IEC
Institute of Electronics and Computer

Journal of the Institute of Electronics and Computer, 2020, 2, 1-11
https://iecscience.org/journals/JIEC
ISSN Online: 2643-8240

An L-Shaped Slot Circularly Polarized Patch Antenna for Wireless Communication

M. Saravanan[1]

[1]Department of Electronics and Communication Engineering, Hindustan Institute of Technology and Science, Chennai, Tamilnadu, and India
Email: msarawins@gmail.com
*Corresponding Author: M. Saravanan, Email: msarawins@gmail.com

How to cite this paper: M.Saravanan (2020) An L-Shaped Slot Circularly Polarized Patch Antenna for Wireless Communication. *Journal of the Institute of Electronics and Computer*, **2**, 1-11. https://doi.org/10.33969/JIEC.2020.21001

Received: November 5, 2019
Accepted: January 17, 2019
Published: January 20, 2020

Abstract

A circular-polarized patch antenna with compact size operating at 2.3 GHz band is presented. The antenna utilizes L shaped slot in the radiator in order to achieve circularly polarized radiation pattern. The prototype of the antenna is fabricated and is fed by a 50Ω strip line. The antenna achieves a symmetrical radiation pattern around zenith. The measured impedance bandwidth of |S11| less than -10dB is from 2.3GHz to 2.35GHz and is in good agreement with simulation results. The antenna achieves better cross-polarization isolation of -19 dB and wider 3dB axial ratio beamwidth (ARBW) of $-50^0 \leqslant ARBW \leqslant 45^0$ at its resonating frequency. The antenna finds application in modern wireless communication system.

Keywords

Antenna feeds; Antenna radiation patterns; Circular polarization; Microstrip antennas; Slot antennas.

1. Introduction

In last few decades, circularly polarized (CP) microstrip antenna serves a crucial role in space, missiles, airborne communications due to its lightweight, planar structure and ease of fabrication [1]. These applications require a better field of view in order to provide better coverage. However circularly polarized antennas suffer from narrow axial ratio beamwidth and hence lots of researches have been carried to enhance axial ratio beamwidth of the circularly polarized antenna. One of the techniques to improve beamwidth is by etching slot of appropriate shape in the antenna radiator and hence perturbing field current to accomplish circular polarization [1-6]. A diagonal slot along with square ring slot around the periphery is etched in the radiating patch for improving axial ratio beamwidth of the antenna

[2].The antenna achieves poor axial ratio bandwidth of 25MHz due to additional incorporation of square slits around the diagonal slot. Shaalan [3] and Lam et.al., [4] in their work propose a slot antenna of different shapes along with truncated corners for achieving CP radiation. Some other ways of enhancing the axial ratio beamwidth is by utilizing spiral-shaped slot with cavity backed reflector [5] and a mixture of a single layer magnetic dipole along with a V-shape open loop [6] for achieving wider axial ratio beamwidth. Luo et.al., [7] employs surface integrated waveguide along with crossed slots for achieving circular polarization [7]. However, Luo et.al., [8] in their work shows that wider axial ratio beamwidth cannot be achieved using crossed dipoles. Helical antenna of various configurations achieves CP radiation [9]. However, it increases the complexity of fabrication at higher frequencies. Patch antenna with suspended substrates [10] enhances the beamwidth and at the same time, it increases the thickness of the substrate. A set of dipoles folded achieves CP characteristics by altering the space between the dipoles is shown [11] which has increased front to back ratio. Bao and Ammann [12] in their work proposed dual frequency circular polarization antenna. In [13] a CP patch with better axial ratio beamwidth is depicted. In this paper, the problem of wider ARBW and good cross-polarization isolation is investigated due to its negative impact on signal coverage in airborne communications. Recently zero index meta-materials [14][15] are used to achieve high gain circularly polarized antenna. However it suffers from narrow band 3dB axial ratio. Several dual polarized antenna is reported [17][18][19][20][21]. These antenna utilizes multilayer substrates which increase overall antenna profile.

An L-slot is etched in the antenna radiator region with wider axial ratio beamwidth is presented. To attain CP radiation, the slot is etched at an offset distance from the midpoint in the radiating region. The length and width of the slot is optimized to achieve better ARBW and cross polarization isolation. The antenna is initially analyzed with HFSS simulator and the simulated results are verified with antenna measurement system. The simulation result agrees with measured results and better suited for wireless communication systems.

2. Methodology

This paper proposes an L-slot antenna slot antenna fabricated on FR4 substrate. Compare to traditional slot antennas, the L shaped slot is etched at some offset distance from the center of radiating element which generates two orthogonal modes TM10 and TM01 with 90 degree phase difference and hence introduces perturbation of surface current over the patch antenna The presence of slot increases the electrical length of the antenna. The length and width of the slot is tuned to achieve wider 3dB ARBW of the antenna with better cross polarization isolation.

2.1. Antenna Geometry

The structure of the L-slot patch antenna fed by 50Ω SMA connector is illustrated in Figure 1 and has single input with an SMA connector. The inner SMA pins are connected through a ground plane hole to a microstrip line. In order to match the impedance between the antenna and the transmission line and 50Ω quarter wave transformer is used. This line connects to a quarter wavelength transformer (50-ohm impedance, 0.96 mm wide, 12 mm length) and then to microstrip sections (2 mm wide, 8mm length). The antenna design is modeled on low-cost FR4 dielectric substrate (Fire retardant) having a relative permittivity of $\varepsilon_r = 4.4$ and dielectric loss tangent of $\zeta = 0.02$. The substrate thickness is taken as 1.6mm to reduce the antenna profile and length and width of the substrate is taken to be 50 mm x 50mm.

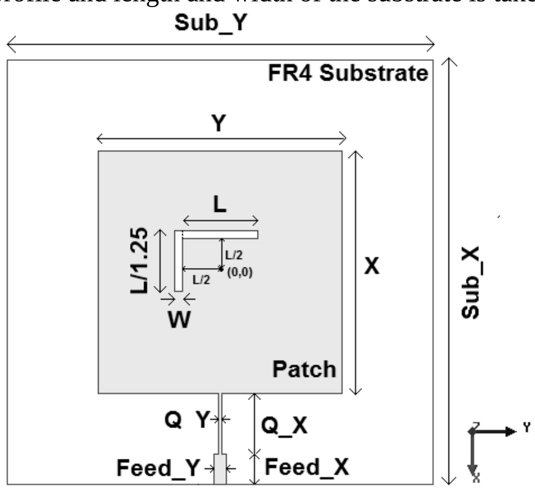


Figure 1. Antenna Geometry (RHCP)

The geometry shown in Figure 1 achieves right-hand circular polarization (RHCP). In order to achieve left-hand circular polarization (LHCP), the orientation of the L shaped slot has to be rotated 180 degree with respect to its center and hence achieves either LHCP or RHCP based on the orientation of the slot.

2.2. Parametric Analysis

Parametric analysis is carried on the slot dimension of the proposed model and its performance is discussed below. The length of the slot is given as primary importance since it greatly affects the operating frequency and also the purity of polarization. A variation of slot length and its effect on the performance of reflection coefficient (dB) is shown in Figure 2. The operating frequency shifts towards lower band with an increase in slot length due to an increase in the electrical length of the antenna radiating patch when compared to the physical length of the antenna radiating patch.

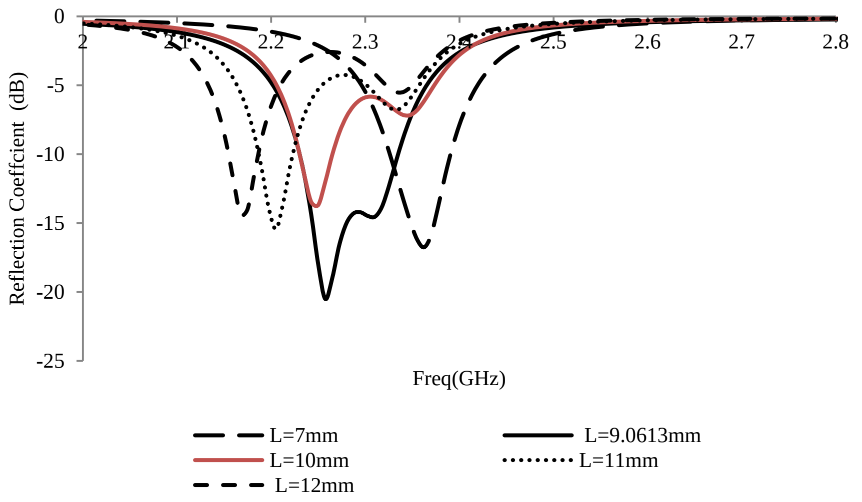


Figure 2. Reflection coefficient (dB) as a function of frequency for different slot length

The increase in the length of the slot also affects the purity of polarization. The length of the slot is chosen in such a way that, the surface current in one-half of the radiating element is delayed by 90 degree when compared to another side of the antenna. Figure 3 shows the effect of slot length over axial ratio. It is observed that at slot length (L) of 9 mm the model achieves optimum 3dB axial ratio.

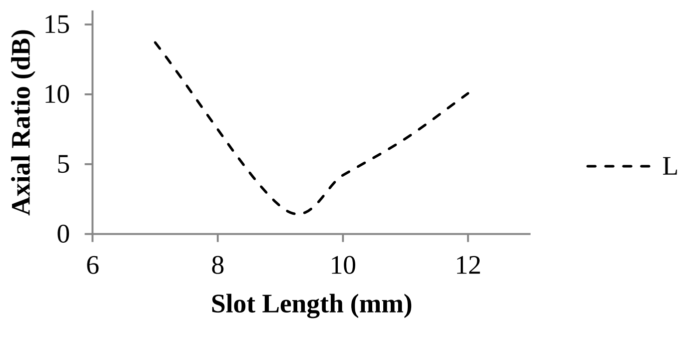
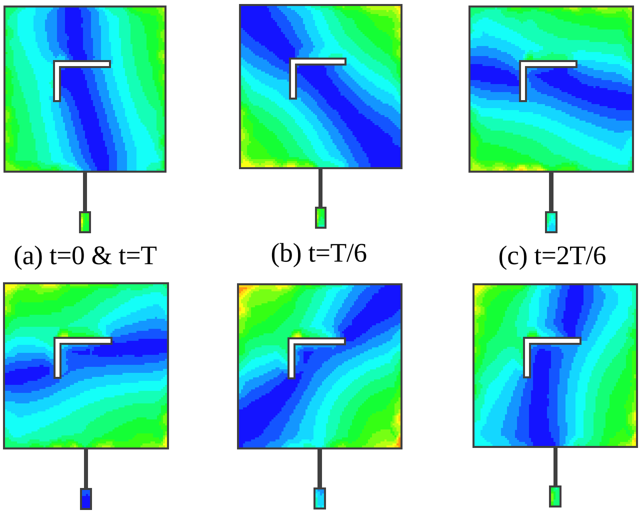


Figure 3. Axial ratio (dB) as a function of slot length (L)

2.3 Electric field distribution

The electric field current distributed on the square-shaped radiating patch is given Figure 4. It is observed that the current fields on the surface of the square patch in the left half closer the corner of the slot perturbs in advance when compared to the current fields on the square patch in the right half distribution and this adds 90 deg phase and results in right hand circularly polarization (RHCP) waves Figure 4(a). Similarly in order to have left-hand circular polarization, the orientation of the slot is rotated to 180 degree which causes the current fields on the square patch in the right half closer the corner of the slot perturbs in advance when compared to the current fields on the surface of the square patch in the left half distribution and adds 90 deg phase Figure 4(b). Thus the antenna generates either LHCP/RHCP based on slot orientation and shows the current distribution over the surface of the radiating patch element at different instances of time (T).



(a) t=0 & t=T (b) t=T/6 (c) t=2T/6

(d) t=3T/6 (e) t=4T/6 (f) t=5T/6

Figure 4. Electric field distribution

3. Results and Discussion

On analyzing the parametric results of slot length, the dimensions of model are synthesized and are shown in Table 1 given below. The fabricated antenna is having a thickness of 1.6 mm as shown in Figure 5.

Table 1. Antenna Design Specification

Parameter	Specification
Sub_X*Sub_Y*Sub_Z	50*50*1.6 mm3
X * Y	29*29 mm2
Q_X * Q_Y	7.25*0.362 mm2
Feed_X * Feed_Y	3.625*1.45 mm2
L *W	9.06*0.967 mm2

Figure 5. Fabricated Model **Figure 6.** Testing of antenna

The performance of the antenna model is measured using network analyzer N9924A as shown in Figure 6. The antenna is intended to function at a resonant band around 2.3 GHz band. In order to radiate effectively by an antenna, the impedance of the antenna should match with input impedance. i.e., the inductive component should match with the capacitive component so that, the reactive component in the impedance becomes zero at the resonant frequency. For this impedance matching, a quarter wave transformer is used to couple SMA connector and the radiating element. The dimension of the quarter-wave transformer is given in Table 1.

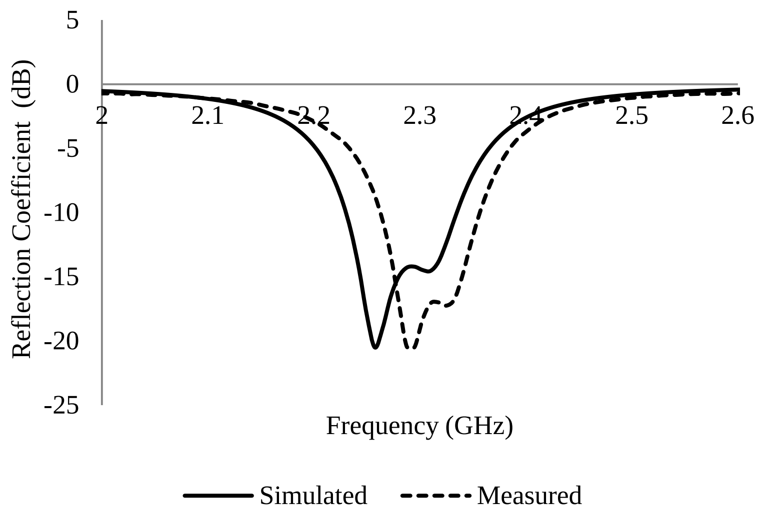


Figure 7. Reflection coefficient (dB)

The measured reflection coefficient curve as a function of frequency for the antenna geometry shown in Figure 1 is compared with simulation result and is shown in

Figure 7. As seen from reflection coefficient curve the antenna resonates at 2.3 GHz operating frequency and achieves -10dB impedance bandwidth of 90MHz (2.265 GHz – 2.355GHz) for RHCP configuration given in Figure 1. The fabricated antenna model is tested under antenna radiation test system. The measured results are related with simulated results and are depicted in Figure 8.

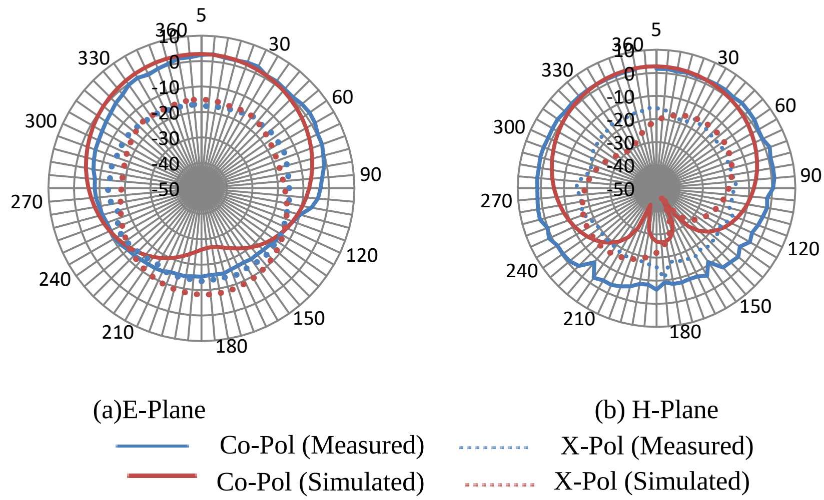


Figure 8. Radiation Pattern

It is observed from the radiation pattern curve that the simulation outputs matches better with measured outputs. The model achieves a cross-polarization isolation of -19dB at its operating frequency.

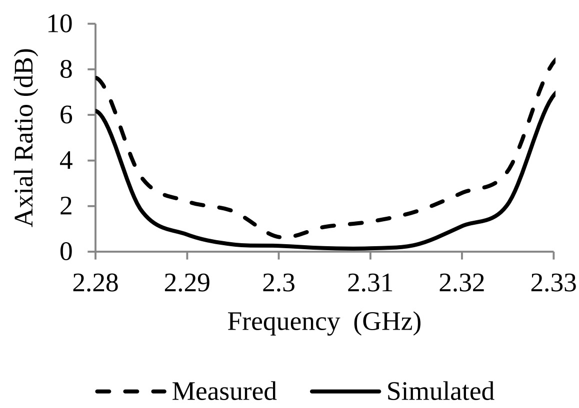


Figure 9. Axial ratio plot

Figure 9 depicts a relation of axial ratio upon frequencies around operating frequency for the proposed antenna. The antenna attains a minimum axial ratio of 0.3096 dB at 2.3 GHz operating frequency.

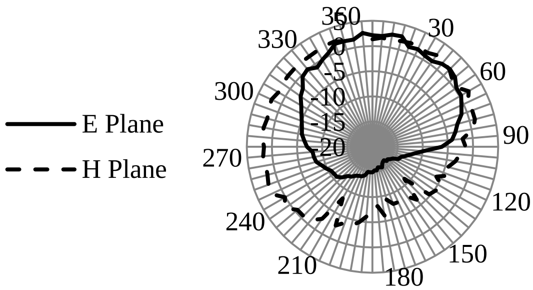


Figure 10. Radiation pattern measured at minimum axial ratio

Figure 10 depicts measured E-plane and H-plane radiation characteristics of the antenna model. It is inferred that the model attains an axial ratio over a wide beam angle of -50^{0} to 45^{0} around zenith. The measured gain is calculated using two antenna method. Initially, the operating band for the proposed antenna is measured using network analyzer. On the transmitter side, a typical horn antenna having peak gain of 9dB is mounted and the test antenna is placed on receiving side. The far-field region distance between antenna$_{transmitting}$ and antenna$_{receiving}$ is given by

$$\frac{P_r}{P_t} = \left(\frac{\lambda}{4\pi R}\right)^2 G_t G_r \quad (1)$$

The measured gain for RHCP is 5.23 dBic at boresight of the antenna.

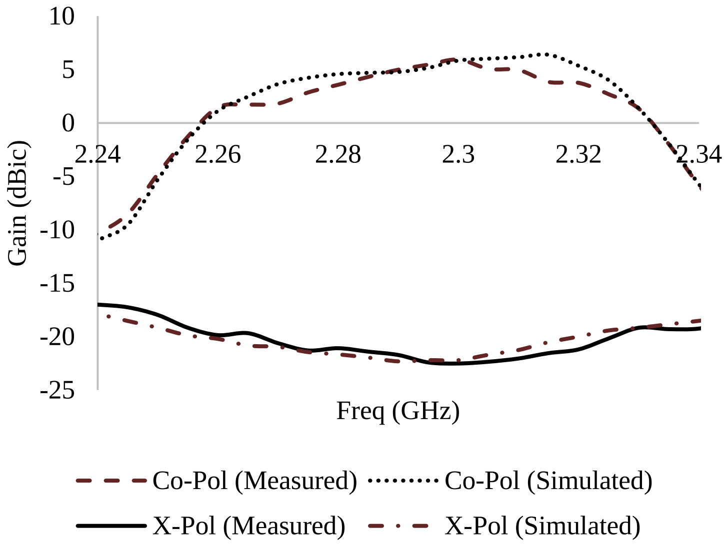


Figure 11. Measured gain across the operating band

Figure 11 presents the gain plot across the operating bandwidth. The model attains a peak gain of 5.23 dBic for RHCP mode with efficiency of 48.1% with better cross-polarization isolation of -19 dB at its operating frequency.

Table 2. Performance comparison of the proposed model with traditional antenna model.

Parameter	Proposed Model	Ref. [13]	Ref. [16]
Reflection Coefficient (dB)	-20.6 dB	-15 dB	-17 dB
Maximum Gain (dB)	5.23 dBic	6.3 dB	1.5 dB
3dB Axial Ratio beam width (dB)	95^0	$85^0 \pm 2^0$	90^0
Cross polarization isolation (dB)	-19 dB	-14.8 dB	-16.8dB

Table 2 shows performances of proposed model with conventional models. It is seen that the proposed model accomplishes better ARBW when related with other models given in Table 2 and thus guarantees better operating performances in communications.

4. Conclusion

An L-slot CP radiating patch modeled on single layer substrate operating at 2.3 GHz is proposed. The antenna attains better cross-polarization isolation of -19 dB and broader 3dB ARBW of $-50^0 \leq AR \leq 45^0$ at operating frequency which best suited for a wide field of view airborne communication. Unlike other conventional model, the proposed model has a low profile and better ease of fabrication. Hence the antenna can be utilized for communication devices.

Acknowledgement

The authors thanks the Hindustan University for supporting the research work by providing HITS Research fellowship and also providing laboratory facilities for modeling and testing of the antenna.

References

[1] Chen, Z.N., Liu, D., Nakano, H., Qing, X. and Zwick, Th. (2016) Handbook of Antenna Technologies. 1st ed. Springer.

[2] Bo Yuan, Xiao Hong Zhang, Zhi Fang Hu and Guo Qing Luo (2016) An Axial-Ratio Beamwidth enhancement of patch antenna with diagonal slot and square ring. *Microwave Opt Technol Lett*, 58,672-675.

[3] Shaalan, A.A. (2009) A Compact Broadband H-Slot and Horizontal H-Slot Patch Antenna for Circular Polarization. *J Infrared Milli Terahz Waves*, 30, 657–669.

[4] Lam, K.Y., Luk, K.M., Lee, K.F., Wong, H. and Ng, K.B. (2011) Small Circularly Polarized U-Slot Wideband Patch Antenna. *IEEE Antennas Wireless Propag*, 10, 87-90.

[5] Xiulong. L. and Ammann, M.J. (2014) A Cavity-Backed Spiral Slot Antenna with Wide Axial Ratio Beamwidth for GPS System. *Microwave Opt Technol Lett,* 56, 1050-1054.

[6] You, M., Lu, W.J., Xue, B., Zhu, L. and Zhu, H.B. (2016) A Novel Planar Endfire Circularly Polarized Antenna with Wide Axial-Ratio Beamwidth and Wide Impedance Bandwidth. *IEEE Trans Antennas Propag,* 64(10), 4554-4559.

[7] Luo, G.Q., Hu, Z.F., Liang, Y., Yu, L.Y. and Sun, L.L. (2009) Development of low profile cavity backed crossed slot antennas for planar integration. *IEEE Trans Antennas Propag,* 57(10), 2972 -2979.

[8] Luo, Y., Chu, Q.X. and Zhu, L. (2015) A Low-Profile Wide-Beamwidth Circularly-Polarized Antenna via Two Pairs of Parallel Dipoles in a Square Contour. *IEEE Trans Antennas Prop*ag, 63(3), 931-936.

[9] Ding, K., Wang, Y. and Xiong, X. (2012) A Novel Wide-Beam Circularly Polarized Antenna for SDARS Applications. *IEEE Antennas Wireless Propag Lett*, 11, 811-813.

[10] Liu, W., Zhu, L. and Choi, W.W. (2016) Low-profile wide-beamwidth circularly-polarised patch antenna on a suspended substrate. *IET Microwaves, Antennas & Propagation,* 10(8), 885-890.

[11] Luo, Y., Chu, Q.X. and Zhu, L. (2015) A Miniaturized Wide-Beamwidth Circularly Polarized Planar Antenna via Two Pairs of Folded Dipoles in a Square Contour. *IEEE Trans Antennas Propag*, 63(8), 3753-3759.

[12] Bao, X.L. and Ammann, M.J. (2008) Dual-frequency dual circularly-polarised patch antenna with wide beamwidth. *Electron Lett*, 44(21), 1233–1234.

[13] Ka Ming Mak and Kwai Man Luk (2009) A Circularly Polarized Antenna with Wide Axial Ratio Beamwidth, *IEEE Trans. Antennas Propag*, 57(10), 3309-3312.

[14] Rajanna, P. K. T., Rudramuni, K. and Kandasamy, K. (2019) A High-Gain Circularly Polarized Antenna Using Zero-Index Metamaterial, *IEEE Antennas and Wireless Propagation Letters,* 18(6),1129-1133. doi: 10.1109/LAWP.2019.2910805

[15] Majumder, B., Kandasamy, K. and Ray, K. P. (2018) A zero index based meta-lens loaded wideband directive antenna combined with reactive impedance surface, *IEEE Access*, 6, 28746-28754.

[16] Gabriel Massie, et al., (2010) A New Wideband Circularly Polarized Hybrid Dielectric Resonator Antenna, *IEEE Antennas Wireless Propag. Lett*, 99, 347-350.

[17] Yang, Y.-H., Sun, B. and Guo, J. (2019) A Low Cost, Single-Layer, Dual Circularly Polarized Antenna for Millimeter-Wave Applications, *IEEE Antennas and Wireless Propagation Letters*, 18(4), 651-655.

[18] Zhou, S.-G., Huang, G.-L. and Chio, T.-H. (2018) A lightweight wideband dual-circular-polarized waveguide cavity array designed with direct metal laser sintering considerations, *IEEE Trans. Antennas Propag.*, 66(2), 675-682.

[19] Cheng, Y. J., Wang, J. and Liu, X. L. (2017) 94 GHz substrate integrated waveguide dual-circular-polarization shared-aperture parallel-plate long-slot array antenna with low sidelobe level, *IEEE Trans. Antennas Propag.*, 65(11),

5855-5861.

[20] Zhao, Y. and Luk, K.-M. (2018) Dual circular-polarized SIW-fed high-gain scalable antenna array for 60 GHz applications, *IEEE Trans. Antennas Propag.*, 66(3), 1288-1298.

[21] Park, S.-J. and Park, S.-O. (2017) LHCP and RHCP substrate integrated waveguide antenna arrays for millimeter-wave applications, *IEEE Antennas Wireless Propag. Lett.*, 16, 601-604.