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Quarterly Progress Report

Division 3

Radio Physics

15 November 1964

Prepared under Electronic Systems Division Contract AF 19(628)-500 by

Lincoln Laboratory
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Lexington, Massachusetts

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INTRODUCTION

This report summarizes the research and development efforts of Division 3 for the period 1 August through 31 October 1964. A substantial portion of the Division's activities is devoted to the PRESS Program, reports for which appear in the Semi-annual Technical Summary Report and the Quarterly Letter Report to ARPA.

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Head, Division 3

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15 November 1964

Accepted for the Air Force
Stanley J. Wisniewski
Lt Colonel, USAF
Chief, Lincoln Laboratory Office

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361	Numerical Methods in the Chemical Kinetics of High Temperature Air	L.B. Raisty	29 July 1964	DDC 449857

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2300	Radar Evidence of Solar Wind and Coronal Mass Motions	J.H. Chisholm J.C. James	Astrophys. J. 140, 377 (1964)
2323	A Note on the Equivalence of Certain Realizations of Boson Annihilation and Creation Operators Due to K.O. Friedrichs	H.E. Moses	Communs. Pure Appl. Math. 17, 355 (1964)
2343	On the Interpretation of Radar Reflections from the Moon	J.V. Evans T. Hagfors	Icarus 3, 151 (1964)
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2350	Video Pulse Amplifier with Wide Dynamic Range	R.E. Richardson	Rev. Sci. Instr. 35, 1600 (1964)
2356	Ionospheric Backscatter Observations	J.V. Evans M. Loewenthal	Planet. Space Sci. 12, 915 (1964)
2357	Radar Echoes from the Sun	J.C. James	Trans. IEEE, PTGMIL MIL-8, 210 (1964)
2365	Backscattering from an Undulating Surface with Applications to Radar Returns from the Moon	T. Hagfors	J. Geophys. Res. 69, 3779 (1964)

* Reprints available.

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2378	Representations of the Inhomogeneous Lorentz Group in Terms of an Angular Momentum Basis: Derivation for the Cases of Nonzero Mass and Zero Mass, Discrete Spin	J.S. Lomont* H.E. Moses	J. Math. Phys. 5, 1438 (1964)
2435	Ionospheric Investigations by the Faraday Rotation of Incoherent Backscatter	G.H. Millman* V.C. Pineo D.P. Hynek	J. Geophys. Res. 69, 4051 (1964)

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UNPUBLISHED REPORTS

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JA No.			
2284	Circular Aperture Synthesis	J. Ruze	Accepted by Trans. IEEE, PTGAP
2382	Measurements of UHF and L-Band Radar Clutter in the Central Pacific Ocean	G.R. Curry	Accepted by Trans. IEEE, PTGMIL
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645F	Studying the Lunar Surface by Radar	J.V. Evans	Planetology Subcommittee, Space Sciences Board, NASA Manned Space Science Division, Chicago, 27 October 1964
1047	Advanced High-Sensitivity Microwave Radiometers	S. Weinreb	International Conference on Microwaves, Circuitry Theory and Information Theory, Tokyo, 7-11 September 1964
1080	Quantum Effects and Information Capacity in an Electromagnetic Wave Communication Channel	T. Hagfors	International Conference on Microwaves, Circuitry Theory and Information Theory, Tokyo, 7-11 September 1964

* Author not at Lincoln Laboratory.

† Titles of Meeting Speeches are listed for information only. No copies are available for distribution.

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1091	Lateral Feed Displacement in a Paraboloid	J. Ruze	IEEE, PTGAP Symposium, New York, 21 September 1964
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1159	Microwave Attenuation Due to Precipitation as Inferred from Weather Radar Measurements	R.E. Newell* M. L. Stone	1964 Fall URSI Meeting, University of Illinois, 11-14 October 1964
1140	Qualitative and Quantitative Measurements Using Schlieren Techniques in a Free-Flight Range	R.E. Slattery W.G. Clay	First International Congress on Instrumentation for Aerospace Simulation Facilities, Paris, 28-29 September 1964
1149	Reflector Tolerance Determination by Gain Measurement	J. Ruze	NEREM, Boston, 4-6 November 1964
1171	ELF Spectrum Measurements of the Earth-Ionosphere Cavity Modes	M. Balser	Symposium on ULF Electromagnetic Fields, Boulder, Colorado, 17-20 August 1964
1195	Pacific Range Electronic Signature Studies Real-Control System	K.E. Ralston	IEEE, PTGMIL-PTGEC Meeting, Syracuse, New York, 1 October 1964
1204	Autocorrelation Receivers for Radio Astronomy	S. Weinreb	Seminar, Harvard College Observatory, 9 October 1964

* Author not at Lincoln Laboratory.

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GROUP 31

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SURVEILLANCE TECHNIQUES
GROUP 31

Group 31 operates and maintains the Millstone radar complex and the Haystack Experimental Facility at the Laboratory's Millstone Hill Field Station. The Group also conducts a program of radio physics, astronomy, and space surveillance research using these facilities.

At Millstone, the emphasis on space surveillance techniques is being increased as planetary observations taper off; at Haystack, the emphasis is on completion of the facility and planning of a program.

I. SPACE SURVEILLANCE

A. Plans and Studies

A more formal program of space surveillance activities has been planned, centered initially at the Millstone radar. Included is development of techniques for improving the effectiveness of satellite tracking radars, and a modest amount of tracking support for the Space Detection Tracking System (SPADATS). Emphasis will be on emergency operations and on tracking objects requiring Millstone's unique range capability.

Some consideration is being given to the incorporation into Haystack or Millstone of radar system techniques affording extreme range resolution. The end objective would be experiments in space object identification.

Group 31 participated with part-time personnel of Divisions 4 and 6 in making the Electronic Systems Precision Orbit Determination (ESPOD) program capable of operation on the Laboratory's IBM 7094 computer. This program, developed by Space Technology Laboratories for Space Track, is a versatile system that will:

(1) Make maximum likelihood orbital determinations from noisy radar data;

(2) Evaluate biases and random errors in the data;

(3) Compute acquisition predictions for any radar site.

The Group is now studying the feasibility of providing a truncated version of this program for use in the new SDS 9300 computer, soon to be installed at Millstone.

B. Tracking Activities

The informal tracking program occupied about four hours per week of Millstone radar time during the reporting period. Nineteen satellites in the "difficult" class were tracked, many of them a number of times, and data were passed to Space Track.

Other observations of particular interest included:

Object	Agency Requesting	Comment
No. 869, Cosmos 41	Space Track	Several passes. Maximum track ranges 8500 to 10,000 nm; observed at apogee (21,000 nm) by incoherent integration.
Voskhod I (three-man spaceship)	Space Track	Two passes; five objects observed.
Scout S129-R	NASA	Wallops Island firing
No. 693 (IMP-1)	NASA	Apogee 100,000 nm; perigee 1000 nm
Trailblazer II g	Lincoln Laboratory Re-entry Program	Wallops Island launch; data obtained through re-entry.
West Ford Belt Examination	Own Interest	Many "blobs" gave L-band returns at altitudes from 1000 to 1750 nm; altitude of X-band dipoles is much lower.

Both coherent and incoherent integration are being considered as techniques for extending tracking range. Syncom II was observed last January at 40,000-km range by coherently integrating a few seconds of data after the manner used in planetary echo processing. Study of Cosmos 41 returns, by contrast, has revealed substantial doppler broadening and no appreciable coherence over an interpulse interval. Such a target must be observed by incoherent integration. Thus, both modes must be provided for in any range improvement system using such techniques.

The application of real-time coherent integration techniques in attempts to track the Lincoln Experimental Satellite (LES) at long ranges (≈12,000 nm) is being studied. A faster program for obtaining the necessary digital filters is being evolved. The search and acquisition problem is also being studied.

The MITRE-Millstone three-terminal* interferometer is in experimental operation four hours per week. Good three-site data are now being obtained. The semiautomatic method used by Group 31 in processing interferometer data is being adopted by MITRE for runs with discontinuous data, since the automatic program for the Stretch computer cannot handle these cases.

II. RADIO AND RADAR ASTRONOMY

A. Plans

In August, a Haystack Program Committee was established under the chief of Haystack Operations. It includes one member for radar astronomy, one for radio astronomy, and one for the Space Communications Program. A schedule is nearly completed for Haystack experimental programs during calendar year 1965. This schedule includes a summary proposal for radiometric studies based upon Group 31 plans, and on requests from MIT and Harvard radio astronomers.

In conjunction with Cornell scientists, a program description of radar and radiometric studies of the lunar surface utilizing Millstone radar, Haystack, the Lincoln millimeter wavelength facility, and the 1000-foot radar at Arecibo, Puerto Rico, was prepared. The aim was to outline to NASA what information concerning the nature of the lunar surface might be obtained with earth-based instruments.

*Millstone illuminates target and receives echoes. Boston Hill and Burlington stations receive only.

B. Planetary Radar Studies

Radar distance measurements to Venus were continued at weekly intervals through 7 October when the path loss approached the value at which the Millstone L-band system could no longer make useful measurements. Through 6 August, range measurements to an accuracy of ±2 km were possible. After that date, range accuracy was degraded in the interest of increased sensitivity.

Analysis of the echo power profile vs range delay leads to the conclusion that the surface of Venus is considerably smoother than that of the moon. Further processing is being undertaken to check the value for the rotation period (247 ± 5 days, retrograde) obtained by I. I. Shapiro and G. H. Pettengill from Arecibo radar observations.

Various subsystems of a preliminary CW planetary radar system for Haystack have been completed, tested, and installed. It is hoped to test this equipment as a system before the end of this calendar year.

C. Radiometric Work

After completing a series of highly accurate flux measurements of bright radio sources, the radiometer box with 8 Gcps and 15 Gcps radiometers was installed on the Haystack antenna and, on 8 September, the moon was observed for the first time. Subsequently, preliminary observations of Cassiopeia A indicated that approximately the expected gain and efficiency are being obtained from the antenna. Because the pointing system was not complete, only approximate measurements were possible.

Other work in progress includes:

(1) A spectral line receiver for Haystack;
(2) A 5-Gcps radiometer;
(3) A feed polarization rotation control unit;
(4) Specification of data analysis programs for the Univac-490 computer.

A 35-Gcps radiometer for Haystack is under construction by Group 45.

III. IONOSPHERIC AND AURORAL STUDIES

A. Ionospheric Backscatter

The bi-weekly 30-hour observations of backscatter at 440 Mcps have continued. On alternate weeks the L-band steerable radar at Millstone has been utilized for similar observations. These, because of limited system sensitivity, can only be conducted for about 6 hours in daytime, when the electron density is high.

Interpretation of the results has continued, limited as before to the case where only 0^+ ions are present. Fair progress is being made on a new computer program to compute spectra for cases involving mixtures of ions. However, failure to fit accurately the function that describes the influence of the equipment on the spectra has resulted in poor accuracy in test runs to date. Interpretation of L-band data will await satisfactory performance of this program.

B. Aurora

Because of a recent increased interest in auroral effects at higher frequencies, the Millstone L-band system has been instrumented to gather data on the spatial and frequency distributions of auroral scatter. A small but important program of observations is anticipated.

IV. STATION EQUIPMENT AND IMPROVEMENTS

A. Haystack*

The U. S. Air Force conducted a formal dedication ceremony at the new Haystack Experimental Facility on 8 October. The unveiling of the dedication plaque was initiated by radio energy received from the radio source Cygnus by the Haystack antenna and radiometer equipment.

Work is under way to heat the radome to prevent formation of ice crystals damaging to the antenna. A pressurization scheme is being tried as a means of excluding water and of preventing destructive flapping of the radome panels.

Antenna system completion and checkout has continued, with emphasis on tests of the servo, hydrostatic bearing, buffer stops, cable wrap, and angle readout system. The behavior of the surface as elevation angle is varied appears most satisfactory. It seems likely that useful 35-Gcps operation will be realized. The hoist system for the "plug-in" RF boxes also appears satisfactory.

The radiometric measurements mentioned in Sec. II-C verified that the beamwidth was 4.3 minutes of arc at 8 Gcps. The antenna system appears to perform as indicated from estimates of Dr. John Ruze, based upon design specifications. Since the pointing system could not yet perform accurately, and since the feed characteristics had not been optimized for these tests, quantitative measurements are not yet available for determining efficiency and rms surface tolerances.

Much of the so-called "ground system electronics" has been installed, including equipment used with the radiometer box and with the Radar/Communications box. Most of the cabling and cooling interconnections tying the large transmitter to the ground system were also installed.

Intersite coupling equipment to permit direction of the Haystack antenna from the Millstone site and vice versa was installed but is not yet operable.

The Radar/Communications box itself was installed on the weight and balance platform in the high-power test dock. Much of the physical interfacing required for test dock operation is complete; on-power tests, including the CW transmitter, at least one receiver channel, and signal test facilities are planned for November.

B. Millstone

Equipment for the anti-backlash modifications to the antenna pedestal was received.

Certain changes in the Millstone tracking receiver chain have eliminated spurious signals, substantially improving tracking performance on weak targets.

An SDS-920 computer was temporarily installed, pending arrival of the SDS-9300 that is expected in November. Its presence has enabled the programming staff to familiarize themselves with FORTRAN and the basic machine language of the SDS series.

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* This section represents work by personnel of Divisions 3, 4, 6, and 7 as well as by contractor personnel.

The L-band radar will be out of operation for about six weeks beginning in late November. Feed modifications will be installed that will permit the radar to transmit in any polarization and to receive both transmitted and orthogonal components. This capability is important in planned radar astronomy experiments.

V. SOLAR RADAR STUDIES

The regular schedule of radar observations of the sun was resumed in July, after a period of radar observations of the planet Venus during late May and June, 1964. A final comprehensive technical report of the solar and planetary studies is nearing completion which will describe the results of these studies over the three-year period from July 1961 to date.

VI. PROPAGATION STUDIES

A. Atmospheric Backscatter

Analysis of the radar backscatter from atmospheric phenomena obtained from the UHF, S-, and X-band radars at Wallops Island, Virginia, in June 1964 has continued. These data were obtained by Group 21 in collaboration with members of the weather radar research group at the Air Force Cambridge Research Laboratories (AFCRL). Some preliminary analyses and interpretation of these results were presented by Dr. David Atlas in an informal conference on 15 October 1964 with members of Divisions 2 and 3 who assisted in the planning and the conducting of the experimental measurements. Several of the observations were obtained simultaneously at wavelengths of approximately 75, 10, and 3 cm. They show returns from apparent stratified layers with a wavelength dependence which favors a model of refractive index fluctuation, possibly related to stratified layers of turbulence. This is in contrast to the inverse wavelength dependence (i.e., stronger radar returns at the shorter wavelengths) observed from precipitation and discrete echoes such as "angels," insects, birds, etc.

Some further exploratory measurements of a similar type have been discussed with Group 21 and the AFCRL group, with possible participation of an aircraft equipped with meteorological and radio refractometer devices operated by the MITRE Corporation. These experiments have been scheduled for November 1964 by Group 21 and the visiting AFCRL participants.

B. Rainfall Attenuation

Some preliminary evaluation of the methods of obtaining a simple statistical model of severe rainfall attenuation at X-band for earth-space communication paths for a New England climate has been accomplished as a result of studies conducted by Dr. Pauline Austin of the Meteorology Department, M.I.T. The work was performed under a study contract from Division 6. These results, together with some tentative recommendations, were described in the Division 6 Joint Advisory Committee presentations on 6 October 1964. The studies were based upon weather-radar measurements obtained on radar located at M.I.T. over the three-year period 1961 to 1963, and encompass radar returns in a circular area having a radius of about 80 miles from Cambridge, Massachusetts. Further detailed computer programs are planned by Group 61 under a continuing contract with the weather-radar group at M.I.T.

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13. ABSTRACT

This report summarizes the research and development efforts of Division 3 for the period 1 August through 31 October 1964. A substantial portion of the Division's activities is devoted to the PRESS Program, reports for which appear in the Semiannual Technical Summary Report and the Quarterly Letter Report to ARPA.

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