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A Broadband Dual-polarized Arm-Overlapped Dipole Antenna for Base Station Applications

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Abstract—A broadband dual-polarized dipole antenna with overlapped dipole arms is proposed in this paper. To obtain a compact radiator size, the arm-overlapped dipole antenna is constituted by splitting and overlapping the edges of a cross loop dipole. Then four open pins are soldered to the dipole to excite a third resonance at high frequency band. Measured results show that the proposed antenna with a small radiator size of $49 \times 49\,\mathrm{mm}^2$ has an impedance bandwidth of 49.5% (1.7–2.82 GHz) for VSWR < 1.5, port isolation $> 28\,\mathrm{dB}$ and half-power beamwidth (HPBW) of $65^\circ \pm 5^\circ$. A 4-element antenna array with $8^\circ \pm 2^\circ$ electrical down tilt is shown to further validate the performance of the antenna.

1. INTRODUCTION

With the rapid expanding of mobile communication systems, the antennas for base stations are undergoing tremendous development. Most of the current mature antennas for 2G/3G/4G base stations are wideband dual-polarized antennas. The dual $+45^\circ/-45^\circ$ polarization can improve the system capacity and signal-to-noise performance. Moreover, a wideband antenna covering the B2 band from 1.7 to 2.7 GHz is preferable in consideration of system integration. Patch antenna [1] and slot antenna [2] are easy to realize dual polarization. But cross dipole antennas are better alternatives in base stations due to their concise structure and wide bandwidth. Various types of cross dipole designs have been reported in the published literatures. Square loop dipole with chamfers [3] and octagonal loop dipole [4] are successful designs with simple Y-shaped feeding lines. A cross loop dipole with modified edges is proposed in [5] with two orthogonal printed baluns. The aforementioned three antennas can cover the bandwidth from 1.7 to 2.7 GHz. Another method to realize wide operation bandwidth is utilizing the coupling between the cross dipoles [6, 7]. When one dipole (bowtie dipole in [6] and loop dipole in [7]) is excited, the orthogonal dipole works as parasitic elements. Thus the bandwidth of the single dipole is broadened. A spline-edged bowtie dipole [8] and an elliptical loop dipole [9] can further broaden the upper frequency band to 2.9 GHz. The folded dipoles can also be used in base station antennas, which can be arranged in an octagon shape [10] or a square shape [11], and can achieve comparable performance. Besides the working bandwidth, port isolation and radiation patterns, antenna size is also an noneligible factor in base station antenna designs. Compact antenna is desirable for easy employment and space resource configuration. A pair of side-by-side dipoles connected in parallel through a coplanar feeding strip line is proposed in [12]. The arrangement of placing dipoles on two sides of a single substrate has a compact antenna dimension. A parallel center-shorted dipole with integrated baluns is introduced in [13]. The radiator size of this antenna is only $51 \times 51\,\mathrm{mm}^2$. But an extremely wide bandwidth for VSWR < 1.5 from 1.7 to 3.7 GHz is still obtained. A tightly-coupled cross dipole with radiator size of $60 \times 60\,\mathrm{mm}^2$ is proposed in [14]. This antenna has a simple radiator structure and exhibits excellent performance.

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In this paper, we present a broadband dual-polarized dipole antenna for 2G/3G/4G base station applications. Owing to the overlapped dipole arms, the antenna has a compact radiator size of $49 \times 49\,\mathrm{mm}^2$. Meanwhile, open pins for impedance bandwidth broadening and short pins for isolation improvement are employed in the antenna. Details of the proposed antenna and the results are discussed as follows.

2. ANTENNA CONFIGURATION AND ANALYSIS

The perspective view of the proposed antenna is shown in Figure 1, and the detailed geometry parameters are given in Figure 2. The antenna consists of an FR4 substrate, four open pins, two $50\,\Omega$ coaxial cables, a square reflector, and two short pins. The FR4 substrate has relative permittivity of 4.4 and loss tangent of 0.02. Each arm of the split loop dipole is divided into two parts with the main part (blue filling in Figure 2) printed on the lower layer of the substrate. The other part (red filling in Figure 2) is on the upper side. One end of the upper arm is connected to the lower arm through a metallic via. The other end is coupled capacitively to the lower arm with an overlapping length of $L_2 \times 2$. The Y-shaped feeding line for Port 1 is on the upper side. To avoid intersection, the center of the feeding line for Port 2 is shifted to the lower side, and metallic vias are used to join the upper and lower strips. The feeding lines are soldered to the inner conductors of the two $50\,\Omega$ RF coaxial cables. Meanwhile, two short pins connecting the lower dipole arm and the reflector are placed symmetrically to the coaxial cables. Four open pins are soldered to the lower side of the substrate. The parameters for the antenna are listed in Table 1, which are optimized by the simulation software Ansys HFSS V.16. The yoz-plane is defined as H-plane and the xoz-plane as V-plane. Port 1 and Port 2 are for $+45^\circ$ and -45° polarizations, respectively.

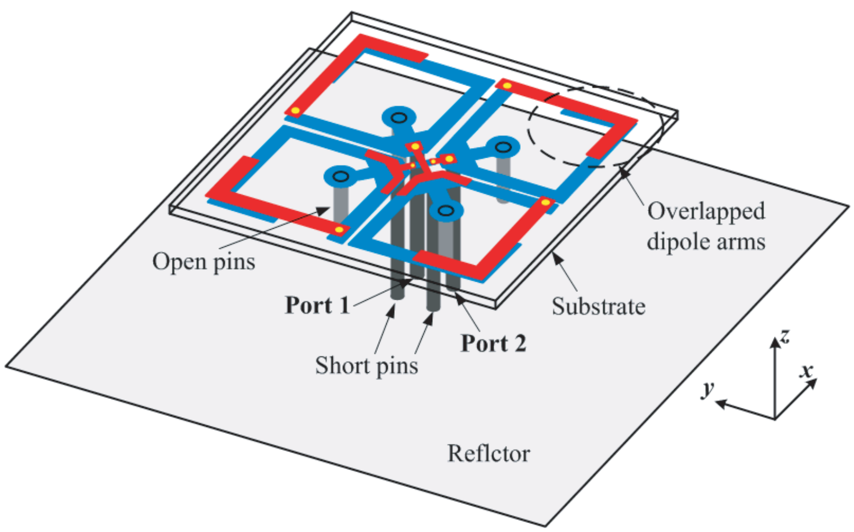

Figure 1. Perspective view of the proposed antenna.

Table 1. Optimal parameters of the antenna.

Parameter	L_1	W_1	L_2	W_2	W_3	W_4	W_5	W_6	L_3
Value (mm)	24	1.7	11.7	1	60	13.8	4.8	5.6	15
Parameter	Wf_1	Lf_1	Wf_2	Lf_2	Wf_3	Lf_3	Wf_4	Lf_4	
Value (mm)	2	2	1	6.8	1.8	4.6	1.3	5.4	
Parameter	r_1	r_2	r_3	r_4	r_v	$Tsub$	$Hsub$	G	
Value (mm)	2.6	1	1	1	0.3	0.75	35	140	

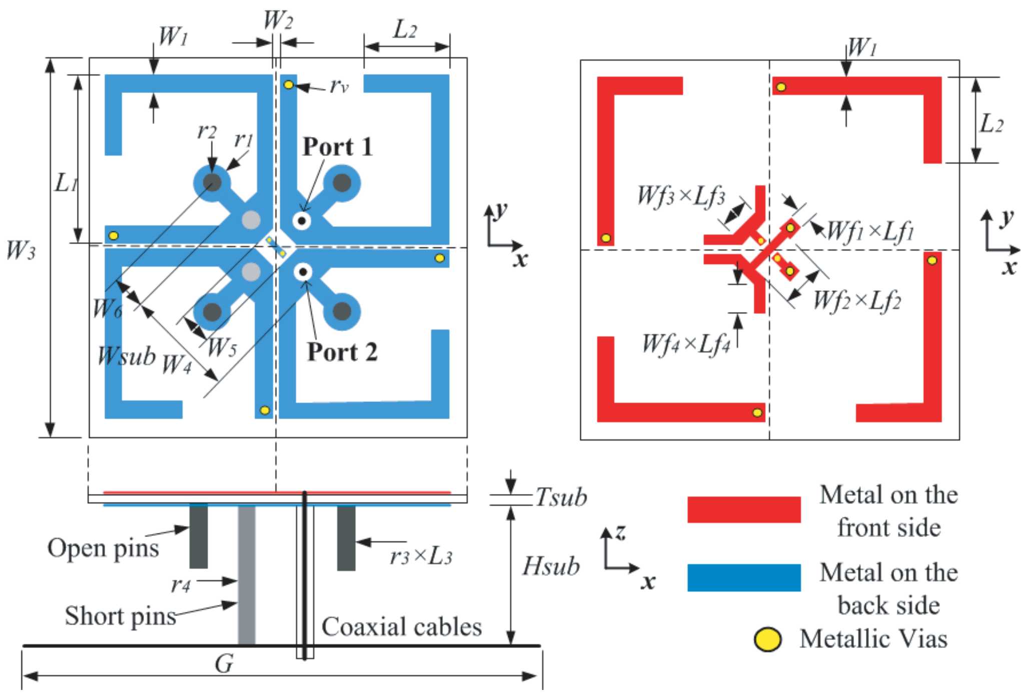

Figure 2. Configuration of the proposed antenna.

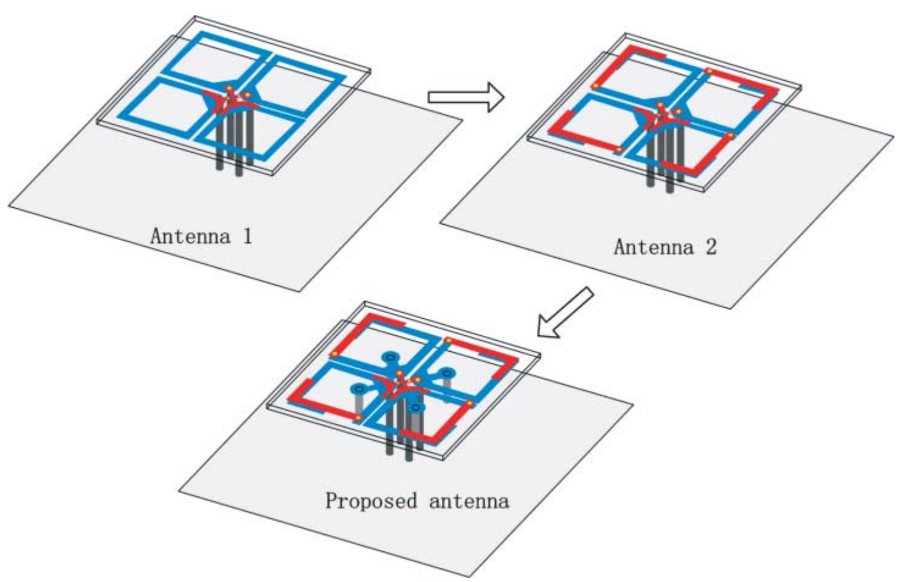

Figure 3. Design steps of the arm-overlapped dipole antenna.

The deign steps of the arm-overlapped dipole antenna are illustrated in Figure 3. A cross square-loop dipole with Y-shaped feeding lines and short pins is established firstly. Then, the arm of the loop dipole is split into the upper and lower parts. The upper and lower arms are overlapped as the square loop is constricted. Finally, four open pins are added near the center of the dipole arms for impedance matching. The comparison of the VSWR for the three evolution antennas is shown in Figure 4. The original length of the square loop dipole (Antenna 1) is set to 34 mm ($0.25\lambda_{2.2}$, $\lambda_{2.2}$ corresponding to the wavelength of 2.2 GHz). It can be seen that Antenna 1 has a narrow bandwidth with resonance at 2.3 GHz. The arm-overlapped dipole without open pins (Antenna 2) has a bandwidth of 1.7–2.5 GHz for VSWR < 1.5. After four open pins are added in the proposed antenna, the high frequency band is broadened to 2.8 GHz while the low and middle frequency bands are affected slightly. There are three resonant frequencies in the VSWR curve, located at 1.8 GHz, 2.4 GHz and 2.8 GHz. The third resonance is introduced by the effects of the overlapped dipole arms and open pins. It can be seen from Figure 5(a) that the length of the square loop L_1 determines the total operating band of the antenna, while the third resonance is affected mostly by the overlapping length L_2 and the length of open pins L_3. The inductance introduced by the open pins can compensate the capacitance between the overlapped dipole arms. Thus a good impedance matching is achieved at high frequency band. Moreover, the isolation

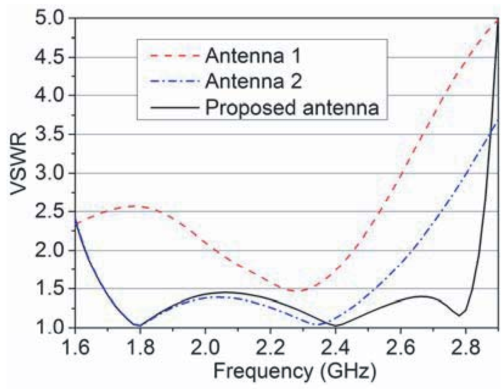

Figure 4. Simulated VSWRs of the evolution antennas.

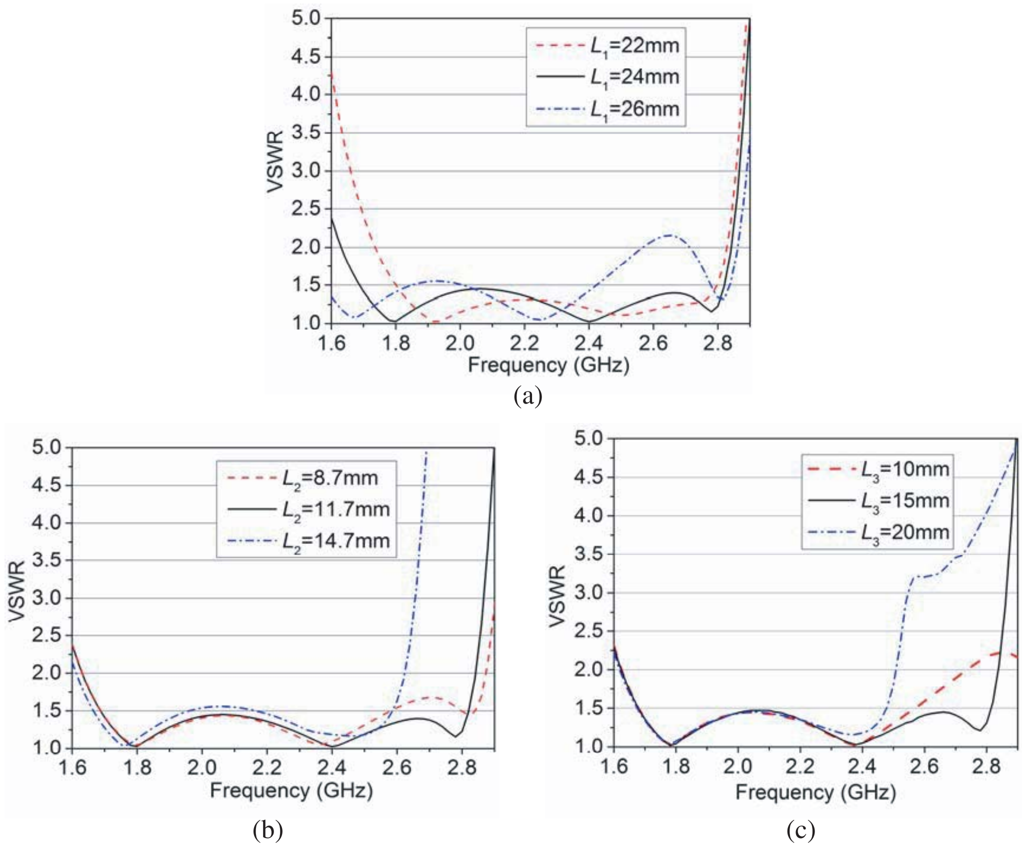

Figure 5. Variation of VSWR with different parameters. (a) L_1, (b) L_2 and (c) L_3.

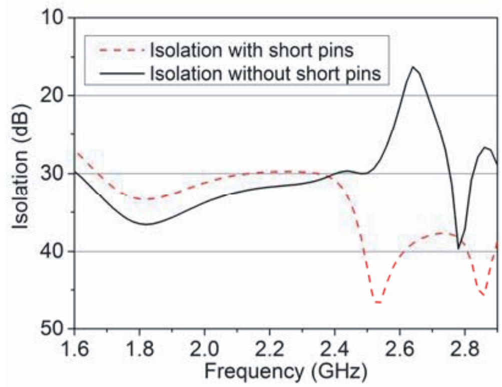

Figure 6. Effect of short pins on port isolation.

between Port 1 and Port 2 is improved from 20 dB to 40 dB around 2.7 GHz when the two short pins are added, as shown in Figure 6. The function of the short pins has been explained in [1] that the currents on the short pin can cancel out the currents on the outer conductor of the coaxial cables. Higher port isolation and lower cross polarization can be obtained by using the short pins consequently.

Figure 7 gives the current distributions on the dipole arms when Port 1 is excited. The currents concentrate on the inner parts of the dipole arms at 1.7 GHz. Nevertheless, more currents flow along the overlapped arms at 2.7 GHz. The current distributions further illuminate that the overlapped parts of the dipole arms have little influence on the low frequency band but great impact on the high frequency band.

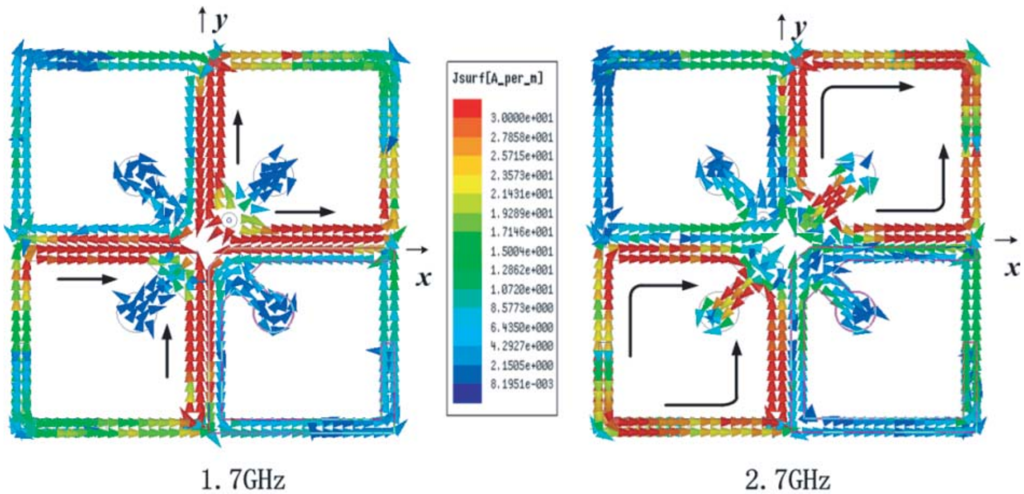

Figure 7. Current distributions on the dipole arms at 1.7 and 2.7 GHz when port 1 is excited.

3. EXPERIMENTAL RESULTS

A prototype of the proposed arm-overlapped dipole antenna is fabricated, as shown in Figure 8. Four plastic posts are employed at the corner of the substrate to support the radiator. Figure 9 shows the simulated and measured VSWRs and isolations of the antenna. The simulated and measured results have a good agreement. The antenna has a wide bandwidth from 1.7 GHz to 2.82 GHz for VSWR < 1.5. The port isolation is better than 28 dB within the impedance bandwidth. Simulated and measured radiation patterns at 1.7 GHz, 2.2 GHz, and 2.7 GHz of both H-plane and V-plane are plotted in Figure 10. The antenna has stable radiation patterns and low cross polarization less than -25 dB at boresight over

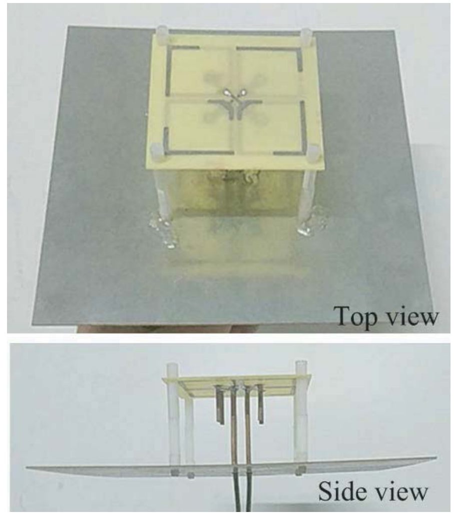

Figure 8. Prototype of the proposed antenna.

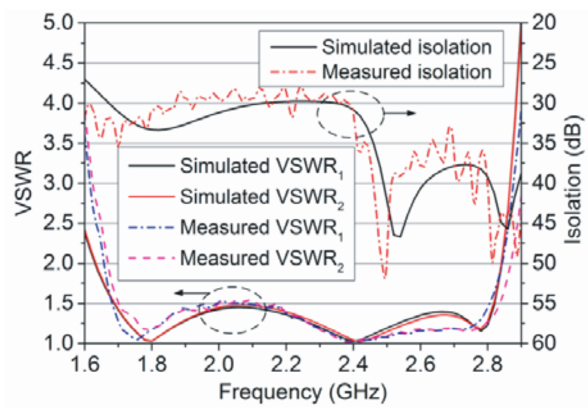

Figure 9. Simulated and measured VSWR and isolation of the proposed antenna.

Table 2. Comparison of several dual-polarized antennas to the proposed antenna.

References	Structures	Radiator size (mm × mm)	Bandwidth (GHz)	Isolation (dB)
[4]	octagonal loop dipole	55.7 × 55.7	1.7–2.7	25
[5]	edge-modified loop dipole	61 × 61	1.68–2.74	22
[6]	bowtie dipole	56 × 56	1.7–2.7	30
[8]	spline-edged dipole	75.4 × 75.4	1.427–2.9	20
[10]	folded dipole	70.38 × 70.38	1.69–2.71	30
[12]	parallel dipole	68 × 68	1.61–2.71	30
[13]	shorted dipole	51 × 51	1.69–3.7	30
[14]	tightly-coupled loop dipole	60 × 60	1.7–2.8	25
This work	arm-overlapped dipole	49 × 49	1.7–2.8	28

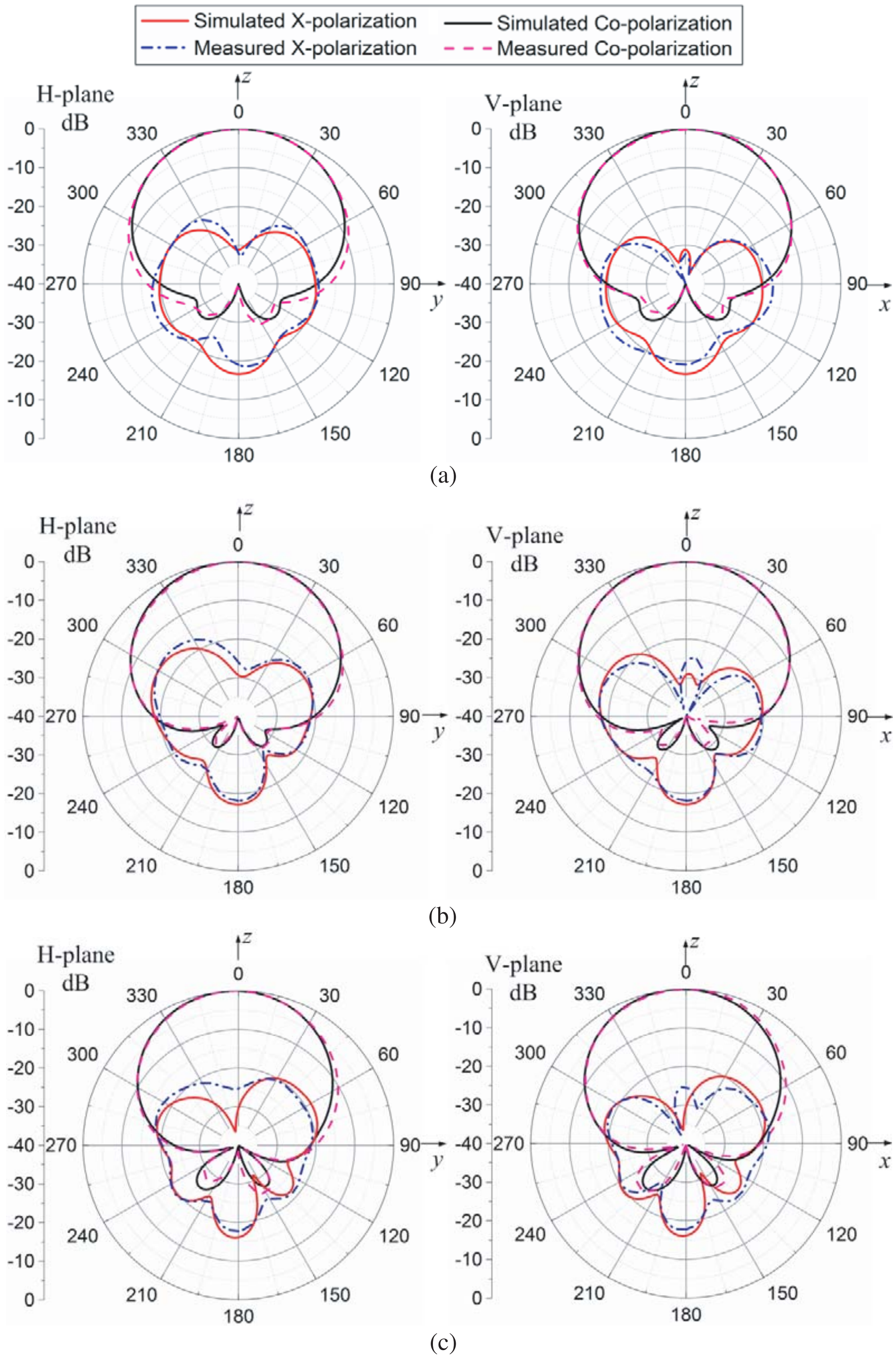

Figure 10. Simulated and measured radiation patterns of the proposed antenna when port 1 is excited at (a) 1.7 GHz, (b) 2.2 GHz and (c) 2.7 GHz.

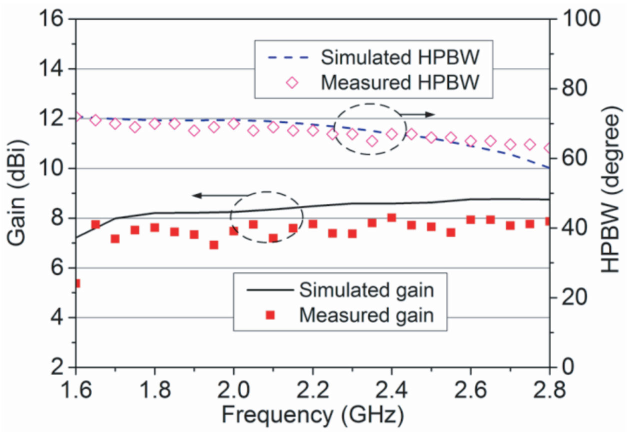

Figure 11. Simulated and measured gain and HPBW at H-plane of the proposed antenna.

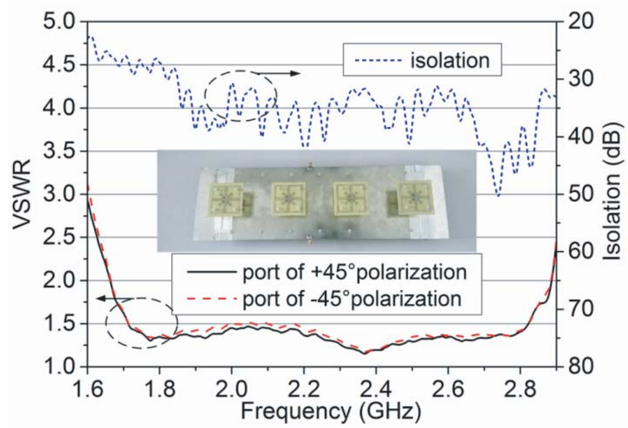

Figure 12. Measured VSWR and isolation of the four element array.

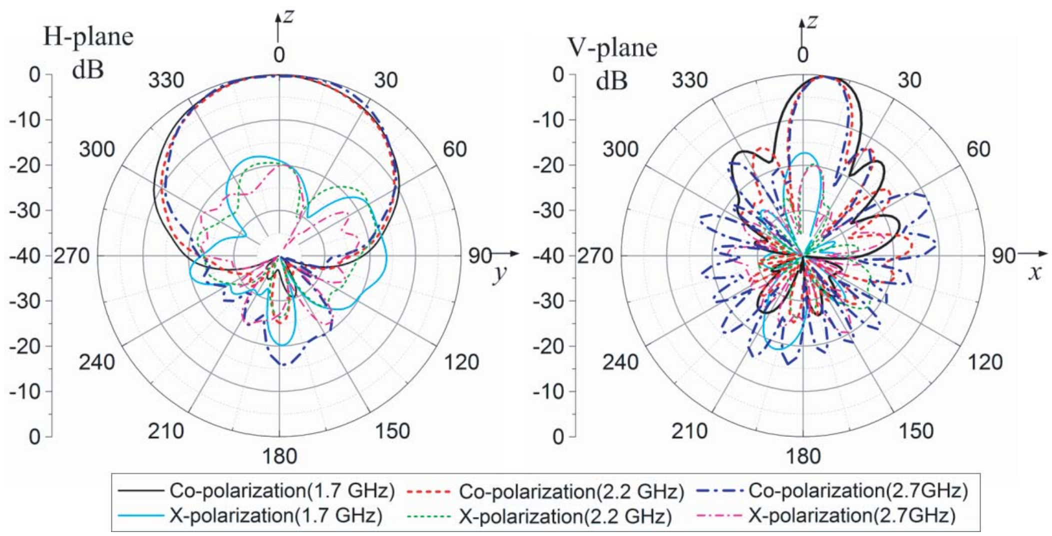

Figure 13. Measured radiation patterns of the antenna array.

the operating band. The variation of gain and half-power beamwidth (HPBW) in H-plane is depicted in Figure 11. It can be seen that the antenna has a gain of 7.6 ± 0.6 dBi and HPBW of $65^\circ \pm 5^\circ$ within the entire bandwidth. It is noteworthy that the results of radiation patterns and gains are for $+45^\circ$-polarization, and the results for -45°-polarization are similar.

A dual-polarized antenna array with electrical down tilt is developed. The array is composed of 4 arm-overlapped dipole antennas with an elements spacing of 110 mm ($0.8\lambda_{2.2}$). To produce down tilt in the V-plane, the four elements are arranged along x-axis and fed by two four-way power dividers with inserted phase shifters. It can be seen from the measured VSWR and isolation of the input ports in Figure 12 that a bandwidth of 49.5% (1.7–2.82 GHz) is obtained for VSWR < 1.5 and isolation > 28 dB. Figure 13 gives the measured radiation patterns of the array at 1.7 GHz, 2.2 GHz, and 2.7 GHz. The down tilt in V-plane is about $8^\circ \pm 2^\circ$. A measured gain from 12 to 14.1 dBi and an HPBW of $63^\circ \pm 6.5^\circ$ are obtained for the array, which are not given in curve style for simplicity.

Table 2 compares the proposed arm-overlapped dipole antenna to the recently reported dual-polarized dipole antennas that cover the band 1.7–2.7 GHz. It can be seen that the proposed antenna has a relatively compact radiator size and comparable performances of bandwidth and isolation.

4. CONCLUSION

A wideband dual-polarized antenna with a small radiator size is proposed in this paper. The size of the radiator is reduced from $69 \times 69\,\text{mm}^2$ to $49 \times 49\,\text{mm}^2$ by cutting and overlapping the arms of the square loop. In addition, open pins are employed to match the impedance at high frequencies. The antenna achieves a wide bandwidth of 49.5% (1.7–2.82 GHz) with stable gain and HPBW. Results of the antenna and its down-tilt array indicate that the proposed antenna is a good candidate for 2G/3G/4G base station and other dual-polarized applications.

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