Radiation characteristics of a parabolic reflector antenna with aperture-distribution shaping

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I. Introduction

In the recent years, interest in the cross polarization problems in dual-polarization antenna systems has been increasing rapidly and many studies have been made so far(1)-(3), etc., in which the topic of interest seems to be centered in offset reflector antennas with low sidelobes. However, such offset reflectors are generally costly and require corrugated horns or dual mode horns as the feeds so as to suppress the cross polarization in the asymmetrical planes of the reflector. These horns are again costly and thereby not suited for low-cost reflector antennas. On the other hand, as the easy-to-fabricate and low-cost antennas, there are many front-fed reflectors used for earth-to-earth communication systems with TE-11-mode horns as the feeds. However, parabolic reflector antennas fed by the TE-11-mode horns generate relatively stronger cross polarization at the 45°-planes to the plane of principal polarization. Naturally, these unwanted cross polarization is required to be eliminated as much as possible so as to maintain high-quality transmission characteristics.
In this paper, some numerical predictions of cross polarization reduction in front-fed reflectors obtained by partially controlling the aperture distribution of the reflectors are presented.

II. Numerical Examples

As is well known, the aperture distribution of a parabolic reflector antenna illuminated by small-aperture circular waveguide horn becomes as in Fig. 1, and the vectors of the cross polarization(E_y)in the first and the third quadrants are directed negative, while those in the second and the fourth quadrants positive.

As illustrated in Fig. 2, when an incident wave, excited along the X axis, goes into the metallic strips, only the perpendicular component to the metallic strips is allowed to pass through the strips and the parallel component is reflected back to the reflector, if the spacing and the width of the strips are properly chosen. It is well understood from this figure that the outgoing polarization is resolved again into the X-polarized(principal polarization)and into the Y-polarized(cross polarization)components. It is then expected that the cross polarization on the aperture would be cancelled by this newly-produced E_y-compo-

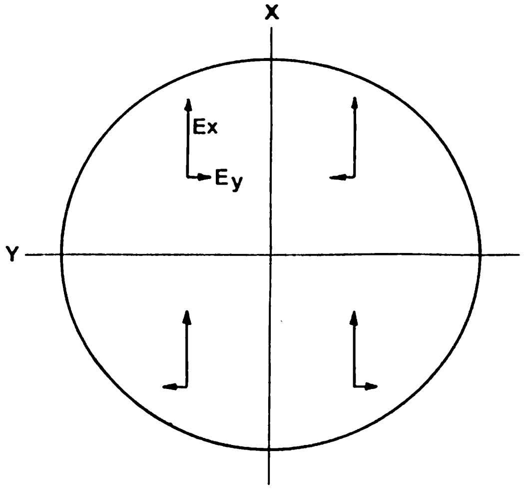


Fig. 1 Field distribution of a parabolic reflector illuminated by a 0.7 λ-aperture circular waveguide horn excited by TE-11 mode along the X axis.

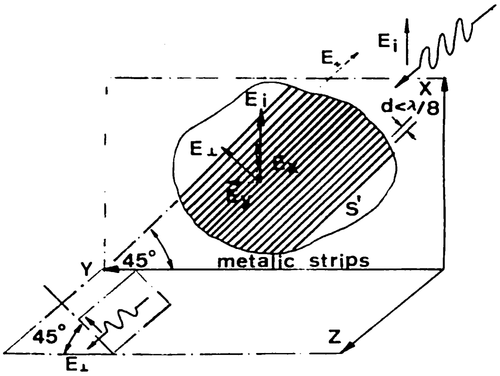


Fig. 2 Principle of polarization conversion by metallic strips.

nents which are obtained by symmetrically mounting metallic strips on the reflector aperture as in Fig. 3. Usually, the amount of cross polarization is of the order of -20dB～-30dB of the peak value of the principal beam. On the other hand, the newly-produced cross polarization by the metallic strips has a strength half that of the incident wave when the angle between the incident polarization and the strips is chosen 45 degrees. Then, it is easily predicted that the area of the metallic strips to be loaded on the aperture for the polarization control would not be so large. With the knowledge that relatively stronger cross polarization on the aperture occurs at the 45°-planes, the loading of the metallic strips was made along these planes.

The far field from the reflector is given by the sum of the field from the S-region and that from the S'-region on the aperture by Silver(4). In the numerical computation, it has been assumed that the effect of the reflected components by the metallic strips

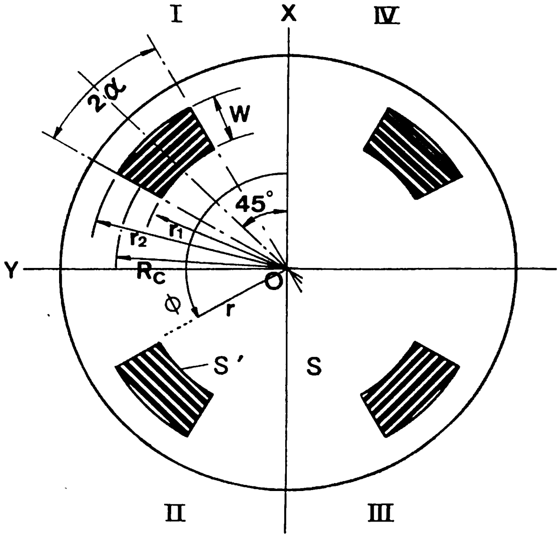


Fig. 3 Configuration of metallic strips.

back to the reflector surface is neglected and that the polarization-conversion by the metallic strips is done uniformly over the S'-region(edge effects are neglected). The reflector used for the numerical computation is a 500㎜-diameter paraboloid reflector with F(focal length)/D(diameter)=0.25. The testing frequency is 10.0 GHz.

Fig. 4 shows the contour lines of the maximum value of cross polarization within the maximum −10dB-angle of the corresponding principal beam. In this example, the value of the −10dB-angle of the secondary principal beam fed by a 0.7 λ -aperture open-ended circular waveguide horn is 3.944 °. The shaded region shows the area where the values of the maximum cross polarization are below −40dB.

Contour lines of the relative again normalized by the peak value of the secondary principal beam maximum are illustrated in Fig. 5 , and it is seen that the rate of the gainloss is found fast when the shaping of the aperture distribution was conducted in the middle portion on the reflector aperture. It is also understood by superposing Fig. 4 and Fig. 5 that the −40dB region appears at the relative gain of about −0.22 dB.

Figs. 6 shows the radiation patterns of the secondary field, in which the dotted lines show those without the shaping, and the solid lines show those with the shaping(W/D=0.04, α=26°, $2R_c/D=0.76$). Fig. 6(a) and Fig. 6(b) show the H-plane and the E-plane patterns respectively, while Fig. 6(c) illustrates the 45°-plane patterns. The maximum −10dB-angle of the principal beam with the shaping is 4.022°. The relative gain with and without the shaping is −0.24 dB. The maximum cross polarization(45°-plane)is observed to be well suppressed below −40 dB within the maximum −10dB-angle. Fig. 6(c) shows that unlike in Figs. 6(a)-6(b), the first sidelobe level of the secondary pattern with the shaping in the 45°-plane is improved by about 4 dB compared with that without shaping.

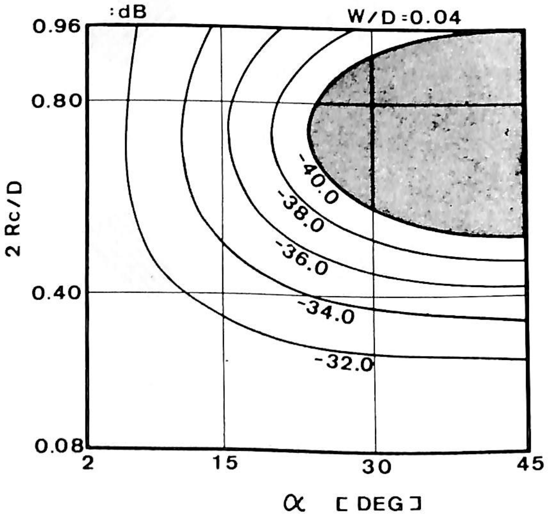


Fig. 4 Contour lines of maximum cross polarization within the −10dB-angle of the principal beam(W/D=0.04).

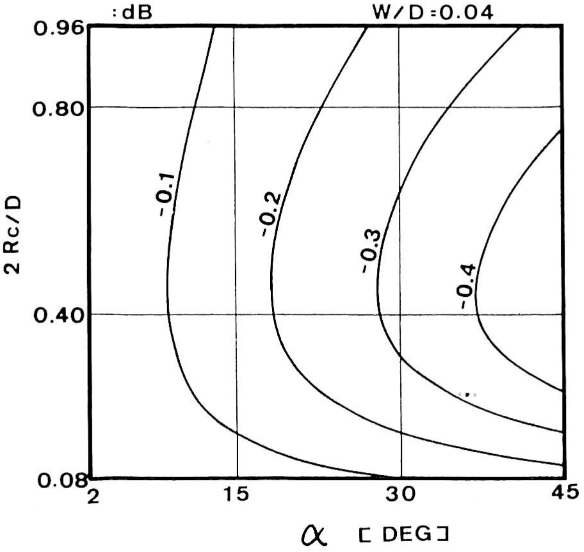
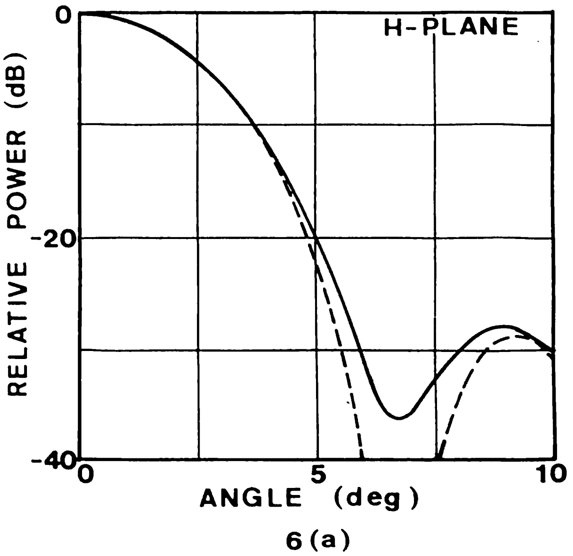


Fig. 5 Contour lines of the gainloss of the secondary beam.

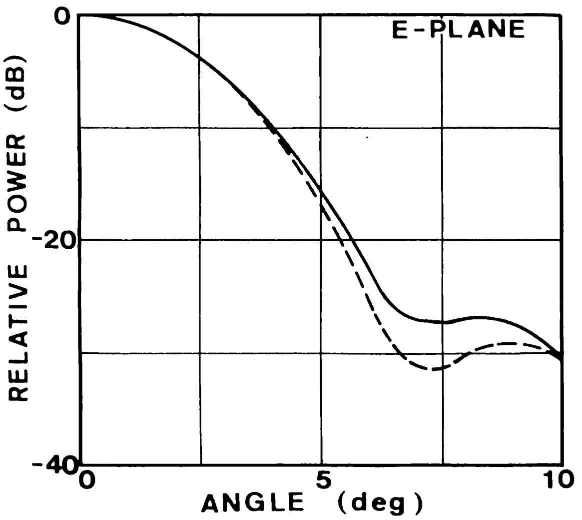
III. Conclusion

It has been shown numerically that the cross polarization from a parabolic reflector could be suppressed by partially controlling the aperture distribution and that the maximum value of cross polarization within the −10dB-angle could be reduced to below −40 dB from the beam maximum. The technique used here in this paper would be applicable to radome-mounted front-fed reflector antennas.

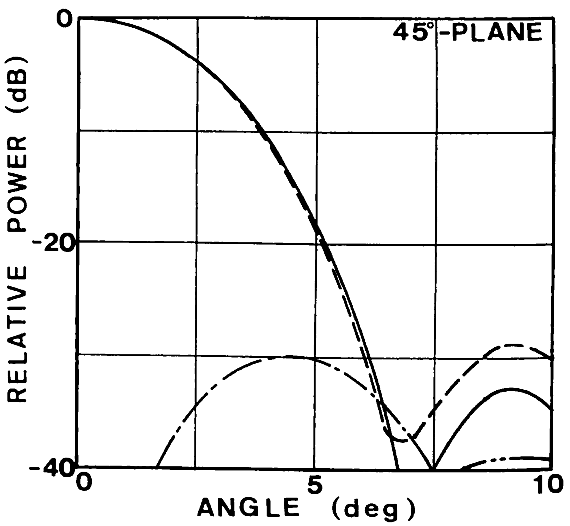
Though not shown here, the value of the maximum cross polarization at the angles



6(a)



6(b)



6(c)

Fig. 6 Radiation patterns of a parabolic reflector antenna fed by a 0.7λ-aperture circular waveguide feed horn at f=10.0 GHz. The dotted lines show the patterns without the aperture distribution shaping, while the solid lines show those with the shaping. In Fig. 6(c), the alternate long and short dash line shows the cross polarization without the shaping, and the alternate long and two short dashes line shows that with the shaping.

wider than the −10dB-angle sometimes becomes relatively higher when the amount of the polarization control exceeded the necessary volume. Some of the problems to be solved further are then (a) to determine the optimum point of polarization shaping on the aperture where the shaping is to be done for a given aperture distribution with lesser gainloss, (b) improvement of frequency response; finite-length metallic strips have a frequency dependency, (c) the suppression of cross polarization at wider angles than the −10dB-angle, (d) to investigate the effects of the loading of the metallic strips on the wider-angle patterns in the principal polarization.

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