

Four Rectangular Shaped DRA Array for Wireless and Satellite Communication

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Abstract

The purpose of this paper is to demonstrate that our proposed design, which consists of a four rectangular shaped dielectric resonator antenna (DRA) array, is capable of being used in a variety of microwave access applications. To reduce return losses and simplify fabrication, the microstrip feed line method is used. We were able to put our concept into action by fabricating it on a sheet of Rogers RT Duroid 5880. The current proposal earns approximately 25%, 40%, and 22.2 percent impedance bandwidth, respectively, from 2.4 to 2.6 GHz, 2.7 to 3.1 GHz, and 5.4 to 5.6 GHz, covering 2.4 GHz, which is a Bluetooth band, 2.9 GHz, which is primarily used for Wi-Fi applications, and 5.2 GHz, which is a WLAN band. DRA's average peak gain is 7.4 dBi at 2.4 GHz and 8.33 dBi at 2.9 GHz, respectively, with directivity ranging from 3.47 dBi to 10.8 dBi over the entire frequency range. At the resonant frequencies the proposed DRA array gives the enhanced gain and better radiation characteristics. The prototype model can also be used for 5.15 GHz to 5.30 GHz which is an operating range of HIPERLAN (high-performance radio LAN) applications. Simulation of the proposed design is performed using CST microwave studio software and a close difference has been noted between the simulation and measured results

Keywords: DRA, Wireless local area network (WLAN), Microstrip feed line, Wi-Fi, WiMAX

1. Introduction

Nowadays, communication requires antennas with high gain and large bandwidth that perform well across a broad frequency spectrum; this necessitates the use of a Dielectric resonator antenna (DRA) array. Comprehensive studies on DRA have centred over the past few decades on resonators of distinct categories, feed-out strategies, and techniques for improving bandwidth. For a variety of applications, DRAs are preferable for applications with millimetre wave specifications [1], [2]. Because of their myriad advantageous characteristics, such as the small profiling, lightweight, low cost and inherent broad bandwidth, DRA's (dielectric resonator antennas) have been used extensively in various applications[3-6].The size of an antenna is a paramount parameter; smaller size antenna is used in low-frequency applications [7]. Ample feeding techniques have been carried out to energies different geometrical shapes (cylindrical, rectangular, spherical, different sided polygon) of DRA in which it is found that rectangular-shaped (DR) is best for excitation, due to its verity in characteristics which gives more flexibility in dimension which is having 2 aspect ratios of width/height and width/depth [8]–[10]. The capacity of circular polarization is showed by a 4×4 subarray dielectric resonator antenna. It is seen that using a 4×4 subarray DRA there has been increase in the bandwidth of circular polarization and the gain of DRA in comparison with the earlier 2×2 subarray DRA. Thus, this shows by increasing the number of elements and size of an element we can [emphasise](#) the efficiency of an antenna [11], [12]. The coupling can be considerably enhanced by using a DRA produced of a high permittivity material, however this carries the risk of bandwidth and cost. [14]. DRA has multiple perks over microstrip antennas. DRAs have scarcity of metal parts, which assists the antenna to operate at superior frequency without any

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conduction losses. That's why by using a dielectric material which is having a very less loss, the radiation productivity could be improved at very high frequencies, as there are no surface waves and conductor losses within the DRA [15]. These types of antennas can be used in various applications such as wall imaging, medical imaging, non-destructive testing, and evaluation through microwave imaging techniques [16]. In this paper, we have presented a 4 x 4 rectangular DR antenna in which the microstrip feed line technique is used to deplete the return losses and for ease of fabrication for mobile and satellite communication. The performance of the presented antenna array was evaluated using the CST microwave studio software. The antenna geometry is explained in Section II. The antenna analysis, experimental results comparison with different size, shape, and material used in antenna, and conclusion are discussed in sections III, IV, and V, respectively.

2. Antenna Geometry

Figure 1 shows a four-element RDRA prototype with a microstrip feedline construction. The suggested array of four elements dual segment rectangular DRA is shown in Fig. 1(a). Table I lists the dimensions of the intended antenna design. The RDRA has been planted over a substrate having dielectric constant ($\epsilon_r=9.6$) with 0.254 mm thickness. Firstly, we have designed an RDRA on Rogers RT Duroid 5880 substrate having dielectric constant 2.20. The material of RDRA is ceramic alumina ($\epsilon_r =9.6$). The RDRA is made of Alumina ceramic materials. The dimension of the finite ground plane used below the substrate is of $GG \times LG$. The substrate length 95mm, width 104 mm, and height 0.254 mm and have a feed line of length 45mm and breadth 4mm.

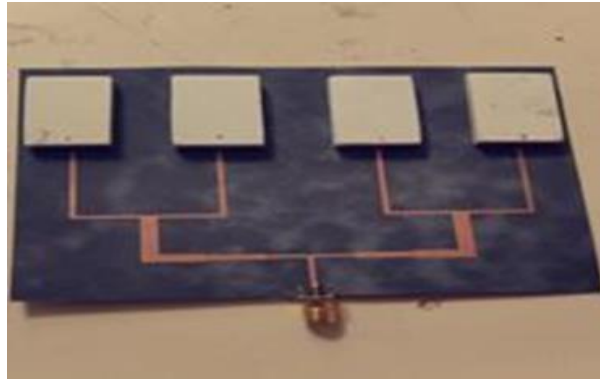


Figure 1. A prototype of four elements RDRA with microstrip feedline

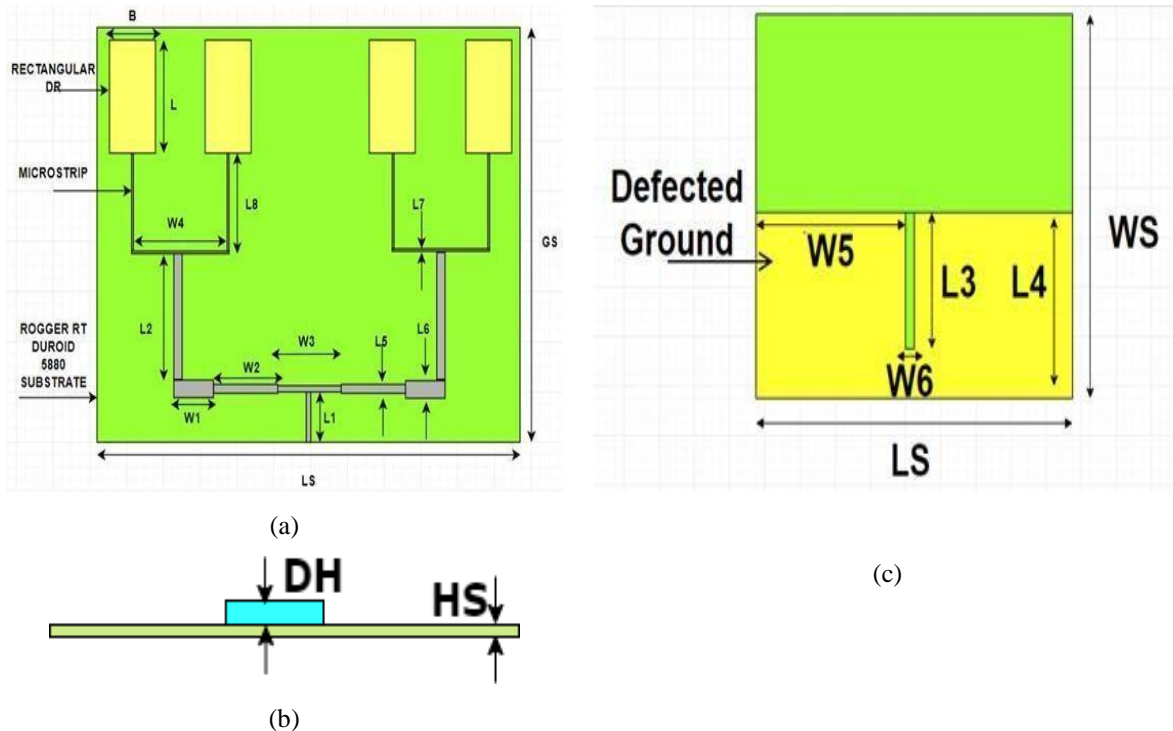


Figure 2. (a) Top View (b) Side View (c) Ground Plane

Table 1. Proposed Antenna Design Parameters

Parameter	Dimension(mm)	Parameter	Dimension(mm)	Parameter	Dimension(mm)
W1	11	L1	15	L8	61
W2	11	L2	18	LS	104
W3	16	L3	45	B	16
W4	28	L4	61	L	30
W5	50	L5	02	DH	4.5
W6	04	L6	03	HS	0.245
GS	95	L7	01		

3. Parametric Study

For our proposed antenna design, analysis is done based on the height of the Alumina Ceramic material. By using the CST microwave studio software analysis is done. From Fig.2 comparison of the results is done at different height of the Alumina Ceramic material. The range of height is from 4mm to 24mm and the spikes show the gain in dB. As we increase the height of the DR material the gain also increases so from that the equation can be made that height of DR material is directly proportional to the gain in dB, from the graph the gain at h=24mm is 40dB whereas other values are just gating gain in between 25-35 dB.

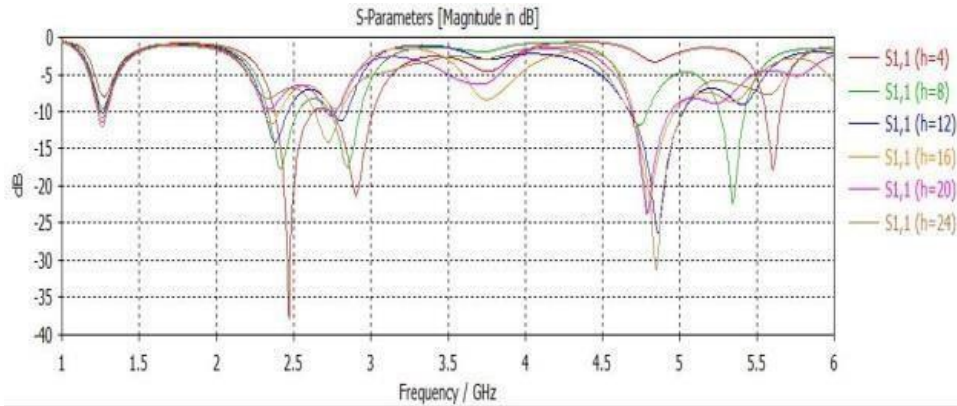
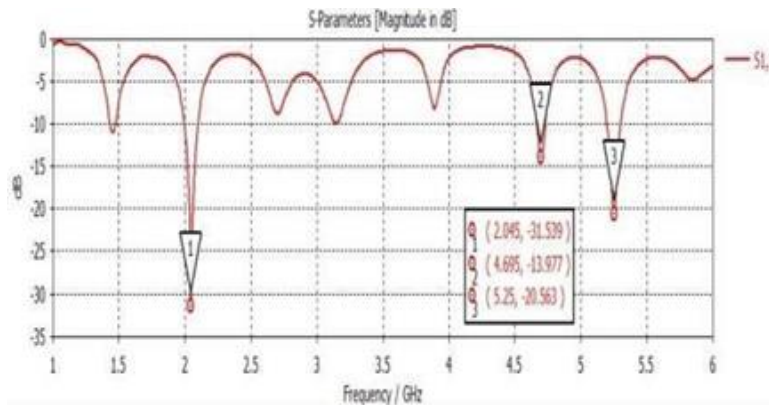


Figure. 3 Parametric analysis of the height of DR material

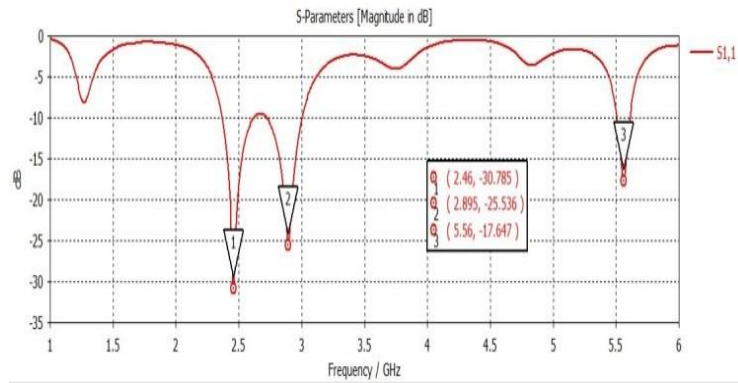
4. Comparison of Substrate material

For FR-4 material as a substrate having height 1.6.mm and the rest of the dimensions are same and the S-Parameter graph of FR-4 substrate is being compared with our proposed design material RT-Duroid 5880. We are not getting the expected result at 2.4 GHz as using the FR-4 material the result is shifted to 2.8 GHz.



(a)

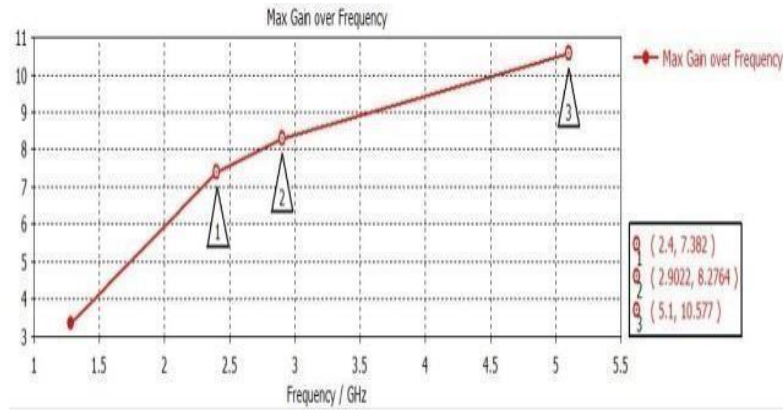
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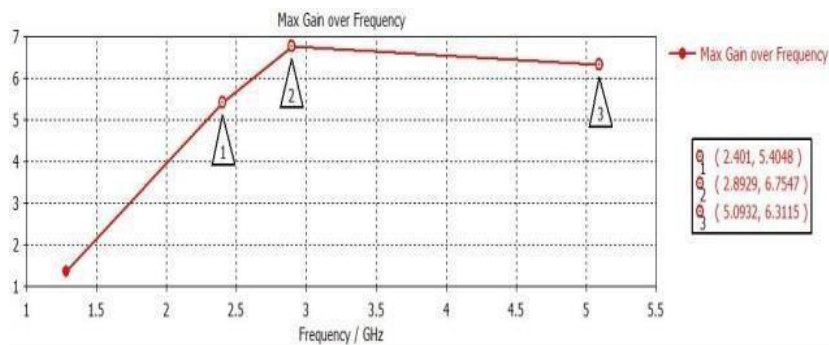
(b)

Fig4 (a) S-Parameter for FR-4 (b) S-Parameter for RT-5880

Here Fig 4.(a) & (b) is showing the comparison of maximum gain over frequencies of RT Duroid 5880 and FR-4 respectively from which it is concluded that the gain is increasing for RT Duroid over an increasing range of frequencies but in the case of FR-4 the gain is decreasing over the increasing range of frequencies and, the gain is considerably low for FR-4 in comparison with RT Duroid 5880.



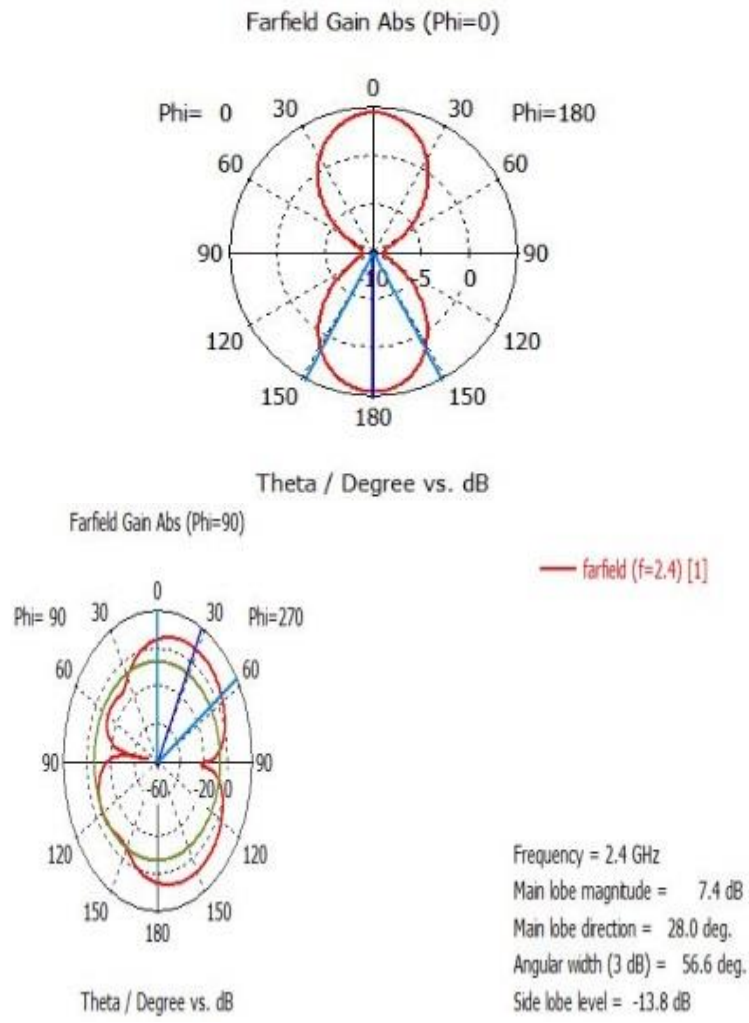
(a)



(b)

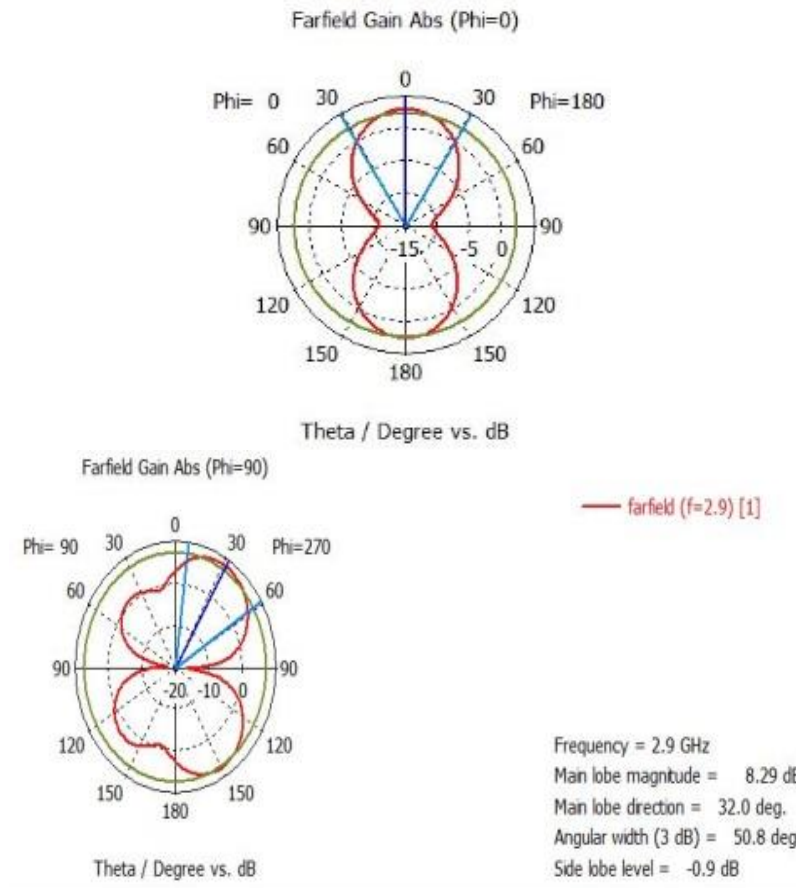
Figure 5. (a) Maximum gain over frequency for RT duroid; (b) Maximum gain over frequency for FR-4

5. Results And Comparison

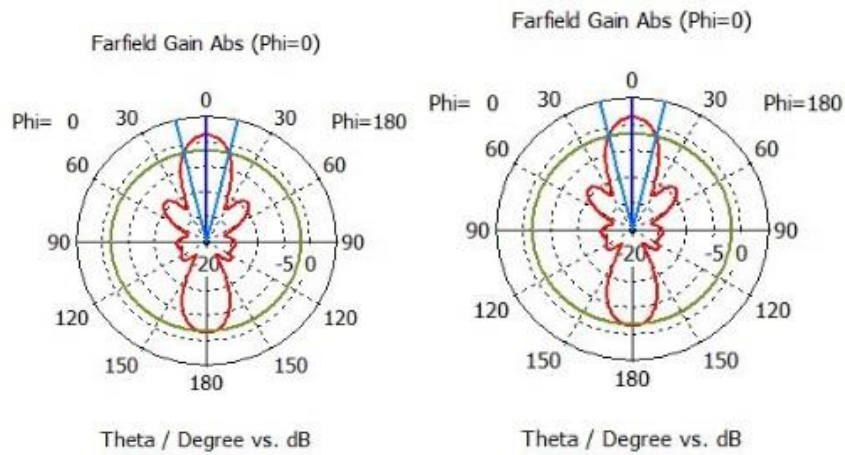


(a)

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(b)



(c)

Figure.6 Simulated RDRA array radiation patterns at b) 2.4GHz, c) 2.9GHz, and d) 5.1GHz

CST microwave studio is used to simulate the proposed design and conducting the parametric analysis. We can deduce from Fig 4 that changing the length of the Dielectric alumina ceramic material has a direct impact on the DRA array's bandwidth. The final simulated return loss (S11) of a 4 x 4 rectangular DRA array with microstrip strip length $L_m = 45\text{mm}$ and RDRs height $DH = 4.5\text{ mm}$ plotted against frequency is shown in Fig. 3(b). The proposed design of rectangular array DRA also gives considerably good radiation patterns over resonating frequency as shown in fig. 6. The simulated radiation patterns at three different resonant frequencies of 2.4 GHz, 2.9 GHz, and 5.1GHz in the E- and H-plane are presented in Fig. 6(a), 6(b), and 6(c) respectively. That shows a good radiation pattern can be used for wireless LAN networks.

6. Conclusion

In this work, we have designed and analyze the working of a four-element RDR antenna. A 4 x 4 array is designed for the sole purpose of enhancing gain and bandwidth. To improve the antenna parameter, the proposed design is fabricated on Rogger's RT Duroid 5880 sheet. The proposed design achieves impedance bandwidth of 25%, 40%, 22.2% for frequency range 2.4 to 2.6 GHz, 2.7 to 3.1GHz, and 5.4 to 5.6 GHz respectively. Furthermore, the result shows that the proposed design is suitable for Bluetooth band, Wi-Fi application, and WLAN band. Practically power reflected by the proposed antenna at 2.4 GHz is -24.43dB and it is close enough to the simulated value of power reflected at 2.4 GHz is -29.675 dB. The construction and simulation of the antenna design are conducted on CST 18 software.

Acknowledgment

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References

- [1] M. Akbari, S. Gupta, M. Farahani, A. R. Sebak, and T. A. Denidni, "Analytic study on CP enhancement of millimeter-wave DR and patch subarray antennas," *Int. J. RF Microw. Comput. Eng.*, vol. 27, no. 1, 2017
- [2] S. Ballav and S. K. Parui, "Aperture coupled dielectric resonator antenna embedded in a secondary substrate for mechanical firmness," *Radioengineering*, vol. 27, no. 3, pp. 679–685, 2018.
- [3] Petosa, A., *Dielectric Resonator Antenna Handbook*, Artech House, Norwood, MA, 2007. Luk, K. M. and K. W. Leung (eds.), *Dielectric Resonator Antennas*, Research Studies Press, London, UK, 2003.
- [4] Petosa, A. and A. Ittipiboon, "Dielectric resonator antennas: A historical review and the current state of the art," *IEEE Antennas and Propag. Mag.*, Vol. 52, 2010.
- [5] Costanzo, S., I. Venneri, G. Di Massa, and G. Amendola, "Hybrid array antenna for broadband millimeter-wave applications," *Progress In Electromagnetics Research*, 173–183, 2008.
- [6] M. Ranjbar Nikkhah, A. A. Kishk, and J. Rashed- Mohassel, "Wideband DRA Array Placed on An array of Slot Windows," *IEEE Trans. Antennas Propag.*, vol. 63, no. 12, pp. 5382–5390, 2015.
- [7] F. Z. Abushakra, A. S. Al-Zoubi, and D. F. Hawatmeh, "Design and measurements of rectangular dielectric resonator antenna linear arrays," *Appl. Comput. Electromagn. Soc. J.*, vol. 33, no. 4, pp. 380–387, 2018
- [8] G. Das, A. Sharma, and R. K. Gangwar, "Two elements dual segment cylindrical dielectric resonator antenna array with annular-shaped microstrip feed," 2016 22nd Natl. Conf. Commun. NCC 2016, pp.1–6, 2016.
- [9] M. F. Ain, U. Ullah, and Z. A. Ahmad, "On design and analysis of broadband 2-segment dielectric resonator array antenna for 5 – 6 GHz applications," pp. 1–10, 2012
- [10] M. Akbari, S. Gupta, R. Movahedinia, S. Zarbakhsh, and A. R. Sebak, "Bandwidth enhancement of 4x4 subarrays circularly polarized rectangular dielectric resonator antenna by sequential feeding network," 2016 10th Eur. Conf. Antennas Propagation, EuCAP 2016, pp. 13–16, 2016
- [11] Gupta and R. K. Gangwar, "Theoretical and Experimental Investigations on Rectangular Dielectric Resonator Antenna Array for Radar and Satellite Application," *Electromagnetics*, vol. 37, no. 1, pp. 27–39, 2017.

- [12] Khan, R. Kumari, and S. K. Behera, "A Notched chamfered rectangular dielectric resonator antenna array for wireless applications," Proc. - 2013 IEEE Int. Multi Conf. Autom. Comput. Control. Commun. Compress. Sensing, iMac4s 2013, pp. 326–329, 2013.
- [13] Gupta and R. K. Gangwar, "Compact two-element cylindrical dielectric resonator antenna array for quad-band applications," 2018 3rd Int. Conf. Microw. Photonics, ICMAP 2018, vol. 2018-Janua, no. 7, pp. 1–2, 2018.
- [14] Q. Lai, G. Almpanis, C. Fumeaux, H. Benedickter, and R. Vahldieck, Comparison of the radiation efficiency for the dielectric reso nano antenna and the microstrip antenna at Ka-band, " IEEE Trans. Antennas Propag., vol. 56, no. 11, pp. 3589– 3592, Nov.2008.
- [15] Rana and S. K. Parui, "Microstrip Line Fed Wideband Circularly-Polarized Dielectric Resonator Antenna Array for Microwave Image Sensing," IEEE Sensors Lett., vol. 1, no. 3, pp. 1–4, 2017