2-11 B1

NUMERICAL SOLUTION OF THE INTEGRO-DIFFERENTIAL EQUATIONS DESCRIBING A DUAL SHAPED-REFLECTOR ANTENNA

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Solution Method

Special cases of shaped reflector designs have been used widely in the recent satellite communication antennas. Most of the designs have been based on uniform aperture illumination and the analytic approximation

$$I_1(\theta_1) = \cos^M \theta_1$$

to the actual feed pattern.

A more general synthesis procedure based on less restrictive assumptions can be easily formulated based on either of two sets of expressions previously derived.[1] With this in mind, two assumptions have been made and two algorithms derived, based on these assumptions.

(1) The feed phase front is spherical over the region of interest, and

(2) The desired aperture phase distribution is to be uniform.

Both algorithms, as implemented, permit calculation of the reflector shapes required to transform an arbitrary feed amplitude pattern into an arbitrary aperture field distribution. Both algorithms are based on the fourth-order Runge-Kutta integration method, together with numerical quadrature and numerical integration.

Solution Accuracy

Accuracy of the algorithms has been verified by

(1) Calculation of reflector shapes for input parameters which should result in either Cassegrain or Gregorian reflectors. Such a solution can be accurately checked.

(2) Comparison of the solutions generated by the two algorithms,

(3) The use of ray-trace techniques to determine the antenna aperture distribution based on feed pattern and calculated reflector shapes.

The accuracy of the Cassegrain solution is shown in figure 1.

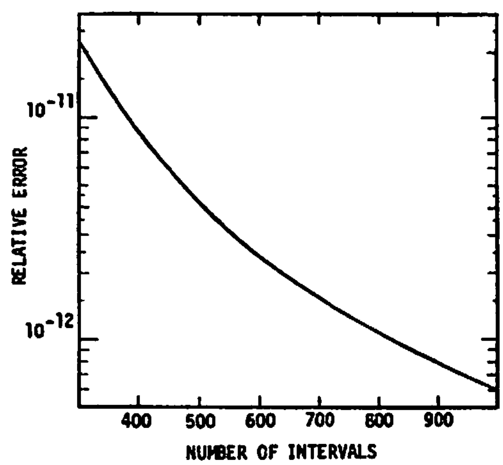

Figure 1.

As an additional test, solutions for a practical shaped reflector design were calculated using both algorithms. Both solutions were identical within the accuracy of figure 1. These solutions were analyzed by ray-trace techniques to verify that the desired aperture field distribution is produced. The result is shown in figure 2.

Solution Types

Three general types of design applications are apparent.

(1) Maximum Gain Design - uniform aperture field illumination,

(2) Maximum Gain-to-Noise Temperature Ratio Design - partially tapered aperture field illumination,

(3) Low Side-Lobe Design - highly tapered aperture field illumination.

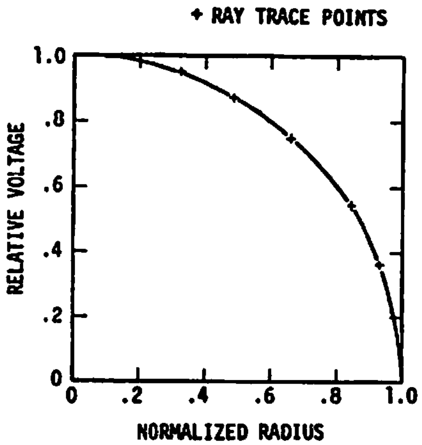

Figure 2.

The most widely used design is the maximum gain design. In the 2000- to 5000-MHz range efficiencies in the 75 to 80 percent range are attainable. The peak side-lobe level is about -15 dB for typical subreflector support structures.

Koenig[2] has shown that G/T can be improved over that of the maximum gain design by shaping to a slightly tapered aperture field distribution. Such improvements are significant only if the system temperature is below 100° K, however.

A more unusual design which could be used to provide very low side and back radiation levels could be based on a Taylor[3] distribution and a very deep main reflector (effective f/D < 0.25). Because of blockage, the minimum first side-lobe level would probably be -22 to -25 dB. The side lobes in the wide-angle regions (70° to 180° off-axis) could be reduced significantly, however.

Conclusions

It has been shown that using numerical techniques, dual shaped-reflector antennas can be designed that can transform an arbitrary feed pattern into an arbitrary aperture field distribution. It has been shown that both feed pattern data and desired aperture field distribution data can be input as discrete data arrays with no significant loss of accuracy. It is felt that the techniques discussed could become quite useful in the design of minimal interference antenna types.

References

[1] Beheler, C. M., "Dual Reflector Shaping as Applied to High-Performance Ground Station Antennas," Presented at Advanced Aerospace Technology Symposium, Toronto, Canada, March 17-18, 1969.

[2] Koenig, W. R., "Optimization of G/T for Large Dish Antennas," Proc. of the National Electronics Conference, Vol 25, 1969.

[3] Taylor, T. T., "Design of Circular Apertures for Narrow Beamwidth and Low Sidelobes," IRE Trans. on Antennas and Propagation, pp 17-22, January 1960.