AD-A070 471 WASHINGTON UNIV SEATTLE DEPT OF ELECTRICAL ENGINEERING F/G 4/2
MULTIPLE SCATTERING EFFECTS ON TRANSMISSION THROUGH THE ATMOSPH--ETC(U)
JUN 79 A ISHIMARU N00014-78-C-0723

UNCLASSIFIED TR-1-ONR NL

| OF |
AD
A070471

END
DATE
FILMED
7-79
DDC

ONR-TR-1

DEPARTMENT OF ELECTRICAL ENGINEERING
University of Washington
Seattle, WA 98195

(9) Annual Report. 1 Sep 78-31 Aug 79

by

(10) Akira Ishimaru

(11) June 1979

(12) 7p.

LEVEL II

(6) MULTIPLE SCATTERING EFFECTS ON TRANSMISSION THROUGH THE ATMOSPHERE

(15) ONR Contract N00014-78-C-0723

September 1, 1978 to August 31, 1979

(14) TR-1-ONR

Dr. B. R. Junker, Contract Monitor
Code 421
Director, Physics Program
Physical Sciences Division
Office of Naval Research
800 North Quincy Street
Arlington, VA 22217

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ONR-TR-1	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* MULTIPLE SCATTERING EFFECTS ON TRANSMISSION THROUGH THE ATMOSPHERE		5. TYPE OF REPORT & PERIOD COVERED Annual Report 9/1/78 to 8/31/79 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Akira Ishimaru		8. CONTRACT OR GRANT NUMBER(s) N00014-78-C-0723
9. PERFORMING ORGANIZATION NAME AND ADDRESS University of Washington Department of Electrical Engineering, FT-10 Seattle, WA 98195		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Office Naval Research Physics Program Office Arlington, Virginia 22217		12. REPORT DATE June 1979 13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited

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)*

Transmission of optical waves through atmosphere, multiple scattering effects, fog, clouds, rain, hail, snow, Monte-Carlo solution, turbulence, diffusion of light pulse, radiative transfer theory, forward scatter theory, beam waves, Henyey-Greenstein scattering pattern, angular broadening, pulse broadening

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

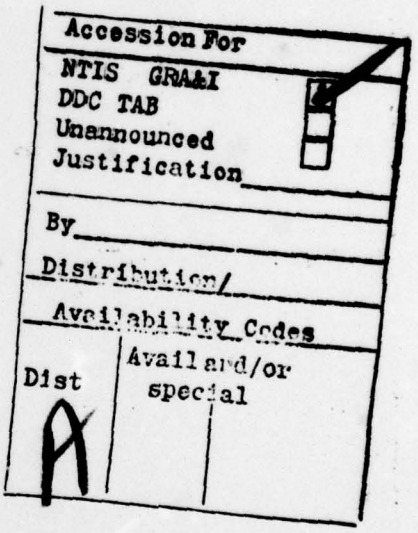
This annual report gives a summary of the work completed and underway on the contract covering the period from September 1, 1978 to June 1, 1979. The work is directed to the investigation of the transmission characteristics of optical waves with wavelengths in the range of 1-15 μm through various atmospheric conditions including clouds, fog, turbulence, rain, hail, snow, and inhomogeneous layers. Progress was made in the areas of the scattering patterns of actual fog, cw plane wave solution, beam wave

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

S/N 0102-LF-014-6601

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

solution, and pulse wave solution of the optical transmission characteristics through fog.



1. Contract Description

This contract is directed to the investigation of the transmission characteristics of a wave with the wavelengths in the range of 1 μm to 15 μm through various atmospheric conditions including clouds, fog, turbulence, rain, hail, snow, and inhomogeneous layers.

2. Scientific Program

In spite of numerous recent investigations a complete understanding of the transmission characteristics is still lacking. In particular, the transition from single scatter to diffusion is not well clarified. The effects of particle sizes ranging from small to large compared with a wavelength and the size distribution are still not clear. The difference between beam waves and plane or spherical waves needs to be investigated. The cw and pulse solutions, polarization effects, and non-uniform medium are among the most important as yet unknown aspects of the problem which we wish to vigorously pursue.

3. Scientific and Technical Approach

We have investigated the following approaches:

(a) Eigenvector solution of the radiative transfer equation,

(b) Monte-Carlo solution of the equation of transfer,

(c) Diffusion theory,

(d) Forward scatter theory.

Each of the above theories has merits and demerits. Eigenvector technique is numerical and convenient for plane-parallel problems, but it is not useful for other wave types. Monte-Carlo is flexible, but requires considerable computer time. The first order theory is convenient, but is applicable only for a short optical distance. The

forward scatter theory is primarily applicable to particle sizes large compared with a wavelength. The diffusion theory is most convenient, but it applies primarily to the scattering medium at relatively large optical distances. There is a definite need to compare these theories and define the range of validity of each theory. We are making a major effort in this direction.

4. Progress

During the past months, progress was made in the following areas:

(a) Calculation of the scattering pattern of fog at $\lambda = 1 \sim 15$ μm using the Mie theory and the size distribution of fog at Point Loma, NOSC and Manson's size distributions at different velocities. These will be used to construct the transmission nodels through fog.

(b) We have also calculated the transmitted and the reflected fluxes through fog using the diffusion theory with the Henyey-Greenstein scattering pattern. Comparison of this solution with the Monte-Carlo calculation shows extremely good agreement except when the optical thickness is small.

(c) We have also conducted detailed study of the pulse propagation characteristics through fog. This should be useful in optical communication through clouds and fog. However, a complete understanding of the pulse problem has not yet been obtained. This will be an important area of study in the coming months.

(d) We also initiated a study of the beam wave characteristics in fog. This has not been adequately studied yet and further effort is needed to determine the beam broadening and the transition region to the diffusion phenomena.

5. Publications

We have several publications, which are listed in our proposal. However, because of the short period since the initiation of the contract, we do not have yet publications carrying ONR citation. It is expected however that there will be several publications in the coming year.

6. Extenuating Circumstances

For the first few months of the contract period, we had difficulty in securing qualified graduate students. It is expected however that the situation will improve soon.

7. Remaining Funds

No unspent funds remaining at the end of the current contract period.

8. Personnel

Graduate students:

(a) Koichi Shimizu

(b) Raymond Chan

(c) J. Machado

(d) K. Painter

(3) R. Cheung

9. Graduate Students who have Earned Advanced Degree

(a) K. Painter, M.S. in E.E., Fall 1978,
with Lockheed Missiles and Space Co.

(b) K. Shimizu, Ph.D. in E.E., Summer 1979
with Hakkaido University, Japan

10. Other Government-Sponsored Research

(a) Title: Tropospheric effects on millimeter wave propagation

Contract No.:	F19628-77-C-0045
Agency:	Deputy for Electronic Technology (RADC)
Term:	October 1, 1978 to September 30, 1979
Funding:	$29,745
Principal Investigator:	Akira Ishimaru

(b) Title: Multiple scattering effects on pulse propagation and scattering

Grant No.:	ENG 77-12544
Agency:	NSF
Term:	January 1, 1978 to December 31, 1979
Funding:	$59,993
Principal Investigator:	Akira Ishimaru and R. A. Sigelmann

(c) Title: Laser-scattering detection of microemboli in blood flowing over biomedical surfaces

Grant No.:	1 P01 HL 22163-01
Agency:	NIH
Term:	August 1, 1978 to July 31, 1979
Funding:	$60,075
Principal Investigator:	Akira Ishimaru and Larry Reynolds