A Dual-Band Circularly Polarized with Large Impedance Bandwidth Planar Monopole Antenna for Wireless Application

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1 Introduction

Printed microstrip patch radiator is largely used in different communication application over the last decades of years due to easy fabrication process, its compact size, and lightweight in structure. However, for multiband application, planar monopole antenna made its own space in couple of years during this modern era of communication [1]. Nevertheless, circularly polarized planar monopole antenna shows a great participation in today's communication system because of its advantages like overcoming from polarization mismatch, multipath reflection problem, and weak weather penetration power [2]. However, the problems in circularly polarized planar monopole antenna (CPMA) are large in size and small axial ratio bandwidth. Therefore, various types of technique are used [3–14] to improve size and ARBW. In this paper, all above factors are aimed to improve. A dual-band ARBW under a broad IBW with an average gain circularly polarized monopole antenna is implemented. A simple half-moon and full moon slotted along with triangular etched rectangular radiator is proposed. A simple microstrip line feeding is used asymmetrically to the radiator to improve ARBW. The details description of proposed structure, design procedures, and response are portrayed.

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2 Antenna Design and Analysis

The design details and the values of length and width of physical parameter are mentioned in Fig. 1. The physical antenna consists of a thin cupper radiator with a microstrip feed, substrate, and partial ground plane from top to down with respect to Z-axis as shown in Fig. 1. Here, substrate is taken as FR-4 dielectric material whose loss tangent is 0.024 and permittivity is 4.4. In this design, length (L) and width (W) are taken in Y-axis and X-axis, respectively. The physical dimension of antenna is $29 \times 31 \times 1.6$ ($L \times W \times h$) in millimeter. A full moon and half-moon-shaped slots are inserted inside the rectangular patch along with triangular-shaped cut at the right side of the radiator to improve IBW and ARBW. The position of microstrip feed line is asymmetrically connected and optimized to improve ARBW. By optimizing different parameters, ARBW and IBW are resulted. Final parameters are summarized in Table 1. The ANSYS HFSS (ver.15) is used to design and simulation of the designed antenna.

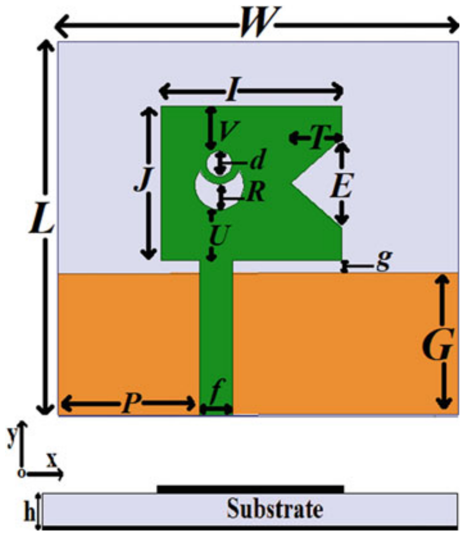


Fig. 1 Simplified diagram with all dimensions of proposed antenna

Table 1 Physical parameters of the proposed antenna (unit in millimeter)

Param.	Value	Param.	Value	Param.	Value	Param.	Value
W	31	*J*	12	*d*	2	*G*	11
L	29	*E*	7	*R*	2	*f*	2.5
h	1.6	*T*	4	*U*	3.95	*P*	11
I	14	*V*	3.5	*g*	1		

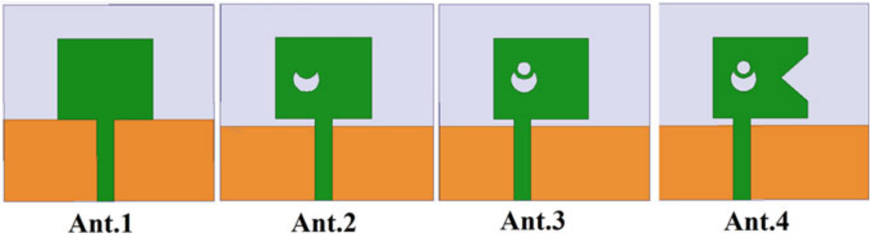


Fig. 2 Design procedure of proposed antenna

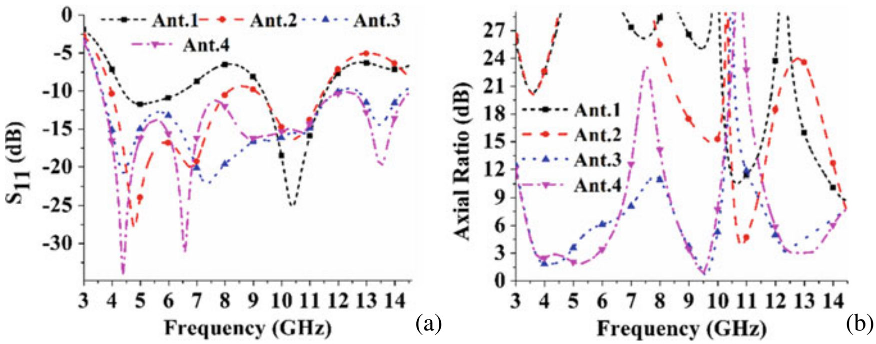


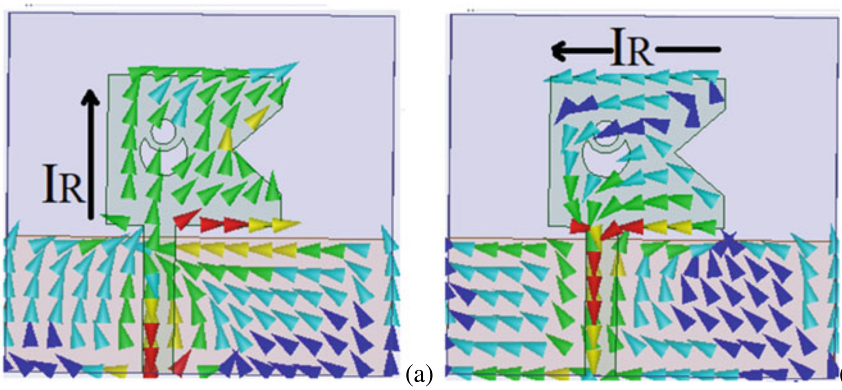
Fig. 3 Responses of Ant.1 to Ant.4: **a** S_{11} and **b** axial ratio

To get the final proposed antenna, four design steps are introduced from Ant.1 to Ant.4 (proposed) which are explained in Fig. 2. The details response of each steps are analyzed in Fig. 3.

To generate CP radiation, the horizontal and vertical component of electrical field should have equal magnitude and 90° phase difference. In Ant.1, very narrow −10 dB IBW is found at a resonant frequency of 10.46 GHz without any CP radiation in Fig. 3. However, IBW is improved largely up to 11.34 GHz and AR approaches toward 3 dB. In next step (Ant.3), IBW is further improved along with dual bands of CP radiation in Fig. 3. Finally, optimized dual band is found in proposed antenna (Ant.4) along with broad IBW. The 1st resonant frequency (f_0) of proposed antenna is found at 4.39 GHz, which is shown in Fig. 3, and its corresponding wavelength is λ_0 (1st resonant wavelength).

2.1 *Surface Current Analysis to Interpret CP Radiation*

The resultant current direction can be determined from the figure of surface current distribution. From that resultant current direction, circular polarization characteristic can be verified by orthogonal orientation of phase angles. Figure 4 shows that surface



(a) (b)

Fig. 4 Proposed antenna surface current distribution effect at 4.39 GHz for phase angle: **a** 0° and **b** 90°

current directions at 4.39 GHz for orthogonal phase angles 0° and 90°. By summing all the current vectors, the resultant current direction is found in a particular direction. All horizontal currents are canceled due to opposite direction of currents and only current is flowing in vertical up direction as shown in Fig. 4a. However, Fig. 4b shows that all verticals currents are canceled due to opposite direction of currents and only current is flowing in horizontal (right to left) direction. From Fig. 4, it is clearly shown that the current distribution oriented counter clockwise direction. From which, it is confirmed that it provides the right hand circularly polarized (RHCP) radiation in broadside direction and left hand circularly polarized (LHCP) radiation in backside direction.

3 Results and Discussion

The results of different characteristic parameters of designed antenna are displayed in Figs. 5 and 6. The IBW of CPMA is from 3.59 to 14.6 GHz confirmed in Fig. 5a. The dual band of ARBW is from 3.65 to 5.89 GHz and from 9.05 to 9.75 GHz are verified in Fig. 5b. The peak gain is found as 4.3 dBi, and average efficiency is more than 90%, which are displayed in Fig. 5c and d.

The far field radiation patterns of the proposed antenna are illustrated in Fig. 6. The YOZ plane and XOZ plane radiation patterns are plotted for variation of angle θ at 4.39, 9.45 GHz to verify the circular polarization in two different CP bands. In both frequency, RHCP and LHCP waves are radiated toward broadside and backside directions, respectively.

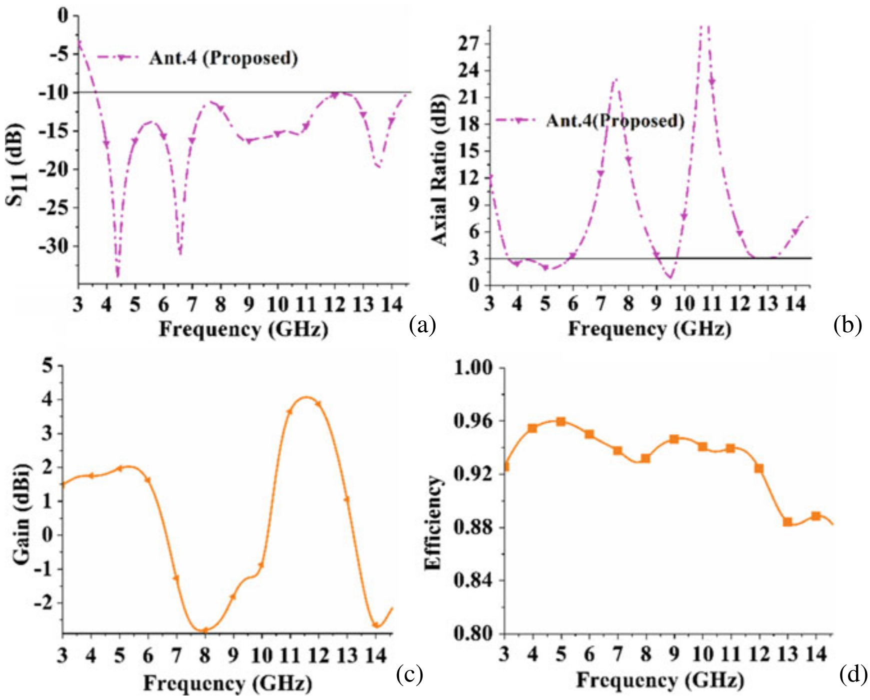


Fig. 5 Results of proposed antenna: **a** return loss, **b** AR, **c** gain, and **d** efficiency

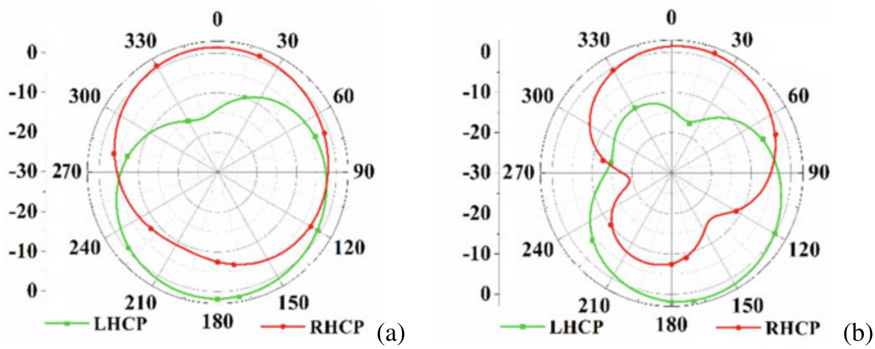


Fig. 6 Radiation pattern: **a** 4.39 GHz in XOZ plane, **b** 4.39 GHz in YOZ plane, **c** 9.45 GHz in XOZ plane, and **b** 9.45 GHz in YOZ plane

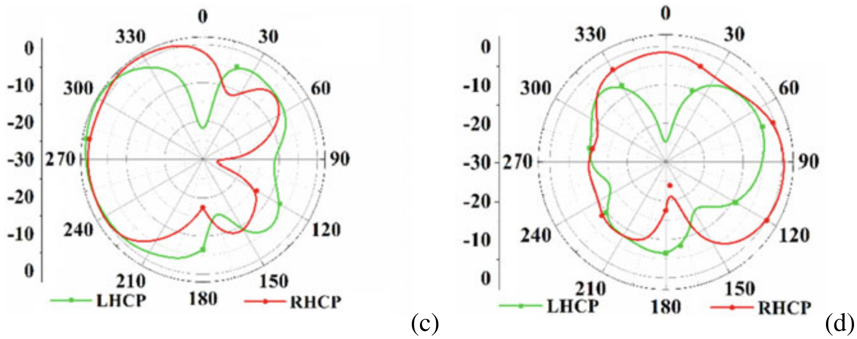


Fig. 6 (continued)

4 Conclusion

A dual-band circularly polarized planar monopole antenna is implemented with very large IBW. Multiple number of slots are inserted to the rectangular radiator to optimize the ARBW and IBW. The IBW of CPMA is 121.05% (3.59–14.6 GHz) achieved. The dual ARBW of 2.24 GHz (3.65–5.89 GHz) and 0.7 GHz (9.05–9.75 GHz) are achieved. The proposed antenna can be used for different wireless communication like 5G application, S-band radar, and maritime radio navigation.

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