DUAL BAND DUAL POLARIZED PLANAR MONOPOLE ANTENNA FOR L, AND C BAND APPLICATIONS

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Abstract

Here a simple, a dual polarized (DBDP) monopole antenna utilizing single feed dual band is present. Proposed design involves a radiating rectangular radiator with a U-shaped slot that produces mutual coupling to achieve dual impedance band (IB). To enhance dual axial ratio bandwidth (ARBW), an edged ground plane is used. This ground plane not only widens IBW but also helps to achieve dual ARBW. The proposed antenna spanned the dual simulated IBW from 1.466 – 1.908 GHz (442 MHz, f_{rc1} = 1.687 GHz, 26.2%) and 4.394- 4.17 GHz (224 MHz, f_{rc2} = 4.282GHz, 5.23%). The simulated dual ARBWs span over 1.615 – 1.538 GHz (77 MHz, f_{cp1} = 1.576GHz, 4.88%) in lower frequency region and 4.312 -4.184 GHz (128 MHz, f_{cp2} = 4.248 GHz, 3.01%) in the higher frequency region. The simulated peak gain between 1.305 – 3.03dBi on the whole IBW region makes the dual CP bands suitable for some part of L- and C-band, particularly GPS and Maritime Mobile communication applications.

Keywords

Dual band dual polarized (DBDP), Axial Ratio Bandwidth, Impedance Bandwidth.

1. Introduction

Now days in wireless communication system multiple requirements of various devices have fulfilled using a dual-band dual-polarized (DBDP) antennas. Vertically / horizontally Omni-directional dual-polarized radiation are generated through superimposing the radiation from a monopole antenna which support vertical polarization and a loop antenna which support horizontal polarization. Now in communication system where the astronomical research is the main attention, several uses communication devices is essential as a substitute to single communication typical device. As a consequence of the striking characteristics like lower footprint, simpler geometry, and lighter in weight, planar monopole antennas help as an utmost suitable practise. This is known to all that a conventional monopole antenna in longitudinal direction creates linearly polarized (LP) wave. But the foremost drawbacks of linearly polarized wave expected to achieve dual band performance are lower sensitivity, multipath fading to the positioning among the Tx (transmitting) also Rx (receiving) antennas, lower movability, also like that [1-3]. That may well be overwhelmed to a great scope consuming by an antenna which can perform the circular polarization. Henceforth, the antennas having dual bands by means of two different frequency bands instantaneously functioning dual circular polarization (anticlockwise or right hand circular polarization (RHCP) and clockwise or left hand circular polarization (LHCP)), are significantly widespread compare to dual band antennas with two quadrature (vertically/ horizontally) linear polarizations. The requirement of multiple antennas decreases due to using an antenna having multiband characteristics also satisfy dual polarization performances. The CP antenna is very attractive for many wireless systems as no strict orientation among transmitting and receiving antenna is required and encountering interference. Different

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researchers [4-8] have been studied different DBDP antennas to generating both LHCP and RHCP polarization to satisfy above criteria.

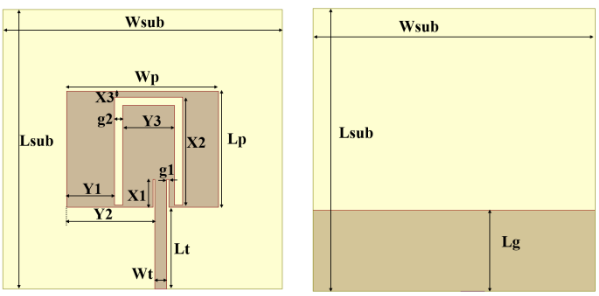
Inspired by the abovementioned antenna performances, a compact, simple a monopole antenna having DBDP with LHCP span over lower frequency region and RHCP span over higher frequency region is planned in this paper. The proposed design can support 1.466-1.908 GHz and from 4.17-4.394 GHz. So as to design a DBDP antenna, it has been appropriately improved in a suitable method that it can generate both circular polarizations.

An actual good reflection coefficient, widespread ARBW and dependable radiation features are gained for the implemented antenna. It became apparent that the implemented antenna is compacted and make available for broader LHCP also RHCP frequency bands.

This paper is presented like: Section II: Design Procedure of Antenna; Section III: Simulation Justifications and Discussions; also, lastly Section IV: ended with Conclusion.

2. Design Procedure of Antenna

An antenna with Dual-band dual-polarized (DBDP) can gratify the several purposes for different device; they are commonly utilized by the devices which can support wireless communication application [9]. The designed antenna simulated structures is shown in Fig. 1(a) and (b). The dimension of the microstrip antenna is 70×70mm^2. Commonly available, low cost workable FR4-epoxy substrate thickness of 1.6mm, having ε_r =4.4 and loss tangent $tan\delta$ =0.02 is utilized to simulated the implemented antenna. Comprehensive optimal dimensions have been recorded in Table I. The progress stages of the implemented antenna are represented in Fig. 2. Figures 3(a) and (b) demonstrations of the return loss and ARBW progress graphs for the designed antenna. First in Antenna.1 is designed at a resonating frequency 2.4 GHz using a rectangular radiator and on the opposite portion of the substrate a square ground plane is used for Wi-Fi, Bluetooth application. Here an asymmetric inset microstrip line feed is utilized, for getting a CP at this resonating frequency. To obtained better impedance matching network this feeding method is utilized. But ARBW is very poor at this frequency. To satisfy the multiband characteristics by using the same dimension of the antenna itneeds an additional current path. For that reason, an optimized U-shaped slot is etched from the rectangular radiator. These slots generate additional current paths [9-10] that rise IBW in addition improve ARBW characteristics related to earlier stage. The 3dB criterion is not satisfy from this generated ARBW. So, more amendments of the ground plane are planned. In next step for improving the ARBW performance, an edged ground is use [11]. The gap (Lt-Lg=0.4mm) between the radiator and edged ground create a coupling effect between them that increase capacitive effect, lowering the quality factor as a result resonating frequency shifted towards the lower frequency region [12-13]. This helps to achieve dual impedance band resonating are at 1.5 GHz and 4.2 GHz respectively, additionally get dual CP responses one is LHCP at lower resonating frequency and another one is RHCP at 4.2 GHz.



Top View Bottom View

Fig.1 Designed antenna Dimensions

Table I

Implemented Antenna Optimal Dimension

Parameter	Value(mm)	Parameter	Value(mm)
Lsub	70	Wsub	70
Lp	29	Wp	38
Lg	20.1	Lt	20.5
g1	0.45	g2	2
X1	7	X2	27
Y1	12	Y2	22.1
X3	1.5	Y3	13

Here the antenna is designed at 2.4GHz frequency but optimized the design lower resonating frequency, which is 1.466 GHz. This help to achieve 11.19% size reduction. Since it satisfied our purpose, it definite to select finalized this design and analyzed its performance.

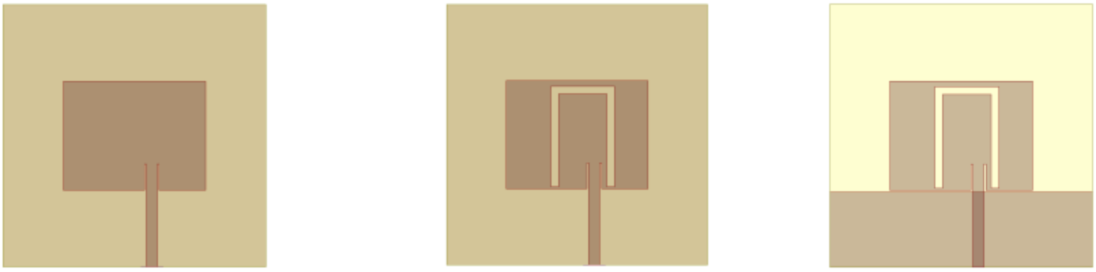
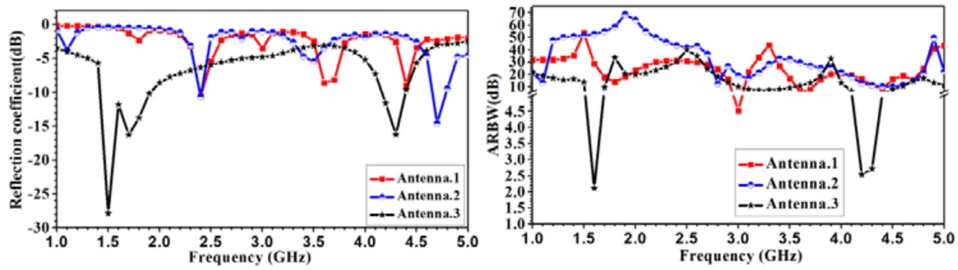


Fig.2 Improvement of Designed Antenna

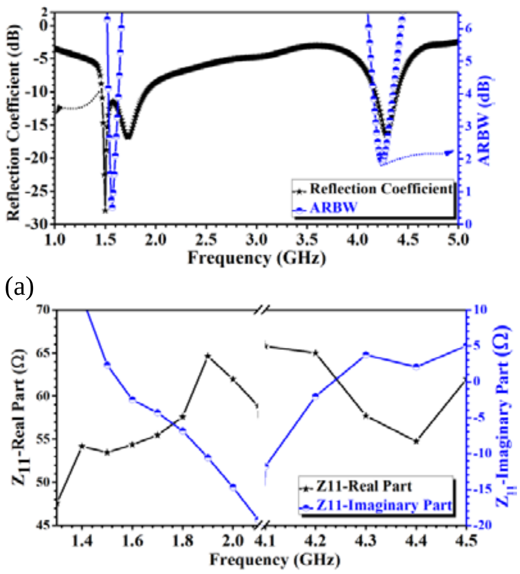


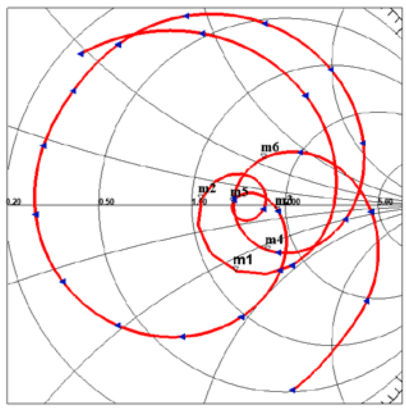
(a) (b)

Fig.3 Evaluation of (a) S_{11} and (b) ARBW for Antenna.1- 3

3. RESULTS AND DISCUSSIONS

To design the antenna using simulation software Ansys Electronics Desktop 2020 R1. The designed antenna the dual simulated IBW ranged from 1.466-1.908 GHz (442 MHz, frc1 = 1.687 GHz, 26.2%) and 4.394-4.17 GHz (224 MHz, frc2 = 4.282GHz, 5.23%) depict on Figure. 4(a).





Name	Freq	Ang	Mag	RX	Q	VSWR
m1	1.47	-55.67	0.28	1.21 - 0.62i	0.51	1.80
m2	1.50	32.69	0.04	1.07 + 0.05i	0.04	1.08
m3	1.91	-4.03	0.31	1.89 - 0.09i	0.05	1.90
m4	4.17	-30.49	0.32	1.62 - 0.58i	0.36	1.93
m5	4.29	2.86	0.15	1.35 + 0.02i	0.02	1.35
m6	4.39	33.08	0.31	1.57 + 0.58i	0.37	1.89

(c)

Fig. 4 (a) Assessment of Simulated Return lossalso ARBW graphs, (b) Antenna impedance (Real and Imaginary) vs. Frequency curves, (c) Results of the effect of complex reflection coefficient (Γ), normalized input impedance (Z11), Q-factor and VSWR using Smith Chart for the Implemented Antenna.

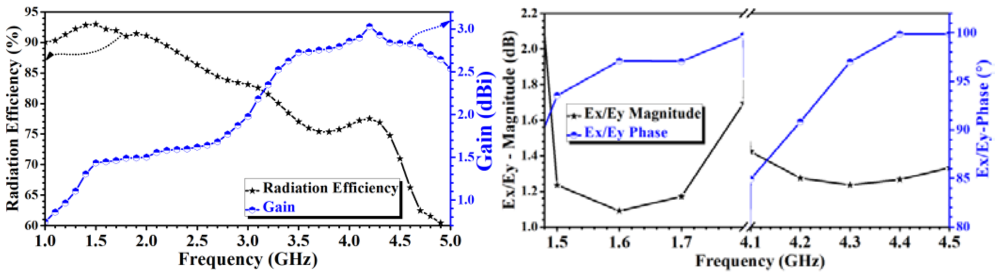
Fig. 4(a) also depicts the ARBW (simulated) of the implemented antenna. The simulated dual ARBW span over 1.615 – 1.538 GHz (77 MHz, fcp1 = 1.576GHz, 4.88%) and 4.312 -4.184 GHz (128 MHz, fcp2 = 4.248 GHz, 3.01%).

Fig. 4(b) simulated input impedance is depicting at 50Ω microstrip feed line for the Resistance which one is real and Reactance which one is imaginary parts. Within the IB match of the impedance is satisfactory because the resistance part of the impedance closer toward 50Ω and whereas the reactance part is closer toward 0Ω.

From Fig. 4(c) using smith chart one can see that on resonance frequency 1.47, 1.50, 1.91, 4.17, 4.29, and 4.39 GHz the normalized impedance (Z11) values are close to 1 whereas the complex reflection coefficient magnitude (Γ) values are also very small . So above values depict that best matching can occur on resonance frequencies because real part of Z 11 approaches to 50Ω and imaginary part tends to 0Ω. Also, VSWR value on those frequencies is also <2. The Q-value on those lower resonating frequency in addition the higher resonating frequency is also very small. That signify widest IBW can occur due to small Q-factor. At centre resonating frequencies 1.576 and 4.248 GHz also depicts that impedance matching can occur on those frequencies as VSWR value <2. From this Smith chart it's also clear that the graph rotates two times nearly equal to kick point (SWR=1) which prove dual impedance bands are generate by using this antenna.

Fig. 5(a) depicts the radiation efficiency (simulated) for the designed antenna respecting frequencies. The ranges of radiation efficiencies in between 75%-93% for two the IB. The maximum efficiency is 93% at 1.48 GHz. Figure 5(a) also depicts the at peak gains respecting frequency. The gain is within 1.305-3.03 dBi for two the IBs. The gain is maximum at 4.2 GHz which is 3.03 dBi.

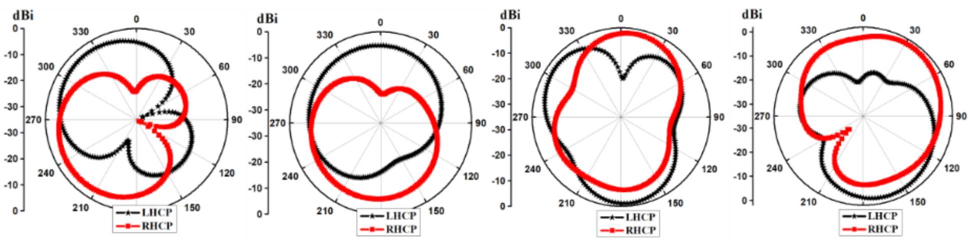
Fig. 5(b) depicts the Ex/Ey magnitude is closely equivalent to 1 or else 0 dB within the two circular polarized bands and the difference of phase among them is likewise nearly 90°. That demonstrates this dual bands gratify circular polarization conditions [14].



(a) (b)

Fig. 5 Simulated Antenna (a) Radiation Efficiency and Gain, (b) E_X/E_Yratio of magnitude and phase plots.

Well defined, LHCP and RHCP radiation patterns are detected in Fig. 6(a), (c) at φ=0° (XZ plane) and (b), (d) φ=90° (YZ plane) which are illustrating at fcp1=1.576 GHz and fcp2=4.248 GHz.



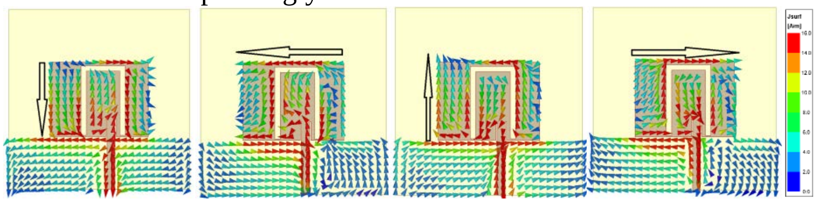
Frequency= 1.576 GHz Frequency= 4.248 GHz

(a) XZ plane (b) YZ plane (c) XZ plane (d) YZ plane

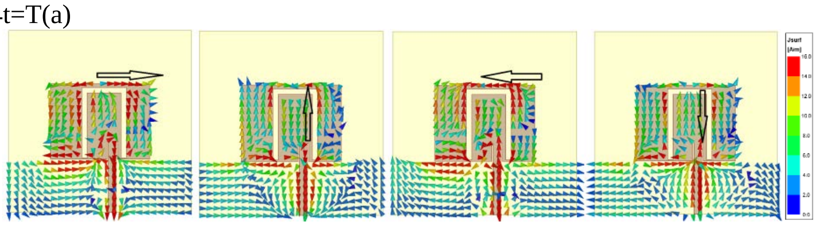
Fig. 6 LHCP and RHCPRadiation patterns for in the (a), (c) XZ (ϕ=0°) and (b), (d) YZ (ϕ=90°) planes.

At broadside direction on two CP resonating frequencies the radiations observed are LHCP and RHCP whereas the polarization (co and cross) differences are 19 dBi, and 17 dBi, correspondingly. Because of the asymmetric inset feeding radiator, the distribution of current is productive, due to that reason radiation is somewhat slanting from its broadside direction.

To understanding the generation of the dual CP modes at 1.576 and 4.248 GHz, a quantitative observation is depicted in Fig. 7. The normalized currents distribution from the below figures it is observed that for four separate time moments (t=0, t= T/4, t= 3T/4, t= T where for one cycle T is the total period of time), dual CP modes could be accomplished at f_{cp1}= 1.576 GHz, f_{cp2}= 4.248 GHz which are LHCP and RHCP correspondingly.



t=0t=T/4 t=3T/4t=T(a)

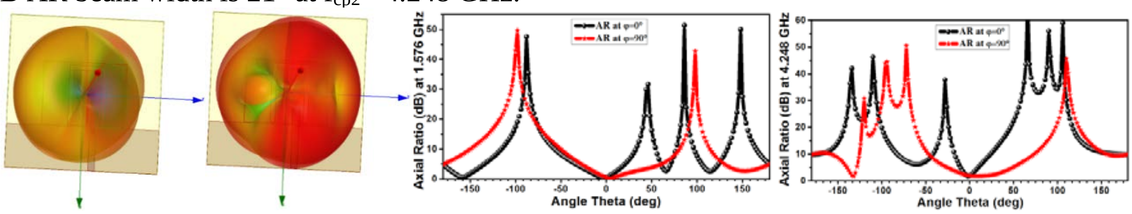


t=0t=T/4 t=3T/4t=T(b)

Fig. 7 Simulated current distribution at (a) f_{cp1}=1.576GHz, (b) f_{cp2}=4.248 GHz.

The 3D directivity patterns at two CP resonance frequencies marked as fcp1= 1.576 GHz and fcp2= 4.248GHz to investigate the radiation characteristics of the antenna are depicting in Fig. 8(a) and 8(b), respectively. From Fig. 8(a) - (b), it can be detected that at f_{cp1} = 1.576GHz and f_{cp2} = 4.248 GHz, y-directed and x-directed currents are almost the same in amplitude and 90° phase leading to create circular polarization. Additionally, it is detected that the main beam of radiation is tilted due to asymmetrical current distribution on the antenna structure. Thus, it may be concluded that at f_{cp1} and f_{cp2}, the antenna has circular polarization radiation.

The simulated axial ratio beam width with f_{cp1}= 1.576 GHz and f_{cp2}= 4.248GHz are plotted vs. θ° in Fig. 8(c) and (d). As obtained the results through simulation, at fcp1 the implemented antenna has a 3dB axial ratio beam width with respect to vertical θ angle of around 10° at XZ (φ=0°) plane and 46° at YZ (φ=90°) plane. So, at broadside direction the difference between co- and cross plane simulated 3 dB axial ratio beam width is 30° at f_{cp1}= 1.576 GHz. Similarly, at f_{cp2} the implemented antenna has a 3dB axial ratio beam width with respect to vertical θ angle of around 34° at XZ (φ=0°) plane and 55° at YZ (φ=90°) plane. So, on broadside direction the difference between co- and cross plane simulated 3 dB AR beam width is 21° at f_{cp2}= 4.248 GHz.



(a) (b) (c) (d)

Fig. 8 3D directivity (total) patterns of the implemented antenna at (a) f_{cp1} = 1.576GHz, (b) f_{cp2} =4.248GHz and Axial Ratio Beam Width vs. θ° at XZ plane (ϕ=0°) and YZ plane (ϕ=90°) (c) f_{cp1} = 1.576GHz, (b) f_{cp2} =4.248GHz.

4. Conclusion

A dual band dual polarized antenna with dual circular polarization characteristics showing LHCP in lower frequency region (4.88 % at 1.576 GHz), and RHCP in the higher frequency region (3.01% at 4.248GHz) is comprehended at here. It's employing the modification on ground plane and asymmetric inset feeding mechanism of a rectangular monopole antenna with an optimized U-shaped slot. The proposed antenna (size 70×70 mm2 which is 0.561×0.561 λg2, λg = guided wavelength at 1.466 GHz, 11.19% size reduction) gives dual IBW, one span over at lower frequency band, 26.2% and another span over higher frequency region, 5.23%. Using a single small form factor device, the dual CP bands of this compact DBDP antenna can support L and C band applications.

Supplementary Document

Detail design procedure for this proposed antenna.

5. References

[1] Toh, B.Y., Cahill, R. and Fusco, V.F., 2003. Understanding and measuring circular polarization. IEEE Transactions on Education, 46(3), pp.313-318. DOI: 10.1109/TE.2003.813519.

[2] Yu, D., Gong, S.X., Xu, Y. and Wan, Y.T., 2015. Dual-band dual-polarized circular microstrip patch antenna with the curved slots on the ground. Progress In Electromagnetics Research, 51, pp.27-31. DOI: 10.2528/PIERL14112004.

[3] Langston, W.L. and Jackson, D.R., 2004. Impedance, axial-ratio, and receive-power bandwidths of microstrip antennas. IEEE transactions on antennas and propagation, 52(10), pp.2769-2774.

[4] Dorsey, W.M. and Zaghloul, A.I., 2013. Dual-band, dual-circularly polarised antenna element. *IET Microwaves, Antennas & Propagation*, *7*(4), pp.283-290. DOI: 10.1049/iet-map.2012.0625.

[5] Lu, J.H. and Liou, C.W., 2014. Planar dual-band circular polarization monopole antenna for wireless local area networks. *IEEE Antennas and wireless propagation letters*, *14*, pp.478-481. DOI: 10.1109/LAWP.2014.2368137.

[6] Yang, D., Zhai, H., Xue, K., Xi, L., Wu, X. and Li, Y., 2019. A dual-band circularly polarized planar monopole antenna for Wireless Local Area Network/Worldwide Interoperability for Microwave Access applications. *Microwave and optical technology letters*, *61*(2), pp.399-404. DOI: 10.1002/mop.31568.

[7] Li, J.F., Wu, D.L., Zhang, G., Wu, Y.J. and Mao, C.X., 2019. A left/right-handed dual circularly-polarized antenna with duplexing and filtering performance. *IEEE Access*, *7*, pp.35431-35437. 10.1109/ACCESS.2019.2904189.

[8] Xu, R., Gao, S.S., Li, J., Wei, K. and Luo, Q., 2020. A Reconfigurable Dual-Band Dual-Circularly Polarized Antenna for Vehicle Global Navigation Satellite System Application. *IEEE Transactions on Vehicular Technology*, *69*(10), pp.11857-11867. 10.1109/TVT.2020.3020261.

[9] Singh, A.K., Patil, S., Kanaujia, B.K. and Pandey, V.K., 2020. A novel printed circularly polarized asymmetric wide slot antenna for digital cellular system. *Microwave and Optical Technology Letters*, *62*(3), pp.1438-1447. DOI: 10.1002/mop.32177.

[10] Ellis, M.S., Effah, F.B., Ahmed, A.R., Kponyo, J.J., Nourinia, J., Ghobadi, C. and Mohammadi, B., 2020. Asymmetric circularly polarized open-slot antenna. *International Journal of RF and Microwave Computer-Aided Engineering*, *30*(5), p.e22141. DOI: 10.1002/mmce.22141.

[11] Dhara, R. and Kundu, T., 2020. A Compact Inverted Y-shaped Circularly Polarized Wideband Monopole Antenna with Open Loop. Engineering Reports. DOI: 10.1002/eng2.12326.

[12] Dhara, R. and Kundu, T., 2021. Compact dual-band circularly polarized inverted y-shaped printed monopole antenna with edge ground. Radioelectronics and Communications Systems, 64(3), pp.125-139. DOI: 10.3103/S073527272103002X.

[13] Dhara, R. 2021. A Compact Dual Band Dual Polarized Monopole Antenna with Enhanced Bandwidth for C, X, and Ku Band Applications. Progress In Electromagnetics Research Letters, 96, pp.65-72. DOI: 10.2528/PIERL20121903.

[14] Dhara, R., Yadav, S., Sharma, M.M., Jana, S.K. and Govil, M.C., 2021. A Circularly Polarized Quad-Band Annular Ring Antenna with Asymmetric Ground Plane Using Theory of Characteristic Modes. Progress In Electromagnetics Research, 100, pp.51-68. DOI: 10.2528/PIERM20102006.