A Compact Dual-Polarized Antenna for Base Station Application

Guan-Feng Cui[1, *], Shi-Gang Zhou[2], Shu-Xi Gong[1], and Ying Liu[1]

Abstract—A compact dual-polarized antenna element integrated with balun is proposed. Two pairs of dipoles are employed for the dual-polarizations of the antenna, and strong mutual coupling between them is introduced to widen the bandwidth of the antenna. Bent dipoles are used to reduce the size of the antenna. The simulated and measured results show that the proposed antenna can cover the bandwidth ranging from 790 MHz to 960 MHz with VSWR < 1.5 and isolation > 26 dB. The antenna element is also fabricated and tested. The measured results show that the antenna can be a good candidate for the design of European Digital Dividend/CDMA800/GSM900 mobile communication base station antenna.

1. INTRODUCTION

Dual-polarized antenna is widely used in modern wireless communication systems since the application of polarization diversity technology [1]. The antenna with two orthogonal polarizations along the directions of slant $\pm 45°$ can decrease fast fading of a signal and increase system capacity. To satisfy the demand of European Digital Dividend ($791 \sim 862$ MHz), CDMA800 ($825 \sim 880$ MHz), and GSM900 ($889 \sim 960$ MHz) simultaneously, the dual-polarized antenna should cover the bandwidth of $790 \sim 960$ MHz. Although many kinds of base station antennas have been proposed in [2–14], there are still some improvements should be made. Some of these antennas [2, 7, 8] have a narrow impedance bandwidth that cannot cover the bandwidth from 790 MHz to 960 MHz. The gain of base station antenna in the forms of patch antenna [4–6, 9, 10] and cross dipole antenna [2, 8] is not high enough to meet the application requirement.

In this paper, we present a compact, dual-polarized antenna element with a simple and stable structure. The proposed antenna can cover a bandwidth ranging from 790 MHz to 960 MHz with low VSWRs and high isolation. The antenna has good impedance and radiation characteristic, and can be used to form an array antenna for the base station.

2. ANTENNA DESIGN

The configuration of the proposed antenna and the corresponding system are shown in Fig. 1. The antenna element consists of four (two pairs) dipoles, four baluns, one base and a metal reflector. The four baluns are integrated with the dipoles and the base at the bottom of the antenna. One pair of dipoles (two opposite dipoles) is used for one polarization, and the dipoles are fed directly by coaxial cables and feeding pads. Each arm of the dipole consists of three segments with different directions. According to the coordinate system shown in Fig. 1(a), the direction of the first segment is along slant $+45°$ or $-45°$, the second segment along X-axis or Y-axis direction and the third segment along $-Z$ direction which leads to the existing strong mutual coupling between the adjacent dipoles. The proposed antenna has a total size of $0.49\lambda_0 \times 0.49\lambda_0 \times 0.2\lambda_0$, where λ_0 is the wavelength corresponding to the center frequency of the bandwidth due to the design of the three parts of the dipole arms. According

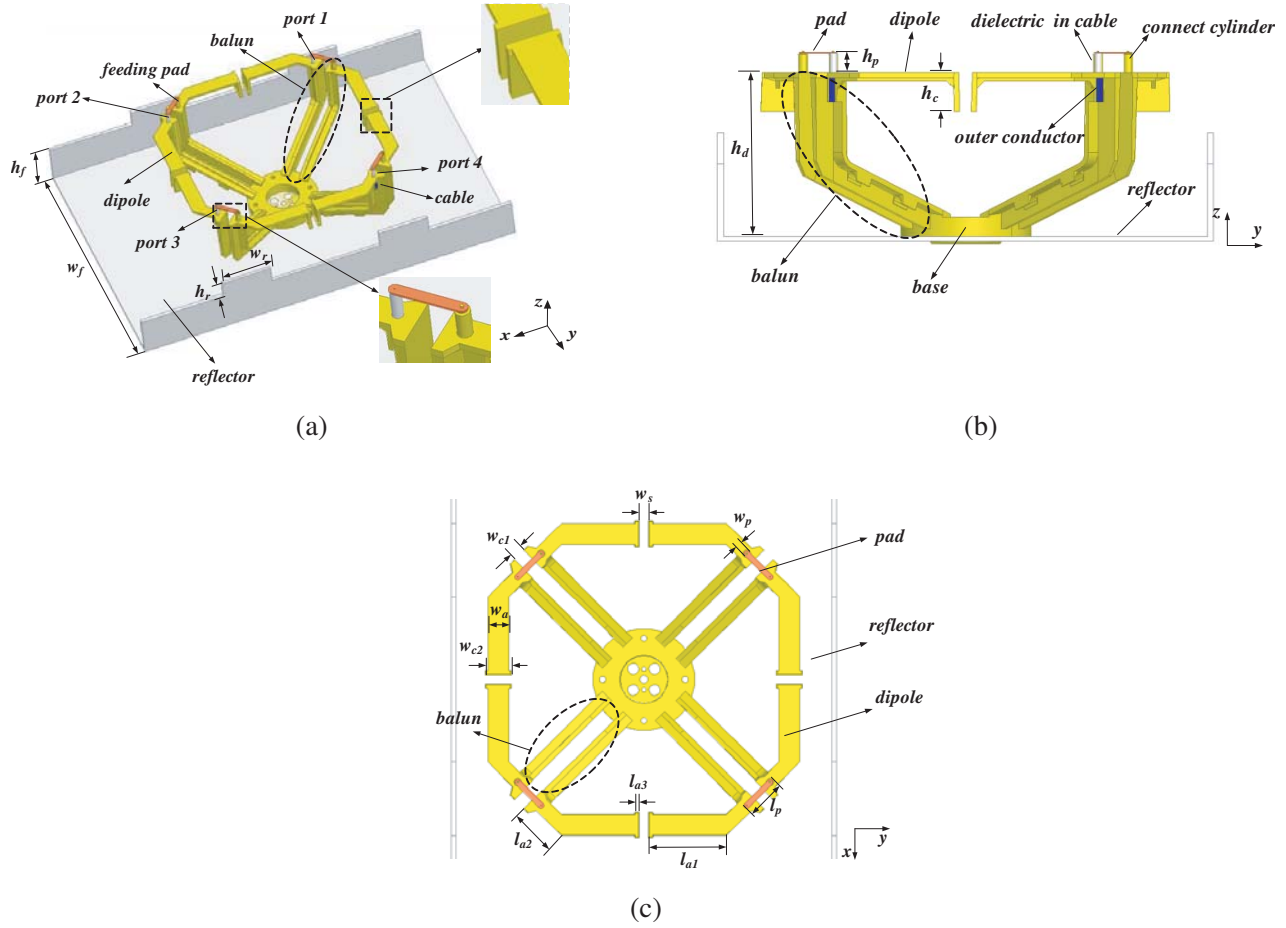(a)   (b)

(c)

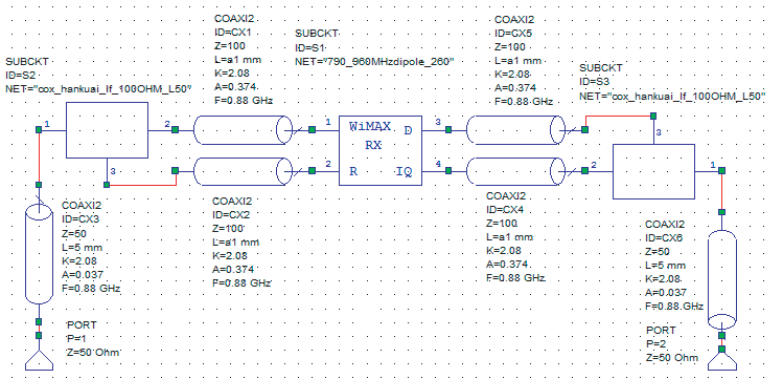**Figure 1.** Geometry of the proposed antenna. (a) 3D view. (b) Side view. (c) Top view.

**Figure 2.** The collaborative simulation model of the antenna element.

to the coordinate system shown in Fig. 1(a), the H-plane of the antenna, which refers to the horizontal plane in the base station antenna specification, is $\varphi = 90°$, and the E-plane that refers to the vertical plane of the antenna is $\varphi = 0°$.

As a pair of dipoles is used for one polarization in this proposed antenna, the input impedance of each dipole is designed to be 100 Ohms. The two dipoles are connected with 100 Ohms cables to form one port match to 50 Ohms. The antenna is simulated and optimized by the software of Ansoft HFSS 15.0 and Microwave Office 10 shown in Fig. 2. The antenna without cables is simulated with HFSS, and

the exported .snp file is used in Microwave Office representing the antenna. Collaborative simulation of the antenna element is realized by using these two softwares simultaneously. The simulated VSWR and input impedance results are shown in Fig. 3.

As mentioned above, to broaden the input impedance bandwidth of the antenna, strong mutual coupling between the adjacent dipoles is introduced. The simulated results of single polarized antenna without mutual coupling effect are also shown in Fig. 3. It can be seen that the bandwidth will be much narrower without mutual coupling. Because of using the other polarization dipole structures and the mutual coupling effect, the structure also can be resonant in lower frequency band, as seen in Fig. 4.

In order to get a directional radiation pattern, a metal reflector with U-shape is needed for the design of the antenna. To reduce the height of the antenna, some further technologies should be employed to improve the radiation performance. Two crenellated side walls of the reflectors are designed to improve the front-to-back ratio of the antenna. All the optimized geometric parameters of the antenna element are listed in Table 1.
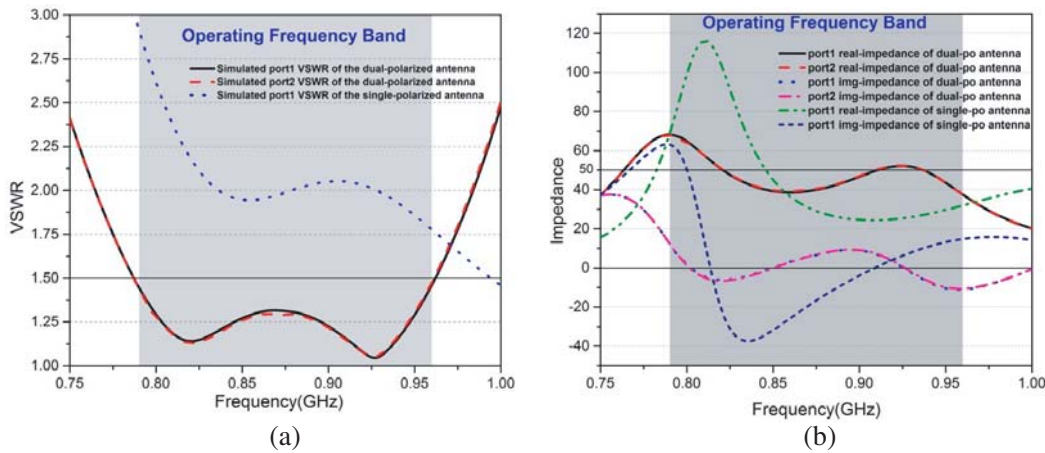
Figure 3. Comparison of the dual-polarized antenna and the single-polarized antenna. (a) VSWR. (b) Impedance.

Table 1. Optimized geometric parameters of the antenna element.

Parameter	Value	Parameter	Value
w_f	250 mm	h_f	32 mm
h_d	69 mm	h_p	9 mm
w_r	39.3 mm	h_r	13 mm
h_c	16 mm	w_{c1}	7 mm
w_{c2}	13 mm	w_a	11 mm
w_s	5.66 mm	w_p	3 mm
l_p	21 mm	l_{a1}	41 mm
l_{a2}	24.3 mm	l_{a3}	2 mm

3. EXPERIMENTAL RESULTS AND DISCUSSION

A prototype of the proposed antenna with the above optimized parameters was fabricated and measured to verify the design method. Photographs of the fabricated antenna element are shown in Fig. 5. S-parameters of the fabricated antenna were measured by Agilent E5071C network analyzer in an anechoic chamber. The radiation pattern performance of the proposed antenna element was measured by the Far-Field test system.
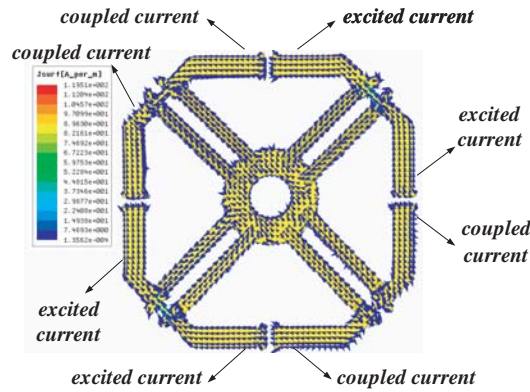
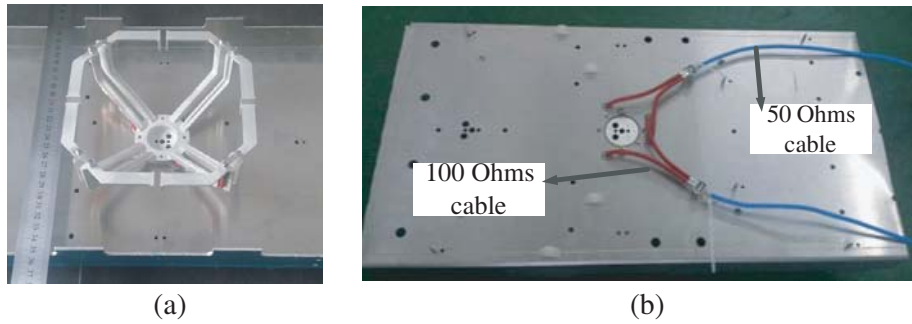**Figure 4.** Current vector distribution on the proposed antenna.

Figure 5. Photograph of the fabricated antenna element. (a) Topside view. (b) Backside view.
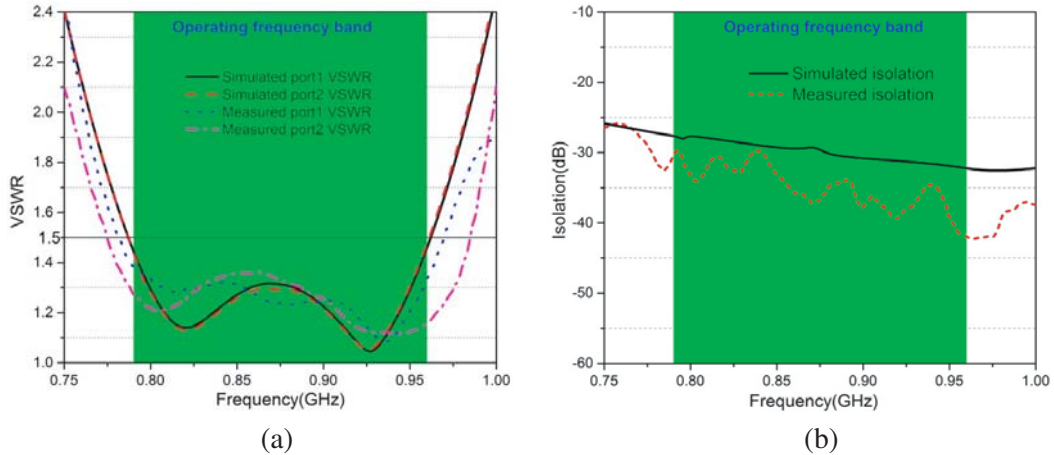

Figure 6. Simulated and measured VSWR and isolation of the proposed antenna. (a) VSWR. (b) Isolation.

The simulated and measured VSWRs and isolations of the antenna versus frequency are shown in Fig. 6. Good agreement is observed between the measured VSWRs of the two polarizations of the antenna with the simulated ones. Due to manufacture precision, the measured isolation result between $+45°$ and $-45°$ polarizations does not agree well with the simulated one, but they are all above 26 dB over the whole working band. The designed antenna has an impedance bandwidth of 19.4% ranging

from 790 to 960 MHz for VSWR < 1.5 and isolation > 26 dB. The polarization isolation is mainly affected by the metal reflector, like the U-shape or the sidewalls height of the reflector, and can be easily adjusted for the array antenna. Therefore, the proposed antenna element has a good impedance characteristic that can satisfy the requirement of the array antenna for base station.

Since the two linearly polarizations of the antenna are highly symmetrical, only the radiation pattern of one polarization is shown here. The simulated and measured radiation patterns of H- and E-planes at the frequencies of 790, 880, 960 MHz are plotted in Fig. 7. The measured results agree well with the simulated ones across the whole operating band except the cross-polarization. At the frequency of 880 MHz, the measured cross-polarization level is higher than the simulated one. At the frequency of 960 MHz, the measured cross-polarization has a larger back direction lobe than the simulated one. The main reason for the difference between the simulated and measured results is that the cross-polarization level of the antenna element is relatively weak in the far-field measured system, and the direction of the linear polarization rotates during the entire testing process.
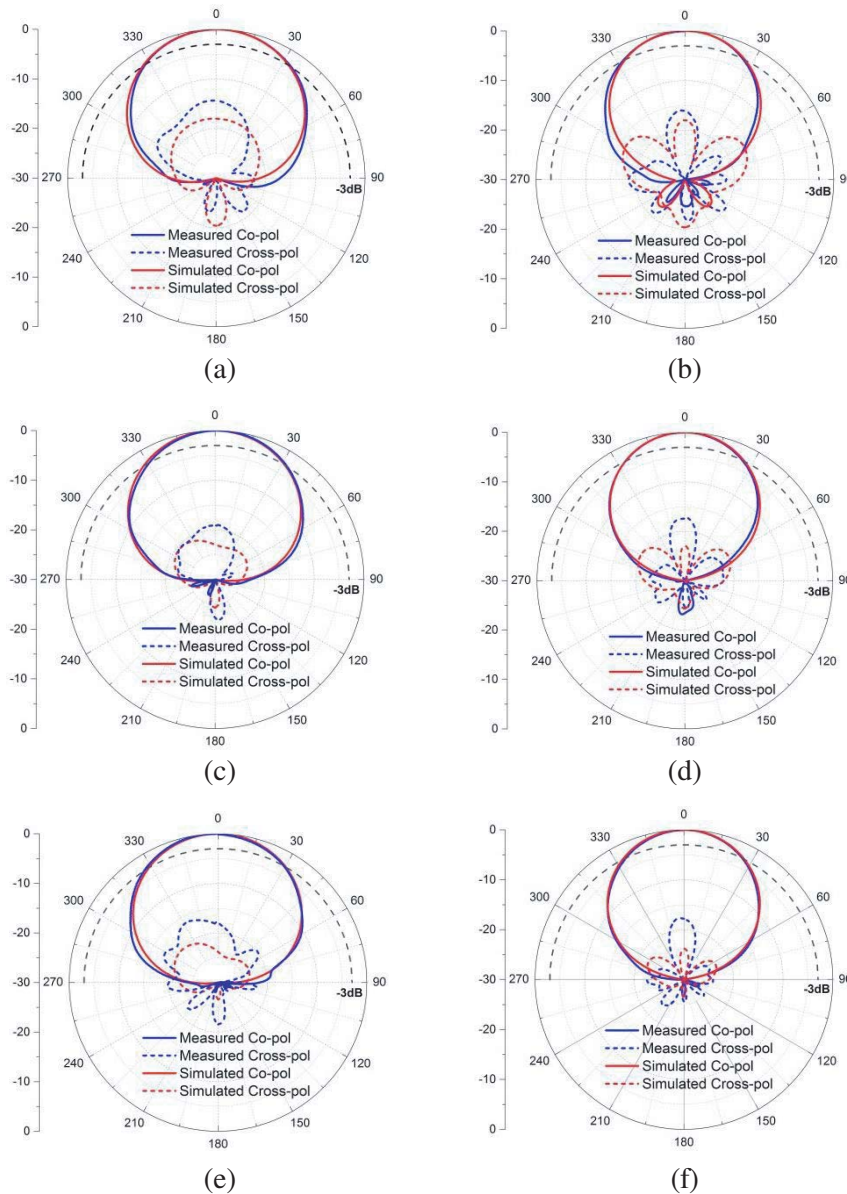
Figure 7. The radiation pattern of the proposed antenna. (a) 790 MHz H-plane. (b) 790 MHz E-plane. (c) 880 MHz H-plane. (d) 880 MHz E-plane. (e) 960 MHz H-plane. (f) 960 MHz E-plane.
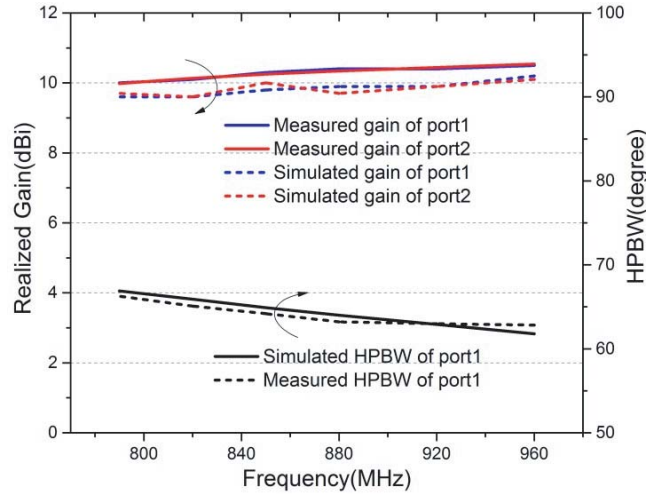
Figure 8. Simulated and Measured realized gain and HPBW of the proposed antenna.

Table 2. Simulated and measured half power beamwidth.

Half-power beamwidth	790 MHz		880 MHz		960 MHz	
	Simulated	Measured	Simulated	Measured	Simulated	Measured
H-plane	66.9	66.27	64.0	63.2	61.8	62.83
E-plane	52.9	53.21	53.2	52.0	53.9	51.47

Table 3. Simulated and measured parameters of the radiation patterns of the proposed antenna.

Frequency (MHz)	Gain (dBi)		Front-to-back ratio (dB) Co (180° ± 30°)		Front-to-back ratio (dB) Cross (180° ± 30°)		Cross polar ratio (dB) 0°		Cross polar ratio (dB) ±60°	
	Sim.	Mea.	Sim.	Mea.	Sim.	Mea.	Sim.	Mea.	Sim.	Mea.
790	10.0	9.6	20.6	30.9	20.4	22.1	18.0	14.4	10.3	6.7
880	10.4	9.9	24.1	26.6	24.3	21.6	23.0	19.0	10.8	11.3
960	10.5	10.2	25.6	22.0	26.6	21.5	23.8	16.3	9.4	11.8

The simulated and measured realized gains and HPBWs of the proposed antenna are shown in Fig. 8. In Table 2 and Table 3, the radiation pattern parameters of the proposed antenna are listed. The measured half-power beam width of the H-plane across the entire working frequency range varies from 62.83° to 66.27°, and the simulated results range from 61.8° to 66.9°. The proposed antenna element has a good convergence of the HPBW. The simulated gain of the radiation pattern ranges from 10.0 dBi to 10.5 dBi, and the measured results range from 9.6 dBi to 10.2 dBi. The feeding coaxial cables and connector used for testing bring the gain loss to the antenna element. The front-to-back ratio of the co- and cross-polarizations across the entire operating frequencies are larger than 20 dB since the introduction of sawtooth shape sidewalls of the reflector.

4. CONCLUSION

A compact, dual-polarized antenna element has been proposed. The strong mutual coupling between the adjacent dipoles is introduced to broaden the impedance bandwidth of the antenna. The proposed antenna can cover the bandwidth ranging from 790 MHz to 960 MHz with VSWRs < 1.5 and isolation > 26 dB, which can satisfy the requirement of an array antenna for base station. Good impedance and radiation characteristics are achieved for the proposed antenna element. The antenna also has a simple and stable structure, and can be easily manufactured.

REFERENCES

1. Vaughan, R. G., "Polarization diversity in mobile communications," *IEEE Transactions on Vehicular Technology*, Vol. 39, No. 3, 177–186, 1990.
2. Bin Asrokin, A., A. Bin Abas, R. Basri, et al., "Design of X-polarized GSM 900 base station antenna with field test measurement," *2010 Second International Conference on Computer Engineering and Applications*, 94–98, IEEE Computer Society, 2010.
3. Kaboli, M., M. S. Abrishamian, S. A. Mirtaheri, et al., "High-isolation XX-polar antenna," *IEEE Transactions on Antennas and Propagation*, Vol. 60, 4046–4055, 2012.
4. Sharma, D. K., S. Kulshrestha, S. B. Chakrabarty, et al., "Shared aperture dual band dual polarization microstrip patch antenna," *Microwave and Optical Technology Letters*, Vol. 55, 917–922, 2013.
5. Gou, Y., S. Yang, Q. Zhu, et al., "A compact dual-polarized double E-shaped patch antenna with high isolation," *IEEE Transactions on Antennas and Propagation*, Vol. 61, 4349–4353, 2013.
6. Chiou, T. W. and K. L. Wong, "A compact dual-band dual-polarized patch antenna for 900/1800-MHz cellular systems," *IEEE Transactions on Antennas and Propagation*, Vol. 5, 1936–1940, 2003.
7. Liu, X., S. He, H. Zhou, et al., "A novel low-profile, dual-band, dual-polarization broadband array antenna for 2G/3G base station," *International Conference on Wireless, Mobile and Multimedia Networks*, 1–4, 2006.
8. Suh, S. Y., W. Stutzman, W. Davis, et al., "A novel low-profile, dual-polarization, multi-band base-station antenna element — The fourpoint antenna," *Vehicular Technology Conference, 2004. VTC2004-Fall. 2004 IEEE 60th. IEEE*, Vol. 1, 225–229, 2004.
9. Chen, Y.-P., H.-J. Sun, and X. Lv, "Novel design of dual-polarization broad-band and dual-band printed L-shaped probe fed microstrip patch antenna," *Journal of Electromagnetic Waves and Applications*, Vol. 23, Nos. 2–3, 297–308, 2009.
10. Jin, Y. and Z. Du, "Broadband dual-polarized f-probe fed stacked patch antenna for base stations," *IEEE Antennas and Wireless Propagation Letters*, Vol. 14, 1121–1124, 2015.
11. Dai, X.-W., T. Zhou, and G.-F. Cui, "Dual-band microstrip circular patch antenna with monopolar radiation pattern," *IEEE Antennas and Wireless Propagation Letters*, Vol. PP, No. 99, 1, 2015.
12. Peng, H.-L., W.-Y. Yin, J.-F. Mao, D. Huo, X. Hang, and L. Zhou, "A compact dual-polarized broadband antenna with hybrid beam-forming capabilities," *Progress In Electromagnetics Research*, Vol. 118, 253–271, 2011.
13. Xie, J.-J., Y.-Z. Yin, J. Ren, and T. Wang, "A wideband dual-polarized patch antenna with electric probe and magnetic loop feeds," *Progress In Electromagnetics Research*, Vol. 132, 499–515, 2012.
14. Moradi, K. and S. Nikmehr "A dual-band dual-polarized microstrip array antenna for base stations," *Progress In Electromagnetics Research*, Vol. 123, 527–541, 2012.