Gain Optimization on Orthogonally Feed U-Slotted Antenna for S-Band Application

Sumit Kumar and Aniket Gunjal

January 4, 2020

Gain Optimization on Orthogonally Feed U-Slotted Antenna for S-Band Application

Sumit kumar [1]
Electronics & Telecommunication Department
Symbiosis Institute of Technology
Symbiosis International
(Deemed University),Pune,India
er.sumitkumar21@gmail.com

Aniket Gunjal [2]
Electronics & Telecommunication Department
Symbiosis Institute of Technology
Symbiosis International
(Deemed University),Pune,India
aniketgunjal89@gmail.com

***Abstract*— A novel compact dual band orthogonally feed circular polarized antenna is proposed. The antenna is composed of two main parts one is ground etched U-slot radiator and another is orthogonal feed lines. The feed lines are connected to the patch forms Q shaped structure. This is to improve the impedance bandwidth of antenna. The gain optimization is majorly done at the last antenna modification which shows the peak gain of 6.29 dB within 3-dB ARBW. This peak gain and axial ratio bandwidth is improved by simply adding rectangular cuts in the outer part and the triangular cut on the middle part of ground U-shaped structure. The gain is also improved by cutting the top portion of both patches on either side of feed lines in earlier stage of optimization. The maximum size of antenna is 48x48x1mm^3.The optimized result shows good isolation between these two asymmetrical ports. The impedance bandwidth (IBW) is 1.99- 8.20 GHz (155.2%) & 3-dB axial ratio bandwidth is 1.93-6.29 GHz (109%) and port isolation of >14.3 dB obtained. The impedances of the two ports are matched exactly such that it is equal to the characteristics impedance of 50 Ω.**

Keywords*—Orthogonal feed structure, Dual band CP operation, Polarization, Gain, ARBW, HFSS *Etc.

I. Introduction

In the last decade, Circular polarized antenna having more and more attention as it is very much suitable for mobile, wireless communication, radar communication and it shows good polarization diversity. The linearly polarized antenna having high gain but because of the polarization issue the attention of researchers is more towards the designing of circularly polarized antenna as it overcomes the polarization issue in linearly polarized antennas. Generally, the circularly polarized antennas having lower gain so it is very necessary to enhance the gain as well as axial ratio bandwidth of antenna. The necessity of improving axial ratio bandwidth is to improve the circular radiation of antenna. A good axial ratio shows that good polarization purity. In order to cover larger distance by the antenna gain improvement is also necessary. There are certain methods for improving axial ratio bandwidth of antenna such as adding micro strip slot [1] the axial ratio is also improved by proper feeding structure of antenna such as substrate integrated waveguide (SIW) slot the further improvement in impedance bandwidth is done through positioning patch feed lines on the slot cut side of the antenna [2].By shifting the position of the feed lines impedance bandwidth of 72% and axial ratio bandwidth of 41.6% is obtained [5]. Another slot monopole antenna uses triangular monopole and etched slot structure on the ground plane is used to generate CP modes with ARBW of 46.8% [7]. Different types of CP antennas are used to achieve wide bandwidth such as loop antenna [3], planer monopole [4-5], slot- planer monopole antenna[6-7]. A wideband CP antenna is designed using the symmetric dipole elements having ARBW of 96.6% [8]. Different article with dual CP mode generation is studied [9-14]. Circular split ring resonator along with two orthogonal feed lines is used to provide two different CP modes designed for RFID reader application [11].The asymmetric T shaped feed lines and inverted L shaped ground strips along with three strips is used to get good ARBW [14] The monopole structure is employed to improve axial ratio bandwidth.[15]

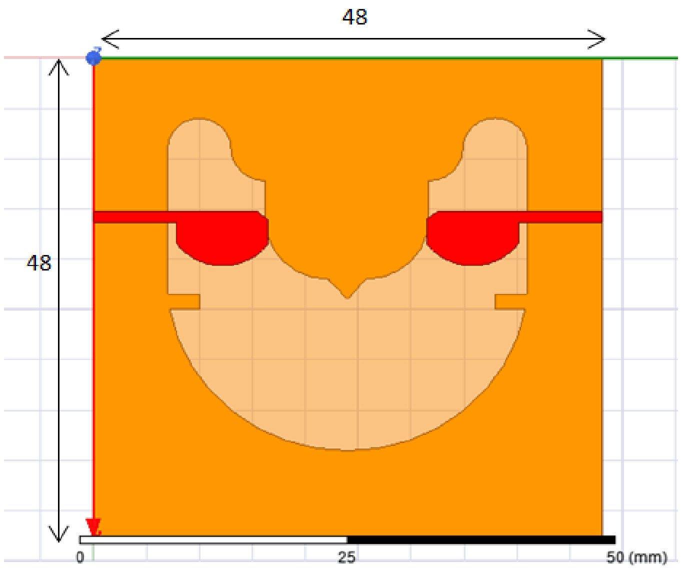

Fig.1 Proposed Structure of CP Antenna

II. ANTENNA DESIGN PROCESS

A. *Structure of Antenna*

A cost effective FR-4 (Flame Retardant) substrate material is used to design an antenna. The dielectric permittivity of the substrate is 4.4 and the tangent loss of 0.02. The height of the substrate is 1mm here. The antenna contains two Q shaped patch feed lines placed at the opposite side to each other. An U slot radiator placed on the lower side of substrate. The CP wave is generated by superimposing two modes generated by U slot radiator and patch feed network. Since the feed ports are orthogonal to each other it will generate 90^0 phase difference between them but having equal amplitude ratio. Because of symmetry in structure both the modes are equal but opposite in direction to each other called as LHCP and RHCP modes. The length of the feed line is adjusted such that the antenna resonates at the center frequency of 4GHz which is approximately quarter wavelength. The U slot length is adjusted such that it forms half wavelength structure.

B. *Antenna Realization Steps*

The simulation result is divided into 6 major design steps:

ANT.1 It contains two asymmetrical feed lines along with a rectangle cut on the middle portion of lower ground. The antenna behaves as dual linearly polarized antenna.

ANT.2 It shows that the rectangle on top portion is cut at lower ground having dimensions of 15x 13 mm. These cut on the ground structure generates one CP mode and the another mode is generated by positioning of the feed lines so that it is shifted upward by 8mm from the middle position. It forms dual band CP antenna.

ANT.3 It shows that the outer portion of the U slot radiator is smoothen by making it circular as well as the inner portion of the U radiator slot is also smoothen to improve the gain & ARBW of antenna.

ANT.4 Along with this modification patch feed network is added to improve ARBW of antenna to a significant level.

ANT.5 The patch feed structure is modified to improve the axial ratio bandwidth and further gain of the antenna. The patch is cut on the top portion by 1mm on either side of both ports.

ANT.6 At the last, the triangular cut is added in the inner portion of U radiator to improve the ARBW. The two small rectangular cuts on the outer side of U slot antenna are added to get improvement in impedance bandwidth, gain and axial ratio bandwidth of antenna. The highest peak gain of 6.29dB is obtained at this stage.

C. *Results and Discussions*

The simulated ARBW is 4.36 GHz. The result shows good gain enhancement within 3-dB ARBW which is 6.29 dB. The isolation of antenna is also good having more than 14 dB isolation between ports. The impedance bandwidth shows that the response is ultra wide band.. The comparison table proves that the antenna having good gain over the 3-dB axial ratio bandwidth of antenna. The simulated result gives better ultra wideband response (1.99–8.20GHz) along with good symmetry between ports. The antenna size is also very compact so that it is very much suitable for microwave frequency applications. The port impedances are shown in fig.5 gives exactly 50 ohm matched impedances. The voltage standing wave ratio in fig.4 depicts that the VSWR is within 2 to 1.The minimum VSWR found is 1.12 at 3.1GHz frequency. The simulation is carried out on HFSS (19.0) software.

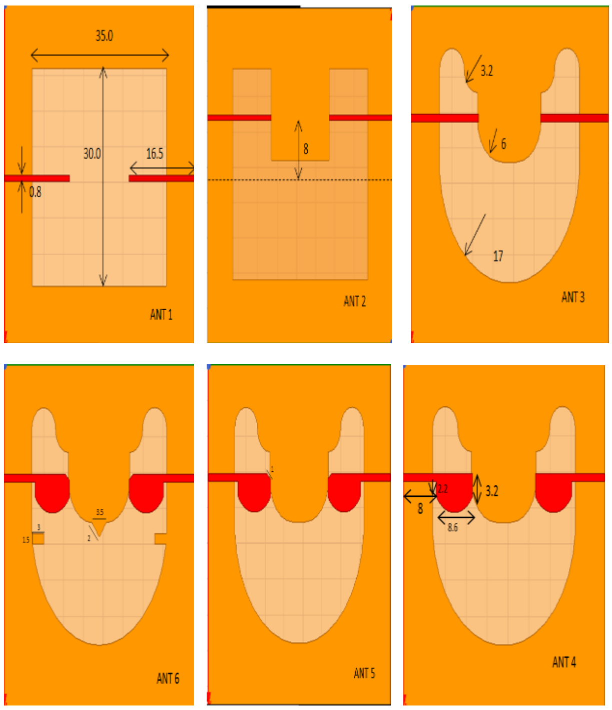

Fig.2 Antenna Reliazation Steps (Ant1 – Ant 6)

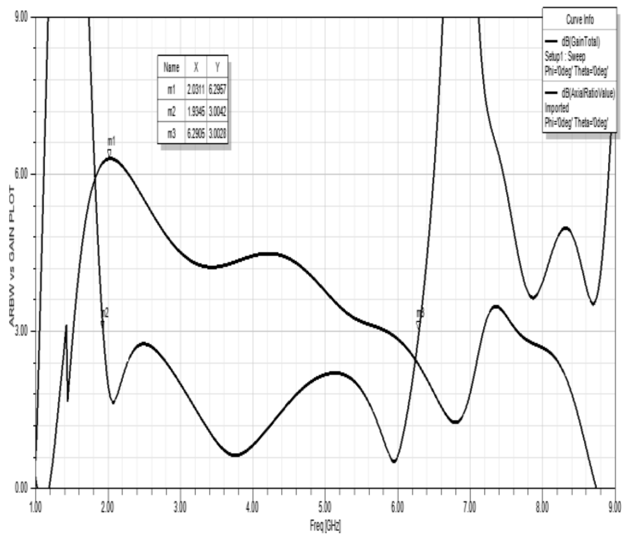

Fig.3 3-dB ARBW vs GAIN

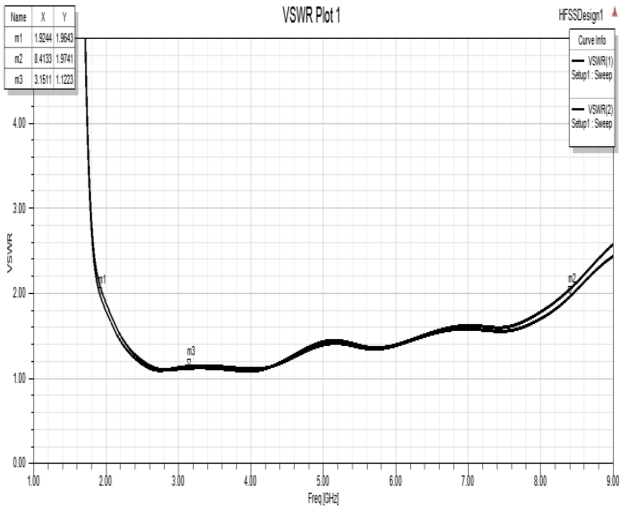

Fig.4 VSWR Plot for Port 1& Port 2

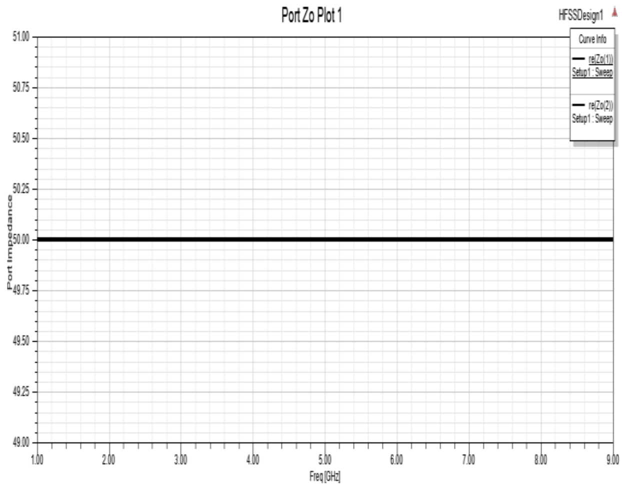

Fig.5 Characteristics Impedance (Z_0)

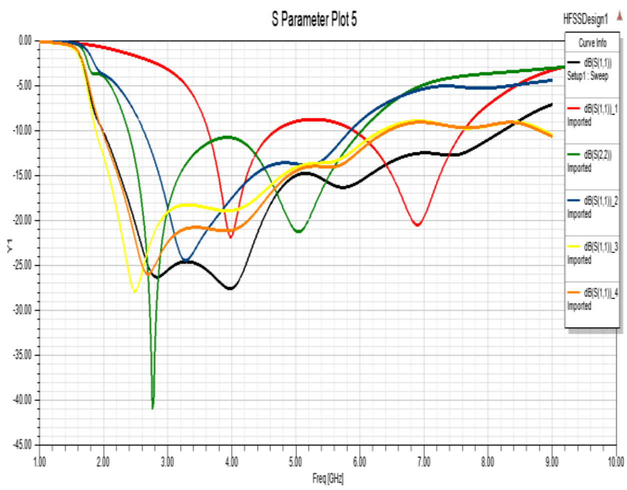

Fig.6 Return Loss Parameter for Port 1 (S11)

Simulation results:-

ANT1 Red, ANT2-Green, ANT3-Blue, ANT4-Yellow, ANT5- Orange, ANT6- Black

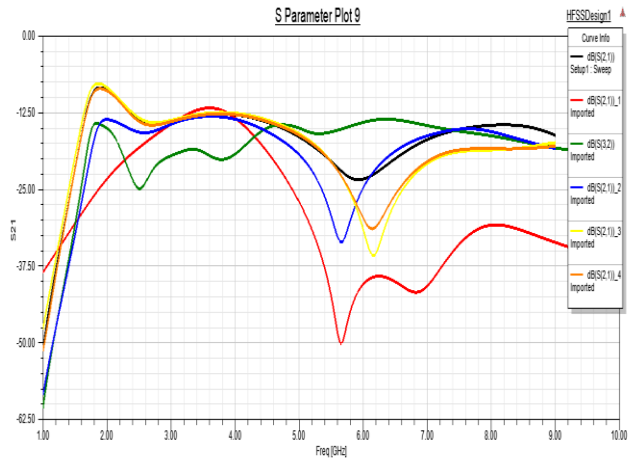

Fig.7 Scattering Parameter for two Ports (S21)

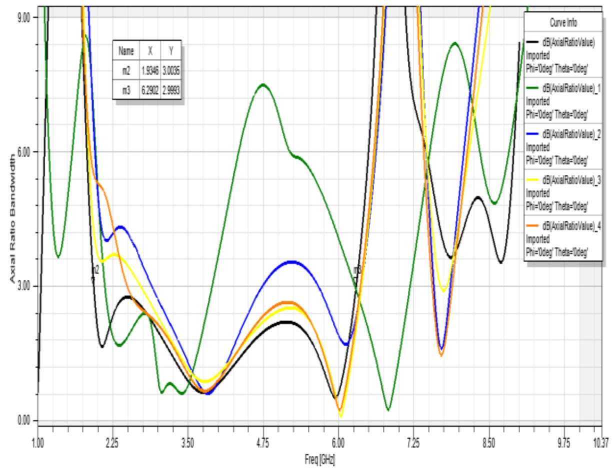

Fig.8 Simulated Axial Ratio Bandwidth (3-dB ARBW) of proposed antenna

The antenna radiation pattern shows bidirectional radiation. The radiation pattern of the antenna for different frequencies is illustrated in figure below.

Ref.	*Size (mm3)*	*IBW (GHz, %)*	*Isolation (dB) Within ARBW*	*3-dB ARBW (GHz, %)*	*Peak Gain (dB)*	*Radiation*
[9]	100×100×22	2.4~2.65, 9.9 %	>11.5	2.38~2.49, 4.8%	3.8	Unidirectional
[10]	120×65×1.0	------	>20.0	2.21~2.69, 19.6 %	------	Bidirectional
[11]	130×130×10	0.82~1.00, 18.0%	------	0.85~0.96, 11.0 %	5.0	Unidirectional
[12]	252×252×20	0.72~0.96, 28.6 %	------	0.81~0.97, 18.0 %	7.0	Unidirectional
[13]	76×76×14.6	3.20~4.10, 24.0 %	>10.0	3.50~4.00, 16.0 %	9.6	Unidirectional
[14]	60×60×1.6	2.00~4.76, 81.7 %	>15.0	2.00~3.70, 59.7 %	4.0	Bidirectional
[15]	32×32×1.0	1.40~9.60, 152.7 %	>20.0	3.74~8.80, 80.7 %	3.8	Bidirectional
[16]	48×48×1.0	1.80~6.61, 114.4 %	>14.7	1.83~6.35, 110.5 %	4.5	Bidirectional
[17]	48×48×1.0	153.1% (1.9–14.3 GHz)	>12.8	102.6%(1.9–5.9 GHz)	5.0	RHCP/LHCP
This Antenna	***48×48×1.0***	***155.2% (1.99~8.20GHz)***	***>14.3***	***109%(1.93~6.29GHz)***	***6.29***	***RHCP/LHCP***

Table 1:- Comparsion table of different wideband dual circularly polarized antennas

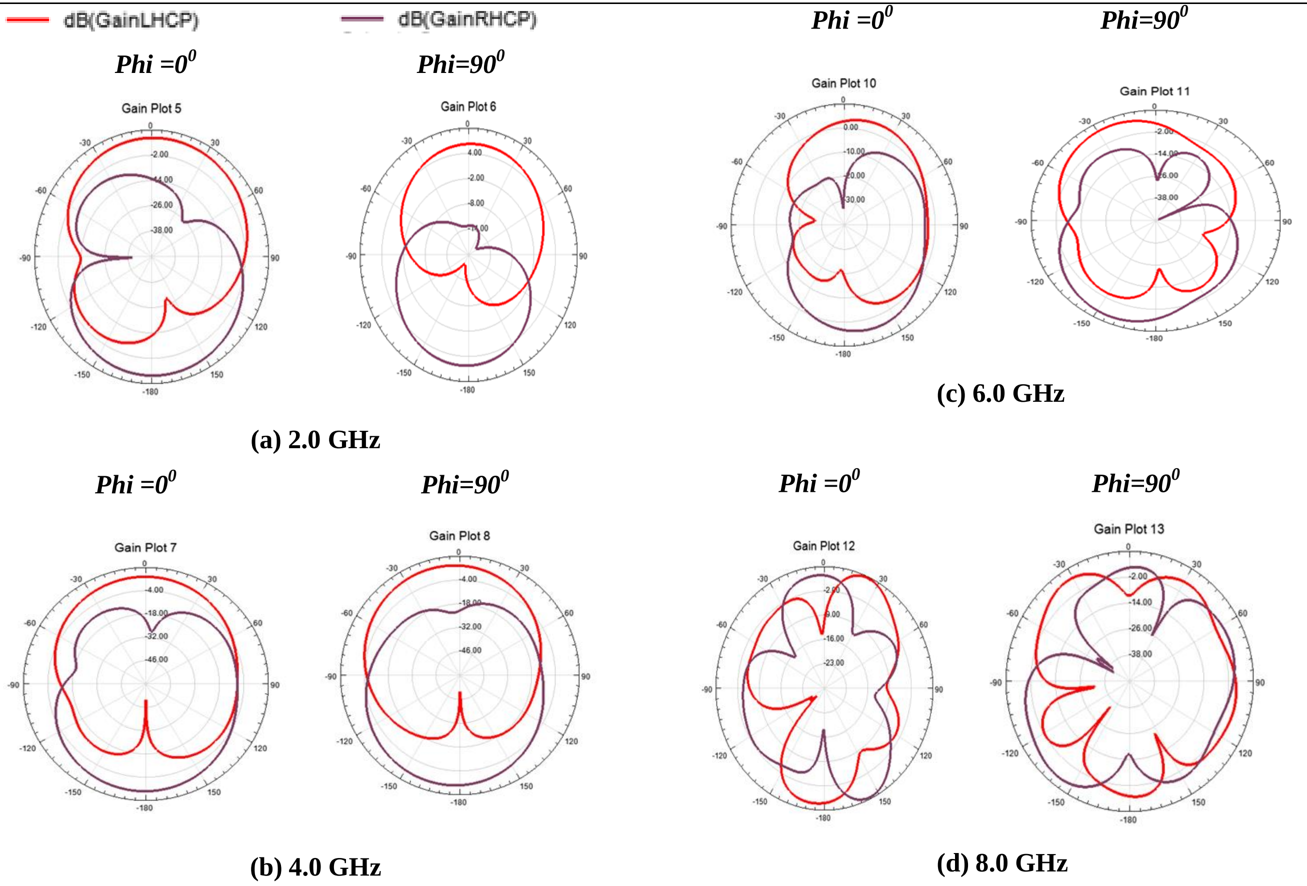

Fig. 9 Radiation pattern of antenna for different operating frequencies

III. Conclusion

The dual feed wideband circularly polarized antenna for S band radar application is presented here. The position of the feed lines and the patch feed width has significant effect on the bandwidth of the antenna. By adjusting the U shaped slot structure and patch feed shape it is possible to improve gain and axial ratio bandwidth of antenna to a significant level. The gain is nearly stable. The peak gain of antenna is 6.29 dB at 2.0 GHz frequency within 3-dB ARBW. The feed lines are adjusted such that impedances of both ports are matched to the characteristics impedance of the antenna elements. This further improves the impedance bandwidth of antenna.

References

[1] Ellis, Mubarak Sani, Zhiqin Zhao, Jiangniu Wu, Xiaoxiang Ding, Zaiping Nie, and Qing-Huo Liu "A Novel Simple and Compact Microstrip-Fed Circularly-Polarized Wide Slot Antenna with Wide Axial Ratio Bandwidth for C-band Applications," IEEE Trans. Antennas Propag., vol. 64, no. 4, pp. 1552-1555, 2016.

[2] Yue Li, Zhining Chen, Xianming Qing, Zhi jun Zhnag, Junfeng Xu, and Zhenghe Feng, "Axial Ratio Bandwidth Enhancement of 60-GHzSubstrate Integrated Waveguide-Fed Circularly Polarized LTCC Antenna Array," IEEE Trans. Antennas Propag., vol. 60, no. 10, pp. 4619-4636, 2012.

[3] Yue Li, Zhi jun Zhnag, and Zhenghe Feng, "A Sequential-Phase Feed Using a Circularly Polarized Shorted Loop Structure," IEEE Trans. Antennas Propag., vol. 61, no. 3, pp. 1443-1447, 2013.

[4] Han, Rong Cang, and S. S. Zhong, "Broadband Circularly-Polarised Chifre-Shaped Monopole Antenna with Asymmetric Feed," Electron. Lett., vol. 52, no. 4, pp. 256-258, 2016.

[5] Ding, Kang, Cheng Gao, Tongbin Yu, and Dexin Qu, "Broadband C-Shaped Circularly Polarized Monopole Antenna," IEEE Trans. Antennas Propag., vol. 63, no.2, pp. 785-790, 2015.

[6] Kumar, T., and A. R. Harish, "Broadband Circularly Polarized Printed Slot-Monopole Antenna," IEEE Antennas Wireless Propag. Lett., vol. 12, no. 3, pp. 1531-1534, 2013.

[7] Cai, Yuan Ming, Ke Li,Ying-Zeng Yin, and Wei Hu, "Broadband Circularly Polarized Printed Antenna With Branched Microstrip Feed," IEEE Antennas Wireless Propag. Lett., vol. 13, no. 13, pp. 674-677, 2014.

[8] Xu, R., Li, J. Y., Wei, K., and Yang, G. W., "Broadband Rotational Symmetry Circularly Polarized Antenna," Electron. Lett., vol. 52, no. 6, pp. 414-416, 2016.

[9] Wu, G. L., Mu, W., Zhao, G., and Jiao, Y. C., "A Novel Design of Dual Circularly Polarized Antenna Fed by L-strip," Progress in Electromagnetics Research, vol. 79, pp. 39-46, 2008.

[10] Zhao, G., Chen, L. N., and Jiao, Y. C., "Design of A Broadband Dual Circularly Polarized Square Slot Antenna," Microw. Opt. Technol. Lett., vol.50, no.10, pp.2639-2642, 2008.

[11] Lai, X. Z., Xie, Z. M., & Cen, X. L., "Design of Dual Circularly Polarized Antenna with High Isolation for RFID Application," Progress in Electromagnetics Research, vol. 139, no. 3, pp. 25-39, 2013.

[12] Lai, X. Z., Xie, Z. M., Xie, Q. Q., and Cen, X. L., "A Dual Circularly Polarized RFID Reader Antenna with Wideband Isolation," IEEE Antennas Wireless Propag. Lett., vol. 12, no. 12, pp. 1630-1633, 2013.

[13] Zhang, C., Liang, X., Bai, X., Geng, J., & Jin, R., "A Broadband Dual Circularly Polarized Patch Antenna with Wide Beamwidth," IEEE Antennas Wireless Propag. Lett., vol.13, no. 4, pp. 1457-1460, 2014.

[14] Saini, R. K., & Dwari, S., "A Broadband Dual Circularly Polarized Square Slot Antenna," IEEE Trans. Antennas Propag., vol. 64, no. 1, pp. 290-294, 2016.

[15] Chandu DS and S. S. Karthikeyan "A Novel Broadband Dual Circularly Polarized Microstrip-Fed Monopole Antenna," IEEE Trans. Antennas Propag., vol. 65, no. 3, pp. 1410-1415, 2017.

[16] Xu, Rui, Jian-Ying Li, Jiang-Jun Yang, Kun Wei, and Yang-Xiao Qi. "A design of U-shaped slot antenna with broadband dual circularly polarized radiation." IEEE Transactions on Antennas and Propagation 65, no. 6 (2017): 3217-3220.

[17] Li, Zhenya, Xiaosong Zhu, and Chengyou Yin. "CPW-fed ultra-wideband slot antenna with broadband dual circular polarization." AEU-International Journal of Electronics and Communications 98 (2019): 191-198.

[18] Girish Kumar and K. P. Ray, "Braodband Microstrip Antennas", Artech House Boston.