CIRCULAR POLARIZATION TESTS

Report No. 1 on Developmental Station W8XUB

owned and operated by

United Broadcasting Company

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MEMORANDUM FOR the Chief Engineer of the
Federal Communications Commission

Subject: CIRCULAR POLARIZATION TESTS

Definition: The term, "Circular Polarization", as used in this report, means the idealized case of elliptical polarization in a plane at right angles to the direction of propagation. In this plane the electric vector is of constant amplitude and rotates at the carrier frequency in a clockwise or counterclockwise direction. In general, elliptical polarization will actually be produced; however, circular polarization may be approached as closely as desired.

1. RECOMMENDATIONS

(1) That the Federal Communications Commission adopt circular polarization as the standard for FM and TV broadcasting stations. If the use of only vertical or horizontal polarization appears desirable in special circumstances, its use may be authorized upon a showing of need.

(2) That the service contours, for circular polarization as recommended above, be retained the same as under the present standards of good engineering practice. The allocation problem will remain substantially unaltered by the adoption of circular polarization.

2. SUMMARY

The purpose of this report is to present experimental data on the performance of a prototype antenna adjusted to produce circularly polarized waves, and to present a preliminary study on the propagation and reception characteristics of these waves.

The transmitting antenna was designed to radiate any type of elliptical polarization with controls to produce circular, diagonal, vertical, or horizontal polarizations. A half-wave dipole with an r-f milliampere meter at its center was used to determine the antenna performance and standardize the radiated field during the field measurements. Nearly perfect circular polarization was produced in two directions while in other directions there was some variation from this ideal but not enough to materially affect the propagation and reception characteristics.

Field equipment was assembled to make quantitative field intensity tape recordings in a field car along radials, as a function of distance, and fixed measuring point recordings as a function of time. Along one radial, (west), nine recordings were made to compare circular, vertical, and horizontal types of polarized transmission, each with circular, vertical, and horizontal types of polarized reception. Along each of the other three radials, (north, east, and south), four recordings were made. The circularly polarized transmission was received on vertical and horizontal receiving dipoles. The pure vertically polarized transmission was received on a vertical receiving dipole, and the pure horizontally polarized transmission was received on a horizontal receiving dipole. The fixed point recordings were made at eight locations, ranging from 0.2 to 19 miles from the transmitting antenna, which was radiating circularly polarized waves. The recordings, taken over a 48-hour period, show one broadcast day each for vertical and horizontal reception, along with a recording of the noise

level when the transmitter was off the air.

In general, the propagation characteristics of circular, vertical and horizontal polarizations are quite similar in nature. Circularly polarized antennas when used for both transmission and reception give the best results because energy from all polarizations of the radiated wave is intercepted. A vertical receiving antenna will receive circularly or vertically polarized waves equally well. Similarly, a horizontal receiving antenna, when placed in the plane of polarization, will receive circularly or horizontally polarized waves equally well. Usually a receiving dipole antenna must be set in a diagonal position to intercept maximum energy from a transmitting antenna radiating circularly polarized waves. The variations of field intensity for horizontal polarization, as measured along a radial, are slightly larger and the curve is slightly smoother than for vertical polarization.

The recordings made at fixed points, in general, show that the field intensity remains substantially constant when recorded as a function of time. The noise level is caused primarily by automotive traffic; hence, varies as a function of distance from this noise source. Vertical receiving antenna positions consistently show a higher noise level than corresponding horizontal receiving antenna positions. This may be due in part to the horizontal directional properties of a horizontal antenna and partly to the low height of the receiving antenna.

Under favorable conditions airplanes may cause a doppler effect in the form of flutter on the received signal. This effect is more pronounced with horizontal than with vertical receiving antennas.

Preliminary results from comparison receivers connected respectively to vertical and horizontal dipoles show that circularly polarized waves produce best results first on one receiver and then on the other receiver as the test car is driven around town.

Home receiver installation experience reveals that an outside antenna is usually worth while for receiving our low powered experimental transmitter. No consistent pattern has developed as to preference between horizontal, vertical, or diagonal receiving dipoles for home receivers. For each receiving antenna location the orientation should be adjusted for best results.

The principal source of annoyance to set users is the tendency of some commercial receivers to have frequency drift during the warm-up period.

3. INTRODUCTION

The United Broadcasting Company, being desirous to pioneer fm in the Cleveland area, engage in a genuine developmental program, and give the only f-m broadcast service to f-m distributors, dealers, and the early purchasers of f-m sets in this area, made formal application to Federal Communications Commission on November 29, 1945, for an f-m developmental station.

This application (B2-PEX-89) was granted on February 27, 1946, a Western Electric, 1 kw, type 503B-1, f-m transmitter was delivered on March 1, 1946, equipment tests started March 10, 1946, program tests started March 30, 1946, and a developmental broadcast station license for W8XUB (B2-LEX-43) was issued on July 1, 1946.

Experimental Station W8XUB in its present operating condition is presented pictorially in Figs. 1, 2, and 3 of this report, along with the executive and engineering personnel responsible for this f-m developmental broadcasting station.

This report covers essentially the first 6 months of operation. Most of the initially planned items of the research program have been completed and are covered in this report. Also, some additional items have been introduced and are covered in this report. In view of the developments it may be desirable to delete some of the initially planned items that have not been completed and exert our efforts along other possibly more productive lines of attack. In regard to these matters it is desired to review the whole program at this time and secure the suggestions of the Chief Engineer of the Federal Communications Commission for the future research work with this experimental facility.

4. TRANSMITTING ANTENNA

a. General.

The transmitting antenna system used in connection with this investigation is shown diagramatically in Fig. 4. Photographs of the antenna and tuning system are shown in Figs. 3, 5, and 7.

The antenna is made up of a vertically polarized co-axial radiator and a horizontally polarized folded dipole loop. The vertical radiator is mounted in the center of the horizontal loop which is located at the lower end of the vertical radiator. When the two antennas are fed from a common point directly below, the radiated fields of the two antennas are ninety degrees out of phase by reason of the ninety degree difference in the lengths of the two transmission lines. This ninety degree phasing of the two polarizations, together with equal fields from the two antennas tends to produce a circularly polarized radiated field.

b. Performance.

The performance of the circularly polarized transmitting antenna was determined by using a half-wave receiving dipole with an r-f milliampere meter at its center. The receiving dipole was placed in the positions shown in Fig. 8. The meter readings taken at each position are tabulated in Table I.

Figure 9a shows the horizontal and vertical polarization field patterns of the antenna together with a graphic representation of the resultant polarizations radiated in eight directions. The field of this antenna is not circularly polarized in all directions from the antenna because the horizontal element does not radiate in the same phase and magnitude in all directions from the center of the antenna. The polarization patterns are approximate ellipses in which

TABLE I

Tabulation of half-wave dipole meter readings
used to plot polarization patterns in the horizontal plane

Azimuth Angle Ø	Direction	Milliamperes Dipole Meter Readings			
		Vertical 0°	Diagonal 45°	Horizontal 90°	Diagonal 135° or -45°
0	N	165	130	150	180
45	NE	145	90	160	205
90	E	140	70	110	160
135	SE	125	95	150	175
180	S	110	110	135	135
225	SW	150	135	135	145
270	W	145	175	170	135
315	NW	160	155	145	150

NOTE: These measurements were made at a horizontal distance of 21' (2.25 wavelengths) from the center of the transmitting antenna which had an input power of approximately 1 kw.

the distance from the origin to a point on the ellipse is proportional to field strength at the polarization angle represented by the direction of the point from the origin. A point on the ellipse 180 degrees from any other point has no special significance; the ellipses were completed in the interest of pictorial completeness. The field pattern of the horizontal antenna shown in Fig. 9a is typical of the field pattern of a loop radiator which approaches dimensions of a quarter wavelength. The irregularities of the vertical antenna field is probably due to currents flowing in the vertical members of the supporting structure.

The pattern at the center of Fig. 9b shows the horizontal field patterns produced in 45 degree planes of polarization. Fields in these planes of polarization are produced by the combined action of the two antennas, and therefore might be expected to produce a more irregular pattern than either of the antennas acting alone.

c. Adjustments.

As previously mentioned, a circularly polarized field is produced by a vertically polarized radiator, and a horizontally polarized radiator having the same center of radiation, and producing fields of equal intensity which are ninety degrees out of phase at all points in the horizontal plane. It is necessary therefore to provide means of accomplishing the required phasing and power division.

The original design called for each radiating element to be adjusted to 70 ohms of pure resistance which would match the 70-ohm transmission lines running to a junction box directly below the antenna where they are connected in parallel to form a 35-ohm resistance load. This junction is fed from the transmitter by means of a 70-ohm transmission line which would then have a standing wave ratio of two. This standing wave ratio is within the tuning range of the transmitter as well as the power handling capacity of the transmission line. Under these conditions, the power distribution and the phasing is automatically accomplished. Three tuning stubs, as shown in Figs. 4 and 6 were added to permit correcting for unpredictable irregularities.

During the course of the investigation, it was found more expedient to carry out all antenna adjustments by means of the tuning stubs located in the tuning house. By this process, standing waves are present on the transmission lines leading from the antennas to the junction box. The impedance at the junction box is controllable over a wide range, and can be adjusted to a value which efficiently loads the transmitter, and at the same time gives the desired phasing and power distribution.

In order to permit the use of the vertical antenna alone, or the horizontal antenna alone, a simple means of shorting either antenna feed line a quarter wavelength from the junction box was provided. With the short made in the line feeding the horizontal antenna, the impedance of this line as seen at the junction box is extremely high, thereby causing all power to flow to the vertical antenna. With the short in the vertical antenna line, all power flows to the horizontal antenna. In either case, the tuning stub that is in the line being used, and the tuning stub at the junction box are adjusted to efficiently load the transmitter. In general, the positions of the tuning stubs are different for each of the three conditions of operation.

Antenna adjustments were made principally on the basis of local relative field intensity measurements made by means of a dipole with a thermocouple meter at its center, as shown in Fig. 7. This dipole was set up on a horizontal line at a distance of seventeen feet from the transmitting antenna, and the meter was read by means of binoculars. It was rotatable in a vertical plane at right angles to the line of propagation, so that the relative field intensity could be measured in any plane of polarization. This dipole and meter, as a receiving unit, was also used to standardize the radiated field during the field measurements.

The polarization and field patterns were determined by means of this same dipole mounted on a twenty-eight foot pole, which was carried in a circle around the transmitting antenna. Measurements of field intensity in four planes of polarization were made at forty-five degree azimuth intervals. An accurate circle was described by pulling taut a twenty-one foot cord tied between the transmitting antenna and the measuring dipole.

5. FIELD EQUIPMENT

a. General.

The field car, as shown in Fig. 10, is a station wagon arranged for the convenient installation of the recording field set and receiving antennas. The field set is located so as to be handy to an operator seated in the extreme back seat. It may be of interest to remark that some states require station wagons to be fitted with at least one seat in addition to the driver's seat, otherwise the car will be classified as a truck and will have to display a truck license and thereby be prohibited from travel on thoroughfares restricted to passenger car use.

b. Field intensity meter.

The field set and recorder photographed in Fig. 11 are mounted on a solidly built heavy table constructed with 2" x 4" lumber and 1" boards. The recorder is blocked solidly under the table, and the field intensity meter is attached to the table top on rubber shock mountings which are sufficiently resilient to absorb the sharp vibrations which would detune the receiver. It was found best to mount the recorder solidly. Vibrations while driving served to advantage in keeping the recording pen free from drag against the paper tape. The table is attached to the car floor by two wing screws threaded into angle iron floor joists under the car floor. The car floor was reinforced to make it solid enough to prevent rocking the recorder on rough roads. With this installation it has been possible to make good recordings even on rough roads while traveling 35 mph. Recordings were normally made at 30 mph.

c. Recorder drive mechanism.

The recorder tape is advanced proportionally to car distance traveled at a rate of five inches of tape for each mile traveled. The recorder is driven from the speedometer drive shaft through gear boxes, as shown in Fig. 12. One gear box divides the drive into two flexible cables, one for the car speedometer and one terminating at a position in the back of the car. A flexible extension shaft continues the drive to a reduction gear box mounted on the recorder table and coupled directly into the recorder, (Fig. 12). The recorder is an Esterline-Angus Model AW, serial No. 44658. The field intensity meter is a Measurements Corporation, Model 58 u-h-f radio noise and field strength meter, serial No. 347.

d. Receiving antennas.

The receiving antenna is arranged so that either horizontal or vertical dipoles, or both together, may be attached to the top of the supporting pole. The supporting pole is hollow wood with the transmission line inside terminating at the antenna mounting bolts at the top and cable connector plug at the field meter.

Figures 13, 14, and 15 are photographs showing the three receiving antennas used to make the recordings. The dipoles are each a half-wave in length. The circular polarization receiving antenna uses a horizontal and vertical dipole spaced one-quarter wavelength apart and connected in parallel. When the two dipoles are properly polarized with respect to each other and the array properly oriented, this antenna will receive all components of a circularly polarized wave. The two dipoles are supported at the ends of spaced aluminum angles $\frac{\lambda}{4}$ in length. These aluminum angles become the connecting conductors as well as the spacers and means of mounting to the top of the wooden pole where the transmission line is attached halfway between the two dipoles.

Calibration was accomplished by comparison with the Measurements Corporation equipment. The Measurements Corporation set was placed in operation and the field intensity of W8XUB was measured using the dipole, stand, and transmission line supplied with the measuring equipment. The field value was determined according to the calibration and instructions of the manufacturer. The field intensity at the same spot measured with the field car equipment was determined and the ratio between the two measured values was used to compute the scale values in µv/m shown on the recordings.

e. <u>Fixed measuring point equipment</u>.

Figure 16 shows a typical setup of the field intensity meter, field intensity antenna, recording meter, and voltage regulator. The antenna used for these measurements was the standard equipment furnished with the Measurements Corporation meter. The figure shows the antenna in a horizontal position. For vertical polarization measurements, this antenna was rotated to a vertical position and the antenna transmission line was run horizontally for a distance so that it would clear the lower end of the dipole. The line voltage regulator, as shown on preliminary tests runs, helps considerably in maintaining a good calibration over the period of time, 48 hours, that these measurements were made.

f. Diversity receiver installation.

In anticipation of gathering additional pertinent information, some preliminary tests were made with diversity reception. Two standard table model f-m receivers were rewired to be operated from the car storage battery and a vibrator power supply, as shown in Fig. 17. These receivers are mounted in a wood frame and installed in the field car. One receiver is connected to a vertical dipole receiving antenna, and the other to a horizontal dipole receiving antenna. The two antennas are mounted on a pole at the back of the field car, as shown in Fig. 18. The mounting is low enough to simulate probable f-m car-radio antennas. At the present writing the system has been used only to compare the reception of vertical and horizontal polarization by listening to the two loud speakers. Likely, a headset will be installed with the two phones connected separately to each receiver, and later, a recorder may be connected in such a manner that it will show quantitatively the difference between the signal outputs of the two receivers and indicate which receiver output is greater. It would also be desirable that these recordings show where the signal has an acceptable signal-to-noise ratio.

6. FIELD MEASUREMENTS

a. General.

The propagation characteristics of circularly polarized waves have been investigated in the field and compared with both vertically and horizontally polarized waves by using the field intensity meter, which was installed in the field car for making radial recordings, and was located at fixed measuring points to determine the propagation characteristics at various distances from the transmitter over a period of time. The location of the transmitter site, the 4 radials, and the 10 fixed measuring points are shown on the map in Fig. 19.

b. Radial recordings.

(1) North radial

The north radial recordings shown in Fig. 20a present four field intensity charts as a function of miles, along with a plot of the ground elevation profile. The radial is approximately 10 miles long, and the calibrating points are numbered from 1 to 7 inclusive, as shown on the map, (Fig. 19), and the radial charts.

In general, these field intensity recordings for circular, vertical, and horizontal polarizations are quite similar in nature. It will be noted that when the receiving antenna is horizontal, the field intensity variations are larger than when the receiving antenna is vertical. This is true regardless of whether the transmitting antenna is producing circularly polarized waves, or only the type of polarization being received. It will also be noted that the horizontally polarized component in each case is in general slightly weaker than the vertically polarized component. The greater attenuation of the horizontally polarized wave may possibly be due to other factors than the fact that the horizontally polarized wave leaving the transmitter is weaker than the vertically polarized wave as shown in Fig. 9a.

(2) East radial

The east radial recordings shown in Fig. 21a present four field intensity charts as a function of miles along with a plot of the ground elevation profile. The radial is only about 4 miles long and the calibrating points are numbered from 1 to 7 inclusive, as shown on the map, (Fig. 19), and the radial charts.

This particular radial was made short because at this distance the attenuation was a thousand fold. This is due primarily to the fact that the receiving antenna drops behind a hill, and is far below line of sight to the transmitting antenna. One radial, (Chart No. 41), using a horizontal receiving antenna, was extended to over 15 miles along this radial, which is approximately the range of the 50 μv/m field intensity contour. For the sake of uniformity with the other charts, the extended portion was deleted from this presentation. The end of the recording run presented in Fig. 21a is in a valley. Beyond this valley, the field intensity increases and is quite useful to about 15 miles, so long as the receiving antenna is not far below line of sight.

In general, these field intensity recordings for circular, vertical, and horizontal polarizations are quite similar in nature. The vertically polarized field intensity from the transmitter, as shown in Fig. 9a is slightly stronger than the horizontally polarized field intensity. The radial recordings also show that the vertically polarized wave, in general, is stronger than the horizontally polarized wave.

(3) South radial

The south radial recordings shown in Fig. 22a present four field intensity charts as a function of miles along with a plot of the ground elevation profile. This radial is approximately 10.5 miles long, and the calibration points are numbered from 1 to 7 inclusive, as shown on the map, (Fig. 19), and the radial charts.

The elevation along the south radial varies considerably with corresponding variations in field intensity, as will be noted by inspecting the charts and comparing the magnitude of the field intensity with the ground elevation profile.

The horizontal field intensity radiated to the south, as shown in Fig. 9a is stronger than the vertically polarized field intensity in this direction. However, the charts at a distance of 5 miles for example, definitely show that the vertically polarized field intensity is stronger than the horizontally polarized field intensity, while at some other distances, the reverse is true. In general, one can say that the propagation characteristics are quite similar in nature for circular, horizontal and vertical polarizations.

The curves for circularly polarized transmission appear to be slightly smoother than for the cases when the transmitted wave is purely vertically or horizontally polarized. This may be due to a slight "filling in" effect when the transmitted wave is circularly polarized.

(4) West radial

The west radial recordings shown in Figs. 23a and 23b present 9 field intensity charts as a function of miles, along with a plot of the ground elevation profile in Fig. 23a. This radial was used to compare all of the possible combinations of three transmitting and three receiving conditions. The radial was only about 4 miles long, and the calibrating points were numbered from 1 to 4 inclusive as shown on the map, (Fig. 19), and the radial charts.

The charts in Fig. 23a correspond with the charts presented for the other three radials. According to Fig.9a the horizontal field intensity radiated from the transmitter is stronger in this direction than is the vertical field intensity. In general, the recordings show that the variations for the horizontally polarized field intensity are larger than for the vertically polarized field intensity. Furthermore, the average of the horizontally polarized field intensity is stronger for the first mile of the recording than is the average of the vertically polarized field intensity. At greater distances, the effect is less marked and the vertically polarized wave may even be a bit stronger on the average when it is compared with the horizontally polarized wave.

When the transmitter and receiver both have circularly polarized antennas, the field intensity, as indicated on the recording, increases somewhat as shown by comparing Chart No. 22 in Fig. 23b with the other charts in both Fig. 23a and Fig. 23b. This is to be expected since it is equivalent to doubling the transmitter power.

When the transmitter is sending out circularly polarized waves and the receiver is receiving only horizontally polarized waves as shown in Chart No.22 of Fig.23a, the results are quite similar to the reversed conditions of transmitting horizontally polarized waves and having a receiver capable of receiving circularly polarized waves as shown in Chart No.23b.

Similarly, transmitting circularly polarized waves and receiving only vertically polarized waves is similar to transmitting vertically polarized waves and being capable of receiving circularly polarized waves as shown in Chart. No. 21 of Fig.23a and Chart No.29 of Fig.23b. The characteristic shapes of the curves are quite similar. For an unexplained reason the magnitude of the field intensity for Chart No.29 is less than for Chart No. 21.

When the transmitter is radiating horizontally polarized waves and the receiver has a vertical antenna as shown in Chart No. 26 of Fig.23b the field intensity measured is very weak. The radial for this condition was traversed twice on the same chart, once using the same sensitivity as was used on the other charts and once using a higher sensitivity to show in more detail the character of the field intensity along the radial. The general conclusion is that a transmitting antenna which is producing a pure horizontally polarized wave will not give good service to vertical receiving antennas. In other words, a horizontally polarized wave does not have much tendency to become vertically polarized along its propagation path.

Similar statements to the above can be made in connection with Chart No. 28 of Fig.23b, which shows the effect of radiating vertically polarized waves and using a horizontal receiving antenna.

c. Fixed point recordings.

In order to obtain data on the variation of the field intensity of W8XUB with respect to time, a series of recordings were made at various fixed locations within a radius of twenty miles from the transmitter. The recorder was left in continuous operation for about 48 hours at each location, so that a recording of noise was obtained during the time that the transmitter was not in operation. These recordings are shown in Fig.24, and the spots at which the recordings were made are shown on the map of Fig. 19. A photograph of a typical fixed point recording installation is shown in Fig.16.

In general, the recordings show that the field intensity remains substantially constant at all of the locations at which recordings were made. Variation in noise levels are evident in the various locations, as well as difference in noise level for horizontal and vertical polarization. Vertical receiving antenna positions consistently show a higher noise level than horizontal receiving antenna positions. At each recording location, the receiving antenna was mounted less than twenty feet above ground, for which antenna heights it has previously been shown by other investigators that the signal to noise ratio for vertical polarization reception is higher than for horizontal polarization reception.

Chart D of Fig.24a is a recording made at a location about forty feet from a main thoroughfare, and about 6.1 miles from the transmitter. This recording shows the high noise level that exists very close to passing automotive traffic, and also the higher noise intensity picked up by the vertical receiving antenna. In contrast to this recording, Chart H of Fig.24b is a recording made at a location 300 feet from a very busy highway, and at a distance of 19 miles from the transmitter. Here the noise level is much lower, and there is not much difference in noise between vertical and horizontal receiving antennas. On the basis of this recording, and the number of cars that pass, a very small percentage of the cars register any noise at all.

The recording shown in Chart E of Fig.24b was made in the engineering offices of the United Broadcasting Company. The field meter, as well as the antenna, was located in the office on the thirteenth floor of the Terminal Tower at a distance of 9.7 miles from the transmitter. The noise level at this location is not very high, but is nearly constant throughout the day and night. The received signal from the transmitter had to pass through or around the 20-story Midland Building, which is about 300 feet away, in addition to passing through a considerable portion of the building group in which the engineering offices are located.

Chart A of Fig.24a and Chart B of Fig.24a show recordings made at locations near the transmitter where the field strength is very high.

Noise did not show up in these cases because the field meter was adjusted to very low sensitivity. The apparent variation of the field strength in these cases can be attributed to drift in the field meter, and to variations of power line voltage at the transmitter.

At all of these fixed recording points entirely satisfactory f-m program reception is obtainable with standard commercial home receivers.

A point of interest is that airplanes passing overhead may cause a doppler effect upon the received signal. The fast recording of Fig. 25 shows the results of such an effect upon the received signal intensity when a horizontal dipole is connected to the receiver. Very much less of this effect is noticed when the receiving antenna is a vertical dipole.

d. Diversity reception.

At this time only a few preliminary remarks will be made on the subject since time has not permitted completing the construction of suitable testing equipment.

Observations were made along the north radial from the transmitter site to Lake Erie. A comparison of the reception from the receiver connected to a vertical dipole and the receiver connected to a horizontal dipole clearly indicates that best results are first from one receiver and then from the other receiver as the radial is traversed.

On one occasion, when the field car was parked, an airplane flew in a straight line so that its path was at right angles to the direction of propagation when it was directly overhead. The strength of the direct ray and the airplane reflected ray were of comparable strength, producing a rapid flutter which decreased to zero frequency when the airplane was directly overhead and then the flutter increased as it flew away on the other side. The rate of variation of the path length from the transmitting antenna to the airplane and thence to the receiver produces this flutter, the frequency of which is proportional to the rate of variation. This doppler effect was observed only on the receiver connected to the horizontal dipole.

It is believed that the continuation of qualitative testing with comparison receivers will yield worth-while results.

7. HOME RECEIVER INSTALLATIONS

The purpose of installing f-m receivers in homes was to have listening posts in different parts of the city. For this reason, a number of sets were purchased by the company from various manufacturers and installed on a loan basis in the homes of persons associated with the United Broadcasting Company, thus assuring their cooperation during the experimental period. In addition to these installations, a number of 45 megacycle band f-m receivers have been converted to the 100 megacycle band by means of Hallicrafter Converters. Company employees have also been encouraged to purchase f-m receivers and these were installed for them by the Engineering Staff. Sets were also placed in the homes of the radio editors of the leading newspapers to acquaint them with fm, and through them, bring fm to the attention of their column readers. As a result of these activities, a number of generalities can be made concerning installation of f-m receivers and the reaction of the home owner to them.

First, installations have in general required outside antennas. In some cases the home owners have indicated satisfaction with the operation before the outside antenna was mounted, but in every case, a marked improvement has been noticeable when an outside antenna was installed. This improvement has manifested itself in reduction or complete elimination of rushing noise, and less critical tuning of the receiver.

Home owners seem to be most impressed with static free reception during electrical storms which are not infrequent during the summer months in this locality. The principal source of annoyance to set users seems to be the tendency of some makes of receivers to drift in frequency until they are thoroughly warmed up.

Antenna installations likewise permit some general conclusions. The antenna should be away from the building on which it is mounted. Generally speaking, raising an antenna causes the most marked improvement in the signal reception, providing that the antenna is still kept away from the building. Mounting an antenna just at the comb of the roof, and close to the roof, seems to be a particularly poor location. In this location the received signal is generally weaker than if the antenna is mounted farther away from the roof or wall of a house even though the resulting installation may mean that the antenna height above ground is lower than if mounted at the comb.

There has been no consistent pattern indicating whether vertical or horizontal antenna installations are preferable. Both have been used and to date no method has been evolved to determine beforehand which will prove the more effective. In a number of cases the dipole has been most effective when mounted diagonally.

In horizontal antenna installations there has been no general rule governing the antenna orientation. Theoretically, the dipole should be broadside to the transmitter, but in many instances some other orientation has given better service. In all cases the antennas mounted have been straight or folded dipoles.

There are indications that properly matched "twin lead" is a more efficient lead-in than coaxial cable of the same impedance. Certainly it is preferred by the home owner since it can be run under a carpet and generally made much less unsightly than the coaxial cable.

In the wooded residential sections of the city, there is a marked difference between the strength of the received signal during wet and dry weather. The signal strength decreases greatly in wet weather.

8. PROGRAMMING OF W8XUB

The programming of W8XUB was from the start kept subordinate to the experimentation, and has remained a secondary activity to date.

The reasons for doing any regular programming at all were first, to provide persons to whom f-m sets had been loaned a basis for reporting on their f-m reception, and second, to bring to the attention of Clevelanders in general, the fact that there was an f-m station and to create a desire on their part to listen to it.

By means of using high quality musical transcriptions, specially constructed high quality amplifiers, and endeavoring to keep all extraneous noise to a minimum, our first objective was accomplished. The program put on the air was comparable to high quality a-m broadcasting at the point of origin, thus listeners could judge fairly between a-m and f-m reception without having to make any allowances for program quality at the point of origin.

In pursuit of our second aim, that of making Clevelanders conscious of f-m and desirous of listening to it, we had two fortunate occurrences. A change of ownership and management of the Cleveland Indians' Baseball Team greatly increased the interest of this normally sports-conscious city in the baseball games. This occurred at a time when no a-m station was in a position to carry all the games played by the team. Through the prompt cooperation of the Federal Communications Commission W8XUB was privileged to be the only station in the city to broadcast the complete Indians' baseball schedule of games.

This fact, through the cooperation of the newspapers which have printed our daily schedule, has been impressed on the public, and has created considerable interest in f-m. There are continous calls through the day from people anxious to receive f-m, and at game time the number of calls has on occasions exceeded the capacity of the WHK telephone switchboard.

Programming has at all times been limited to the afternoon and evening to leave ample time for equipment changes coincident to the experiments that have been conducted. Specifically the hours of programming have been from 2:00 P.M. until 10:00 P.M. As long as the experimentation continues, it is planned to continue the programming as described.

To replace baseball as an f-m interest builder during the fall, a request has been submitted to the Federal Communications Commission to carry college football games that are of national interest and which are not carried by any other local station.

9. ACKNOWLEDGMENTS

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H. K. Carpenter, Executive Vice President, who furnished overall supervision and assisted in training the Engineering Staff Operators who do the announcing, Ralph H. DeLany, Chief Engineer of Radio Station WHK, who helped plan, procure and construct this experimental facility, Mills T. Bennett, WHK Transmitter Supervisor, who assisted with the installation and maintenance of the f-m transmitter, P.C. Tuttle, WHK Technician, who constructed much of the high-quality audio equipment used by this station, Saul Glantz, WHK Publicity Director, who took the pictures used in this report, Don Campbell, WHK Sports Announcer, who handled all of the Cleveland Indian baseball games, the WHK Technicians who operated the f-m transmitter during this period of experimentation, and the Engineering Staff Operators who handled the studio programs and baseball games during this period.

10. CONCLUSIONS

a. It is feasible to construct a transmitting antenna that will radiate elliptical polarization that closely approaches circular polarization.

b. The propagation characteristics of circular, vertical, and horizontal polarizations are quite similar in nature, making it feasible to match service area contours with any chosen polarization.

c. The adoption of circular polarization as the Federal Communications Commission standard for FM and TV broadcasting stations would have the following effects:

(1) increase the installation and operating cost to the broadcaster,

(2) decrease the antenna requirements for the home and car radio receiver,

(3) materially increase the possibility that a receiving antenna located at random will provide satisfactory reception,

(4) not alter the allocation problem.

Fig. 1.—Experimental f-m building.

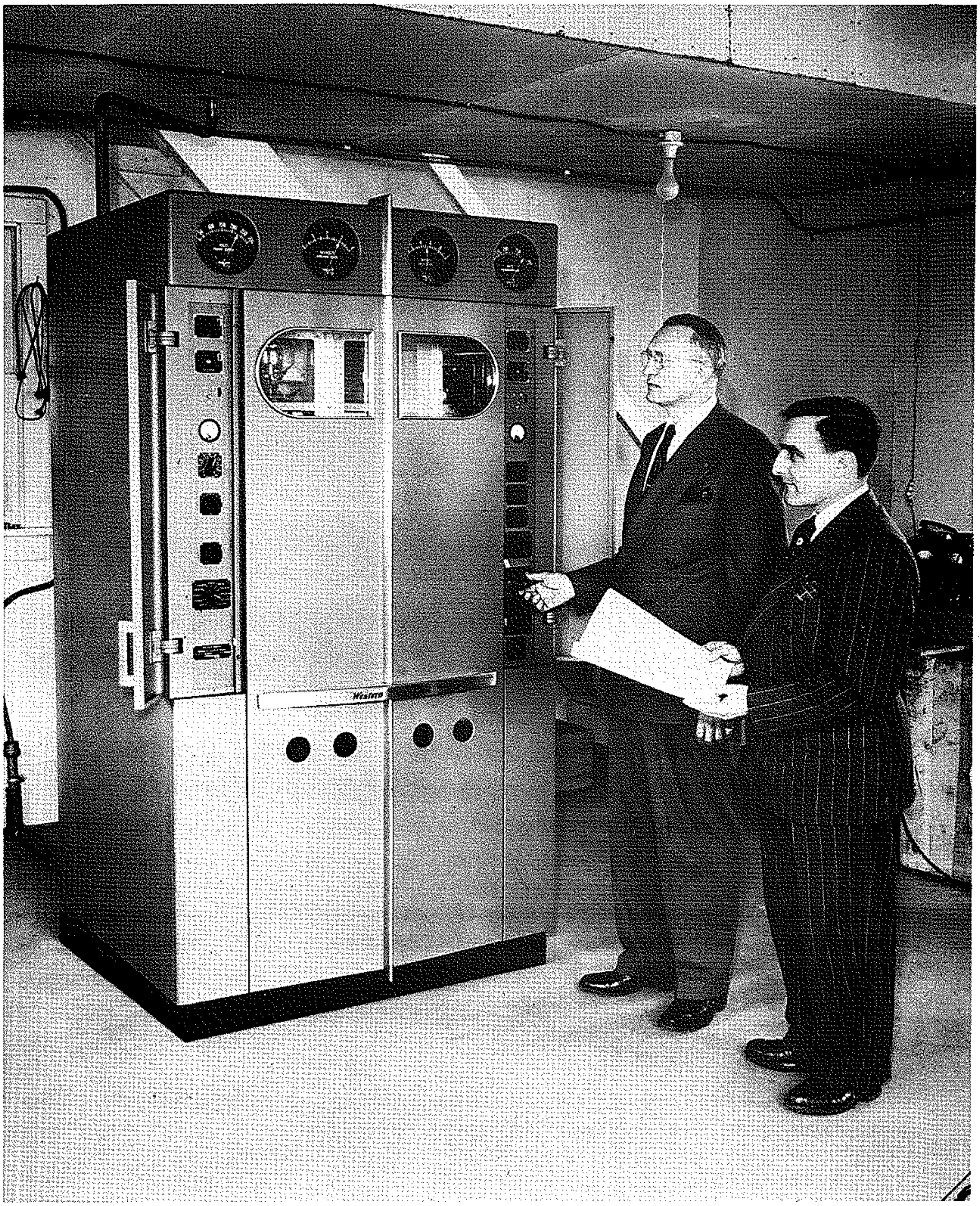


Fig. 2.—Western Electric 1 kw type 503B-1 f-m transmitter.

(left) H.K. Carpenter, Executive Vice President and (right) Carl E. Smith, Vice President In Charge of Engineering

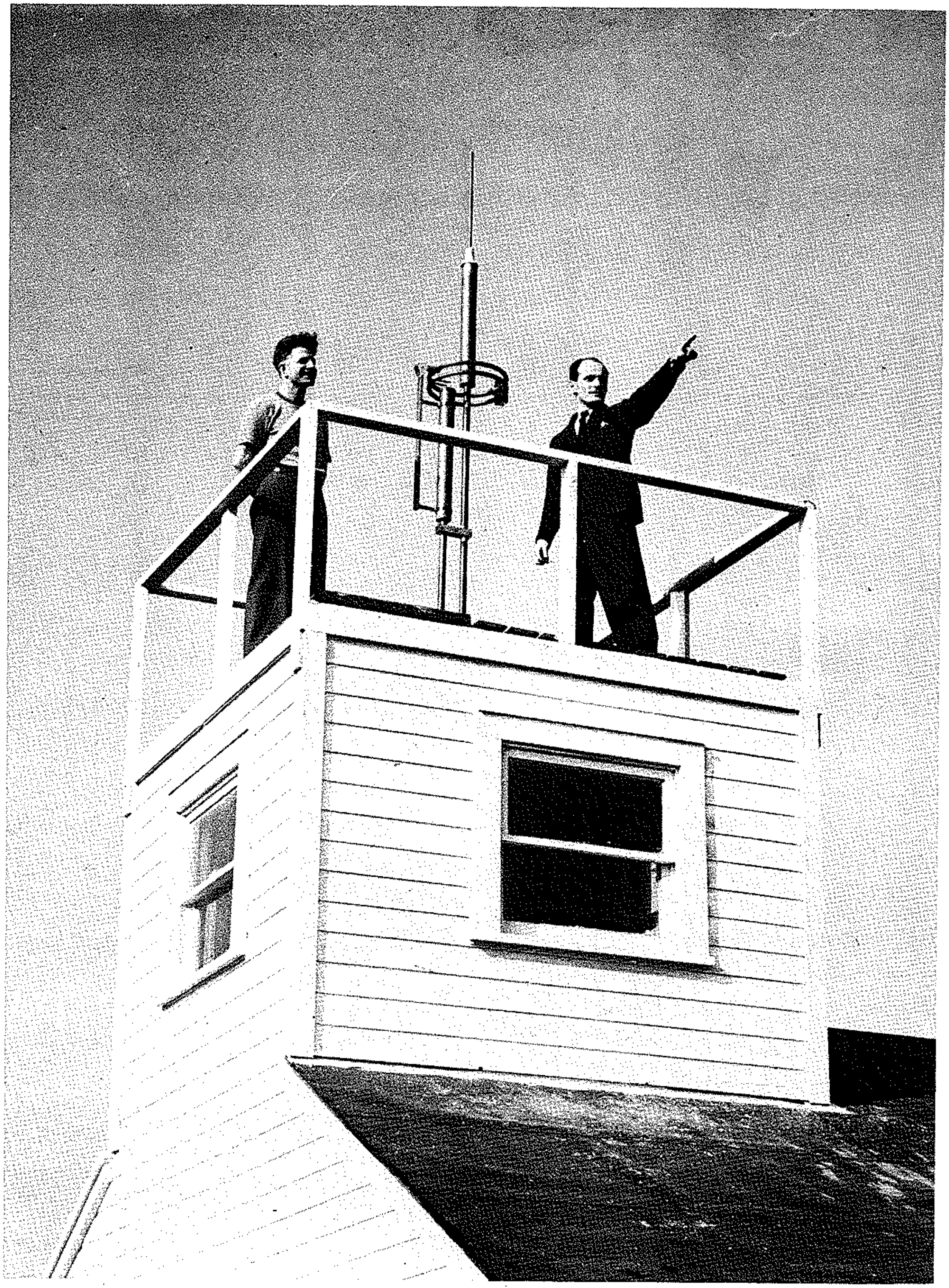


Fig. 3.—Circular polarization antenna.

(left) E.K. Ackerman, Facilities Engineer and (right) J. F. Dobosy, Development Engineer

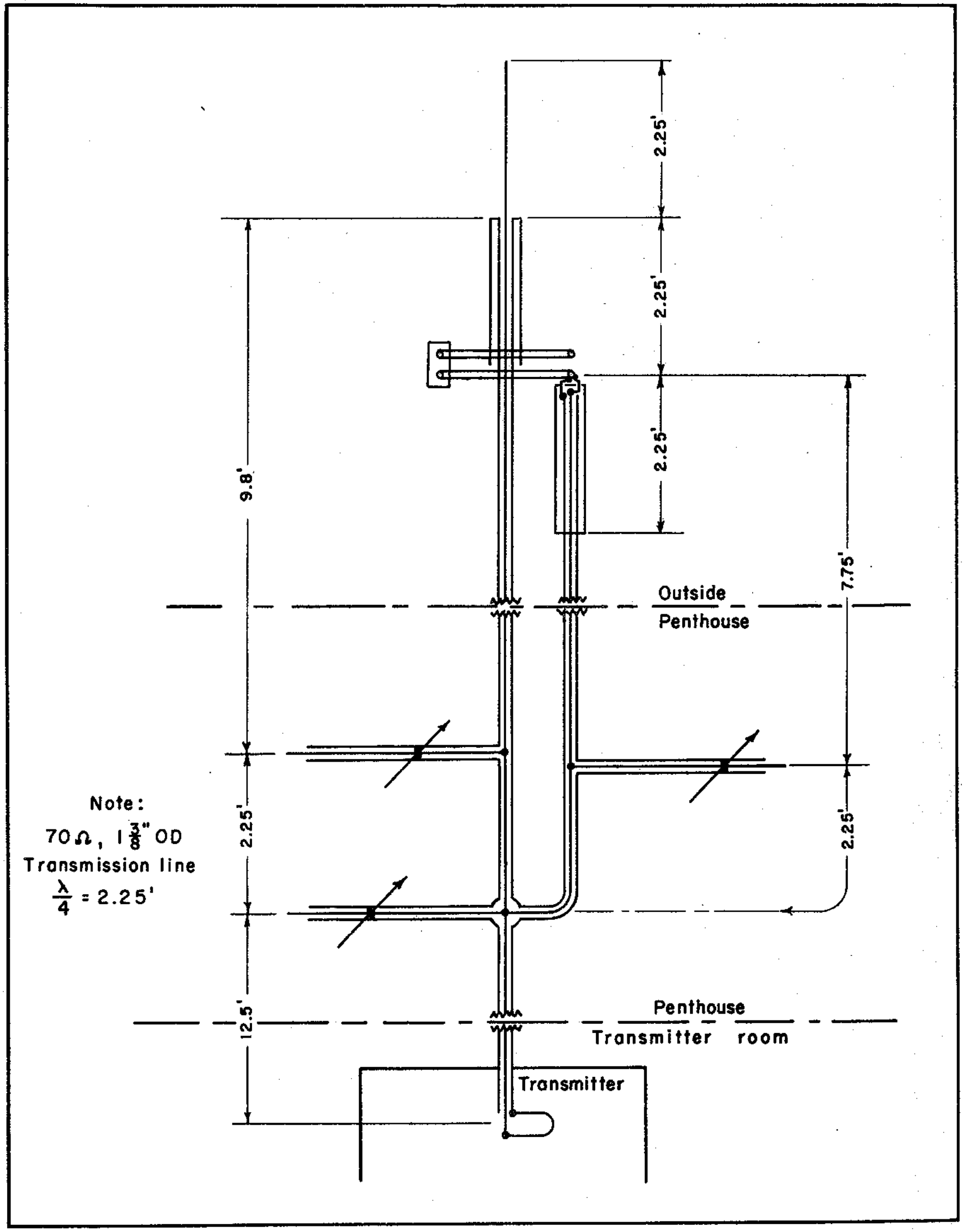


Fig. 4.— Sketch of transmitting antenna system.

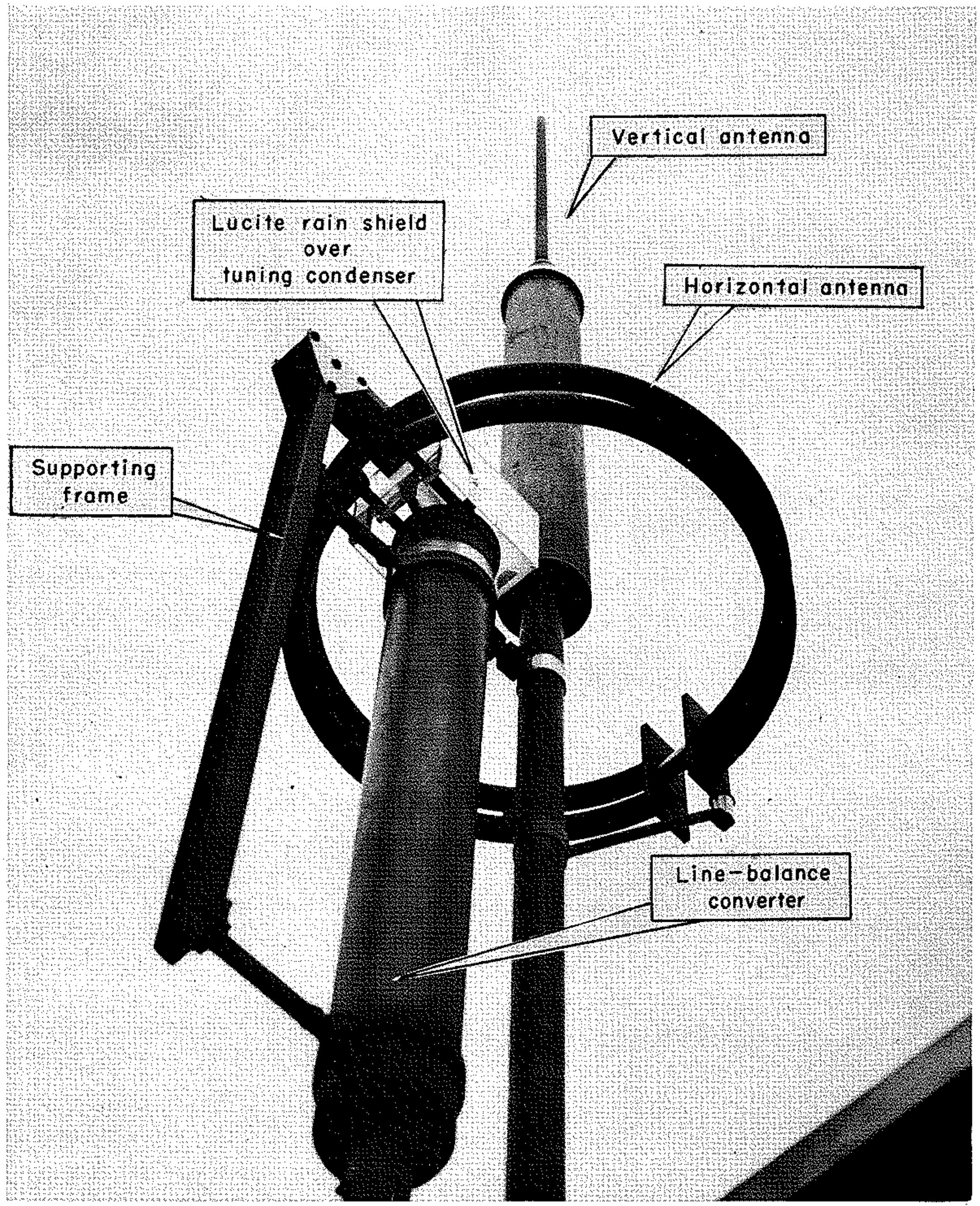


Fig. 5.— Transmitting antenna close-up.

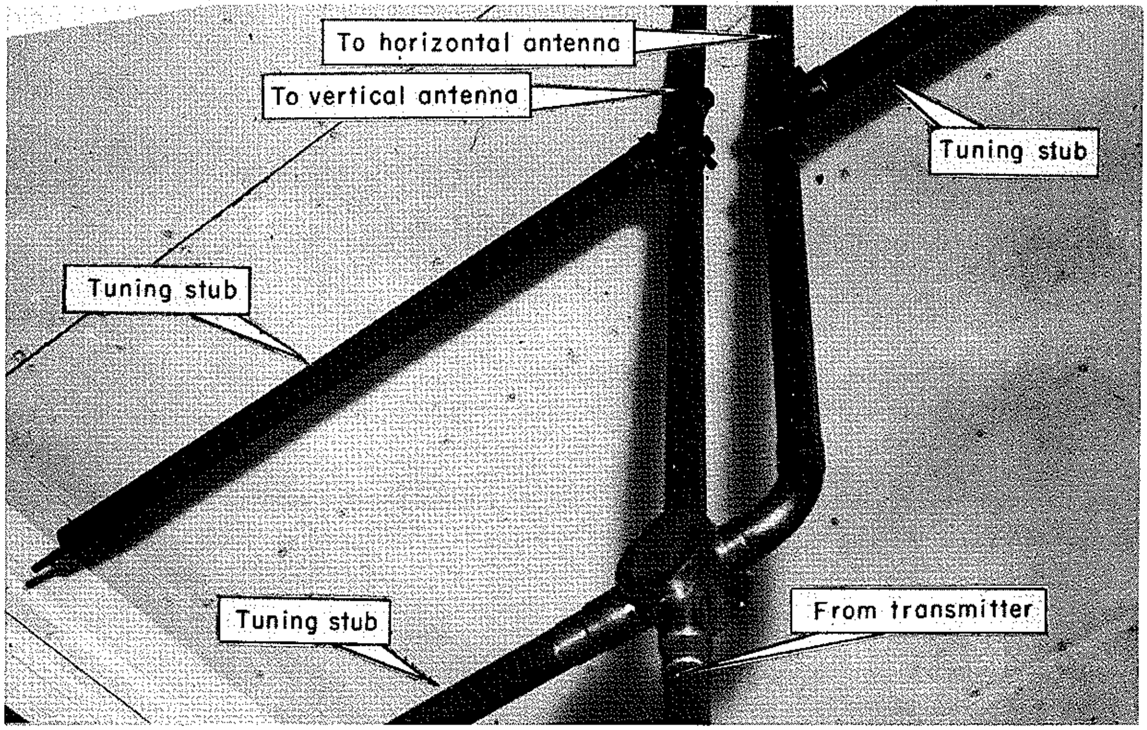


Fig.6.— Transmission line power dividing and phasing system in penthouse.

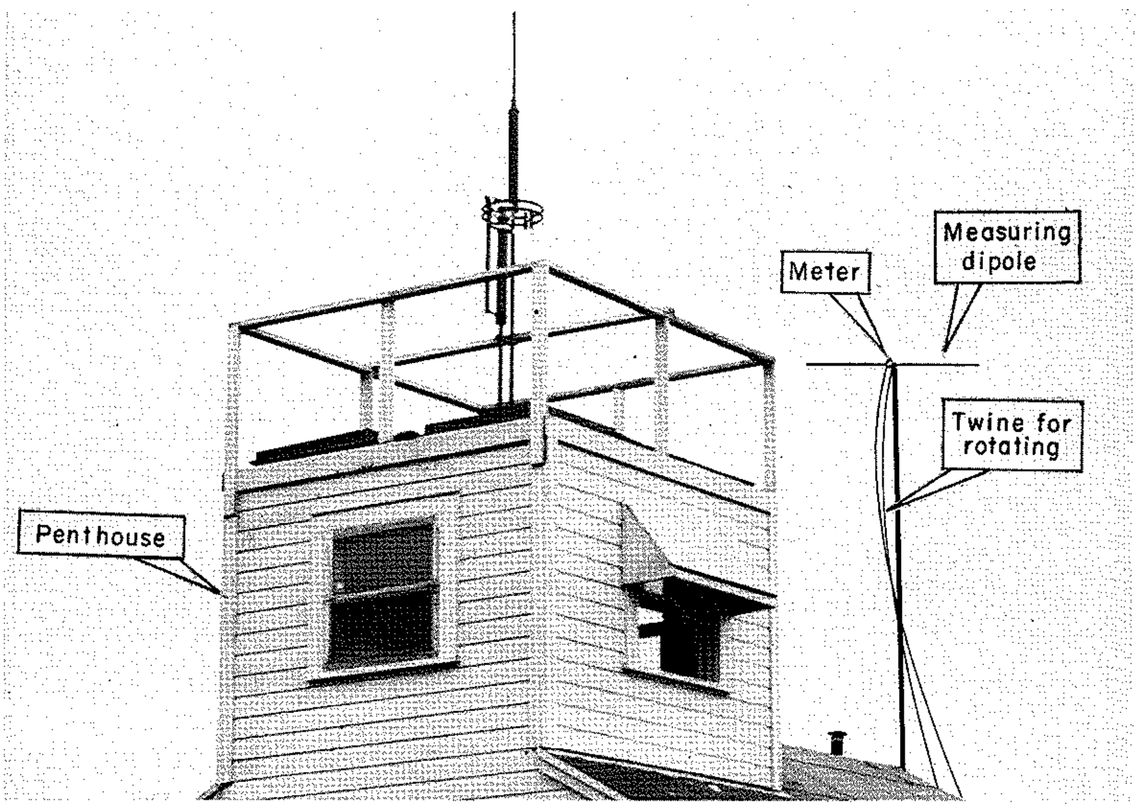
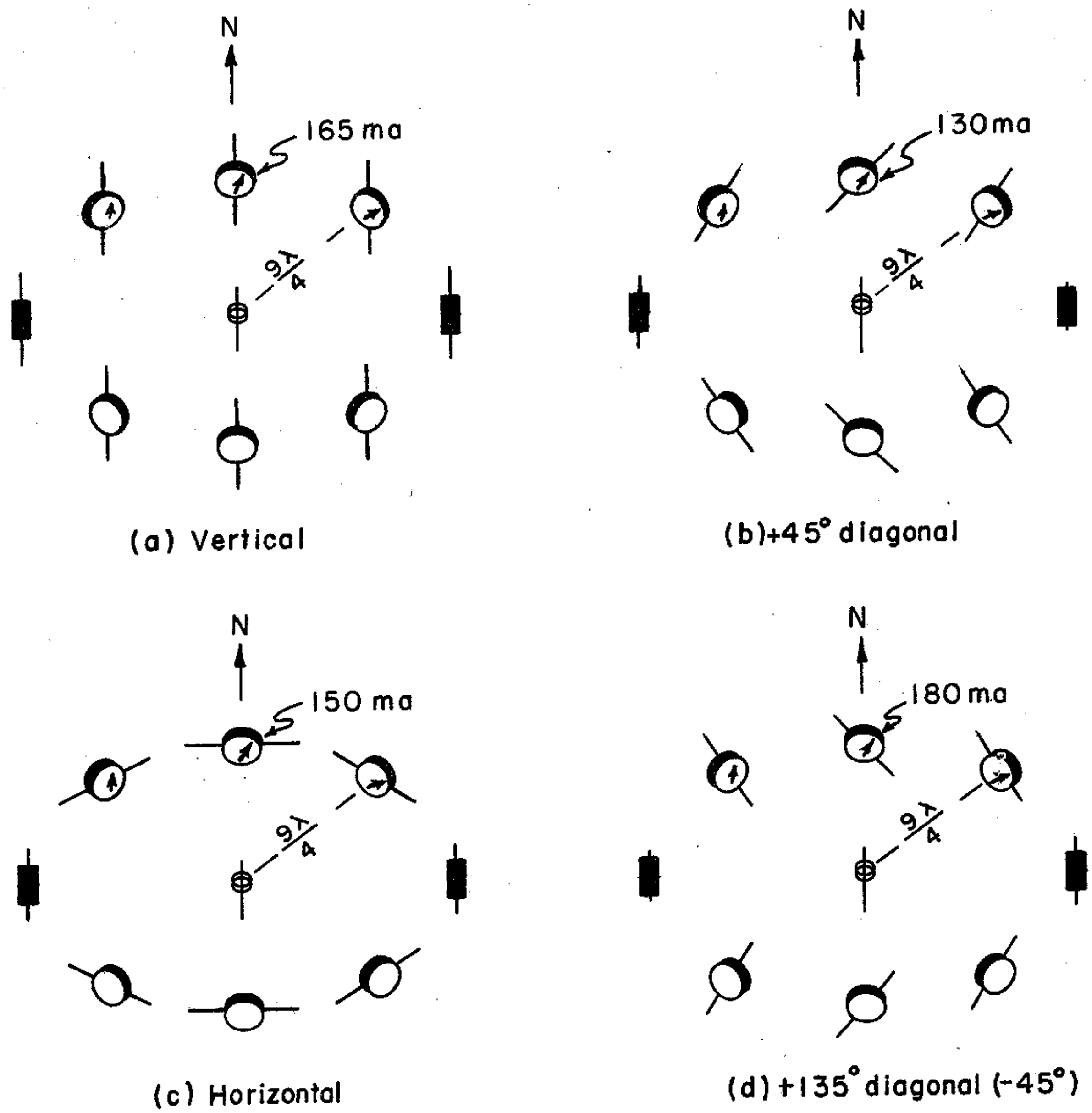


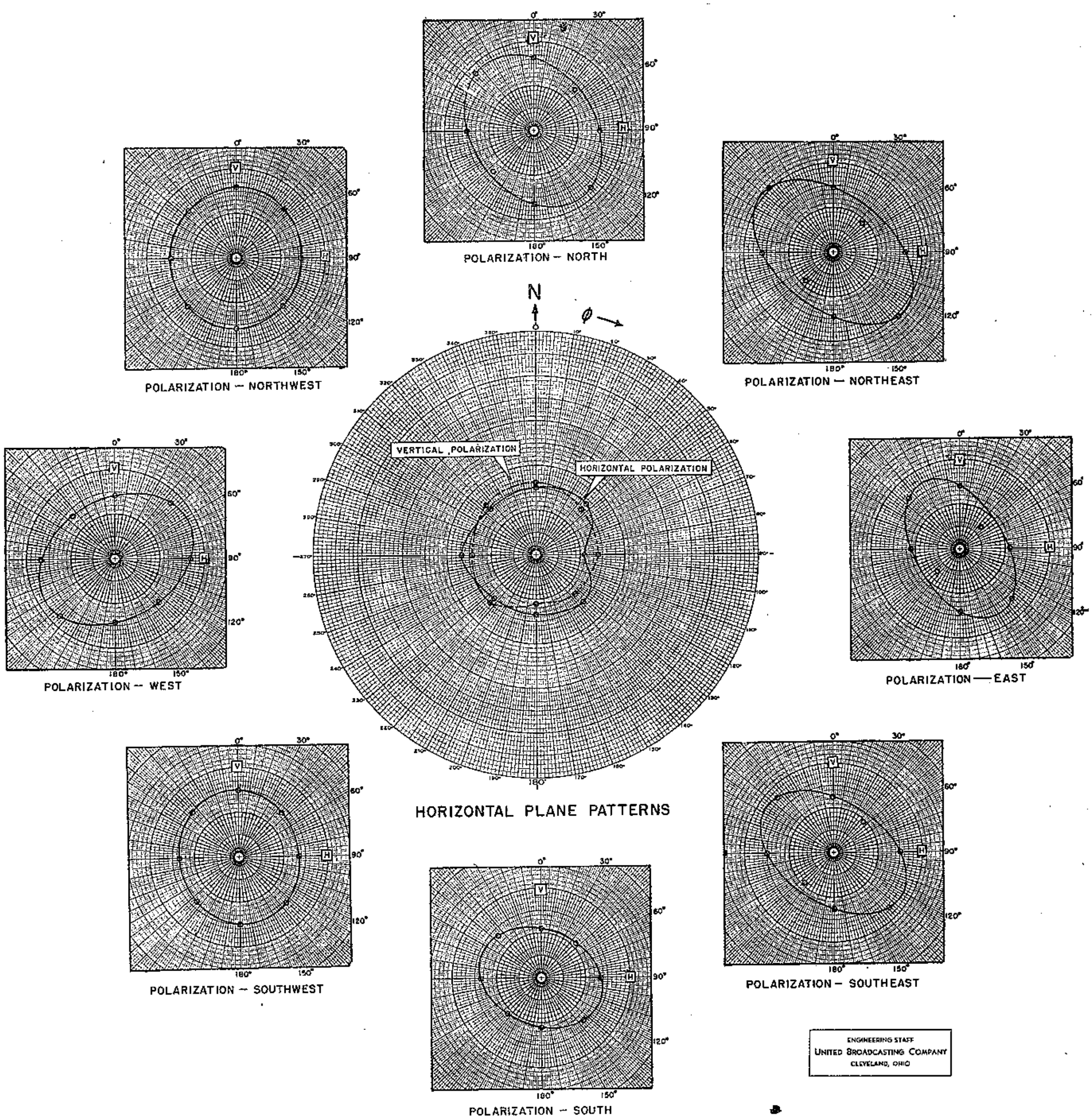
Fig. 7.— Transmitting antenna showing receiving dipole used to measure the relative field intensity and polarization in the horizontal plane.



NOTE: ⊕ indicates transmitting antenna.

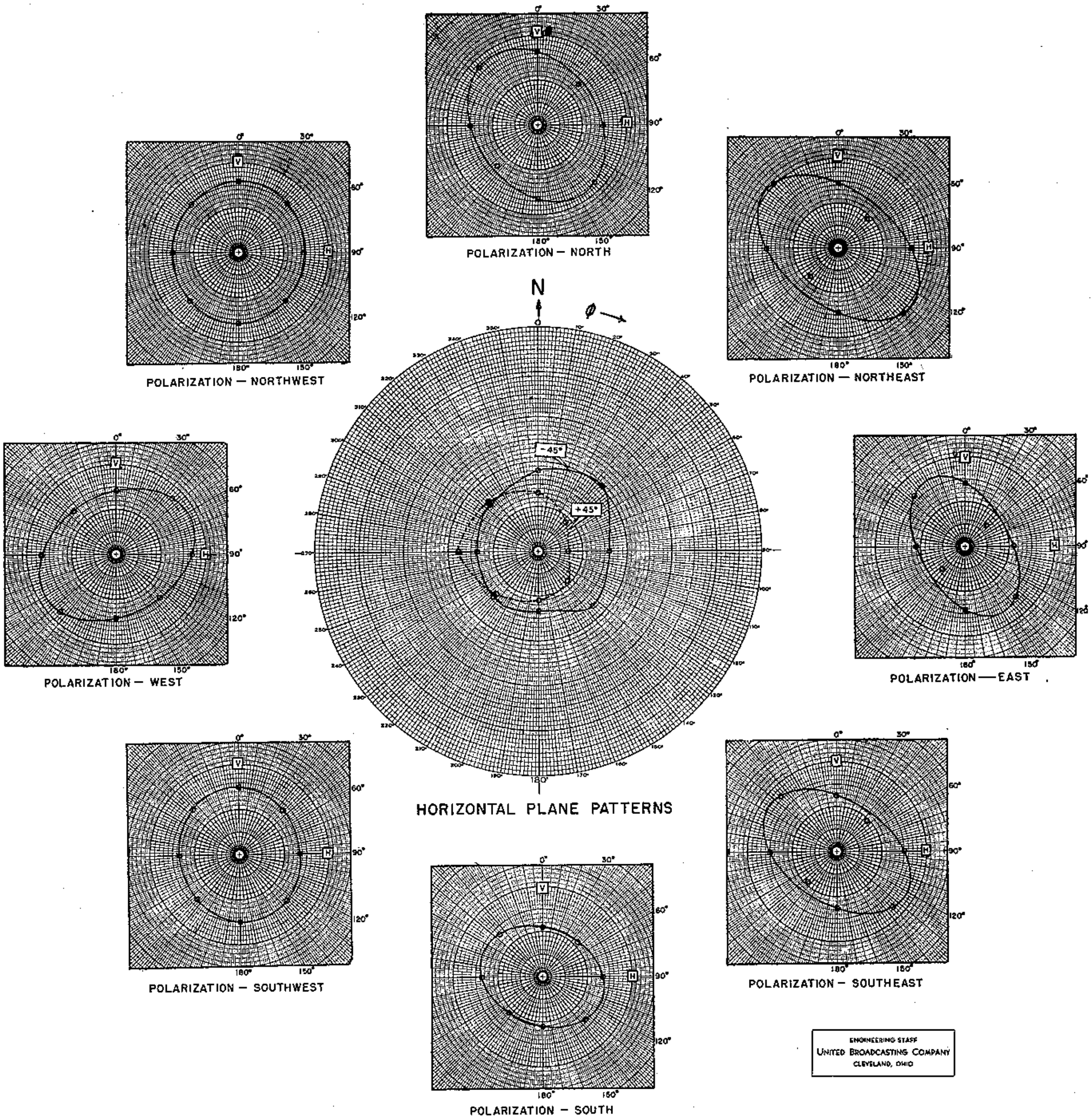
Perspective view showing transmitting antenna at center and the 8 locations of the receiving dipole as used to measure the relative field intensity in the horizontal plane for all polarizations in a plane at right angles to the direction of propagation.

Fig.8.—Performance measuring positions.



PATTERN AT CENTER SHOWS RELATIVE VERTICAL AND HORIZONTAL POLARIZATION FIELD INTENSITY IN THE HORIZONTAL PLANE AND THE 8 PATTERNS FOR THE INDICATED DIRECTIONS GIVE THE RELATIVE FIELD INTENSITY PATTERN IN THE HORIZONTAL PLANE FOR ALL POLARIZATIONS IN A VERTICAL PLANE AT RIGHT ANGLES TO THE DIRECTION OF PROPAGATION.

FIG. 9 a. —PERFORMANCE PATTERNS



PATTERN AT CENTER SHOWS RELATIVE DIAGONAL POLARIZATION FIELD INTENSITY IN THE HORIZONTAL PLANE AND THE 8 PATTERNS FOR THE INDICATED DIRECTIONS GIVE THE RELATIVE FIELD INTENSITY PATTERN IN THE HORIZONTAL PLANE FOR ALL POLARIZATIONS IN A VERTICAL PLANE AT RIGHT ANGLES TO THE DIRECTION OF PROPAGATION.

FIG. 9 b.—PERFORMANCE PATTERNS

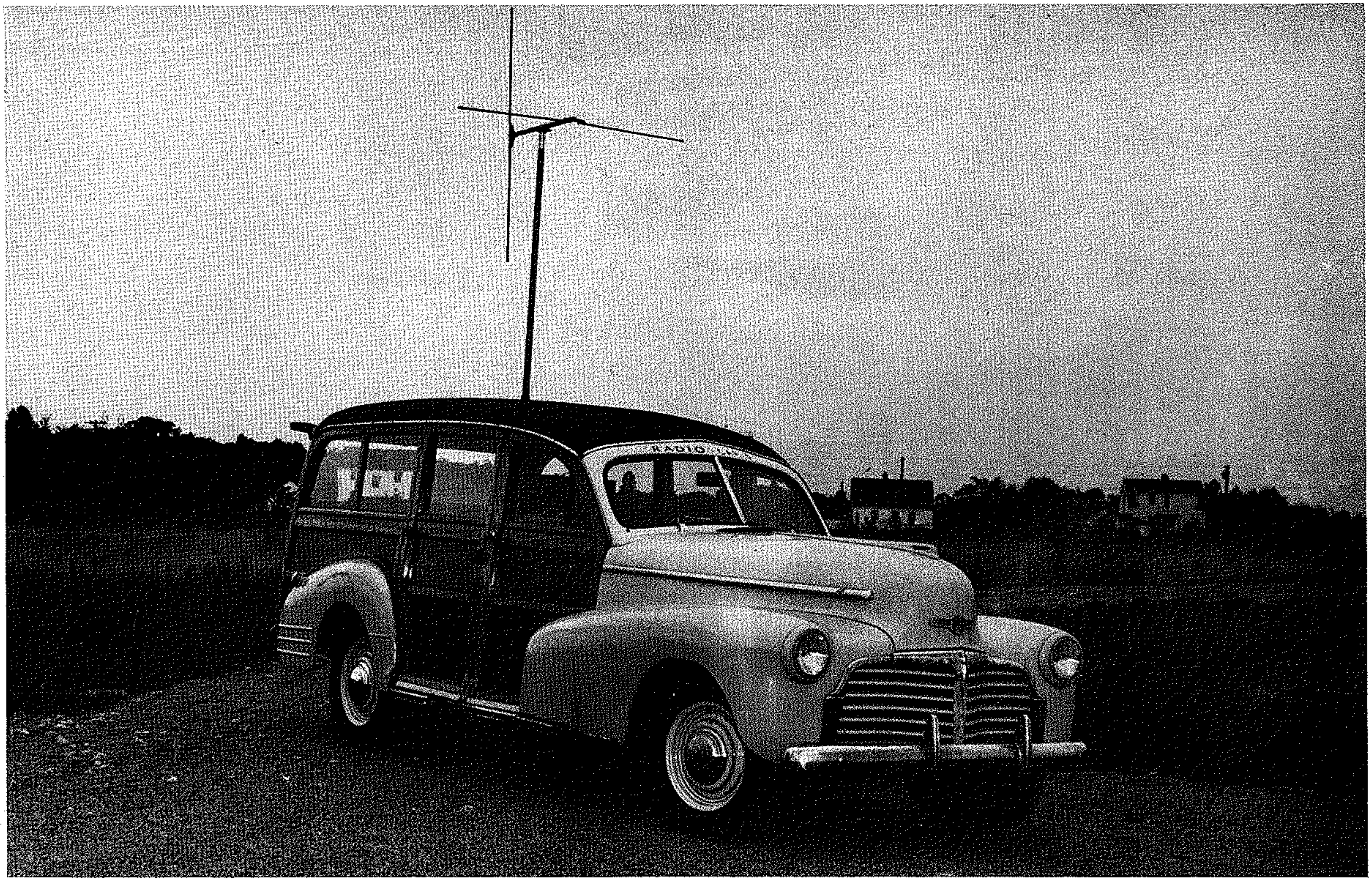


Fig. 10.— Field car showing installation of circular receiving antenna.

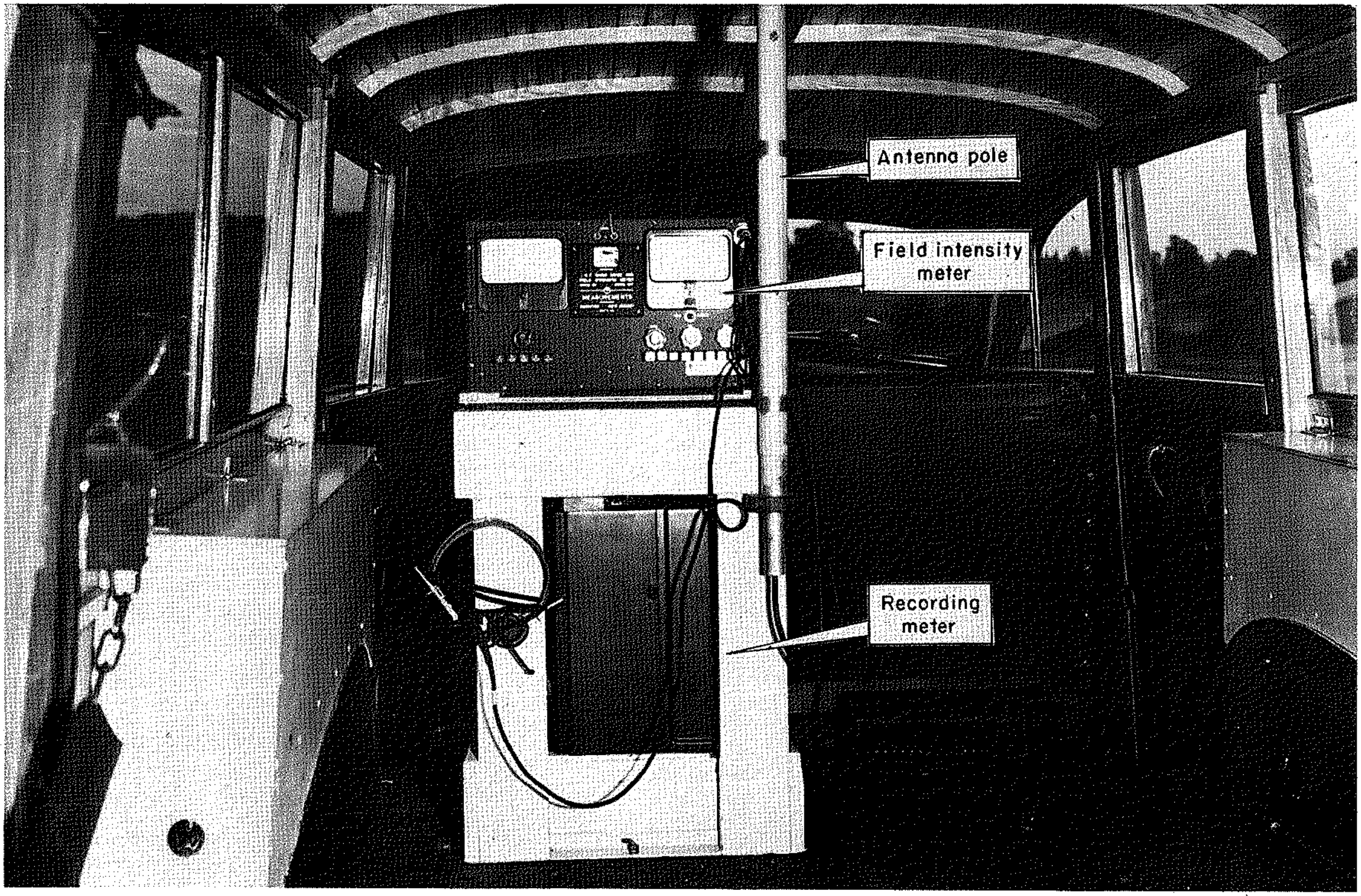


Fig. 11. — Field intensity measuring installation in field car.

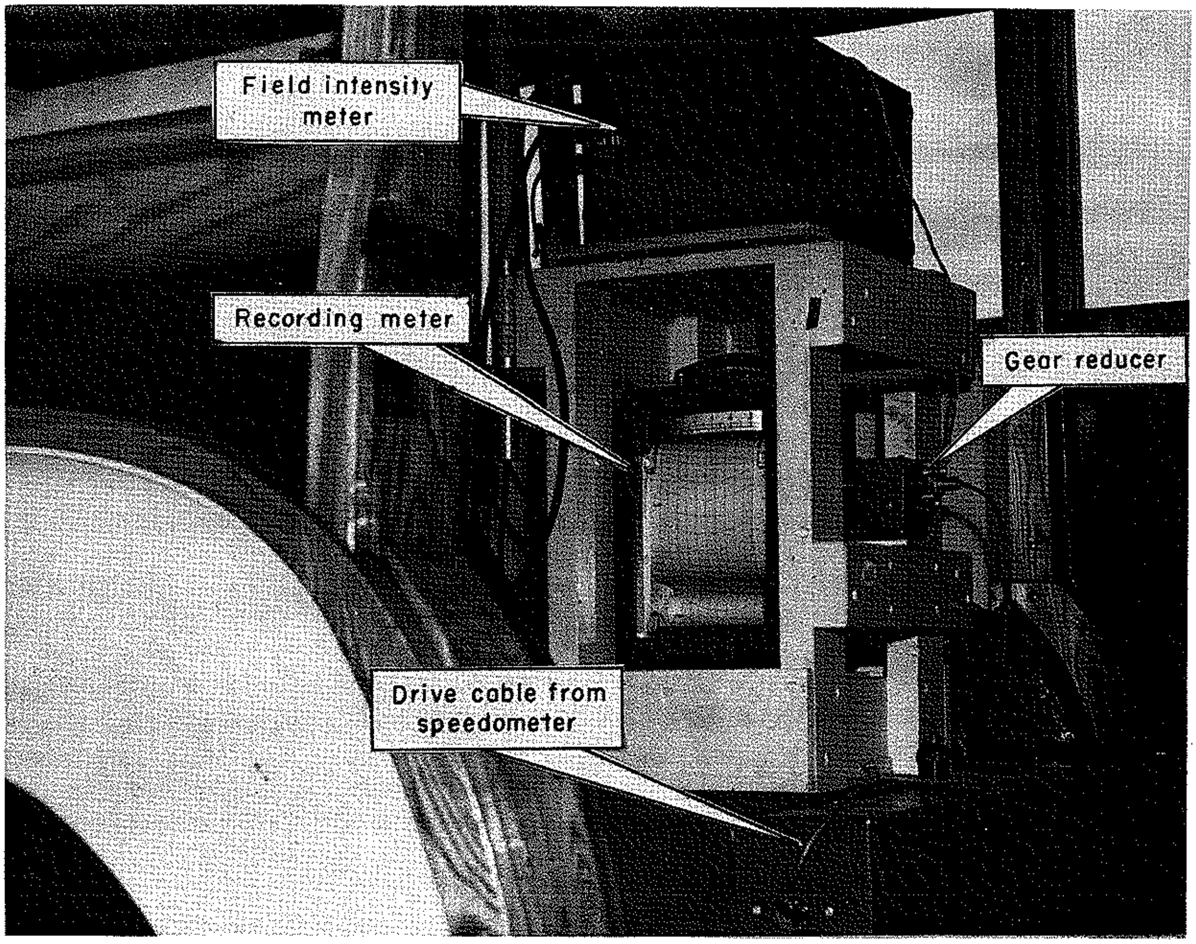


Fig. 12.—Detail showing recorder, chart drive cable, and gear reducer.

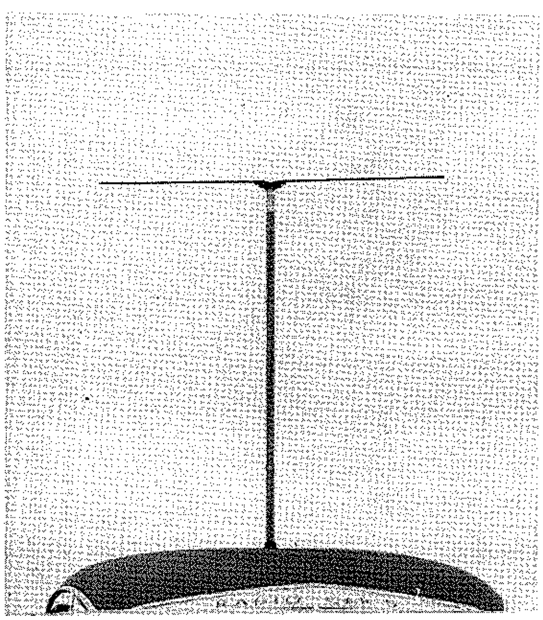


Fig. 13. — Horizontal receiving antenna on field car.

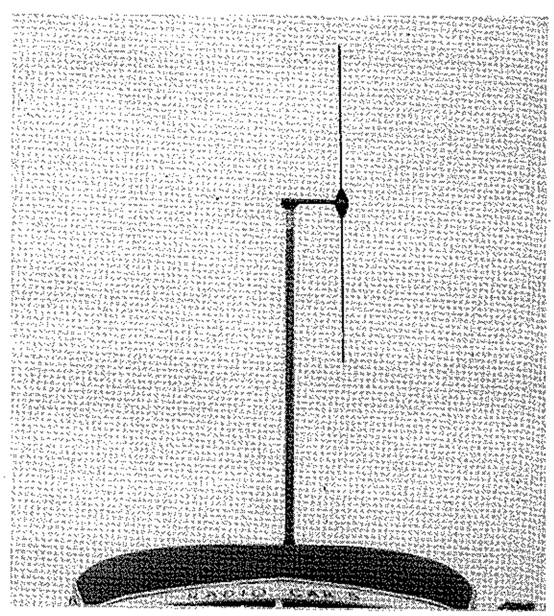
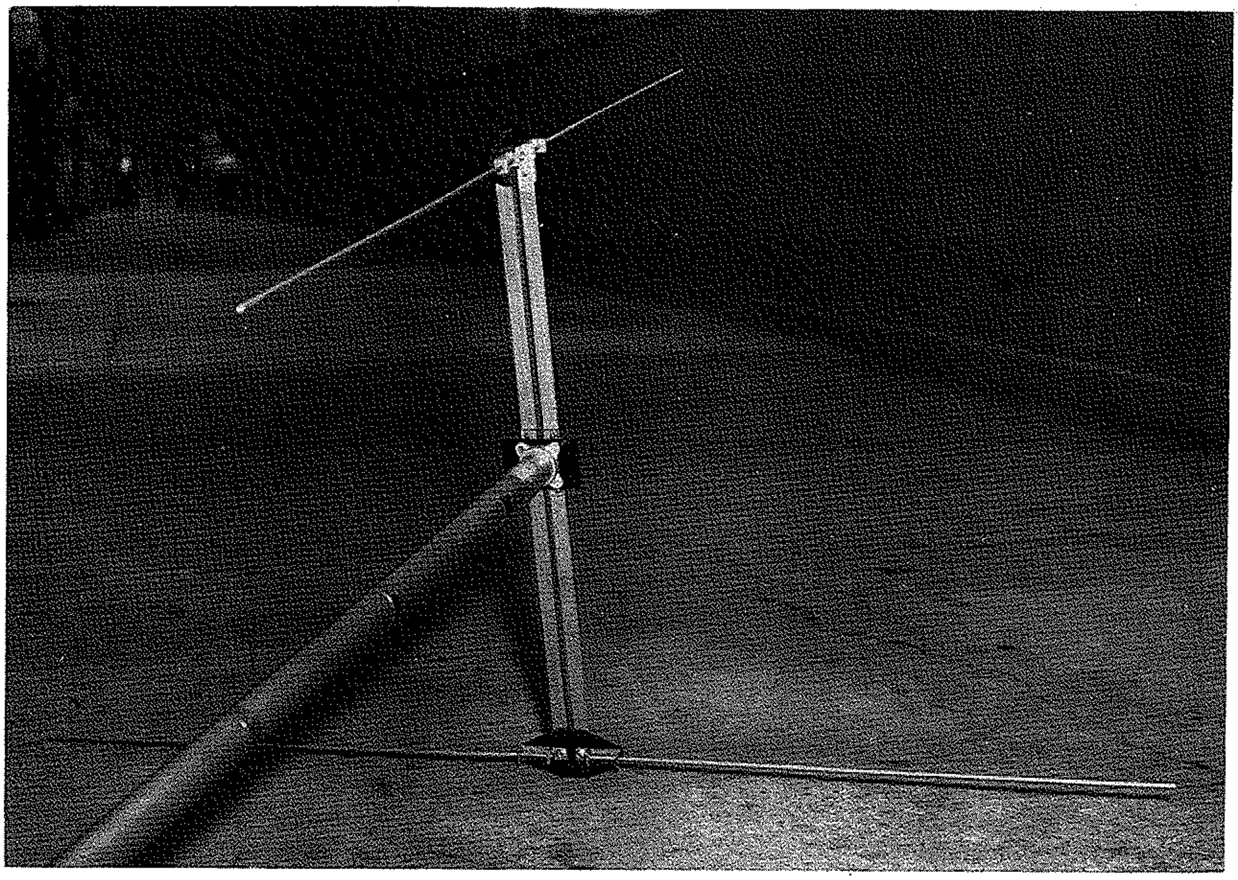
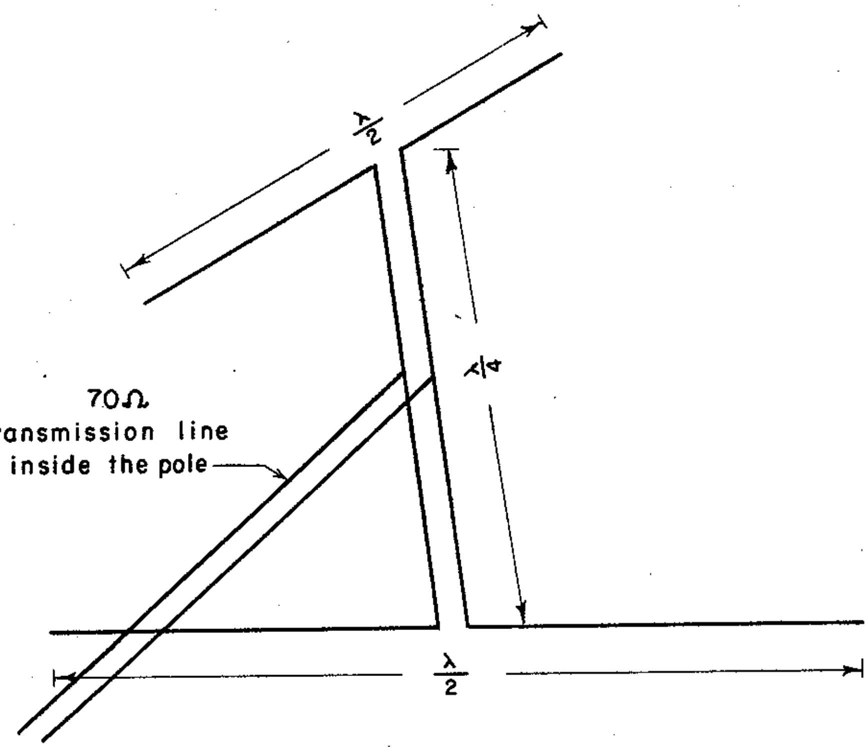


Fig. 14.— Vertical receiving antenna on field car.



(a) — Close up photograph



(b)-Sketch of antenna as shown above

Fig. 15.— Details of circular receiving antenna.

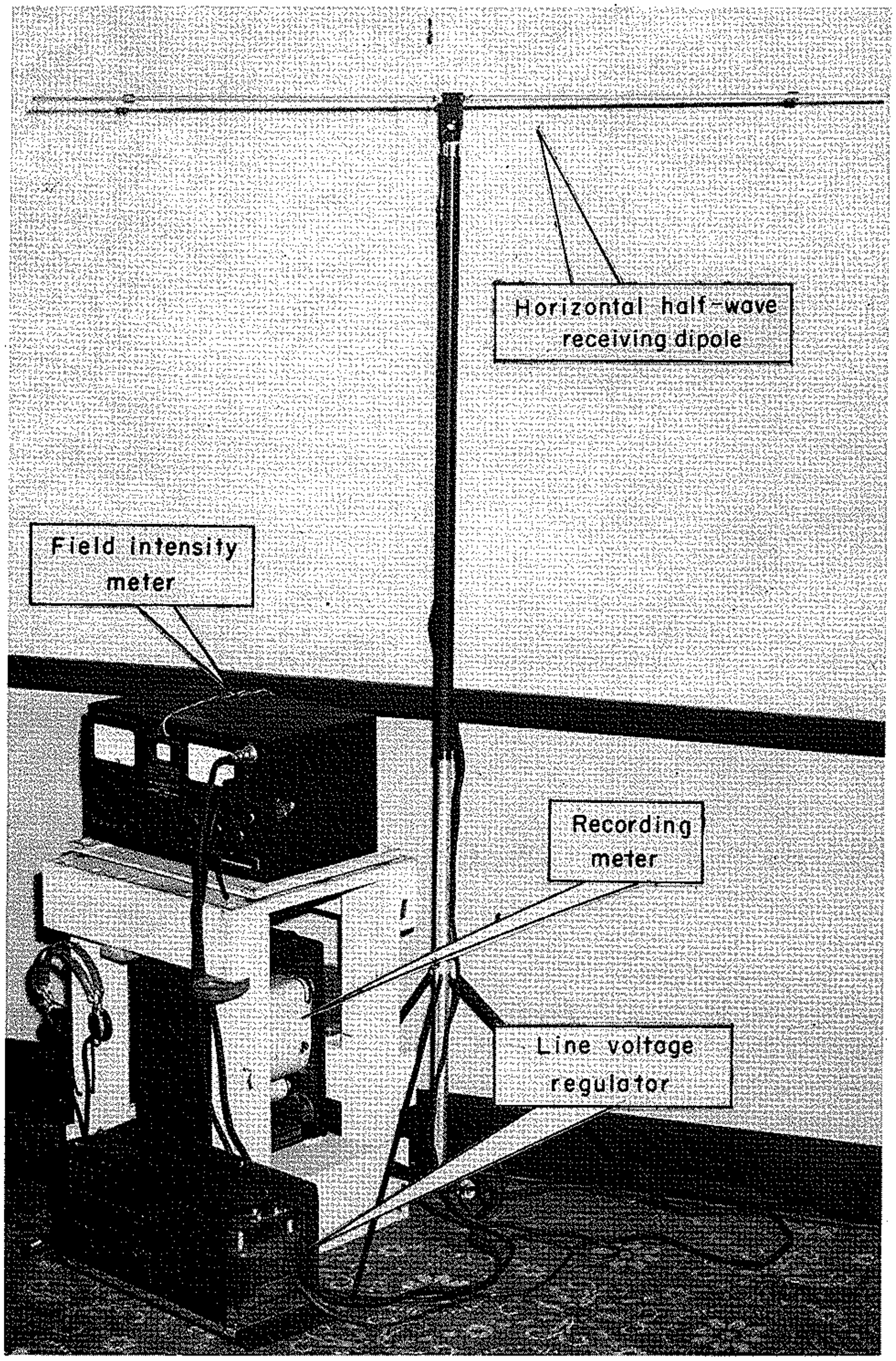


Fig.16.—Typical field intensity recording installation at fixed measuring point.

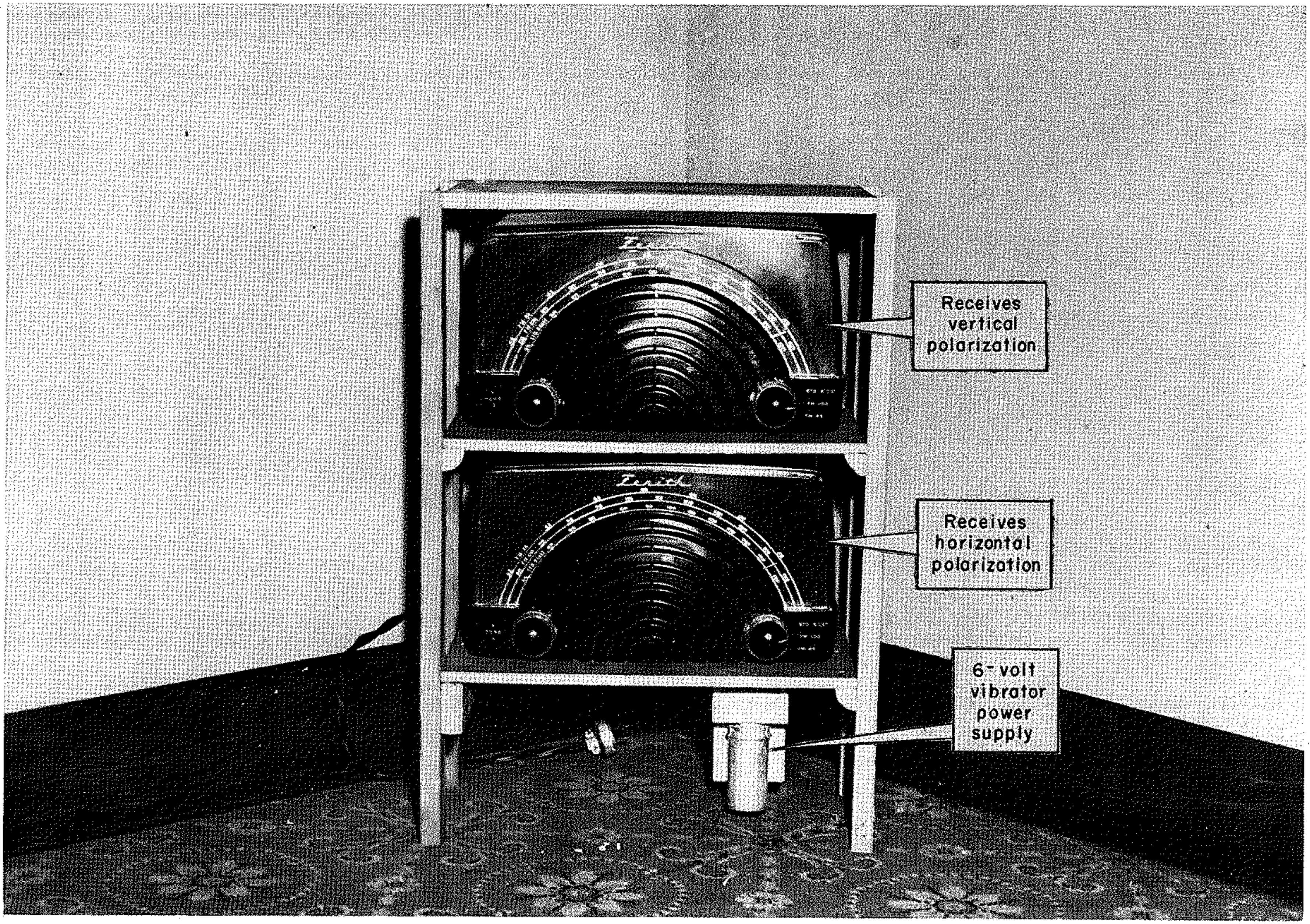
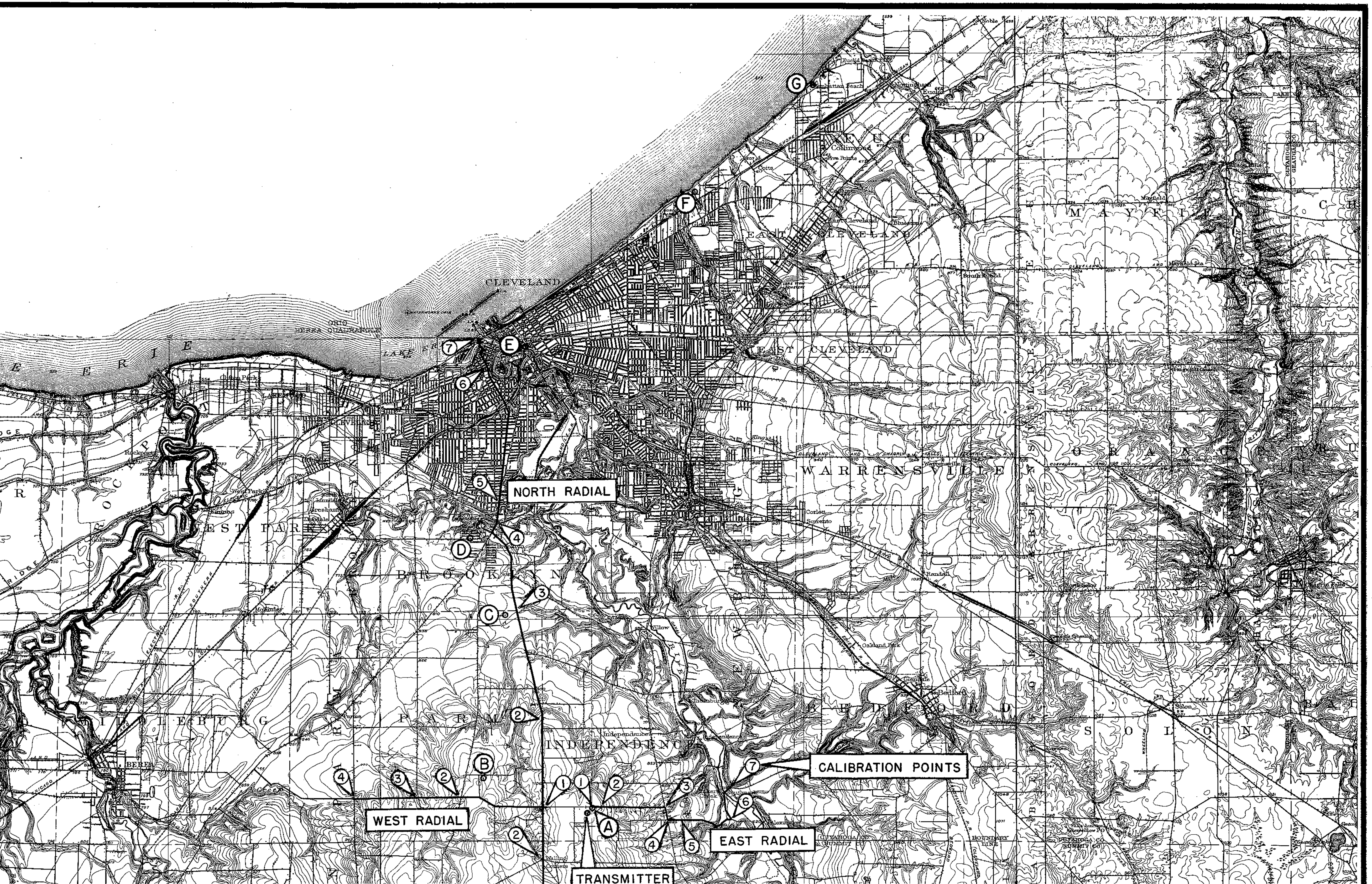
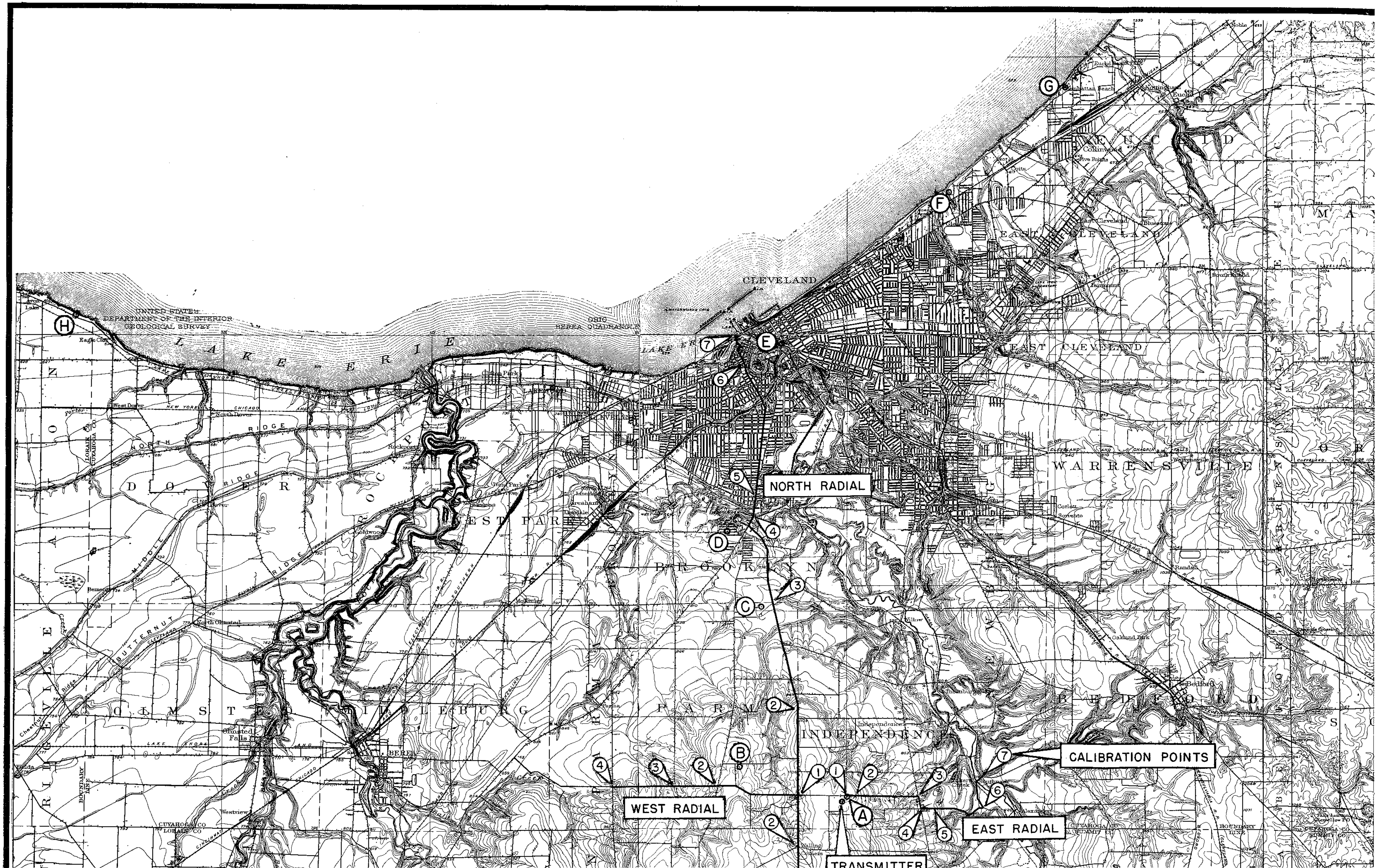


Fig. 17.—Receivers for simultaneous reception of vertically and horizontally polarized waves.

Fig. 18.—Antennas for simultaneous reception of vertically and horizontally polarized waves.



NORTH RADIAL
WEST RADIAL
EAST RADIAL
CALIBRATION POINTS
TRANSMITTER
CLEVELAND
EAST CLEVELAND
WARRENSVILLE
BROOKLYN
PARMA
INDEPENDENCE
BEDFORD
SOLON
MAYFIELD
EUCLID
WEST PARK
A
B
C
D
E
F
G



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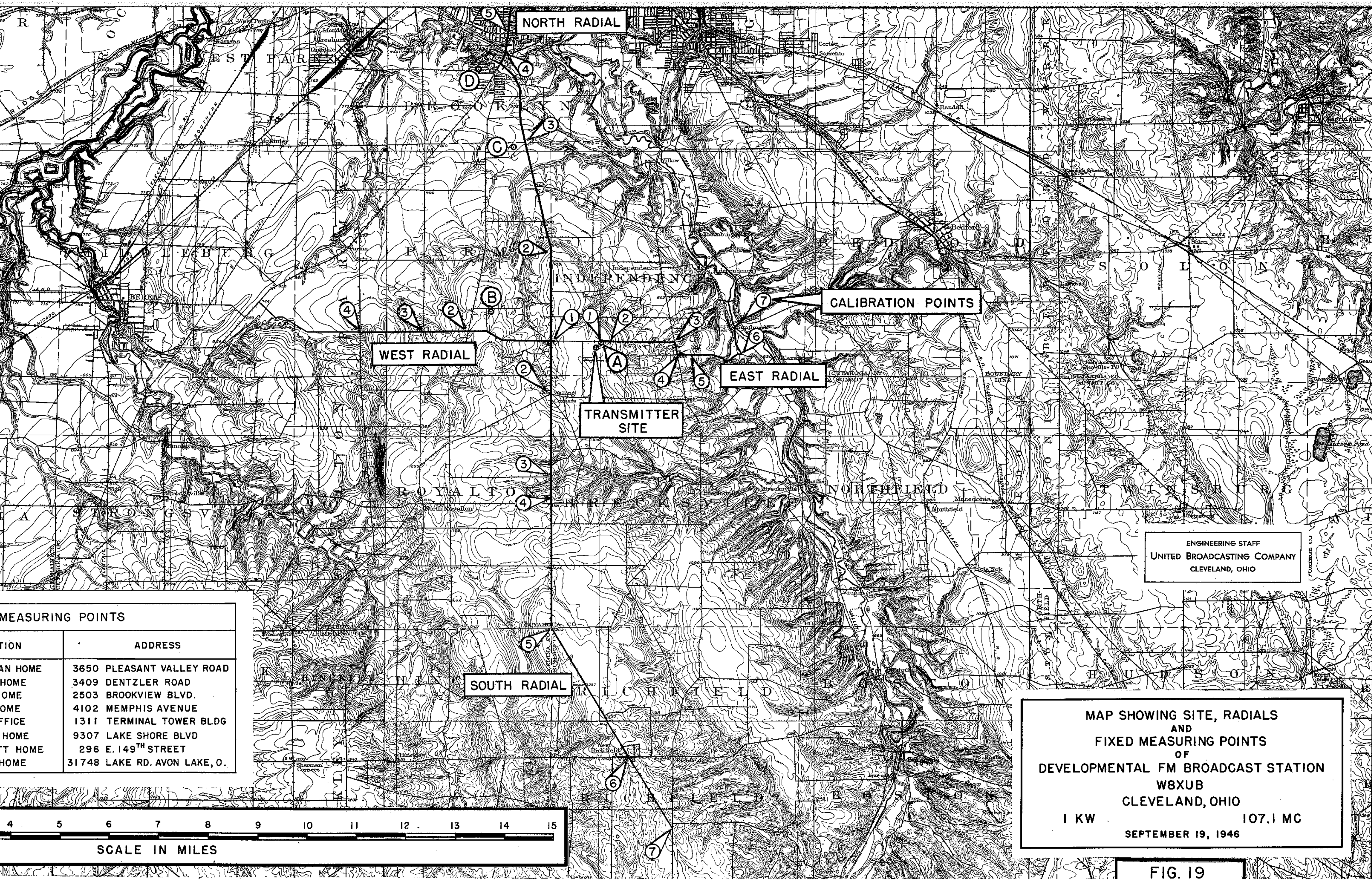
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
OHIO
BEREA QUADRANGLE
LAKE ERIE
CLEVELAND
NORTH RADIAL
WEST RADIAL
EAST RADIAL
CALIBRATION POINTS
TRANSMITTER
EAST CLEVELAND
WARRENSVILLE
BROOKLYN
PARMA
INDEPENDENCE
BEDFORD
DOVER
WEST PARK

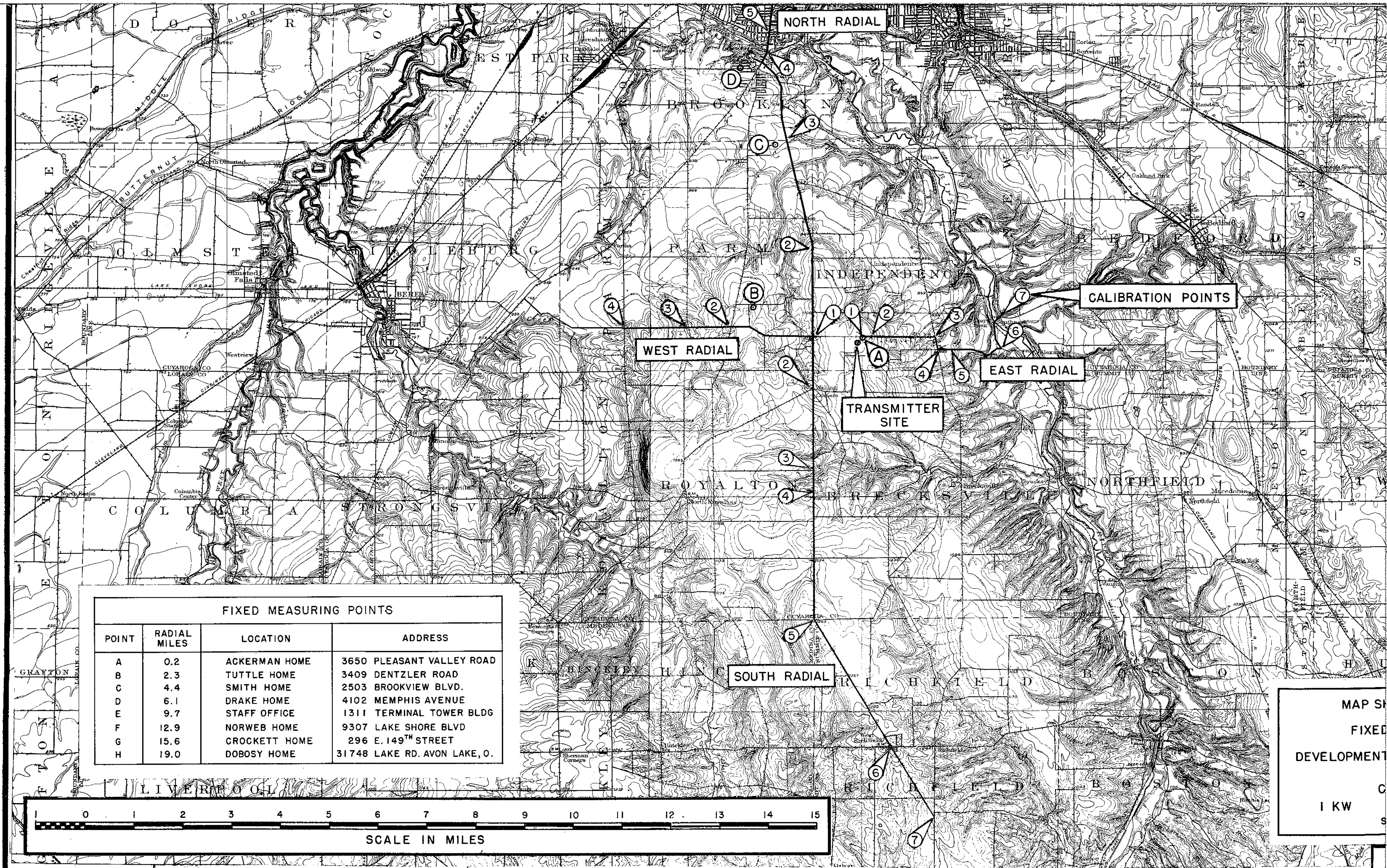


MEASURING POINTS

...TION	ADDRESS
...AN HOME	3650 PLEASANT VALLEY ROAD
...HOME	3409 DENTZLER ROAD
...OME	2503 BROOKVIEW BLVD.
...OME	4102 MEMPHIS AVENUE
...FFICE	1311 TERMINAL TOWER BLDG
...HOME	9307 LAKE SHORE BLVD
...TT HOME	296 E. 149TH STREET
...HOME	31748 LAKE RD. AVON LAKE, O.

MAP SHOWING SITE, RADIALS
AND
FIXED MEASURING POINTS
OF
DEVELOPMENTAL FM BROADCAST STATION
W8XUB
CLEVELAND, OHIO
1 KW 107.1 MC
SEPTEMBER 19, 1946

FIG. 19



FIXED MEASURING POINTS

POINT	RADIAL MILES	LOCATION	ADDRESS
A	0.2	ACKERMAN HOME	3650 PLEASANT VALLEY ROAD
B	2.3	TUTTLE HOME	3409 DENTZLER ROAD
C	4.4	SMITH HOME	2503 BROOKVIEW BLVD.
D	6.1	DRAKE HOME	4102 MEMPHIS AVENUE
E	9.7	STAFF OFFICE	1311 TERMINAL TOWER BLDG
F	12.9	NORWEB HOME	9307 LAKE SHORE BLVD
G	15.6	CROCKETT HOME	296 E. 149TH STREET
H	19.0	DOBOSY HOME	31748 LAKE RD. AVON LAKE, O.

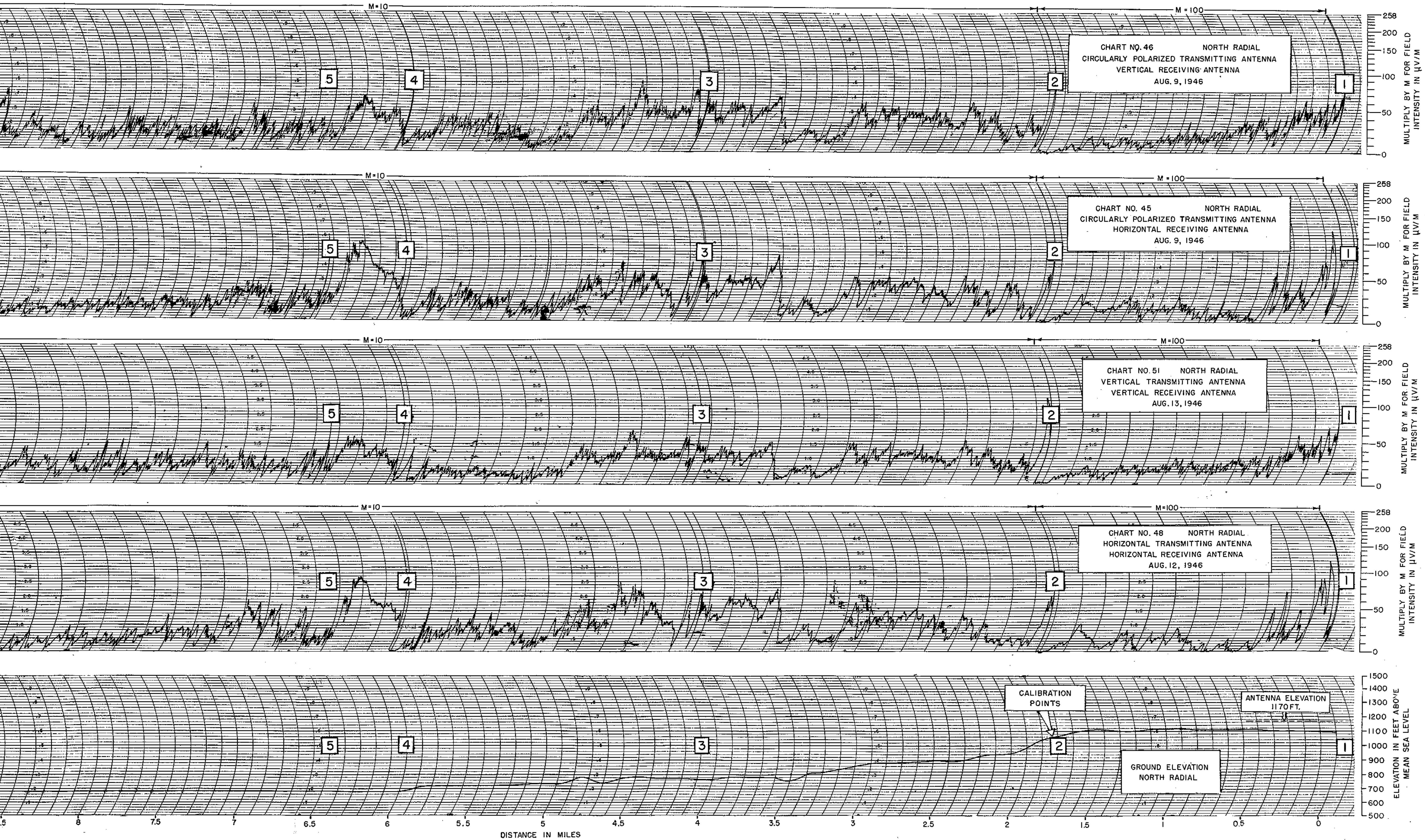


FIG. 20a. — NORTH RADIAL RECORDINGS

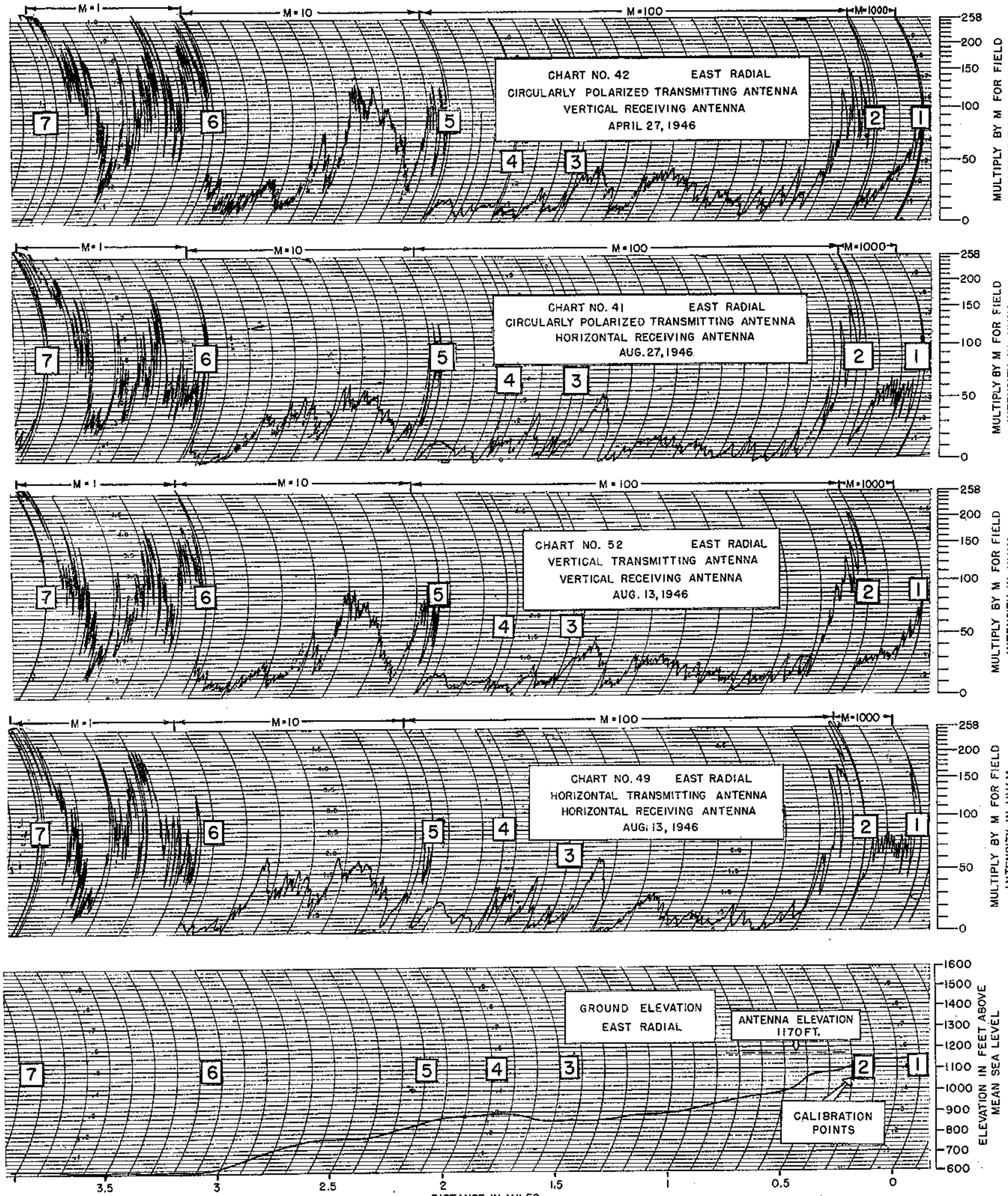
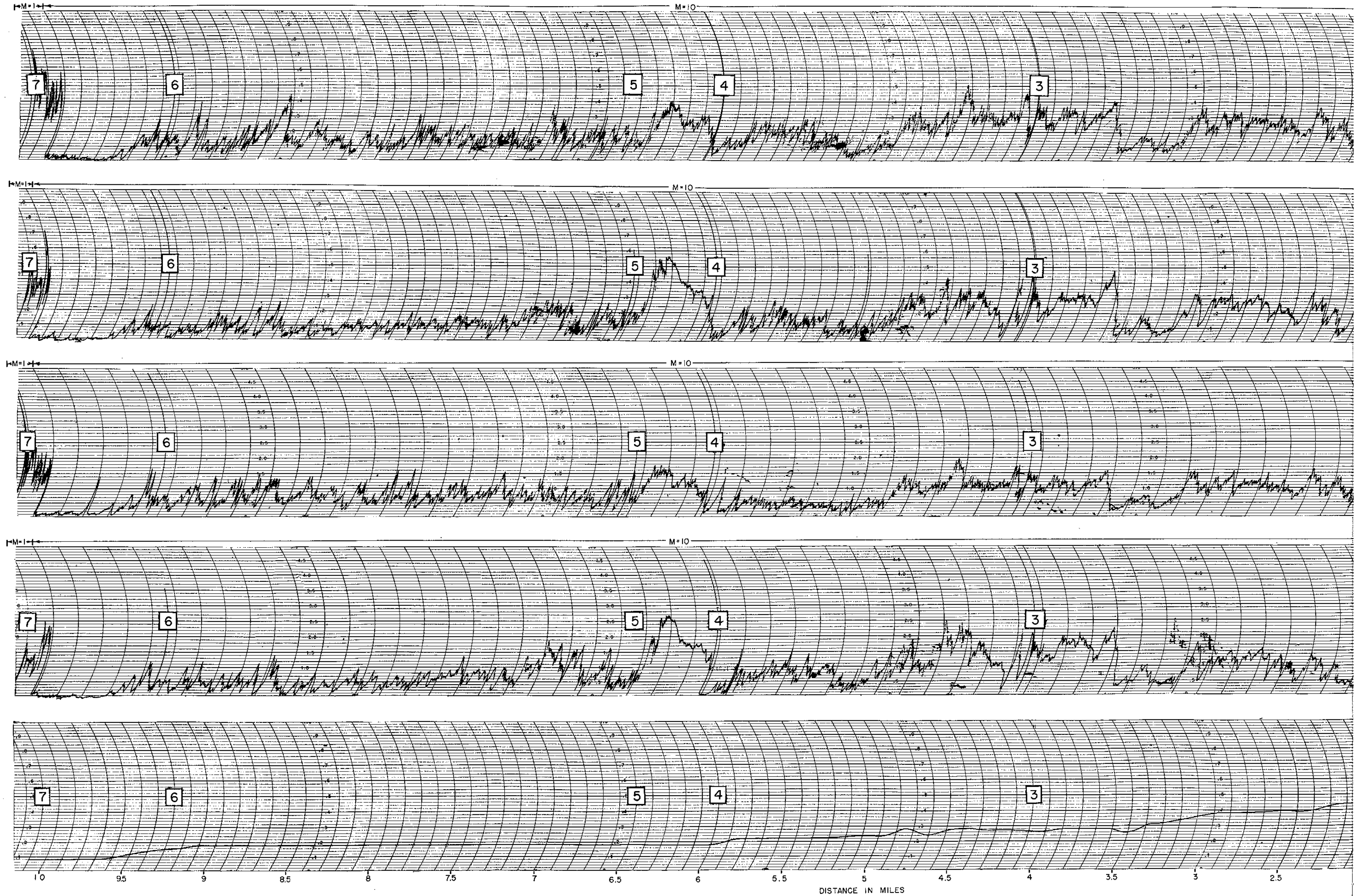


FIG. 21a.—EAST RADIAL RECORDINGS



M=1
M=10
7
6
5
4
3
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
DISTANCE IN MILES

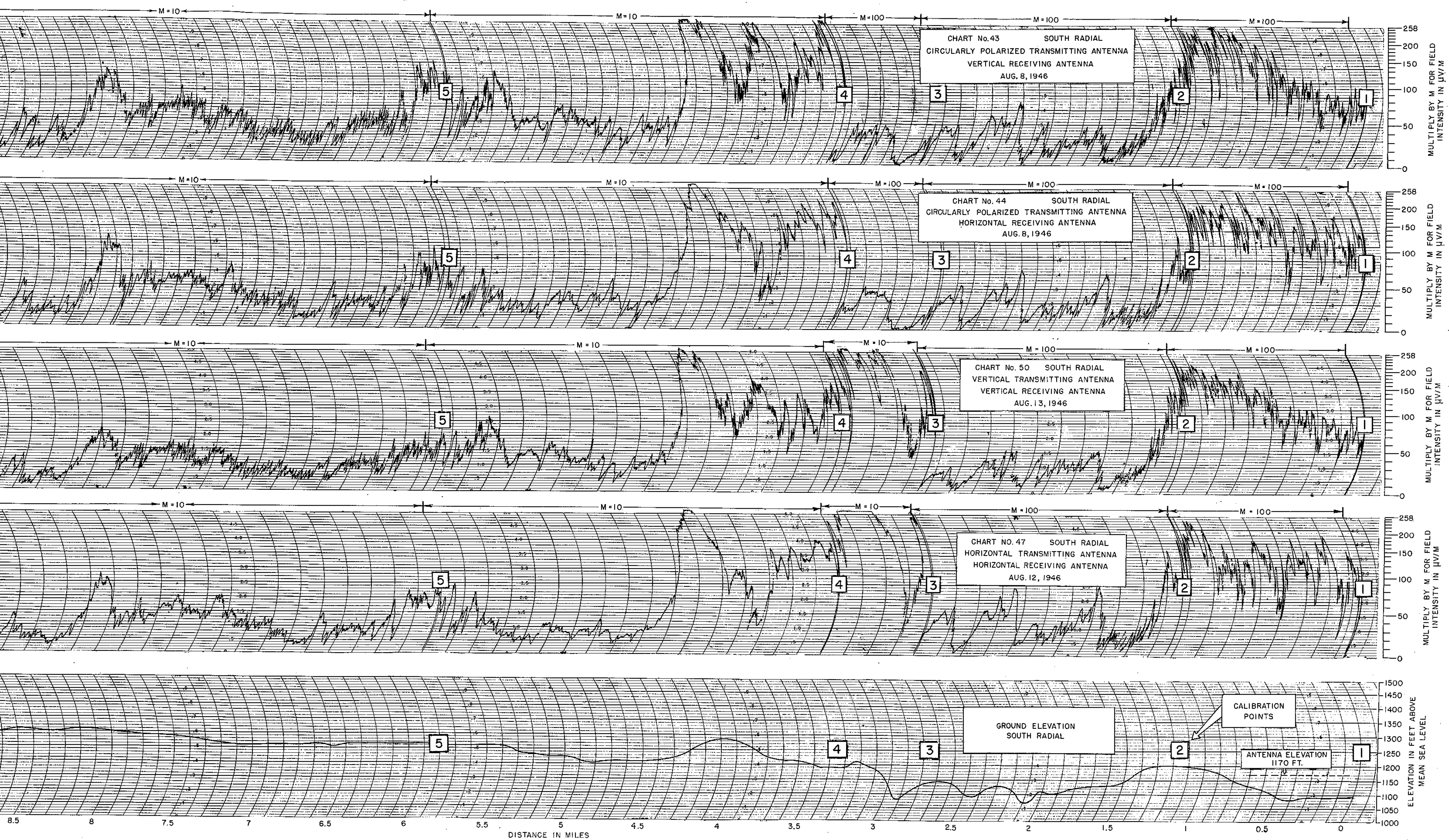
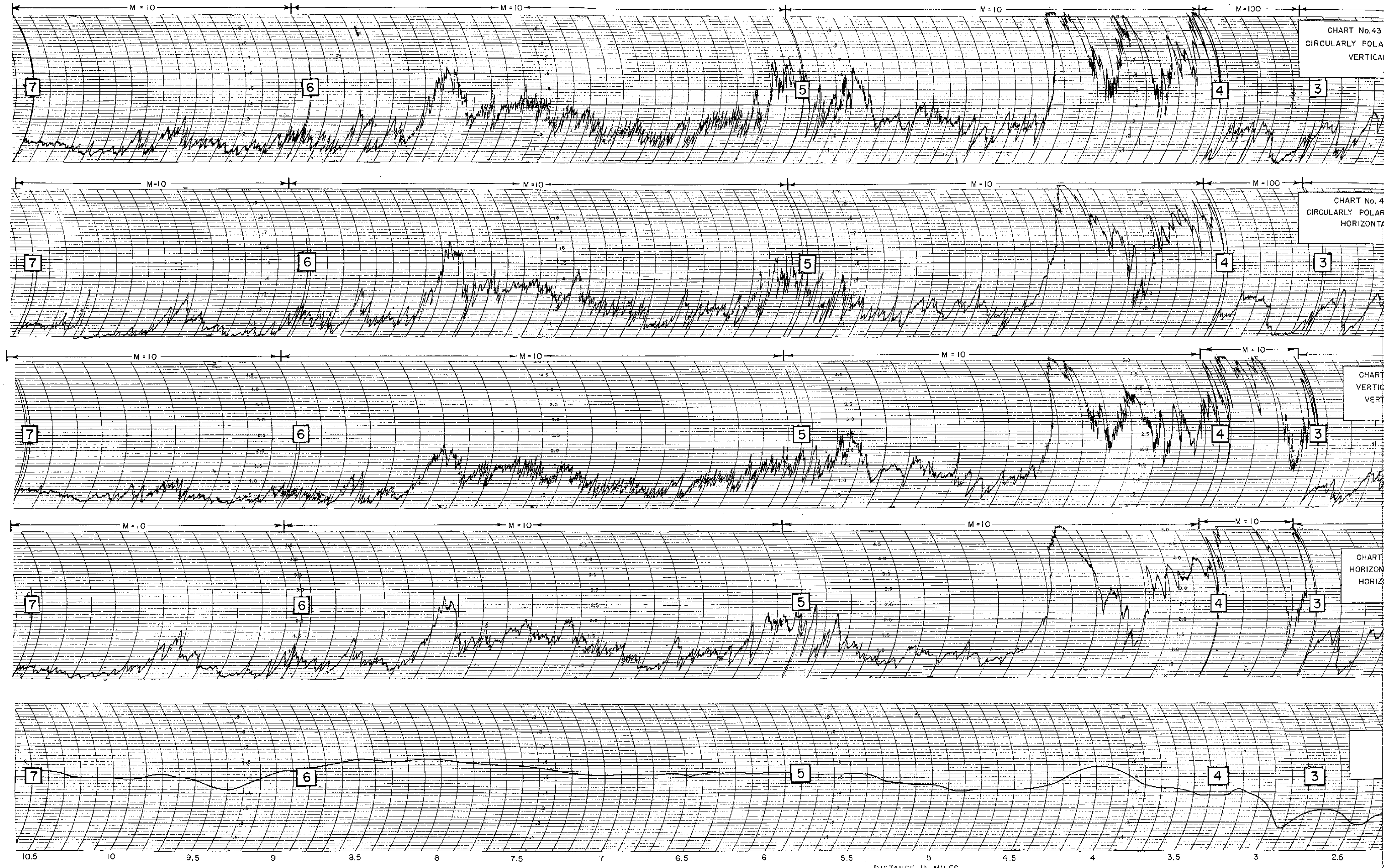


FIG. 22 a. — SOUTH RADIAL RECORDINGS



M = 10
M = 10
M = 10
M = 100
CHART No. 43
CIRCULARLY POLA
VERTICA
7
6
5
4
3
M = 10
M = 10
M = 10
M = 100
CHART No. 4
CIRCULARLY POLAR
HORIZONTA
7
6
5
4
3
M = 10
M = 10
M = 10
M = 10
CHART
VERTIC
VERT
7
6
5
4
3
M = 10
M = 10
M = 10
M = 10
CHART
HORIZON
HORIZ
7
6
5
4
3
7
6
5
4
3
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
DISTANCE IN MILES

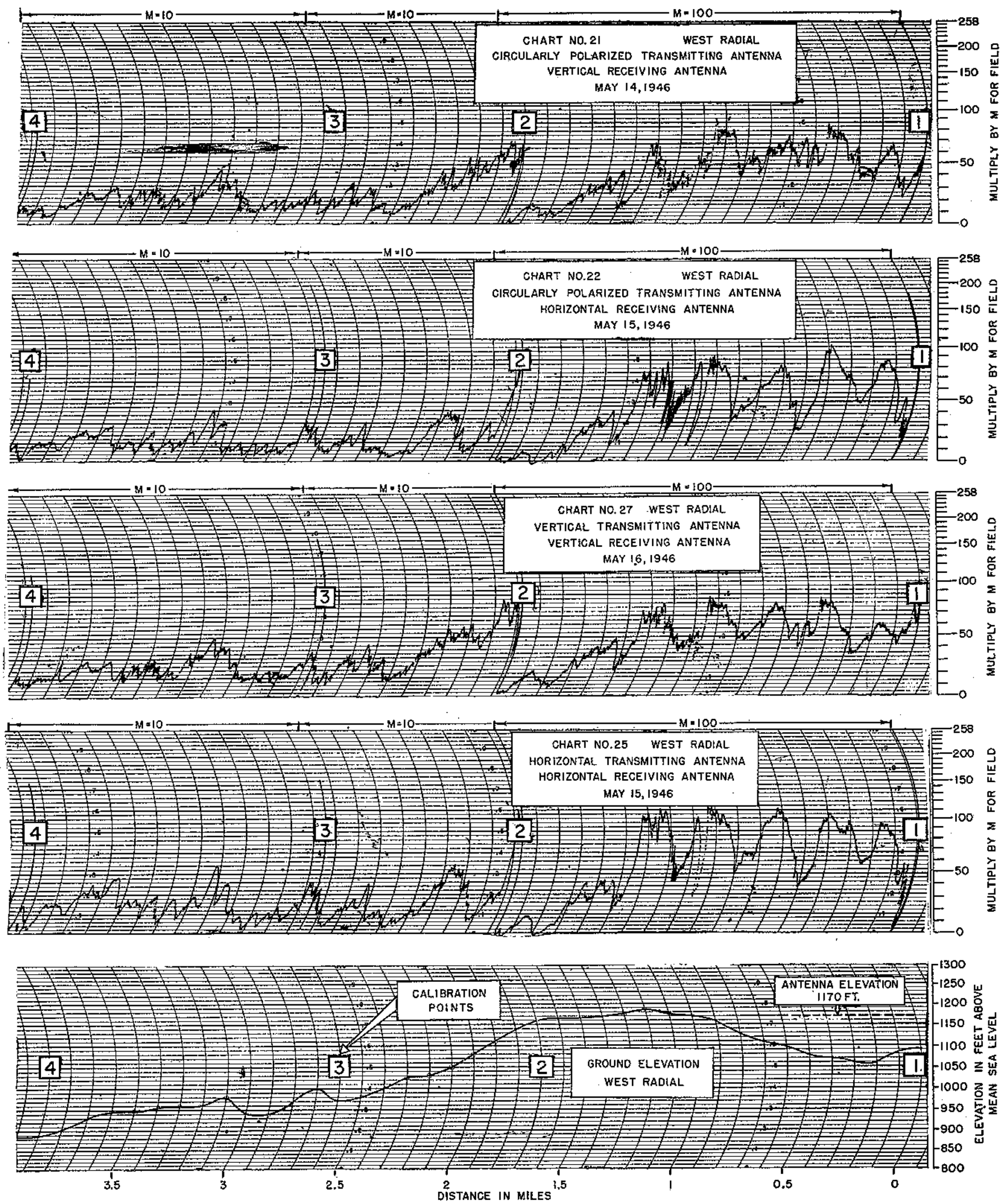


FIG. 23 a. — WEST RADIAL RECORDINGS

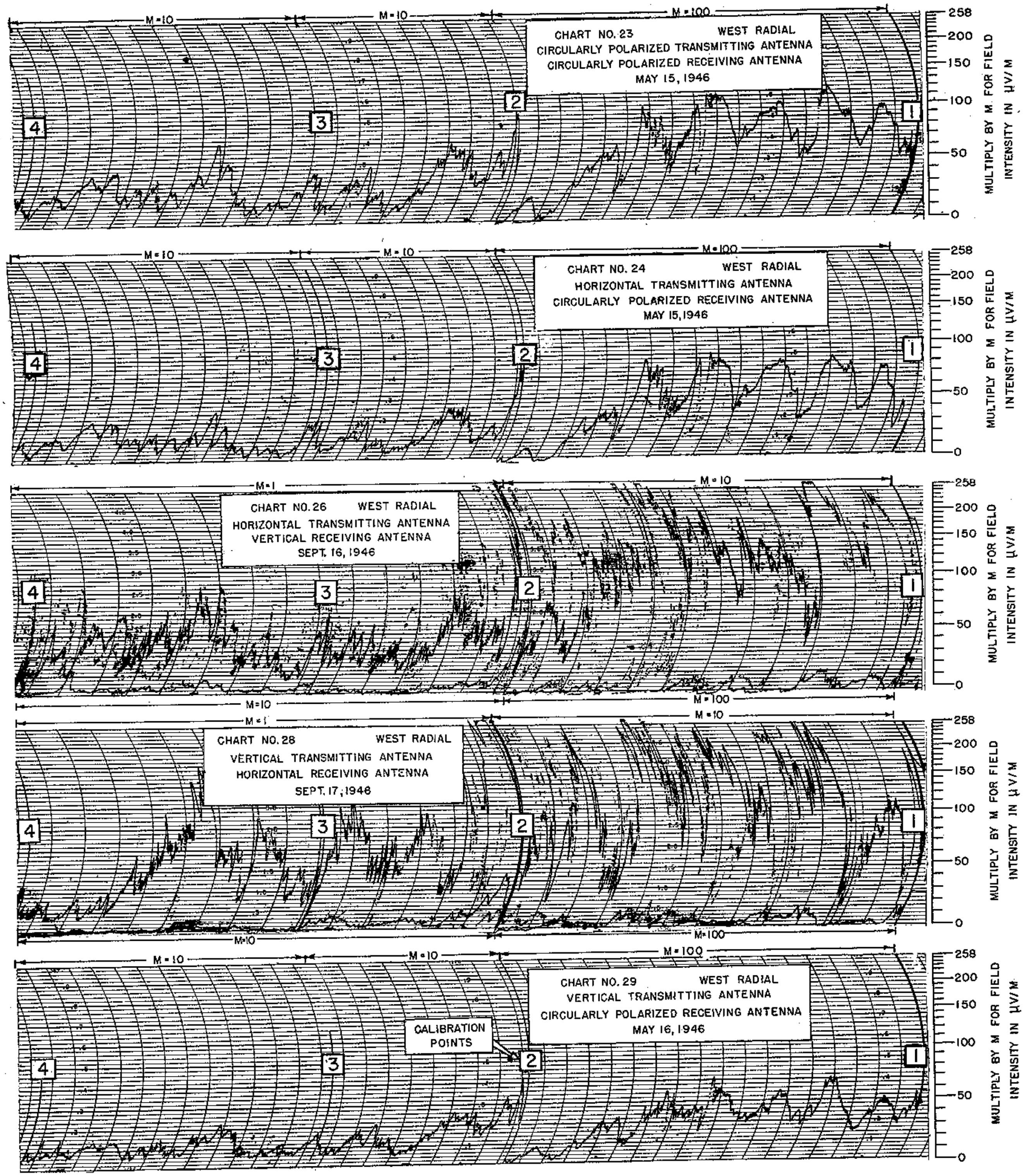


FIG. 23 b.— WEST RADIAL RECORDINGS

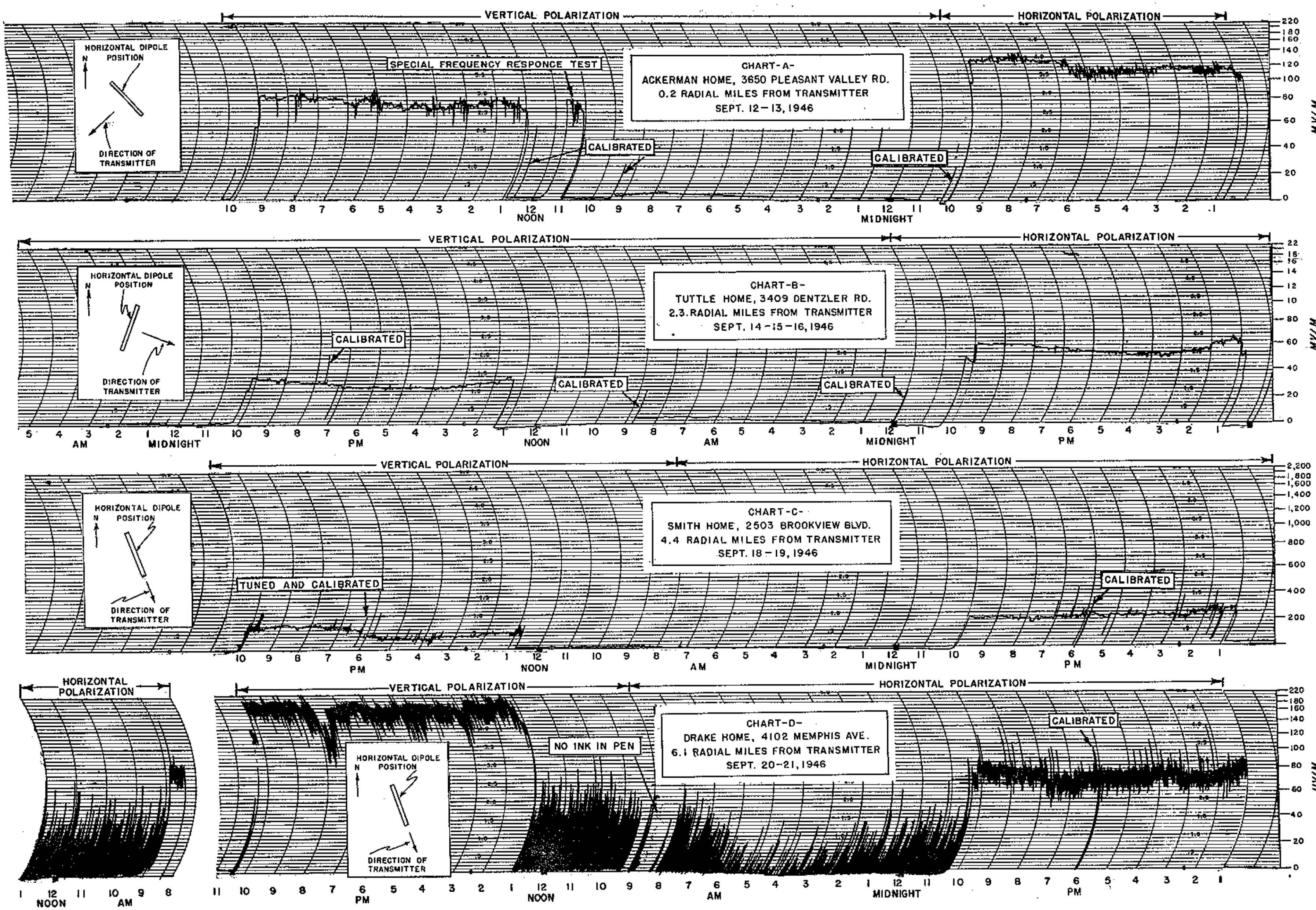


FIG. 24 a.— FIXED POINT RECORDINGS OF CIRCULARLY POLARIZED PROPAGATION

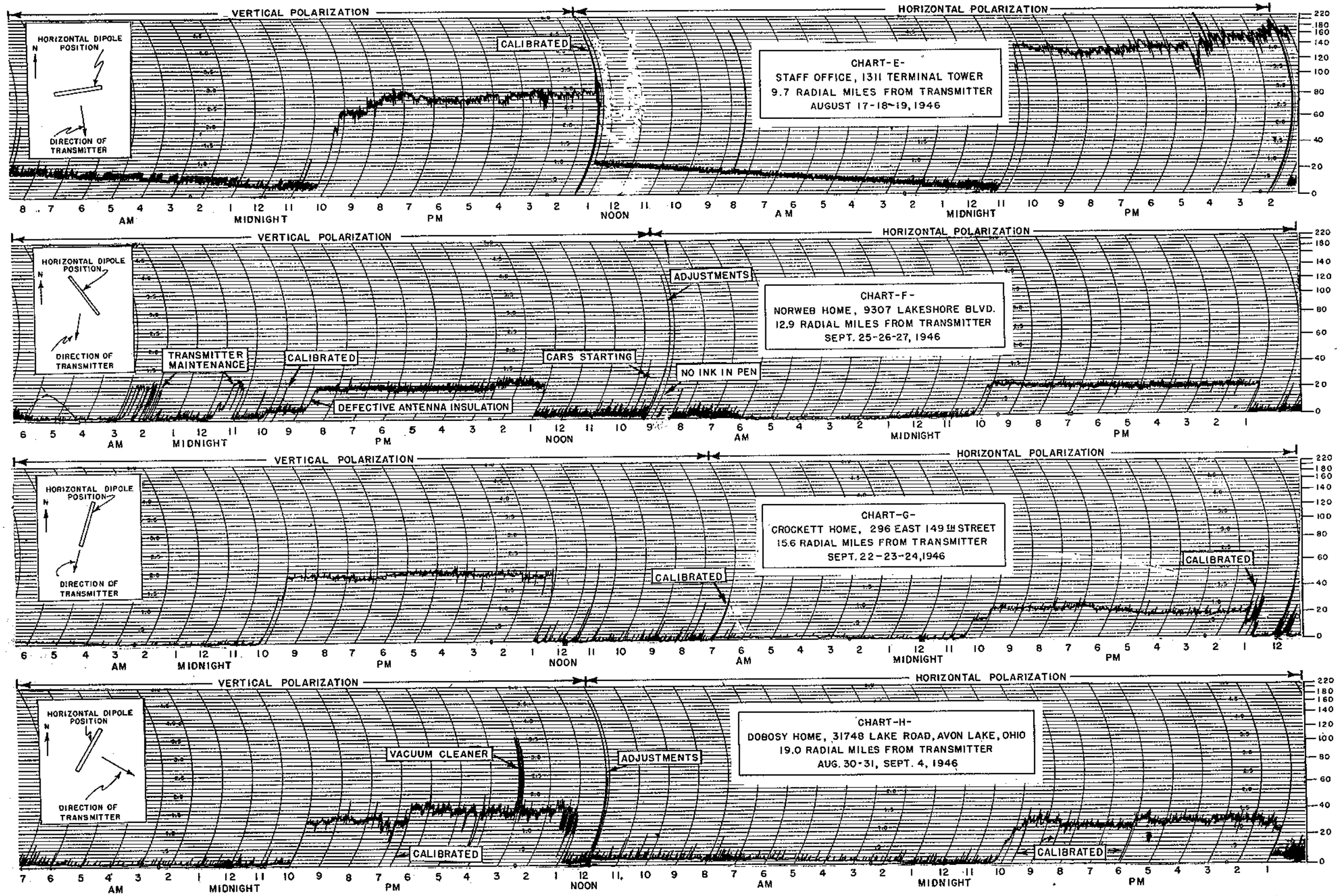
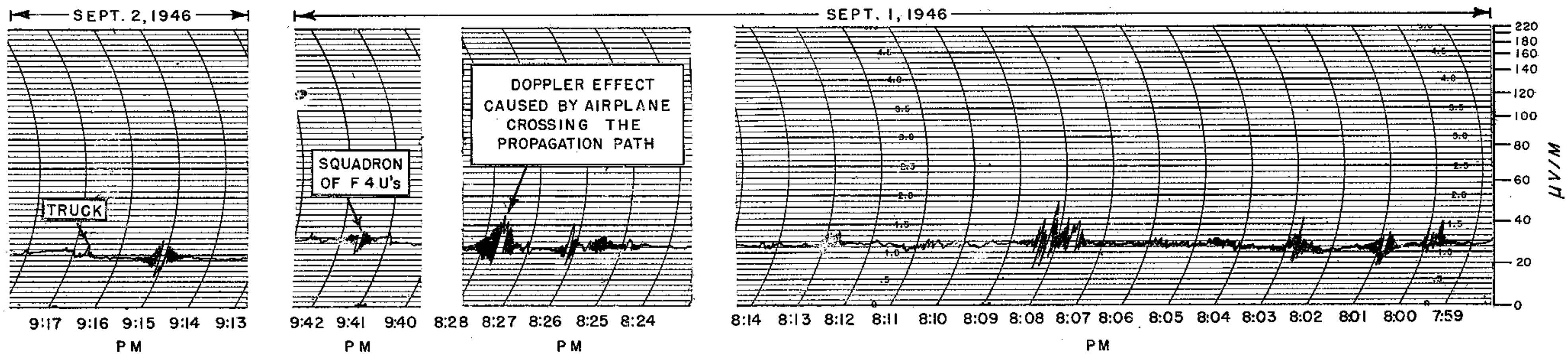
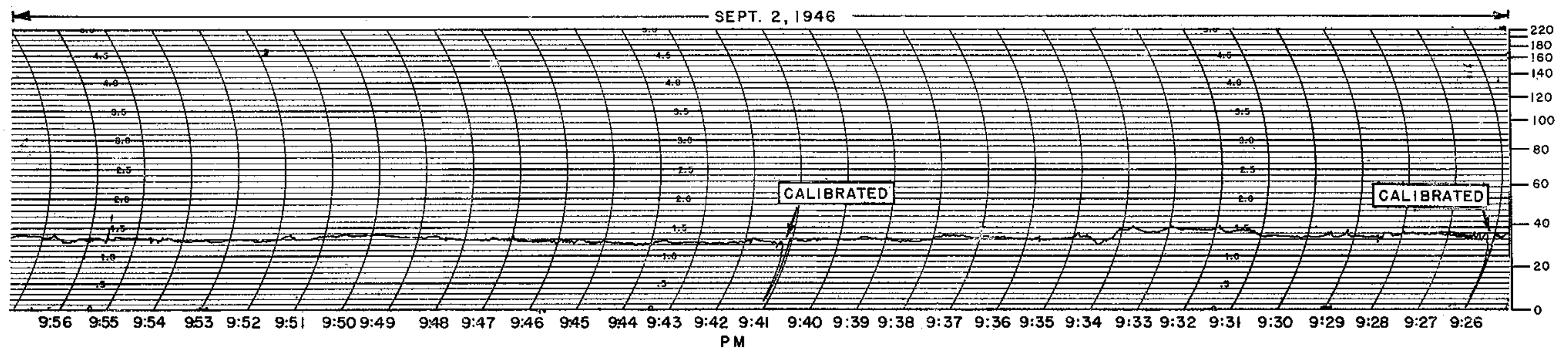


FIG. 24b.— FIXED POINT RECORDINGS OF CIRCULARLY POLARIZED PROPAGATION



(a) RECEIVING ANTENNA HORIZONTAL *



(b) RECEIVING ANTENNA VERTICAL *

* NOTE: CIRCULARLY POLARIZED PROPAGATION.

FIG. 25.—EXPANDED TIME SCALE RECORDING TAKEN AT FIXED LOCATION H.