

AEOSR-TR- 80-0130

ELECTROMAGNETICS LABORATORY
TECHNICAL REPORT NO. 79-13

August 1979

LEVEL

10
55

FINAL REPORT

STUDIES OF SOME BASIC PROBLEMS RELATED TO SATELLITE ANTENNA SYSTEMS

S. W. LEE

R. MITTRA

DTIC
ELECTE
MAR 3 1980
S C D



Approved for public release;
distribution unlimited.

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

SUPPORTED BY
AFOSR 77-3375
AIR FORCE OFFICE OF
SCIENTIFIC RESEARCH
BOLLING AFB
WASHINGTON, D.C. 20332

80 3 3 027

ADA081313

FILE COPY

Attch 2

"The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies or endorsements, either expressed or implied, of the Air Force Office of Scientific Research or the U. S. Government."

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

1. REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM	
1. REPORT NUMBER 18 AFOSR/TR-80-0130	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER	
6. STUDIES OF SOME BASIC PROBLEMS RELATED TO SATELLITE ANTENNA SYSTEMS.		9. Final Report. 1 Jul 77 - 30 Jun 79.	
14. 47 EM79-13, UILU-ENG 79-2557		15. ✓ AFOSR-77-3375	
7. AUTHOR(s) 10 S. W. Lee R. Mittra		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 16 61102F 2375 BA	
9. PERFORMING ORGANIZATION NAME AND ADDRESS → Electromagnetics Laboratory Department of Electrical Engineering University of Illinois, Urbana, Illinois 61801		11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Office of Scientific Research /NE Building 410 Bolling AFB, Washington, D.C. 20332	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) 12 10		15. SECURITY CLASS. (of this report) UNCLASSIFIED	
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)			
18. SUPPLEMENTARY NOTES			
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Reflector antennas, lens, mutual coupling, antenna pattern, GTD			
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This final report summarizes our technical effort in the past years on reflector and lens antennas. In particular, we studied the computation of dual-reflector patterns by series expansion method and by GTD, synthesis of shaped dual reflectors, and mutual coupling effect in lens.			

408102

Gm

DD FORM 1 JAN 73 1473

EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Electromagnetics Laboratory Report No. 79-13

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

August 1979

Submitted to

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

Supported by

Grant No. 77-3375
Air Force Office of Scientific Research
Bolling AFB, Washington, D.C. 20332

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

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH (AFSC)
NOTICE OF TRANSMITTAL TO DDC

This technical report has been reviewed and is
approved for public release IAW AFR 190-12 (7b).
Distribution is unlimited.

A. D. BLOSE
Technical Information Officer

TABLE OF CONTENTS

	Page
I. INTRODUCTION	1
II. SUMMARY OF SCIENTIFIC RESULTS.	1
A. Series Expansion for Calculating Vector Secondary Pattern of Arbitrary Reflector	1
B. GTD Solution for Diffraction by an Arbitrary Subreflector	1
C. Synthesis of Shaped Dual Reflectors.	2
D. Mutual Coupling Effect in Waveguide Lens	3
III. PUBLICATION LIST	4

Accession For	
NTIS GRA&I	☒
DOC TAB	☐
Unannounced	☐
Justification	
By _____	
Distribution/ _____	
Availability Codes	
Dist	Avail and/or special
A	

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

III. PUBLICATION LIST

- [1] R. Mittra, Y. Rahmat-Samii, V. Galindo-Israel, and R. Norman, "An efficient technique for the computation of vector secondary patterns of offset paraboloid reflectors," Electromagnetics Laboratory Report No. 78-7, University of Illinois, 1978; also in IEEE Trans. Antennas Propagat., AP-27, pp. 294-304, 1979.
- [2] R. Mittra, "Efficient computation of radiation patterns and contour beam synthesis using reflector antennas," Electromagnetics Laboratory Report No. 77-18, University of Illinois, 1977.
- [3] R. Mittra and V. Galindo-Israel, "Technique for designing shaped-beam antennas for satellite broadcasting - a review," Electromagnetics Laboratory Report No. 78-15, University of Illinois, 1978; also presented (by invitation) at the Pacific Telecommunications Conference in Honolulu, Hawaii, January 8-9, 1979.
- [4] S. W. Lee, P. Cramer, K. Woo, and Y. Rahmat-Samii, "Diffraction by an arbitrary subreflector: GTD solution," Electromagnetics Laboratory Report No. 78-6, University of Illinois, 1978; also in IEEE Trans. Antennas Propagat., AP-27, pp. 305-316, 1979.
- [5] C. L. Law and S. W. Lee, "Calculating diffraction from an arbitrary reflector by a ray technique," Electromagnetics Laboratory Report No. 78-11, University of Illinois, 1978.
- [6] R. Mittra and A. Rushdi, "A numerically efficient approach for computing the geometrical optics field reflected from a specified surface," Electromagnetics Laboratory Report No. 78-16, 1978; also presented in USNC/URSI meeting at the University of Maryland, May 1978 and to appear in IEEE Trans. Antennas Propagat., AP-27, No. 6, November 1979.
- [7] R. Mittra and F. Hyjazie, "A method for synthesizing offset dual reflector antennas," Digest of 1978 International Symposium on Antennas Propagat. (College Park, Maryland), pp. 239-246.
- [8] R. Mittra, "Some recent approaches to analysis and synthesis of reflector antenna systems," Summary of 1978 International Symposium on Antenna Propagat. (Sendai, Japan), pp. 535-538.
- [9] L. Grun and S. W. Lee, "Mutual coupling effect in metal waveguide lens," Digest of 1979 AP-S Symposium, (Seattle, Washington), pp. 336-340.
- [10] R. Mittra, V. Galindo-Israel, Y. Rahmat-Samii and A. Rushdi, "On the efficient computation of Fraunhofer and Fresnel region fields radiated by reflector and planar-aperture antennas," invited paper for Rassegna Internazionale, Electronics Nucleare ed Aerospaziale held in Rome, Italy, March 1979.
- [11] V. Galindo-Israel, Y. Rahmat-Samii, and R. Mittra, "A plane-polar approach for far-field reconstruction from near-field reconstruction from near-field measurements," Digest of 1979 AP-S Symposium, (Seattle, Washington), pp. 569-573.

- [12] A. M. Rushdi and R. Mittra, "An efficient approach for computing fresnel zone fields," Electromagnetics Laboratory Report No. 79-9, University of Illinois, April 1979.
- [13] R. Mittra and A. M. Rushdi, "Generalized ray optical analysis of reflection from a smooth convex conducting surface," Electromagnetics Laboratory Report No. 79-12, University of Illinois, September 1979; also presented in USNC/URSI meeting at the University of Washington, June 1979.