

AD-A099 235 WASHINGTON UNIV SEATTLE DEPT OF ELECTRICAL ENGINEERING F/6 20/6  
MULTIPLE SCATTERING EFFECTS ON TRANSMISSION THROUGH THE ATMOSP--ETC(U)  
MAY 81 A ISHIMARU N00014-76-C-0723

UNCLASSIFIED TR-3-ONR

1 of 1

AD-A  
198234



END  
DATE  
FILMED  
6-81  
DTIC

ONR-TR-3

LEI #

12

DEPARTMENT OF ELECTRICAL ENGINEERING  
University of Washington  
Seattle, WA 98195

AD A 099 235

Annual Summary Report

by

Akira Ishimaru

May 1981

MULTIPLE SCATTERING EFFECTS ON TRANSMISSION THROUGH THE ATMOSPHERE

ONR Contract N00014-78-C-0723

September 1, 1980 to August 31, 1981

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

DTIC  
ELECTE  
MAY 22 1981  
A

Reproduction in whole or in part is permitted for any purpose of the  
United States Government.

DTIC FILE COPY

This document has been approved  
for public release and sale; its  
distribution is unlimited.

81 5 15 183

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ONR-TR-3 <del>ONL</del>	2. GOVT ACCESSION NO. AD-A099235	3. RECIPIENT'S CATALOG NUMBER 9
4. TITLE (and Subtitle) MULTIPLE SCATTERING EFFECTS ON TRANSMISSION THROUGH THE ATMOSPHERE		5. TYPE OF REPORT & PERIOD COVERED Annual Summary Report 9/1/80 to 8/31/81
		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 of Naval Research Physics Program Office Arlington, VA 22217		12. REPORT DATE May 1981
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		13. NUMBER OF PAGES
		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, 1980 to April 15, 1981. The work is directed to the investigation of the transmission characteristics of optical waves with wavelengths in the range of 1-15 $\mu\text{m}$ through various atmospheric conditions including clouds, fog, turbulence, rain, hail, snow, and inhomogeneous layers. Progress was made on the thorough understanding of plane wave transmission characteristics through fog.		

Project	57
Task	<input type="checkbox"/>
Phase	<input type="checkbox"/>
Location	
Distribution/	
Availability Codes	
Available for	
Special	

1. Principal Investigator: Akira Ishimaru

2. Contract Description

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

3. Scientific Program

As a result of our studies in the past year on the transmission characteristics of an optical beam through particles in the atmosphere, such as fog and clouds, we now have a good understanding of the overall characteristics and the dependence on various parameters. It is expected that in the coming year we will be able to show quantitative results for CW cases. We will also pursue the pulse broadening and the beam broadening problems.

4. Scientific and Technical Approach

We have successfully employed the matrix eigenvalue technique for CW plane-parallel problems. We intend to extend this to include pulse broadening and polarizations. This also needs to be extended to pulse broadening problems which require frequency spectrum analysis.

5. Progress

For the past year, we have made significant progress in the understanding of the transmission characteristics of a wave through the atmosphere. We have almost completed the calculation of the exact transmission characteristics of plane optical waves through fog in the wavelengths

of 0.5  $\mu\text{m}$  to 15  $\mu\text{m}$  based on the matrix eigenvalue technique. We expect to publish this result shortly. Based on this study, we now have a good understanding of the effects of particle sizes and albedo on the transmission characteristics.

## 6. Publications

### Journal Publications with ONR Sponsorship

1. A. Ishimaru and K. J. Painter, "Backscattered pulse shape due to small-angle multiple scattering in random media," Radio Science, to appear.
2. K. Shimizu, A. Ishimaru, L. Reynolds, and A. P. Bruckner, "Back-scattering of a picosecond pulse from densely distributed scatterers," Applied Optics, 18, 20, pp. 3484-3488, October 1979.
3. K. Shimizu and A. Ishimaru, "An experimental test of the reduced effective velocity of light in a diffuse medium," Optics Letters, to appear.
4. A. Ishimaru, "Theory of optical propagation in the atmosphere," Optical Engineering, 20, 1, pp. 63-70, January-February 1981.
5. "Theoretical and experimental study of transient phenomena in random media," Proceedings of the Symposium on Multiple Scattering and Waves in Random Media, ed. by P. L. Chow, W. Kohler, and G. Papanicolaou. North-Holland Publishing Co., Amsterdam, 1981.
6. "Multiple scattering effects on optical propagation in turbulence and particles," NATO-AGARD Conference on "Special Topics on Optical Propagation," pp. 4-1 to 4-12, 1981.

### Paper Presentations Related to this Contract Since September 1978

1. A. Ishimaru, "Optical scattering and diffusion in turbulence and scatterers," OSA Meeting, San Francisco, October 1978.
2. K. Shimizu and A. Ishimaru, "Estimation of size distribution of randomly distributed scatterers," OSA Meeting, San Francisco, October 1978.
3. A. Ishimaru, "Forward scatter and diffusion of pulses in a random distribution of scatterers," URSI Meeting, Boulder, November 1978.

4. A. Ishimaru, "Multiple scattering effects on pulse propagation through fog and clouds," Naval Ocean Systems Center Program Review, San Diego, November 1978.
5. A. Ishimaru, "Forward scatter theory and diffusion theory for wave in random media," Bremmer Session, National Radio Science Meeting, Seattle, June 1979.
6. A. Ishimaru, "Multiple scattering effects on backscattering of a pulse from terrain," National Radio Science Meeting, Seattle, June 1979.
7. K. J. Painter and A. Ishimaru, "Backscattered pulse shape due to small-angle multiple scattering from a slab of random medium," National Radio Science Meeting, Seattle, June 1979.
8. K. Shimizu, A. Ishimaru, and A. P. Bruckner, "Backscattering of a picosecond pulse from a dense scattering medium," National Radio Science Meeting, Seattle, June 1979.
9. R. L-T Cheung and A. Ishimaru, "Multiple scattering of millimeter waves in rain," National Radio Science Meeting, Seattle, June 1979.
10. A. Ishimaru was invited to speak at the Chemical Systems Laboratory Scientific Conference on Obscuration and Aerosol Research, U.S. Army, Aberdeen Proving Ground, Maryland, September 1979.
11. K. Shimizu, A. Ishimaru, and L. Reynolds, "Diffusion and scattering of a picosecond pulse in a dense scattering medium," OSA Meeting, Rochester, October 1979.
12. A. Ishimaru was invited to speak on "Theoretical and experimental study of transient phenomena in random media" at the workshop on "Wave Propagation in Turbulent Media," sponsored by the Mathematics Division, U.S. Army Research Office, at Virginia Polytechnic Institute, Virginia, March 24-26, 1980.
13. A. Ishimaru and R. L-T Cheung, "Multiple scattering effects on wave propagation due to rain," URSI Commission F Symposium, Lennoxville, Canada, May 1980.
14. R. Woo, A. Ishimaru, and F-C Yang, "Radio scintillations during occultations by turbulent planetary atmospheres," North American Radio Science Meeting, Quebec, June 1980.
15. A. Ishimaru, R. L-T Cheung, and Y. Kuga, "Diffusion of a beam wave in random discrete scatterers," North American Radio Science Meeting, Quebec, June 1980.
16. A. Ishimaru, "Characterization and remote-sensing of terrain," ICC '80, Seattle, June 1980.

17. A. Ishimaru, "Pulse propagation and diffusion in random media," International URSI Symposium on Electromagnetic Waves, Munich, August 1980.
18. A. Ishimaru, "A statistical model of electromagnetic interference," EMC '80, Baltimore, October 1980.
19. A. Ishimaru and R. L-T Cheung, "Incoherent intensities due to rain," National Radio Science Meeting, Boulder, January 1981.
20. A. Ishimaru, "Multiple scattering effects on optical propagation in turbulence and particles," NATO-AGARD Meeting, Monterey, California, April 1981.
21. Y. Kuga and A. Ishimaru, "Attenuation constant of coherent field in dense spherical particles," National Radio Science Meeting, Los Angeles, June 1981.
22. R. L-T Cheung and A. Ishimaru, "Transmission and backscattering of optical waves through fog," National Radio Science Meeting, Los Angeles, June 1981.
23. A. Ishimaru, R. A. Sigelmann, K-L Peng, and R. Campbell, "A theoretical and experimental study on statistical EMI," IEEE Symposium on Electromagnetic Compatibility, Boulder, August 1981.
24. A. Ishimaru, "Multiple scattering in turbulence, scatterers, and rough surfaces," URSI Symposium on Mathematical Models of Radio Propagation, Washington, DC, August 1981.

#### 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) João Machado
- (d) Kirk Painter
- (e) Rudolf Cheung
- (f) Yasuo Kuga

9. Graduate Students who have Earned Advanced Degrees

- (a) Kirk Painter, M.S. in E.E., Fall 1978
- (b) Koichi Shimizu, Ph.D. in E.E., Summer 1979
- (c) Raymond Chan, M.S. in E.E., Fall 1980

10. Other Government-Sponsored Research

- (a) Title: Laser-Scattering Detection of Microemboli in Blood Flowing over Biomedical Surfaces

Grant No.: 1 P01 HL 22163-01  
Agency: NIH  
Term: August 1, 1980 to July 31, 1981  
Funding: \$33,333  
Principal Investigators: Akira Ishimaru and Larry Reynolds

- (b) Title: Statistical Study of Electromagnetic Interference

Grant No.: NB80RAC00012  
Agency: National Bureau of Standards  
Term: March 16, 1981 to September 30, 1981  
Funding: \$15,000  
Principal Investigator: Akira Ishimaru

- (c) Title: Wave Propagation in Dense Geophysical Media

Grant No.: DAA G29-81-K-0065  
Agency: ARO  
Term: April 1, 1981 to March 31, 1982  
Funding: \$53,165  
Principal Investigator: Akira Ishimaru



END

DATE  
FILMED

6 - 8 - 1

DTIC