Metallic post-array loaded cylindrical dielectric resonator antenna

Byeong-Yong Park, Tae-Wan Kim, Seong-Ook Park

Department of Electrical Engineering, Korea Advanced Institute of Science and Technology (KAIST), 291 Daehak-ro, Yuseong-gu, Daejeon 305-701, Republic of Korea
E-mail: bogo3617@kaist.ac.kr

Abstract: An investigation of a novel cylindrical dielectric resonator antenna (DRA) configuration has been carried out. It is shown that two resonances including the full- and half-cylindrical $HE_{11\delta}$-like modes can coexist simultaneously at different frequencies by placing a metallic post array in the resonator. Moreover, compared with the conventional $HE_{11\delta}$ mode cylindrical DRA having the same size, the proposed antenna operates in lower frequency band and shows improved bandwidth. The experimental results including the return loss and the radiation patterns are demonstrated.

1 Introduction

Dielectric resonator antennas (DRAs) are attractive for high-frequency applications because of their merits including compact size, high radiation efficiency, ease of excitation, light weight, and low cost [1]. Many efforts have been paid to evaluate the modes of operation of the DRAs [2] and to excite the DRAs with various feeding mechanisms such as probe, microstrip line, microstrip slot-coupled, and co-planner waveguide [3]. Furthermore, with the development of wireless communications, size reduction methods for DRAs have been investigated in the literatures [4–6]. However, size reduction and bandwidth enhancement of DRAs are still a technical challenge. In this paper, a simple cylindrical DRA (CDRA) having two adjacent resonances with similar radiation performance is presented to operate in the typical $HE_{11\delta}$-like mode and a unique mode. The latter consists of two half-cylindrical $HE_{11\delta}$ modes, which are introduced by a metallic post array (MPA). The proposed antenna combines a conventional
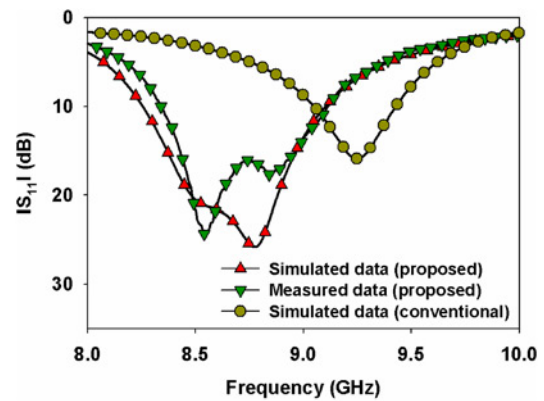

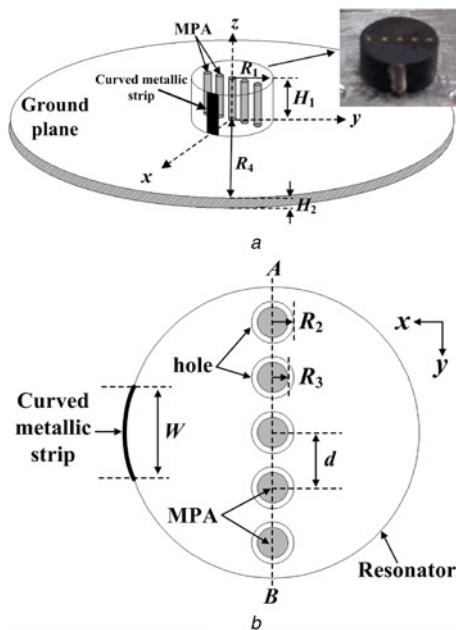**Fig. 2** *Return loss characteristics for the proposed antenna and conventional CDRA*

Fig. 1 *Geometry of the proposed antenna*
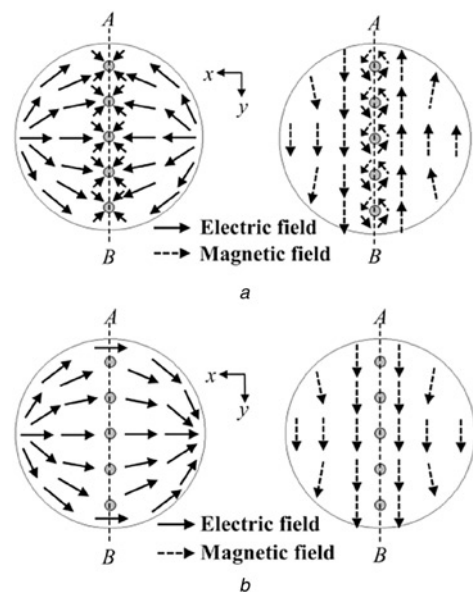*a* Three-dimensional view
b Top view

Fig. 3 *Simulated field distribution inside resonator at two resonant frequencies*
a 8.45 GHz
b 8.795 GHz

CDRA and an MPA, thereby achieving not only lowered operating band (miniaturisation) but also improved bandwidth.

2 Antenna configuration

The geometry of the proposed antenna is illustrated in Fig. 1. The antenna consists of a resonator, a ground plane, and an MPA. The proposed antenna is based on $HE_{11\delta}$ mode CDRA. The resonator is made of a ferrite material (3-2002 from Pacific ceramics) with permittivity $\varepsilon_r = 16.8$ and a saturation magnetisation of $4\pi M_s = 1960$ G and is chosen to be a disk of circular cross-section with a radius of R_1. The resonator consists of five holes with a radius of R_2 to place the MPA elements with a radius of R_3, and both have the same height of H_1. Distance between the adjacent holes is d. The MPA is located at the centre of the holes along the centre line AB and is connected to ground. The resonator is placed on a conducting ground plane, which was made of aluminium with a radius of R_4 and a height of H_2, and is excited using a curved metallic strip connected to a coaxial probe. A width of the feed strip is W. Note that

the permeability of the ferrite in completely demagnetised state is scalar and can be readily calculated by using (3) in [7]. Though the ferrite is used as the resonator, the proposed antenna without a static magnetic field operates as a DRA.

3 Results and discussion

The proposed antenna has been fabricated and measured successfully. The radius R_2 of the holes was chosen as small as possible due to limitation of fabrication. The geometrical dimensions of the fabricated antenna are as follows: $R_1 = 3.83$ mm, $R_2 = 0.225$ mm, $R_3 = 0.2$ mm, $R_4 = 150$ mm, $H_1 = 3.5$ mm, $H_2 = 3$ mm, $d = 1.45$ mm, and $W = 1.5$ mm. Silver paste was utilised to fix the resonator and the MPA to the ground. Fig. 2 shows the simulated and measured return loss of the proposed antenna. Dual resonances were obtained at 8.54 and 8.84 GHz. The measured impedance bandwidth with 2:1 voltage standing wave ratio (VSWR) is 770 MHz, corresponding to 8.8% with respect to the centre frequency of 8.725 GHz. There is a good agreement with the simulated and measured data.
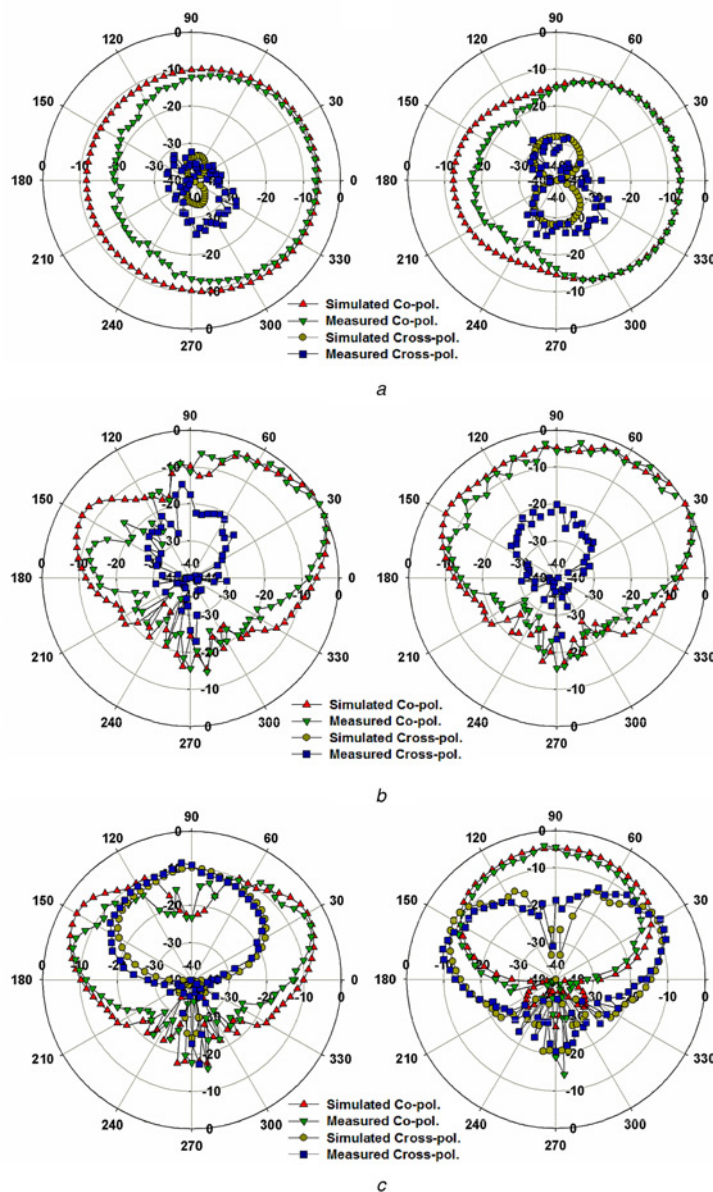

Fig. 4 *Simulated and measured radiation patterns at two resonant frequencies (left: first resonance and right: second resonance)*
a xy-Plane
b xz-Plane
c yz-Plane

Fig. 3 shows the simulated electric and magnetic-field distributions at two resonant frequencies. The fields inside the resonator of the proposed structure are excited by superposing two current components: current on the vertical feeding strip and coupled current on the MPA. The former helps to excite typical $HE_{11\delta}$ mode (full-cylindrical $HE_{11\delta}$ mode), whereas the latter leads to the rotating magnetic field around the posts and the electric field directed toward the centre line AB in which the posts are located. At the lower resonant frequency (8.45 GHz), the electric-field pattern has an even symmetry and the magnetic-field pattern has an odd symmetry with respect to the centre line AB. This is due to strong coupling between the resonator and the MPA. The field patterns look like those induced by a virtual magnetic wall along the centre line AB. The fields on either side of the resonator resemble those of the half-cylindrical $HE_{11\delta}$ mode (see Fig. 1b in [4]). At 8.795 GHz, the coupling of the feeding strip is much stronger than that of the MPA. As a result, the fields in this case closely resemble those of the full-cylinder $HE_{11\delta}$ mode. Though the MPA is placed along the centre line AB, we can preserve the full-cylindrical $HE_{11\delta}$ mode and excite the additional resonance which consists of two half-cylindrical $HE_{11\delta}$ modes.

The antenna without the MPA was simulated for the comparison. The simulated return loss is also presented in Fig. 2. The simulated impedance bandwidth (VSWR < 2) is 380 MHz (9.05–9.43 GHz), corresponding to 4.1% with respect to the centre frequency of 9.24 GHz. Both the electric and magnetic-field distributions of the conventional $HE_{11\delta}$ mode were observed, though they are not shown here for brevity. For the proposed antenna compared with the conventional CDRA, the operating band has been shifted to lower frequency significantly due to the parasitic capacitance originating from the MPA and the bandwidth has been enhanced by two times.

Fig. 4 shows the normalised radiation patterns of the proposed antenna at two resonant frequencies. There is a good agreement with the simulated and measured data. The radiation patterns revealing at the first resonant frequency are similar to those of half-CDRA (see Fig. 9 in [5]), whereas the radiation patterns revealing at the second resonant frequency are similar to those of full-CDRA. However, the proposed antenna demonstrates butterfly-pattern in the yz-plane and improved directionality in the xz-plane for both cases due to the existence of the MPA. These directional characteristics are also found to be similar for the other frequencies in the entire range of frequencies. The gain varies from 7.4 to 8.4 dBi in the operating band with a peak value of 8.4 dBi at 8.74 GHz. In addition, the simulated total efficiency is more than 97% in the operating band.

4 Conclusion

A novel CDRA with an MPA is presented in this paper. Two resonant modes including the full- and half-cylindrical $HE_{11\delta}$ modes were successfully achieved due to an additional coupling to CDRA by introducing the MPA. The proposed antenna has wider bandwidth while retaining a good impedance matching and operate in the lower band compared with the conventional $HE_{11\delta}$ mode CDRA having same size. On the basis of the results, the MPA is found to be sufficiently effective in terms of antenna miniaturisation and bandwidth. Moreover, the proposed antenna offers an acceptable radiation performance with improved directionality in the entire range of frequencies. It could be suitable for various X-band applications.

5 Acknowledgments

6 References

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