Progress In Electromagnetics Research Letters, Vol. 44, 107–111, 2014

High Gain Circularly-Polarized Dielectric Resonator Antenna Array with Helical Exciter

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Abstract—A novel (2×2) high-gain circularly-polarized cylindrical dielectric resonator antenna array integrated with helical exciter is proposed. The array offers a maximum gain of 13.8 dBi at the operating frequency. The circular polarization is obtained by incorporating helical exciter in the array structure. A prototype of the proposed configuration integrated with helical exciter has been fabricated, tested and the idea has been verified. A good agreement has been obtained between the measured and the simulated results.

1. INTRODUCTION

The dielectric resonator antenna (DRA) has received increasing attention because of their attractive features such as small size, low cost, versatile and flexible excitation techniques, wider impedance bandwidth, high radiation efficiency, high temperature tolerance [1–5]. DRA can be excited by different feeding mechanisms, such as direct microstrip line feed [6, 7], co-axial probe [8], aperture coupled by microstripline or coplanar waveguide [9–11], conformal strip feed [12], and designed with various shapes. Recently, circularly polarized (CP) DRA has attracted extensive attention due to insensitivity to the orientation between the transmitter and receiver. This feature is very useful in various communication systems. There are different mechanisms, by which a circularly-polarized DRA can be obtained, such as dual coaxial probe [13], dual conformal strip [14], with parasitic strips [15], rotated sequential feed [16], aperture feed [17], spiral slot [18], special shaped DRA. The method of producing circularly-polarized radiation using DRA with helical exciter has been reported [19] recently. The helix feed excites two orthogonal $HE_{11\delta}$ modes in phase quadrature in the DRA, resulting in a circularly-polarized wave. The maximum measured 7.7 dBi gain is reported in this paper. To the best of our knowledge, no one has explored high-gain DRA array integrated with helical exciter in the open literature.

In this paper, an array has been proposed to achieve high-gain circularly-polarized DRA array integrated with helical exciter. The maximum measured gain 13.8 dBi has been achieved for the proposed antenna. The proposed antenna is simple and inexpensive to fabricate. The design of the antenna has been performed using Ansys High-Frequency Structure Simulator (HFSS) based on the three-dimensional finite element method (FEM) [20]. Details of the proposed antenna design and measurement results are presented and discussed in the following sections.

2. ANTENNA DESIGN

The proposed antenna has been designed at a centre frequency of 5.2 GHz, and accordingly the characteristic parameters of FR-4 and DRA have been optimized during the process of simulation. In this design, initially a single cylindrical DRA with radius of 4.7625 mm, height of 20 mm and dielectric constant of 20 has been taken for the base element, then a four-element array has been designed to operate at 5.2 GHz. Fig. 1 shows the schematic diagram of the proposed antenna array. FR-4 substrate

Received 16 December 2013, Accepted 9 January 2014, Scheduled 13 January 2014
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with thickness of 1.58 mm, loss tangent of 0.002 and dielectric constant of 4.4 has been taken for this design consideration. A power divider using a $\lambda/4$ transformer has been designed on the FR-4 substrate to feed the array. A coaxial line fed technique has been used, and the array is fed by a SMA connector through power divider.

An adhesive copper tape has been used as a helical exciter. The helical exciter with width of 1 mm has been wrapped anti-clock wise on the DRA spirally with an angle of 12 degree. Six turns on the DRA surface has been used. The helical exciter has been connected with the arms of the power divider for the excitation through vertical arms which is also an adhesive copper tape of thickness of 1 mm and height of 2 mm. A photograph of the fabricated antenna is shown in Fig. 2. The optimized design parameters of the antenna are given in Table 1.

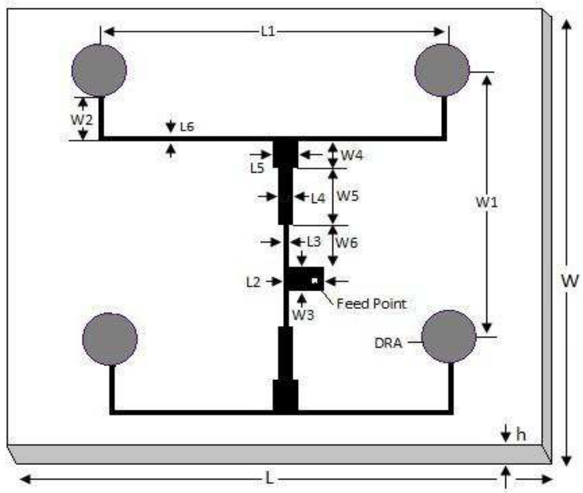
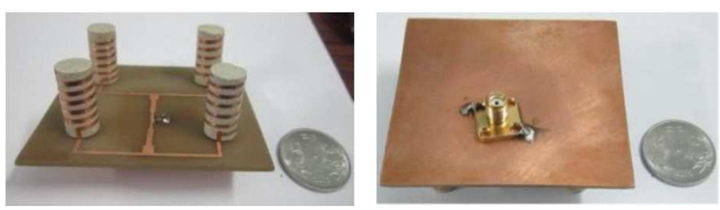


Figure 1. Configuration of proposed antenna.



(a) (b)

Figure 2. Photograph of fabricated antenna. (a) Top view. (b) Bottom view.

Table 1. Design parameters of optimized antenna (units: mm).

Parameters	Value	Parameters	Value
L	70	W	60
h	1.58	W_1	32
L_1	41	W_2	7.6
$W_3 = W_4 = L_5$	3.05	L_2	6.35
$L_3 = L_6$	0.7	W_6	2.9
L_4	1.61	W_5	8.03

3. RESULTS

A prototype of the proposed antenna has been fabricated and tested. The simulated resonant frequency of the proposed antenna array is 5.2 GHz with 3.4% impedance bandwidth. The measured return loss is obtained by the Anritsu MS2025B vector network analyzer. The return loss characteristics of the single element and proposed DRA array are studied in Fig. 3. From the Fig. 3, it is seen that the −10 dB impedance bandwidth of the simulated single element antenna is 12%. The measured result of the proposed array is compared to that of simulated one, and a shift of 63 MHz frequency is observed in the measurement result. This is due to the error occurred during the process of fabrication. The measured −10 dB impedance bandwidth of the array is 4.3%. The gain and radiation pattern were measured in an anechoic chamber, and the measurement was performed by an Agilent network analyser along with far-field measurement software. The simulated *E*- and *H*-plane radiation patterns of the single element antenna are shown in Fig. 4. From Fig. 4, it is observed that the maximum gain for both *E*- and *H*-plane radiation pattern is 6.22 dBi, and the cross-polarization level is also very low for the single element antenna. The simulated and measured *E*-plane and *H*-plane radiation patterns of the proposed DRA array are shown in Figs. 5 and 6 respectively. A simulated gain of 14.7 dBi is observed, and measured gain of 13.8 dBi is achieved for the *E*-plane radiation pattern of the array. For the *H*-plane radiation pattern, simulated and measured gains were 14.7 dBi and 13.8 dBi, respectively. A good agreement between the simulated and measured radiation patterns for both *E*-plane and *H*-plane is observed for the proposed array. The measured levels of cross-polarisation (RHCP) at the broadside direction are also very low as for both *E*- and *H*-plane radiation patterns. The measured and simulated axial ratios are shown in the Fig. 7. The simulated 3 dB axial-ratio bandwidth at 5.2 GHz is 3.3% while the measured axial-ratio bandwidth at the operating frequency is 3.8%.

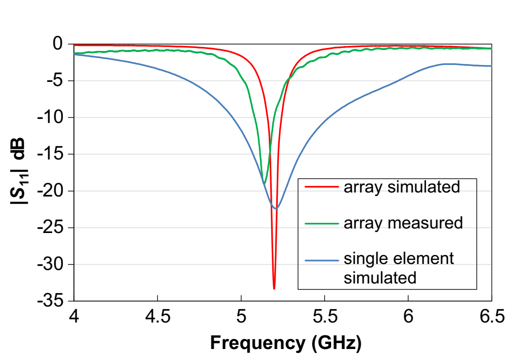


Figure 3. Simulated and measured return loss of proposed antenna.

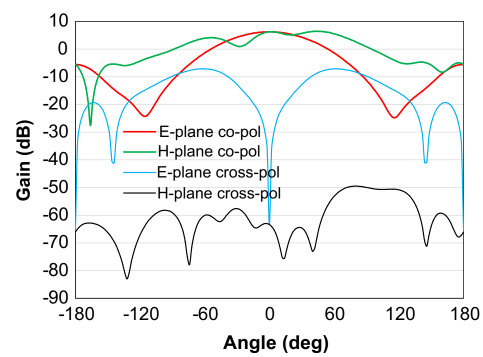


Figure 4. Simulated radiation pattern of the single element antenna.

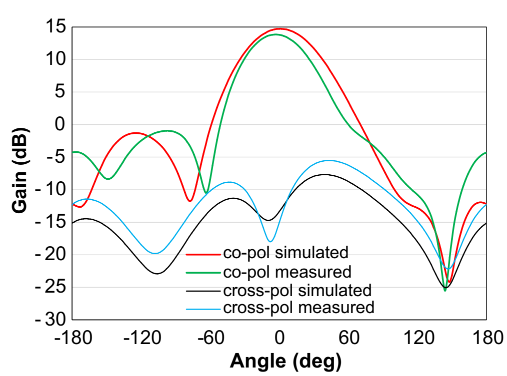


Figure 5. Simulated and measured *E*-plane radiation pattern of antenna array.

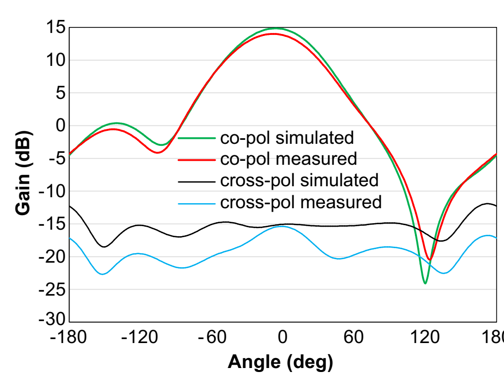


Figure 6. Simulated and measured *H*-plane radiation pattern of antenna array.

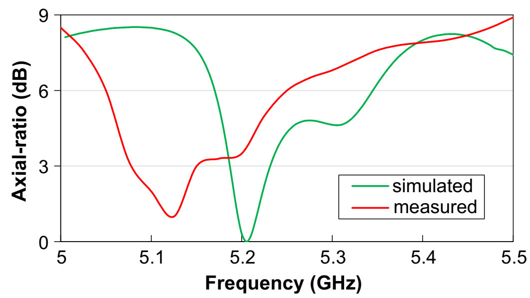


Figure 7. Simulated and measured axial-ratio of proposed antenna array.

4. CONCLUSION

An array is proposed as a technique of increasing gain of the circularly-polarized DRA with external helical exciter. By optimising the array structure, a circularly-polarized radiation pattern and high gain are obtained. A prototype has been fabricated and measured. There is good agreement between the simulated and measured results. The measured 13.8 dBi gain has been found for the proposed antenna.

ACKNOWLEDGMENT

This work was supported by Council of Scientific and Industrial Research (CSIR), Government of India (Project code DRC/CSIR/ETC/SKP/017/12-13).

REFERENCES

1. Luk, K. M. and K. W. Leung, *Dielectric Resonator Antennas*, Research Studies Press LTD., Baldock, Hertfordshire, England, 2003.
2. Petosa, A. and A. Ittipiboon, "Dielectric resonator antenna: A historical review and the current state of the art," *IEEE Antennas Propag. Mag.*, Vol. 52, No. 5, 91–116, Oct. 2010.
3. Long, S. A., M. W. McAllister, and L. C. Shen, "The resonant cylindrical dielectric cavity antenna," *IEEE Trans. on Antennas and Propagat.*, Vol. 31, 406–421, May 1983.
4. Tadjalii, A., A. R. Sebak, and T. A. Denidni, "Resonance frequencies and far field patterns of elliptical dielectric resonator antenna: Analytical approach," *Progress In Electromagnetics Research*, Vol. 64, 81–98, 2006.
5. Song, Y. and A. R. Sebak, "Radiation pattern of aperture coupled prolate hemispheroidal dielectric resonator antenna," *Progress In Electromagnetics Research*, Vol. 58, 115–133, 2006.
6. Petosa, A., R. K. Mongia, A. Ittipiboon, and J. S. Wight, "Design of microstrip fed series array of dielectric resonator antennas," *Electron. Lett.*, Vol. 31, No. 16, 1306–1307, 1995.
7. Saed, M. A. and R. Yadla, "Microstrip-fed low profile and compact dielectric resonator antennas," *Progress In Electromagnetics Research*, Vol. 56, 151–162, 2006.
8. Leung, K. W., K. M. Luk, K. Y. A. Lai, and D. Lin, "Theory and experiment of a coaxial probe-fed hemispherical dielectric resonator antenna," *IEEE Trans. on Antennas and Propagat.*, Vol. 41, 1390–1398, 1993.
9. Leung, K. W., K. Y. A. Lai, K. M. Luk, and D. Lin, "Input impedance of aperture coupled hemispherical dielectric resonator antenna," *Electron. Lett.*, Vol. 29, 1165–1167, 1993.
10. Kranenburg, R. A., S. A. Long, and J. T.Williams, "Coplanar waveguide excitation of dielectric resonator antennas," *IEEE Trans. on Antennas and Propagat.*, Vol. 39, 119–122, 1991.
11. Rao, Q., T. A. Denidni, A. R. Sebak, and R. H. Johnston, "On improving impedance matching of a CPW fed low permittivity dielectric resonator antenna," *Progress In Electromagnetics Research*, Vol. 53, 21–29, 2005.

12. Leung, K. W., "Conformal strip excitation of dielectric resonator antenna," *IEEE Antennas and Propagation Society International Symposium Digest*, Vol. 2, 132–135, Boston, Massachusetts, USA, 2001.
13. Drossos, G., Z. Wu, and L. E. Davis, "Circular polarized cylindrical dielectricresonator antenna," *Electron. Lett.*, Vol. 32, No. 4, 281–283, 1996.
14. Leung, K. W., W. C. Wong, K. M. Luk, and E. K. N. Yung, "Circular-polarized dielectric resonator antenna excited by dual conformal strips," *Electron. Lett.*, Vol. 36, No. 6, 484–486, 2000.
15. Long, R. T., R. J. Dorris, S. A. Long, M. A. Khayat, and J. T. Williams, "Use of parasitic strip to produce circular polarization and increased bandwidth for cylindrical dielectric resonator antenna," *Electron. Lett.*, Vol. 37, No. 7, 406–408, 2001.
16. Kishk, A. A., "Application of rotated sequential feeding for circular polarization bandwidth enhancement of planar arrays with single-fed DRA elements," *Proc. IEEE Antennas and Propagat. Soc. Symp.*, 664–667, 2003.
17. Chair, R., S. L. S. Yang, A. A. Kishk, K. F. Lee, and K. M. Luk, "Aperture fed wideband circularly polarized rectangular stair shaped dielectric resonator antenna," *IEEE Trans. on Antennas and Propagat.*, Vol. 54, No. 4, 1350–1352, 2006.
18. 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.
19. Motevasselian, A., A. Ellgardt, and B. L. G. Jonsson, "A circularly polarized cylindrical dielectric resonator antenna using a helical exciter," *IEEE Trans. on Antennas and Propagat.*, Vol. 61, No. 3, 1439–1443, 2013.
20. "Ansoft high frequency structure simulator (HFSS)," Ver. 13, 2010, http://www.ansoft.com.