URSI-RCRS 2024, ARIES/GEHU, Bhimtal, India, 22 - 25 October, 2024

Bi-Directional Back-to-back Dielectric Resonator Two-Port Antenna System with Dual Radiation

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Abstract

This article first demonstrates the dual radiation of bidirectional monopole radiation as well as bidirectional broadside radiation from a back-to-back rectangular dielectric resonator antenna (RDRA) structure. The pair of RDRA has been deployed on a double-layer ground substrate. To achieve the desired radiations quasi-$TM_{10\delta}$ mode and $TE_{11\delta}$ mode have been produced. These modes have been excited by two individual feedlines consisting of stripline and probe feed. Quasi-$TM_{10\delta}$ mode is realized through a probe feed line with center drilling in both RDRA. On the other hand, to achieve $TE_{11\delta}$ mode, both RDRA are excited by rectangular aperture feed. The antenna system demonstrates a common impedance bandwidth from 3.18 GHz to 4.1 GHz with inter-port isolation better than 16 dB. Each feedline achieves a maximum gain of approximately 5 dB. Consequently, this configuration operates effectively within the 3.5 GHz application band.

1. Introduction

Dielectric resonator antennas (DRAs) have become increasingly important in modern communication systems due to their attractive features [1]. Since their introduction in 1983 [2], DRAs have garnered significant interest due to diverse feeding strategies that can be employed. These feeding techniques excite different modes and polarizations within the DRA cavity [3]-[7]. Following Mongia's initial successful demonstration [8], a single-probe feeding configuration can excite fundamental or higher-order TM modes in single or multiple DRA structures. [9]-[16]. Conversely, predominantly RDRAs can be excited using various feeding techniques to generate TE modes [1][17].

Typically, DRAs are positioned on a single side of the ground plane. However, limited research has explored the potential of back-to-back DRA configurations [18]-[22]. Back-to-back arrangements offer significant potential for creating bidirectional radiation patterns or spatial diversity. Bidirectional antennas can be realized in two primary configurations: the bidirectional monopole antenna and the bidirectional broadside antenna. Bidirectional monopole antennas and bidirectional broadside antennas each offer unique advantages for various communication systems. Bidirectional monopole antennas can transmit and receive signals equally well from two opposite directions, providing good bandwidth, efficiency, and high gain. Especially when paired with an appropriate ground plane, making them suitable for applications like radio broadcasting, mobile communication, and wireless networks. On the other hand, bidirectional broadside antennas offer strong signal coverage and higher gain due to their directional nature, making them ideal for focused communication along specific axes, such as highways, railways, or tunnels [23]-[29]. Both types of antennas are valued for their ability to enhance signal performance and coverage in their respective applications. To produce bidirectional monopole antennas and bidirectional broadside antennas in a back-to-back DRA structure is a challenging task and has not been previously reported in the literature.

This article demonstrates the bidirectional monopole radiation and bidirectional broadside radiation from a back-to-back RDRA structure. Excitation of two different modes, quasi-$TM_{10\delta}$ and $TE_{11\delta}$, produces the desired radiation with the help of two different feed lines. Both feeds share a common impedance bandwidth ranging from 3.18 GHz to 4.1 GHz, with an isolation between ports better than 16 dB. Both feeds can achieve a maximum gain of approximately 5 dB. Consequently, the proposed structure operates within the 3.5 GHz application band, supporting mobile broadband, fixed wireless access (FWA), IoT, smart cities, and various other modern communication applications.

2. Antenna Geometry

The geometry of the proposed structure is illustrated in Figure 1, which includes a 3-D view as shown in Figure 1(a), a side view in the YZ plane in Figure 1(b), and a top view in the XY plane as represented in Figure 1(c). Two RDRAs (Al_2O_3, ε_r= 9.8) are mounted back-to-back on double layer ground substrate (FR4, ε_r= 4.4). The excitation of two different modes, quasi-$TM_{10\delta}$ and $TE_{11\delta}$, within both RDRA using two distinct feed lines. To excite the quasi-$TM_{10\delta}$ mode (Port 1), drilling is performed through the center of both DRAs along the Z-axis. A stripline, attached to two probes placed in opposite directions, is inserted through a specific distance within the drilling to generate the desired mode. For the $TE_{11\delta}$ mode

(Port 2), a rectangular aperture feed is used to excite both RDRAs. A Y-shaped stripline feeds the rectangular aperture. This approach enables the simultaneous generation of both modes, achieving bidirectional monopole and bidirectional broadside antenna functionalities within a back-to-back RDRA arrangement using two different feeds.

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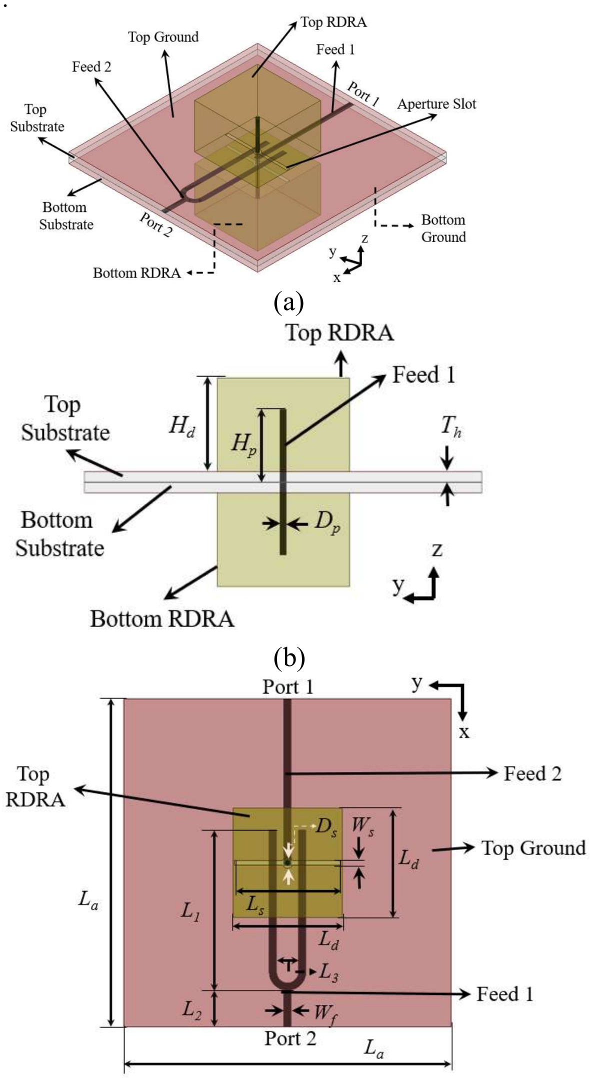


Figure 1. Proposed Antenna geometry. (a) 3D antenna geometry. (b) Side view in YZ plane. (c) Top view in XY plane. Dimensions are: H_d= 14.2mm, H_p= 9.8mm, D_p= 1mm, T_h= 0.8mm, L_a= 60mm, L_d= 10mm, L_s= 19.5mm, L_1= 22.12mm, L_2= 13.38mm, L_3= 2mm, W_s= 0.9mm, W_f= 0.65mm, D_s= 2mm.

3. Experimental results and discussion

The proposed geometry was designed, simulated, and analyzed using HFSS software [30]. The scattering parameters for the two ports are shown in Figure 2. The impedance bandwidth for Port 1 ranges from 3.09 GHz to 4.14 GHz, while for Port 2, it ranges from 3.18 GHz to 4.1 GHz. Additionally, the mutual coupling or port isolation is better than 16 dB within the operating regions of the structure.

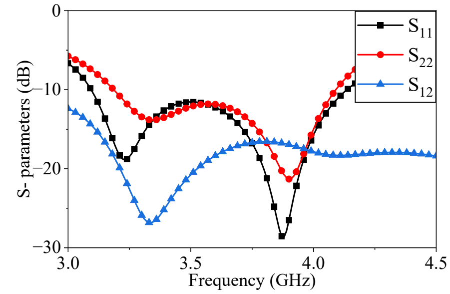


Figure 2. Scattering Parameter of proposed 2-port antenna

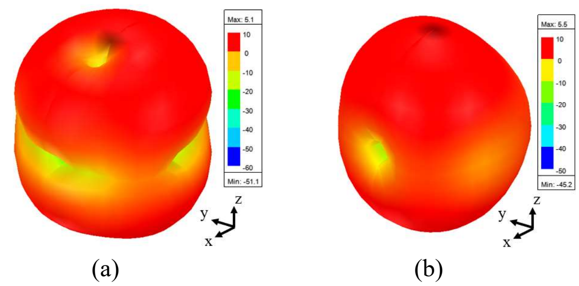


Figure 3. Radiation pattern of proposed Antenna geometry. (a) 3D radiation pattern of port 1. (b) 3D radiation pattern of port 2.

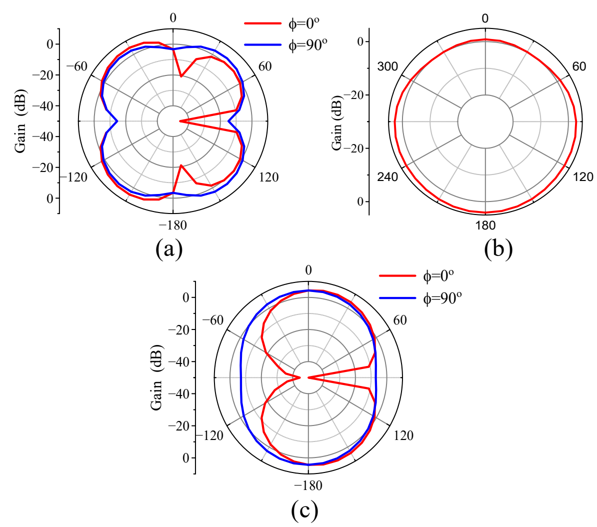
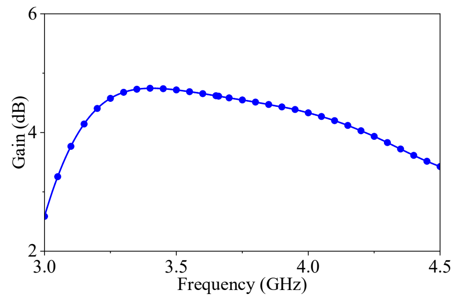


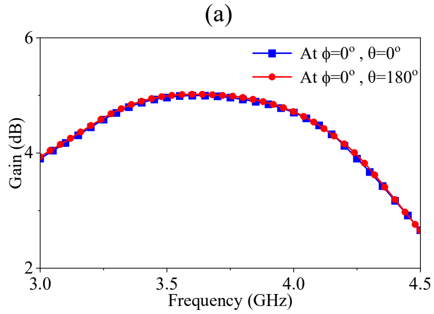
Figure 4. Far-field radiation patterns: (a) at port 1, variation with θ. (b) at port 1, variation with ∅, θ=45°. (c) at port 2, variation with θ.

The 3D radiation pattern of the structure is illustrated in Figure 3, with Figure 3(a) showing the radiation from Port 1 and Figure 3(b) displaying the radiation from Port 2. The corresponding 2D far-field radiation patterns are presented in Figure 4. Specifically, Figure 4(a) shows the far-field radiation pattern of Feed 1 for the variation of θ at ∅=0° and ∅=90°, while Figure 4(b) illustrates the far-field radiation pattern of Feed 1 for the variation of ∅ at θ =45°.

Figure 4(c) depicts the far-field radiation pattern of Feed 2 for the variation of θ at ∅=0° and ∅=90°. These radiation plots demonstrate that the proposed structure can achieve bi-directional monopole radiation from Port 1 and bi-directional broadside radiation from Port 2.

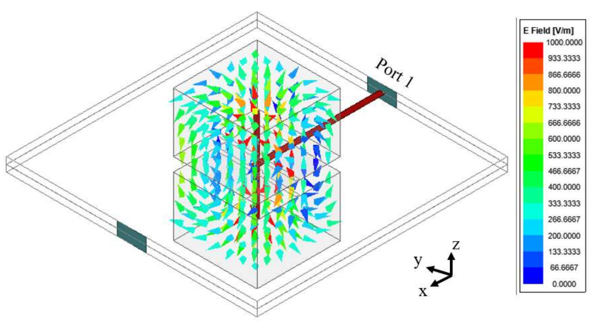


(a)

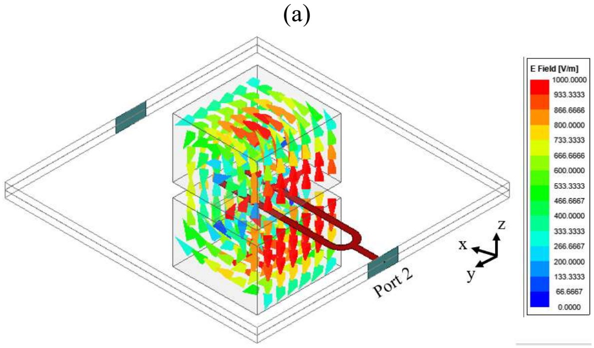


(b)

Figure 5. Gain polt of the proposed structure with respect to frequency. (a) For port 1 at ∅=0° and θ=45°. (b) For port 2 at θ=0° and θ=180°.



(a)



(b)

Figure 6. Mode inside back-to-back RDRA. (a) Due to port 1. (b) Due to port 2.

To understand the total gain of the antenna within the operating band, the gain plot with respect to frequency is shown in Figure 5. Figure 5(a) presents the gain plot for Port 1 at ∅=0° and θ=45°, while Figure 5(b) shows the gain plot for Port 2 at ∅=0° and θ=0° as well as θ=180°. Both plots indicate a maximum gain of approximately 5 dB.

The electric field orientation within both back-to-back RDRA configurations, resulting from individual port excitation, is illustrated in Figure 6. Figure 6(a) displays the modes inside the back-to-back RDRA when Feed 1 is energized, while Figure 6(b) shows the modes when Feed 2 is energized. Port 1 generates the quasi-$TM_{10\delta}$ mode, and Port 2 generates the $TE_{11\delta}$ mode inside both RDRA.

4. Conclusion

In this article, a two-port bidirectional dual-radiation back-to-back rectangular dielectric resonator antenna (RDRA) has been introduced successfully. This design effectively demonstrates both bidirectional monopole radiation and bidirectional broadside radiation, achieved through the utilization of two distinct feed lines. This work showcases the unique incorporation of the quasi-$TM_{10\delta}$ mode excited by Port 1 and the $TE_{11\delta}$ mode generated by Port 2 within the back-to-back RDRA. This particular combination of modes has not been previously documented in existing literature. The innovative design offers significant advantages for modern communication systems by providing a unified operating bandwidth ranging from 3.18 GHz to 4.1 GHz. Additionally, the antenna exhibits port isolation, exceeding 16 dB, and achieves a maximum gain of approximately 5 dB. This advancement in RDRA technology not only expands the possibilities for antenna design but also enhances the performance and efficiency of communication systems, making it a valuable contribution to the field.

6. Acknowledgements

The authors would like to express their gratitude to Prof. Debatosh Guha of the Institute of Radio Physics and Electronics at Calcutta University in Kolkata for their help and support during this work.

7. References

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