2-11 B3

THE HORN-REFLECTOR ANTENNA WITH ELLIPTICAL BEAM CROSS-SECTION

Yoshihiro Takeichi and Takashi Katagi
Electronics Laboratory
Mitsubishi Electric Corporation
Kamakura City, Japan

Introduction

The satellite antenna for use in domestic communication system is desired to have a beam which covers only the aimed area as shown in Fig.1, to decrease the radio interference and to increase the effective radiated power.

As a mechanically despun antenna for spin-stabilized satellite, an antenna of conical horn-reflector type is convenient.

Here is shown a method to design the horn-reflector antenna with shaped beam cross-section. According to this method, the shape of the wave front corresponding to the beam cross-section is first designed, and the shape of the reflector is then determined from the wave front by the law of the optical path[1].

Design of the wave front

The wave front is devided into two domains as shown in Fig. 2. The inner domain is a part of a spherical wave front, and the projection of its contour on the earth coincides with the contour of the aimed area. The outer domain is a ruled surface, whose generating line passing a point on the contour is perpendicular to both the normal of the spherical wave front and the tangent of the contour at the point on the contour. The outer contour of the wave front is determined from the edge of the conical horn, and therefore the total energy radiated from the horn is utilized.

From the point of view of the geometrical optics, the energy in the inner domain is radiated into the aimed area, and that in the outer domain is concentrated into the edge of the aimed area.

With the coordinates θ and φ as shown in Fig. 2, to define the contour of the aimed area is to define θ as an function of φ. Here the sufficient condition to be able to determine the shape of the reflector is expressed as

$$\frac{d^2}{d\varphi^2}\{\log(\tan\theta)\} \leq 1 + \left[\frac{d}{d\varphi}\{\log(\tan\theta)\}\right]^2 \quad (1)$$

Satisfying above condition, the beam cross-section of an ellipse or a polygon with rounded corners is able to be designed.

Reflector

With the designations of F to the apex of the horn, W to the point on the wave front and M to the point on the reflector, in Fig. 3, M situates on the normal of the wave front at the point W, and the coordinates of M are determined by the law of the optical path,

$$|\overrightarrow{FM}| + |\overrightarrow{MW}| = \text{Const.} \quad (2)$$

Let a the unit vector along the horn axis, the contour of the reflector is determined by Eq. (3).

$$\overrightarrow{FM} \cdot a = |\overrightarrow{FM}| \cos\psi_0 \quad (3)$$

where ψ_0 is a half of the total flare angle of the horn.

Radiation Pattern

The design procedure shown above is based on the geometrical optics. The radiation pattern that will actually be obtained is calculated by the current distribution method.

As an example, an antenna with elliptical beam cross-section for use on the synchronous satellite which illuminates the Islands of Japan is designed. The diameter of the aperture is equal to 1000mm, the maximum and minimum angles subtended by the aimed area are $2^\circ 44'$ and $1^\circ 18'$ respectively, $\gamma = 53^\circ$, $\delta = 6^\circ 2'$ and the frequency is 18 GHz. The total flare angle of the horn is 32° and the maximum angle which the inner domain of the reflector subtends to F is 16°.

The radiation pattern calculated by the current distribution method is shown in Fig. 4. and the calculated value of the gain is 41.7 dB.

The realized beam shape is slightly different from the designed one due to diffraction. Therefore to obtain the desired beam shape, it is necessary to calculate the radiation pattern for various parameters.

Conclusion

The sufficient condition to be able to design the horn-reflector antenna with shaped beam cross-section has been cleared, and the result of calculation has verified the usefulness of the antenna of this type for the application to the domestic communication satellites.

References

1. S. Silver, "Microwave Antenna Theory and Design", MIT Rad. Lab. Ser. 12, McGraw-Hill Inc., 1949, P125

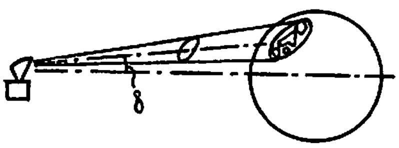

Fig. 1 The antenna with elliptical beam cross-section.

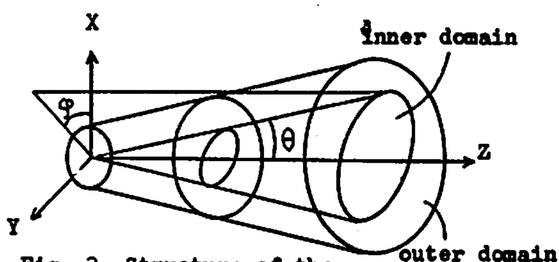

Fig. 2 Structure of the wave front.

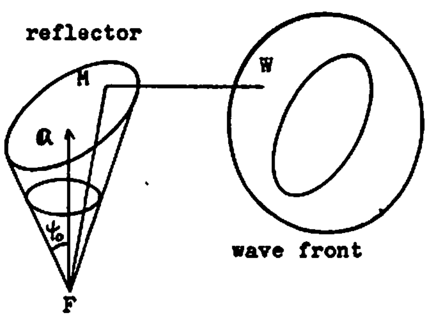

Fig. 3 Reflector and the wave front.

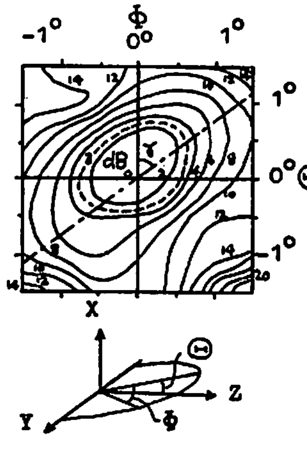

Fig. 4 Calculated radiation pattern.