THE EFFECT OF ATMOSPHERIC CONDITIONS ON THE
PROPAGATION CHARACTERISTICS OF ELECTROMAGNETIC WAVES
IN THE MICROWAVE REGION

VOL. 2

J. E. BOYD
PROJECT DIRECTOR

CONTRACT NO. W28-099-ac-175

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PROJECT NO. 109-8
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The purpose of this project is to investigate the effect of atmospheric conditions, such as ducts, turbulence and subsidence inversions, on the propagation characteristics of electromagnetic waves in the microwave region. An ultimate objective is to determine the optimum frequency (or frequencies) for a microwave radio relay system providing two-way communication and video operation over a distance of 30 to 50 miles point-to-point.

The method of attack is to make simultaneous signal strength measurements on several microwave frequencies over the same propagation path and, at the same time, to make extensive meteorological measurements along the path of transmission. Signal strength records and meteorological data can then be compared to determine the effects of various atmospheric conditions on radio propagation. In the analysis of the data to determine an optimum frequency, various factors will be considered, including: refraction due to atmospheric stratification or vertical gradients of temperature and water vapor; attenuation by rain, water vapor and atmospheric gases; interference between direct and earth-reflected waves, polarization effects, etc.

Up to the present time major effort has been expended in the design, construction, test, calibration, and installation of transmitters, receivers, psychrometers, and other equipment, and in the development and refinement of measuring techniques. Considerable effort has also been devoted to literature study and methods of data analysis. Large quantities of weather data have been obtained from the Atlanta Weather Bureau and from aircraft and balloon soundings. Partial analyses and summaries of these data have been given in monthly progress reports.

Propagation measurements at S-Band and X-Band frequencies began in May. Since that time four extended periods of operation have been conducted. The results of these operations have been included in recent progress reports. Propagation measurements at L-Band frequency in addition to measurements at X-Band and S-Band frequencies were made during October and November. The data and graphical summary for this period will be presented in a future report.
I. CURRENT REPORT SUMMARY

The work on the L-Band system and its installation was completed during the first week of October. Preliminary checks of antenna beam width were included in the above.

A TS-128 signal generator has been mounted in the receiver truck for calibration of the L-Band receiver. Other equipment in the truck has been rearranged to further improve portable operation of the receiving systems.

Final assembly of the improved camera meteorograph using ceramic resistance elements has been started. This unit will enable more rapid soundings to be made.

An additional survey of Kennesaw Mountain as a receiving site has been made. Facilities for operation of receiving equipment and features of the Georgia Tech-Kennesaw Mountain path were studied.

Propagation measurements over the Georgia Tech-Mt. Oglethorpe path were made during the period from 11 October to 21 November 1947. Data and results of these measurements will be presented in a future report.
II. ADMINISTRATIVE REPORT

A. Personnel and Administration.

1. Personnel Terminating Employment.
   a. George, Ralph C.

2. Personnel Added to Project.
      Qualifications: Two years college training; Army training and Weather Observer School; and experience in Army Weather Station.
      Mr. Coates is assigned to flight operations.
   b. Markwalter, J. L., Research Engineer.
      Qualifications: B. S. degree in E. E., Georgia Tech, 1945; candidate, M. S. degree in E. E., Georgia Tech, June, 1948; one year experience as instructor in E. E., Georgia Tech; eight months experience, transmitter operator, broadcast station.
      Mr. Markwalter will serve as engineer at the receiving station.
   c. Savage, Elizabeth M., Technical Assistant.
      Qualifications: three and one-half years training in physical and biological sciences at George Washington University and the University of Colorado; four years experience in meteorology, U. S. Weather Bureau, Washington, D. C.
      Miss Savage will have charge of meteorological computations and will assist in the data analysis.
   d. Vickery, George W., Technical Assistant.
      Qualifications: one year college training, three years Marine Corps technical experience.
      Mr. Vickery is assigned to the meteorological group and will assist in data analysis.
B. Communications.

1. Correspondence.

   a. Incoming.

   (1) Watson Laboratories.

      | Date  | Attention      | Subject            | Office     |
      |-------|----------------|--------------------|------------|
      | 9/2/47| F. E. Lowance  | Progress Report    |            |
      | 9/9/47| F. E. Lowance  | Conference         |            |
      | 10/6/47| Roy A. Martin | Equipment          | WLBCF-1    |

   (2) Reports Received.

      | Date  | Title                                               | Institution       |
      |-------|-----------------------------------------------------|-------------------|
      | 9/2/47| Progress Report No. 15 for September, 1947          | New York University|
      |       |                                                     | New York          |
      | 9/5/47| Scattering and Radiation from Circular Cylinders and Spheres| U. S. Navy Department|
      | 9/10/47| Report No. 10                                       | The University of Texas|
      | 9/10/47| Report No. 11                                       | The University of Texas|
      | 10/10/47| Report No. 9                                       | The University of Texas|

   (3) Miscellaneous.

      | Date  | Correspondent                           | Subject           |
      |-------|----------------------------------------|-------------------|
      | 9/2/47| New York University Washington Square College New York | Progress Report |
      | 9/12/47| Bureau of Standards Washington, D. C. | Conference       |
      | 9/22/47| MB Instruments, Inc. New Haven, Conn. | Instruments      |

      12 miscellaneous replies Electronics Equipment
b. Outgoing.

(1) Watson Laboratories.

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2. Conferences.

The Central Radio Propagation Laboratory, National Bureau of Standards, Washington, D. C., was visited on 18 and 19 September, 1947, by R. L. Allen, J. E. Boyd, and F. E. Lowance. Extended conferences on micro-
wave propagation problems were held with Dr. T. J. Carroll, Chief of the Basic Microwave Research Section, and other members of the CRPL staff, including D. L. Randall, J. H. Chisholm, H. E. Bussey, C. T. Zahn, F. W. Dunmore, and H. Lyons. Principal topics of discussion were:

a. Recent progress in microwave propagation investigations.

b. Methods of analysis of data on signal strength variations and correlation of the data with meteorological measurements.

c. Meteorological instruments used in tropospheric propagation investigations.

d. Additional experiments and refinements of measuring techniques which appear desirable in studies of microwave propagation characteristics.

Considerable time was spent in examination and study of signal strength records and associated meteorological data obtained in our measurements with S-Band and X-Band equipment. The amplitude and frequency of the signal strength variations were considered somewhat surprising for a line-of-sight path. In view of the limitations on atmospheric soundings, and the variety of factors affecting signal strength, exact analysis of the data is not considered possible. However, definite correlations were noted between large signal strength variations and atmospheric sounding data obtained during the same periods of the day. The results emphasize the need for more rapid and accurate methods of taking atmospheric soundings which would cover the path both horizontally and vertically.

The need for more data on the effects of rain on microwave propagation was also emphasized. This locality is particularly well suited to studies of attenuation by rain, because of the exceptionally high annual amount of rainfall, among the highest in the eastern part of the United States. Attenuations of the order of 10 to 20 db at X-Band have already been observed during scattered
showers, whose extent it is difficult to estimate. A large number of automatic recording rain guages distributed over the path of propagation would probably yield valuable information, particularly during the general winter rains. In this connection, it is interesting to note that a report is being prepared at CRPL to show the number of hours per year when various magnitudes of attenuation may be exceeded over a 50-km microwave transmission path. It is understood that theoretical values of attenuation versus rainfall rate are to be given in the report and that experimental checks are desirable. For the few attempts at measurements of rainfall attenuation to date, it appears that there is considerable variance between theory and experiment.

Recent work with wired recording was discussed, and the circuits currently in use were explained. Considerable information was obtained on the use of wire-wound temperature elements and associated problems. Of particular interest was the technique employed in the calibration of the temperature and humidity-sensitive elements.

Cavity resonator equipment for measurement of the dielectric constant of gases and water vapor was demonstrated by H. Lyons, Chief of the Microwave Standards Section of CRPL. Laboratory measurements of the dielectric constant of the air flowing through a cavity have been made with this equipment, and the results agreed closely with calculated values determined from measurements of temperature, humidity, and pressure. This method shows definite promise of application in rapid, direct measurement of the index of refraction of the atmosphere. Improved, stabilized oscillators are also being developed by Mr. Lyons' group. It was stated that a frequency
drift of less than one part in a million during a period of five minutes had been obtained with one of these oscillators.

As a result of these conferences it is suggested that additional studies be made along the following lines:


b. Measurement of variations in signal strength versus frequency of transmission, using a sweep frequency method. This experiment should give information on path length differences in multipath transmission.

c. Measurement of changes in signal strength with changes in polarization.

d. Measurement of possible beam width changes with rain at the transmitter station.

C. Financial Statement.

Expenditures to date: $106,434.35
Encumbrances (Materials and Supplies): 1,412.09
Balance: 13,773.56
III. THEORETICAL AND EXPERIMENTAL PROGRESS

A. Principal Problems Undertaken during Month.

1. L-Band Work.
   a. Receiver.

   The schematic circuit diagrams of the completed L-Band receiver are shown in Figures 1 through 4. As indicated in these diagrams the L-Band receiver is of conventional design. It employs a crystal mixer, reflex klystron as local oscillator, 15 mc IF strip, detector, AFC circuit consisting of a 15 mc discriminator, and a vacuum tube voltmeter. A Fleming-Williams sweep circuit for searching when the signal is lost is incorporated in the AFC circuit. Photographs of the receiver and receiver power supply are shown in Figures 5 and 6.

   In normal operation the vacuum tube voltmeter operates an Esterline-Angus recording meter and a panel meter.

   b. Transmitter.

   A 2040 disc sealed tube is used in the transmitter unit. This tube is rated at 6 watts plate dissipation, but tests indicate that it can be operated at 10 watts plate loss. At this level one watt of RF power will be delivered to the antenna. Schematic diagrams of the transmitter and its power supply are shown in Figures 7 and 8.

   The present transmitter is quite unstable and extremely sensitive to temperature changes. A new transmitter has been constructed and is being adjusted to provide sufficient power at the desired frequency. This transmitter is of the re-entrant cavity type, and it is expected to show greater stability than our present model. It will be described in detail in a later report.
c. Antennas.

Construction of the L-Band antennas is complete. Photographs of the antennas, showing the feeds, appear in Figure 9. Preliminary measurements indicate a voltage standing wave ratio in the rigid coaxial line of less than 1.1. While the impedance match to the flexible coaxial conductor is not exact, the slight mismatch does not give an appreciable error in calibration.

d. Calibration.

The transmitter power is monitored continuously by a probe connected to a crystal detector. The power output is also measured directly on a thermistor bridge at regular intervals.

The receiver is calibrated daily by use of an L-Band signal generator which has been installed in the receiver truck.

e. Signal Strength at Receiving Station.

Free space considerations on L-Band show that the power received at the Mt. Oglethorpe location, which is 49 miles airline from the transmitting station, should be 62 db below a milliwatt when 600 milliwatts are being transmitted. Since the receiver has a sensitivity of 100 db below a milliwatt, this permits a fading of 37 db without loss of signal.

2. Installation, Maintenance, and Servicing of Equipment.

Routine maintenance and servicing of equipment was conducted during the month of September in preparation for the October operations.

Transmitter site wiring and control circuits were checked, and temporary wiring and shielding used in the developmental stage were replaced and re-arranged in accordance with standard engineering practice. During this period the transmitter, monitoring circuits, feed line, and antenna were installed for the L-Band transmitting system. Photographs of the transmitter rack and
antennas at the transmitter station on top of the Physics Building at Georgia Tech are given in Figures 10 and 11.

Installation of the L-Band receiver, signal generator, feed lines, and antenna in the Receiver Truck was completed during the latter part of September. Other equipment in the receiver truck has been rearranged to further improve the portable operation of the receiving systems.

Communication facilities were improved by installation of convenience jacks and outlets at the microwave transmitter racks and antenna mounts. This permits remote operation of the communications sets and will aid in the rapid adjustment and alignment of the transmitting and receiving antennas.

The transportation of personnel and of small supplies to the receiving station during field operation has been facilitated by the vehicle (jeep) furnished by the Watson Laboratories. A shift of personnel can now be made entirely during the daylight hours. Use of the jeep saves time, reduces expenses, and greatly lessens the danger of accident on the unimproved road between Jasper and Mt. Oglethorpe.

3. Camera Meteorograph.

The components for the new meteorograph to be used with the moored balloon have been completed and are ready for final assembly.

This instrument will use ceramic resistance elements for the measuring of wet and dry-bulb temperatures. The wet and dry-bulb elements will be alternately switched into the circuit, actuating a 200-microampere meter. A camera similar to the one used in the original meteorograph will photograph the meter face at 10 to 20 second intervals. The desired temperatures will then be obtained from the photographed meter readings.

By using the ceramic elements, faster response to temperature changes
is obtained, thus permitting more rapid soundings. A second advantage is an appreciable reduction in weight which will increase the maximum height that can be reached by the balloon. The maximum height characteristics of the balloon have been further improved by replacing the nylon cable, that was originally supplied, with a different type of cable. The new cable tests 580 lbs. and weighs 4 1/4 lbs. per thousand feet. The original cable weighed 7 1/2 lbs. per thousand feet.


Measurements were made over the path from the Georgia Tech Physics Building to Mt. Oglethorpe during the period from 11 October to 21 November 1947. The most comprehensive operations to date were conducted during this period. Data were recorded on "X", "S", and "L" Band frequencies during a seasonal change in which unusual weather conditions were encountered for a large portion of the period. The installation of the "L" Band system was completed just prior to the start of this operation, and after initial adjustment and checking it provided data for approximately a full month.

During the six weeks operating period, no serious "X" and "S" Band equipment difficulties were encountered. The new "L" Band transmitter proved quite satisfactory, but several refinements and improvements were indicated as a result of operating experience. A new and improved transmitter is now under construction and will be installed at an early date.

Records of signal strength and weather measurements, data analysis, and results for the above operating period will be included in a future report.

5. Planning for Short-Range Measurements.

On 30 October 1947, a field trip was made to Kennesaw Mountain for
the purpose of again studying the existing facilities and the suitability of the site for short-range propagation measurements.

Kennesaw Mountain is located near Marietta, Georgia, at an airline distance of 18 miles from the Physics Building, Georgia Tech. The mountain top is at latitude 35° 58' and longitude 84° 34', and the elevation is 2000 feet.

The proposed path between the Physics Building and Kennesaw Mountain affords line-of-sight transmission at approximately the same angle of elevation as the present Mt. Oglethorpe path and over the same type of terrain. This similarity is considered very desirable for comparison of results over the two paths. The profiles of pages 11 and 12, Progress Report No. 2, dated 31 August 1946, illustrate the general nature of the path.

Operation of the receiving equipment at the proposed Kennesaw Mountain site should prove much easier than at Mt. Oglethorpe. There is an all-weather road from Georgia Tech to the Mountain, an AC power line running to the Civil Aeronautics Authority tower on the peak, and a flat area on the South side of the mountain at approximately 1800 foot elevation for positioning the receiving van and associated equipment. Actual road distance to the site is approximately 25 miles. This should make automatic operation of the receivers feasible, without an operator on 24-hour duty, since checks and maintenance trips can be made daily.

From considerations of accessibility, existing facilities at the receiving site, and transmission path features, it appears very desirable that propagation measurements be made over this path.
IV. SCHEDULE OF WORK FOR NEXT PERIOD

1. Final assembly, calibration, and testing of camera meteorograph Model II.
2. Additional study of methods of propagation data presentation and analysis.
3. Compilation and analysis of data.
4. Completion of new L-Band transmitter.
5. Additional propagation measurements.

Submitted by
F. E. Lowance,
Project Director
J. E. Boyd,
Associate Project Director

Approved:
Gerald A. Rosselot,
Director

DECLASSIFIED
APPENDIX

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Figure 4: I.F. Amplifier - L-Band Receiver

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Note: All capacitors are 0.005 MF unless otherwise indicated.
The oscillator consists of a coaxial, folded-back, double cavity with a small feedback probe from plate-grid cavity to grid-cathode cavity. Air is driven directly through the cavity for cooling.
Rear View

Front View (Feed not at Focal Point)

L-BAND ANTENNA

Figure 9.
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JANUARY 31, 1948
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PROJECT ABSTRACT

The purpose of this project is to investigate the effect of atmospheric conditions, such as ducts, turbulence, and subsidence inversions, on the propagation characteristics of electromagnetic waves in the microwave region. An ultimate objective is to determine the optimum frequency (or frequencies) for a microwave radio relay system providing two-way communication and video operation over a distance of 30 to 50 miles point-to-point.

The method of attack is to make simultaneous signal strength measurements on several microwave frequencies over the same propagation path and, at the same time, to make extensive meteorological measurements along the path of transmission. Signal strength records and meteorological data can then be compared to determine the effects of various atmospheric conditions on radio propagation. In the analysis of the data to determine an optimum frequency, various factors will be considered, including: refraction due to atmospheric stratification or vertical gradients of temperature and water vapor; attenuation by rain, water vapor, and atmospheric gases; interference between direct and earth-reflected waves; polarization effects; etc.

During the first several months of the program the major effort was expended in the designing, construction, testing, calibration, and installation of transmitters, receivers, psychrographs, and other equipment, and in the development and refinement of measuring techniques. Considerable effort has also been devoted to literature study and methods of data analysis. Large quantities of weather data have been obtained from the Atlanta Weather Bureau and from aircraft and balloon soundings. A camera-type meteorograph of new and improved design that is used for lower level balloon soundings has resulted in greater accuracy of these data. Partial analyses and summaries of these data have been given in monthly progress reports.

Propagation measurements at S-Band and X-Band frequencies began in May. Since that time five extended periods of operation have been conducted. The results of three of these operations have been included in recent progress reports, and the data obtained during a period in October and November, 1947, are presented in this report. The first signal strength recordings at L-Band frequency, in addition to the measurements at X-Band and S-Band frequencies, were made during this period. The data for the last operation, 24 January to 1 February 1948, will be included in a report which will be prepared during March, 1948.
I. CURRENT REPORT SUMMARY

A new L-Band transmitter using a 2043 tube has been completed. This transmitter replaces the first model. Several changes and improvements have been made in the L-Band receiver and antennas and in the X-Band antenna.

The camera meteorograph using thermistor elements has been completed and calibrated. Very rapid balloon soundings may be made with this instrument. Photographs of the assembled unit are included.

An alarm has been designed and constructed which gives instant warning of any difficulties in any of the L-, S-, and X-Band receiving equipment. An electronic voltage regulator has been constructed for use with the PE-95 and PE-197 power units. Remote start and stop convenience switches for the power units have been installed in the receiver truck.

Results of the propagation measurements made from 10 October 1947 to 21 November 1947, including signal strength measurements and corresponding meteorological data, are presented in graphical form.
II. ADMINISTRATIVE REPORT

A. Personnel and Administration.

1. Personnel Terminating Employment.
   a. de Court, Henry F.
   b. Vickery, George W.

2. Personnel Added to Project.

   Qualifications: One quarter college training; five years naval technical experience.

   Mr. Roberts has been assigned to the meteorological staff and will assist in the collection of data.

B. Communications.

1. Correspondence.

   a. Incoming.

   (1) Watson Laboratories.

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<th>Date</th>
<th>Title</th>
<th>Institution</th>
</tr>
</thead>
</table>
(2) Reports.

Date | Title | Institution
--- | --- | ---
1/7/48 | Report No. F-895-17 | Motorola Inc.

(3) Miscellaneous.

Date | Correspondent | Subject
--- | --- | ---

b. Outgoing.

(1) Watson Laboratories.

Date | Attention | Subject | Office
--- | --- | --- | ---
12/8/47 | Chief, Supply Division | Equipment | WLSUB1G
12/8/47 | B. N. Haggquist | Shipping Tickets | WLSUB1G
12/29/47 | B. N. Haggquist | Contract | WLSUB1G
12/29/47 | B. N. Haggquist | Shipping Tickets | WLSUB1G
12/29/47 | Theodore M. Natt | Equipment | WLSUB1G

(2) Miscellaneous.

Date | Address | Subject
--- | --- | ---
12/6/47 | Washington Square College New York, N. Y. | Progress Report

C. Financial Statement.

Expenditures to date: $116,762.15
Encumbrances (Materials and Supplies): $ 814.48
Balance: $ 4,043.37
III. THEORETICAL AND EXPERIMENTAL PROGRESS

A. Principal Problems Undertaken during Period from 1 December 1947 to 31 January 1948.

1. L-Band Equipment.

a. L-Band Transmitter.

The new L-Band transmitter described in an earlier report* has been completed. This transmitter, operating at 1310 megacycles, consists of a continuous wave oscillator with D.C. power furnished by a regulated supply. The oscillator consists of a 2C43 disc-seal tube in a re-entrant cavity. A stable output of 900 milliwatts is fed directly to the antenna by means of coaxial lines. The stability of output is largely due to the regulated power source. The first model, using the 2C40 folded-back cavity transmitter, has been replaced by this new improved unit.

b. L-Band Receiver.

During the previous operation, it was necessary to frequently replace the last tube (6AK5) in the I. F. amplifier strip of the L-Band receiver. As a result, the daily L-Band calibrations showed a varying receiver sensitivity. On investigation it was found that the difficulty was being caused by a wiring error which removed the cathode bias from the tube. This has been corrected, and bench tests have been made which indicate that the receiver is now stable.

c. L-Band Antennas.

Recent tests showed that the impedance of the transmitting and receiving antennas was improperly matched to the transmission lines. It was discovered that a slight error in absolute signal level had resulted.

from this mismatch. The fault was further verified by checking the antenna patterns and feed positions. This was corrected by the installation of redesigned matching transformers in the transmission lines and repositioning of feeds.

2. S-Band and X-Band Equipment.

General maintenance work, such as cleaning and tuning, was necessary for the S- and X-Band equipment.

a. S-Band Antennas.

The patterns and feed positions of the S-Band antennas were checked. The gains of these antennas were found to approach closely the calculated values.

b. X-Band Antennas.

The patterns and feed positions of the X-Band antennas were also checked. The gains of these antennas were found to be considerably below the calculated values, and the transmitting antenna beam pattern was found to have a slight dip in the center. Both receiving and transmitting antennas have been modified, and higher antenna gains are indicated. A more detailed discussion of these modifications will be given in the next report which will be prepared during March, 1948.

Flexible sections have been inserted in the wave guides feeding the transmitting antenna in order to allow adjustment of the antennas without changing the position of the feeds with respect to the parabolic reflectors.

3. Camera Meteorograph.

The camera meteorograph using thermistor elements has been completed and calibrated. The entire unit weighs five pounds, with the camera assembly
contributing approximately one half this weight.

The thermistor elements were coated with Harvel insulating varnish, No. 6126, which was baked on the elements at a temperature of about 250°F. A suitable coating material was difficult to locate for it not only had to be a good insulator, but also waterproof, durable, and reasonably flexible. Of the materials tested, the Harvel varnish most nearly satisfied all of the above conditions.

For calibration, the thermistors were enclosed in a neoprene rubber casing and connected in the electrical circuit of the meteorograph. They were then immersed in a bath of salt water and calibrated against mercury glass thermometers at temperatures from -14°F to +90°F. Temperatures below freezing were obtained by the addition of cracked ice to the salt water bath.

Very rapid balloon soundings may be made with this instrument because the reaction time of the thermistors, for adjustment to temperature changes, is less than ten seconds for 60% of the total temperature change.

Photographs of the complete camera meteorograph are shown in Figures 67, 68, and 69; a complete wiring diagram and detailed description of the unit will be included in the next report.


An alarm has been designed and constructed to be operated by the signal output of the L-, S-, and X-Band receivers whenever the signal output falls below a certain pre-set value. The alarm gives instant warning of most receiver troubles, transmitted signal decreases, and deep fades due to atmospheric conditions. This unit renders invaluable service, since it prac-

* Good insulating properties are necessary so that the wet wick surrounding the wet-bulb element will not affect temperature readings.
tically eliminates all chances of overlooking any of these difficulties that might occur when both operators are momentarily not observing the recorders.

The principle of operation and circuit diagrams of this alarm will be presented in the next report.

5: Installation and Maintenance of Equipment.

General repairs were made on all vehicles in preparation for the Mt. Oglethorpe operation in January.

The power-generating equipment and auxiliary units were checked and improvements made. An electronic voltage regulator of the vibrating relay type was designed and has been constructed. This is used as the regulator for the PE-95 power unit and as an auxiliary regulator for the PE-197 power unit.

Remote start and stop convenience switches for the power units have been installed in the receiver truck.

In the past, difficulties have been encountered from water condensation in the gasoline drums supplying fuel to power units. A metal tube of adjustable depth which is fitted with a strainer has been constructed and permanently attached to a standard bung plug. This allows the supply to be drawn off above the water level.
A. Propagation Results.

Propagation measurements were made over the 49 mile Georgia Tech-Mt. Oglethorpe path from 10 October 1947 to 21 November 1947. All reliable data have been collected and are presented in the Appendix. The signal strength records are shown in Figures 1 through 42; hourly signal level ranges in Figures 43 through 51; and percentage curves for signal strength values in Figure 52. To facilitate the interpretation of the signal strength charts, the conditions under which they were recorded are presented as follows:

1. S-Band.

- Frequency: 2860 mc
- Pulse Recurrence Frequency: 500 pps
- Peak Transmitted Power: 38.2 kw
- Calculated Free Space Level: 8.4 dbm
- Calculated Transmitting Antenna Gain: 27 db
- Calculated Receiving Antenna Gain: 27 db
- Line Attenuation (Antenna to Receiver): 33 db
- Receiving System Noise Level: 50 dbm

2. L-Band.

- Frequency: 1225 mc
- Continuous Wave: 600 mw
- Average Transmitted Power: 62.4 dbm
- Calculated Free Space Level: 62.4 dbm
- Calculated Transmitting Antenna Gain: 20 db
- Calculated Receiving Antenna Gain: 20 db
- Line Attenuation (Antenna to Receiver): zero
- Receiving System Noise Level: 85 dbm

3. X-Band.

- Frequency: 9400 mc
- Pulse Recurrence Frequency: 500 pps
- Peak Transmitted Power: 29.2 kw
- Calculated Free Space Level: 20.2 dbm
- Measured Transmitting Antenna Gain: 27 db*
- Measured Receiving Antenna Gain: 27 db*

B. Atmospheric Soundings.

Three methods were used to obtain meteorological data: (1) radiosondes; (2) balloon soundings; and (3) aircraft soundings.

The radiosondes were received each day at 1000 EST and 2200 EST from the U. S. Weather Bureau in Atlanta. However, because the radiosonde unit requires such large changes in altitude for a measurable response, low level soundings were made up to a height of 1000 meters msl with a captive balloon carrying a camera meteorograph.* A new type balloon consisting of a nylon bag and a latex bladder with nylon tail fins has been obtained from the Motorola Corporation. This has replaced the previous balloon which had been worn to such an extent that the leakage of gas rendered it impractical.

Aircraft soundings were made at times when pertinent data could most probably be obtained. These soundings were made to a height of 1700 meters msl.

The results of all significant meteorological soundings are presented in the Appendix in Figures 53 through 66.

C. Weather Summary from Synoptic Charts for Operation Period of 11 October to 21 November 1947.

11 October 1947

This region is in a ridge of high pressure with northeasterly flow of cool, moist air. Light intermittent showers occurred entire day.

12 October 1947

Ridge of high pressure continued to bring cool, moist air to this area with scattered showers in the morning and gradually clearing conditions in the afternoon.

* Progress Report No. 16, January 31, 1948, p. 6, Camera Meteorograph.
13 October 1947

A Low forming off Bermuda tended to bring northeasterly circulation of increasingly warm air.

14 October 1947

Circulation became northerly as the Low deepened off the coast of North Carolina. Increased warming and rise of moisture content brought showers to North Georgia in the afternoon.

15 October 1947

The low pressure area moved westward over south Georgia with continuous light rain in this region beginning in the afternoon.

16 October 1947

The Low continued over west-central Alabama giving this area easterly circulation and continuous light rain the entire day.

17 October 1947

Light showers occurred in the morning as the Low dissipated over Mississippi, and circulation became southerly under the influence of the Bermuda High.

18 October 1947

Southerly circulation continued with widely scattered showers over north Georgia. Not much change in temperature or moisture content.

19 October 1947

A weak cold front through central Tennessee with low pressure area over Louisiana affected the circulation of this area but produced no change of weather.

20 October 1947

The cold front passed Atlanta near 0200E accompanied by widely scattered

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showers. A large High centered over Kentucky-Indiana gave this area northeasterly circulation. Considerable cooling and loss of moisture content brought clearing skies by 0700E.

21 October 1947

Northeasterly circulation of cool, dry air continued as the high pressure cell moved slowly eastward.

22 October 1947

Synoptic situation remained unchanged.

23 October 1947

A squall-line ahead of a weak cold front to the west of this area brought showers in the afternoon. Circulation became southerly with increases in temperature and moisture content.

24 October 1947

The cold front moved from the northwest to this area passing Atlanta at 1800E. Immediate cooling was evident as the circulation changed to northeasterly.

25 October 1947

The cold front became stationary southwest of this area. Temperatures continued to drop, and rain was recorded for the entire day.

26 October 1947

A low pressure area formed over Iowa-Illinois with a weak cold front south of that area. A squall-line that formed in the late afternoon brought considerable cloudiness and scattered rain-showers to this area. Temperatures increased as circulation became southeasterly.

27 October 1947

The cold front moved east as the low pressure area deepened over
Wisconsin. This cold front brought frequent rain-showers and steadily lowering temperatures to this area by 1700E.

28 October 1947

Cold front passed this area at 0700E with heavy rain-showers during passage. Skies cleared rapidly after cold front passage, and circulation changed to a westerly direction.

29 October 1947

The northwesterly circulation of cool, dry air from a high pressure ridge following the cold front moved over this area causing continued clearing. The ridge moved off the coast into the Atlantic Ocean.

30 October 1947

Synoptic situation unchanged.

31 October 1947

Synoptic situation remained unchanged.

1 November 1947

Low pressure area formed with center located over Memphis, Tennessee. A warm front formed along a Montgomery, Alabama-Tallahassee, Florida line. This front caused low cloudiness and light continuous rain throughout this area for the entire day.

2 November 1947

Circulation over this area remained easterly as the Low moved over south Georgia. Light rain continued the entire day.

3 November 1947

The low pressure area moved Northeast along coast with a stationary occluded front south of this region bringing low cloudiness and rain until noon.
4 November 1947

Skies became clear in early morning. Circulation became southwesterly with slight warming as a high pressure cell formed over the Gulf.

5 November 1947

A cold front over eastern Arkansas moved rapidly eastward, passing Atlanta near 0900E with scattered showers along the frontal zone. Circulation became northwesterly with rapidly clearing skies and lowering temperatures behind the front.

6 November 1947

High pressure area over central United States gave northwesterly circulation of cool, dry air with clear skies over this region.

7 November 1947

Circulation became southeasterly as the high pressure ridge passed this area in morning. A cold front moved in from the west with a squall-line affecting this region by 1300E. Frequent showers in the afternoon became continuous light rain after 1900E.

8 November 1947

The cold front passed Atlanta in the early morning with clearing skies and rapidly lowering temperatures and moisture content.

9 November 1947

A high pressure area formed over the Gulf and drifted northward with westerly circulation the entire day. Low temperatures and clear skies prevailed the entire day.

10 November 1947

The High centered over the Carolinas gave this area southeasterly circulation with light rain beginning after noon and continuing the rest
of the day.

11 November 1947

A warm front to the south, overrunning this area, and a cold front moved in from the west and passed Atlanta near 1900E. Light rain the entire day ended immediately after the cold front passed. Considerable cooling and drop in moisture content with the passage of the cold front.

12 November 1947

This region in northerly circulation from high pressure cell centered over Kentucky. Clear skies, low temperatures, and low moisture content prevailed the entire day.

13 November 1947

Synoptic situation remained unchanged.

14 November 1947

Circulation became strong easterly as the High moved over New England. A warm front formed to the southwest with lowering cloudiness and intermittent rain beginning 1300E, and becoming continuous light rain after 1800E.

15 November 1947

The warm front moved northeastward, becoming stationary over this area at 2000E. Low cloudiness and continuous light rain prevailed the entire day.

16 November 1947

The warm front dissipated by 0900E. Drizzle and fog until 0900E with rapidly clearing skies as circulation became northwesterly under the influence of a strong Canadian High.

17 November 1947

Strong northwesterly circulation continued as the High moved south
and east over Ohio. Clear skies, low temperatures, and low moisture content prevailed the entire day.

18 November 1947

A low pressure cell formed in the Gulf with warm air overrunning this area. Considerable low cloudiness and continuous light rain began 0600E and lasted entire day.

19 November 1947

The low pressure area moved across northern Florida into the Atlantic Ocean with low cloudiness, light rain, and fog continuing entire day.

20 November 1947

This area in northeasterly circulation with continued overrunning from static warm from over south Florida. Light intermittent rain, drizzle, and fog prevailed the entire day.

21 November 1947

Synoptic situation remained unchanged, but the fog and drizzle ended by noon.
V. SCHEDULE OF WORK FOR FEBRUARY

1. Compilation and analysis of data obtained during January operation.
2. Inventory of property.
3. Consolidation of records.
4. Periodic sampling of weather data.

Submitted by
F. E. Lowance
Project Director

J. E. Boyd
Associate Project Director

Approved:
Gerald A. Rosselot,
Director
APPENDIX

1. Signal Strength Charts for X-, S-, and L-Band
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2. Hourly Signal Values
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3. Percentage Curves for Signal Strength Values
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SIGNAL STRENGTH CHARTS  
(X-, S-, and L-Band)  
11 October 1947 - 21 November 1947  

Figures 1 through 42 Inclusive
GRASSTOWN DUE TO VIBRATION OF ANTENNA BY EXTREME WINDS

CALCULATED FREE-SPACE SIGNAL LEVEL 20.2 GHz

CALCULATED FREE-SPACE SIGNAL LEVEL 8.4 GHz

CALCULATED FREE-SPACE SIGNAL LEVEL 6.4 GHz
X-BAND 43.5
RCVR 520
10-14-47
600
680 DBMS

0000-2400 GRASS DUE TO VIBRATION OF ANTENNA BY EXTREME WINDS.
SIGNAL DOWN DUE TO ANTENNA MISALIGNMENT

CALCULATED FREE-SPACE SIGNAL LEVEL 20.2 DBM

S-BAND 290
RCVR 340
10-14-47 369
0000-2400 SIGNAL DOWN DUE TO ANTENNA MISALIGNMENT AND
MOISTURE IN ANTENNA CABLES

CALCULATED FREE-SPACE SIGNAL LEVEL 8.4 DBM

L-BAND 66.5
RCVR 620
10-14-47 667
11.5 DBMS

CALCULATED FREE-SPACE SIGNAL LEVEL 62.4 DBM
CALCULATED FREE-SPACE SIGNAL LEVEL 20.2 DBM

CALCULATED FREE-SPACE SIGNAL LEVEL 8.4 DBM

CALCULATED FREE-SPACE SIGNAL LEVEL 62.4 DBM
CALculated FREE-SPACE SIGNAL LEVEL 20.4 DBm

CALculated FREE-SPACE SIGNAL LEVEL 8.4 DBm

CALculated FREE-SPACE SIGNAL LEVEL 62.4 DBm
Figure 25.

**Calculated Free-Space Signal Level**: 20.2 dBm

**Calculated Free-Space Signal Level**: 8.4 dBm

**Calculated Free-Space Signal Level**: 62.6 dBm
CALCULATED FREE-SPACE SIGNAL LEVEL 20.2 DBM

CALCULATED FREE-SPACE SIGNAL LEVEL 8.4 DBM

CALCULATED FREE-SPACE SIGNAL LEVEL 6.2 DBM

CALCULATED FREE-SPACE SIGNAL LEVEL 6.2 DBM
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<th>X-BAND</th>
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<tr>
<td>10.2</td>
<td>7.5</td>
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<td>12.5</td>
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<td>260</td>
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<td>14/47</td>
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<td>0.5</td>
<td>14/47</td>
</tr>
<tr>
<td>54.5</td>
<td>1.0</td>
<td>14/47</td>
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**L-BAND**

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<td>01/3</td>
<td>71/3</td>
</tr>
<tr>
<td>75/3</td>
<td>01/3</td>
</tr>
<tr>
<td>75/3</td>
<td></td>
</tr>
</tbody>
</table>

**Recoder Calibration Chart**

- **Power Off**
- **Sync Off**

**Calculated Free-Space Signal Level**

- 20.2 dBm
- 5.4 dBm
- 6.4 dBm

**Input Band**

- 0000 - 1200
HOURLY SIGNAL VALUES
16 October 1947 - 16 November 1947

Figures 43 through 51 Inclusive
PERCENTAGE CURVES FOR SIGNAL STRENGTH VALUES
16 October 1947 - 16 November 1947

Figure 52
METEOROLOGICAL RECORDS

Aircraft Sounding Data
Balloon Sounding Data
Radiosonde Data

11 October 1947 - 21 November 1947

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Figure 55.

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Figure 56.

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Figure 59.

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Figure 63.

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Figure 66.
CAMERA METEOROGRAPH PHOTOGRAPHS

Figures 67 through 69 Inclusive
PROGRESS REPORT NO. 17

PROJECT NO. 109-8

CONTRACT NO. W23-099-ac-175

THE EFFECT OF ATMOSPHERIC CONDITIONS ON THE
PROPAGATION CHARACTERISTICS OF ELECTROMAGNETIC WAVES
IN THE MICROWAVE REGION

By

F. E. LOWANCE, J. E. BOYD, R. A. MARTIN, and CATHERINE YOE

FEBRUARY 29, 1948
PROGRESS REPORT NO. 17
PROJECT NO. 109-8
CONTRACT NO. W28-099-ac-175

THE EFFECT OF ATMOSPHERIC CONDITIONS ON THE
PROPAGATION CHARACTERISTICS OF ELECTROMAGNETIC WAVES
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By
F. E. LOWANCE, J. E. BOYD, R. A. MARTIN, and CATHERINE YOE

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PROJECT ABSTRACT

The purpose of this project is to investigate the effect of atmospheric conditions, such as ducts, turbulence, and subsidence inversions, on the propagation characteristics of electromagnetic waves in the microwave region. An ultimate objective is to determine the optimum frequency (or frequencies) for a microwave radio relay system providing two-way communication and video operation over a distance of 30 to 50 miles point-to-point.

The method of attack is to make simultaneous signal strength measurements on several microwave frequencies over the same propagation path and, at the same time, to make extensive meteorological measurements along the path of transmission. Signal strength records and meteorological data can then be compared to determine the effects of various atmospheric conditions on radio propagation. In the analysis of the data to determine an optimum frequency, various factors will be considered, including: refraction due to atmospheric stratification or vertical gradients of temperature and water vapor; attenuation by rain, water vapor, and atmospheric gases; interference between direct and earth-reflected waves; polarization effects; et cetera.

During the first several months of the program, the major effort was expended in the design, construction, testing, calibration, and installation of transmitters, receivers, psychrographs, and other equipment; and in the development and refinement of measuring techniques. Considerable effort has also been devoted to literature study and to methods of data analysis. Large quantities of weather data have been obtained from the Atlanta Weather Bureau and from aircraft and balloon soundings. A camera-type meteorograph of new and improved design is used for lower level balloon soundings. Extremely accurate and reliable data have been recorded by this instrument. Partial analyses and summaries of these data have been given in the monthly progress reports.

Propagation measurements at S-Band and X-Band frequencies began in May, 1947, and measurements at L-Band frequency began in October, 1947. Five extended periods of operation have been conducted, and the results of four of these operations have been included in recent progress reports. The data obtained during the last operation period in January, 1948, are presented in the current report.
I. CURRENT REPORT SUMMARY

The signal-operated alarm has been completed and used successfully. The operating principle is given, and circuit diagrams are included.

A detailed discussion of the redesigned camera meteorograph is presented, including (1) a general description of the unit, (2) a detailed description and operating principles of each component part, and (3) the advantages of this unit over the first model of the meteorograph. A wiring diagram of the electrical circuit and a layout of the assembled unit are shown.

Tests and improvements have been made on the X-Band and the L-Band antenna systems. Beam patterns and gains were checked, and both systems are now functioning properly.

Meteorological data of all current climatic conditions are being collected at periodic intervals between operations.

An inventory of all property has been made. The files have been checked and important records and data consolidated.

Propagation measurements were made from 25 January 1948 to 1 February 1948. The results of these measurements, including signal strength and meteorological data, are presented in graphical form.
II. ADMINISTRATIVE REPORT

A. Personnel and Administration.

1. Personnel Terminating Employment.
   a. Bedenbaugh, T. S.
   b. Bove, Elizabeth (Savage)
   c. Elfe, T. B.
   d. Jones, F. S.
   e. Markwalter, J. L.
   f. Roberts, Marshall
   g. Roberts, T. E.
   h. Tolan, D. J.
   i. Tolan, J. H.

B. Communications.

1. Correspondence.
   a. Incoming.
      (1) Watson Laboratories.
          Date   Attention       Subject       Office
                  2/9/48   G. A. Rosselot  Contract       WLBCF-1
   b. Outgoing.
      (1) Watson Laboratories.
          Date   Attention       Subject       Office
                  2/3/48   B. N. Haggquist  Shipping Ticket

C. Financial Statement.

Expenditures to date: $120,166.10
Encumbrances (Materials and Supplies): $ 321.81
Balance: $ 1,132.09

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Page 3 of 42 Pages
III. THEORETICAL AND EXPERIMENTAL PROGRESS

A. Principal Problems Undertaken during February, 1948.

1. Signal-Operated Alarm.

The signal-operated alarm, designed to give warnings of receiver troubles, transmitted signal decreases, and deep fades caused by atmospheric conditions, has been completed and was successfully used during the January operating period. Diagrams of the alarm circuit and the power supply circuit are shown in the Appendix in Figures 1 and 2, respectively.

Basically, the alarm consists of three channels - one each for X-Band, S-Band, and L-Band. These channels operate at certain pre-set carrier levels, normally 0.3 scale reading on the receiver record meters. If one of the input signals should fall below this designated level, an alarm bell rings and a colored indicating lamp is automatically lighted. The alarm bell is external to the chassis and is actuated by a relay which is common to the thyratrons of the three channels. Thus, the bell will operate if the relay is closed by any or all of the thyratrons. For each channel there is an indicating lamp located on the front panel of the alarm unit, and the color of the lamp identifies the channel.

The X-Band and S-Band channels are identical, and both operate from the video output of their respective receiver. The video pulse is first amplified and rectified and is then superimposed on an adjustable positive voltage and applied to the grid of a thyratron. This adjustable voltage control determines the carrier level at which the thyratron will fire. If the signal is below the carrier level, the thyratron fires, the alarm rings, and the indicating lamp is turned on.

The L-Band channel operates from a positive D.C. voltage which is proportional to the strength of the received signal. This voltage is obtained in the L-Band receiver from the cathode circuit of the D.C. bridge driving the Esterline-Angus recorder. The D.C. signal passes through a modified D.C. amplifier and is then applied to the grid of a thyratron. The voltage level on the grid of the thyratron is varied by the adjustment of a potentiometer connected between the plate of the amplifier and ground, which controls the firing level of the thyratron. Proper grid-cathode relations in the thyratron circuit are maintained by a voltage regulator tube. When the signal falls below the pre-set value, the thyratron fires, causing the alarm to ring and the L-Band indicating lamp to be lighted.

The channel circuits are of customary design and are stable electrically. Setting of the alarm is most easily accomplished by use of the signal generators which are installed in the receiver truck for calibration purposes. In this process, a signal is fed into the receiver from the generator, and then, by varying the output of the generator, the alarm can be set to go off at the desired reading of the receiver record meter. Since the gains of the pulse amplifier in the X-Band and the S-Band alarm circuits vary with pulse width, for proper setting of the alarm the output signal of the generator must have the same pulse width as that of the signal to be received from the transmitter.
2. **Camera Meteorograph.**

The redesigned camera meteorograph, recently completed and calibrated, was tested during the January operating period and was found to be superior to the electronic psychrograph and the first model of the camera meteorograph, instruments previously used for recording of balloon sounding data. A wiring diagram of the electrical circuit and a layout of the assembled unit are shown in Figure 3 of the Appendix.

The meteorograph, which is carried aloft by the captive balloon moored by a strong, stranded nylon cable, is composed of the following four basic parts:

1. a moisture-proof, light-tight, cloth-covered housing unit;
2. an instrument panel on which are mounted an aneroid barometer, a watch, and a 100-microampere meter;
3. a 16 mm. aircraft gunsight camera;
4. two Friez ceramic thermistor elements (wet-bulb and dry-bulb);
   a propeller-type ventilating fan with motor and batteries for the wet-bulb element.

The housing unit is a box of rectangular cross-section, tapered at one end. The framework of the box is made of aluminum tubing, 3/16" in diameter, and is covered with broadcloth. To produce a firm and rigid casing, this structure was first coated with airplane dope. Aluminum paint was then applied to the outside of the casing to make the box completely light-tight. The aircraft camera is mounted on the tapered end of the housing unit, and the instrument panel, which is enclosed in a casing of construction similar to that of the housing unit, is hinged at the other end. The two thermistor elements and the ventilating fan are enclosed in

---

an "aluminum sleeve," mounted on the side of the housing unit, which aids in keeping on the thermistors a direct flow of air from the fan. The motor driving the fan is mounted directly in back of the sleeve. On the top of the housing unit is a selector switch with positions for "Off," "High Temperature Range" (50°F to 91°F), and "Low Temperature Range" (14°F to 61°F).

The thermistors, which are rod-shaped, approximately 2 inches long, and 1/32 inch in diameter, are connected in a circuit with the microammeter. They have a low thermal capacity and a resistance varying from 30,000 ohms at 0°C to 15,000 ohms at 30°C. Because the elements possess the above properties, they have a very small time lag and a response to temperature change which is less than ten seconds for 60% of the total change. As a result, extremely rapid balloon soundings may be made. The propeller-type fan which ventilates the wet-bulb thermistor is driven by a six-volt motor modified to operate on three volts. The thermistors are arranged in the "aluminum sleeve" so that air pulled through the sleeve by the fan passes the dry element first. Thus, evaporation from the wet-wick of the wet element cannot affect the dry temperature.

The 16 mm. aircraft gunsight camera is mounted so as to take pictures of the instrument panel. It is driven by a spring-powered motor which replaces the original 24-volt motor. A small air piston and a cylinder are driven by the gear train in the camera, and a variable orifice in the piston is set to release the camera shutter automatically at regular intervals. By proper adjustment of the orifice, the intervals can be varied from one second to several minutes. A friction governor installed in the gear train is used to keep the exposure time of the film constant. Also driven by the gear train are two switches, one of which turns on the two small lamps.
mounted in the framework of the housing unit. These lamps illuminate the
instrument panel for one second during each exposure. The other switch
places the wet and dry thermistors alternately in the meter circuit - the
wet thermistor is switched in the circuit at the beginning of one interval,
and the dry thermistor at the beginning of the next interval. Pictures of
both wet- and dry-bulb data can thus be obtained. At the present time,
pictures are being taken at 15-second intervals. The film used is regular
Super XX.

As shown in the schematic diagram of Figure 3 in the Appendix, there
are three separate circuits in the meteorograph unit: the thermistor cir-
cuit, the ventilating motor circuit, and the light circuit. These circuits
are turned on simultaneously by the selector switch located on the top of
the housing unit. The thermistor and light circuits are operated by Bur-
gess No. Z penlight cells which last for several hours when exposures are
being made at the 15-second intervals. The motor circuit is operated by
two Burgess No. 1 flashlight cells. When the motor is running continuously,
these cells will operate for approximately one hour.

The first model of the meteorograph was very similar in its general
construction to the present model. However, two serious difficulties were
encountered: wet- and dry-bulb thermometers were used and were found to
have a considerable time lag; and the height to which the balloon could
be uplifted was limited because of the heavy weight of the meteorograph
unit (about 6 1/2 pounds) and the nylon cable (7 1/2 pounds per 1000 ft.)
which was used to moor the balloon. These difficulties have been over-
come, and using the new model, very rapid readings may now be taken to
elevations as high as 2000 ft. above ground level. The time lag was reduced considerably by replacing the thermometers with the thermistor elements. The nylon cable was replaced by the new stronger and lighter stranded cable (4 1/2 pounds per 1000 ft.). Moreover, the weight of the complete unit was reduced to five pounds by: (1) using lighter-weight batteries, (2) removing all superfluous camera parts, (3) tapering the housing box at one end and using aluminum tubing in place of aluminum rods for the framework, and (4) replacing the thermometers by the light-weight thermistors. It is thought that with a specially built camera and barometer, a meteorograph could be built weighing three pounds or less.

3. Antenna Systems Studies and Measurements.

The importance of the calibration of the antenna systems in providing accurate data has led to continual study of these systems. Tests at regular intervals indicated that the S-Band was functioning properly, but that additional measurements on the X-Band and the L-Band were necessary. After these measurements were made, it was found that analysis and interpretation of the propagation data were much less difficult than before.

a. X-Band Antenna Tests.

The X-Band tests were made only on the receiver unit, since the receiving and transmitting antennas are identical. This unit was mounted with the associated equipment in the receiver van in the normal manner for operation. The truck was then placed a distance of about 60 ft. from the Electronics Laboratory and a signal was fed through a horn antenna, located at the laboratory, to the receiver system. All obstructions in the path were removed, and the horn, excited by a signal generator, was aimed upward at an angle of about 15° and carefully aligned with the receiving
antenna. Although some reflections from the ground were present, it is believed that reasonably good checks were obtained by this method.

The beam patterns were obtained by making the horn stationary and rotating the antenna in a horizontal plane. The received signal strength and angles of rotation were recorded and plotted. If nonsymmetrical patterns resulted, corrective action was taken by adjustment of the feeds. Another pattern was then found, plotted, and compared with the first. This process was continued until symmetrical patterns were obtained.

Gain measurements were made by comparing the received signal strength of the antenna to that of a substituted calibrated horn. Since a smaller signal is received by the horn, the difference in the signals constituted a db gain in the signal of the antenna over that of the horn. Then, by adding this db gain to the original horn gain, the antenna gain was obtained.

The above tests showed that the antenna pattern had a slight dip in the center of the main lobe and that the gain was approximately 27 db, a value 9 db below that calculated. Since adjustments of the feed did not seem to correct these difficulties, the feed itself was checked, and it was discovered that it was not illuminating the dish properly. A further study revealed that a more complete illumination of the 40 inch dish could be achieved if the double-dipole, double-reflector type feed were replaced by a single-dipole, single-reflector type feed. This new feed is shown in Figure 4 of the Appendix. The two dipoles and reflectors were removed and a new dipole and reflector of the proper lengths were installed and properly oriented with respect to the tapered end of the wave guide. The iris was removed from the wave guide end so that the new feed would correctly match the wave guide. This feed was installed and adjusted, and
new beam patterns and gain measurements were made. There was a considerable improvement in the shape of the beam patterns, and the antenna gain was found to be 36 db, approximately the same as the calculated value.

Additional gain measurements were made over the propagation path during the January operating period. These gains measured 33 db, and since the test was made under actual operating conditions, this db gain was taken as the value to be used in the data analysis.

b. L-Band Antenna Tests.

The beam patterns for the L-Band antenna were found by the same method as for the X-Band, with the exception that the horn antenna was replaced by the L-Band transmitting paraboloid antenna. Again, as in the X-Band case, tests were made only on the receiving antenna, since both antennas are alike.

The gain measurements were roughly checked by calculating the antenna gain and the received signal, and then comparing the actual received signal with this calculated signal.

A slight mismatch in the antenna was discovered at the point in the tapered section which joins the flexible 50-ohm coax with the rigid 50-ohm coax. This mismatch was found when the antenna was replaced by an artificial termination and a change in the plate current meter reading was noticed. An examination showed that an error made in the machining of the tapered section was the cause of the mismatch. The necessary correction was made by remachining the section.

The transformer which matches the feed to the rigid 50-ohm coax was redesigned because of a change in the operating frequency.

After the above corrections had been made, additional beam pattern

Meteorological data are being collected at periodic intervals between operations so that any necessary short-range forecasts can be furnished easily and complete up-to-date files can be kept of all current climatic conditions. The data are analyzed and significant information is recorded.

Radiosonde data are collected from the Atlanta Weather Bureau twice each day, and aircraft soundings are made approximately twice each week. Also, synoptic charts and data on winds aloft and rainfall, made available by the weather bureau, are kept up-to-date at all times.

5. Inventory of Property and Consolidation of Records.

An inventory has been taken of all government-furnished and commercially purchased equipment. The equipment was checked carefully and then tagged with all necessary information. This property is in good condition.

All records, including transmitter and receiver logs, weather observer logs, rainfall rates, and aircraft, balloon, and radiosonde data were consolidated into one file. The general files were checked and placed in good order.
IV. ASSEMBLED DATA

A. Propagation Results.

Propagation measurements were made over the Georgia Tech-Mt. Oglethorpe path during the operating period from 25 January 1948 to 1 February 1948. The operating conditions are presented as follows:

1. S-Band.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>S-Band Values</th>
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<tbody>
<tr>
<td>Frequency</td>
<td>2860 mc</td>
</tr>
<tr>
<td>Pulse Recurrence Frequency</td>
<td>500 pps</td>
</tr>
<tr>
<td>Pulse Length</td>
<td>1.3 microsec.</td>
</tr>
<tr>
<td>Peak Transmitted Power</td>
<td>38.2 kw</td>
</tr>
<tr>
<td>Calculated (Free Space) Received Signal</td>
<td>8.4 dbm</td>
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<tr>
<td>Calculated Antenna Gain</td>
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<tr>
<td>Transmitter</td>
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</tr>
<tr>
<td>Receiver</td>
<td>27.2 db</td>
</tr>
<tr>
<td>Line Attenuation (Antenna to Receiver)</td>
<td>33 db</td>
</tr>
<tr>
<td>Receiving System Noise Level</td>
<td>50 dbm</td>
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<tr>
<td>Receiver Noise Level</td>
<td>83 dbm</td>
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2. L-Band.

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<td>Frequency</td>
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<td>Continuous Wave</td>
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<td>Average Transmitted Power</td>
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<tr>
<td>Calculated (Free Space) Received Signal</td>
<td>61.4 dbm</td>
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<tr>
<td>Calculated Antenna Gain</td>
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<tr>
<td>Transmitter</td>
<td>21.8 db</td>
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<tr>
<td>Receiver</td>
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<td>Line Attenuation (Antenna to Receiver)</td>
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3. X-Band.

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<tr>
<td>Pulse Length</td>
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</tr>
<tr>
<td>Peak Transmitted Power</td>
<td>29.2 kw</td>
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<tr>
<td>Calculated (Free Space) Received Signal</td>
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<tr>
<td>Measured Antenna Gain</td>
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</tr>
<tr>
<td>Transmitter</td>
<td>33 db</td>
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<tr>
<td>Receiver</td>
<td>33 db</td>
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<tr>
<td>Line Attenuation (Antenna to Receiver)</td>
<td>24.4 db</td>
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<tr>
<td>Receiving System Noise Level</td>
<td>50 dbm</td>
</tr>
<tr>
<td>Receiver Noise Level</td>
<td>74.4 dbm</td>
</tr>
</tbody>
</table>
All reliable data have been collected and are presented in the Appendix. The signal strength records are shown in Figures 5 through 12, hourly signal level ranges in Figures 13 and 14, and percentage curves for signal strength values in Figure 15.

B. Atmospheric Soundings.

Meteorological data for the January operating period were obtained from captive balloon soundings and radiosondes.

The balloon soundings were scheduled for periods when the dynamic and the synoptic conditions indicated that significant data could be obtained. The new camera meteorograph and balloon were used and found to be highly satisfactory.

Radiosondes were obtained every day from the Atlanta Weather Bureau at 1000 EST and 2200 EST.

The M-Curves for this operating period, as calculated from the atmospheric soundings, are shown in the Appendix in Figures 16, 17, and 18.


25 January 1948.

This area is just to the south of a quasi-stationary cold front. Circulation from east brought cool temperatures and a little cloudiness.

26 January 1948.

Cold front passed to just southeast of Atlanta with warm, moist air over-running at low levels. Intermittent rain began in the early morning and continued the rest of the day.

27 January 1948.

The synoptic situation remained the same, but the over-running became
stronger as a wave formed on the front near New Orleans. Intermittent rain became continuous and changed to sleet and snow after 1500 EST.

28 January 1948.

A high pressure cell over Missouri drifted slowly southeastward as the wave on the cold front moved rapidly east to Jacksonville by 2400 EST. Rain, sleet, and snow fell continuously, except in the mid-afternoon.

29 January 1948.

The cold wave on the stationary front moved off toward Bermuda, and another warm wave formed near Mobile late in the day. Continuous light rain in the morning became intermittent by 1000 EST and continuous again by 1600 EST.

30 January 1948.

Wave off coast of Mississippi deepened and occluded and moved slowly eastward. Light continuous rain occurred entire day.

31 January 1948.

Continuous rain during day as occluded wave neared this area. Front passed near 1900 EST, and rapid clearing took place as circulation changed from easterly to westerly.

1 February 1948.

Strong westerly and northwesterly circulation brought clear skies and low temperatures, and no rain occurred.
V. SCHEDULE OF WORK FOR MARCH

1. Study and analysis of all data obtained during the five operating periods.

2. Preparation of a technical report showing a correlation and an analysis of the above data.

Submitted by

F. E. Lawance
Project Director

Approved:

J. E. Boyd
Associate Project Director

Gerald A. Rosselot,
Director
APPENDIX

1. Signal-Operated Alarm Circuit Diagrams
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SIGNAL-OPERATED ALARM CIRCUIT DIAGRAMS

Figure 1 - Alarm Circuit
Figure 2 - Power Supply Circuit
ALL CONDENSER VALUES MFD.
ALL RESISTORS 1/8 WATT UNLESS OTHERWISE NOTED.
All condenser values mfd.
All resistors 1 watt unless otherwise noted.

UTC S-39

Regulated power supply
Signal operated alarm

RAM R AM Em: R AM
FDS FDS 2-13-48 R.A. Martin
CAMERA METEOROGRAPH DIAGRAMS

-Figure 3-
Part A - Schematic Diagram
Part B - Layout Diagram
Switches A and B are operated by camera mechanism - i.e. A switches wet and dry bulb thermistors into meter circuit - alternating at 15 sec. intervals; B lights lamps for 1 sec. at 15 sec. intervals for photographing of instrument panel.

Schematic Diagram - Part A

Temperature elements are Friez temperature responsive elements (thermistors) Model No. 50/377.

Figure 3.

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MODIFIED X-BAND ANTENNA FEED

Figure 4
MODIFIED X-BAND ANTENNA FEED
SIGNAL STRENGTH CHARTS
(X-, S-, and L-Band)
25 January 1948 - 1 February 1948

Figures 5 through 12 Inclusive
CALCULATED FREE-SPACE SIGNAL LEVEL 8.4 DBM
SWITCHED POWER UNITS CALIBRATION BEGIN OPERATION

---LEGEND---

WEATHER NOTES FOR ALL CHARTS APPEAR WITH THOSE OF A-BAND RCVR.
POLARIZATION OF ALL ANTENNAS IS VERTICAL.
ABRUPT SMALL CHANGES IN SIGNAL LEVEL ARE DUE TO SHAKING RECORDER STYLUS.
ABRUPT SWINGS OF STYLUS CAUSED BY SLOW RESPONSE OF THE VOLTAGE REGULATOR TO CHANGES IN POWER AND BY MANIPULATION OF RCVR CONTROLS.
HOURLY SIGNAL VALUES
25 January 1948 - 1 February 1948

Figures 13 and 14
Figure 14.
PERCENTAGE CURVES FOR SIGNAL STRENGTH VALUES
25 January 1948 - 1 February 1948

Figure 15
Legend:
- X-Band
- S-Band
- L-Band

Percent of time signal was above or below free space
MEΤEΟΡΟΛΟΓICAL RECORDS
Radiosonde Data
Aircraft Sounding Data
Balloon Sounding Data

24 January 1948 - 1 February 1948

Figures 16, 17, and 18
Figure 16.

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Figure 17.

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M Curves from Sounding Data
PROGRESS REPORT NO. 18
PROJECT NO. 109-8
CONTRACT NO. W28-099-ac-175

THE EFFECT OF ATMOSPHERIC CONDITIONS ON THE
PROPAGATION CHARACTERISTICS OF ELECTROMAGNETIC WAVES
IN THE MICROWAVE REGION

By
F. E. LOWANCE, J. E. BOYD, R. A. MARTIN, and CATHERINE YOE

MAY 31, 1948
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PROJECT ABSTRACT

The purpose of this project is to investigate the effect of atmospheric conditions, such as ducts, turbulence, and subsidence inversions, on the propagation characteristics of electromagnetic waves in the microwave region. An ultimate objective is to determine the optimum frequency (or frequencies) for a microwave radio relay system providing two-way communication and video operation over a distance of 30 to 50 miles point-to-point.

The method of attack is to make simultaneous signal strength measurements on several microwave frequencies over the same propagation path and, at the same time, to make extensive meteorological measurements along the path of transmission. Signal strength records and meteorological data can then be compared to determine the effects of various atmospheric conditions on radio propagation. In the analysis of the data to determine an optimum frequency, various factors will be considered, including: refraction due to atmospheric stratification or vertical gradients of temperature and water vapor; attenuation by rain, water vapor, and atmospheric gases; interference between direct and earth-reflected waves; polarization effects; et cetera.

During the first several months of the program, the major effort was expended in the design, construction, testing, calibration, and installation of transmitters, receivers, psychrometers, and other equipment; and in the development and refinement of measuring techniques. Considerable effort has also been devoted to literature study and to methods of data analysis. Large quantities of weather data have been obtained from the Atlanta Weather Bureau and from aircraft and balloon soundings. A camera-type meteorograph of new and improved design is used for lower level balloon soundings. Extremely accurate and reliable data have been recorded by this instrument. Partial analyses and summaries of these data have been given in the monthly progress reports.

Propagation measurements at S-Band and X-Band frequencies began in May, 1947, and measurements at L-Band frequency began in October, 1947. Five extended periods of operation have been conducted, and the results of these five operations have been included in recent progress reports. During March, April, and May, 1948, improvements were made in the receiving and transmitting equipment. A short operation was conducted during the latter part of May.
I. CURRENT REPORT SUMMARY

The entire equipment of the 2½-ton Field Truck has been modified and outstanding improvements made.

Additional personnel have been employed and trained for operation of transmitting equipment and for maintenance work in the laboratory.

A short operation was conducted during the period from 27 May through 31 May 1948. The results of the propagation measurements made during this operation will be presented in the next report.

Design has been begun on a new camera meteorograph having a gross weight of approximately three pounds. It is hoped to construct three of these instruments in the immediate future.

Trial aircraft soundings were made during the month of May. Several different methods were tried, and one of these will be used during future operating periods.

Conferences were held with Dr. James A. Peoples, Captain G. E. Austin, and Mr. N. C. Gerson, all of Watson Laboratories. During the discussions, future plans were made for the project, and helpful suggestions were given.

The University of Florida project was visited, and plans were made to share the AT-11 aircraft with the Florida project to as great an extent as can be arranged.

An automatic camera-recording weather station has been designed, and work has been begun on a pilot model. It is planned to use this station during the next operation.

It is proposed to make a detailed study of the terrain between the Physics Building at Georgia Tech and Mount Oglethorpe, Georgia. A contour map has been prepared as an initial part of this study.
II. ADMINISTRATIVE REPORT

A. Personnel and Administration.

1. Personnel Terminating Employment.
   a. Cheney, I. L.

2. Personnel Added to Project.

      Qualifications: Pre-radio training, U. S. Navy, Wright
      (E.E. & R.M.) School, U. S. Navy, Delmonte, California; Aviation Radio
      Technician (ART) instructor, U. S. Navy, Corpus Christi, Texas; transmitter
      operator, WHAL Radio Station, Macon, Georgia; Jr. in Electrical Engineering,
      Georgia Tech, 1948.

   b. Elfa, T. B., Electronics Technician.

      Previously employed by this project. For qualifications,
      see Progress Report No. 12, June, 1947, p. 3.

   c. Farmer, Rhesa S., Electronics Technician.

      Qualifications: Pre-radio training, U. S. Navy, Pre-Radio
      School, Chicago, Illinois; Electronics Technician Mate, 2nd Class, U. S.
      Navy; Radio Materiel training, Naval Research Laboratory, Washington, D. C.;
      in Electrical Engineering, Georgia Tech, 1948.

   d. Hudson, John A., Meteorological Technician.

      Qualifications: Jr. in Electrical Engineering, Georgia
      Tech, 1949.

   e. Roberts, Robert E., Meteorological Technician.

      Qualifications: Engineer, U. S. Army Air Corps; Sr. in
Physics, Georgia Tech, 1948.

f. Simpson, George, Electronics Technician.


g. Smith, Claiborne P., Electronics Technician.


h. Webb, Cleo J., Secretary.

Qualifications: Graduate, Athens Business College, Athens, Georgia, 1948.

B. Communications.

1. Correspondence.

a. Incoming.

(1) Watson Laboratories.

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<td>WLGET</td>
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b. Outgoing.

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<td>Film Samples</td>
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2. Conferences.

a. The Georgia Institute of Technology and the various laboratories of the State Engineering Experiment Station were visited on 9 March 1948 by Dr. James A. Peoples and Captain G. E. Austin of the Watson Laboratories. Conferences were held with Dr. Gerald A. Rosselot and with personnel of this project, including F. E. Lowrance, James E. Boyd, Roy A. Martin, Frank D. Stringer, and Catherine Yee.

Future plans for the project were discussed, including modification of the camera meteorograph for additional uses, and continuation of the one-way propagation measurements at X-, S-, and L-Band frequencies over the present path from the Physics Building to Mt. Cogletherpe in order to obtain representative signal strength data for all periods of the year.

Possible variations in the operational set-up to obtain additional data were also discussed. In particular, it was considered desirable that some measurements be made at grazing incidence or with receiving equipment.
Progress Report No. 18  
Project No. 109-S

located on, or possibly below, the horizon in order to compare results for high and low receiving sites.

Possible uses of radar in studying microwave reflections from meteorological phenomena, such as sharp inversion layers, cloud layers, etc., were also considered, and helpful suggestions were made as to new methods of data analysis which might be applicable to the microwave propagation study.

b. The meeting of the Physical Society in Washington, D. C., 29 April and 30 April 1948, was attended by F. E. Lowance of this project. At this time Dr. Lowance discussed the progress of the project with Mr. N. C. Gerson of Watson Laboratories. The following significant points were emphasized:

with respect to the present contract:

(1) the importance of continuing the daily signal strength recordings for as great a portion of each month as possible;

(2) the desirability of making a detailed correlation study of the meteorological and signal strength data including possible classification of "\( N \)" curves versus signal strengths for average seasonal and extreme meteorological conditions;

with respect to other studies which might be attempted:

(3) the feasibility of employing paths (about 20-30 miles in length) over homogeneous terrain to determine average refractive conditions over the specified path;

(4) the possibility of employing sweep frequency transmitters having the requisite frequency range, in order to study rain and cloud particle sizes and distributions.

There was also discussed the possibility of:

(5) construction of a camera meteorograph with a gross weight of not over three pounds and having two or more temperature ranges.
planned to construct three of these instruments in the immediate future);

(6) the value of cooperation with the University of Florida project in regard to the use of the aircraft assigned to this project, with the understanding that the aircraft will be shared with the Florida project to as great an extent as can be arranged.

c. On 18 May 1948 F. E. Lowrance, Roy A. Martin, Frank D. Stringer, and Lt. R. E. Randall of this project visited the University of Florida in connection with the scattering and cloud attenuation project located there. The project laboratories were visited, and discussions concerning electronic and meteorological problems involving both the Florida project and this project were held with Dean Joseph Weil, Dr. Ralph A. Morgan, and Messrs. M. H. Latour and F. H. Pumphrey. It was learned that the Florida project would have no immediate need for use of the aircraft assigned to this project, but it was suggested that it might be used advantageously during September, 1948. A special camera-recording weather station which has recently been developed for this project was discussed, and plans were made to furnish the Florida project with detailed plans and specifications of this weather station as soon as possible, in order that they might use the station in connection with their work.

C. Financial Statement.

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III. THEORETICAL AND EXPERIMENTAL PROGRESS

A. Principal Problems Undertaken During Period from 1 March Through 31 May 1948.

1. Preparations for Extended Field Operations.

   The months of March, April, and May were spent in training an additional operating staff and in partially rebuilding and modifying all equipment in preparation for extended field operations during the summer and fall months of this year.

   A considerable part of the operation of the transmitting and receiving equipment is conducted by students on a part-time basis. Due to normal changes, several of these have left the project, and, as a result, considerable time has been spent during the past month in securing and training new personnel.

   The entire equipment of the $2\frac{1}{2}$-ton Field Truck has been modified, and, consequently, improvements have been made in operating efficiency, reduction of set-up time, simplification of maintenance and repair, appearance, and comfort.

   The interior of the truck was painted Navy Gray which is a considerable improvement over the former olive-drab interior. The new light color has greatly brightened the truck, thus reducing eye strain and permitting the indicators to be seen more easily than before. Night working conditions have been improved by the installation of additional overhead lights at key points.

   A system of ducts, raceways, and conduits was installed in the truck for all inter-unit cables and control leads, and a master control panel was installed to provide for centralized power control of all equipment, in-
including the two power plants. Adequate overload protection is provided by fuses and circuit breakers in the control panel. A tail outlet for outside lights and the refrigerator and a roof outlet, both controlled from the control panel, have proven to be a considerable aid in setting up the truck in the field, thus reducing the set-up time. Provision has been made for installation of equipment to be used for immediate changeover from one power unit to the other in case of power failure; thus, any time which would otherwise be lost due to power failure will be eliminated.

A new antenna for the communications radio has been constructed which is rigid but also readily portable. The time required for antenna alignment has been reduced by the use of a portable signal level meter which may be connected to any of the receivers and by the use of a telephone between the roof and interior of the truck.

A variac has been added for fine adjustment of receiver and signal generator line voltage. This variac is also available in case of generator voltage regulator failure. Changeover from the electronic to the magnetic voltage regulator is now possible on the stand-by power plant.

The mounting of the receiver has been improved by the use of larger shock mounts. These mounts reduce the vibration of the receiver en route.

Slight alteration of equipment position necessitated several new radio frequency cables. The old and the new cables were calibrated as a check on measurement accuracy.

Following the modifications just described of the field equipment, routine calibrations of both receiver and transmission lines were made.

The receiving equipment was moved to Mount Oglethorpe on 27 May 1948 and set up for operations on 28 May 1948. The operating period extended
through 31 May 1948. No serious equipment faults were discovered during this time other than oscillations in the L-Band receiver. It is expected that these oscillations will be corrected by redesign and modification of the present receiver. The data gathered from this operation will be presented in the next report.

Extended field operations will start during the latter part of June. All work on field equipment is to be completed by that time.

2. Redesign of Camera Meteorograph.

Design has been started on a new camera meteorograph of minimum size and weight. The weight of the present meteorograph is approximately five pounds, and it is expected to reduce this weight to between three and three and one-half pounds. The following methods will be used to accomplish the above objectives:

(1) Dry cell batteries and a small six-volt motor will be used instead of springs to drive the camera. This will decrease the weight of the meteorograph approximately one pound.

(2) The camera, camera mount, and housing will be redesigned to effect a reduction in weight. Steel or iron structures will be replaced with aluminum wherever possible. Steel or iron structures that cannot be replaced by aluminum will be redesigned for minimum weight. This reduction in weight is necessary, because the present camera accounts for approximately half the total weight of the complete meteorograph.

(3) A smaller aneroid barometer which is sensitive enough to provide readings of pressure changes resulting from changes in height of 15 feet to 20 feet at altitudes of 3000 feet will be used in the new meteorograph. Since the dial of this barometer is smaller than the one used at
present, the size of the instrument panel will be reduced. As a result of using the smaller panel, the camera lens can be placed much closer to the panel, thus reducing the over-all size of the meteorograph and, consequently, the over-all weight.

It is hoped to secure for the thermistor elements a new coating material which will provide good insulation against moisture and also be reasonably flexible. The present coating material is a good insulator; however, it is not flexible.

The thermistors for the new meteorograph will be calibrated at temperatures from \(-40^\circ F\) to \(+90^\circ F\). Some redesign of the electrical system may be necessary to provide for this wide temperature range.

3. Aircraft Soundings.

Aircraft soundings were made during the month of May at irregular intervals averaging about four hours per week. Since there were no operating periods during this time, it was possible to try out new techniques for taking soundings which, it was hoped, would result in obtaining more desirable and accurate data. The two methods described below were developed, and these are believed to be the most useful and practical in this work.

(1) A vertical sounding was made at a point fifteen miles from the transmitter station with the aircraft following a spiral path from the lowest level. A similar sounding was then made at the mid-point of the propagation path with the aircraft descending. Next, a sounding was made fifteen miles from the receiver station with the aircraft ascending, followed by a horizontal sounding back to the transmitter station. This type of run takes about 90 minutes.

(2) A sounding was begun at approximately the center of the
propagation path with the aircraft ascending. A rectangular path was then flown with legs eight miles by two miles. Soundings were made at each end of the eight-mile leg, and on each two-mile leg the aircraft ascended to the next sounding level. This type of run takes about 75 minutes.

Both of the above types of soundings were made from 400 to 1400 meters MSL at 100-meter intervals varied to 50-meter intervals depending upon the atmospheric conditions.

The first sounding method will be used during future operating periods as it provides more complete coverage of the transmission path.

4. **Automatic Camera-Recording Weather Station.**

The design of an automatic weather station has been completed and work begun on a pilot model for test purposes. The weather station will serve to record the following meteorological readings: (1) rainfall in a standard four-inch rain gage, (2) wet-bulb temperature, (3) dry-bulb temperature, (4) wind direction, (5) wind speed, and (6) time. These data will be recorded by means of an aircraft gun-camera at half-hour intervals.

The station will be tested during the next operating period. If proven successful, weather stations will be set up at each of the three auxiliary meteorological stations* along the propagation path for use during all future operations, and, as a result, the local personnel who have been recording the meteorological data up to the present time will no longer be necessary.

A detailed description and operating principle of the weather station

will be given in the next report.

5. Terrain Studies.

A contour map, in different colors according to altitude, has been prepared from a study of available topographic charts of the region between the Georgia Tech Physics Building (transmitter station) and Mount Oglethorpe (receiver station). The region covered is wide enough to include the beam angles of all three transmitters and indicates clearly all major surface irregularities from which appreciable reflections may occur.

It is also planned to make a series of more detailed profile charts, using the four-thirds earth's radius presentation. Profile charts will be prepared for the direct path and for closely adjoining paths included in the beam width pattern, in order to show again, in a different form, all possible major reflecting areas.

It is hoped that a photographic study from the air can be made of the region to show other features of interest, such as percentage coverage by forested areas. From a careful search, it appears that aerial photographs of the propagation path region have not been made previously.
IV. SCHEDULE OF FUTURE WORK

1. Continuation of signal strength measurements between Georgia Tech and Mount Oglethorpe and the collection of all related meteorological data.

2. Additional engineering changes and improvements in the 2½-ton receiver truck.

3. Construction of the new camera meteorograph weighing approximately three pounds.


5. Study of terrain propagation path.

6. Study and analysis of data recorded during operating period from 27 May through 31 May 1948.

7. Additional study of the literature and the current work of other activities in the field of microwave propagation.

Submitted by

F. E. Lowance,
Project Director

Approved:

Gerald A. Rosselot,
Director
PROGRESS REPORT NO. 19
PROJECT NO. 109-8
CONTRACT NO. W28-099-ac-175

THE EFFECT OF ATMOSPHERIC CONDITIONS ON THE
PROPAGATION CHARACTERISTICS OF ELECTROMAGNETIC WAVES
IN THE MICROWAVE REGION

By
F. E. Lowance, J. E. Boyd, R. A. Martin, and Catherine Yoe

AUGUST 31, 1948
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AUGUST 31, 1948
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The purpose of this project is to investigate the effect of atmospheric conditions, such as ducts, turbulence, and subsidence inversions, on the propagation characteristics of electromagnetic waves in the microwave region. An ultimate objective is the determination of the optimum frequency (or frequencies) for a microwave radio relay system providing two-way communication and video operation over a distance of 30 to 50 miles point-to-point.

The method of attack is to make simultaneous signal strength measurements on several microwave frequencies over the same propagation path and, at the same time, to make extensive meteorological measurements along the path of transmission. Signal strength records and meteorological data can then be compared to determine the effects of various atmospheric conditions on radio propagation. In the analysis of the data to determine an optimum frequency, various factors will be considered, including: refraction due to atmospheric stratification or vertical gradients of temperature and water vapor; attenuation by rain, water vapor, and atmospheric gases; interference between direct and earth-reflected waves; polarization effects; etc.

During the first several months of the program, the major effort was expended in the design, construction, testing, calibration, and installation of transmitters, receivers, psychrometers, and other equipment, and in the development and refinement of measuring techniques. Considerable effort has also been devoted to literature study and to methods of data analysis. Large quantities of weather data have been obtained from the Atlanta Weather Bureau and from aircraft and balloon soundings. Partial analyses and summaries of these data have been presented in periodic progress reports. A light-weight camera-type meteorograph has been designed and constructed for use with a moored balloon for lower level soundings. Extremely accurate and reliable data have been recorded by this instrument. A new lighter-weight model of the meteorograph is now under construction. A camera-recording weather station has been designed and constructed which automatically records at 30-minute intervals the time, wet- and dry-bulb temperatures, wind direction, wind velocity, and amount of rainfall. The records are made on 16-mm. film. Three of these stations will be located at regular intervals at ground level along the propagation path, and two additional units will be placed at the transmitter and receiver stations.

Propagation measurements at S-Band and X-Band frequencies began in May, 1947, and measurements at L-Band frequency began in October, 1947. Five extended periods of operation were conducted prior to March, 1948, and the results of these operations have been given in the progress reports. During March, April, and May, 1948, improvements were made in the receiving and transmitting equipment. From May, 1948, through August, 1948, four periods of operation have been conducted, and the results of these operations are being presented in current progress reports.
I. CURRENT REPORT SUMMARY

Propagation measurements were made over the Georgia Tech-Mount Oglethorpe path during two operations conducted from 29 June through 12 July 1948 and from 27 July through 9 August 1948. A new lower receiving site has been located on Rich Mountain, about two miles southeast of the Mount Oglethorpe site, and an operating period over this path was started on 24 August 1948 and will be completed early in September 1948. The results of the May-June and the June-July operating periods are presented in this report. Results of the July-August and August-September operations will be presented in the next report.

Improvements in the electronics equipment have included redesign and modification of the L-Band receiver, repair of damaged dipoles of the K-Band antennas, installation of an automatic signal chart time marking system that is operated from the transmitter station, and a wiring system that permits immediate switching of the 110V power plants at the receiver truck.

Work has been started on the redesign and construction of the new lighter-weight model of the camera meteorograph. Because of difficulties encountered in the procurement of parts, the unit will not be completed as soon as had been anticipated.

The pilot model of the automatic camera-recording weather station has been completed and tested successfully. This unit is now being used at the receiving station during the August-September operating period.

A study is being conducted to determine suitable methods for analyzing the combined meteorological and signal strength data which have been obtained during the operating periods.
A C-45 aircraft has been assigned to the project by the 4149th AAFBU as a replacement for the AT-11 aircraft.
II. ADMINISTRATIVE REPORT

A. Personnel and Administration.

1. Personnel Terminating Employment.
   a. Barga, Robert H.
   b. Hudson, John A.

2. Personnel Added to Project.
      Qualifications: Electronics work, U.S. Army; senior in Physics, Georgia Institute of Technology, 1948; student assistant in Physics Department, Georgia Institute of Technology, 1948.
   b. Collins, James T., Meteorological Technician.
   c. David, Edward E., Jr., Research Assistant.
   d. Ethridge, Noel H., Electronics Technician.
      Qualifications: B.S. in Physics, Georgia Institute of Technology, 1948.
3. Aircraft Facilities.

As a replacement for the AT-11 which was used previously for meteorological soundings, the 4149th AAEMU has assigned a C-45 aircraft to the project. This plane will be based at the Marietta Army Air Base, Marietta, Georgia, during operating periods. The C-45 aircraft is equipped with a psychrometer, ML313-AM, and an aerograph, AN/AMQ-3.

B. Communications.

1. Correspondence.

a. Incoming.

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CONFIDENTIAL

Page 6 of 64 Pages
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## C. Financial Statement

- Expenditures to 1 August 1948: $137,993.89
- Encumbrances (Materials and Supplies) as of 1 August 1948: $1,166.43
- Balance as of 1 August 1948: $42,459.68
III. THEORETICAL AND EXPERIMENTAL PROGRESS

A. Principal Problems Undertaken during Period from 1 June through 31 August 1948.

1. Refinement and Improvement of Electronics Equipment.
   a. Redesign of L-Band Receiver.

   Work on the redesign of the L-Band receiver was started during the first part of June and completed prior to the June-July operating period. A photograph of the redesigned receiver is shown in Appendix A, Figure 1.

   A new mount made of 1/8" brass has been constructed for the local oscillator cavity and securely suspended from the front panel of the receiver. Fastened to the mount are brackets lined with rubber which hold the cavity in place. This mount is a much more stable and secure support for the oscillator cavity than the original mount which was made of sheet metal, mounted between and fastened to the AFC and IF amplifier chassis.

   The RF input system has been redesigned mechanically because the original system was not durable enough to withstand the shock encountered when the receiver truck was in motion. A metal bracket which clamps the crystal mixer assembly rigidly in place has been mounted on the back of the receiver panel, and the RF input cable and the cable between the local oscillator and mixer have been shortened to reduce RF losses. A new coupling loop, made of a heavy copper wire, which feeds energy to the crystal mixer has been installed in the local oscillator cavity.

   Regulation of the intermediate frequency amplifier filament voltage ha

(1) Progress Report No. 18, May, 1948, p. 11.
been made possible by the installation of a 9A ballast tube in the power supply, and necessary additional current capacity in the negative voltage power supply has been provided for by the addition of a second 6L6 regulator tube in the power supply. These two tubes are connected in parallel.

A complete new cabling system for the receiver has been installed as a replacement for the old system which was badly in need of repair. The new cables are color-coded and located so as to minimize fraying due to vibrations when the truck is in motion.

The redesigned receiver was operated successfully during the June-July and July-August operations.

b. X-Band Antenna Tests.

In a study of the signal strength charts for the June-July operation, a comparison was made of the actual received X-Band signal with the calculated received signal. This comparison showed that the X-Band antenna gain was down considerably. Therefore, during the July-August operation, gain measurements, using calibrated horns, were made of both the X-Band transmitting and receiving antennas. As a result of these tests, the receiving antenna gain was found to have dropped from 33.0 decibels to 21.4 decibels. The corrected gain value (21.4 db) was used in calculation of the free space received signal values for the June-July and July-August operations.

During an examination of the antenna it was discovered that the two feed dipoles, which are hidden by a pliable plastic bulb, had become damaged.

---

These dipoles have been repaired, and gain measurements will be made during the August-September operating period to determine if the antenna is functioning properly.

c. Power Unit Changeover.

A system which provides for the immediate changeover from the FE-95 110V power plant to the FE-197 110V standby power plant has been designed and all the necessary equipment has been installed. This system enables the load to be placed on either power unit by means of a toggle switch mounted on the control panel in the 25-ton truck. Spring-return push-button switches, which control the starting and stopping of the power units, and a metering system for checking the output voltage of either unit have also been mounted on the control panel. The necessary cables have been provided for the connection of the power units to these controls and the load. Power changeover relays operated by the toggle switch have been installed in the truck beneath the control panel.

d. Signal Chart Time Markings.

In the past, it has been difficult to obtain accurate time markings on the signal strength charts at the exact specified time intervals because the operator at the receiving station had to make these markings on the charts by hand and the time recorded was that shown by his watch. These difficulties have been corrected by the installation of a marking system at the transmitting station which brings about automatically marking of the charts at the receiving station. By means of a push-button switch, the plate voltage or


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b. **L-Band.**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>Continuous Wave:</td>
</tr>
<tr>
<td>Average Transmitted Power:</td>
<td>2.4 kw</td>
</tr>
<tr>
<td>Calculated (Free Space) Received Signal:</td>
<td>10.9 dbm</td>
</tr>
<tr>
<td>Calculated Antenna Gain Transmitter:</td>
<td>33 db</td>
</tr>
<tr>
<td>Receiver:</td>
<td>33 db</td>
</tr>
<tr>
<td>Line Attenuation (Antenna to Receiver):</td>
<td>24.4 db</td>
</tr>
<tr>
<td>Receiving System Noise Level:</td>
<td>60.6 dbm</td>
</tr>
</tbody>
</table>

No recordings made during this operating period.

---

2. **Operating Period from 29 June through 12 July 1948.**

a. **S-Band.**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
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</tr>
<tr>
<td>Pulse Recurrence Frequency:</td>
<td>500 pps</td>
</tr>
<tr>
<td>Pulse Length:</td>
<td>1.3 microsec.</td>
</tr>
<tr>
<td>Peak Transmitted Power:</td>
<td>45.0 kw</td>
</tr>
<tr>
<td>Calculated (Free Space) Received Signal:</td>
<td>8.3 dbm</td>
</tr>
<tr>
<td>Calculated Antenna Gain Transmitter:</td>
<td>27.2 db</td>
</tr>
<tr>
<td>Receiver:</td>
<td>27.2 db</td>
</tr>
<tr>
<td>Line Attenuation (Antenna to Receiver):</td>
<td>39.4 db</td>
</tr>
<tr>
<td>Receiving System Noise Level:</td>
<td>42.6 dbm</td>
</tr>
<tr>
<td>Receiver Noise Level:</td>
<td>22 db</td>
</tr>
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</table>

b. **L-Band.**

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<thead>
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<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>1310 mc</td>
</tr>
<tr>
<td>Continuous Wave:</td>
<td></td>
</tr>
<tr>
<td>Average Transmitted Power:</td>
<td>900 mw</td>
</tr>
<tr>
<td>Calculated (Free Space) Received Signal:</td>
<td>61.4 dbm</td>
</tr>
<tr>
<td>Calculated Antenna Gain Transmitter:</td>
<td>21.8 db</td>
</tr>
<tr>
<td>Receiver:</td>
<td>21.8 db</td>
</tr>
</tbody>
</table>
Line Attenuation (Antenna to Receiver): None
Receiving System Noise Level: 80 dbm

c. X-Band.

Frequency: 9404 mc
Pulse Recurrence Frequency: 500 pps
Pulse Length: 1.3 microsec.
Peak Transmitted Power: 21.6 kw
Calculated (Free Space) Received Signal: 18.2 dbm

Measured Antenna Gain
Transmitter: 36.2 db
Receiver: 21.4 db

Line Attenuation (Antenna to Receiver): 27.1 db
Receiving System Noise Level: 61.9 dbm
Receiver Noise Level: 88.0 dbm

B. Atmospheric Soundings.

Meteorological data for the May-June and June-July operating periods were obtained from captive balloon soundings and radiosondes, and the h-Curves, calculated from these data, are presented in Appendices B and C, respectively.

1. Radiosondes.

Radiosonde data were obtained from the Atlanta Weather Bureau for each day of the operating periods. The radiosonde observations were made at the Atlanta Municipal Airport which is located about seven miles south of the transmitting station.

2. Captive Balloon Soundings.

Captive balloon soundings with the camera meteorograph were made near Roswell, Georgia, (about 18 miles north of the transmitting station) at 0500 EST and 1700 EST on each day when weather conditions permitted balloon flights.

Maximum heights of 1200 ft. to 2000 ft. above ground surface level, depending on the wind velocities, were obtained in the balloon soundings.
It was found that for strong or gusty winds the incident angle of the balloon was increased to such an extent that heights above 1200 ft. could not be reached, while for very light winds, heights from 1200 ft. to 1500 ft. were possible. Wind velocities from 5 to 15 miles per hour were observed to be ideal for the highest soundings.

C. Weather Summary for Periods of Operation from 28 May through 1 June 1948 and 29 June through 12 July 1948.

1. Operation Period from 28 May through 1 June 1948.
   Circulation was light southwesterly throughout entire period with moderately high temperatures and moisture content. Widely scattered small showers occurred over the transmission path in the late afternoons.

2. Operation Period from 29 June through 12 July 1948.
   29 June 1948.
   A southwesterly circulation of moderately warm, unstable gulf air produced frequent scattered thunderstorms over the entire southeast.

   30 June 1948.
   Circulation changed at midday to northwesterly under the influence of a large High centering over Iowa and moving eastward. Considerable warming and drying of the air produced scattered cloudiness but no rain.

   1 July 1948.
   A weak cold front passed Atlanta with no associated weather conditions and dissipated to the south. Circulation continued northerly with an influx of warm, dry air.

   2 July 1948.
   Circulation became northeasterly as the High drifted eastward. The moisture content of the air increased slightly; however, no rain was
recorded.

3 July 1948 and 4 July 1948.

There were clear skies and warm dry air. No rain was reported.

5 July 1948 and 6 July 1948.

Circulation became southeasterly under the influence of a strong Bermuda High. Slight moisture increases and cooling of air produced scattered thundershowers.

7 July 1948.

Circulation became southerly and then south-easterly veering to the northwest and north as a cold front passed this region near 1930 EST. A sharp drop of temperature was recorded, but no rain occurred.

8 July 1948 through 11 July 1948.

The cold front became stationary just to the south of Atlanta with a low overrunning to central Tennessee. Low temperatures (70°F–80°F) and a high moisture content were recorded. Continuous light to moderate rain and fog occurred over the transmission path.

12 July 1948.

The stationary front began dissipating to the south and the low cloudiness began rising. Scattered showers replaced the continuous rain. The air remained cool and moist.
V. SCHEDULE OF FUTURE WORK

1. Continuation of signal strength measurements over Georgia Tech-Rich Mountain path.

2. Construction of additional units of automatic camera-recording weather station.

3. Completion of the lighter-weight model camera meteorograph.

4. Continuation of analysis of signal strength and associated meteorological data.

5. Continuation of terrain studies.

Submitted by

F. E. Lowence,
Project Director

Approved:

J. E. Boyd,
Associate Project Director

Gerald A. Rosselot,
Director
## APPENDIX A

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<td>Schematic Diagram of Automatic Camera-Recording Weather Station</td>
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Figure 1.

REDESIGNED L-BAND RECEIVER - AUGUST, 1948
IND SPEED

IMO

INTECTIC

is,-

AC LINE

TWIST -LOCK

mom

BASE

CAMERA meT

AWN

Jr

NES WEATHERPRoof

Ake

6 PLI/6

/1134-4

ANCOR WIND DIRECTION

COMMUTATOR

1G 2 - AC LINE

TWIST -LOCK

MOTOR BASE

OFF

ON

1

2

3A

3

4

5

6

7

8

CLOCK

WET BULB

BLOWER

MOTOR

WET AND DRY

BULB

TEMPERATURE

CIRCUITS

“BANANA”

PLUGS AND

JACKS

9V

200mA

4.7K

3.3K

HIGH RANGE

LOW DRY

ELEMENT

83

3.3n

6W

GEAR TRAIN

TEST

WIND DIRECTION

RESISTORS IN WIND

SPEED AND DIRECTION

CIRCUITS ARE SELECTED

VALUES.

TEMPERATURE ELEMENTS

ARE FRIEZ = 501377.

SWITCHING

CYCLE

FOR

TIMER

A AND B OFF

A ON

B ON FOR 1 SEC.

STATE ENGINEERING EXPERIMENT STATION

GEORGIA SCHOOL OF TECHNOLOGY

ATLANTA, GEORGIA

SCHEMATIC

AUTOMATIC CAMERA

RECORDING WEATHER STATION

or.

RAM

Or.

RAM

ENGINEER:

RAM

PROGRESS REPORT No. 18

8-24-48

R.A. MARTIN
### APPENDIX B

**DATA OBTAINED DURING OPERATING PERIOD FROM 28 MAY THROUGH 1 JUNE 1948**

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<tr>
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<td>34</td>
</tr>
<tr>
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<td>35</td>
</tr>
<tr>
<td>12. Modified Index of Refraction Relative to Ground Level Value (Graphical Presentation): 1 June 0600E</td>
<td>36</td>
</tr>
</tbody>
</table>
S- AND X-BAND SIGNAL STRENGTH CHART: 28 May AND 29 May 1948
Operating Period from 28 May through 1 June 1948

Figure 4.
CALCULATED FREE-SPACE SIGNAL LEVEL 9.2 dBm

CALCULATED FREE-SPACE SIGNAL LEVEL 10.2 dBm

CALCULATED FREE-SPACE SIGNAL LEVEL 9.2 dBm

CALCULATED FREE-SPACE SIGNAL LEVEL 10.2 dBm

S- AND X-BAND SIGNAL STRENGTH CHART: 30 MAY AND 31 MAY 1948
Operating Period from 28 May through 1 June 1948

Figure 5.
S- AND X-BAND SIGNAL STRENGTH CHART; 1 JUNE 1948
Operating Period from 28 May through 1 June 1948

Figure 6.
GRAPHICAL COMPILATION OF SIGNAL STRENGTH AND ATMOSPHERIC DATA: 28 MAY - 31 MAY 1948
Operating Period from 28 May through 1 June 1948

Figure 7.
GRAPHICAL COMPILATION OF SIGNAL STRENGTH AND ATMOSPHERIC DATA: 1 JUNE 1948
Operating Period from 28 May through 1 June 1948
Figure 8.

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LEGEND:

X-BAND -x-x- TIME DISTRIBUTION OF INSTANTANEOUS RECEIVED POWER: X AND S-BAND
S-BAND -S-S- L-BAND

Operating Period from 28 May through 1 June 1948

Figure 9.
MODIFIED INDEX OF REFRACTION RELATIVE TO GROUND LEVEL VALUE: 26 MAY 2200E - 28 MAY 2200E 1948
Operating Period from 28 May through 1 June 1948

Figure 10.

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Operating Period from 28 May through 1 June 1948
Figure 11.
MODIFIED INDEX OF REFRACTION RELATIVE TO GROUND LEVEL VALUE: 31 MAY 1000E - 1 JUNE 1000E 1948
Operating Period from 28 May through 1 June 1948

Figure 12.
## APPENDIX C

**DATA OBTAINED DURING OPERATING PERIOD FROM 29 JUNE THROUGH 12 JULY 1948**

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<th>Description</th>
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<tbody>
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<td>Signal Strength Chart, S-, X-, and L-Band: 29 June</td>
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<tr>
<td>14</td>
<td>Signal Strength Chart, S-, X-, and L-Band: 30 June</td>
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<tr>
<td>15</td>
<td>Signal Strength Chart, S-, X-, and L-Band: 1 July</td>
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<tr>
<td>16</td>
<td>Signal Strength Chart, S-, X-, and L-Band: 2 July</td>
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<td>17</td>
<td>Signal Strength Chart, S-, X-, and L-Band: 3 July</td>
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<tr>
<td>18</td>
<td>Signal Strength Chart, S-, X-, and L-Band: 4 July</td>
<td>44</td>
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<tr>
<td>19</td>
<td>Signal Strength Chart, S-, X-, and L-Band: 5 July</td>
<td>45</td>
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<tr>
<td>20</td>
<td>Signal Strength Chart, S-, X-, and L-Band: 6 July</td>
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</tr>
<tr>
<td>21</td>
<td>Signal Strength Chart, S-, X-, and L-Band: 7 July</td>
<td>47</td>
</tr>
<tr>
<td>22</td>
<td>Signal Strength Chart, S-, X-, and L-Band: 8 July</td>
<td>48</td>
</tr>
<tr>
<td>23</td>
<td>Signal Strength Chart, S-, X-, and L-Band: 9 July</td>
<td>49</td>
</tr>
<tr>
<td>24</td>
<td>Signal Strength Chart, S-, X-, and L-Band: 10 July</td>
<td>50</td>
</tr>
<tr>
<td>25</td>
<td>Signal Strength Chart, S-, X-, and L-Band: 11 July</td>
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<td>26</td>
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<td>29</td>
<td>Graphical Compilation of Signal Strength and Atmospheric Data: 7 July - 10 July</td>
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Operating Period from 29 June through 12 July 1948

Figure 13.
L-, S-, AND X-BAND SIGNAL STRENGTH CHART: 30 JUNE 1948
Operating period from 29 June through 12 July 1948

Figure 14.
L-, S-, AND X-BAND SIGNAL STRENGTH CHART: 1 JULY 1948
Operating Period from 29 June through 12 July 1948

Figure 15.
L-, S-, AND X-BAND SIGNAL STRENGTH CHART: 2 JULY 1948
Operating Period from 29 June through 12 July 1948

Figure 16.
CALCULATED FREE SPACE SIGNAL LEVEL 6.6 DBM

CALCULATED FREE SPACE SIGNAL LEVEL 0.3 DBM

CALCULATED FREE SPACE SIGNAL LEVEL 0.8 DBM

L-, S-, AND X-BAND SIGNAL STRENGTH CHART: 3 JULY 1948
Operating Period from 29 June through 12 July 1948

Figure 17.
L-, S-, AND X-BAND SIGNAL STRENGTH CHART: 4 JULY 1948
Operating Period from 29 June through 12 July 1948

Figure 18.
L-, S-, and X-BAND SIGNAL STRENGTH CHART: 5 JULY 1948
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Figure 19.
L-, S-, and X-Band Signal Strength Chart: 6 July 1948
Operating Period from 29 June through 12 July 1948

Figure 20.
L-, S-, AND X-BAND SIGNAL STRENGTH CHART: 7 JULY 1948
Operating Period from 29 June through 12 July 1948

Figure 21.
L-, S-, AND X-BAND SIGNAL STRENGTH CHART: 8 JULY 1948
Operating period from 29 June through 12 July 1948

Figure 22.
L-, S-, AND X-BAND SIGNAL STRENGTH CHART: 9 JULY 1948
Operating period from 29 June through 12 July 1948

Figure 23.
L-, S-, and X-BAND SIGNAL STRENGTH CHART: 10 JULY 1948
Operating Period from 29 June through 12 July 1948

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L-, S-, AND X-BAND SIGNAL STRENGTH CHART: 11 JULY 1948
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Operating Period from 29 June through 12 July 1948
Figure 29.
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SIGNAL VARIATION - L-BAND

SIGNAL VARIATION - S-BAND

SIGNAL VARIATION - X-BAND

ATMOSPHERIC CONDITIONS

RAINFALL RATES

GRAPHICAL COMPILATION OF SIGNAL STRENGTH AND ATMOSPHERIC DATA: 11 AND 12 JULY 1948
Operating Period from 29 June through 12 July 1948

Figure 30.

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PERCENT OF TIME RECEIVED POWER IS BELOW ORDINATE.

LEGEND:

X-BAND
S-BAND
L-BAND

TIME DISTRIBUTION OF INSTANTANEOUS RECEIVED POWER: X-, S-, AND L-BAND

Operating Period from 29 June through 12 July 1948

Figure 31.
MODIFIED INDEX OF REFRACTION RELATIVE TO GROUND LEVEL VALUE: 29 JUNE 0600E - 30 JUNE 2200E 1948
Operating Period from 29 June through 12 July 1948

Figure 32.
MODIFIED INDEX OF REFRACTION RELATIVE TO GROUND LEVEL VALUE: 1 JULY 0500E - 2 JULY 1000E 1948
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Figure 33.
MODIFIED INDEX OF REFRACTION RELATIVE TO GROUND LEVEL VALUE: 2 JULY 1830E - 4 JULY 0600E 1948
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MODIFIED INDEX OF REFRACTION RELATIVE TO GROUND LEVEL VALUE: 4 JULY 0700E - 5 JULY 1000E 1948
Operating Period from 29 June through 12 July 1948
Figure 35.
MODIFIED INDEX OF REFRACTION RELATIVE TO GROUND LEVEL VALUE: 5 JULY 2200E - 8 JULY 0600E 1948
Operating Period from 29 June through 12 July 1948

Figure 36.
MODIFIED INDEX OF REFRACTION RELATIVE TO GROUND LEVEL VALUE: 8 JULY 1000E - 10 JULY 2200E 1948
Operating Period from 29 June through 12 July 1948

Figure 37.
MODIFIED INDEX OF REFRACTION RELATIVE TO GROUND LEVEL VALUE: 11 JULY 1000E - 12 JULY 1020E 1948
Operating Period from 29 June through 12 July 1948

Figure 38.
PROGRESS REPORT NO. 20

PROJECT NO. 109-8

CONTRACT NO. W28-099-ac-175

THE EFFECT OF ATMOSPHERIC CONDITIONS ON THE

PROPAGATION CHARACTERISTICS OF ELECTROMAGNETIC WAVES

IN THE MICROWAVE REGION

By

F. E. LOWANCE, J. E. BOYD, R. A. MARTIN, and CATHERINE YOE

NOVEMBER 30, 1948
PROGRESS REPORT NO. 20
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NOVEMBER 30, 1948

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B. Operating Period from 25 August through 6 September 1948

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C. Operating Periods from 9 October through 18 October 1948
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V. SCHEDULE OF FUTURE WORK

APPENDIX A
APPENDIX B
The purpose of this project is to investigate the effect of atmospheric conditions, such as ducts, turbulence, and subsidence inversions, on the propagation characteristics of electromagnetic waves in the microwave region. An ultimate objective is the determination of the optimum frequency (or frequencies) for a microwave radio relay system providing two-way communication and video operation over a distance of 30 to 50 miles point-to-point.

The method of attack is to make simultaneous signal strength measurements on several microwave frequencies over the same propagation path and, at the same time, to make extensive meteorological measurements along the path of transmission. Signal strength records and meteorological data can then be compared to determine the effects of various atmospheric conditions on radio propagation. In the analysis of the data to determine an optimum frequency, various factors will be considered, including: refraction due to atmospheric stratification or vertical gradients of temperature and water vapor; attenuation by rain, water vapor, and atmospheric gases; diffraction by terrain irregularities; polarization effects; etc.

The first year of the program (July, 1946 to June, 1947) was devoted to the design, construction, testing, calibration, and installation of transmitters, receivers, psychrometers, and associated equipment and to the development and refinement of signal strength and meteorological measuring techniques. Considerable effort was also devoted to literature study and to methods of data analysis.

During the summer of 1947, a light-weight, camera-type meteorograph was designed and constructed for use with a moored balloon for low level soundings. Extremely accurate and reliable data have been recorded by this instrument. A portable camera-recording weather station has been built and stationed at the receiver site. This station automatically records at thirty minute intervals the time, wet- and dry-bulb temperatures, wind direction, wind velocity, and amount of rainfall on 16 mm. film.

Propagation measurements at S-Band and X-Band frequencies were begun in May, 1947, and additional measurements at L-Band frequency were initiated in October, 1947. Five extended periods of operation were conducted prior to March, 1948. During March, April, and May, 1948, improvements were made in the receiving and transmitting equipment. From May through November, 1948, six operations were conducted. Large quantities of weather data were obtained from the Atlanta Weather Bureau and from aircraft and balloon soundings during the operating periods.

The signal strength and meteorological data for all except the last two operations have been presented in periodic progress reports. Partial analyses and summaries of these data have also been given in the progress reports.
I. CURRENT REPORT SUMMARY

Propagation measurements were made over the Georgia Tech-Rich Mountain path during the operating period from 25 August through 6 September 1948, and over a new path between Tolen Mountain and Georgia Tech from 9 October through 18 October. During another field operation in November, measurements were made over the Georgia Tech-Tolen Mountain path from the 10th through the 15th, and over the Georgia Tech-Rich Mountain path from the 16th through the 22nd. The results of the July-August and August-September operating periods are presented in this report. Data for the October and November operating periods will be presented in a later report.

Various improvements and modifications have been made in the receiver and transmitter units. These modifications improve the procedure for aligning the discriminators of the receivers, provide a method of detecting trouble and irregularities in the transmitted signals, avoid some of the irregularities in the L-Band transmitter operation due to poor temperature control, and facilitate general maintenance of the entire system. The pilot model of the automatic camera-recording weather station was operated satisfactorily at the receiver site during the August-September, October and November operations.

Data for the first five operating periods (May, 1947 to February, 1948) have been carefully examined in an attempt to correlate the transmission data with particular atmospheric conditions, such as surface and elevated superrefracting layers. The signal strength data were first grouped according to the particular atmospheric conditions indicated by the meteorological soundings. Each group of data was then analyzed on a statistical basis by plotting time distributions of instantaneous received power. A general interpretation of the
graphical results is presented for each of the selected atmospheric conditions. It is planned to extend this type of analysis to include the other operating periods for the Georgia Tech-Mount Oglethorpe path. Other methods of graphical presentation and interpretation are also under study.
II. ADMINISTRATIVE REPORT

A. Personnel and Administration.

1. Personnel Terminating Employment.
   a. Chamberlain, William C.
   b. David, Edward E.
   c. Heard, Joseph F.

2. Personnel Added to Project.
   a. Abbett, Tarlton J., Meteorological Technician.
      Qualifications: Pre-Radio School, Herzel Junior College, Chicago, Illinois; Primary Electronics School, Texas A. & M. College, Bryan, Texas; Aviation Electronics Technician School, Corpus Christi, Texas; electronics maintenance of radar equipment, Banana River, Florida; Junior in Industrial Management, Georgia Institute of Technology, 1948.
   b. Clarke, Walter C., Electronics Technician.
      Qualifications: Radar School, Camp Lejeune, New River, North Carolina; two years radar experience, U. S. Marine Corps; student in Physics, Georgia Institute of Technology, 1948.
   c. Coker, Quillian W., Electronics Technician.
      Qualifications: Maintenance work at Chicopee Manufacturing Corp., Chicopee, Georgia; Airplane Engine School, Miami, Florida; General Electric Turbo-Supercharge School, Lynn, Massachusetts; instrument repairman, Army Air Forces; B. S. degree in Physics, North Georgia College, 1946.
   d. Robertson, Douglas W., Electronics Technician.
      Qualifications: Radio operation and maintenance training, N.Y.A. College Park, Georgia; pre-radar training, N.C. State College, Raleigh.
North Carolina; Radio and Radar Technician School, Philco Training School, Baltimore, Maryland; Radar Training School, Bell Telephone Laboratories, New York, N. Y.; three years electronics experience, WRML, Robins Field, Warner Robins, Georgia; two years radar experience, USN.F; student in Electrical Engineering, Georgia Institute of Technology, 1948.

3. Aircraft Accident Report.

The C-45 aircraft was damaged as the result of a minor flight accident which occurred on the morning of 13 October 1948, during the first scheduled aircraft sounding run of the October operating period. The necessary repairs on the plane were begun immediately, but lack of a critical structural part delayed completion of the work considerably, and the aircraft was not made available for use during any of the remainder of the operation.

4. Loss of Captive Balloon and Camera-Meteorograph.

On 17 October 1948, during an early morning balloon run made at the balloon site near Roswell, Georgia, the Seyfang captive balloon carrying the camera-meteorograph escaped from the operators, apparently due to a breakage of the nylon mooring cable, and was lost.

At the time of the accident, the balloon was at an altitude of approximately 1000 ft. when it was observed to be making a free descent which is believed to have been caused either by a leak in the balloon or by gusty air currents which were prevailing at the time. As the balloon descended, it disappeared behind a low ridge and was lost from the view of the operators. The mooring cable was traced until a broken end was located, and it appeared that the cable had either been broken or cut at a point approximately 200 ft. from the balloon. Extensive searches for the equipment were immediately begun.
These searches were conducted both by air and on foot over an area of a 20-mile radius. The C... was notified and a bulletin sent out over their teletype, and notices were run on the screen of the Roswell movie theater for several days following the accident. As there was some indication that the mooring cable had been cut, a report of the accident was made to the Atlanta office of the Federal Bureau of Investigation. Their investigation provided no significant information, however, and to date, no trace of either the balloon or meteorograph has been found.

B. Communications.

1. Correspondence.

a. Incoming.

   (1) Watson Laboratories.

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   (2) Miscellaneous.

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   (3) Reports.

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### b. Outgoing.

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<td>M.L. Wessel</td>
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### 2. Conferences.

#### a. Conferences with Mr. Donald E. Kerr

On 1, 2, and 3 September
1948, this project was visited by Mr. Donald E. Kerr, consultant to the Watson Laboratories of the Air Materiel Command. The purpose of Mr. Kerr's visit was to observe and study the operation of the transmitting and receiving equipment used in this particular research; to discuss with members of the project staff the various problems involved in their work; and to make recommendations as to means of gathering data, methods of data analysis, and future work. During his visit, Mr. Kerr held conferences with Dr. Gerald A. Rosselot, director of the Experiment Station, and with the following personnel of the project: F. E. Lowance, J. E. Boyd, R. A. Martin, E. E. David, F. D. Stringer, and Catherine Yee. These conferences included discussions pertaining to the general operation of the project, equipment and field operations, and theoretical data analysis. Mr. Kerr also visited the transmitter station atop the Physics Building and made a trip to the receiver station on Rich Mountain, approximately 47 miles north of the transmitting station.

During the discussions with Mr. Kerr concerning the electronics and meteorological equipment, the following suggestions and recommendations were formulated:

1. A directional coupler should be provided for power measurements of the L-Band transmitter.

2. The present plan to use a temperature-controlled box as the housing unit for the L-Band transmitter should be carried out. This unit will provide for better stabilization of the L-Band transmitter frequency.

3. The plastic feed coverings of the receiving and transmitting antennas should be removed in order to eliminate the collection of moisture which forms on the coverings during a rain or very humid weather, thus causing mismatching of the antennas to the feed lines and probably sparking at the transmitters and receivers. Individual blower systems installed on the respective waveguides would serve as a method of driving warm air down the feed lines and out the feeds, thus preventing
any moisture collection and condensation in the lines.

(4) Provision should be made for aural monitoring of the video output of each receiver to facilitate the detection of equipment difficulties and stray interferences.

(5) Additional test equipment should be secured for field uses.

(6) The ML-313 psychrometer should be replaced with continuous recording instruments such as a dew point hygrometer and a dry-bulb temperature recorder utilizing thermistor temperature elements, as it is believed that more accurate and reliable air sounding data can be obtained with these instruments. If these instruments are used it would be preferable to make soundings when the plane is making a constant spiral ascent or descent at the rate of 100 feet per minute.

(7) The present technique of making balloon soundings using the camera-meteorograph seems to be satisfactory. However, if possible, smaller thermistor elements should be secured for the meteorograph to help reduce thermal lag in the soundings. A more desirable approach to low level soundings would be the development of a new improved type psychrograph which uses thermistors spaced at small intervals along a tower or balloon cable and a recording system which provides for progressive switching of the elements. Work on the lightweight camera-meteorograph should be continued as it will probably be of value in other meteorological work.

(8) Automatic camera-recording weather stations should be located at both the transmitter and receiver points. In order to assure more accurate readings, the thermistor elements should be mounted with the wind vane and anemometer rather than on the bottom of the housing box, and this equipment should be situated at the most significant meteorological location of the respective stations. No attempt should be made to make a quantitative correlation of the rainfall data with transmission data as the accuracy of these data over an extended path is not good and also because there is already considerable data of this type available.

The propagation and meteorological data obtained from all operations through the May-June 1948 operating period were carefully examined by Mr. Kerr and members of the project staff. From the analysis of these data, the following observations were made:

(1) It should not be assumed that there is homogeneity in hori-
Progress Report No. 20
Project No. 109-8

Two-dimensional strata along the propagation path.

(2) Many cases of localized weather conditions do not appear to appreciably affect propagation.

(3) The smallest earth undulations produce appreciable diffractive effects. A study of the Physics Building-Mount Oglethorpe path profile showed that there are at least three possible points of diffraction along this path; the first, and presumably most critical of these points, is located approximately 12 miles north of the transmitter station, and the second and third, about 33 and 40 miles, respectively, from the transmitter station. Under favorable conditions the atmosphere between the Physics Building and the first diffraction point could conceivably act as a waveguide, thereby increasing the received signal level. Thus, propagation could show characteristics similar to those existing when a duct exists over the path.

(4) Ground-based weather layers or slightly elevated layers have a larger effect on propagation than the layers lying above the path of transmission.

Mr. Kerr made the following general recommendations concerning the work of the project as a whole:

(1) Closer examination of signal strength and meteorological data during the periods of operation and acquisition of additional data during intervals of anomalous propagation.

(2) Propagation measurements at different height levels so as to obtain observations in the tangent, diffraction, and interference regions. (This is in agreement with plans previously made to obtain measurements at several new receiver heights.)

(3) Use of a helicopter, if possible, to obtain signal strength measurements and vertical sounding data for use in plotting height-gain functions.

(4) Services of a well trained theoretical meteorologist for analysis work and a theoretical physicist for a mathematical study of the various problems involved.

The visit of Mr. Kerr was valuable to the project, and it is believed that future progress will be materially improved if he will be able to maintain contact with this work. It might be noted, in particular, that Mr. Kerr's contact with other research projects of this nature at San Diego,
California, and Austin, Texas, immediately prior to his visit to Atlanta, was of great value in his appraisal of techniques employed here.

b. The Symposium on Communication Research. F. E. Lowance attended the Symposium on Communication Research held in Washington, D. C., on 11, 12, and 13 October 1948 by the Committee on Electronics of the National Research and Development Board. While in Washington Dr. Lowance discussed the work being done in microwave propagation on this project with Mr. Donald E. Kerr, Dr. T. J. Carroll, Dr. A. W. Streiton, and others. Of particular interest in the Symposium were the paper on "Tropospheric Propagation as Related to Communication" presented by Mr. M. Katzin, and the round table discussion on tropospheric propagation participated in by T. J. Carroll, B. Crawford, J. W. Green, M. Katzin, D. E. Kerr, G. Lukas, and A. W. Streiton.

C. Financial Statement.

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III. THEORETICAL AND EXPERIMENTAL PROGRESS

A. Principal Problems Undertaken during Period from 1 September through 30 November 1948.

1. Equipment Improvements.


All propagation receivers have been given general servicing and maintenance checks. The following modifications and improvements have been made.

A method has been developed for visual alignment of the discriminator in the automatic frequency control circuit of each receiver and for adjustment of the cross-over frequency of the discriminator to the center intermediate frequency by observation of the discriminator and I.F. response curves simultaneously on the screen of an oscilloscope. This method follows a standard procedure described by Hund and replaces the previous method of alignment which involved adjustment of the variable condensers in the discriminator circuit and manual plotting of the discriminator curve. All test equipment necessary to carry out this procedure was procured recently.

A jack has been mounted on the front panel of both the X- and S-Band receivers and connected to the respective video output, so that earphones can be plugged into these jacks and used to listen to the pulsed signal. In this way, one may detect power supply troubles, such as bad voltage regulator tubes and the break-down and healing of electrolytic condensers, and also irregularities in the transmitted signal due to transmitter equipment difficulties. Such

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monitoring is an aid in determining whether unusual data being recorded on the
Esterline-Angus meters are the result of natural propagation conditions or
equipment malfunctioning.

A metering switch has been built into the front panel of each receiver
so that either an electronic voltmeter or ordinary voltmeter may be connected
to the receiver during actual operation to determine the D.C. voltage of
each section of the power supply and also the I.F. filament voltages. Before
these switches were installed, the power supply chassis had to be removed be-
fore the above voltages could be measured.

A flexible section has been inserted in the rigid waveguide of the trans-
mission line between the X-Band antenna and receiver to allow for a wider ad-
justment of the antenna both horizontally and vertically. At the Mount
Oglethorpe receiving site, oriented concrete footings were used as a platform
for the receiver truck so that only small adjustments in antenna alignment
were necessary. Such footings are not available at the present Rich and Tolen
Mountain sites, however, and as a result it is a very difficult problem to
position properly the truck at these sites so that the X-Band antenna can be
accurately aligned within the small limits (± 2°) permitted by the rigid line.
Installation of the X-Band flexible section makes alignment possible over a
range of approximately 20° in azimuth and elevation.

A system of preventive maintenance has been inaugurated for care of the
receiver equipment. At the end of each operation all receiver tubes are
checked and their respective operating conditions recorded. Each tube is

stamped with a four-digit serial number which represents (1) the receiver in which the tube is used, (2) the physical position of the tube in the receiver, and (3) the total number of tube replacements made to date. Thus, one can observe when it has been necessary to make an unusual number of tube replacements. In such a case, the tube circuit can be checked and the probable cause for the replacements determined. After each operating period the discriminator of each receiver is aligned as previously described so as to insure proper performance during the subsequent operation, and a calibration of its sensitivity is made and compared with former calibrations.

Recent photographs of the interior of the 2½-ton receiver truck are shown in Figures 1 and 2.

b. X-, S-, and L-Band Transmitters.

The X-, S-, and L-Band transmitter equipment has undergone a general maintenance check and cleaning. A safety master relay controlling the line supply voltages to the transmitters has been installed at the transmitter station, and as a preventive maintenance measure all transmitter tubes have been numbered serially by the same four-digit method as that used with the receiver tubes.

(1) X-Band Transmitter.

New relay rack panels made from 1/8" steel have been procured for all components of the X-Band transmitter. These panels are replacements for the old 1/16" steel panels which were being used until these stronger, more stable panels could be obtained. Installation of the new panels has made possible relocation and respacing of the component transmitter units so as to facilitate their operation, servicing, and maintenance. The panels have also improved the appearance of the transmitter considerably and provided for greater mechanical strength of the units.
INTERIOR OF 21/2-TON RECEIVER TRUCK SHOWING X-, S-, AND L-BAND SIGNAL GENERATORS AND L-BAND POWER METER

Figure 1.
INTERIOR OF 2½-TON RECEIVER TRUCK SHOWING X-, S-, AND L-BAND RECEIVERS AND ASSOCIATED POWER SUPPLIES, ESTERLING-ANGUS RECORDERs, SIGNAL-OPERATED ALARM AND POWER SUPPLY, AND SYNCHROSCOPE

Figure 2.
Until the present time, switches and fuses for each unit of the X-Band transmitter have been located on the panels of the respective units. However, in order to simplify and speed operation of the transmitter, a new switching and fuse arrangement has been devised. Switch and fuse series combinations for each unit have been installed on a central meter panel at the top of the transmitter rack. With such an electrical arrangement, the switches can be operated only in sequence, thus preventing improper operation of or damage to any of the transmitter circuits.

The transmitter has recently been recabled due to wear and fraying of the old cables, and all plugs and sockets have been color-coded. In addition, an emergency synchronizer, to be used in case of failure of the main synchronizer, has been installed in the transmitter rack. This emergency unit, consisting of a multivibrator and amplifier, is operated fundamentally the same as the main unit.

(2) L-Band Transmitter.

During the winter of 1947-48 considerable difficulty was encountered in keeping the frequency of the L-Band transmitter stable enough to remain within the limits of the automatic frequency control incorporated in the L-Band receiver. It was found that this transmitter frequency instability was due to slight variations in the physical and electrical characteristics of the reentrant cavity oscillator used as the transmitter proper and that these variations were caused by sudden changes in room temperature brought about when the doors and windows of the transmitter station were opened and closed. Therefore, in order to provide a constant temperature atmosphere for the transmitter, a temperature-controlled box maintained at an average temperature of a few degrees
above room temperature has been designed and constructed to house the cavity oscillator. Photographs of this new housing unit are shown in Figure 3, and a functional diagram of the unit in Figure 4. The description and operating principle of the box can best be given by reference to the functional diagram.

The box, 20" x 20" x 12" in size, is constructed from 3/8" plywood and lined with a 1/2" layer of celotex. The interior of the box is divided into two sections by a plywood partition extending across approximately four-fifths the width of the box. The space between this partition and the back wall acts as an air intake duct. As shown in the diagram, an opening B is cut in the plywood partition and an opening C (air intake duct entrance) is cut adjacent to B in the side of the box. A hinged door is located common to both these openings; therefore, when B is opened, C is closed, and vice versa. Another hinged door opens and closes a third opening D (air exhaust exit) which is cut in the same side as opening C.

Mounted on the inside of the box are (1) the reentrant cavity oscillator and 10 CFM (cubic feet per minute) blower unit connected to the cavity by a rubber tubing, (2) a 50 CFM blower, (3) a gaseous temperature control element, 60° - 100° F. range, (4) a lamp-type heating element, (5) a crystal monitor, and (6) all necessary coaxial cabling and electrical wiring. The control element is connected by a small piece of copper tubing to a mercury switch mounted on the front of the box, and this switch is connected electrically to a solenoid also mounted on the front of the box and to the lamp heating element inside the box. The solenoid actuates a mechanical arrangement for opening and closing the two hinged doors. The control element is constructed so that when it undergoes a temperature change of ± 2° F. from its set temperature, the mercury switch is actuated. Thus, when the temperature in the box rises above the
TEMPERATURE-CONTROLLED HOUSING UNIT FOR L-BAND TRANSMITTER

Figure 3.
set temperature of the control element, the switch is actuated, and immediately the lamp heating element is turned off and the partition opening closed. Cool air is then brought in from the outside through the intake door and circulated through the intake duct by the 50 CFM blower, around the inside of the box, and out the exhaust door, as shown by the solid arrows. When the air in the box has cooled below the set temperature of the control element, the switch is again actuated. In this case, the heating element is turned on and the solenoid is deenergized. The exhaust and intake doors are then closed and the partition door is opened. The 50 CFM blower continues to circulate air; however, now the air passes over the heating element, through the opening in the partition, and on around the inside of the box, as shown by the dotted arrows. Then, when the air is heated to the necessary temperature, the solenoid is again energized. The temperature of the circulating air inside the box is thus held constant to within approximately three degrees F. (allowing one degree for lag due to the thermal capacity of the box and for air circulation time). The 10 CFM blower connected to the cavity continually furnishes a stream of this temperature-regulated air for ventilation of the metal-to-glass seals of the 2C4 tube used in the cavity. This new housing unit was used successfully during the October and November operating periods.

Construction of the above housing necessitated the dismounting of the transmitter proper from its original frame. Therefore, while the transmitter was disassembled, the cavity was silver plated to reduce RF losses and the power monitoring system was modified. Heretofore the crystal monitor and crystal current meter (0-1 mA.) were bracketed to a board beside the transmitter. The monitor has now been mounted on the inside of the housing unit as previously stated, and the meter has been mounted on the front of the box. In addition, a
quarter-wave matching section has been installed in the sampling line leading to the crystal monitor, thus providing for better matching of the crystal to the sampling line and more stable indication of the transmitted power.

c. X-Band Antenna Tests.

During the August-September and October operations, measurements were made of the X-Band receiving and transmitting antenna gains, using calibrated horns. As a result of these tests, the transmitting antenna was found to have a gain of 36.2 db., and the receiving antenna, recently repaired because of damages to the feed dipoles, a gain of 27.0 db. These values were used in calculation of the free space received signal values for the above operating periods.

The receiving antenna gain of 27.0 db. is 6.0 db. below the original measured gain. However, due to the fact that this antenna is subjected to vibration and rough treatment during movement of the mobile field station, further adjustment to improve its gain is not considered practical. In order to assure a close check on the condition of the antenna and to provide accurate gain measurement, the gain will be measured during each operation using the calibrated horns.

d. Redesign of Camera-Meteorograph.

All component parts for the new lighter-weight model of the camera-meteorograph have been assembled, and construction of the unit is now well under.
A complete description of this new meteorograph with photographs and circuit diagrams will be presented in the next report.

e. Automatic Camera-Recording Weather Station.

The pilot model of the automatic camera-recording weather station was placed at the receiver station during the August-September, October, and November operating periods. For operational use, the unit was placed on top of the receiver truck and the wind vane and anemometer were strapped to the top of a nearby tree in a direct wind path. From observations of the film data recorded by the weather station during these operations, the instrument appears to be a satisfactory means for obtaining data over an extended period of time. It is believed, however, that the unit can be modified so as to improve the accuracy of these data. As a result, a new model of the weather station, essentially a refinement of the pilot model, has been designed and is now under construction. Although this new unit will be similar to the original model in appearance and design, the following modifications will be made in its structure.

The thermistors and blower, which in the pilot model are encased in an aluminum shelter-type covering mounted on the bottom of the housing box, will be placed in an aluminum box in the new model and mounted on the rod supporting the wind vane and anemometer. By thus locating the thermistors, they are removed from the truck, ground, housing unit, and other objects with a large thermal capacity which cause erroneous temperature readings and thermal lag in the readings. A new eight-conductor cable to accommodate this new arrangement will replace the original four conductor cable leading from the wind vane and anemometer to the meter panel and will furnish, in addition to the above leads, leads from the thermistor elements to their recording meters. The new cable will be approximately 100 ft. in
length as compared with the original 50 ft. cable.

All electrical components, including rectifiers, battery packs, relays, thermistor circuits, switching controls, and timing mechanisms, which in the pilot model are mounted at random in the space in back of the instrument panel, have been mounted on a standard radio type chassis, 7" x 12", which will be located in this same space in the new unit. The components have been mounted thus so as to make the electrical circuit more compact, durable, and convenient for servicing.

It was previously planned to operate a weather station at the transmitter station, receiver station, and at three places at ground level along the propagation path. However, since now it does not seem advisable to use stations along the path, as stated on page 9 of this report, only two stations will be necessary -- one for operation at the receiver station and the other for operation at the transmitter station. Therefore, as soon as the new model has been completed, it will be tested, and, if found to operate satisfactorily a second unit will be built.

Photographs and circuit diagrams of the new weather station will be presented in the next report.

2. Receiver Sites.

As has been noted in previous progress reports, the Mount Oglethorpe receiver location is well above the optical and radar horizons as seen from the transmitters on the Georgia Tech Physics Building. Large quantities of data were gathered for this high path of propagation during operating periods between May, 1947 and August, 1948. Signal variations as great as 30 db. occurred rather frequently, particularly during summer and early fall months, when atmospheric refraction is strongly influenced by variations in humidity.
Assessing of additional data for the elevated path of transmission might contribute to a better understanding of the relationship between atmospheric variables and microwave propagation. However, it was considered more fruitful to extend the scope of the propagation studies to include transmission paths nearer grazing line of sight, where even more pronounced effects were to be expected from changes in refraction near the surface. Low receiver sites should also provide data on diffraction of short electromagnetic waves by intervening irregularities of terrain, provided that the effects of superrefraction or duct formations can be separated from diffractive effects.

An attempt was made to locate accessible receiver sites directly along the line from the Physics Building to Mount Oglethorpe in order to provide a better basis for comparison of results for the Mount Oglethorpe optical path and the grazing paths of transmission. The search for ideal sites was unsuccessful, but two barely accessible locations were found about two degrees east of the Mount Oglethorpe line on Rich Mountain and Tolen Mountain. Path profiles for the old and new sites are shown in Figure 5. Comparative data on the Mount Oglethorpe location and the two new receiver sites, which were used during recent operations, are presented in Table I.

<table>
<thead>
<tr>
<th>Receiver Site</th>
<th>Distance from Physics Bldg. (miles)</th>
<th>Direction in degrees East of North</th>
<th>Elevation of Receiver above Mean Sea Level (ft.)</th>
<th>Approximate Height above Radar Horizon for 4/3 Earth Radius (ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mt. Oglethorpe</td>
<td>49</td>
<td>3.5°</td>
<td>3300</td>
<td>900</td>
</tr>
<tr>
<td>Rich Mt.</td>
<td>47</td>
<td>6.0°</td>
<td>2040</td>
<td>-400</td>
</tr>
<tr>
<td>Tolen Mt.</td>
<td>47</td>
<td>5.5°</td>
<td>2280</td>
<td>-200</td>
</tr>
</tbody>
</table>

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-25-
Profiles of Paths of Propagation from Georgia Tech Physics Bldg. to Rich Mtn., Tolkien Mtn., and Mt. Ogilthorpe Receiver Stations, showing grazing ray path for standard atmospheric conditions

Figure 5.
The negative values in the fifth column of Table I are to be interpreted as meaning that the receiver sites are below the radar horizon by the amounts listed. The values of the receiver heights relative to the radar horizon may be in error by appreciable amounts (possibly 50 to 100 ft.), since the exact heights of the intervening terrain cannot be determined from available charts which have contour intervals of 50 to 100 ft. The nature of the tree coverage on the hills is also uncertain.

Ray plots on the Mount Oglethorpe path profile indicated that a ray leaving the transmitter horizontally would barely clear a ridge at a distance of about 11 miles from the transmitter under standard conditions (M-value gradient dM/dh=0.036/ft.). The height of this horizontally emitted ray at the receiver distance was taken originally as the radar horizon level at each of the receiver sites. Recently drawn profiles for the Rich and Tolen Mountain paths, however, show a slightly higher point at a range of nine miles from the transmitters. In order to clear the high point at a distance of nine miles, the grazing ray must leave the antennas at an angle of elevation of approximately one mil. Thus, the heights of the Rich and Tolen Mountain sites relative to the radar horizon were calculated for a ray emitted at an angle of one mil above the horizontal. The profiles indicate that under standard conditions (dM/dh = 0.036/ft.) both new sites lie below the radar horizon, in the diffraction zone. Under substandard conditions (dM/dh>0.036/ft.), the rays would be refracted upward, and very severe fading might then be expected for receivers at the low receiver heights. Conversely, for superrefractive conditions (dM/dh < 0.036/ft.), the average signal strength might be expected to increase to near its free space value. The effect of changes in the modified index of refraction gradient (dM/dh) for horizontally emitted rays is illustrated in Figure 6.
Figure 6.

EFFECT of M-GRADIENT on PATH of HORIZONTALLY EMITTED RAY
for the Physics Building-Mount Oglethorpe path of propagation.

The receivers were located at the Rich Mountain site during the two weeks operation of 25 August through 6 September 1948, and on Tolen Mountain during the operation of 9 October through 18 October 1948. During the November period of operation the receivers were located first on Tolen Mountain, from 10 November through 15 November, and then on Rich Mountain from 16 November through 22 November. If a search for a still lower site in the same general locality proves successful, it is expected that the next operation will be divided between Rich Mountain and the future site. Lowering of the receivers by approximately 200 ft. should place them about 600 ft. below the radar horizon for standard atmospheric conditions and should result in reception of only diffracted signals during the greater part of the time.

3. Data Analysis.

a. General.

The propagation records for the first five periods of operation have been examined critically in an attempt to interpret the effects of pronounced atmospheric phenomena on microwave transmission over the optical path from the Physics Building to Mount Oglethorpe. The principal atmospheric conditions considered were:

(1) the moist standard atmosphere,
(2) ground-based superrefractive layers and ducts,
(3) elevated superrefractive layers and ducts between the transmitter and receiver levels,
(4) elevated superrefractive layers and ducts above the receiver level,
(5) substandard atmospheric layers.

From a study of the available meteorological data, those portions of the signal
strength records for which there were definite indications of the above atmospheric conditions were selected and grouped for further analysis. The analysis was carried out on a statistical basis, by plotting time distributions of instantaneous received power for transmission under the particular types of atmospheric conditions.

The operating periods covered by the analysis were as follows:

1. 15 to 28 May 1947 - S- and X-Band,
2. 1 to 11 July 1947 - S- and X-Band,
3. 9 to 30 August 1947 - S- and X-Band,
4. 16 October to 16 November 1947 - L-, S-, and X-Band,
5. 25 January to 1 February 1948 - L-, S-, and X-Band.

For all of these operations the transmitters were located on the Georgia Tech Physics Building at an elevation of about 1060 ft. above mean sea level, and the receivers were located on Mount Oglethorpe at an elevation of approximately 3300 ft. above mean sea level. The transmission path length was approximately 49.5 statute miles. The receivers were approximately 900 ft. above grazing line of sight for propagation under standard conditions. The Georgia Tech-Mount Oglethorpe propagation path profile is presented in Figures 5 and 6, pages 26 and 28 of this report, respectively. By reference to Figure 6, in which the paths of horizontally emitted rays are plotted for various M-gradients, it is seen that there was little probability that the receivers were ever below the radar horizon. Substandard layers of great enough intensity to increase the M-gradient to 0.22/meter over a large height interval were not observed in any of the soundings.

b. Results and Conclusions.

Up to the present time attempts to obtain a direct analytical solution to the propagation problem have proved entirely inadequate in so far as calculation of instantaneous values of received signal power is concerned.
It appears doubtful that a solution of this type will be forthcoming in the
near future. In the first place, it is not yet practicable to determine the
meteorological conditions existing over the entire path of propagation. Even
if it were possible to fix all of the atmospheric parameters at a given time,
the mathematical complexity of the problem might prove prohibitive. It is
believed that future research in the propagation field will be concerned with
correlation functions which express the statistical nature of the signal as
a function of atmospheric conditions. Accordingly, the results of this analysis
are presented graphically (Figures 7-12) as time distributions of instantane-
ous received power. These time-distribution curves express the proba-
bility that the received signal will be below a particular intensity level at
a specified time. The shapes of the curves also provide information on the
fading characteristics of the received signal. For example, the vertical
extent of the curves shows the maximum fading range to be expected.

Time distributions of instantaneous received power at X-Band for four
different atmospheric conditions are presented in Figure 7. The distribution
functions for "standard" conditions and for "elevated superrefractions above
receiver height" have the same form and approximately the same vertical extent
indicating that atmospheric stratifications above the receiver level have
little effect on transmission. When the atmospheric disturbances are ground-
based or below the receiver level, however, a large increase in the amount
of fading and the maximum fading range is apparent. Under these conditions
the fading range increases about 7.5 db. as compared to the "standard" case.

The effects of different atmospheric conditions on S-Band transmission
are shown by the time distribution curves of Figure 8. These distribution
curves have the same general form as the X-Band curves except for the condition of a superrefractive layer above the receiver level. A curve of this form indicates that the received signal was either high and steady, or low and steady, during a large fraction of the time. Therefore, although fading is less frequent, changes in average signal level seem quite pronounced under this condition.

Figure 9 presents time distribution curves for L-Band propagation under the four special atmospheric conditions. Since only sparse L-Band data were available, these curves are not considered as significant as those for X-Band and S-Band. They are included in this report only for the sake of completeness.

In general then, the effects of ground-based superrefracting layers are:

1. There is a decrease of average signal level of one to four db. from the standard level. This may be due to the trapping of waves and their subsequent scattering and absorption by the terrain coverage. In no case is there evidence of guided propagation directly to the receiver. Such action is considered improbable because of the nature of the intervening terrain and the relative positions of transmitter and receiver. Trapping in ducts which extend over only part of the path is considered possible. Such action would give a highly varying signal whose average level is free space or slightly above. Since the average signal level was slightly below the free space level, it appears that this phenomenon occurred infrequently, if at all.

2. Average deviations increased greatly over those obtaining under standard conditions. This increase is of the order of 8-11 db. on X-Band, 4-8 db. on S-Band, and 3-6 db. on L-Band. These deviations show the usual fading characteristics of sharp, brief minima and broad maxima. Since the atmospheric conditions causing a ground-based superrefraction are unstable and
TIME DISTRIBUTION OF INSTANTANEOUS RECEIVED POWER UNDER SPECIAL ATMOSPHERIC CONDITIONS: X-BAND

Figure 7.
TIME DISTRIBUTION OF INSTANTANEOUS RECEIVED POWER UNDER SPECIAL ATMOSPHERIC CONDITIONS: S-BAND

Figure 8.
TIME DISTRIBUTION OF INSTANTANEOUS RECEIVED POWER UNDER SPECIAL ATMOSPHERIC CONDITIONS: L-BAND

Figure 9.
highly transient, it is to be expected that the signal perturbations will be rapid and of large amplitude. Figure 10 shows the relative effect of ground-based phenomena on the three experimental frequencies.

The effect of elevated superrefractions when they lie between transmitter and receiver seems almost identical to that of ground-based layers. The same general reduction of signal level and increase of fading occurs, and they are of the same order of magnitude as for ground-based layers. When the elevated layer lies above receiver height, propagation conditions seem almost standard. The peculiar shaped curve for S-Band under this condition is not believed to be significant although further investigation is desirable. Figure 11 shows the relative effect of elevated superrefractions on X- and S-Band transmission.

The substandard atmospheric condition is almost always associated with rainfall and storm conditions. The signal under these conditions showed small amplitude scintillations and a decrease of average level of from one to six db. from adjacent propagation periods. Perturbations of the signal show amplitudes of from four to eight db. on X-Band, and somewhat smaller amplitudes on S- and L-Band.

Table II contains a summary of the average signal levels and average maximum deviations for the three frequencies under various atmospheric conditions. These data were taken from the time distributions and tabulations of the propagation records.
TIME DISTRIBUTION OF INSTANTANEOUS RECEIVED POWER UNDER GROUND-BASED SUPERREFRACTIVE ATMOSPHERIC CONDITIONS

Figure 10.
TIME DISTRIBUTION OF INSTANTANEOUS RECEIVED POWER UNDER ELEVATED SUPERREFRACTIVE ATMOSPHERIC CONDITIONS

Figure 11.
### TABLE II

**SUMMARY OF AVERAGE SIGNAL LEVELS AND AVERAGE MAXIMUM DEVIATIONS FOR VARIOUS ATMOSPHERIC CONDITIONS**

<table>
<thead>
<tr>
<th></th>
<th>X-Band</th>
<th>S-Band</th>
<th>L-Band</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Signal Level</td>
<td>-0.9</td>
<td>+1.0</td>
<td>-2.4</td>
</tr>
<tr>
<td>Average Maximum Deviations</td>
<td>4.2</td>
<td>5.0</td>
<td>2.3</td>
</tr>
<tr>
<td><strong>Ground-Based Layers</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Signal Level</td>
<td>-2.0</td>
<td>-2.8</td>
<td>-1.5</td>
</tr>
<tr>
<td>Average Maximum Deviations</td>
<td>16.9</td>
<td>11.6</td>
<td>4.2</td>
</tr>
<tr>
<td><strong>Elevated Layers Below 600M</strong></td>
<td>-0.3</td>
<td>-4.6</td>
<td>-5.9</td>
</tr>
<tr>
<td>Average Signal Level</td>
<td>17.0</td>
<td>12.5</td>
<td>3.2</td>
</tr>
<tr>
<td><strong>Elevated Layers Above 700M</strong></td>
<td>+2.0</td>
<td>0.0</td>
<td>-1.0</td>
</tr>
<tr>
<td>Average Signal Level</td>
<td>14.2</td>
<td>5.5</td>
<td>2.9</td>
</tr>
</tbody>
</table>

Since much of the meteorological data is of a doubtful and incomplete nature, the results presented here may be taken as only a rough indication of true conditions. Of the 42 periods during which ground-based superrefractions were indicated in the weather data, only 24 periods showed the fading characteristics discussed above. Of 23 periods during which elevated superrefractions below the receiver level were indicated, ten periods showed severe fading. There were two cases of severe fading in 16 indicated periods of superrefraction above the receiver level. There were several periods of severe fading during which no atmospheric stratification was indicated by the meteorological data. However, soundings were made at only one or two points along the path and these apparent discrepancies may have resulted from lack of horizontal homogeneity of the atmosphere. There is little doubt that the
weather data in many cases indicated highly localized conditions having a negligible effect on transmissions. These periods are nevertheless included in the calculation of the time distributions. Another possible source of error is receiver and transmitter calibration. Figure 12 gives an indication of the average magnitude of this error, in the average separations of signal level for the three frequencies under standard atmospheric conditions.

General weather conditions in the Atlanta area show the following yearly cycle. The May through July operations show strong and frequent ground-based and slightly elevated superrefractions; August through November is a period of decreasing atmospheric activity with many weak elevated weather layers; the December through February period shows infrequent, very weak superrefractions. These conditions are strongly indicative of the type of propagation to be expected.

c. Future Data Analysis.

The above method of analysis should be considered by no means complete, even for the first five periods of operation. It may be taken as representative of a general trend toward a statistical type of analysis which should include all periods of transmission over the optical path from the Physics Building to Mount Oglethorpe, and which should be amplified to include additional factors which influence propagation. It is planned to make a more thorough analysis of all the signal strength data for both optical and non-optical paths of propagation. It is believed that other significant propagation factors will be revealed by different methods of plotting the statistical distributions of signal strength data. An example of a different type of plot is shown in Figures 13 and 14 where the distribution of the ratio
TIME DISTRIBUTION OF INSTANTANEOUS RECEIVED POWER UNDER STANDARD ATMOSPHERIC CONDITIONS

Figure 12.
TIME DISTRIBUTION OF INSTANTANEOUS ELECTRIC FIELD STRENGTH: X-, S-, AND L-BAND

Operating Period from 29 June through 12 July 1948

Figure 13.
TIME DISTRIBUTION OF INSTANTANEOUS ELECTRIC FIELD STRENGTH; X-, S-, AND L-BAND
Operating Period from 27 July through 9 August 1948

Figure 14.
of instantaneous field intensity to free space field intensity \((E/E_0)\) is plotted as the ordinate on probability paper for the entire operating periods, 29 June to 12 July 1948, and 27 July to 9 August 1948, respectively. It should be noted that the actual ratio of field strengths is used, rather than the logarithmic or decibel comparison of instantaneous values with the free space value. Close approximations to straight lines result. Since a straight line for a distribution function on this type of probability paper represents a normal frequency distribution (Gaussian error curve), it appears that the signal strength distributions for long periods of time may be of a similar random nature. This type of plot will be investigated further in connection with the analysis of the optical path data. It is doubtful, however, that the non-optical path data will follow the same distribution law. Plots on other types of probability paper may yield information as to the type of statistical distribution followed in the diffraction region.
IV. ASSEMBLED DATA

A. Operating Period from 27 July through 9 August 1948.

1. Propagation Measurements.

Data obtained from the propagation measurements made over the Georgia Tech-Mount Oglethorpe path during the July-August operation are presented in Appendix A. These data include (1) signal strength chart recordings, (2) graphical compilations of signal variations and atmospheric data, and (3) time distribution curves of instantaneous received power.

The operating conditions for the period are as follows:

a. X-Band.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>9404 mc</td>
</tr>
<tr>
<td>Pulse Recurrence Frequency</td>
<td>500 pps</td>
</tr>
<tr>
<td>Pulse Length</td>
<td>1.3 microsec.</td>
</tr>
<tr>
<td>Peak Transmitted Power</td>
<td>22.0 kw</td>
</tr>
<tr>
<td>Calculated (Free Space) Received Signal</td>
<td>18.7 dbm</td>
</tr>
<tr>
<td>Measured Antenna Gain</td>
<td></td>
</tr>
<tr>
<td>Transmitter</td>
<td>36.2 db</td>
</tr>
<tr>
<td>Receiver</td>
<td>21.4 db</td>
</tr>
<tr>
<td>Line Attenuation (Antenna to Receiver)</td>
<td>19.2 db</td>
</tr>
<tr>
<td>Receiving System Noise Level</td>
<td>58.2 db</td>
</tr>
<tr>
<td>Receiver Noise Level</td>
<td>78.0 db</td>
</tr>
</tbody>
</table>

b. S-Band.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>2860 mc</td>
</tr>
<tr>
<td>Pulse Recurrence Frequency</td>
<td>500 pps</td>
</tr>
<tr>
<td>Pulse Length</td>
<td>1.3 microsec.</td>
</tr>
<tr>
<td>Peak Transmitted Power</td>
<td>39.5 kw</td>
</tr>
<tr>
<td>Calculated (Free Space) Received Signal</td>
<td>8.8 dbm</td>
</tr>
<tr>
<td>Calculated Antenna Gain</td>
<td></td>
</tr>
<tr>
<td>Transmitter</td>
<td>27.2 db</td>
</tr>
<tr>
<td>Receiver</td>
<td>27.2 db</td>
</tr>
<tr>
<td>Line Attenuation (Antenna to Receiver)</td>
<td>39.7 db</td>
</tr>
<tr>
<td>Receiving System Noise Level</td>
<td>42.3 db</td>
</tr>
<tr>
<td>Receiver Noise Level</td>
<td>82 dbm</td>
</tr>
</tbody>
</table>

(6) Ibid., p. 17.
c. L-Band.

Frequency: 1310 mc
Continuous Wave: 900 mw
Average Transmitted Power: 59.4 dbm
Calculated (Free Space) Received Signal: 21.8 db
Calculated Antenna Gain
Transmitter: 21.8 db
Receiver: None
Line Attenuation (Antenna to Receiver): None
Receiving System Noise Level: 80 dbm

2. Atmospheric Soundings.

Meteorological sounding data for the July-August operation were obtained from radiosondes, captive balloon soundings, and aircraft soundings. Significant M-curves, as calculated from these data, are presented in Appendix A.

Radiosonde data were secured for each day of the operating period from the Atlanta Weather Bureau at the Atlanta Municipal Airport, located about seven miles south of the transmitter station, and captive balloon soundings were obtained with the camera meteorograph at the balloon site near Roswell, Georgia, at 0500 EST and 1630 EST each day when weather conditions permitted balloon flights to be made.

Aircraft soundings were made using the ML-313-AM aircraft psychrometer in the AT-11 aircraft. The aircraft flights were made at 0400 EST and 1600 EST every day when weather conditions were favorable for flying. The vertical sounding procedure was used in which three soundings are made at approximately equally spaced distances along the propagation path.7

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3. Weather Summary from Synoptic Charts.

27 July 1948.
Region was in southwesterly circulation of the Bermuda High. Squall line just to the west of Georgia dissipated during the day. Temperatures and humidity were high with showers in Tennessee, Alabama, and north Georgia.

28 July 1948.
Temperatures dropped but humidity remained high as a new squall line passed, causing showers in Georgia.

29 July and 30 July 1948.
This region remained in southwesterly flow of warm, moist air, but no rain was reported.

31 July 1948.
A weak cold front entered this area late in the afternoon bringing scattered showers over the entire southeast.

1 August 1948.
The cold front became stationary on a northeast-southwest line through Atlanta with frequent showers along the front. Temperatures dropped while the humidity remained very high.

2 August 1948.
The stationary front dissipated and this region came under the influence of the southeasterly circulation of the Bermuda High. Showers of convective nature occurred in the afternoon over the southeast.

3 August and 4 August 1948.
Circulation remained generally southerly with the influx of warm, moist, unstable air causing fog in the morning and convective showers in the afternoon.
5 August 1948.

A cold front passed Atlanta near 0730 EST with a shift to northerly circulation and an immediate drop in temperature and humidity due to the influx of cold, stable air.

6 August through 8 August 1948.

Clear skies still prevailed, but circulation became southeasterly as the High moved off the Atlantic coast and weakened.

B. Operating Period from 25 August through 6 September 1948.

1. Propagation Measurements.

Propagation measurements were made over the new operating path between Georgia Tech and Rich Mountain from 25 August through 6 September. All data obtained are presented in Appendix B in the same form as the data for the July-August operation.

The operating conditions were as follows:

a. X-Band.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency:</td>
<td>9404 mc</td>
</tr>
<tr>
<td>Pulse Recurrence Frequency:</td>
<td>500 pps</td>
</tr>
<tr>
<td>Pulse Length:</td>
<td>1.3 microsec.</td>
</tr>
<tr>
<td>Peak Transmitted Power:</td>
<td>22.8 kw</td>
</tr>
<tr>
<td>Calculated (Free Space) Received Signal:</td>
<td>14.1 dbm</td>
</tr>
<tr>
<td>Measured Antenna Gain Transmitter:</td>
<td>36.2 db</td>
</tr>
<tr>
<td>Receiver:</td>
<td>27.0 db</td>
</tr>
<tr>
<td>Line Attenuation (Antenna to Receiver):</td>
<td>19.2 db</td>
</tr>
<tr>
<td>Receiving System Noise Level:</td>
<td>60.6 dbm</td>
</tr>
<tr>
<td>Receiver Noise Level:</td>
<td>79.8 dbm</td>
</tr>
</tbody>
</table>

(a) Progress Report No. 19, August 31, 1948, p. 17.
b. S-Band.

- Frequency: 2860 mc
- Pulse Recurrence Frequency: 500 pps
- Pulse Length: 1.3 microsec.
- Peak Transmitted Power: 31.4 kw
- Calculated (Free Space) Received Signal: 9.9 dbm
- Calculated Antenna Gain:
  - Transmitter: 27.2 db
  - Receiver: 27.2 db
- Line Attenuation (Antenna to Receiver): 23.0 db
- Receiving System Noise Level: 53.1 dbm
- Receiver Noise Level: 76.1 dbm

c. L-Band.

- Frequency: 1310 mc
- Continuous Wave: 900 mw
- Average Transmitted Power: 59.4 dbm
- Calculated (Free Space) Received Signal: 21.8 db
- Calculated Antenna Gain:
  - Transmitter: 21.8 db
  - Receiver: 21.8 db
- Line Attenuation (Antenna to Receiver): 9 db
- Receiving System Noise Level: 79.1 dbm

2. Atmospheric Soundings.

Meteorological soundings for the August-September operating period were obtained from radiosondes, captive balloon soundings, and aircraft soundings. The soundings were made following the same procedure used during the July-August operation. However, the C-45 aircraft assigned to the project in August was used for the air soundings as a replacement for the AT-11 aircraft. The significant M-curves as calculated from the sounding data are presented in Appendix B.

3. Weather Summary from Synoptic Charts.

23 August through 29 August 1948.

High temperatures and low humidity prevailed as a large high cell over the entire eastern United States gave easterly to southeasterly circulation of stable air.
30 August 1948.

A low pressure area caused by a hurricane off the North Carolina coast brought warm, moist air into this area with cloudy skies by nightfall.

31 August through 2 September 1948.

The Low moved off and northerly circulation of cool, stable, dry air began with clearing skies and no precipitation.

3 September 1948.

Same as for 2 September, except cloudy skies and stronger circulation of moist air indicated the approach of a hurricane and accompanying weather conditions from the southwest.

4 September 1948.

Strong easterly circulation, cloudy skies, and rain occurred the entire day as the hurricane moved in shore at New Orleans and dissipated into slower cyclonic flow and a warm front developed.

5 September 1948.

The Low moved north and the warm front dissipated on a northwest-southwest line through Atlanta. Showers and light rain occurred until late in the day when the front dissipated entirely.

6 September 1948.

Clear skies and low humidity prevailed as circulation became southwesterly and stable air entered this region.

C. Operating Periods from 9 October through 18 October 1948 and from 10 November through 22 November 1948.

An operation was conducted over the new Georgia Tech-Tolen Mountain path from 9 October through 18 October. It was during this operating period that the captive balloon and camera-meteorograph were lost and the C-45 aircraft
was damaged, as previously discussed. As a result of these accidents, only a negligible quantity of meteorological sounding data was obtained.

Propagation measurements were made over the Georgia Tech-Tolon Mountain path from 10 November through 15 November and over the Georgia Tech-Rich Mountain path from 16 November through 22 November. Meteorological data were obtained from radiosondes and aircraft soundings.

The data for these above operating periods will be presented in a supplementary report at a later date.
1. Field operation during month of December.

2. Continuation of data analysis.

3. Preparation of technical papers on methods of obtaining and analyzing propagation data and submission of abstracts to Watson Laboratories for publication approval.

4. Preparation of a supplementary report to this report which will include the assembled data obtained during the October, November, and December, 1948 operations.

Submitted by

F. E. Lawance,
Project Director

Approved:

J. E. Boyd
Associate Project Director

Gerald A. Rosselot
Director
## APPENDIX A

DATA OBTAINED DURING OPERATING PERIOD FROM 27 JULY THROUGH 9 AUGUST 1948

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ATMOSPHERIC CONDITIONS

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