Radiation Characteristics of a 1/4 wavelength-plate loaded Parabolic Reflector Antennas

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Introduction

An increasing interest in cross-polarization reduction in reflector antennas has resulted in the development of various primary feeds such as scalar horns, corrugated horns, dielectric-loaded horns, and multi-mode horns having almost circularly symmetric radiation patterns with very low cross-polarized radiations. However, it is of interest to investigate the cross-polarization properties of the parabolic reflector antenna loaded with 1/4 wavelength-plates on the reflector surface converting the incoming wave phase by 180° thereby cancelling the cross-polarized surface currents. In this paper, several numerical computation examples of the radiation pattern of a parabolic reflector antenna with the aperture angle of 90° are presented.

Analysis

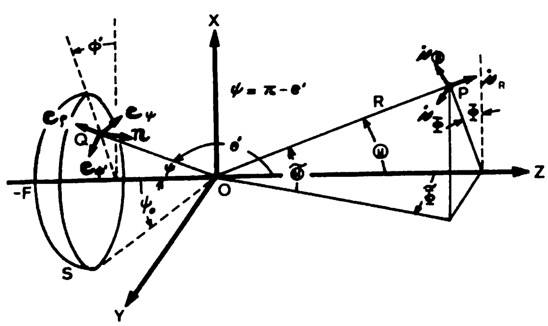

Fig.1 Reflector and observation point co-ordinate system

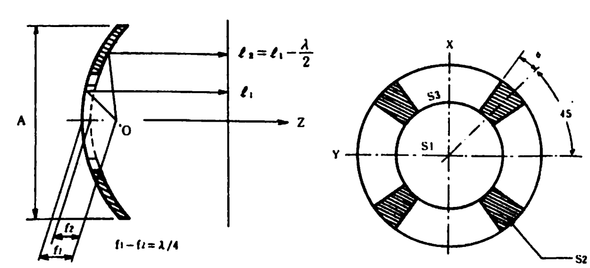

Fig.2 1/4 wavelength-plate loaded reflector geometry

The far-field secondary field intensity $\mathbf{E}_p$ from the parabolic reflector antenna shown in Fig. 1 is computed by the well-known formula by S.Silver (1)

$$\mathbf{E}_P = -j\frac{\omega\mu}{4\pi R}\cdot \exp(-jkR)\int_S [\mathbf{J} - (\mathbf{J}\cdot\boldsymbol{i}_R)\,\boldsymbol{i}_R]\cdot \exp(jk\boldsymbol{\rho}\cdot\boldsymbol{i}_R)\,ds \quad \text{①}$$

where

$$\mathbf{J} = 2\,(\mathbf{n}\times\mathbf{Hi}) \quad \text{②}$$

In eqs. ①-②, **Hi** corresponds to the reflector-surface incoming magnetic field, R is the distance from the origin to the observation point P, $\boldsymbol{i}_R$ is the unit position vector of the observation point, $\boldsymbol{\rho}$ is the position vector of an arbitrary reflector surface point, and η is the outwaid unit normal to the reflector. As shown in Fig.2, 1/4 wavelength-plates are loaded at 45°-planes from the X,Y axses where most of the cross-polarization is produced, and total secondary field is obtained by the vector sum of the fields from region S1,S2,S3. In region S2, the focal length of the reflector f_2 is shorter than f_1 by 1/4 wavelength to change the relative phase by 180 degrees. Though the thickness of the plates loaded to form S2 region doesn't bocome uniform-thickness plates theoretically, 1/4 wavelength-plates can make the S2 region with minor errors if the reflector diameter D satisfies D $\gg$ λ.

Nnumerical computation examples

Fig.3 shows the radiation patterns (principal-and cross-polarized) of the reflector antenna without the plates (aperture angle = 90°, f = 10 GHz) illuminated by an open-ended ciroular waveguide of which aperture diameter is 0.7λ and the maximum cross-polarization level is−29.9 dB from the peak value of the principal polarization. Fig.4 illustrates the plate-loaded reflector patterns fixing α = 10° and varyingβ, and it is shown that the maximum cross-polarization level for β = 50° is going down to−39.0 dB about 9dB lower than that in Fig.3. However, the first sidelobe level of the principal-polarization is simultaneously going up to—17 dB about 12 dB higher and the gain loss for the principal pattern of Fig. 3 is−2.4 dB. Radiation characteristics of the reflector setting β = 60° and changing α is presented is Fig.5, in which maximum cross-polarization level for α = 10° is found to be−36.8 dB with 1.8 dB gain loss, and principal pattern sidelobe level is also going up more than 10 dB. Fig. 6-7 show the two-dimensional patterns without and with the 1/4 wavelength plates (α = 10°, β = 60°) . when plates are loaded, 8 sidelobes higher than−20 dB are found at 45° planes from the principal planes. Concerning cross-polarization, there arise four peaks(−29.9dB) without the plates and the peak value goes down to−36.8 dB with the plates as shown in Fig.5, but the shape of the cross-polarizatios is observed to be divided into two spreading along the principal planes. Simultaneously, other cross-polarized levels are also increasing.

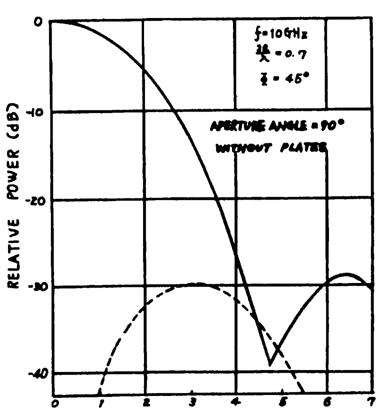

Fig.3 Reflector patterns without 1/4 wavelength-plates
(———— principal-pol. , ······cross-pol.)

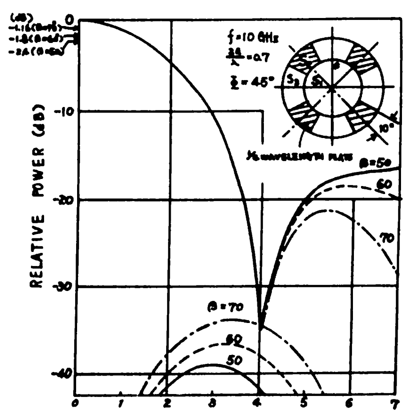

Fig.4 Plate-loaded reflector patterns illuminated by TE-11 mode feed

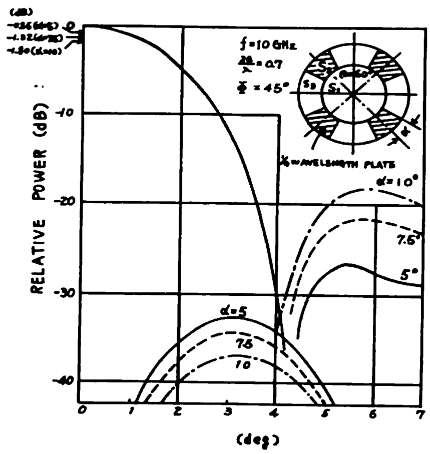

Fig.5 Plate-loaded reflector patterns illuminated by TE-11 mode feed

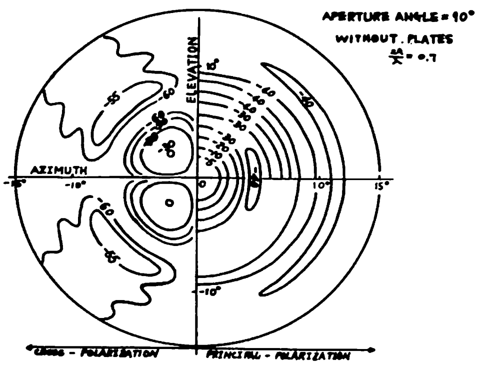

Fig.6 Two-dimensional reflector patterns illuminated by TE-11 mode feed

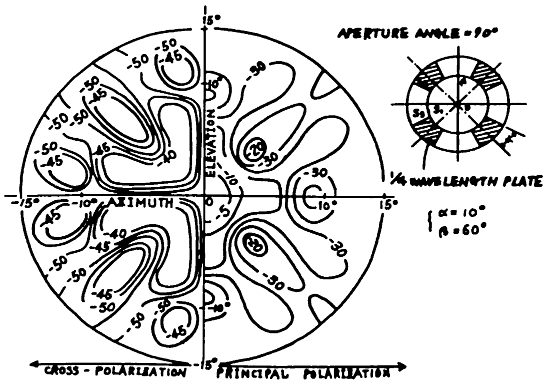

Fig.7 Two-dimensional reflector patterns with 1/4 wavelength plates illuminated by TE-11 feed.

Conclusion

It is shown from the numerical computation that the 45° -plane cross-polarization is suppressed to some extent by the loading of 1/4 wavelength plates on the reflector surface. On the other hand, however, gain loss and principal pattern sidelobe variation are incured. It must further be investigated to what extent the maximum value of the cross-polarization is suppressed under a fixed gain loss.

Acknowledgement

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Reference (1) S.Silver, "Microwave antenna theory and design," pp.149-150, Dover publications, Inc., 1949.