

A Compact Dual Polarisation Antenna with Improved Impedance Matching and Reduced Cross Polarisation

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Abstract—The built antenna resonates 5.9 GHz with peak gain 6.85 dBi in this configuration; a dual polarization microstrip patch antenna is achieved. It is necessary to cause a 90-degree phase delay between the components of the electric and magnetic field in order to provide circular polarization, to achieve right hand polarisation, to add a slot at the edge of the radiating patch and to achieve left hand polarisation in the cut of the ground corner. Both polarisations have an axial ratio of 1. Parallel slots and arc shaped slots are introduced as defected ground structure to improve impedance matching and reduce cross polarisation respectively. The antenna is manufactured and tested and it offers reasonable agreement between the effects of the simulation and measurement. This antenna is ideal for interacting with vehicles.

Index Terms— circular patch antenna, Defected Ground Structure, Impedance matching, Dual polarisation, Cross Polarisation.

I. INTRODUCTION

Like wireless communication system Wi-Fi, WI-MAX and vehicular interaction system utilize the dual-polarized antenna to overcome multipath fading problem and reuse the frequency for increasing channel capacity or to optimize the complete system performance by enhancing the channel throughput [1, 2]. Dual-band circularly polarized [3] and multi-band circularly polarized [4] characteristics of microstrip antennas (MSAs) have been investigated. Various dual-polarization techniques for different geometries have been highlighted on existing works [5–11]. Single-feed dual-polarized antennas having advantages over dual-feed antennas such as cost effective, less in weight, simple in structure and fabrication procedure and having less RF loss.

A hexagonal shaped slot loaded single-feed dual-frequency square shape MSA is presented having polarization planes of two frequencies perpendicular to each other and providing better bandwidth [12]. Two U-slot loaded patches are introduced for obtaining better bandwidth, high gain and dual-polarized performance in different bands [13]. A multi-layered, dual-frequency and dual-polarized antenna is designed consisting of two DGSs of spiral and dumbbell shape [14]. In [15], a drum shape compact dual-band dual-polarized MSA is designed by

utilizing a single co-axial feed line having resonant frequencies of 1.593 GHz and 1.797 GHz. An arrow shaped patch antenna is described in for application of dual-band and dual-polarization using single microstrip feed line [16]. By introducing a Boolean particle swarm optimization technique, a dual-band dual-polarized single-feed MSA is designed [17].

However, with the use of a Microstrip line, the dependence of impedance develops proportionate to the fourth-power cosine [18]. While the input impedance is zero for the feed probe at middle of the patch, the input impedance of inset-fed rectangular Microstrip Patch Antenna is influenced by the notch dimensions and the aspect ratio of the patch [19]. This implies that the H-plane cross-polarization is influenced by the notch depth and width dimensions. For fixed input impedance, however, the cross-polarization level is largely insensitive to the notch width.

Flexible impedance matching and low cross-polarization has been realized using a novel technique of loading the rectangular Microstrip Patch Antenna with a pair of shorting pins [20]. The symmetric arrangement of the shorting pins retains the symmetric-odd pattern of surface current with respect to the H-plane, and therefore the level of cross-polarization is diminished considerably. The input impedance of the Microstrip Patch Antenna also plays a role in achieving a suitable impedance-bandwidth. An improved bandwidth for a Microstrip Patch Antenna in the X-band has been achieved by implementing a z-shaped defected ground structure [21].

However, the integration of a Defected Ground Structure for enhancing input impedance matching has not been studied. The Defected Ground Structure has also been used to boost the bandwidth of an ultra-wide band antenna along with the suppression of cross-polarization [22]. Although, the level of cross-polarization has been improved by between 10 dB to 25dB in both the principal planes, a decline in matching can be observed after introducing the Defected Ground Structure. Among various effects; a simple rectangular Microstrip Patch Antenna is impinged by cross-polarized radiation in the far field, particularly the H-plane.

Irregularities in the positioning of probes leads to this proportioned antenna near-fields, resulting in higher cross-polarized radiation in the H-plane. The reduction of cross-polarization using Defected Ground Structure approaches have been studied, such as an arc-shaped symmetrical Defected Ground Structure [23]. From these studies, it can be observed that the reduction of cross-polarization along with proper impedance tuning is a challenging assignment for designers of Microstrip Patch Antenna. Since, an asymmetric feed position is often required for accurate matching of impedance; this unfortunately plays a role in increasing cross-polarization in the H-plane.

This proposed antenna resonate 5.9 GHz frequency with peak gain of 6.85 dBi. In the proposed communication, a single-feed dual-frequency dual-polarized MSA loaded with assemblies of parallel slots and arc shaped slots on the ground plane is proposed. This paper is summarized into following sections: Sect. 2 describes the antenna geometry with design procedure; Sect. 3 describes the results and validation. Conclusion followed by references is then discussed in Sect. 4.

II. ANTENNA GEOMETRY

Theoretically, the radiating patch of the antenna can be of any shape. However, for ease of design and low fabrication cost, a circular shape is chosen in this work. In general, circular patch antennas suffer from narrow bandwidth and poor gain constraints which can be mitigated by use of additional slots in the radiating patch (to improve bandwidth), and the use of circular patch arrays (to improve gain). In this design, the top plane of the antenna is designed as in [7].

A quarter wave transformers are used to balance the impedance between radiating patch and the input port. In general, the circular patch antenna gives linear polarization. In order to have circular polarization, it is necessary to induce a 90-degree phase delay between the electric and magnetic field components. To this end, two slots, 90 degrees apart, are used in the radiating element [8]. Figure 2 shows the modified circular patch antenna with slots to generate circular polarized radiation; the antenna gives left-hand circular polarization. In order to have right-hand circular polarization, the corner edge of the ground plane is truncated.

Etching Parallel slots and arc slots on ground plane are used to improve the impedance matching and reduce cross polarisation of the antenna respectively. The proposed antenna has an edge slotted circular radiating patch and a defected ground structure; a single band circular patch antenna is firstly designed and then in the second step, dual circular polarization at the frequency is achieved. Improved impedance matching and high gain is achieved by inserting two pairs of parallel slots on ground surface as defected ground structure as shown in Fig b. and a slot etched on the radiation surface as well as in the ground plane. The RHCP is obtained at one frequency by truncating the edge of the radiating patch perfectly and corner truncation on ground surface make LHCP and also it makes the designed antenna more compact, efficient radiator and diversely polarized.

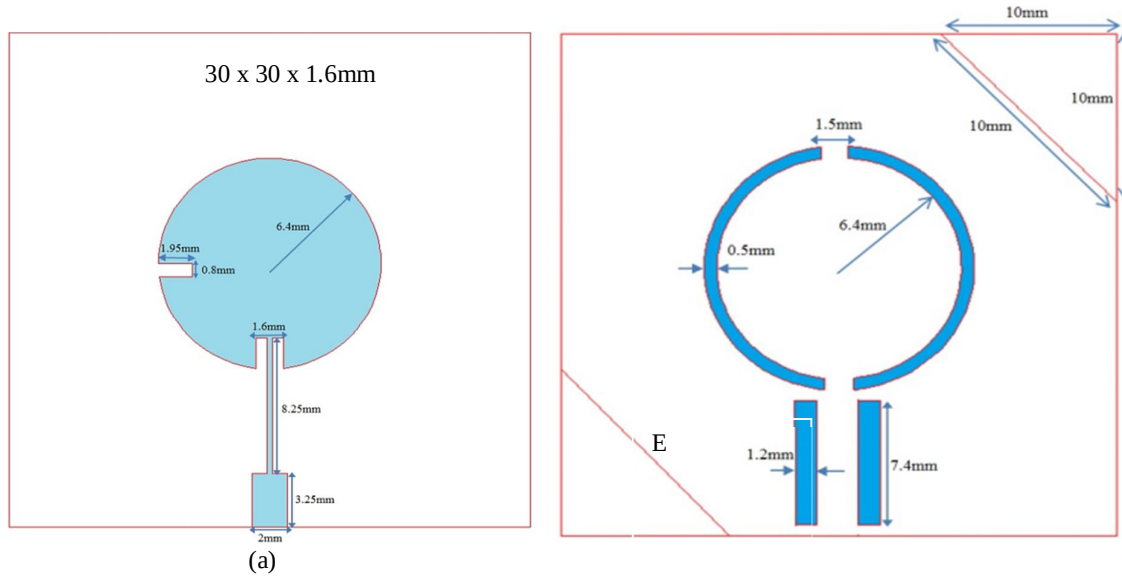


Figure.1. Antenna geometry (a) Front View (b) Back View

III. RESULTS AND DISCUSSION

To further identify the key factors affecting the performance of the proposed antenna and to provide design guidelines, the parameters study is carried out. Fig.2 and Fig.3 shows the effects of the slot geometry on radiating patch and on truncation of corner edge of ground plane of the antenna on $|S_{11}|$ and Fig 3 shows the varying of axial ratio (AR). The prototype of the proposed antenna is shown in Fig 7. The prototype is measured using Agilent's network analyser and an automated anechoic chamber. Fig. 4 shows the measured characteristics of the circular patch with and without DGS.

Perfect impedance matching in either unit is revealed. Identical versus frequency plots in Fig. 4 directly indicate that the new DGS has hardly any effect on the input impedance and as such on the resonance mechanism of the patch. The radiation properties of the proposed design are examined through Fig 8, it compares the relative radiated power from a circular patch with and without DGS. To give a comprehensive view, both measured and simulated data are presented, although our main focus is to examine the XP radiation.

In H-plane [Fig 8], a significant reduction in XP level is evident using the DGS, particularly around 45° with respect to the boresight. Suppression by 14.4 dB has been obtained experimentally, and this is corroborated by the simulated data. Indeed, the simulated results are used for a general verification of the measurements. The arc-DGS thus provides compared to the identical prototype with normal GP. The DGS hardly causes any change in the copolarized at least 30dB co- to cross-pol isolation in H-plane.

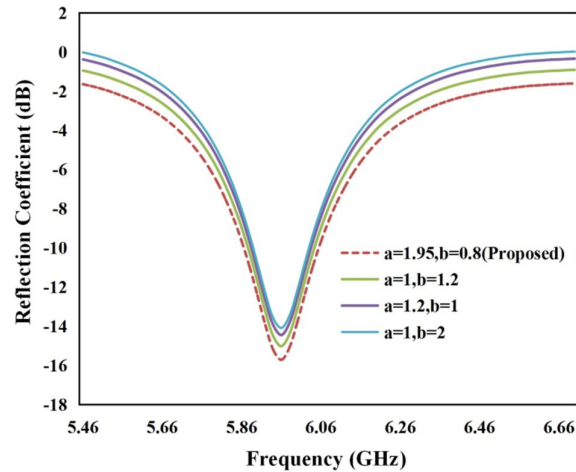


Figure.2 Effect of varying slot of the radiating plane (RHCP)

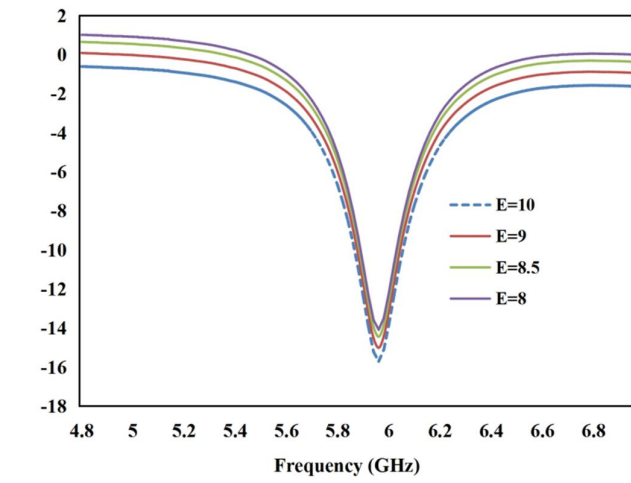


Figure.3 Effect of varying the truncation of ground plane (LHCP)

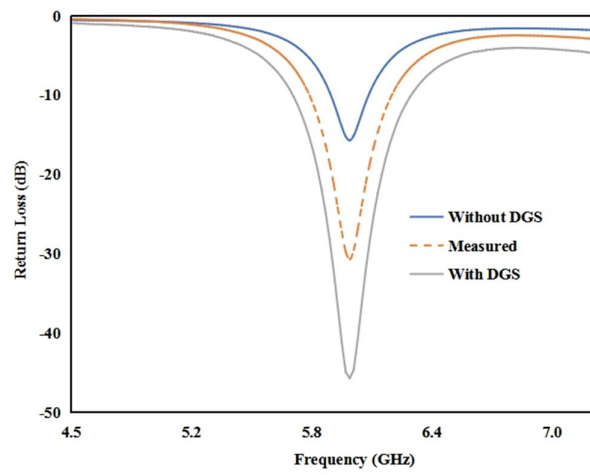


Figure.4 Simulated and measured $|S_{11}|$ of the proposed antenna

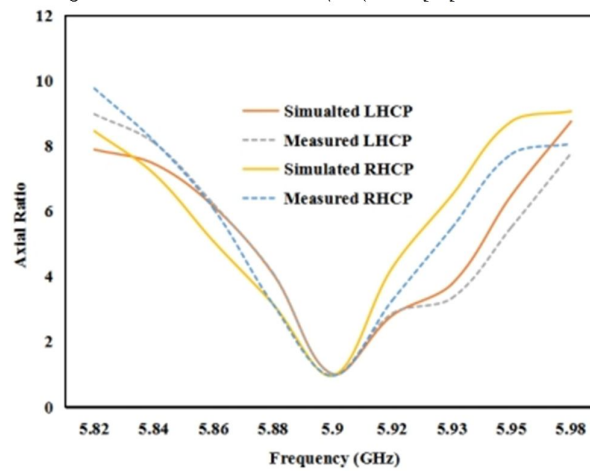


Figure.5 Axial Ratio

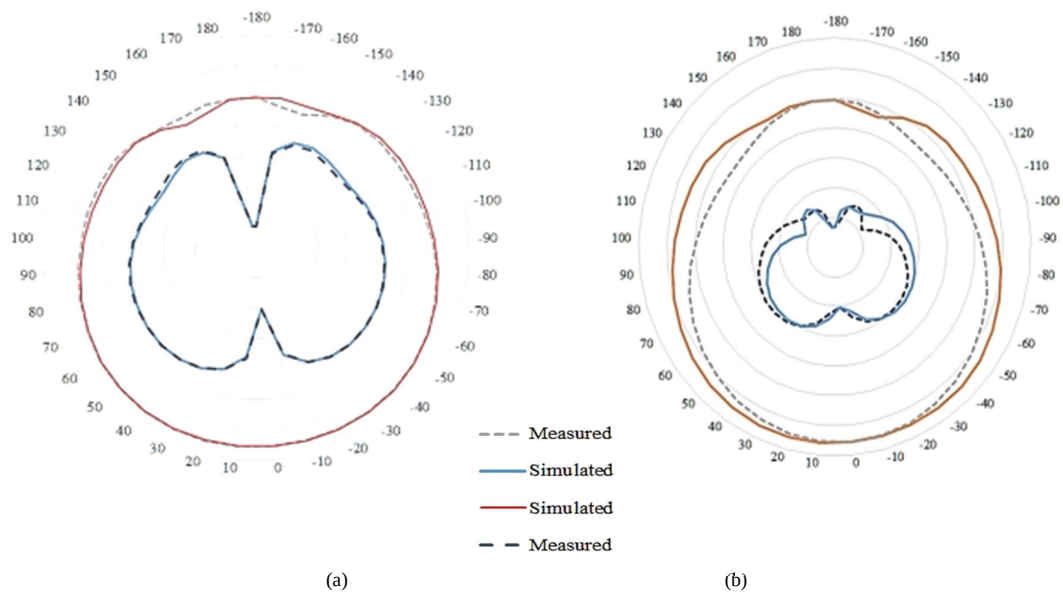


Figure 6. Radiation pattern (a) xy and (b) yz plane of antenna at 5.9 GHz

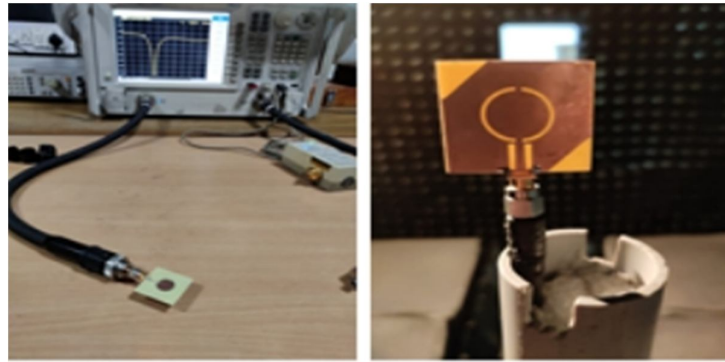


Figure. 7 Images of Measurement Setups and Prototype (a) Agilent vector network analyser and (b) Anechoic chamber

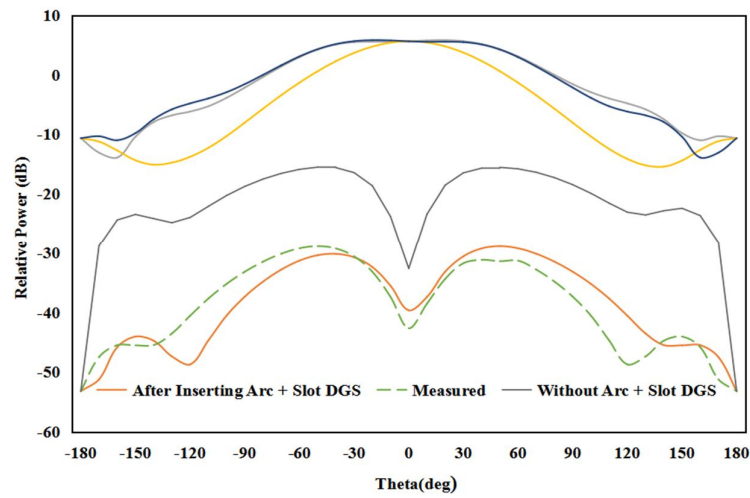


Figure.8 Patterns of co-polarization for the H and E planes and the patterns of cross-polarization for the H-plane

In E-plane [Fig. 8], the XP level is found to maintain 30 dB or more isolation from the peak value, and the effect of DGS is not revealed radiation patterns around broadside in either principal plane, except in a slight increase in the backward radiation and the antenna Gain (G) can be related to directivity (D) and antenna efficiency by:

$$G = \epsilon_r D \quad (1)$$

The Table I shows the comparison of existing and the proposed antenna.

TABLE I. COMPARISON OF THE PROPOSED ANTENNA WITH EXISTING REFERENC

Reference(dB)	Antenna size (mm ³)	Frequency (GHz)	Maximum gain(dBi)	Polarisation	Reduction in Cross Polarisation(dB)
[24]	24.12×24.12×15.48	1.40–2.70	6.38	Vertical polarisation	-
[25]	41.3×48.5×1.52	1.75–2.50	7.02	Vertical polarisation	-
[26]	19×16×0.8	0.50–6.60	4.00	Omnidirectional polarisation	-
[27]	54.91×68.18×14.55	0.10–0.90	1.20	Vertical polarisation	-
This Paper	30×30×1.6	5.9	6.85	Dual circular Polarisation	14.4

IV. CONCLUSION

Dual polarisation antenna with reduced cross polarisation and improved impedance matching is achieved. Defected ground structure is used to achieve dual circular polarisation and both polarisations have an axial ratio of 1. The built antenna resonates 5.9 GHz with peak gain 6.85 dBi in this configuration.. The cross polarisation is reduced on H-Plane by 14.4 dB. This antenna is ideal for interacting with vehicles.

REFERENCES

- [1] S. Kumar et al., "Single-feed cross-slot loaded compact circularly polarized microstrip antenna for indoor WLAN applications," *Microw. Opt. Technol. Lett.*, vol. 56, no. 6, pp. 1313-1317, March 2014.
- [2] C. Kumar and D. Guha, "linearly polarized elliptical microstrip antenna with improved polarization purity and bandwidth characteristics," *Microw. Opt. Technol. Lett.*, vol. 54, no. 10, pp. 2309-2314, October 2012.
- [3] S. Kumar et al., "Single-feed circularly polarized stacked patch antenna with small-frequency ratio for dual-band wireless applications," *Int. J. Microw. Wirel. Technol.*, vol. 8, no. 8, pp. 1207-1213, April 2016.
- [4] M. K. Khandelwal et al., "Triple band circularly polarized compact microstrip antenna with defected ground structure for wireless applications," *Int. J. Microw. Wirel. Technol.*, vol. 8, no. 6, pp. 943-953, March 2016.
- [5] S. Gao and A. Sambell, "Simple broadband dual-polarized printed antenna," *Microw. Opt. Technol. Lett.*, vol. 46, no. 2, pp. 144-148, July 2005.
- [6] X.-L. Liang et al., "Design of a dual-polarized microstrip patch antenna with excellent polarization purity," *Microw. Opt. Technol. Lett.*, vol. 44, no. 4, pp. 329-331, January 2005.
- [7] M. A. Jamlos et al., "Circular polarized 5.8GHz directional antenna design for base station application," *Lect. Notes Electr. Eng.*, vol. 666, July 2020.
- [8] T. Y. Yang et al., "Wideband high-gain low-profile dual-polarized stacked patch antenna array with parasitic elements," *Microw. Opt. Technol. Lett.*, vol. 57, no. 9, pp. 2012-2016, September 2015.
- [9] S. Gao and A. Sambell, "Dual-polarized broad-band microstrip antennas fed by proximity coupling," *IEEE Trans. Antennas Propag.*, vol. 53, no. 1, pp. 526-530, Jan 2005.
- [10] C. -Y. D. Sim et al., "Dual-feed dual-polarized patch antenna with low cross polarization and high isolation," *IEEE Trans. Antennas Propag.*, vol. 57, no. 10, pp. 3321-3324, July 2009.
- [11] S. Shad et al., "Design of a wideband dual-polarized microstrip patch antenna with novel structure for WLAN application," *Microw. Opt. Technol. Lett.*, vol. 58, no. 7, pp. 1599-1602, April 2016.
- [12] S. V. Shynu et al., "Single-feed dual-frequency dual polarized microstrip antenna with hexagonal slot". *IEEE Antennas Propag. Soc. Symp.*, vol. 4, pp. 4380-4383, June 2004.
- [13] S. Lin et al., "Single-fed dual-band dual-polarized U-slot patch antenna" in *IEEE MTT-S International Microwave workshop s. on RF and wirel. technol. biomed. and healthc. appl. (IMWS-BIO)*, vol. 2013, pp. 1-3, December 2013,
- [14] P. R. Prajapati et al., "Design of single feed dual band dual polarized microstrip antenna with defected ground structure for aeronautical and radio navigation applications" in *General Assembly and Scientific Symposium (Ursi GASS)*, vol. 2014 XXXIth URSI (pp. 1–4), October 2014.
- [15] S. O. Kundukulam et al., "Dualband dual-polarized compact microstrip antenna," *Microw. Opt. Technol. Lett.*, vol. 25, no. 5, pp. 328-330, June 2000.

- [16] M. Paulson et al., "A new compact dual-band dual-polarized microstrip antenna," *Microw. Opt. Technol. Lett.*, vol. 29, no. 5, pp. 328-332, April 2001.
- [17] F. Afshinmanesh et al., "Design of a single-feed dual-band dualpolarized printed microstrip antenna using a boolean particle swarm optimization," *IEEE Trans. Antennas Propag.*, vol. 56, no. 7, pp. 1845-1852, July 2008.
- [18] T. Samaras et al., "A note on the impedance variation with feed position of A rectangular microstrip-patch antenna," *IEEE Antennas Propag. Mag.*, vol. 46, no. 2, pp. 90-92, April 2004.
- [19] Y. Hu, et al., "Characterization of the input impedance of the inset-Fed Rectangular Microstrip Antenna," *IEEE Trans. Antennas Propag.*, vol. 56, no. 10, pp. 3314-3318, October 2008.
- [20] X. Zhang and L. Zhu, "Patch antennas with loading of A pair of shorting pins toward flexible impedance matching and low cross polarization," *IEEE Trans. Antennas Propag.*, vol. 64, no. 4, pp. 1226-1233, February 2016.
- [21] A. Kandwal et al., "Bandwidth enhancement using CSRR defected ground structure for A microstrip antenna," *Microw. Opt. Technol. Lett.*, vol. 55, no. 10, p. 27836, October 2013.
- [22] M. K. Khandelwal, et al., "Bandwidth enhancement and cross-polarization suppression in ultrawide band microstrip antenna with defected ground plane," *Microw. Opt. Technol. Lett.*, vol. 56, no. 9, pp. 2141-2146, September 2014.
- [23] D. Guha et al., "Improved cross-polarization characteristics of circular microstrip antenna employing arc shaped defected ground structure (defected ground structure)," *IEEE Antennas Wirel. Propag. Lett.*, vol. 8, no. P, p. 367-1369, December 2009.
- [24] K. Chen et al., "Compact dual-band dual circularly polarized annular-ring patch antenna for BeiDou navigation satellite system application," *IET Microw. Antennas Propag.*, vol. 11, no. 8, pp. 1079-1085. 24, May 2017.
- [25] C. Roy et al., "Performance parameters prediction of slotted microstrip antennas with modified ground plane using support vector machine," *Int. J. Microw. Wirel. Technol.*, vol. 9, no. 5, pp. 1169-1177. 25, November 2016.
- [26] M. Alibakhshikenari et al., "Triple-band planar dipole antenna for omnidirectional radiation," *Microw. Opt. Technol. Lett.*, vol. 60, no. 4, p. 1048-1051, March 2018.
- [27] M. Alibakhshikenari et al., "A novel monoflar-Archimedean metamaterial inspired leaky-wave antenna for scanning application for passive radar systems," *Microw. Opt. Technol. Lett.*, vol. 60, no. 8, pp. 2055-2060, June 2018.