CPW-Fed Circularly Polarized Slot Antenna with Elliptical-Shaped Patch for UWB Applications

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***Abstract-* A new design of coplanar waveguide (CPW)-fed antenna with circular polarization (CP) and excellent impedance matching is presented. In this design a pair of circular-shaped slits is applied to opposite corners of the slot for enhancing the impedance matching and realizing bandwidth of 134.43 % across 2.98-15.20 GHz for VSWR ≤ 2. Furthermore, this structure exhibits axial ration bandwidth (ARBW) of 36.22 % across 4.43-6.39 GHz by embedding two inverted L-shaped ground arms in the slot. The total dimension of the proposed antenna is 25 × 25 × 0.8 mm^3. This new design has advantages of, supporting the ultra-wideband (UWB) systems and covering the WLAN spectrums with 3 dB CP radiation and VSWR ≤ 2 simultaneously. The numerical and experimental results of the antenna explain the superiority of the proposed antenna performance in comparison with recent similar works.**

Index Terms- Slot antenna; CPW-fed; ultra-wideband antenna; circular polarization.

I. INTRODUCTION

CP antennas have become a proper choice in modern systems such as wireless communications, radar and satellites, because of its ability to suppress multipath fading, provide better mobility and in consequence deliver an enhanced service. Other advantages that make circularly polarized antennas favorite are its good operation in the adverse weather conditions and needless of the accurate polarization alignment between antennas [1]. In recent times numerous CP antennas with multifarious techniques and structures have been reported including: utilizing the embedded arc-shaped metallic strip [2], square slot antenna fed by an asymmetric coplanar waveguide from a corner of the slot [3], CPW-fed circularly polarized antenna with corrugated structure and meander line loaded [4], square slot antenna loaded with a cross patch [5], protruding into the slot a halberd-shaped metal strip from the signal line of the CPW [6], printed slot antenna excited by an L-shaped strip with a taper end [7], CPW-fed broadband circularly polarized square slot antenna with a widened L-type strip along the diagonal line of the square slot [8], Sequentially Rotated Feed Network [9], etching a longitudinal slot at a middle point of a

Manuscript received 19-June-2017 and revised 27-August-2017,
Accepted on 17- Oct.-2017
P- ISSN: 2322-4088
E- ISSN: 2322-3936

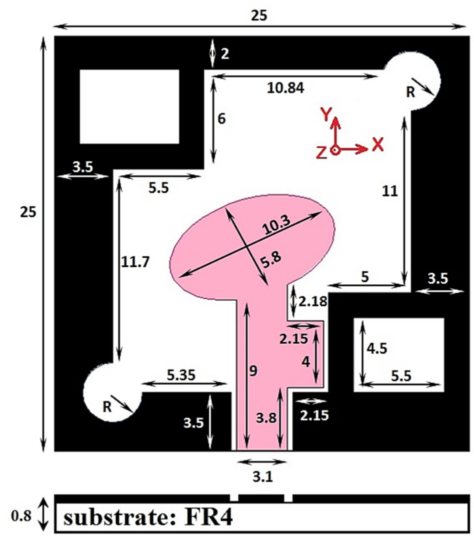

Fig. 1. Basic structure of the proposed antenna (Optimized dimensions in mm)

stair-shaped slot [10], CP antenna consists of a symmetric aperture along the diagonal axis [11], protruding a T-shaped metallic strip from the ground plane toward the slot center [12] and using spiral slots [13].

These techniques have many advantages and disadvantages in every case, but in 2008, Jia-Yi Sze et al. proposed a new method for generating the circularly polarized radiation which is very popular for the CP antenna designers. In this technique the CP operation of the antenna is mainly attributed to the two grounded inverted-L metallic strips placed around two opposite corners of the square slot [14]. Till now a lot of CP antennas are proposed according to this technique [15-19].

In this paper, a circularly polarized antenna with a new configuration is presented that make available a significantly wide IBW of 134.43 % (2.98–15.20 GHz) and ARBW of 36.22 % for AR ≤ 3 dB across the WLAN (5.15–5.825 GHz) band.

II. ANTENNA DESIGN

Fig.1 shows the geometry and dimensions of the proposed CP antenna. This structure consists of an elliptical-shape radiating patch and a CPW feed-line. A rectangular stub which is connected to the feed-line is the tuning element to enhance the impedance matching. In this design two circular-shaped notches are applied to opposite diagonal corners of the slot to significantly improve the IBW. Furthermore by inserting two inverse L-shaped ground strips to other opposite diagonal corners of the slot the CP operation can be achieved. The CP proposed antenna was fabricated on a commercially FR4 dielectric substrate with a loss tangent of 0.02, permittivity of 4.4 and total dimensions of $25 \times 25 \times 0.8$ mm^3. The length and width of the feed-line are 9 and 3.1 mm respectively and the gap size between the feed-line and the ground plane is 0.3 mm correspond to a characteristic impedance of 50Ω.

The proposed antenna design was realized in four steps, as demonstrated in Fig.2.

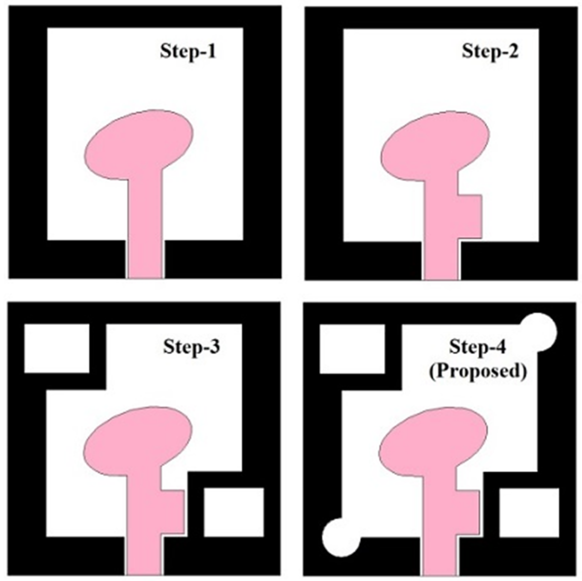

Fig. 2. Four steps to design the CP antenna

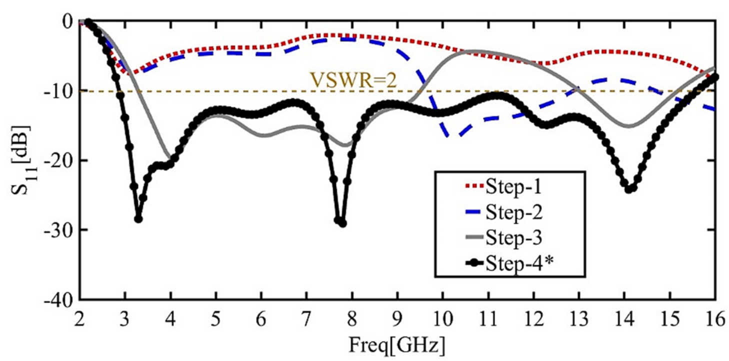

Fig. 3. Reflection Coefficient of the antenna in four implementation steps

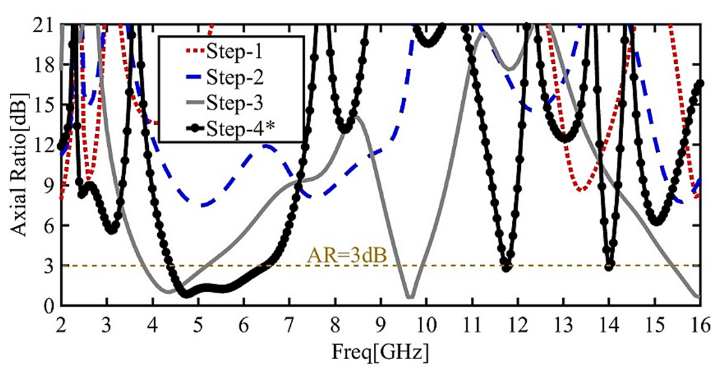

Fig. 4. AR curves of the antenna in four implementation steps

of the slot to enhance the IBW. The reflection coefficient and the axial ratio curves of the proposed antenna in the four steps are represented in the Fig. 3 and Fig. 4 respectively. From the figures it is clear that successive steps expand the impedance BW and axial ratio features of the antenna. Application of circular-shaped

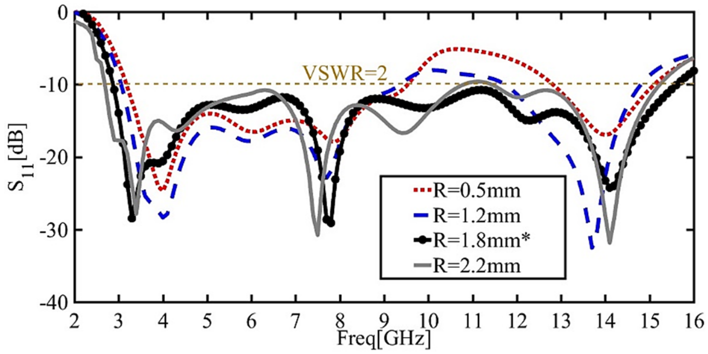

Fig. 5. Simulated S11 characteristics of the proposed antenna for various dimensions of R

notches of the ground plane in the fourth step produces additional surface current paths that dramatically increase impedance BW to 12.80 GHz (2.81–15.61 GHz) for VSWR ≤ 2, [20] and [21].

Additionally by applying the ground-plane notches in the fourth step significantly enhances ARBW between 4.39 and 6.51 GHz for an AR ≤ 3 dB.

The first step contains the construction of the feed-line, elliptical-shaped patch and ground-plane, in the second step a rectangular stub is connected to the feed-line as a tuning element, in the third step two inverse L-shaped ground strips is applied to opposite diagonal corners of the slot to create the CP radiation and finally in the fourth step two circular-shaped notches are applied to other opposite corners

III. PARAMETRIC STUDY

In this section, the effect of the consequential parameter of the antenna on the impedance BW is studied. In fact, the effect of the circular-shaped notches radius (R) on the antenna's reflection coefficient was investigated by using a commercial electromagnetic (EM) simulation tool (HFSS 11) in this section. Fig. 5 shows the simulated S11 response characteristics of the antenna as a function of R. This figure illustrates the IBW improves significantly as R was increased from 0.5 to 1.8 mm then IBW extends between 2.81 and 15.61 GHz for R=1.8 mm. It is clear in the figure that increasing the radius of the circular-shaped notches more than 1.8 mm leads to lose the frequency band around 11 GHz.

IV. ANTENNA PERFORMANCE AND ANALYSIS

In this section the simulated and measured results of the antenna such as; S11 response, axial ratio and gain have been compared. Fig. 6 shows comparison of the numerical and experimental results of the S11 characteristics of the proposed antenna. The measured IBW is 134.43 % for VSWR ≤ 2. The simulated and measured AR and gain curves, plotted in Fig. 7 and Fig. 8, are at the direction of maximum radiation (θ = 0°). The measured CP bandwidth is 1.96 GHz (36.22 %) from 4.43 to 6.39 GHz. Fig.8

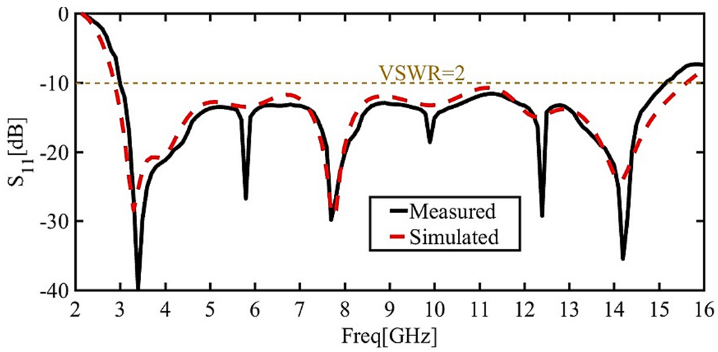

Fig. 6. Measured and simulated reflection coefficient of proposed antenna

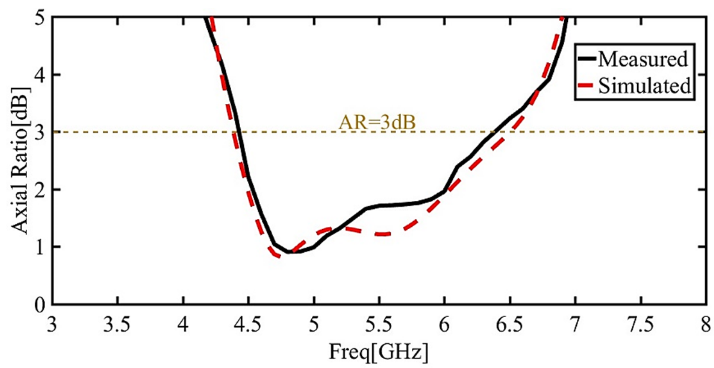

Fig. 7. Antenna's measured and simulated AR

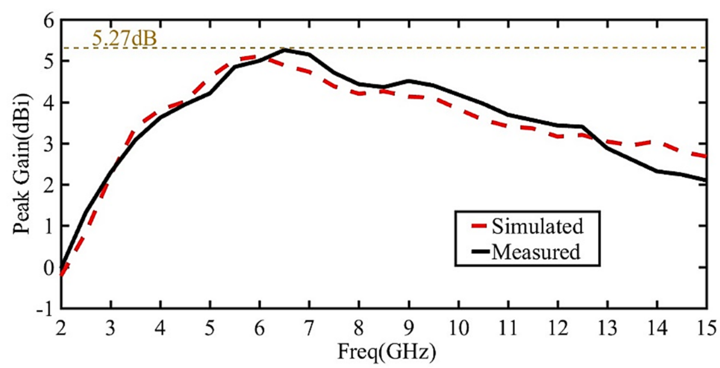

Fig. 8. Antenna's measured and simulated Gain

shows the gain of the proposed antenna for the optimized values given in Fig.1, and the peak gain is about 5.27 dBi at 6.55 GHz. The simulated and measured results are in good agreement and any discrepancy is attributed to measurement errors and fabrication tolerance of the prototype. All of the measured results have been accomplished by Agilent Vector Network Analyzer 8722ES.

The simulated surface current distribution for the antenna at 4.8 GHz which plotted in Fig. 9 clearly shows phase reversal of the current vectors at 0° and 180°, and at 90° and 270°. In fact the circularly polarized radiation of the proposed antenna is mainly attributed to the two inverse L-shaped ground strips located around two opposite diagonal corners of the slot. Each arms of the metallic L-shaped strips

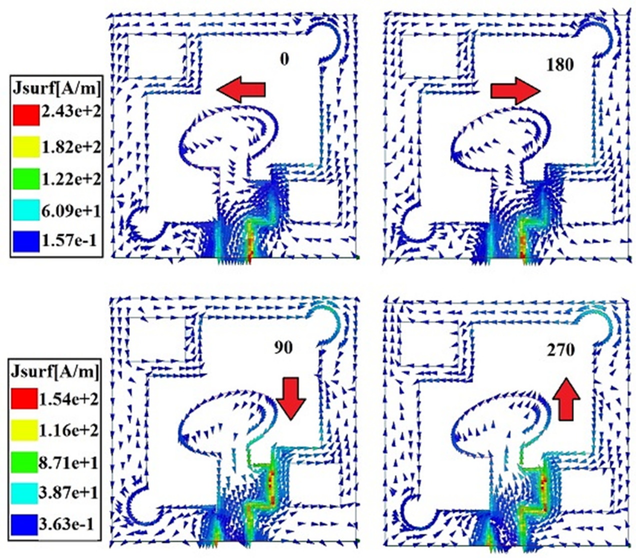

Fig. 9. Surface current distribution on the antenna at 4.8 GHz

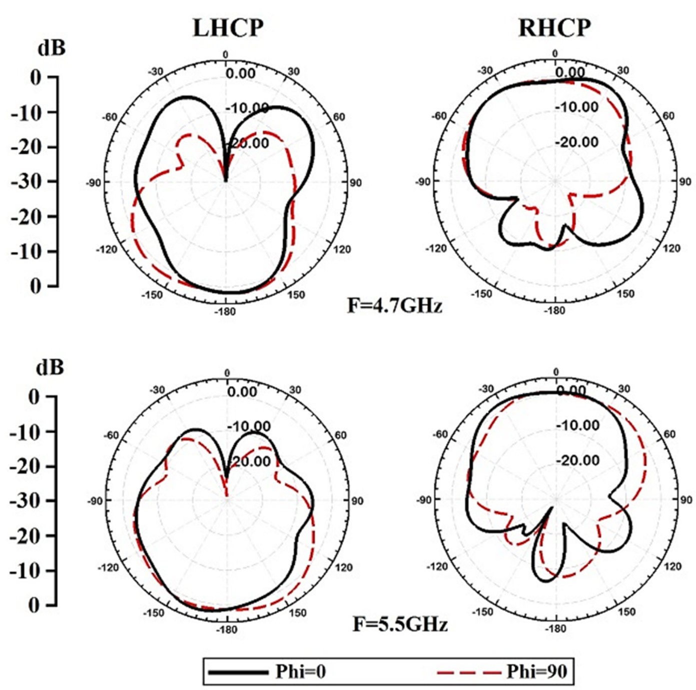

Fig. 10 Measured radiation patterns of the proposed antenna at 4.7 and 5.5 GHz.

has a length in the directions perpendicular and parallel to the feed line that will create right- and left-hand CP (RHCP and LHCP) radiations in the +Z and –Z directions, respectively. Opposite-handed CP radiations can be produced if the inverse L-shaped ground strips are applied around the other two opposite corners of the square slot [14]. Fig. 10 presents the measured CP radiation patterns of the elliptical-shaped patch slot antenna at 4.7 GHz and 5.5 GHz.

TABLE I. SUMMARY OF THE CPSSA PROPERTY

Ref.	IBW (VSWR<2 (GHz)	3 dB AR (%)	Dimensions (mm^3)
[14]	(1.600-3.055), 62.5%	25	60×60×0.8
[15]	(2.023-3.421), 51.36%	48.8	60×60×0.8
[16]	(1.510-2.650), 54.8%	32.8	60×60×1.6
[17]	(2-7), 110%	85	60×60×0.8
[18]	(2.67-13), 132%	32.2	60×60×0.8
[19]	(2.93-11.43), 118%	22.2	25×25×0.8
Proposed	**(2.98-15.20), 134.43%**	**36.22**	**25×25×0.8**

In this figure the right hand circular polarization and left hand circular polarization radiation patterns of the proposed antenna at the specified frequencies are plotted. It shows the antenna exhibits omnidirectional radiation characteristics but whose gain variation is evident over certain angular directions. In fact RHCP is generated in the +z-direction and LHCP in the – z direction.

V. COMPARISON AND FABRICATION OF THE ANTENNA

In the CP antennas, the fundamental tradeoff between compactness and wide impedance and AR characteristics of an antenna, will allow antenna designers to compare the performances of a CP antenna with the other works. The proposed CP antenna exhibits comparatively wide IBW, large axial-ratio bandwidth that covers the WLAN band and compact size. All these properties are listed in Table I and compared to recent publications. Table I is plotted in order to compare the characteristics of the proposed antenna in this article with the recent works reported in [14–19] that are manufactured on the same substrate and use a same technique to generate CP operation for a fair comparison. Although the ARBW of the antennas are reported in [15] and [17] are wider than proposed antenna with 48.8% and 85% respectively, whilst, they size are 5.27 times larger than this work. It is clear that the axial ratio bandwidth of the proposed antenna is one of the best in the Table I, while the impedance BW and total size of the antenna with 134.43% and 25×25×0.8 mm^3 (500 mm^3) respectively are the most outstanding ones and so admirable.

Photograph of the fabricated antenna with optimized dimensions are displayed in the Fig.11.

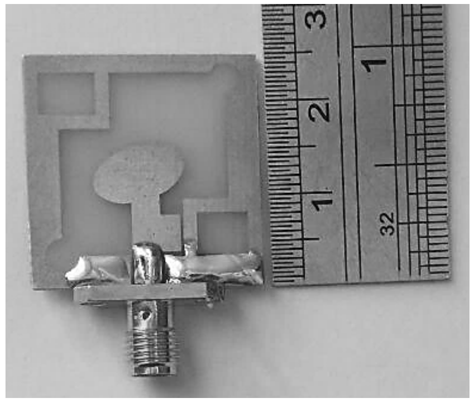

Fig. 11. Photograph of the proposed antenna

CONCLUSION

A new design of compact CPW-fed slot antenna is presented with circular polarization for UWB and WLAN applications. Experimental and numerical results of the proposed antenna explain that the inserting of circular-shaped notches and inverse L-shaped ground strips in the opposite corners of the ground slot can considerably improve the axial ratio BW and impedance BW to 36.22 % and 134.43 %, respectively. In this design the total dimension of the antenna is 25 × 25 × 0.8 mm^3.

REFERENCES

[1] M. Shokri, V. Rafii, S. Karamzadeh, Z. Amiri and B. Virdee, "Miniaturized ultra-wideband circularly polarized antenna with modified ground plane," *Electronics Letters*, vol. 50 no. 24, pp. 1786-1788, 2014.

[2] Meng-Ju Chiang, Tian-Fu Hung and Sheau-Shong Bor, "Dual-band circular slot antenna design for circularly and linearly polarized operations," *Microwave and Optical Technology Letters*, vol. 52, no. 12, pp. 2717-2721, 2010.

[3] J.-Y. Sze, J.-C. Wang and C.-C. Chang, "Axial-ratio bandwidth enhancement of asymmetric-CPW-fed circularly-polarised square slot antenna," *Electronics Letters*, vol. 44, no. 18, pp. 1048-1049, 2008.

[4] C.H. Chen, E.K.N. Yung and B.J. Hu, "Miniaturized CPW- fed circularly polarized corrugated slot antenna with meander line loaded," *Electronics Letters*, vol. 43, no. 25, pp. 1404 - 1405, 2007.

[5] C.C. Chou, K.H. Lin and H.L. Su, "Broadband circularly polarized crosspatch-loaded square slot antenna," *Electronics Letters*, vol. 43, no. 9, pp. 485-486, 2007.

[6] Jia-Yi Sze and Shien-Piao Pan, "Design of CPW-Fed Circularly Polarized Slot Antenna with a Miniature Configuration," *IEEE Antennas Wireless Propag. Letters*, vol. 10, pp. 1465-1468, 2011.

[7] Lin-Yu Tseng and Tuan-Yung Han, "Microstrip-Fed Circular Slot Antenna for Circular Polarization," *Microwave and Optical Technology Letters*, vol. 50, no. 4, pp. 1056–1058, 2008.

[8] Y.B. Chen, X.F. Liu, Y.C. Jiao and F.S. Zhang, "CPW-Fed Broadband Circularly Polarized Square Slot Antenna," *Electronics Letters*, vol. 42, no. 19, pp. 1074-1075, 2006.

[9] F. Jalili; J. Pourahmadazar; J. Nourinia; V. Rafii. "Circularly Polarized Circular Slot Antenna Array Using Sequentially Rotated Feed Network". *Journal of Communication Engineering*, 1, 1, 2016, 38-46.

[10] Chien-Jen Wang and Chih-Hsing Chen, “CPW-Fed Stair Shaped Slot Antennas with Circular Polarization” *IEEE Transactions on Antennas & Propagation*, vol. 57, no. 8, pp. 1483-2486, 2009.

[11] Nasimuddin, Zhi Ning Chen, and Xianming Qing, “Symmetric-Aperture Antenna for Broadband Circular Polarization” *IEEE Transactions on Antennas & Propagation*, vol. 59, no. 10, pp. 3932 - 3936, 2011.

[12] Jia-Yi Sze, Kin-Lu Wong, and Chieh-Chin Huang, “Coplanar Waveguide-Fed Square Slot Antenna for Broadband Circularly Polarized Radiation,” *IEEE Transactions on Antennas & Propagation*, vol. 51, no. 8, pp. 2141-2144, 2003.

[13] Canhui Chen and E. K. N. Yung, “Dual-Band Dual-Sense Circularly-Polarized CPW-Fed Slot Antenna with Two Spiral Slots Loaded,” *IEEE Transactions on Antennas & Propagation*, vol. 57, no. 6, pp. 1829-1833, 2009.

[14] Jia-Yi Sze and Chi-Chaan Chang, “Circularly Polarized Square Slot Antenna with a Pair of Inverted-L Grounded Strips,” *IEEE Antennas and Wireless Propagation Letters*, vol. 7, pp. 149-151, 2008.

[15] Jia-Yi Sze, Chung-I. G. Hsu, Zhi-Wei Chen and Chi-Chaan Chang, “Broadband CPW-Fed Circularly Polarized Square Slot Antenna with Lightening-Shaped Feedline and Inverted L Grounded Strips,” *IEEE Transactions on Antennas & Propagation*, vol. 58, no. 3, pp. 973-977, 2010.

[16] Qing-Xin Chu and Shu Du, “A CPW-Fed Broadband Circularly Polarized Square Slot Antenna,” *Microwave and Optical Technology Letters*, vol. 52, no. 2, pp. 409–412, 2010.

[17] Nader Felegari, J. Nourinia, C. Ghobadi and Javad Pourahmadazar, “Broadband CPW-Fed Circularly Polarized Square Slot Antenna with Three Inverted-L-Shape Grounded Strips,” *IEEE Antennas and Wireless Propagation Letters*, vol. 10, pp. 274-977, 2011.

[18] Javad Pourahmadazar, Ch. Ghobadi, J. Nourinia, Nader Felegari and Hamed Shirzad, “Broadband CPW-Fed Circularly Polarized Square Slot Antenna with Inverted-L Strips for UWB Applications,” *IEEE Antennas and Wireless Propagation Letters*, vol. 10, pp. 369-372, 2011.

[19] Hamed Shirzad, Majid Shokri, Zhaleh Amiri, Somayeh Asiaban and Bal Virdee, “Wideband Circularly Polarized Square Slot Antenna with an Annular Patch,” *Microwave and Optical Technology Letters*, vol. 56, no. 1, pp. 229-233, 2014.

[20] M. Asaadi and A. Sebak, "Gain and Bandwidth Enhancement of 2 × 2 Square Dense Dielectric Patch Antenna Array Using a Holey Superstrate," *IEEE Antennas and Wireless Propagation Letters,* vol. 16, pp. 1808-1811, 2017.

[21] M. A. Amiri, C. A. Balanis and C. R. Birtcher, "Gain and Bandwidth Enhancement of a Spiral Antenna Using a Circularly Symmetric HIS," IEEE Antennas and Wireless Propagation Letters, vol. 16, pp. 1080-1083, 2017.