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30 November 1943

NRL Report No. R-2201
Problem S74T-S (X7-7S)

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Navy Department

Report on

Study of Radiation Patterns of the

CW66 AAH Antenna

(Model FD Radar Equipment)

UNCLASSIFIED

Naval Research Laboratory

Anacostia Station

Washington, D.C.

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Authorization: BuShips conf ltr C-NOs-83608(917) Serial C-917-4544 to NRL dated 17 December 1942.

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A.H. VanKeuren, Rear Admiral, U.S.N.
Director.

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1. AUTHORIZATION.

The investigations herein reported were directed and authorized by Bureau of Ships letter of reference (a) assigning Problem X7-7S. This and additional references pertinent to this problem are listed below:

(a) BuShips conf ltr C-NOs-83608(917) Serial C-917-4544 to NRL dated 17 December 1942.
(b) NRL conf ltr C-S67/36(378)agm to BuShips, dated 31 August 1942.
(c) BuShips conf ltr C-NOs-83608(485-4b) Serial C-485-4333 to NRL dated 3 June 1942.

2. OBJECT.

2-1. References (a) and (b) requested that the Naval Research Laboratory conduct tests to determine the extent to which the radiation pattern of Navy Type CW-66 AAH antenna was affected by the installation of four braces, as indicated by drawing B of reference (a). This laboratory was also asked to comment, on the basis of these tests, upon the probable effect of similar braces on the CW-66 AAF antenna.

3. ABSTRACT.

3-1. The present report includes FD patterns taken with and without braces, at three frequencies, and at the four positions of the lobe switch. The side lobes, which turn out to be larger than had been anticipated, are in good agreement with those in calculated patterns of the antenna. The presence of braces has no discernible effect upon the patterns.

3-2. This work was carried out during the period 1 February to 24 May 1943. The report has been delayed because of a desire to include data on the effect in the FD patterns of mounting Mark III BL radiators on the same screen. Since it now appears that this data will not be available for several weeks, it seems desirable to pass along the information contained in this report without further delay.

4. MEASURING EQUIPMENT.

4-1. A necessary preliminary to obtaining FD patterns was the design and construction of (1) a cw oscillator, (2) a standing wave indicator, and (3) a field strength meter, all of which would cover the 630 to 720 mc band. Of these, the oscillator required the most experimentation, as the number of tube types capable of oscillation at these frequencies was quite limited. Experience had shown that a minimum output of 5 watts was required, so that the use of a GL 446 was precluded. No type 449 tubes were available; a single WE D156548 failed after a short period of operation. A pair of RCA 8012 tubes gave 10 watts at 600 mc in several different circuits, but in every case the power dropped to 2 watts or less at 700 mc. Finally four WE 368-A tubes were built into a ring oscillator. As the rated output of each was 2 watts, there was a reasonable expectation of 5 watts from the combination. The conventional grounded plate arrangement proved impractical because the plate leads could not be brought sufficiently close together. However, with resonant lines on the plates as well as the grids and cathodes (Plate 1), the oscillator delivered six watts at FD frequencies. It could be tuned from 500 to 1200 mc by adjustment of the shorting bars on the plate and grid frames. While the filament lines had no effect on the frequency, they had to be adjusted for maximum power output. It was possible to draw all available power from the circuit by coupling a hairpin loop to one grid frame. Plate 2 is a top view of the oscillator.

4-2. The tuned circuit of the standing wave indicator consisted of a quarter-wave coaxial stub with its inner conductor extending into the slotted line. An RCA type 9005 diode, connected across this stub, was the detector. The tube and stub formed a small sliding pick-up unit, from which a three-wire shielded cable led to the meter and associated batteries. Plate 3 is a photograph of the standing wave indicator, and Plate 4 a schematic of the circuit. Calibration of the two ranges was effected by shorting the slotted line and assuming the standing wave voltage was proportional to <u>sin BL</u>, where $B = 2\pi/\lambda$, and L = distance from a node. The "Low Scale" calibration is reproduced in Plate 5.

4-3. The field strength meter consisted of a half-wave dipole with a 9005 diode at its center (Plate 6). High r-f impedance at the tube was provided by a twin coaxial stub which was capacitively coupled across the cathode and plate. There were three advantages in using the stub: (1) the selectivity was improved, eliminating interference, (2) a larger voltage, E_s, was developed across the diode, and (3) the actual field strength could then be computed by the formula

$$E = \frac{\pi}{\lambda} E_s = 7.3\, E_s \text{ Volts/meter}$$

The diode was part of a slide-back vacuum-tube voltmeter (Plates 6 and 7). If the tube had been operated at cut-off, the slide-back voltage would have been exactly equal to E_s. In practice it was necessary to adopt a definite diode current, 2 microamperes, as a reference point. Operated in this way the field strength meter was strictly linear only for large signals and had to be calibrated against the standing wave indicator as follows: The main lobe of the antenna was beamed on the receiving dipole and the maximum value of E_s noted. Then the oscillator coupling was reduced by steps; the relative output, obtained from the calibrated standing wave indicator, was compared with the field meter reading. For values of E_s less than 2 volts, the meter response was far from linear, but at $E_s = 4.0$ volts, a fairly straight calibration curve

[redacted]

was obtained (Plate 8). For this reason, before each FD pattern was taken, the power level was adjusted to give a rectified signal of 4.0 volts on the main beam. Readings were then taken at other settings of the antenna and corrected according to Plate 8 before being recorded. It is a matter of interest that the high field strength required by this type of meter (30 volts/meter) was realized at a distance of 120 feet by using a six foot parabaloid reflector with the receiving dipole.

5. DESCRIPTION OF FD ANTENNA.

5-1. The FD antenna comprises two horizontal parabolic cylinders stacked one above the other. Eight half-wave dipoles occupy the focal line of each reflector, a line 11 cm (a quarter-wave) ahead of the vertex. The vertical spacing between these rows of dipoles is 92 cm (two and a sixth wave lengths). The dipoles are end-fed in four pairs, and feed points being separated by 47 cm (1.1 wave lengths). The aperture of the screen is 186 cm (4.4 λ) wide by 216 cm (5 λ) high. Either of the parabolas would have a vertical aperture of 121 cm (2.85 λ) except for the intersection of the two screens in a central rib.

5-2. For purposes of lobe switching, the antenna is energized through four coaxial branch feeders, each of which leads to a row of four dipoles in a corner of the array. The branch feeders diverge from the main line at a common point, A. From a point B on each feeder at a distance of 0.178 λ from A, a half-wave line runs to a stator of the lobe switch condenser. When the rotor meshes one of these stators, a capacitive reactance of 70 ohms is thrown across the line at B, introducing a certain amount of delay in the phase of the power passing through that branch feeder. When the rotor is not meshed, the open-circuited half-wave stub has no effect whatever. Thus, if the lobe switch rotor is assumed to mesh the two left-hand stators (as seen from the back of the antenna), the eight dipoles constituting the left half of the array carry currents which are retarded in phase over the right hand elements. Consequently the beam tilts to the left; i.e., in the direction to which the center of the rotor points. As the rotor revolves, the beam is deflected in turn to the left, down, right, and up.

6. PATTERN TAKING PROCEDURE.

6-1. The arrangement for taking patterns of the FD antenna is shown in Plate 9. The FD was mounted on a BI pedestal at the west end of the roof of Bldg. 30, while the receiving parabola was supported on a level with it by a wooden tower on the penthouse of Bldg. 12, at a distance of 120 feet.

6-2. It was first of all necessary to determine the settings on the FD train and elevation circles corresponding to mechanical alignment of the antenna with the receiving parabola.

This was done without assuming that when lobed vertically the beam was undeflected in the horizontal plane and vice versa. With the lobe switch in any fixed position, the antenna was adjusted in train and elevation to give a maximum reading on the field strength meter. This setting was noted as T, E. Then the antenna was rotated approximately 180° round both axes and again set accurately for maximum reading. Denoting the new position by T', E', it could be concluded that the antenna was mechanically head-on at the setting $\frac{1}{2}(T + T' - 180°)$, $\frac{1}{2}(E + E' - 180°)$. These values were taken as the reference in all the patterns.

7. DATA RECORDED.

7-1. Horizontal and vertical patterns were taken for all four lobe switch positions at three frequencies: 680, 700, and 720 megacycles. One pattern (horizontal, right lobe) was taken at each frequency while the FD was braced in the standard manner with 1" x 2" steel box tubing. A total of 27 patterns are shown in Plates 10 to 30 inclusive. Horizontal patterns with right and left lobing, and vertical patterns with upper and lower lobing are plotted on the same sheet of paper to illustrate the cross-over points; i.e., angles in which equal signals are received on the two lobe switch positions. The positions and amplitudes of main and side lobes are tabulated in Tables 1 and 2 for all the patterns.

7-2. The reproducibility of the data was considered satisfactory. The side lobe readings could be repeated within one or two per cent of the field strength in the main lobe, which meant an error of about 5% in the amplitude of the average side lobe. The position of the main lobe checked to $\frac{1}{2}°$ each way, which was as close as the scales could be read. It was established in all cases that the large side lobes were in the same plane as the main lobe.

8. CONCLUSIONS.

8-1. On the average, seven cross-over points appeared on the duplex patterns, one in the center and six spurious ones. Of these only four were of sufficient intensity to be a source of confusion. In practice there seems to be no danger of tracking a target on a false cross-over due to side lobes, for if the antenna is at the wrong train angle, no signals will be received from vertical lobing and the elevation scope will be blanked out.

8-2. The effect of braces on the FD patterns may be inferred from comparison of Plates 10 and 11, 17 and 18, and 24 and 25 and from Table 3, which summarizes the effect on the side lobes. The general conclusion is that braces make no important difference.

9. THEORETICAL PATTERNS.

9-1. As a check against the reliability of the pattern measurements, theoretical radiation patterns were calculated for the FD antenna. These included vertical and horizontal patterns for all positions of the lobe switch.

9-2. In computing horizontal patterns it is sufficient to consider the FD as a colinear array of 8 half-wave dipoles mounted a quarter-wave in front of a perfectly reflecting flat screen. The current antinodes in these dipoles are assumed to have a uniform spacing of a half-wave. Taking first the case of lobing up or down, the formula is

$$H(\phi) = \frac{\sin(360 \sin\phi)}{4 \sin(90 \sin\phi)} \times \cos(360 \sin\phi) \times \sin(90 \cos\phi) \times \cos\phi \quad (1)$$

where the first factor gives the distribution of field strength from four omni-directional sources in a line, spaced a half-wave apart, the next combines two such units, whose centers are 2 waves apart, the third factor takes care of the screen, and the last the directivity of a single dipole. A simple modification gives the case for lobing to the right or left:

$$V(\phi) = \frac{\sin(360 \sin\phi)}{4 \sin(90 \sin\phi)} \times \cos(360 \sin\phi \pm 33) \times \sin(90 \cos\phi) \times \cos\phi \quad (2)$$

Here the angle 33° represents half the phase difference between left and right sides of the antenna in horizontal lobing. This figure was derived from the measured beam deflection; i.e., 4°. The calculated horizontal patterns, Plates 31 and 32, are in good agreement with the measured ones.

9-3. The vertical pattern of one of the FD parabolic cylinders is calculated as follows: since the aperture plane is an equi-phase surface, it is merely necessary to obtain the field strength at each point in this plane, divide the plane into horizontal strips, and compute the pattern of these strips as if they were radiators. Thus, referring to Plate 34, the vertical pattern is

$$V_1(\phi) = \int_0^{y_{max}} \cos\left(\frac{2\pi}{\lambda} y \sin\phi\right) \times \text{Illumination at } \underline{y} \times dy \quad (3)$$

Since all the radiation leaving the radiator in the wedge $d\theta$ appears in the strip dy, and the distribution of radiation may be considered uniform in θ, the illumination at y is proportional to $\frac{1}{dy/d\theta}$. For a parabola

[redacted]

$$y = \rho \sin \theta = \frac{2f \sin \theta}{1 - \cos \theta}, \tag{4}$$

$$dy/d\theta = -\rho .$$

Expressing ρ in rectangular coordinates, $\rho = \sqrt{y^2 + (x - f)^2}$,

$$V_1\,(\varphi) = \int_0^{y_{max}} \cos\left(\frac{2\pi}{\lambda}\, y \sin \varphi\right) \times \frac{4f\ dy}{4f^2 + y^2},$$

$$= \int_0^{y_{max}/2f} \cos y\left(\frac{4\pi}{\lambda} f \sin \varphi\right) \times \frac{dy}{1 + y^2}. \tag{5}$$

With $\underline{f} = 11$ cm, $\lambda = 42.8$ cm, and $y_{max} = 62.5$ cm,

$$V_1\,(\varphi) = \int_0^{2.85} \cos y(184 \sin \varphi) \times \frac{dy}{1 + y^2} \tag{6}$$

As a first step in carrying out the integration, the function $1/(1 + y^2)$ is expressed in terms of exponentials. In the interval (0, 2.85), it is equal to

$$0.05 + 0.4\, e^{-0.666\, y} + 0.55\, e^{-0.64\, y^2}$$

with a maximum error of 9% (Plate 33). Substituting this into equation (6), it is seen that the first two terms are easily integrated, but the last is not. However, a very small error is incurred by extending the limits on the third one from 0 to ∞, which yields a well-known definite integral. Finally, the vertical pattern of one parabola is given by

$$V_1\,(\varphi) = \frac{1}{1.265}\left[0.0156\, \frac{\sin(525 \sin \varphi)}{\sin \varphi} + 0.61\, e^{-4.0 \sin^2 \varphi} + \frac{0.0188 \sin \varphi\ \sin(525 \sin \varphi) - 0.00388 \cos(525 \sin \varphi) + 0.0261}{\sin^2 \varphi + 0.0434}\right] \tag{7}$$

The vertical spacing between the foci of the two FD parabolas is 780 electrical degrees. The interference between radiation from the two sections is therefore:

$$V_2\,(\varphi) = \cos\,(390 \sin \varphi) \qquad \text{for Left-Right Lobing}$$

$$= \cos\,(390 \sin \varphi \pm 34.6) \quad \text{for Upper-Lower Lobing}$$

[redacted]

The product of V_1 and V_2 gives the vertical pattern of the FD. Plates 35 and 36, calculated for horizontal and vertical lobing, compare closely with the corresponding measured patterns. Tables 1 and 2 summarize the results obtained from all the theoretical patterns.

10. STANDING WAVE RATIO.

10-1. The input impedance of the FD antenna was measured by means of a 50 ohm slotted line. From this the standing wave ratio on a 70 ohm line was inferred and the result plotted in Plate 37. The match appeared to be poor at the high end of the band, but was better than 2 to 1 from 675 to 715 mc.

[redacted]

TABLE 1

HORIZONTAL PATTERNS

Position and Amplitude of Main and Side Lobes

1. Lobed left

680 Mc		700 Mc		720 Mc		Theoretical	
356°	100%	356°	100%	356°	100%	356°	100%
335	10	-	-	338	5	335	9
328	8	323	14	324	13	320	16
300	3	280	1	285	2	296	1
180	2	180	2	180	2	-	-
50	3	46	5	70	1	53	10
32	9	-	-	33	2	35	6
15	37	15	50	15	37	17	40

2. Lobed right

680 Mc		700 Mc		720 Mc		Theoretical	
4°	100%	4°	100%	4°	100%	4°	100%
24	10	-	-	22	4	25	9
40	12	36	17	37	13	40	16
80	2	75	2	72	3	64	1
180	2	180	3	180	5	-	-
310	3	-	-	295	1	307	10
328	8	312	6	328	3	325	6
344	41	345	53	345	43	343	40

3. Lobed up

680 Mc		700 Mc		720 Mc		Theoretical	
0°	100%	0°	100%	0°	100%	0°	100%
20	18	19	20	18	19	21	22
36	8	37	9	35	8	37	11
55	2	70	2	67	3	58	5
180	2	180	3	180	4	-	-
-	-	280	2	287	2	302	5
324	7	324	9	325	10	322	11
340	19	341	21	342	21	339	22

4. Lobed down

680 Mc		700 Mc		720 Mc		Theoretical	
0°	100%	0°	100%	0°	100%	0°	100%
20	18	19	19	18	21	21	22
36	9	36	9	34	10	37	11
-	-	68	1	67	3	58	5
180	2	180	3	180	6	-	-
-	-	-	-	305	3	302	5
323	7	323	8	325	9	322	11
340	18	340	22	342	21	339	22

[redacted]

TABLE 2

VERTICAL PATTERNS

Position and Amplitude of Main and Side Lobes

1. Lobed up

680 Mc		700 Mc		720 Mc		Theoretical	
356°	100%	356°	100%	356°	100%	356°	100%
333	26	330	23	331	24	333	26
270	1	270	2	–	–	290	11
180	2	180	4	180	5	–	–
48	9	47	10	44	10	54	10
17	56	16	58	16	52	17	50

2. Lobed down

680 Mc		700 Mc		720 Mc		Theoretical	
4°	100%	4°	100%	4°	100%	4°	100%
29	26	30	23	27	26	27	26
70	1	–	–	63	3	70	11
180	2	180	3	160	4	–	–
310	10	312	10	315	9	306	10
343	56	344	60	344	54	343	50

3. Lobed left

680 Mc		700 Mc		720 Mc		Theoretical	
0°	100%	0°	100%	0°	100%	0°	100%
22	38	21	36	22	36	22	32
60	3	55	4	55	5	60	8
193	2	180	1	160	2	–	–
308	5	305	5	305	4	300	8
338	39	337	36	338	35	338	32

4. Lobed right

680 Mc		700 Mc		720 Mc		Theoretical	
0°	100%	0°	100%	0°	100%	0°	100%
22	35	22	36	22	39	22	32
60	5	53	5	52	6	60	8
180	3	180	2	175	4	–	–
308	3	303	5	303	5	300	8
338	36	338	38	337	38	338	32

[redacted]

TABLE 3

EFFECT OF BRACES ON FD PATTERNS

Horizontal Pattern, Lobed Right

680 Mc

With Braces		Without Braces	
Bearing	Amplitude	Bearing	Amplitude
004	100%	004	100%
023	12	024	10
039	10	040	12
070	2	080	2
180	1	180	2
305	3	310	3
327	7	328	8
344	40	344	41

700 Mc

With Braces		Without Braces	
Bearing	Amplitude	Bearing	Amplitude
004	100	004	100
035	15	036	17
065	1	075	2
180	2	180	3
314	5	312	6
344	54	345	53

720 Mc

With Braces		Without Braces	
Bearing	Amplitude	Bearing	Amplitude
004	100	004	100
022	4	022	4
035	10	037	13
072	2	072	3
185	2	180	5
296	2	295	1
		328	3
345	41	345	43

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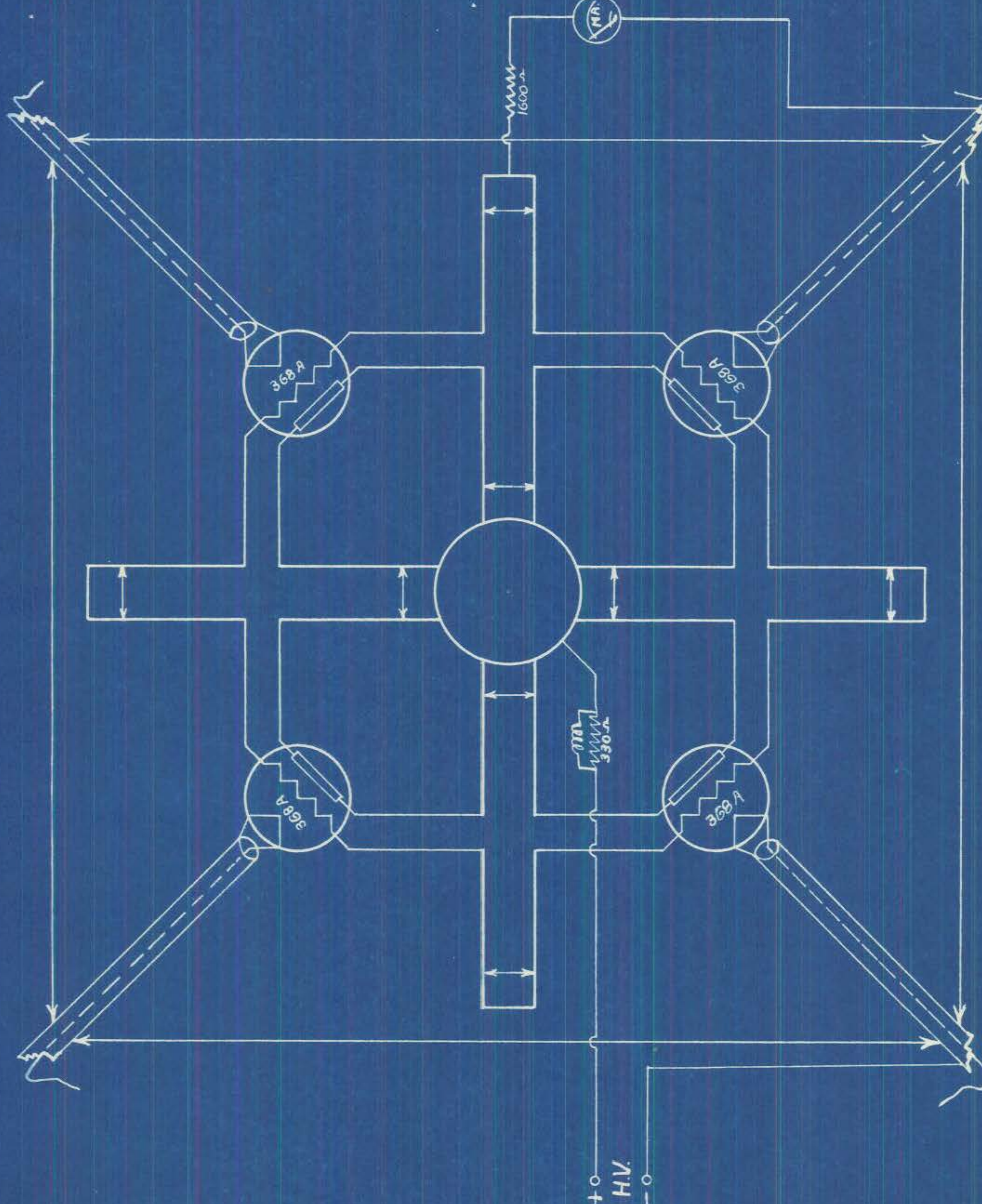


500 TO 1200 MC. OSCILLATOR

PLATE I

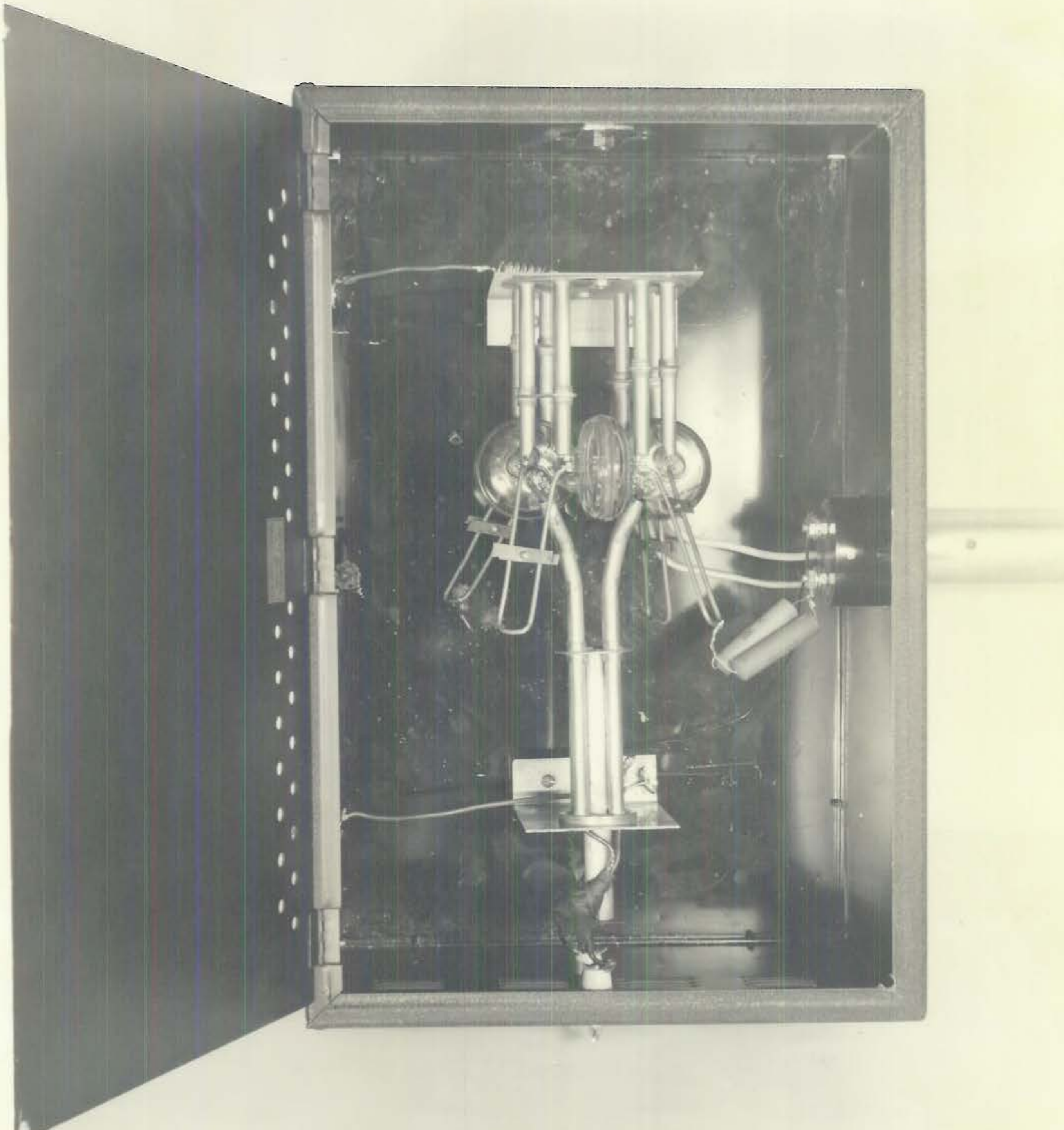


PLATE 2

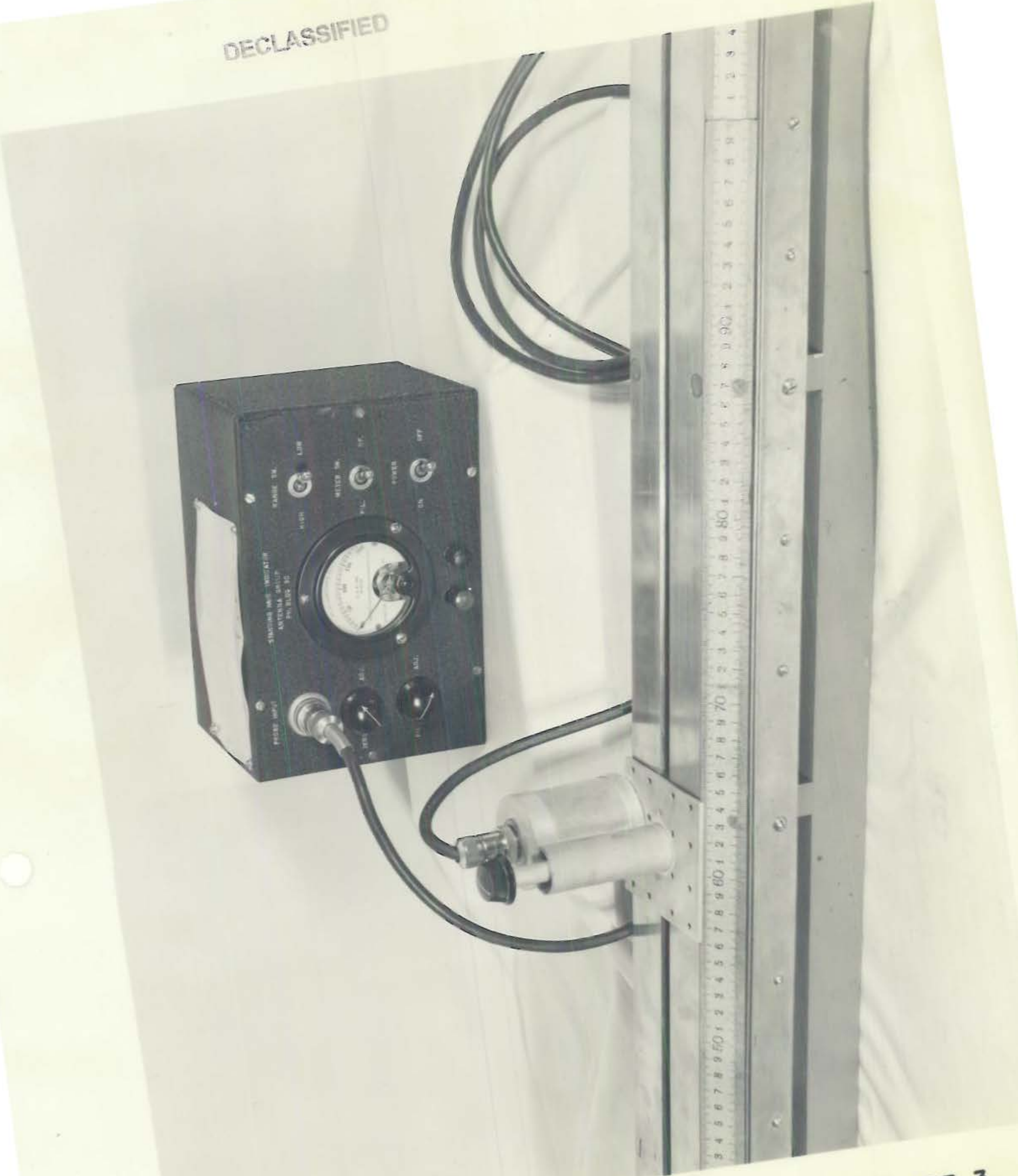
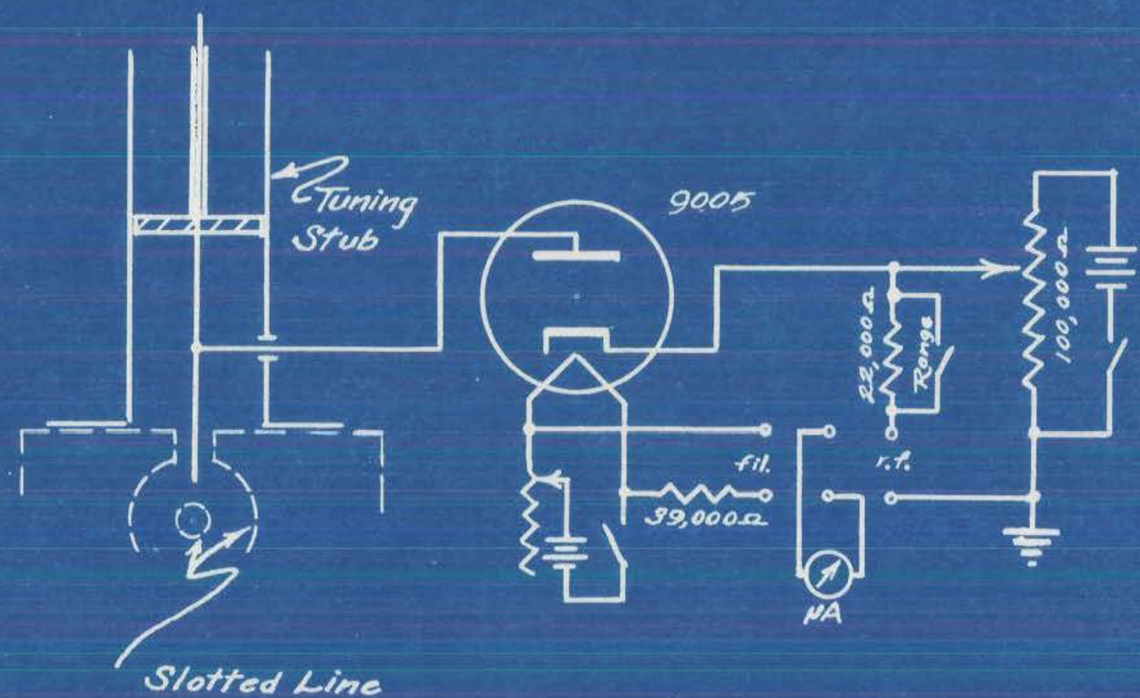


PLATE 3



STANDING WAVE INDICATOR

PLATE 4

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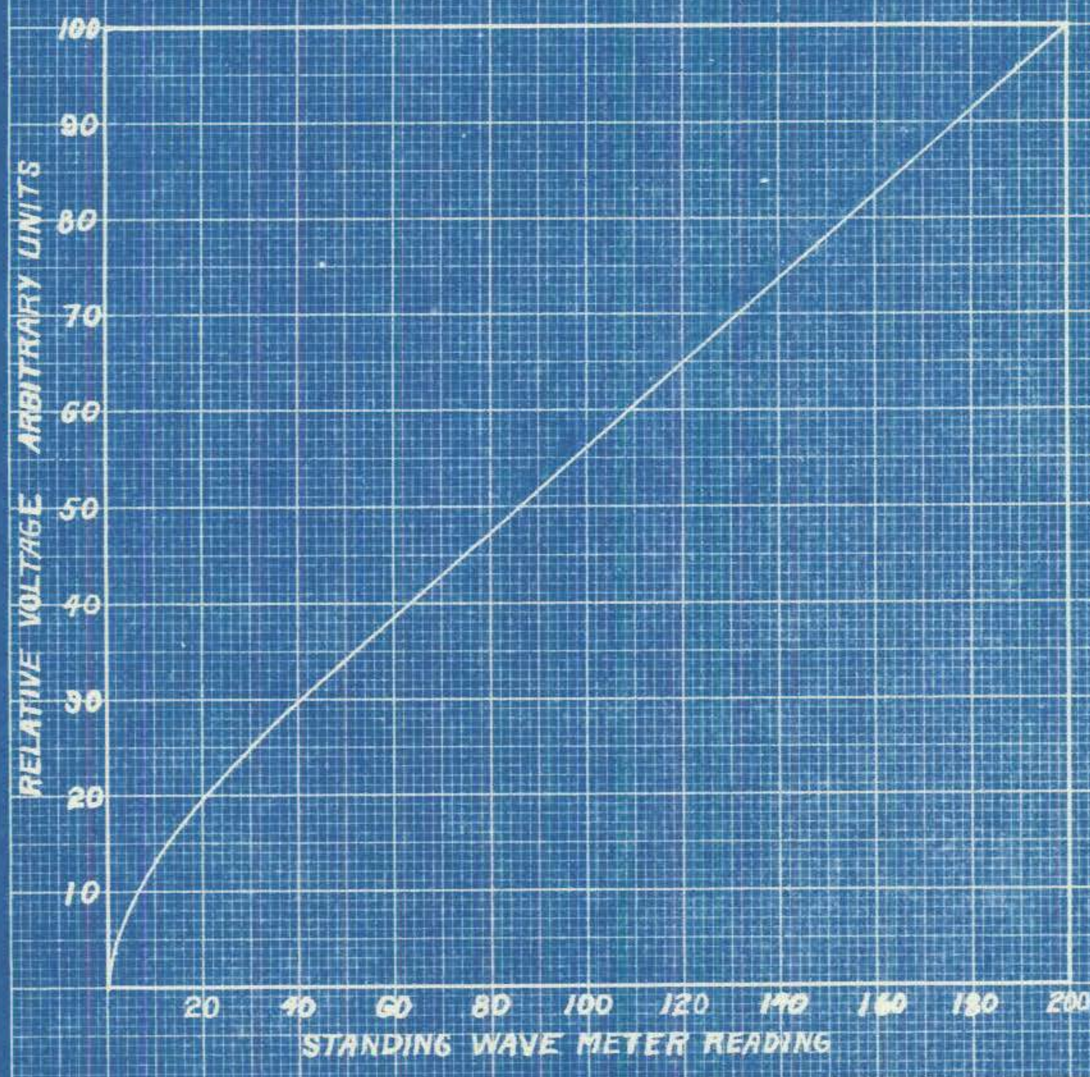
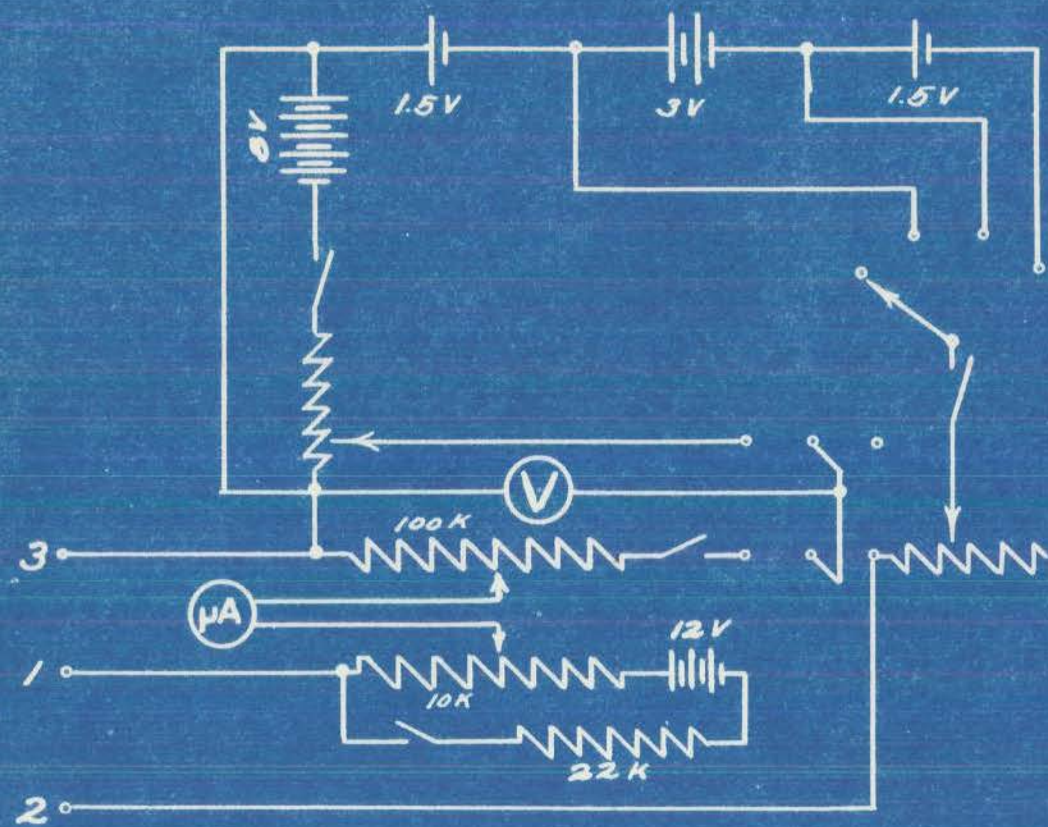


STANDING WAVE INDICATOR

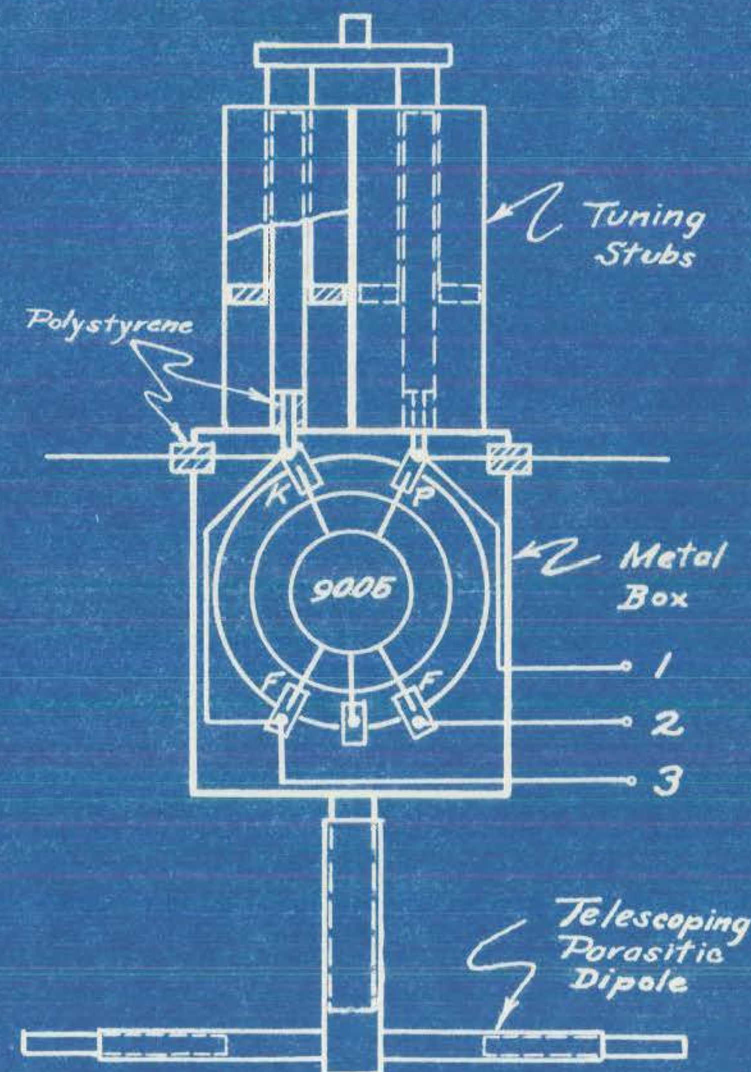
700 MC. CALIBRATION CURVE

LOW SCALE

PLATE 5



SLIDE-BACK FIELD METER



DIPOLE ASSEMBLY

PLATE 6

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PLATE 7

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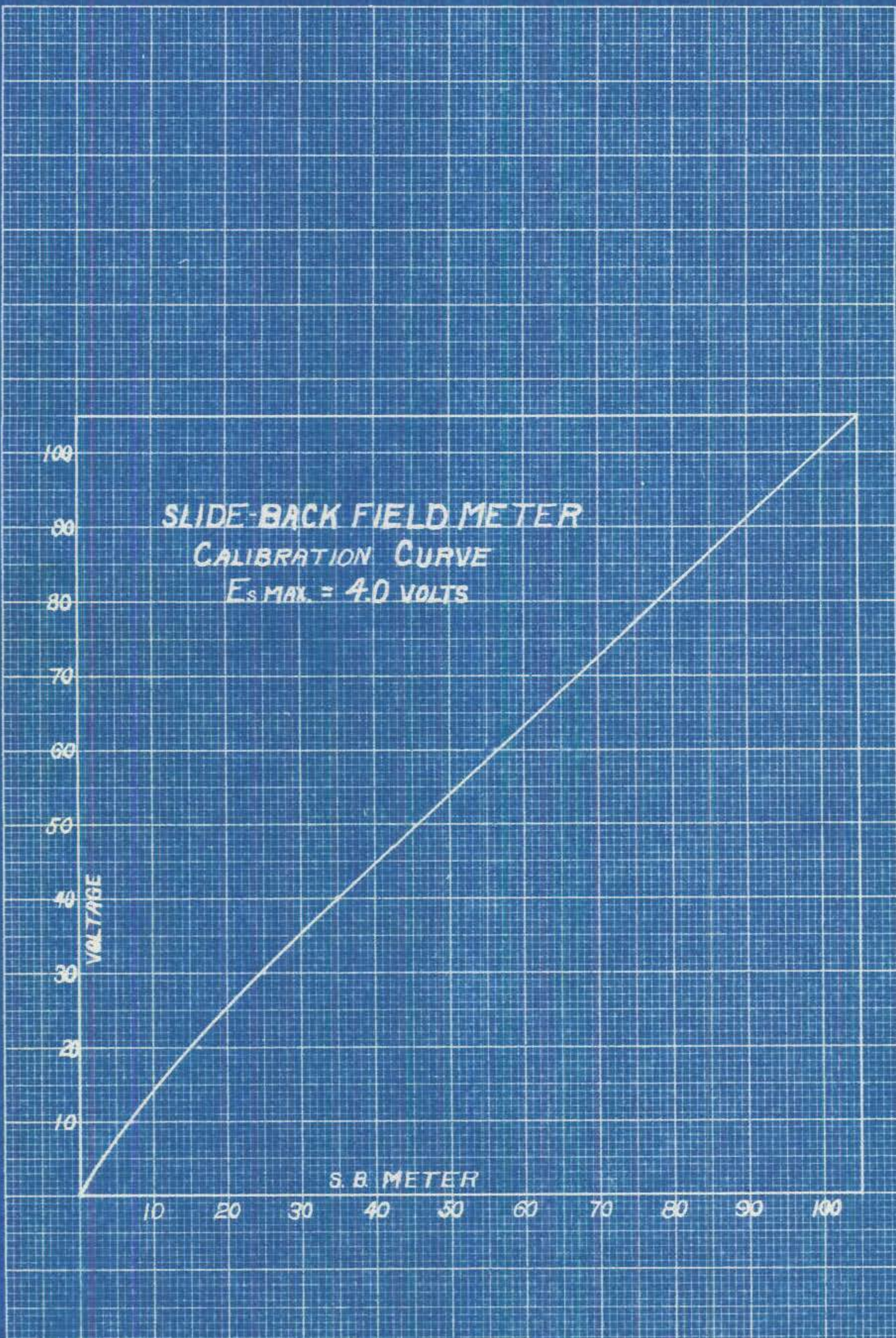
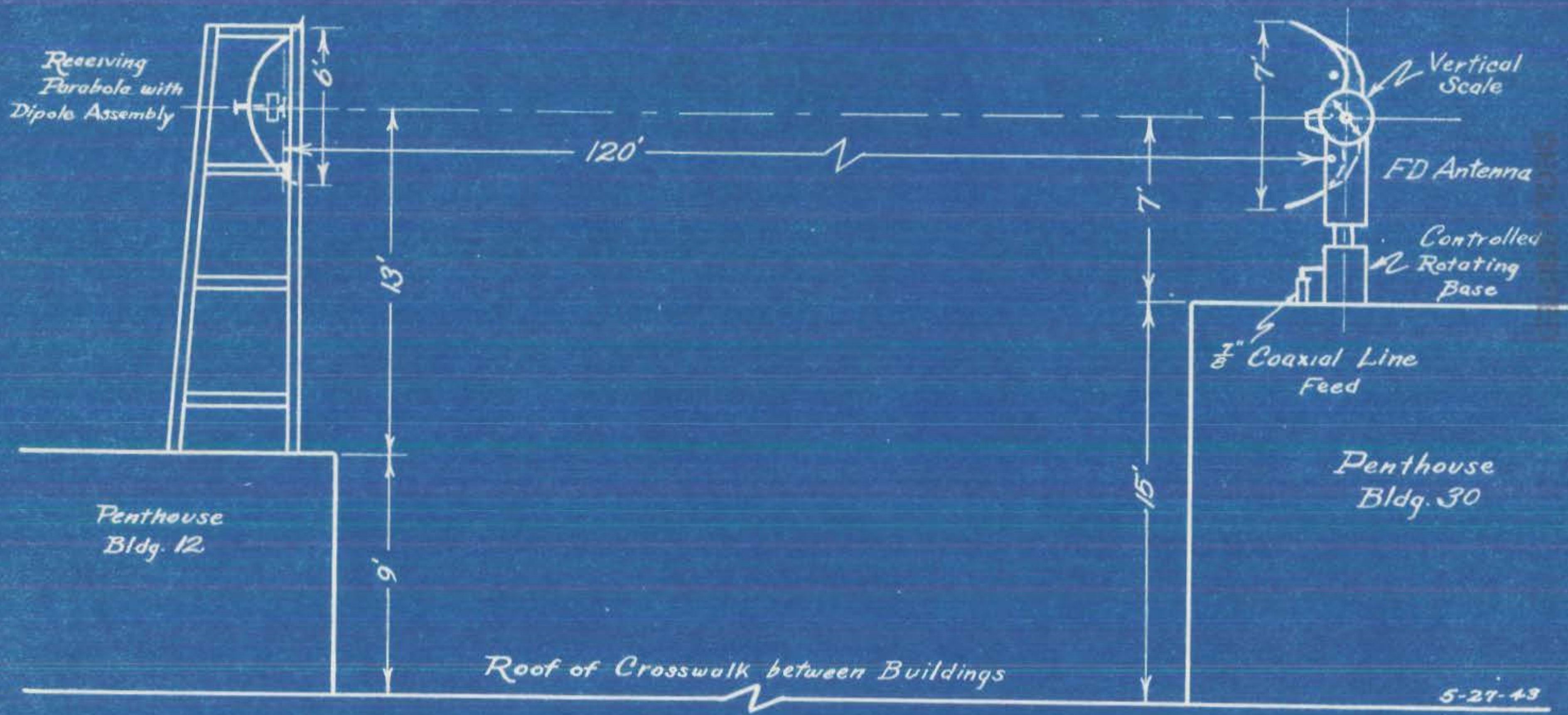

SLIDE-BACK FIELD METER
CALIBRATION CURVE
Es MAX. = 4.0 VOLTS
VOLTAGE
S. B. METER
10
20
30
40
50
60
70
80
90
100

PLATE 8



LOCATION OF FD ANTENNA AND RECEIVER FOR TAKING OF PATTERNS

PLATE 9

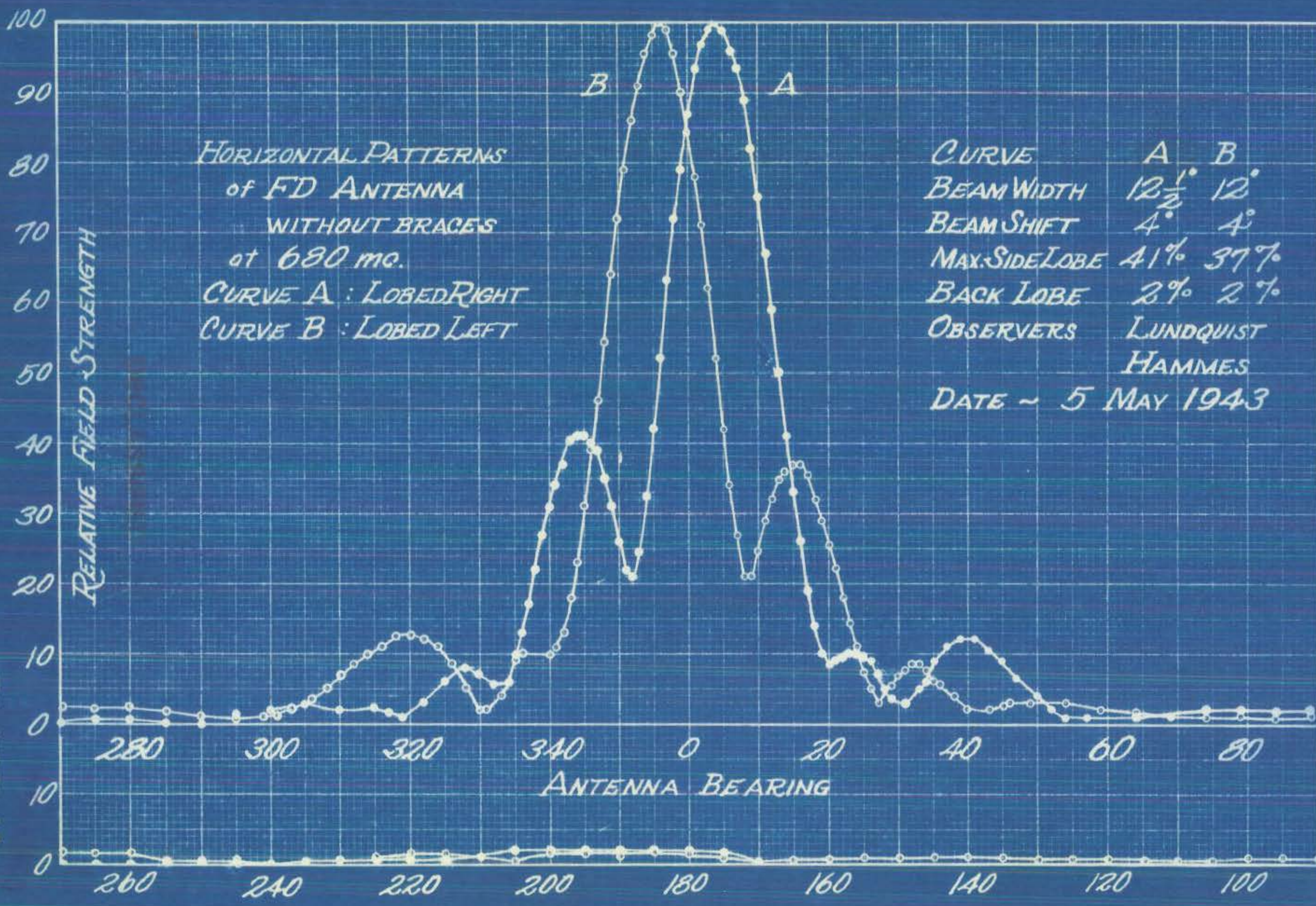

HORIZONTAL PATTERNS
of FD ANTENNA
WITHOUT BRACES
at 680 mc.
CURVE A : LOBED RIGHT
CURVE B : LOBED LEFT
CURVE A B
BEAM WIDTH 12½° 12°
BEAM SHIFT 4° 4°
MAX. SIDE LOBE 41% 37%
BACK LOBE 2% 2%
OBSERVERS LUNDQUIST
HAMMES
DATE ~ 5 MAY 1943
B
A
RELATIVE FIELD STRENGTH
ANTENNA BEARING
100
90
80
70
60
50
40
30
20
10
0
10
0
280 300 320 340 0 20 40 60 80
260 240 220 200 180 160 140 120 100

PLATE 10

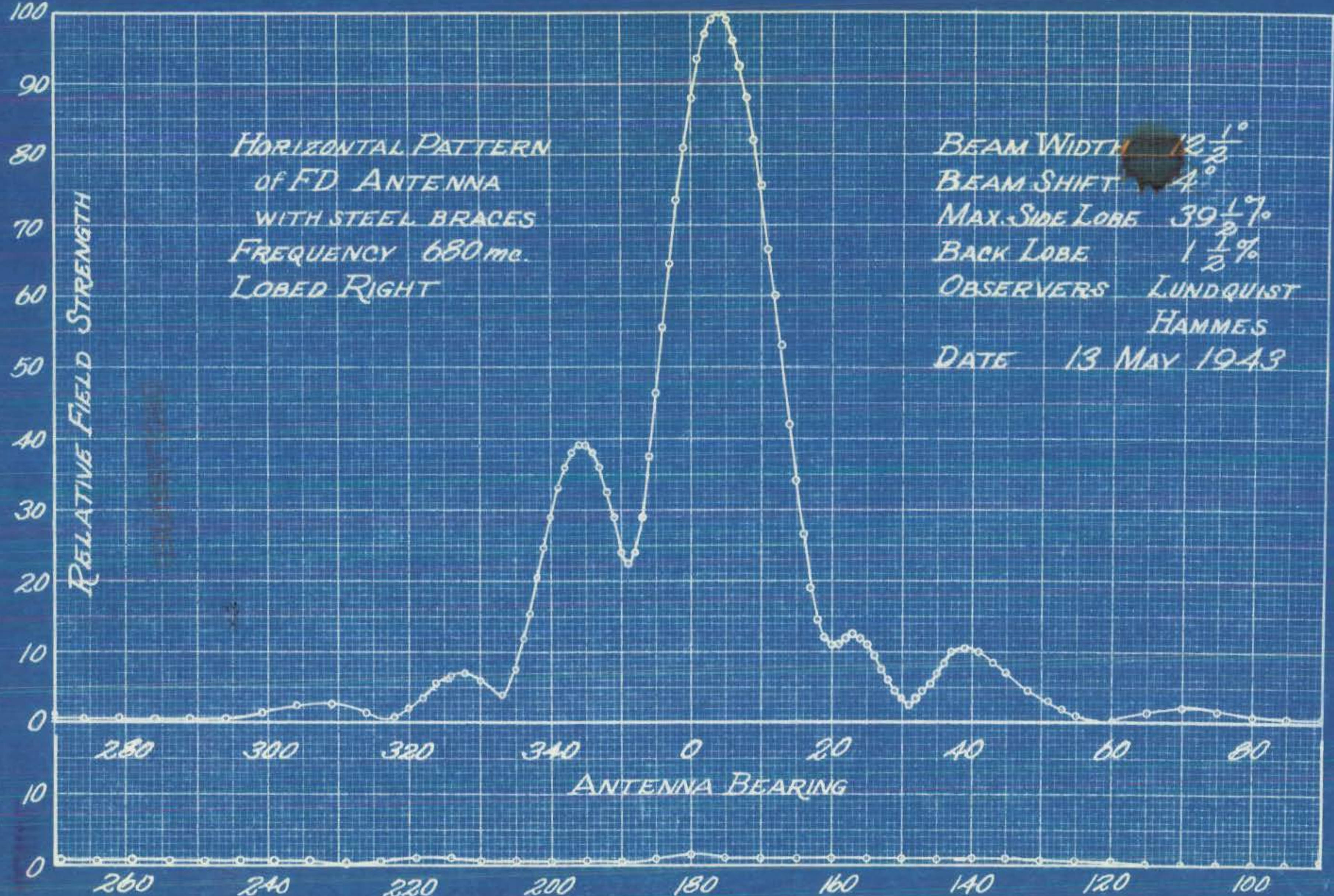

HORIZONTAL PATTERN
of FD ANTENNA
WITH STEEL BRACES
FREQUENCY 680 mc.
LOBED RIGHT
BEAM WIDTH 12 1/2°
BEAM SHIFT 4°
MAX. SIDE LOBE 39 1/2 %
BACK LOBE 1 1/2 %
OBSERVERS LUNDQUIST
HAMMES
DATE 13 MAY 1943
RELATIVE FIELD STRENGTH
ANTENNA BEARING
100
90
80
70
60
50
40
30
20
10
0
280
300
320
340
0
20
40
60
80
260
240
220
200
180
160
140
120
100

PLATE 11

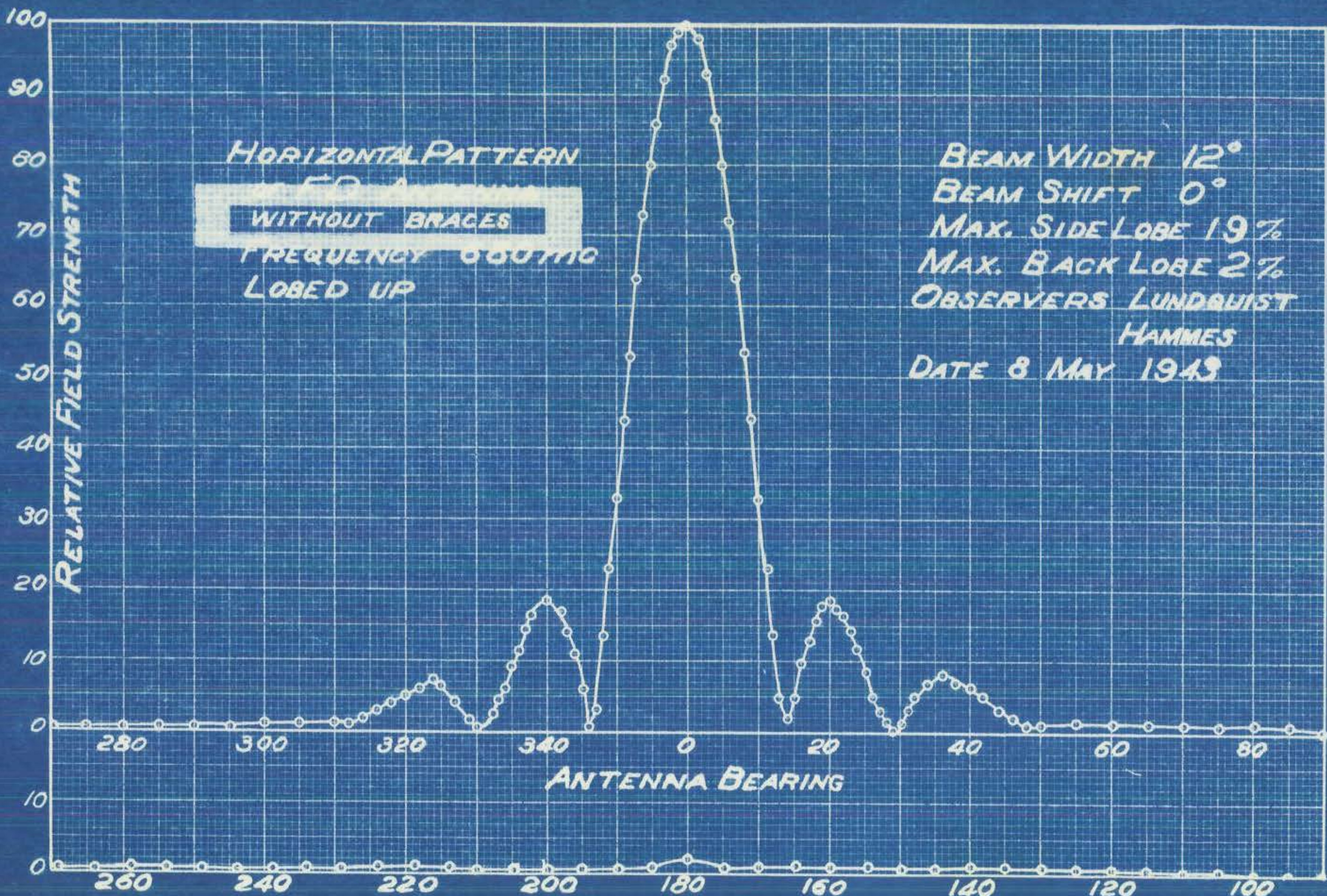

HORIZONTAL PATTERN
WITHOUT BRACES
LOBED UP
BEAM WIDTH 12°
BEAM SHIFT 0°
MAX. SIDE LOBE 19%
MAX. BACK LOBE 2%
OBSERVERS LUNDQUIST
HAMMES
DATE 8 MAY 1943
RELATIVE FIELD STRENGTH
100
90
80
70
60
50
40
30
20
10
0
280
300
320
340
0
20
40
60
80
ANTENNA BEARING
10
0
260
240
220
200
180
160
140
120
100

PLATE 12

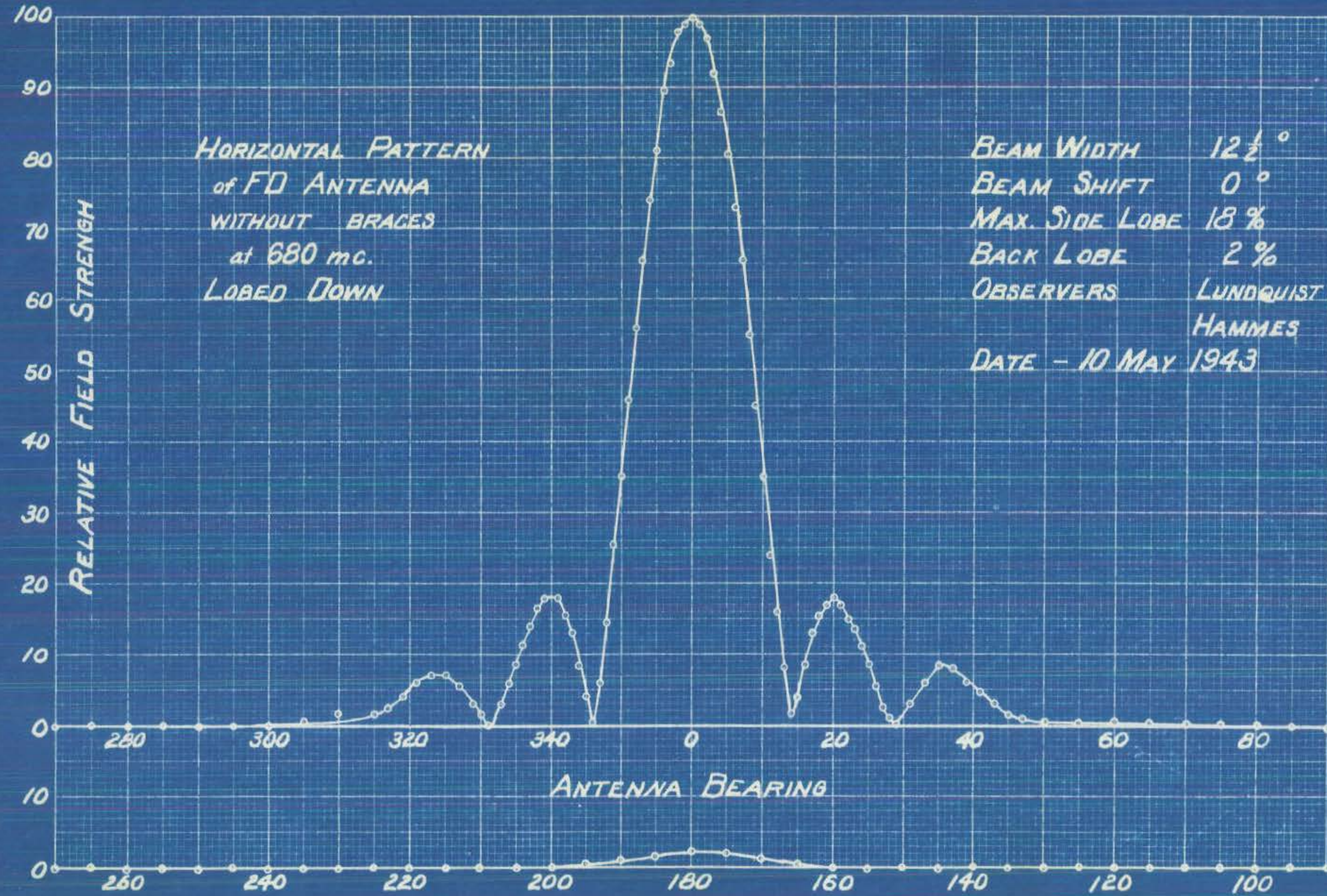
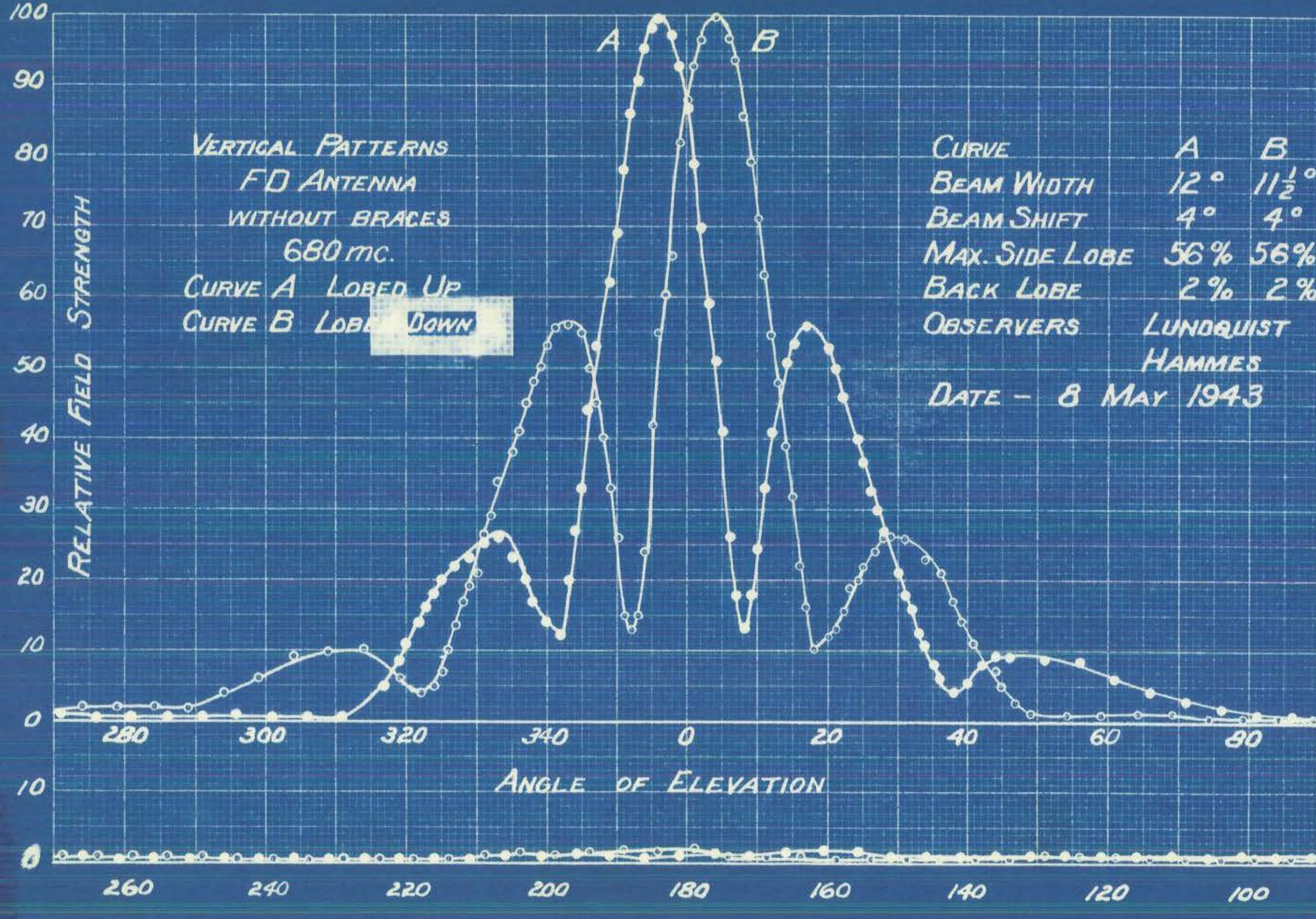

HORIZONTAL PATTERN
of FD ANTENNA
WITHOUT BRACES
at 680 mc.
LOBED DOWN
BEAM WIDTH 12½°
BEAM SHIFT 0°
MAX. SIDE LOBE 18%
BACK LOBE 2%
OBSERVERS LUNDQUIST
HAMMES
DATE - 10 MAY 1943
RELATIVE FIELD STRENGH
100
90
80
70
60
50
40
30
20
10
0
10
0
280
300
320
340
0
20
40
60
80
ANTENNA BEARING
260
240
220
200
180
160
140
120
100

PLATE 13



A
B
VERTICAL PATTERNS
FD ANTENNA
WITHOUT BRACES
680 mc.
CURVE A LOBED UP
CURVE B LOBED DOWN
CURVE A B
BEAM WIDTH 12° 11½°
BEAM SHIFT 4° 4°
MAX. SIDE LOBE 56% 56%
BACK LOBE 2% 2%
OBSERVERS LUNDQUIST
HAMMES
DATE - 8 MAY 1943
RELATIVE FIELD STRENGTH
100
90
80
70
60
50
40
30
20
10
0
10
0
280
300
320
340
0
20
40
60
80
ANGLE OF ELEVATION
260
240
220
200
180
160
140
120
100

PLATE 14

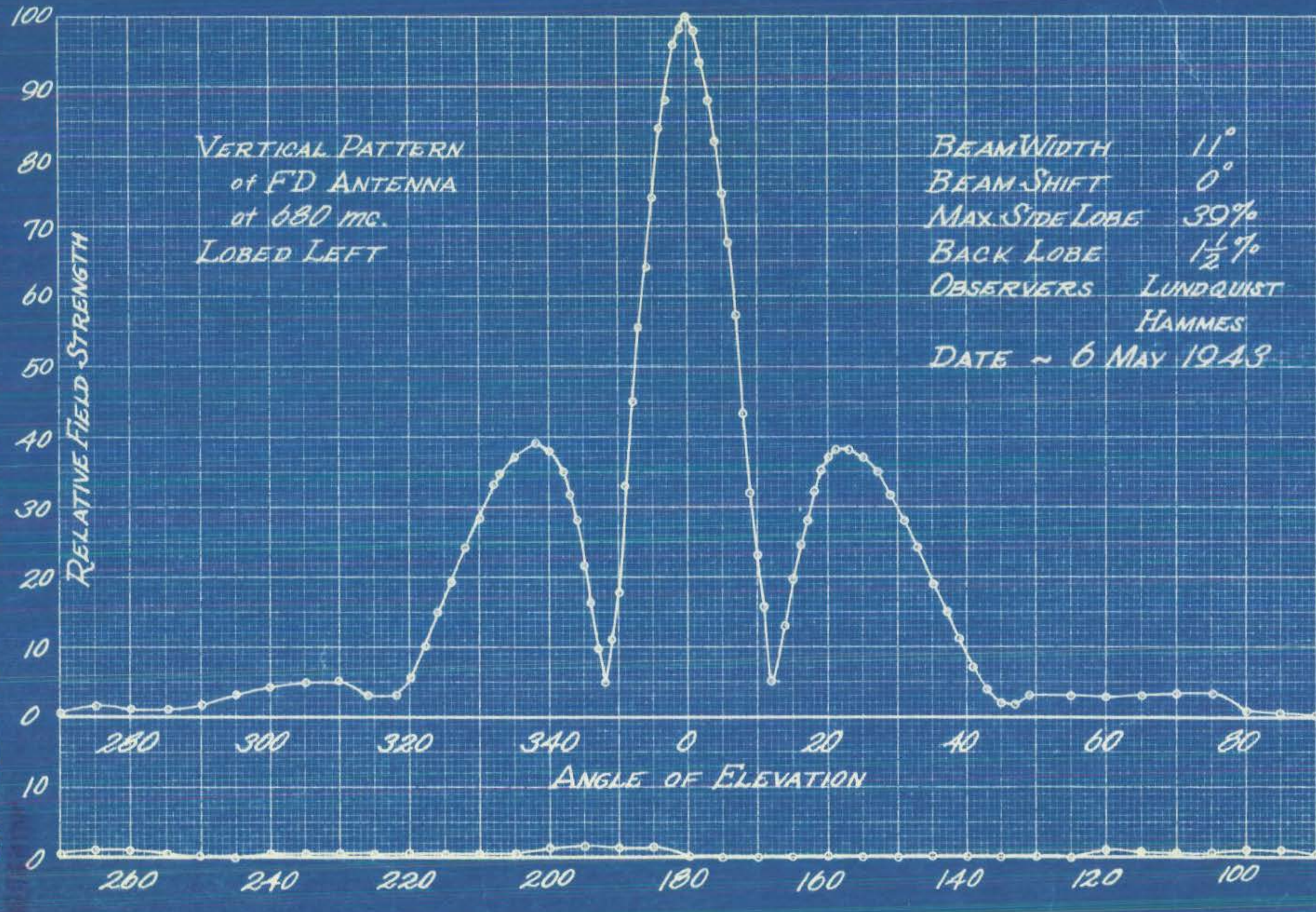

VERTICAL PATTERN
of FD ANTENNA
at 680 mc.
LOBED LEFT
BEAM WIDTH 11°
BEAM SHIFT 0°
MAX. SIDE LOBE 39%
BACK LOBE 1½%
OBSERVERS LUNDQUIST
HAMMES
DATE ~ 6 MAY 1943
RELATIVE FIELD STRENGTH
100
90
80
70
60
50
40
30
20
10
0
10
0
280
300
320
340
0
20
40
60
80
ANGLE OF ELEVATION
260
240
220
200
180
160
140
120
100

PLATE 15

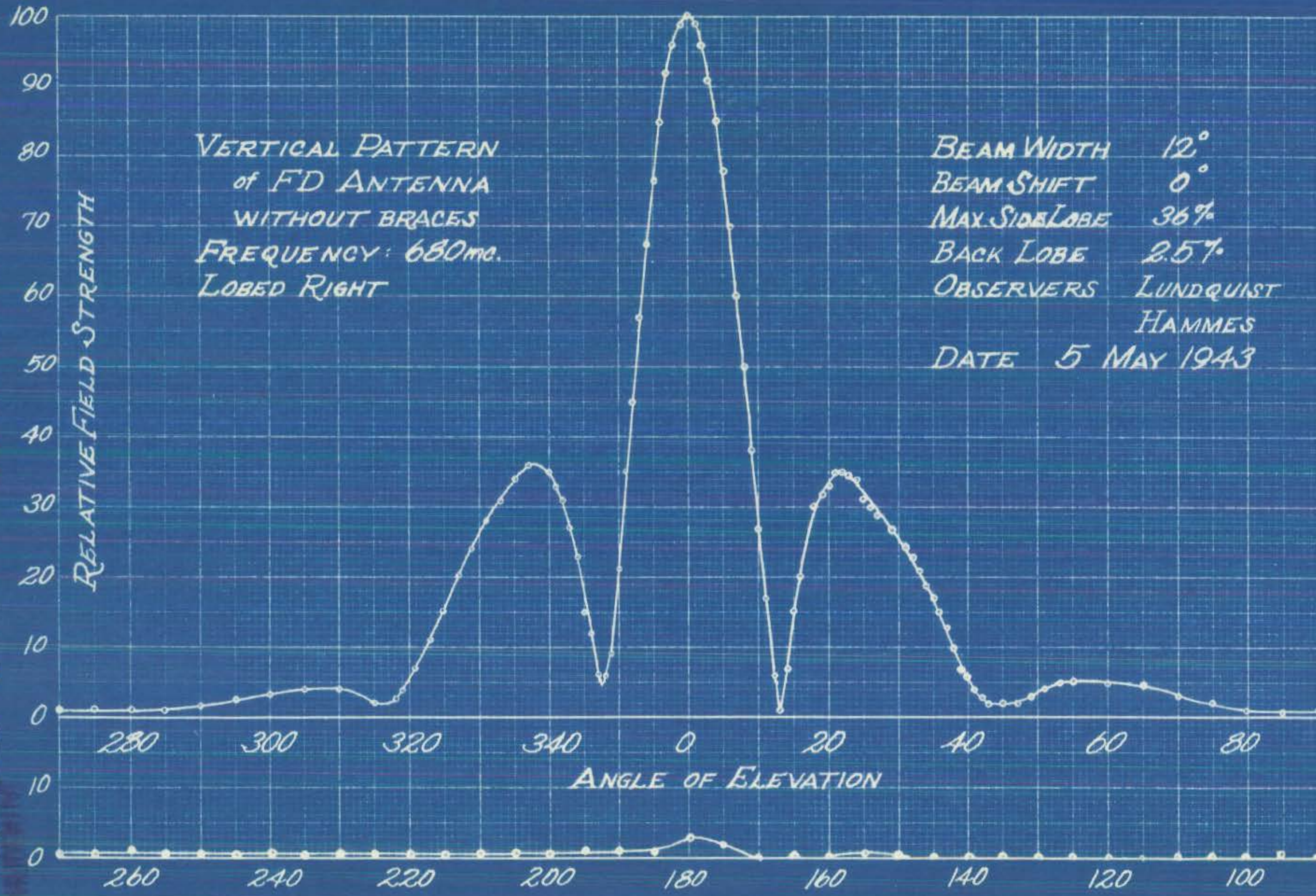
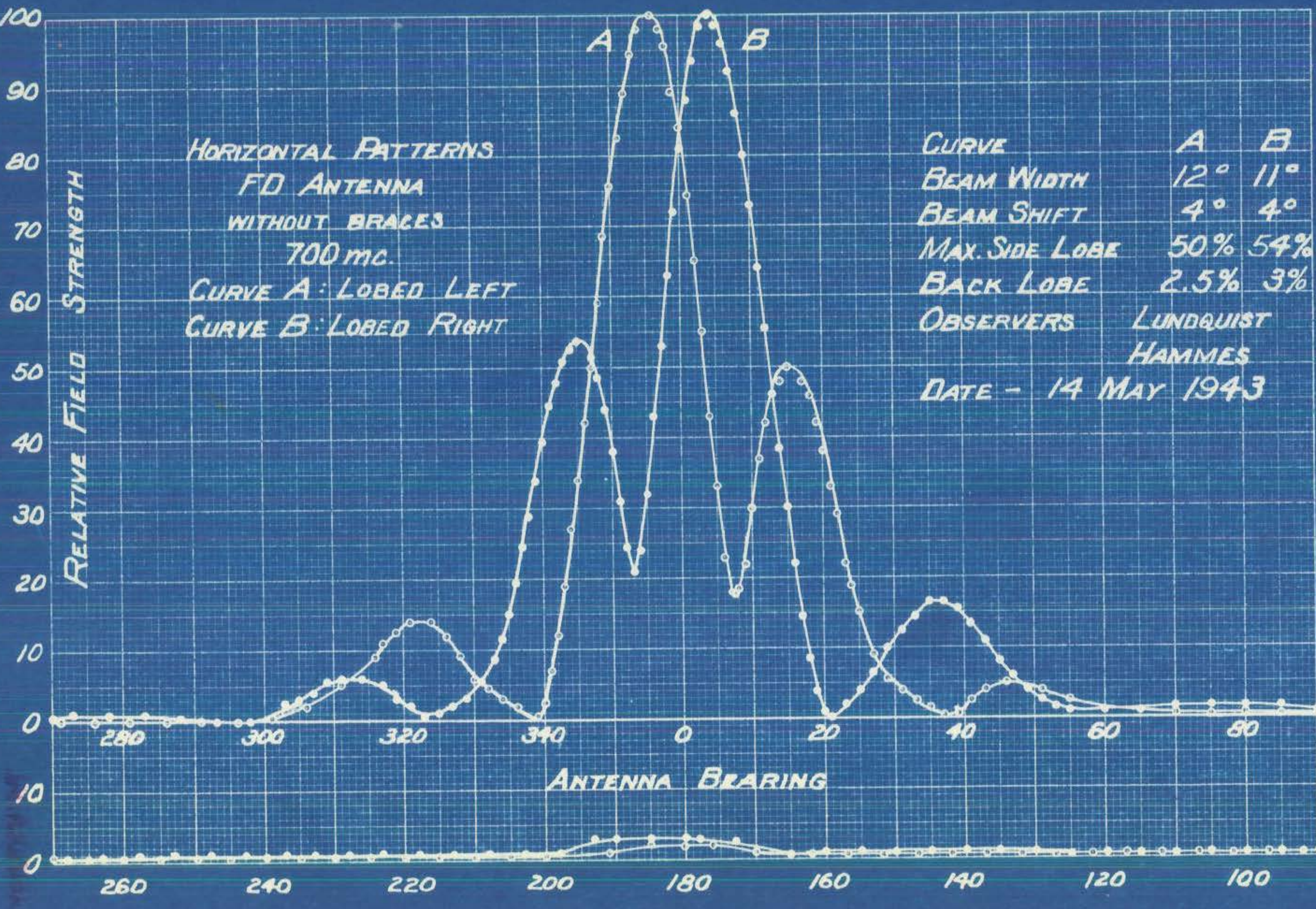

VERTICAL PATTERN
of FD ANTENNA
WITHOUT BRACES
FREQUENCY: 680mc.
LOBED RIGHT
BEAM WIDTH 12°
BEAM SHIFT 0°
MAX. SIDE LOBE 36%
BACK LOBE 2.57%
OBSERVERS LUNDQUIST
HAMMES
DATE 5 MAY 1943
RELATIVE FIELD STRENGTH
100
90
80
70
60
50
40
30
20
10
0
10
0
280
300
320
340
0
20
40
60
80
ANGLE OF ELEVATION
260
240
220
200
180
160
140
120
100

PLATE 16



HORIZONTAL PATTERNS
FD ANTENNA
WITHOUT BRACES
700 mc.
CURVE A: LOBED LEFT
CURVE B: LOBED RIGHT
CURVE A B
BEAM WIDTH 12° 11°
BEAM SHIFT 4° 4°
MAX. SIDE LOBE 50% 54%
BACK LOBE 2.5% 3%
OBSERVERS LUNDQUIST
HAMMES
DATE - 14 MAY 1943
A
B
RELATIVE FIELD STRENGTH
ANTENNA BEARING
100
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

PLATE 17

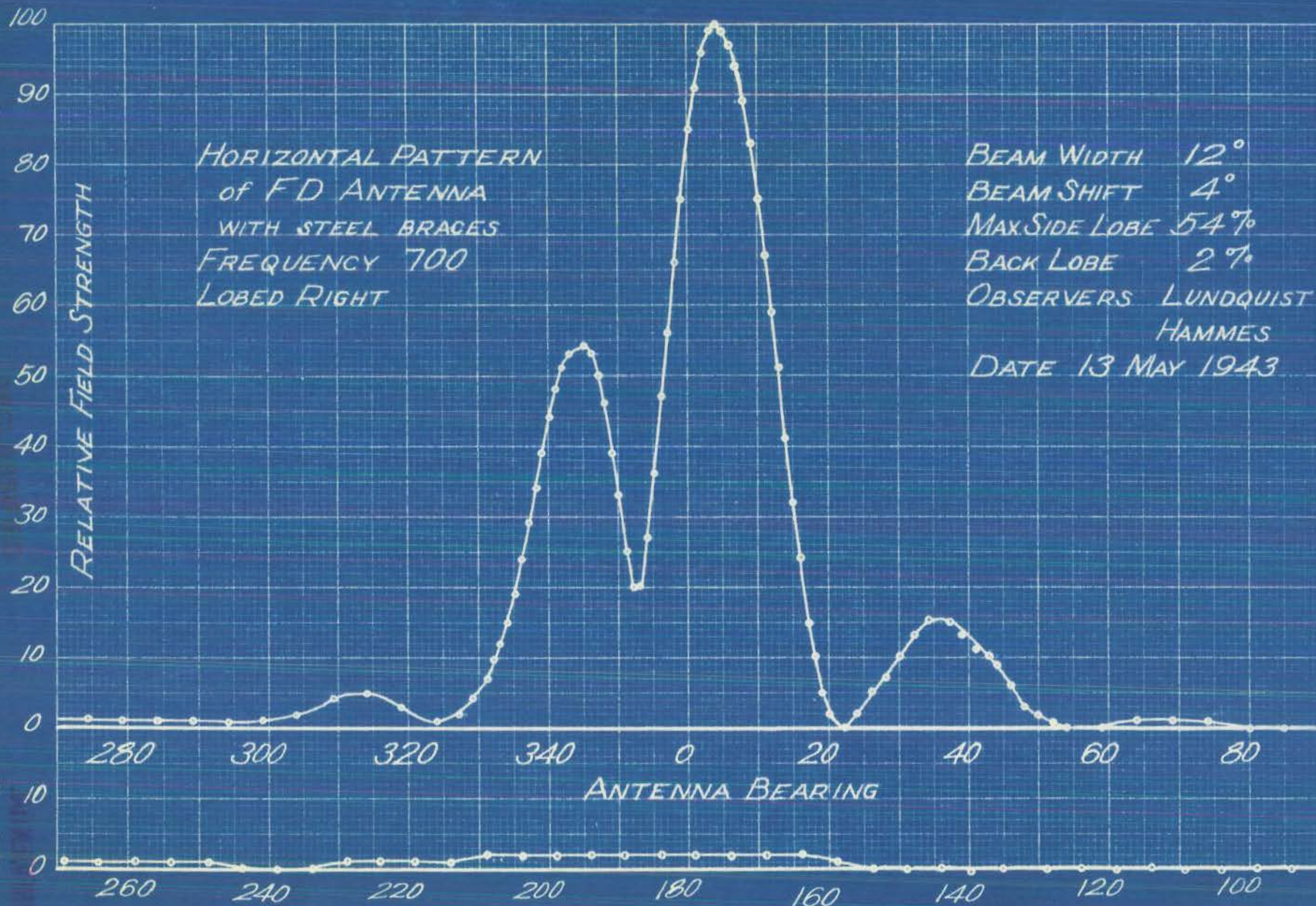

HORIZONTAL PATTERN
of FD ANTENNA
WITH STEEL BRACES
FREQUENCY 700
LOBED RIGHT
BEAM WIDTH 12°
BEAM SHIFT 4°
MAX SIDE LOBE 54%
BACK LOBE 2%
OBSERVERS LUNDQUIST
HAMMES
DATE 13 MAY 1943
RELATIVE FIELD STRENGTH
ANTENNA BEARING
100
90
80
70
60
50
40
30
20
10
0
10
0
280
300
320
340
0
20
40
60
80
260
240
220
200
180
160
140
120
100

PLATE 18

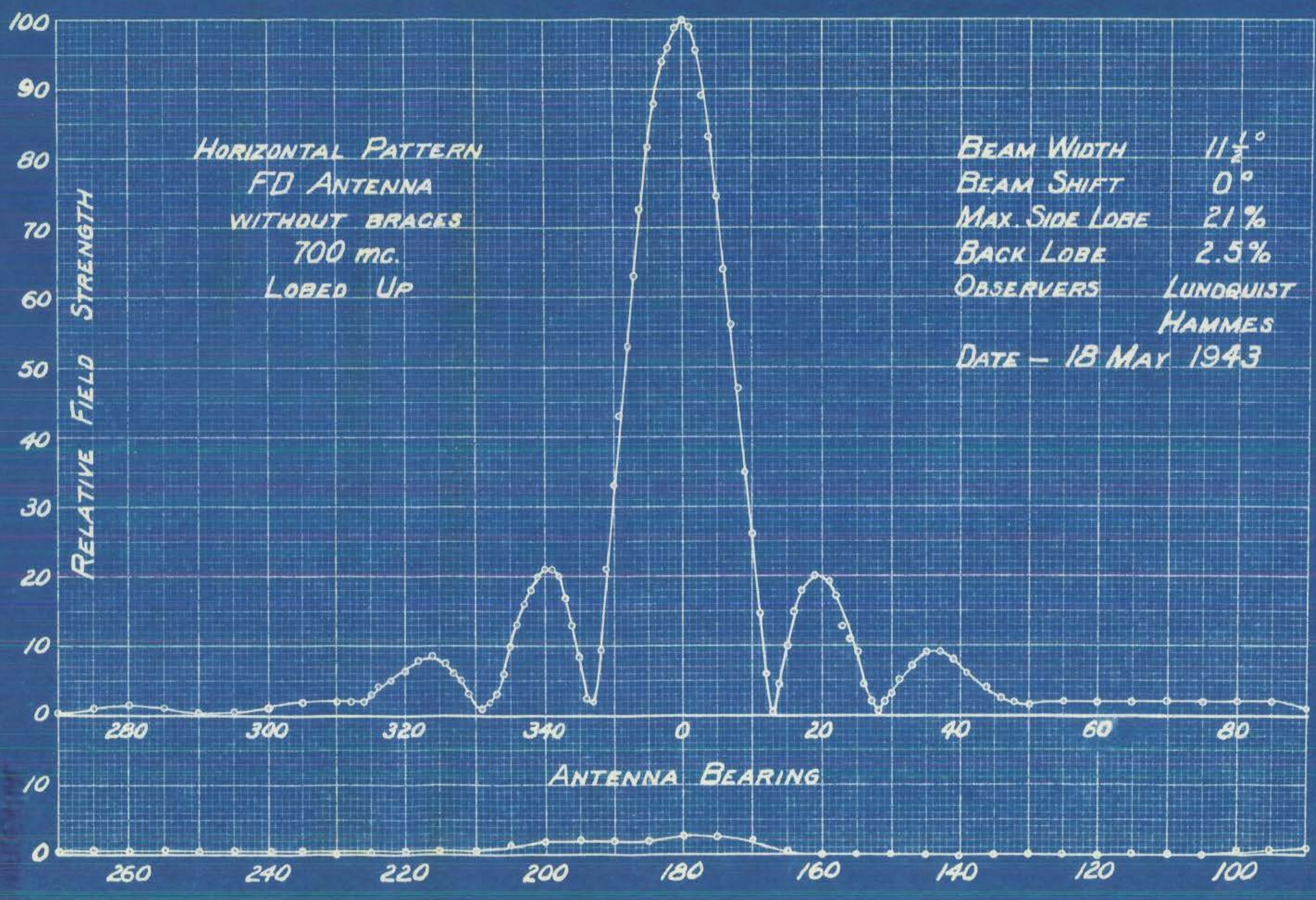

HORIZONTAL PATTERN
FD ANTENNA
WITHOUT BRACES
700 mc.
LOBED UP
BEAM WIDTH 11½°
BEAM SHIFT 0°
MAX. SIDE LOBE 21%
BACK LOBE 2.5%
OBSERVERS LUNDQUIST
HAMMES
DATE – 18 MAY 1943
RELATIVE FIELD STRENGTH
ANTENNA BEARING
100
90
80
70
60
50
40
30
20
10
0
10
0
280
300
320
340
0
20
40
60
80
260
240
220
200
180
160
140
120
100

PLATE 19

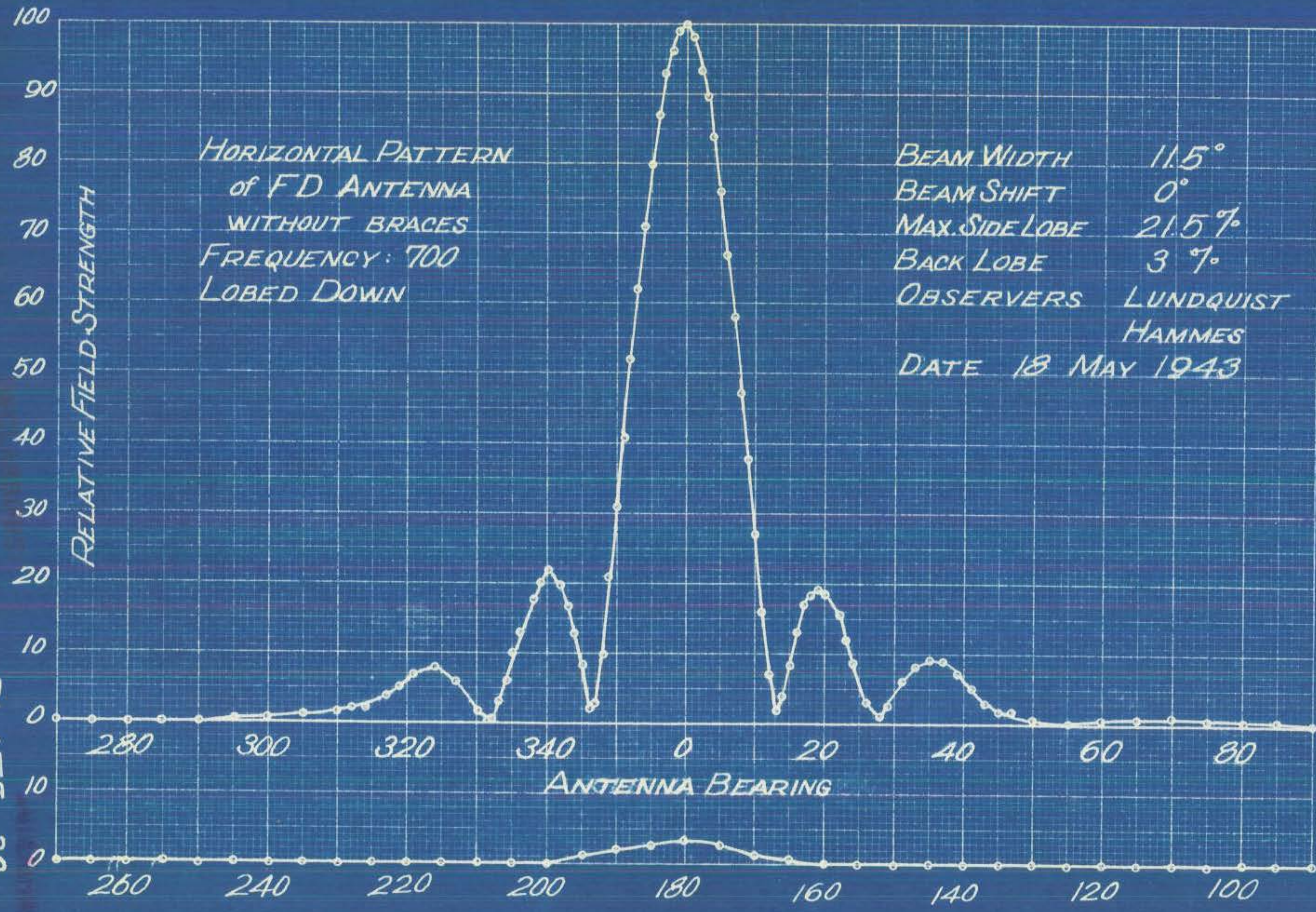

HORIZONTAL PATTERN
of FD ANTENNA
WITHOUT BRACES
FREQUENCY: 700
LOBED DOWN
BEAM WIDTH 11.5°
BEAM SHIFT 0°
MAX. SIDE LOBE 21.5 %
BACK LOBE 3 %
OBSERVERS LUNDQUIST
HAMMES
DATE 18 MAY 1943
RELATIVE FIELD STRENGTH
ANTENNA BEARING
100
90
80
70
60
50
40
30
20
10
0
280
300
320
340
0
20
40
60
80
10
0
260
240
220
200
180
160
140
120
100

PLATE 20

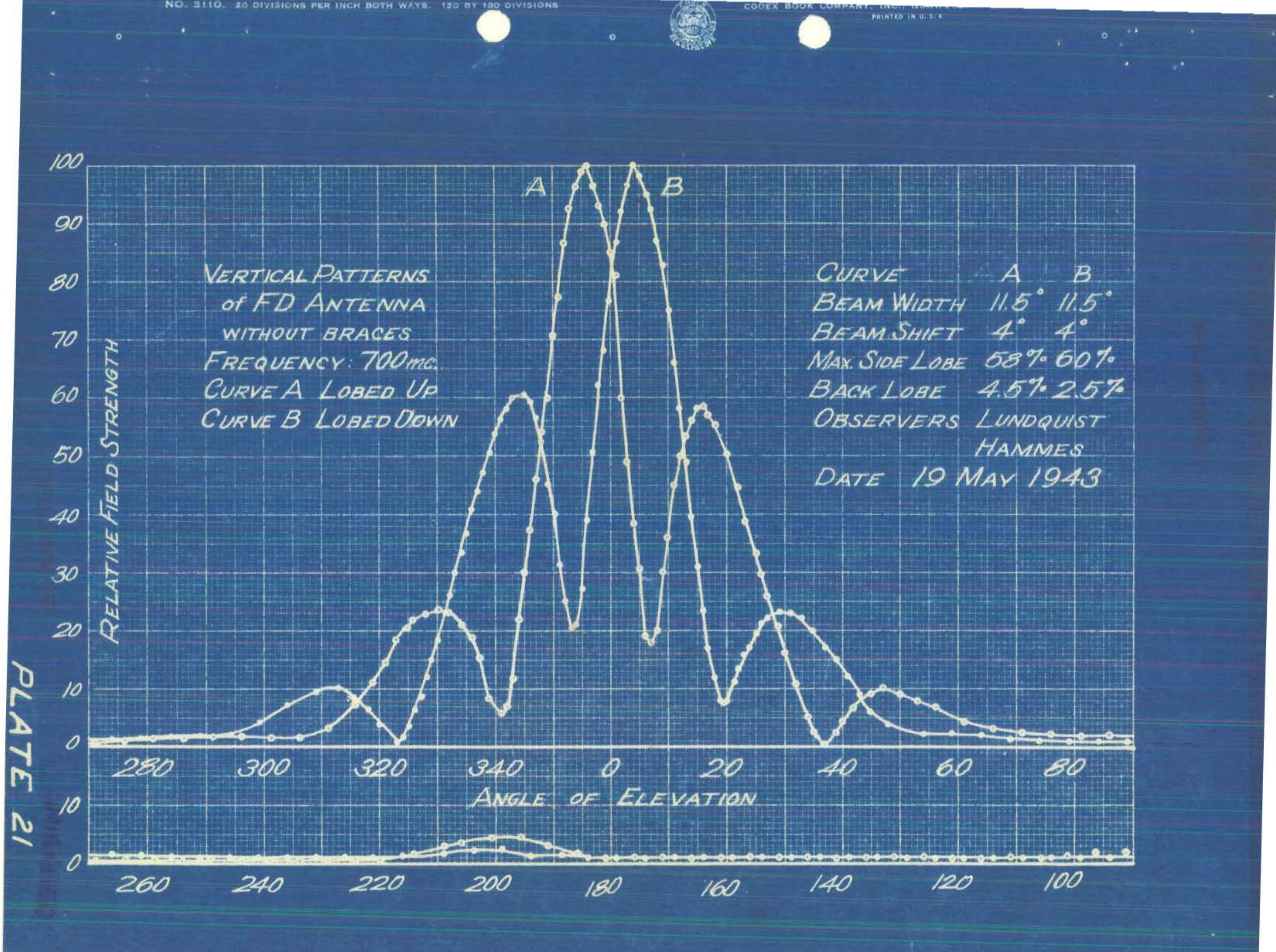

NO. 3110. 20 DIVISIONS PER INCH BOTH WAYS. 120 BY 180 DIVISIONS
CODEX BOOK COMPANY, INC.
PRINTED IN U.S.A.
VERTICAL PATTERNS
of FD ANTENNA
WITHOUT BRACES
FREQUENCY: 700mc.
CURVE A LOBED UP
CURVE B LOBED DOWN
CURVE A B
BEAM WIDTH 11.5° 11.5°
BEAM SHIFT 4° 4°
MAX. SIDE LOBE 58% 60%
BACK LOBE 4.5% 2.5%
OBSERVERS LUNDQUIST
HAMMES
DATE 19 MAY 1943
A
B
RELATIVE FIELD STRENGTH
100
90
80
70
60
50
40
30
20
10
0
10
0
280
300
320
340
0
20
40
60
80
ANGLE OF ELEVATION
260
240
220
200
180
160
140
120
100

PLATE 21

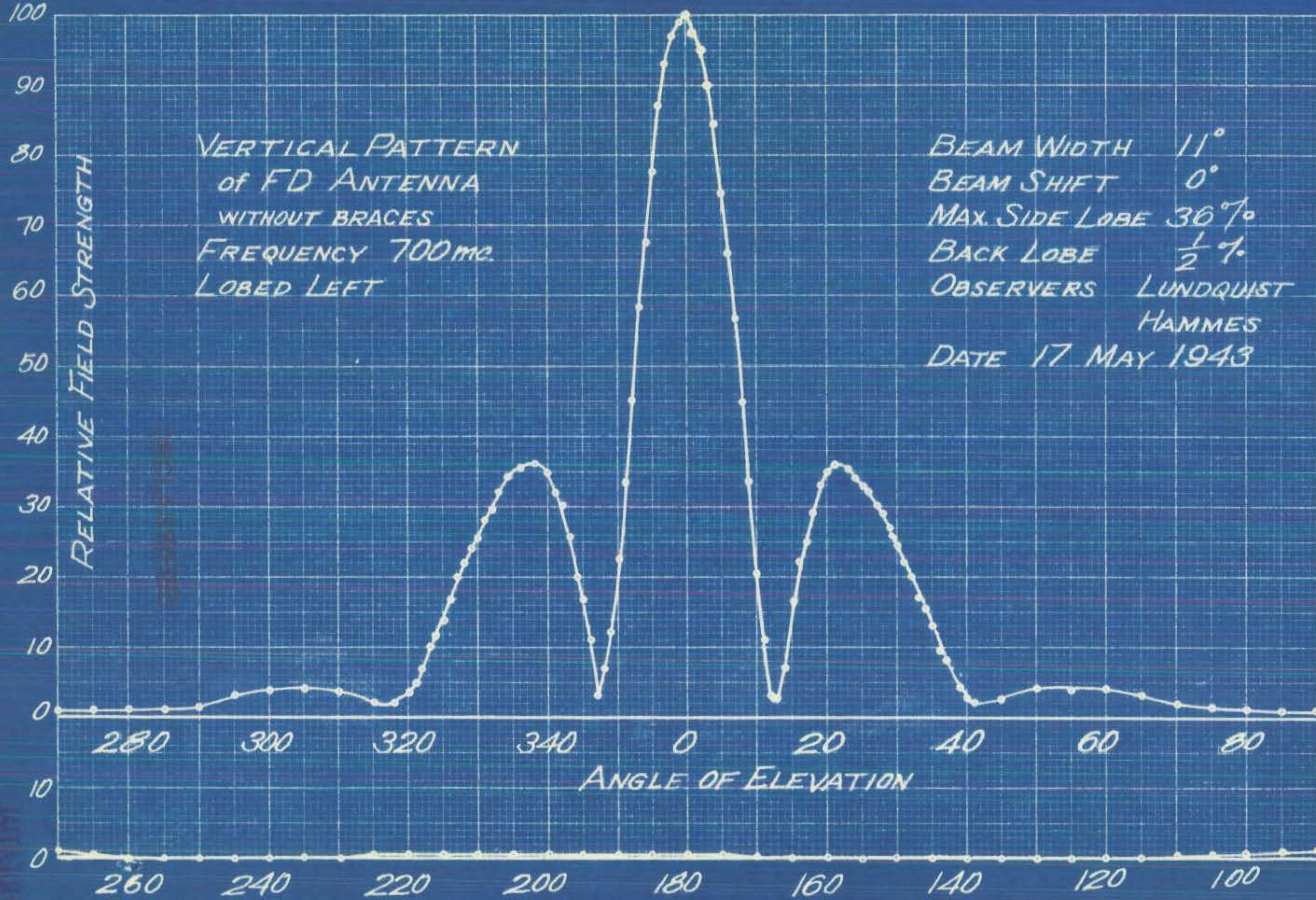

VERTICAL PATTERN
of FD ANTENNA
WITHOUT BRACES
FREQUENCY 700 mc.
LOBED LEFT
BEAM WIDTH 11°
BEAM SHIFT 0°
MAX. SIDE LOBE 36%
BACK LOBE 1/2 %
OBSERVERS LUNDQUIST
HAMMES
DATE 17 MAY 1943
RELATIVE FIELD STRENGTH
100
90
80
70
60
50
40
30
20
10
0
280
300
320
340
0
20
40
60
80
ANGLE OF ELEVATION
10
0
260
240
220
200
180
160
140
120
100

PLATE 22

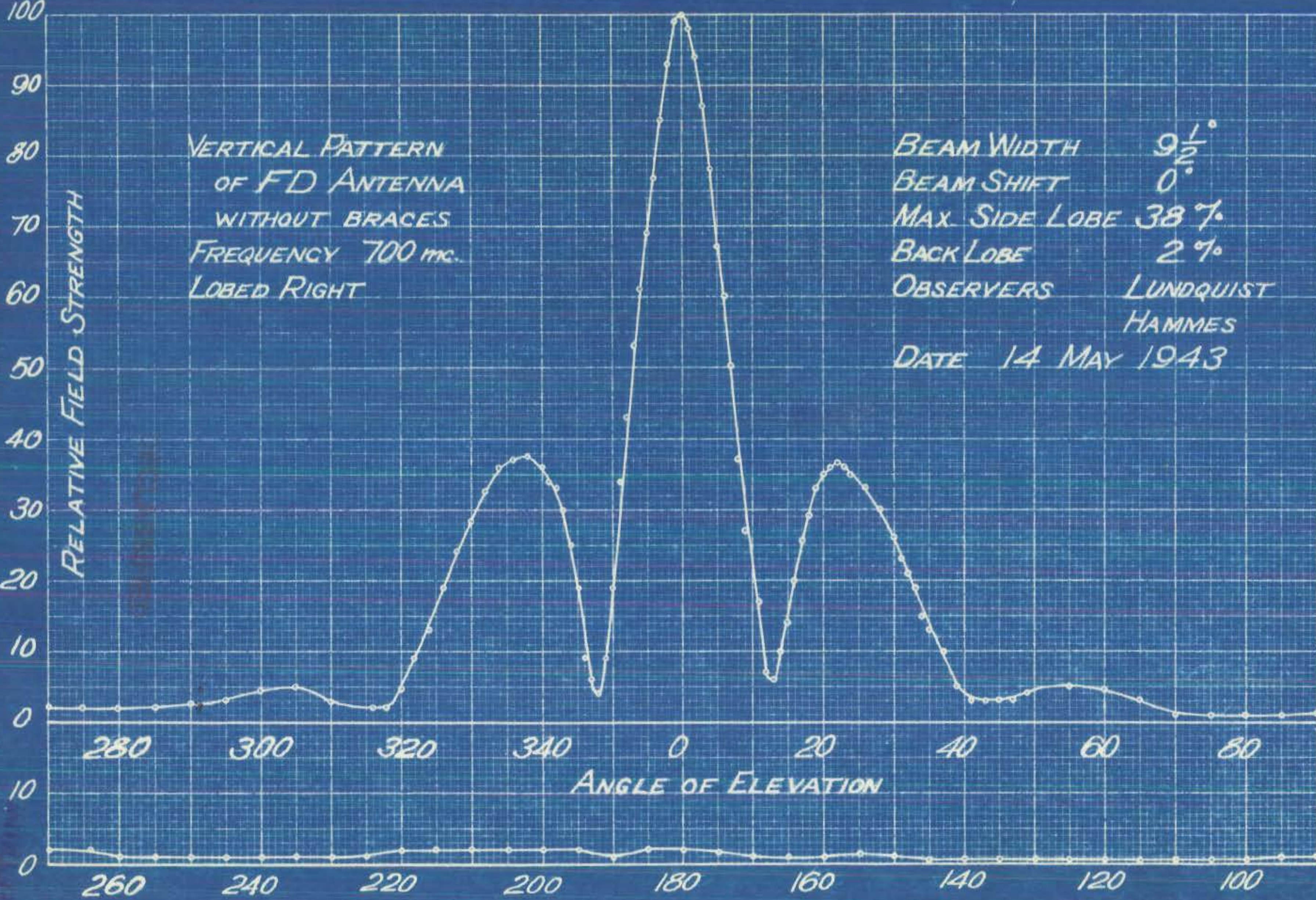

VERTICAL PATTERN
OF FD ANTENNA
WITHOUT BRACES
FREQUENCY 700 mc.
LOBED RIGHT
BEAM WIDTH 9½°
BEAM SHIFT 0°
MAX. SIDE LOBE 38 %
BACK LOBE 2 %
OBSERVERS LUNDQUIST
HAMMES
DATE 14 MAY 1943
RELATIVE FIELD STRENGTH
ANGLE OF ELEVATION
100
90
80
70
60
50
40
30
20
10
0
10
0
280
300
320
340
0
20
40
60
80
260
240
220
200
180
160
140
120
100

PLATE 23

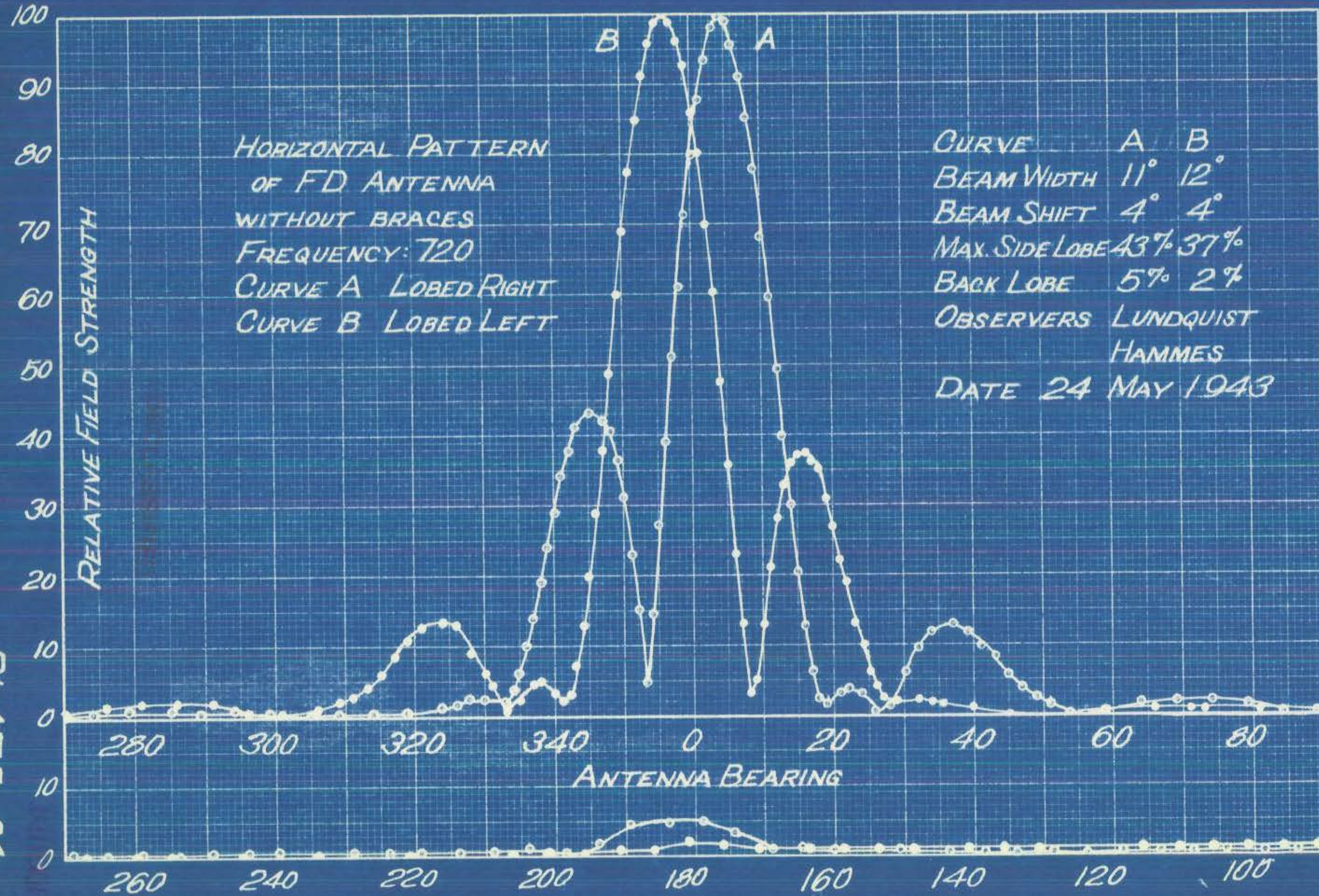

HORIZONTAL PATTERN
OF FD ANTENNA
WITHOUT BRACES
FREQUENCY: 720
CURVE A LOBED RIGHT
CURVE B LOBED LEFT
CURVE A B
BEAM WIDTH 11° 12°
BEAM SHIFT 4° 4°
MAX. SIDE LOBE 43% 37%
BACK LOBE 5% 2%
OBSERVERS LUNDQUIST
HAMMES
DATE 24 MAY 1943
RELATIVE FIELD STRENGTH
ANTENNA BEARING
B
A
100
90
80
70
60
50
40
30
20
10
0
280 300 320 340 0 20 40 60 80
260 240 220 200 180 160 140 120 100

PLATE 24

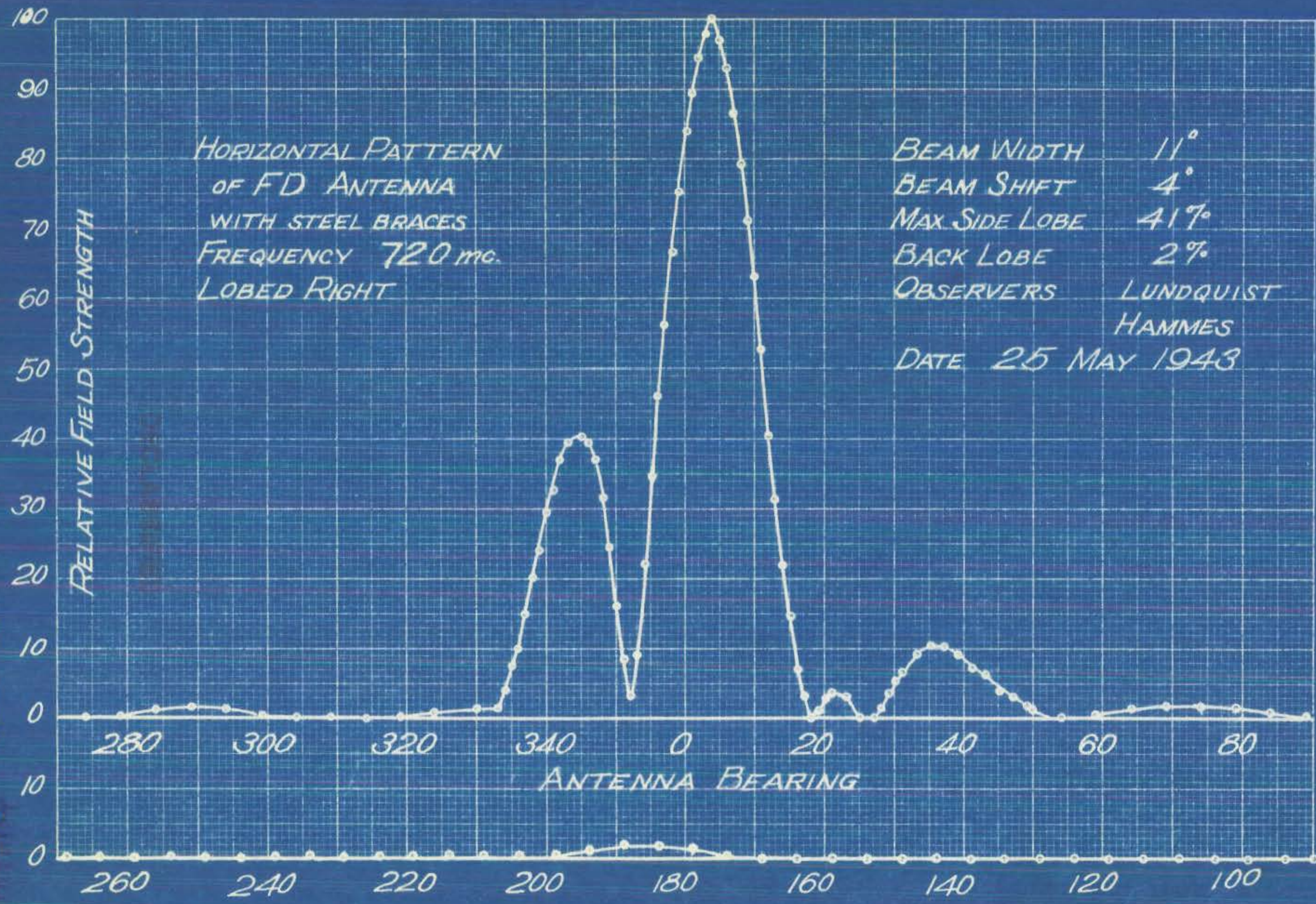

HORIZONTAL PATTERN
OF FD ANTENNA
WITH STEEL BRACES
FREQUENCY 720 mc.
LOBED RIGHT
BEAM WIDTH 11°
BEAM SHIFT 4°
MAX. SIDE LOBE 41%
BACK LOBE 2%
OBSERVERS LUNDQUIST
HAMMES
DATE 25 MAY 1943
RELATIVE FIELD STRENGTH
100
90
80
70
60
50
40
30
20
10
0
10
0
280 300 320 340 0 20 40 60 80
ANTENNA BEARING
260 240 220 200 180 160 140 120 100

PLATE 25

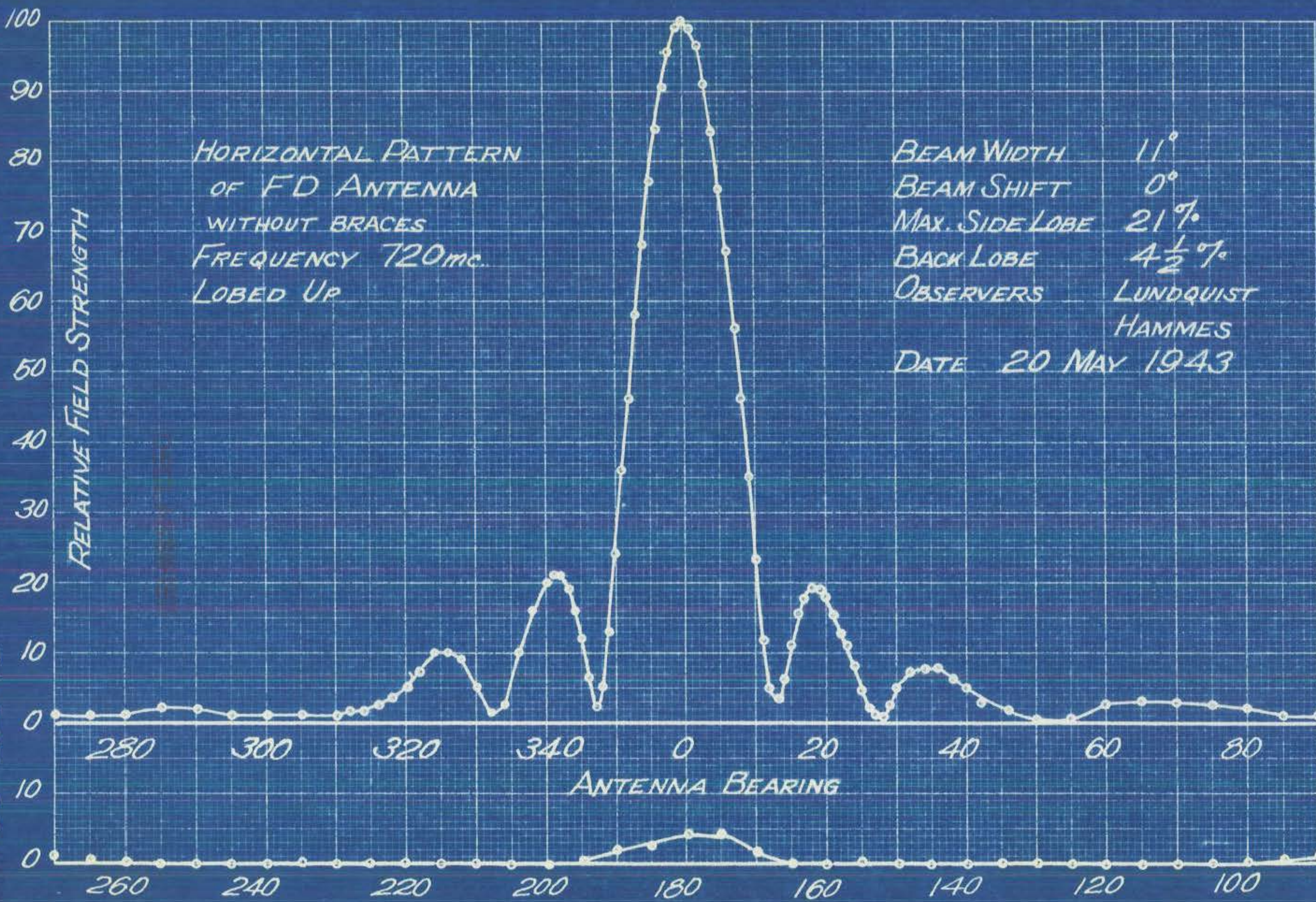
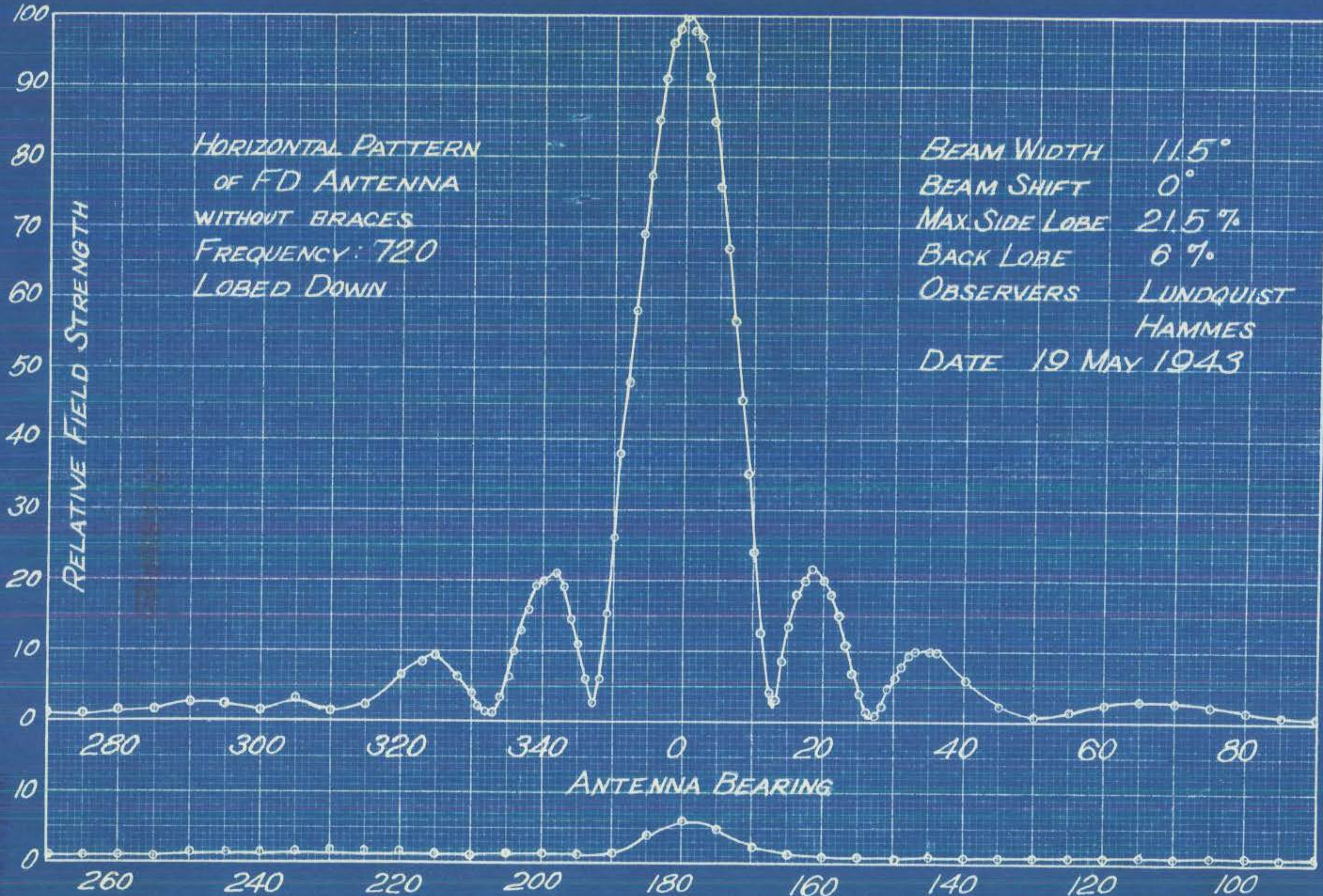

HORIZONTAL PATTERN
OF FD ANTENNA
WITHOUT BRACES
FREQUENCY 720mc.
LOBED UP
BEAM WIDTH 11°
BEAM SHIFT 0°
MAX. SIDE LOBE 21%
BACK LOBE 4½%
OBSERVERS LUNDQUIST
HAMMES
DATE 20 MAY 1943
RELATIVE FIELD STRENGTH
100
90
80
70
60
50
40
30
20
10
0
10
0
280
300
320
340
0
20
40
60
80
ANTENNA BEARING
260
240
220
200
180
160
140
120
100

PLATE 26



HORIZONTAL PATTERN
OF FD ANTENNA
WITHOUT BRACES
FREQUENCY: 720
LOBED DOWN
BEAM WIDTH 11.5°
BEAM SHIFT 0°
MAX. SIDE LOBE 21.5 %
BACK LOBE 6 %
OBSERVERS LUNDQUIST
HAMMES
DATE 19 MAY 1943
RELATIVE FIELD STRENGTH
ANTENNA BEARING
100 90 80 70 60 50 40 30 20 10 0
280 300 320 340 0 20 40 60 80
10 0
260 240 220 200 180 160 140 120 100

PLATE 27

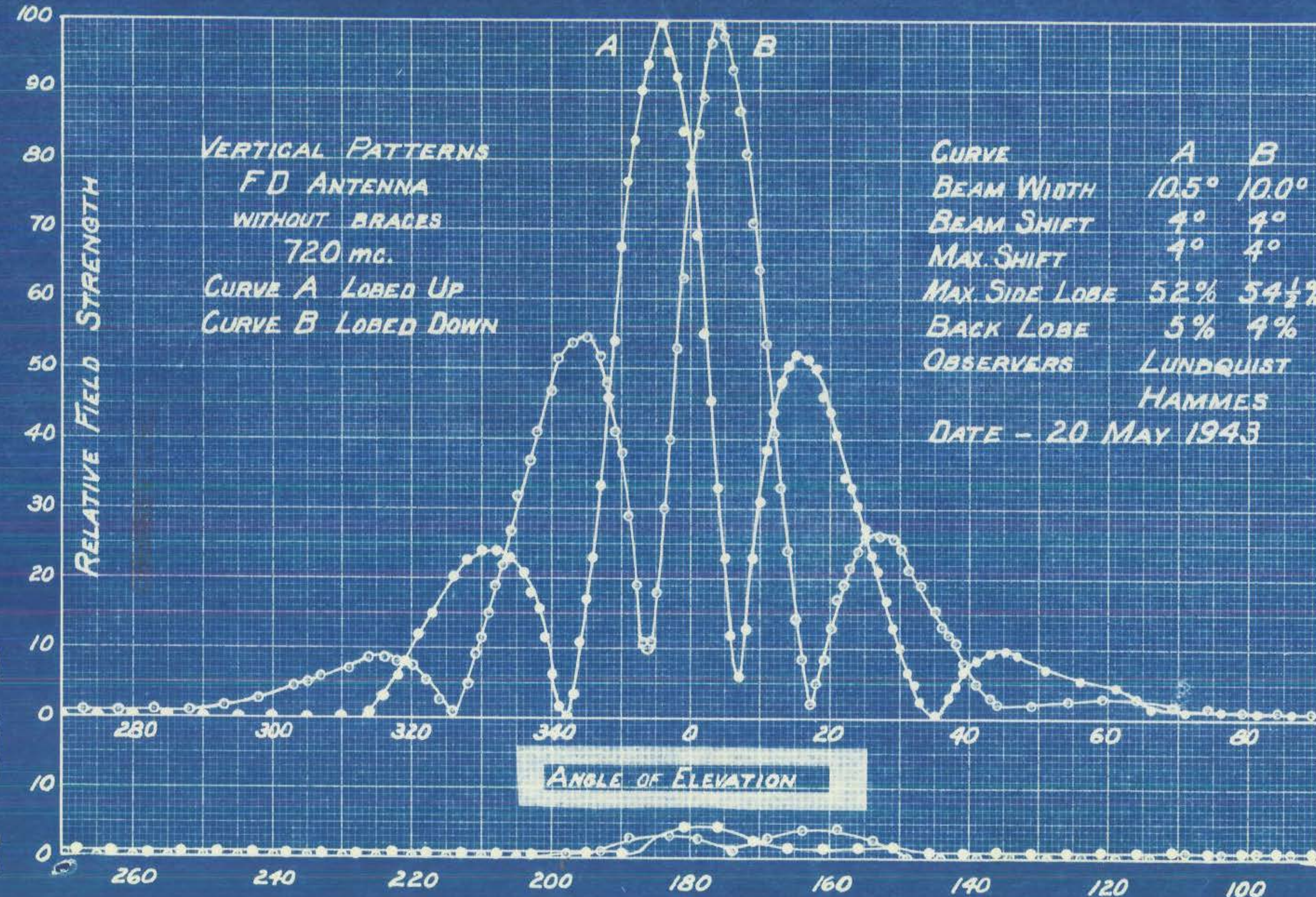

VERTICAL PATTERNS
FD ANTENNA
WITHOUT BRACES
720 mc.
CURVE A LOBED UP
CURVE B LOBED DOWN
CURVE A B
BEAM WIDTH 10.5° 10.0°
BEAM SHIFT 4° 4°
MAX. SHIFT 4° 4°
MAX. SIDE LOBE 52% 54½%
BACK LOBE 5% 4%
OBSERVERS LUNDQUIST
HAMMES
DATE - 20 MAY 1943
A
B
RELATIVE FIELD STRENGTH
ANGLE OF ELEVATION
100
90
80
70
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

PLATE 28

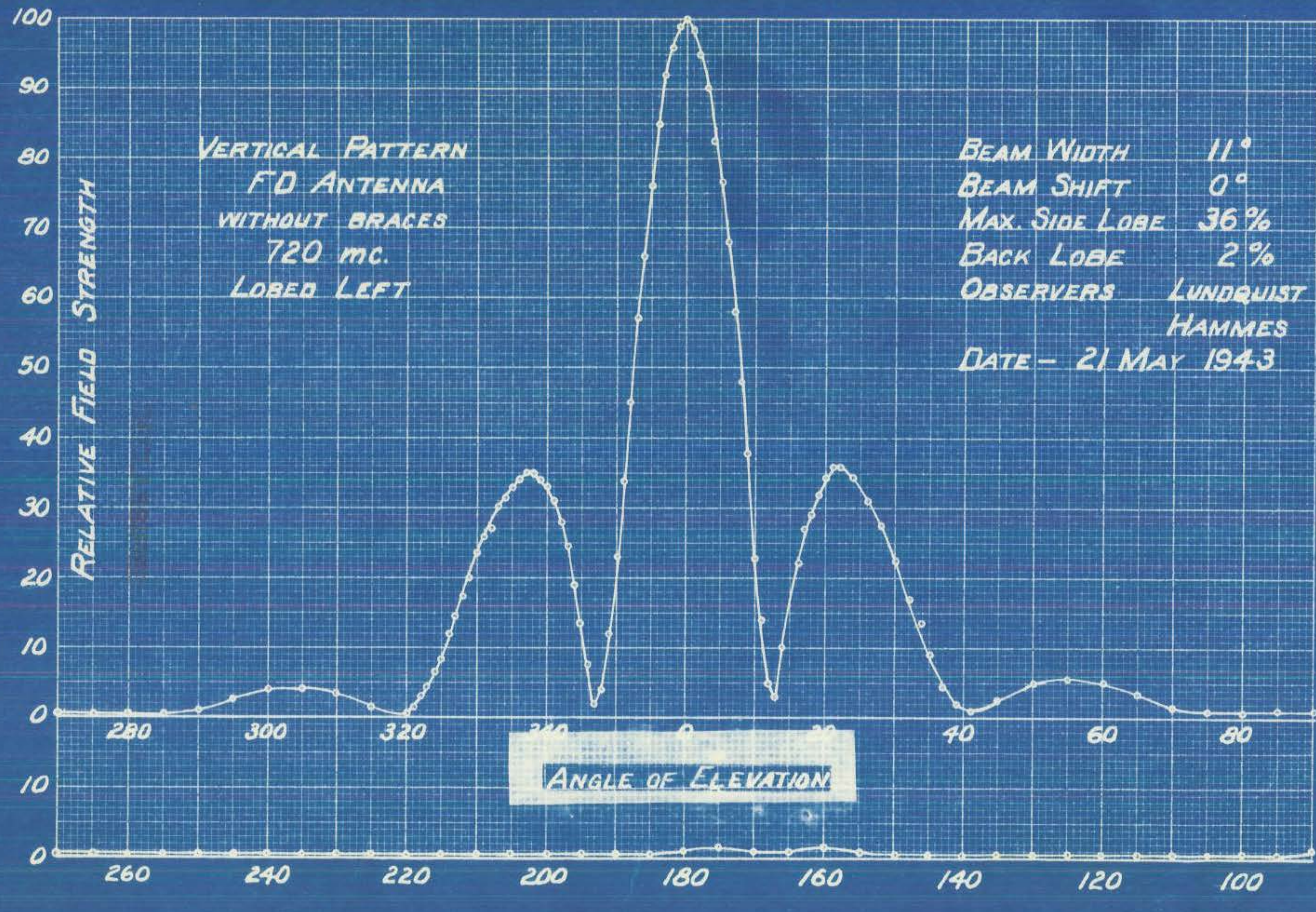

VERTICAL PATTERN
FD ANTENNA
WITHOUT BRACES
720 mc.
LOBED LEFT
BEAM WIDTH 11°
BEAM SHIFT 0°
MAX. SIDE LOBE 36%
BACK LOBE 2%
OBSERVERS LUNDQUIST
HAMMES
DATE – 21 MAY 1943
RELATIVE FIELD STRENGTH
100
90
80
70
60
50
40
30
20
10
0
10
0
280
300
320
0
40
60
80
260
240
220
200
180
160
140
120
100
ANGLE OF ELEVATION

PLATE 29

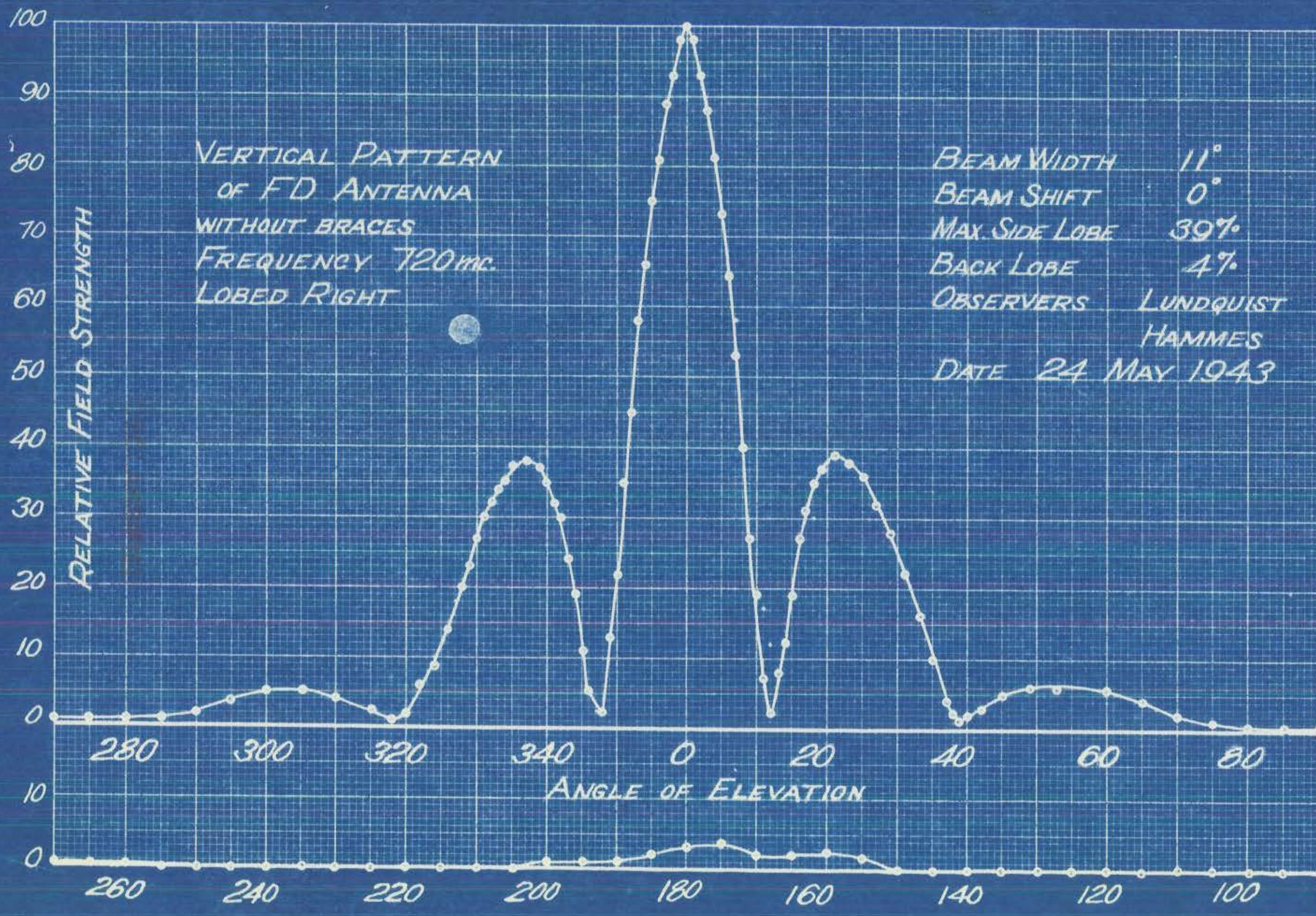

VERTICAL PATTERN
OF FD ANTENNA
WITHOUT BRACES
FREQUENCY 720 mc.
LOBED RIGHT
BEAM WIDTH 11°
BEAM SHIFT 0°
MAX. SIDE LOBE 39%
BACK LOBE 4%
OBSERVERS LUNDQUIST
HAMMES
DATE 24 MAY 1943
RELATIVE FIELD STRENGTH
ANGLE OF ELEVATION
0 10 20 30 40 50 60 70 80 90 100
280 300 320 340 0 20 40 60 80
260 240 220 200 180 160 140 120 100

PLATE 30

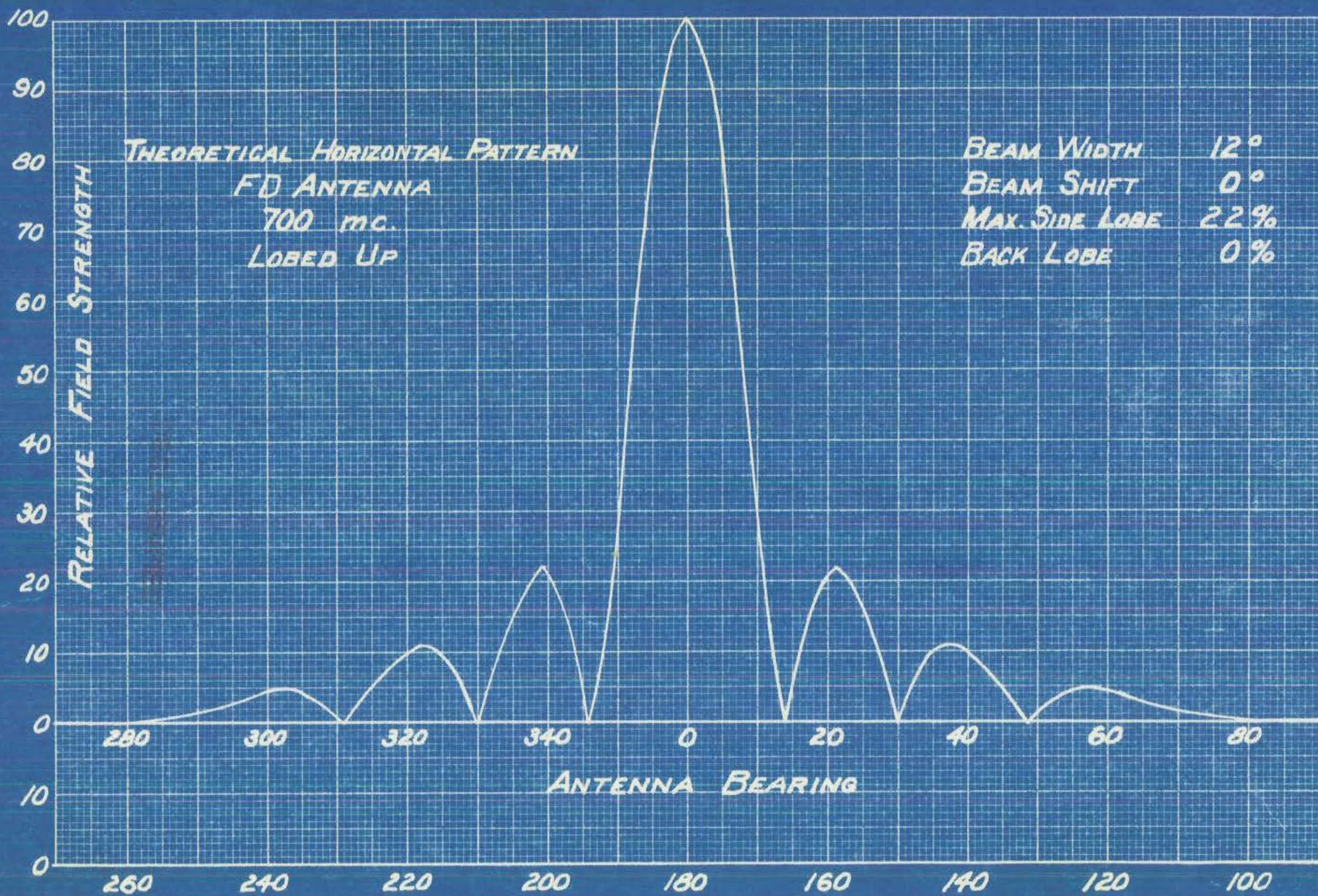
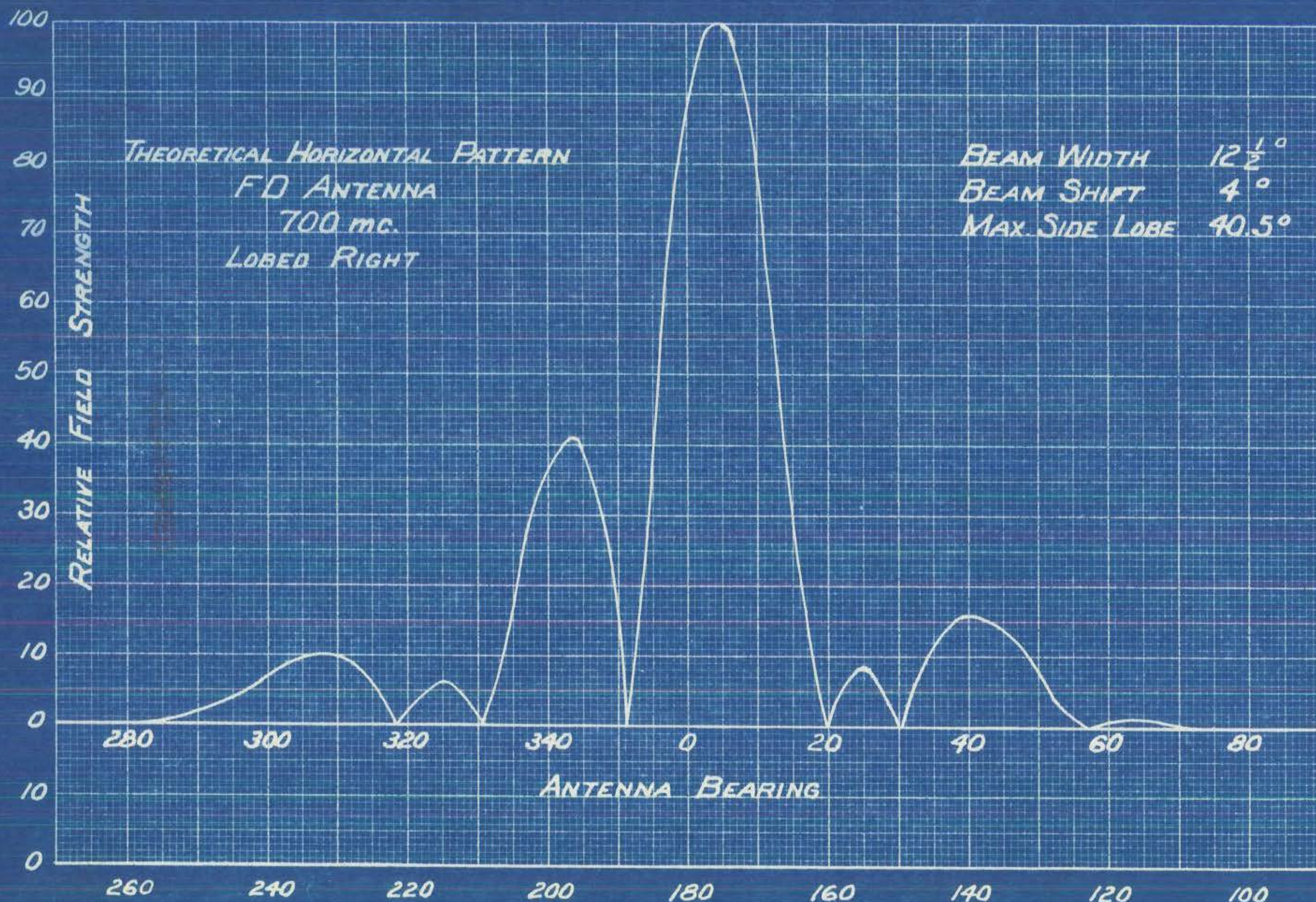

THEORETICAL HORIZONTAL PATTERN
FD ANTENNA
700 mc.
LOBED UP
BEAM WIDTH 12°
BEAM SHIFT 0°
MAX. SIDE LOBE 22%
BACK LOBE 0%
RELATIVE FIELD STRENGTH
100
90
80
70
60
50
40
30
20
10
0
10
0
280
300
320
340
0
20
40
60
80
ANTENNA BEARING
260
240
220
200
180
160
140
120
100

PLATE 31

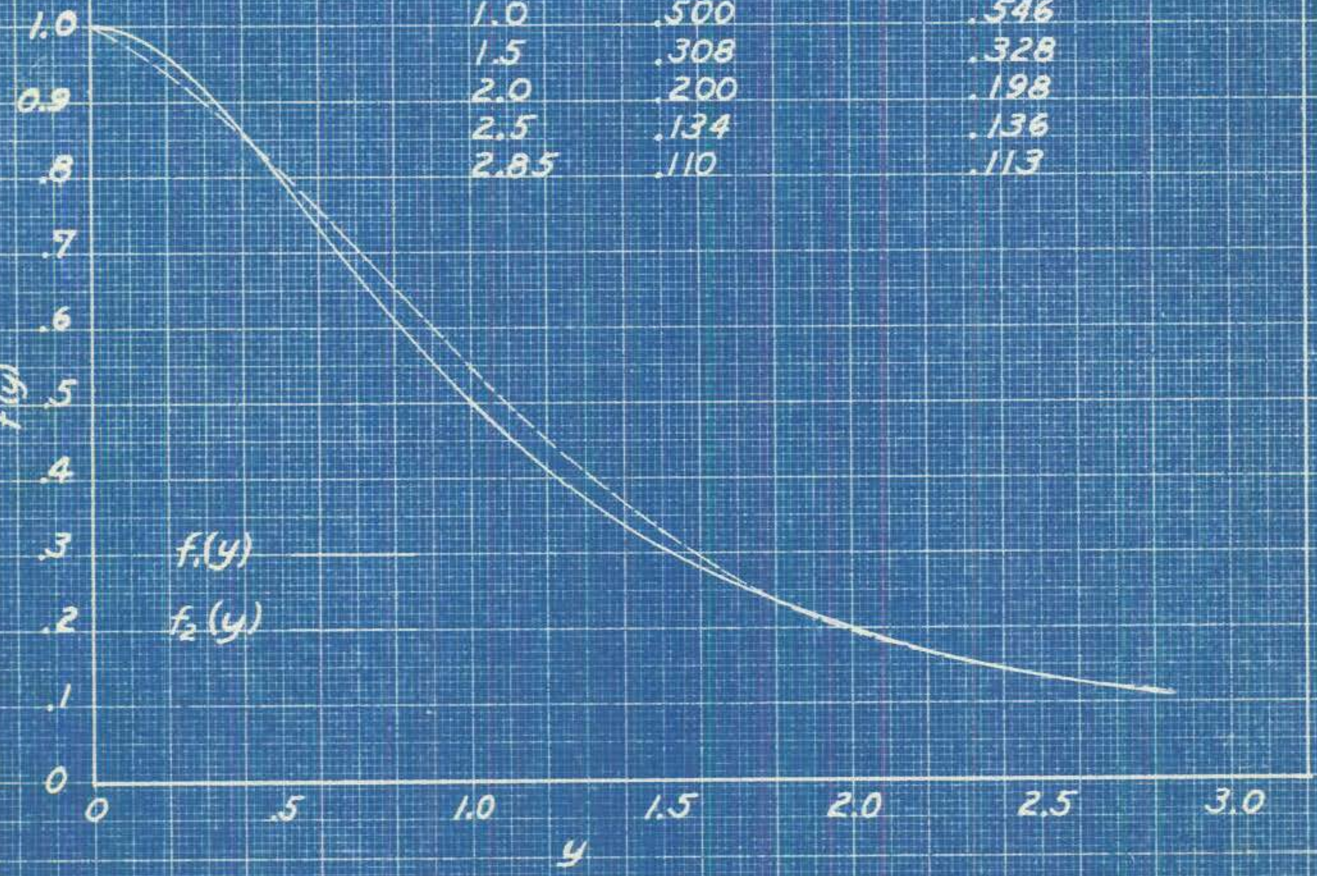


THEORETICAL HORIZONTAL PATTERN
FD ANTENNA
700 mc.
LOBED RIGHT
BEAM WIDTH 12½°
BEAM SHIFT 4°
MAX. SIDE LOBE 40.5°
RELATIVE FIELD STRENGTH
100
90
80
70
60
50
40
30
20
10
0
10
0
280 300 320 340 0 20 40 60 80
ANTENNA BEARING
260 240 220 200 180 160 140 120 100

PLATE 32

REPRESENTATION OF $\frac{1}{1+y^2}$ IN EXPONENTIALS

y	$f_1(y)$ $\frac{1}{1+y^2}$	$f_2(y)$ $.05+.4e^{-.666y}+.55e^{-.64y^2}$
0	1.000	1.000
0.1	0.990	.971
.25	.940	.918
.5	.800	.805
1.0	.500	.546
1.5	.308	.328
2.0	.200	.198
2.5	.134	.136
2.85	.110	.113



by WRDeHart

PLATE 33

CALCULATION OF VERTICAL PATTERN OF FD

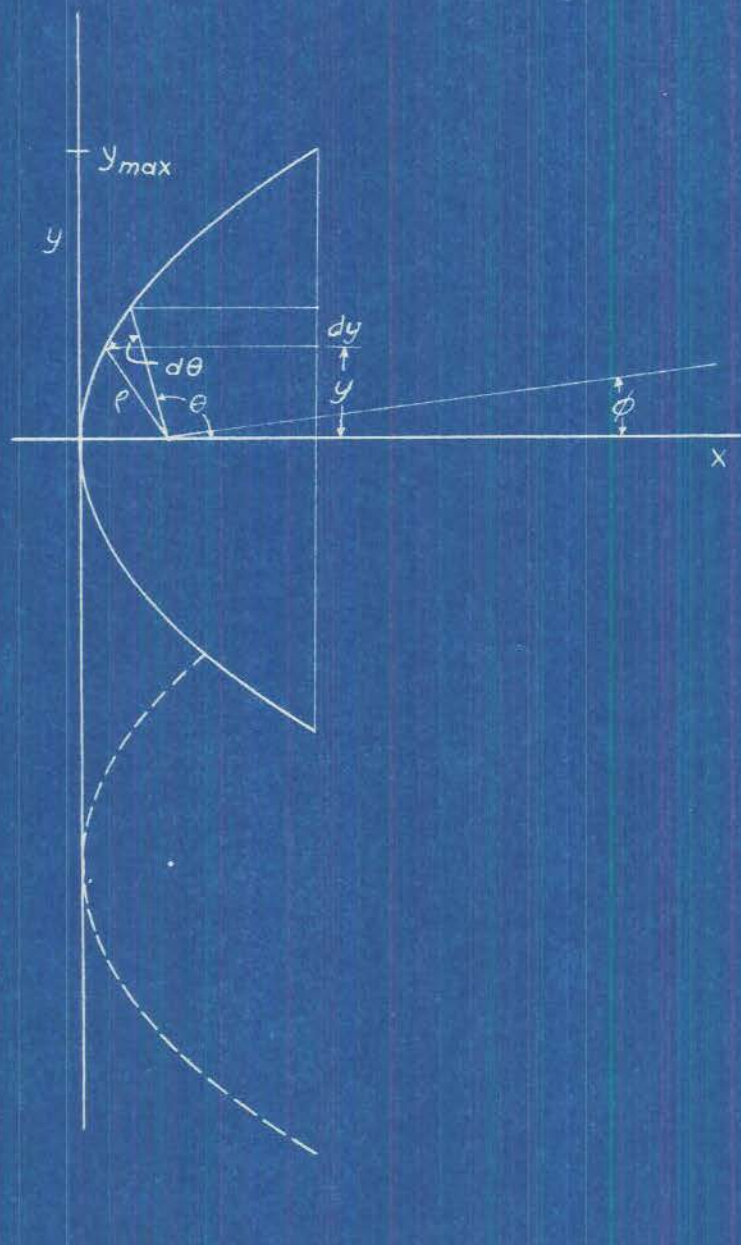


PLATE 34

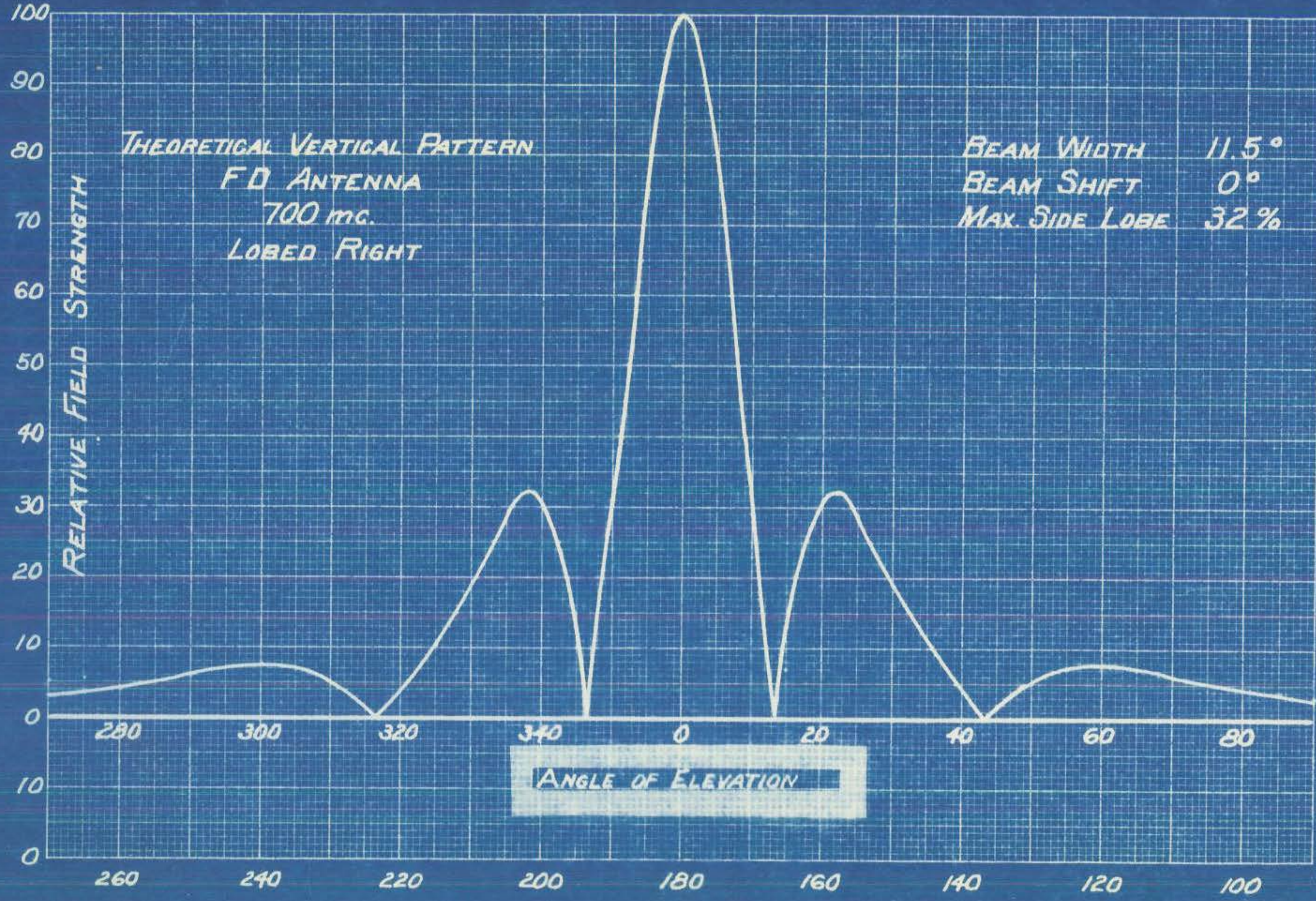

THEORETICAL VERTICAL PATTERN
FD ANTENNA
700 mc.
LOBED RIGHT
BEAM WIDTH 11.5°
BEAM SHIFT 0°
MAX. SIDE LOBE 32%
RELATIVE FIELD STRENGTH
100
90
80
70
60
50
40
30
20
10
0
10
0
280
300
320
340
0
20
40
60
80
ANGLE OF ELEVATION
260
240
220
200
180
160
140
120
100

PLATE 35

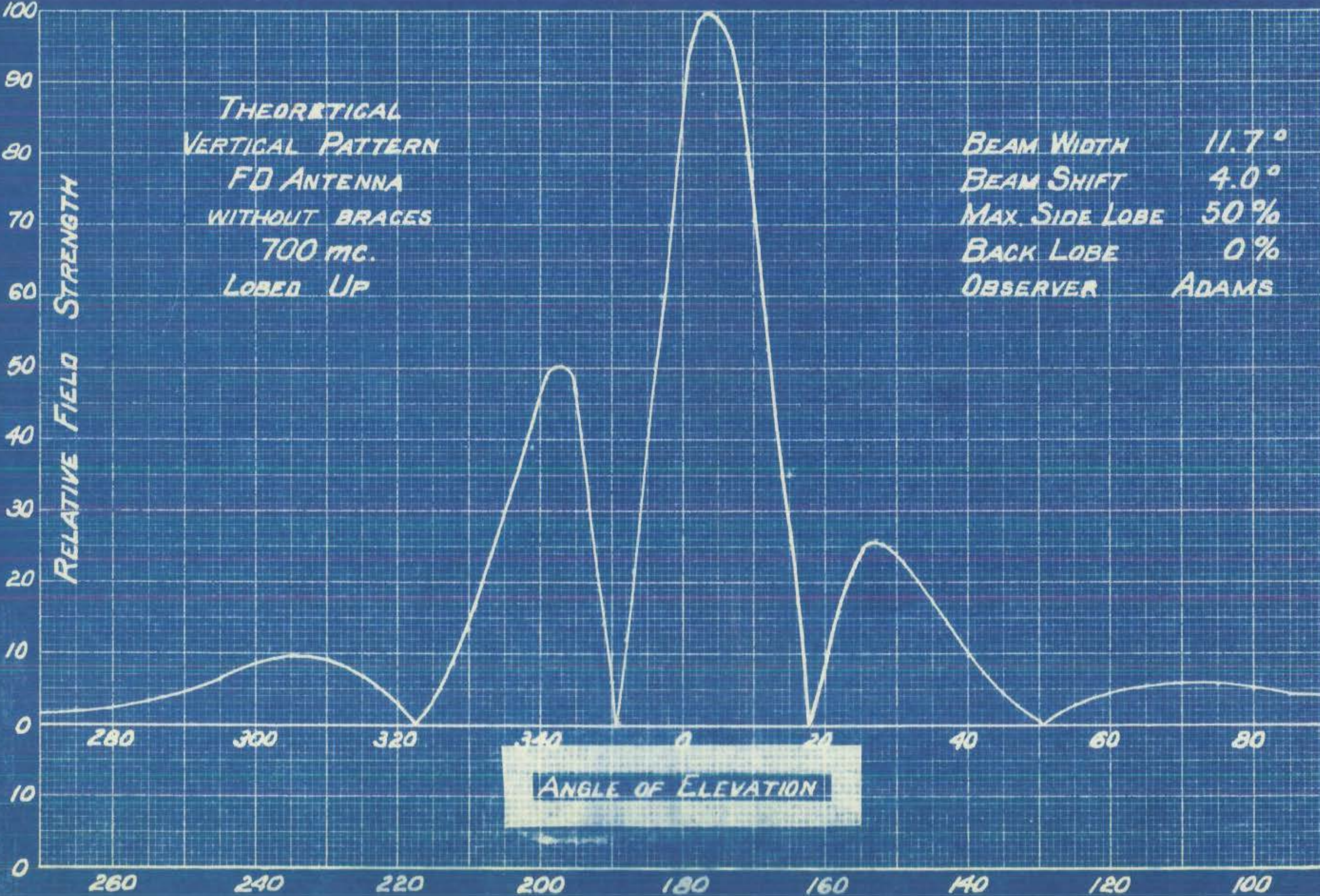
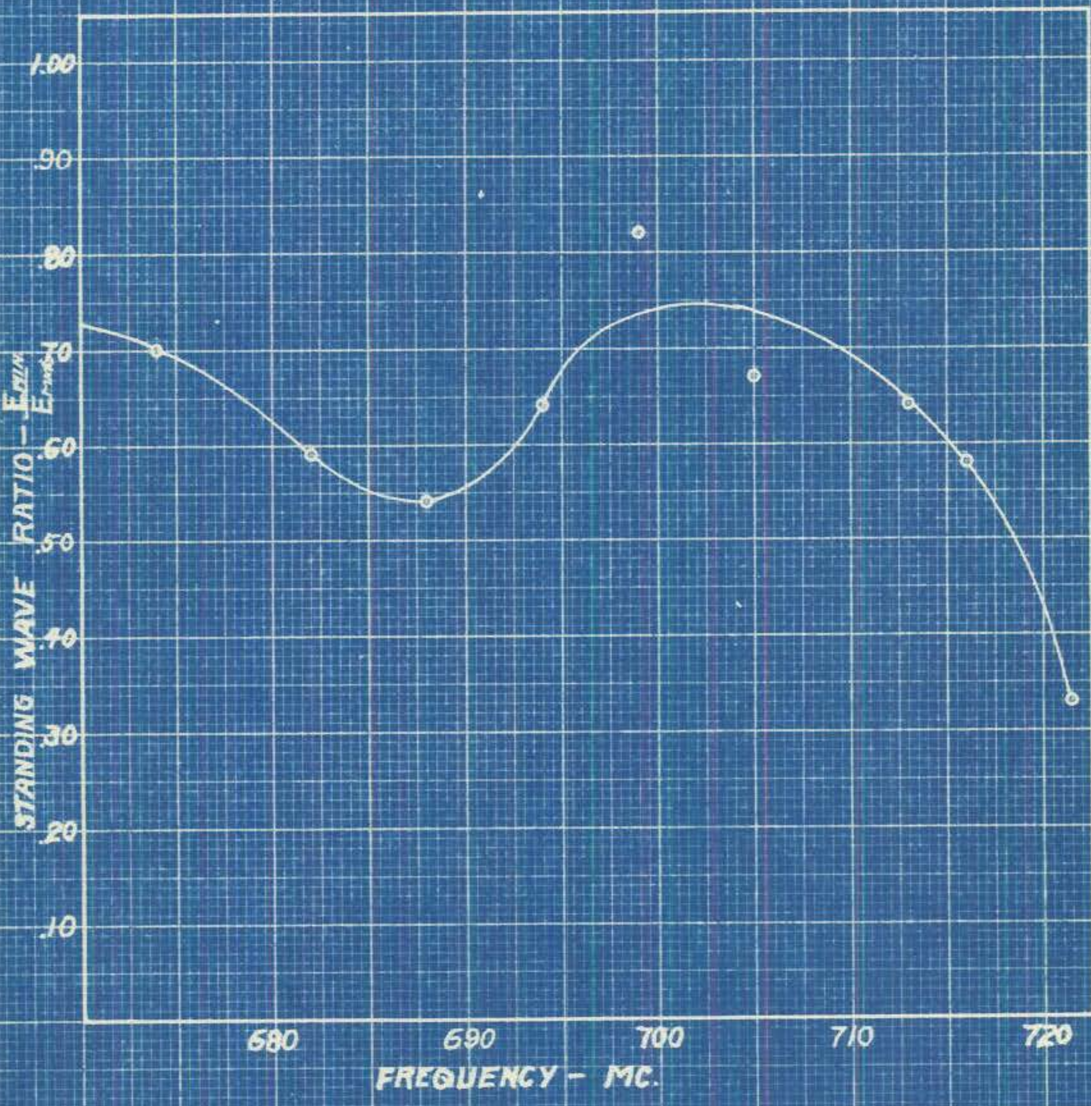

THEORETICAL
VERTICAL PATTERN
FD ANTENNA
WITHOUT BRACES
700 mc.
LOBED UP
BEAM WIDTH 11.7°
BEAM SHIFT 4.0°
MAX. SIDE LOBE 50%
BACK LOBE 0%
OBSERVER ADAMS
RELATIVE FIELD STRENGTH
ANGLE OF ELEVATION
100
90
80
70
60
50
40
30
20
10
0
10
0
280
300
320
340
0
20
40
60
80
260
240
220
200
180
160
140
120
100

PLATE 36



STANDING WAVE RATIO
FD ANTENNA

PLATE 37