*Progress In Electromagnetics Research Letters, Vol. 72, 39–44, 2018*

# A Single-Layer and Compact Circularly Polarized Wideband Slot Antenna Based on "Bent Feed"

**Zhe Wu***, **Gen Ming Wei, Xi Li, and Lin Yang**

**Abstract**—This communication presents a novel compact and wideband circularly polarized (CP) slot antenna fed by microstrip feedline. The proposed antenna consists of a corner-truncated square-ring slot patch and a novel bent strip. The CP radiation is formed by using the bent strip to excite CP resonance modes. By intruding several open stubs to the corners of the square-ring slot patch, the impedance matching and axial ratio (AR) bandwidth are improved. The measured results show that the proposed antenna has the advantage of wideband characteristics in terms of an impedance bandwidth of 90.59% (3.2–8.5 GHz) and 3-dB axial ratio bandwidth of 84.2% (3.3–8.1 GHz). The principle as well as simulated and measured results of the proposed antenna is revealed.

## 1. INTRODUCTION

With the rapid development of wireless communication systems, broadband circularly polarized (CP) antennas are highly demanded. Recently, the design of a broadband CP antenna has been a topic of concern for antenna designers. However, the traditional CP antennas suffer from narrow impedance and axial ratio bandwidth.

Circularly polarized mode can be realized by various antenna types, such as slot antenna [1–8], coplanar waveguide model [9], and dielectric resonator antenna [10]. Among these antennas, slot antenna has attracted much attention due to the advantagious features of simple structure, wide band, and easy integration. In [3], a perturbation structure was embedded in an annular-ring slot, dedicated to produce a wide CP bandwidth, and a bent feeding line was used to improve impedance matching within a wide CP band. This antenna achieves 65% impedance and the axial ratio bandwidth in L-band. [8] presents a (CP) rectangular slot antenna fed by a microstrip feedline. The broadband CP operation can be achieved by simply positioning the feedline beneath the extended stub. It is found that by adding the short stub to the top of the feedline, the AR bandwidth can be significantly improved. The antenna exhibits an impedance bandwidth of 90.2% and a 3-dB axial ratio bandwidth of 40%. However, antennas discussed above have the disadvantages of narrow bandwidth, complex structures, and large size.

In this communication, a simple compact and wideband CP antenna is proposed. The presented antenna consists of a bent microstrip feedline and a square-ring slot patch. A pair of open stubs is loaded at the corners of the square-ring slot patch for the perturbation of two orthogonal CP components. Using an additional open-circuited stub near the feeding port can broaden the impedance bandwidth. Table 1 manifests the performances of the proposed antenna and the antennas in [1–10].

## 2. ANTENNA DESIGN

The geometry of the proposed broadband circularly polarized antenna is illustrated in Fig. 1. The proposed antenna is fed by a 50-Ω microstrip feedline printed on the bottom of an FR4 substrate

*Received 30 September 2017, Accepted 23 November 2017, Scheduled 6 December 2017*
* Corresponding author: Zhe Wu (qpljiayou@sina.com).
The authors are with the Xidian University, Xi'an, China.

**Table 1.** CP bands and size of some existing ring- and wide-slot antennas.

| Ref. | $f_0$ (GHz) | IBW (%) | ARBW (%) | IBW and ARBW (%) | Antenna size (mm × mm) |
|---|---|---|---|---|---|
| [1] | 3.15 | 62.5 | 64 | 62.5 | 39 × 39 |
| [2] | 5.535 | 84 | 41.3 | 41.3 | 28 × 28 |
| [3] | 1.463 | 65 | 65 | 65 | 45 × 45 |
| [4] | 3.7 | 111 | 27 | 27 | 50 × 50 |
| [5] | 3.25 | 54.5 | 57.4 | 54.5 | 106.4 × 106.4 |
| [6] | 3.7 | 60.33 | 56.06 | 56.06 | 40 × 40 |
| [7] | 5.4155 | 130.38 | 35.7 | 35.7 | 20 × 20 |
| [8] | 5.50 | 90.2 | 40 | 40 | 25 × 25 |
| Proposed | 6.03 | 90.59% | 84.2% | 84.2% | 25 × 25 |

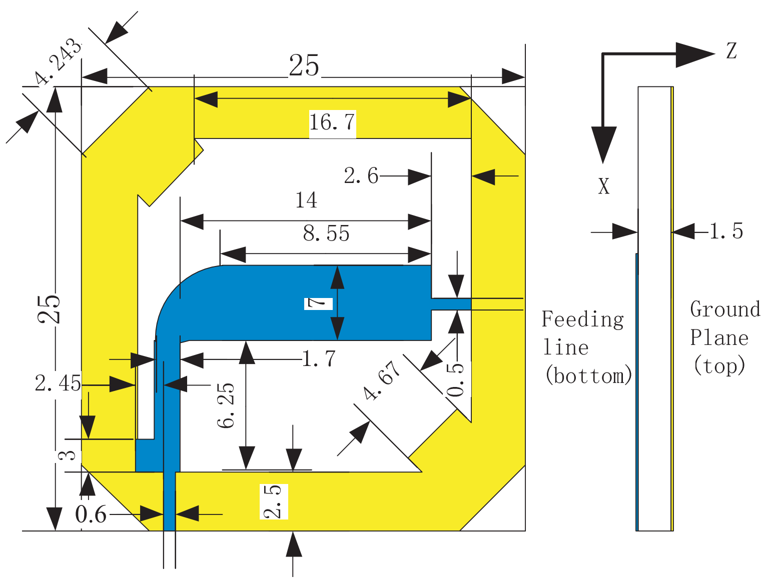



**Figure 1.** Geometry of the proposed antenna (units: mm).

(relative permittivity $\varepsilon_r = 4.4$ with a thickness of 1.5 mm). A "bent-shape" microstrip feedline with perpendicular open-circuited stub added can achieve broadband CP characteristics. The right angle of the bent feedline is modified into an arc elbow to improve the impedance matching. The overall dimensions of the proposed antenna are $25 \times 25 \times 1.5\,\text{mm}^3$.

The evolution of the proposed antenna is depicted in Fig. 2 to illustrate the CP performance enhancement. The following four antenna modes are discussed here. Ant. 1 has a basic slot structure and a Γ-shaped feedline as used in [5]. In antenna 2, a horizontal open-circuited stub is added near the input port (along $-y$-axis direction). In antenna 3, the right-angled elbow of the corner of the bent feedline is modified into an arc elbow. Ant. 4 is the proposed antenna in this communication, whose one diagonal's corners are loaded by a metallic structure. The performance of the four antenna structures is discussed in Section 3.

## 3. RESULTS AND DISCUSSION

The antennas aforementioned are simulated by using Ansoft commercial high frequency structure simulator (HFSS ver. 13) software. To explain the circularly polarized performance of the proposed antenna accurately, the simulation $S_{11}$ and AR are shown in Fig. 3. The square-ring slot is fed by a

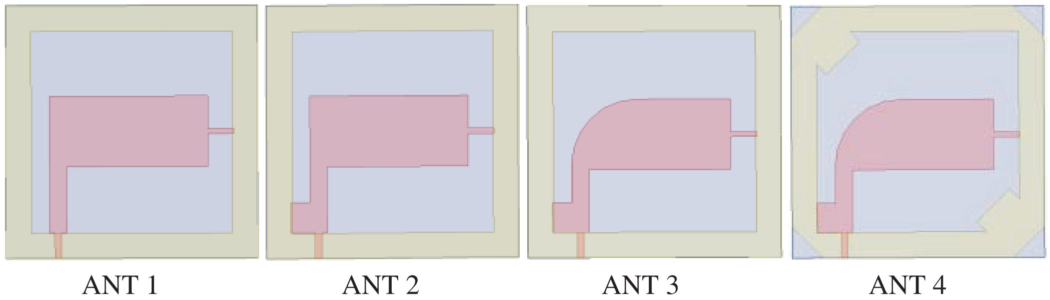



**Figure 2.** Evolution of the proposed antenna.

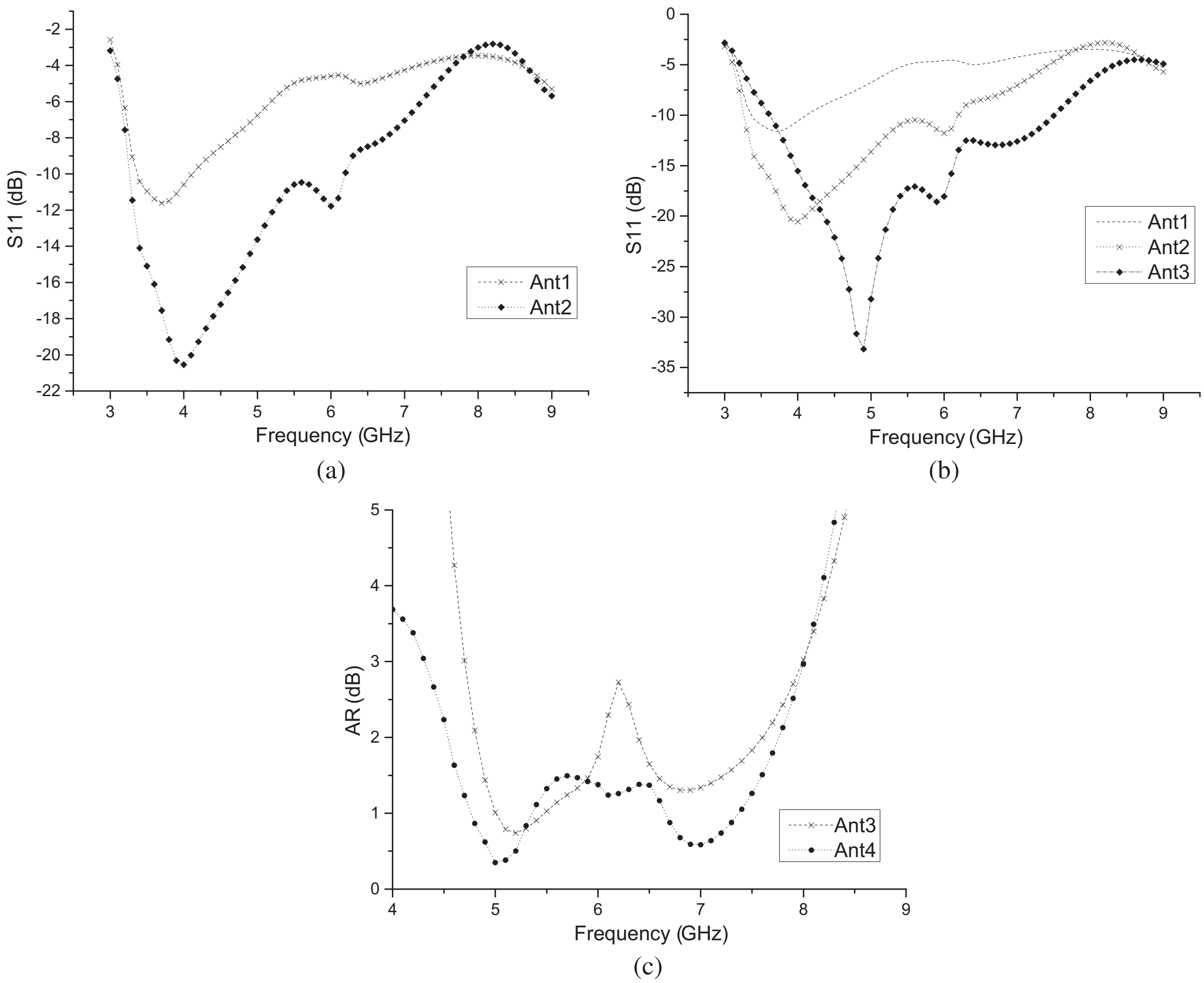



**Figure 3.** Simulated (a), (b) $S_{11}$ and (c) AR results for evolution antennas.

conventional Γ-type microstrip feedline in antenna 1. Two orthogonal electric field components which are equal in amplitude with 90° phase difference are formed by the proposed antenna, so the circularly polarized radiation mode is achieved. To reduce the reflection coefficient, the feeding line structure is changed in Fig. 2 (ANT1). However, the impedance bandwidth of this structure is relatively narrow.

Therefore, antenna 2 is loaded by an open-circuited stub near the feeding port as depicted in Fig. 2 (ANT2). By adjusting the length and position of the open-circuited stub, the imaginary part of input impedance can be improved, leading to a wider bandwidth as depicted in Fig. 3(a). In antenna 3, the right angle section of the feedline is changed into an arc elbow, which increases the impedance bandwidth. This is because it reduces the discontinuity of the energy transmission, so that the impedance matching is improved. The axial ratio is improved by the introduction of perturbation of a pair of open stubs at corners of the square-ring slot patch along the diagonal direction. The operation mechanism of the open-stubs has been mentioned in [3]. As can be seen from Fig. 3(c), the AR of antenna 4 is improved significantly compared with antenna 3.

To further comprehend the circularly polarized radiation mechanism, the simulated time-varying surface current distributions of the proposed antenna are shown in Fig. 4 at 6 GHz. It is observed that the surface current distributions at 180° and 270° are equal in magnitude and opposite at phase of 0° and 90°. At 0° time, the surface current flows upward, and at 90° time, the surface current flows to the right. Similarly, the surface current flows down at 180° time and flows to the left around the patch ring at 270° time. This shows that the proposed antenna is left-hand circularly polarized (LHCP) in the $+z$-direction, whereas a right-hand circular polarization (RHCP) is produced in the $-z$-direction. Fig. 5 shows the fabricated prototype having a total size of $25 \times 25 \times 1.5\,\text{mm}^3$. By optimizing the curvature of the arc elbow, the proposed antenna has excellent impedance and axial ratio bandwidth, as observed from Fig. 6. As well, the far-field performance of the prototype antenna is shown in Fig. 7.

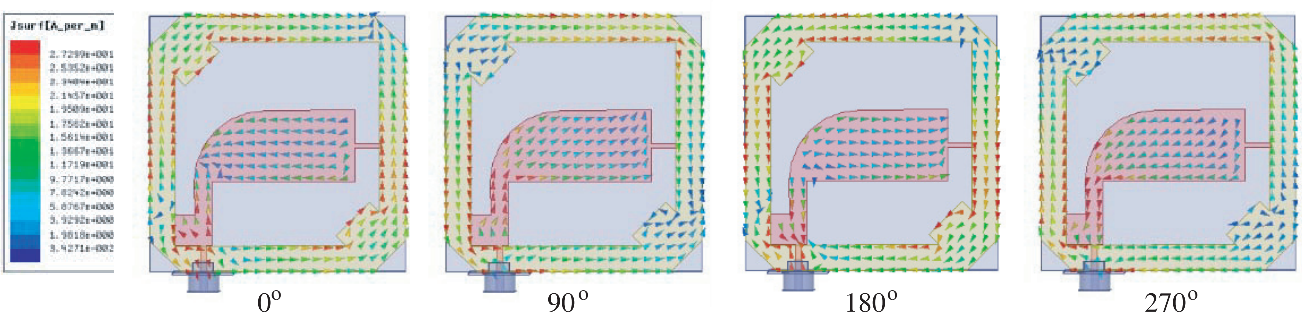
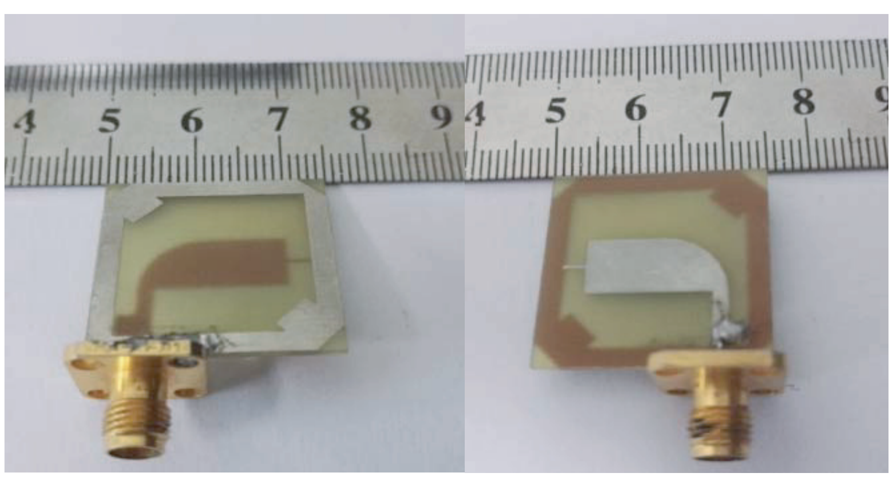
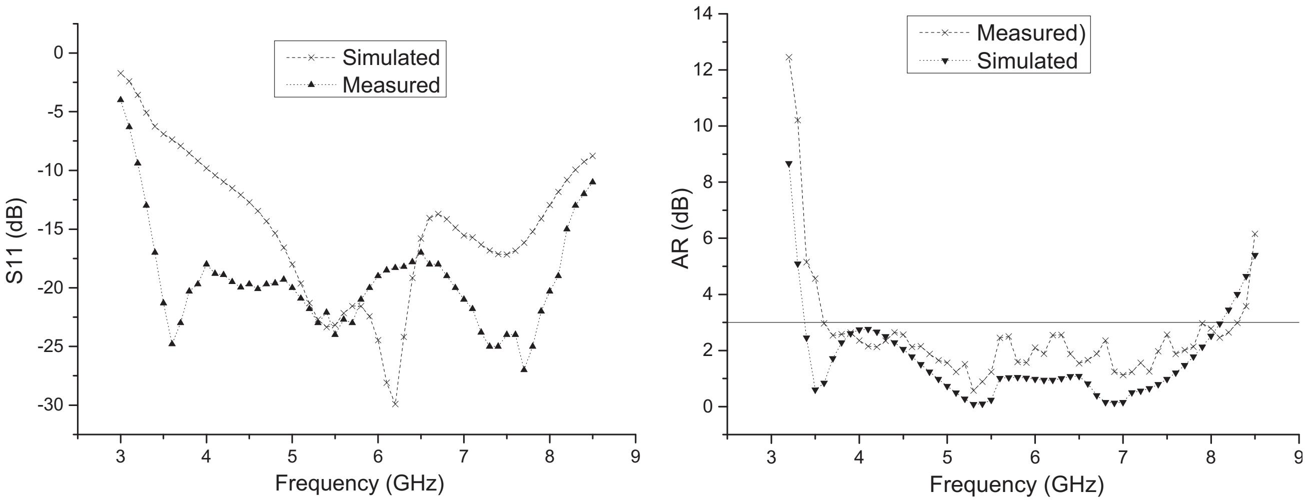



**Figure 4.** Distributions of the surface currents on the feed and ground plane of Ant. 4 at 6 GHz at 0°, 90°, 180°, and 270°.



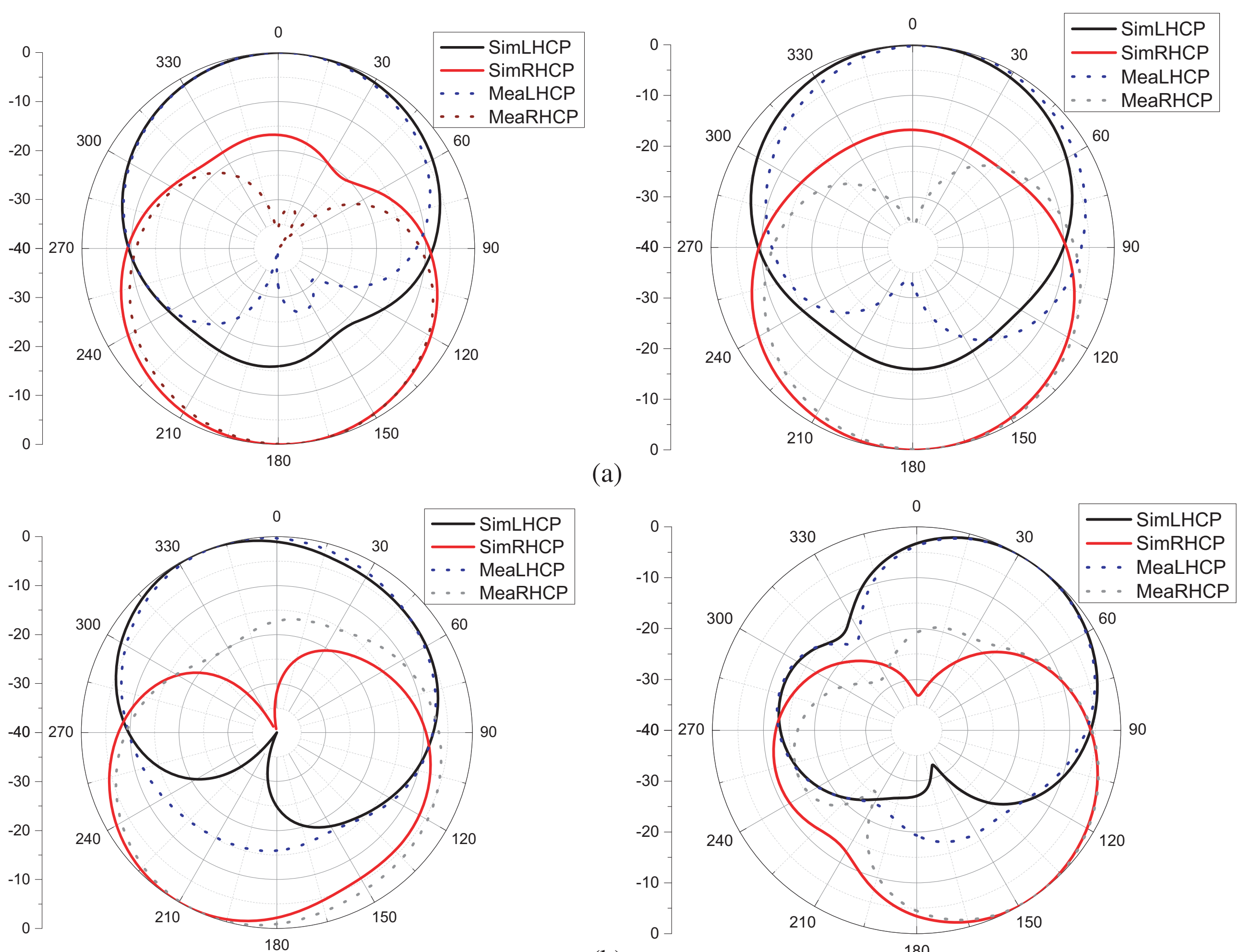

(a) (b)

**Figure 5.** Photograph of the fabricated prototype. (a) Top view. (b) Bottom view.




(a) (b)

**Figure 6.** Measured and simulated (a) $S_{11}$ and (b) AR results of Ant. 4.




(a)

(b)

**Figure 7.** Measured and simulated radiation pattern at $yz$-(*right*) and $zx$-planes (*left*) of Ant. 4 at (a) 4 GHz and (b) 7 GHz.

## 4. CONCLUSION

The design of a compact and wideband CP slot antenna with a bent feeding structure is proposed in this paper. This proposed antenna uses a "bent-shape" microstrip feedline to excite a square-ring slot based on the theory that two orthogonal electric fields have equal amplitude, and 90° phase difference can form circularly polarized wave. The increased impedance bandwidth is due to applying the method of adding an open-circuited stub aside the input port. A pair of corners of an annular slot is loaded by a perturbation structure, which can improve the axial ratio property significantly. After adjusting and optimizing the crucial parameters, the proposed antenna is able to achieve the relative bandwidth of 84.2% (3.3–8.1 GHz) of the impedance and axial ratio bandwidth. The peak gain of this antenna ranges from 0.81 to 3.56 dBi over the entire band. It is useful for wireless applications in the C-band.

## ACKNOWLEDGMENT

The paper is supported by "the Fundamental Research Funds for the Central Universities" (No. JB160215).

## REFERENCES

1. Pazoki, R., A. Kiaee, P. Naseri, H. Moghadas, H. Oraizi, and P. Mousavi, "Circularly polarized monopole L-shaped slot antenna with enhanced axial-ratio bandwidth," *IEEE Antennas and Wireless Propagation Letters*, Vol. 15, 2016.
2. Nosrati, M. and N. Tavassolian, "Miniaturized circularly polarized square slot antenna with enhanced axial-ratio bandwidth using an antipodal Y-strip," *IEEE Antennas and Wireless Propagation Letters*, 2605099, 2016.
3. Sze, J.-Y. and W.-H. Chen, "Axial-ratio-bandwidth enhancement of a microstrip-line-fed circularly polarized annular-ring slot antenna," *IEEE Transactions on Antennas and Propagation*, Vol. 59, No. 7, July 2011.
4. Jan, J.-Y., Pan, C.-Y., K.-Y. Chiu, and H.-M. Chen, "Broadband CPW-fed circularly-polarized slot antenna with an open slot," *IEEE Transactions on Antennas and Propagation*, Vol. 61, No. 3, March 2013.
5. Yeung, S. H., K. F. Man, and W. S. Chan, "A bandwidth improved circular polarized slot antennausing a slot composed of multiple circular sectors," *IEEE Transactions on Antennas and Propagation*, Vol. 59, No. 8, August 2011.
6. Zhang, H., Y.-C. Jiao, L. Lu, and C. Zhang, "Broadband circularly polarized square-ring-loaded slot antenna with flat gains," *IEEE Antennas and Wireless Propagation Letters*, Vol. 16, 2017.
7. Karamzadeh, S., V. Rafii, M. Kartal, and H. Saygin, "Compact UWB CP square slot antenna with two corners connected by a strip line," *Electronics Letters*, Vol. 52, No. 1, 10–12, January 8, 2016.
8. Ellis, M. S., Z. Zhao, J. Wu, X. Ding, Z. Nie, and Q.-H. Liu, "A novel simple and compact microstrip-fed circularly polarized wide slot antenna with wide axial ratiobandwidth for C-band applications," *IEEE Transactions on Antennas and Propagation*, Vol. 64, No. 4, April 2016.
9. Pourahmadazar, J., Ch. Ghobadi, J. Nourinia, N. Felegari, and H. Shirzad, "Broadband CPW-fed circularly polarized square slot antenna with inverted-L strips for UWB applications," *IEEE Antennas and Wireless Propagation Letters*, Vol. 10, 2011.
10. Pan, Y. and K. W. Leung, "Wideband circularly polarized trapezoidal dielectric resonator antenna," *IEEE Antennas and Wireless Propagation Letters*, Vol. 9, 2010.