CROSSPOLARIZATION OF A PARABOLIC REFLECTOR ANTENNA DUE TO ASYMMETRICAL FEED PATTERN

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1. INTRODUCTION

To meet a rapidly increasing information, microwave antennas have been required to have better electrical, transmission characterristics over wide range. One of the probloms which degrades the transmission quality of a microwave antenna is the crosspolarization. Some studies on the problem have been made already, [1] and it is known that there occurs no crosspolarization theoreticaliy in the E–plane, and H–plane if the primary radiator is excited linearly at the focus of the parabolic antenna. Measured E–plane and H–plane pattern, however, give some crosspolarization even in these two planes.

Several reasons for that are asymmetrical primary radiation, reflector surface error, scattering from the supporting poles of a primary radiator and from a vertex plate (which is used for better impedance matching between the feed and the reflector), etc.

In this paper are described the crosspolarization due to asymmetrical feed radiation.

2. INCIDENT FIELD AND FAR FIELD

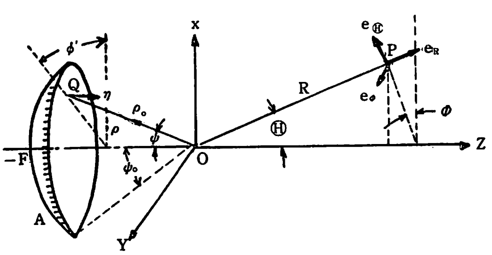

Fig. 1 Coordinate System

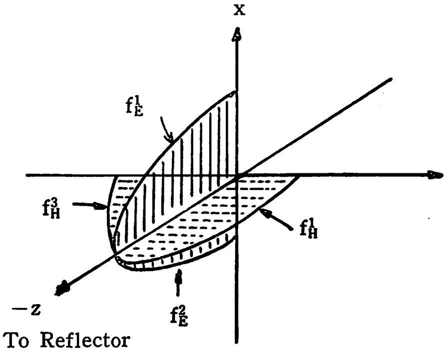

Fig. 2 Asymmettrical Feedpattern

Fig. 1.shows the coordinate system used here, and P, Q are the observation and a surface point on the reflector, respectively.

Radiated field intensity is calculated under the following conditions.

1. The specific parabolic reflector antenna under consideration is located at far zone area from tha feed point, that is;

$$\mathbf{J}_s=\begin{cases}2(\mathbf{n}\times\mathbf{H}_i), & \text{in the illuminated regions.}\\ 0, & \text{in the shadowed regoins.}\end{cases} \quad \cdots\cdots ①$$

2. No backward radiation(scattering) from the feed at the focus.
3. Observation point P is located at far zone area from the reflector, that is; R≫F

Incident field $\mathbf{E}_i$ on the reflector by the feed is given as follows;

$$\mathbf{E}_i=[f_1(\phi',\psi)\mathbf{e}_\psi+f_2(\phi',\psi)\mathbf{e}_{\phi'}]\frac{\exp(-jk\rho)}{\rho}\cdots\cdots ②$$

ρ : distance between the feed point and a point Q on the reflector
k : free–space wave number

Then, the secondary field $\mathbf{E}_p$ at P is, [2]

$$\mathbf{E}_p=-j\frac{e^{-jkR}}{2\lambda R}\left(\frac{\mu}{\varepsilon}\right)^{1/2}[\mathbf{N}-(\mathbf{N}\cdot\mathbf{e}_R)]\cdots\cdots ③$$

where $\mathbf{N}=\int_A 2(\mathbf{n}\times\mathbf{H}_i)e^{jk(\boldsymbol{\rho}_0\cdot\mathbf{e}_R)}dA$

$$=\int_A \mathbf{J}_s\cdot e^{jk(\boldsymbol{\rho}_0\cdot\mathbf{e}_R)}dA$$

$$\mathbf{H}i=\left(\frac{\varepsilon}{\mu}\right)^{1/2}\boldsymbol{\rho}_0\times\mathbf{E}_i$$

3. ASYMMETRICAL FEED PATTERN

To consider asymmetrically radiated field from the feed, the primary feed is divided into four regions, Fig. 2. Assuming the feed is linearly polarized along the X–axis, the field by the feed is described;

$$\mathbf{E}_I^N=[f_E^N(\psi)\cos\phi'\mathbf{e}_\psi+f_H^N(\psi)\sin\phi'\mathbf{e}_{\phi'}]\frac{\exp(-jk\rho)}{\rho}\cdots\cdots ④$$

where N : region number (1–4)

Wrting $f_E^N(\psi)$ as f_E^N, $f_H^N(\psi)$ as f_H^N, then

$$\left.\begin{aligned}f_E^1=f_E^4,\ f_E^2=f_E^3\\ f_H^1=f_H^2,\ f_H^3=f_H^4\end{aligned}\right\}\cdots\cdots ⑤$$

4. CALCULATION OF SECONDARY PATTERN

Surface current density $\mathbf{J}_S^N$ induced by the radiated field from the N th division of the feed is obtained substituting Eq. ④ into Eq. ③ as both $\mathbf{n}$ and $\boldsymbol{\rho}_0$ are easily known in the case of a parabolic reflector,

$$\mathbf{J}_S^N=2\left(\frac{\mu}{\varepsilon}\right)^{1/2}\cdot\left\{-f_E^N\sin\frac{\psi}{2}\cos\phi'\mathbf{e}_\rho+\cos\frac{\psi}{2}(f_E^N\cos\phi'\mathbf{e}_\psi+f_E^N\sin\phi'\mathbf{e}_{\phi'})\right\}\cdots ⑥$$

substituting Eq. ⑥ into Eq. ③, we get secondary pattern.

4—1 FIELD INTENSITY IN THE E-PLANE [$\Phi=0$]

Let normal-polarization and cross-polarization component of $\mathbf{E}_P$ be $E_{NP}(\textcircled{H})$ and $E_{XP}(\textcircled{H})$, respectively,

$$E_{NP}(\textcircled{H})=-j\frac{e^{-jkR}}{\lambda R}\int_0^{\phi_0}\Big[\sum_{N=1}^{4}\int_{(N-1)\frac{\pi}{2}}^{N\frac{\pi}{2}}\{-\cos\textcircled{H}\cos\frac{\phi}{2}(f_E^N\cos^2\phi'+f_H^N\sin^2\phi') + f_E^N\cdot\sin\textcircled{H}\sin\frac{\phi}{2}\cos\phi'\}\cdot 2\rho\sin\frac{\phi}{2}e^{-jk\rho s}d\phi'\Big]d\phi \tag{7}$$

$$E_{xp}(\textcircled{H})=-j\frac{e^{-jkR}}{\lambda R}\int_0^{\phi_0}\Big[\sum_{N=1}^{4}\int_{(N-1)\frac{\pi}{2}}^{N\frac{\pi}{2}}\Big\{(f_H^N-f_E^N)\sin 2\phi'\Big\}\cdot\rho\sin\frac{\phi}{2}e^{-jk\rho s}d\phi'\Big]d\phi \tag{8}$$

where $s=1+\cos\textcircled{H}\cos\phi-\sin\textcircled{H}\sin\phi\cos\phi'$

Integration of Eq. ⑦, ⑧ with respect to ϕ' from 0 to 2π gives the forms;

$$E_{NP}(\textcircled{H})=-j\frac{2e^{-jkR}}{\lambda R}\int_0^{\phi_0}\sum_{N=1}^{4}\Big[-\frac{1}{2}\cos\textcircled{H}\cos\frac{\phi}{2}\Big\{(f_E^N+f_H^N)\cdot C_Z(N,0)+(f_E^N-f_H^N)\cdot C_Z(N,2) + f_E^N\cdot\sin\textcircled{H}\sin\frac{\phi}{2}\cdot C_Z(N,1)\Big]\rho\sin\frac{\phi}{2}e^{-jk\rho(1+\cos\textcircled{H}\cos\phi)}d\phi \tag{9}$$

$$E_{XP}(\textcircled{H})=-j\frac{e^{-jkR}}{\lambda R}\int_0^{\phi_0}\sum_{N=1}^{4}(-f_E^N+f_H^N)\cdot S_Z(N,2)\,\rho\cos\frac{\phi}{2}\sin\frac{\phi}{2}e^{-jk\rho(1+\cos\textcircled{H}\cos\phi)}d\phi \tag{10}$$

where.
$$\left.\begin{aligned}S_Z(N,p)&=\int_{(N-1)\frac{\pi}{2}}^{N\frac{\pi}{2}}\sin p\phi'\cdot e^{jz\cos\phi'}d\phi'\\ C_Z(N,p)&=\int_{(N-1)\frac{\pi}{2}}^{N\frac{\pi}{2}}\cos p\phi'\cdot e^{jz\cos\phi'}d\phi'\end{aligned}\right\} \tag{11}$$

$z=k\rho\sin\textcircled{H}\sin\phi$

Evaluation of Eq. ⑩ substituting Eq. ⑤ gives;

$$E_{XP}(\textcircled{H})=8\frac{e^{-jkR}}{\lambda R}\int_0^{\phi_0}\sum_{m=0}^{\infty}(-1)^m\frac{J_{2m+1}(z)}{(2m-1)(2m+3)}(-f_H^1+f_H^3)\rho\sin\frac{\phi}{2}e^{-jk\rho(1+\cos\textcircled{H}\cos\phi)}d\phi \tag{12}$$

where $J_m(z)$ is Bessel function of order m and argument z.

4—2 NUMERICAL COMPUTATION RESULTS

Giving asymmetrical feed patterns to Eq. ⑤. we have near-axis pattern of $E_{NP}(\textcircled{H})$, $E_{XP}(\textcircled{H})$in Fig. 3. Equation ⑬ means that feed pattern is asymmetrical in the H-plane, and this gives rise to a crosspolarization in secondary pattern. Fig. 4. shows maximum crosspolarization level wih respect to F/D ratios.

$$\left.\begin{aligned}&f_E^1=f_E^2=f_H^1=\cos\phi\\ &f_H^3=\cos^\alpha\phi\end{aligned}\right\} \tag{13}$$

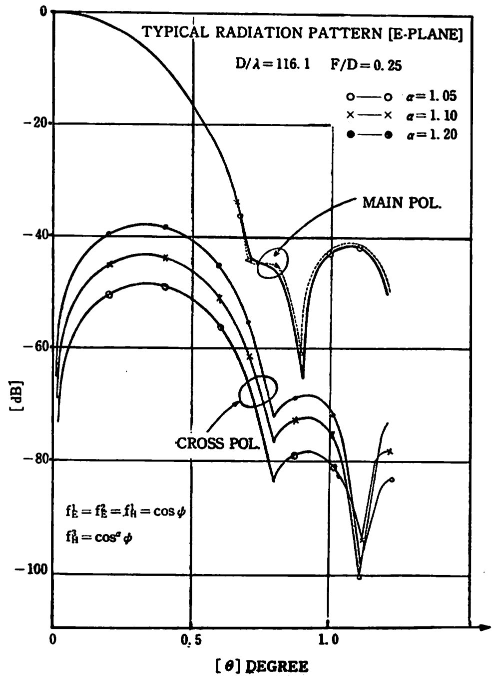

Fig. 3

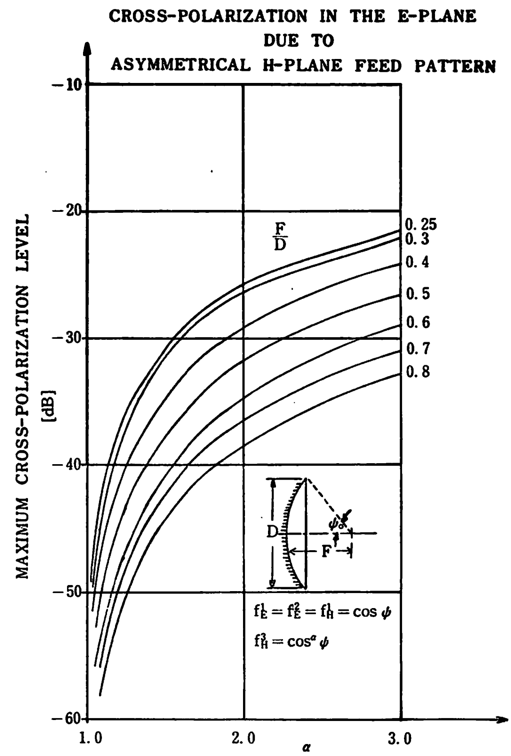

Fig. 4

5. CONCLUSIONS

Out of several causes contributing to the crosspolarization of a reflector antenna, those by asymmetrical feed pattern are described. As is easily understood from Eq. ⑫, only H-plane feed pattern contributes to the crosspolarization in the secondary E-plane, and E-plane feed pattern does not contribute. Calculation and numerical computation results show that axially symmetrical horn antenna, such as scalar horn, corrugated horn are effective to suppress the crosspolarization.

6. REFERENCES

〔1〕 Vassilios Kerbemelidis, "A Study of Crosspolarization Effects in Paroboloidal Antennas," technicalreport AF49(638)-1266, California Institute of Technology, May. 1966.

〔2〕 S. Silver, "Microwave Antenna Theory and Design" MIT Rad. Lab. Ser. 12, P, 149 Mcgraw-Hill Book Company Inc. (1949).