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NAVY DEPARTMENT

Report
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Test of Type P540 Radio Receiving Equipment

Made by General Radio Company

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D. C.

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AUTHORIZATION OF TEST

1. The tests to be reported were authorized by reference (a). Other references are listed below.

- Reference:
- (a) BuShips ltr. S-S67/36 (485j), Ser. No. 1805 of December 23, 1941.
 - (b) BuShips ltr. S-S67/36 (485), Ser. No. 1730, of November 28, 1941.
 - (c) NRL ltr. S-S67/36, Ser. No. 455, of December 17, 1941, to BuShips.
 - (d) NRL ltr. S-S67/36, Ser. No. 480, of January 7, 1942, to BuShips.
 - (e) Operating Instructions for Type P540 Receiver, General Radio Company, Form 582-A.
 - (f) BuShips, General Specifications for Radio and Underwater Sound Equipments. RE 13A 554D.

OBJECT OF TEST

2. The object of the tests was to determine the suitability of the Type P540 Receiver for Radar intercept work over the frequency range 70 to 1000 megacycles. Although no specifications applying particularly to the equipment under test were available, comments have been based on Bureau of Ships specifications, reference (f).

ABSTRACT OF TEST

3. The Type P540 Receiver was given a general inspection for mechanical construction and wiring. The following tests were completed:

- (a) Sensitivity
- (b) Multiple Responsiveness
- (c) Resonant Overload (Automatic-Volume-Control Characteristic)
- (d) Automatic-Volume-Control Circuit Recovery Time
- (e) Oscillator Voltage Appearing at Receiver Antenna Terminals
- (f) Effects of Temperature and Humidity Variations on Operation
- (g) Mobile Tests in Aircraft and Truck
- (h) Oscillator Tube Operating Voltages and Currents
- (i) Intermediate-Frequency Signal Rejection
- (j) Vibration and Rocking

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Conclusions

(a) The Model P540 Receiver is unsuitable for Navy intercept work when compared in convenience and speed of operation with Navy receivers covering frequencies up to 30 Mc. However, no other equipment is known to be available for the frequency range 75 - 1030 Mc, and therefore the subject Receiver has a certain stop-gap value in indicating the presence of signals in this band and making checks on their frequencies under good conditions until improved equipment, preferably of a panoramic nature, becomes available.

(b) In general, the construction of the Receiver is sturdy and appears mechanically adapted to Naval aircraft service with certain exceptions, such as the failure to operate at low temperatures because of slippage of the main tuning control drive belt.

(c) The Receiver cannot be conveniently precalibrated for more rapid searching work because of the lack of a scale on the converter circuit tuning control (marked "antenna tuning" on the panel).

(d) The presence of numerous responses to each signal makes positive and rapid frequency determinations slow under ideal conditions, and difficult or perhaps impossible in the presence of many signals having similar modulation.

(e) Electrically, the Receiver did not appear to be suited to give a long life of trouble-free operation because of apparent short service life of the type 955 heterodyne oscillator tube. The crystal converter appears fragile and its life of reliable service under Naval operating conditions has not been determined.

(f) In spite of its many disqualifications and limitations, the Receiver would appear to have value in establishing the presence of enemy transmissions within the frequency range 75 - 1030 megacycles.

(g) Although the Receiver is intended for intercept service involving rapid tuning and ready estimates of signal frequencies, it is not at all well adapted for this purpose. However, it is recognized that the design of oscillator and mixer circuits covering wide frequency ranges at the ultra-high-frequencies available in this Receiver represents a definite achievement.

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Recommendations

In order that the General Radio Company ultra-high-frequency Receiver, Type P540, be made somewhat more suitable for Naval radio intercept and searching work, it is recommended:

- (a) That the converter circuit tuning control (labeled "Antenna Tuning") be provided with a counter and scale, preferably indicating frequency directly, and also an arbitrary logging scale. It is considered desirable that a calibration be made with the antenna connected through its transmission line to the Receiver; this would automatically allow for antenna feeder mismatch reactions on the converter tuning circuit. Ref. par. 25 and 35.
- (b) That the oscillator tuning control be provided with an arbitrary scale to be used in conjunction with an arbitrary counting scale on the main tuning dial to permit more precise precalibration. The frequency scale on the oscillator dial as furnished with the present model of the Receiver could be retained for the usual rapid checking purposes. Ref. par. 35.
- (c) That the audio-frequency transformer and the filter choke be potted in cans and sealed to prevent loss of potting compound during normal operation which may be at temperatures ranging from -25 to $+60^{\circ}\text{C}$. Ref. par. 39.
- (d) That an improved socket or clips be provided for mounting the type 955 oscillator tubes. Ref. par. 40.
- (e) That a voltage regulator tube be included with the power supply system to increase the constancy of d-c voltages on the oscillator tube plate and intermediate-frequency amplifier tube screen grids. Ref. par. 41.
- (f) That preselection circuits be added (necessarily without providing amplification at signal frequency until suitable radio-frequency amplifier tubes become available) ahead of the converter. Ref. par. 35.
- (g) That the oscillator circuit be electromagnetically shielded from the converter circuit and that oscillator power be supplied to the converter through a selective circuit designed to pass predominantly only that oscillator harmonic which is to be utilized in reception. This would avoid much confusion arising from harmonics which are not requisite to operation of the Receiver within its nominal frequency range. Ref. par. 27.
- (h) That frequency controls be ganged to provide a single tuning adjustment. Ref. par. 35.
- (i) That a positive gear drive be substituted for the V belt in the main tuning control. Ref. Par. 33 and 34.
- (j) That steps be taken to improve the operating life of the acorn type 955 tube in the oscillator circuit. Ref. par. 36.

(k) That all metallic surfaces be suitably treated to prevent corrosion. All finished aluminum surfaces should be given a primer coat such as zinc chromate under the final finish in order to afford suitable protection against corrosion. Ref. par. 42.

(l) That sockets for i-f and a-f vacuum tubes be secured to the chassis by means of screws through a suitable mounting yoke to permit ready removal if necessary in servicing. Ref. par. 43.

(m) That components, such as fixed resistors, fixed condensers, and radio-frequency choke coils be wax-dipped for protection against moisture. Ref. par. 44.

(n) That the mounting arrangement of fixed resistors and condensers be improved in orderliness and accessibility of each component for servicing. Ref. par. 45.

(o) That suitable grommets be employed where leads are passed through metallic shields or chassis. Ref. par. 46.

(p) That hook-up wire be used which will pass Navy specifications relative to moisture, spray and heat resistance. In particular, that rubber (or equivalent homogeneous) covering be used on all wiring carrying direct currents or radio-frequency voltages of any amounts. Ref. par. 47.

(q) That any special wrenches or tools, such as Bristo type wrenches, necessary in servicing the equipment be mounted conveniently on the inside frame of the Receiver. Ref. par. 48.

(r) That improved shielding cans be provided for the i-f circuits. Attention should be accorded the grounding of these shields and their clearance to the components within them. Ref. par. 49.

(s) That the input meter case and the wire-wound volume control be completely encased for protection against salt-spray conditions. Ref. par. 50.

(t) That all wires be well secured to terminal lugs before soldering and that increased attention be given to neatness of soldering as well as cleaning of soldered joints. Ref. par. 51.

(u) That a frame-type phone jack of Navy-approved design be used. Ref. par. 52.

(v) That the dynamotor be shock-mounted on the receiver chassis to reduce microphonic noise from this source. Ref. par. 53.

(w) That an improved type of concentric line be used within the Receiver for connection from the antenna jack to the input circuit. Improvement in the direction of lower capacitance and lower loss per unit length would appear to be in order. Ref. par. 54.



(x) That the copper strap providing coupling of oscillator power into the converter circuit in the type P540-P1 tuning unit be mounted in an improved manner giving adequate mechanical support. Ref. par. 55.

(y) That all component parts be suitably marked in accordance with their circuit diagram symbols. Ref. par. 56.

(z) That a consistent system of color coding be adopted for hook-up wiring. Ref. par. 56.

(aa) That the sharp cotter pin edges on the cylindrical securing dog stud at the front of the Receiver be eliminated. Ref. par. 57.

(bb) That nameplates be provided in conformity with Navy specifications. Ref. par. 58.

(cc) That the dial light and power switch circuits be redesigned to make these devices operative on 250-volt and 6-volt external supply, as well as during dynamotor operation. Ref. par. 59.

(dd) That steps be taken to reduce the amount of voltage from the first oscillator appearing at the antenna. Ref. par. 31.

(ee) That the intermediate frequency rejection characteristics of the receiver be improved. Ref. par. 37.

(ff) That the nominal lower frequency limit of 70 Mc be altered to agree with the actual lower limit of approximately 75 Mc. Ref. par. 22.

(gg) That steps be taken to reduce the number of responses to a strong signal. Or, alternatively, that means be provided for attenuating strong signals before they reach the converter circuit. Ref. par. 28.

(hh) That the sturdiness of the cabinet be increased to prevent vibration and instability of the cabinet top. Ref. par. 60.

(ii) That the converter tuning circuit of the type P540-P1 tuning unit be redesigned to permit satisfactory resonating over the entire tuning range of this tuning unit. Ref. par. 28.

(jj) That steps be taken to reduce the noise output incidental to mechanical vibration of the Receiver at certain vibrational frequencies. Ref. par. 38.

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MATERIAL UNDER TEST

4. The material under test consisted of the following Type P540 Receiving Equipment:

- (a) One Type P540 Receiver Unit with provision for interchangeable use of Tuning Units (b) or (c).
- (b) Type P540-P1 Tuning Unit: 75 to 370 Mc.
- (c) Type P540-P2 Tuning Unit: 250 to 1030 Mc.
- (d) Type P540-P3 Fixed Antenna.
- (e) Type P540-P4 Cradle Rack for mounting the Type P540 Receiver Unit and locking either of the Tuning Units in place.

5. The Type P540 Receiving Equipment was manufactured (and supplied via the Bell Telephone Laboratories) by the General Radio Company, Cambridge, Massachusetts. It was delivered to the Laboratory for test on December 30, 1941.

METHOD OF TESTS

6. The following instruments were used for electrical tests:
- (a) Signal Generator, General Radio Company, Model 804B, Serial No. 206.
 - (b) Signal Generator, General Radio Company, Type P522-A, Serial No. 101.
 - (c) Electronic Voltmeter, Ballantine Laboratories, Model 300, Serial No. 194.
 - (d) Output Meter, General Radio Company, Type 483F, Serial No. 650.
 - (e) Radio Receiver, General Radio Company, Type P521-A, Serial No. 101.
 - (f) Large Temperature and Humidity Test Room, Machine Shop.
 - (g) Vibration Table; Transmitter Section.

7. Upon inspecting the Type P540 Receiving Equipment after unpacking, it was found that there were no damaged or loosened components, and that the Receiver was in operating condition when used with either of its tuning units. Because of the limited time during which the equipment could remain at the Laboratory, tests were confined to those believed most essential in evaluating its capabilities for intercept and searching use in the Naval Service. Consequently, many tests of general importance were omitted, and this report is less exhaustive than desirable in presenting a thorough estimate of the value of this equipment to the Service.

8. During a portion of the tests, power for operating the Receiver was obtained from a 12-volt storage battery. Tests were also carried out with power at 250 volts d.c. and 6.3 volts a.c. derived from a rectifier type power supply, Model 672A, Serial No. 139, made by the General Radio Company.

Sensitivity Measurements

9. Measurements of sensitivity at the ultra-high frequencies employed in the Type P540 Receiver are unreliable and likely to be inaccurate due to the following causes:

(a) No microvolt standard has become available for calibration purposes at these frequencies.

(b) Leakage from the signal generator oscillator, by-passing the attenuator.

(c) Presence of frequency modulation. The lack of a microvolt standard is so serious that no estimate of probable error appears possible for frequencies above 200 megacycles. Calibrations at frequencies below 200 megacycles indicate that signal generator outputs may be in error by as much as a factor of three. Signal generator leakage was not serious during these tests because of the adequate shielding of the Receiver, and because of its insensitivity as compared with Navy communication receivers operating at lower frequencies. Frequency modulation may not be a great source of error in these measurements because of the wide pass band of the i-f system, permitting acceptance of the major f-m components.

Measurements up to 300 megacycles were made by connecting the General Radio Company Signal Generator, Type 804B, direct to the Receiver through the concentric cable furnished with the Receiver. The Receiver input impedance and the Generator output impedance are stated by the manufacturer to be about 70 ohms. At frequencies from 300 to 1000 megacycles, the General Radio Company Signal Generator, Type P522, was used with one output terminal grounded, to provide the required unbalanced output, and the other concentric terminal connected direct to the Receiver. The sensitivity measurements were made with a 30%, 400-cycle modulated signal and were based on a signal carrier noise ratio of 7 decibels.

Check on Multiple Responsiveness

10. Each signal is present at two or more points on the receiver oscillator dial because of the presence of the image and of the possible presence of other pairs of signals associated with the various harmonics of the heterodyne oscillator. The relative responsiveness at several of these points was determined as a part of the sensitivity test.

Resonant Overload (AVC Characteristic) Test

11. The resonant overload characteristic was determined by applying a signal from the General Radio Company, Type P522A Signal Generator to the

Receiver as in the sensitivity tests and noting the output, for increasing values of input. 30%, 400-cycle modulation was used and the output was measured by a Ballantine Model 300 electronic voltmeter.

Automatic-Volume-Control Circuit Recovery Time

12. AVC time constants were measured by reference to the receiver noise level as indicated by a Ballantine Model 300 voltmeter connected across a 600-ohm load fed from an audio phone jack. Inputs from the General Radio ultra-high frequency signal generator, Model P522-A, were controlled by means of a special switch developed at this Laboratory for this purpose. With .5 volt input to the Receiver at a desired frequency, fed through a 35-ohm dummy antenna, this switch was operated to short circuit the signal generator output. A stop watch was then used to indicate the time required for the receiver noise level to increase to a point two decibels below the noise level as measured with zero input signal.

Oscillator Voltage Appearing at Receiver Antenna Terminals

13. The first oscillator radiation was estimated by using a second receiver, General Radio Company Type P521-A, to determine the oscillator output at the antenna posts, an ultra-high frequency signal generator being used to produce the same received signal strength and consequently provide an estimate of the amount of voltage present. Proper values of dummy antenna and comparison receiver isolating resistors were used, and the latter receiver and its connecting leads were well shielded. At least two harmonics as well as the fundamental oscillator frequency were measured.

Effects of Temperature and Humidity Variations on Operation

14. The Receiving Equipment was tested in the large Laboratory temperature and humidity test room by observing its changes in gain and oscillator frequency relative to the P522-A signal generator. The heterotone oscillator was used in the Receiver under test in order to permit the use of unmodulated signals from the generator. Observations were made on the effects of temperature changes on mechanical operation of the Receiver.

Mobile Tests in Aircraft and Truck

15. Two field tests were made, using the antenna furnished with the Equipment. One of these, a truck test, was not satisfactory as the terrain covered was such as to make line-of-sight reception practically impossible when more than one mile from the Laboratory. The other, a flight test from the Naval Air Station, Anacostia, was in keeping with the anticipated use of the Equipment. No ignition noise or deleterious vibration was encountered in the plane test, although some ignition noise was present in the truck. Moderately strong intermediate-frequency signal interference from a police transmitter was audible during a portion of the aircraft test. In the flight test, the plane was maintained at an altitude of approximately two thousand feet and within the beam of the Radar transmitting antennas.

Oscillator Tube Operating Voltages and Currents

16. The static operating conditions of the Type 955 heterodyne oscillator tubes in the tuning units were determined in an attempt to diagnose the difficulty resulting in apparently short operating life of these tubes.

Intermediate-Frequency Signal Rejection

17. Signals from the General Radio Company Type 804B Signal Generator were fed, at the intermediate frequency, to the antenna input terminals of the Receiver. The i-f input, modulated 30% at 400 cycles, required to produce a 7 db signal/carrier noise ratio was compared with the sensitivity of the Receiver. The intermediate-frequency rejection ratio for each tuning unit was evaluated with respect to an average sensitivity over the tuning range appropriate to the unit.

Vibration and Rocking

18. The Receiver was mounted, by its shock mountings, on a board which was secured to the vibration table operated by the Radio Transmitter Section of this Laboratory. During the rocking and vibration tests, a variable signal, modulated 30% at 2500 cycles, was applied to the Receiver through a flexible concentric line. Sensitivity checks were not feasible because of the high and variable ambient noise level. The Receiver was supplied with power from 12-volt storage batteries. After a short rocking test in which the Receiver was tipped $+ 45^\circ$ from the horizontal, each tuning unit was inserted in turn into the Receiver for a more extended vibration test in which the vibration frequencies were varied from 0 to about 1800 per minute.

DATA RECORDED DURING TEST

19. Data were recorded, to the extent permitted by the limited time during which the Equipment was at the Laboratory, for all tests made and this information is contained in Tables 1 to 4, and Plates 1 to 11, inclusive.

PROBABLE ERRORS IN RESULTS

20. Tabulated below are estimates of the probable errors in the results of the various tests. These estimates are based on the assumption that the equipment has been operated for sufficient time to permit stabilization to take place prior to test. The estimates also include the advertised errors for the instruments used.

<u>Name of Test</u>	<u>Estimated Overall Accuracy</u>
Sensitivity up to 300 Mc	$\pm 60\%$
Sensitivity up to 1000 Mc	(No standards)
Resonant Overload (Signal Voltage)	(No standard)
(Output Voltage)	$\pm 5\%$
Automatic Volume Control Recovery Time	$\pm 10\%$
Oscillator Voltage Appearing	
At Antenna Terminals (up to 300 Mc)	$\pm 60\%$
(up to 1000 Mc)	(No standards)

RESULTS OF TESTS

21. A general description of the Equipment under test is presented in reference (e). Only those features requiring further elucidation will be discussed in the present report.

22. The frequency range indicated in reference (e) is 70 to 1000 Mc. Rough tests in this Laboratory indicated that the range is more nearly 75 to 1030 Mc with ample overlap between the two tuning units.

23. While the "butterfly" r-f tuning circuits are successful in covering a very wide frequency range for ultra-high-frequency equipment, it is not believed that they would lend themselves readily to ganged operation, partly because of difficulties in trimming and aligning balanced circuits.

24. The heterotone oscillator, an audio-frequency oscillator modulating the screen voltage of the last intermediate-frequency tube, provides an audible response to unmodulated signals. This device may be of some use in searching for unmodulated signals when interference is not troublesome.

25. The converter circuit tuning control (referred to in reference (e) as "Antenna-tuning control") is provided with no dial or other means of setting it to a precalibrated position. This is regarded as a considerable disadvantage since it leaves no method, other than the use of a local signal generator, for maintaining the Receiver in a sensitive condition during searching operations.

26. Selectivity and fidelity characteristics are given in Figures 2, 3 and 4 of reference (e). When using the Type P540-P1 tuning unit, the overall selectivity curve at 100 Mc is about 1.83 Mc wide at 6 db attenuation and 5.26 Mc wide at 60 db. When using the Type P540-P2 tuning unit, the overall selectivity curve at 300 Mc is 2.61 Mc wide at 6 db and 6.14 Mc wide at 60 db attenuation.

27. The application to the mixer of voltages corresponding to various harmonics of the heterodyne oscillator is undesirable, as it is one of the factors responsible for the multiplicity of responses to a single signal.

28. The sensitivity and multiple response characteristics are given in Table 1. When using the Type P540-P1 tuning unit at signal frequencies above 250 Mc, it was not always possible to resonate the "Antenna tuning" control to obtain an optimum response. For example, when receiving a 300 Mc signal with the oscillator set at 270 or 330 Mc, it was found that no setting of the "antenna tuning" condenser gave a peak output, but that certain settings gave small, sharp dips in the output. In spite of this behavior, however, the Receiver sensitivity was superior under these conditions to that obtained at 300 Mc or any other frequency when using the Type P540-P2 tuning unit. The short useful life of the Type 955 oscillator tubes used in both tuning units is a source of considerable uncertainty in sensitivity measurements. Therefore, in interpreting Table 1,



it should be noted that some of the sensitivity observations may be inferior to the normal values because of the fact that the oscillator tubes show a short life of optimum operation and that it was therefore necessary, before the sensitivity runs could be satisfactorily completed, to replace the oscillator tube with a new spare. It was found, in tests with the Type P540-P2 tuning unit that detuning the "antenna tuning" adjustment might result in an 8 to 40 db decrease in sensitivity, depending on the frequency of the received signal and the oscillator frequency selected for heterodyning. A strong signal may give dozens of responses arising from overload conditions. No preselection circuits are provided to alleviate this condition.

29. The resonant overload (automatic volume control) characteristics, measured as indicated in paragraph 11, are plotted on Plate 11.

30. The automatic volume control recovery times, determined as described in paragraph 12, were checked at signal frequencies of 300 and 1000 megacycles, corresponding to somewhat different noise levels and therefore different recovery periods. At 300 Mc, the recovery time, as defined in paragraph 12, was about 4.5 seconds, while at 1000 Mc it measured about 2.1 seconds. These measurements are based on audio outputs from a phone jack.

31. The amount of oscillator voltage appearing at the receiver antenna terminals was measured as described in paragraph 13. The antenna terminal voltage, available for radiation from the receiving antenna, was found to range from 4 to 200 millivolts, averaging about 100 millivolts, the greatest output occurring at the high-frequency end of each tuning unit. This amount of radiation would constitute a serious menace to local Radar reception.

32. As mentioned in paragraph 14, an attempt was made to evaluate the effects of temperature and humidity variations on the operation of the Receiver. For variations in gain and oscillator frequency, the type P522-A signal generator was used as the standard of reference, time not being available to set up for more precise determinations. Because of this lack of adequate reference standards, gain and frequency stability results are not presented quantitatively. However, the data obtained indicate a fairly satisfactory degree of stability under exposure to temperatures ranging from +53°C to -18°C as well as to relative humidities from 30% to 96% with the temperature at 40°C. No impairment of receiver operation for searching purposes was observed during or as a result of these tests with the exception discussed in paragraph 33.

33. At temperatures in the region of -15°C, it was found that the main tuning control drive belt slipped when it was attempted to adjust the type P540-P1 tuning unit in the direction corresponding to decreasing frequencies, rendering the unit inoperative, since the tuning dial and condenser could not be actuated in this direction (although it would operate in the increasing frequency direction) by turning the main tuning knob. This defect, apparently caused by stiffening of the grease on the gears and the lack of a positive gear drive, disappeared when the temperature

was returned to +20°C. At temperatures near -15°C, the "antenna tuning" control became quite stiff in operation; however, it did not become inoperative since it is provided with a positive gearing drive.

34. Cuttings from the V-belt used in actuating the oscillator drive gears were found to be strewn about the left-hand gearing compartment. This V-belt, which is kept taut by a spring-supported take-up pulley, apparently cuts against the sharp shoulders of the belt slot on the main-tuning-knob shaft.

35. Mobile tests were carried out both in truck and aircraft as described in paragraph 15. Although the truck tests were not illuminating, as a line-of-sight range was not maintained, the plane tests yielded the results shown in Table 2. In the flight test, fifteen to twenty minutes were required to check the complete frequency range of the Receiver. In service, however, this time requirement would depend on the number of signals present. Twenty response points were noted; when later calculated they indicated five transmitted frequencies. During the flight, several check tests were made, including observations by two operators. The received signals were so strong that it was not necessary to manipulate the "antenna tuning" control. If the use of this control had been necessary, as would have been the case for weaker signals, reception would have been more difficult and searching would have consumed more time. The "antenna tuning" control was adjusted for optimum response to each signal, but it may have been that this control was not properly set when searching for a low power, 880 megacycle signal that was not heard although known to be present. This illustrates the difficulty of adjusting the Receiver to maximum sensitivity in the absence of a signal and indicates the desirability of providing the "antenna tuning" control with a scale which could be precalibrated to permit proper setting at all times when searching. Time was not available during the flight to calculate the actual signal frequencies; this computation was carried out later and resulted in the data given in Table 2. Some of the twenty received responses could not be correlated; others were easily calculated because of the presence of characteristic modulations which were noted to facilitate proper grouping of image response pairs.

These operating tests suggest the desirability of providing arbitrary scales on the tuning controls to facilitate precise precalibration and to permit correct tuning with controls kept in proper manual "alignment" at all times during searching. The tests also underline the inconvenience of the Receiver for searching work and indicate the urgent need of further development in the direction of providing preselection circuits and means for suppressing all harmonics of the heterodyne oscillator frequency except the one actually used in reception. Practical usefulness of the equipment would, of course, be greatly enhanced by provision of ganged adjustments permitting tuning by a single control.

36. In an attempt to determine the reason for apparent short operating life of the type 955 oscillator tube, which was particularly noticeable in the type P540-P2 tuning unit, measurements were made of its d-c potentials and currents. Ref. par. 28. The average grid current was

0.16 ma and the grid resistor 25,000 ohms. The average plate voltage was 110 volts obtained through a 10,000-ohm resistor from a 190-volt supply. The average plate current was about 8.2 ma. These measurements indicate conservative operation with the possible exception of plate current which is just above the manufacturer's recommended maximum value of 8.0 ma. This would not be considered serious in tubes operating at frequencies so low that transit-time effects are of negligible importance. However, it has been found that the cathode of a tube operating at ultra-high frequencies may be called upon to supply an emission greatly in excess of that required at lower frequencies. If the cathode is not capable, at the normal operating temperature, of supplying the peak current demand, then there will result a lack of space charge during a part of the oscillator frequency cycle with consequent damage to the oxide cathode and shortening of operating life. The actual reason for short oscillator tube life in the subject Receiver has not been determined by this Laboratory, and the above discussion is meant only to point out a possible cause. An immediate remedy might be to operate the oscillator tube at a somewhat lower average plate current.

37. The intermediate frequency signal rejection, measured as shown in paragraph 17, is very poor and hence a strong signal at the intermediate frequency could make the Receiver inoperative over its entire frequency range. The i-f rejection ratio, averaged over the range of signal frequencies, was about 29 decibels for the type P540-P1 tuning unit, while for the type P540-P2 tuning unit it was only 6 decibels.

38. Vibration and rocking tests, ref. paragraph 18, were withstood by the Receiver without apparent mechanical damage. After 5 minutes of rocking without vibration, the Receiver with the type P540-P1 tuning unit was subjected to vibration at frequencies up to 1800 per minute for a period of one-half hour during which time the Receiver was fed with a 300 Mc signal. The same test was then repeated using the type P540-P2 tuning unit, also operating with a 300 Mc signal. Vibration modulation of moderate intensity was audible in the output when using either preselector at a table vibration frequency of 850 cycles per minute and also over the range 1100 - 1430 cycles per minutes, corresponding to mechanical resonant frequencies of the receiver cabinet or other component parts. Apart from this vibration modulation, which was of sufficient intensity to disturb reception of fairly strong signals, say, less than 1000 microvolts, the Receiver performed satisfactorily during and after vibration and rocking tests.

39. The filter reactor in the power supply and the audio-frequency transformer are not provided with suitable terminals, "pigtail" leads being used. These iron-core coils appear to have been treated with a protective coating but are not potted and sealed.

40. The "acorn" type 955 oscillator tube is secured by spring clips mounted in bars connecting with the "butterfly" circuit stator assembly. These spring clips do not appear to insure adequate bite for secure and stable contact. These clips are not plated or otherwise protected against corrosion. The type 955 tube is held in place by a spring strip which bears upon the top of its envelope. In the type P540-P1 tuning unit, this spring is mounted on a removable aluminum plate in the sub-chassis

partition at the left of the Unit. This plate, which fits, without being secured by screws, into an opening of dimensions approximately 2-5/8 by 1-3/8 inches, carries two springs, apparently of unplated beryllium copper strip 1/2-inch wide and 0.020-inch thick. One of these springs is bent at right angles to bear against the top of the acorn tube envelope; the other spring is bent into a portion of a circle and is held in place by the cover on the left side of the tuning unit, at the same time pressing the first spring against the top of the tube envelope. These springs and also the "acorn" tube contact clips do not appear to be protected against corrosion. The "acorn" oscillator tubes are mounted, particularly in the type P540-P1 tuning unit, in a location which makes their replacement inconvenient and time-consuming.

41. The power supply is not fitted with a voltage regulator tube or other means to assure stability of frequency and gain against changes in line voltage.

42. Except for the cabinet and panel outer surfaces, no protection against corrosion was apparently provided on the metallic surfaces. No primer coat was noticed under the panel and cabinet finish.

43. The audio and intermediate frequency amplifier and the hetero-tone oscillator tube sockets are secured to the chassis with locking rings which are often difficult to remove without disturbing surrounding wiring and components.

44. So far as was determined by cursory inspection, the component parts such as fixed condensers, fixed resistors, radio-frequency chokes, and intermediate-frequency transformers were not wax treated for protection against moisture.

45. The mounting arrangement of the smaller components such as fixed resistors and condensers as shown in Plates 3, 7, and 8, does not present an orderly appearance. However, it is recognized that the necessity for very short leads in high-frequency circuits renders a systematic layout more difficult to plan than in equipment operating at lower frequencies.

46. Leads are passed through sharp-edged holes in the intermediate-frequency stage shields without the use of grommets, and the insulation might be cut at these points after some amount of servicing operations or vibration.

47. The hook-up wiring is of stranded tinned conductors apparently insulated with two layers of wax-impregnated cotton or similar material. The inner insulation layer is wrapped while the outer is braided. This type of covering would appear to afford insufficient protection against moisture.

48. Several Bristo wrenches for operating special set screws in the Receiver were furnished with the spare parts. It would facilitate servicing work, if these wrenches could be mounted in some conveniently accessible location on the Receiver chassis.

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49. The intermediate-frequency amplifier stage shield cans are of aluminum. They lock into place on the aluminum mounting rims by a small rotation which engages a protrusion in the base with a groove in the shield can. The contact from aluminum to aluminum would appear to be very unsatisfactory for grounding the shield. There is no provision for locking the shield can securely in place and it could be loosened by vibration. Insufficient clearance appears to have been provided between the lower inside surface of these cans and the wiring of some of the components within it.
50. No protective cases are provided with the input meter and the volume control to insure that they will not be damaged by salt-spray.
51. The wiring is not always secured to the lugs before soldering. Thus, there is some dependence on solder for mechanical support.
52. The phone jacks do not appear to have non-corrosive contacts. They do not conform to Bureau of Ships specifications RE 13A 481.
53. The dynamotor is not shock mounted on the chassis of the Receiver. Under some conditions a strong modulation was heard in the output which was apparently due to commutator ripple or mechanical vibration from the dynamotor.
54. The concentric line connecting the antenna jack through the tuning-unit jack and plug to the converter circuit consists of thin-walled nickel-plated copper tubing about 3/16 inch in outside diameter containing a rubber-covered, tinned solid copper conductor about 3/64 inch in diameter. This line would appear to have rather high loss and high capacitance per unit length and does not seem suitable for operation up to 1000 megacycles.
55. In the type P540-P1 tuning unit, the diode converter circuit is coupled to the oscillator circuit stator by means of a copper strap which appears to be nickel-plated on its faces but not protected against corrosion at its edges. This strap is curved to lie very near the outside of the oscillator stator plates for a distance of about two inches. A portion of this strap is insulated with loose-fitting cambric tubing. The diode end of this strap is not secured except by clipping to the diode dome terminal. This condition should be remedied by properly mounting this strap to prevent its displacement by vibration and shock.
56. No consistent scheme of wire color coding appears to have been used and the components (with the exception of tube sockets) are not marked to designate their location in the circuit.
57. The cylindrical securing dog, shown at the front end of the mounting cradle in Plate 6, is used for holding the tuning unit in place. The stud on which this cylinder is mounted carries a cotter pin having sharp edges which might cause injury to the hands of personnel.
58. The nameplate does not carry adequate information relative to the equipment and is not in accord with Bureau of Ships specifications RE 13A 516.



59. A power on-off switch and a pilot lamp are provided on the front panel to control and indicate operation on 12-volt d-c supply. However, they are not operative on 250-volt and 6-volt supply, and no devices are provided to take their place for the latter power sources.

60. The cabinet of the Receiver is not well braced. It was noticed that small loads produced considerable deflections of the top of the cabinet. This would appear unfavorable from the point of view of stability in the presence of vibration or shock. The top of the cabinet is not secured to the front panel of the Receiver.

61. According to paragraph 1.7 of reference (e), the audio output circuits are designed to feed 600-ohm headphones. The video output is designed to feed a 100-ohm concentric cable or the grid of a vacuum tube in an amplifier which operates a cathode ray tube. An oscilloscope may prove practicable and useful in determining Radar modulation characteristics of intercepted signals.

SUMMARY OF DEFECTS

62. The following is a summary of defects which might adversely affect satisfactory operation as a searching receiver in Naval aircraft or shipboard service.

- (a) Ref. par. 35. - No scale is provided with the "antenna tuning" control.
- (b) Ref. par. 39. - The audio-frequency transformer and the filter choke are not potted in sealed containers.
- (c) Ref. par. 40. - The clips supporting and providing electrical contact to the "acorn" type 955 oscillator tubes in the tuning units do not appear to give entirely satisfactory contact at all times and apparently were not protected against corrosion.
- (d) Ref. par. 35. - No preselection circuits are provided.
- (e) Ref. par. 27. - A number of oscillator harmonic frequencies are available at the mixer, resulting in multiple pairs of responses to a received signal.
- (f) Ref. par. 35. - Two controls must be manipulated in tuning.
- (g) Ref. par. 33. - A belt drive is used in the main tuning control system.
- (h) Ref. par. 36. - The "acorn" type 955 heterodyne oscillator tube does not appear to have a satisfactorily long life of useful operation.

- (i) Ref. par. 42. - Metallic surfaces do not appear to be adequately protected against corrosion in the presence of moist saline atmospheres.
- (j) Ref. par. 43. - Locking rings are used for securing tube sockets to the chassis. This mounting method is unsatisfactory because of difficulties in removal of the socket for servicing.
- (k) Ref. par. 44. - Fixed resistors, fixed condensers, radio-frequency chokes and intermediate-frequency transformers are not wax treated.
- (l) Ref. par. 45. - The mounting arrangement of the smaller components is not orderly nor apparently well planned.
- (m) Ref. par. 46. - Grommets are not used where leads are passed through metallic shields.
- (n) Ref. par. 47. - The hook-up wire insulation does not appear to be sufficiently impervious to moisture.
- (o) Ref. par. 48. - Special wrenches necessary for servicing are not mounted in a conveniently accessible location on the chassis.
- (p) Ref. par. 49. - The intermediate-frequency amplifier shielding cans do not appear satisfactory as they do not insure a stable, low-resistance contact to ground, they may be loosened by vibration and do not provide adequate clearances to the wiring within.
- (q) Ref. par. 50. - No protective cases are provided with the input meter and the wire-wound volume control to prevent damage by salt spray.
- (r) Ref. par. 51. - Some dependence is placed on solder for mechanical support of small components and of hook-up wire.
- (s) Ref. par. 52. - The phone jacks do not conform to Navy specifications.
- (t) Ref. par. 53. - The dynamotor is not shock mounted on the frame of the Receiver.
- (u) Ref. par. 54. - The concentric line employed within the Receiver does not appear to be appropriate for signal-frequency currents.
- (v) Ref. par. 55. - The copper coupling strap connecting to the diode converter tube in the type P540-PI tuning unit is not sufficiently well secured nor mechanically stable.

- (w) Ref. par. 56. - No consistent scheme of color coding appears to have been adopted for hook-up wiring.
- (x) Ref. par. 56. - All components are not suitably marked to indicate their positions in the circuit.
- (y) Ref. par. 57. - The cylindrical securing dog below the lower right-hand corner of the receiver front panel is mounted on a stud having a cotter pin with sharp edges which might injure the hands of operators.
- (z) Ref. par. 58. - The nameplate does not conform to Naval specifications.
- (aa) Ref. par. 59. - The dial light and power switch do not function during operation on 250-volt and 6-volt external power supply.
- (bb) Ref. par. 37. - The intermediate-frequency signal rejection characteristics of the Receiver are poor.
- (cc) Ref. par. 22. - The low frequency limit of the Receiver appears to be approximately 75 megacycles instead of 70 megacycles as indicated in reference (e) and on the front panel of the tuning unit type P540-P1.
- (dd) Ref. par. 28. - A strong signal may produce many responses in the Receiver. This greatly complicates the reception and identification of weaker signals even at frequencies far removed from the strong interfering signal.
- (ee) Ref. par. 60. - The cabinet does not appear sufficiently sturdy or well braced.
- (ff) Ref. par. 26. - The converter tuning circuit of the type P540-P1 tuning unit does not resonate properly over the entire tuning band of the unit.
- (gg) Ref. par. 38. - A considerable amount of microphonic noise output was observed during mechanical vibration at certain frequencies.

CONCLUSIONS

63. The Model P540 Receiver is unsuitable for Navy intercept work when compared in convenience and speed of operation with Navy receivers covering frequencies up to 30 Mc. However, no other equipment is known to be available for the frequency range 75 - 1030 Mc and therefore the subject Receiver has a certain stop-gap value in indicating the presence of signals in this band and making checks on their frequencies under good conditions until improved equipment, preferably of a panoramic nature, becomes available.

64. In general, the construction of the Receiver is sturdy and appears mechanically adapted to Naval aircraft service with certain exceptions such as the failure to operate at low temperatures because of slippage of the main tuning control drive belt.

65. The Receiver cannot be conveniently precalibrated for more rapid searching work because of the lack of a scale on the converter circuit tuning control (marked "antenna tuning" on the panel).

66. The presence of numerous responses to each signal makes positive and rapid frequency determinations slow under ideal conditions and difficult or perhaps impossible in the presence of many signals having similar modulation.

67. Electrically, the Receiver did not appear to be suited to give a long life of trouble-free operation because of apparent short service life of the type 955 heterodyne oscillator tube. The crystal converter appears fragile and its life of reliable service under Naval operating conditions has not been determined.

68. In spite of its many disqualifications and limitations, the Receiver would appear to have value in establishing the presence of enemy transmissions within the frequency range 75 - 1030 megacycles.

69. Although the Receiver is intended for intercept service involving rapid tuning and ready estimates of signal frequencies, it is not at all well adapted for this purpose. However, it is recognized that the design of oscillator and mixer circuits covering wide frequency ranges at the ultra-high-frequencies available in this Receiver represents a definite achievement.

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TABLE 1

U.H.F. Receiver Type P540, Serial No. 102, Made by General Radio Co.

Sensitivity and Multiple-Response Characteristics

Checked by General Radio Signal Generators Type P522A, Serial No. 101 and Model 804-B, Serial No. 206 - 30% modulated at 400 cycles. Receiver fed through the coaxial line furnished with the generator, with one side of the line of the P522A generator shorted at its termination. 7 db signal/carrier noise ratio. Average output carrier noise level approximately .04 volt. Maximum audio gain. Output Meter: Ballantine Model 300, Serial No. 194, across 600-ohm load. Antenna trimmed when possible at each setting. Ref. par. 9, 20, and 28.

<u>Signal Generator Frequency Mc</u>	<u>Order of Receiver Oscillator Harmonic</u>	<u>Receiver Oscillator Fundamental Freq. Mc</u>	<u>Sensitivity Microvolts</u>
<u>Preselector P540-P1</u>			
75	1	105	55
135	1	105	15
110	1	140	18
170	1	140	18
140	1	170	12
200	1	170	28
170	1	200	18
230	1	200	40
240	1	270	40
*300	1	270	35
*310	1	340	35
<u>Preselector P540-P2</u>			
300	2	165	55
360	2	165	50
360	2	195	46
420	2	195	145
420	2	225	145
480	2	225	105

*Antenna tuning control does not trim properly at these frequencies.

(continued)

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TABLE 1 (Continued)

<u>Signal Generator Frequency Mc</u>	<u>Order of Receiver Oscillator Harmonic</u>	<u>Receiver Oscillator Fundamental Freq. Mc</u>	<u>Sensitivity Microvolts</u>
<u>Preselector P540-P2 (Continued)</u>			
480	2	255	87
540	2	255	35
540	2	285	49
600	2	285	58
600	2	315	79
660	2	315	80
660	2	345	55
720	2	345	98
720	2	375	120
780	2	375	200
780	2	405	170
840	2	405	58
840	2	435	78
900	2	435	170
900	2	465	400
970	2	470	198
1030	2	500	12,000
Multiple Responses Taken at 310 Mc on Signal Generator			
310	1	310	28
310	1	280	23
310		295	13,000
310		253	140,000
310		169	50
310		139	60
310		113	900

Many other responses were present when a strong signal was introduced.

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TABLE 2

Flight Test Data

<u>Receiver Dial Frequency Mc</u>	<u>Modulation Frequency Cycles</u>	<u>Frequency Difference Kc</u>	<u>Oscillator Harmonic</u>	<u>Signal Frequency Mc</u>
<u>Low Frequency Unit</u>				
105	1000	keying V's		
110	1600			
117	1000	weak		
121	60	20	3rd	393
141	60			
142	60			
159	1000	60	1st	189
219	1000			
174	1600	60	1st	204
234	1600			
181	60	16(15)	4th	694*
197	60			
<u>High Frequency Unit</u>				
160	1000	60	1st	190
220	1000			
176	1600	60	1st	206
236	1600			
333	1600	30	2nd	696
363	1600			
366	60	64(60)	1st	396
430	60			

*not known to be on.

During the flight test, Radar equipments at the Naval Research Laboratory were known to be transmitting on the following frequencies:

114,	195,	204
395,	700,	880 Mc.

TABLE 3

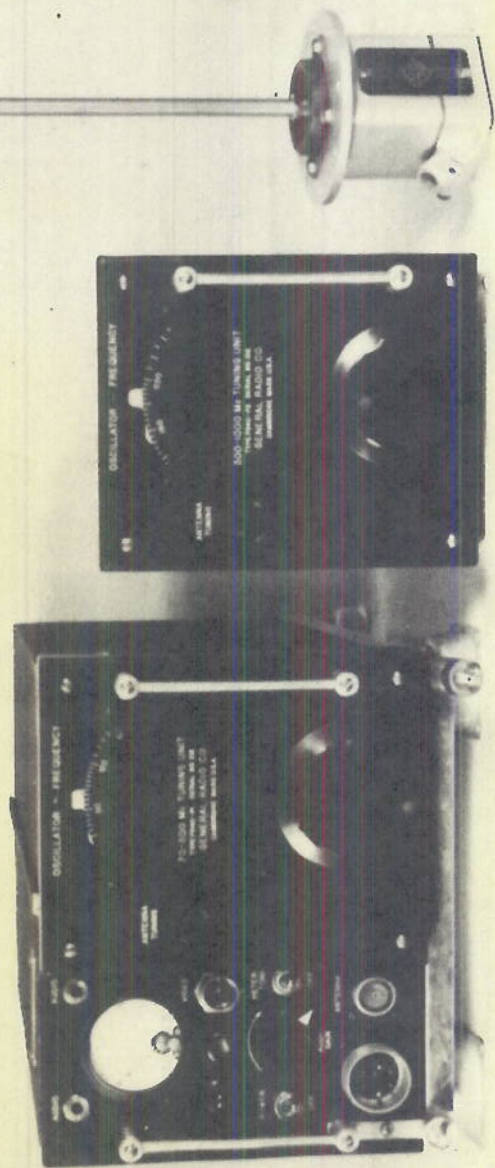
Dimensions of General Radio Type P540 Receiver

Overall dimensions, including chassis locking devices and mounting feet.

Length: 24 inches
 Width : 11-1/8
 Height: 9-1/4
 Overall Volume : 2500 cu. in.

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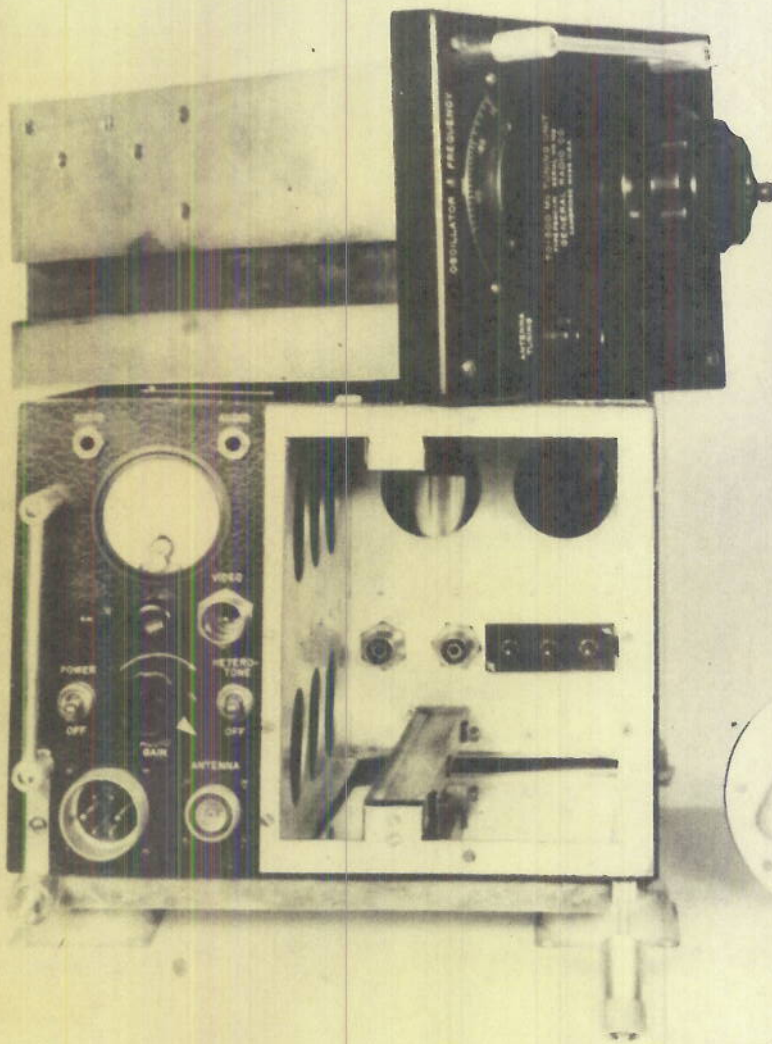




1. This unit is used for the purpose of receiving and transmitting signals in the frequency range of 500 to 10,000 Mc. It is a variable frequency unit and is used for the purpose of receiving and transmitting signals in the frequency range of 500 to 10,000 Mc.

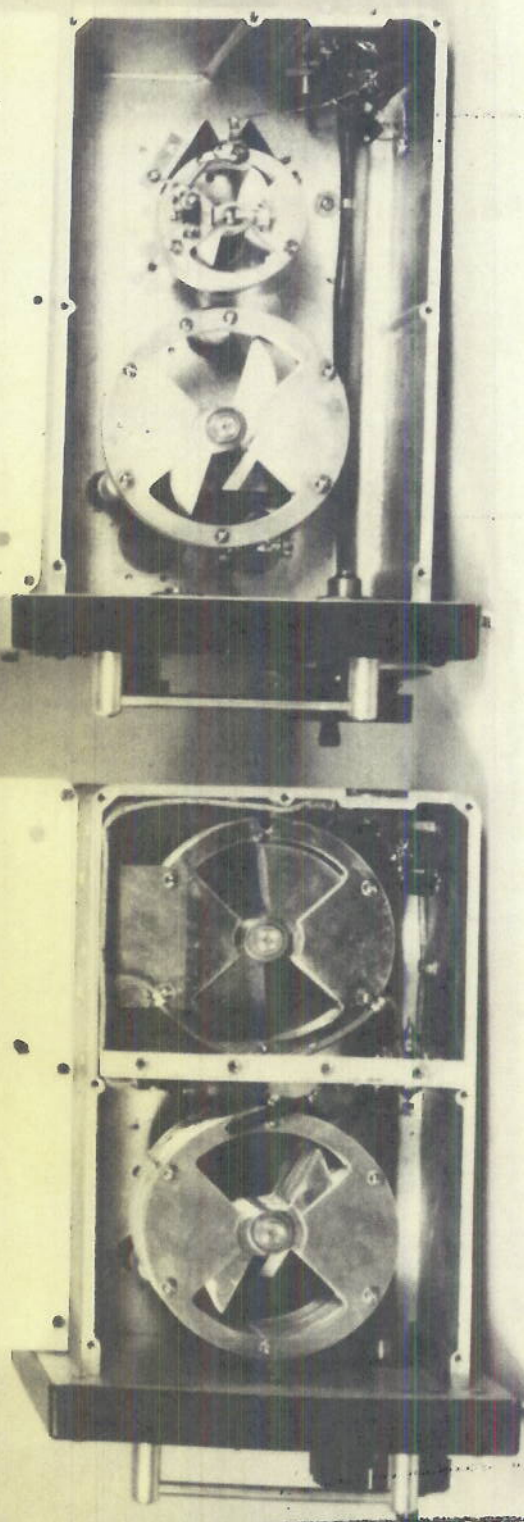
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PLATE I



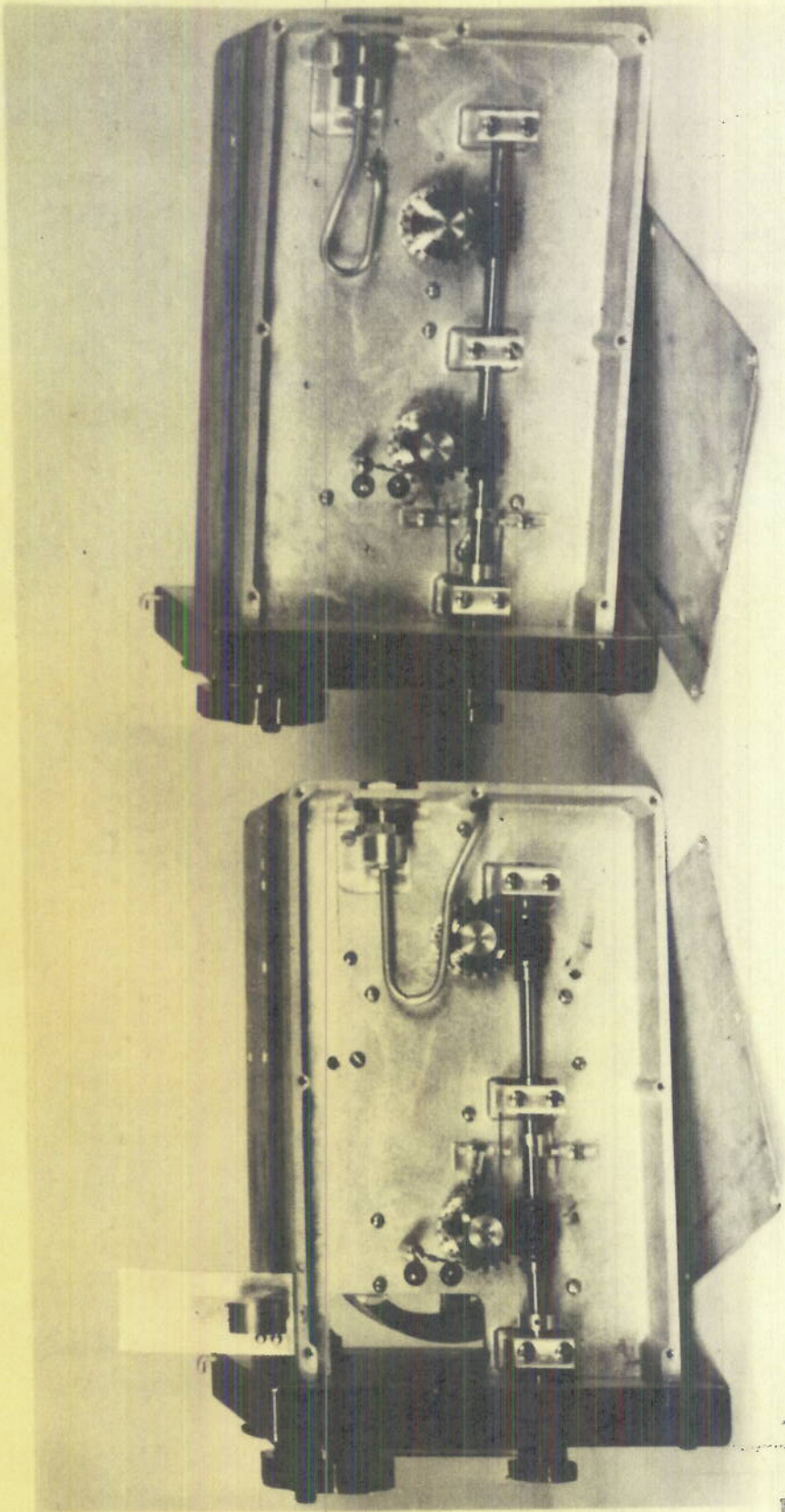
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PLATE 2



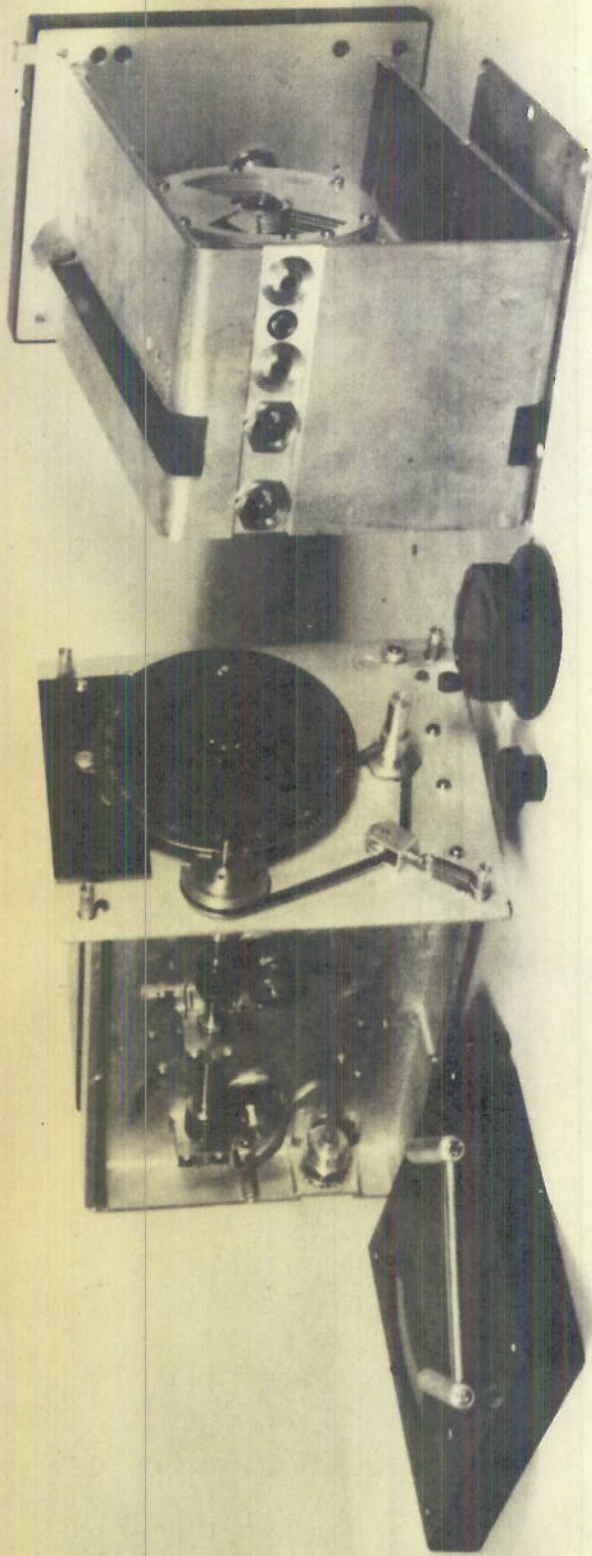
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PLATE 3



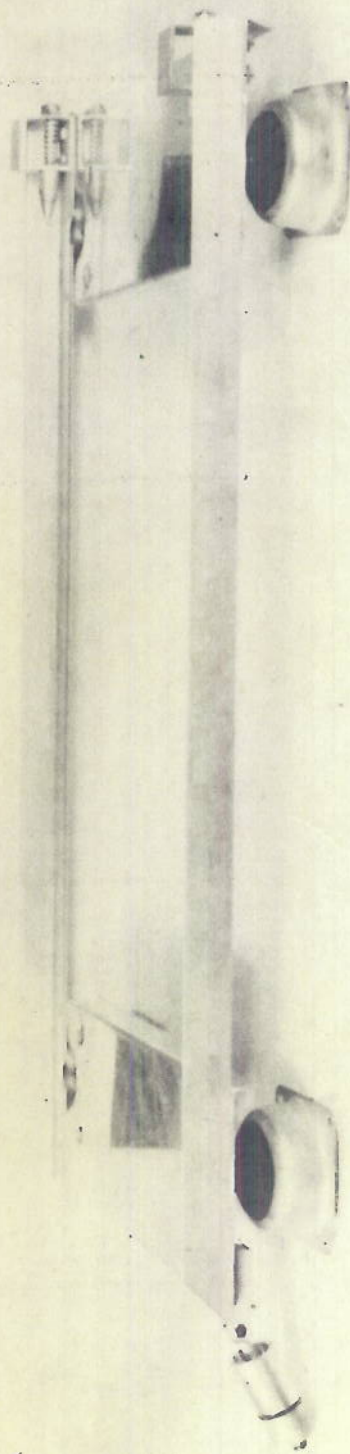
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PLATE 4



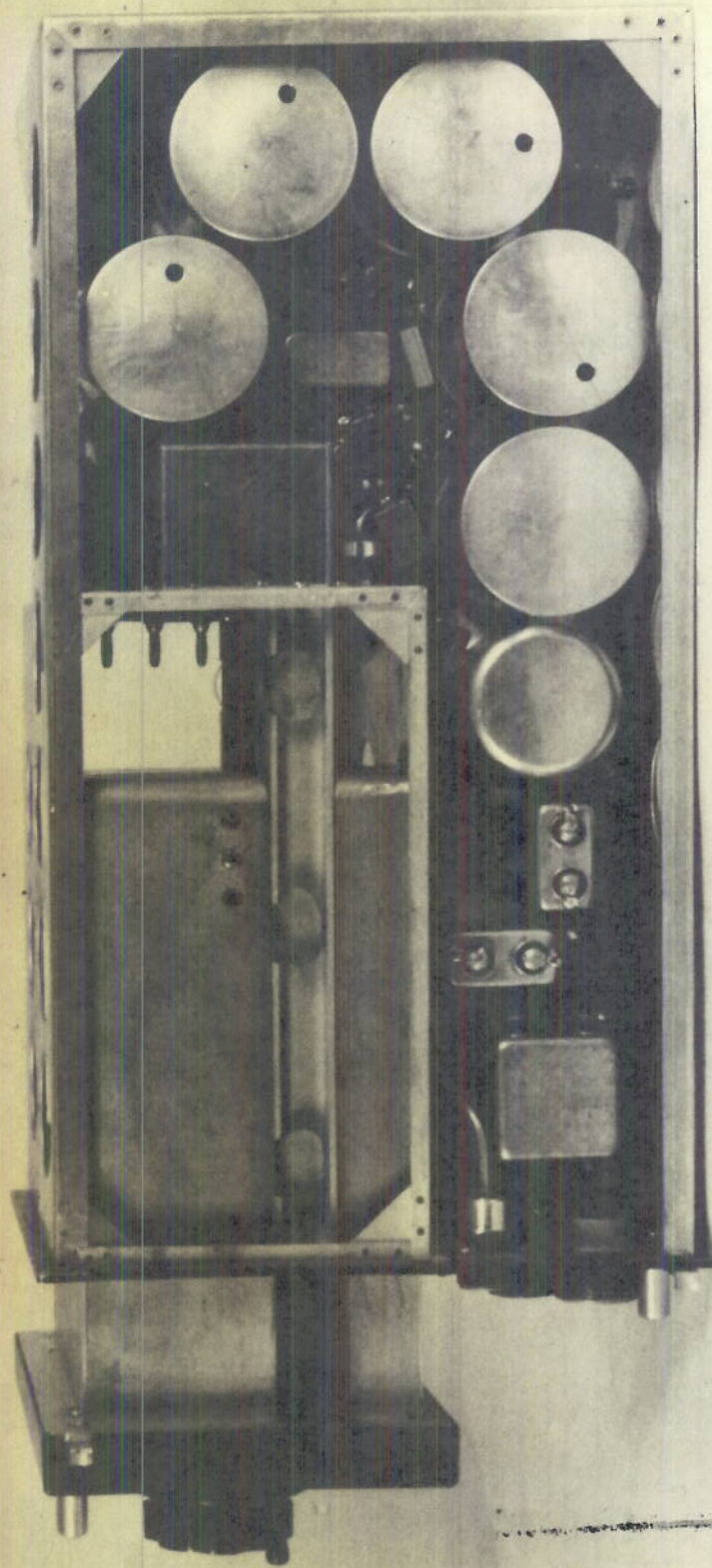
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PLATE 5



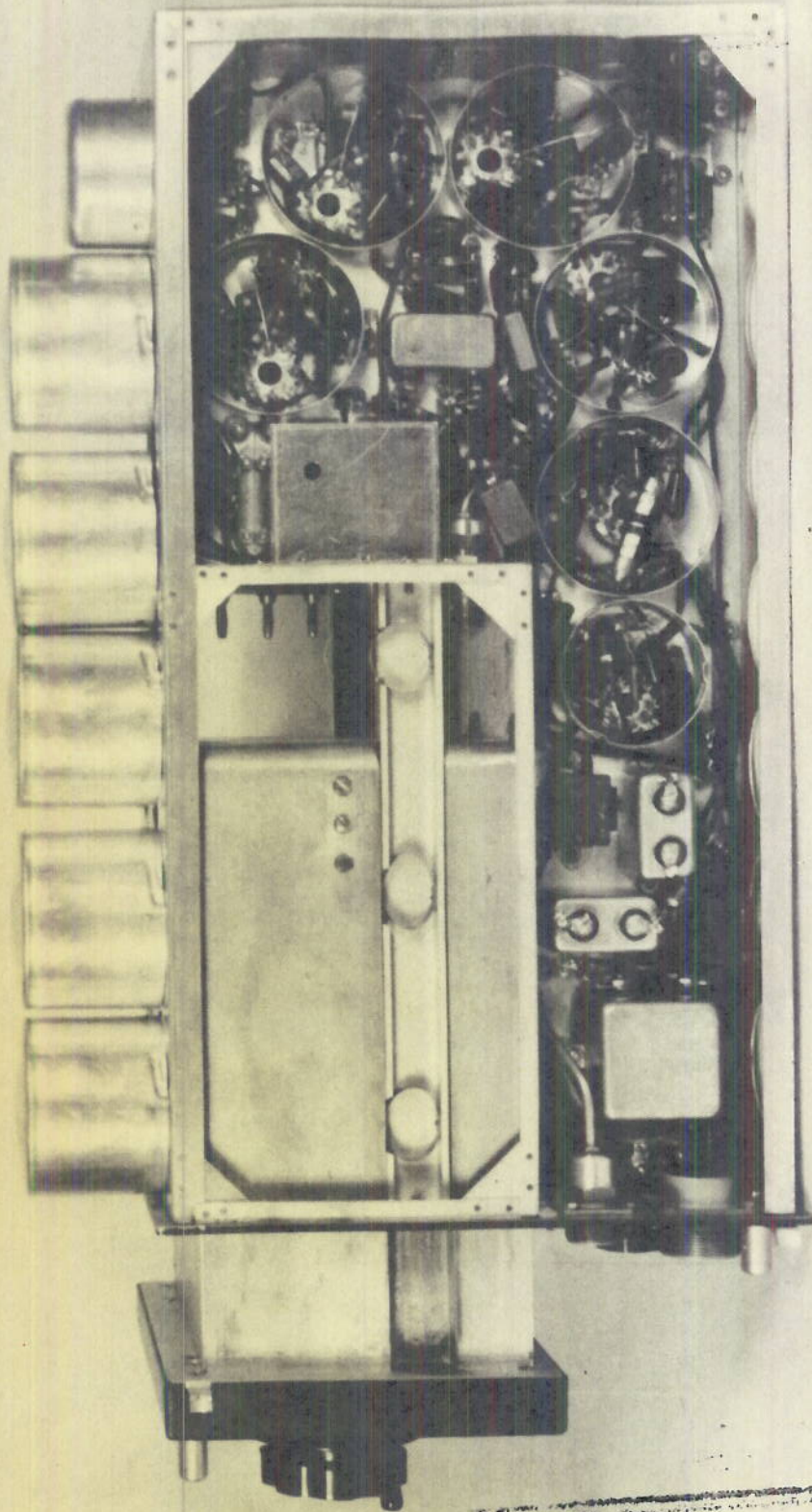
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PLATE 6



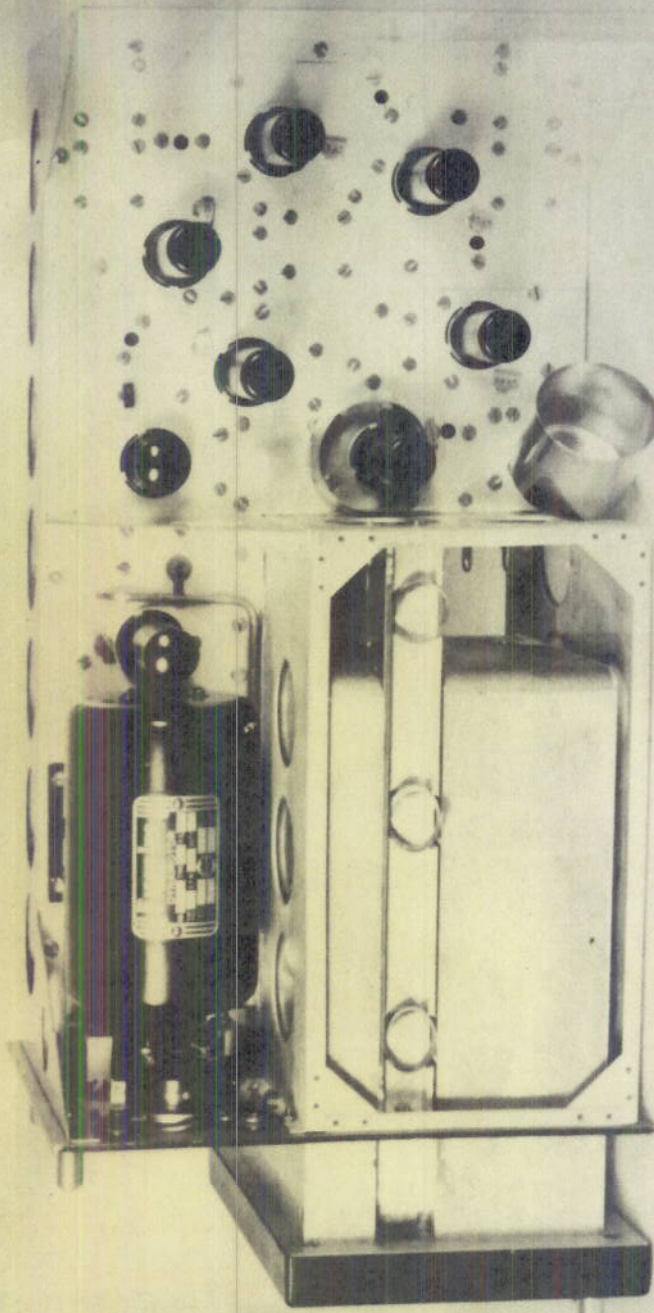
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PLATE 7



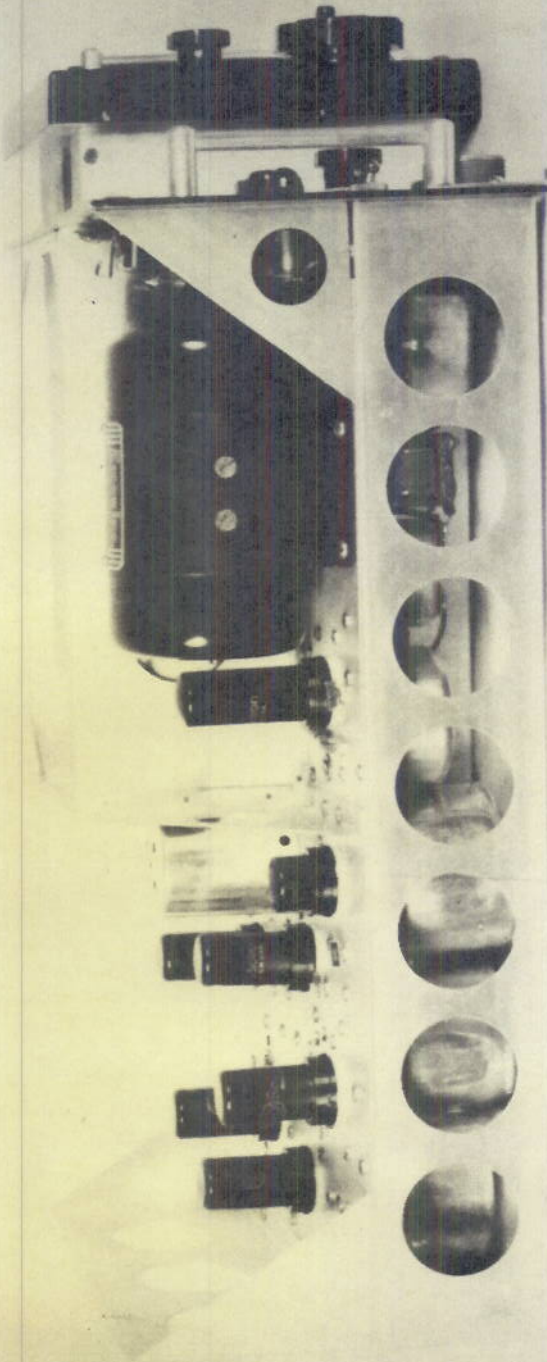
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PLATE 8



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PLATE 9

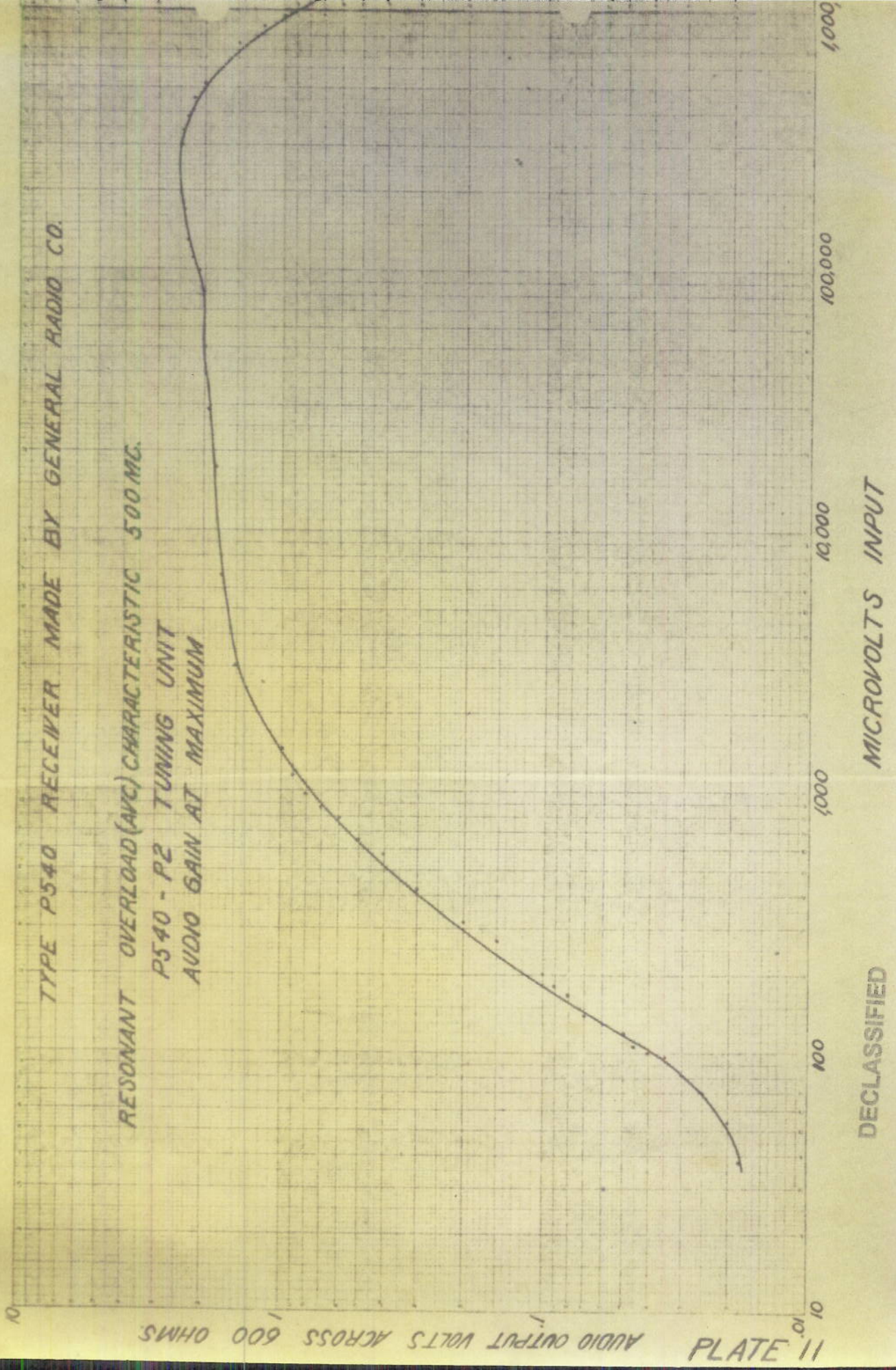


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PLATE 10

TYPE P540 RECEIVER MADE BY GENERAL RADIO CO.

RESONANT OVERLOAD (AVC) CHARACTERISTIC 500 MC.
P540 - P2 TUNING UNIT
AUDIO GAIN AT MAXIMUM



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MICROVOLTS INPUT