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A Circularly Polarized Truncated Conical Dielectric Resonator Antenna with Parasitic Element

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1. Introduction

For satellite and land mobile communication systems, circularly polarized antennas with good axial ratio over wide angular range are required. Small and lightweight antennas with good characteristics are needed in the particular case of mobile terminals. However, realization of small antennas with good axial ratio over wide angular range is difficult because of amplitude and phase differences between two orthogonal components of electric field in the wide range of angle.

Dielectric resonator antenna (DRA) has several merits such as small size, low loss characteristics and flexible design for system requirements. For circularly polarized DRA, many types of DRA have been proposed such as a DRA excited by a cross-slot [1], a cross-rectangular DRA [2], and a DRA with a parasitic element [3]. A cylindrical DRA with parasitic element has been studied and low axial ratio was realized [4]. Though the DRA has 3 dB axial ratio within ±48° beam width, DRA with wider beam width are possible through changing shape of the dielectric resonator.

We have proposed a truncated pyramidal DRA to improve axial ratio in the wide range of angle [5]. The angular range of 3 dB axial ratio of the truncated pyramidal DRA could be ±62°. In this paper, circularly polarized truncated conical DRA (TC-DRA) is investigated to have rotational symmetry of the radiation pattern and axial ratio. Relative power and phase differences between field components of E_θ and E_ϕ are analysed by the use of FEM. The effect of conical shape on relative power of E_θ component is shown in wide angular range for TC-DRAs. Measurement results are shown to confirm calculation results.

2. Antenna model

A TC-DRA is consisting of a truncated conical dielectric resonator, a parasitic element using a strip conductor and a slot for feed on ground plane as shown in figure 1. The parameters of the dielectric resonator are radii a_1 and a_2 of bottom and top, height d and relative permittivity ε_r is of 10. The angle between the surface of the ground plane and the side of the dielectric resonator is α as shown in figure 1 (b). In order to excite circularly polarized wave, the parasitic element on the top of the dielectric resonator is employed and it has parameters of length $2\ell_p$, width w_p and inclination angle ϕ_p from the x-axis as shown in figure 1 (c). The slot length and width were selected so that VSWR could be less than 2 at 3 GHz. In the calculation using FEM, an infinite ground plane was assumed and lumped port was used in the middle of the slot as shown in figure 1 (a). In the measurement, a finite ground plane of disk was used.

Table 1 shows the values of the antenna parameters operating at 3GHz in the $HEM_{11\delta}$ mode. In the table, λ_ε shows wavelength in the dielectric resonator and λ_e also represents wavelength for the parasitic element. The dimensions of the dielectric resonator and parasitic element were selected to obtain good axial ratio in the beam direction [4].

ISBN: 978-4-88552-223-9 C3055©IEICE

3. Radiation characteristics

To investigate the effect of the truncated conical dielectric resonator, the angle α was changed and radiation characteristics versus the angle α were calculated. The selected parameters of the truncated conical dielectric resonator without parasitic element are shown as table 2. The radiation patterns of the TC-DRA with the variation of the angle α are shown in figure 2. The relative power of the field component E_ϕ has almost no variation with respect to the angle α as shown in figure 2 (a), while that of the component E_θ becomes smaller in wide angular range as shown in figure 2 (b). Since the level of the field component E_θ of the TC-DRA almost coincides with the component E_ϕ over the angular range of $\theta = \pm 60°$, the good axial ratio in wide angular range can be achieved.

Radiation characteristics for linear polarization of the TC-DRA with a parasitic element are shown in figure 3. Relative powers of orthogonal field components in the *yz*- and *zx*-planes are nearly equal each other in wide angular range. Phase differences between components become almost constant values of 90° and -270° in the *yz*- and *zx*-planes.

Axial ratios and radiation patterns for circular polarization are plotted in figure 4. In the calculation results, good axial ratio over wide angular range is obtained and its beam width of 3 dB axial ratio is ± 62° in the *yz*- and *zx*-planes. In the radiation patterns of circular polarization, relative power of the field component E_L of left-handed polarization is less than –20 dB within the angle $\theta = \pm 60°$.

Measurement was implemented for the TC-DRA with a circular ground plane of one wavelength. Calculation was also carried out for the same model and radiation characteristics were compared between measured and calculated results. Radiation patterns and axial ratios in the *yz*-plane obtained by using the spin linear method are designated as shown in figure 5. In the figure, calculated E_{max} and E_{min} patterns agree with the outline of the measured pattern. In the beam direction, axial ratios in the measurement and calculation are 0.29 dB and 0.65 dB, respectively. The range of 3 dB axial ratio is ± 45° in the calculation.

4. Conclusion

A circularly polarized truncated conical dielectric resonator antenna with a parasitic element was proposed to obtain wide beam width of good axial ratio over wide angular range. In the calculation for the antenna with an infinite ground plane, the beam width of 3 dB axial ratio could be obtained ± 62° in the *yz*- and *zx*-planes. Measurement for the antenna with a circular ground plane was implemented and comparison for calculated results were shown.

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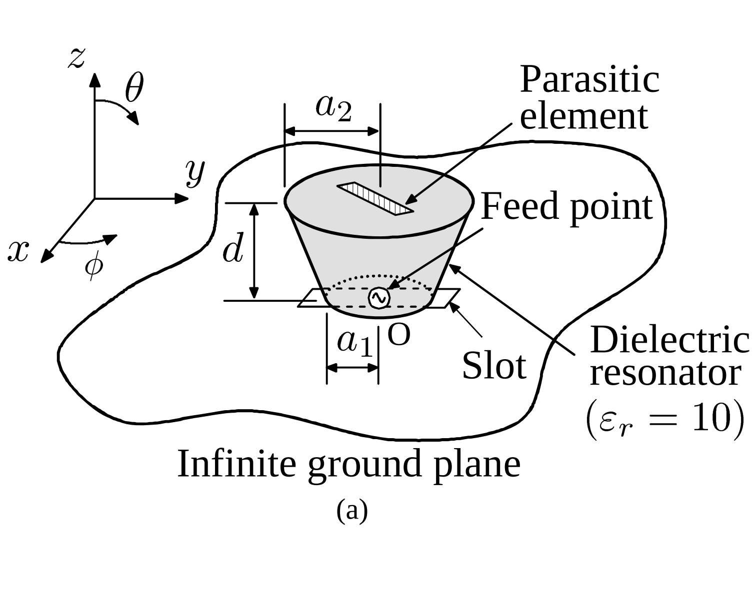


Figure 1: Antenna model of a TC-DRA: (a) perspective view, (b) side view and (c) top view.

Table 1: Antenna parameters of the TC-DRA.

Parameter	a_1 [mm]	a_2 [mm]	d [mm]	α [deg.]	$2\ell_p$ [mm]	w_p [mm]	ϕ_p [deg.]
Value	7.8 $(0.25\lambda_\varepsilon)$	17.0 $(0.54\lambda_\varepsilon)$	16.0 $(0.51\lambda_\varepsilon)$	60	14.6 $(0.34\lambda_e)$	3.8 $(0.089\lambda_e)$	45

$$\lambda_\varepsilon = \lambda_0 \big/ \sqrt{\varepsilon_r}\ ,\ \lambda_e = \lambda_0 \Big/ \sqrt{(\varepsilon_r + 1)\big/ 2}$$

Table 2: Parameters of the TC-DRA without parasitic element.

α [deg.]	a_1 [mm]	a_2 [mm]	d [mm]
90	7.8	7.8	16
60		17.0	
45		23.8	
30		35.5	

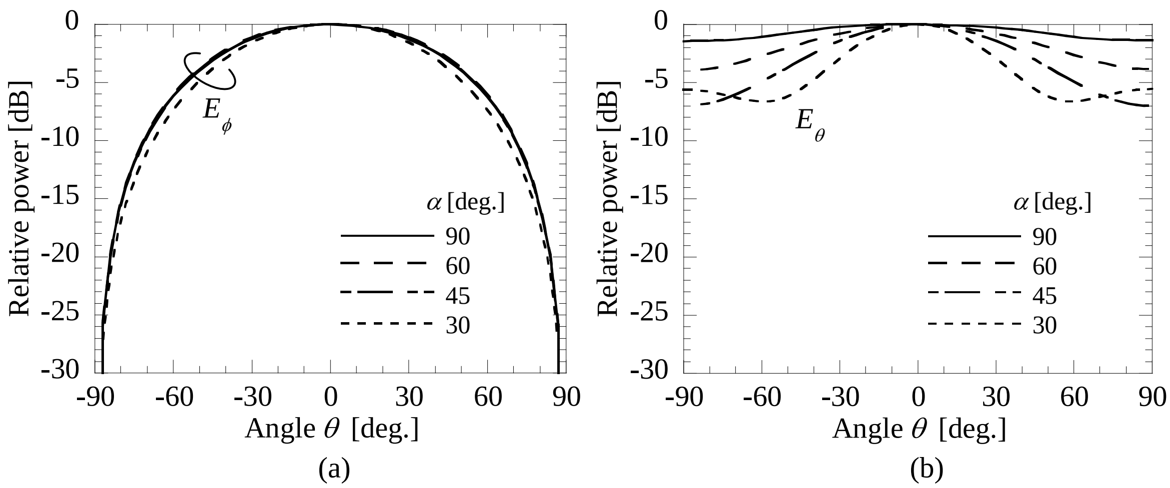
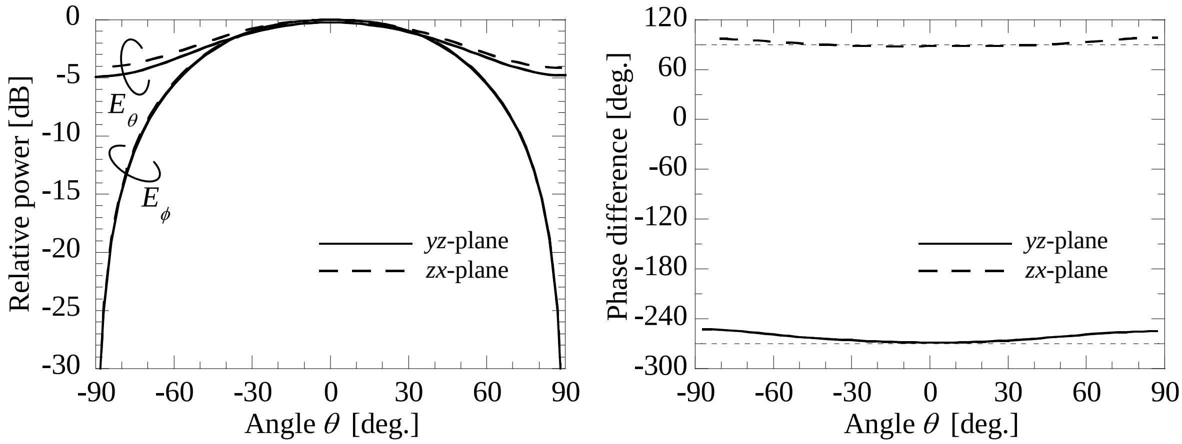
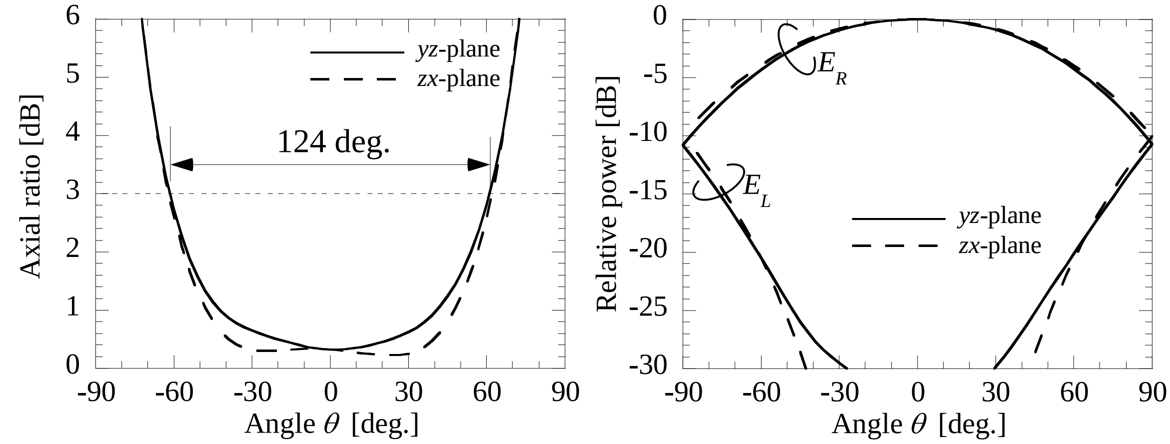


Figure 2: Radiation patterns (a) E_ϕ in the *yz*-plane and (b) E_θ in the *zx*-plane for the TC-DRAs without parasitic element with respect to different α. The relative power was obtained by normalization with a maximum level for model of each angle α.



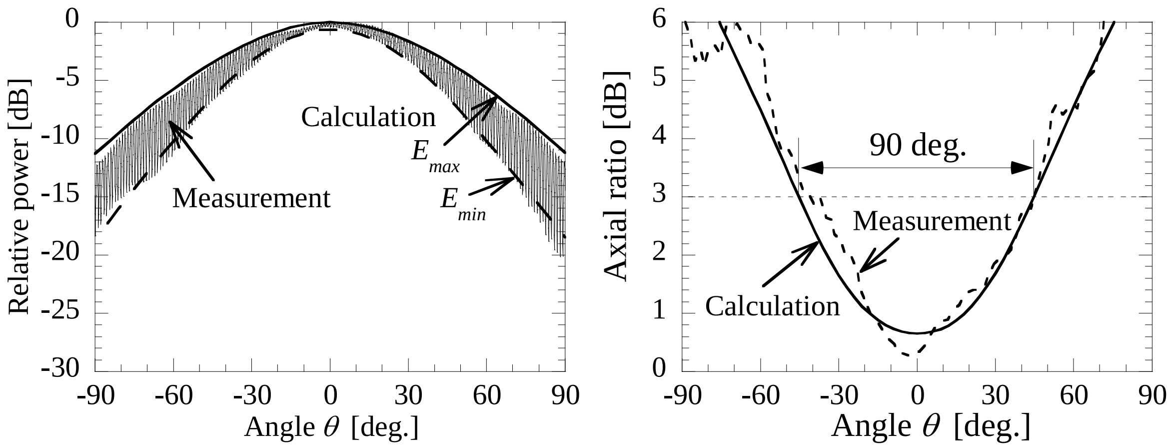
(a) (b)

Figure 3: Radiation characteristics for linear polarization of the TC-DRA with parasitic element: (a) radiation patterns and (b) phase differences between E_θ and E_ϕ.



(a) (b)

Figure 4: Radiation characteristics for circular polarization of the TC-DRA with parasitic element: (a) axial ratios and (b) radiation patterns.



(a) (b)

Figure 5: Comparison between measured and simulated results for the TC-DRA on a circular ground plane: (a) radiation patterns and (b) axial ratios in the *yz* plane.