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Ring Dielectric Resonator Antenna for Broadband Application

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***Abstract*— A ring dielectric resonator antenna (DRA) design with an air gap between the dielectric resonator and ground is presented for broadband applications. In this proposed antenna, microstrip line feeding is used for easy fabrication. This DRA is simulated using a CST microwave studio suite™ 2010. The simulated results show the wider impedance bandwidth of around 86% covering the frequency range of 3.20–7.39 GHz with much better broadside radiation characteristics. Parametric studies of the antennas with CST microwave based design data and simulated results are presented here.**

***Keywords*- Dielectric Resonator Antenna (DRA), CST Microwave Studio suite™ 2010, Ring DRA, Broadband, Microstrip Line feed.**

I. INTRODUCTION

Dielectric Resonator Antennas (DRA) possess some peculiar properties which render them very promising, especially for millimeter wave applications. DRAs can be designed with different shapes to accommodate various design requirements. DRAs can also be excited with different feeding methods, such as probes, microstrip lines, slots, and co-planar lines [1]. As compared to the Microstrip antenna, the DRA has a much wider impedance bandwidth due to their many advantageous features. These include their compact size, light weight, the versatility in their shape and feeding mechanism, simple structure, easy fabrication and wide impedance bandwidth [1]. DRA requires adhesive to mount the DR over the ground plane and more manual effort in the alignment of the DRA with the feeding structure.

Among the different shapes DRA, the cylindrical DRA offers greater design flexibility, where the ratio of radius to height (r/d) controls the resonant frequency and the Q-factor. Fabrication is also simpler than the other shaped DRA. Various modes can be easily excited within the cylindrical DRA, which results in either broadside or Omni-directional radiation pattern. Analytical studies carried out on cylindrical dielectric resonators have demonstrated that the Q-factor could be reduced by removing a central portion of the dielectric material to form a ring. By applying perturbation theory, the removal of dielectric material would result in lowering of the Q-factor and an increase in the resonant frequency [1]. Thus, the ring DRA is a subclass of the cylindrical DRA that offers increased impedance bandwidth performance.

Bandwidth enhancement is becoming the major design considerations for most practical applications of Dielectric resonator antennas. Several bandwidth enhancement techniques have been reported on modified feed geometries and changing the shape of the DRA (including conical, tetrahedron, ring, triangular). Some advanced methods to achieve wide bandwidth are optimizing the feeding mechanism and the DRA parameters, use of parasitic coupling with different resonators & introduction of air gap between the ground plane and DR.

In this paper, enhancement of bandwidth of the proposed DRA has been designed by removing the central portion of a cylindrical DRA. As a result of which a ring DRA is obtained. The ring dielectric resonator of the DRA is mounted on a vertical ground plane edge for broadband application. Generally using the ground plane edge resulted in a conceptual 75% volume reduction as compared to a perpendicular ground plane and in a lighter antenna weight [11]. It is discussed that the introduction of air gaps between the dielectric resonator and the ground plane can improve the impedance bandwidth of the antenna significantly [1]. The DRA is excited by using microstrip line feeding. With these features, this design of ring DRA is suitable for broadband wireless communication systems.

II. ANTENNA DESIGN

A cylindrical DRA and a ring DRA for enhancing the bandwidth of the original DRA is schematically shown in Fig. 1. The proposed cylindrical DRA is of height (h_1) =7.56 mm, radius (R_d) = 8.5 mm and relative permittivity (ε_{r1}) =4.82. The ring DRA consists of the cylindrical DRA where a cylindrical section of radius (r_d) =2 mm has been removed. It is expected that by removing the centre portion of the cylindrical DRA, its bandwidth can be increased. The DRA is supported by Rogers RT 6002 substrate having dimension 30 × 30 mm^2 (L_s × W) with height (h_2) = 0.762 mm and dielectric constant (ε_{r2}) =2.94. On one side of the substrate, half portion of DR with microstrip line feeding is there and the other side shown in Fig. 1(d) having the partially printed ground plane and DR with an air gap (g)= 0.5 mm. The introduction of air gap between the DRA and ground is a simple method to enhance the bandwidth. There is generally an increase in the resonant frequency and a decrease in the Q- factor when an air gap is introduced. The dimension of the ground plane is 12 × 30 mm^2 (W × L_g). As Microstrip line feeding offers the advantage of easy and cost-effective fabrication of DRA, so the proposed DRA is excited by microstrip line feeding shown in Fig. 1(c), which has dimensions L_{f1} = 18 mm, W_1 = 1 mm, L_{f2} = 4 mm and W_2 = 2.3 mm.

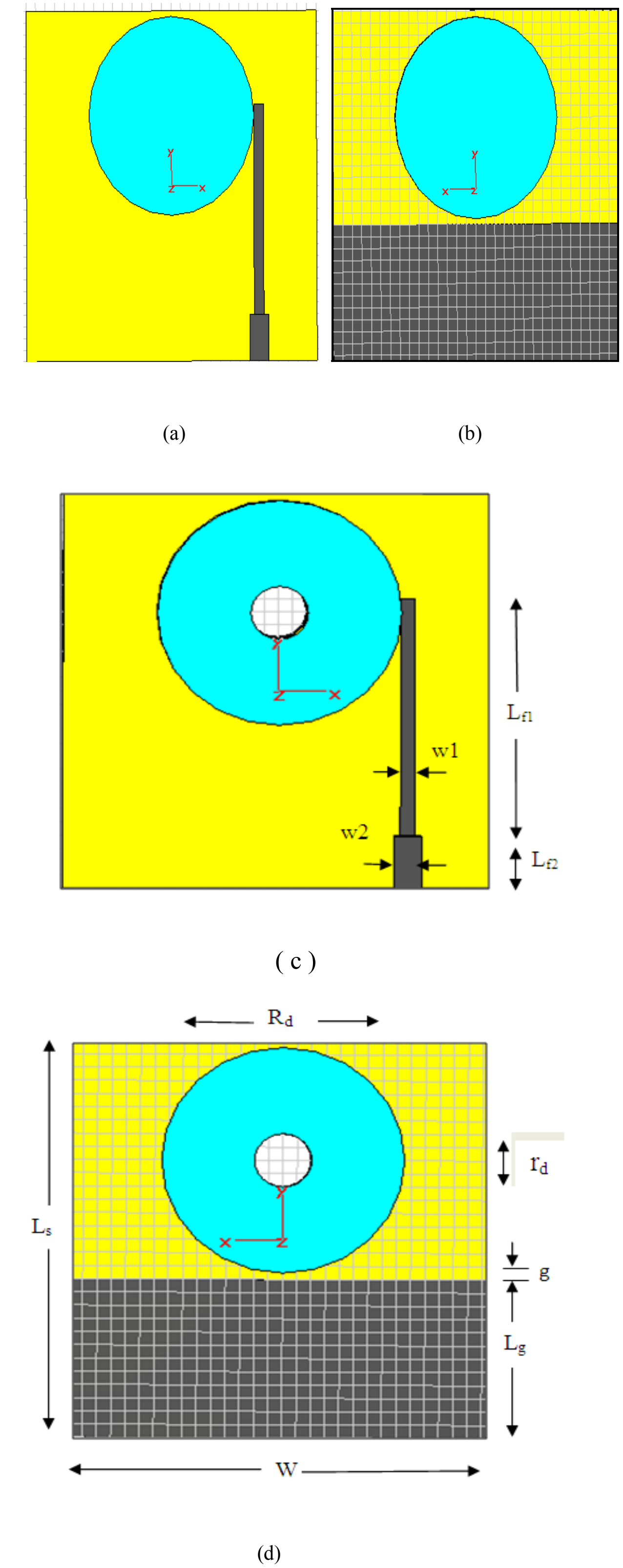


Fig. 1 The proposed DRA (a) Front-view of Cylinderical DRA (b) Rear-view of Cylinderical DRA (c) Front-view of Ring DRA (d) Rear-view of Ring DRA

III. PARAMETRIC STUDY

As discussed in the previous section that a wide bandwidth can be achieved by modifying the basic shape of the DRA and also by introducing an air gap between the DR and ground. So the first design step was to modify the shape of a cylindrical DRA.

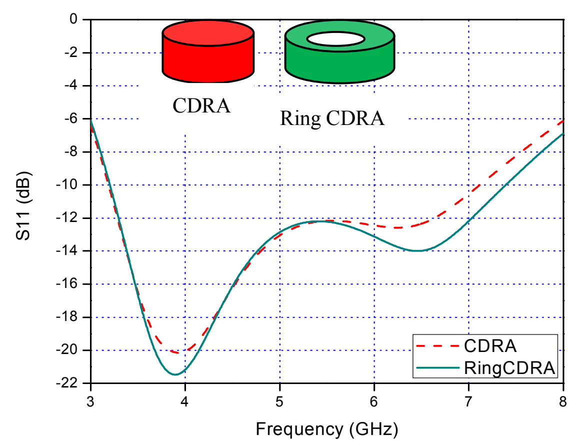


Fig 2. Comparison of return loss plot of a typical cylindrical DRA (CDRA) with a ring DRA (Ring CDRA).

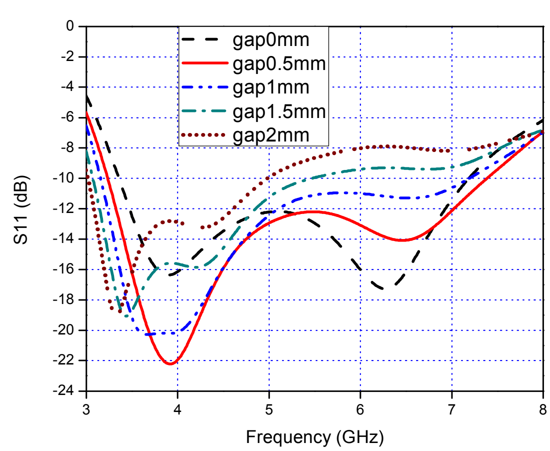


Fig. 3 Simulated return loss with different values of air gap

The radius of the basic cylindrical shaped DRA is taken as 8.5 mm. By drilling out from the centre a cylindrical region of radius r_d (which is nearly equal to 1/4 of the radius R_d of the original cylinder) resulting in a wide impedance bandwidth as shown in Fig. 2. Similarly in the next design step, to further improve the bandwidth an air gap was introduced in between DRA and ground. So to achieve optimum antenna performance, a parametric study is carried out by varying the air gap. Fig. 3 shows the simulated return loss with different values of air gap g. For the case g = 0.5 mm, a wide bandwidth with less return loss is observed.

IV. RESULTS & DISCUSSION

The proposed DRA is analyzed using CST Microwave studio suite™ 2010. The simulated return loss of the ring DRA plotted against frequency is shown in Fig. 2. An improvement of approximately 4 % in impedance bandwidth can be seen from the return loss plot. As a result, the wide band achieves impedance bandwidth of 86% (for $S_{11} < -10$ dB) ranging from 3.2 GHz to 7.39 GHz.

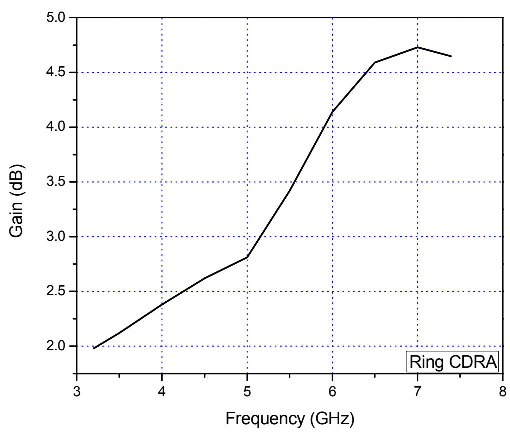


Fig. 4 Simulated Gain of the Ring DRA versus Frequency

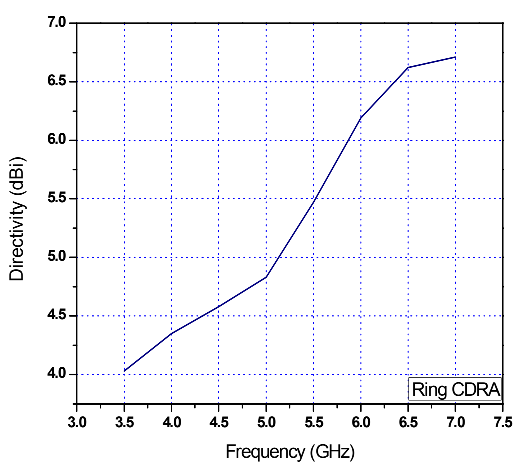
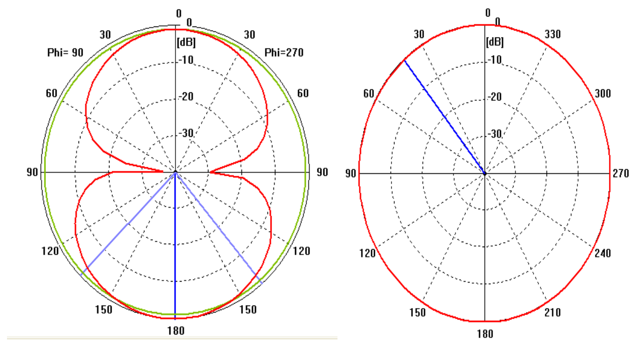
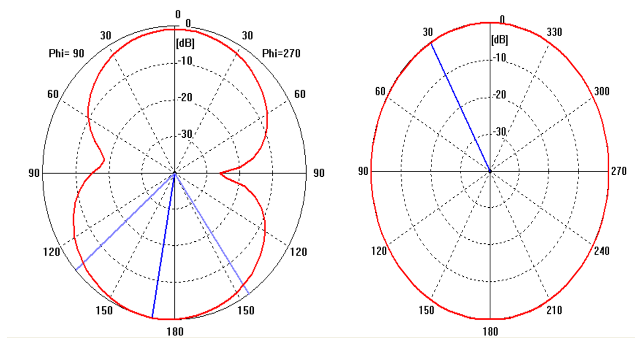


Fig. 5 Simulated Directivity versus Frequency



(a)



(b)

Fig. 6 Simulated E plane (left) and H plane (right) radiation patterns of Ring DRA at (a) 3.9 GHz and (b) 6.5 GHz

Fig. 4 presents the gain versus frequency for the proposed DRA. The simulated peak directivity varies from 4.26 dBi to 6.71 dBi within the overall band. The directivity versus frequency is shown in Fig 5. The far field radiation patterns of the proposed DRA are also simulated. Fig. 6 plots the simulated radiation patterns at two different frequencies (3.9 GHz and 6.5 GHz). It is observed that the E plane radiation patterns are similar to a half wave length dipole antenna over the entire frequency range. In H plane, omni-directional radiation patterns are found.

V. CONCLUSION

A new ring dielectric resonator antenna is realized by drilling off the central portion of the cylindrical DRA. The ring DRA is mounted on a vertical ground plane edge for wireless applications. In this design, the impedance bandwidth of 86% ($S_{11} < -10$dB) is obtained as the band covers the range of frequency from 3.2 GHz to 7.39 GHz. This antenna can be use for WLAN as well as RFID applications. The proposed ring DRA design is overall suitable for broadband wireless communication system. Fabrication of the proposed antenna will be carried out in future.

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