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# SIZE REDUCTION OF RECTANGULAR DIELECTRIC RESONATOR ANTENNA WITH SYMMETRIC RADIATION PATTERNS AND LOW CROSS POLARIZATION

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**Abstract**—A 50% size reduction of the rectangular dielectric resonator antenna (DRA) is achieved by introducing shorting posts at the edge of the DRA in this paper. By choosing proper height of the shorting posts, the radiation pattern in $E$-plane maintains almost the same shape as the conventional rectangular DRA. The cross polarization can also be controlled to be a relative low level. By adding an open stub in the feed line, the proposed antenna has almost the same resonant frequency with the conventional rectangular DRA. The measured results for the constructed prototype are also exhibited and discussed.

## 1. INTRODUCTION

Dielectric resonator antennas (DRAs) have been widely discussed since it was introduced in 1983 [1]. DRAs offer many advantages, such as low-profile, low-cost, ease of excitation and high radiation efficiency [2–19]. Applications exist, such as mobile handsets, laptops, or for covert operations equipment, where compact antennas are required. Since the volume of the DRA increases by a factor of eight each time the frequency is halved, the use of DRAs at lower frequencies becomes questionable, due to the increase in their dimensions (and thus their weight and cost). The most popular method to reduce the DRA size is the use of very high dielectric constant materials [20]. In [21], a metal plate is placed on top of the rectangular DRA to reduce the size. An alternative method involves the introduction of a short circuit [22, 23].

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By placing the short circuit at a location of symmetry in the $E$-fields, a portion of the DRA can be removed, while maintaining the proper mode configuration. It should be mentioned that these techniques reduces the size at the expense of the radiation characteristic or the bandwidth of the antenna.

Rectangular DRAs offer more design flexibility since two of the three of its dimensions can be varied independently for a fixed resonant frequency and known dielectric constant of the material. Hence, we chose the rectangular DRAs for our investigations in this paper. We use here shorting posts at the edge of the rectangular DRA which gives us size reduction of 50%. Three reference antennas are presented and discussed, showing that the radiation patterns deformation and high level of cross polarization could be avoided by the shorting posts. The numerical and experimental results of the proposed antenna are presented and compared, showing a good performance in terms of return loss and radiation pattern.

## 2. ANTENNA GEOMETRY AND DESIGN

The geometry of the proposed antenna is shown in Fig. 1(a), where a rectangular dielectric resonator (DR) is located at the center of a square substrate with a size of $60 \times 60 \times 1\,\mathrm{mm}^3$ and a relative

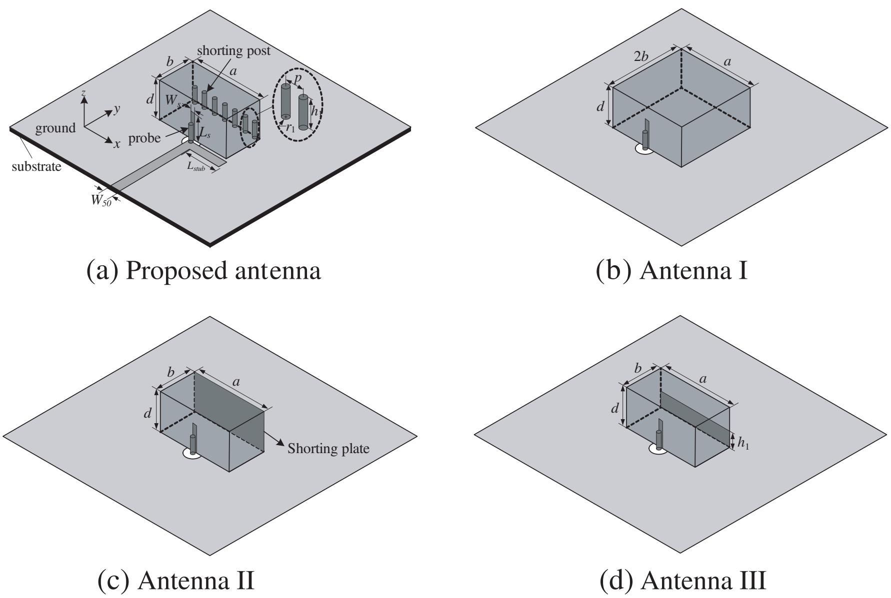



**Figure 1.** Geometry of DRAs.

permittivity constant $\varepsilon_r = 2.65$. The design parameters of the rectangular DRA are $a = 20$ mm, $b = 10$ mm, $d = 10$ mm, with a dielectric constant $\varepsilon_d = 9.8$. A row of shorting posts is arranged at the edge of the DRA. The height and the radius of the shorting post are $h_1 = 4$ mm and $r_1 = 0.5$ mm, and the space between the posts is $p = 3$ mm. The DRA is excited by a probe with height of 4 mm and radius of 0.5 mm, which is soldered to a flat metal strip with dimensions of $L_s = 7$ mm, and $W_s = 1.2$ mm. The feeding strip is placed at the center of the DRA side wall. A 50-Ω microstrip feed line with an open stub (length $L_{stub} = 9.6$ mm) is etched on the bottom-side of the substrate and a ground plane is printed on the opposite side of the substrate.

To better understand size reduction of the proposed antenna, three reference antennas were also designed and shown in Figs. 1(b)–(d). Fig. 1(b) shows a rectangular DR on a ground plane. The size of the DR is $a \times 2b \times d$. Fig. 1(c) shows an edge-grounded rectangular DR on a ground plane, with the same size as the proposed DR. Fig. 1(d) shows the similar configuration of Fig. 1(c) with the same height of the shorting posts in the proposed antenna. These four antennas have the same size of ground plane.

By using the dielectric waveguide model (DWM) [24], the resonant frequency of the $TE^x_{111}$ mode for antenna I is estimated to be 3.77 GHz. The simulated resonant frequency of the antenna I is 3.74 GHz, which is very close to the calculated one. Here, the simulations are performed using Ansoft HFSS 11 [25], a commercially available 3-D electromagnetic field solver based on the finite element method (FEM). By placing the short circuit at a location of symmetry in the $E$-fields [22, 23], a portion of the DRA can be removed, while maintaining the proper mode configuration. It should be mentioned that these techniques reduces the size at the expense of the radiation characteristic. The simulated normalized co-polarized radiation patterns in $E$-plane ($yz$-plane) for four antennas at 3.74 GHz are plotted in Fig. 2. As shown in Fig. 2, antenna III and the proposed antenna have the similar radiation patterns as antenna I; however obvious differences are observed in the case of antenna II. This is due to the large height of shorting plate at the edge of the DRA. By reducing the height of shorting plate, which refers to antenna III, the differences between radiation patterns become small. It can be also concluded that the shorting posts have the same influence as the shorting plate on the radiation patterns in $E$-plane.

There could be a significant increase in the cross-polarization level in $H$-plane if the shorting plate is added. This is due to the radiation of the shorting plate. The simulated normalized cross polarizations in $H$-

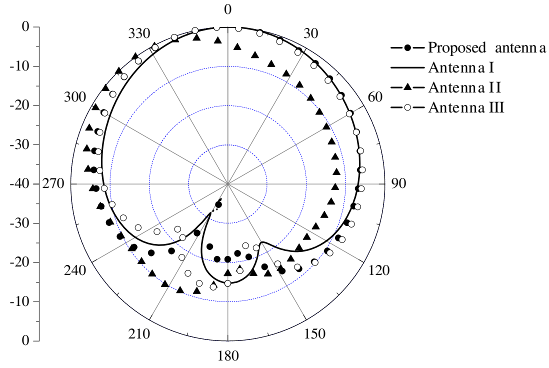



**Figure 2.** Simulated normalized co-polarized radiation patterns in $E$-plane for DRAs at 3.74 GHz.

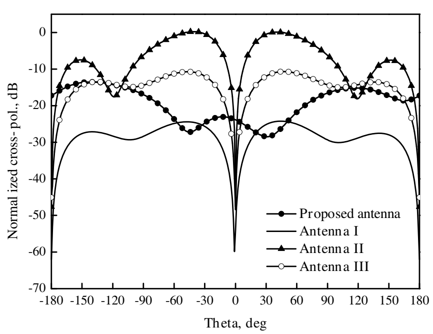



**Figure 3.** Simulated normalized cross polarizations in $H$-plane for DRAs at 3.74 GHz.

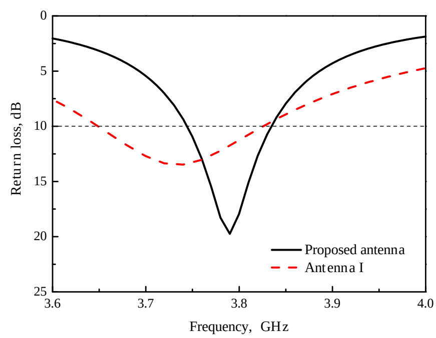


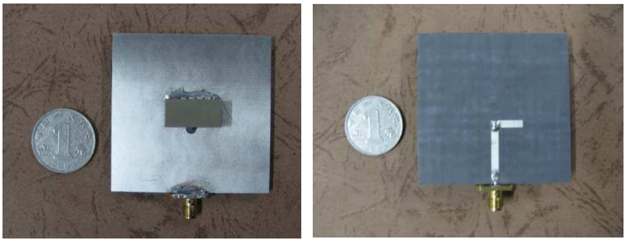

**Figure 4.** Simulated return losses of the proposed antenna and antenna I.

plane ($xz$-plane) for these antennas at 3.74 GHz are plotted in Fig. 3. High cross polarization level is observed in the shorting plate cases. The cross polarization level could be lower while reducing the height of the shorting plate, but it is still high in the broadside direction. When replacing the shorting plate by shorting posts with the same height, which refers to the proposed antenna, the cross polarization level falls dramatically in the broadside direction.

Since the shorting posts could not be equivalent to perfect electric conductor (PEC) plane completely, the simulated resonant frequency of the proposed antenna without the microstrip feed line is 4.4 GHz, which is different from the one of antenna I, 3.74 GHz. An open stub is added in the microstrip feed line to adjust the resonant frequency of the proposed antenna. The simulated return losses of the proposed antenna and antenna I are presented in Fig. 4. The resonant frequency of the proposed antenna is 3.79 GHz, which is very close to the resonant frequency of antenna I. Like the results in [23], the bandwidth of the proposed antenna decreases with the size reduction. The performances of the four antennas are compared in Table 1.

## 3. EXPERIMENTAL RESULTS

A prototype of the proposed antenna was fabricated and tested. The DR was fabricated with a ceramic material of relative permittivity 9.8. The DR was constituted by five substrates of height 2 mm, and two of the substrates with metal via holes are placed at the bottom of the DR. The photography of the antenna prototype is shown in Fig. 5. The prototype has been measured using WILTRON37269A vector network analyzer and the anechoic chamber. Some representative measured



(a) (b)

**Figure 5.** The photography of the proposed antenna. (a) Front view. (b) Rear view.

**Table 1.** Details of simulated results for studied antenna prototypes.

| | Proposed antenna | Antenna I | Antenna II | Antenna III |
|---|---|---|---|---|
| Resonant frequency (GHz) | 3.79 | 3.74 | 3.40 | 4.42 |
| 10 dB impedance bandwidth (MHz) | 100 (3740 $\sim$ 3840) | 170 (3650 $\sim$ 3820) | 220 (3300–3520) | 220 (4320–4540) |
| Radiation patterns in $E$-plane | Symmetry | Symmetry | Asymmetry | Symmetry |
| Cross-pol in $H$-plane | Low | Low | High | High |

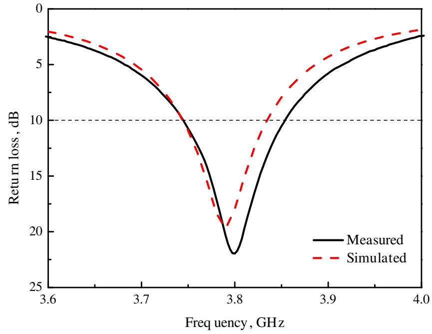
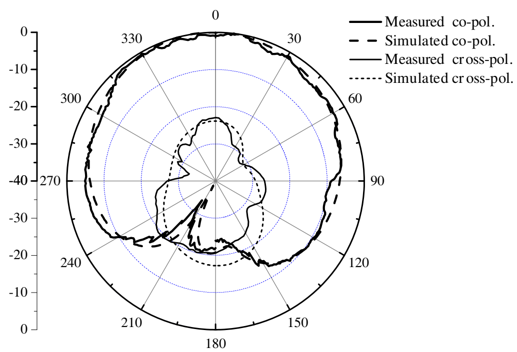
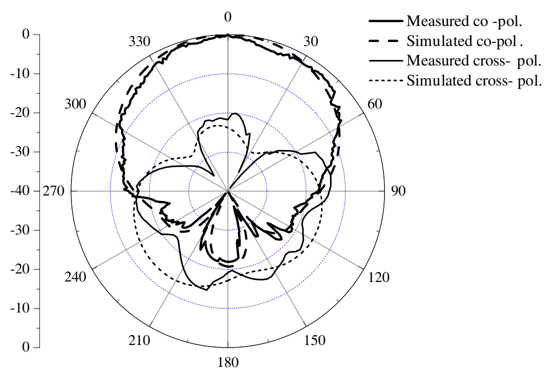



**Figure 6.** Measured and simulated return losses of the prototype.




(a) yz-plane




(b) xz-plane

**Figure 7.** Measured and simulated normalized radiation patterns for the proposed antenna at 3.8 GHz.

results along with some simulated data are presented.

The measured and simulated return losses of the prototype are shown in Fig. 6. It is observed that a good agreement between simulated and measured results is obtained. The measured resonant frequency of the proposed antenna is 3.8 GHz, which is very close to the simulated one. The measured and simulated normalized radiation patterns for the proposed antenna at 3.8 GHz are plotted in Fig. 7, showing a good agreement in the broadside radiations in both principle planes. Good symmetric broadside radiation patterns with low cross polarizations are also observed in the two principal planes. The measured peak gain of the proposed antenna at 3.8 GHz is 6.31 dBi, which is close to the simulated peak gain of antenna I.

## 4. CONCLUSION

A 50% size reduction of the rectangular dielectric resonator antenna (DRA) is achieved by introducing shorting posts at the edge of the DRA in this paper. Three reference antennas are presented and discussed, showing that the radiation patterns deformation and high level cross polarization could be avoided by the shorting posts. By adding an open stub in the feed line, the proposed antenna has almost the same resonant frequency as the conventional rectangular DRA. A prototype of the proposed antenna was fabricated and tested. Good agreement between simulated and measured return losses is obtained and good symmetric broadside radiation patterns with low cross polarizations are also observed in the two principal planes.

## REFERENCES

1. Long, S. A., M. W. McAllister, and L. C. Shen, "The resonant cylindrical dielectric cavity antenna," *IEEE Transactions on Antennas and Propagation*, Vol. 31, No. 3, 406–412, May 1983.
2. Luk, K. M. and K. W. Leung, *Dielectric Resonator Antennas*, Research Studies Press Ltd., Hertfordshire, England, 2003.
3. Saed, M. and R. Yadla, "Microstrip-fed low profile and compact dielectric resonator antennas," *Progress In Electromagnetics Research*, Vol. 56, 151–162, 2006.
4. Rezaei, P., M. Hakkak, and K. Forooraghi, "Design of wide-band dielectric resonator antenna with a two-segment structure," *Progress In Electromagnetics Research*, Vol. 66, 111–124, 2006.
5. Kumar, A. V. P., V. Hamsakutty, J. Yohannan, and K. T. Mathew, "Microstripline fed cylindrical dielectric resonator

antenna with a coplanar parasitic strip," *Progress In Electromagnetics Research*, Vol. 60, 143–152, 2006.

6. Weng, Z. B., X. M. Wang, Y. C. Jiao, and F. S. Zhang, "Wideband rectangular dielectric resonator antenna (DRA) with slot-fed design," *Progress In Electromagnetics Research Letters*, Vol. 16, 181–190, 2010.
7. Al-Zoubi, A. S., A. A. Kishk, and A. W. Glisson, "Analysis and design of a rectangular dielectric resonator antenna fed by dielectric image line through narrow slots," *Progress In Electromagnetics Research*, Vol. 77, 379–390, 2007.
8. Denidni, T. A., Y. Coulibaly, and L. Talbi, "Design of a broadband hybrid dielectric resonator antenna for X-band applications," *Journal of Electromagnetic Waves and Applications*, Vol. 20, No. 12, 1629–1642, 2006.
9. Fayad, H. and P. Record, "Multi-feed dielectric resonator antenna with reconfigurable radiation pattern," *Progress In Electromagnetics Research*, Vol. 76, 341–356, 2007.
10. Rezaei, M., M. Hakkak, and K. Forooraghi, "Design of wide-band dielectric resonator antenna with a two-segment structure," *Progress In Electromagnetics Research*, Vol. 66, 111–124, 2006.
11. Qian, Z. H., K. W. Leung, and R. S. Chen, "Analysis of circularly polarized dielectric resonator antenna excited by a spiral slot," *Progress In Electromagnetics Research*, Vol. 47, 111–121, 2004.
12. Fayad, H. and P. Record, "Mutual coupling between a pair of identical beam steering dielectric resonator antennas," *Progress In Electromagnetics Research B*, Vol. 14, 23–44, 2009.
13. Zainud-Deen, S. H., H. A. El-Azem Malhat, and K. H. Awadalla, "Dielectric resonator antenna mounted on a circular cylindrical ground plane," *Progress In Electromagnetics Research B*, Vol. 19, 427–444, 2010.
14. Jamaluddin, M. H., R. Sauleau, X. Castel, R. Benzerga, L. Le Coq, R. Gillard, and T. Koleck, "Design, fabrication and characterization of a dielectric resonator antenna reflectarray in Ka-band," *Progress In Electromagnetics Research B*, Vol. 25, 261–275, 2010.
15. Wang, X.-M., Z.-B. Weng, Y.-C. Jiao, Z. Zhang, and F.-S. Zhang, "Dual-polarized dielectric resonator antenna with high isolation using hybrid feeding mechanism for WLAN applications," *Progress In Electromagnetics Research Letters*, Vol. 18, 195–203, 2010.
16. Gürel, Ç. S., H. Coşar, and Ö. Akalın, "Accurate resonant

frequency computation of multisegment rectangular dielectric resonator antennas," *Journal of Electromagnetic Waves and Applications*, Vol. 24, No. 5–6, 839–847, 2010.

17. Ahmed, O. M. H., A. R. Sebak, and T. A. Denidni, "Size reduction and bandwidth enhancement of a UWB hybrid dielectric resonator antenna for short-range wireless communications," *Progress In Electromagnetics Research Letters*, Vol. 19, 19–30, 2010.
18. Z. Ding, S.-Q. Xiao, Y. Bai, and B.-Z. Wang, "Hemisphere dielectric resonator pattern reconfigurable antenna and its linear phased array," *Progress In Electromagnetics Research Letters*, Vol. 6, 183–192, 2009.
19. Kishk, A. A., A. W. Glisson, and G. P. Junker, "Bandwidth enhancement for split cylindrical dielectric resonator antennas," *Progress In Electromagnetics Research*, Vol. 33, 97–118, 2001.
20. Mongia, R. K., A. Ittipiboon, and M. Cuhaci, "Low profile dielectric resonator antennas using a very high permittivity material," *Electronics Letters*, Vol. 30, No. 17, 1362–1363, Aug. 1994.
21. Mongia, R. K., "Reduced-size metalized dielectric resonator antenna," *IEEE Antennas and Propagation Symposium Digest AP-S*, 2202–2205, Montreal, Canada, 1997.
22. Copper, M., "Investigation of current and novel rectangular dielectric resonator antennas for broadband applications at L-band frequencies," Master's Thesis, Carleton University, 1997.
23. Tam, M. T. K. and R. D. Murch, "Half volume dielectric resonator antenna designs," *Electronics Letters*, Vol. 33, No. 23, 1914–1916, Nov. 1997.
24. Mongia, R. K. and A. Ittipiboon, "Theoretical and experimental investigations on rectangular dielectric resonator antennas," *IEEE Transactions on Antennas and Propagation*, Vol. 45, No. 9, 1348–1356, Sep. 1997.
25. Ansoft High Frequency Structure Simulator (HFSS), Ver. 11.0, Ansoft Corp., 2007.