



# NAVAL RESEARCH LABORATORY REPORT

3 June 1941

TEST OF TYPE RA-46125 EXPERIMENTAL MODELS  
OF SUPERFREQUENCY RADIO RECEIVERS FOR  
SINGLE AND DOUBLE MODULATION.

By G. Emerson Pray

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Report

on

Test of Type RA-46125

Experimental Models of Superfrequency

Radio Receivers for Single and Double Modulation.

A Part of Model XAP Equipment.

NAVAL RESEARCH LABORATORY  
ANACOSTIA STATION  
WASHINGTON, D. C.

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## AUTHORIZATION

1. The tests herein reported were authorized by reference (a). Other pertinent data are listed as references (b) to (e), inclusive.

- (a) BuShips Project R3-5C.
- (b) Specifications RA 13A 240
- (c) Specifications RE 13A 557D
- (d) Specifications RE 13A 593B
- (e) Engineering Report R-1737

## OBJECT OF TEST

2. The objects of the test were to determine the performance characteristics of two experimental superfrequency receivers, to obtain comparative data on double versus single modulation, and to show what practical results may be obtained with the newly developed and unique preselector systems provided in these receivers.

## ABSTRACT OF TEST

3. The receivers were first set up in the Laboratory and given an electrical performance test on single and double modulation. For the double modulation tests it was necessary to modify a Ferris Model 18B Superfrequency Microvolter, and to construct a modulation amplifier. The attenuator calibration of the microvolter was carefully checked to assure accuracy of test results. After the Laboratory tests were completed, the two receivers were mounted beside their respective transmitters, one in the Laboratory and one in a field test truck, and two-way communication tests were conducted over land at distances up to 15 miles. Tests were also conducted of two different types of antennas to determine their relative suitability.

## DESCRIPTION OF MATERIAL UNDER TEST

4. The material under test was developed and constructed at this Laboratory, and consists of:

- (1) Two receivers, type RA-46125
- (2) One fixed tuned antenna, type RA-66030
- (3) One variable tuned antenna and drive unit, type RA-66031
- (4) One control unit for (3) above, type RA-23179.

In accordance with reference (a), two superfrequency receivers were developed, each capable of receiving either single or double modulation. Each receiver is provided with Lord shock mountings for table top mounting. On single modulation, each receiver in its present form covers a frequency range of 130-210 Mc with 4 to 5 per cent overlap at each end; and is capable of receiving a carrier, which is modulated at audio frequency.

5. On double modulation, each receiver covers the same carrier frequency range of 130-210 Mc as on single modulation. It is capable of

receiving a carrier, modulated at an intermediate or primary modulation frequency between 175 and 225 kc, which in turn may be modulated at audio frequency. It is also capable of receiving a carrier with intermediate modulation but without audio modulation, making possible the communication by stable cw telegraph signals. If the carrier is modulated by five intermediate frequency channels simultaneously, the receiver will pick the desired channel to the exclusion of the other four channels.

6. Each receiver is of the superheterodyne type, and is constructed in three sections combined into a single unit. The first section contains the superfrequency preselector; the second section contains all i-f and a-f components; and the third section contains the power pack. This type of construction was adopted to facilitate the convenient interchange of experimental preselectors in order to determine their relative merits and practicality. The power pack may be replaced by a dynamotor or other unit for tests in aircraft.

7. All controls are mounted on the front panel and have been kept to a minimum as shown in the photograph of Plate 2. The photograph of Plate 3 shows a receiver with two tuning dials on the preselector. This preselector was later replaced by another one similar to that of Plates 1 and 5 which proved to be superior electrically and mechanically.

8. The tube complement is as follows:

<u>Use</u>	<u>Type</u>	<u>Quantity</u>
<u>Preselector</u>		
R-F Amplifier	954	1
1st Mixer	954	1
1st Oscillator	955	1
<u>I-F Amplifier</u>		
1st I-F Group	6AC7	2
Single Modulation - )	6AC7	1
2nd I-F Group )		
Double Modulation )	6SJ7	1
Detector )		
Double Modulation - )	6SA7	1
2nd Mixer )		
Double Modulation - )	6SJ7	1
2nd Oscillator )		
Double Modulation - )	6SK7	1
2nd I-F Group )		
Double Modulation - )	6SJ7	1
(CW Beat) Oscillator )		
<u>Final Detector</u>	6H6	1
<u>A-F Amplifier</u>		
1st Stage	6SJ7	1
2nd Stage	6F6	1
<u>Power Pack</u>		
Rectifier	5T4	1
Voltage Regulator	VR-105	1

9. The preselector contains one stage of r-f amplification using a type 954 tube, a type 954 mixer, and a type 955 heterodyne oscillator, all ganged to a single tuning dial of 500 scale divisions. This preselector makes use of tuned frames for resonant circuits as shown in Plate 5. The frames are equivalent to parallel conductor transmission lines, with a length that is considerably less than one quarter wavelength to make them inductive, and loaded by the capacitance of the tuning condensers for resonating at the desired frequencies. The frames are constructed of invar, heavily silver plated to provide good surface conductivity. The tuning condensers are air dielectric rotary condensers, produced by the Hammarlund Manufacturing Company, and ganged by means of flexible couplings to a single tuning dial. The condensers are manufactured according to Laboratory drawings 48A361D, which are a modification of the Hammarlund air trimmer type. The mounting plate is of isolantite; the shaft and plate mounting studs are of brass; and the plates are of a 42 per cent nickel-steel alloy whose temperature coefficient of expansion is equal to that of isolantite. All metal parts are heavily silver plated and gold flashed. The resulting condenser has very nearly zero temperature coefficient of capacitance over its capacity range. Because of the construction described above, the resulting circuit has very slight drift in frequency due to temperature changes. This drift is further reduced by employing ceramic compensating condensers shunted across each tuned frame.

10. Another preselector developed for these receivers consists of two concentric line circuits, one for the oscillator, and one for coupling the antenna circuit to the grid of the mixer. No r-f amplifier stage was included since the design required separate tuning dials for each circuit. The frequency range covered is 130 to 160 Mc by the manipulation of two tuning dials as shown on Plate 3. The concentric line is constructed entirely of invar, silver plated, and consists of an inner and an outer conductor, short circuited at one end, and loaded by the tuning capacity at the other end. The tuning capacity consists of two silver plated invar discs, one mounted rigidly on the end of the inner conductor, the other mounted by a differential thread in the corresponding end of the outer conductor in such manner that the spacing between the discs is controlled by the tuning dial to vary the capacity between the discs.

11. The antenna input to each preselector is through a 70-ohm flexible concentric transmission line patch cord which plugs into fittings in the back of the preselector shown in Plate 4. Each preselector is provided with two input fittings so that either a single or a balanced double line may be used. In the tuned frame preselectors, each input fitting is coupled through a 10 micromicrofarad series condenser to a low impedance point on the r-f amplifier input frame. In the concentric line preselector the input fittings are inductively coupled to the inner conductor of the mixer input circuit by means of a low impedance loop. The attempt has been made in both cases, with apparently good success, to provide a reasonable impedance match between the 70-ohm input line and the tuned circuit.

12. The first oscillator operates at frequencies which are 13 Mc higher than the carrier frequency, to generate the first intermediate frequency. A concentric plug fitting couples the 13 Mc intermediate frequency signal from the mixer in the preselector section to the first i-f transformer

in the i-f and audio section. The first two i-f stages using type 6AC7 tubes have a band width of 600 kc, and are used for both single and double modulation reception. From the second 13 Mc i-f stage to the final detector, the circuit is split into two paths, one for single and one for double modulation.

13. For single modulation, the signal passes through a third i-f amplifier stage, consisting of one type 6AC7 tube and two transformers of 250 kc band width, then to one anode of the 6H6 final detector. For double modulation, the signal passes through a third i-f transformer of 600 kc band width to a type 6SJ7 tube used as a double modulation detector. The output of this detector is the primary modulation frequency of 175 to 225 kc, which is applied to the grid of a type 6SA7 second mixer tube through a channel selector circuit. A type 6SJ7 second heterodyne oscillator, controlled by another selector circuit, is coupled to the injector grid of the second mixer. Both selector circuits are tuned by combinations of fixed and adjustable condensers, controlled by a five-position ganged switch to provide five primary modulation channels. The second oscillator operates at frequencies which are 480 kc above the primary modulation frequency. The 480 kc output of the second mixer goes through one stage of i-f amplification consisting of one type 6SK7 tube and two transformers of 8.8 kc band width, then to the second anode of the 6H6 final detector.

14. An i-f gain control potentiometer operates in the cathodes of all i-f stages to control the gain for cw reception or when the AVC switch is in the "off" position. This control is operative for both single and double modulation, and should be at a position for nearly maximum gain when the AVC switch is in the "on" position. The potentiometer is supplied with definite biasing voltage from a bleeder circuit across the plate supply. The bleeder circuit consists of the potentiometer of 1000 ohms, and two fixed resistors of 25,000 and 15,000 ohms respectively, and provides screen potential for the i-f tubes.

15. The rectified and filtered output of the final detector provides AVC bias for all i-f stages and for the second mixer. The a-f output of the final detector provides audio signal for the a-f amplifier.

16. For cw operation on double modulation, a cw beat oscillator, using a 6SJ7 tube, injects a beat frequency voltage of about 0.5 volt into the final detector input circuit. The beat oscillator frequency may be varied from 480 kc over a small range, by adjustment of a control on the front panel, to provide the desired audio beat note. An "on-off" switch is provided to control the operation of this oscillator.

17. The final detector is biased at one volt to delay the AVC action, but is not biased for detection. The detector output circuit is common for both single and double modulation, and is coupled to the a-f volume control potentiometer through a .01 microfarad condenser. The arm of the potentiometer is connected to the grid of the type 6SJ7 first audio tube. The output of the first audio tube is coupled by a resistance and capacity network to the type 6F6 power output tube. The output tube is coupled to the 600-ohm

output load through a transformer.

18. The power pack contains a power transformer, one type 5T4 rectifier tube, a filter network, and a type VR-105 voltage regulator tube. The power pack operates from a 110 to 120 volt, 60 cycle supply, and delivers 6.3 volts a.c. for heaters, 105 volts regulated d.c. for oscillator circuits and mixer screens, and 250 volts d.c. for plate circuits. The i-f screens obtain their 115 volts from a fixed bleeder potentiometer in the i-f chassis across the 250 volt plate supply. The three sections of the receiver are connected together electrically by means of cables and Jones plug fittings as shown in the photograph of Plate 4, except for the 13 Mc intermediate frequency connection between the preselector and the i-f unit, which is made through a concentric plug fitting shown in Plate 6.

19. Two different types of antennas were constructed for these receivers. One of them is a fixed ground plane type, shown in Plate 1, with a vertical collector member that is  $1/4$  wavelength long at the mid-frequency of the receiver tuning range, and with horizontal ground plane members extending radially, also for a distance of  $1/4$  wavelength, and insulated from the low impedance end of the collecting member. A 70-ohm concentric transmission line, with the center conductor connected to the collector member of the antenna, and the outer conductor to the ground plane, conducts the signal to the receiver junction box shown in Plate 2. Although the impedances of the antenna and the transmission line are somewhat mismatched, the effect upon the signal strength is not serious.

20. The other antenna is a tunable "J" type, shown in Plate 7, and having two parallel members. One member is  $3/4$  wavelength long, the upper  $1/2$  wavelength acting as the collector member, with the lower  $1/4$  wavelength acting as a matching section. The second member is a  $1/4$  wavelength matching stub, and tends to cancel any antenna effect in the matching section of the longer member. The resulting antenna is equivalent to a voltage fed half wave vertical dipole. The antenna is tuned by varying the length of the two parallel members, always maintaining an optimum ratio of  $2.61/1$  in their lengths. The tuning is done by an electric motor drive through gears, threaded shafts, and threaded sleeves mounted inside the vertical antenna members. These members are each constructed in two sections, one of which slides within the other telescopically to vary the overall length in tuning. A serrated spring contact sleeve is provided at the juncture to insure good electrical contact. A heater unit is provided within the sleeve for melting ice from the joint when necessary. The heater operation is controlled by a switch in the remote control unit at the receiver location. The tuning system is remotely controlled, and remotely monitored by an autosyn motor and indicator in the remote control unit. A limit switch is provided in the antenna unit to prevent running the tuning beyond the designed range. Two 70-ohm concentric transmission lines are used to couple the antenna to the receiver. These lines are connected to the matching stubs at points which provide proper matching of impedances for the mid-frequency point of the tuning range. The mismatch at the ends of the range is negligible.

21. A marine type permanent magnet loud speaker with a 7-inch cone, encased in a copper plated steel housing for magnetic shielding, and with a wrinkled paint finish, is provided with each receiver. The input impedance of the speaker is 600 ohms to match the output of the receiver. Brackets are provided for bulkhead mounting. The speaker is not considered satisfactory

for Navy use in an exposed location, as the paper cone is not felt to be impervious to moisture, nor strong enough to withstand excessive concussion from gunfire. The speaker is furnished for the purpose of demonstrating the capabilities of the receiver, and should be replaced by a more satisfactory type for permanent installations in exposed locations.

#### METHOD OF TEST

22. The receivers were tested according to Specification RA 13A 240 in so far as possible, additional tests being made to cover double modulation and other items not covered in the specification.

23. Sensitivity tests for single modulation were made in the normal manner, using a General Radio Signal Generator, type 804B, Serial No. 206. Results were checked over a portion of the range against a Ferris Microvolter, type 18B, Serial No. 65. For purposes of comparison with the type XRAQ receiver, an additional sensitivity curve was taken, holding the input and output voltages constant, and measuring the signal to noise ratios at different frequencies. Normal sensitivity tests for double modulation were made, using the Ferris Microvolter, type 18B, Serial No. 65, which was doubly modulated by a Ferris Signal Generator, type 16C, Serial No. 44. The output of the type 16C generator was amplified by a Naval Research Laboratory amplifier to provide sufficient modulating voltage for the type 18B generator. Receiver output was measured by a Ballantine Voltmeter, type 300, Serial No. 14, shunted by a 600-ohm resistor.

24. Image rejection was measured by means of General Radio Signal Generator, type 804B, Serial No. 206.

25. I-F selectivity was measured by means of Ferris Signal Generator, type 16C, Serial No. 44. Channel selectivity on double modulation was measured by use of this same generator. The overall weak signal selectivity could not be measured by the normal method due to severe frequency modulation of all available superfrequency generators. The i-f selectivity was therefore considered as a satisfactory substitute for the overall curves.

26. Overload selectivity was measured by using General Radio Signal Generator, type 804B, Serial No. 206, as the desired signal, and a Model XTBT transmitter as the undesired signal. Spacings between receiving and transmitting antennas were varied. Further tests were made, replacing the XTBT transmitter by a transmitter of the Model XAO equipment.

27. A heterodyne calibrator unit constructed by the Naval Research Laboratory was used for calibration, resettability, frequency change with line voltage and line frequency, and frequency change with temperature. A special Frigidaire temperature chamber was also used in the temperature tests.

28. The General Radio Generator, type 804B, Serial No. 206, was used in vibration and rocking tests, each receiver being vibrated and rocked for one hour, and vibrated for 10 minutes at each resonant vibration frequency. The laboratory vibration table was used in these tests.

29. Resonant overload tests were made, using the General Radio Generator, type 804B, Serial No. 206.

30. Distortion and fidelity tests were made at the 13 Mc intermediate frequency, using Ferris Generator, type 16C, Serial No. 44, and General Radio Wave Analyzer, type 736A, Serial No. 289. The tests could not be made at the carrier frequency due to the serious distortion and frequency modulation present in the available superfrequency signal generators.

#### DATA RECORDED DURING TEST

31. Complete data were recorded on all tests conducted, the results being given in Tables 1 to 5, inclusive, and in Plates 8 to 30, inclusive.

#### PROBABLE ERRORS IN RESULTS

32. Measuring instruments were in general checked for accuracy of calibration. In some cases tests were repeated using other instruments, to avoid any possibility of serious error in results. The results are felt to be well within the tolerances listed in the following table.

<u>Test</u>	<u>Estimated Maximum Error</u>
Sensitivity 130-210 Mc	+ 50%
Image Rejection	+ 2 db
Fidelity	+ .2 db
Distortion	+ 2%
Resonant Overload	+ .2 db
Power Consumption	+ 2%
Oscillator Stability	+ .005%

#### RESULTS OF TESTS

33. Par. 4-1. The receiver may be operated from an a-c power source of 115 volts,  $\pm 5$  per cent, 57-63 cycles, single phase. The rectifier is integral with the receiver, but the power pack as a whole is removable from the unit, as is also the preselector.

34. Par. 4-2. Using a tuned frame preselector with single dial tuning, the receiver may be adjusted to any frequency in the band 130-210 Mc within 5 seconds. It may be used to search the band 130-210 Mc for weak signals within 15 seconds. Using a concentric line preselector with two dial tuning, the receiver may be adjusted to any frequency in the band 132-156 Mc within 10 seconds, but searching the band for weak signals is not convenient. No plug-in coils are used.

35. Par. 4-3. The receiver is capable of adjustment to receive a signal, modulated 30 per cent at 1000 cycles, of any assigned frequency between 130 and 210 Mc. The receiver was designed for an output of 1 watt at low distortion levels. However, at higher distortion levels the receiver is capable of an output of 5.5 watts into a 600-ohm resistive load. The receiver will deliver in excess of 1 watt output when the input signal fre-

quency is varied 0.039 per cent on either side of the assigned frequency and when the amplitude of the input signal is less than 10 microvolts. These conditions are met for both single and double modulation. The maximum input signal obtainable from the signal generator was 20,000 microvolts. At frequencies 850 kc above or below the resonant frequency, an input of 20,000 microvolts produces no output from the receiver on single modulation. Due to frequency modulation of the signal generator, and its coarse tuning, no similar test could be made on double modulation. However, from design data and tests made using carrier without modulation, the double modulation carrier acceptance band is twice as wide as for single modulation. The primary modulation channels are spaced 12.5 kc apart for double modulation. A channel 12.5 kc from the desired channel is attenuated 40 db, and a channel 25 kc from the desired channel is attenuated 60 db. The receiver meets the above conditions under certain of the following circumstances as specified, and fails to meet the conditions under other circumstances as specified.

(1) "For adjustment to the assigned frequency using only the calibrating means provided within the equipment." For greatest accuracy this would require that a crystal calibrator and a complex and expensive first oscillator tuning control be employed. This receiver is not equipped with either of these items, but has a simple and inexpensive single dial reduction drive tuning control and a frequency calibration chart which may be read to 0.1% of the desired frequency. From Table 1 it is shown that by rocking the tuning dial about the calibration point and then bringing it to rest, it is possible to reset to within 75 kc at 200 Mc, and 20 kc at 140 Mc. However, if the dial is turned only up to the calibration point, and stopped there without rocking through the point, the error may be 622 kc at 200 Mc or 0.31 per cent. This is due to torque lash in the mechanical assembly, most of which could be eliminated by improvement in the mechanical design. Rocking the dial through the calibration point brings all the circuits into line and releases the torsional stresses in the system. In practical operation no difficulty is encountered in tuning to a preassigned frequency, but the receiver cannot be said to comply with the specification in this respect.

(2) "During 2 hours of continuous operation." No temperature control heaters are used in this receiver and none are required. During a 10 minute warm-up period from a cold start, the oscillator drifts 62 kc in 160 Mc as shown on Plate 24, and remains substantially stable thereafter. The receiver meets the requirements of the specification in this respect if a 5 or 10 minute warm-up period is allowed.

(3) "During variations in ambient temperature between limits of 0°C to 50°C." Examination of Plate 22 shows a maximum overall frequency change of 87 Kc in Frame Preselector No. 1 for a temperature change of 50°C. Plate 23 shows a maximum overall change of 73 kc in Frame Preselector No. 2 under the same temperature conditions. Plate No. 24 shows a maximum change of 490 kc for the Concentric Line Preselector. The mechanical design of the Concentric Line Preselector did not lend itself to temperature compensation. The Tuned Frame units were compensated by means of negative temperature coefficient ceramic condensers of approximately 2 micromicrofarads capacitance, and a coefficient of  $-.00035 \text{ uuf/uof/}^\circ\text{C}$ . The Tuned Frame units meet the tempera-

ture requirements of the specification with a large margin. In production, however, each receiver might possibly require individual measurement to determine the proper compensation.

(4) "During variations in humidity between 30 and 95 per cent." No humidity tests were conducted. It is probable that the receiver would require the installation of a dryer unit in the oscillator compartment to give satisfactory performance in this respect.

(5) "During variations of a-c supply line voltage of from 115 volts  $\pm$  5 per cent, and between 57 and 63 cycles." Table 2 shows a maximum deviation of 7.1 kc in 150 Mc when the line voltage is increased 5 per cent, and a deviation of 1.4 kc upon decreasing the voltage by 5 per cent. Table 3 shows a deviation of 2.8 kc upon decreasing the line frequency to 57 cycles, and no deviation upon increasing the line frequency to 63 cycles. The receiver meets the requirement of the specification in this respect with a large margin.

(6) "For a complete change of vacuum tubes." (Readjustment as in (1) above is permitted.) The r-f amplifier and the mixer circuit have a sufficiently broad acceptance band that they are unaffected by tube changes. The first oscillator circuit remains constant to within .1% at 220 Mc and .03% at 140 Mc without readjustment after a normal tube change. These figures are within the readable accuracy of the calibration charts provided with the receivers. Since no calibrating means is provided in the receiver, readjustment of the oscillator trimmer would require the use of an external crystal calibrator; therefore the receiver does not meet the requirements of the specification in this respect.

36. Par. 4-4. The tuning of the receiver is continuously variable between 130 and 210 Mc with adequate overlap at the ends of the range by means of a single tuning dial. It is possible to adjust the receiver to any assigned frequency in this range to within 0.1 per cent by reference to the calibration curves. This does not meet the requirements of the specification. The present spread of the calibration curve is felt to be approximately equal to the mechanical limitations of the present tuning drive assembly.

37. Par. 4-5. The sensitivity of the receiver as shown in Plates 11 and 12 is such that less than 2 microvolts of carrier signal modulated 30 per cent at 1000 cycles is required on single modulation to produce an audio output of 1 watt into a 600-ohm resistive load with a signal to noise ratio of 7.4 db. On double modulation, less than 7 microvolts is required for the same output with 15 per cent net modulation. The receiver meets the design intentions as to sensitivity, and will also meet the single modulation requirements of the specification for 5.5 watts output. Two separate receivers, one for single, the other for double modulation, could each give performance superior to that of the present combination receiver for the corresponding type of reception. Plate 13 shows the sensitivity using the Concentric Line Preselector.

38. Plate 14 shows an image rejection of 54 to 62.5 db over the range 130 to 210 Mc for the receiver when using a Tuned Frame Preselector, and 26 to 30 db over the range 132 to 156 Mc when using the Concentric Line Pre-

selector. Neither unit meets the requirements of Par. 4-3 of the specification in this respect, as the specification figures would require a rejection of at least 75 db. In order to realize this high rejection and still use the same intermediate frequency, it would be necessary to employ one additional tuned frame circuit in the Tuned Frame Preselector, or two additional concentric line circuits in the Concentric Line Preselector. This would make gang tuning of the circuits much more difficult, and probably impractical at the present state of the art.

39. The i-f selectivity on single modulation is shown on Plate 15 and meets the specification requirements. The channel selectivity on double modulation is shown on Plate 16 and meets the design intentions, no specification requirements having been set up.

40. Par. 4-6. Fidelity curves for both single and double modulation are shown on Plate 17. On single modulation the output between 150 and 3500 cycles is within 2 db of the output at 1000 cycles. On double modulation the output between 160 and 2000 cycles is within 2 db of that at 1000 cycles. The fidelity on double modulation is restricted by the channel selectivity. The distortion for various outputs up to 3 watts is shown on Plate 18, the total distortion being less than 10 per cent for outputs from 1.2 milliwatts to 1.6 watts.

41. Par. 4-7. The overload curves on Plate 19 show that for maximum gain the output remains constant within  $\pm 1$  db of 5.5 watts for variation of signal input between 5 microvolts and 100,000 microvolts. Curves of initial receiver noise, noise modulation on the signal generator, effect of AVC on noise, and reduced output signal are also shown on Plate 19. Similar curves for double modulation are shown on Plate 20. The AVC circuit was not provided with any adjustable time constant in the present receiver, and no measurement of time constant was made. The AVC circuit prevents excessive overloading and distortion when the transmitter and receiver and their antennas are adjacent to each other. An "on-off" switch is provided in the AVC circuit to enable operation without AVC action when desired.

42. Par. 4-8. No "anti-noise" feature was provided in this receiver, due to the developmental nature of the preselector and the multiple modulation features, but could be included in future models.

43. Par. 4-9. The output impedance of the receiver is 600 ohms, and contains no d-c potentials.

44. Par. 4-10. No input or output meters were provided in this receiver. The receiver is provided with an output jack for 600-ohm headphone or speaker operation. An audio volume control potentiometer is provided on the front panel.

45. Par. 4-11. The receiver may be completely removed from the cabinet upon removing the transmission line input plug. The receiver may be operated and serviced while removed from its cabinet, or while only partly withdrawn from the cabinet. For replacement of the acorn type tubes in the preselector, it is necessary to remove the receiver from the cabinet, and to

remove the cover plate from the preselector unit. The transmission line plugs into the rear of the receiver chassis, into one or both of the fittings shown on Plate 4.

46. Par. 4-12. The total volume inclosed by overall dimensions, including all protuberances, shock mountings, knobs, dials, and handles is 2.32 cubic feet. The receiver cabinet itself occupies 1.76 cubic feet, the remainder being taken up by the shock mountings and other protuberances. The receiver could be constructed to occupy less volume. The receiver, complete with tubes and power cord, weighs 54 pounds. The power pack is included in the above.

47. Par. 4-13. The receiver is completely shielded, externally and internally.

48. Par. 4-14. The power transformer and chokes are oversize, and could be reduced in size and weight without serious loss of efficiency. The receiver draws a current of 0.65 ampere from the 115-volt, 60-cycle supply under normal operation, or a power of 74.8 watts at unity power factor.

49. Par. 4-15. The receiver may be installed and operated beside the transmitter, or at any desirable distance from the transmitter.

50. Par. 4-16. Both receivers were subjected to vibration and rocking tests, the results being given in Tables 4 and 5. Receiver No. 2 showed no change in sensitivity or response except at one critical vibration frequency of 18.7 cycles. At this point, the amplitude of vibration built up to approximately 10 times the specified test amplitude, and the output signal was slightly modulated by the severe vibration. The receiver was vibrated for a period of one hour, with 10 minutes at each critical frequency, with no damage to the receiver or its characteristics. Receiver No. 1 showed slight modulation at 16.7 cycles, and severe modulation at 18.7 cycles, but normal at all other frequencies during the first part of the test. During the second part of the test, on 140 Mc, a decrease of three to one in sensitivity and a change in frequency of one megacycle took place during vibration at 16.7 cycles, and remained throughout the rest of the vibration test. Examination of the receiver showed that the screen terminal of the r-f amplifier socket had developed a partial short circuit to ground, reducing the normal regulated 105 volts of the preselector screen and oscillator plate circuits to only 50 volts. After the socket was replaced by a new one, operation of the receiver was normal. Rocking the receivers through a 90° arc had no effect upon the output.

51. Par. 4-18. One antenna, with transmission line, couplings, and junction box, is provided with each receiver. These antennas were described in Paragraphs 19 and 20 of this report. The Fixed Ground Plane Antenna, RA-66030, weighs 14 pounds, and was designed for the range 130-160 Mc. However, it performs efficiently over the range 130-210 Mc. The Variable Tuned J Type Antenna and Drive Unit, RA-66031, weighs 85 pounds, and tunes over the range 130-200 Mc. The Control Unit, RA-23179, for this antenna weighs 24 pounds. At distances of only fifty yards the tunable J type antenna seemed superior to the fixed ground plane type, but at distances of 10 miles or more the difference appeared small. It would appear that an extensive investiga-

tion is warranted, to determine the relative efficiencies of the two types of antenna, both for transmission and reception. It is considered that the ground plane antenna has an inherently low radiation angle, which makes it desirable for communication between two equipments at equal altitudes. The field pattern of the J type antenna is not definitely known as yet.

52. Par. 5-6. The loud speaker provided with the receiver has been discussed in Paragraph 21 of this report. No tests other than listening tests and measurement of impedance were made. The impedance at cone resonance of 150 cycles is 610 ohms. Otherwise the impedance rises gradually with frequency from 350 ohms at 50 cycles, to 1020 ohms at 4000 cycles. The impedance characteristic is satisfactory, the speaker is within the dimensional requirements, and is suitable for bulkhead mounting. The speaker cone is not considered of satisfactory material, however. This speaker unit contains no amplifier, nor is it mounted in a heavy cast metal housing. Reference is made to a speaker and amplifier of the type covered in Specification RE 13A 593B, which may be used to replace the above speaker.

53. The overload selectivity curves are shown on Plates 25 to 30, inclusive. Plates 25, 26 and 27 indicate the results obtained with the receiver and desired signal from the General Radio signal generator tuned to 185 megacycles, and the undesired signal frequency varied through receiver resonance. Curves were plotted for separations of 66, 46, and 26 feet between the antennas of the receiver and the interfering signal. The antenna for the XRAQ receiver was used for the receiving antenna, and the XTBT transmitter and its antenna were used to produce the interfering signal. At points that are 6.5 megacycles off each side of resonance, secondary images were found as would be expected in an extremely strong field. At a frequency of 1 to 1.5 megacycles below receiver resonance, a peculiar and very sharp kink appears in each curve. This appears to be due to overloading in the pre-selector unit which is not provided with AVC bias.

54. The curves on Plates 28 and 29 were taken at 130 Mc under the same conditions as for Plates 25 and 26. At this frequency, the kink occurs on the opposite side of resonance from the previous curves. No explanation is offered for this change. Because of the dissymmetry of the two sides of the curves, a further test was conducted, shown on Plate 30. The transmitter of the XAO equipment was used as the undesired signal in place of the XTBT. The curve of Plate 30 represents conditions similar to those of Plate 29, except that the XAO transmitter power is only about one-fourth that of the XTBT, and the curve is shown only above resonance. The kink at 1.5 Mc is now negligible even though the conditions of test were still unusually severe. A secondary image is indicated at 5 per cent above receiver resonance.

55. With an antenna separation of 100 yards, using the XAO transmitter, no secondary images and no dissymmetry could be detected. No curve was plotted on this test.

56. In the field tests, two XAP equipments were operated with an XAO and an XAQ transmitting equipment for two-way tests at distances up to 15 miles over land, with low hills in between. Satisfactory operation of the receivers was obtained over the frequency ranges of 132 to 156 Mc and 130 to 180 Mc provided by the transmitters on both single and double modulation. At distances

where the field strength was noticeably weak, the voice communication was in general slightly better on single modulation than on double modulation, except for one location where the reverse was true. It is to be expected that the double modulation signal on voice would drop out sooner than the single modulation signal because of two factors. One is that the sensitivity of the receivers is slightly poorer on double modulation; the other is that due to the two rectifying detectors on double modulation, the detection of weak signals follows the fourth power law instead of the square law as in single modulation. Both these factors are readily observed from an examination of the rate of curvature of the overload characteristics for very weak signals, as shown on Plates 19 and 20. On telegraphic communication however, the keyed tone on single modulation should be comparable with cw keying on double modulation. In these tests, the cw signal of double modulation was in all cases superior to the single modulation keyed tone.

57. Each receiver was positioned adjacent to its corresponding transmitter during the field tests, and operated to determine how closely the carrier channels could be spaced for duplex operation without interference. On single modulation at a distance of 10 miles, duplex operation on voice was reliable with a carrier channel separation of 1 Mc. On double modulation at a distance of 10 miles, duplex operation on voice was reliable with a carrier separation of 4 Mc and primary modulation channel separation of 12.5 Kc. At times it was possible to operate on the same primary modulation frequencies without interference. When the carrier separation on double modulation was less than 4 Mc on duplex operation, interference resulted due to the proximity of the receiver to its corresponding transmitter.

#### CONCLUSIONS

58. The single dial tuning of the tuned frame receiver showed itself to be entirely practical for the frequency range covered, and much more desirable than any multiple dial system from the standpoint of ease of operation, reliability, and searching the spectrum.

59. The frequency stability, and the accuracy of calibration (as referred to tables or curves) and resettability are superior to any equipments formerly produced for equivalent band coverage ratio in any frequency range without the use of temperature control units or crystals.

60. Any closer channel spacing than obtained with this receiver would require complications in design which would be expensive and might reduce the general utility and simplicity of operation of the equipment.

61. More precise adjustment to the assigned frequency would require expensive complications in design which might reduce the utility and simplicity of operation of the equipment.

62. The resettability should be improved by more satisfactory mechanical design.

63. A five-minute warm-up period is all that is necessary for stable operation of the receiver.

64. The image rejection is of a high order and can only be increased by complications in design, or an increase in the intermediate frequency, or both.

65. The fidelity is superior to that of any receivers now in naval service.

66. The fixed ground plane antenna gave reliable results such that its simplicity and economy of manufacture might warrant its use in preference to a more expensive variable tuned antenna. A further investigation of receiving antennas should be conducted however.

67. Double modulation has been demonstrated to be practical. Its value to naval service remains to be proven.

68. The present dial system, being calibrated in divisions only, (0-500) with ability to estimate the 0.1 divisions requires that frequency settings be obtained by reference to a tabulation or curves. This system permits setting the receiver to within approximately 33.3 kc at the worst condition around 205 Mcs, and without reference to torque or back lash or other variables resulting from temperature, humidity or line voltage variations. It is evident that the torque and back lash should be greatly improved before the design can be considered satisfactory. In redesign, a direct calibrated dial could be considered but would involve a major mechanical problem if accurate enough to rely upon without reference to a chart and would in all probability not be justified due to the magnitude of other variables which must be considered. It appears that the most practicable solution considering economy and reliability is to tune receivers by reference to crystals or other stabilized oscillators depending upon the dial markings for approximate settings only, which may be calibrated in frequency or divisions as may be desired.

69. The principal contribution resulting from this development is the knowledge that single dial tuning can be considered practicable within this range of frequencies if the band spread is not greater than 1.5 to 1, and further, that by the proper selection of materials, design, and temperature compensating condensers, a continuously variable receiver can be produced without the use of crystals or regulated temperature compartments, which when employed with reference calibrators should permit reliable communication on channels separated not greatly over one megacycle, and generally less than 1% of the fundamental frequency. This assumes that reception is not required on the same ship using a transmitter on the next adjacent channel.

TABLE 1

Accuracy of Resettability of Frame Preselectors

<u>Receiver Serial No.</u>	<u>Osc. Freq. Mc</u>	<u>Clockwise Approach of Dial to Calibration Point</u>	<u>Counter-Clockwise Approach of Dial to Calibration Point</u>	<u>Rocking of Dial Coming to Rest at Calibration Point</u>
1	140	84.2	163	18
1	200	335.0	622	75
2	140	62.7	257	20
2	200	323.6	448	71

TABLE 2

Frequency Change with Line Voltage  
Receiver No. 1

<u>AC Line Volts</u>	<u>Frequency Change Kc</u>
109	+1.4
115	0
121	-7.1

TABLE 3

Frequency Change with Line Frequency  
Receiver No. 1

<u>AC Line Cycles</u>	<u>Frequency Change Kc</u>
57	-2.8
60	0
63	0

**UNCLASSIFIED**

DECLASSIFIED

TABLE 4

Vibration and Rocking Test of Receiver No. 1  
with Frame Preselector

<u>Signal Freq.</u> <u>Mc</u>	<u>Vibration Freq.</u> <u>Cycles</u>	<u>Type of</u> <u>Resonance</u>	<u>Sensitivity</u>	<u>Damage</u>
200	10.7	Receiver	Normal	None
200	14.0	Power Pack	Normal	"
200	16.7	Receiver	Slight Modulation	"
200	18.7	Receiver	Severe Modulation	"
200	32.5	None	Normal	"
140	10.7	Receiver	Normal	None
140	14.0	Power Pack	Normal	"
140	16.7	Receiver	*Decrease and Slight Modulation	Permanent Freq. Shift of 1 Mc
140	18.7	Receiver	*Decrease and Slight Modulation	" "
140	32.5	None	*Decrease	" "

Rocking through 90° produced no effect at any frequency.

\*See par. 50 (4-16).

TABLE 5

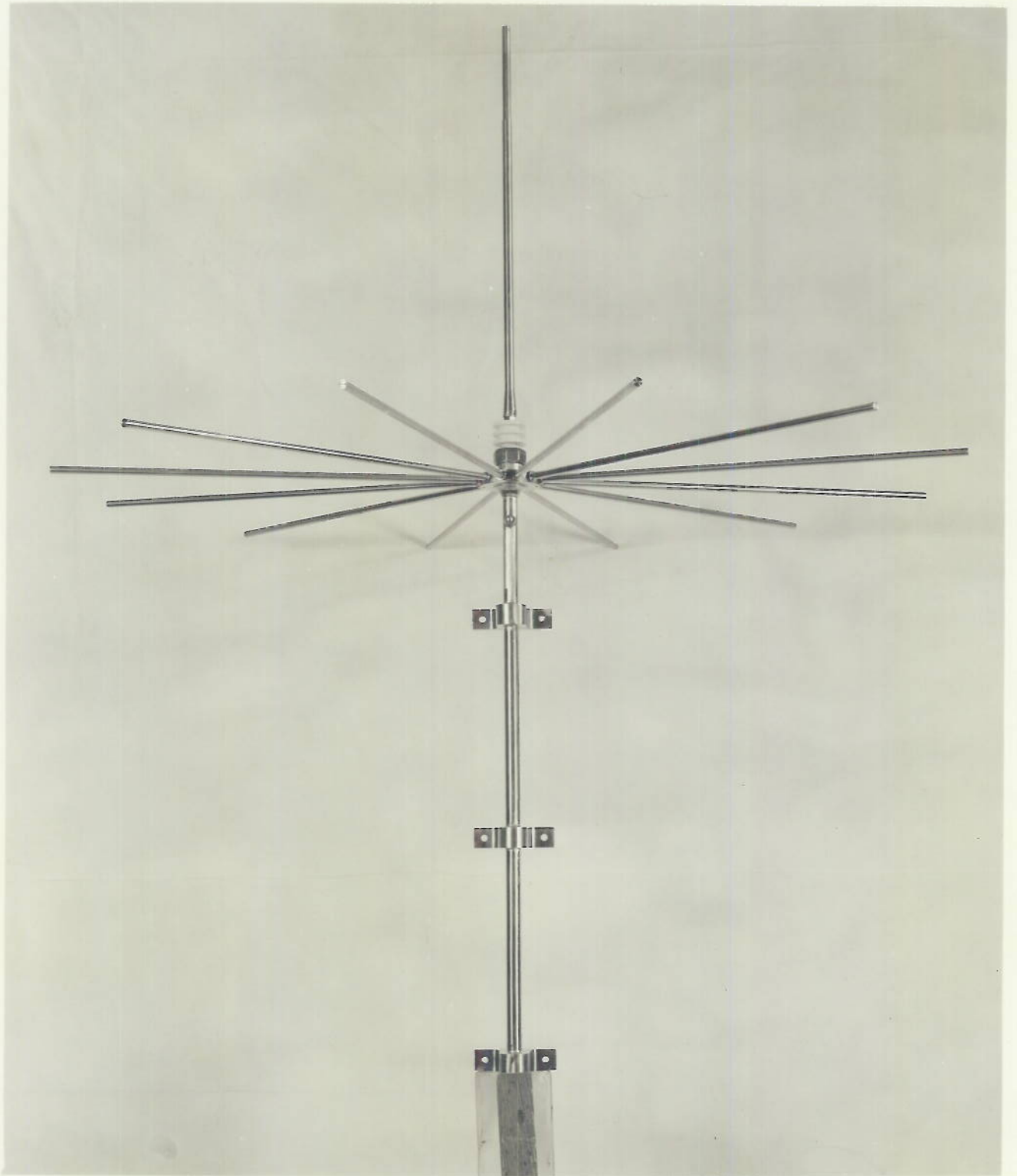
Vibration and Rocking Test of Receiver No. 2  
with Frame Preselector

<u>Signal Freq.</u> <u>Mc</u>	<u>Vibration Freq.</u> <u>Cycles</u>	<u>Type of</u> <u>Resonance</u>	<u>Sensitivity</u>	<u>Damage</u>
200	10.7	Receiver	Normal	None
200	14.0	Power Pack	Normal	"
200	16.3	Receiver	Normal	"
200	18.7	Receiver	Slight Modulation	"
200	32.5	None	Normal	"
140	10.7	Receiver	Normal	"
140	14.0	Power Pack	Normal	"
140	16.3	Receiver	Normal	"
140	18.7	Receiver	Slight Modulation	"
140	32.5	None	Normal	"

Rocking through 90° produced no effect at any frequency.

DECLASSIFIED

UNCLASSIFIED

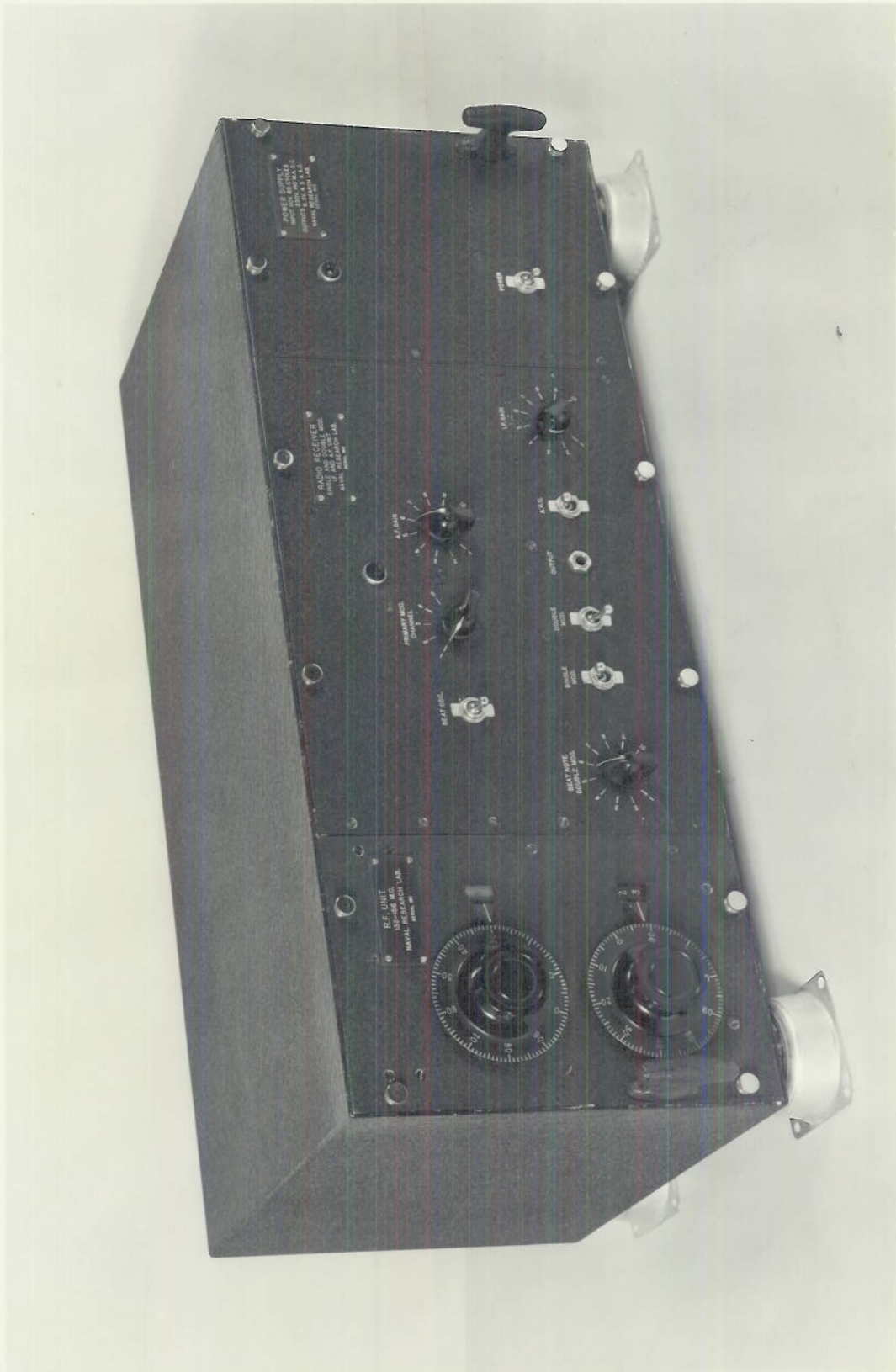


DECLASSIFIED

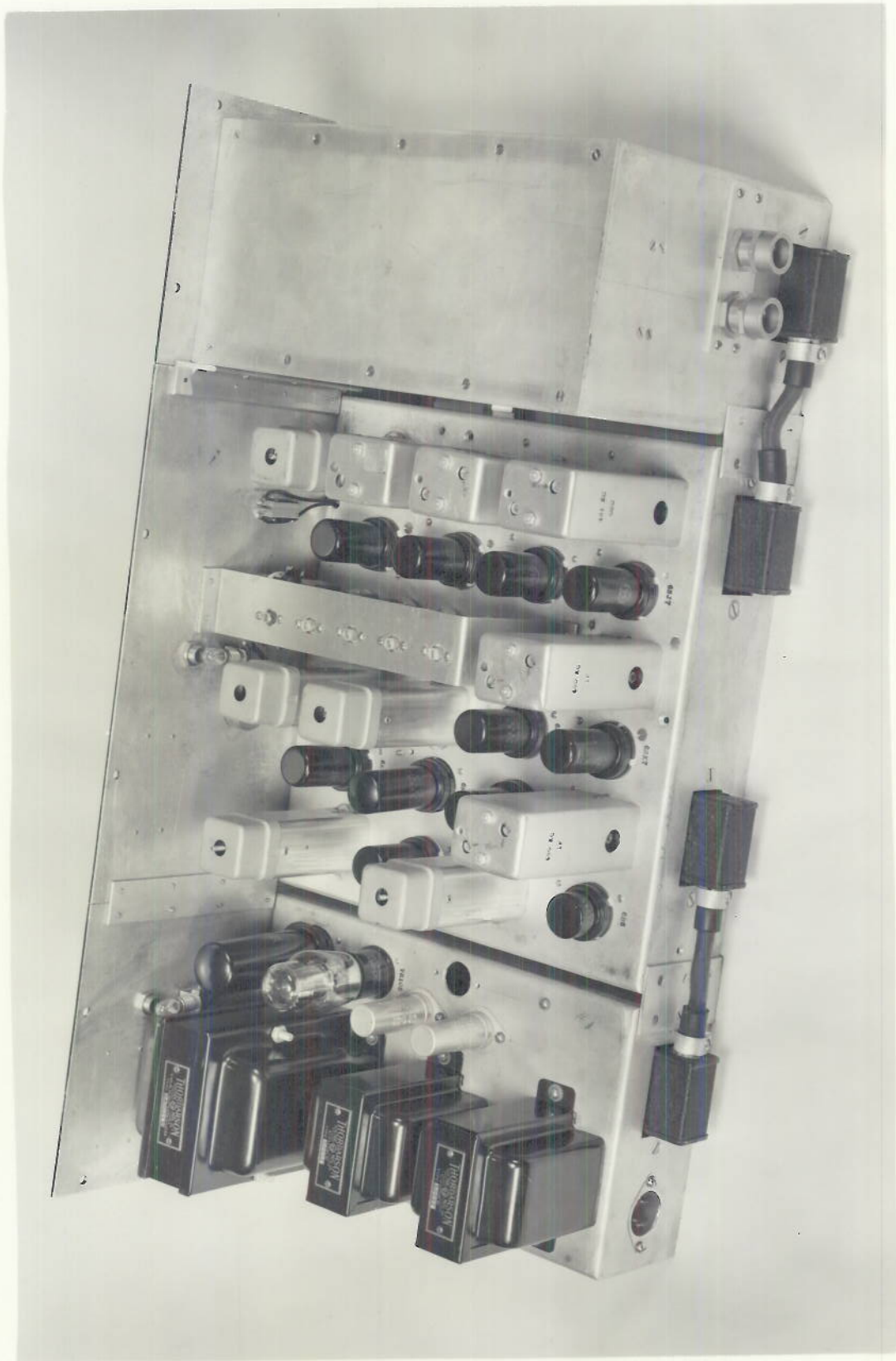
PLATE I



DECLASSIFIED

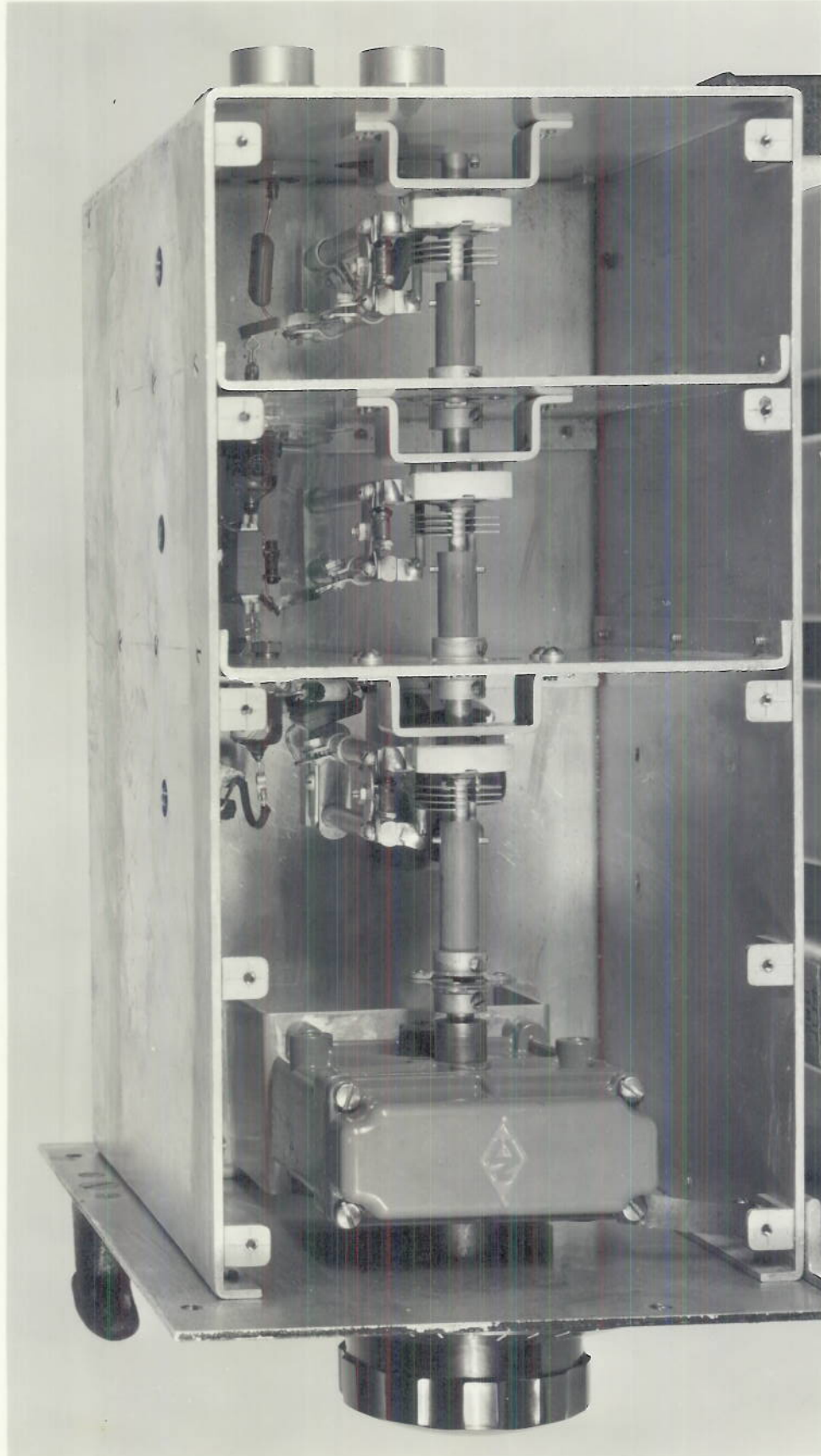


DECLASSIFIED PLATE 3

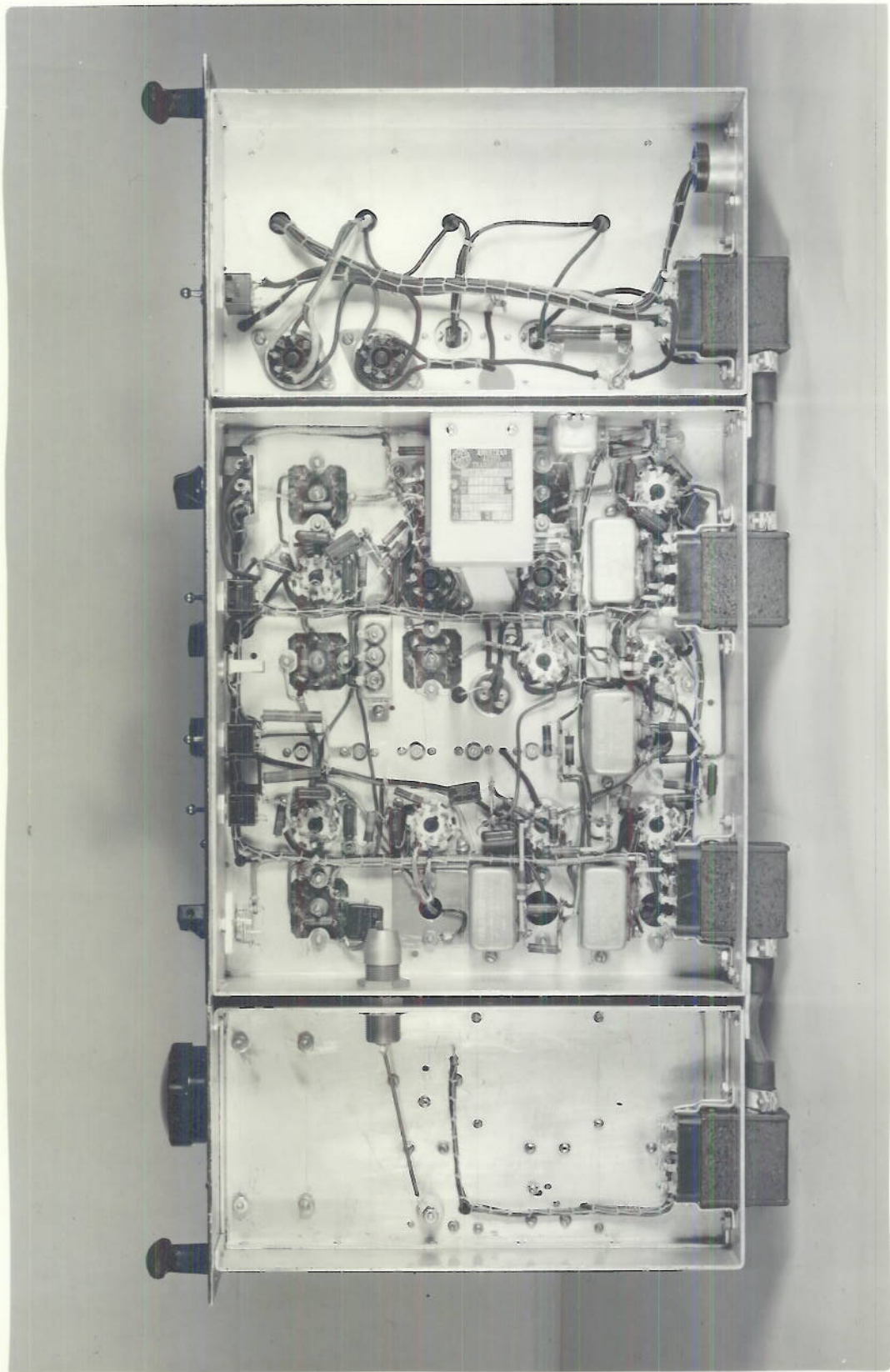


DECLASSIFIED

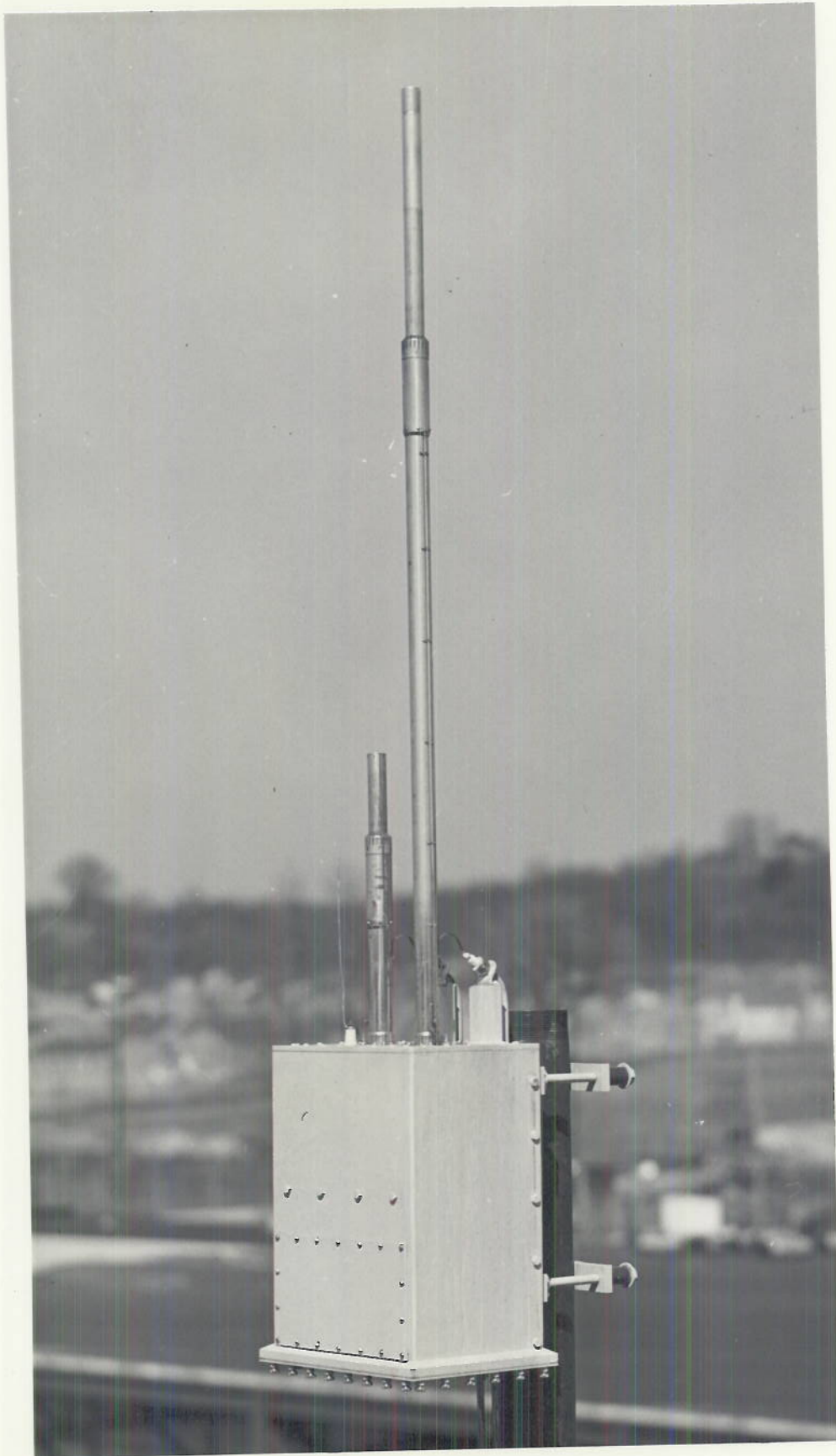
PLATE 4



DECLASSIFIED PLATE 5

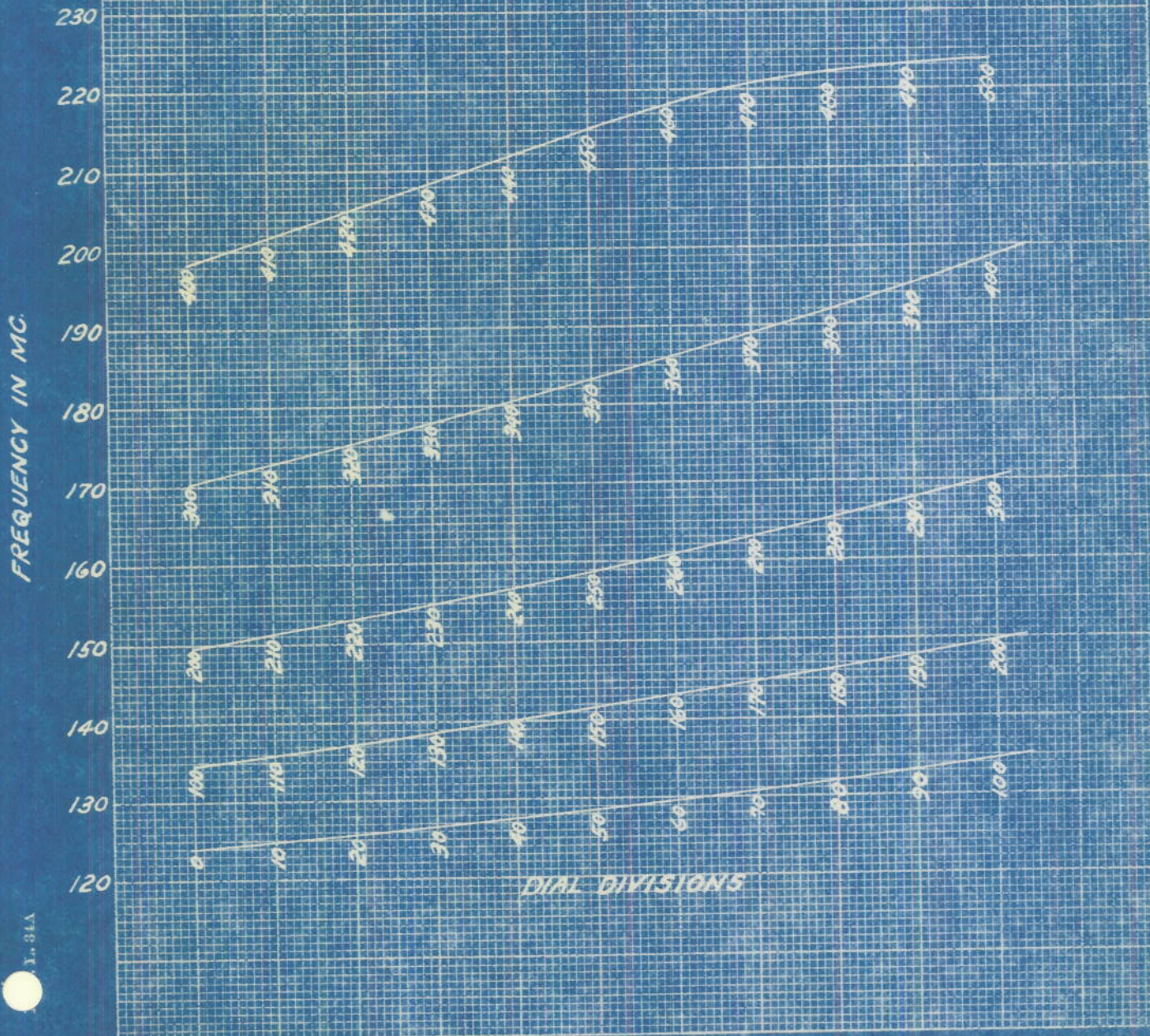


DECLASSIFIED PLATE 6



DECLASSIFIED Plate 7

CALIBRATION CURVES  
NO. 1 MULTI-MOD. RECEIVER



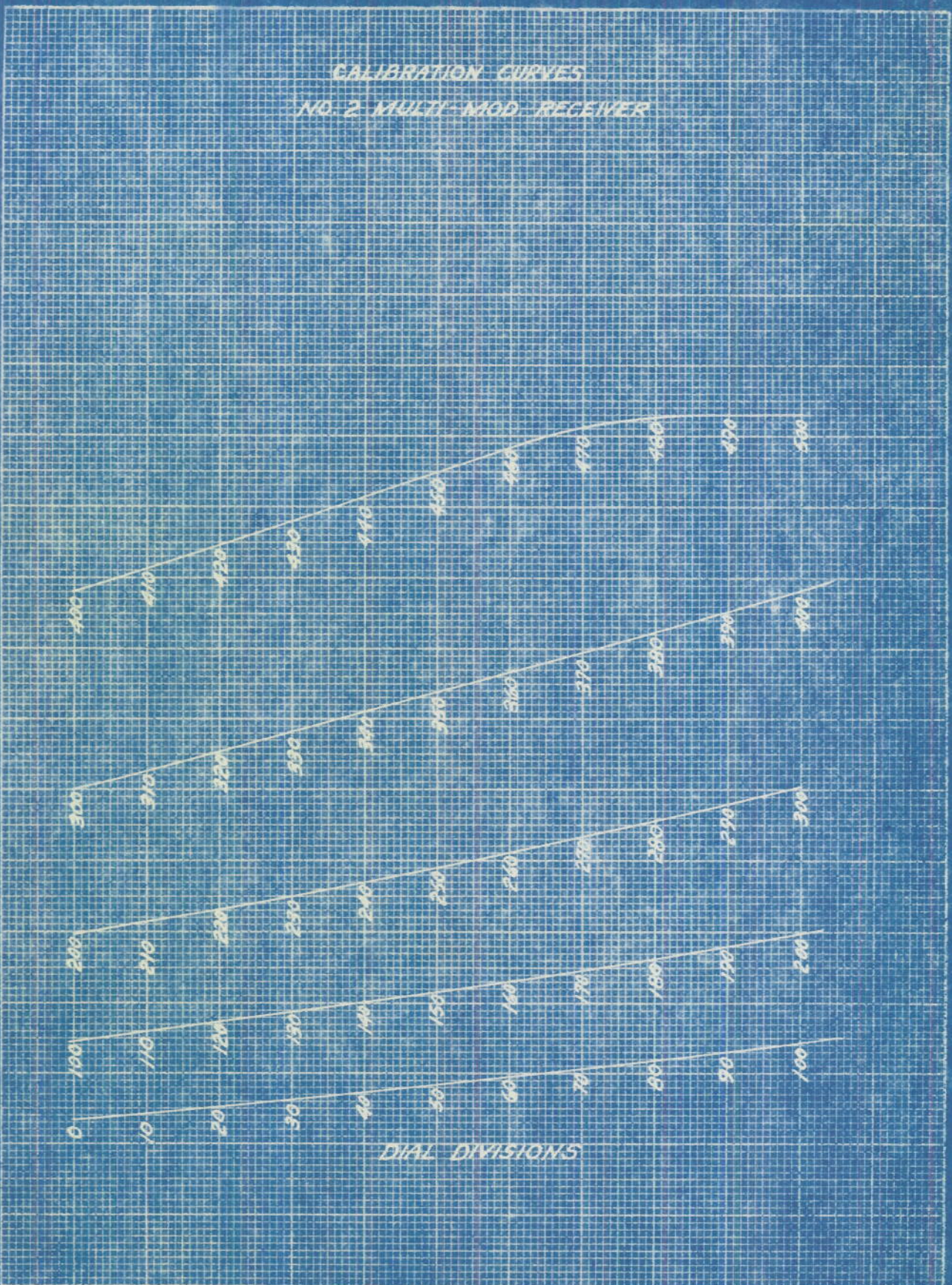
IF SHEET IS READ THIS WAY (HORIZONTALLY) THIS MUST BE TOP. IF SHEET IS READ THE OTHER WAY (VERTICALLY) THIS MUST BE LEFT.

CALIBRATION CURVES  
NO. 2 MULTI-MOD. RECEIVER

FREQUENCY IN MC.

230  
220  
210  
200  
190  
180  
170  
160  
150  
140  
130  
120

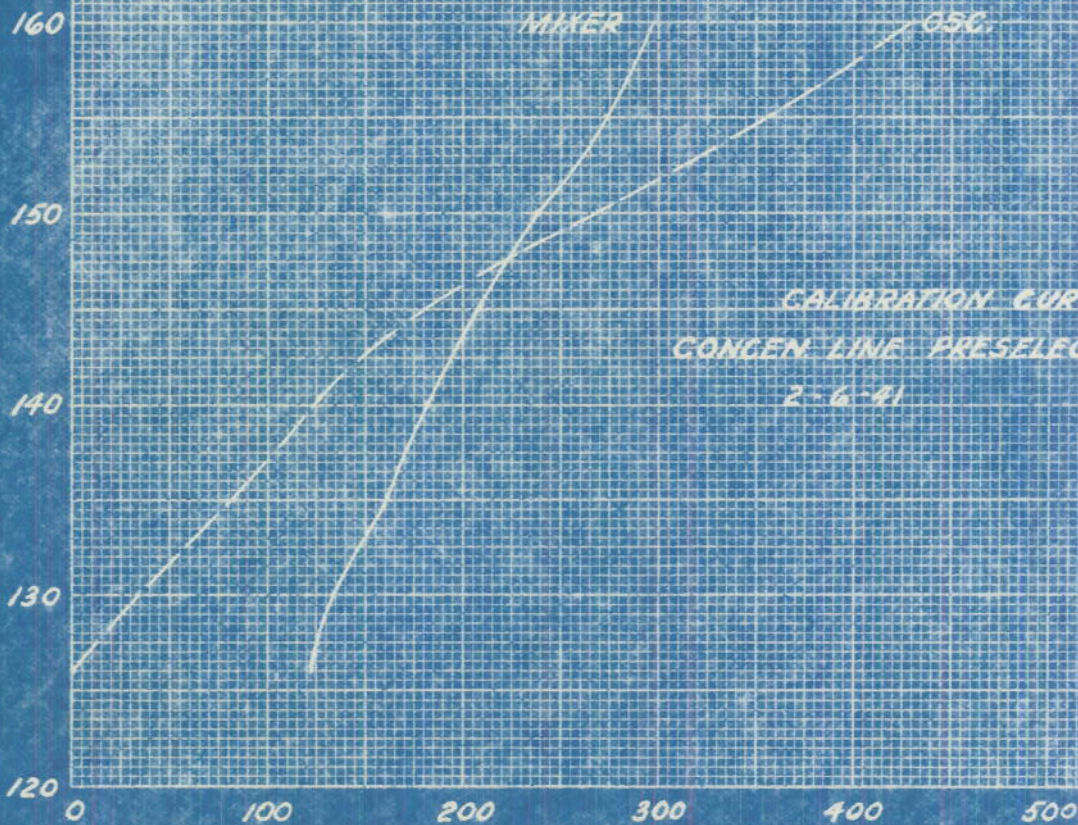
DIAL DIVISIONS



R. L. 31A

IF SHEET IS READ THIS WAY (HORIZONTALLY) THIS MUST BE TOP. IF SHEET IS READ THE OTHER WAY (VERTICALLY) THIS MUST BE LEFT-HAND SIDE.

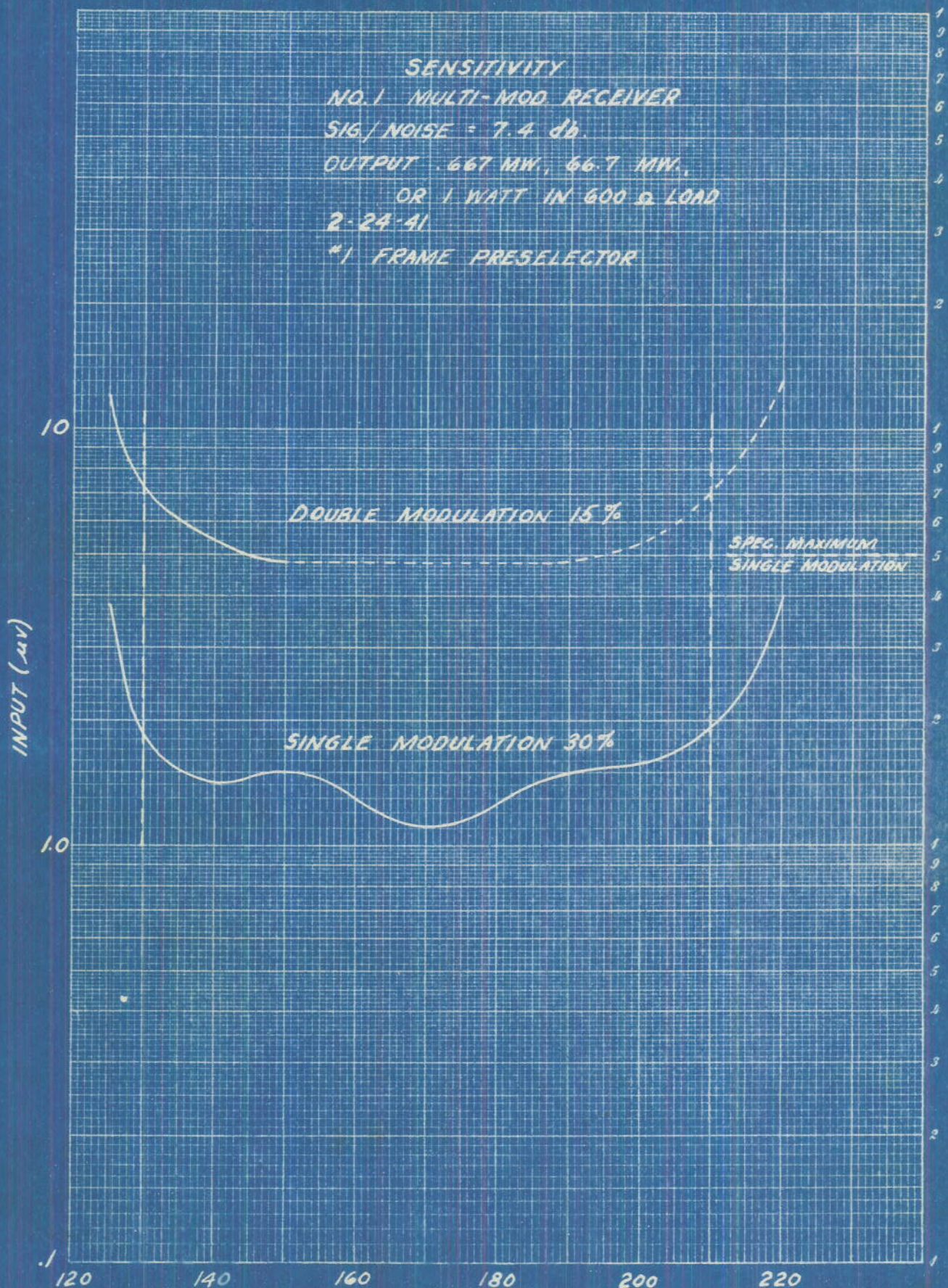
R. L. 31A



DIAL READINGS

DECLASSIFIED PLATE 10

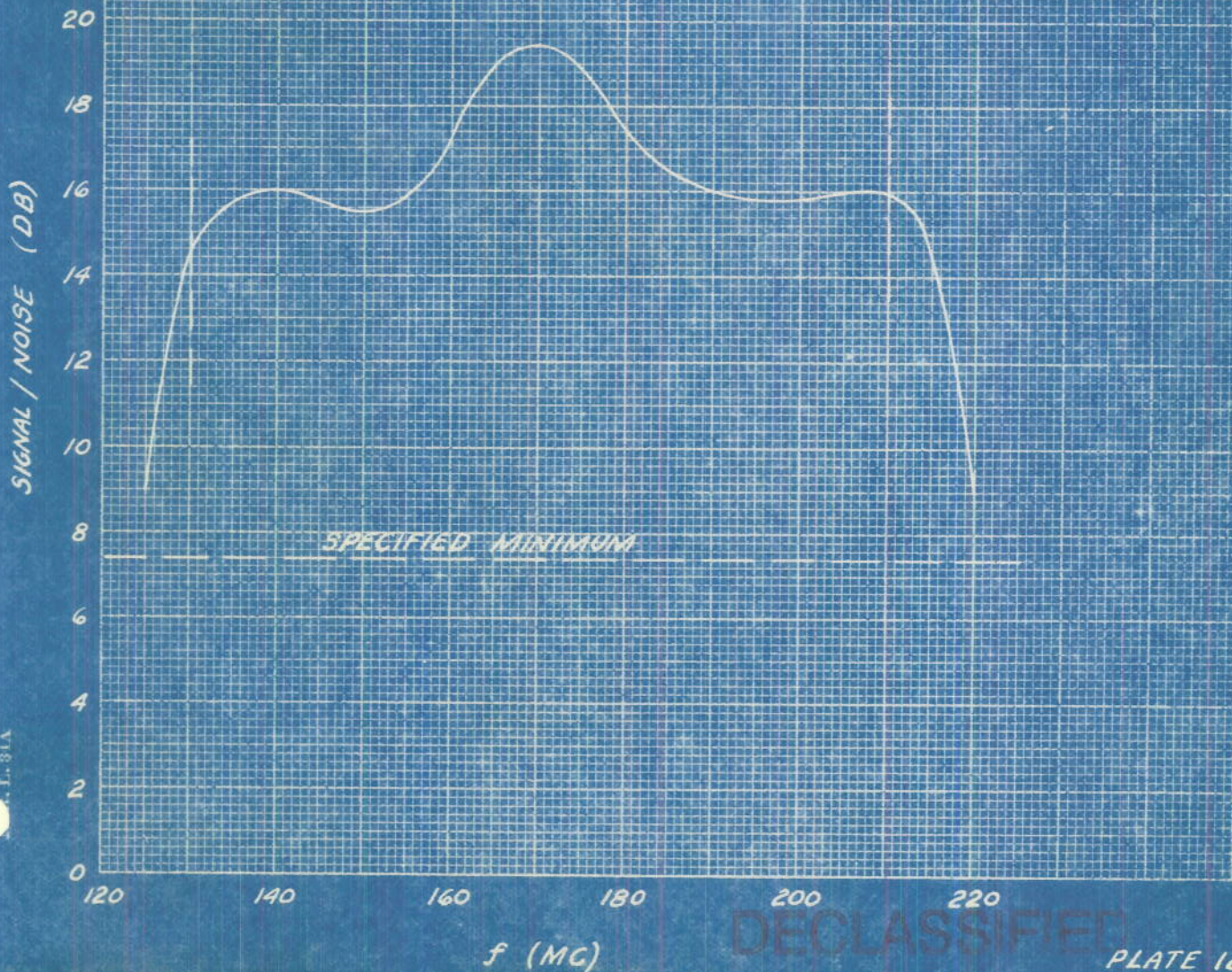
**SENSITIVITY**  
 NO. 1 MULTI-MOD. RECEIVER  
 SIG./NOISE = 7.4 db.  
 OUTPUT .667 MW., 66.7 MW.,  
 OR 1 WATT IN 600  $\Omega$  LOAD  
 2-24-41  
 \*1 FRAME PRESELECTOR



f (MC)

*SENSITIVITY (SIGNAL / NOISE DB)  
NO. 1 MULTI-MOD. RECEIVER, NO. 1 FRAME UNIT  
FOR COMPARISON WITH XRAY DATA  
CONSTANT INPUT 5 μV OUTPUT 667 MW OR 1 WATT  
2-12-41*

*SINGLE MODULATION*



DECLASSIFIED

IF SHEET IS READ THIS WAY (HORIZONTALLY) THIS MUST BE TOP. IF SHEET IS READ THE OTHER WAY (VERTICALLY) THIS MUST BE LEFT-HAND SIDE.

U. S. N. R. L. 81A

**SENSITIVITY**  
**NO. 2 MULTI-MOD. RECEIVER**  
**SIG./NOISE = 7.4 db.**  
**OUTPUT .667 MW, 66.7 MW**  
**OR 1 WATT IN 600  $\Omega$  LOAD**  
**2-24-41**  
**\*1 CAN PRESELECTOR**

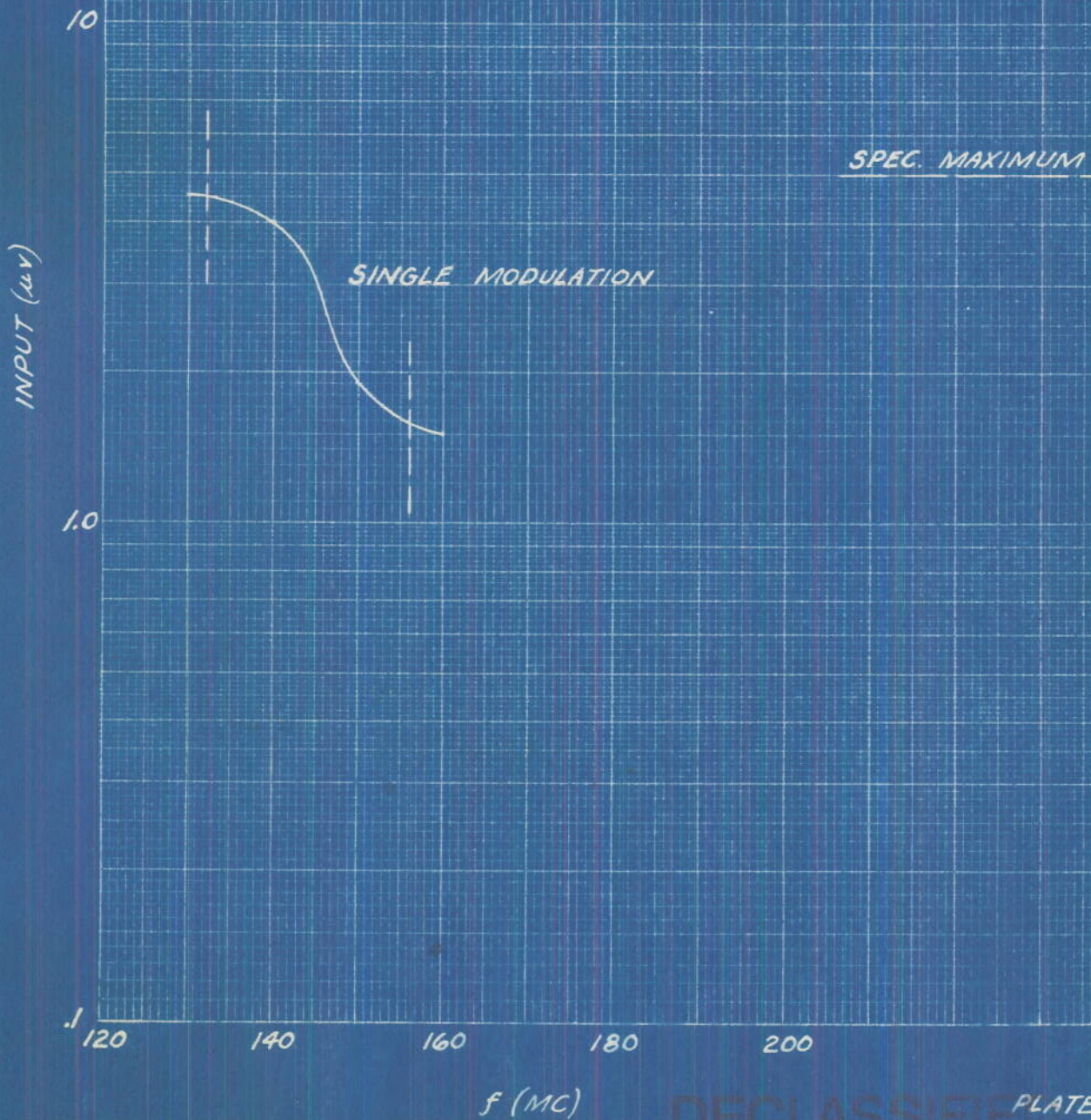


IMAGE REJECTION  
MULTI-MOD RECEIVERS  
SIG/NOISE = 7.4 db  
OUTPUT 667 MW, 66.7 MW, OR 1 WATT  
2-26-41

ATTENUATION (db)

70  
60  
50  
40  
30  
20  
10  
0

NO. 1 FRAME PRESELECTOR

NO. 1 CONCENTRIC  
LINE PRESELECTOR

120 140 160 180 200 220

f (MC)

PLATE 14

R. L. 31A

IF SHEET IS READ THIS WAY (HORIZONTALLY) THIS MUST BE TOP. IF SHEET IS READ THE OTHER WAY (VERTICALLY) THIS MUST BE LEFT-HAND SIDE.

I-F SELECTIVITY

NO. 1 MULTI-MOD. RECEIVER  
AT 13 MC. - SINGLE MODULATION  
OUTPUT 60 MW. SIG./NOISE = 10 db.

INPUT VOLTAGE RATIO

$(10)^4$

$(10)^3$

$(10)^2$

10

1

-5

-4

-3

-2

-1

0

+1

+2

+3

+4

+5

PERCENT OFF RESONANCE

80

60

40

20

0

DB.

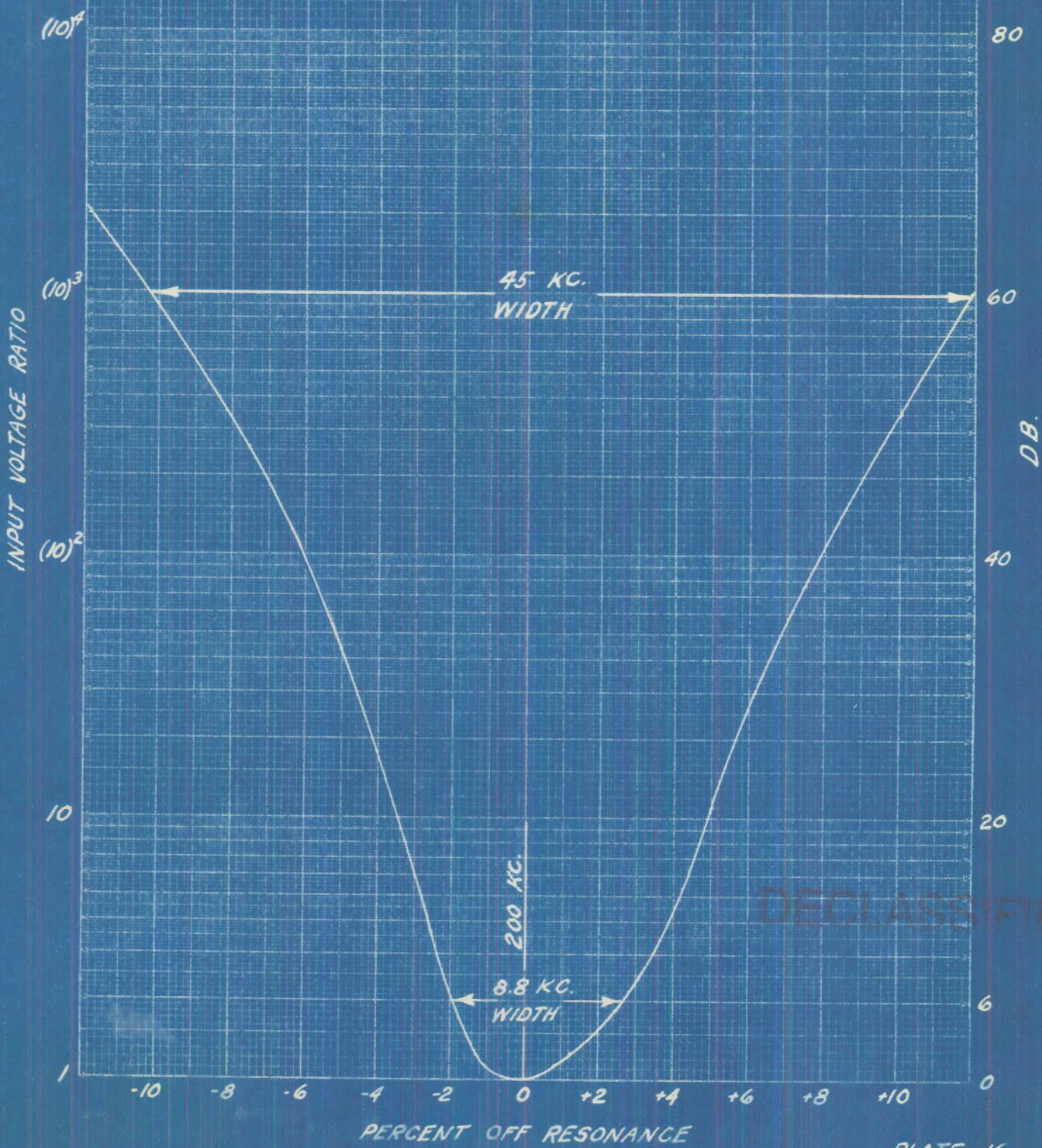
911 KC. WIDTH

13 MC.

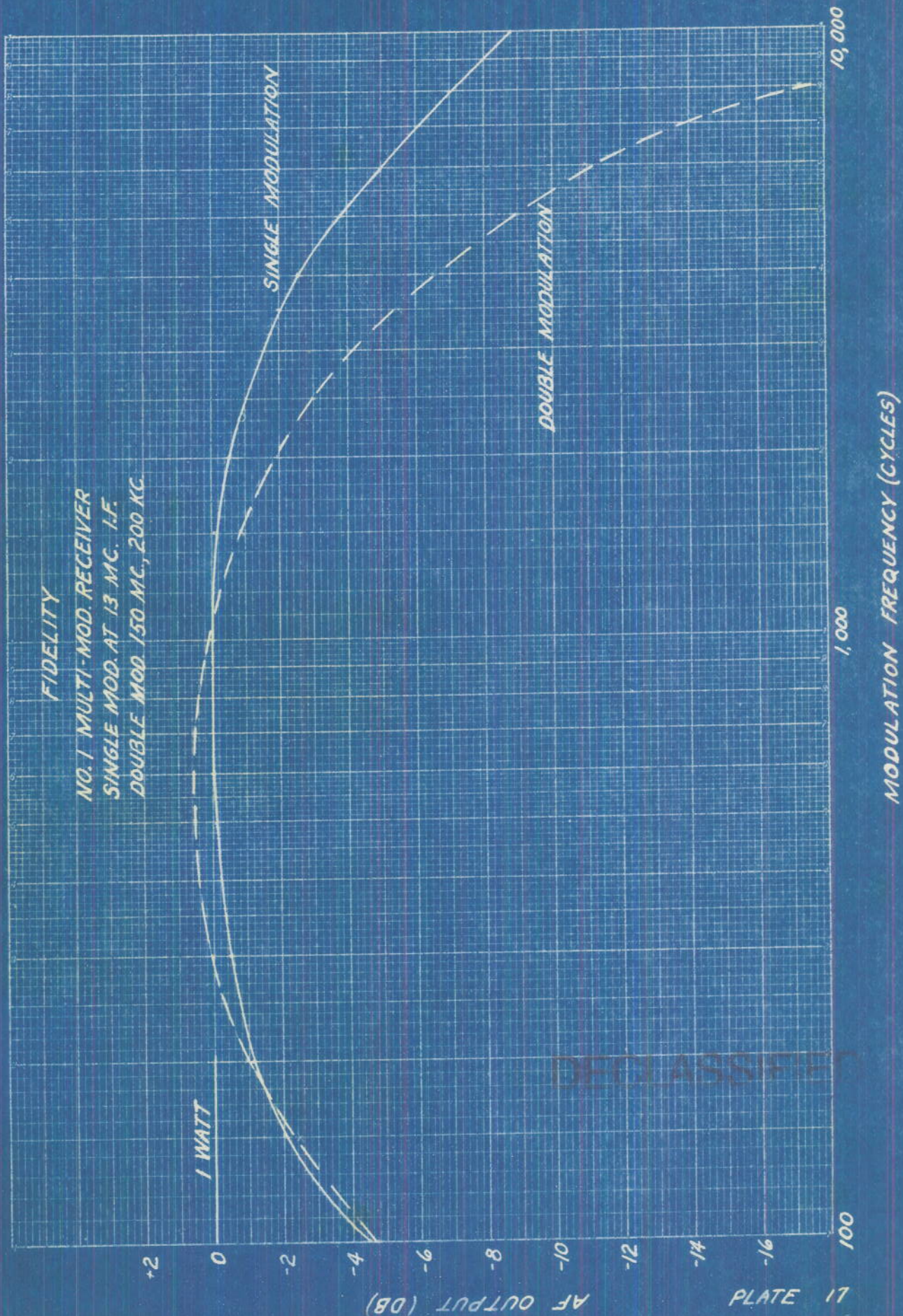
210 KC. WIDTH

DECLASSIFIED

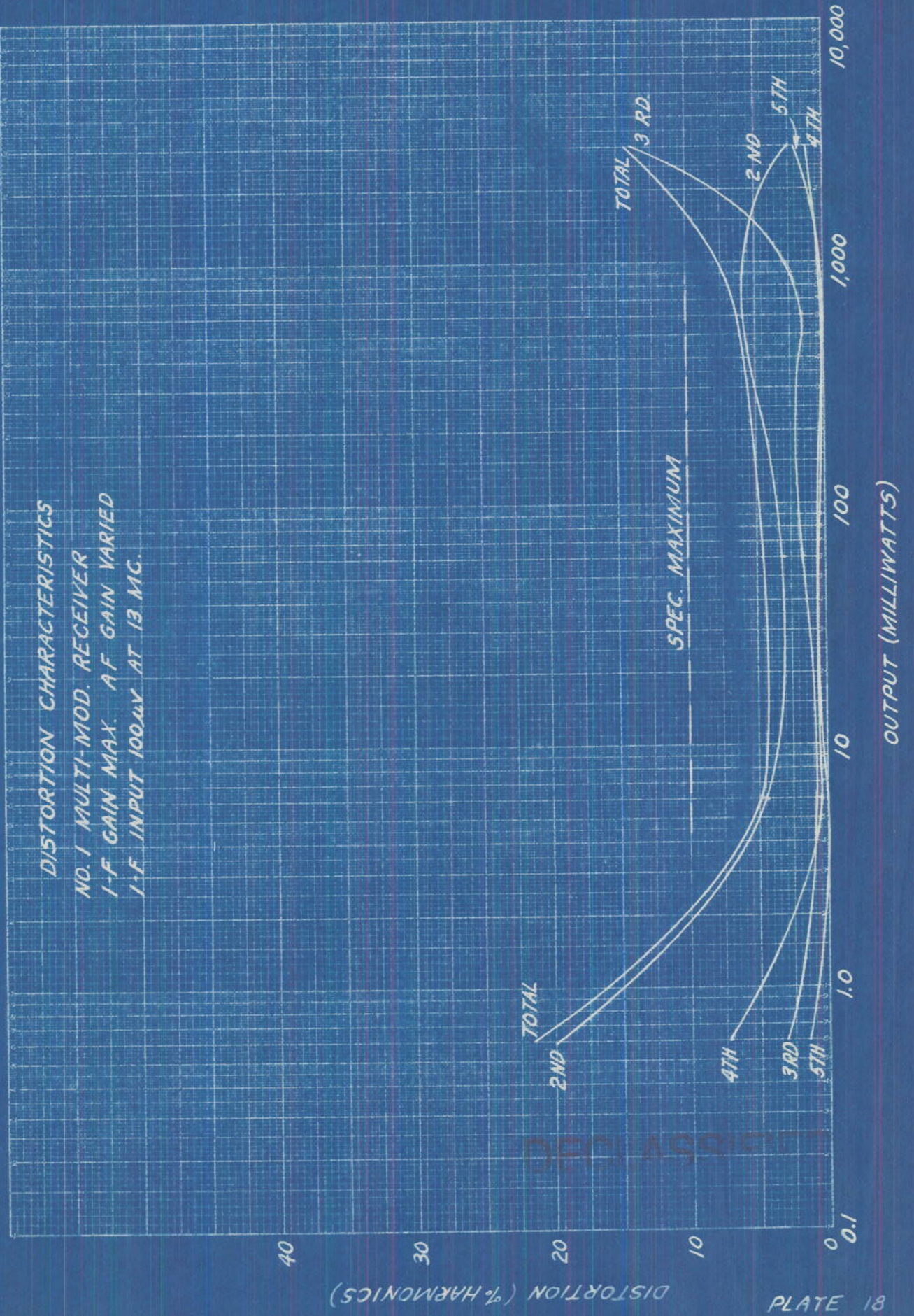
CHANNEL SELECTIVITY  
NO. 1 MULTI-MOD. RECEIVER  
ON 200 KC. DOUBLE MOD. CHANNEL  
OUTPUT 60 MW. SIG./NOISE = 10 db.



DECLASSIFIED

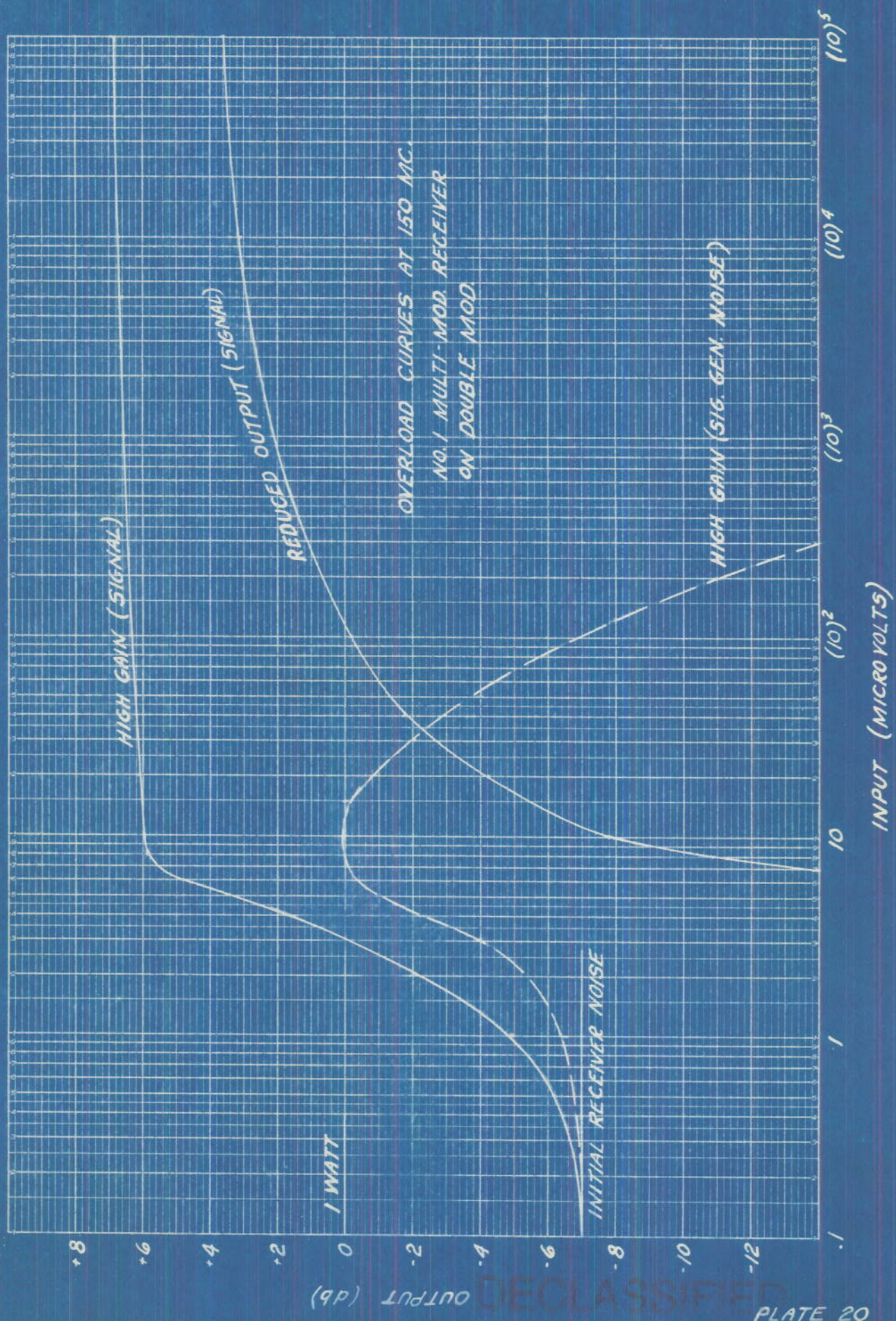


**DISTORTION CHARACTERISTICS**  
 NO. 1 MULTI-MOD. RECEIVER  
 I-F GAIN MAX. AF GAIN VARIED  
 I-F INPUT 100μV AT 13 MC.

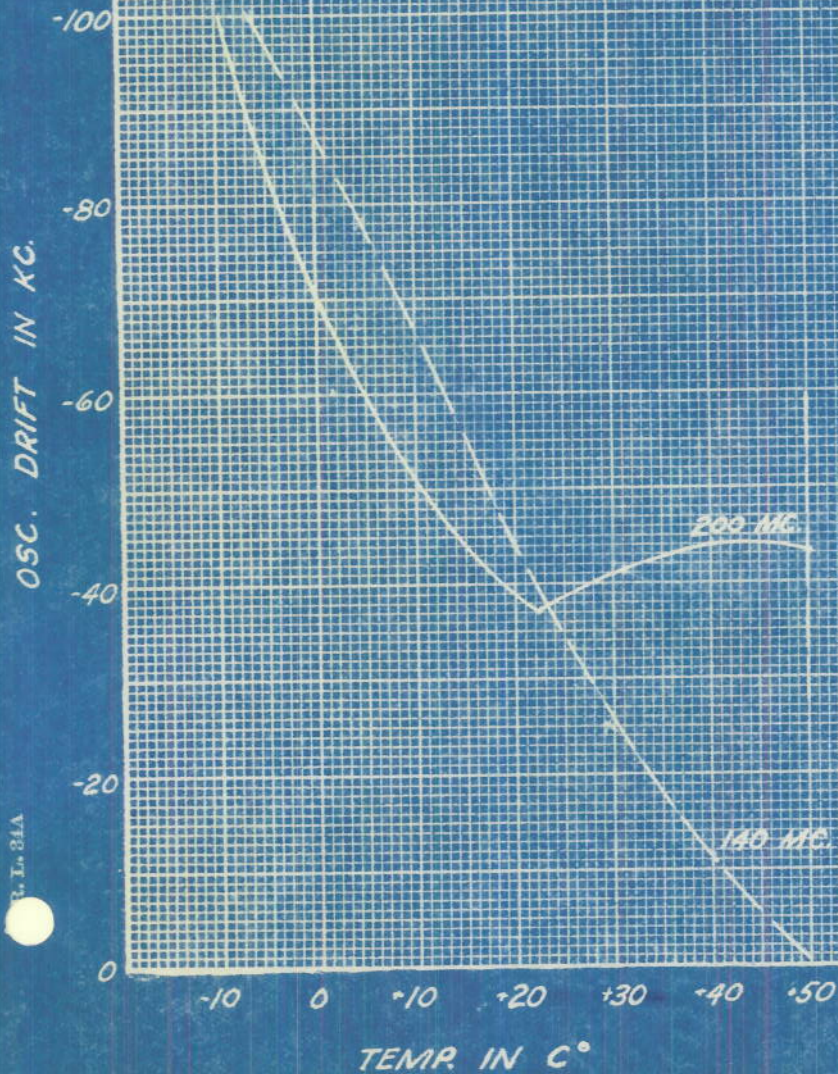


DISTORTION (% HARMONICS)

OUTPUT (MILLIWATTS)



FREQUENCY DRIFT WITH TEMPERATURE  
NO. 1 MULTI-MOD RECEIVER  
FRAME PRESELECTOR



R. I. 31A

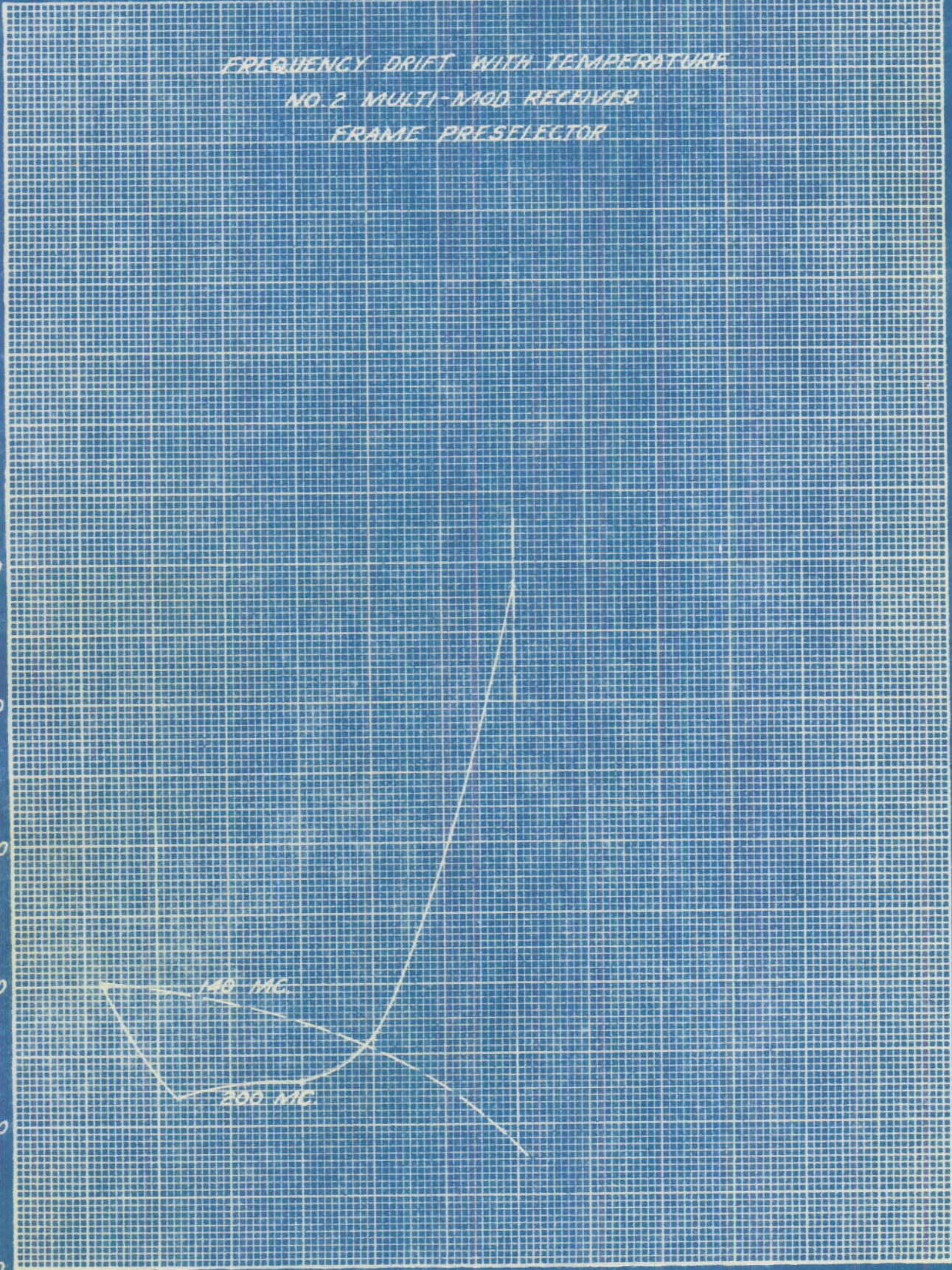
FREQUENCY DRIFT WITH TEMPERATURE  
NO. 2 MULTI-MOD RECEIVER  
FRAME PRESELECTOR

OSC. DRIFT IN MC.

+100  
+80  
+60  
+40  
+20  
0

-10 0 +10 +20 +30 +40 +50

TEMP. IN C°

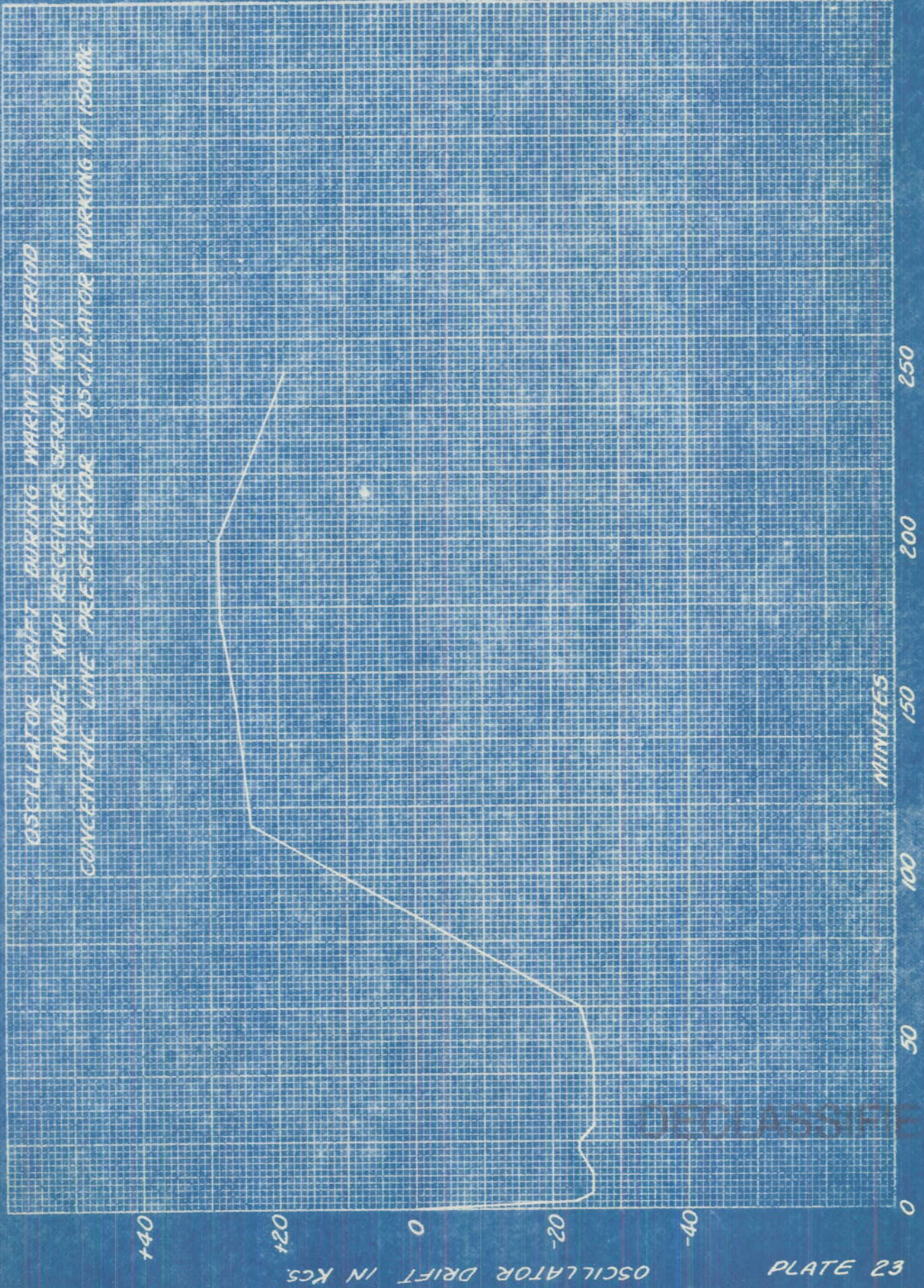


IF SHEET IS READ THIS WAY (HORIZONTALLY) THIS MUST BE TOP, IF SHEET IS READ THE OTHER WAY (VERTICALLY) THIS MUST BE LEFT OR RIGHT SIDE.

R. L. 31A

IF SHEET IS READ THIS WAY (HORIZONTALLY) THIS MUST BE TOP. IF SHEET IS READ THE OTHER WAY (VERTICALLY) THIS MUST BE LEFT-HAND SIDE.

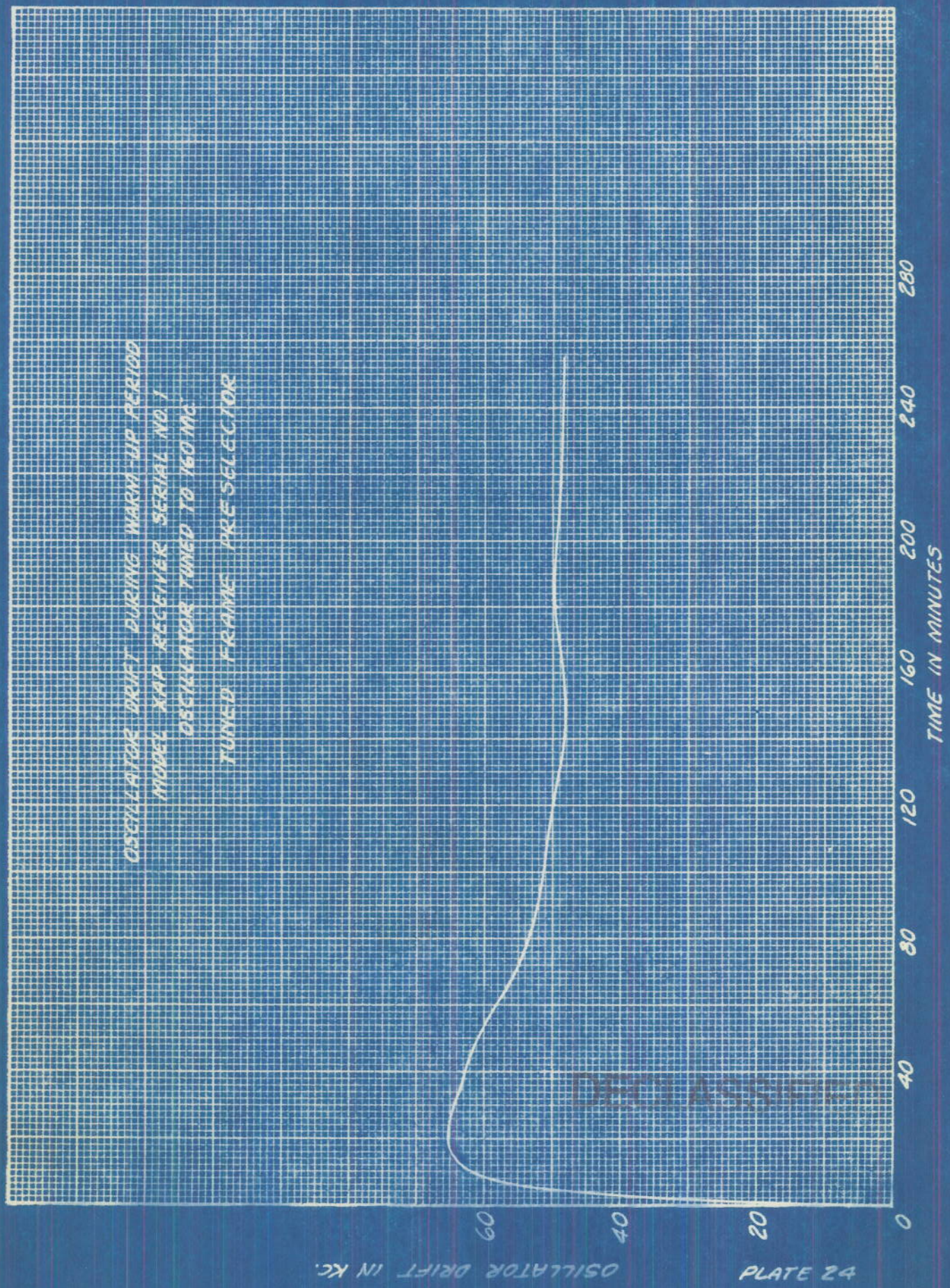
R. L. 31A



WARM-UP TIME, IN MINUTES, AFTER CLOSING RECEIVER POWER SWITCH

DECLASSIFIED

V.R.L. 3A

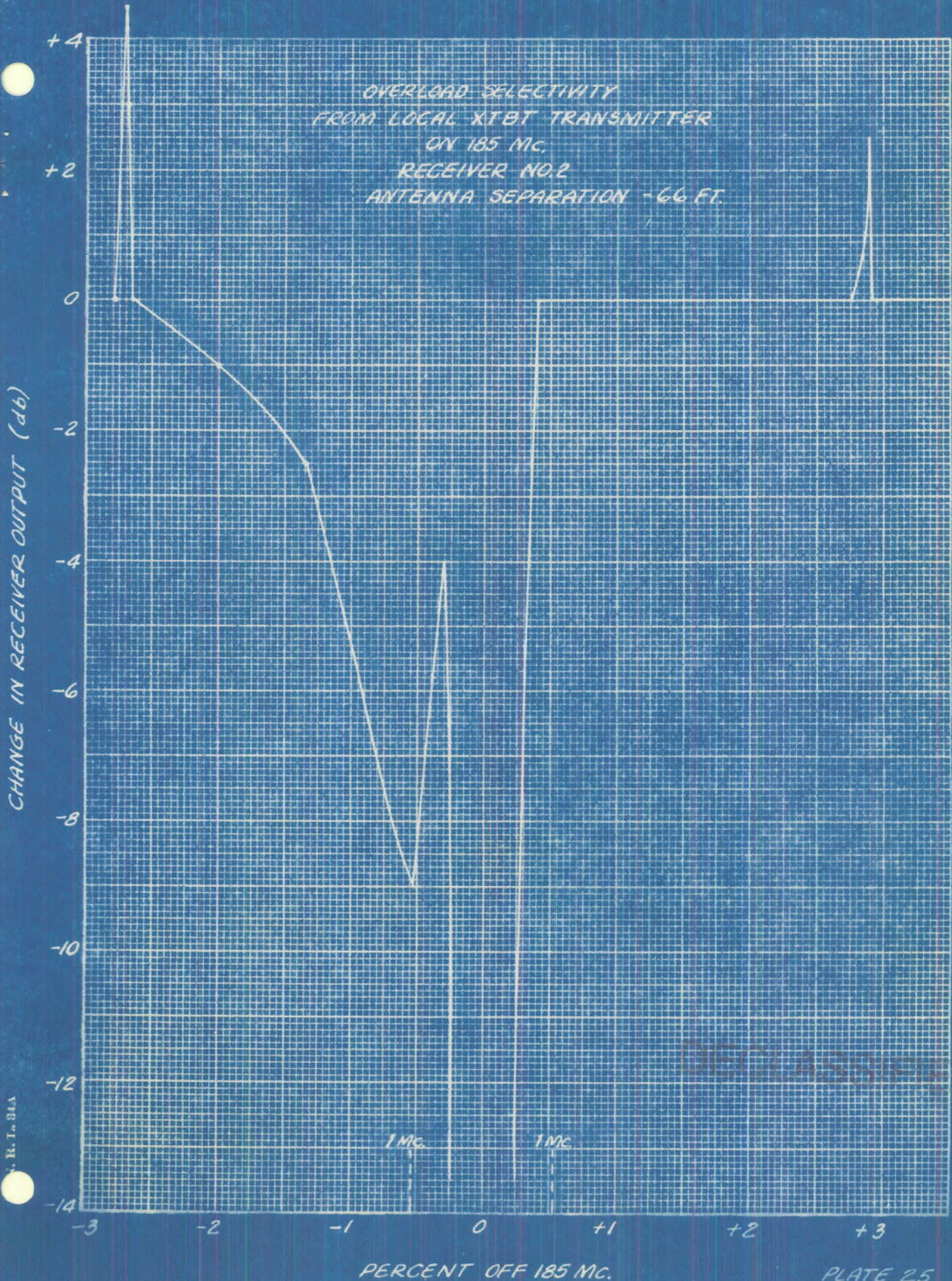


OSCILLATOR DRIFT DURING WARM-UP PERIOD  
MODEL XAP RECEIVER SERIAL NO. 7  
OSCILLATOR TUNED TO 160 Mc  
TUNED FRAME PRE-SELECTOR

OSILLATOR DRIFT IN KC.

PLATE 4

DRIFT ASSOCIATED



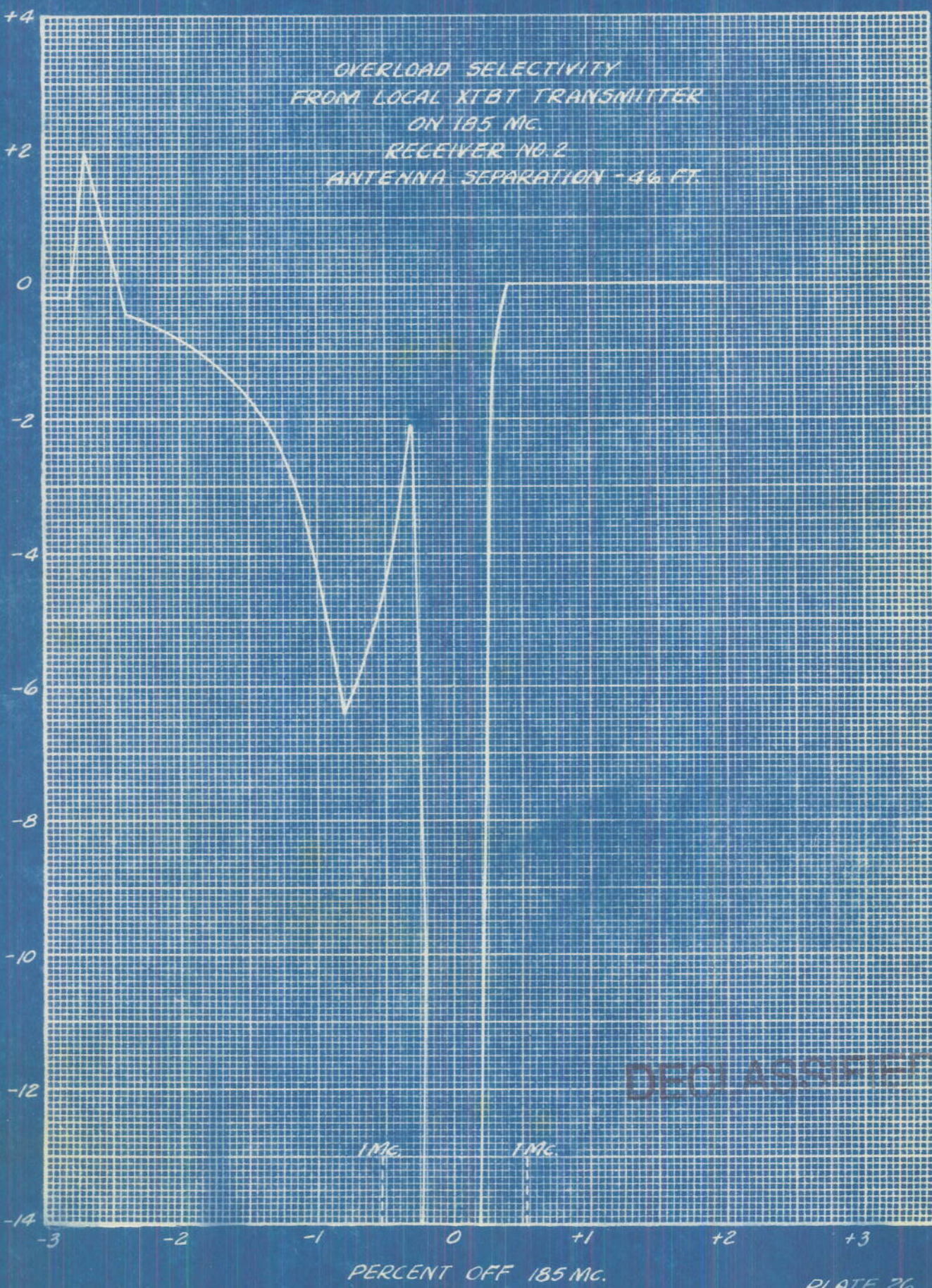
R. T. 34A

DEKASRE

IF SHEET IS READ THIS WAY (HORIZONTALLY) THIS MUST BE TOP. IF SHEET IS READ THE OTHER WAY (VERTICALLY) THIS MUST BE LEFT-HAND SIDE.

CHANGE IN RECEIVER OUTPUT (db)

OVERLOAD SELECTIVITY  
FROM LOCAL XTBT TRANSMITTER  
ON 185 MC.  
RECEIVER NO. 2  
ANTENNA SEPARATION - 46 FT.



DECLASSIFIED

R. L. 34A

PERCENT OFF 185 MC.



DECLASSIFIED

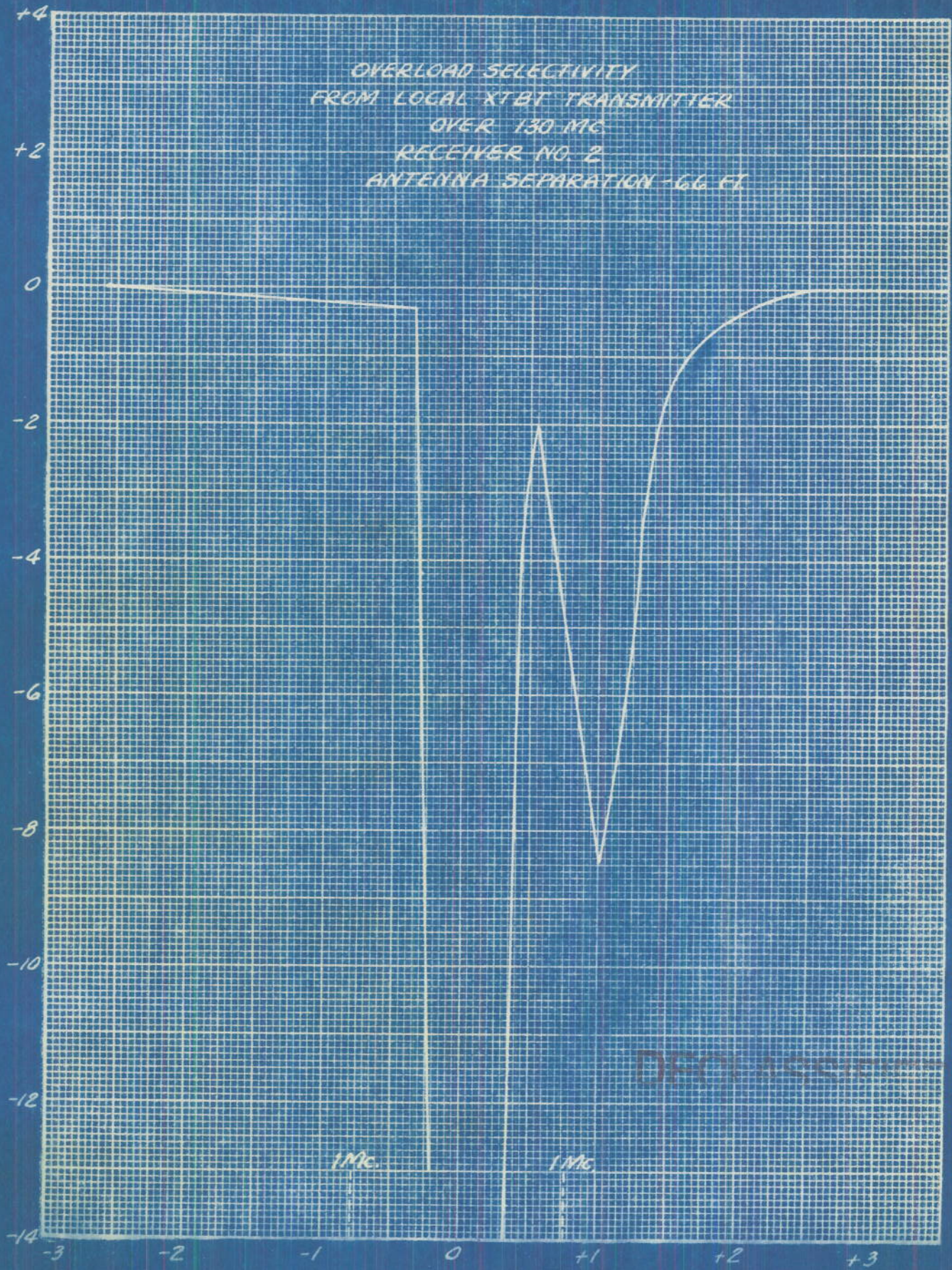
IF SHEET IS READ THIS WAY (HORIZONTALLY) THIS MUST BE TOP. IF SHEET IS READ THE OTHER WAY (VERTICALLY) THIS MUST BE LEFT-HAND SIDE.

N. R. L. 31A

IF SHEET IS READ THIS WAY (HORIZONTALLY) THIS MUST BE TOP. IF SHEET IS READ THE OTHER WAY (VERTICALLY) THIS MUST BE LEFT-HAND SIDE.

CHANGE IN RECEIVER OUTPUT (db)

OVERLOAD SELECTIVITY  
FROM LOCAL XTBT TRANSMITTER  
OVER 130 MC  
RECEIVER NO. 2  
ANTENNA SEPARATION - 66 FT



DECLASSIFIED

R. L. 34A

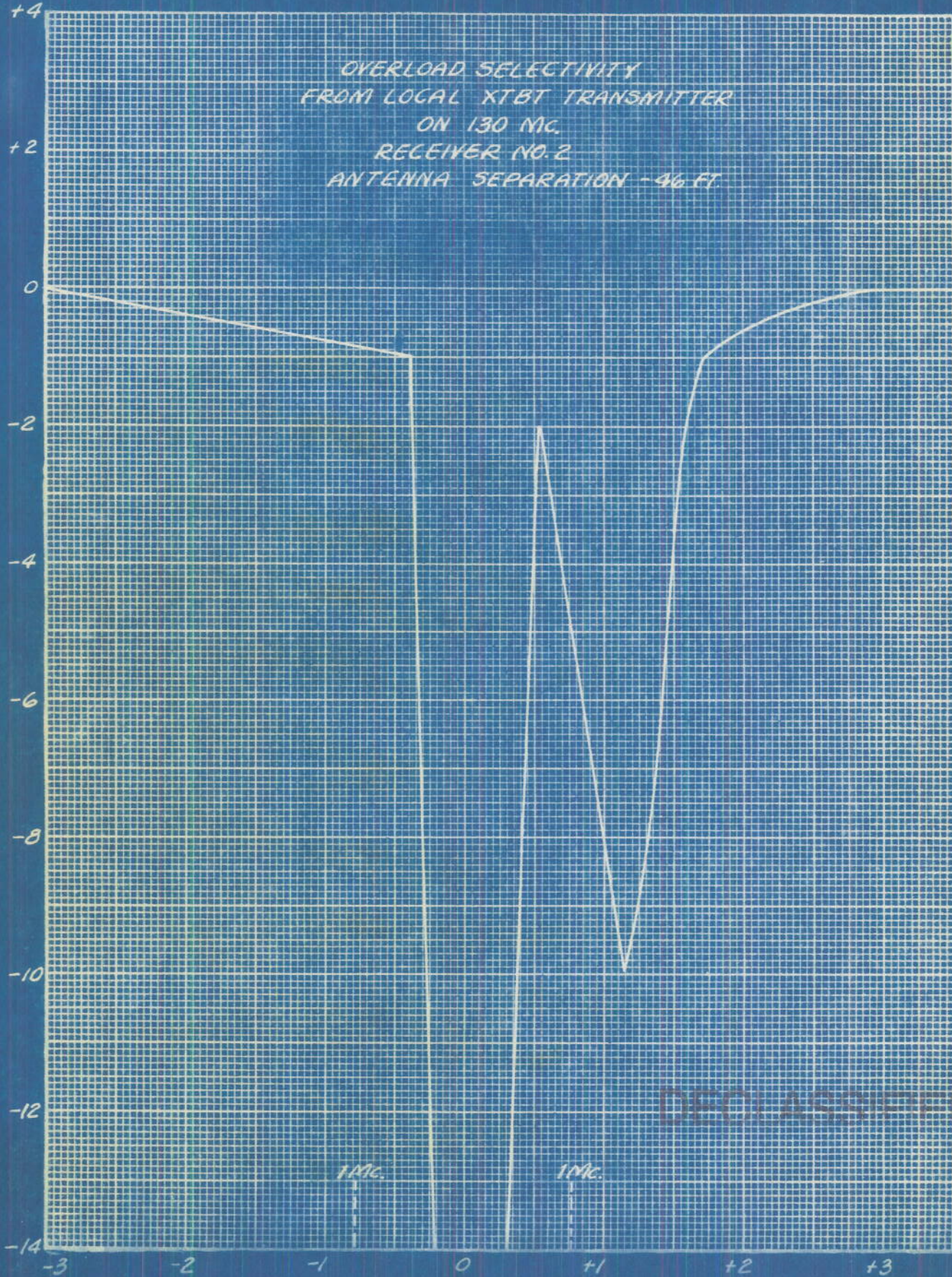
PERCENT OFF 130 MC.

PLATE 28

IF SHEET IS READ THIS WAY (HORIZONTALLY) THIS MUST BE TOP. IF SHEET IS READ THE OTHER WAY (VERTICALLY) THIS MUST BE LEFT-HAND SIDE.

CHANGE IN RECEIVER OUTPUT (db)

OVERLOAD SELECTIVITY  
FROM LOCAL XTBT TRANSMITTER  
ON 130 MC.  
RECEIVER NO. 2  
ANTENNA SEPARATION - 46 FT.

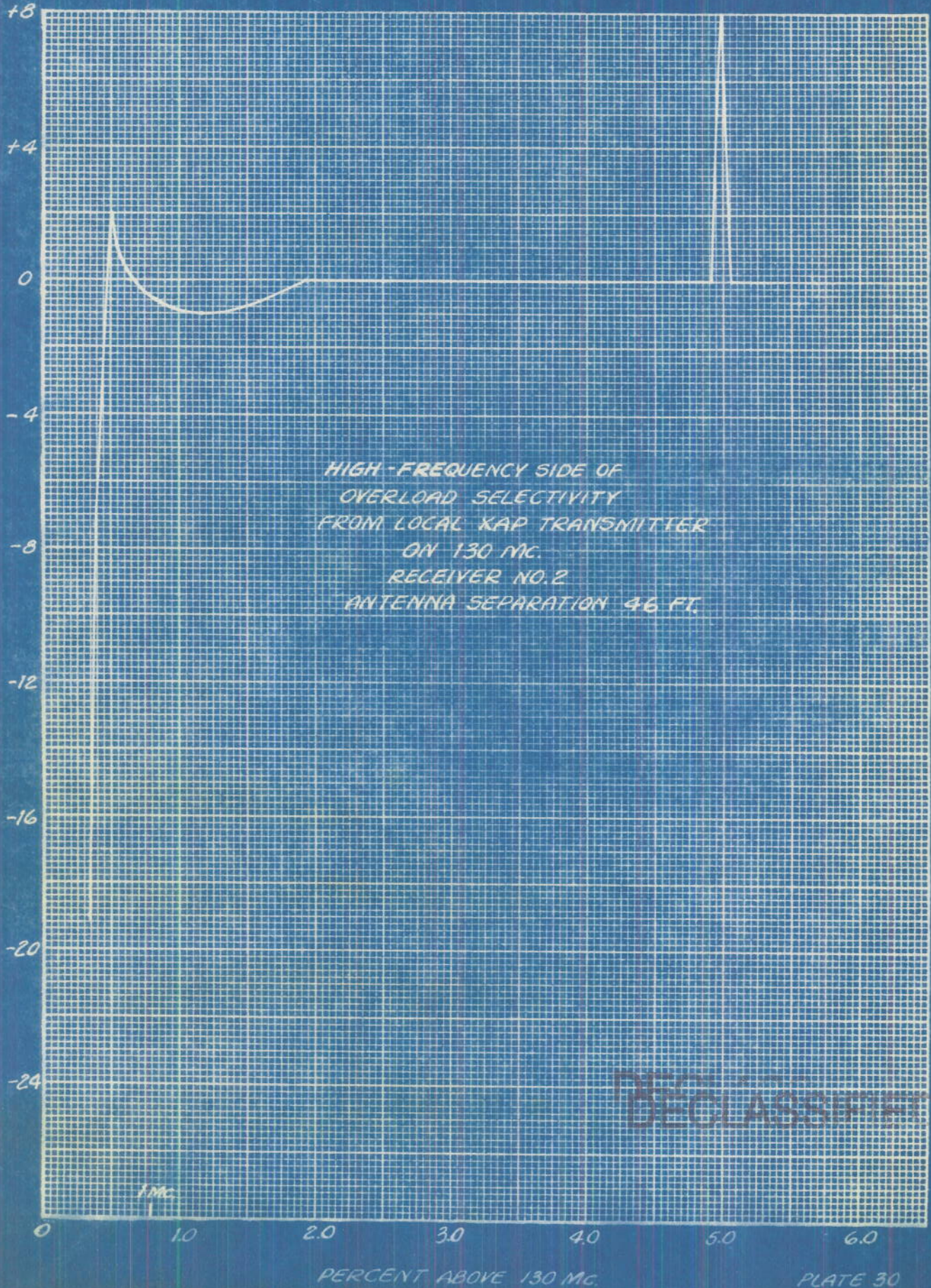


DECLASSIFIED

R. L. 34A

PERCENT OFF 130 MC.

PLATE 29



HIGH-FREQUENCY SIDE OF  
OVERLOAD SELECTIVITY  
FROM LOCAL KAP TRANSMITTER  
ON 130 MC.  
RECEIVER NO. 2  
ANTENNA SEPARATION 46 FT.

DECLASSIFIED

IF SHEET IS READ THIS WAY (HORIZONTALLY) THIS MUST BE TOP. IF SHEET IS READ THE OTHER WAY (VERTICALLY) THIS MUST BE LEFT-HAND SIDE.

d-b DROP IN DESIRED SIGNAL

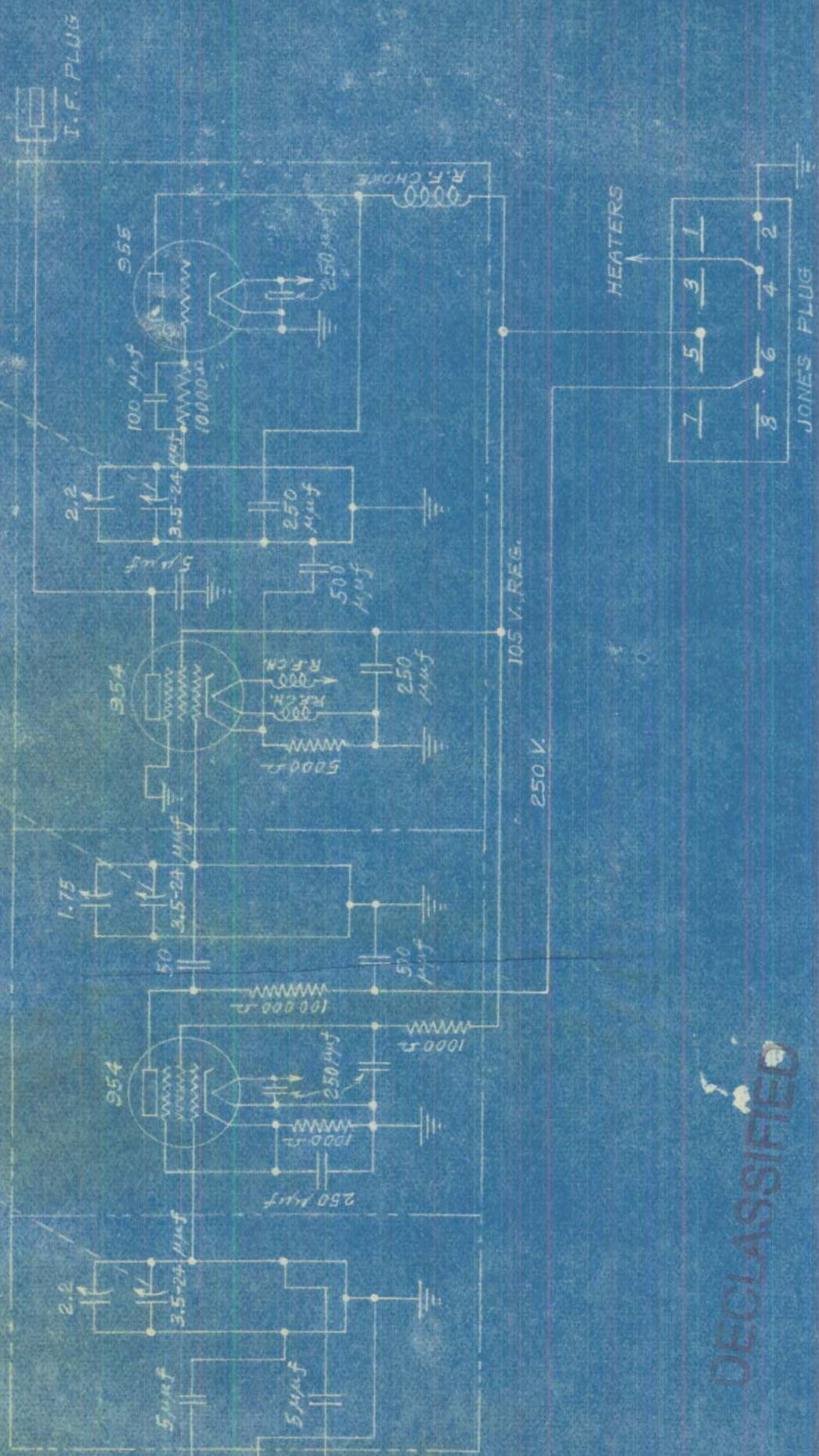
NRRL 31A

1 MC

PERCENT ABOVE 130 MC

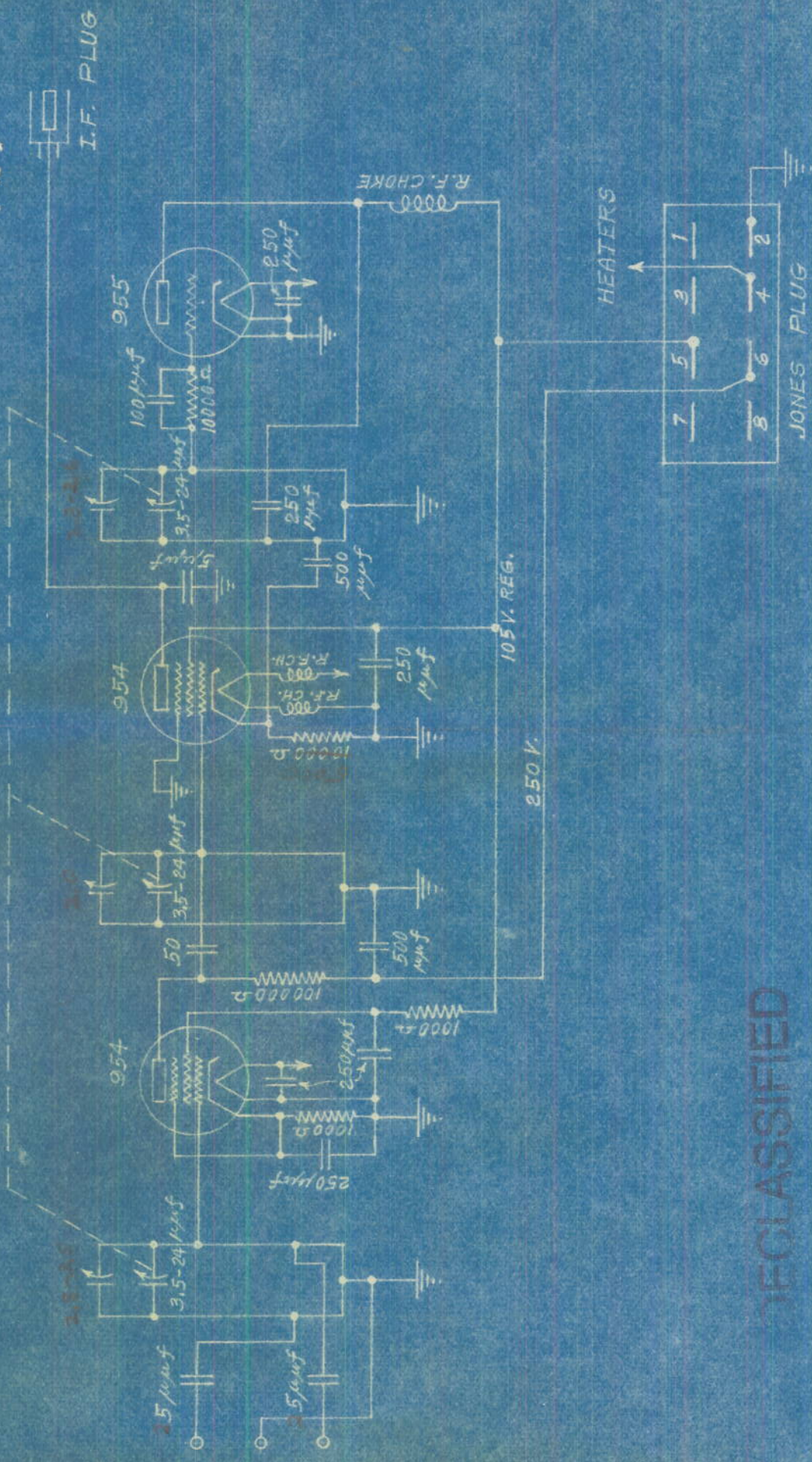
PLATE 30





DECLASSIFIED

NOTE: ALL DIMENSIONS PLUS OR MINUS UNLESS OTHERWISE SPECIFIED <b>U.S. NAVAL RESEARCH LABORATORY BELLEVUE, D.C.</b>		NAME TUNED FRAME PRESELECTOR FOR MULTIPLE MODULATION RECEIVER, 130-210 MC WIRING DIAGRAM	
ALTERATIONS	DRAWN <i>A.G.H. 3-12-44</i>	MATERIAL	REFERENCE NUMBER 46A455
CHECKED	APPROVED	FINISH	



DECLASSIFIED

NOTE: ALL DIMENSIONS PLUS OR MINUS UNLESS OTHERWISE SPECIFIED

U.S. NAVAL RESEARCH LABORATORY BELLEVUE, D.C.

NAME TUNED FRAME PRESELECTOR FOR MULTIPLE MODULATION RECEIVER, 130-210 MC WIRING DIAGRAM

ALTERATIONS

DRAWN <i>A.G.P. 9-13-40</i>	MATERIAL
CHECKED	FINISH
APPROVED	REFERENCE NUMBER
	46A455