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LINCOLN LABORATORY

PROGRESS REPORT #2
TO
WESTERN ELECTRIC COMPANY

Subcontract X-213
(Prime Contract AF 18 (600)-572)

1 January 1954 - 31 May 1954

1 June 1954

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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PROGRESS REPORT NO. 2

to

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under

Subcontract X-213

(Prime Contract AF 18(600)-572)

1 January 1954 – 31 May 1954

This report is submitted by Lincoln Laboratory as a subcontractor under Contract No. AF 18(600)-572 (Western Electric Contract X-213). Other work within Lincoln Laboratory, supported directly by the Department of the Army, the Department of the Navy, and the Department of the Air Force, under Contract No. AF 19(122)-458, has contributed in varying degrees to the research described herein.

1 June 1954

LEXINGTON MASSACHUSETTS

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I. INTRODUCTION

This report summarizes the work performed by Lincoln Laboratory, Massachusetts Institute of Technology, under Western Electric Company Subcontract X-213 during the period January 1954 through May 1954. Work carried out during the period 8 December 1952 through 31 December 1953 was the subject of a progress report issued in April 1954.

Pursuant to discussions among representatives of Western Electric Company, Bell Telephone Laboratories and Lincoln Laboratory at a meeting held in December 1953, the program of the Lincoln Laboratory for the support of Project CORRODE, under Subcontract X-213, was adjusted at the beginning of 1954 to include the following three continuing tasks:

(a) Further development of automatic-alarm units for application to ground-based search radars.

(b) Further development of Fluttar.

(c) Further development of techniques and facilities for tropospheric radio-wave propagation.

Accordingly, the scope of this progress report is limited to these three tasks, although the Laboratory is continuing to work on certain other tasks relating to distant early warning which formerly were included in Subcontract X-213, and which were described in the aforementioned April 1954 report.

In the future, progress reports will be scheduled on a monthly basis.

II. DEVELOPMENT OF GROUND-BASED AUTOMATIC-ALERTING RADAR

A. AUTOMATIC-ALERTING RADAR X-1 (X-1 SYSTEM)

As a result of experience in the operation of the X-1 System at the Project CORRODE sites, certain steps have been taken to improve the maintenance and reliability of the System as follows:

(1) A possible replacement magnetron for the 5J26 incorporating a "getter" has been developed by Raytheon Manufacturing Company and is under evaluation;

(2) A modification to the AN/TPS-1D modulator has been made consisting of the removal of one thyratron and the current-balancing transformer;

(3) A new cooling fan arrangement has been designed for the transmitter-modulator unit.

The last two modifications are being incorporated as field changes in the Project CORRODE radars. J. W. Meyer (Group 37) spent two weeks at the Arctic CORRODE sites in March 1954 to observe and assist site personnel in the operation of the X-1 Systems.[1*]

B. AUTOMATIC-ALERTING RADAR X-3 (X-3 SYSTEM INTENDED)

The X-3 System, an improved automatic-alerting radar intended to replace the lash-up X-1 System, comprises a modified AN/TPS-1D radar (the same as in the X-1 System), the 25- × 14-foot $\csc^2$ antenna built for the AN/FPS-8 radar, and the Radalarm X-3. Characteristics of the Radalarm X-3 and vertical-coverage diagrams showing the relative performance of the X-1 and X-3 Systems were included in the preceding progress report. A more complete description of the X-3 System is given in a Group 31 report.[2]

The Raytheon Manufacturing Company, under subcontract to Lincoln Laboratory, has delivered to Lincoln Laboratory two production prototype models of the X-3 System. In April, the first model was installed on the roof of Building C of the Laboratory. The Western Electric Company plans to install the second X-3 System at Domestic Main Station (DMS) in the vicinity of Streator, Illinois.

The antenna of the Laboratory's X-3 System is housed in a 31-foot fiberglass radome built according to a design by Mr. R. Buckminster Fuller. A photograph of the Fuller radome is shown in Fig. II-1. The radome is non-pressurized and is considerably less expensive than the pressurized radomes currently in use. The one-way transmission loss at L-band of a sample of the radome material measured less than 0.2 db.

Flight testing of the X-3 System installed at the Laboratory is scheduled to begin the first week in June.

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*Please refer to numbered References at the end of the report.

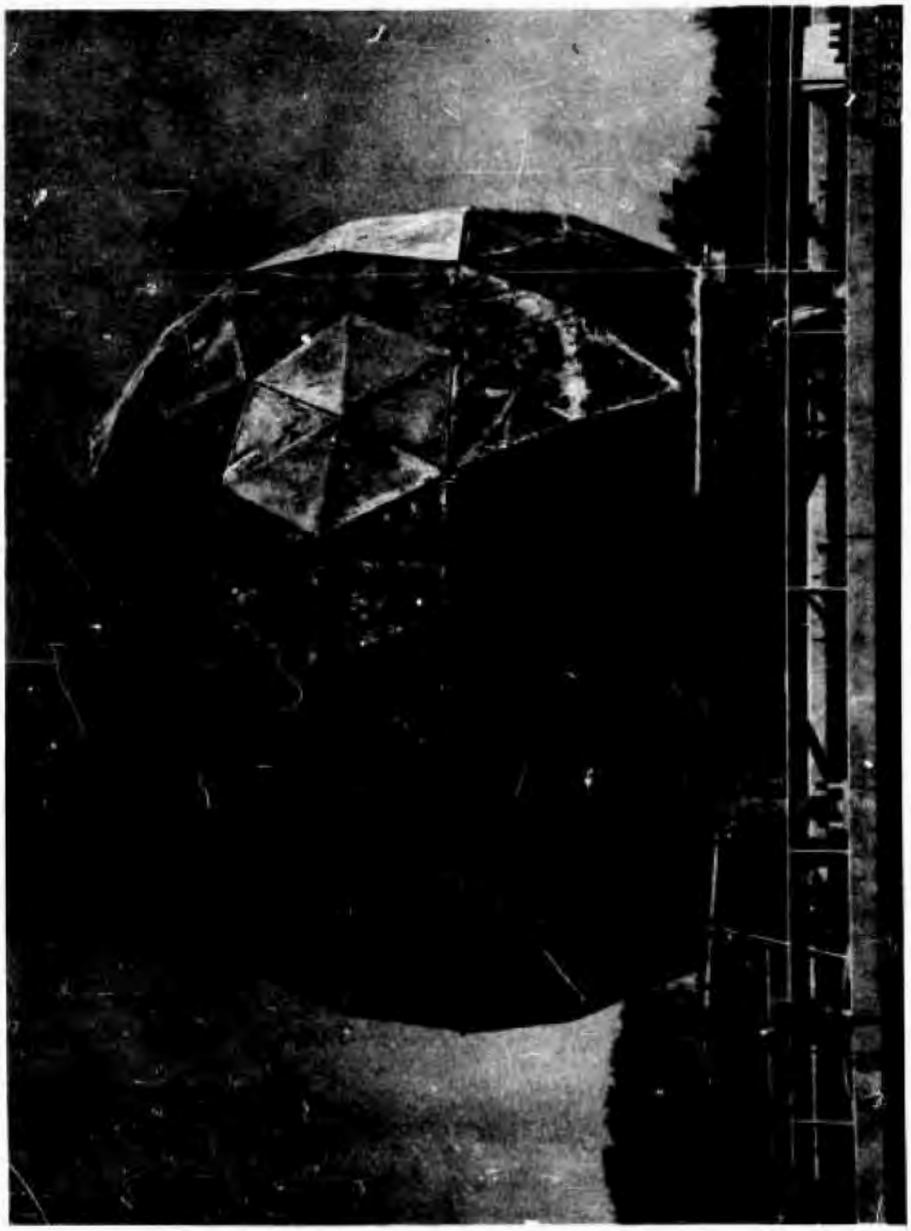


Fig. II-1. Fuller Radome Installation at Lincoln Laboratory.

C. EVALUATION OF AN/FPS-8

An AN/FPS-8, Serial No. 2, was installed at the Lexington Field Station in the fall of 1953 for the purpose of evaluating its suitability as an automatic-alerting radar. Because of difficulties encountered in operating the set, due mainly to instability of the QK358 magnetron, there has been some delay in carrying out the planned evaluation program. The set is now fully operational, and the next phase of the flight testing – to investigate the high-altitude coverage – is scheduled for the first week in June.

By virtue of its better layout and provision of built-in test equipment, the AN/FPS-8 is perhaps better suited for use as an automatic-alerting radar than the AN/TPS-1D. However, to date only a few AN/FPS-8 sets have been produced and, consequently, reliability data are almost entirely lacking. Also, the cost of the AN/FPS-8 appears to be disproportionately high in comparison with the cost of the X-3 System which is certainly competitive in performance.

Preliminary discussions have been held with personnel of General Electric Company concerning the development of automatic-alarm circuitry [redacted]

5 USC 552 (b)(3), 10 USC 130

D. ALARM CIRCUITRY FOR AN/FPS-3

An alarm unit, called Radalarm X-5, has been developed for the AN/FPS-3. The alarm circuitry operates on the lower beam of the radar when it is set for early warning; and the design parameters have been optimized [redacted]

5 USC 552 (b)(3), 10 USC 130

made for desensitizing the automatic-alarm equipment in two independently adjustable azimuth sectors. A preliminary manual for the Radalarm X-5 has been prepared.[3]

In March, the two shop models of Radalarm X-5 were installed by Group 31 personnel on operational AN/FPS-3 radars, one at the site near

Thule, Greenland, and the other at the site on Northeast Cape, St. Lawrence Island, Alaska. These sites were selected because their operating problems and traffic densities seemed to be representative of the type of sites that could derive optimum benefit from automatic-alerting devices.

A problem encountered at the Thule site was interference from AN/TPS-1D radars used by nearby Army antiaircraft forces. An Interference Blanking Unit is being developed to overcome this problem, or for use wherever L-band radars are so sited as to cause mutual interference.

At the request of the Lincoln Laboratory, Bendix Radio is building four additional Radalarm X-5 units, following the Laboratory's design. One unit has been delivered. Development of improved automatic-alarm circuitry for the AN/FPS-3 is continuing in the Laboratory.

III. DEVELOPMENT OF FLUTTAR

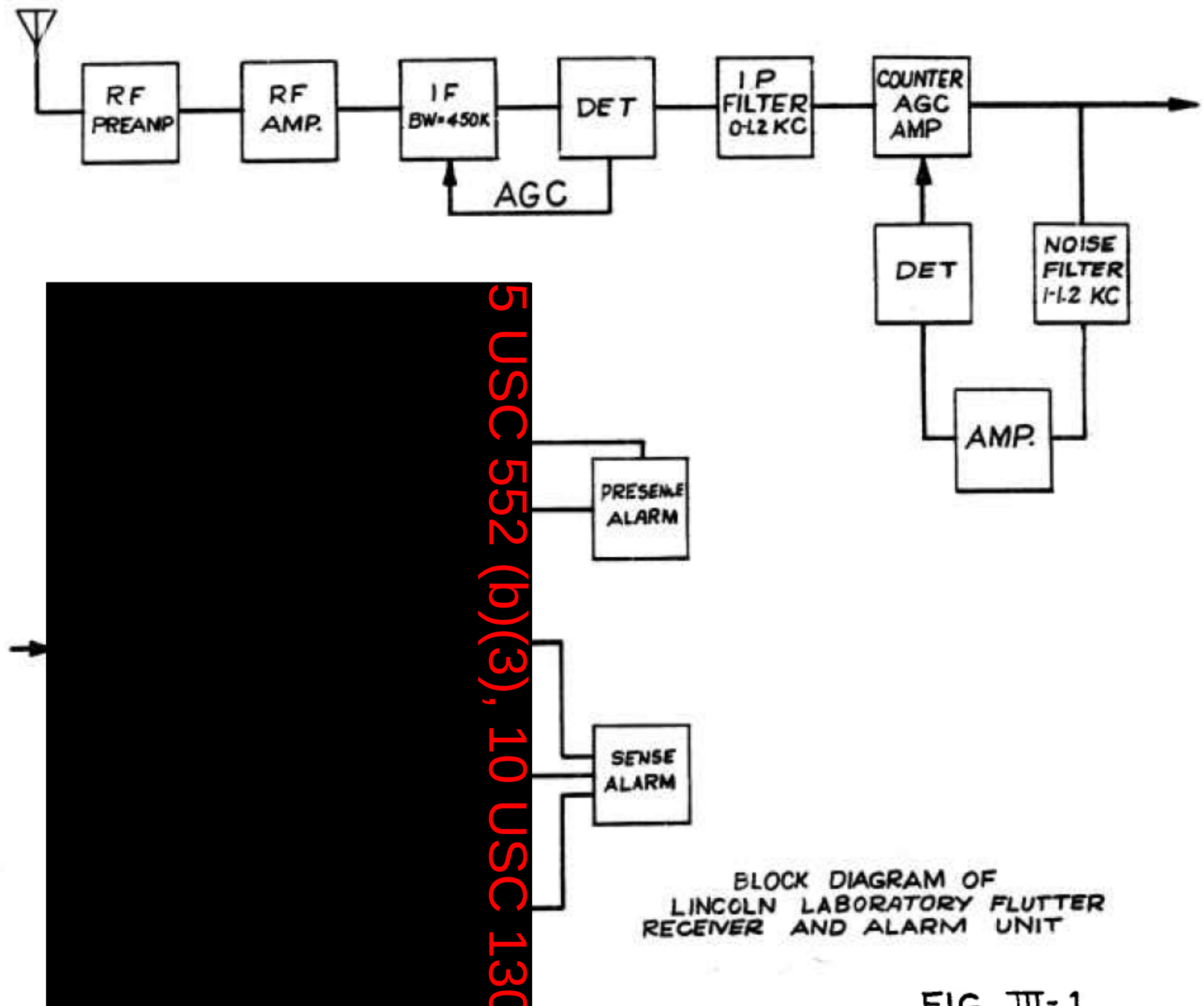
During the period covered by this report, the work on Fluttar has been concentrated on two projects:

(a) The further refinement of specifications for the prototype 50-mile baseline system being developed by Motorola, Inc.,

(b) The development and construction of suitable equipment for use by the Laboratory in verifying calculated performance of a 50-mile baseline system as regards detection, coverage and sense, and in testing alarm circuitry.

The basic specifications for the prototype 50-mile baseline system were given in the preceding progress report. Motorola, Inc., contractor for the system, has blocked out the system design and is currently investigating breadboard models of the receiver and transmitter exciter. The 1-kw klystron amplifier is to be supplied by Eitel-McCullogh, Inc.

Early in May, the Lincoln Laboratory 50-mile Fluttar system was installed on an overwater path from North Truro (transmitter) to Magnolia (receiver). This system consists of an RCA (Canada) 50-watt transmitter driving a push-pull power amplifier (using 2 Eimac Type 4X150G tetrodes); a modified RCA (Canada) receiver with an REL preamplifier, a new Lincoln Laboratory alarm and presentation unit, and RCA (Canada) antennas.



BLOCK DIAGRAM OF
LINCOLN LABORATORY FLUTTER
RECEIVER AND ALARM UNIT

FIG. III-1

With 30 watts of RF drive, the power amplifier has an output of [redacted] efficiency of 48 per cent. The main difficulty with the trans- [redacted] 5 USC 552 (b)(3), 10 USC 130 exciter power supply by an electronically regulated supply, replacing the AC filament supply by a DC supply, and by electronically regulating the plate and screen supplies for the power-amplifier stage.

Since it is expected that the amplitude of the direct signal on the 50-mile path will vary as much as 70 db, an additional gain-controlled IF stage has been added to the RCA (Canada) receiver. For this extreme variation in signal strength, there results a residual noise-level variation of 40 db at the detector output. Since the alarm unit operates as a fixed threshold device, an additional, independent AGC circuit (counter-AGC) has been employed to maintain a fixed noise level at the input to the alarm circuitry independent of variations in the level of the input signal to the receiver. This is accomplished in the following manner: A portion of the noise spectrum outside the information band is sampled, amplified, detected and integrated. The resulting voltage is then used to control the gain of the counter-AGC amplifier. The present circuitry is capable of controling the noise level to within 2 db for a 40-db variation in the input level from the detector.

The alarm circuitry provides three different outputs, as follows: (a) a "presence" alarm, (b) a "sense" alarm, and (c) a visual record of the target signal. The "presence" alarm, which is the most sensitive, is produced by feeding the output of the receiver through a filter having a bandpass [redacted] 5 USC 552 (b)(3), 10 USC 130 alarm actuates a paper recorder through a relay and records the information that has been stored for 2 minutes on a continuous magnetic-tape loop. This provides information for visual analysis. The "sense" alarm is obtained by [redacted] 5 USC 552 (b)(3), 10 USC 130 band for 1.8 sec. The sequence in which the alarms are actuated determines the direction of crossing through the asymetrical beam pattern, produced by offsetting the antennas slightly in the same direction from the baseline.

The Antenna Group of the Air Force Cambridge Research Center has completed the design and fabrication of a set of slotted waveguide antennas for use on 50-mile Fluttar links. Each antenna is a 24-foot section of 6- × 18- [redacted] power points. These antennas will shortly be installed on the North Truro-Magnolia link, and will be tested with the Fluttar system described above. They will probably also be used with the Motorola Fluttar equipment, although the final configuration for the prototype antenna has not been decided.

IV. LONG-RANGE RADIO COMMUNICATIONS

Work has continued, substantially along lines summarized in the previous progress report, on the development of techniques and equipment for beyond-the-horizon point-to-point radio communication at UHF and SHF. Particular attention has been given to:

(a) Propagation tests at UHF and SHF to determine path losses, transmitter power requirements, practical limitations on antenna aperture, bandwidth limitations, and requirements for effective space-diversity reception;

(b) Performance tests with a full duplex multichannel system;

(c) Development and/or procurement of additional equipment for use in the UHF/SHF program.

Support for the work in this general area has been provided under the regular Lincoln Laboratory program as well as under Project CORRODE.

A. TROPOSPHERIC RADIO-PROPAGATION TESTS

[redacted]

paraboloidal antennas described in the previous progress report. The operating schedule has permitted signal-level recording throughout two or three

24-hour periods each week. A marked seasonal decrease in received signal level was observed during the winter months. This reduction in signal level was most pronounced during periods of subfreezing temperatures. Recordable signals were present at all times, although the minimum hourly median values during periods of subfreezing temperature were only a few db above the receiver threshold level. The data obtained are being subjected to detailed analysis. Curves showing typical diurnal variations in hourly median signals exceeded 10, 50, and 90 per cent of the hour on certain days in the months of January, February, and March 1954 are plotted in Figures IV-1, IV-2 and IV-3. Analysis is being made of signal-level data obtained in March using both 5-foot diameter and 28-foot diameter paraboloidal antennas for transmission and reception.

Arrangements have been made with Stavid Engineering Company to provide technical assistance in connection with operations at Holmdel.

Certain changes were initiated in the facilities on Crawfords Hill at Holmdel. These changes included: relocation of the transmitter building; installation of a second 28-foot diameter paraboloidal antenna; installation of a 17-foot diameter antenna; and installation of a 5-foot diameter antenna – all of

5 USC 552 (b)(3), 10 USC 130

[redacted]

transmitted from Holmdel. Much of the time, however, received-signal levels were too low for satisfactory recording. Also, difficulties were encountered with the receiving equipment. A new preamplifier furnished by Bell Telephone Laboratories was installed for the [redacted] with some improvement in performance. A new receiver for operation [redacted]

5 USC 552 (b)(3), 10 USC 130

[redacted]

the month of January 1954 are plotted in Fig. IV-4.

Measurements were made [redacted] diameter paraboloidal antenna at Holmdel. The effective gain was found to be [redacted] Some filling of the pattern nulls was observed.

[redacted] recordings on [redacted] Two double-conversion superheterodyne receivers with common first and second oscillators were arranged for observation of relative phase of RF signals arriving at a pair of separated antennas. For use in this experiment, 5 identical dipole reflector antennas have been mounted at Round Hill on a horizontal structure normal to the bearing of the Alpine transmitter. These antennas are spaced at intervals [redacted] The associated recording system is capable of reproducing fluctuations in phase and amplitude occurring at rates as high as 50 cps. Initial tests indicated that results were seriously affected by aircraft in the path, and nighttime operation is indicated.

A Navy Type URR-13A receiver has been modified and installed temporarily at Holmdel for recording signals received from [redacted] Mcps klystron transmitter operated at Round Hill in connection with multiplex transmissions toward Fort Monmouth. This receiver is to be replaced soon with an improved Radio Engineering Laboratories unit having a better noise figure.

Plans have been established to provide facilities for simultaneous [redacted] dual feeds. Tentatively, it is planned also to establish additional receiving sites at distances from Round Hill of approximately 90 and 250 to 300 miles. These facilities will be used solely for signal-level recordings and will not be involved in modulation tests.

B. UHF MULTIPLEX SYSTEMS TESTS

Multiplex transmission tests have been made between Round Hill and the Signal Corps Engineering Laboratories at Red Bank, N. J. (Fort Monmouth). The path length is approximately 188 miles. The system has been arranged for full duplex operation and employs Ewen-Knight Corporation 5-kw klystron amplifiers at each terminal in conjunction with Signal Corps AN/TRC-24 radio relay sets and AN/TCC-7 (12-channel) or AN/TCC-3 (4-channel) multiplex equipment. Preamplifiers (cascode design by Lincoln Laboratory) have been provided for use with the AN/TRC-24 receivers. Two 28-foot diameter paraboloidal antennas are used at SCEL (Fig. IV-5) and, temporarily, two 17-foot diameter paraboloidal antennas are used at Round Hill. The latter are now being replaced by 28-foot diameter antennas. No arrangements have been made for space-diversity reception. Transmissions from [redacted]

This experiment is being conducted primarily as a task under the regular Lincoln Laboratory contract. The results will be of particular interest to the Signal Corps as well as to Project CORRODE.

The circuit has been operated about 900 hours since the last week in March 1954. Path attenuation is substantially in agreement with the [redacted] median values of received signal levels are typically be- [redacted]

The effective IF bandwidth of the AN/TRC-24 is approximately [redacted] Twelve-channel tests with the AN/TCC-7 terminal equipment yielded satisfactory operation, with occasional noise bursts much of the time with a 30-db signal-to-noise ratio in a single voice channel. Less satisfactory results were obtained with loop tests corresponding to effective circuit distances of 400, 800, and 1600 miles.

Four-channel tests were also made with the AN/TCC-3 terminal equipment which has a [redacted] The performance using this equipment was generally better than with the AN/TCC-7 12-channel equipment. Although the performance of the system under all conditions is somewhat marginal, it operates reliably and generally in accord with predictions.

Possible advantages of circularly polarized antennas are being investigated. On the basis of preliminary results, it appears that with circular-polarization fading due to aircraft reflections will be less serious. Crossed dipole feeds are being installed in the 28-foot diameter antennas. These are arranged to provide horizontally, vertically, or circularly polarized signals.

V. RECOMMENDATIONS FOR 1955 DISTANT EARLY-WARNING INSTALLATION

A memorandum[4] was prepared summarizing suggestions of the Lincoln Laboratory with respect to detection and communication facilities and other details of a land-based distant early-warning line which could be installed in 1955.

REFERENCES

(1) "Report on a Visit to the Northern Sites," Group 31 Report No. 103, Lincoln Laboratory, M.I.T. (9 March 1954).

(2) "Automatic Alerting Radar X-3," Group 31 Report No. 100, Lincoln Laboratory, M.I.T. (9 February 1954).

(3) "Preliminary Instruction Manual for Radalarm X-5," Lincoln Manual No. 9, Lincoln Laboratory, M.I.T. (26 February 1954).

(4) "Proposed Distant Early-Warning System for 1955 Installation," Lincoln Laboratory, M.I.T. (SECRET) (17 May 1954).

Hourly signal levels exceeded 10, 50, and 90% of the hour - January 1954.

[redacted] 5 USC 552 (b)(3), 10 USC 130

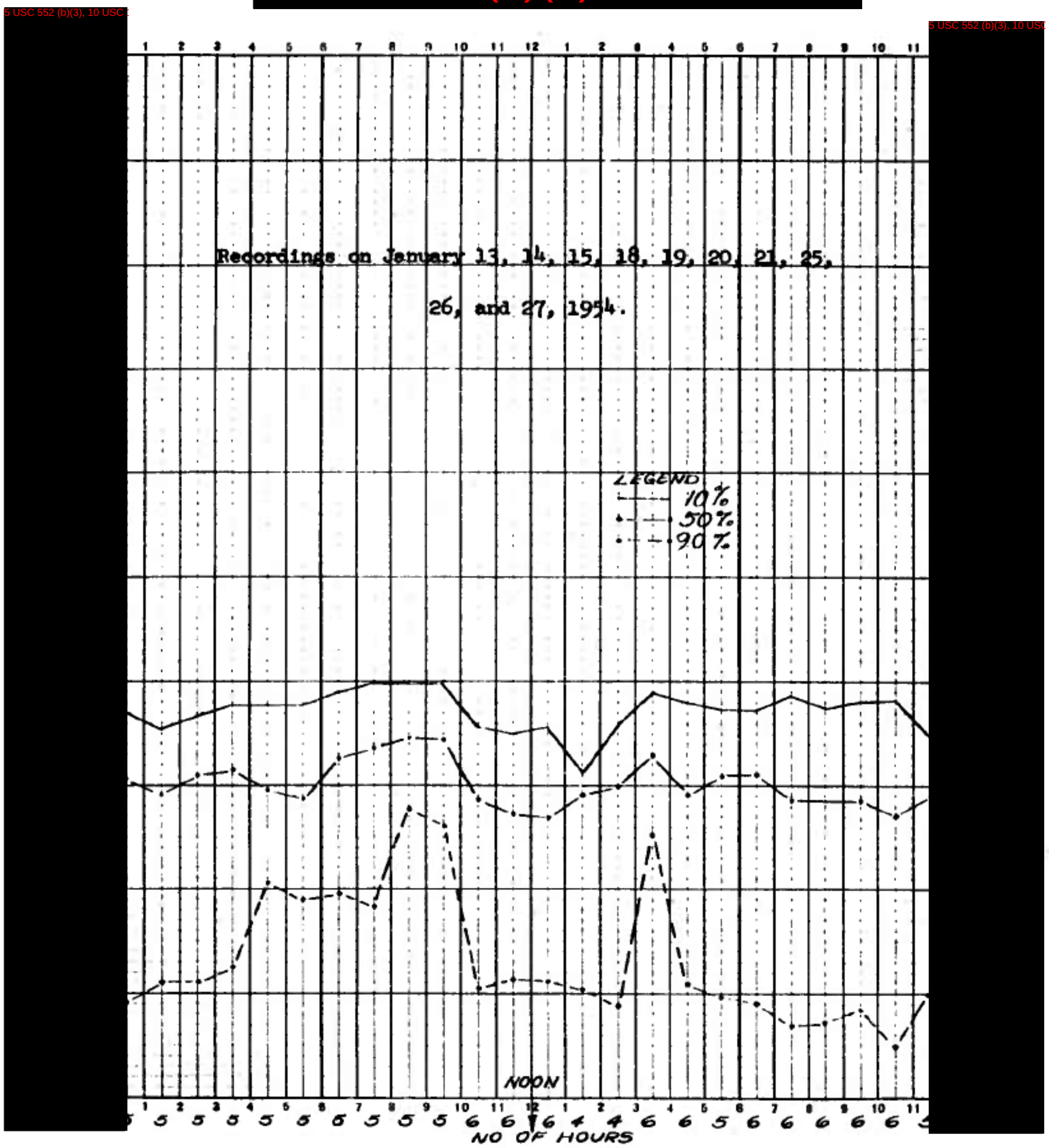


FIGURE IV-1

Hourly signal levels exceeded 10, 50, and 90% of the hour - February 1954.

[redacted]

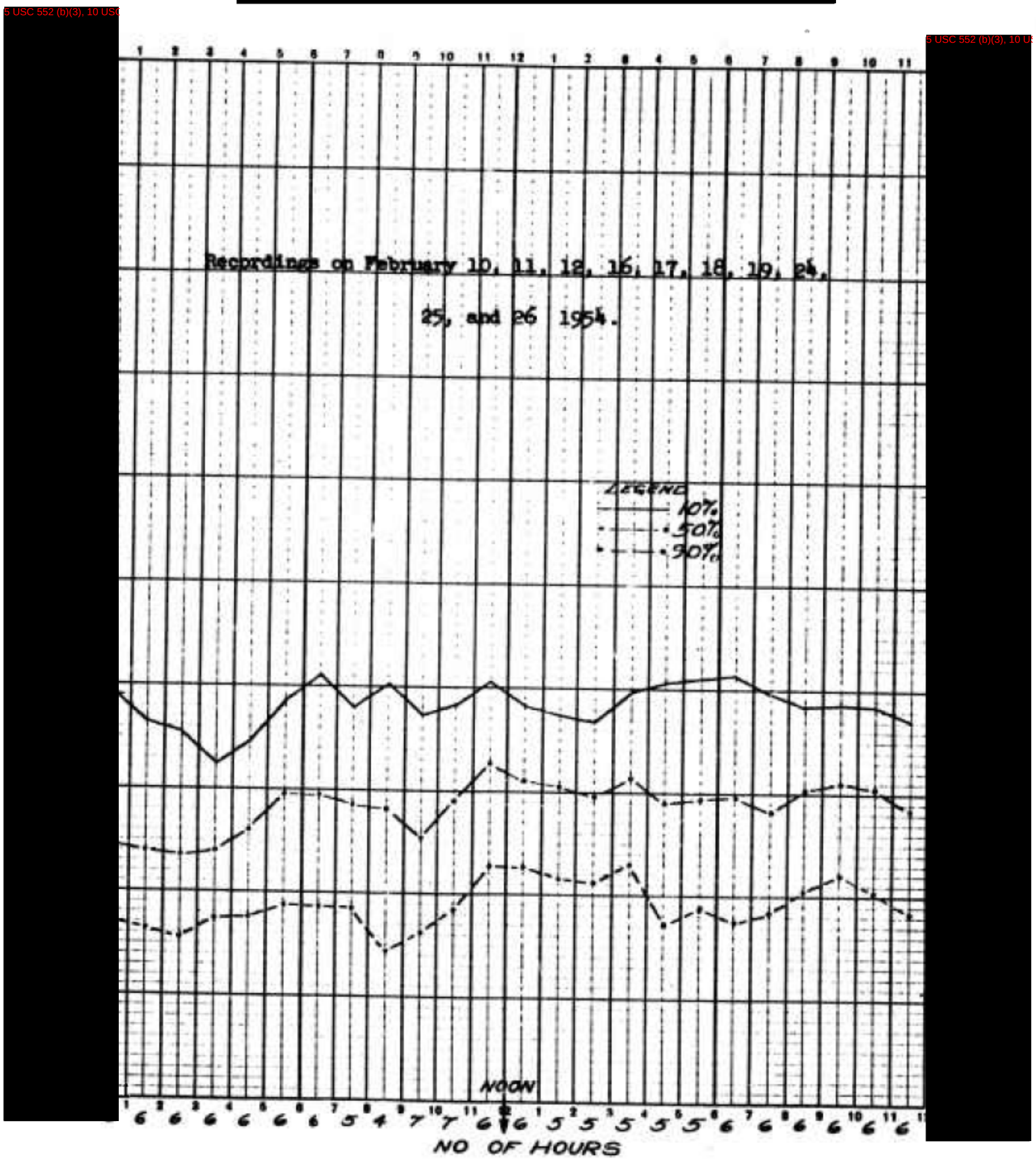


FIGURE IV-2

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Hourly signal levels exceeded 10, 50, and 90% of the hour - March 1954.

[redacted]

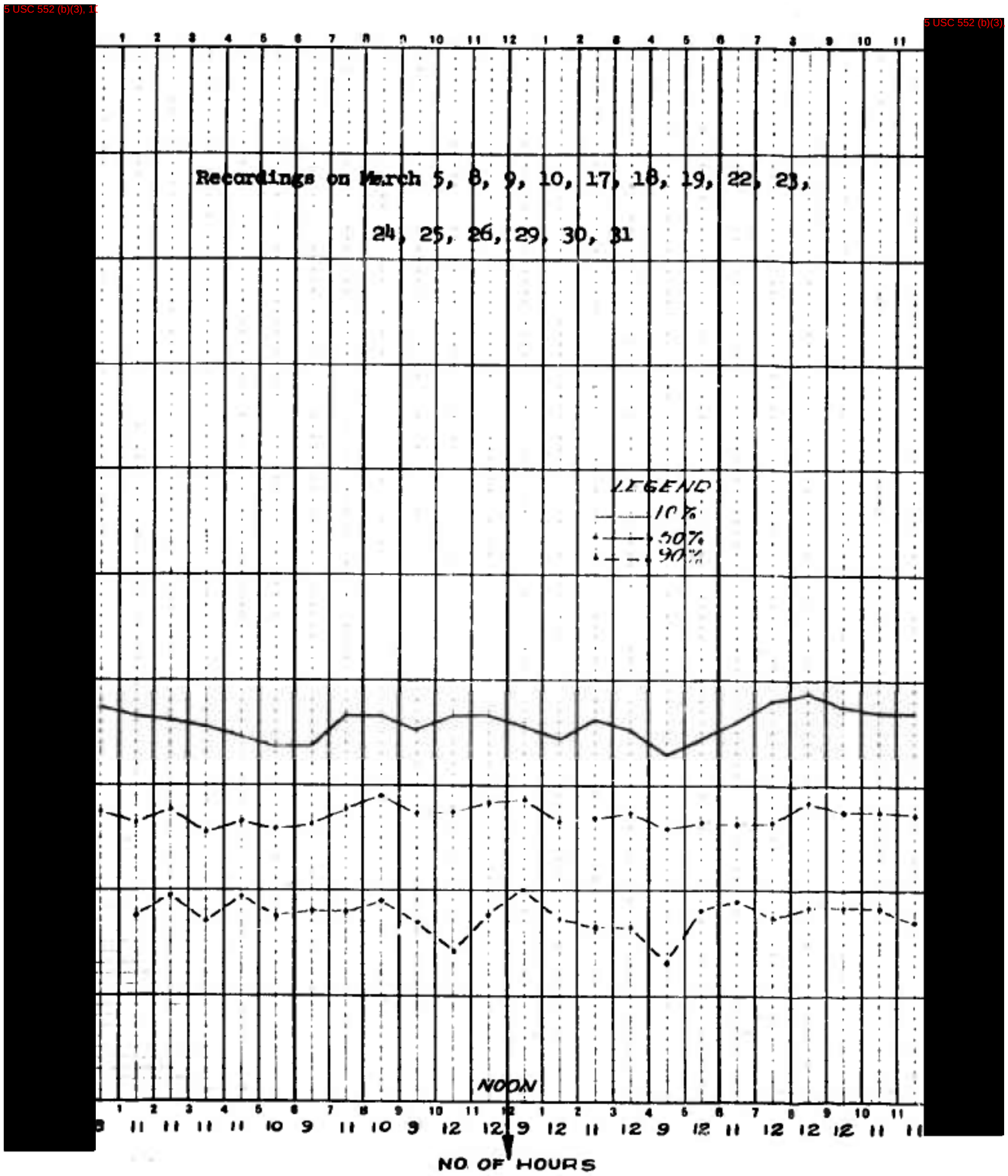

FIGURE IV-3

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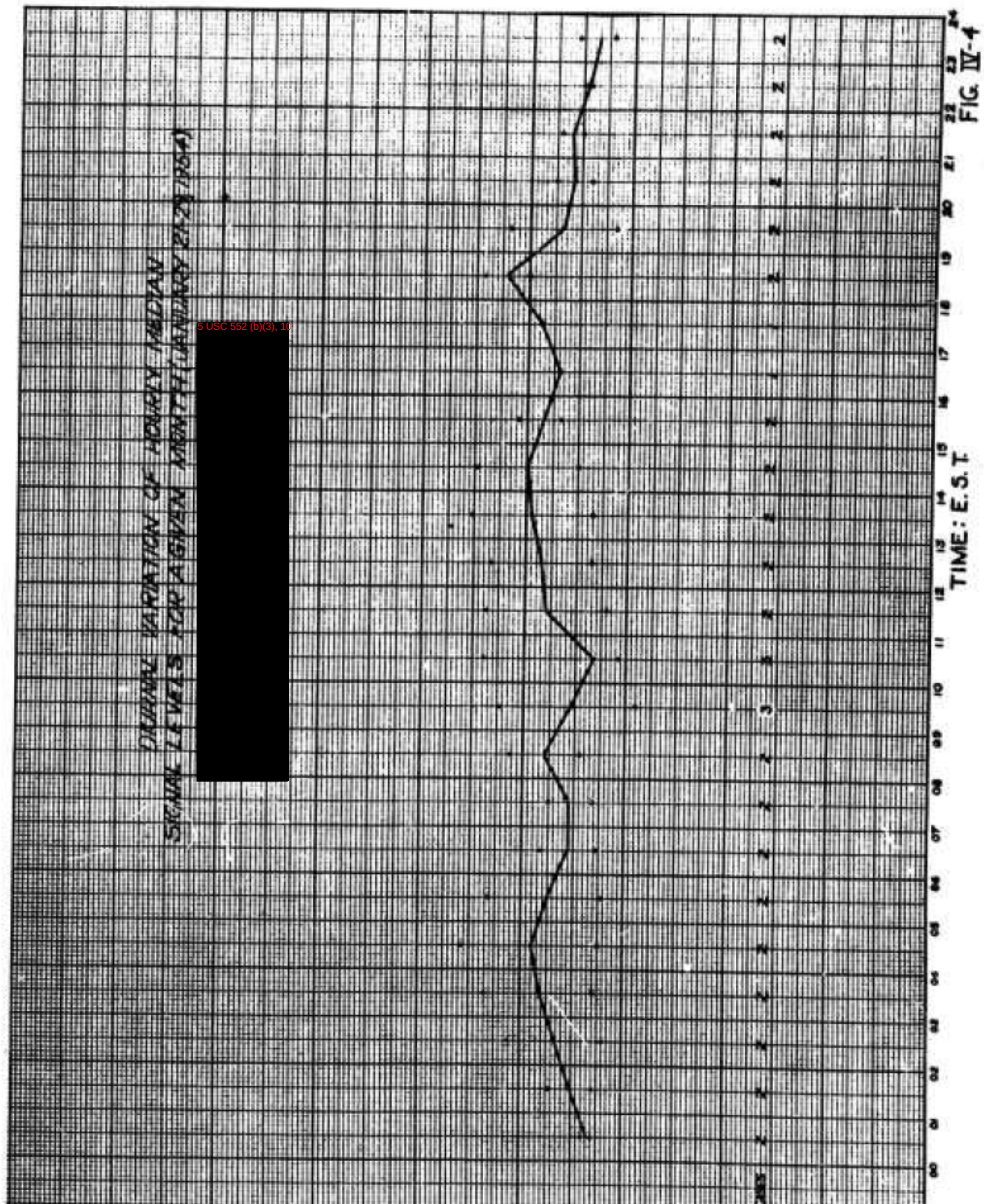
DIURNAL VARIATION OF HOURLY MEDIAN
SIGNAL LEVELS FOR A GIVEN MONTH (JANUARY 21-29 1954)
[redacted]
TIME: E.S.T.
FIG. IV-4

[redacted]

J-1003

Fig. IV-5. 28-Foot Diameter Paraboloidal Antennas Installed at Signal Corps Engineering Laboratories at Fort Monmouth, New Jersey.