DEPARTMENT OF COMMERCE

BUREAU OF AIR COMMERCE

SAFETY AND PLANNING DIVISION

REPORT NO. 17

TESTS OF THE FIRST MANUFACTURED FAN MARKER

By

W. E. Jackson
P. D. McKeel
H. I. Metz
Radio Development Section

July - 1938

TABLE OF CONTENTS

12498

TESTS OF THE FIRST MANUFACTURED FAN MARKER

By

W. E. Jackson, P. D. McKeel, and H. I. Metz

SUMMARY

The first commercially-manufactured fan type marker was installed in February, 1938, in the vicinity of New Brunswick, N. J., at light beacon site No. 73, 20 miles out on the southwest leg of the Newark radio range (See Fig. 1). The equipment installed consists of a counterpoise, directive antenna array, and two crystal-controlled transmitters. One transmitter serves as an automatic standby unit and is started in case of tube or equipment failure of the other. This installation is the first of 22 on Bureau contract No. Cc-2615. Adjustments and flight tests were made in the period between February 14 and March 12, 1938. The marker was commissioned on March 2, 1938, for continuous operation.

INTRODUCTION

The development of fan type ultra-high frequency markers for use as fixes and let-down aids in airways traffic control was covered in two reports recently released by the Safety and Planning Division.* The development of these markers was accomplished at Washington, D. C., and Bowie, Md., in 1936 and 1937.

*Report No. 5 — Development of Fan Type Ultra-High Frequency Radio Markers as a Traffic Control and Let-Down Aid.

Report No. 14— Development of an Improved Ultra-High Frequency Fan Marker.

12498

The first installation of commercially-made fan marker equipment was made at New Brunswick for two reasons. First, the site was near the manufacturer's plant (New York) and was easily accessible. It is about 200 feet from U. S. Route No. 1, and is only a few thousand feet from the intersection of Routes Nos. 1 and 25. Thus the work at this site could be efficiently handled. Second, a large amount of scheduled airline traffic, Army, Navy, and itinerant flights pass this site daily. Therefore, the marker could be observed conveniently and studied at once by the majority of those concerned with the marker installation program.

APPARATUS

The equipment installed at New Brunswick consists of the marker antenna and counterpoise, the transmission line, and the transmitter house containing two transmitters. This equipment is clearly shown in the photographs, Figs. 2 to 8, inclusive. These photographs show the relative position of the equipment with respect to the 90-foot beacon light tower. Drawings 9 to 11 inclusive give the exact dimensions of the equipment installed and the position with respect to the tower. The two transmitters are of identical construction, and when properly adjusted are each capable of producing a 100-watt 75-megacycle carrier with 100 per cent modulation at 3000 cycles. Both units are permanently connected to the transmission line, and by means of an automatic monitoring and switching device, power is removed from the regular channel and the standby equipment is caused to operate. The transmitter details are shown in photographs, Figs. 12, 13, and 14.

NS-31, a fabric-covered Fairchild monoplane, used in some of the flights during earlier fan marker development at Washington, was available for flight checking of the new marker installation. The aircraft receiving antenna arrangement is shown in Fig. 15. A Bureau type RUD marker receiver and a Bureau experimental crystal-controlled superheterodyne receiver were available for the flights. Neither of these receivers conform entirely with the specifications for the type of receiver which eventually will be made standard for marker reception on transport aircraft. The RUD receiver, Fig. 16, is of the detector-amplifier type and has been described in the Air Commerce Bulletin.* Its circuit diagram is given in Fig. 17. The radio frequency selectivity of the receiver is inherently poor. The circuits overload tremendously when the strong central portion of the marker signal pattern is encountered. These faults, however, do not affect the reliability of the receiver or the minimum signal which will light the marker indicator lamp; they merely affect the relation between the true maximum signal strength and that indicated on the recordings taken during flights. The use of this receiver to determine size and shape of fan marker patterns, therefore, was considered satisfactory. The superheterodyne receiver, having been constructed with the same audio and output circuit as the RUD receiver, possesses the same general overloading features.

The RUD receiver was used throughout the New Brunswick tests. The recordings of receiver output made during these tests are consequently inaccurate with respect to signal amplitude on flights near the station where overloading occurs, except on certain flights during which the receiver was intentionally rendered less sensitive in order to avoid this overloading. The graphic recording equipment consisted of a standard

*"Cone of Silence Markers Identify Exact Locations of Range Stations", A.C.B. Vol. 8, No. 8, page 169, February 15, 1937.

12498

Esterline Angus (0-5 ma) instrument equipped with a rectox rectifier and a single tube input amplifier. The receiver output was connected to a pair of headphones and the recording amplifier.

TRANSMITTER TESTS

Ground tests conducted prior to and concurrently with the installation of the equipment at New Brunswick covered the following points:

1. Investigation of the monitor control action.
2. Tests on balancing and phasing the antenna system.
3. Tests on operation of the mercury vapor rectifier tubes at high and low ambient temperatures.

The investigation of the monitor circuit was conducted at the manufacturer's plant in which data were taken on the watts output of the transmitter for normal operating conditions and for the critical conditions at which the automatic monitor transfer circuit should function. For a given setting of the monitor current, the point at which the transfer operation takes place was observed for both a reduction of modulation and a reduction of carrier. These values were observed for line potentials above and below the normal 110-volt value and a curve plotted in Fig. 18. Similar data were taken for other conditions of the monitor current, resulting in a series of curves from which it was possible to determine the most desirable setting of the monitor current. This value was found to be 3.5 ma., and curves of Fig. 18 are based thereon. At this setting and with normal conditions existing in the transmitter, the equipment will not transfer to the standby transmitter until the supply voltage has dropped to a value of about 96 volts. A reduction of 20 per cent from normal modulation or 50 per cent in the carrier power will cause

12498

operation of the automatic transfer feature for this monitor adjustment.

From the carrier output curves of Fig. 18, one might be led to believe that since the carrier output of the transmitter could be reduced from 100 watts to 50 watts before operation of the automatic transfer feature takes place, a serious reduction in field pattern might occur just prior to operation of the transfer. This, however, is not exactly true, because in taking the curves of carrier output versus transfer operation, the modulator output was held constant. This means that as the carrier is reduced below its normal 100 watt value the percentage of modulation is continuously increasing. The operation of the transfer device depends upon the rectified audio component of the output signal which is identical to the operation of the receivers used aboard aircraft in receiving signals from this marker station. The operation of the monitor depends, therefore, upon modulated power output of the transmitter and it may be observed that a reduction of about 20 per cent in this power will cause operation of the transfer rather than the 50 per cent as indicated by the carrier curves of Fig. 18.

An investigation was conducted at the New Brunswick installation to determine optimum antenna current balance and transmission line termination. After adjustments were completed the following antenna currents were obtained and considered satisfactory:

Antenna No.	1	2	3	4	Ratio Min. to Max.
Current	68	84	84	68	.81

The antenna elements are numbered starting with the one farthest from the transmitter. After adjustment of line termination, a line current having substantially uniform distribution (ratio 1:1) was obtained. As the transmitters are identical in construction and are connected to the antenna by lines which are of equal length, identical operation was obtained from both transmitters. The final arrangement of the antenna is illustrated in the photographs of Figs. 4 and 5; the dimensions and placement are shown in Figs. 9 and 10.

It was found in the New Brunswick installation that when the ambient temperature was below about 20 degrees F., the normally idle standby transmitter would not start correctly. The ventilating fans used in these transmitters caused excessive circulation of cold air around the mercury vapor rectifier tubes, maintaining the tube at a temperature too low for correct operation. Heaters were installed between two pairs of rectifier tubes, and were connected to the power mains through a 60-degree thermostat. A thermostat was also added to the ventilating fan motor circuit to prevent its operation when the temperature dropped below about 70 degrees F. Thus the mercury vapor rectifier tubes were maintained between about 50 and 70 degrees F. for moderate changes in ambient temperatures. An investigation was made in cooperation with the manufacturer which resulted in the design of an enclosure for the rectifier tubes and the installation of suitable thermostatically-controlled heaters within the enclosure (See Fig. 19). It was then possible to maintain the tubes within the required temperature limits for operation in ambient temperatures as low as minus 40 degrees F. Sufficient openings were provided in the enclosure to allow the ventilating fan to circulate air around the rectifier tubes to prevent their heating in summer weather beyond the limits prescribed by their manufacturer. The position of the installed enclosure is shown in Fig. 14.

12498

During the development and manufacture of the transmitting equipment there was considerable discussion concerning the method of keying that should be used. Two methods were considered: that of keying the complete output (carrier and modulation), and that of keying only the modulation. It was at first considered advisable and desirable to key the complete output and eliminate all radiation during periods when the key is open. This would incidentally increase the life of the transmitting tubes. Tone modulation on the other hand was believed to be much easier to accomplish, and the power supply surges inherent in carrier keying would be avoided. Furthermore, the receivers which will eventually be used with the marker system will contain a limited AVC action and it was believed they would therefore operate better when on constant carrier.

The main transmitter at New Brunswick was arranged for modulation keying and the standby transmitter was connected for carrier, or complete, keying. In flights made with the RUD type receiver described in this report, both types of keying appeared to be satisfactory. Only a slight increase in keying clicks was observed in the carrier type of keying. Tests were made later in cooperation with the Bell Telephone Laboratories using a marker receiver built in accordance with airlines' specifications which contains a limited AVC action, and from these it was apparent that the use of keyed carrier was entirely unsatisfactory. A slight click was heard in the headphones on the break of each dash for tone keying, but the amplitude of the click was of negligible value. Using carrier keying, however, the headphone signal appeared to contain a short dot after the break of each dash. This may have been the result

12498

---

and recording equipment having remained unchanged in the interim. Fig. 20 is a copy of the recordings, showing only the peak deflections of the

After the completion of the New Brunswick tests, and while enroute from Newark to Washington, the relative patterns of the New Brunswick and Bowie markers were again recorded. On this occasion the receiver sensitivity was reduced by detuning in order to avoid overloading. Copies of the recordings are reproduced in Fig. 21. The slight dissimilarity in the shape of these two recordings can be attributed to the difference in altitude between the two flights and difference in the power output of the two transmitters. The recording of the New Brunswick marker shows definite receiver overloading not present in the Bowie recording.

A number of flights were made at New Brunswick, particularly at 2000- and 7000-foot altitudes. Flights were also made at other altitudes between 500 and 7000 feet, in order to assure a complete exploration of the pattern. The first flights were made with the receiver tuned, in order to provide data for plotting the area over which the marker indicator would light. Final flights were made with the receiver detuned, to reduce sensitivity, so that a more accurate knowledge of the amplitudes and positions of the three radiated lobes could be obtained. Recordings were made on all flights, but not all of them have been used in this report.

From some of the recordings made with the de-sensitized receiver, it was possible to determine the relative value of the three lobes found to exist in the pattern directly over the station. To do this, the receiver and recorder were returned to the laboratory and were calibrated against a Ferris signal generator, Model No. 18B, the generator output being adjusted to give the same recording amplitudes that were obtained in flight. The ratio of the main lobe to either side lobe

12498

was approximately 7 to 1 microvolts, approaching closely the correct 15 per cent ratio obtained by mathematical analysis of the type of transmitting antenna array used.

The most important feature of the tests at New Brunswick was the determination of the effect of the 90-foot steel beacon light tower adjacent to which the marker transmitting antenna is located. The center of the antenna array was placed only 39 feet from the center of the tower base, in order that the entire installation would be within the limits of property already under lease for the beacon light site. The vertical patterns shown in Figs. 22a and 22b were made from recordings taken during flights directly over the station at altitudes of between 500 and 5000 feet, and with the receiver sensitivity reduced. The patterns of Fig. 22a were made in southwest flights, and others in northeast flights. These patterns show the relative position of the tower and radiated lobes, from which effects of the proximity of the tower can be observed. It appears that there is only a slight shadowing effect caused by the tower. It will be noted in Fig. 22a that the small minor lobe appears on the side where shadowing by the tower might be expected. In Fig. 22b this same lobe appears larger and almost equal to the other minor lobe. The reason for this difference can be explained by a possible slight leaning of the receiving antenna pattern behind a true vertical line drawn between airplane and earth. There is, however, a definite effect of the tower on the minor lobe and a slight leaning effect caused by the tower on the main lobe. Neither of these are of any consequence to the performance of the system. The recordings from which the patterns of Fig. 22 were obtained were copied and are reproduced in Fig. 23. Fig. 23 shows definitely the effect of overloading of the

12498

receiver on the recording. The top recording (5000 ft. altitude) appears to contain three lobes, whereas there is but one. The side (minor) lobes have diverged and diminished to an almost imperceptible value.

In Fig. 24, the relative pattern at 3000 feet altitude is plotted to show the presence of reflections and shadows, and for the study of the relative position of the minor lobes. It will be noted from the recordings included in Fig. 24 for flight courses northwest 1.5 miles and northwest 2 miles from the station that there is no evidence of irregularities which might be caused by the beacon light tower. The minor lobes, present in the central portion, are not observed in the flights on these courses.

From the record data taken at the 7000-foot altitude, the approximate pattern at this altitude was plotted in Fig. 25. The relative position of the two minor lobes at this altitude is shown in this figure. Two of the recordings taken during flights at this altitude are reproduced in Fig. 26. It will be observed that directly over the station, the two minor lobes are very evident, whereas in the flight made 6 miles on the southeast side of the station, the pattern is clear and free of the minor lobes.

From the composite data obtained on all flights made at the New Brunswick marker, the pattern dimensions in two vertical planes were plotted in Fig. 27. In this figure, curve 27a represents, for various altitudes, the distance in miles to either side of the station within which the signal is strong enough to operate the indicator light. It represents the number of miles which a ship may be off course and yet receive the marker signals. The curve, Fig. 27b, represents pattern "thickness" for various altitudes. The "miles through" dimension for

12498

each altitude is based on total operating time of indicator light, including operation caused by the two minor lobes. At some altitude the effect of the side lobes will be zero and the time of lighting on such flights directly over the station will depend only upon the extent of the major lobe. It is expected that the effect of the minor lobes will be insufficient to operate the indicator light at some altitude above 10,000 feet for normal receiver sensitivity. At this altitude, the thickness of the pattern will be somewhat decreased. This effect can be observed in examining the small dotted pattern shown in Fig. 27b. The dotted pattern was made with the receiver sensitivity reduced by detuning. Under these conditions the effect of the minor lobes was lost between altitudes of 3000 and 4000 feet.

RESULTS

The operation of the marker at New Brunswick adjacent to the 90-foot beacon light tower seems entirely satisfactory as far as could be determined from the flights made. A pattern measuring approximately 18 miles on the major axis and 4 miles thick was obtained at an altitude of 7000 feet which appears to be adequate and satisfactory for itinerant and scheduled transport use. On the basis of the patterns obtained, the power output and antenna system are considered to be satisfactory. It is believed that the ceiling or height of the pattern is well over 20,000 feet; however, flights have not yet been made on this type of marker at altitudes above 13,000 feet, due to lack of aircraft equipped for flight at higher altitudes.

Some difference of opinion may develop concerning the width-to-thickness ratio provided by this type of marker, and the ability of the

12498

pilot to determine accurately his position with a pattern 4 miles thick at 7000 feet. In the tests conducted by the Bureau with this type of marker, and with the Z marker, it appears desirable to take the time at which the marker indicator light first comes on, or the first complete group of flashes, as the indication of position over the station, rather than to use an average time of duration of light. The time at which the indicator light first flashes is slightly before the ship is over the station and the position varies only slightly with altitude, with normal changes in receiver sensitivity, and with transmitter power output. At any given altitude, the first complete flash group is a rather definite indication of the ship's entrance in the field pattern of the transmitter, and the position can be rechecked with reasonable accuracy.

CONCLUSIONS

On the basis of the many tests conducted on the experimental markers and particularly the tests conducted on the commercial model at New Brunswick, it is concluded that:

1. A satisfactory pattern, in both size and shape, is produced by the equipment being purchased on the existing contract. This presumes the use of an antenna on the aircraft having a pattern similar to that used in the Bureau tests, and with a receiver sensitivity approximately equal to that of the RUD receiver (1400 microvolts — measured by direct connection to Ferris 18B signal generator) used in the test flights.

2. The operation is not impaired appreciably when the transmitting antenna is placed adjacent to steel beacon light towers or other similar metallic objects provided these are in line with the antenna and not to either side.

12498

3. The use of tone keying is satisfactory on this type of marker for either the type of receiver used in the Bureau tests or for the type made in accordance with present airline specifications which provide for a limited AVC action.

4. The keying of the transmitter in various groups of dashes is a reasonable and simple way to identify the several markers associated with a given range station.

5. The operation of the monitor unit which controls the automatic transfer from the regular transmitter to the standby in the event of failure of the regular unit is satisfactory and reliable.

6. The operation of the transmitter, including the automatic transfer and starting of the standby unit, will be satisfactory in temperatures between the limits of minus 40 and plus 60 degrees C.

7. Operation at locations where there is considerable fluctuation in line voltage can be rendered more stable through the use of reliable automatic line voltage regulators.

FIGURE INDEX

No.

12498

19. Sketch of heating device and enclosure used to maintain correct temperature on the mercury vapor rectifier tubes.

20. Graphic records of two fan marker signals, Bowie and New Brunswick, with normal receiver sensitivity.

21. Graphic records of two fan marker signals, Bowie and New Brunswick, with reduced receiver sensitivity.

22. Patterns showing the relative effect of the adjacent 90-foot beacon light tower.

23. Graphic records made with reduced receiver sensitivity and used in plotting Figs. 22a and 22b.

24. Pattern and graphic records of signals at 3000 feet altitude showing negligible effect of beacon light tower.

25. Pattern at 7000 feet altitude showing the approximate position of the minor lobes.

26. Graphic records taken directly over station and at 6 miles southeast of station at 7000 feet altitude.

27. Pattern dimensions in a vertical plane showing thickness and width of pattern.

12498

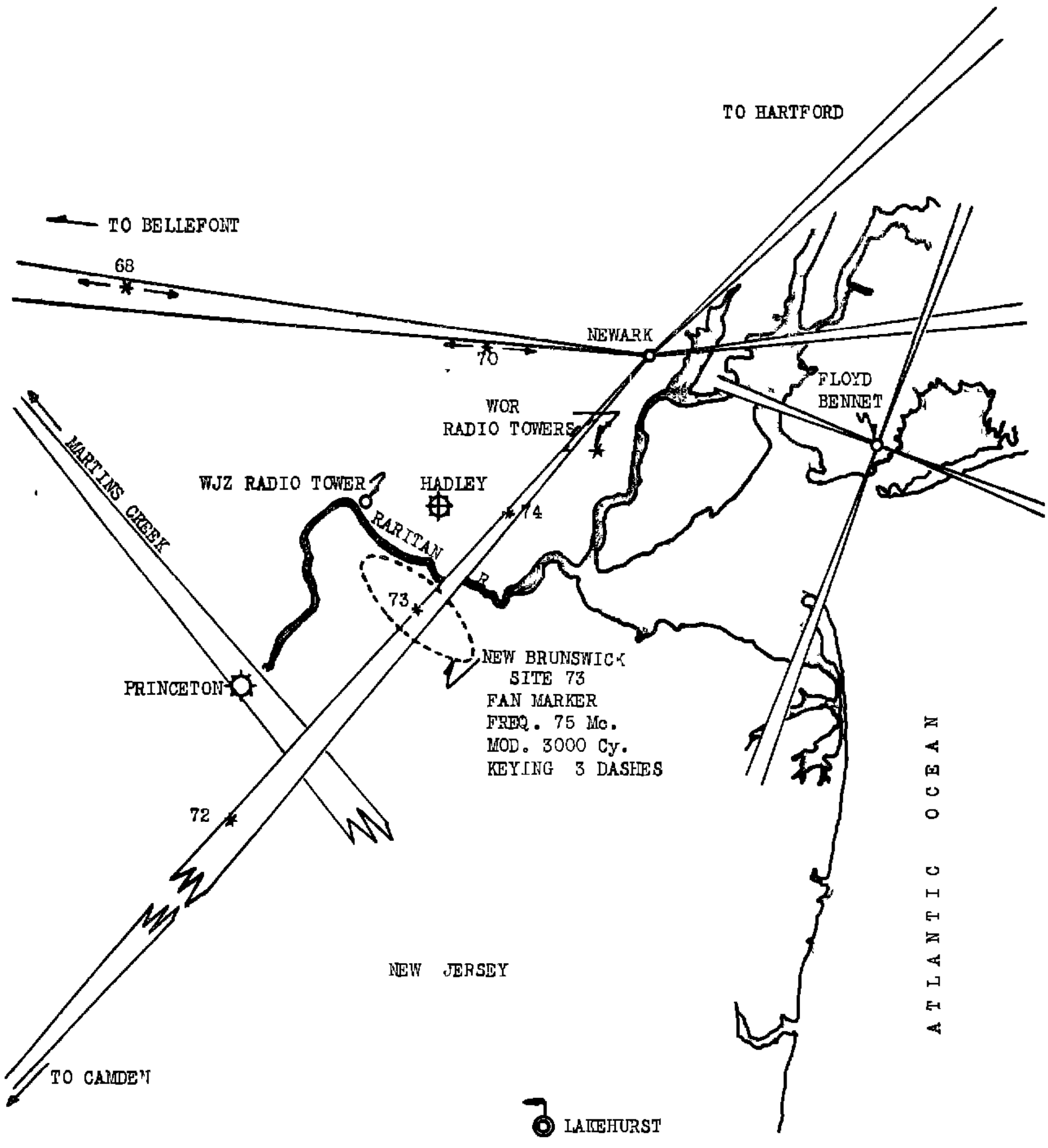


FIG. 1 FAN TYPE MARKER AT NEW BRUNSWICK, N.J.
SHOWING ITS POSITION WITH RESPECT TO THE AIRWAYS

12498

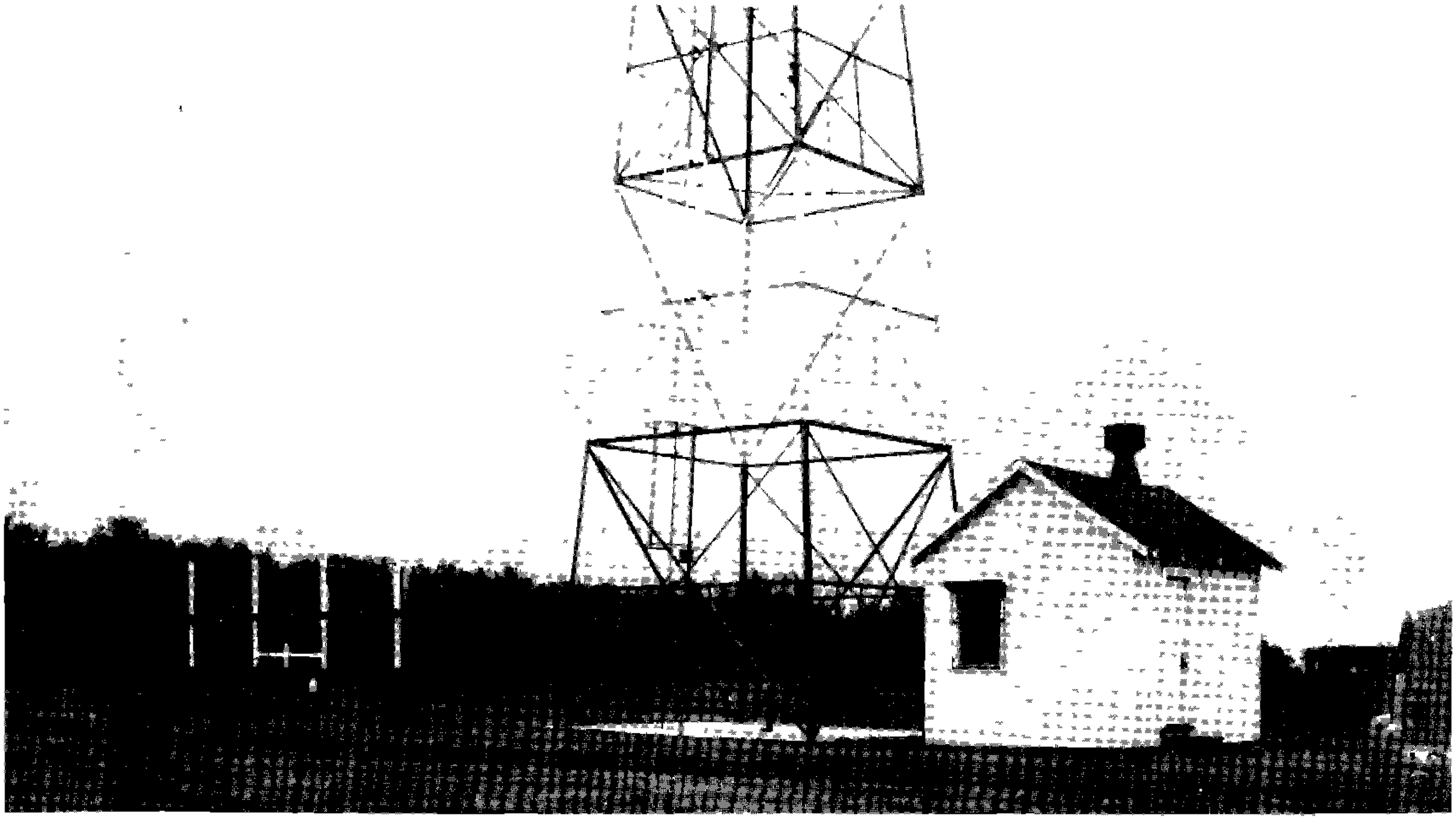


FIG. 2 FAN MARKER INSTALLATION, NEW BRUNSWICK, N. J.

Showing relative position of tower, building, and antenna

12498

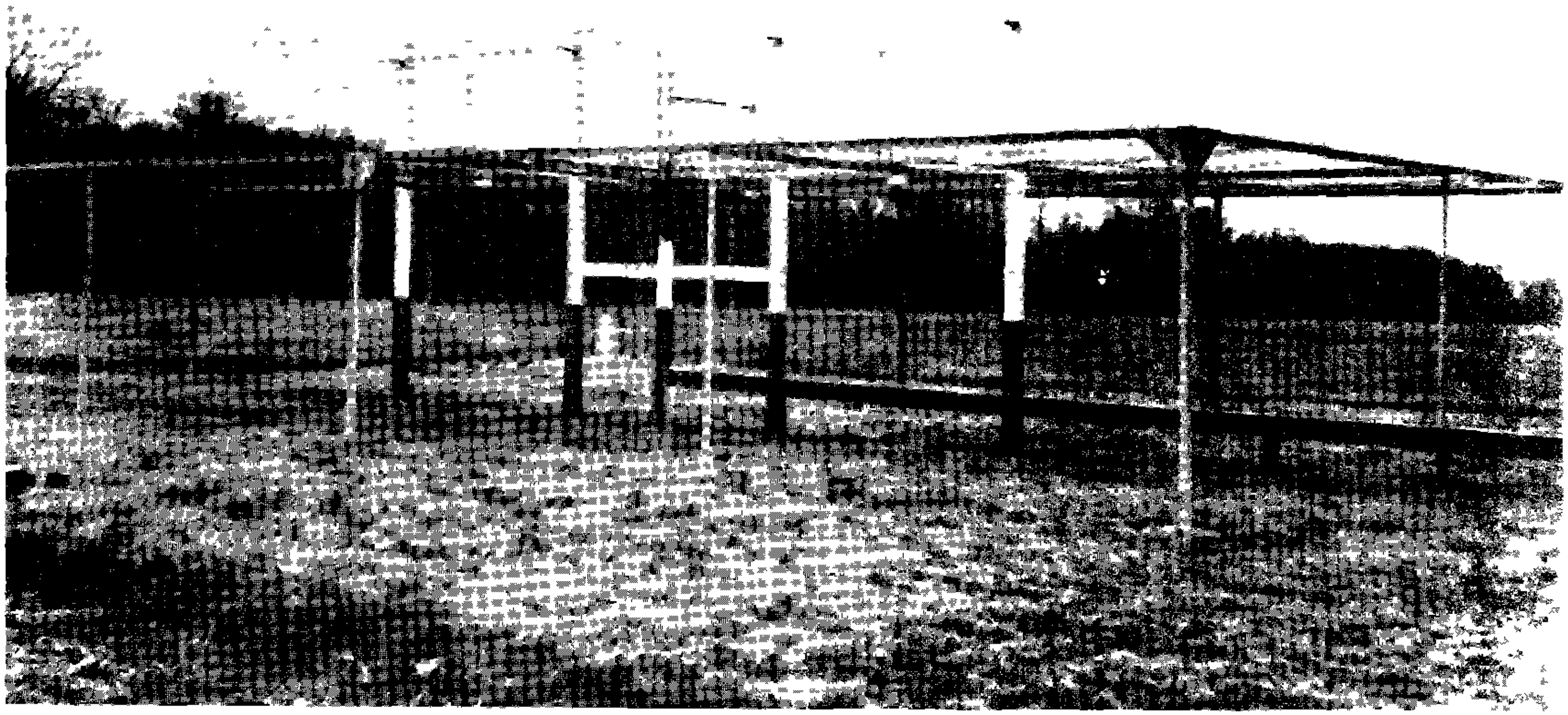


FIG. 3 FAN MARKER INSTALLATION, NEW BRUNSWICK, N. J.

Close-up view of antenna and counterpoise.

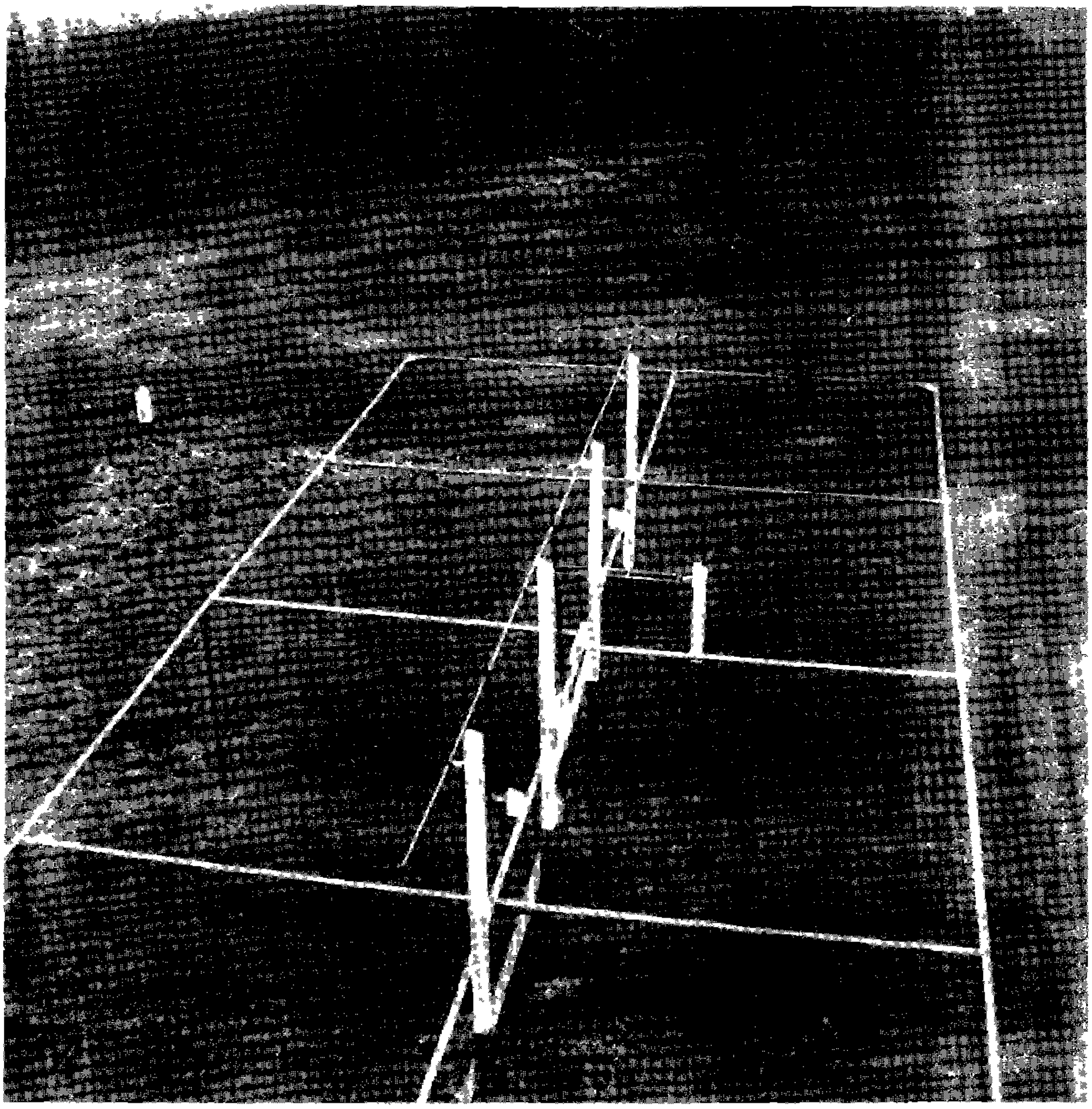


FIG. 4 FAN MARKER INSTALLATION, NEW BRUNSWICK, N. J.

View of antenna and counterpoise taken from tower.

12498

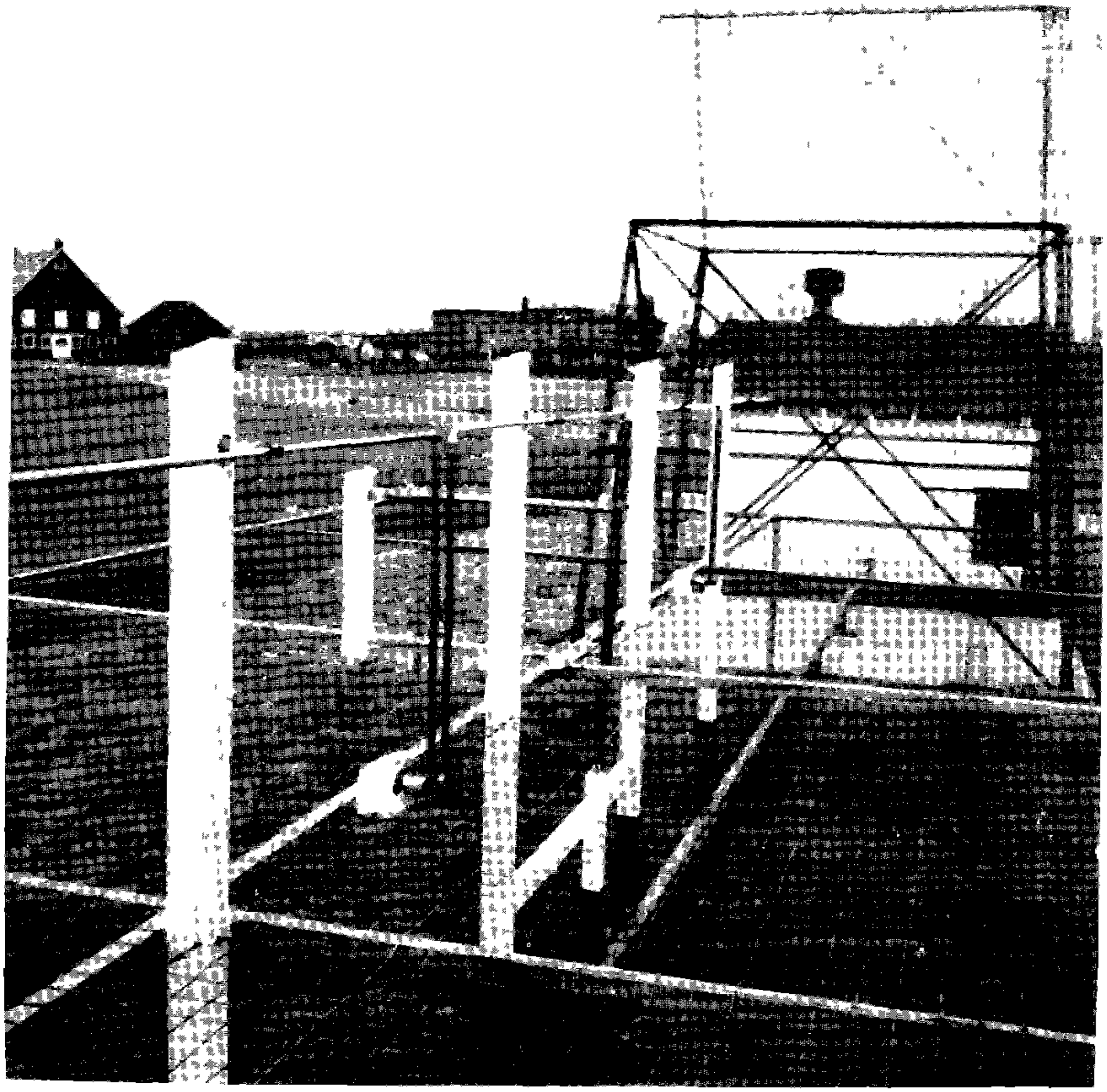


FIG. 5 FAN MARKER INSTALLATION, NEW BRUNSWICK, N. J.

Showing antenna supporting details.

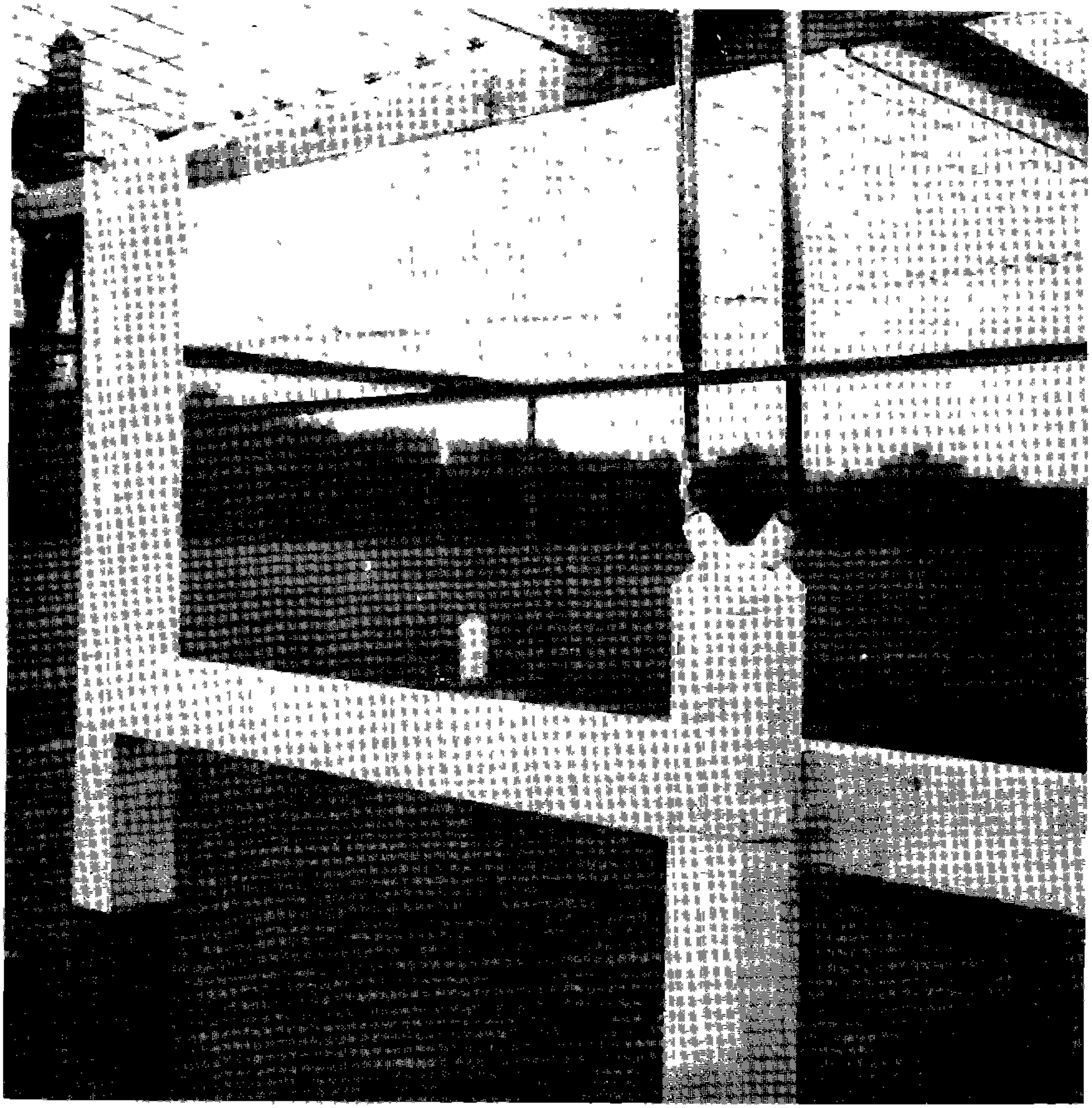


FIG. 6 FAN MARKER INSTALLATION, NEW BRUNSWICK, N. J.

Transmission line end details

12498

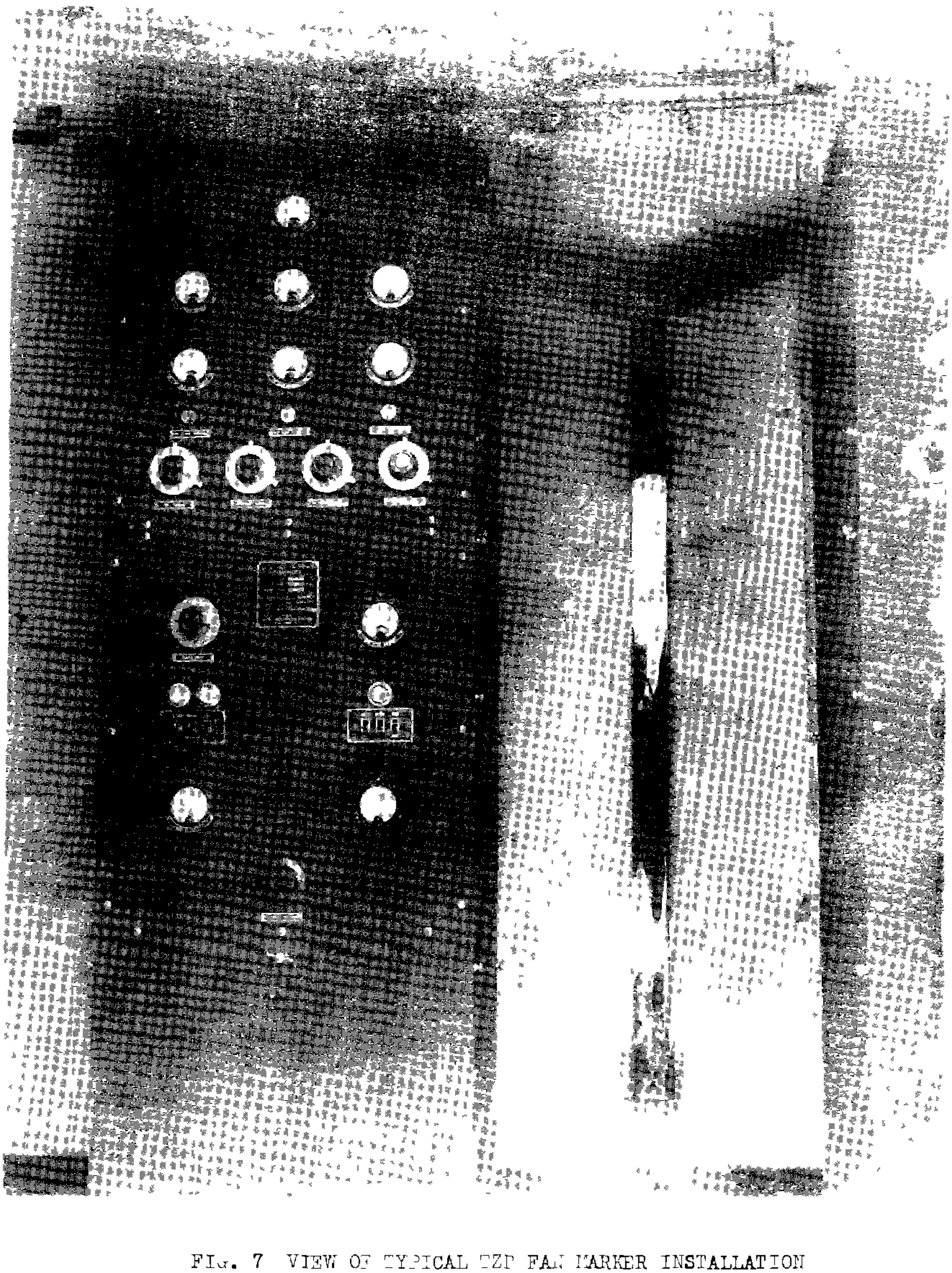


FIG. 7 VIEW OF TYPICAL TZP FAN MARKER INSTALLATION

12498

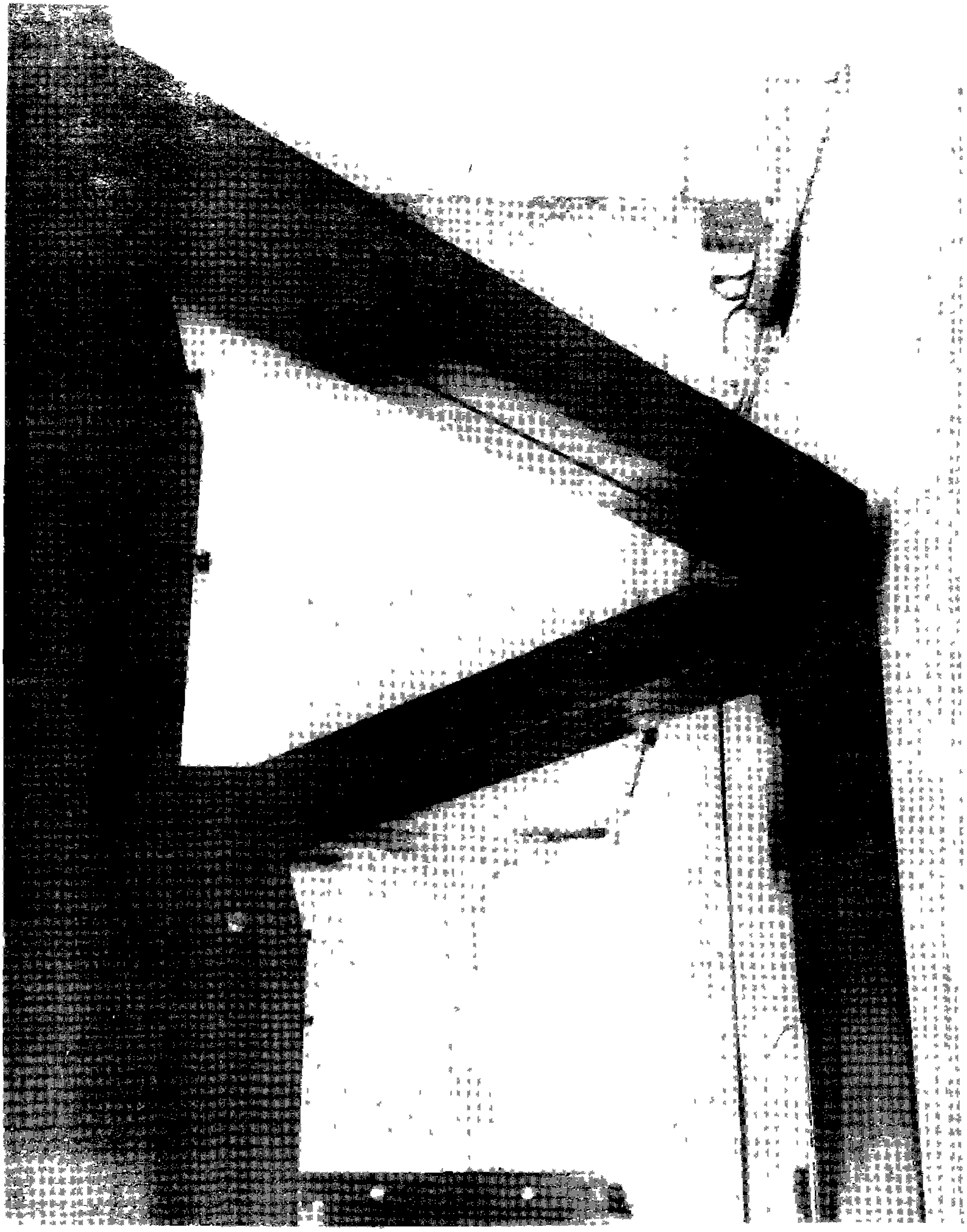


FIG. 8 METHOD OF CONNECTING THE TRANSMISSION LINE TO THE TWO TRANSMITTERS

12498

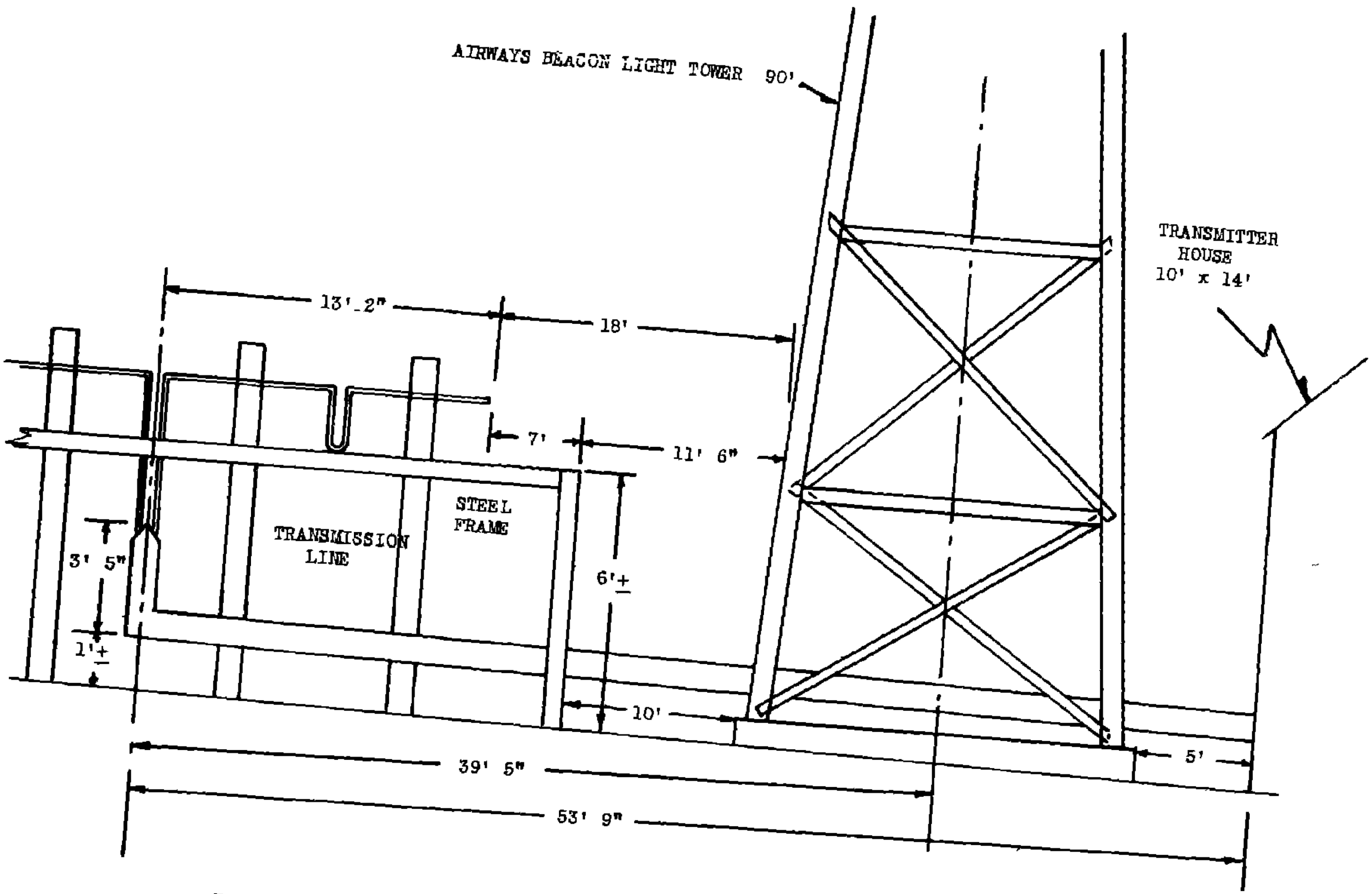


FIG. 9 DRAWING SHOWING RELATIVE PLACEMENT OF ANTENNA AND COUNTERPOISE WITH RESPECT TO THE BEACON LIGHT TOWER

12498

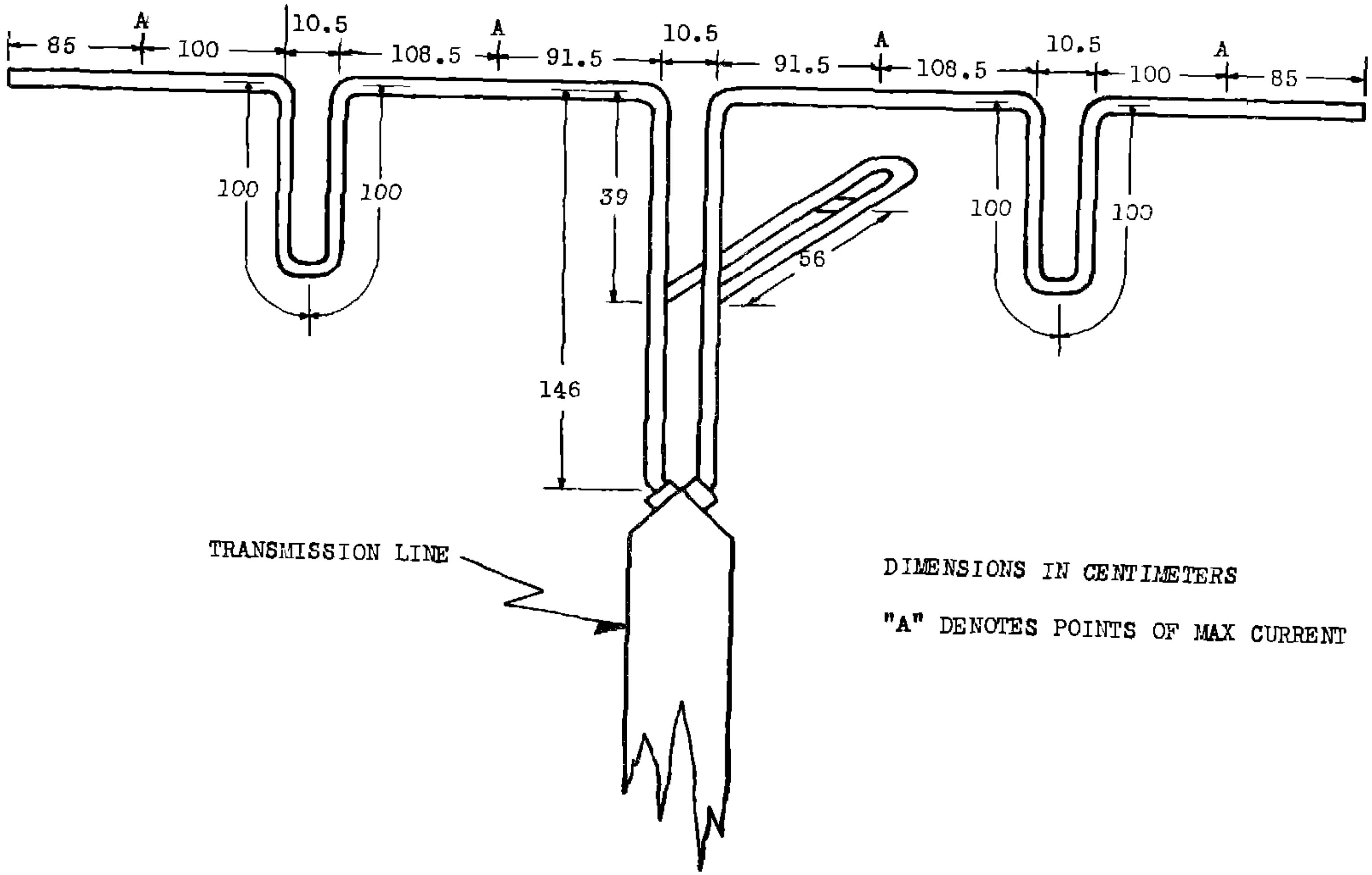


FIG. 10 DRAWING SHOWING EXACT DIMENSIONS OF ANTENNA DETAILS

12498

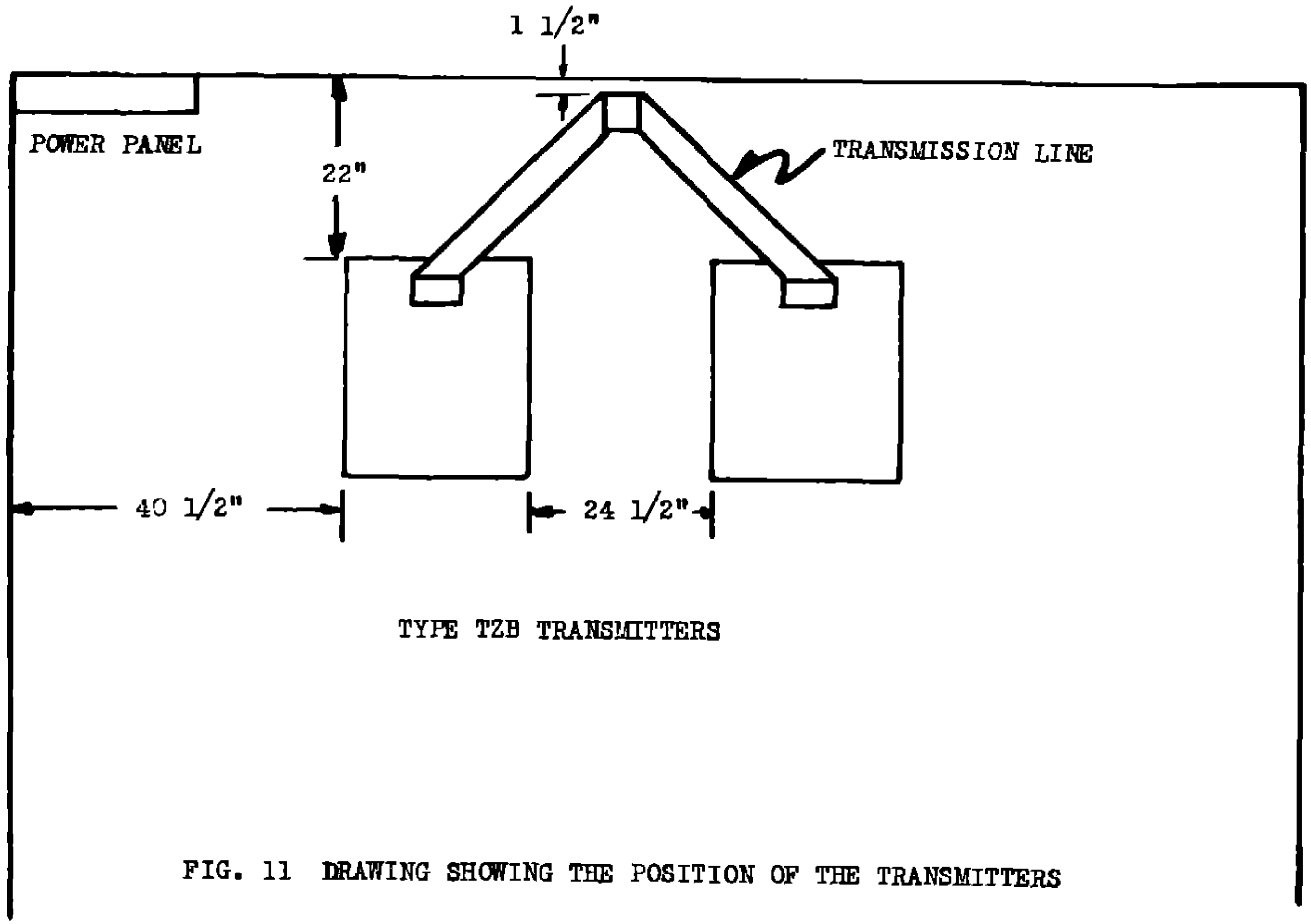


FIG. 11 DRAWING SHOWING THE POSITION OF THE TRANSMITTERS

12498

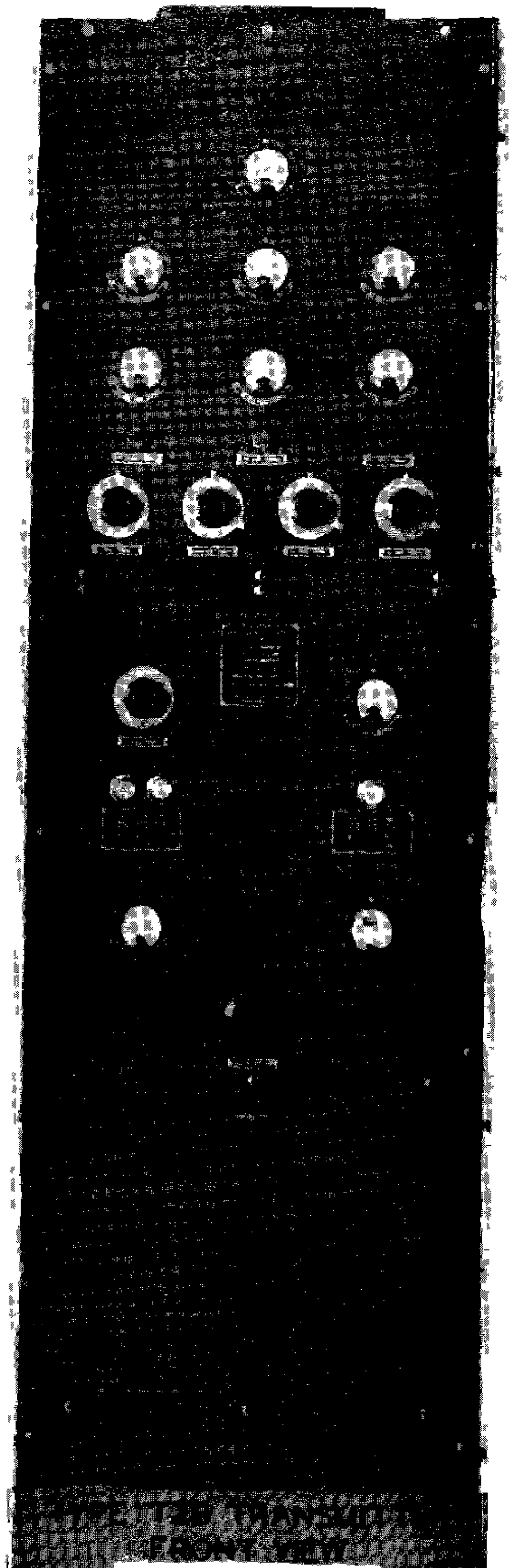


FIG. 12

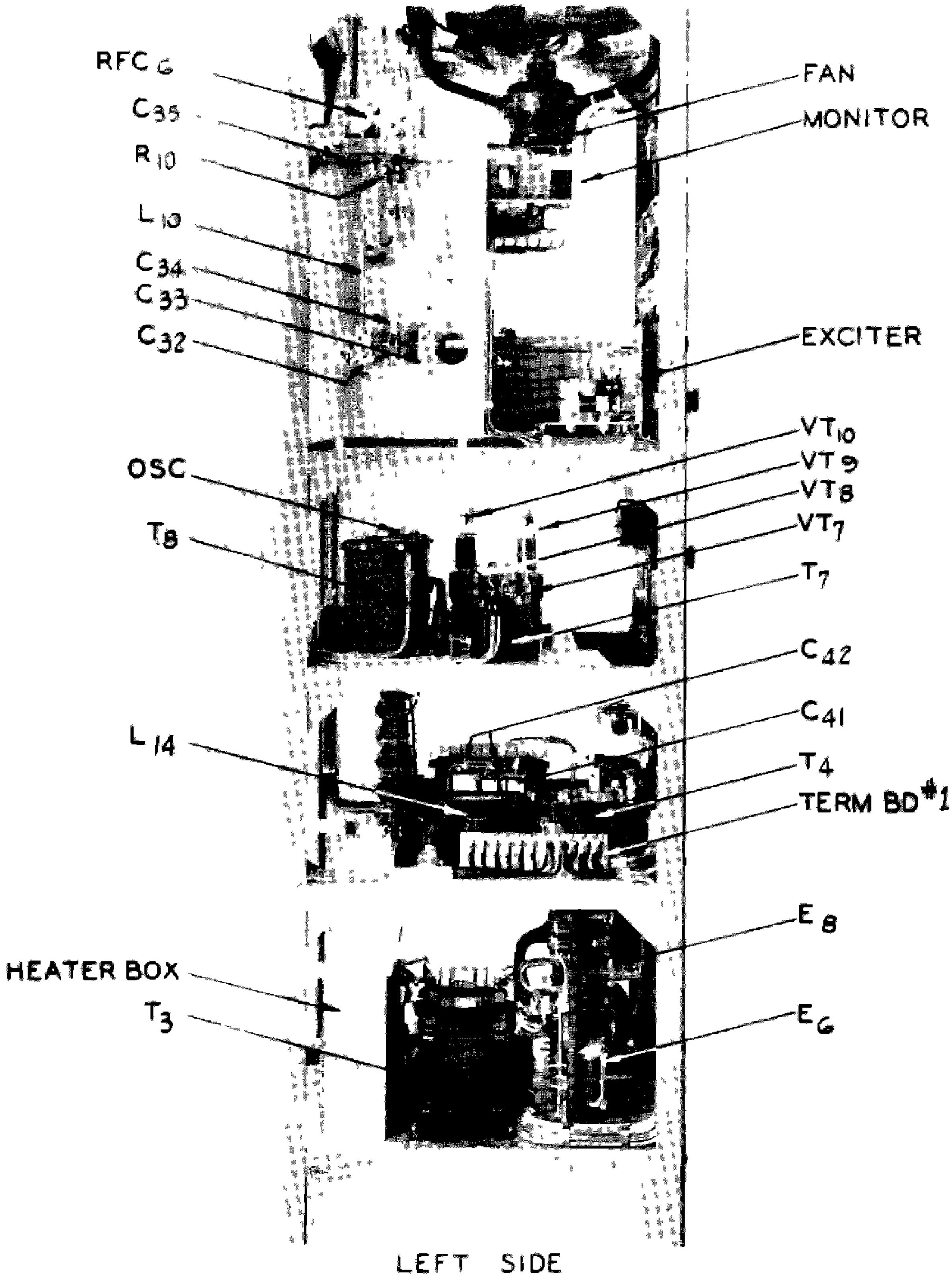
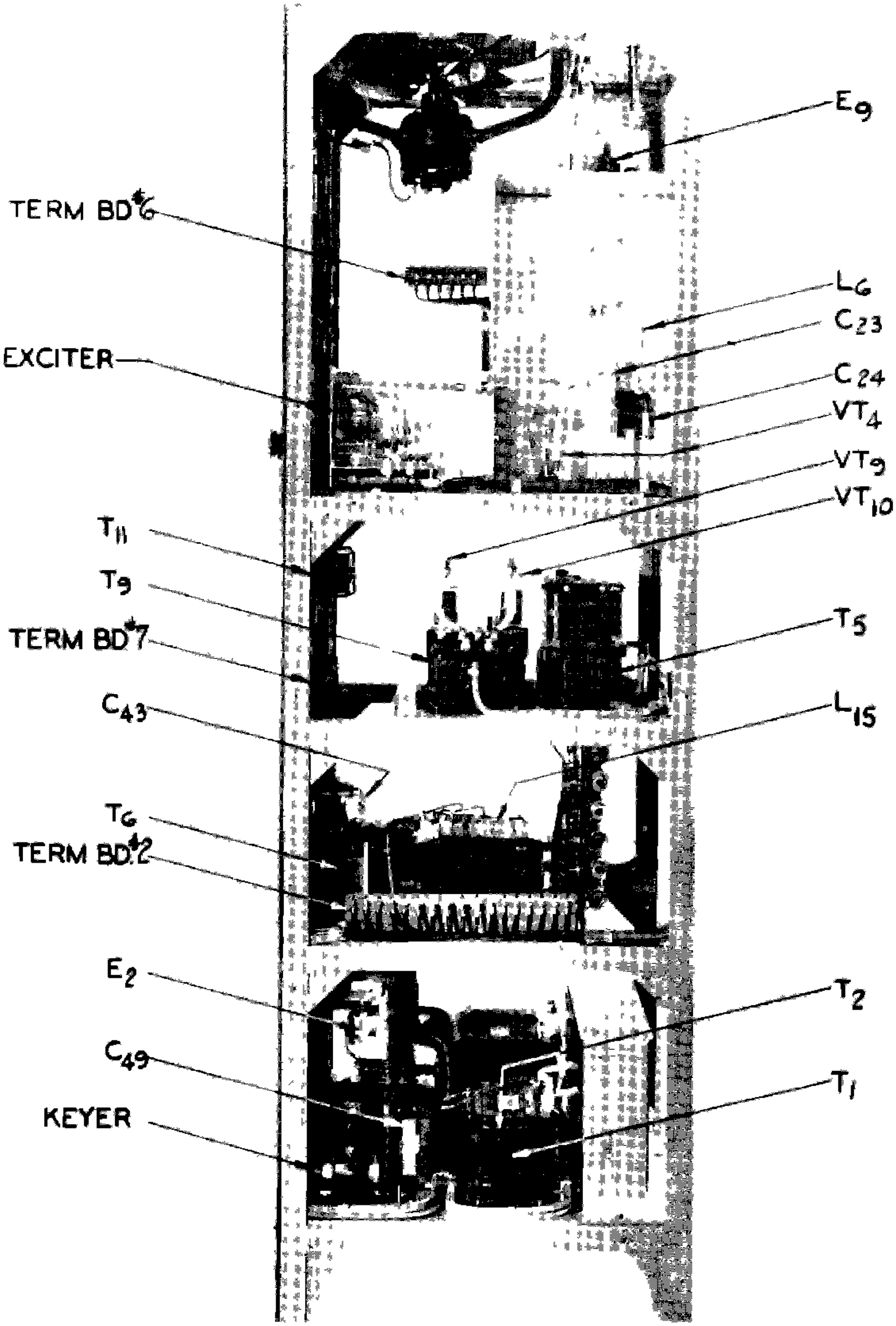


FIG. 13 TYPE TZB MARKER TRANSMITTER



RIGHT SIDE

FIG. 14 TYPE TZB MARKER TRANSMITTER

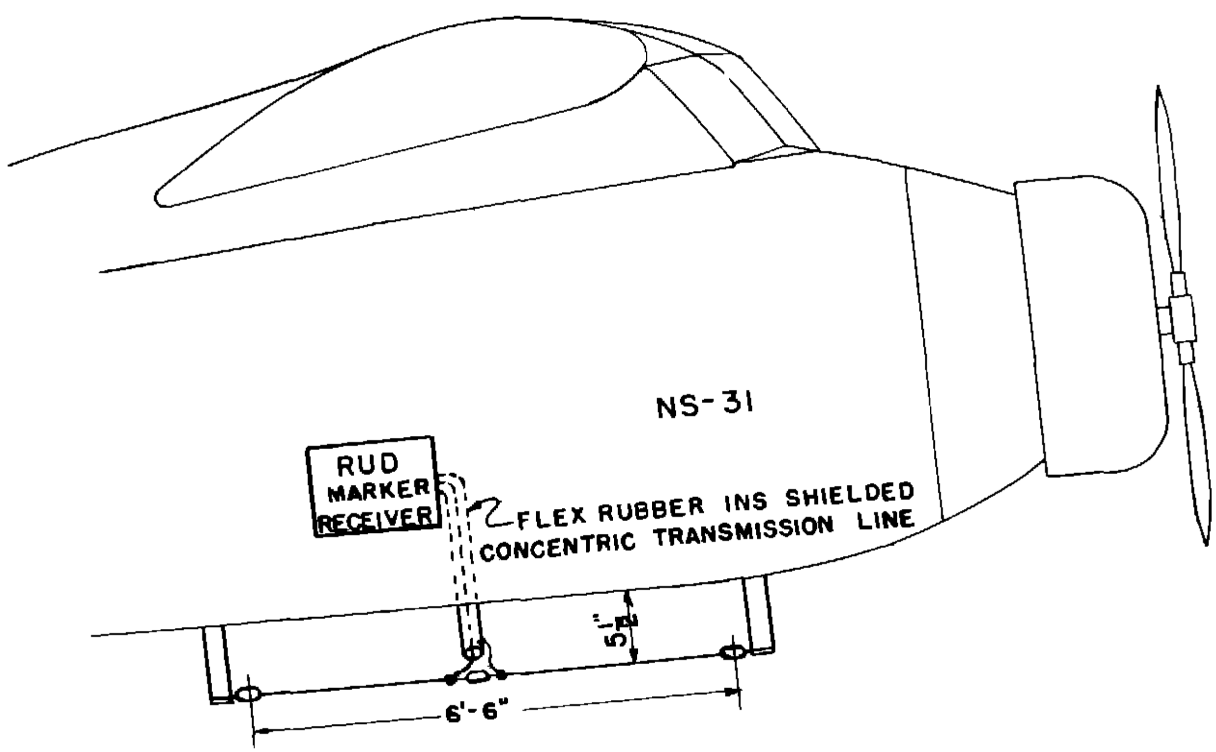


FIG 15

MARKER RECEIVING ANTENNA

NS31 FABRIC-NO SCREEN 7-7-37

DR NO 1517

18804

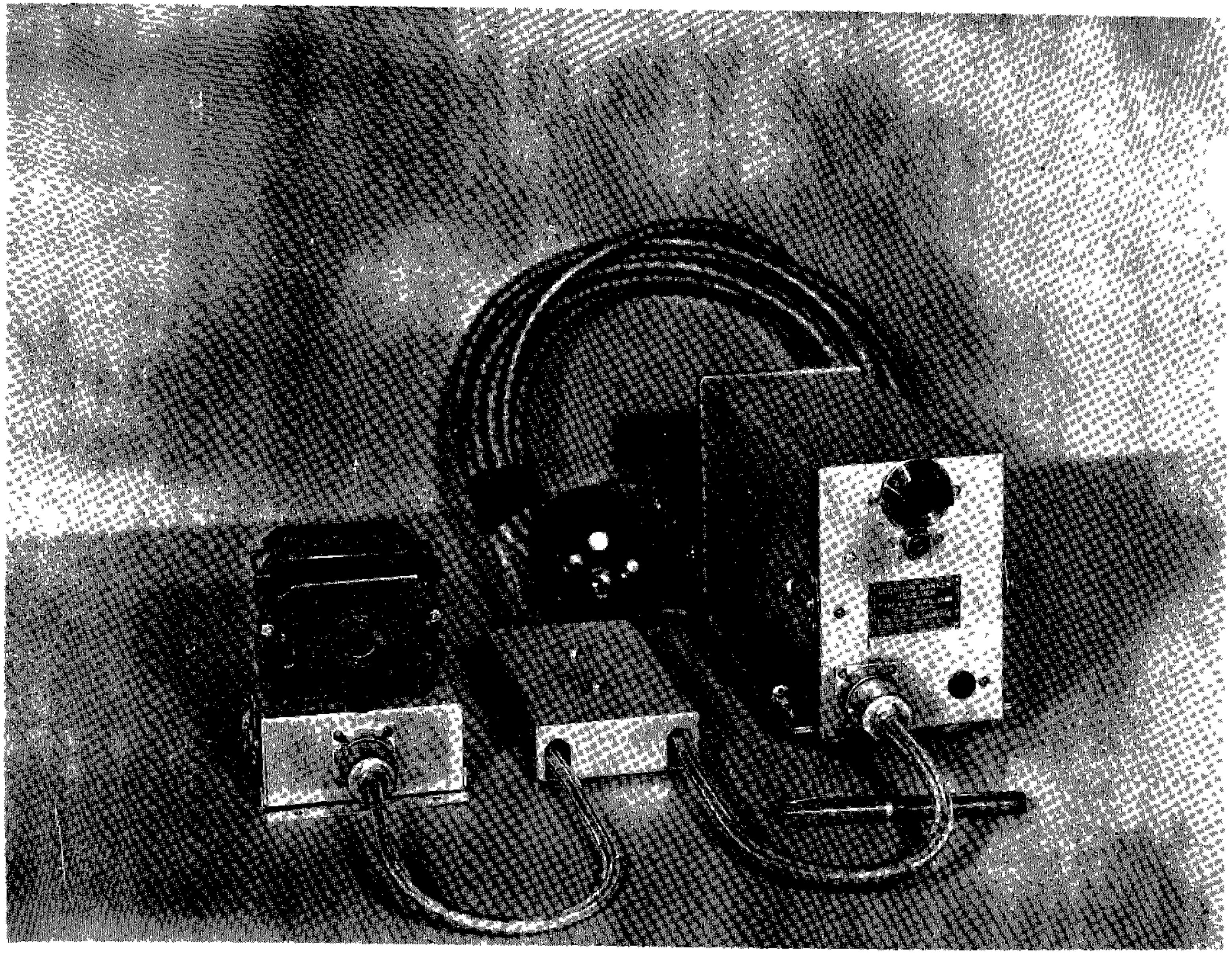
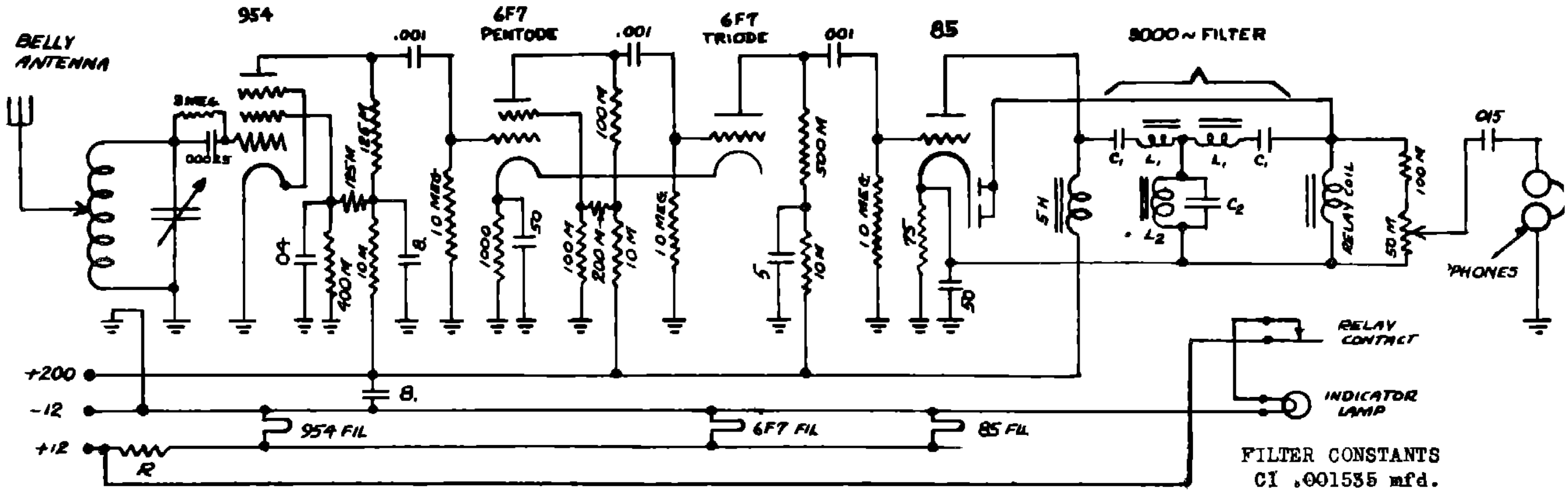


FIG.16. ULTRA HIGH FREQUENCY MARKER RECEIVER
TYPE RUD



FILTER CONSTANTS
C1 .001535 mfd.
C2 .0573 mfd.
L1 1.83 h.
L2 .0491 h.

FIG. 17 SCHEMATIC DIAGRAM TYPE RUD MARKER RECEIVER

12219

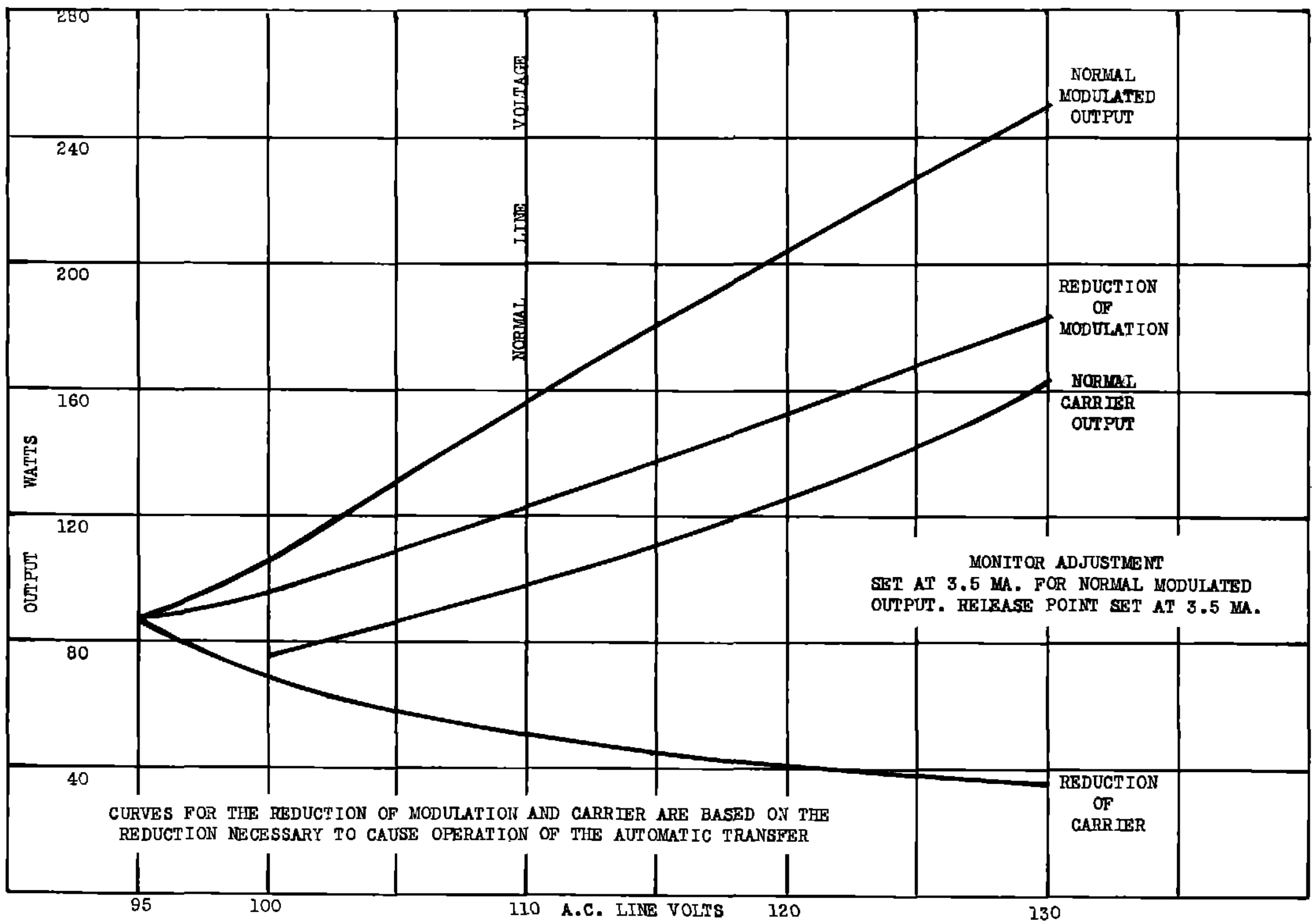


FIG. 18 CONDITIONS RELATIVE TO OPERATION OF THE AUTOMATIC MONITOR CHANGE-OVER DEVICE FOR VARIOUS LINE VOLTAGES

1241J

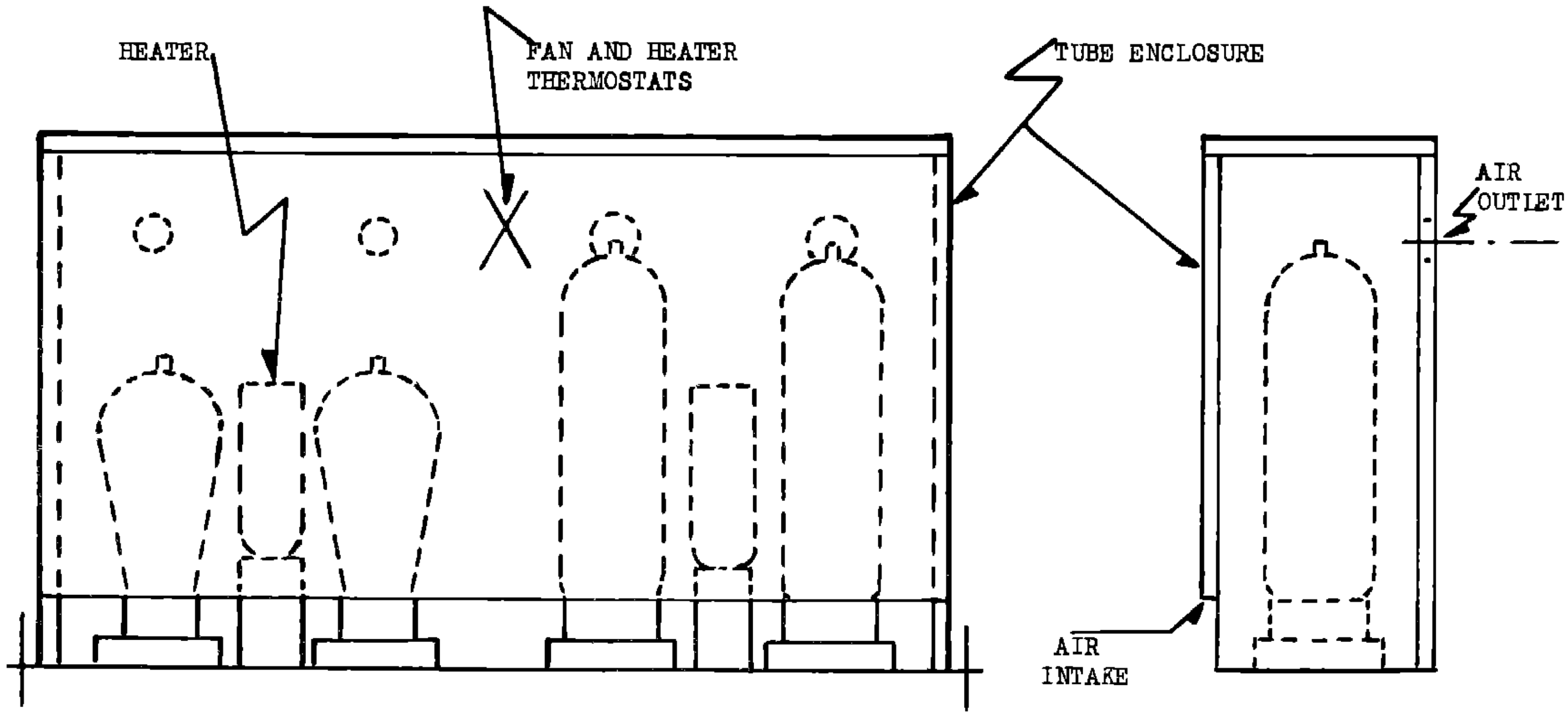
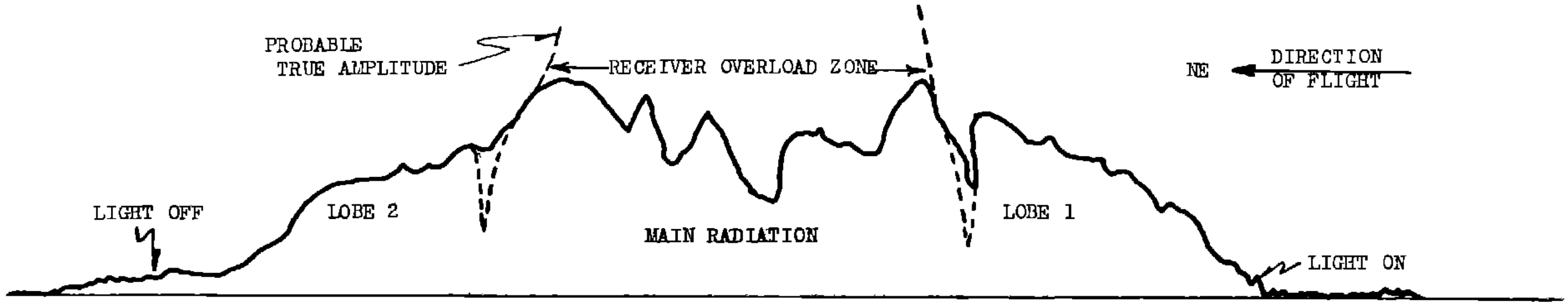
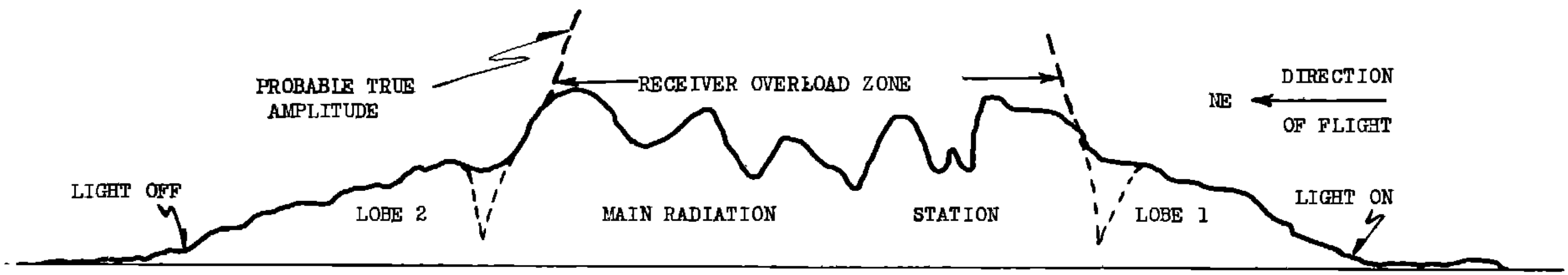


FIG. 19 ENCLOSURE FOR RECTIFIER TUBES

12498



BOWIE, Md. ALTITUDE 3000',, AIR SPEED 100 M.P.H., Time of light 100 sec.



NEW BRUNSWICK, N.J. ALTITUDE 3000', AIR SPEED 100 M.P.H., Time of light 110 Sec.

FIG. 20 GRAPHIC RECORDS OF TWO FAN MARKER SIGNALS, BOWIE AND NEW BRUNSWICK, WITH NORMAL RECEIVER SENSITIVITY

12498

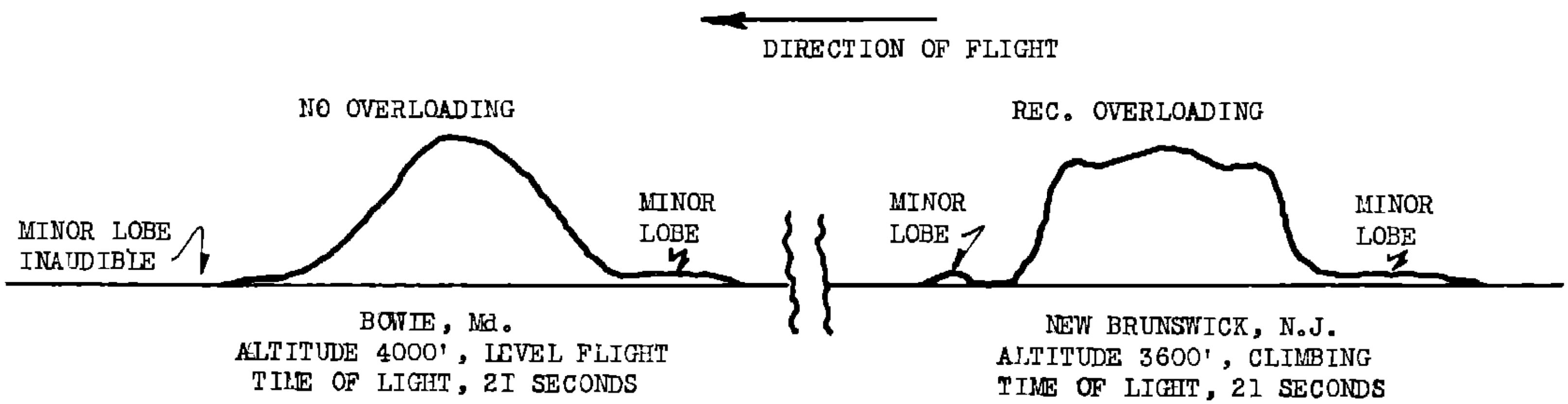


FIG. 21 GRAPHIC RECORDS OF TWO FAN MARKER SIGNALS, BOWIE AND NEW BRUNSWICK, WITH REDUCED RECEIVER SENSITIVITY

12498

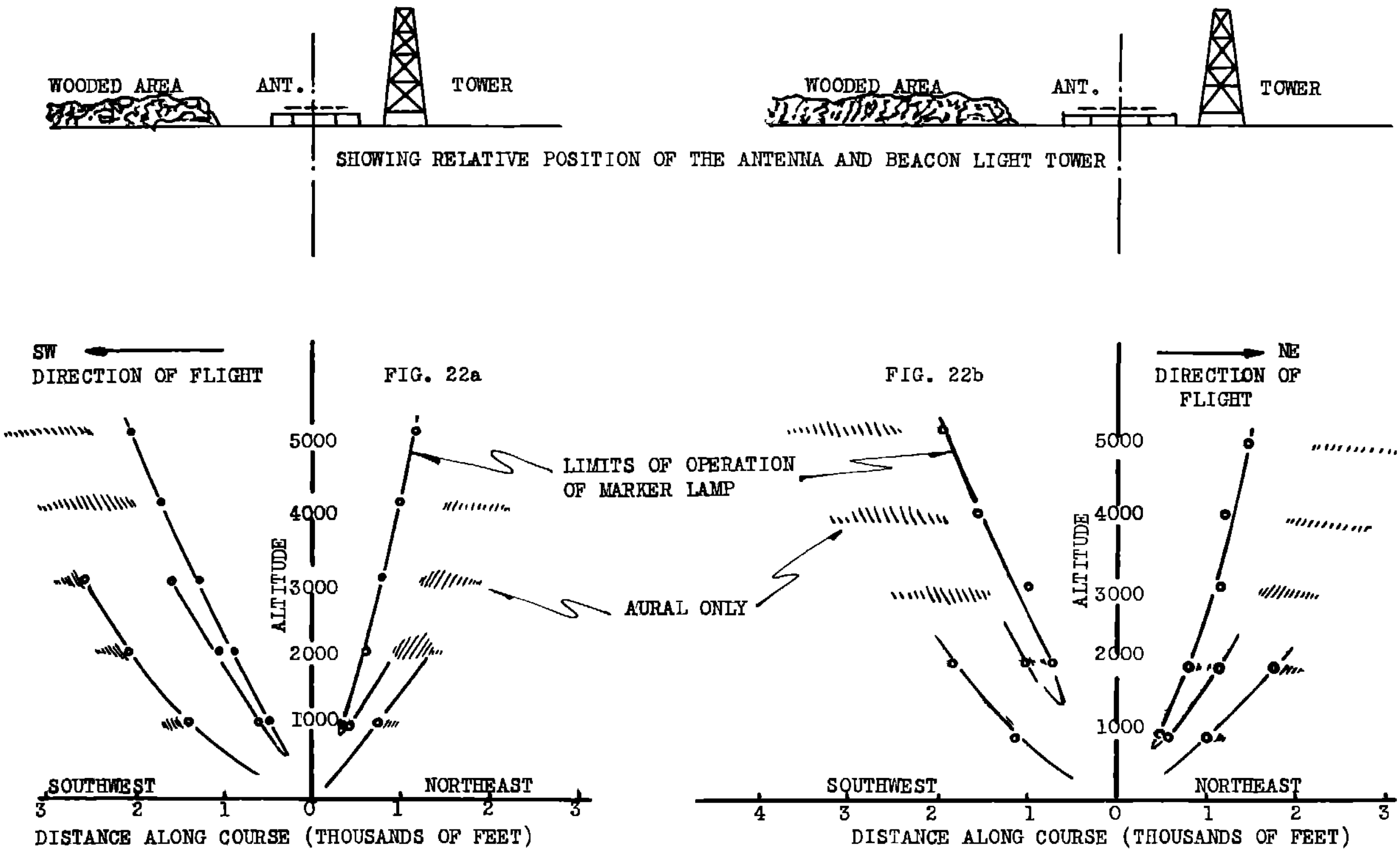


FIG. 22 PATTERNS SHOWING RELATIVE EFFECT OF 90-FOOT BEACON LIGHT TOWER

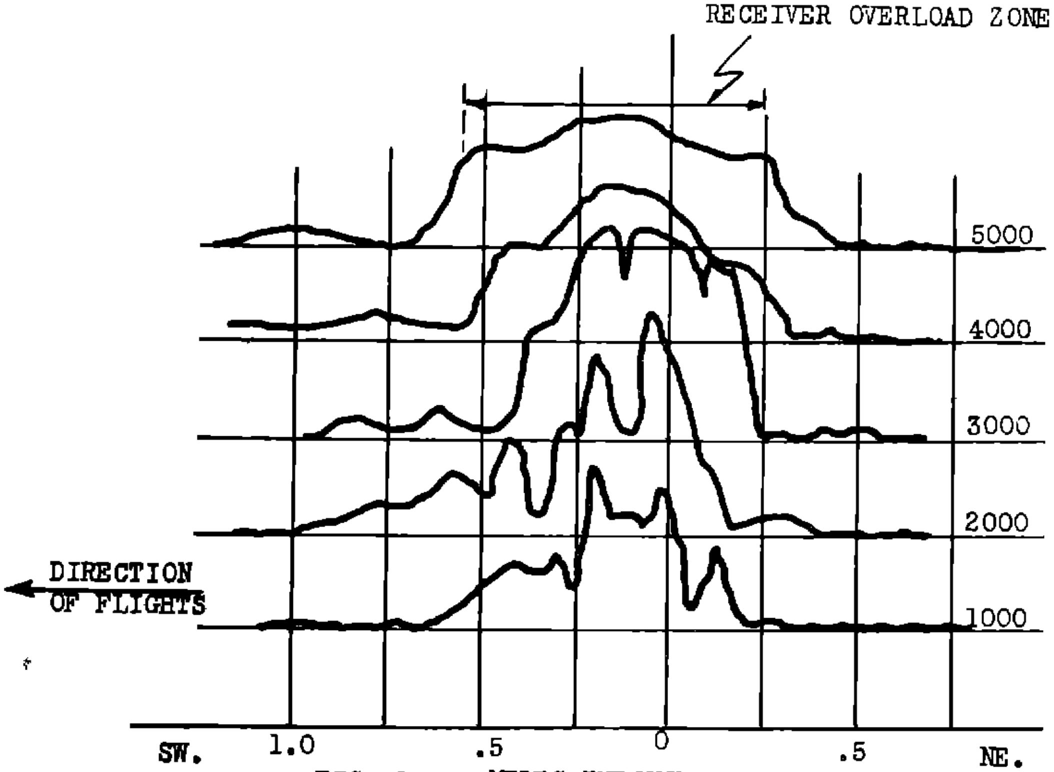


FIG. 23a MILES THROUGH PATTERN

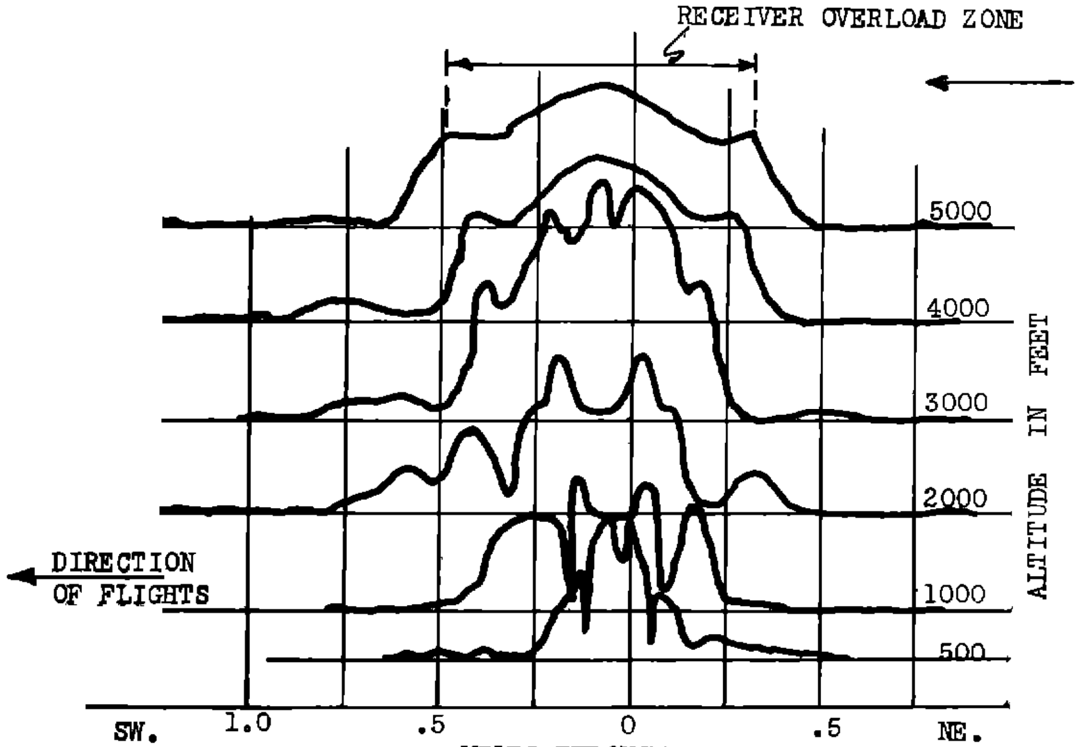


FIG. 23b MILES THROUGH PATTERN

FIG. 23. GRAPHIC RECORDS MADE WITH REDUCED RECEIVER SENSITIVITY AND USED IN PLOTTING FIGS. 22a AND 22b

12498

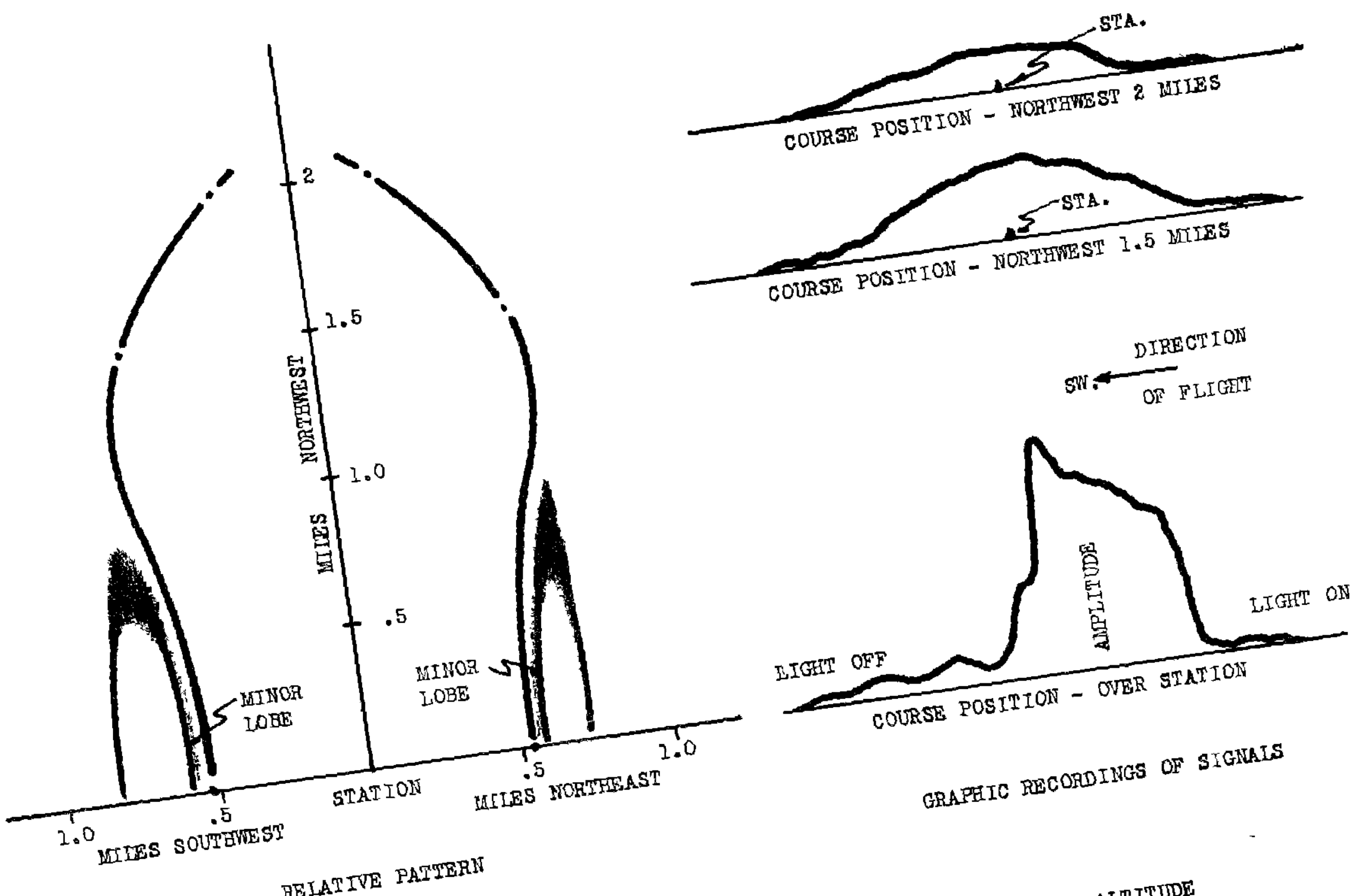


FIG. 24 PATTERN AND GRAPHIC RECORDS OF SIGNALS AT 3000' ALTITUDE SHOWING PLACEMENT OF LOBES AND NEGLIGIBLE EFFECT OF BEACON TOWER

12498

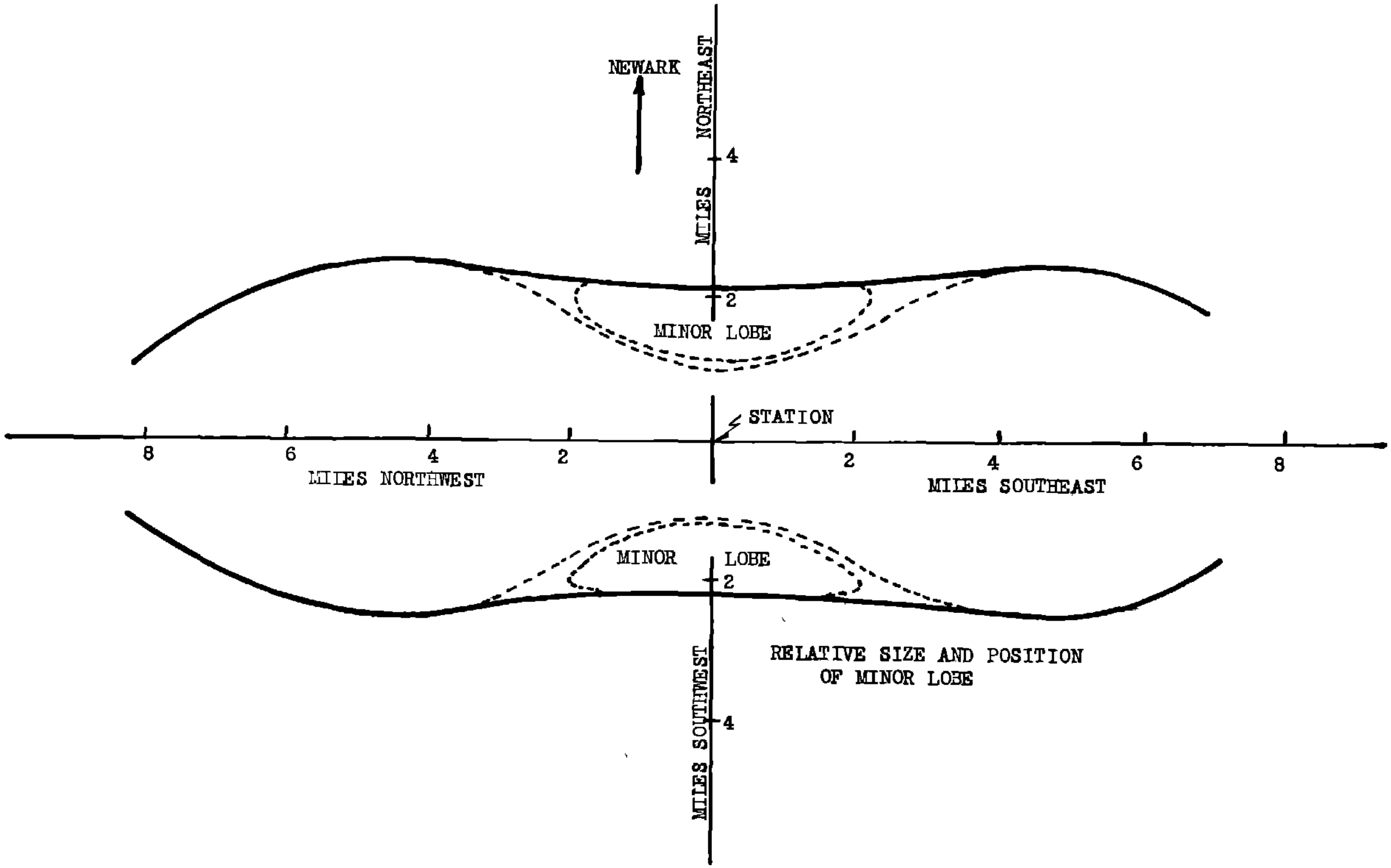


FIG. 25 PATTERN AT 7000' ALTITUDE SHOWING THE APPROXIMATE SIZE AND POSITION OF THE MINOR LOBES

12498

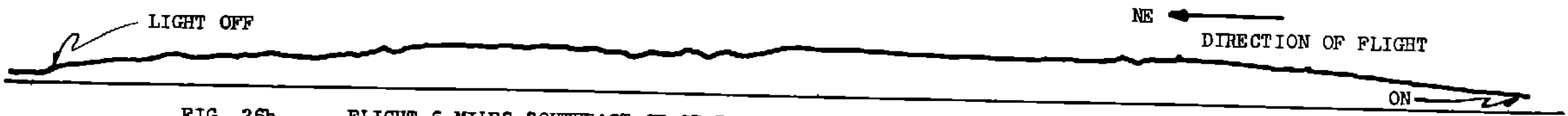


FIG. 26b FLIGHT 6 MILES SOUTHEAST OF STATION, PARALLEL TO ON-COURSE ALT. 7000' t= 160 Sec.

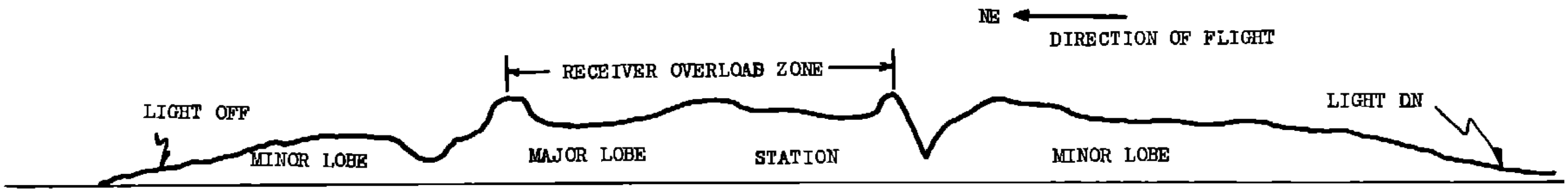


FIG. 26a FLIGHT DIRECTLY OVER STATION, ON-COURSE ALT. 7000' t = 135 Sec.

FIG. 26 GRAPHIC RECORDS TAKEN DIRECTLY OVER STATION AND 6 MILES SOUTHEAST OF STATION AT 7000 FEET ALTITUDE

12498

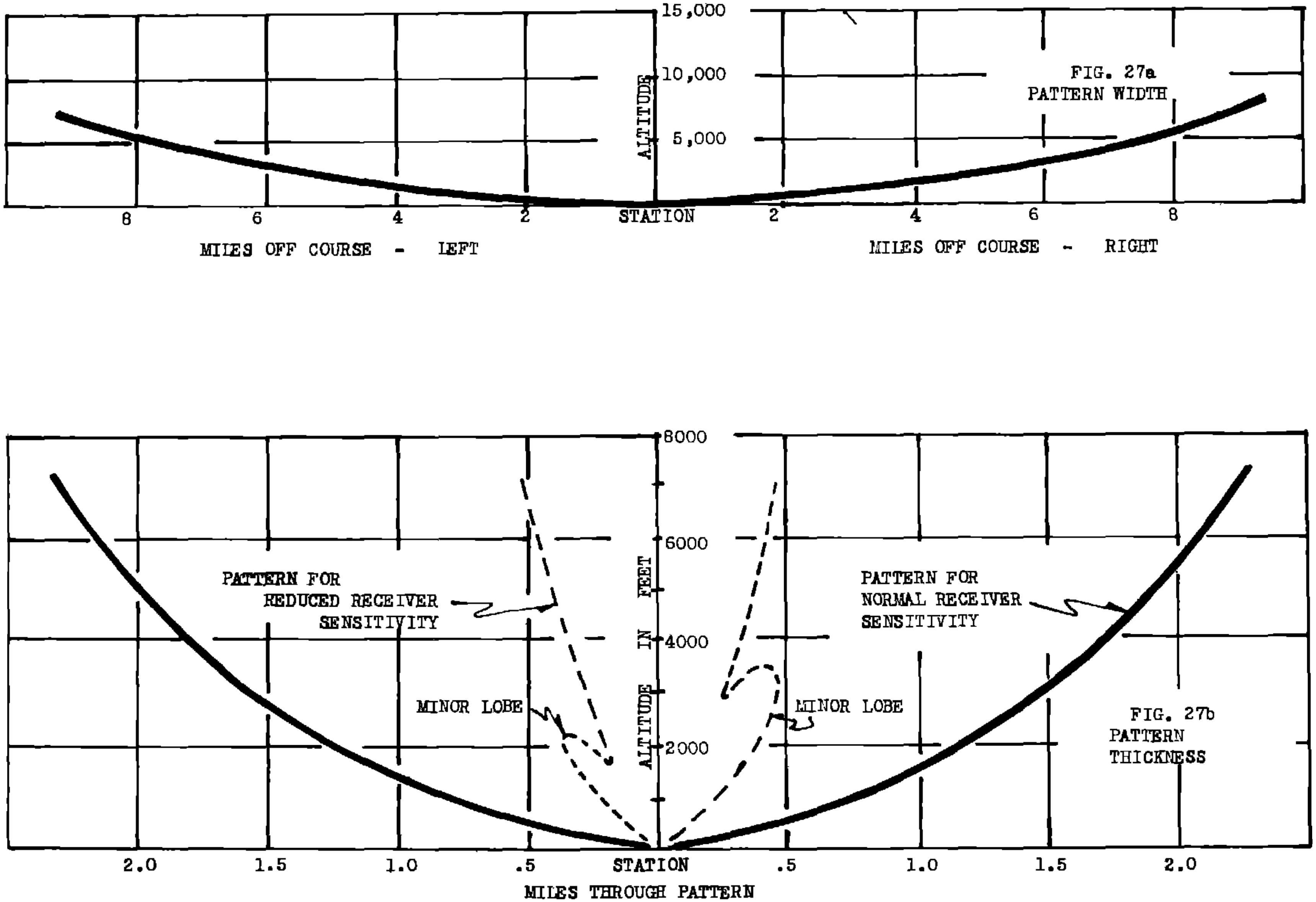


FIG. 27 PATTERN DIMENSIONS IN A VERTICAL PLANE SHOWING THICKNESS AND WIDTH OF PATTERN

12498