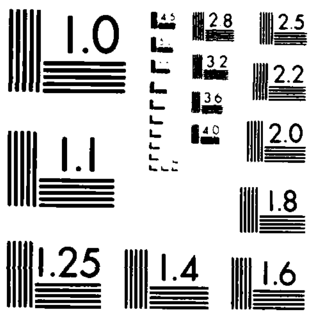
AD-A143 196 ATMOSPHERIC PROPAGATION EFFECTS ON INFRARED RADARS(U) 1/1
MASSACHUSETTS INST OF TECH CAMBRIDGE J H SHAPIRO
05 JUN 84 ARO-16632.8-EL DAAG29-80-K-0022

UNCLASSIFIED F/G 17/9 NL

END
DATE
FILMED
9-84
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

AD-A143 196

DTIC FILE COPY

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER ARO 16632.8-EL	2. GOVT ACCESSION NO. AD-A143 196 ~~N/A~~	3. RECIPIENT'S CATALOG NUMBER N/A
4. TITLE (and Subtitle) Atmospheric Propagation Effects on Infrared Radars		5. TYPE OF REPORT & PERIOD COVERED 15 Jun 80-31 Mar 84 Final Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Jeffrey H. Shapiro		8. CONTRACT OR GRANT NUMBER(s) DAAG29-80-K-0022
9. PERFORMING ORGANIZATION NAME AND ADDRESS MIT		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Army Research Office Post Office Box 12211 Research Triangle Park, NC 27709		12. REPORT DATE Jun 84
		13. NUMBER OF PAGES 8
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)

NA

18. SUPPLEMENTARY NOTES

The view, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

laser radars
atmospheric propagation
infrared radars
radars

DTIC ELECTE JUL 19 1984 E

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

Improved statistical signal models were developed, and corroborated through measurements, for turbulence and speckle effects in 2-D pulsed imager operation. Speckle and clutter effects in 2-D Doppler imager operation were also studied through analysis and measurements. Possible bad-weather laser radar operation, using scattered light, was considered theoretically. A theoretical study of the use of high time-bandwidth (TW) product signal waveforms in 3-D imaging radars was also performed.

DD FORM 1473 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

84 07 12 061

ARO 16632.8-EL

ATMOSPHERIC PROPAGATION EFFECTS ON INFRARED RADARS

Final Report

Jeffrey H. Shapiro

Massachusetts Institute of Technology

U.S. Army Research Office Contract DAAG29-80-K-0022

Period Covered: 6/15/80 - 3/31/84

Report Date: 6/5/84

84 07 12 061

Table of Contents

ATMOSPHERIC PROPAGATION EFFECTS ON INFRARED RADARS

Abstract

Compact coherent CO_2 laser radars have the potential for greatly improved angle, range, and velocity resolution relative to their microwave radar counterparts. This research program was aimed at obtaining quantitative understanding of target reflection and atmospheric propagation effects on such laser radars through a combination of theory and experiments. Toward those ends, improved statistical signal models were developed, and corroborated through measurements, for turbulence and speckle effects in 2-D pulsed imager operation. Speckle and clutter effects in 2-D Doppler imager operation were also studied through analysis and measurements. Possible bad-weather laser radar operation, using scattered light, was considered theoretically, but shown to require use of a different laser wavelength than the 10.6 μm CO_2 laser wavelength. A theoretical study of the use of high time-bandwidth (TW) product signal waveforms in 3-D imaging radars was also performed. The experimental portions of the research were carried out under a collaboration arrangement with the Opto-Radar Systems Group at MIT Lincoln Laboratory.

I. Research Summary

The development of laser technology offers new alternatives for the problems of target detection and imaging. In particular, compact coherent CO_2 laser radars have the potential for greatly improved angle, range, and velocity resolution relative to their microwave radar counterparts. The performance of laser systems, however, may be severely limited by target-return fluctuations originating from target reflection characteristics (notably laser speckle) and atmospheric turbulence. This document constitutes the final report on a program aimed at developing a quantitative understanding of the impact of speckle and turbulence on coherent laser radar systems through a combination of theoretical and experimental work. Under a collaboration arrangement with the Opto-Radar Systems Group of the MIT Lincoln Laboratory, the experimental portions of the research were carried out on the compact CO_2 laser radars under development there [1], [2]. In what follows, we shall summarize the principal results that were obtained in the various problem areas that were studied.

2-D Pulsed Imager: In a precursor to this program, which was funded through the MIT Lincoln Laboratory [3], [4] and later published in [5], we developed statistical models for the combined effects of target speckle and glint plus atmospheric turbulence on the performance of a 2-D pulsed imager coherent laser radar. Under the program being reported here, experiments to corroborate the preceding analysis were performed, and improvements and extensions of the models were developed [6]-[11]. The key findings were as follows: turbulence-induced beam jitter must be included in realistic radar modeling; jitter-corrected retro-reflector returns do show turbulence-induced lognormal scintillation; and turbulence-induced beam jitter is the cause for staring-mode speckle target decorrelation. We also showed that any contemplated use of scattered light to achieve useful radar operation deep into bad weather conditions will have to choose a wavelength with much higher albedo than that of the 10.6 μm CO_2 laser wavelength.

2-D Doppler Imager: In order to understand the potential utility of a 2-D Doppler imager as a moving target indicator (MTI) radar [12], we extended our analysis and measurements work to include the speckle and clutter statistics of such systems [13], [14]. Here we found the far-field observations of moving, rough-surfaced hard targets did show the expected speckle behavior, but, unaccountably, speckle noise was greatly reduced in near field observations. We also succeeded in decomposing the spectrum of clutter returns from wind-blown trees into a micro-motion contribution plus a macro-motion contribution. From this decomposition, the clutter-limited false alarm probability can be calculated as a function of the minimum velocity being sought in the radar, subject to some remaining uncertainties in the amplitude statistics of the clutter signature.

3-D Imager: The use of high time-bandwidth (TW) product signal waveforms may offer some advantages in laser radars which seek to do 3-D imaging. In a theoretical study [15], we addressed the relative merits of three principal high TW waveform classes: sinusoidal amplitude-modulated (am-cw) waves, sinusoidal frequency-modulated (fm-cw) waves, and linearly frequency-modulated (chirped) waves. This work concentrated on the effects of range-spread speckle targets and assumed the simple signal processors that have been suggested for practical use of the preceding waveforms. We found that chirped signals have a definite advantage over the sinusoidal waveforms in that they can be used against multiple targets in a given azimuth/elevation bin without seriously degraded range accuracy.

II. References

[1] R.C. Harney and R.J. Hull, "Compact Infrared Radar Technology," Proc. SPIE 227, 162-170 (1980).

[2] D.G. Biron and B.E. Edwards, "Moving Target Imaging Radar Utilizing Both Intensity and Velocity Information," CLEO '82 Technical Digest, Paper FB-6 (Opt. Soc. Am., Washington D.C., 1982) pp. 128-129.

[3] J.H. Shapiro, "Imaging and Target Detection with a Heterodyne-Reception Optical Radar," Project Report TST-24, MIT Lincoln Laboratory (Oct. 13, 1978).

[4] B.A. Capron, J.H. Shapiro, and R.C. Harney, "Turbulence Effects on the Receiver Operating Characteristics of a Heterodyne-Reception Optical Radar," Project Report TST-33, MIT Lincoln Laboratory (July 25, 1979).

[5] J.H. Shapiro, B.A. Capron, and R.C. Harney, "Imaging and Target Detection with a Heterodyne-Reception Optical Radar," Appl. Opt. 20, 3292-3313 (1981).

[6] D.M. Papurt, J.H. Shapiro, and R.C. Harney, "Atmospheric Propagation Effects on Coherent Laser Radars," Proc. SPIE 300, 86-99 (1981).

[7] J.H. Shapiro and S.T. Lau, "Turbulence Effects on Coherent Laser Radar Target Statistics," Appl. Opt. 21, 2395-2398 (1982).

[8] D.M. Papurt, "Atmospheric Effects on Heterodyne-Reception Optical Radars," Ph.D. Thesis, Dept. of Elect. Eng. and Comput. Sci., MIT, May 1982.

[9] S.T. Lau, "Decorrelation Time of Speckle Targets Observed with a Heterodyne-Reception Optical Radar," S.M. Thesis, Dept. of Elect. Eng. and Comput. Sci., MIT, June 1982.

[10] D.M. Papurt, J.H. Shapiro, and S.T. Lau, "Measured Turbulence and Speckle Effects in Laser Radar Target Returns," Proc. SPIE 415, 166-178 (1983).

References (Cont'd)

[11] R.R. Robertson, "Target-Return Statistics from Optical Radar Systems in Staring Mode," S.B. Thesis, Dept. of Elect. Eng. and Comput. Sci., MIT, June 1982.

[12] R.C. Harney, "Design Considerations for the Infrared Airborne Radar (IRAR) MTI Subsystem," Project Report TST-26, MIT Lincoln Laboratory (July 21, 1980).

[13] P.L. Mesite, "Laser Speckle and Clutter Effects on Moving Targets Observed with an Optical Radar," S.M. Thesis, Dept. of Elect. Eng. and Comput. Sci., MIT, Sept. 1983.

[14] J.H. Shapiro and P.L. Mesite, "Performance Analyses for Doppler and Chirped Laser Radars," IRIS Active Systems Specialty Group, 1983.

[15] A.H. Tewfik, "Range-Spread Speckle Target Effects on CW Coherent Laser Radar Range Measurements," S.M. Thesis, Dept. of Elect. Eng. and Comput. Sci., MIT, March 1984.

III. Personnel

The research reported here was carried out by

Prof. Jeffrey H. Shapiro, principal investigator

Dr. Robert C. Harney, senior investigator (6/15/80 - 4/30/82)

Dr. Robert J. Hull, senior investigator (5/1/82 - 3/31/84)

Dr. David M. Papurt, research assistant (Ph.D. 1982)

Mr. Sun T. Lau, research assistant (S.M. 1982)

Ms. Paula L. Mesite, research assistant (S.M. 1983)

Mr. Ahmed H. Tewfik, graduate student (S.M. 1984)

Mr. Martin B. Mark, graduate student

Mr. Hai V. Tran, research assistant

Mr. Rodney R. Robertson, undergraduate student (S.B. 1982)

IV. Publications

The following journal articles, meeting papers, and theses have been produced under U.S. Army Research Office Contract DAAG29-80-K-0022.

1. J.H. Shapiro, "Linear vs. Logarithmic Frame-Integration for Coherent Laser Radars," presented at the 1981 IEEE International Sympos. on Inform. Theory, Santa Monica, CA, Feb. 1981.
2. D.M. Papurt, J.H. Shapiro, and R.C. Harney, "Atmospheric Propagation Effects on Coherent Laser Radars," Proc. SPIE 300, 86-99 (1981).
3. J.H. Shapiro and S.T. Lau, "Turbulence Effects on Coherent Laser Radar Target Statistics," Appl. Opt. 21, 2395-2398 (1982).
4. D.M. Papurt, "Atmospheric Effects on Heterodyne-Reception Optical Radars," Ph.D. Thesis, Dept. of Elect. Eng. and Comput. Sci., MIT, May 1982.
5. S.T. Lau, "Decorrelation Time of Speckle Targets Observed with a Heterodyne-Reception Optical Radar," S.M. Thesis, Dept. of Elect. Eng. and Comput. Sci., MIT, June 1982.
6. R.R. Robertson, "Target-Return Statistics from Optical Radar Systems in Staring Mode," S.B. Thesis, Dept. of Elect. Eng. and Comput. Sci., MIT, June 1982.
7. D.M. Papurt, J.H. Shapiro, and S.T. Lau, "Measured Turbulence and Speckle Effects in Laser Radar Target Returns," Proc. SPIE 415, 166-178 (1983).
8. J.H. Shapiro, "Random-Medium Propagation Theory Applied to Communication and Radar System Analyses," Proc. SPIE 410, 98-102 (1983).
9. P.L. Mesite, "Laser Speckle and Clutter Effects on Moving Targets Observed with an Optical Radar," S.M. Thesis, Dept. of Elect. Eng. and Comput. Sci., MIT, Sept. 1983.

Publications (Cont'd)

10. J.H. Shapiro and P.L. Mesite, "Performance Analyses for Doppler and Chirped Laser Radars," IRIS Active Systems Specialty Group, 1983.

11. A.H. Tewfik, "Range-Spread Speckle Target Effects on CW Coherent Laser Radar Range Measurements," S.M. Thesis, Dept. of Elect. Eng. and Comput. Sci., MIT, March 1984.

MED

8