THE UNIVERSITY OF MICHIGAN

COLLEGE OF ENGINEERING

DEPARTMENT OF ELECTRICAL ENGINEERING

Radiation Laboratory

ANTENNA AND SCATTERING STUDIES PERFORMED FOR THE STUDY OF PREDICTIVE SENSORS

32512-1-F

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ANTENNA AND SCATTERING STUDIES PERFORMED BY THE RADIATION LABORATORY

In this section we summarize the results of our studies of both the antenna and scattering aspects of a proposed remote sensing system for vehicles. In order to achieve isolation between identical radars approaching each other, it has been proposed that the antennas be orthogonally polarized. Whether the polarizations actually employed are circular or linear, the concept is equally valid for each. Thus, in the cross polarized work performed in both the antenna and scattering measurements, the antennas were linearly polarized 45 degrees above the horizontal.

The results are presented essentially in two subsections, the first of which describes the antenna work. We were a little surprized that the cross polarized forward scatter of a strong depolarizing target (a small sign) had less effect than anticipated. In the second subsection we describe the scattering measurements. The results show that the magnitude of the target echo is in no way an indication of target mass.

ANTENNAS FOR REMOTE SENSING

As now envisioned, it does not appear that the antenna will prove to be a critical component in the sensing system. If an unsophisticated antenna is to be used, it will produce the familiar pencil beam, rounded or tapered, at the peak. Such beams can be produced most economically at X-band or K-band frequencies by the use of horns. Parabolic dishes may be preferrable when dimensions exceed six inches or so but the cost of such antennas may be slightly more costly due to the requirement for carefully made and carefully positioned feed: a third type, even more costly would be a flat slot array. It is not likely that either the parabolic reflector or the array would be used for apertures less than 5 wavelengths or so.

In all cases one can easily generate horizontal, vertical or 45 degree polarization. Circular polarization can be produced fairly easily in either the horn or dish antenna and with more difficulty in the slot array. In any aperture antenna, the width of the antenna beam is inversely proportional to the antenna dimensions, measured in wavelengths. The half power beamwidth, BW, is approximately equal to $\frac{65\lambda}{D}$ degrees, where λ is the wavelength and D is the antenna aperture. Some beamwidths of interest for this project and the required dimensions in inches are shown in Table I.

Frequency GHz	Beamwidth (in degrees) 5	10	30
9	17	8.5	2.9
36	4.3	2.2	1.

TABLE I: Antenna Dimension and Half-power Beamwidths.

Thus, it is feasible to produce any reasonable beamwidth of interest. To produce a shaped beam more sophistication is required and the required aperture-dimensions will increase by a factor of 2 or 3. It is doubtful if a square top or any other unusual beam shape is worth the additional cost for the present program.

In the proposed system, a way must be found to prevent the RF transmission from an oncoming vehicle from triggering the inflation mechanism. The use of circular polarization to help to solve this problem has been proposed. If each vehicle would transmit right hand circular (RHC) for example and receive LHC, the receiving antenna in a vehicle would tend to be cross polarized with respect to the RF transmissions from an approaching vehicle. A similar objective is achieved by having all vehicles transmit and receive with a + 45 degrees linear polarization. Thus two systems facing each other are cross polarized. We favor this latter method since it calls for a simple antenna.

It is not certain, however, that the receiver protection obtained in either case is sufficient. By the use of carefully aligned cross polarized horn antennas, we have been able to measure isolations of 31 to 40 dB. (That is, the signal received with the receiving antenna cross polarized is 31 to 40 dB less than that obtained when the two have the same polarization.) These data were obtained with two X-band horns with an aperture about 5 1/2 x 7 1/2 inches and about 12 inches in length.

The 40 dB isolation is achieved only by a careful alignment of the two horns to ensure that the two E vectors are at an angle of 90 degrees, a mis-alignment of only one degree will decrease the maximum isolation by several dB. The above variation from 31 to 40 dB occurred when the frequency was swept from 9.0 to 9.6 GHz.

We also found that the degree of isolation obtainable was influenced by the shape of the horn. A horn having a long taper will have less cross polarization than an open end waveguide or short tapered horn. Heavy edge illumination on the horn apertures tends to increase the cross polarization content. The degree of isolation also varies with angular distance from the beam axis. For some antennas, the cross polarized pattern will show a null on axis; in others the cross polarized pattern is roughly similar to the properly polarized pattern.

The cross polarization in a reflector antenna is generally higher than in horns. It will be higher with a deep reflector (small f/d) than with a shallow reflector.

In an experiment performed in the anechoic chamber pattern range two horn antennas were set up at a separation distance of about 45 feet. In the first test each horn was polarized in the 45-degree direction, but for optimum transfer of energy. With this arrangement, the pattern shown in Figure 1 was obtained. This is neither an E or H plane pattern and would be called a '45-degree' plane pattern; the horn dimensions are those given above. The second pattern shown on the same figure was obtained with the two horns cross polarized, that is the polarization for both horns was in the + 45 degree direction. The peaks of the two patterns are misaligned in angle due to improper positioning on the pedestal. These patterns show an isolation of about 25 dB on peak. The isolation remains close to 25 dB over an azimuth range of at least 20 degrees. The noise level in the system obscures the performance at wider azimuth angles.

In Figure 2 the cross polarized pattern of Figure 1 is repeated as pattern No. 1. We then investigated the effect of a scatterer in the vicinity of the two antennas. The scatterer used was a 12 x 18 inch sign on a five-foot steel channel, a sign of the type likely to be encountered along a street or country road; see Figure 4. The cross polarized patterns were repeated for three different sign arrangements. For pattern No. 2 the sign was half-way between the two antennas but five feet to one side. This produced no measurable effect. For Pattern No. 3, the sign was at the midpoint of the line between the two antennas and the plane of the sign was parallel to the direction of propagation. Pattern No. 3 was for a similar position, but with the sign perpendicular to the direction of propagation.

We had expected that a scatterer such as this one would increase the cross polarized signal thus decreasing the isolation. We reasoned that the vertical channel would create a strong vertically polarized signal in the forward direction. Such a signal would be detected by the 45 degree polarized receiving antenna with only a few dB loss.

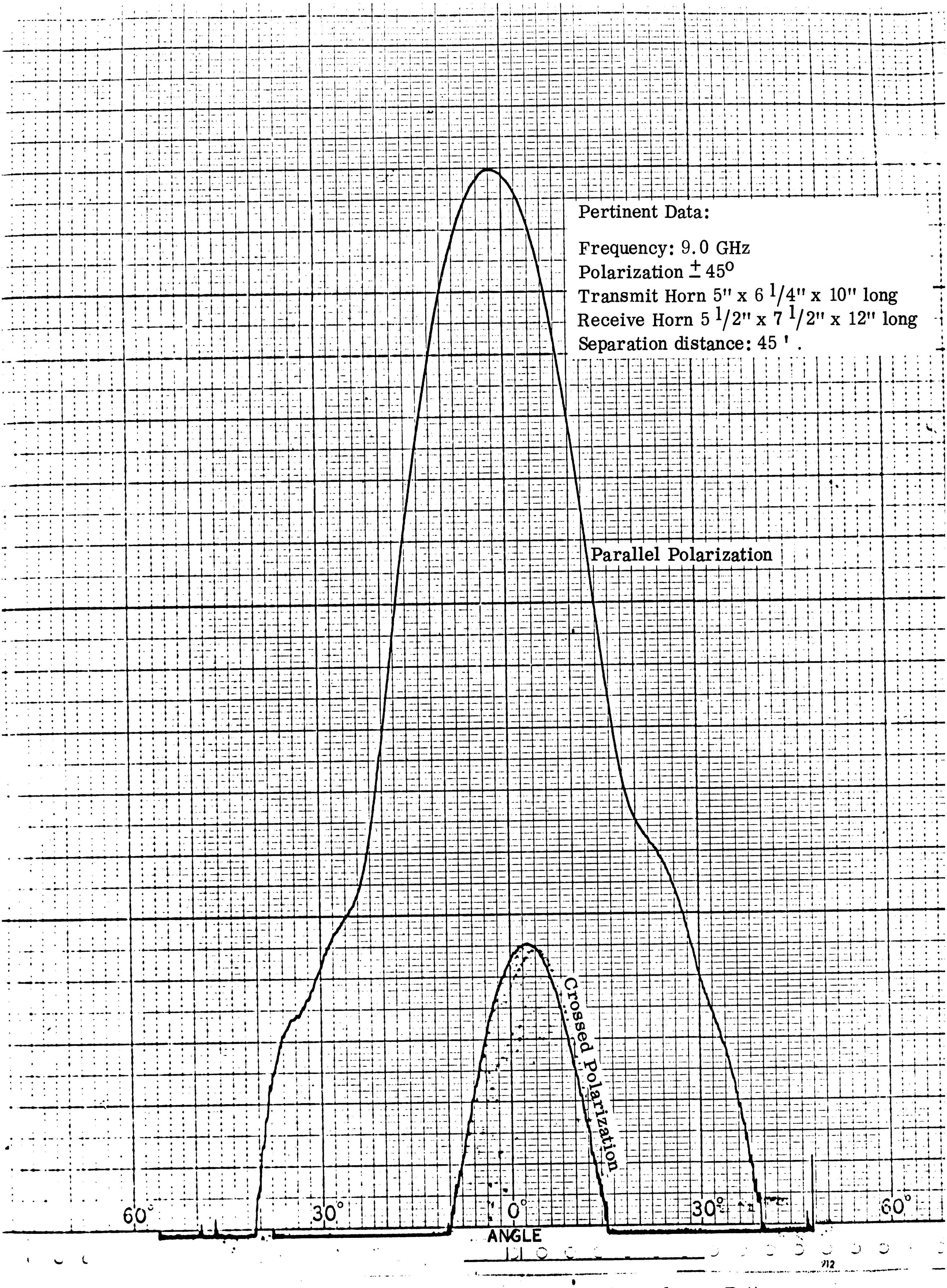

Figure 1: Comparison of Parallel and Cross Polarized Horn Patterns.

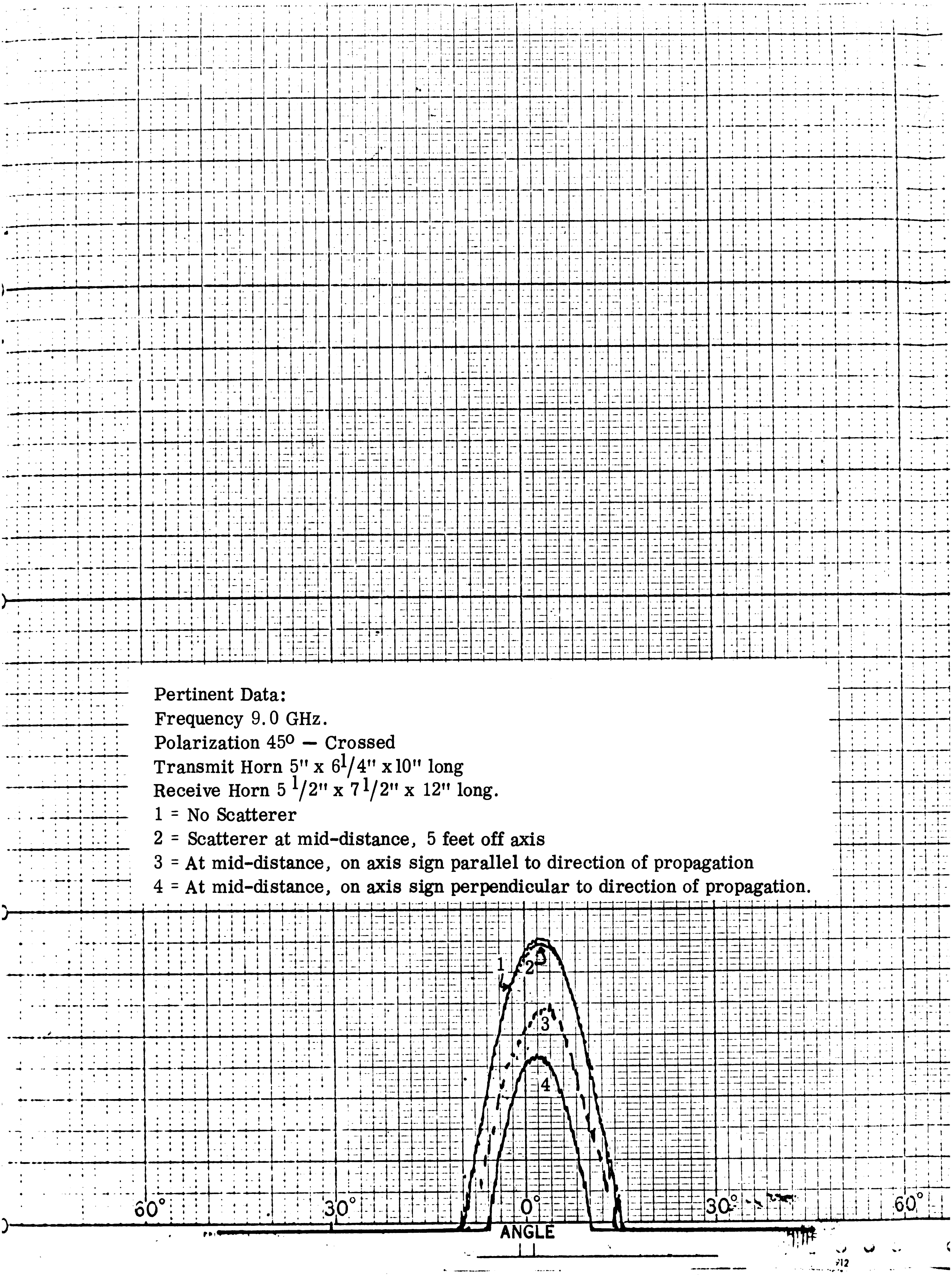

Figure 2: Effect of a Roadside Sine on the Isolation Between a Pair of Cross Polarized Antennas.

If cross polarized antennas are to be used in a future system, further studies should be performed to obtain a better understanding of forward scatter behavior when cross polarizations are involved.

If and when system parameters are determined, further work is needed to develop the optimum antenna configuration.

RADAR CROSS SECTION MEASUREMENTS

We measured the radar returns of signs, trees, a man, and a concrete wall, but due to time limitations other targets of interest (i.e. autos, dogs, birds) were not measured. The measurements confirm the fundamental notion that the amplitude of the echo from a target is not necessarily indicative of the mass of the target. The data presented below, for example, show that an 800-pound wall backscatters only one tenth the energy that a 20-pound sign does.

The measurements were all carried out in the Radiation Laboratory's anechoic chamber at Willow Run Airport. The chamber, which is shown in the photograph of Figure 8, is 105 feet long, 28 feet wide, and 15 feet tall, and is lined for the most part with absorbing material rated at a -20 dB reflectivity level at X-band. The rear wall of the chamber is the exception, with the absorbent material there rated at -50 dB.

The radar used for the measurements is a conventional CW system with transmission and reception both taking place via a single horn antenna. Operation of the system requires that residual chamber reflections be cancelled out with a bucking signal and this must be done with the target removed from the chamber. Calibration of the measured patterns is effected by the removal of the unknown target and the substitution of a scatterer whose return is known. The calibration scatterer is a 10.5 inch wquare plate for direct polarization and a 90-degree dihedral having 10.5-inch square faces for the crossed polarization.

All the targets were separated from the antenna by a range of 50 feet, except for the tree specimens when 52 feet was used. The frequency used in the measurements was 9.13 GHz except for the direct (parallel) polarization measurements

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PAGE

of the trees, when 10.525 GHz was used. These slight differences in range and frequency are of no consequence in the interpretation of the results, since the targets were not of resonant size or dimensions.

In order to collect as much data as possible, as quickly as possible, we first measured the targets that were easiest to handle, saving the more difficult targets until last. Thus the signs were measured first, then the trees and a man, and finally the concrete wall. A summary of the targets measured and their representative cross section values appears in Table II, more or less in chronological order. Photographs of the targets are shown in Figure 4 through 7.

The targets were all measured in the near field, which is to say that they were close enough in range that the incident phase fronts were spherical instead of planar. The great majority of radar cross section work involves radars that are remote from the target, hence demanding planar phase fronts, but in this particular study, typical targets will in fact be relatively close to the radar. Thus the far field criterion does not apply. The half-power beamwidth of the antenna is about 6.5 feet wide at a range of 50 feet and most of the targets measured lay entirely within the beam as defined.

The measurements fall into four natural groups, depending on the target(s), and below we describe them and interpret the results. The first two groups, signs and trees, were the only ones in which cross polarized data were acquired. Of the last two groups, man and wall, we have a single pattern each.

Signs

Of the seven patterns recorded in this group of measurements, three were obtained with the signpost mounted horizontally atop the Styrofoam support column and with the incident wave horizontally polarized; the patterns appear in Figures 8 through 10. The patterns show that the returns fall off rapidly as the aspect angle swings away from broadside. At broadside the return of the post alone is 10 dBsm (Fig. 8), reaches 18 dBsm when a 12x18 inch sign is attached (Fig. 9), and is as large as 33 dBsm when a 36x36-inch sign is attached (Fig. 10).

In a roadside environment, signs are mounted vertically in the ground and thus Figures 8 through 10, which represent patterns taken in an elevation plane, suggest that the sign echoes would drop by 10 to 15 dB from the broadside value if the sign happened to be pushed as little as 3 degrees away from the verticel.

The next four figures, Figures 11 through 14, are patterns taken of the sign mounted vertically and rotated about its own axis. These patterns, being taken in the azimuth plane, are much broader than those taken in the elevation plane because the target length projected in the plane of rotation is much shorter. A transverse section of the signpost is channel-shaped and the pattern of Figure 11, taken of the post with no sign attached, shows that the return is smaller when the channel is viewed from the back side than from the open (front) side. Moreover, the return from the open side exhibits none of the deep nulls seen from the back side because the channel sides form dihedral faces which tend to give a constant return due to multiple reflections off the internal channel surfaces.

The pattern of Figure 12 results when a 12x18-inch sign is bolted to the face of the channel. Observe that the left side of the pattern shows the sin(x)/x behavior characteristic of a flat plate but that the right side does not. This is because the entire flat surface of the sign is unobstructed over the left portion of the pattern, whereas the supporting channel lies in front of the face of the sign over the right portion of the pattern. The presence of the channel breaks up the 'clean' flat plate pattern and its effect is to lower the net signal returned from the ensemble.

Figure 13 is a cross polarized, or orthogonally polarized, pattern of the vertical post without its sign. The transmitted signal was polarized +45 degrees, and the received signal was -45 degrees, both measured with respect to the vertical. Note that the orthogonal return tends to be smaller than the direct on the whole, but that the orthogonal return of the open side of the channel is of the order of 7 to 10 dB greater than that of the back side. The largest cross polarized return of the post is only 5 dB below the larger direct return, but these values occur at different aspect angles.

When the 12x18-inch sign is attached to the post (Figure 14), large cross polarized returns are seen near aspects of 30 and 150 degrees on the right side of the pattern. These are due to dihedral corner reflectors formed by the outside surfaces of the channel and the flat surface of the sign itself. The orthogonal return of the ensemble is barely 0 dBsm on the left side of the pattern, which is some 20 dB below the peak specular value measured for the direct returns, but that the difference is more typically 10 dB or less on the right side of the pattern.

These seven patterns of the direct and orthogonal returns from a signpost (both with and without its sign) show that these kinds of targets can return substantial echoes to the radar. The major contribution to the direct echo are large flat surfaces, while the orthogonal return seems to arise from dihedral corner reflectors and sharp edges. Both the direct return from a flat plate and the cross polarized return from a dihedral increase with the square of the frequency, so that if the frequency is doubled, the radar cross section will quadruple.

Trees

The next four figures , Figures 15 through 18, are patterns of 7-foot sections of tree trunks approximately 6.5 inches in diameter. The patterns, representing both direct and cross polarized measurements, were recorded as the horizontally mounted logs were rotated in a horizontal plane. Like the first few patterns of the sign, these represent elevation cuts and, since the logs are essentially axially symmetric bodies, the azimuthal patterns would show virtually constant returns.

Two samples were measured, one being a relatively dry section of black walnut, the other being a freshly cut section of elm. The elm log had a small spray of leaves still attached to the trunk near its mid-point. The direct patterns of the logs are shown in Figures 15 and 16, for which the polarization was horizontal.

Since the logs were large compared to the wavelength, the same amplitudes are to be expected for the other (vertical) polarization, but this was not verified experimentally. The radar return of the walnut log attains a peak broadside value of 4 dBsm, while the elm log reaches nearly 6 dBsm. At aspect angles removed from broadside, the elm leaves produce a rapidly scintillating pattern that is virtually non-existent for the naked walnut log.

Figures 17 and 18 show the cross polarized return of the logs. These echoes are more than 20 dB below the direct returns and are, to all intents, negligible compared to the returns from roadside signs. The cross polarized returns are small because the logs have no sharp edges as do metallic signs, to depolarize the incident wave and, moreover, are non-metallic. The leaves on the elm log, however, do generate some very small returns, as can be seen from the occasional spikes rising one or two dB above the bottom of the chart in the zero to 60-degree aspect region.

Although much more data on trees would be desirable, it is evident from the patterns that the magnitudes of the radar echoes from trees and metallic signs are in no way a direct measure of the threat these targets present to an approaching vehicle.

Man

Figure 19 is a pattern of one Chester Grabowski, an adult male, 67 inches tall and weighing 160 pounds. The center of the pattern (zero degrees) corresponds to a face-on view and at $\pm$ 90 degrees, the subject is viewed laterally. Peak returns of about 4 dBsm are occasionally seen, but a mean value of 0 to -2 dBsm may be more descriptive. Cross section patterns of living people taken at these frequencies are difficult to repeat with any accuracy because the very act of breathing causes scintillations in the lobe structure. Mean levels, however, are fairly representative. Based on radar cross section amplitudes alone, Chester would represent the same threat to an oncoming vehicle as would one of the logs measured earlier; on the other hand, the actual threat would be quite different.

We did not measure other animals because of the limitations of time, but the returns of dogs and birds would certainly be of interest. Such measurements are likely to be difficult unless the subject can be immobilized or restrained.

Cement Wall

In an attempt to simulate a portion of a bridge abutment, we constructed a four-foot square section of wall with conventional 12-inch concrete blocks. The blocks had hollow cores and were 16 inches long by 8 inches high. The wall was built up in 6 courses of 3 blocks each. Since the CW measurement system demands that residual signals reflected from the chamber be cancelled out with a bucking signal in the absence of the target, the wall had to be constructed quickly. Since more than 800 pounds of material had to be hauled into the chamber and assembled for the measurement in a short time, this was no small task.

The wall was measured in two attempts, the first of which was unsuccessful. In the first attempt, the turntable was removed from the chamber and a stout platform substituted in its place in order to elevate the center of the wall (to be built) up to the center of the transmitted beam. The materials for the wall were stacked on a heavy cart so they could rolled into the chamber quickly. With the scene thus prepared, the residual chamber reflections were tuned out and the cart was hauled to the construction site.

The first course of blocks was laid and its orientation double-checked to be sure the wall would be perpendicular to the incident beam. When this had been done, the rest of the wall was built. The uppermost courses were more difficult to lay, since the 'mason' had to stand on a stool to place the final course. Construction time was about ten minutes.

The site was cleared of cart and stool and the equipment registered a relatively small signal. When metallic rods were inserted in the hollow cores of the wall, the signal was still small. Believing that the wall had been built askew from normal incidence, we dismantled it and decided to try to build it on the turntable so that it could be rotated in azimuth.

Thus, in the second attempt, the turntable was restored to its conventional position in the chamber and the platform (on which the wall would be built) was bolted to it. Again the cart bearing the cement blocks was made ready and the system was balanced out. The wall was built in about ten minutes and the turntable seemed to take the load without damage. A pattern was recorded, the wall dismantled, and the chamber cleared. The system tuning was checked and adjusted, and the calibration standard was measured. The measurement results are shown in Figure 20.

Note that the broadside amplitude of the wall return is about 23 dBsm, scarcely 6 dB about the flat plate calibration standard. Had the wall been covered with a metallic sheet its return would have been 26 dB above the standard, suggesting that the difference - 20 dB - is due to a reflection coefficient associated with the air-concrete interface at the wall surface. Since the voltage reflectioncoefficient depends on the linear size of the wall, and since the radar return depends on the square of the area, the reflection coefficient is

$$R \simeq (.01)^{1/4} = .362 ,$$

and this in turn leads to an estimate of 6.6 for the dielectric constant of concrete, a quite reasonable value. Thus the measurements conform to what may have been expected at the outset.

CONCLUSIONS

The measurements are not as extensive as we would have liked them to be, but they clearly show the deficiencies of a sensing and triggering system based on radar returns alone. For example, a man has a radar return of the order of that of a 6-inch diameter tree trunk, but the man constitutes a far smaller hazard to an approaching vehicle than does the tree. A more dramatic comparison is between the returns of an 800-pound section of concrete wall and a 20-pound metallic sign; the sign can easily appear to the radar to be 10 or a 100 times larger than the wall, when in fact the wall is the lethal obstacle, not the sign.

TABLE II: Summary of Targets Measured and Typical X-band Radar Cross Sections

Target	Radar Cross Section dBsm	Remarks
Signpost without sign	10	Made of steel channel with holes perforated in the web; dimensions 1 5/8" x 3 1/4" x 60"
Small sign on signpost	22	Sign dimensions 12"x18", 18" along the post
Large sign on signpost	33	Sign dimensions 36" x 36"
Walnut log	-2	Speciman was dry, having been stored indoors for several months; mean diameter 6.8", length 78", weight 64 pounds
Elm log	4	Specimen had been freshly cut, with a spray of leaves still attached to the trunk; mean diameter 6.4", length 88", weight 79 pounds.
Homo sapiens	2	Adult male; height 67", weight 160 pounds
Cement block wall	23	Wall was built of 18 cement blocks in 6 courses; dimensions 47" x 47" x 11.5" .

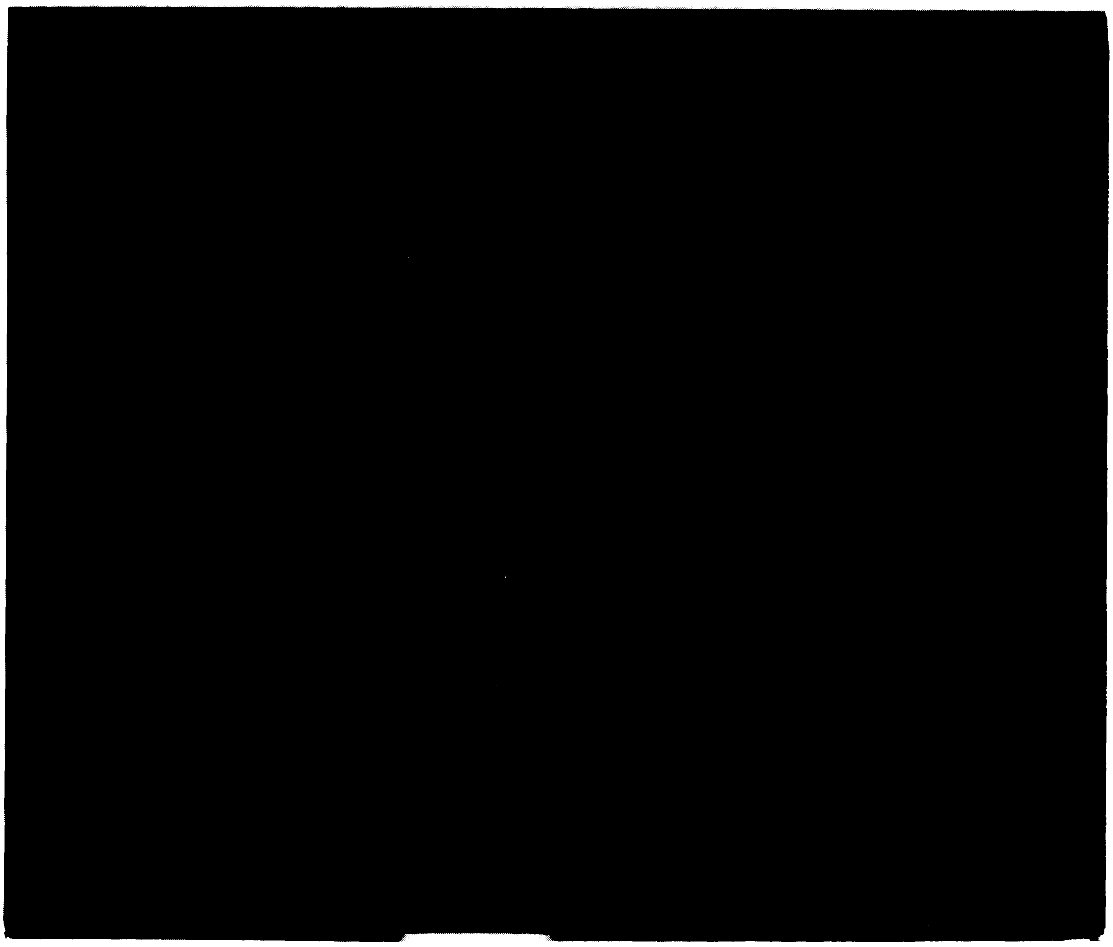


Figure 4: This sign was used for both antenna and backscatter measurements. It was mounted vertically for the antenna work and backscatter patterns were recorded for both vertical and horizontal (shown above) orientations. Backscatter patterns were also taken of the bare post and of the post bearing a much larger sign.

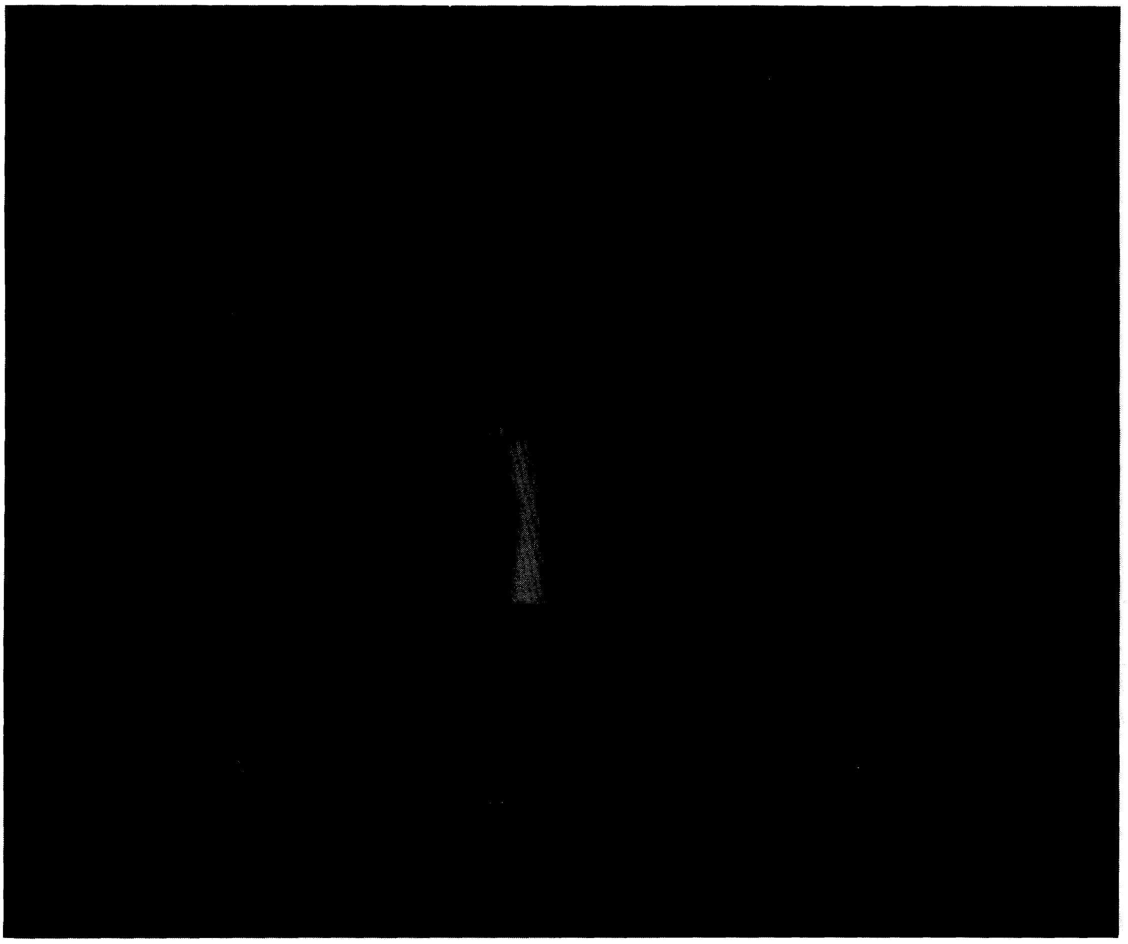


Figure 5: This is the walnut log mounted horizontally. An elm log of very nearly the same size was also measured; the elm log had a few dozen leaves still growing from the trunk.

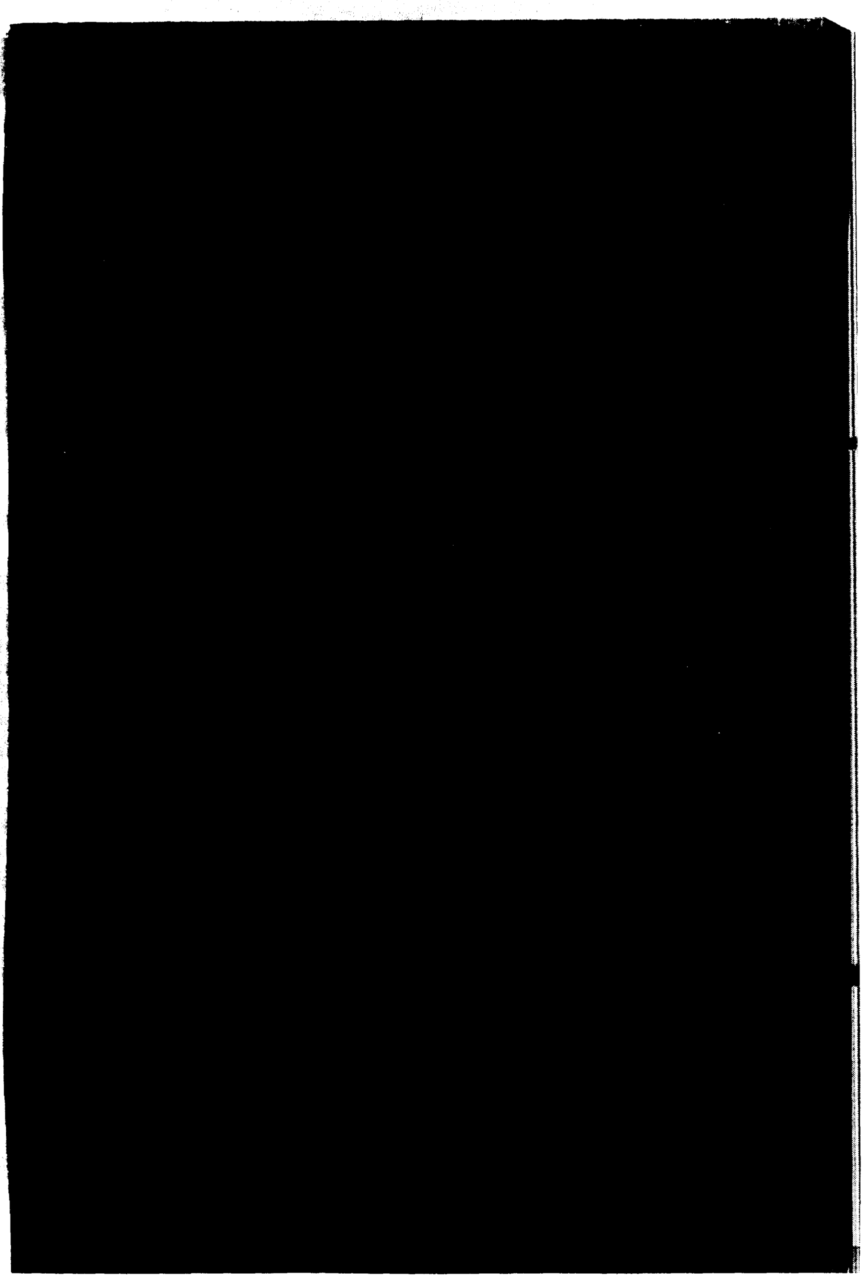


Figure 6: Measurements of <u>homo sapiens</u> were made using this subject.

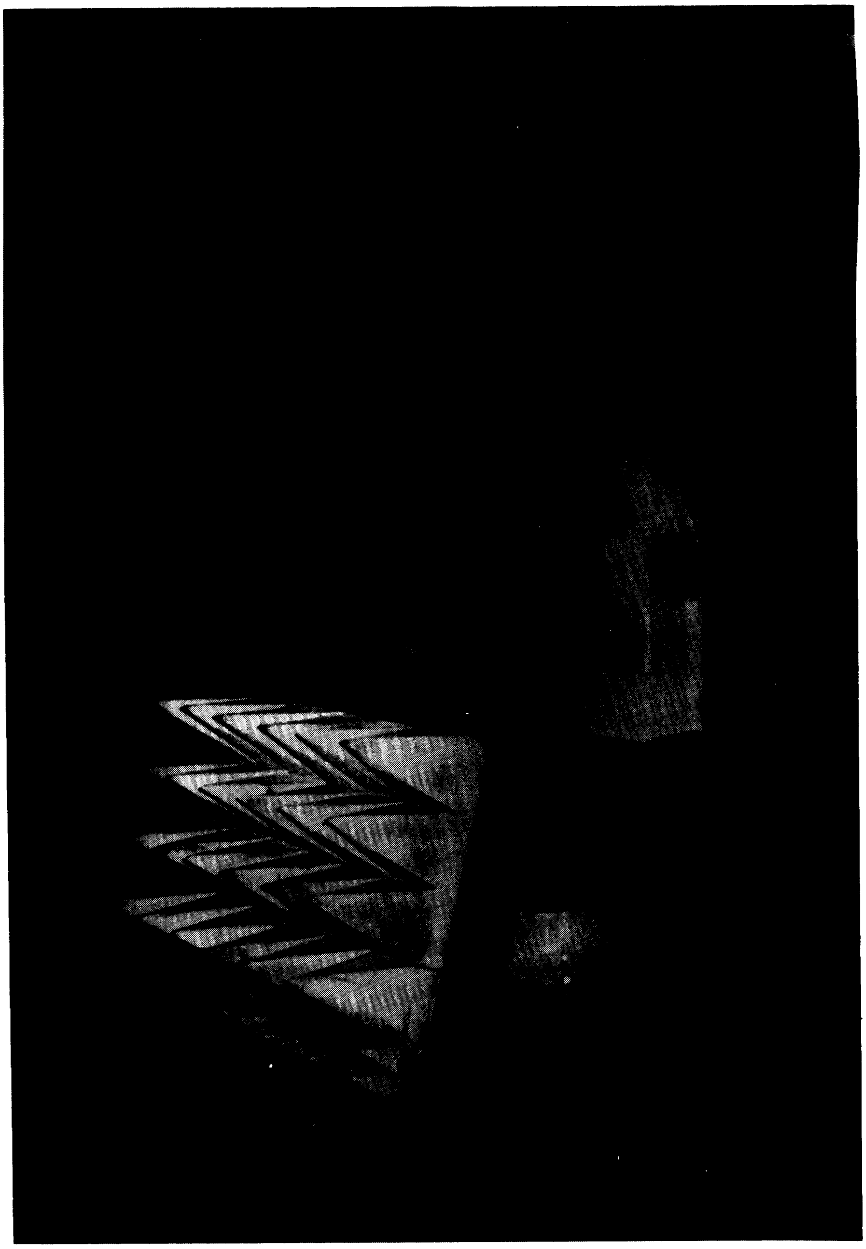


Figure 7: A concrete wall weighing 800 pounds was built upon the chamber turntable with no damaging effects.

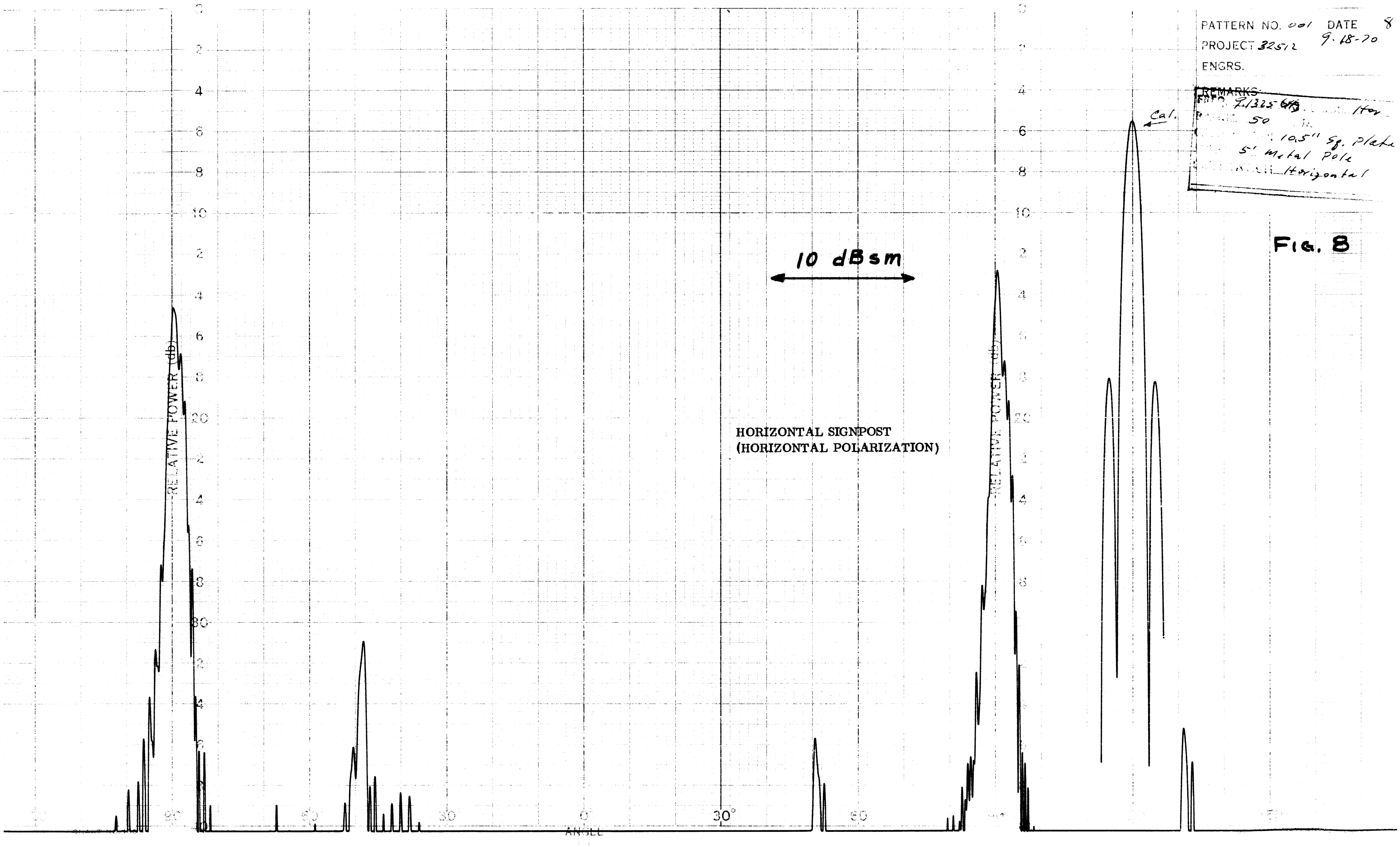
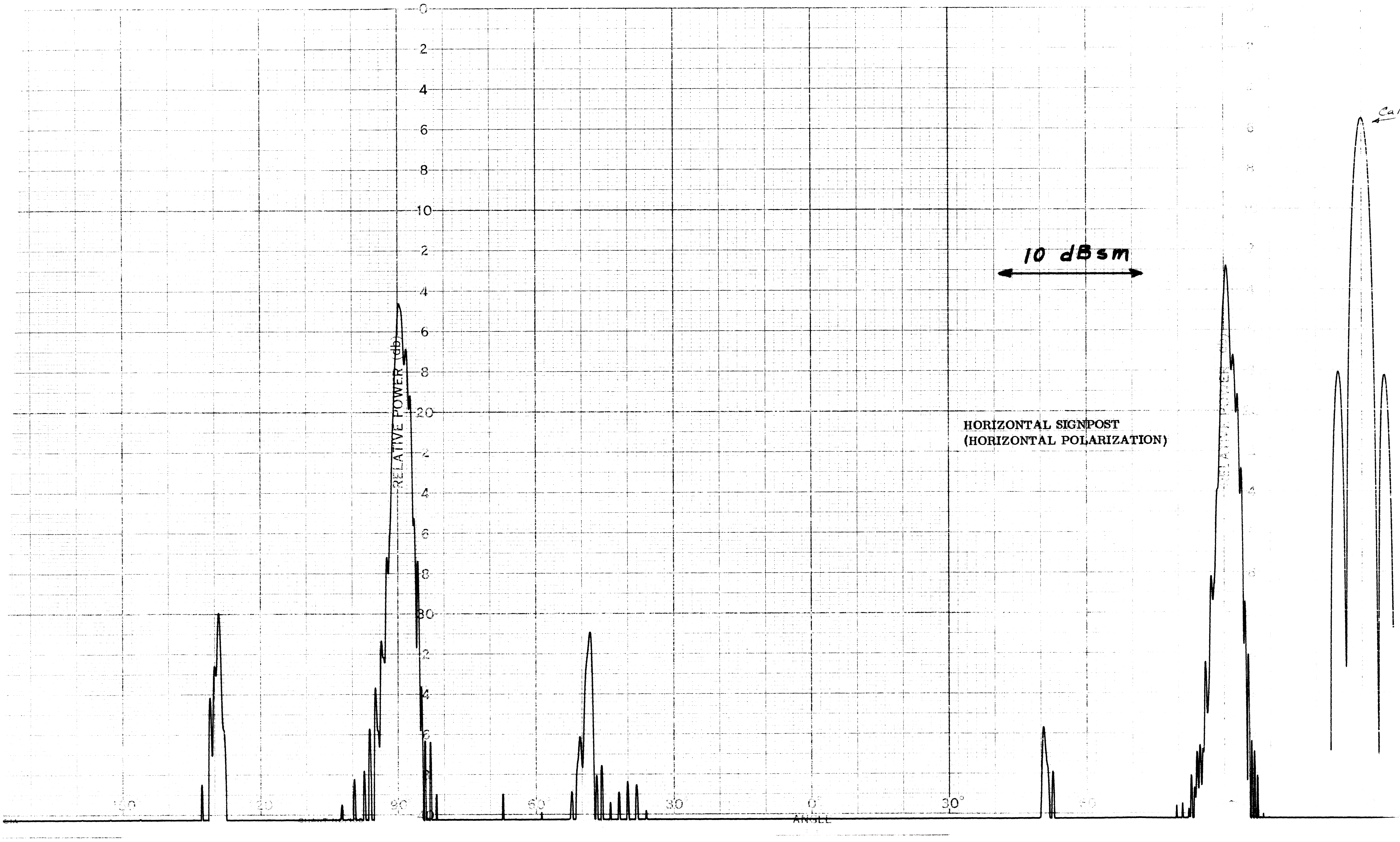

PATTERN NO. 001 DATE 9-18-70
8
PROJECT 32512
ENGRS.
REMARKS:
FREQ. 7.1325 GHz Hor
50
10.5" Sq. plate
5' Metal Pole
Horizontal
Cal.
10 dBsm
HORIZONTAL SIGNPOST
(HORIZONTAL POLARIZATION)
RELATIVE POWER (db)
ANGLE
30°

Fig. 8


10 dBsm
HORIZONTAL SIGNPOST
(HORIZONTAL POLARIZATION)
RELATIVE POWER (db)
ANGLE
Cal.
0
2
4
6
8
10
20
30°
60°
90°
120°

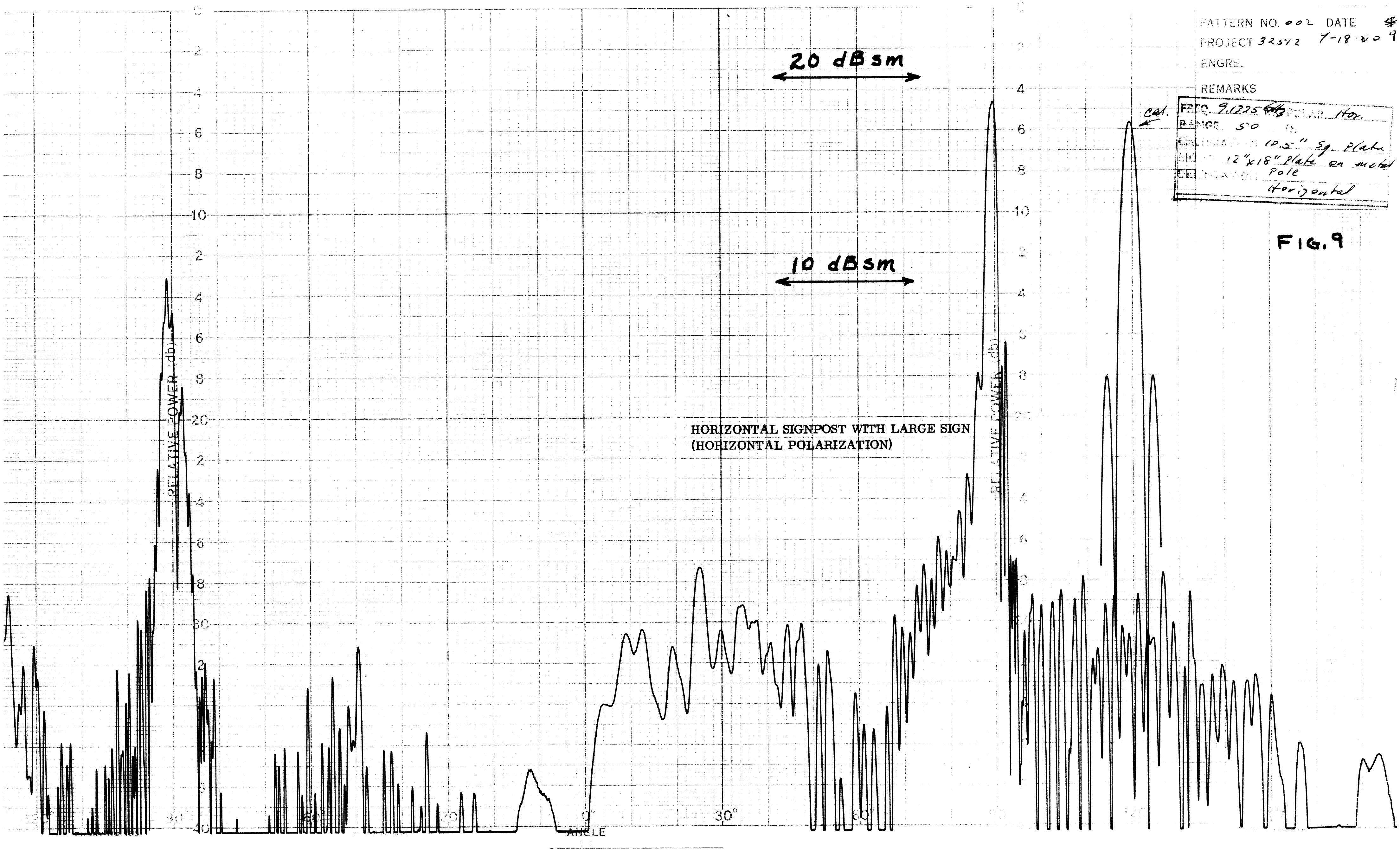
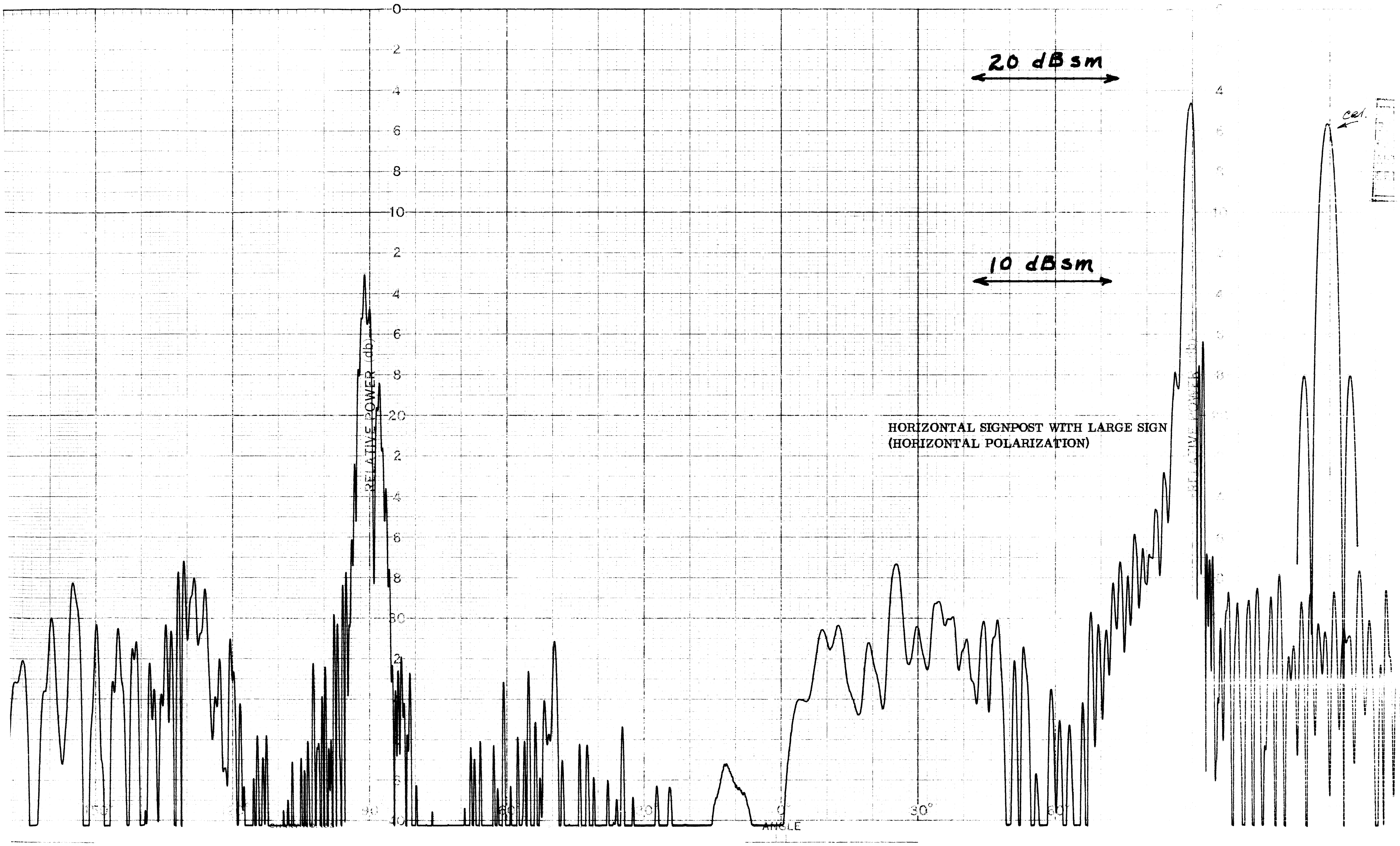

PATTERN NO. 002 DATE 7-18-209
PROJECT 32512
ENGRS.
REMARKS
FREQ. 9.1225 GHz POLAR. Hor.
RANGE 50
10.5" Sq. plate
12"x18" plate on metal pole
Horizontal
cal.
20 dBsm
10 dBsm
HORIZONTAL SIGNPOST WITH LARGE SIGN
(HORIZONTAL POLARIZATION)
RELATIVE POWER (db)
ANGLE
30°
60°

FIG. 9



HORIZONTAL SIGNPOST WITH LARGE SIGN
(HORIZONTAL POLARIZATION)

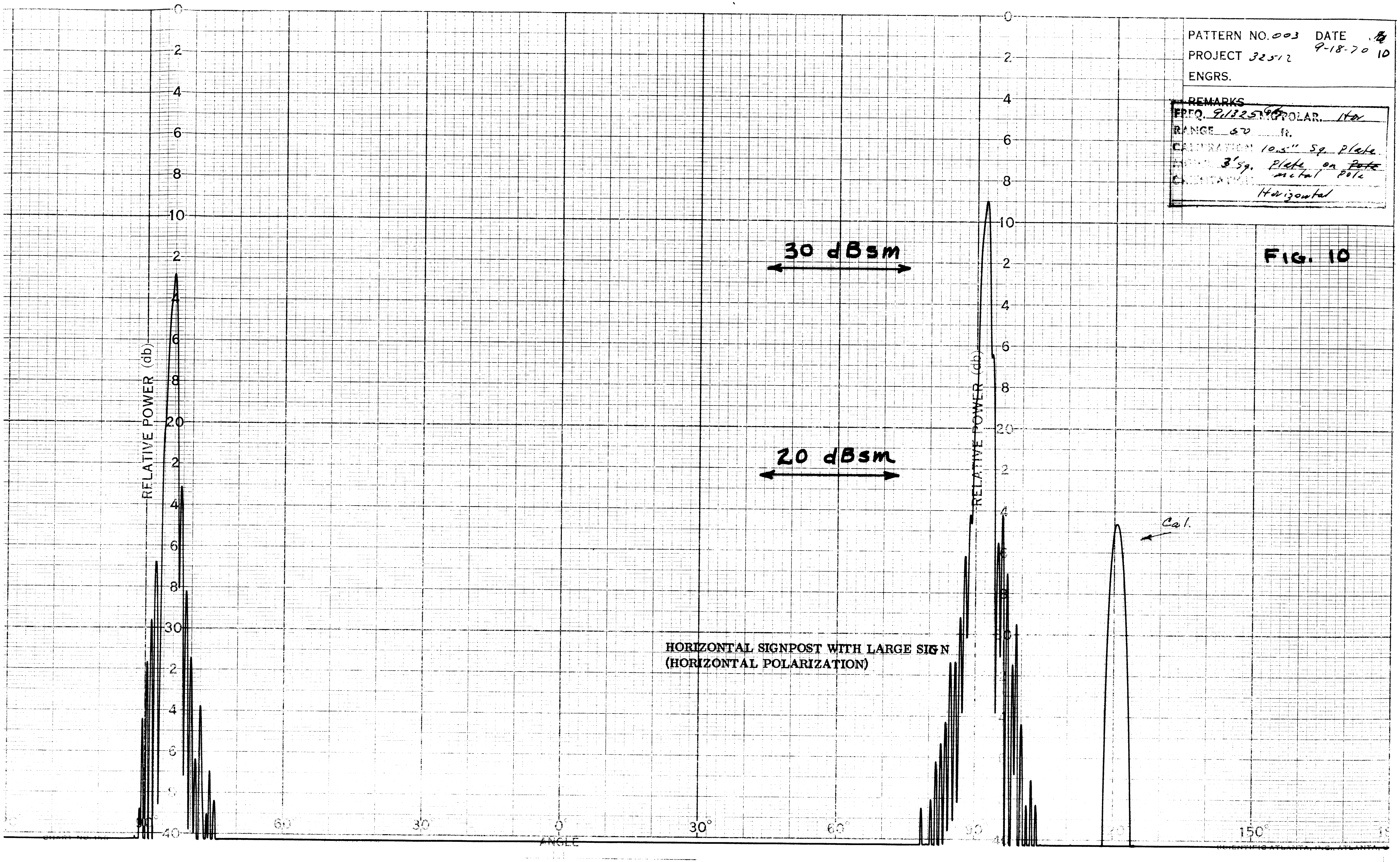
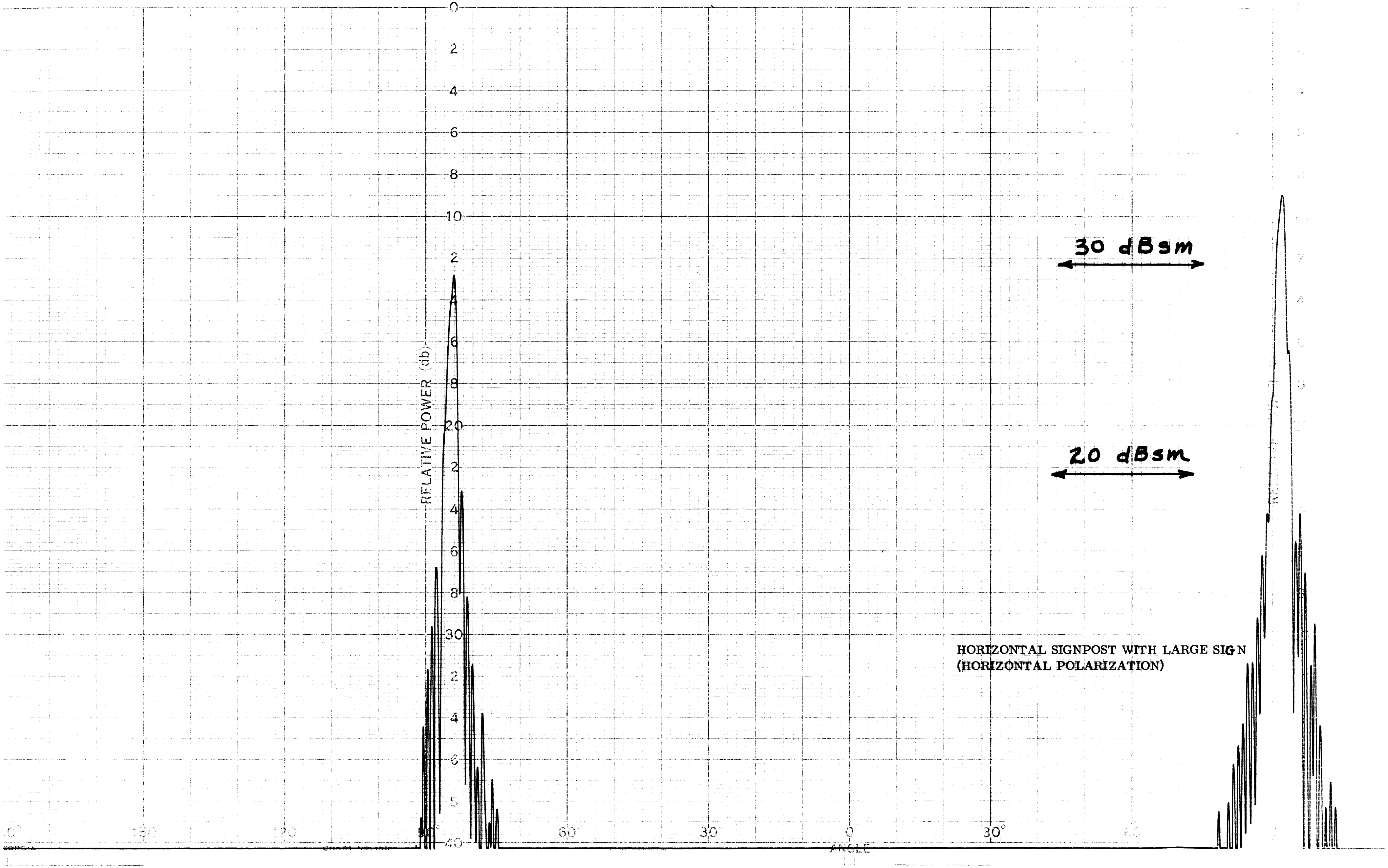
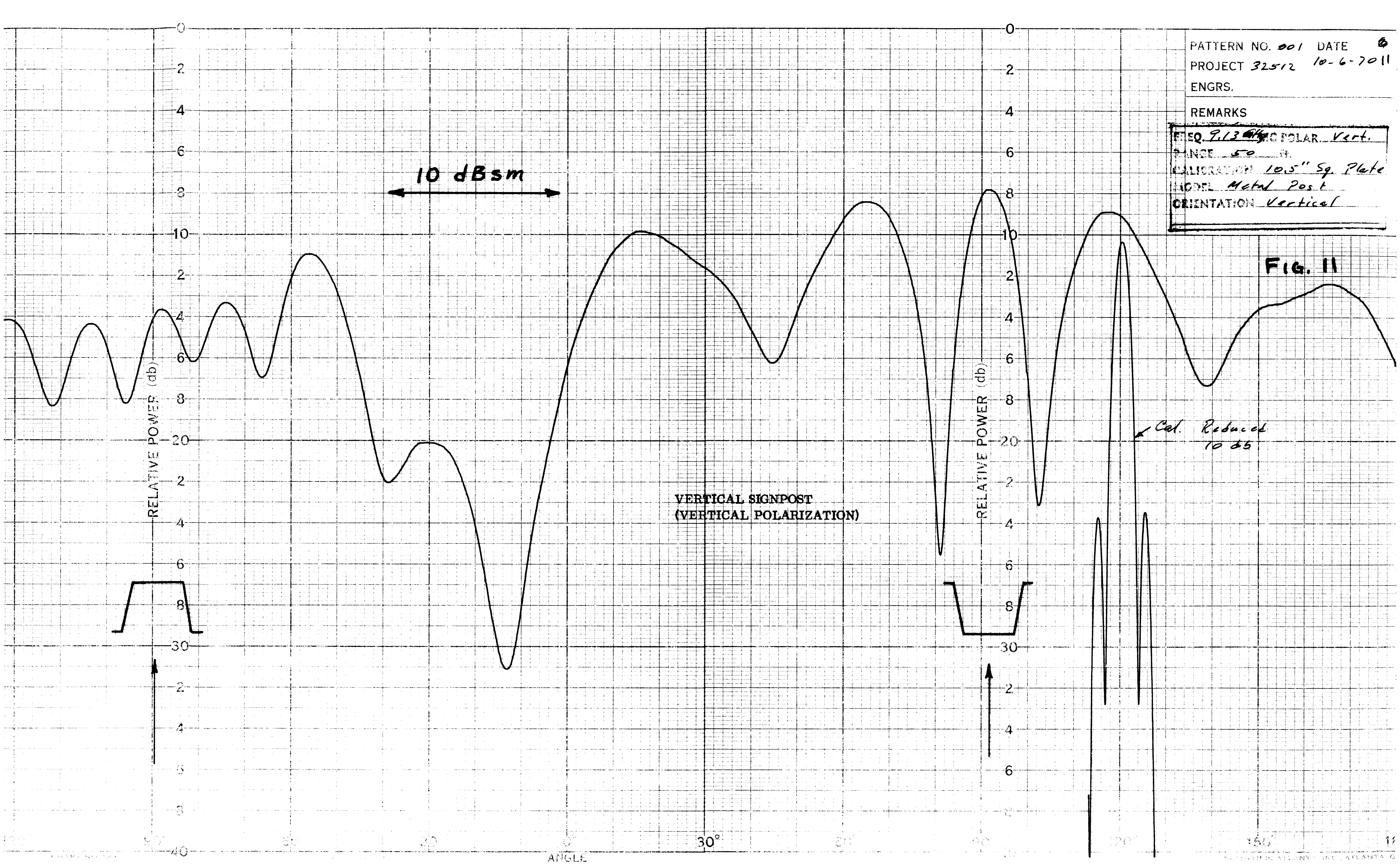

PATTERN NO. 003
DATE 9-18-70
PROJECT 32512
ENGRS.
REMARKS
FREQ. 9.1325 GHz POLAR. Hor
RANGE 50 ft.
CALIBRATION 10.5" Sq. plate
3' Sq. plate on metal pole
Horizontal
30 dBsm
20 dBsm
Cal.
RELATIVE POWER (db)
ANGLE
30°
60°
90
150°
0°
HORIZONTAL SIGNPOST WITH LARGE SIGN
(HORIZONTAL POLARIZATION)

Fig. 10

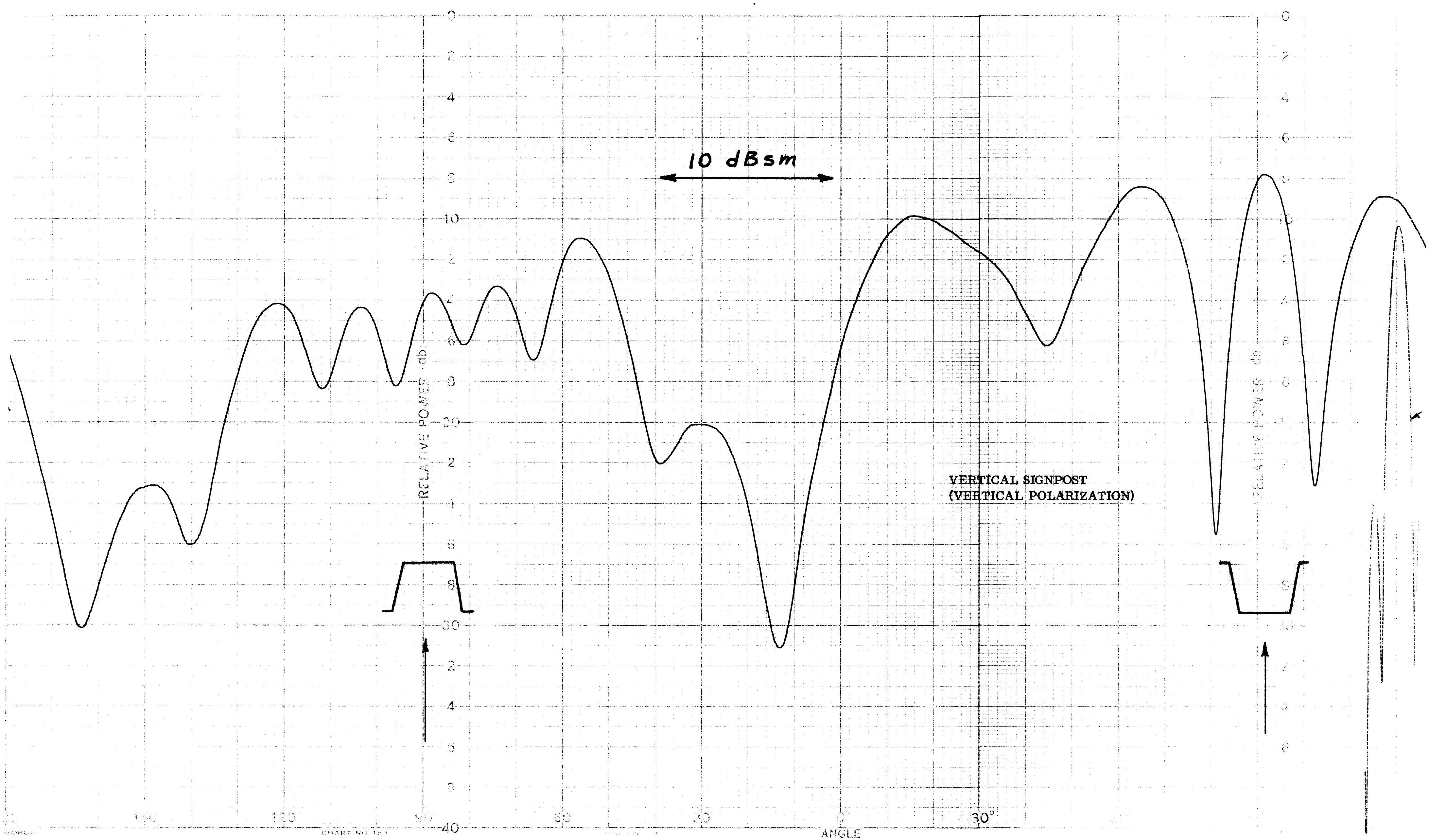


HORIZONTAL SIGNPOST WITH LARGE SIGN
(HORIZONTAL POLARIZATION)

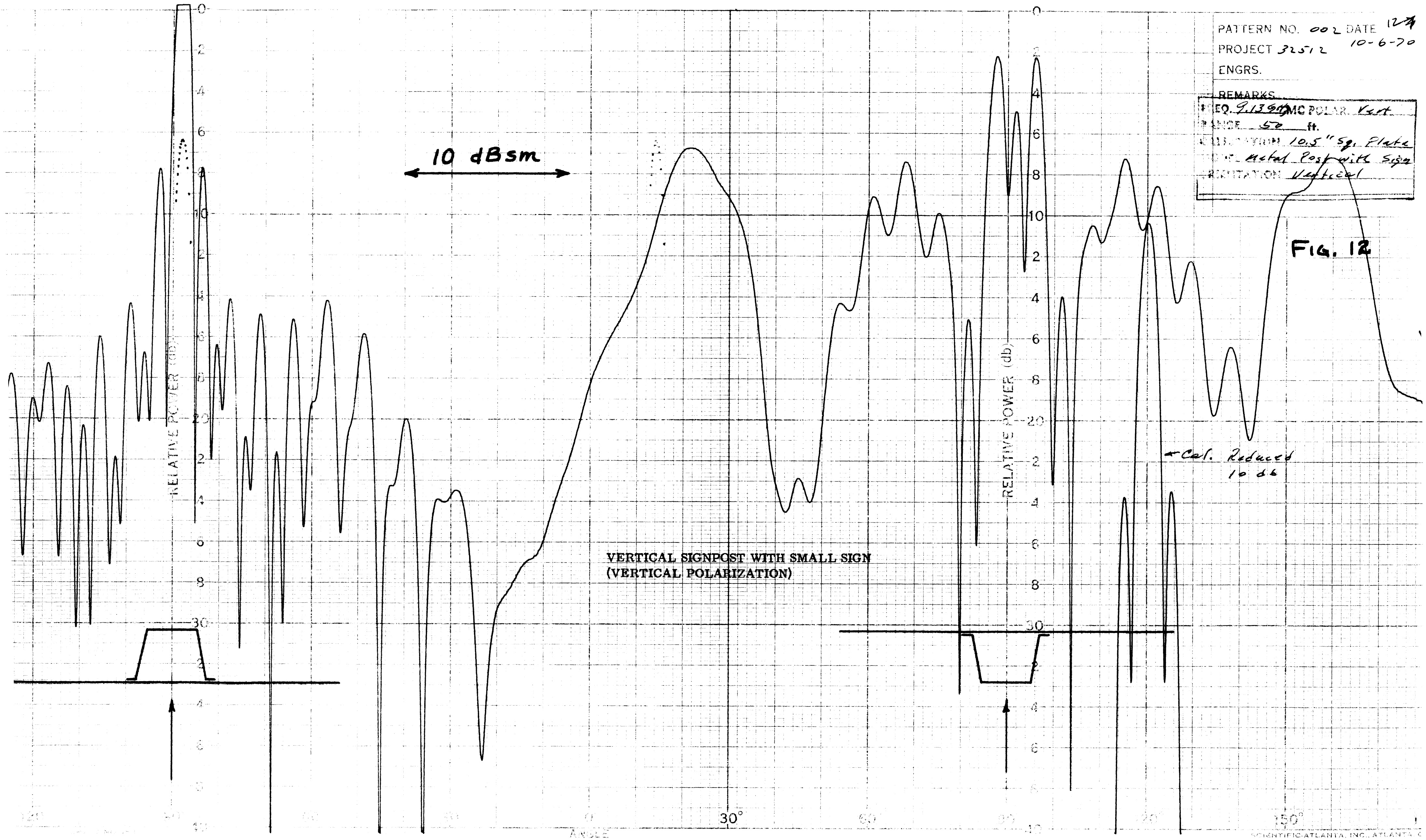


PATTERN NO. 001 DATE
PROJECT 32512 10-6-7011
ENGRS.
REMARKS
FREQ. 9.13 GC POLAR. Vert.
RANGE 50 ft.
CALIBRATION 10.5" Sq. Plate
MODEL Metal Post
ORIENTATION Vertical
10 dBsm
RELATIVE POWER (db)
VERTICAL SIGNPOST
(VERTICAL POLARIZATION)
Cal. Reduced 10 db
ANGLE
30°

FIG. 11

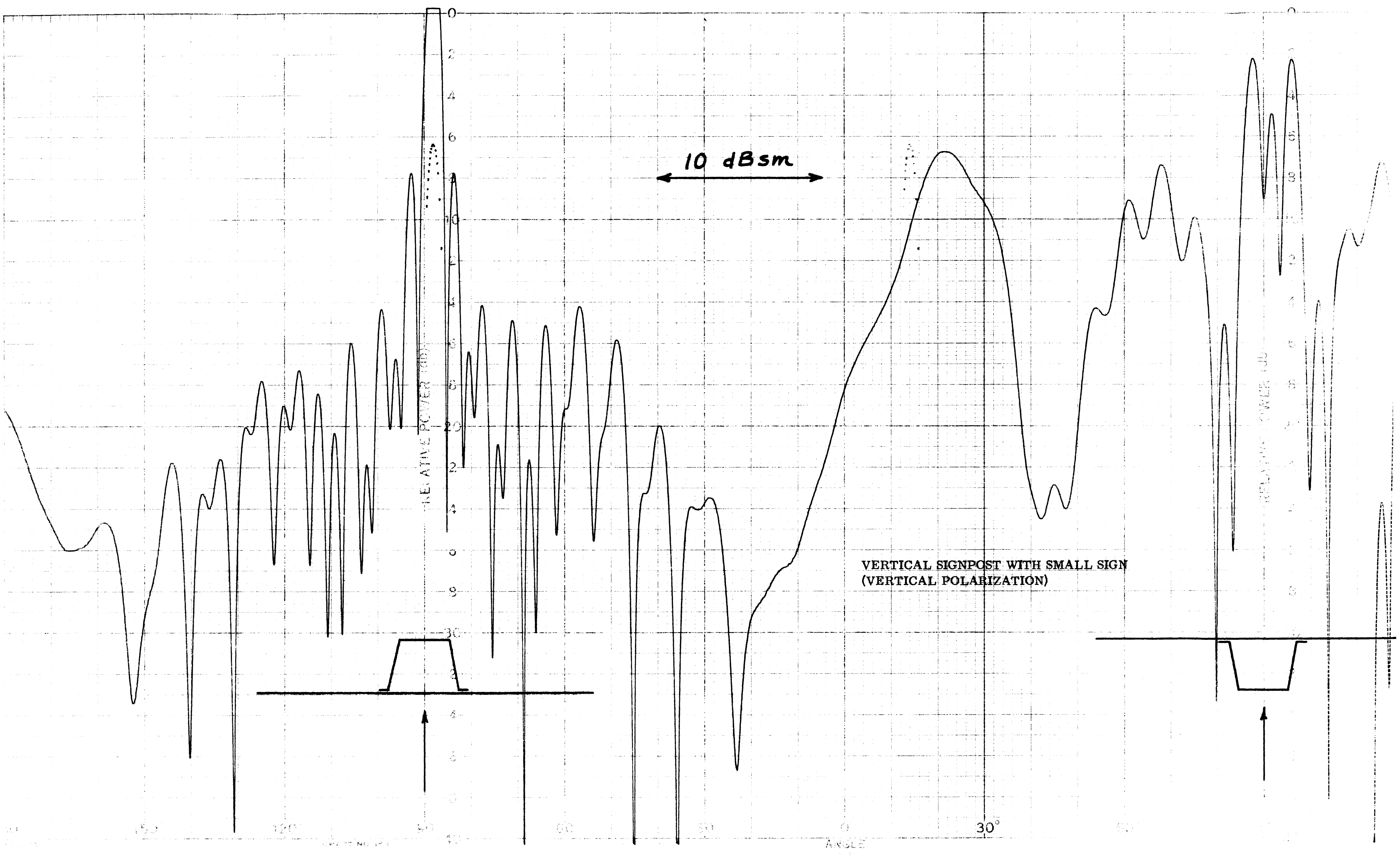


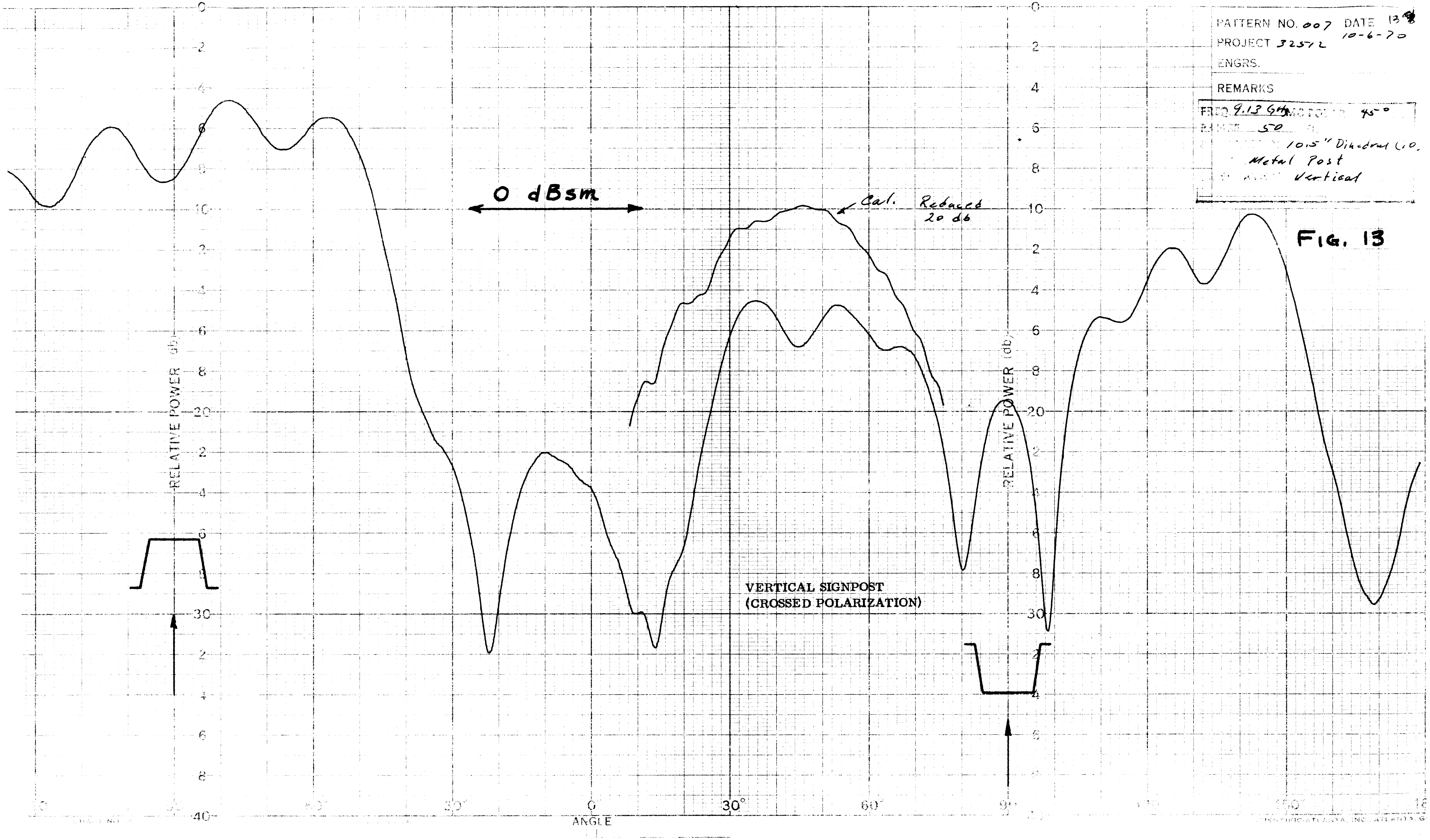
10 dBsm
VERTICAL SIGNPOST
(VERTICAL POLARIZATION)
RELATIVE POWER (db)
ANGLE
30°



VERTICAL SIGNPOST WITH SMALL SIGN
(VERTICAL POLARIZATION)

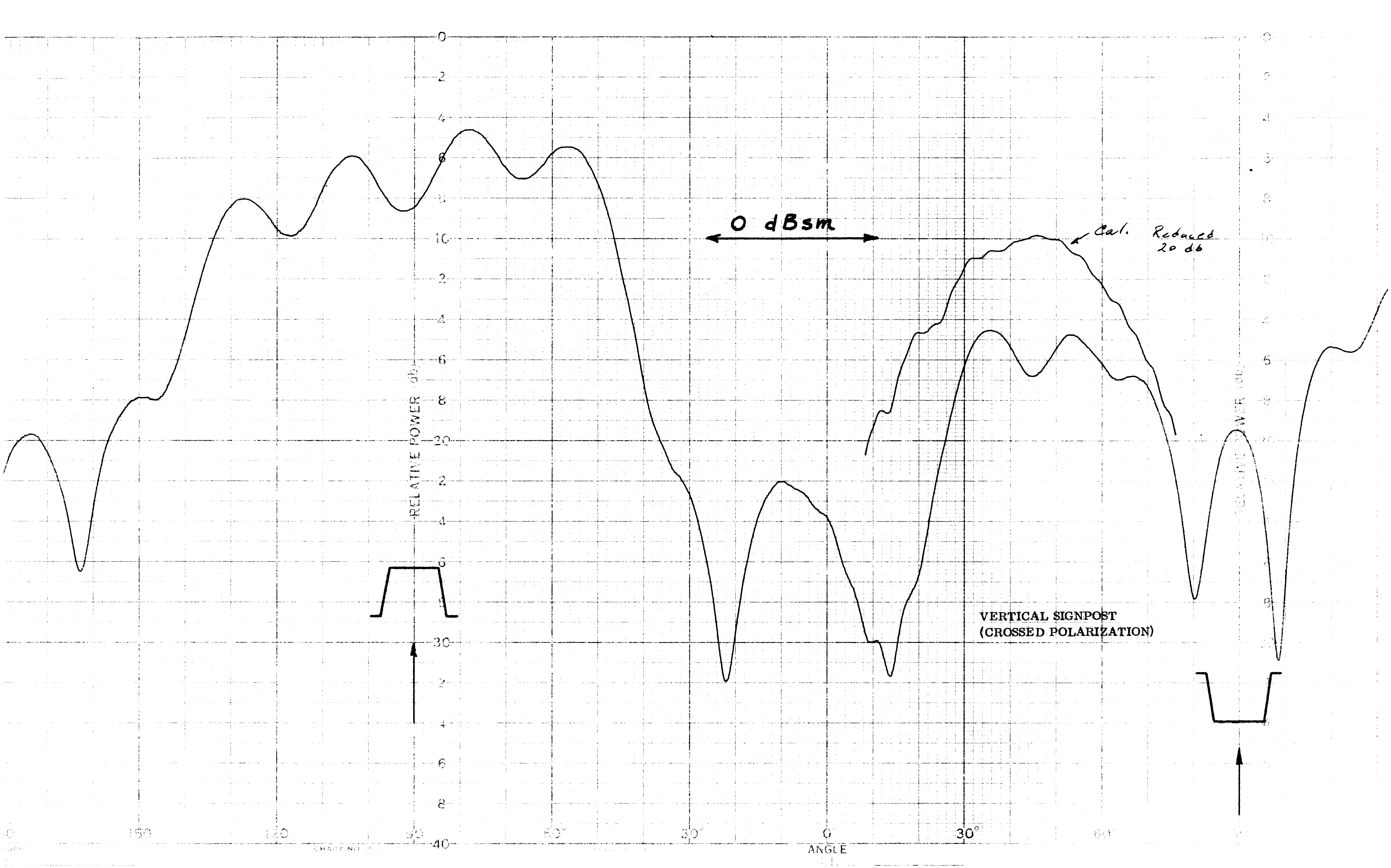
FIG. 12


10 dBsm
30°
VERTICAL SIGNPOST WITH SMALL SIGN
(VERTICAL POLARIZATION)



PATTERN NO. 007 DATE 13
10-6-70
PROJECT 32572
ENGRS.
REMARKS
FREQ 9.13 GHz 45°
RANGE 50
10.5" Dihedral
Metal Post
Vertical
0 dBsm
Cal. Reduced 20 db
VERTICAL SIGNPOST
(CROSSED POLARIZATION)
RELATIVE POWER (db)
ANGLE

FIG. 13



0 dBsm
Cal.
Reduced 20 db
RELATIVE POWER (db)
ANGLE
VERTICAL SIGNPOST
(CROSSED POLARIZATION)

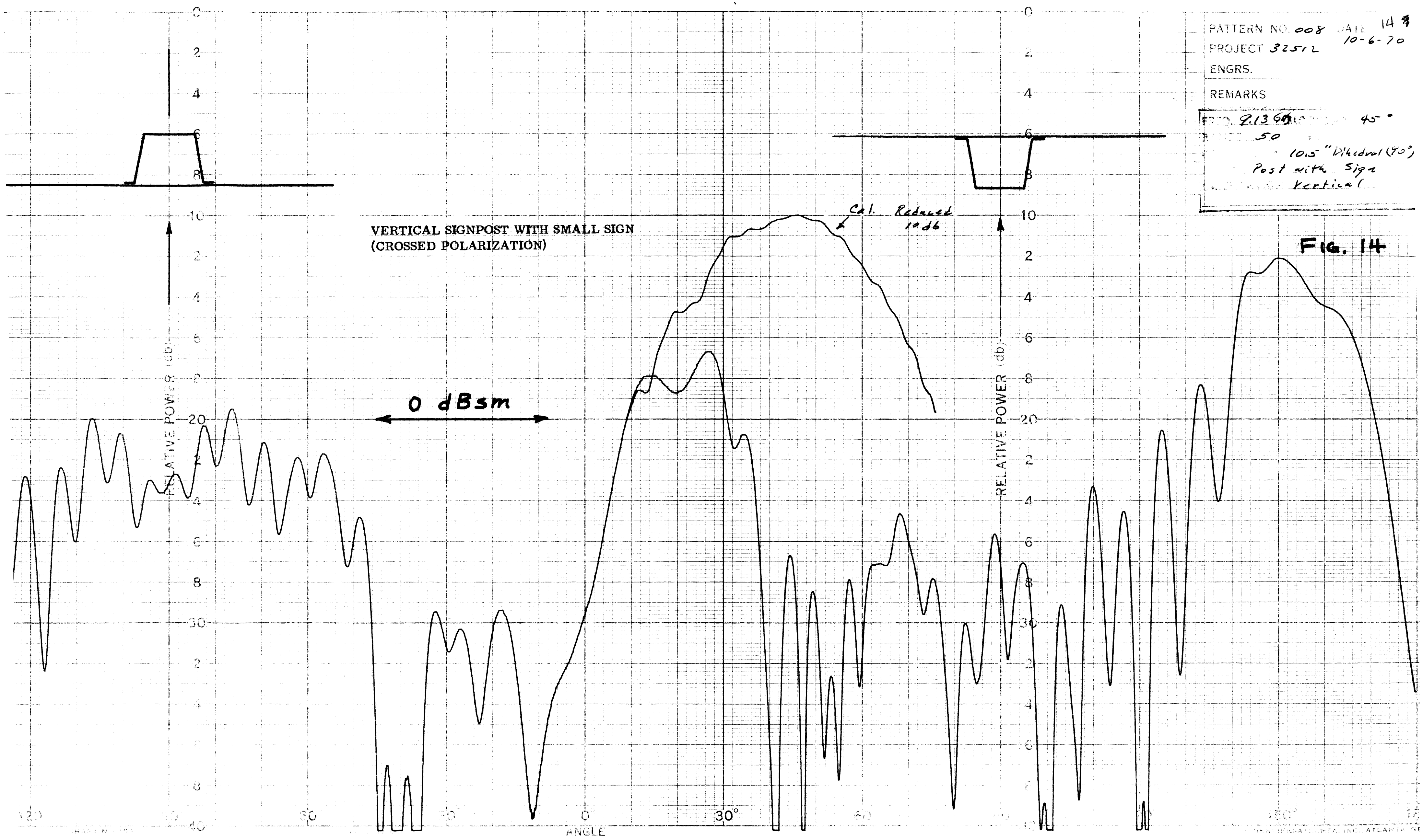
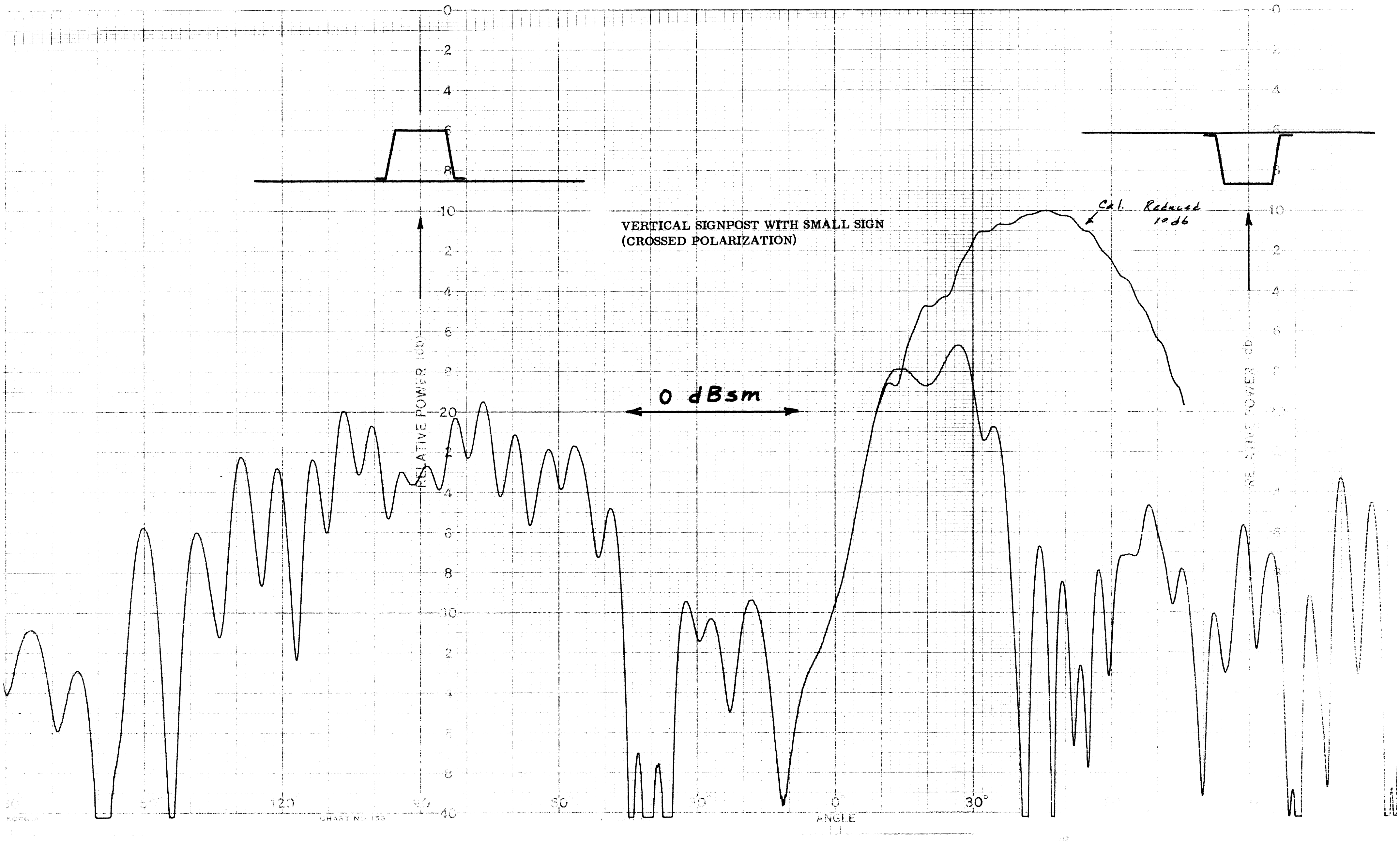

PATTERN NO. 008
DATE 10-6-70
PROJECT 32512
ENGRS.
REMARKS
45°
50
10.5" Dihedral (90°)
Post with Sign
Vertical
VERTICAL SIGNPOST WITH SMALL SIGN
(CROSSED POLARIZATION)
0 dBsm
Cal. Reduced 10 db
RELATIVE POWER (db)
ANGLE
30°

FIG. 14



VERTICAL SIGNPOST WITH SMALL SIGN
(CROSSED POLARIZATION)
0 dBsm
Cal. Reduced 10 db
RELATIVE POWER (db)
ANGLE

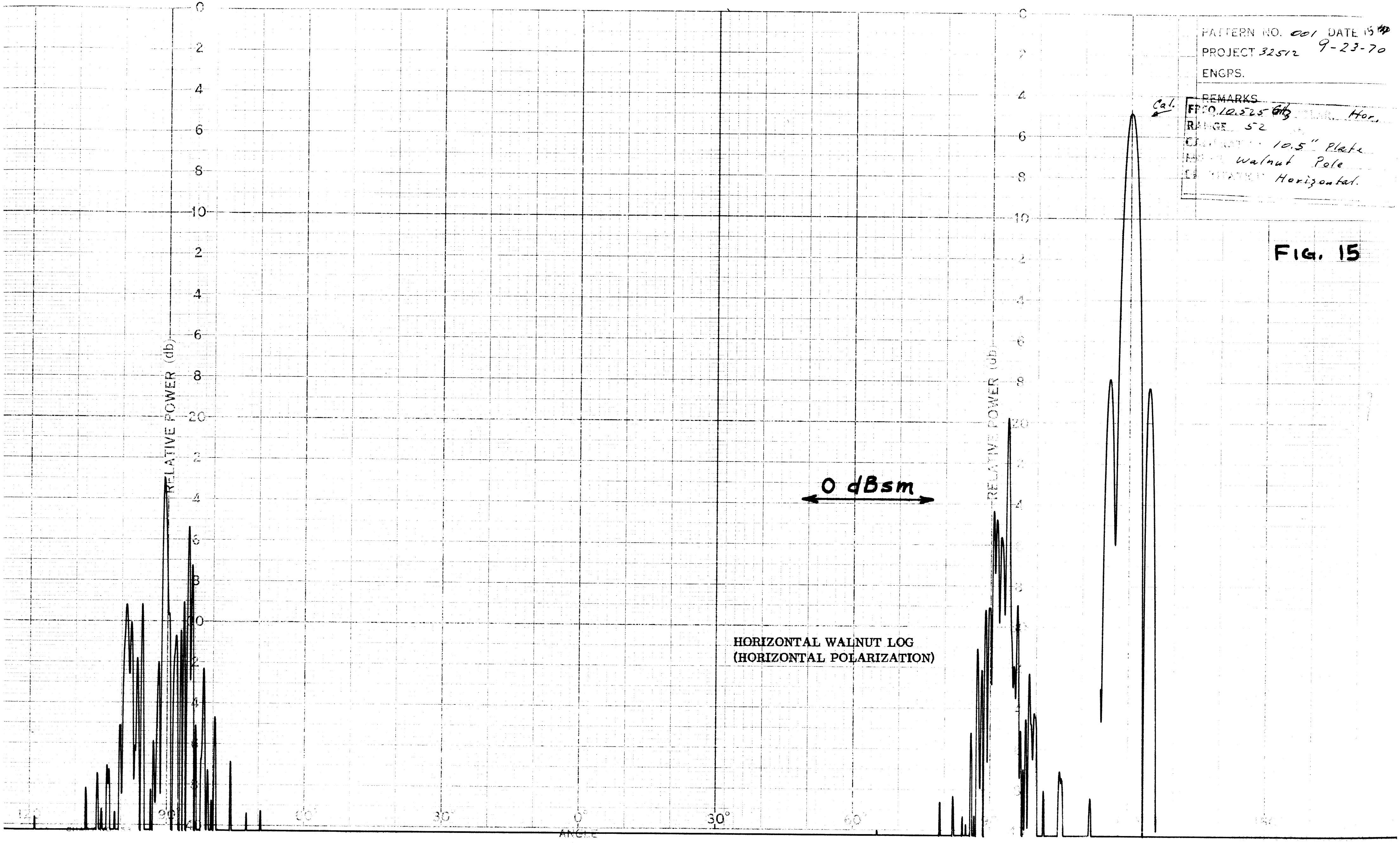
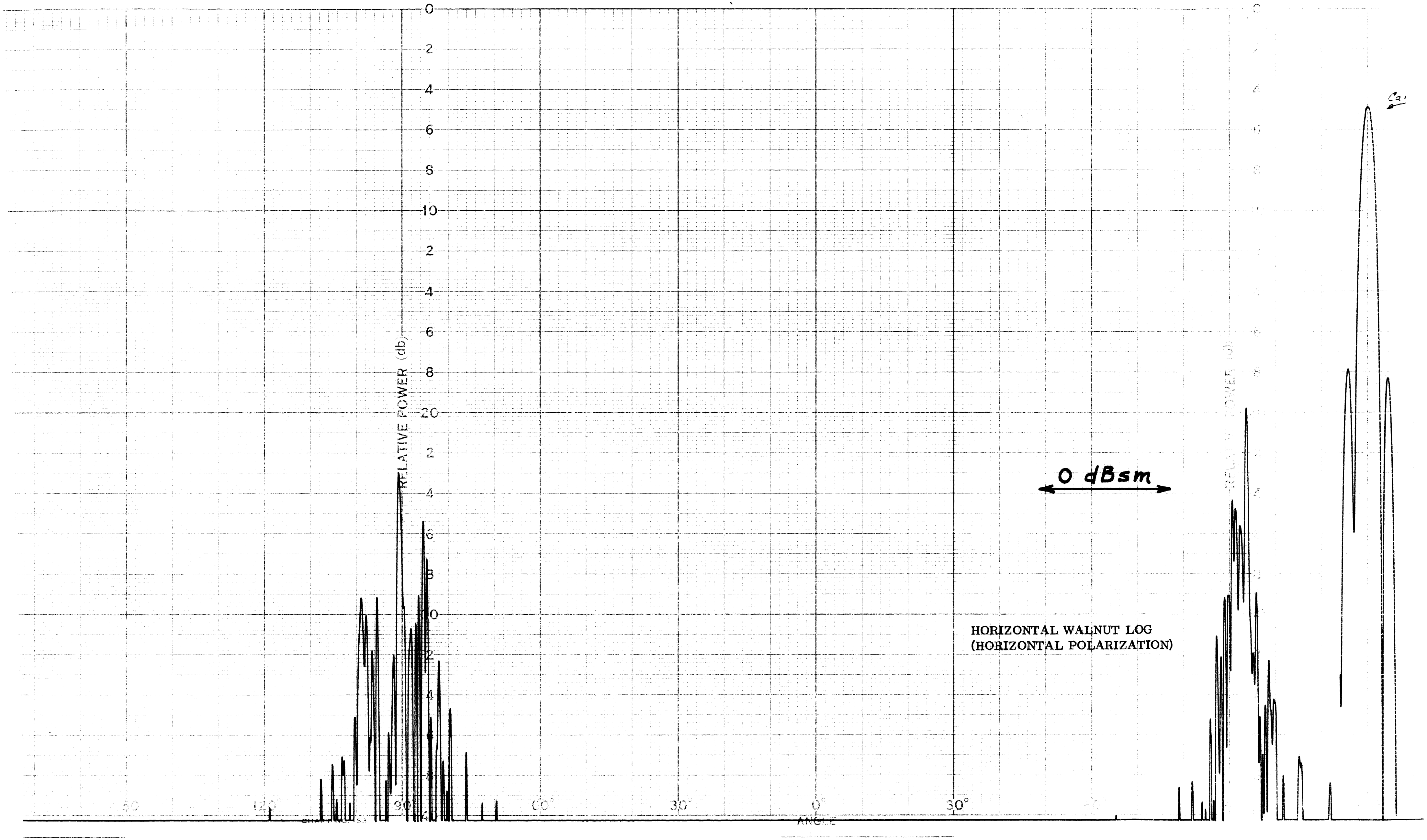


FIG. 15

HORIZONTAL WALNUT LOG
(HORIZONTAL POLARIZATION)


RELATIVE POWER (db)
0 dBsm
HORIZONTAL WALNUT LOG
(HORIZONTAL POLARIZATION)
ANGLE
0°
30°
60°
90°
120°
C2'

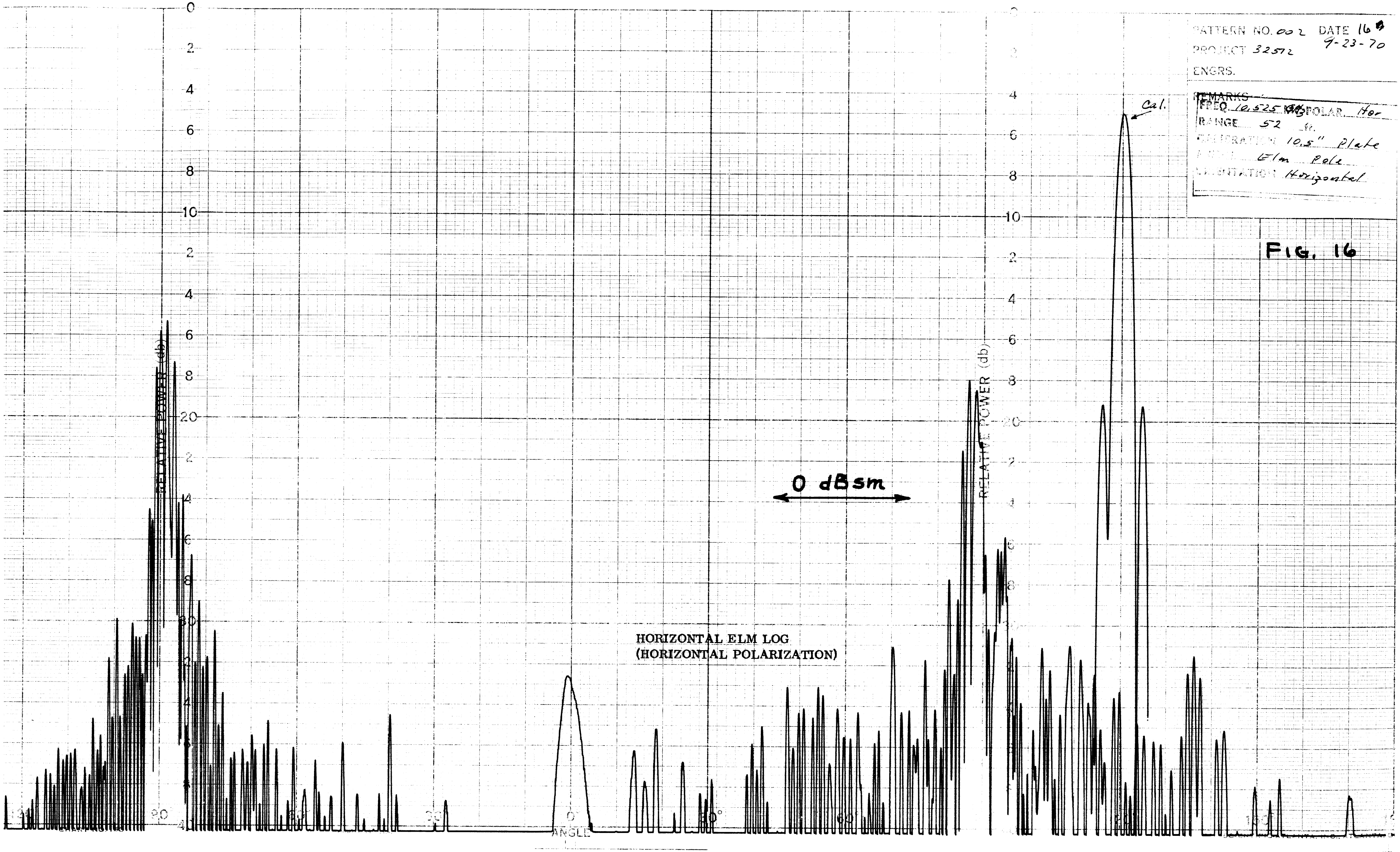
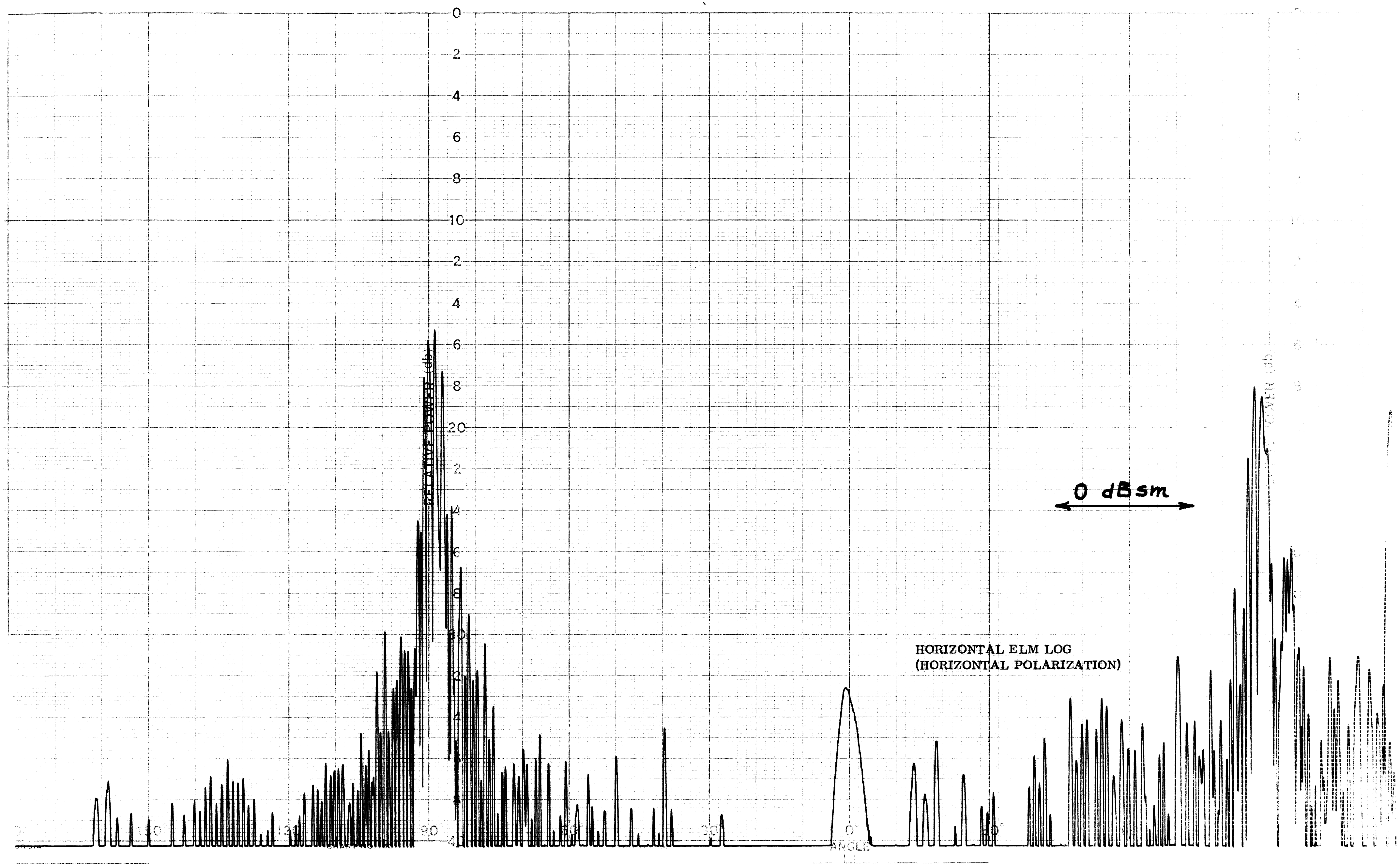

PATTERN NO. 002 DATE 16
9-23-70
PROJECT 32572
ENGRS.
REMARKS
FREQ 10.525 GHz POLAR. Hor
RANGE 52 ft.
CALIBRATION 10.5" Plate
Elm Pole
ORIENTATION Horizontal
Cal.
0 dBsm
HORIZONTAL ELM LOG
(HORIZONTAL POLARIZATION)
RELATIVE POWER (db)
ANGLE
0°
30°
60°
90°

FIG. 16


0 dBsm
HORIZONTAL ELM LOG
(HORIZONTAL POLARIZATION)
RELATIVE POWER (db)
ANGLE

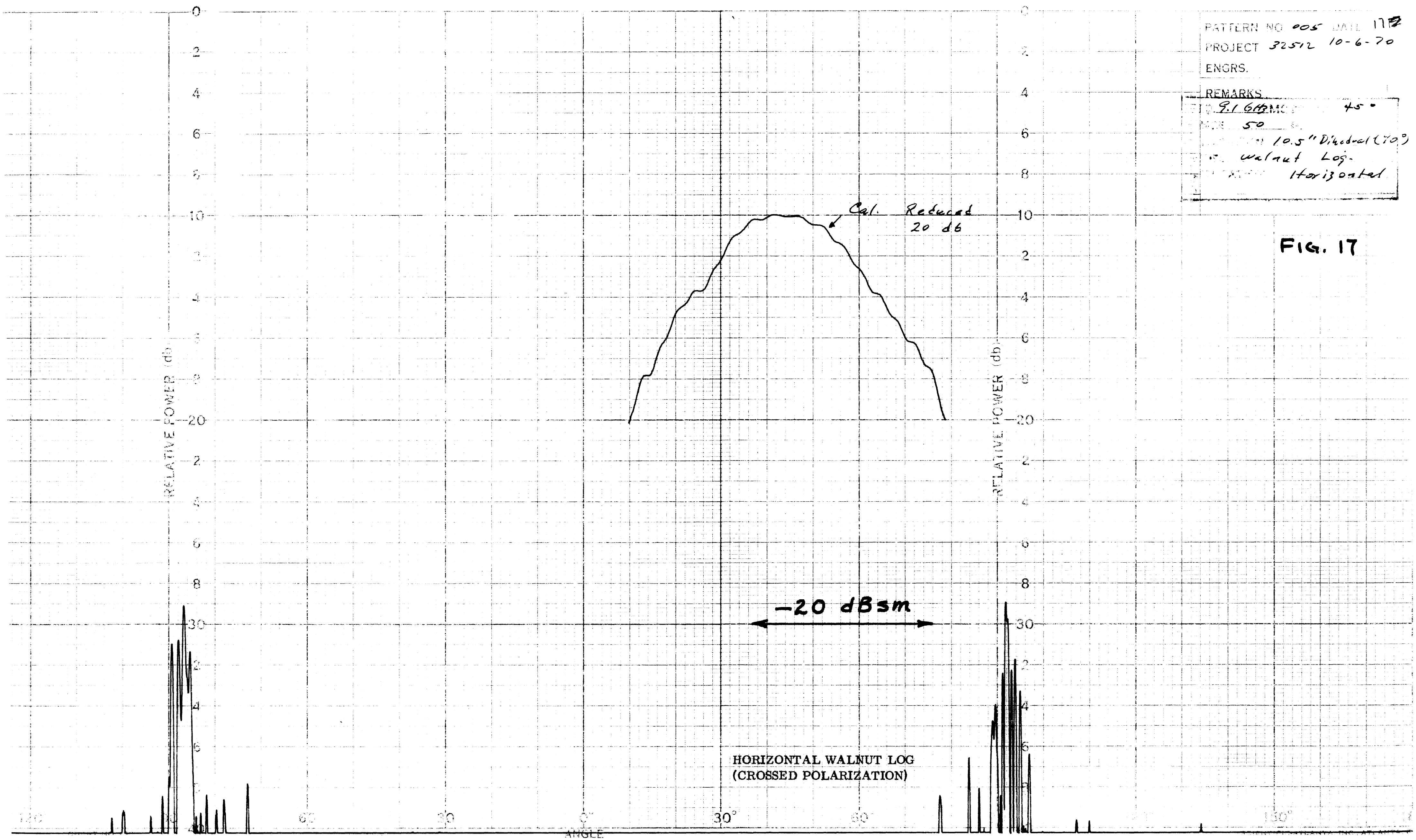
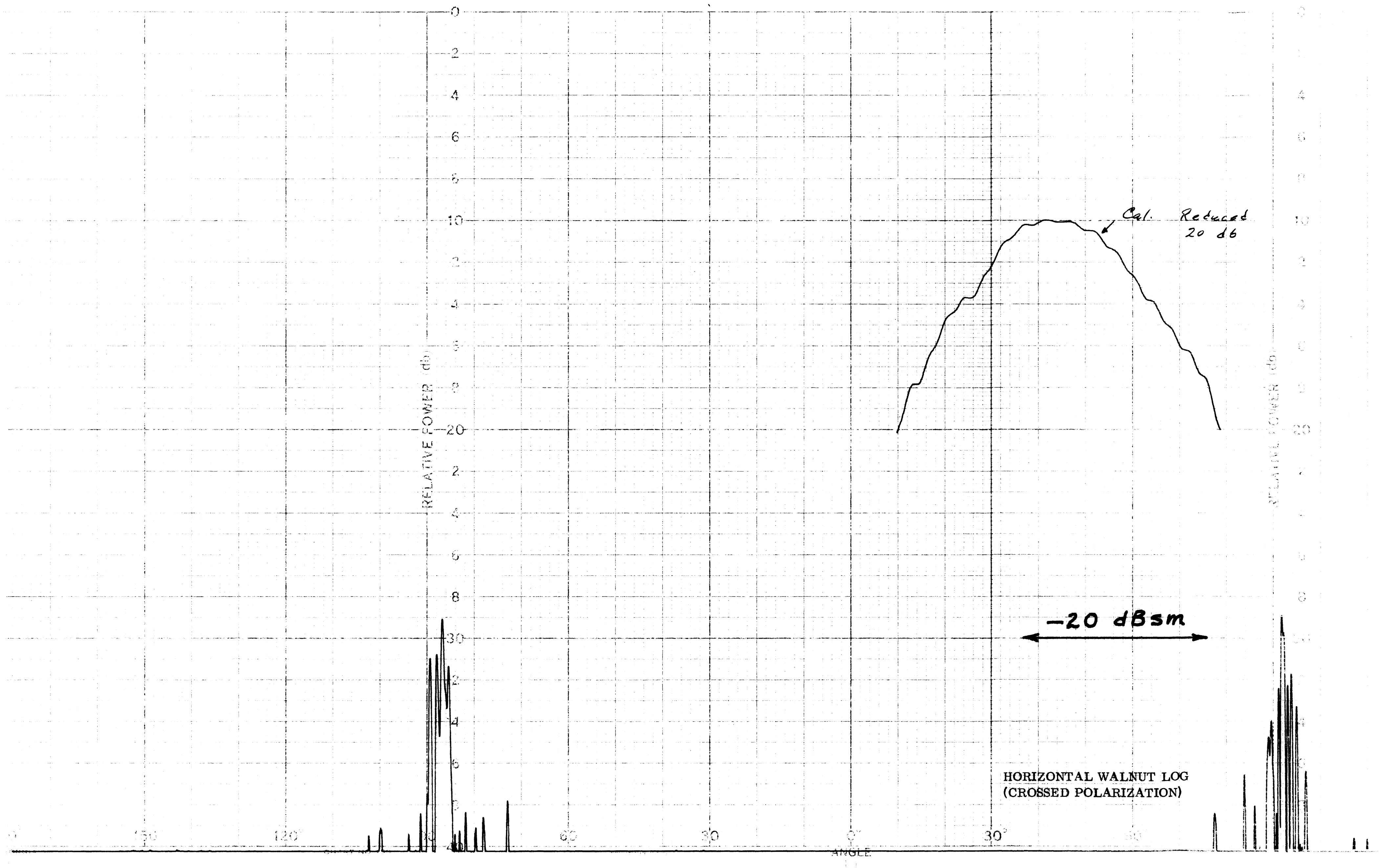
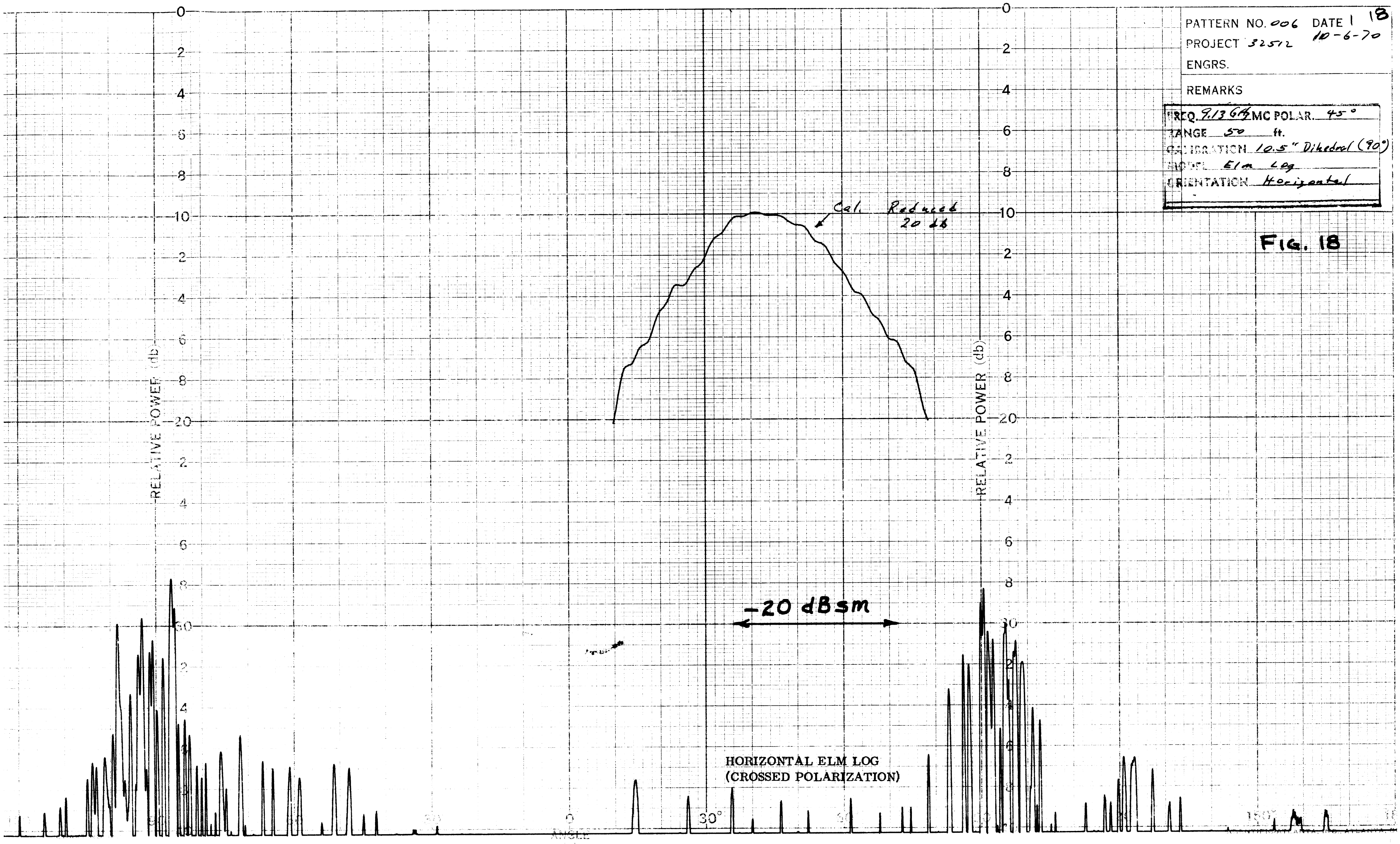

PATTERN NO 005 17
PROJECT 32512 10-6-70
ENGRS.
REMARKS
9.1 GHz 45°
50
10.5" Dihedral (70°)
Walnut Log.
Horizontal
Cal. Reduced 20 db
-20 dBsm
RELATIVE POWER (db)
ANGLE
HORIZONTAL WALNUT LOG
(CROSSED POLARIZATION)

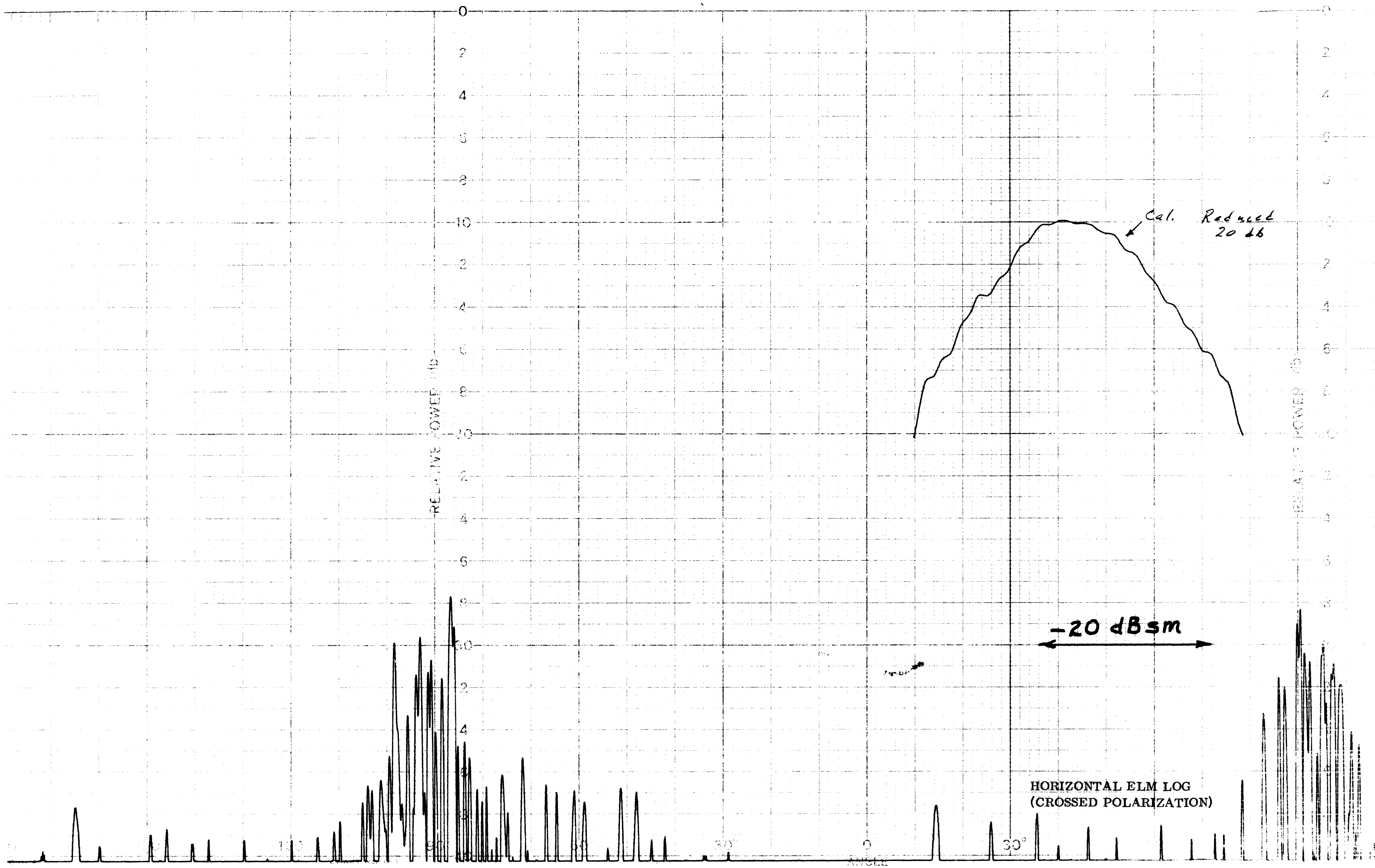
FIG. 17


RELATIVE POWER (db)
ANGLE
Cal. Reduced 20 db
-20 dBsm
HORIZONTAL WALNUT LOG
(CROSSED POLARIZATION)


PATTERN NO. 006 DATE 10-6-70
PROJECT 32512
ENGRS.
REMARKS
FREQ. 9.13 GHz MC POLAR. 45°
RANGE 50 ft.
CALIBRATION 10.5" Dihedral (90°)
MODEL Elm Log
ORIENTATION Horizontal
RELATIVE POWER (db)
Cal. Reduced 20 db
-20 dBsm
HORIZONTAL ELM LOG
(CROSSED POLARIZATION)
30°
ANGLE

18

FIG. 18


RELATIVE POWER (db)
Cal. Reduced 20 db
-20 dBsm
30°
0
ANGLE
HORIZONTAL ELM LOG
(CROSSED POLARIZATION)

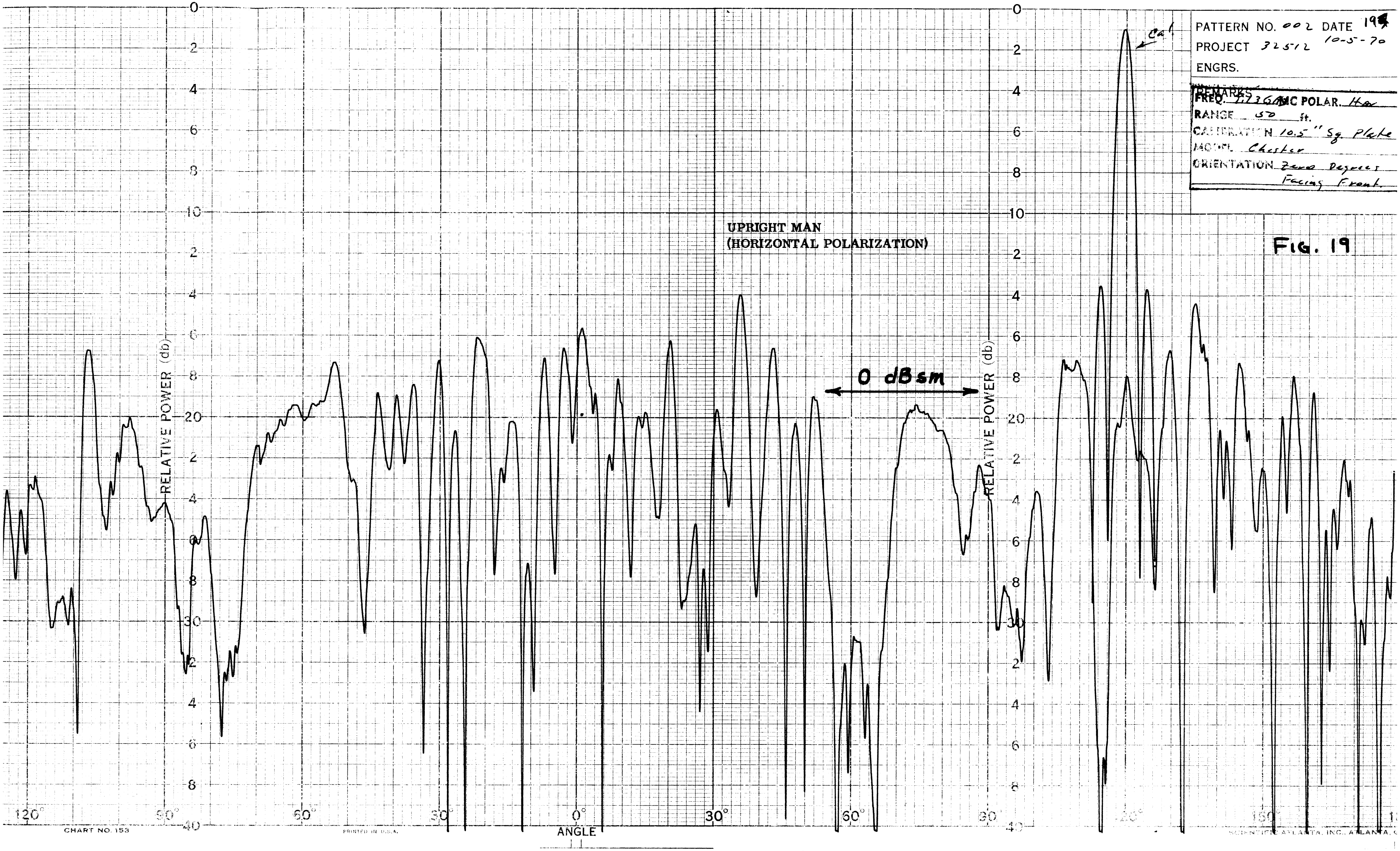
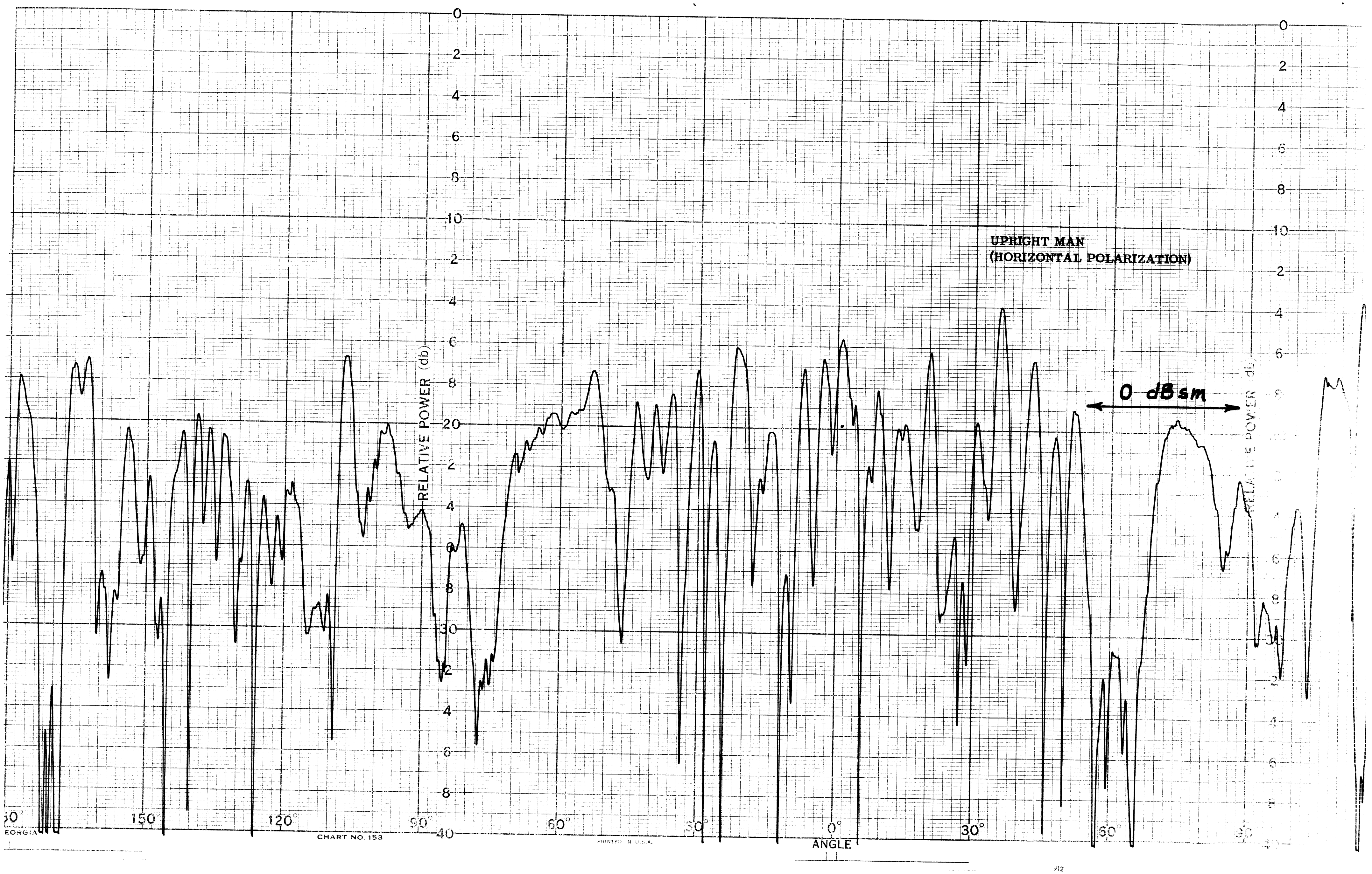
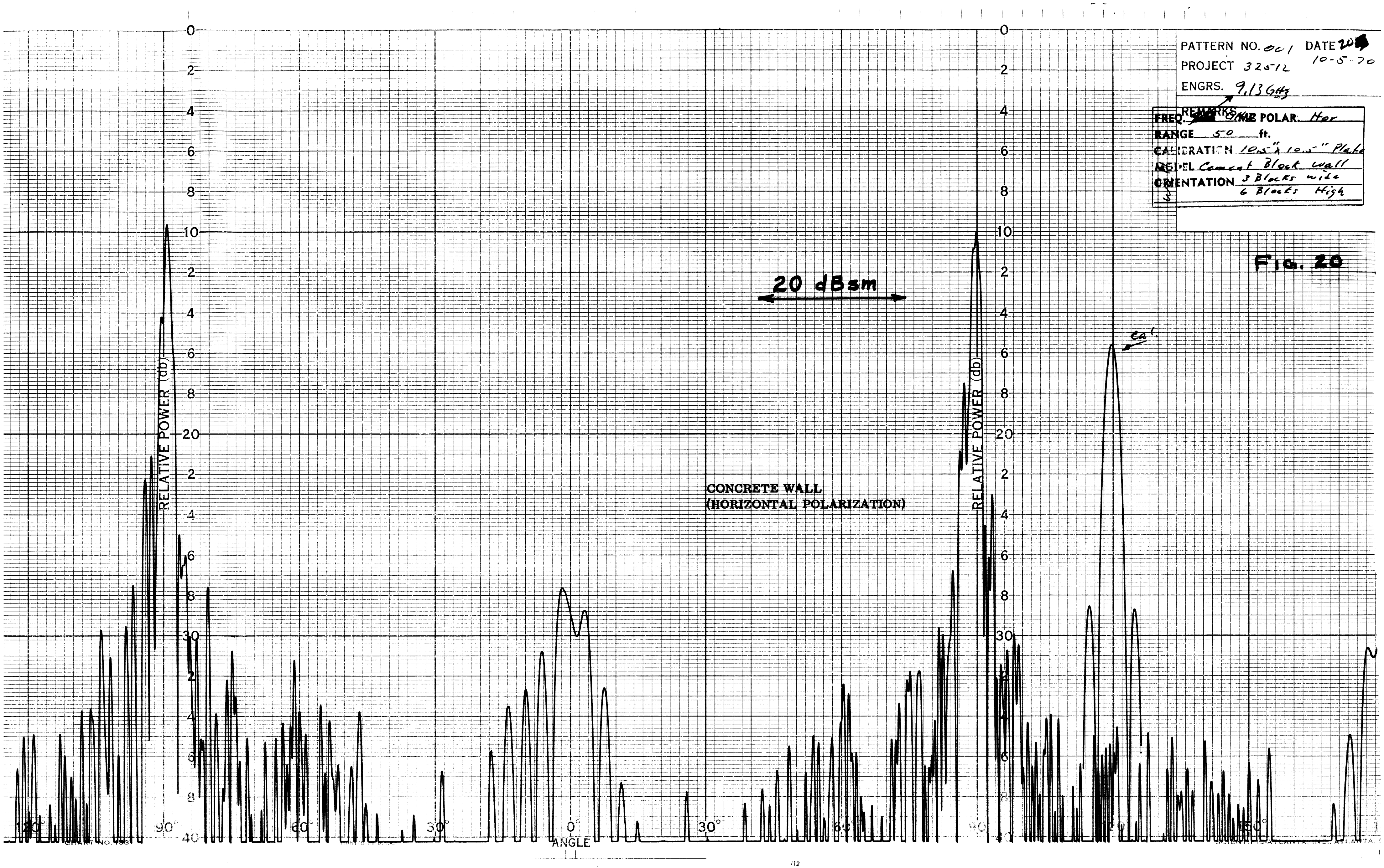
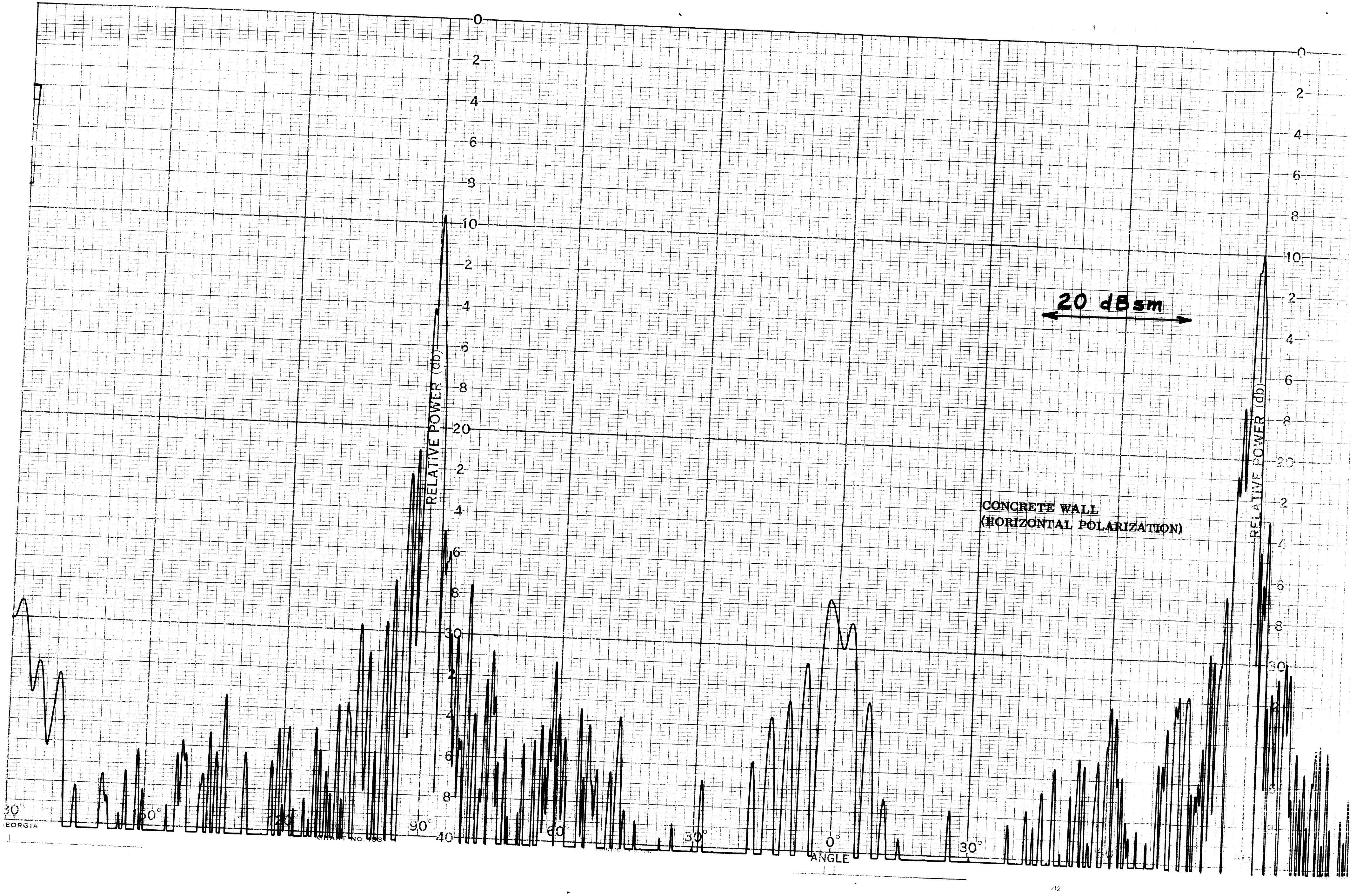

PATTERN NO. 002 DATE 10-5-70
PROJECT 325-12
ENGRS.
REMARKS
FREQ. 7.73 GMC POLAR. Hor
RANGE 50 ft.
CALIBRATION 10.5" Sg. Plate
MODEL Chester
ORIENTATION Zero Degrees Facing Front
Cal
UPRIGHT MAN
(HORIZONTAL POLARIZATION)
0 dBsm
RELATIVE POWER (db)
ANGLE
CHART NO. 153
PRINTED IN U.S.A.
120° 90° 60° 30° 0° 30° 60° 90° 120° 150°

Fig. 19


UPRIGHT MAN
(HORIZONTAL POLARIZATION)
0 dBsm
RELATIVE POWER (db)
ANGLE
150°
120°
90°
60°
30°
0°
30°
60°
CHART NO. 153
PRINTED IN U.S.A.


PATTERN NO. 001 DATE 10-5-70
PROJECT 325-12
ENGRS. 9.13 GHz
REMARKS
FREQ. POLAR. Hor
RANGE 50 ft.
CALIBRATION 10.5" x 10.5" Plate
MODEL Cement Block wall
ORIENTATION 3 Blocks wide 6 Blocks High
Fig. 20
20 dBsm
cal.
CONCRETE WALL
(HORIZONTAL POLARIZATION)
RELATIVE POWER (db)
RELATIVE POWER (db)
ANGLE
0°
30°
60°
90°
120°
150°


20 dBsm
CONCRETE WALL
(HORIZONTAL POLARIZATION)
RELATIVE POWER (db)
RELATIVE POWER (db)
ANGLE
0°
30°
30°
60°
90°
120°
150°
180°