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SLIGHTLY RIGHT-LEFT ASYMMETRIC FEED PATTERN EFFECTS ON A CENTER-FED PARABOLIC REFLECTOR ANTENNA CROSS-POLARIZATION

Katsumasa Miyata
Electrical Engineering, Akita National Technical College

I. Introduction

Precisely measured feed patterns of microwave reflector antennas, both in the E- and in the H-planes, are mostly not completely right-left(R-L) symmetric and have slightly different R-L intensity which produces asymmetrical reflector surface currents. Though the amount of the power difference due to this asymmetry is generally very small and seems to give little effects on the secondary principal patterns, it is of interest to take this even negligibly small amount of asymmetry into consideration of principal plane cross-polarization in a center-fed axial symmetric reflector antenna (no cross-polarization theoretically) and for the investigation of the effects on the two-dimensional cross-polarized patterns.

II. Analysis

The coordinate system of the parabolic reflector antenna with an illuminating primary feed located at the focus of the reflector is shown in Fig.1(a), where R is the distance from the origin to the observation point P, and $\boldsymbol{i}_R, \boldsymbol{i}_\Theta, \boldsymbol{i}_\Phi$ are the unit vectors of the spherical coordinate system (R, Θ, Φ) of the observation point.

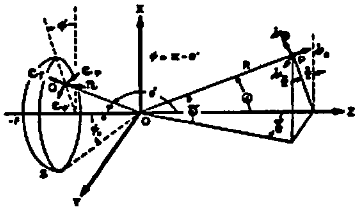

Fig.1(a)
Reflector coordinate system

To consider asymmetrical R-L radiation, E- and H-plane feed patterns are independently expressed as

$$F_E^N(\psi)=f_E^N(\psi)\exp\{j\Psi_E^N(\psi)\} \longrightarrow F_E^N=f_E^N\exp(j\Psi_E^N)$$

$$F_H^N(\psi)=f_H^N(\psi)\exp\{j\Psi_H^N(\psi)\} \longrightarrow F_H^N=f_H^N\exp(j\Psi_H^N)$$

where N is the region number and f_E^N, f_H^N are the feed amplitude patterns in the E- and H-planes, while Ψ_E^N, Ψ_H^N are the phase patterns in these planes. Assuming that the feed is linearly excited along the X axis for the purpose of obtaining specific numerical results, the primary incident field $\mathbf{E}_i^N$ to the reflector at an arbitrary point in the N region(N=1,4) is given by

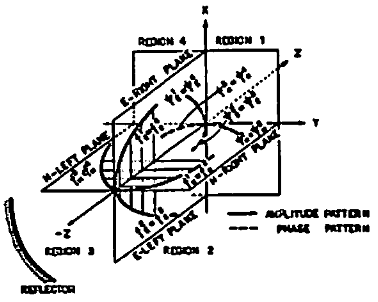

Fig.1(b) Asymmetrical feed patterns

$$E_i^N = (-F_E^N \cos\phi' \, \mathbf{e}_\psi + F_H^N \sin\phi' \, \mathbf{e}_{\phi'}) \exp(-jk\rho)/\rho$$

$$\rho = F/\cos^2(\psi/2)$$

where $k(=2\pi/\lambda)$ is a wave number, F is the focal length, ρ is the distance from the origin O(focus of the reflector) to the reflector surface, and $\mathbf{e}_\psi, \mathbf{e}_{\phi'}$ are the unit vectors of the spherical coordinate system (r', ψ, ϕ'). With the boundary condition

$$F_E^1 = F_E^4 \quad , \; F_E^2 = F_E^3 \; , \; F_H^1 = F_H^2 \; , \; F_H^3 = F_H^4$$

the far-field secondary pattern at the observation point P in above reflector system is computed by the formula by S. Silver(1).

III. Numerical computation examples

The parabolic reflector antenna, used here for the numerical computation is the one with F/D=0.375, D=1800mm, and an illuminating frequency from the feed =19.35 GHz. First in section III-I, the cross-polarization patterns caused by the feeds' amplitude R-L asymmetry are presented and second those by phase R-L asymmetry are shown in section III-II.

III-I. Cross-polarization by amplitude R-L asymmetry(no phase asymmetry)

Following two feeds are chosen for the numerical computation as the typical models:

$$\text{(A)} \quad \left[\begin{array}{l} f_E^N = \cos^{\alpha_N}\psi \\ f_H^N = \cos^{\beta_N}\psi \end{array} \right.$$

$$\text{(B)} \quad \left[\begin{array}{l} f_E^N = \left\{ (1+\cos\psi) \dfrac{J_1(R)}{R} \right\}^{\alpha_N} \\ f_H^N = \left\{ (1+\cos\psi) \, S_{11}^2 \dfrac{J_1'(R)}{S_{11}^2 - R^2} \right\}^{\beta_N} \end{array} \right. \qquad R = \frac{2\pi a}{\lambda}\sin\psi$$

where S_{11} (=1.841184) is the first root of $J_1'(S) = 0$; a is the aperture radius of the primary feed and selected 0.35λ; α_N , β_N (N: region number) are the parameters chosen to simulate a practical feed of R-L asymmetric patterns by giving an arbitrary amplitude to above feeds, and determined, as one of the examples, so as to produce 3% and 6% power difference in the E-and H-planes, respectively, that is

$$\sum\{(f_E^1)^2-(f_E^2)^2\} \,/\, \sum(f_E^1)^2 \to 3\% \quad , \sum\{(f_H^1)^2-(f_H^3)^2\} / \sum(f_H^1)^2 \to 6\%$$

Feed (A) is chosen to investigate cross-polarization properties by the R-L asymmetry under the radiation state of axial symmetry as given by a corrugated horn or a scalar horn, while feed (B) is taken up to investigate the properties again by R-L asymmetry, but under the radiation state of E-H asymmetry as given by a TE-11 mode horn.

Two-dimensional cross-polarized patterns of the reflector antenna by above feed (A) and (B), normalized by the peak value of the principal polarization, are shown in Figs.2-Figs.3, respectively. In both Figs., (a) show the patterns illuminated by the R-L symmetric feed($f_E^1=f_E^2$, $f_H^1=f_H^3$,particularly in Fig.2(a), $f_E^1=f_E^2=f_H^1=f_H^3$) and no cross-polarization appears in both principal planes, (b) show the cases by the feed of both E- and H-plane asymmetry(cross-polarization in both principal planes). It is seen in Fig.2(b) that the whole two-dimensional pattern is completely disturbed by the feed's R-L asymmetry since this is the only factor collapsing axial symmetric feed pattern thereby yielding an unwanted polarization, of which peak value, number of peaks, and their peak position depending upon the amount of the asymmetry.

On the other hand, it is observed in Fig.3(a) that there appears comparatively high level of cross-polarization having four peaks in the $\Phi=45°$planes and that these peaks, unlike in Fig.2(b), still remain dominant even in Fig. 3(b) in which above-determined amount of R-L asymmetry is given showing that R-L-asymmetry-caused cross-polarization is pushed near the principal planes.

III-II. Cross-polarization by phase R-L asymmetry (no amplitude asymmetry)

In the case of a phase R-L asymmetry, several properties not found in the amplitude asymmetry appear. Let the phase patterns be assumed for an example as

$$\psi_H^1=\psi_H^3=0\ ,\ \psi_E^{\overset{1}{2}}=\mp\frac{r_p}{\psi_0}\psi$$

where r_p represents linearly varied phase at the reflector edge. Fig.4 shows some radiation properties of the secondary pattern when above phase term was added to the Fig.3(a) pattern. Fig.5 illustrates principally- and cross-polarized two-dimensional patterns for $r_p=20°$, of which E-plane principal and H-plane cross-polarized patterns are shown in Fig.6. It is observed from these figures that both principally- and cross-polarized two-dimensional patterns move in opposite direction to each other by the R-L phase asymmetry leading to the result that there occur principal pattern beamshift, sidelobe variation, and cross-polarized peaks' position

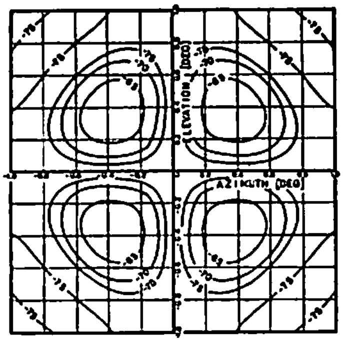

Fig.2(a) Feed(A) with no asymmetry

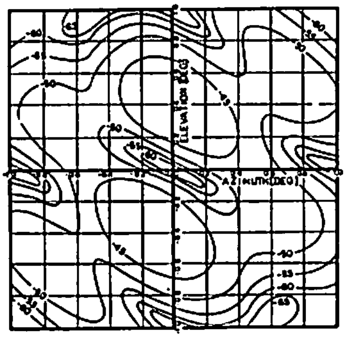

Fig.2(b) Feed(A) with R-L asymmetry

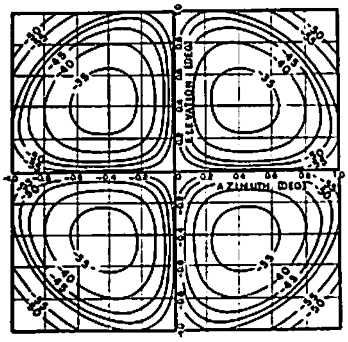

Fig.3(a) Feed(B) with no asymmetry

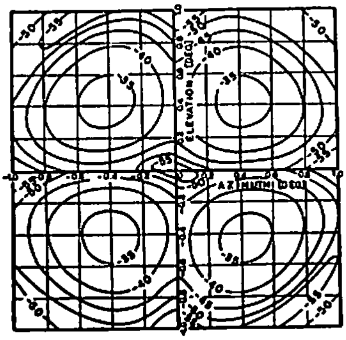

Fig.3(b) Feed(B) with R-L asymmetry

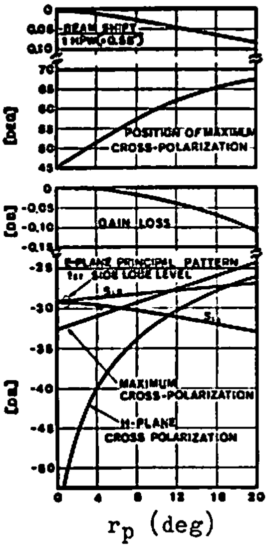

Fig.4 Radiation characteristics due to R-L phase asymmetry

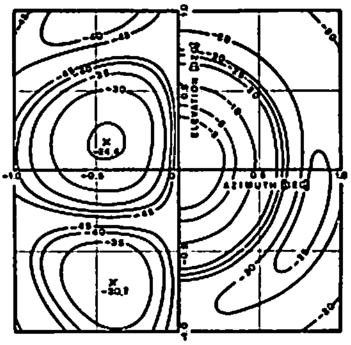

Fig.5 Two-dimensional patterns by phase R-L asymmetry(r_p =20°)

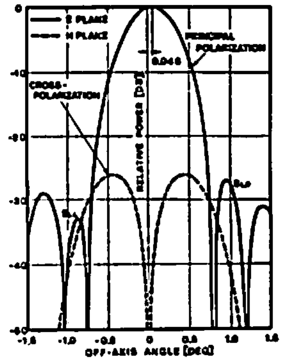

Fig.6 Principal plane patterns of Fig.5

deviation. The principal pattern beamshift in this example is to positive-elevation direction due to the leading ψ_E^2 and lagging ψ_E^1 , and the amount of the shift for the half power beamwidth(HPW) of the E-plane principal pattern of Fig.3(a) is 0.08. The sidelobe patterns become asymmetrical around the principal beam and E-plane first sidelobe level near Θ =0, normalized by the beam maximum, becomes lower(-33.1 dB) than that(-27.0 dB) of the corresponding sidelobe on the other side of the principal beam, whereas the second sidelobe shows inverse structure to the first sidelobe. Cross-polarized peak, increasing its peak value, exists at Φ =67.5° in this example as a result of the whole pattern movement to negative-elevation direction, by which H-plane cross-polarization level accordingly is pulled up to -26.1 dB unlike in the case of the one generated by amplitude R-L asymmetry(Fig.3(b)) with four dominant cross-polarized peaks nearly at Φ =45° planes.

IV. Conclusion

Center-fed parabolic reflector antenna cross-polarization due to slightly R-L asymmetric feed patterns are described. It is shown that even a slight feed asymmetry, both amplitude and phase, gives rise to a cross-polarization in the secondary principal planes and that, in particular, phase R-L asymmetry incurs a movement of the two-dimensional patterns.

V. Acknowledgment

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