A DESIGN METHOD OF MULTIMODE HORN WITH LOW CROSS POLARIZATION FOR HIGH EFFICIENCY REFLECTOR ANTENNAS

Hiroyuki DEGUCHI, Mikio TSUJI, and Hiroshi SHIGESAWA
Department of Electronics, Doshisha University
Kyotanabe, Kyoto 610-0321, Japan
E-mail: hdeguchi@mail.doshisha.ac.jp

1. Introduction

Dual- and triple-modes conical-horns, which have a rotationally symmetrical radiation pattern and a low cross-polarization in a simple structure, have been widely used as global-beam antennas and primary radiators of reflector antennas [1]. However, in use of the global-beam antennas, the horns have an aperture distribution with tapered amplitude and phase, so that it is difficult to increase sufficiently the aperture efficiency. For realizing a high efficiency horn, we have developed a multimode horn with a negative flare angle in order to excite effectively higher-order modes [2]. To obtain a novel primary horn for high efficiency reflector antennas, this paper proposes a design method for multimode horns without the corrugations or coaxial-rings.

2. Design and examples

Let us consider a parabola antenna fed by a primary horn with cylindrical waveguide TE_{1n} and TM_{1m} modes on a circular aperture as shown in Fig. 1. Since the secondary pattern of such an antenna can be calculated from secondary radiation fields due to TE_{1n} and TM_{1m} modes and excitation coefficients of these modes on the horn aperture, in case that a diameter of the horn aperture D_h/λ normalized by a wavelength and an angular aperture θ_0 are given, the unknown mode-coefficients are determined by formulas similar to synthesis of array patterns maximizing the antenna gain. These coefficients are actually given by complex conjugate of the secondary radiation field due to each mode in the parabola-axis direction. Figure 2 (a) and (b) show these values to maximize the aperture efficiency of the parabola antenna, where the angular aperture is chosen so that θ_0 becomes sufficiently small. The power of each mode is normalized by that of the dominant TE_{11} mode and is shown as a function of a parameter $u_0 = D_h/\lambda \sin\theta_0$.

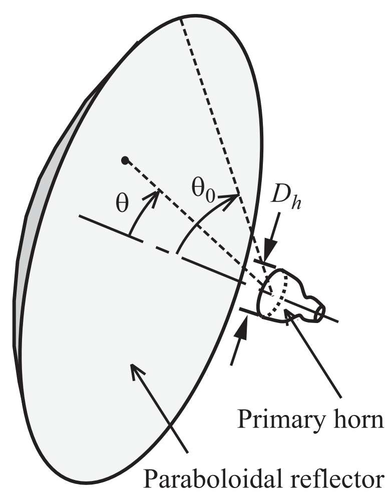
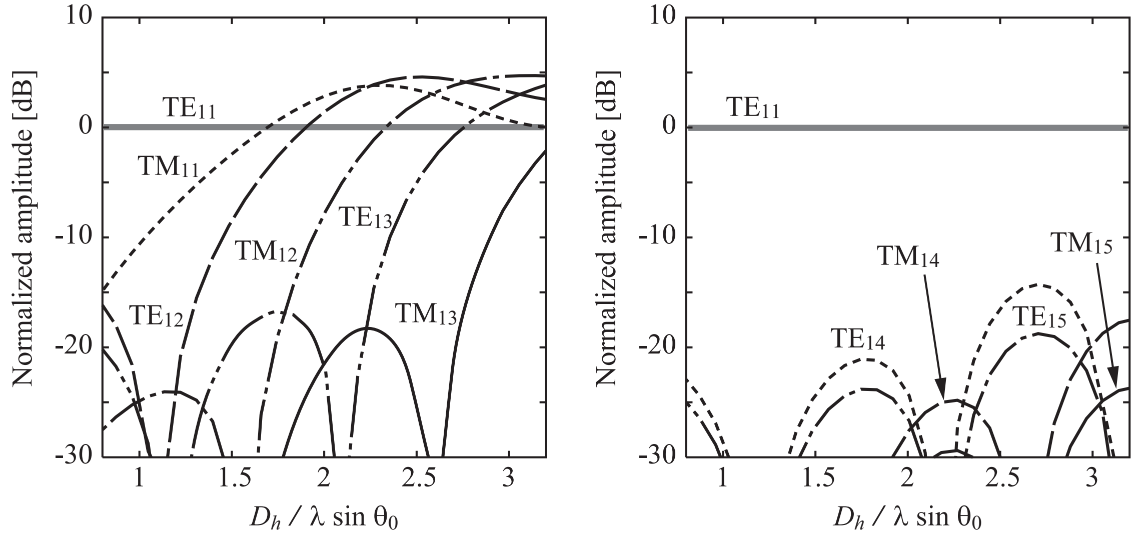


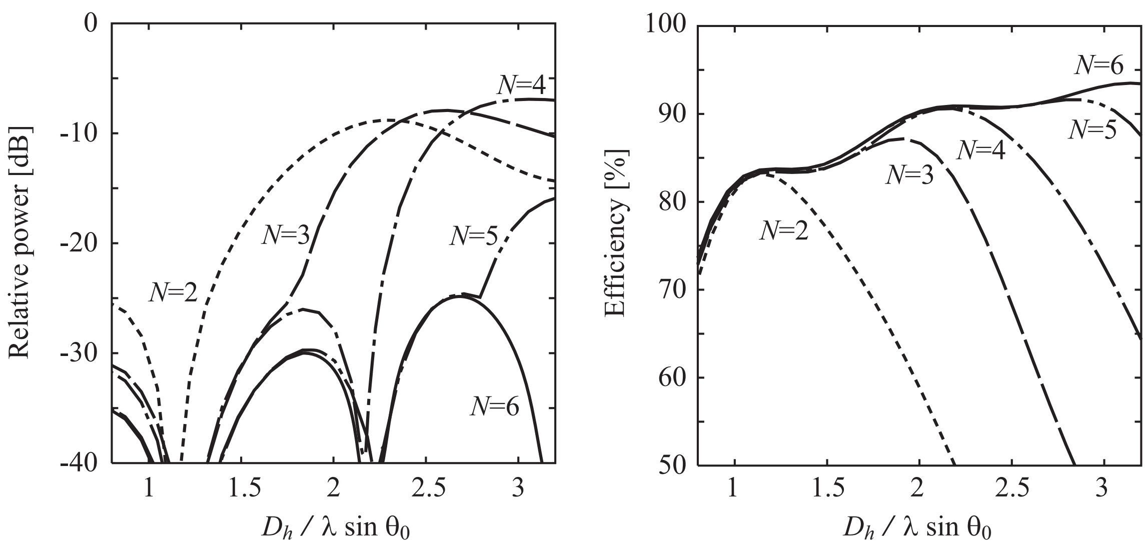
Fig. 1. Design parameters.

Figure 3 (a) shows the peak level of the cross polar-field radiated by the primary horn and (b) shows the aperture efficiency of the parabola antennas as a function of u_0 with the number of modes $N = 2, 3, \cdots 6$. It is found that the cross-polarization level takes periodically the local minimum depending on the parameters u_0 and N. The aperture diameter D_h/λ minimizing the cross polar-field of the primary pattern is determined from null points $u_0 = 1.15, 2.16$ and 3.17 (see Fig. 3 (a)). The first null point is produced by first two modes as shown in Fig. 2 (a), so it corresponds to dual-mode horns used as the primary radiators. As shown in Fig. 3(b), the aperture efficiency becomes higher as the number N increases. In consequence, the aperture efficiency more than 90 % can be achieved at $N \geq 4$.



(a) $n = 2, 3,\ m = 1, 2, 3.$ (b) $n = 4, 5,\ m = 4, 5.$

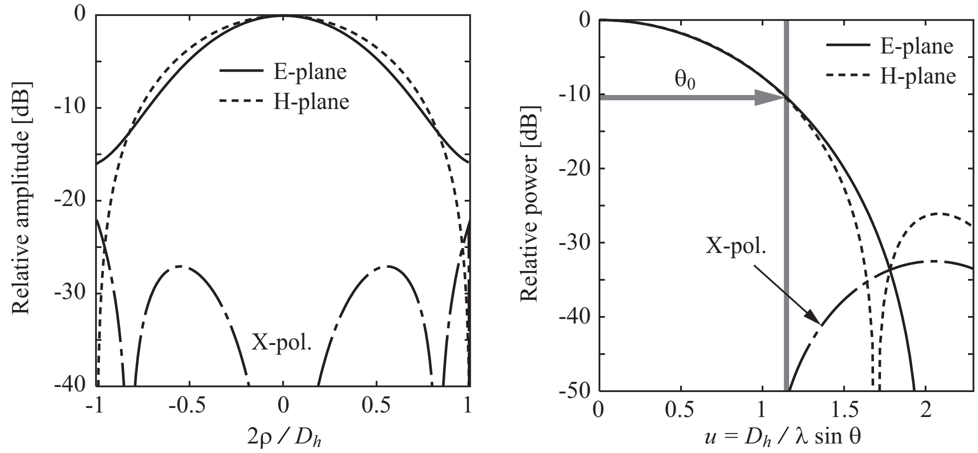
Fig. 2. Excitation coefficients of cylindrical waveguide TE_{1n} and TM_{1m} modes on the horn aperture.



(a) Peak cross-polarization level of primary pattern. (b) Aperture efficiency of parabola antenna.

Fig. 3. Radiation characteristics.

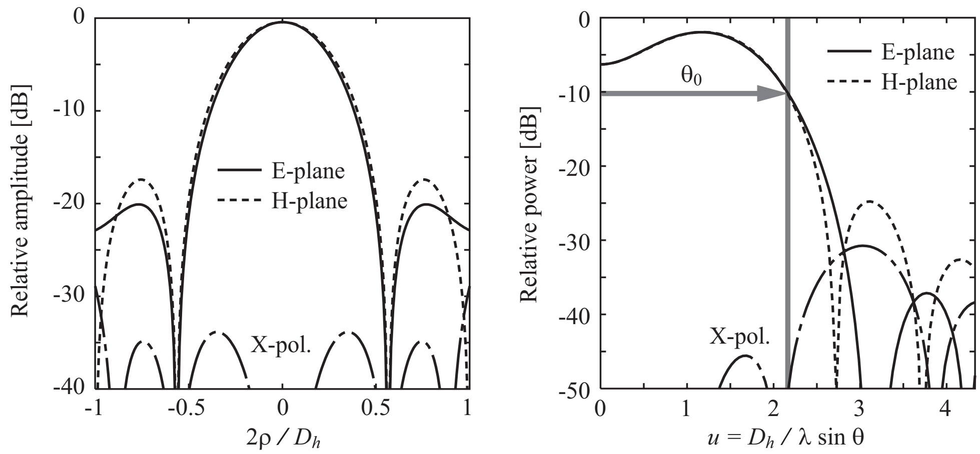
Figures 4, 5 and 6 show the aperture distribution and the primary pattern of horns with $N = 2, 4$ and 6 at sufficiently small θ_0, where $u_0 = 1.15, 2.16$ and 3.17, respectively. In these figures, the co-polar components on the E- and H-planes excited by a linear polarization and the cross-polar component excited by a circular polarization are illustrated, where ρ denotes the radial aperture coordinate. These horns provide rotationally symmetrical co-polar field on both the horn aperture and the reflector surface. The horns in Figs. 4, 5 and 6 have low spillover loss of -0.33 dB, -0.18 dB and -0.13 dB and high aperture efficiencies of 83.4 %, 90.6 % and 93.5 %, respectively. Also the horns with $N = 4$ and 6 (see Figs. 5 and 6) have aperture distribution similar to choke feeds in [3], and yet the low cross-polarization less than -40 dB can be achieved in a simple structure without the corrugations or coaxial-rings.



(a) Horn aperture distribution.

(b) Primary pattern.

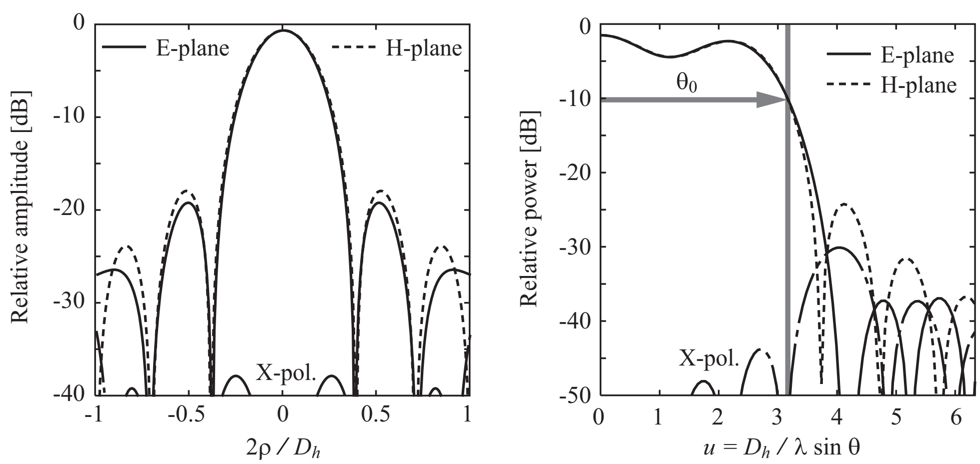
Fig. 4. Primary horn with TE_{11} and TM_{11} modes ($N = 2$), where $u_0 = 1.15$.



(a) Horn aperture distribution.

(b) Primary pattern.

Fig. 5. Primary horn with TE_{11}, TM_{11}, TE_{12} and TM_{12} modes ($N = 4$), where $u_0 = 2.16$.



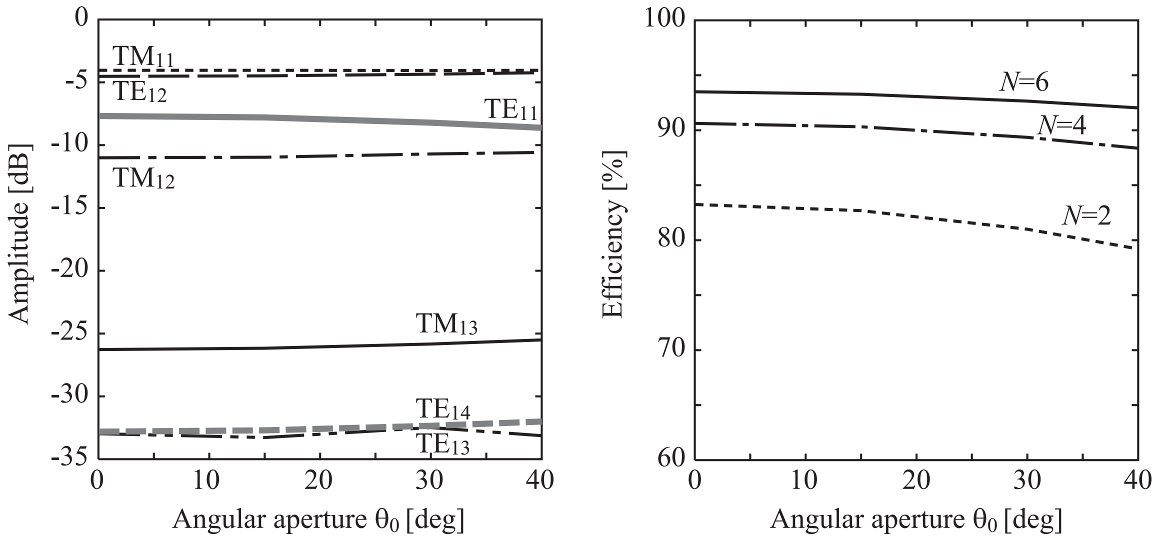
(a) Horn aperture distribution.

(b) Primary pattern.

Fig. 6. Primary horn with TE_{11}, TM_{11}, TE_{12}, TM_{12}, TE_{13} and TM_{13} modes ($N = 6$), where $u_0 = 3.17$.

3. Evaluation and conclusions

Figure 7 (a) shows the excitation mode coefficients at the second null point of u_0 minimizing the cross polar-field of the primary pattern. The effect of the angular aperture θ_0 is sufficiently small. Also Fig. 7 (b) shows the effect of θ_0 on the aperture efficiency at $N = 2, 4$ and 6. It is found that a decrease of the aperture efficiency in an increase of the angular aperture becomes smaller as the number of modes increases. The configuration of the horn realizing the mode coefficients in Fig. 2 can be effectively determined by design methods in [2], [4]. Consequently, high efficiency reflector antennas without shaped-reflectors will be designed by using the proposed horns. At the talk, we will discuss experimentally the test antennas.



(a) Mode coefficients. (b) Aperture efficiency.

Fig. 7. Effect of angular aperture.

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