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A Compact Wideband Bidirectional Dielectric Resonator Antenna Array Based on Back-to-Back structure

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Abstract

In this paper, a novel four-element compact bidirectional cylindrical dielectric resonator antenna (CDRA) array is proposed based on the back-to-back structure, which exhibits the bidirectional radiation without introducing additional plane size. The microstrip line acts as feeding structure for both the upper and lower antennas by slot coupling, which reduces the overall feeding network size and insertion loss. The -10dB impedance bandwidth is 2.01-2.45GHz (fractional bandwidth of 19.7%). The maximum gain of the proposed CDRA array is 8.6dBi, which is suitable for ISM band of the 2.4GHz and the application of tunnel communication.

1 Introduction

DRA has been extensively reported in recent years due to the characteristics of the high efficiency, wideband, and high degree of design freedom. Unidirectional [1-2] and omnidirectional [3-4] DRAs have been reported extensively. But few of the bidirectional DRAs [5-7] have been studied. Compared with traditional bidirectional antenna, bidirectional DRA has the advantages of high radiation efficiency due to the absence of conducting material ohmic loss.

Two CDRAs placed on top of a cylindrical ground plane are fed by a coaxial probe to realize the bidirectional radiation in [5], but the maximum gain of the proposed antenna array is only 3.7dBi with a narrow bandwidth of 2.25%. A bidirectional dielectric resonator antenna is designed by placing a pair of a quarter wavelengths height monopole reflectors to achieve the bidirectional radiation in [6], but the two radiation directions are not typical bidirectional radiation. The reported antenna in [7] consisting of two rectangular DRs with the same size mounted on the ground plane, which realized bidirectional radiation characteristic and achieved the high gain of 5.53dBi. But the bandwidth of 2.4% should be enhanced.

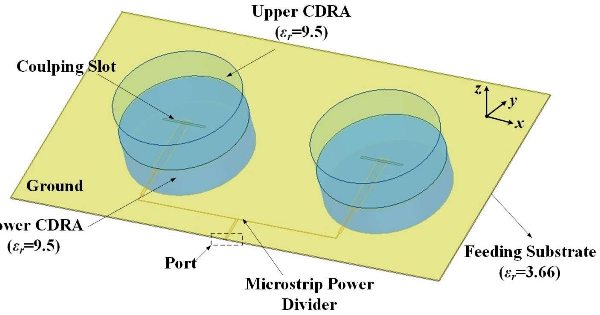
In this paper, the proposed CDRA array is composed of back-to-back structure, two 1×2 DRA arrays are placed symmetrically on both sides of dielectric substrate. The microstrip line transition structure is employed to feed and excite the back-to-back CDRA array through the coupling slot structure and direct contact. The feeding structure is realized by 1-2 way microstrip power divider, and compact CDRA array with bidirectional radiation is realized. Eventually, the proposed CDRA array realizes the bidirectional radiation with the maximum gain of 8.6dBi and fractional bandwidth (FBW) of 19.7%, which indicates the proposed CDRA array is a good candidate for tunnel communication applications.

2 Antenna Design

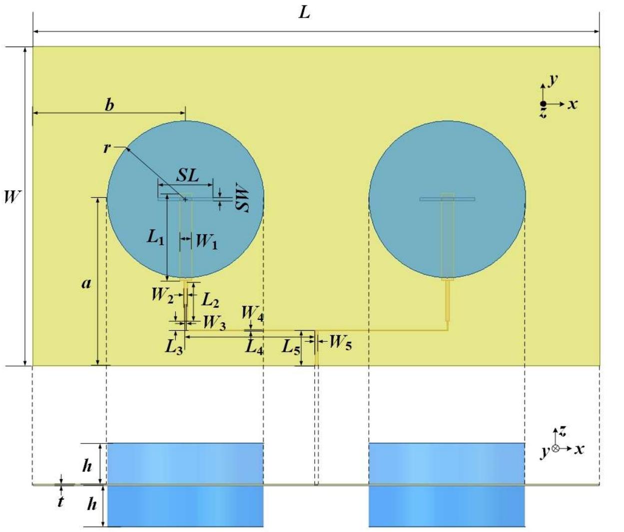
The structure of the proposed bidirectional CDRA array is shown in Fig. 1, it consists of four-element CDRA array, ground, coupling structure, feeding substrate and the microstrip power divider. The CDRA consists of 99% alumina ceramics (relative permittivity $\varepsilon_r = 9.5$), and two 1 × 2 CDRA arrays are located on the upper and lower sides of the feeding substrate back-to-back. The feeding substrate adopts Rogers 4350B with the relative permittivity $\varepsilon_r = 3.66$, a thickness t =0.508mm and loss tangent $tan\delta = 0.004$. The microstrip line feeding structure is also employed to feed the CDRA array through the coupling slot structure and direct contact simultaneously. The coupling aperture equals to a magnetic dipole, which provides a fairly good impedance matching for the $HEM_{11\sigma}$ mode. Similarly, the microstrip line feeds the CDRA directly, which also can excite the $HEM_{11\sigma}$ mode. The dimensions of the CDRA can be deduced as follows [1]:

$$f_0 = \frac{2.735c\varepsilon_r^{-0.436}}{2\pi r}[0.213 + 0.589(\frac{r}{h}) - 0.05(\frac{r}{h})^2] \quad (1)$$

Where, r, h, and ε_r are the radius, the height, and the relative permittivity of the CDRA, respectively. When r =3.6mm, h =12.6mm and the relative permittivity ε_r =9.5 of the CDRA are determined, the resonant frequency of $HEM_{11\sigma}$ mode at 2.34 GHz can be obtained, which is basically consistent with the simulated resonant frequency of 2.33GHz. When the port is excited, the resonant frequency of 2.33 GHz is introduced by the $HEM_{11\sigma}$ mode. Fig. 2 displays the electric field vector distribution of $HEM_{11\sigma}$ mode in the top and side view. It can be seen that the electric field vector flows along the same direction in the top view, and the electric field vector flows along the semicircle in side view, which are almost identical to the theoretical schematic diagrams of the $HEM_{11\sigma}$ mode. Ultimately, it is verified that the two different feeding methods excite the same resonant modes of the CDRA, which ensure the stability of the gain in both radiation directions of the CDRA.

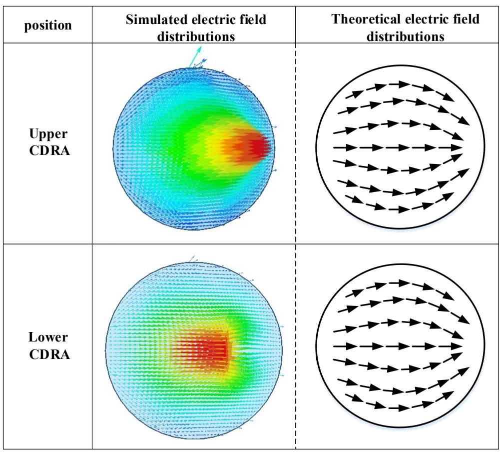


(a)

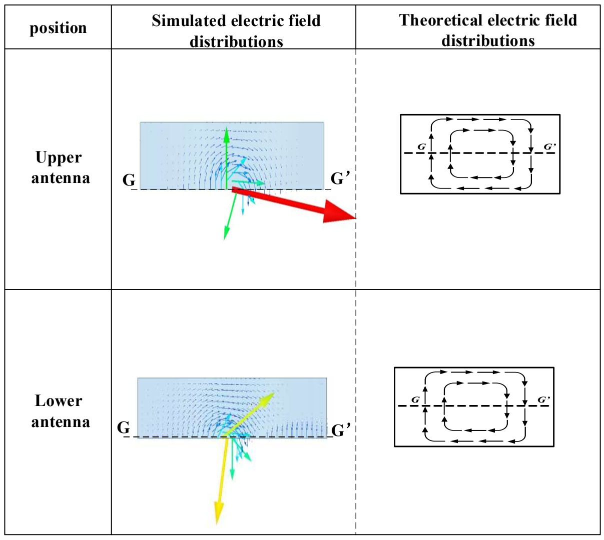


(b)

Figure 1. Geometry of the proposed bidirectional CDRA array: a=50.9mm, b=20.6mm, W=97.6mm, L=173.4mm, W_1=3.63mm, L_1=26.6mm, W_2=1.17mm, L_2=12.4mm, W_3=0.33mm, L_3=2.91mm, W_4=0.2mm, L_4=39.68mm, W_5=0.96mm, SL=16.8mm, SW=0.86mm, r=24mm, h=12.6mm, t=0.508mm. (a) 3D view, (b) Top view and side view.



(a)



(b)

Figure 2. Simulated and schematic electric field of CDRA: $HEM_{11\sigma}$ resonant mode at 2.33 GHz. (a) Top view, (b) Side view. (G-G' is the location of the ground plane.)

3 Results and Discussion

The simulated results were achieved by using ANSYS HFSS software in this paper. The simulated reflection coefficients of the proposed CDRA array are presented in Fig. 3, and the -10dB impedance bandwidth is 2.01-2.45GHz (FBW of 19.7%). The bandwidth is suitable for the ISM band applications (2.4-2.48GHz). Since both the upper and lower antennas excite the $HEM_{11\sigma}$ resonant modes, the gain of the antenna in both end-fire directions is symmetrically, as shown in Fig. 4. Moreover, it can be seen that the efficiency of the antenna in the working frequency range is greater than 95%.

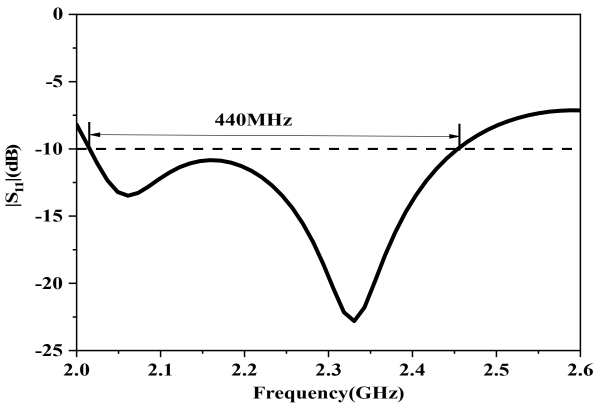


Figure 3. Simulated reflection coefficients of the proposed CDRA array.

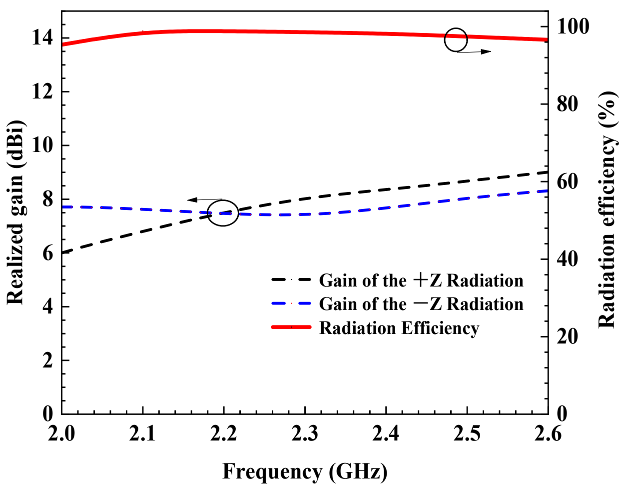
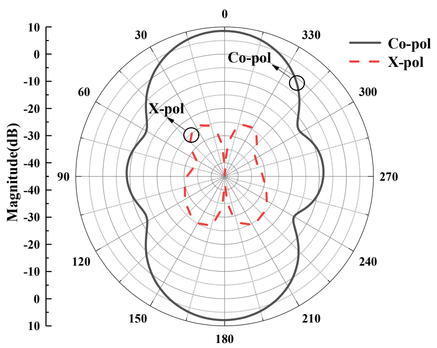
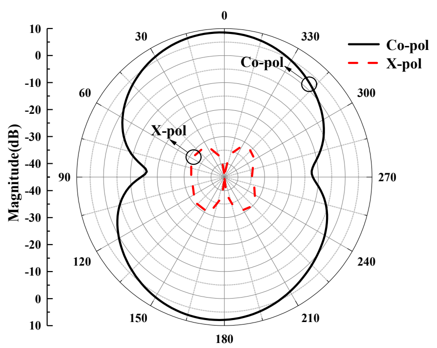


Figure 4. Realized gain and efficiency of the proposed antenna array.

Fig. 5. shows the simulated radiation patterns of the proposed DRA at 2.45 GHz. The difference of the gain in the two radiation directions is only 0.6dB, which achieves a good bidirectional radiation characteristic. At the same time, good cross polarization performance is obtained.



(a)



(b)

Figure 5. Simulated radiation patterns of the proposed CDRA array at 2.45GHz. (a)xoz plane, (b)yoz plane.

Table I gives the performance comparisons between the proposed CDRA array and recent reported bidirectional DRAs recently. The proposed CDRA array has the advantages of compact size, wideband, high gain, simple and easy fabrication. It worth noting that the proposed semi-cylindrical grooved CDRA can achieve a high gain by only adjusting the radius parameters of semi-cylindrical groove, which not increase the antenna's profile.

TABLE I
Comparison with previously related designs

Reference	FBW (%)	Gain (dBi)	Size (λ_0^2)
[5]	2.25	3.7	0.67×0.67
[6]	9.2	3.19	0.68×0.68
[7]	2.4	5.53	3.4×3.4
[8]	11.72	<6	NA
Proposed	19.7	8.6	1.28×0.72

4 Conclusion

The design of a novel bidirectional CDRA array is presented, which can realize the stable bidirectional radiation in the working frequency band. The impedance bandwidth and the maximum gain of the CDRA array is 2.01GHz-2.45GHz (FBW of 19.7%) and 8.6dBi, respectively. Owing to the high gain and wideband characteristics of the proposed CDRA, it can be applied to ISM band wireless communication of the 2.4GHz and the tunnel communication.

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