 = 12$, four for each kind of fastener), and four dipoles that are orthogonal with each other. Compared with the prototype without parasitic plastic fasteners, the impedance bandwidth of the proposed antenna element can be significantly improved. Measured results show that the proposed antenna element can operate from 698 to 960 MHz with VSWR <1.7 at both ports, high port-to-port isolation of >25 dB, a stable radiation pattern with half-power beamwidth of $65.92^\circ \pm 5.44^\circ$ at H plane and V plane, and a relatively stable gain of 9.41 ± 0.48 (dBi). In addition, the size of the proposed antenna element is $0.469\lambda_0 \times 0.469\lambda_0 \times 0.22\lambda_0$ (λ_0 is the free-space wavelength referring to the antenna center frequency). Good agreement is observed between simulated and measured results.

INDEX TERMS Broadband antenna, dual-polarized antenna, LTE700 MHz, parasitic plastic fastener.

I. INTRODUCTION

Although great development of mobile communication systems has taken place in recent decades, bandwidth resources become increasingly scarce, faced with the explosive growth of data traffic consumption. Furthermore, as an increasing number of mobile users are plunged in mobile networks, huger capacity and wider coverage are deadly required for more and more base stations, especially in rural and open areas. Since polarization diversity is a common method to address the issue of multipath fading [1], an antenna with dual-polarization characteristic is also required [2] for the base stations in mobile communication systems. Therefore, base station antennas with dual-polarization, broad frequency bandwidth and wide coverage have attracted much attention in mobile communications, including microstrip antenna [3], patch antenna [4], [5], printed dipole [6], [7], metal dipoles [8]–[10], and magneto-electric dipole [11], but their bandwidths of low frequency band are still not wide enough to cover the LTE700 MHz service.

The proposed antenna element can operate in the frequency range from 698 to 960 MHz, including LTE700 MHz (also named as the second digital dividend), which has following advantages: (1) low frequency bands, low power dissipation of equipment and low networking cost; (2) long wavelength, wide signal coverage and strong penetrability. These distinctive advantages easily enable it to construct large-scale mobile network coverage, which means that base stations composed of the proposed antenna can be placed further apart leading to a more cost-effective development for the service providers. Therefore, 700 MHz has become one of the international mainstream LTE frequency band, especially in Europe and America. However, in China, 700 MHz is always used by TV broadcasting services. Along with the spectrum released by digital terrestrial television and completion of analog-to-digital conversion, 700 MHz could be deployed to establish LTE system in rural or sparsely populated areas.

In this paper, a novel broadband and dual-polarized antenna element for LTE700 MHz/GSM850 MHz/GSM900 MHz applications is developed. The impedance bandwidth of the proposed antenna element is 31.60% from 698 to 960 MHz, extending more than 100 MHz from the primary frequency band (820-960 MHz). The prototype of the proposed antenna element is fabricated and tested. Good agreement can be observed between simulated and measured results. In addition, it has the advantages of simple structure, low cost, high reliability, and good radiation performance, all of which can be easily applied to form a single band, dual-band, and multi-band base station antenna, together with high-frequency antenna element. Compared to those traditional antennas, the proposed antenna is more attractive since it reduces the numbers of base stations and minimizes the installation cost of base stations.

II. ANTENNA CONFIGURATION

The configuration of the proposed antenna is illustrated in Fig. 1, which consists of an annular base, four couples of baluns, three different kinds of parasitic plastic fasteners (PPFs), and four dipoles that are orthogonal with each other. In addition, the PPFs are made of polyoxymethylene (POM), with a relative permittivity of 2.7, and dielectric loss tangent of 0.0023. After employing the three different kinds of parasitic plastic fasteners, the operating impedance bandwidth is obviously improved. As depicted in Fig. 1(b), to ensure that the proposed antenna have symmetrical radiation patterns in both horizontal and vertical planes, the dipole1 and dipole3 are symmetrical with respect to the plane of bulun3&4 and bulun7&8, while the dipole2 and dipole4 are symmetrical with respect to the plane of bulun1&2 and bulun5&6. Meanwhile, the dipole1 and dipole3 are +45° polarization, while the dipole2 and dipole4 are −45° polarization. What‘s more, as shown in Fig. 1(b), the distinctive advantage of the proposed antenna is that the radiation arm of each dipole consists of two parts of arc, and each arc is composed of straight line and curved line. Furthermore, the curvature center of the first section and the center of the proposed antenna are on the same side, while the curvature center of the second section and the center of the proposed antenna are on the opposite side. On one hand, this arrangement makes it possible to decrease the dimension of the proposed antenna under the condition of maintaining excellent electrical performance. On the other hand, it increases the length of the radiation arm and significantly reduces the influence on the high frequency element, especially the performance of VSWR and isolation. Four screw holes at the bottom of the proposed antenna element are used to enhance its stability. These four couples of baluns are connected by an annular base [12].

It has to be mentioned that the dipoles and baluns are first made of aluminum using die-casting technique, then electroplated with nickel and tin last, which makes the electrical connection between the antenna element and the coaxial cables easier. Each dipole is fed by a coaxial cable whose inner conductor is electrically connected to the corresponding feeding point and the outer conductor is soldered on the radiation arm just below the feeding point. As shown in Fig. 1(c), the proposed antenna is mounted above a baffle with two upward folded edges to obtain unidirectional radiation pattern and the angle formed between radiation arm and horizontal baffle is 85°. However, it is not common to use only a antenna element but an antenna array as a base station, after taking into consideration the gain, one of the

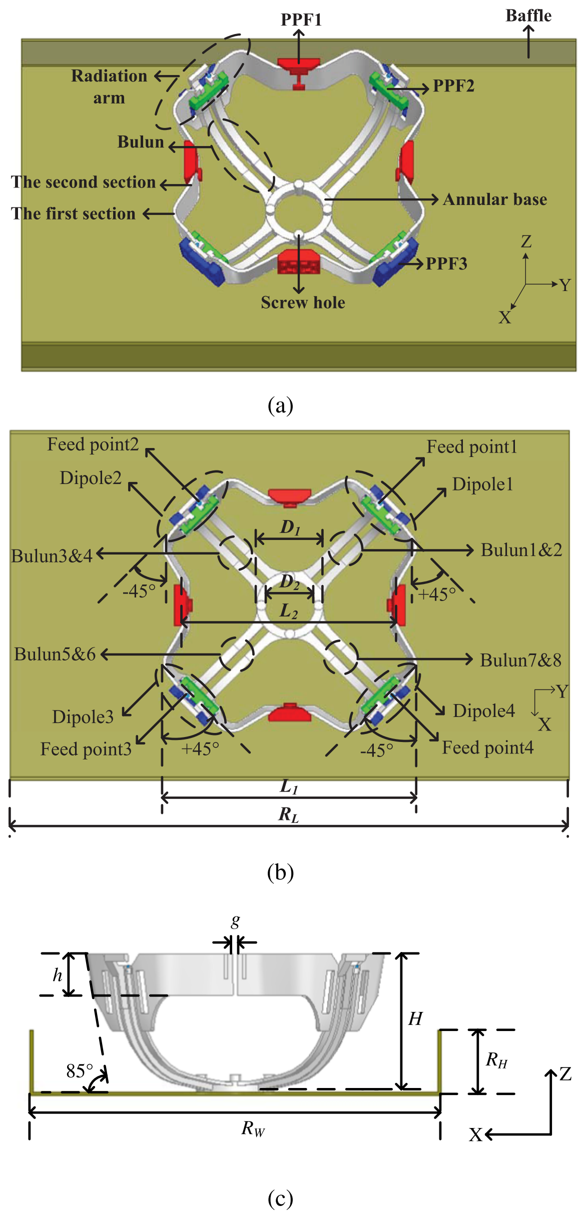

FIGURE 1. Geometry of the proposed antenna element, (a) 3D perspective view, (b) Top view, (c) Side view.

TABLE 1. Optimal dimensions of the proposed antenna element.

Parameter	Value(mm)	Parameter	Value(mm)
R_L	380 ($1.05\lambda_0$)	L_1	170 ($0.469\lambda_0$)
R_W	240 ($0.66\lambda_0$)	L_2	151 ($0.417\lambda_0$)
R_H	40 ($0.11\lambda_0$)	g	3 ($0.008\lambda_0$)
h	25 ($0.07\lambda_0$)	D_1	36 ($0.099\lambda_0$)
H	80 ($0.22\lambda_0$)	D_2	48 ($0.133\lambda_0$)

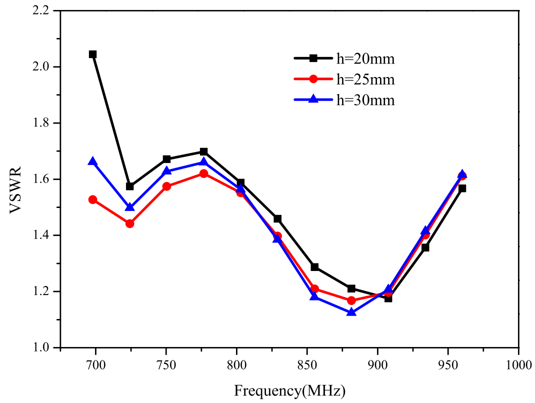

FIGURE 2. Effects of *h* on the proposed antenna element's VSWR performance.

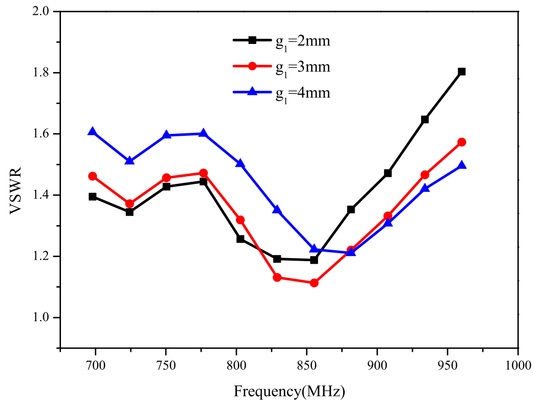

FIGURE 3. Effects of g_1 on the proposed antenna element's VSWR performance.

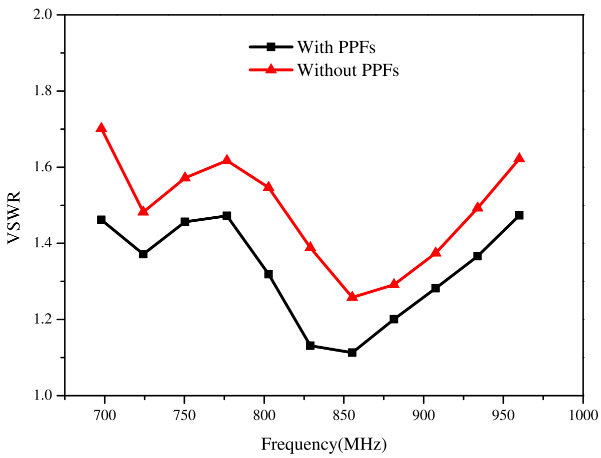

FIGURE 4. Effects of PPF on the proposed antenna element's VSWR performance.

key specifications of base station antenna. Therefore, for the sake of simplicity, the dimensions of the baffle aren't included in Table 1 and Table 3.

III. PARAMETRIC STUDIES

The first and most important parameter of the proposed antenna is the height of the radiation arm as depicted in Fig. 2. With an increase of h, the VSWR performance at the low

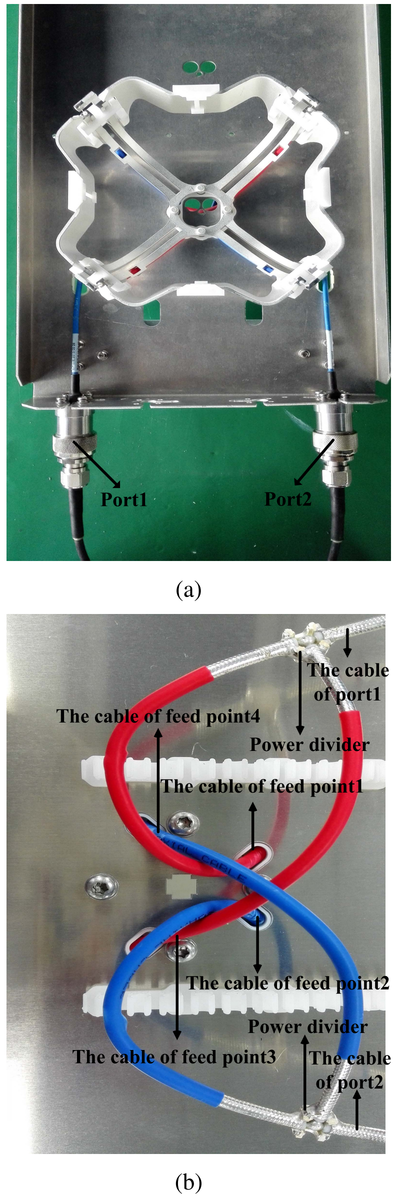

FIGURE 5. (a) Photo of the fabricated antenna element, (b) Photo of the connection relationship of the four feed points.

frequency (about 725 MHz) is first improved obviously at 25 mm and then degraded slightly at 30 mm. Thus, $h = 25$ mm is chosen to achieve a better impedance matching over the overall frequency band.

The second parameter studied is g_1. It has a significant effect on the coupling between the radiation arms of the adjacent dipoles. As depicted in Fig. 3, the matching condition at high frequency changes dramatically as g_1 increases. Thus, it can be easily concluded that the VSWR performance at high frequency is mainly controlled by the gap between the radiation arms of the adjacent dipoles.

The third factor is the three different kinds of parasitic plastic fasteners. As shown in Fig. 4, the whole frequency band changes obviously after employing three parasitic plastic fasteners (PPFs). In order to better explain the effects

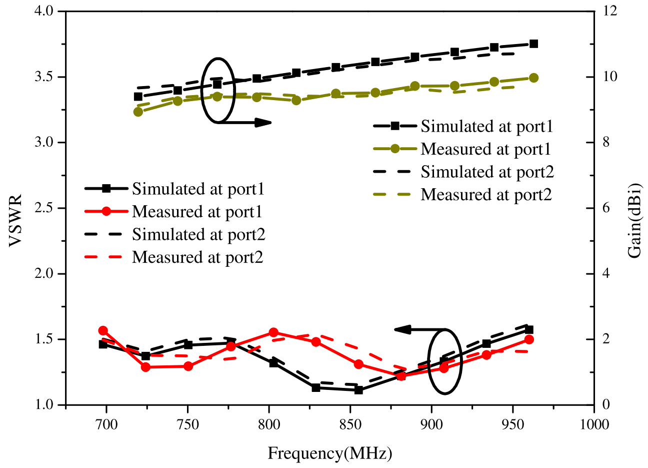

FIGURE 6. Simulated and measured VSWR and gain results of the proposed antenna element at both ports.

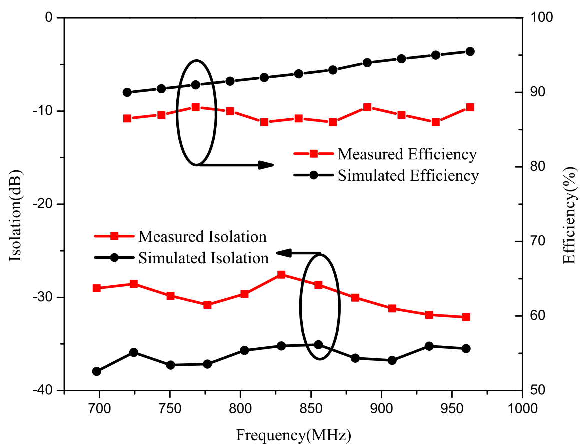

FIGURE 7. Simulated and measured isolation and efficiency results of the proposed antenna element.

of PPFs, we consider that each PPF is composed of two parts. One part is located between adjacent dipoles (red PPF1 as shown in Fig. 1(a)) or inside dipoles (green PPF2 and blue PPF3 as shown in Fig. 1(a)). We treat this part of PPFs and corresponding dipoles as a capacitor, which the dielectric is replaced from the previous air into the PPFs. Thus the relative permittivity of the dielectric becomes bigger and then the parasitic capacitance becomes bigger (according to the formula $C = \epsilon * S/4\pi * k * d$), finally the capacitive reactance also becomes bigger, which is beneficial to the impedance matching. Therefore, the impedance matching of the proposed antenna element is improved due to this part of PPFs. The other part is located next to the surface of the dipoles. Taking into account the skin effect of the high-frequency signal, the current path of the high-frequency signal is extended, owing to the introduction of this part of PPFs. And the VSWR performance is slightly shifted left as shown in Fig. 4. Therefore, it is concluded that the introduction of three different kinds of parasitic plastic fasteners not only enhances the stability of dipoles, but also improves the impedance matching at the entire frequency.

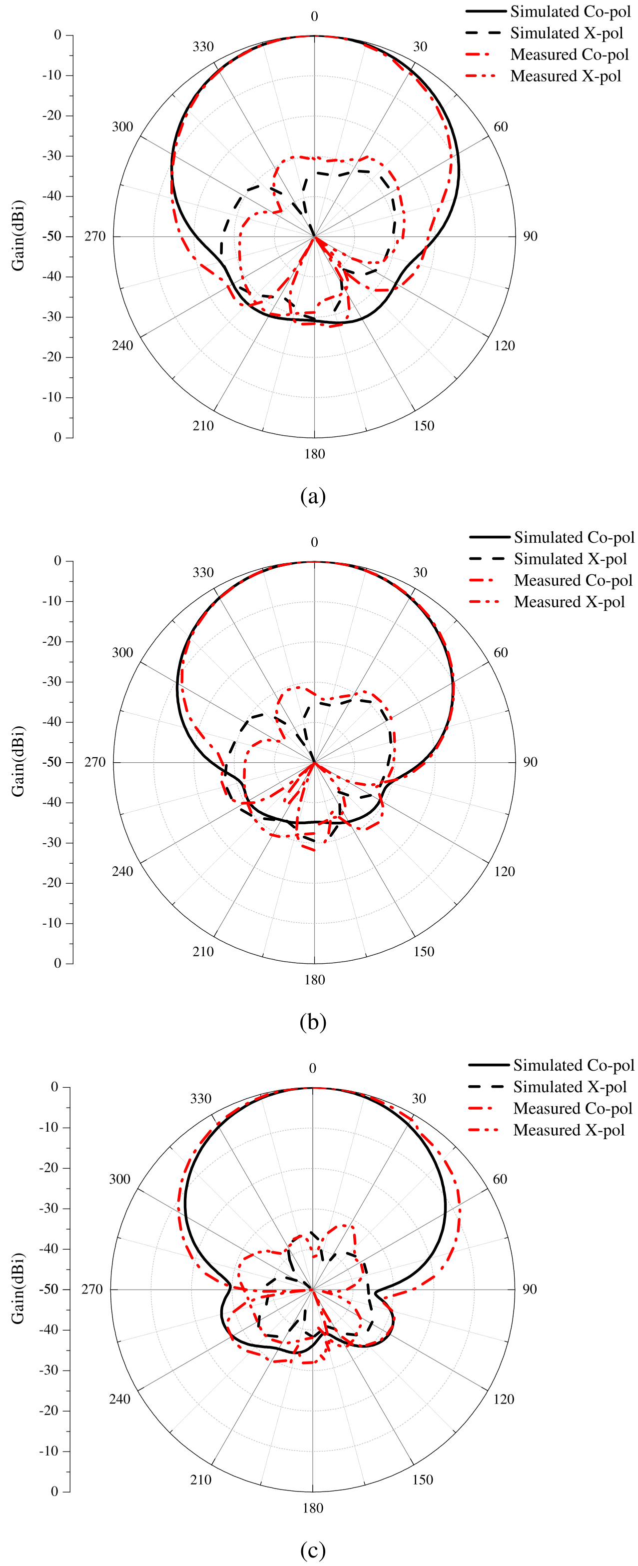

FIGURE 8. Simulated and measured radiation patterns of the proposed antenna element excited at Port 1, (a) $f = 698$ MHz, (b) $f = 829$ MHz, (c) $f = 960$ MHz.

IV. SIMULATED AND MEASURED RESULTS

In order to verify the design concept, a prototype of the proposed antenna element is fabricated and tested. The photo

TABLE 2. Simulated and measured half-power beam-width of the proposed antenna element.

Freq. (MHz)	HPBW (°)							
	Simulation				Measurement			
	H-plane		V-plane		H-plane		V-plane	
698	68.55	67.45	68.53	70.29	69.18	70.74	69.64	71.36
829	62.39	63.26	63.65	64.55	61.99	62.75	63.92	64.07
960	60.24	61.38	60.37	62.54	63.94	60.53	61.31	60.48

TABLE 3. Comparisons with previously reported antennas works at low frequency band.

References	Antenna Type	Relative Bandwidth	Size(mm^3)	Peak Gain (dBi)
[3]	Microstrip	16.94%(810-960 MHz)	$240 \times 240 \times 38$	9.4
[4]	Patch	20.45%(790-970 MHz)	$258 \times 270 \times 114$	10.2
[5]	Patch	34.04%(780-1100 MHz)	$181 \times 108 \times 57$	7.5
[6]	Printed dipole	17.44%(806-960 MHz)	$200 \times 200 \times 50$	2.2
[7]	Metal dipole	20.22%(800-980 MHz)	$155 \times 128 \times 45$	9.0
[8]	Metal dipole	8.15%(824-894 MHz)	$161 \times 161 \times 60$	7.1
[9]	Metal dipole	15.7%(820-960 MHz)	Not Given	9.57
[10]	Metal dipole	15.7% (820-960 MHz)	$105 \times 105 \times 74$	9.0
[11]	Magneto-electric dipole	21.23%(800-990 MHz)	Not Given	8.8
Our work	Metal dipole	31.6%(698-960 MHz)	$180 \times 180 \times 85$	9.89

of the fabricated antenna and the four feed points are shown in Fig. 5. As shown in Fig. 5, the two red coaxial cables are soldered to the feed point1 and feed point3,respectively, while the two blue coaxial cables are soldered to the feed point2 and feed point4, respectively. Meanwhile, the two red coaxial cables are separated by a power divider, and another adjacent coaxial cable is connected to a 7/16 DIN connector as port1, then the two blue coaxial cables are separated by a power divider, and another adjacent coaxial cable is connected to 7/16 DIN connector as port2. After optimizing several key parameters of the proposed antenna, the optimal dimensions of the proposed antenna element are listed in Table 1.

Simulated and measured VSWR results are depicted in Fig. 6. It can be seen that both simulated and measured VSWR values are less than 1.7 from 698 to 960 MHz. In addition, simulated VSWR results are in good agreement with measured ones. The measured gain results are also shown in Fig. 6. Although the simulated gain varies around 10 dBi and the measured one varies around 9.5 dBi, both simulated and measured gain results are stable across the whole operating frequency band. The small difference between them may be caused by the loss of the coaxial cables and other discrepancies between simulation and measurement models. As the two ports are constructed by four feeding points, which are connected by four coaxial cables, mutual coupling effects must be taken into consideration to ensure the excellent isolation performance of the proposed antenna. High isolation between the two ports is required for base station antennas. As shown in Fig. 7, the simulated port-to-port isolation is more than 30 dB, while the measured port-to-port isolation is more than 25 dB. The difference between the simulated and measured isolation results may also be attributed to the loss of the coaxial cables and other discrepancies between simulation and measurement models. The proposed antenna element efficiency is also shown in Fig. 7. The simulated efficiency of the proposed antenna element is about 92% while the measured efficiency of the proposed antenna element is about 87%. The discrepancy may originate from the surroundings.

Since the proposed antenna has symmetrical radiation patterns in both horizontal plane (xoz) and vertical plane (yoz), only the radiation patterns of the antenna excited at Port 1 in the horizontal plane at 698 MHz, 829 MHz and 960 MHz are plotted in Fig. 8. It can be seen that the measured results agrees well with simulated ones. The radiation patterns of the co-polarization are stable across the entire frequency band, while the radiation patterns of the cross-polarization become better with an increasing frequency. In addition, a stable radiation pattern with half-power beam-width $65.92° \pm 5.44°$ in H-plane and V-plane are obtained, as summarized in Table 2. The comparisons with previously reported antennas works at low frequency band are given in Table 3.

V. CONCLUSION

A novel broadband and $\pm 45°$ slant orthogonal dual-polarized antenna element has been designed for LTE700 MHz/ GSM850 MHz/GSM900 MHz applications. Compared with the one without parasitic plastic fasteners, the impedance bandwidth of the proposed antenna is significantly improved. A wider impedance bandwidth, a stable antenna gain, and a relatively stable radiation pattern have been obtained for the proposed antenna. In addition, it has the advantages of simple structure, low cost, high reliability, and good radiation performance. Further research efforts include realizing dual-band and multi-band base station antenna arrays together with other high-frequency antenna elements.

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