

A Wideband Dual-polarized Modified Bowtie Antenna for 2G/3G/LTE Base-station Applications

Zhao Yang*, Cilei Zhang, Yingzeng Yin, and Yong Wang

Abstract—A novel wideband dual-polarized antenna is presented for 2G/3G/LTE base-station applications. The proposed antenna consists of two orthogonal modified bowtie dipoles, parasitic elements and a cavity. By using parasitic elements and compact cavity, the antenna achieves a wide impedance bandwidth about 77.3% (VSWR < 1.5) for both ports. Both simulated and measured results show that the proposed antenna has a port isolation higher than 31 dB and high gain (> 8.5 dBi) over the entire operating band. Moreover, good cross-polarization (> 25 dB) performance and a front-to-back ratio better than 20 dB are also verified by measured results.

1. INTRODUCTION

Nowadays, wideband dual-polarized antennas are very important for modern communication base stations. It is highly desirable to design a base-station antenna to cover several frequency bands for different wireless communication systems such as 2G, 3G, LTE and WLAN, with a wide operating band, stable radiation patterns, and high gain. A number of broadband dual-polarized antennas have been developed for base stations. The conventional choices mainly include patch antenna [1–3], slot antenna [4–6] and cross-dipole antenna [7–10]. Patch antenna is popular with low profile, potential low cost, conformal nature, and ease of mass construction, but the use of patch antenna is limited because of its narrow bandwidth. The bandwidths of [1] and [2] are only 26% and 37% for return loss higher than 10 dB, respectively. Similar to patch antenna, wideband and dual-polarized characteristics can also be achieved with slot antenna. The slot antenna has a simple planar structure and is easy to manufacture. Although the antenna in [4] has a bandwidth of 45.8% (RL > 10 dB), it has a relatively low antenna gain and poor cross-polarization performance. The bandwidths of the slot antennas in [5] and [6] are far less than 45% (1.71–2.70 GHz) and they are only used for WLAN applications. The cross-dipole antenna is a good choice to achieve both dual polarization and broad impedance bandwidth. With a large-size reflector placed below the cross dipole, the antenna can produce broadside radiation patterns with narrow beams and high gain. A novel polarization diversity antenna that consists of a cross-pair of folded dipoles is proposed in [7]. It can operate within 1.71–2.17 GHz band (VSWR < 1.4). However, its impedance bandwidth is not broad enough to cover the LTE2600 frequency band. Though a wide impedance bandwidth is achieved in the designs of [8–10], the bandwidth respected to VSWR < 2 still maintains a gap from application demands.

In this letter, a wideband dual-polarized modified bowtie antenna (MBTA), which can be used in 2G/3G/LTE base-station applications, is presented. By using a pair of MBTA with cavity and parasitic elements, wider impedance bandwidth (77.3% for VSWR less than 1.5 from 1.70 to 3.84 GHz) and higher isolation (> 31 dB) can be achieved simultaneously. The proposed antenna achieves wide impedance bandwidth, which covers the frequency bands of 2G/3G/LTE wireless communications. The

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measured gain is higher than 8.5 dBi, and the cross-polarization level within main lobes is higher than 25 dB across the entire operating band. Besides, the antenna is compact in structure and can be used to construct large scale antenna arrays. All these features make it become an ideal candidate for base-station applications. The antenna structure, its radiation mechanism and far-field results are successively presented below.

2. ANTENNA DESIGN AND DISCUSSION

The configuration of the proposed antenna is illustrated in Fig. 1. The overall size of the antenna is $120 \text{ mm} \times 120 \text{ mm} \times 34 \text{ mm}$. It consists of two orthogonally modified bowtie dipoles, parasitic elements, a cavity, two short pins and two coaxial feeders. The modified bowtie dipoles are printed on the front side of a dielectric substrate (FR4, $\epsilon_r = 4.4$ and thickness = 1 mm), while the parasitic elements are etched on the back side of the substrate. The radiating elements are excited by two coaxial lines. In addition, for each dipole element, the outer conductor of the coax-line is connected to one arm of the bowtie antenna, while the inner conductor of the coax-lines is connected to the other arm of the bowtie antenna by a microstrip stub and short pin. Different from the air-bridge structure in [8], the microstrip stubs are printed on two stacked orthogonal substrates ($\epsilon_r = 2.2$), which is helpful for the ease of antenna fabrication. It is noteworthy that the parasitic elements are not connected to the coax-lines. Two short pins are introduced in order to improve the isolation between the two ports. The simulation and analysis for the proposed antenna are performed using ANSYS HFSS15. The optimised dimensions of design parameters shown in Fig. 1 are listed as follows (unit: mm): $L = 120$, $W = 64$, $W_1 = 26.5$, $W_2 = 11.6$, $W_3 = 3.4$, $H = 34$, $h = 28$, $h_1 = 1$, $h_2 = 0.5$, $s = 1.4$, $s_1 = 6$, $s_2 = 14$, $s_3 = 6$, $d_1 = 2$, $d_2 = 1$, $r = 10.5$, $L_1 = 5$.

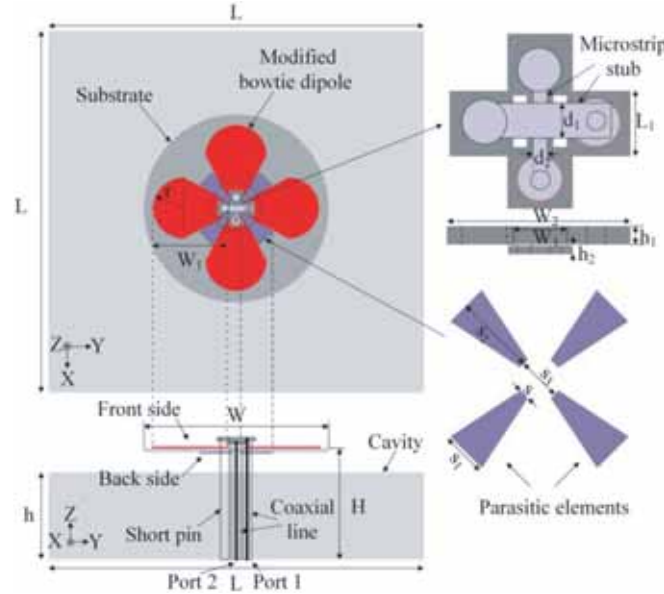


Figure 1. Configuration of the proposed antenna.

To take a further illustration of the antenna bandwidth, as shown in Fig. 2, comparisons among three different types of dual-polarized antennas are presented. Firstly, Ant 1 is composed of modified bowtie dipole, the ground plane, coaxial lines, short pin and microstrip stub. Then, Ant 2 is designed by applying four parasitic elements to Ant 1. Finally, Ant 3 is a cavity-backed form of Ant 2.

Figure 3 depicts the simulated VSWRs of port 1 and port isolations between two ports for Ant 1, 2 and 3 (proposed dual-polarized antenna). It is obvious that VSWRs of port 2 are similar to VSWRs of port 1. Fig. 3(a) shows that Ant 2 gives a wider impedance bandwidth than that of Ant 1. In addition, a wider impedance bandwidth (VSWR < 1.5) of Ant 3 is obtained. The impedance bandwidth of Ant 1 is achieved by dual resonances at 1.75 GHz and 3.75 GHz, respectively. By adding parasitic elements, a

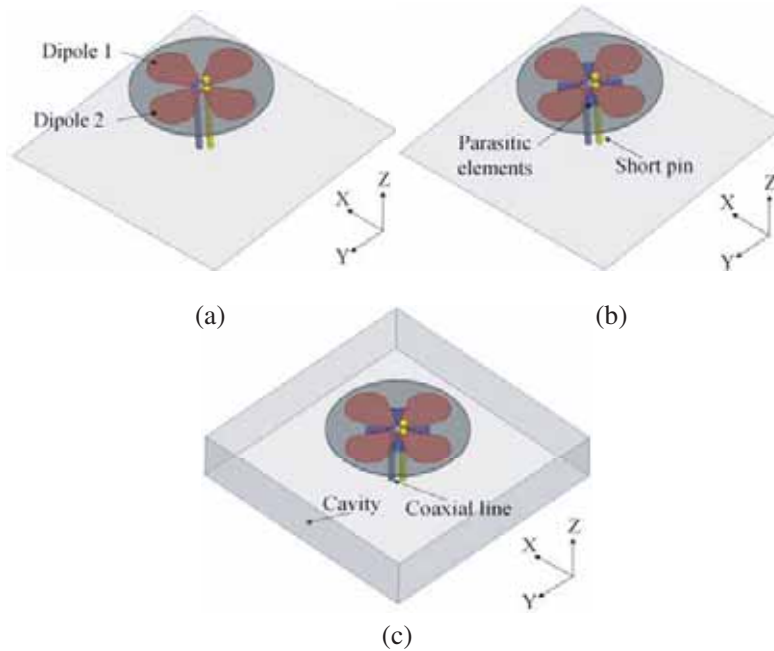


Figure 2. Structures of different types of dual-polarized antennas: (a) Ant 1, (b) Ant 2, and (c) Ant 3 (proposed dual-polarized antenna).

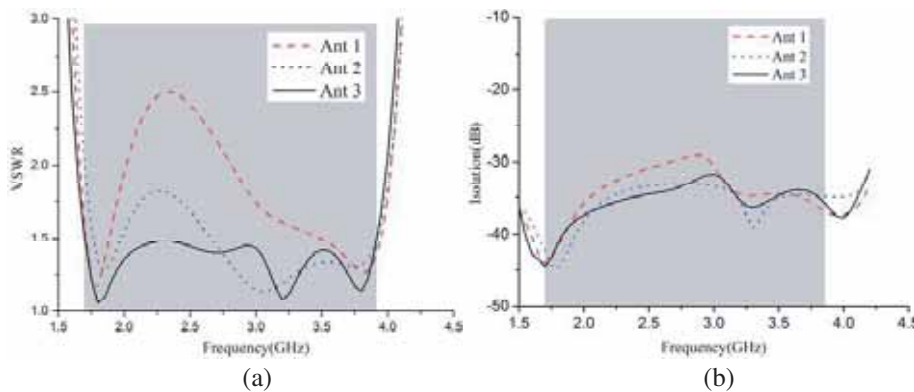


Figure 3. Simulated VSWRs and isolations for different antenna types: (a) VSWRs of port 1, and (b) isolations of both ports.

new resonance is generated. Hence, the impedance of the Ant 2 is significantly improved. The length of the parasitic elements is about $\lambda_e / 4$, where λ_e is the effective wavelength at 3.0 GHz. With the optimal location and length, the parasitic element can act as an impedance matching element, thus increasing the bandwidth of antenna. Furthermore, compared with Ant 1 and Ant 2, Ant 3 can obtain a wider impedance bandwidth. The cavity of Ant 3 can acquire another resonance at 2.7 GHz. So the cavity helps Ant 3 achieve a wider impedance bandwidth (VSWR < 1.5), of about 77.3% (1.70–3.84 GHz) for both ports. Fig. 3(b) exhibits that Ant 2 achieves a higher isolation (> 31) than that of Ant 1 in the entire operating frequency band (1.7–2.69 GHz). It can be observed that isolation of Ant 3 and Ant 2 are almost identical in the whole frequency band.

Figures 4 (a) and (b) show the simulated VSWRs for the proposed antenna with various parameters of W_1 and S_2 , respectively. As indicated in Fig. 3(a), the resonant frequency of the lower notched band varies with different lengths of modified bowtie dipoles W_1 . As expected, the lower notched band of the proposed antenna shifts down with the increase in W_1 . In Fig. 4(b), it can be seen clearly that as the

length of the parasitic elements S_2 increase from 8 mm to 20 mm, the high end of the frequency band expands, while the low end of the frequency band stays almost the same as before. By optimizing the parameters above, low VSWR and good radiation patterns can be achieved within the desired operating band.

Current distributions of the proposed antenna are depicted in Fig. 5. In Fig. 5(a), it can be seen that the current distributions focus mainly on the modified bowtie dipoles at the low frequency (1.7 GHz). Fig. 5(b) shows the current distributions focus mainly on parasitic elements and the center of the modified bowtie antenna at the high frequency (3.6 GHz).

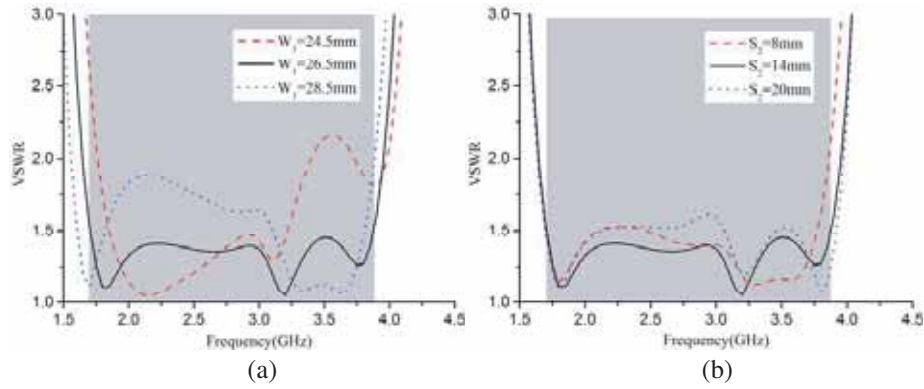


Figure 4. Simulated VSWRs for the proposed antenna with various parameters of (a) W_1 , and (b) S_2 .

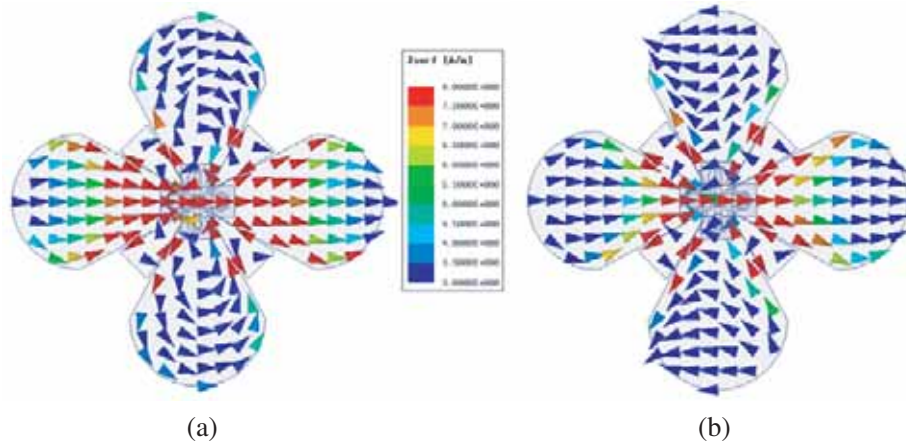


Figure 5. Current distributions of the proposed antenna when only the port 1 is fed. (a) 1.7 GHz, (b) 3.6 GHz.

3. SIMULATED AND MEASURED RESULTS

A prototype of the proposed antenna with optimised dimensions is fabricated and tested, and photographs of the prototype are shown in Fig. 6. Fig. 7 compares the measured and simulated VSWRs and isolation of the proposed dual-polarized antenna. It is obvious that the measured results agree well with the simulated ones. For $VSWR < 1.5$, the proposed antenna achieves a bandwidth of 2.14 GHz ranging from 1.70 to 3.84 GHz with the isolation higher than 31 dB in most frequency band. Performance comparisons of the proposed dual-polarized antenna and the above mentioned works, including bandwidth, VSWR, isolation and size, are listed in Table 1. By observing this table, the bandwidth ($VSWR < 1.5$) of the proposed antenna is widest. The isolation level of the proposed antenna is very similar to those in Table 1.

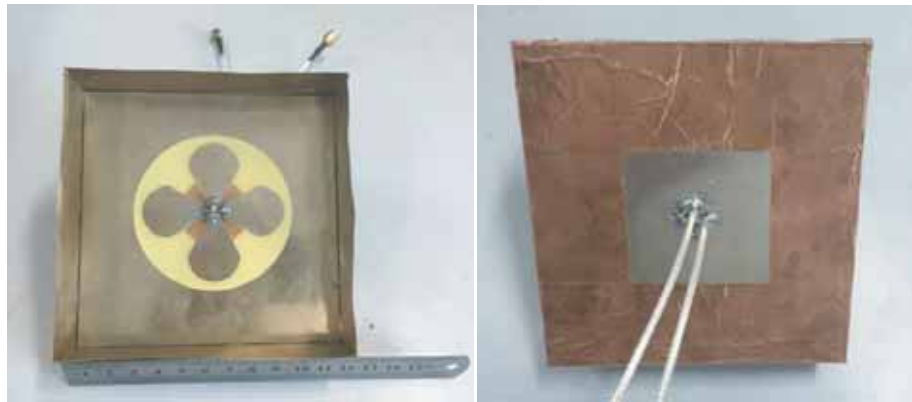


Figure 6. Photographs of the proposed antenna.

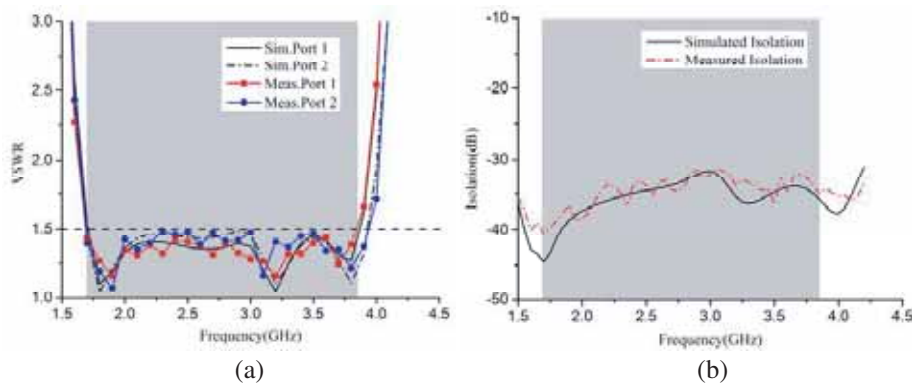


Figure 7. Simulated and measured VSWRs and isolation for the proposed antenna: (a) VSWRs of both ports, and (b) isolation of both ports.

Table 1. Performance of different wideband dual-polarized antennas.

Ref.	BW (GHz)	BW (%)	VSWR	Isolation (dB)	Size (mm ³)
[4]	1.7–2.71	45.8	2	33	150 × 150 × 1
[7]	1.71–2.17	23.7	1.4	25	130 × 130 × 42
[8]	1.70–2.73	46.5	2	38	160 × 160 × 28
[9]	1.68–2.3	31.2	2	30	200 × 200 × 23
[10]	0.80–2.30	92	2	Not given	562 × 562 × 64
proposed	1.70–3.84	77.3	1.5	31	120 × 120 × 34

The measured and simulated far-field normalised radiation patterns at 1.7, 2.2, 2.7 and 3.6 GHz are exhibited in Fig. 8. As expected, the antenna achieves good cross-polarization, which is roughly -25 dB lower than the co-polarization within the main lobes. At operating frequency of 3.6 GHz, its sidelobes at xoz -plane become large. It is caused by the deteriorated radiation pattern of the proposed MBTA with a cavity in high operating band. The measured and simulated gains, shown in Fig. 9, also have a reasonable agreement. We can see that the proposed antenna achieves a high gain ranging from 8.5 to 11 dBi in the entire frequency bands. Therefore, the proposed MBTA with a cavity has a high gain performance in the operating band. The measured efficiency of the antenna as well as the simulated one is depicted in Fig. 10. It is evident that the antenna achieves an average efficiency of 87.2%. Meanwhile, a front-to-back ratio better than 20 dB is obtained.

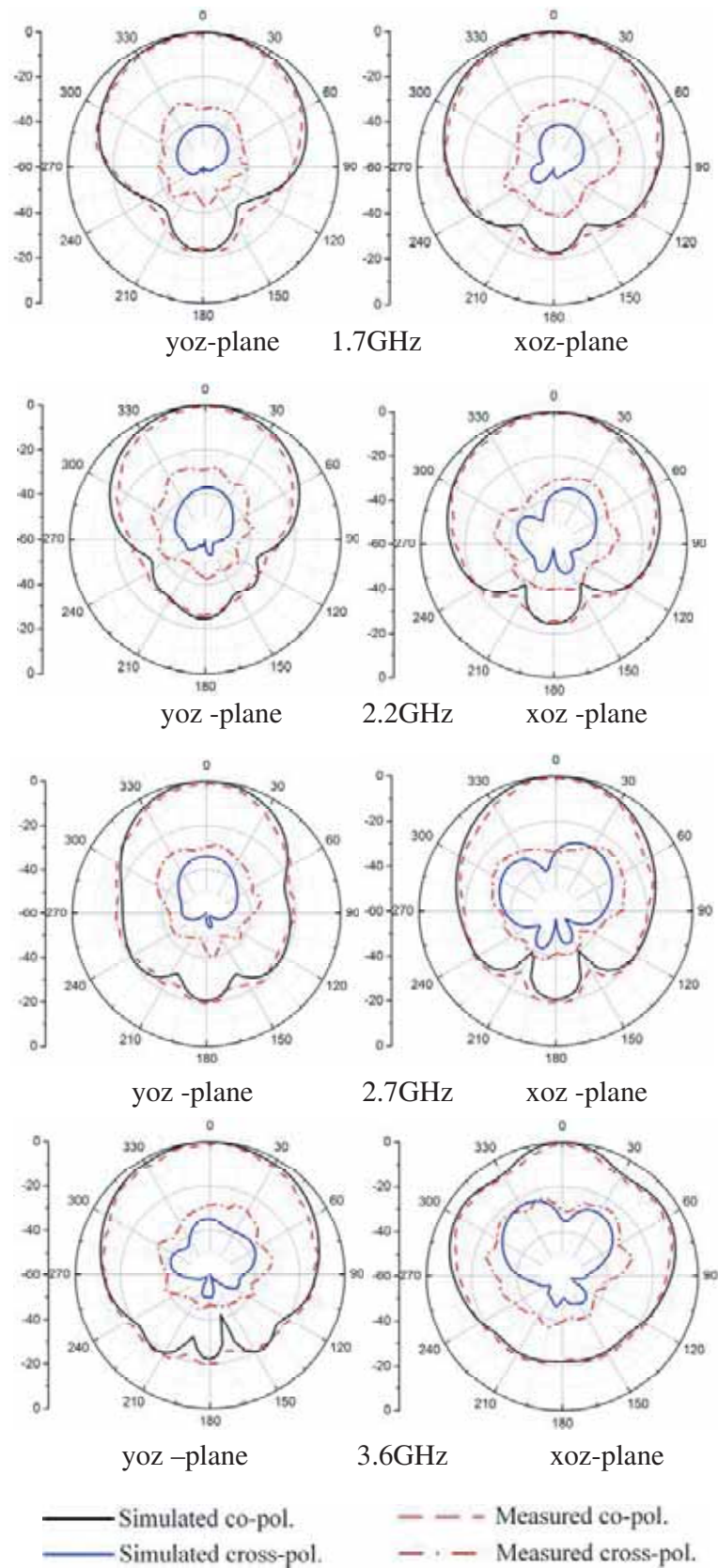


Figure 8. Simulated and measured radiation patterns at 1.7, 2.2, 2.7 and 3.6 GHz.

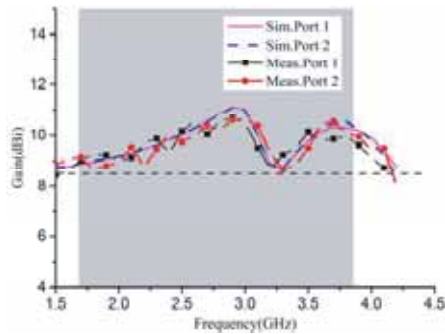


Figure 9. Simulated and measured gains of the proposed antenna.

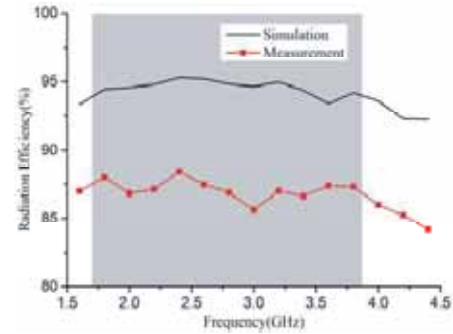


Figure 10. Measured and simulated radiation efficiencies for the proposed antenna.

4. CONCLUSION

A broadband dual-polarized antenna for mobile communication base stations is proposed. By using both the parasitic elements and the cavity, the proposed antenna provides a broad bandwidth (VSWR < 1.5) about 77.3% from 1.70 to 3.84 GHz and a gain higher than 8.5 dBi. The proposed dual-antenna provides high isolation about 31 dB between the two ports. Both stable low cross polarization level of -25 dB and front-to-back ratio higher than 20 dB are also obtained. These good performances demonstrate that the proposed antenna is a good candidate for 2G/3G/LTE base-station applications.

REFERENCES

1. Lai, H.-W. and K.-M. Luk, "Dual polarized patch antenna fed by meandering probes," *IEEE Trans. Antennas Propag.*, Vol. 55, No. 9, 2625–2627, Sep. 2007.
2. Ryu, K.-S. and A.-A. Kishk, "Wideband dual-polarized microstrip patch excited by hook shaped probes," *IEEE Trans. Antennas Propag.*, Vol. 56, No. 12, 3645–3649, Dec. 2008.
3. Gou, Y. S., S. W. Yang, Q. J. Zhu, and Z. P. Nie, "A Compact dual-polarized double-shaped patch antenna with high isolation," *IEEE Trans. Antennas Propag.*, Vol. 61, No. 12, 4349–4353, Aug. 2013.
4. Jiang, X. L., Z. J. Zhang, Y. Li, and Z. H. Feng, "A wideband dual-polarized slot antenna," *IEEE Antennas Wireless Propag. Lett.*, Vol. 12, 1010–1013, 2013.
5. Soliman, E. A., M. S. Ibrahim, and A. K. Abdelmageed, "Dual-polarized omnidirectional planar slot antenna for WLAN applications," *IEEE Trans. Antennas Propag.*, Vol. 53, No. 9, 3093–3097, Sep. 2005.
6. Tan, M. T. and B. Z. Wang, "A compact dual-band dual-polarized loop-slot planar antenna," *IEEE Antennas Wireless Propag. Lett.*, Vol. 14, 1742–1745, 2015.
7. Su, D., J. J. Qian, H. Yang, and D. Fu, "A novel broadband polarization diversity antenna using a cross-pair of folded dipoles," *IEEE Antennas Wireless Propag. Lett.*, Vol. 4, 433–435, 2005.
8. Li, B., Y. Z. Yin, W. Hu, Y. Ding, and Y. Zhao, "Wideband dual-polarized patch antenna with low cross polarization and high isolation," *IEEE Antennas Wireless Propag. Lett.*, Vol. 11, 427–430, 2012.
9. Lian, R. N., Z. D. Wang, Y. Z. Yin, J. J. Wu, and X. Y. Song, "Design of a low-profile dual-polarized stepped slot antenna array for base station," *IEEE Antennas Wireless Propag. Lett.*, Vol. 15, 362–365, 2016.
10. Suh, S.-Y., W. L. Stutzman, W. A. Davis, A. Waltho, K. Skeba, and J. Schiffer, "A novel low-profile, dual-polarization, multi-band base-station antenna element — The fourpoint antenna," *Proc. IEEE Veh. Technol. Conf. Fall*, 225–229, Los Angeles, CA, USA, Sep. 2004.