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SHIP-SHORE RADIO DIVISION
RADIO COUNTERMEASURES SECTION

6 August 1946

AN 800 MEGACYCLE PER SECOND INTERMEDIATE FREQUENCY AMPLIFIER

BY

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- Report R-2925-

FR-2925

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Preliminary Pages ....a-c
Numbered Pages 4
Plates 5
Distribution ....d

NRL Problem N30R-S
BuShips Problem 1255

ABSTRACT

This report describes the development of a 800 megacycle intermediate frequency amplifier using 2C39 "oil can" tubes. Results of tests on the amplifier indicate that it has an overall gain of 78 db, a bandwidth of approximately 5.5 Mc/s and a noise figure of 6.4 db. These values are within reasonable limits of the calculated values and show that such an amplifier is entirely practical. The unit has the disadvantage of being relatively large in size and weight, however, further work can reduce these items to more practical values.

TABLE OF CONTENTS

INTRODUCTION

1. Present day microwave receiver technique has been to employ intermediate frequency amplifiers operating at frequencies of 30 to 60 Mc/s. Such systems have the obvious disadvantage of a large number of spurious responses or images as it is a practical impossibility to obtain the required radio frequency selectivity to suppress such responses. One method of overcoming this difficulty is to increase the operating frequency of the i.f. amplifiers. For example, consider a receiver using a 30 Mc/s i.f. amplifier, the radio frequency circuit of which consists of a single resonant cavity tuned to 3000 Mc/s. A simple calculation indicates that the image rejection of such a system would be approximately 8.3 db. On the other hand, if the intermediate frequency were 1000 Mc/s and the oscillator were tuned to 2000 Mc/s, the image rejection would be of the order of 50 db. This represents a vast improvement in the performance of the system. Furthermore the requirements on the preselector are not nearly so stringent to obtain a given image rejection with a prescribed bandwidth assigned to the radio frequency circuits.

2. It was for the previous mentioned reasons that the development of an 800 Mc/s intermediate frequency amplifier was started at this Laboratory. The particular frequency of 800 Mc/s was chosen because there were no other services assigned there at that particular time, so that the possibility of i.f. break through was reduced.

GENERAL DESCRIPTION

3. The 800 Mc/s i.f. amplifier in its present form consists of six grounded grid stages using 2C39's operating in cascade. Several views of the complete amplifier are shown in Plates 1 to 3 inclusive. The over-all dimensions of the amplifier is 15" x 22½" x 3" and it weighs approximately 15 pounds. This large size and poor form factor are obvious disadvantages but there are several means by which these factors can be improved. It should be noted that this model is still in the experimental stage and several improvements can be effected.

4. A schematic diagram of the general construction of the individual stages is shown in Plate 4. It is observed that the plate grid line operates in the quarter wave mode and is trimmed by a small variable capacitance between the grid and the outer shell; this additional capacity is kept as small as possible so as to obtain to greatest possible gain bandwidth product per stage. A small loop near the low impedance end of the plate-grid "cavity" couples the energy out at a 50 ohm impedance level. The grid-cathode line operates in the three quarter wave mode and is tuned

by means of a shorting plunger at the end of the line. Energy is coupled into the cathode circuits, from the preceeding stages, by means of a variable tap on the line which allows a proper impedance match to be made between the output of the preceeding amplifying stage.

5. The general construction of the complete amplifier is as follows: the six grid-plate cavity shells were made of brass tubing of $2\frac{1}{2}$ inch diameter and 3/64" wall. These six shells were then clamped between two brass plates, in each of which six holes 1/8" deep by $2\frac{1}{2}$" diameter were bored to hold the shells in the proper position. On one plate, the fingers to hold the anode of the tube and the by-pass condensers were mounted. The grid by-pass condensers and cathode lines were mounted on the other plate. A duct was fitted over the "anode" supporting plate to allow air to be forced over the anodes and also to act as a support for the series decoupling circuits between the individual tubes. All of the component parts were silver plated before assembling. The plate and grid by-pass condensers are approximately 200 $\mu\mu f$ each. D.C. is supplied to the grid through a 33,000 ohm resistor as indicated on Plate 4.

DESIGN OF CIRCUITS

6. The design of this amplifier was accomplished in a somewhat arbitrary manner; the characteristic impedances of the plate and cathode lines were first chosen to be 73 and 58 ohms respectively. Next the resonant lengths of the lines were found from

$$\omega C_{sg} = Y_0 \cot \beta l$$

where C_{sg} is the capacitance between the tube elements under consideration. Assuming that the plate-grid line operates in the quarter wave mode and the cathode-grid line in the three quarter wave mode, the resonant line lengths for 800 Mc/s were found to be 7.5 cm and 23 cm respectively, for $C_{pg} = 1.0\ \mu\mu f$ and $C_{kg} = 4.0\ \mu\mu f$.

7. The resonant impedance of the plate-grid line when loaded will be approximately Rp/2 so that the Q of this circuit will be approximately 65. Since the Q of the cathode line is much less than that of the plate line, this Q determines the selectivity of the six stages in cascade so that the bandwidth is

$$\Delta f_1 = \frac{f_0}{Q}\sqrt{2^{1/6}-1} = 4.1 \text{ Mc/s.}$$

Rp = anode resistance

8. If it is assumed that the system feeds a matched load and is driven by a generator of the same impedance as the load then it can be shown that the gain of the system should be

$$G = \frac{1}{2}\left(\sqrt{|\mu|/2}\right)^{1/6} \approx 86\,db.$$

where $\mu = 75$ is the amplification factor of the tubes.

RESULTS OF TESTS

9. Experimental data was gathered on a single stage before attempting to build the complete amplifier. The mean data for several 2C39 tubes may be summarized as follows:

$\Delta f = 12.0$ Mc/s (3 db bandwidth)

$G = 13.5$ db (into a matched load)

This data is very close to that indicated from the calculated performance above.

10. When the complete amplifier consisting of six stages was constructed, difficulty due to feedback, as was to be expected, was encountered. The result of this feedback was to narrow the bandwidth and increase the gain. However, by stagger tuning the system, reasonable values of bandwidth and gain was obtained. An overall selectivity curve is shown in Plate 5; the large "dip" is due to improper staggering of the circuits. However, the 3 db bandwidth was 5.5 Mc/s and the overall gain was 78 db which is reasonably close to the expected values. It can be appreciated that it requires a considerable amount of labor to properly align the system. Had it not been for a wide band frequency modulated signal generator constructed in the laboratory it would have been a hopeless task to properly align the system. Measurements of noise figure indicate that it is of the order of 6.4 db, while calculations showed that it should be approximately 5.5 db. This difference, is due partly to an improper match between the signal generator and the first tube and partly to inexact knowledge of the high frequency parameters of the tubes.

CONCLUSIONS

11. The results of tests on an experimental model of the 800 Mc/s, amplifier, indicated that such systems are entirely practical as the gain, bandwidth and noise figure are all within usable limits. The main disadvantage of the amplifier in its present form is (a) its large size and (b) its complexity of tuning.

The first item can be improved by changing the mode of operation of the cathode lines from three qurater to one quarter. It was only for mechanical convience that the system was constructed using the three quarter wave mode in the cathode line. The second item can not be improved, however, it is a relatively simple matter to properly align the amplifier, if a wide band frequency modulated signal source is available.

REFERENCES

1. BuShips ltr. Ser. 492(925C) of 22 Oct. 1943 to Dir., NRL.
2. BuShips ltr. C-Receivers (925) Ser. 1273 of 18 Oct. 1944 to NRL.

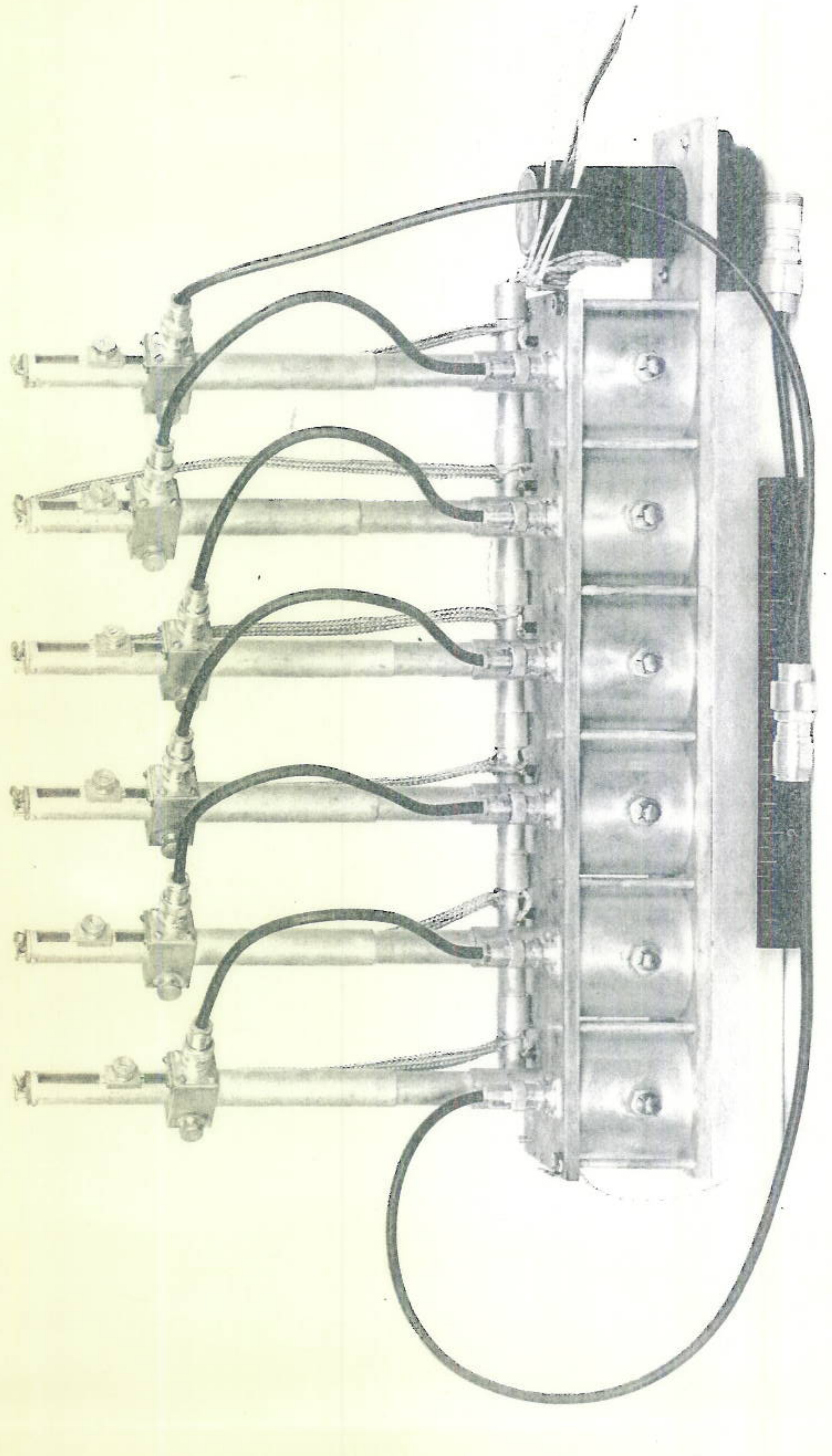

PLATE I

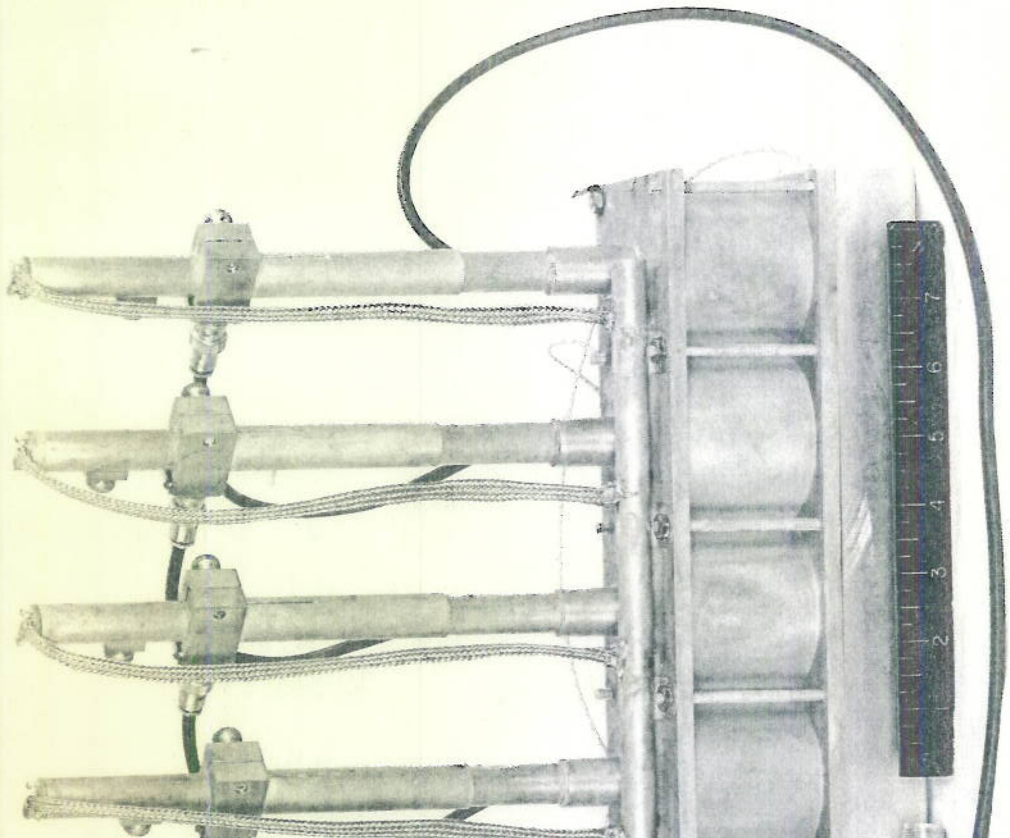

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PLATE 2

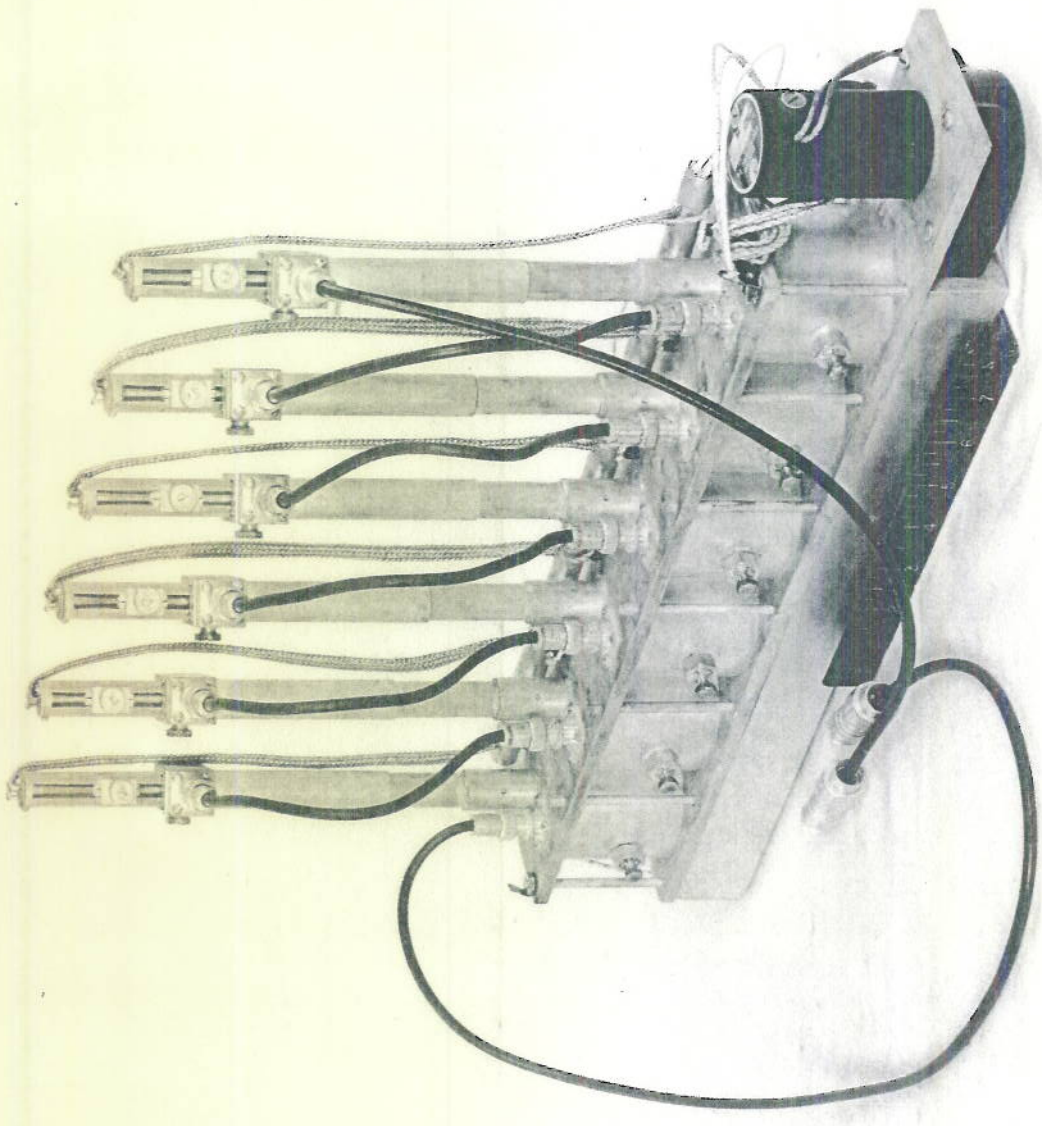

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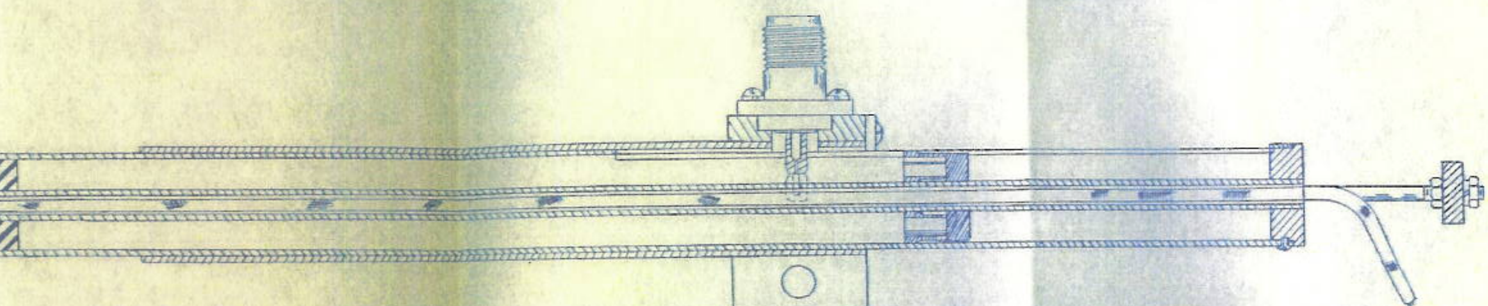
PLATE 3



CIRCUIT DIAGRAM

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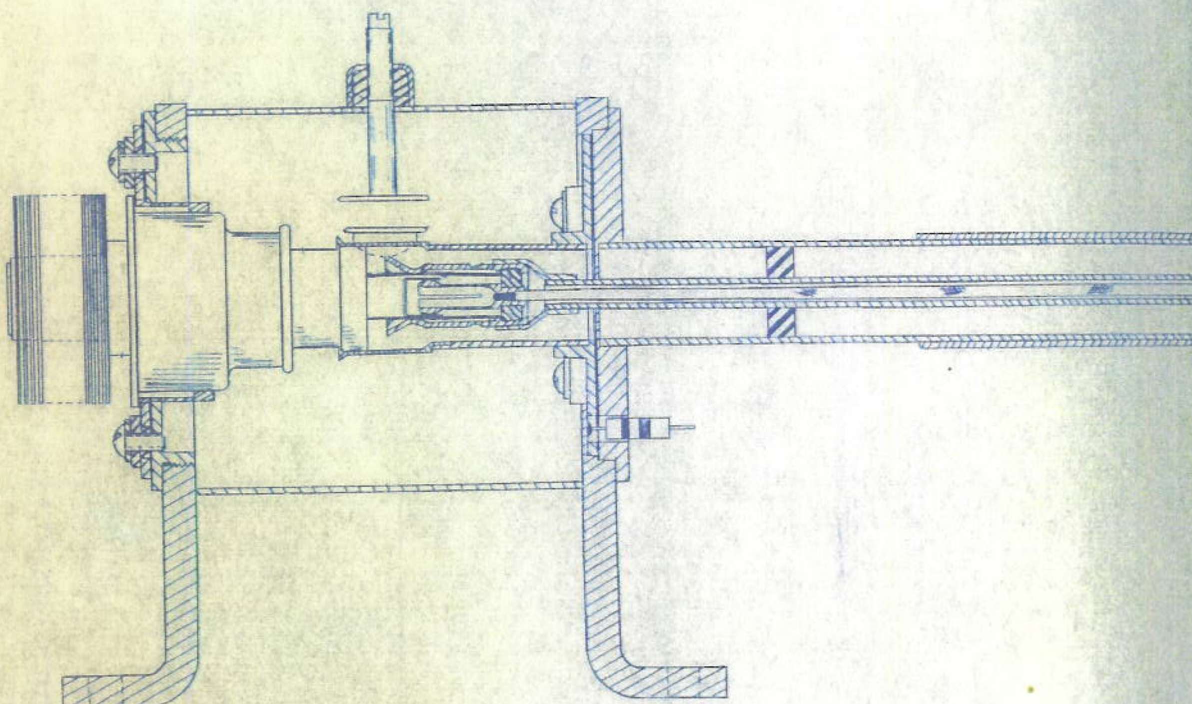
PLATE 4



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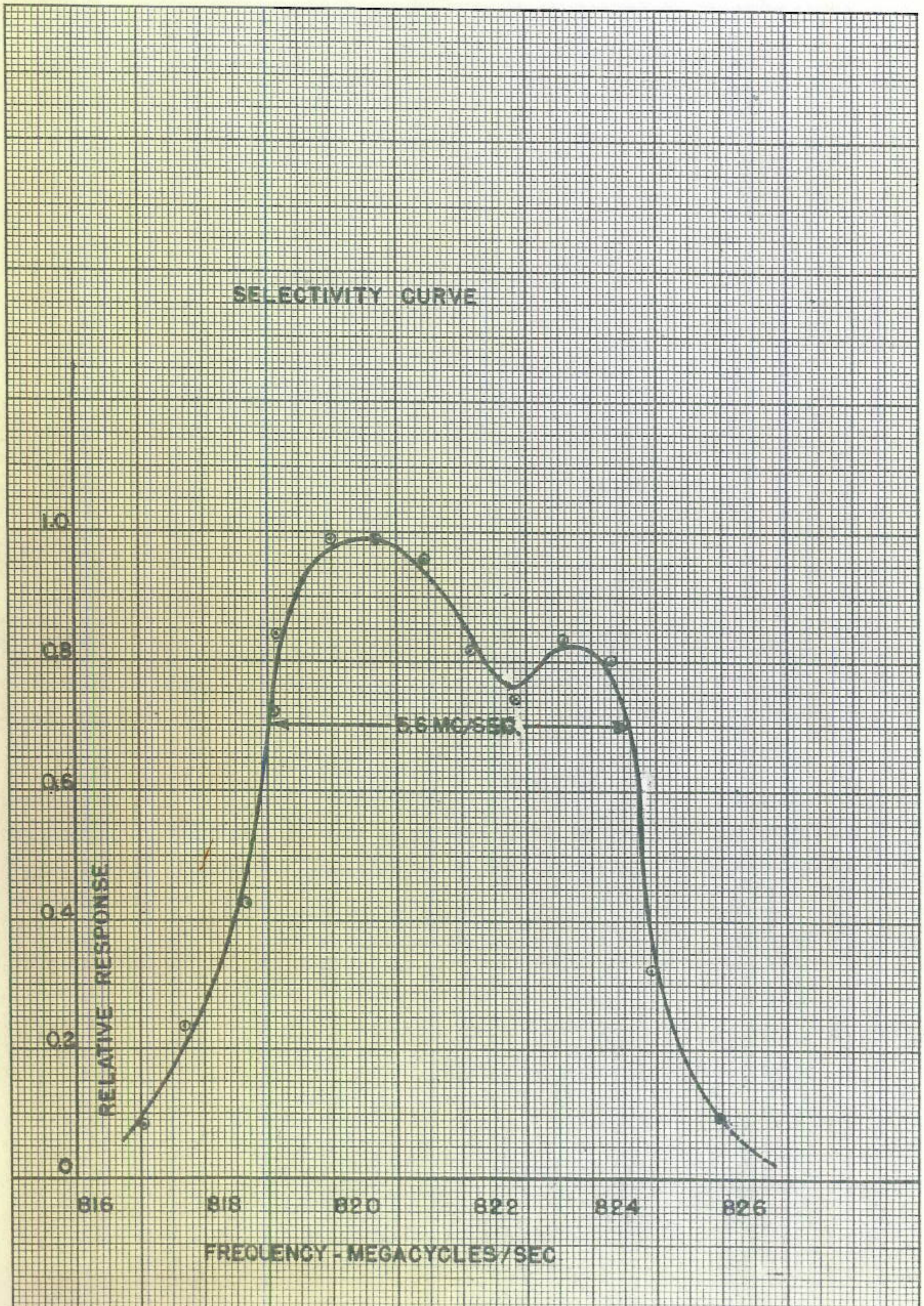
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0.6
0.4
0.2
0
RELATIVE RESPONSE
5.5 MC/SEC.
816
818
820
822
824
826
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Subj: AN 800 Megacycle Per Second Intermediate Frequency Amplifier. Report on Problem No. N30 R-S by W.R. Faust, Forwarding of.

Encl: (HW)
(A) Ten (10) copies of subject report R-2925 of 6 August 1946.

1. Enclosure (A) is forwarded herewith.

By direction of the Director.

J. B. J. Glanzman
Project Officer

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See Page d

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