

# Extended Microstrip Line-Fed Circularly Polarized Dielectric Resonator Antenna for WiMAX and 5G Applications



Ayan Pal, Arunabho Panja, Amibrata Samadder, Saswata Banerjee, Juin Acharjee, and Kaushik Mandal

**Abstract** In this paper, a unique, simple, and concise structure of a circularly polarized (CP) cylindrical dielectric resonator antenna (CDRA) usable for wireless band applications is proposed. The CDRA is excited by a meandered-shaped microstrip feedline ending with a circular extension. The combined effect of this feeding mechanism along with a partial ground plane satisfies the criteria for generating circular polarization. The proposed design is operating in the frequency range of 2.80–3.41 GHz centered at 3.39 GHz with an axial ratio (AR) bandwidth of 9.14% and peak gain of 3.9 dBi. The designed structure exhibits 3-dB axial ratio beamwidth (ARBW) of  $42^\circ$  and  $102^\circ$  with  $AR_{\min}$  of 0.54 dB and cross-polarization discrimination (XPD) of 30 dB and 31 dB in two principal planes at  $\phi = 0^\circ$  and  $\phi = 90^\circ$ , respectively. The reconfigurability between left-hand CP (LHCP) and right-hand CP (RHCP) field can be obtained by taking the mirror image of the extended meandered-shaped microstrip feedline. The antenna can be preferred for different wireless applications such as WiMAX and 5G.

**Keywords** Circular polarization · Dielectric resonator antenna · Cylindrical DRA · Axial ratio · Axial ratio beamwidth · Cross-polarization discrimination

## 1 Introduction

In the last few decades, dielectric resonator antenna (DRA) has been extensively researched by scientists due to its beneficial features such as higher impedance bandwidth, small space requirement, negligible conductor loss, significant gain improvement, and ease of applying various excitation techniques [1, 2]. A circularly polarized (CP) wave radiates power in the horizontal and vertical planes as well as every plane in

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between it, and the plane of polarization rotates in a pattern by making one complete revolution during each wavelength. For CP, an antenna must support two orthogonal modes (perpendicular field of equal amplitude) with a  $90^\circ$  phase difference between them [3]. The antenna is insensitive to transmitter and receiver orientation, offers less sensitivity to propagation effects, and is suitable for satellite communications [4]. As a result of the mentioned reasons and considering its operating range, it can be concluded that CP is necessary for smooth and hassle-free wireless communication for WIMAX and 5G applications. CPDRA has gained immense popularity in the field of wireless and satellite communication over linearly polarized DRA as it is not affected due to polarization mismatch and nullifies the effect of multipath interference [5, 6]. CPDRA can be achieved in various ways. Researchers have found that one of the ways by which CP can be achieved in DRA is by varying the coupling slots [7–9]. Another technique that has been found is by varying the feed structure used to excite the DRA and by changing the dimensions of the ground plane to achieve CP [10–12]. For instance, a question-mark shaped feed has been used which provides a quadrature-phase difference between two orthogonal modes, thus generating CP [13]. Similarly, a rectangular feed has been modified by removing parts of it to obtain the required conditions to generate CP [12]. CP has also been achieved by restructuring the shape of the DRA [14–16]. Very recently insertion of slots for CP generation is one of the reported techniques [17, 18]. A single feed CP rectangular DRA using the new coupling method of dual-mode slot-line ring resonator (SSRR) has also been investigated [19]. Conformal rectangular open half-loops can also be used for excitation [20].

In this article, the design of a cylindrical DRA (CDRA) with a modified feeding structure for realizing CP is presented. A meandered-shaped microstrip feedline is used to enhance the electrical length. The feedline is ended with a circular extension that produces mutual coupling with the partial ground plane to realize CP. All the simulations are conducted in full-wave-based ANSYS HFSS. Large separation between the LHCP and RHCP justifies the performance of CP in the operating frequency band.

## 2 Circularly Polarized Dielectric Resonator Antenna Design and Analysis

### 2.1 Antenna Design

Figure 1 shows the geometrical structure of the proposed CDRA. Easily available low-cost FR4 substrate with dielectric constant  $\epsilon_r = 4.4$ , height  $h = 1.6$  mm is used as the base of DRA, and the feedline is printed on it. A cylindrical-shaped dielectric resonator is designed using the substrate Arlon AD410 with relative permittivity of  $\epsilon_r = 4.1$ , height  $H = 20.8$  mm, and loss tangent  $\tan \delta = 0.003$ . A meandered-shaped microstrip feedline of length 67.5 mm with a circular extension of radius  $r = 5.2$  mm



through a meandered-shaped microstrip feedline ending with a circular extension identified as design 1. For the reference antenna and design 1, a full metallic ground plane is used. In the final design in Fig. 2c, a partial ground plane has been taken for proper mutual coupling with the placed CDRA. With the improvement of the structure, stepwise improvement of their response in terms of reflection coefficient and AR bandwidth is depicted in Fig. 2d and e.

### 2.1.1 Antenna Parametric Analysis

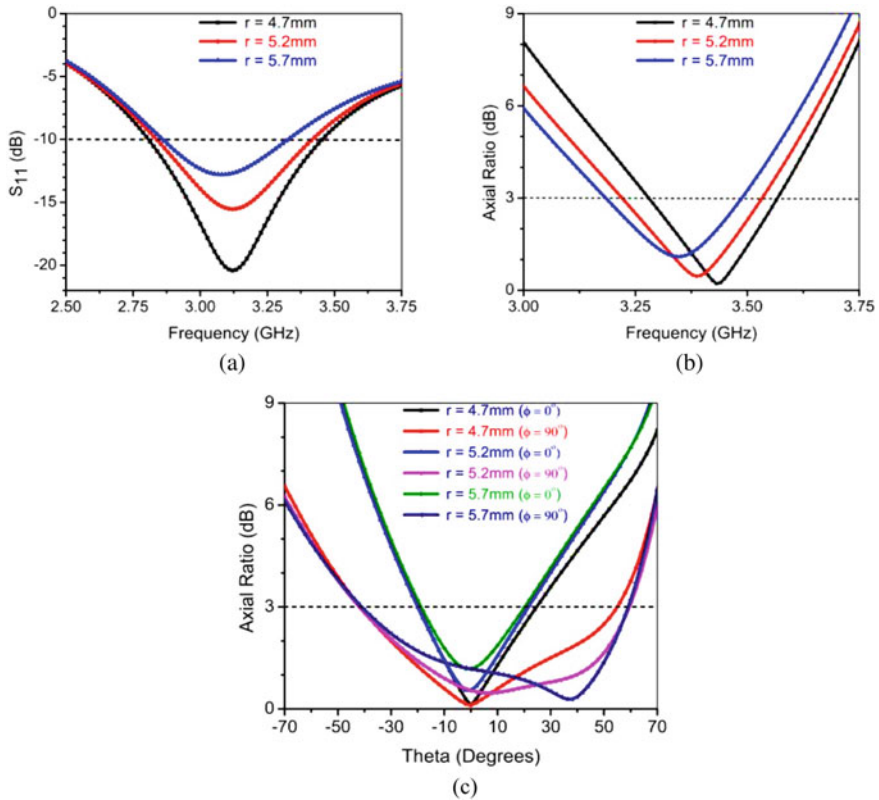
Some of the parameters of the proposed structure play an important role in the performance improvement of the designed CP CDRA. The effects of these parameters are discussed below.

#### Effect of Change in Radius of Circular Extension

In Fig. 3, the effect of changing the radius of the circular extension of the feedline is shown. In Fig. 3a, reflection coefficient is shown for the different values of the radius of the circular extension. For a radius of 4.7 mm, the  $-10$  dB bandwidth obtained is 640 MHz. On increasing the radius to 5.2 mm, a slight reduction in impedance bandwidth (IBW) is observed. However, on increasing the radius to 5.7 mm, the IBW is diminished by 210 MHz resulting in a bandwidth of 400 MHz. Figure 3b depicts the AR bandwidth for varying radii. For radii of 4.7 mm and 5.7 mm, the AR bandwidth is 284 MHz and 293 MHz, respectively. However, for radius of 5.2 mm, the secured AR bandwidth increases to 310 MHz. In Fig. 3c, the value of 3-dB ARBW is illustrated for  $\phi = 0^\circ$  and  $\phi = 90^\circ$  after changing the radius of circular extension. It is observed that for only  $r = 5.2$  mm, the 3-dB ARBW is greater than  $100^\circ$  and  $42^\circ$  for  $\phi = 90^\circ$  and  $\phi = 0^\circ$ , respectively.

#### Effect of Change in Height of DRA

The effect of change in the height of CDRA on various parameters is depicted in Fig. 4. It is observed in Fig. 4a that the IBW is maximum when  $H = 20.8$  mm. For  $H = 19.2$  mm and 22.4 mm, the bandwidth is 546 MHz and 560 MHz, respectively. The AR Bandwidths for  $H = 20.8$  mm and 22.4 mm are approximately the same, but it is a bit wider for  $H = 19.2$  mm as shown in Fig. 4b. However, when compared to  $H = 19.2$  mm and 22.4 mm, the convergence of IBW and AR bandwidth is more for  $H = 20.8$  mm. From Fig. 4c, it can be observed that the 3-dB ARBW for  $H = 19.2$  mm at  $\phi = 0^\circ$  is less than that of  $H = 20.8$  mm while that of  $H = 22.4$  mm is same as that of  $H = 20.8$  mm. The 3-dB ARBW for  $\phi = 90^\circ$  is maximum for  $H = 19.2$  mm and 20.8 mm. Hence, optimum results are obtained for when  $H = 20.8$  mm.

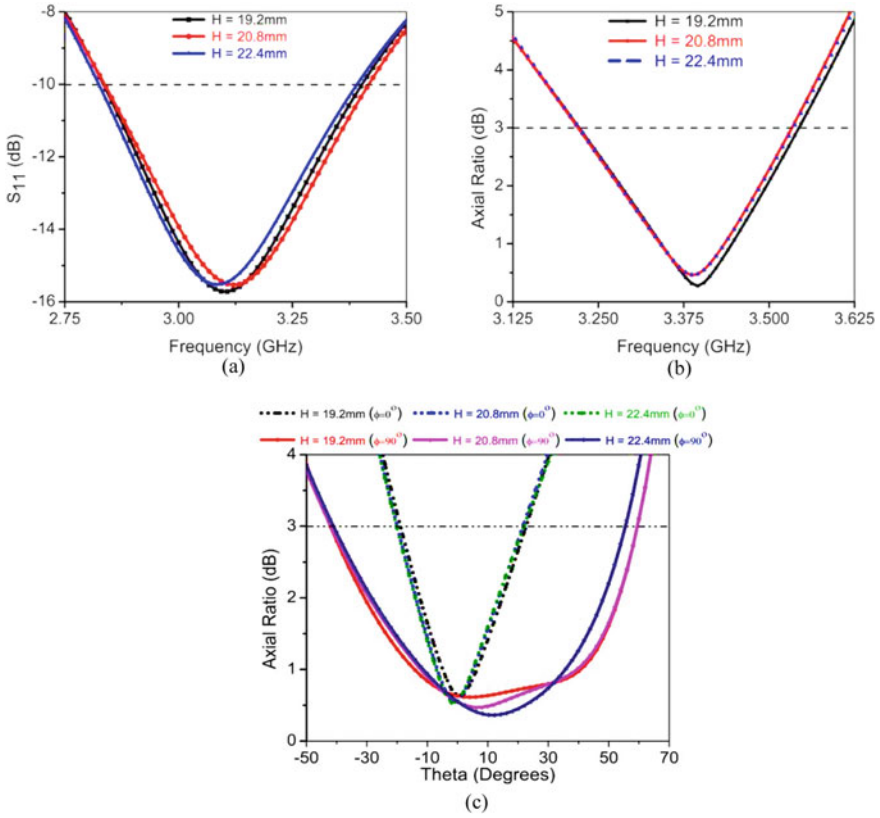


**Fig. 3** Effect of change in radius of circular extension in **a** Reflection coefficient **b** AR bandwidth and **c** 3-dB ARBW in different planes

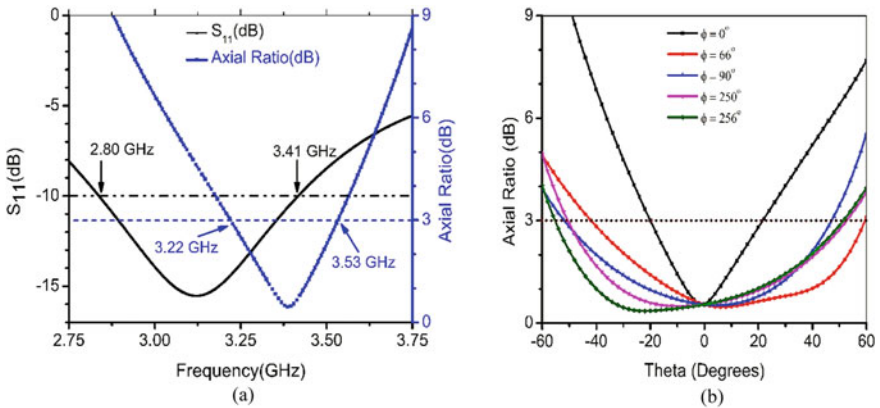
### 3 Result and Discussion

The proposed designed structure provides IBW of 19.55% (2.80–3.41 GHz) and AR bandwidth of 9.14% (3.22–3.53 GHz) as observed in Fig. 5a. The resonating frequency is achieved at 3.39 GHz with an ARmin of 0.54 dB. Justification of the generation of CP at the operating frequency is reflected in Fig. 5b. It shows that for different planes, a large variation of the elevation angle AR achieved is below 3 dB. The CP radiation patterns for the primary planes  $\phi = 0^\circ$  and  $90^\circ$  are displayed in Fig. 6. In the boresight direction, the difference between LHCP and RHCP, i.e., XPD, is 30 dB and 31 dB, respectively.

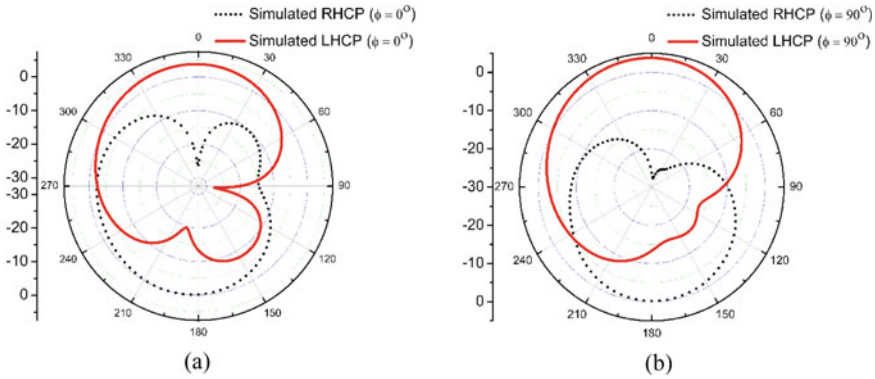
Less variation of gain throughout the operating frequency band is observed which also justifies the stable performance of the proposed antenna as shown in Fig. 7. The maximum realized gain at the operating band is 3.9dBi. Radiation efficiency variation from 85.5% to 94%, which is acceptable for practical applications, has also been portrayed in Fig. 7.



**Fig. 4** Effect of change in height of CDRA on **a** Reflection coefficient **b** AR bandwidth and **c** 3-dB ARBW in different planes

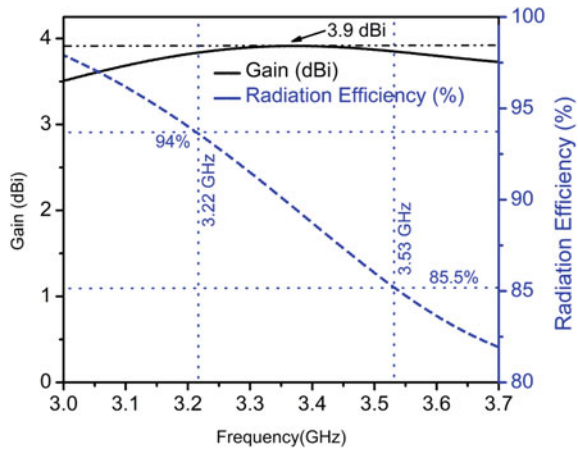


**Fig. 5** Simulated  $S_{11}$ , AR bandwidth and 3-dB ARBW of proposed CP antenna



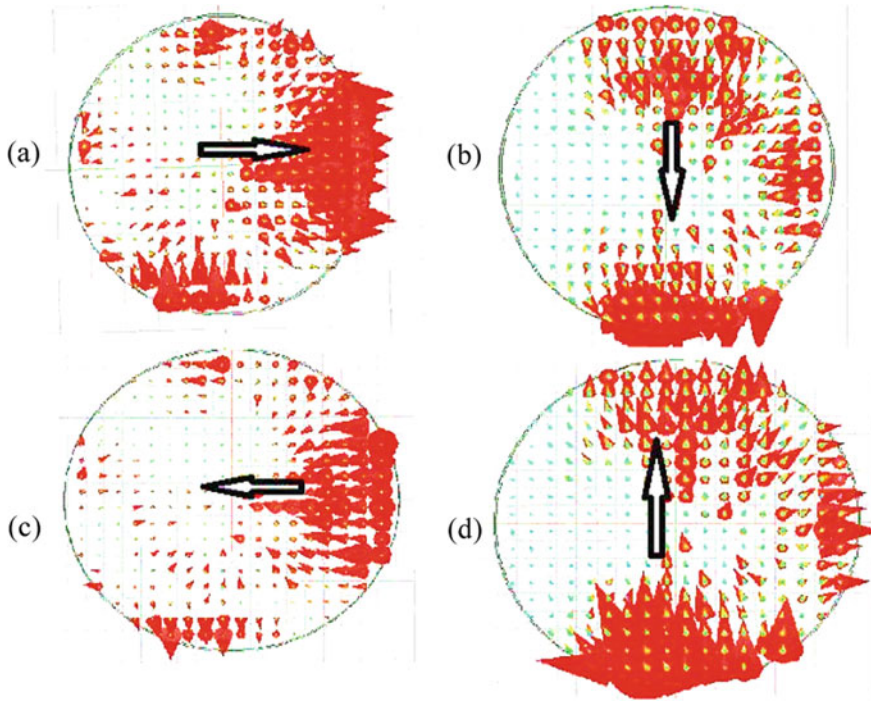
**Fig. 6** Simulated CP radiation patterns of proposed design at 3.39 GHz for the plane of **a**  $\phi = 0^\circ$  and **b**  $\phi = 90^\circ$

**Fig. 7** Effect on gain and radiation efficiency with frequency variation



The recognition of CP nature can be easily understood by observing the electric field distribution with changing phase angle as shown in Fig. 8. Clockwise movement of field distribution is observed which ensures LHCP radiation. The alteration of CP nature (LHCP to RHCP) can be adjusted by considering the mirror image of the extended microstrip feedline.

Table 1 shows the performance analysis of the proposed antenna in comparison with the other similar reported structures.



**Fig. 8** Electric field distribution at the CP frequency of 3.39 GHz for  $\theta =$  a  $0^\circ$  b  $90^\circ$  c  $180^\circ$  d  $270^\circ$

## 4 Conclusion

In this article, the design of a CDRA with CP characteristics of higher XPD performance is presented and analyzed. Due to the mutual coupling effect between the partial ground plane and meandered-shaped microstrip feedline, orthogonal fields with equal magnitude and opposite phase are being generated. The obtained IBW and AR bandwidth are 19.55 and 9.1%, respectively. A gain of 3.9dBi is procured at the operating frequency 3.39 GHz with a substantial amount of ARBW ( $42^\circ$  at  $\phi = 0^\circ$  and  $102^\circ$  at  $\phi = 90^\circ$ ). LHCP is observed at the upper CP band, whereas RHCP can be obtained by the mirror image of the extended microstrip line. Owing to its operating range, the proposed design is expected to be purposive as an economical alternative in WiMAX and 5G applications.



**Table 1** Performance of the proposed antenna with other reported articles

References	DRA structure	Size of antenna	S <sub>11</sub> (GHz)	Axial ratio bandwidth (%)	Gain (dBi)	Radiation efficiency (%)	Cross-polarization discrimination (dB)	
							$\phi = 0^\circ$	$\phi = 90^\circ$
[8]	Cylindrical	$\pi \times 0.25 \lambda \times 0.25 \lambda$	2.33–2.54	8.3	1.3	80 (approx.)	25 (approx.)	20 (approx.)
[11]	Cylindrical	$0.40\lambda \times 0.40\lambda$	2.57–3.78	19.26	1.97	88 (approx.)	20.37	NM
[12]	Rectangular	$0.468 \lambda \times 0.468 \lambda$	2.0–4.0	58.36	2.31	NM	19	30
[18]	Hemisphere	$1.19 \lambda \times 1.19 \lambda$	2.15–2.66	2.36	6.7	NM	33	17
[19]	Rectangular	$0.7 \lambda \times 0.7 \lambda$	3.16–3.66	2.85	3.84	NM	NM	NM
[20]	Cylindrical	$7.8 \lambda \times 7.8 \lambda$	5.61–6.8	3.63	4	NM	18	20
Proposed	Cylindrical	$0.45 \lambda \times 0.45 \lambda$	2.80–3.41	9.1	3.9	94	30	31

NM Not mentioned

## References

1. Kumari R, Gangwar RK (2016) Circularly polarized dielectric resonator antennas: design and developments. *Wireless Pers. Commun* 86:851–886
2. Fakhte S, Oraizi H, Karimian R (2014) A novel low-cost circularly polarized rotated stacked dielectric resonator antenna. *IEEE Antenn Wirel Pr* 13:722–725
3. Sharma S, Tripathi CC (2016) A comprehensive study on a circularly polarized antenna. In: 2016 second international innovative applications of computational intelligence on power, energy and controls with their impact on humanity (CIPECH)
4. Qian ZH, Leung KW, Chen RS (2004) Analysis of circularly polarized dielectric resonator antenna excited by a spiral slot. *Progress in Electromagnetics Research (PIER 47)*, pp 111–121
5. Altaf A, Yang Y, Lee KY, Hwang KC (2015) Circularly polarized Spidron fractal dielectric resonator antenna. *IEEE Antenn Wirel Pr* 14:1806–1809
6. Bao XL, Ammann MJ (2011) Monofilar spiral slot antenna for dual-frequency dual-sense circular polarization. *IEEE Trans Antennas Propag* 59:3061–3065
7. Perron A, Denidni TA, Sebak AR (2010) Circularly polarized microstrip/elliptical dielectric ring resonator antenna for millimeter-wave applications. *IEEE Antenn Wirel Pr* 9:783–786
8. Yang N, Leung KW, Lu K, Wu N (2016) Omnidirectional circularly polarized dielectric resonator antenna with logarithmic spiral slots in the ground. *IEEE Trans Antennas Propag* 65:839–844
9. Yang SLS, Kishk AA, Lee KF (2008) Wideband circularly polarized antenna with L-shaped slot. *IEEE Trans Antennas Propag* 56(6):1780–1783
10. Iqbal J, Illahi U, Sulaiman MI, Alam M, Mazliham MS (2018) A circularly polarized rectangular dielectric resonator antenna excited by E-shaped feed. *Int J Eng Technol* 7:1448–1450
11. Kumar R, Park, CW, Chaudhary RK (2017) A wideband circularly polarized cylindrical DRA loaded with SRR and excited with a question shaped microstrip feed line. In: 32nd general assembly and scientific symposium of the international union of radio science (URSI GASS). *IEEE*, pp 1–4
12. Kumari R, Gangwar RK (2018) Circularly polarized rectangular dielectric resonator antenna fed by a flag shape microstrip line for wideband applications. *Microw Opt Techn Let.* 60:2577–2584
13. Kumar R, Chaudhary RK (2015) A wideband circularly polarized cubic dielectric resonator antenna excited with modified microstrip feed. *IEEE Antenn Wirel Pr* 15:1285–1288
14. Chair R, Yang SLS, Kishk AA, Lee KF, Luk KM (2006) Aperture fed wideband circularly polarized rectangular stair shaped dielectric resonator antenna. *IEEE Trans Antennas Propag* 54:1350–1352
15. Pan Y, Leung KW (2010) Wideband circularly polarized trapezoidal dielectric resonator antenna. *IEEE Antenn Wirel Pr* 9:588–591
16. Zhou YD, Jiao YC, Weng ZB, Ni T (2015) A novel single-fed wide dual-band circularly polarized dielectric resonator antenna. *IEEE Antenn Wirel Pr* 15:930–933
17. Ray M, Mandal K, Nasimuddin (2019) Low profile circularly polarized patch antenna with wide 3-dB Beamwidth. *IEEE Trans Antennas Propag* 18(12):2473–2477
18. Bhagat SK, Karra AK, Babu SS (2019) A compact size dielectric resonator antenna for multiband application: design and analysis. *Int J Recent Technol Eng* 7:390–392
19. Wang C, Chen G, Liu H, Ma Z, Zhang X (2019) Single-feed circularly polarized rectangular dielectric resonator antenna coupled with a dual-mode slot-line square ring resonator. *IEICE Electron Expr* 16:83–88
20. Sulaiman MI, Khamas SK, Basarudin H (2014) A singly-fed wideband circularly polarized cylindrical dielectric resonator antenna using conformal half-loop excitation. In: 2014 4th international conference on engineering technology and technopreneuship (ICE2T), *IEEE*, pp 209–212