**Preliminary report on second-order beams of the AN/FPS-502 antenna**
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NATIONAL RESEARCH COUNCIL OF CANADA
RADIO AND ELECTRICAL ENGINEERING DIVISION



# PRELIMINARY REPORT ON SECOND-ORDER BEAMS OF THE AN/FPS-502 ANTENNA

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## ABSTRACT

Radiation patterns of a production model of the AN/FPS-502 antenna have been taken in order to locate and measure the second-order beams. No second-order beams were found at a frequency of 2700 Mc/sec., while at 2800 and 2900 Mc/sec. the second-order beams were 14.5 percent and 12.7 percent, respectively. Percentages are in terms of field strength and are relative to the peak of the main beam.

A modified feed using quarter-wave chokes between the slotted array and the horn was then installed and all patterns were repeated. In this case there were no second-order beams at 2700 and 2800 Mc/sec., but at a frequency of 2900 Mc/sec. the second-order beam was 6.5 percent.

In no case were second-order beams found on the load side of the main beam. In all cases they were found between the main beam and the feed end of the array, with one second-order beam situated slightly above and the other slightly below the horizontal plane containing the main beam.

At all three frequencies there was a reduction in antenna gain when the modified feed was used.

# PRELIMINARY REPORT ON SECOND-ORDER BEAMS OF THE AN/FPS-502 ANTENNA

- W. Lavrench -

## INTRODUCTION

The AN/FPS-502 Radar when put into service was found to have a double picture on the PPI screen on very strong permanent echoes. The second paint of the permanent echoes lagged the first by about 30 to 35 degrees and indicated the presence of a side lobe between the main beam and the feed end of the slotted waveguide array. Several measurements were made in the field of the relative sizes of the side lobe and the main beam. Indications were that the side lobe was a second-order beam[1] and hence did not lie in the same plane containing the peak of the main beam and the array. This beam was known to exist but had given no trouble previously, probably because the sites used on early experimental tests were considerably lower than the operational site. It was therefore decided to take accurate patterns of the antenna.

A production model of the antenna was then obtained from the manufacturer and installed on a turntable. A tilt mechanism, consisting of a pivot under the antenna and a turnbuckle at the back, was installed. This made it possible to tilt the whole antenna assembly back and forth and thereby locate and measure the second-order beam accurately.

## PATTERNS OF THE PRODUCTION MODEL

Horizontal patterns were taken at 2700, 2800, and 2900 Mc/sec. At each frequency a set of patterns was obtained by tilting the complete antenna back about $\frac{1}{2}°$ to 1° between patterns. A sample of the patterns so obtained is shown in Figs. 1 to 12. The distance "d" is a measure of the amount of tilt and can be converted readily to degrees by means of Fig. 21. In the antenna patterns shown, the load end of the array is on the right end of the chart. The behaviour of the second-order and main beams can be seen more readily in Fig. 15 which is obtained by plotting the information contained in Figs. 1 to 12. Fig. 15 is then used to obtain the relative size of the second-order beam with respect to the peak of the main beam. In this case it is 14.5 percent. This second order beam is located below the plane containing the main beam.

Fig. 13 is a repetition of Fig. 12 with the main beam shifted about 30 degrees on the paper to disclose a possible second-order beam towards the load end of the array. No such beam is present.

Fig. 14 is a pattern taken with the main beam pointing down (antenna tilted forward) and indicates the presence of a second-order beam above the plane of the main beam.

These patterns indicate that at 2800 Mc/sec. the second-order beam is 14.5 percent of the main beam and is located 34.4 degrees from the main beam and about 3.6 degrees below the plane of the main beam.

Similar sets of antenna patterns were taken at 2700 and 2900 Mc/sec. No second order beams were found at 2700 Mc/sec. At 2900 Mc/sec. the second-order beam was 12.7 percent of the main beam and was located 32.6 degrees from the main beam and about 4.0 degrees below the main beam. A summary of these patterns is found in Figs. 16 and 17.

In all these measurements the noise level in the recording system was about 1% of the main beam, hence any side lobes of this order or less would be undetected.

ANTENNA PATTERNS WITH MODIFIED FEED

The primary feed assembly was then removed, and a modified feed supplied by Canadian Arsenals Limited and designed by M. Katchky of that establishment was installed. The modifications on the feed assembly consist of quarter-wave chokes between the slotted waveguide and the horn. The chokes are 1/4" in width.

Three sets of patterns were again taken and the results are summarized in Figs. 18, 19, and 20. At 2700 and 2800 Mc/sec. there are no second-order beams, while at 2900 Mc/sec. the second order beam is 6.5 percent of the main beam and is located 32.7 degrees from the main beam and about 3.9 degrees below the plane of the main beam.

CONCLUSIONS

With the modified feed the second-order beam remains at zero at 2700 Mc/sec., is reduced to zero at 2800 Mc/sec., and is reduced to 6.5 percent at 2900 Mc/sec. Therefore the modification is entirely satisfactory in this respect. However, from Figs. 15 to 20 it is evident that there is a change in the vertical beamwidth of the main beam. At all three frequencies the vertical beamwidth using the modified feed is greater than with the original feed. This results in a reduction in the gain of the antenna (assuming that side lobes and spill-over have a negligible effect) and hence of the range of the radar set. This reduction can be approximated by comparing the half-voltage vertical beamwidths as obtained from Figs. 15 to 20. These results are summarized in Table I.

Half-voltage vertical beamwidths obtained on a four-foot mock-up using a resonant feed have also been included in the table. These values were measured some time ago by standing the section on end and plotting the vertical pattern. This procedure is impractical for the AN/FPS-502 antenna.

It will be noted that there is a small difference in the half-voltage vertical beamwidth of the four-foot section and the antenna with the original feed. Similar results were previously obtained on the MZPI antenna. In that instance, the prototype antenna was shorter than the 502 antenna and could be stood on end to obtain vertical patterns. The vertical beamwidths obtained in this manner did not correspond well to values obtained using a short section of reflector fed by a resonant array. The vertical beamwidth measured on the prototype was wider than on the mock-up, and furthermore tended to increase with frequency. Therefore it may be concluded that a knowledge of the vertical beamwidth produced by a short section of reflector flooded by a resonant array should be used only as a guide in predicting the behaviour of a full-length reflector fed by a non-resonant array.

Since the vertical coverage obtained with the original feed is adequate, there is no need to increase the vertical beamwidth. Hence the resultant loss in range using the modified feed is unnecessary, and should be recovered if possible with a more refined design.

A study of methods of suppressing the second-order beam of the 502 antenna is now under way and will be reported on later. Special attention is being given to the method employed by Canadian Arsenals Limited in the modified array used in these tests.

An attempt will be made to narrow the vertical beam while retaining the second-order beam suppression already realized. It is believed that a change of the flare of the horn on the feed will restore the vertical beamwidths to their original value. The spill-over will be checked for the modified and original feeds and the amount of power in the end of the array will be measured.

REFERENCE

[1] Gruenberg, H. "Second-Order Beams of Slotted Waveguide Arrays". Canadian Journal of Physics, Vol. 31, pp. 55-69 January, 1953.

TABLE I

| Antenna With Original Feed | Frequency 2700 Mc/s | 2800 Mc/s | 2900 Mc/s |
|---|---|---|---|
| Percentage of second-order beam | -- | 14.5 | 12.7 |
| Horizontal separation from main beam | -- | 34.4° | 32.6° |
| Vertical separation from main beam | -- | 3.6° | 4.0° |
| Half-voltage vertical width of main beam | 7.2° | 7.4° | 7.9° |
| **Antenna With Modified Feed (1/4" quarter-wave chokes)** | | | |
| Percentage of second-order beam | -- | -- | 6.5 |
| Horizontal separation from main beam | -- | -- | 32.7° |
| Vertical separation from main beam | -- | -- | 3.9° |
| Half-voltage vertical width of main beam | 8.9° | 8.5° | 8.4° |
| Percent reduction in gain | 19 | 13 | 6 |
| Percent reduction in radar range | 10 | 7 | 3 |
| **NRC Four-Foot Mock-Up With Resonant Feed** | | | |
| Half-voltage vertical width of main beam | 7.25° | 6.7° | 6.6° |

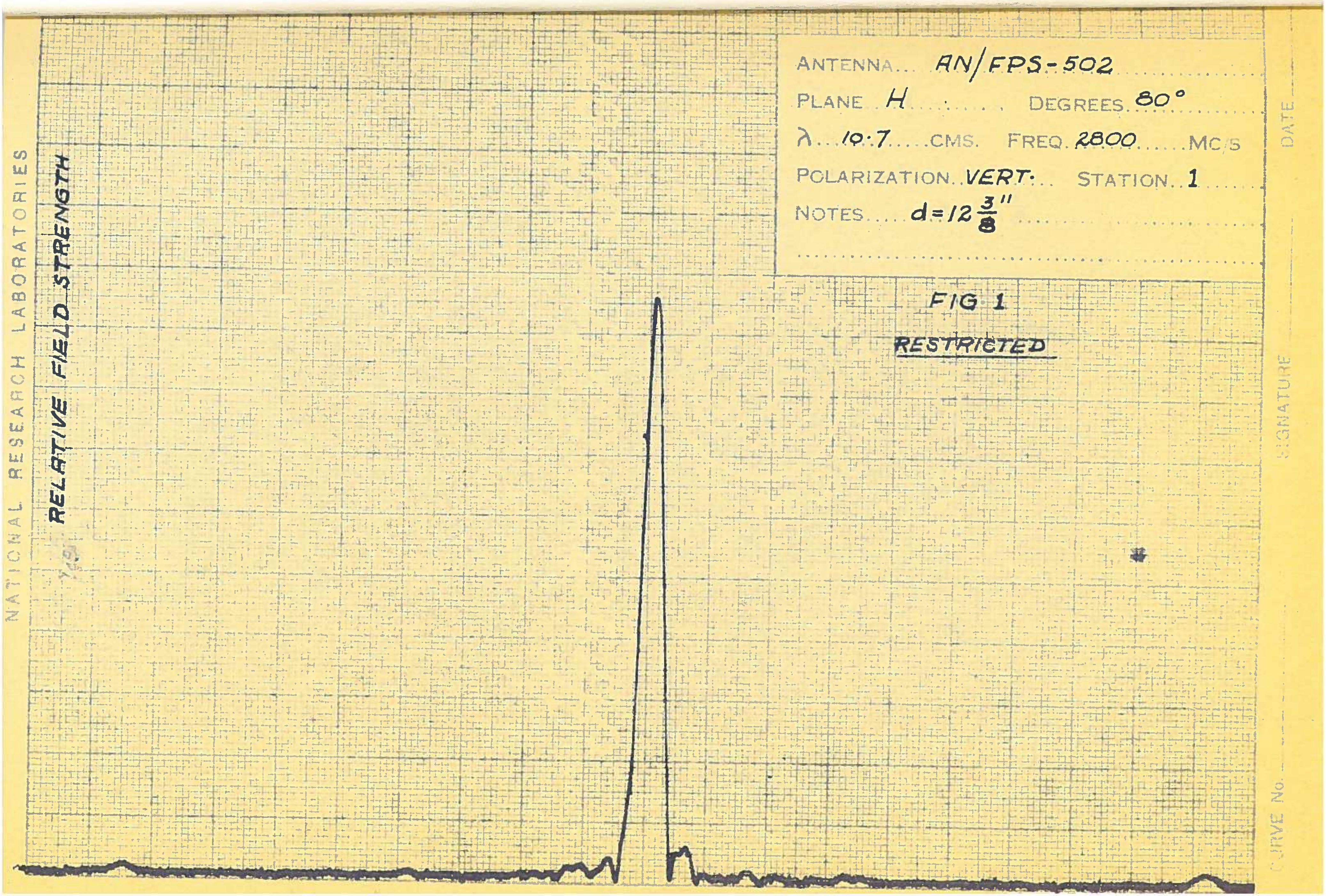


FIG 1

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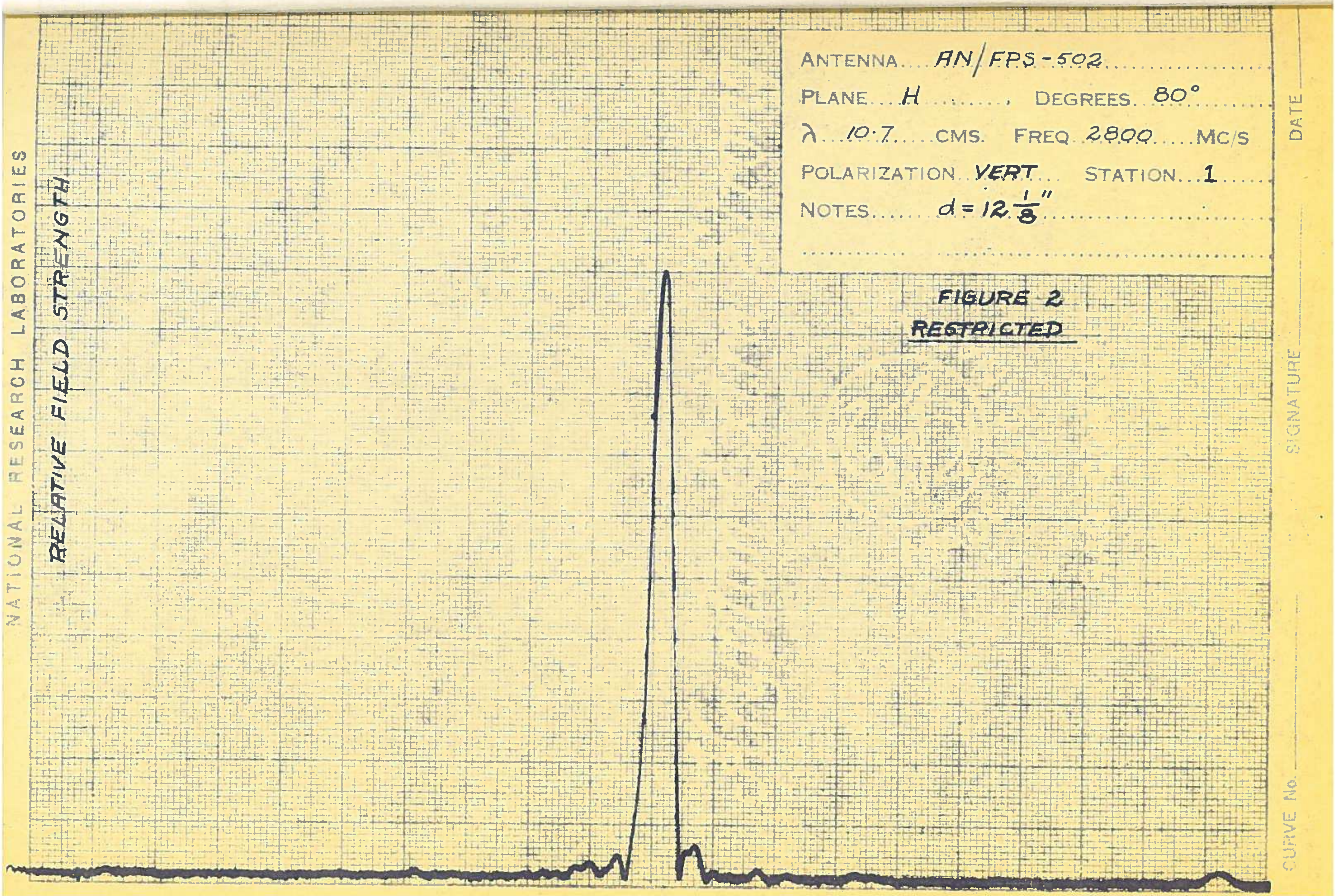


FIGURE 2
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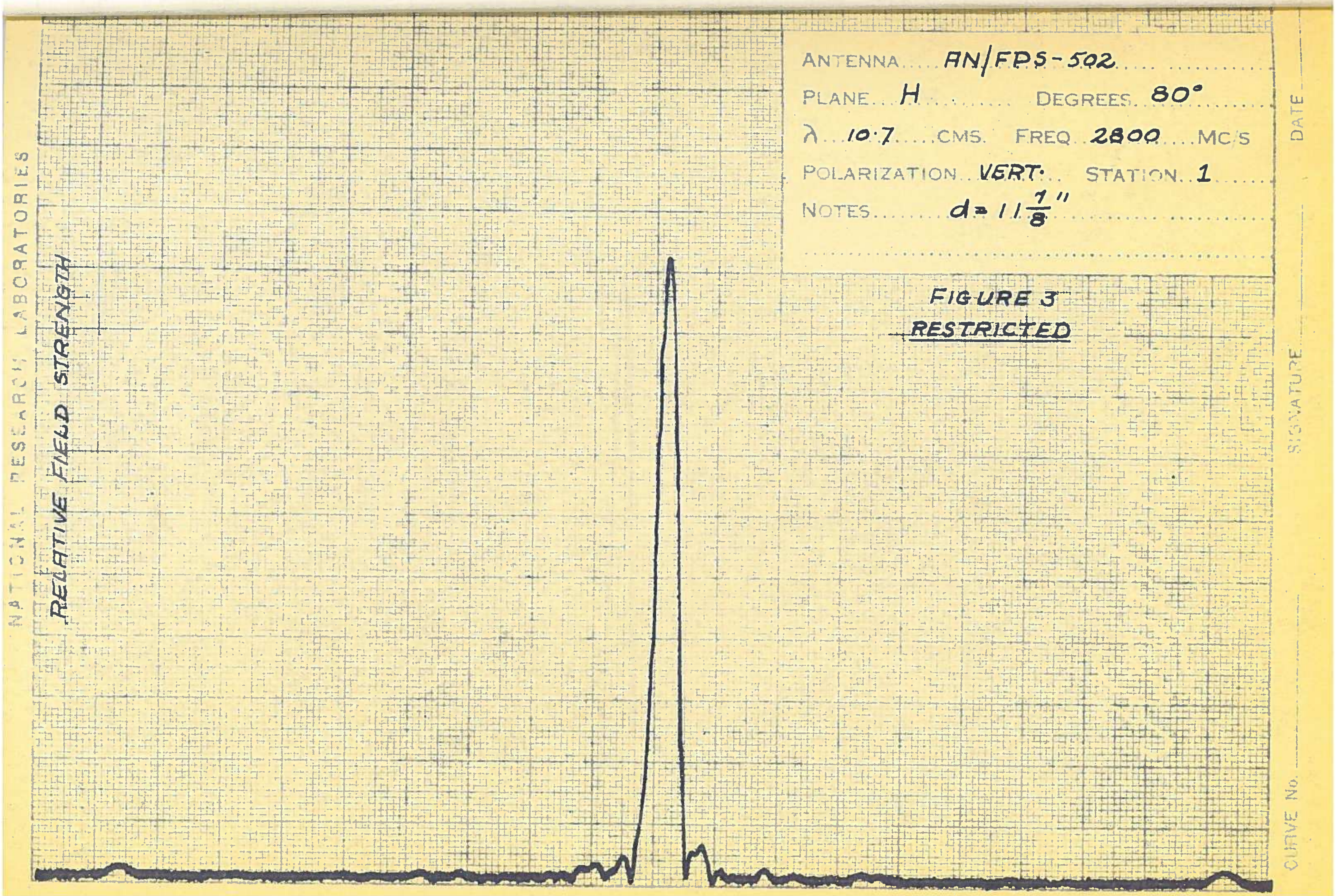


FIGURE 3

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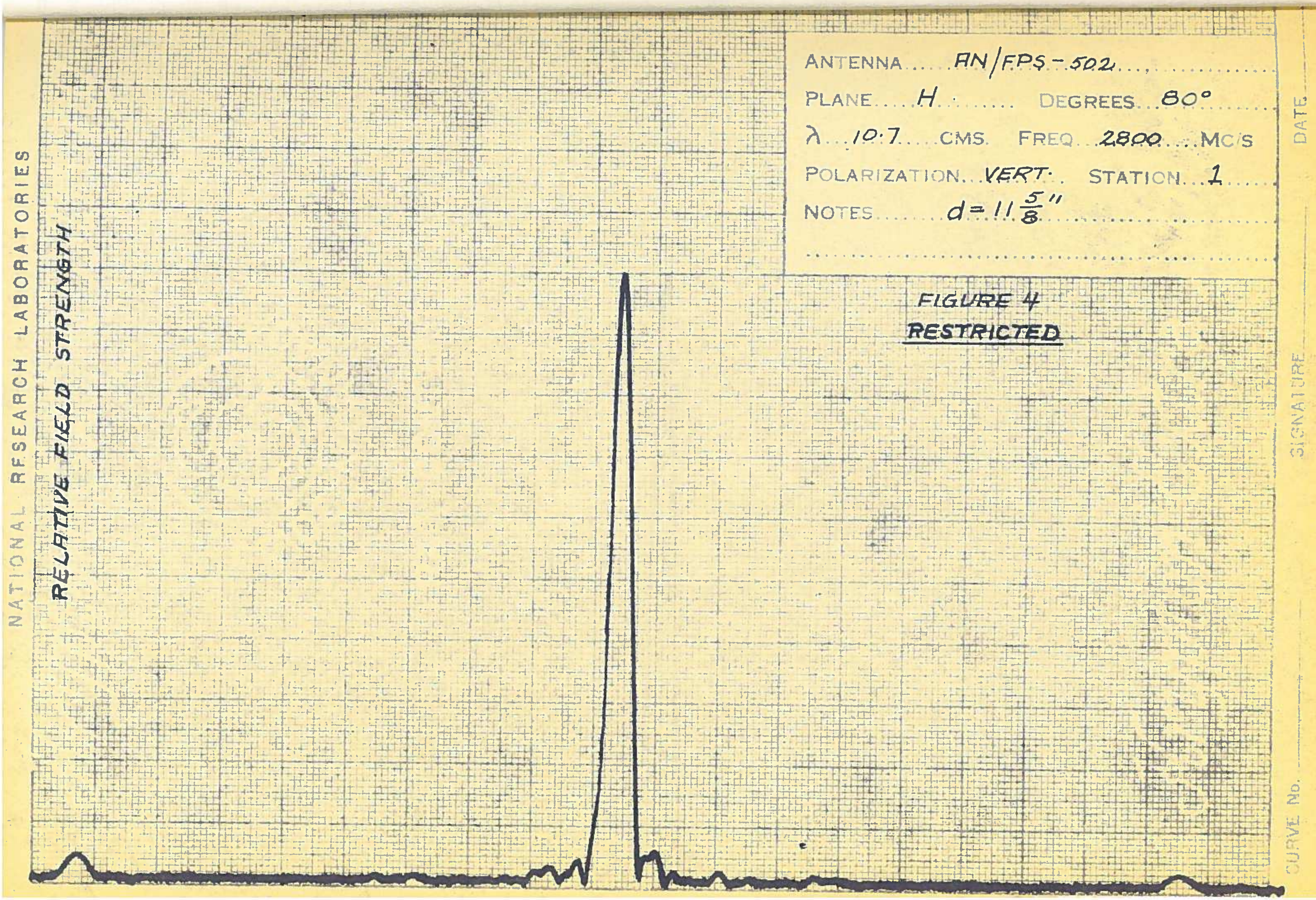


FIGURE 4
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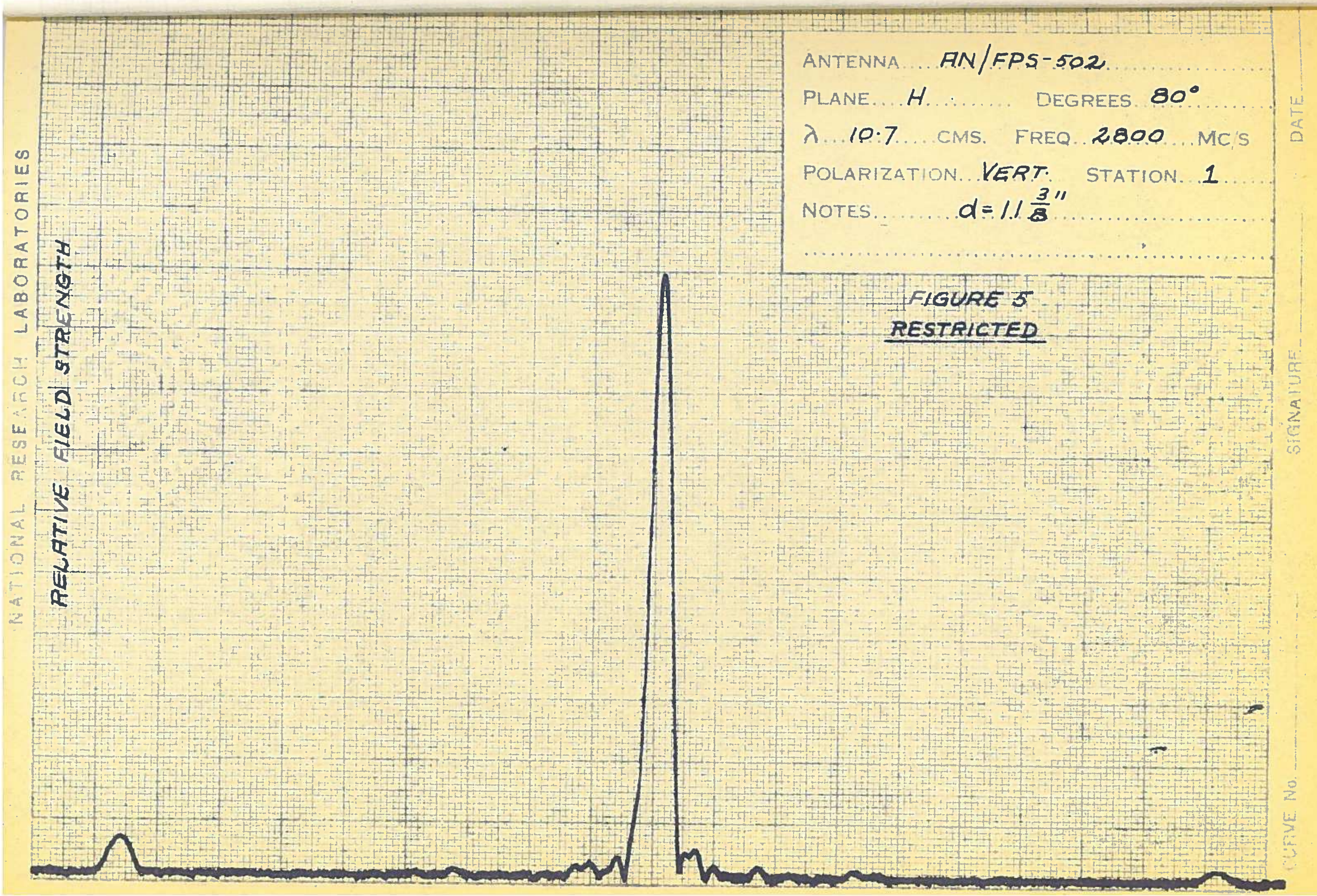


FIGURE 5

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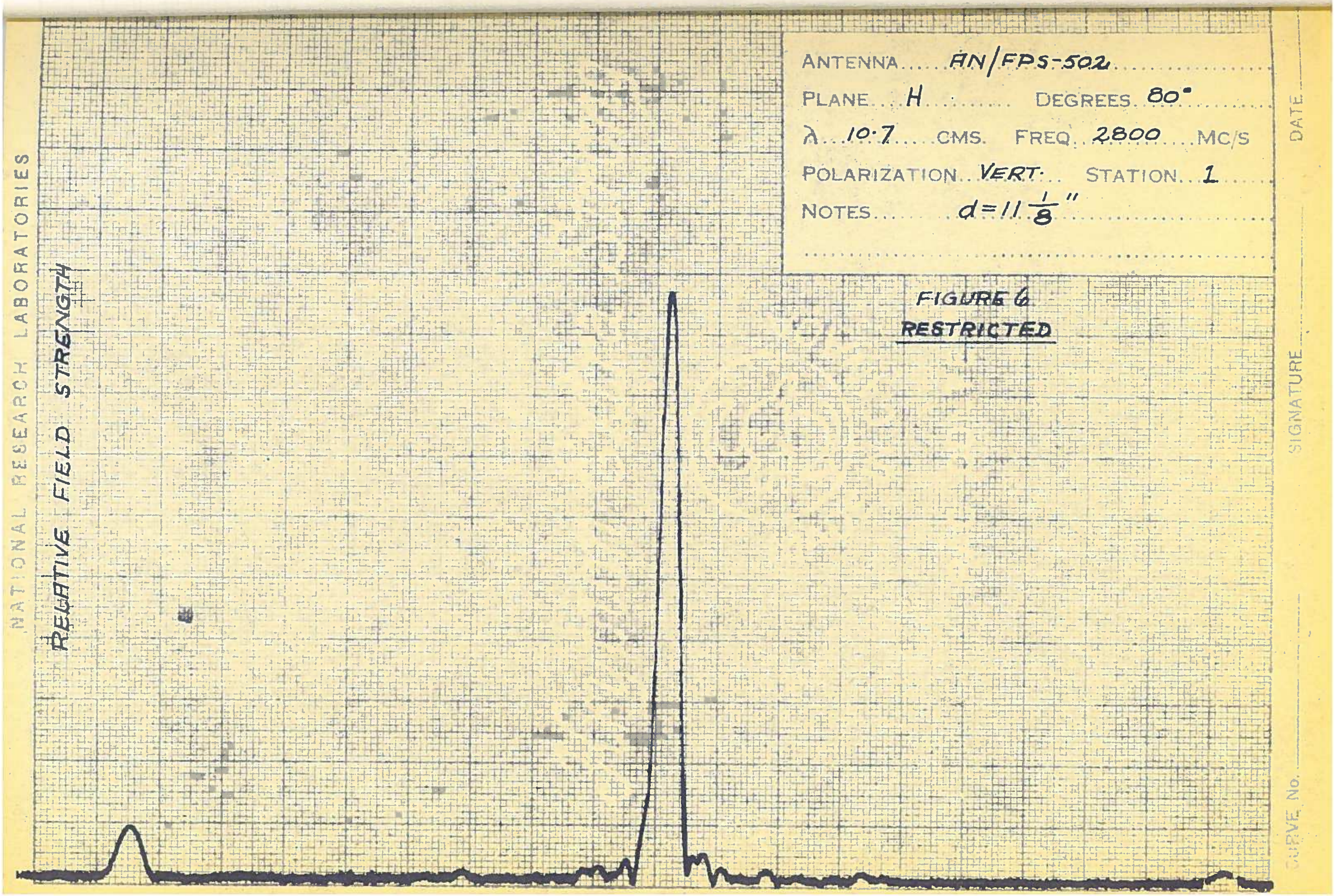


FIGURE 6

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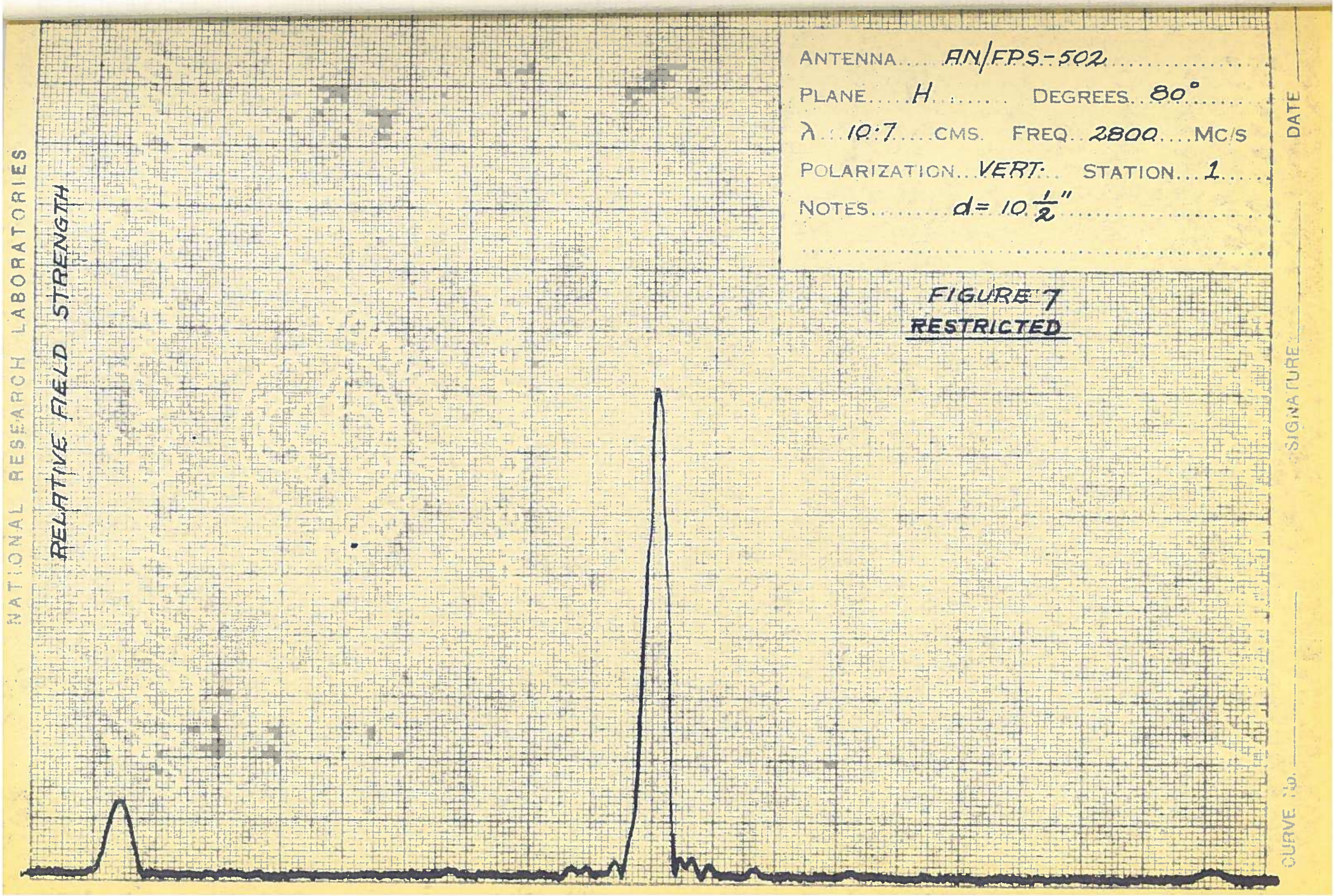


FIGURE 7

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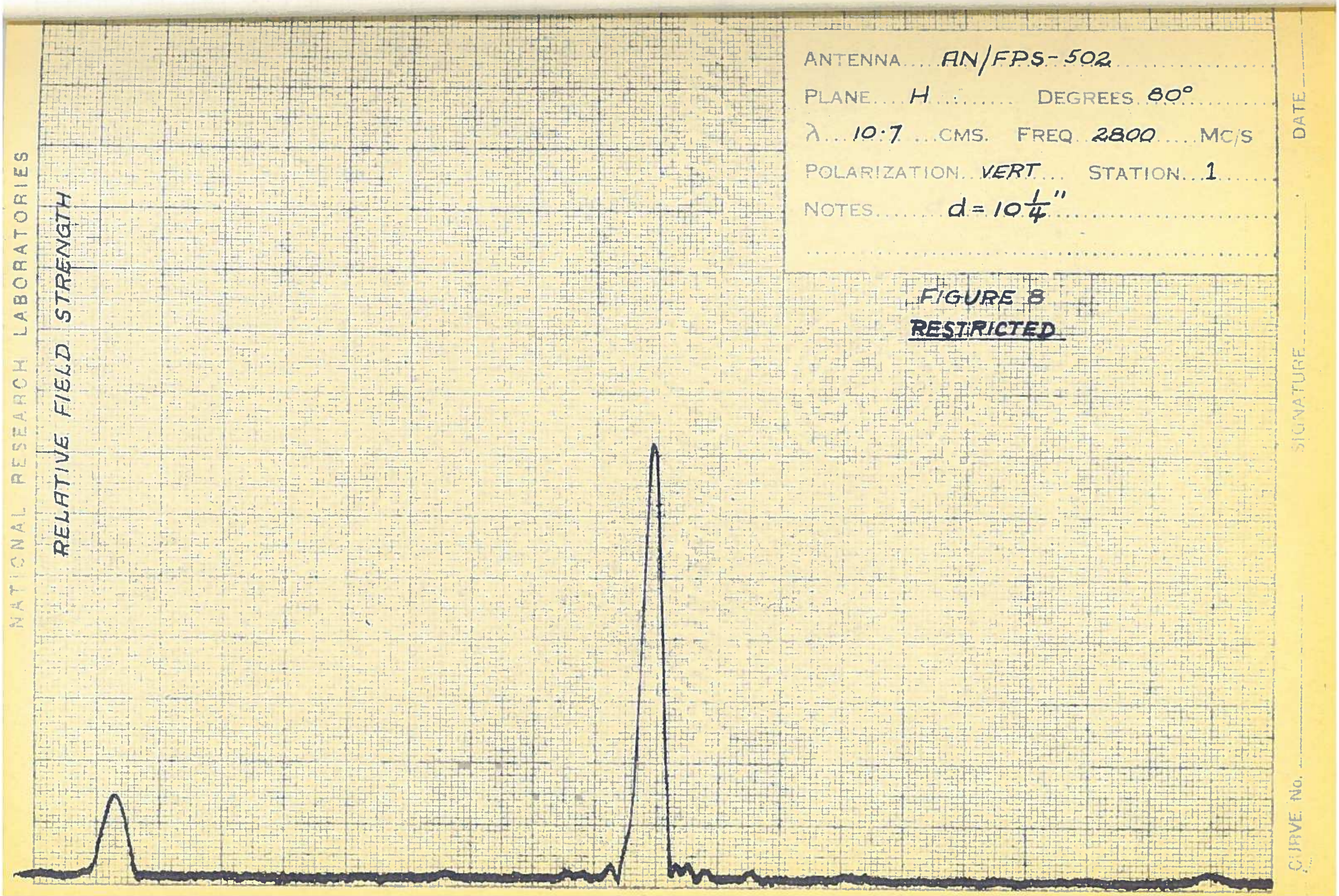


FIGURE 8

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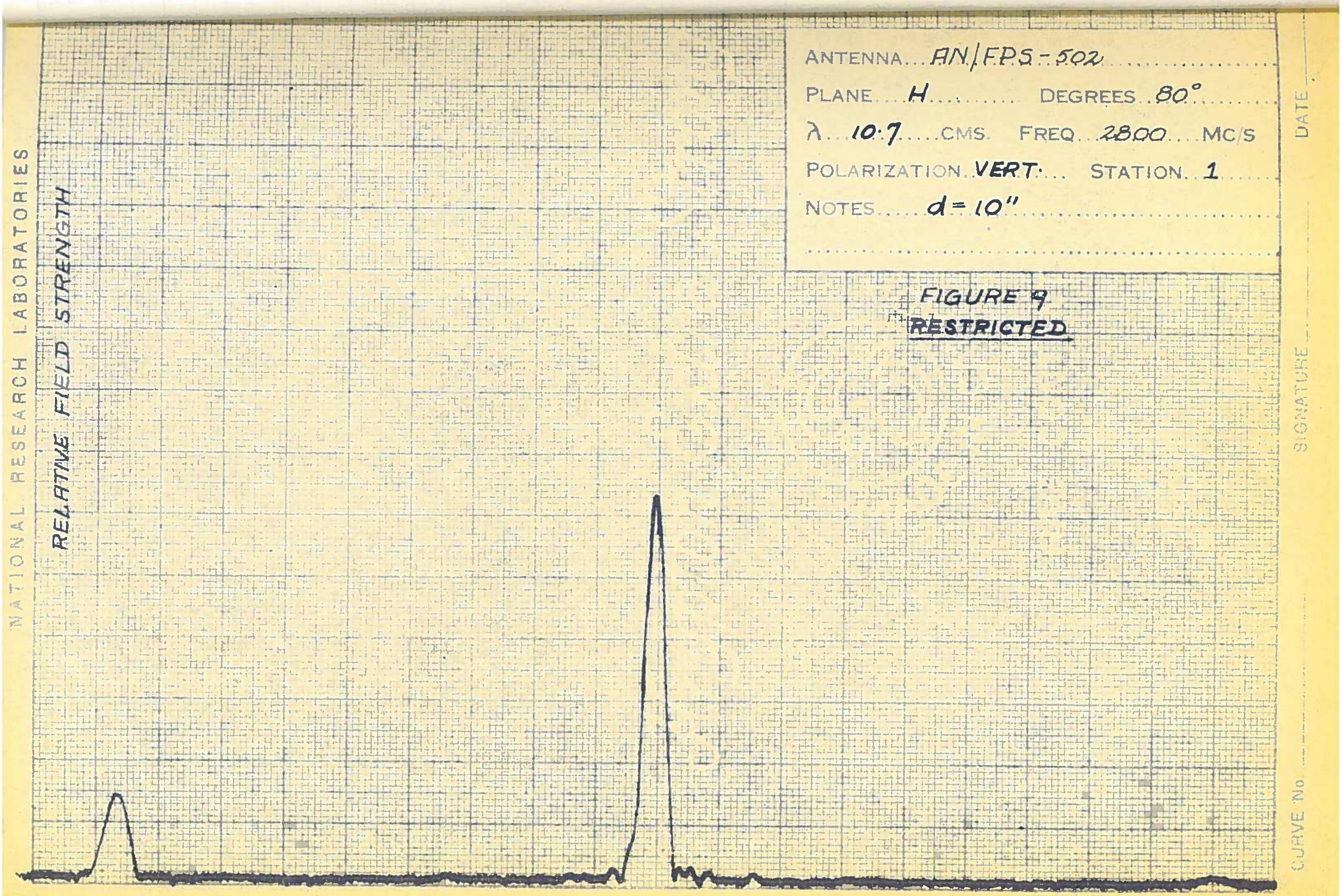


FIGURE 9

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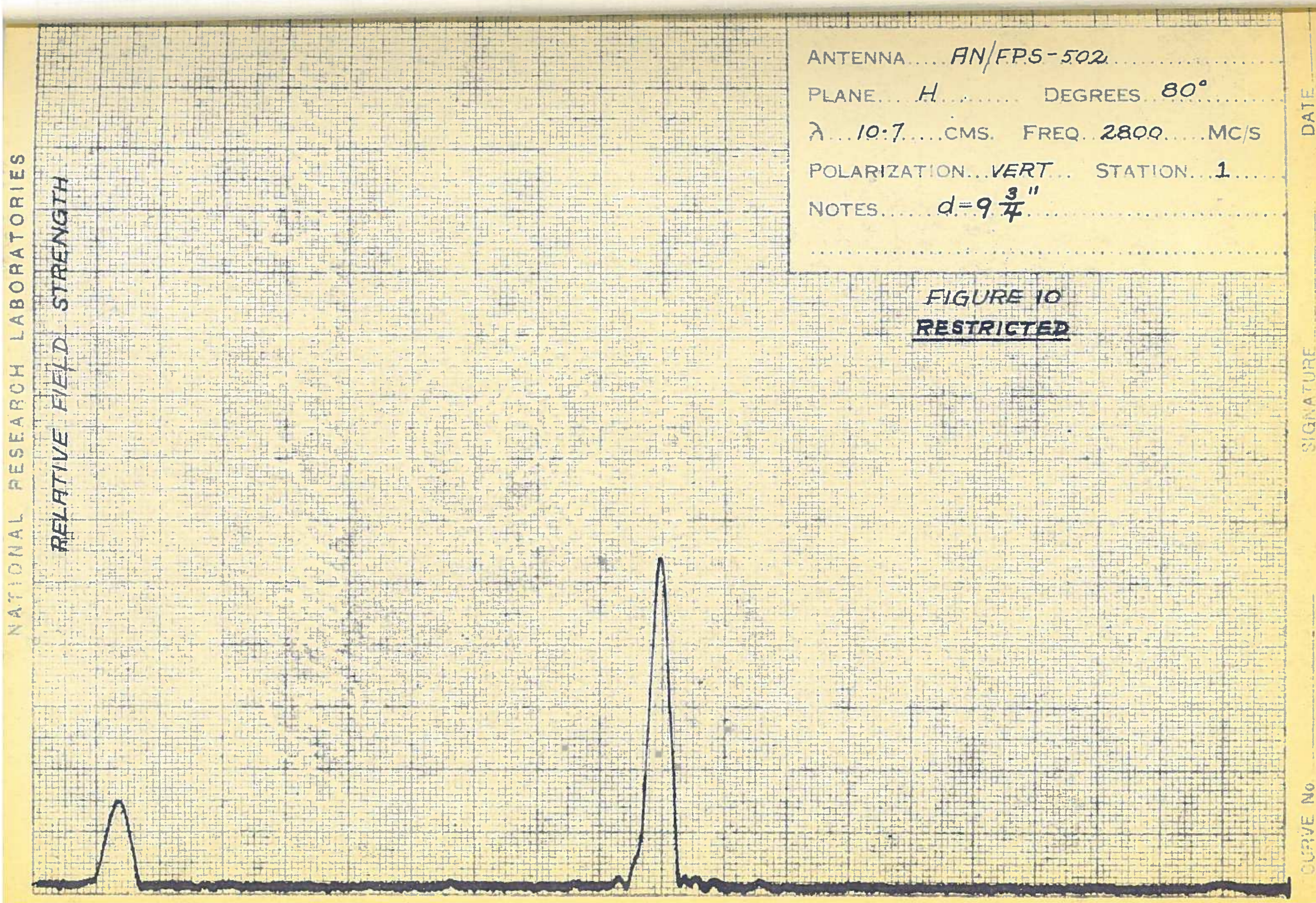


FIGURE 10

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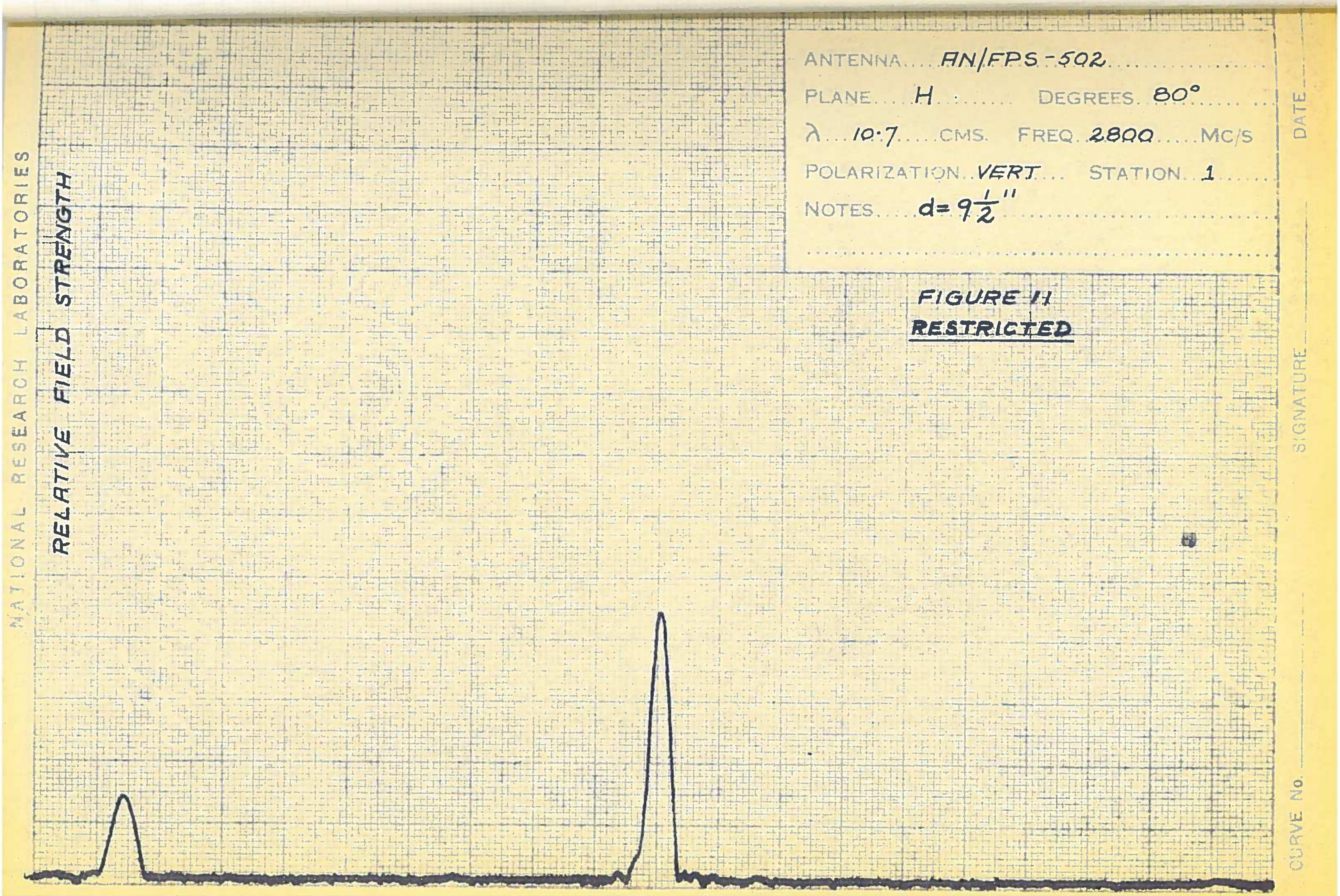


FIGURE 11
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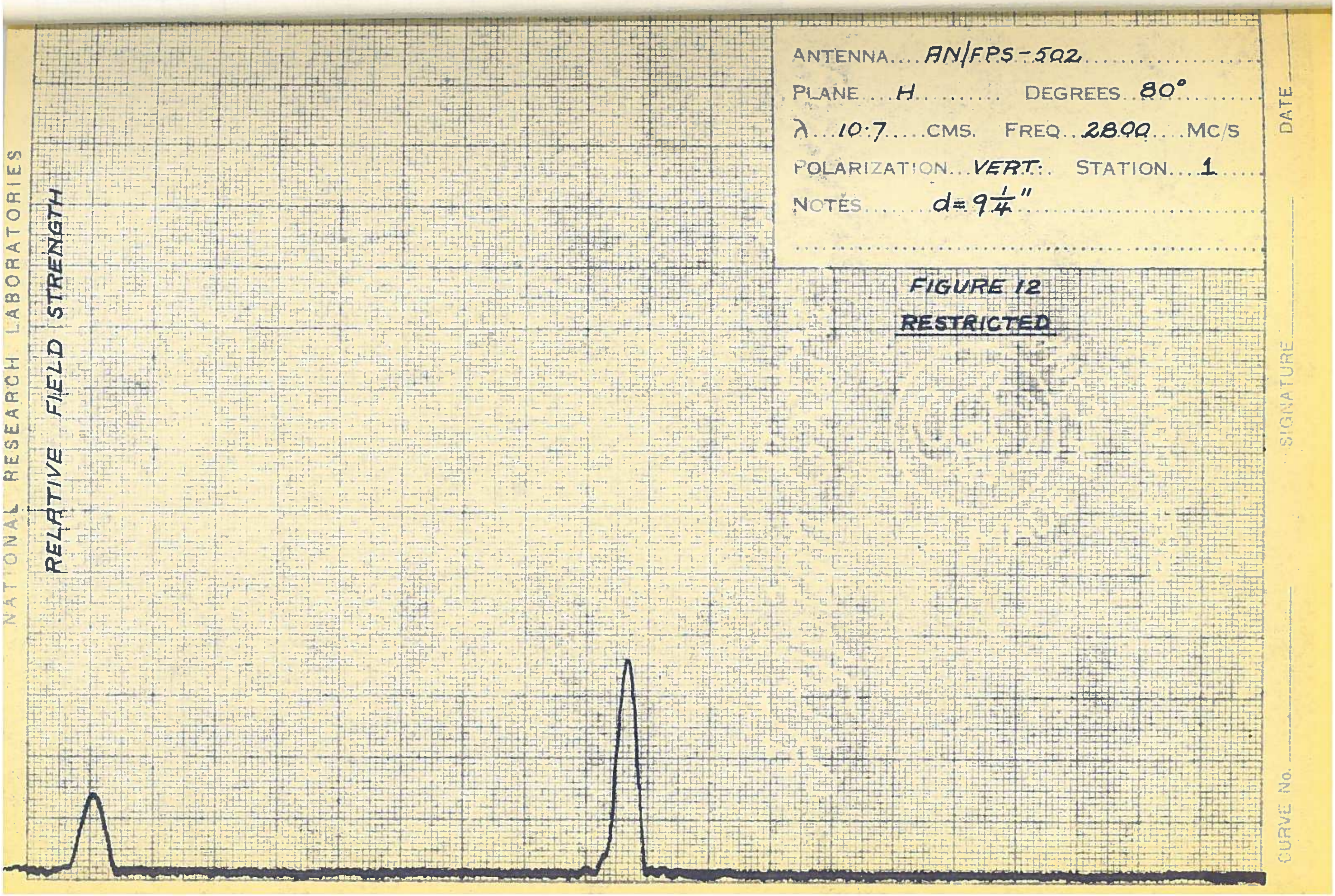


FIGURE 12

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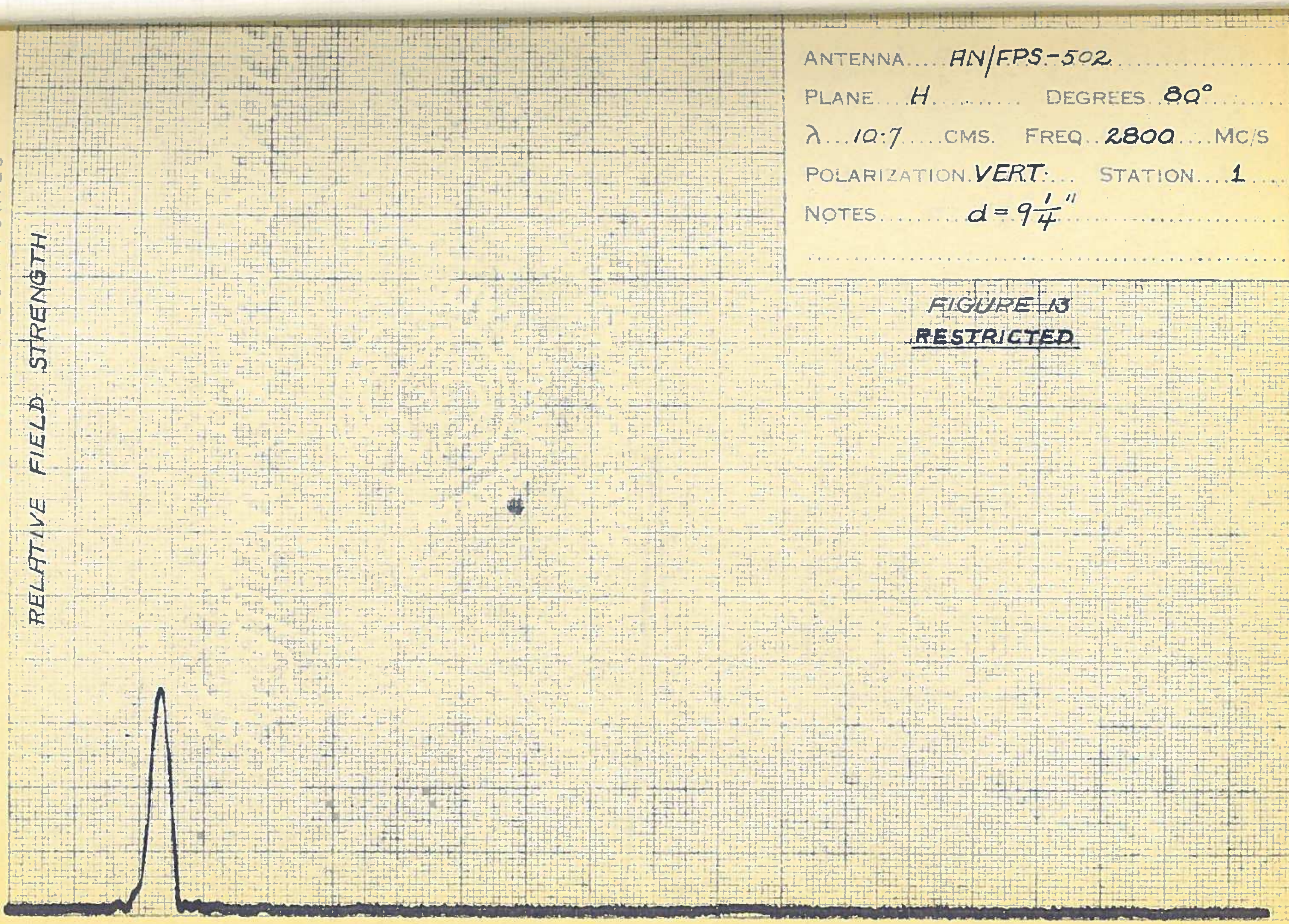


FIGURE 13

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DATE

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CURVE No.

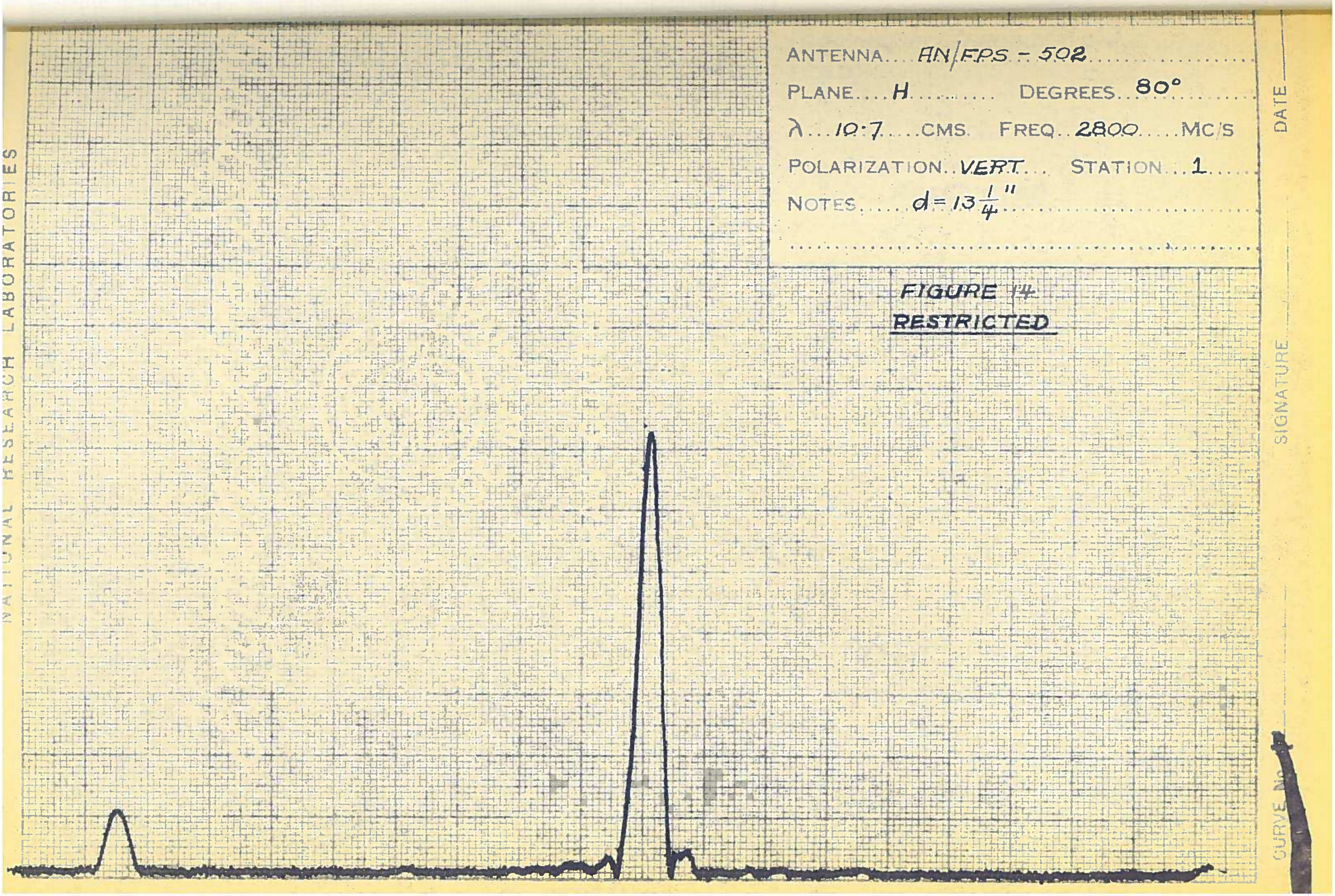


FIGURE 14
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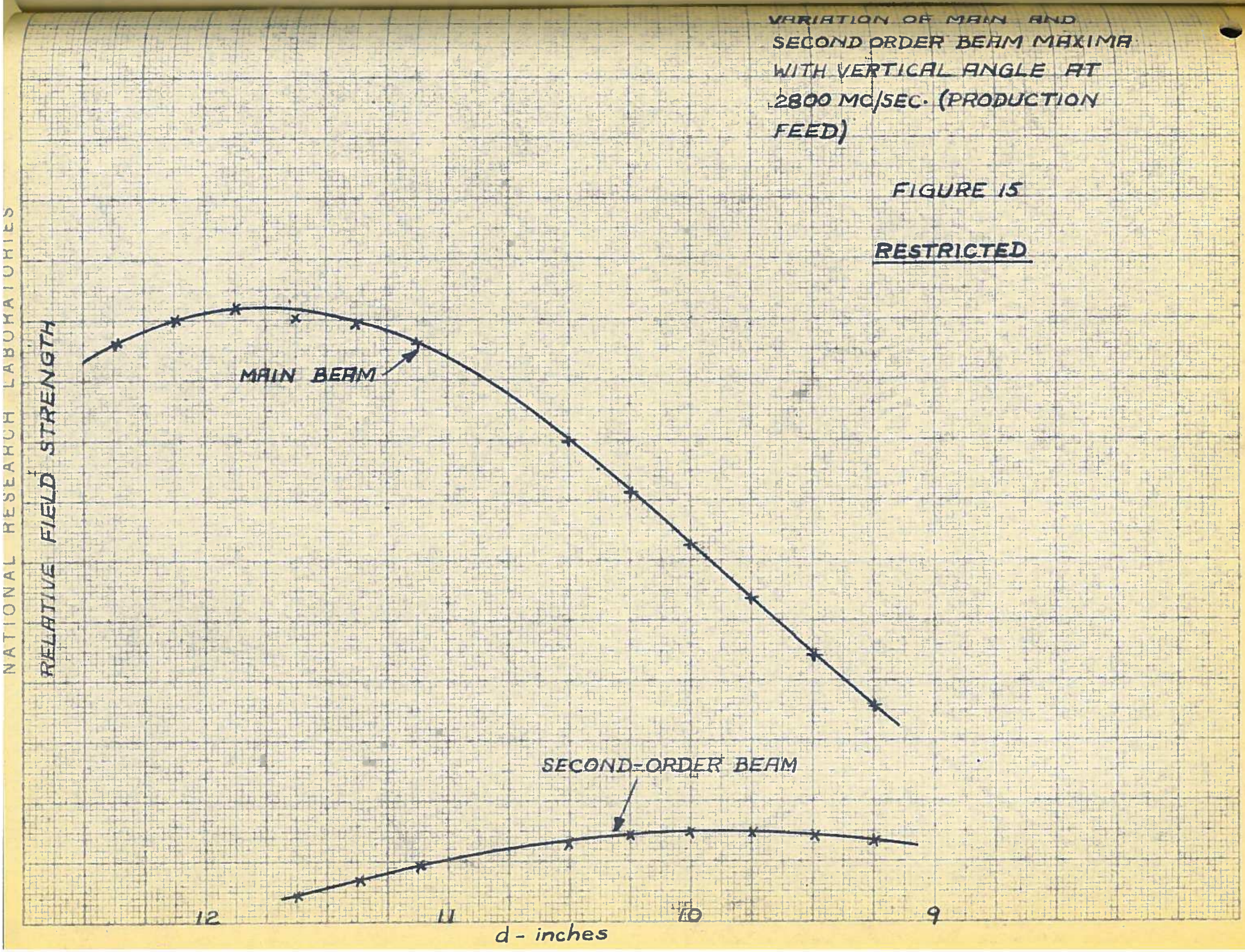


VARIATION OF MAIN AND SECOND ORDER BEAM MAXIMA WITH VERTICAL ANGLE AT 2800 MC/SEC. (PRODUCTION FEED)

FIGURE 15

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VARIATION OF MAIN BEAM MAXIMUM WITH VERTICAL ANGLE AT 2700 MC/SEC (PRODUCTION FEED).

FIGURE 16

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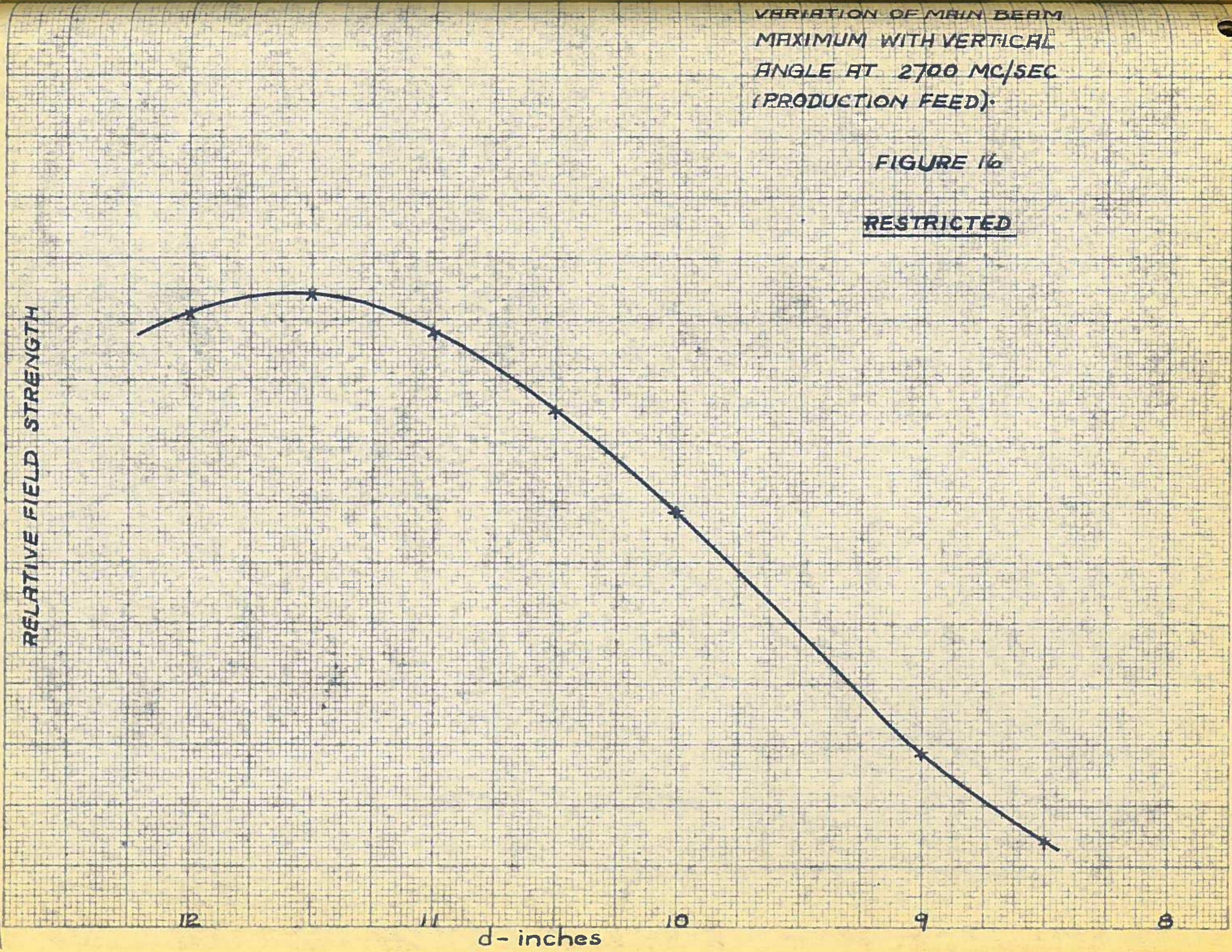
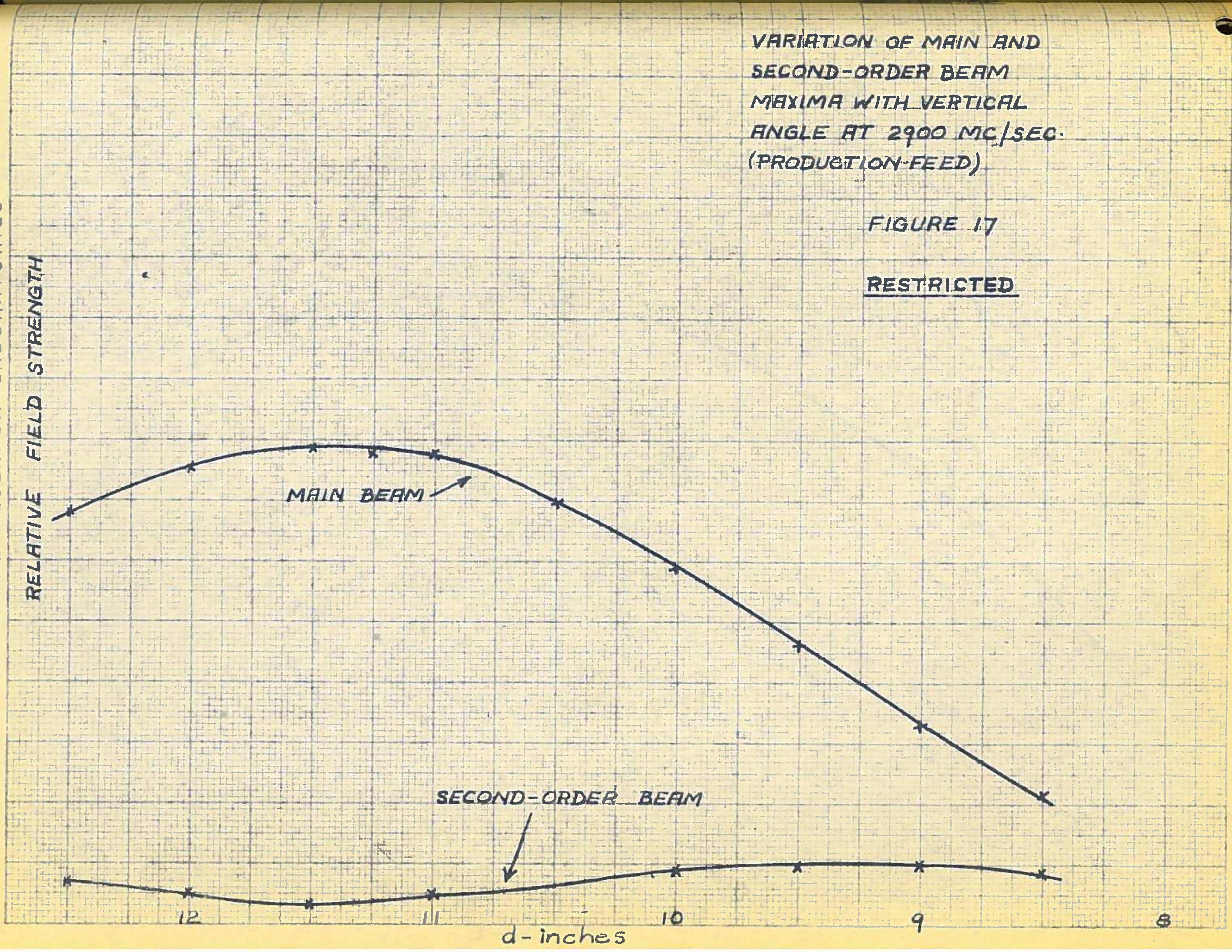
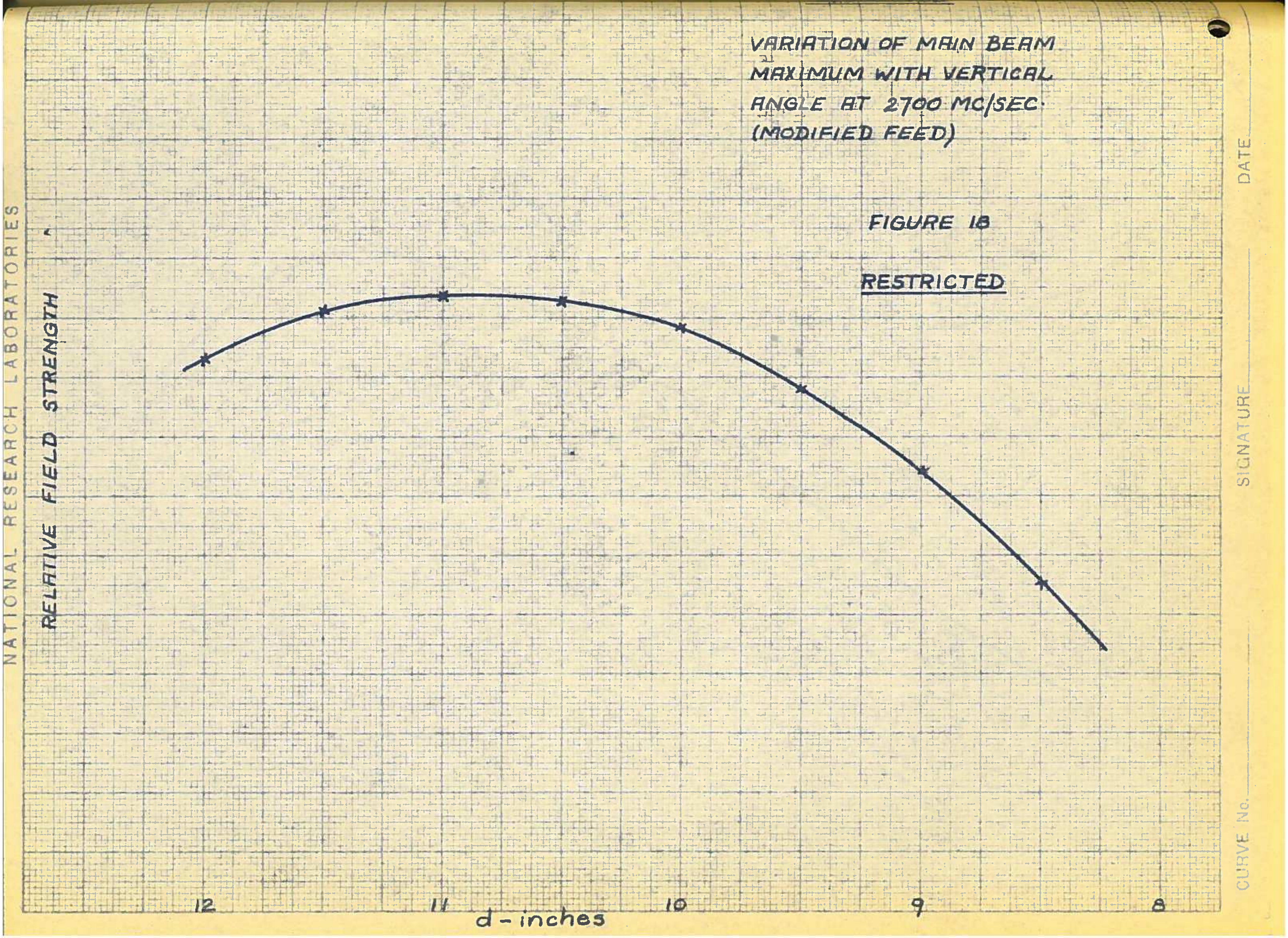





VARIATION OF MAIN AND SECOND-ORDER BEAM MAXIMA WITH VERTICAL ANGLE AT 2900 MC/SEC. (PRODUCTION FEED)

FIGURE 17

**RESTRICTED**



VARIATION OF MAIN BEAM MAXIMUM WITH VERTICAL ANGLE AT 2700 MC/SEC (MODIFIED FEED)
FIGURE 18
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RELATIVE FIELD STRENGTH
12
11
10
9
8
d - inches
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DATE

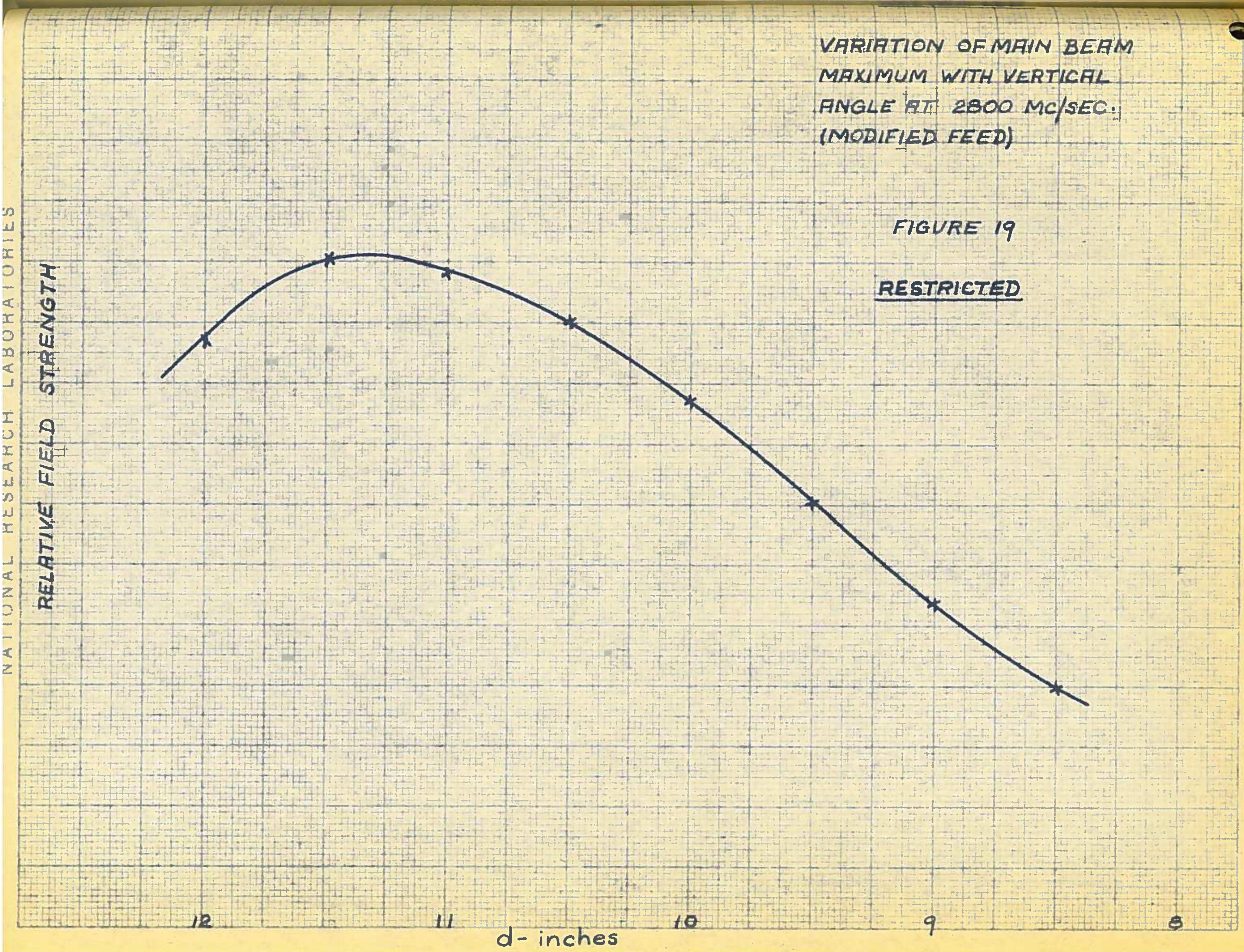


FIGURE 19

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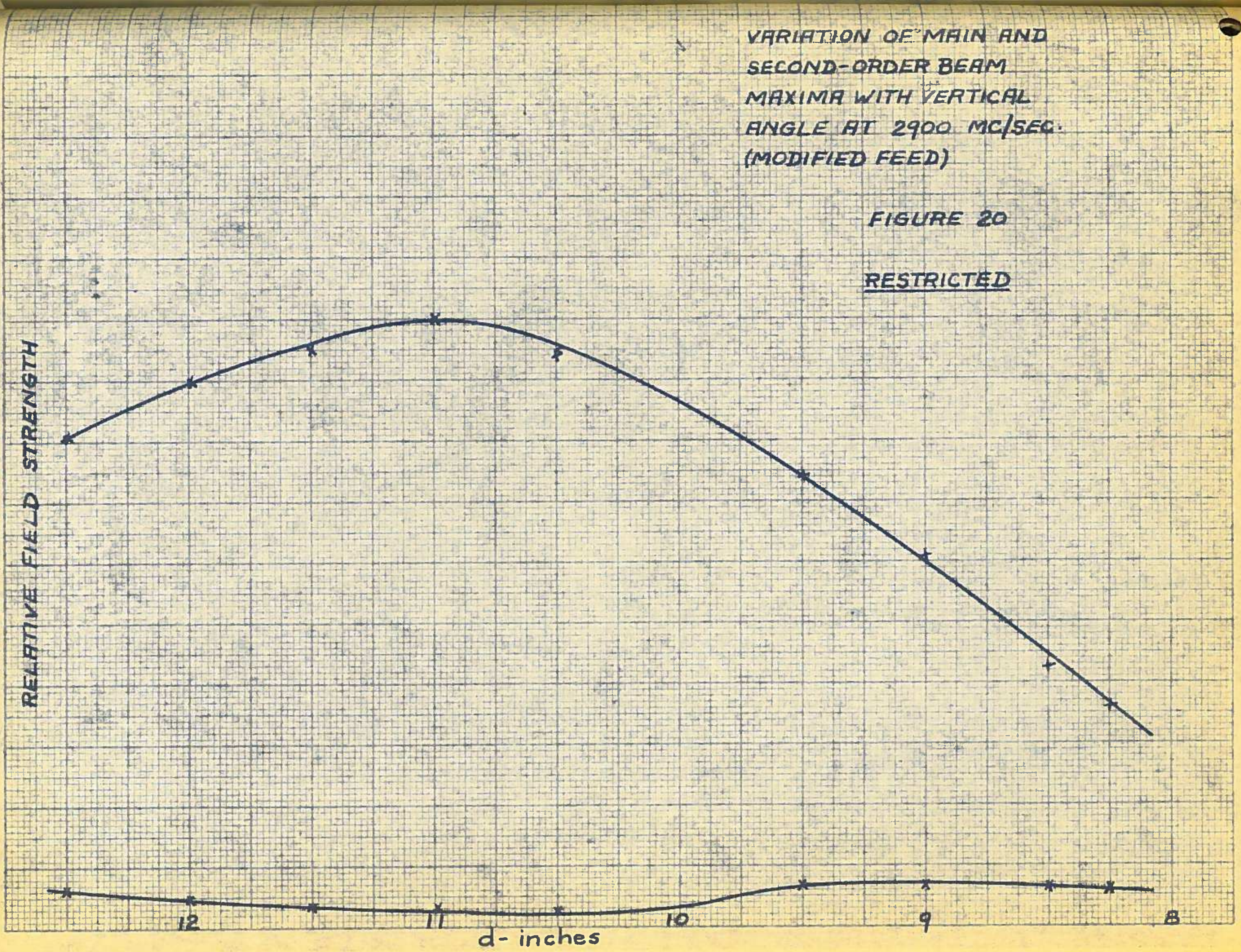
VARIATION OF MAIN AND
SECOND-ORDER BEAM
MAXIMA WITH VERTICAL
ANGLE AT 2900 MC/SEC.
(MODIFIED FEED)
FIGURE 20
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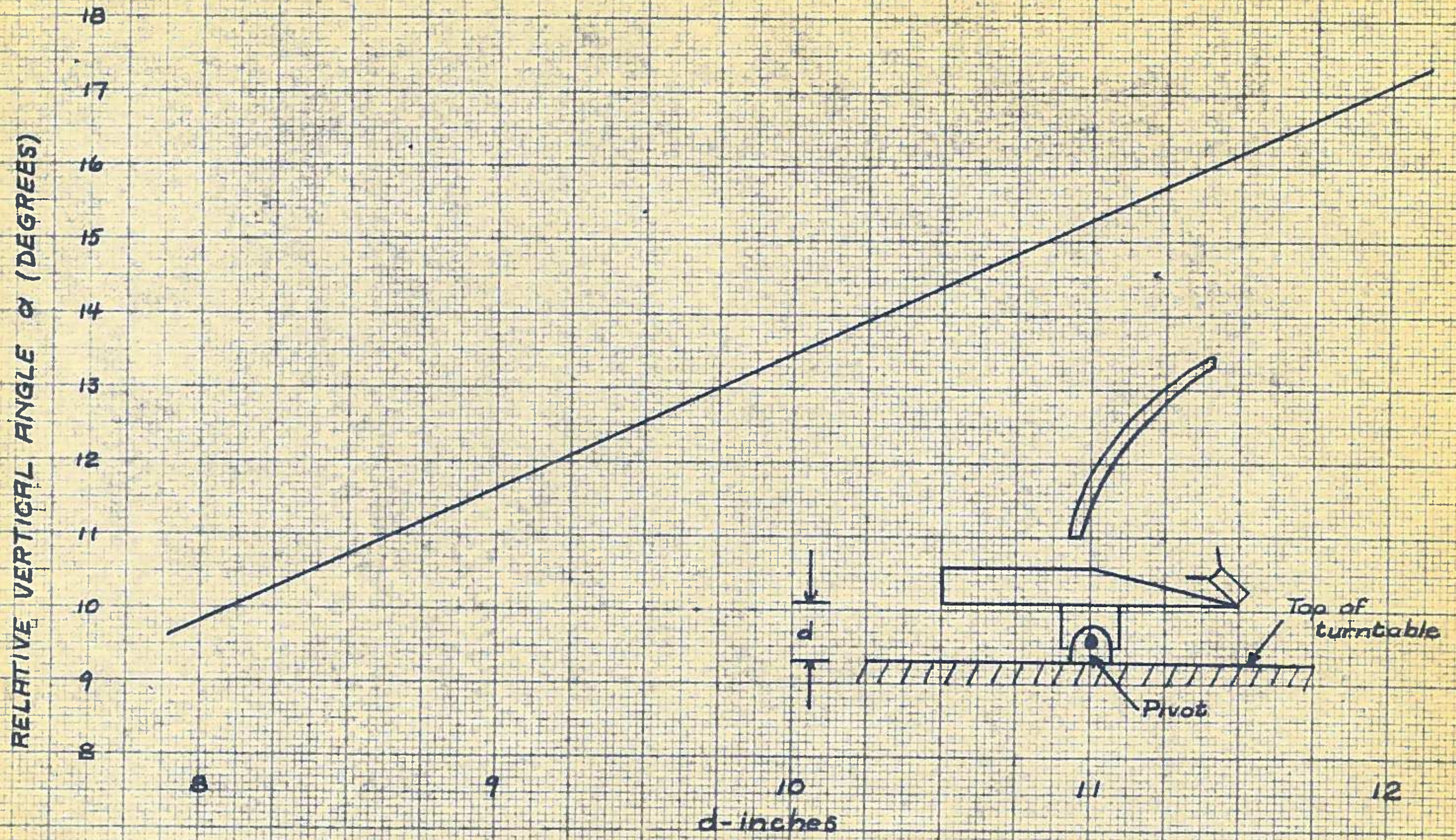
RELATIVE FIELD STRENGTH
12
11
10
9
8
d- inches




CONVERSION OF DISTANCE "d" TO
RELATIVE VERTICAL TILT "α"

FIGURE 21

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