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# An Antenna for Simultaneous Reception of Broadcasting from BS and CS's

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## 1. Intoroduction

Japanese commercial communications satellites (CS's), which are $50-60$ degree apart from Japanese broadcasting satelite (BS), are scheduled to start direct broadcasting service. A multibeam antenna with wide beam-spacing is desired for simultaneous reception of broadcasting from BS and CS's. A multibeam antenna for this purpose, using a merged parabola, has been reported[1]. In this paper an optimum configuration of a multibeam antenna with wide beam-spacing is presented.

## 2. Wave aberration of a defocus-fed paraboloidal reflector

The configuration of a defocus-fed paraboloidal reflector is shown in Figure 1. $F$ is the focus of the paraboloidal reflector, $M_0$ is the center of the paraboloidal reflector, and $\mathbf{n}$ is the normal vector of the reflector at $M_0$. Wave aberration $\delta_p$ at an aperture of a defocus-fed paraboloidal reflector is expressed as follows.

$$\delta_p = a_2 r_a^2 + a_3 r_a^3 + a_4 r_a^4 + \cdots \tag{1}$$

where $r_a$ is a component of the polar coordinates in the aperture plane.

In this paper only the lowest term of the equation, $a_2 r_a^2$, is considered to simplify the analysis. $a_2$ is expressed as follows.

$$a_2 = U + S \sin 2(\phi_a + \psi) \tag{2}$$

$$U = \frac{1}{l} - \frac{1}{l_0} \frac{\{1+\cos^2(\theta_0/2)\}\{1+\cos^2(\theta/2)\} - \sin^2(\theta_0/2)\sin^2(\theta/2)\cos 2\phi}{\cos(\theta_0/2)\cos(\theta/2)} \tag{3}$$

$$\psi = \frac{1}{2}\tan^{-1}\frac{1}{2}\frac{\sin^2(\theta/2)\{1+\cos^2(\theta_0/2)\} - \sin^2(\theta_0/2)\{1+\cos^2(\theta/2)\}\cos 2\phi}{\sin^2(\theta_0/2)\cos(\theta/2)\sin 2\phi} \tag{4}$$

$$S^2 = \left(\frac{1}{8l_o}\right)^2 \frac{[\{1+\cos^2(\theta_0/2)\}\{1+\cos^2(\theta/2)\} - \sin^2(\theta_0/2)\sin^2(\theta/2)\cos 2\phi]^2 - 16\cos^2(\theta_0/2)\cos^2(\theta/2)}{\cos^2(\theta_0/2)\cos^2(\theta/2)} \tag{5}$$

where $\phi_a$ is a component of the polar coordinates in the aperture plane, $l_0$ is a distance between $F$ and $M_0$, $l$ is a distance between the horn and $M_0$, $\theta_0/2$ is an offset angle of $F$ from $\mathbf{n}$, $\theta/2$ is an offset angle of the horn from $\mathbf{n}$, and $\phi$ is a rotation angle of the horn from $F$ around $\mathbf{n}$. The offset angle $\Theta_0$ of the horn from $F$ is expressed as

$$\cos\Theta_0 = \sin(\theta_0/2)\sin(\theta/2)\cos\phi + \cos(\theta_0/2)\cos(\theta/2) \tag{6}$$

From equition (3) $U$ can be eliminated with appropriate $l$. From equations (5) and (6) the condition for minimum $S$ with constant $\Theta_0$ is given by equation (7), which indicates that the horn is located on the symmetrical plane of the reflector.

$$\theta = |\theta_0 - 2\Theta_0| \quad , \quad \phi = \begin{cases} 0^\circ & (\theta_0 - 2\Theta_0 \geq 0) \\ 180^\circ & (\theta_0 - 2\Theta_0 < 0) \end{cases} \tag{7}$$

From equation (7) $\theta = \Theta_0$ and $\phi = 180^\circ$ in the case of $\Theta_0 = \theta_0$, therefore from equation (5) $S$ is eliminated. In other words, second-order wave aberration $a_2 r_a^2$ could be eliminated in the case that the horn is located on the ray starting from the focus $F$ and reflected at $M_0$.

The relation between $\theta$ and the directive gain is shown in Figure 2 in the case that $\theta_0 = 60^\circ$, aperture diameter $2r_\omega = 25\lambda$, and the horn is located on the symmetrical plane of the reflector. Directive gain could be predicted by subtracting gain reductions caused by second-order wave aberration $a_2 r_a^2$, aperture distribution, and spillover from 100 percent gain. In the case of $r_\omega/l_0 = 0.25$, the predicted directive gain agrees well with the PO result. But in the case of $r_\omega/l_0 = 0.50$, the predicted disagree with the PO result around $\theta = 60^\circ$ and $\Theta = 60^\circ$. This disagreement results from the aberration of higher-order terms such as $r_a^3, r_a^4, \cdots$ neglected in the above analysis.

## 3. Design example

A multibeam antenna with wide-beam spacing is designed with 695 mm diameter paraboloidal reflector for simultaneous reception of broadcasting from BS and CS's. Primary radiators for CS's are located near the focus of the paraboloidal reflector, and a primary radiator for BS is located close to the ray starting from the focus and reflected at the center of the paraboloidal reflector. Figure 3 shows the calculated radiation pattern.

Calculated results agree well with experimental results. The antenna is confirmed to receive broadcasting from BS and CS's simultaneously.

## 4. Conclusion

The optimum configuration for a multibeam antenna with wide beam-spacing has been presented. This antenna is useful for simultaneous reception of broadcasting from BS and CS's.

## Reference


[1] Ryuichi IWATA and Susumu TAMAGAWA, "Five beam antenna for simultaneous reception of Japanese broadcasting satellite and communication satellites," 1990 Autumn Nat. Conv. Rec. IEICE, B-116 (Oct. 1990).


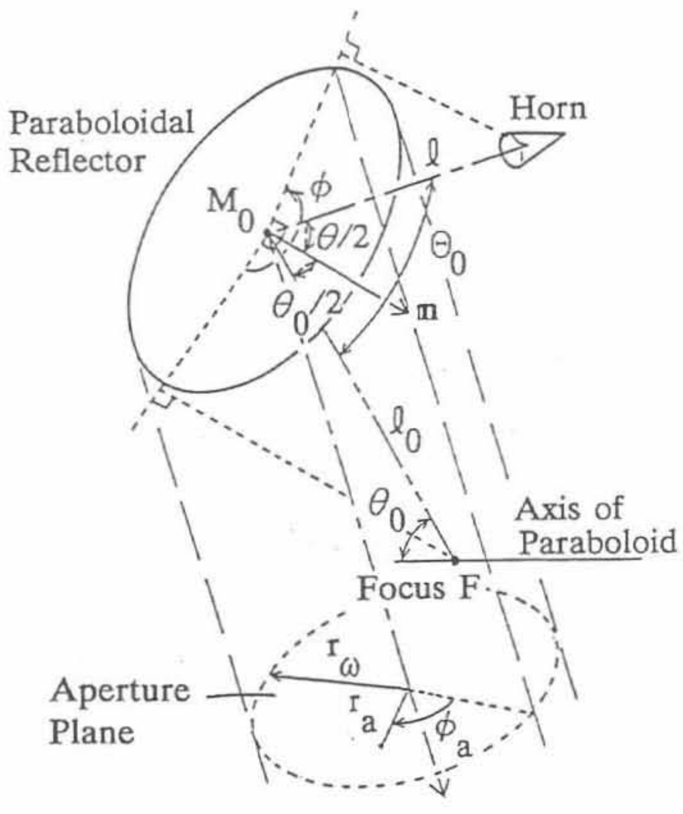


Figure 1 Parameters of a defocus–fed paraboloidal reflector.

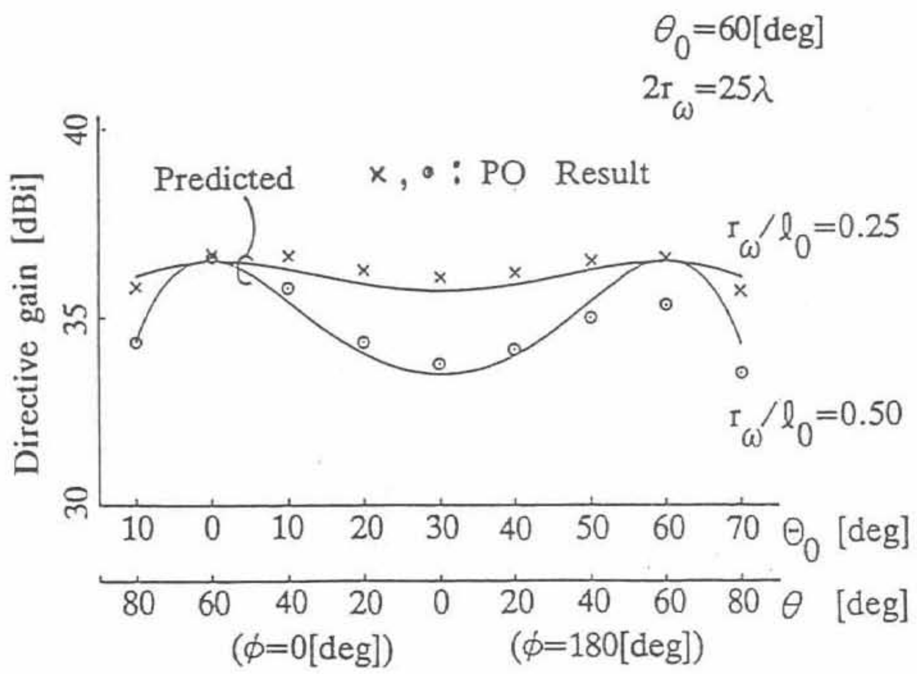


Figure 2 The relation between $\theta$, the horn position shown in Figure 1, and the directive gain.

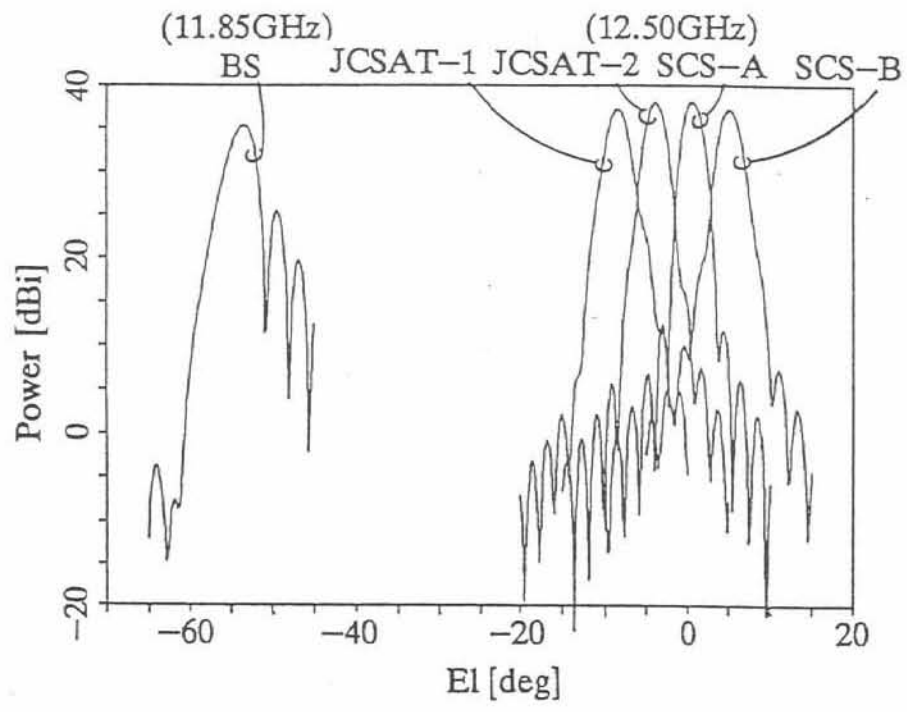


Figure 3 Calculated radiation pattern.