NAVAL RESEARCH LABORATORY

REPORT

1 October 1946

DEVELOPMENT OF THE ANTENNA
(IDENTIFICATION) MARK 18 MOD 0

By P. A. Lantz and R. J. Adams

- Report R-2924 -

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Navy Department - Office of Research and Inventions

NAVAL RESEARCH LABORATORY
Washington, D.C.

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SHIP-SHORE RADIO DIVISION - SEARCH RADAR SECTION

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ABSTRACT

The Mark 18 Antenna is a lobing array for use with Radar Equipments Mark 32 Mod 1 installed in the Mark 37 Director with Fire Control Radar Mark 25 Mod. 2. While the array itself is essentially the same as one described in an earlier report (R-2791), it has been modified for mounting on the director face. Satisfactory coverage in the vertical plane has been obtained by elevating the antenna 25 degrees with respect to the deck. The horizontal beam width now ranges between 36 and 40 degrees, the main crossover lies between 2.3 and 3.5 db, and all spurious crossovers are at least 16 db down from maximum response over the 157-175 Mc band. The train error is less than 2 degrees at elevation angles up to 80 degrees, and less than 3 degrees at the 20 degree extremes of cross-level. The standing wave ratio does not exceed 3.5 db with the beam deflected in either position.

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INTRODUCTION

Statement of the Problem

1. Problem 0-174.IR-R (References 1 and 2) requested the development of a lobing Mark III IFF array for use with the Fire Control Radar Mark 25 Mod. 2 on Gun Director Mark 37, and it was suggested that an array which had been designed earlier for mounting on the Mark 28 Radar antenna (References 3, 4, and 5) might be adapted to this purpose. In the present case, however, it was desirable to provide a separate mount for the IFF on the director face rather than attach it to the microwave reflector. Ideally, the array would be linked mechanically with the radar antenna, which can be controlled in elevation from -20 to +105 degrees and is stabilized both in elevation and cross level. However, the essential requirement was that the IFF provide coverage and reasonably accurate bearing information on friendly targets at any angle of elevation within the range of the radar set.

Mount with Elevation Control

2. The Washington Naval Gun Factory designed a mount for the IFF antenna which would keep it pointing in the same direction as the radar, and constructed the wooden mock-up shown in Plate 3. In this arrangement, 20 degrees of cross level were provided through the rotating joint at the director face, while the elevation drive ran through one arm of the yoke. The antenna had to be set a considerable distance from the director in order to clear it when elevated 90 degrees. Unfortunately, this increased the turning radius of the director beyond practical limits.

Mount with Fixed Elevation

3. It was suggested at this time that the IFF array could be brought closer to the director by installing it at a fixed angle of elevation of 30 degrees or less. At the same time, this would simplify the mount and reduce its weight. However, two other questions arose:

(a) Would the ship's roll then introduce bearing errors for high angle targets?

(b) Did the array have sufficient vertical beam width to cover 90 degrees, and if so, what was the optimum angle of elevation?

The first question was easily disposed of by considering the fact that cross level stabilization maintained the transverse (elevation) axis of the antenna horizontal at all times, and that the equi-signal plane was therefore vertical, since it was perpendicular to this axis. Thus the antenna elevation could have no effect on the bearing of even high angle targets. Of course the fact that the rotational axis of the director itself was not stabilized introduced bearing errors, but this was unavoidable, and, further, had no connection with the matter of elevation control. To decide the second question, vertical plane antenna patterns were taken (Plates 16-19), and the beam widths were found to be as follows:

Table 1

Vertical Patterns of Mark 18 Antenna

Frequency	Beam Width
157 Mc	69°
160 Mc	69°
172 Mc	74°
175 Mc	72°

Inspection of the patterns revealed that satisfactory overhead coverage could be obtained by elevating the antenna 25 degrees, for the field strength (and range) along the horizon would be reduced only 15%, while the overhead signal would be 25% of maximum. Further, the interference nulls would be smoothed out very considerably by the reduction in intensity of the ray reflected from the water. As 25 degrees seemed to be the optimum elevation angle, the Naval Gun Factory designed a second mount, shown in their sketch number 510592, for holding the antenna at this angle.

Electrical Specifications

4. In accordance with Reference 6, the IFF antenna was to cover the band 160 to 172 Mc and maintain the following r-f characteristics:

(a) Horizontal beam width less than 50 degrees.

(b) Vertical beam width 75 degrees or greater.

(c) Main crossover between 1 and 3 db below maximum signal.

(d) Spurious crossovers at least 16 db below main crossover.

(e) Input standing wave ratio less than 4 db for either position of the lober.

DEVELOPMENT OF THE ANTENNA

Horizontal Radiation Patterns

5. The laboratory model of the Mark III IFF array for Mark 28 (Plate 1) was installed on a Mark 37 Director at the Chesapeake Bay Annex as shown in Plate 2. In realigning the antenna for its new mount, it was necessary to extend each radiator by 1/4 inch. Then the feed system was readjusted to the dimensions shown in Plate 22 to obtain the best possible horizontal

patterns over the band, which are represented in Plates 4-8. The pattern characteristics were as follows:

Table 2

Frequency	Beam Width R	Beam Width L	Main Crossover	Spurious Crossover	Train Error
157 Mc	39°	38°	74%	--	1°
160 Mc	39°	39°	76%	--	1-1/2°
166 Mc	39°	40°	66%	--	--
172 Mc	40°	40°	74%	--	--
175 Mc	36°	39°	70%	15%	--

The only serious defect was the spurious crossover at 175 Mc, and it was found later that this resulted from a lack of symmetry in the feed lines. Although the back radiation is not shown, it was always less than 10% between 120 and 240 degrees, and led to no false crossovers of any consequence. The main crossover was purposely set at a low level to compensate for the increase in this level for high angle patterns.

High Angle Azimuth Patterns

6. High angle patterns of the Mark 18 Antenna were taken by suspending a corner reflector receiving antenna (with the dipole vertical) from the boom of a mobile crane and adjusting its height to obtain elevation angles of 20, 40, 60, and 80 degrees. As may be seen from Plates 9-15 and Table 3, the patterns were all quite usable. Although the beam width increased somewhat with elevation, the main crossover remained at a reasonable level and was fairly sharp; no serious false crossover was observed.

Table 3

High Angle Azimuth Patterns of Mark 18 Antenna

Frequency	Elevation Angle	Beam Width R	Beam Width L	Main Crossover	Spurious Crossover	Train Error
172 Mc	20°	45°	42°	67%	10%	- -
160 Mc	40°	39°	46°	71%	- -	1°
172 Mc	40°	47°	47°	70%	- -	1-1/2°
160 Mc	60°	58°	52°	85%	- -	1/2°
172 Mc	60°	55°	59°	74%	- -	1°
160 Mc	80°	47°	54°	78%	11%	- -
172 Mc	80°	54°	61°	83%	13%	- -

[redacted]

Cross Level Tests

7. As the face of the Mark 37 Director is somewhat unsymmetrical, there was a possibility that when the antenna reached cross level angles of 15 or 20 degrees, the beam would be distorted sufficiently to introduce a bearing error. This point was checked as follows: The Naval Gun Factory mock-up of the director (Plate 3) was sprayed with copper to form a reflecting surface. Then it was mounted on an SC pedestal on the roof of Building 30, and inclined at an angle of 20 degrees. The array was installed with its transverse axis level with the roof. This arrangement simulated a condition where the director is trained forward and the ship is at the end of a 20 degree roll. The horizontal patterns taken under these conditions (Plates 20 and 21) were quite normal, and showed a maximum train error of 2-1/2 degrees:

Table 4

Patterns at 20 Degrees Cross Level

Frequency	Beam Width		Main	Train
	R	L	Crossover	Error
160 Mc	45°	50°	79%	--
172 Mc	47°	45°	70%	$2\text{-}1/2^\circ$

In practice this error could be eliminated by watching the pips for a complete period of the ship's roll.

Impedance Matching

8. As the standing wave ratio at the input to the antenna was greater than 4 db at some frequencies, a section of RG-11/U, 3.42 inches long, was spliced into the main RG-8/U feed cable. The exact location of this transformer may be determined from Plate 22. The resulting match (Plate 23) was better than 3.5 db over the entire band.

Drawings of the Antenna

9. The final dimensions of the antenna and its feed system (See References 7 and 8) are given in Naval Research Laboratory Drawing RA 66F 342B, the assembly of which has been reproduced in Plate 24. The overall weight of the installation has been estimated at 185 lbs, distributed as follows: array, 25 lbs; lober, 21-1/2 lbs; feed harness, 3-1/2 lbs; mount, 135 lbs.

CONCLUSIONS

10. The IFF antenna described in this report gives satisfactory electrical performance from 157 to 175 Mc when installed on a Mark 37 Director in a Naval Gun Factory mount. By using a fixed elevation angle of 25 degrees, it has been possible to simplify the mount and still provide acceptable high angle coverage.

[redacted]

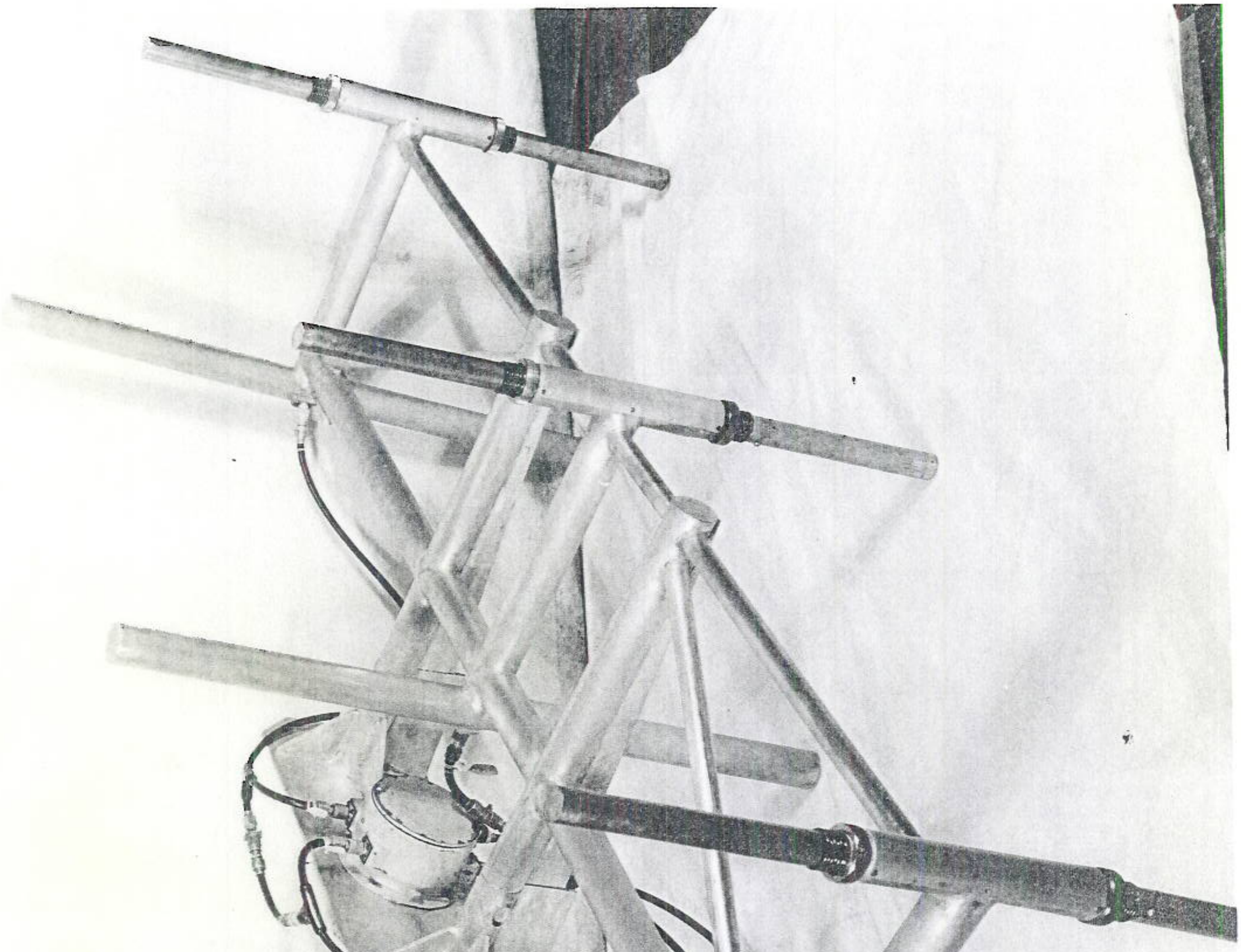

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PLATE 1

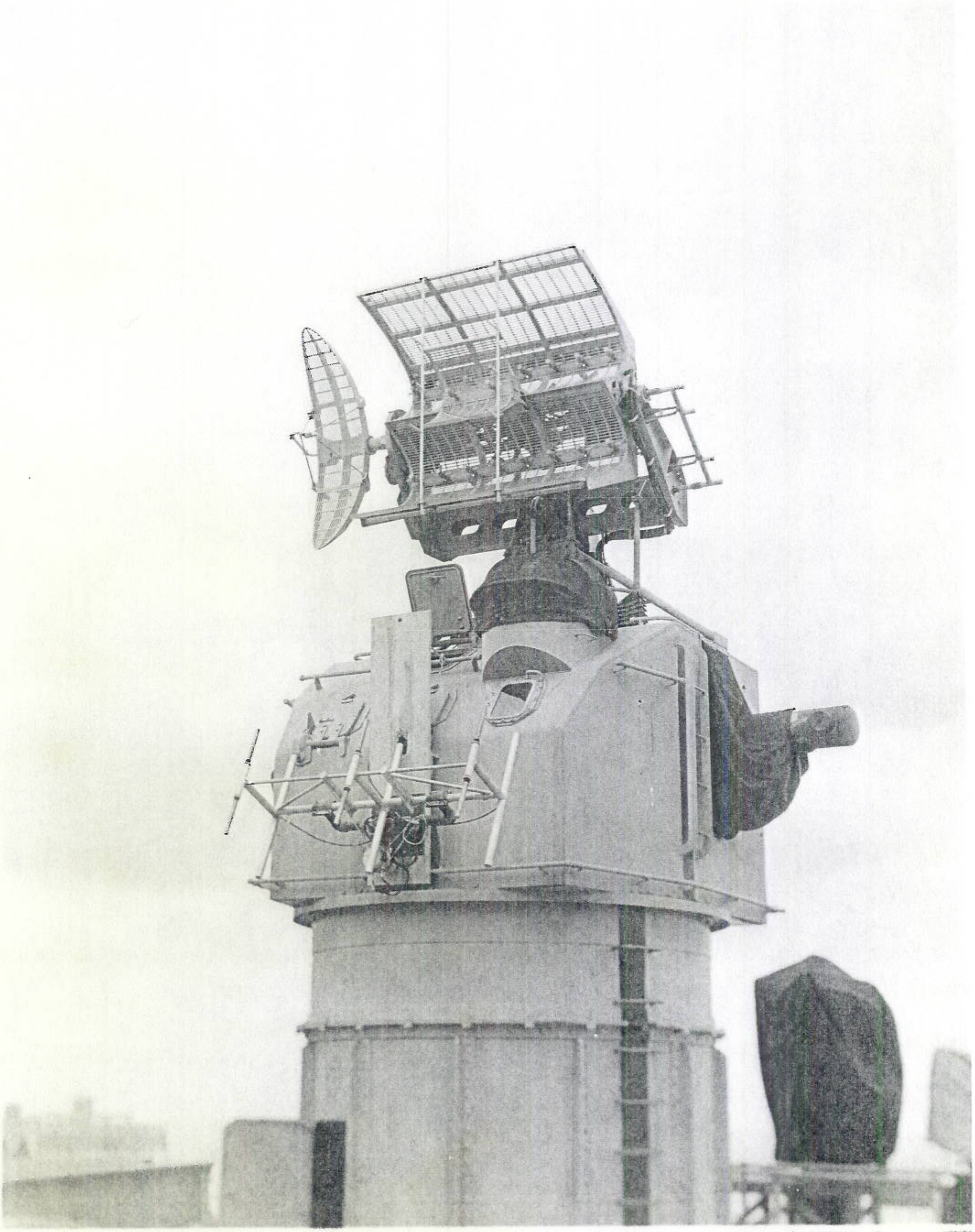

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PLATE 2

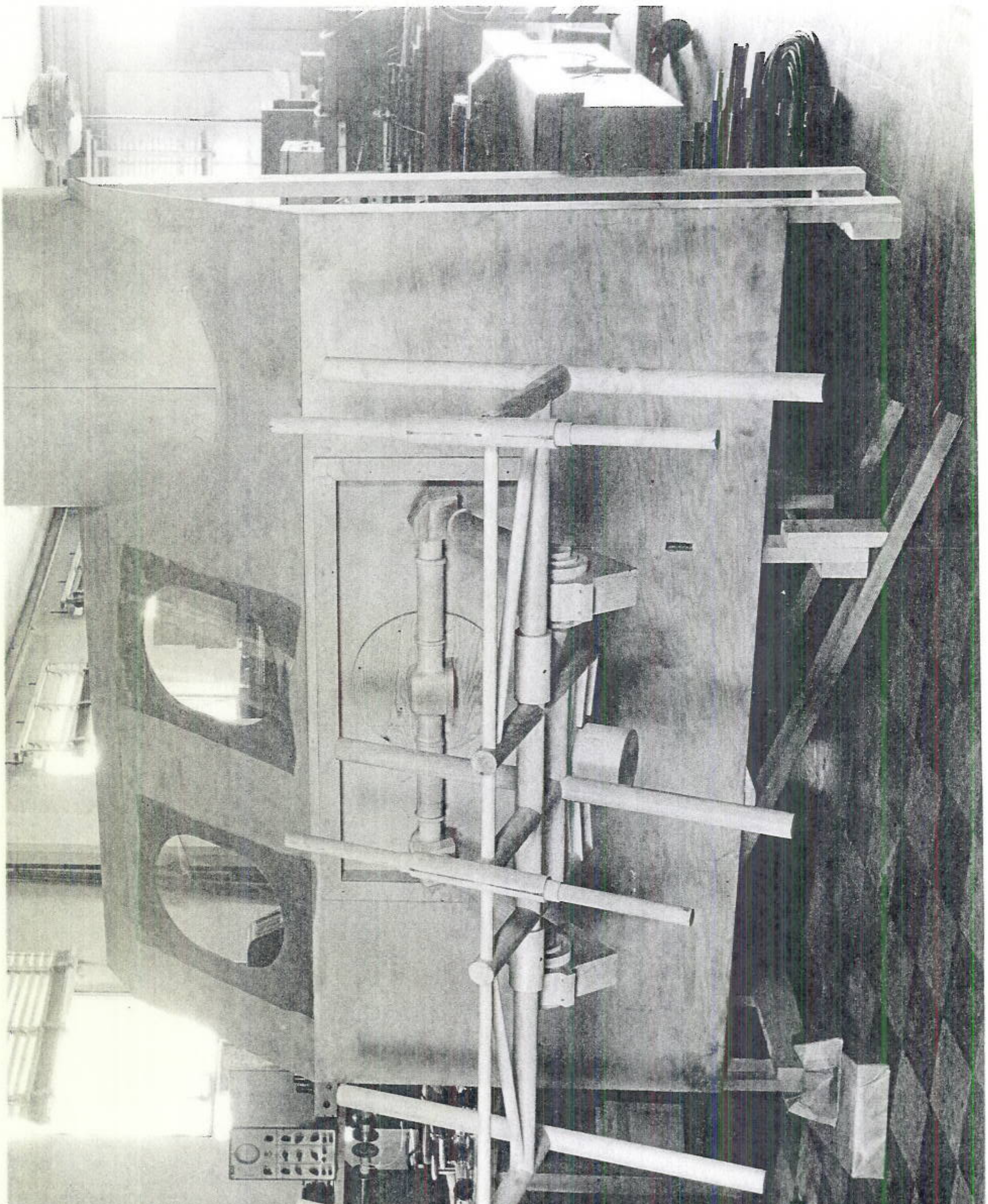

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PLATE 3

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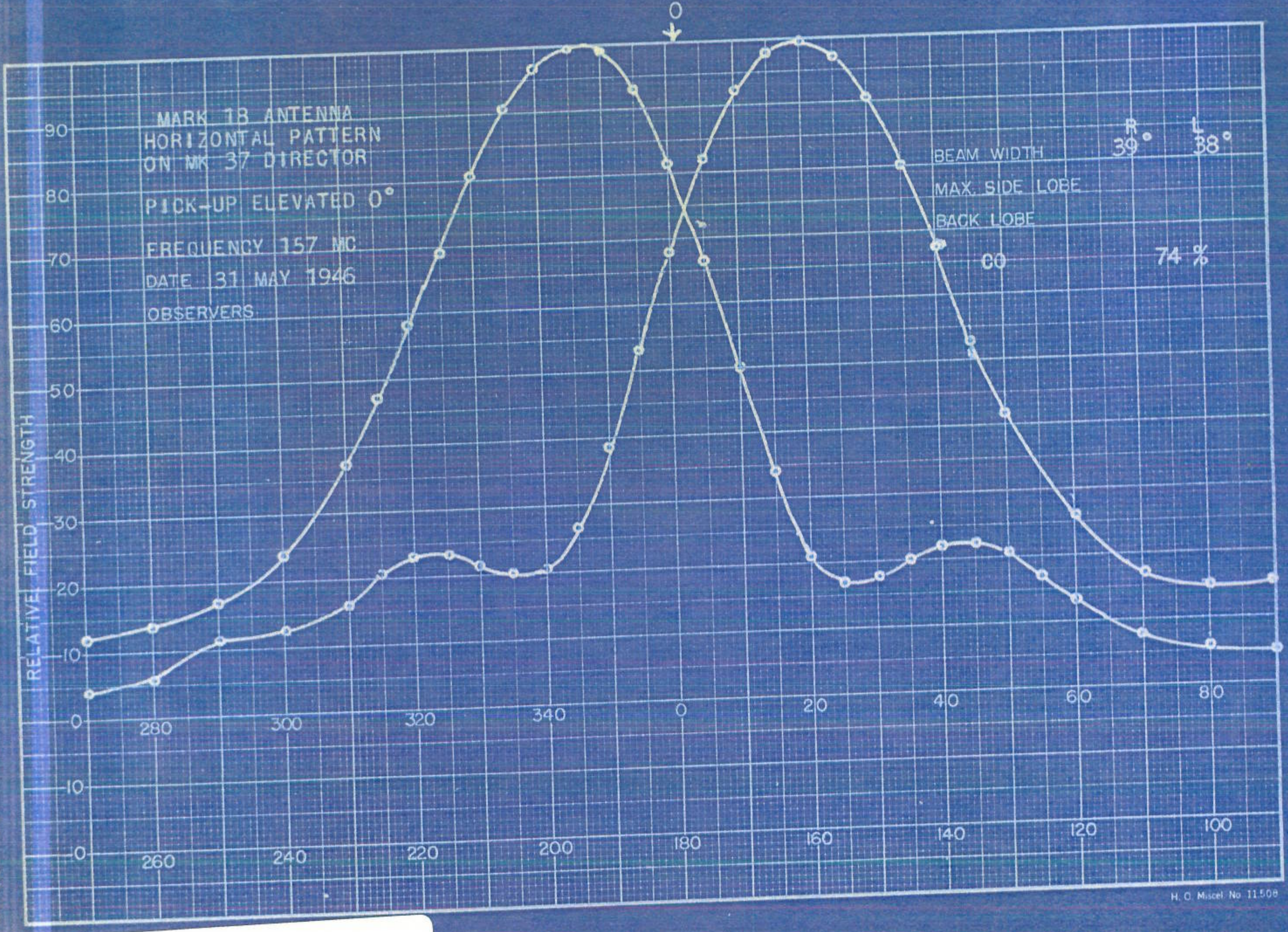

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PLATE 4

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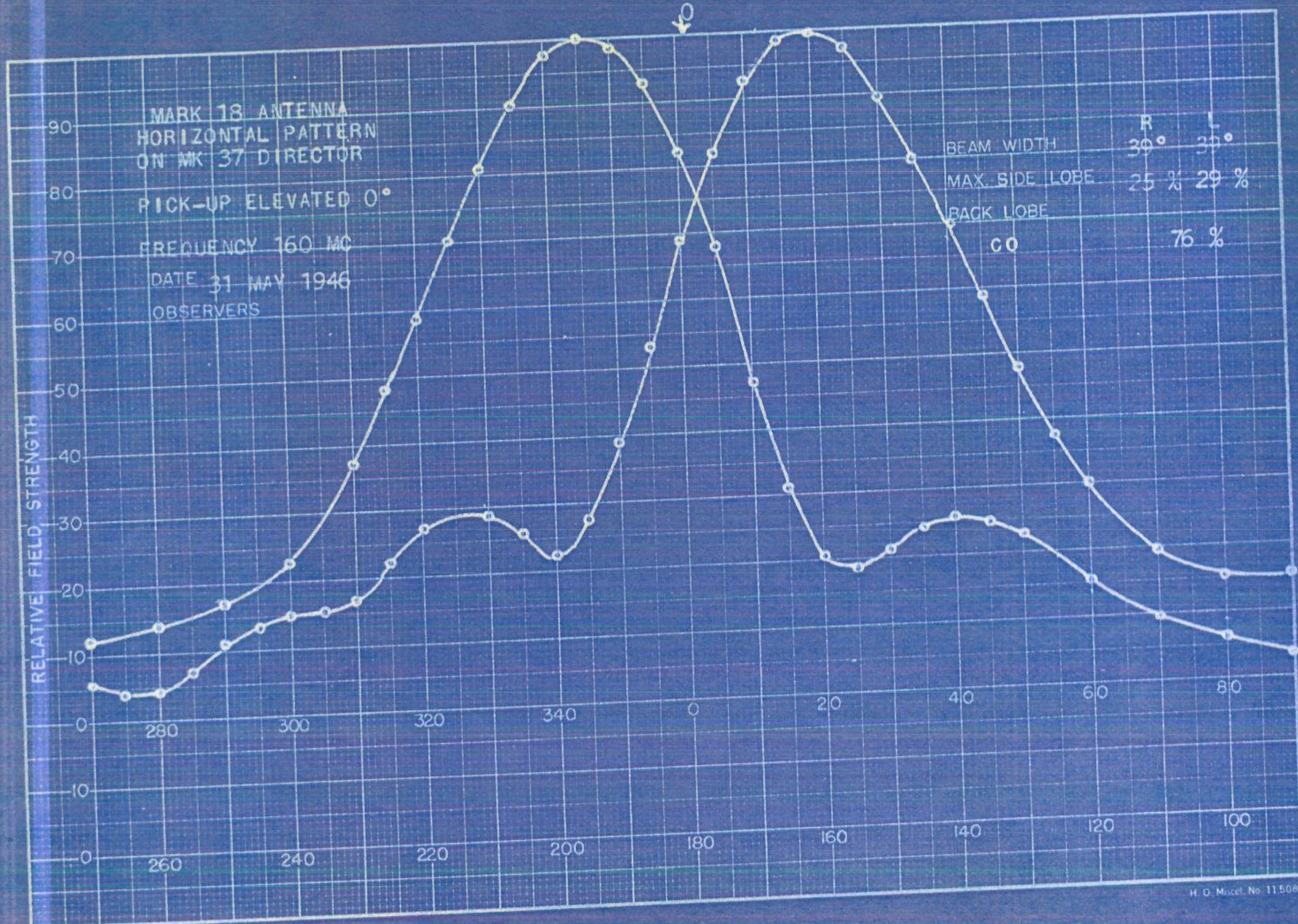
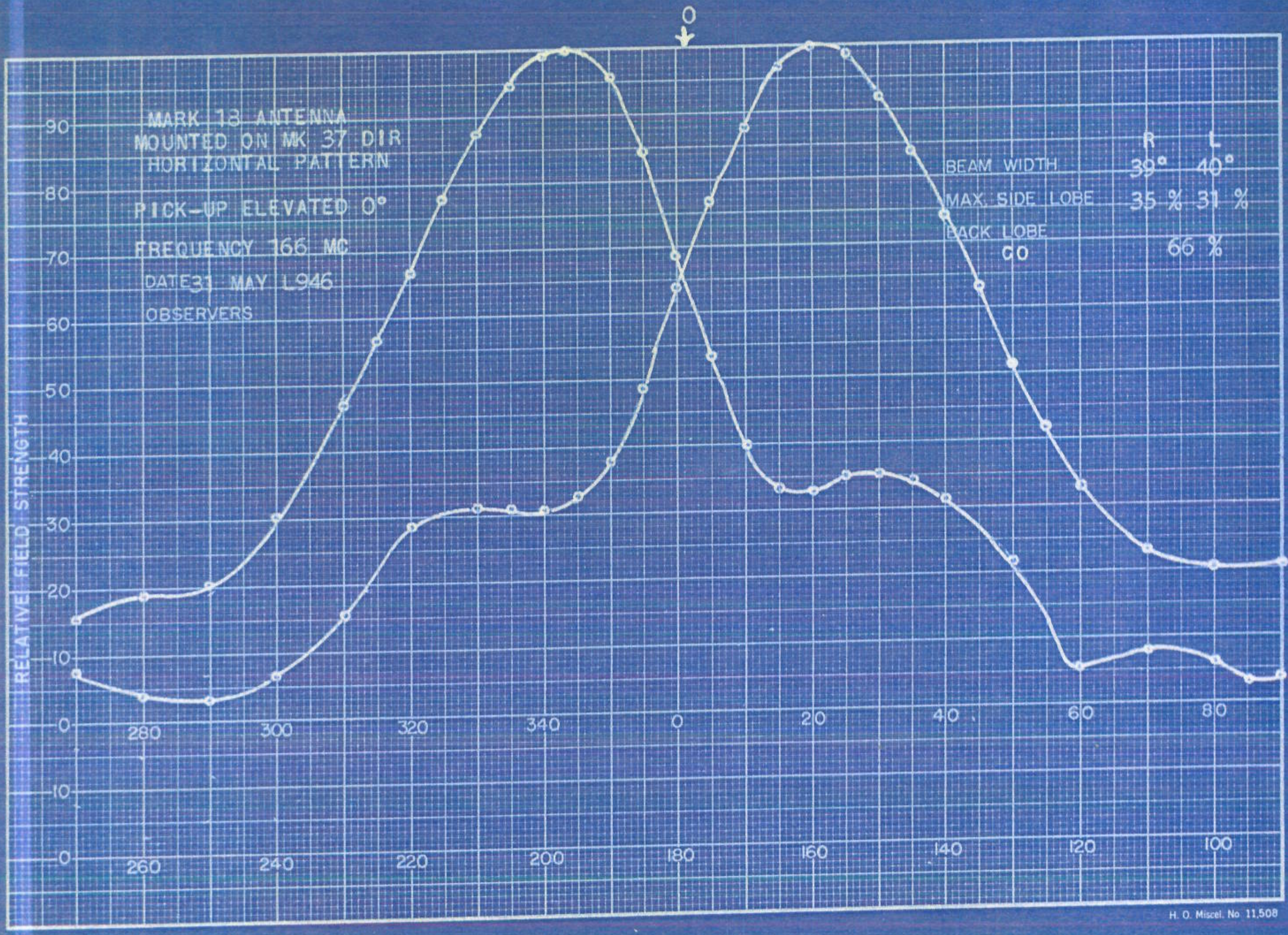
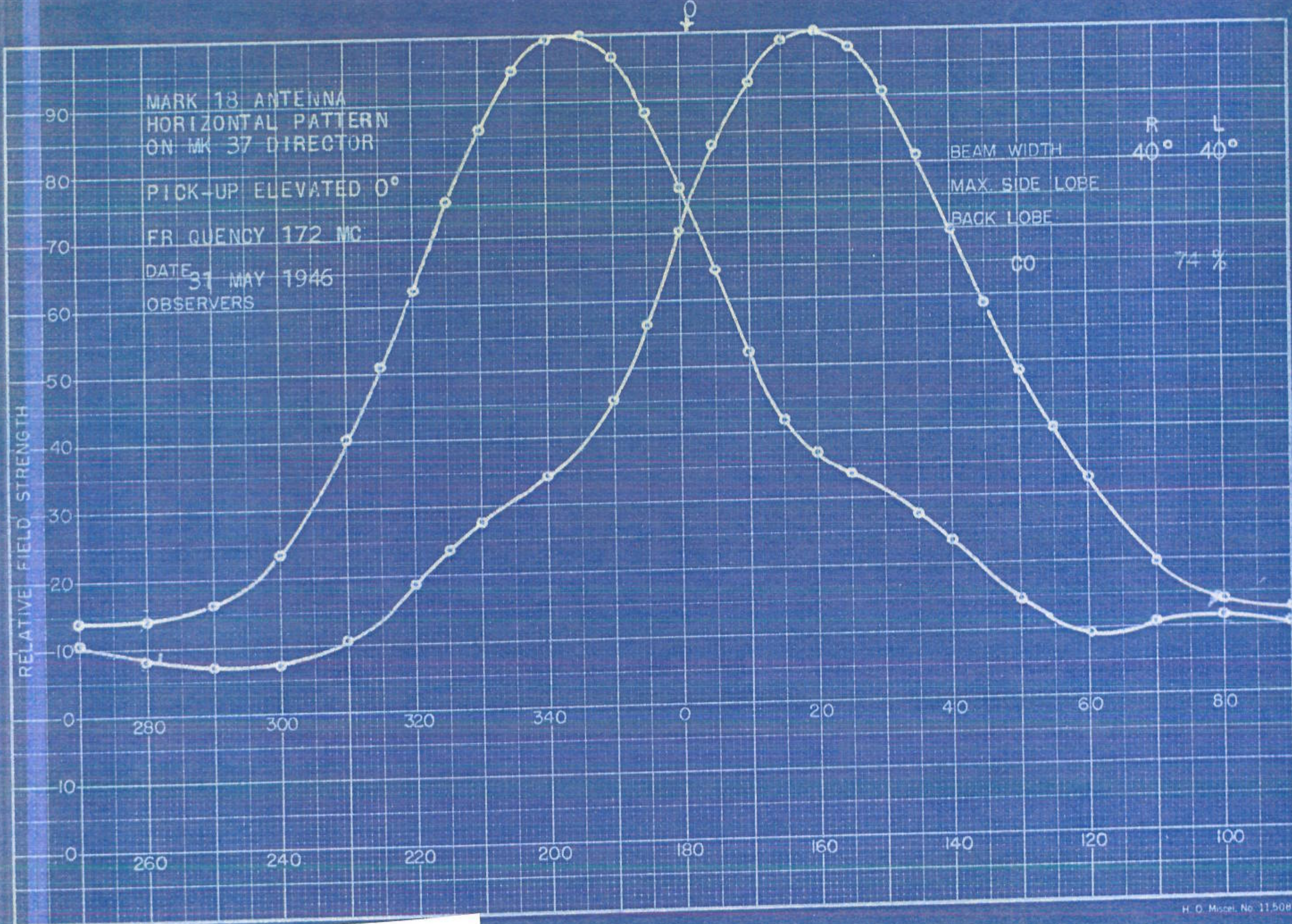


R-2924

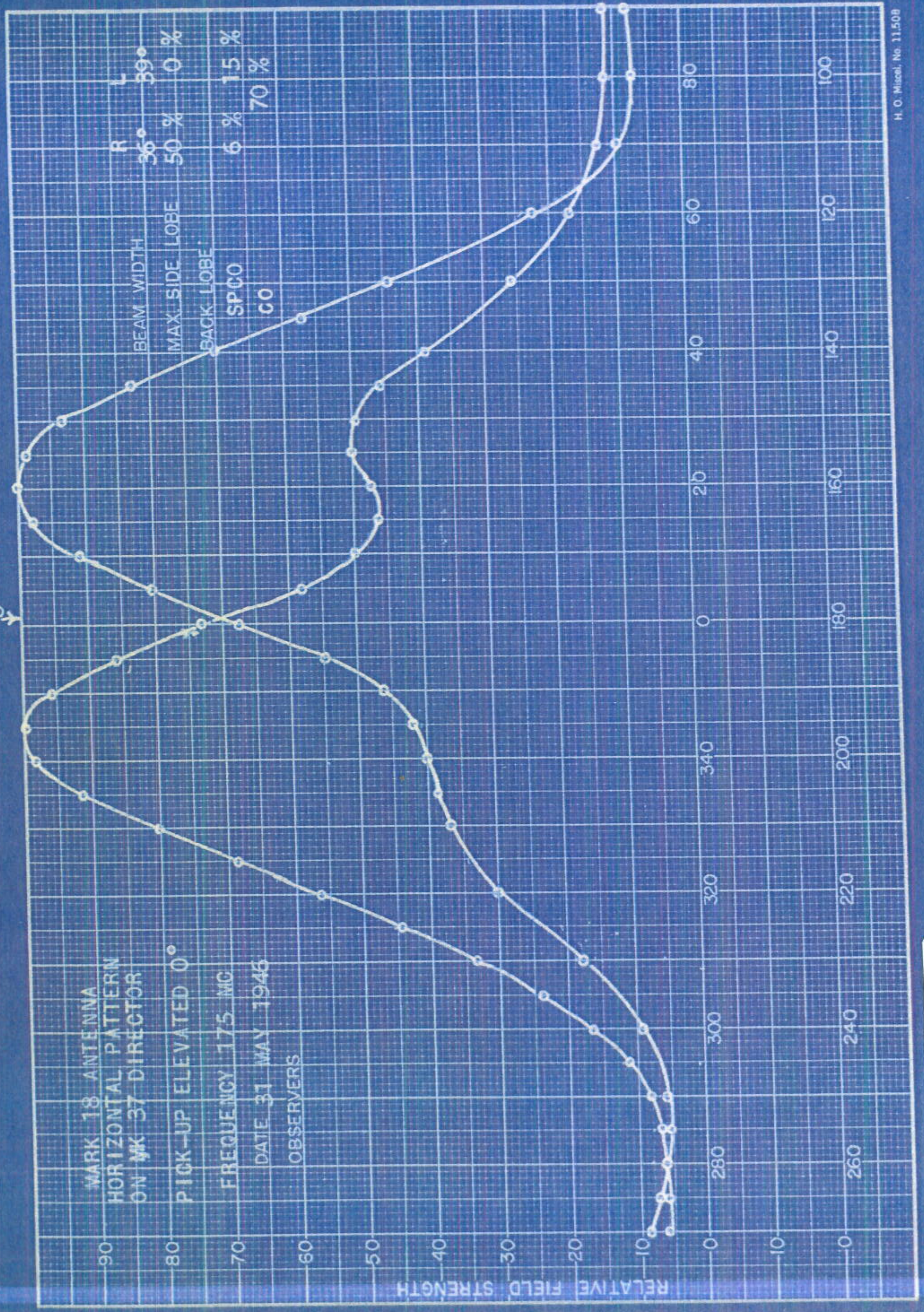
PLATE 5



MARK 18 ANTENNA
MOUNTED ON MK 37 DIR
HORIZONTAL PATTERN
PICK-UP ELEVATED 0°
FREQUENCY 166 MC
DATE 31 MAY 1946
OBSERVERS
R L
BEAM WIDTH 39° 40°
MAX. SIDE LOBE 35 % 31 %
BACK LOBE 66 %
GO
0
RELATIVE FIELD STRENGTH
90
80
70
60
50
40
30
20
10
0
10
0
280 300 320 340 0 20 40 60 80
260 240 220 200 180 160 140 120 100
H. O. Miscel. No 11,508



MARK 18 ANTENNA
HORIZONTAL PATTERN
ON MK 37 DIRECTOR
PICK-UP ELEVATED 0°
FR QUENCY 172 MC
DATE 31 MAY 1946
OBSERVERS
BEAM WIDTH R 40° L 40°
MAX. SIDE LOBE
BACK LOBE
CO 74 %
RELATIVE FIELD STRENGTH
90
80
70
60
50
40
30
20
10
0
10
0
280 300 320 340 0 20 40 60 80
260 240 220 200 180 160 140 120 100
H. O. Miscel. No. 11,508



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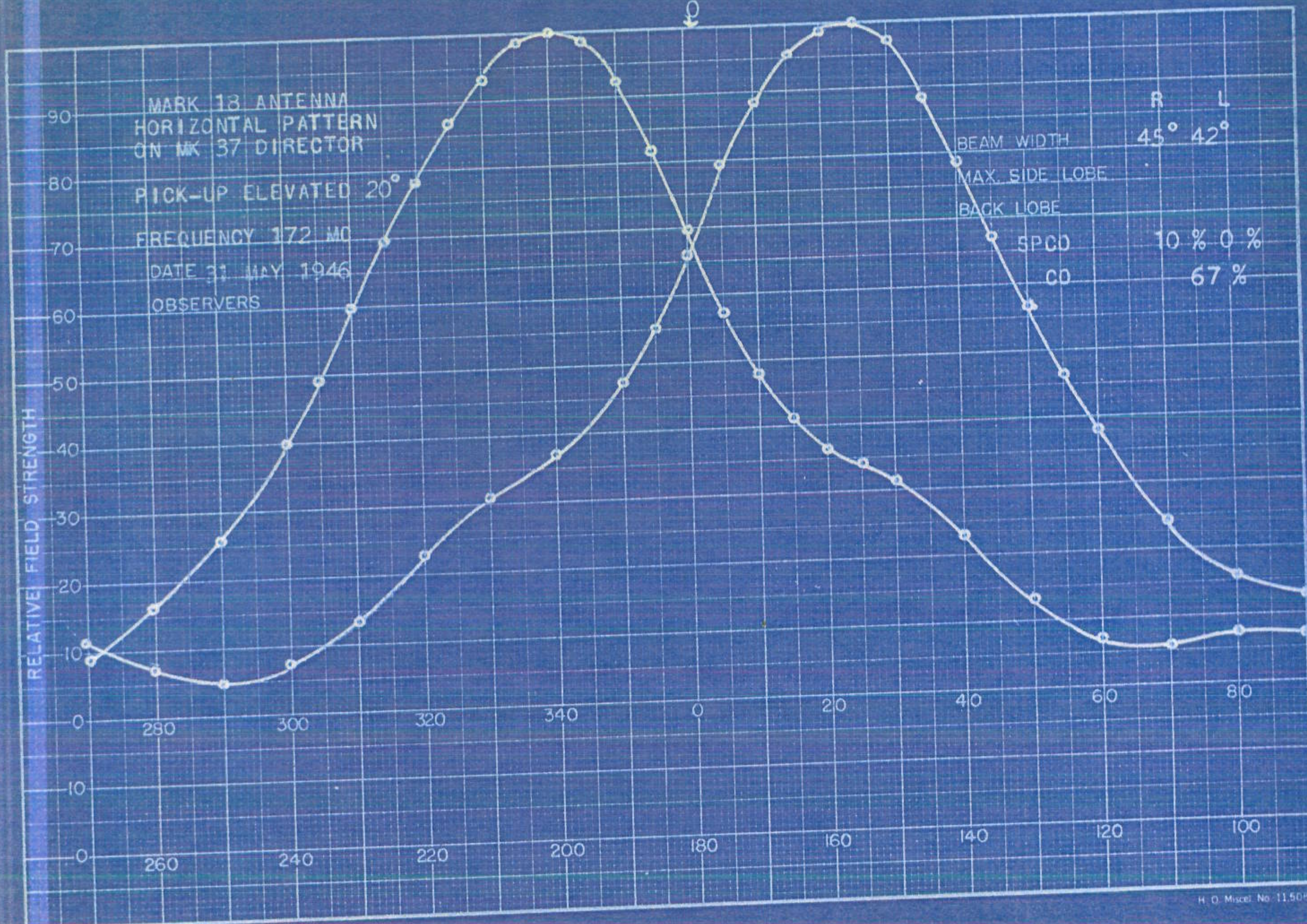

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PLATE 9

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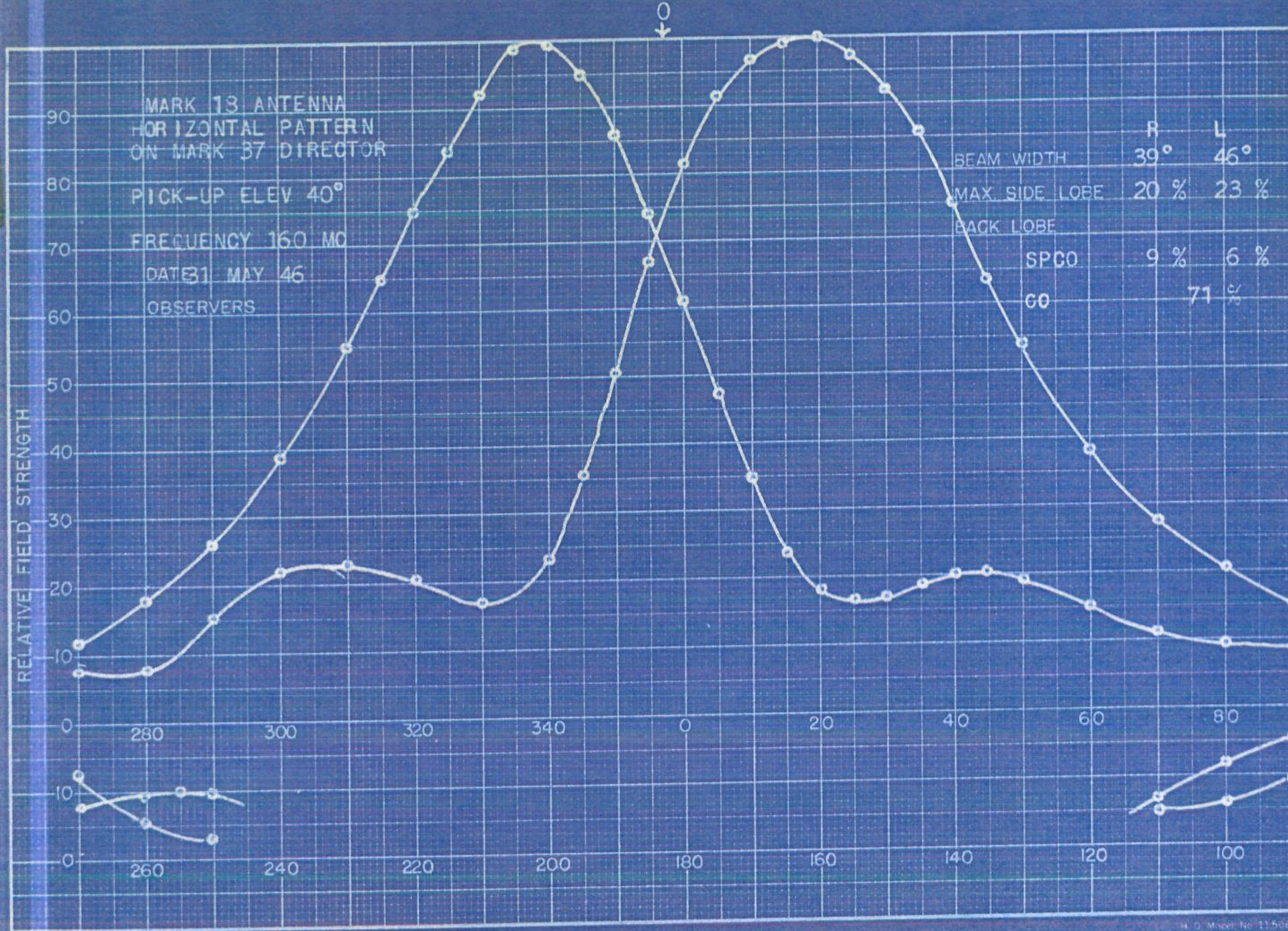

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PLATE 10

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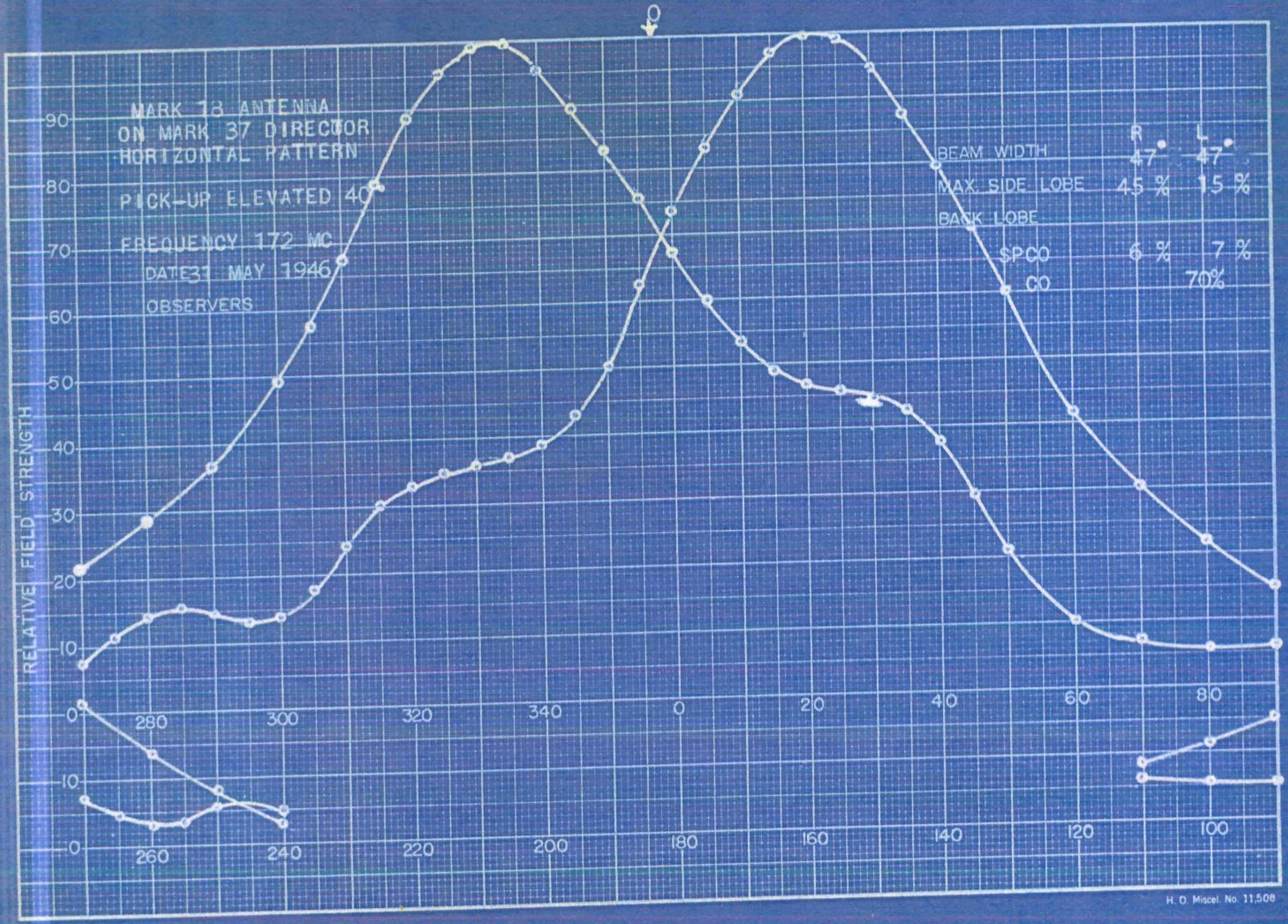

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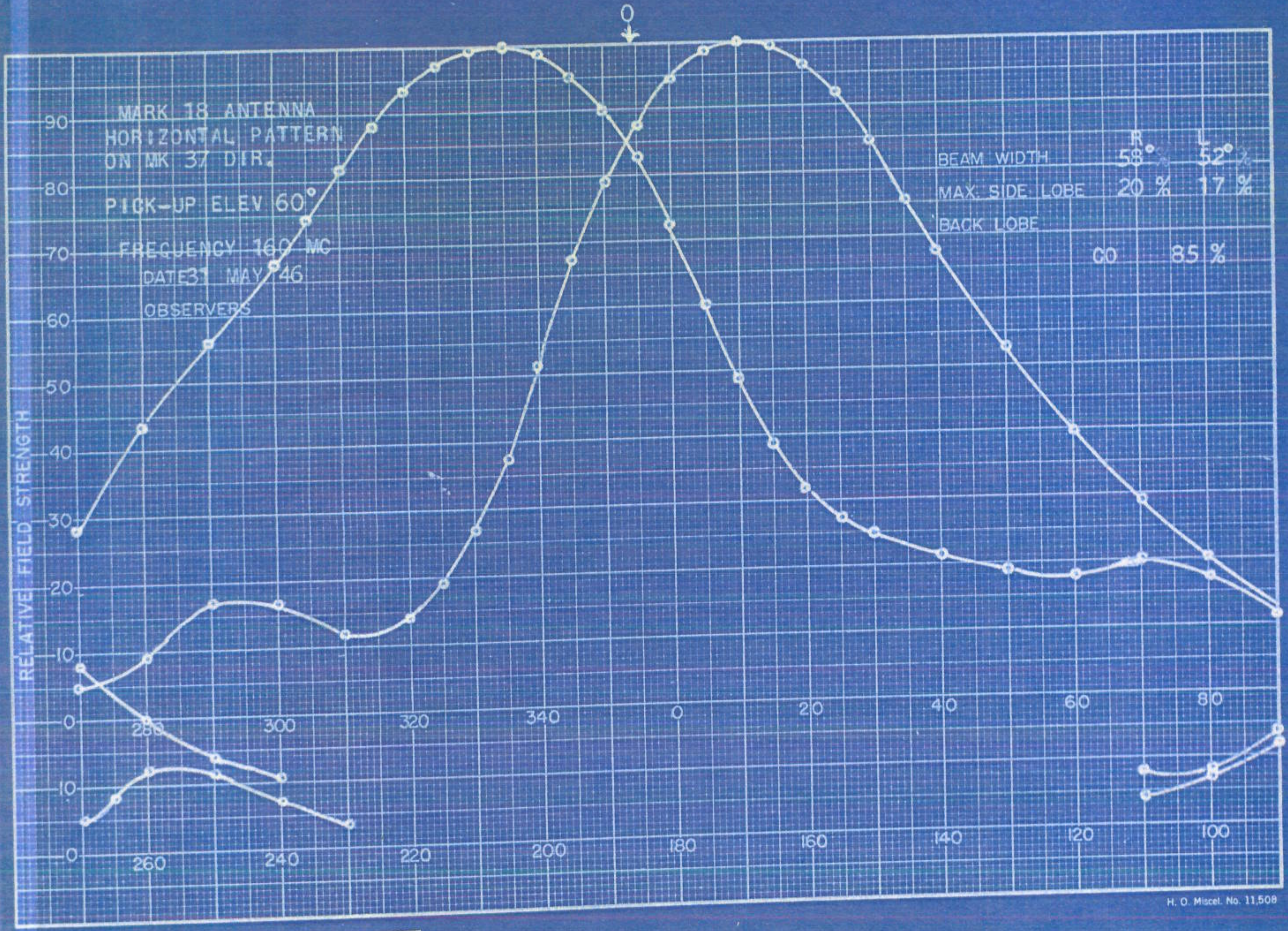

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R-2924

PLATE 12

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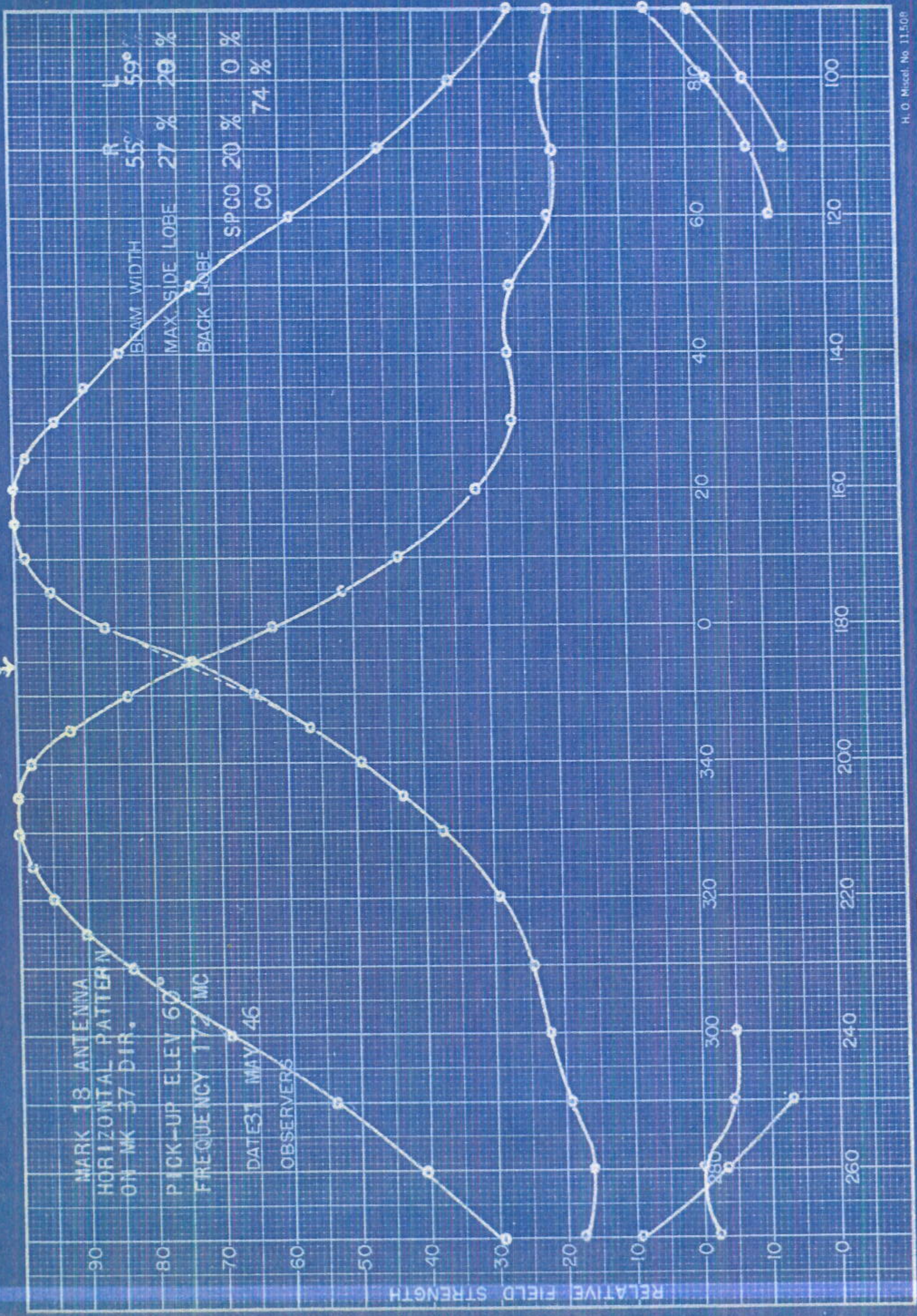

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PLATE 13

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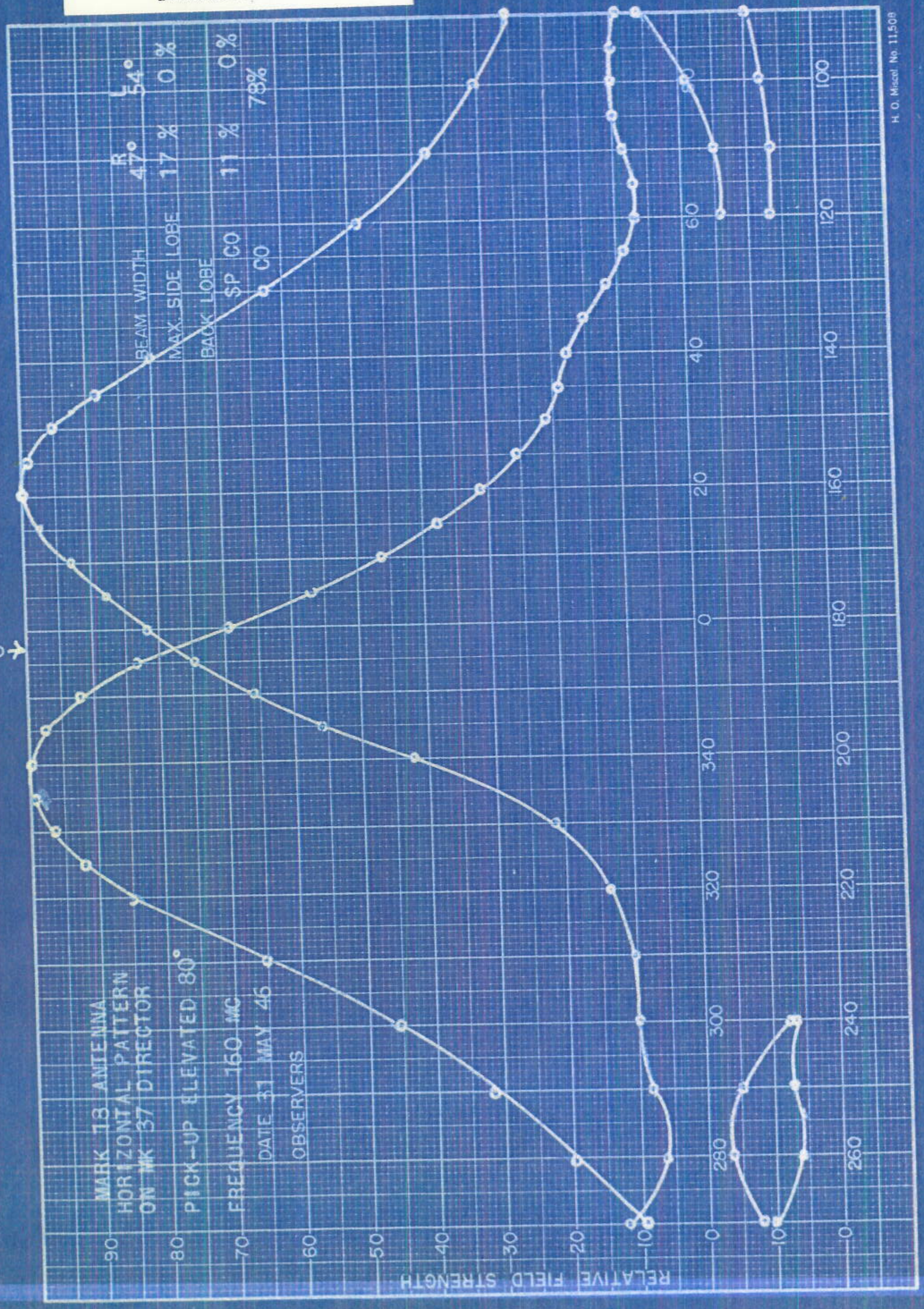
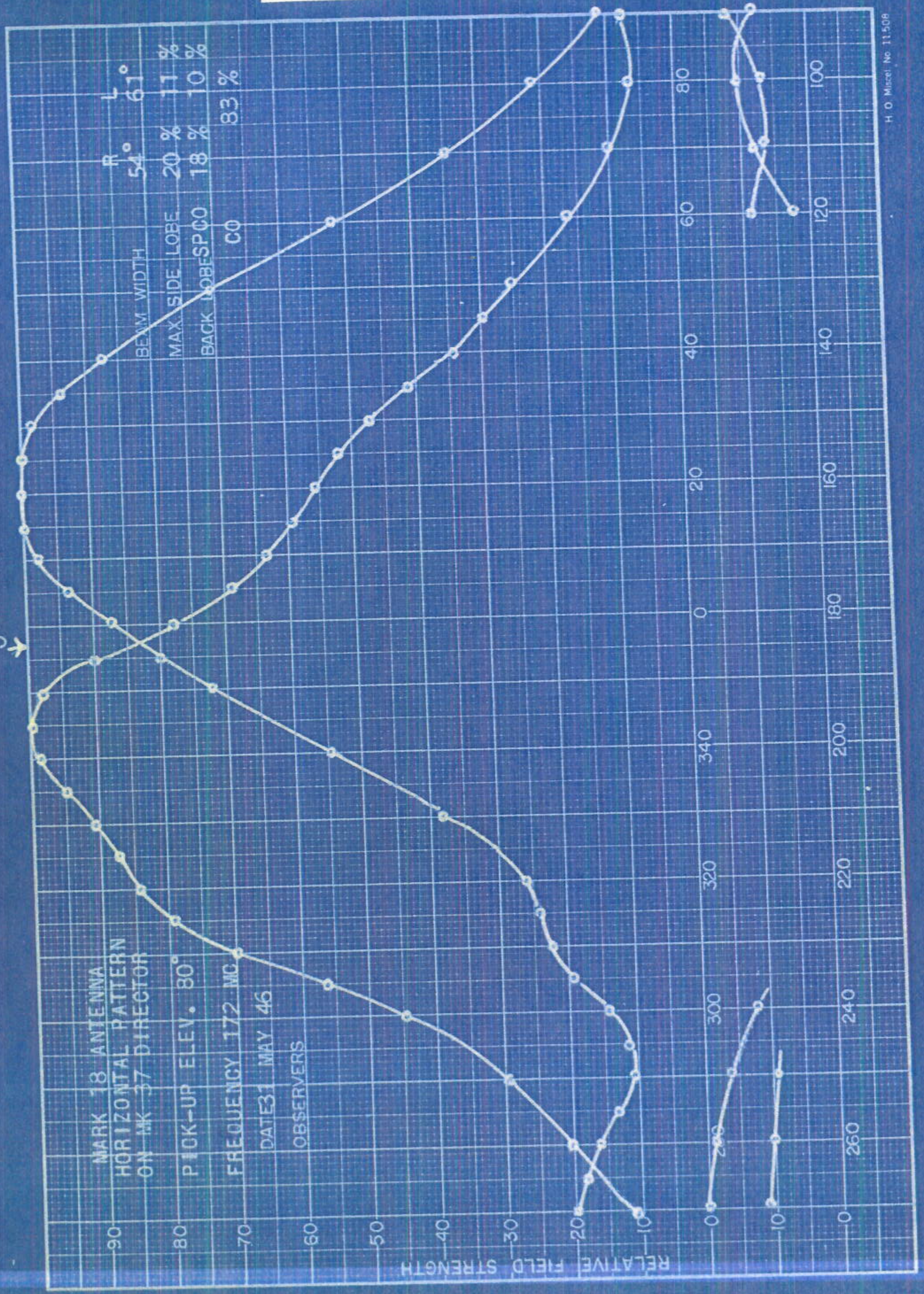
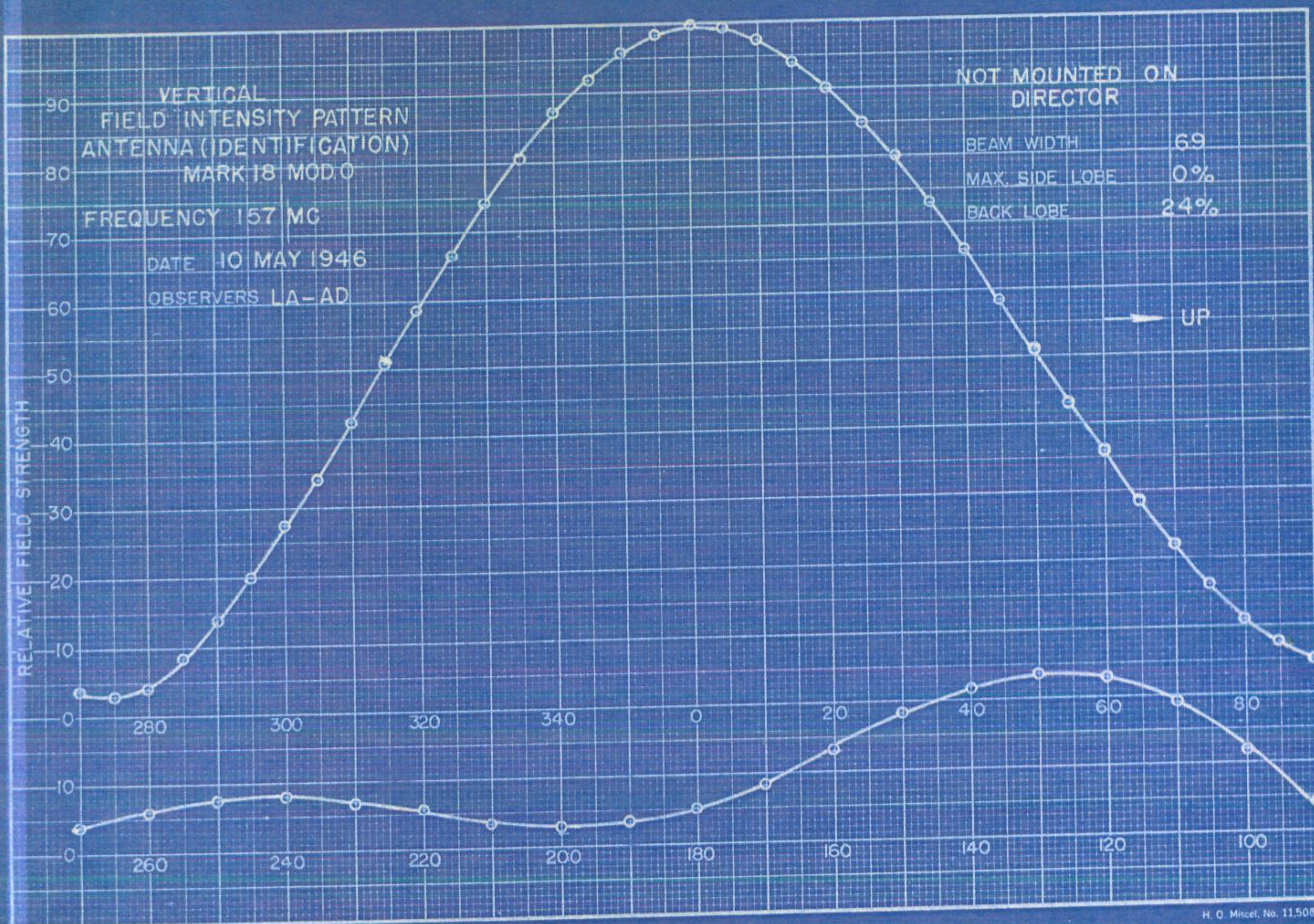


[redacted] R-2924 PLATE 14


MARK 18 ANTENNA
HORIZONTAL PATTERN
ON MK 37 DIRECTOR
PICK-UP ELEV. 80°
FREQUENCY 172 MC
DATE 31 MAY 46
OBSERVERS
R L
BEAM WIDTH 54° 61°
MAX SIDE LOBE 20 % 11 %
BACK LOBES 18 % 10 %
SPCO CO 83 %
RELATIVE FIELD STRENGTH



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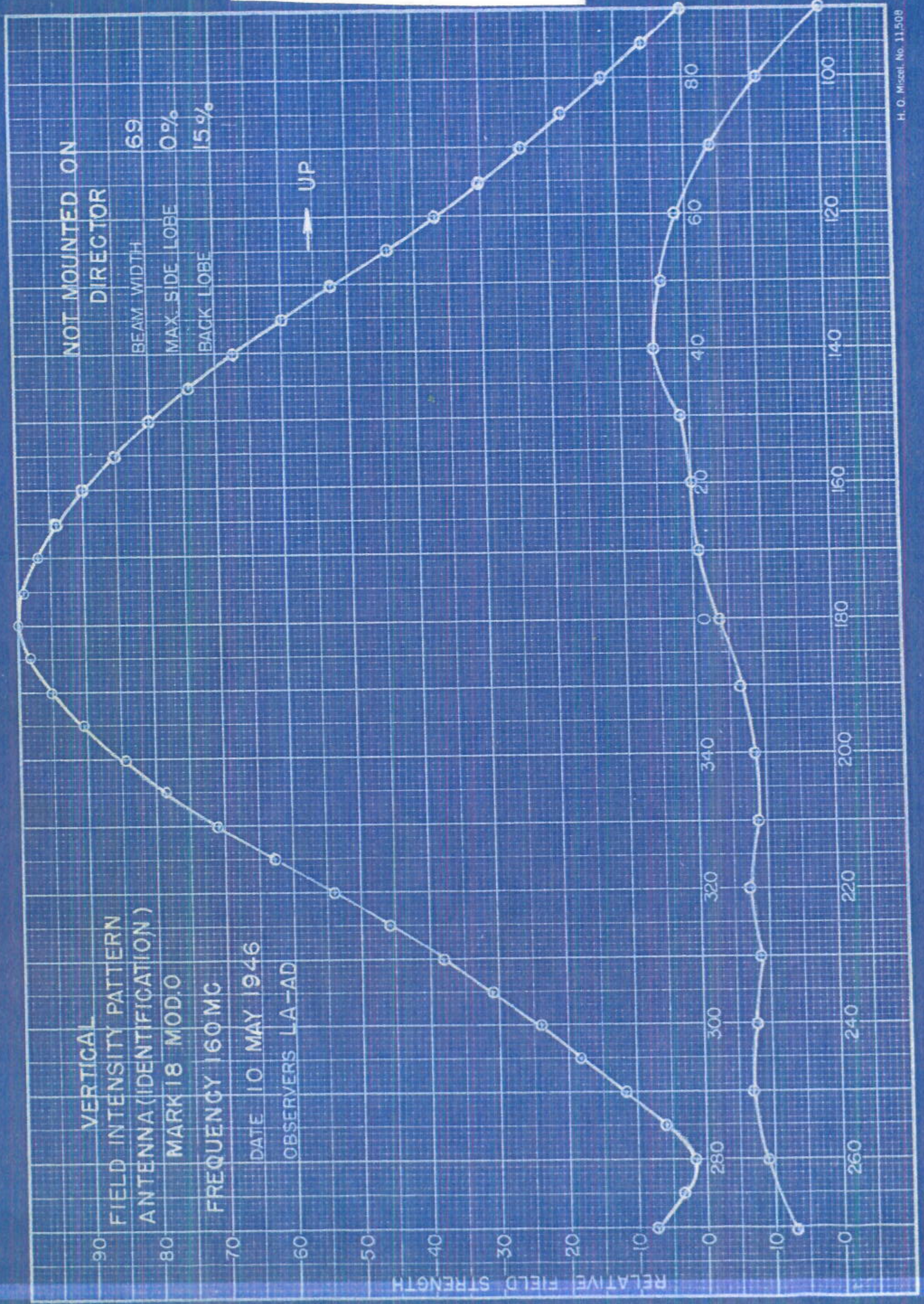

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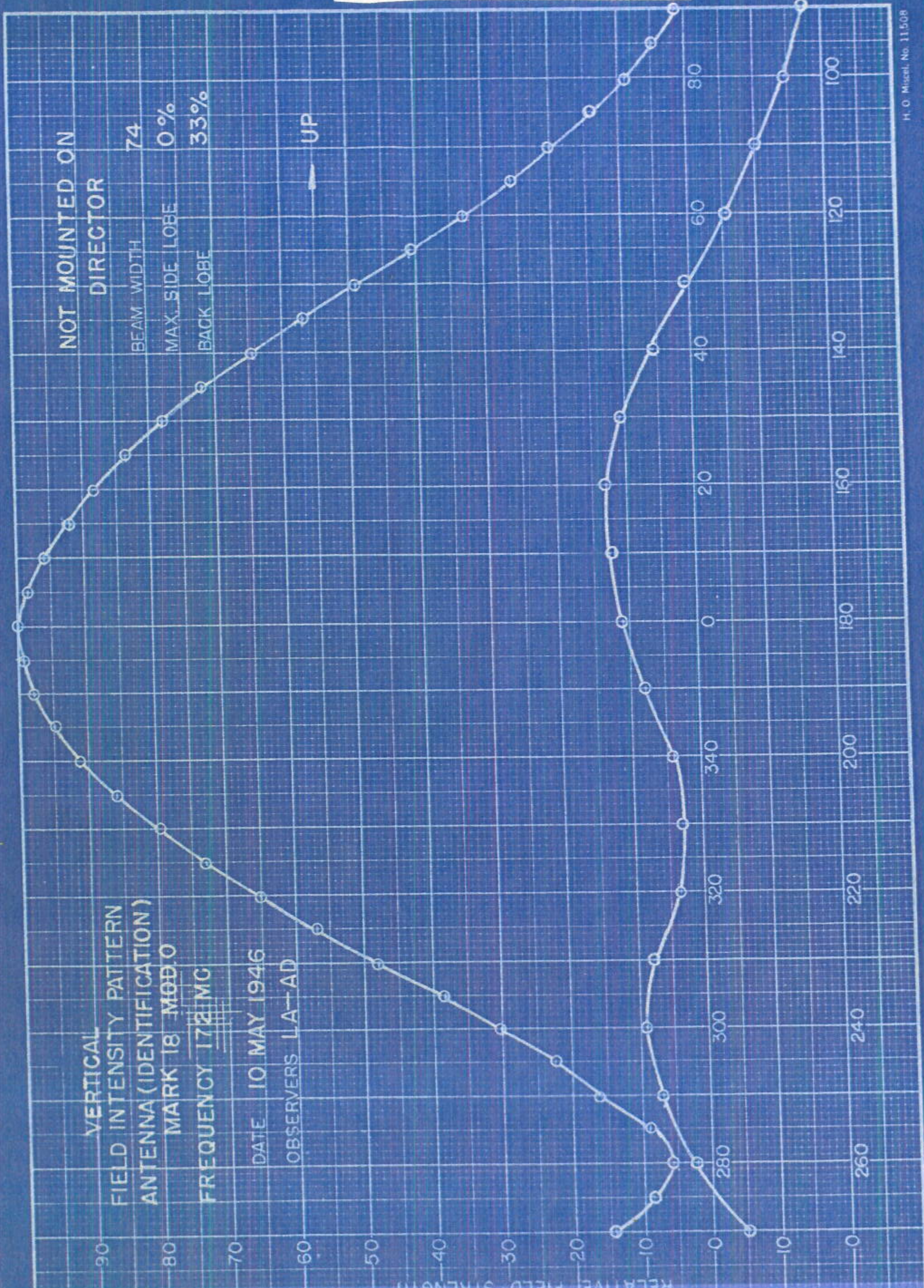
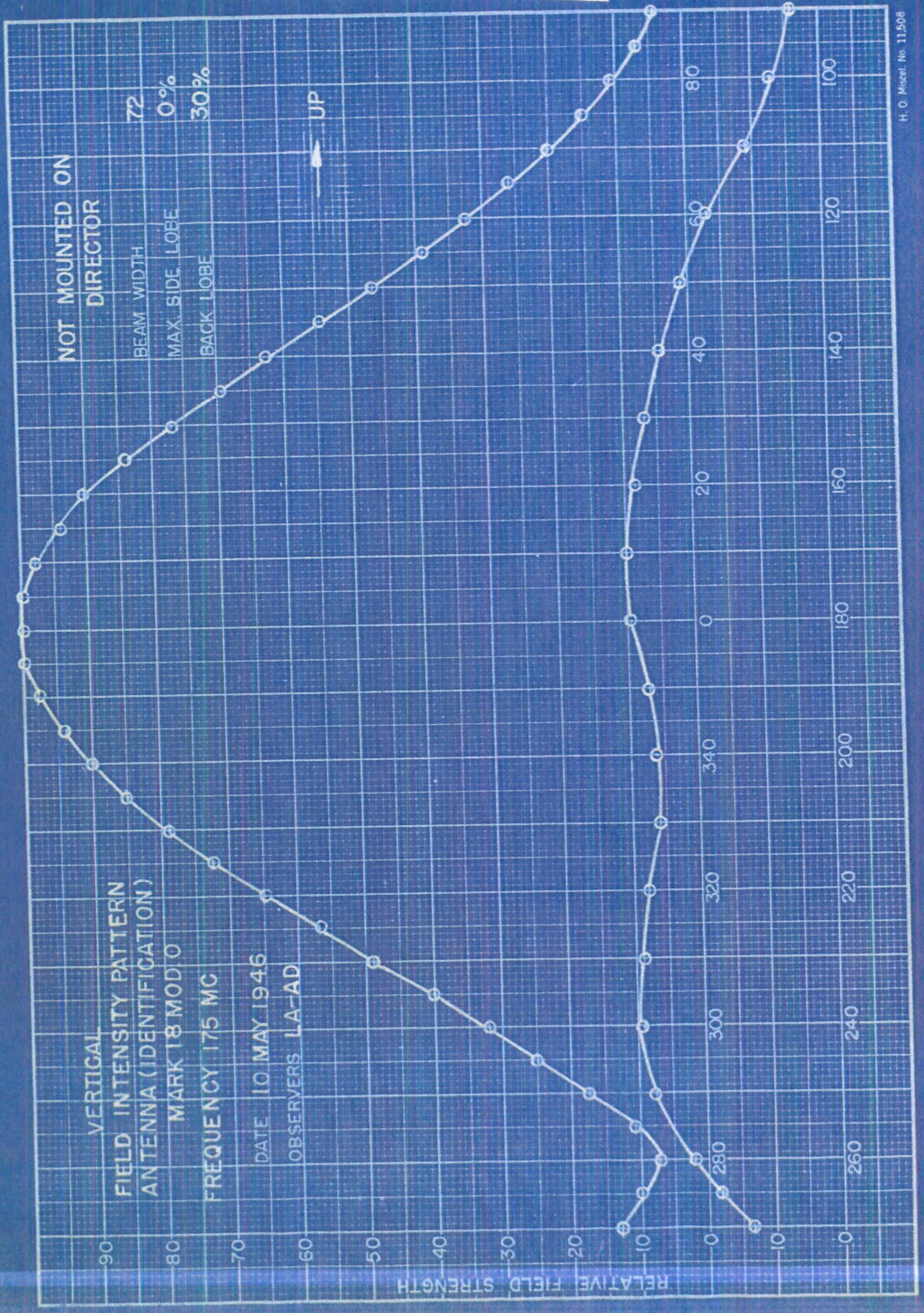
PLATE 17


VERTICAL
FIELD INTENSITY PATTERN
ANTENNA (IDENTIFICATION)
MARK 18 MOD 0
FREQUENCY 172 MC
DATE 10 MAY 1946
OBSERVERS LA-AD
NOT MOUNTED ON
DIRECTOR
BEAM WIDTH 74
MAX. SIDE LOBE 0%
BACK LOBE 33%
UP
RELATIVE FIELD STRENGTH
H. O. Miscel. No. 11,508

DECLASSIFIED



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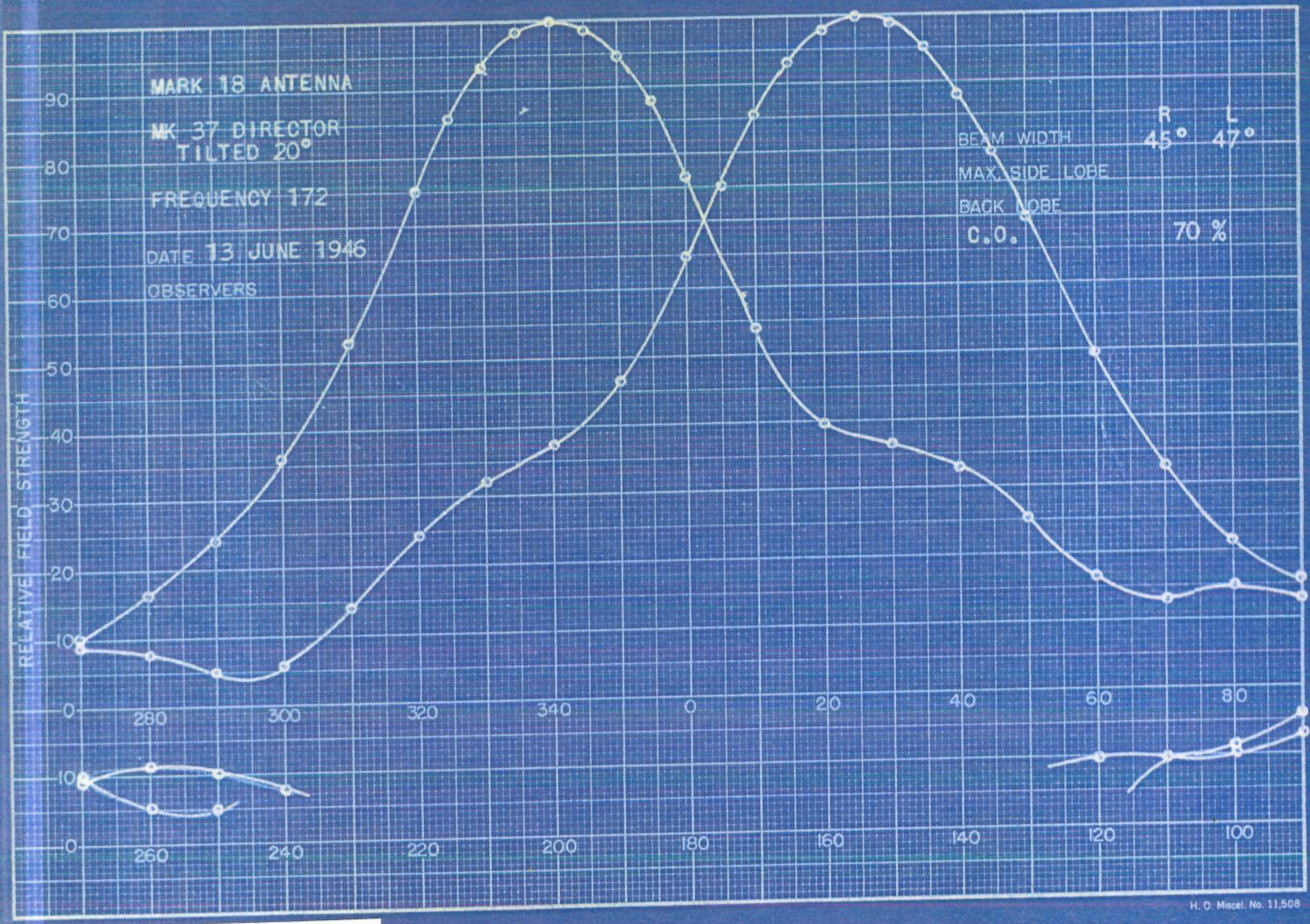

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PLATE 20

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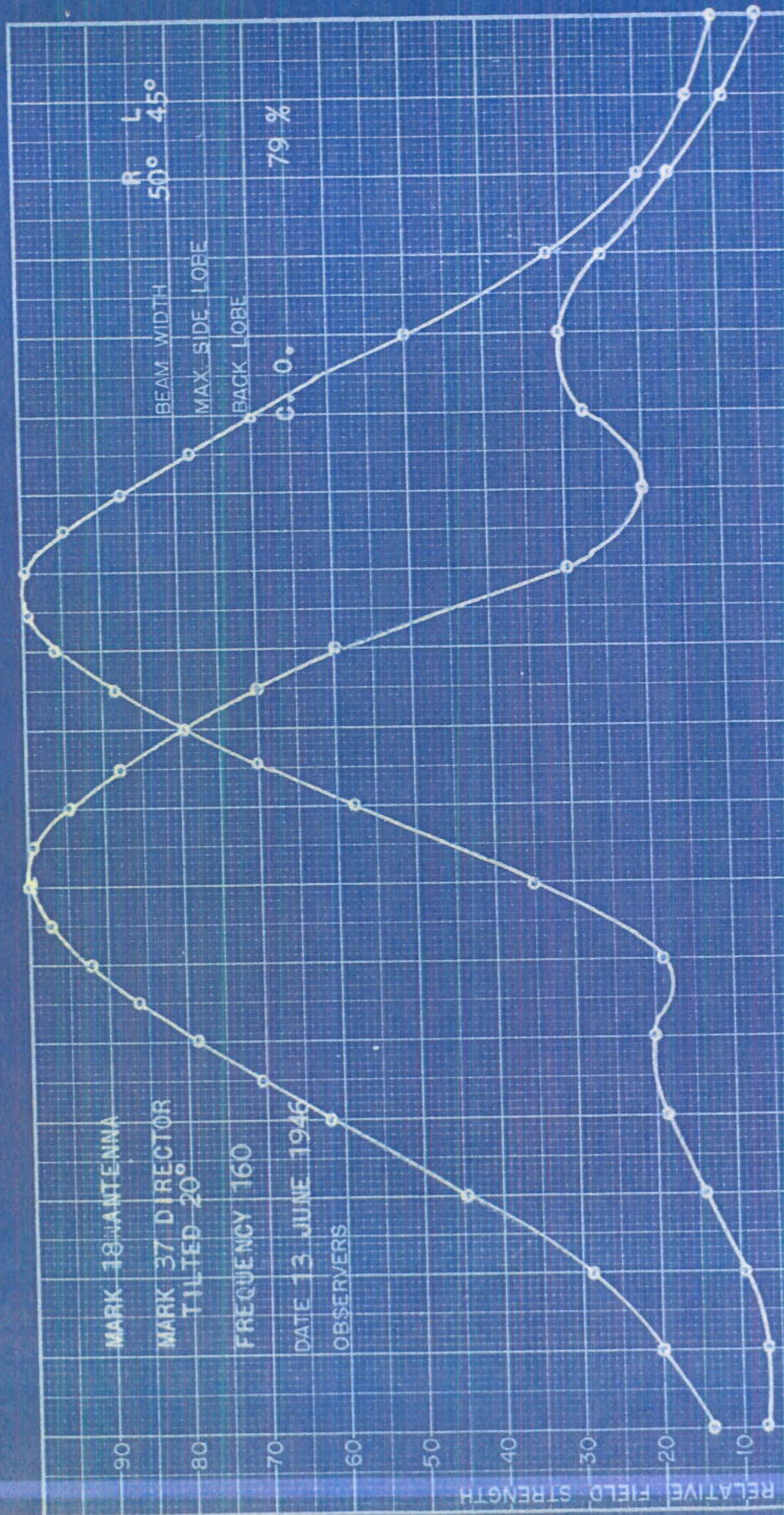

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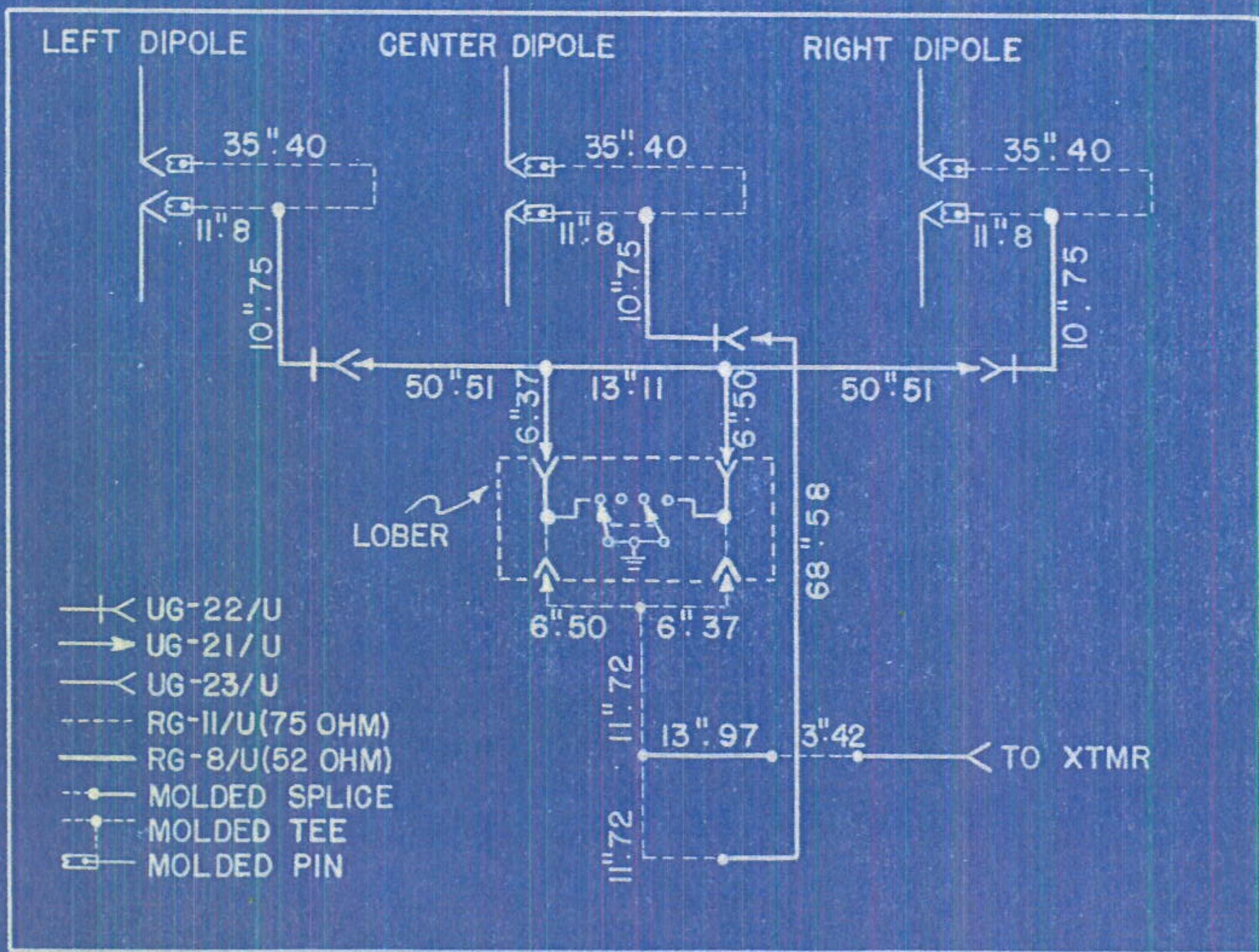
PLATE 21

DIAGRAM OF FEED HARNESS FOR MARK 18 ANTENNA
FOR MARK 25 RADAR



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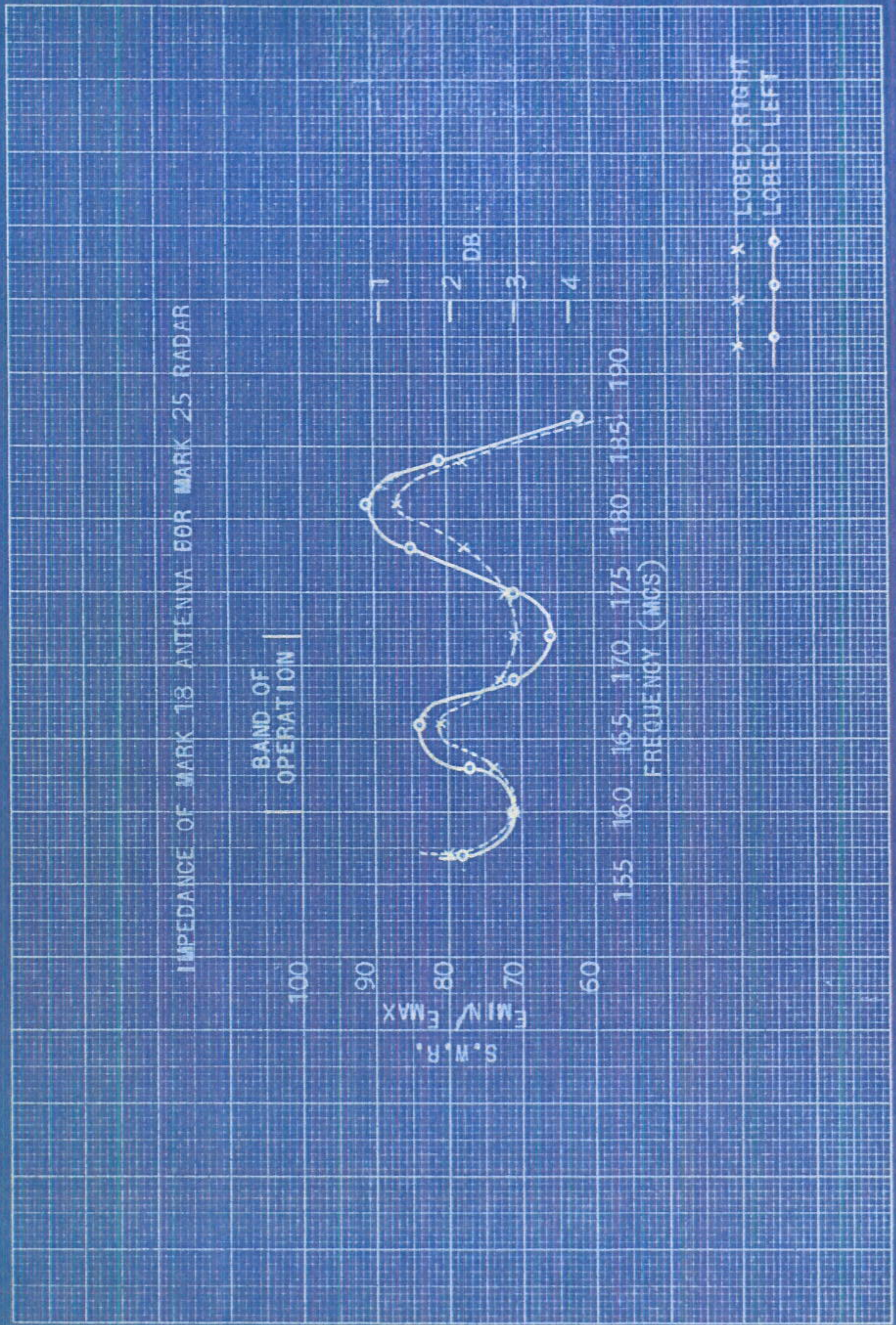
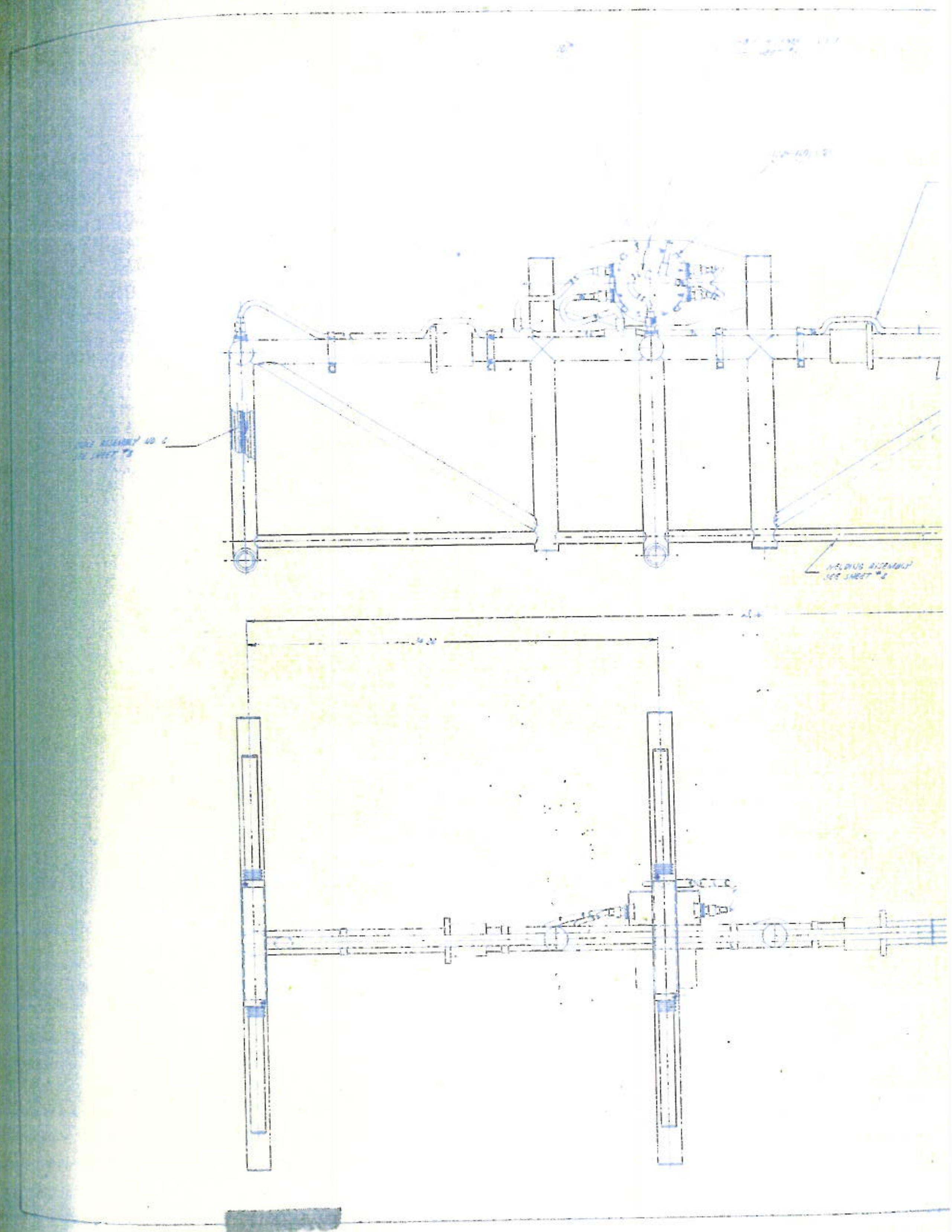
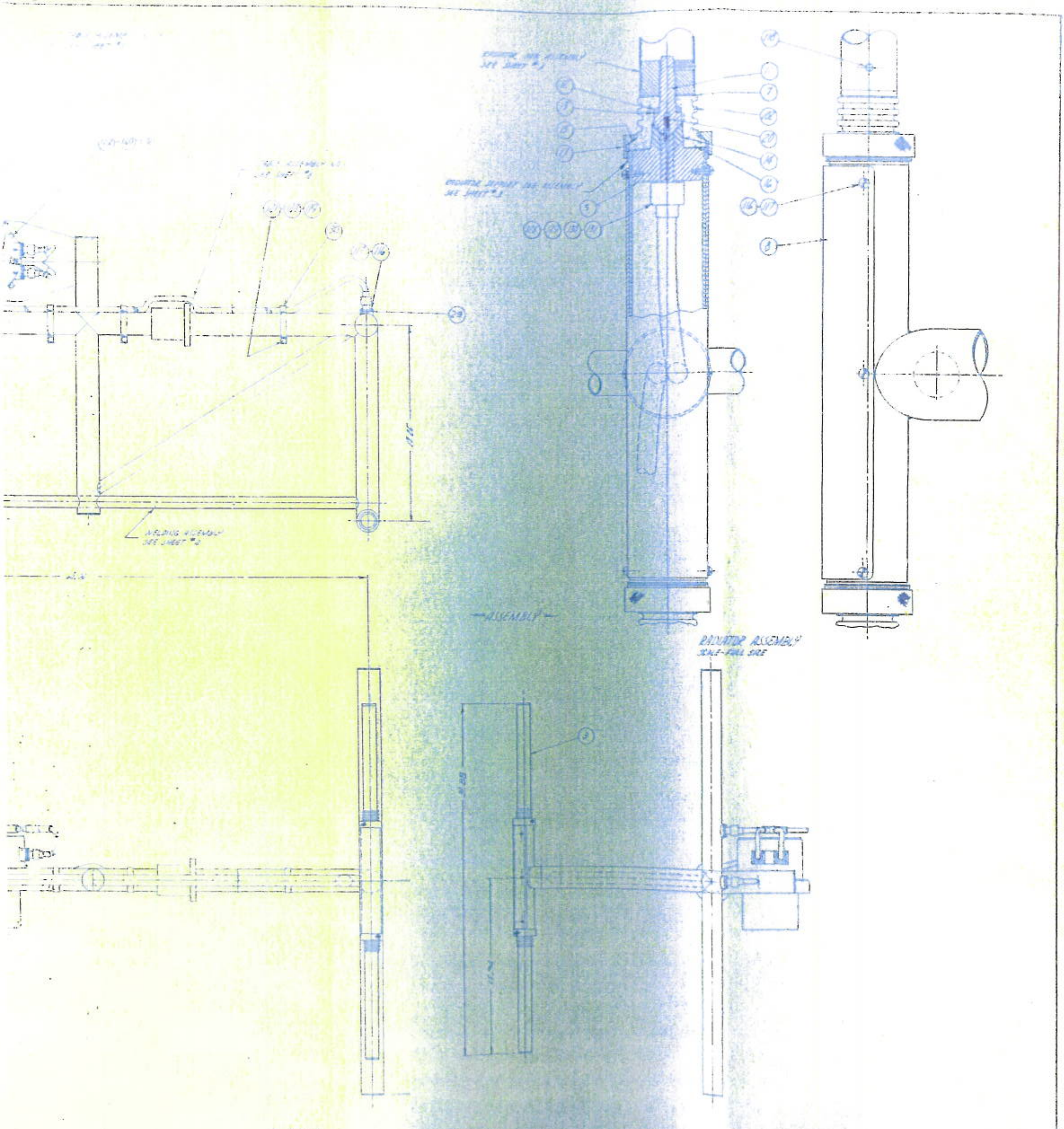


IMPEDANCE OF MARK 18 ANTENNA FOR MARK 25 RADAR
BAND OF OPERATION
S.W.R., E_{MIN}/E_{MAX}
100
90
80
70
60
155 160 165 170 175 180 185 190
FREQUENCY (MCS)
1
2
3
4
DB
LOBED RIGHT
LOBED LEFT





ASSEMBLY
RADIATOR ASSEMBLY
SCALE-FULL SIZE
WELDING ASSEMBLY
SEE SHEET #2

PLATE 34