

Circular Polarization Dielectric Resonator Antenna Excited by Single Loop Feed

Sinhyung Jeon, Hyengcheul Choi, and Hyeongdong Kim

ABSTRACT—A new feeding method for the circular polarization (CP) dielectric resonator antenna (DRA) is proposed in this letter. Two orthogonal modes ($TE_{\delta 11}^x$, $TE_{1\delta 1}^y$) of the rectangular DRA are excited by a 90° phase difference of the differential and common modes currents of the proposed feeding structure. To demonstrate the good CP performance of the proposed method, a right-hand CP DRA for a global positioning system was designed. The impedance bandwidth of the proposed antenna for $S_{11} < -10$ dB and 3 dB axial ratio bandwidth are about 5.4% and 1.95% at 1.57 GHz, respectively.

Keywords—Dielectric resonator antenna, global positioning system (GPS) antenna, right-hand circular polarization (RHCP) antenna, circular polarization.

I. Introduction

Various studies related to the metallic path antenna for wireless communication have been reported [1], [2]; however, the dielectric resonator antenna (DRA) has high radiation efficiency in contrast with metallic antennas which incur conductor loss. In addition, it offers the advantages of small size, a simple structure, low weight, and low cost [3]. For these reasons, DRAs for application in communication systems have been increasingly investigated. Past studies of DRAs have been mainly conducted for linear polarization (LP) [4]; however, interest in circular polarization (CP) DRAs has recently increased. Several methods have been devised for building a CP DRA, such as quadrature feed, cross-slot feed, and parasitic

patches [5]–[7]. In contrast to these complicated techniques, we propose a simple but efficient feeding method using a single strip line shaped into a loop. A finite-element-method (FEM)-based commercial software, Ansoft HFSS, was used to design a CP DRA for a global positioning system (GPS).

II. Theory and Proposed DRA Design

The geometry of the proposed DRA is shown in Fig. 1. The square ceramic DRA ($a=34$ mm, $b=34$ mm, and $c=12$ mm) with dielectric constant $\epsilon_r=30$ is placed in the center of a ground plane ($L=68$ mm), and it is fed by a probe of $50\ \Omega$ coaxial cable. The parameters of the microstrip feed line are

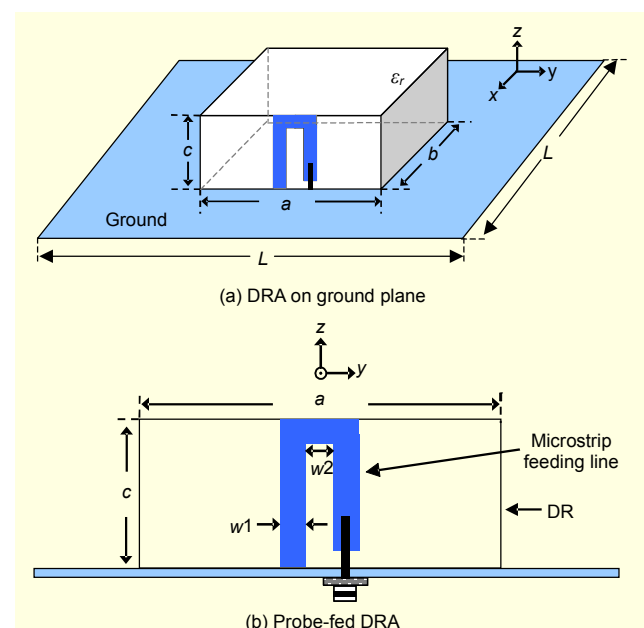


Fig. 1. Geometry of the proposed DRA.

Manuscript received Oct. 17, 2008; revised Nov. 25, 2008; accepted Dec. 11, 2008.

This research was supported by the MIC (Ministry of Information and Communication), Rep. of Korea under the ITRC (Information Technology Research Center) support program supervised by the IITA (Institute of Information Technology Advancement) (IITA-2008-C1090-0801-0003).

Sinhyung Jeon (phone: +82 2 2220 0373, email: jsinhyung@daum.net), Hyengcheul Choi (email: hyengcheul@hanyang.ac.kr), and Hyeongdong Kim (phone: +82 2 2298 0373, email: hdkim@hanyang.ac.kr) are with the Department of Electronics and Computer Engineering, Hanyang University, Seoul, Rep. of Korea.

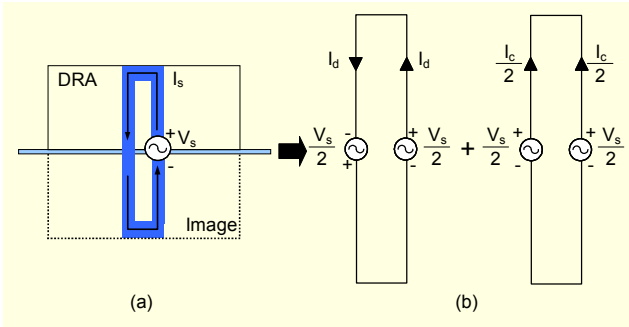


Fig. 2. Proposed feeding method: (a) feed line by image theory and (b) decomposition of the proposed feeding method into differential and common modes.

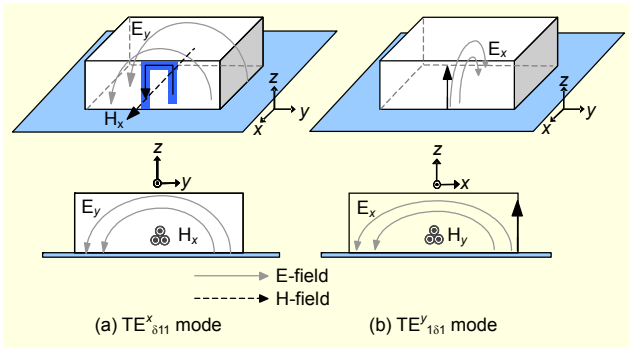


Fig. 3. Electric and magnetic field distribution of DRA modes.

$w1=3$ mm and $w2=4$ mm.

The CP is obtained when two orthogonal modes of equal amplitude are excited with a 90° phase difference between the two modes. The proposed feed method can excite two different resonance modes using the currents of a loop-shaped strip line. As shown in Fig. 2(a), the proposed feed line can be considered according to image theory to be a folded dipole. The current of the folded dipole can be decomposed into two distinct modes: the loop type differential and the z -directed common modes [8]. The current I_d of the differential mode excites the $TE_{\delta 11}^x$ mode of the DRA, and the common mode current I_c excites the $TE_{1\delta 1}^y$ mode as shown in Figs. 2(b) and 3. The distributions of the electric and magnetic fields of each mode of the DRA are shown in Fig. 3. As shown in Fig. 3(a), for the $TE_{\delta 11}^x$ mode, the magnetic fields (H_x) are generated in the x -axis by I_d at the center of the DRA, and the electric fields (E_y) circulate around these magnetic fields. In the same manner, for the $TE_{1\delta 1}^y$ mode, orthogonal electric fields (E_x) are generated by I_c which can be considered the vertical electric source current as shown in Fig. 3(b).

The currents for the differential and common modes are considered inductive and capacitive currents, respectively. Generally, pure inductive and capacitive currents have a 180° phase difference; however, inductive and capacitive currents that include resistance have a phase difference of less than 180° .

As the loop size increases as the $w2$ parameter increases, the inductance and capacitance currents become resistive. Therefore, a 90° phase difference can be obtained by appropriately designing the loop feed parameters $w1$ and $w2$. Two field components among the twelve field components of two modes ($TE_{\delta 11}^x$, $TE_{1\delta 1}^y$) are derived from [9] as follows:

$$TE_{\delta 11}^x: E_y = -Ak_z \cos(k_x x) \cos(k_y y) \sin(k_z z), \quad (1a)$$

$$TE_{1\delta 1}^y: E_x = -Ak_z \cos(k_x x) \cos(k_y y) \sin(k_z z). \quad (1b)$$

The $TE_{\delta 11}^x$ and $TE_{1\delta 1}^y$ modes are excited via the following equations:

$$TE_{\delta 11}^x: \int \vec{E}^* \cdot I_d d\vec{l}, \quad (2a)$$

$$TE_{1\delta 1}^y: \int \vec{E}^* \cdot I_c d\vec{l}. \quad (2b)$$

In the feeding strip line, the common mode current I_c leads the differential mode current I_d by a 90° phase. Thus, the E_x component of the $TE_{1\delta 1}^y$ mode is 90° faster than the E_y component of the $TE_{\delta 11}^x$ mode, and the resulting radiated field is a clockwise rotating right-hand CP (RHCP). When the feeding point is interchanged with the shorting point, the direction of I_d is reversed while I_c remains the same. Now I_d is 90° faster than I_c and it is easily understood that left-hand CP (LHCP) can be obtained.

III. Experimental Results and Discussion

Optimizations of return loss and the axial ratio are obtained by designing the loop feed parameters $w1$ and $w2$, and they are optimized near $w1=3$ mm and $w2=4$ mm. Measured radiation patterns in the x - z and y - z planes of GPS bands (1.57 GHz) are shown in Fig. 4. The cross-polarization level is about 15 dB lower than the co-polarization level.

Figures 5 and 6 show the simulated and measured return losses and axial ratios of the proposed DRA, respectively. The simulated return loss and measured return loss exhibit impedance bandwidths ($S_{11} < -10$ dB) of 8.5% and 5.4%,

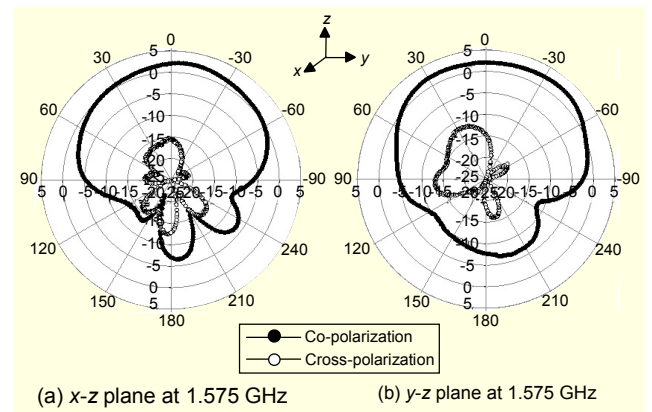


Fig. 4. Measured radiation patterns.

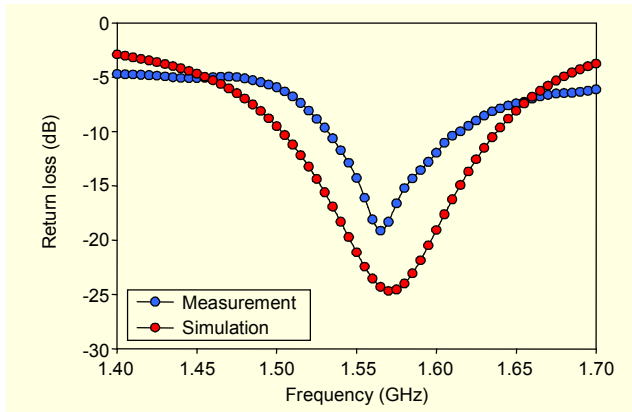


Fig. 5. Simulated and measured return losses of DRA.

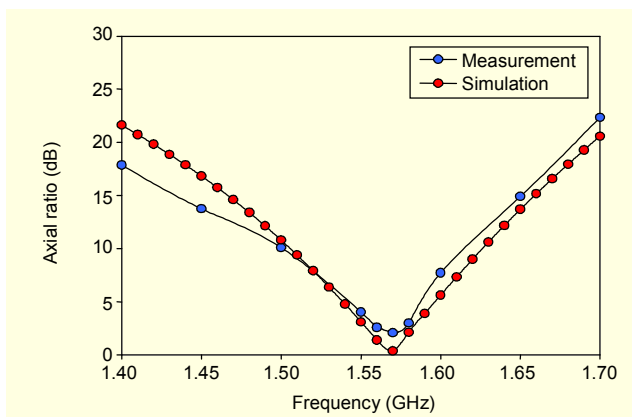


Fig. 6. Simulated and measured axial ratios of DRA.

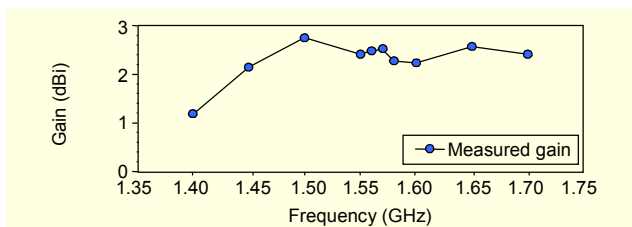


Fig. 7. Measured gains of the proposed antenna.

respectively. The measured resonant frequency is 1.565 GHz, which is in good agreement with the simulated resonant frequency of 1.57 GHz. The simulated and measured 3 dB axial ratio bandwidths were found by measurement to be 2.3% and 1.95%, respectively. The simulated and measured 3 dB axial ratios are similar to those of conventional single-fed CP DRAs [10].

The gain of the proposed antenna was measured to be about 2.5 dBi in the GPS band as shown in Fig. 7.

IV. Conclusion

A new feeding method for the CP DRA was proposed. The

proposed CP DRA is fed by the currents of the differential and common modes having a 90° phase difference from a loop-type single feed structure. An RHCP DRA for application in GPS was designed using the proposed feeding method, and good CP performance was obtained. Reasonable agreement between simulation and measurement data was obtained.

References

- [1] Liping Han et al., "Differential Dual-Frequency Antenna for Wireless Communication," *ETRI Journal*, vol. 30, no. 6, Dec. 2008, pp. 877-879.
- [2] Youngie Sung, "A Corner-Fed Microstrip Circular Antenna with Switchable Polarization," *ETRI Journal*, vol. 30, no. 5, Oct. 2008, pp. 718-722.
- [3] R.K. Mongia and P. Bhartia, "Dielectric Resonator Antennas: A Review and General Design Relations for Resonant Frequency and Bandwidth," *Int. J. Microwave Millimeter-Wave Eng.*, vol. 4, no. 3, July 1994, pp. 230-247.
- [4] K.W. Leung and K. Wa, "Conformal Strip Excitation of Dielectric Resonator Antenna," *IEEE Trans. Antennas Propag.*, vol. 48, no. 6, June 2000, pp. 961-967.
- [5] G. Drossos, Z. Wu, and L.E. Davis, "Circular Polarised Cylindrical Dielectric Resonator Antenna," *Electronics Lett.*, vol. 32, no. 4, Feb. 1996, pp. 281-283.
- [6] G. Almpanis, C. Fumeaux, and R. Vahldieck, "Offset Cross-Slot-Coupled Dielectric Resonator Antenna for Circular Polarisation," *Electronics Lett.*, vol. 16, no. 8, Aug. 2006, pp. 461-463.
- [7] R.T. Long et al., "Use of Parasitic Strip to Produce Circular Polarisation and Increased Bandwidth for Cylindrical Dielectric Resonator Antenna," *Electronics Lett.*, vol. 37, no. 7, Mar. 2001, pp. 406-408.
- [8] G.A. Thiele, E.P. Ekelman, and L.W. Henderson, "On the Accuracy of the Transmission Line Model of the Folded Dipole," *IEEE Trans. Antennas Propag.*, vol. 28, no. 5, Sept. 1980, pp. 700-703.
- [9] R.K. Mongia and A. Ittipiboon, "Theoretical and Experimental Investigations on Rectangular Dielectric Resonator Antennas," *IEEE Trans. Antennas Propag.*, vol. 45, no. 9, Sept. 1997, pp. 1348-1356.
- [10] M.B. Oliver, R.K. Mongia, and Y.M.M. Antar, "Circularly Polarised Rectangular Dielectric Resonator Antenna," *Electronics Lett.*, vol. 31, no. 6, Mar. 1995, pp. 418-419.