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NAVAL RESEARCH LABORATORY REPORT

MODIFICATION OF INTERMEDIATE-FREQUENCY AMPLIFIER DESIGN IN RECEIVER UNIT OF RADAR TRANSPONDER BEACON MODEL AN/CPN-6 TO MINIMIZE UNINTENDED INTERROGATIONS CAUSED BY "ECHO STRETCHING"

By D. O. Collum, L. E. Clements, and J. K. Steckel

-Report R-2713-

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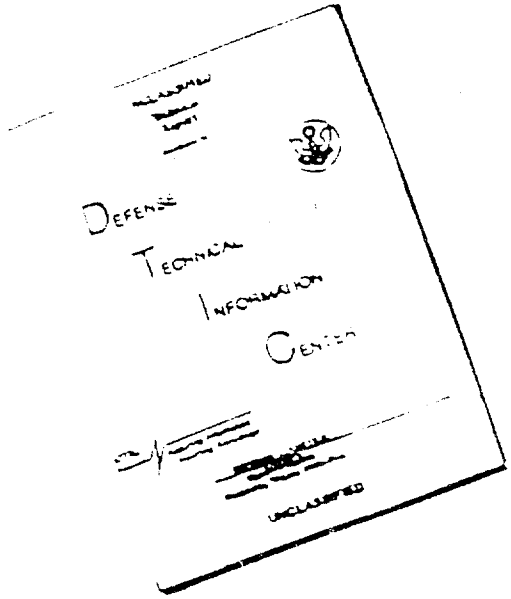

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SHIP-SHORE RADIO DIVISION - RECEIVER SECTION

12 December 1945

MODIFICATION OF INTERMEDIATE-FREQUENCY AMPLIFIER DESIGN IN RECEIVER UNIT OF RADAR TRANSPONDOR BEACON MODEL AN/CPN-6 TO MINIMIZE UNINTENDED INTERROGATIONS CAUSED BY "ECHO STRETCHING".

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Preliminary Pages	a-c
Numbered Pages	6
Plates	1-9
Distribution	d

NRL Problem 3456.1R-C

3-538

ABSTRACT

The reliability of a microwave radar transponder beacon as a navigational aid has been improved by materially reducing unnecessary traffic handled by the beacon. A rapid build-up, slow recovery system of automatic gain control is used in the i-f amplifier to prevent echo saturation of the receiver with resultant pulse width distortion. Additional operational trials are recommended as a basis for future beacon designs and modifications.

TABLE OF CONTENTS

INTRODUCTION

1. The AN/CPN-6 Radar Transpondor Beacon is a shipboard or land-based equipment operating on the "X" band. The equipment supplies range, azimuth, and identification information to airborne radar operators. The capacity of transpondor beacons to carry "heavy traffic", i.e. to respond to a large number of interrogations, depends largely upon the ability of the pulse width discriminator to reject unintentional interrogations. Since the average power dissipation of the beacon transmitter is limited by tube ratings, it is highly desirable that unintentional interrogations be kept to a minimum, thus making the power capability of the transmitter available for reply to intentional interrogation. Difficulty has been experienced in the field, particularly in land-based installations, with "echo-stretching" of pulsed signals and the consequent failure of the pulse-width discriminator to reject unwanted signals. The effects of this pulse stretching may be reduced by a simple method of automatic gain control which has been developed and tested at this Laboratory, in accordance with reference (1). Models of this circuit have been fitted into an AN/CPN-6 receiver and field tested. It was observed that considerable improvement in discriminator performance was gained by the incorporation of this circuit in the beacon receiver.

SUMMARY OF DEVELOPMENT

2. The pulse-width discriminator of a transpondor beacon is intended to allow the beacon to reply only to pulsed signals of approximately 2 microseconds duration, that being the type of signal radiated by airborne radars desiring beacon response. Signals of appreciably longer or shorter duration, such as those radiated by airborne radars during searching, should be positively rejected in order to minimize traffic and allow only usable signals to be transmitted by the beacon. The performance of the pulse width discriminator in the field was disappointing in view of results obtained in laboratory tests. The poorer performance in the field has been traced to echo stretching effects. When it is realized that a one-microsecond radar search signal, originating several miles distant, need arrive at the beacon by two paths differing only 300 yards to add in such a manner that a two-microsecond pulse is formed, this situation can be understood. The object of the work to be described in this report was to improve the ability of the beacon pulse-length discriminator to function more efficiently by reducing echo-stretching.

3. A strong pulsed signal, received and amplified by a conventional superheterodyne beacon receiver, will reach an amplitude great enough to drive the video and latter i-f amplifiers to plate current cut-off and grid current regions. The signal is also amplitude limited intentionally, as shown by Plate 1, at a level slightly greater than noise by the pulse-width discriminator, in order to make that circuit function properly. It can be seen that any echoes of amplitude greater than noise will also limit at the same amplitude as the stronger,

directly-received signal which precedes them in time, thus forming in the receiver a signal of longer duration than the one originally transmitted. This effect is shown on Plate 2. When dealing with strong signals, this limiting effect takes place in the i-f amplifier, thus making the problem of greater scope than video overload.

4. Except in unusual and complex situations, the strongest signal received from an airborne radar will be the one traveling the direct path from plane to beacon antenna. Also, axiomatically, this signal will arrive before any of its echoes; Therefore, a circuit which would recognize amplitude differences, even at strong signal levels, and eliminate the weaker echoes could be expected to give better discrimination information than the conventional superheterodyne receiver.

5. A fast-acting, automatic-gain-control circuit was designed to control the gain of the i-f amplifier, providing a rapid reduction of gain and a relatively slow recovery.

6. A circuit diagram of an amplifier having these properties is shown in Plate 3. The last four stages of the amplifier provide the echo suppression, the level in the first five stages seldom exceeding their handling ability on even extremely strong signals. The "T" section high-pass filters between the latter stages of the amplifier serve to reduce the video component of the rapid changes in grid bias by giving the amplifier a sharper cutoff at the low frequency end of its bandpass. Gain, bandwidth, and power consumption are comparable to the original AN/CPN-6 i-f amplifier. Plate 4 shows the operation of the last stage which is typical.

7. Laboratory measurements were made to determine the signal-to-echo ratio which could be tolerated by a receiver employing this circuit, and compared to the calculated performance of a conventional receiver as shown in Plate 5. The input signal is plotted as abcissa and maximum non-triggering echo signal input is plotted as the ordinate. Gain reduction as a function of input signal is plotted against time on Plate 6.

8. Preliminary flight tests were made at Radiation Laboratory, Boston, Massachusetts, using two CXEH equipments at Deer Island. The stand-by equipment was modified by installing the "echo suppression" circuit in the i-f amplifier of the receiver. Laboratory tests showed it to have comparable performance to that shown on Plate 5. An aircraft, SNB 091, carrying model ASD Radar Equipment, was used in the tests. A flight of 60 miles was made to assure satisfactory operation of both Radar and Beacon, using conventional 2 microsecond interrogating signals. The local oscillator of the radar model ASD receiver was then tuned to receive the beacon frequency while the radar radiated a 1 microsecond "Search" signal. Thus, it was possible to determine when the beacon was interrogated by "search" signals. A plot of the data obtained is shown by Plate 7. At the

suggestion of Mr. John Tinlot, of Radiation Laboratory, a servo multivibrator was triggered from the trailing edge of the signals and a negative rectangular wave from the multivibrator applied to the suppressor grid of the third i-f amplifier tube of the stand-by receiver. This served to reduce the gain of the receiver for a period of 20 microseconds and return it to normal very quickly, in contrast to the approximately exponential recovery of the "echo suppression" circuit alone. Flight test data for this arrangement is also shown on Plate 7. In all cases, the greatest range at which the beacon signal was visible is plotted in order to present the comparison from a pessimistic viewpoint. This is considered merited by the difficulty of duplicating several variables in the airborne and ground equipments, such as receiver sensitivities, antenna tilt, correct tuning at exact instant interrogation began, etc.

9. Flight tests were also made, using two AN/CPN-6 Radar Transpondor Beacon equipments installed at the Naval Research Laboratory atop building 42. One beacon was modified to include the "Echo Suppression I-F Amplifier" in the receiver. The receiver gain control was rewired to vary the gain of the video amplifier, thus allowing maximum gain to be used at all times in the i-f amplifier in order to obtain optimum operation of the suppression feature. Power supply and space limitations ruled out the multivibrator circuit described in paragraph 8 for the present modification. A 0.1 microfarad condenser replaced C308 in the video amplifier. The original condenser was a purposely inadequate by-pass aiming to obtain a steeper trailing edge of the pulse by slight differentiation. This feature was no longer necessary and was removed to make operation more straightforward. A shipboard type antenna was used for one beacon and land-based type for the other. In order to be able to record data on both beacons simultaneously, a Type CW-60ABZ Radar Range Calibrator was used to delay the Discriminator trigger to the Coder of one equipment. The delay was adjusted to increase the apparent range ten miles. To provide a better comparison of the two receivers, they were interchanged after the data for Plate 8 was obtained and the tests repeated, yielding the data from which Plate 9 was plotted. A Naval aircraft, SNB39819, flying from Naval Air Station, Washington, D.C. and equipped with radar model ASH, was used in obtaining the data. The "Search" local oscillator of the model ASH was tuned to receive the beacon frequency in order that the beacon transmitter could be received when the airborne equipment radiated either a 0.6 microsecond "Search" or 2.0 microsecond "Beacon" signal. Plates 8 and 9 show the results obtained when flying toward the beacons from different directions. The shaded areas represent the area enclosed by the maximum range points at which the standard and modified beacons could be interrogated by the 0.6 microsecond "Search" signal.

10. A production prototype of the "Echo-Suppression I-F Amplifier" was constructed and taken to the Galvin Manufacturing Corporation by engineers of this Laboratory. The manufacturer's engineers were familiarized with the theory of operation and methods of testing the performance.

11. Plans to incorporate the amplifier in all production equipments were cancelled when the entire beacon contract was terminated, although a trial production run of ten amplifiers was completed. It is understood that these units will be shipped to this Laboratory, with the intention that they be installed in operational beacons where echo-stretching problems have been encountered.

CONCLUSIONS

12. It has been found that microwave beacons are not always reliable navigational aids because of their inherent traffic-handling limitations imposed by surrounding objects and equipments. The beacons are often unintentionally interrogated by airborne radars in search operation and by others on test benches and in maintenance shops in the vicinity of the beacon installation. The amplifier described in this report, when properly incorporated in a model AN/CPN-6 Radar Transponder Beacon Equipment, is capable of relieving that equipment of much unnecessary traffic, leaving it free to serve legitimate interrogations.

RECOMMENDATIONS

13. In view of the decided improvement shown in field tests, it is recommended that ten "Echo Suppression I-F Amplifiers", built by Galvin Manufacturing Corporation, be installed in operational AN/CPN-6 Radar Transponder Beacons which are known to give unsatisfactory performance because of excessive traffic requirements. A careful analysis of their operation should then be made to serve as a guide in future microwave beacon designs and modifications.

ACKNOWLEDGMENTS

Acknowledgment is made to Mr. John Tinlot, of Radiation Laboratory, Massachusetts Institute of Technology, for his help in making beacon equipment and flight test facilities available for preliminary trials, and to Mr. Henry Magnuski of Galvin Manufacturing Corporation for his efforts toward incorporation of the improved circuit into production equipment. Acknowledgment is also made to Lt. G. E. Hart, of the Airborne Coordinating Group of this Laboratory, for his assistance in aligning the radar model ASH equipment used in later tests and in ground checks against test bench radar interrogation.

REFERENCES

1. BuShips ltr. (9180g) Serial C-918-11042 of 8 August 1944 to NRL - Request for Assignment of Problem S458.1R-C.

2. NRL ltr. C-F42-9(350:RGH) of 11 July 1944 to BuShips - Interim Report on Pulse Length Discriminator and Automatic Gain Control.

3. Galvin Mfg. Corp. ltr. of 21 July 1945 signed by Henry Magnuski to NRL - Receiver Gain Control.

4. NRL ltr. F42-9(355:JKS) R-350-24122/45 of 12 October 1945 to BuShips - Receiver Gain Control.

Original data recorded in NRL Log Book 511.

BASIC DISCRIMINATOR OPERATION

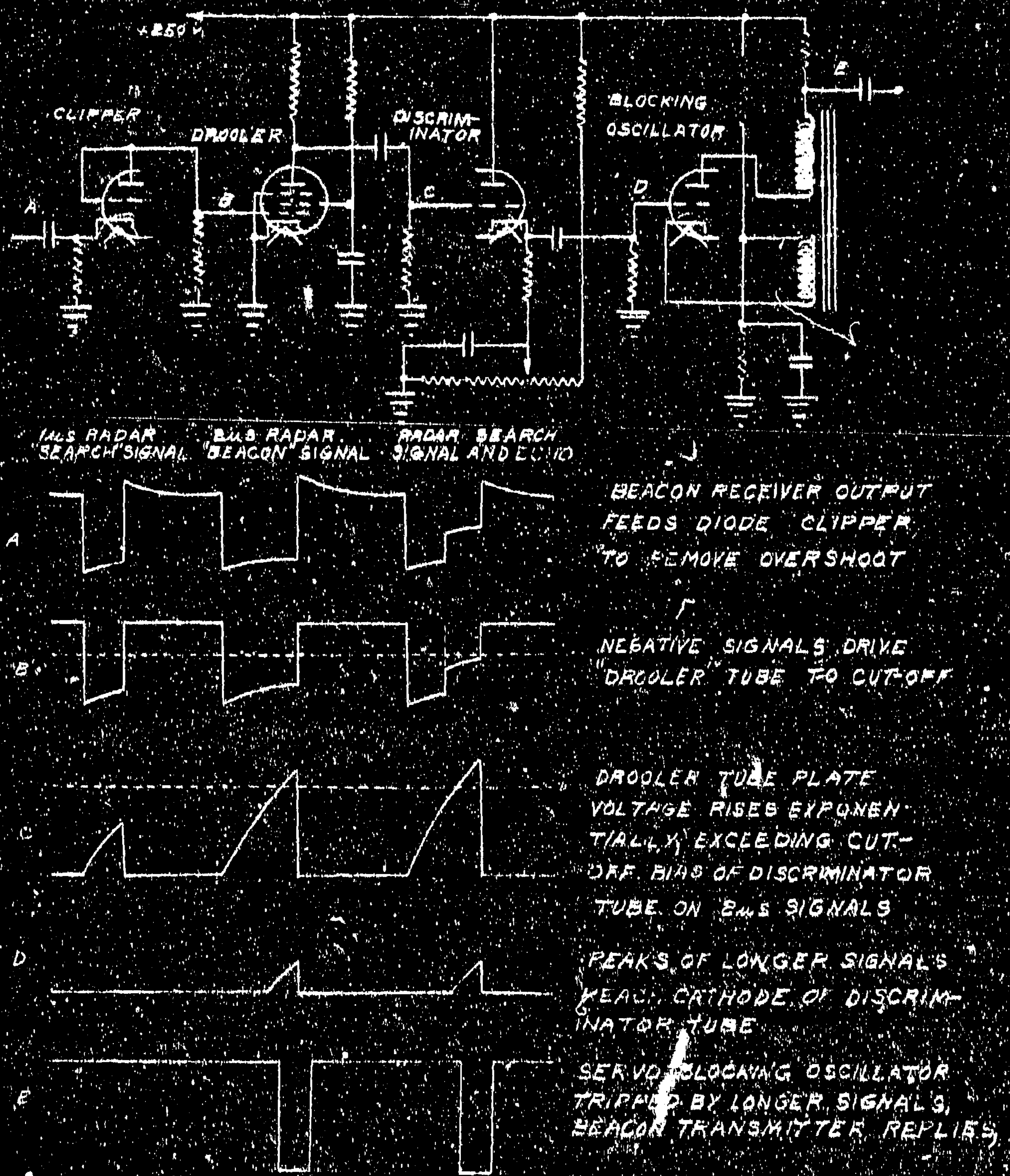

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PLATE I

ECHO STRETCHING

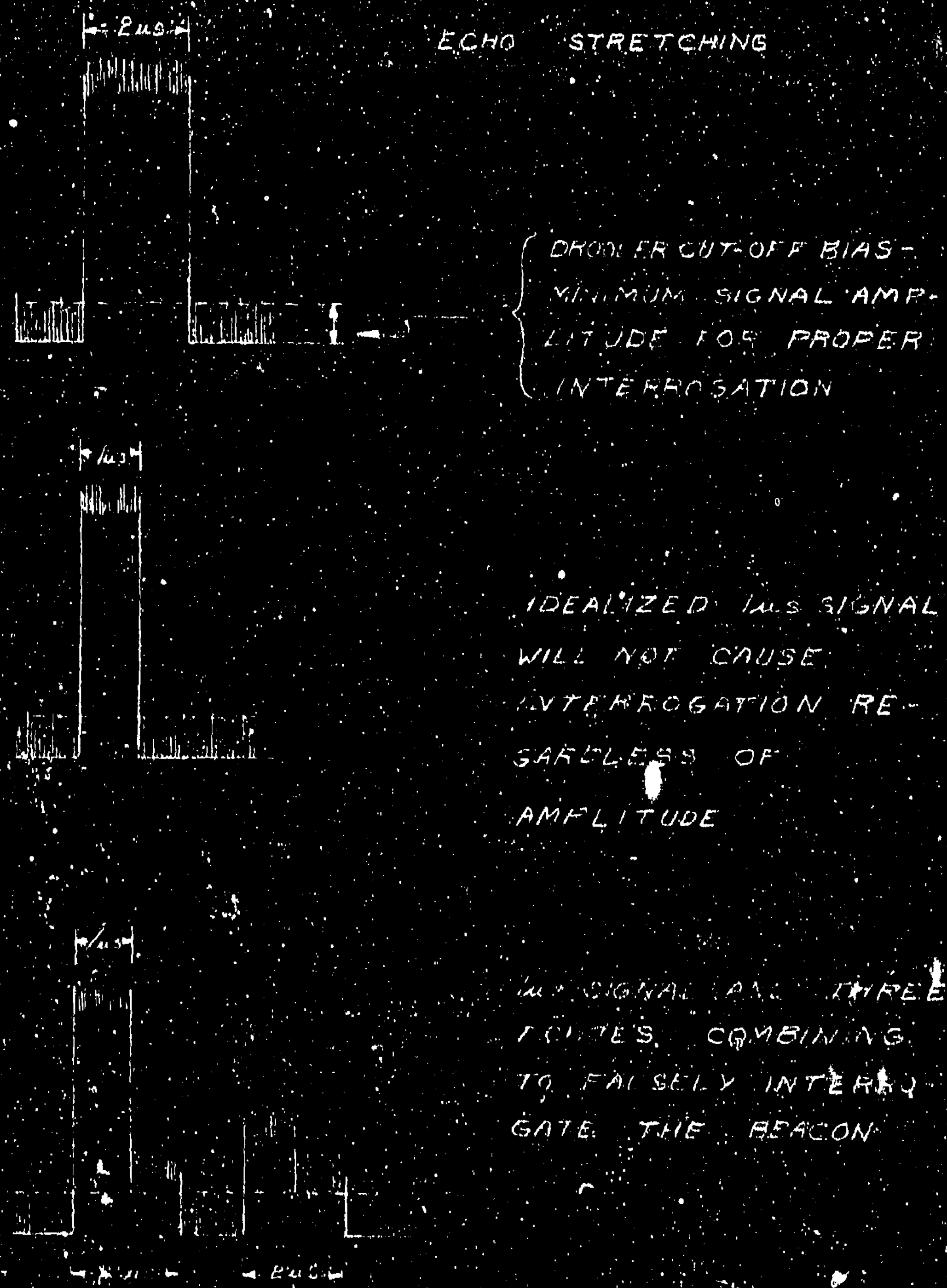
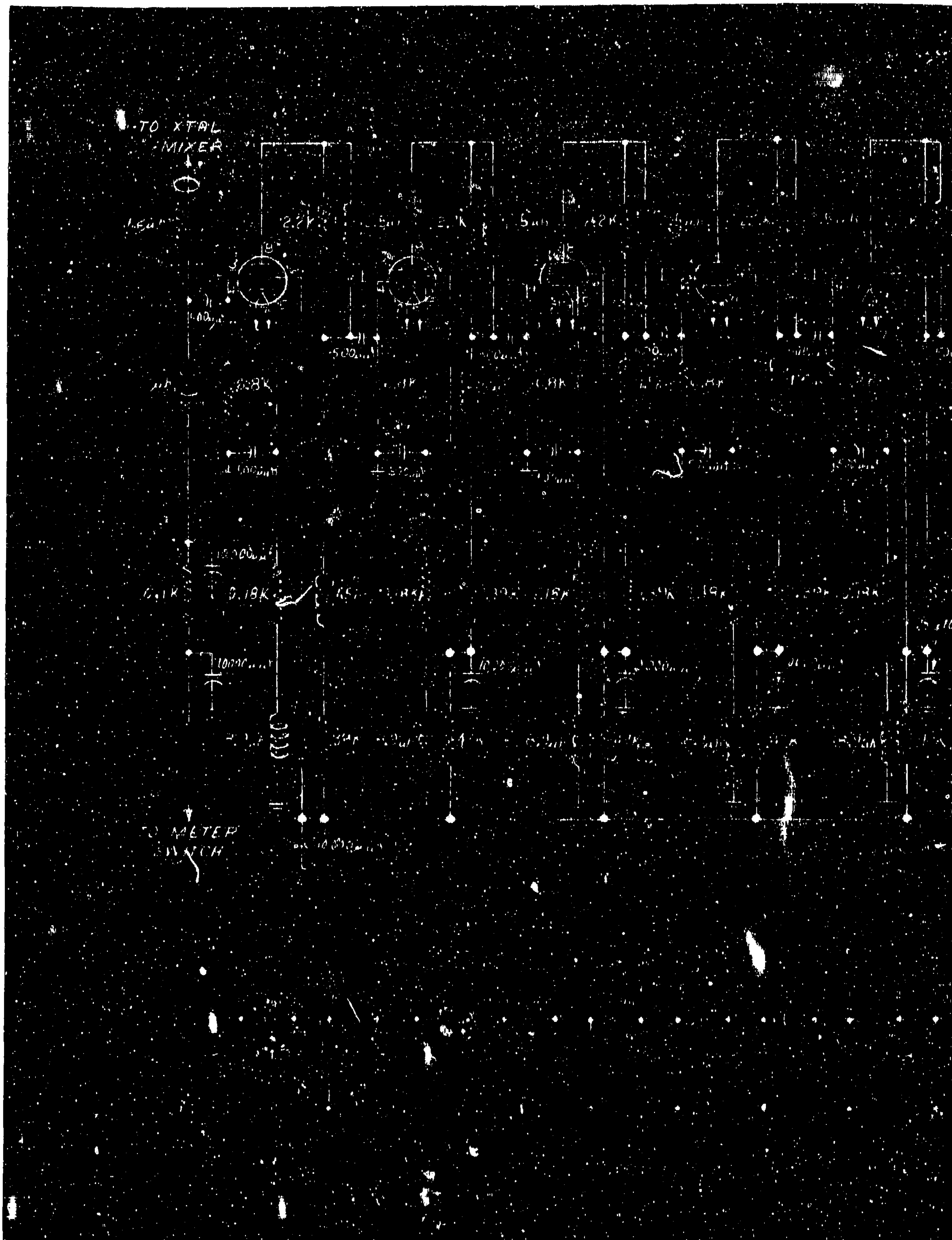
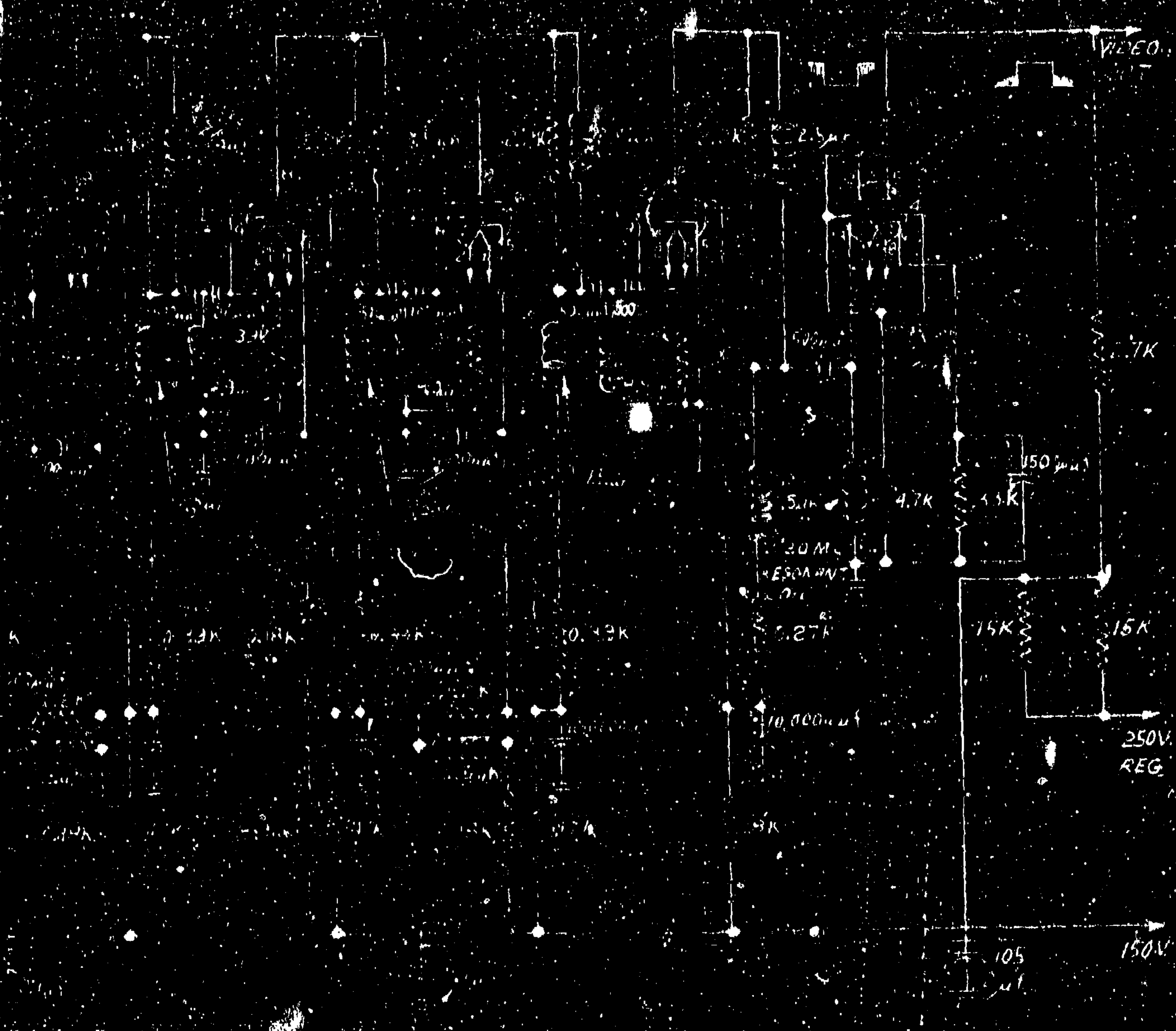


PLATE 2


TO XTAL MIXER
2.2K
0.18K
TO METER SWITCH



AMPLIFIER

PLATE

A.G.C. ACTION OF TYPICAL I-F AMPLIFIER STAGE

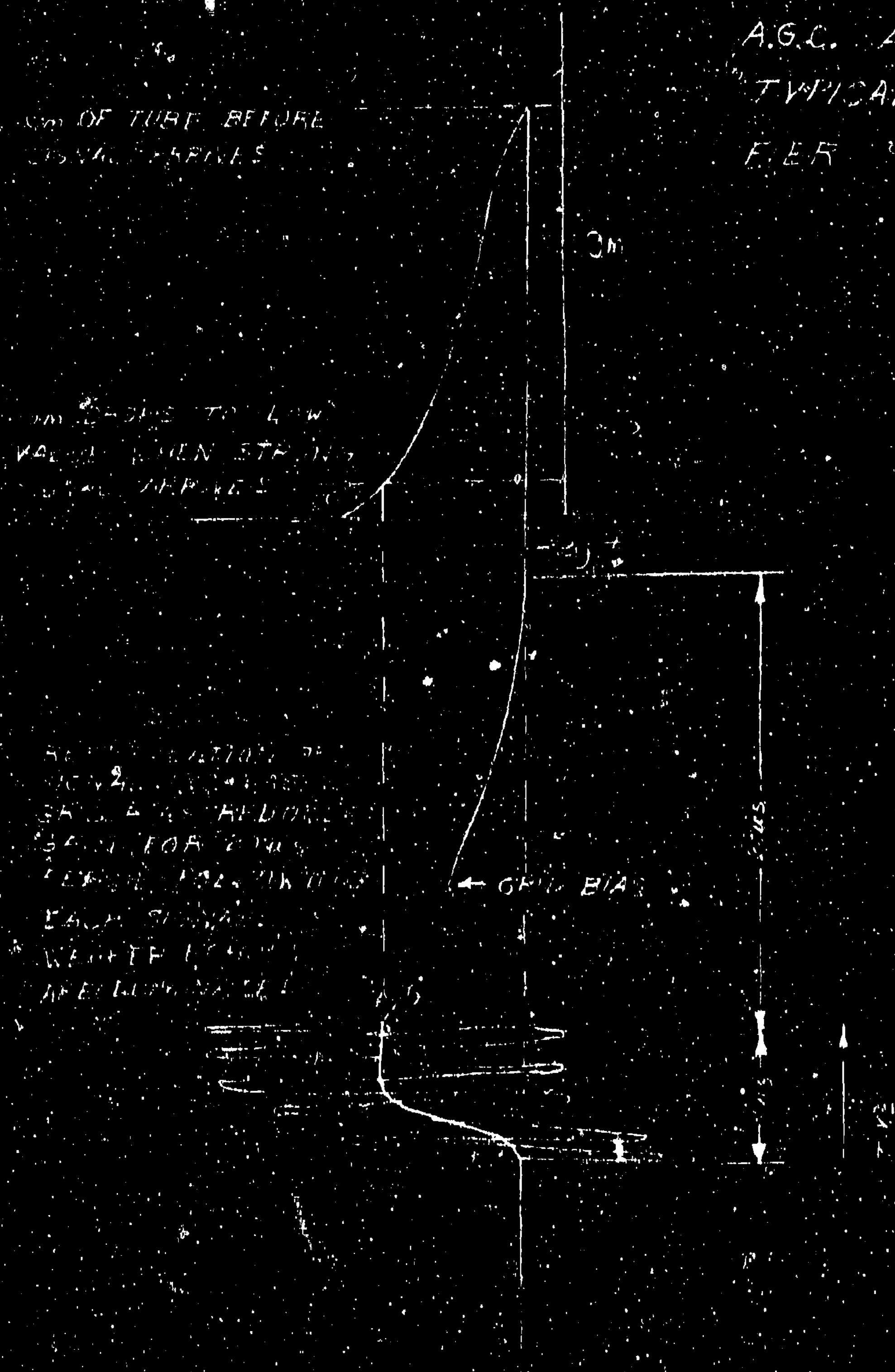


PLATE 4

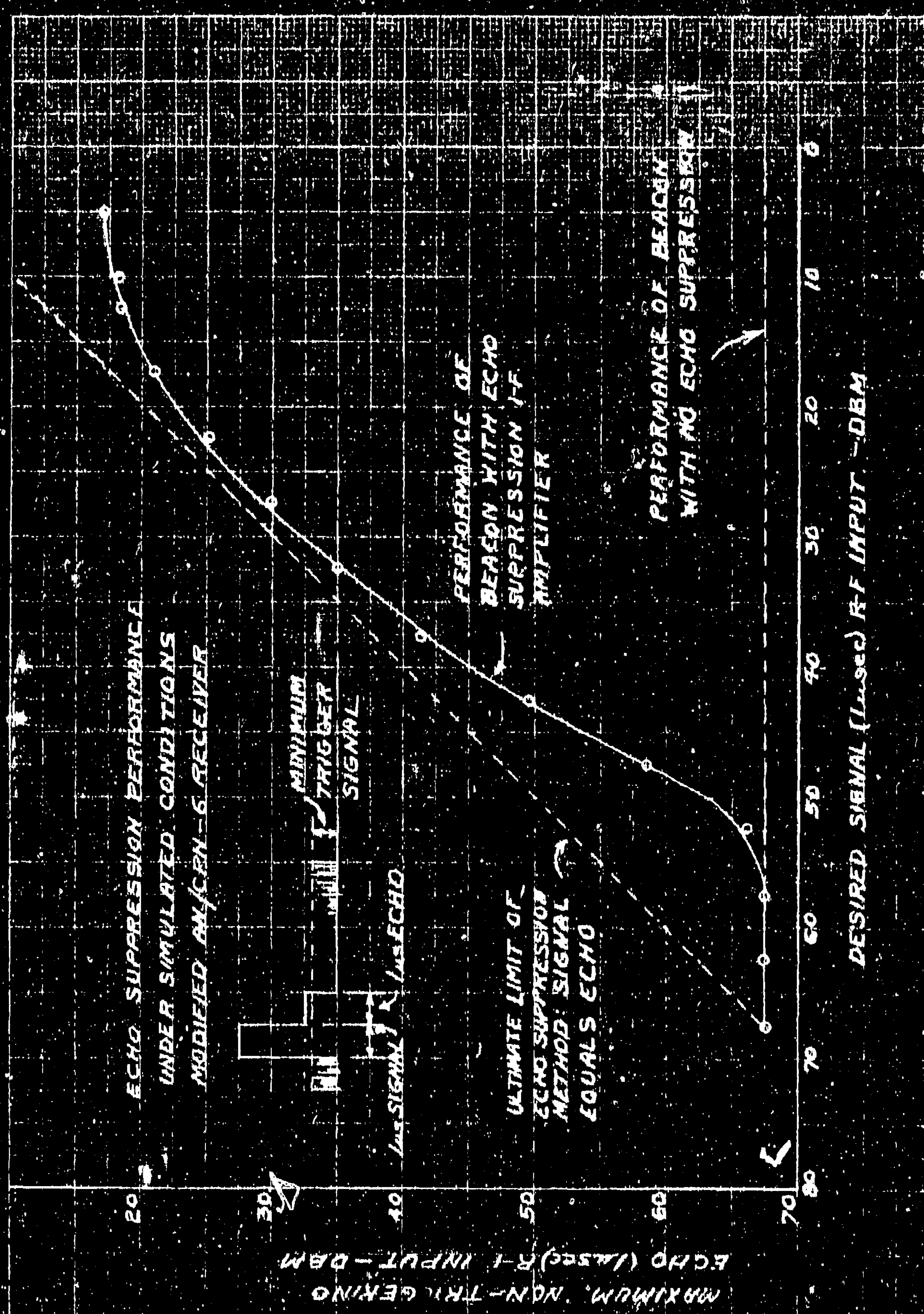


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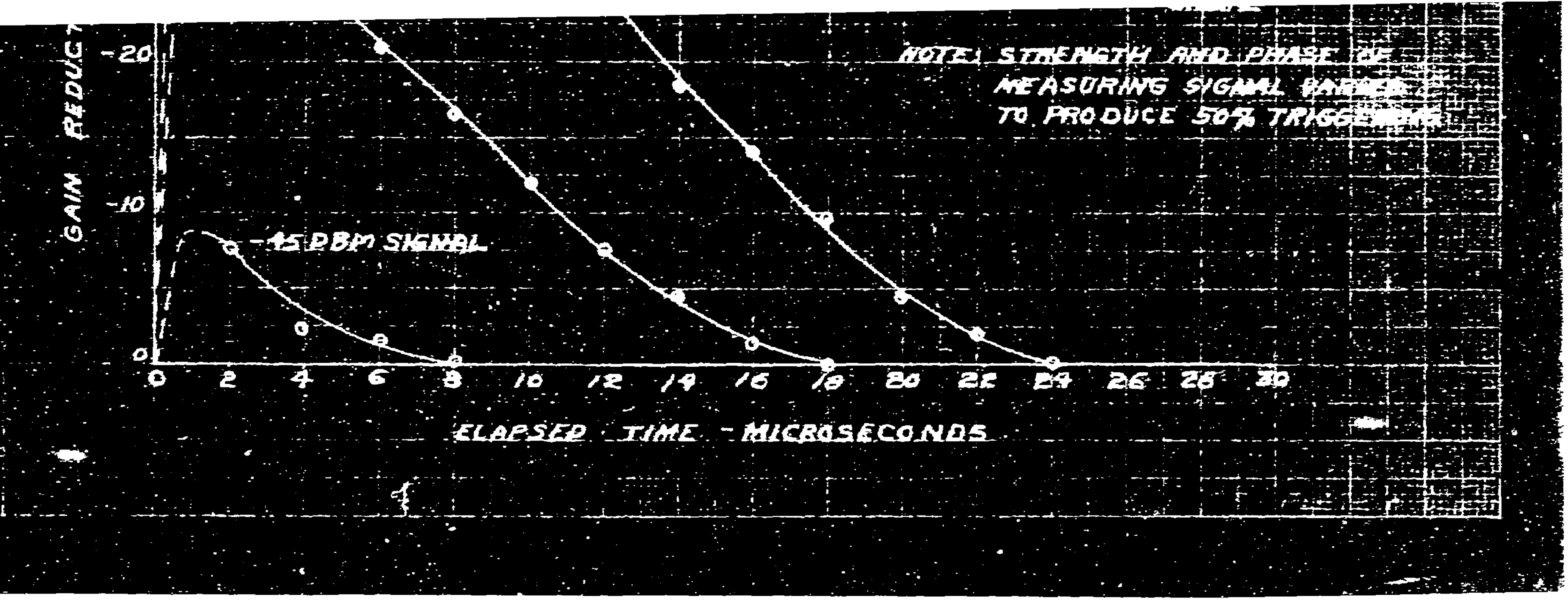
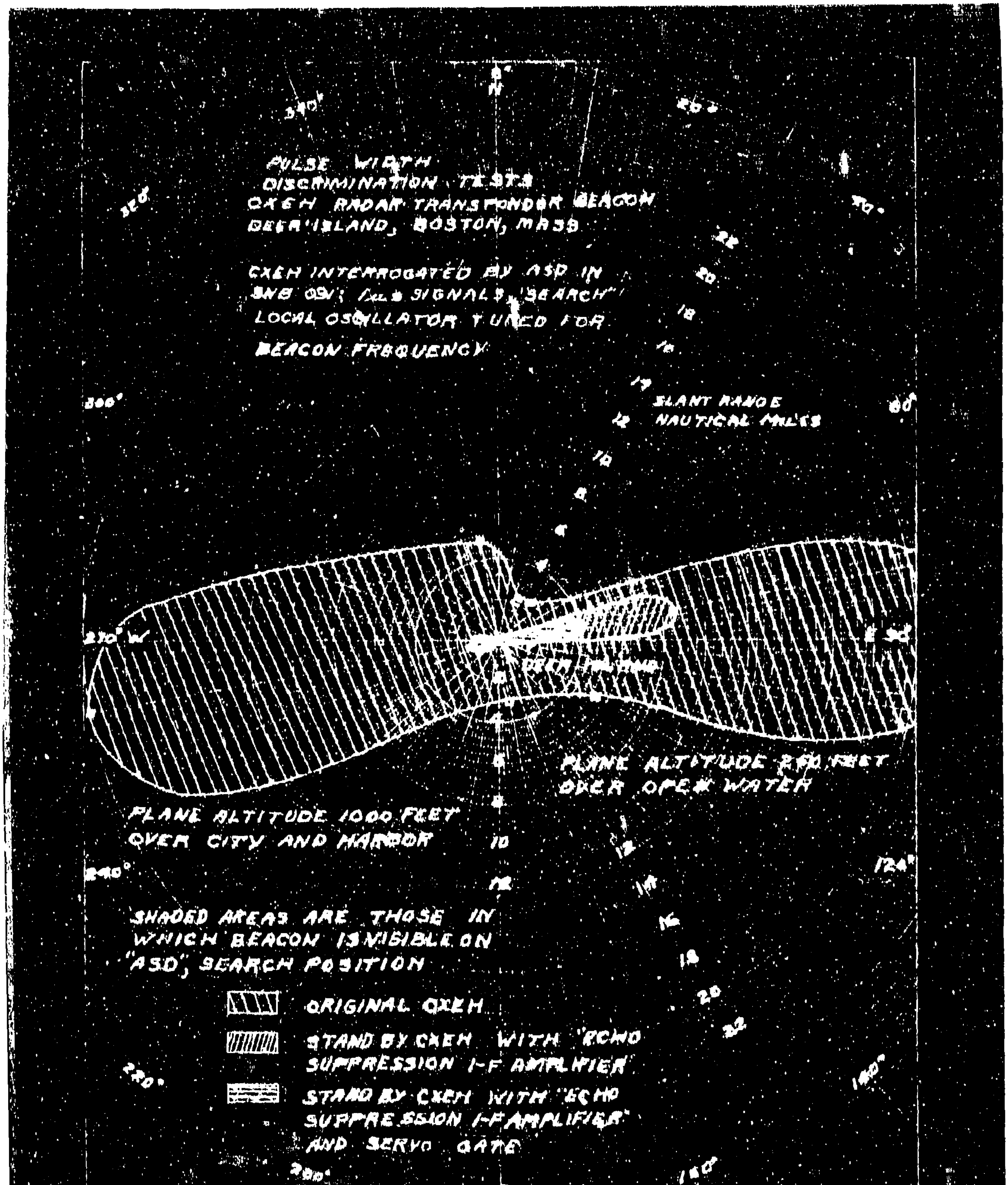
PLATE 5



NOTE: STRENGTH AND PHASE OF
MEASURING SIGNAL
TO PRODUCE 50% TRIGG
GAIN REDUCT
-20
-10
0
-45 DBM SIGNAL
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
ELAPSED TIME - MICROSECONDS

PLATE 6



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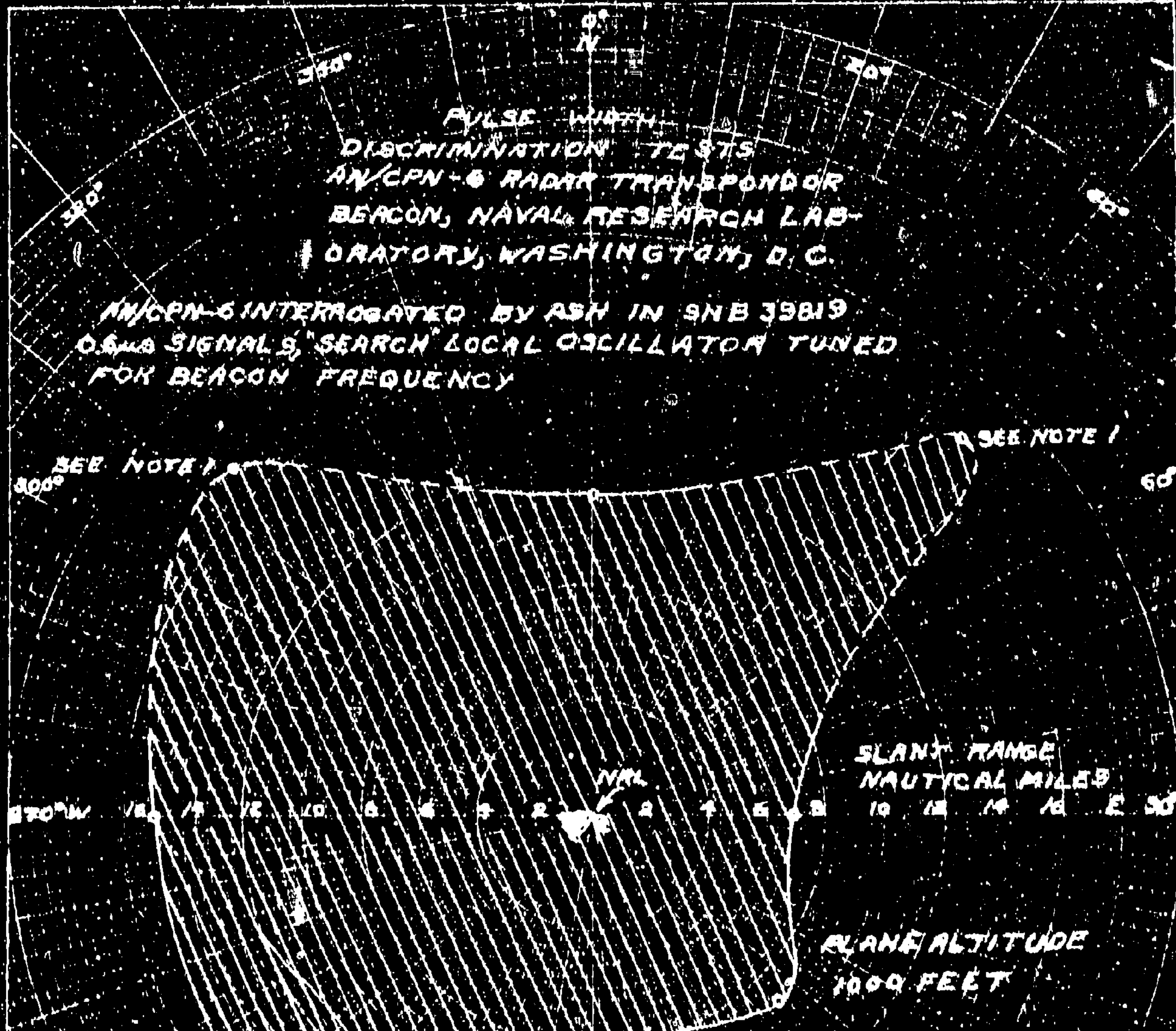

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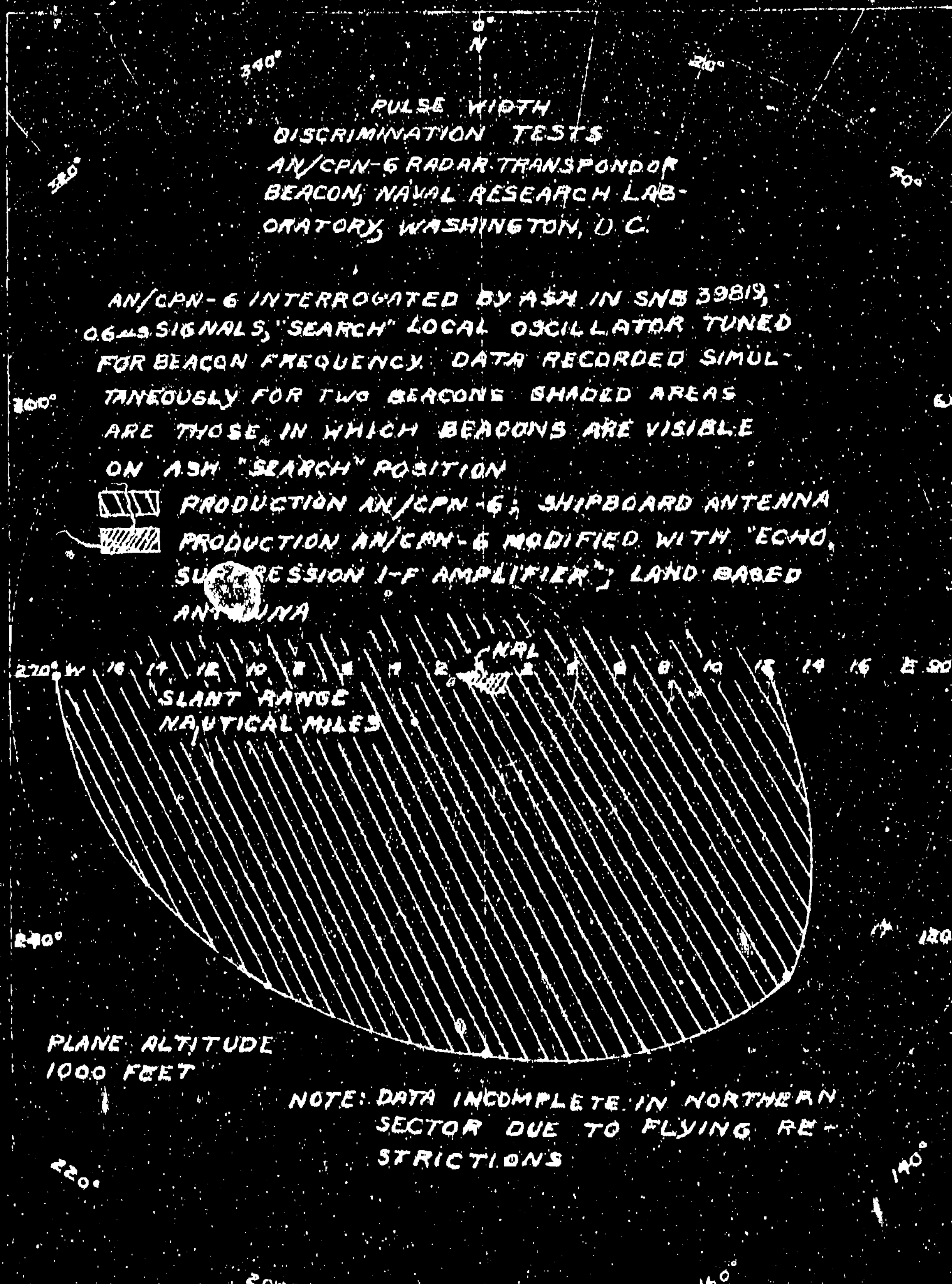
PLATE 8


0°
N
340°
20°
PULSE WIDTH
DISCRIMINATION TESTS
AN/CPN-6 RADAR TRANSPONDOR
BEACON; NAVAL RESEARCH LAB-
ORATORY, WASHINGTON, D.C.
320°
40°
AN/CPN-6 INTERROGATED BY ASH IN SNB 39819,
0.6 μs SIGNALS, "SEARCH" LOCAL OSCILLATOR TUNED
FOR BEACON FREQUENCY. DATA RECORDED SIMUL-
TANEOUSLY FOR TWO BEACONS. SHADED AREAS
ARE THOSE IN WHICH BEACONS ARE VISIBLE
ON ASH "SEARCH" POSITION
300°
60°
PRODUCTION AN/CPN-6; SHIPBOARD ANTENNA
PRODUCTION AN/CPN-6 MODIFIED WITH "ECHO
SUPPRESSION I-F AMPLIFIER"; LAND BASED
ANTENNA
NRL
270° W 16 14 12 10 8 6 4 2 2 4 6 8 10 12 14 16 E 90°
SLANT RANGE
NAUTICAL MILES
240°
120°
PLANE ALTITUDE
1000 FEET
NOTE: DATA INCOMPLETE IN NORTHERN
SECTOR DUE TO FLYING RE-
STRICTIONS
220°
140°
200°
160°
S
180°

PLATE

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