A DESIGN METHOD OF CASSEGRAIN REFLECTOR ANTENNA FOR SPILLOVER SUPPRESSION

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1. Introduction

When Cassegrain reflector antenna for application to high power microwave system is designed, the spillover effect of the antenna should be considered carefully. The reason is that the radiated power out of broadside resulted by the spillover of a fed horn antenna can be a main constraint at the use of a high power system [1]. In this paper, a new structure of the Cassegrain reflector antenna whose spillover is efficiently reduced by modified subreflector is proposed for high power microwave system. Because the proposed structure is based on the technique of the displaced-axis Cassegrain antennas for blockage minimization, the reflected wave toward the aperture of horn antenna which decreases efficiency of antenna system can be also reduced.

2. Design

1. Geometry of a conventional Cassegrain reflector antenna

First of all, the geometry of a classical Cassegrain reflector antenna is given in fig. 1, and the definitions of its parameters are given in table 1 [2].

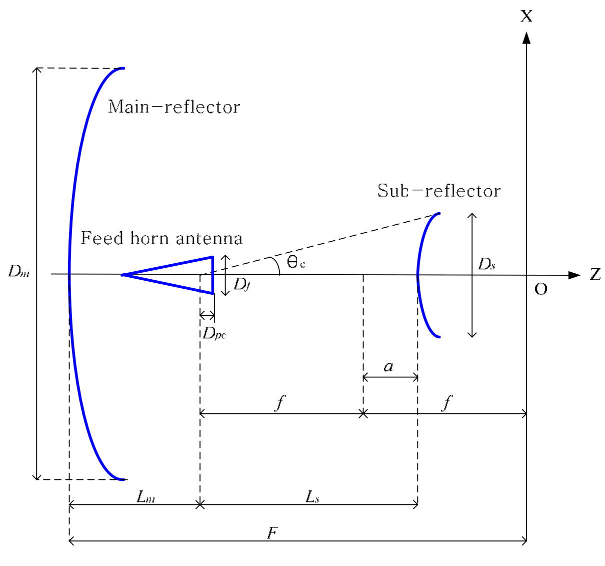

Fig. 1. The antenna geometry for the Cassegrain reflector antenna

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Table 1. parameters of the Cassegrain reflector antenna

	Definition of parameters
F	focal distance of the main reflector
f	focal distance of the subreflector
L_m	distance between the focus, F_0, of the antenna and the projection of the bottom-edge of the half main reflector onto the Z axis
L_s	distance between the focus, F_0, of the antenna and the apex of the subreflector
a	distance between the center of hyperbolic and the apex of the subreflector
θ_e	angle between the Z axis and the ray emanating from the focus, F_0, of the antenna in the direction of the subreflector edge
D_{pc}	distance between aperture center and phase center of feed horn antenna

The main reflector profile, (x_{mr}, y_{mr}, z_{mr}), is of the form

$$z_{mr} = \frac{x_{mr}^2 + y_{mr}^2}{4F} - F \quad with \quad (x_{mr}^2 + y_{mr}^2) \leqslant \frac{D_m^2}{4} \qquad (1)$$

The subreflector profile, (x_{sr}, y_{sr}, z_{sr}), is of the form

$$z_{sr} = a\sqrt{1 + \frac{x_{sr}^2 + y_{sr}^2}{f^2 - a^2}} - f \quad with \quad (x_{sr}^2 + y_{sr}^2) \leqslant \frac{D_m^2}{4} \qquad (2)$$

11. Geometry of a displaced-axis Cassegrain reflector antenna

A displaced-axis Cassegrain reflector antenna is a special case of the Cassegrain antennas, in which the focal axis of the main parabolic reflector is displaced from the axis of symmetry and the prime focus of the hyperbolic subreflector is also located on this axis [3].

In fig. 2, the main reflector and subreflector are defined in their own coordinate systems, (O_{mr}, X_{mr}, Y_{mr}, Z_{mr}) and (O_{sr}, X_{sr}, Y_{sr}, Z_{sr}), respectively. The overall antenna structure is defined in one coordinate system, (G, X, Y, Z) in which the main reflector and subreflector are finally expressed. Two origins of main- and subreflector coordinates are located at the same point, O.

The main reflector profile, $z_{mr}(x_{mr})$, is defined in the upper part of the (O, X_{mr}, Z_{mr}) plane. It is of the form

$$z_{mr} = \frac{x_{mr}^2}{4F} - F \quad with \quad \frac{D_s + 2d}{2} \leqslant x_{mr} \leqslant \frac{D_m + 2d}{2} \qquad (3)$$

The subreflector profile, $z_{sr}(x_{sr})$, is defined in the (O, X_{sr}, Z_{sr}) plane. It is of the form

$$z_{sr} = a\sqrt{1 + \frac{x_{sr}^2}{f^2 - a^2}} - f \quad with \quad d \leqslant |x_{sr}| \leqslant \frac{D_s + 2d}{2} \qquad (4)$$

In these configurations, following two properties of classical Cassegrain reflector antenna are still valid. Firstly, the path length is $2F$ for any ray from the origin, O, to $z = 0$ plane, i.e.

$$|OQ_1| + |Q_1R_1| = |OQ_2| + |Q_2R_2| = 2F \quad (5)$$

Secondly, the distance relationship in a hyperboloid gives

$$|F_0P_3| - |OP_3| = 2a \quad (6)$$

From (5) and (6), the path length is the same for any ray from the focus, F_0, to the aperture, it follows that

$$|F_0P_1| + |P_1Q_1| + |Q_1R_1| = |F_0P_2| + |P_2Q_2| + |Q_2R_2| = 2(F + a) \quad (7)$$

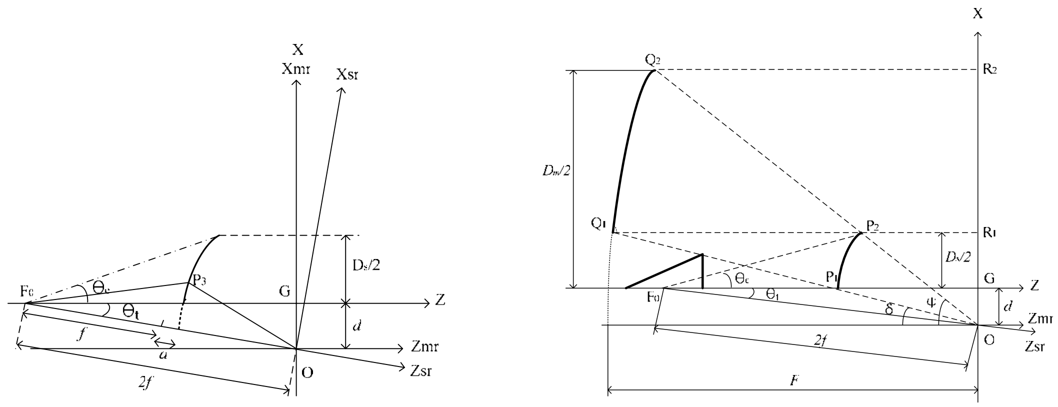

Fig. 2. A cross-sectional view of a displaced-axis Cassegrain reflector antenna

Ⅲ. Geometry of a modified Cassegrain reflector antenna for spillover suppression

In typical Cassegrain systems, a subtended angle of subreflector, $2\theta_e$, is decided to correspond to -10~-15 dB beamwidth of feeding pattern for taper efficiency [4]. But it should be extended over -15 dB beamwidth(θ_{e1}) for higher spillover suppression in high power system. But if we try this using the geometry of conventional Cassegrain reflector antenna, the taper efficiency of antenna will decrease and the main reflector will be larger for keeping the gain of antenna. Thus modified subreflector consisting of two hyperboloids shown in fig. 3 is proposed.

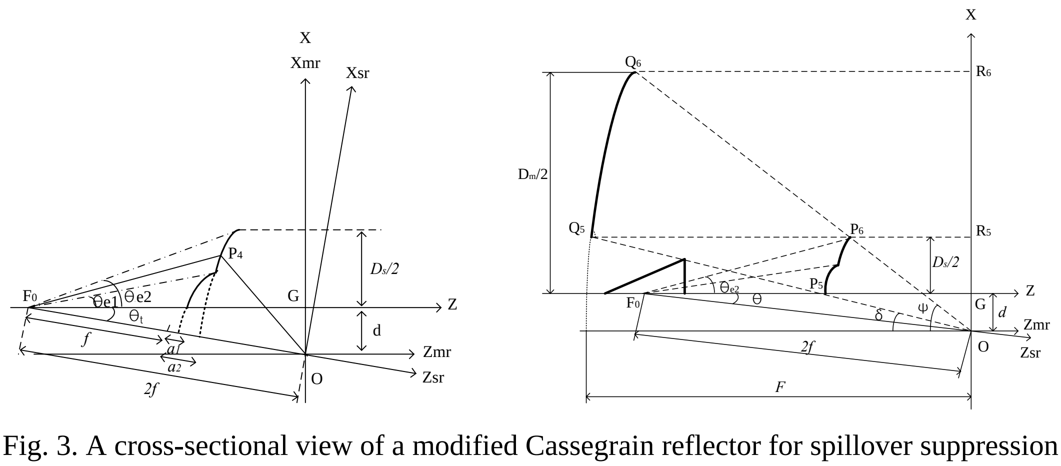

Fig. 3. A cross-sectional view of a modified Cassegrain reflector for spillover suppression

The inner part of subreflector profile, $z_{sr}(x_{sr})$, is defined in the (O, X_{sr}, Z_{sr}) plane, and depends on the two parameters a_1 and f. It is given by

$$z_{sr} = a_1\sqrt{1 + \frac{{x_{sr}}^2}{f^2 - {a_1}^2}} - f \quad with \quad d \leqslant |x_{sr}| \leqslant \frac{D_{s1} + 2d}{2} \quad (8)$$

The outer part of subreflector profile, $z_{sr}(x_{sr})$, is also defined in the same plane, and depends on the two parameters a_2 and f. It follows that

$$z_{sr} = a_2\sqrt{1+\frac{x_{sr}^2}{f^2 - a_2^2}} - f \quad with \quad \frac{D_{s1}+2d}{2} \leqslant |x_{sr}| \leqslant \frac{D_s+2d}{2} \qquad (9)$$

Then different path lengths via two subreflectors should satisfy the following equation for equi-phase condition at z = 0 plane.

$$|F_0P_5| + |P_5Q_5| + |Q_5R_5| = |F_0P_6| + |P_6Q_6| + |Q_6R_6| = 2(F + a_1) - 2(F + a_1) = 2(a_1 - a_2) = n\lambda \quad (n : \text{integer}) \qquad (10)$$

When the geometry of subreflector is designed by eqns. (8)~(10), all rays starting at the phase center of horn antenna will propagate to broadside and satisfy equi-phase condition at z = 0 plane.

3. Experimental results

The geometry of a modified Cassegrain reflector antenna is designed by the proposed structure of Cassegrain systems assuming that the wavelength of signal is 0.03 m and -15 dB beamwidth(θ_{e1}) is 11°, extended beamwidth(θ_{e2}) is 18°. And parameters of antenna are F = 2.6 m, D_f = 0.284 m, D_{pc} = 0.05 m, θ_{e1} = 11°, θ_{e2} = 18°, a_1 = 0.292 m,and a_2 = 0.322 m. In this conditions, the diameter of main reflector(D_m) is 4.5 m. In fig. 2, types of lines respectively show the ray paths whose θ_e are 0°, 11°, and 18°. In case of the the structure of a conventional displaced-axis Cassegrain systems, θ_e is 18° at a = 0.292 m, and other parameters are equal to the former. Then, D_m is 4.8 m. Therefore, we can reduce the diameter of main reflector using proposed design method of Cassegrain reflector antenna.

4. Conclusion

New structure of Cassegrain reflector antenna is presented in this paper. Unlike other conventional design techniques in using common geometries for the reflectors, the subreflector shape is designed by two hyperbolic curves. The main advantage of this antenna is that the spillover of antenna can be suppressed without additional expansion of main reflector.

5. References

1. B. M. Lee, K. Park and Y. J. Yoon, "A Multi-Mode Circular Horn Antenna for Low Side Lobe Characteristic", *PIERS* 2003, pp.621, Oct. 2003.

2. C. Granet, "Designing Axially Symmetric Cassegrain or Gregorian Dual-Reflector Antennas from Combinations of Prescribed Geometric Parameters", IEEE Antennas and Propagation, vol.40, no.2, pp.76-82, Apr. 1998.

3. C. Granet, "A Simple Procedure for the Design of Classical Displaced-Axis Dual-Reflector Antennas Using a Set of Geometric Parameters", IEEE Antennas and Propagation, vol.41, no.6, pp.64-72, Dec. 1999.

4. Warren L. Stutzman, Gary A. Thiele, Antenna Theory and Design: 2nd edition, John Wiley & Sons Inc., 1998.