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Report on

Test of Model CXCK Pulse Communication Equipment

Contractor

Federal Telephone and Radio Laboratory

NAVAL RESEARCH LABORATORY
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Section I and IV submitted by: ____________________
C. E. Cleeton, Head of Communication Security Section

Section II submitted by: ____________________
R. B. Meyers, Head of Transmitter Section

Section III submitted by: ____________________
T. McL. Davis, Head of Receiver Section

Reviewed by: ____________________
A. Hoyt Taylor, Superintendent Radio Division

Approved by: ____________________
A. H. VanKeuren, Rear Admiral, U.S.N. Director

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I. Introduction.

This report covers the tests made by the Naval Research Laboratory on the Model CXCK Radio Link P-1 equipment as authorized by reference (a). Four units, serial numbers 1, 2, 3, and 4 were received, complete with antennas, junction boxes, 200 feet of twin conductor pressurized line and two Model 2200 Auto-Dryaire units, but no spare parts. This report has been prepared jointly as follows. Part II covers the mechanical and electrical tests made on Unit #1 by the Transmitter Section. Part III covers the electrical tests made upon the receiver of Unit #2, the mechanical tests made upon the receiver of Unit #1, and a re-inspection of the Auto-Dryaire unit performed by the Receiver Section. Part IV includes additional comments on the mechanical construction and a report of the operational tests made with Units 3 and 4 by the Communication Security Section.

II. Tests Made By The Transmitter Section.

1. Physical Description

The CXCK Radio Link P-1 Equipment is mounted in a steel cabinet the cabinet being shock mounted in an angle iron cradle. The top of the cabinet is provided with a grill to facilitate ventilation of the cabinet interior. An opening 10 inches by 20 inches covered by an air filter with a 10 inch fan just above the filter provides circulation of air from bottom to top of the cabinet. Seven chassis are mounted on the front door, thereby providing increased accessibility to the components of the equipment when the door is opened. No lifting eyes or other means of attaching a lifting cable are provided on the equipment. It should be noted that the cradle type of shock mounting employed in this equipment increases the installation space required by 5 - 3/4 inches in width and 3 inches in depth over the space that would be required to mount the cabinet itself to the deck or floor, as is done in the case of conventional Navy transmitting equipment. (See Table 5).

2. Dimensions and Weights

(a) The over all dimensions of the equipment are: height, 72-1/2 inches; width, 29 inches; depth, 28 inches. In addition to these dimensions, the front doors when open extend 17-3/4 inches to the front of the transmitter.

(b) The weight of the equipment including all tubes and shock mountings is 937 pounds. The antenna including cover weighs 162 pounds.

3. Shock Mountings

The cabinet weight of approximately 837 pounds is supported on four double 180-pound U. S. Rubber Company shock mounts. Six rubber snubbers are used near the top of the cabinet to restrain it from

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top sway within the mounting cradle. The cradle itself is shock mounted from the floor or deck by a rubber sheet beneath the cradle and by eight rubber bumpers, two on each side of the cradle; this arrangement allows the cradle to move with respect to the floor or deck. These rubber bumpers, through which the equipment securing bolts pass, are in a compressed condition against the cradle. This makes the equipment difficult to secure to the deck, since the bumpers must be compressed before the mounting bolts may be put in place. This is a difficult operation to perform in the restricted space available and it is recommended that a more satisfactory method of mounting these snubbers be employed.

4. Power Requirements.

The unit requires 850 watts, 115 volts, 60 cycles A. C. single phase at a power factor of 81 per cent when operating in the transmitting position. No provision has been incorporated in the equipment whereby the input voltage to the equipment can be maintained at 115 volts for line voltages of plus or minus 10 per cent of the rated 115 volts.

5. Power Output.

Power output data are summarized in Tables 1, 2, and 3. It will be observed that 8.5 to 12.4 watts average power is delivered to the transmission line terminals throughout the frequency range. This is considerably less than the power output of 25 watts stated in the descriptive specifications. This deficiency in power output is the result of the two following conditions:

(a) First, the filament voltage on the h-f oscillator tubes (V103 and V104) is 10.6 per cent below normal voltage. These tubes, with normal filament voltage, are operating near their peak filament emission capabilities and operation at 10.6 per cent below normal filament voltage results in an average power output drop of 45 per cent at 300 mc (see Table 3). The usual tolerance allowed on thoriated tungsten filaments is plus or minus 5 per cent, which is exceeded in this equipment by over 100 per cent. In view of this fact it is recommended that this condition be corrected and that a constant voltage transformer be provided in the equipment to prevent changes in input supply voltage from greatly affecting the power output.

(b) Secondly, there is an unduly large loss of power in the antenna relay and connecting cables associated with it. Power measurements made directly out of the h-f oscillator (Table 2) and at the antenna terminals (Table 1) indicate a 30 per cent loss of power through this relay and associated cables. This relay is an ordinary D.P.D.T. relay to which metal plates have been attached around the armature to make the relay take on a low impedance

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characteristic and thus avoid standing wave reflection losses. However, the metal pieces added to this relay do not achieve the desired effect, and produce a power loss that is too large to be tolerated. Therefore, it is recommended that a concentric line type of relay of suitable characteristics be employed in lieu of the existing relay in the CXCK equipment.

6. Operation of Vacuum Tubes.

Vacuum tube voltages, currents, and dissipations were found to be within Navy specifications, with the possible exception of the h-f oscillator tubes V103 and V104, Eimac type no. 35TG. During the course of the tests four tubes failed in the equipment. These tubes exhibited burned out filaments after less than 50 hours operation as pulsed oscillators. The peak emission demand on the no. 35TG tubes was investigated. Calculated peak emission (duty cycle and average plate current) indicates 1 ampere per tube based on a square pulse. Actually the wave form is triangular (see Plate 1) and peak current demand may be at least 2 amperes. The attached curves (Plate 2) show peak emission characteristics for two tubes measured at NRL. These curves seem to indicate the tubes are being operated near saturation, particularly at the filament voltage of 4.75 volts, which is applied to the filaments in this equipment. The fact that the power output of the tubes rises so rapidly with a slight increase in filament voltage also indicates that the tubes are operating near their peak emission capabilities. After the failure of four tubes in the equipment the filament voltage applied to these tubes was raised to the normal 5 volts and since that time no further tube failures have occurred. It is suggested that Eimac be consulted as to the operation of these tubes under pulsed conditions of operation. Type 35TG tubes are not Navy approved tubes and it is recommended that the Contractor investigate the possibility of employing Navy approved type tubes in lieu of the type 35TG tubes now used in the equipment.

7. Modulation Characteristics.

The modulator contained in the transmitter is capable of modulating the h-f oscillator 25 per cent on amplitude modulation and is capable of producing the maximum pulse displacement of plus and minus 1 microsecond on time modulation with an audio input level of 0.15 volt applied to the input of the audio system. An automatic "clipper" is provided which reduces the gain of the audio system after a certain input level has been reached, thus preventing over-modulation on either a. m. or t. m. The threshold of clipping action is adjustable over a wide range so that satisfactory operation is obtainable under different conditions of background noise and audio inputs.

A 500-cycle audio oscillator is employed in the audio system to provide modulated c-w operation on either the a-m or the t-m channel.

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It is recommended that the frequency of this tone oscillator be changed to 800 cycles to conform with the standard Navy tone. Standard Navy earphones are constructed so that they are most responsive to frequencies near 800 cycles.

Actual listening tests were conducted between two equipments and the intelligibility was entirely satisfactory at both low and high audio input levels on both the a-m and t-m channels.

8. Frequency Stability and Range

The various conditions under which the stability of the transmitter was tested and the results obtained are summarized in Table 4.

The stability of the CXCK transmitter is approximately 0.25 per cent over the frequency range and thus is satisfactory for the purpose intended. The stability under conditions of shock and vibration was especially good. Under no conditions of the temperature or humidity tests was it found necessary to retune or "trim" the transmitter due to circuit frequency drift.

The frequency range of the transmitter is 280 mc to 353.5 mc, which is considered satisfactory for the desired frequency range of 300 mc to 350 mc.

9. Operation at High Humidity

In addition to the normal tests in which the relative humidity was varied from 30 per cent to 95 per cent with the transmitter continuously in operation, the equipment was left idle overnight in an atmosphere of 95 per cent humidity at 40°C. When power was first applied to the equipment and the test key depressed the overload relays tripped open. Subsequent investigation showed the "Pulse Generator Unit" to be inoperative. Repeated efforts to obtain operation of the unit were futile, so the humidity was lowered to 30 per cent at 40°C. After remaining in this atmosphere for an hour the "Pulse Generator Unit" functioned normally and an attempt was made to put the equipment in operation. When the test key was pressed a violent arc-over occurred inside the equipment and the overload relays tripped open. Investigation of this condition revealed that the main high-voltage rectifier plate power transformer had arced over. This arc-over (on the secondary side of the transformer) occurred between one of the high-voltage terminals and the center tap of the winding and between the center tap and the case of the transformer. It should be noted here that the minus side of the high-voltage supply is not grounded and operates at a potential of 120 volts above ground. The transformer used here has the two high-voltage terminals brought out through isolantite bushing standoffs. The center tap of this winding is brought directly through the bakelite terminal board by a metal stud. This undesirable condition, made worse by the collection

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of moisture around these high-voltage terminals, caused the arc-over described above. Therefore, it is recommended that a transformer having all secondary winding terminals mounted on isolantite feed-through standoffs be employed in this equipment in lieu of the transformer now in use. It is further recommended that a source of heat of several hundred watts capacity be provided in the unit along with a method of controlling it in order to make possible a reduction of the relative humidity inside the equipment when the equipment is standing idle.

10. Operation at Low Ambient Temperatures

The equipment was allowed to remain idle with no power applied at a temperature of 0° C. for four hours. At the end of this idle period an attempt was made to put the equipment in operation. When the test key was pressed the 866 rectifier tubes flashed back and the overload relays tripped out. This occurred three times before the equipment could be operated normally. However, operation was not entirely satisfactory, as the 866 rectifier tubes showed only a faint blue color near the very top of the tubes and there was excessive mercury condensation on the envelopes of the tubes. It is recommended that vacuum type rectifier tubes such as the type 836 be used in lieu of the type 866 mercury vapor tubes now used in the equipment.

11. Vibration

The equipment was subjected to vibration at various rates up to 2000 cycles per minute. At approximately 750 cycles the equipment vibrated at its maximum amplitude. Due to the low frequency the vibration was not severe. At higher frequencies the cradle vibrated rather violently; however, the cabinet was almost stationary. Frequency stability under vibration conditions is shown in Table 4.

12. Shock

The equipment successfully withstood 40 shocks, all administered at the maximum test table peak acceleration of over 500 g. Listening tests were made using both tone and voice modulation. No breaks in the carrier could be detected when the shock was administered. Frequency stability under conditions of shock is shown in Table 4.

13. Inclination

The inclination tests were successfully withstood in both the front-to-back and side-to-side directions. Frequency was not measurably affected by inclination up to an angle of 45 degrees from the vertical.

14. Mechanical Considerations

The chassis type of construction used on the CXCK equipment makes it relatively simple to perform maintenance and servicing

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operations. The cradle type of shock mounting employed in this equipment protects the equipment adequately against shock and vibration and can be considered suitable for its intended purpose. There are, however, certain undesirable mechanical features in the equipment which should be remedied. These are as follows:

(a) A micro-switch is used for the top door interlock. These switches sometimes do not operate properly due to their close tolerances and small movement in opening and closing. Slight rusting of the drive shafts or other internal movement would ruin the switch. Therefore, it is recommended that the type of interlock that has male and female parts such as is used on the bottom door be used as an interlock in lieu of this micro-switch.

(b) None of the control knobs, gears, etc., are pinned to their respective shafts as is required by basic Naval specifications. Some of these controls must transmit considerable torque, and it is recommended that the use of steel taper pins be employed for fastening these parts.

(c) Many of the control dials are not equipped with dial locks. No trouble was experienced during shock or vibration tests, as the transmitter controls are sufficiently "stiff" to withstand shock and vibration. However, it is recommended that dial locks be provided on the controls to prevent accidental movement of the controls.

(d) The clamps that secure wiring, cables, and harnessed wiring are not equipped with buffers of any type beneath the clamp, and as a result the clamps are cutting into the wiring at numerous places and it is merely a question of time until short circuits develop at these points. It is recommended that felt or other suitable buffers be used beneath all cable clamps to prevent this condition.

(e) None of the fuse mountings in the equipment are marked with the fuse rating as is required by basic Naval specifications. It is recommended that this be done to facilitate servicing operations.

15. <u>Electrical Defects</u>

There are certain electrical characteristics of the equipment that must be corrected before satisfactory operation can be obtained

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under Naval conditions.

(a) The overload relay K-805 is set to "trip" at approximately 200 ma. The normal current through the relay is 192 ma. Under line voltage variations this relay "trips" open. It is recommended that an adjustable rheostat be used across the coil of this relay in lieu of the fixed resistors now employed in order that the tripping current of this relay can be adjusted to any point up to 125 per cent of normal current.

(b) The audio input circuit consists of a 500-ohm input transformer. This transformer is used for audio input from the local microphone or from the standard Navy remote control telephone unit. The audio output voltage of the Navy remote control telephone unit is sufficiently high so that the first audio stage of the audio amplifier is overloaded, the a-v-c circuit becomes inoperative, and unintelligible speech modulation of the transmitter is the final result. It is recommended that an input transformer with two primary windings, one for the remote audio input, and one for the local microphone, be provided in lieu of the input transformer now employed and that an input attenuator pad be provided to control the audio input from the Navy remote control unit or from the ship's telephone circuits. The control circuits and headphone circuits function normally from the standard Navy remote telephone unit and these circuits of the equipment are considered capable of giving satisfactory operation.

(c) In some cases there are resistors in the equipment which are overloaded. These are all small one-watt composition resistors. For example, resistor R-725 is rated at 1 watt in free air. This resistor is dissipating 1.875 watts in an enclosed space where there is no circulation of air. It is deemed good engineering practice to work this type of composition resistor at 50 per cent or less of its rating in confined spaces. No attempt was made to measure all of the resistors of this type in the equipment, but it was observed that many of the resistors (R-725, R-209, R-309, R-319, R-321, R-314, etc.) were dripping wax and were exceedingly hot to the touch. These overloads must be corrected before the equipment can be considered capable of providing reliable service.

(d) The a-v-c- circuit in the audio amplifier is unstable in that it causes the audio amplifier to "motorboat" if the amount of a-v-c is set too high and there is no audio input to the audio amplifier. A complete redesign of the a-v-c-circuit is necessary to obtain satisfactory operation as is required by Naval usage.

(e) There is no provision made to set the transmitter to exact frequency settings. The control dial is roughly calibrated directly in frequency but has considerable error over the band. It is recommended that an accurate wavemeter or other frequency determining apparatus be incorporated in the equipment so that the frequency of the transmitter may be set accurately.

(f) Type 902 cathode-ray tube is not a Navy preferred type tube. Type 2AP1, which has the same electrical characteristics as the type 902, is a Navy approved type tube. It is recommended that the 902 tube in this equipment be replaced with the type 2AP1.

16. Antenna

A broad band antenna of the type not requiring adjustment over the band of frequencies from 300 to 350 megacycles was provided with the equipment. No electrical tests were conducted on this antenna by the Transmitter Section of the Naval Research Laboratory. The Antenna was subjected to tests to determine its ability to withstand shock and vibration. The antenna is mounted on top of a 50-inch, 2-1/2 inch diameter steel pipe, which has sufficient flexibility to adequately protect the antenna against shock and vibration.

17. Recommendations

It is recommended:

(a) That lifting eyes be provided on the equipment (par. 1).

(b) That a constant voltage transformer be incorporated in the equipment to reduce the effect of line voltage variation (par. 4 and 5a).

(c) That a concentric line relay be used for antenna switches (par. 5b).

(d) That the frequency of the m-c-w- tone oscillator for code transmission be made 800 c.p.s. (par. 7).

(e) That means be provided to heat the interior of the equipment when the equipment is idle to reduce troubles caused by humidity (par. 9).

(f) That an improved type of h-v rectifier plate supply transformer be employed (par. 9).

(g) That type 836 rectifier tubes be used in the high-voltage power supply (par. 10).

(h) That the use of micro-switches for interlocks be discontinued (par. 14a).

(i) That all control knobs, gears, spacers, etc., be secured to their respective shafts by means of taper pins (par. 14b).

(j) That dial locks be provided on all control dials (par. 14c).

(k) That all clamps that secure wiring to the frame or chassis be equipped with felt buffers beneath them to prevent the clamps from cutting into the wires (par. 14d).

(l) That fuse mountings be marked with the rating of the fuses (par. 14e).

(m) That the overload relay K-805 be equipped with an adjustable rheostat across its coil in lieu of the fixed resistors now employed. (par. 15a)

(n) That the audio input circuit be redesigned so that satisfactory operation of the equipment can be obtained from the standard Navy remote control telephone unit (par. 15b).

(o) That resistors of greater power ratings be used in lieu of certain overloaded resistors now employed in the equipment (par. 15c).

(p) That the a-v-c circuit in the audio amplifier unit be redesigned to prevent "motorboating" when no audio signal is applied to the amplifier (par. 15d).

(q) That an accurate wavemeter or other frequency determining apparatus be incorporated in the equipment in order that the frequency of the transmitter can be accurately set (par. 15e).

(r) That Eimac be consulted as to the operation of the type 35TG tubes under pulsed condition of operation, and if possible that Navy approved type tubes be employed in lieu of the type 35TG tubes now used in the equipment. (par 6)

(s) That a more satisfactory method of mounting the rubber snubbers at the bottom of the cradle be employed. (PAR. 3)

18. Conclusions

(a) Many of the components employed in the construction of the CXCK equipment are of a design or material normally prohibited in Naval equipment. However, the equipment withstood the various tests to which it was subjected without serious trouble and the quality of the components is sufficiently high to insure reliable operation under average operating conditions.

(b) The majority of components are easily accessible. Access to the under side of all units mounted on the front door is obtained by removing the front panel from this door. The transmitter and modulator unit may be withdrawn from the front of the cabinet after disconnecting leads at the bottom. Tubes are not visible from the front panel and may be removed and replaced when the front doors are opened.

(c) The power output of the equipment is not considered satisfactory. Certain defects in the antenna relay and coupling circuits and low filament voltage on the h-f oscillator tubes seriously reduce the available power output of the equipment. These defects must be corrected and the power output raised to the specified level before the equipment can be considered entirely satisfactory.

(d) Tests indicate that the shock mounting provided affords satisfactory protection against the effects of vibration and shock. Certain minor deficiencies in the design must be corrected before the performance can be considered entirely satisfactory.

(e) The mechanical construction and design of the equipment are considered generally satisfactory. Many components are not mounted with desirable rigidity but no trouble occurred during the test period which could be attributed to mechanical weakness. Wiring has been done neatly and leads are cabled wherever possible. Workmanship is of a satisfactorily high quality.

(f) Frequency changes within the range of the equipment may be quickly and easily accomplished. The adjustment of dial controls is not critical.

(g) No attempt has been made to indicate all changes necessary to cause the equipment to comply with basic Naval specifications. Such a course would involve a complete redesign of the apparatus. With the alterations recommended, it is considered that the Model CXCK Radio Link P-1 Equipment will provide satisfactory and reliable communication when

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installed on Naval surface craft.

III. Tests Made By The Receiver Section

1. Description

The receiver and blocking circuits are mounted on the three rack panels immediately below the control strip on the door. The balanced antenna is connected through the change-over relay to a 6J6 twin triode converter driven by a 9002 oscillator. No R. F. preselection nor image rejection circuits are employed. The input and oscillator transmission line circuits are tuned by a two-gang floating rotor condenser driven by a single dial. IF amplification is obtained at two frequencies, 25 Mc and 9 Mc, with a bandwidth of 1.5 Mc. The output of the second IF amplifier is fed to a grid-leak limiter which also serves as a grid-leak detecter for AM reception. With TM reception the limiter output is fed through a biased diode, for threshold control, to the TM detecter in the blocking unit. TM detection is obtained by shock excitation of a tuned circuit in the detecter screen lead tuned to an odd harmonic, together with an integrating low-pass coupling circuit between the detecter plate and the following audio amplifier. Blocking pulses are generated in synchronism with the pulse transmission by phase shift type selective circuits tuned to the 12 KC pulse repetition frequency followed by pulse shaping stages.

2. Effects of Variations in Ambient Relative Humidity

The following paragraphs, to and including paragraph 15, describe the measured receiver performance characteristics which appear to be acceptable.

The receiver heterodyne oscillator frequency drifted -0.745 Mc (oscillator frequency -300 Mc; receiver frequency -325Mc) when the equipment was subjected to a change in ambient relative humidity from 15% to 97%. The receiver power supply voltage variation was from 295 to 288 V, D-C and the receiver sensitivity changed -10db. The ambient temperature was maintained at +40° C throughout the test.

3. Heterodyne Oscillator Frequency Drift with Variations in Line Voltage. (Reference, Plate 3)

A variation in line-supply voltage from 90 to 125 V resulted in a maximum heterodyne oscillator frequency drift of -0.43 Mc to +0.035 Mc. The oscillator frequency with 115-V input was 300 Mc (receiver frequency -325 Mc).

4. Heterodyne Oscillator Frequency Drift during Warm-Up (Reference, Plate 4)

Approximately 40 minutes was required for the receiver heterodyne oscillator to warm up sufficiently to approximate stable operation. The oscillator frequency drifted a total of -0.93 Mc from

[redacted]

the first frequency determination obtainable after turning the equipment "on". The nominal oscillator frequency was 300 Mc. 0.60Mc of this drift occurred during the first five minutes and the drift subsequent to this five minute warm-up period was only 0.33 Mc.

5. Effects of Inclination, Shock, and Vibration

The entire unit, while in operation, was subjected to: (a) an inclination of 45° either side of vertical for one-half hour, each complete rolling cycle requiring about 7 seconds; (b) vibration at frequencies from 400 to 2000 cps; (c) ten shocks (simulating gun-fire aboard ship) directed toward each of the four faces of the equipment.

The receiver suffered no adverse effects, mechanical or electrical, during the test outlined above.

6. Sensitivity (Reference, Table 6)

The sensitivity (input, modulated 30% at 1000 cps, for 10 db S/N ration with 6 mw total output in 600-ohm load) on a-m, channel, varied from a maximum of 9 microvolts to a minimum of 45 microvolts.

7. Intermediate-amplifier Selectivity (Reference, Plate 5)

The total bandwidth of the i-f amplifier channel was found to be 1.5 Mc at the half-voltage points.

8. Resonant Overload (Reference, Plate 6)

Using a-m (white channel) reception and 30%, 1000 cps (sine wave) modulated input, resonant overload occurs at an output of approximately 27 mw (in 600-ohm load).

9. Audio Fidelity (Reference, Plate 7)

Separate audio amplifiers are employed for the two modulation channels. The audio response is down 6 db at 18 cps and 4600 cps for T-M. The response on A-M is down 6 db at 50 cps and 4600 cps.

10. Tube Electrode Voltages

The manufacturer's recommended maximum values of tube electrode voltages are not exceeded in any instance in the receiver circuits.

11. Audio Hum

The maximum hum output from both the T-M and A-M audio amplifiers (last two i-f amplifier tubes removed) was 17 microwatts in a 600-ohm load.

12. Power Consumption

The power requirement for receiver operation is 530 watts

[redacted]

(115 V, 4.9 a, 94% power factor)

13. Receiver Tuning Range

The nominal tuning range of the P-1 receiver is 299-352 Mc.

14. Ease of Alignment of IF Amplifier

Though no instructions for IF alignment are presented in the instruction book, the alignment is not difficult and all IF transformers may be adjusted for maximum output at their mid-frequencies in the conventional manner.

15. Power Supply Regulation (Reference, Plate 8)

A ±10% variation in a-c supply volts results in a + 12.5% to 10.5% variation in d-c output volts. However, the heterodyne oscillator voltage is well-regulated; hence, overall operation of the receiver is not too adversely affected by the poor power-supply regulation.

16. Continued Exposure to High Ambient Relative Humidity

The following paragraphs, to and including paragraph 23, describe the measured receiver performance characteristics which appear to fall below the usual Naval standards and contain recommendations for their improvement.

The entire P-1 unit was allowed to remain inoperative (power "off") in an ambient relative humidity of 95% for 15 hours. At the end of the 15-hour period power was applied to the receiver and the measured sensitivity (using the Measurements Corporation standard signal generator Model 75, Serial No. 100) was found to be 2 millivolts at 325 Mc as compared to the normal value of 45 microvolts. However, as soon as the ambient humidity was lowered to 30%, the sensitivity was found to be 45 microvolts. The power supply voltage was normal -287 V.

It is desirable that the receiver unit be provided with satisfactory protection from the effects of high ambient relative humidities, particularly as regards sensitivity.

17. Effects of Variation in Ambient Temperature

The equipment was subjected to a change in ambient temperature from 50° to 0° C. (relative humidity was maintained below 30%), total time for the change being 6 1/2 hours. The receiver sensitivity at 0° C. was 6 db below the normal value and the power supply voltage varied between the limits of 285-292 V. The heterodyne oscillator frequency drifted a total of 3.05 Mc above the initial frequency of 300 Mc.

Although the sensitivity change for a change in ambient temperature from 50° to 0° C. is not prohibitive, the 3.05-Mc drift

[redacted]

of the oscillator frequency is considered excessive. This drift is approximately two times the receiver pass-band and it is desirable, therefore, that the drift be substantially reduced.

18. Image-frequency Rejection (Reference, Table 6)

Since the first IF frequency is 25 Mc and the local oscillator frequency lies below the signal frequency, the image frequency lies 50 Mc below the signal frequency. The image rejection ratio was found by measuring the receiver sensitivity at the image frequency (signal frequency -50Mc) and forming the ratio of this sensitivity to the sensitivity at the signal frequencies. The values thus obtained are tabulated in Table 6.

The image rejection ratio varies between the limits of 6 to 37 db. This low image rejection ratio results largely from the lack of any RF preselection except the single tuned converter input circuit. It is true that image interference from within the CXCK band would not be anticipated, since the band is only 50 Mc wide, but serious image interference would be encountered from other strong signals in the 250 to 300 Mc band. This interference probably would be most severe on the A. M. channel which will respond to modulated carriers as well as pulsed signals.

It is recommended that at least one stage of tuned R. F. amplification be used ahead of the converter.

19. Heterodyne Oscillator Voltage at Antenna Terminals

To approximate the heterodyne oscillator voltage appearing at the antenna terminals the concentric transmission line was plugged into the input of the General Radio Receiver, Model P-521-A, Serial No. 104. The G. R. receiver was tuned to the oscillator frequency and the tuning meter deflection noted. The equivalent microvolts (approximately) were obtained by substitution of the Measurements Model 75 signal generator.

From the results of the test just outlined, it appears that the voltage at the antenna terminals due to the heterodyne oscillator fundamental is greater than 200,000 microvolts throughout the receiver tuning range. The corresponding power, in a 140-ohm load, would be greater than 0.3 milliwatt; hence, the receiver in its present condition would constitute a menace to security of position when operated on shipboard. Therefore, it is desirable that steps be taken to effect a reduction in oscillator radiation - i. e., by the addition of r-f amplifier circuits preceeding the converter input, and/or better isolation of the oscillator circuit from the input circuit by shielding, reduction of circulating currents on the tuning-condenser shaft, etc.

20. Gain Control Characteristic (Reference, Plate 9)

With a constant 30 microvolt input (modulated 30% at 1,000 cps) to the receiver, the audio output volts across a 600-ohm resistor load was recorded for various angular positions of the gain control

[redacted]

shaft. The calculated attenuation in db was plotted against degrees rotation to obtain the curve on Plate 9.

The maximum gain-control attenuation attainable with the present control is 41 db, whereas a maximum attenuation of 100 db is desirable. Further, the linear relationship (within ±12 db) should be maintained between attenuation and angular rotation of the control shaft.

21. Tuning Meter Calibration (Reference, Plate 10)

The signal generator output was coupled to the antenna terminals of the receiver and the tuning-meter reading noted for different values of C-W input. The plot of tuning-meter deflection (ma) vs. r-f input (microvolts) is shown on Plate 10.

It would be desirable that the overall tuning-meter calibration be more nearly linear; i. e., the meter sensitivity should be increased at the lower input levels: 10-400 microvolts.

22. 12 Kc Amplifier Selectivity (Reference, Plate 11)

Gain vs. frequency measurements were made on the two-stage 12-Kc selective amplifier which preceeds the blocking-pulse shaper and amplifier. The total pass-band width of the amplifier (at the 6 db points) was found to be 1.5 Kc, corresponding to an effective Q of but 14.

This lack of selectivity was probably responsible for the poor performance of the blocking circuit during operational tests under heavy ignition interference, as strong random pulses during the unblocked period upset the synchronization of the blocking oscillator.

The contractor's justification for using an R-C phase shift selective amplifier was the freedom of its components from temperature drift, in comparison with inductances. Actually, it is difficult to see how temperature drift could be significant with such low Q circuits. It is recommended that a much more selective amplifier be used, preferably having a band-pass type response characteristic to allow for slight frequency drift but providing very rapid attenuation of undesired frequencies.

23. Effects of Interfering Signals

A qualitative investigation of the effects of interfering signals of various types was made to determine the freedom from "jamming" of the T-M ("black channel") channel. A T-M signal equivalent to 700 microvolts at the antenna was received on 325 Mc (500 cps modulation) and three types of interfering signals were introduced separately. The results of this test were as follows:

(a) A C-W Signal equivalent to 5 millivolts at the antenna effectively "jammed" the T-M receiver. However, satisfactory T-M reception was obtained by detuning slightly either above or below the C-W signal frequency.

[redacted]

(b) A pulsed signal of 1.5 millivolts was required to produce appreciable interference, but the T-M signal was still readable. Pulses of about 30 microseconds duration (and greater) at repetition rates of 2 Kc and higher were most effective.

(c) A 400-cps sine-wave amplitude-modulated (30%) signal of 3.5 millivolts was barely audible above the T-M signal.

24. <u>Notes on Mechanical and Electrical Construction</u>

It is recommended that consideration be given to the following mechanical changes which would render the P-1 receiver unit more suitable for general Naval service:

(a) Suitable scales should be provided on the following controls to permit their being set to a precalibrated position: "Head Phone Volume", "Demodulation Tuning", "Blocking Tuning". The main tuning dial should be provided with a zero-reference mark.

(b) All control knobs should have two set-screws each and the screws should fit in tapped metal inserts instead of tapped holes in the bakelite knob handles.

(c) All electrical indicating meters should be provided with a suitable anti-glare glass cover.

(d) Electrical indicating meters should be easily replaceable from the front of the equipment without necessitating the removal of the front panel.

(e) The dial lock provided on the "Demodulator Tuning" control should be further removed from the tuning-control knob to permit unhindered rotation of either.

(f) Frequency calibration charts for the main tuning-control dial should be provided on the front panel of the equipment, mounted under a suitable water-proof cover.

(g) To facilitate circuit-tracing and trouble-shooting, it is desirable that wiring to beneath terminal boards be minimized.

(h) All threaded fasteners should be provided with suitable lock-washers.

[redacted]

(i) It is desirable that all nameplates and control markings shall be of reversed etched aluminum, with the etched surfaces having a "frosted" finish.

(j) All metallic surfaces (chassis, tuning-condenser bearings, screw heads, condenser containers, potentiometer shafts, etc.) should be provided with an approved plating or paint of good adherence to prevent deleterious effects of high humidity, moisture, and salt spray.

(k) Some screws are too short to project through their nuts and are holding by too few threads. Navy standards prescribe that screws should be of such length that at least one and one-half (1 1/2) threads will project beyond the nut.

(l) A more effective tube clamp should be employed and all horizontally-mounted tubes should be provided with clamps.

25. Inspection of Model 2200 Auto-Dryaire

This unit, built by the Communication Products Company, was not tested for adsorption capacity, etc., the operating characteristics having been reported for a pre-production model in NRL letter report S67/66(353-HWC), of January 14, 1943 to Bureau of Ships. The equipment was inspected mechanically, however, with particular reference to the recommendations contained in Section 11 of that report. The only items noted which are not in conformity therewith are as follows:

(a) No provision is made for shock-proofing the rear of the dehydrator.

(b) No provision is made for cushioning the panels; consequently, the top, back and both end gratings rattle abnormally from the slightest shock or vibration. It was further noted that several of the No. 10-32 machine screws provided for securing these panels come dangerously near to impacting the lead-covered cables mounted inside the angular framework.

(c) No instruction book was received with the unit.

(d) Only the Communication Products Company's commercial nameplate is mounted on the front panel. Consequently, the unit bears no contractual data for subsequent identification.

[redacted]

(e) The sequence switch terminals are color coded to match the wiring, rather than numbered. The present arrangement is considered to be an improvement over the original recommendation.

(f) The gel-cylinder heater terminals have been protected with micanite tubing, which does give satisfactory protection of operating personnel. The tubes are open at the top, however, so that a short-circuit could be caused by dropping a screwdriver, nail, or similarly shaped metallic object through perforations in the top panel. It is accordingly recommended that the open tops of these insulating tubes be suitably plugged.

(g) The bezel of the output pressure guage is chromium plated and that of the sight glass is finished with black wrinkle lacquer. The combination is not unsightly, and both finishes are considered satisfactory.

(h) No spare parts were received.

(i) No change has been made in the designation of the "Dew Point Control."

(j) In all other respects, the design, workmanship and finish appears to be first-class throughout.

26. Instruction Book

The instruction book, in its final form, should contain many corrections and refinements, some of which are listed below:

(a) In at least one case, the vacuum tube numbers stamped on the chassis do not agree with the vacuum tube numbers in the instruction book. The oscillator and converter sockets, numbered V401 and V402 in the book are not numbered on the chassis, but instead their numbers appear on the voltage regulator sockets.

(b) All adjustments for operation (controls, screw-driver adjustments, i-f alignment, etc.) should be very clearly outlined.

(c) Interchangeability of metal tubes and their "GT" counter-parts should be noted.

(d) Complete servicing instructions, including "trouble-shooting", realignment proceedure, etc. should be included.

[redacted]

(e) The servicing section should contain tables of socket pin numbers and voltages above ground thereof.

(f) Current and voltage data should be included for all voltage-dividers and bleeders.

(g) It is desirable that tables or lists be included showing all color coding, such as resistors, capacitors, wiring, etc.

(h) Performance curves should be presented.

(i) All circuit diagrams should be checked more carefully for errors and omissions. For example NL-27450 shows the telegraph key connected to terminals 835 and 836 on the fan shelf though the telegraph terminals of the remote control box connect to terminals 833 and 834. Also, the receiver circuit, NL 24805 fails to specify the vacuum tube types.

(j) As an aid to installing or replacing tubes, there should be one chart listing <u>all</u> tube numbers with the corresponding tube types.

(k) The derivation of the Fourier series in NL-10435 is inadequate and inaccurate. This should be clarified and corrected, or else omitted.

(l) In a final instruction book to be used in large quantities, it would be desirable to reduce all circuits and drawings to page size to avoid large folded blueprints.

IV. Tests made by the Communication Security Section

1. Scope of Tests

This portion covers the operational tests performed with the CXCK equipment and also includes another list of recommendations for mechanical changes based upon the experience gained from these tests. Three sets of ship to shore operational tests have been conducted; the first on May 4, 5, and 6, the second on May 17 and 18, and the last on June 12. For the first tests P-1 unit #4 was located in the aft cabin on the NAVAJO, while for the second test the same unit was located in the large sound room of the AQUAMARINE. Unit #3 was located in Building 2 of the Naval Research Laboratory Chesapeake Bay Annex with its antenna on the roof at a height of 135 feet above the water. The antenna on the NAVAJO

[redacted]

was 15 feet above water level, giving an optical path of 16.6 nautical miles. The antenna on the AQUAMARINE was 28 feet above water giving an optical path of 18.1 miles. The test on June 12 was made as the AQUAMARINE approached the Annex for the countermeasures demonstration of June 18th.

2. Preliminary Tests on May 4

The tests on May 4 were terminated abruptly by the failure of the filament of an 813 modulator tube before any significant data were obtained. No reason for this failure was determined.

3. Test of Tuning Adjustment

On May 5th, tests of the tuning adjustments were made with the NAVAJO at dock. These tests were made at frequencies of 300, 310, 320, 330, 340 and 350 Mcs while varying the antenna coupling. Plates 12, 13, 14, and 15 show the transmitter antenna current, grid current, receiver tuning dial setting, and tuning indicator meter reading as functions of the antenna coupling dial setting for each of the above six frequencies and for operation in both directions. As anticipated, the antenna couplings which produced the maximum antenna meter reading also produced the strongest received signals as indicated by the tuning indicator, and also provided the clearest reception. Therefore, it should always be satisfactory to adjust antenna current for maximum meter reading.

4. Distance Tests from NAVAJO and Effect of Ignition Noise

In determining the operational range, readings were taken of the tuning indicator meter versus distance. No calibrations have been made of the tuning indicators of Units 3 and 4, but it is reasonable to assume that they should be similar to the calibration of Unit #2 shown in Plate 10. The tuning indicator readings are not too reliable a measure of field strength because they are influenced by the presence or absence of the blocking pulse, fluctuations in line voltage, and heat of the receiver tubes. Also, there is a tendency to detune the receiver dial slightly from its maximum reading for the clearest reception of AM signals. Nevertheless these tuning indicator readings furnish a useful relative indication of the received field strength. Plate 16 shows a curve of tuning indicator reading versus distance as recorded at the Annex. The reception at the Annex was relatively quiet with but a slight amount of radar and ignition interference. Plate 17 shows tuning indicator readings versus distance as recorded on the NAVAJO. The noise level on the NAVAJO was extremely severe because of its gasoline engines with a total of 72 unshielded spark plugs which were located only about 25 feet from the antenna. The wood hull of the NAVAJO did not confine this noise to the engine room as would be the case with steel vessels. In all cases the tuning indicator was adjusted to zero while the NAVAJO was at dock with all engines stopped.

[redacted]

Plate 17 shows that with the main engines stopped and only the auxiliaries running, the tuning indicator reading was .06. With the main engine idling, this reading rose to .11, while both engines idling raised it to .12. The noise level increased greatly with speed, giving a tuning indicator reading of .15 at slow speed, .18 at half speed, and .25 at full speed. Rough checks with a pulsed signal generator at 300 Mcs indicated that the peak amplitude of the full speed ignition noise was of the order of 10 millivolts. This high noise level was responsible for the limited range obtained in the NAVAJO tests and made communication objectionably noisy even at 3 miles and unsatisfactory beyond 5 miles.

5. Articulation Testing Technique

In conducting these tests it appeared desirable to evaluate the quality of transmission more accurately than by merely guessing as to whether it was satisfactory or not. Word articulation tests were made repeatedly for this purpose. The word lists were taken from part III of OSRD Report No. 383, dated February 1, 1942. These are sometimes referred to as the "Harvard Word Lists" and consist of lists of 100 phonetically balanced one and two syllable words. These words were used in the carrier sentence "I will say soft now". Only 20 words were used per test because the ship would have covered too great a distance during the time required for a test with the entire 100 words. This, together with the limited number of observers, lack of repeat tests and other variables, limited the accuracy of these tests. Beyond distances at which these word tests became unsatisfactory, two digit numbers were substituted for the words to give higher scores and thus extend the range of the tests. No definite correlation has been obtained between number and word articulation scores. It was found that time modulated tone telegraph communication could be used at even greater distances than could be used for number articulation tests.

6. Results of NAVAJO Articulation Tests

The data obtained from these first articulation tests were too meager and erratic to present as curves, so are shown as vertical blocks at the proper distance on Plates 16 and 17. Plate 16 shows that for the tests received at the Annex the articulation remained generally above 80 per cent to 16 miles, with one test of 50 per cent at 17 miles. Plate 17 shows similar articulation tests received on the NAVAJO. With the engines running, tests with amplitude modulated transmission dropped below 40 per cent beyond 3 miles, though they were satisfactory at 5 miles with the engines stopped. The time modulation signals held up better, though the noise was bad, -but dropped to less than 50 per cent beyond 7- 1/2 miles. Tests with numbers were received satisfactorily with time modulation through the noise out to 15 miles.

7. Effect of Blocking Circuit

No improvement was noticed from the use of the blocking circuit through the full engine noise which seemed to be too solid for this circuit to handle. Some improvement from the blocking circuit was noted when only the auxiliary engines were running but the degree of improvement was disappointing.

8. Antenna Patterns

Tests were made to determine the polar pattern of the horizontal loop antennas at distances of 5 and 7- 1/2 miles. These antennas were designed for broad-band operation over the 300 - 350 Mc range and employ two stacked Alvord loops to obtain some directivity in the vertical plane while maintaining a circular horizontal pattern. It was anticipated that the increased vertical directivity might produce a null near 45° from the vertical which would be objectionable in a severe roll. Plates 18, 19, 20, and 21 show that the patterns obtained with the antenna vertical were essentially circular except for slight dips near 20° and 200°. These dips probably were caused by the shielding action of the stack and the vertical communication antenna respectively. These tests were made by swinging the ship with its two engines driven forward and in reverse so that the ship remained at a constant distance during the test. Tests were made at 7- 1/2 miles with the antenna inclined forward at an angle of 47- 1/2° with the vertical to simulate the effect of a 45° roll. Plates 22 and 23 show that as anticipated, this produced severe minima near 20° and 200° bearings, which probably also were accentuated by the shielding effect. These and one subsequent test on the AQUAMARINE indicate that the antenna would be satisfactorily omnidirectional in a calm sea but "drop outs" might be produced at extreme ranges when the ship was rolling severely.

9. Ignition Noise Tests

It was evident that the poor performance of the CXCK equipment on the NAVAJO was caused by the abnormally high level of ignition noise. Since the unshielded ignition system was less than 25 feet from the antenna and in a wooden hull it was believed that these tests were not necessarily representative of the noise level to be anticipated in other Naval vessels. It was first suspicioned that this ignition noise was entering the 25 Mc IF amplifier through the power leads. Line filters were installed on the night of May 5th, but produced a negligible improvement. It was also suspicioned that the interference might be entering the 25 Mc IF amplifier directly through the antenna since no RF preamplification is employed in the receiver. Certainly most of the noise entered through the antenna because disconnecting the antenna reduced the noise to an almost negligible level. Reconnecting the antenna but disabling the frequency converter by removing the local oscillator tube also dropped the noise level greatly, proving that most of the ignition interference was entering the receiver at the RF frequency rather than at the IF frequency. Very rough tests with a pulsed signal generator indicated that the peak noise level at the antenna was about 10 millivolts with the main engines idling. Noise measurements made by Mr. Dinger and Mr. Best on the AQUAMARINE showed that the power level of noise originating on that ship was only 100 to 200 microvolts so it was decided to repeat the range tests and make the demonstration with the equipment installed in the AQUAMARINE.

10. Preliminary Tests on AQUAMARINE

Dr. S. G. Lutz and Ensign J. E. Jackson made the trip from the Laboratory to the Chesapeake Bay Annex on the AQUAMARINE on Monday, May 17th, and arranged to test with Mr. N. R. Best and Mr. E. W. Deeters, operating the equipment at the Annex, as the AQUAMARINE approached the Annex. This test was unsatisfactory as contact was not established, even on time modulated tone telegraph, until at a distance of 15 miles from the Annex. At this distance it was found that there was a bad antenna cable connection and transmission was perfect when this connection was repaired. By this time the ship was too near to the Annex for any significant tests. However, these tests confirmed the fact that the noise level on the AQUAMARINE was far lower than on the NAVAJO as the noise was a pure hiss and no impulse interference was detectable.

11. Antenna Pattern and Tuning Indicator Tests on AQUAMARINE

On Tuesday, May 18th, Dr. Lutz and Ensign Jackson were joined on the AQUAMARINE by Mr. N. Young of the Federal Telephone and Radio Laboratory and Lieutenant Mathes of the Bureau of Ships. Articulation tests were made almost continuously as the AQUAMARINE proceeded on a course up the Bay. One stop was made at 7 - 1/2 miles to take data for the antenna polar diagram shown in Plate 24. The antenna was located on top of the pilot house clear of any large metallic obstructions but near to the communication antenna and mast stays. Figure 13 shows that the antenna pattern was circular except for a slight flattening near 350°. Plates 25 and 26 show tuning indicator readings plotted against distances as measured at both terminals. No adequate explanation can be offered for the difference between the shapes of these two curves. Possible differences may be attributed to different receiver calibrations and to the normal spread of readings due to fluctuations in line voltage and mistuning; however, both curves show readings of about 0.1 ma out to the maximum optical path length, and detectable deflections out to 5/4ths times the maximum optical path length.

12. Results of Articulation and Distance Tests

Plate 27 shows composite curves plotted from the results of the articulation tests performed at both terminals. The average articulation dropped below 50% with either time or amplitude modulation at distances beyond 18 miles and it was concluded by all observers that this optical range was the maximum distance for satisfactory voice

[redacted]

communication. Articulation tests with two digit numbers showed perfect scores to 18 miles but dropped abruptly to below 80% beyond 22 miles. Random noise was noticeable at 18 miles and became very heavy beyond 22 miles. Time modulated tone telegraph signals were readable at 23 - 1/2 miles but were lost at 25 miles. While no impulse noise was noticed on the AQUAMARINE the terminal at the Annex suffered heavier interference than during the NAVAJO tests. Impulse noise was first noticed at a distance of but 5 miles and was identified as being partially radar interference but chiefly ignition interference from large construction trucks just outside the building. On the outward trip this noise became very bad beyond 13 miles and made it impossible to receive articulation tests beyond 14 miles, therefore most articulation tests at greater distances were received only at the AQUAMARINE and instructions to the Annex were furnished by tone telegraph. Even the tone telegraph was lost at 20 miles so the Annex terminal transmitted tone telegraph V's for test until communication was re-established later. On the return trip both terminals transmitted tone telegraph alternately. The noise level at the Annex was lower and telegraph signals were first detected at the Annex at 23 - 1/2 miles and could be read at 21 - 1/2 miles. Voice communication was re-established at 20 - 1/2 miles and was thoroughly satisfactory at 17 - 1/2 miles. The AQUAMARINE again went out to 22 miles before returning to dock, to collect additional data on the operation at ranges just beyond optical distance.

13. Final Test on AQUAMARINE

On June 12, the AQUAMARINE returned to the Chesapeake Bay Annex for the final demonstration of the CXCK circuit which formed a part of the countermeasure demonstration of June 18th. Mr. Best and Mr. Davison made the trip and tested with Ensign Jackson and Mr. Bourdeau at the Annex as the AQUAMARINE came up the bay. Voice contact was established at a distance of 17 miles, indicating that the equipment was operating normally.

14. Anti-Jam Characteristics of "Prep" Modulation

No adequate quantitive data on the relative immunity to jamming of the amplitude and time (prep) modulated channels has been obtained but there is considerable qualitative evidence to indicate that the time modulated channel is less vulnerable to jamming. The NAVAJO tests (Paragraph 6) showed that under heavy ignition interference, the range for 50% articulation was about three times as great with time modulation as with amplitude modulation. This difference cannot be attributed to heavier modulation or greater effective power with time modulation because under quiet conditions aboard the AQUAMARINE (Paragraph 12), there was no significant difference between the two circuits even at extreme ranges. Again, during rehearsals for the countermeasure demonstration, the circuits often were subjected to heavy interference from radar and radar jammers. Under these conditions the amplitude modulated channel frequently was heavily jammed while the time modulated channel was entirely servicable. Contrasted to this, local jamming tests with a noise modulated signal generator showed no significant difference in the degree of jamming of the two circuits when the jammer was accurately tuned. Since the noise modulation bandwidth was only about 20 Kc wide, the jamming could be avoided on either channel by detuning the receiver, but the results were more satisfactory and the detuning was less critical with the time modulated channel.

15. Conclusions from Operational Tests

From the above operational tests it may be concluded that in the absence of severe impulse noise both time modulated and amplitude modulated operation of the CXCK equipment are satisfactory out to the optical range and that tone telegraph operation may be used to 5/4ths of the optical range. Either type of modulation gives equally intelligible communication in the absence of impulse noise but under heavy impulse noise the amplitude modulation fails first, indicating that the time modulation has somewhat better anti-jam characteristics under conditions of impulse noise jamming. The anticipated anti-jam advantages of the blocking circuit were not realized in these tests and it seems that considerable improvement of the blocking circuit is possible, as has been discussed previously.

16. Recommendations for Mechanical Modifications

The following recommendations for mechanical modifications to promote ease of installation and servicing and to better withstand Naval service are based upon experience gained from these operational tests.

(a) Certain tubes are very inaccessable for installation and replacement. It is very difficult to make the plate connections to the 35 TG transmitting oscillators, V103, and V104, because of their inaccessability and the plate seal of one tube was broken during installation. The two diodes, V950 and V951, in the antenna relay unit are located above and behind the transmitter unit and only a person with long slender arms can replace these tubes without unbolting the transmitter and drawing it forward to give access to these tubes by reaching up inside the cabinet behind the transmitter frame. The receiver converter and oscillator tubes, V401, and V402, are mounted in a slanting position such that they are very difficult to replace without removing the front panel. A pair of tongs, similar to a fuse puller, might be supplied to facilitate changing these tubes. The cathode ray tube socket on

[redacted]

Unit #4 was in poor alignment so that it is difficult to insert the tube.

(b) Eye bolts or hooks should be provided on the top of the cabinet or its shock cradle to facilitate moving the unit with a crane and lowering it through hatches.

(c) No reference pointers are provided for any of the front panel dials. Such pointers are needed for logging dial settings.

(d) The coaxial cable from the receiver to the 2nd IF of unit #4 is too short and is under tension.

(e) Certain tubes, such as the VR105 voltage regulators, fit too loosely in their sockets and have no tube clamps.

(f) The labeling of the "local-extension" switch on the control panel is confusing. It is recommended that the up position be labeled "local", the center position be labeled "extension", and the down position be labeled "test".

(g) The demodulator unit employs several large uninsulated 2 and 4 watt carbon resistors, some of which are dangerously close to the metal panel. It is recommended that insulated wire wound resistors be used.

(h) All metal parts should be protected by corrosion resistant paint or plating. On one occasion, one unit was exposed to rain and rust developed on the receiver RF shield can and on other unprotected parts.

(i) Heavier insulation is needed on the high voltage leads. Just prior to the demonstration on June 18, a short developed in the high voltage power supply through breakdown of the insulation on one of the rectifier filament leads laying along a metal bracket.

17. Recommendations for Major Electrical Modifications

The above operational tests showed the need for redesigning the equipment to meet the following objections:

(a) The performance of the blocking circuit is inadequate under heavy impulse noise and better selectivity is needed.

[redacted]

(b) A squelch circuit should be provided to quiet the noise in the absence of a signal.

(c) In most cases the clearest reception of pulse amplitude modulated signals has been obtained with the receiver detuned considerably from the maximum tuning indicator reading, indicating that there may be considerable phase modulation accompanying the amplitude modulation. This should be corrected.

(d) Steps should be taken to further minimize reception of the amplitude modulated wobbler tone on the time modulated channel.

(e) The present antenna system is bulky, requires a special balanced cable, and has severe nulls in its directive pattern when inclined to 45 degrees as the ship rolls. It is believed that the slight gain in vertical directivity resulting from the two stacked loops does not outweigh the disadvantage of the sharp nulls in a 45 degree roll. It is believed that some simpler form of broad band vertical antenna which can be fed from a 50 ohm PT-5 cable would be more suitable for Naval service.

(f) Measurements by the Receiver Section (Part III) indicate that the frequency drift of the receiver under the combined effects of warm-up and change of ambient temperature, humidity and line voltage may total 4.59 Mc, or more than 1.5% at 300 Mc. Contrasted to this, the IF bandwidth is only 1.5 Mc. If the standard Navy practice of making the IF bandwidth at least twice as great as the total drift, an IF bandwidth of about 10 Mc would be required and this is absurd. Far better receiver stability is required to compare with the stability standards of present communication receivers.

18. Conclusion

In view of the fact that these units are the first commercial models of a radically new type of communication equipment and were not designed for a specific tactical application, it is believed that their general mechanical, electrical, and operational characteristics are very good. In certain respects, such as receiver frequency stability, the present equipment fails to meet Navy standards, but with the experience gained from this contract, it is believed that subsequent designs of similar equipment by this contractor could be entirely satisfactory.

Table 1

Model CXCK Radio Link P-1 Equipment

VARIATION OF POWER OUTPUT WITH FREQUENCY

Freq. (Mc)	Power Input (Watts)	Power Output (Watts) Aver.	Peak	Duty Cycle %	Repetition Rate (Kc/Sec.)	Oscillator Plate Voltage (Volts)	Plate Current (Ma)	Grid Current (Ma)
302.5	850	12.4	590	2.1	12.030	1660	18.5	2.9
312.7	850	12.3	585	2.1	12.009	1660	18.5	3.0
326.5	850	11.2	531	2.1	11.964	1660	19.0	2.5
342.0	845	9.9	470	2.1	11.964	1660	19.0	1.9
354.2	845	8.5	403	2.1	11.925	1660	19.0	1.5

Line Voltage = 115 Volts
Filament Voltage = 4.75 Volts

Note: These measurements were made at the antenna terminals of the equipment.

[redacted]

Table 2

Model CXCK Radio Link P-1 Equipment

VARIATION OF POWER OUTPUT WITH FREQUENCY

Freq. (Mc)	Power Input (Watts)	Power Output (Watts) Average	Power Output (Watts) Peak	Duty Cycle %	Oscillator Plate Voltage (Volts)	Oscillator Plate Current (Ma)	Oscillator Grid Current (Ma)
298.4	850	17.8	625	2.8	1660	18.5	3.0
306.0	850	16.5	590	2.8	1660	19.0	3.0
321.4	850	12.5	447	2.8	1660	20.0	2.7
340.0	850	10.6	394	2.7	1660	19.5	2.2
349.4	850	6.4	237	2.7	1660	20.0	1.4

Line Voltage = 115 Volts
Filament Voltage = 4.75 Volts.

Note: These measurements were made directly out of the h-f oscillator coupling loop.

[redacted]

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Table 3

Model CXCK Radio Link P-1 Equipment

VARIATION OF POWER OUTPUT WITH FILAMENT VOLTAGE

						Oscillator	
Freq. (Mc)	Oscillator Filament Voltage (Volts)	Power Output (Watts) Average	Peak	Duty Cycle %	Plate Voltage (Volts	Plate Current (Ma)	Grid Current (Ma)
300	4.70	16.0	615	2.6	1660	17.5	2.1
300	4.75	17.5	673	2.6	1660	18.0	2.76
300	4.90	19.4	746	2.6	1660	17.5	3.0
300	5.00	21.0	810	2.6	1660	19.0	3.4
300	5.10	22.3	860	2.6	1660	19.5	3.6
300	5.20	23.3	896	2.6	1660	20.0	4.0
300	5.30	24.0	924	2.6	1660	20.5	4.2

Line Voltage = 115 Volts.

[redacted]

Table 4

Model CXCK Radio Link P-1 Equipment

FREQUENCY STABILITY

Two-Hour Locked Key Test at 336 Mc.

Maximum variation from frequency at start: 0.208%
Decrease in power output from start: 7.55%

Variation of Ambient Temperature

Ambient Temperature Range (°C)	350 Mc. Frequency Change per °C (%)
50 - 40	0.0000
40 - 30	0.0283
30 - 20	0.0141
20 - 10	0.0876
10 - 0	0.0680

Variation of Relative Humidity

Relative Humidity Change (%)	350 Mc. Frequency Change (%)
30 to 95	0.0000
95 to 30	0.0000

Vibration

Maximum deviation during 45 minutes of vibration at 353 mc: 0.0283%.

[redacted]

Table 4 (Cont'd)

Inclination

The frequency change with inclination, either front-to-back or side-to-side, was negligible, being too small to measure.

Shock

Output Frequency - 353 Mc.

Forty shocks, 10 applied to each side of the equipment, were administered to the equipment at a momentary table acceleration of 490 g.

The frequency change with shock was negligible, being too small to measure.

[redacted]

Table 5

Model CXCK Radio Link P-1 Equipment

COMPARISON OF DIMENSIONS AND WEIGHT OF
EQUIPMENT WITH AND WITHOUT MOUNTING CRADLE

Dimensions with Cradle:	Weight of Equipment:
Height - 72-1/8 inches	937 pounds
Depth - 27-1/2 inches	
Width - 28-7/8 inches	

Dimensions without Cradle:	Weight of Equipment:
Height - 67-7/8 inches	837 pounds (approx.)
Depth - 25-3/16 inches	
Width - 23-1/8 inches	

[redacted]

Table 6

SENSITIVITY & IMAGE REJECTION RATIO

CXCK Receiver

Fed. Tel. & Radio Labs.

New York City

Sensitivity is input (modulated 30% at 1000 cps) for 10 db S/N ratio, 6 Mw total output in 600-ohm load across audio output. (A-m reception).

Receiver Freq.	Sensitivity	Image Freq.	Sensitivity To Image	Resection Ratio
300 Mc.	30 Mv.	250 Mc.	340 Mv	21 db
305	50	255	210	12
310	9	260	250	29
315	13	265	570	33
320	18	270	110	15.5
325	45	275	160	11
330	3	280	220	37
335	9	285	16	6
340	16	290	30	6
345	20	295	200	20
350	20	300	40	6

[redacted]

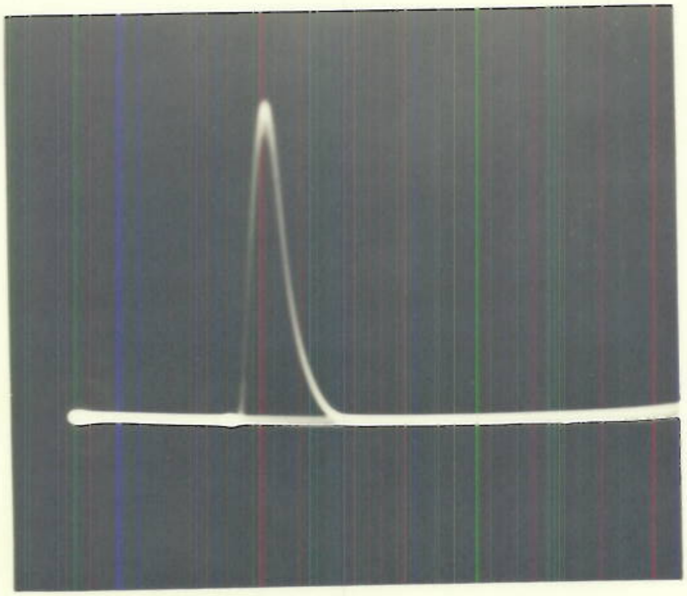


FIG. 1 ←TRACE

PLATE CURRENT IN H.F. OSCILLATOR TUBES

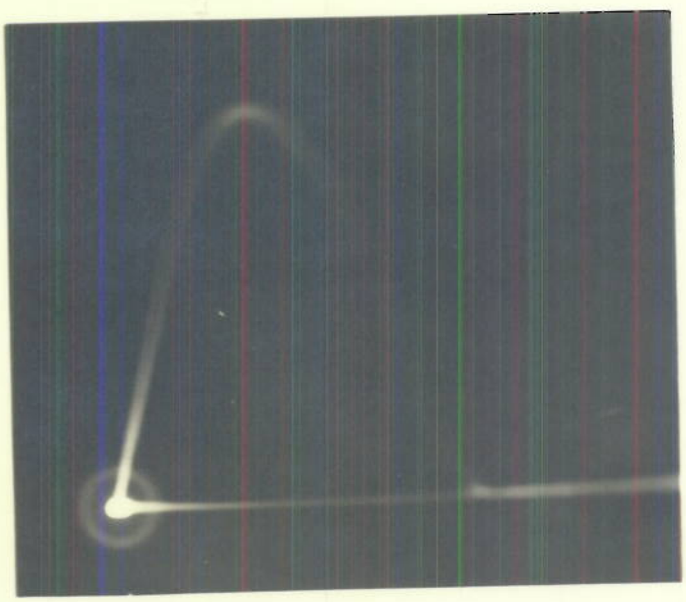


FIG. 2 ←TRACE

R.F. POWER OUTPUT PULSE

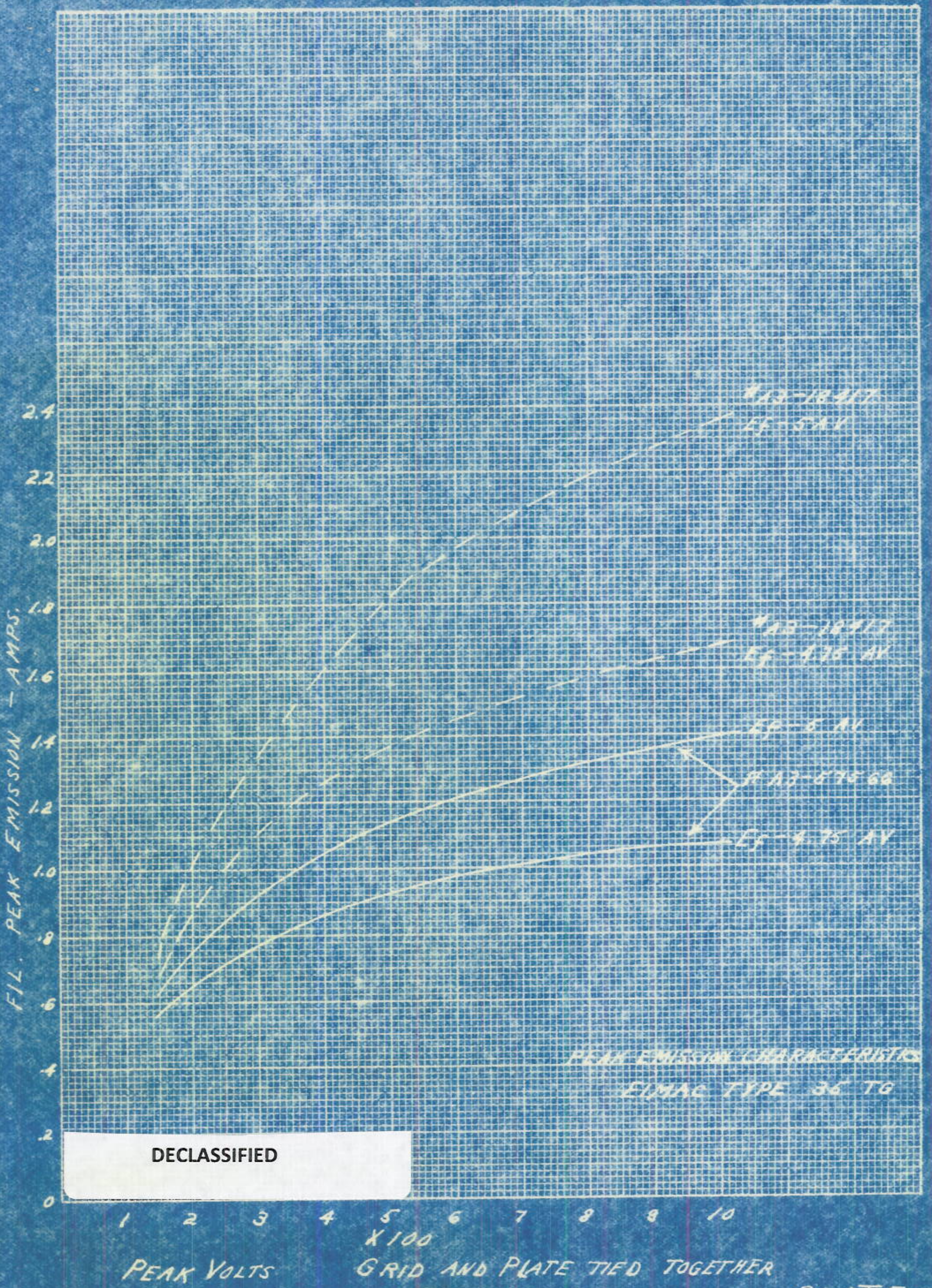
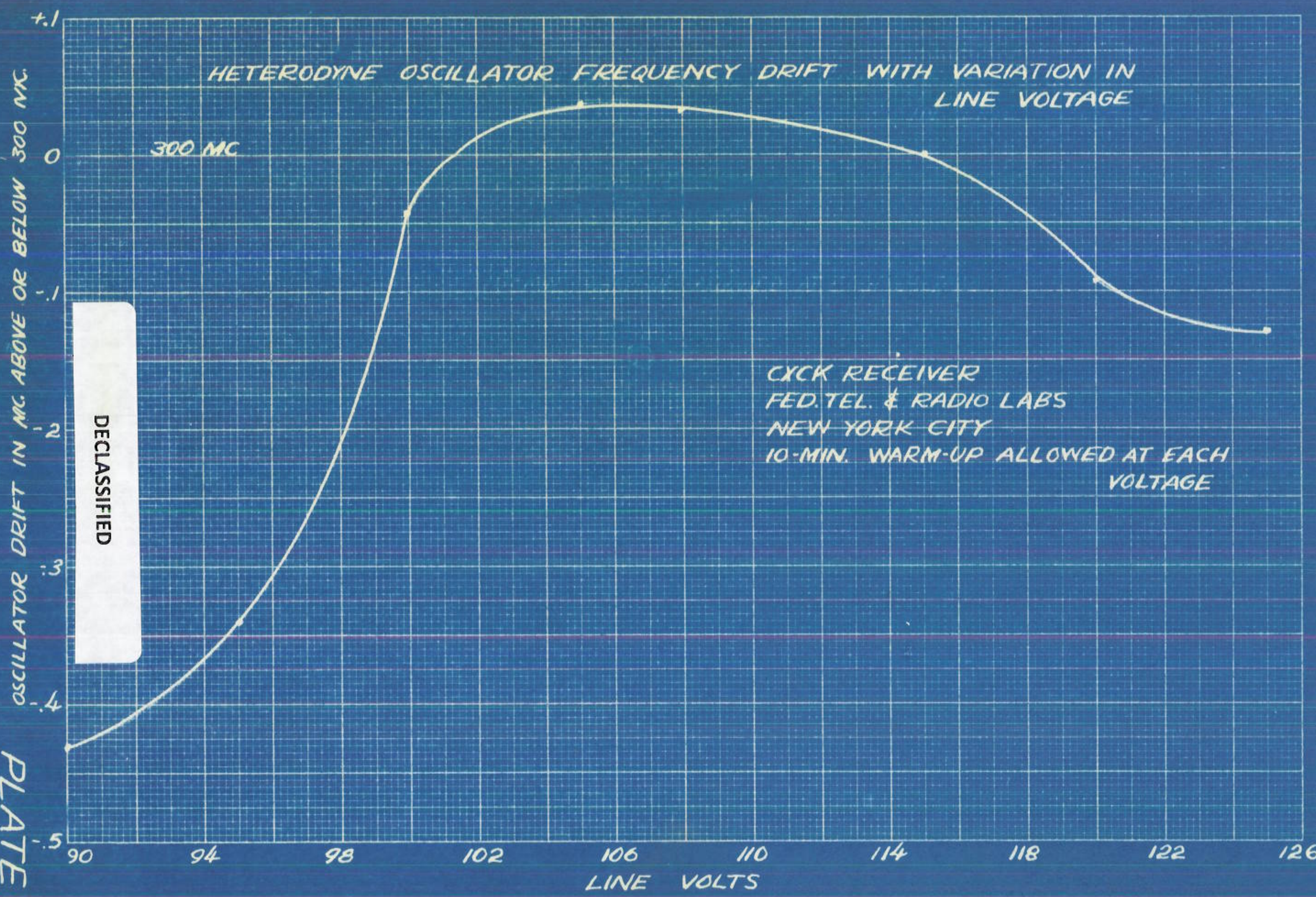
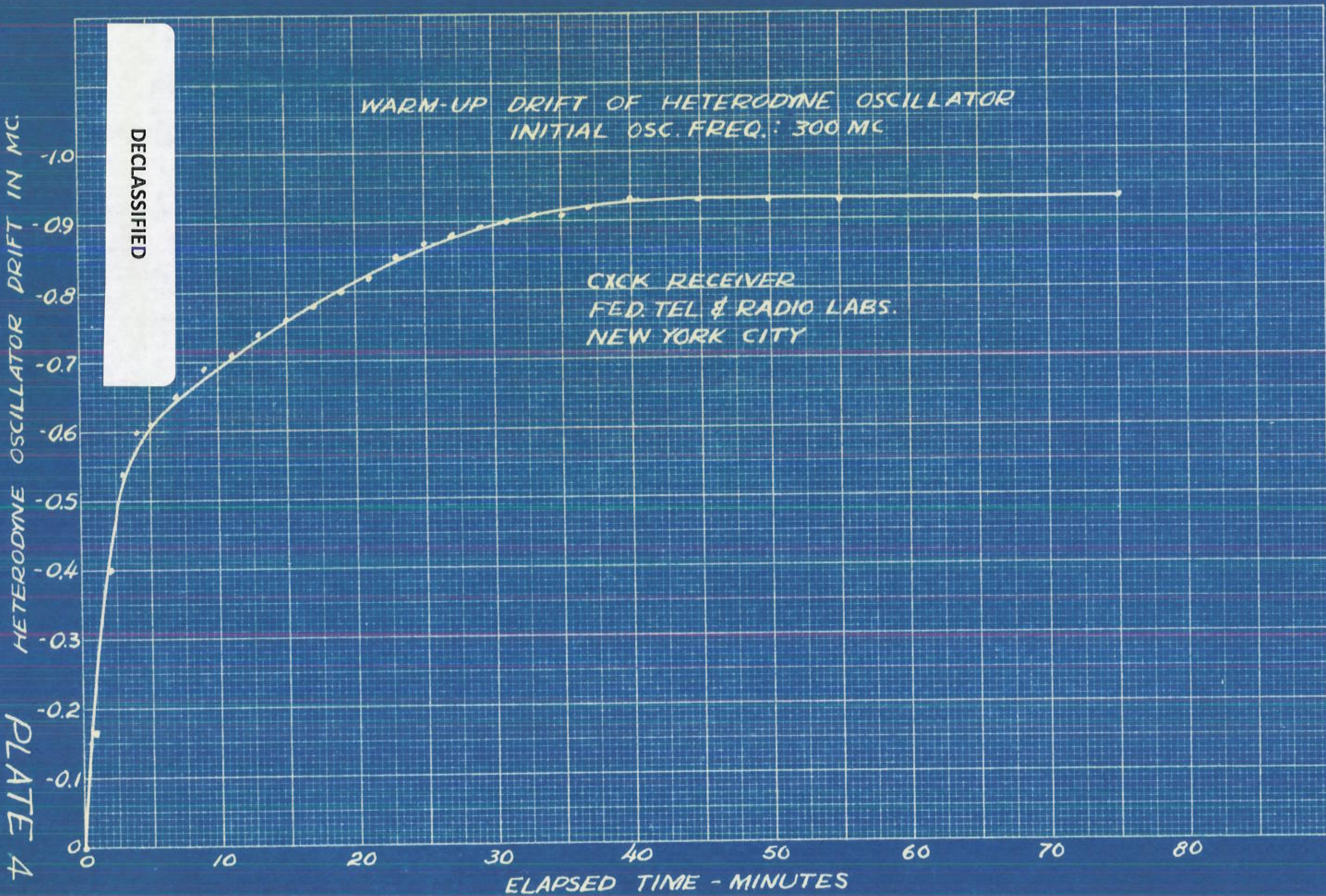

PEAK EMISSION CHARACTERISTICS
EIMAC TYPE 35 TG
FIL. PEAK EMISSION - AMPS.
Ef - 5 AV
Ef - 4.75 AV
Ef - 5 AV
Ef - 4.75 AV
X 100
PEAK VOLTS GRID AND PLATE TIED TOGETHER

PLATE 2



HETERODYNE OSCILLATOR FREQUENCY DRIFT WITH VARIATION IN LINE VOLTAGE
300 MC
CXCK RECEIVER
FED. TEL. & RADIO LABS
NEW YORK CITY
10-MIN. WARM-UP ALLOWED AT EACH VOLTAGE
OSCILLATOR DRIFT IN MC. ABOVE OR BELOW 300 MC.
+.1
0
-.1
-.2
-.3
-.4
-.5
90
94
98
102
106
110
114
118
122
126
LINE VOLTS
DECLASSIFIED

PLATE 3



DECLASSIFIED

PLATE 4

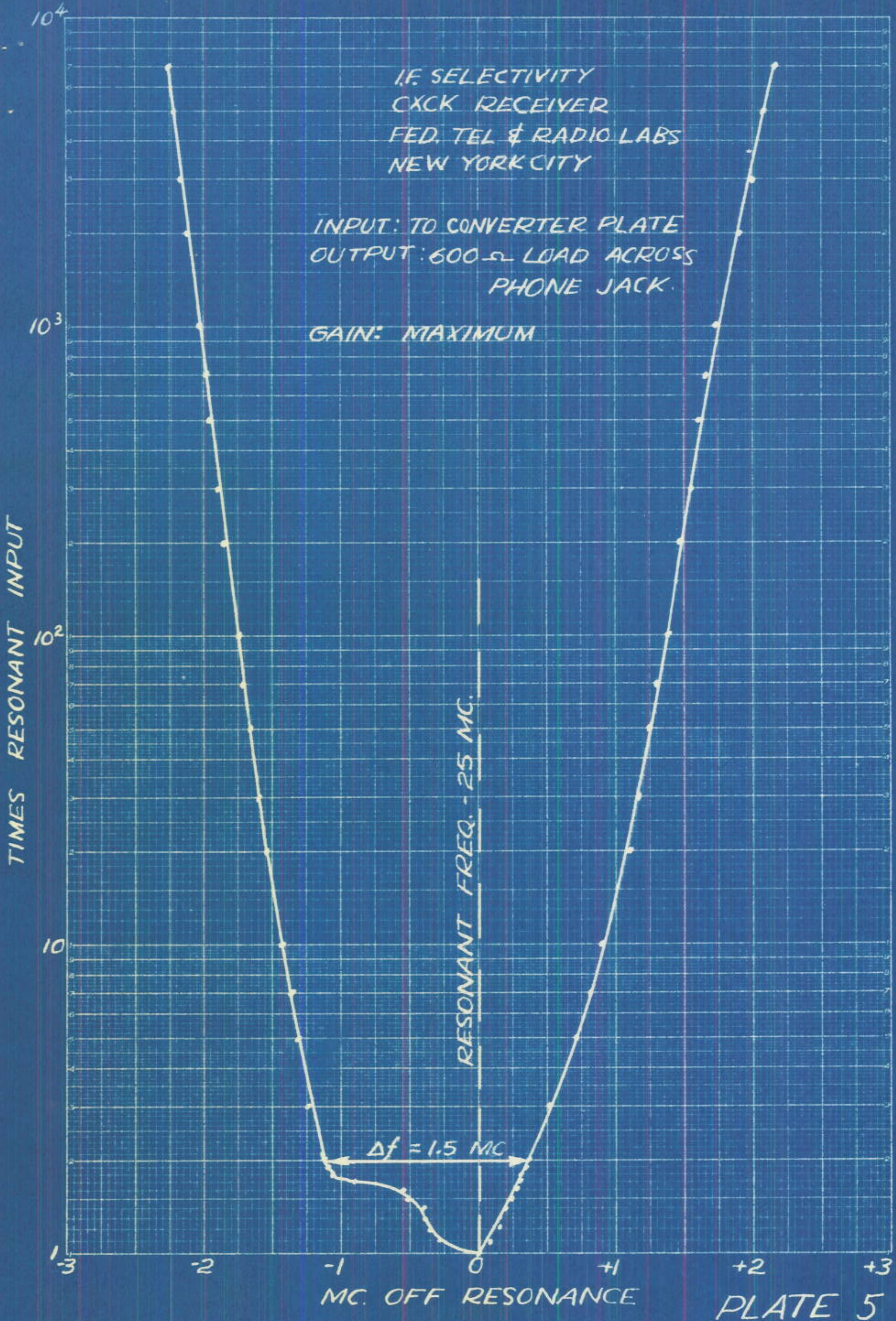


PLATE 5

DECLASSIFIED

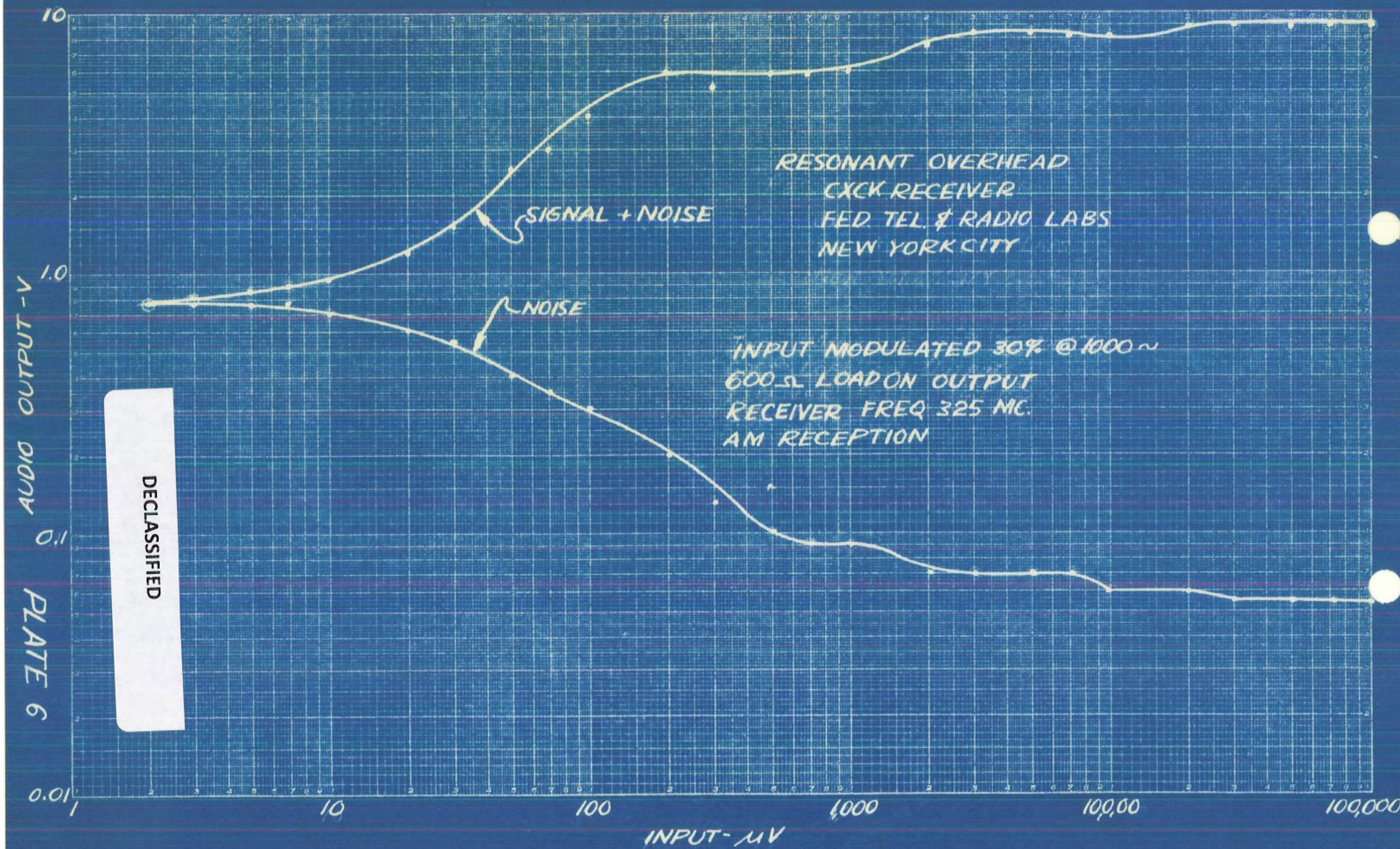


PLATE 6

DECLASSIFIED

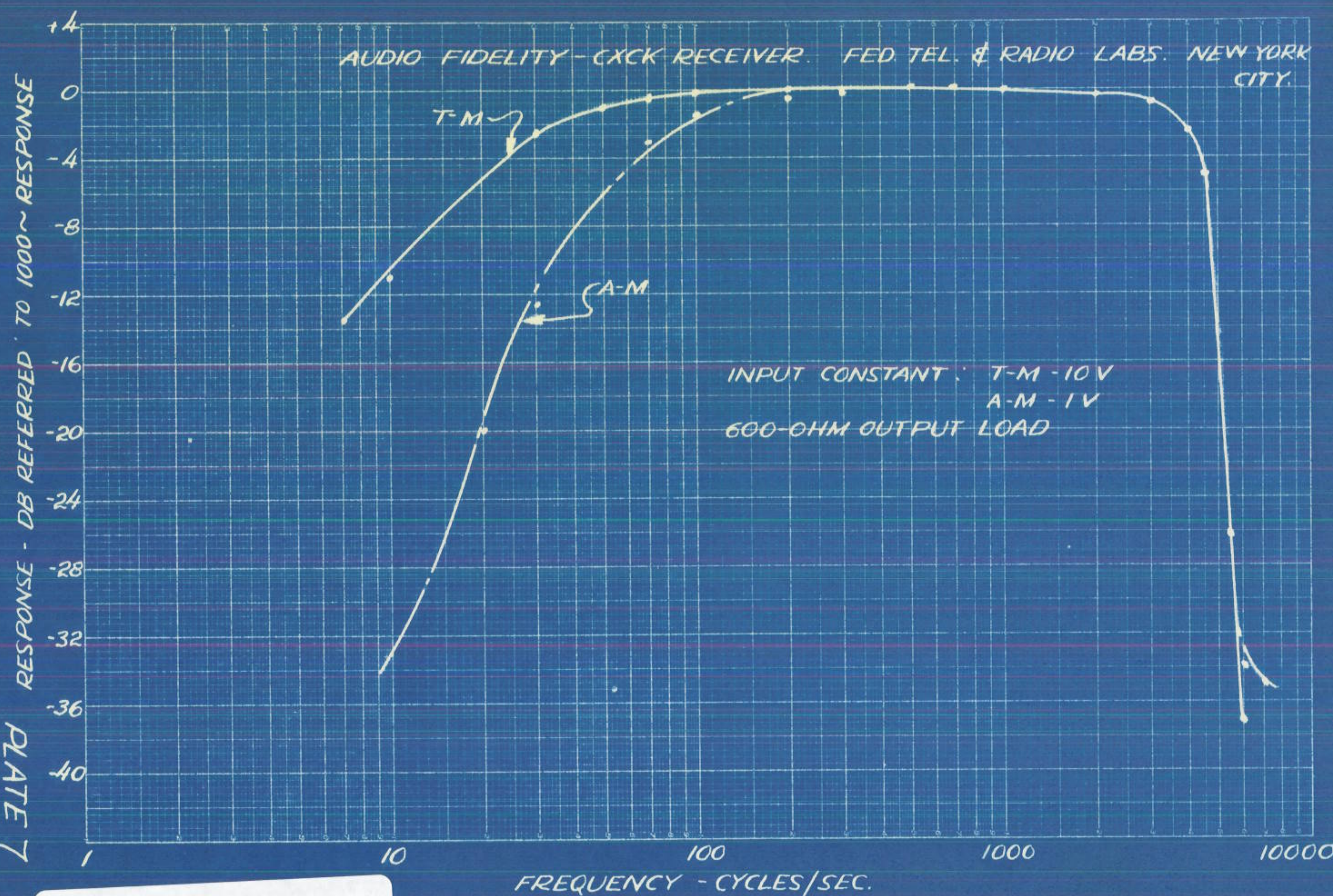
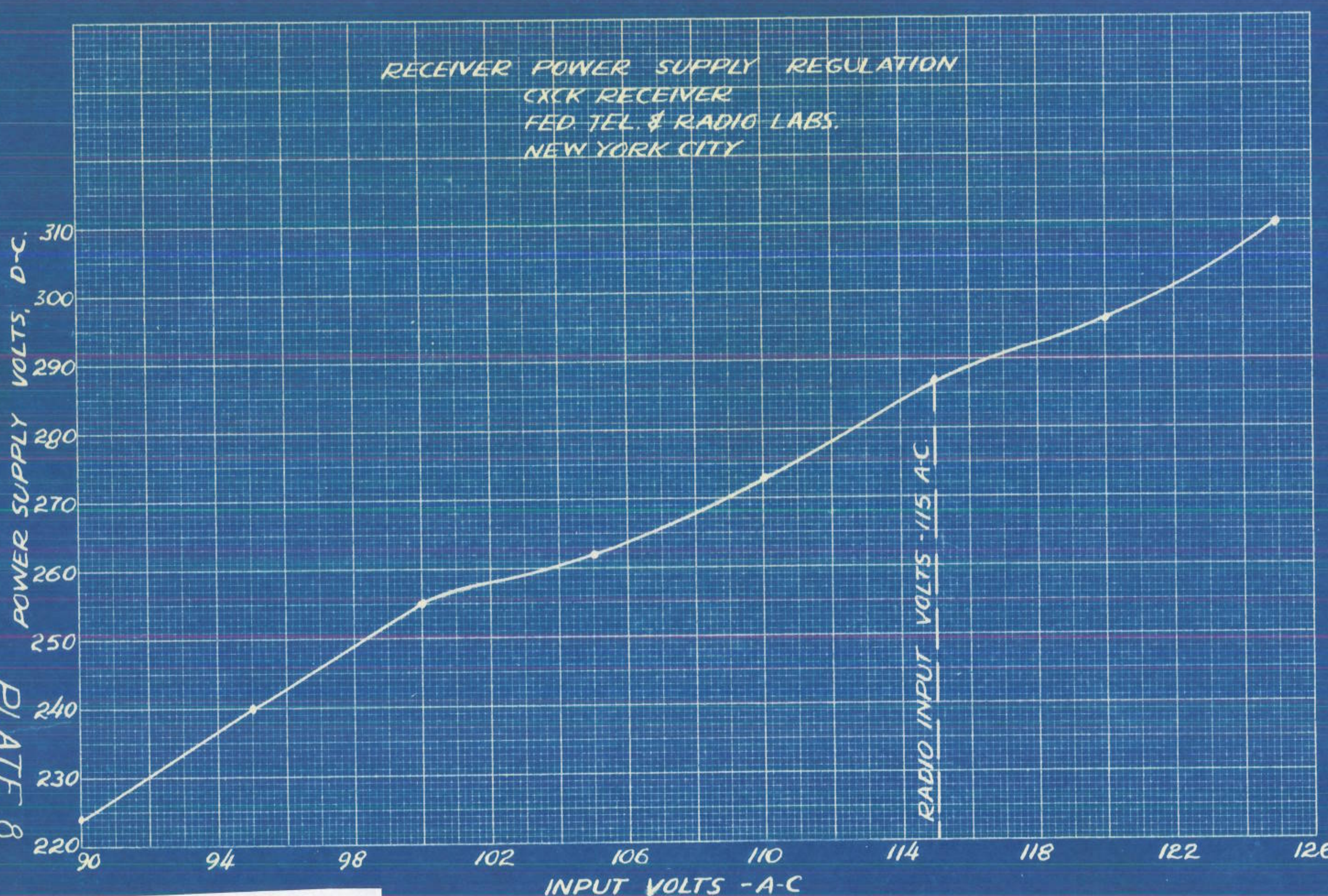


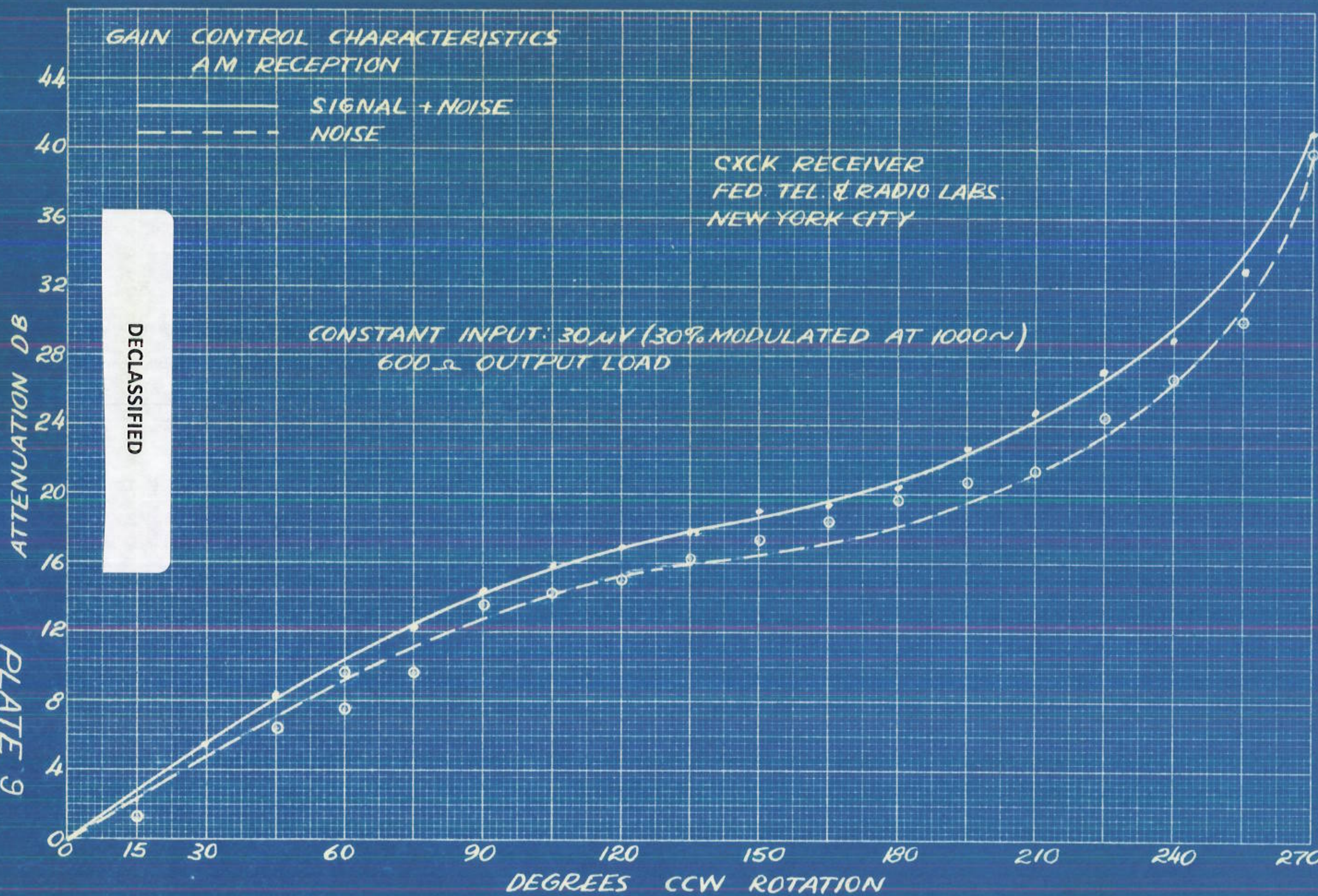
PLATE 7

DECLASSIFIED



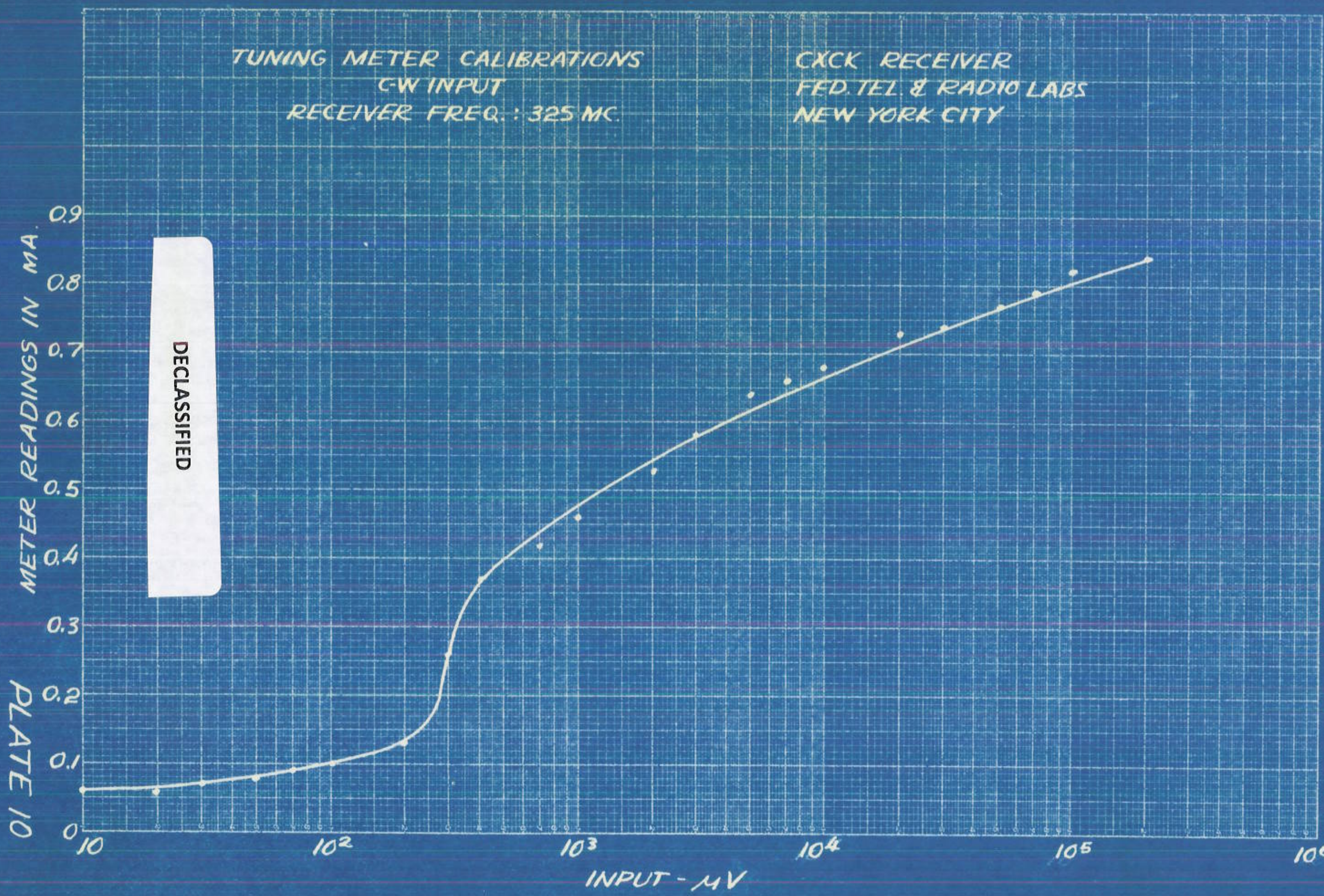
RECEIVER POWER SUPPLY REGULATION
CXCK RECEIVER
FED. TEL. & RADIO LABS.
NEW YORK CITY
POWER SUPPLY VOLTS, D-C.
310
300
290
280
270
260
250
240
230
220
90
94
98
102
106
110
114
118
122
126
INPUT VOLTS -A-C
RADIO INPUT VOLTS - 115 A-C

PLATE 8



DECLASSIFIED

PLATE 9



DECLASSIFIED

PLATE 10

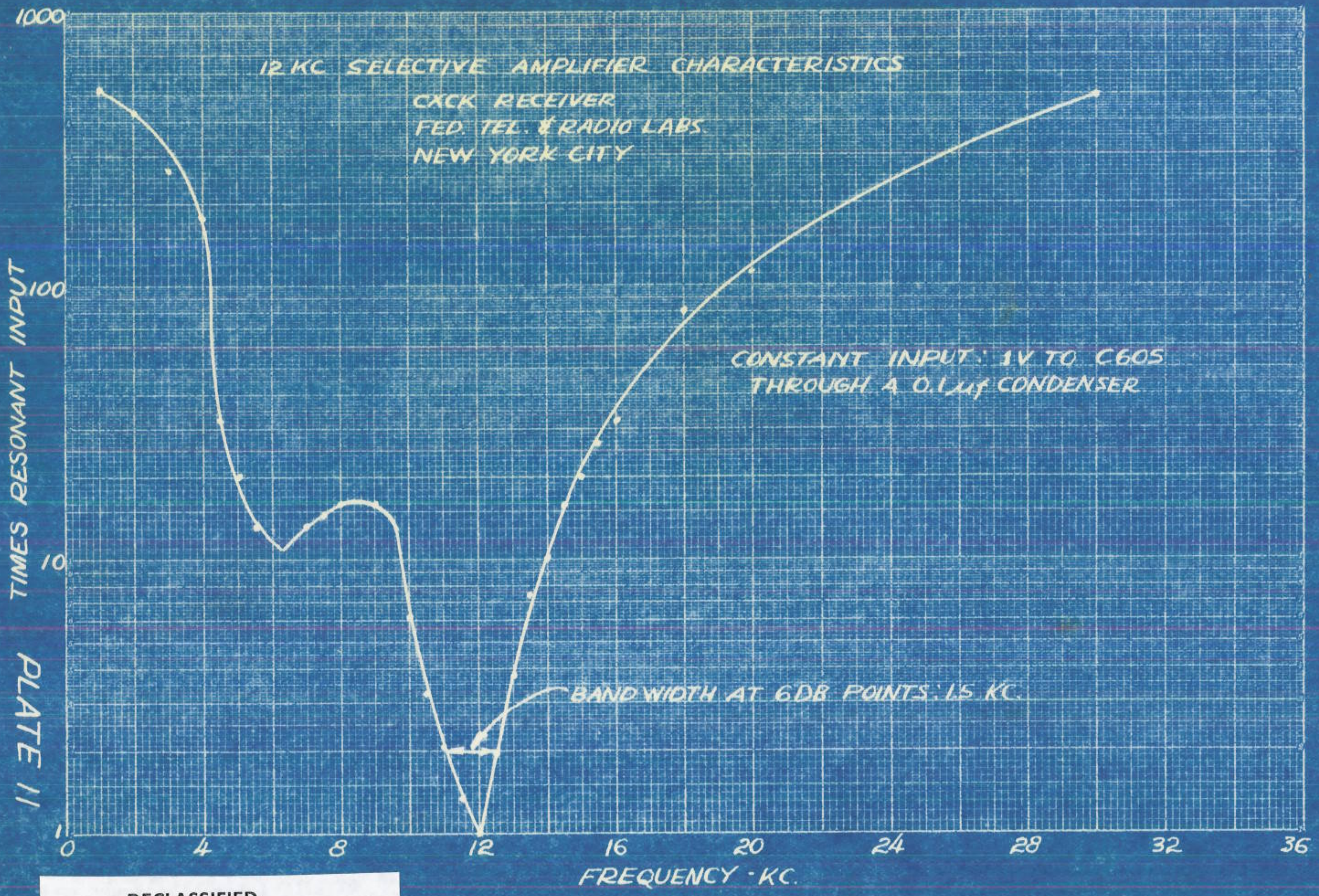


PLATE II

DECLASSIFIED

EFFECT OF FREQUENCY AND ANTENNA COUPLING
TRANSMISSION FROM CHESAPEAKE BAY ANNEX TO "NAVAJO"

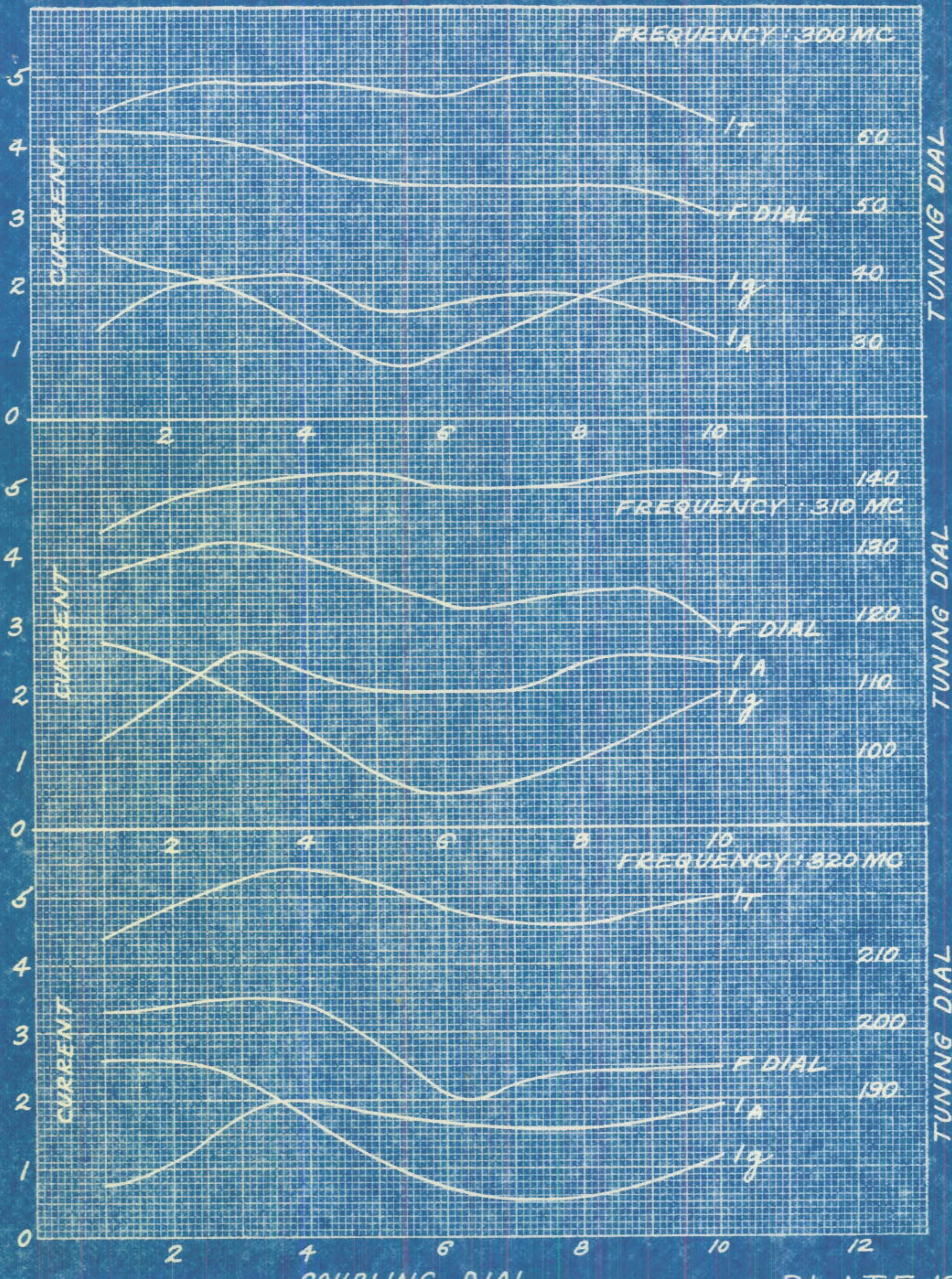
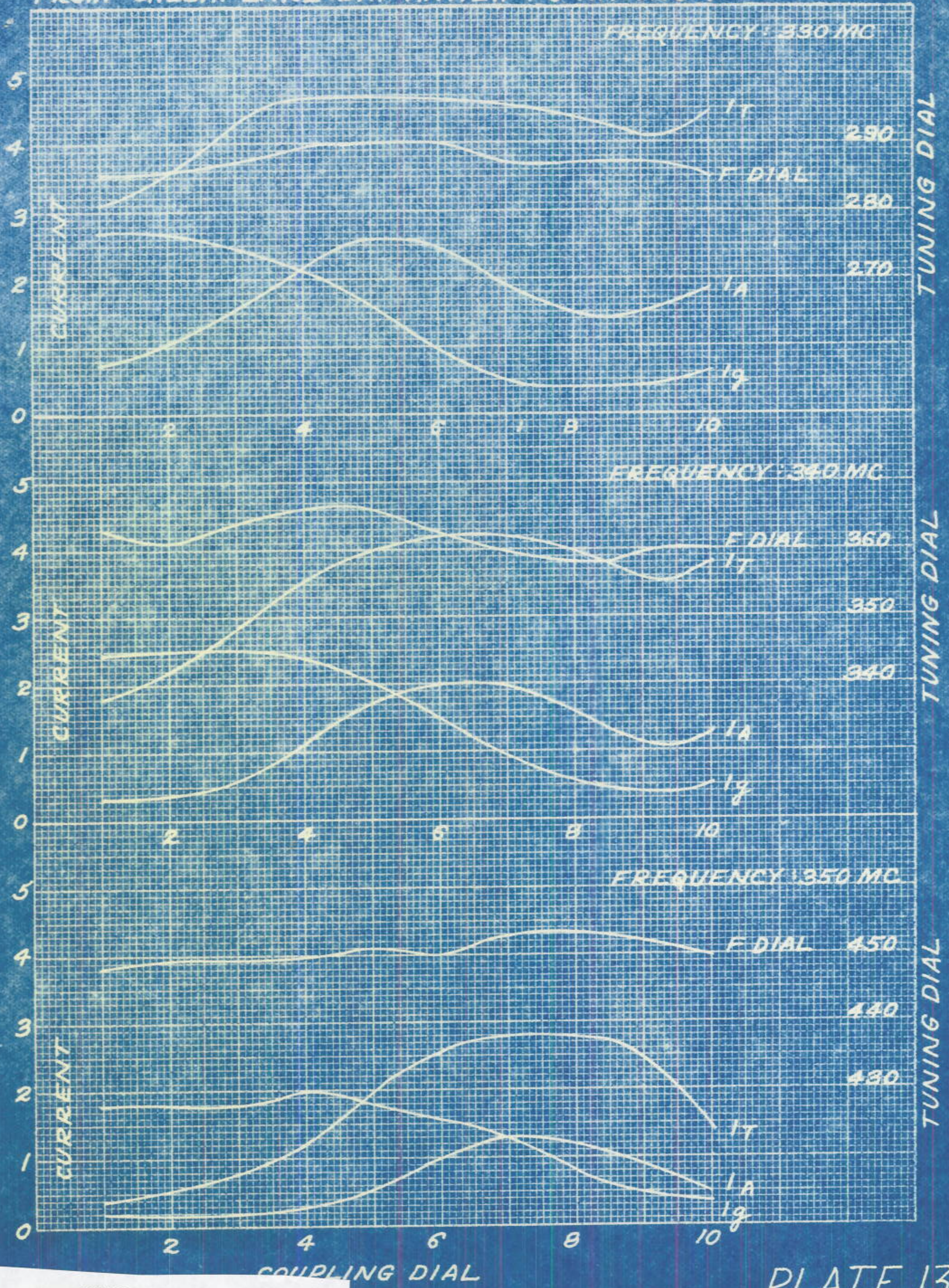


PLATE 12

EFFECT OF FREQUENCY AND ANTENNA COUPLING - TRANSMISSION FROM CHESAPEAKE BAY ANNEX TO "NAVAJO".



N. R. L. 34A

PLATE 13

EFFECT OF FREQUENCY AND ANTENNA COUPLING
TRANSMISSION FROM "NAVAJO" TO CHESAPEAKE BAY ANNEX

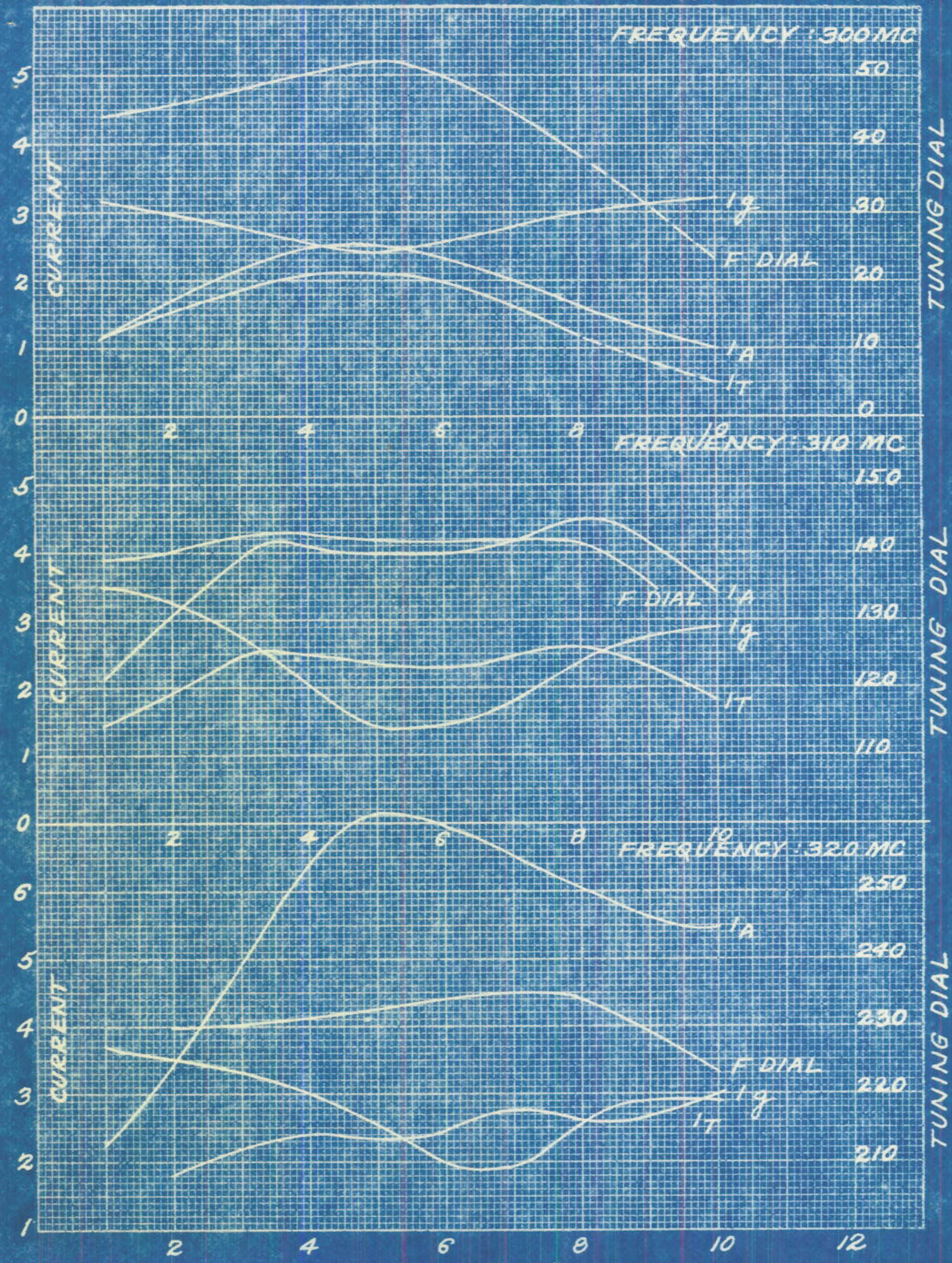


PLATE 14

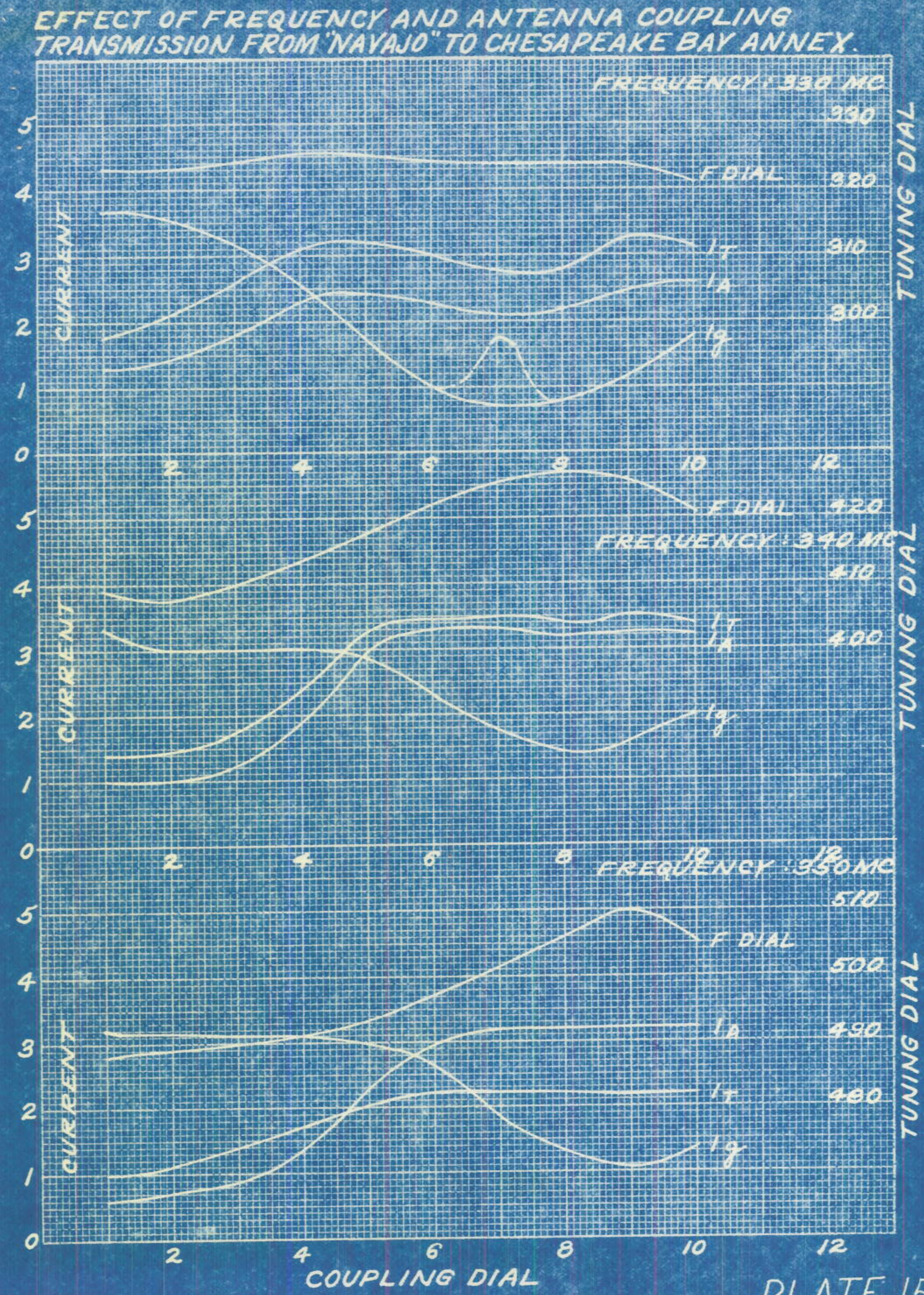

EFFECT OF FREQUENCY AND ANTENNA COUPLING
TRANSMISSION FROM "NAVAJO" TO CHESAPEAKE BAY ANNEX.
FREQUENCY: 330 MC
F DIAL
CURRENT
TUNING DIAL
FREQUENCY: 340 MC
FREQUENCY: 350 MC
COUPLING DIAL

PLATE 15

N. R. L. 31A

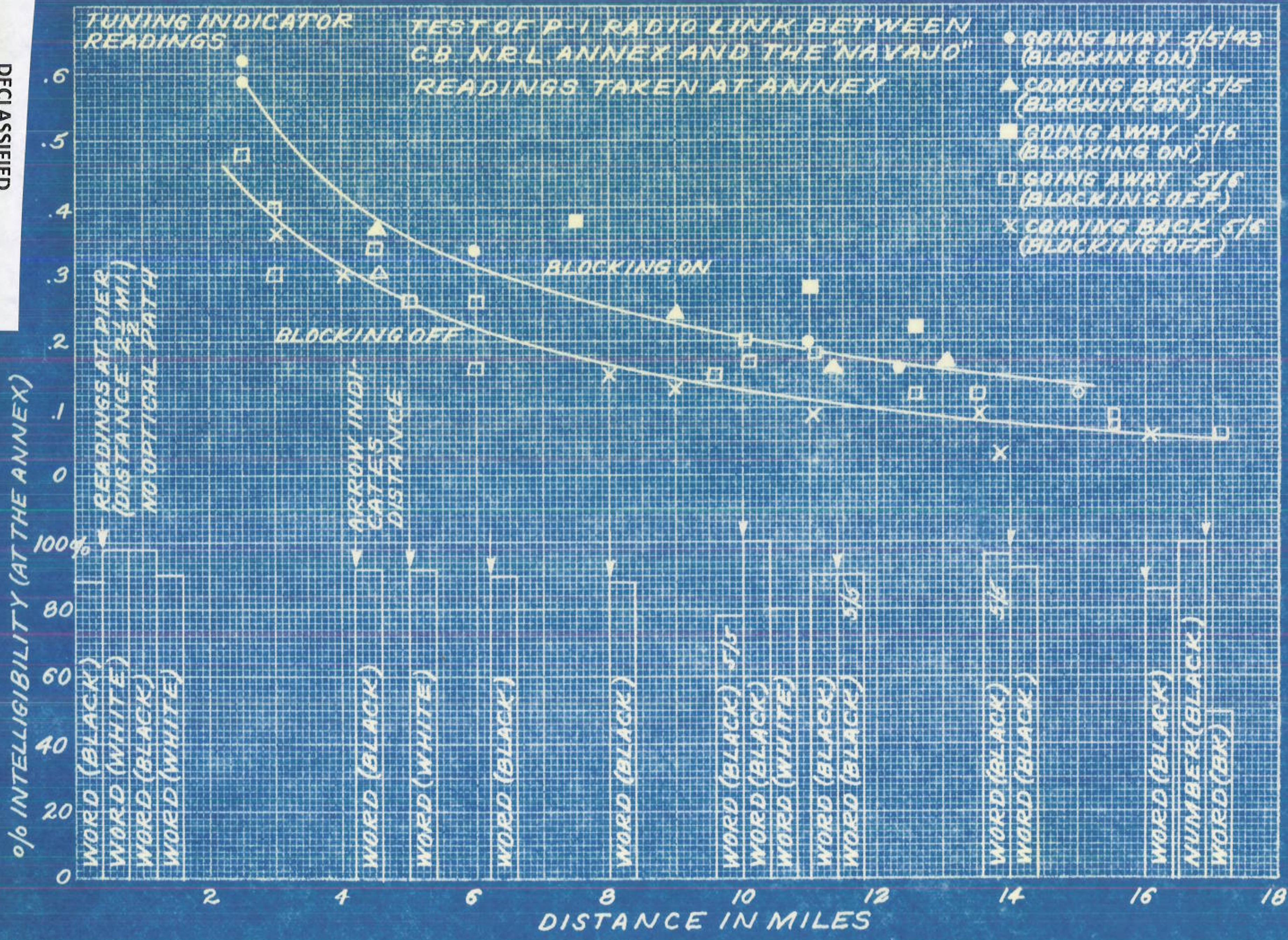


PLATE 16

DECLASSIFIED

N. R. L. 34A

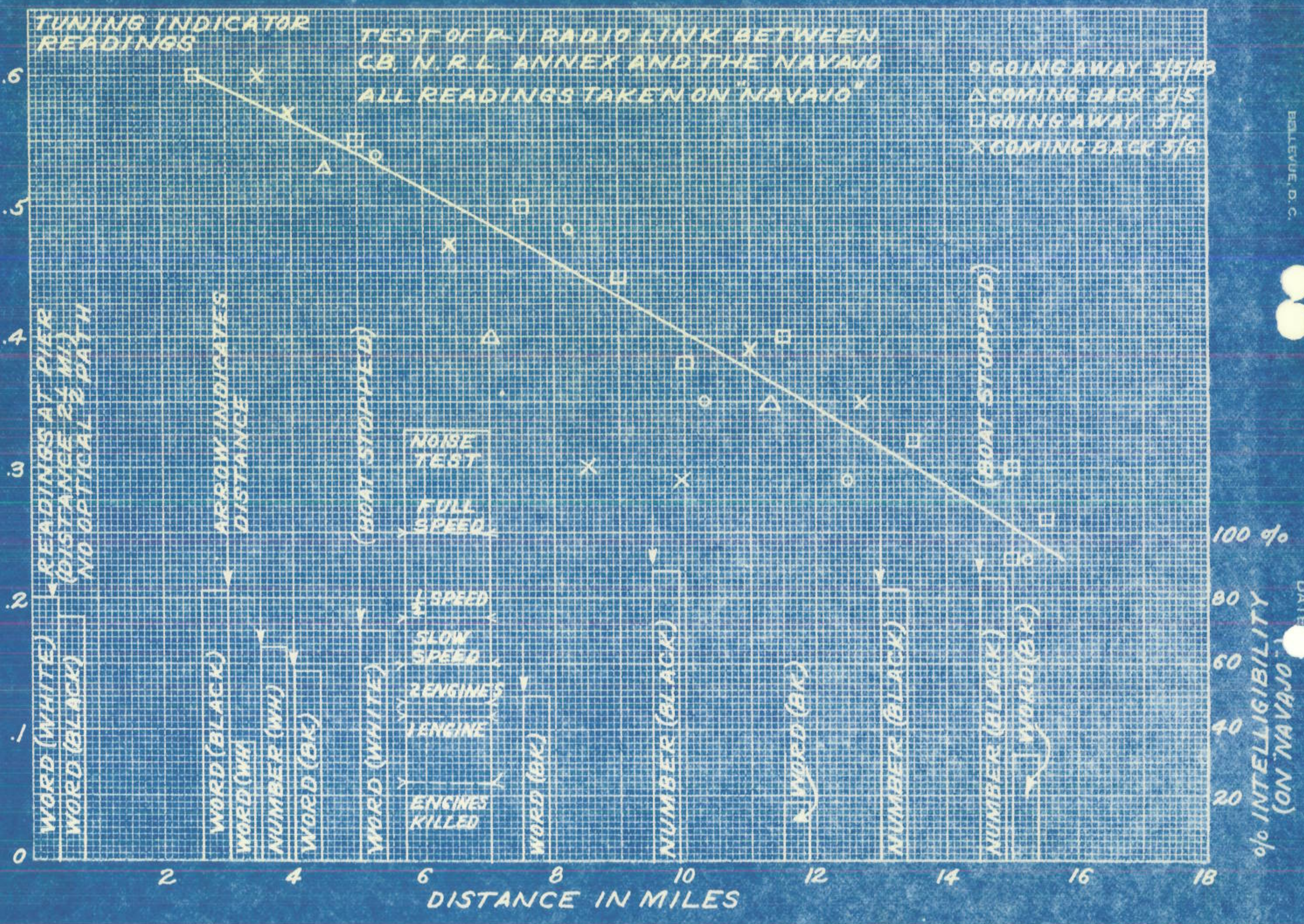


PLATE 17

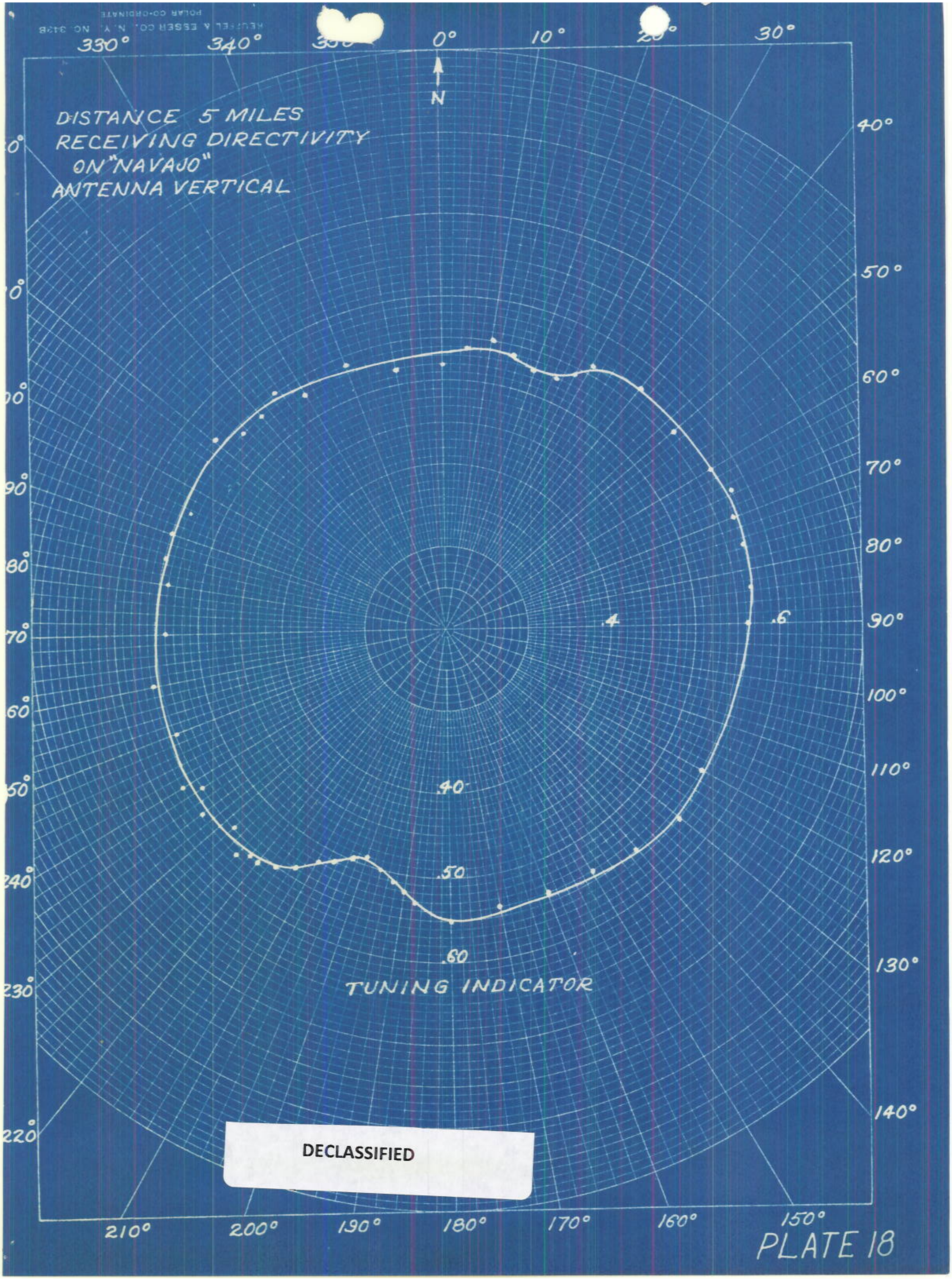

DISTANCE 5 MILES
RECEIVING DIRECTIVITY
ON "NAVAJO"
ANTENNA VERTICAL
N
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
190°
200°
210°
220°
230°
240°
330°
340°
.4
.6
.40
.50
.60
TUNING INDICATOR

PLATE 18

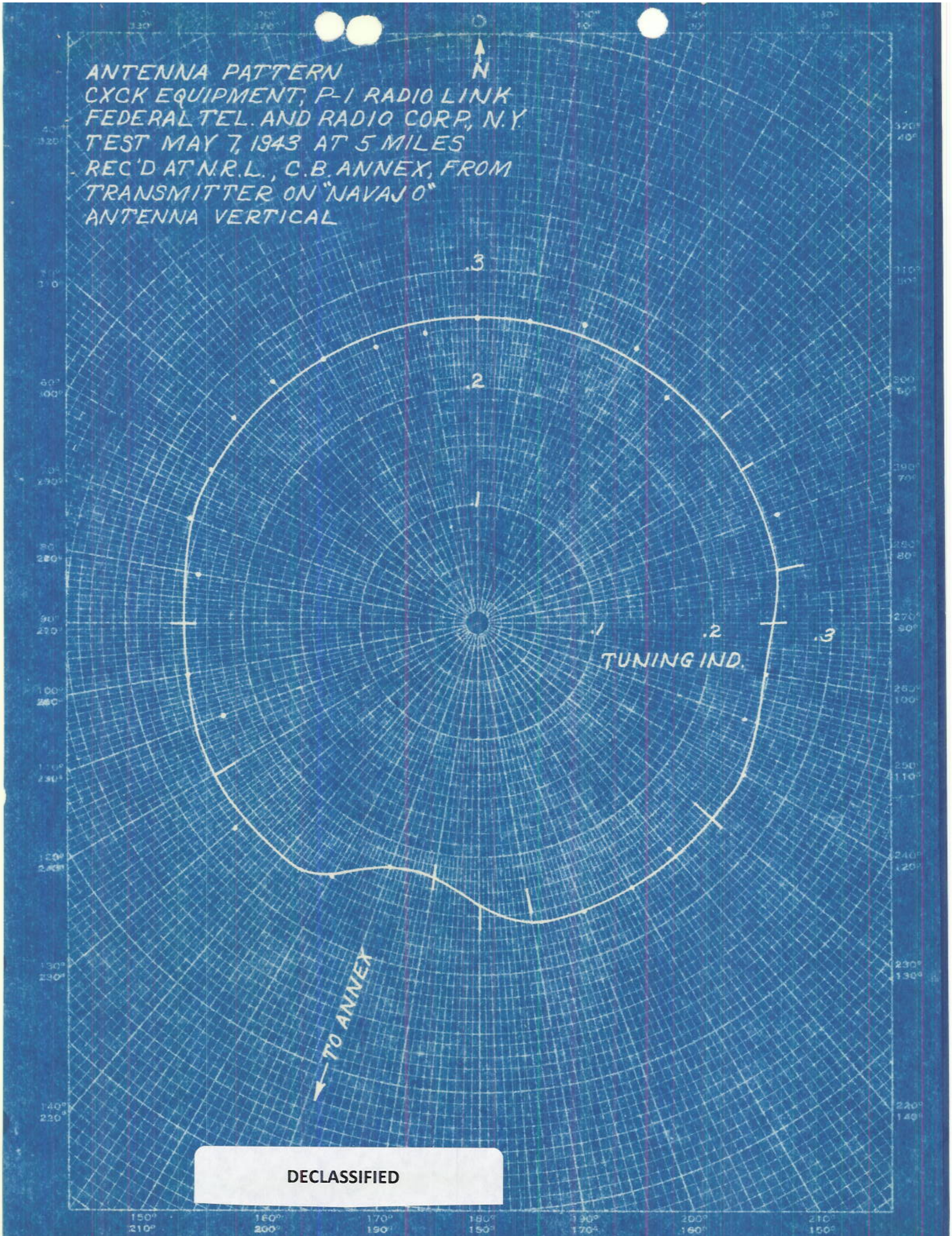

ANTENNA PATTERN
CXCK EQUIPMENT, P-1 RADIO LINK
FEDERAL TEL. AND RADIO CORP., N.Y.
TEST MAY 7, 1943 AT 5 MILES
REC'D AT N.R.L., C.B. ANNEX, FROM
TRANSMITTER ON "NAVAJO"
ANTENNA VERTICAL
N
.3
.2
.1
.1
.2
.3
TUNING IND.
TO ANNEX

PLATE 19

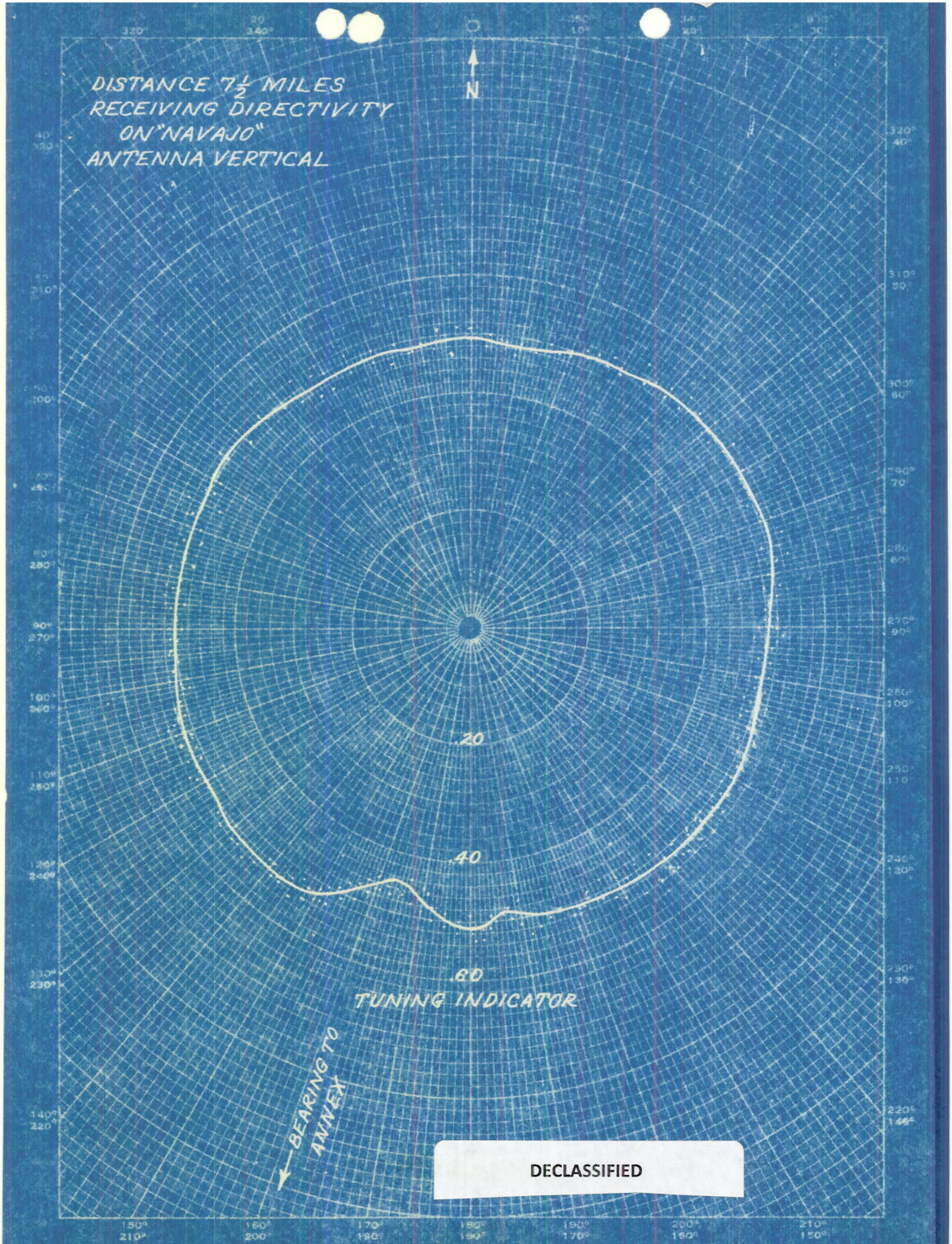

DISTANCE 7½ MILES
RECEIVING DIRECTIVITY
ON "NAVAJO"
ANTENNA VERTICAL
N
.20
.40
.60
TUNING INDICATOR
BEARING TO
ANNEX

PLATE 20

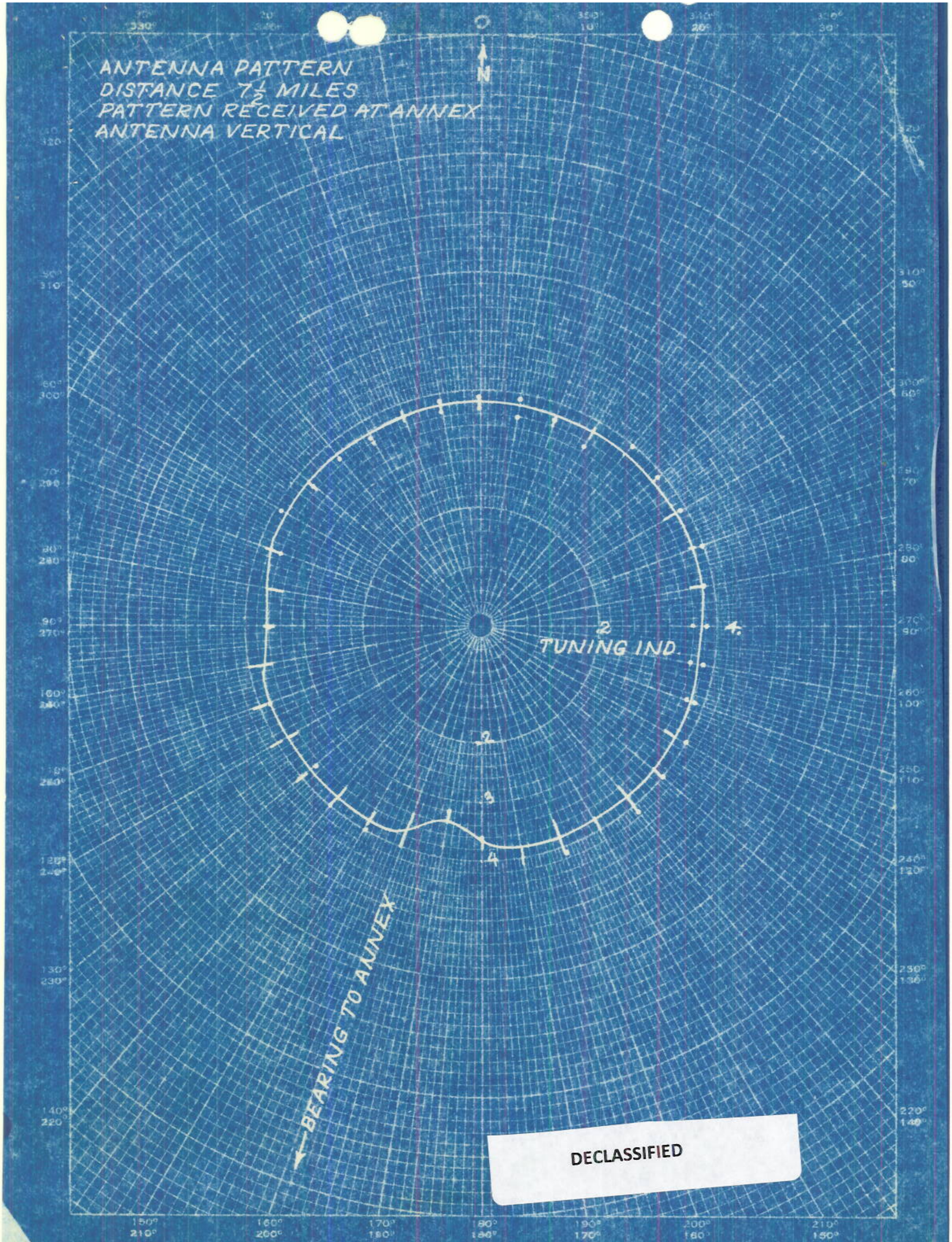
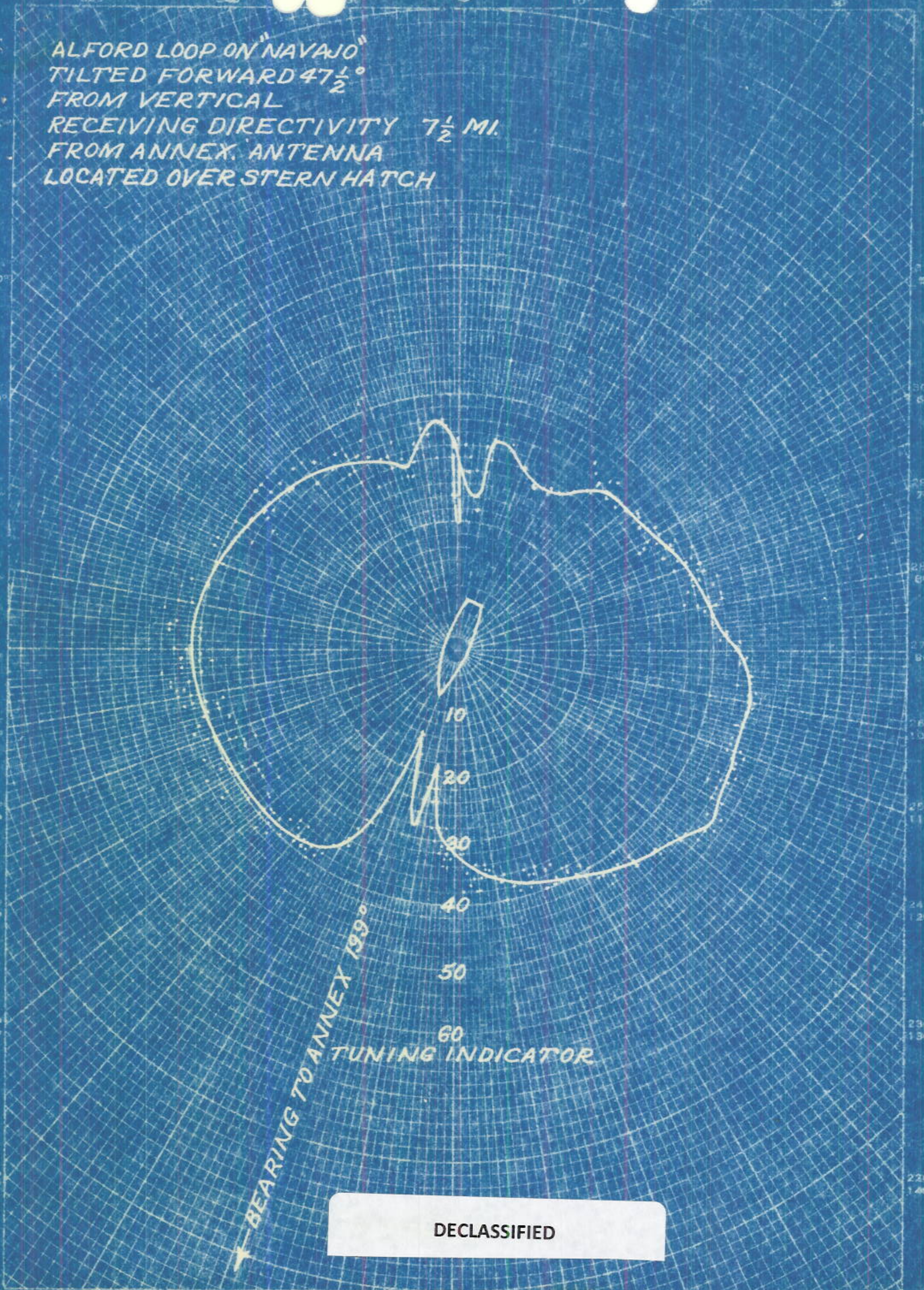

ANTENNA PATTERN
DISTANCE 7½ MILES
PATTERN RECEIVED AT ANNEX
ANTENNA VERTICAL
N
TUNING IND.
2
4
2
3
4
BEARING TO ANNEX

PLATE 21



ALFORD LOOP ON "NAVAJO"
TILTED FORWARD 47½°
FROM VERTICAL
RECEIVING DIRECTIVITY 7½ MI.
FROM ANNEX. ANTENNA
LOCATED OVER STERN HATCH
10
20
30
40
50
60
TUNING INDICATOR
BEARING TO ANNEX 199°

PLATE 22

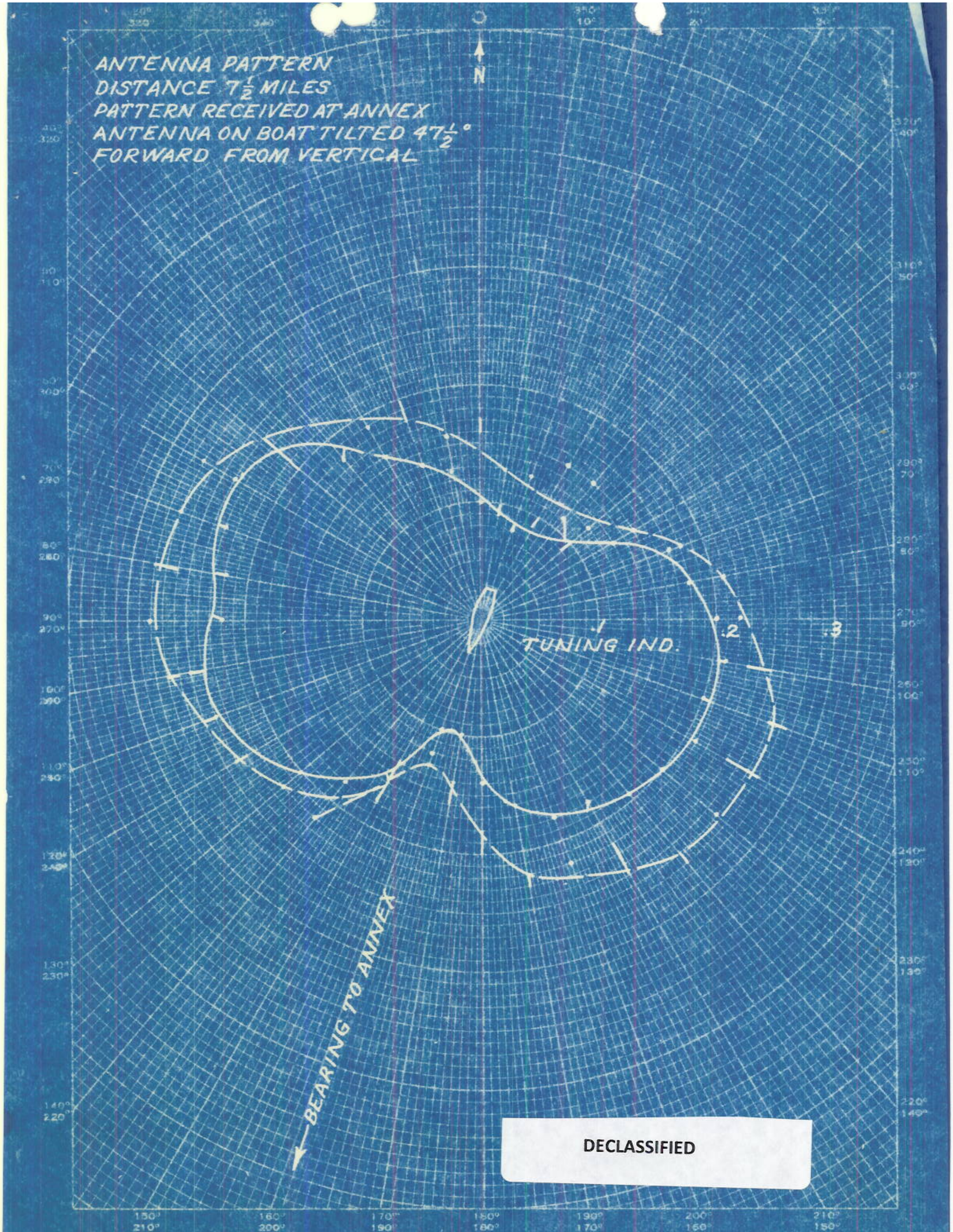

ANTENNA PATTERN
DISTANCE 7½ MILES
PATTERN RECEIVED AT ANNEX
ANTENNA ON BOAT TILTED 47½°
FORWARD FROM VERTICAL
N
TUNING IND.
.1
.2
.3
BEARING TO ANNEX
DECLASSIFIED

PLATE 23

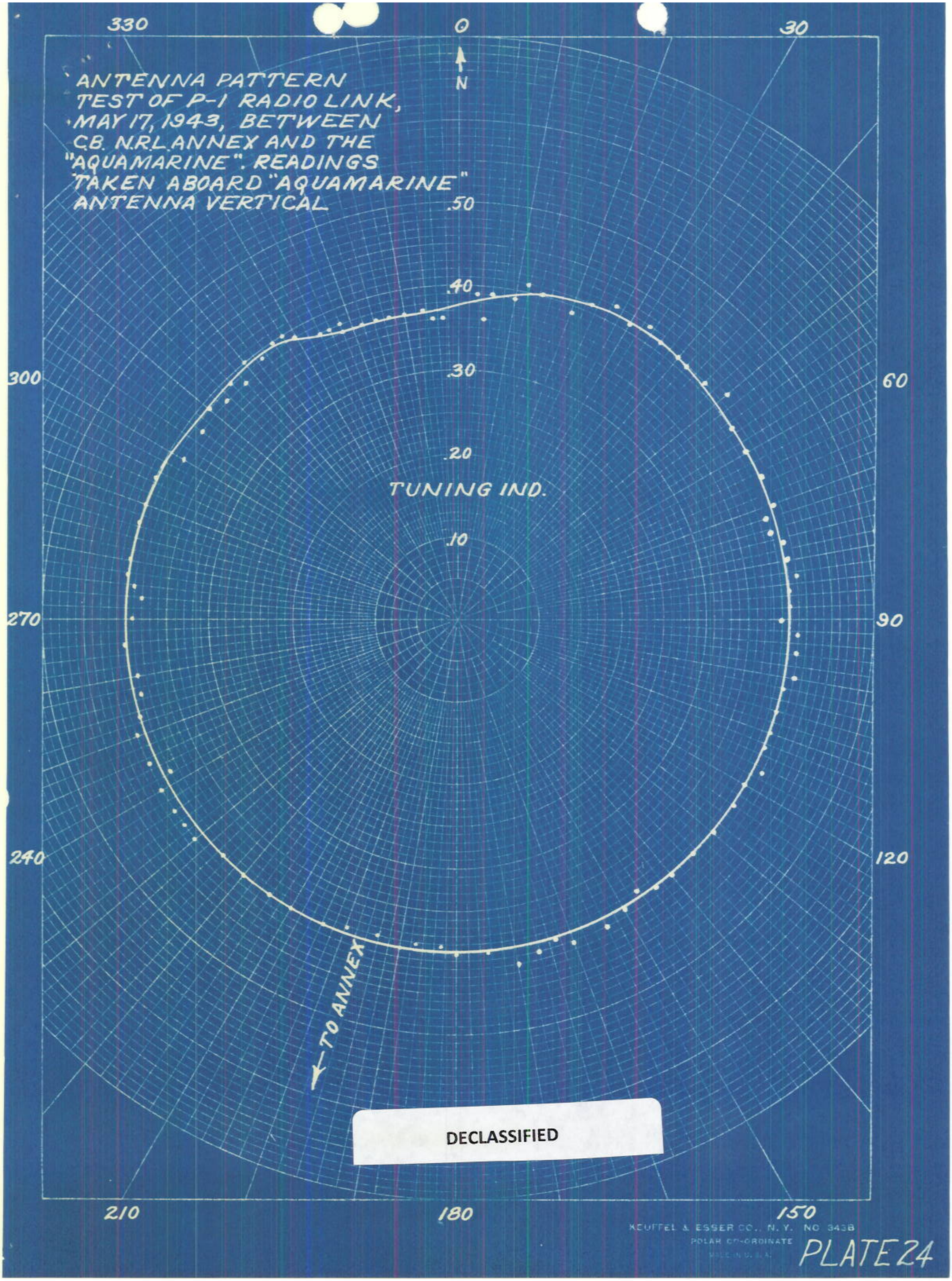

ANTENNA PATTERN
TEST OF P-1 RADIO LINK,
MAY 17, 1943, BETWEEN
C.B. N.R.L. ANNEX AND THE
"AQUAMARINE". READINGS
TAKEN ABOARD "AQUAMARINE"
ANTENNA VERTICAL
0
N
30
60
90
120
150
180
210
240
270
300
330
.50
.40
.30
.20
.10
TUNING IND.
TO ANNEX
DECLASSIFIED
KEUFFEL & ESSER CO., N.Y. NO. 343B
POLAR CO-ORDINATE
MADE IN U.S.A.

PLATE 24

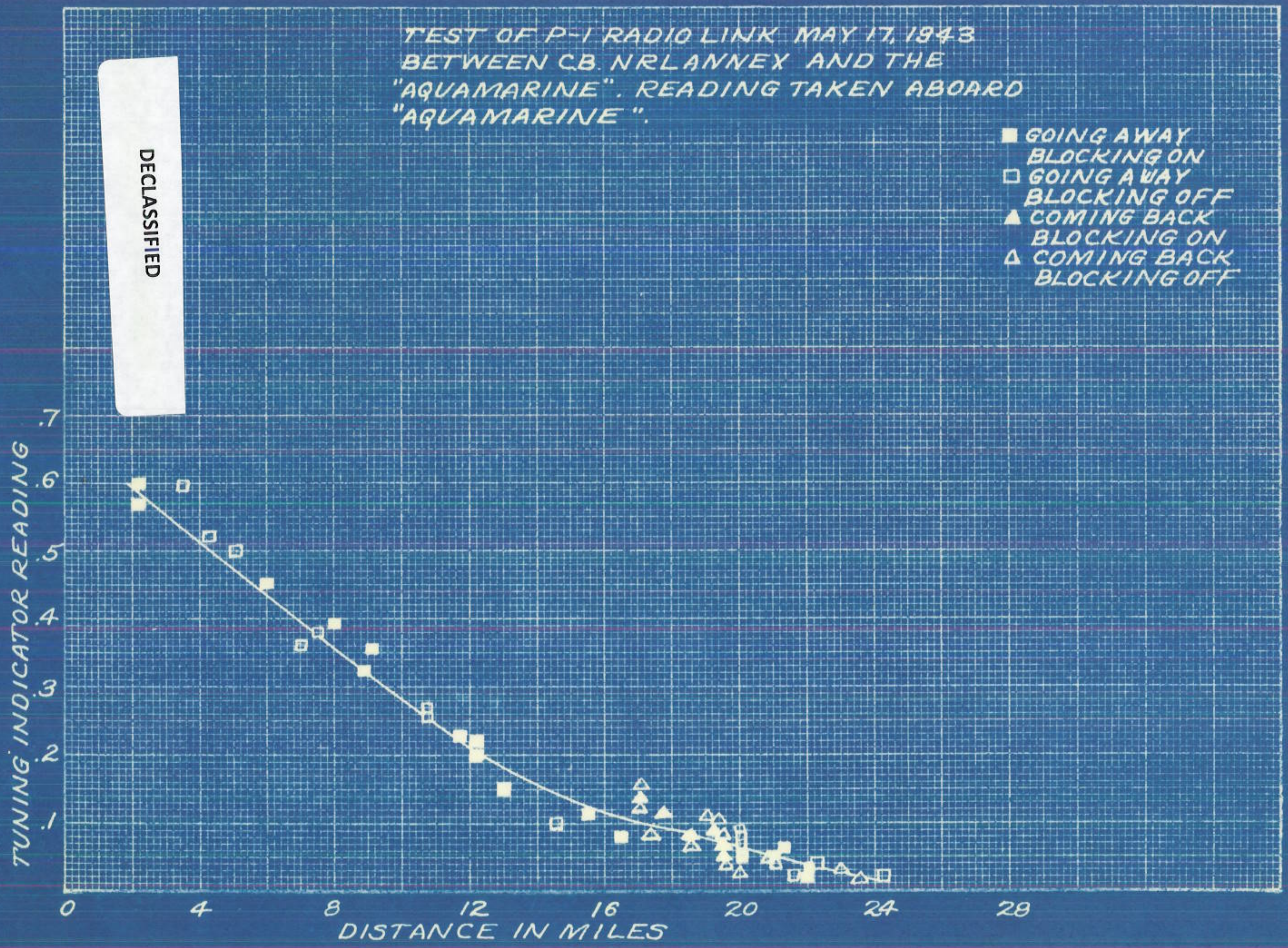
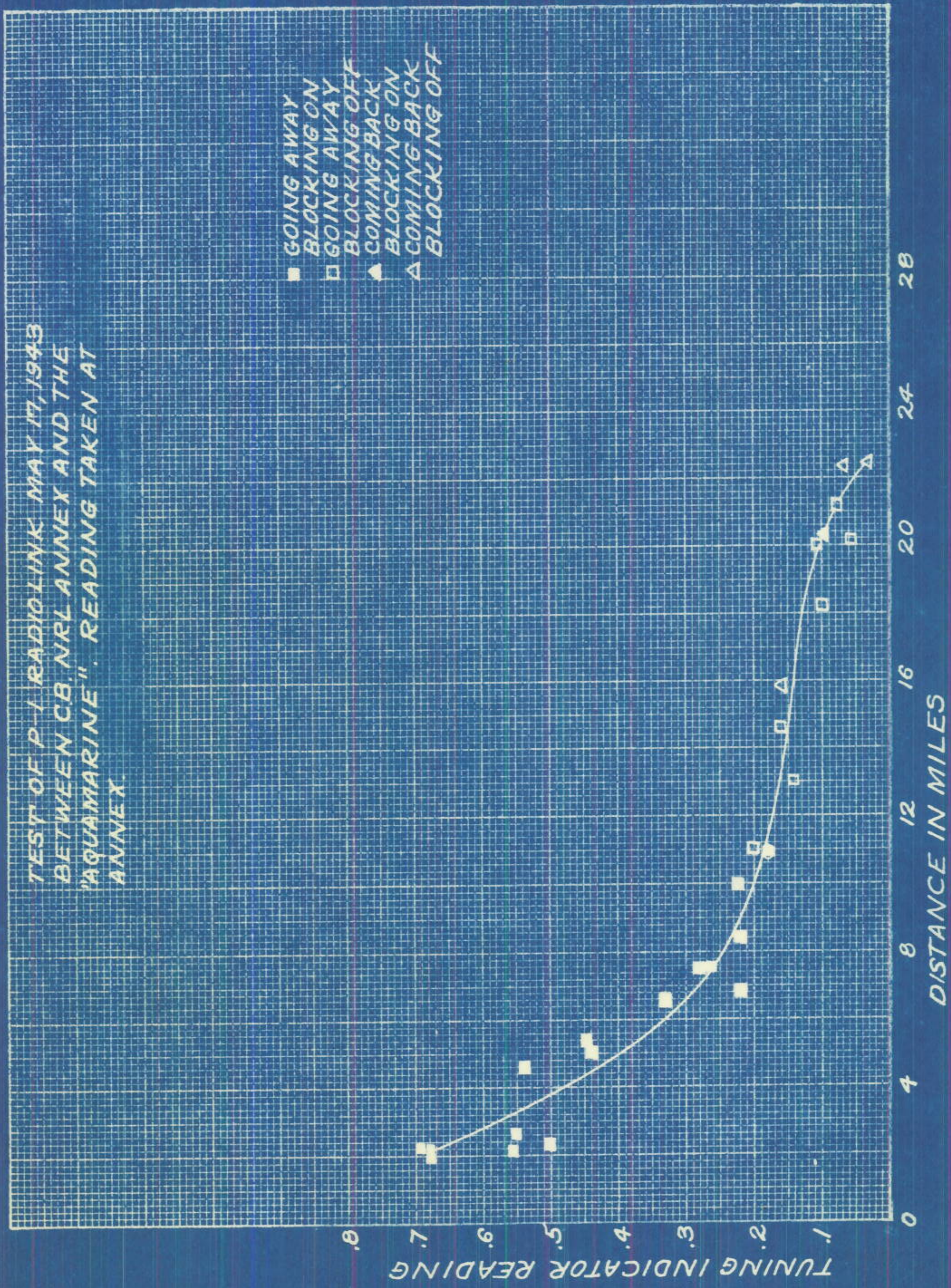

TEST OF P-1 RADIO LINK MAY 17, 1943
BETWEEN C.B. NRL ANNEX AND THE
"AQUAMARINE". READING TAKEN ABOARD
"AQUAMARINE".
GOING AWAY BLOCKING ON
GOING AWAY BLOCKING OFF
COMING BACK BLOCKING ON
COMING BACK BLOCKING OFF
TUNING INDICATOR READING
.1
.2
.3
.4
.5
.6
.7
0
4
8
12
16
20
24
28
DISTANCE IN MILES
DECLASSIFIED

PLATE 25

U. S. NAVAL RESEARCH LABOR

BELLEVUE, D. C.

DATE



N. R. L. 24A

PLATE 26

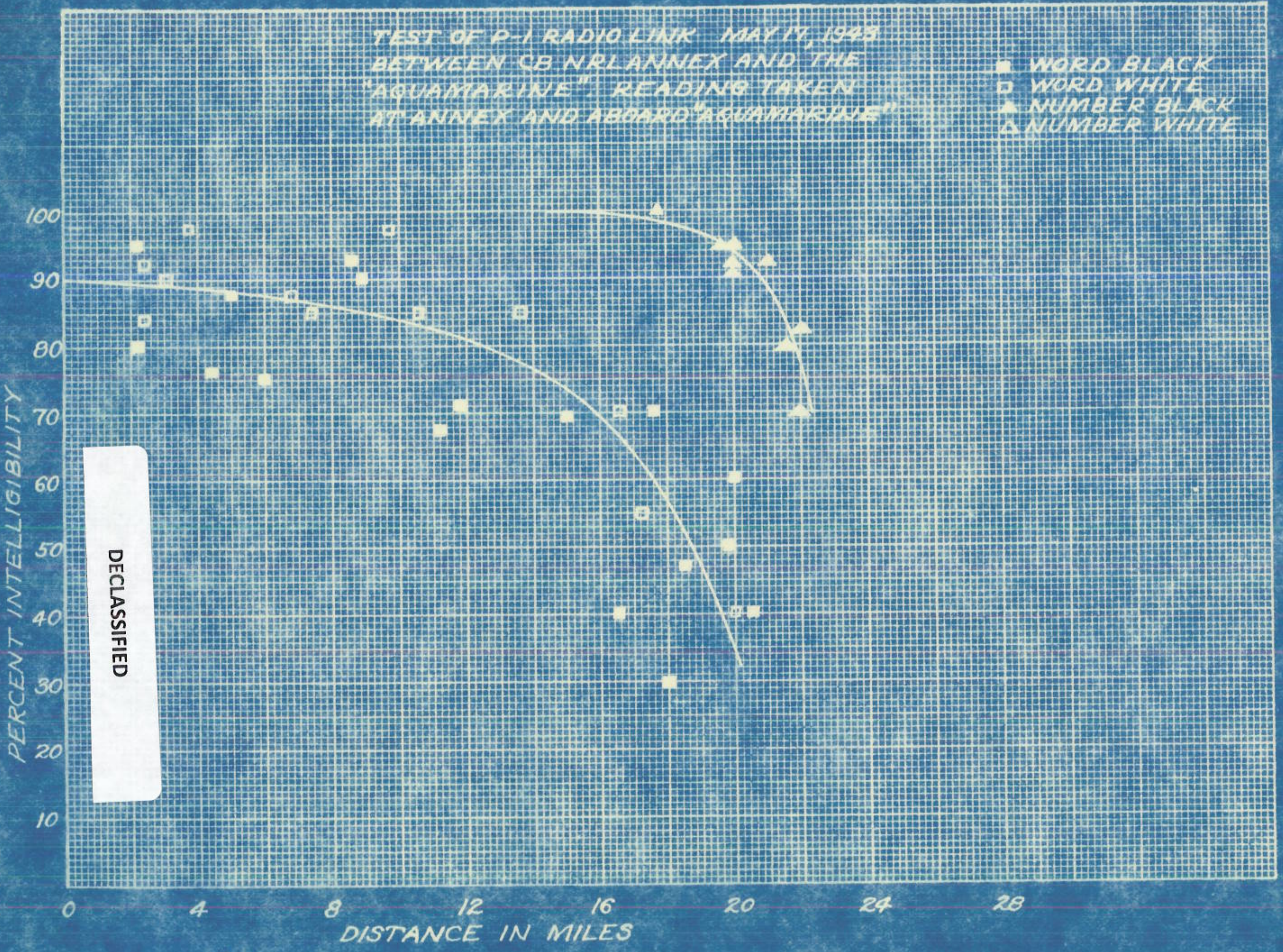

TEST OF P-1 RADIO LINK MAY 17, 1943
BETWEEN CB NRL ANNEX AND THE
"AQUAMARINE" READING TAKEN
AT ANNEX AND ABOARD "AQUAMARINE"
WORD BLACK
WORD WHITE
NUMBER BLACK
NUMBER WHITE
PERCENT INTELLIGIBILITY
100
90
80
70
60
50
40
30
20
10
0
4
8
12
16
20
24
28
DISTANCE IN MILES

PLATE 27