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FINAL REPORT

STUDIES OF SOME BASIC PROBLEMS RELATED TO SATELLITE ANTENNA SYSTEMS

S. W. LEE

R. MITTRA

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ELECTROMAGNETICS LABORATORY
DEPARTMENT OF ELECTRICAL ENGINEERING
ENGINEERING EXPERIMENT STATION
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
URBANA, ILLINOIS 61801

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STUDIES OF SOME BASIC PROBLEMS RELATED TO
SATELLITE ANTENNA SYSTEMS

by

S. W. Lee
R. Mittra

Final Report

1 July 1977 to 30 June 1979

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Submitted to

Dr. R. J. Mailloux
Wilbert Williams, Capt. USAF

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Electromagnetics Laboratory
Department of Electrical Engineering
Engineering Experiment Station
University of Illinois at Urbana-Champaign
Urbana, Illinois 61801

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A. D. BLOSE
Technical Information Officer

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I. INTRODUCTION

The AFOSR Grant 77-3375 entitled "Studies of some basic problems related to satellite antenna systems," was awarded to the University of Illinois for a two-year period (July 1, 1977 to June 30, 1979) with Dr. R. J. Mailloux of RADC acting as the technical monitor. This is the final report for our effort in the past two years.

II. SUMMARY OF SCIENTIFIC RESULTS

A. Series Expansion for Calculating Vector Secondary Pattern of Arbitrary Reflector

The secondary pattern $\vec{P}(\theta, \phi)$ of a reflector is typically and traditionally calculated by the physical optics integral. This calculation is usually rather time-consuming. The problem becomes especially critical when the reflector size is large and/or repeated calculations of $\vec{P}(\theta, \phi)$ are needed. In a recent paper, Galindo and Mittra (IEEE Trans. Antennas Propagat., AP-25, pp. 631-634, 1977) have reported the development of a new series expansion method for calculating $\vec{P}(\theta, \phi)$ in an extremely efficient manner. In the present grant, we have successfully extended this method to the case of an offset parabolic reflector [1] and are presently investigating the problem of arbitrarily shaped reflectors. We have verified that the new method enables one to calculate $\vec{P}(\theta, \phi)$ at a cost which is a small fraction of that required for the conventional calculation of the physical optics integrals. Using this method as a computation tool, we have studied the synthesis of contour beams for satellite communication systems [2], [3].

B. GTD Solution for Diffraction by an Arbitrary Subreflector

Our studies have shown that the most efficient method for calculating the diffraction pattern from a subreflector is by using ray techniques. In

this grant, we have successfully developed a computational method based on Keller's GTD and the newly developed uniform theory. An important feature of the computational method is its ability to handle a subreflector shape, which can be completely arbitrary. In fact, it is only necessary to specify the surface of the subreflector numerically at a set of discrete points over a random net. Our computer program [4], [5], and [6] will fit these points with the cubic spline functions and calculate the necessary geometrical parameters of the subreflector. We believe that the series method described in A, when combined with the subreflector program, will result in an efficient "universal" computation method suitable for analyzing arbitrary dual-reflector antennas.

C. Synthesis of Shaped Dual Reflectors

A fruitful area of research into reflector antenna design is the shaping of a dual reflector system to synthesize a prescribed field pattern with the objective of controlling the gain, sidelobe, and other characteristics of the antenna. During the past two years, we have been working on this problem, which is well-recognized for its importance as well as its difficulty. We have concluded that an exact solution to the synthesis problem is unattainable. However, we have been able to develop a new synthesis procedure that yields an optimized approximate solution. Our procedure makes use of geometrical optics to calculate the reflected fields from the two reflector surfaces and constructs the dual reflectors by enforcing (i) the equal-path-length condition and/or the Snell's law; (ii) the energy condition dictated by the desired aperture distribution and the given feed pattern; and (iii) the surface smoothness (consistency) condition. Preliminary results are reported in [7], [8] and [9].

D. Mutual Coupling Effect in Waveguide Lens

The Dion-Ricardi waveguide lens was first reported in 1971. Since then, several prototypes have been constructed, and the main characteristics of a D-R lens have been experimentally confirmed. It is well-known that a major assumption in the current analysis of a D-R lens is that the mutual coupling among waveguides is negligibly small. The validity of this assumption has never been rigorously verified. We are examining this hypothesis in the present project. Using an equivalent, two-dimensional lens, we have analyzed the mutual coupling effects using ray techniques, which include Keller's GTD and the newly developed uniform theories. The theoretical analysis of this problem was completed some time ago. The computer program based on this analysis was recently finished and has yielded some useful and important results. Some of the conclusions obtained from our results are given below:

- (i) The mutual coupling effects can cause the phase distribution in the waveguide to deviate from the simple optical design by 0 to 40 degrees. The deviation becomes much larger when the lens is zoned. This information suggests that the lens surface can be reshaped from the optical design in order to compensate for the phase errors introduced by the diffraction effects.
- (ii) The method we have developed has enabled us to rigorously calculate the amplitude distribution of the field across the aperture of the lens. Our computations show that the nature of the amplitude taper on the lens surface due to a focal feed is opposite to that predicted by the classical theories (see Eq. (38) on p. 405 of Silver or Fig. 11.14 on p. 404).

Our result has been reported in AP-S Symposium in Seattle, June 1979

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