Radiation patterns of paraboloids
National Research Council Canada. Radio Branch

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RADIO BRANCH

RADIATION PATTERNS OF PARABOLOIDS

OTTAWA

MARCH, 1942

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NATIONAL RESEARCH COUNCIL OF CANADA

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INDEX

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RADIATION PATTERNS OF PARABOLOIDS

This report contains the results of a study of various methods of exciting paraboloids, made in an effort to obtain methods which would give usable radiation patterns and at the same time permit wobbling the beam for split-beam direction finding. The curves (Dwgs. #241 to #258) attached to this report give representative radiation patterns and much of the information derived from this study is given in tabular form on pages 8 & 9.

I. 30 INCH PARABOLOID WITH FOCUS IN PLANE OF MOUTH

1. Wave Guide - Front Feed (Dwgs. #241 to #245)

A 4 cm. x 5.5 cm. wave guide is fed in from the bottom of the paraboloid. The mouth of the wave guide is placed in the focus. (See Fig. 1)

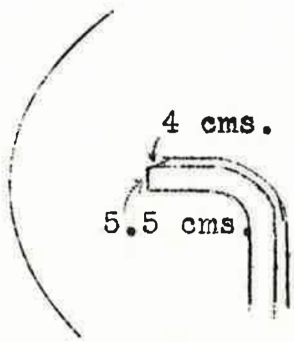


FIG. 1

In the horizontal plane the pattern consists of a main lobe directed along the axis of the paraboloid and several secondary lobes. On a voltage basis the half-width (width at 1/2 voltage) of the main lobe is about 10°. The first minimum is at 10° and has a magnitude of 5% of the peak value. Lobes of approximately 12% appear at 12°, 25° and 50°, and a smaller lobe at 85°. These secondary lobes may be to some extent due to the back radiation of the wave guide in which lobes appear at about 25°, 50° and 95°. In the horizontal patterns of the paraboloid, lobes at 25°, 50° and 90° appear with more or less consistent crystal reading magnitude. (See Dwg. #241).

In the vertical plane the main lobe of the pattern is almost identical with that of the horizontal pattern. Secondary lobes of approximately 12% appear at 12°, 18°, 25°, 35° and 42°. In the 45° plane the pattern is quite similar.

Keeping the mouth of the wave guide in the focal plane and displacing it from the focus causes marked changes in the pattern. As the pipe is displaced horizontally, the horizontal pattern becomes asymmetrical. The main lobe is shifted off the axis in the direction of displacement, this shift increasing with increasing displacement. A displacement of $\lambda/8$ gives a shift of 3°; $\lambda/4$ gives 5°. As the displacement is increased, a lobe at 12° on the side opposite the displacement increases in magnitude, being 12% at zero displacement, 18% at $\lambda/8$ 19% at $\lambda/4$. Other lobes become broader and a little higher. (See Dwg. #242).

As the pipe is displaced vertically, the central position of the main lobe is changed very little. The main lobe spreads out at the base to include the secondary lobes near it. Other secondary lobes become at first larger and then very small. The pattern remains symmetrical. (See Dwg. #243).

As the mouth of the pipe is displaced along the axis, a similar but less marked broadening of the main lobe is observed. (See Dwgs. #244 and #245).

Rotating the pipe 6° about a vertical axis through the focus makes little change in the pattern. An experiment was conducted to find the effect of bringing the wave guide back through the edge of the paraboloid. (See Fig. 2). No effect on the pattern was observed.

FIG. 2

It was thought that if standing waves were set up on the outside of the pipe, they might be removed by painting the pipe with aquadag. No effect on the radiation pattern was observed.

The wave guide was replaced by one whose central portion was only half as wide i.e. 2 cm. x 5.5 cm. No change in the pattern was observed.

The radiation pattern of the wave guide differs markedly from the theoretical pattern. The theoretical pattern is quite smooth; the experimentally obtained pattern contains many lobes. It was thought that the secondary lobes in the pattern of the paraboloid might be to some extent due to the lobes in the pattern of the open pipe. The pipe is made with a 90° bend 1λ from the mouth. A 1λ extension at the mouth of a 1λ horn produces a small improvement in the pattern of the wave guide but little improvement in the pattern of the paraboloid.

2. <u>Wave Guide - Back Feed - and Plane Reflector (Dwg. #246)</u>

A wave guide was fed in through the back of the paraboloid and a plane circular reflector placed in front. Best results were obtained with a reflector 1λ in diameter at the focus and the mouth of the wave guide in an optimum position near the reflector. Here the pattern is quite comparable with the best obtained with the wave guide fed in from the front. As the wave guide is moved away from the optimum position, the main lobe becomes wider and secondary lobes become relatively larger. This, and the fact that there is a lobe at the angle at which the mouth of the pipe is looking past the edge of the reflector, suggest that the lobes in the pattern of the wave guide contribute somewhat to the secondary lobes in the paraboloid patterns obtained. (See Dwg. #246)

Other positions of the reflector give less satisfactory patterns.

Rotating the reflector about a vertical axis through the focus does not deflect the main lobe. The beam can be deflected by moving the reflector horizontally in the focal plane. Such a displacement of $\lambda/4$ deflects the beam about 4° in the direction of the displacement but brings up a high lobe (45%) at 14° on the opposite side.

A $\lambda/2$ reflector at the focus with the mouth of the wave guide at the optimum position gives a pattern comparable with that of a 1λ reflector. A good pattern has not been obtained with a $3\lambda/2$ reflector.

It is seen that the reflection is not specular. The reflector must resonate with the radiation and remit it in some way. With the reflector midway between the focus and the vertex, and the mouth of the wave guide at the vertex, the pattern would be the same as is obtained with a wave guide at the focus if the reflection were specular. The pattern is quite different. It is difficult to come to any conclusion on this point because of the possible effect on the radiation pattern of the wave guide.

3. Dipole and Plane Reflector

With a circular plane reflector 1λ in diameter at the focus, and a dipole in the optimum position, 3.2 cm. inside the reflector, the radiation pattern consists of a main lobe on the axis of the paraboloid of half width, 13°, and a secondary lobe of 12% at 25° on each side. As the dipole is moved along the axis either way from the optimum position, the main lobe becomes broader and secondary lobes more numerous and larger. Similar results are obtained with $\lambda/2$ and $3\lambda/2$ reflectors and with the dipole at the focus and the reflector at the optimum position 2.2 cm. outside.

In the vertical plane the half-width of the main lobe is 13°. The first minimum is 12% at 12°. The secondary lobes are about 15% at 15°. Other secondary lobes appearing on one side are probably due to asymmetry in the experimental arrangement. Asymmetry is in evidence in a 2° deflection of the main lobe.

Displacing the dipole horizontally deflects the main lobe from the axis without producing any serious asymmetry. A deflection of 2° is produced by a displacement of $\lambda/8$, 4° by $\lambda/4$. The number of secondary lobes is increased but none is greater than 12%.

Displacing the reflector $\lambda/4$ horizontally deflects the main lobe 4° in the direction of the displacement. On the opposite side is one broad secondary lobe of a little less than 20% at 25°. On the other side are three lobes of 10%. The half-width of the main lobe is 15°. In the vertical plane the half-width is 13° and there are no lobes greater than 10%.

Displacing the reflector $\lambda/4$ vertically produces a vertical deflection of the main lobe of 3°. The half-width is 14°. There are no lobes greater than 12%. In the horizontal plane the half-width is 15°. There is one lobe of 14%. This may be due to an asymmetry in the pattern which is indicated by a small deflection of the main lobe.

4. Dipole and Line Reflector

With a dipole at the focus and a $\lambda/2$ line reflector at a distance $\lambda/8$ outside the focus, the pattern is quite clean. In the horizontal plane, the half-width of the main lobe is 14°. A secondary lobe of about 5% appears at 25° on each side. No other lobes are observed. If the reflector is moved outwards a few millimeters, the main lobe becomes wider and secondary lobes a little greater. At a distance of $\lambda/4$ the pattern is the same as at $\lambda/8$. A rough experiment indicated that it might also be the same at $3\lambda/8$. Moving the dipole and the reflector short distances along the axis makes little change in the pattern.

In the vertical plane, the half-width of the main lobe is 10°. There are more secondary lobes of less than 10%.

Horizontal displacement of the reflector does not deflect the main lobe, but produces a number of asymmetrical secondary lobes. Rotating the reflector 6° about a vertical axis, and rotating 6° and displacing $\lambda/4$ produce little change in the pattern.

The main lobe is deflected by displacement of the dipole and reflector together. A horizontal displacement of $\lambda/8$ gives a deflection of 2° and a horizontal displacement of $\lambda/4$ gives 3° deflection. These patterns show only one secondary lobe of about 10% on the side opposite the deflection. A vertical displacement of $\lambda/4$ displaces the main lobe about 2°.

II <u>30 INCH PARABOLOID - FOCAL LENGTH ~10.5 INCHES</u>

The pattern obtained with a wave guide fed in from the front seems to be little different from that of the paraboloid discussed in Section I of this report. The secondary lobes are, perhaps, smaller. The half-width of the main lobe is about the same.

III <u>48 INCH PARABOLOID WITH FOCUS NEAR PLANE OF MOUTH</u>

1. <u>Dipole and Line Reflector (Dwgs. #248 and #249)</u>

In the horizontal plane the main lobe has a half-width of 10°. Secondary lobes of less than 10% occur at 80°. (See Dwg. #248). In the vertical plane, the half width is about 7°. (See Dwg. #249). The power gain over a dipole is approximately 700.

It was thought that the concentric feed used in the GL trailer might result in an asymmetry in the pattern.

No asymmetry was found when the outside conductor of the concentric cable was equipped with or without a skirt. Using only a half dipole, with the reflector centred on the centre of the concentric or on the centre of the half dipole, also gives a good pattern. (See Fig. 3). In the case of the half dipole, there is a slight difference in the slopes of the two sides of the main lobe.

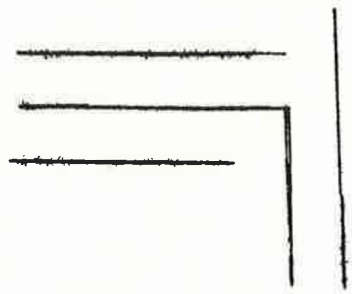


FIG. 3

The beam can be deflected by displacing the dipole and reflector at the same time. Data in this connection is given in Section IV of this report.

2. Dipole and Plane Reflector (Dwg. #247)

The beam can also be deflected by using a 1λ disc reflector at the focus and displacing the dipole. (See Section IV of this report).

IV WOBBLING

Data on wobbling are expressed in tabular form on pages 8 and 9 of this report.

T indicates that the transmitter beam is wobbled.

R indicates that the receiver beam is wobbled.

The split is the angular separation of the signal maxima.

The maximum signal is received when the peak of the transmitter pattern and the peak of the receiver pattern are both on the target. We call this signal 100. Thus, with both beams wobbled the same amount, in the direction of the peak of the radiation pattern, the signal will be 100.

In all others, it will be less than 100. In the case where only one beam is wobbled the peaks are never both in the same direction, and a signal of strength 100 is not obtained.

Let us call S_1 and S_2 the signal strengths received on the split beams where $S1 > S2$. If $F = \frac{S1 - S2}{S_1}$, then the sensitivity is defined as $\frac{dF}{d\theta}$ when the target is on the axis of the system.

The range of scan is arbitrarily defined here as the angular separation of the positions at which one signal is very small and the other has a strength of 50.

J.G. Retallack.

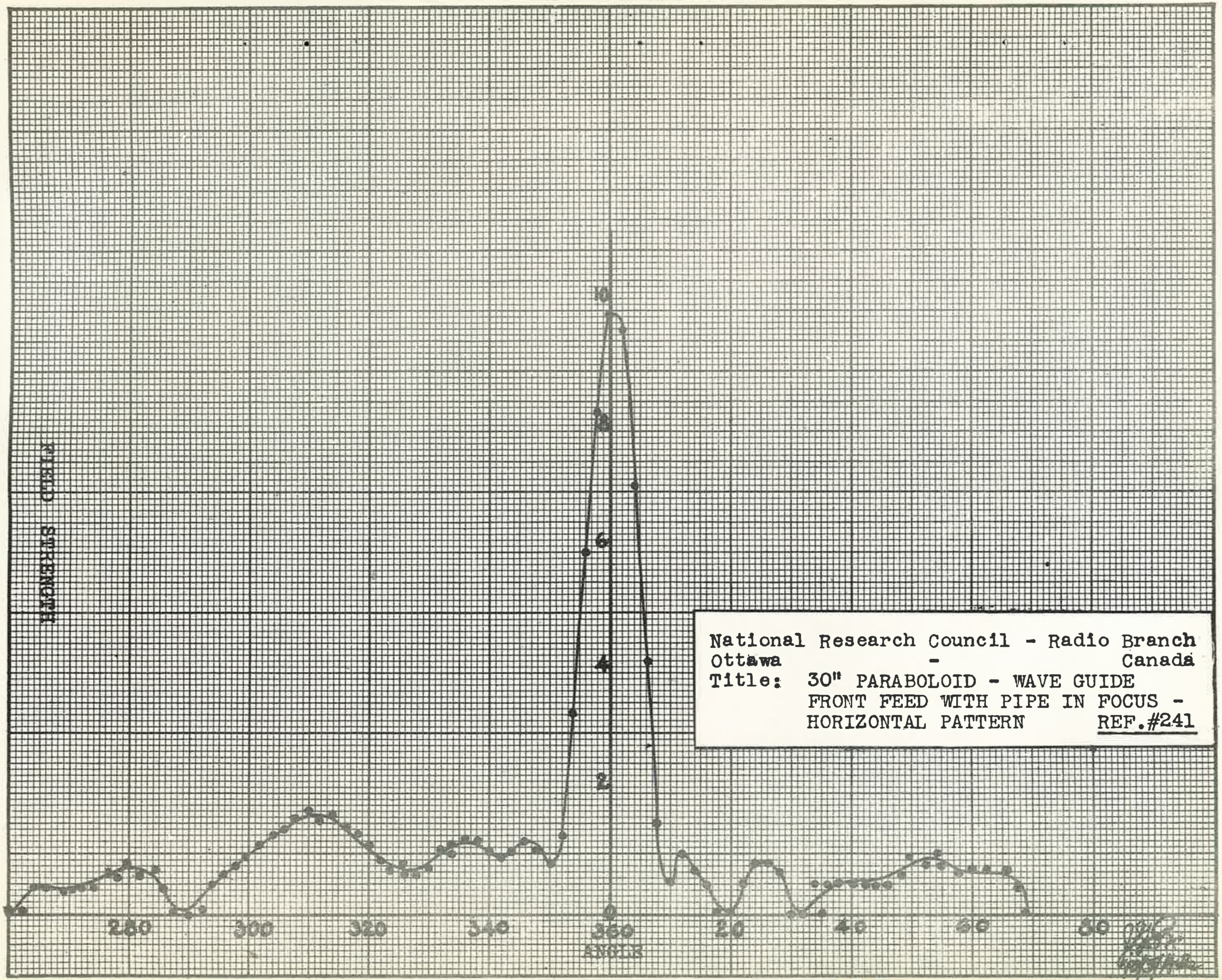
30 in. Paraboloid		Split	Signal on Target	Maximum	Sensitivity	Range of Scan
Plane reflector displaced λ/4 horizontally	R	2°	96	98	0.7	17.5°
	T,R	4.5°	92	100	1.6	~ 15°
Dipole and line reflector displaced λ/4 horizontally	R	4°	85	91	1.4	13°
	T,R	8°	72	100	2.6	~ 21°

Two dipoles and two line reflectors, or two dipoles and one line reflector give splits in the horizontal and vertical directions which are too large to be useful.

48 in. Paraboloid						
Plane reflector and dipole displaced λ/4 horizontally (See Dwg. #247)	R	2.5°	77.5	88	3.7	7.5°
	T,R	5°	59	100	5.9	11°
Dipole and line reflector displaced λ/4 horizontally (See Dwg. #248)	R	3°	78	90	2.6	9°
	T,R	7°	61	100	4.8	> 16°

48 in. Paraboloid		Split	Signal on Target	Maximum	Sensitivity	Range of Scan
Dipole and line reflector displaced vertically $\lambda/16$	R	0.8°	96	98.5	1.9	5.7°
	T,R	1.3°	94	100	2.7	7°
$\lambda/8$ (See Dwgs. #250 & #253)	R	0.8°	95	96.5	2.2	6.0°
	T,R	2.4°	91	100	4.1	6.7°
$3\lambda/16$ (See Dwgs. #251 & #254)	R	2.5°	66	83	8.5	6.9°
	T,R	5.7°	45	100	12.5	10.6°
$\lambda/4$ (See Dwgs. #249, #252 & #255)	R	3.5°	57	75	16.8	6.7°
	T,R	5.9°	28	100	35.0	10.5°

For curves giving additional data see Dwgs. #256, #257 & #258



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Ottawa - Canada
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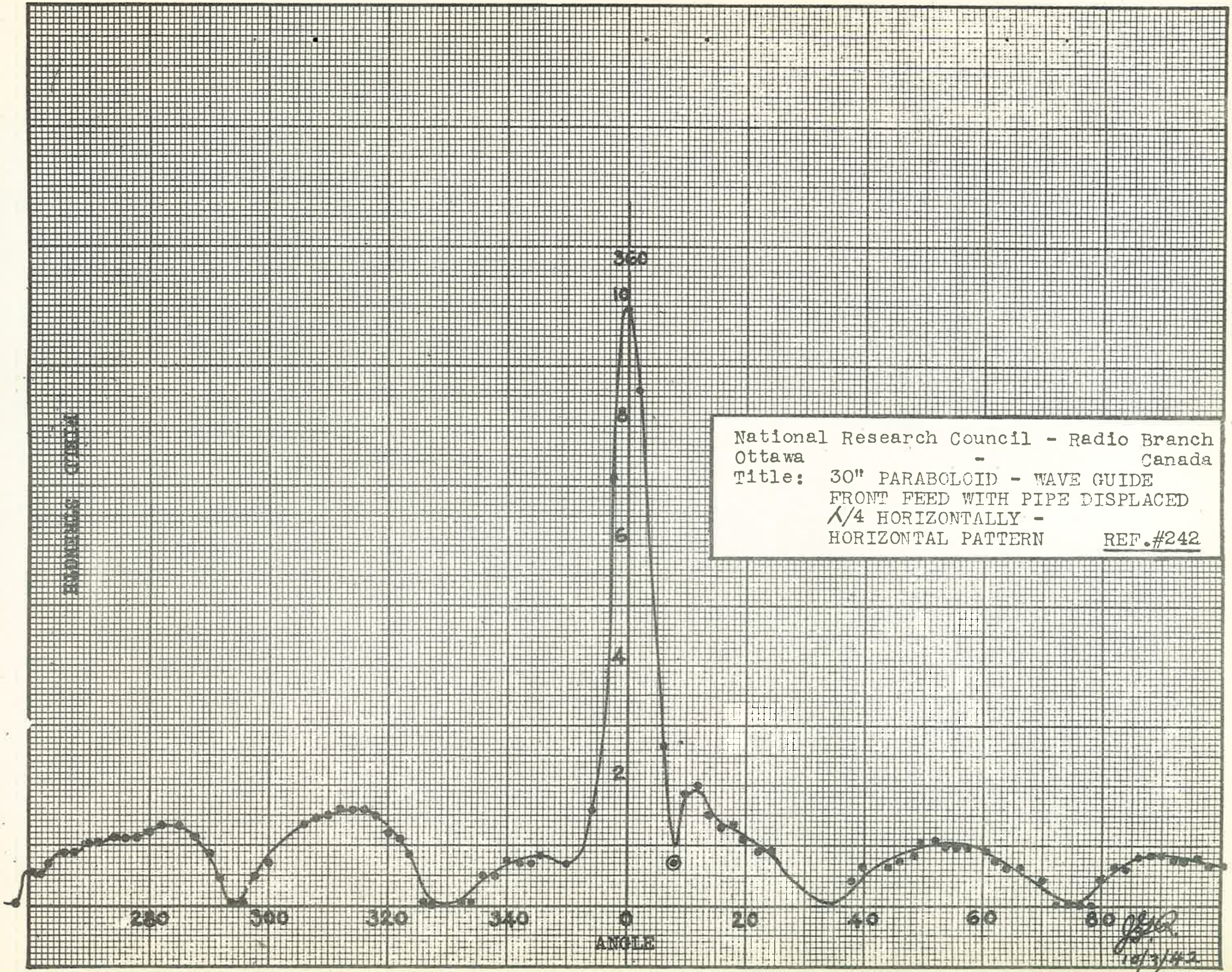
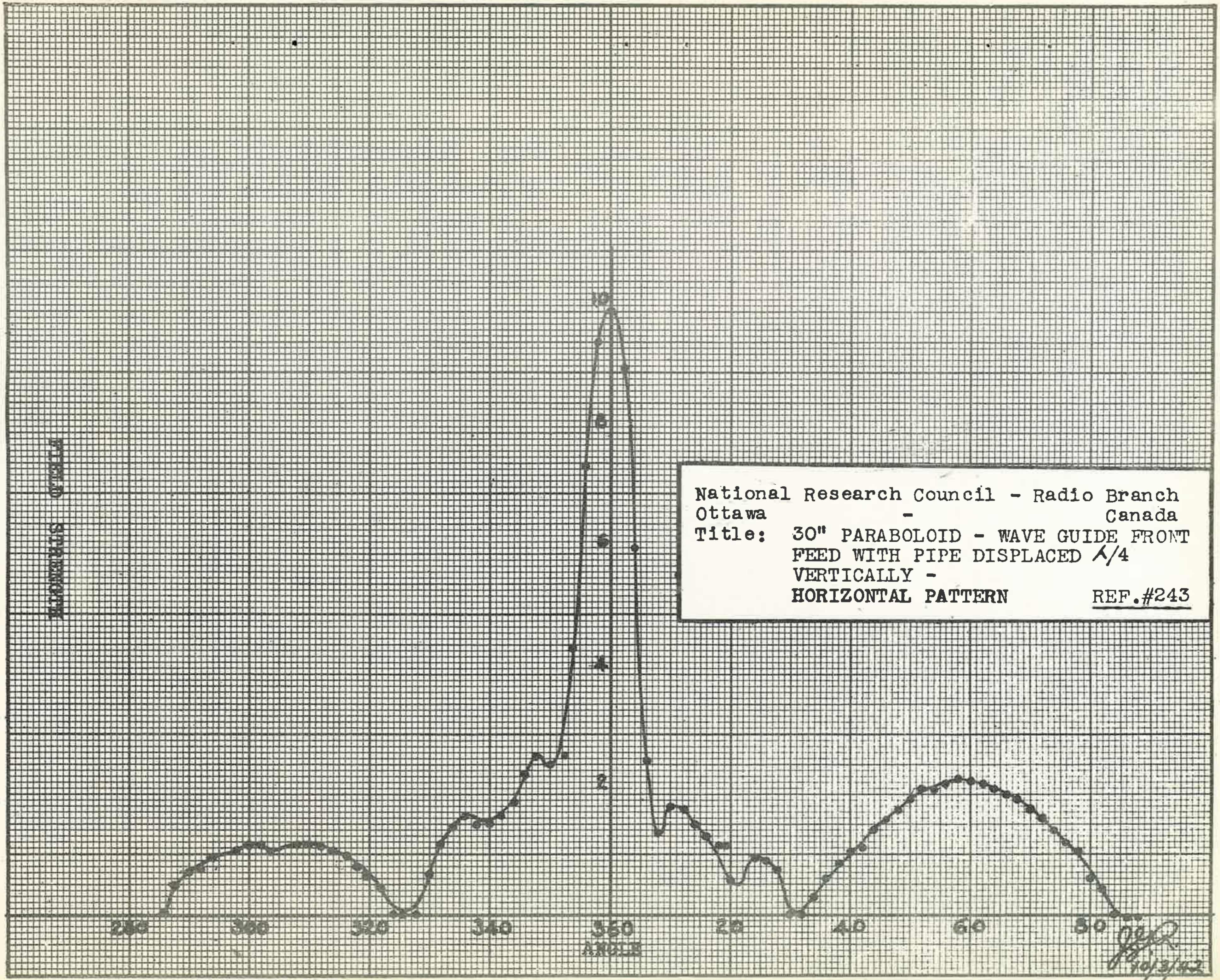
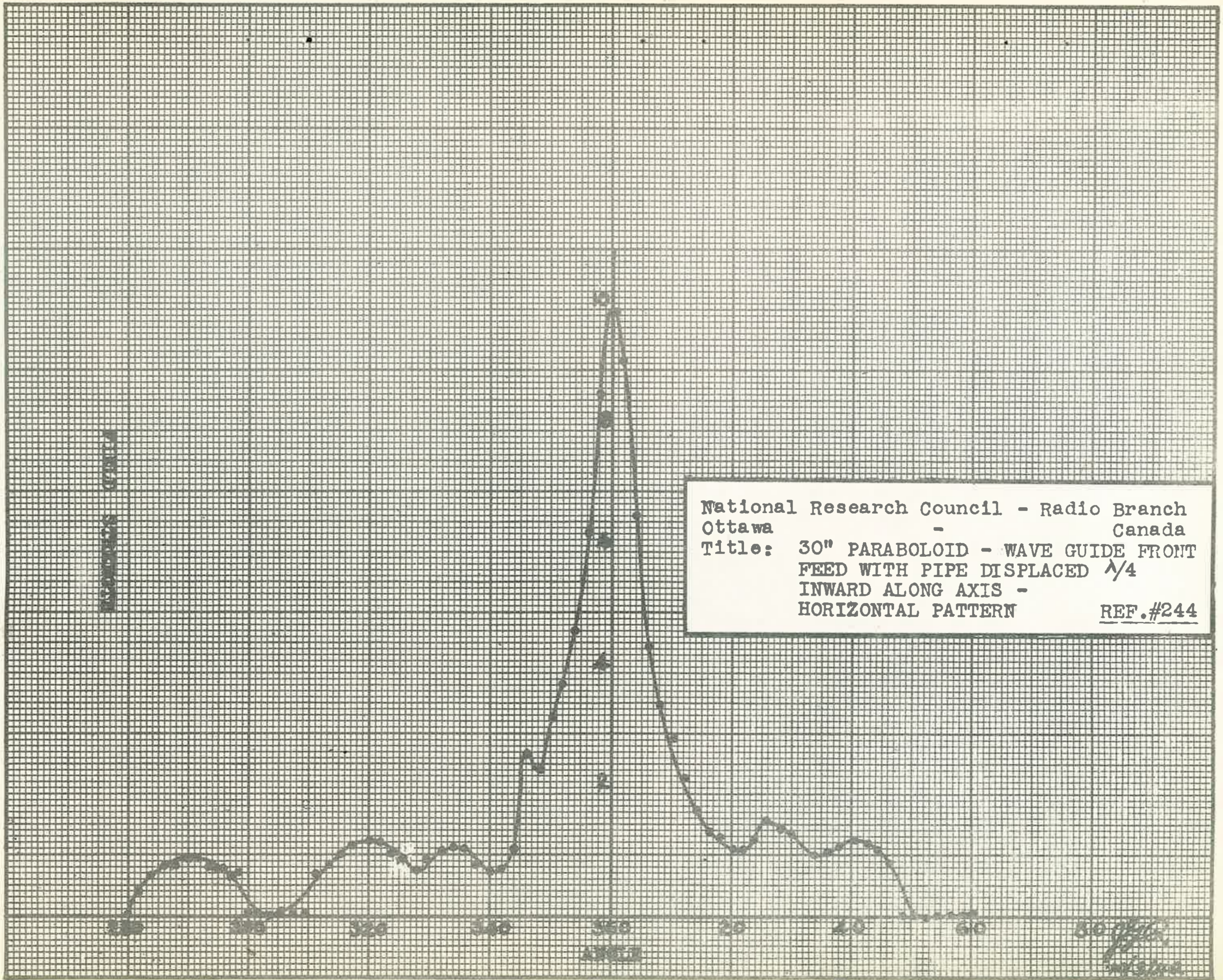

National Research Council - Radio Branch
Ottawa - Canada
Title: 30" PARABOLOID - WAVE GUIDE
FRONT FEED WITH PIPE DISPLACED
λ/4 HORIZONTALLY -
HORIZONTAL PATTERN REF.#242
FIELD STRENGTH
360
10
8
6
4
2
280
300
320
340
0
20
40
60
80
ANGLE
10/3/42


National Research Council - Radio Branch
Ottawa - Canada
Title: 30" PARABOLOID - WAVE GUIDE FRONT FEED WITH PIPE DISPLACED λ/4 VERTICALLY -
HORIZONTAL PATTERN
REF.#243
FIELD STRENGTH
ANGLE
280
300
320
340
360
20
40
60
80
2
4
6
8
10



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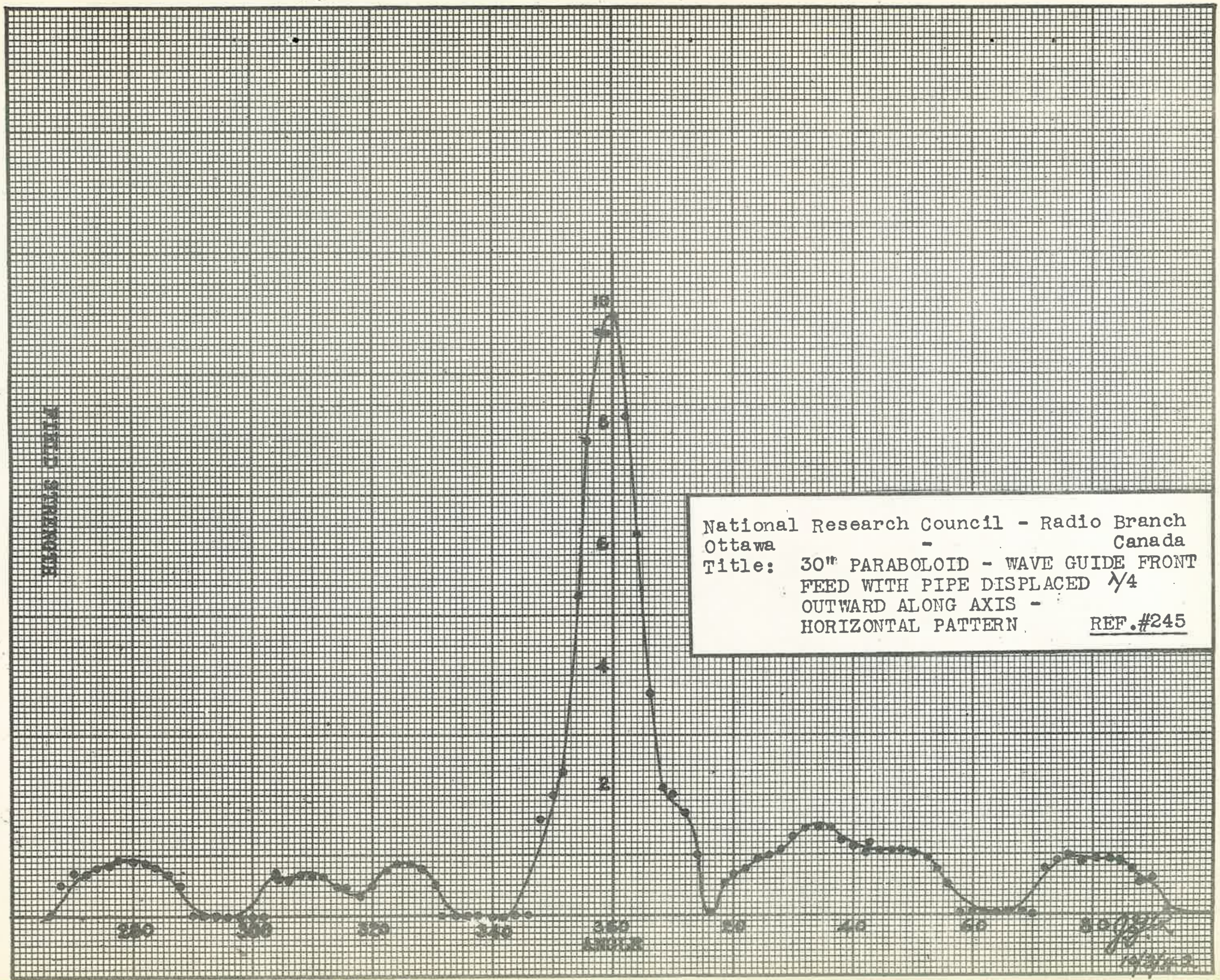
Title: 30" PARABOLOID - WAVE GUIDE FRONT FEED WITH PIPE DISPLACED $\lambda/4$ INWARD ALONG AXIS - HORIZONTAL PATTERN

REF. #244



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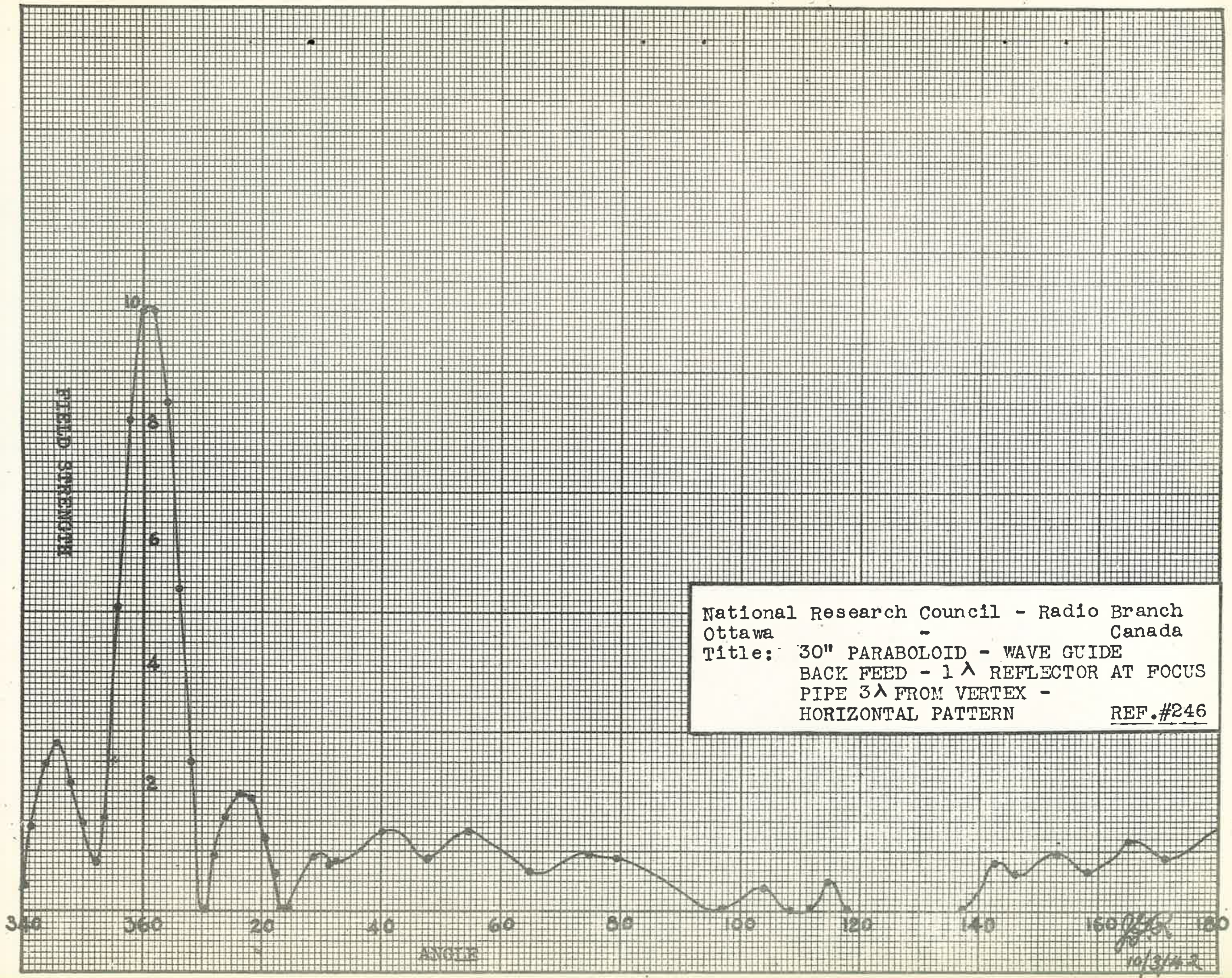
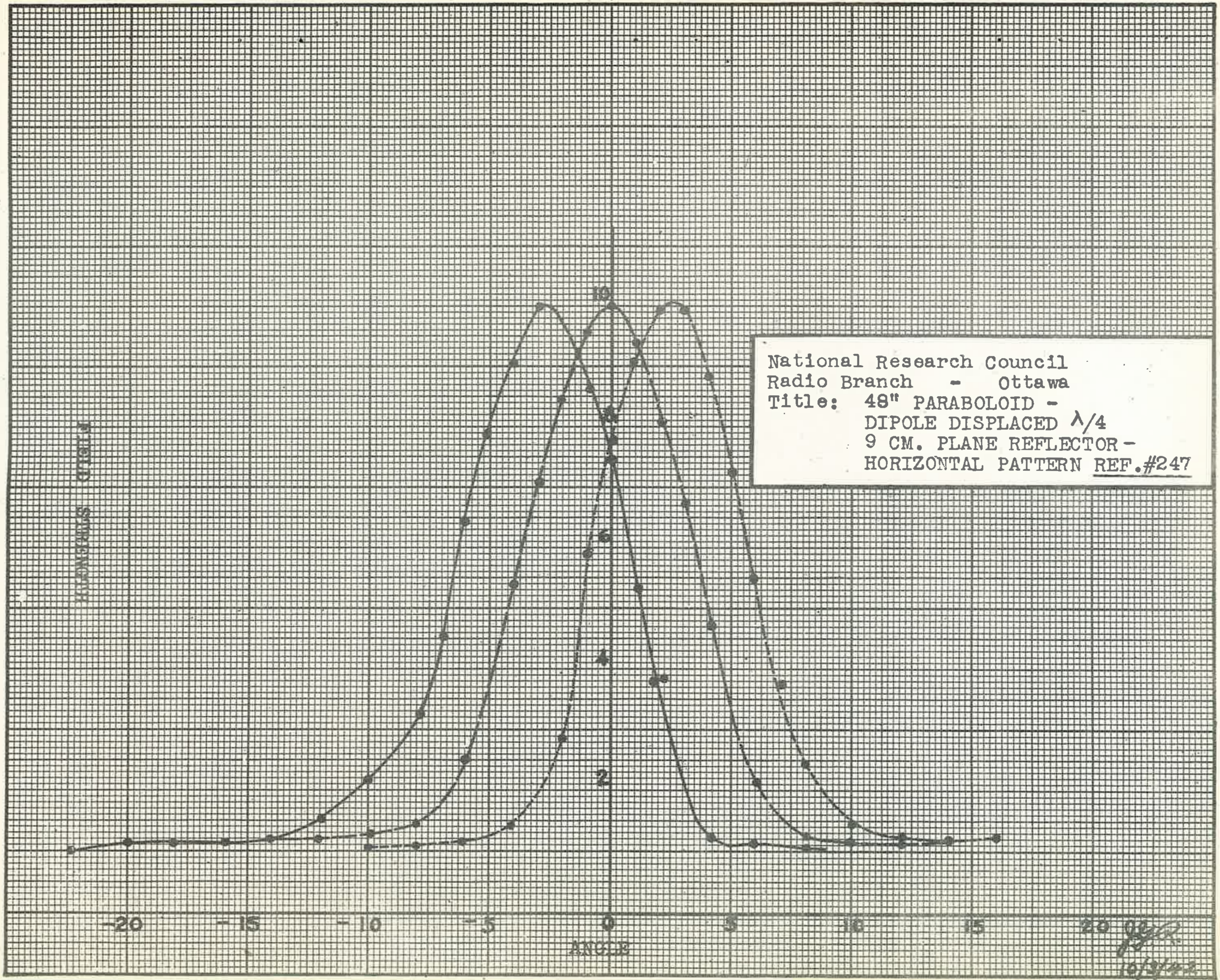
Title: 30" PARABOLOID - WAVE GUIDE FRONT FEED WITH PIPE DISPLACED λ/4 OUTWARD ALONG AXIS - HORIZONTAL PATTERN

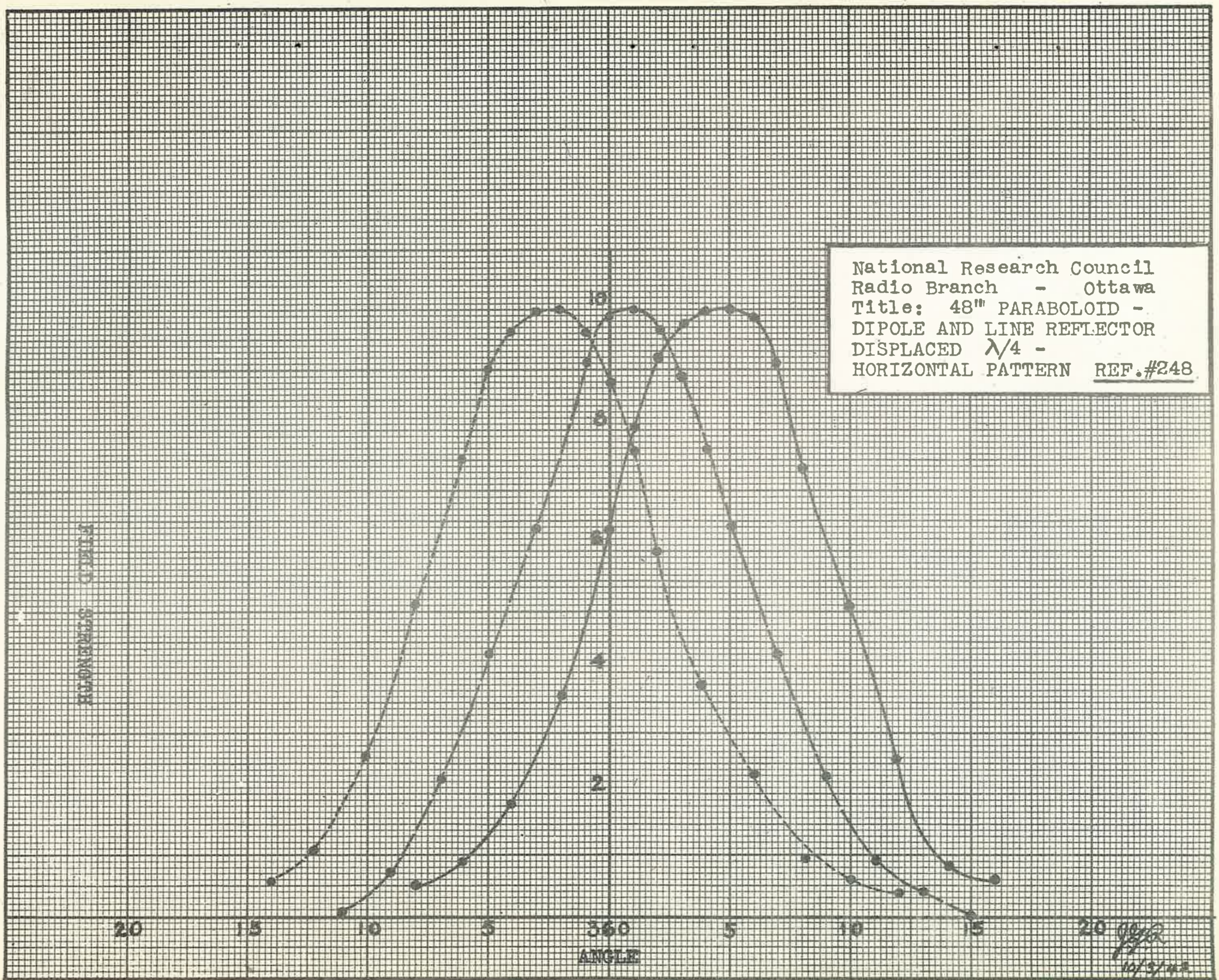
REF. #245



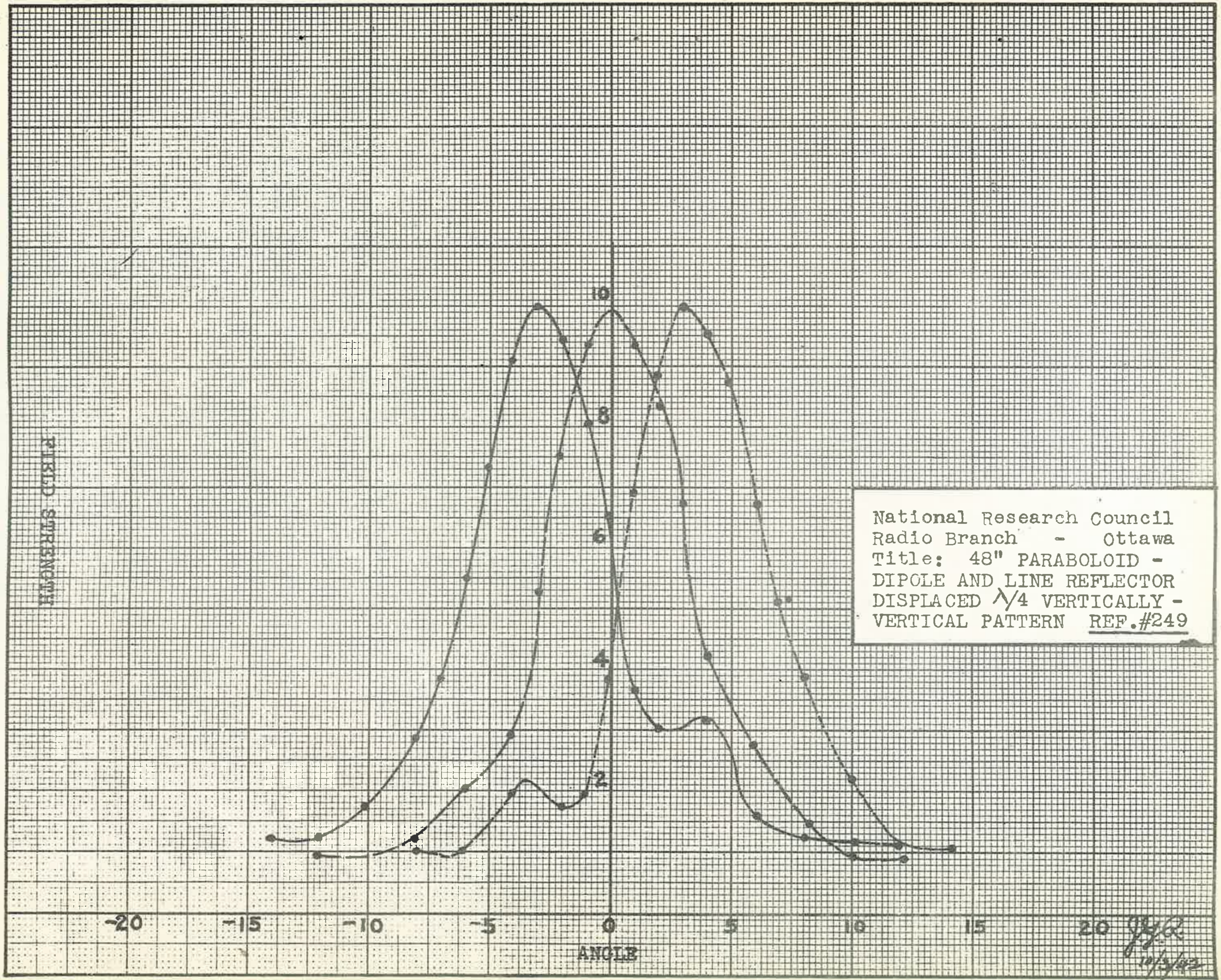
National Research Council - Radio Branch
Ottawa - Canada
Title: 30" PARABOLOID - WAVE GUIDE BACK FEED - 1 λ REFLECTOR AT FOCUS PIPE 3 λ FROM VERTEX - HORIZONTAL PATTERN

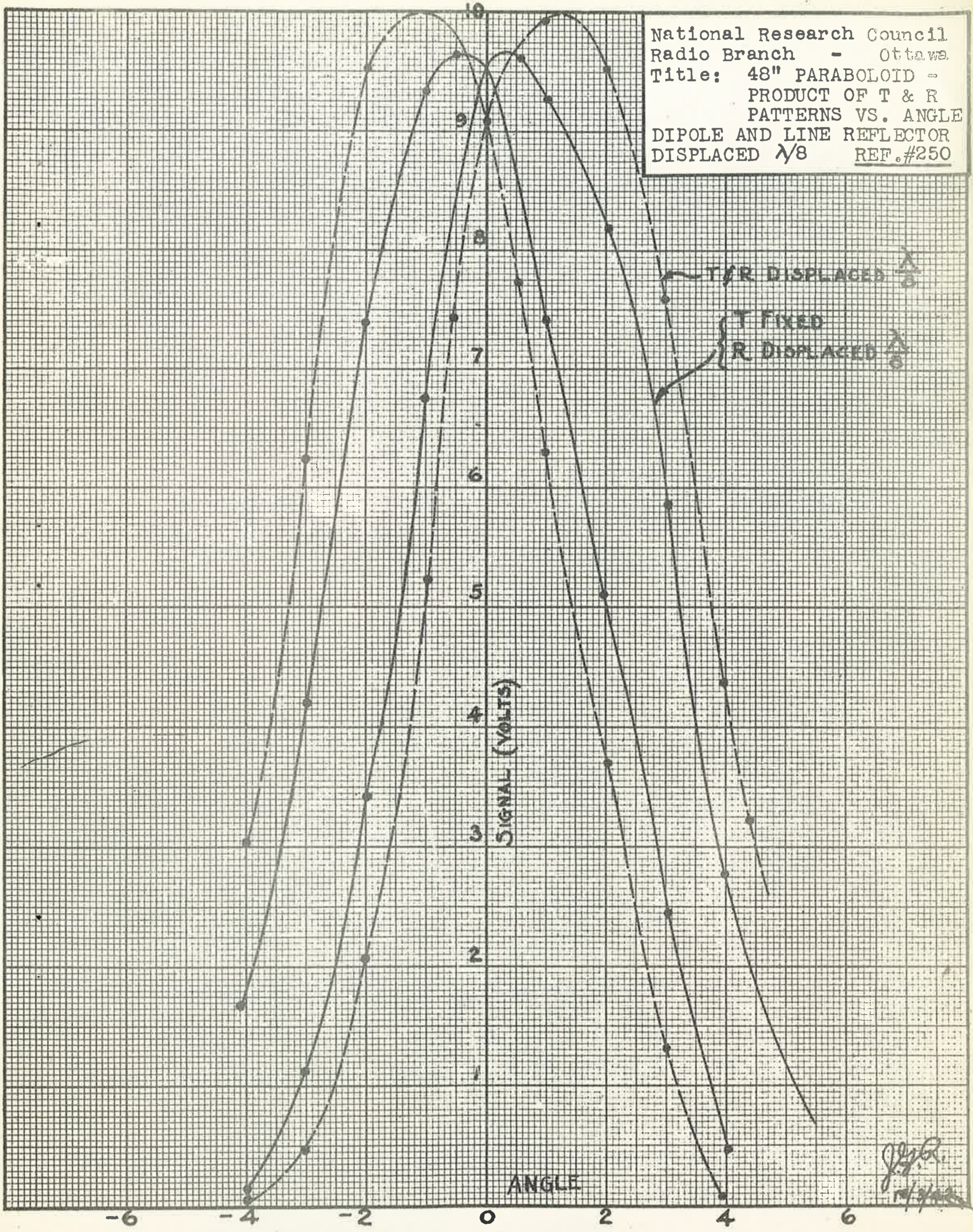
REF. #246


National Research Council
Radio Branch - Ottawa
Title: 48" PARABOLOID -
DIPOLE DISPLACED λ/4
9 CM. PLANE REFLECTOR -
HORIZONTAL PATTERN REF.#247
FIELD STRENGTH
10
6
4
2
-20
-15
-10
-5
0
5
10
15
20
ANGLE
10/3/42



National Research Council
Radio Branch - Ottawa
Title: 48" PARABOLOID -
DIPOLE AND LINE REFLECTOR
DISPLACED λ/4 -
HORIZONTAL PATTERN REF.#248
FIELD STRENGTH
10
8
6
4
2
20
15
10
5
360
5
10
15
20
ANGLE


National Research Council
Radio Branch - Ottawa
Title: 48" PARABOLOID -
DIPOLE AND LINE REFLECTOR
DISPLACED λ/4 VERTICALLY -
VERTICAL PATTERN REF.#249
FIELD STRENGTH
ANGLE
-20
-15
-10
-5
0
5
10
15
20
2
4
6
8
10
10/3/42


National Research Council
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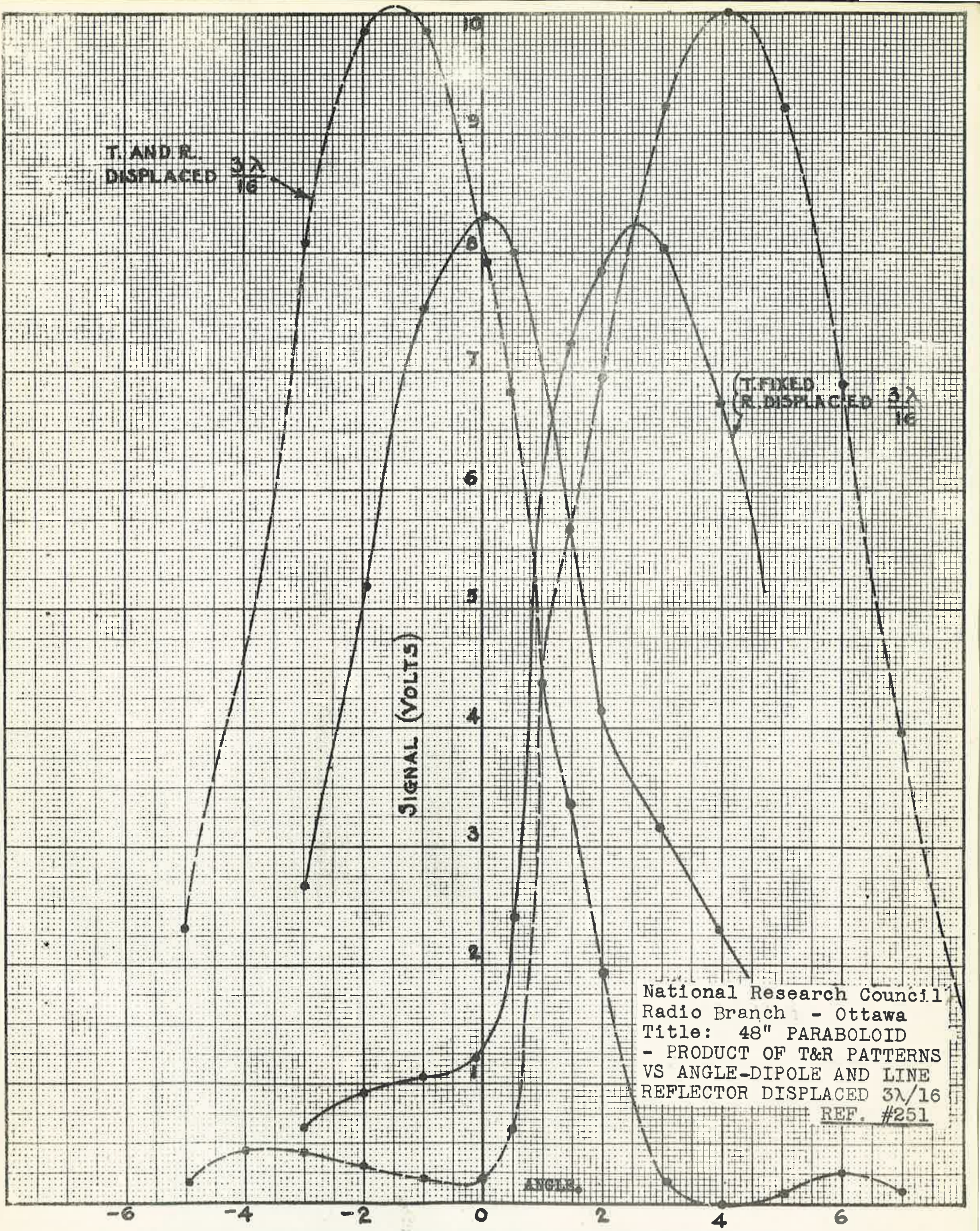
Title: 48" PARABOLOID -
PRODUCT OF T & R
PATTERNS VS. ANGLE
DIPOLE AND LINE REFLECTOR
DISPLACED λ/8 REF.#250
T & R DISPLACED λ/8
T FIXED
R DISPLACED λ/8
SIGNAL (VOLTS)
ANGLE
10
9
8
7
6
5
4
3
2
1
-6
-4
-2
0
2
4
6



National Research Council
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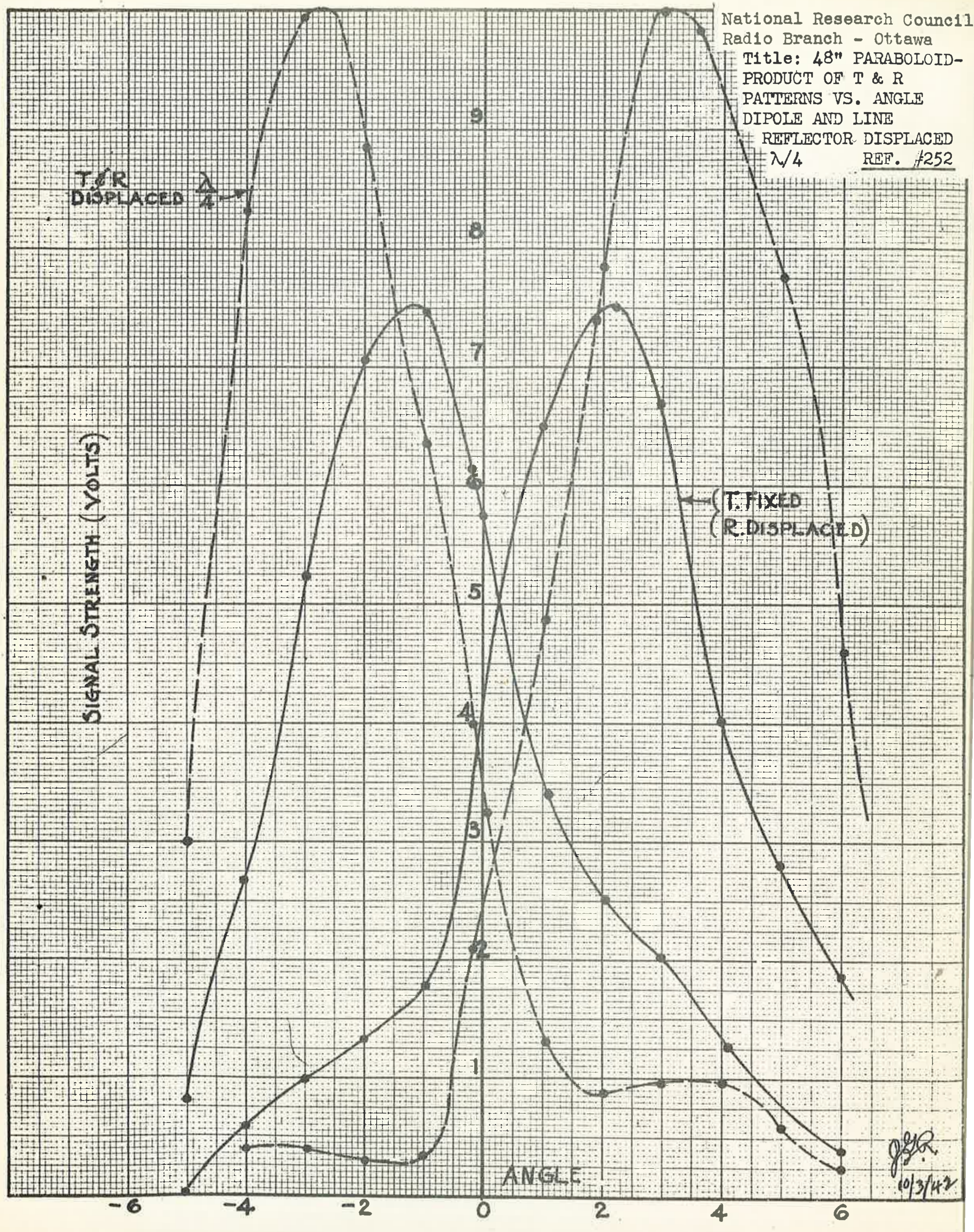
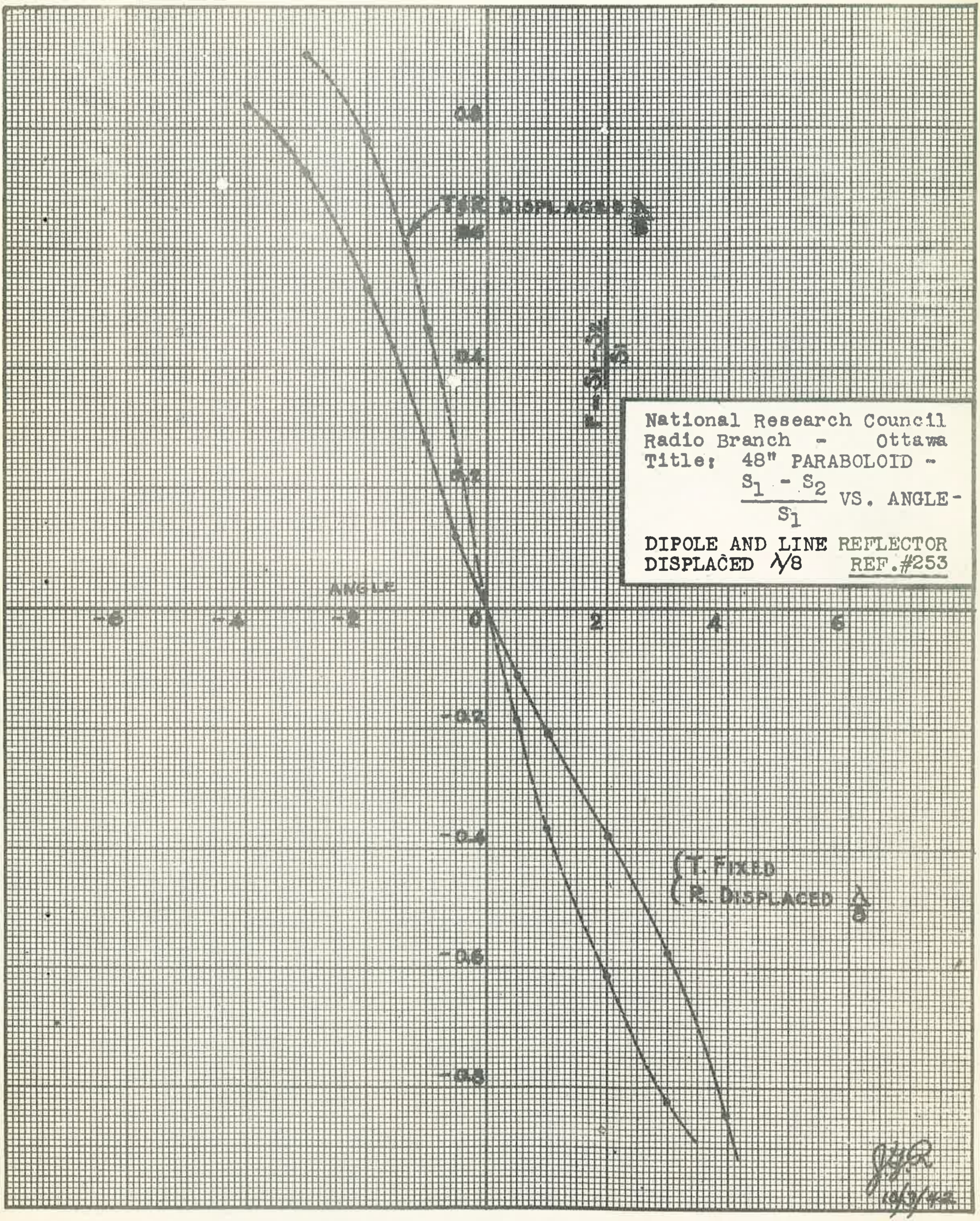
- PRODUCT OF T&R PATTERNS
VS ANGLE-DIPOLE AND LINE
REFLECTOR DISPLACED 3λ/16
REF. #251


National Research Council
Radio Branch - Ottawa
Title: 48" PARABOLOID-
PRODUCT OF T & R
PATTERNS VS. ANGLE
DIPOLE AND LINE
REFLECTOR DISPLACED
λ/4 REF. #252
T & R DISPLACED λ/4
T. FIXED
R. DISPLACED
SIGNAL STRENGTH (VOLTS)
ANGLE
9
8
7
6
5
4
3
2
1
-6
-4
-2
0
2
4
6
10/3/42


National Research Council
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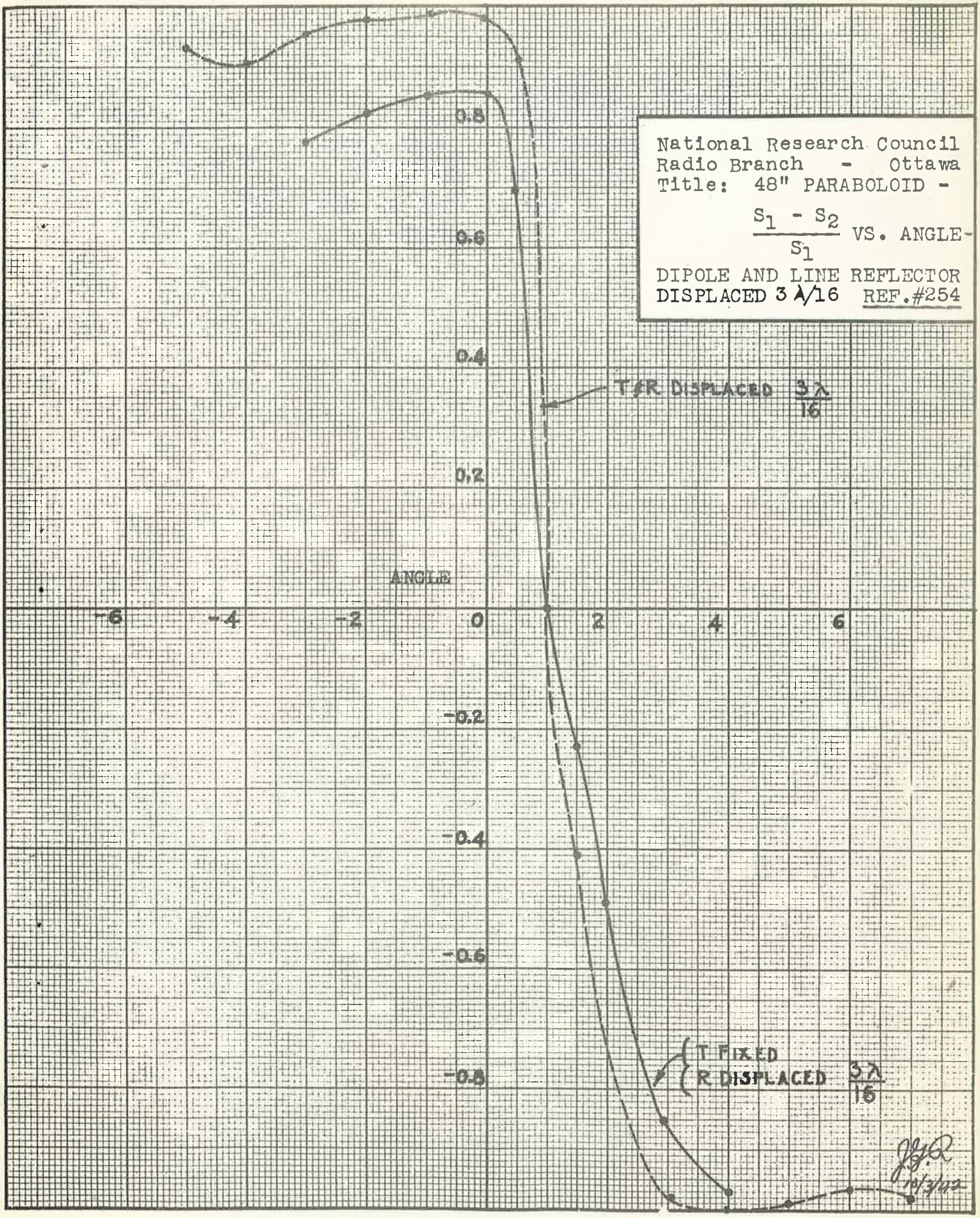
Title: 48" PARABOLOID -
$\frac{S_1 - S_2}{S_1}$ VS. ANGLE-
DIPOLE AND LINE REFLECTOR
DISPLACED λ/8 REF.#253
T&R DISPLACED λ/8
T. FIXED
R. DISPLACED λ/8
ANGLE
$F = \frac{S_1 - S_2}{S_1}$
0.6
0.4
0.2
-0.2
-0.4
-0.6
-0.8
-6
-4
-2
0
2
4
6
J.G.R.
10/3/42



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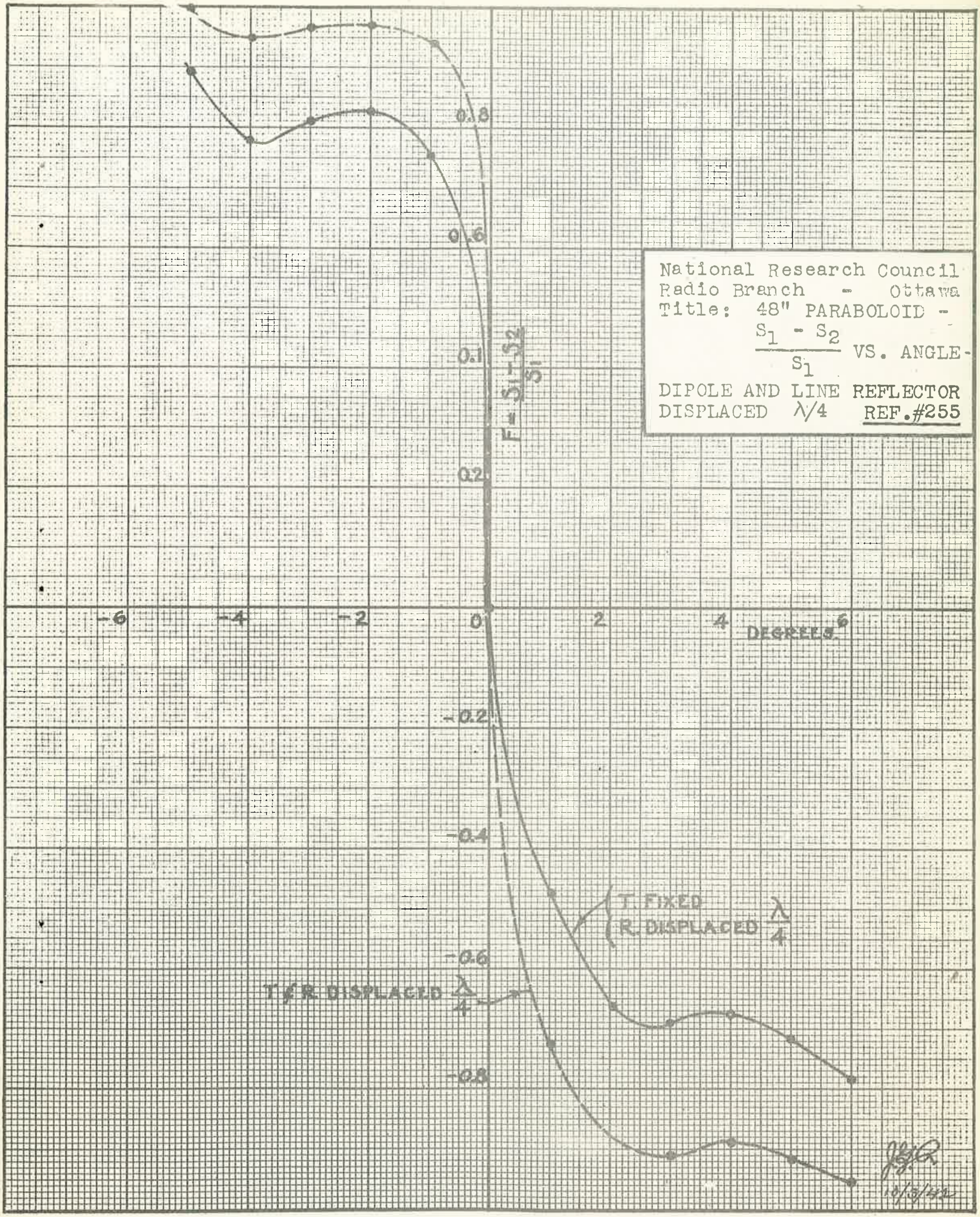
Title: 48" PARABOLOID -
$\frac{S_1 - S_2}{S_1}$ VS. ANGLE-
DIPOLE AND LINE REFLECTOR
DISPLACED 3 λ/16 REF.#254
T/R DISPLACED 3λ/16
T FIXED
R DISPLACED 3λ/16
ANGLE
0.8
0.6
0.4
0.2
-0.2
-0.4
-0.6
-0.8
-6
-4
-2
0
2
4
6


National Research Council
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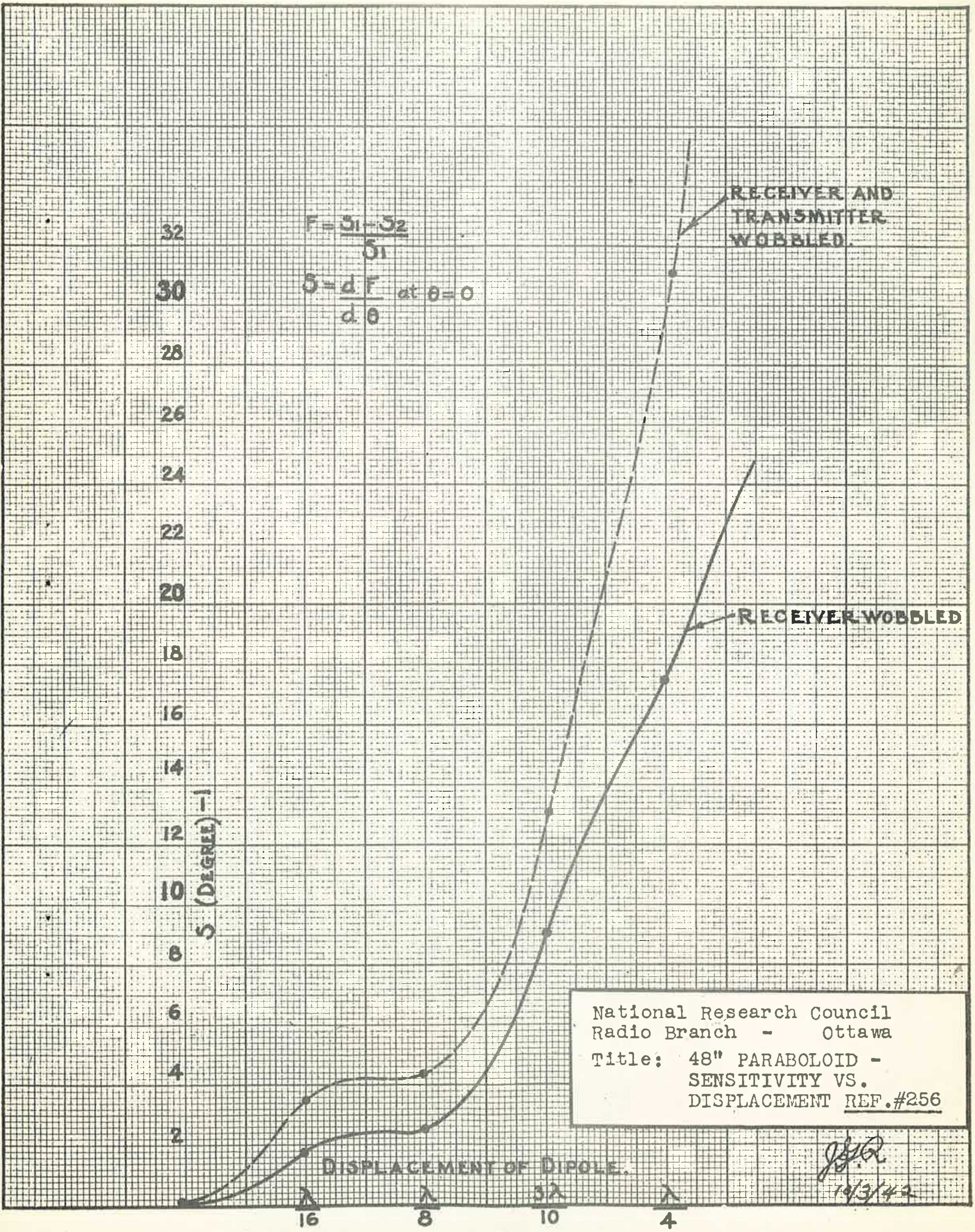
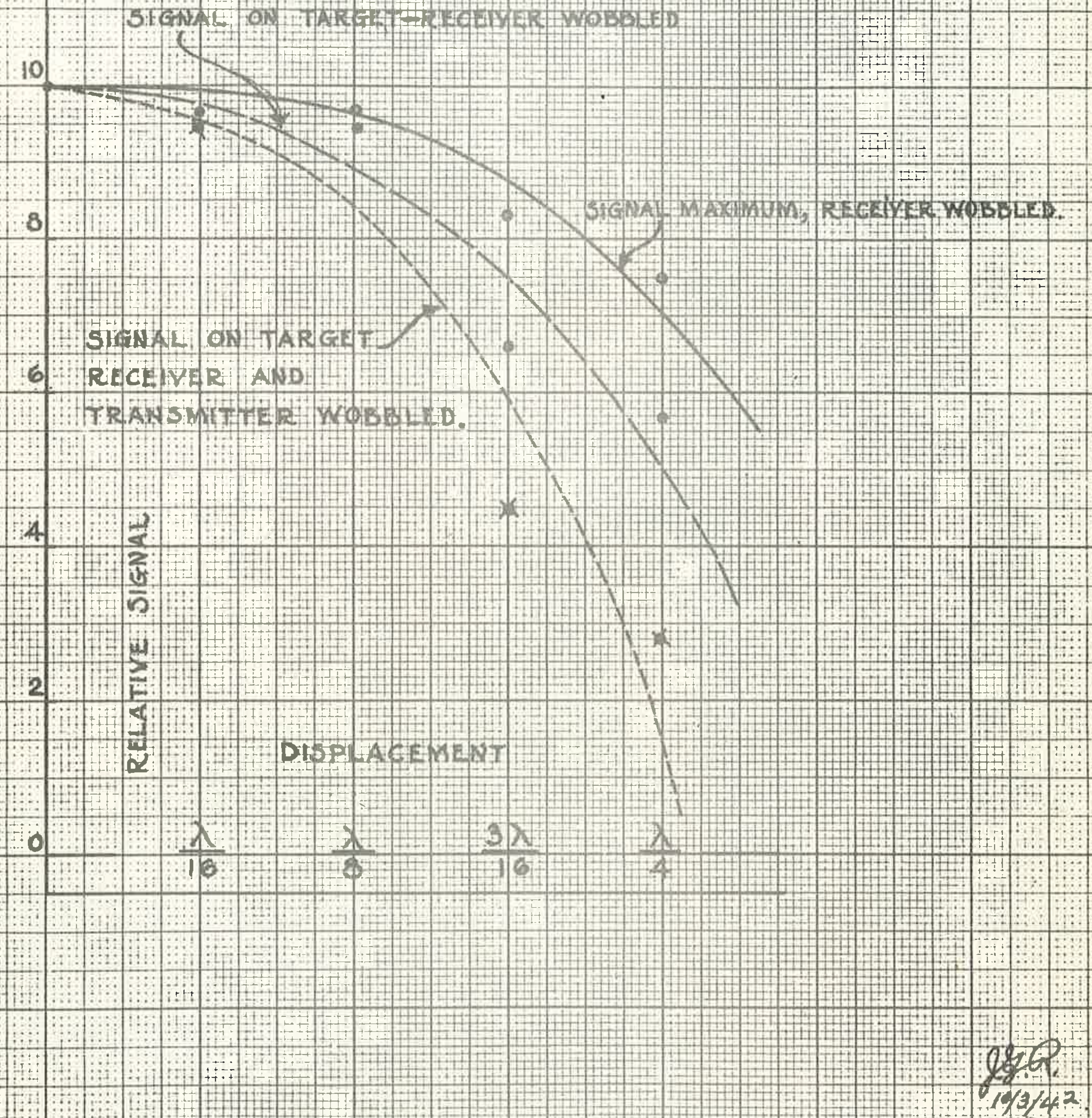
Title: 48" PARABOLOID -
$\frac{S_1 - S_2}{S_1}$ VS. ANGLE-
DIPOLE AND LINE REFLECTOR
DISPLACED λ/4 REF.#255
$F = \frac{S_1 - S_2}{S_1}$
0.8
0.6
0.4
0.2
-6
-4
-2
0
2
4
6
DEGREES
-0.2
-0.4
-0.6
-0.8
T. FIXED
R. DISPLACED $\frac{\lambda}{4}$
T & R DISPLACED $\frac{\lambda}{4}$
10/3/42



RECEIVER AND TRANSMITTER WOBBLED.
RECEIVER WOBBLED
F = (S1 - S2) / S1
S = dF / dθ at θ = 0
S (DEGREE)^-1
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
DISPLACEMENT OF DIPOLE.
λ/16
λ/8
3λ/10
λ/4
National Research Council
Radio Branch - Ottawa
Title: 48" PARABOLOID - SENSITIVITY VS. DISPLACEMENT REF.#256
JGR
14/3/42



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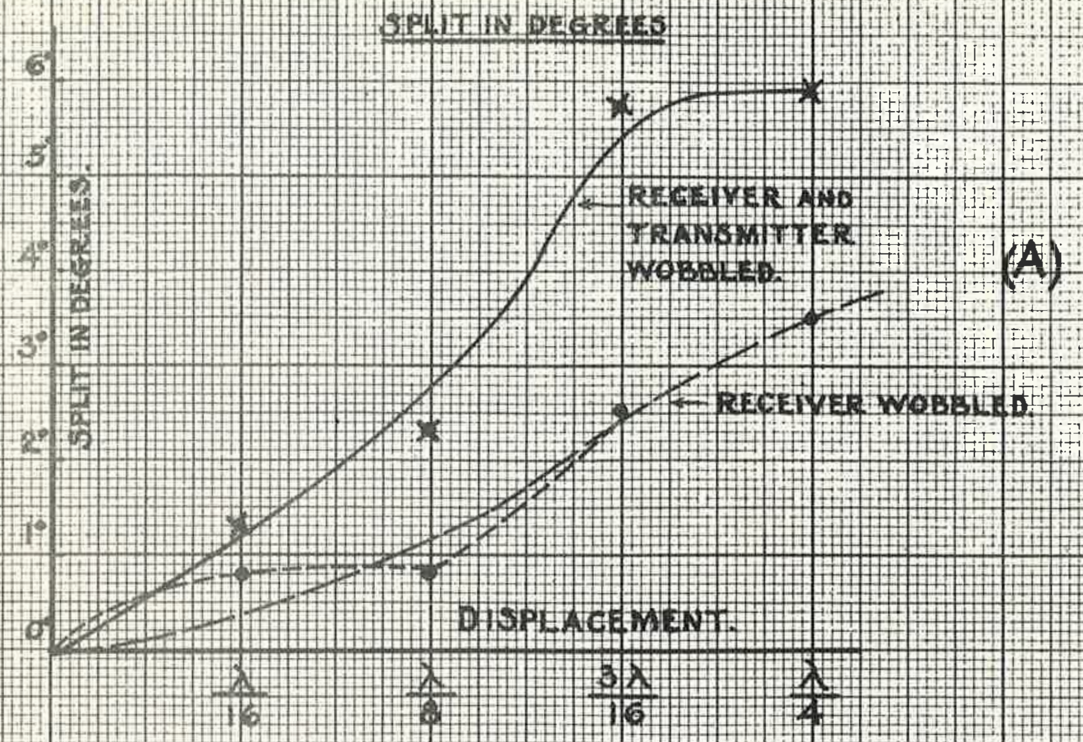
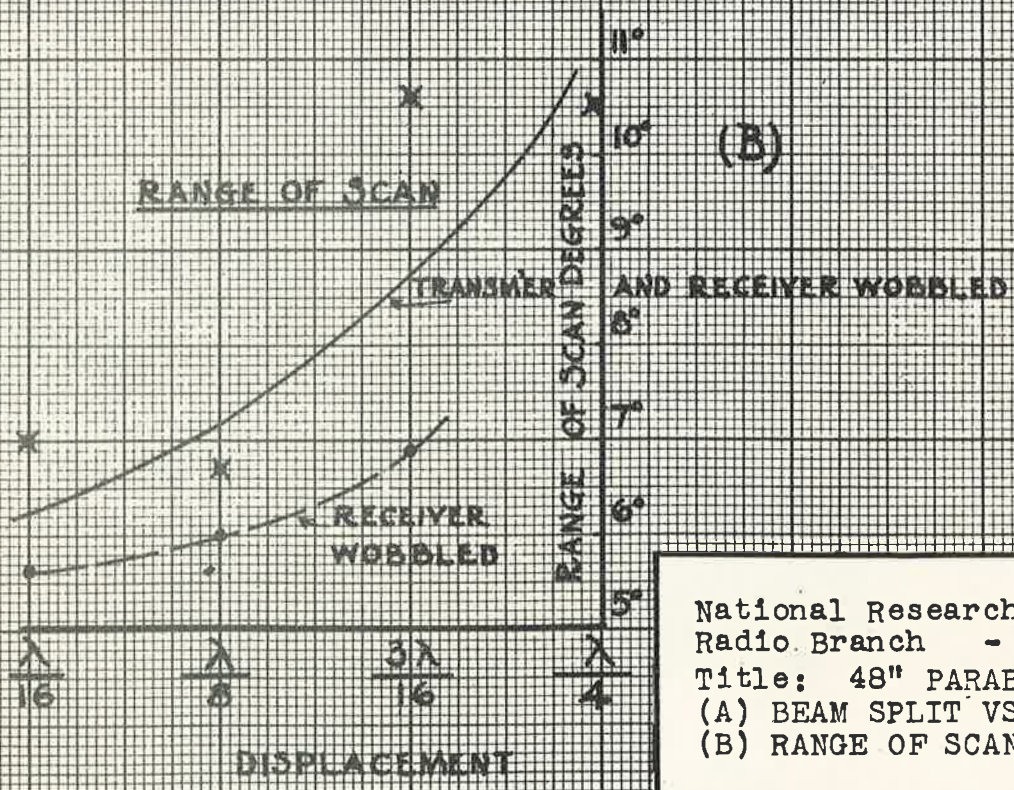
Title: 48" PARABOLOID -
SIGNAL STRENGTH VS. DISPLACEMENT

REF.#257





JGR
10/3/42

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Title: 48" PARABOLOID -
(A) BEAM SPLIT VS. DISPLACEMENT
(B) RANGE OF SCAN VS. DISPLACEMENT
REF.#258