NBS REPORT

7274

NATIONAL BUREAU OF STANDARDS MEASUREMENT PROGRAM ON UHF AIRBORNE TELEVISION

by

R. S. Kirby, A. P. Barsis, and P. L. McQuate

NBS

U. S. DEPARTMENT OF COMMERCE
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The measurements described in this report were sponsored by the U. S. Army Signal Research and Development Laboratory, Fort Monmouth, New Jersey.

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INTRODUCTION

During the 1961-1962 school year the Midwest Program on Airborne Television Instruction, Inc. (MPATI) transmitted television signals from an aircraft flying over Indiana at 23,000 feet. The primary purpose of this experiment was to test the effectiveness of the airborne broadcast technique in providing television instruction over a large geographic area.

The Central Radio Propagation Laboratory of the National Bureau of Standards became interested in the program in its early planning stages, and under sponsorship of the Ford Foundation made studies of some of the technical factors involved in air-ground broadcasting and in the planning of an airborne television network [Decker, 1959 and 1962].

The purpose of this report is to describe a series of propagation measurements made over several air-ground propagation paths during the 1961-1962 school year. These measurements are being made under the sponsorship of NBS and with financial assistance from the U. S. Army Signal Research and Development Laboratory, Fort Monmouth, New Jersey. Altogether six continuous recordings have been made at four locations ranging from 87 to 222 miles from the transmitter. Another location is currently being activated and will record signals during summer 1962 test transmissions. Plans are being made to continue the recording program during the 1962-1963 school year.

Two transmitters operate simultaneously on Channels 72 and 76 while the aircraft orbits at 23,000 feet over Montpelier, Indiana. All recordings of transmission loss are made on paper charts, which are later transferred to magnetic tape. Because of some difficulties in financing the measurements early in the program none of the recordings covers the entire broadcast schedule and most did not commence until around the beginning of 1962.

1. TRANSMISSION FACILITIES

The MPATI organization has two Douglas DC-6AB transport aircraft each equipped to transmit UHF television signals on Channels 72 and 76 simultaneously. Flights have been carried out on a four-day-per-week schedule throughout the school year 1961-1962. The broadcasts are made during the period between 8:45 a.m. and 2:15 p.m. EST while the aircraft orbits at 23,000 feet nominally over Montpelier, Indiana.

One of the unique features of the aircraft installation is the transmitting antenna, which is lowered on a stabilized boom approximately twenty-four feet below the aircraft while in flight. Thus time variations in transmission loss due to changes in attitude of the aircraft are all but eliminated. A photograph of one of the aircraft in flight with the antenna extended in shown in Figure 1. Significant features of the transmitting installation are listed in Table 1.

Table 1

Airborne Transmitter Facilities

Main Transmitting Equipment	
Aircraft: Douglas DC-6AB, Serial 6815C	
Channel 72, KS2XGA, 818-824 Mc/s	
Power Rated Visual Plus Aural	12 kw peak
Actual	6 kw peak
Aural	-10 db below peak visual
Antenna Gain Relative to Isotropic	8.7 db
Polarization	Horizontal
Channel 76, KS2XGD, 842-848 Mc/s	
Power Rated Visual Plus Aural	12 kw peak
Actual	5 kw peak
Aural	-10 db below peak visual
Antenna Gain Relative to Isotropic	8.2 db
Polarization	Horizontal
Alternate Main Transmitting Equipment	
Aircraft: Douglas DC-6AB, Serial N6813C	
All data are the same except that the actual power output is somewhat less--on the order of 3-4 kw peak.	

The high gain of the transmitting antennas is obtained through the use of vertical directivity which in turn necessitates the use of antenna stabilization. Model measurements were made to determine the patterns. Figure 2 shows typical vertical H-plane patterns obtained by the Westinghouse Electric Corporation from one of several model antennas used. The transmitting antennas employ a small amount of electrical tilting downward. The horizontal patterns are quite uniform and no serious antenna-gain variations due to changes in aircraft heading should be observable.

The orbit of the aircraft is maintained within a 10-mile radius centered over Montpelier, Indiana. Normally a figure-eight pattern is flown oriented in accordance with the prevailing wind. A special computer using TACAN inputs keeps the aircraft position constantly on display so that the orbit can be flown with accuracy. Occasionally stabilization of the antenna is defective and it becomes necessary to fly a circle with a constant roll angle. In this situation the antenna can be maneuvered manually to a position counteracting the roll but must remain essentially in one position during the flight.

2. RECEIVING FACILITIES

The five receiving locations were chosen to represent paths from relatively short to beyond the horizon. Figure 3 shows a map with the various propagation paths superimposed. The operation at the five locations is essentially identical. Field-strength meters or crystal-controlled recording receivers are used to record on Esterline-Angus paper charts. These are run at a fairly fast rate of 45 inches per hour. The reason for this speed is so that the most rapid fluctuations in transmission loss likely to occur can be followed, and by a special technique the data can later be put on magnetic tape for analysis.

Terrain profiles from the center of the orbit at Montpelier to each of the five receiving locations are shown in Figure 4. Descriptions of the sites and the recordings being obtained are as follows.

a. Lafayette, Indiana

Recordings at this site are being obtained by Westinghouse Electric Corporation. A Stoddard Model NM52A field strength meter is operated with receiving antennas on the Purdue University Airport.

Originally the receiving antennas were put on the hangar, but a deep and persistent fading of the signal resulted due to interference between direct and ground-reflected rays. This fading was virtually eliminated by lowering the receiving antennas to approximately twelve feet above the terrain. Figure 5 shows a photograph of the receiving antennas. The distance to the center of the orbit is 87 miles.

The recording procedure at Purdue is somewhat different from that at all other sites. Each day one half of the broadcast day is recorded on Channel 72 and the other half on Channel 76. The choice of channels to be recorded during the first half of the day was alternated somewhat at random.

b. Allegan, Michigan

Next in distance from the transmitters is Allegan, Michigan, at 147.2 miles. A recording is obtained by the FCC at its Monitoring Station using a special, crystal-controlled receiver tuned to the audio signal of Channel 72 (823.75 Mc/s) and a corner reflector antenna elevated 30 feet above the terrain. Recordings have been made continuously since November 27, 1961. Figure 6 shows a photograph of this recording installation.

c. Urbana, Illinois

At about the same distance as Allegan but in a westerly rather than northerly direction is the University of Illinois at Urbana. No data were obtained during the initial school year ending in May 1962 at Urbana, but it is planned to make recordings during the test broadcasts on Tuesdays and Thursdays during the summer of 1962. Figure 7 is a photograph of the Electrical Engineering Building at the University of Illinois where the recordings will most likely be made.

d. Cleveland, Ohio

The most extensive recording effort is undertaken at Cleveland, Ohio, where three recordings are obtained simultaneously by Smith Electronics, Inc. This site is particularly interesting because it is very close to the radio horizon at 198 miles, and there is available a 500-foot tower making possible observations at different heights and consequently both within and beyond the radio horizon. Two of the recordings are made with receiving antennas at the 30-foot level, one each on Channel 72 and Channel 76. At this elevation the antennas are beyond the horizon. Channel 76 is also observed on another antenna at the 476-foot level, which is within the horizon. A photograph of this installation is shown in Figure 8.

e. Milwaukee, Wisconsin

The longest propagation path in this program is the Milwaukee, Wisconsin, path at 222.2 miles. The Journal Company, WTMJ-TV is operating a recorder on Channel 76. The terrain profile shows that the path is normally within the line of sight for the receiving antenna at 200 feet above the terrain. A photograph of this installation is shown in Figure 9.

f. Summary

A summary of the propagation paths used in the recording program is given below.

Table 2

Summary of Propagation Paths

Location	Channel	Path Length Miles	Antenna Height Feet	Terrain Height Feet	Date Started
Lafayette, Indiana	72 76	87	12	605	October 26, 1961
Allegan, Michigan	72	147	30	675	November 27, 1961
Urbana, Illinois	76	158	-	715	--
Cleveland, Ohio	76	198	30	1169	January 16, 1962
	76	198	467	1169	January 17, 1962
	72	198	30	1169	April 27, 1962
Milwaukee, Wisconsin	76	222.2	200	640	February 27, 1962

3. RECORDING AND ANALYSIS TECHNIQUES

In all cases recordings of field strength are made on paper tape recording oscillographs. The tapes are run at a speed of 45 inches per hour. Calibrations are made with standard signal generators to determine values of receiver input voltage at the receiver input. From the receiver input voltages together with line losses, antenna gains and radiated power, the basic transmission loss is determined and expressed in decibels. Figure 10 shows sample chart recordings from four receivers simultaneously between 1300 and 1400 EST on April 1, 1962. The Alternate Main Aircraft was operating on this day, and its flight pattern was a figure eight oriented NE/SW.

All data recorded on paper tape at 3/4 inches per minute are converted to magnetic tape by means of a chart follower. The chart follower operates at a 16 to 1 or an 8 to 1 speedup from the original recording time. The process requires an operator simply to follow the inked line with a stylus. There are many advantages of making the analysis from magnetic tape, primarily in the large amount of data that can be processed and the versatility of the procedures. On the other hand, consideration of economy and practicability prevented us from employing magnetic tape recorders directly at the field locations. The ink records permit preliminary screening of the data, so that questionable portions can be eliminated from further analysis and overall characteristics can be determined visually. The transcribing operator is also able to adjust the gain of the magnetic tape modulator in accordance with the variability apparent on the ink record. This would not be a simple procedure if the magnetic tape was used in the field, even if the receiving stations were continuously manned.

The periodicity of the signal is easily recognized from the recording chart samples shown on Figure 10, especially for the Cleveland 30 foot antenna. The basic period is determined by the size of the figure-eight pattern flown by the aircraft, and by the aircraft speed. Inspection of a number of chart samples showed that the aircraft speed is quite constant, resulting in an average period of about 22 minutes. The Milwaukee chart sample suggests a period half as long. This phenomenon and the relative depths of the fades depends quite strongly on the path geometry and the direction of the pattern axis flown by the aircraft. Studies are in progress to determine the signal variability at each receiving antenna introduced by the aircraft flight pattern as a function of the terrain profile; the degree of lobing would be strongly influenced by the magnitude of the reflection coefficient (including the effect of terrain roughness).

The analysis of the data has a two-fold purpose. First, it is desirable to study the total variability of a signal of this type, including the component of variability introduced by the aircraft flight pattern. This would produce estimates of field strength behavior in such an application, which obviously has potentials for communication as well as broadcast applications. Second, it is possible to isolate the variability component introduced by the aircraft either by path geometry considerations or by analysis methods. The remaining variability should ideally be solely due to the atmosphere, and its characteristics can be compared with those obtained from point-to-point within-the-horizon paths using substantially lower transmitting terminals. It is especially of interest if the phenomenon of prolonged space-wave fade-outs [Bean, 1954; Barsis and Johnson, 1962] would still be observed where one of the terminals is substantially above all surface ducts and most elevated refractive index layers.

The analysis of the data will be initially directed toward the first objective, namely a description of the total variability of the signal. Cumulative distributions of field strength or basic transmission loss levels will be obtained for each day of operation. The aircraft flight pattern will be reflected in these distributions. Hourly medians and their variability will also be obtained and studied; for these it is expected that most of the effect of the aircraft motion is eliminated due to the averaging processes involved.

For the second objective, automatic analysis methods using magnetic tape will permit identification of the principal periods caused by the aircraft, and possibly de-trending of the data with respect to these periods. Analysis of what is left will provide an estimate of atmospheric effects on the received signal. It may also be possible to calculate the variability introduced by the aircraft motion as a function of flight pattern and path parameters in the form of a cumulative distribution of field strength, and to "subtract" statistically this distribution from the previously obtained total distribution. This again should provide an estimate of the residual field strength variability as a function of the atmosphere only.

4. ACKNOWLEDGEMENTS

In addition to the support of the project provided by the U. S. Army Signal Research and Development Laboratories, the authors also wish to acknowledge the efforts expended by personnel of the participating agencies; namely Westinghouse Electric Corporation and MPATI (at Purdue), the FCC Monitoring Station (at Allegan), Smith Electronics, Inc. (at Cleveland), the Journal Company (at Milwaukee), and the University of Illinois (at Urbana). Technical assistance and data analysis were provided by personnel of the Propagation-Terrain Effects Section and the Data Reduction Instrumentation Section of the Radio Propagation Engineering Division, Boulder Laboratories, National Bureau of Standards.

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* Order by PB number from the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C. Foreign remittances must be in U. S. exchange and must include one-fourth of the publication price to cover mailing costs.

AIRBORNE TELEVISION TRANSMITTERS BROADCASTING FROM
23,000 FEET OVER MONTPELIER, INDIANA

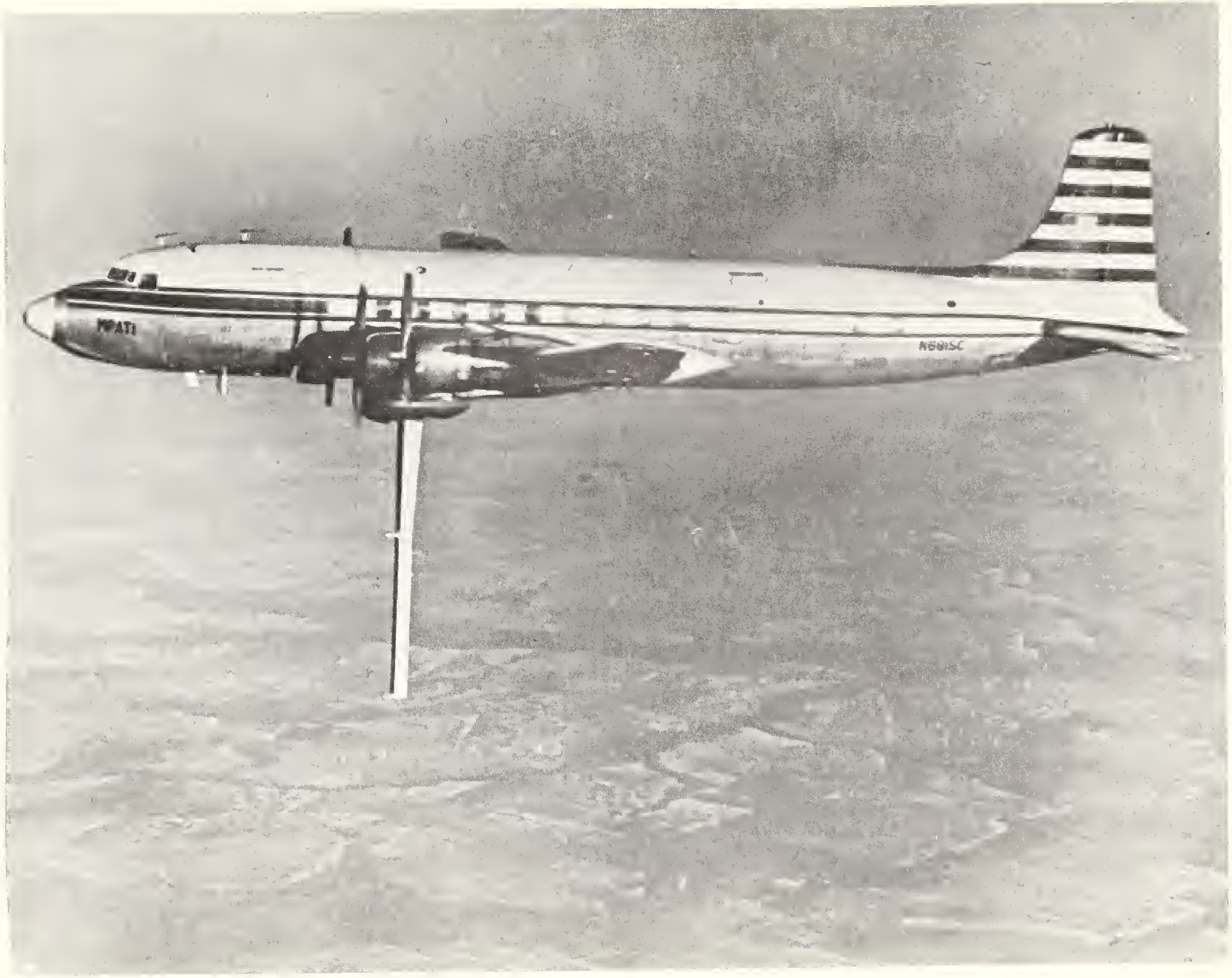

Figure 1

VERTICAL RADIATION PATTERNS OF MODEL AIRBORNE TRANSMITTING ANTENNA. DATA FROM WESTINGHOUSE ELECTRIC CORP.

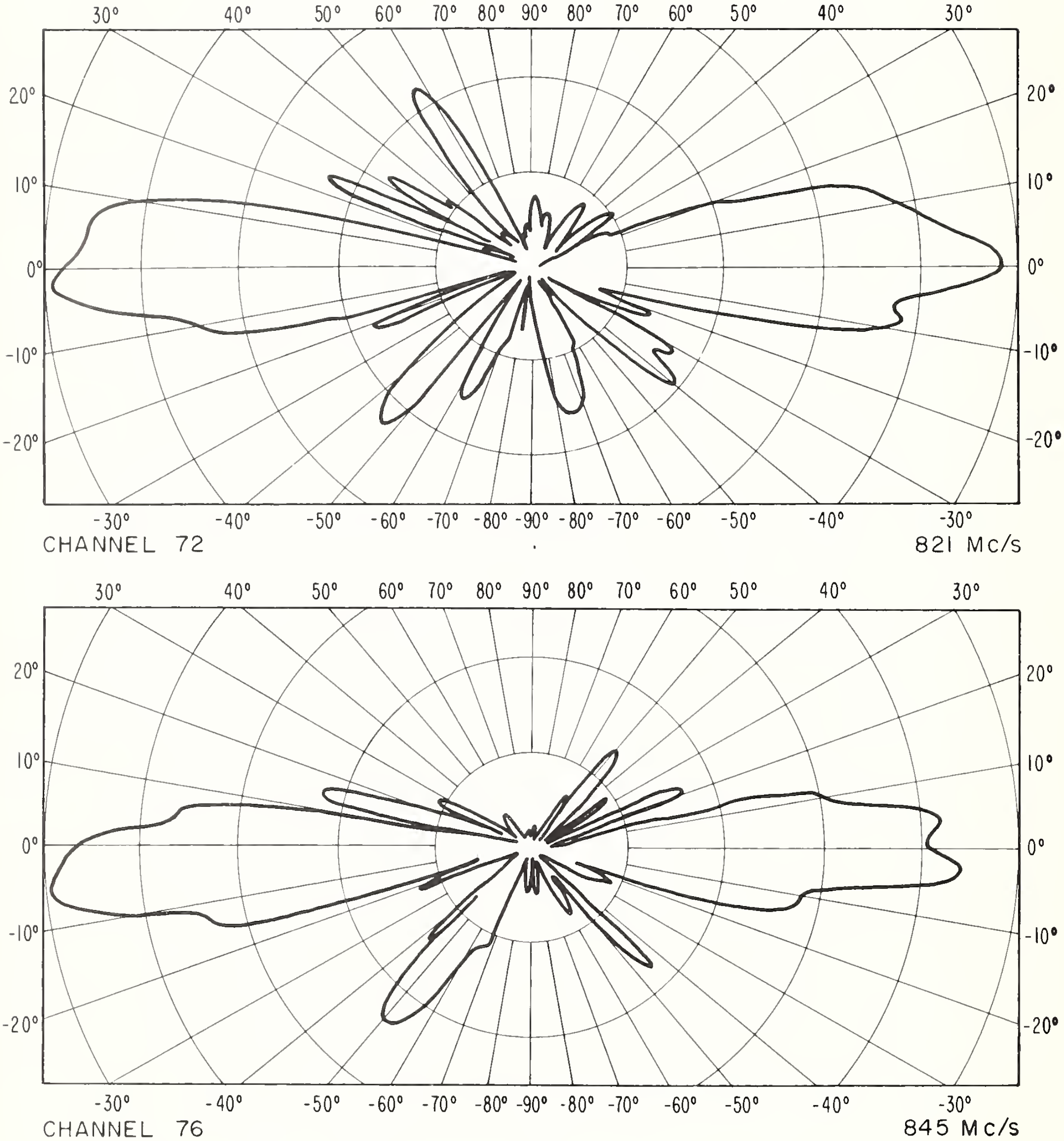

Figure 2

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MAP OF PROPAGATION PATHS

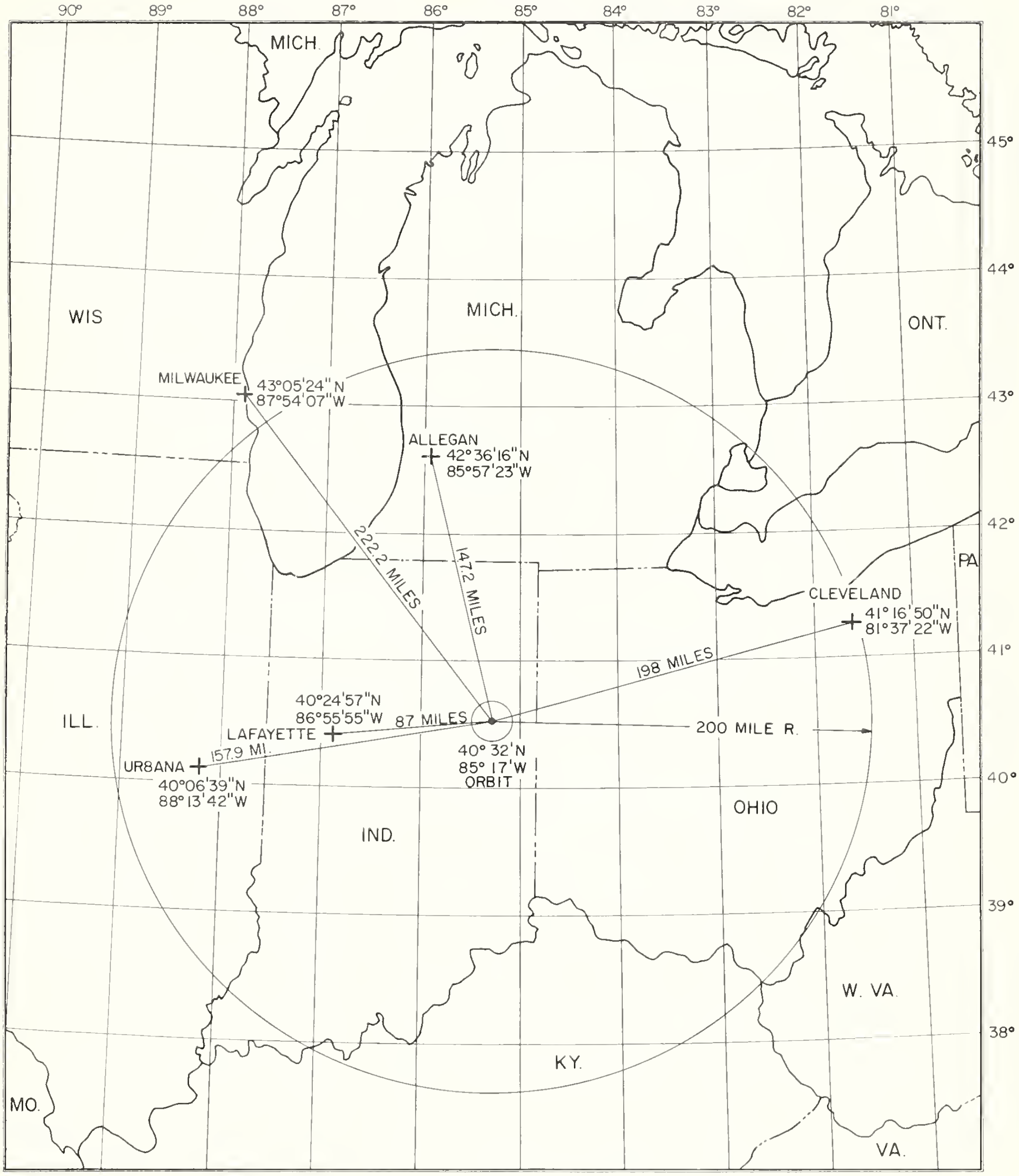

Figure 3

B- 33926

TERRAIN PROFILES OF PROPAGATION PATHS FROM THE ORBIT CENTER TO EACH OF FIVE RECEIVER LOCATIONS.

RECEIVER LOCATIONS ARE ON THE LEFT AND THE AIRBORNE TRANSMITTER IS ON THE RIGHT. THE ARROW INDICATES THE APPROXIMATE RAY PATH AT THE RECEIVER.

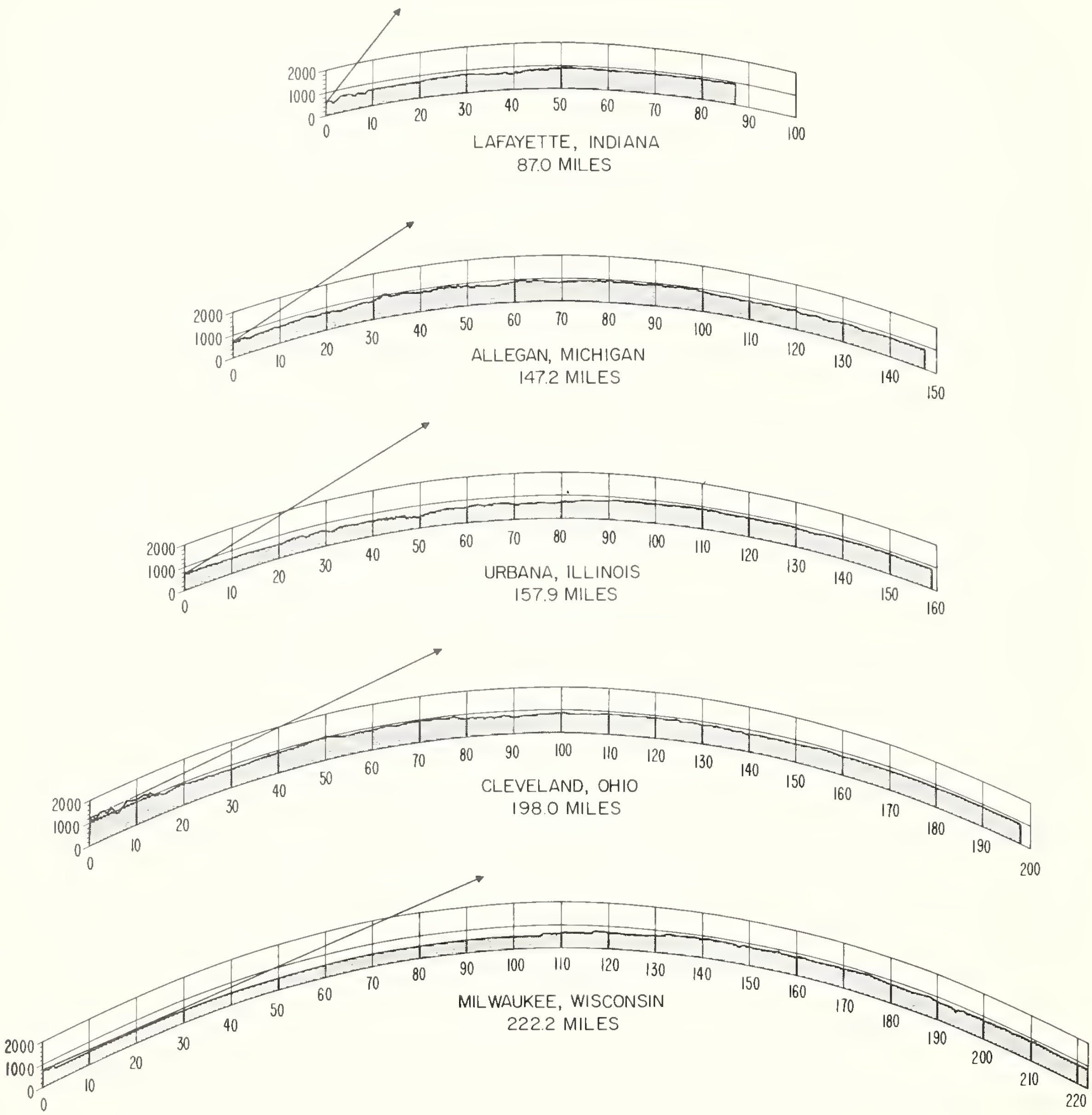

Figure 4

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RECEIVING ANTENNAS INSTALLED ON PURDUE UNIVERSITY
AIRPORT, LAFAYETTE, INDIANA

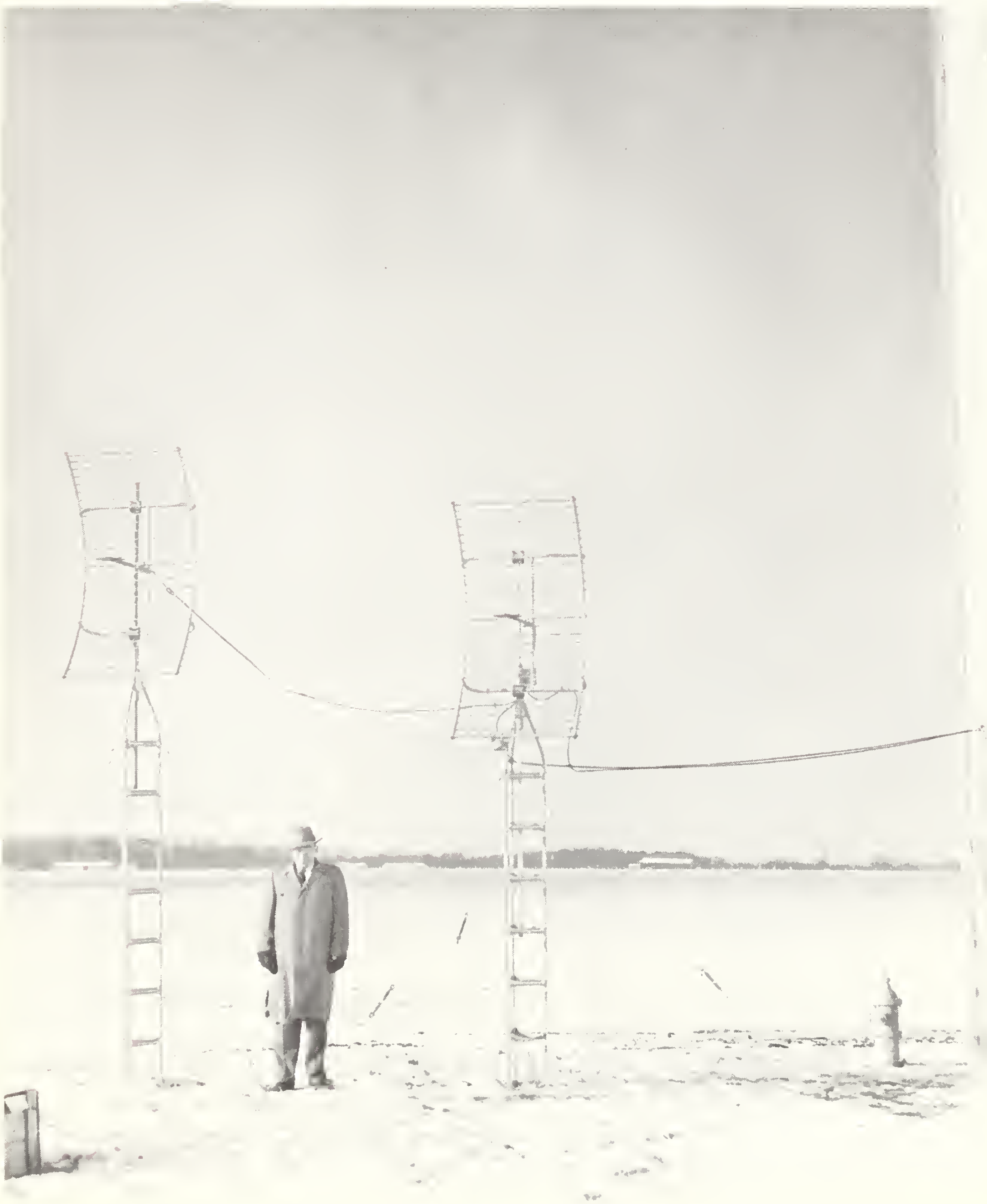

Figure 5

RECORDING SITE AT ALLEGAN, MICHIGAN

Figure 6

ELECTRICAL ENGINEERING BUILDING AT UNIVERSITY OF ILLINOIS, URBANA, ILLINOIS

Figure 7

RECORDING SITE AT CLEVELAND, OHIO. RECEIVING ANTENNAS AT THE 30-FOOT AND 467-FOOT LEVELS.

Figure 8

RECORDING LOCATION IN MILWAUKEE, WISCONSIN. RECEIVING ANTENNA IS AT THE 200-FOOT LEVEL ON THE TOWER.

Figure 9

SAMPLE CHART RECORDINGS OBSERVED SIMULTANEOUSLY
AT CLEVELAND, ALLEGAN AND MILWAUKEE, APRIL 2, 1962

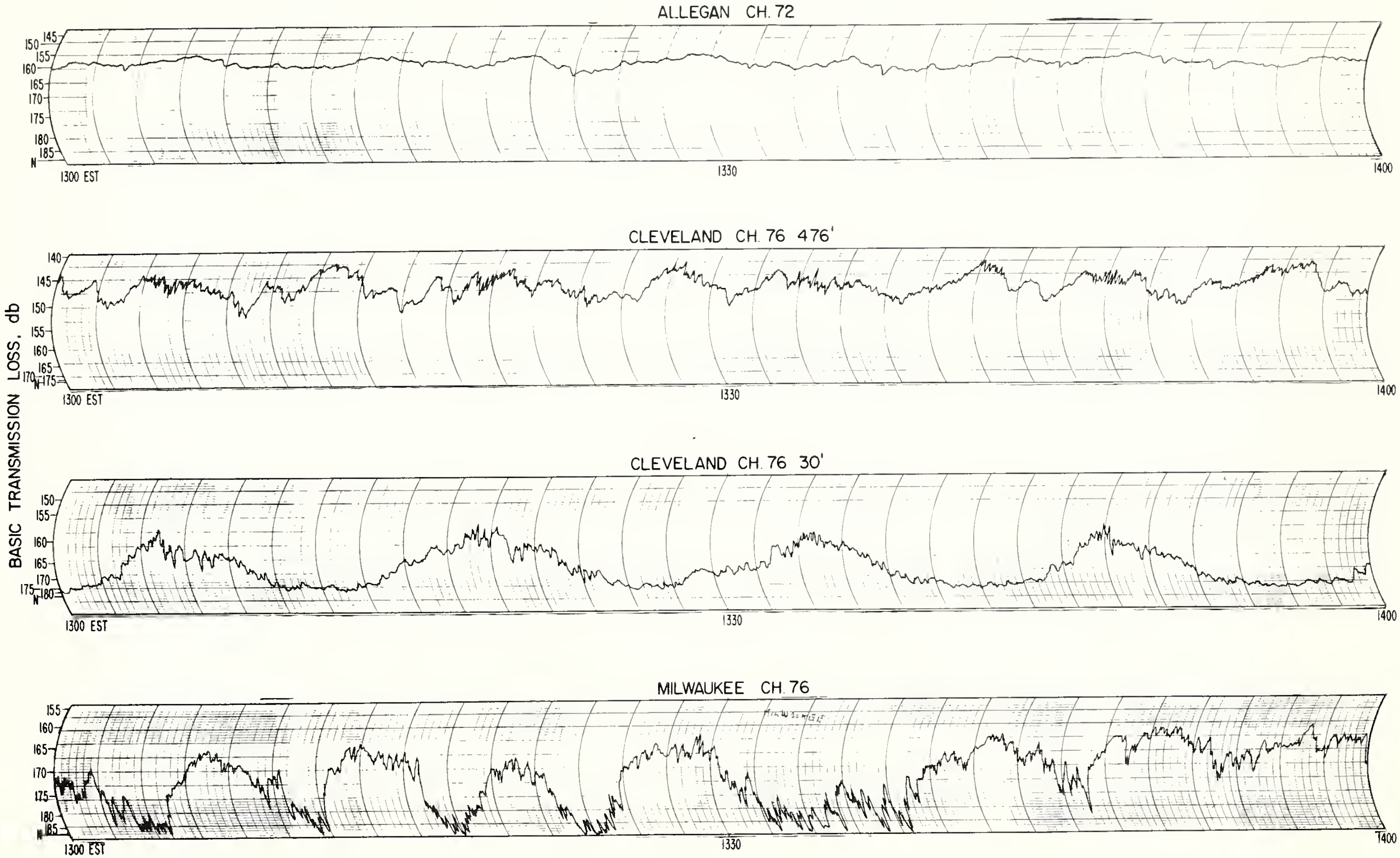

Figure 10

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