AN EXPERIMENTAL STUDY OF NEW ANTENNA DESIGNS FOR AUTOMOTIVE ENTERTAINMENT SYSTEMS

by

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EXECUTIVE SUMMARY

The radiation characteristics of some selected flush-mounted antennas and of the standard whip antenna have been investigated experimentally. The main objective of the study has been to collect sufficient data so that the performance of these antennas may be compared with that of the whip antenna, and that the feasibility of using the former antennas in aerodynamically styled car lines may be estimated.

Measurements were performed with the heated backlite antenna, the capacitive antenna and the standard whip antenna. Specifically, the investigation consisted of the following:

(i) Measurement of the sensitivities of the selected antennas relative to that of the whip antenna at the AM, FM, CB, VHF and UHF bands of frequencies. This was done in the laboratory environment by receiving commercially available RF signals using the appropriate antenna (suitably mounted on a ground plane) in conjunction with a spectrum analyzer. The results indicated the strength and the number of commercial signals received by each antenna, hence, its sensitivity relative to that of the whip antenna.

(ii) Measurement of radiation patterns of the (isolated) antennas, suitably mounted on a ground plane, using the laboratory signals in the frequency range 50 to 1000 MHz. These provided valuable data which may be used to judge the relative pattern behavior of the antennas under various conditions.

(iii) Measurement of the detailed pattern characteristics of the heated backlite and whip antennas mounted on a Ford Tempo body shell using laboratory signals in the frequency range 50 to 1000 MHz.

(iv) Theoretical derivation of the gain of the heated backlite antenna relative to the whip antenna using the results of (iii).

(v) Measurement of the input VSWR characteristics of the heated backlite antenna mounted on Tempo body shell in the frequency range 50 to 1000 MHz.

Significant findings of the investigation are:

(i) Sensitivity. At the AM band of frequencies the sensitivity of the heated backlite antenna is larger than that of the whip and the capacitor antennas.

At the FM band of frequencies, the whip antenna has more sensitivity than the other two antennas; the sensitivity of the capacitor antenna is lower than the heated backlite antenna.

At the upper UHF band, the heated backlite antenna is more sensitive than the whip antenna. At these frequencies the sensitivity of the capacitor antenna appears to be of the same order as that of the whip antenna.

(ii) Isolated Antenna Patterns. The whip antenna mounted on a five-foot diameter ground plane maintains the horizontal plane omni-directionality fairly well up to about 300 MHz. Beyond 300 MHz the pattern develops a number of minima which at selected frequencies can be deep.

The side-fed heated backlite antenna yields figure-of-eight patterns up to about 110 MHz and beyond 110 MHz its pattern becomes multilobed with deep nulls.

The bottom-fed heated backlite antenna patterns are similar to those of the whip up to about 110 MHz although its horizontal plane

omnidirectionality is not as good as that of the whip. Beyond 110 MHz, the pattern becomes multilobed, and may have deep minima at certain frequencies.

The horizontal plane patterns of the capacitor antenna are omnidorectional throughout the band of frequencies, although near the upper end of the UHF band there may be slight variations. In fact, among the three antennas the capacitor antenna seems to possess the best omnidirectional behavior. The vertical plane pattern of the capacitor antenna is similar to figure-of-eight patterns.

(iii) Heated Backlite and Whip Antennas Mounted on Tempo Body Shell. For vertical polarization the whip antenna has better overall omnidirectionality; however, in the frequency range 400 to 600 MHz the two antennas have similar patterns. For horizontal polarization the two antennas have similar pattern characteristics, and the heated backlite antenna seems to have slightly better patters.

Bottom-fed heated backlite and the whip: For vertical polarization and above 200 MHz the pattern characteristics of both antennas are comparable although at certain frequencies the heated backlite antenna patterns show some significant minima. At lower frequencies, the bottom-fed heated backlite antenna patterns are slightly inferior to those of the whip but they are significantly better than those of the side-fed heated backlite case.

For horizontal polarization the bottom-fed heated backlite antenna consistently provides comparable and sometimes superior patterns than those of the whip over the entire band of frequencies.

(iv) Relative Gain. The whip antenna has more gain than the heated backlite antenna for frequencies up to about 200 MHz. Beyond

200 MHz both side-fed and bottom-fed heated backlite antennas provide more gain.

(v) VSWR. The input vswr obtained with the side-fed and bottom-fed heated backlite antennas stays below 2.5 and 2.0, respectively, over most of the band of frequencies used.

I. INTRODUCTION

This report presents the results of an experimental investigation of some selected antennas having the potential of being flushmounted on automobiles. The main objective of the study has been to explore the feasibility of developing antennas to satisfy the needs of the latest aerodynamically styled car lines for which the conventional whip antenna may not be desirable.

The specific antennas investigated were the capacitor and the heated backlite antennas which will be described later, and will be referred to as the test antennas. The program mainly consisted of the following:

(i) Measurement of the sensitivity of the test antennas relative to the standard whip antennas in the AM, FM, CB, VHF and UHF bands of frequencies. This was done in the laboratory environment by receiving commercially available signals using the appropriate antenna in conjunction with a spectrum analyzer. This gave an indication of the number of stations received by each antenna, and also the relative sensitivity of the test antennas with respect to the whip antennas.

(ii) Measurements of the radiation patterns of the isolated antennas obtained with our outside pattern range using laboratory signals.

(iii) Measurement of the radiation patterns of the heated backlite and whip antennas mounted on a selected car body placed on a rotating pedestal.

(iv) Measurement of the input VSWR of the heated backlite antenna.

From (iii) the relative gain of the heated backlite antenna with respect to the whip antenna has been obtained as a function of frequency.

II. DESCRIPTION OF ANTENNAS, MEASUREMENT AND DATA REDUCTION PROCEDURES

The measurement techniques and equipment setup used to obtain the desired results have been described elsewhere [1], [2] and will not be repeated here. The present section describes briefly the test antennas, certain relevant aspects of the procedure followed to reduce some of the measured results to the desired forms.

2.1 Antennas

During laboratory measurements all antennas (two test antennas and standard whip antennas) were mounted suitably on a 6 ft x 6 ft ground plane frame. The aluminum ground plane was fabricated from a 6 ft x 6 ft plate from which a portion of the central material of dimension 2 ft x 5 ft was taken out, as shown in Fig. 1. The configuration of Fig. 1 was installed in a frame such that it could be oriented in a vertical or horizontal position, as desired.

The region A of Fig. 1 when filled with another appropriate aluminum plate (ensuring proper electrical contact, served as the grounded plate for the horizontally oriented capacitor antenna. The second plate of the antenna consisted of a five foot diameter aluminum plate placed symmetrically above the larger plate separated by a distance d; initially d = 1 inch and d = 1 1/2 inches were used, but later only the former distance was used. The system was excited by a coaxial probe from underneath the lower plate. A sketch of the capacitor antenna is shown in Fig. 2.

The heated backlite antenna was fabricated from 13 approximately five foot long sections of No. 22 gauge wires placed parallel to each

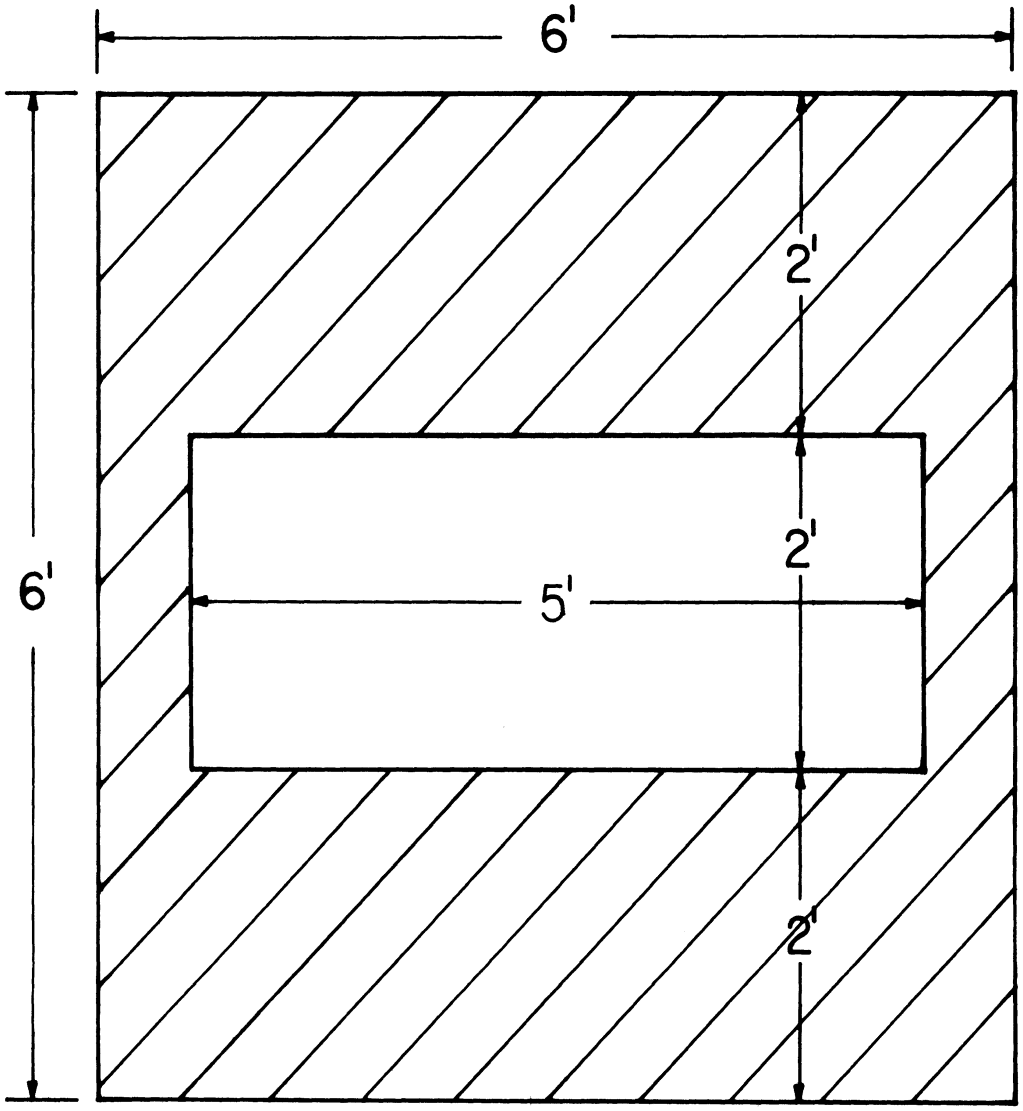

Fig. 1: Sketch of the ground plane bracket.

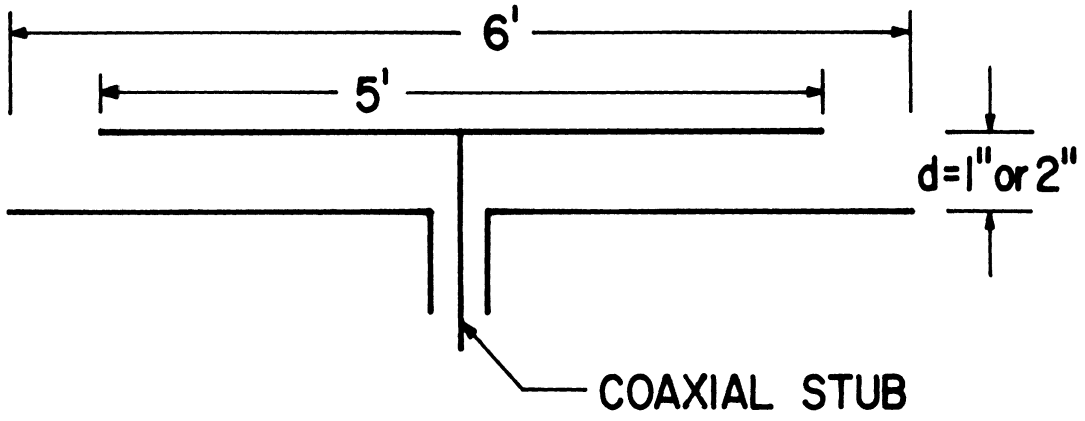

Fig. 2: Sketch of the capacitor antenna fed by a coaxial stub at the center.

other and spaced one inch apart. All the wires were placed in one plane; at the two ends the wires were shorted with a one-inch wide aluminum tape. The entire section we mounted in the region A of Fig. 1. The main section of the antenna is shown in Fig. 3 which also shows the two alternate feed arrangements referred to as the side-fed and bottom-fed.

The whip antenna is of standard design and is 31 inches long; during laboratory measurements it was mounted at the center of the five foot diameter aluminum ground plane.

2.2 Measurements

In addition to the sensitivity measurements of the above antennas mentioned in Section I, detailed radiation patterns of each antenna were obtained at the frequencies of interest using our outside antenna pattern range. Later, the patterns of the heated backlite and whip each mounted on a car body, were also obtained at the desired frequencies. The measurement procedures were standard.

2.3 Pattern Data Reduction

A measure of the gain of a test antenna mounted on a car body relative to that of the standard whip on the same car body can be obtained from their measured horizontal plane patterns. The gain of the test antenna relative to the whip is defined as

$$G_R = W_T/W_R \quad , \tag{1}$$

where W_T is the total power received (transmitted) by the test antenna,

W_R is the total power received (transmitted) by the whip.

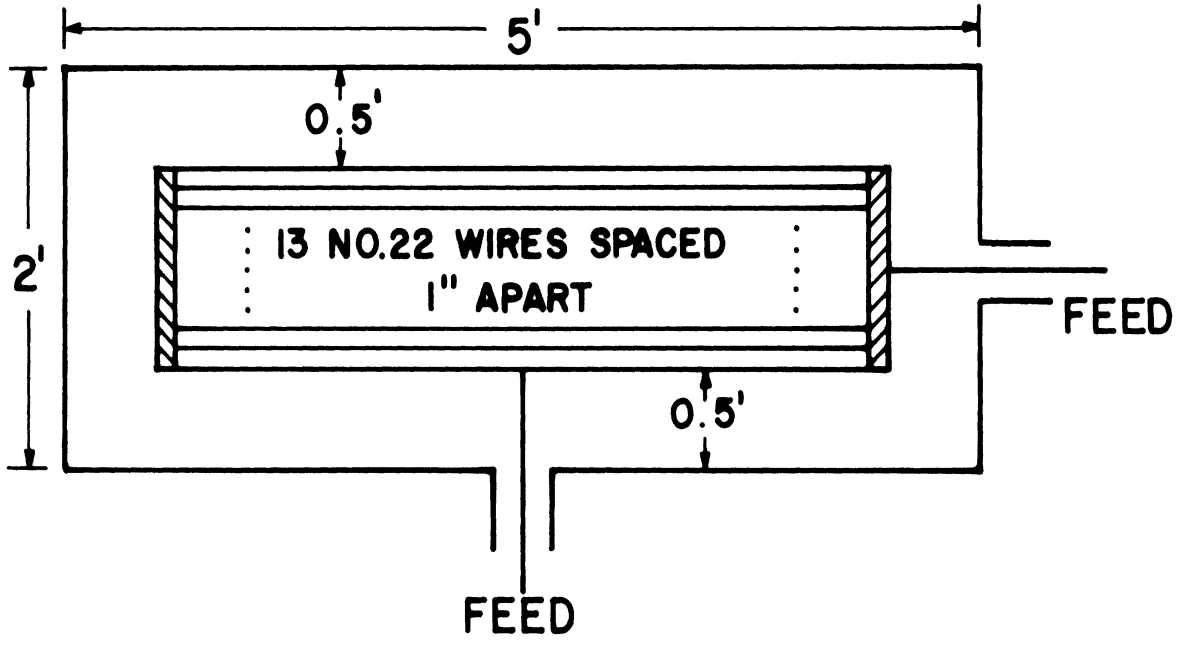

Fig. 3: Sketch of the heated backlite antenna showing the two methods of feeding.

To determine W_T or W_R it is necessary to know the antenna's complete three dimensional radiation pattern. In the present study only the horizontal plane patterns were measured. On the basis of these measured patterns a parameter called the "pseuod relative gain" G_S can be defined which will be proportional to the actual relative gain G_R defined by (i). Assuming that the vertical plane patterns of the test and whip and antennas are similar, W_T and W_R may be approximated by

$$W_T = \alpha A_T$$
$$W_R = \alpha A_R \qquad (2)$$

where α is some constant,

A_T is the total area of the measured horizontal plane pattern of the test antenna,

A_R is the total area of the measured horizontal plane pattern of the whip antenna.

Thus, the pseudo-gain of the test antenna is defined as [3]

$$G_S = \frac{A_T}{A_R} \quad . \qquad (3)$$

Note by definition G_S is proportional to G_R defined by (1).

A_T and A_R are obtained numerically from the measured horizontal patterns. The pseudo gain characteristics of the heated backlite antenna, under two feed conditions, were determined in this manner and will be presented later.

III. MEASUREMENT OF SENSITIVITY

The purpose of these measurements was to obtain rough estimates of the ability of the test and whip antennas to receive signals in the frequency range 0 to 1 GHz. The measurements were carried out inside the laboratory using an experimental arrangement shown as a block diagram in Fig. 4 where the antenna under test was used to receive the commercially available signals at the frequencies of interest, specifically, the following antennas were used to receive the signals: (i) the standard whip mounted vertically at the center of the horizontally oriented five foot diameter ground plane; (ii) the heater backlite (side and bottom fed cases) mounted on the ground plane bracket (Fig. 1) and the antenna system oriented vertically; (iii) the capacitor antenna (d = 1 inch, 1 1/2 inch) shown in Fig. 2 mounted on the ground plane bracket (Fig. 1) and the system oriented in the horizontal plane. In addition, we also collected some results using an appropriately fed side-view mirror mounted on the five foot diameter ground plane but these results are given in the Appendix and will not be discussed here.

Results obtained with the whip antenna are shown in Figs. 5(a) through 5(f). Although the gain of the spectrum analyzer (Fig. 4) was kept constant during the measurements, the strengths of the available signals being variable it is not possible to use the results of Fig. 5 to estimate the sensitivity of the whip antenna to signals of various frequencies. However, they may be used to estimate the approximate number of stations that the antenna received during the time of the

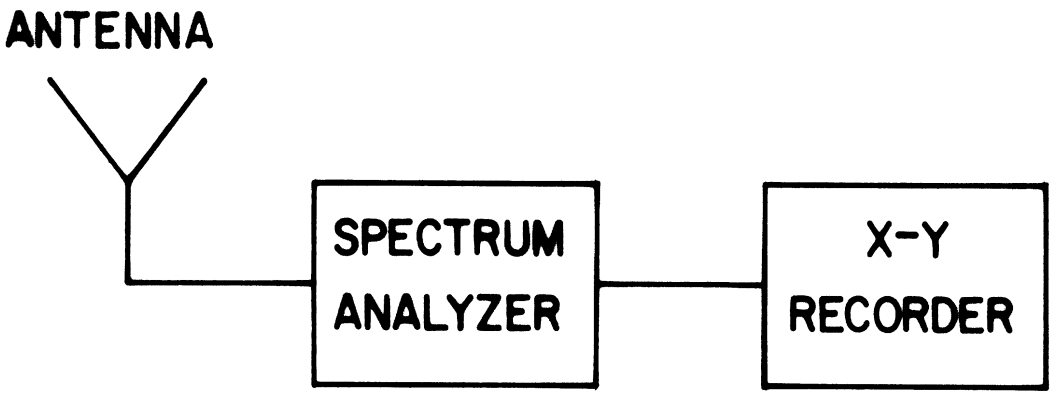

Fig. 4: Block diagram of the experimental setup for sensitivity measurement.

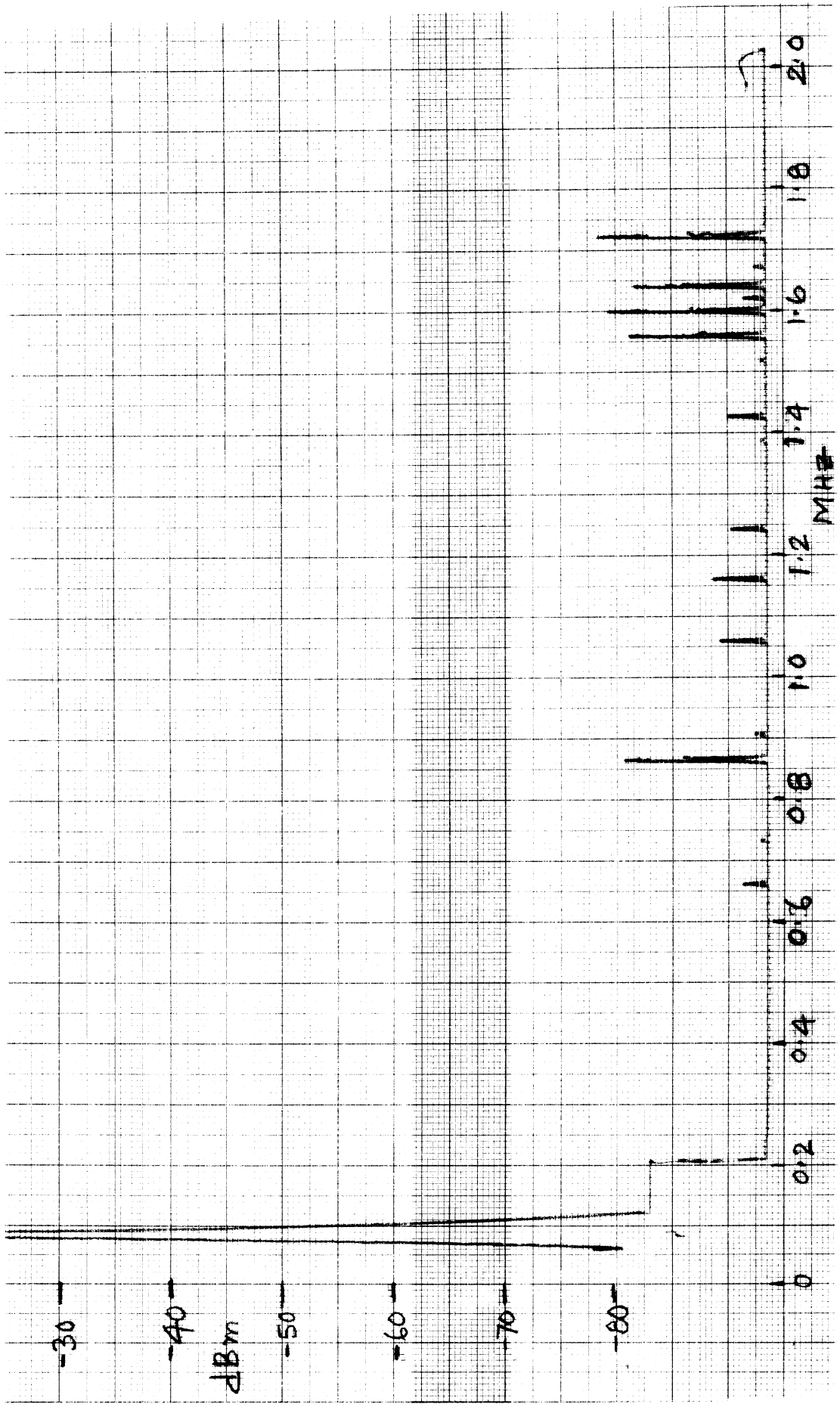

Fig. 5(a): Response of the whip antenna vs. frequency of the commercially available signals. (0 - 2 MHz).

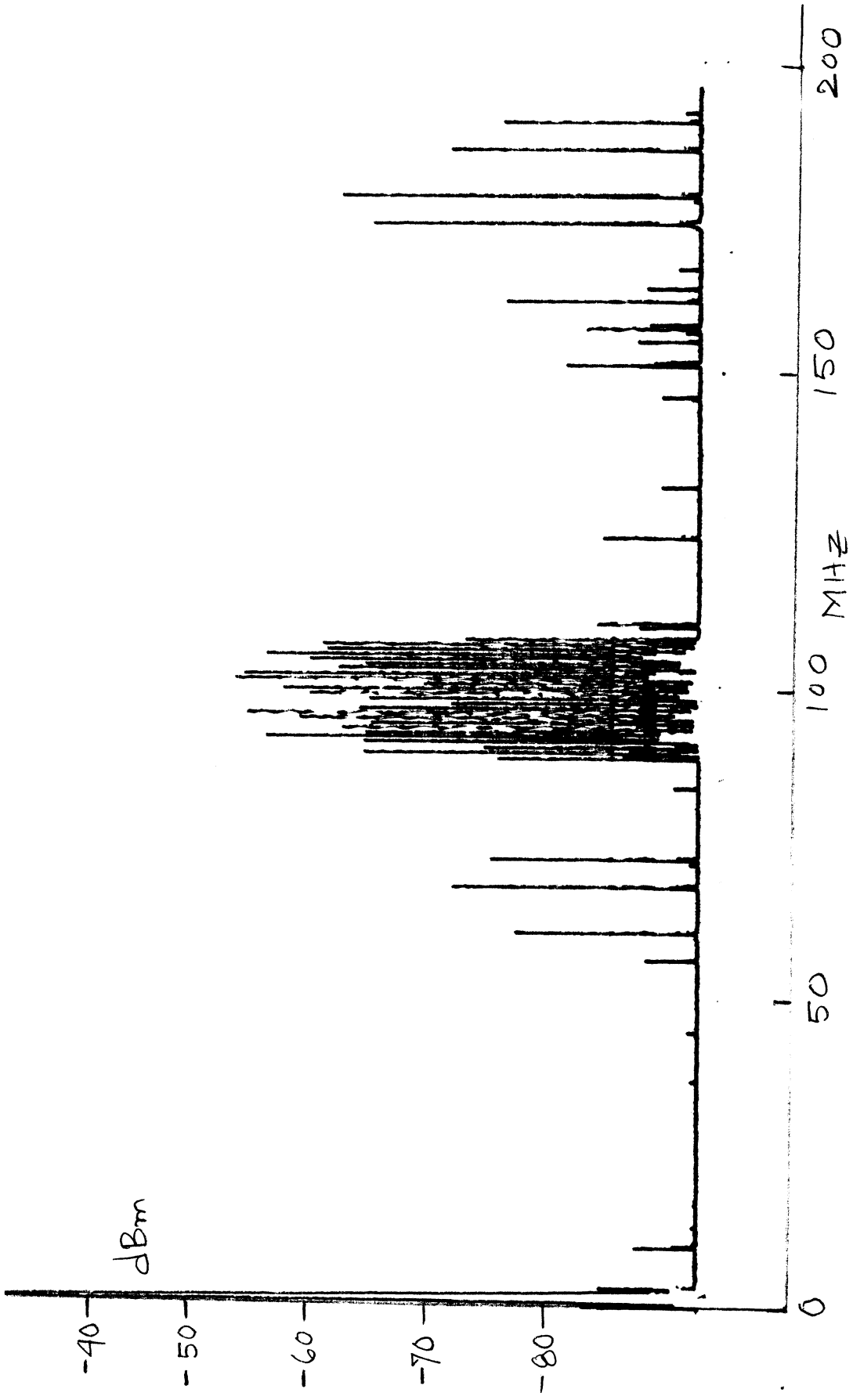

Fig. 5(b): Response of the whip antenna vs. frequency of the commercially available signals. (0 - 200 MHz)

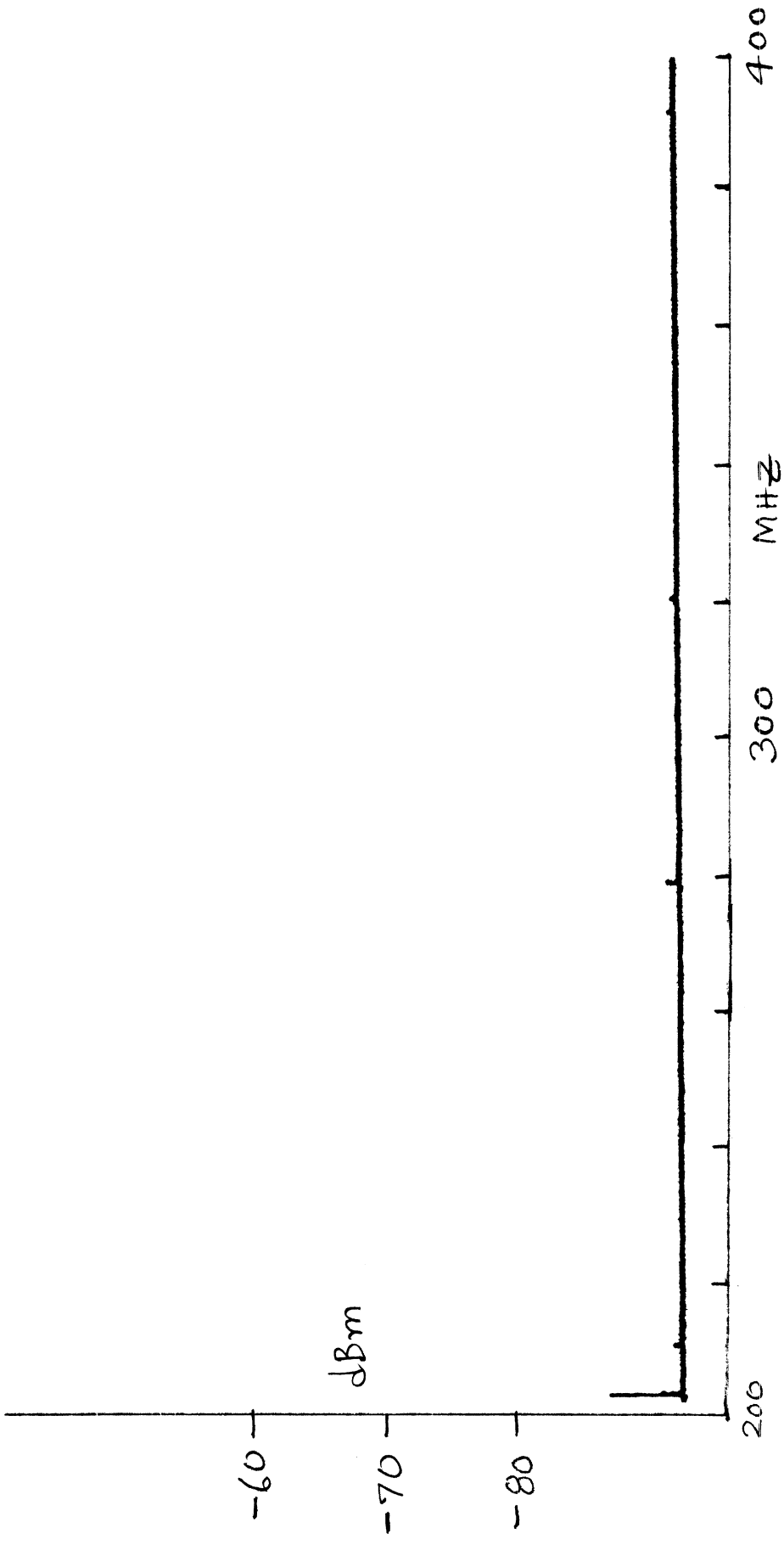

Fig. 5(c): Response of the whip antenna vs. frequency of the commercially available signals. (200 - 400 MHz)

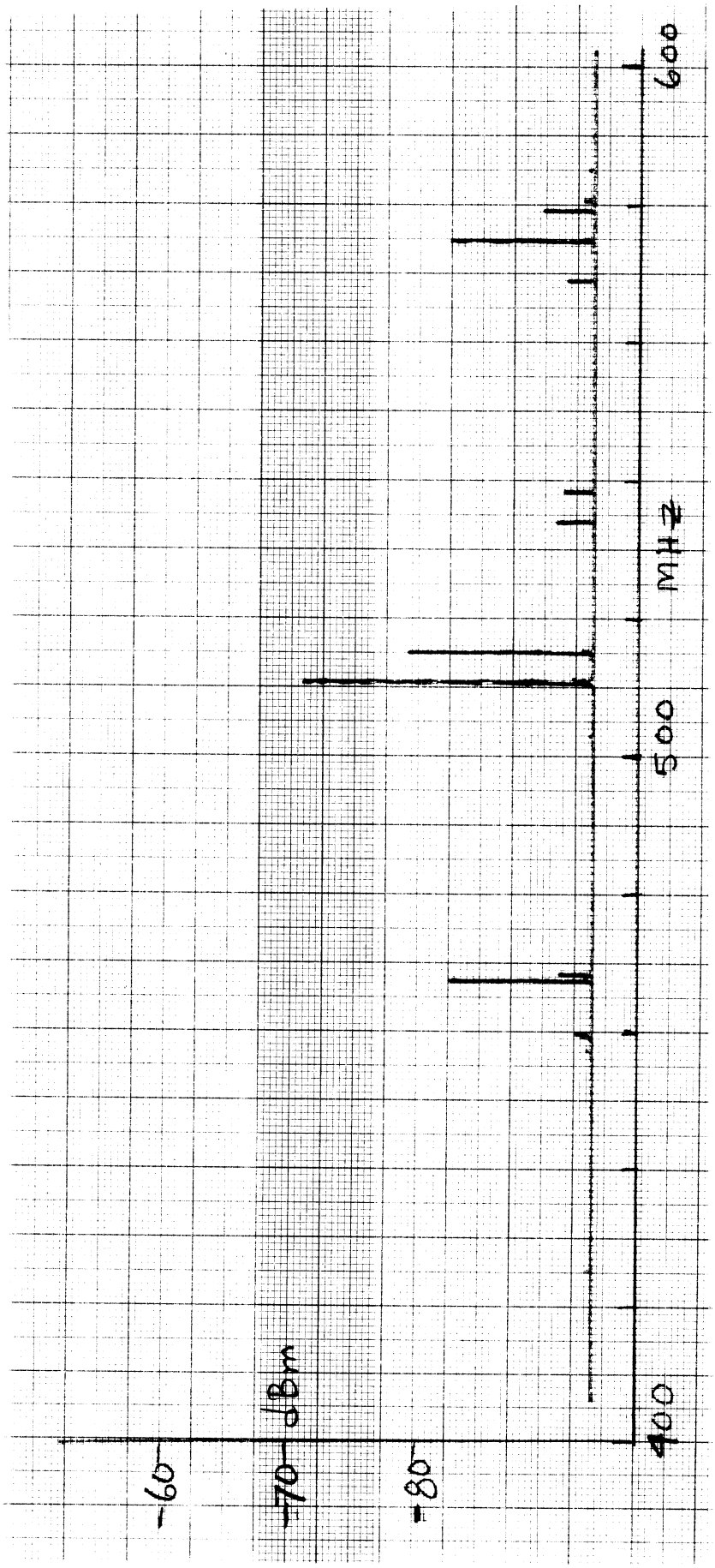

Fig. 5(d) Response of the whip antenna vs. frequency of the comercially available signals (400 - 600 MHz)

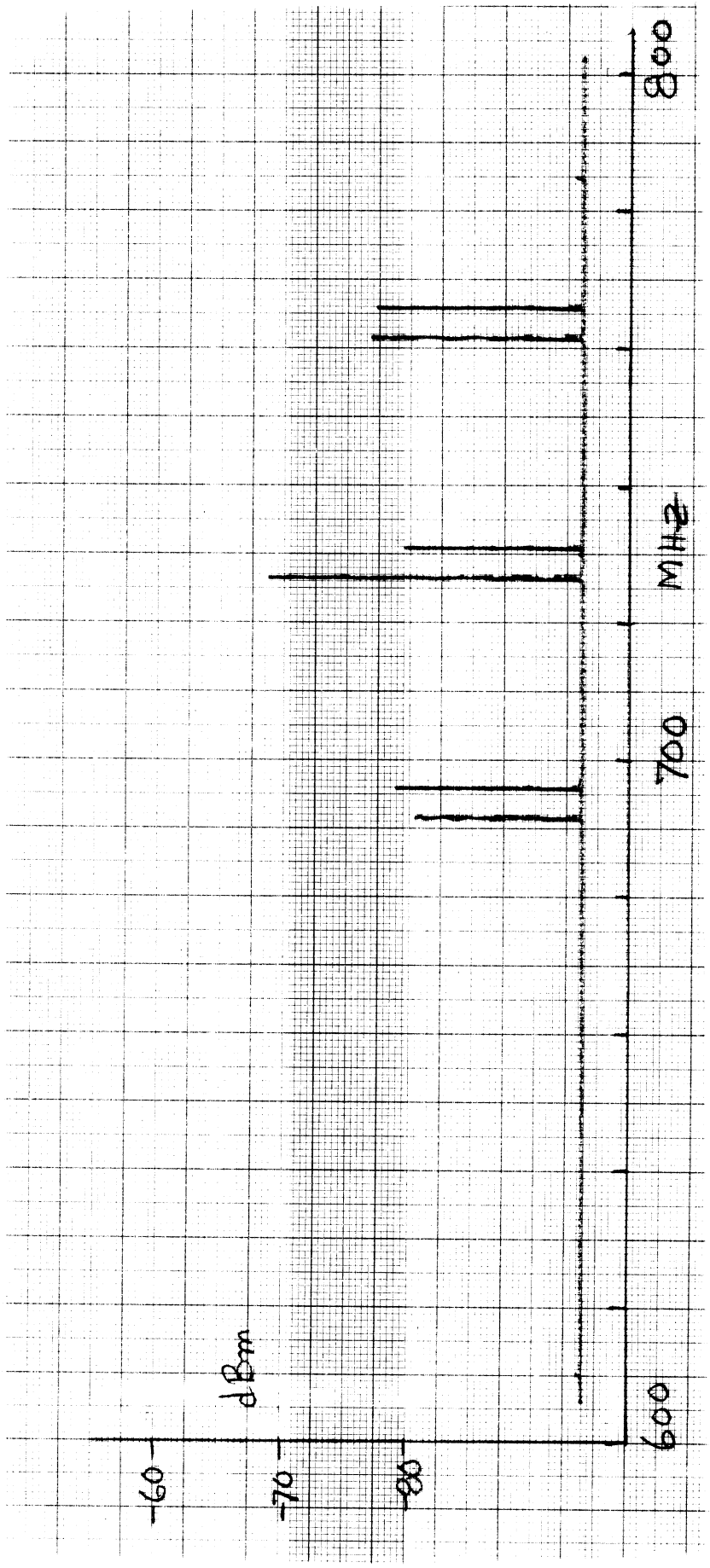

Fig. 5(e): Response of the whip antenna vs. frequency of the commercially available signals. (600 - 800 MHz)

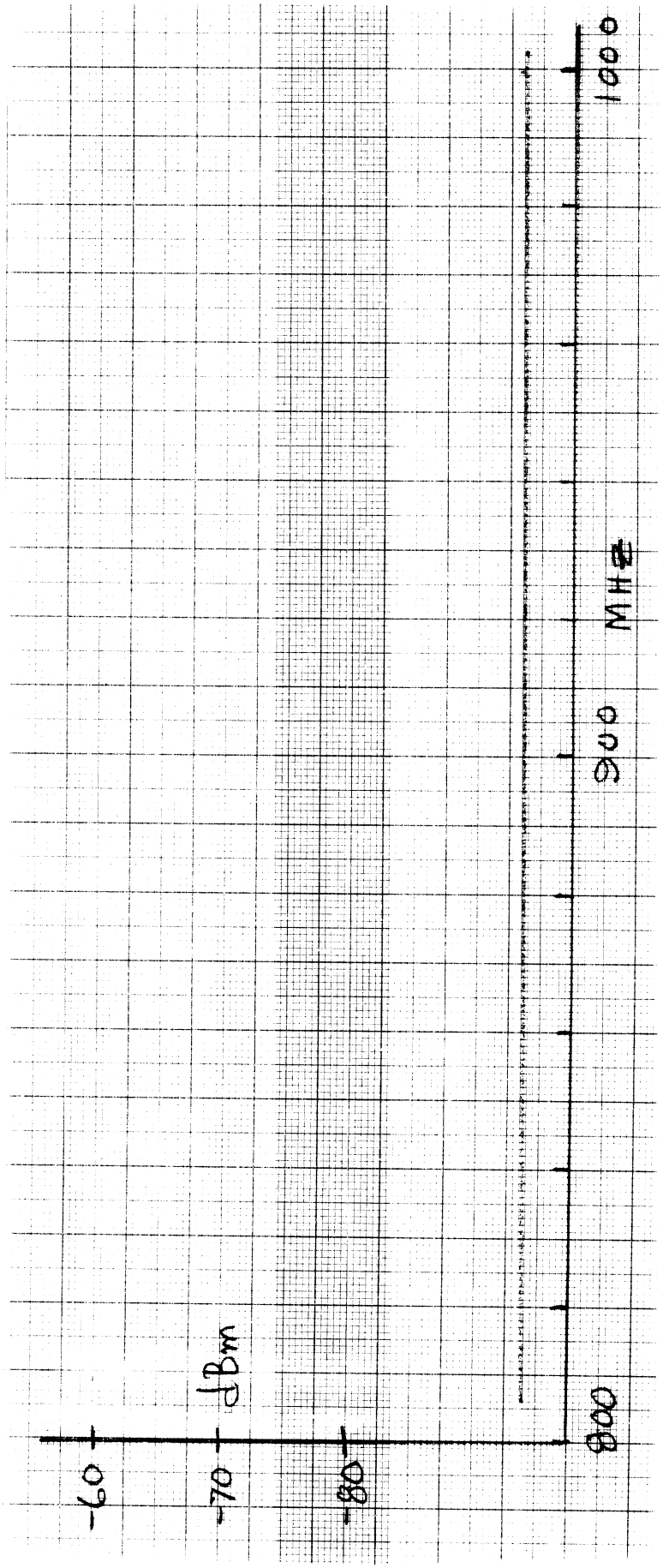

Fig. 5(f): Response of the whip antenna vs. frequency of the commercially available signals. (800 - 1000 MHz)

measurement. Similar comments will also apply to the results given below for the other antennas.

Figures 6 and 7 give similar results obtained with the heated backlite antenna under side-fed and bottom-fed conditions, respectively. Since the gain of the spectrum analyzer was not varied and assuming the signal strength of a specific station was constant, the results of Figs. 5 and 6 or 7 can be used to estimate the relative sensitivity of the heated backlite antenna with respect to the whip. For example, the relative FM band sensitivities of the heated backlite antennas may be obtained by comparing Figs. 6(b) and 7(b) with those of 5(b). Similar results obtained with the capacitor antenna for d = 1 inch and 1 1/2 inches are shown in Figs. 8 and 9 respectively. From the results shown in Figs. 8 and 9 it appears that the capacitor antenna has similar sensitivities for d = 1 inch and 1 1/2 inches. For this reason only the case with d = 1 inch will be retained for further study.

The following general observations are made from a study of the results shown in Figs. 5 through 9.

(a) The FM sensitivities of the heated backlite antennas are about 5 to 10 dB lower and that of the capacitor antenna about 20 dB lower than that of the whip antenna.

(b) The heated backlite antenna appear to be more sensitive than the whip at the higher range of frequencies, particularly in the 600 to 800 MHz range (see Figs. 5(e), 6(e), 7(e)). In this frequency range the sensitivity of the capacitive antenna is of the same order as that of the whip.

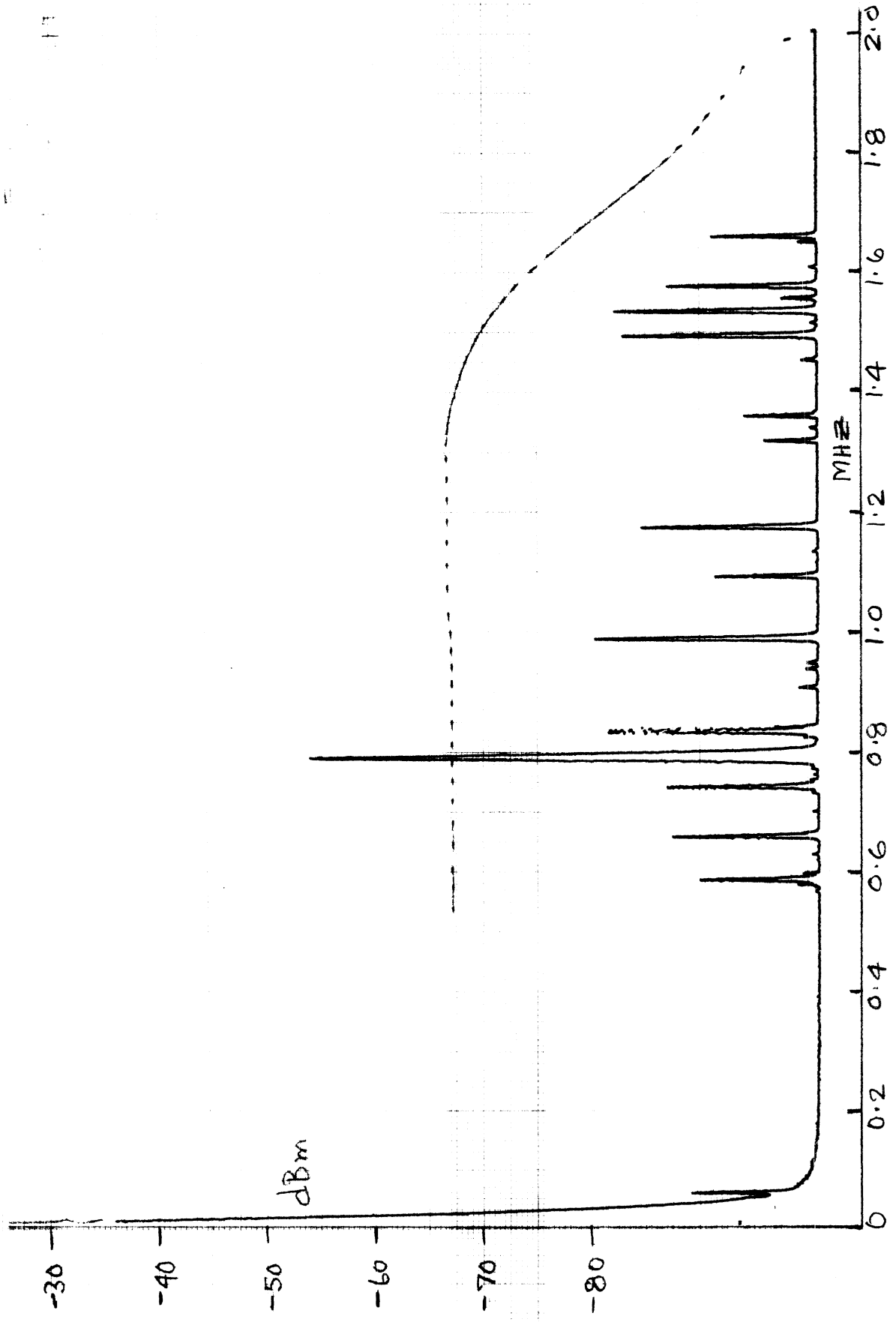

Fig. 6(a) Response of the side-fed heated backlite antenna vs. frequency of the commercially available signals. (0 - 2 MHz)

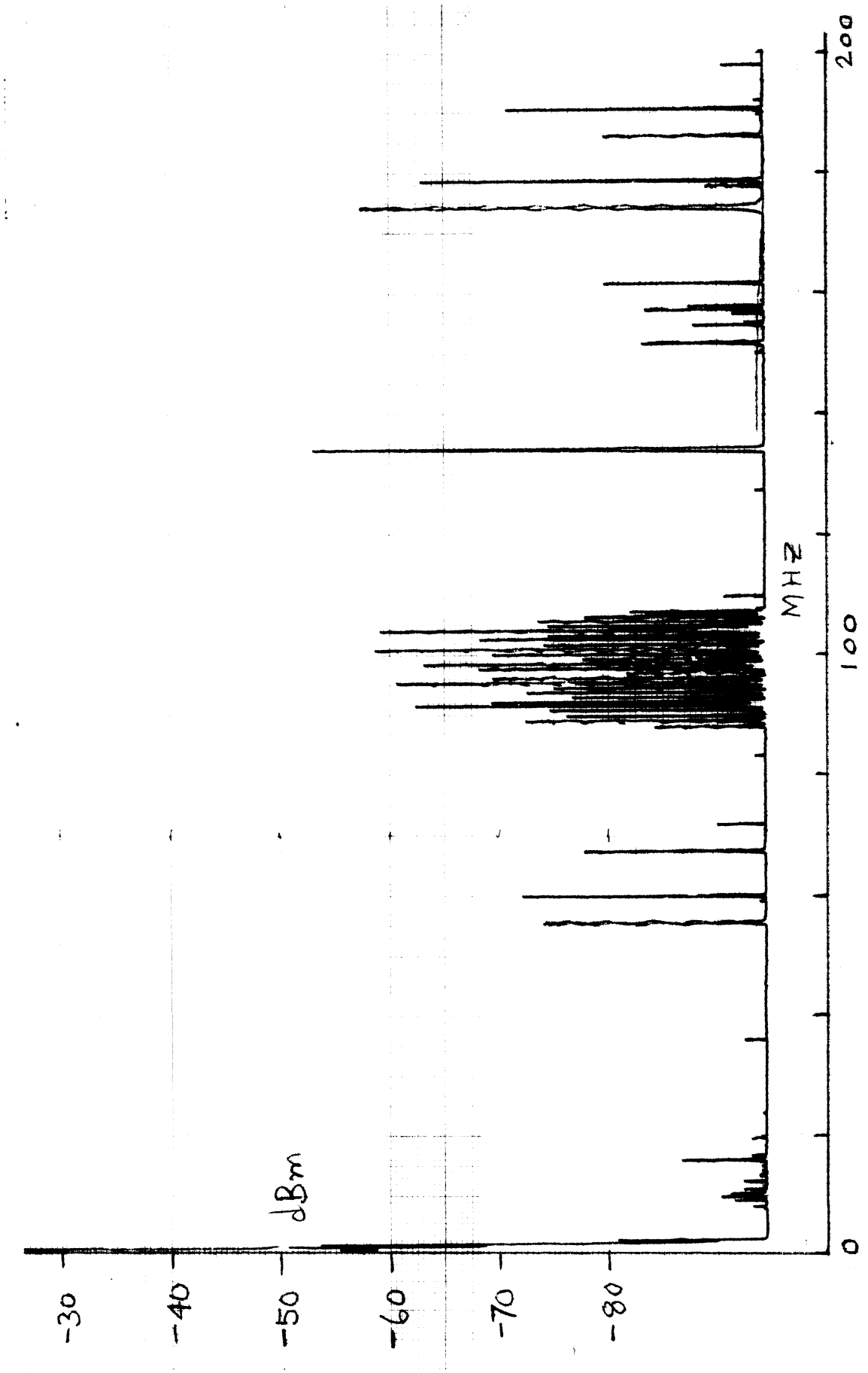

Fig. 6(b): Response of the side-fed heated bqcklite antenna vs. frequency of the commercially available signals. (0 - 200 MHz)

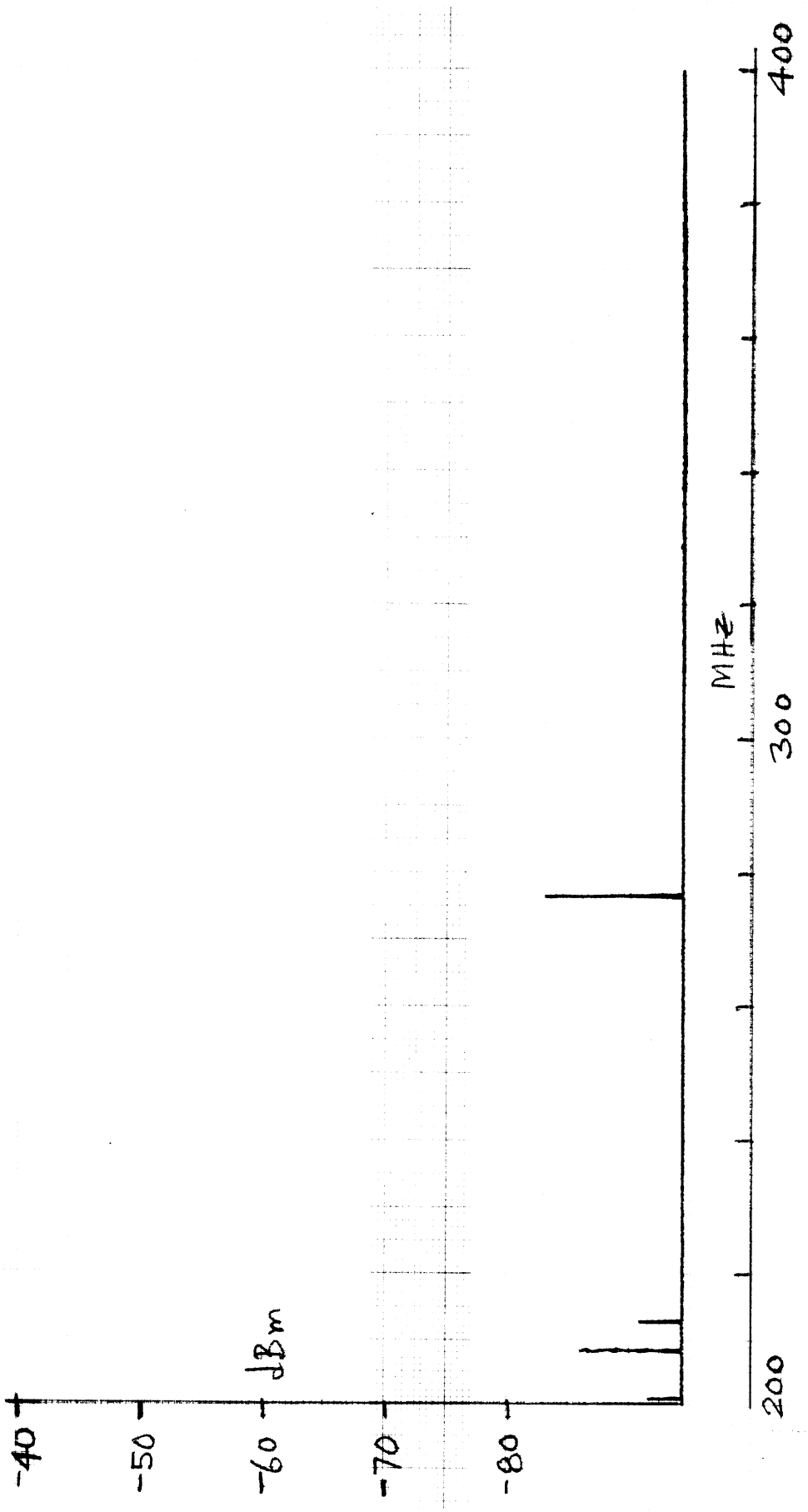

Fig. 6(c) Response of the side-fed heated backlite antenna vs. frequency of the commercially available signals. (200 - 400 MHz)

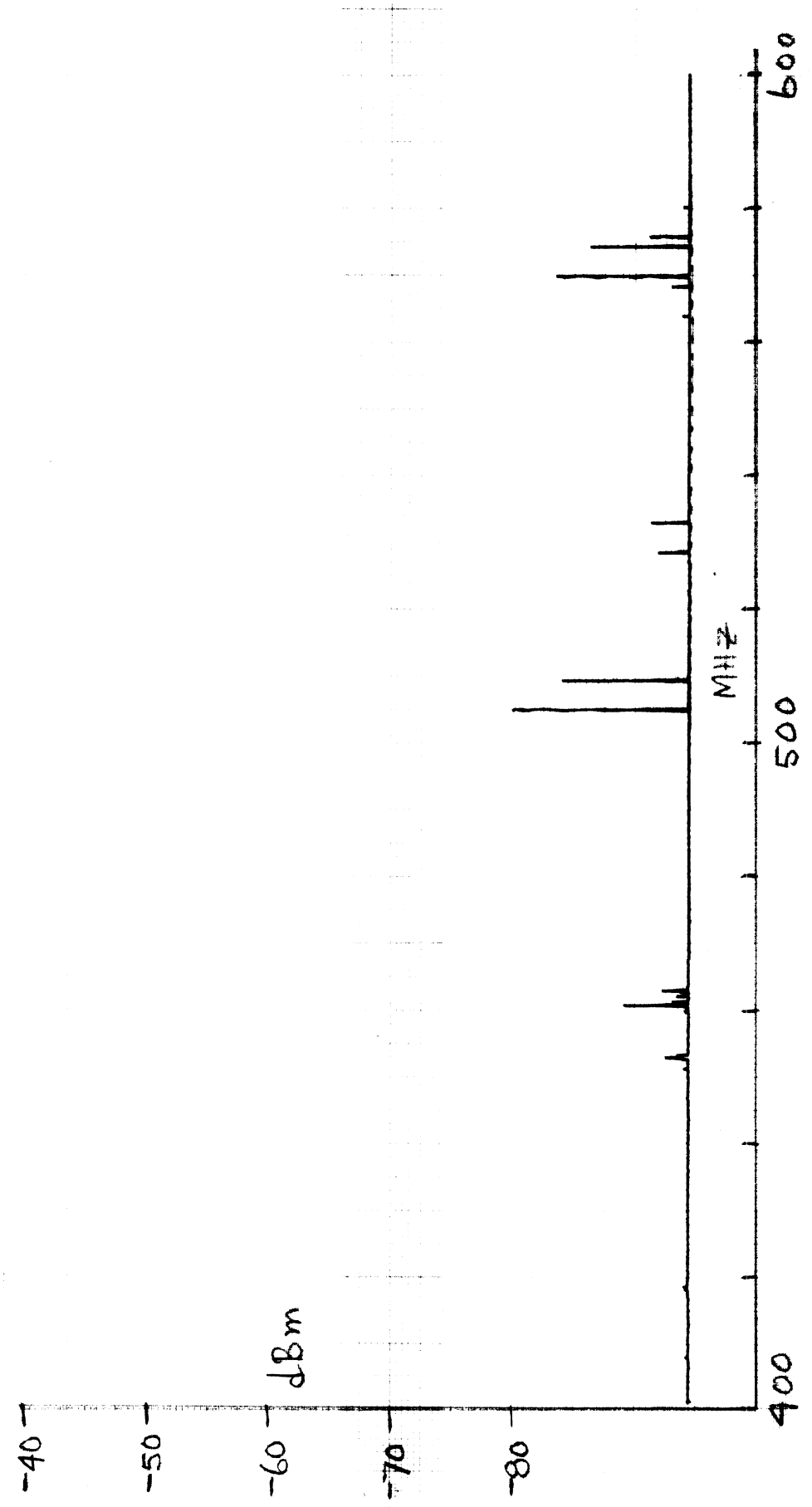

Fig. 6(d): Response of the side-fed heated backlite antenna vs. frequency of the commercially available signals. (400 - 600 MHz)

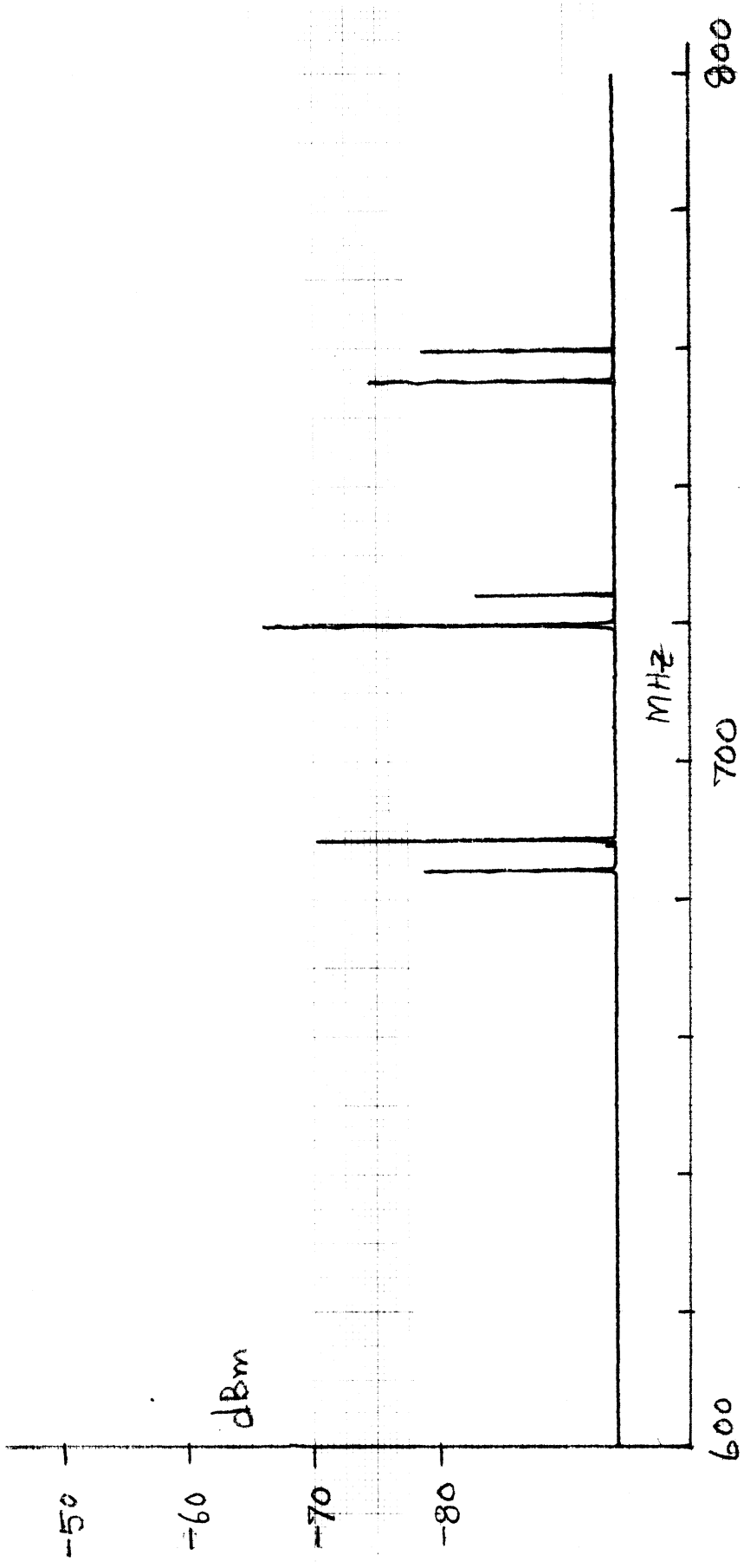

Fig. 6(e): Response of the side-fed heated backlite antenna vs. frequency of the commercially available signals. (600 - 800 MHz)

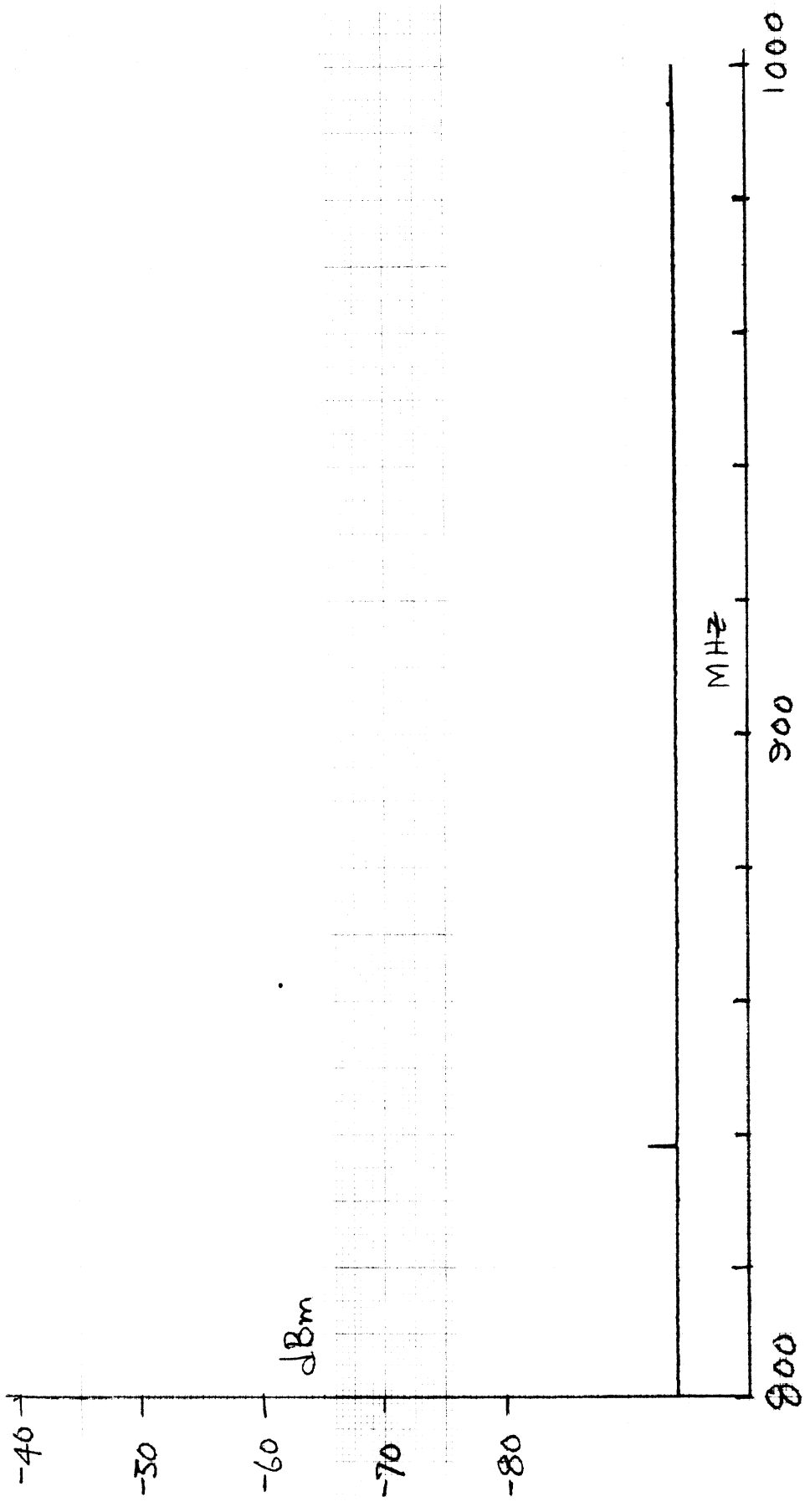

Fig. 6(f): Response of the side-fed heated backlite antenna vs. frequency of the commercially available signals. (800 - 1000 MHz)

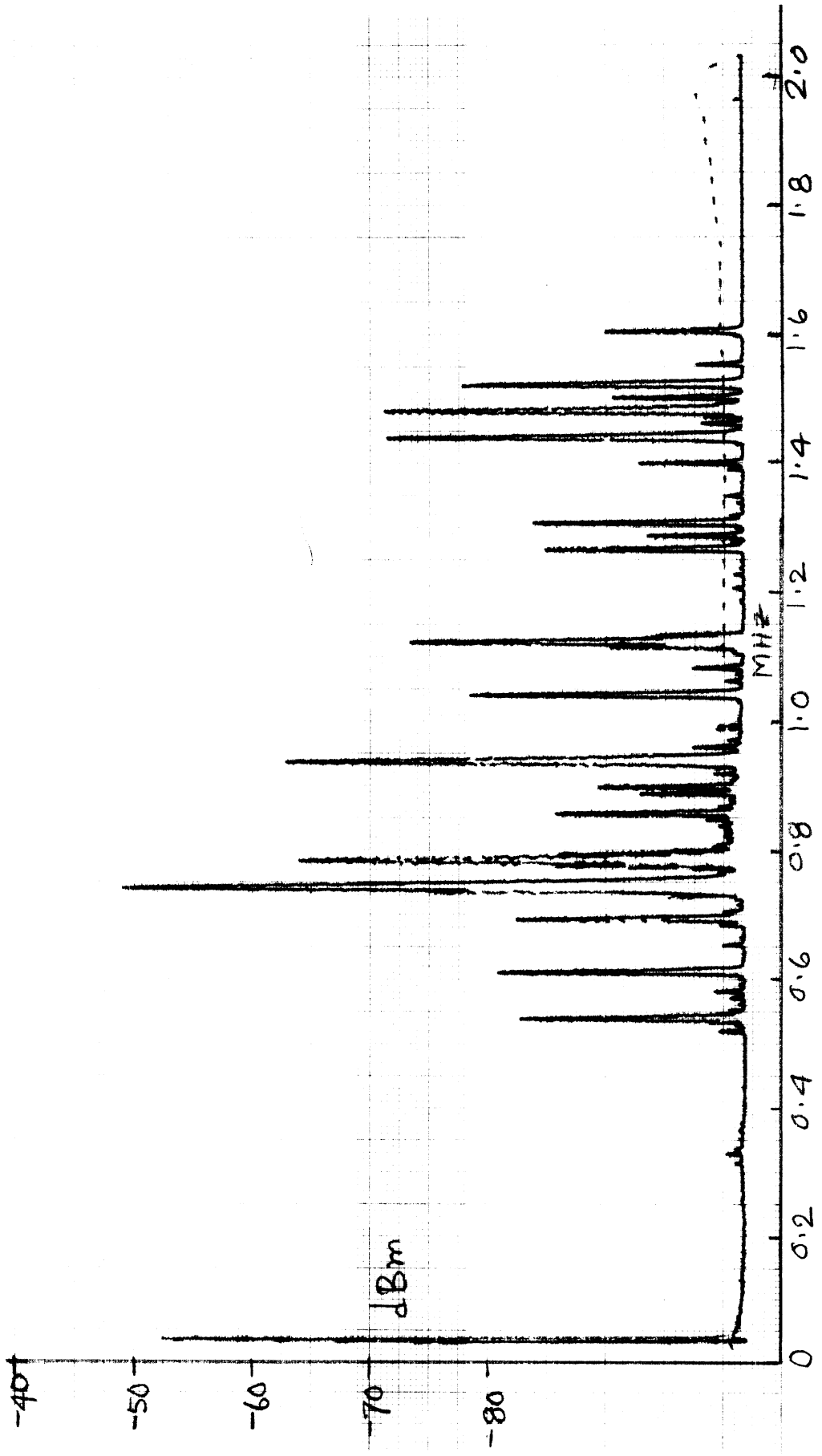

Fig. 7(a): Response of the bottom-fed heated backlite antenna vs. frequency of the commercially available signals. (0 - 2 MHz)

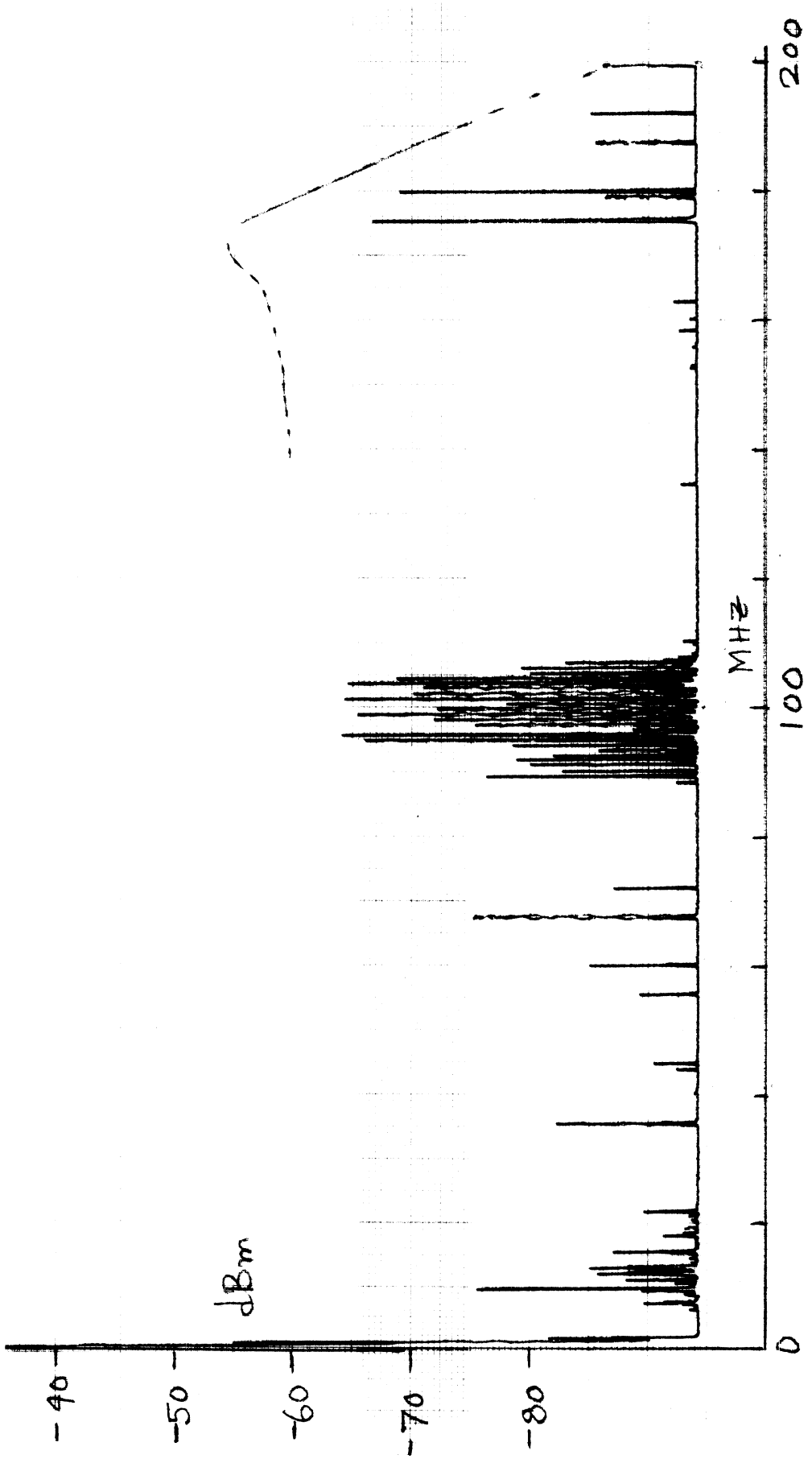

Fig. 7(b): Response of the bottom-fed heated backlite antenna vs. frequency of the commercially available signals. (0 - 200 MHz)

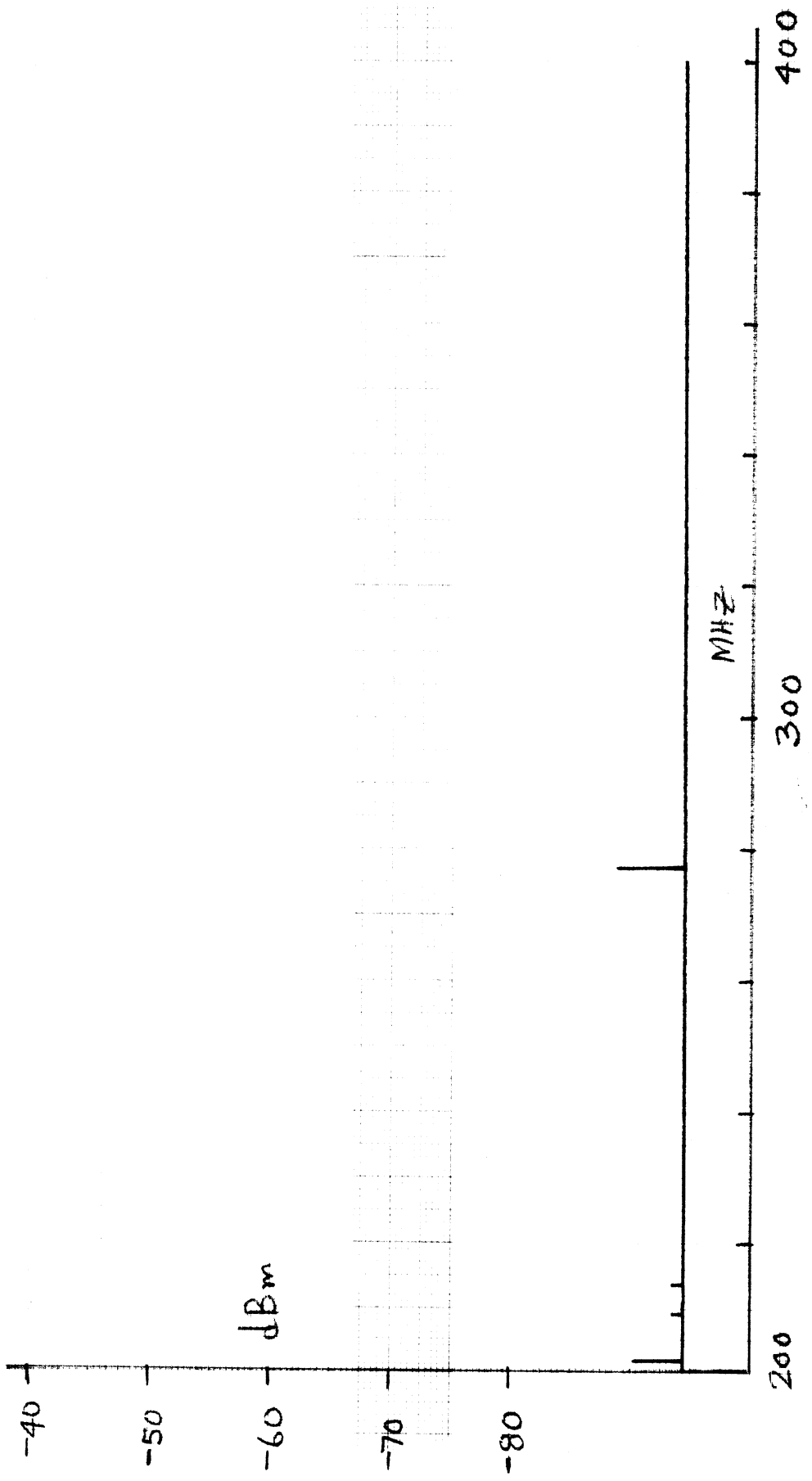

Fig. 7(c): Response of the bottom-fed heated backlite antenna vs. frequency of the commercially available signals. (200 - 400 MHz)

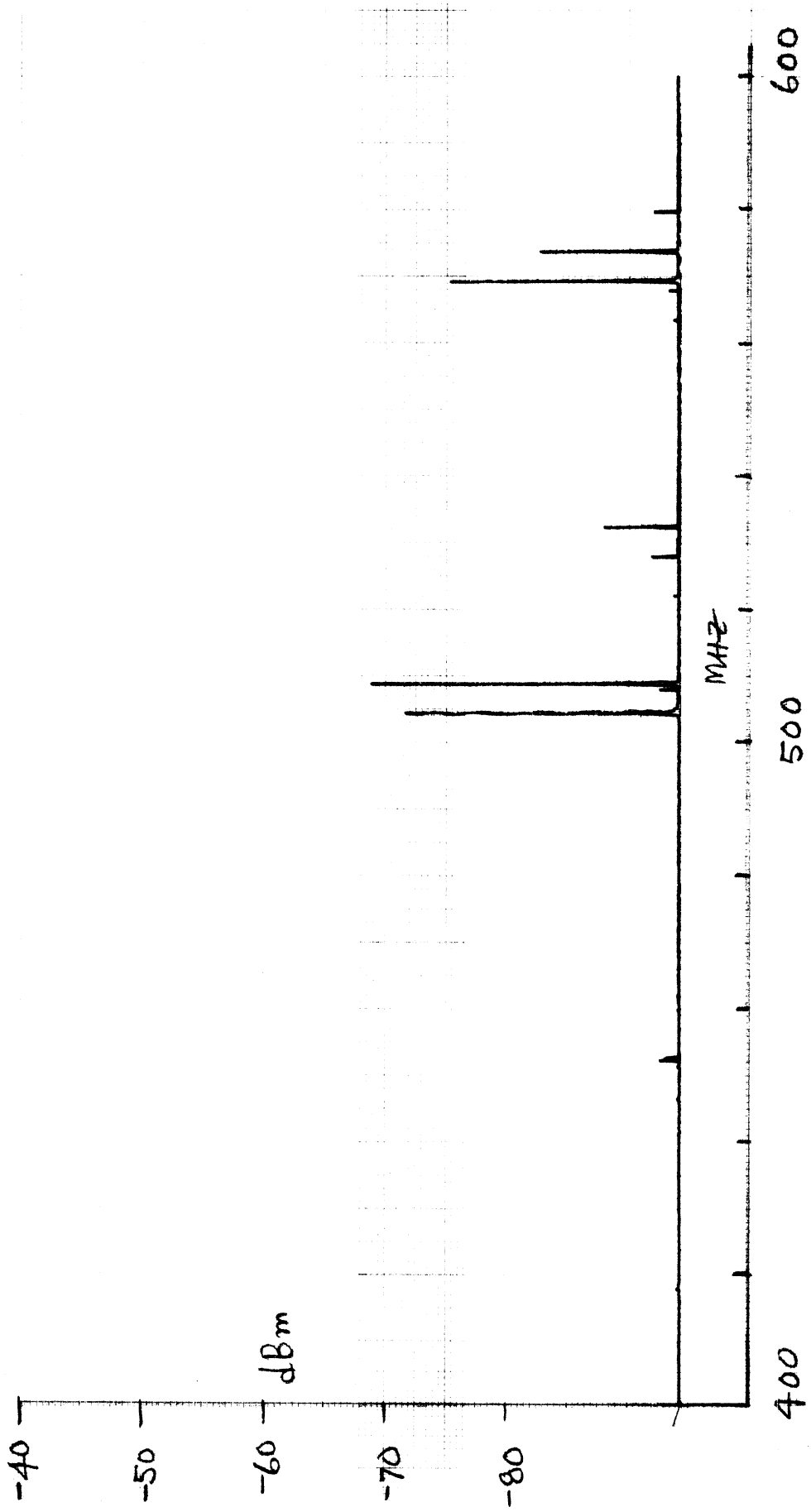

Fig. 7(d): Response of the bottom-fed heated backlite antenna vs. frequency of the commercially available signals. (400 - 600 MHz)

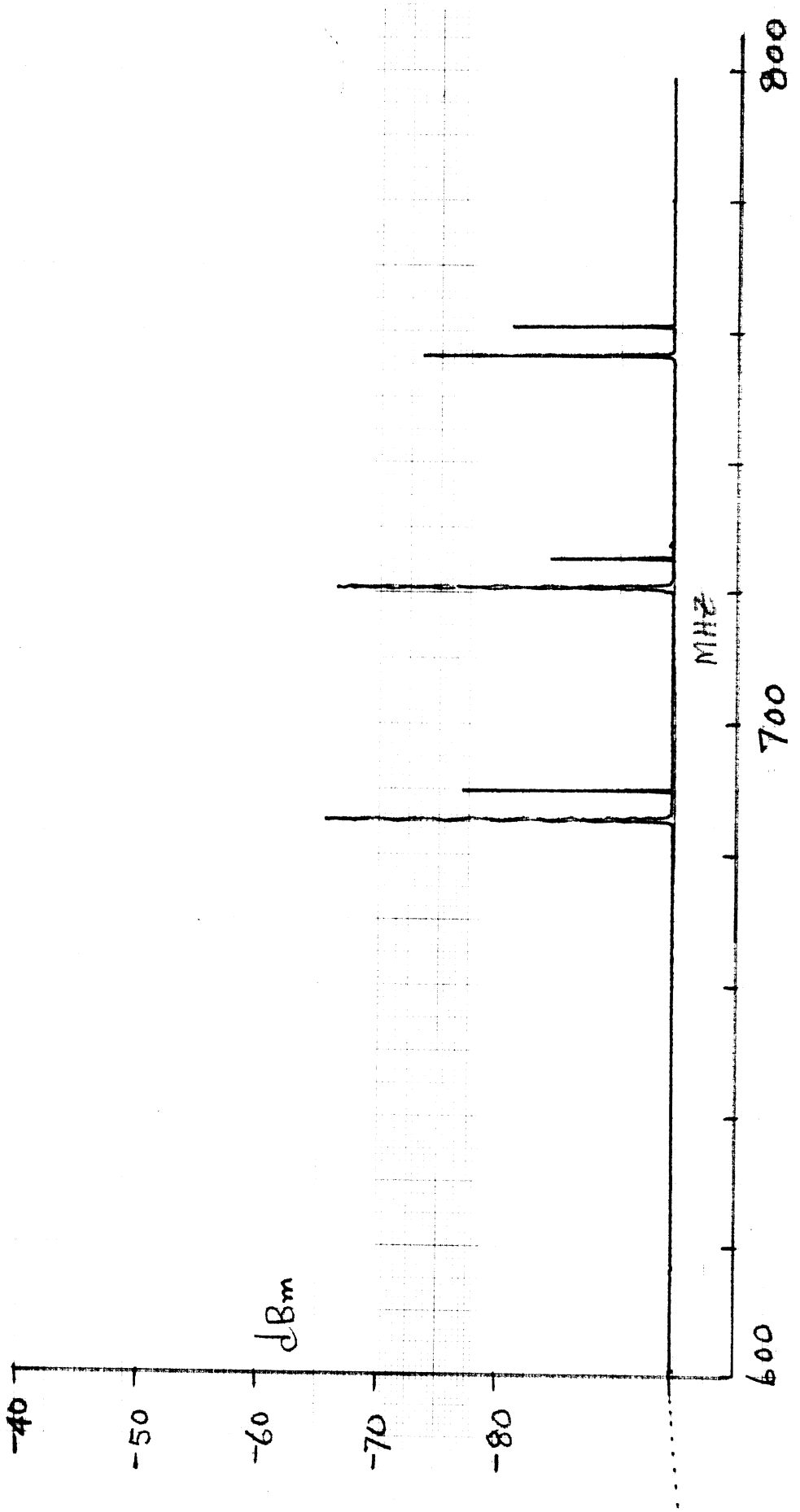

Fig. 7(e): Response of the bottom-fed heated backlite antenna vs. frequency of the commercially available signals. (600 - 800 MHz)

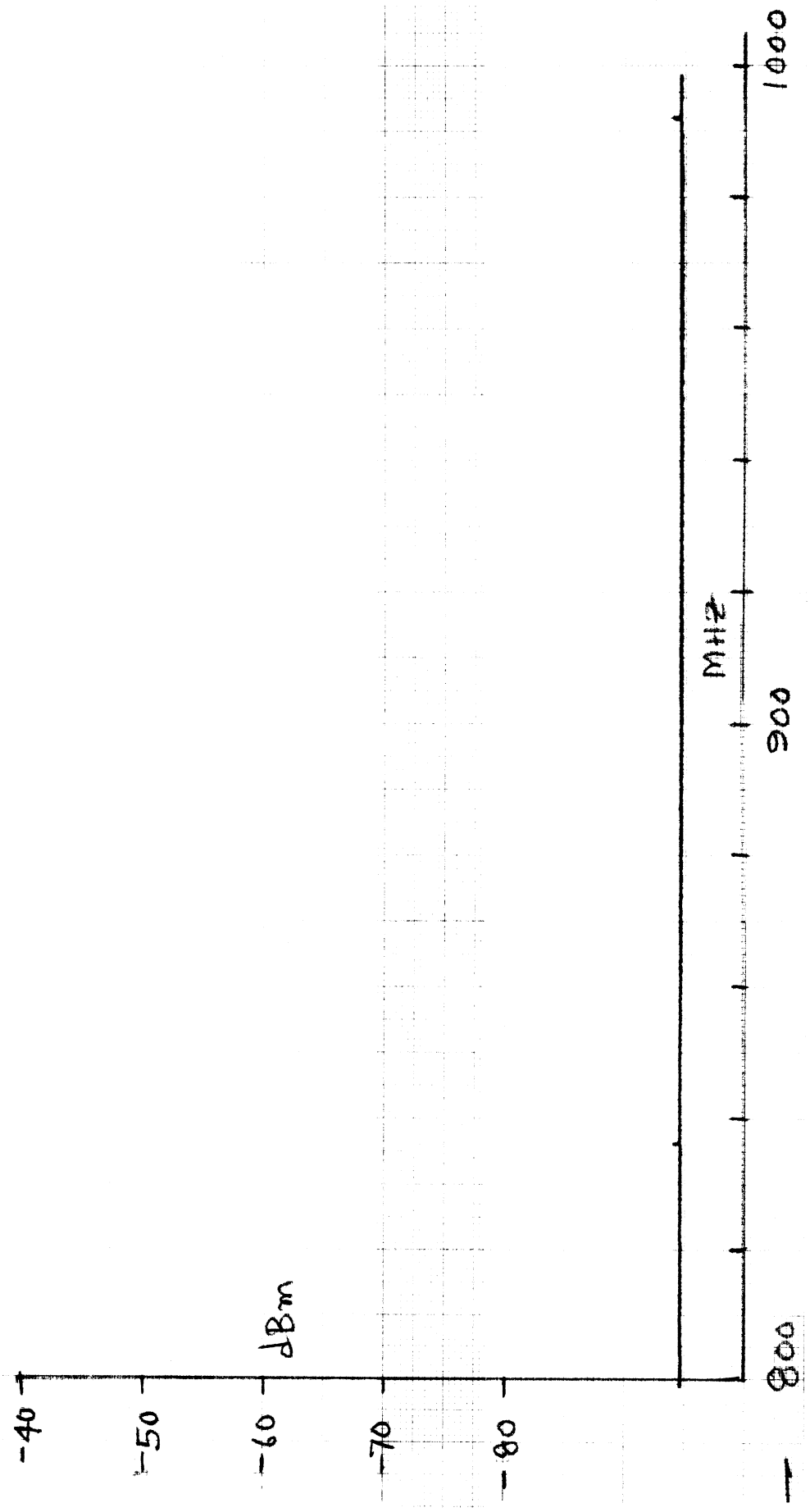

Fig. 7(f): Response of the bottom-fed heated backlite antenna vs. frequency of the commercially available signals. (800 - 1000 MHz)

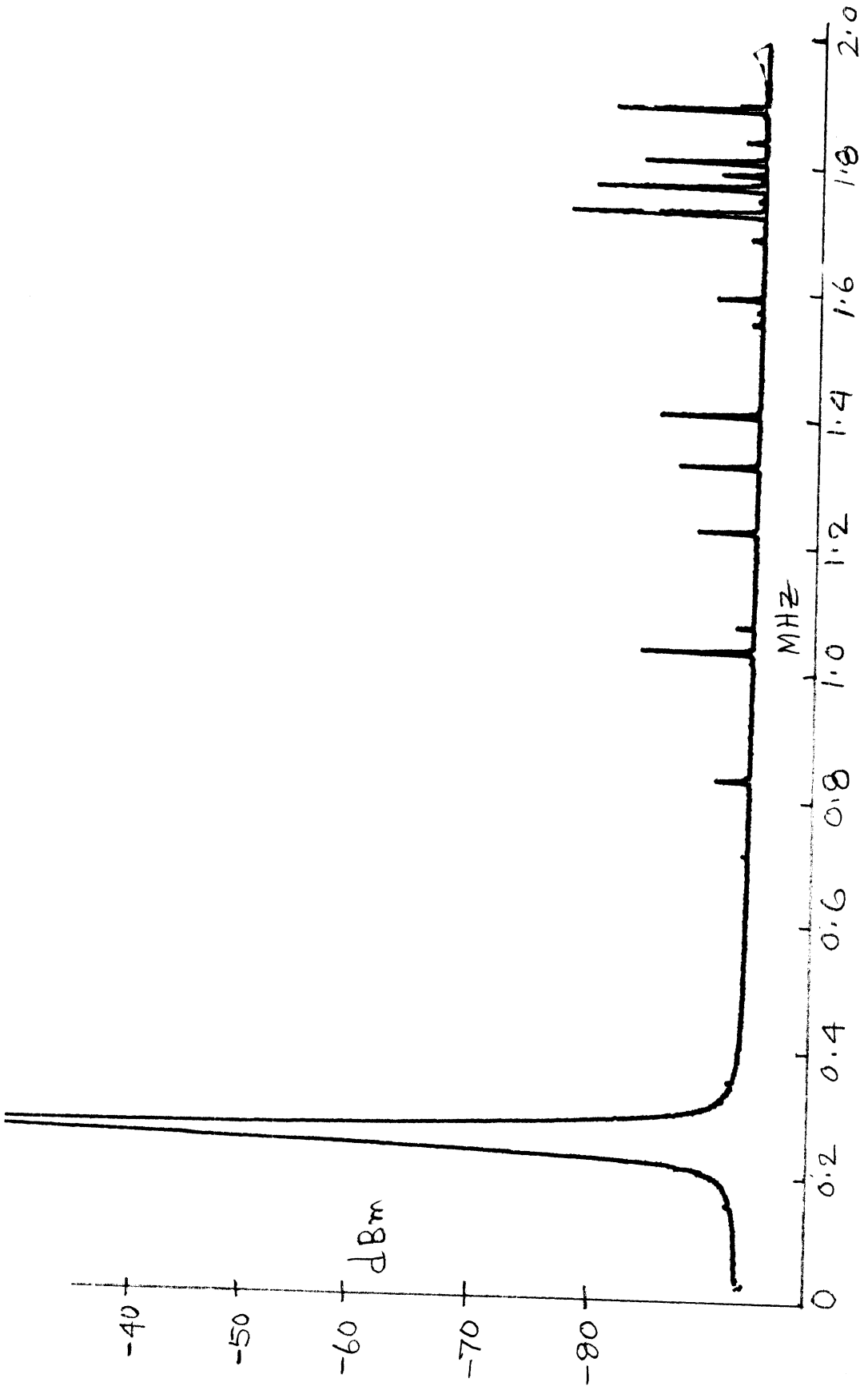

Fig. 8(a): Response of the capacitor antenna (d = 1.0 inch) vs. frequency of the commercially available signals. (0 - 2 MHz)

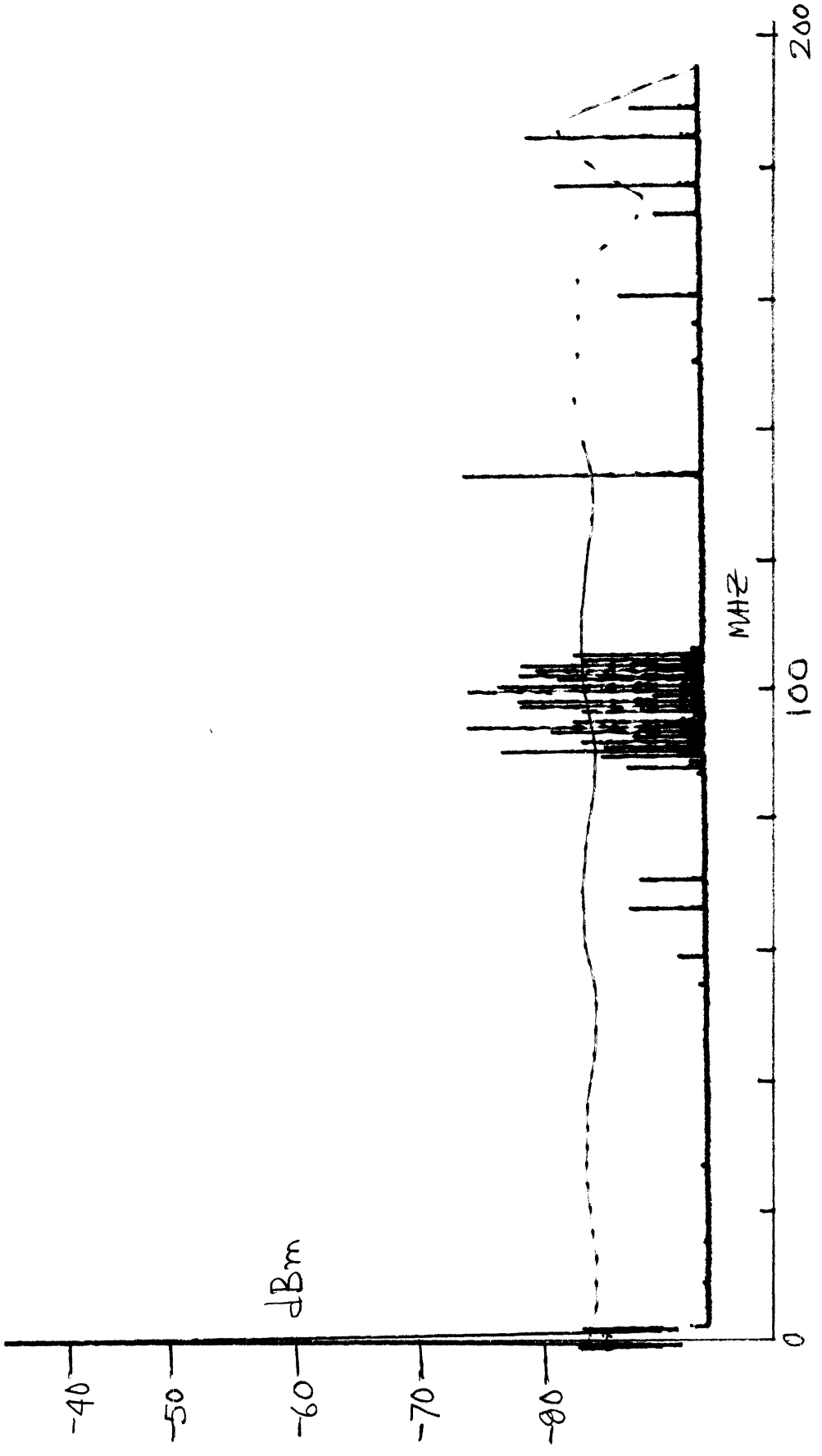

Fig. 8(b): Response of the capacitor antenna (d = 1.0 inch) vs. frequency of the commercially available signals. (0 - 200 MHz)

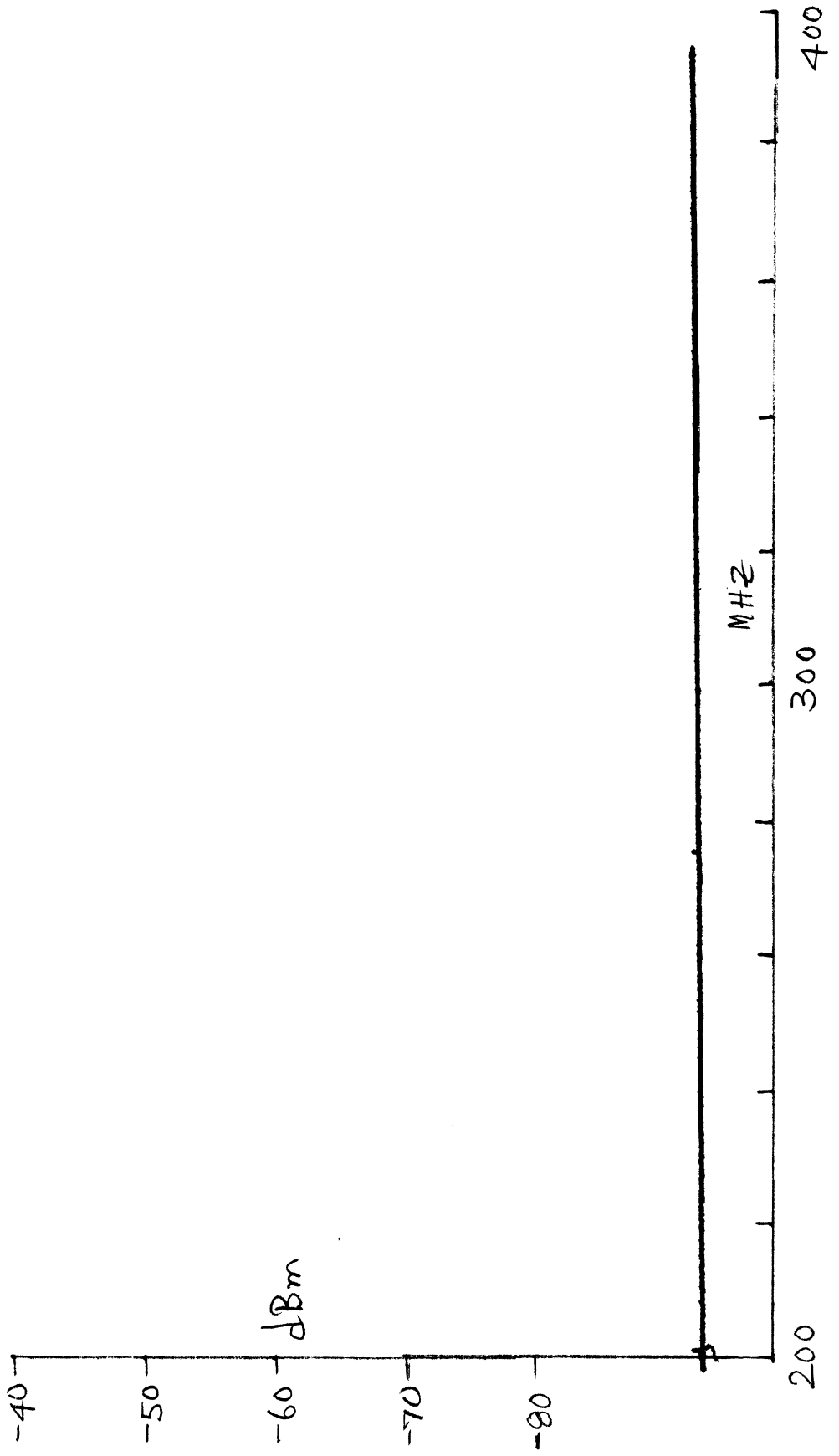

Fig. 8(c): Response of the capacitor antenna (d = 1.0 inch) vs. frequency of the commercially available signals. (200 - 400 MHz)

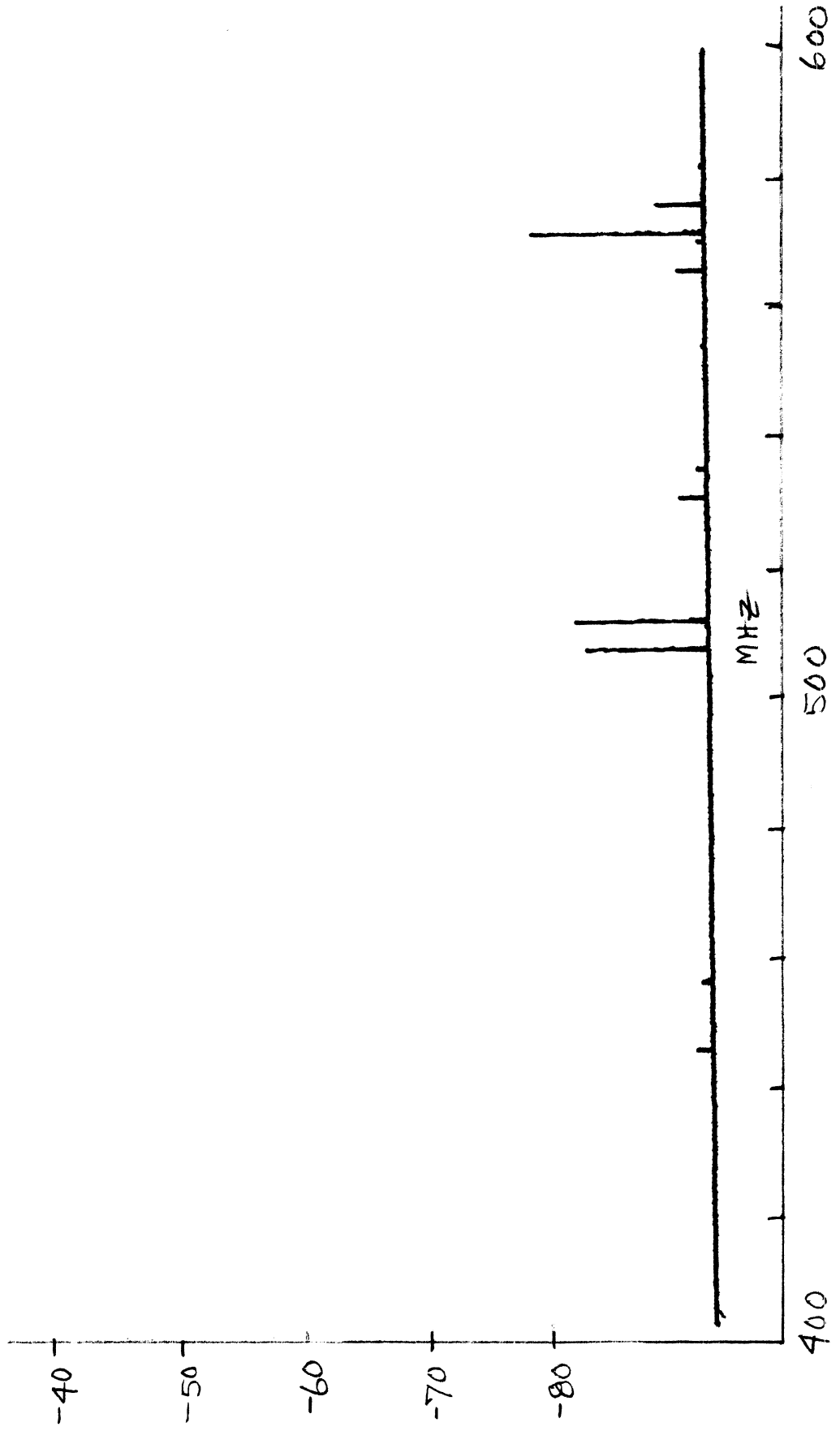

Fig. 8(d): Response of the capacitor antenna (d = 1.0 inch) vs. frequency of the commercially available signals. (400 - 600 MHz)

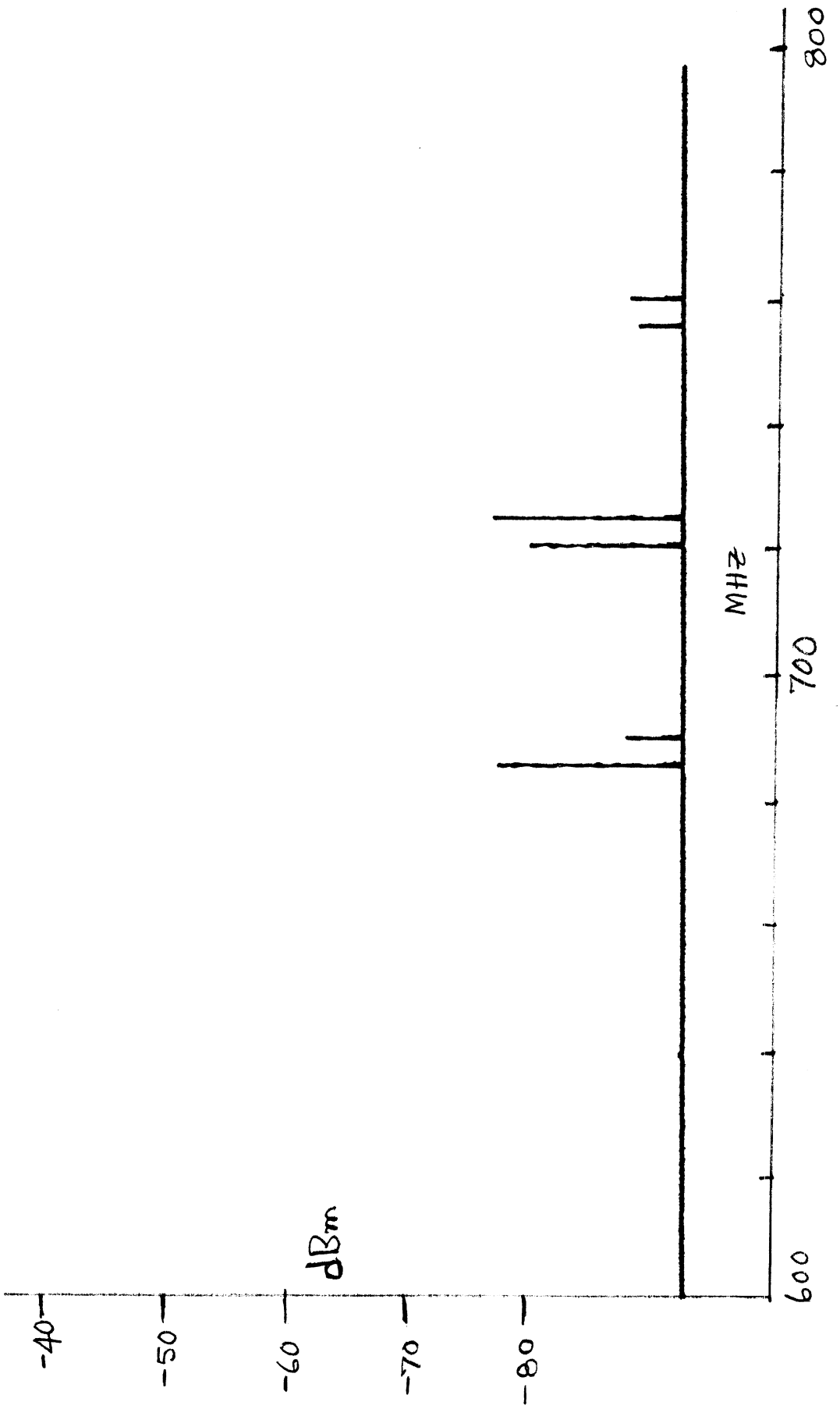

Fig. 8(e): Response of the capacitor antenna (d = 1.0 inch) vs. frequency of the commercially available signals. (600 - 800 MHz)

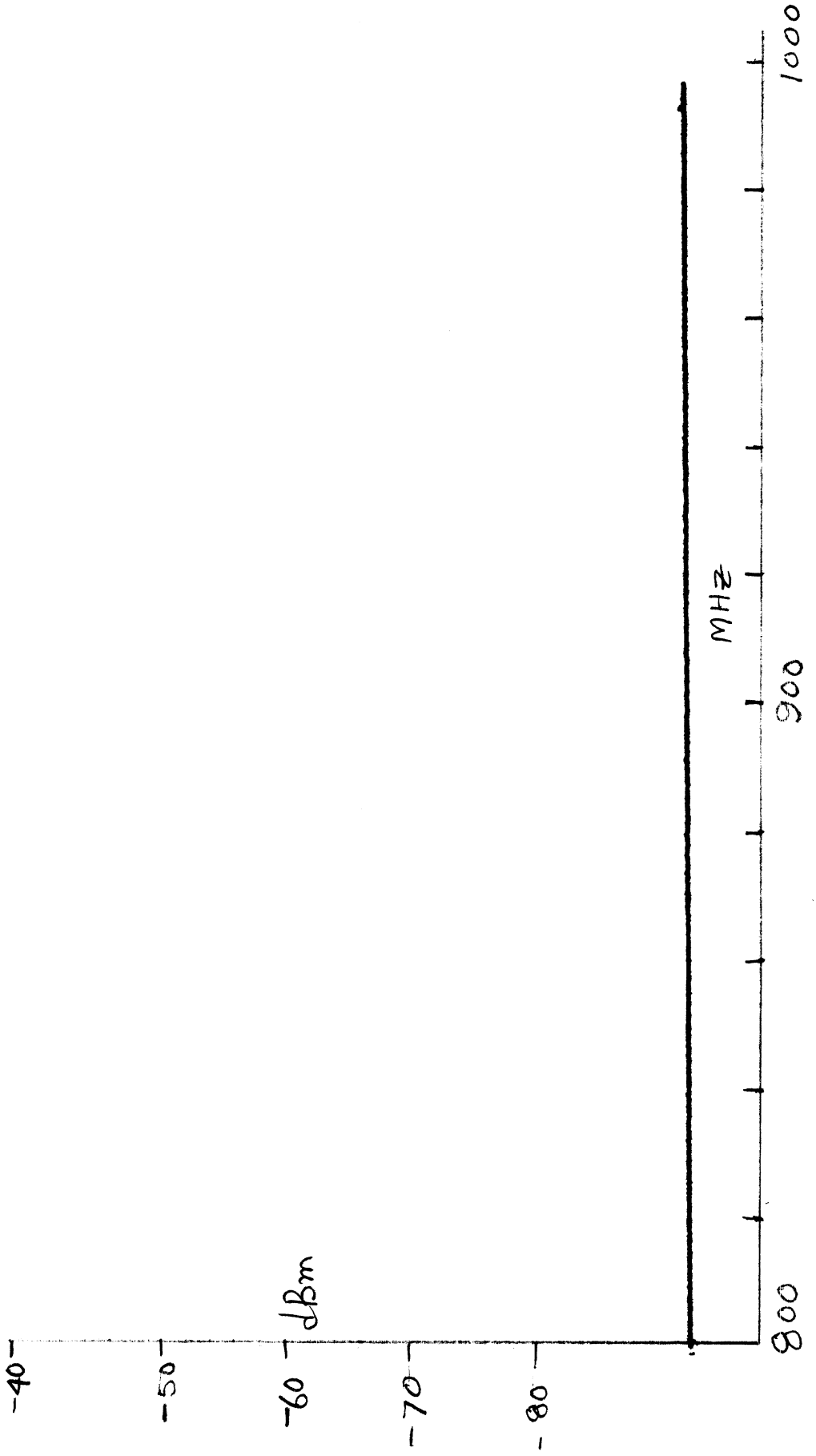

Fig. 8(f): Response of the capacitor antenna (d = 1.0 inch) vs. frequency of the commercially available signals. (800 - 1000 MHz)

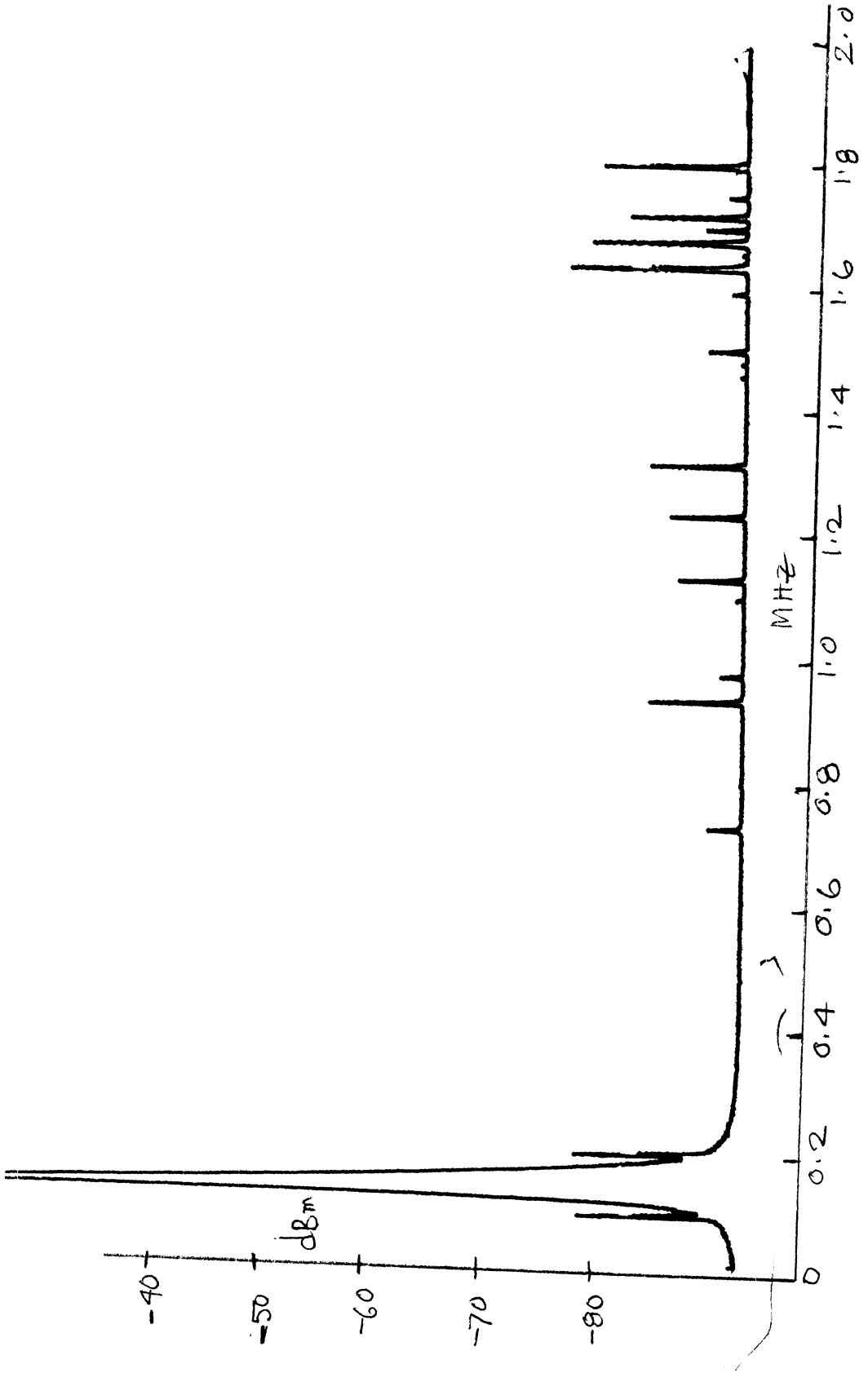

Fig. 9(a): Response of the capacitor antenna (d = 1.5 inches) vs. frequency of the commercially available signals. (0 - 2 MHz)

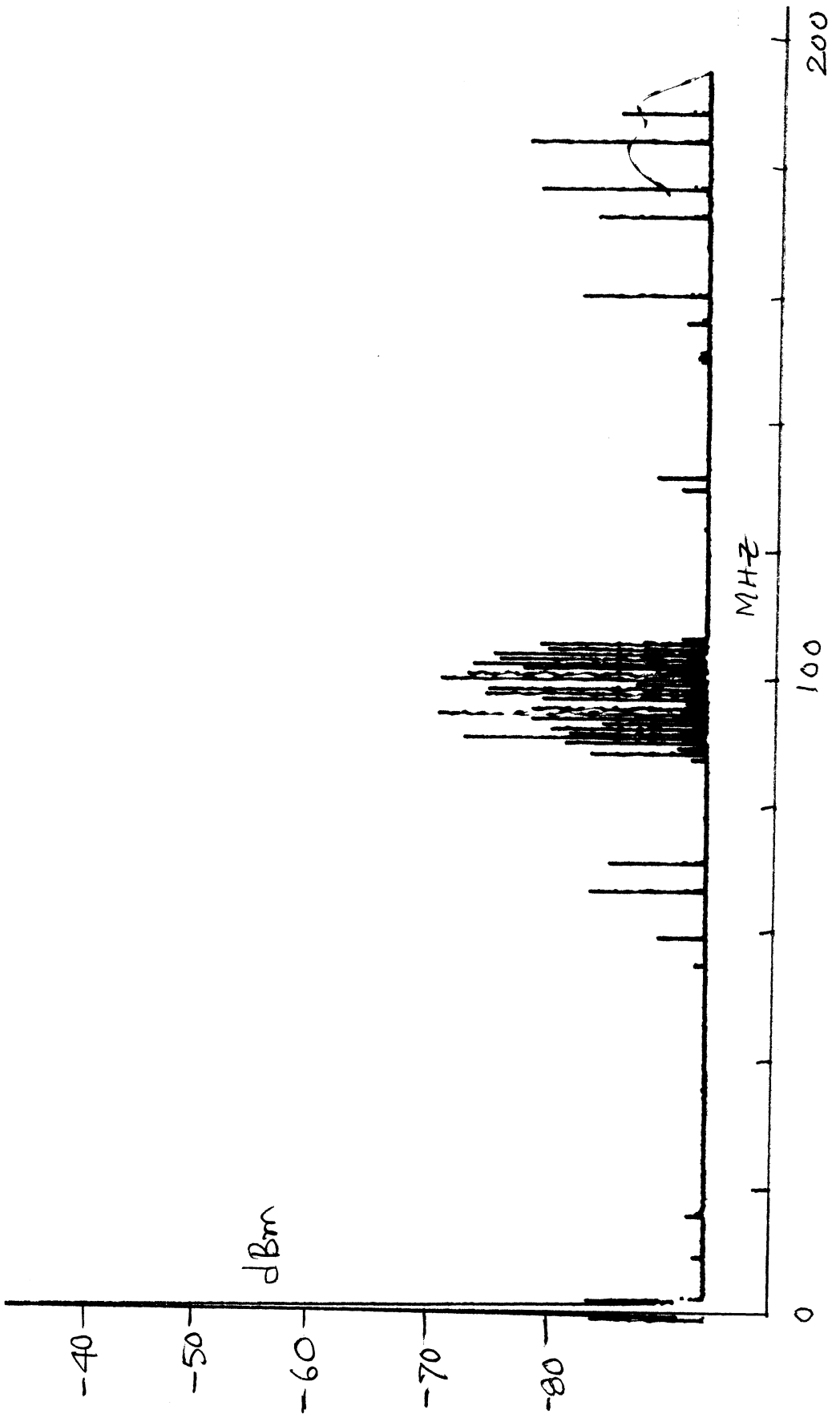

Fig. 9(b): Response of the capacitor antenna (d = 1.5 inches) vs. frequency of the commercially available signals. (0 - 200 MHz)

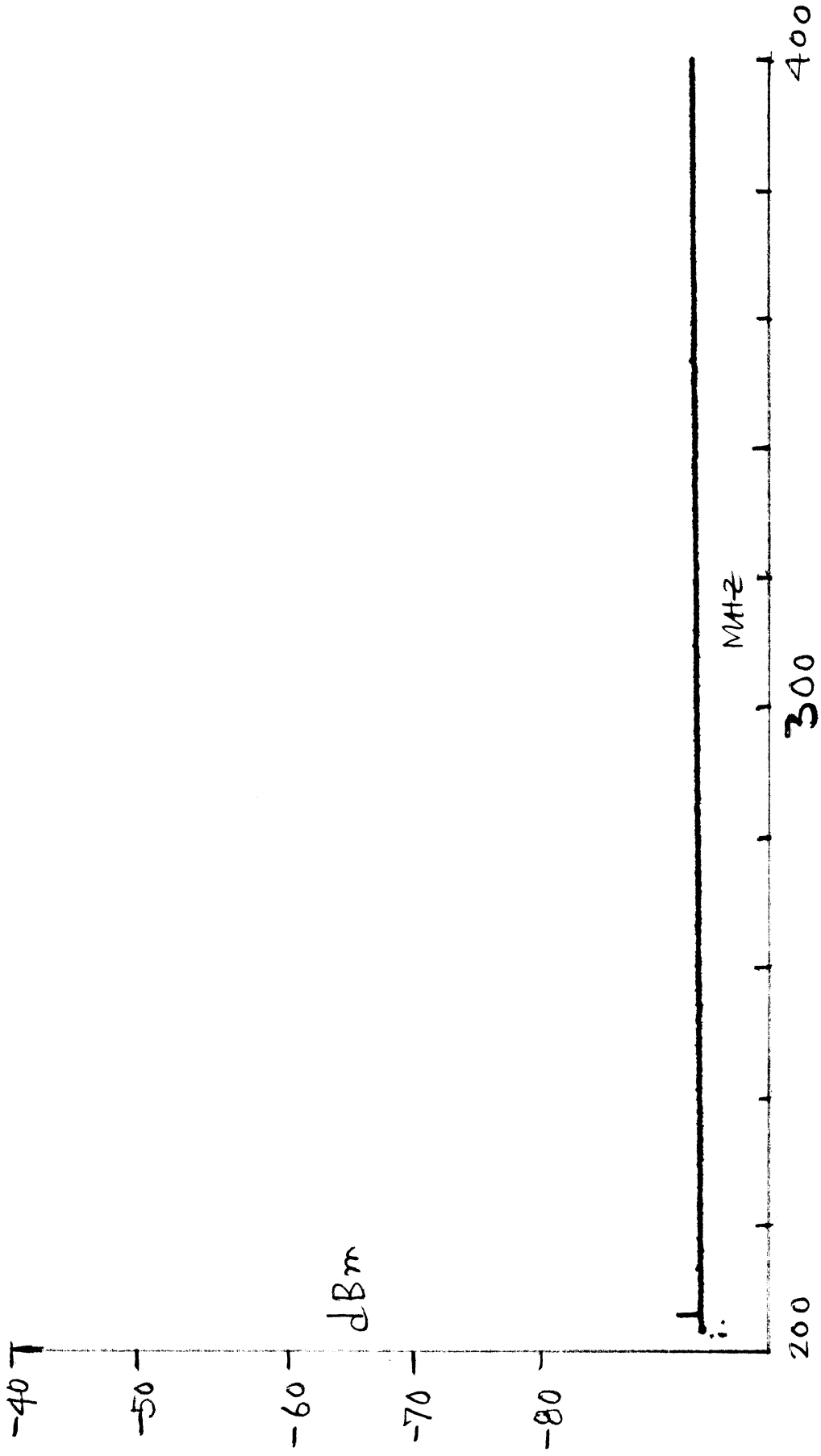

Fig. 9(c): Response of the capacitor antenna (d = 1.5 inches) vs. frequency of the commercially available signals. (200 - 400 MHz)

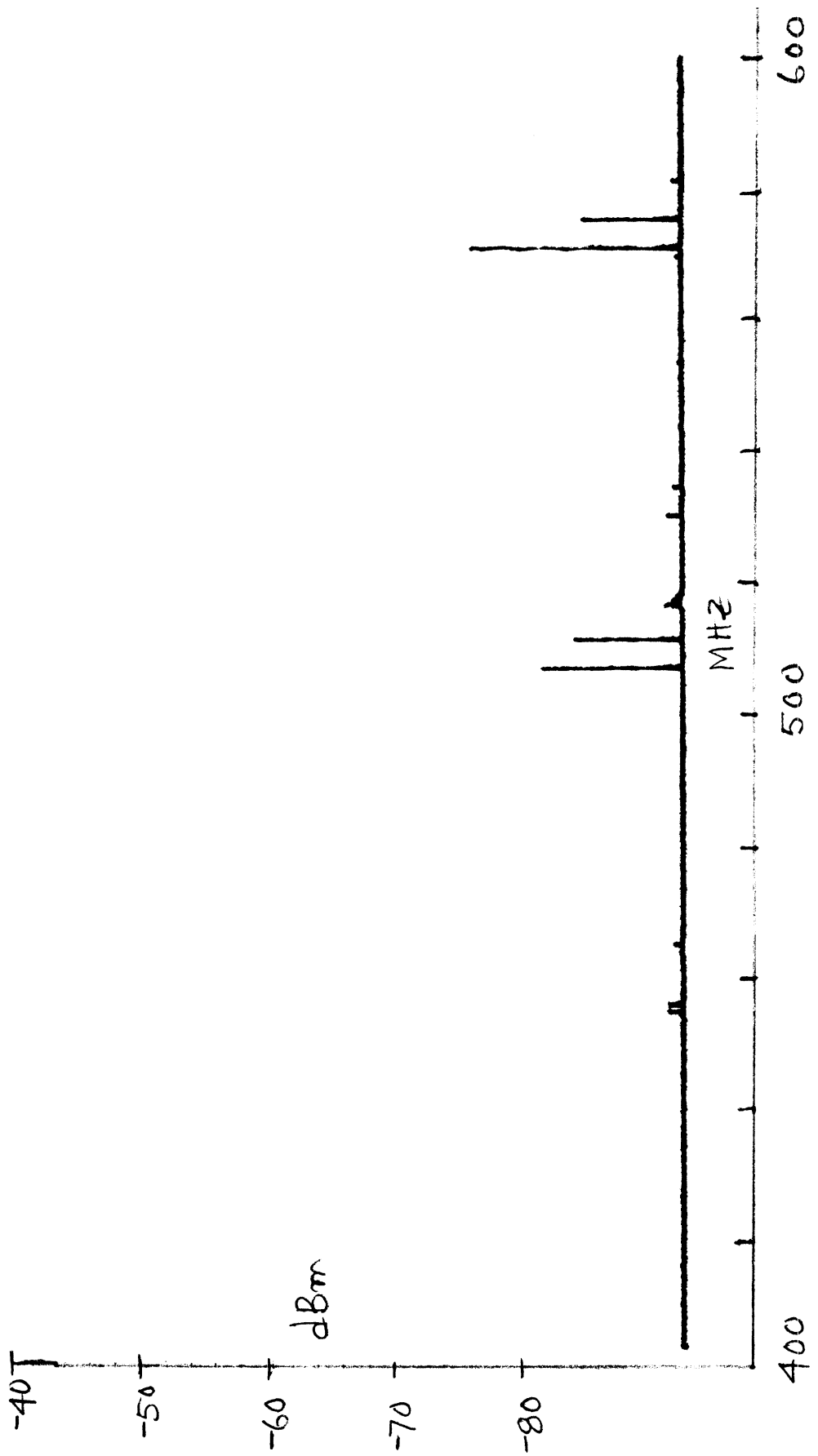

Fig. 9(d): Response of the capacitor antenna (d = 1.5 inches) vs. frequency of the commercially available signals. (400 - 600 MHz)

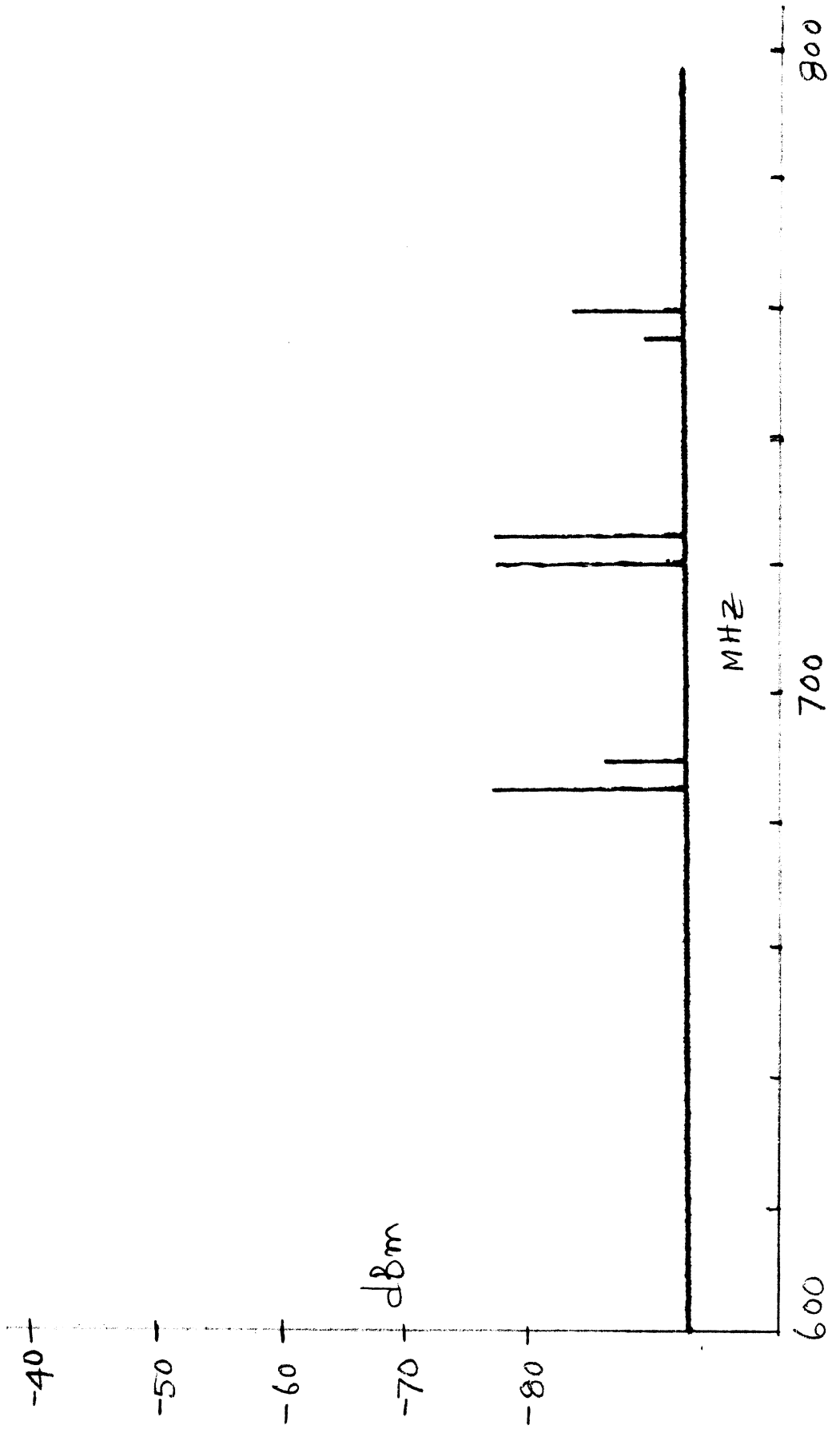

Fig. 9(e): Response of the capacitor antenna (d = 1.5 inches) vs. frequency of the commercially available signals. (600 - 800 MHz)

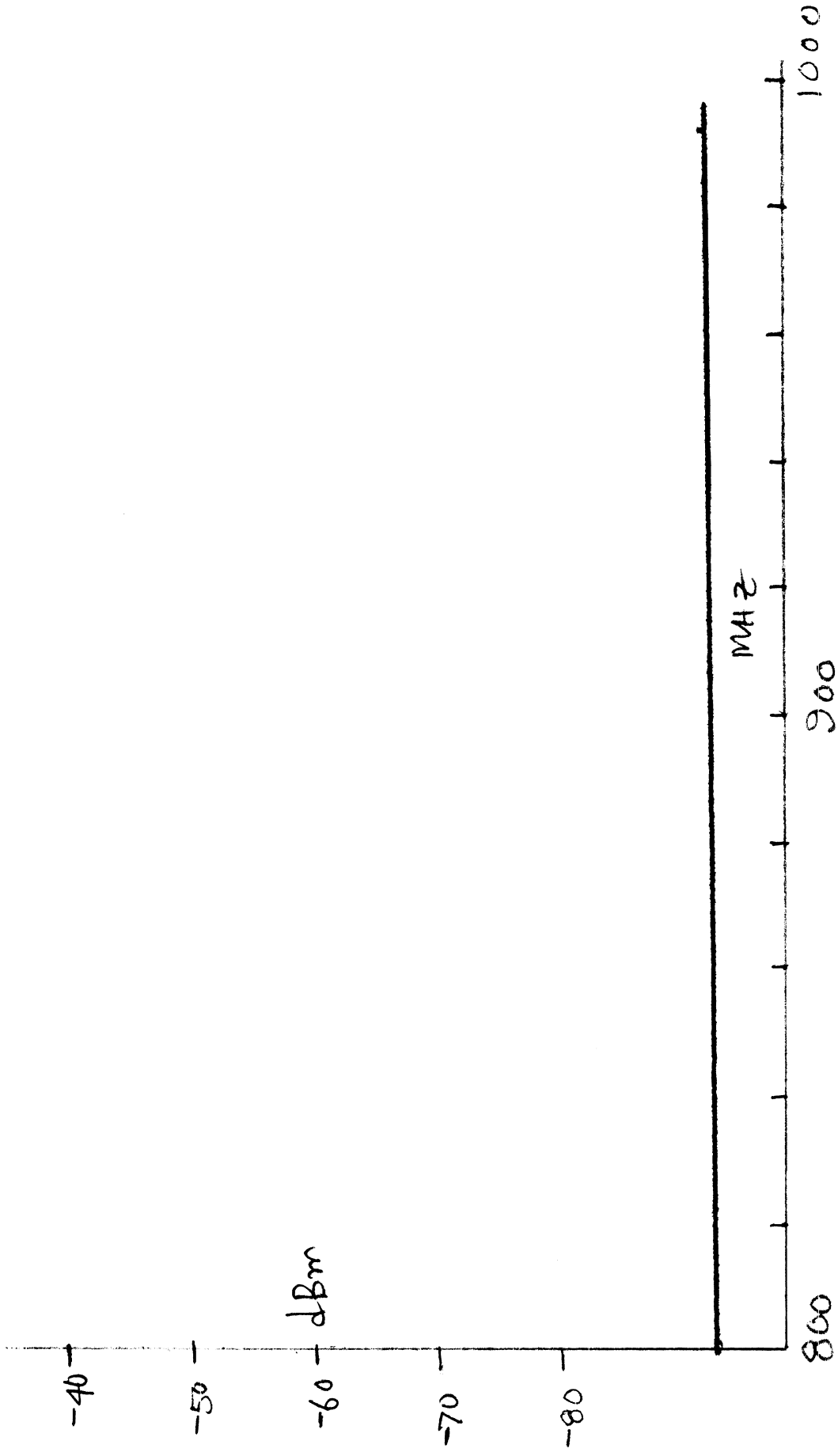

Fig. 9(f): Response of the capacitor antenna (d = 1.5 inches) vs. frequency of the commercially available signals. (800 - 1000 MHz)

IV. RADIATION PATTERNS OF ISOLATED ANTENNAS

In this section we present the receiving patterns of the whip, heated backlite (side-fed and bottom-fed) and capacitor (with d = 1.0 inch) antennas obtained with laboratory signals in an outside antenna pattern range. During these measurements the antenna under test, suitably mounted on the ground plane and placed on a rotating platform, received the signals of desired frequency radiated by a standard antenna located at a fixed point at a convenient distance from the platform. With the platform rotating, the signal received by the test antenna was recorded as a function of the platform rotation which in turn yielded the horizontal plane receiving pattern of the antenna.

Figures 10(a) through 10(g) show the vertically polarized horizontal plane patterns of the whip antenna obtained at selected frequencies within the range 50 to 1000 MHz. Since the level of the signal transmitted changed with frequency, it is not possible to compare the absolute values of the received signal strengths at different frequencies. The general omnidirectional nature of the patterns over most of the frequencies is as expected; the overall variations overriding the main variations of the patterns at higher frequencies are attributed to the high frequency effects and to the fact that the whip length is comparable to and larger than one wavelength at these frequencies.

The horizontal plane patterns of the heated backlite antenna were obtained with the plane of the antenna oriented vertically and by using vertically polarized signals. The patterns obtained

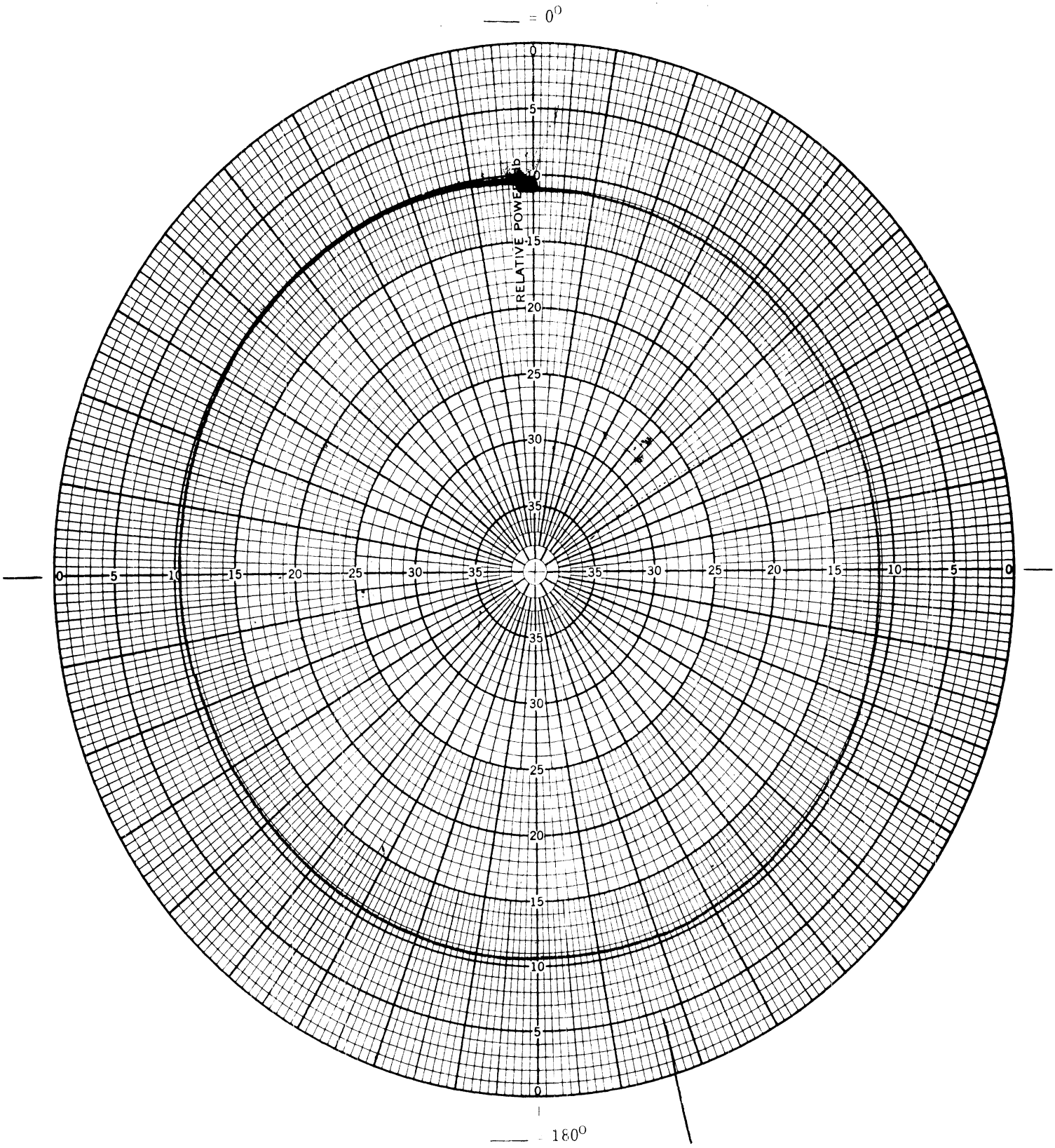

Fig. 10(a): Measured horizontal plane pattern of the whip antenna mounted on a ground plane. Vertical polarization, f = 49.5 MHz.

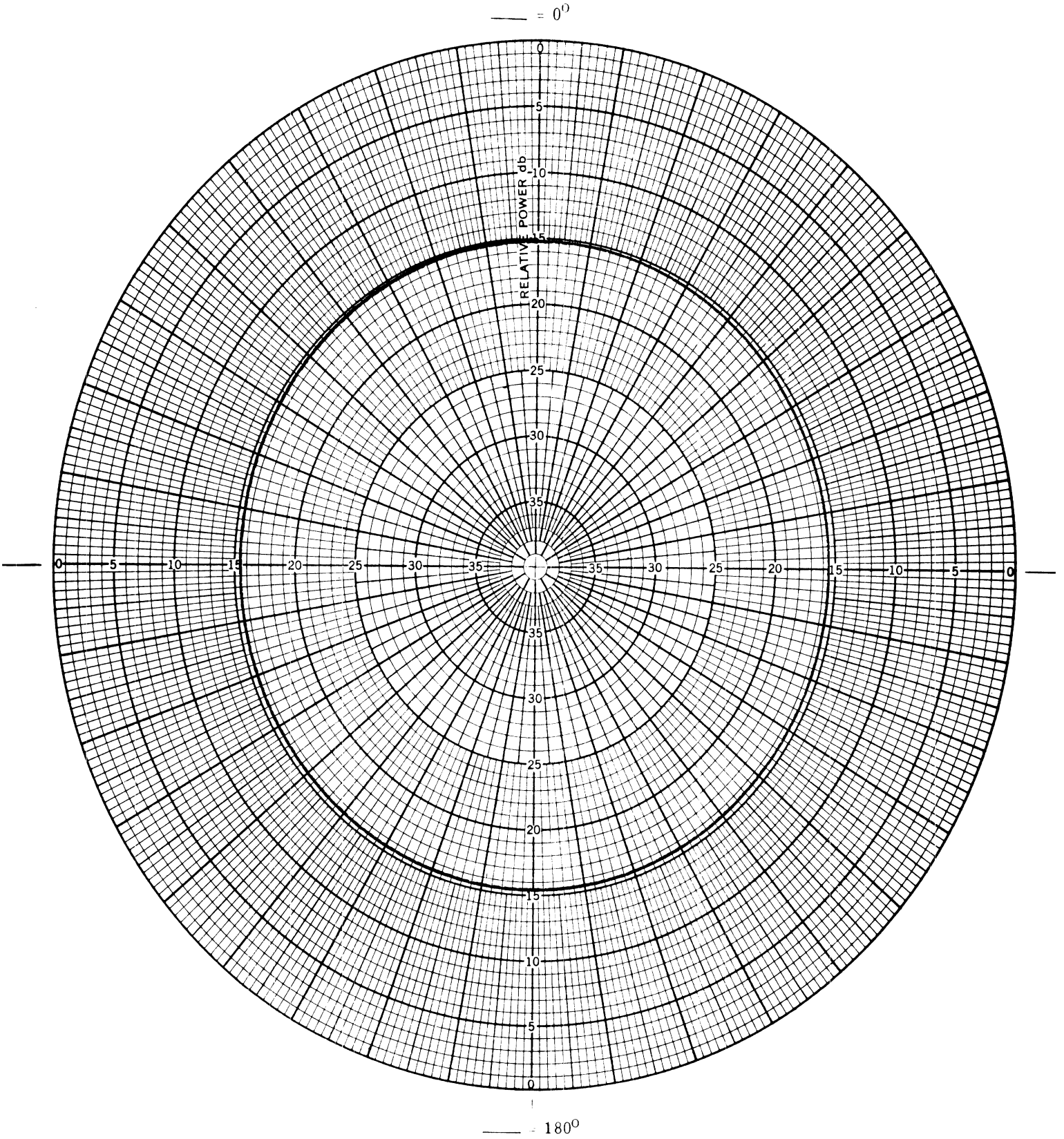

Fig. 10(b): Measured horizontal plane pattern of the whip antenna mounted on a ground plane. Vertical polarization, f = 62.6 MHz.

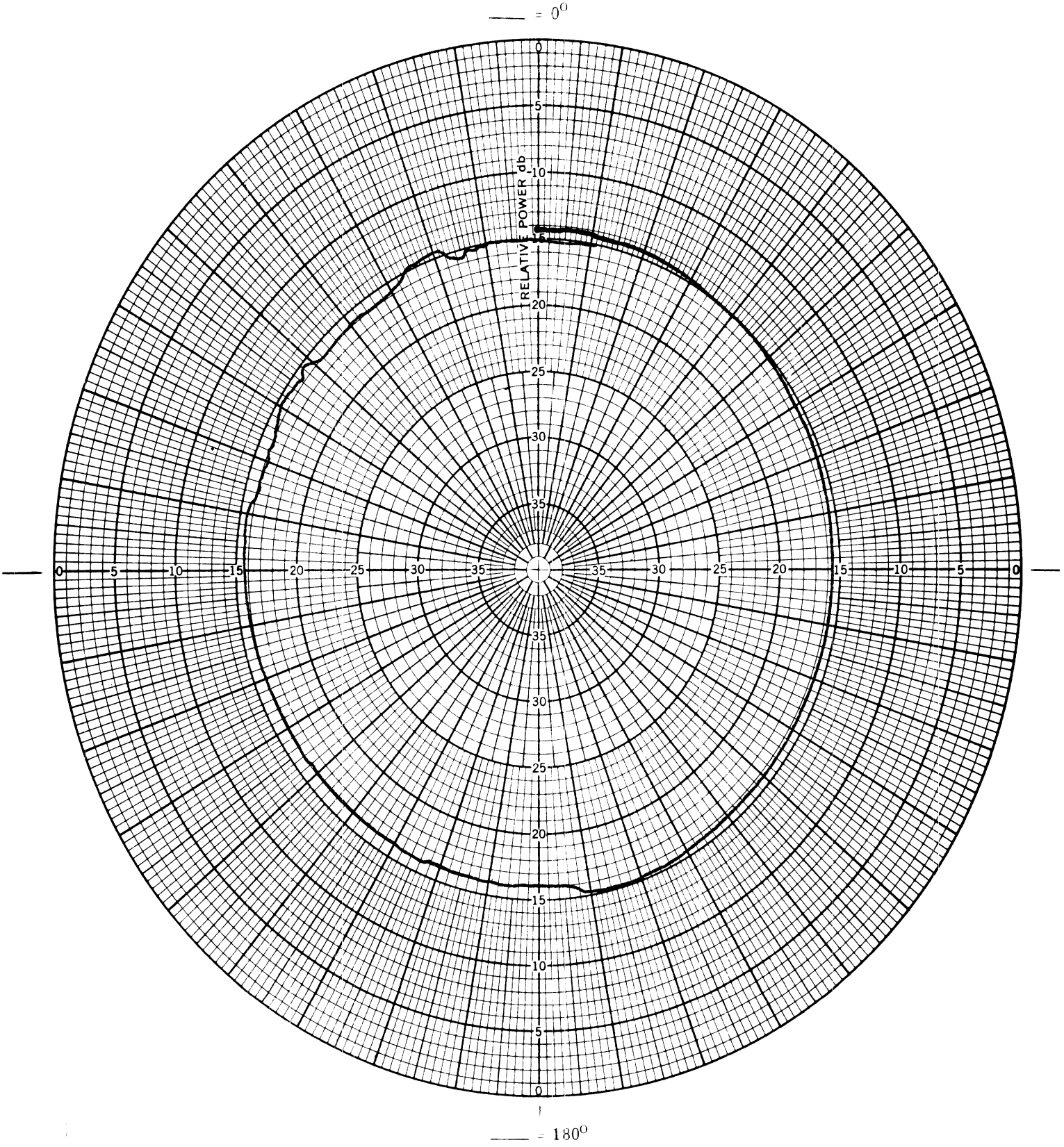

Fig. 10(c): Measured horizontal plane pattern of the whip antenna mounted on a ground plane. Vertical polarization, f = 74.4 MHz.

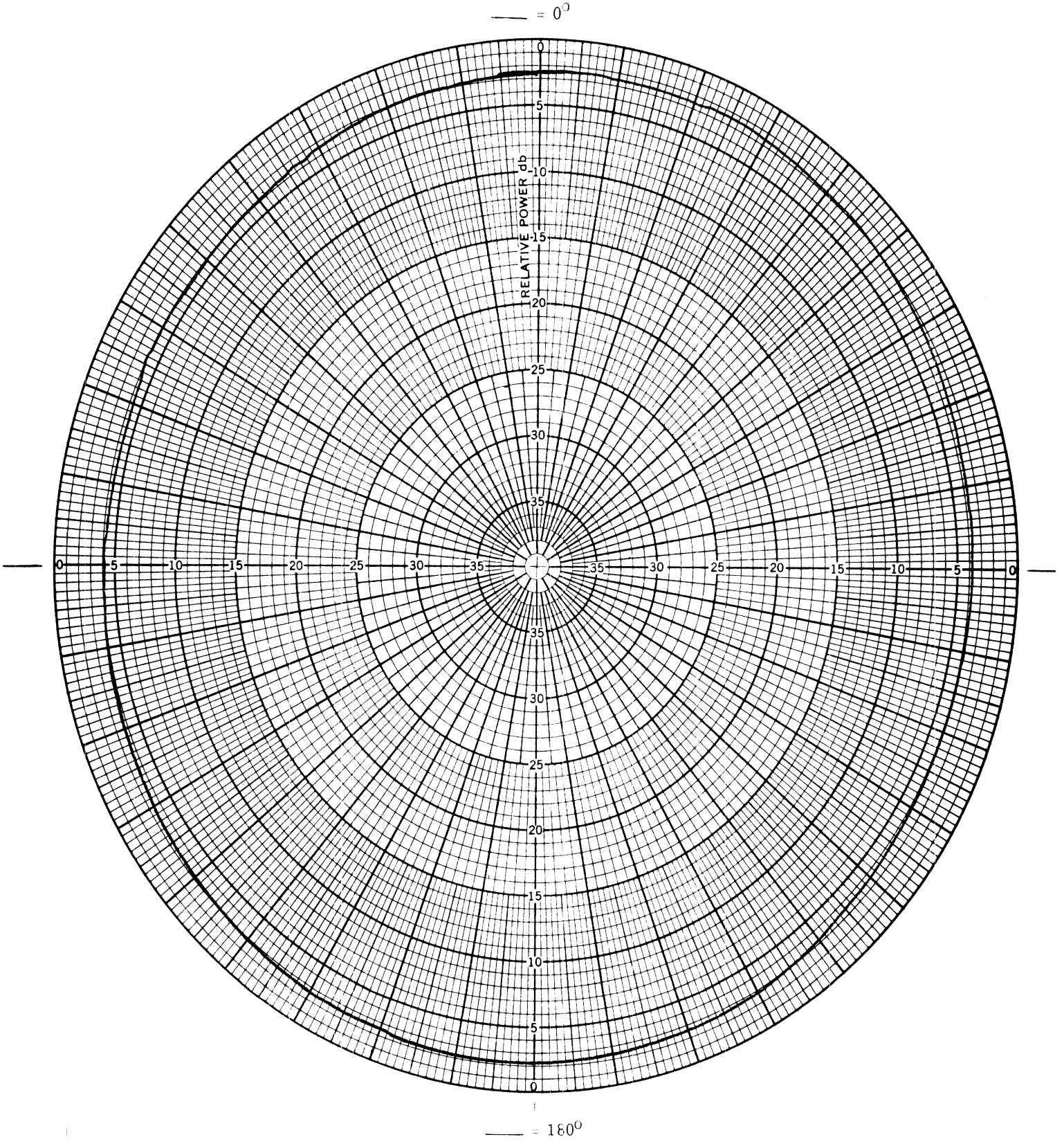

Fig. 10(d): Measured horizontal plane pattern of the whip antenna mounted on a ground plane. Vertical polarization, f = 81.7 MHz.

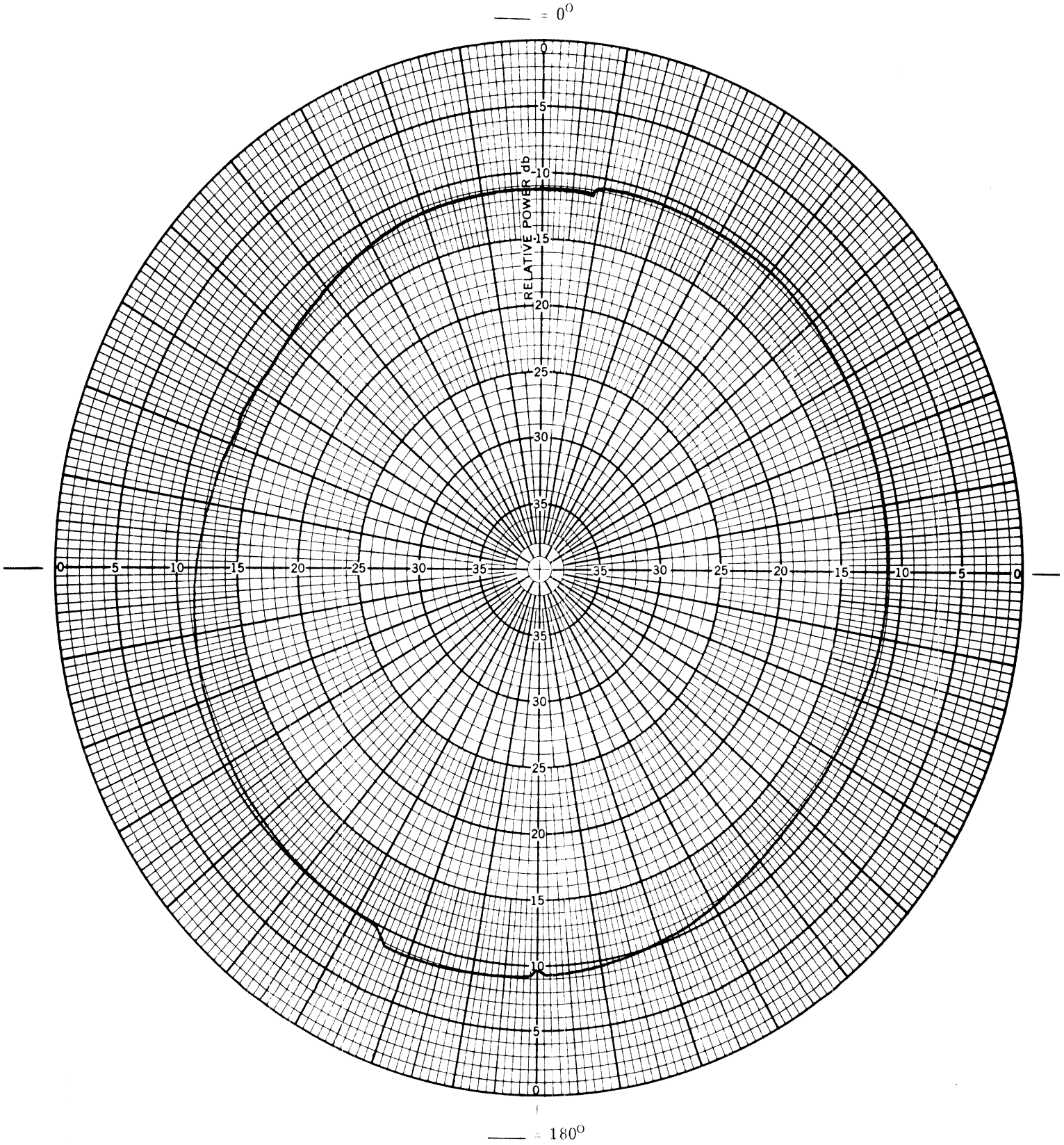

Fig. 10(e): Measured horizontal plane pattern of the whip antenna mounted on a ground plane. Vertical polarization, f = 113.5 MHz.

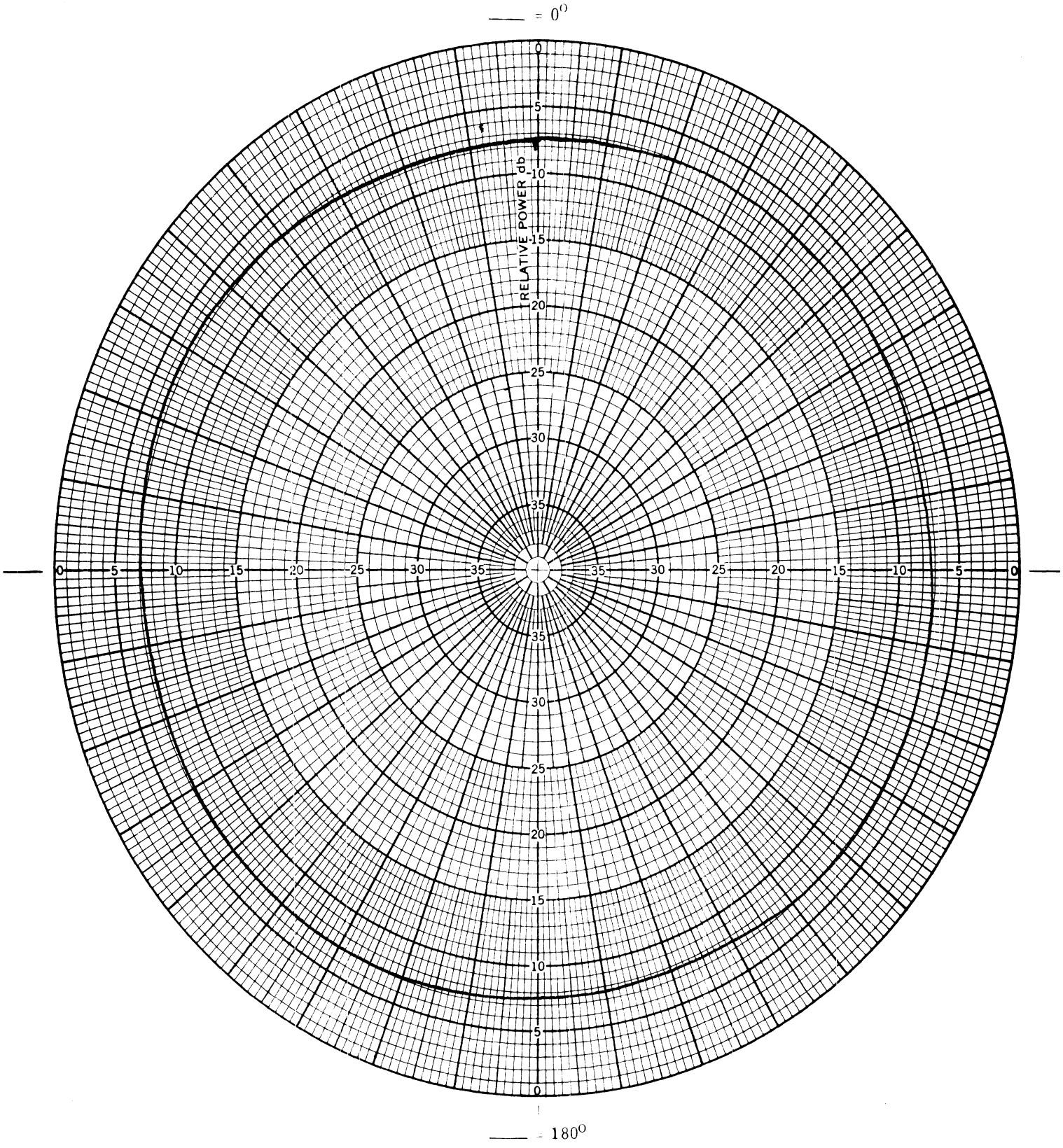

Fig. 10(f): Measured horizontal plane pattern of the whip antenna mounted on a ground plane. Vertical polarization, f = 150.1 MHz.

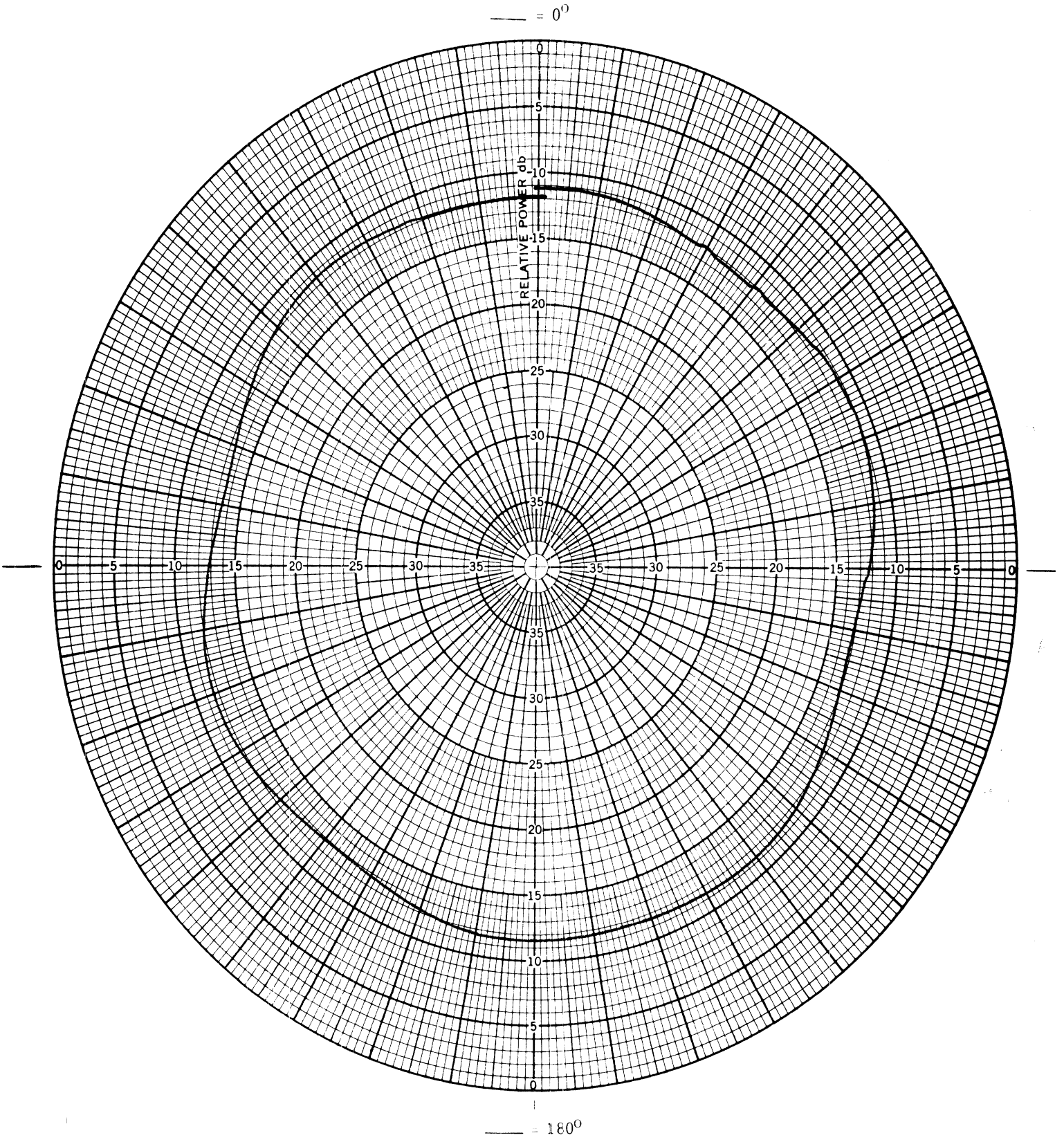

Fig. 10(g): Measured horizontal plane pattern of the whip antenna mounted on a ground plane. Vertical polarization, f = 196.5 MHz.

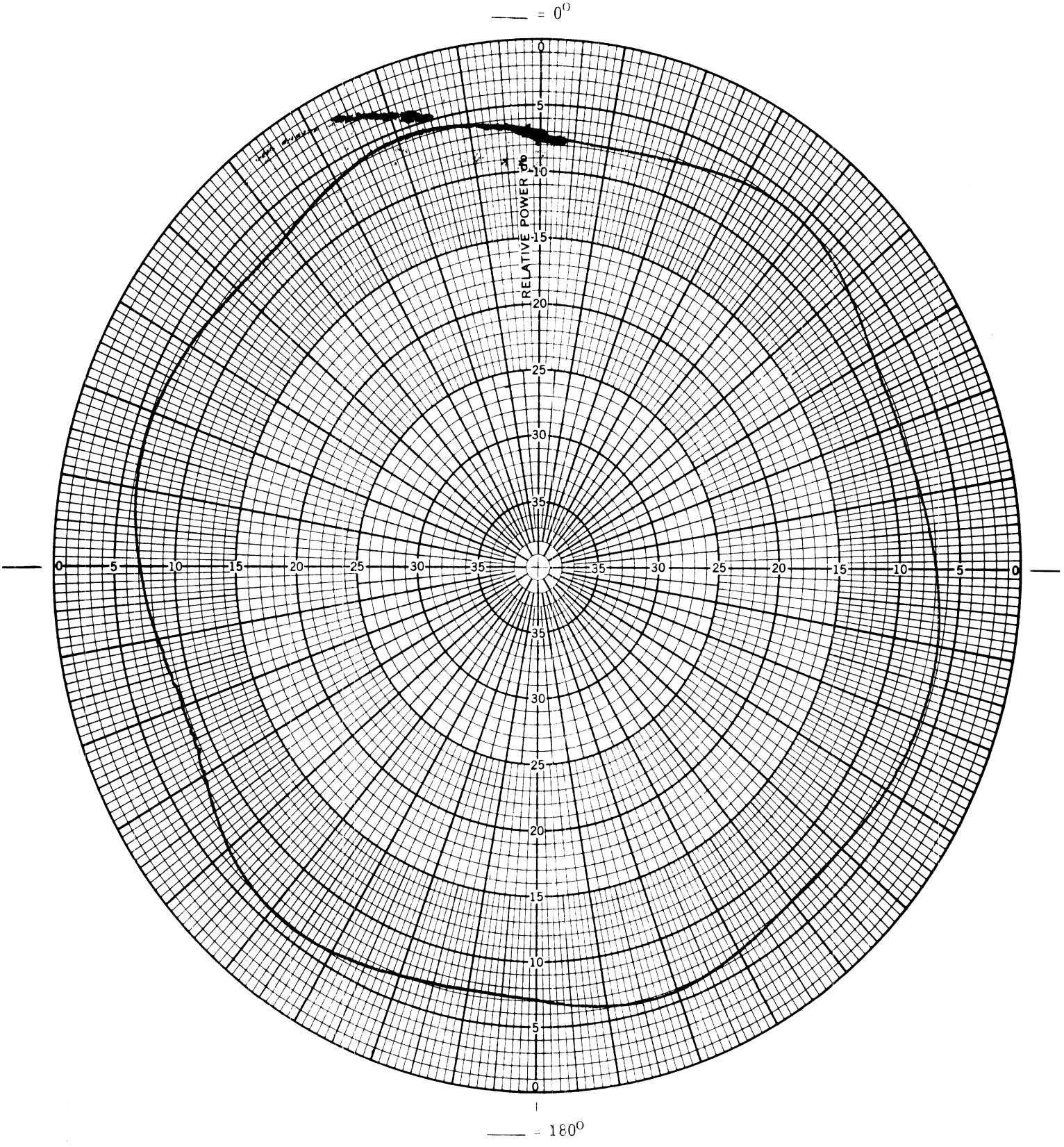

Fig. 10(h): Measured horizontal plane pattern of the whip antenna mounted on a ground plane. Vertical polarization, f = 247.0 MHz.

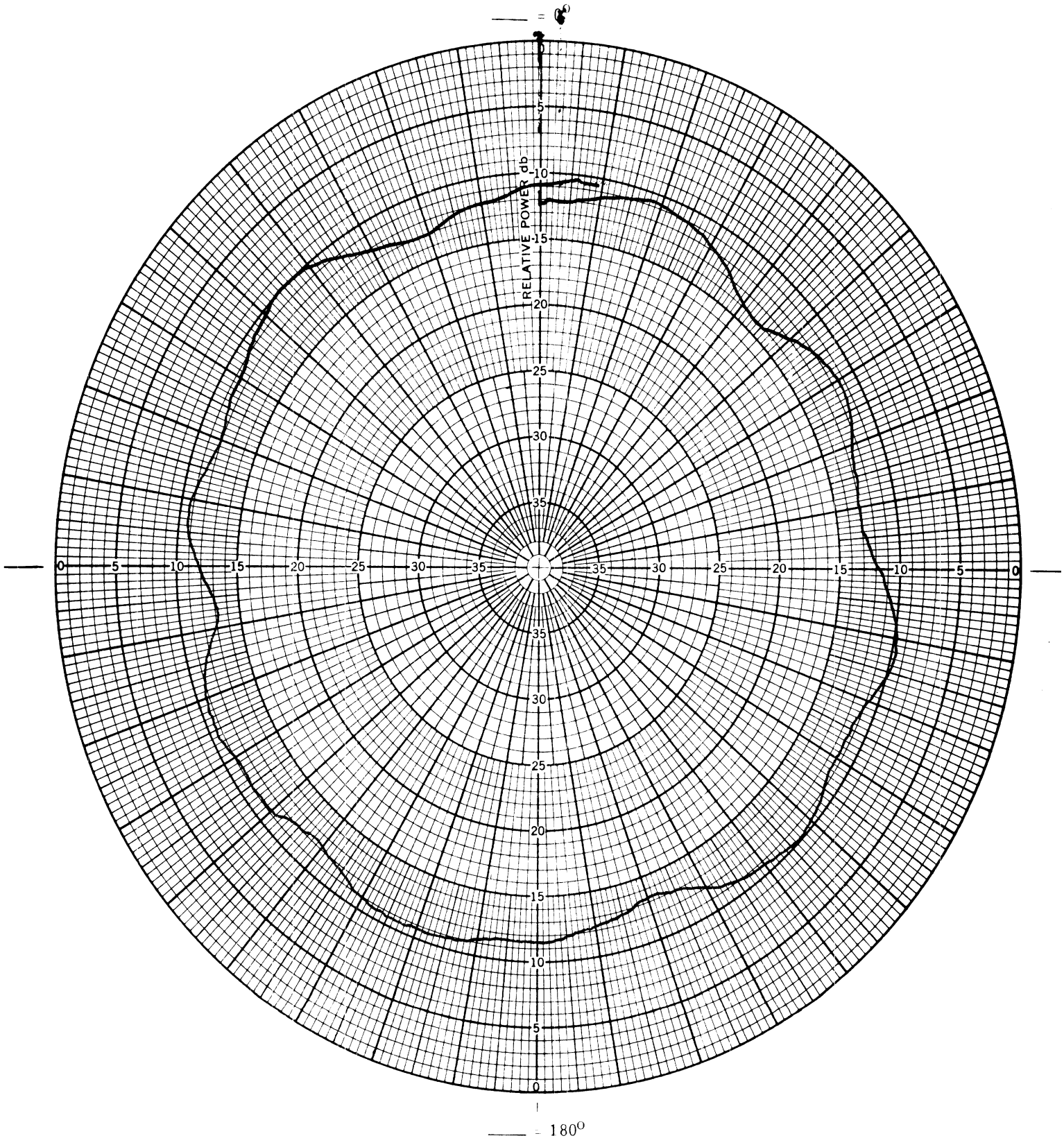

Fig. 10(i): Measured horizontal plane pattern of the whip antenna mounted on a ground plane. Vertical polarization, f = 301.0 MHz.

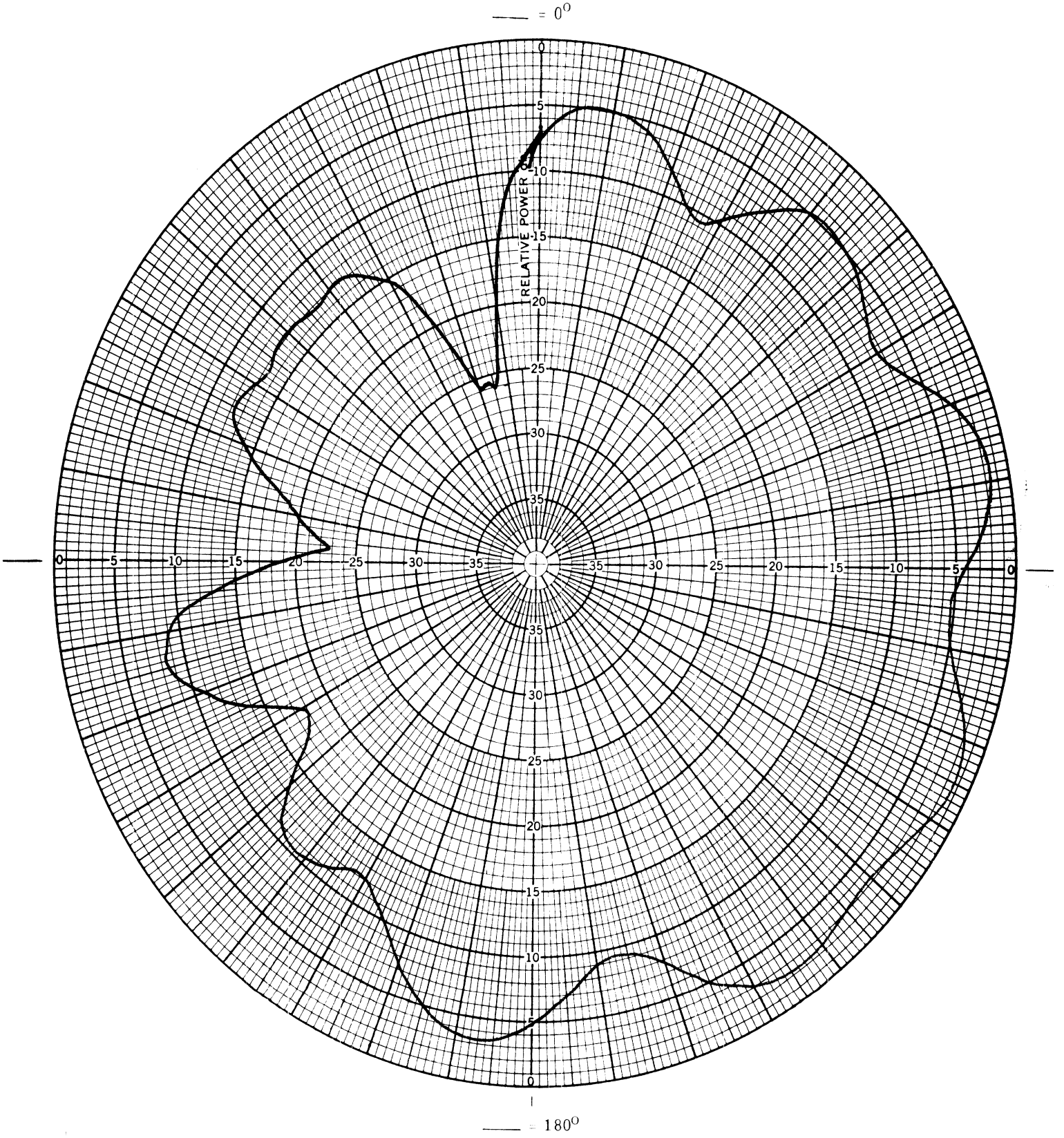

Fig. 10(j): Measured horizontal plane pattern of the whip antenna mounted on a ground plane. Vertical polarization, f = 350.0 MHz.

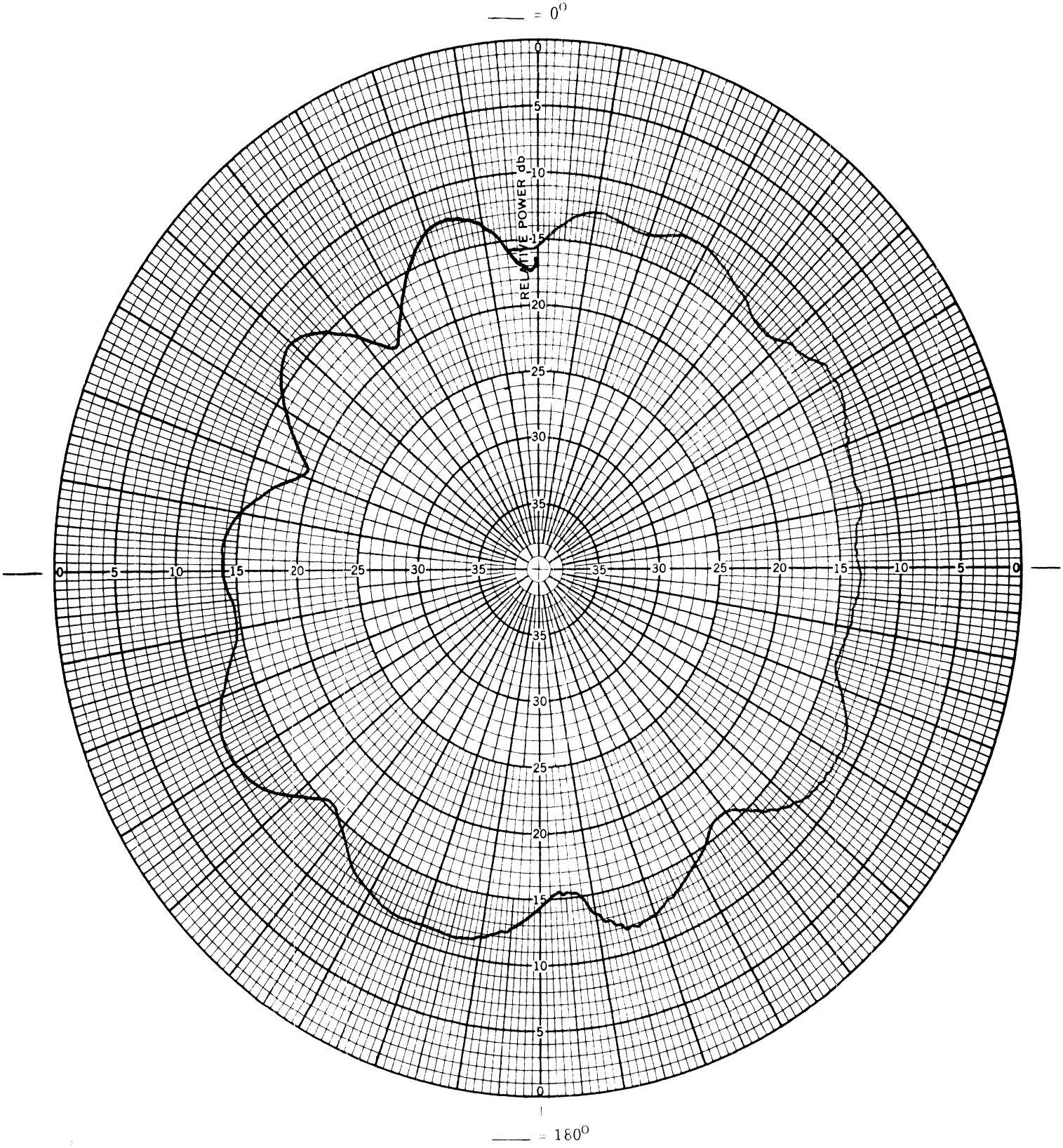

Fig. 10(k): Measured horizontal plane pattern of the whip antenna mounted on a ground plane. Vertical polarization, f = 400.0 MHz.

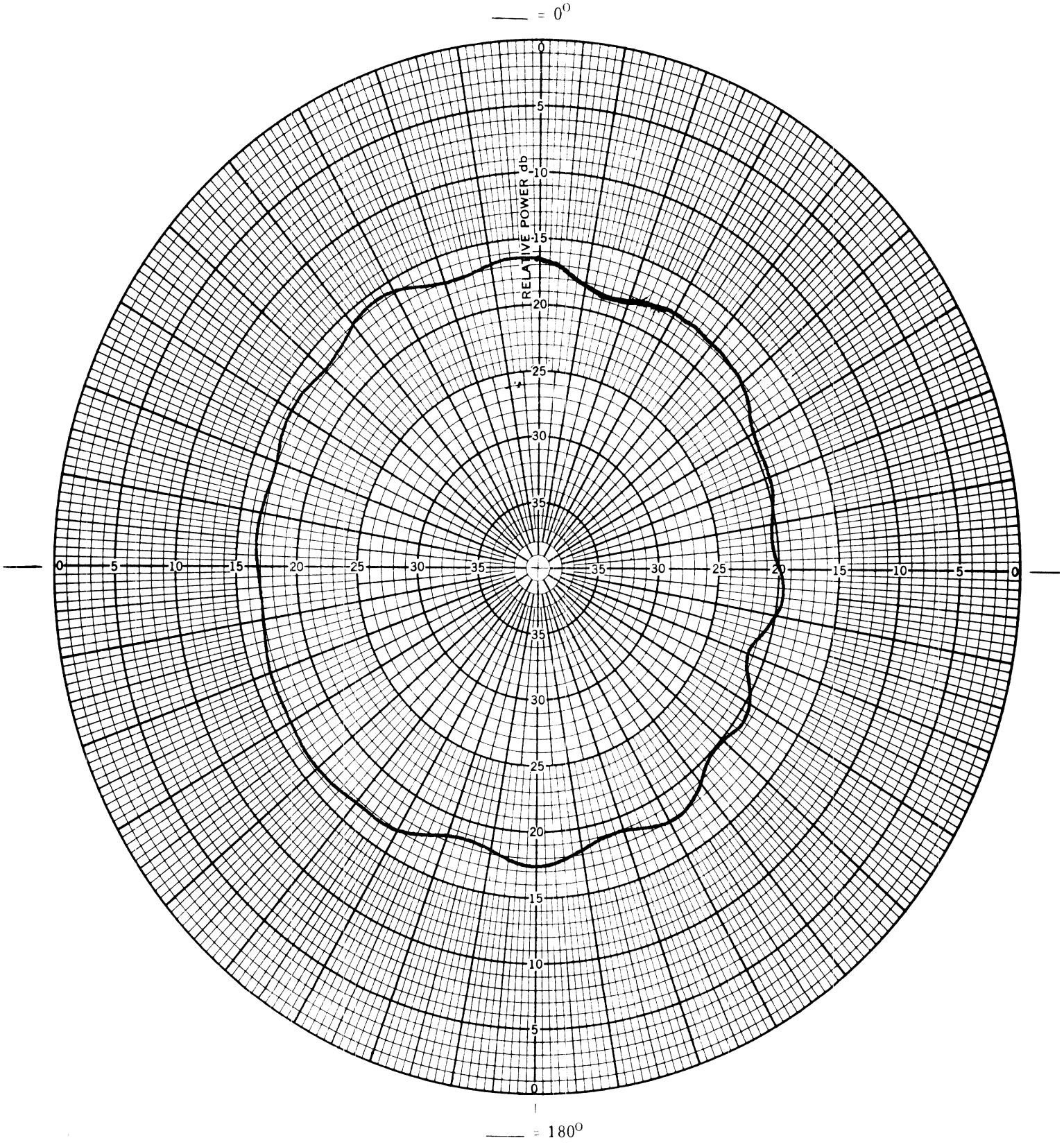

Fig. 10(1): Measured horizontal plane pattern of the whip antenna mounted on a ground plane. Vertical polarization, f = 500.0 MHz.

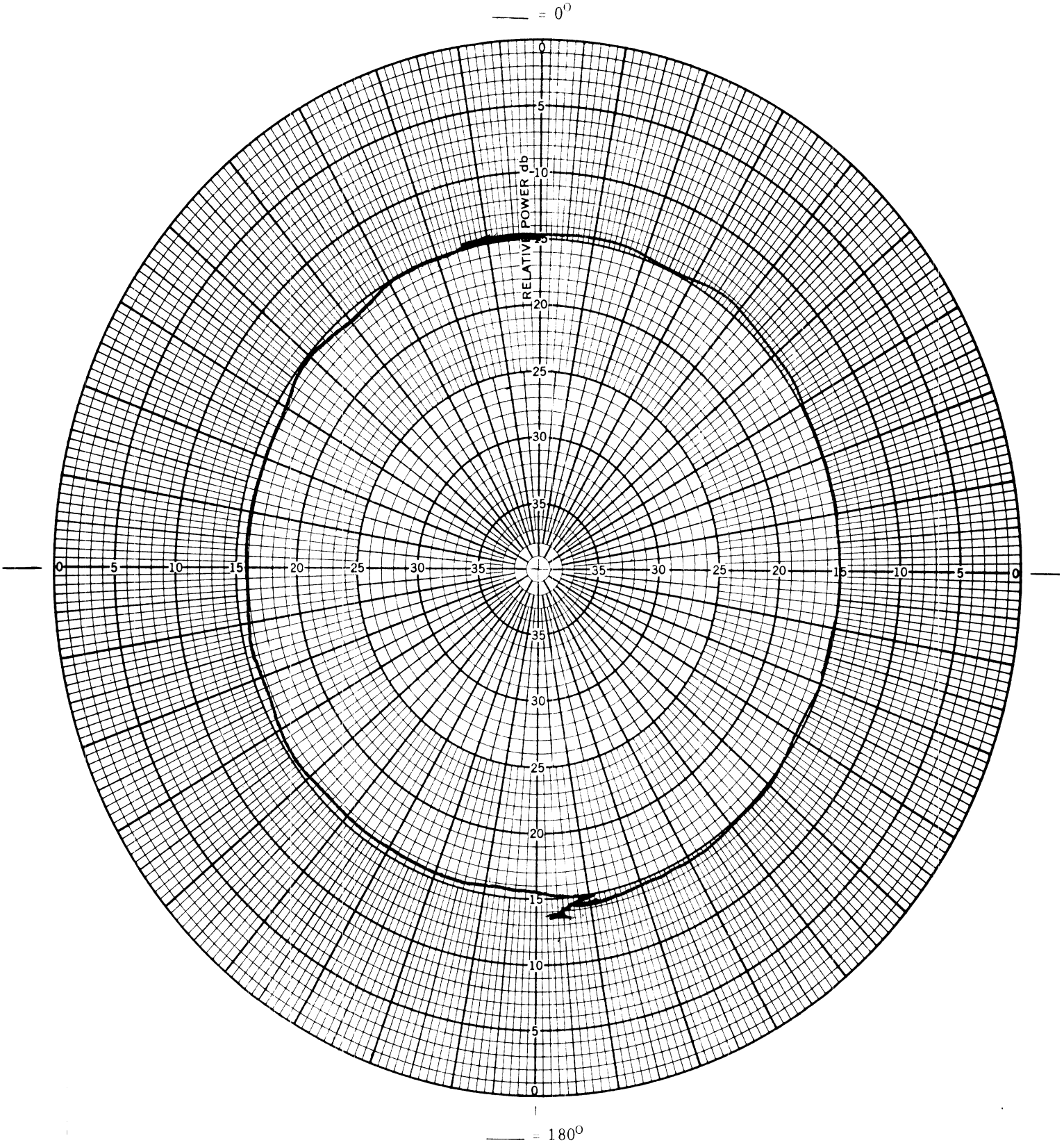

Fig. 10(m): Measured horizontal plane pattern of the whip antenna mounted on a ground plane. Vertical polarization, f = 600.0 MHz.

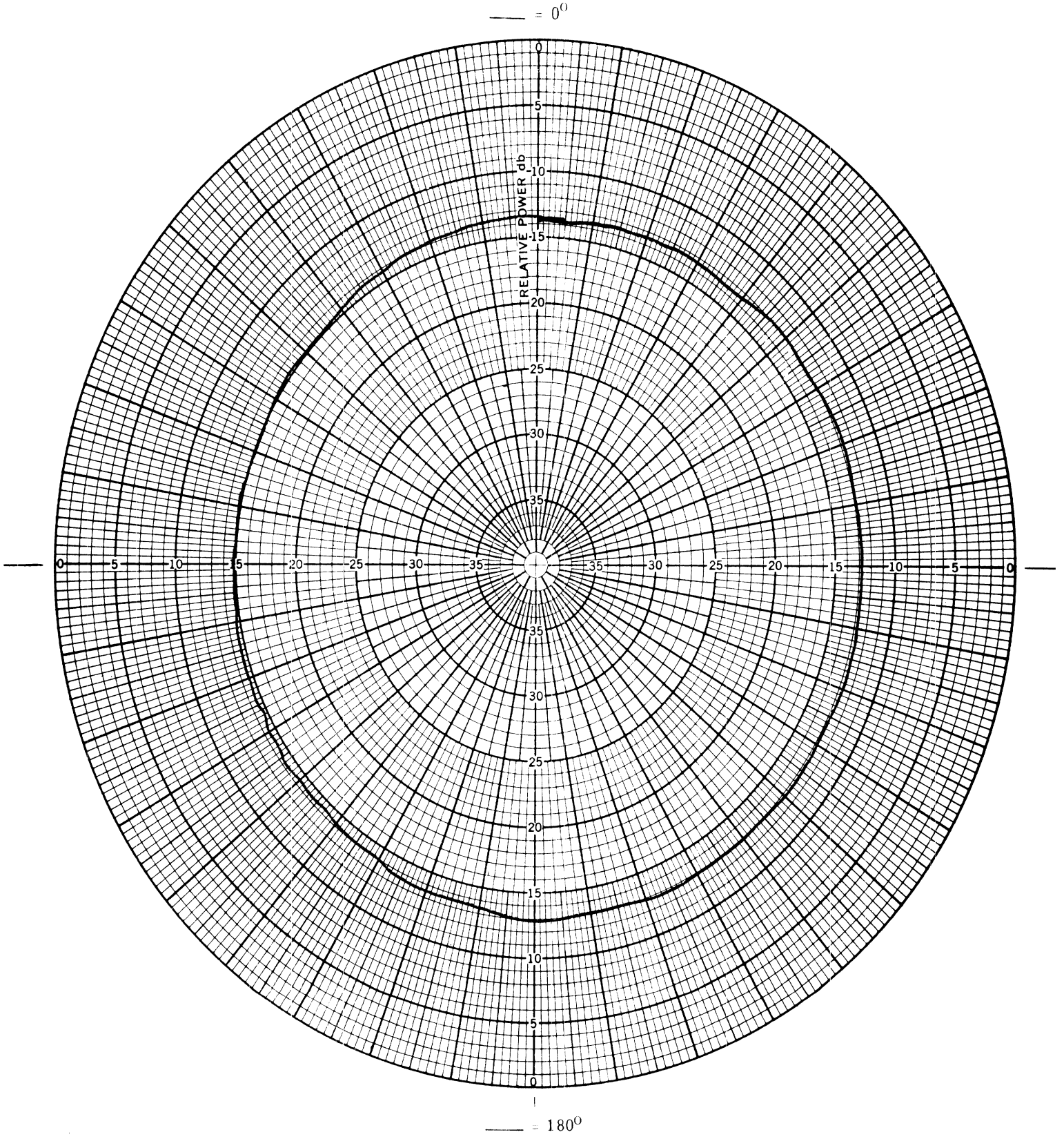

Fig. 10(n): Measured horizontal plane pattern of the whip antenna mounted on a ground plane. Vertical polarization, f = 700.0 MHz.

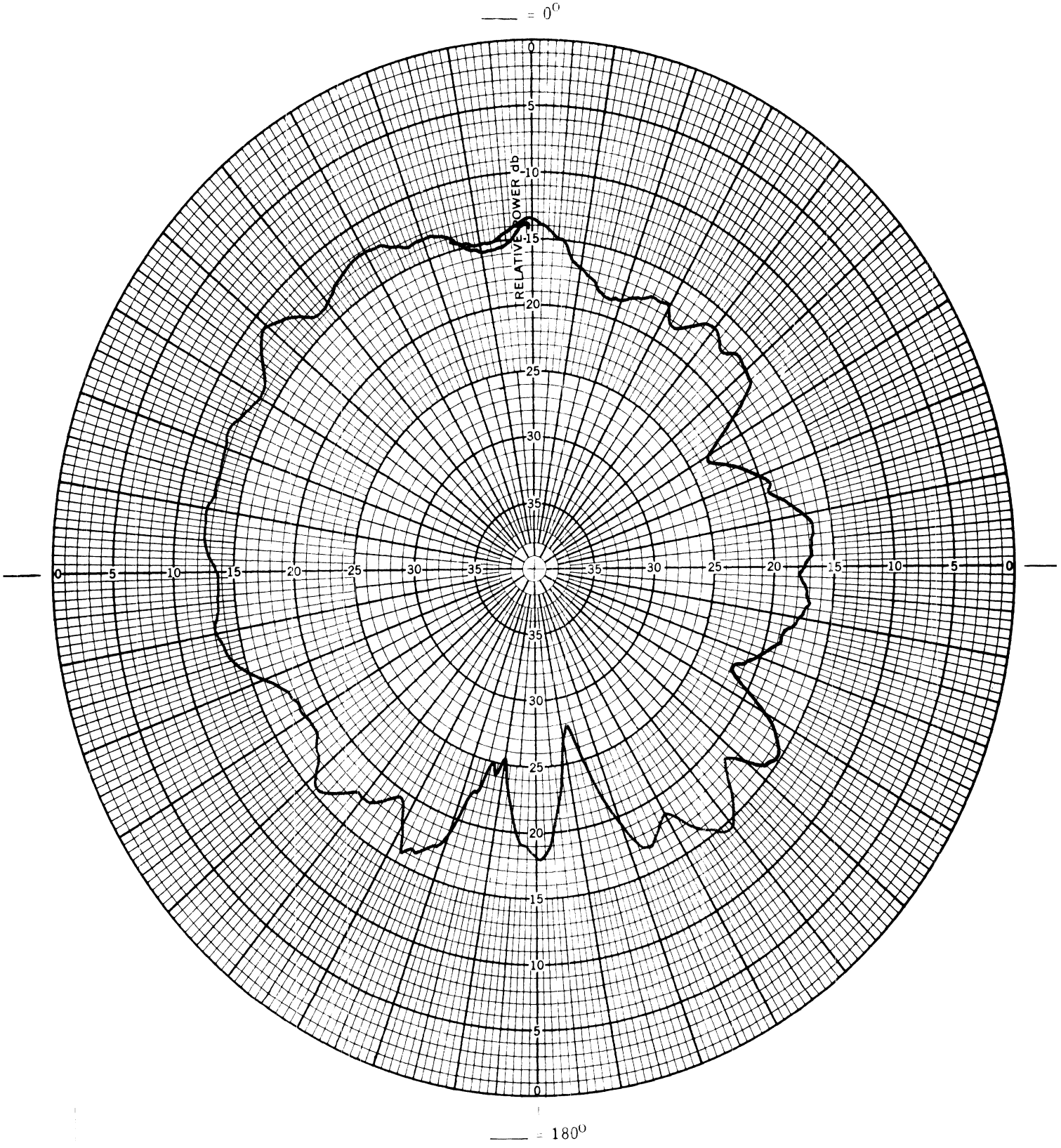

Fig. 10(o): Measured horizontal plane pattern of the whip antenna mounted on a ground plane. Vertical polarization, f = 800.0 MHz.

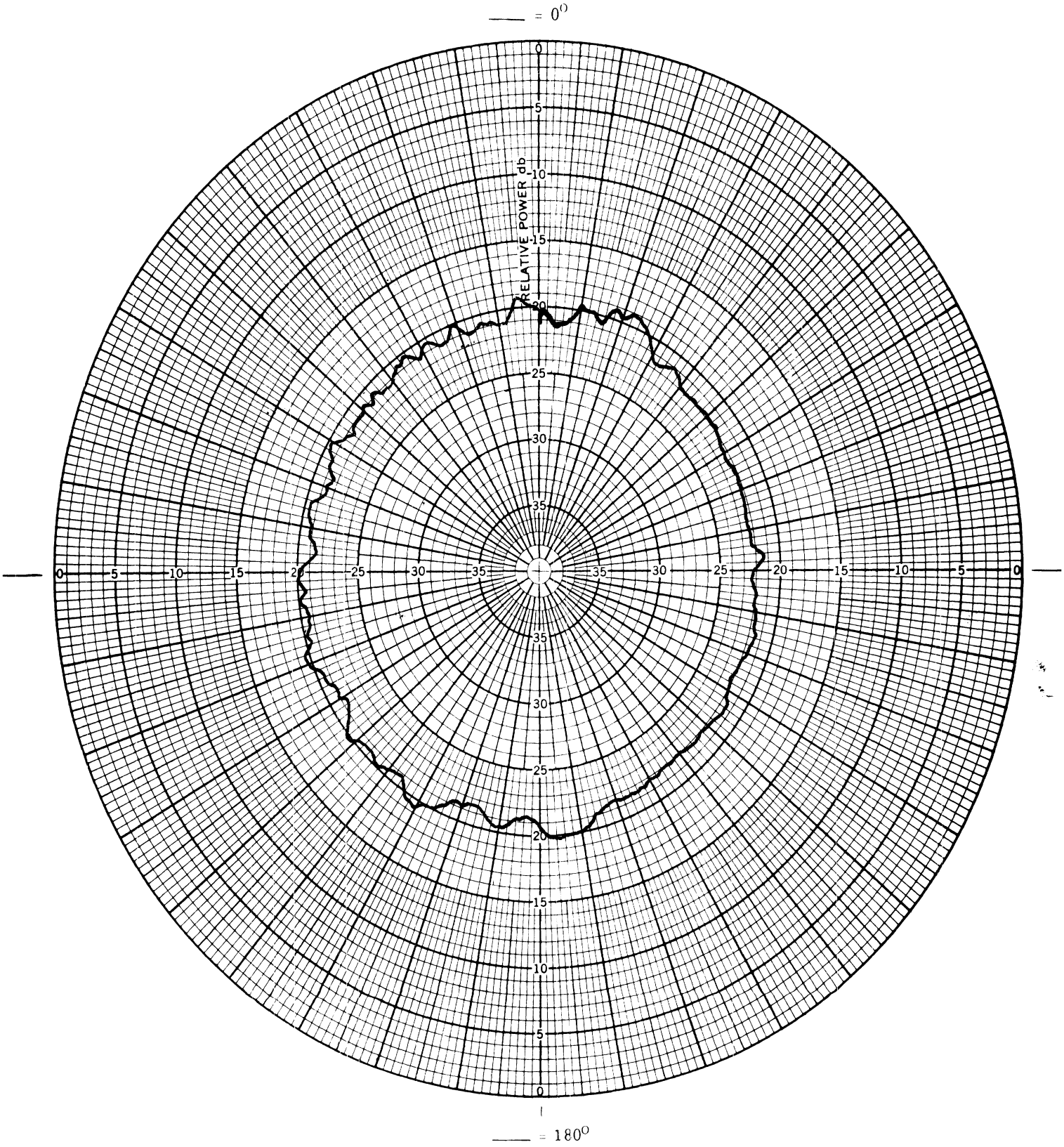

Fig. 10(p): Measured horizontal plane pattern of the whip antenna mounted on a ground plane. Vertical polarization, f = 1000.0 MHz.

with the side-fed heated backlite antenna are shown in Figs. 11(a) through 11(p) where the 0 degrees and 180 degrees directions correspond to the two broadside directions of the plane of the antenna. The patterns resemble those of a horizontally oriented linear current element. The radiation length of the antena being less than $\lambda/2$ up to about 110 MHz, the patterns shown in 11(a) through 11(e) are similar to the patterns of linear antennas of corresponding lengths; the multi-lobed patterns obtained for frequencies larger than 110 MHz are symptomatic of the fact that the length of the antenna $> \lambda/2$ at these frequencies.

Similar results obtained with the bottom-fed heated backlite antenna are shown in Figs. 12(a) through 12(p) where, again, the 0 degrees and 180 degree directions correspond to the two broadside directions of the antenna. In this case, up to the frequency $f \cong 110$ MHz the antenna effectively behaves like a short vertically oriented current element; however, for $f > 110$ MHz the pattern develops many lobes and its general performance appears to be rather complicated.

Figures 13(a) - 13(p) show the horizontal plane (H-plane) patterns of the capacitor antenna, oriented in the horizontal plane, and for vertically polarized signals. The corresponding vertical (E-plane) plane patterns of the same antenna are shown in Fig. 14(a) through 14(p). Results of Fig. 13 indicate that the antenna maintains its horizontal plane omnidirectionality fairly well throughout the band of frequencies used. Results shown in Fig. 14 were obtained with the capacitor plates oriented in the vertical plane and by using horizontally polarized signals. Thus, in all of the Figs. 14(a) through 14(p), the 0 degrees and 180 degree directions correspond to

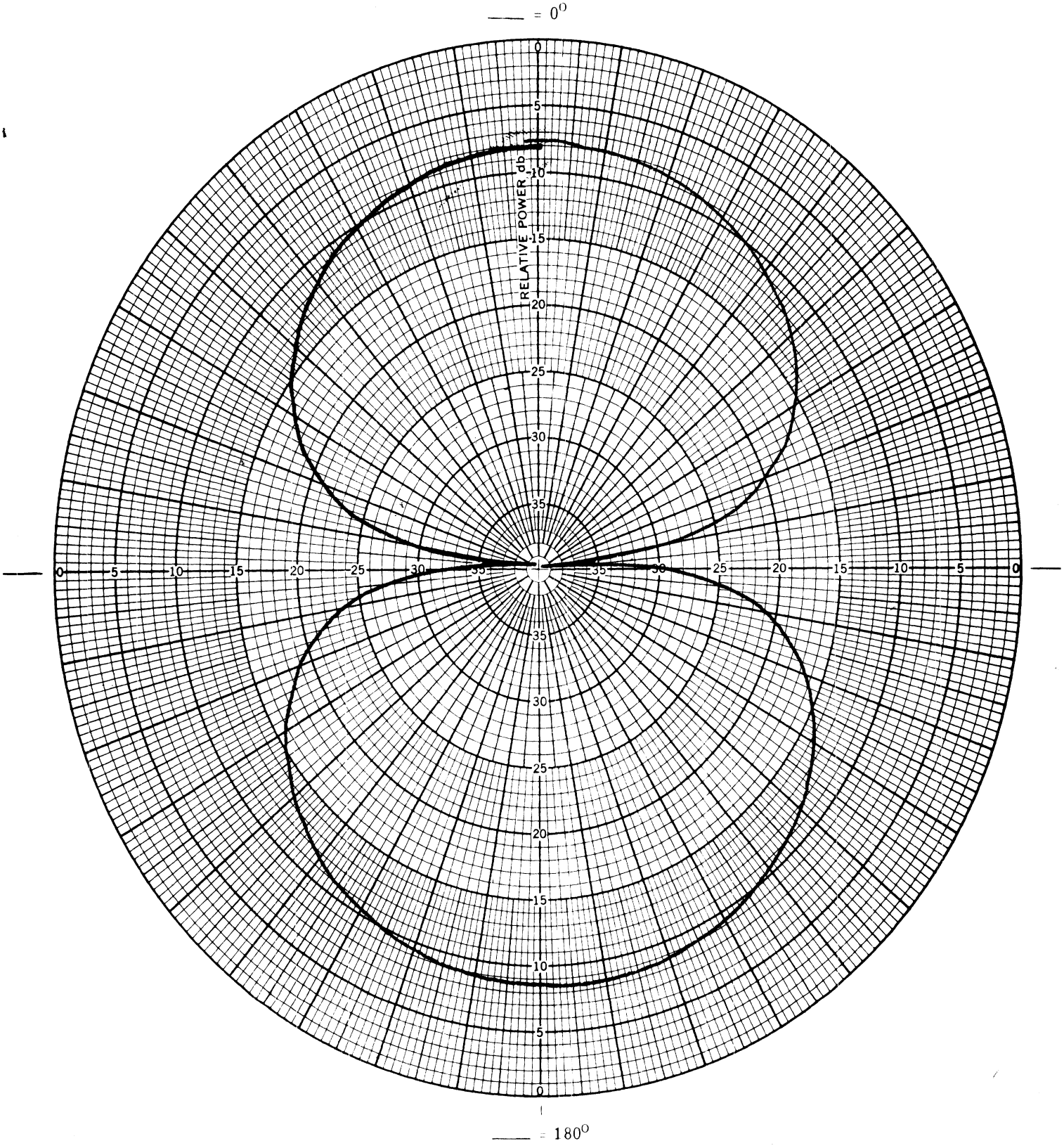

Fig. 11(a): Measured horizontal plane pattern of the side-fed heated backlite antenna. Vertical polarization, f = 50.2 MHz.

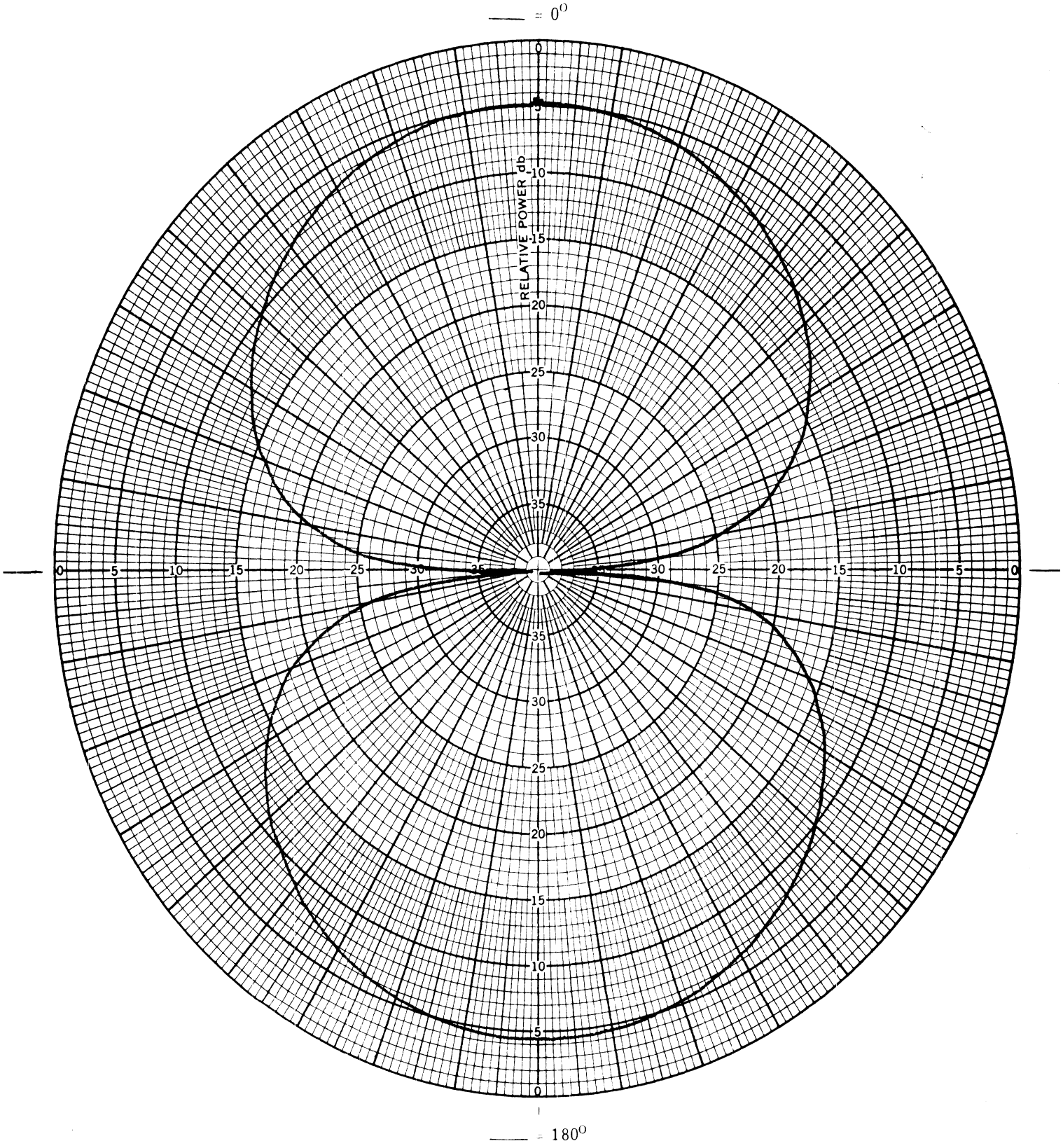

Fig. 11(b): Measured horizontal plane pattern of the side-fed heated backlite antenna. Vertical polarization, f = 63.8 MHz.

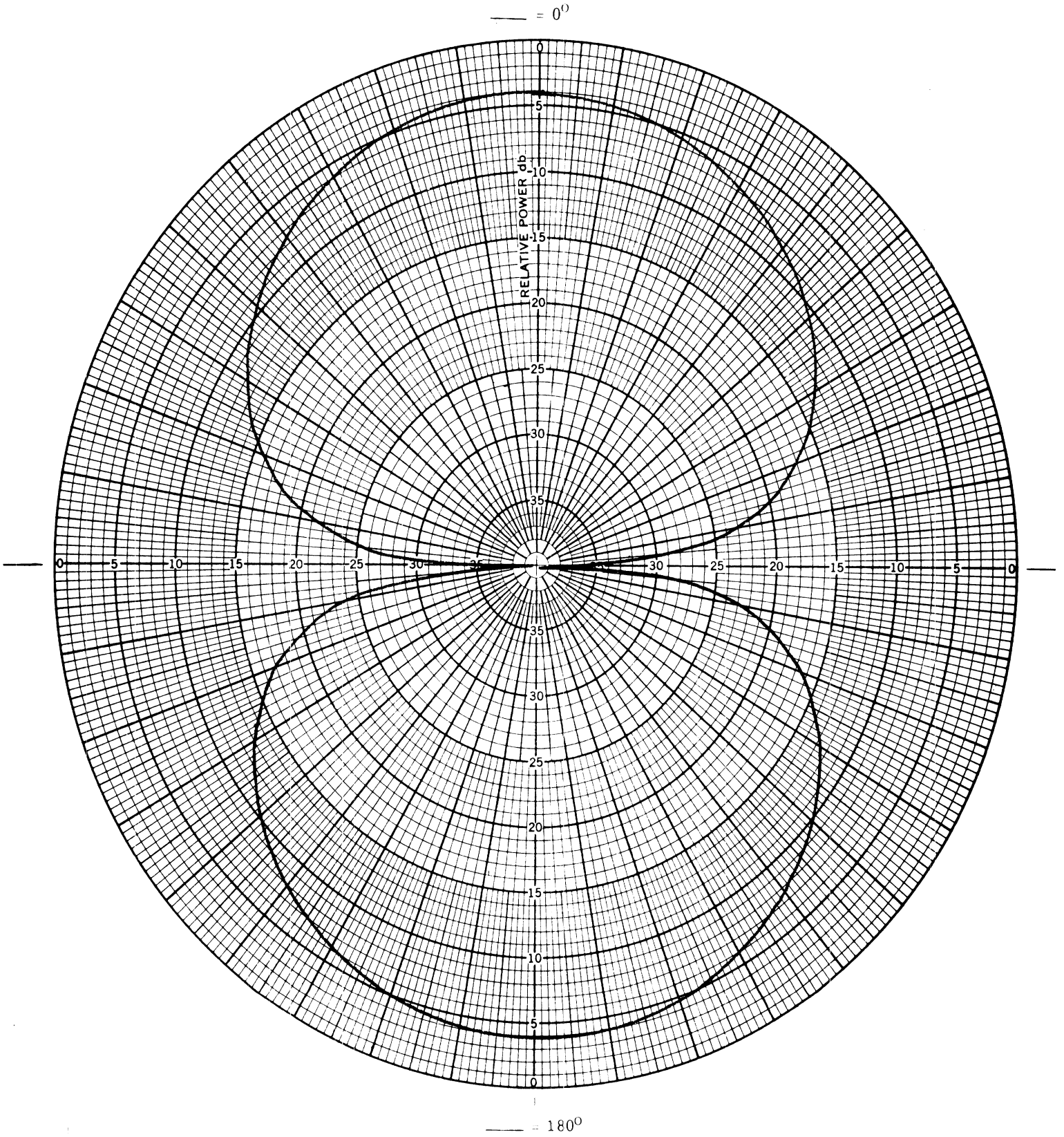

Fig. 11(c): Measured horizontal plane pattern of the side-fed heated backlite antenna. Vertical polarization, f = 75.6 MHz.

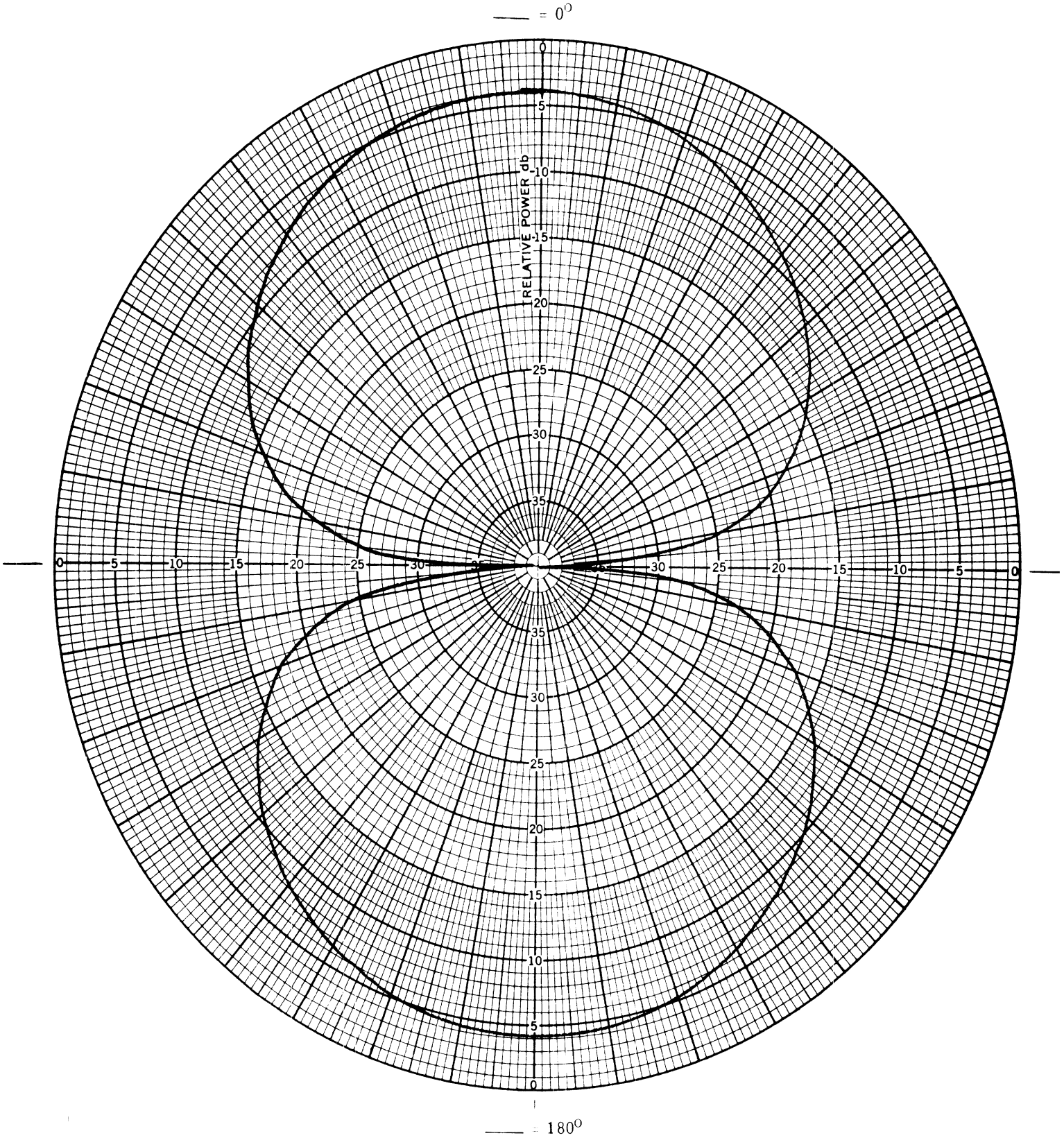

Fig. 11(d): Measured horizontal plane pattern of the side-fed heated backlite antenna. Vertical polarization, f = 84.8 MHz.

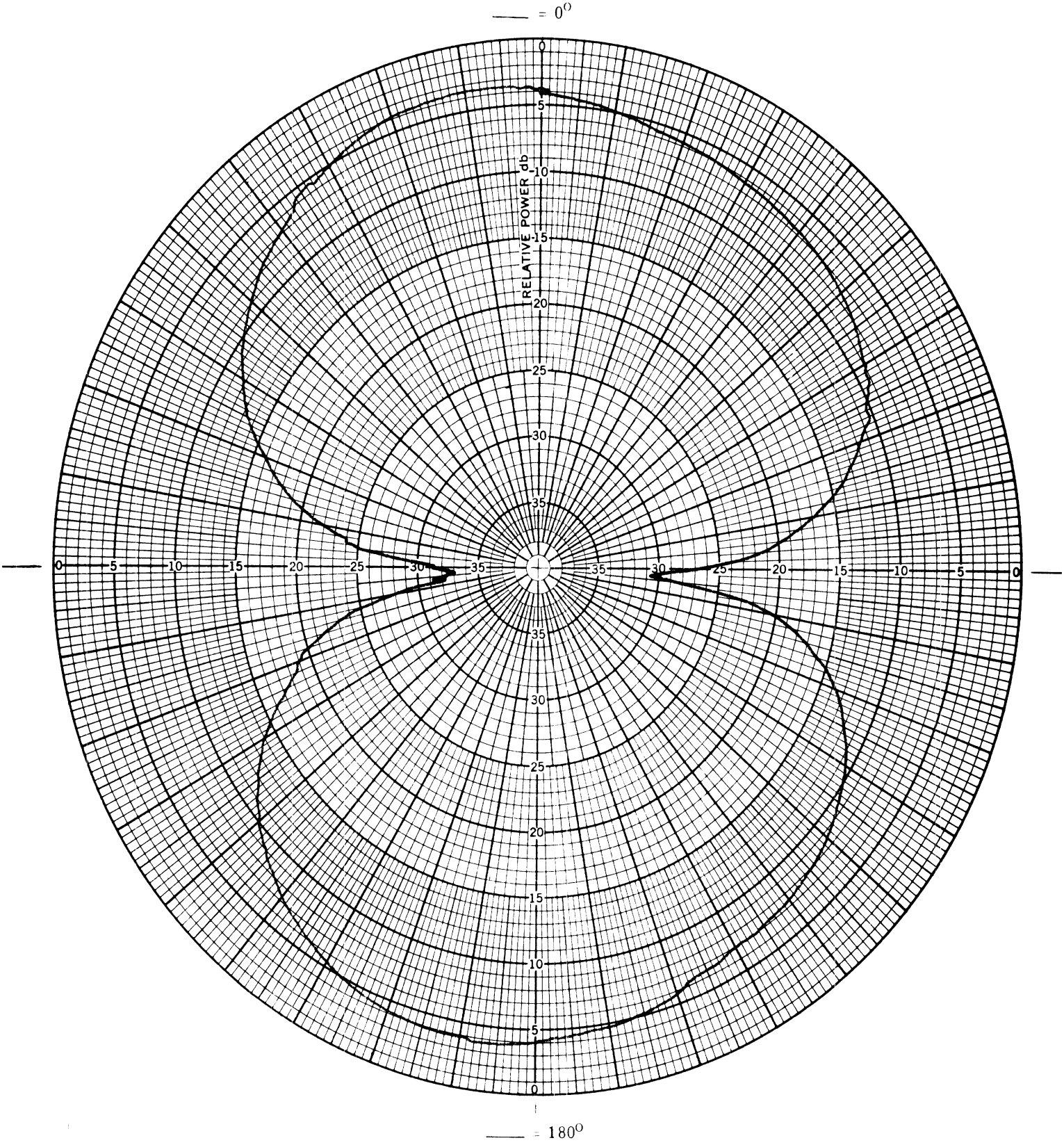

Fig. 11(e): Measured horizontal plane pattern of the side-fed heated backlite antenna. Vertical polarization, f = 110.2 MHz.

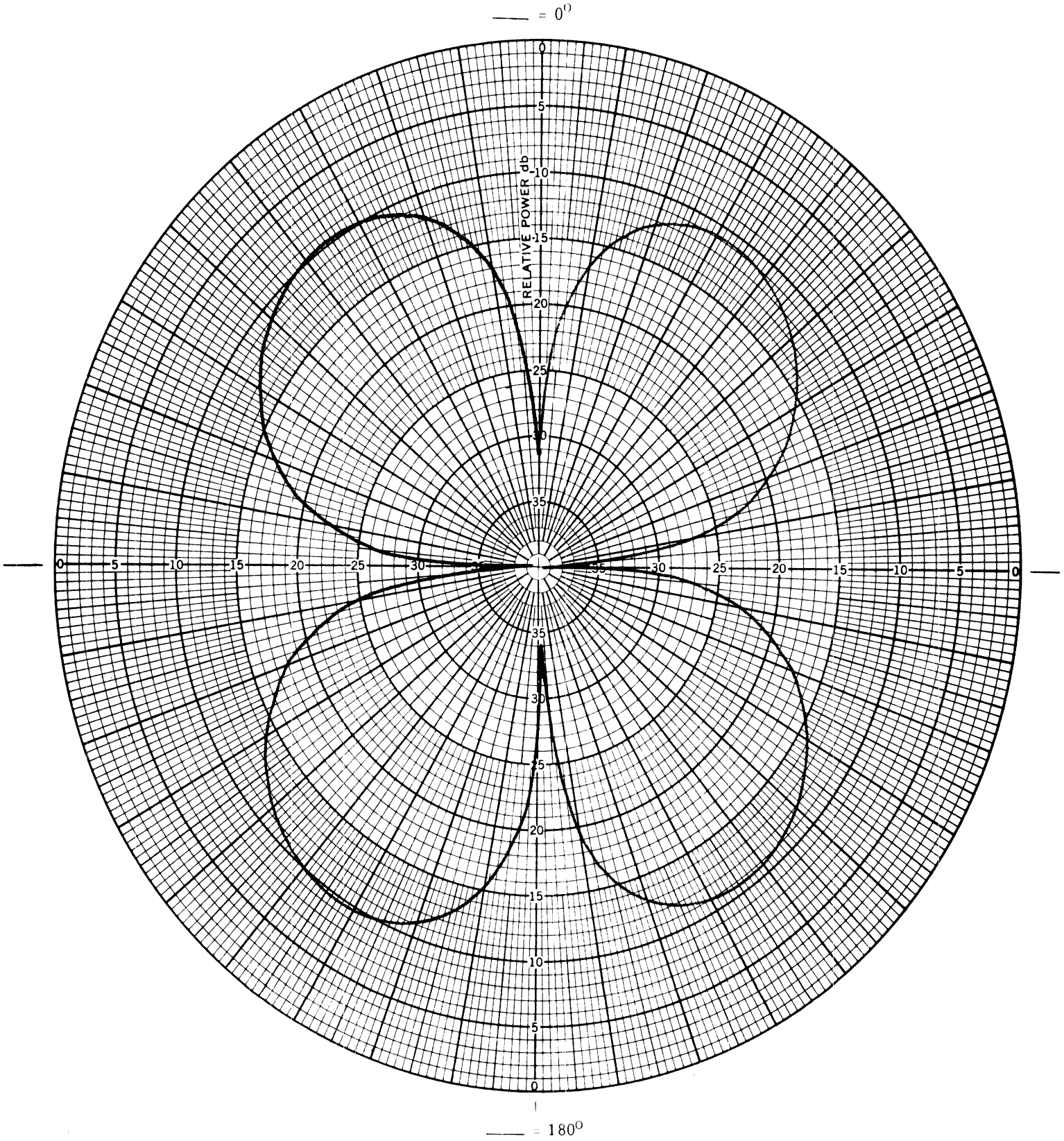

Fig. 11(f): Measured horizontal plane pattern of the side-fed heated backlite antenna. Vertical polarization, f = 149.2 MHz.

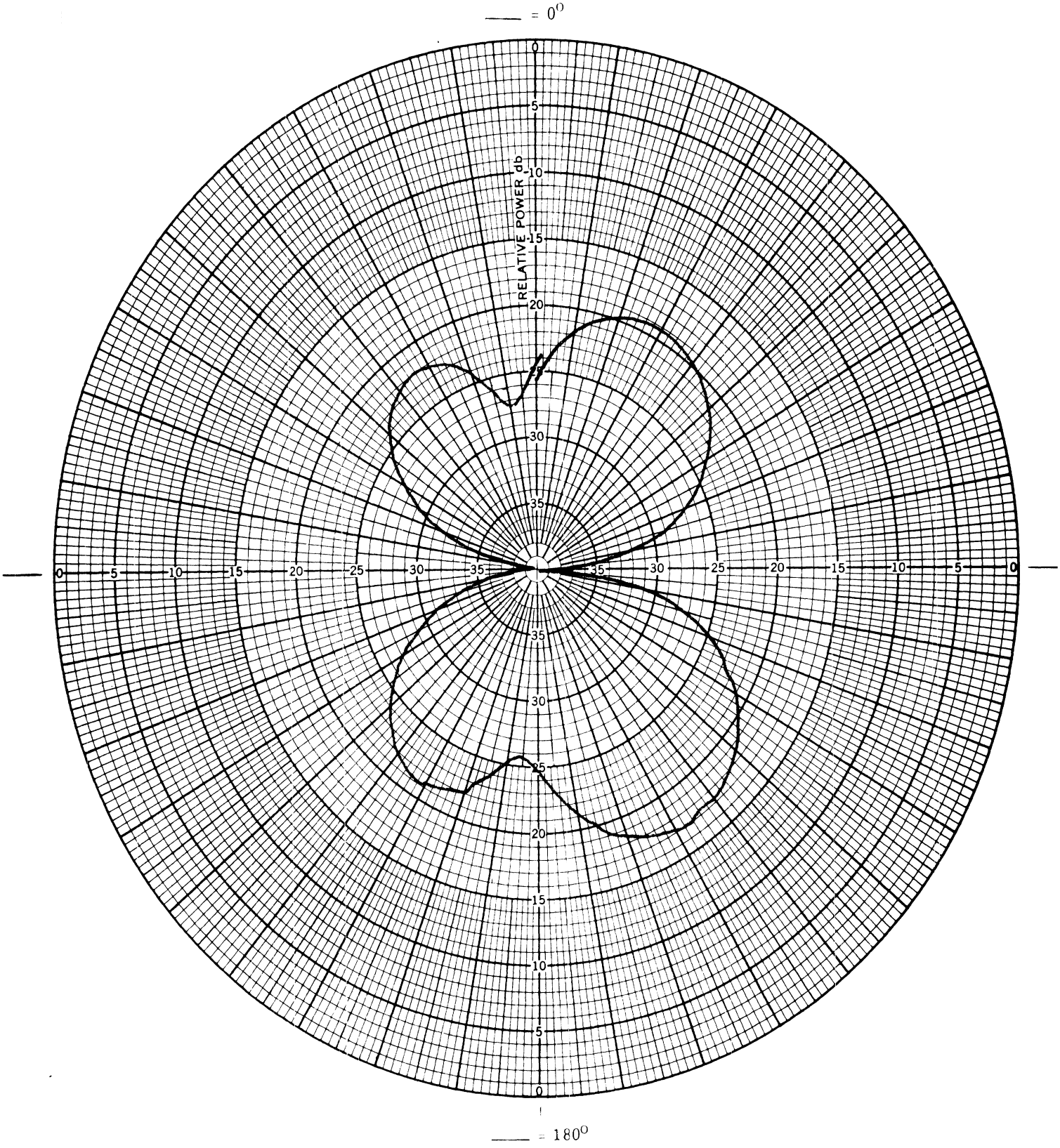

Fig. 11(g): Measured horizontal plane pattern of the side-fed heated backlite antenna. Vertical polarization, f = 198.2 MHz)

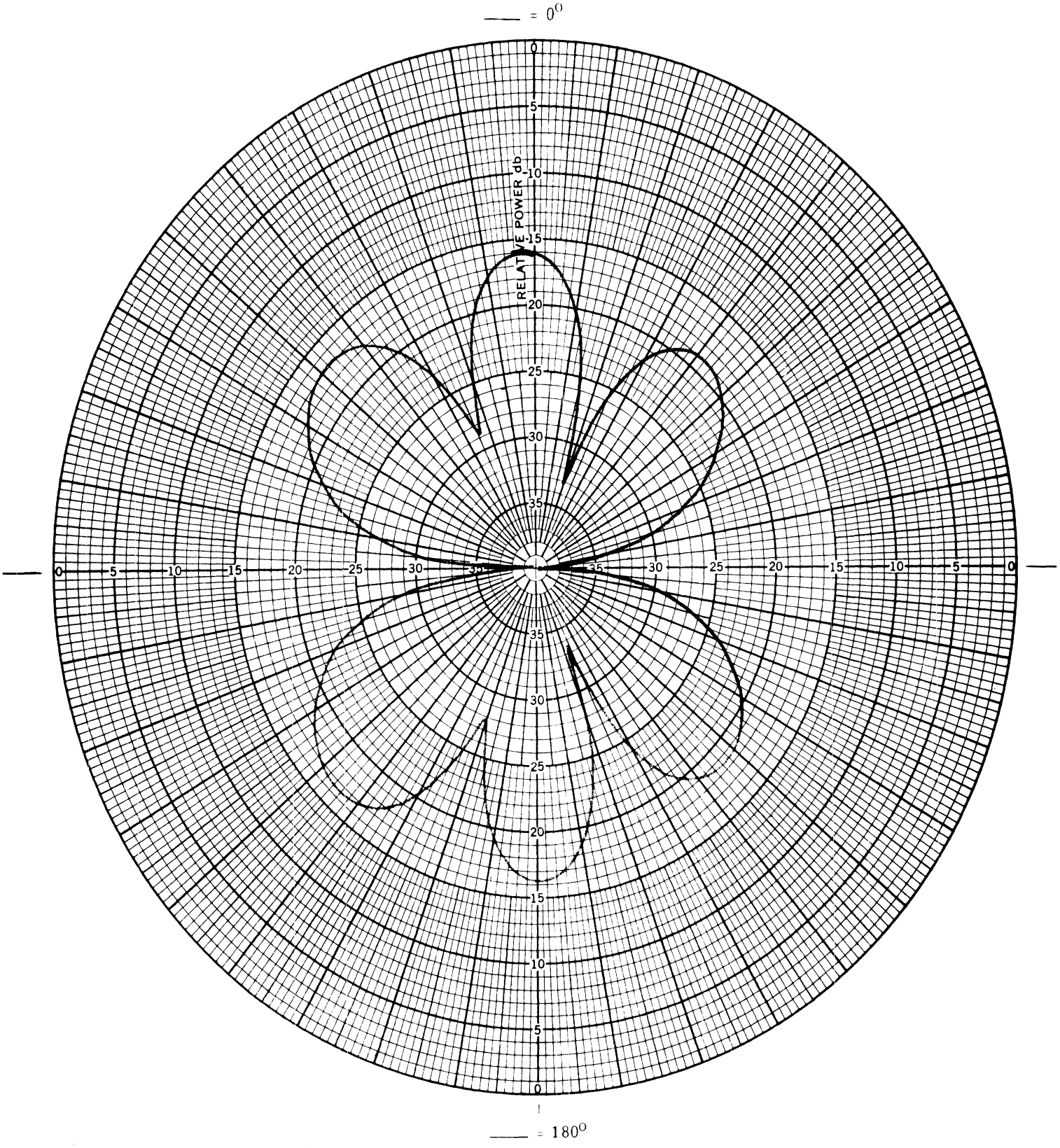

Fig. 11(h): Measured horizontal plane pattern of the side-fed heated backlite antenna. Vertical polarization, f = 250.0 MHz.

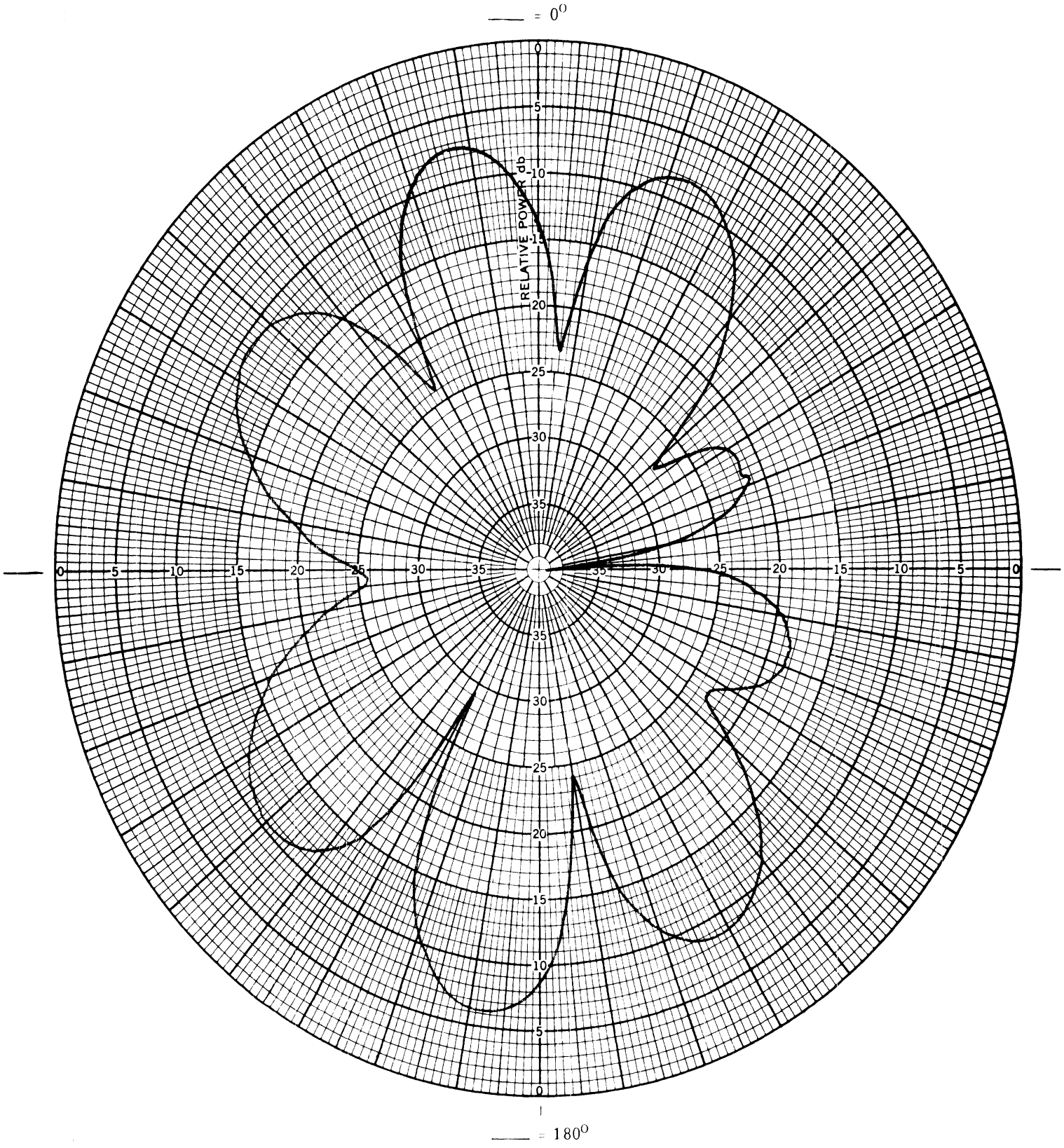

Fig. 11(i): Measured horizontal plane pattern of the side-fed heated backlite antenna. Vertical polarization, f = 299.9 MHz.

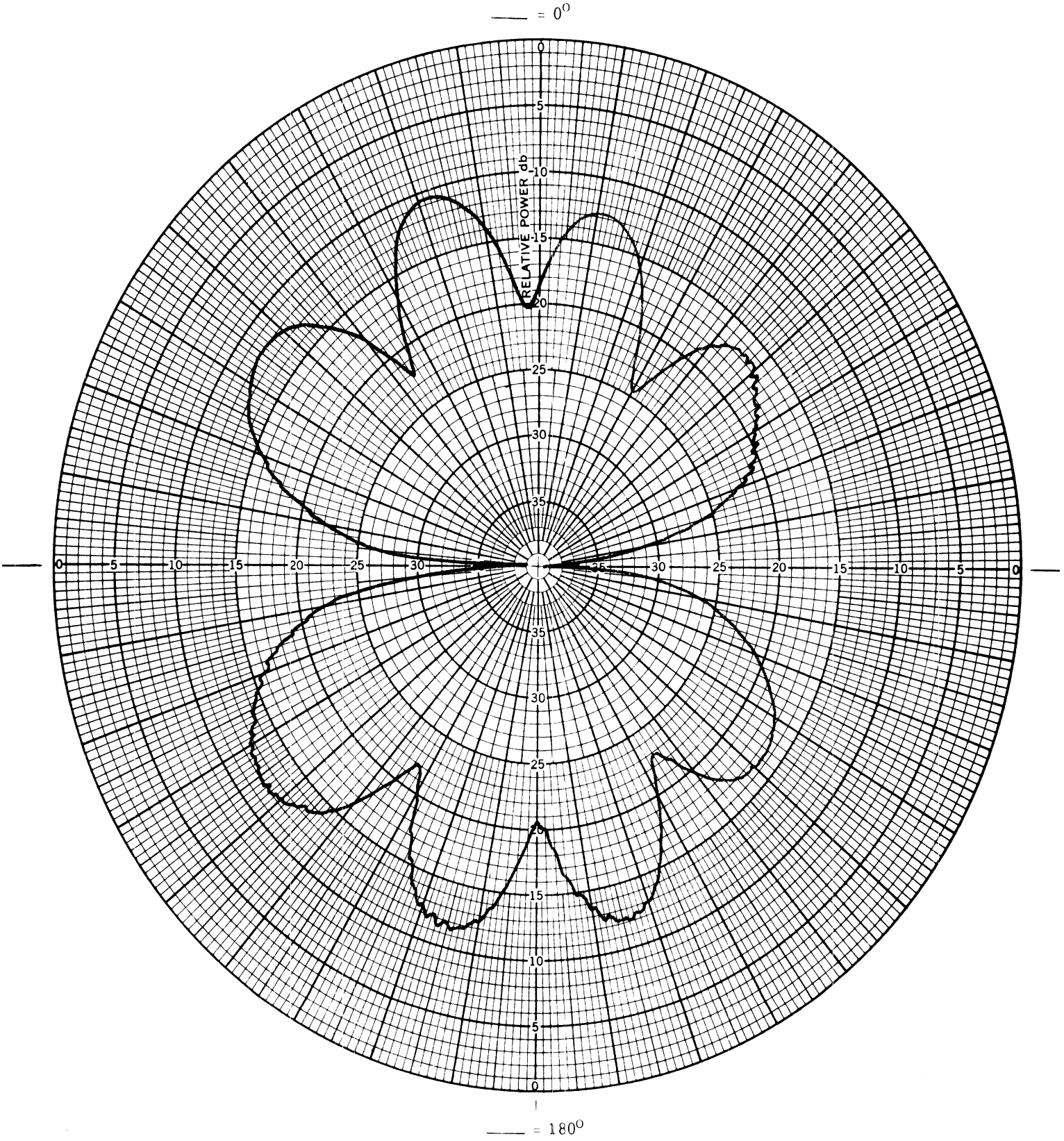

Fig. 11(j): Measured horizontal plane pattern of the side-fed heated backlite antenna. Vertical polarization, f = 350.0 MHz.

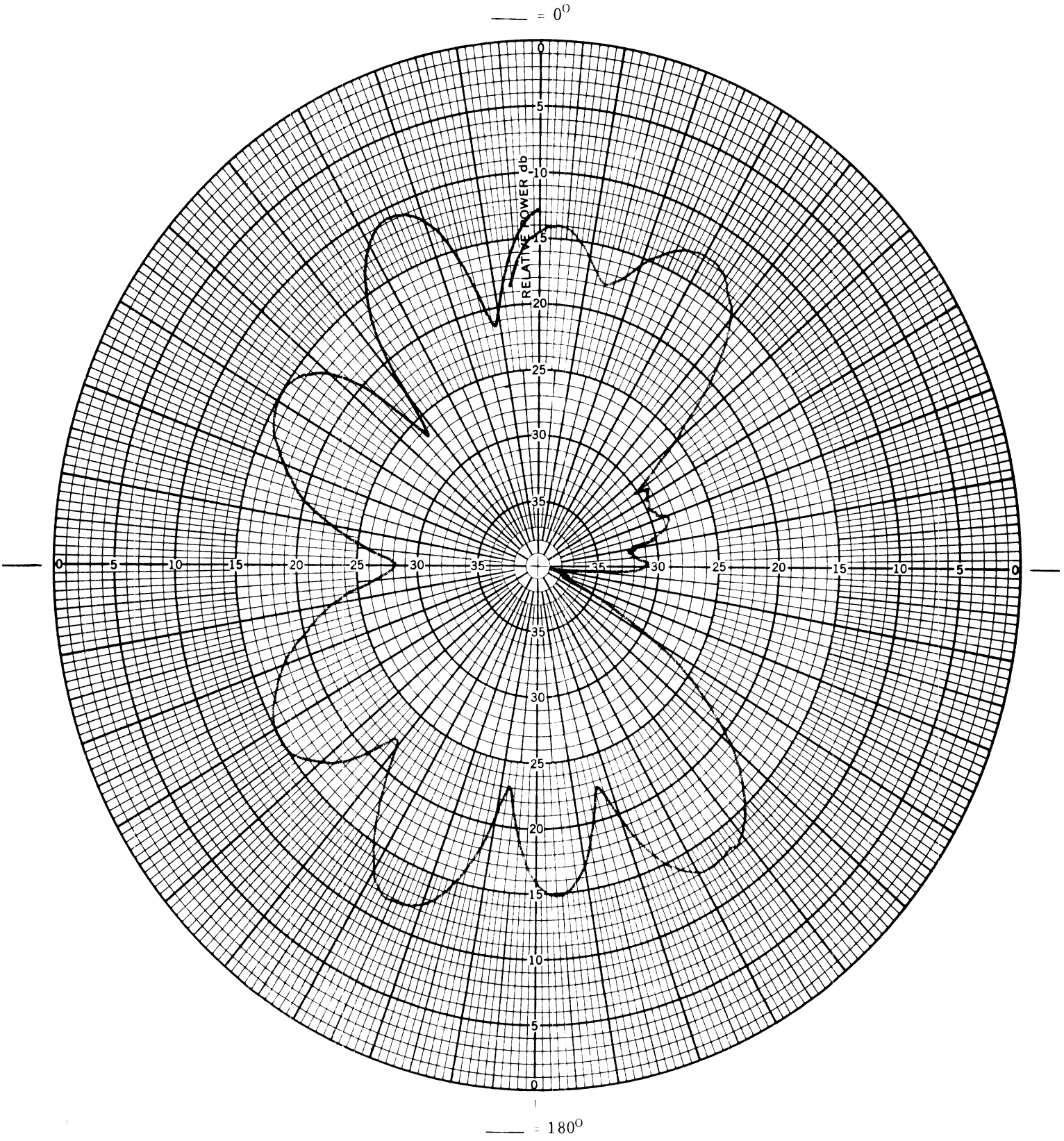

Fig. 11(k): Measured horizontal plane pattern of the side-fed heated backlite antenna. Vertical polarization, f = 402.0 MHz.

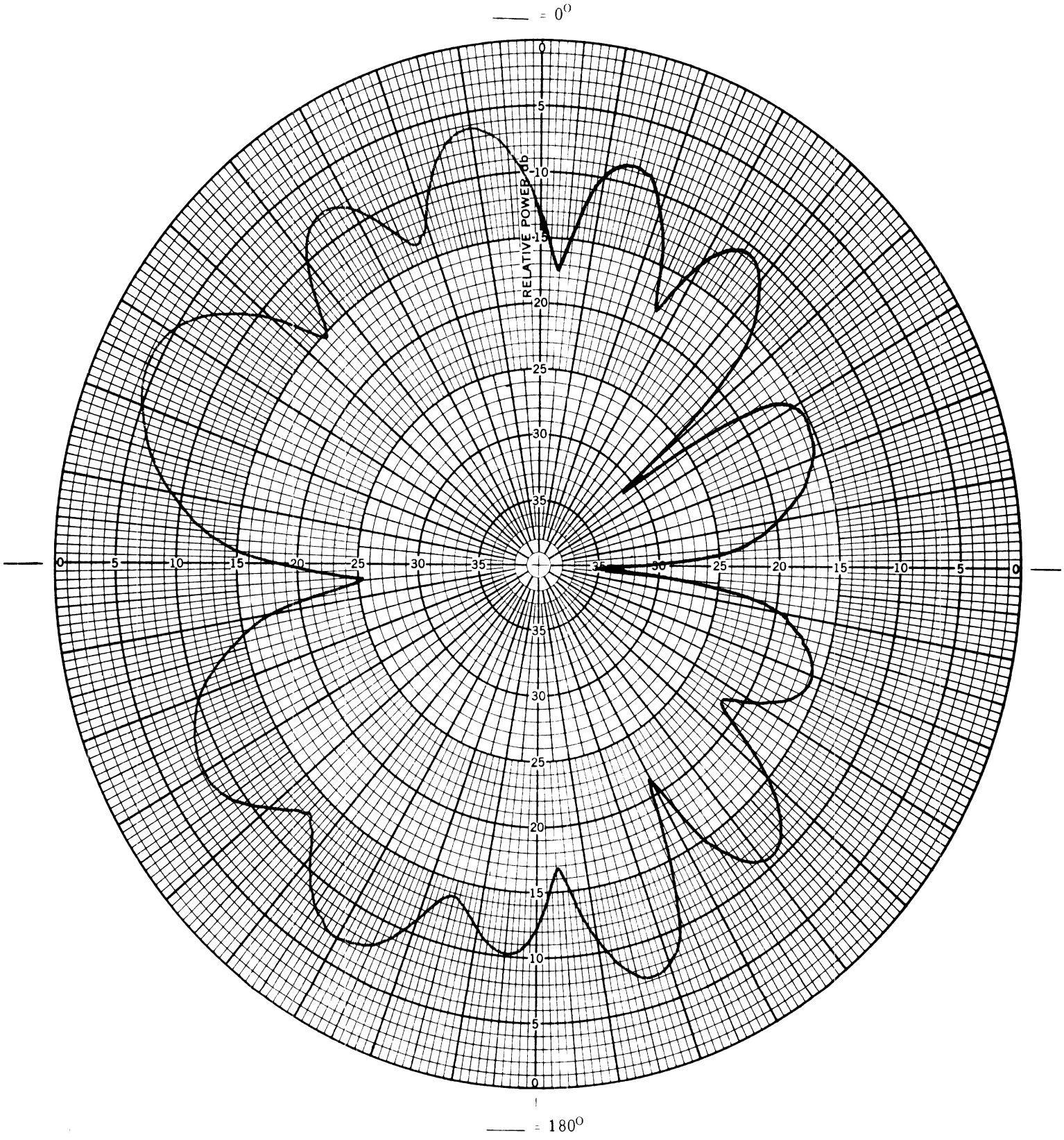

Fig. 11(1): Measured horizontal plane pattern of the side-fed heated backlite antenna. Vertical polarization, f = 502.0 MHz.

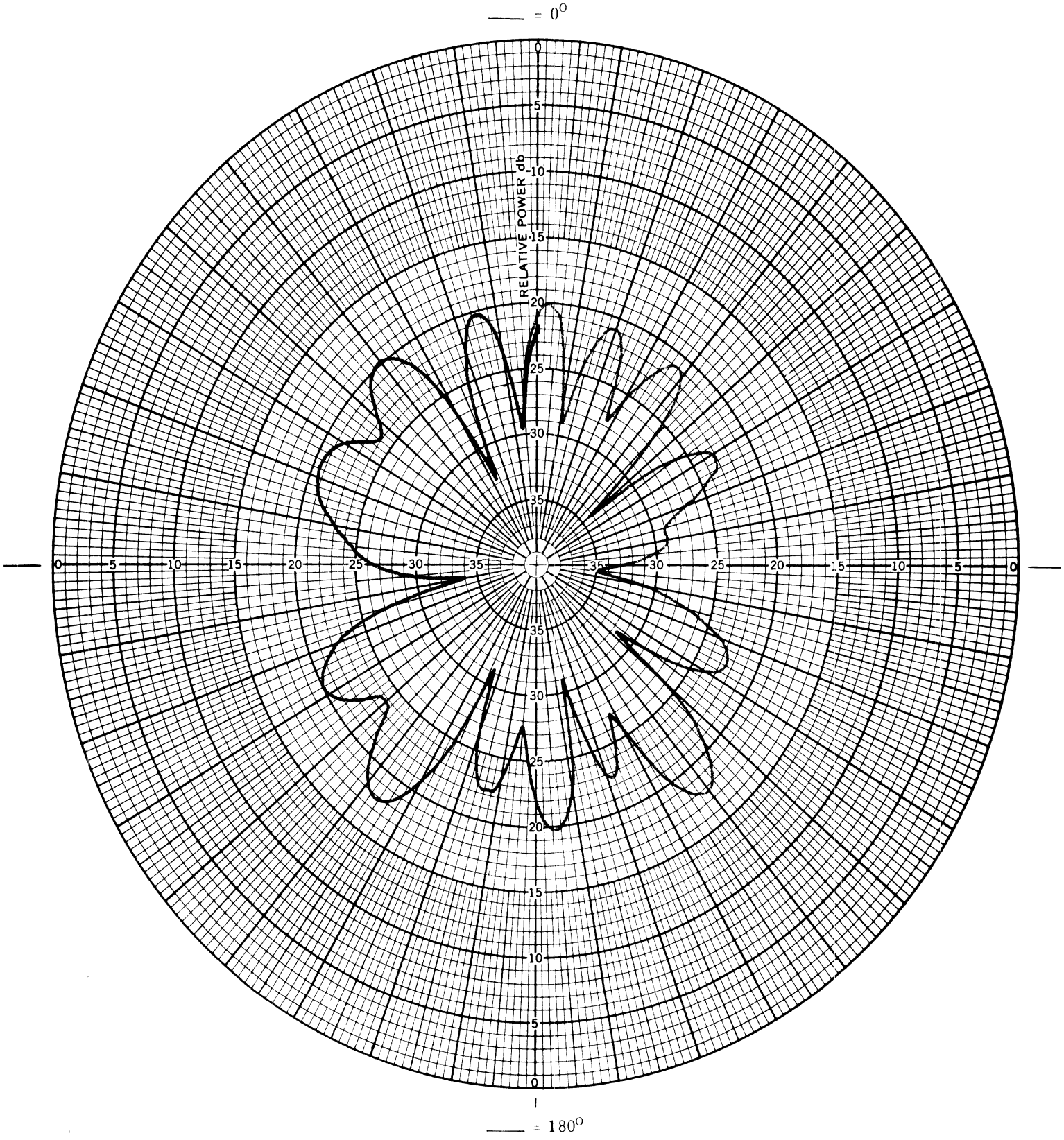

Fig. 11(m): Measured horizontal plane pattern of the side-fed heated backlite antenna. Vertical polarization, f = 604.0 MHz.

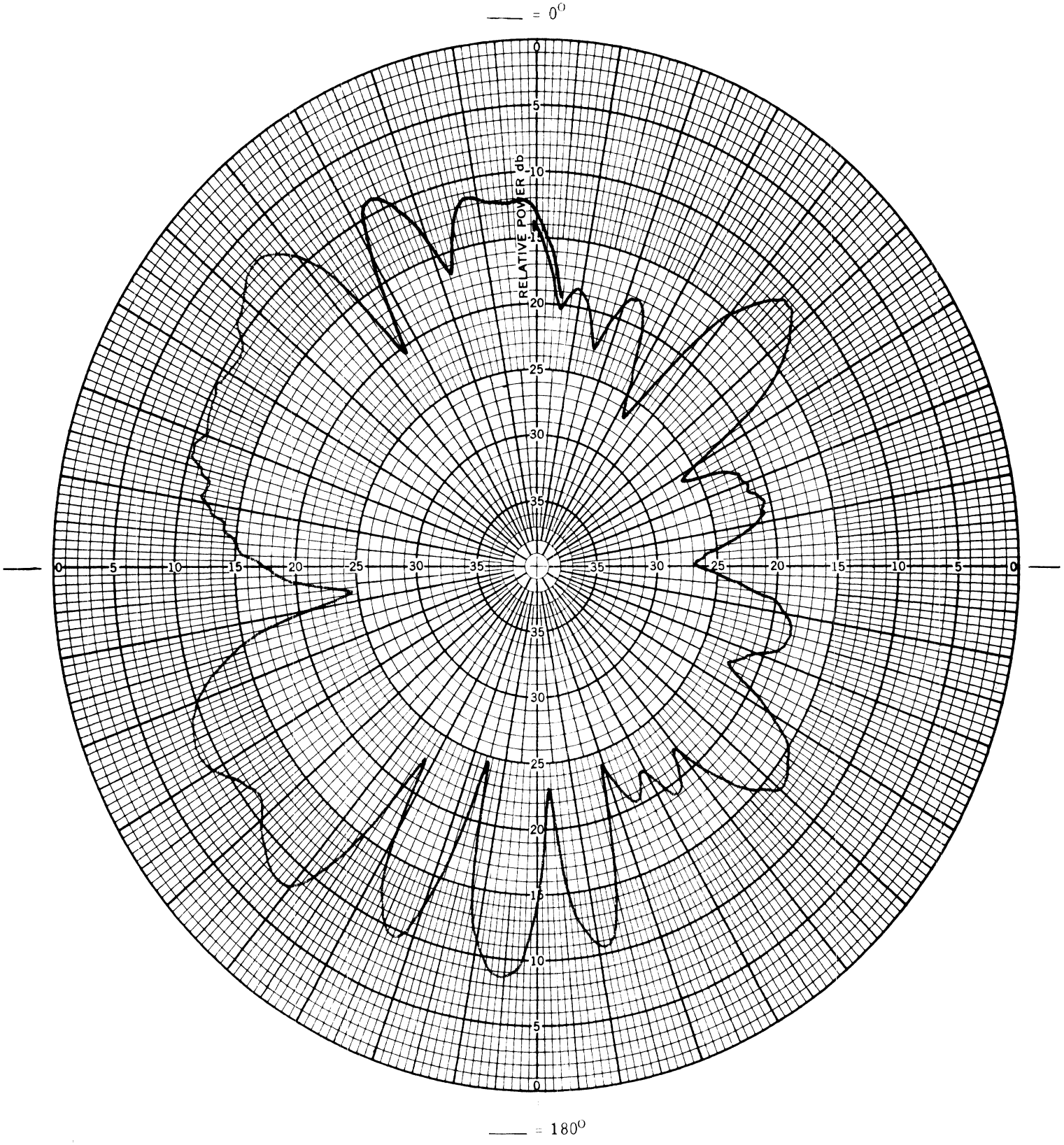

Fig. 11(n): Measured horizontal plane pattern of the side-fed heated backlite antenna. Vertical polarization, f = 701.0 MHz.

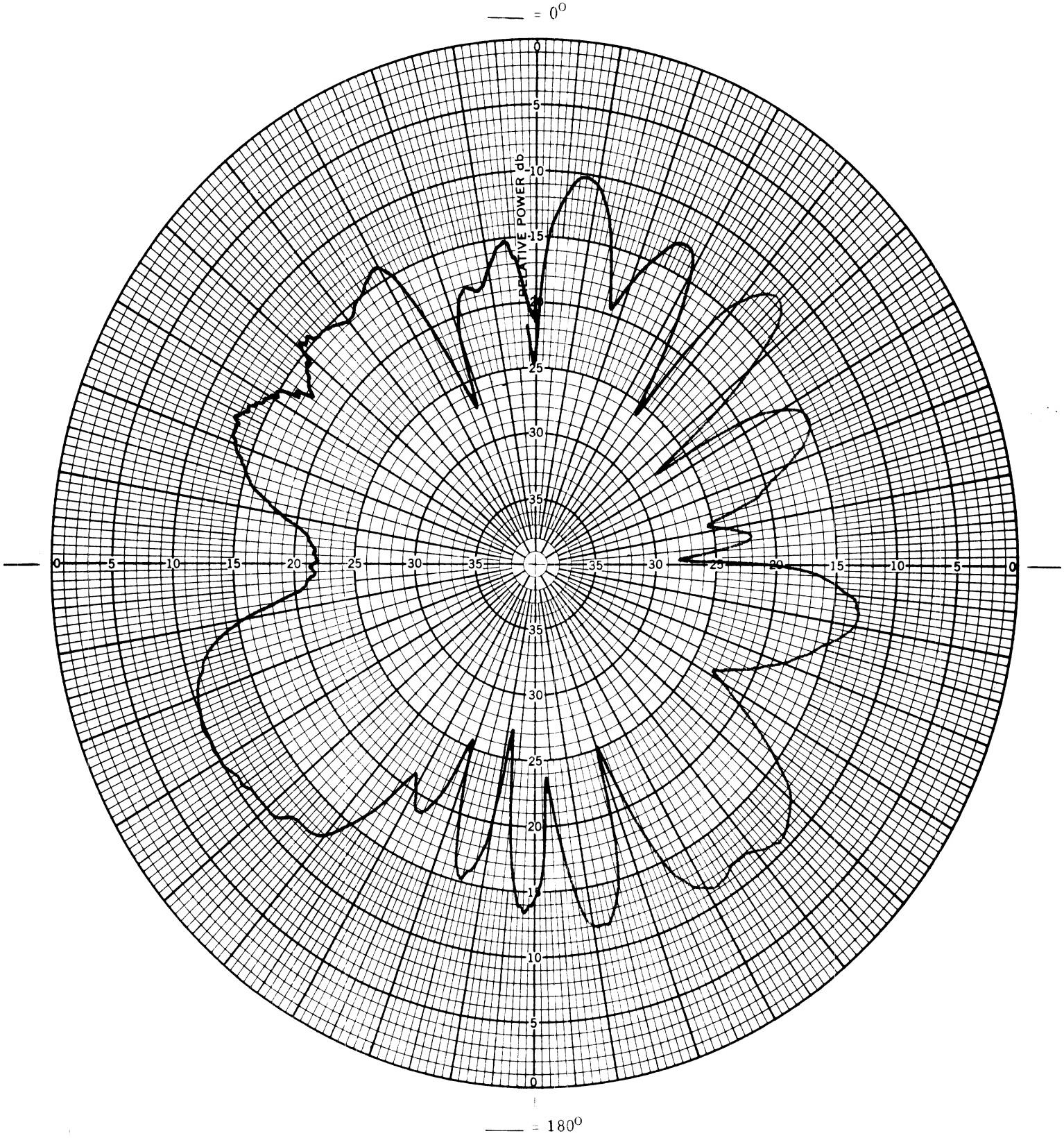

Fig. 11(o): Measured horizontal plane pattern of the side-fed heated backlite antenna. Vertical polarization, f = 800.0 MHz.

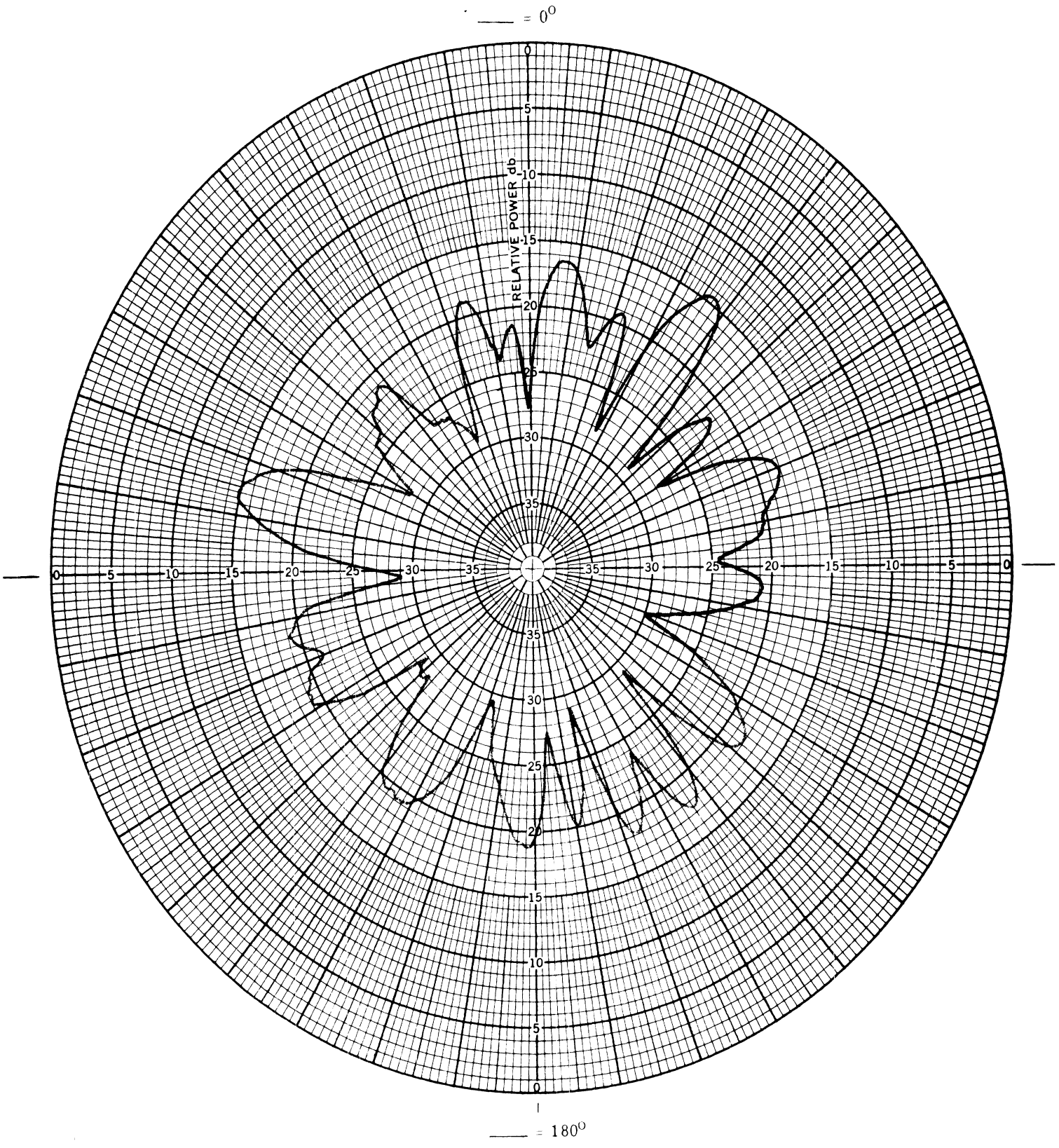

Fig. 11(p): Measured horizontal plane pattern of the side-fed heated backlite antenna. Vertical polarization, f = 965.0 MHz.

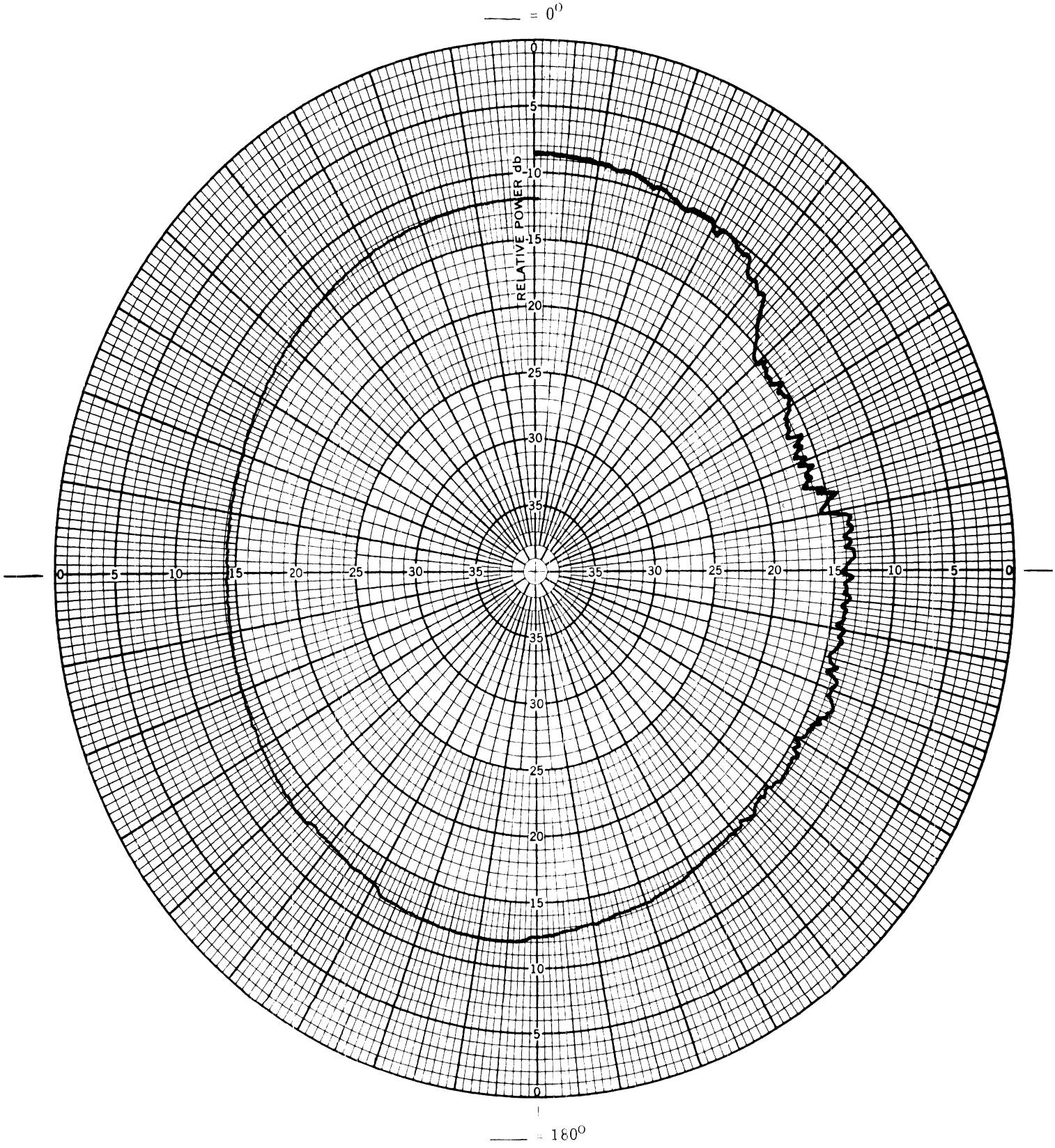

Fig. 12(a): Measured horizontal plane pattern of the bottom-fed heated backlite antenna. Vertical polarization, f = 51.8 MHz.

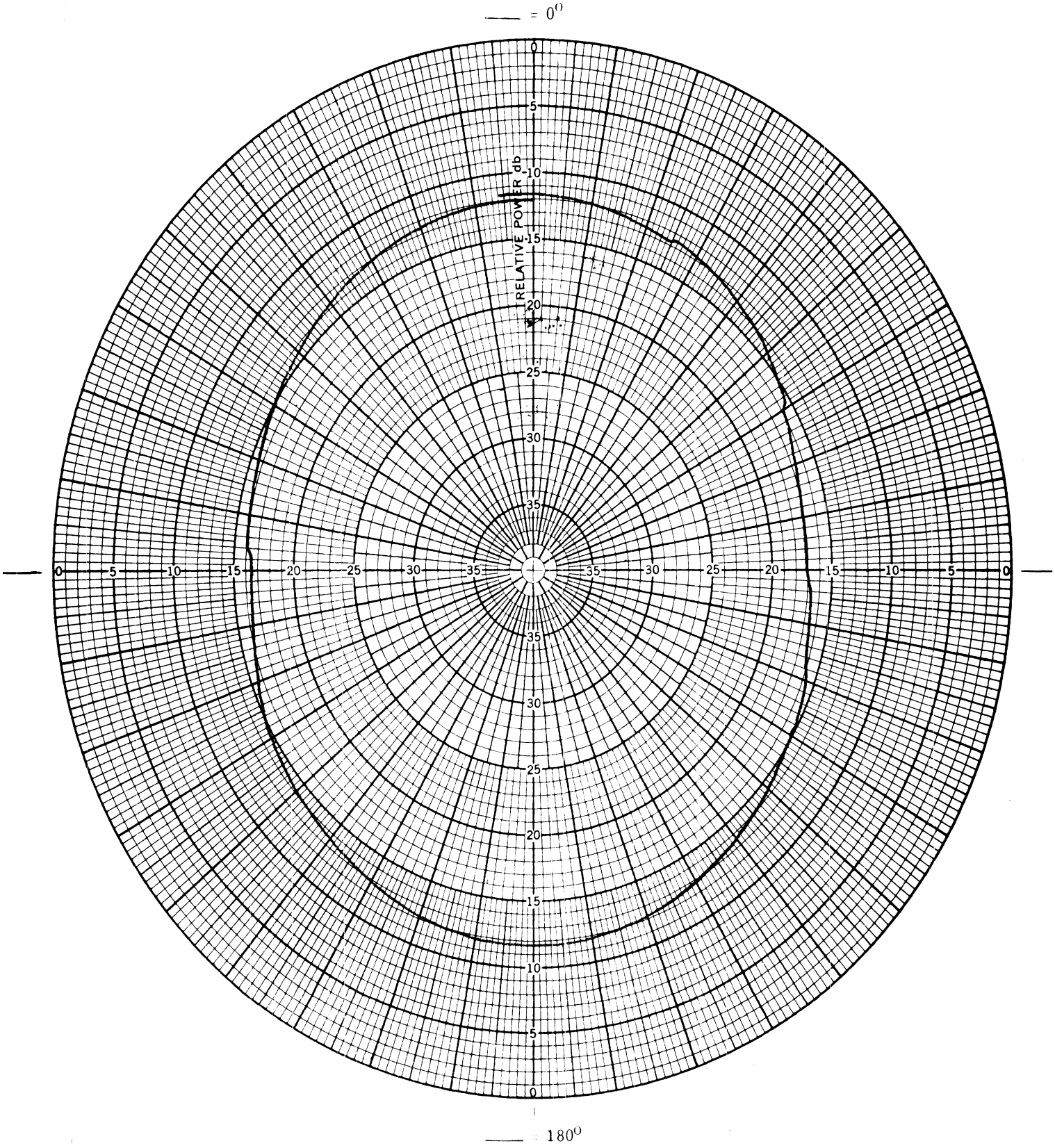

Fig. 12(b): Measured horizontal plane pattern of the bottom-fed heated backlite antenna. Vertical polarization, f = 63.6 MHz.

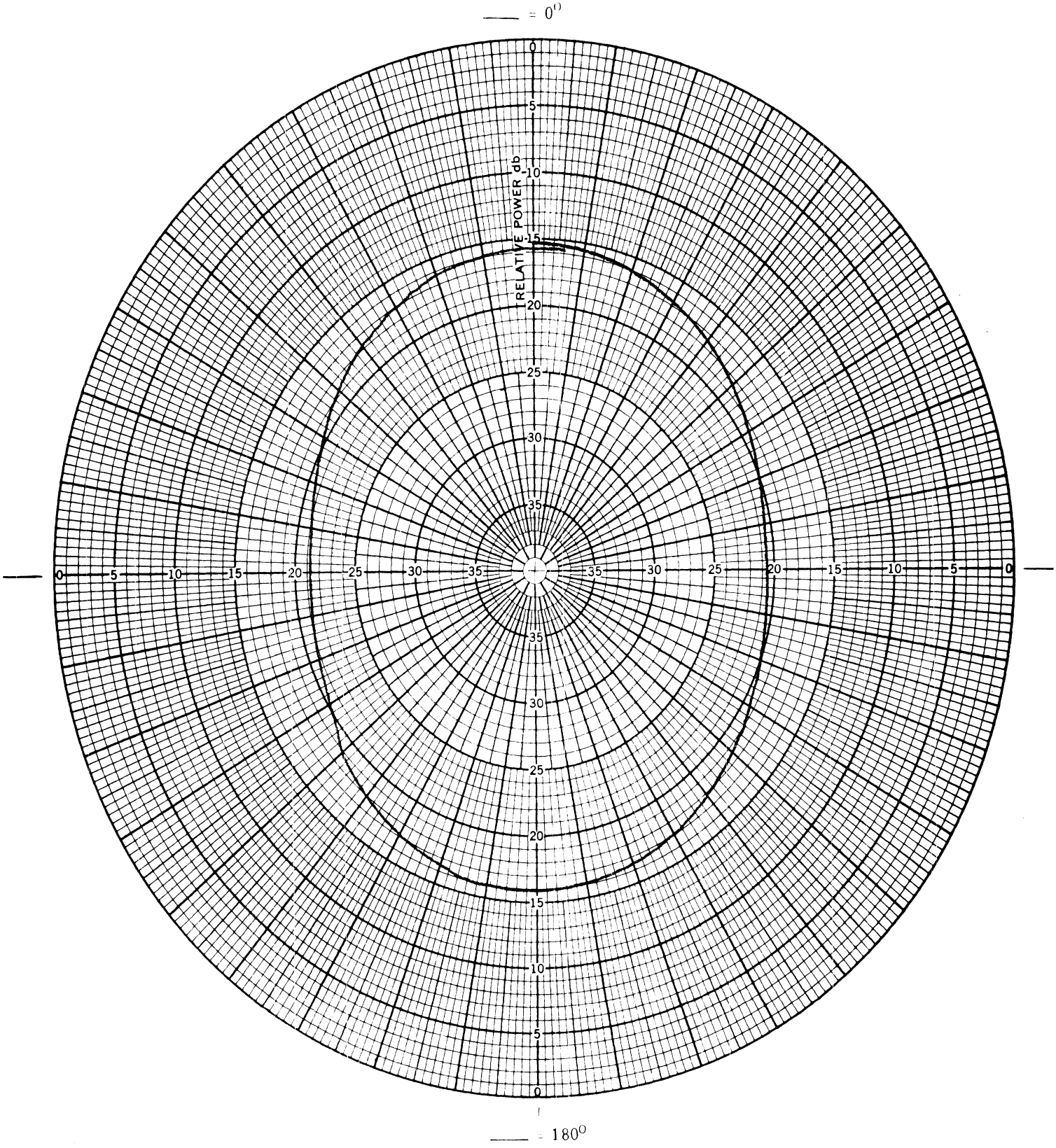

Fig. 12(c): Measured horizontal plane pattern of the bottom-fed heated backlite antenna. Vertical polarization, f = 75.2 MHz.

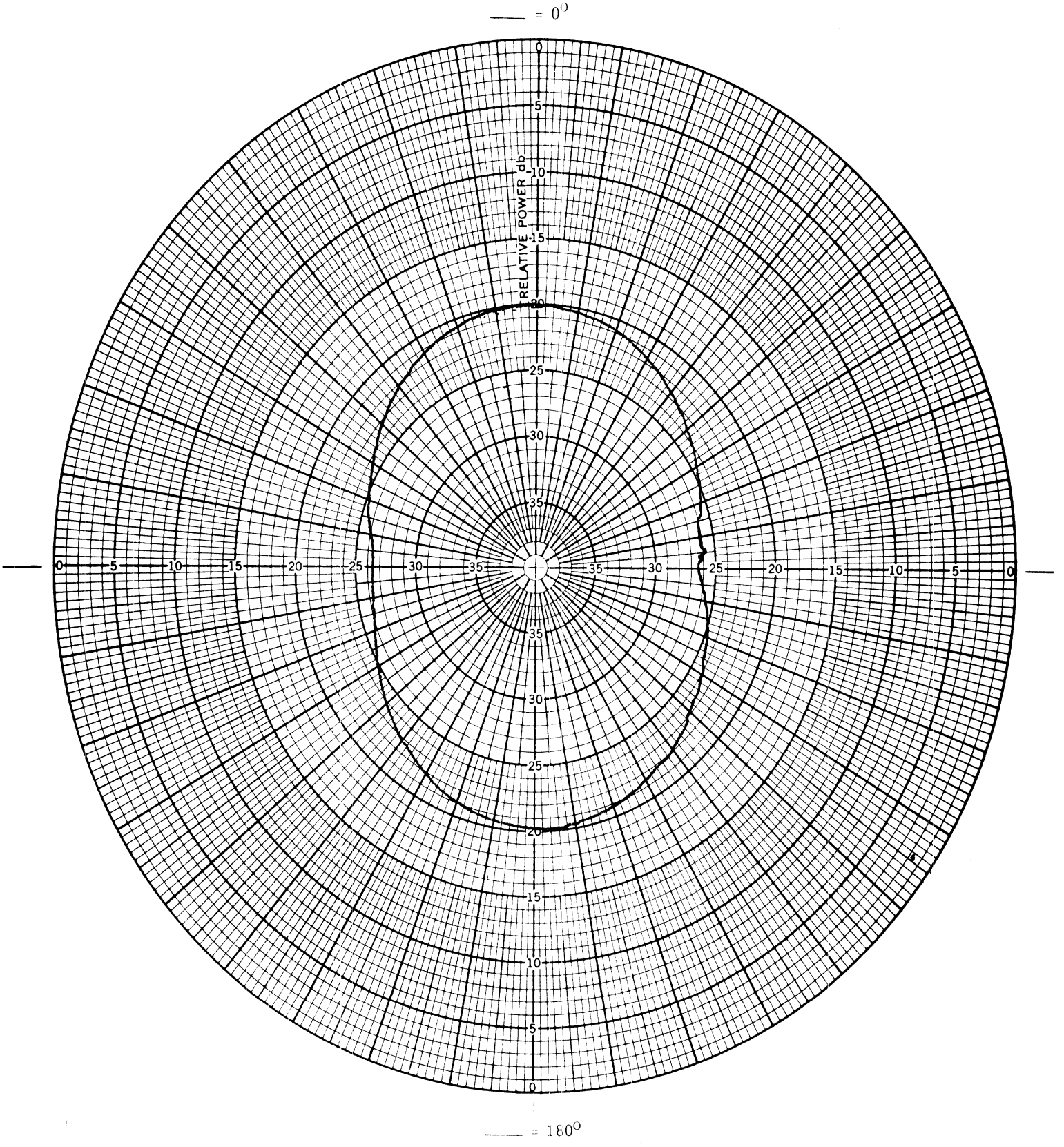

Fig. 12(d): Measured horizontal plane pattern of the bottom-fed heated backlite antenna. Vertical polarization, f = 84.3 MHz.

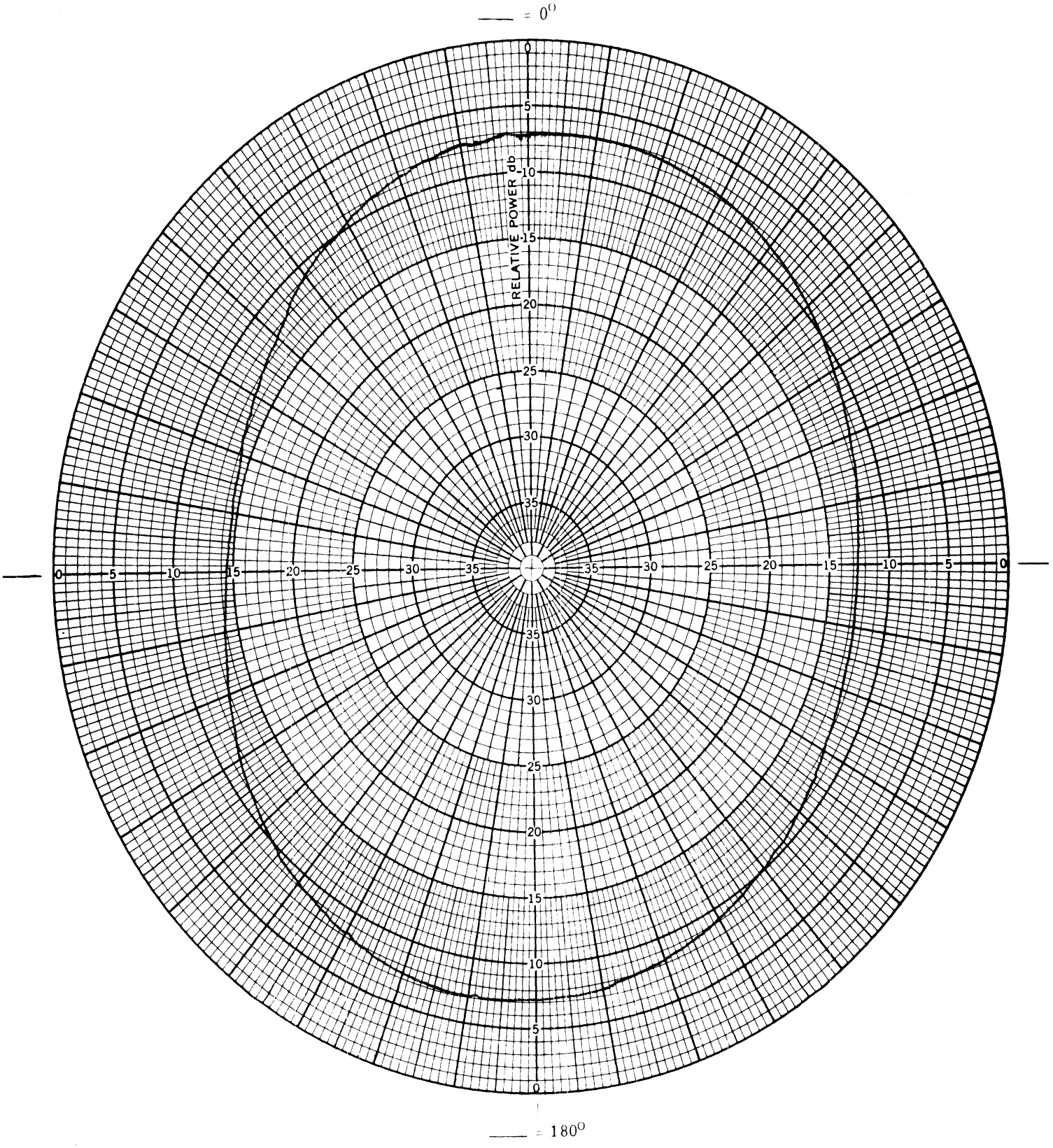

Fig. 12(e): Measured horizontal plane pattern of the bottom-fed heated backlite antenna. Vertical polarization, f = 113.1 MHz.

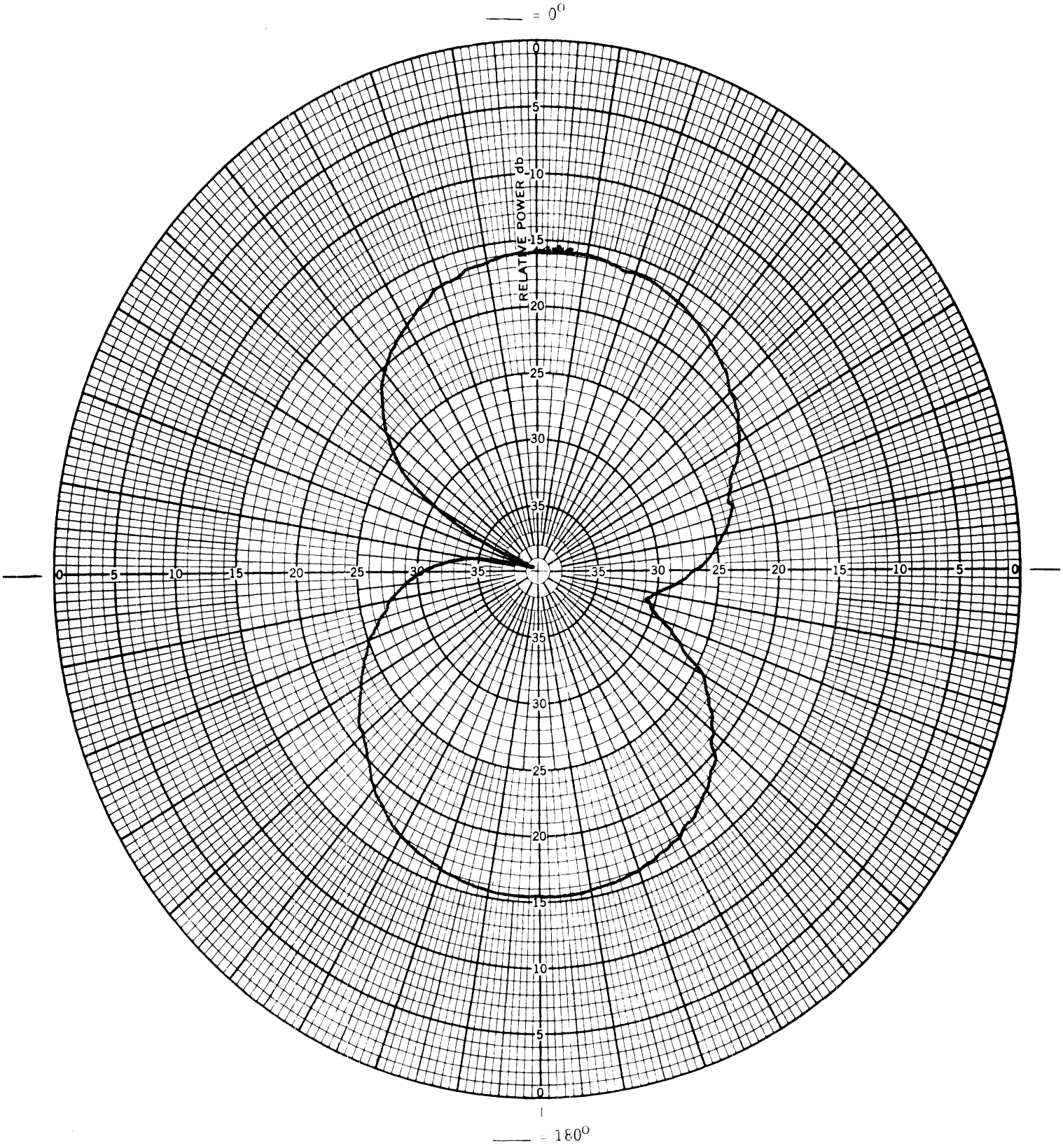

Fig. 12(f): Measured horizontal plane pattern of the bottom-fed heated backlite antenna. Vertical polarization, f = 149.2 MHz.

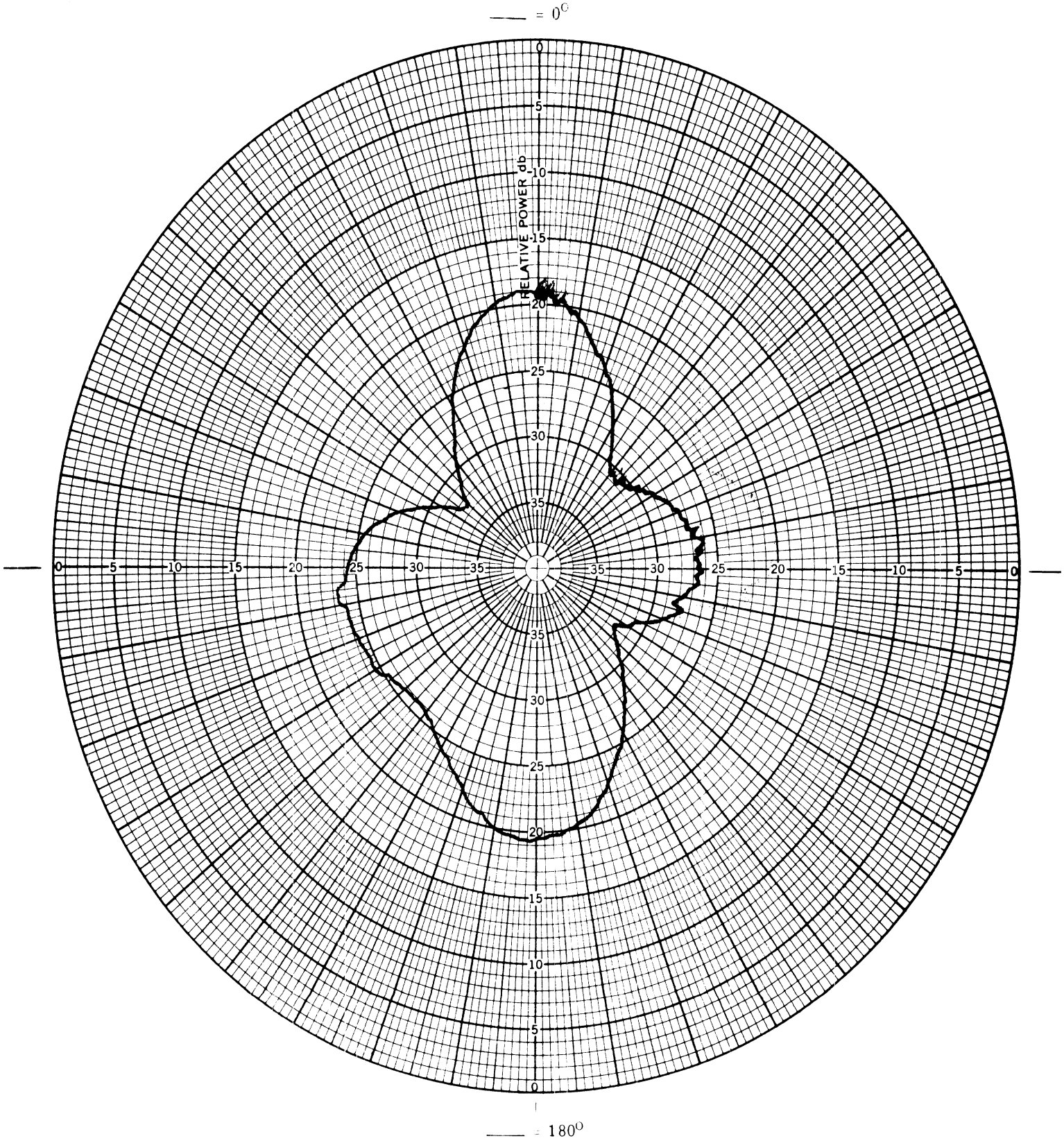

Fig. 12(g): Measured horizontal plane pattern of the bottom-fed heated backlite antenna. Vertical polarization, f = 206.0 MHz.

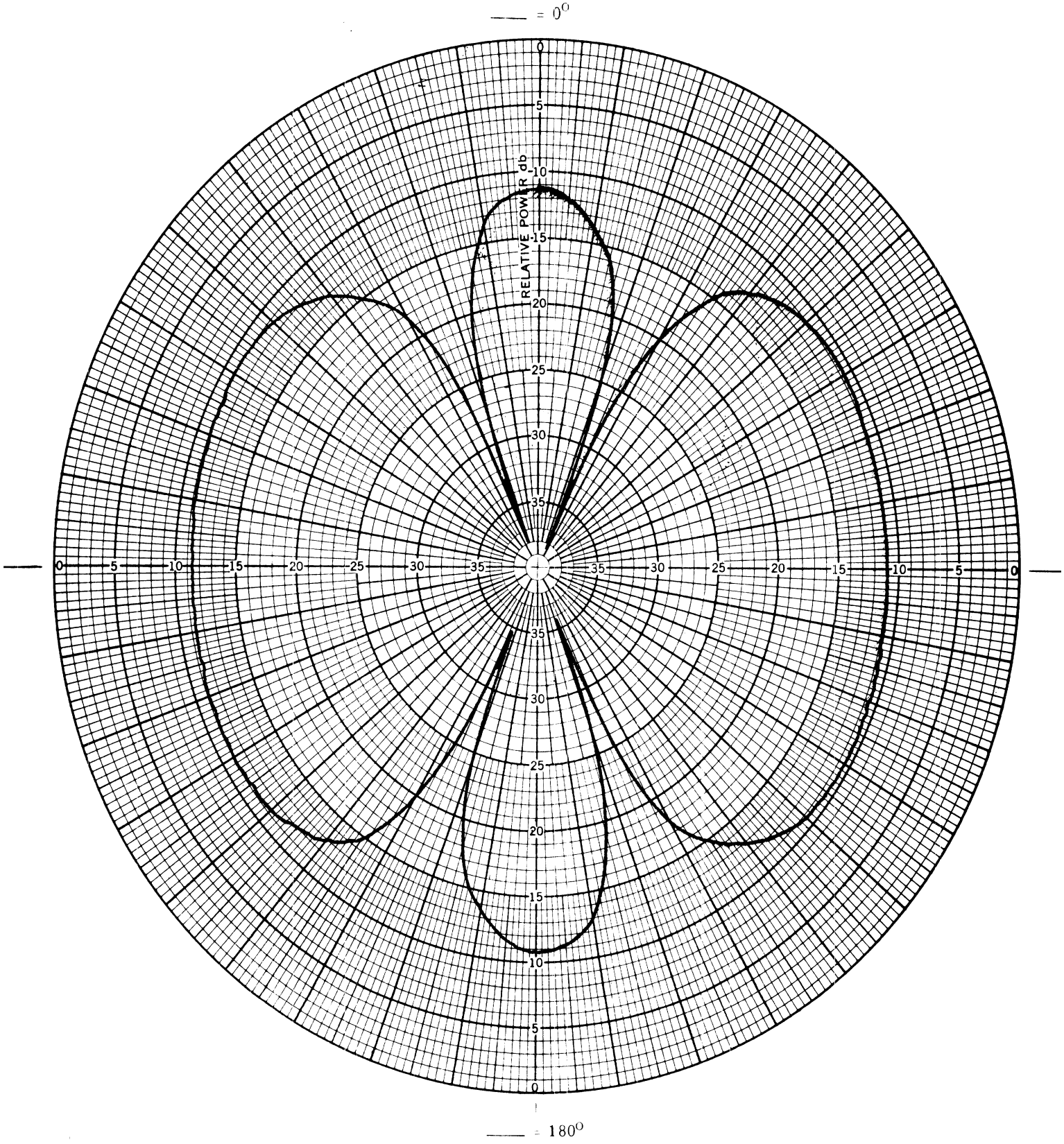

Fig. 12(h): Measured horizontal plane pattern of the bottom-fed heated backlite antenna. Vertical polarization, f = 252.0 MHz.

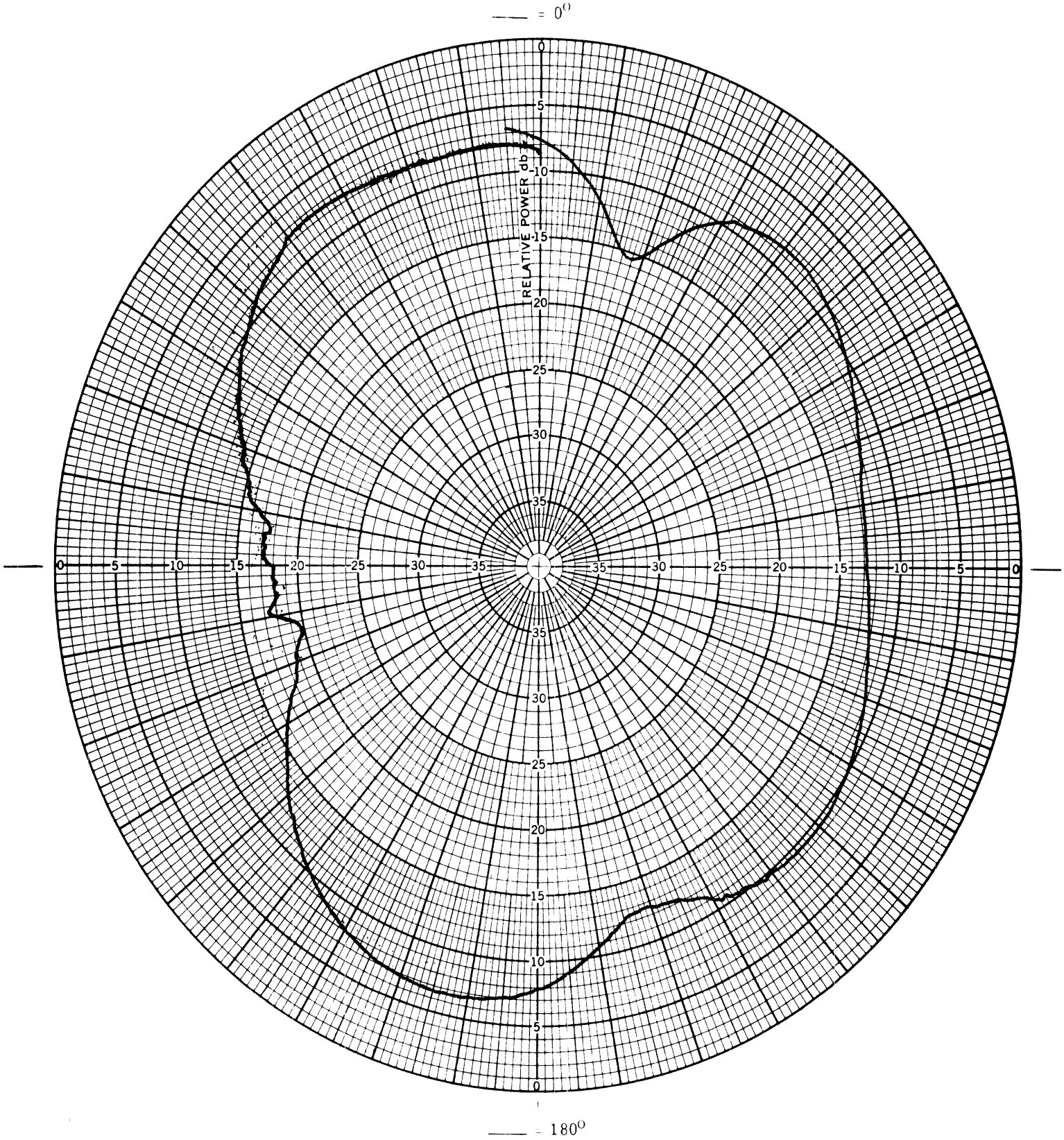

Fig. 12(i): Measured horizontal plane pattern of the bottom-fed heated backlite antenna. Vertical polarization, f = 302.0 MHz.

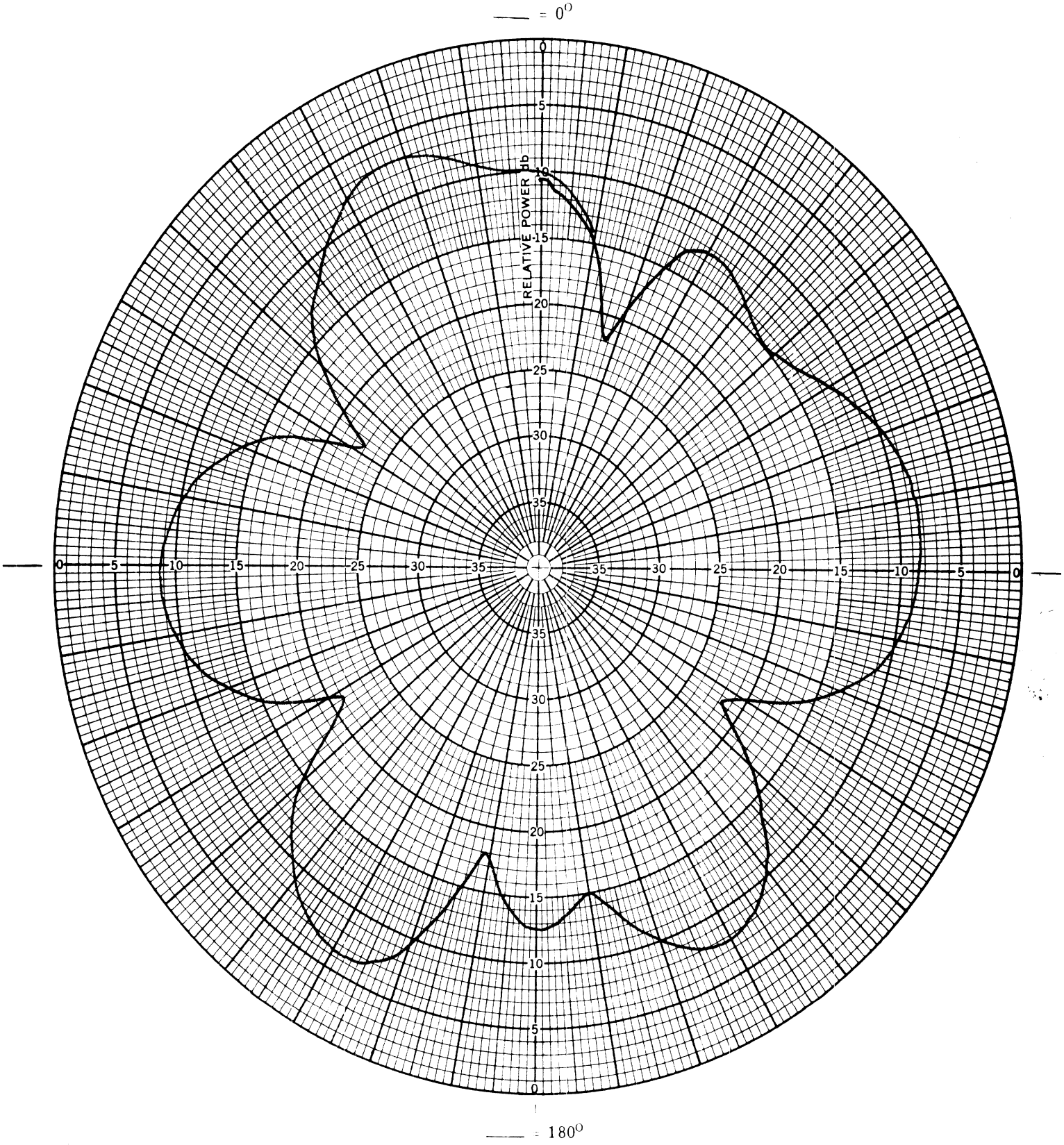

Fig. 12(j): Measured horizontal plane pattern of the bottom-fed heated backlite antenna. Vertical polarization, f = 350.0 MHz.

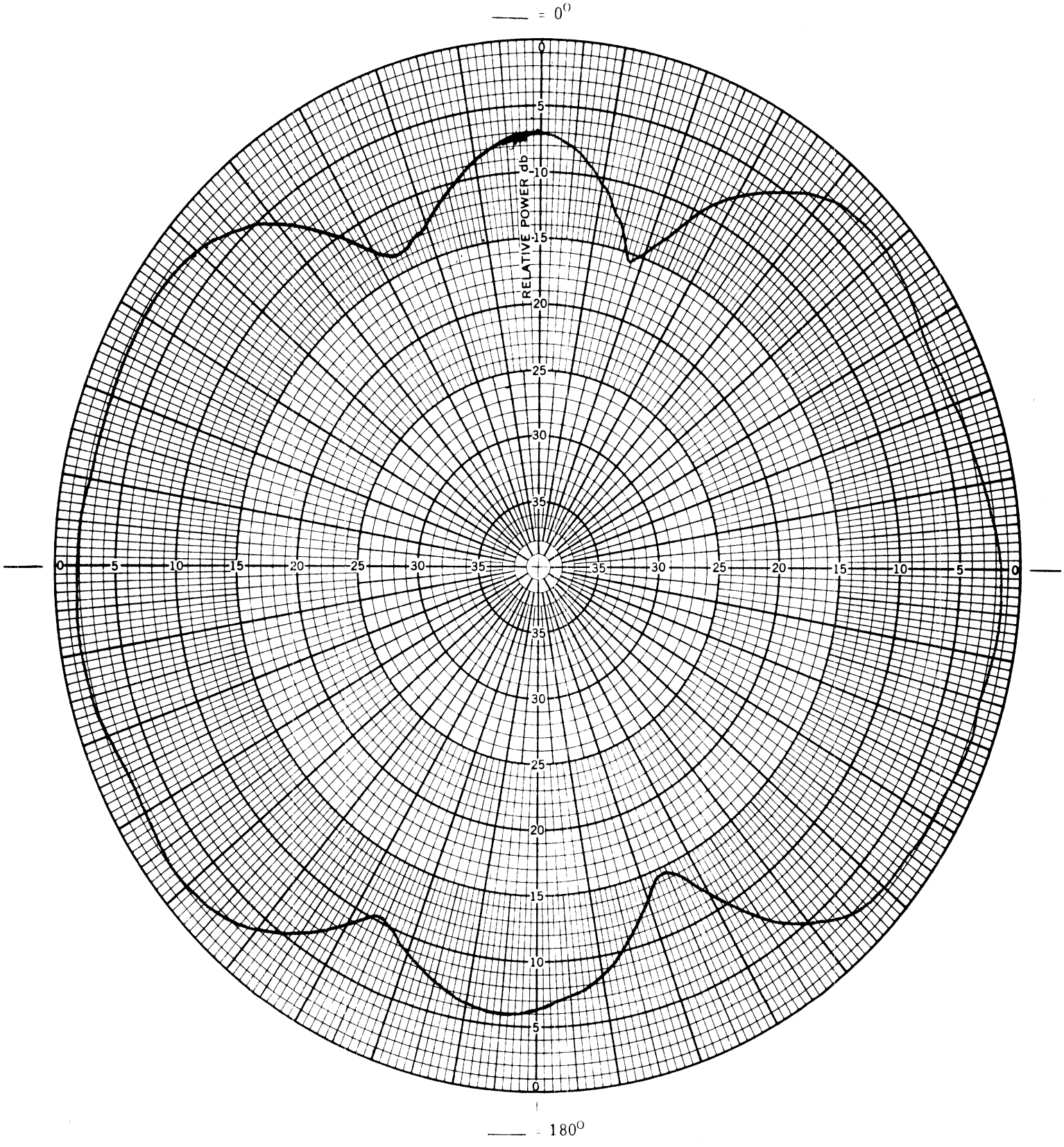

Fig. 12(k): Measured horizontal plane pattern of the bottom-fed heated backlite antenna. Vertical polarization, f = 400.0 MHz.

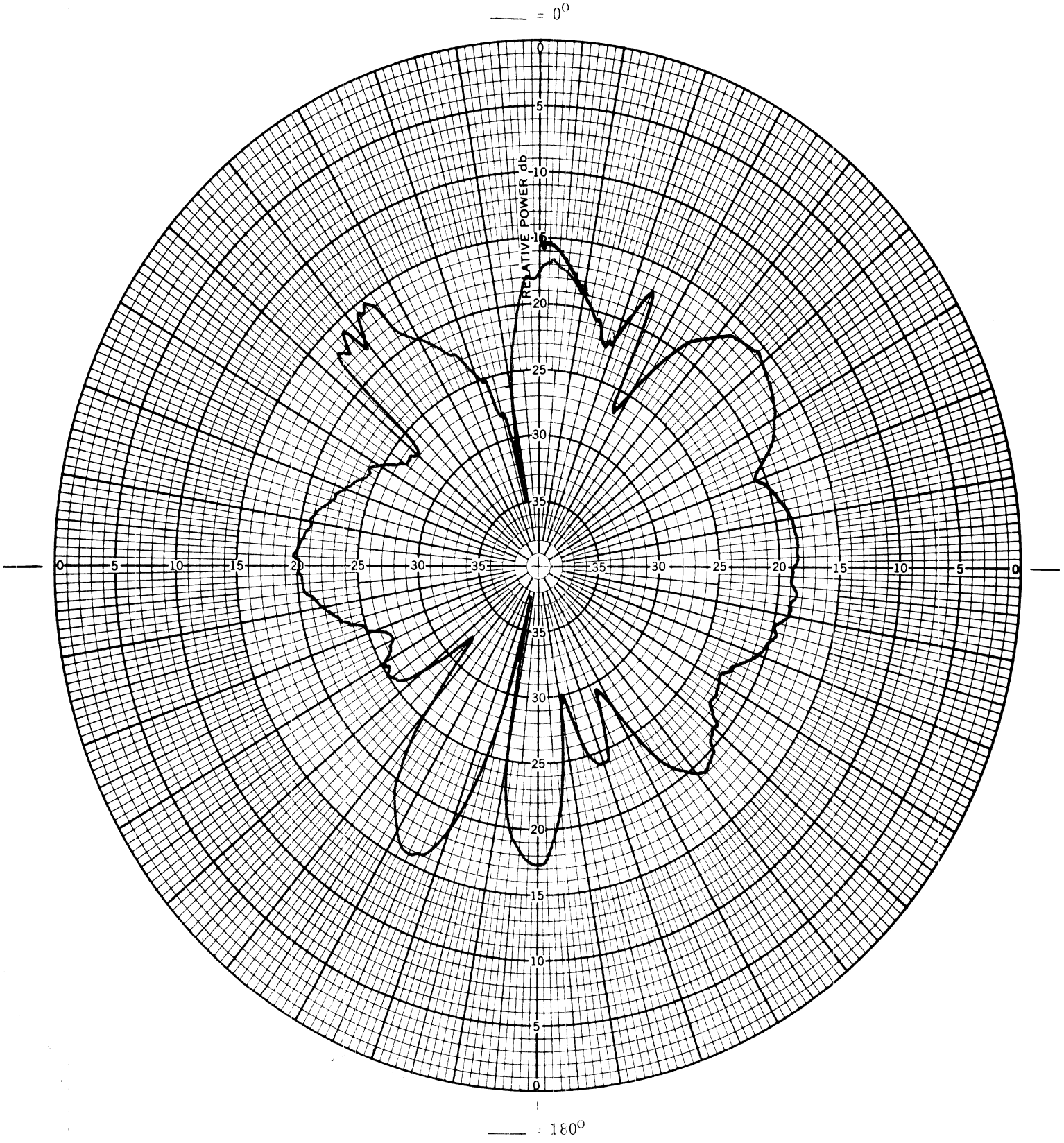

Fig. 12(1): Measured horizontal plane pattern of the bottom-fed heated backlite antenna. Vertical polarization, f = 501.0 MHz.

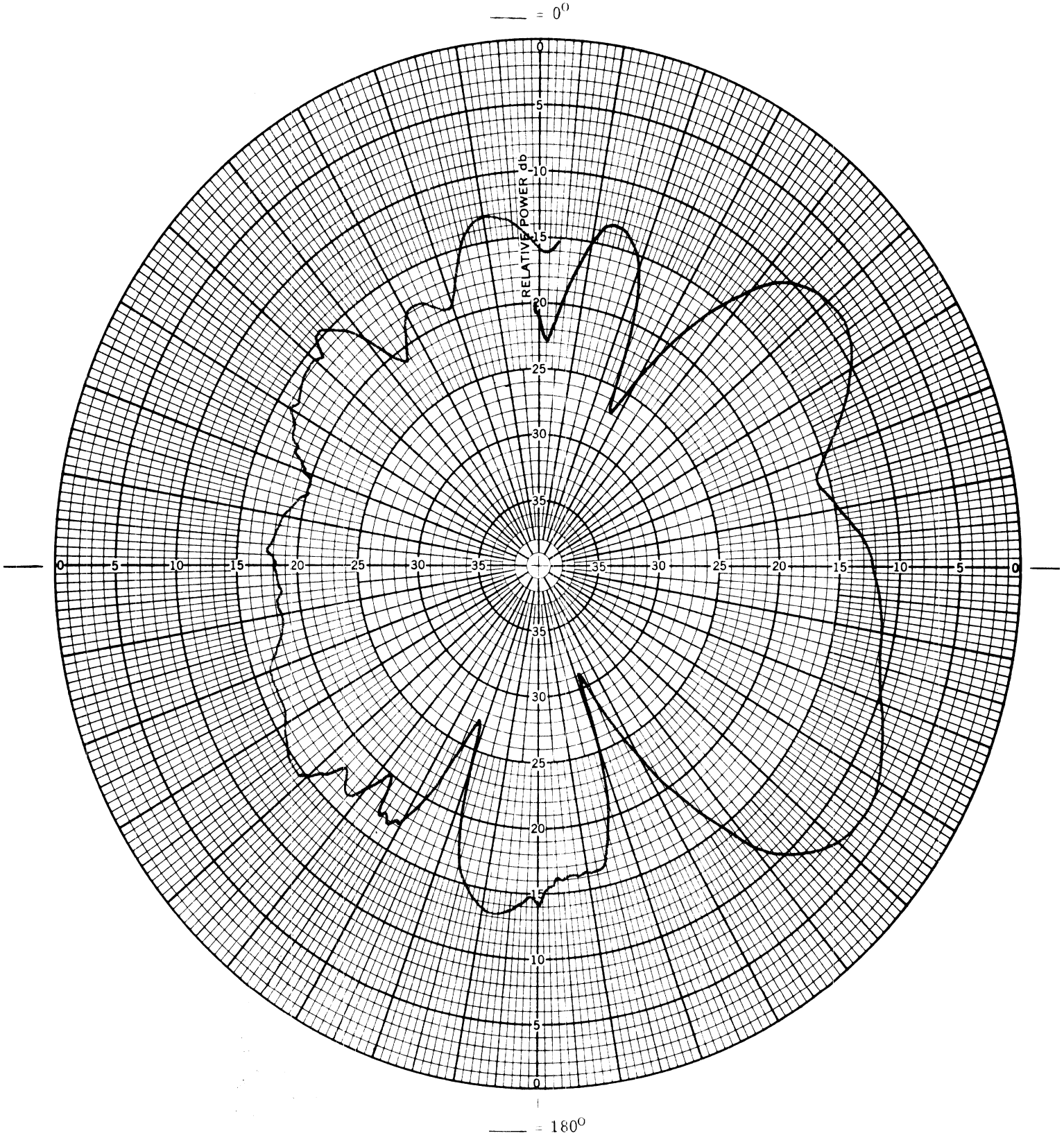

Fig. 12(m): Measured horizontal plane pattern of the bottom-fed heated backlite antenna. Vertical polarization, f = 600.0 MHz.

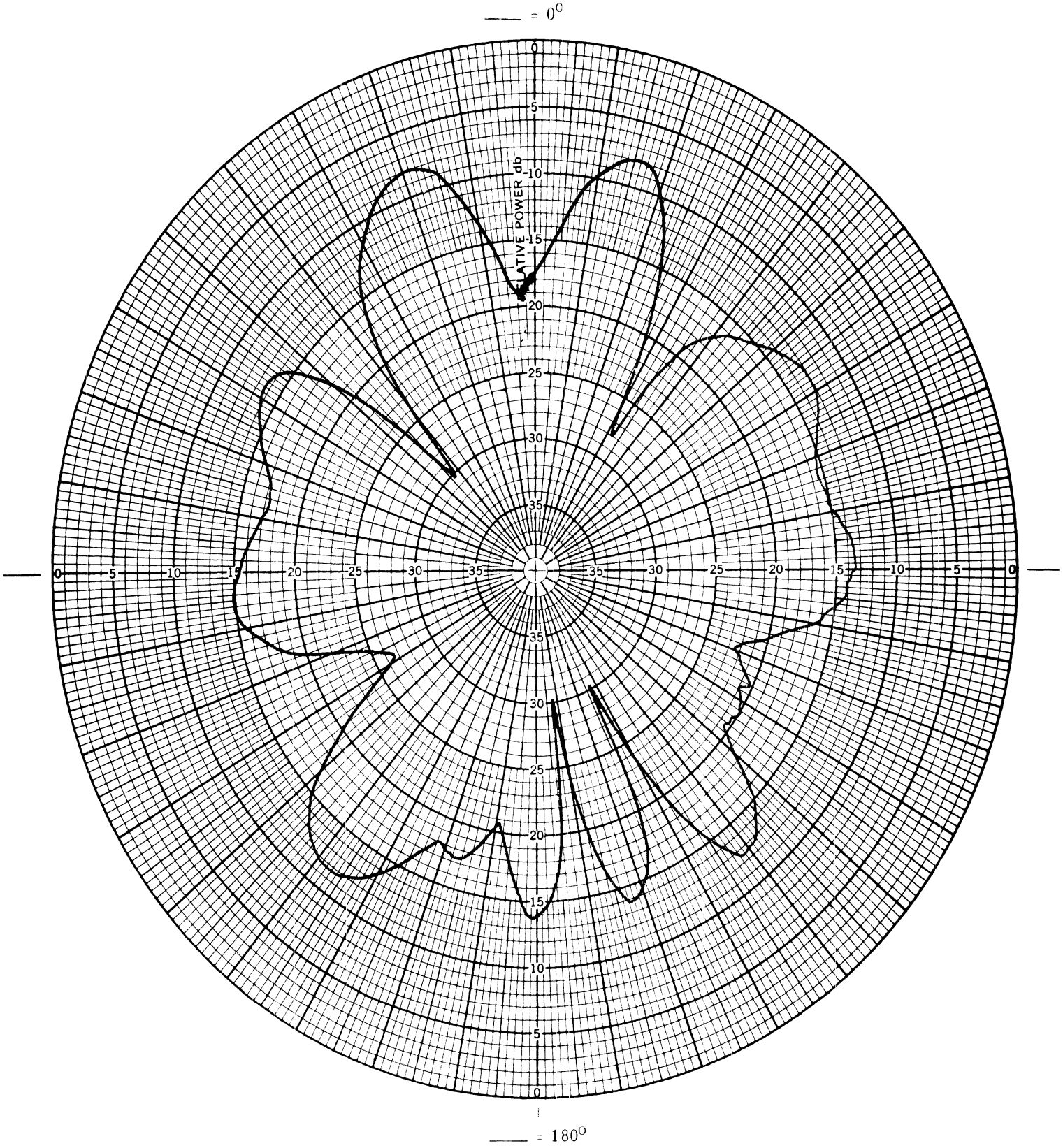

Fig. 12(n): Measured horizontal plane patterns of the bottom-fed heated backlite antenna. Vertical polarization, f = 700.0 MHz.

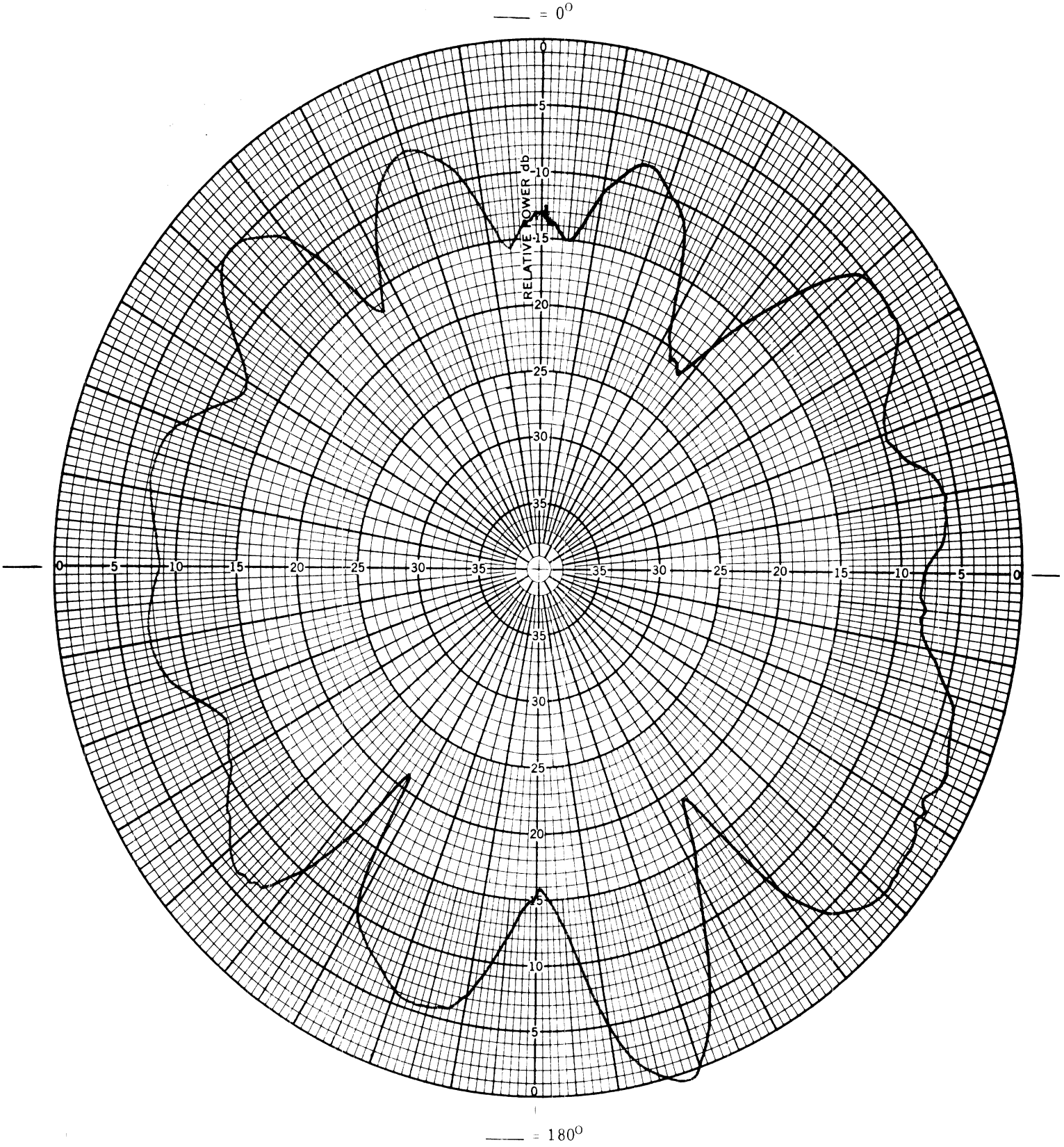

Fig. 12(o): Measured horizontal plane patterns of the bottom-fed heated backlite antenna. Vertical polarization, f = 800.0 MHz.

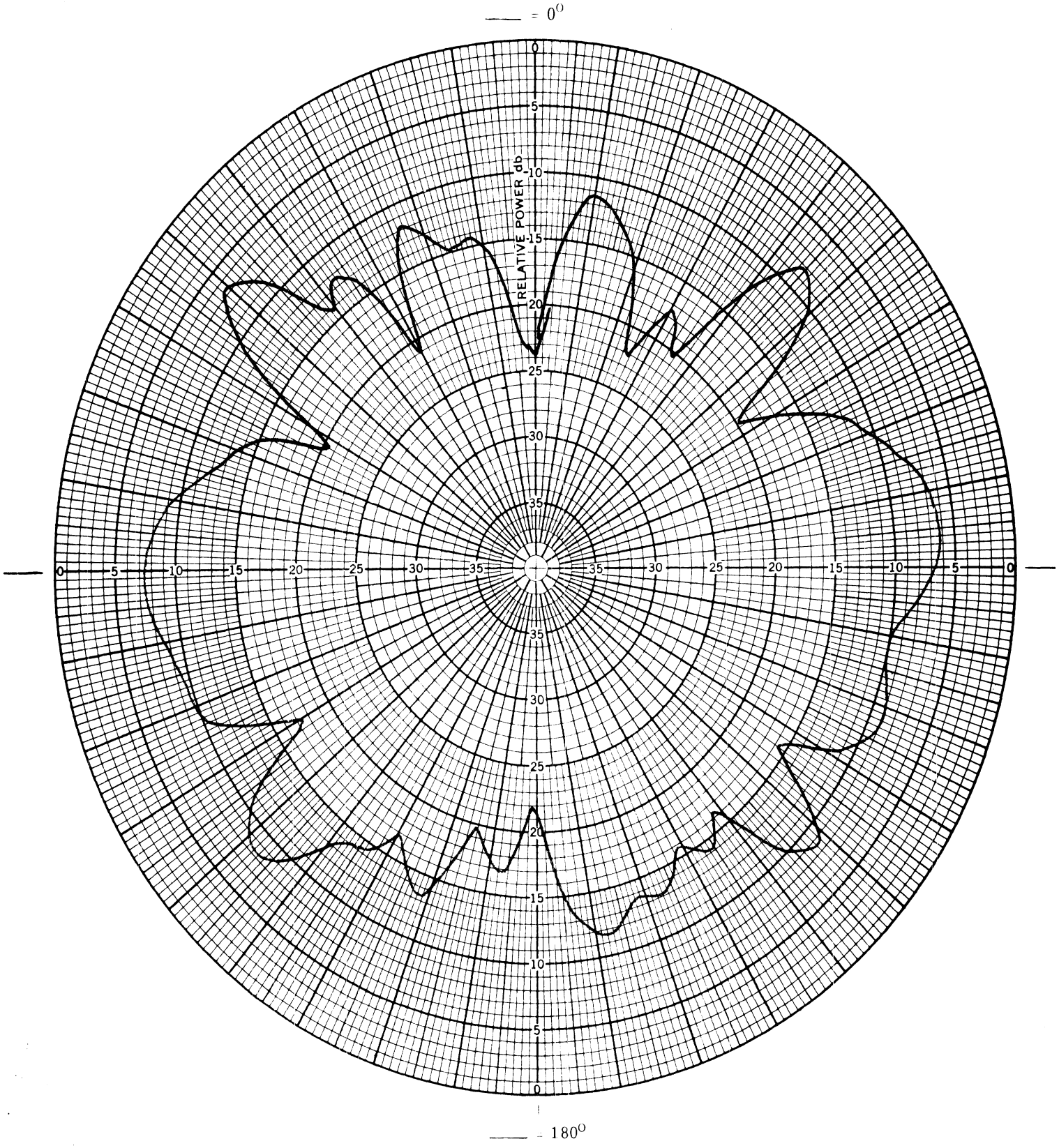

Fig. 12(p): Measured horizontal plane patterns of the bottom-fed heated backlite antenna. Vertical polarization, f = 970.0 MHz.

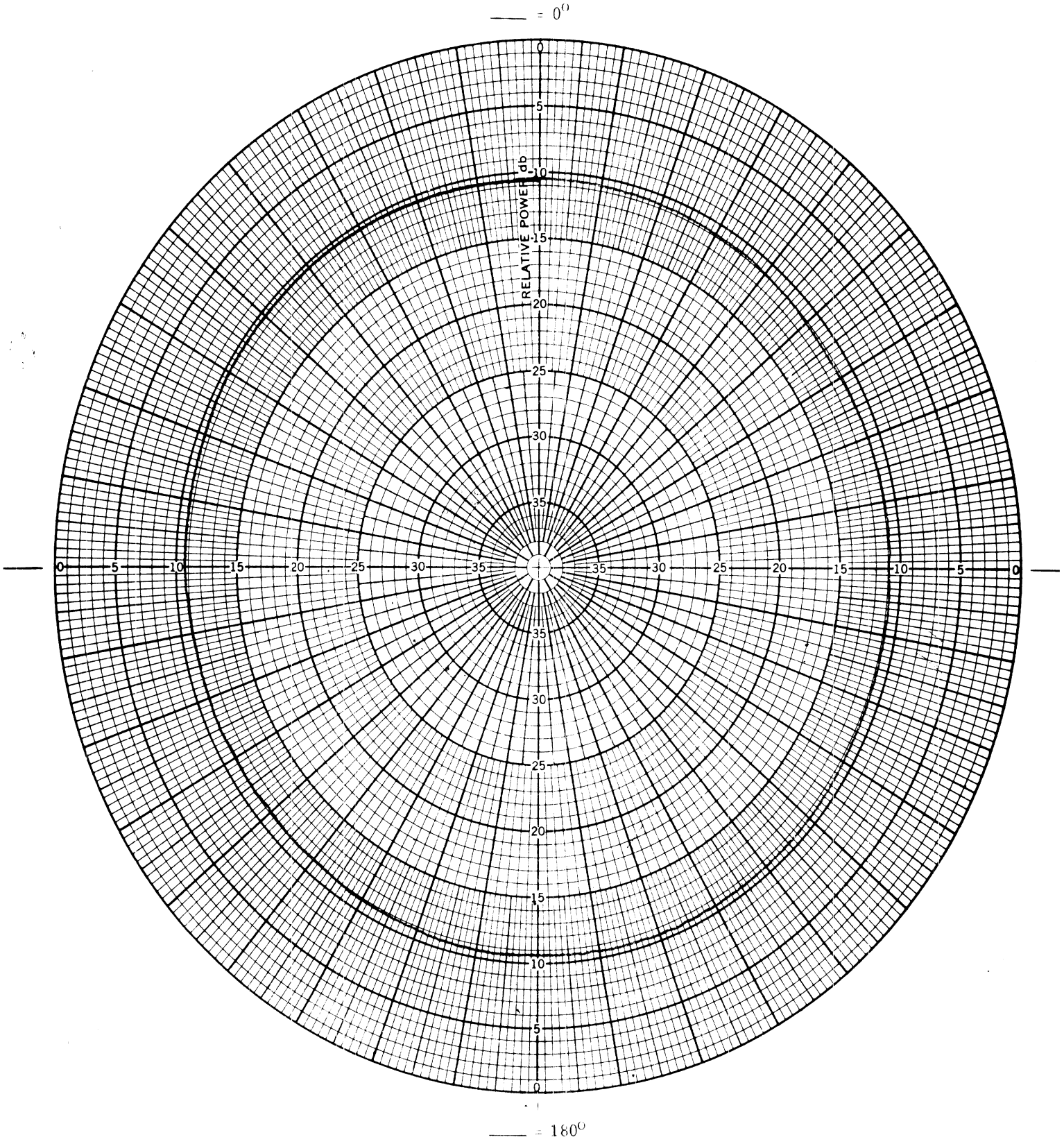

Fig. 13(a): Measured horizontal plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 51.5 MHz.

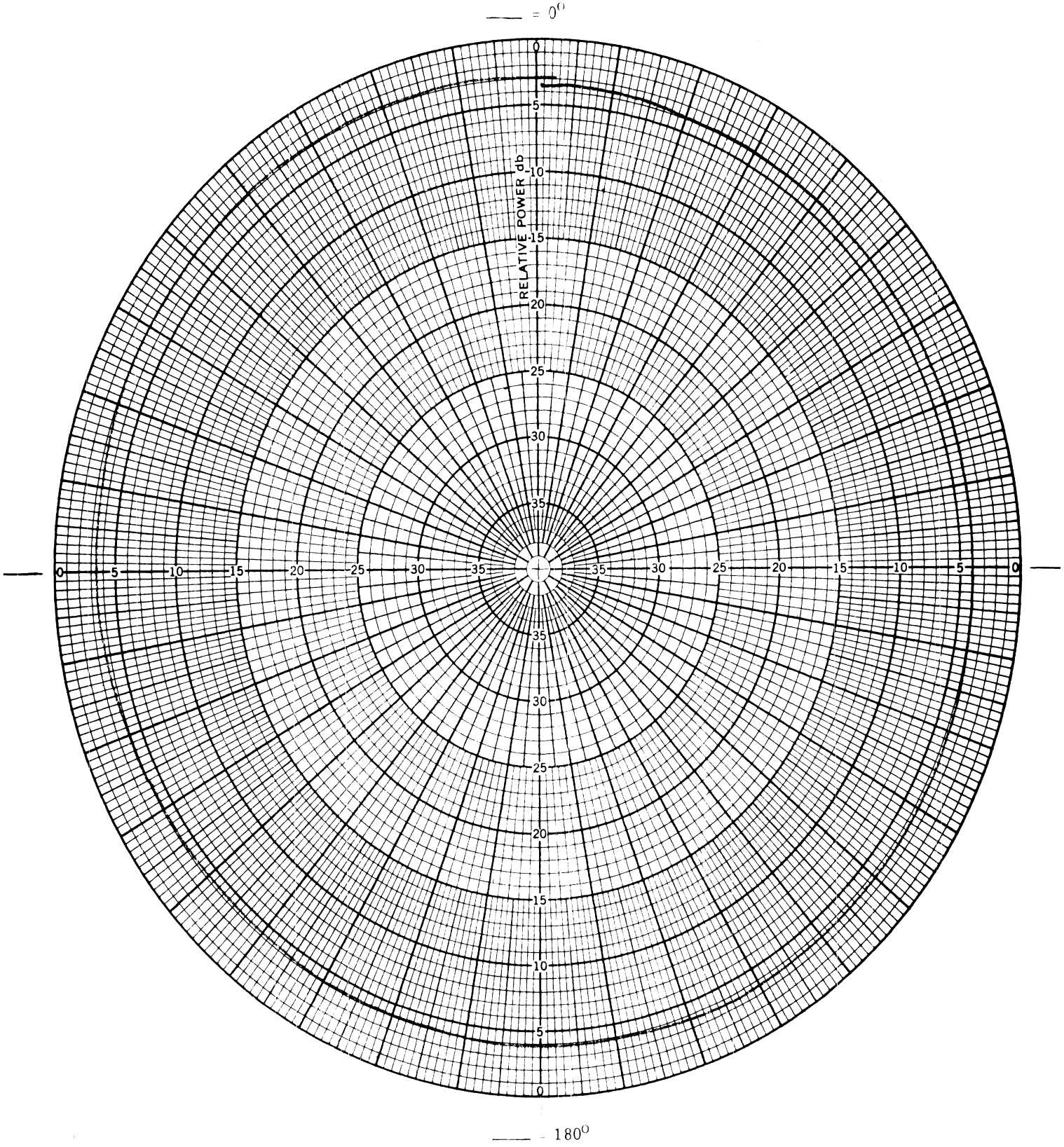

Fig. 13(b): Measured horizontal plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 62.5 MHz.

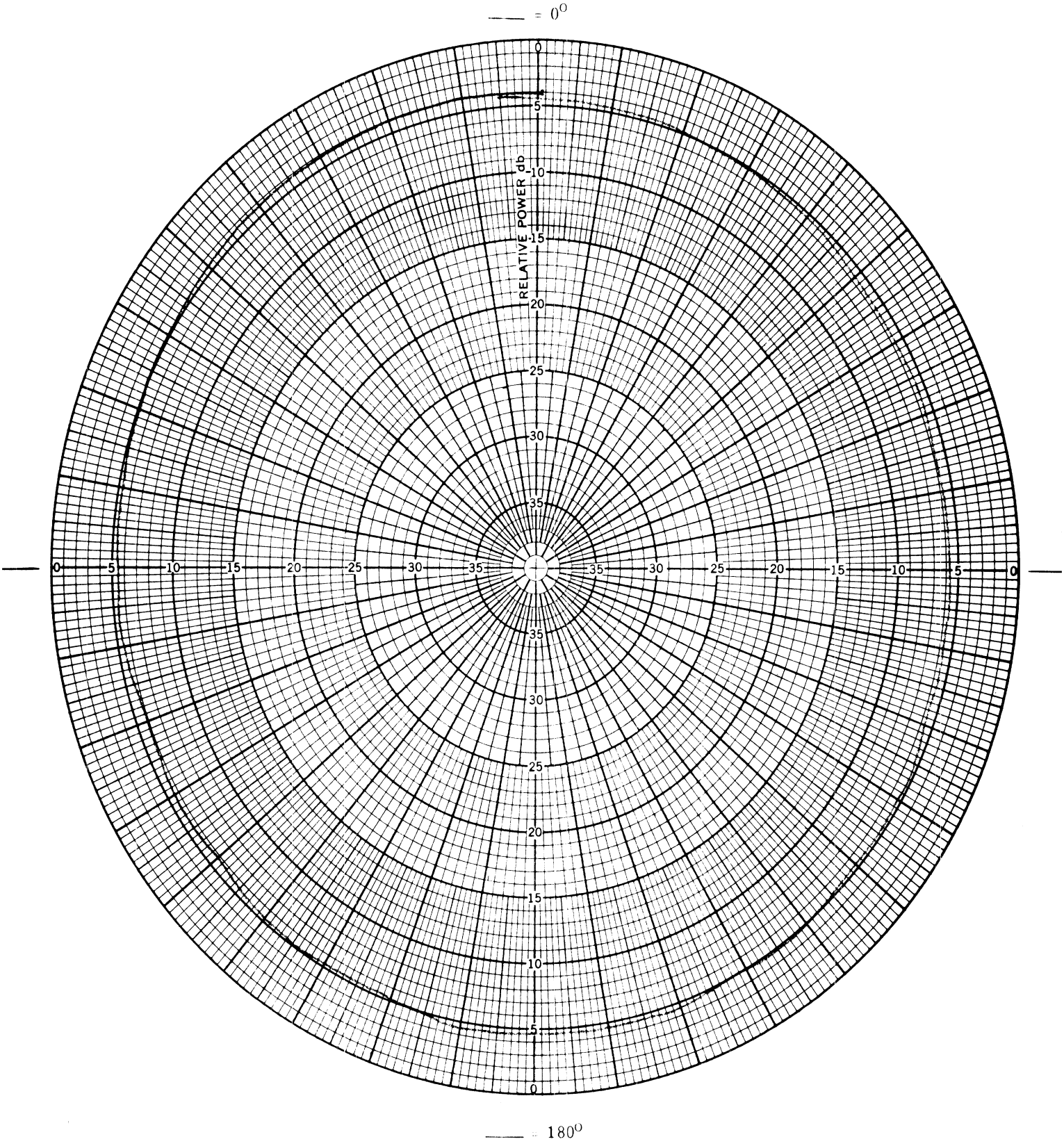

Fig. 13(c): Measured horizontal plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 70.8 MHz.

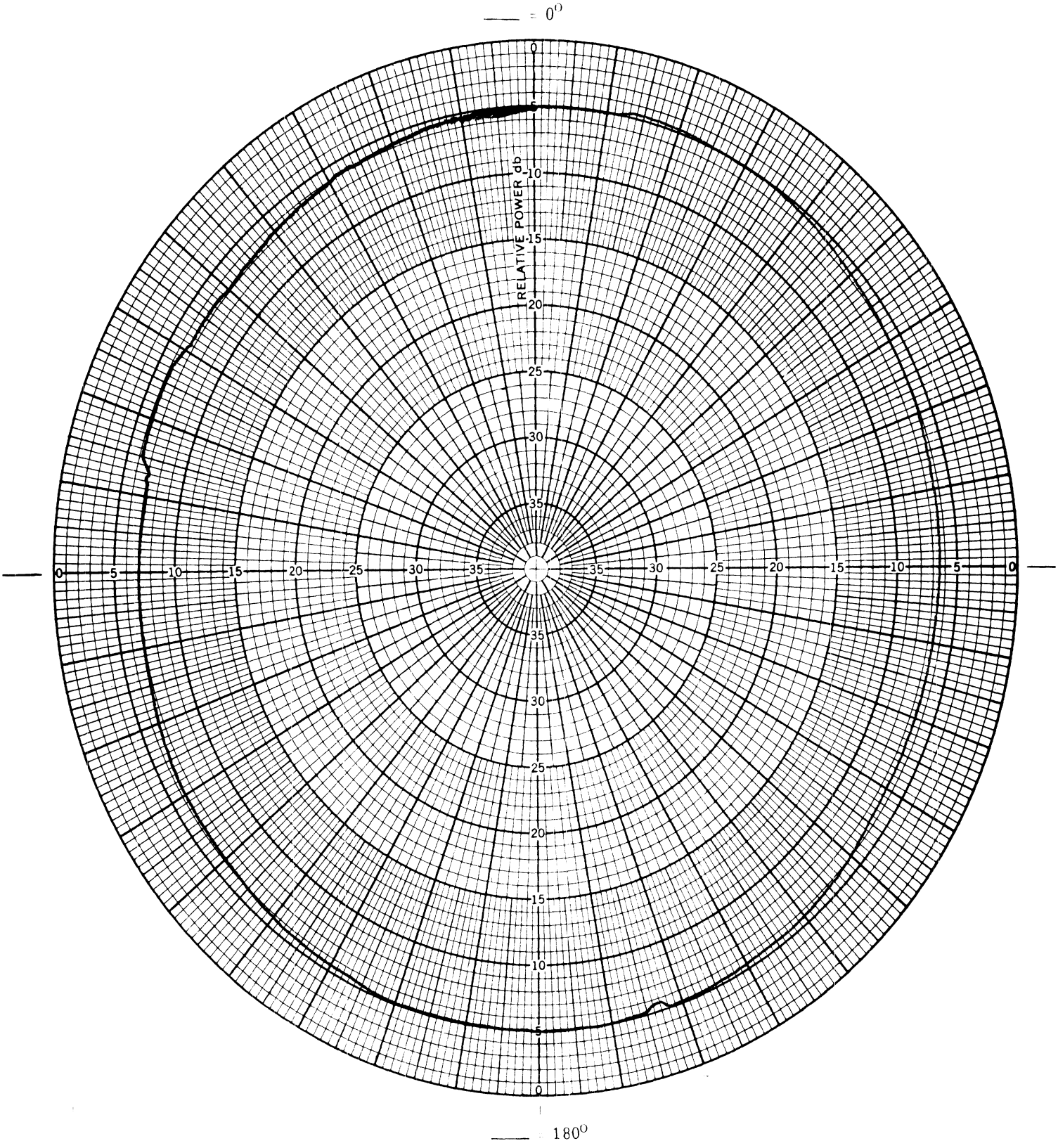

Fig. 13(d): Measured horizontal plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 87.6 MHz.

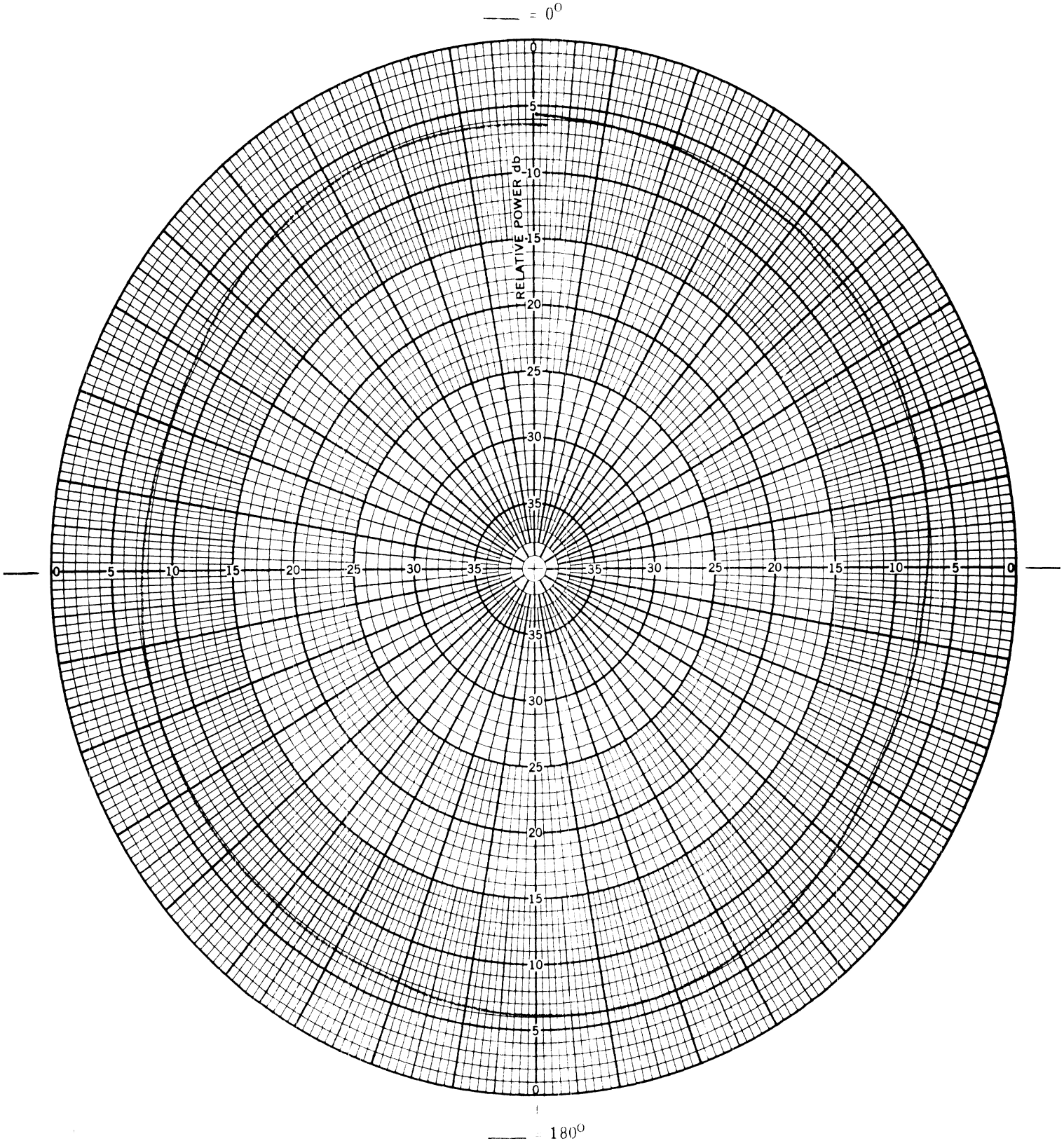

Fig. 13(e): Measured horizontal plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 109.7 MHz.

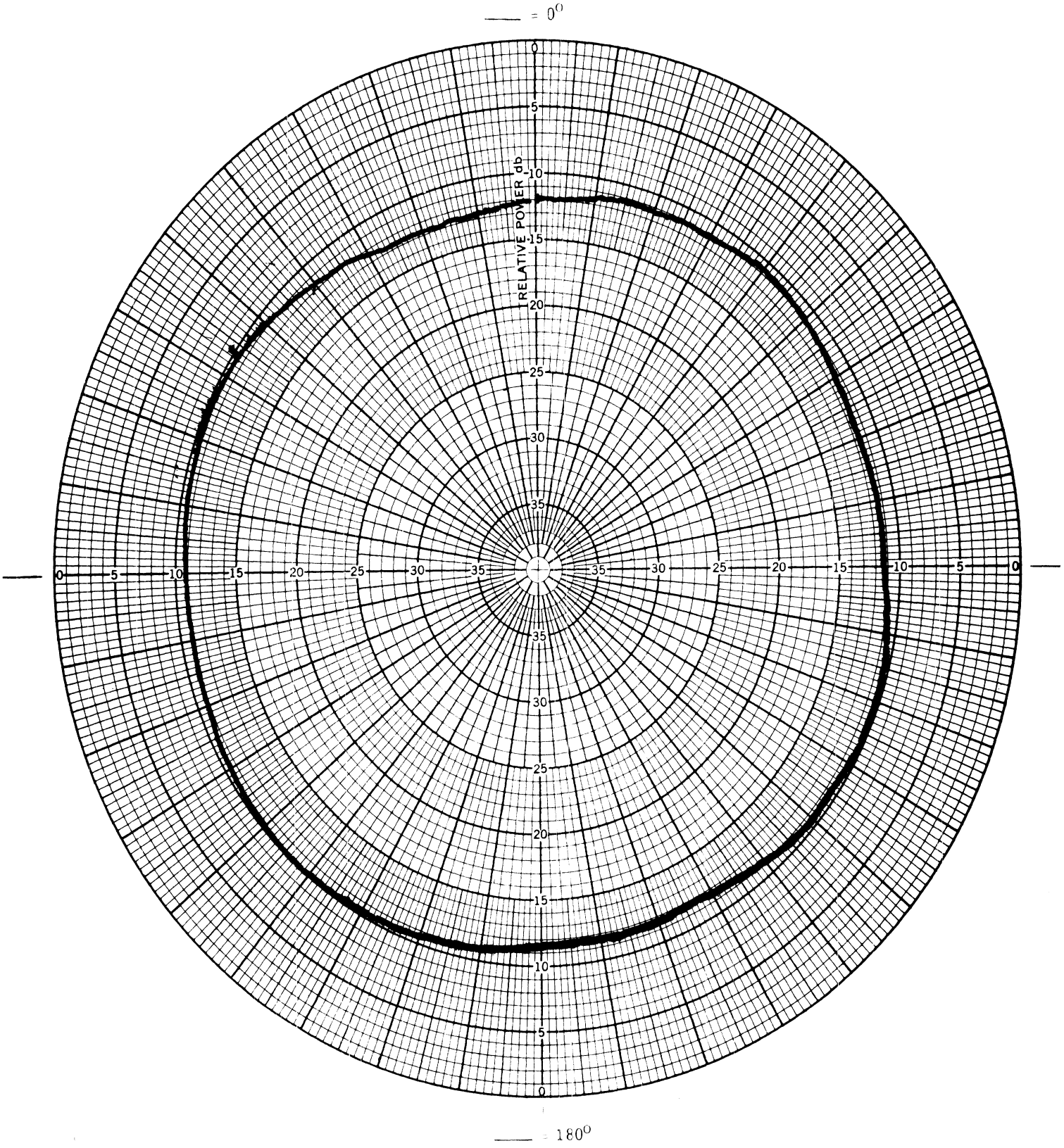

Fig. 13(f): Measured horizontal plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 150.0 MHz.

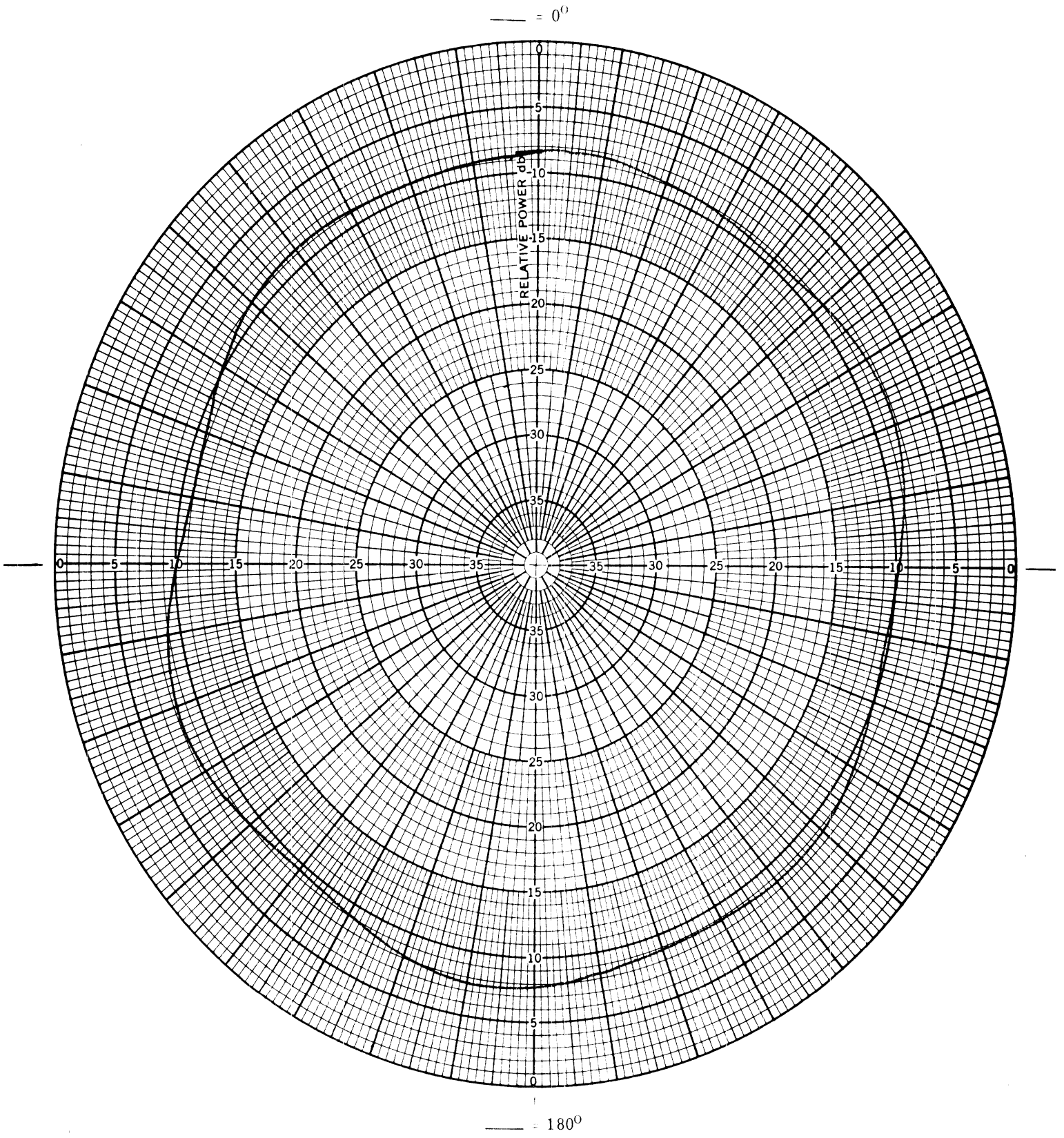

Fig. 13(g): Measured horizontal plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 200.0 MHz.

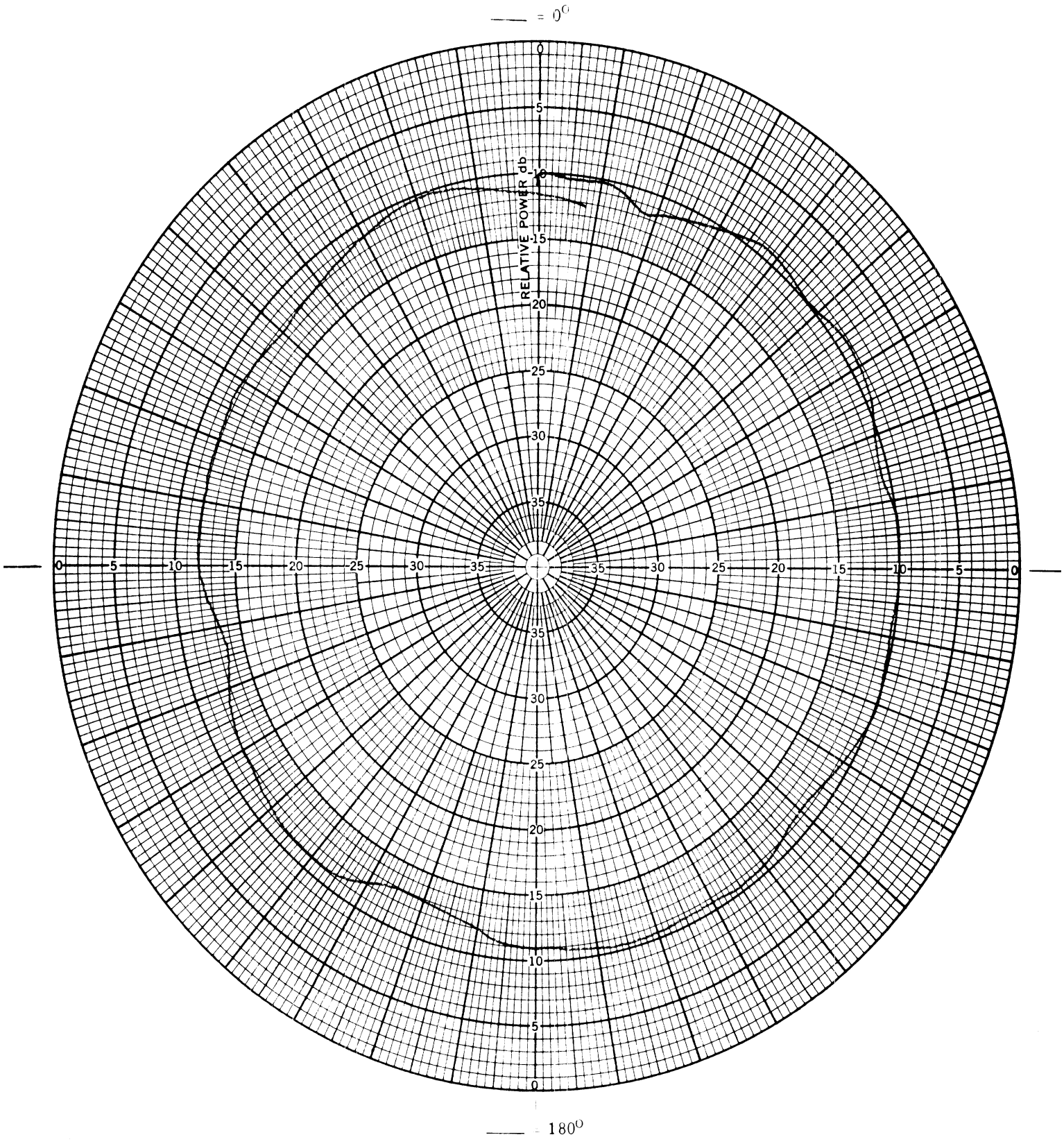

Fig. 13(h): Measured horizontal plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 250.0 MHz.

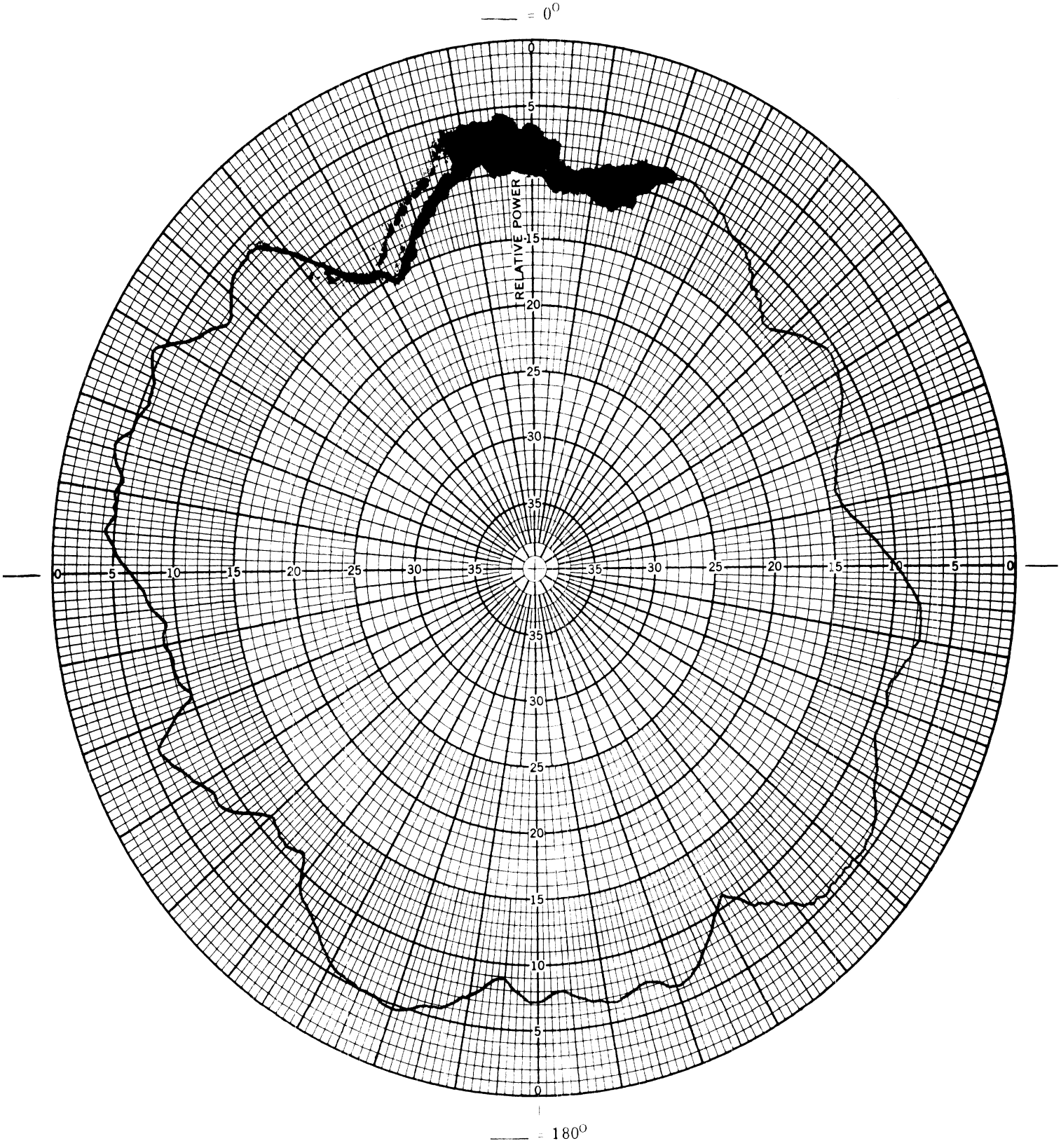

Fig. 13(i): Measured horizontal plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 302.0 MHz.

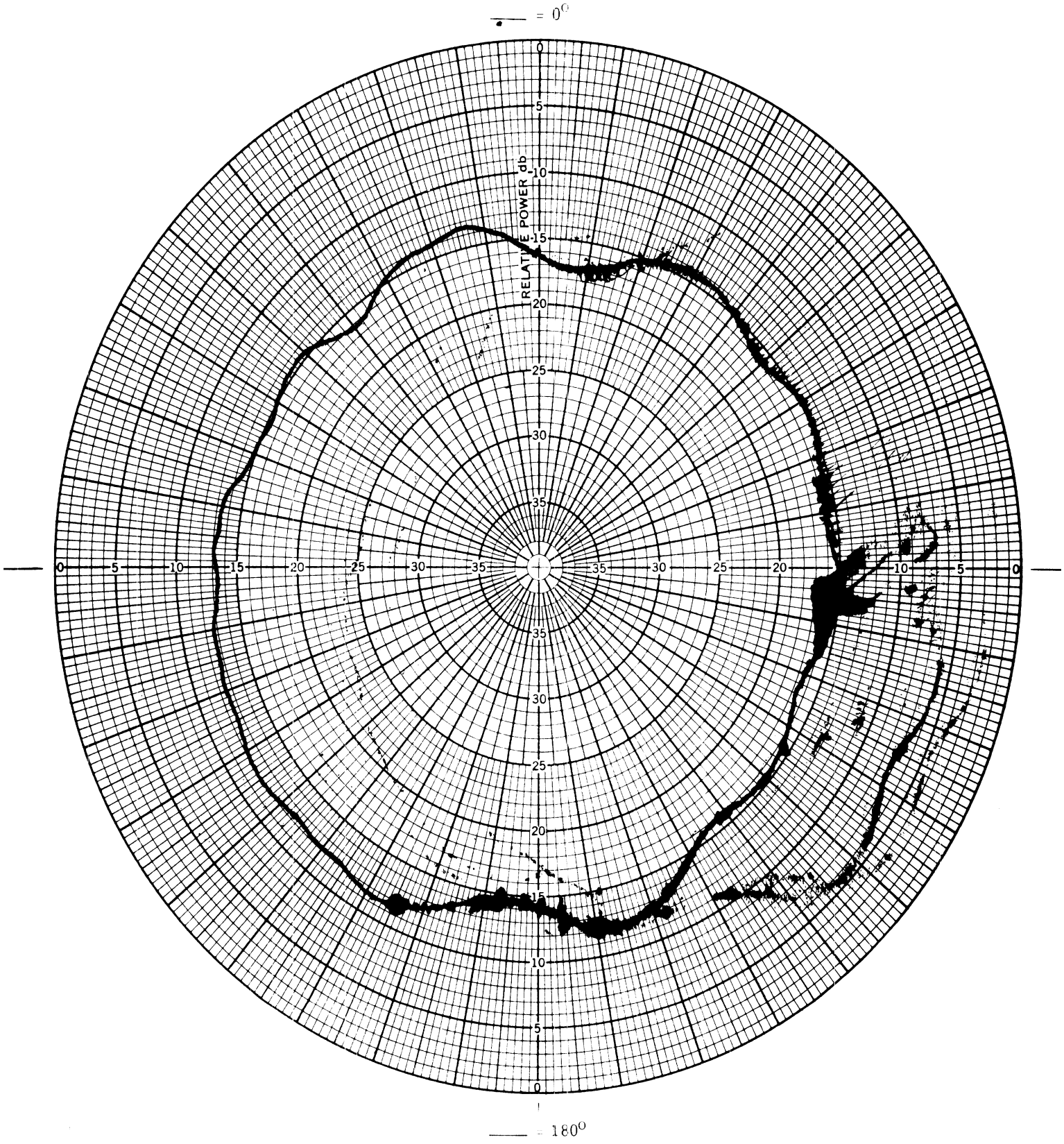

Fig. 13(j): Measured horizontal plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 350.0 MHz.

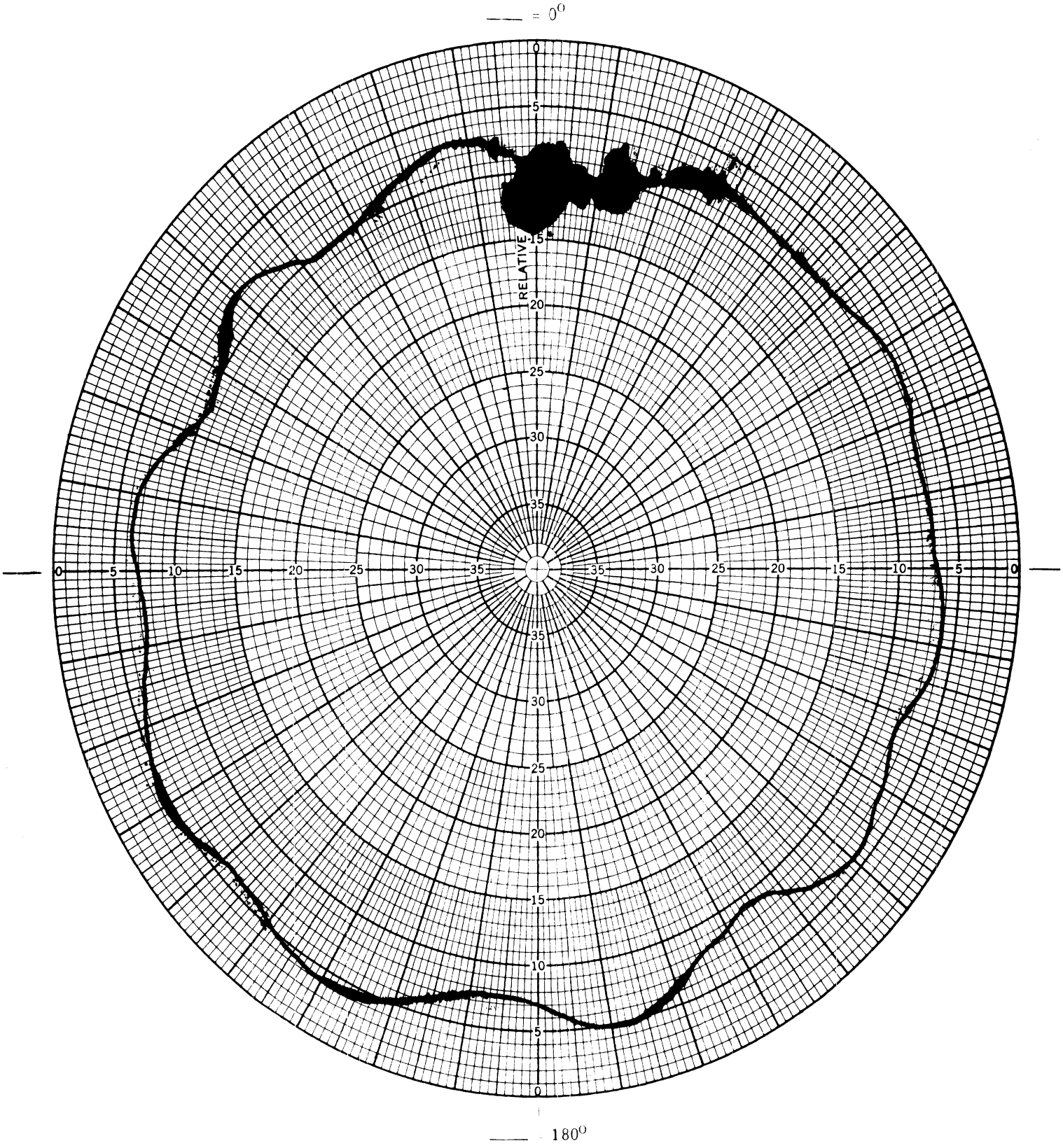

Fig. 13(k): Measured horizontal plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 400.0 MHz.

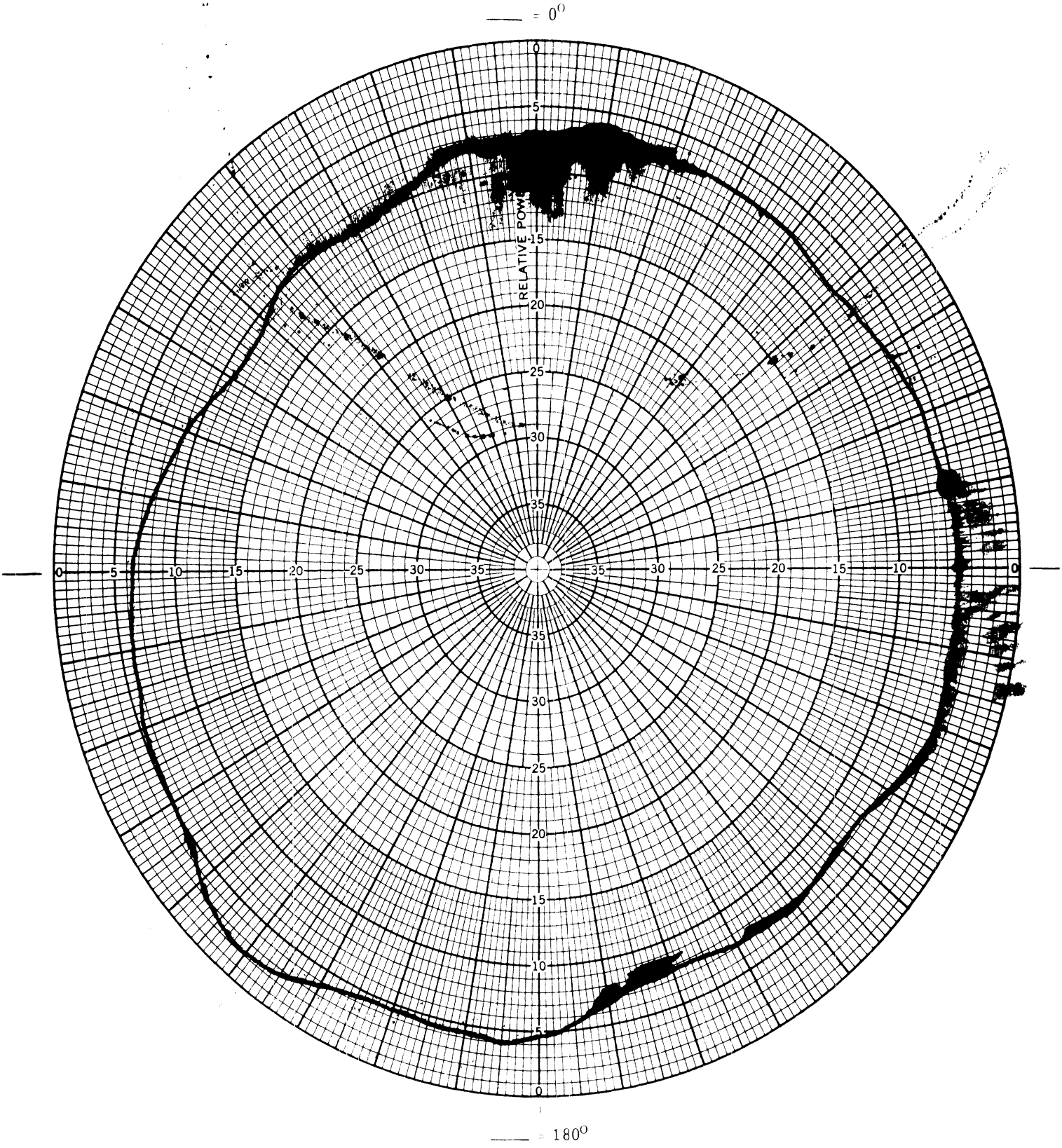

Fig. 13(1): Measured horizontal plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 500.0 MHz.

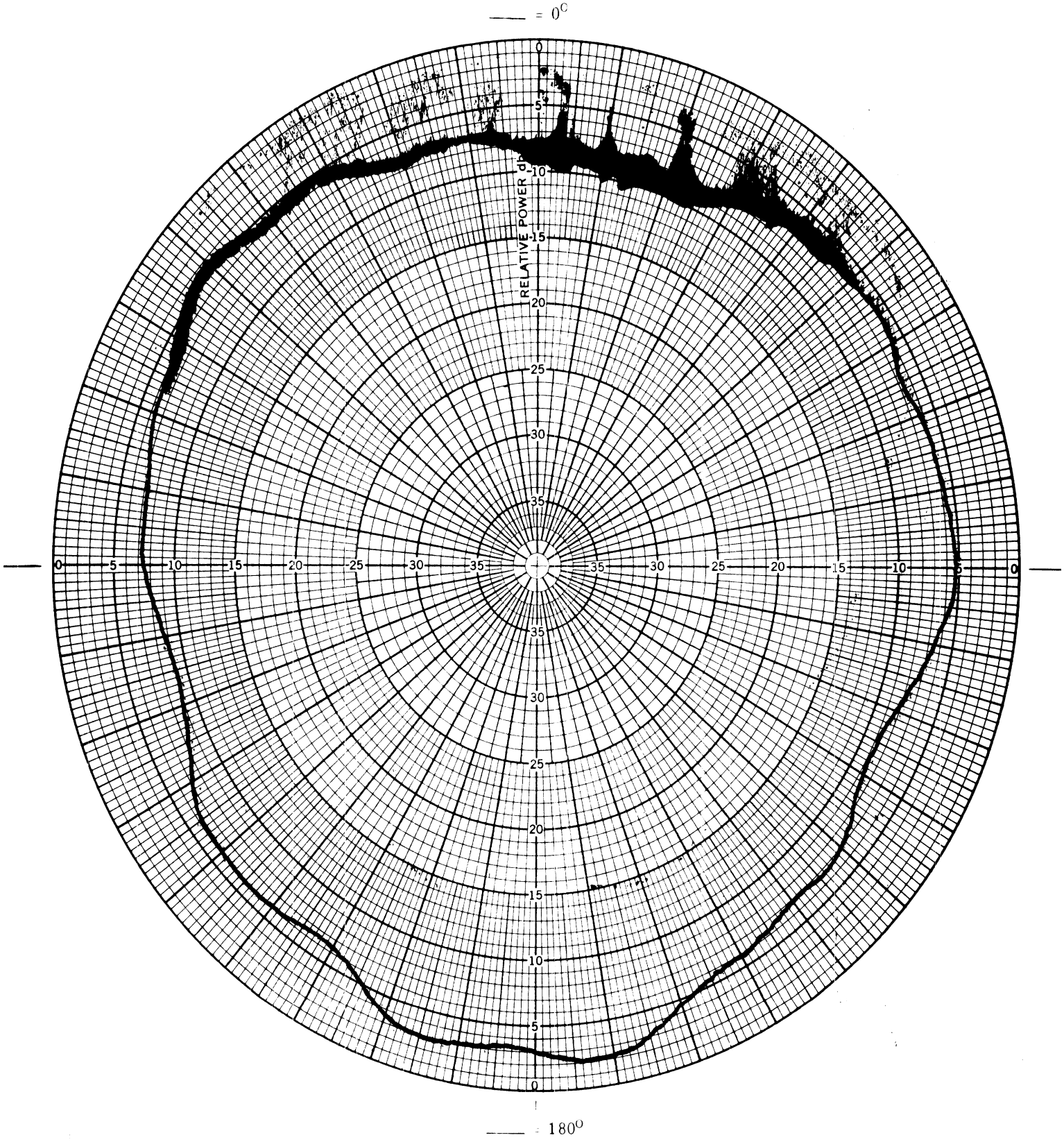

Fig. 13(m): Measured horizontal plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 600.0 MHz.

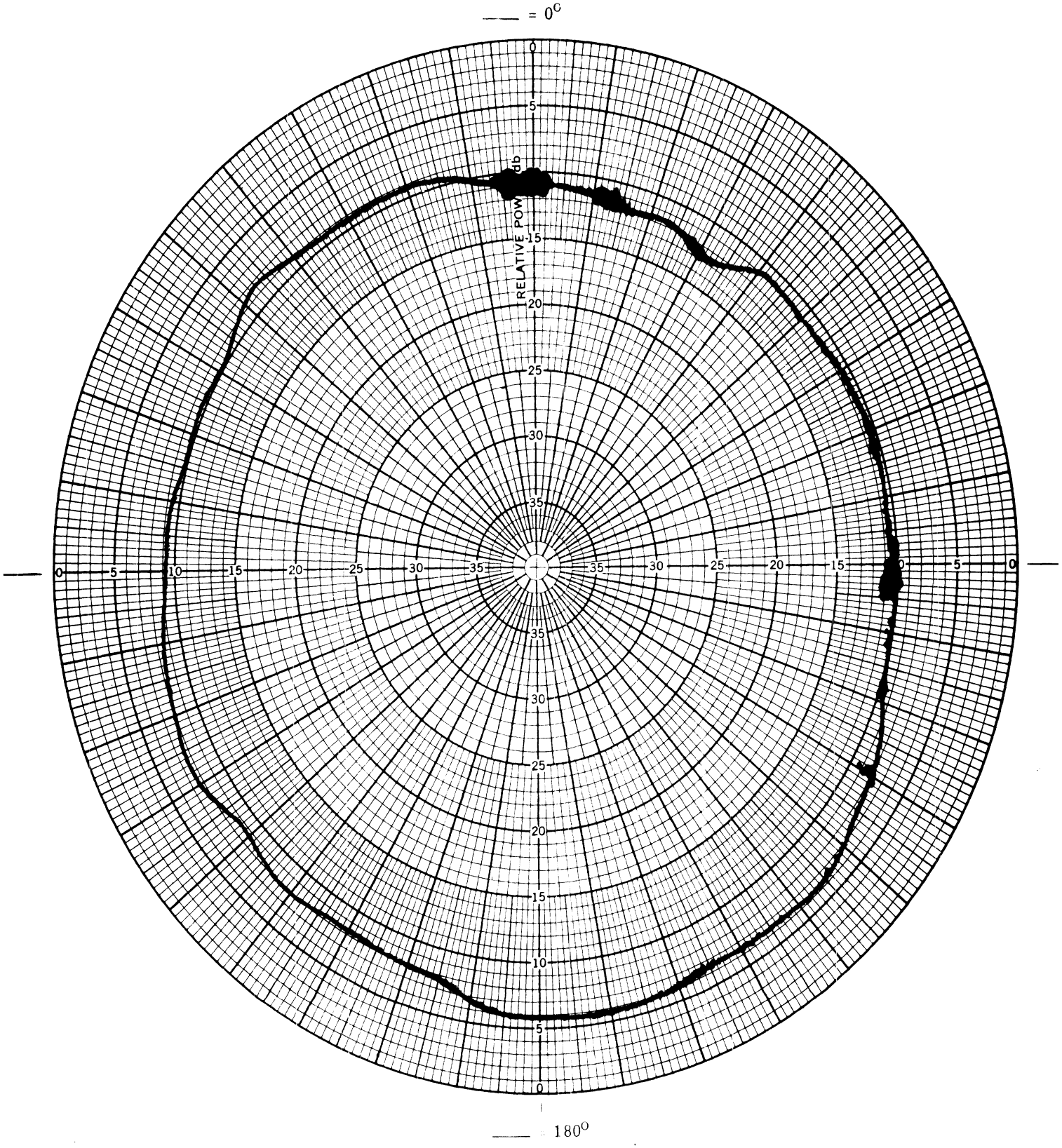

Fig. 13(n): Measured horizontal plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 700.0 MHz.

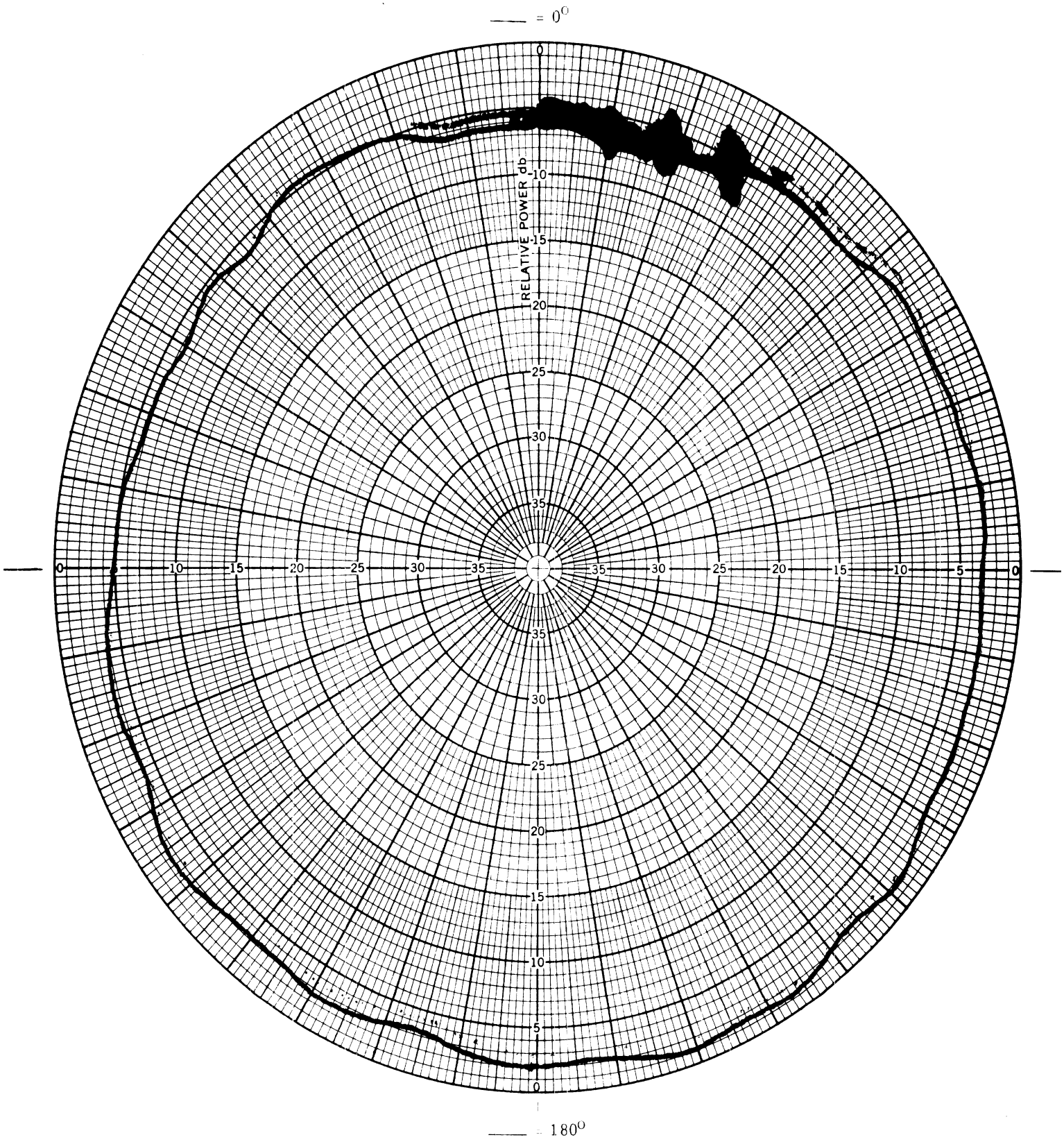

Fig. 13(o): Measured horizontal plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 800.0 MHz.

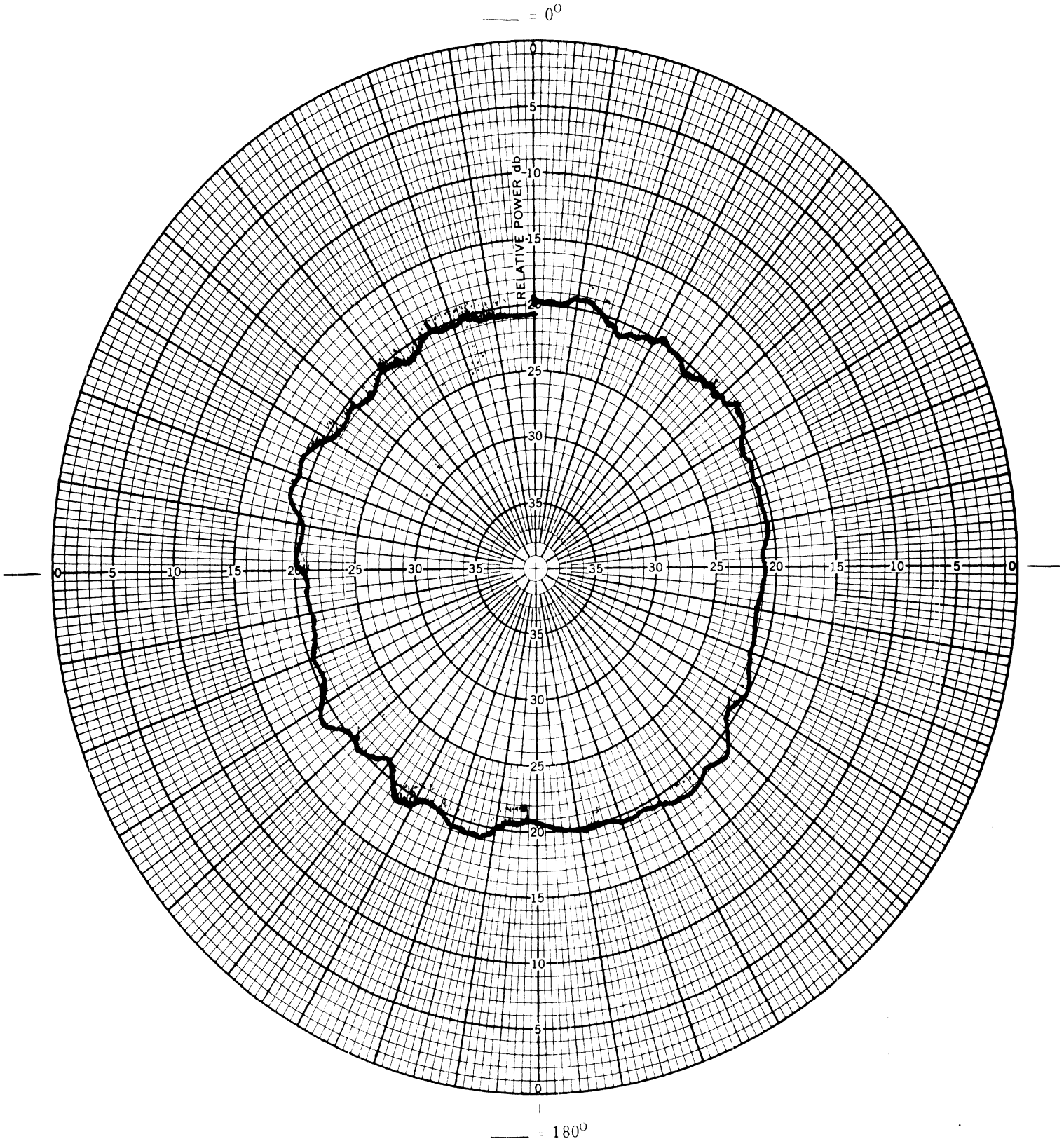

Fig. 13(p): Measured horizontal plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 969.0 MHz.

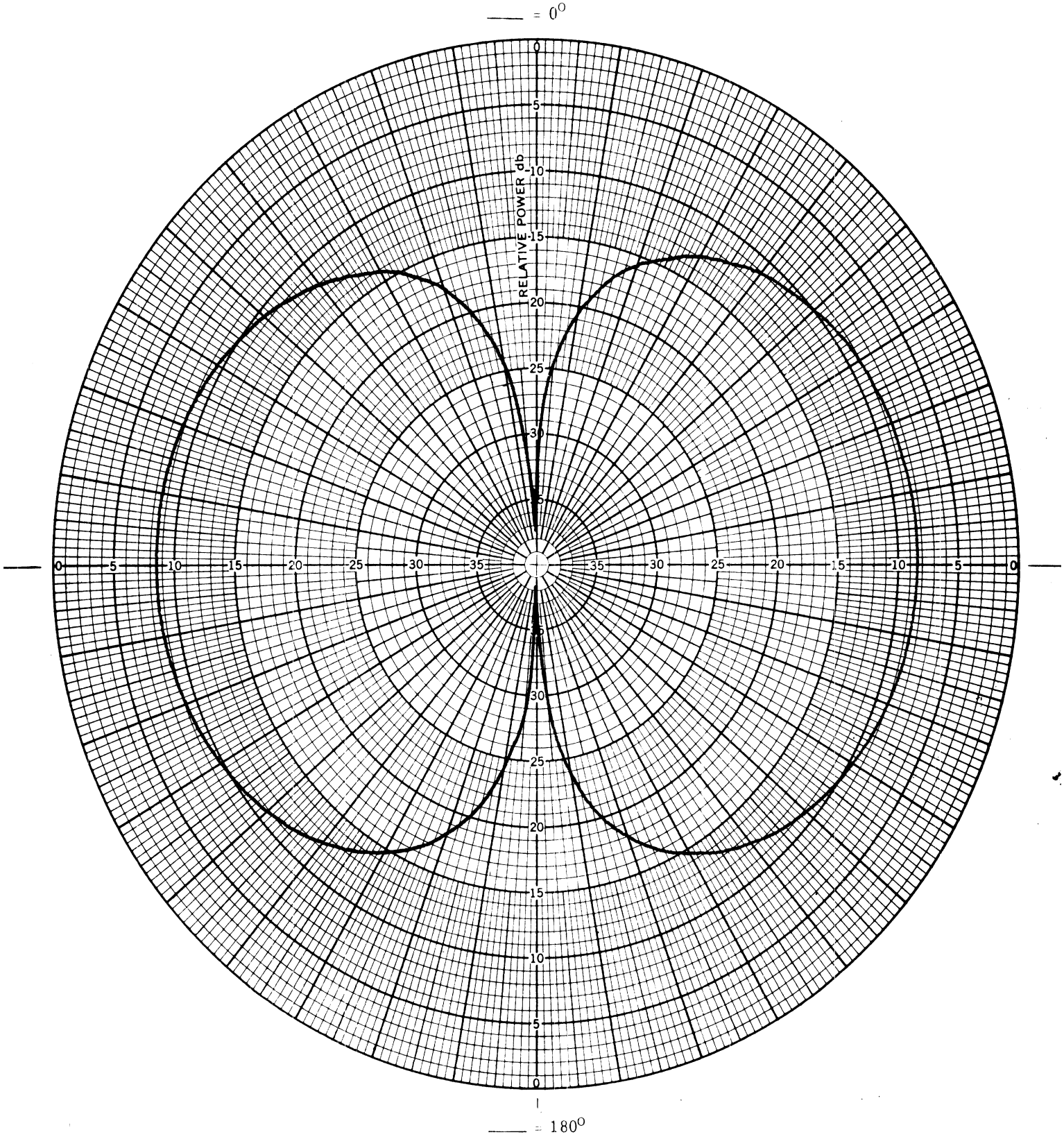

Fig. 14(a): Measured vertical plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 50.3 MHz.

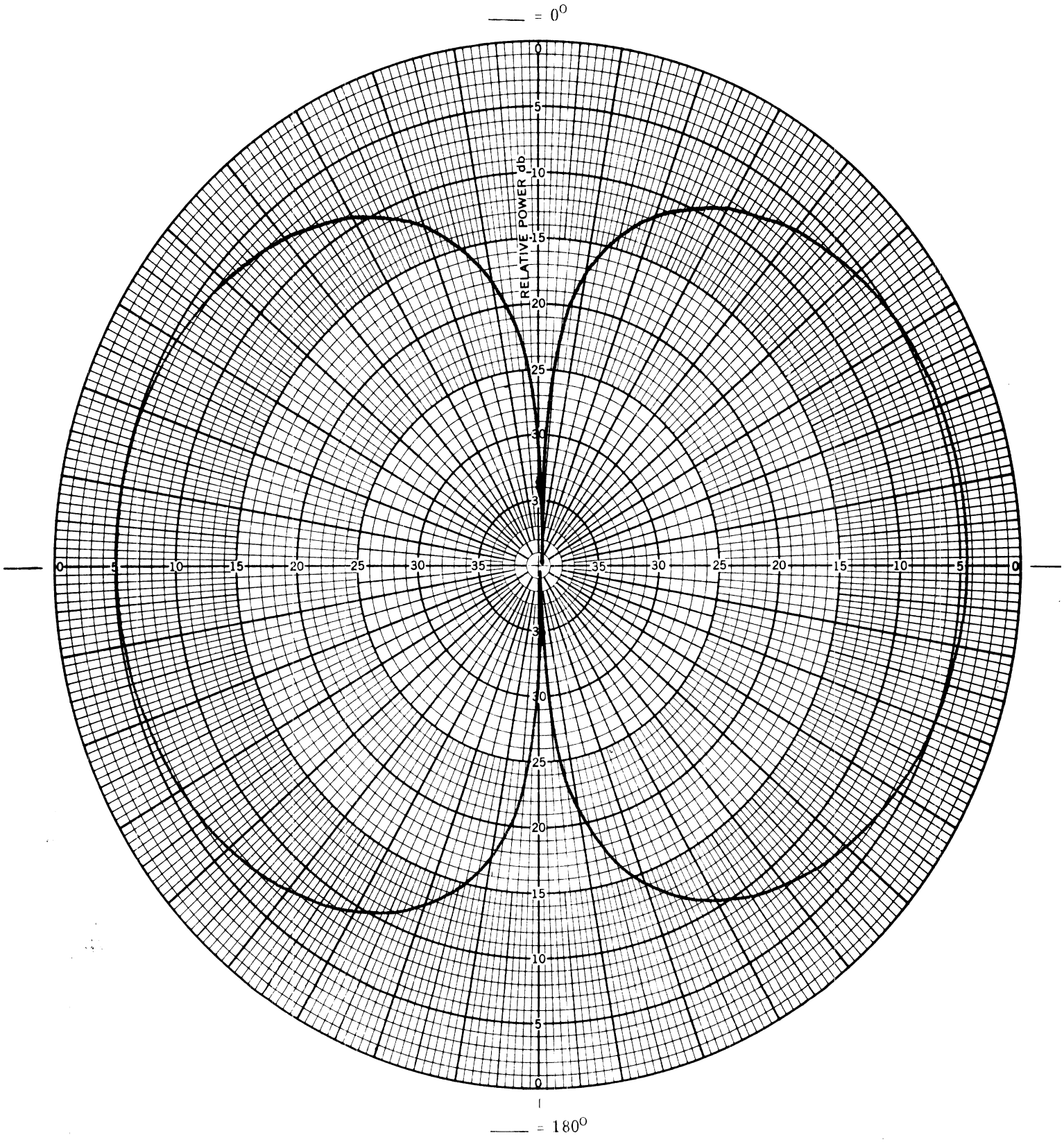

Fig. 14(b): Measured vertical plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 57.5 MHz.

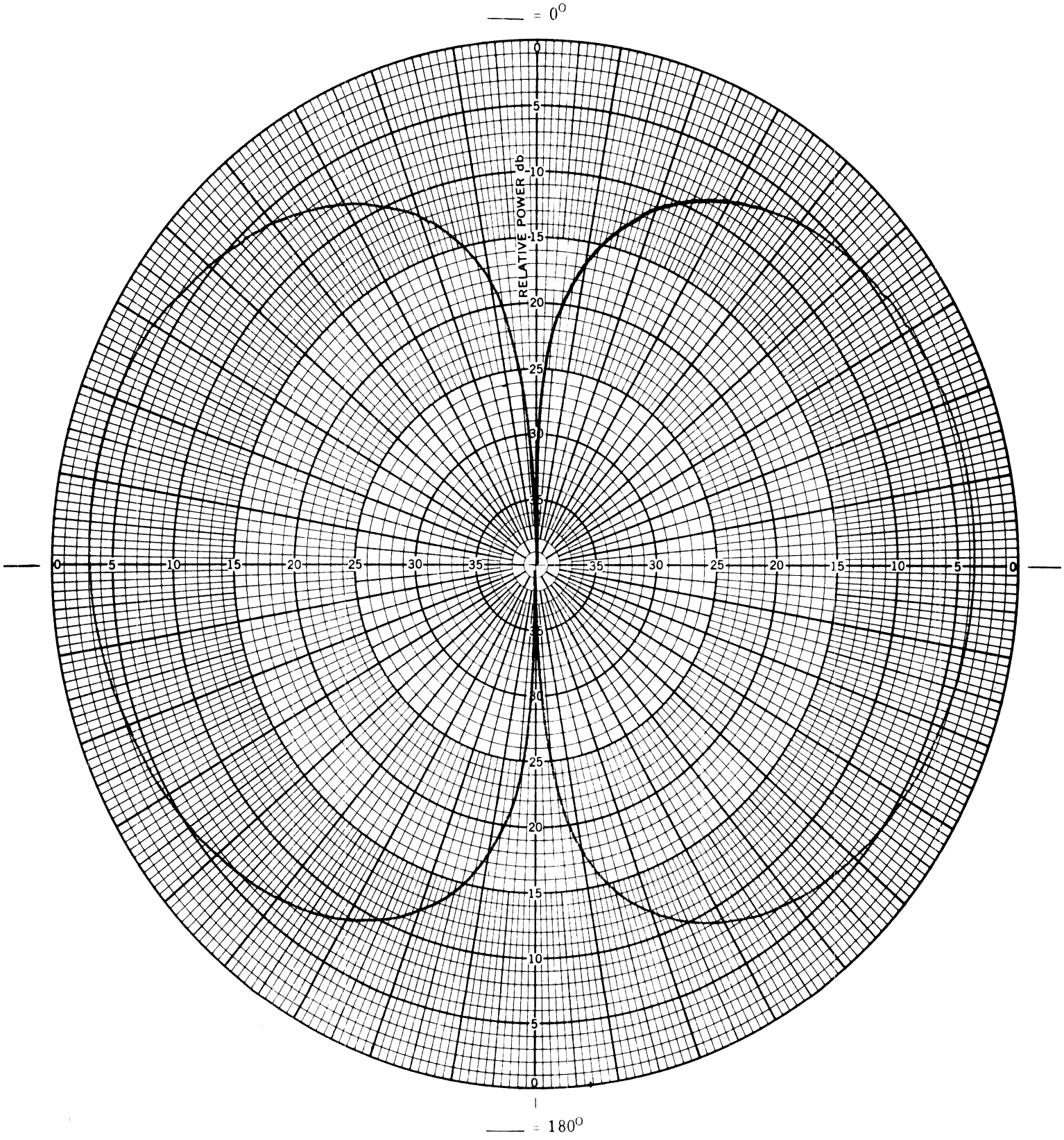

Fig. 14(c): Measured vertical plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 69.8 MHz.

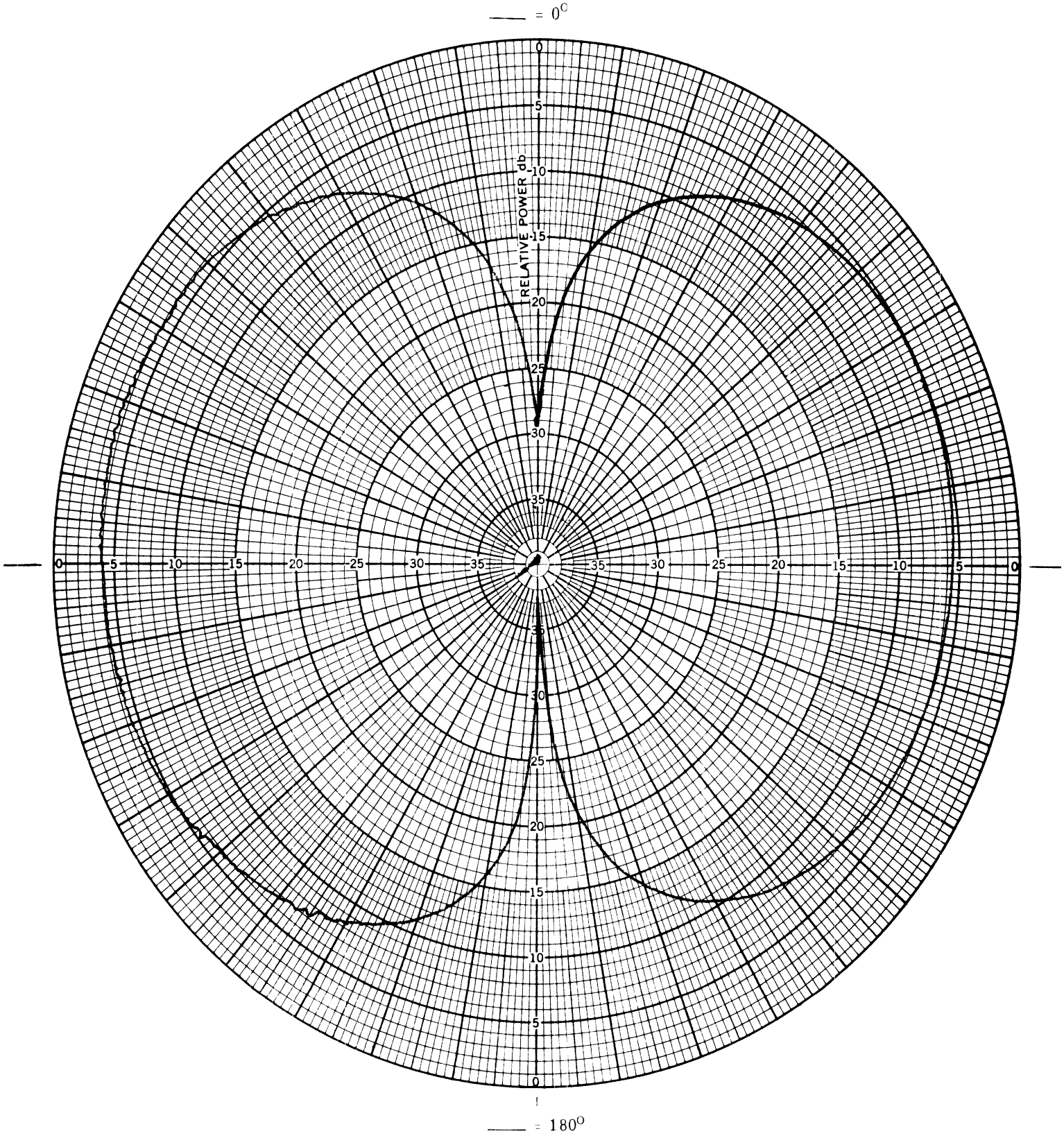

Fig. 14(d): Measured vertical plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 87.3 MHz.

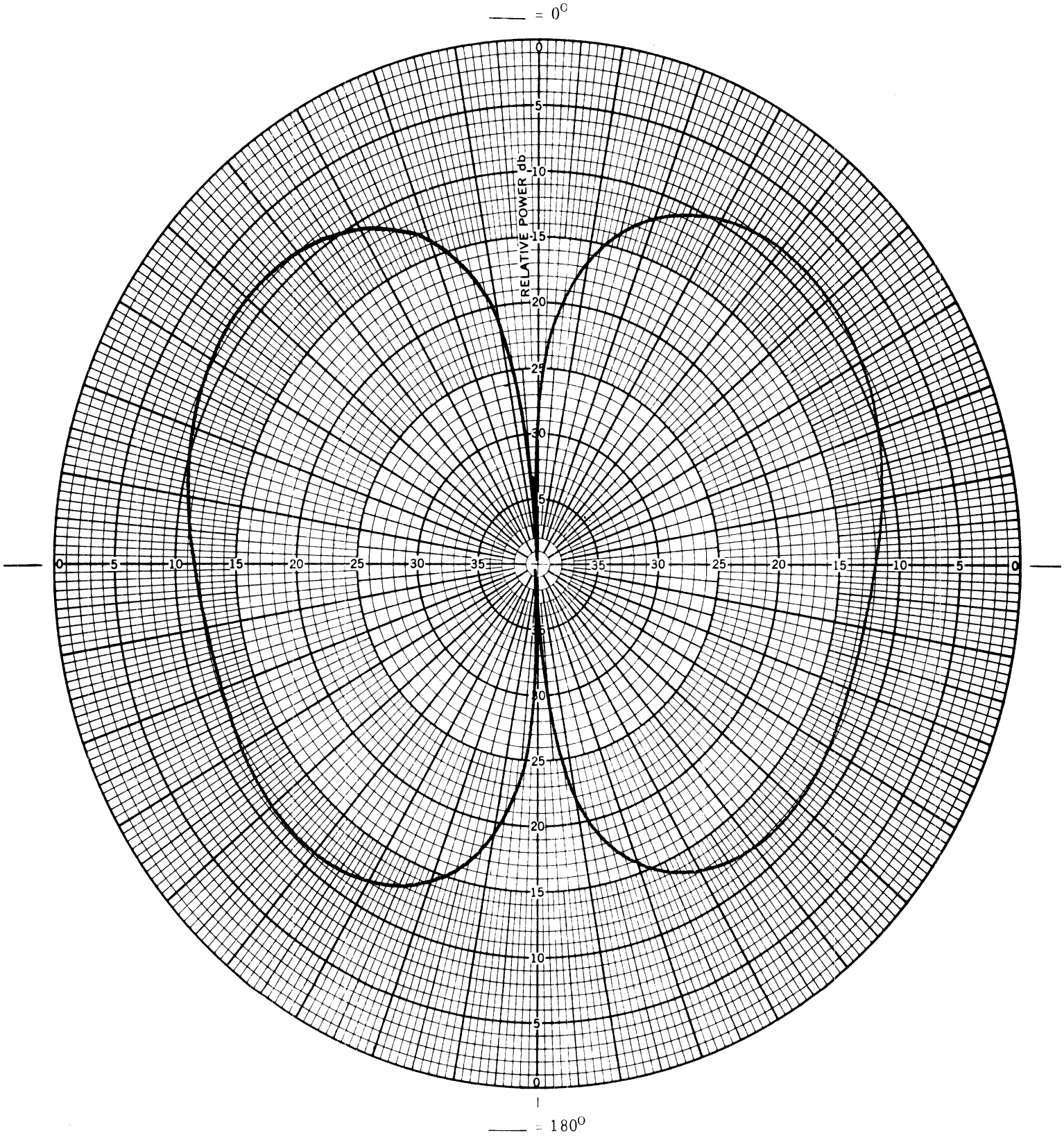

Fig. 14(e): Measured vertical plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 110.7 MHz.

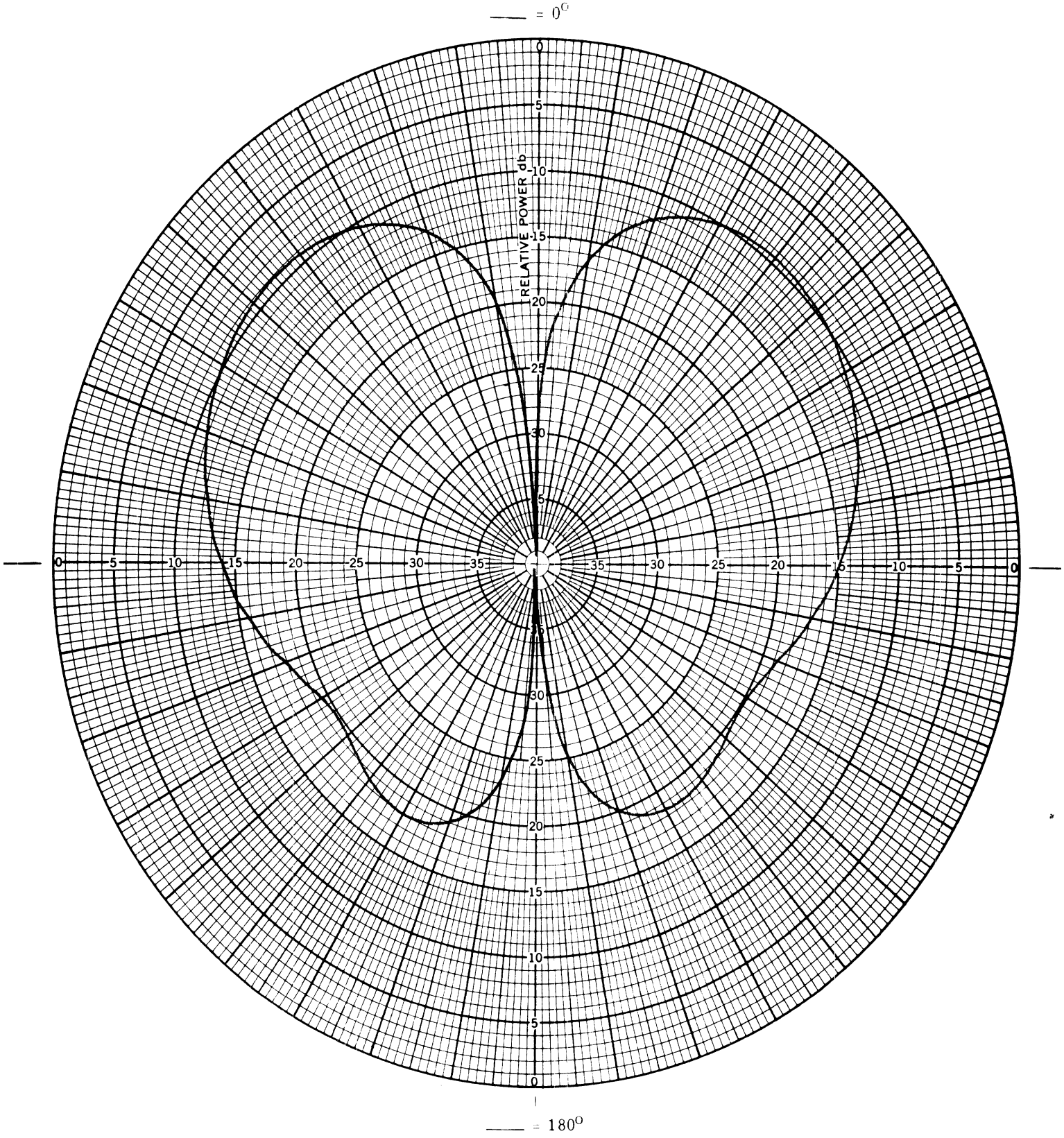

Fig. 14(f): Measured vertical plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 151.5 MHz.

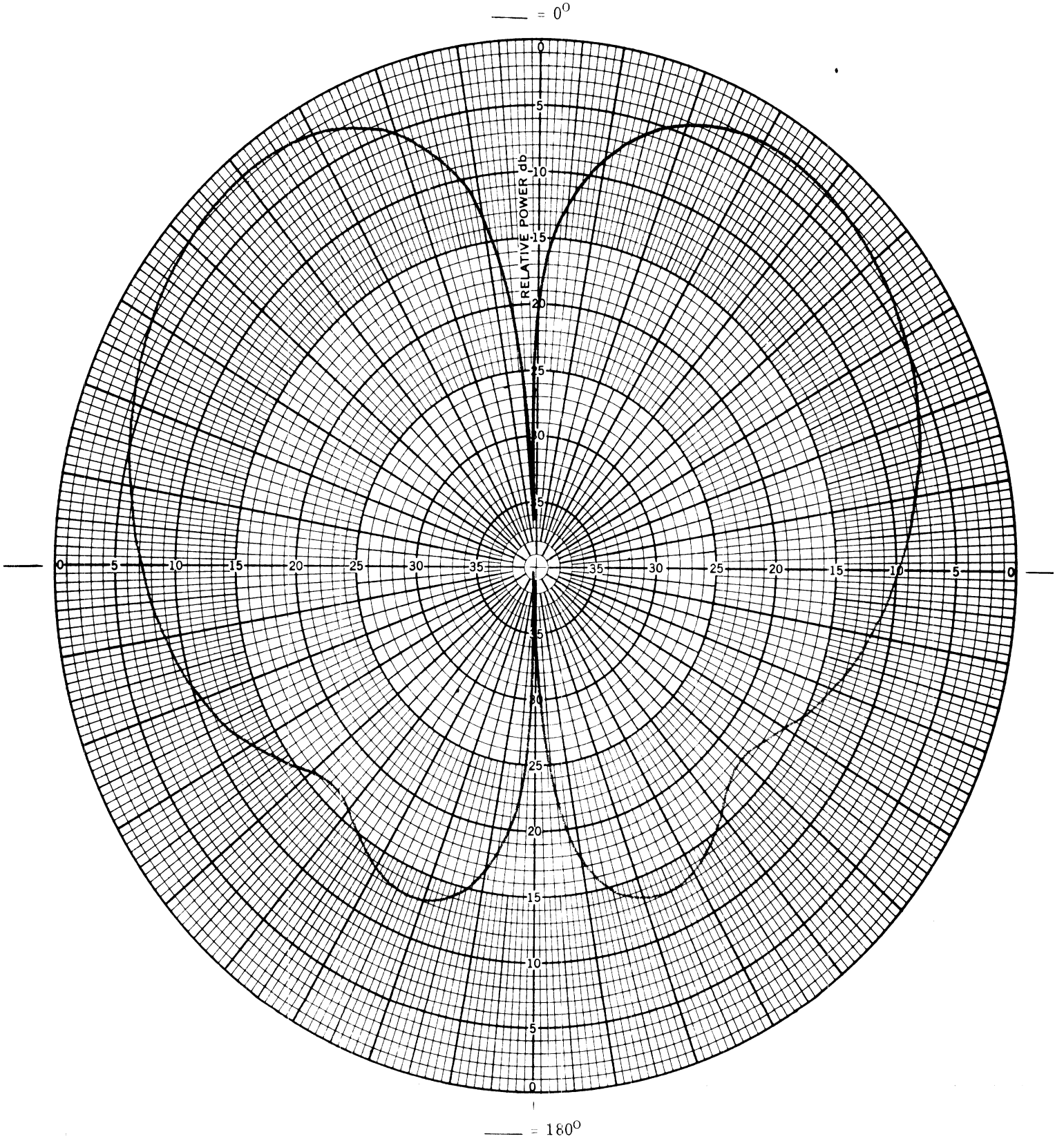

Fig. 14(g): Measured vertical plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 207.0 MHz.

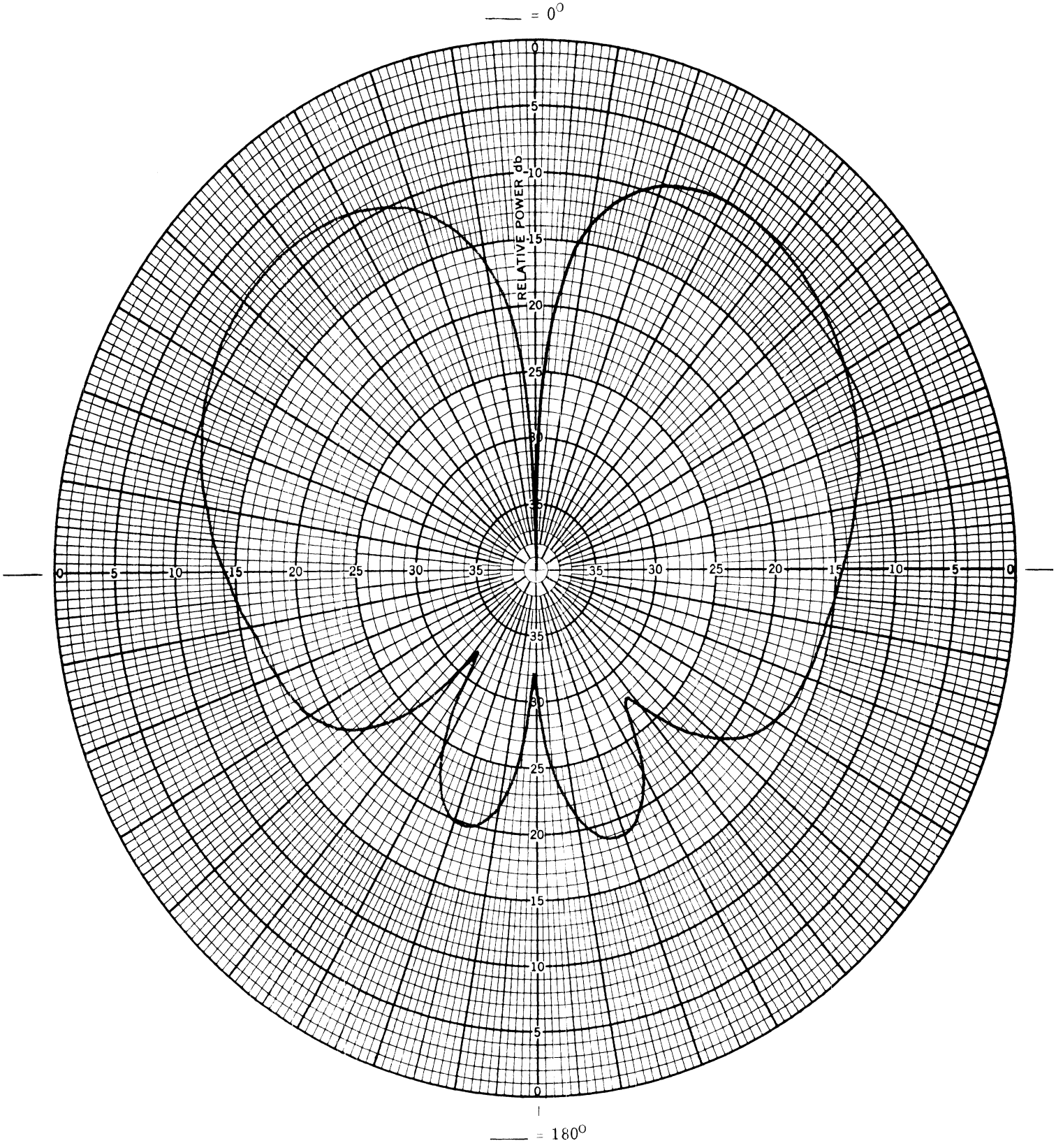

Fig. 14(h): Measured vertical plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 250.0 MHz.

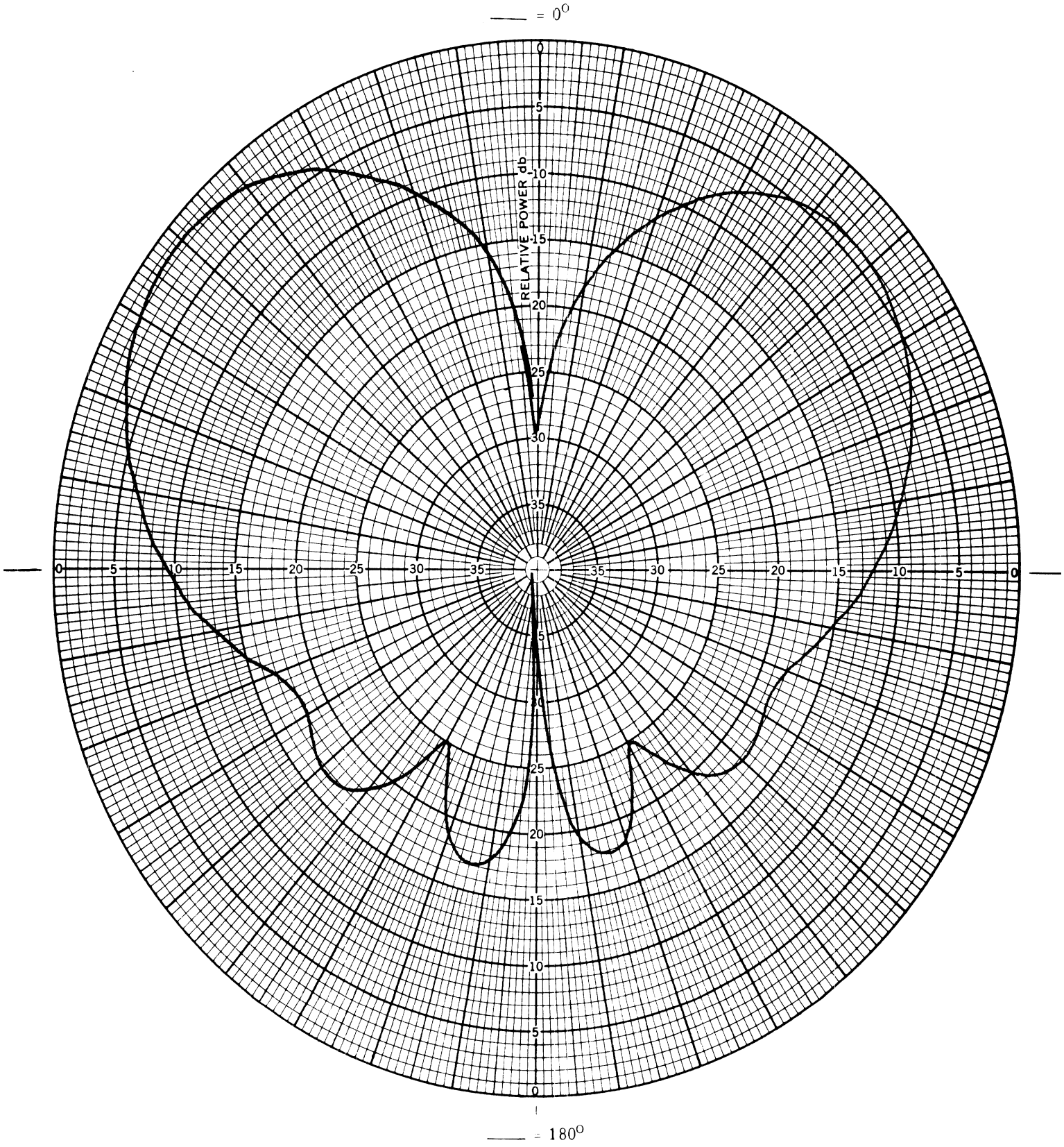

Fig. 14(i): Measured vertical plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 303.0 MHz.

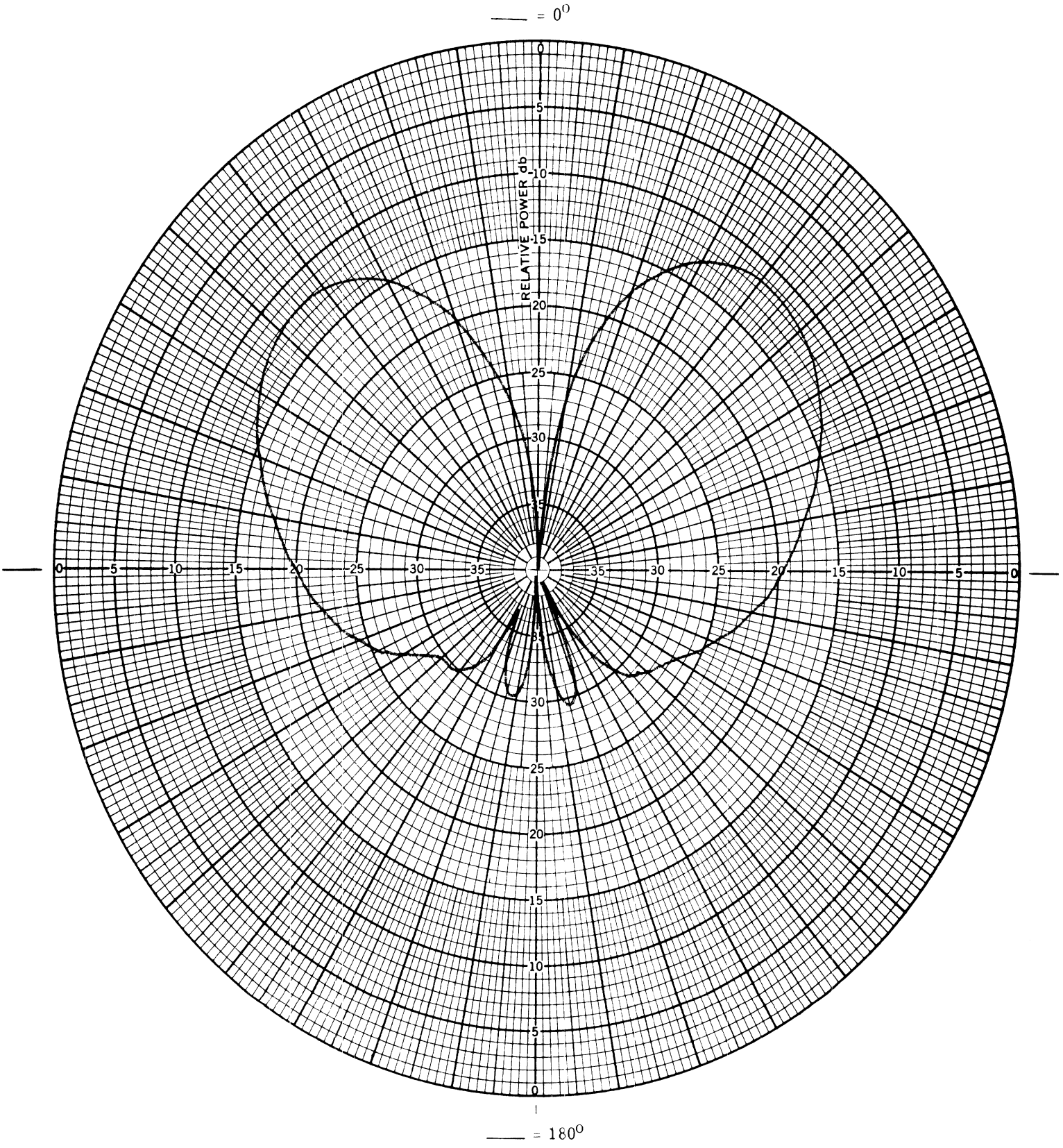

Fig. 14(j): Measured vertical plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 352.0 MHz.

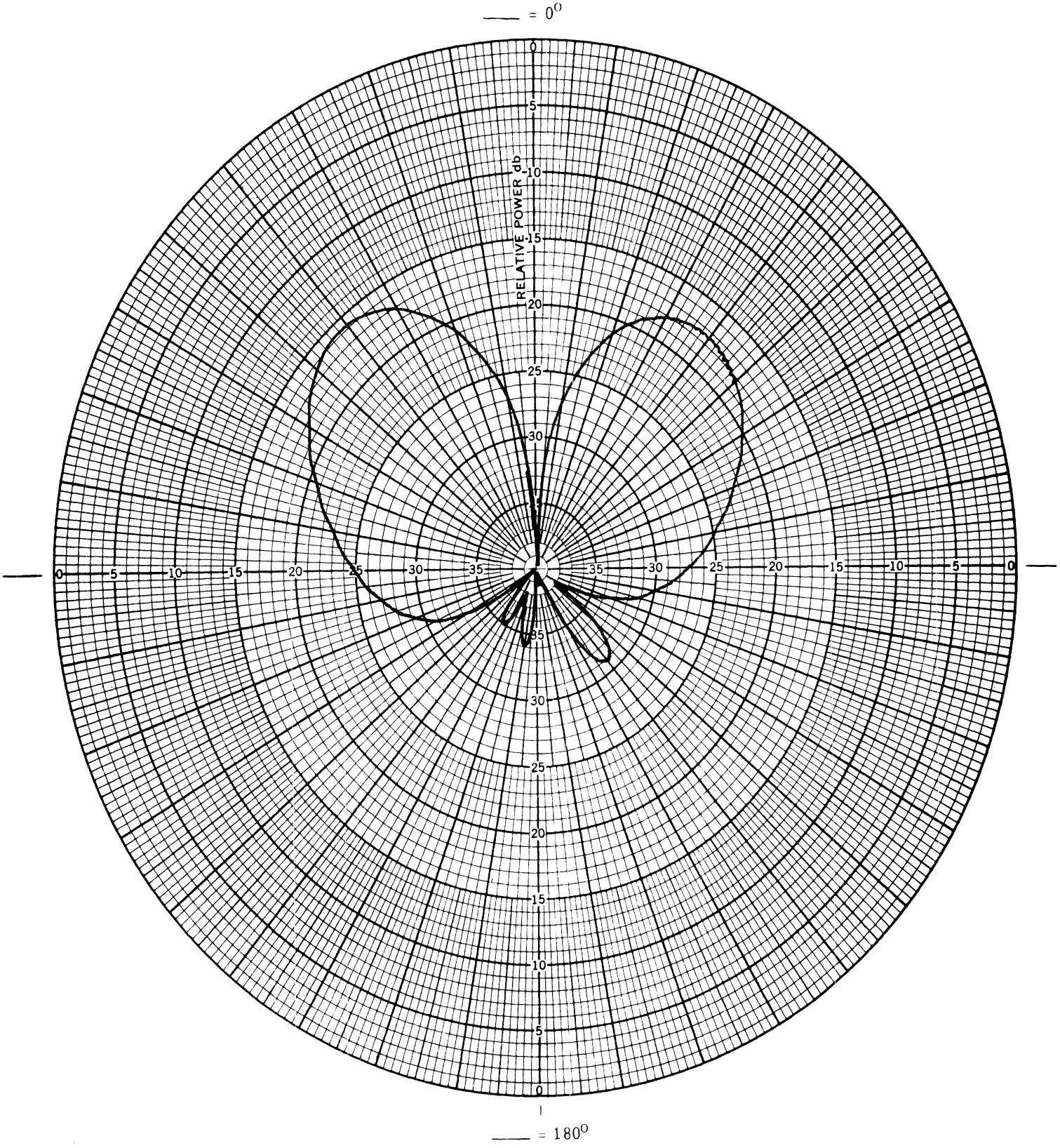

Fig. 14(k): Measured vertical plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 402.0 MHz.

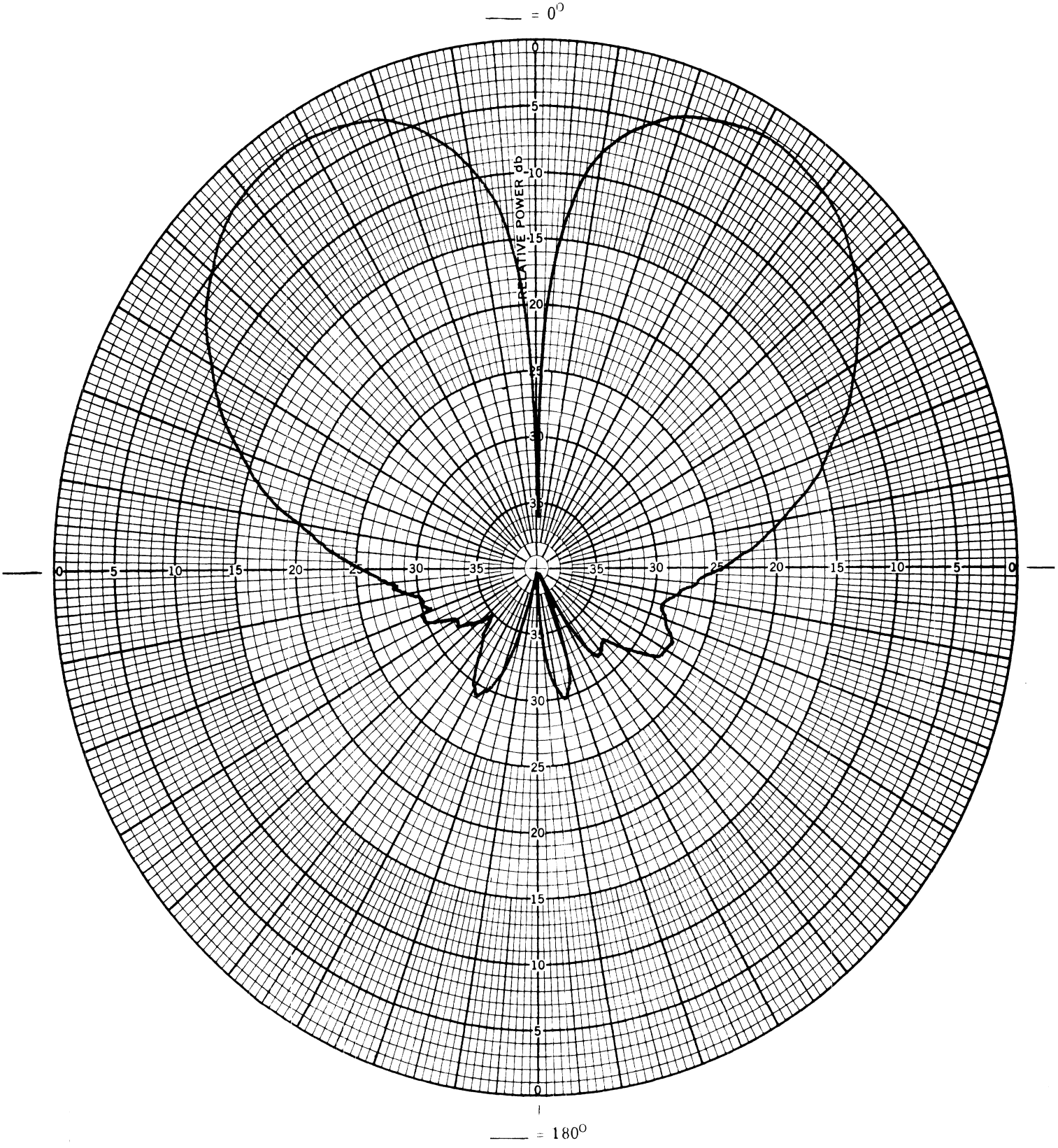

Fig. 14(1): Measured vertical plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 500.0 MHz.

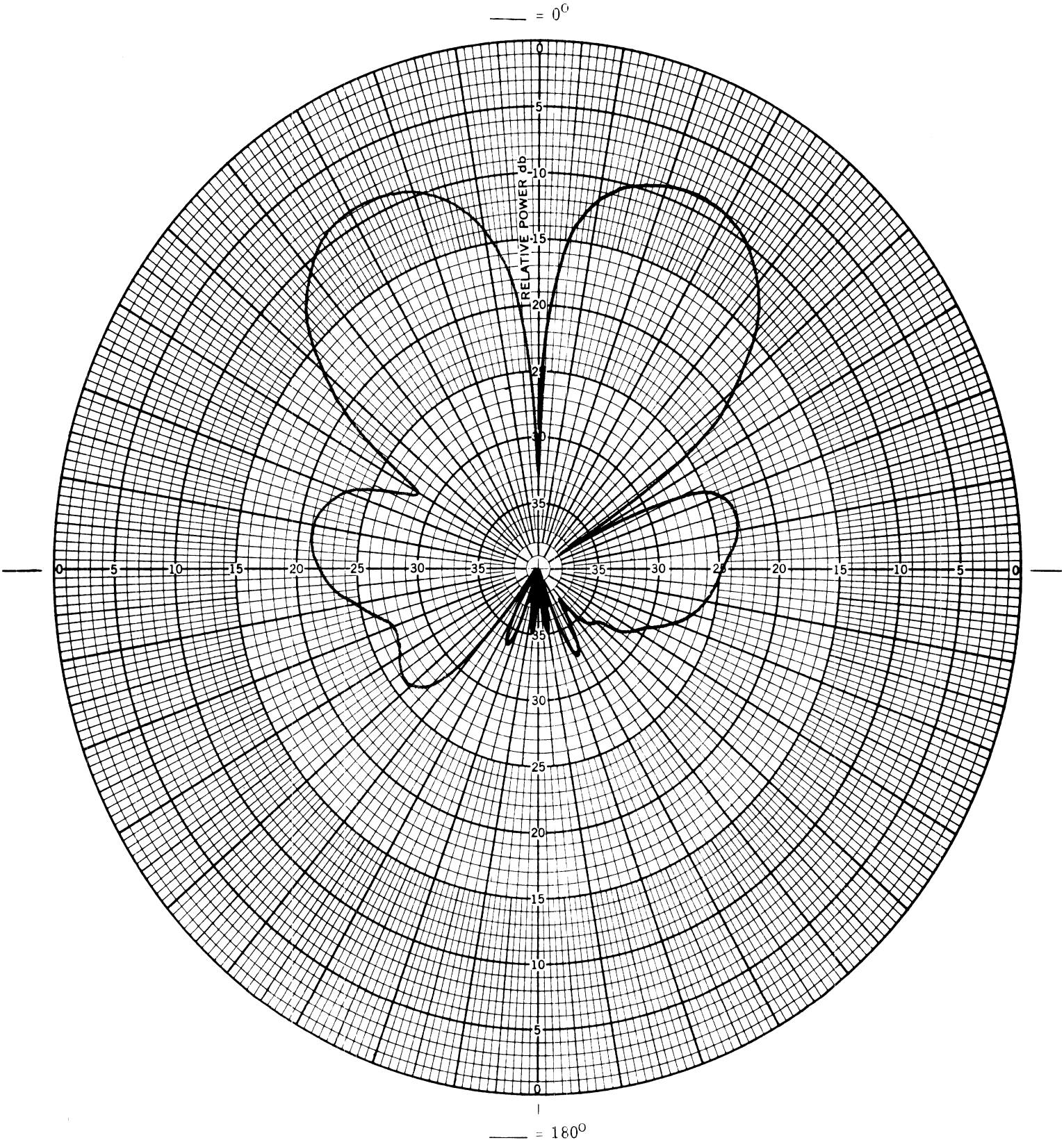

Fig. 14(m): Measured vertical plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 600.0 MHz.

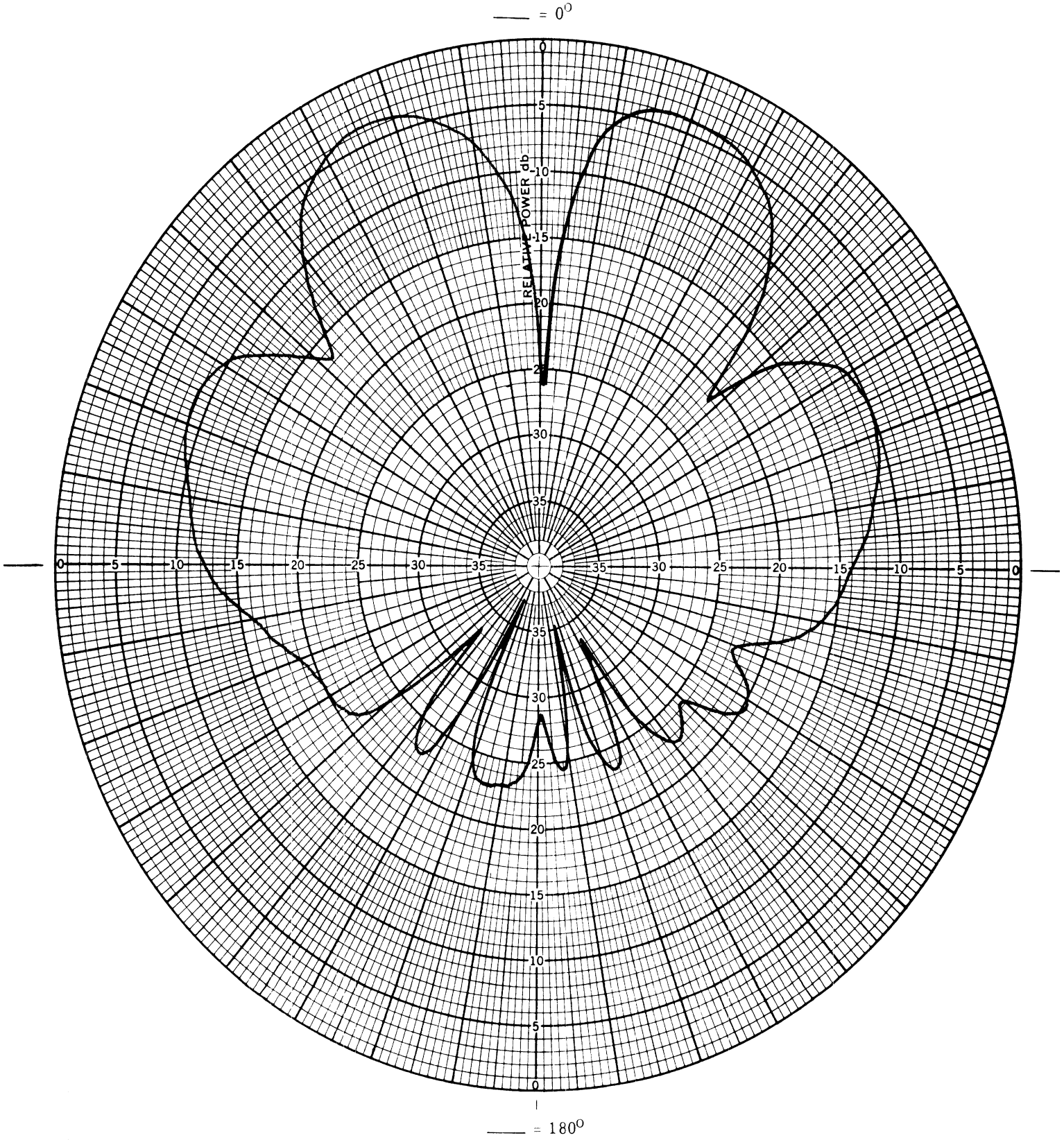

Fig. 14(n): Measured vertical plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 701.0 MHz.

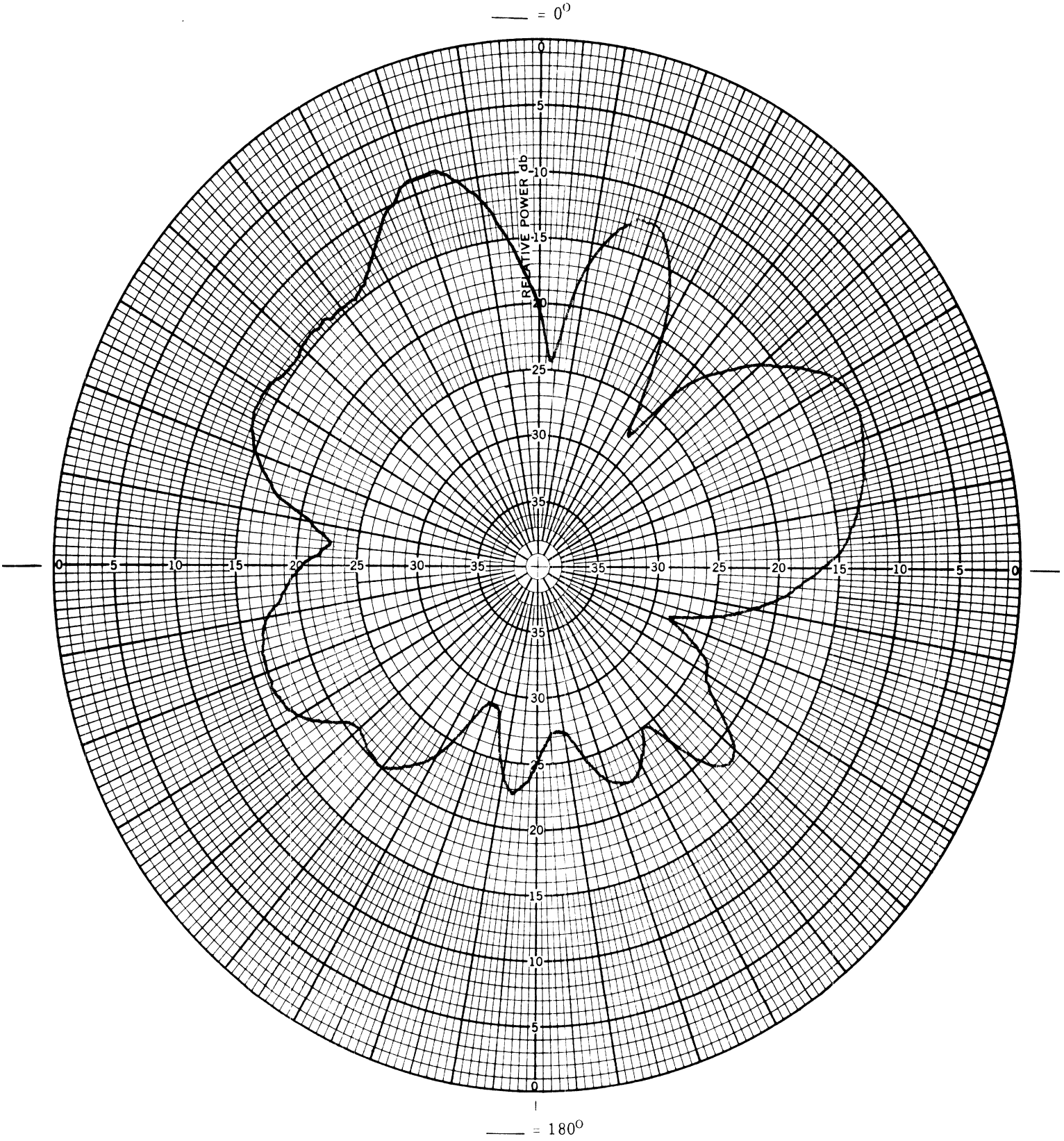

Fig. 14(o): Measured vertical plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 800.0 MHz.

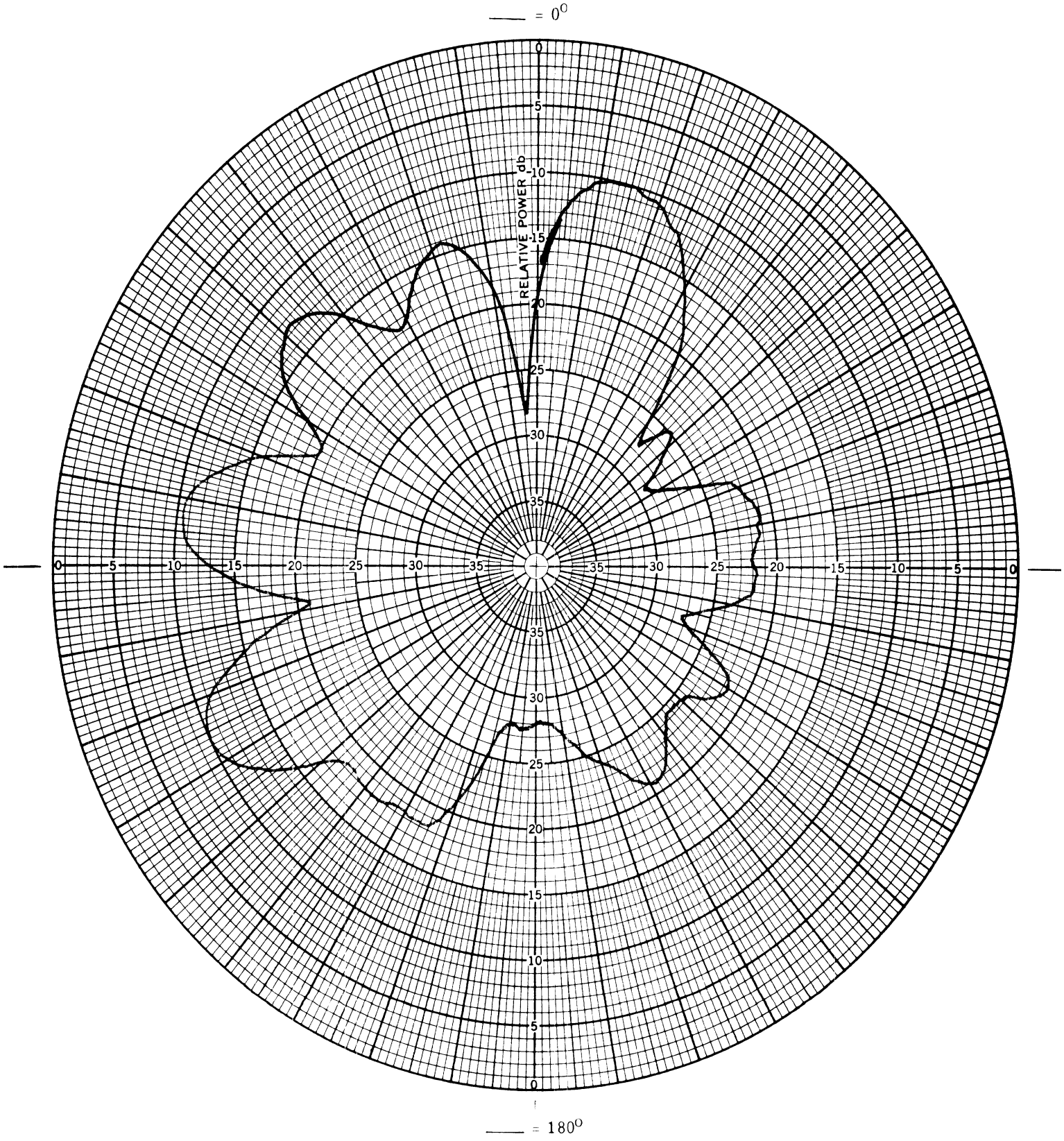

Fig. 14(p): Measured vertical plane pattern of the capacitor antenna (d = 1.0 inch). Vertical polarization, f = 970.0 MHz.

the directions broadside to the plates (or edge on to the radiating aperture) and the 90 degree and 270 degree directions correspond to the edge-on directions to the plates. The results of Fig. 14 indicate that this antenna behaves like a short current element.

The results presented in Figs. 10 through 14 should be used to judge the general behavior of the patterns of the antennas tested over the frequency range 50 to 1000 MHz. They cannot be used to estimate or compare the gain of a specific antenna at different frequencies, because of the variation of the transmitted signal. However, comparison may be made between the results for different antennas obtained at approximately the same frequency.

V. PATTERN AND GAIN CHARACTERISTICS OF ANTENNAS MOUNTED ON A CAR BODY SHELL

On the basis of the results presented in Section IV it was decided to collect the horizontal plane patterns of the heated backlite antenna mounted on a car body shell (Ford Tempo) supplied by the sponsor, and compare these with those of the standard whip antenna (mounted on the same car body shell) obtained under similar conditions. For this purpose the antennas were suitably mounted on the car body shell and placed on the rotating platform. Using laboratory signals of both vertical and horizontal polarization, the radiation patterns were obtained at selected frequencies in the usual manner. At each frequency, during the measurements with the heated backlite and the whip antenna the power transmitted by the standard antenna was kept constant. The relative gain of the heated backlite antenna with respect to the standard whip antenna was then obtained at each frequency in a manner described in Section 2.3.

5.1 Radiation Patterns

For convenience, the radiation pattern results (Figs. 15 through 58) are presented here in a manner slightly different from that of Section IV. For example, in each of the figures, say Fig. x, of this section we present the results for the heated backlite and the whip antennas obtained at the same frequency as Figs. x(a) and x(b), respectively. This should enable the reader to compare the pattern characteristics of the two antennas conveniently.

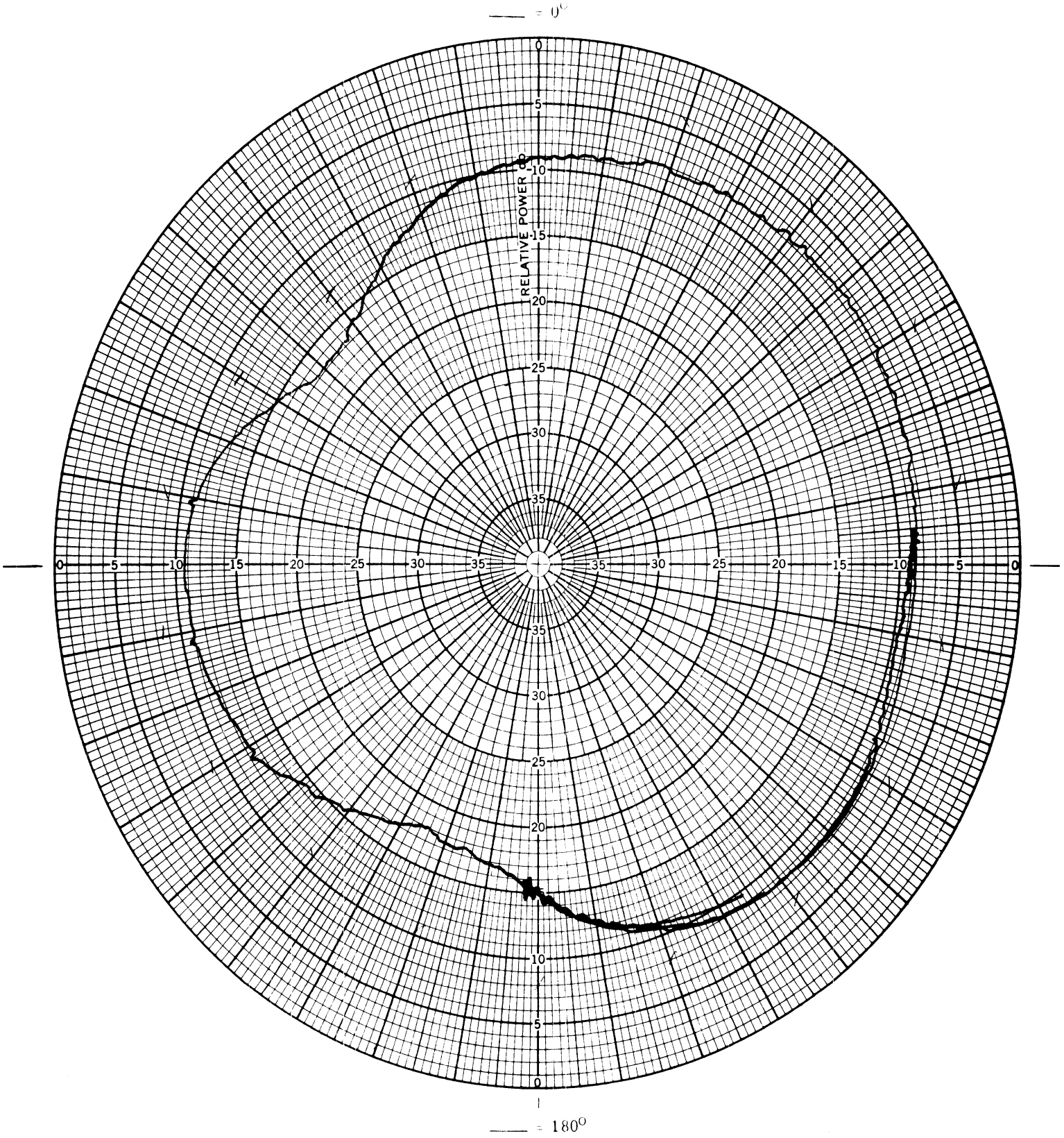

Fig. 15(a): Measured horizontal plane pattern of the side-fed heated backlite antenna mounted on Tempo body shell. Vertical polarization, f 59.0 MHz.

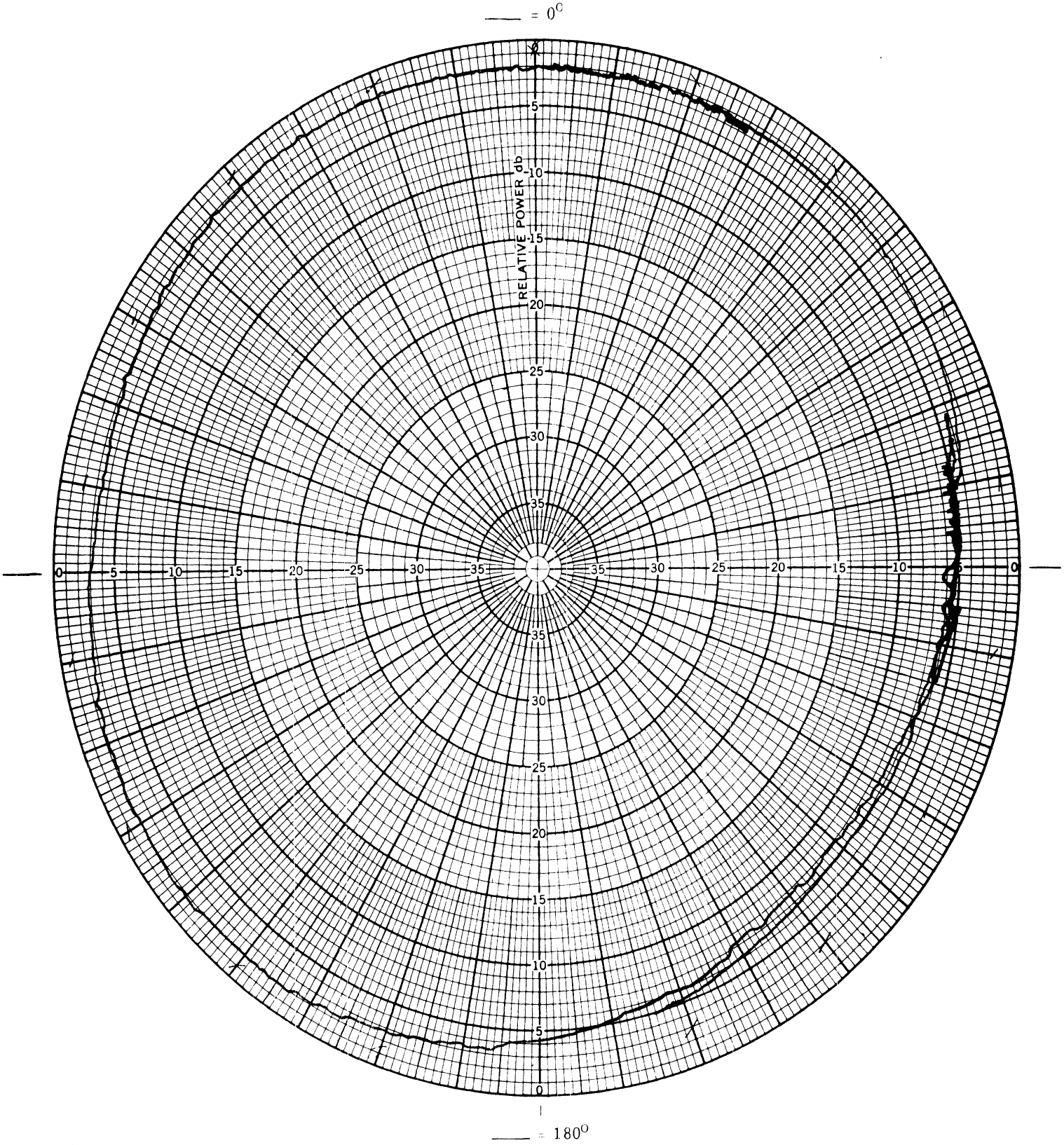

Fig. 15(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Vertical polarization, f = 59.0 MHz.

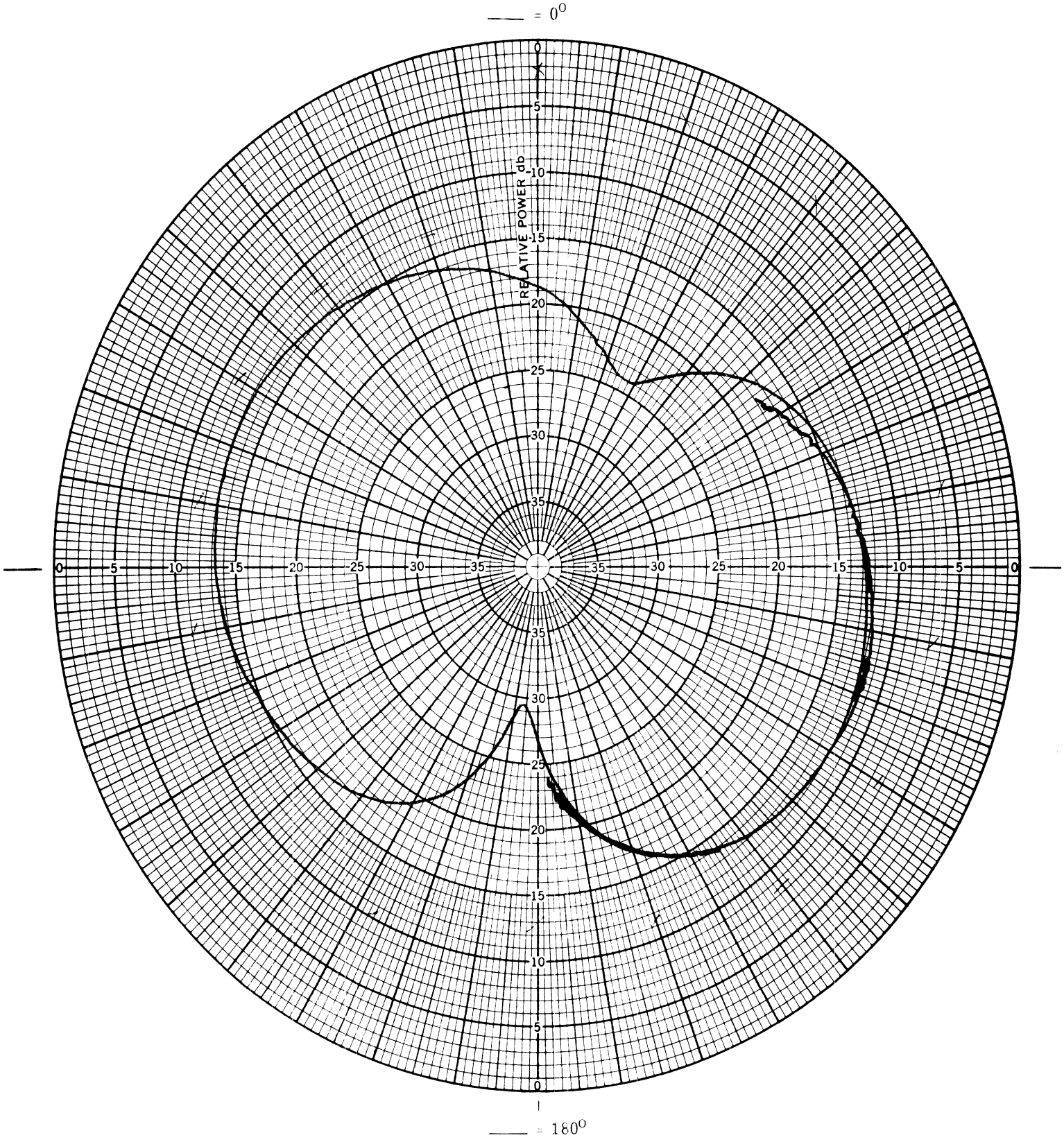

Fig. 16(a): Measured horizontal plane pattern of the side-fed heated backlite antenna mounted on Tempo body shell. Vertical polarization, f = 71.5 MHz.

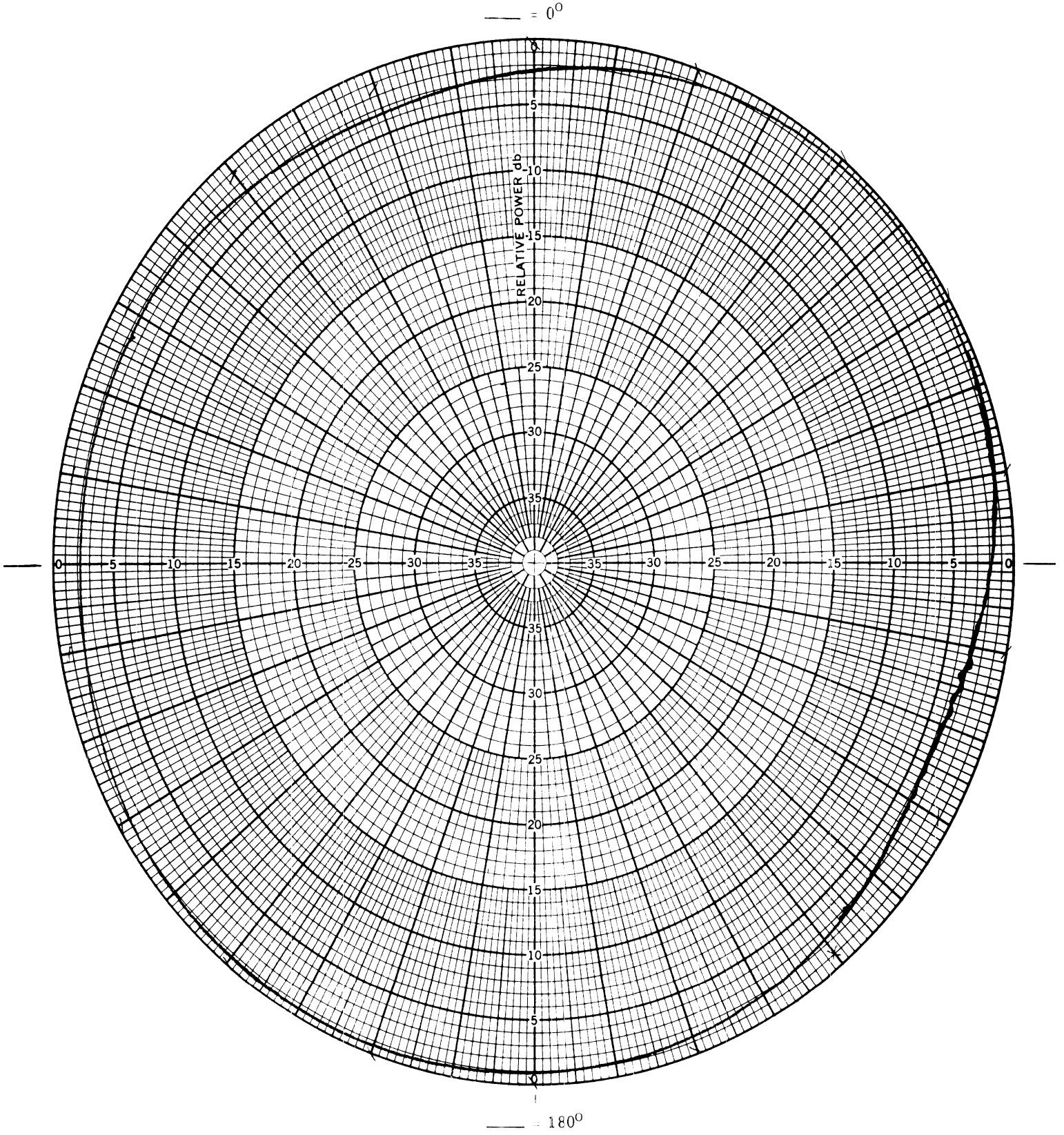

Fig. 16(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Vertical polarization, f = 71.5 MHz.

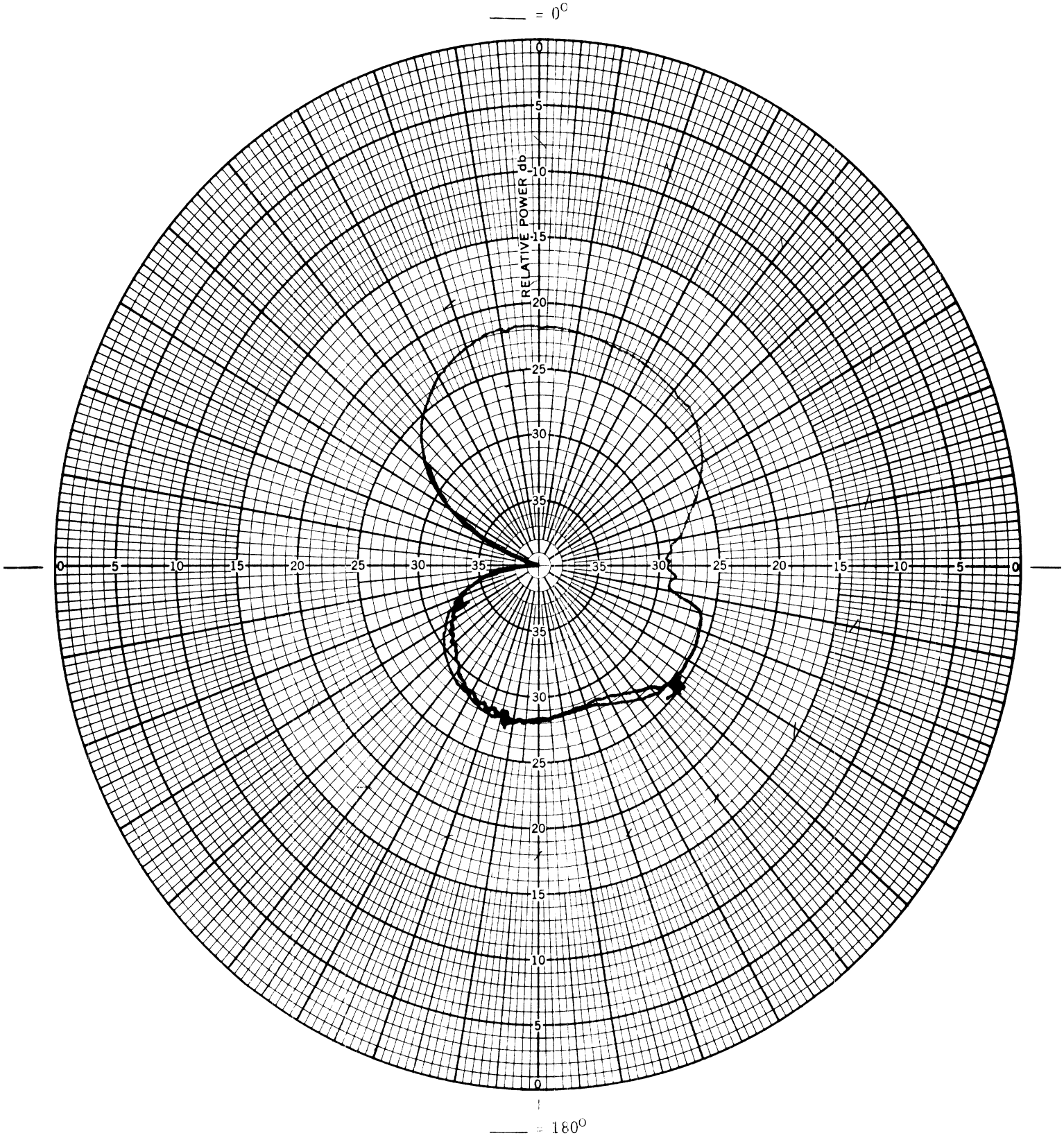

Fig. 17(a): Measured horizontal plane pattern of the side-fed heated backlite antenna mounted on Tempo body shell. Vertical polarization, f = 87.5 MHz.

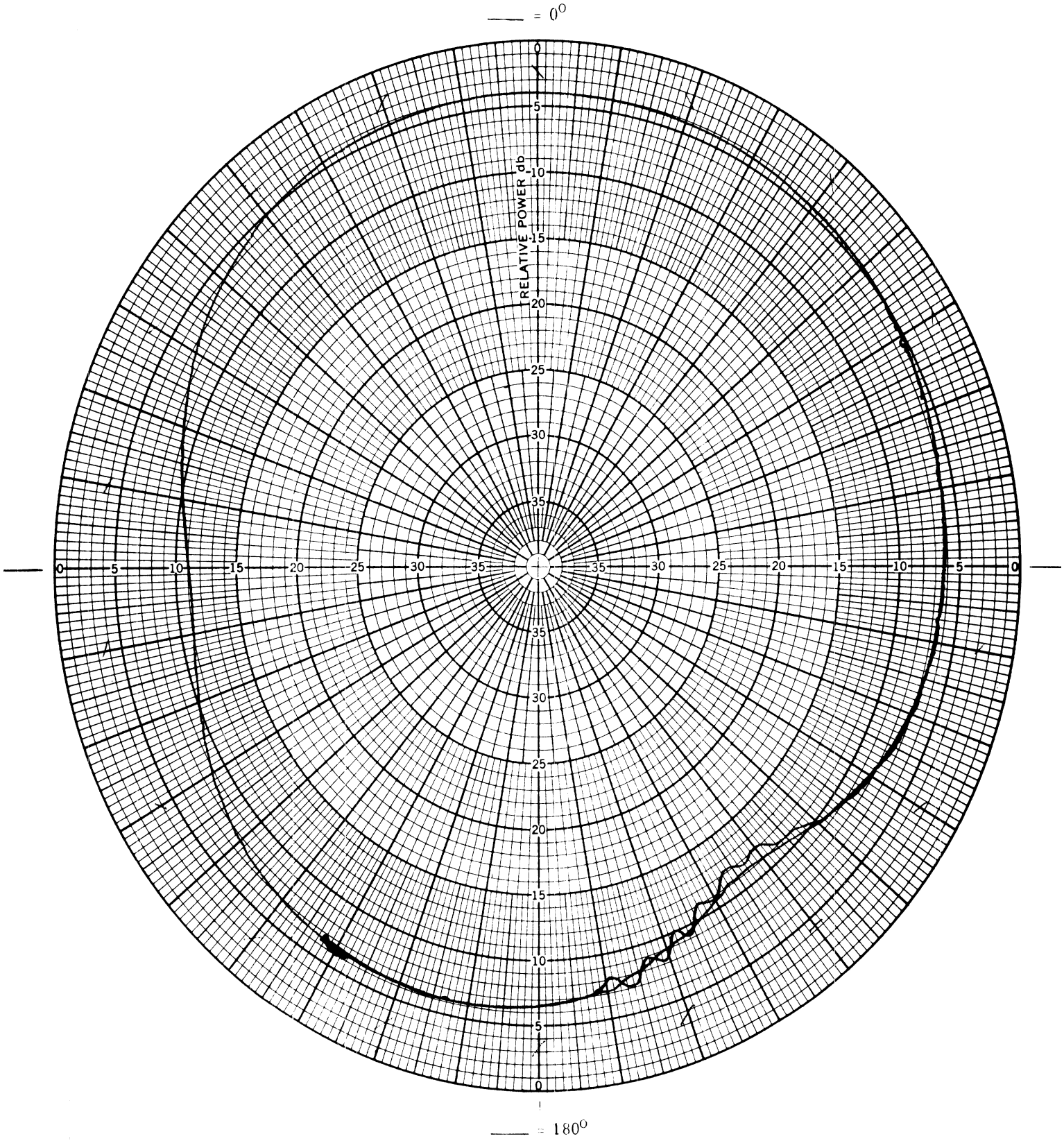

Fig. 17(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Vertical polarization, f = 87.5 MHz.

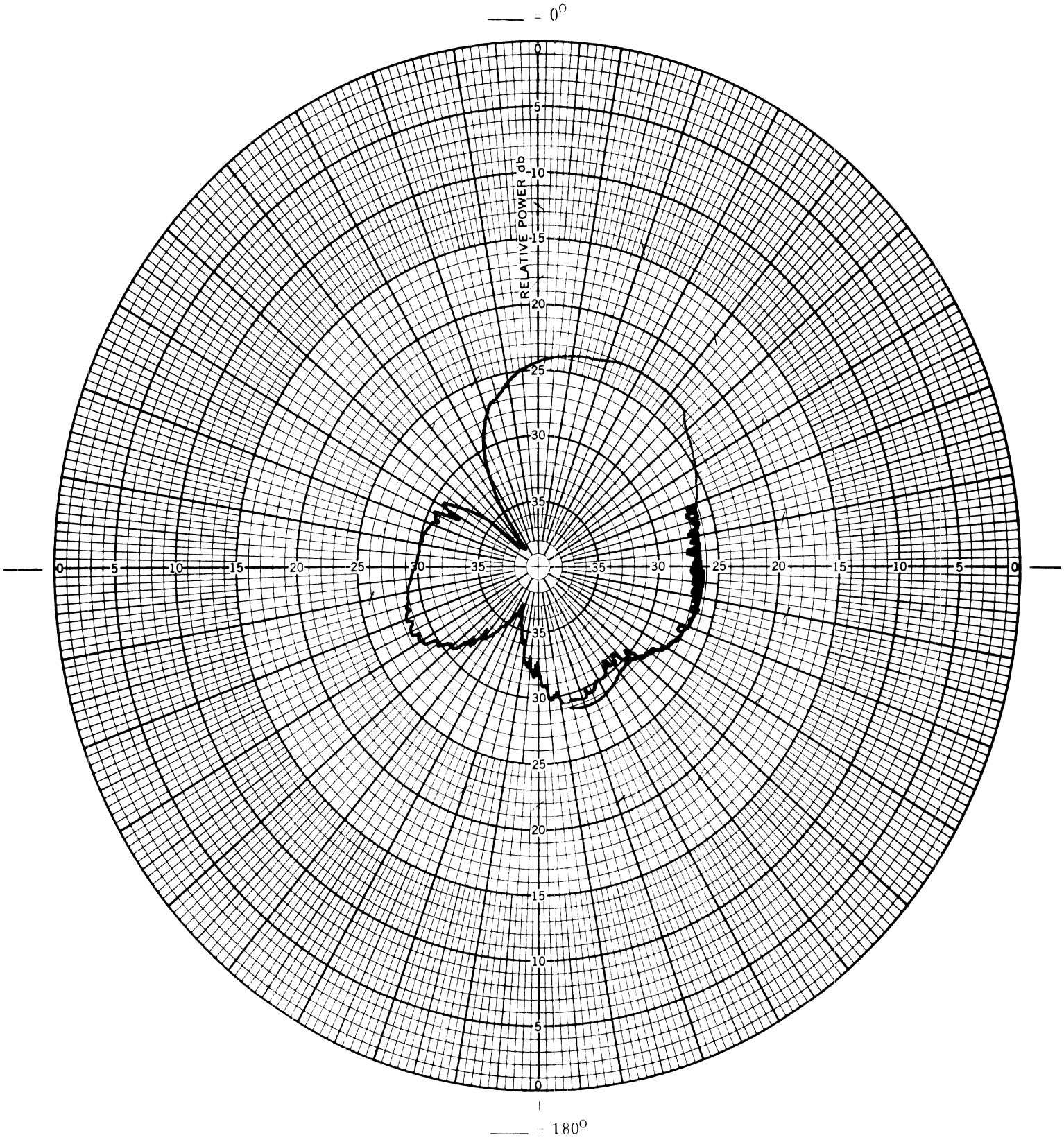

Fig. 18(a): Measured horizontal plane pattern of the side-fed heated backlite antenna mounted on Tempo body shell. Vertical polarization, f = 98.0 MHz.

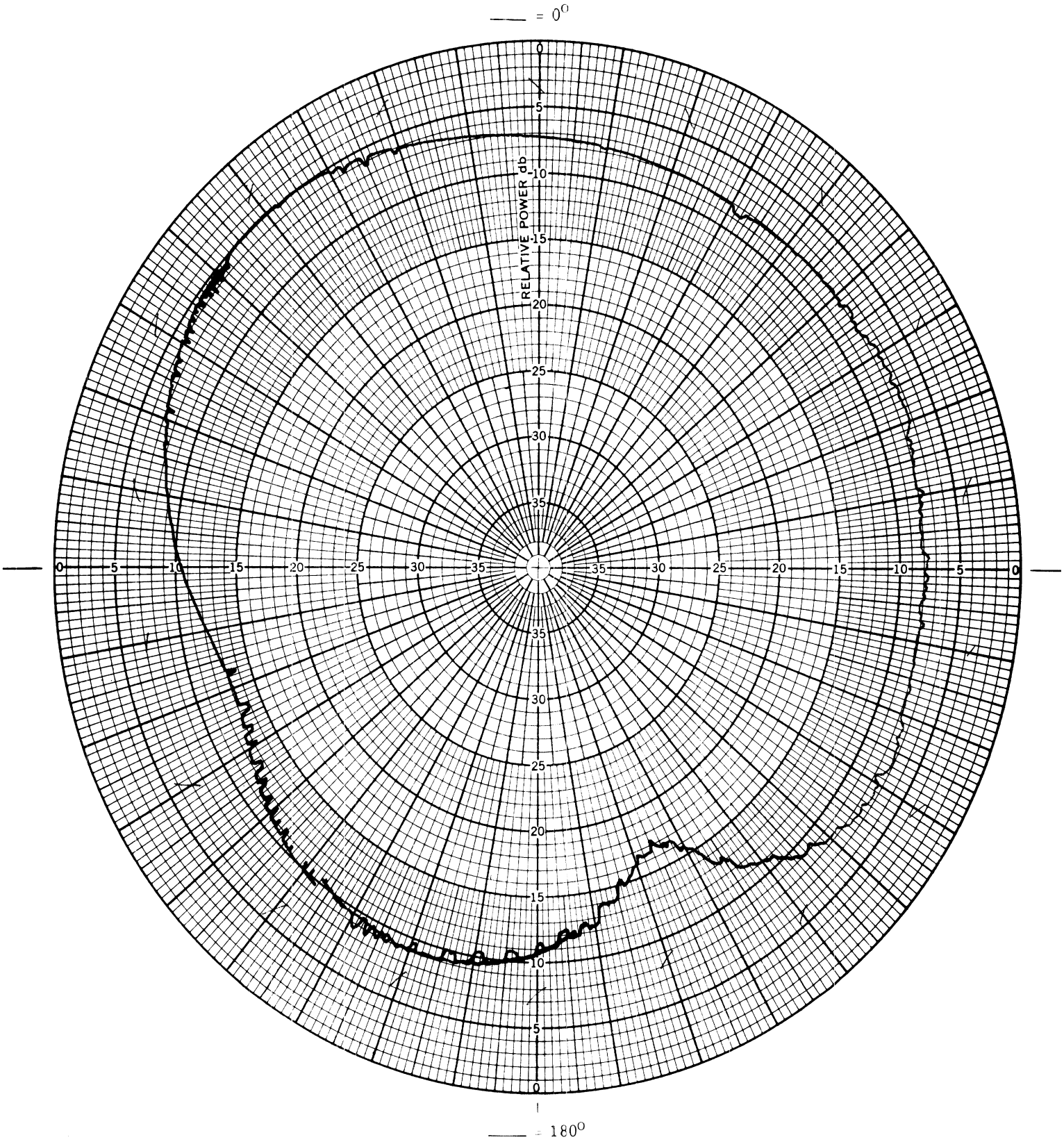

Fig. 18(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Vertical polarization, f = 98.0 MHz.

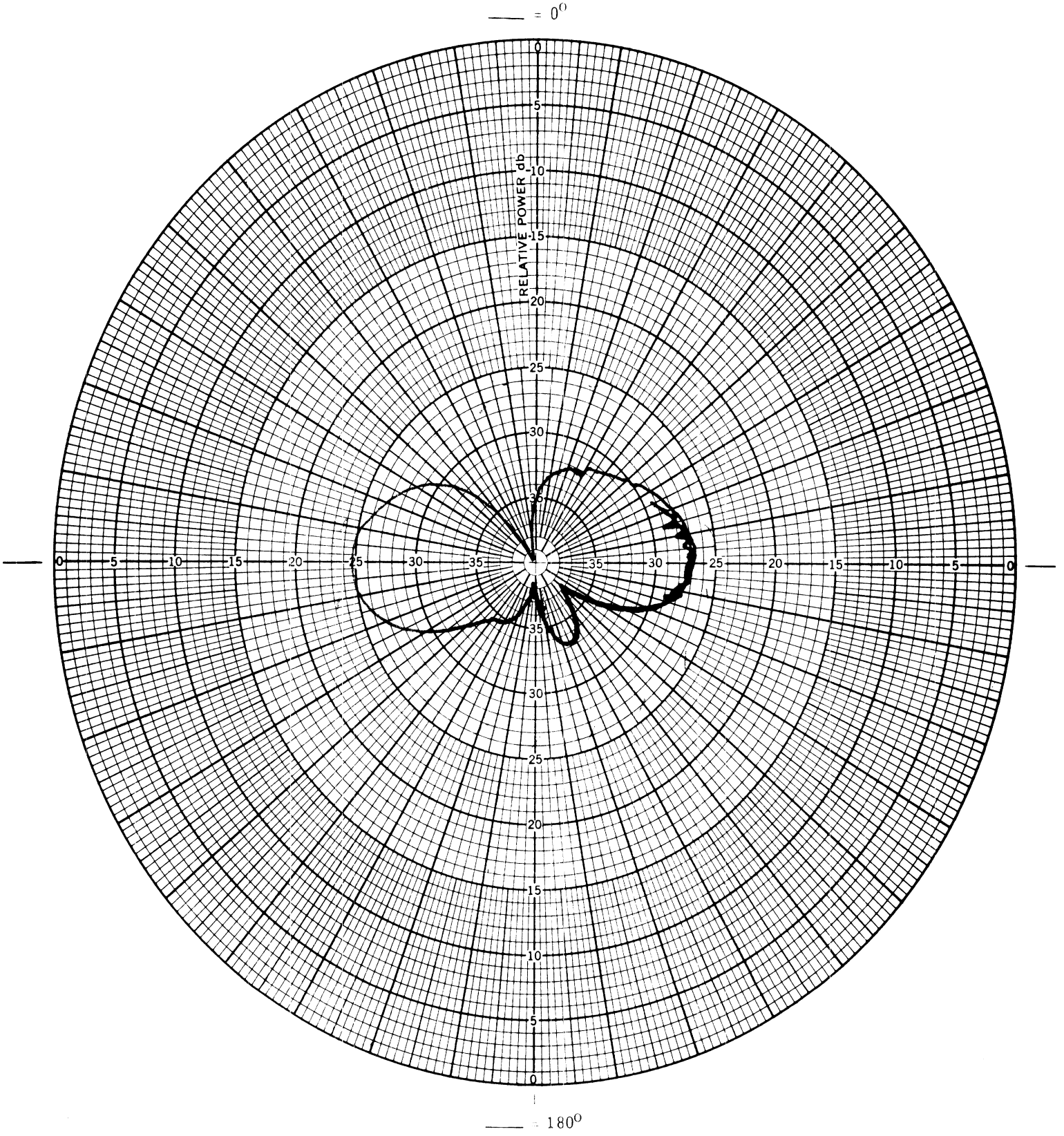

Fig. 19(a): Measured horizontal plane pattern of the side-fed heated backlite antenna mounted on Tempo body shell. Vertical polarization, f = 108.5 MHz.

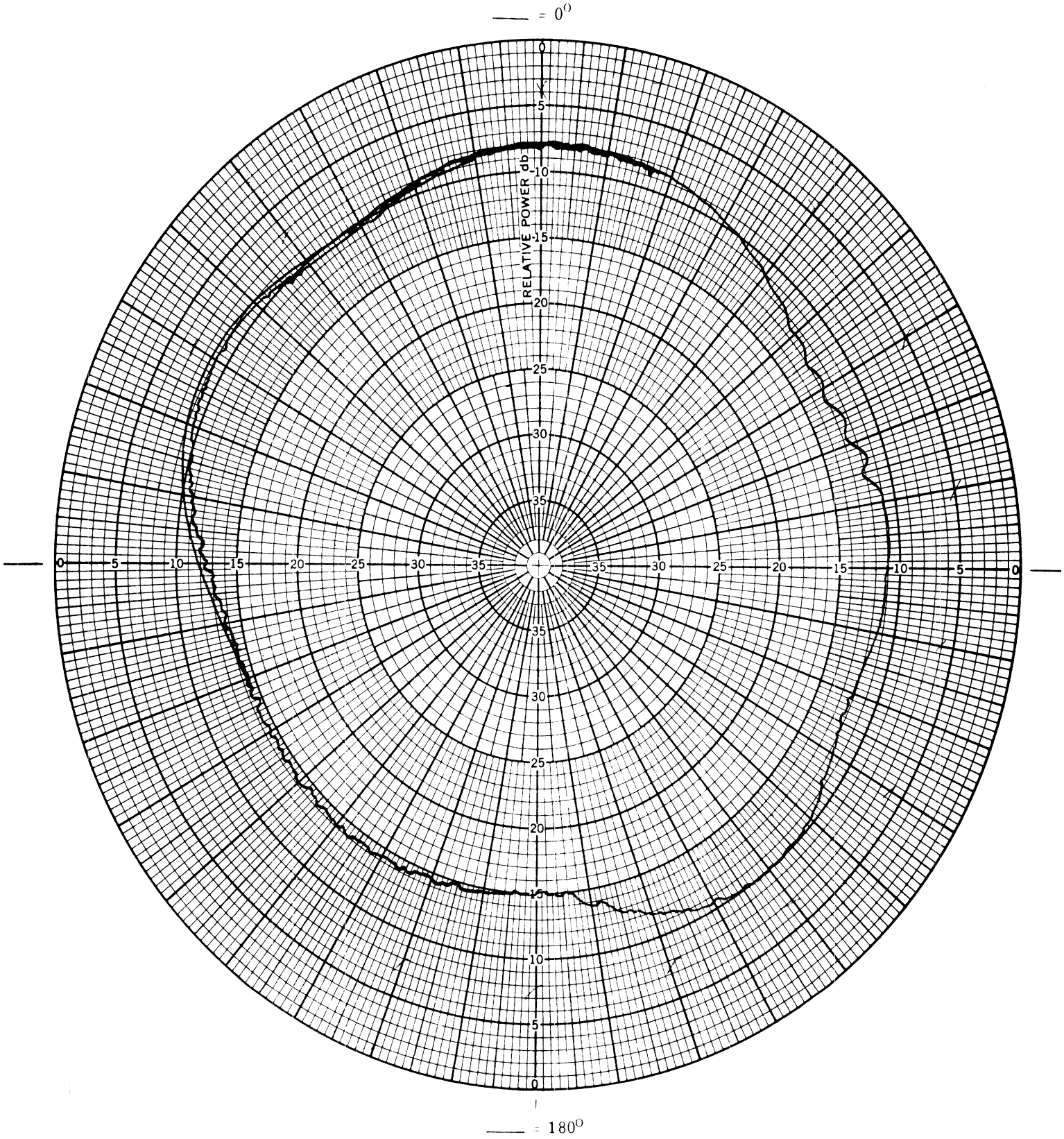

Fig. 19(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Vertical polarization, f = 108.5 MHz.

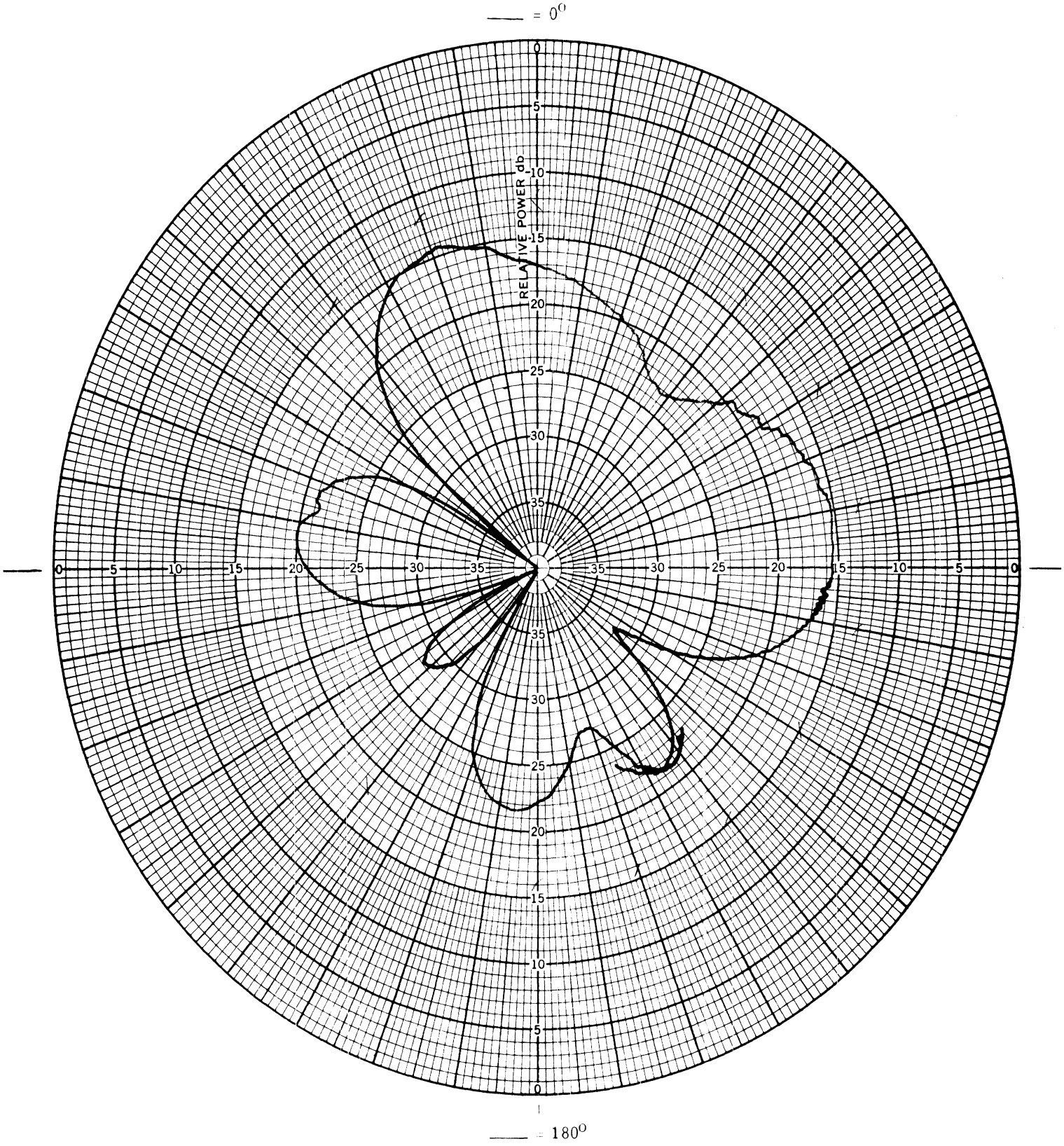

Fig. 20(a): Measured horizontal plane pattern of the side-fed heated backlite antenna mounted on Tempo body shell. Vertical polarization, f = 179.5 MHz.

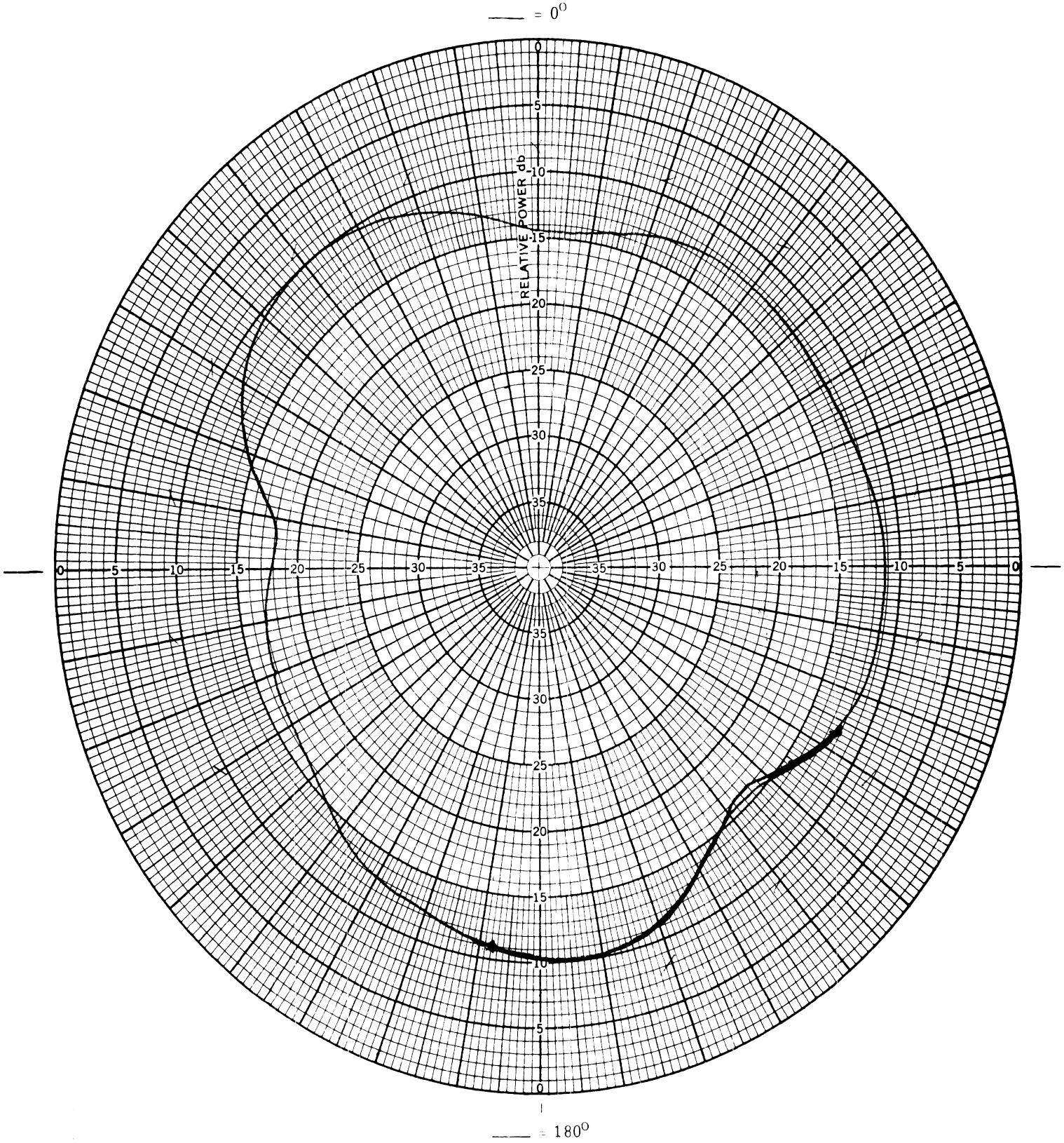

Fig. 20(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Vertical polarization, f = 179.5 MHz.

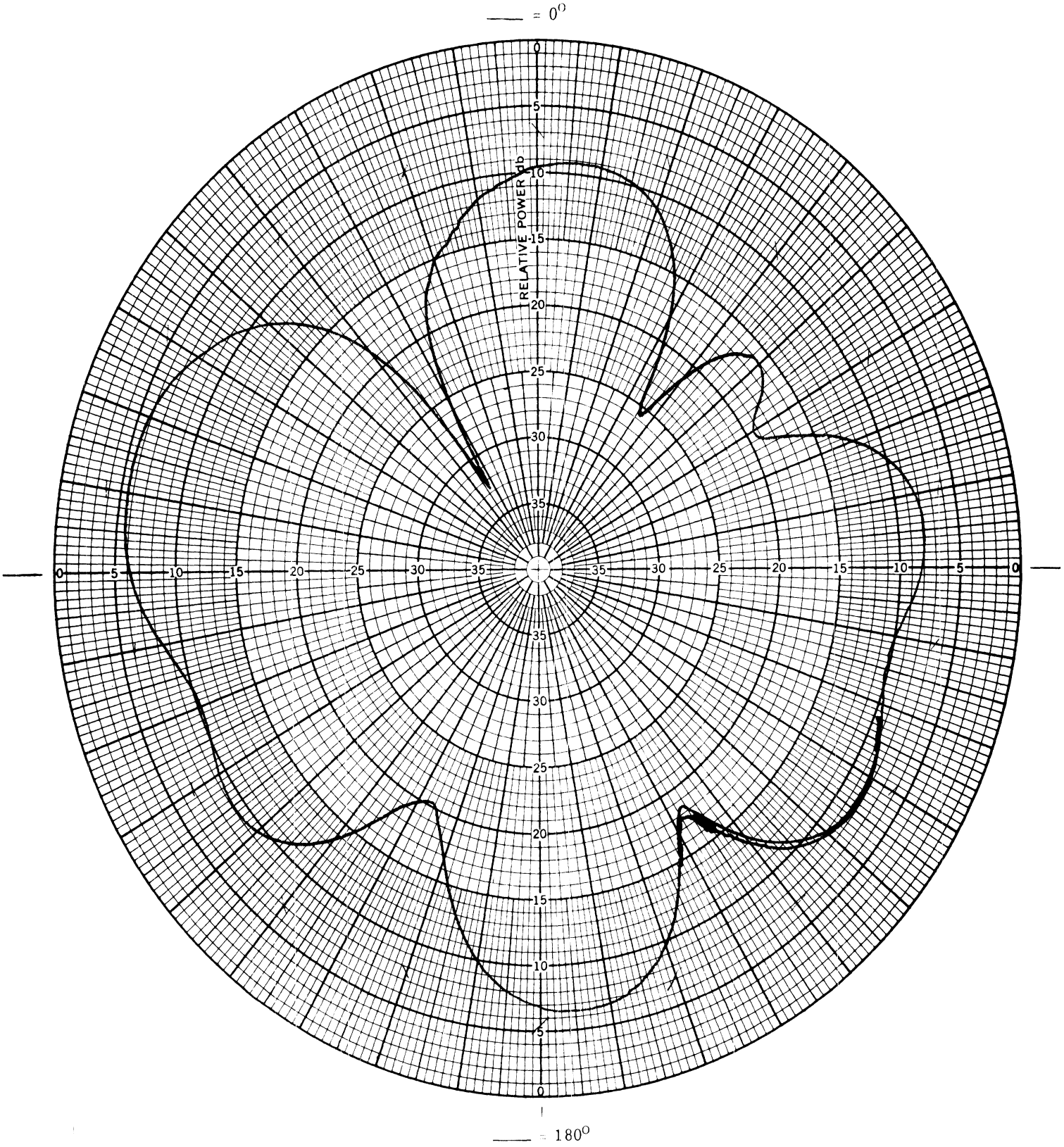

Fig. 21(a): Measured horizontal plane pattern of the side-fed heated backlite antenna mounted on Tempo body shell. Vertical polarization, f = 215.0 MHz.

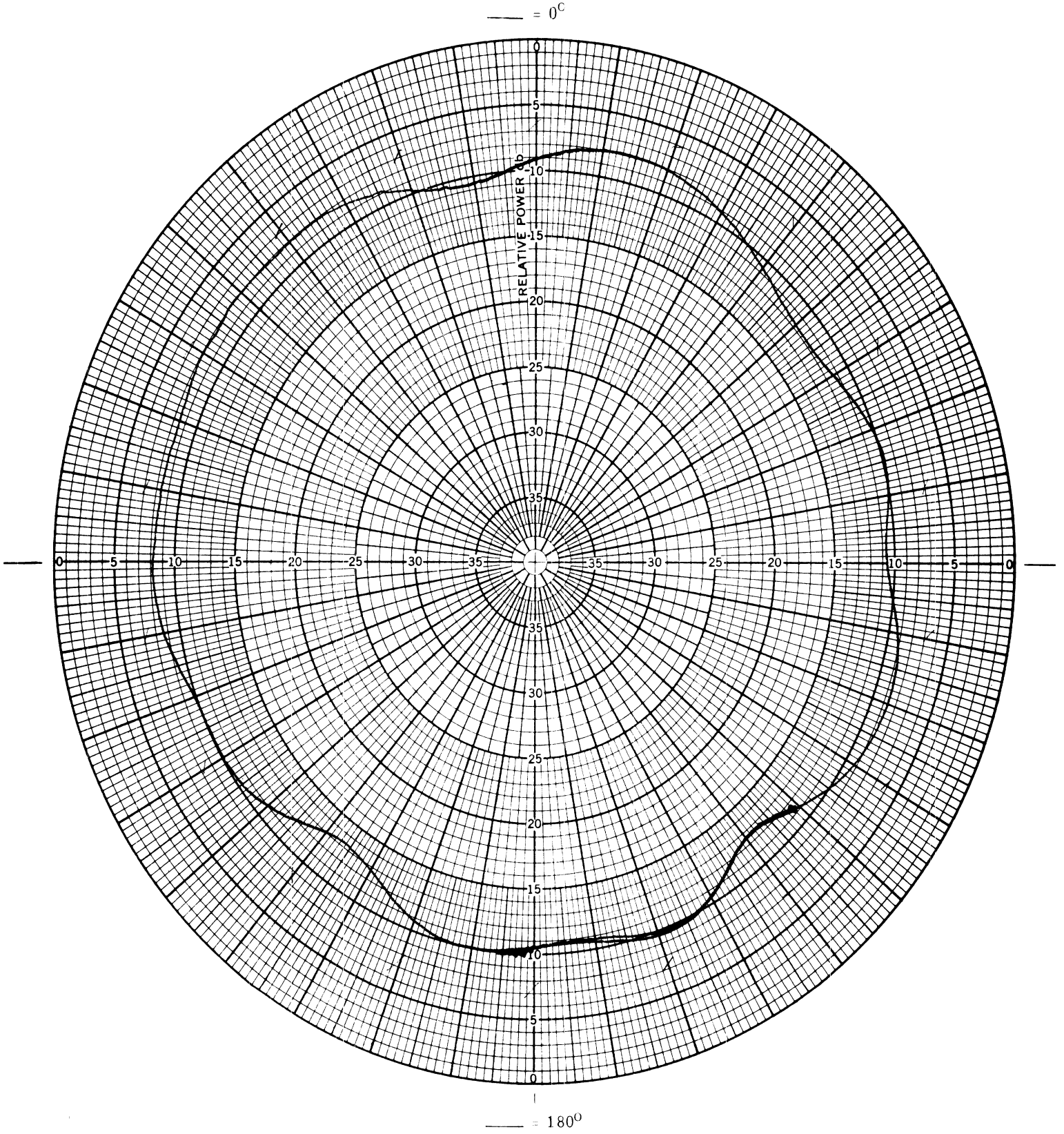

Fig. 21(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Vertical polarization, f = 215.0 MHz.

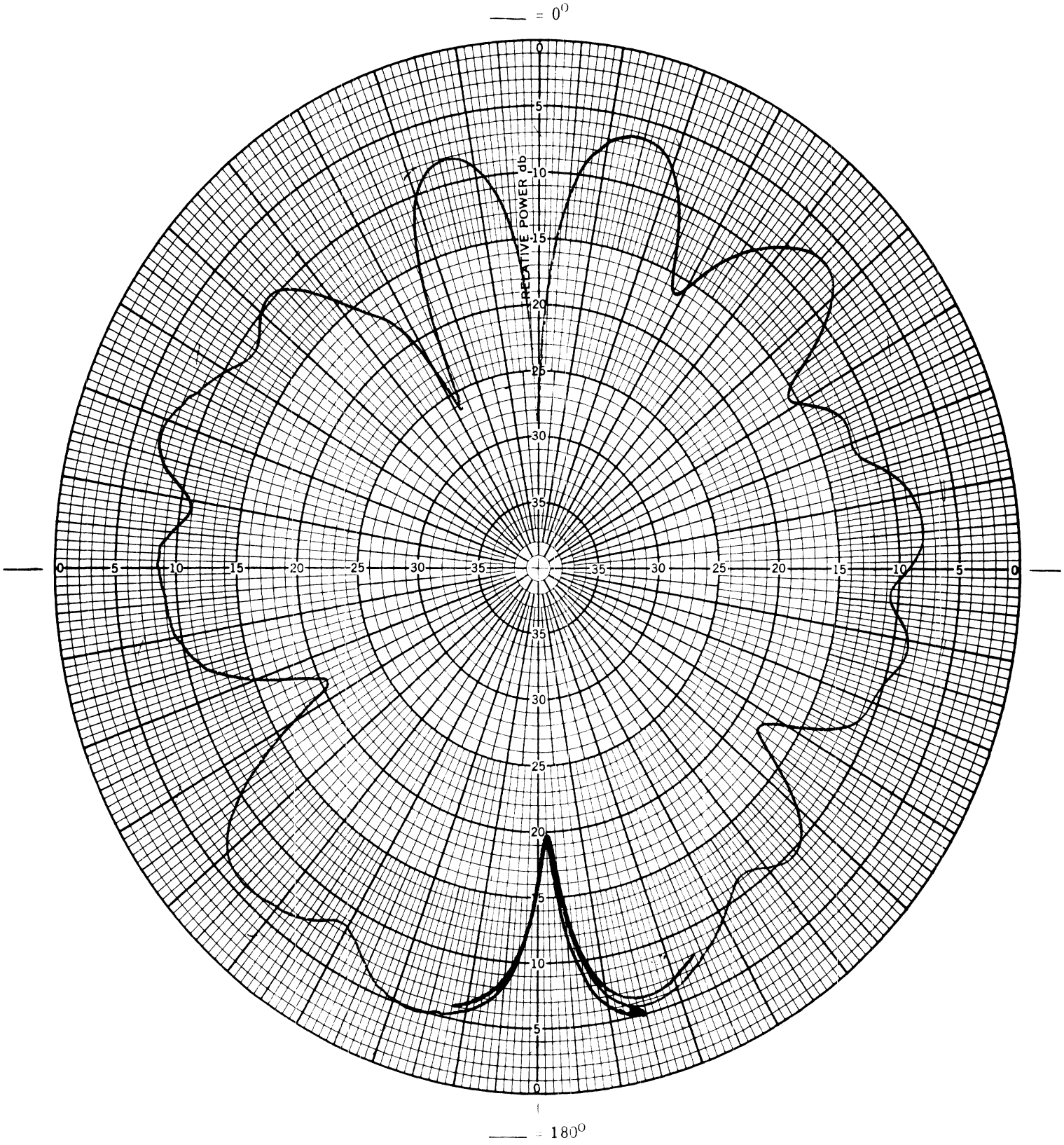

Fig. 22(a): Measured horizontal plane pattern of the side-fed heated backlite antenna mounted on Tempo body shell. Vertical polarization, f = 475.0 MHz.

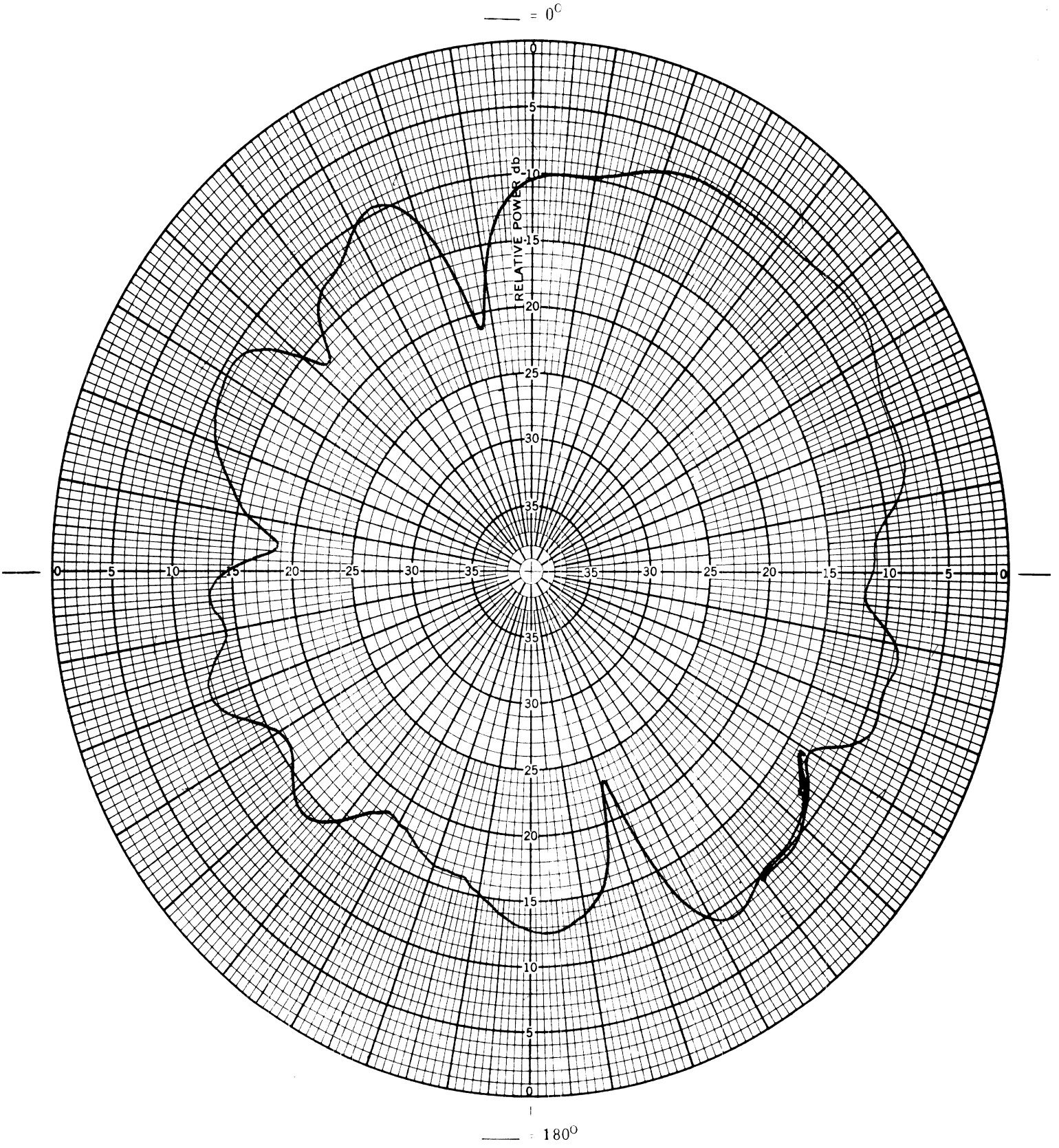

Fig. 22(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Vertical polarization, f = 475.0 MHz.

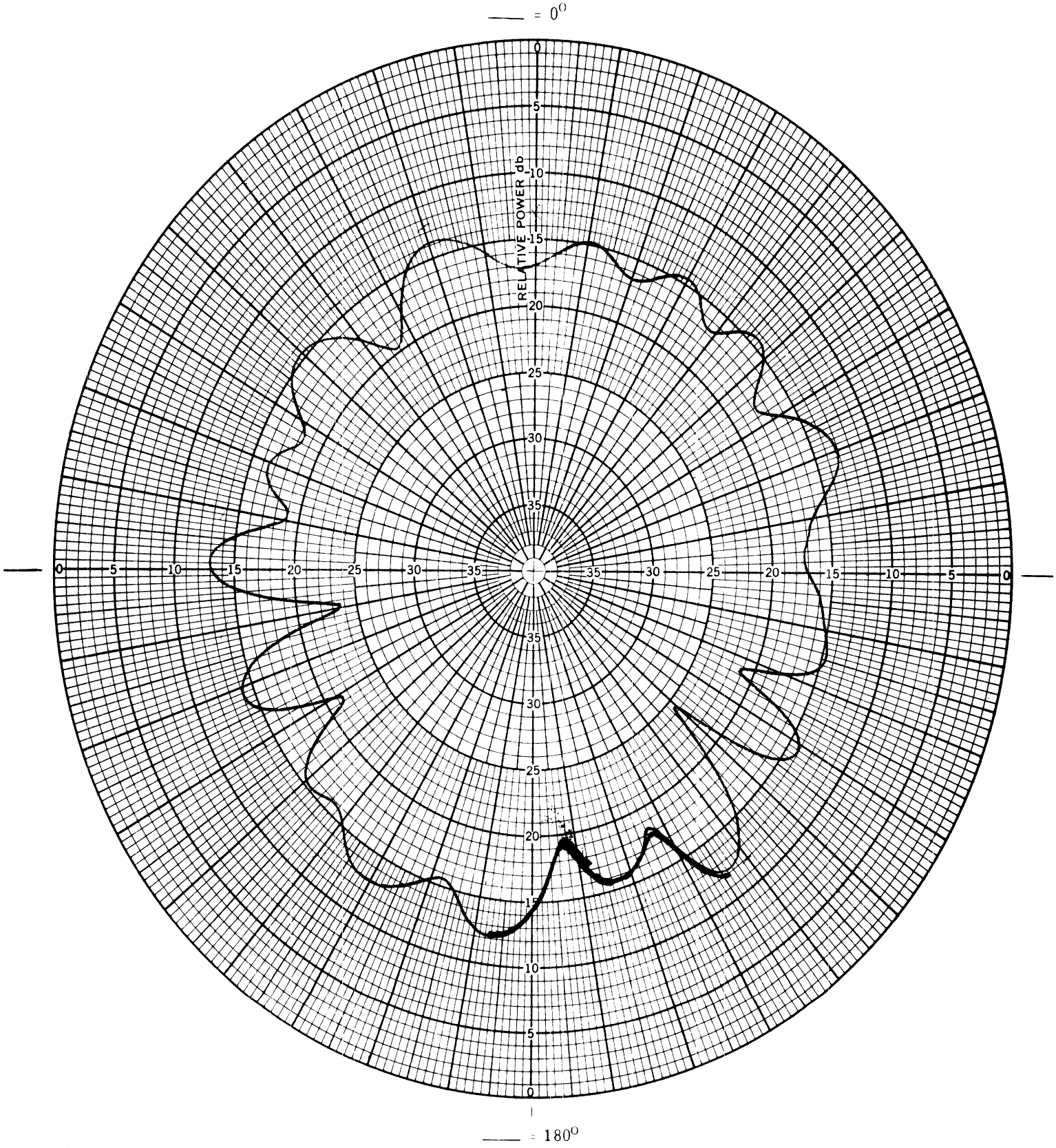

Fig. 23(a): Measured horizontal plane pattern of the side-fed heated backlite antenna mounted on Tempo body shell. Vertical polarization, f = 637.0 MHz.

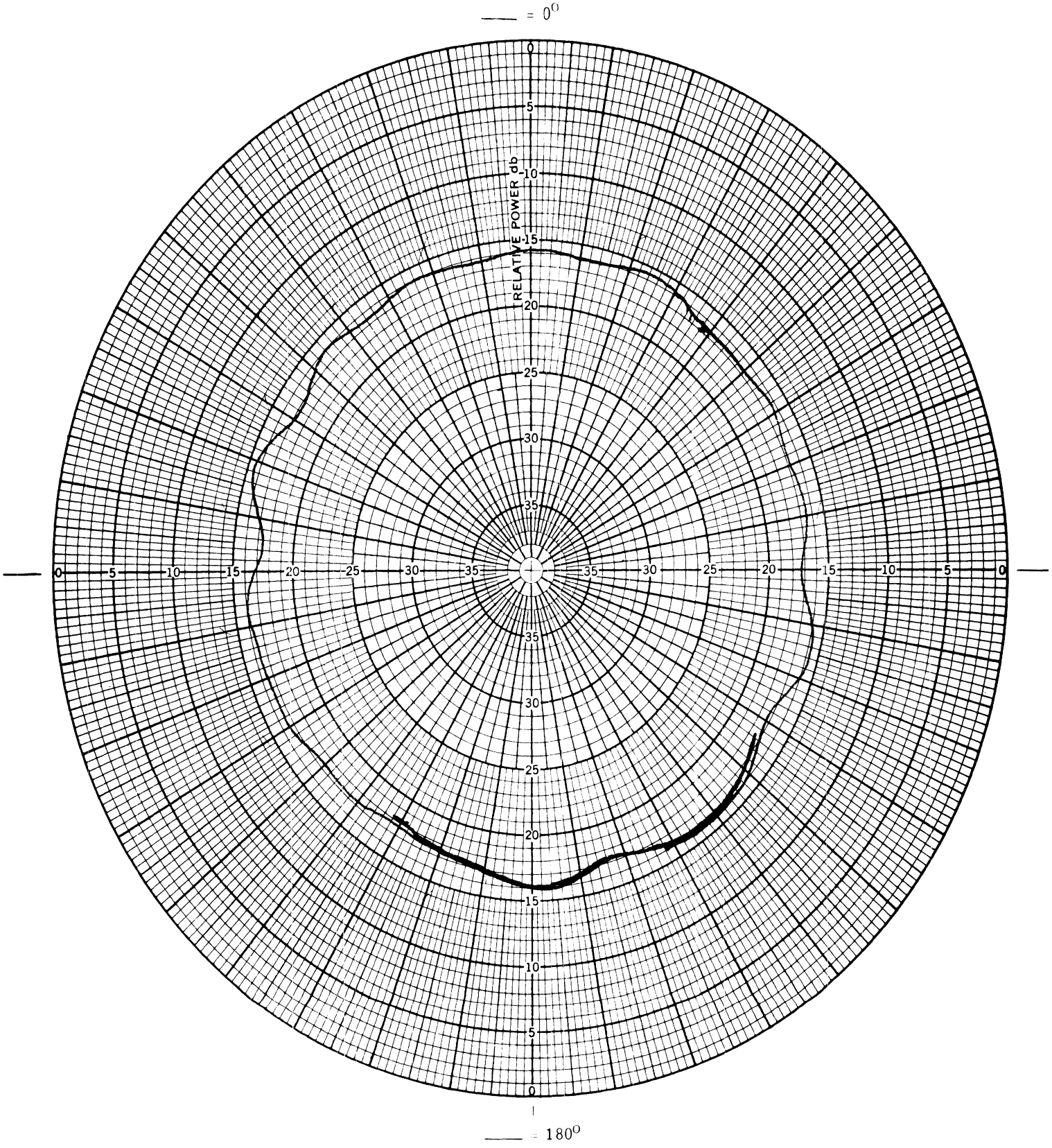

Fig. 23(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Vertical polarization, f = 637.0 MHz.

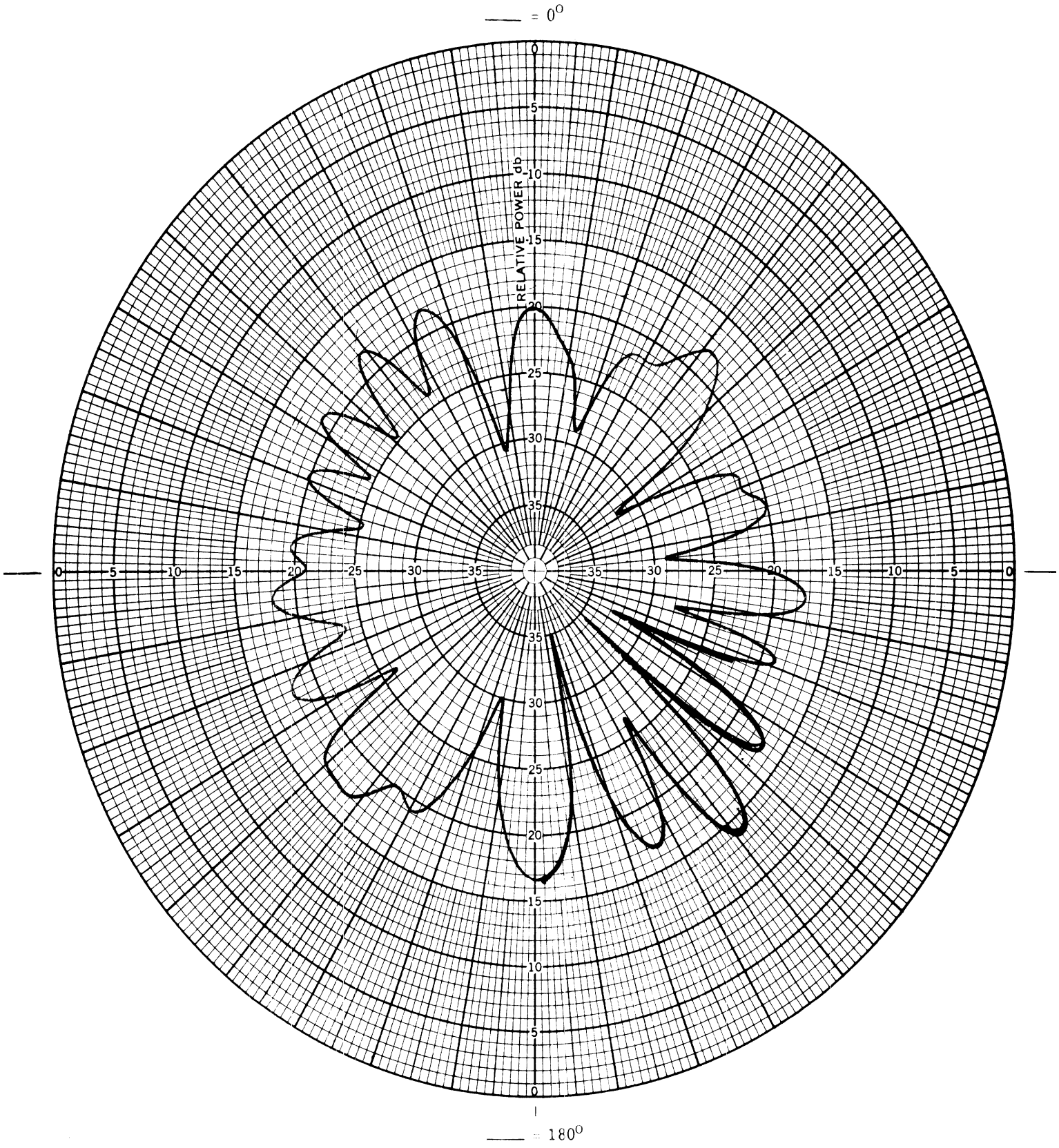

Fig. 24(a): Measured horizontal plane pattern of the side-fed heated backlite antenna mounted on Tempo body shell. Vertical polarization, f = 825.0 MHz.

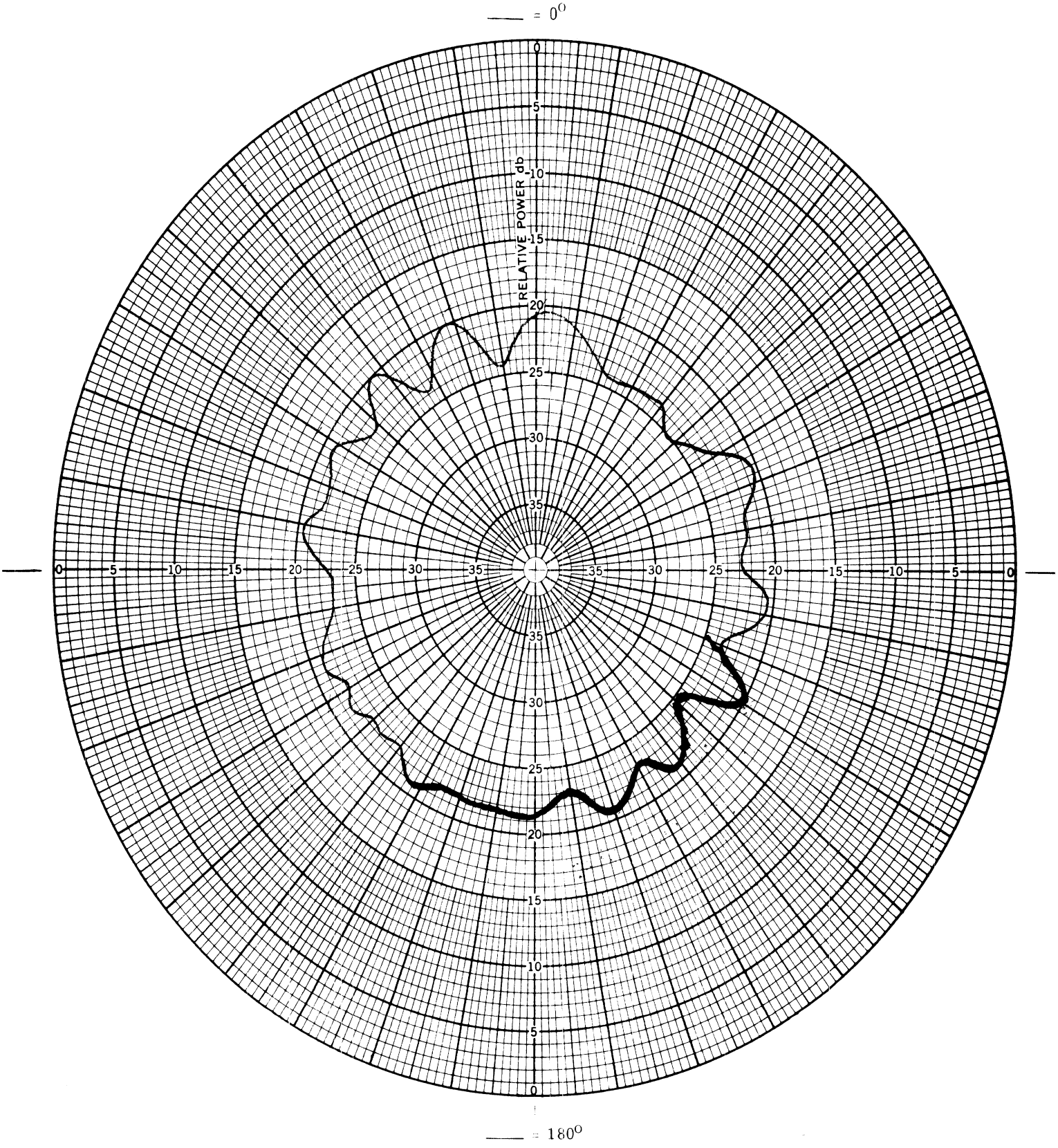

Fig. 24(b): Measured horizontal pattern of the whip antenna mounted on Tempo body shell. Vertical polarization, f = 825.0 MHz.

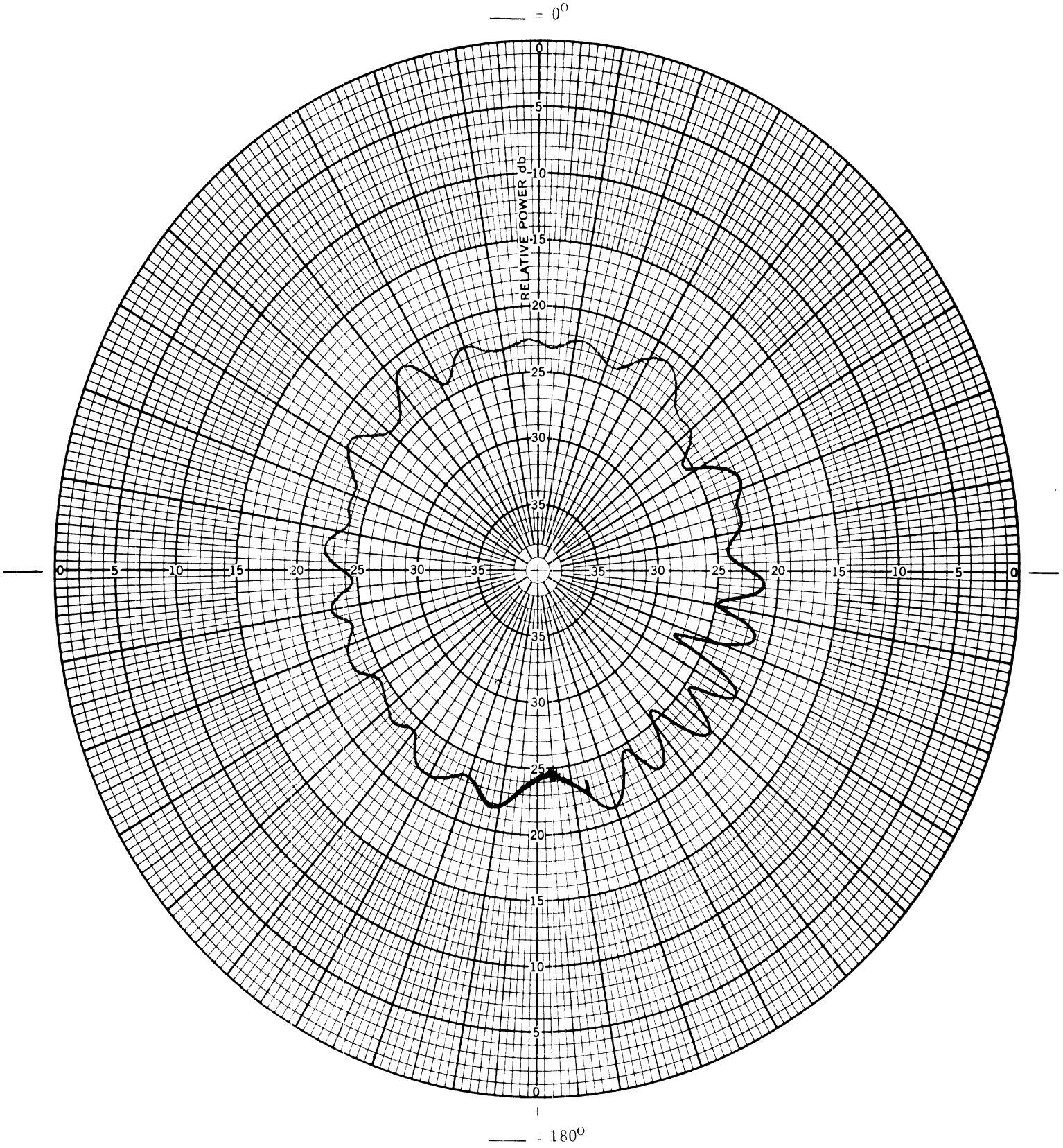

Fig. 25(a): Measured horizontal plane pattern of the side-fed heated backlite antenna mounted on Tempo body shell. Vertical polarization, f = 890.0 MHz.

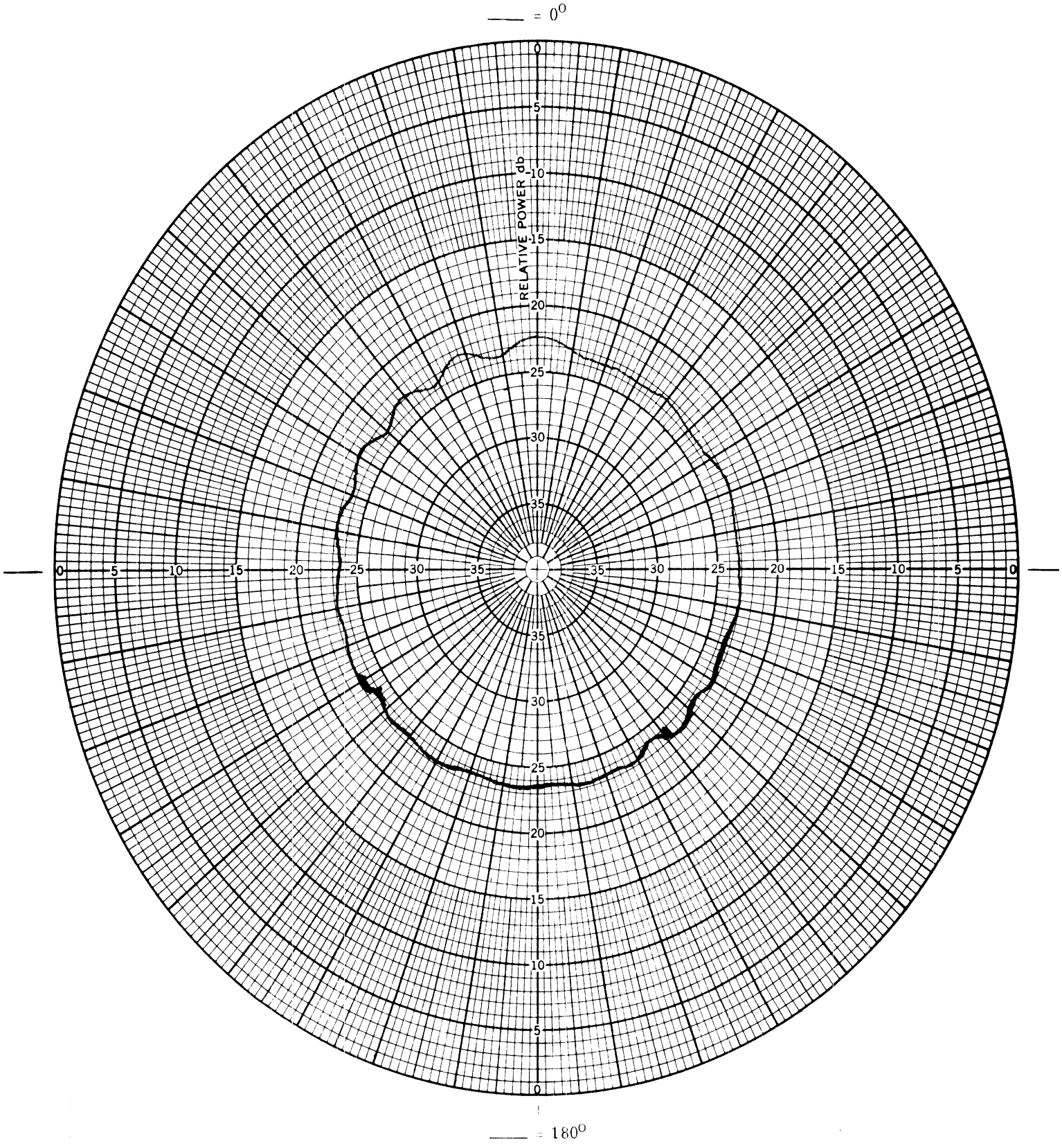

Fig. 25(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Vertical polarization, f = 890.0 MHz.

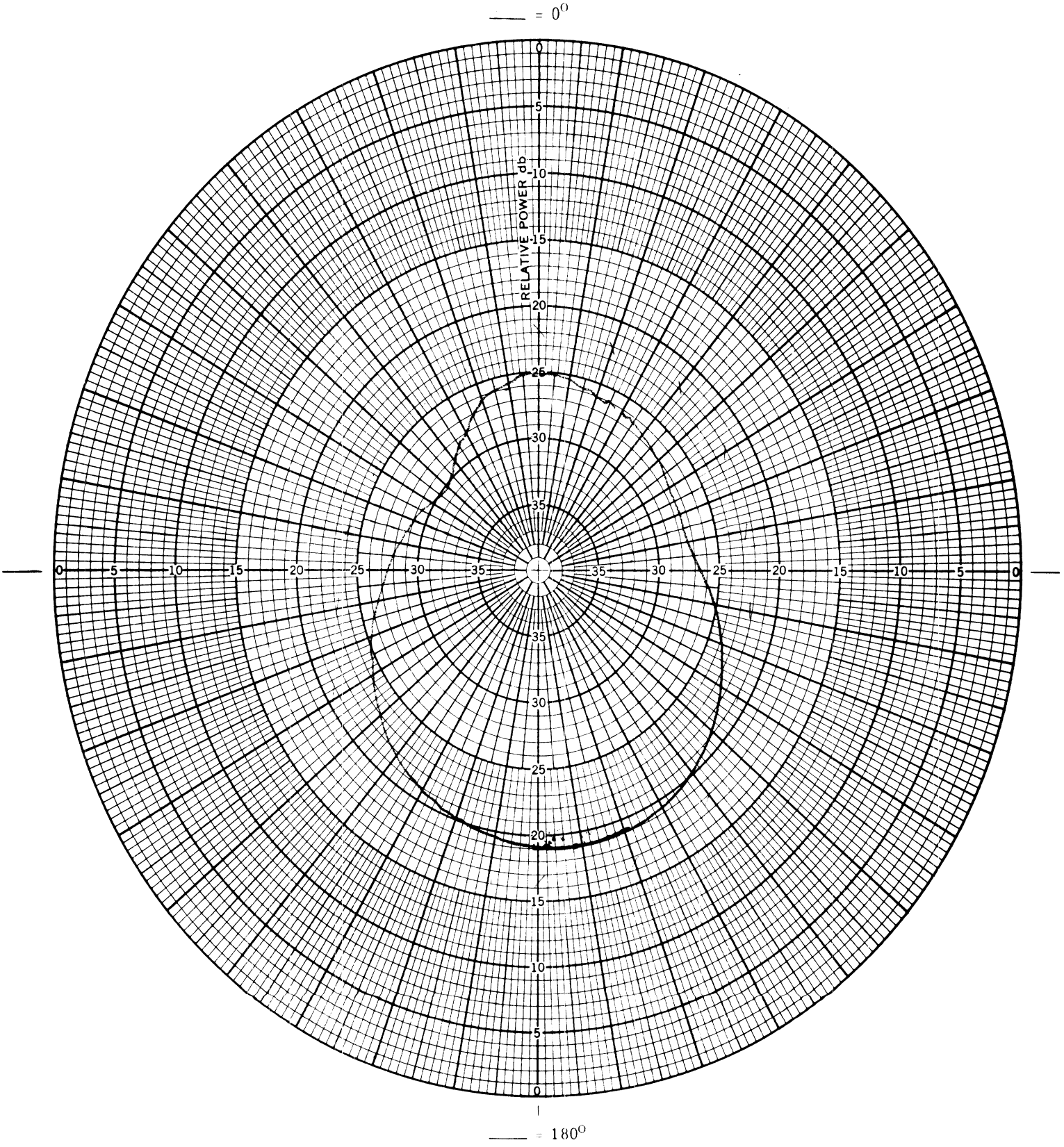

Fig. 26(a): Measured horizontal plane pattern of the side-fed heated backlite antenna mounted on Tempo body shell. Horizontal polarization, f = 61.0 MHz.

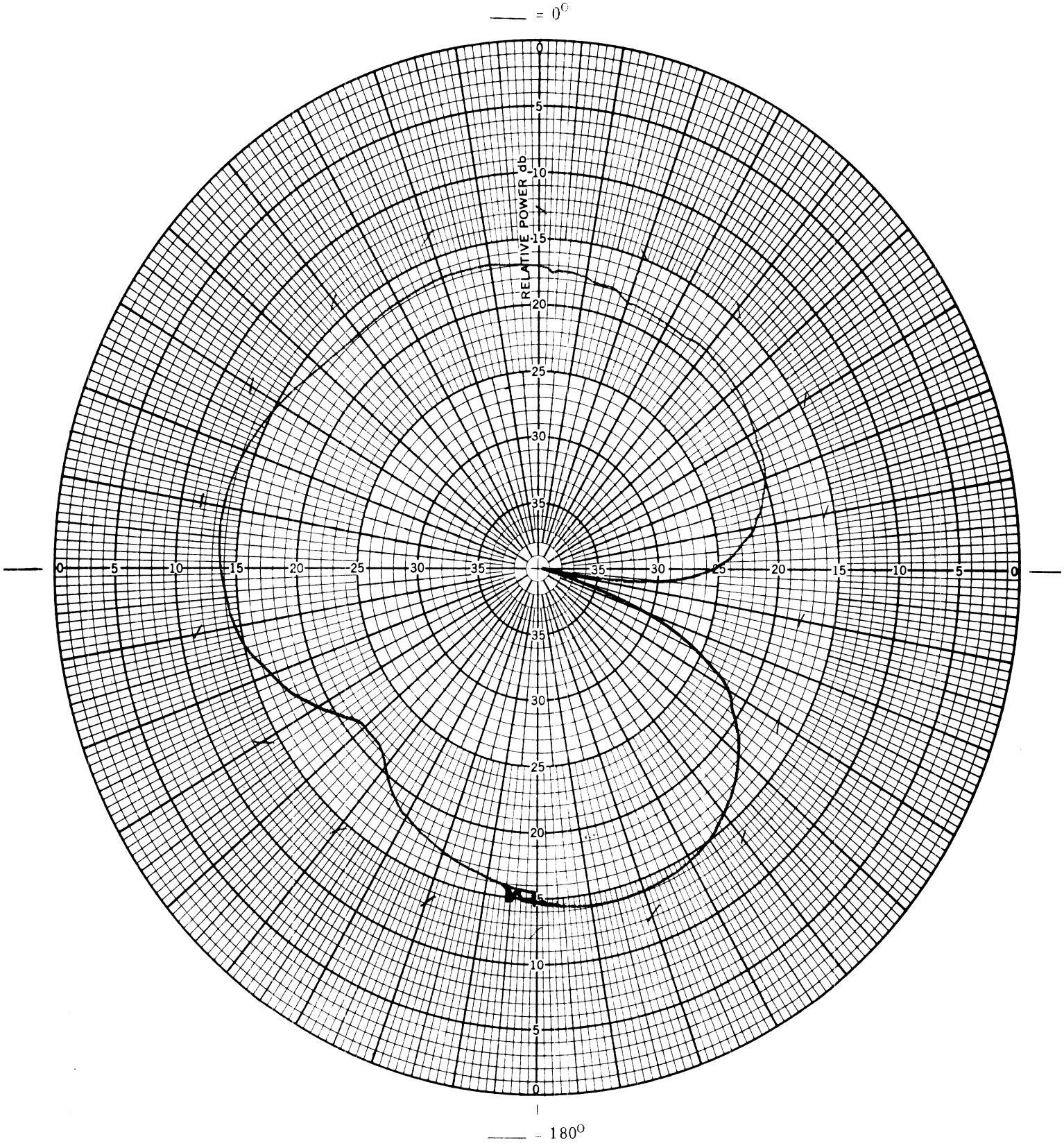

Fig. 26(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Horizontal polarization, f = 61.0 MHz.

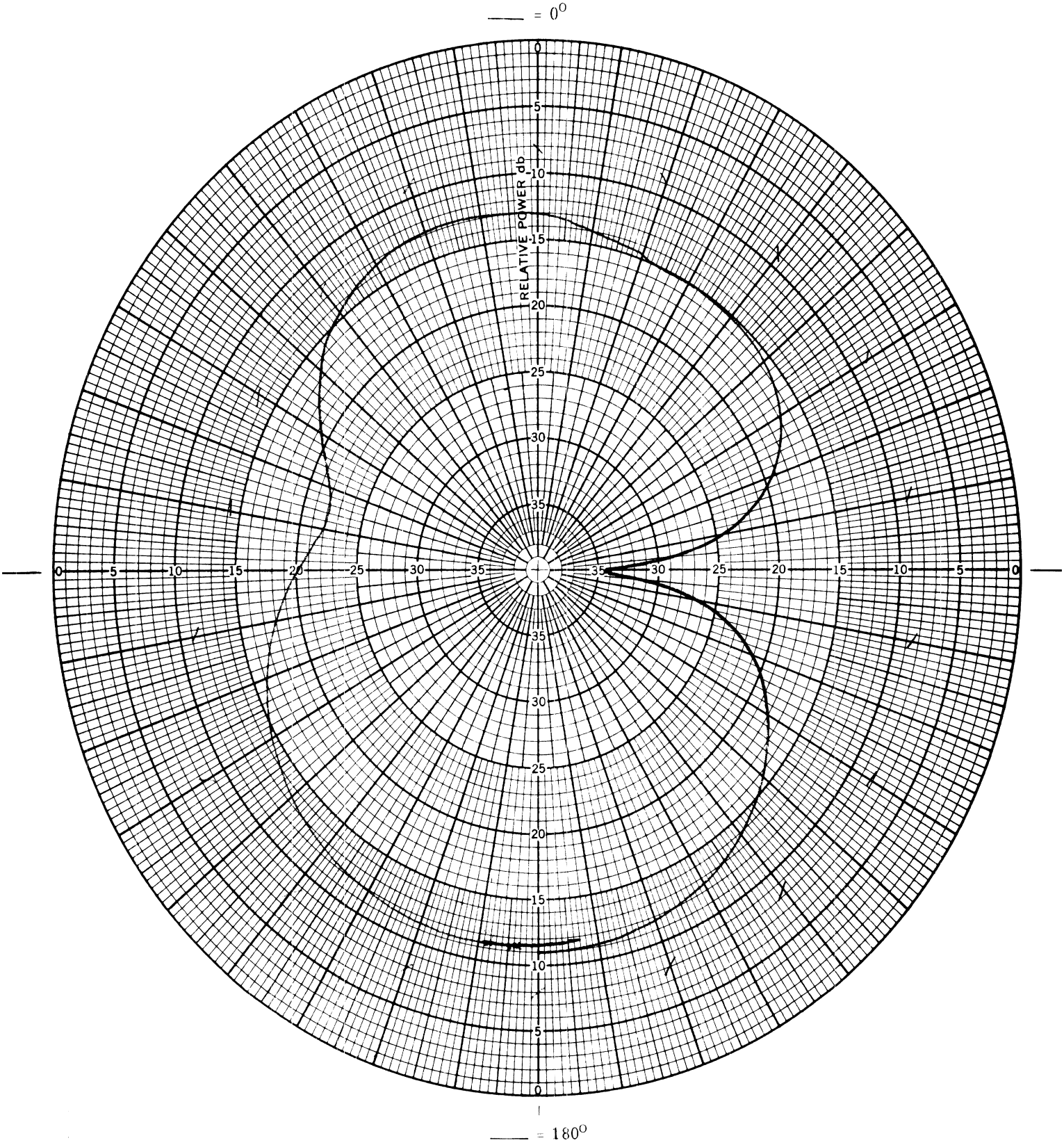

Fig. 27(a): Measured horizontal plane pattern of the side-fed heated backlite antenna mounted on Tempo body shell. Horizontal polarization, f = 72.0 MHz.

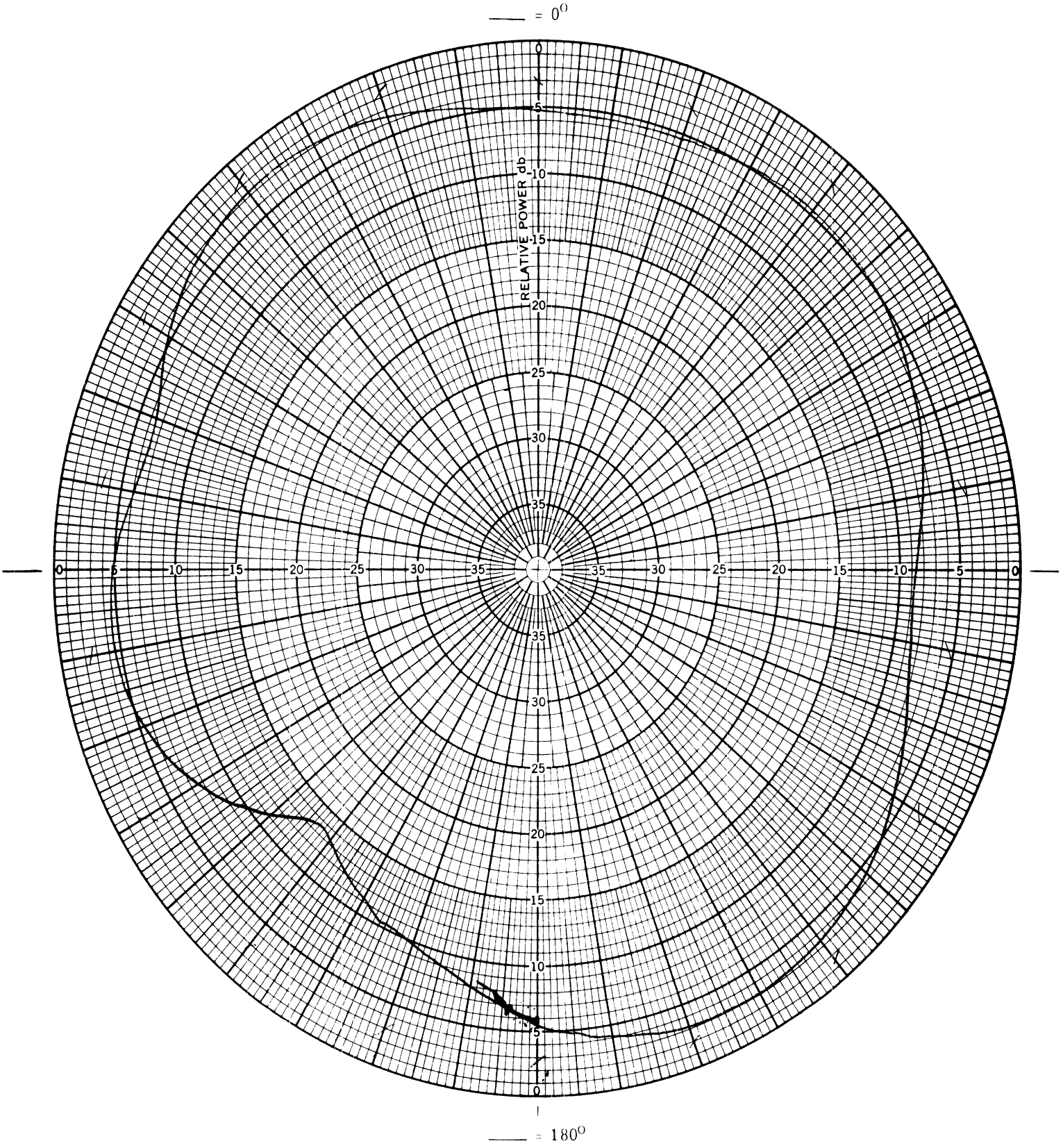

Fig. 27(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Horizontal polarization, f = 72.0 Mhz.

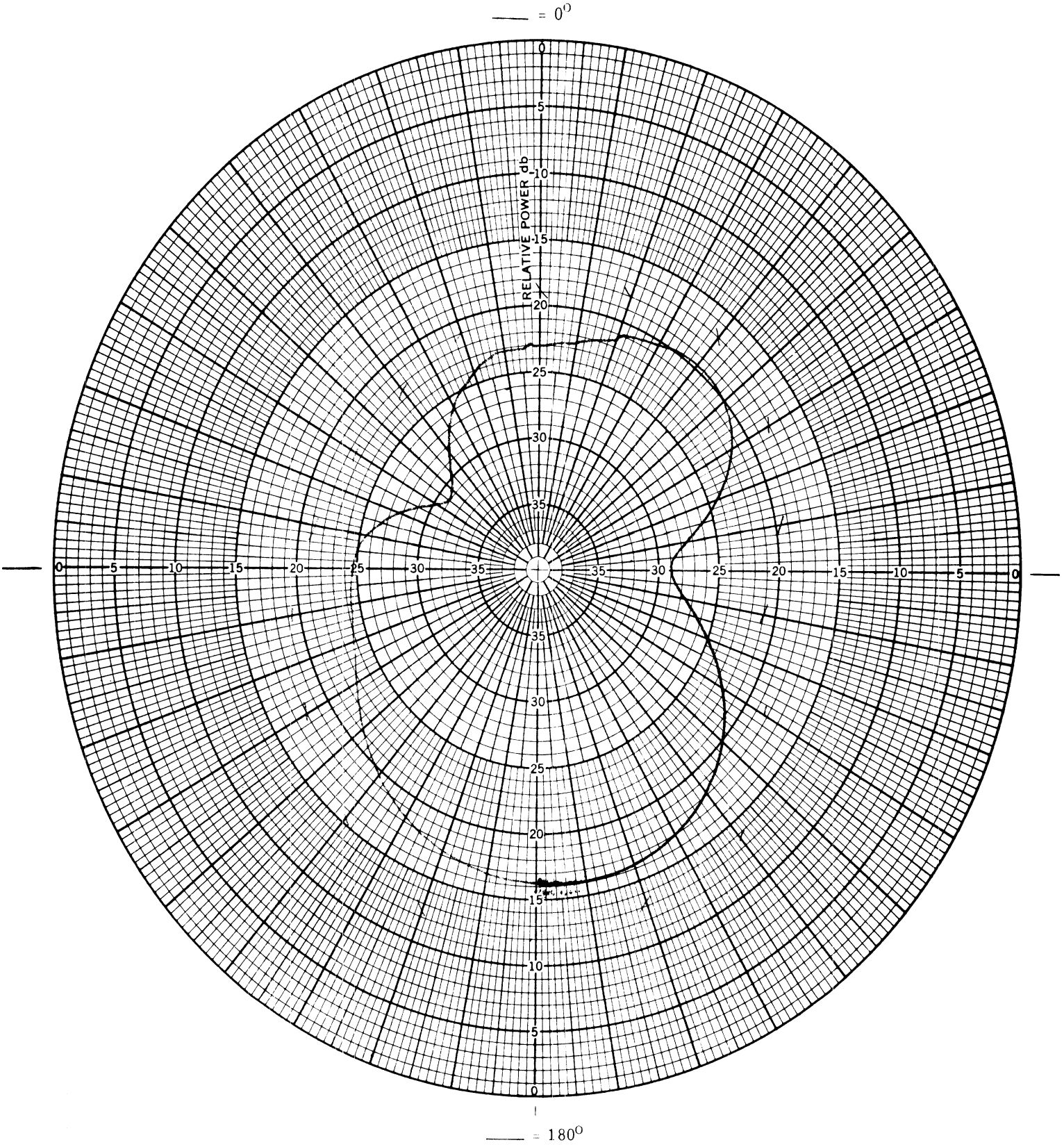

Fig. 28(a): Measured horizontal plane pattern of the side-fed heated backlite antenna mounted on Tempo body shell. Horizontal polarization, f = 88.0 MHz.

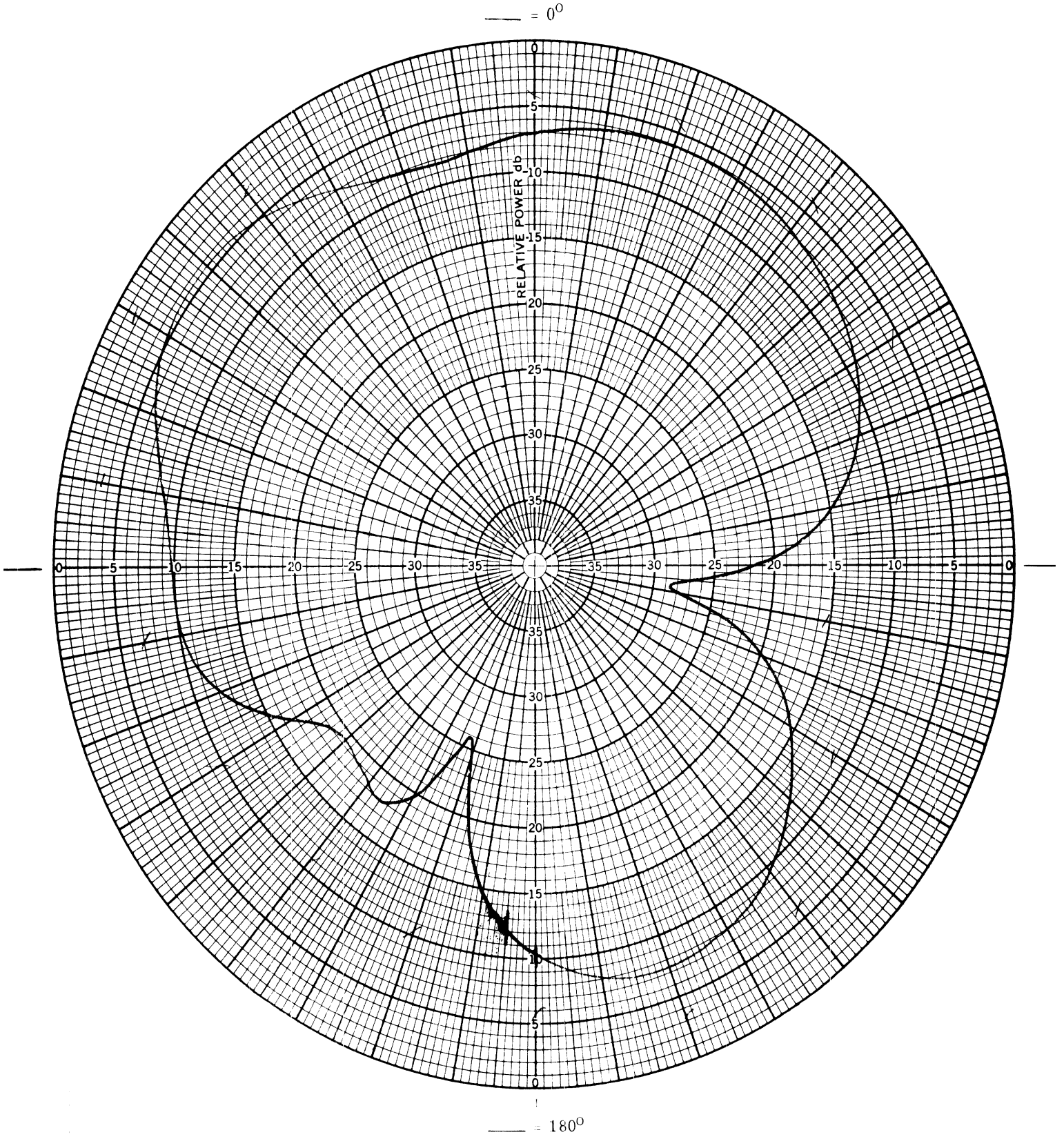

Fig. 28(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Horizontal polarization, f = 88.0 MHz.

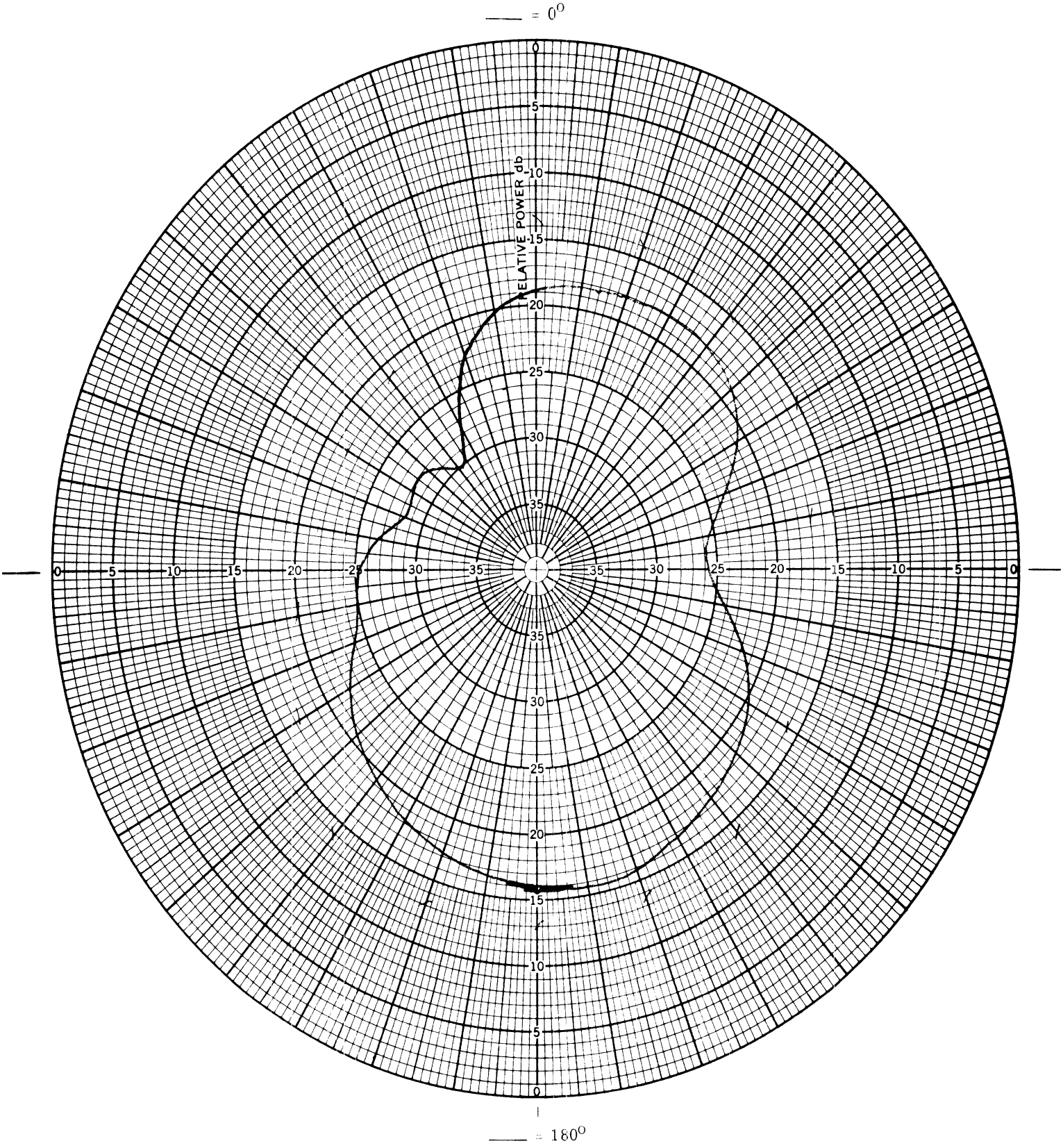

Fig. 29(a): Measured horizontal plane pattern of the side-fed heated backlite antenna mounted on Tempo body shell. Horizontal polarization, f = 98.0 MHz.

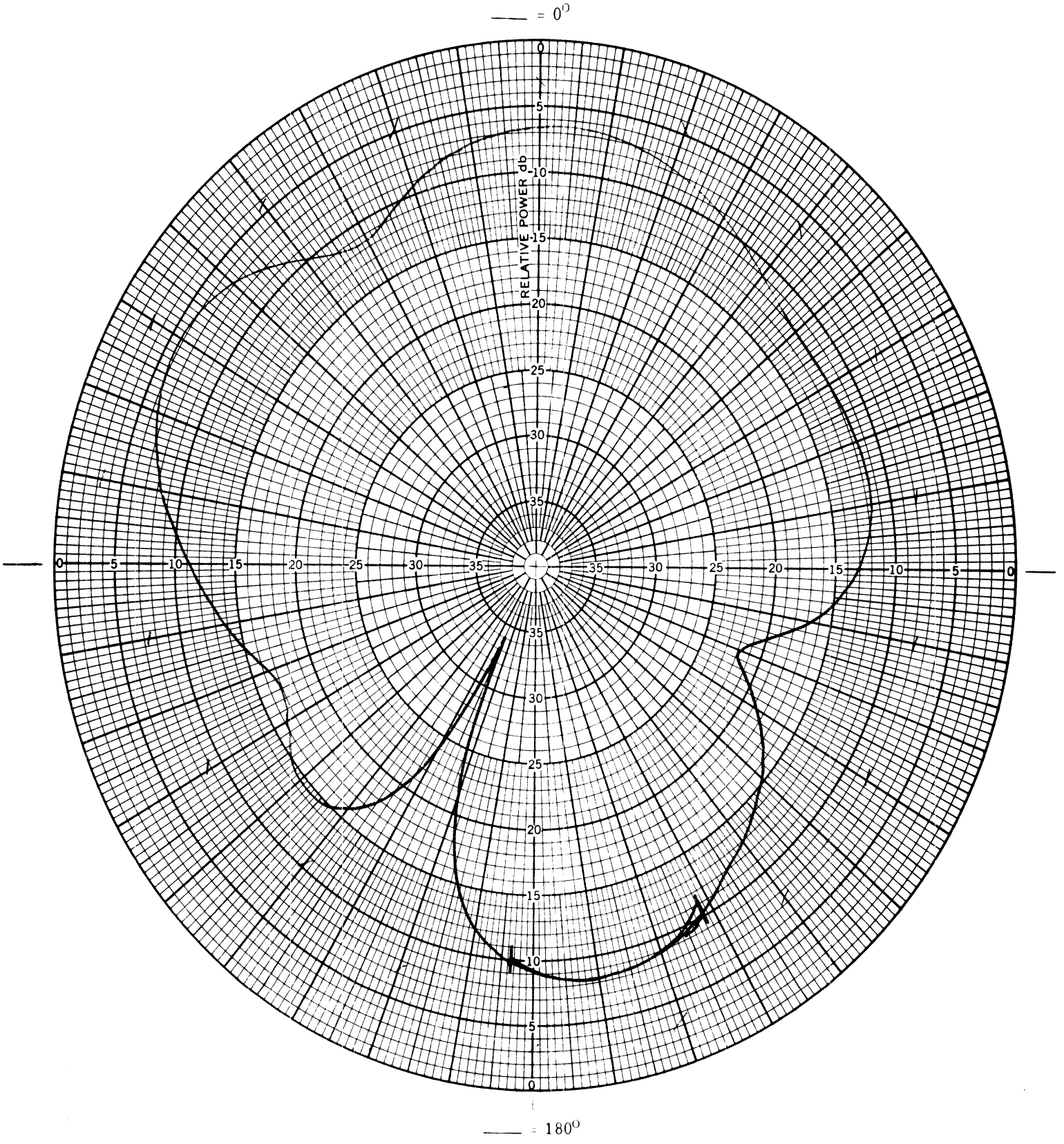

Fig. 29(b): Measured horizontal plane pattern of the side-fed heated backlite antenna mounted on Tempo body shell. Horizontal polarization, f = 98.0 MHz.

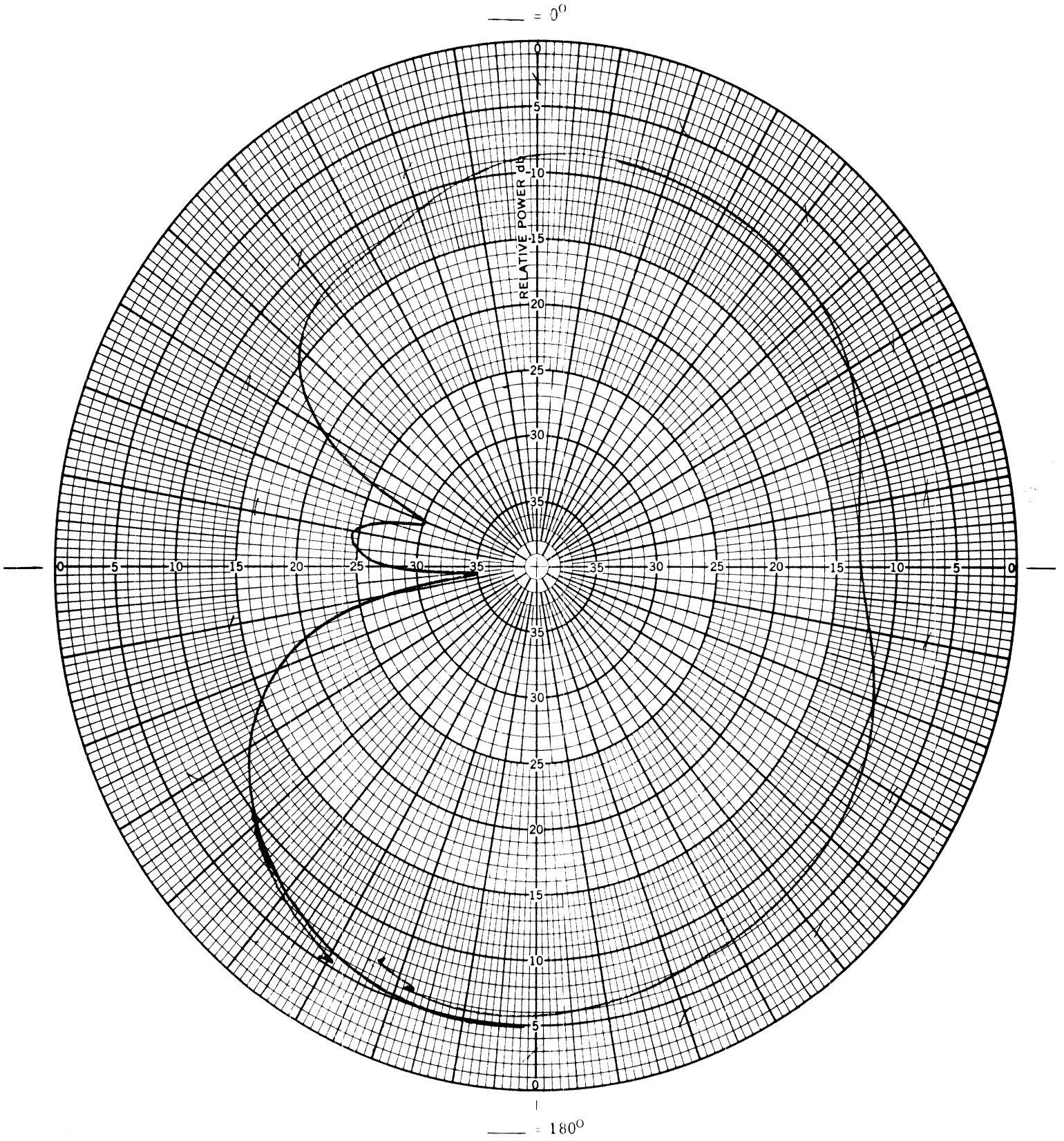

Fig. 30(a): Measured horizontal plane pattern of the side-fed heated backlite antenna mounted on Tempo body shell. Horizontal polarization, f = 108.5 MHz.

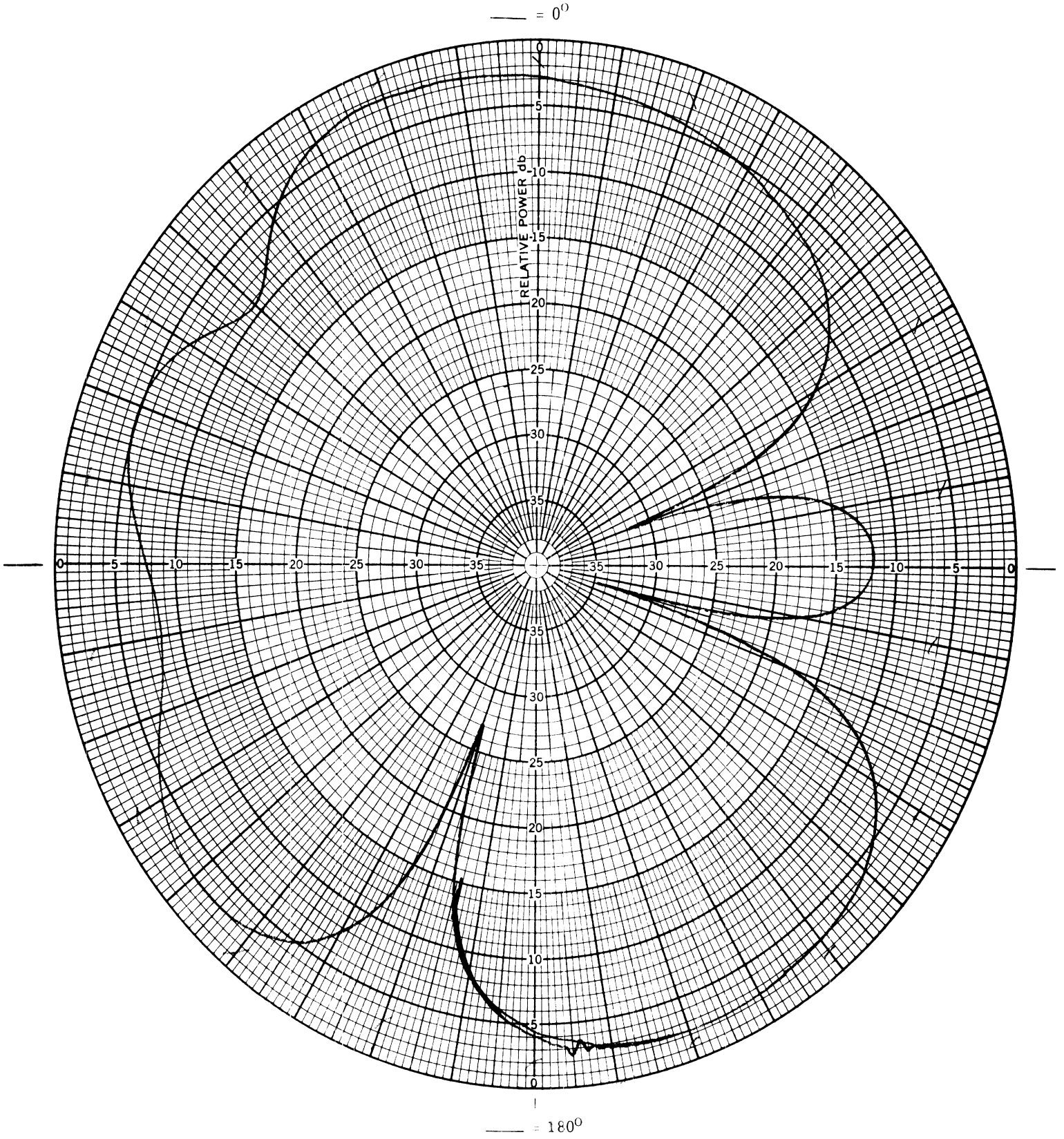

Fig. 30(b): Measured horizontal plane pattern of the side-fed heated backlite antenna mounted on Tempo body shell. Horizontal polarization, f = 108.5 MHz.

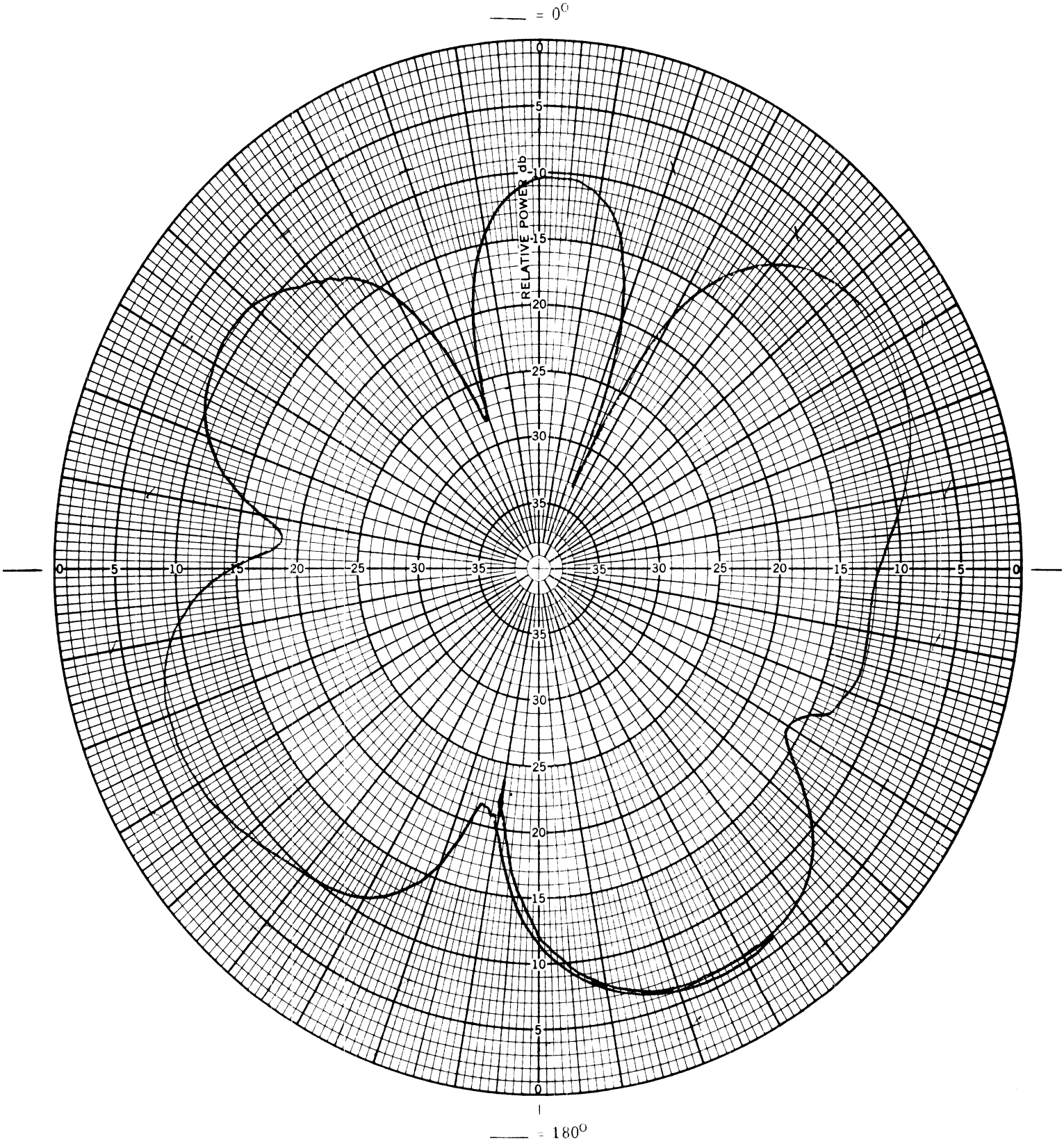

Fig. 31(a): Measured horizontal plane pattern of the side-fed heated backlite antenna mounted on Tempo body shell. Horizontal polarization, f = 180.0 MHz.

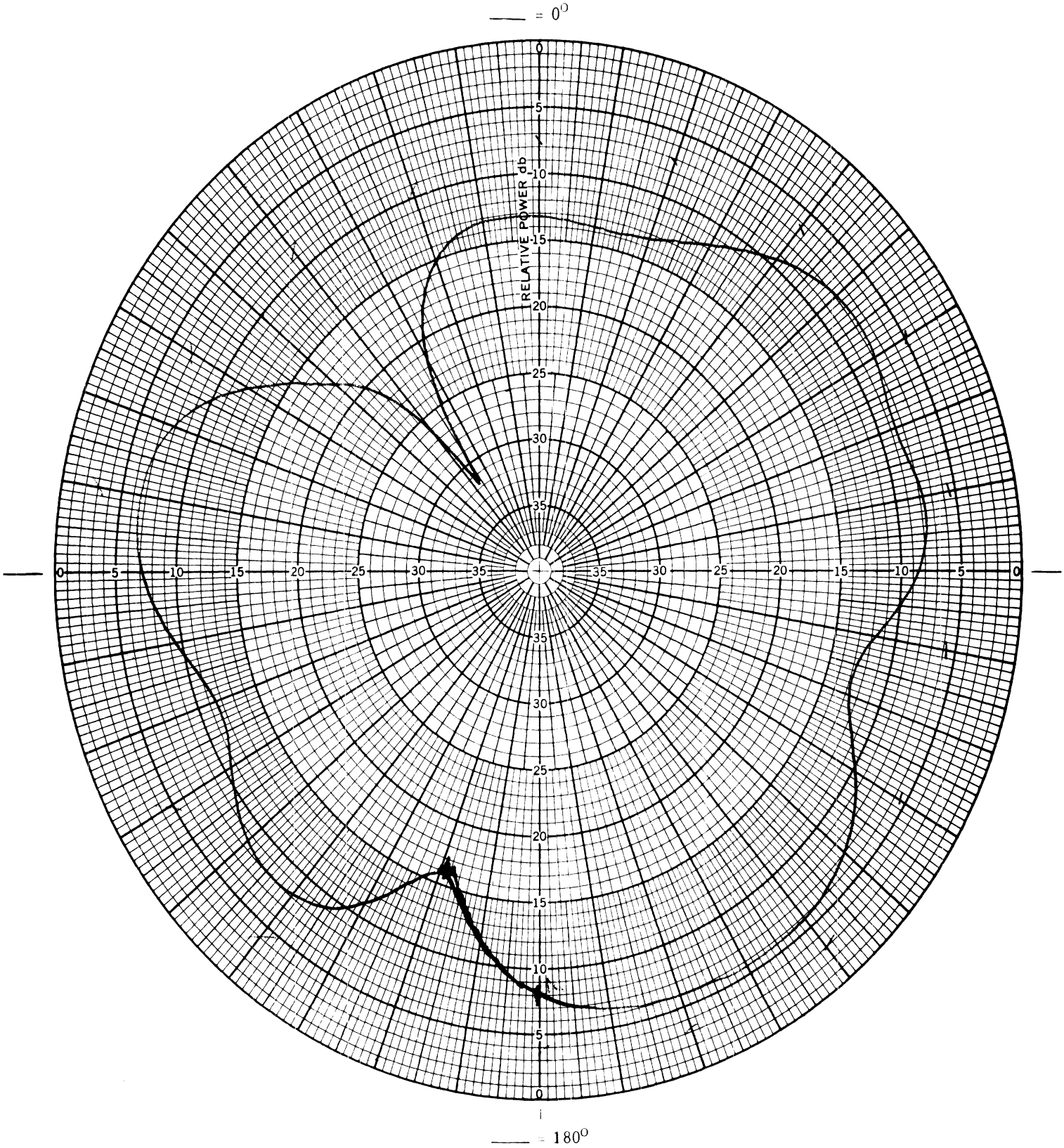

Fig. 31(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Horizontal polarization, f = 180.0 MHz.

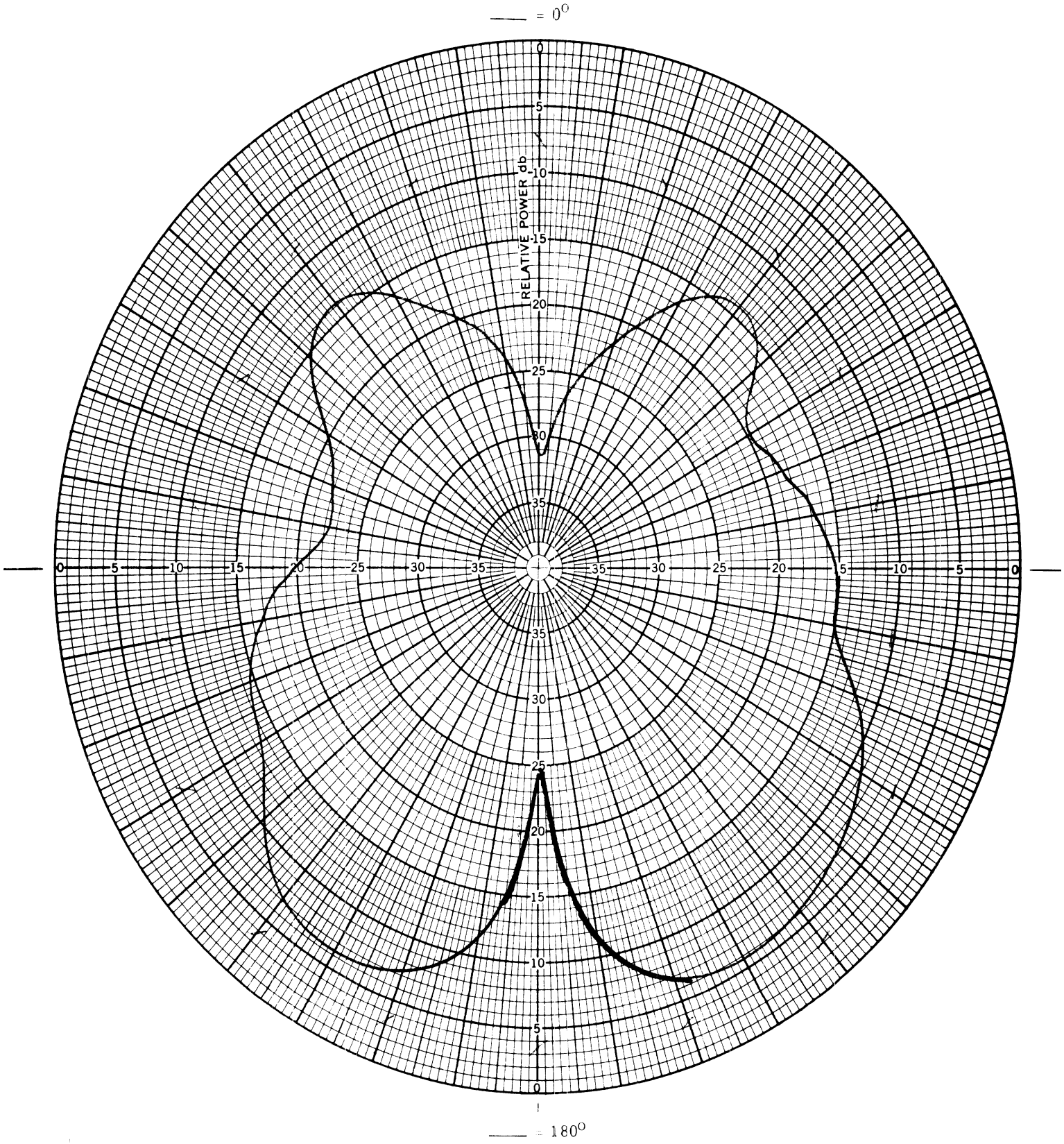

Fig. 32(a): Measured horizontal plane pattern of the side-fed heated backlite antenna mounted on Tempo body shell. Horizontal polarization, f = 215.0 MHz.

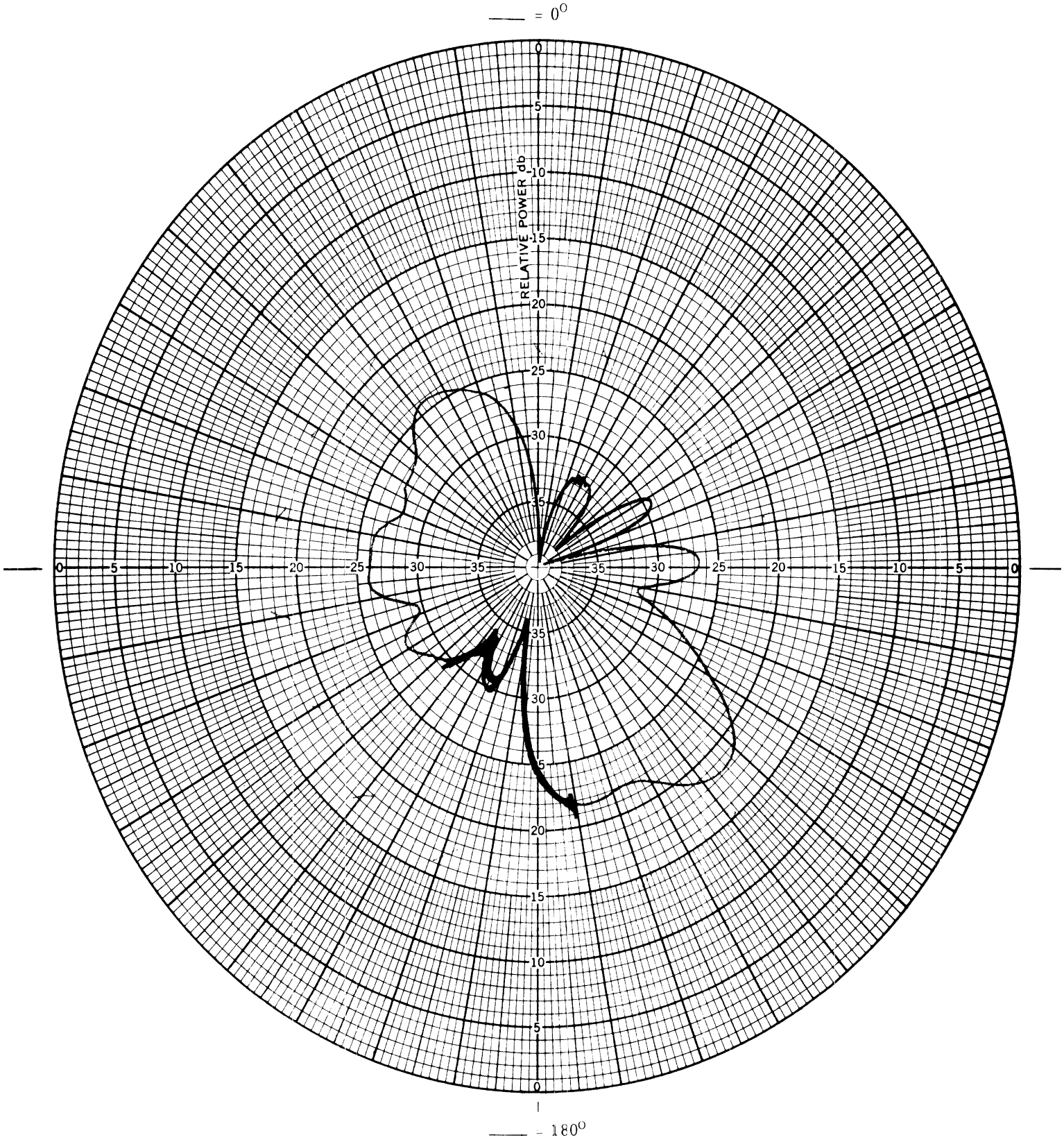

Fig. 32(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Horizontal polarization, f = 215.0 MHz.

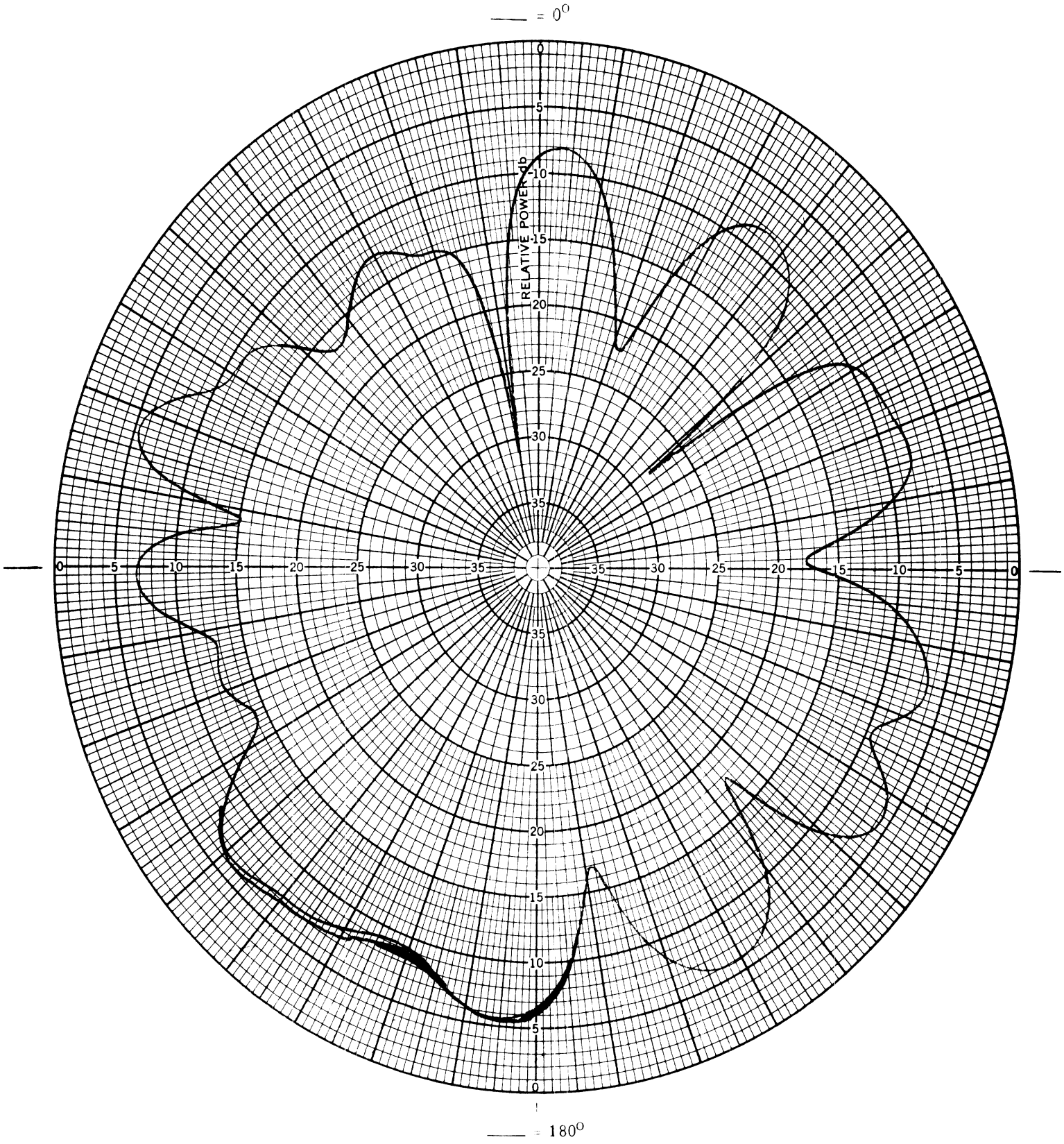

Fig. 33(a): Measured horizontal plane pattern of the side-fed heated backlite antennta mounted on Tempo body shell. Horizontal polarization, f = 475.0 MHz.

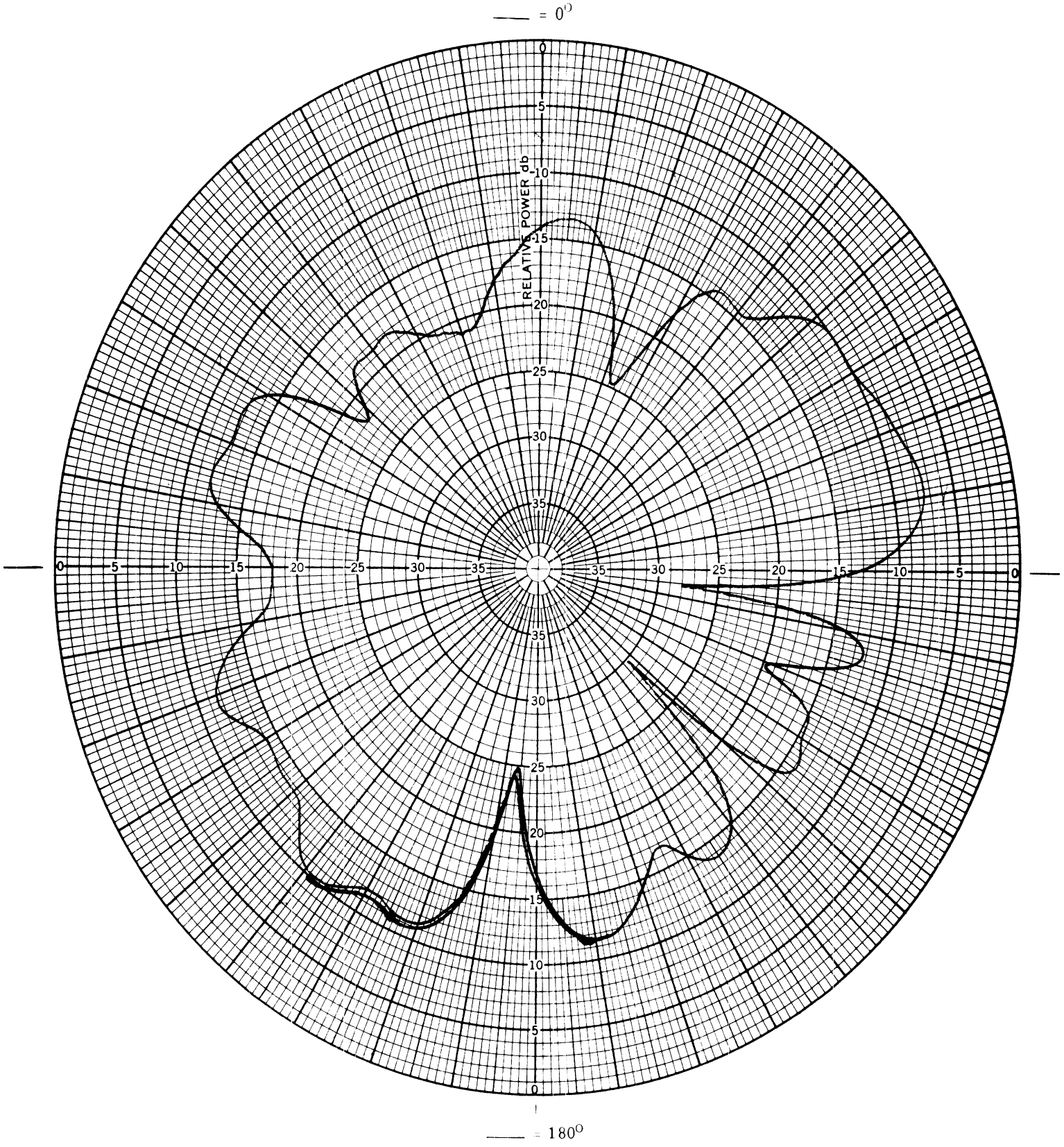

Fig. 33(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Horizontal polarization, f = 475.0 MHz.

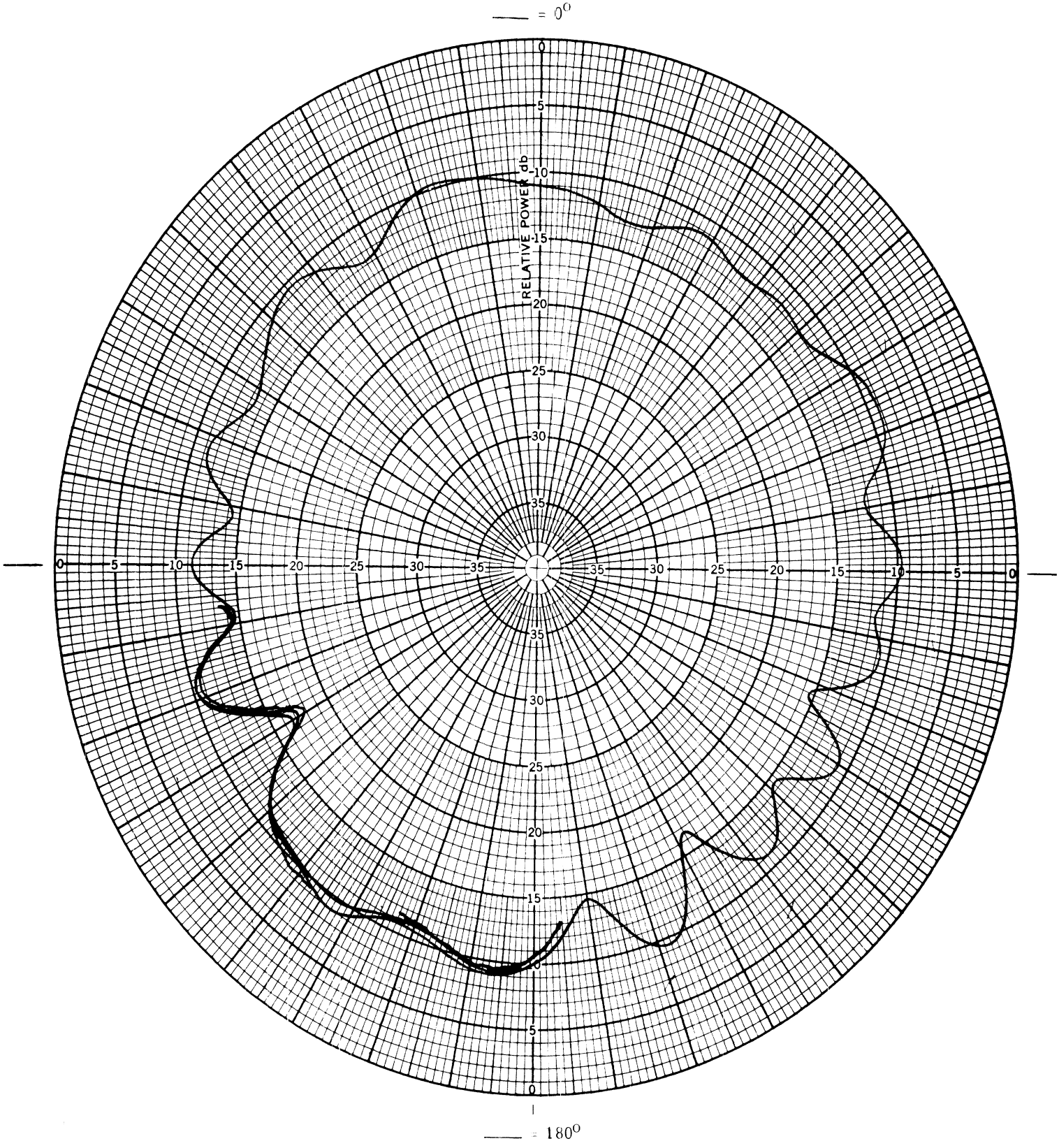

Fig. 34(a): Measured horizontal plane pattern of the side-fed heated backlite antenna mounted on Tempo body shell. Horizontal polarization, f = 637.0 MHz.

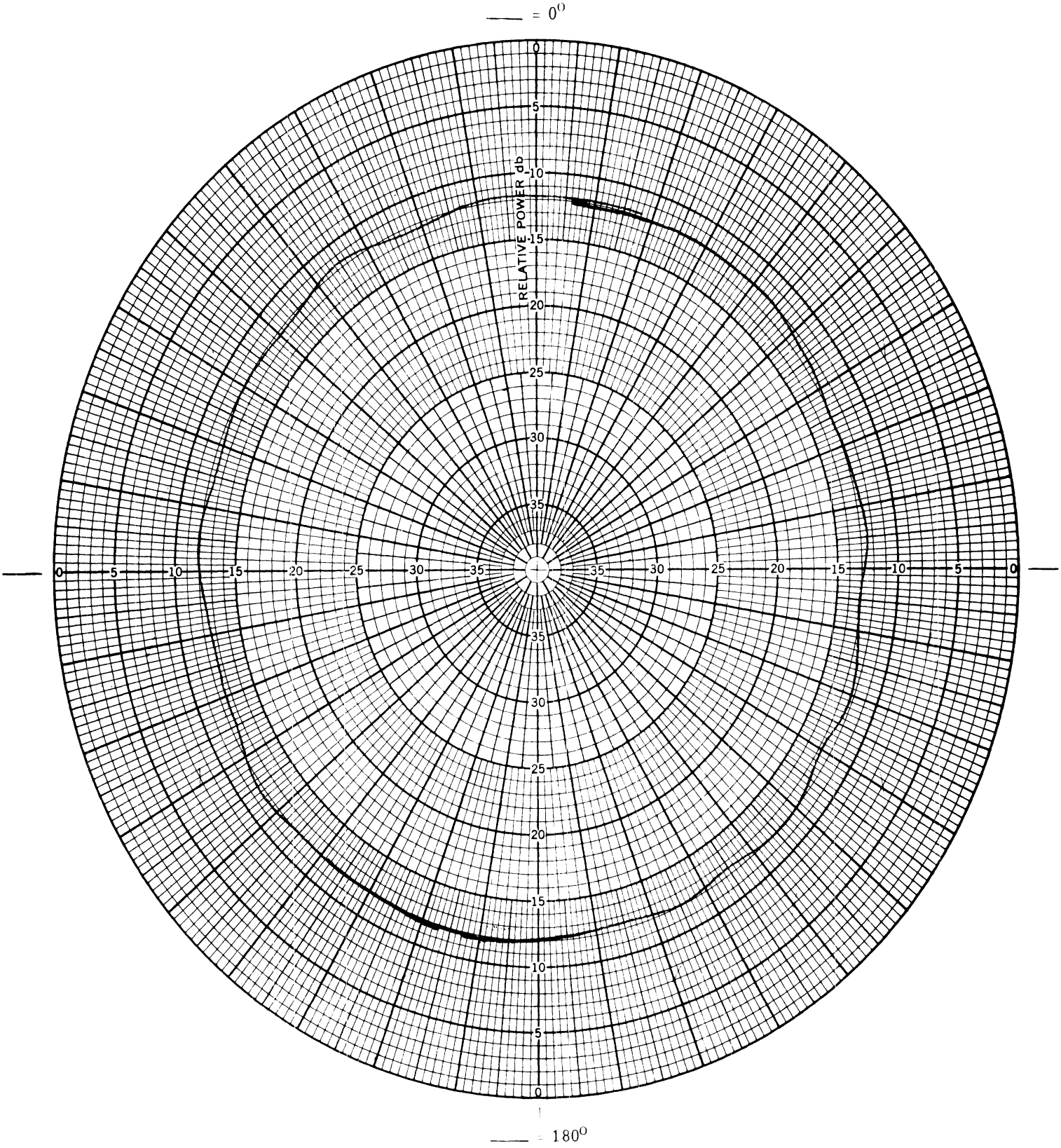

Fig. 34(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Horizontal polarization, f = 637.0 MHz.

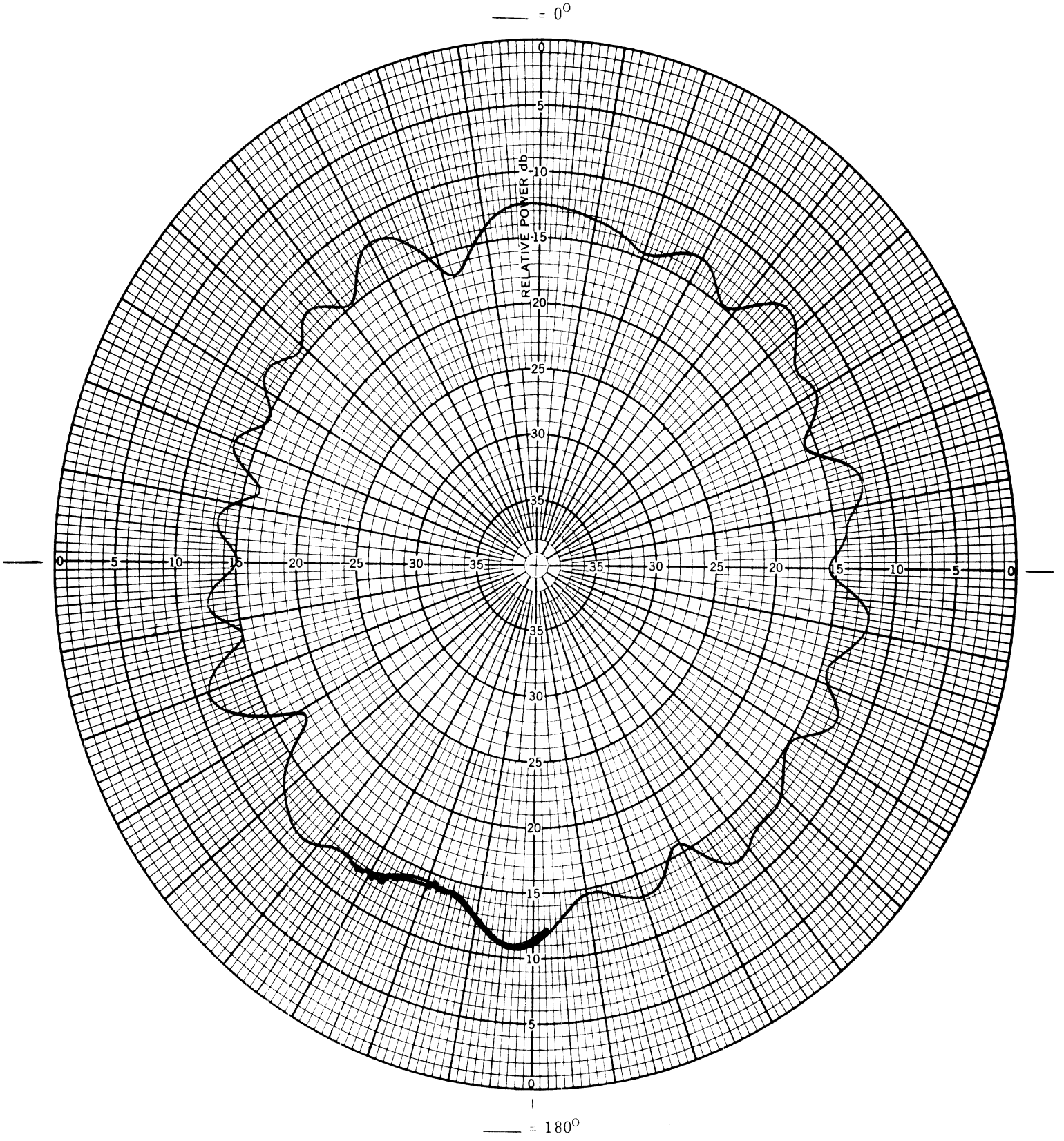

Fig. 35(a): Measured horizontal plane pattern of the side-fed heated backlite antenna mounted on Tempo body shell. Horizontal polarization, f = 825 MHz.

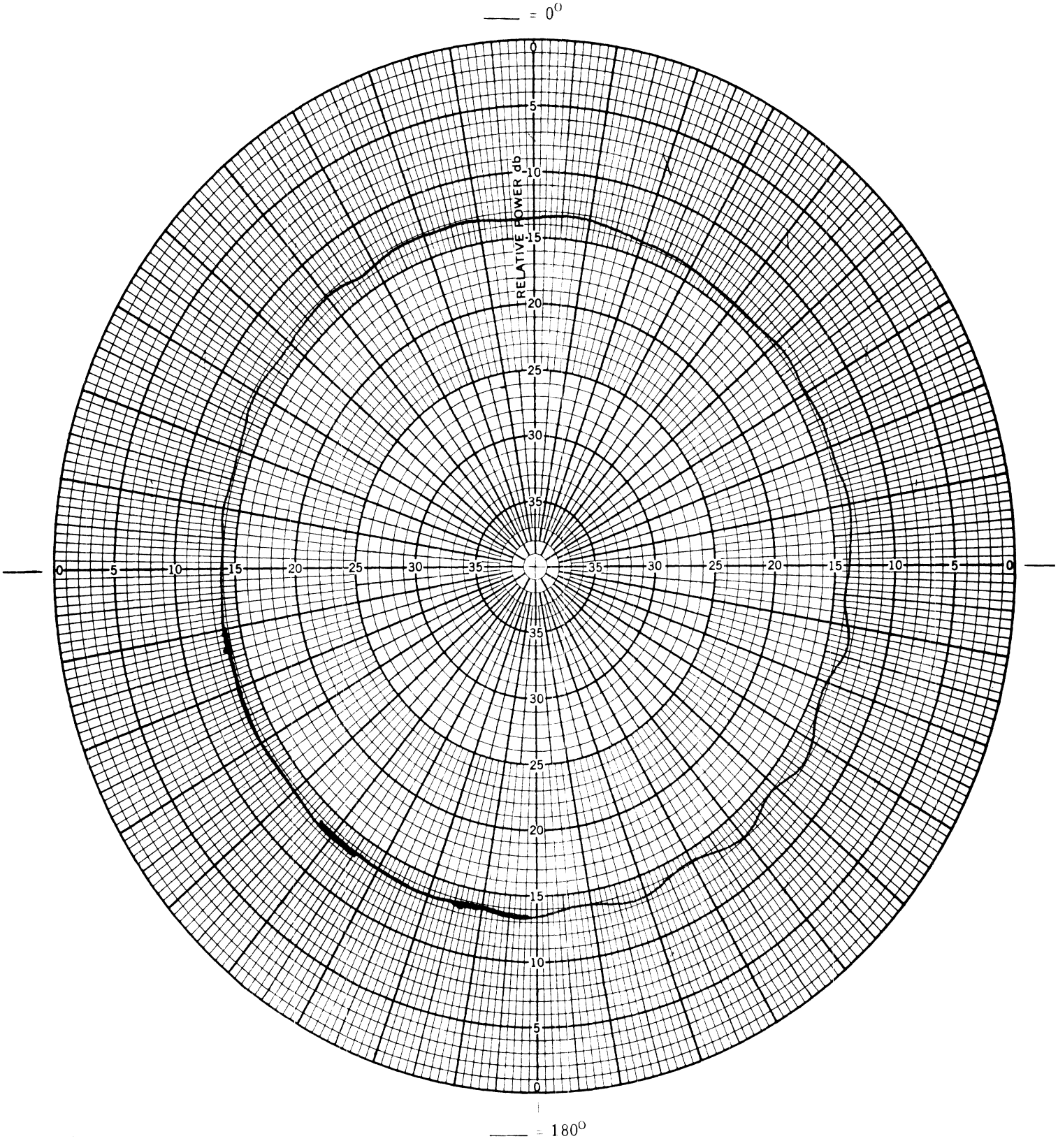

Fig. 35(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Horizontal polarization, f = 825 MHz.

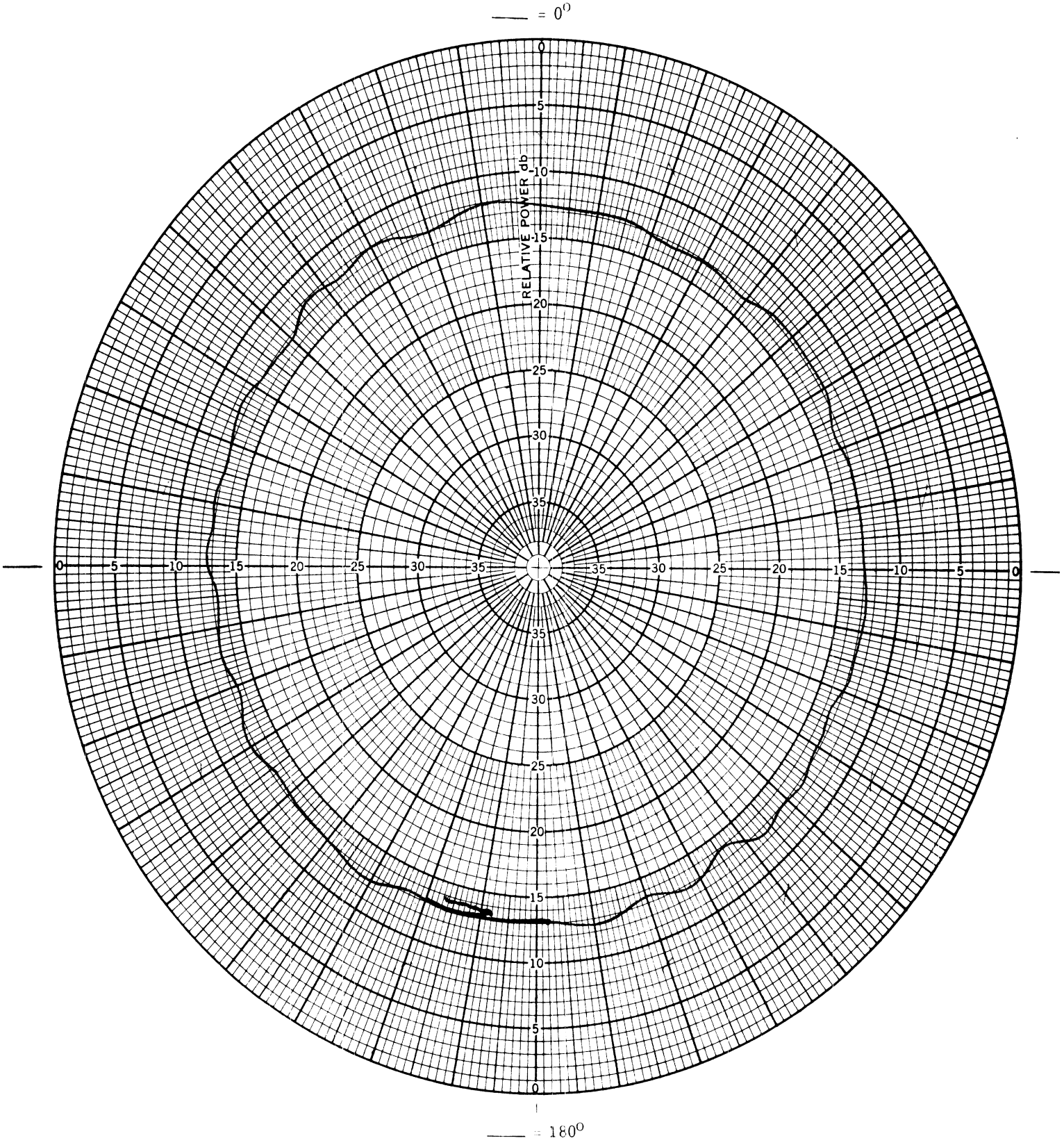

Fig. 36(a): Measured horizontal plane pattern of the side-fed heated backlite antenna mounted on Tempo body shell. Horizontal polarization, f = 890 MHz.

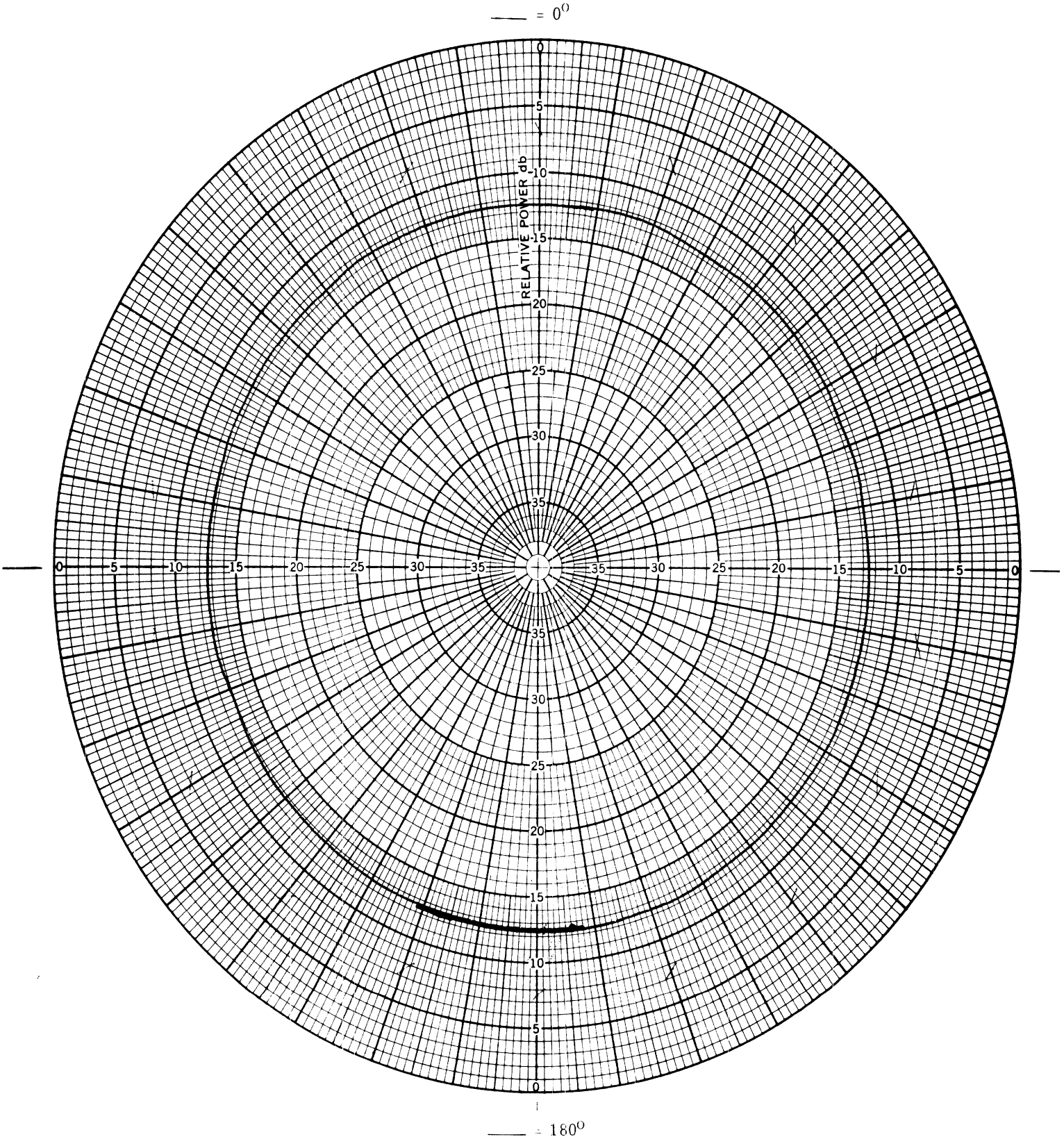

Fig. 36(b): Measured horizontal plane pattern of the side-fed heated backlite antenna mounted on Tempo body shell. Horizontal polarization, f = 890 MHz.

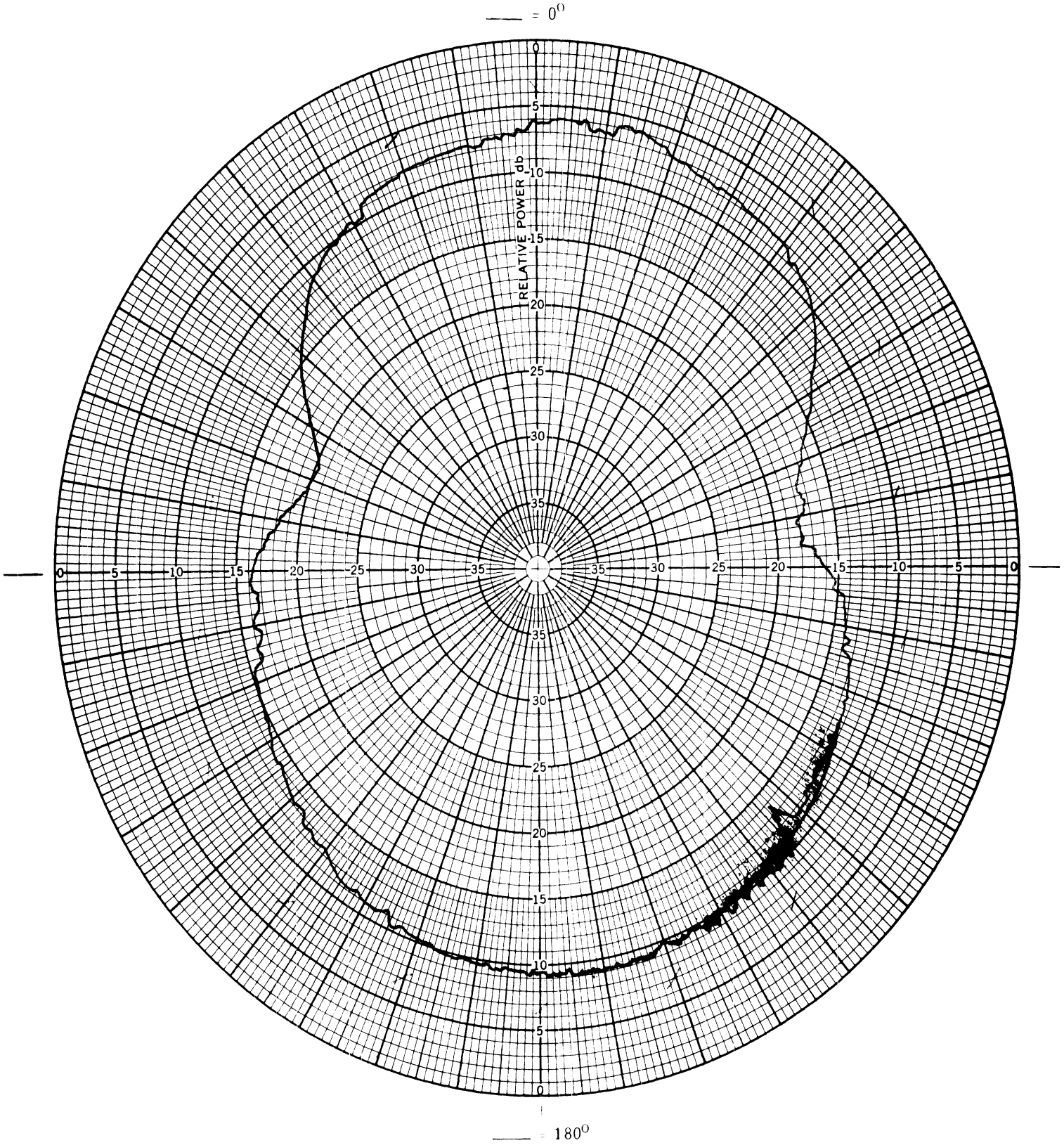

Fig. 37(a): Measured horizontal plane pattern of the bottom-fed heated backlite antenna mounted on Tempo body shell. Vertical polarization, f = 60.0 MHz.

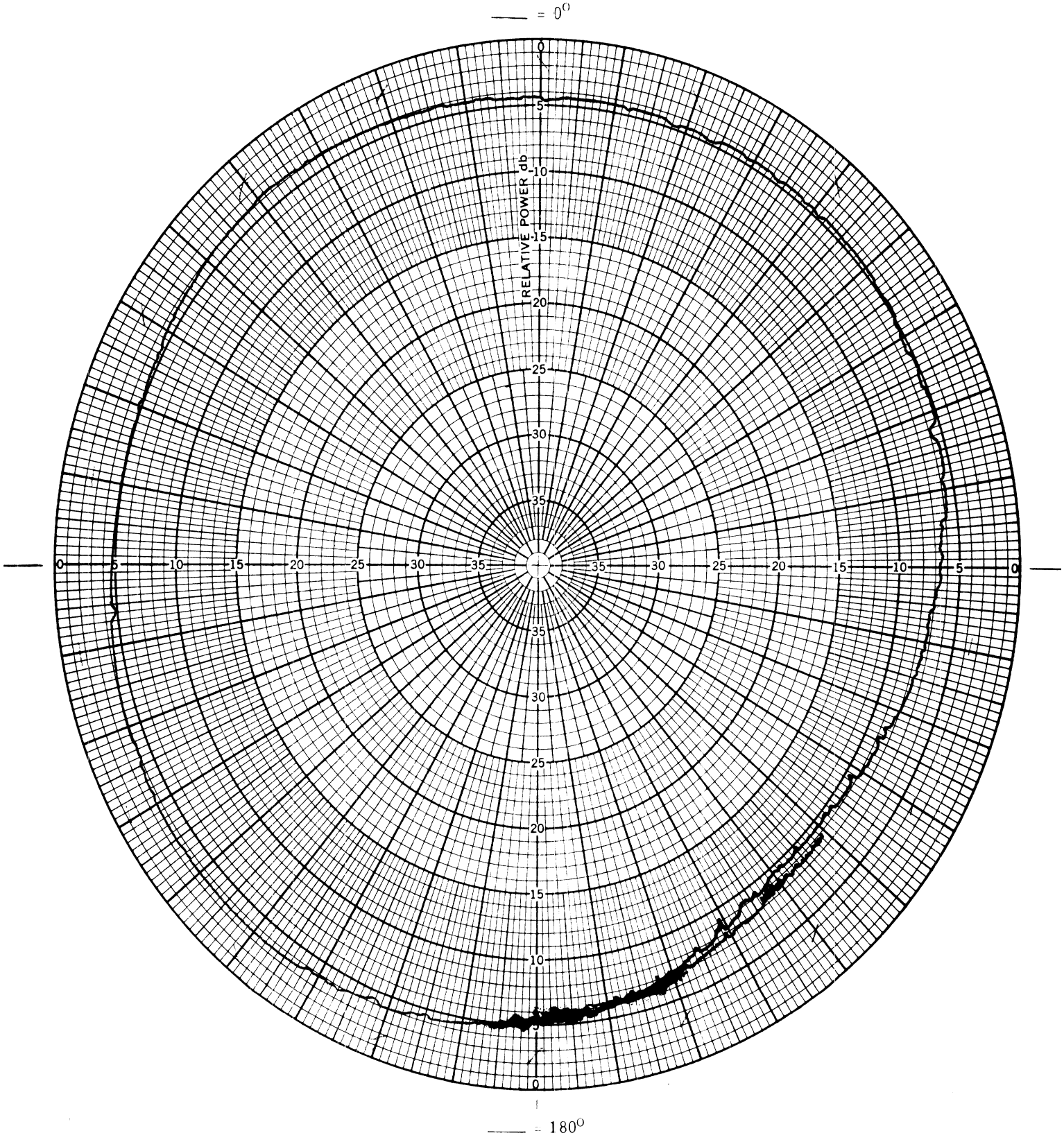

Fig. 37(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Vertical polarization, f = 60.0 MHz.

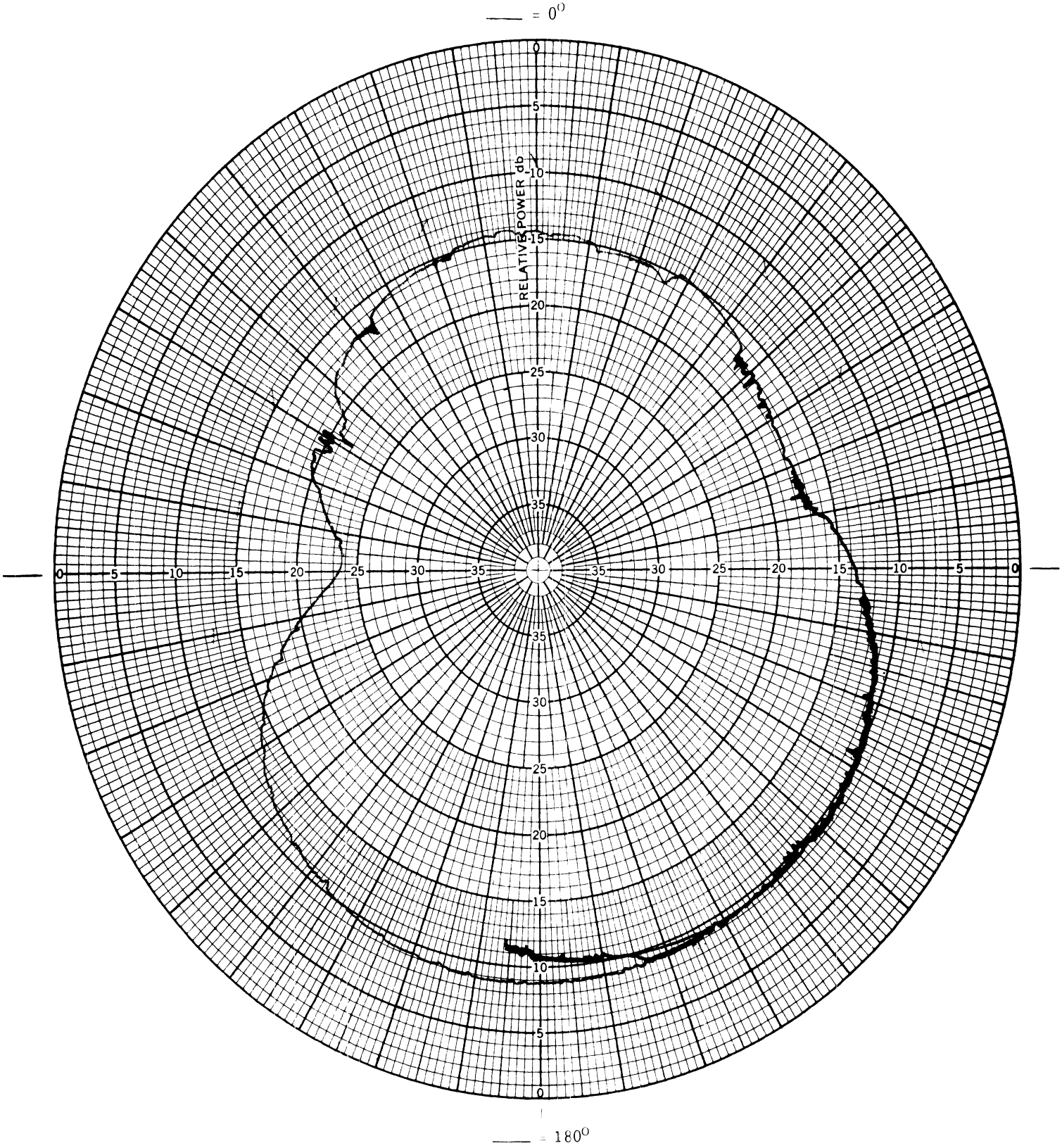

Fig. 38(a): Measured horizontal plane pattern of the bottom-fed heated backlite antenna mounted on Tempo body shell. Vertical polarization, f = 71.5 MHz.

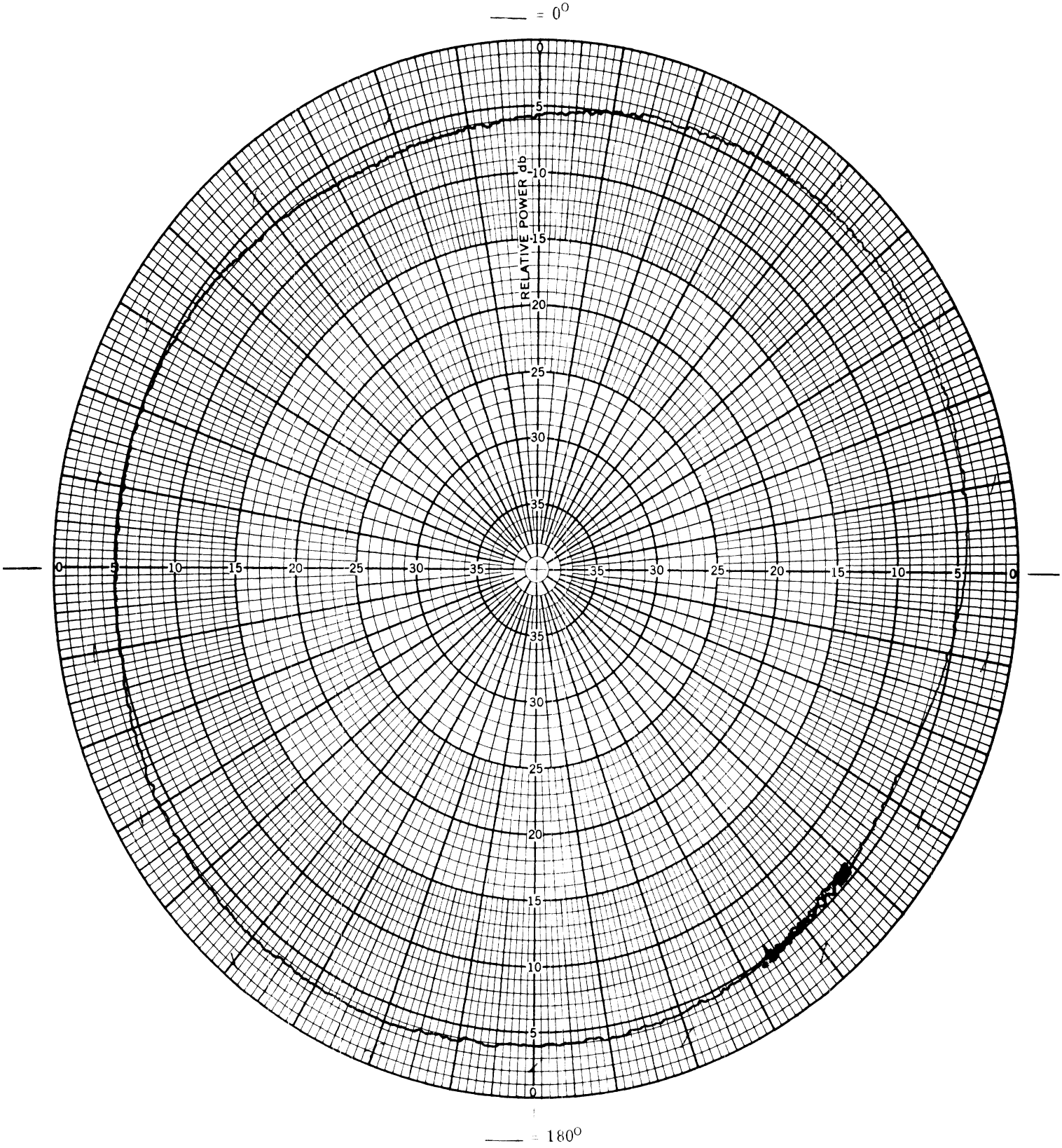

Fig. 38(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Vertical polarization, f = 71.5 MHz.

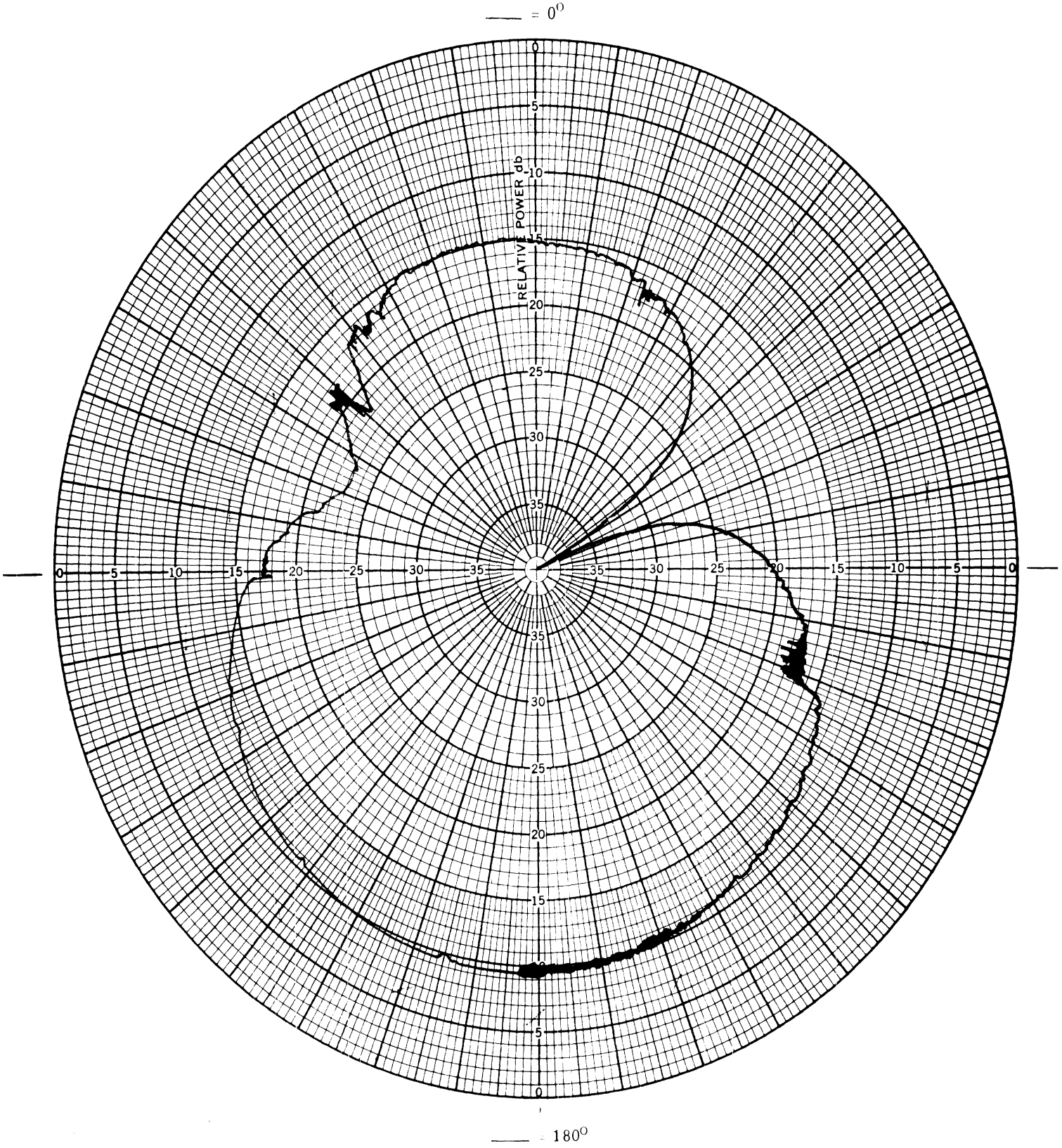

Fig. 39(a): Measured horizontal plane pattern of the bottom-fed heated backlite antenna mounted on Tempo body shell. Vertical polarization, f = 87.7 MHz.

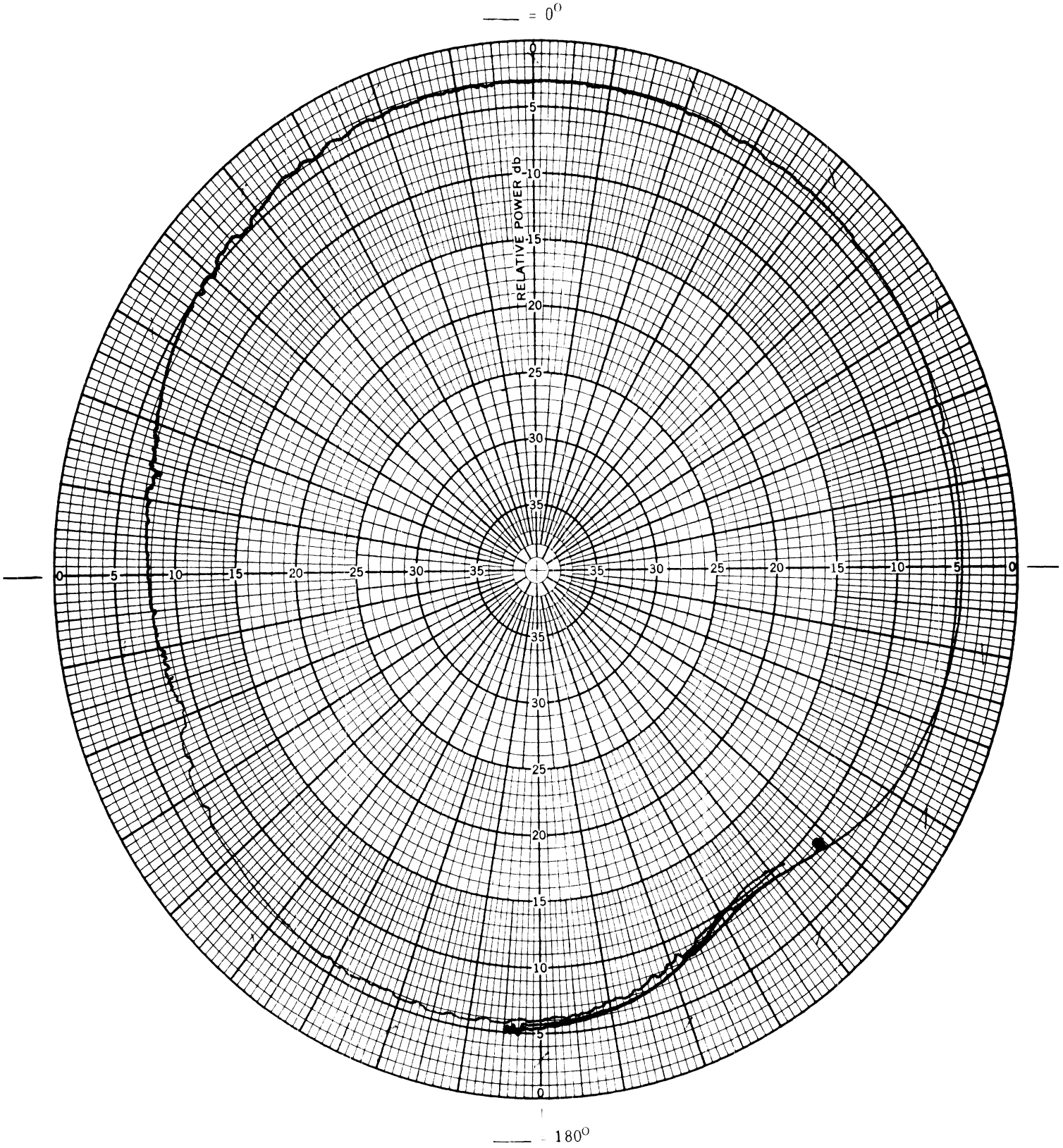

Fig. 39(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Vertical polarization, f = 87.7 MHz.

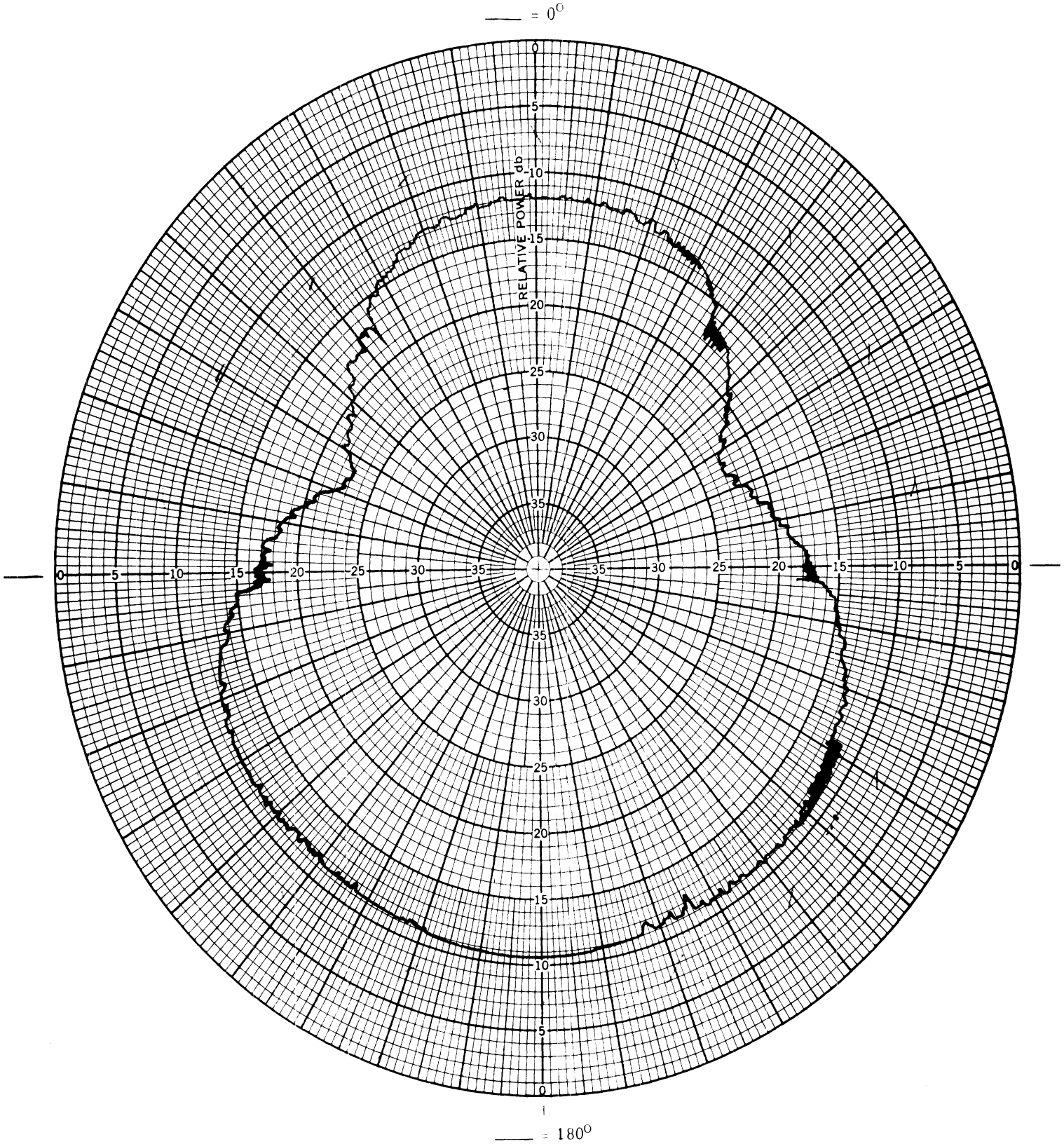

Fig. 40(a): Measured horizontal plane pattern of the bottom-fed heated backlite antenna mounted on Tempo body shell. Vertical polarization, f = 97.8 MHz.

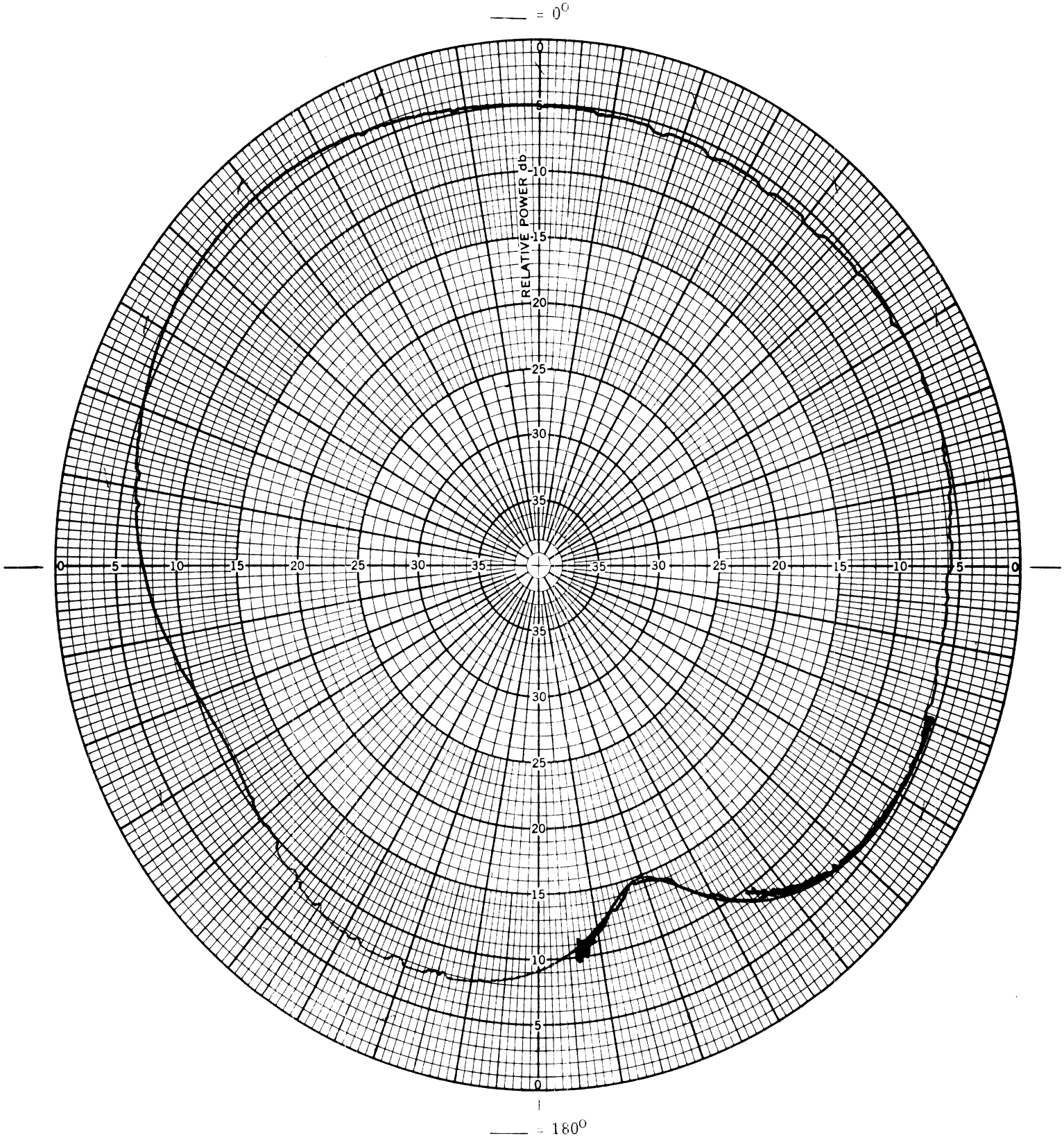

Fig. 40(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Vertical polarization, f = 97.8 MHz.

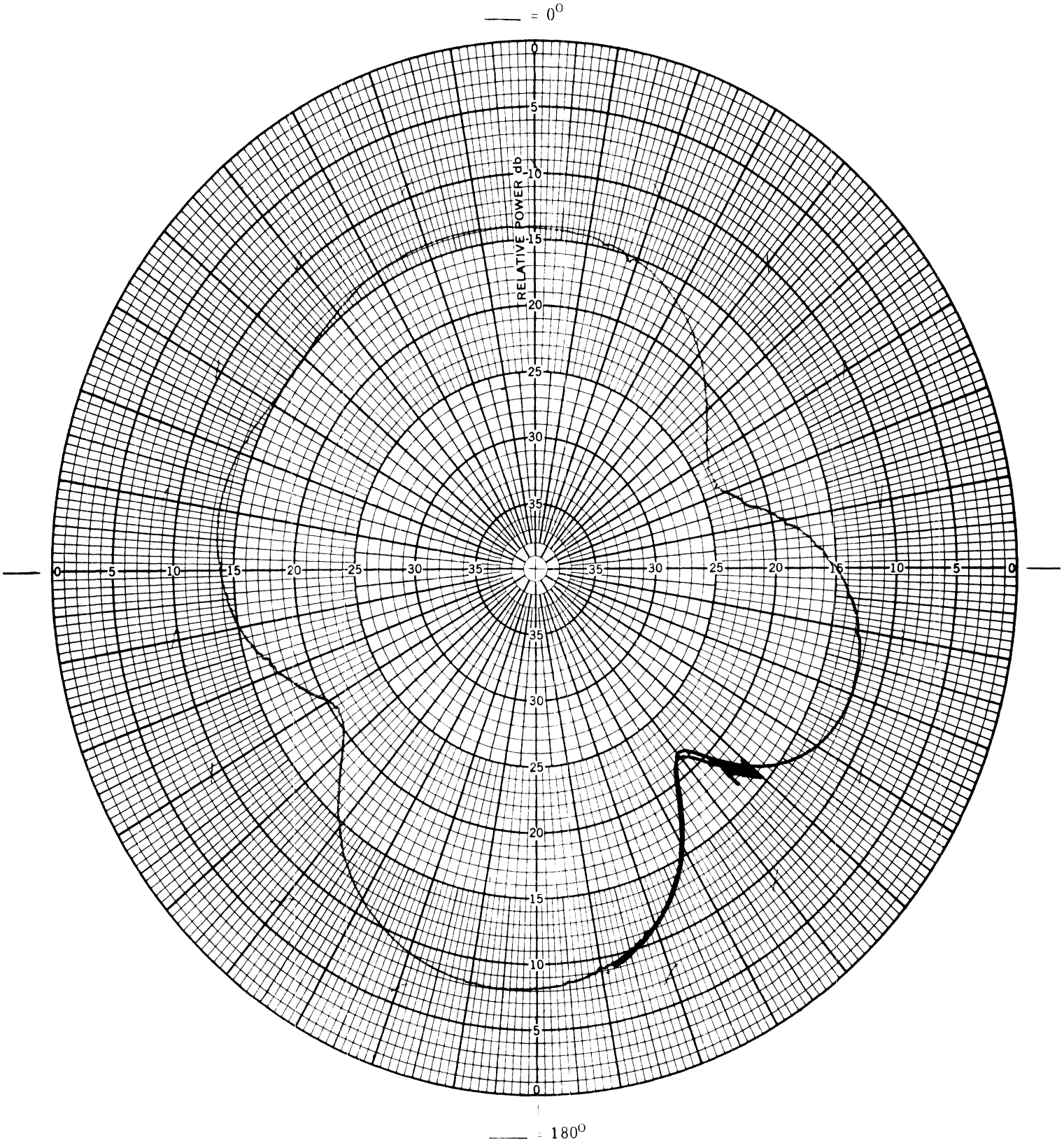

Fig. 41(a): Measured horizontal plane pattern of the botton-fed heated backlite antenna mounted on Tempo body shell. Vertical polarization, f = 108.0 MHz.

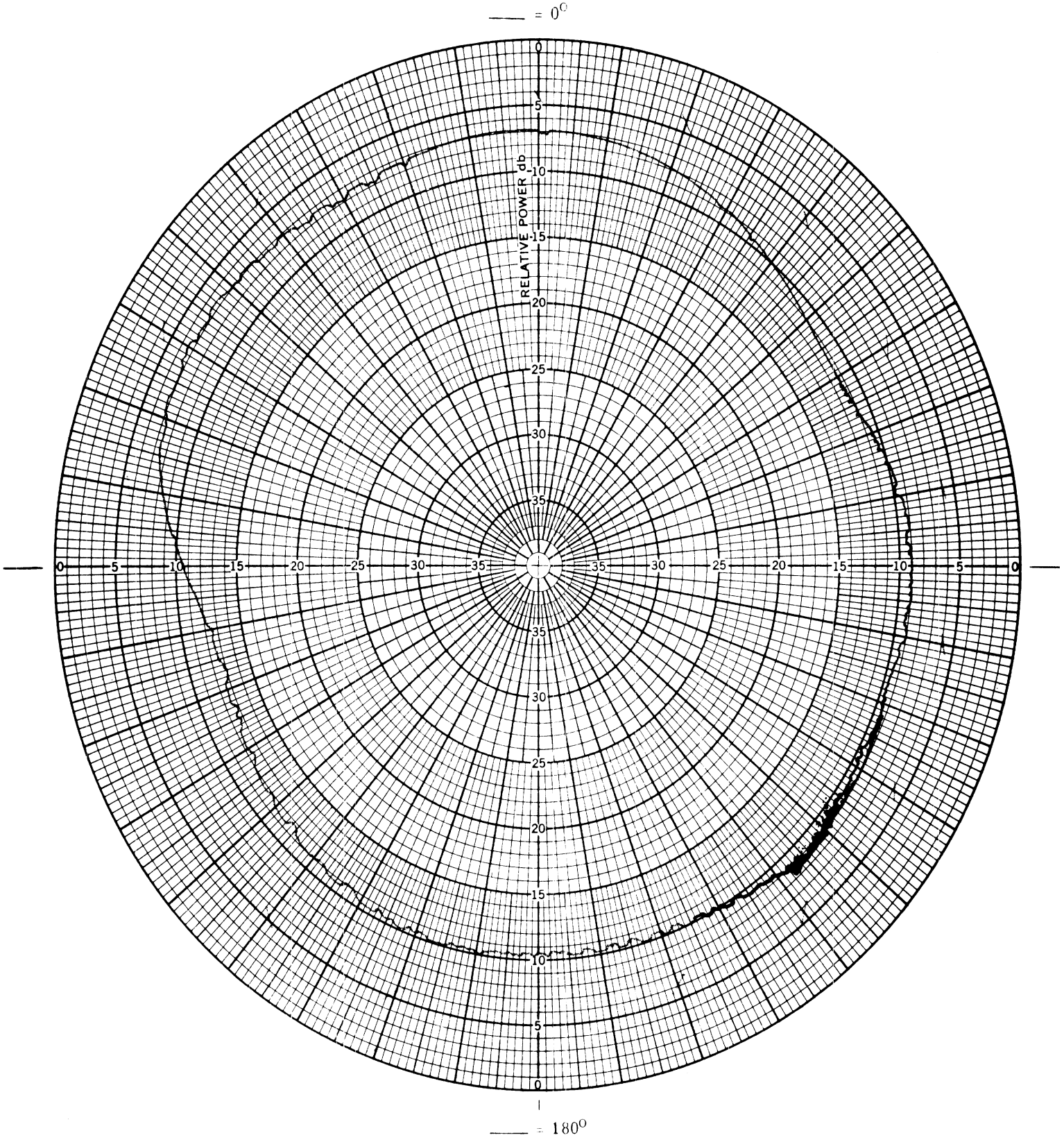

Fig. 41(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Vertical polarization, f = 108.0 MHz.

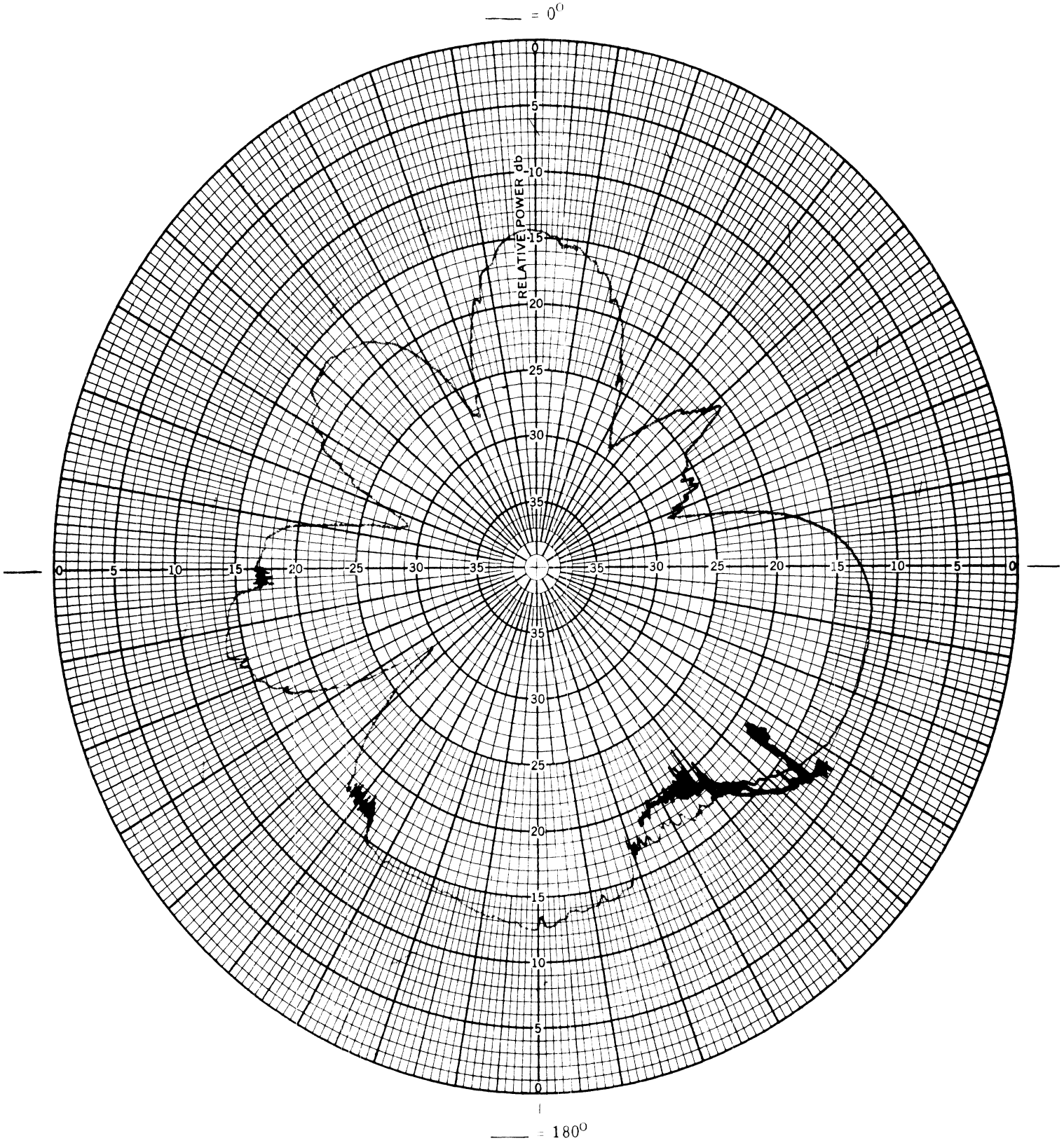

Fig. 42(a): Measured horizontal plane pattern of the bottom-fed heated backlite antenna mounted on Tempo body shell. Vertical polarization, f = 178.0 MHz.

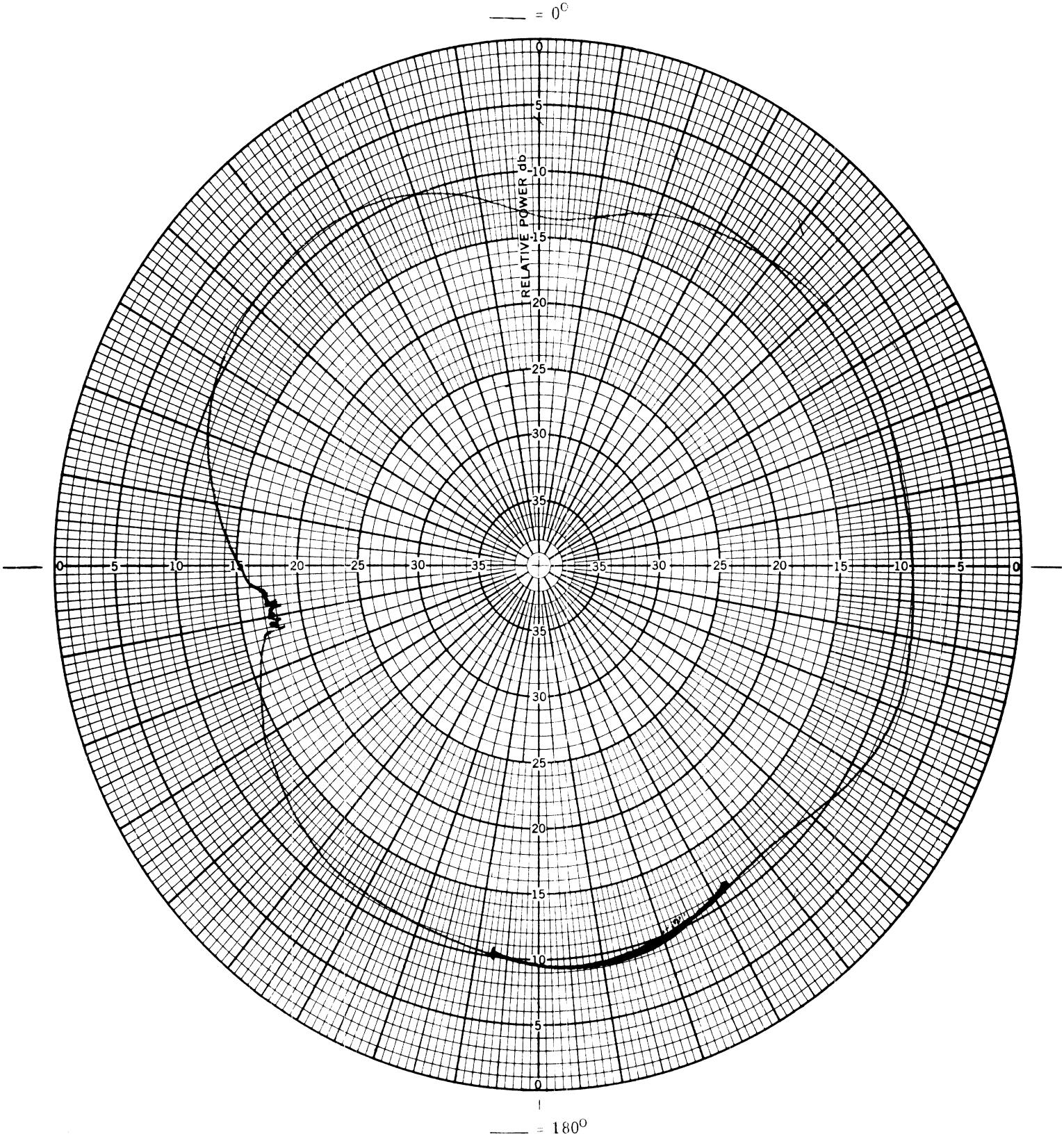

Fig. 42(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Vertical polarization, f = 178.0 MHz.

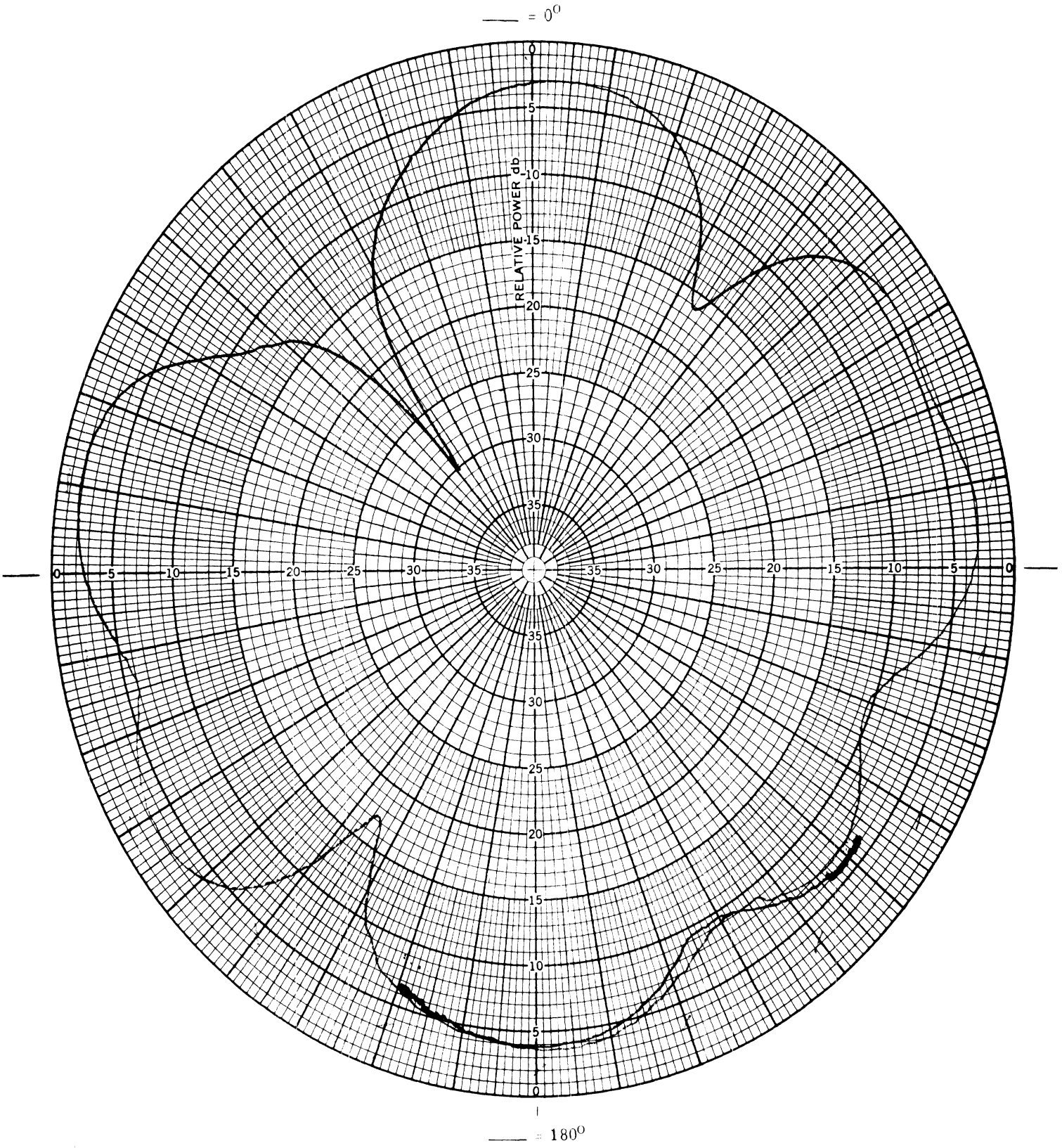

Fig. 43(a): Measured horizontal plane pattern of the bottom-fed heated backlite antenna mounted on Tempo body shell. Vertical polarization, f = 215.0 MHz.

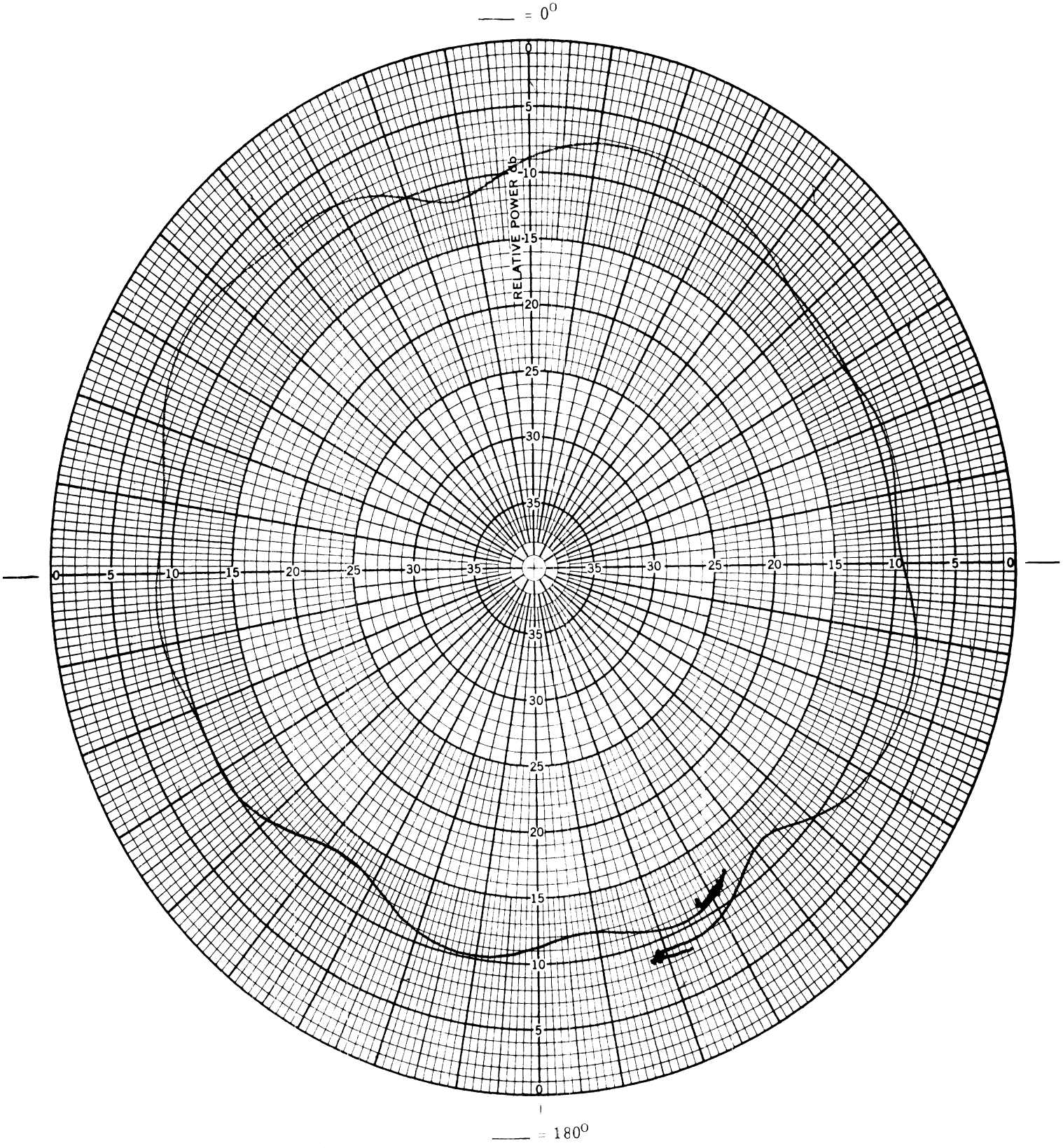

Fig. 43(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Vertical polarization, f = 215.0 MHz.

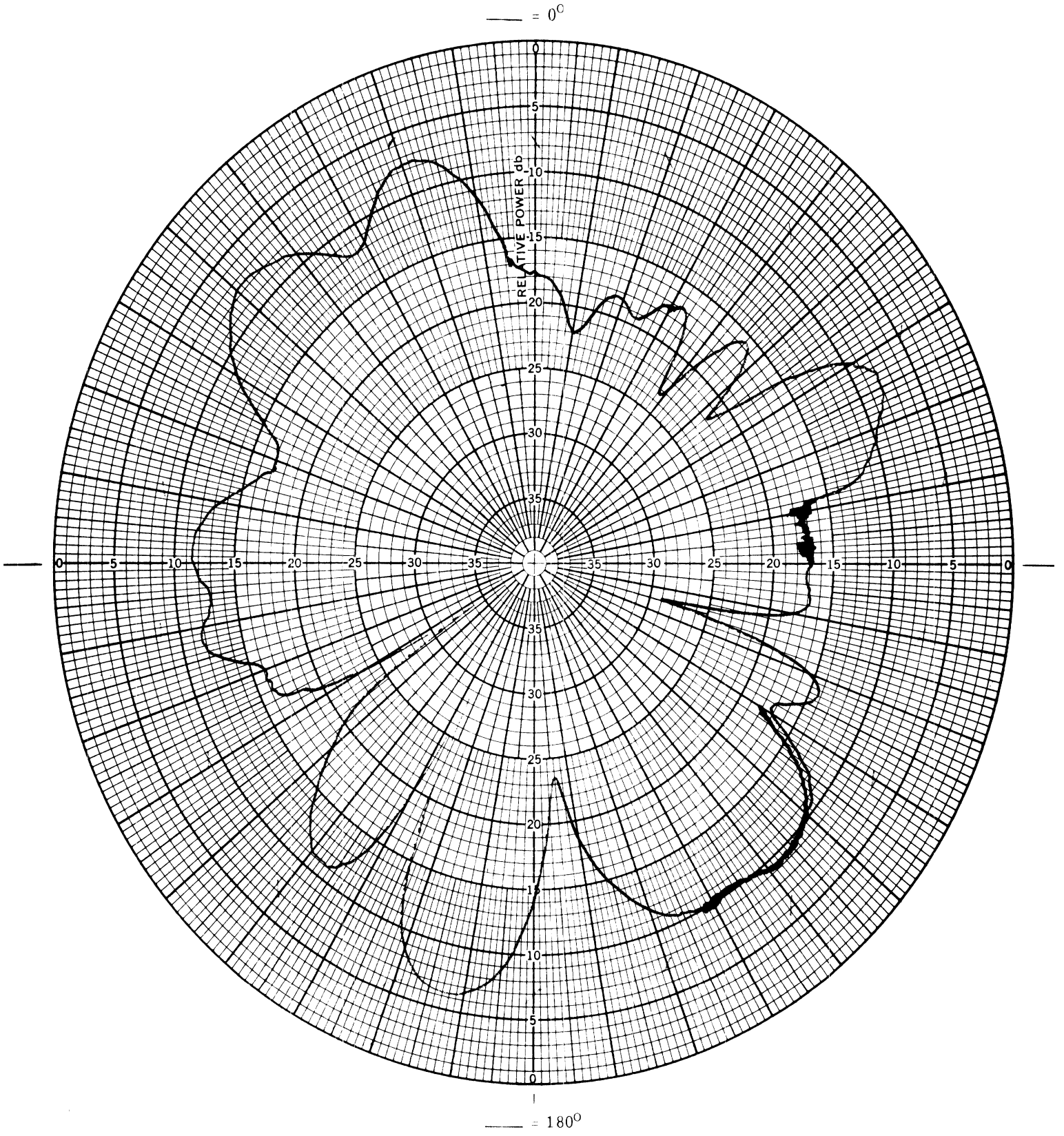

Fig. 44(a): Measured horizontal plane pattern of the bottom-fed heated backlite antenna mounted on Tempo body shell. Vertical polarization, f = 475.0 MHz.

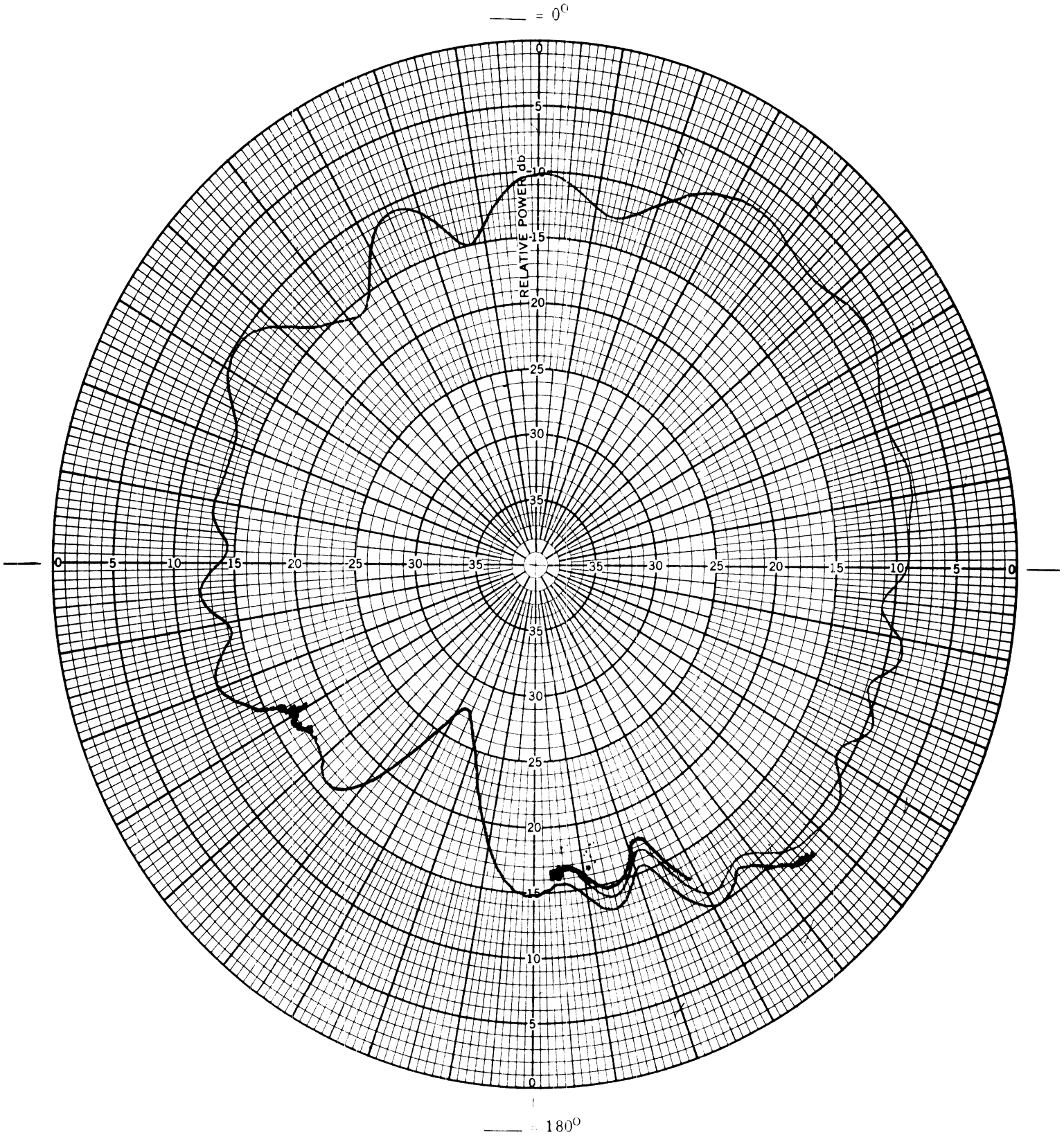

Fig. 44(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Vertical polarization, f = 475.0 MHz.

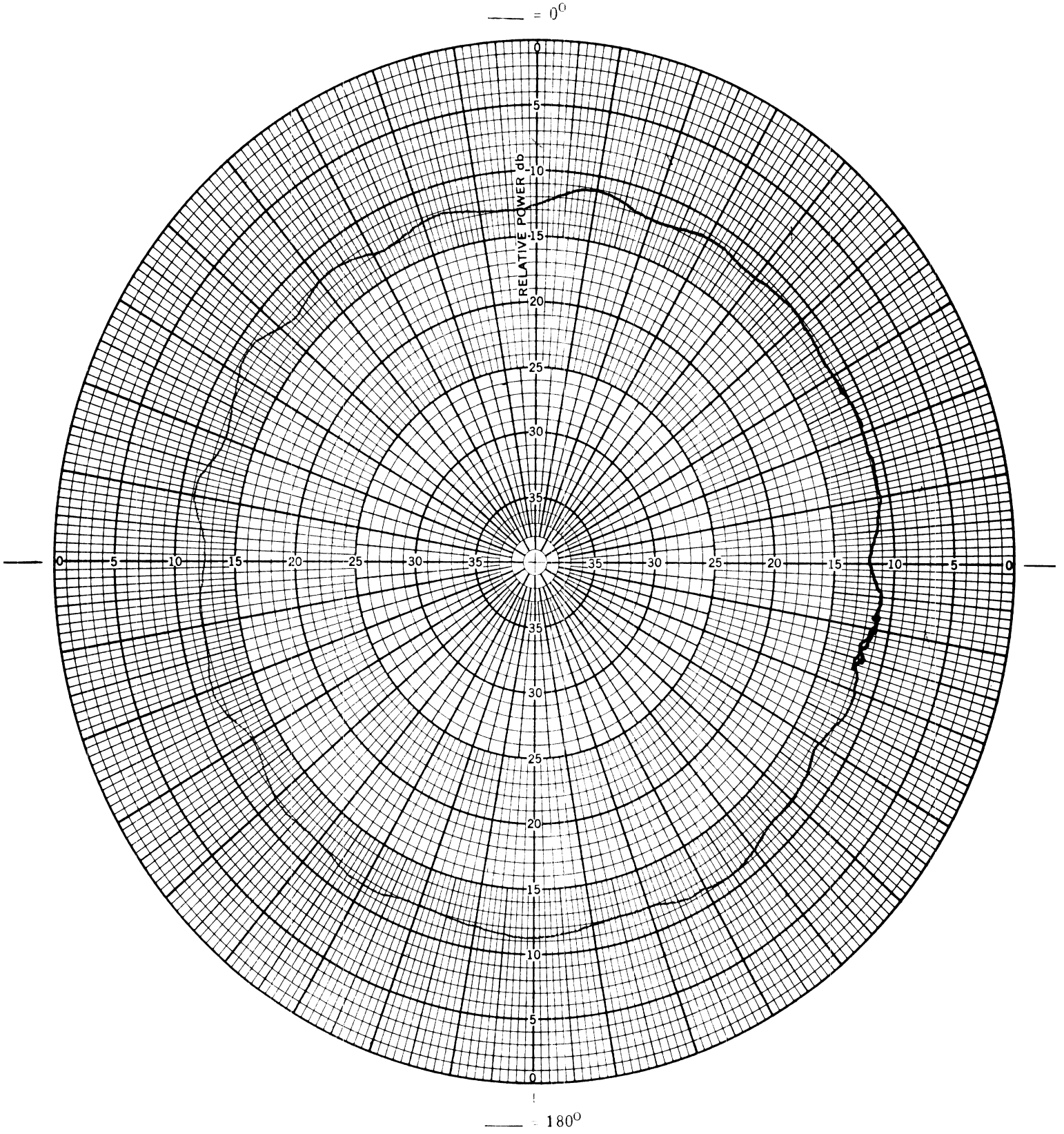

Fig. 45(a): Measured horizontal plane pattern of the bottom fed heated backlite antenna mounted on Tempo body shell. Vertical polarization, f = 637.0 MHz.

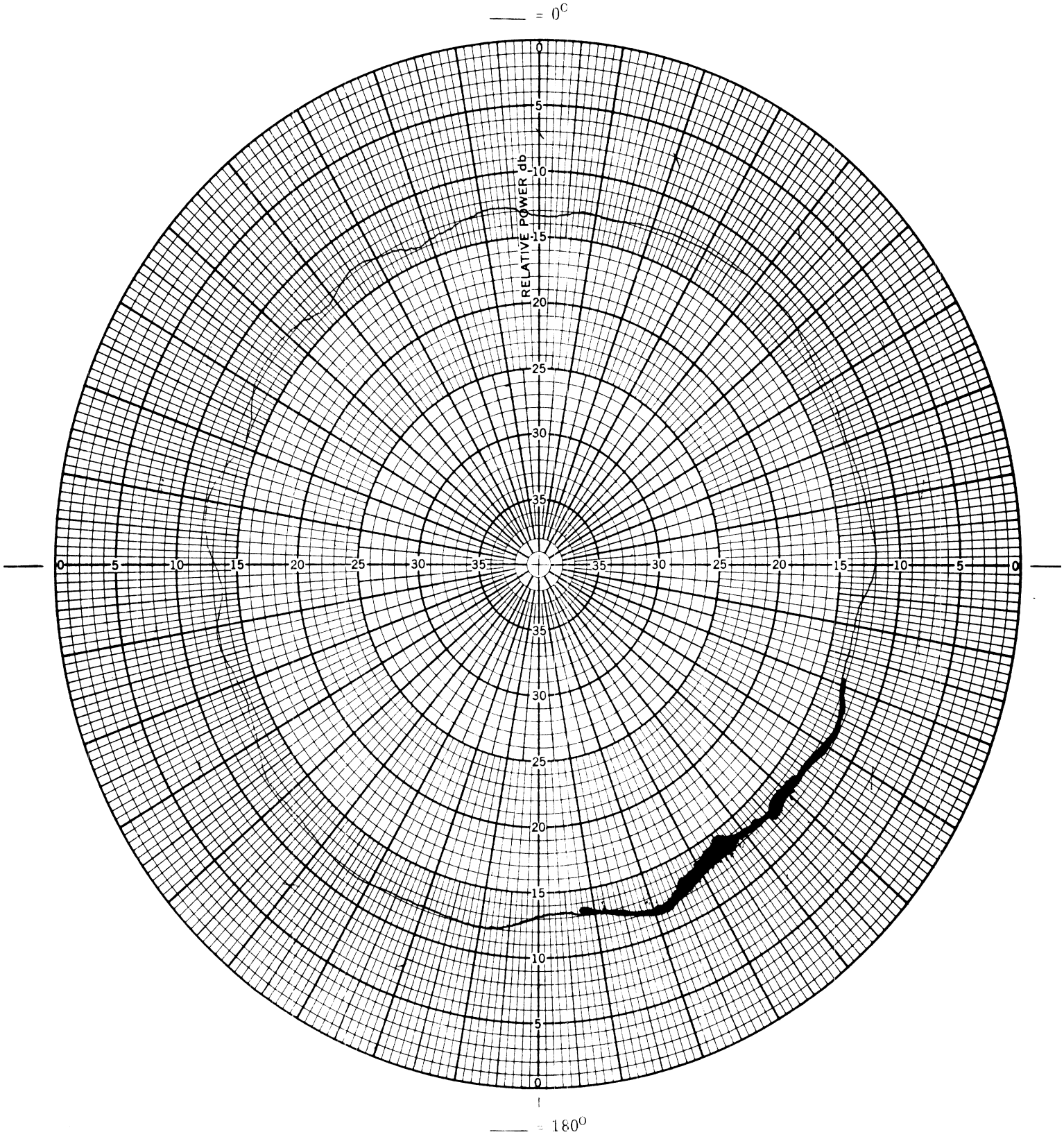

Fig. 45(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Vertical polarization, f = 637.0 MHz.

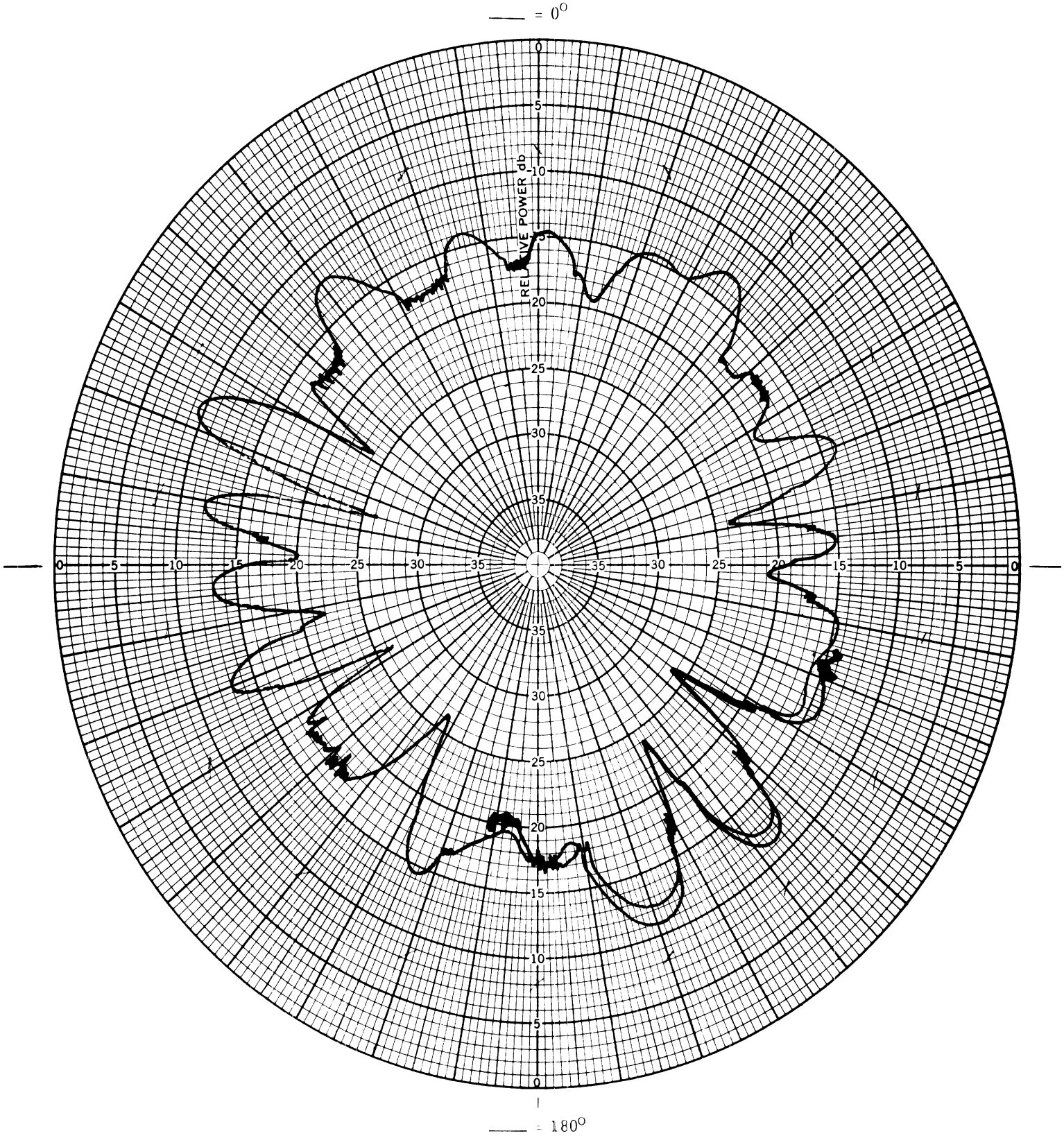

Fig. 46(a): Measured horizontal plane pattern of the bottom-fed heated backlite antenna mounted on Tempo body shell. Vertical polarization, f = 825.0 MHz.

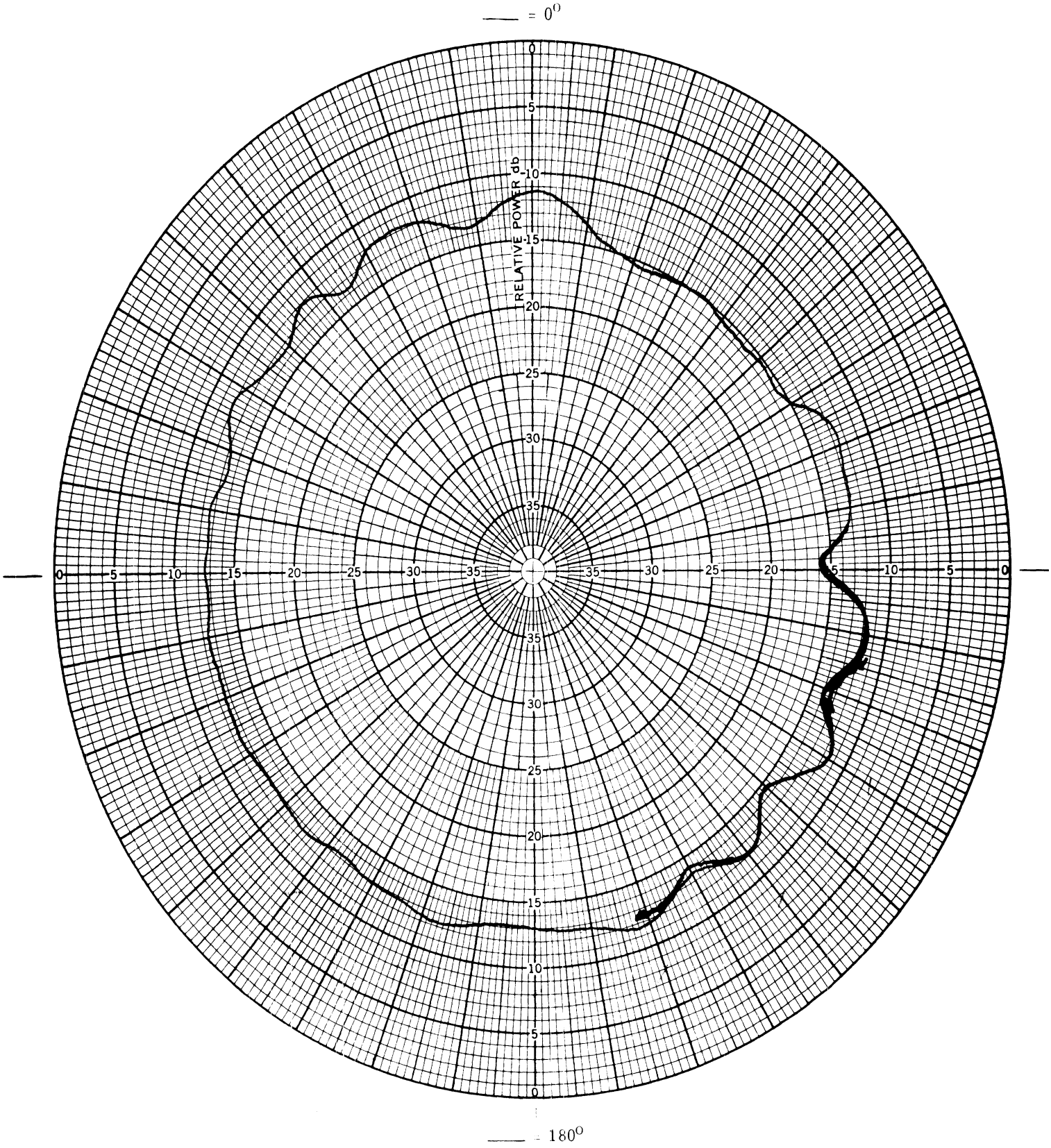

Fig. 46(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Vertical polarization, f = 825.0 MHz.

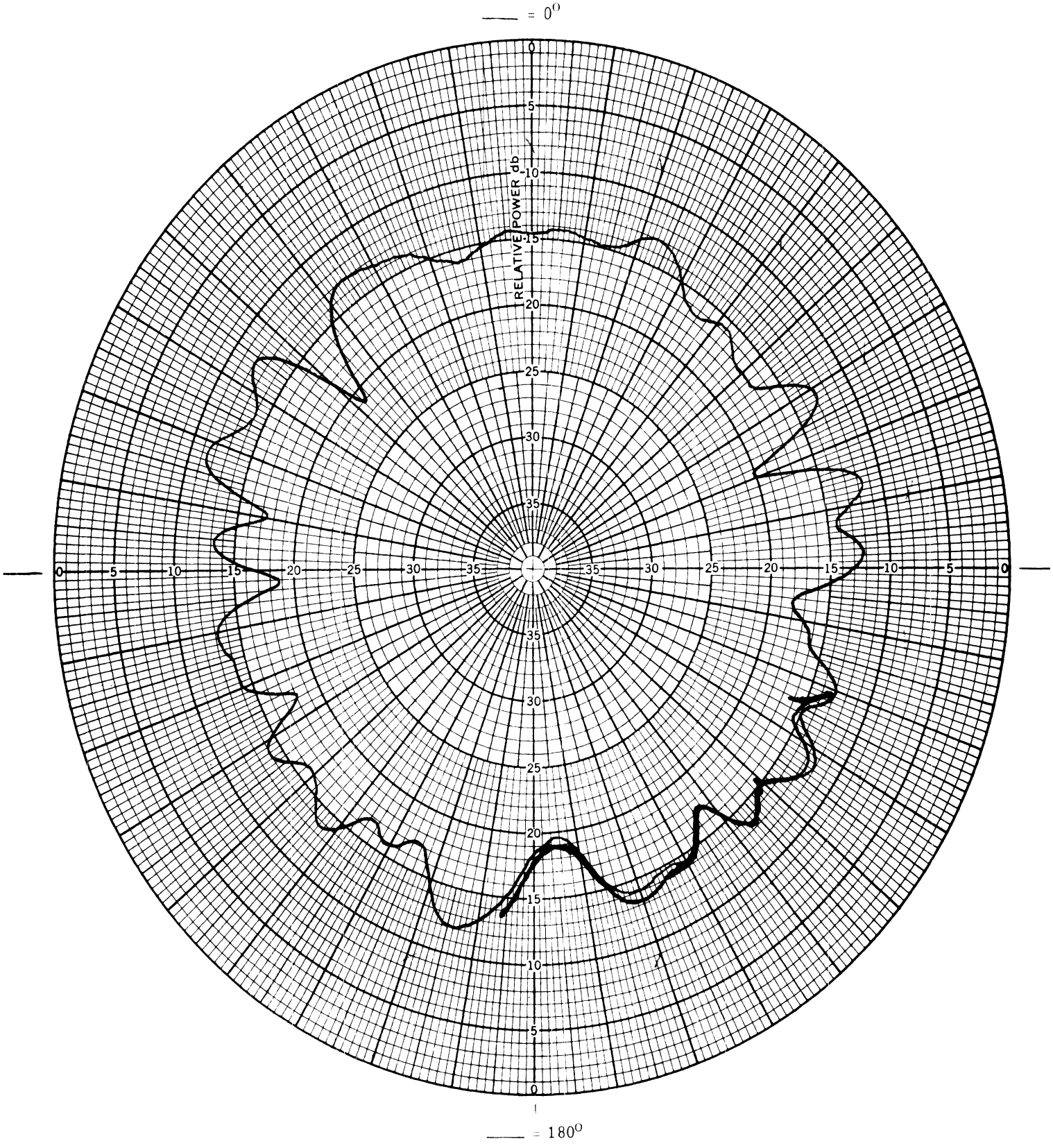

Fig. 47(a): Measured horizontal plane pattern of the bottom-fed heated backlite antenna mounted on Tempo body shell. Vertical polarization, f = 890.0 MHz.

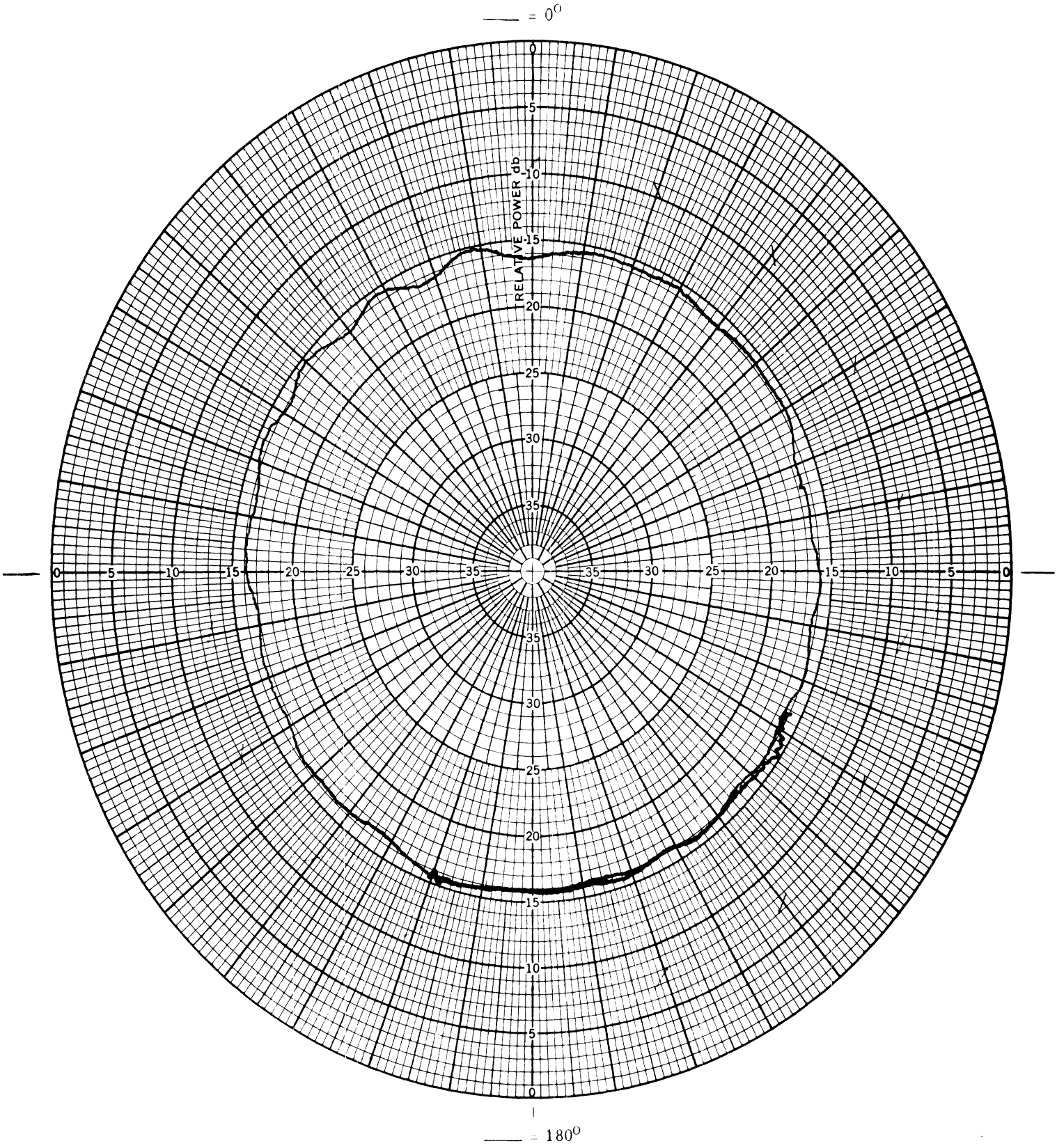

Fig. 47(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Vertical polarization, f = 890.0 MHz.

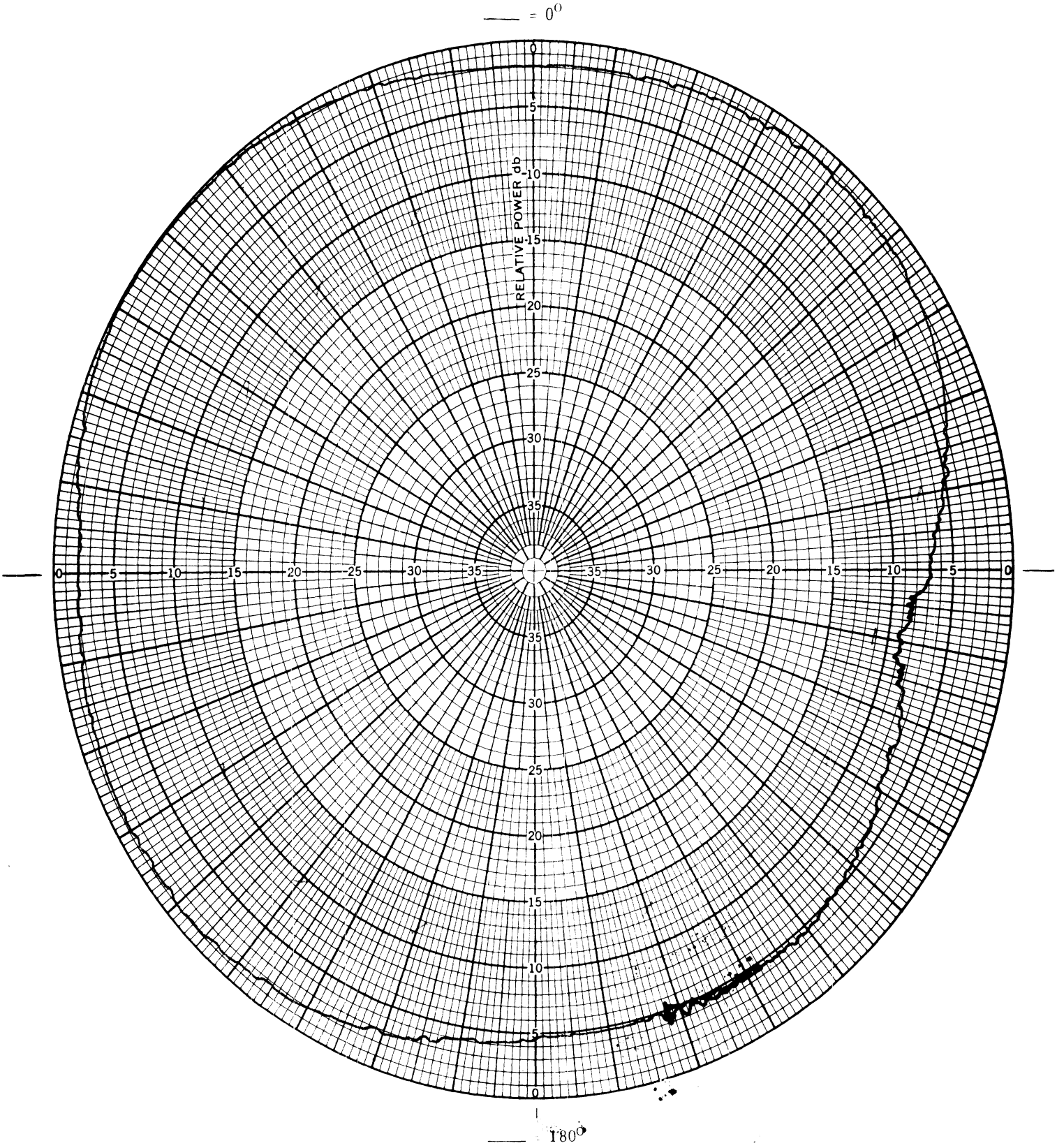

Fig. 48(a): Measured horizontal plane pattern of the bottom-fed heated backlite antenna mounted on Tempo body shell. Horizontal polarization, f = 58.9 MHz.

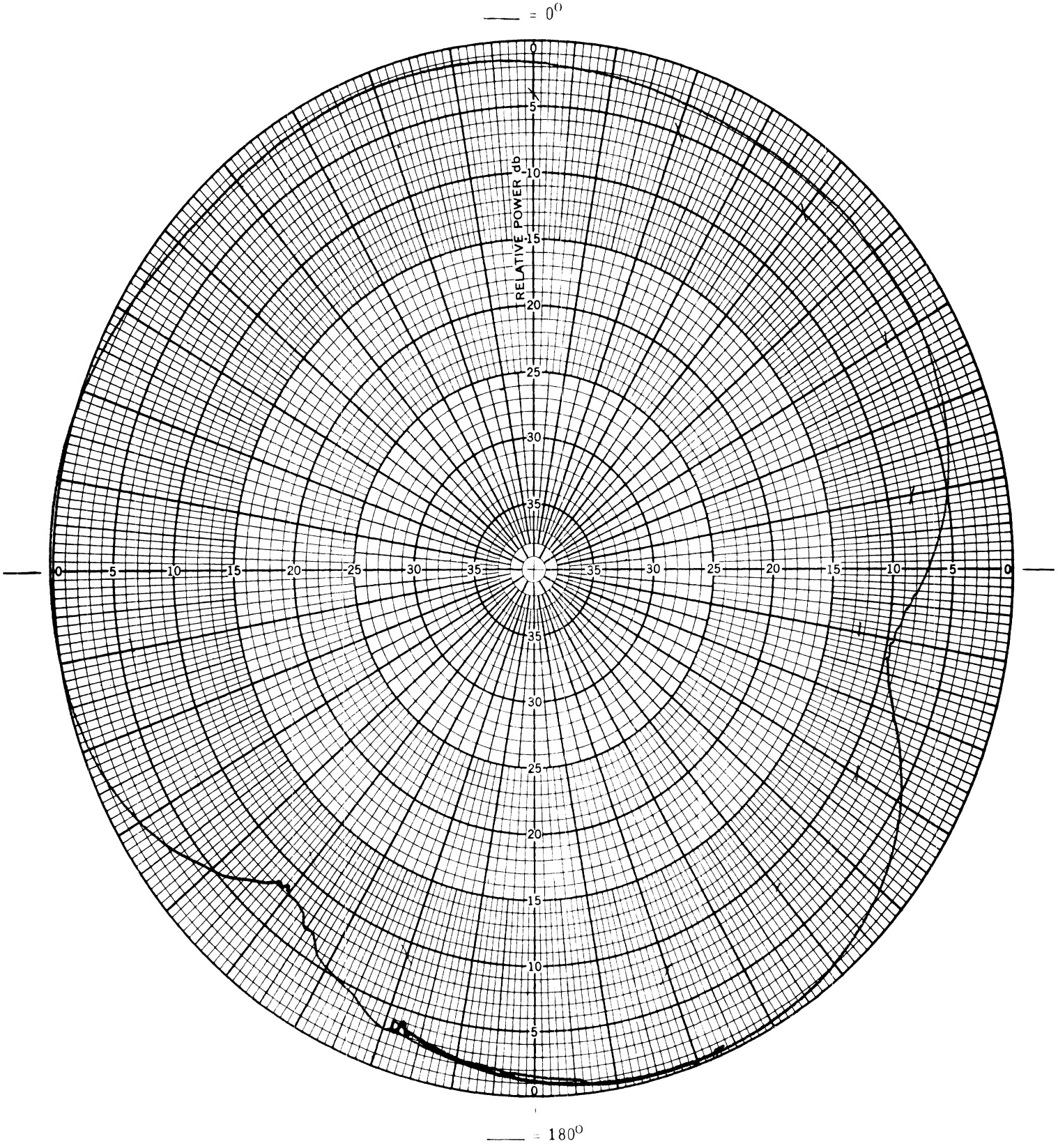

Fig. 48(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Horizontal polarization, f = 58.9 MHz.

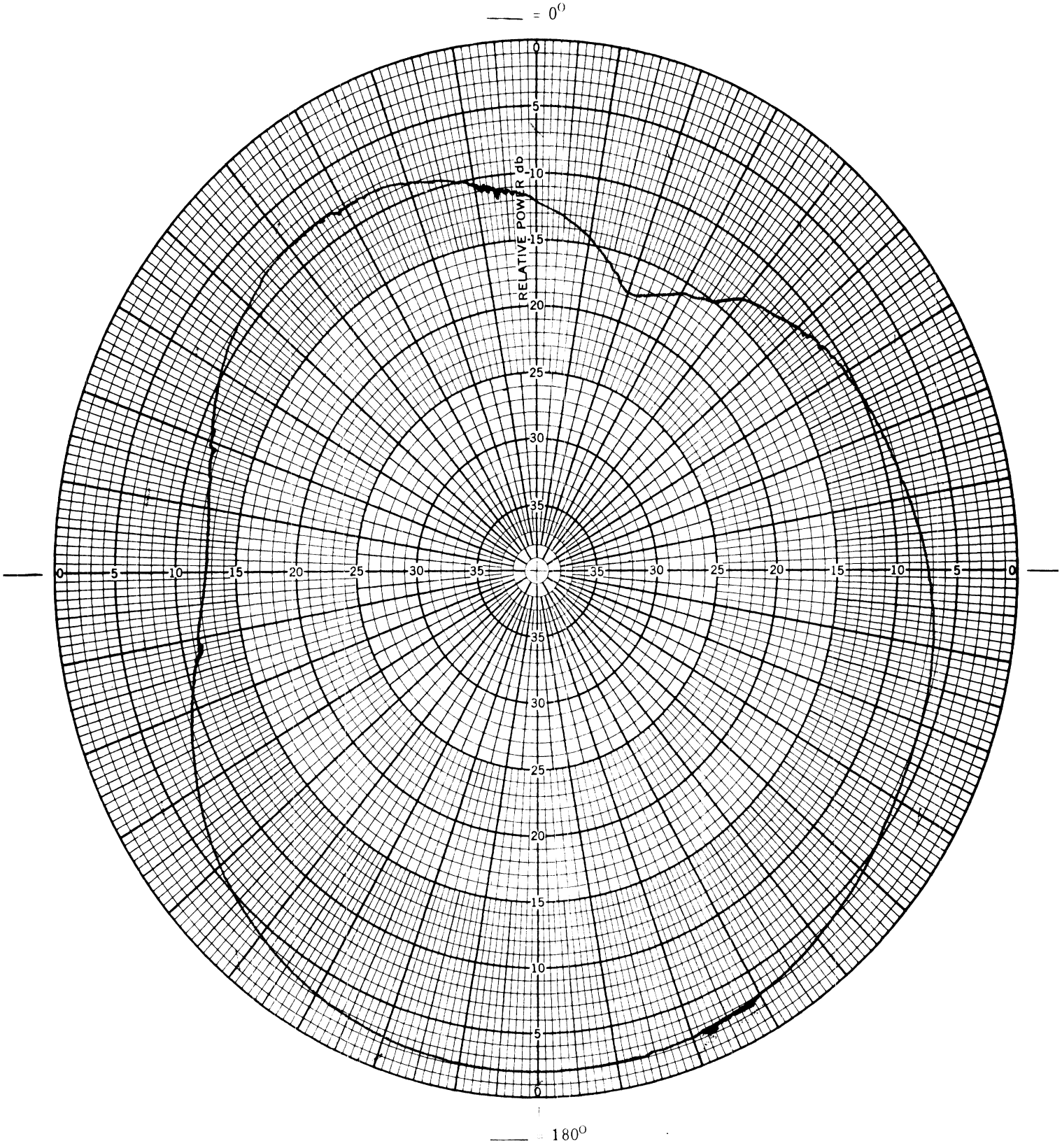

Fig. 49(a): Measured horizontal plane pattern of the bottom-fed heated backlite antenna mounted on Tempo body shell. Horizontal polarization, f = 73.1 MHz.

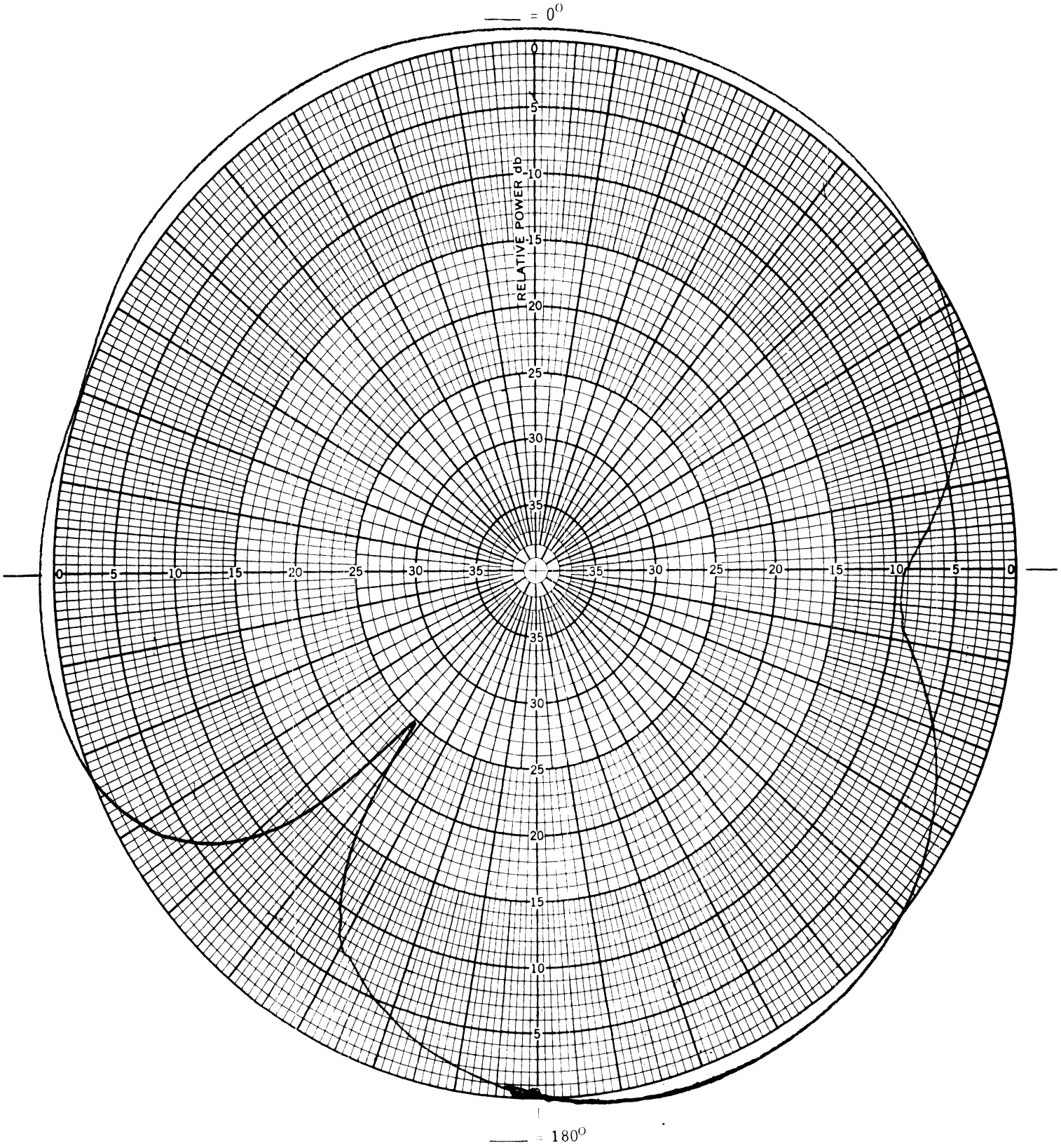

Fig. 49(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Horizontal polarization, f = 73.1 MHz.

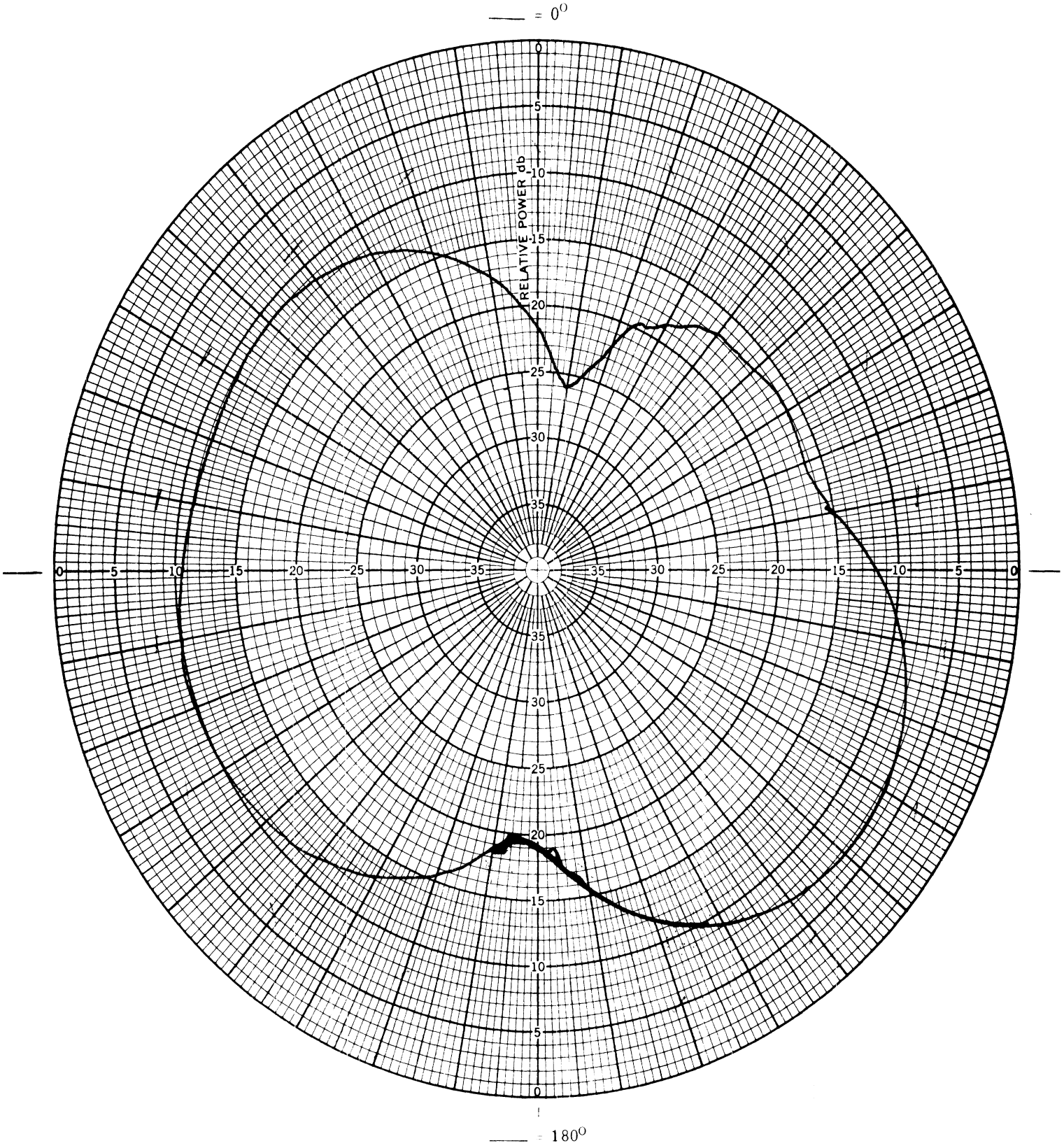

Fig. 50(a): Measured horizontel plane pattern of the bottom-fed heated backlite antenna mounted on Tempo body shell. Horizontal polarization, f = 87.3 MHz.

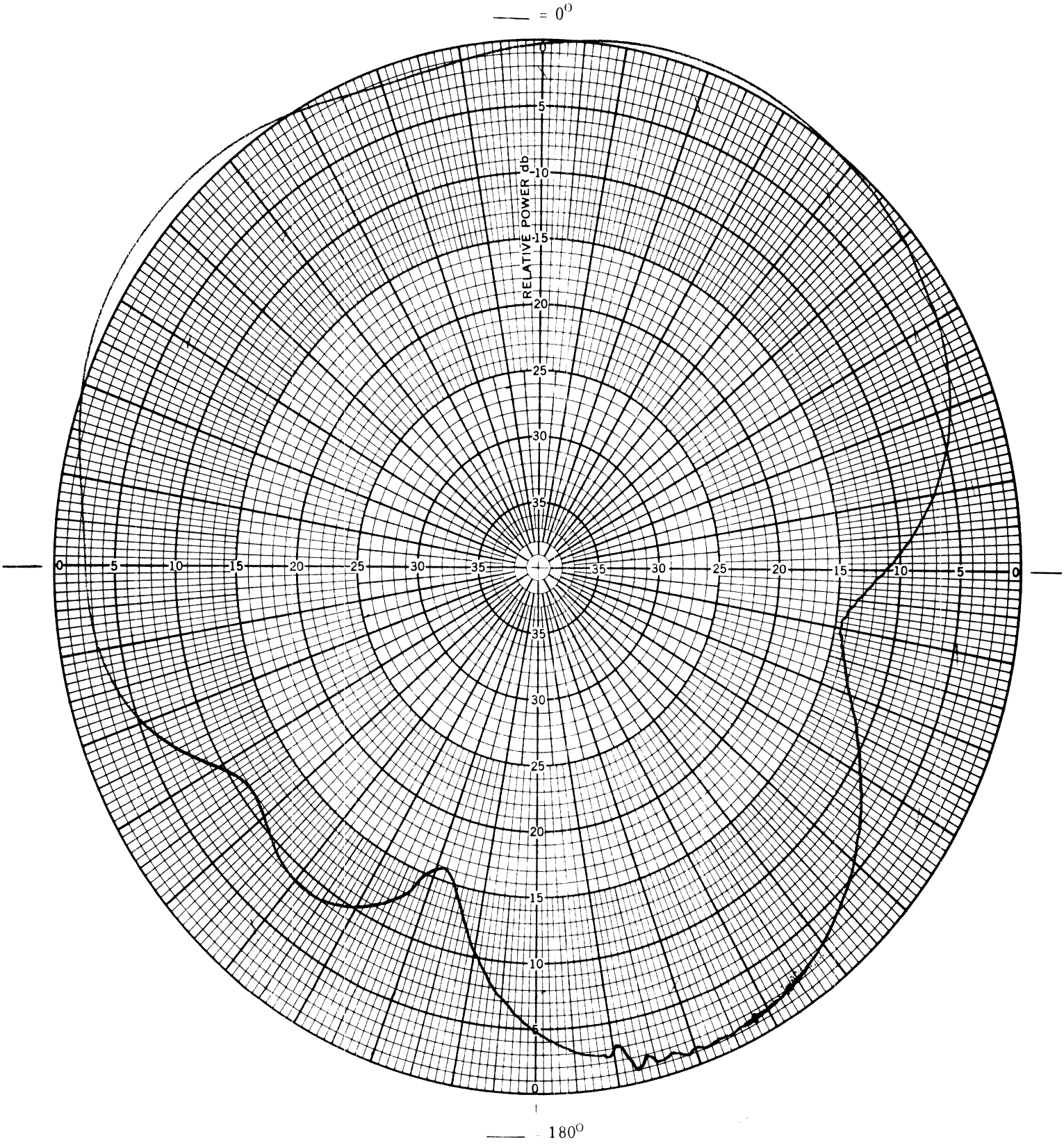

Fig. 50(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Horizontal polarization, f = 87.3 MHz.

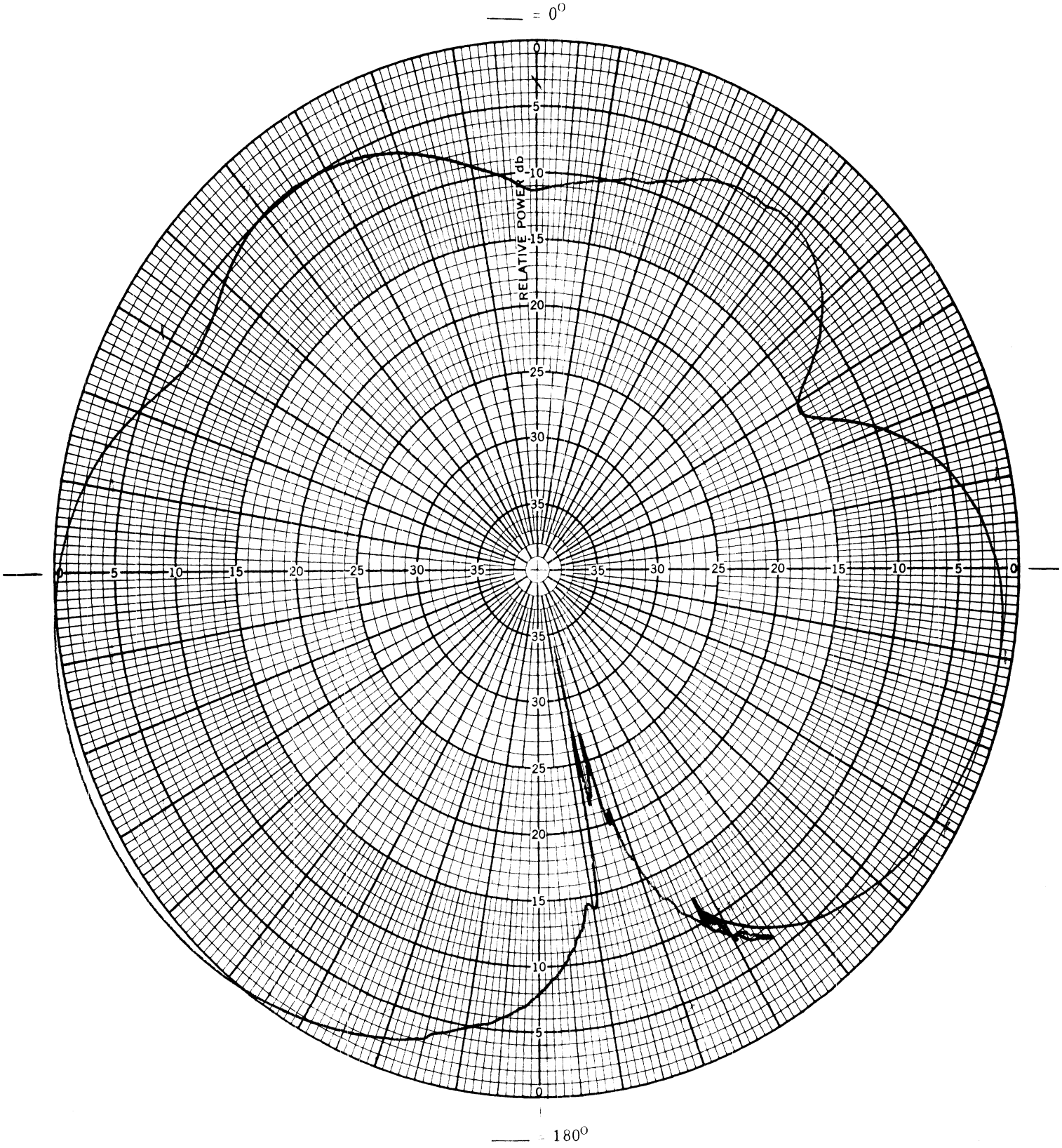

Fig. 51(a): Measured horizontal plane pattern of the bottom-fed heated backlite antenna mounted on Tempo body shell. Horizontal polarization, f = 97.7 MHz.

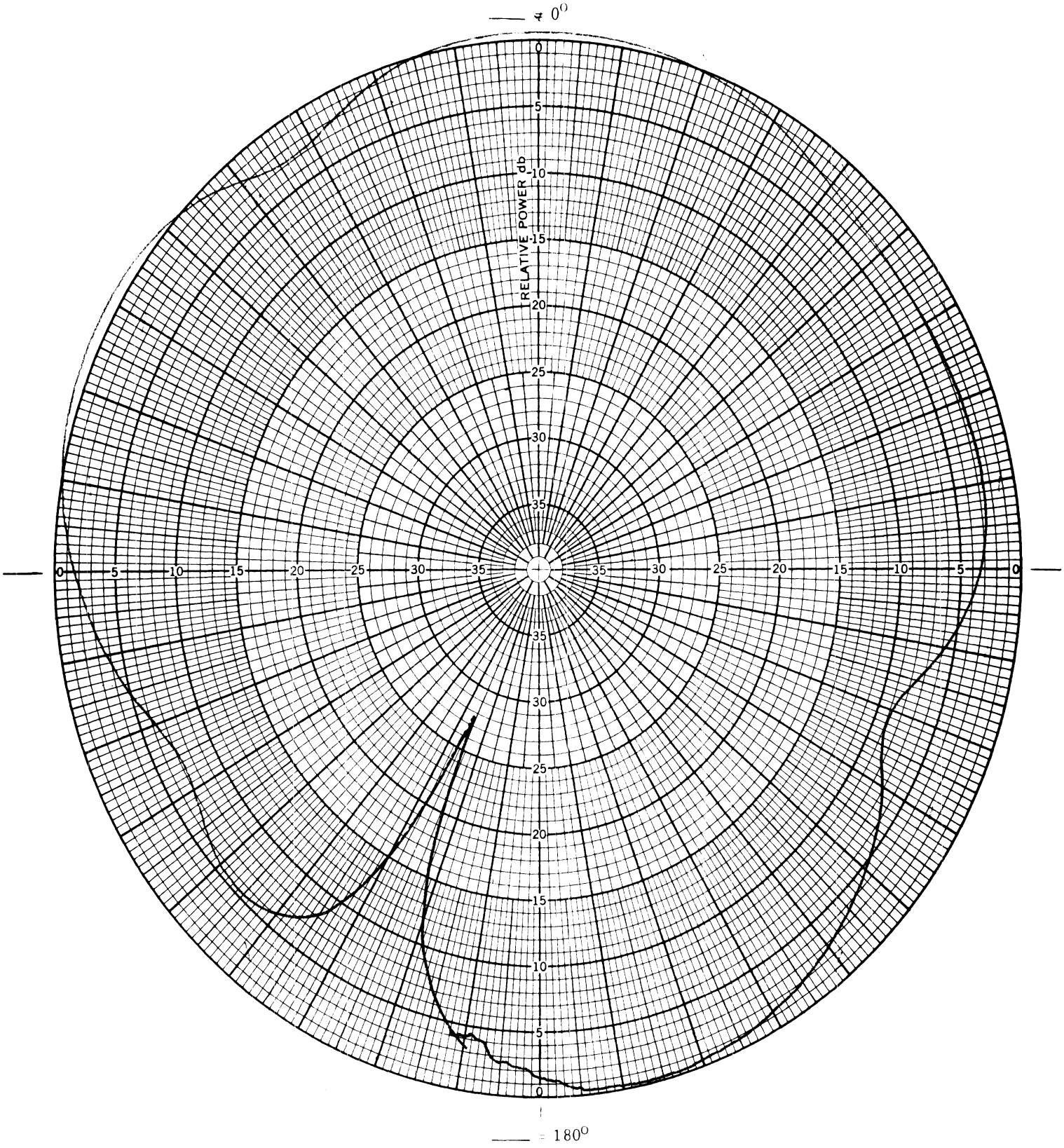

Fig. 51(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Horizontal polarization, f = 97.7 MHz.

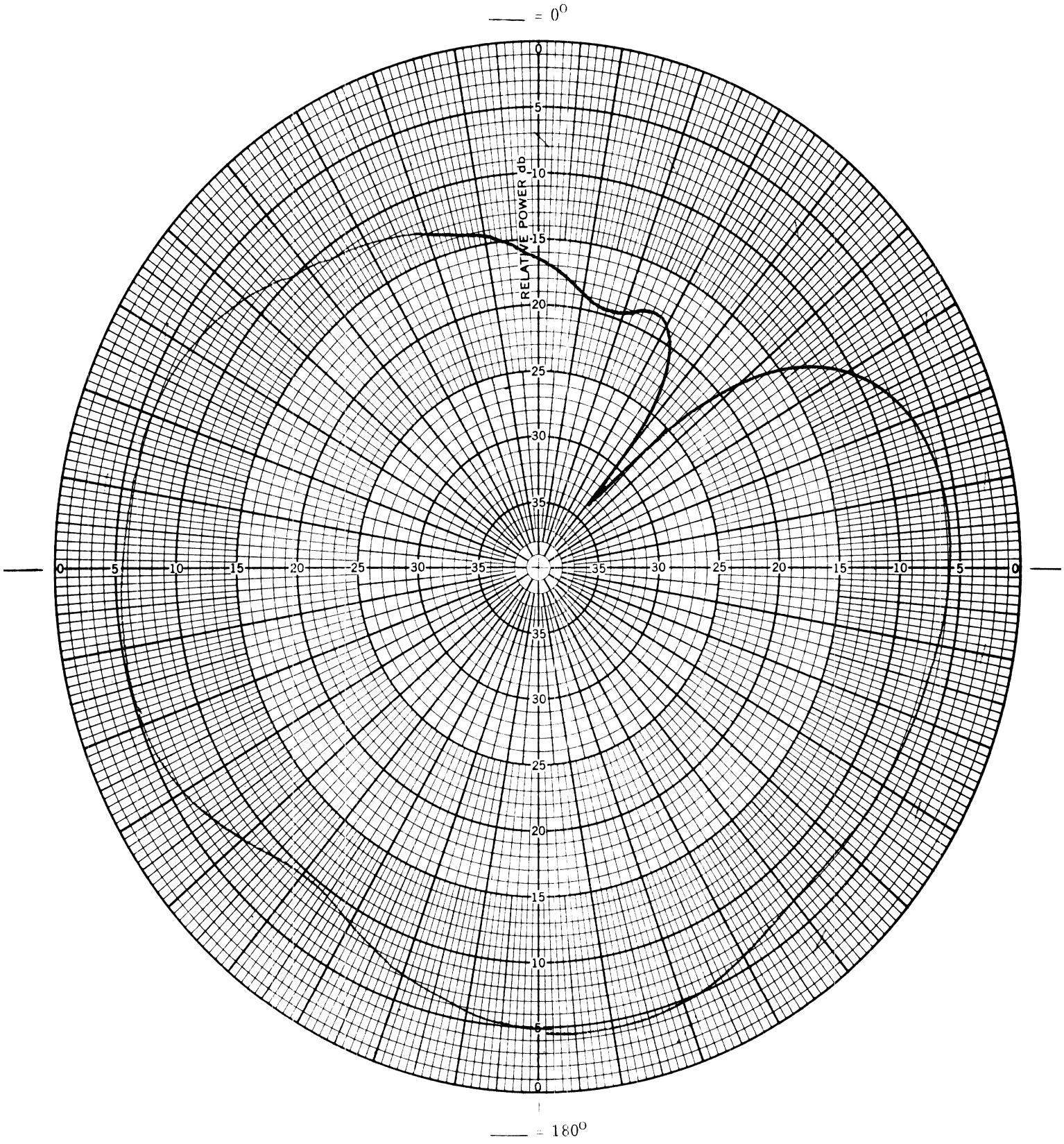

Fig. 52(a): Measured horizontal plane pattern of the bottom-fed heated backlite antenna mounted on Tempo body shell. Horizontal polarization, f = 108.4 MHz.

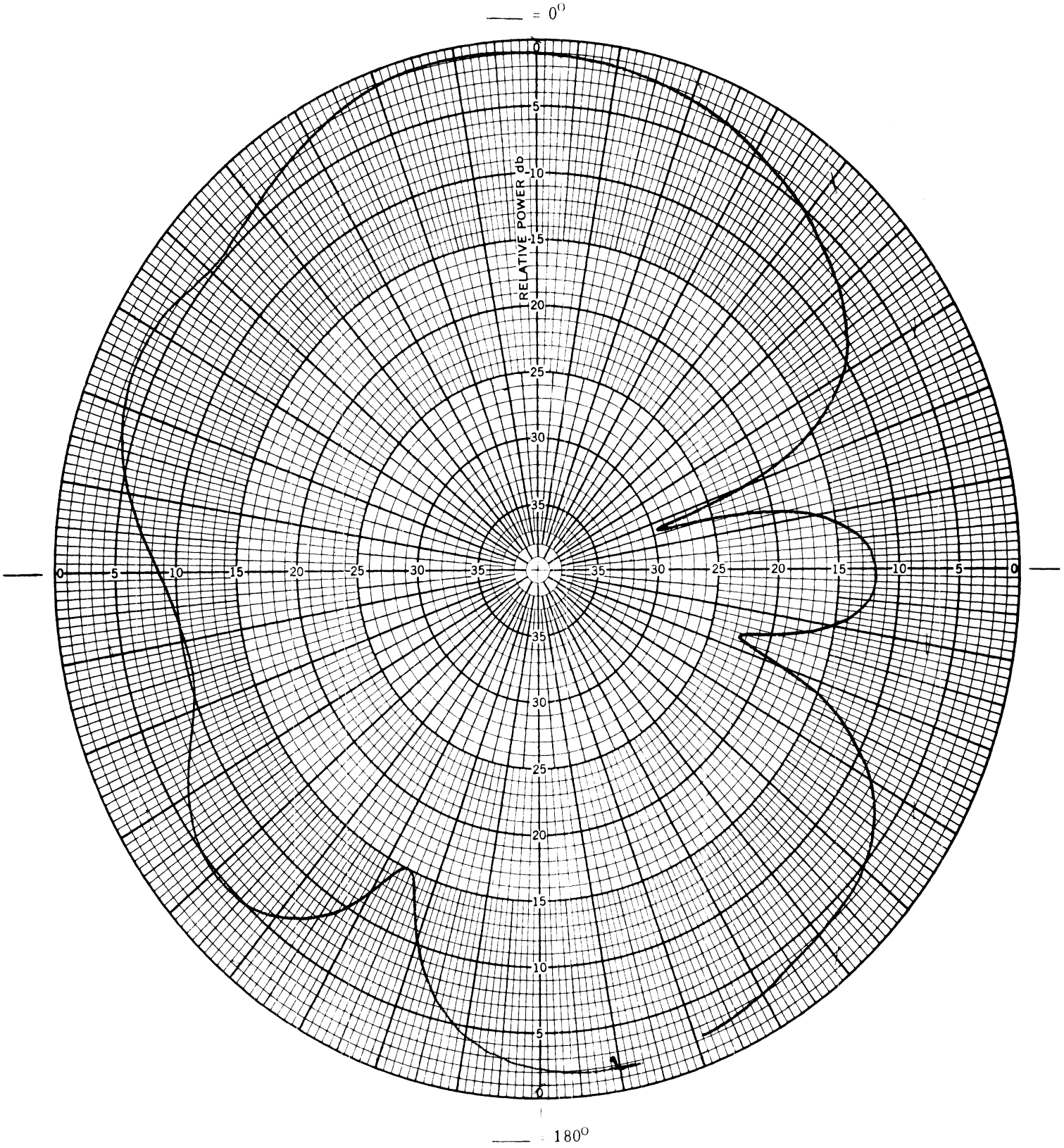

Fig. 52(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Horizontal polarization, f = 108.4 MHz.

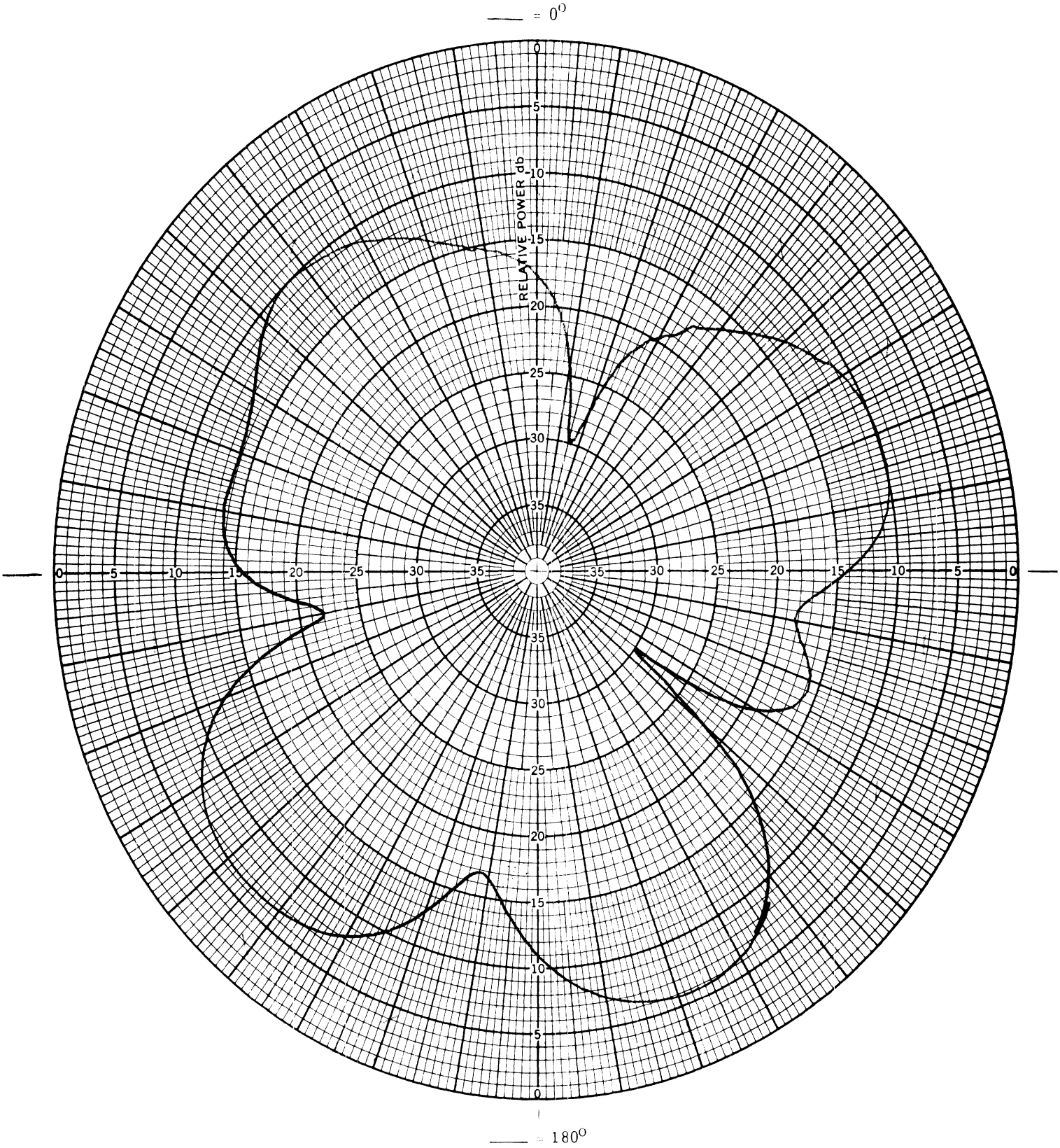

Fig. 53(a): Measured horizontal plane pattern of the bottom-fed heated backlite antenna mounted on Tempo body shell. Horizontal polarization, f = 179.5 MHz.

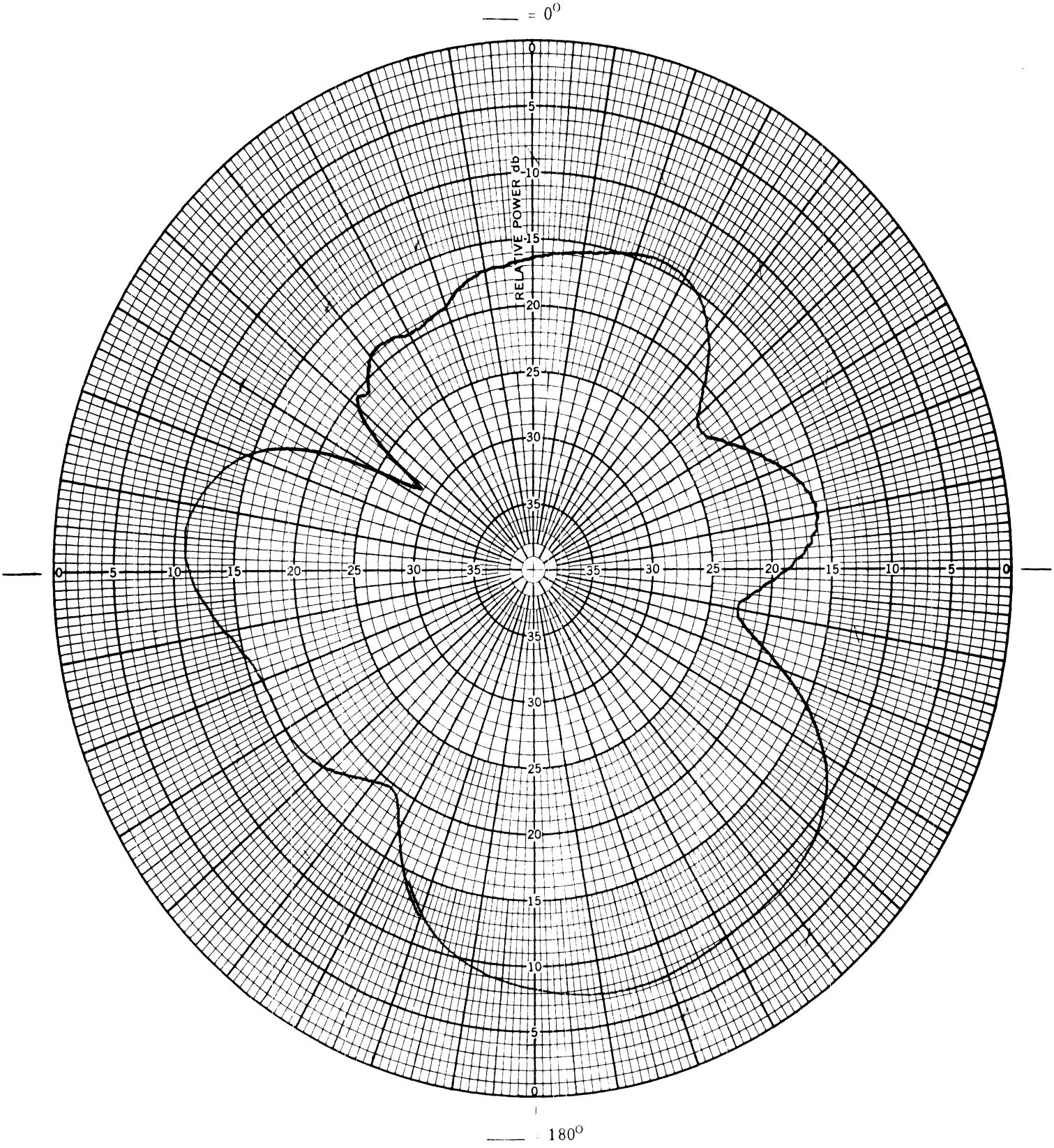

Fig. 53(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Horizontal polarization, f = 179.5 MHz.

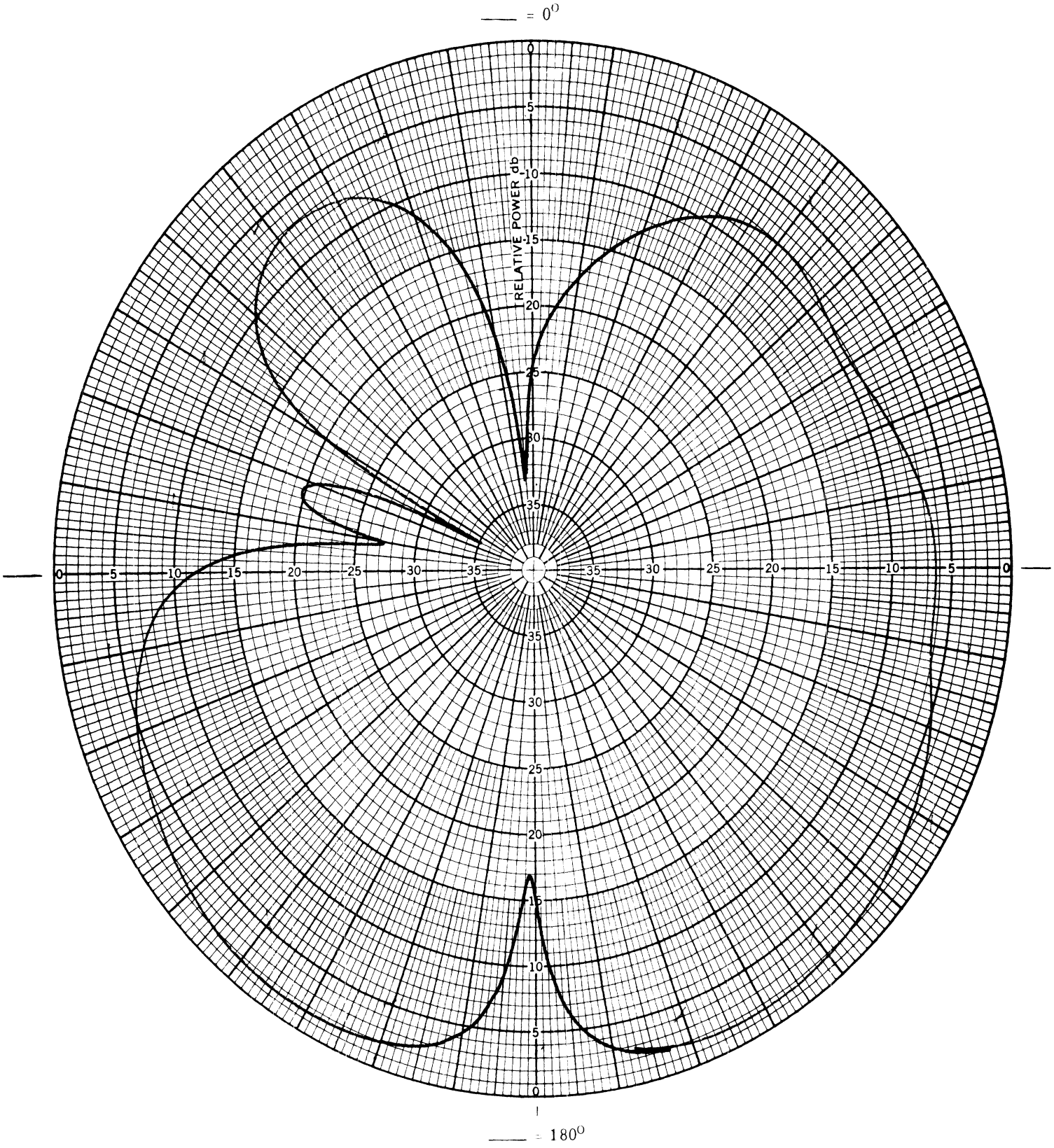

Fig. 54(a): Measured horizontal plane pattern of the bottom-fed heated backlite antenna mounted on Tempo body shell. Horizontal polarization, f = 215.0 MHz.

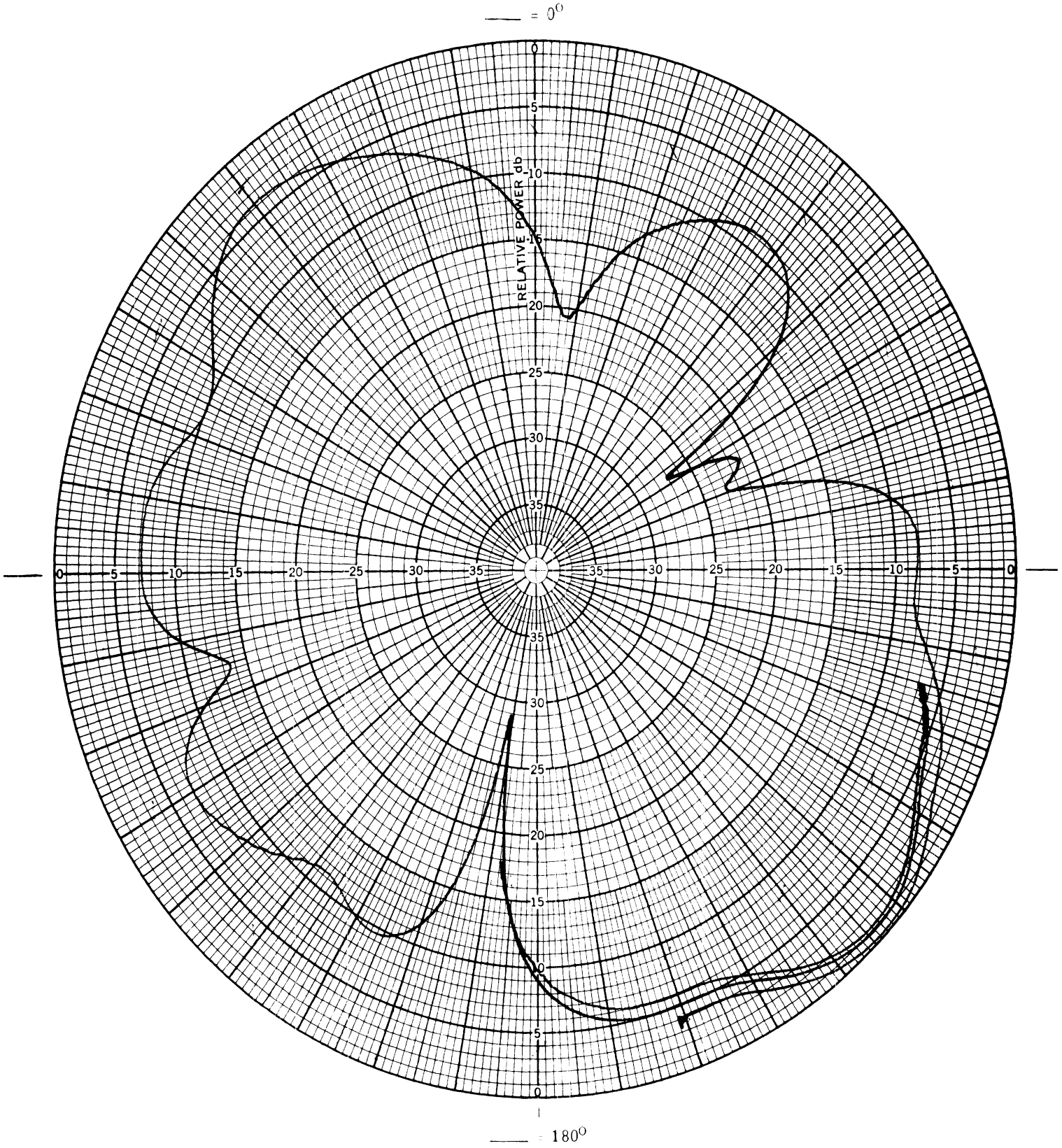

Fig. 54(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Horizontal polarization, f = 215.0 MHz.

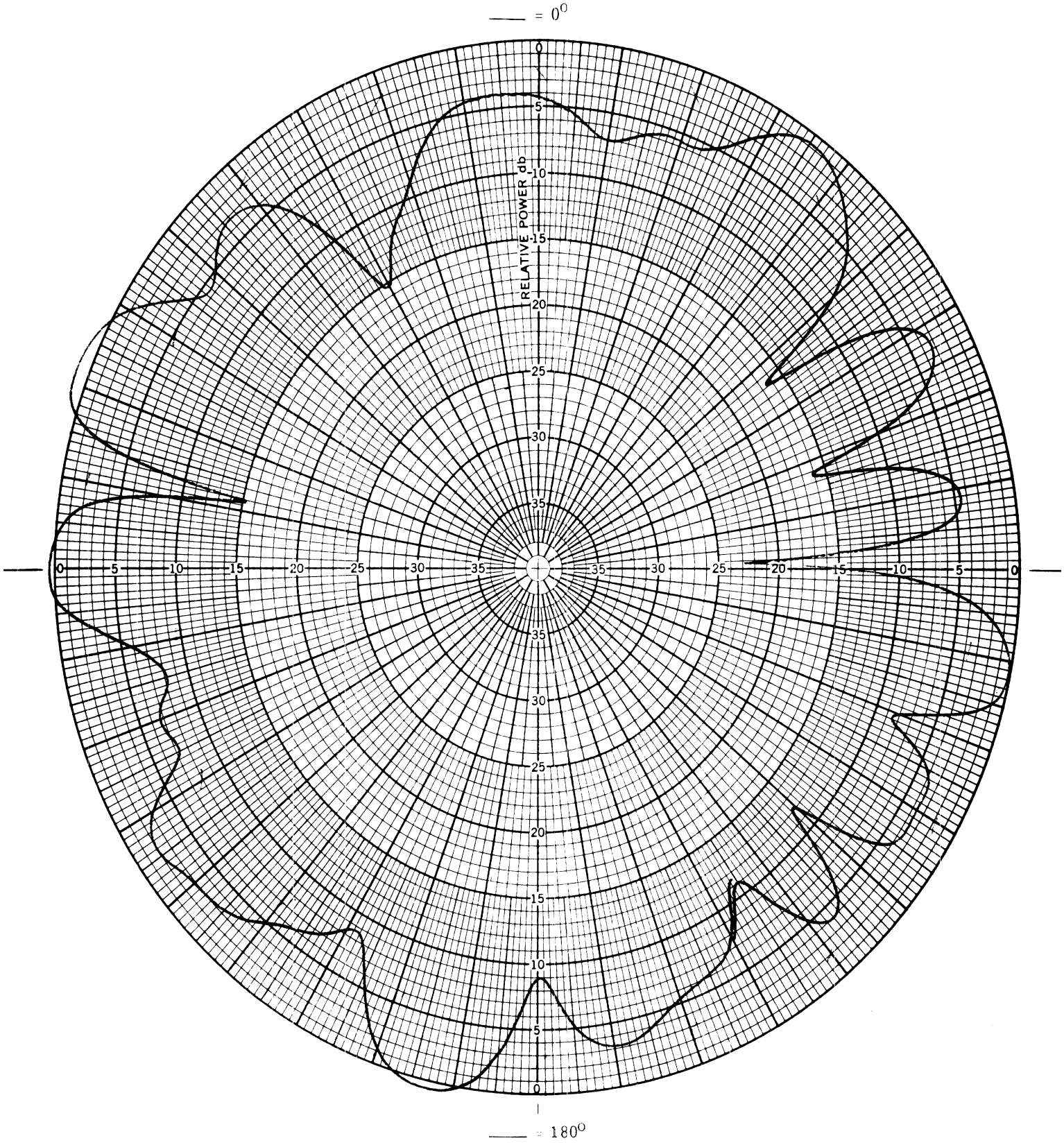

Fig. 55(a): Measured horizontal plane pattern of the bottom-fed heated backlite antenna mounted on Tempo body shell. Horizontal polarization, f = 475.0 MHz.

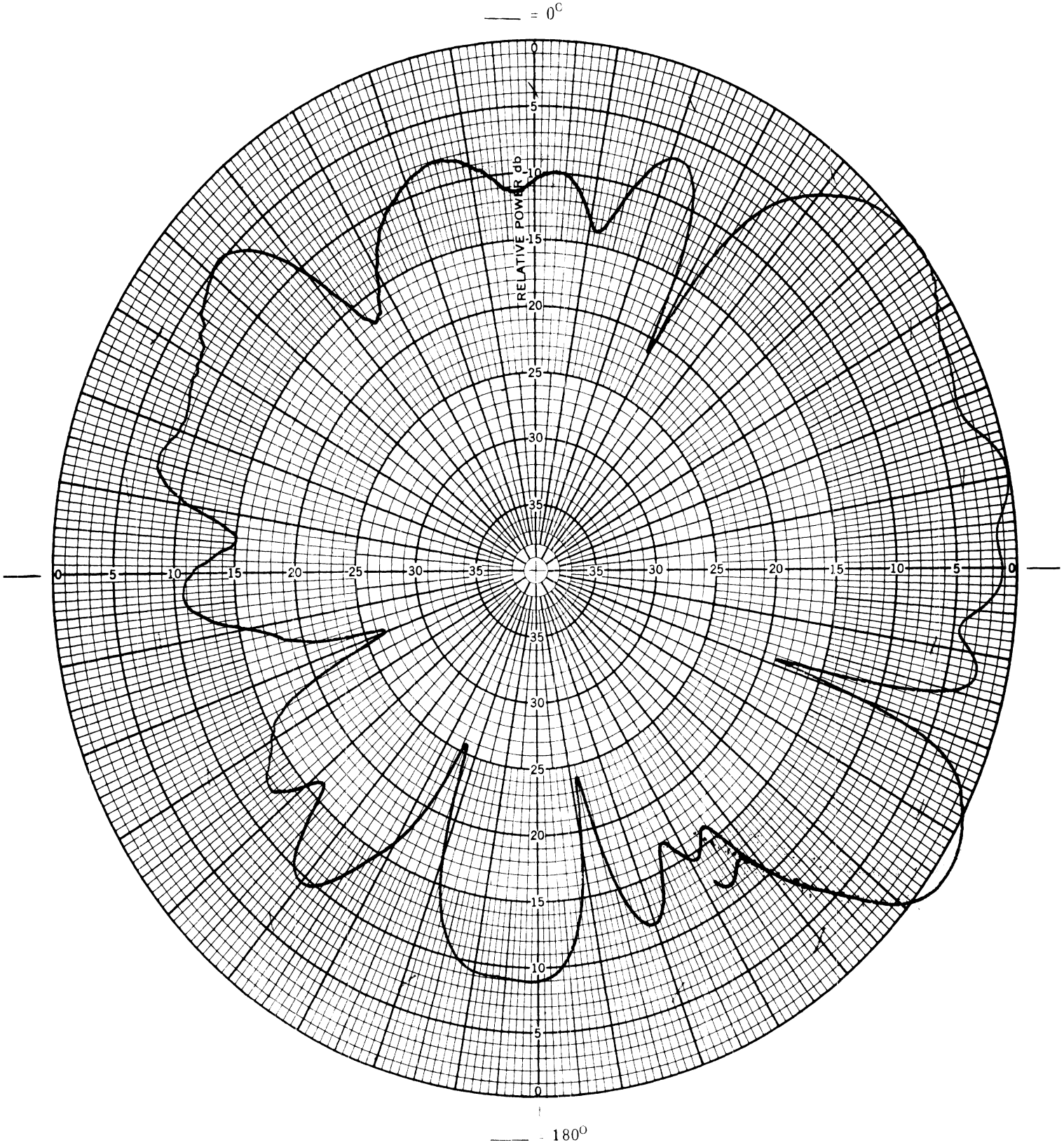

Fig. 55(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Horizontal polarization, f = 475.0 MHz.

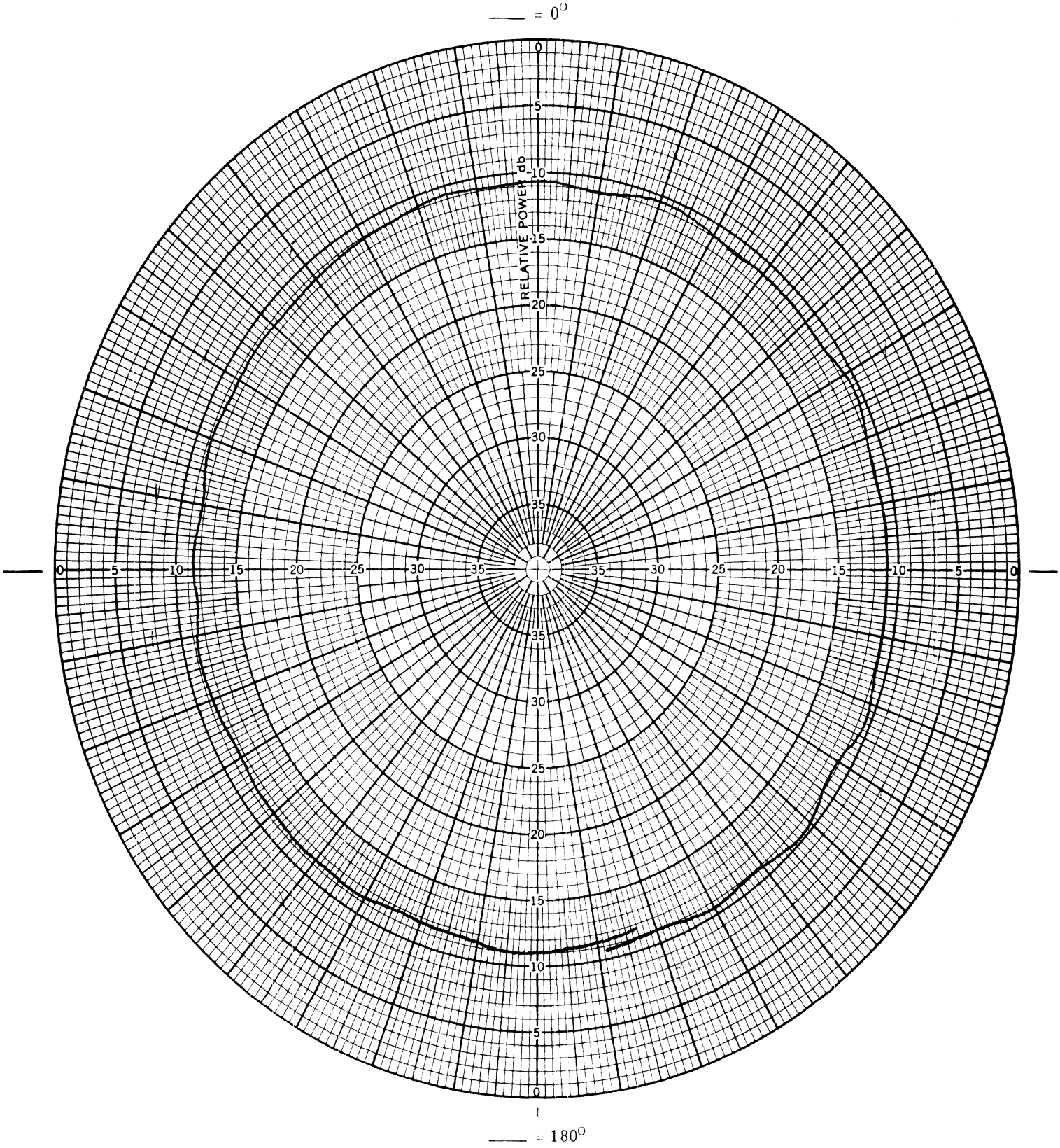

Fig. 56(a): Measured horizontal plane pattern of the bottom-fed heated backlite antenna mounted on Tempo body shell. Horizontal polarization, f = 637.0 MHz.

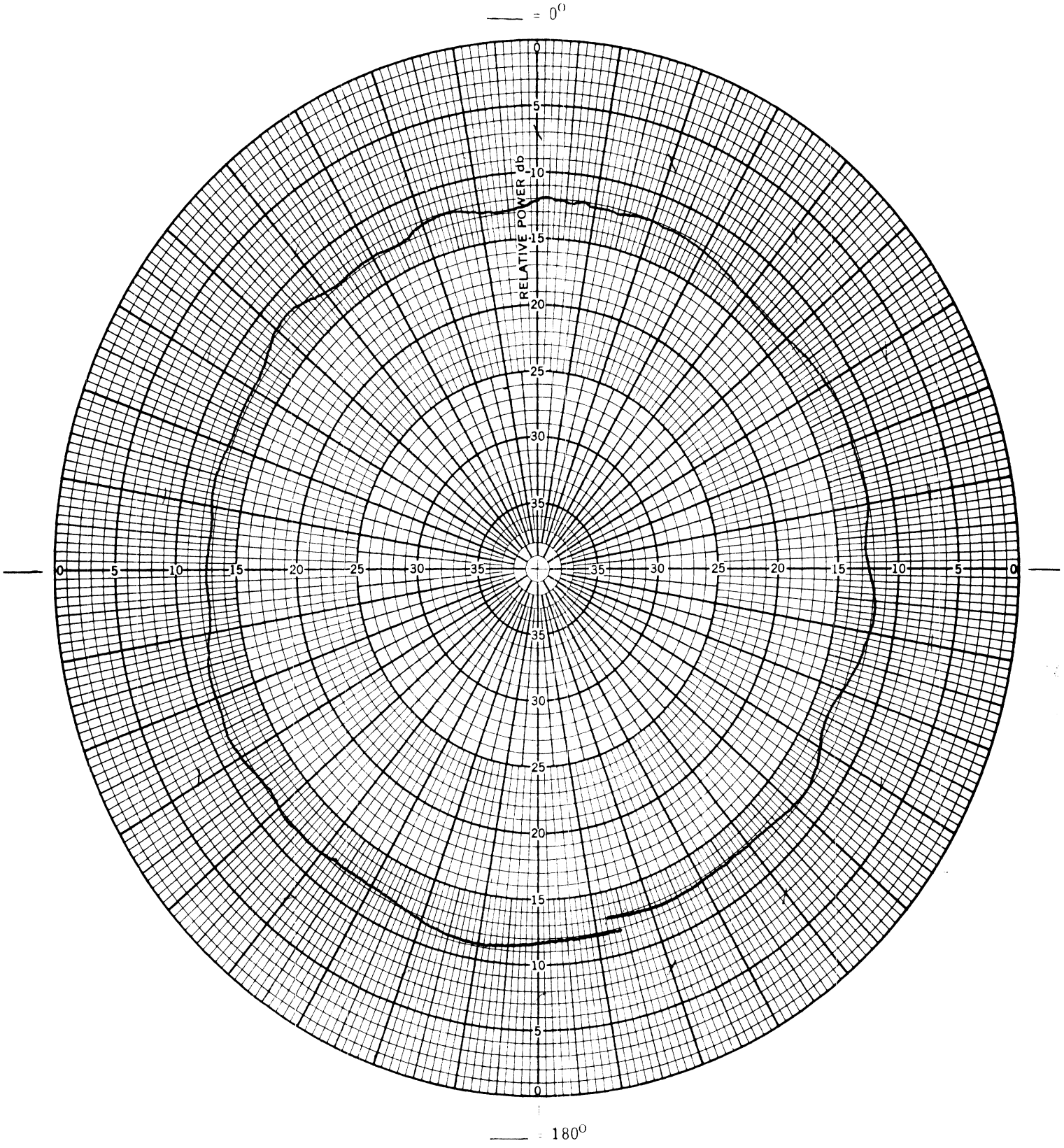

Fig. 56(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Horizontal polarization, f = 637.0 MHz.

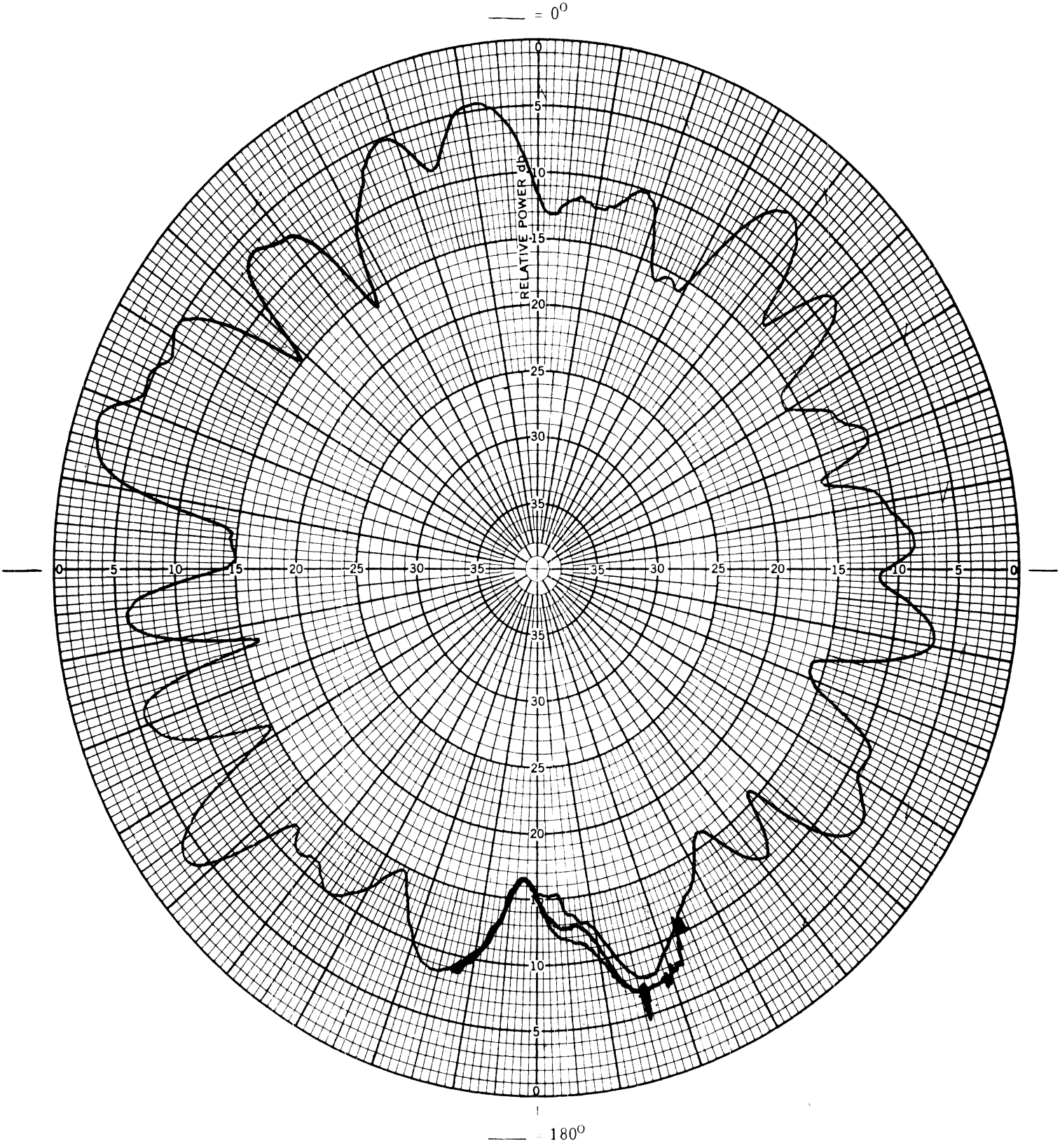

Fig. 57(a): Measured horizontal plane pattern of the bottom-fed heated backlite antenna mounted on Tempo body shell. Horizontal polarization, f = 825.0 MHz.

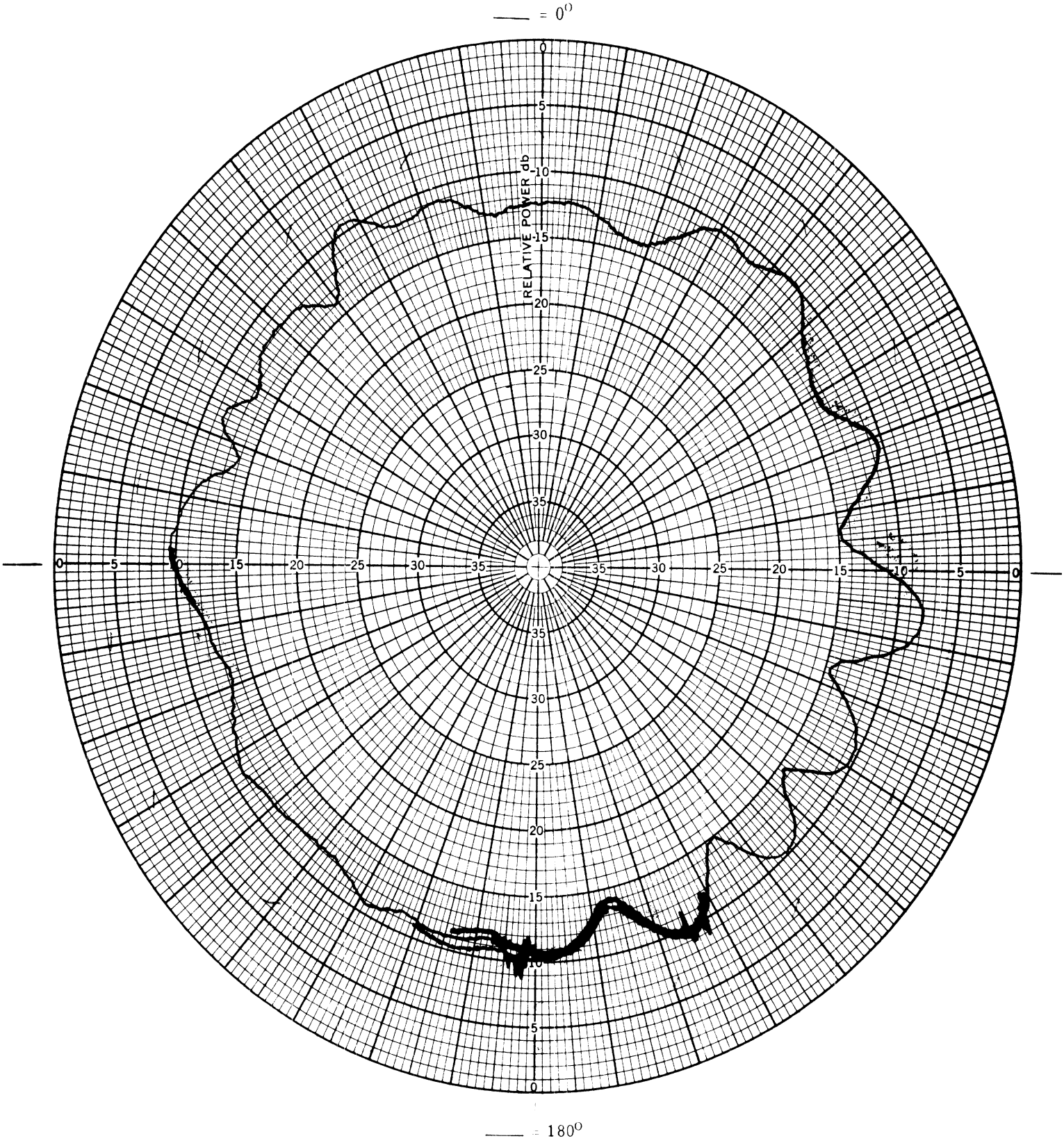

Fig. 57(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Horizontal polarization, f = 825.0 MHz.

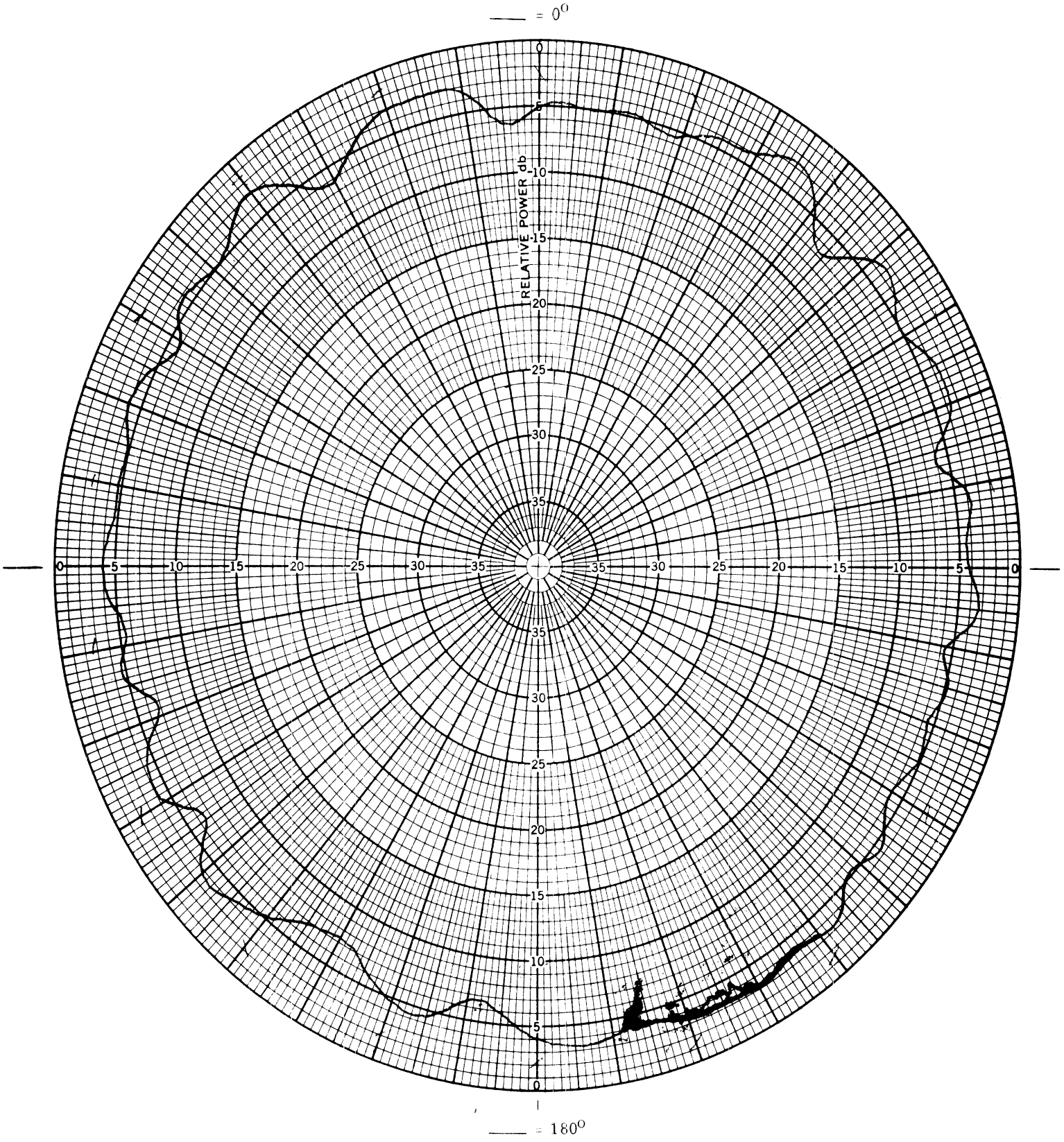

Fig. 58(a): Measured horizontal plane pattern of the bottom-fed heated backlite antenna mounted on Tempo Body shell. Horizontal polarization, f = 890.0 MHz.

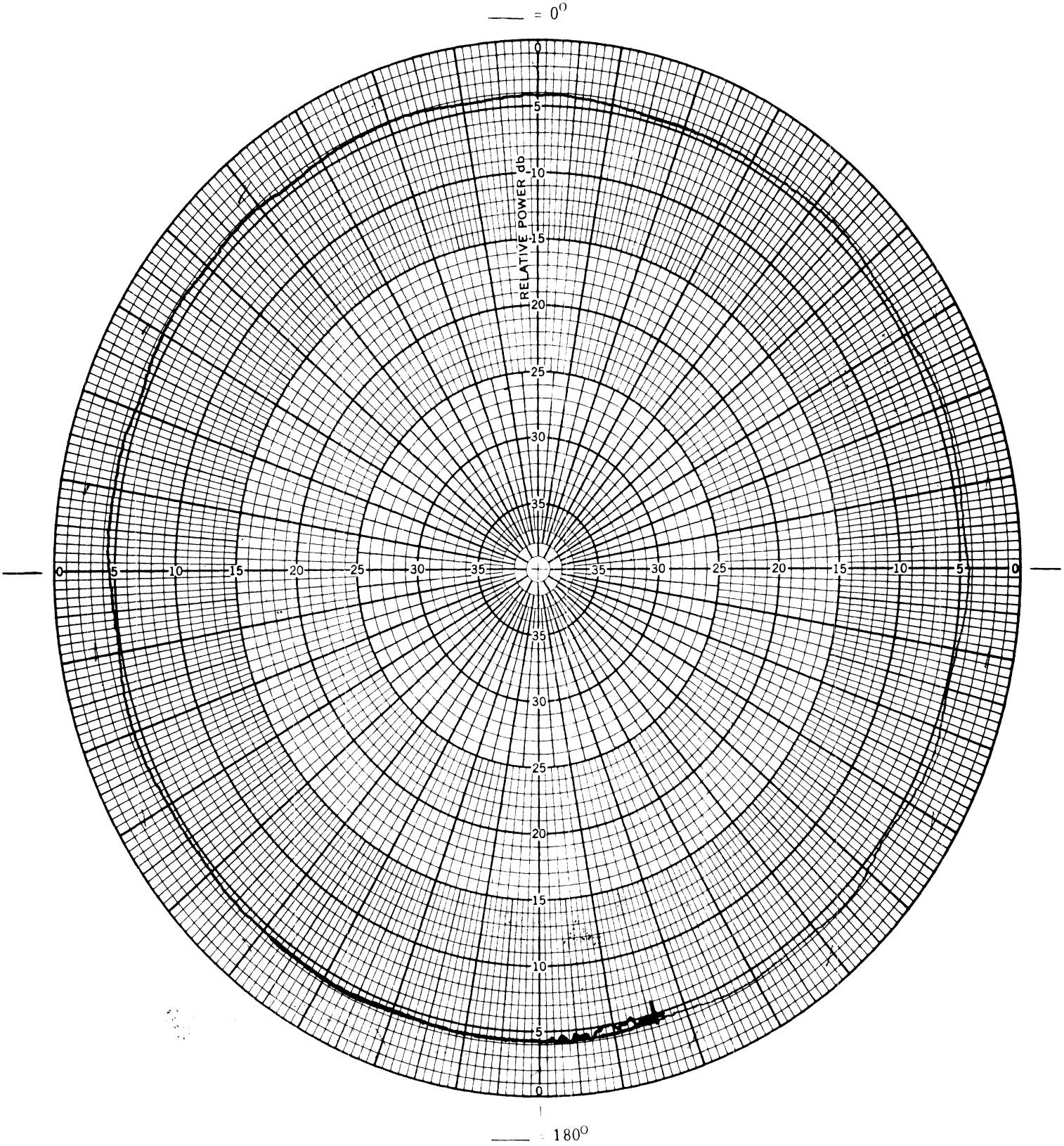

Fig. 58(b): Measured horizontal plane pattern of the whip antenna mounted on Tempo body shell. Horizontal polarization, f = 890.0 MHz.

Figures 15 through 58 show the vertically and horizontally polarized radiation pattern characteristics of the side-fed and bottom-fed heated backlite antenna and of the whip antenna obtained at selected frequencies. In all cases the 0 degree and 180 degree directions refer to the front and back directions of the car, respectively.

The following general observations are made from a study of the detailed pattern characteristics of the heated backlite and whip antennas given in Fig. 15 through 18.

(i) Side-Fed Heated Backlite and the Whip Antenna: For vertical polarization the whip antenna maintained better overall omnidirectionality. The heated backlite antenna seems to be more directive having deep nulls in the pattern at certain frequencies. However, at higher frequencies (400 to 600 MHz) the patterns of the two antennas are comparable.

For horizontal polarization the pattern characteristics of the two antennas are similar and, in fact, the heated backlite antenna seems to provide superior patterns.

(ii) Bottom-Fed Heated Backlite and the Whip Antenna: For vertical polarization and above 200 MHz the characteristics of the two antennas are comparable, although at certain frequencies the heated backlite antenna patterns show some significant minima. At lower frequencies, although the performance of the heated backlite antenna is slightly worse than the whip, it is significantly better than the side-fed case and the patterns do not have any deep nulls.

For horizontal polarization the heated backlite antenna consistently provides a comparable, and in many cases, superior patterns over the entire band of frequencies.

5.2 Relative Gain

The relative gain of the heated backlite antennas with respect to the whip has been computed from the measured patterns for both vertical and horizontal polarizations, and the results are given in Tables 5.1 and 5.2. The results are also shown graphically in Figs. 59 and 60. A study of the results indicate that, in general, the whip antenna has more gain at frequencies lower than about 200 MHz; however, above 200 MHz the heated backlite antenna appears to have comparable and more gain.

Table 5.1

Relative Gain (Δ) of the Heated Backlite Antenna

(Vertical Polarization)

Freq. (MHz)	Whip (dB)	Heated Backlite Bottom-fed (dB)	Δ (dB)	Whip (dB)	Heated Backlite Side-fed (dB)	Δ (dB)
60	-5.02	-10.63	-5.61	-3.29	-10.28	-6.99
71.5	-4.62	-12.57	-7.95	-1.68	-15.20	-13.52
88	-5.20	-13.65	-8.45	-6.34	-25.94	-19.60
98	-6.18	-13.19	-7.01	-8.32	-27.50	-19.18
108	-9.08	-13.52	-4.44	-11.11	-30.06	-18.98
179	-10.48	-16.36	-5.88	-12.60	-19.97	-7.37
215	-9.12	-5.58	+3.54	-9.58	-9.99	-0.41
475	-11.31	-11.99	+0.68	-10.98	-9.53	+1.45
637	-12.71	-11.77	+0.94	-16.49	-15.89	+0.06
825	-12.66	-15.34	-2.68	-21.52	-19.67	+1.85
890	-16.16	-14.76	+1.40	-23.10	-22.97	+0.13

Δ (dB) = Heated Backlite (dB) - Whip (dB)

Table 5.2

Relative Gain of Heated Backlite Antenna

(Horizontal Polarization)

Freq. (MHz)	Whip (dB)	Heated Backlite Bottom-fed (dB)	Δ (dB)	Whip (dB)	Heated Backlite Side-fed (dB)	Δ (dB)
60	-2.09	-2.31	-0.22	-16.87	-23.31	-6.44
71.5	-0.09	-6.37	-6.28	-5.33	-14.61	-9.28
88	-2.26	-11.64	-9.38	-8.96	-20.75	-11.77
98	-2.10	-3.49	-1.39	-10.29	-19.83	-9.54
108	-4.65	-7.58	-2.93	-5.43	-9.46	-4.03
179	-13.03	-11.16	+1.87	-9.39	-10.04	-0.65
215	-6.93	-5.74	+1.19	-25.77	-11.76	+14.01
475	-5.39	-3.74	+1.65	-13.15	-9.46	+3.69
637	-12.25	-11.10	+1.15	-12.21	-11.43	+0.78
825	-11.53	-8.83	+2.70	-13.52	-13.45	+0.07
890	-4.44	-4.50	-0.06	-12.58	-12.91	+0.33

Δ (dB) Heated Backlite (dB) - Whip (dB)

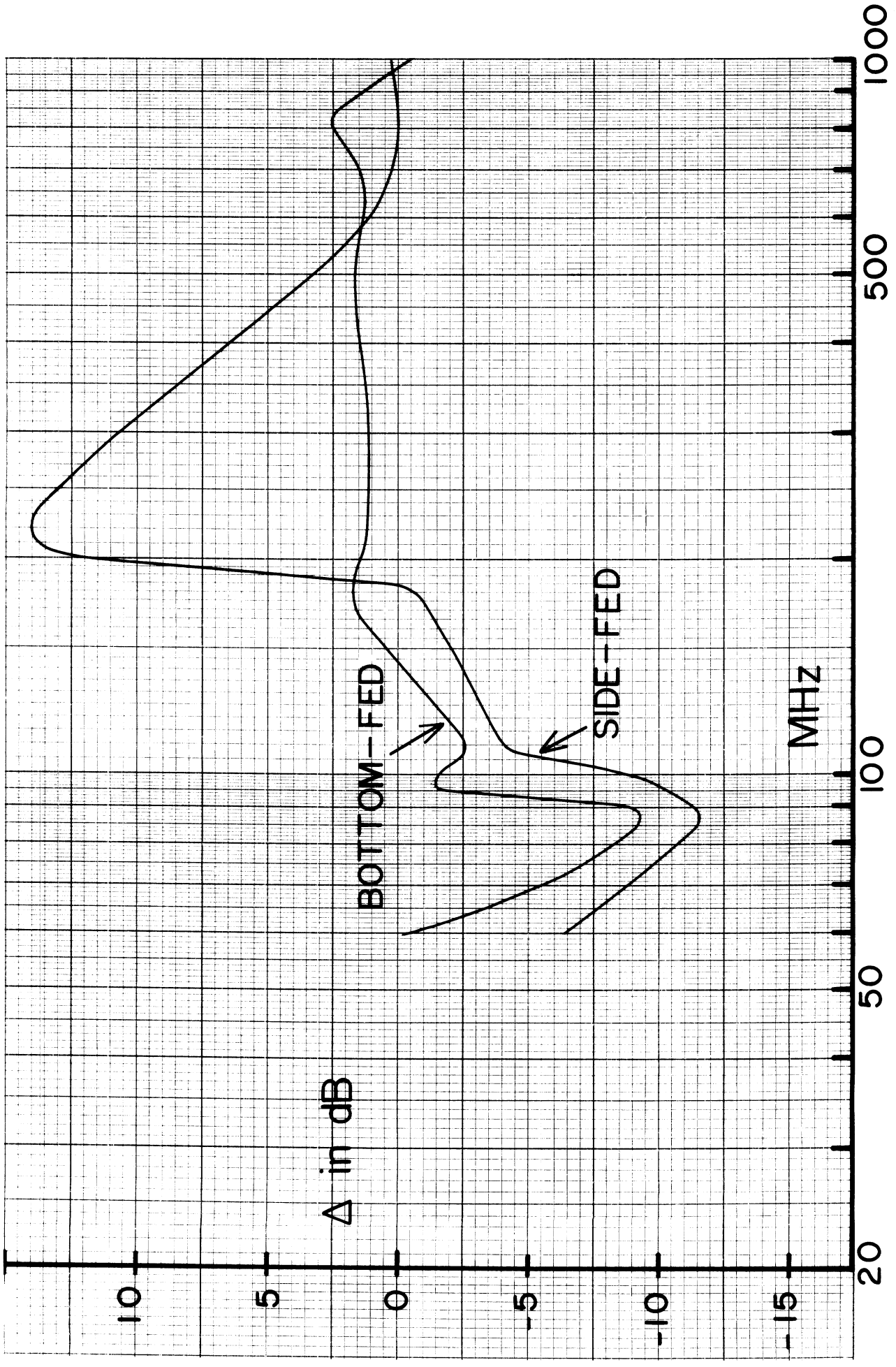

Fig. 59: Gain relative to the whip vs frequency for the side-fed and bottom-fed heated backlite antennas under vertical polarization.

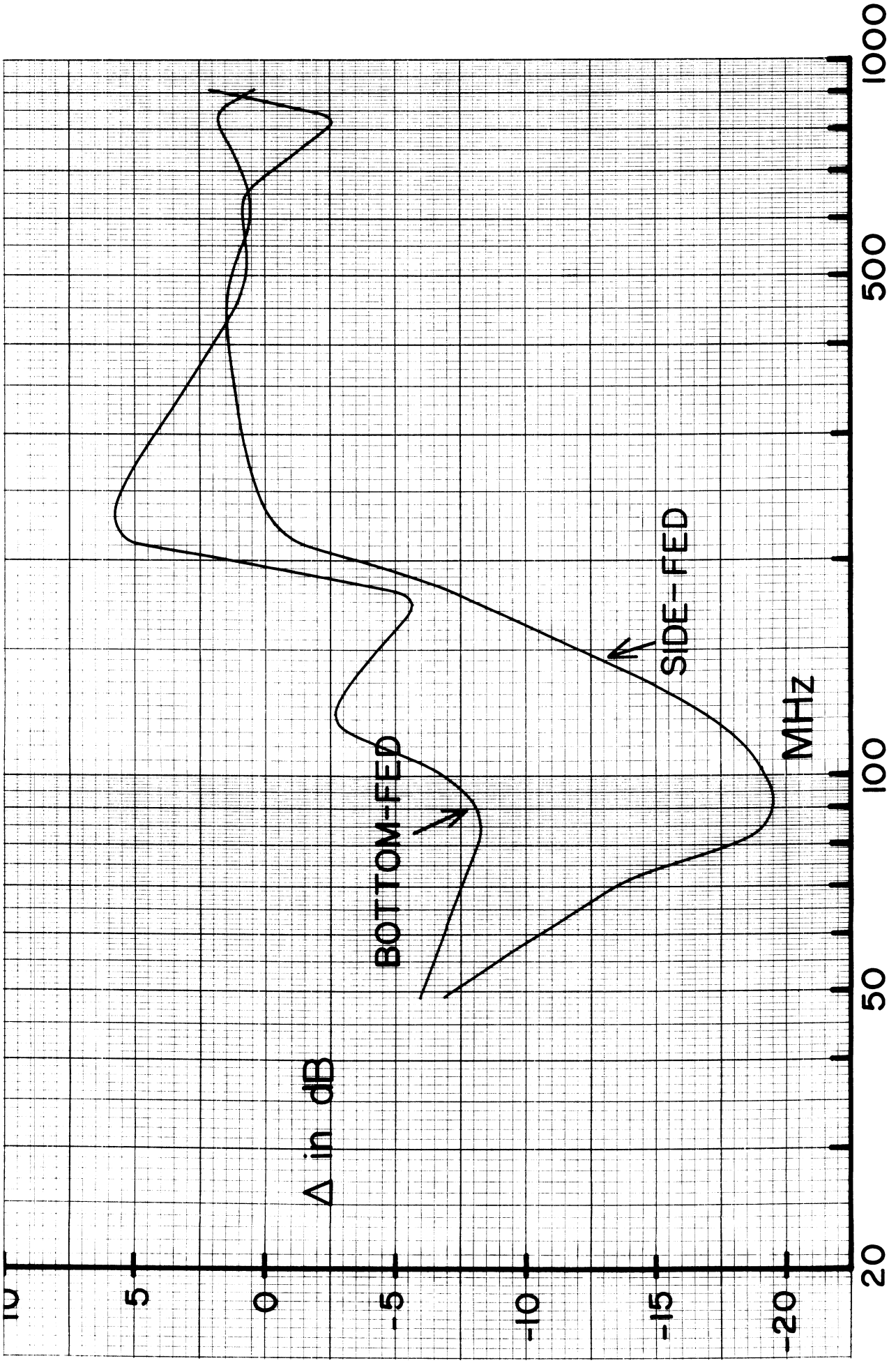

Fig. 60: Gain relative to the whip vs frequency for the side-fed and bottom-fed heated backlite antennas under horizontal polarization.

5.3 Input VSWR

The input VSWR of the heated backlite antenna mounted on the car body shell has been measured as a function of frequency for both side- and bottom-fed cases. The results are given in Table 5.3. The results indicate that for the bottom-fed case the VSWR $\leq$ 2.0 throughout the band of frequencies used except at 60 MHz. For the side-fed case the VSWR $\leq$ 2.0 for frequencies above 108 MHz. No further work was carried out to pursue the impedance behavior of these antennas.

Table 5.3

VSWR Data on HBL

Freq. (MHz)	VSWR Bottom Fed	VSWR Side Fed
60	2.8	2.3
71.5	1.9	1.9
88	1.9	2.5
98	1.3	2.3
108	1.9	2.2
180	1.4	1.8
215	1.4	1.4
475	1.4	1.3
637	1.2	1.1
825	1.1	1.1
890	1.1	1.04

VI. CONCLUSIONS

The sensitivities of the heated backlite, the capacitor and the whip antennas, suitably mounted on a ground plane, have been measured inside a laboratory environment by receiving commercially available signals in the frequency range 0 to 1000 MHz. The whip antenna appears to be more sensitive up to the FM band of frequencies; at high frequencies the other two antennas seem ot have comparable and, sometimes, more sensitivity.

The radiation patterns of the above isolated antennas have been measured at the frequencies 50 to 1000 MHz. For frequencies up to slightly above the FM band, the whip antenna maintains better omni-directionality of the pattern; at higher frequencies the heated backlite antenna seems to provide omnidirectionality. Overall, the capacitor antenna provides superior omnidirectionality over the entire band of frequencies.

The radiation patterns of the heated backlite and whip antennas mounted on a Tempo body shell have been obtained at frequencies 50 to 1000 MHz under various conditions over the same band of frequencies. The gain of the former antenna relative to that of the whip antenna has been obtained theoretically from the measured patterns. These results can be used to estimate the overall performance of the heated backlite antenna relative to the standard whip antenna. Limited measurements performed indicate that the input VSWR of the heated backlite antenna can be maintained below 2.0 over most of the band of frequencies considered.

VIII References

[1] J. E. Ferris and D. L. Sengupta, "A Study of Windshield Antenna Performance Levels for Automobiles," University of Michigan Radiation Laboratory Report No. 320673-1-F, Ann Arbor, Michigan, July 1977.

[2] D. L. Sengupta and J. E. Ferris, "A Study of CB, FM, and AM Antennas for Automobiles," University of Michigan Radiation Laboratory Report No. 320863-1-F, Ann Arbor, Michigan, November 1978.

[3] J. E. Ferris and D. L. Sengupta, "An Experimental Study of Windshield Antennas for Automobiles," University of Michigan Radiation Laboratory Report No. 320857-1-F, Ann Arbor, Michigan, February 1979.

VII. ACKNOWLEDGEMENTS

The author is pleased to acknowledge with thanks the help provided by Mr. Joseph E. Ferris, formerly of the Radiation Laboratory, who was responsible for the collection of all the experimental data discussed in the report. Several discussions with the technical personnel, in particular with Mr. Ray Spitz, of Ford Motor Co. are gratefully acknowledged.

APPENDIX

Additional data obtained with the frame of the side-view mirror used as an antenna to receive the commercially available signals are given here. The mirror was mounted orthogonally to the ground plane. Figures A.1 and A.2 show the results obtained with the ground plane oriented horizontally and vertically, respectively. These results should be compared with those given in Section III.

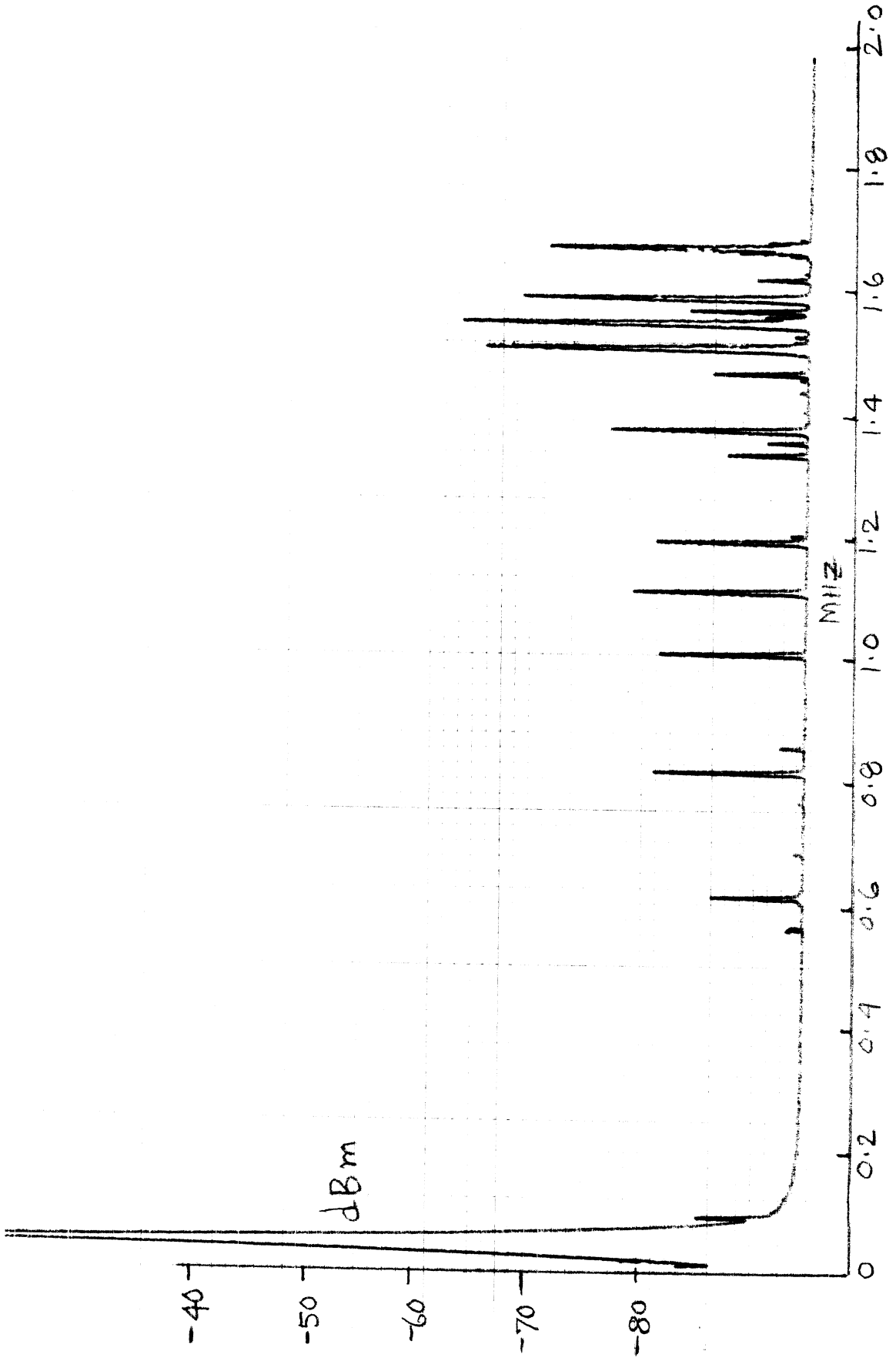

Fig. A.1(a): Response of the mirror antenna (ground plane horizontal) vs frequency of the commercially available signals. (0 - 2 MHz)

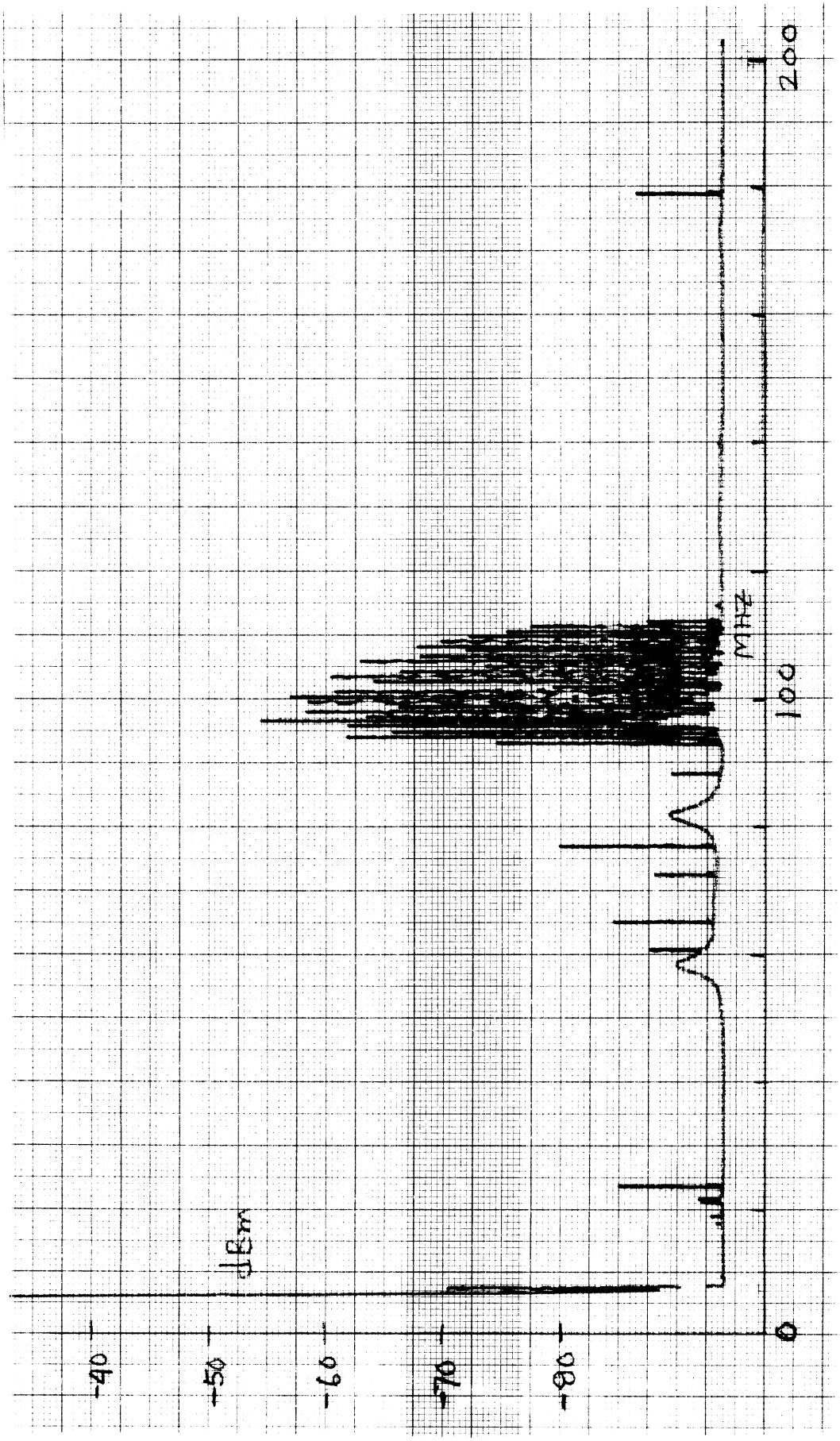

Fig. A.1(b): Response of the mirror antenna (ground plane horizontal) vs frequency of the commercially available signals. (0 - 200 MHz)

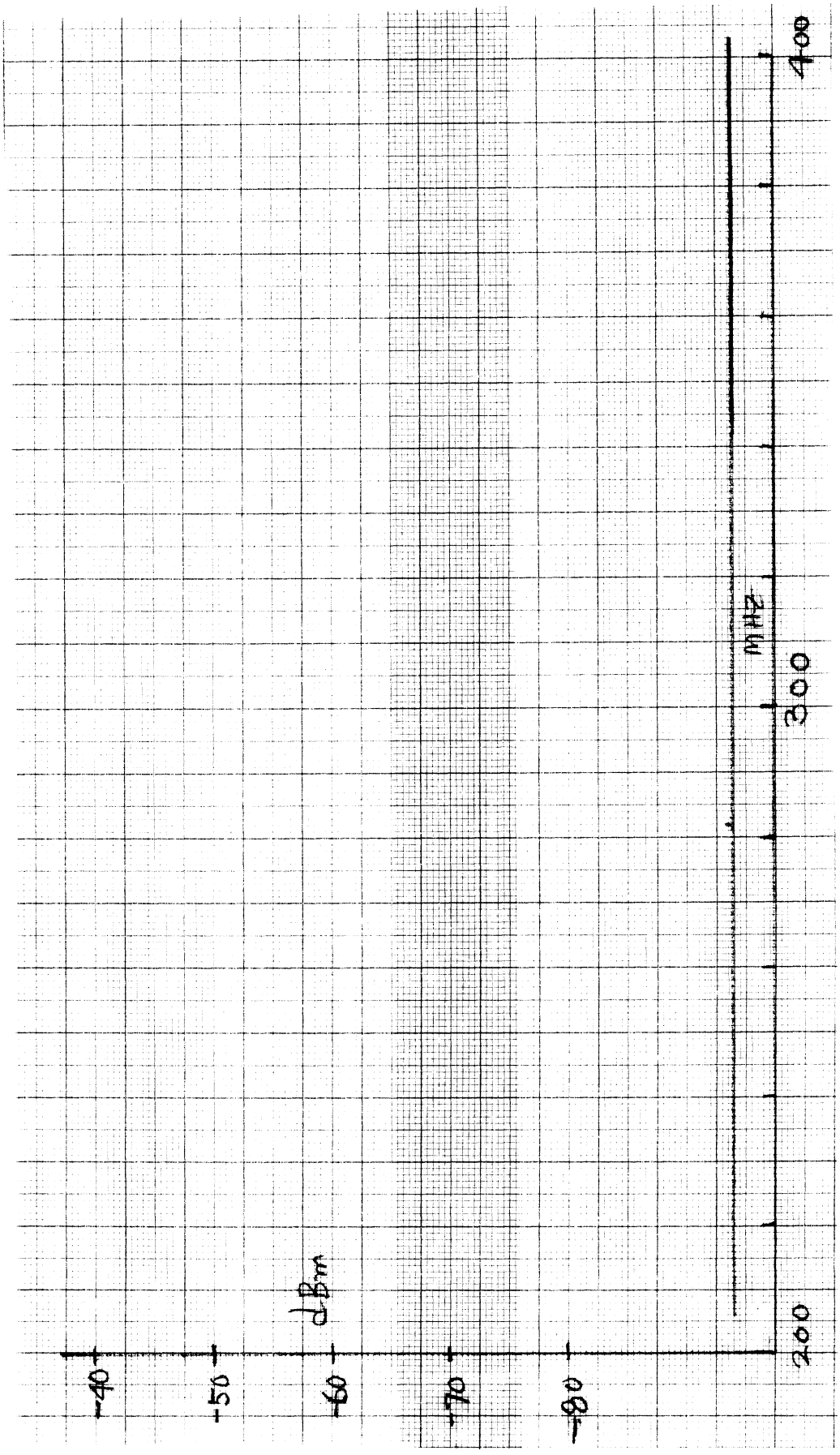

Fig. A.1(c): Response of the mirror antenna (ground plane horizontal) vs frequency of the commercially available signals. (200 - 400 MHz)

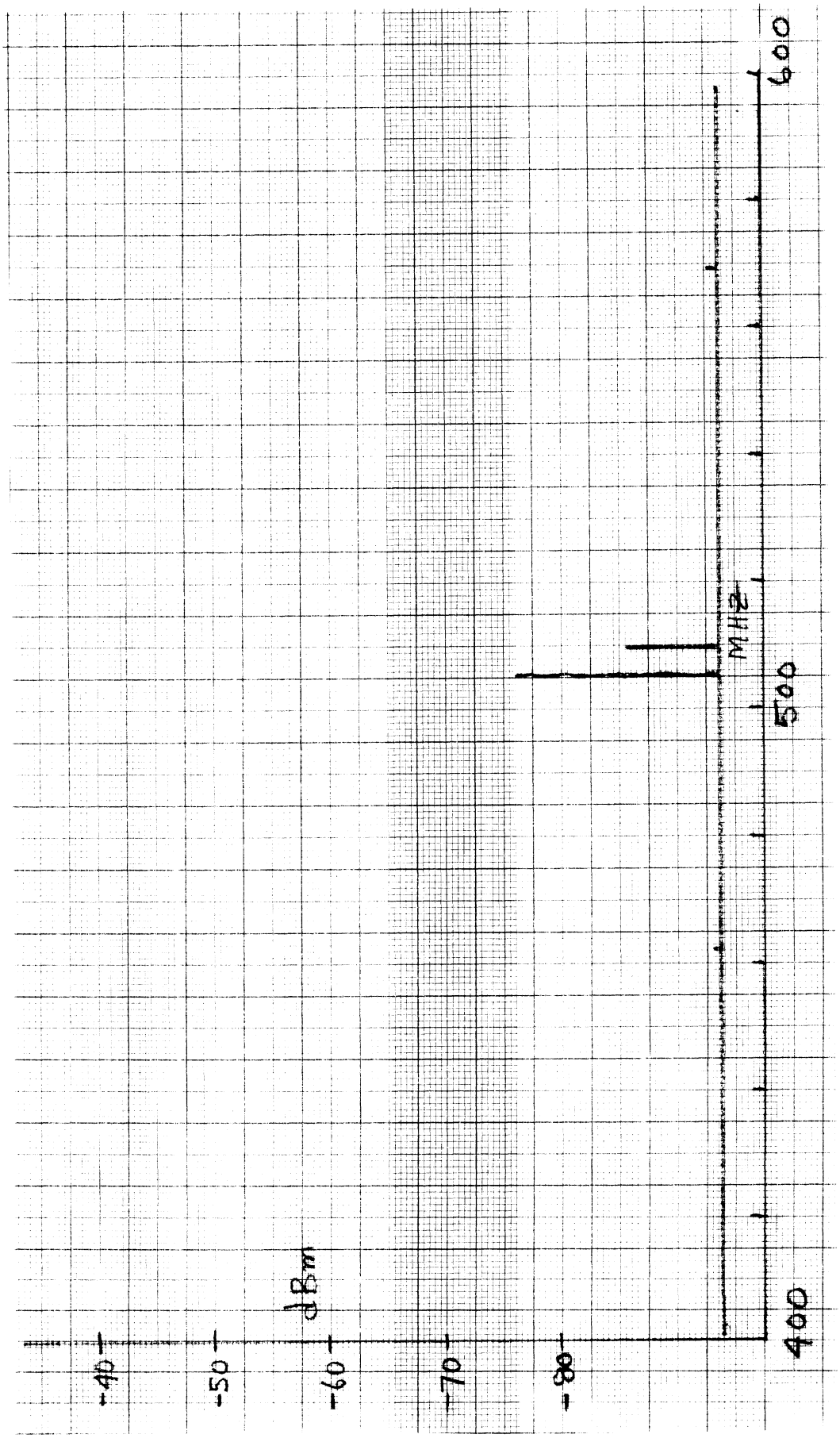

Fig. A.1(d): Response of the mirror antenna (ground plane horizontal) vs frequency of the commercially available signals. (400 - 600 MHz)

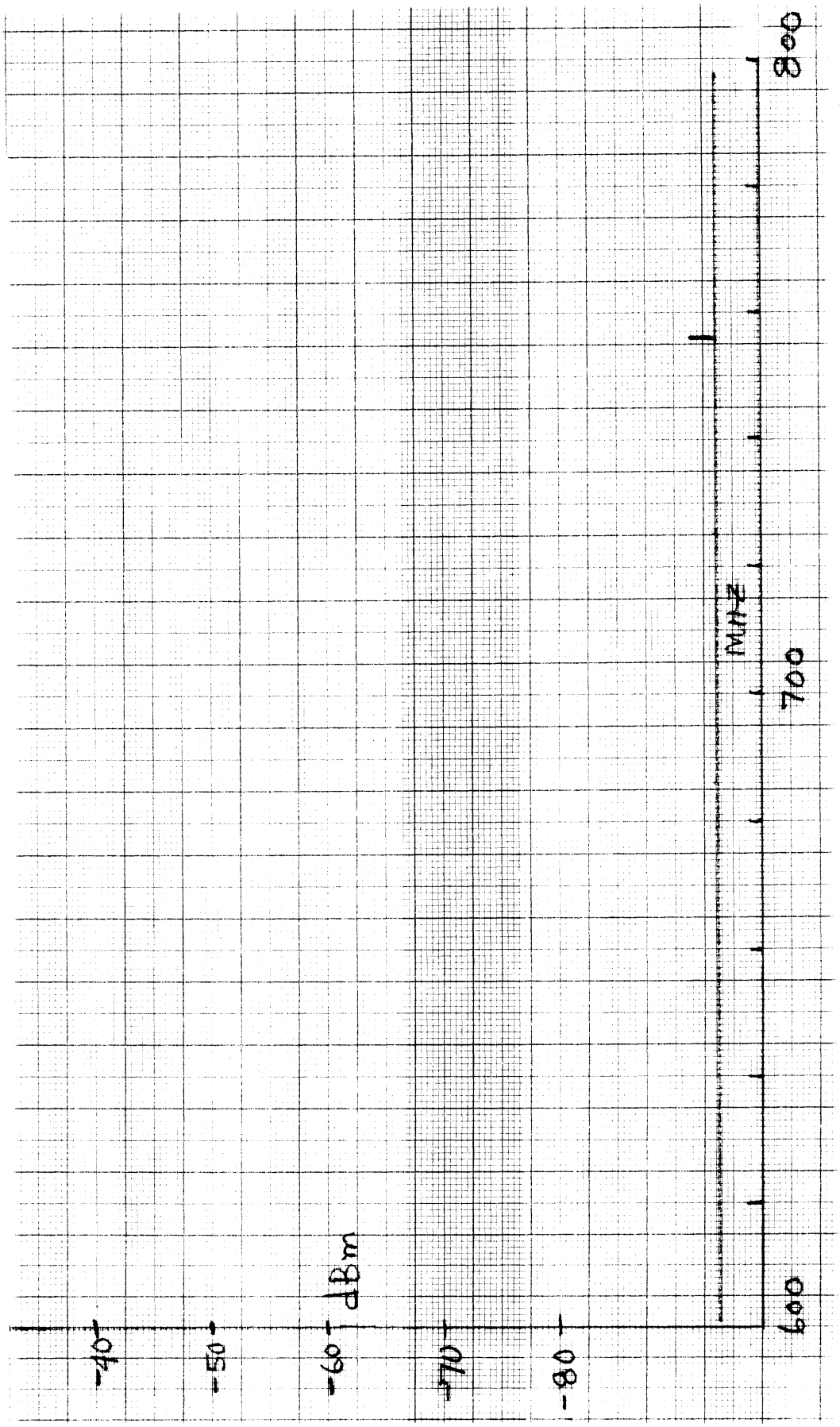

Fig. A.1(e): Response of the mirror antenna (ground plane horizontal) vs frequency of the commercially available signals. (600 - 800 MHz)

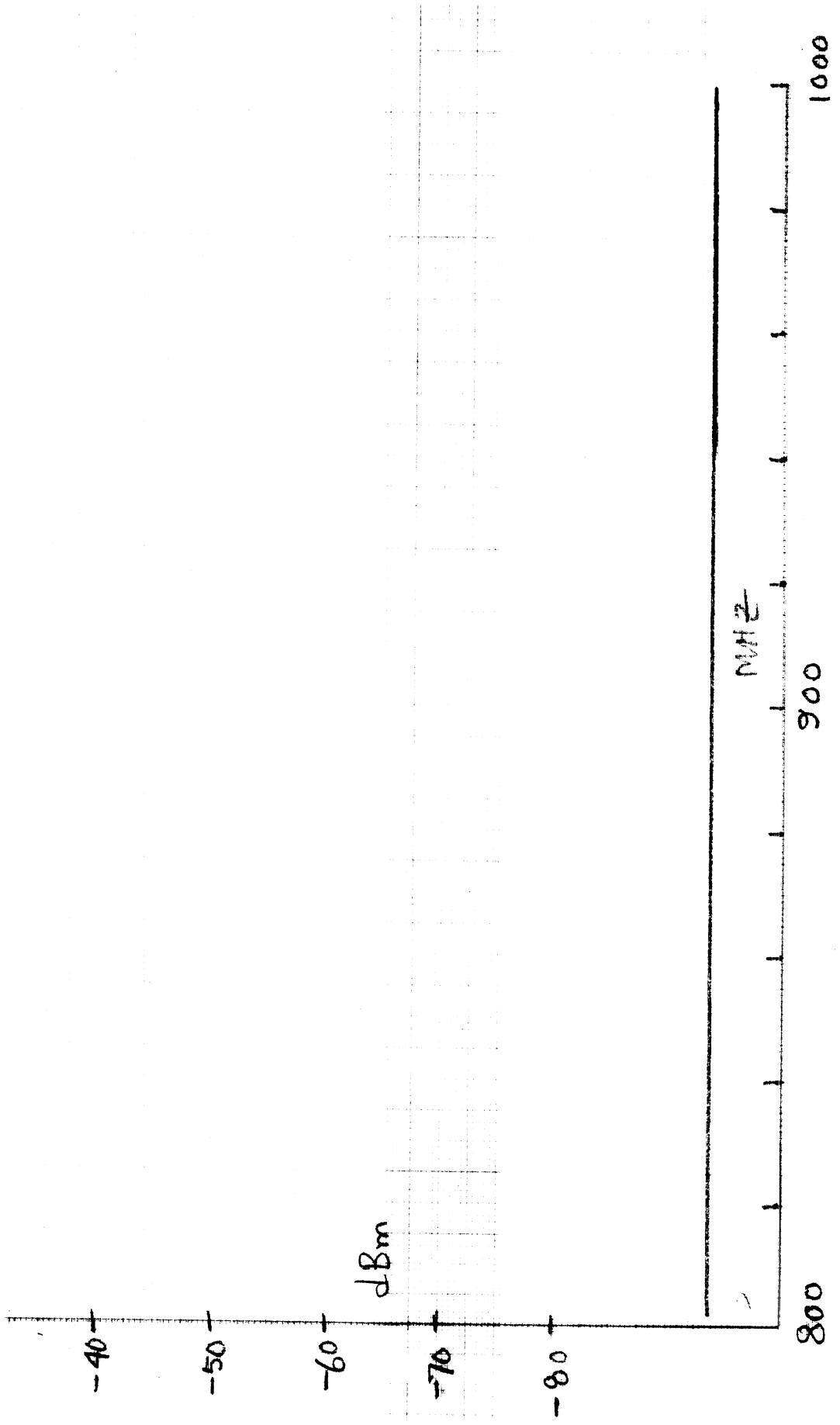

Fig. A.1(f): Response of the mirror antenna (ground plane horizontal) vs frequency of the commercially available signals. (800 - 1000 MHz)

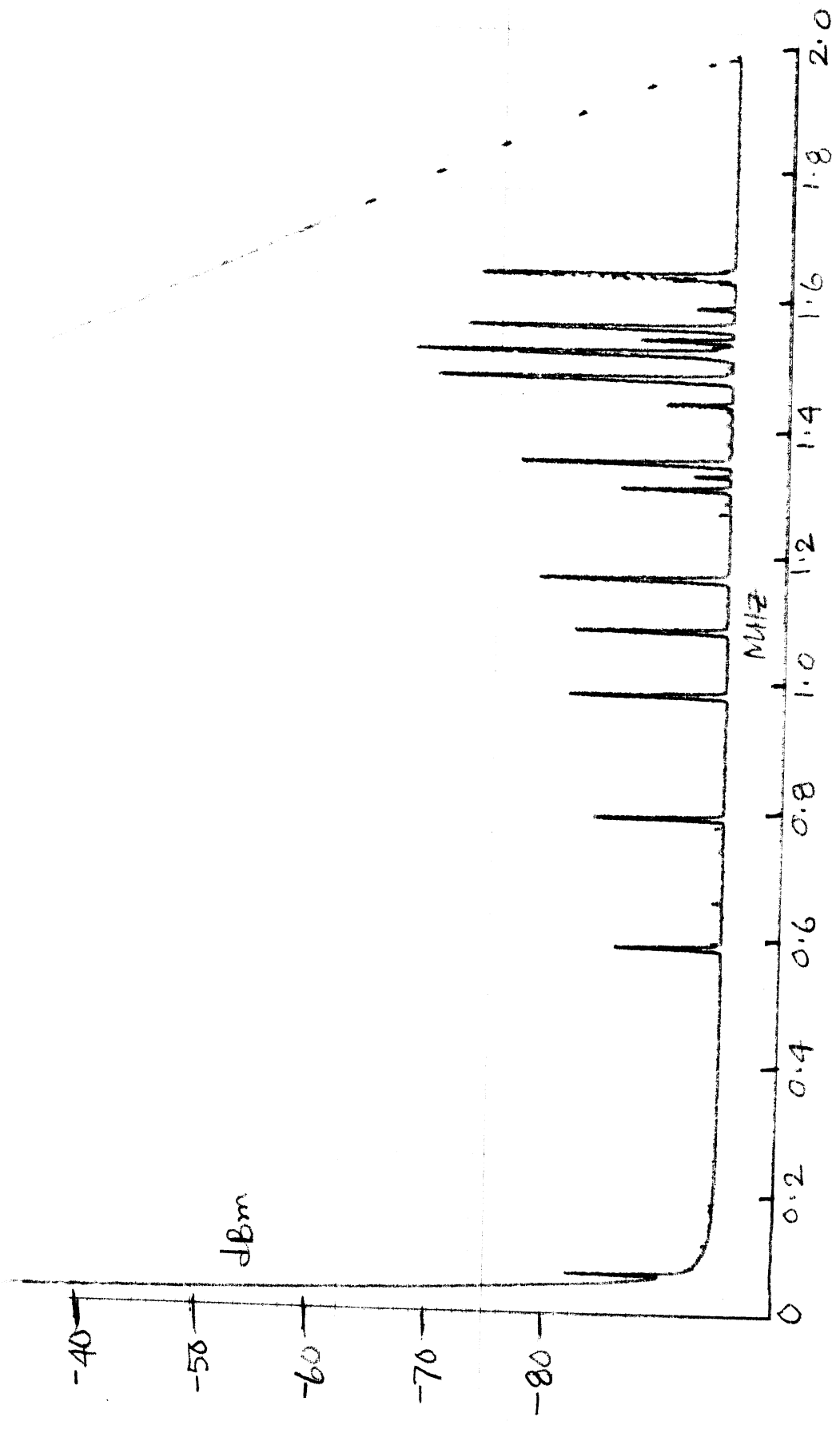

Fig. A.2(a): Response of the mirror antenna (ground plane vertical) vs frequency of the commercially available signals. (0 - 2 MHz)

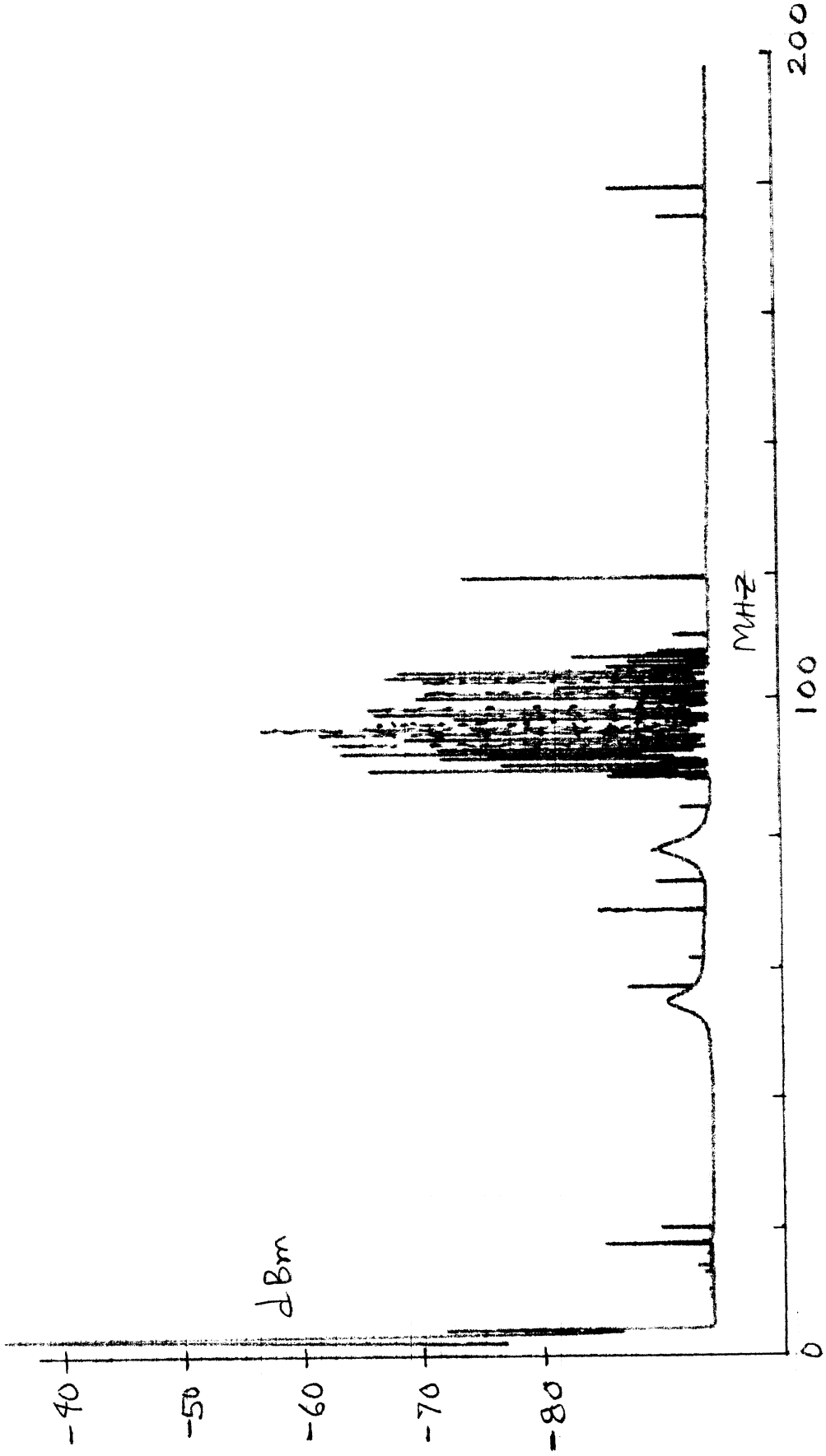

Fig. A.2(b): Response of the mirror antenna (ground plane vertical) vs frequency of the commercially available signals. (0 - 200 MHz)

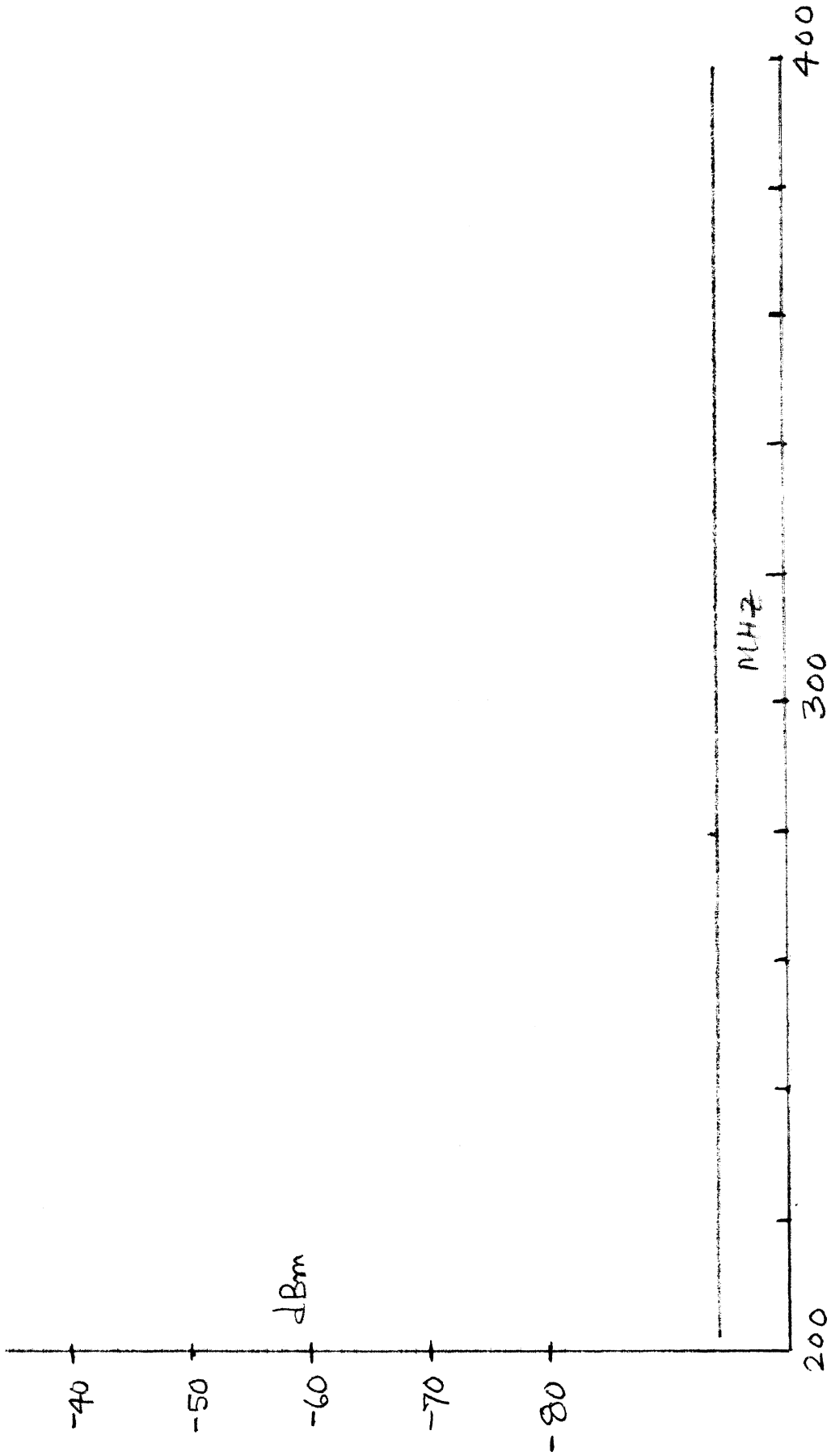

Fig. A.2(c): Response of the mirror antenna (ground plane vertical) vs frequency of the commercially available signals. (200 - 400 MHz)

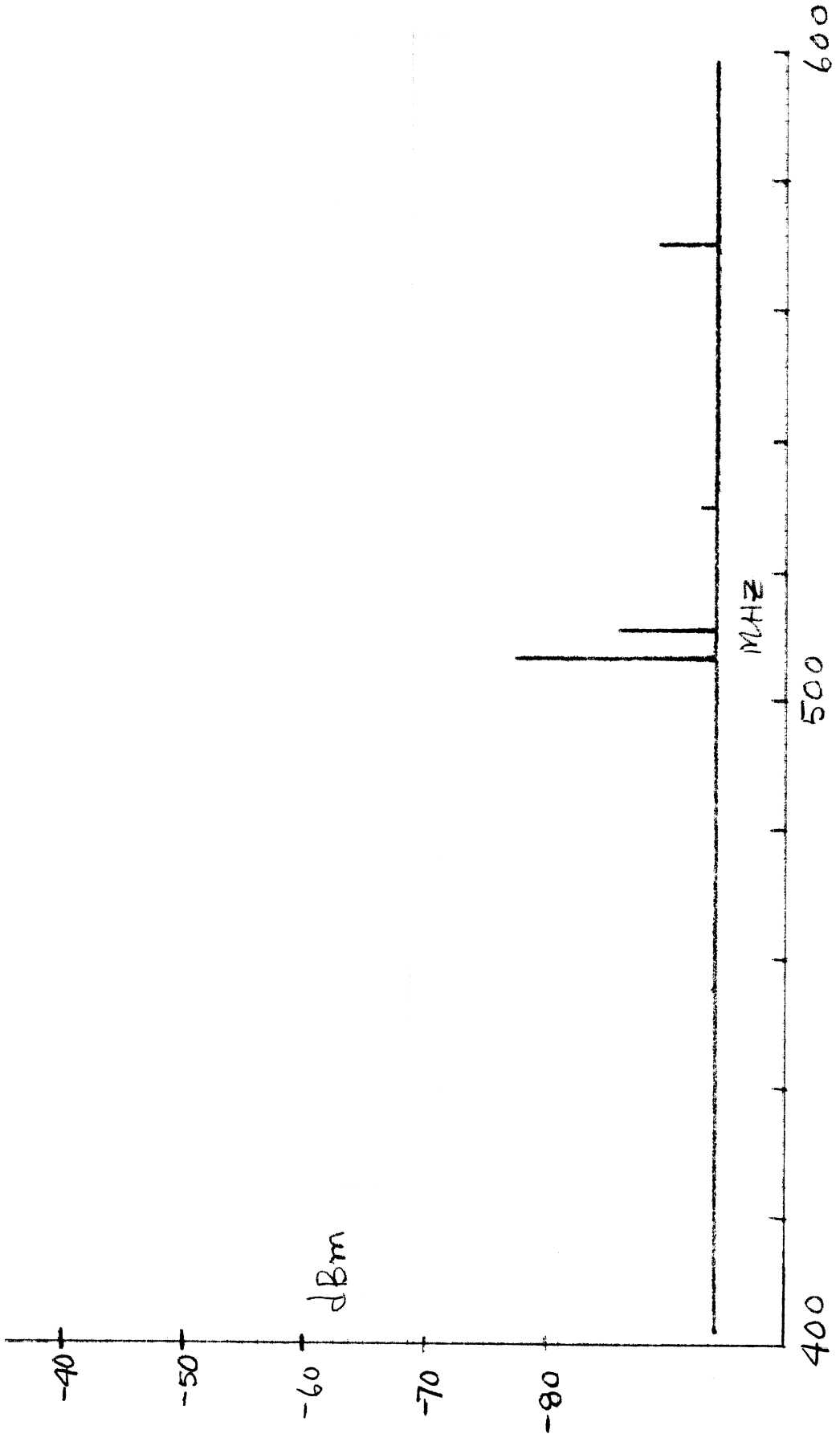

Fig. A.2(d): Response of the mirror antenna (ground plane vertical) vs frequency of the commercially available signals. (400 - 600 MHz)

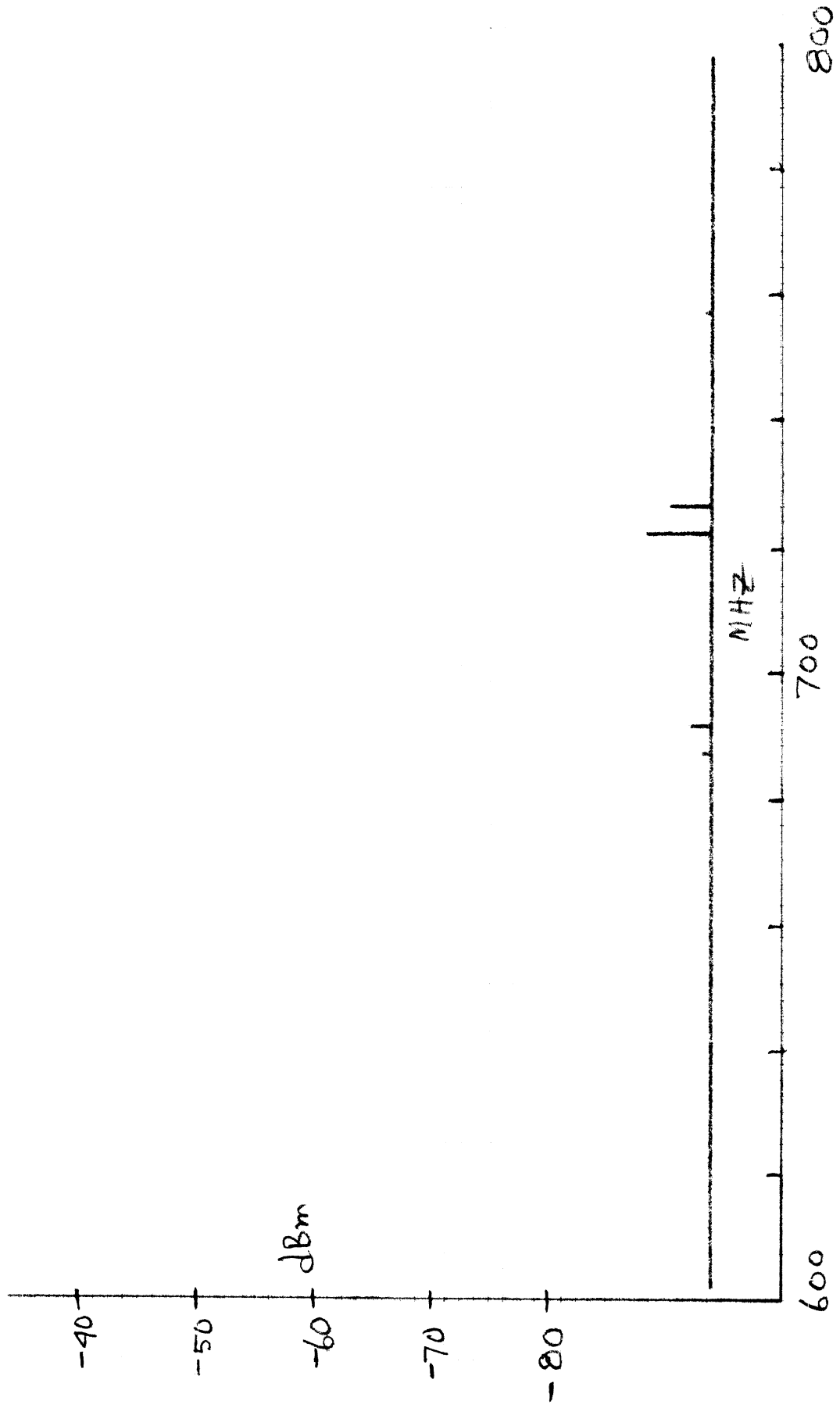

Fig. A.2(e): Response of the mirror antenna (ground plane vertical) vs frequency of the commercially available signals. (600 - 800 MHz)

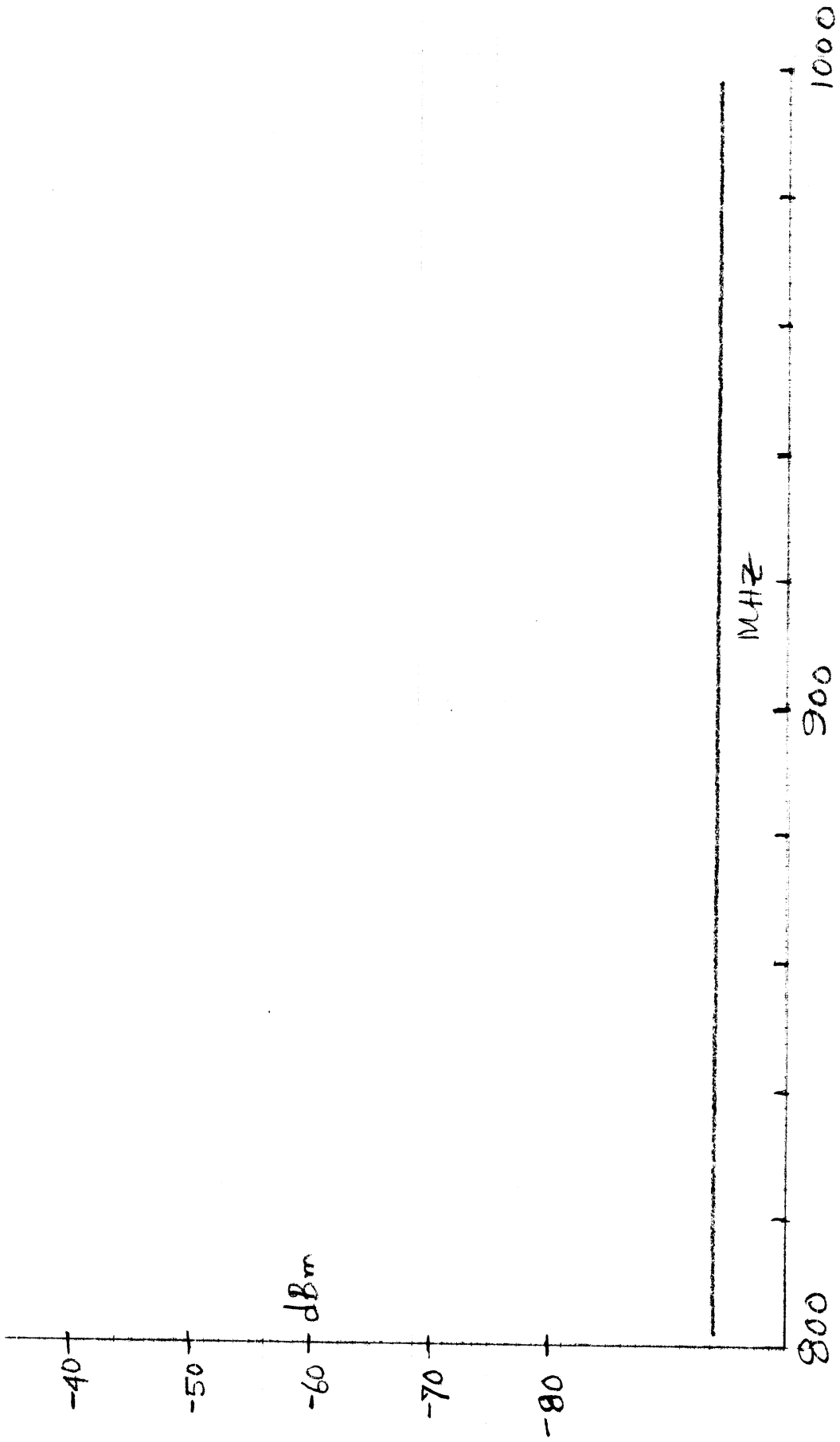

Fig. A.2(f): Response of the mirror antenna (ground plane vertical) vs frequency of the commercially available signals. (800 - 1000 MHz)