# A Wideband Dual-Polarized Slot Antenna

Xiaolei Jiang, *Student Member, IEEE*, Zhijun Zhang, *Senior Member, IEEE*, Yue Li, *Member, IEEE*, and Zhenghe Feng, *Fellow, IEEE*

***Abstract*—In this letter, we have proposed a dual-polarized planar circular slot antenna for wideband application. Two orthogonal polarizations were achieved by adopting different feeding mechanisms with high ports isolation. The horizontal polarization is excited by a meander-line coupled slot, and the vertical polarization is fed by a stepped monopole. The prototype of the proposed antenna has been built and tested. The proposed design obtained a fairly wide bandwidth (1.70–2.71 GHz) and a high isolation (>33 dB) over the entire band. The gain of the dual polarizations is also measured and discussed.**

***Index Terms*—Dual polarization, high isolation, slot antenna, wideband.**

## I. Introduction

MOBILE communication is undergoing a rapid evolution nowadays, and it spurs engineers to design a wideband antenna in a single system to cover several frequency bands for different wireless technologies like GSM, UMTS, WLAN, WiMAX, and the new one—LTE—also known as 4G. On the other hand, dual-polarized antennas have been widely used for the past several years to enhance the channel capability of the system. Therefore, an antenna having both wideband and dual-polarized characteristics is desirable for modern mobile communication systems.

In previous works [1], [2], dual-polarized antennas were proposed for the bandwidth from 1710 to 2170 MHz, i.e., a 24% bandwidth covering the GSM1800, GSM1900, and UMTS bands. A stacked patch antenna that had a 33% bandwidth was proposed in [3] to cover more bands. Nevertheless, for a modern mobile system operating at all the frequency bands mentioned here from GSM1800 up to LTE2500, i.e., 1710–2690 MHz, a bandwidth of more than 45% is required. A magneto-electric dipole antenna excited by two $\Gamma$-shaped strips could achieve a common bandwidth of 65.9% at both input ports [4], and a patch antenna with two pairs of T-shaped slots could also achieve a 46.5% bandwidth [5] in recent studies. However, these wideband dual-polarized antennas [4], [5] are all patch antennas with a three-dimensional structure, and their implementations are inconvenient.

Manuscript received April 26, 2013; revised June 27, 2013; accepted July 27, 2013. Date of publication July 31, 2013; date of current version August 28, 2013. This work was supported by the National Basic Research Program of China under Contract 2009CB320205, and in part by the National High Technology Research and Development Program of China (863 Program) under Contract 2011AA010202, the National Natural Science Foundation of China under Contract 61271135, the National Science and Technology Major Project of the Ministry of Science and Technology of China under Grant 2013ZX03003008-002, and Qualcomm, Inc.

The authors are with the State Key Laboratory of Microwave and Communications, Tsinghua National Laboratory for Information Science and Technology, Tsinghua University, Beijing 100084, China (e-mail: zjzh@tsinghua.edu.cn).

Color versions of one or more of the figures in this letter are available online at http://ieeexplore.ieee.org.

Digital Object Identifier 10.1109/LAWP.2013.2276016

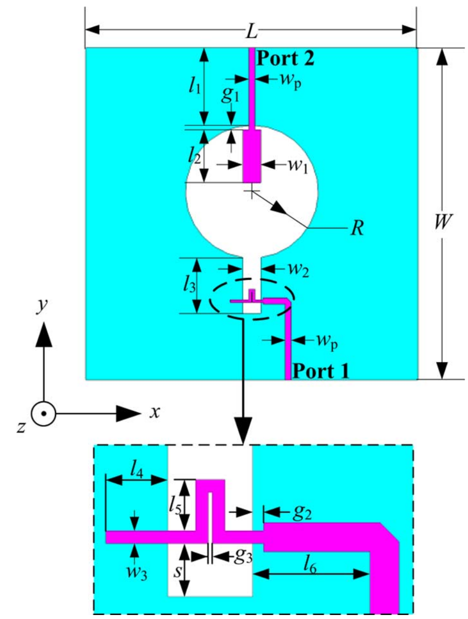


Fig. 1. Geometry of the proposed slot antenna.

Similar to the patch antenna, wideband and dual-polarized characteristics can also be achieved in a slot antenna. Moreover, the slot antenna has a simpler planar structure and is easy to fabricate. Therefore, several dual-polarized slot antennas have been introduced in recent years [6]–[10]. However, these antennas are only used for WLAN applications, and their bandwidths are far away from 45%. Furthermore, some of them did not have a common bandwidth at the two input ports, which reduced their operating bands further [7], [8].

In this letter, we have presented a circular slot antenna with two high-isolated ports for bidirectional radiation applications. The design is inspired by the work of Lee *et al.* [7]. A monopole and a narrow rectangular slot along with a meander line are applied to excite two polarizations. A common bandwidth of 45.8% (1700–2710 MHz) for both ports is obtained by the delicate adjustment of the feeding structure. The isolation stays higher than 33 dB over the entire operating band.

## II. Antenna Design

The geometry of the circular slot antenna is shown in Fig. 1. The proposed antenna is printed on a 1-mm-thick substrate with permittivity 2.65 and loss tangent 0.002. It consists of a circular slot with a small narrow rectangular slot etched on the bottom layer and two microstrip lines printed on the top layer. It is known that the circular slot could support two orthogonal degenerate $TE_{11}$ modes, as illustrated in Fig. 2, which shows the electric fields at 2.2 GHz, and one of them is $x$-directed and the

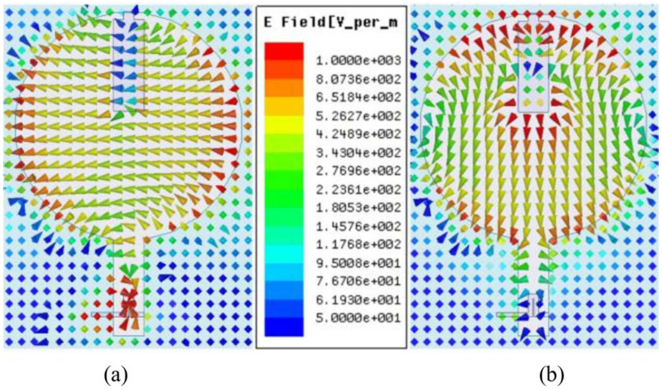


Fig. 2. Electric fields in the circular slot at 2.2 GHz: fed from (a) Port 1 and (b) Port 2.

other $y$-directed, thus generating two orthogonal linear polarizations along the $x$- and $y$-axis in the far field of the antenna. $x$-directed $TE_{11}$ mode is generated by a meander structure whose details are enlarged and shown in Fig. 1, and $y$-directed $TE_{11}$ mode is generated by a monopole-like structure.

Before the proposed structure in Fig. 1, we have studied the situation that two ports are located in orthogonal position, i.e., two narrow slots (or two monopoles) in $x$- and $y$-axis respectively. However, the simulation shows poor isolation between the two ports.

Thus, as shown in Fig. 1, we put the two ports in opposite position and use a narrow slot and a monopole to obtain two orthogonal polarizations. The structure that applies a slot with a meander line is inspired by [7], and it can achieve a wide bandwidth. The wideband characteristic was explained by studying a traditional rectangular slot antenna in [11]. It was found that when properly choosing the ratio of the width and length of the slot and the position of the feedline, a second resonance at a higher frequency would appear due to a fictitious short circuit near the feedline, thus expanding the bandwidth of the antenna. Based on the design [7], we first replace the triangular slot by a circular slot for the consideration of symmetry. Subsequently, we extend the slot using another rectangular slot to enhance the impedance matching for $x$-directed polarization. For $y$-directed polarization, wide bandwidth can be achieved by elaborately choosing the length and width of the monopole.

To investigate some critical parameters that contribute to the bandwidth enhancement, a parametric study was carried out by using Ansoft High Frequency Structure Simulator (HFSS). As described earlier, the rectangular slot length $l_3$ and feeding position $s$ are the major factors that affect the bandwidth of Port 1; hence, we will concentrate on these two parameters. In the following discussion, when one parameter is studied, the other will keep the value as listed in Table I. As for Port 2, we could first choose a specific $l_2$ to obtain the desired band and then adjust $w_1$ to achieve a desired bandwidth. This technique for expanding the bandwidth is well known to us.

Fig. 3 shows the simulated $S_{11}$ in Smith chart with different rectangular slot lengths $l_3$. It demonstrates that when $l_3$ equals 25 mm, bandwidth could reach the maximum with good impedance matching, and either smaller or larger value will lead to bad performance. It can also be clearly observed that

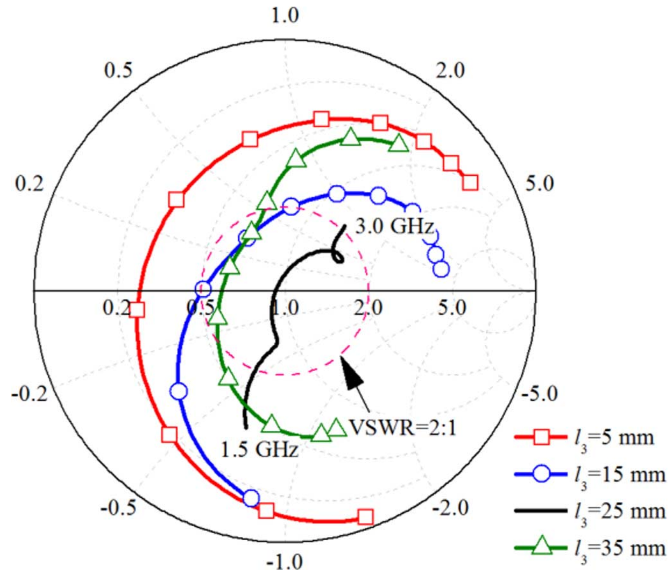


Fig. 3. $S_{11}$ in Smith chart with different $l_3$.

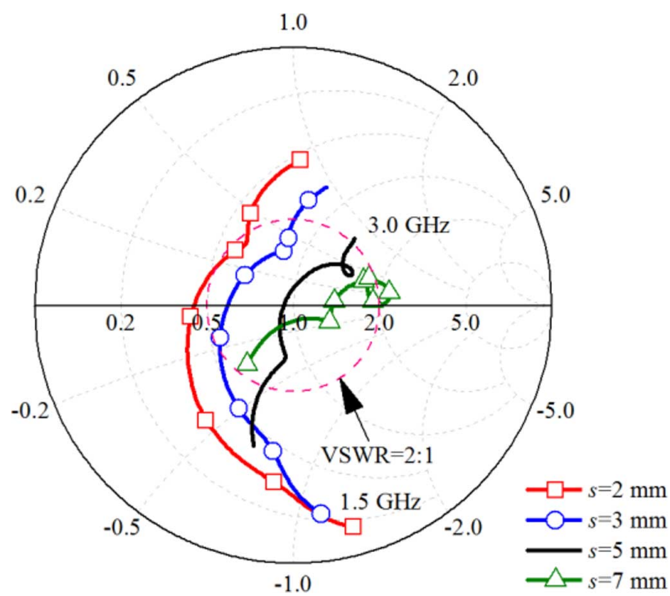


Fig. 4. $S_{11}$ in Smith chart with different $s$.

TABLE I
ANTENNA PARAMETERS (UNIT: MILLIMETER)

| Parameter | Value | Parameter | Value | Parameter | Value |
|---|---|---|---|---|---|
| $L$ | 150 | $l_4$ | 5.8 | $w_p$ | 2.73 |
| $W$ | 150 | $l_5$ | 4.8 | $g_1$ | 2 |
| $R$ | 30 | $l_6$ | 11 | $g_2$ | 1 |
| $l_1$ | 35 | $w_1$ | 8 | $g_3$ | 0.36 |
| $l_2$ | 24 | $w_2$ | 8 | $s$ | 5 |
| $l_3$ | 25 | $w_3$ | 1.2 | | |

there are two resonances at lower and upper band, respectively, thus expanding the bandwidth for Port 1. Fig. 4 shows the simulated $S_{11}$ in Smith chart with different feeding positions $s$. It is seen that the two resonances always existed with different $s$, and when $s$ is increased, those two resonances appear more remarkable and could achieve a wider bandwidth. Here, $s$ is chosen to be 5 mm for 50 Ω in the required band.

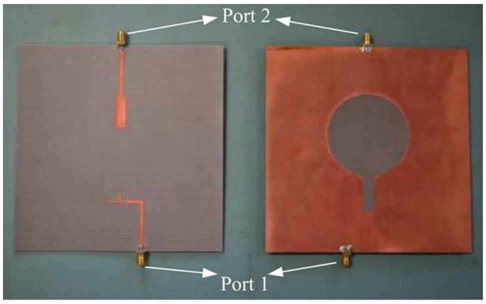


Fig. 5. Photographs of the proposed antenna. *(left)* Front and *(right)* back view.

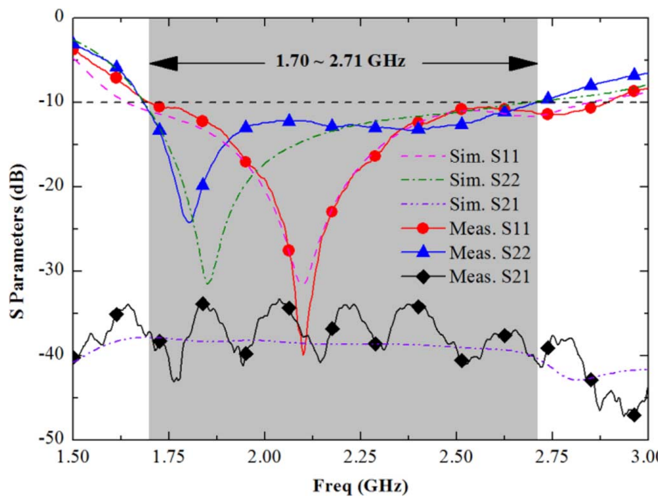


Fig. 6. Simulated and measured $S$-parameters of the proposed antenna.

TABLE II
COMPARISON OF BANDWIDTH FOR DUAL-POLARIZED SLOT ANTENNAS

| Antennas | Port 1 | Port 2 | Common Bandwidth |
|---|---|---|---|
| Antenna in [7] | 26.1%<br>4.83-6.28 GHz | 19.7%<br>4.99-6.08 GHz | 19.7%<br>4.99-6.08 GHz |
| Antenna in [8] | 27.9%<br>1.96-2.63 GHz | 35.4%<br>1.93-2.75 GHz | 27.9%<br>1.96-2.63 GHz |
| Proposed antenna | 51.8%<br>1.70-2.89 GHz | 46.9%<br>1.68-2.71 GHz | 45.8%<br>1.70-2.71 GHz |

## III. MEASURED RESULT

A prototype of the proposed antenna with parameters tabulated in Table I is fabricated, whose photographs are shown in Fig. 5. Fig. 6 shows the measured $S$-parameters in comparison to the simulated ones. As can be seen from the figure, good agreement between the measured and simulated reflection efficiencies is obtained. The measured impedance bandwidth ($S_{11} \leq -10$ dB) covers a frequency range from 1.70 to 2.89 GHz and 1.68 to 2.71 GHz for Port 1 and Port 2, respectively, which indicates a similar impedance characteristic of the two ports and a percentage bandwidth of 45.8% (1.70–2.71 GHz) for the proposed dual-polarized slot antenna. The bandwidth of the proposed antenna is compared to previous work in Table II. The circular slot antenna proposed in this letter achieves a considerable wide impedance bandwidth when compared to the isosceles triangular slot antenna [7] and the rectangular slot antenna [8].

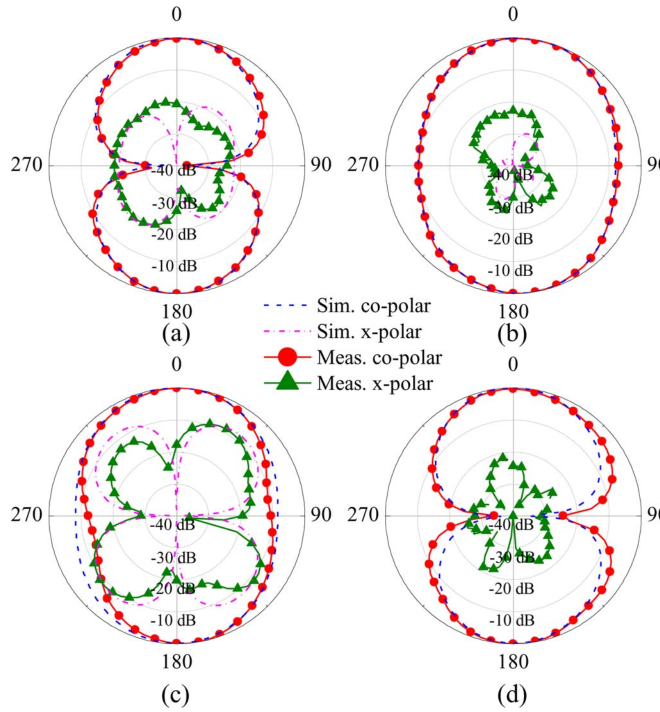


Fig. 7. Measured and simulated radiation patterns at 1.8 GHz for Port 1 (a) E-plane and (b) H-plane and Port 2 (c) H-plane and (d) E-plane.

Fig. 6 also shows that the simulated isolation is higher than 38 dB while the measured result still stays above 33 dB. High isolation is up to the two degenerate modes that are orthogonal to each other along with the special feeding positions of two input ports positioned on the opposite margins of a circular slot.

The measured and simulated radiation patterns are plotted in Fig. 7–9 at frequencies of 1.8, 2.0, and 2.5 GHz, respectively. Each figure illustrates both the H-plane and E-plane patterns of Port 1 and Port 2 at a specific frequency. From these figures, we can see that simulated and measured results for the coplanar polarizations of both ports agree well with each other. Patterns for E-plane of both ports at these three frequencies are all figure-8-like shapes that indicate the pattern stability of the E-plane. For the H-plane, however, patterns of Port 2 stay almost the same at different frequencies, whereas those of Port 1 deteriorate as the frequency increases. It presents directional characteristics at high frequency. From these figures, it may be noted that cross polarization in $xz$-plane is much higher than that in $yz$-plane and even higher than $-15$ dB. However, it is really small in $yz$-plane, and the cross polarizations of Port 2 even cannot be seen in such a scale in the figures. The high polarization for $xz$-plane is caused by the asymmetrical structure of the antenna. However, as the radiation patterns of the coplanar and cross polarization are uncorrelated [8], this antenna can still provide two independent channels in the mobile communication system.

Fig. 10 shows the measured and simulated gains against frequency. Due to the limit of experimental conditions, the measured results are given only up to 2.5 GHz, but simulated results above 2.5 GHz are plotted as reference. The simulated gains for Port 1 and Port 2 are better than 5 and 4 dB, respectively, and both the ports have a consistent gain. The measured and simulated gains also have a reasonable agreement. A less than 2-dB

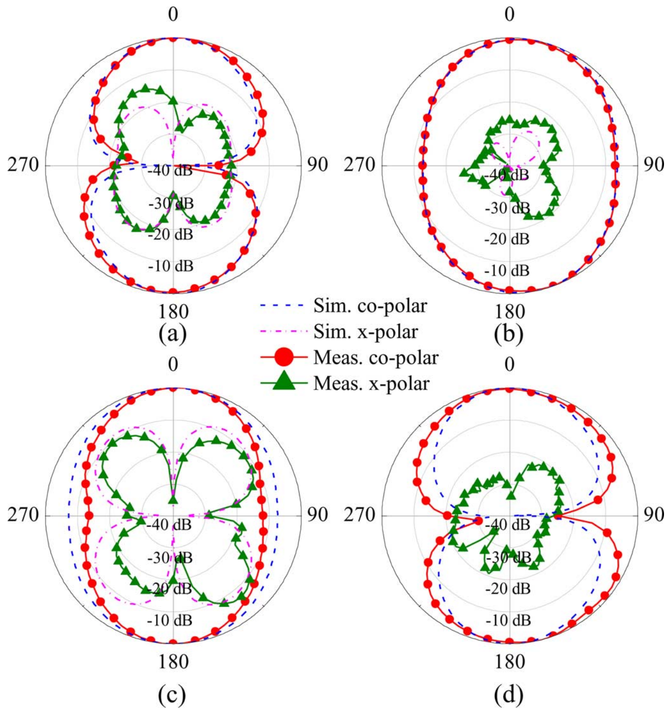


Fig. 8. Measured and simulated radiation patterns at 2.0 GHz for Port 1 (a) E-plane and (b) H-plane and Port 2 (c) H-plane and (d) E-plane.

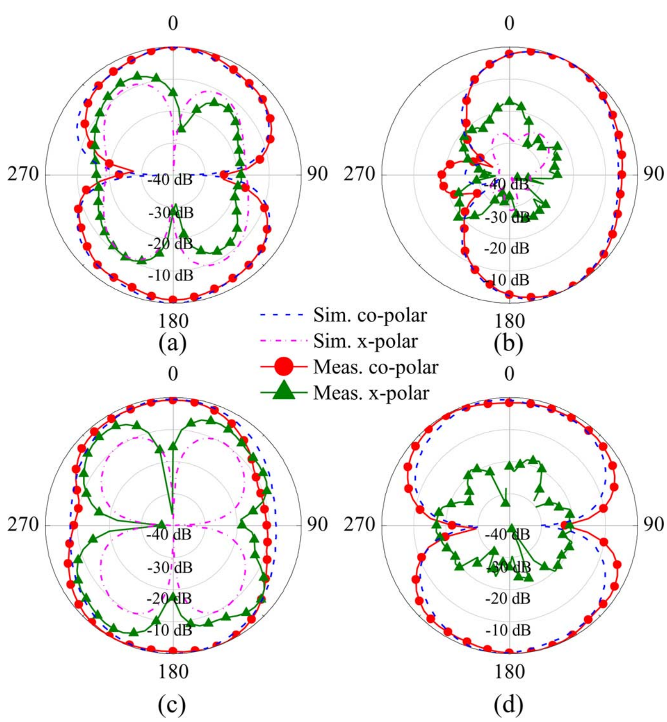


Fig. 9. Measured and simulated radiation patterns at 2.5 GHz for Port 1 (a) E-plane and (b) H-plane and Port 2 (c) H-plane and (d) E-plane.

gain difference can be found between the two ports. This reason is similar to that explained in [8], which is the impact of the monopole extended into the circular slot.

## IV. Conclusion

In this letter, a dual-polarized circular slot antenna is proposed. By applying two different feeding structures, this antenna obtains a fairly wide bandwidth with high ports isolation. The prototype is built and measured, which achieves a common bandwidth from 1.70 to 2.71 GHz for both the input ports. Its isolation between the two input ports keeps higher than 33 dB over the entire operating band. Both the horizontal and vertical polarization obtain a consistent gain. Owing to its planar structure, the cost of the proposed antenna is definitely lower than that of the patch antennas. With these good features, the proposed antenna can be used in the wideband system for GSM1800, GSM1900, UMTS, WLAN/WiMAX, and LTE applications.

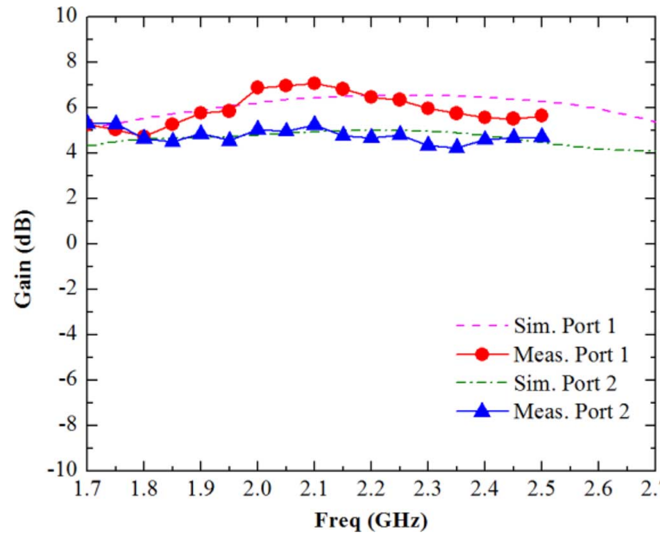


Fig. 10. Measured and simulated gain of the proposed dual-polarized antenna.

## References

[1] K.-M. Mak, H. Wong, and K.-M. Luk, "A shorted bowtie patch antenna with a cross dipole for dual polarization," *IEEE Antennas Wireless Propag. Lett.*, vol. 6, pp. 126–129, 2007.

[2] M. Barba, "A high-isolation, wideband and dual-linear polarization patch antenna," *IEEE Trans. Antennas Propag.*, vol. 56, no. 5, pp. 1472–1476, May 2008.

[3] A. A. Serra, P. Nepa, G. Manara, G. Tribellini, and S. Cioci, "A wideband dual-polarized stacked patch antenna," *IEEE Antennas Wireless Propag. Lett.*, vol. 6, pp. 141–143, 2007.

[4] B. Q. Wu and K.-M. Luk, "A broadband dual-polarized magneto-electric dipole antenna with simple feeds," *IEEE Antennas Wireless Propag. Lett.*, vol. 8, pp. 60–63, 2009.

[5] B. Li, 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, pp. 427–430, 2012.

[6] E. A. Soliman, M. S. Ibrahim, and A. K. Abdelmageed, "Dual-polarized omnidirectional planar slot antenna for WLAN applications," *IEEE Trans. Antennas Propag.*, vol. 53, no. 9, pp. 3093–3097, Oct. 2009.

[7] C.-H. Lee, S.-Y. Chen, and P. Hsu, "Isosceles triangular slot antenna for broadband dual polarization applications," *IEEE Trans. Antennas Propag.*, vol. 57, no. 10, pp. 3347–3351, Oct. 2009.

[8] Y. Li, Z. Zhang, W. Chen, Z. Feng, and M. F. Iskander, "A dual-polarization slot antenna using a compact CPW feeding structure," *IEEE Antennas Wireless Propag. Lett.*, vol. 9, pp. 191–194, 2010.

[9] Y. Li, Z. Zhang, Z. Feng, and M. F. Iskander, "Dual-mode loop antenna with compact feed for polarization diversity," *IEEE Antennas Wireless Propag. Lett.*, vol. 10, pp. 95–98, 2011.

[10] X. Jiang, Z. Zhang, Z. Tian, Y. Li, and Z. Feng, "A low-cost dual-polarized array antenna etched on a single substrate," *IEEE Antennas Wireless Propag. Lett.*, vol. 12, pp. 265–268, 2013.

[11] N. Behdad and K. Sarabandi, "A wide-band antenna design employing a fictitious short circuit concept," *IEEE Trans. Antennas Propag.*, vol. 53, no. 1, pp. 475–482, Jan. 2005.