A Scanning Multiple-Beam Antenna Using Double Spherical Reflectors

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1 Introduction

Double spherical reflector antennas provide a scanning beam over wide angle by rotating auxiliary reflectors and beam waveguide feeds around center of the sphere while the spherical reflectors are fixed [1]. The spherical aberration caused by the spherical reflectors is eliminated by phase-correcting reflectors[2],[3] and line feeds. In this paper, for achieving multiple beams in addition to a scanning beam, we propose a double spherical reflector antenna constructed by the phase-correcting reflectors (correctors) in oversize diameter magnified in order to improve the performance at maximum separating angle between multiple beams, and auxiliary reflectors in small diameter arranged at the beam-waist in the caustics to improve minimum separating angle. A design procedure to obtain scanning multiple-beam antennas is presented, and as a result, a design example is shown.

2 Scanning multiple-beam

Figure 1 shows a double spherical reflector antenna to achieve scanning multiple beams. The origin is the center of curvature of both the spherical main and sub reflectors. Therefore, these spherical reflectors are used in common by multiple beams. On the other hand, the correctors and the auxiliary reflectors correspond to each beam.

For symmetrical dual beams on a plane, the antenna consists of dual correctors, dual auxiliary reflectors, and dual beam waveguide feeds corresponding to beams 1 and 2 on the same plane including z-axis as shown in Figure 1, and spherical main/sub reflectors. For scanning beams, the spherical reflectors are fixed, each corrector, auxiliary reflector, and beam waveguide feed are symmetrically rotated around the curvature center O of the spherical reflectors, and therefore the beams can be symmetrically scanned in Θ- and Φ-directions.

In conventional spherical reflector antennas using correctors, the diameter of correctors is limited due to the caustics of ray reflected by spherical reflectors, so it is difficult to sufficiently reduce minimum separating angle, because the minimum angle is directly determined by the diameter of correctors. In this paper, for minimizing the separating angles, auxiliary reflectors in small diameter are arranged at the beam-waist in the caustics of the ray between the corrector corresponding to each beam and the spherical sub reflector. Futhermore, for improving the performance at the maximum separating angle at the view points of spillover, the aperture dimension of the reflectors except main reflector is magnified by using the geometrical optics techniques.

The diameter D'_s of the spherical sub reflector magnified according to maximum separating angle $2\Theta_{max}$ is given for $\Theta_{max} << 1$ as follows:

$$\begin{aligned} D'_s &= 2r\sin(2\theta'_m - \alpha') \\ &\simeq D_s + 2\Theta_{max} R\cos\theta_s (2\frac{r}{R} - \frac{\cos\theta_m}{\cos\alpha}) \end{aligned} \quad (1)$$

with

$$\theta'_m = \theta_m + \Theta_{max}, \quad (2)$$

$$\alpha' = \sin^{-1}\frac{H'}{r}, \quad (3)$$

$$\alpha = \sin^{-1}\frac{H}{r}, \quad (4)$$

$$H' = R\sin\theta'_m, \quad (5)$$

where $H = D/2$, D is diameter of the spherical main reflector, and D_s is diameter of the spherical sub reflector as shown in [1], which is determined by the reflected ray after plane wave propagating in −z-direction is reflected on the main reflector. The efficiency taking account of blocking effect by the sub reflector can be evaluated by using the above equations. Furthermore, we can constitute it for four beams by adding dual reflectors on y-z plane, in addition to dual reflectors on x-z plane, in the same way too.

3 Design procedure

The design parameters are determined by the following procedure based on the geometrical optics techniques for the diameter D of the main reflector, the maximum separating angle $2\Theta_{max}$ and the minimum separating angle $2\Theta_{min}$.

- The radius of the curvature of the sub reflector normalized by that of the main reflector, r/R, is determined by taking account of both dimension of the sub reflector and the gain loss due to its blocking effect.
- The radius of the curvature of the main reflector, R, is determined as a minimum value of R to achieve the minimum separating angle $2\Theta_{min}$, as shown in Figure 2.
- The phase-correcting reflectors are determined from the standpoint of both eliminating spherical aberration[2],[3] and minimizing dimension of the aperture.

4 Design example

Figure 3 shows a design example for $2\Theta_{max} = 5°$, and $2\Theta_{min} = 0.1°$. The dimensions of the designed parameters were normalized by the diameter D of the main reflector. For scanning beams, the main reflector is efficiently used by magnifying reflectors except the main reflector according to the maximum separating angle. The efficiency taking account of blocking effect by the sub reflector was 53 % for the aperture distribution illuminated by the edge level of -10dB (72 % for the uniform aperture distribution), and the first sidelobe level was -12.4dB. In conclusion, we showed the design procedure and the design example to realize the scanning multiple-beam antenna using double spherical reflectors.

References

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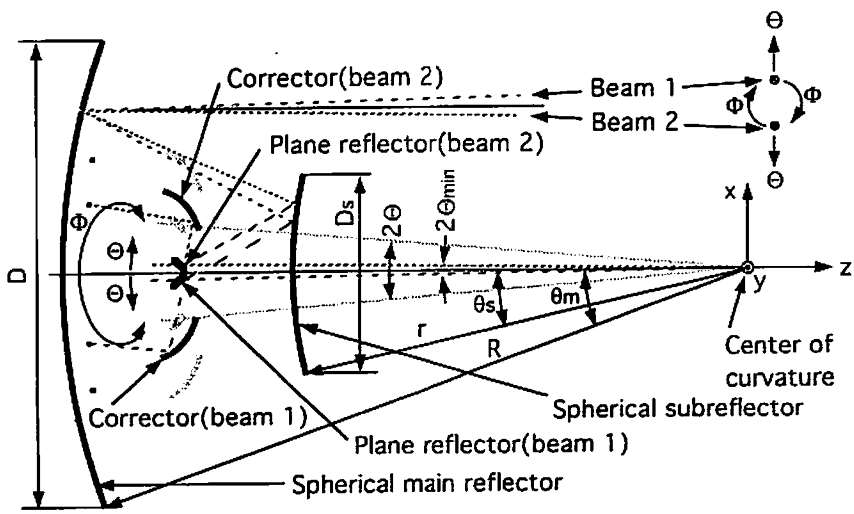

Figure 1: A scanning multiple-beam antenna using double spherical reflectors.

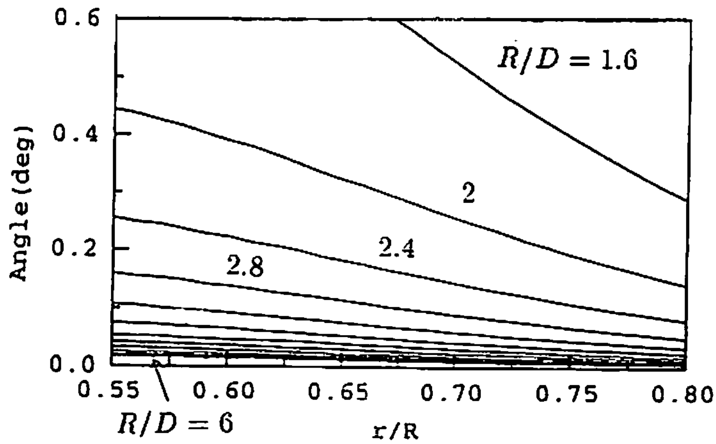

Figure 2: Minimum separating angle for the scanning multiple-beam antenna as shown in Figure 1.

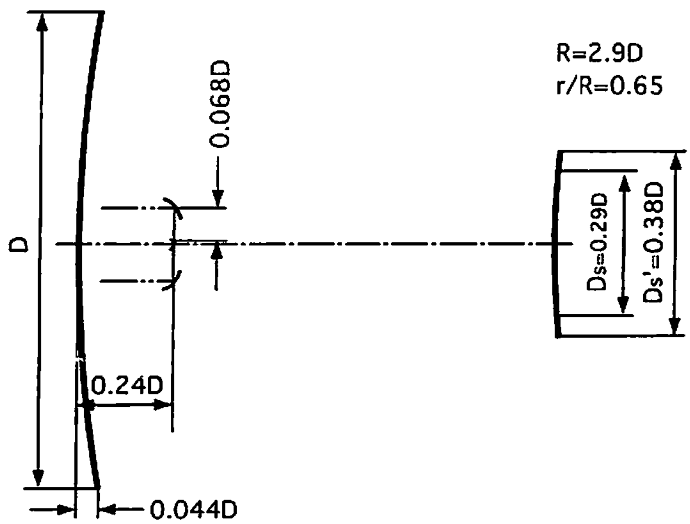

Figure 3: An example of the scanning multiple-beam antenna designed by using geometrical optics.