RADIATION CHARACTERISTICS OF A SHORT DIELECTRIC ROD ANTENNA WITH ZONE PLATES

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1. Introduction

A dielectric rod antenna has been known as an end fire radiator in the microwave and millimeter-wave regions [1],[2]. The directivity of the antenna is characterized by the radiation fields generated at the free and feed ends of the rod [3],[4]. The radiation from the feed end significantly affects the sidelobe level. Therefore, an appropriate feed arrangement must be used to minimize unwanted radiation from the feed end.

When the rod is fed by a metallic waveguide, the unwanted radiation from the feed end can be minimized by the use of a horn launcher [1],[2]. However, the horn needs a bulky space in the longitudinal direction. To reduce the dimension in the longitudinal direction, we propose an antenna system in which a short dielectric rod is mounted on a launcher composed of a rectangular waveguide with a planar ground plane (GP) and metallic zone plates (ZPs) [5].

First, consideration is given to the radiation from a rectangular aperture with a finite GP. The radiation pattern and gain of the antenna system are evaluated using the FD-TD method [6]. The gain shows a cyclical variation with an increase in the GP size. To obtain an increased gain, the GP is partially covered by the ZPs.

Second, we discuss the performance of a dielectric rod antenna with two ZPs. The antenna realizes a sharp beam with a low sidelobe level. It is found that the antenna maintains a gain of $11\,\mathrm{dB}$ with a rod length reduced to one-quarter of that without the ZPs.

2. Configuration

Fig. 1 shows the configuration and coordinate system of a dielectric rod antenna with two ZPs. The relative permittivity of the rod is chosen to be $\varepsilon_{r,rod} = 2.25$. The dimensions of the rectangular aperture of a metallic waveguide, which are the same as those of the rod, are specified by *a* and *b*.

A launcher is composed of an elliptical GP and ZPs. It is assumed that the GP and ZPs are perfectly conducting. The size of the GP is adjusted by L_G shown in Fig.1. The waveguide is excited with the TE_{10} mode at a frequency of $9\,\mathrm{GHz}$ ($\lambda_0 \cong 33.3$ mm).

3. Discussion

The FD-TD method is used for evaluating the radiation characteristics. The grid widths are fixed to be $\Delta x = a/22$ ($\cong$ 1.04 mm), $\Delta y = b/10$ (= 1.02 mm), and Δz = 1 mm. Owing to the symmetry of the configuration with respect to the x-z and y-z planes, the antenna can be analyzed using a quarter region of $L_x \times L_y \times L_z = 120\Delta x \times 120\Delta y \times 100\Delta z$.

Before considering the antenna system shown in Fig. 1, we investigate the radiation from the rectangular aperture with a finite GP under the condition that the ZPs and the rod are removed from Fig. 1. The directivity is characterized by the electric and magnetic fields in the aperture and the electric current density on the GP. Based on this fact, we study the influence of the electric current density on the radiation characteristics.

Fig. 2(a) shows the distribution of the electric current density J_y ($= n \times H_x$) on a GP whose size is large enough to neglect the reflection from the GP edge. It is observed that J_y in the y-z plane is greater than that in the x-z plane. J_y exhibits a traveling wave characteristic with decay in the radial direction. The corresponding phase in Fig. 2(b) shows that the equiphase lines form ellipses, and that the wavelength of the traveling wave is close to λ_0. There are two regions in terms of phase relationship between J_y and aperture fields. One is the region where desirable J_y dominates, which is in-phase with respect to the aperture fields. The other is the region where undesirable J_y dominates, which is out-of-phase. Hence, the radiation pattern and gain must be varied with a change in L_G.

Figs. 3(a) and (b) present the typical radiation patterns for two values of L_G. Comparison between the patterns shows that the main beam in the H-plane becomes narrow when L_G is increased from 8.2 mm to 80 mm: the half-power beamwidth (HPBW) changes from $\pm 35°$ to $\pm 12.5°$. It is also noted that ripples are observed in the E-plane (y-z plane) for $L_G \cong$ 80 mm. The ripples are caused by the effect of the undesirable J_y. Owing to the variation in the pattern, the gain has a cyclical variation with an increase in L_G as shown in Fig. 4 (●). It is expected that a higher gain can be obtained by shielding the radiation from the undesirable J_y.

To eliminate the effects of the undesirable J_y, the ZPs with a width of λ_0 / 2 ($\cong$ 17 mm) are placed with a spacing of λ_0 / 2, as illustrated in Fig. 1. The distance from the GP to the ZP is fixed to be λ_0 / 4 ($\cong$ 8 mm).

The effect of the ZPs on the gain is also presented in Fig. 4. When a GP of $L_G \cong$ 42 mm is partially covered by one (inner) ZP, the gain increases by 4.1 dB (○). To further increase the gain, the size of the GP is extended to $L_G \cong$ 80 mm and two ZPs are placed above the GP. In this case, the gain is increased by 5.8 dB (▲), with the radiation patterns shown in Fig. 5. The HPBW is calculated to be $\pm 7°$ and $\pm 12°$ in the E- and H-planes, respectively. The maximum sidelobe level is -6.9 dB in the E-plane. The launcher composed of the GP and ZPs has a sharper beam than that without the ZPs. It is worth mentioning that the launcher has a planar-type configuration with a thickness of λ_0 / 4, as opposed to a horn launcher.

We finally mount a short dielectric rod on a GP of $L_G \cong$ 80 mm with the two ZPs. Fig. 6 shows the radiation patterns for a rod length of L_R = 24 mm. The maximum sidelobe level is reduced to -9.4 dB, and the gain is calculated to be 11 dB. Note that the conventional antenna in which a long dielectric rod is mounted on the GP without the ZPs needs at least a length of L_R = 90 mm to obtain a gain of 11 dB. It can be said that the use of the launcher composed of the GP and the ZPs contributes to a reduction in the rod length without losing high gain.

4. Conclusions

We have analyzed a short dielectric rod antenna launched by a rectangular waveguide with a planar GP and ZPs using the FD-TD method. It is found that the antenna has a sharp beam with a low sidelobe level. A gain of 11 dB is obtained with a rod length reduced to one-quarter of that without the ZPs.

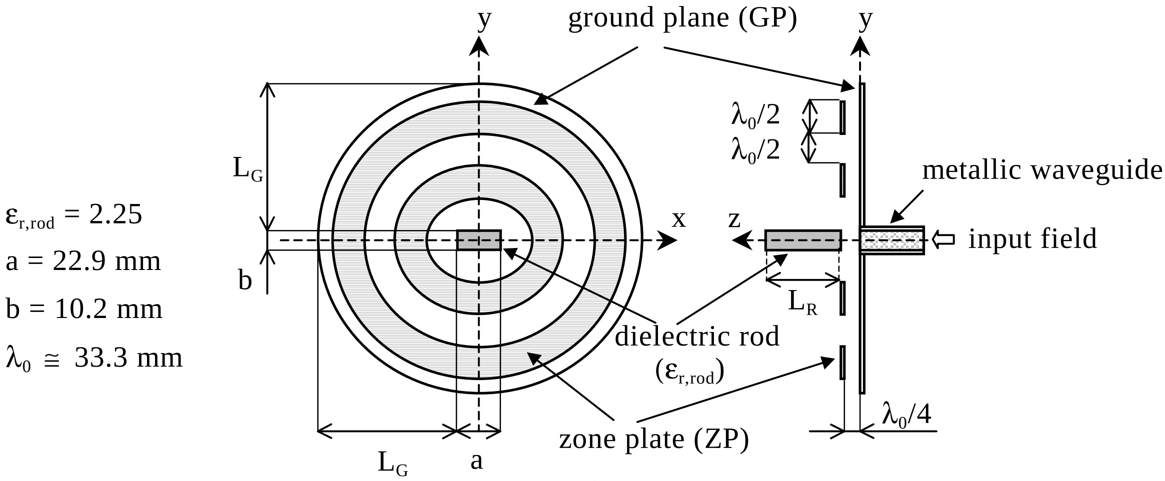
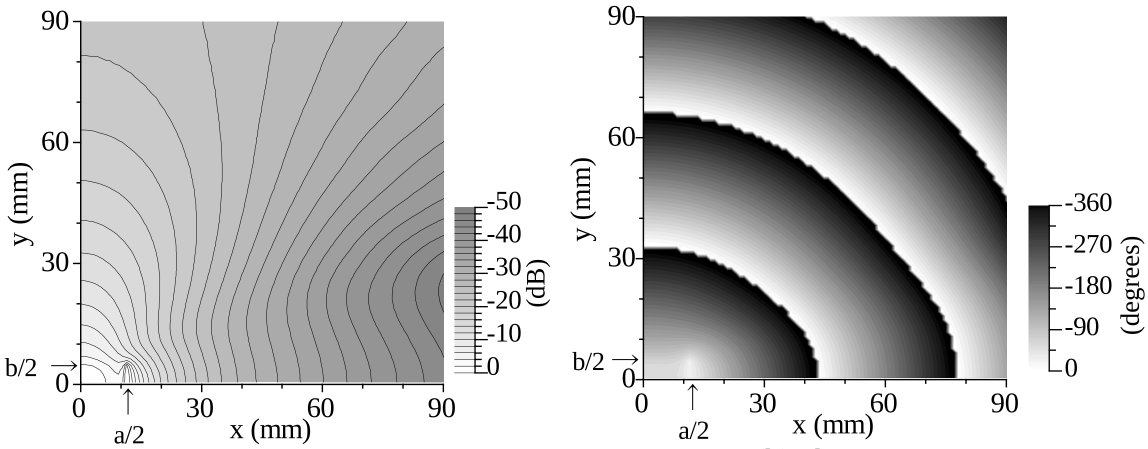
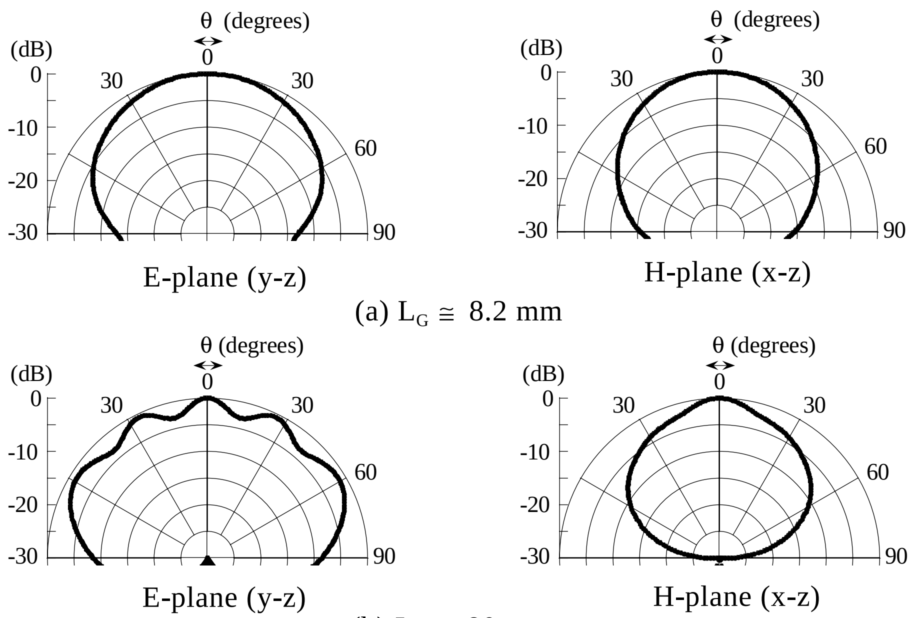


Fig. 1 Configuration



(a) density (b) phase

Fig. 2 Distributions of J_y on the GP (quarter region)



(a) $L_G \cong$ 8.2 mm

(b) $L_G \cong$ 80 mm

Fig. 3 Radiation patterns of rectangular aperture with GP

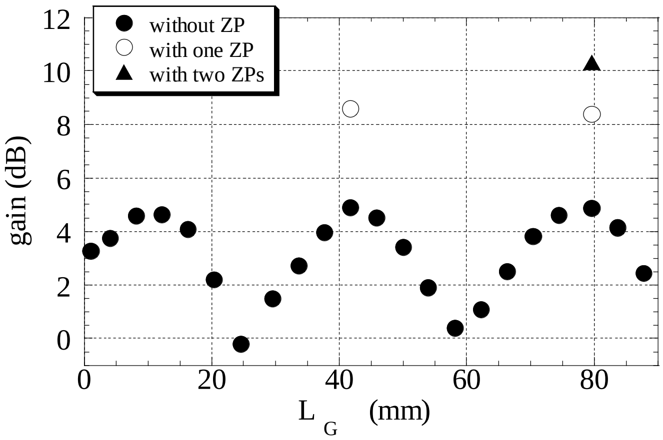


Fig. 4 Gain as a function of L_G

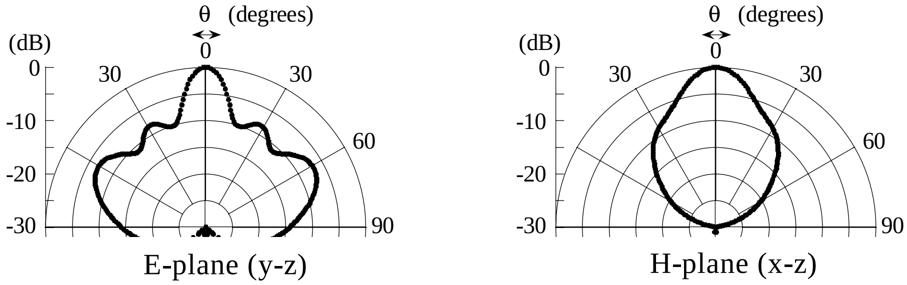


Fig. 5 Radiation patterns of rectangular aperture with GP covered by two ZPs

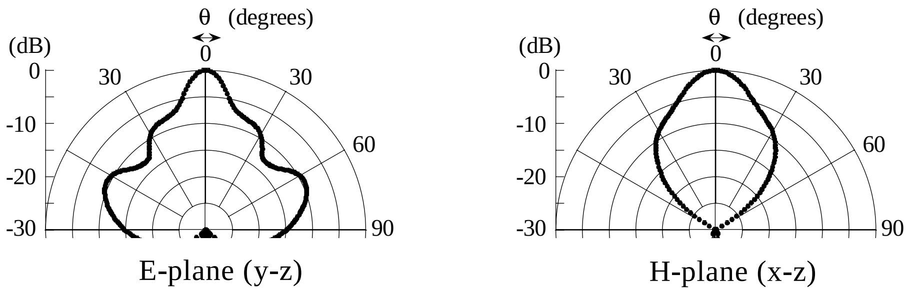


Fig. 6 Radiation patterns of rod antenna with two ZPs (L_R=24mm)

References

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