

# Investigation of the DGS-CDRA Design with the Aperture Coupling Technique for Wide Band Application

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**Abstract** In this paper, a design of wideband antenna by tuning the aperture slot parameters and using two dielectric pellets is investigated and discussed. The performance of the resonant frequencies, impedance bandwidth and radiation pattern of the DGS-CDRA (Defected Ground Structure Cylindrical Dielectric Resonator Antenna) are analyzed. The design achieved a wideband impedance bandwidth of 4.0 GHz (50.74 %) by using two slots aperture and thick substrate. Two dielectric pellets with the same type and size are coupled to a microstrip line through two rectangular slots. The slots positions are tuned along (below) microstrip line to a position where impedance bandwidth from both dielectric pellets are merged and form a wide impedance bandwidth. Subsequently, performance of the antenna is being analyzed based on the simulation results of return loss and radiation pattern. The design is fabricated and the measurement results of impedance bandwidth are compared with the simulation results.

**Keywords** Wide band · DGS-CDRA

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## 1 Introduction

The design of DRA provides a large degree of freedom and makes them complicated since a lot of variable interplay with each other [1]. It is possible to design the DRA to operate at any rational input impedance and also eliminating the need of matching circuit by having a good understanding on its physic studies. Many complex design of DRA can be exploited [2–5]. The techniques for tuning the impedance bandwidth of the DRA can be categorized into three approaches: multiples resonance, aperture coupled and hybrid resonator. In this paper, aperture coupled technique is implemented and discussed. The approach of aperture coupled technique reported that method exhibits with the impedance bandwidth of 10–24 % [5–7]. In this technique, the active devices are integrated on dielectric substrate on the same side of the feed network and enabling the use of DR antenna with monolithic microwave integrated circuits (MMIC's). Furthermore, the aperture-coupled technique together with hemispherical shape of DRA and a parasitic patch providing wide range of frequency tuning characteristics and bandwidth enhancement features [8].

The wide band applications are also achievable with the array configuration [9, 10]. It is reported that the design of seven elements rectangular DRA array is coupled to narrow slot apertures that are fed by dielectric image guide [11]. In the DRA arrays design, the separation between elements is critically being analyzed and it is critically depends on the wavelength of a dielectric image guided (DIG). It is required all the elements to be excited in phase. With a good selection of element spacing, the grating lobes are minimized and the antenna is produces high magnitude into main lobes direction.

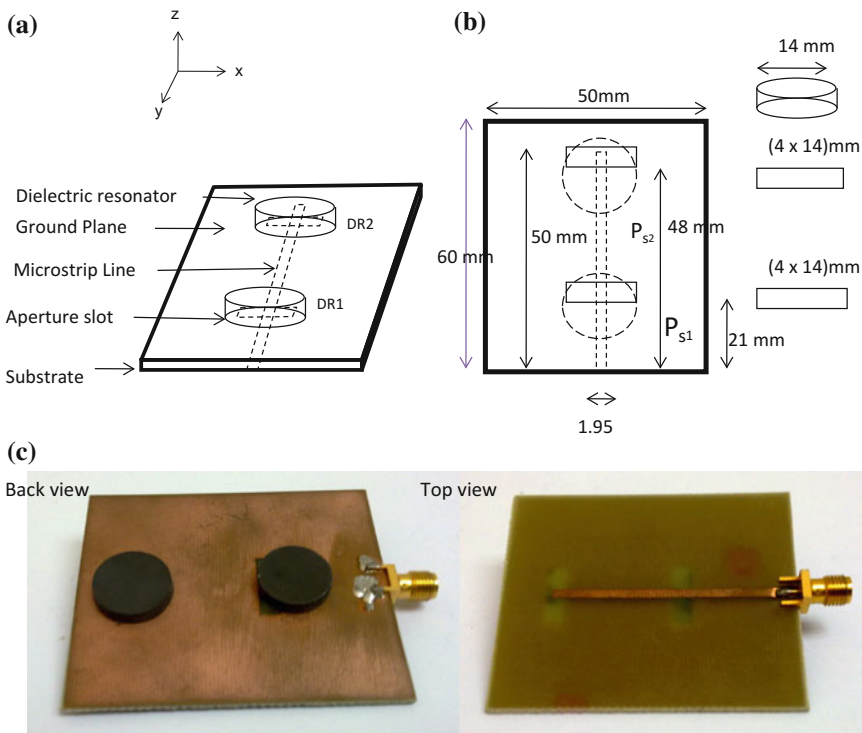
Another technique for tuning the impedance bandwidth of the DRA is multiple-resonance technique [12–15]. This approach introduces various shapes of DR antennas. The technique employed two or more resonant element in a same device, with slightly different resonant frequencies and proximity coupled to each other. Impedance bandwidth is controlled by the coupling mechanism from the resonant element. The stacked DRA consists of a dielectric resonator of high permittivity is attached together with a thin dielectric segment of relatively low permittivity. Both of the resonators are positioned on ground plane. A coaxial probe is used to feed the resonators through different shaped of stacked DR. This approach of designing the antenna able to contributes the impedance bandwidth between 40–109.5 % [16–18].

## 2 Wide Band of DRA Design

The view of the optimum configuration of aperture coupled DGS-CDRA for wide band application is shown in the design layout of Fig. 1. The FR4 material with dielectric constant of 4.42 and thickness of 1.42 mm is used for the substrate of the ground plane. The FR4 material is chosen as it is easy to fabricate. The design used

identical dielectric resonator (DR) with radius of 7.0 mm, height of 2.0 mm and dielectric constant of  $\epsilon_{r1} = 55$ . The design structure combines the resonance elements of both aperture coupled DGS-CDRA ( $P_{s1} = 21$  mm and  $P_{s2} = 48$ ) on the same ground plane. The aperture slot for DR1 and DR2 are placed at position 21.0 mm ( $P_{s1}$ ) and 48.0 mm ( $P_{s2}$ ) respectively. The aperture slot size for both dielectric resonators is selected to be  $4 \times 14$  mm<sup>2</sup> and it is etched on the ground plane. From literature it is found that the implementation of large size of aperture produces multi modes of resonant from the dielectric pellet [19, 20]. Figure 1a and b shows the top view of the design layout and detail dimensions of the design.

The selection of size and the position of the two aperture slots are tuned to provide the resonant frequencies that are neighboring to each others. Initially, the first slot and the second slot DR is tuned separately. The DR1 slot is tuned at lower band of frequencies; meanwhile the second slot is tuned to higher band resonant frequencies. The resonant generates by DR2 is tuned at slightly above the resonant frequency. The resonant of both DR1 and DR2 are tuned from position of 20.0 mm from input port with increment of 1 mm for each step. Subsequently the slot



**Fig. 1** Antenna configuration **a** perspective view, **b** geometry of tuning slot, **c** fabricated wide band DGS-CDRA

position combines these two resonant frequencies thus producing wider impedance bandwidth. The actual fabricated wide band DGS-CDRA is shown in Fig. 1c.

### 3 Results and Discussion

The result of combining the resonant frequencies from DR1 and DR2 is shown in Fig. 2. It is depicted that the simulated return loss level of  $-10$  dB is achieved from 5.6 to 8.2 GHz. Meanwhile, the measurement result produces impedance bandwidth from 4.48 to 8.48 GHz. The simulation and measurement results obtained an impedance bandwidth of 2.6 GHz (37.6 %) and 4.0 GHz (50.74 %) respectively. The simulation and measured results shown that wider impedance bandwidth is achieved from combination of several resonant frequencies that are neighboring to each others. The simulated impedance bandwidth of the antenna is determined at  $-10$  dB level as depicted in Fig. 2. It is shown that the resonant frequencies of below  $-10$  dB level is a combination of 5.8, 6.4, 6.9 and 7.9 GHz resonant. The measured results show deviation of 13.14 % as compared to the simulations. Dissimilarity between measured and simulated results is due to the fabrication process during the circuit preparation.

In this design, the multiples resonant frequency with wide resonant respond is merged together and produces wide band of impedance bandwidth respond. It is also observed that the magnitude of return loss for each resonant frequency within the impedance bandwidth is lower as compared to simulation plot. As a result the measurement result produces wider bandwidth with low amplitude of return loss level. The measurement result also shows that the Q-factor of the resonant is decreased. The additional of two aperture slots beneath the transmission line had decreased the effective Q-factor of the dielectric pellets, thus increasing the

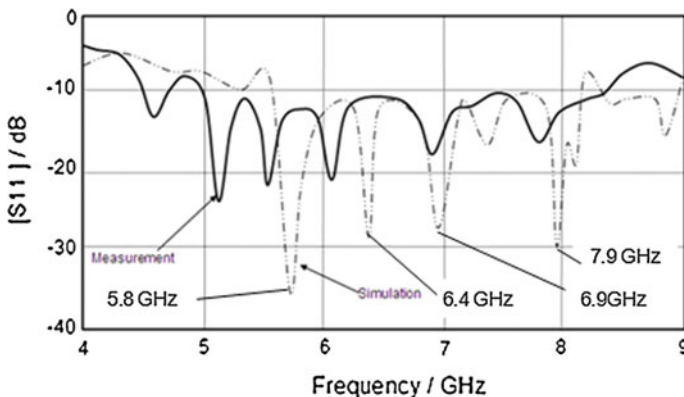
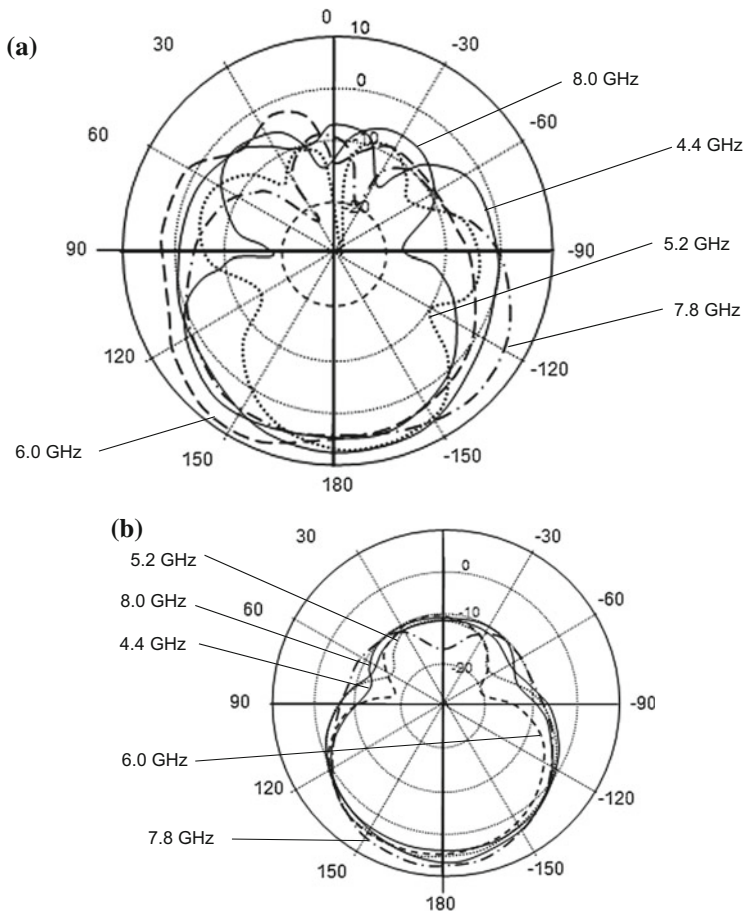


Fig. 2 Simulation and measured results of return loss

impedance bandwidth of the overall response. The result shows that the impedance bandwidth is inverse proportional to Q-factor as  $BW = 1/Q$  [21].

The simulated radiation patterns in  $xz$ - and  $yz$ -planes for the wide band DGS-CDRA are presented in 2D polar plot in Fig. 3a, b. The radiation pattern for resonance frequencies of 4.4, 5.2, 6.0, 7.8 and 8.0 GHz are observed and analyzed accordingly. The selected frequencies are used to analyze the performance of radiation gain across the operating frequency band of the antenna (4.4–8.0 GHz). It is depicted that the aperture coupled CDRA produces a broad beam width radiation with a symmetrical shape along the  $xz$ -plane and  $yz$ -plane. The back lobe of the antenna shows slightly asymmetry due the back radiation from dielectric resonators through the aperture slots. The radiation pattern in  $yz$ -plane shown in Fig. 3b depicted that the antenna produces a symmetrical radiation and the shape is consistent for all resonance frequencies.



**Fig. 3** Simulated radiation patterns at 4.4, 5.2, 6.0, 7.8 and 8.0 GHz. **a**  $xz$ -plane **b**  $yz$ -plane

**Table 1** Simulated radiation pattern characteristics across bandwidth of the DGS-CDRA

| Frequency (GHz)           | 4.4   | 5.2   | 6.0   | 7.8   | 8.0   |
|---------------------------|-------|-------|-------|-------|-------|
| Main lobe magnitude (dBi) | 4.8   | 6.6   | 6.7   | 7.9   | 7.4   |
| Main lobe direction (°)   | 180.0 | 150.0 | 145.0 | 170.0 | 180.0 |
| Angular width (−3 dB) (°) | 89.9  | 112.2 | 103.0 | 57.4  | 71.5  |
| Back lobes level (dBi)    | −15.3 | −16.5 | −10.7 | −8.0  | −13.1 |

Table 1 summarized the simulated radiation characteristic across the resonant bandwidth. The antenna generates a wide angular beam width angle within  $89.9^{\circ}$ – $112.2^{\circ}$  for the resonant frequencies range of 4.4–6.0 GHz. It is found that the magnitude of forward radiation is decreased with the increment of angular beam width. For wider angular beam width, the result shows that the energy is emitted into wide angle of radiation and consequently increased the angle of signal coverage. As the frequency increases from 7.8 to 8.0 GHz, the angular beam width is decreases between  $57.4^{\circ}$  and  $71.5^{\circ}$  and the magnitude of main is increased between 7.4 and 7.9 dBi. It is shown that within these frequency ranges, the antenna had increased the magnitude of the main lobe and the emitted energy is focused to small angle of radiation. From the result, it is depicted that antenna produces a good features for broadcasting purpose within frequency range of 4–6 GHz. Furthermore, with higher magnitude of main lobe on forward radiation, the antenna able to provide greater distance of radiation signal with reduced angle of coverage within frequency range of 7.8–8.0 GHz.

At 4.4 GHz, the antenna produces a broad radiation pattern with main lobe magnitude of 4.8 and  $-3$  dB angular bandwidth of  $89.9^{\circ}$ . It is illustrated that the antenna generates wider main lobe with low magnitude. Meanwhile, at frequency of 8 GHz the antenna produces gain magnitude of 7.4 dBi for the main lobe with  $-3$  dB angular width of  $71.5^{\circ}$ . It is observed that the magnitude of main lobe is increased with decreasing of  $-3$  dB angular width. As a result, the antenna produces smaller size of main lobe as at 8 GHz with magnitude of gain is higher than 4.4 GHz. It is also shown the back lobes magnitude increased since dual slot and DRA are used in the design. Addition slots allow the main signal radiates on the back side. Consequently it radiates the magnitude of the main lobe and reduces the efficiency of the antenna. The results show that the impedance bandwidth is increased by using two aperture slot technique. Somehow, the addition of aperture slot contributes to high back lobes. As a result the main beam magnitude is reduced.

## 4 Conclusion

In this paper, the DGS-CDRA design with the aperture coupling technique for wideband application is designed, simulated, fabricated and analyzed. Two slots are fabricated to provide the aperture coupled effect for the CDRA are investigated. The investigation shows that by adding the slots create a multiple resonance thus

enhances the impedance bandwidth. The slot application provides directional radiation patterns throughout the targeted frequency range. In addition the slot's structure is capable to merge the multimode resonance with two dielectric pellets for the impedance bandwidth optimization. Thus proves that the proposed design exhibits an improvement of 50.74 % bandwidth.

## References

1. Long A, McAllister MW, Shen LC (1983) The resonant cylindrical dielectric cavity antenna. *IEEE Trans Antennas Propag* 31:406–412
2. Kishk A (2002) Tetrahedron and triangular dielectric resonator antenna with wideband performance. In: *Antennas and propagation society international symposium, IEEE*, pp 462–465
3. Kishk A, Yin Y, Glisson AW (2002) Conical dielectric resonator antennas for wide-band applications. *IEEE Trans Antennas Propag* 50:469–474
4. Kishk A, Ahn B, Kajfez D (1989) Broadband stacked dielectric resonator antennas. *Electron Lett* 25:1232–1233
5. Al-Zoubi AS, Kishk A, Glisson AW (2009) Aperture coupled rectangular dielectric resonator antenna array fed by dielectric image guide. *IEEE Trans Antennas Propag* 57:2252–2259
6. Denidni T, Liang X-L (2009) E-shaped slot-coupled dielectric resonator antenna for millimeter-wave applications. In: *EuCAP 3rd European conference on antennas and propagation*, pp 2581–2583
7. Omar A, Al-Hasan M (2009) Dual-band coplanar-waveguide-fed slot-coupled rectangular dielectric resonator antenna. In: *International conference of future computer and communication, ICFCC*, pp 62–64
8. Yau D, Shuley N (1999) Numerical analysis of an aperture coupled rectangular dielectric resonator antenna using a surface formulation and the method of moments. In: *IEEE Proceedings, microwaves of antennas and propagation*, pp 105–110
9. Baba AA, Zakariya MAB, Baharudin Z, Khir MHM, Ahmad ZA, Qasaymeh YMA (2013) Aperture and mutual coupled cylindrical dielectric resonator antenna array. *Progr Electromag Res C* 37:223–233
10. Ain MF, Qasaymeh YMA, Ahmad ZA, Zakariya MA, Othman MA, Olokede SS et al (2012) Novel modeling and design of circularly polarized dielectric resonator antenna array. *Progr Electromag Res C* 28:165–179
11. Al-Zoubi AS, Kishk A, Glisson AW (2010) A linear rectangular dielectric resonator antenna array fed by dielectric image guide with low cross polarization. *IEEE Trans Antennas Propag* 58:697–705
12. Sreekantan S, Ling YK, Ahmad ZA, Ain MF, Othman MA, Hassan SIS (2009) Simulation and experimental investigations on rectangular, circular and cylindrical dielectric resonator antenna. *Progr Electromag Res C* 7:151–166
13. Leung K, Lo H, Luk K, Yung E (1998) Two-dimensional cylindrical dielectric resonator antenna array. *Electron Lett* 34:1283–1285
14. Kumari R, Parmar K, Behera S (2011) A dual band triangular shaped DRA array for WLAN/WiMAX applications. In: *India conference (INDICON), 2011 annual IEEE*, pp 1–4
15. Dashti H, Neshati M, Mohanna F (2010) RDRA array fed by dielectric image line with improved gain and low back radiation. In: *1st international conference on communication engineering, journal of mathematics*

16. Kumari R, Parmar K, Behera S (2010) Conformal patch fed stacked triangular dielectric resonator antenna for wlan applications. In: International conference of emerging trends in robotics and communication technologies (INTERACT), pp 104–107
17. Ge Y, Esselle KP (2009) A UWB probe-fed dielectric resonator antenna
18. Ge Y, Esselle KP, Bird TS (2007) Wideband stacked dielectric resonator antennas
19. Luk KM, Leung KW (2003) Dielectric resonator antennas. Research Studies Press
20. Mongia RK, Bhartia P (1994) Dielectric resonator antennas. A review and general design relations for resonant frequency and bandwidth. *Int J Microwave Millimeter Wave Comput Aided Eng* 4:230–247
21. Petosa A, Ittipiboon A, Antar Y (2003) Broadband dielectric resonator antennas. *Dielectric Reson Antennas* 177