[redacted]

R-2392

FR-2392

[redacted]

COPY NO. 71

1 November 1944

NRL Report R-2392
Problem S45R-S

DECLASSIFIED

Navy Department

Report on

Investigation of Anti-Jam Receivers

for Search Radar

Naval Research Laboratory

Anacostia Station

Washington, D. C.

No. of Pages: Text: 37 Tables: 4 Appendix: 2 Plates: 85

Authorization: BuShips letter S-S67/36(485-J) Ser. 2184 to NRL of 18 March 1942.

Prepared by: T. H. Chambers
T.H. Chambers, Contract Engineer.

Submitted by: R. C. Guthrie
R.C. Guthrie, Head of Search Radar Section.

Reviewed by:
A. Hoyt Taylor, Supt. of Radio Division.

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

[redacted]

DECLASSIFIED

DECLASSIFIED

Distribution List

1 Commander-in-Chief, U.S. Fleet, Code F45, Navy Department, Washington, 25, D.C.
1 Chief of Naval Operations, Code Op-20-S, Navy Department, Washington, D.C.
1 Chief of Naval Operations, Code Op-16-1-V, Navy Department, Washington, 25, D.C.
2 Chief of Naval Operations, Code Op-16-FA-1 (for transmission 1 copy to Alusna, London; 1 copy retain).
5 Chief of the Bureau of Ships, Navy Department, Washington, 25, D.C. (1 copy for Code 938, 1 copy for Code 920, 1 copy for Code 919, and other distribution as desired).
1 Chief of the Bureau of Aeronautics, Code Aer-E-3143, Navy Department, Washington 25, D.C.
1 Chief of the Bureau of Ordnance, Navy Department, Code Re4f, Washington, 25, D.C.
1 Coordinator of Research and Development, Navy Department, Washington, 25, D.C.
1 Commander-in-Chief, Pacific Fleet, Fleet Post Office, San Francisco, Calif.
2 Commander, 7th Fleet, Fleet P.O., San Francisco, California.
1 Commander, 8th Fleet, Fleet P.O., New York, New York.
1 Commander, 12th Fleet, Fleet P.O., New York, New York.
1 Officer-in-Charge Post Graduate School, U.S. Naval Academy, Annapolis, Maryland.
1 Commanding Officer, Radio Materiel School, Anacostia, D.C. Att: Code 493A
1 Director, Naval Radio and Sound Laboratory, San Diego, California.
1 Commandant, U.S. Marine Corps, Plans and Policies Division, Washington, D.C.
10 Military Intelligence Service, Att: Distribution Branch, Room 2C800, Pentagon Bldg., Washington, D.C.
1 Air Communications Officer, Army Air Force, Project Status Section, Room 5D176, Pentagon Bldg., Washington, D.C.
3 British Admiralty Delegation, Room 3030, Navy Department, Washington, D.C. Att: Lt. Comdr. J.H. Buscombe, RNVR (for transmission to Admiralty Signal Establishment.)
4 Royal Air Force Delegation, Room 717, 1424 - 16th Street, N.W., Washington, D.C. Att: Director of Signals (for transmission 1 copy to TRE London, 3 copies to RCM Board, London).

1 British Army Staff, Grafton Hotel, Room 528, 1139 Connecticut Ave., N.W., Washington, D.C. Att: Col. A.J. Fisher (for transmission to A.D.R.D.E.).
1 Joint Intelligence Committee, Canadian Joint Staff, 2222 S Street, N.W., Washington, D.C.
2 New Zealand Air Mission, Room 2503 Munitions Building, Washington, D.C. Att: Squadron Leader A.W. Stockwell.
1 NDRC, Division 15, 1 River Road, Schenectady, New York.
2 OSRD, Liaison Office, Room 724, Dupont Circle Bldg., Washington, 25, D.C. (1 copy for transmission to ABL-15, 1 copy retain).
1 Navy Liaison Office, Radio Research Laboratory, Harvard University, Cambridge, Massachusetts.

[redacted]

DECLASSIFIED

Distribution List (Cont'd)

1 Navy Liaison Office, Radiation Laboratory, MIT, Cambridge, Mass.
1 Naval Representative, JEIA, c/o Joint Communications Board, Room 2103 Munitions Building, Washington, D.C.

[redacted]

ABSTRACT

This report covers the work done at this laboratory during the past year, on anti-jam receivers for search radar equipments.

The first part of the report covers the development of a standard test procedure to be used in the testing of all a-j receivers handled at this laboratory. The second part covers the investigation of the a-j characteristics of the PPI with a view to determining what characteristics the system as a whole, as well as the PPI itself, must possess if the PPI is to perform well in the presence of jamming. This is followed by three parts covering the work done on three specific systems. The SC-3 was thoroughly investigated and field changes recommended to bring it up to date in a-j performance. Several models of the receiver for the AN/TPS-1B Marine Radar System were tested during its development by Bell Telephone Laboratories, and recommendations for improvements were made. The original receiver for the XBF-1 system, under development at this laboratory, was tested and a new receiver for this system was built and tested in order to test several new back-bias systems and compare their performance. A great deal has been learned of the fundamentals of anti jamming during this work and these fundamentals are discussed as they come up in the work. The final part contains a summary of the design features necessary in an a-j receiver together with references to specific earlier divisions of the report in which the discussions of particular requirements occur.

[redacted]

DECLASSIFIED

Table of Contents

[redacted]

DECLASSIFIED

Table of Contents (Cont'd)

[redacted]

DECLASSIFIED

Table of Contents (Cont'd)

[redacted]

DECLASSIFIED

Table of Contents (Cont'd)

1. INTRODUCTION.

1-1. Authorization.

1-1-1. The work of this problem, as applied to the "A" scope, was conducted under the authorization of NRL problem S45R-S in accordance with reference (a) in the list of references which follows the text.

1-1-2. The extension of this problem to cover work on the PPI was authorized by the letter of reference (b) in the list of references which follows the text.

1-2. References.

1-2-1. Other references pertinent to the problem or to special phases of it are included as references (c) to (k) in the list of references which follows the text.

1-3. Problem.

1-3-1. Up to the present time there has been no standard procedure for testing and comparing a-j receivers for search radar equipments. The present work was undertaken both to develop and to standardize on such a procedure for use at this laboratory, and at the same time to extend the a-j work to cover the PPI.

1-3-2. The development of this test procedure involved an investigation of the fundamentals of anti jamming, in order to determine what receiver characteristics are important to a-j performance and how they are likely to vary. This study of fundamentals was then, quite logically, extended to the development of better receivers and to a better understanding of present receivers and their short-comings.

1-3-3. A form of reporting the data taken in the tests had also to be developed. This form had to make it possible to describe entirely the a-j properties of a receiver with a minimum of complexity and to make it possible to evaluate its performance without excessive study of a large number of curves.

1-4. Search Versus Fire Control.

1-4-1. Attention should be called to the fact that the work described in this report is intended to be applied only to receivers for search equipments and does not necessarily apply to receivers for fire control equipments. It is true that the basic requirements for the two systems are similar; however, the use of lobe-switching and the accuracy requirements of fire control equipment place much more stringent requirements on the receiver. As a result, entirely different test procedures, which will not be dealt with here, must be used to determine the suitability of a receiver to fire control service.

[redacted]

1-5. Theoretical Considerations.

1-5-1. It is immediately apparent that there are three characteristics of a jamming signal with respect to which an a-j receiver must be tested. These are:

(a) Jamming Frequency (relative to radar frequency).
(b) Jamming Level.
(c) Jamming Modulation Type.

1-5-2. Experience has shown that it is extremely difficult to tune a jammer on frequency. This difficulty is the result of several factors; the tendency of the high power of the jammer to mask the weak radar signal and make it difficult to distinguish, the frequency modulation and frequency drift of the jammer and the complexity of its controls, the lack of suitable receiving equipment of the "panoramic" type for use in setting jammers on frequency, the frequency drift in available "setting-on" receivers, and the frequency modulation on the radar pulse signal. Because of these difficulties zero-beat jamming will seldom if ever be encountered. Thus it is as important, if not more important, to test the receiver with off-frequency jamming as with on-frequency jamming.

1-5-3. Little need be said about the necessity of testing with various levels of jamming. It is only necessary to set a maximum level up to which the receiver should be tested. This maximum level should be sufficiently high to include the levels likely to be encountered with future higher powered jammers. We may calculate theoretically this probable maximum by means of the equation:

$$(1)\ \text{Received Jamming Power} = \frac{P_j\ G_j\ G_r\ h_r^2\ h_j^2}{r^4}$$

where:

P_j = Jammer Power, watts (within receiver pass band).

G_j = Power Gain of jammer antenna.

G_r = Power Gain of receiver antenna.

h_r = Height of receiver antenna in feet.

h_j = Height of jammer antenna in feet.

r = Distance from receiver to jammer in feet.

[redacted]

Assume that the maximum for each of these factors will be of the order of:

$P_j = 1000$ watts.

$G_j = 10$

$G_r = 150.$

$h_r = 150$ feet

$h_j = 100$ feet.

And the minimum range likely to be encountered in jamming directed against search radars will be:

$r = 10{,}000$ yards.

(This minimum range does not hold in the case of fire control equipments. Much shorter minimum ranges will be encountered in jamming directed against them).

Calculating received power from equation (1) gives:

$P_{max} = .00042$ watts.

Converting to voltage gives:

$E_{max} = \sqrt{PR} = .14$ volts

where $R = 50$ ohms.

Thus the maximum voltage likely to be encountered is of the order of 100 mv.

1-5-4. A consideration of the types of signals to be used for test reveals an infinite variety of possible combinations. It therefore becomes a problem of selecting a small number of types which will accurately describe the receivers a-j characteristics and still keep the amount of time required to make the test at a minimum. It is immediately apparent that a test with cw will be necessary to test the static overload characteristics of the detector and back-bias (or other overload protection) circuits. Selected values of low and high frequency amplitude-modulated cw, and a complex amplitude-modulated cw signal modulated with the combination of both, will then test the dynamic properties of the system.

1-5-5. It should be noted that no f-m signals are needed for the test. A narrow band f-m signal looks like cw to the back-bias circuits, since they are not frequency selective; and a wide band f-m signal looks like amplitude-modulated cw, since it will swing outside the pass band of the receiver on peak swings.

[redacted]

1-5-6. No tests of performance against "railings" need be included for two reasons. Firstly, they have proven so inefficient for jamming that they are not used to any great extent, and secondly, performance against "railings" is a function of recovery time and can be checked quite simply by a measurement of recovery time.

1-5-7. Recovery time is also the most important factor determining the performance of a receiver against ground, sea and cloud clutter. The use of fast-acting back-bias circuits (IAVC) against these forms of clutter has become one of the most important applications of a-j circuits; and since recovery time determines the "differentiating" action of the receiver against this clutter, it should be measured as an indication of performance in this service.

1-5-8. Recovery time is also important as an indication of performance against high frequency amplitude-modulated cw. In the presence of high frequency amplitude-modulated cw (or "railings") jamming, the receiver will be insensitive to an echo pulse during the positive part of the jamming modulation cycle due to normal limiting. This, however, will not result in a serious loss in sensitivity. The signal will be visible in the negative "holes" between the positive parts of the cycle of jamming modulation, and will be lost only when a positive peak of jamming happens to hit the receiver at the same time that it does. But since the jamming modulation is not synchronized to the radar sweep, these positive peaks will not fall in the same place on successive sweeps, and if the signal is lost on one sweep it will be seen on the next. If, however, the receiver blocks on strong peaks, a portion of the "holes" will be lost due to recovery time, and in receivers where recovery time is long the "holes" may not be long enough for complete recovery, and a very serious loss in sensitivity will result.

1-5-9. It might be of some value to test receivers in the presence of noise modulated jamming. True a-j circuits will not dejam this type of jamming (any circuit that does will improve receiver sensitivity in the unjammed condition and therefore is a "minimum signal" (improving) circuit rather than an a-j device) but they will prevent receiver overload and thus show some improvement against high level jamming. Such a test is not made on receivers at the present time since signal generators which will take wide band random noise modulation are not available.

1-5-10. In summation, the receiver should be tested with jamming of the following general character:

Frequency ----------------	Both on and off frequency
Level --------------------	0 to 100 mv
Modulation Types ---------	cw
	Low frequency amplitude-modulated cw
	High frequency amplitude-modulated cw
	"Complex" amplitude-modulated cw.

[redacted]

[redacted]

1-6. Early Work.

1-6-1. Early work at this laboratory did not give the receivers as complete a test as indicated above. It was customary to test receivers at only two levels (low and high) and to use on-frequency jamming only. CW and amplitude-modulated cw using numerous modulation frequencies were employed (see reference e).

2. MEASURING PROCEDURE - "A" SCOPE.

2-1. Anti-Jam Measurements - General Procedure.

2-1-1. All tests run at this laboratory have been based on the application of a simulated echo signal to the receiver and the measurement of the loss in sensitivity to this simulated echo as jamming is applied.

2-1-2. The receiver is set up and a pulsed r-f signal is applied to it from a signal generator. This generator is a self-pulsed generator with variable pulse rate, variable pulse width, and variable pulse-delay time. A series of such generators has been developed at this laboratory for this and other uses. The generator is set to the pulse repetition rate and the pulse width of the system with which the receiver is to be used. An oscilloscope synchronized to the synchronizing-signal output of the generator is used as indicator, and the pulse delay time is set to place the pulse at a convenient point on its trace. "Jamming" is supplied by another signal generator, generally of the same type as the echo generator, set to deliver cw or amplitude-modulated cw as required. The outputs of the two r-f signal generators are mixed and fed to the receiver by means of a "Tee" fitting.

2-1-3. Minimum detectable signal measurements are made by slowly increasing the simulated echo signal from zero until it is just distinguishable. Several readings are taken in this manner with the pulse delay time being changed between readings to eliminate the observational error which will result if the pulse appears in the same place each time. The average of these readings gives the minimum detectable signal. The same procedure is used whether jamming is or is not present.

2-1-4. The minimum detectable signal is first measured by the method of paragraph 2-1-3 with no jamming applied. This measurement gives the unjammed sensitivity of the receiver, in db referred to an arbitrary level, depending on the losses in the r-f cables and connectors used to connect the generators and receiver. This unjammed sensitivity is taken as the zero level from which the loss in sensitivity is computed for each level of each type of jamming.

[redacted]

2-1-5. The jamming signal under study is then applied and adjusted to the desired level. The minimum visible signal is again determined by the method of paragraph 2-1-3, and the difference between this sensitivity and the unjammed sensitivity gives the loss due to jamming. Since the attenuator on the signal generator reads directly in db, the loss is given in db.

2-2. Test Schedule.

2-2-1. The procedure just outlined is used to determine the loss in sensitivity for each condition of jamming. In all tests the levels of jamming used are as follows:

(a) 10 uv
(b) 100 uv
(c) 1 mv
(d) 10 mv
(e) 100 mv.

The only deviation made from this schedule is when the 100 mv level cannot be reached due to high losses in the cables (and in PPI tests, in the choppers) connecting the jamming generator to the receiver. In this case the highest level that can be reached is used.

2-2-2. The types of jamming used are as follows:

(a) cw
(b) amplitude-modulated cw - Low frequency modulation (approx. rep. rate)
(c) amplitude-modulated cw - High frequency modulation (approx. $\frac{1}{2}$ i-f band width).
(d) amplitude-modulated cw - Complex modulation (both b and c of above).

It is sometimes necessary to reduce the modulating frequency of the high frequency amplitude-modulated cw because of the difficulty of modulating most signal generators at high frequency. In all cases a modulation level of from 25 to 50% is used.

2-2-3. In the first tests made using this procedure three different jammer frequencies were used. These were "zero beat", and the frequencies corresponding to the 6 and 12 db down points on the receiver band-pass characteristic. These three frequencies were called on frequency, off frequency I and off frequency II respectively.

2-3. Presentation of Results.

2-3-1. Data taken in this manner was plotted as shown in Plates 1A to 4B inclusive. It will be noted that all curves are plotted to show loss in sensitivity versus jamming level for each

[redacted]

type of jamming used. This method of plotting is used instead of that in which jam-to-signal ratio is plotted against jam level rather than the absolute value of the loss against the jam level. Since radar performance is dependent on the sensitivity of the receiver, rather than on the j/s ratio, the method of plotting used here probably better describes the usefulness of the receiver. If j/s is needed, it can be obtained quite easily from the scale at the bottom of each set of curves. This scale shows the ratio, in db, of the jam level to the minimum detectable signal in the unjammed condition. The j/s ratio is then the difference between the abscissa and the ordinate of the curve at a given point, since the ordinate actually shows the ratio in db of the minimum detectable signal in the presence of jamming (s) to the minimum detectable signal in the unjammed condition (V_{min}).

Thus:

$$j/V_{min} \text{ (in db)} - s/V_{min} \text{ (in db)} = j/s \text{ (in db)}.$$

2-4. Accuracy of Results.

2-4-1. Data taken by the three-frequency system of paragraph 2-2-3 has shown some rather serious inaccuracies at times. Table 1 shows the mean deviations from a series of repeated tests. It will be noted that in most cases the deviation is of the order of 1 db or less but in several cases it is high, being 2 db in the extreme case.

2-4-2. These errors have been traced to drift in the jammer frequency during the long period of time required to run the complete test. Since the off-frequency curves are taken at points on the receiver pass characteristic where the slope is quite steep the jammer frequency must be maintained constant within extremely close limits to obtain consistent results. It has not proven practical to hold the frequency constant within the required limits, especially on the higher frequency equipments, so, to eliminate this source of error, a new system of testing has been adopted.

2-5. Revision of Test Schedule.

2-5-1. In the new system of testing the loss is measured at a number of points as the jammer is tuned through the receiver pass band. In this case the drift will show up as a shift of the curve as a whole. This shift can then be corrected in plotting since the peak of the loss will always occur at zero beat, and all curves can be plotted to show zero beat at the same frequency. The drift of the generators has been found to be negligible during the time required to make only one run, so no error appears in individual curves.

2-6. Revision of Presentation of Results.

2-6-1. Using the new system of test the loss in sensitivity is plotted as a function of jammer frequency, plotting one

[redacted]

curve for each of the levels at which the receiver is tested. The j/s ratio can be found from these curves by subtracting the loss in sensitivity, as shown by the curve at the point in question, from the value of j/V_{min} corresponding to that curve. The value of j/V_{min} for each curve is given in the legend. Plates 44 to 47 show a set of curves taken in this manner.

2-7. Accuracy of Results of Revised Test Schedule.

2-7-1. Sufficient data has not as yet been taken according to the schedule of section 2-5 to check statistically the probable error; however, indications are that the data taken in this way will be perfectly satisfactory.

2-8. Proposed Further Revision of Test Schedule.

2-8-1. In the light of work to be described in part 9 of this report, it has become apparent that a test of a receiver against amplitude-modulated cw modulated at one or two frequencies does not adequately describe its performance. Some method of testing at various modulation frequencies should be included.

2-8-2. Plate 43 (discussed in paragraphs 7-5-4 and 7-5-5) shows the results of a test of the AN/TPS-1B a-j receiver in which loss in sensitivity is taken as a function of jamming modulation frequency. A curve of this type would be of considerable value in describing the performance of a receiver. As yet, however, curves such as these can not be conveniently taken because of the difficulty of modulating available signal generators at high frequencies (see paragraph 7-5-5).

2-8-3. Work is at present under way at this laboratory to develop a modulated amplifier in which the output of a jamming signal generator will be modulated up to about 2 Mc. A coaxial-line amplifier will be used, with cathode modulation, for frequencies between 500 and 1200 Mcs, while a capacity tuned coaxial-tank amplifier, again with cathode modulation, will be used for the lower frequencies.

2-8-4. When this work has been carried to a successful conclusion, it will be applied to the development of a test procedure to describe adequately the performance of a receiver as a function of the modulation frequency of the applied amplitude-modulated cw jamming.

2-8-5. At present two possible test schedules are under consideration. In the first of these the width and the depth of the zero beat area of the loss curve would be measured and plotted as a function of the modulating frequency. This would necessitate the determination and standardization of the optimum point at which to measure the width of the loss curve.

2-8-6. The other method under consideration is the plotting of two complete loss curves (one at 100 uv and one at 10 mv jam

[redacted]

[redacted]

level) for each of about six different modulation frequencies. These six modulation frequencies would be the PRF, and 1/16, 1/8, 1/4, 1/2, and 1 times the overall bandwidth of the receiver. The data would then be plotted as described in section 2-6 using one sheet for each modulating frequency. For convenience, data would then be taken from these curves and plotted to show directly both depth and width of the zero-beat area.

2-8-7. If either of these test procedures is adopted, the two families of curves at present taken with simple modulation will not be taken. The complex modulation would still be retained using modulating frequencies equal to the PRF and to one-half of the overall bandwidth.

2-9. <u>Tests With Noise Modulated Jamming.</u>

2-9-1. As pointed out in part 1, it would be of some value to test receivers in the presence of noise jamming. It is hoped that the modulated amplified under development will modulate well enough on noise to make it possible to include such a test in the routine testing of receivers.

2-10. <u>Other Measurements Pertinent to A-J Performance.</u>

2-10-1. As a part of each complete test of an a-j receiver several other more or less standard measurements are made. They are as follows:

(a) Overall Bandwidth
(b) Video Characteristics
(c) Stability
(d) Recovery Time.

2-10-2. <u>Overall Bandwidth.</u> At first glance it would seem that the methods of measuring overall bandwidth are so well known to those skilled in the art that they need not be discussed here. However, it must be remembered that a-j receivers possess some rather unusual characteristics, and some rather amazing results may be obtained if special precautions are not taken. Firstly, the standard method using fixed cw input and recording output as the signal is tuned through the receiver pass band cannot be used. Even if the receiver is stable with a meter connected in the detector load (and an unfortunately large number are not) it will not be linear. If output is maintained constant and input varied, this method may be used, but it is not to be recommended since, even though the receiver may appear to be perfectly stable, there may be some regeneration with its consequent narrowing of the band width.

2-10-3. Another possible method is the use of amplitude-modulated cw, reading output on the indicator screen. This

[redacted]

method again may lead to errors since most signal generators, at the frequencies of present radar equipments, have, when "amplitude" modulated, sufficient frequency modulation to give more demodulated output from discriminator action of the sloping sides of the receiver pass band than true detected output from the amplitude modulation component.

2-10-4. The method found most satisfactory at this laboratory is as follows: A long r-f pulse is applied to the receiver and the input signal level necessary to provide a fixed output level is recorded as the signal generator is tuned through the receiver pass band. The pulse used should be about 35 microseconds long so that its main sideband energy will occupy only about 30 kc and will not introduce any appreciable error. The inverse of the required input level is then plotted to give the curve of overall response. This method has been found to give consistent and accurate results.

2-10-5. In any case, regardless of what method is used to make the measurement, there are three points which should be kept in mind. First, the method should not require the connection of extraneous leads to the receiver since these leads are likely to introduce regeneration with its attendant narrowing of the bandwidth. Second, output should be maintained constant and input varied in order to overcome as much as possible the non-linear characteristic inherent in an a-j receiver. Third, the full pass curve should be taken (a measurement of bandwidth at the ½ power points is not enough) to determine the shape of the skirts of the pass band. Plate 59 shows a sample curve.

2-10-6. <u>Video Pass Characteristics</u>. The measurement of video pass characteristics is perfectly straightforward except that, if a short time constant or other video filters are incorporated in the receiver, the characteristic should be measured for each of these as well as for the normal pass. Plate 58 shows a sample curve.

2-10-7. <u>Stability</u>. Stability is checked by first increasing gain to maximum and noting any regeneration. If regeneration is present the noise structure will become much coarser. A high level of jamming is then applied and the gain control turned throughout its range, to check for oscillation in the presence of jamming.

2-10-8. <u>Recovery Time</u>. Recovery time is checked by applying a pulse of 50 to 100 mv level to the receiver and measuring the time for the noise to build up again after the pulse. This pulse should be of the length for which the receiver was designed and the recovery time should be measured from the leading edge of the pulse. Photographs are sometimes made as a graphic record of the recovery of the receiver. Plates 66 and 67 show sample photographs.

2-10-9. <u>Special Tests</u>. Each receiver presents a new and individual problem and in many cases it is necessary to run special tests to show special characteristics of a receiver. Plate 43, which is described in paragraphs 7-5-4 to 7-5-5 inclusive, shows the results of such a special test.

3. MEASURING PROCEDURES - PPI.

3-1. Test Equipment.

3-1-1. The test set-up used in making tests on a PPI is the same as that used for the "A" scope except for two new items that are necessary. The first of these is a PPI type indicator, and the second a PPI Signal Simulator.

3-1-2. The PPI Signal Simulator must receive the outputs of two continuously operating signal generators (one for simulated echo and one for jamming) and chop these signals into a pattern approximating that of an antenna. The requirements placed on this unit are quite severe when it is used to chop a jamming signal. Since the maximum jamming levels fed into it will be of the order of 100 mv and the receivers are sensitive to less than 1 uv, the attenuation of the "chopper" in the off position must be 90 to 100 db. At the same time it is desirable to have low attenuation in the on position since it is desired to test the receiver at as near 100 mv as possible and, in most cases, the signal generator used for jamming will be capable of delivering little more than this 100 mv. A PPI Signal Simulator which has proven satisfactory was developed at this laboratory.

3-1-3. This PPI Signal Simulator, which is shown in Plate 37, consists of two choppers (one for signal and one for jamming), a motor drive system, a Selsyn system for PPI drive and the necessary coaxial r-f fittings. Each chopper consists of a pair of coaxial loops close-spaced in a shielded cavity with a rotating disc between them. This disc is maintained at ground potential for r.f. by close spacing to the shield case. This spacing is about .002 inches, and the resultant high capacity effectively grounds the disc. A circular aperture in the disc allows signal to pass through the chopper during a small portion of its rotation cycle. Coupling between the loops is essentially proportional to area and since the coupling area exposed by the circular aperture of the disc as it passes the circular cavity in which the loops are mounted approximates the directivity pattern of an antenna, the simulated directivity pattern obtained with the chopper closely approximates that of an antenna. Plate 36 shows the construction of the chopper. Plate 35 shows its simulated directivity pattern. It will be noted that the "beam width" is $6\frac{1}{2}$ degrees at the $\frac{1}{2}$ power points. Plates 38 to 40 inclusive are photographs of the parts of the chopper.

3-1-4. The input loop of each chopper is tuned by a coaxial line to increase current in the loop and reduce the loss in the chopper. This coaxial line is loaded with a series inductance and a shunt condenser (made variable to permit tuning) to shorten it mechanically to a convenient physical length. The loop and the coil and tuning condenser may be seen in Plate 40. The output loop has a resistor in series with it to match the line, and the outputs of both choppers are connected together and to the receiver by means of a "Tee" fitting.

[redacted]

3-1-5. The choppers are driven at 4.5 r.p.m. by means of a gear drive. The echo signal chopper has a differential gear in its drive so that its phase may be changed and the echo may be made to appear either in the jammed sector or out of it. The PPI is driven through its normal "synchro" system from a Selsyn generator connected to the jamming chopper. This drive system may be seen in Plate 37.

3-2. Anti-Jam Measurements - General Procedure.

3-2-1. The general test procedure used for the PPI is the same as that used for the "A" scope (par. 2-1-3 to 2-1-5). It has been found necessary, however, to test the receiver both with the echo in the jammed sector and with it in the unjammed sector. This arises from the fact that under some conditions of jamming the dejamming controls on the receiver will be set in such a manner as to adversely affect unjammed performance.

3-3. Test Schedule.

3-3-1. The test schedule for the PPI is the same as, and underwent the same revision as that for the "A" scope (Sections 2-2 and 2-5).

3-4. Presentation of Results.

3-4-1. The presentation of results of PPI tests is the same as, and underwent the same revision as, that for the "A" scope (Sections 2-3 and 2-6). Plates 5A to 16B show a set of curves for PPI tests taken according to the three frequency schedule (Paragraph 2-2-3). No curves are as yet available showing the results of PPI tests taken according to the new schedule of testing throughout the receiver pass band (Section 2-5).

3-5. Accuracy of Results.

3-5-1. Table 2 is a tabulation of mean deviations taken from a series of repeated PPI tests made with the three-frequency system. It will be noted that in most cases the mean deviation is of the order of 1 to 2 db but in a few cases it is greater, being in the extreme case 4 db.

3-5-2. A sufficient number of readings has not as yet been taken by the schedule of paragraph 2-5 to check its accuracy statistically, but it is expected to be satisfactory.

3-6. PPI Performance Tests - Short Method.

3-6-1. Experience at this laboratory has shown that a good check of PPI a-j performance may be obtained without using the somewhat lengthy procedure outlined above.

[redacted]

3-6-2. Part 5 of this report covers a study of the requirements of a PPI for good a-j performance. This study revealed that the performance of the PPI in the presence of jamming will be approximately the same as that of the "A" scope if the following characteristics are satisfactory:

(a) Video Pass Band
(b) Recovery Time
(c) Constancy of Gain with Variation in Jamming Level.

It is therefore possible to check PPI performance by a measurement of these characteristics.

3-6-3. The measurement of video pass band and recovery time were discussed in paragraphs 2-10-6 and 2-10-8 and need not be discussed here. The relative overall gain is measured by measuring the approximate noise height on an oscilloscope at each jam level. Measurements are made using cw jamming and a reading is taken every 10 db as the jam level is increased from 1 uv to 100 mv. It has been customary in the past to measure the constancy of gain with the jamming off frequency about $\frac{1}{2}$ band width (measured to the $\frac{1}{2}$ power points). In future tests it will be measured both at this point and at zero-beat.

4. SINGLE FREQUENCY TESTING.

4-1. Effect of R-F Characteristics on A-J Performance.

4-1-1. Since the characteristics of the r-f system in most a-j receivers has relatively little effect on a-j performance it would be possible to test all receivers at a single r-f system frequency simply by feeding the output of a standard r-f amplifier and converter unit into the i-f amplifier of the receiver under test.

4-2. Simplicity and Accuracy.

4-2-1. Testing in this way would considerably simplify the problem of obtaining suitable signal generators since they would have to operate at only one frequency. At the same time it would improve the validity of a comparison between two receivers since the signal generators would be operating at the same frequency for both receivers and the errors resulting from the change in pulse shape (on the simulated echo generator) and change in modulation characteristics (on the jamming generator) as the frequency is varied, would not have to be dealt with.

4-3. R-F System.

4-3-1. This laboratory is at present working on the design of an r-f system to use in the testing of all receivers at a single frequency. This r-f system will use two r-f amplifier stages using "lighthouse" tubes in capacity-tuned concentric tanks, a converter of

[redacted]

similar design, and an oscillator using a "lighthouse" tube in a capacity tuned re-entrant tank circuit which uses a "leaky" grid-pedestal for field penetration to secure the feedback necessary for oscillation. The entire unit will be tuned to a frequency of about 450 Mc and will deliver 15, 30 or 60 Mc i-f output. It is hoped that sufficient oscillator injection will be available to permit operation at 120 Mc intermediate frequency also.

4-3-2. Sensitivity will be about 7 db and will, if necessary, be reduced to equal that of the receiver's r-f system by putting an attenuator in the antenna lead. Gain will be about 25 db, and will be reduced to equal that of the receiver's r-f system by putting an attenuator in the i-f lead.

5. INVESTIGATION OF THE GENERAL REQUIREMENTS OF A PPI FOR SATISFACTORY A-J PERFORMANCE.

5-1. General Procedure.

5-1-1. An investigation was made of the SC-3 radar system to determine the general requirements necessary in a system for the PPI to perform satisfactorily in the presence of jamming. The entire SC-3 system was first given a complete test according to parts 2 and 3 of this report. Plates 1 to 16, series 3, show the results of this test.

5-2. Constancy of Gain.

5-2-1. An analysis of these curves showed that there was a considerable loss in sensitivity in the unjammed sector when the receiver was adjusted to dejam the jammed echo. Investigation showed that this resulted largely from the fact that the receiver under test lost gain in the presence of jamming. To compensate for this, the gain was increased with the result that, when the equipment moved out of the jammed sector and jamming was removed, gain increased to many times normal and overloaded the system. A curve was then taken of "Loss in Sensitivity Versus Overall Gain" to show the dynamic range of the PPI. This curve is included as Plate 22. With a normal amount of noise showing on the PPI the gain will be running at about 30 on this curve, and thus an increase in gain of more than 6 to 1 will cause considerable loss in sensitivity. If, however, the gain in the jammed condition is reduced to the point where only about ¼ the normal amount of noise is showing, a change in gain of about 25 to 1 can be tolerated. This figure should not, however, be exceeded.

5-2-2. Two methods may be used to limit this change in gain. The first involves operating the tubes at reduced gain under unjammed conditions. If this is done it is possible to design the back-biasing circuits in such a manner as to obtain almost constant gain, regardless of jamming level. The other method is the application of AVC to the video amplifier. This AVC should operate on the video amplifier only, since it may interfere with operation of the back-biasing circuits if applied to i-f amplifier stages.

[redacted]

5-3. Characteristics Necessary in the Video Amplifier.

5-3-1. The video pass band should be as wide as, or wider than that of the receiver overall pass band. Under some conditions of off-frequency jamming the signal will come through the receiver as a beat between the jamming carrier and the pulse carrier. This beat may have a frequency (in Mc) considerably greater than the reciprocal of the pulse length (in Microseconds), and may be lost if the video pass band is not sufficient. The maximum frequency of this beat is determined by the shape of the skirts of the i-f pass characteristic of the receiver, so no general rule can be laid down for it. In the case of an i-f amplifier using single tuned circuits the video pass should be at least as wide as the i-f pass band measured to the 3 db down points. Plate 68 shows photos of the video output of a representative a-j receiver in the presence of off-frequency jamming. The beat note can be seen quite easily in these photos. In one case it is 1.5 Mc and in the other it is 2 Mc. The receiver had an overall pass band of .92 Mc. The one-sided character of this beat note results from the use of d-c reinsertion in the video amplifier.

5-3-2. A wide video pass is also extremely important from the standpoint of definition.

5-3-3. The video amplifier should be protected against blocking, or if allowed to block should have extremely fast recovery (Paragraphs 1-5-7 and 1-5-8).

5-3-4. Protection is best achieved by the use of a short-time-constant video coupling followed by d-c reinsertion. The use of the short-time constant not only helps recovery time after strong echoes but also removes the low frequency energy from long jamming pulses and thus helps dejamming action. D-C reinsertion should be applied following the short time constant to remove the over-swing and prevent its rendering the amplifier insensitive. If a short-time constant video coupling is used in the receiver also, it will be necessary to take precautions against ghost echoes appearing on the PPI. This can best be done by means of complete d-c reinsertion on the first short time constant and by making the second longer than the first.

5-3-5. Sharp limiting should be applied in the video amplifier following the short time constant coupling. The limiter should be set to clip both positive and negative sides of the video signal at the points resulting in maximum sensitivity and should be sufficiently flat to prevent "blooming" of the scope tube on strong signals.

5-4. Interaction of Circuits.

5-4-1. In the present receiver indicator system synchronization was lost completely with the application of a few microvolts (8 uv) of 60 cycle modulated jamming signal. Investigation showed this to be the result of operating the timing circuits in the indicator from the same power supply that operates the receiver video amplifier. When the 60 cycle signal was amplified by this amplifier some 60 cycle

[redacted]

modulation was put on the power supply. This modulation was sufficient to completely destroy the accuracy of the indicator timing circuits. Plates 27 and 28, which are described in paragraph 6-2-1, show this effect. A short-time constant in the detector output circuit cured the trouble.

5-4-2. The present receiver used a separate supply for the i-f stages, so no trouble was encountered from them. However, if a separate supply were not used trouble would probably result, since back-biasing action causes a change in plate current. This change in plate current would undoubtedly modulate the power supply voltage and again react on the timing circuits.

5-5. Clean Design.

5-5-1. Reference (c) relates to the general design considerations of a-j receivers. The necessity of clean design in an a-j receiver cannot be stressed too much. Stability, quick recovery, wide dynamic range and wide range of gain control are absolutely essential. Without these, the advantages of special dejamming circuits cannot be fully realized.

6. INVESTIGATION AND REVISION OF SC-3.

6-1. Preliminary Test.

6-1-1. The SC-3 receiver-indicator and master PPI were set up and given a complete a-j test according to the procedures of parts 2 and 3 of this report. These tests were made using the three frequency system (paragraph 2-2-3). The results are included as Plates 1 to 16, series B.

6-2. Analysis of Results.

6-2-1. The first thing that became apparent during the testing of this system was the very pronounced effect that a very small amount of low frequency modulated jamming has on the synchronization of the PPI. Plates 27 and 28 show this effect. Plate 27, top, shows, in the left-hand half, the effect of 8 uv of 62 cycle modulated jamming. It will be noted that not only are the light and dark sectors very pronounced, but the entire sweep is periodically displaced outwards as is evident from the bulges in the marker. The lower picture on this plate shows the PPI with 1000 uv of jamming applied. In this case the video signal has been removed from the indicator tube grid so that the black sectors are removed and the displacement of the sweep can be seen. It will be noted that the sweep is displaced entirely off the screen. In both the photographs on this plate the right-hand part shows the way the scope should appear. Plate 28 shows two photographs of the PPI in the presence of low frequency modulated jamming at other modulation frequencies. The difficulty was traced to interaction through power supply circuits. When the demodulated low frequency signal passed through the video amplifier, it varied the video amplifier plate current over a

[redacted]

very wide range and this varying current modulated the power supply voltage. The modulation of the power supply voltage in turn destroyed the accuracy of the timing circuits and caused the abnormal PPI operation. For the present tests two 40 microfarad condensers were put across the 150 volt and 300 volt power supply terminals to correct the defect.

6-2-2. The curves of Plates 4 to 16, series B, show a considerable loss in sensitivity in the unjammed sector. This is due largely to the excessive change in gain as the jamming level drops to zero.

6-2-3. The definition of the PPI was found to be very poor. This results from the narrow pass band of the PPI video amplifier (only 100 kc).

6-2-4. Recovery time was found to be very long, being of the order of 2500 yards.

6-2-5. Stability was very bad. With the AVC switch in the short time-constant position the receiver would break into oscillation with about 5 mv of jamming applied.

6-3. Proposed Field Changes.

6-3-1. The receiver was completely revised in an effort to correct the defects of section 6-2. These revisions were then written up as a field change and submitted to the Bureau of Ships (letter of reference g). Plate 23 shows the circuit of the receiver after the field changes have been made. Plates 24 and 25 show the coupling unit and PPI video amplifier after the field changes have been made.

6-3-2. The difficulty described in paragraph 6-2-1 was eliminated by the addition of a short time-constant detector-to-video coupling. This short time-constant completely eliminates the trouble since it removes the demodulated low frequency signal before it enters the video amplifier and thus prevents power supply modulation. The right-hand half of the photographs on Plate 27 show the PPI with the short-time constant in.

6-3-3. The balanced video circuit was removed when this short-time constant was put in. Experience has shown that this balanced video circuit is not as useful as it was expected it would be when it was developed. It is primarily for use against "railings" jamming and, since "railings" are ineffective against an "A" scope, and a good video limiter makes them ineffective against PPI, they are not used to any great extent.

6-3-4. The defects described in paragraphs 6-2-2, 6-2-4, and 6-2-5 were corrected by revision of the back-biasing circuits. Since the design of this receiver a great deal has been learned about back-bias circuits, and in the light of this knowledge the circuits of this receiver were revised to secure better performance.

[redacted]

6-3-5. The definition of the PPI was improved greatly by broadening both its pass band and the pass band of the receiver video amplifier. Plates 19 and 20 show the video pass characteristics of the receiver after the proposed field changes have been made.

6-4. Results.

6-4-1. A final check of the receiver after these field changes had been made showed considerable improvement. The receiver was perfectly stable even with 100 mv of jamming applied and the "AVC" (back-bias) in the short time constant position. The recovery time was reduced to about 700 yards and the ratio of maximum to minimum gain as jamming was applied was reduced to well within the dynamic range of the PPI. A-J performance has been improved as is shown by Plates 1 to 16, series A. It should be noted that the unjammed-sector curves of Plates 5 to 16 do not apply to this receiver. Plates 31 and 32 are photographs of the field-changed receiver.

6-5. Video AVC.

6-5-1. A more complete revision of the video system of a receiver was made to include an AVC system. This AVC helped to limit the change in gain as the jamming level was varied and thus helped to improve performance in the unjammed sector of the PPI. Plates 1 to 16, series A, apply directly to this receiver. Plates 17 and 18 show its video pass characteristics for "A" and PPI scopes respectively. It will be noted that they are somewhat better than for the field-changed unit. Plates 33 and 34 are photographs of this revised receiver, and Plate 26 is a schematic diagram showing the extent of the changes made to it.

6-5-2. It will be seen that the circuit used on the 6SA7 AVC tube is very unusual. It was necessary, in order to keep the polarity of the video signal correct, to use a tube that would not reverse phase. The 6SA7 has an unusual grid characteristic in that the third grid merely diverts current from plate to screen, with the result that grid-screen Gm is the same as grid-plate Gm, but of opposite polarity. Output may therefore be taken from the screen circuit to secure in-phase amplification with only the slight loss in gain due to the degeneration caused by the swinging screen.

6-5-3. The AVC system operated satisfactorily but the overall gain was not sufficient to get the sharp gain-limiting action necessary for a considerable improvement in performance of the system. The available chassis space was not sufficient to permit the installation of the more complex system that would have been required to obtain higher gain and sharper gain-limiting action.

6-6. Conclusions.

6-6-1. The field changes made to this receiver bring it as nearly up to date in a-j features as is possible without constructing a completely new receiver.

[redacted]

6-6-2. The use of an AVC circuit in the video is not of sufficient value to warrant its inclusion. It does somewhat improve performance in the unjammed sector, but in the space available in the present chassis sufficient gain cannot be had to fully utilize an AVC system.

6-7. Nomenclature.

6-7-1. In the present receiver the back-bias circuits have been called "AVC" circuits. This is undoubtedly an unfortunate name. The back-bias circuits are not "AVC" or "AGC" circuits. One of the basic requirements of "AVC" or "AGC" circuits is that the amplifier remain linear to the signal being handled, while the opposite is the case in back-bias circuits. For them to operate the amplifier must be driven beyond cut-off, into the region of class C operation, and hence become non-linear. For this reason the use of the term "AVC" may lead to confusion and is not to be recommended.

7. DEVELOPMENTAL TESTING OF THE AN/TPS-1B A-J RECEIVER.

7-1. General.

7-1-1. Three models of the AN/TPS-1B receiver have been tested at this laboratory and letter reports on these tests have been submitted (references h, j and k). The following is a general summary of this work and is intended to show the general procedure followed in the development of an a-j receiver.

7-2. First Prototype.

7-2-1. The first prototype was brought to this laboratory from Bell Telephone Laboratories (where it was designed and constructed) for test early in April (1944). It had been designed to incorporate amplified back-bias, but it was found that this back-bias was applied to too many stages from a single amplifier tube. This resulted in a reduction of gain in all stages without driving any stage into class C operation, so that the system operated as an "AVC" system rather than as a back-bias system. This difficulty was cured by disconnecting all but the last two i-f stages from the back-bias amplifier and putting non-amplified back-bias on the stages thus disconnected. Considerable difficulty was experienced with oscillation in the amplified back-bias loop, but when this was cleared up the receiver was satisfactory.

7-2-2. The difficulty experienced with oscillation in the amplified back-bias loop led to the belief that non-amplified back-bias on all stages would be more satisfactory. For this reason it was decided to use it throughout on the second prototype.

7-3. Second Prototype.

7-3-1. The second prototype was brought to this laboratory for test early in May (1944). It used non-amplified back-bias throughout but was found, even so, to be unstable. A study of this instability revealed that it was the result of the combination of two effects. First, the i-f amplifier had considerable gain at video frequency, and second, the decoupling in the power circuits was insufficient at these video frequencies, with the result that the i-f amplifier oscillated at video frequency. This was easily remedied by the addition of several condensers to the power supply decoupling circuits. These condensers were of about ½ microfarad capacitance, and after they were added the receiver was perfectly stable even with 200 mv of jamming applied to its r-f input terminals and with maximum gain.

7-3-2. The receiver was then tested according to Part 2 and Section 3-6 of this report. The results of this test showed the receiver to be excellent when compared to other receivers that have been tested at this laboratory. It was therefore, decided to use this system for the final receiver.

7-4. Third Prototype.

7-4-1. The third prototype was brought to this laboratory for test early in September (1944). This unit was in general the same as the second, differing only in that it had been "cleaned up" and was in a form suitable for manufacture. The purpose of this test was to secure data on the receiver actually to be manufactured. The test deviated from this purpose to the extent that two slight modifications were made to the video system to improve performance.

7-5. A-J Measurements - "A" Scope.

7-5-1. The overall pass characteristic was measured by the method of paragraph 2-10-4, and is included as Plate 41.

7-5-2. The a-j characteristics were measured by the method of Part 2 of this report, using the schedule of paragraph 2-5-1, and are included as Plates 44 to 47. Since measurements on the two previous prototypes had been made according to the schedule of paragraph 2-2-3 and plotted in the form described in paragraph 2-3-1, the necessary data was taken from Plates 44 to 47 and re-plotted in the form of paragraph 2-3-1, so that this receiver could be compared directly with the previous prototypes. Plates 48 to 51 show this re-plotted data.

7-5-3. A check of stability showed no sign whatsoever of regeneration, at any gain setting, and with any jamming level up to the test maximum of 200 mv applied to the r-f input.

7-5-4. The video pass characteristics were measured and found to be satisfactory but permitting some improvement. The short time-constant detector-to-video coupling in this receiver uses a 2 mh choke in parallel with a 150 uuf condenser. This condenser is used to lower the resonant frequency of the circuit to match the pulse-component frequencies better. It has been found at this laboratory that the

[redacted]

capacitance in this circuit should be kept as low as possible. The circuit was therefore tested with this condenser removed. Plate 42 shows the video response curve of this circuit as well as that of the original. Plate 43 shows the unjammed sensitivity and the loss in sensitivity as a function of modulation frequency. The loss was measured using 1 mv of jamming 200 kc off frequency. It will be noted that the revised short time-constant gives an improvement in performance of 1 to 3 db depending on modulation frequency.

7-5-5. The curves of Plate 43 show what is apparently a reduction in the loss in sensitivity as the modulation frequency is increased beyond about 200 kc. This is not a true reduction in loss. It results from the fact that the generator used as jammer did not modulate well above about 200 kc. This gave a progressive reduction in percent modulation as the modulating frequency was raised. This does not, however, affect the validity of the results since only the relative losses at each frequency are of interest.

7-5-6. In reporting the tests of the second prototype of this receiver, it was recommended that d-c reinsertion be applied following the short time-constant by operating the first video tube at zero bias. This is done in the present receiver but no protective resistor for the diode formed by grid and cathode of the video amplifier tube has been put in. This resistor, which must be put in to secure correct operation, should be in series with the grid, and should be between the short time-constant circuit and the video amplifier tube. Plate 42 shows the video response curve after it has been put in. Plate 43 shows the unjammed sensitivity and the loss in sensitivity as a function of modulation frequency. It will be noted that the inclusion of this resistor gives an improvement in performance of 2 to 5 db over the first change and of 3 to 6.5 db over the unchanged receiver. Unjammed sensitivity is improved about 1 db. These results are in line with what would be expected from previous experience.

7-6. A-J Measurements - PPI.

7-6-1. No direct tests of a-j performance on a PPI were made. A check was made by the method of section 3-6. The curve showing gain versus jamming level is included as Plate 52.

7-7. Limit Tubes.

7-7-1. This receiver was also tested with limit tubes in the i-f amplifier. Two sets of limit tubes were used. One set had the maximum input capacity allowable under JAN specifications, and the other had the minimum Gm allowable. The results of these tests are included in Plates 52, 53, and 54. They show that tube characteristics have little or no effect on receiver performance.

7-8. Results.

7-8-1. The a-j characteristics of this receiver are shown in Plates 44 to 51. The loss shown by these curves is in

[redacted]

line with what would be expected from experience with other a-j receivers. The change in gain as jamming level is changed is well within the dynamic range of a PPI and is entirely satisfactory. Stability and recovery time are excellent.

7-8-2. Plates 44 to 47 show two peaks of loss displaced about 2 Mc on either side of the zero-beat peak. These peaks, or "side lobes" if we borrow from antenna terminology, are the result of skirts on the i-f pass characteristic which are not sufficiently steep. There is enough pass 2 Mc off frequency to allow the jamming signal to pass through the i-f amplifier and beat with the echo carrier in the detector, producing a beat note pulse of too high a frequency to pass through the video amplifier.

8. TESTING OF THE XBF-1 MODEL NO. 1 RECEIVER.

8-1. General.

8-1-1. Two models of the XBF-1 Model No. 1 receiver were tested at this laboratory. The first of these was a test model used in the development of the circuits for the final model. The second was the final receiver to be used in the XBF-1 system.

8-2. Description of the Receiver.

8-2-1. The XBF-1 Model No. 1 receiver uses two r-f stages, converter, oscillator, eight i-f stages employing non-amplified back-bias and variable bandwidth, diode detector, and a single stage of video amplification. Plates 69 to 71 show front, top and bottom views of the receiver. Plate 65 shows a schematic diagram of the receiver circuit.

8-2-2. While the pre-amplifier is not strictly within the scope of this paper, it merits a description because of its novel features. It consists of two r-f stages, the oscillator, and the converter; all are tuned by means of a single tuning control on the front panel. Trimmers are provided on the side of the unit for alignment. The two r-f stages are identical and consist of capacity-tuned concentric tank circuits using "lighthouse" tube amplifiers. The converter uses a similar circuit for its grid-cathode tank, and its plate circuit feeds into the first i-f stage. The oscillator, also using a "lighthouse" tube, consists of a capacity tuned re-entrant tank using a "leaky" grid pedestal for field penetration to obtain the feedback necessary for oscillation. It is so proportioned that it will track the r-f and converter stages directly. Plates 72 to 74 show photographs of the pre-amplifier partially disassembled. The general arrangement of the parts can be seen in these photographs.

8-2-3. The i-f amplifier consists of eight stages using 6AC7 amplifier tubes with non-amplified back-bias applied to all stages but the first, which is a "standard" stage. Gain is controlled

[redacted]

by controlling grid bias on the second and third stages. Provision is also made for applying a delayed sensitivity control to these grids. All i-f transformers are double tuned, using slug tuning, with the exception of the third, which is a single-tuned variable-bandwidth transformer. Its bandwidth is controlled by controlling the resistance across it, and gain is simultaneously equalized by changing the cathode resistor of the second stage.

8-2-4. The detector is a 6H6 diode which supplies negative output and is coupled directly to a 6AC7 video amplifier. A relay, operated by either a local or a remote switch, connects a small choke across the detector output for "inductive" short time-constant. D-C reinsertion is accomplished by operating the grid of the first video tube at zero bias.

8-3. <u>Developmental Model.</u>

8-3-1. The final circuit of the developmental model of this receiver was identical with that of the final receiver except for the pre-amplifier. Since development work on the pre-amplifier was not yet complete, the receiver was tested using another pre-amplifier similar in gain and sensitivity characteristics but lacking the single-dial-tuning feature.

8-3-2. This receiver was given a complete test according to Parts 2 and 3 of this paper. This test was made using the three-frequency schedule of paragraph 2-2-3. It showed the a-j characteristics to be satisfactory when compared to other receivers tested at this laboratory.

8-4. <u>A-J Measurements - "A" Scope - Final Model.</u>

8-4-1. The video pass characteristics were measured and are shown in Plate 58.

8-4-2. The overall pass was measured by the method of paragraph 2-10-4 and is shown in Plate 59.

8-4-3. Complete a-j tests were run in accordance with the procedure of Part 2 of this report. The results of these are included as Plates 60 to 63.

8-4-4. Servo-scope traces showing receiver recovery time were photographed. These photographs are included as Plates 66 and 67.

8-5. <u>A-J Measurements - PPI - Final Model.</u>

8-5-1. No direct tests of a-j performance on a PPI were made. However, PPI performance was checked by the method of Section 3-6. The curve showing gain versus jam level is included as Plate 64.

[redacted]

8-6. Results - Final Model.

8-6-1. The receiver was excellent from an a-j standpoint. "A" scope performance was as good as that of any other receiver yet tested. With various jamming levels the increase or decrease in gain did not exceed 25%. This promises excellent PPI performance.

8-6-2. Plates 66 and 67 show the recovery of the receiver from a strong pulse (50 mv). These photographs show no indication whatsoever of delay in recovery, there being "noise" showing on the trailing edge of the pulse. Plate 66, lower, shows the recovery from a 5 usec pulse when the short time-constant (F.T.C.) is in the circuit. In this case the receiver is essentially back-to-normal 4 usec after the start of the pulse.

8-7. Points of Special Interest.

8-7-1. It will be noted that the loss in sensitivity shown for cw jamming is a maximum of 24 db. This loss is partly due to bad pulse shape from the simulated-echo generator. The direct detector-to-video coupling used in the receiver necessitated the use of the short time-constant to prevent overloading of the video by the d-c output of the detector. The pulse from the simulated-echo generator had a long build-up time and therefore suffered a loss in the short-time-constant (F.T.C.) coupling circuit. The loss using an actual echo pulse with its short build-up time was 5 to 10 db less than that shown in the curves.

8-7-2. It will also be noted that the curves are distinctly assymetric. This results from the assymetry of the overall pass characteristic as shown in Plate 59.

8-7-3. The peaks of loss which appear displaced about 2½ Mc from the zero-beat peak are the result of the video pass being somewhat narrow for the particular i-f characteristic. In the presence of off-frequency cw jamming the pulse comes through as a beat between the echo and the jamming. If the jamming is strong and several megacycles off frequency it will get through to the detector and cause this beat, which, unless the video pass is sufficient, will not pass through the video amplifier. Plate 68 shows two photographs in which this beat is visible. The one-sided character of the beat is due to the use of d-c reinsertion in the video amplifier. In this receiver there is a slight loss in the "side lobes" resulting from this effect. But it is not sufficient to warrant an increase in video bandwidth.

9. TESTING OF THE XBF-1 MODEL NO. 2 RECEIVER.

9-1. General.

9-1-1. Although the XBF-1 Model No. 1 receiver was entirely satisfactory, a new test receiver, the XBF-1 Model No. 2 has been built in the hope of learning more about and improving the performance in the zero-beat area. This receiver was tested with several systems of amplified back-bias (recently developed at this laboratory) which showed promise of giving this improved performance in the zero-beat area without the instability often encountered in amplified-back-bias systems.

9-2. Description of the XBF-1 Model No. 2 Receiver.

9-2-1. The receiver, XBF-1 Model No. 2, uses eight i-f stages and a diode detector with permanently connected short-time-constant (F.T.C.) coupling to its single-stage video amplifier. The F.T.C. is left permanently connected only for the sake of simplicity, and in the final receiver it will be controlled by a switch. No r-f unit has been built into the test-model receiver.

9-2-2. The first two i-f stages used 6AC7 tubes and were normal stages, unprotected except for abnormally high cathode resistors (470 ohms), with the resulting high grid-bias and slight amount of non-amplified back-bias. The last six i-f stages were arranged in pairs as described in Sections 9-5, 9-8, or 9-9 according to the back-bias system being tested. The detector was a 6H6 diode and fed through an "inductive" short time-constant circuit into a single stage video amplifier using a 6AC7.

9-3. A-J Measurements - "A" Scope.

9-3-1. In each case the receiver was set up for test using an r-f unit from an obsolete receiver. This r-f unit, which was used simply because it happened to be available, had gain and sensitivity characteristics similar to those of the Model No. 1 receiver. The remainder of the test set-up was as described in paragraph 2-1-2.

9-3-2. A-J tests were run on each system by the methods of Part 2 of this report.

9-3-3. Overall bandwidth was measured by the method of paragraph 2-10-4.

9-3-4. The video pass characteristics were measured and plotted. Although no switch is provided to disconnect the fast time constant in the test model, one will be incorporated in the final model, so this test was made both with and without F.T.C. coupling.

9-3-5. Recovery time of each system was checked on a servo-scope.

9-3-6. A check of stability was made on each system according to the method of paragraph 2-10-7.

9-4. A-J Measurements - PPI.

9-4-1. No direct tests of performance on a PPI were made. Instead the change in gain was measured for each system to check the expected PPI performance.

[redacted]

9-5. <u>First Back-Bias System.</u>

9-5-1. Plate 83 shows a pair of stages using the first system tested. Operation is as follows: When a strong signal is applied, the second tube will draw more current and increase its cathode bias. When this happens the potential of the diode cathode will rise in a positive direction and will cut off the diode current, allowing the first tube to bias itself back as its plate current charges the condenser in its cathode circuit. The first tube cannot be overloaded because of this back-biasing action, while the second will not overload because of its relatively high bias and remote cut-off characteristic and its small amount of non-amplified back-bias action. When the signal is removed the second tube will return to normal, and with the drop in cathode voltage the diode will again begin to conduct and will discharge the condenser in the cathode of the first tube through the 300 ohm resistor. Since the condenser is discharged through the 300 ohm resistor and diode (total resistance of about 500 ohms) instead of through the 2200 ohm resistor normally used in non-amplified back-bias, it may be made 4 or 5 times larger without increasing recovery time. At the same time the use of this larger condenser increases build-up time. Since the loss at and in the vicinity of zero beat is a function of build-up time, performance in this area is improved. As in non-amplified systems, the operating voltages of the tubes and the circuit constants may be adjusted to give extremely low change in gain as the jamming is applied.

9-5-2. This circuit has shown no tendency toward regeneration or instability. The only possible feedback path is through the diode, and since the by-pass capacitors have a reactance of the order of 2 ohms at the intermediate frequency there is little chance of feedback here. Furthermore, a choke, parallel-resonant at the intermediate frequency, may be put in this lead without detrimental effect.

9-5-3. The curves of Plates 78 to 81, showing the results of the a-j tests, show the performance to be about the same as that of the XBF-1 Model No. 1. The part of the curves showing loss in sensitivity in the vicinity of zero beat are narrower and shallower for this system than for the Model No. 1 receiver when the jamming is cw or low frequency mcw. This is as was expected, but the curves are broader and deeper for high-frequency mcw and for the combination low- and high-frequency mcw. Examination shows this to be the result of the longer build-up time. When high-frequency mcw is encountered, the longer build-up time reduces the degenerative effect of the back-bias circuits on the modulation components of the jamming and thus reduces the dejamming action.

9-5-4. The performance at or near zero beat is not of great importance since it is highly improbable that jamming in this region will ever be encountered. On the other hand, high-frequency mcw is already in use by the enemy and is very likely to be encountered. For this reason it is probably best to use the shorter build-up time even though it does entail a slight sacrifice in performance in the zero-beat area.

[redacted]

9-5-5. Plate 82 shows a maximum ratio of gains of 5/1 up to 10 mv jamming level. This is not as good as the Model No. 1 receiver but is still satisfactory. Stage gain of these i-f stages was slightly better than for the non-amplified back-bias stages of the Model No. 1 receiver.

9-6. Revision of First System.

9-6-1. Revisions were made to the receiver to check performance with faster build-up. Condensers marked C in the circuit diagram (Plate 83) were changed to 500 uuf. This gave a build-up time about equal to that of the model No. 1 receiver and a recovery time about 1/5 as long.

9-6-2. The receiver was then re-tested. The results of this test showed the curves to be slightly broadened and deepened on cw so that they were about the same as the curves of the Model No. 1 receiver.

9-7. Re-Check With Non-Amplified Back-Bias.

9-7-1. To ascertain definitely that there was no unforeseen circuit peculiarity that was affecting the results of these tests, the receiver was converted to the circuit of the Model No. 1 receiver and again checked. The results of this check were the same as the results given for the Model No. 1 receiver in Part 8 (except for the absence of "side lobes" on the loss curves).

9-8. Second Back-Bias System.

9-8-1. The last six i-f stages were then revised to use the pairs shown in Plate 84. Operation of this revised pair of tubes is as follows. When a signal is applied the second tube will draw a small amount of grid current and develop a small amount of grid bias across condenser C_1 and resistor R_1 (ordinary grid detection). This grid resistor is purposely made high enough and the grid condenser made low enough that appreciable signal power will not be dissipated and the amplifier will continue to amplify. However, the negative bias developed on the grid will bias the tube back and prevent appreciable swing into the positive grid region of the tube's characteristic. At the same time, this negative bias will reduce cathode current, cause the cathode to go negative, and bias back the grid of the first tube. When the signal is removed, the bias on the second tube will drop to zero, the second tube will recover to normal, and at the same time return the first tube to normal. Build-up and recovery times are equal, since the second tube, with its grid returned to cathode, acts like a high resistance instead of as a cathode follower.

9-8-2. The complete results obtained with the second system will not be given here since they show no appreciable improvement over the Model No. 1 receiver. Furthermore, this second circuit showed signs of slight instability, and therefore should not be used in any

[redacted]

receiver for fleet service. It is essential that a receiver, especially an a-j receiver, be absolutely stable. Thus, no circuit which shows a tendency toward regeneration should be used, especially if its performance characteristics can be duplicated by a circuit which is inherently stable.

9-8-3. Like the first system tried (Section 9-5), this system had slightly more gain per stage (with the same constancy of gain as jamming is applied) than the non-amplified back-bias system of the Model No. 1 receiver.

9-9. <u>Third Back-Bias System.</u>

9-9-1. The last six i-f stages of the receiver were then revised to use the pairs of stages of Plate 85. Operation of these pairs is as follows: When a signal is applied, the second tube will bias itself back in the normal manner for a non-amplified back-bias stage, but in so doing it will also bias the first tube back through the common cathode connection. When the signal is removed both tubes will return to normal. The use of a power tube as the second tube allows a relatively small resistor to be used in the cathode circuit; this in turn allows the use of a relatively large by-pass condenser without sacrificing fast recovery. In this circuit the recovery time is slower than the build-up time since the second tube is acting as a cathode follower. It is not, however, as much greater as in the case of non-amplified back-bias since the second tube has a remote cut-off characteristic and will not be completely cut off on recovery, as will the non-amplified stage.

9-9-2. This system also showed approximately the same a-j characteristics as the non-amplified system used in the Model No. 1 receiver. Like the other two amplified back-bias systems (described in Sections 9-5 and 9-8) it had more gain per stage with the same constancy of gain as the jamming level was varied.

9-10. <u>Revisions of Third System.</u>

9-10-1. The third system was then revised to use 6AC7's throughout. This revision showed no improvement over the system as tried originally (Section 9-9).

9-10-2. A second revision was then made converting the system to use 6AG7's throughout. This revision showed some improvement over the original third system. However, this improvement was not sufficient to be of any consequence and did not make this system enough better than the non-amplified system of the Model No. 1 receiver to warrant its use.

9-11. <u>Zero-Beat Performance and the Cathode Condenser.</u>

9-11-1. In all work up to this time it had been assumed (without proof) that the zero-beat performance was a function of the size of the cathode condenser. The tests so far described did not

[redacted]

seem to show this to be the case, so it was decided to check it directly.

9-11-2. The amplifier was set up using non-amplified back-bias as in the Model No. 1 receiver and tested with cathode condensers of three different sizes. No attention was paid to recovery time in this test since no practical use was to be made of the amplifier with the large condensers in the cathode circuits.

9-11-3. Table III shows the results of this test. It shows quite clearly that the zero-beat performance is improved as the size of the condenser is increased, however, this improvement is a very slow function of condenser size.

9-12. Conclusions.

9-12-1. The zero-beat performance of the receiver cannot be noticeably improved by the use of amplified back-bias. A slight improvement can be obtained but zero-beat performance is a very slow function of condenser size and the increase in condenser size that can be realized is limited by recovery time to such an extent that the improvement obtainable in practice is very small. The use of amplified back-bias will generally reduce effective recovery resistance by a factor of only about 6 to 1, and this much increase in condenser capacity will give an improvement in zero-beat performance of only about 5 db. At the same time, since the build-up time is increased in order to obtain this slight improvement, a loss will have to be taken in performance against high frequency amplitude-modulated cw.

9-12-2. If the build-up time (and hence the zero beat performance) of an amplified back-bias system is made the same as that of a non-amplified back-bias system, the recovery time can be made much shorter. This being the case, it would be expected that the performance against high frequency amplitude-modulated cw could be improved. The test of Section 9-6 indicates that this is not true. It is not, however, a conclusive test. As soon as suitable generators are available, whose characteristics make reliable measurements using high frequency amplitude-modulated cw possible, further tests will be run on this subject.

9-13. Points of Special Interest.

9-13-1. "Side Lobes" of Loss. Plates 78 to 81 show no "side lobes" of loss as appear on Plates 60 to 63. A comparison of Plates 76 and 59 shows the reason for this. The Model No. 2 receiver has very steep skirts on the overall pass characteristic and thus rejects the off-frequency jamming which would produce the beats shown in Plate 68. On the other hand the skirts of the pass band of the Model No. 1 receiver are very broad and allow the jamming to pass and cause this beat note which is rejected by the video.

[redacted]

9-13-2. Apparent Gain in Sensitivity in the Presence of Jamming. The curves of Plates 78 to 81 show areas of apparent gain in sensitivity in the presence of jamming between .5 and 1.0 Mc off frequency. These are not true gains but are the result of a slow build-up of the echo generator pulse. This slow build-up caused a loss in the F.T.C. detector-to-video coupling. This is a loss which would not be suffered by a pulse with sharp build-up, such as an actual echo pulse. Thus, the true zero of the curves would be three to five db above the zero established by the tests. This loss due to slow build-up is not suffered in the presence of jamming .5 to 1.0 Mc off frequency, since the jamming beats with the echo to produce a beat note which falls within the pass band of the video amplifier (Plate 76 - Short Time Constant In).

10. AMPLIFIED VERSUS NON-AMPLIFIED BACK-BIAS.

The work covered in Parts 7 to 9 of this report led to the general conclusion that non-amplified back-bias is as satisfactory as amplified back-bias in its performance characteristics and perhaps more satisfactory in other respects. The following is a summary of the factors leading to this conclusion.

10-1. Constancy of Gain.

10-1-1. Plate 64 shows the variation in gain of the XBF-1 Model No. 1 receiver to be about plus or minus 25% as the jamming level is increased from zero to 50 mv. This variation is about the same as that obtained in the best receiver using amplified back-bias that has yet been tested at this laboratory. It not only indicates that performance on a PPI will be excellent, but also that such a system using non-amplified back-bias could be adapted to fire-control equipment.

10-2. Number of Tubes.

10-2-1. The gain per stage in a non-amplified back-bias system will generally be lower than in an amplified back-bias system. This will result in the use in a larger number of i-f stages in some cases. In others, however, the improvement in gain secured by the use of amplified back-bias is so small that not even one stage can be dispensed with.

10-2-2. In the case where fewer stages can be used the number of tubes will not be smaller. In most amplified back-bias systems several extra back-bias amplifier tubes must be used, with the result that the final number of tubes will be about the same in either case. A receiver similar to the XBF-1 Model No. 1, but using amplified back-bias used only six i-f stages but had a total of eight tubes in the i-f amplifier.

10-3. Recovery Time.

10-3-1. Plates 66 and 67 clearly show that the recovery time in a non-amplified back-bias system can be made extremely short (Paragraph 8-6-2).

[redacted]

10-4. Zero Beat Performance.

10-4-1. The zero-beat performance of an amplified back-bias system can be improved only about 5 db over that of a non-amplified system, and this entails a loss in performance against high frequency amplitude--modulated cw.

10-5. High Frequency Amplitude-Modulated CW Performance.

10-5-1. As yet tests do not show any improvement in the performance of an amplified back-bias system against high-frequency amplitude-modulated cw over the performance of a non-amplified system. These tests are not as yet conclusive, but do indicate, at least, that if any improvement actually can be had it will be very small.

10-6. Stability.

10-6-1. Non-amplified back-bias circuits are inherently very stable because of the slight degenerative effect of the high-value cathode resistors. On the other hand, amplified back-bias circuits are likely to be unstable because of the feedback path created by the back-bias loop.

10-7. Simplicity.

10-7-1. One of the most important advantages of non-amplified back-bias is its simplicity and ease of servicing. All stages are identical, except for the application of gain control to some, and are perfectly standard except for the high cathode resistor and the biasing of the grid. In many systems the grid is returned to ground with no positive bias being necessary, and in that case the only difference from a standard i-f stage is in the value of the cathode resistor. This simplicity greatly reduces the problem encountered by fleet radar technicians in understanding and speedily servicing equipment.

10-8. Controls.

10-8-1. Operation of the a-j controls in a properly designed non-amplified back-bias system is extremely simple. The gain control is non-critical and no overload takes place at even the highest jam levels for any setting. Thus, the operation of this control is normal even when heavily jammed, and it is not really an a-j control. The receiver will generally have a short time constant detector-to-video coupling, and the switch which operates it will be the only true a-j control. It will not, of course, be possible to suffer a loss in sensitivity due to improper adjustment of this control in the absence of jamming since unjammed performance is not adversely affected by its being turned on.

10-8-2. If it were not for the necessity of using an echo box on the system in tuning it up, it would be possible to make a receiver such as the XBF-1 Model No. 1 entirely automatic in its de-jamming action. It would only be necessary to leave the F.T.C. in at

[redacted]

all times. The receiver would then automatically dejam all echoes to the best of its ability and without suffering any loss to unjammed echoes.

10-9. Anti-Clutter Performance.

10-9-1. The use of fast-acting back-bias circuits (IAVC) to work through ground, sea and cloud clutter is one of the most important uses of a-j circuits. The performance of a receiver against this clutter is determined largely by its recovery time.

10-9-2. The recovery time of a non-amplified back-bias system can be made extremely short (Paragraph 8-6-2) and thus it will perform extremely well in this respect. Theoretically, the recovery time of an amplified back-bias system can be made shorter than that of a non-amplified system using the same build-up time. It would therefore be assumed that it would perform better in this service. Preliminary tests, which unfortunately cannot be termed "conclusive", indicate that this is not the case, that, in fact, non-amplified will perform just as well against clutter as amplified will.

10-9-3. Plate 66 shows the recovery of a typical non-amplified back-bias system. It will be seen that recovery is complete 4 usec after the start of a 5 usec pulse.

11. SUMMARY.

Although all the points to be brought out in this part have been brought out and discussed earlier in this report, they will, for convenience, be collected and presented here, with references to the earlier divisions of the report in which a complete discussion of these points will be found.

11-1. A-J Receiver Design Considerations.

11-1-1. I-F Pass Characteristics. The skirts of the i-f pass should be attenuated as much as possible. The use of an excessively wide pass in most stages with only one or two stages to limit the pass band is not recommended. Refer to paragraphs 8-7-3, and 9-13-1.

11-1-2. Back-Bias. If overload protection is secured by means of back-bias protection of the i-f amplifier, non-amplified back-bias will perform as well as if not better than amplified. Refer to Part 10.

11-1-3. Change in Gain. The circuit constants and operating voltages in the back-biased amplifiers should be adjusted to give the least possible change in gain as jamming is applied. Refer to Section 5-2; Paragraph 6-5-1.

11-1-4. Back-Bias Time Constant. The back-bias time constant should be made as short as possible consistent with good unjammed performance. Refer to Section 9-11; Paragraph 11-2-2.

11-1-5. Recovery Time. Recovery time should be made as short as possible. Refer to Paragraphs 1-5-7 and 1-5-8.

11-1-6. Detector. In most cases a diode detector is most satisfactory because of its linear characteristic and wide dynamic range.

11-1-7. Video Pass Band. The video pass band for both "A" scope and PPI video amplifiers should be wide enough to provide good definition and to pass the beat between off-frequency jamming and echo carrier when there is insufficient attenuation in the skirts of the i-f pass. This will often be considerably greater (Mc) than the reciprocal of the pulse length (usec).

If the first video stage is operated with d-c reinsertion applied to its grid so that the beat is detected, the video pass may be narrowed to normal in its plate circuit and in following circuits. However, in all cases the pass band of the detector and video input circuits should be wide enough to pass any beats that may occur. Refer to Paragraphs 5-3-1 and 5-3-2; Paragraph 8-7-3.

11-1-8. Short Time Constant Detector to Video Coupling (F.T.C.). A short time constant detector to video coupling is of great value as an a-j measure and will generally be incorporated in an a-j receiver. An inductive short time constant gives somewhat better performance than a resistance-capacity short time constant. Refer to Reference (f).

11-1-9. D-C Re-Insertion. When a short-time-constant detector-to-video coupling is used, complete d-c re-insertion should be applied. Refer to Paragraph 7-5-6.

11-1-10. Balanced Video. The balanced video circuit used in early a-j receivers has not proven sufficiently useful to warrant its inclusion in future receivers. Refer to Paragraph 6-3-3.

11-1-11. Blocking of PPI Video Amplifier. The PPI video amplifier, like the "A" scope video system should be protected against blocking on strong signals. Refer to Paragraph 5-3-3 and 5-3-4.

11-1-12. Video Limiting in PPI. The limiters in a PPI video amplifier help greatly in a-j protection of the PPI and should limit completely and at the optimum level. Refer to Paragraph 5-3-5.

11-1-13. Clean Design. The need for clean design in an a-j receiver cannot be stressed too much. Refer to Paragraph 5-5-1.

11-1-14. Inter-action of Circuits. Complete freedom from inter-action of circuits is essential in a-j receivers and associated equipment. Refer to Paragraph 5-4-1.

[redacted]

11-2. Interpretation of Results of A-J Tests.

11-2-1. Zero Beat Loss. Experience at this laboratory has shown that the loss in sensitivity of a good a-j receiver in the presence of zero-beat cw jamming will be about as shown in Table III. These values are based on a back-biased i-f amplifier without filters. Filters reduce the loss greatly but are difficult to adjust under fleet operating conditions. Furthermore, they cannot be made effective on the higher frequency equipments because of the difficulty of getting high rejection ratios and because the frequency modulation used on jammers gives them a very wide spectrum.

11-2-2. Width of Zero-Beat Area of Loss. The width of the zero-beat area of loss (measured at the 10 db loss points on the curve for cw at the highest jam level) should approximate the bandwidth of the receiver. If it is considerably narrower the performance against high frequency mcw is probably bad, while if it is broader an unnecessary loss is being taken in the presence of cw and low-frequency mcw jamming.

11-2-3. "Side Lobes" on the Loss Curves. "Side lobes" on the loss curves indicate that either there is insufficient attenuation in the skirts of the overall pass curve or that the video pass band is too narrow. Refer to Paragraph 8-7-3, 9-13-1, and 5-3-1.

11-2-4. Apparent Gain in Sensitivity as Off Frequency Jamming is Applied. An apparent gain in sensitivity will sometimes be noted as off-frequency jamming is applied. This may be due to either one of two things. It may be the combined effect of a short time constant detector to video coupling and a bad pulse shape from the simulated echo generator, or it may be due to too short an F.T.C. while the pulse shape from the echo generator is good. Which of these is the cause may be determined by putting the receiver into the complete system and noting if there is any loss in sensitivity to returning echoes with the short time constant in. If there is, the short time constant is too short and should be lengthened; if there is not, the fault is in the simulated echo generator and may be disregarded. Refer to Paragraph 9-13-2.

[redacted]

REFERENCES

(a) BuShips letter S-S67/36(485-J) Serial 2184 to NRL of 18 March 1942 assigning problem S45R-S.

(b) BuShips letter C-NXs-17055(916A) Serial C-916-6948 to NRL of 12 May 1943.

(c) Report No. HB-1 of A-J Practices Panel titled "Fundamentals of Radar Anti-Jamming".

(d) NRL letter S-S67-5/RCM(374:THC) Serial 3748 of 31 August 1944 to BuShips reporting the general requirements for satisfactory a-j performance of a PPI.

(e) NRL letter C-S67-5/RCM(370:THC) of 22 December 1943 to BuShips reporting an early test of an a-j receiver.

(f) NRL letter S-S67-5/RCM(374) Serial 2692 of 7 March 1944 to BuShips giving comments on video filters and back-bias circuits.

(g) NRL letter C-S67-5/RCM(370:THC) C-370-348 of 29 September 1944 to BuShips suggesting field modifications to the SC-3 system.

(h) NRL letter S-S67-5/RCM(374:THC) Serial 2965 of 5 May 1944 to BuShips reporting test of the first prototype of the AN/TPS-1B a-j receiver.

(j) NRL letter S-S67-5/RCM(374:THC) Serial 3100 of 16 May 1944 to BuShips reporting test of the second prototype of the AN/TPS-1B receiver.

(k) NRL letter C-S67-5/RCM(370:THC) C-370-355 of 2 October 1944 to BuShips reporting test of the third prototype of the AN/TSP-1B receiver.

[redacted]

[redacted]

DECLASSIFIED

APPENDIX I

GLOSSARY OF TERMS AND SYMBOLS

A - Terms.

1. Chopper - A mechanical device used in the testing of a PPI to simulate the directivity pattern of an antenna.

2. Clutter - A form of interference or jamming resulting from the reflection of radar pulse energy from extraneous targets, such as nearby land, waves, or clouds.

3. Differentiating Action - The frequency selective action of a circuit whereby the low frequencies are not passed.

4. "Holes" (negative) - The negative peaks of a modulated jamming signal where the instantaneous jamming level is reduced to a very low value.

5. Minimum Signal - A contraction of the term "minimum detectable signal". Generally refers to circuits for, or a study of means for improving the absolute sensitivity of a receiver.

6. On-Frequency Jamming - Jamming whose frequency is within a few kilocycles of the radar frequency.

7. Off-Frequency Jamming - Jamming whose frequency is several hundred kilocycles or more removed from the frequency of the radar but still close enough to have some effect on radar performance.

8. Panoramic - A type of receiver used in adjusting a jammer. It shows the complete spectrum of both the radar and the jammer and allows the jammer spectrum to be set to coincide with the radar spectrum.

9. PPI Signal Simulator - A unit used in the testing of a PPI. It consists of one or more choppers, a motor drive system and a synchro system for synchronizing the PPI rotation.

10. Railings - A form of jamming consisting of a series of pulses of fixed repetition rate with no carrier present between pulses.

11. Setting-On Receiver - A receiver, used in conjunction with a jammer, for the purpose of adjusting the jammer to the frequency of the radar being jammed.

12. Side-Lobes - A term, borrowed from antenna terminology, used to describe the peaks of loss which appear on the curves of loss plotted against frequency and are displaced several megacycles from the zero-beat peak.

[redacted]

DECLASSIFIED

13. Zero-Beat Jamming - A jamming signal whose frequency is within a few hundred cycles of the frequency of the radar.

14. Zero-Beat Area - The portion of the curve of loss plotted against frequency which includes the peak of loss at zero-beat and the sloping sides of this peak out as far as the first minimum of loss.

B - Symbols.

1. F.T.C. - Symbol adopted for the SR-1, 2, 3, 4 and SG-3 video unit control for short-time-constant coupling. Abbreviation for "fast time constant". STC is the symbol adopted for "sensitive-time-control", sometimes referred to as delayed sensitivity control.

2. J/S - The ratio, generally given in db, of the jamming level to the minimum detectable signal in that jammed condition.

3. PRF - Pulse repetition rate.

4. s - Minimum detectable signal for the jammed condition under consideration.

5. V_{min} - Minimum detectable signal in the unjammed condition.

[redacted]

Table I

Mean Deviations of Repeat Readings on A-J Tests on "A" Scope Using Three Frequency System

A. As a function of Level

Level	Mean Deviation
10 uv	.5 db
100 uv	.5 db
1 mv	.7 db
10 mv	1.0 db
100 mv	2.0 db

B. As a function of Frequency

Frequency	Mean Deviation
On Freq.	.3 db
Off Freq. I	.6 db
Off Freq. II	.8 db

[redacted]

Table II

Mean Deviation of Repeat Readings on A-J Tests on PPI Using Three-Frequency System.

A. As a Function of Level

Level	Mean Deviation
10 uv	.4 db
100 uv	1.1 db
1 mv	2.0 db
10 mv	3.7 db
100 mv	4.0 db

B. As a Function of Frequency

Frequency	Mean Deviation
On Freq.	1.2 db
Off Freq. I	2.6 db
Off Freq. II	3.8 db

[redacted]

Table III

Effect of Cathode Capacitance on

Zero-Beat Loss Area

Jam Level	Cathode Condenser	Zero-Beat Area	
		Width	Depth
50 mv	.01 mfd	260 kc	16 db
50 mv	.002 mfd	720 kc	22 db
50 mv	.0005 mfd	1200 kc	29 db

[redacted]

[redacted]

Table IV

Loss in Sensitivity of a Representative Good A-J Receiver in the Presence of Zero-Beat CW Jamming

Jam Level	Loss
10 uv	5 - 10 db
100 uv	10 - 15 db
1 mv	15 - 20 db
10 mv	17 - 22 db
100 mv	20 - 25 db

[redacted]

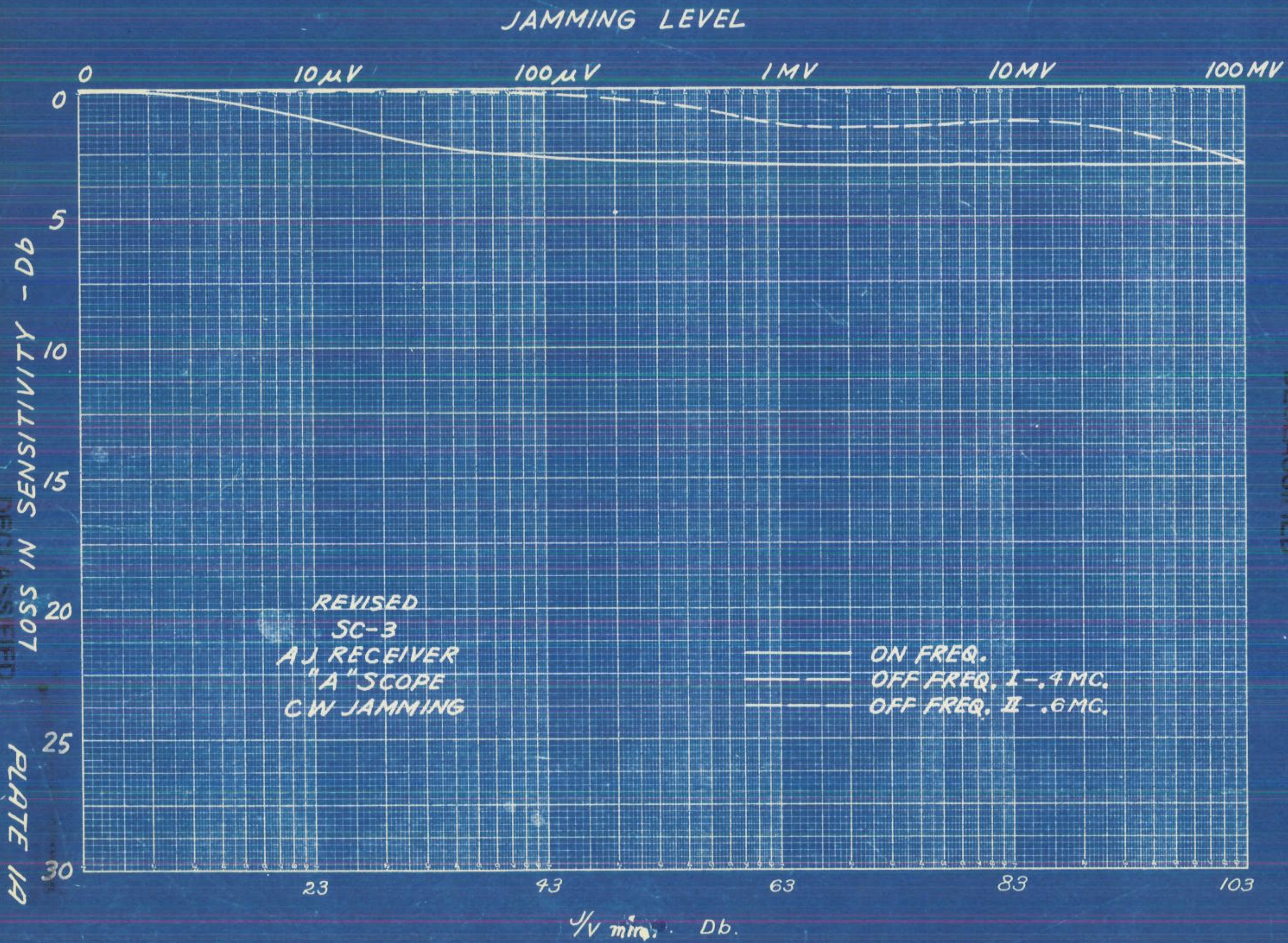

JAMMING LEVEL
0
10 μV
100 μV
1 MV
10 MV
100 MV
LOSS IN SENSITIVITY - Db
0
5
10
15
20
25
30
23
43
63
83
103
1/V min. Db.
REVISED
SC-3
AJ RECEIVER
"A" SCOPE
CW JAMMING
ON FREQ.
OFF FREQ. I - .4 MC.
OFF FREQ. II - .6 MC.

PLATE IA

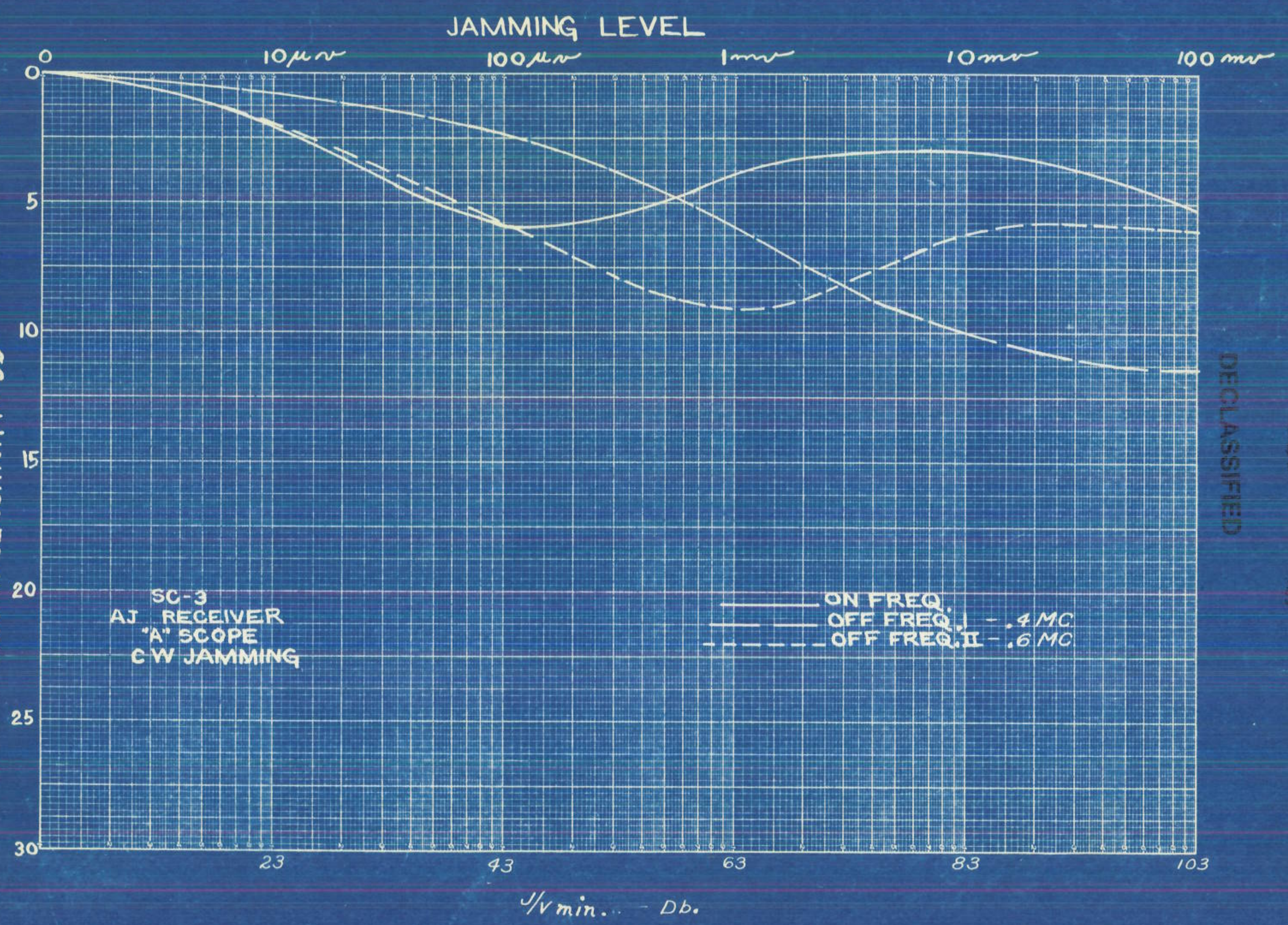


PLATE 18

DECLASSIFIED

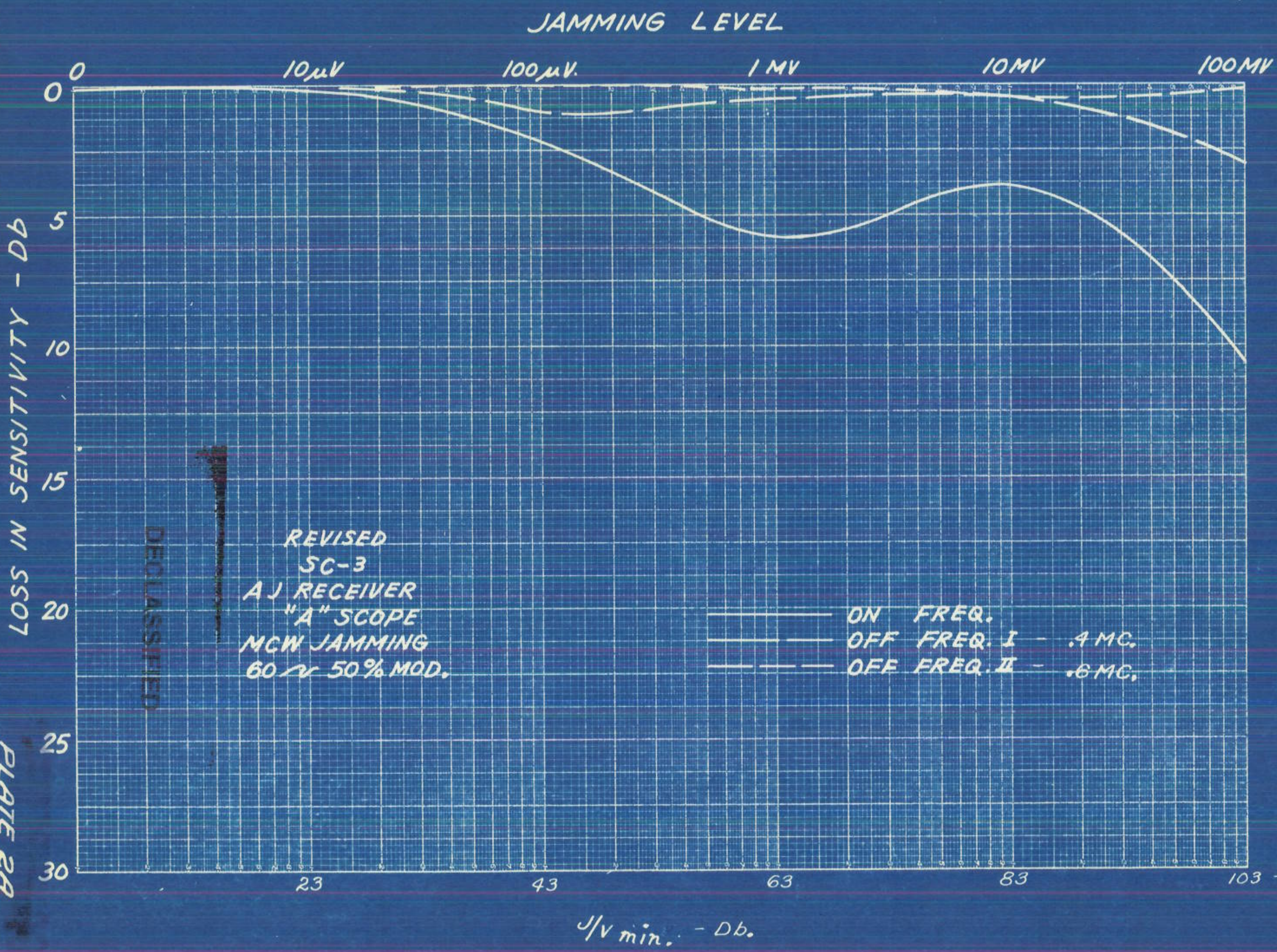

JAMMING LEVEL
0
10μV
100μV.
1 MV
10MV
100MV
LOSS IN SENSITIVITY - Db
0
5
10
15
20
25
30
23
43
63
83
103
J/V min. - Db.
REVISED
SC-3
AJ RECEIVER
"A" SCOPE
MCW JAMMING
60 ~ 50% MOD.
ON FREQ.
OFF FREQ. I - .4 MC.
OFF FREQ. II - .6 MC.

PLATE 2A

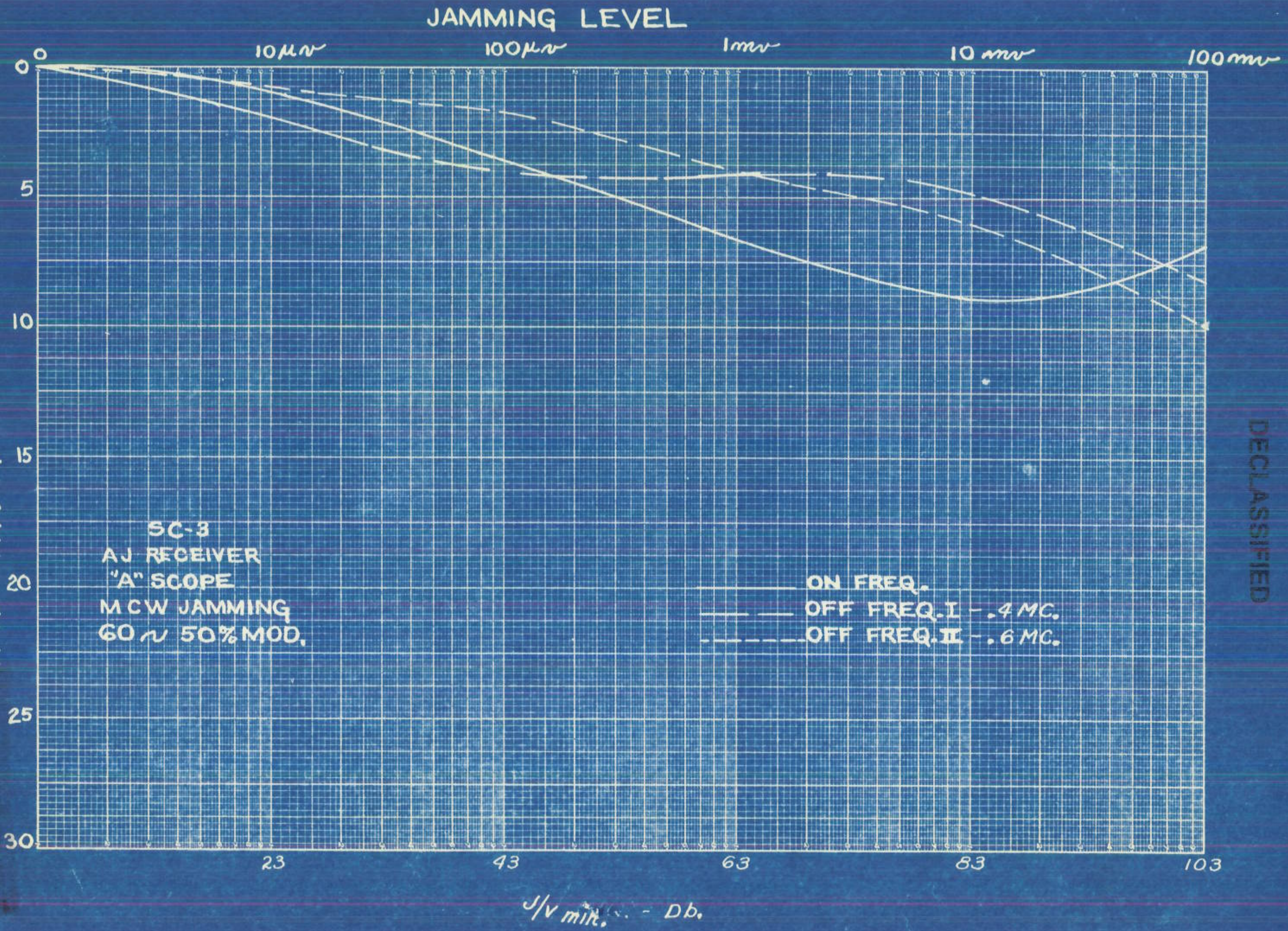

JAMMING LEVEL
0
10μv
100μv
1mv
10 mv
100mv
0
5
10
15
20
25
30
LOSS IN SENSITIVITY - Db
23
43
63
83
103
J/v min. - Db.
SC-3
AJ RECEIVER
"A" SCOPE
MCW JAMMING
60 ~ 50% MOD.
ON FREQ.
OFF FREQ. I - .4 MC.
OFF FREQ. II - .6 MC.

PLATE 2B

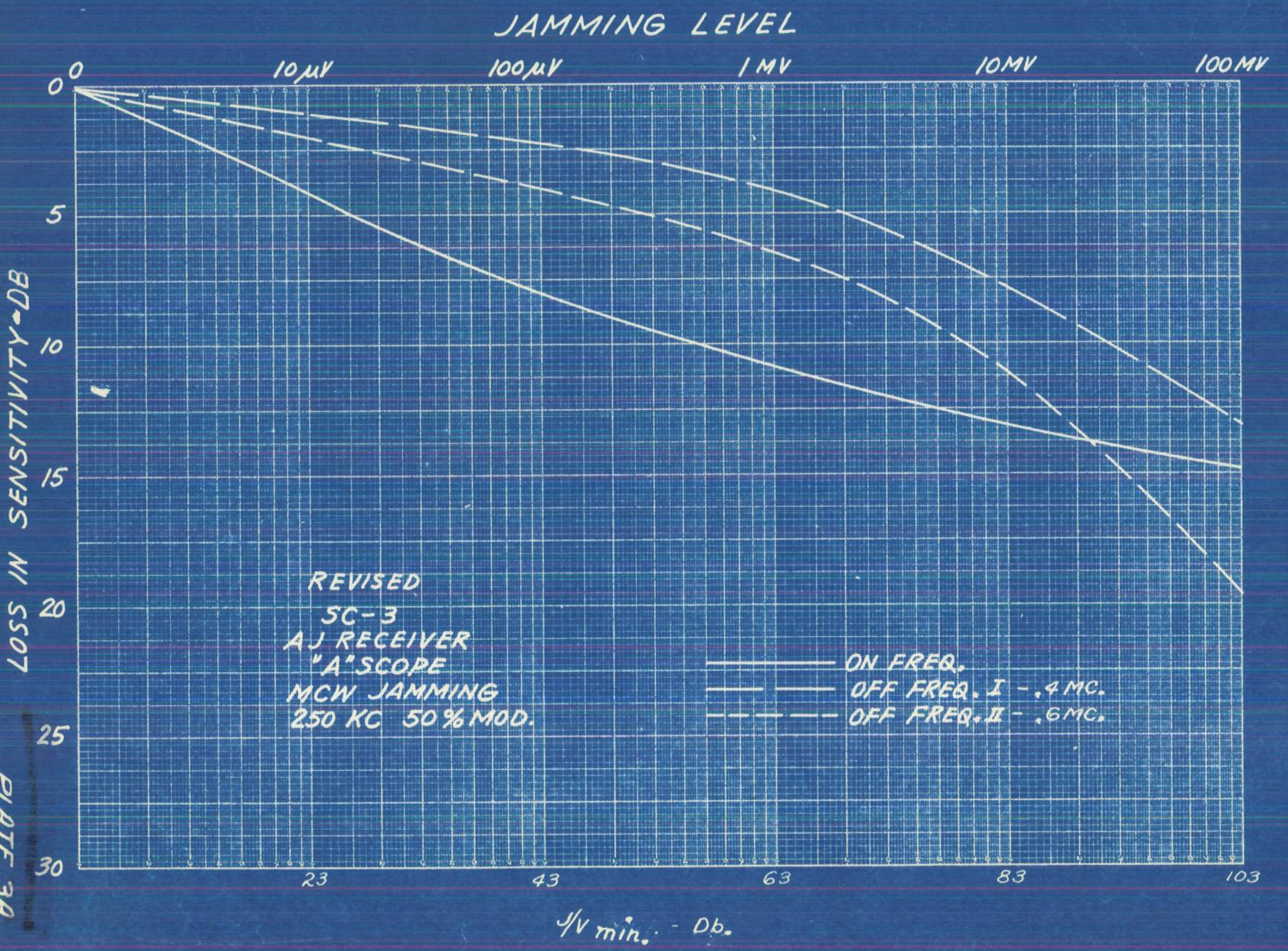


PLATE 3A

DECLASSIFIED

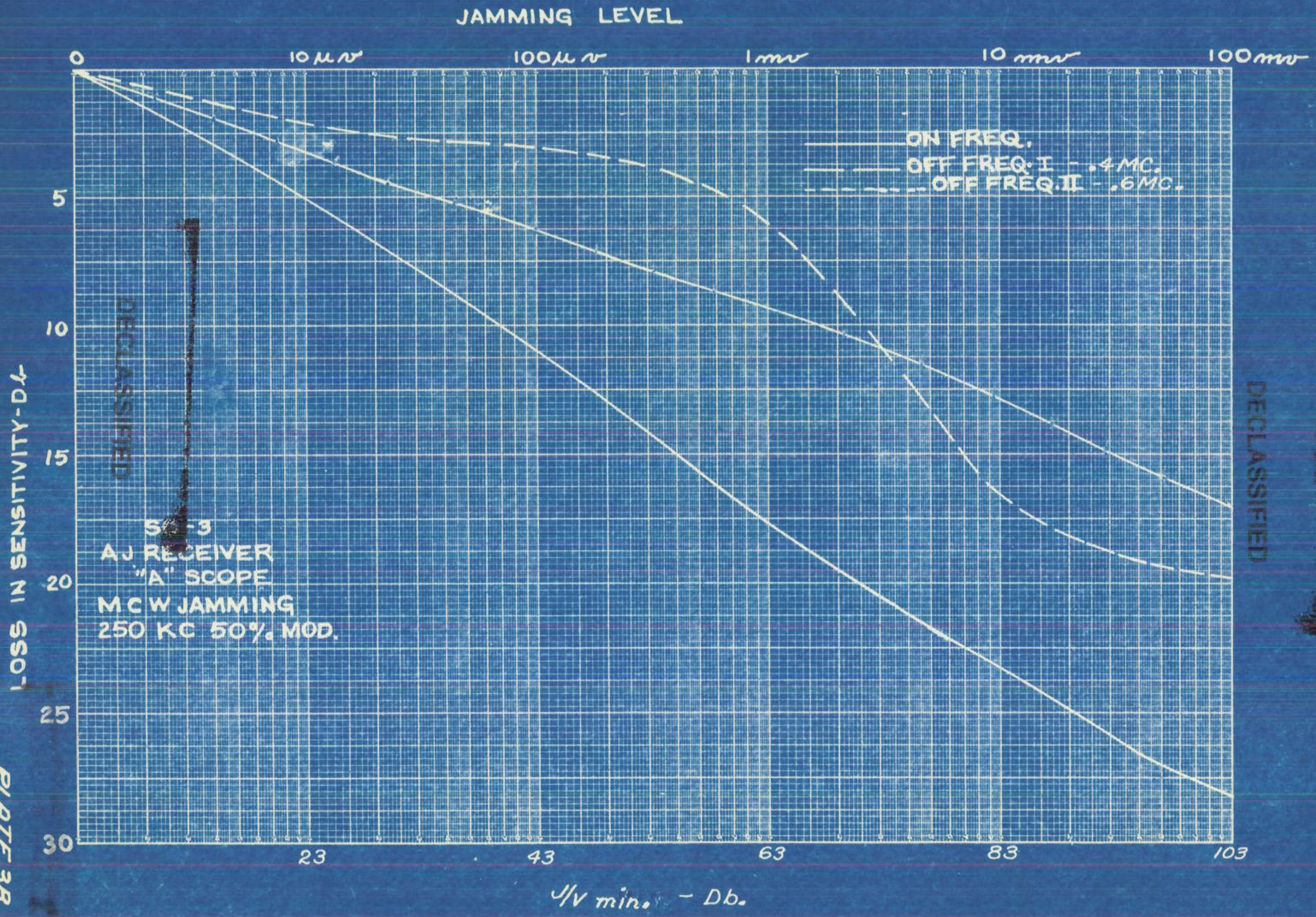

JAMMING LEVEL
0
10 μv
100 μv
1 mv
10 mv
100 mv
ON FREQ.
OFF FREQ. I - .4 MC.
OFF FREQ. II - .6 MC.
S[redacted]3
A J RECEIVER
"A" SCOPE
M C W JAMMING
250 KC 50% MOD.
5
10
15
20
25
30
LOSS IN SENSITIVITY-Db
23
43
63
83
103
J/V min. - Db.

PLATE 38

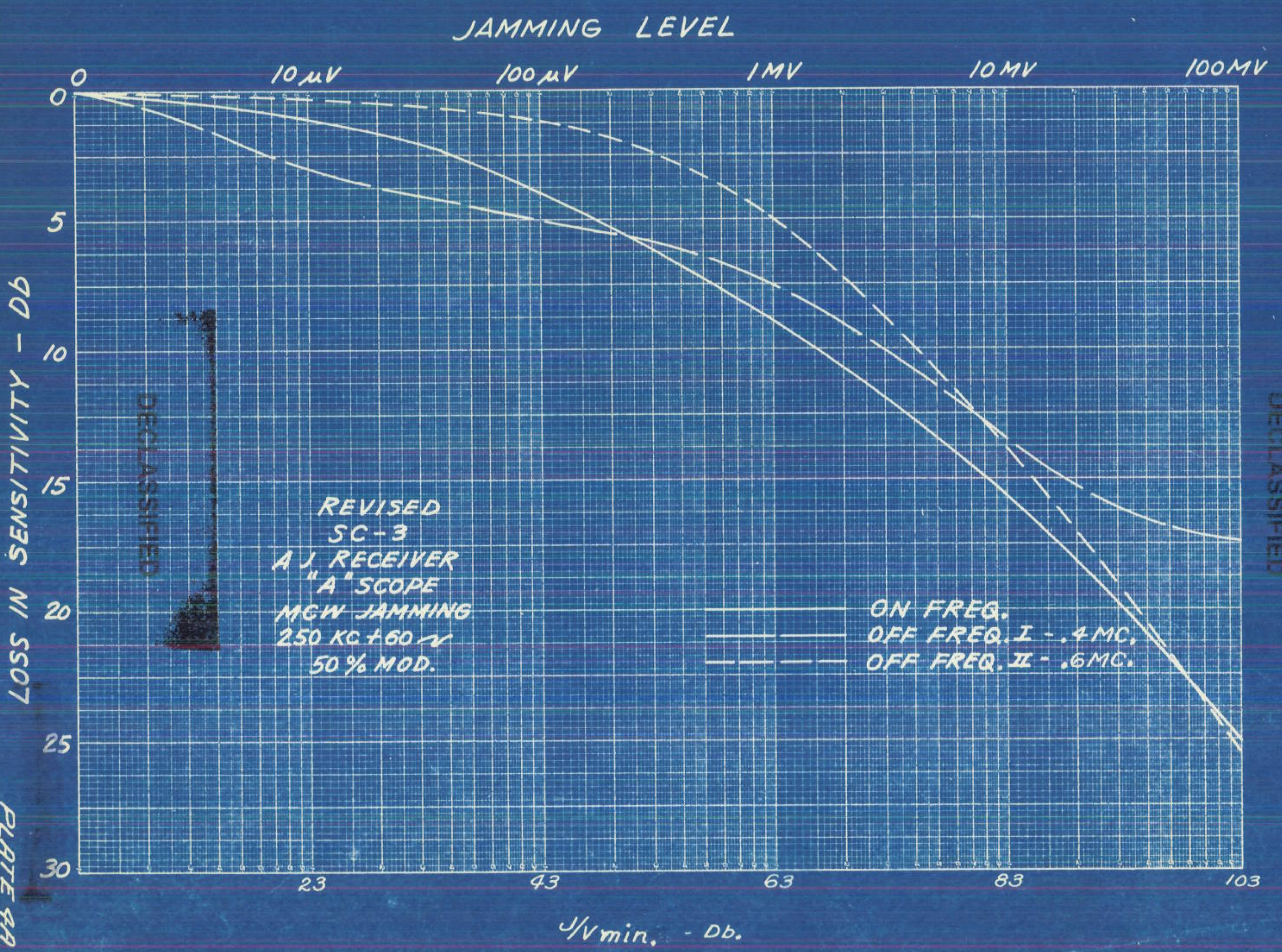
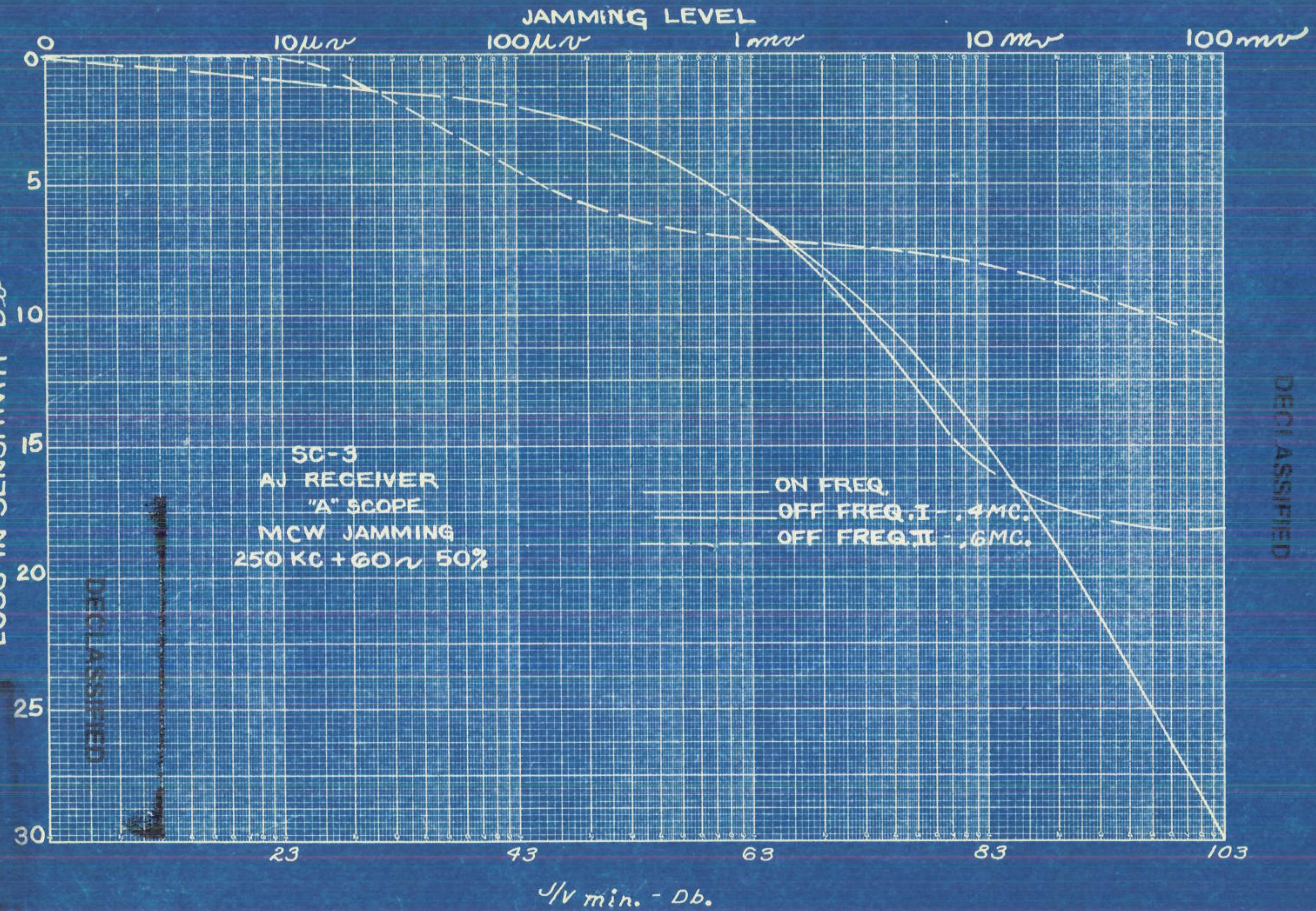


PLATE 4A

DECLASSIFIED



[redacted]

PLATE 4B

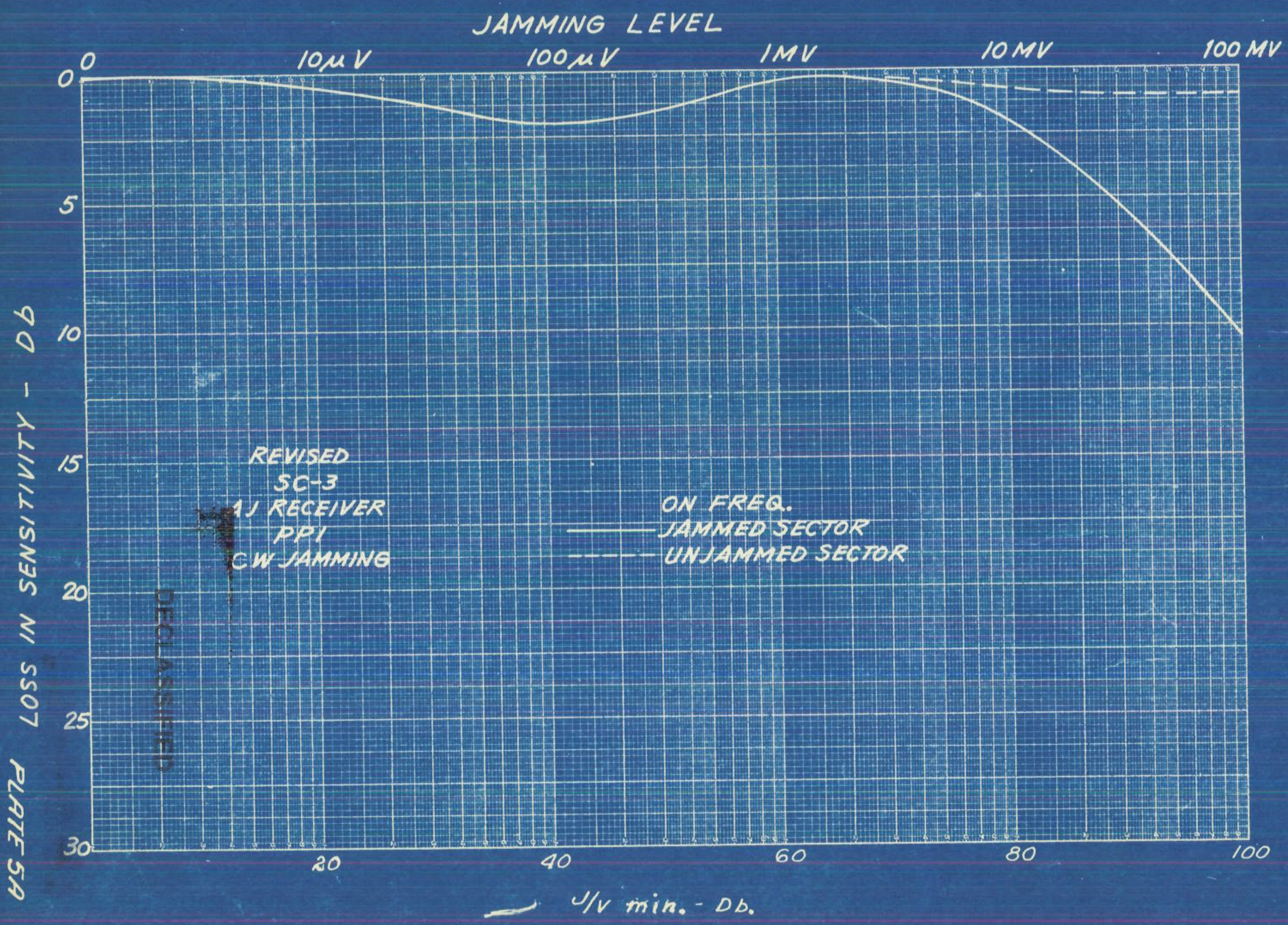

JAMMING LEVEL
0
10μV
100μV
1MV
10MV
100MV
0
5
10
15
20
25
30
LOSS IN SENSITIVITY - Db
20
40
60
80
100
J/v min. - Db.
REVISED
SC-3
AJ RECEIVER
PPI
CW JAMMING
ON FREQ.
JAMMED SECTOR
UNJAMMED SECTOR

PLATE 5A

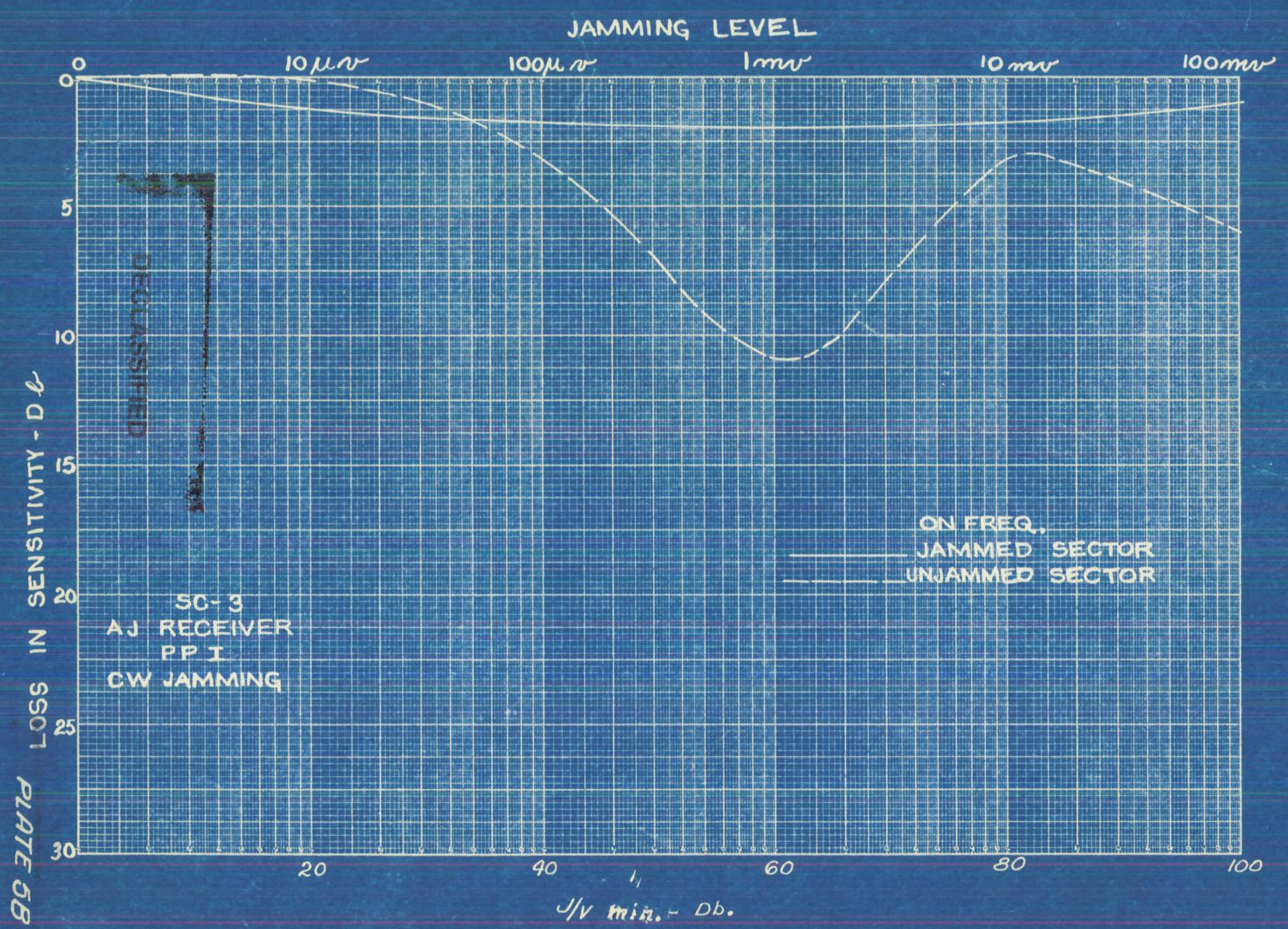
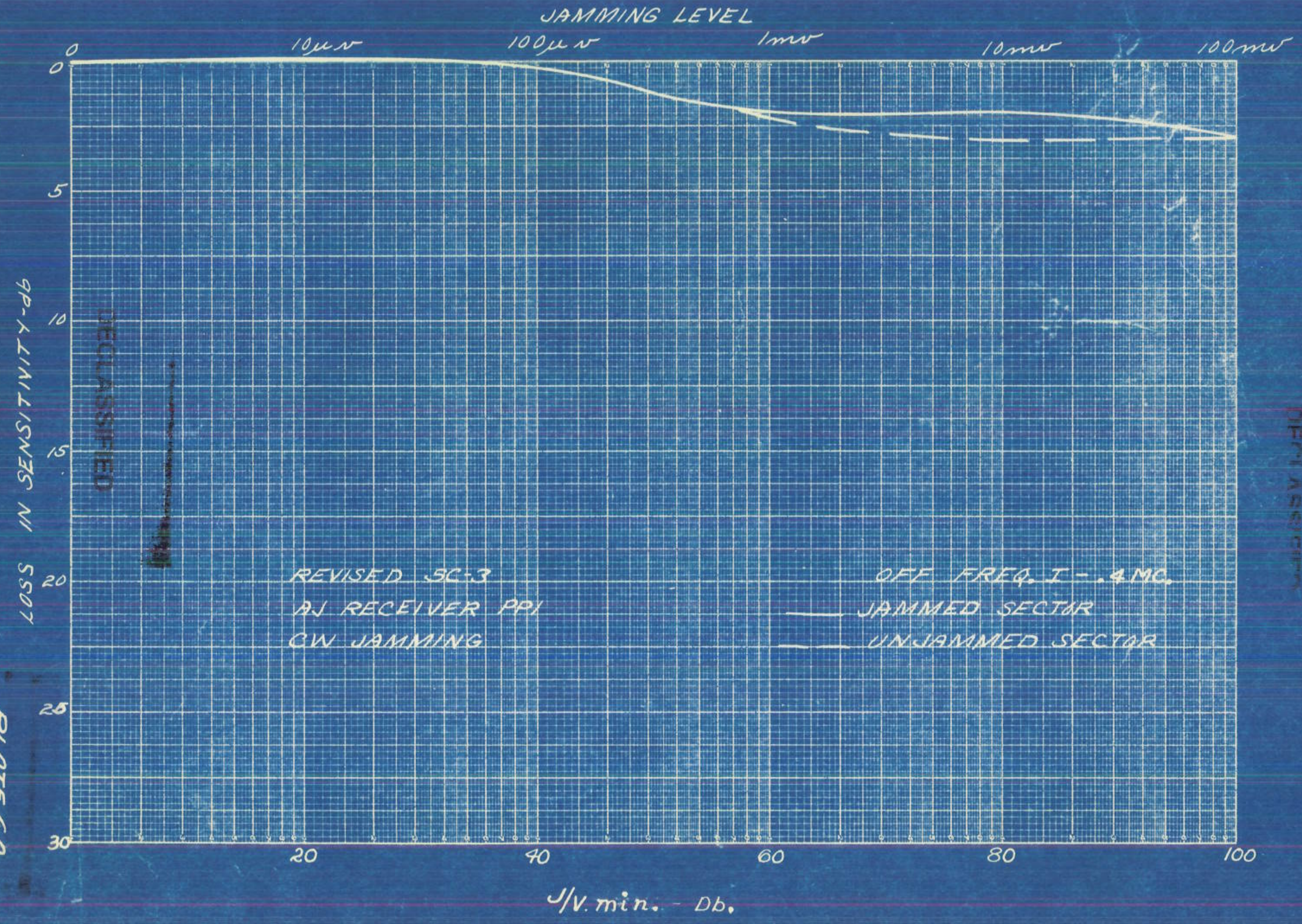

JAMMING LEVEL
0
10 μv
100 μv
1 mv
10 mv
100 mv
LOSS IN SENSITIVITY - Db
0
5
10
15
20
25
30
20
40
60
80
100
J/V min. - Db.
ON FREQ.
JAMMED SECTOR
UNJAMMED SECTOR
SC-3
AJ RECEIVER
PPI
CW JAMMING

PLATE 5B



JAMMING LEVEL
0
10μv
100μv
1mv
10mv
100mv
0
5
10
15
20
25
30
LOSS IN SENSITIVITY-db
20
40
60
80
100
J/V. min. - Db.
REVISED SC-3
AJ RECEIVER PPI
CW JAMMING
OFF FREQ. I - .4MC.
JAMMED SECTOR
UNJAMMED SECTOR

PLATE 6A

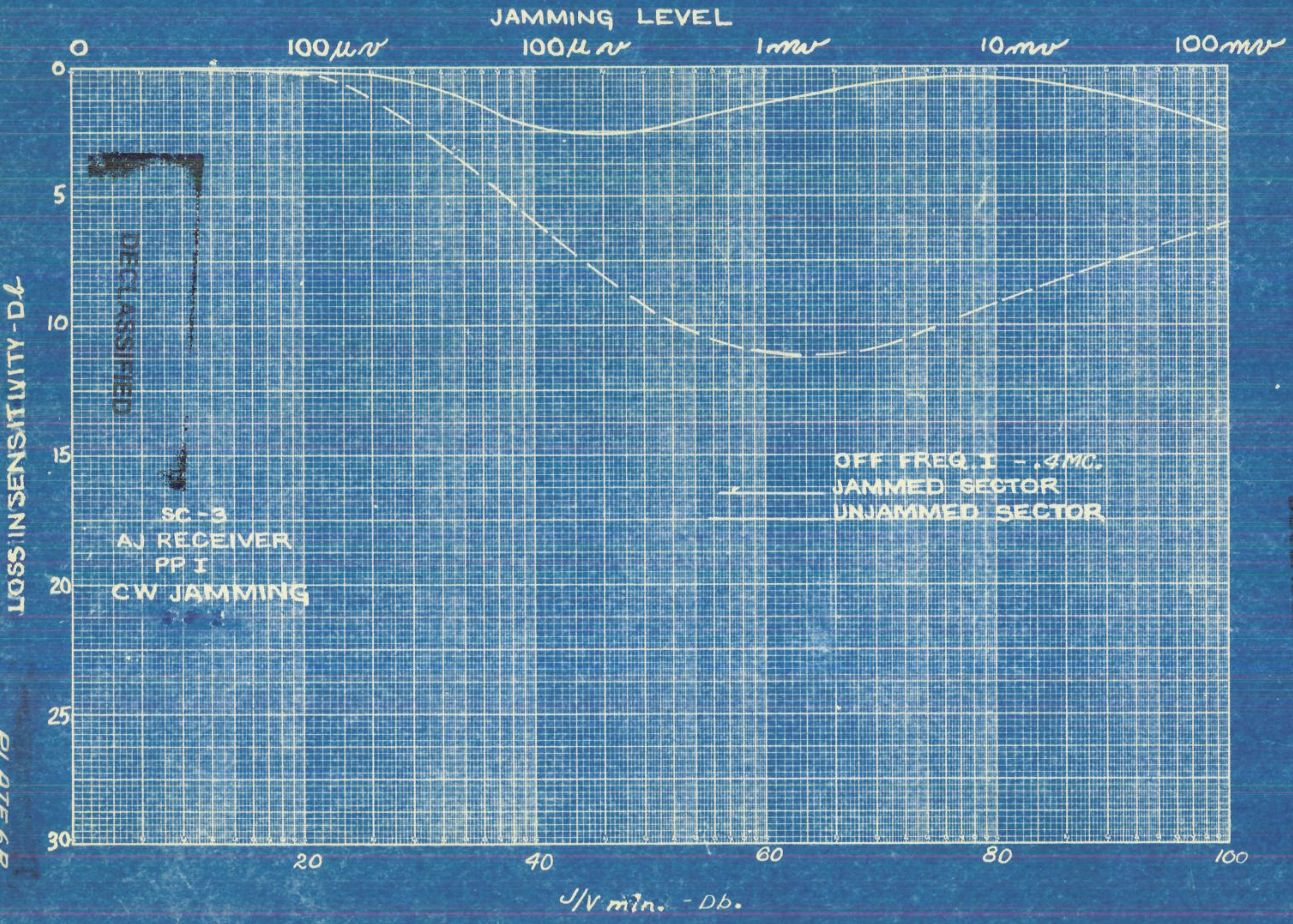
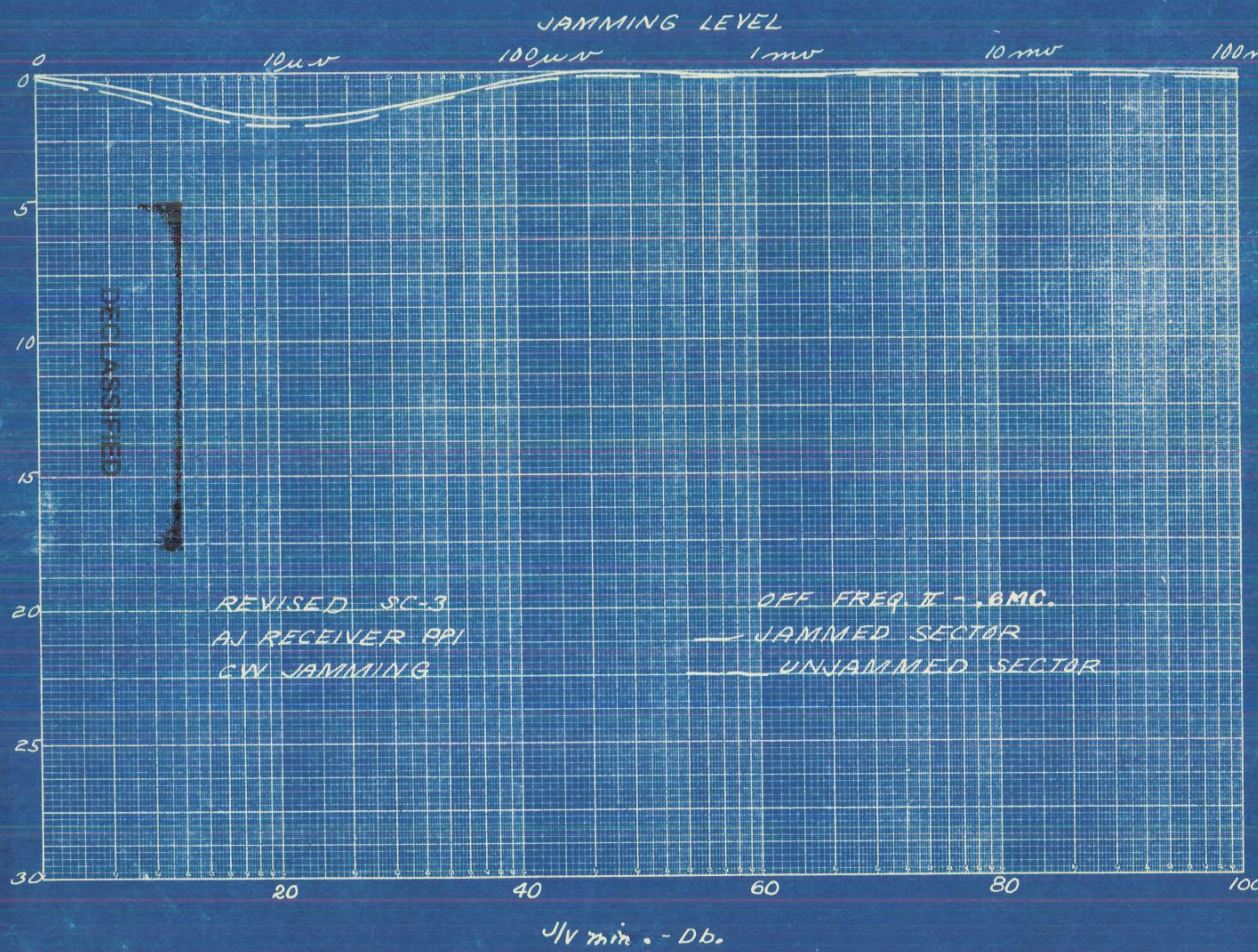

JAMMING LEVEL
0
100µv
100µv
1mv
10mv
100mv
LOSS IN SENSITIVITY - Db
0
5
10
15
20
25
30
20
40
60
80
100
J/V min. - Db.
SC-3
AJ RECEIVER
PP I
CW JAMMING
OFF FREQ. I - .4MC.
JAMMED SECTOR
UNJAMMED SECTOR

PLATE 6B



DECLASSIFIED

PLATE 7A

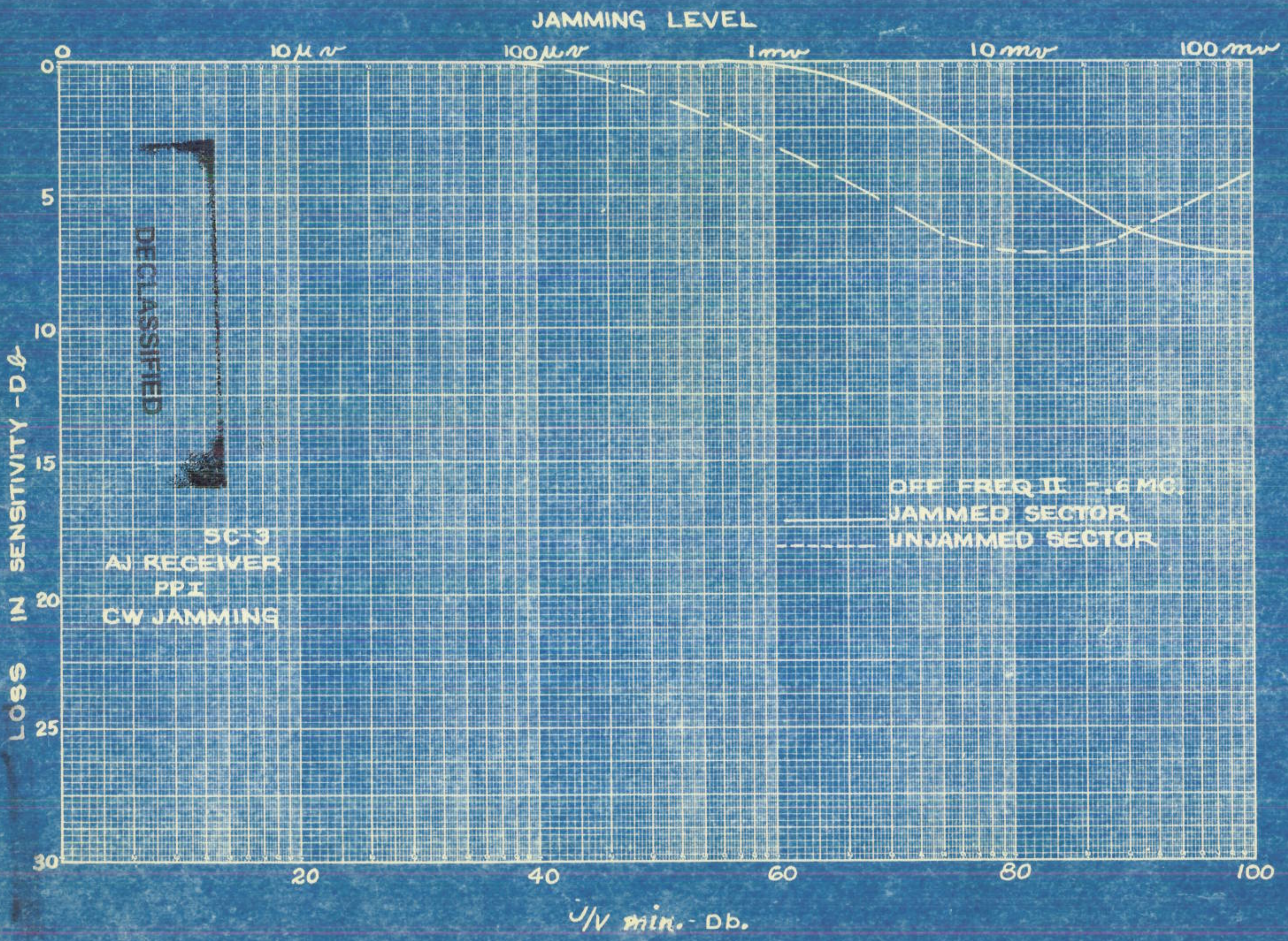
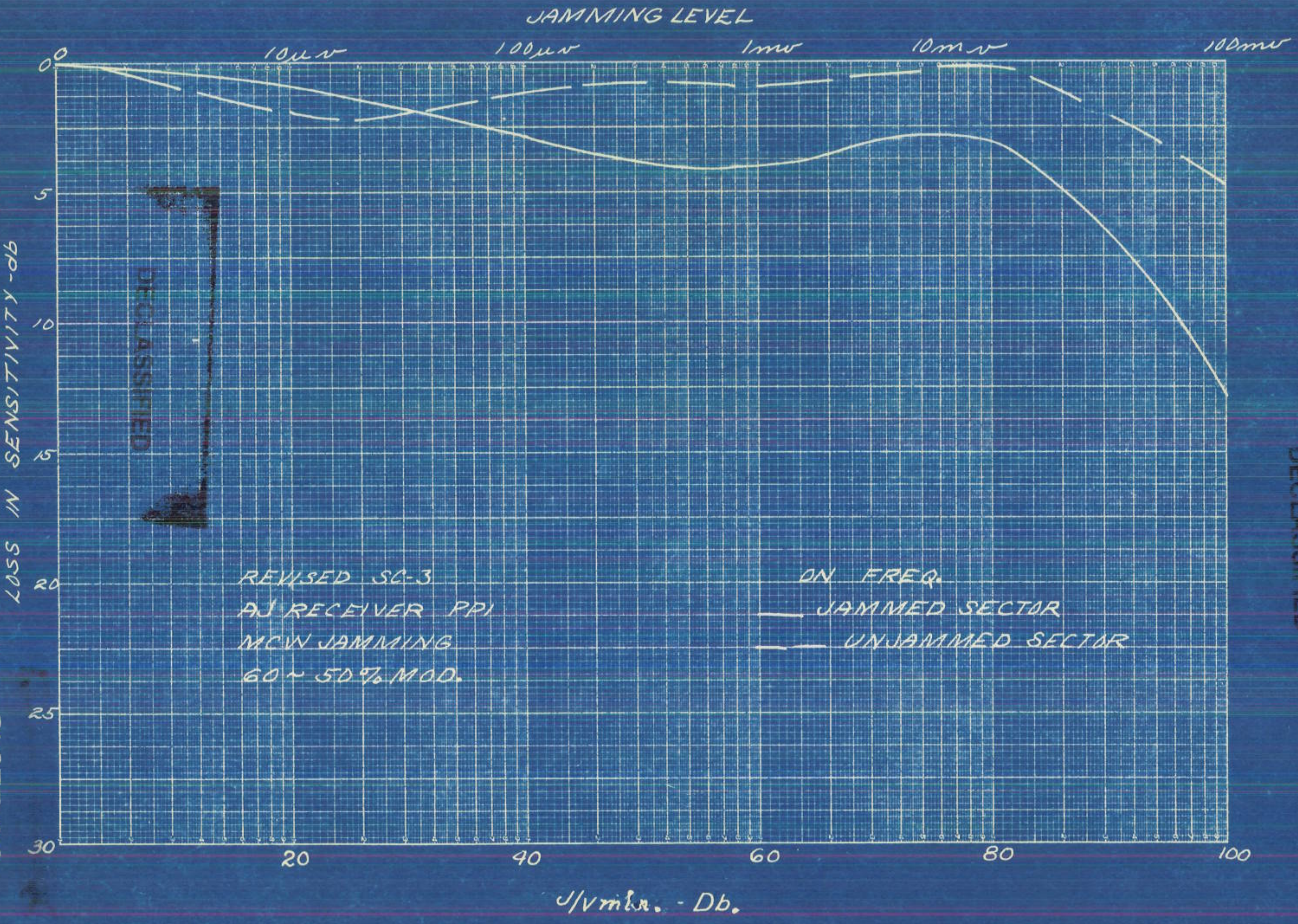

JAMMING LEVEL
0
10 μv
100 μv
1 mv
10 mv
100 mv
0
5
10
15
20
25
30
LOSS IN SENSITIVITY - Db
20
40
60
80
100
J/V min. - Db.
SC-3
AJ RECEIVER
PPI
CW JAMMING
OFF FREQ II - .6 MC.
JAMMED SECTOR
UNJAMMED SECTOR

PLATE 78



JAMMING LEVEL
10μv
100μv
1mv
10mv
100mv
0
5
10
15
20
25
30
20
40
60
80
100
LOSS IN SENSITIVITY - db
J/vmin. - Db.
REVISED SC-3
AJ RECEIVER PPI
MCW JAMMING
60~ 50% MOD.
ON FREQ.
JAMMED SECTOR
UNJAMMED SECTOR

PLATE 8A

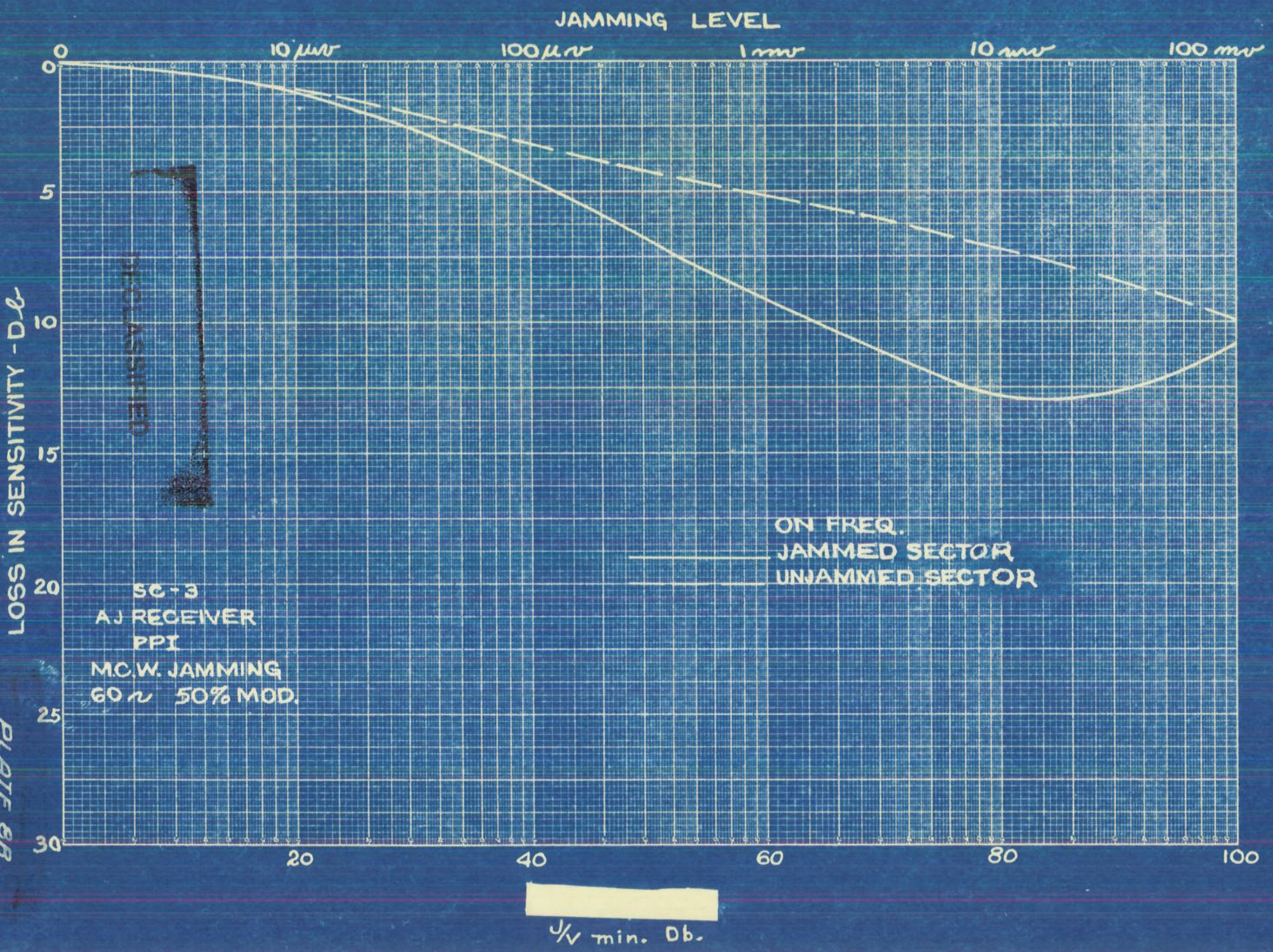

JAMMING LEVEL
0
10 μv
100 μv
1 mv
10 mv
100 mv
LOSS IN SENSITIVITY - Db
0
5
10
15
20
25
30
20
40
60
80
100
S/N min. Db.
ON FREQ.
JAMMED SECTOR
UNJAMMED SECTOR
SC-3
A J RECEIVER
PPI
M.C.W. JAMMING
60 ~ 50% MOD.

PLATE 88

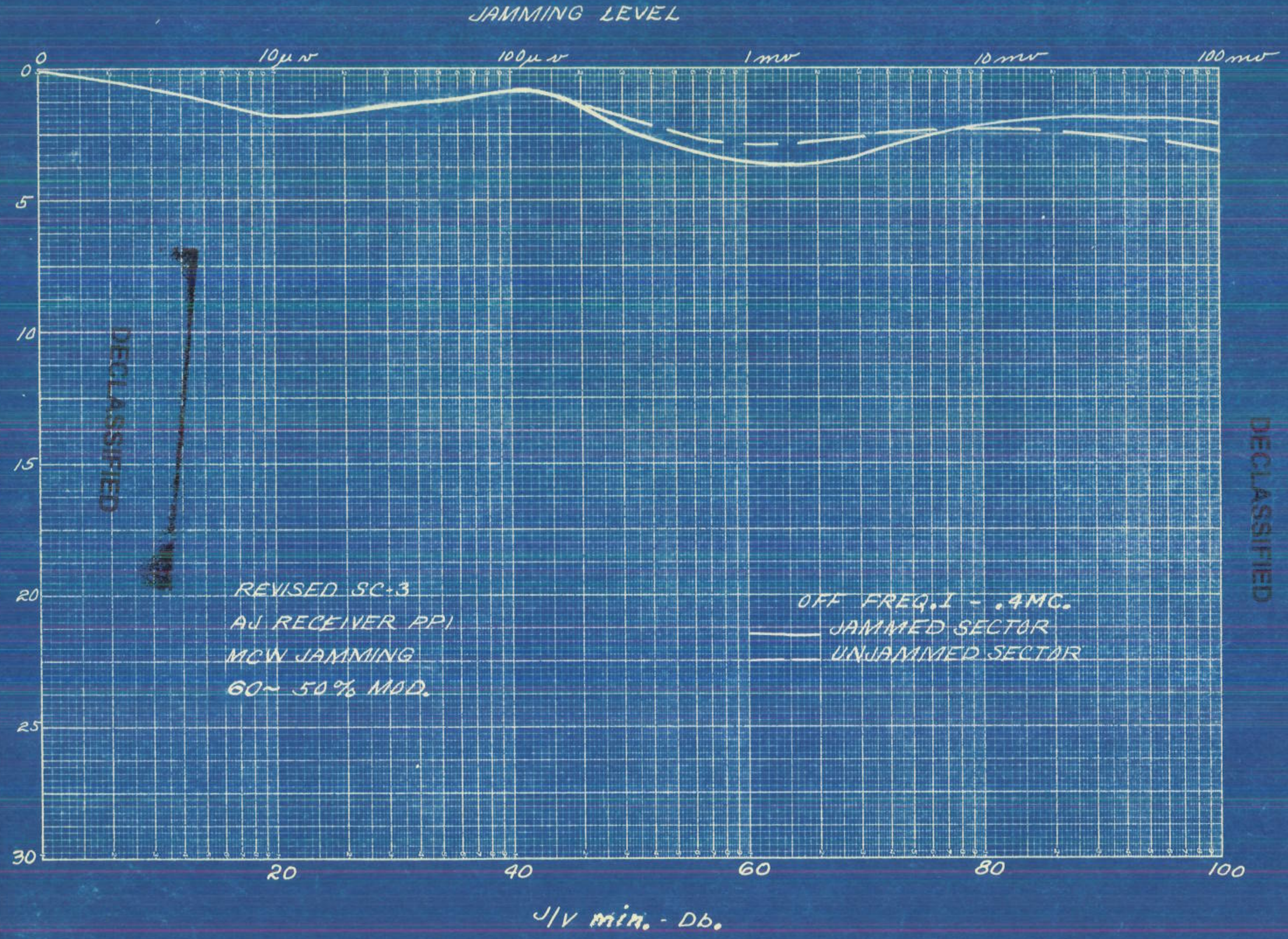


PLATE 9A

DECLASSIFIED

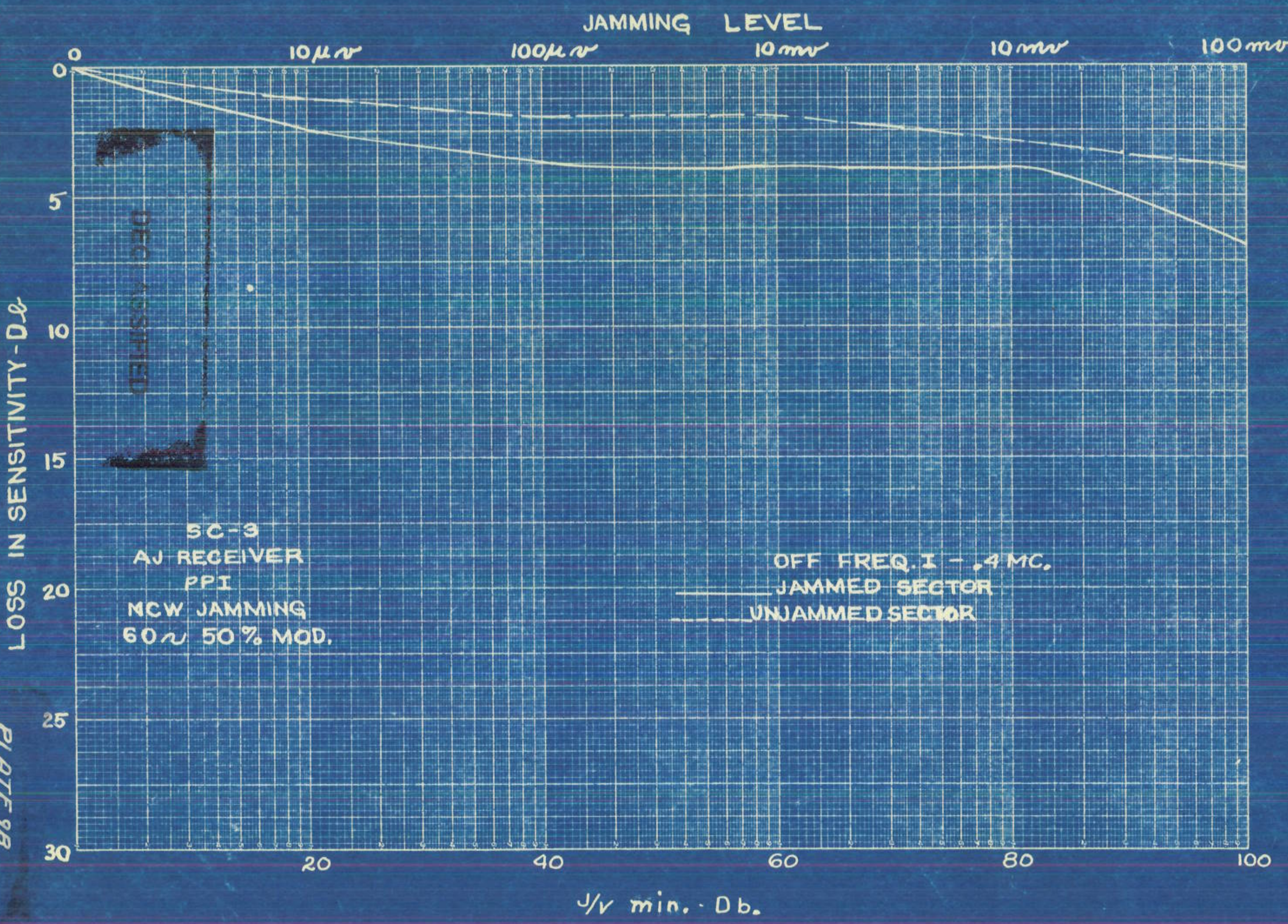

JAMMING LEVEL
0
10μv
100μv
10mv
10mv
100mv
LOSS IN SENSITIVITY - Db
0
5
10
15
20
25
30
20
40
60
80
100
J/v min. - Db.
SC-3
AJ RECEIVER
PPI
NCW JAMMING
60~ 50% MOD.
OFF FREQ. I - .4 MC.
JAMMED SECTOR
UNJAMMED SECTOR

PLATE 9B

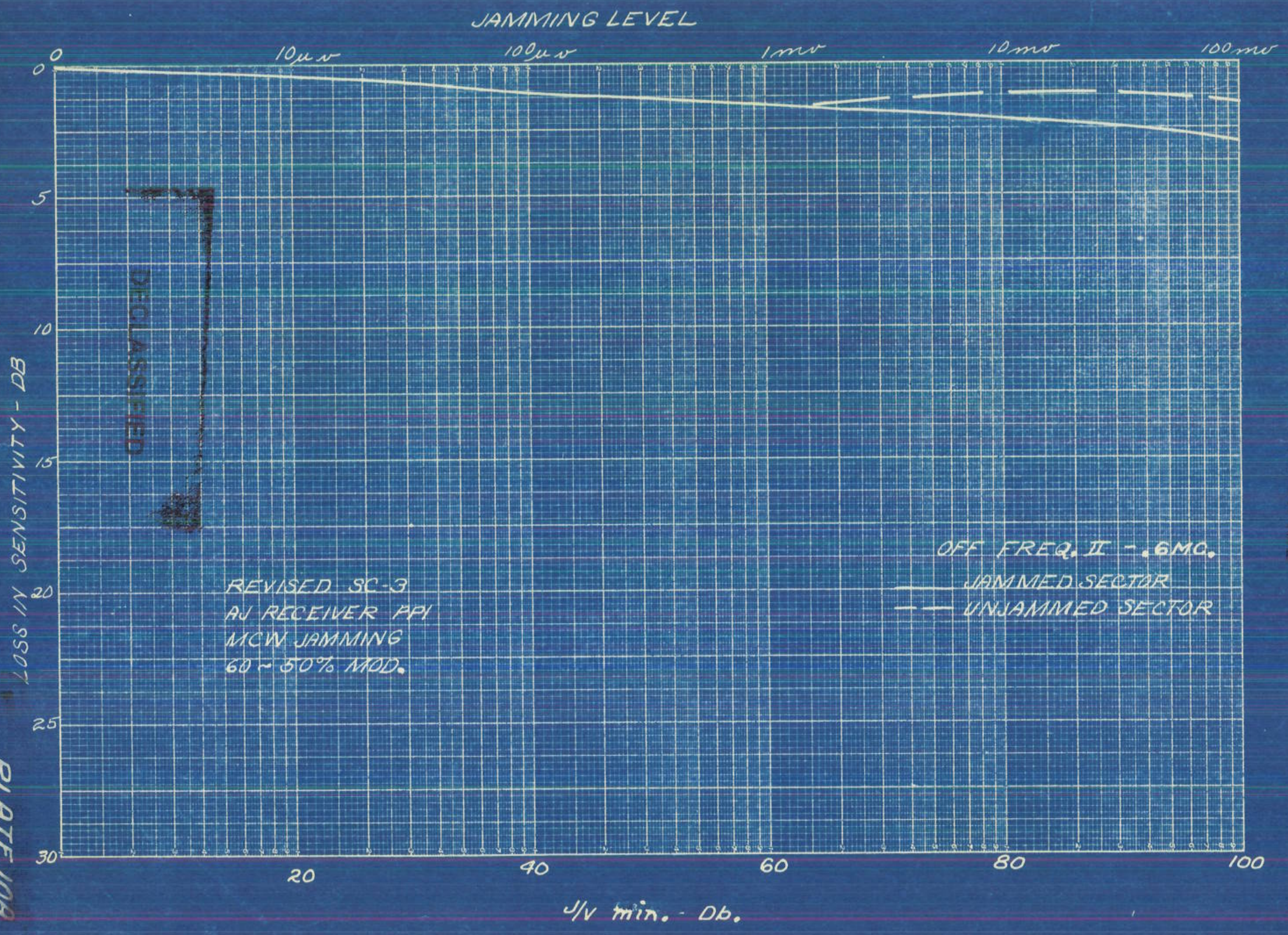
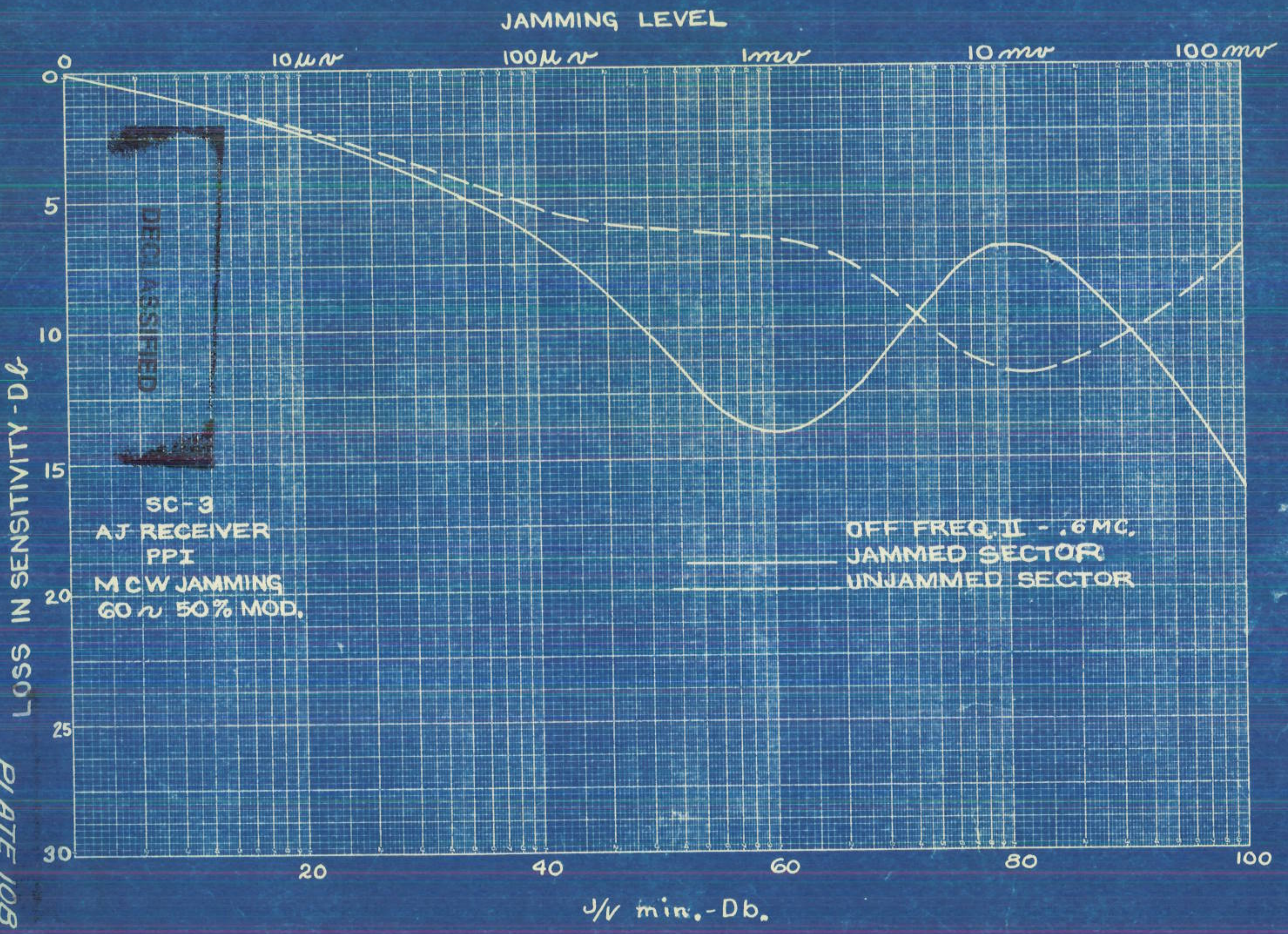

JAMMING LEVEL
0
10μv
100μv
1mv
10mv
100mv
0
5
10
15
20
25
30
LOSS IN SENSITIVITY - DB
20
40
60
80
100
J/v min. - Db.
OFF FREQ. II - .6MC.
JAMMED SECTOR
UNJAMMED SECTOR
REVISED SC-3
AJ RECEIVER PPI
MCW JAMMING
60 ~ 50% MOD.

PLATE 10A



DECLASSIFIED

PLATE 10B

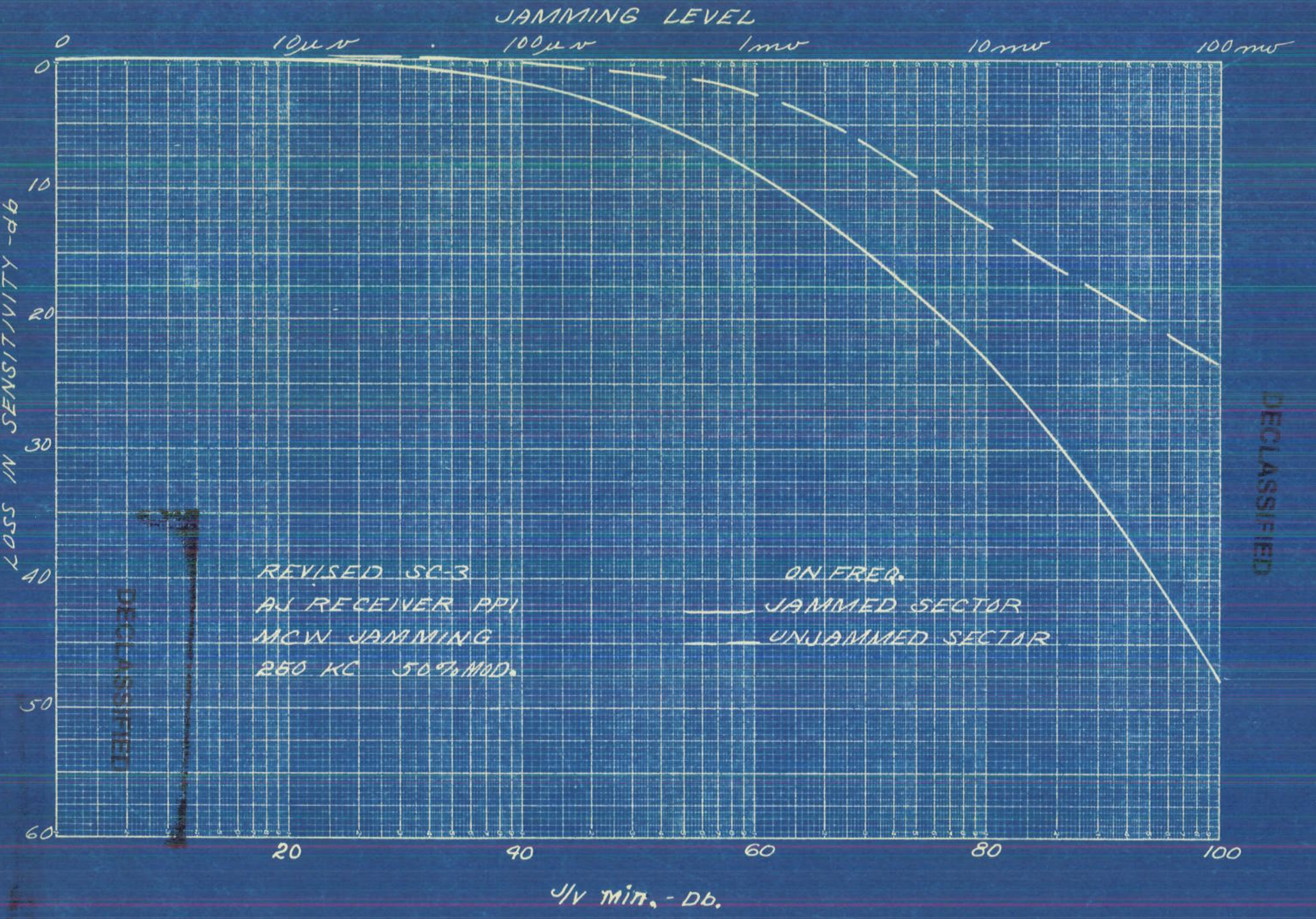

JAMMING LEVEL
0
10μv
100μv
1mv
10mv
100mv
0
10
20
30
40
50
60
LOSS IN SENSITIVITY -db
20
40
60
80
100
J/V min. - Db.
REVISED SC-3
AJ RECEIVER PPI
MCW JAMMING
250 KC 50% MOD.
ON FREQ.
JAMMED SECTOR
UNJAMMED SECTOR
DECLASSIFIED
DECLASSIFIED

PLATE IIA

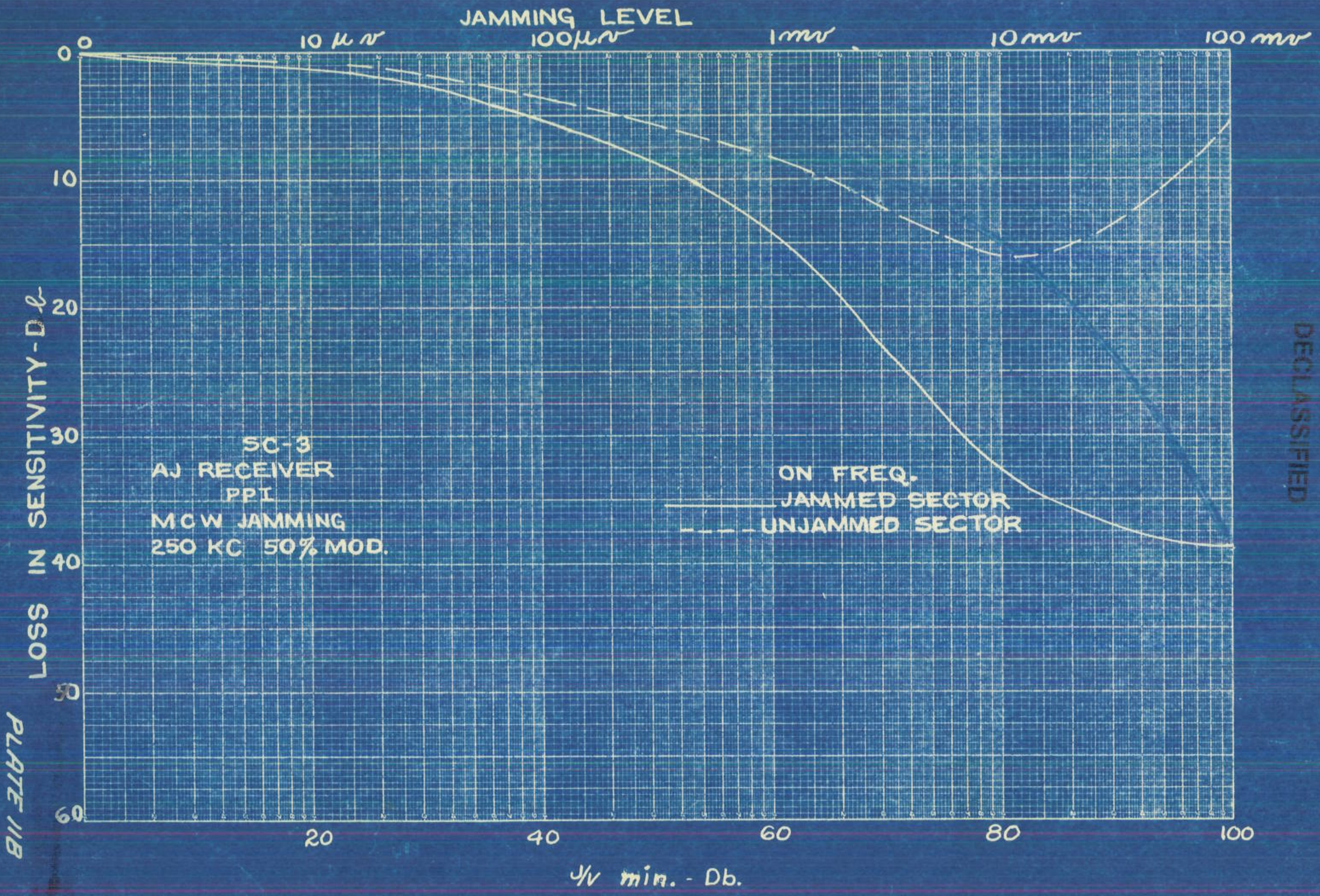
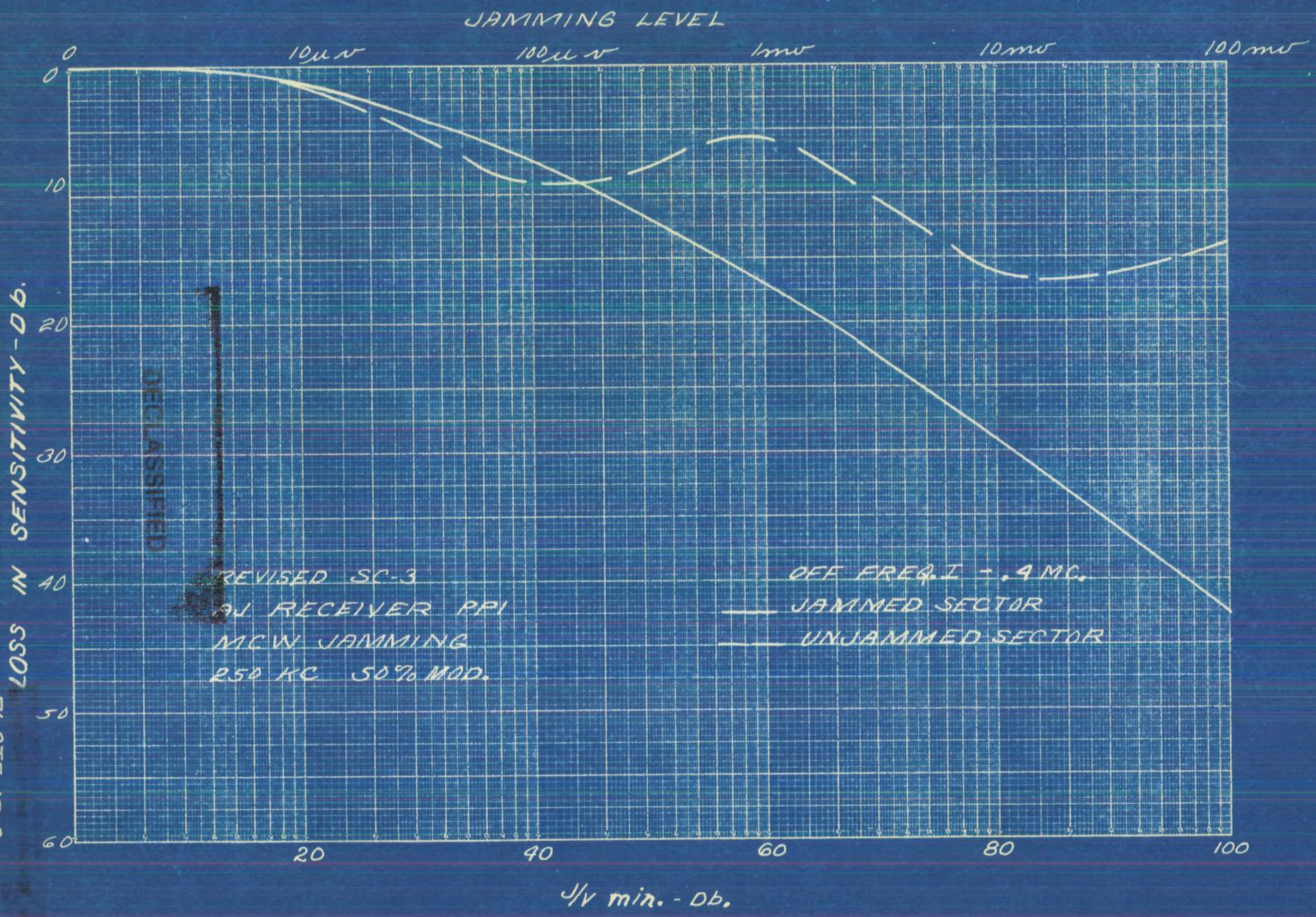
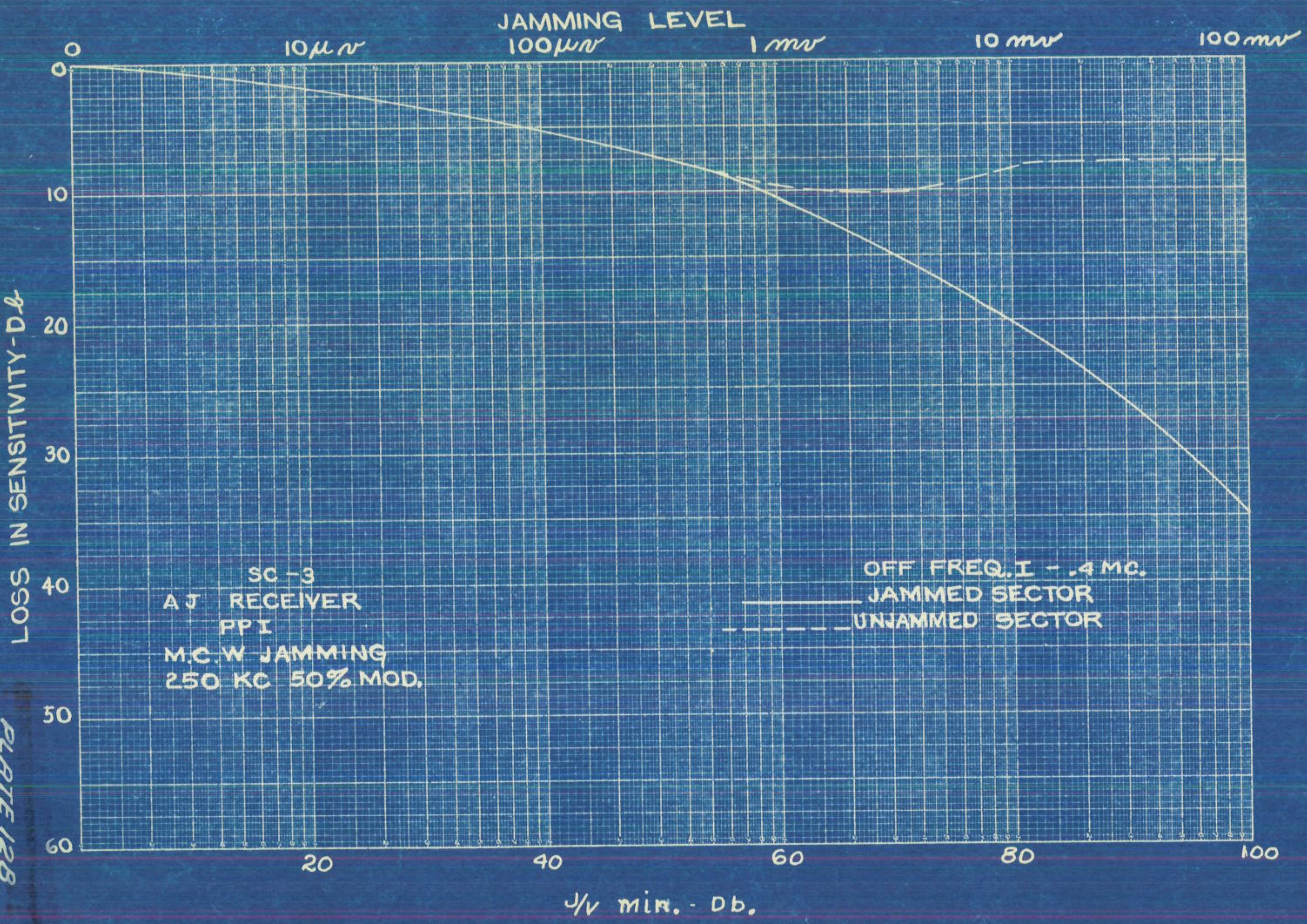

JAMMING LEVEL
0
10 μv
100μv
1mv
10mv
100mv
SC-3
AJ RECEIVER
PPI
MCW JAMMING
250 KC 50% MOD.
ON FREQ.
JAMMED SECTOR
UNJAMMED SECTOR
LOSS IN SENSITIVITY-D ℓ
0
10
20
30
40
50
60
20
40
60
80
100
J/V min. - Db.

PLATE 11B



JAMMING LEVEL
0
10 μv
100 μv
1 mv
10 mv
100 mv
LOSS IN SENSITIVITY - Db.
0
10
20
30
40
50
60
REVISED SC-3
[redacted] RECEIVER PPI
MCW JAMMING
250 KC 50% MOD.
OFF FREQ. I - .4 MC.
JAMMED SECTOR
UNJAMMED SECTOR
20
40
60
80
100
J/V min. - Db.

PLATE 12A



DECLASSIFIED

PLATE 128

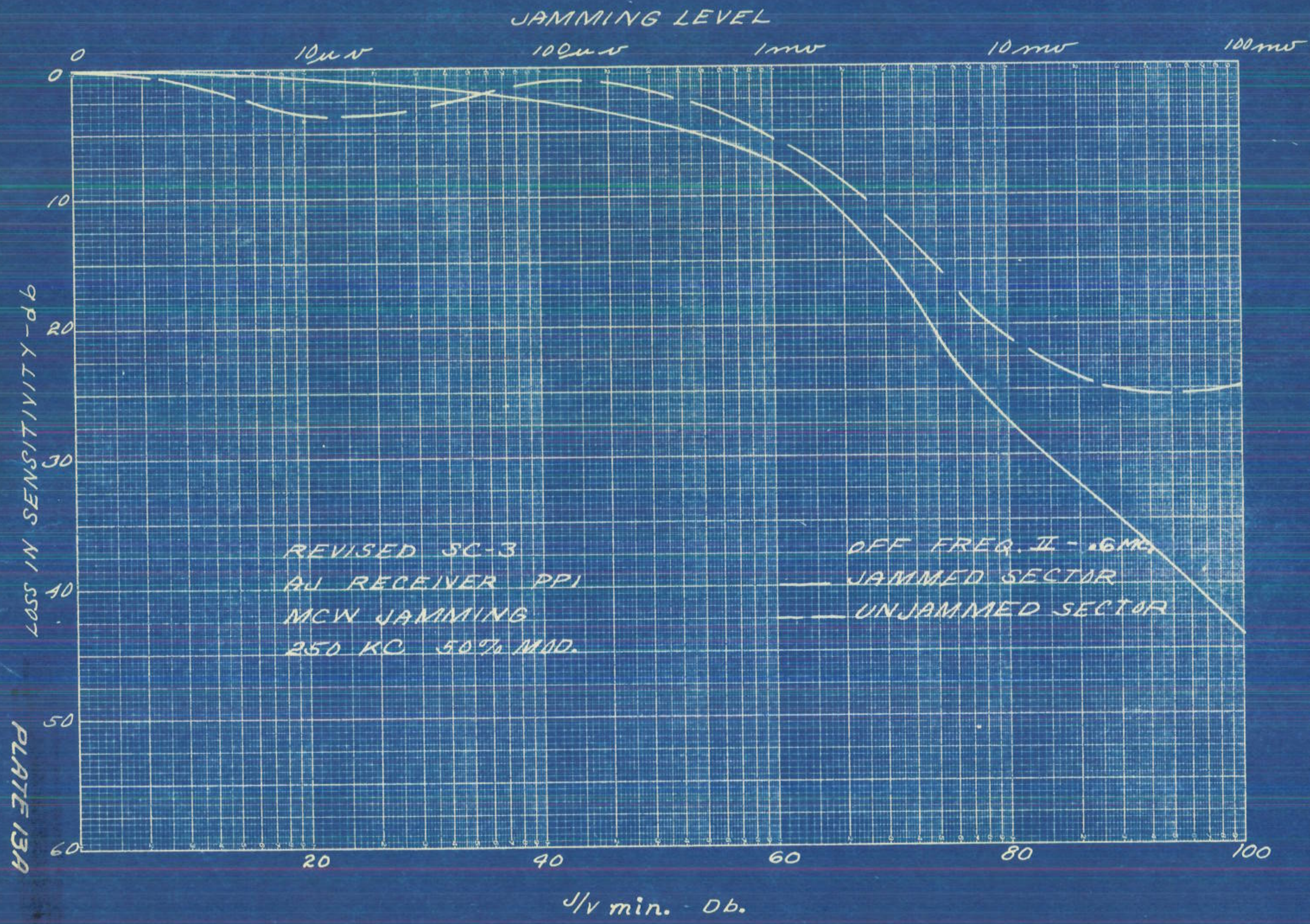


PLATE 13A

DECLASSIFIED

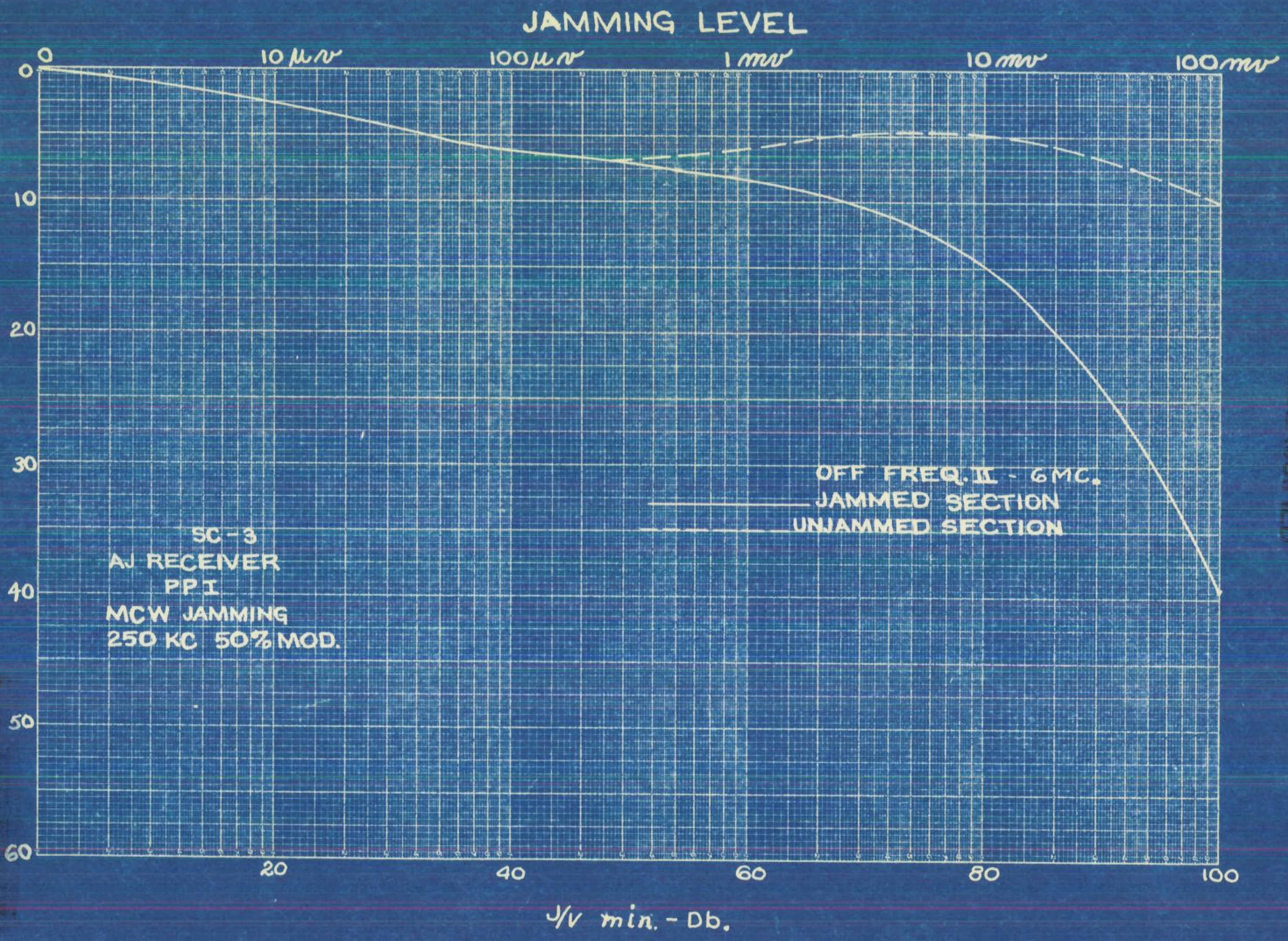

JAMMING LEVEL
0
10 μv
100 μv
1 mv
10 mv
100 mv
LOSS IN SENSITIVITY - Db
0
10
20
30
40
50
60
J/V min. - Db.
20
40
60
80
100
OFF FREQ. II - 6 MC.
JAMMED SECTION
UNJAMMED SECTION
SC-3
AJ RECEIVER
PPI
MCW JAMMING
250 KC 50% MOD.

PLATE 13B

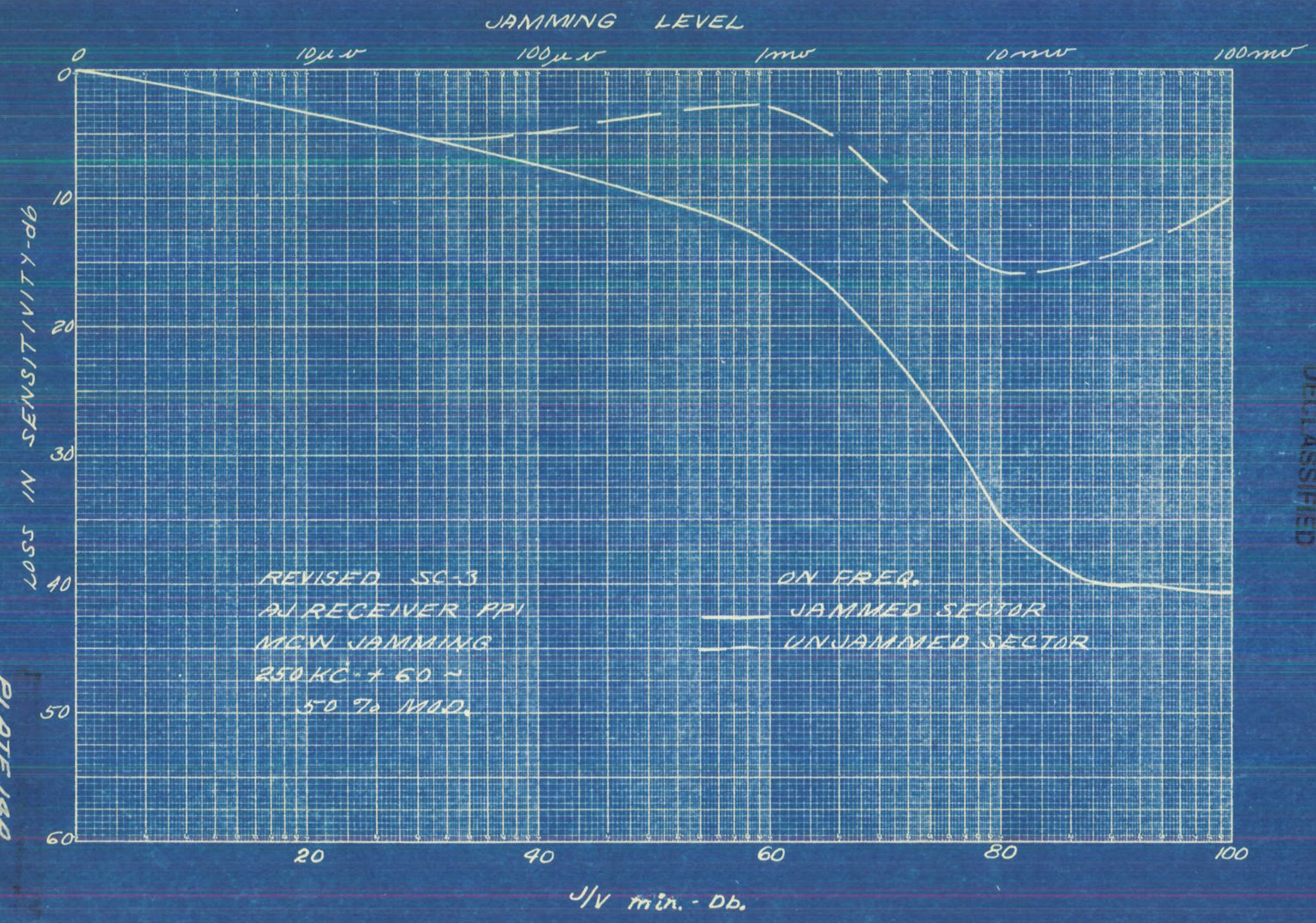


PLATE 14A

DECLASSIFIED

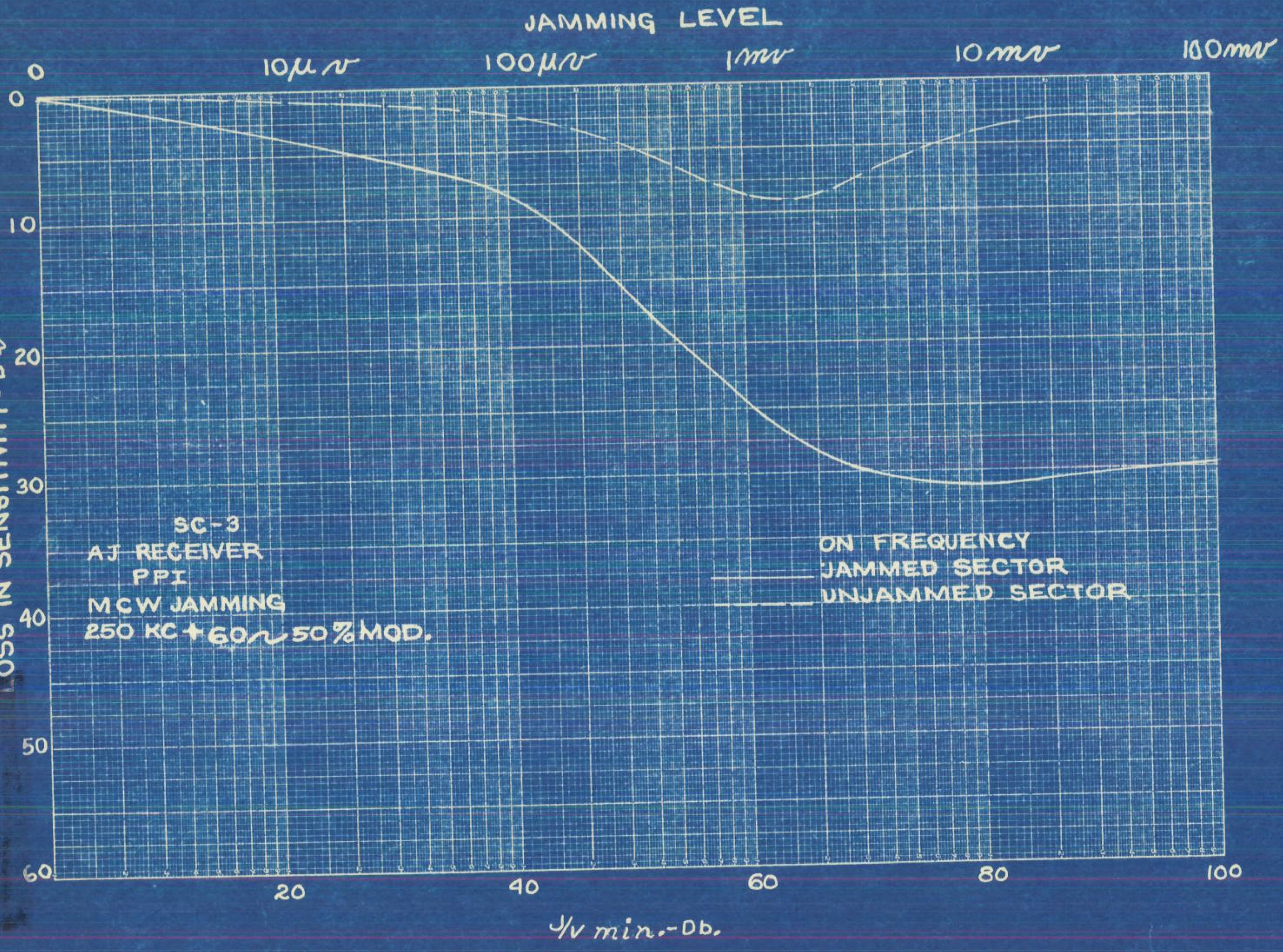

JAMMING LEVEL
0
10μv
100μv
1mv
10mv
100mv
LOSS IN SENSITIVITY - D ℓ
0
10
20
30
40
50
60
20
40
60
80
100
J/v min.-Db.
SC-3
AJ RECEIVER
PPI
MCW JAMMING
250 KC + 60~ 50% MOD.
ON FREQUENCY
JAMMED SECTOR
UNJAMMED SECTOR

PLATE 14B

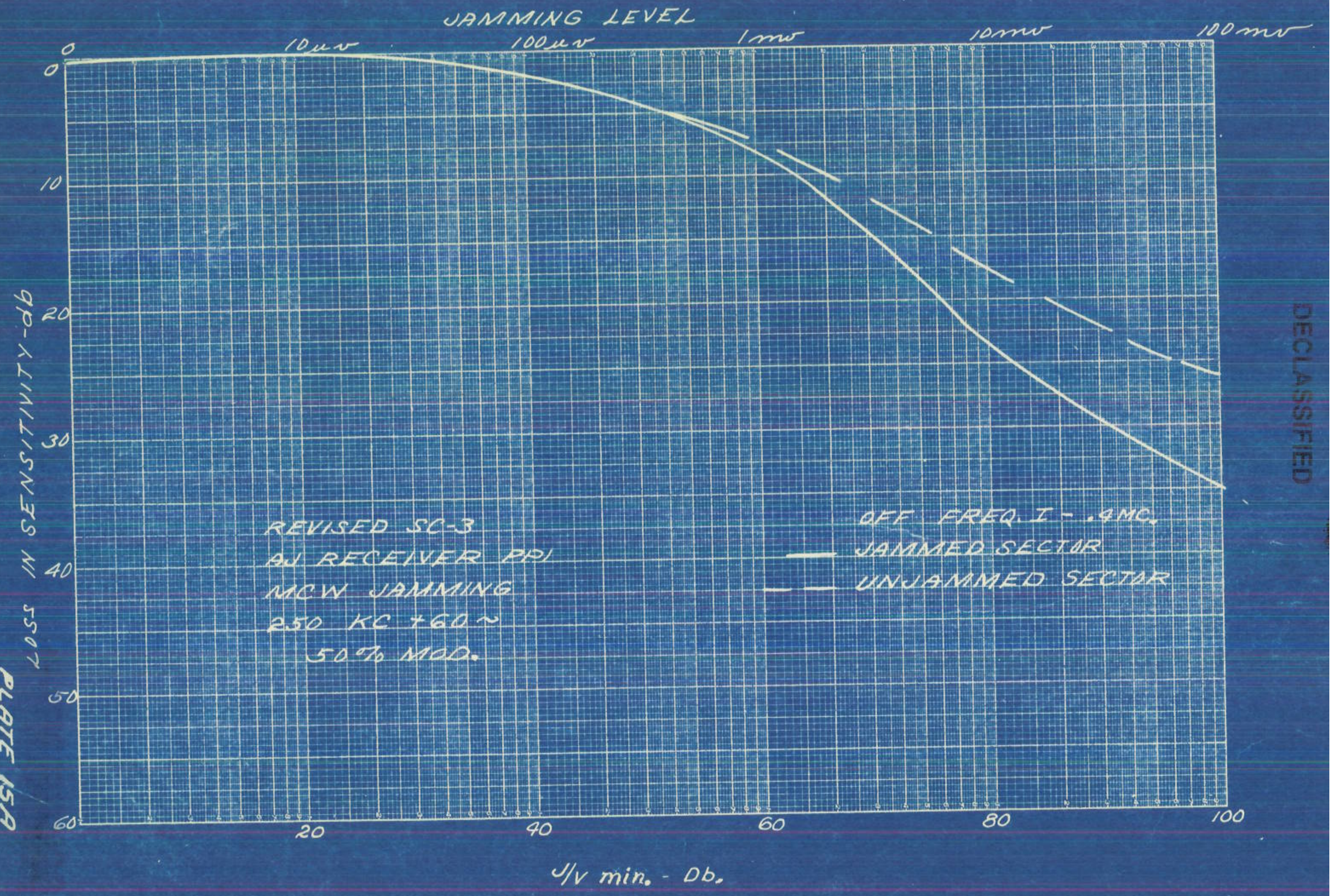


PLATE 15A

DECLASSIFIED

DECLASSIFIED

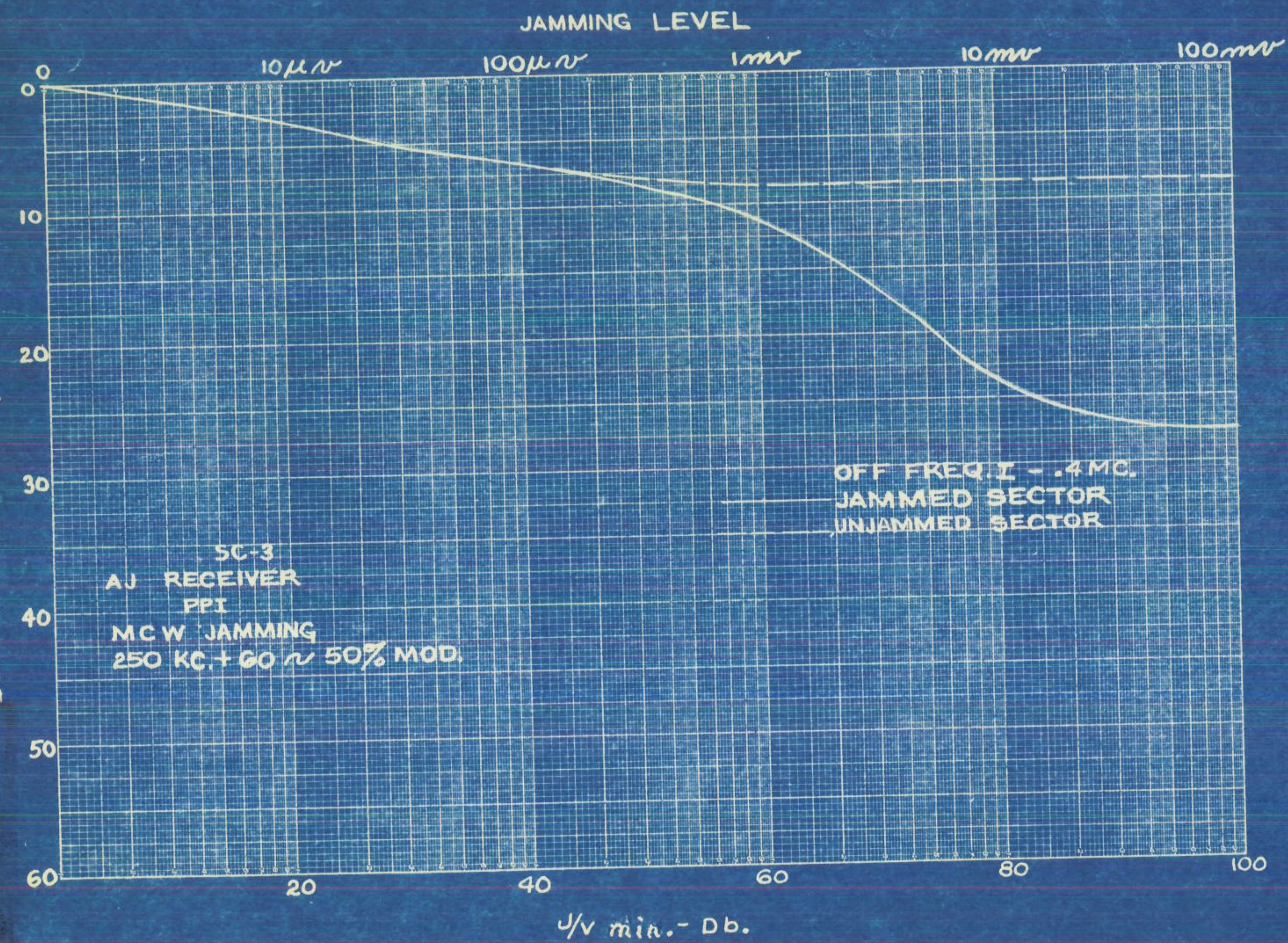


PLATE 15B

DECLASSIFIED

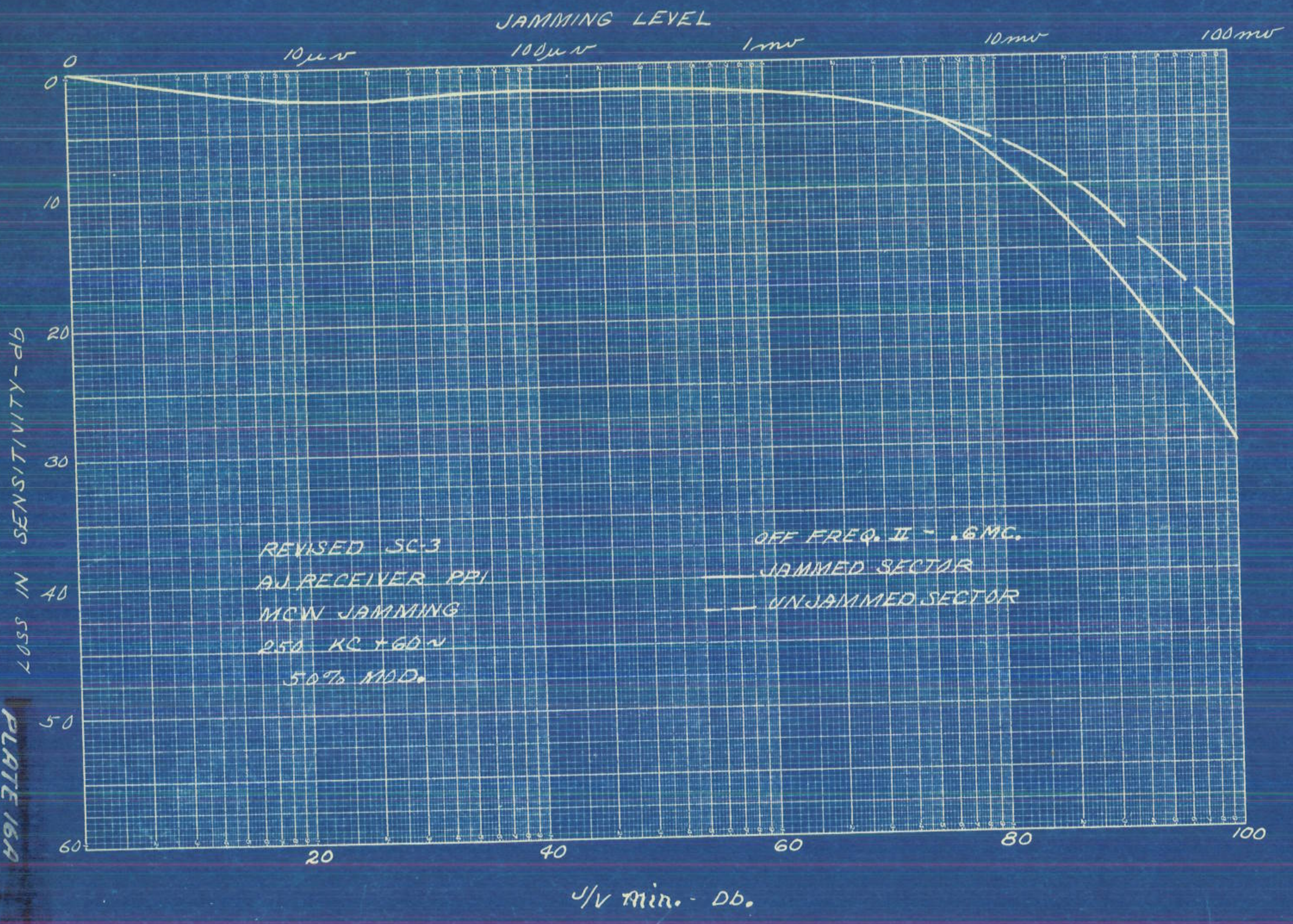


PLATE 16A

DECLASSIFIED

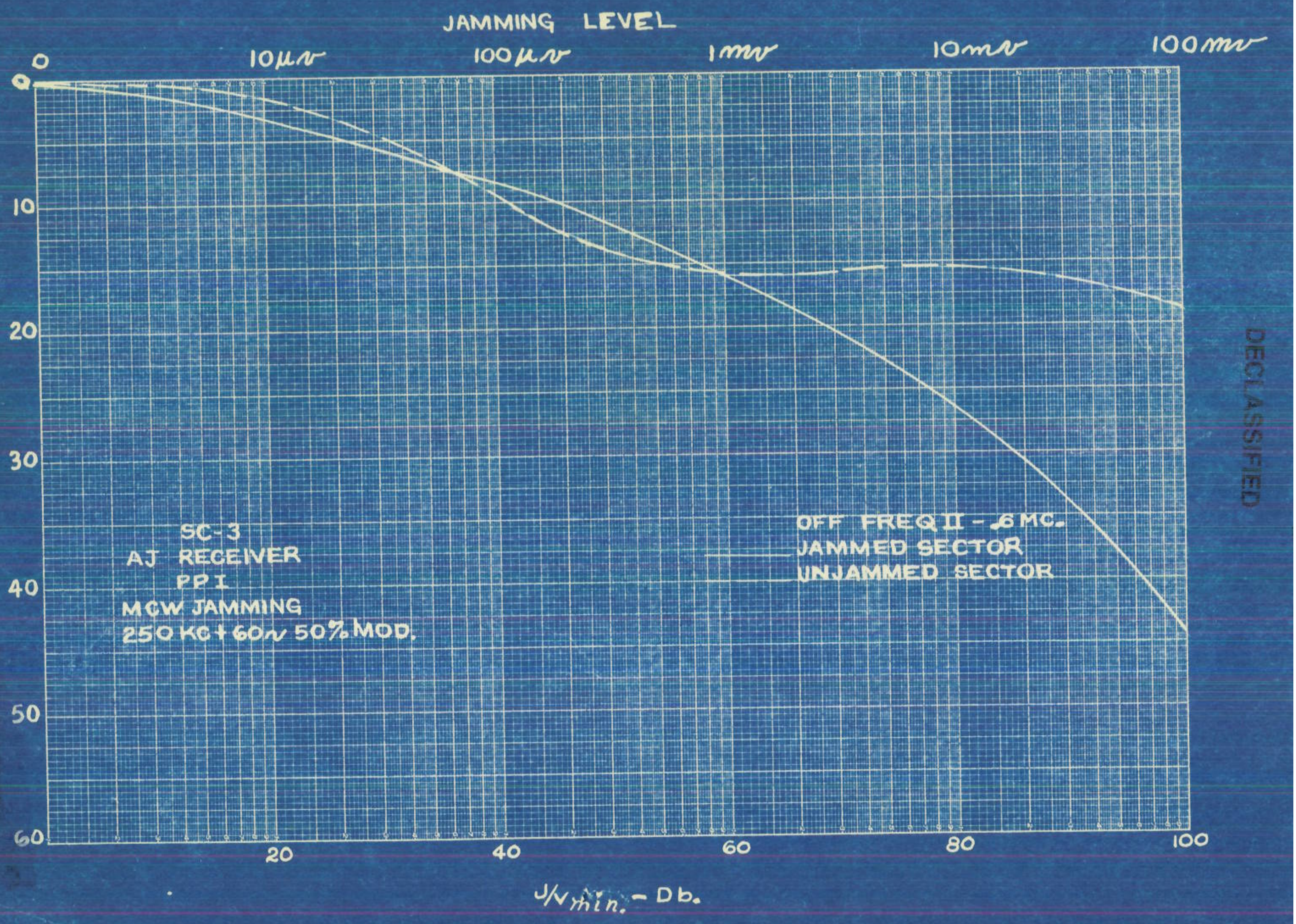

JAMMING LEVEL
0
10μv
100μv
1mv
10mv
100mv
LOSS IN SENSITIVITY - Db
0
10
20
30
40
50
60
20
40
60
80
100
J/N min. - Db.
SC-3
AJ RECEIVER
PPI
MCW JAMMING
250 KC + 60~ 50% MOD.
OFF FREQ II - .6 MC.
JAMMED SECTOR
UNJAMMED SECTOR

PLATE 16B

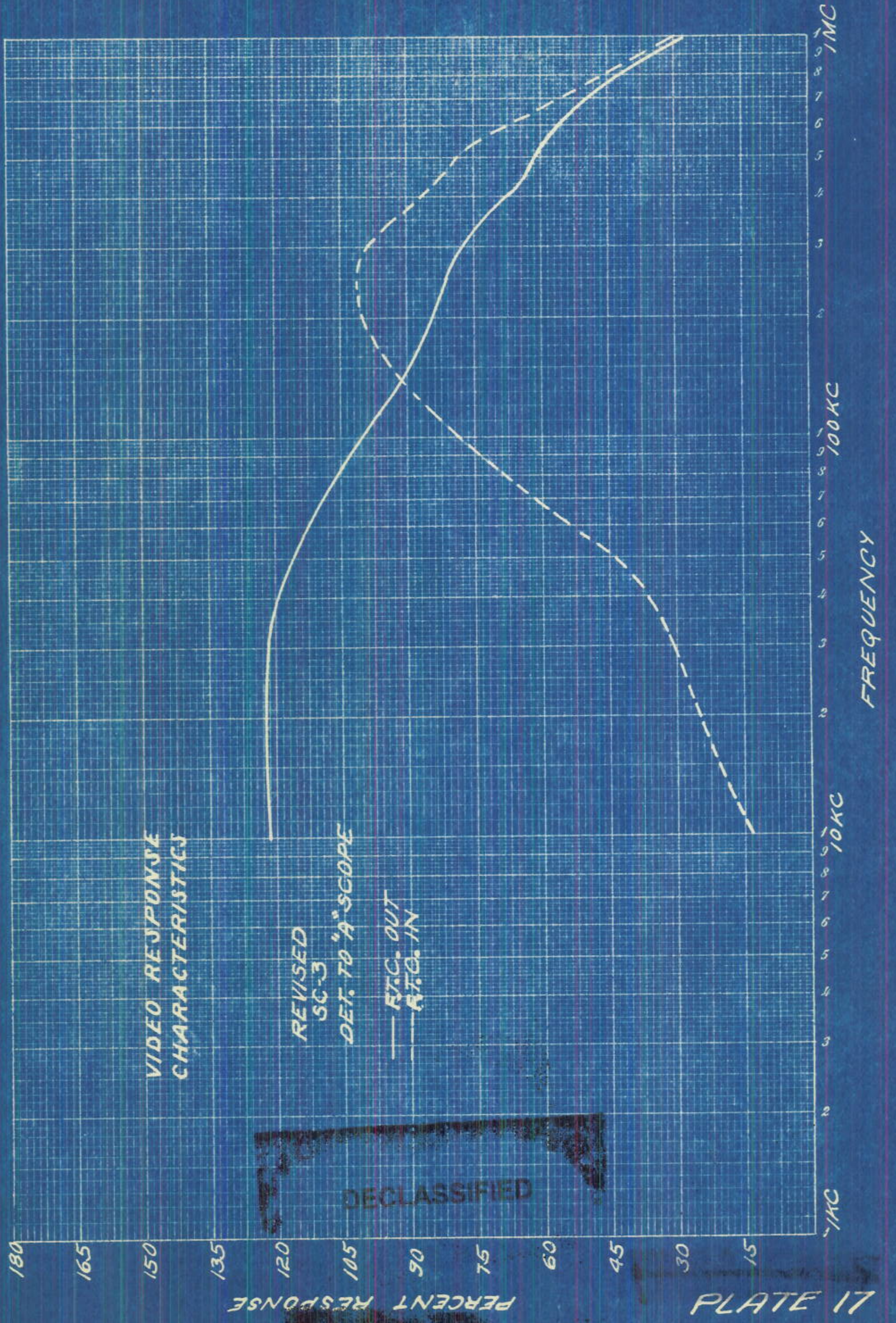

VIDEO RESPONSE
CHARACTERISTICS
REVISED
SC-3
DET. TO "A" SCOPE
— F.T.C. OUT
--- F.T.C. IN
FREQUENCY
1KC
10KC
100KC
1MC
PERCENT RESPONSE
180
165
150
135
120
105
90
75
60
45
30
15

PLATE 17

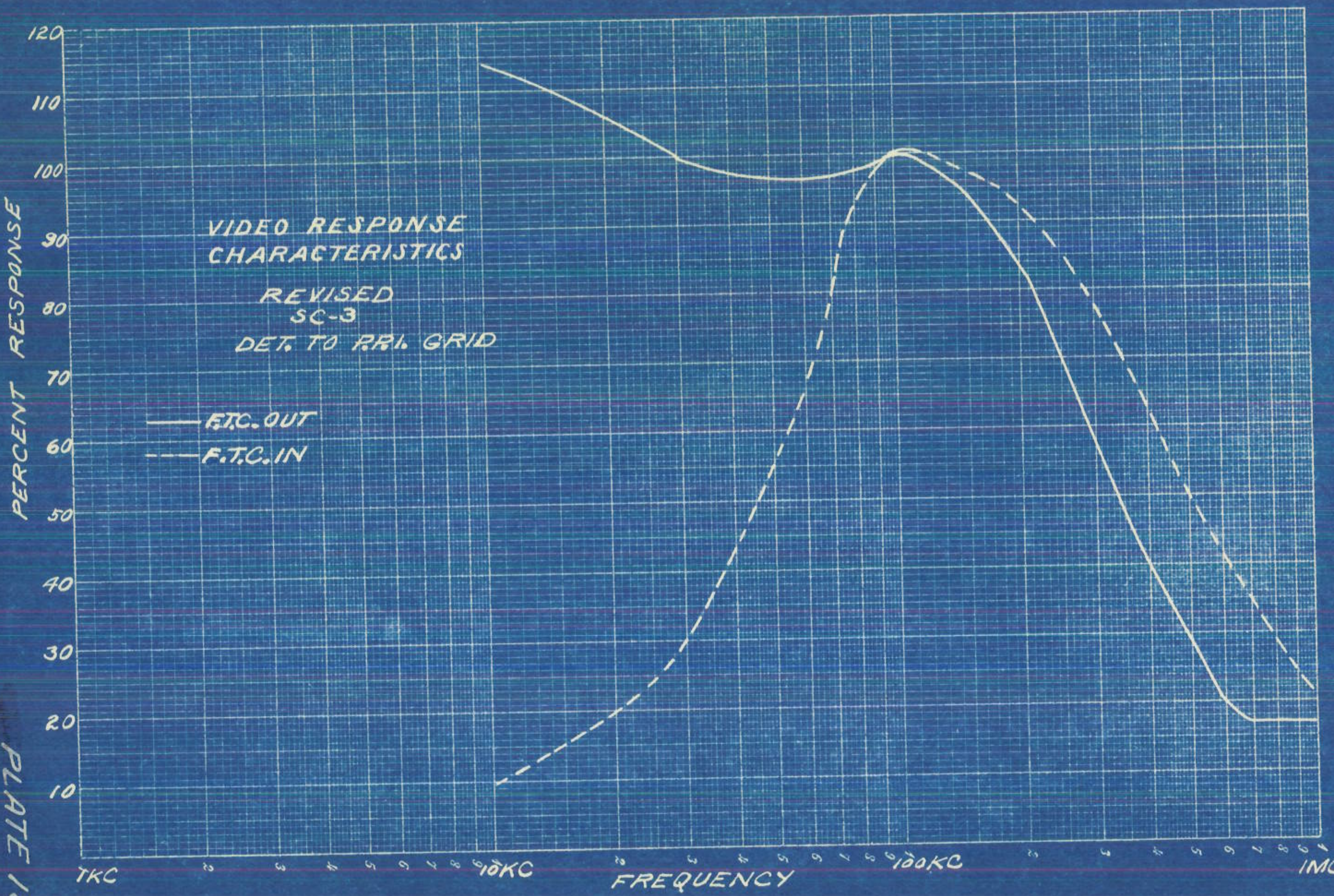
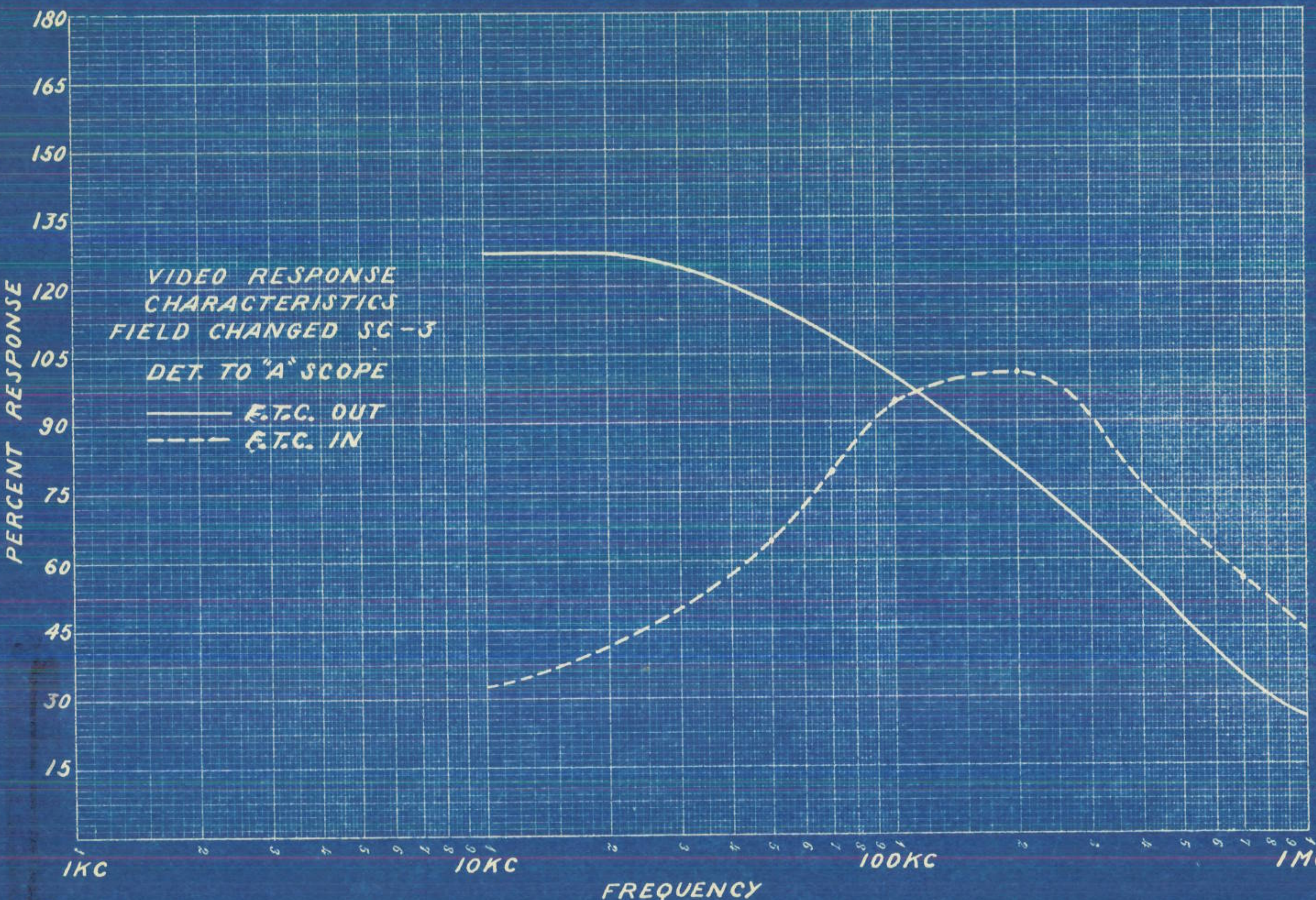


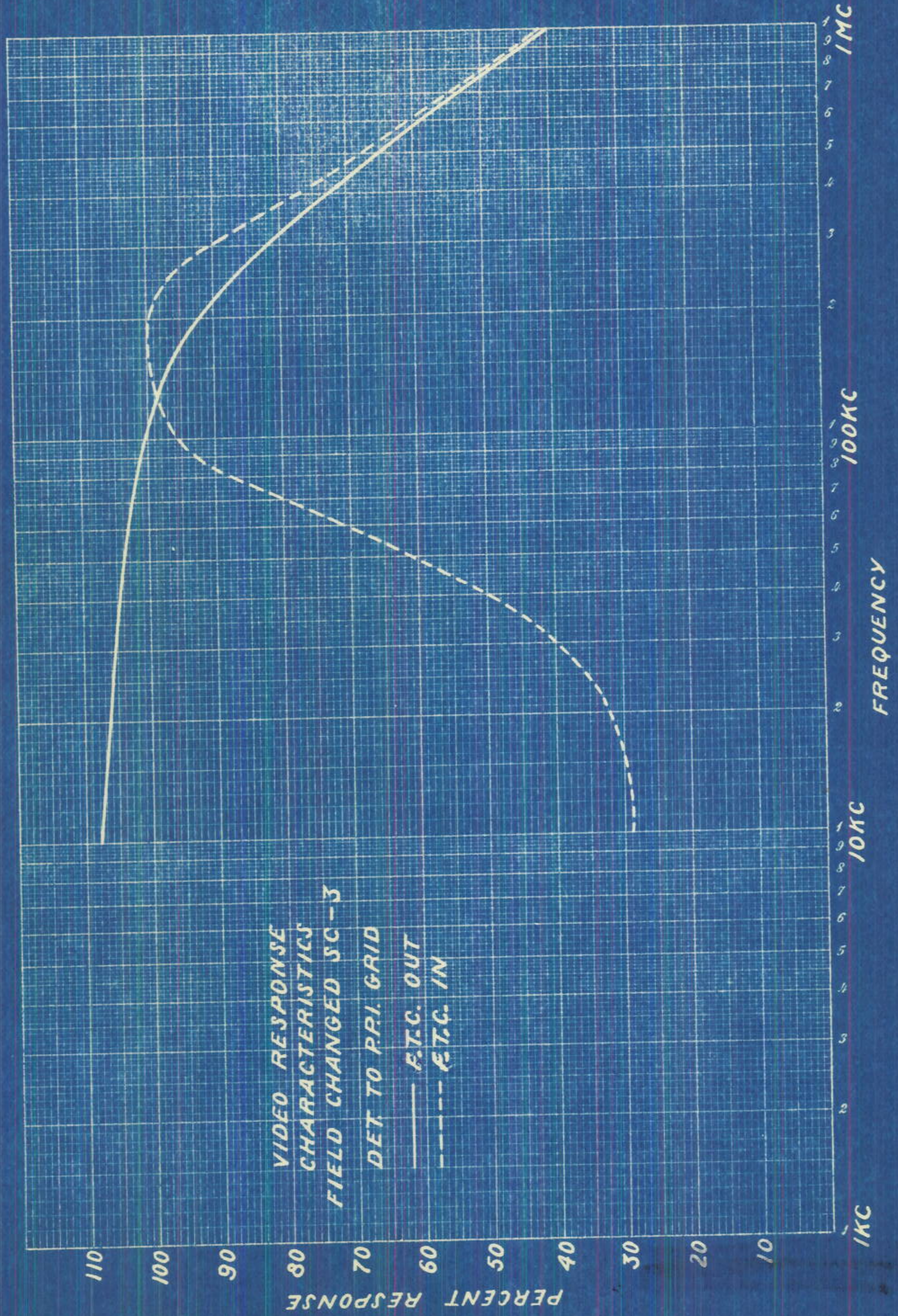
PLATE 18

DECLASSIFIED



DECLASSIFIED

PLATE 19



DECLASSIFIED

PLATE 20

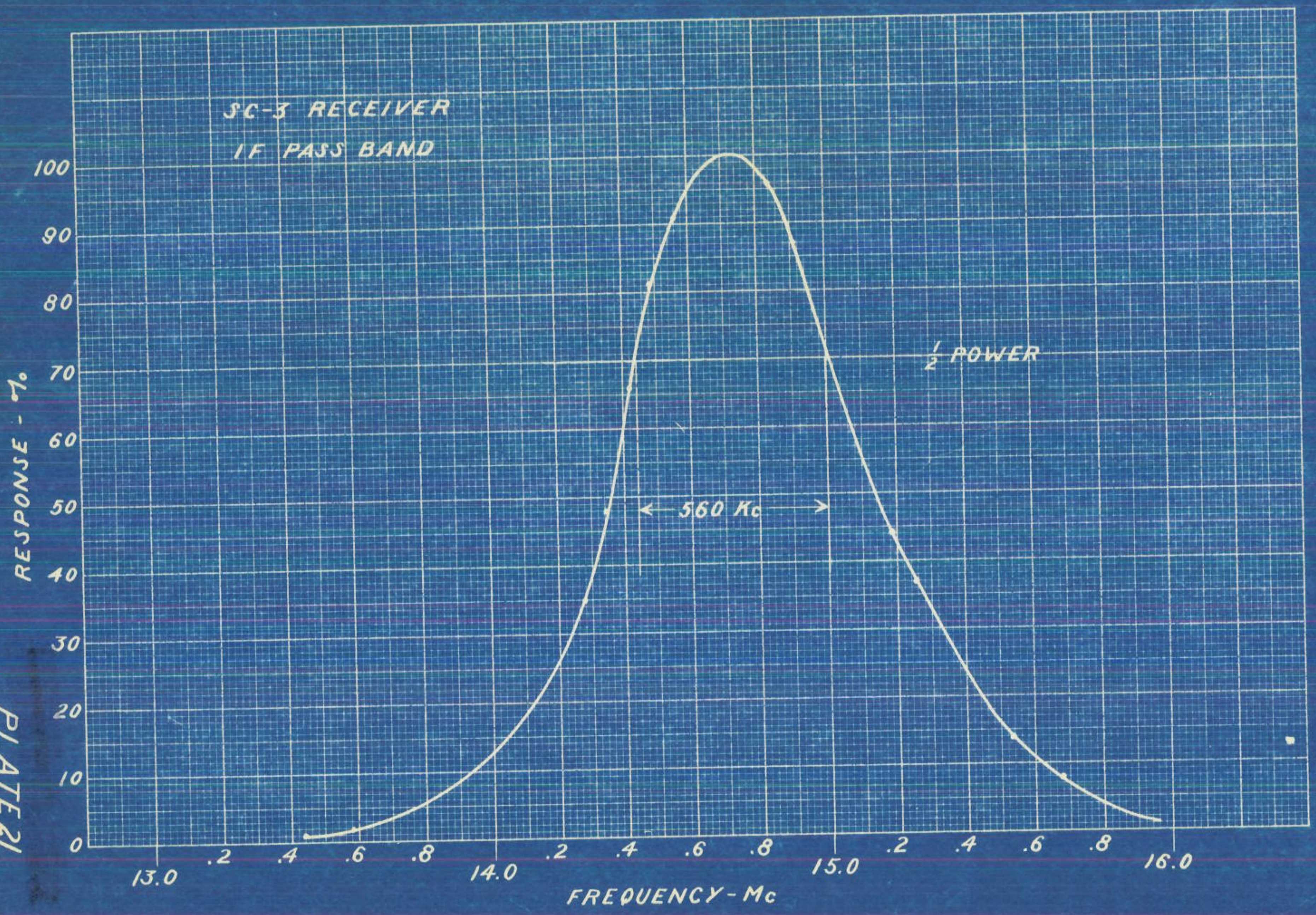


PLATE 21

DECLASSIFIED

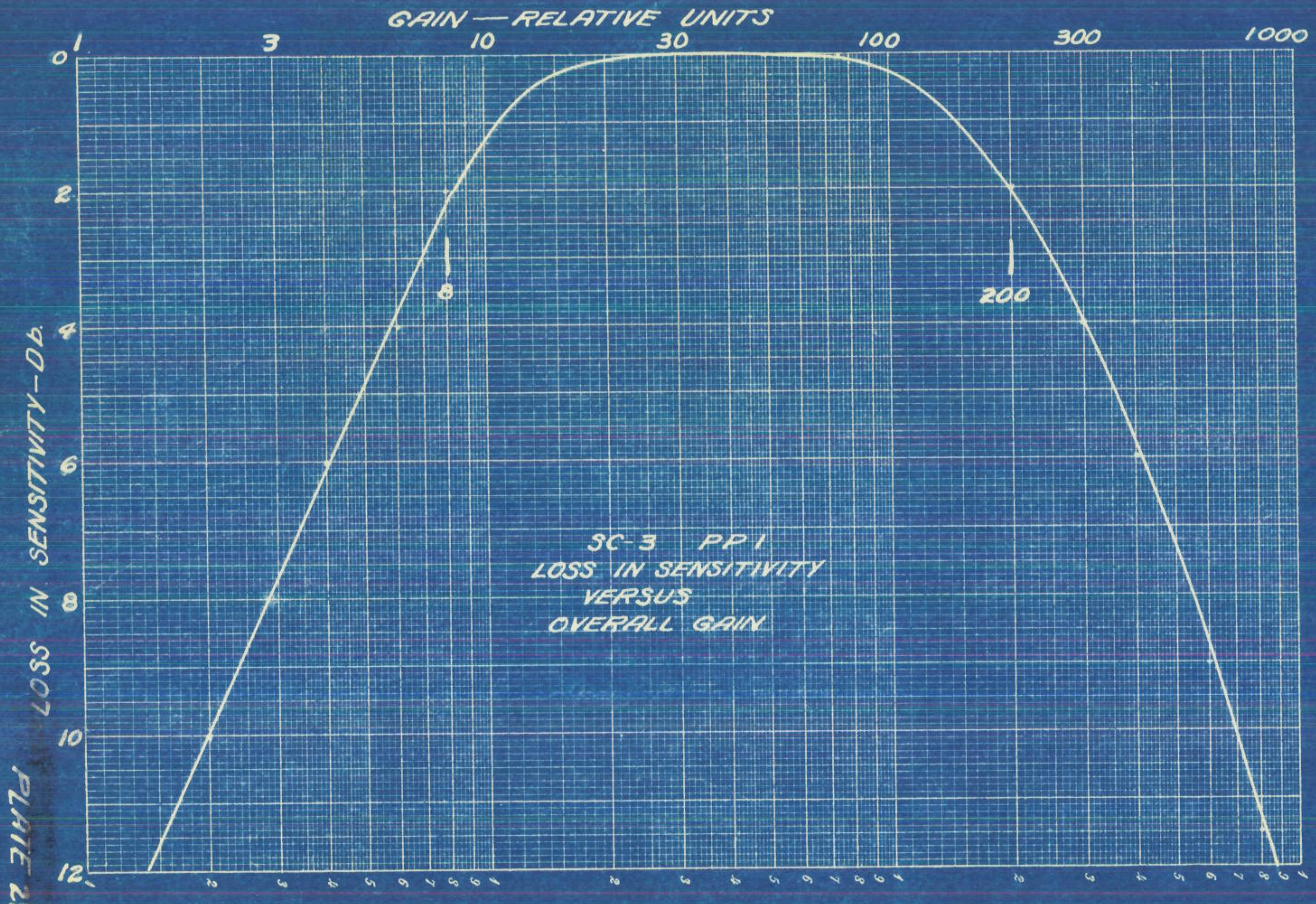
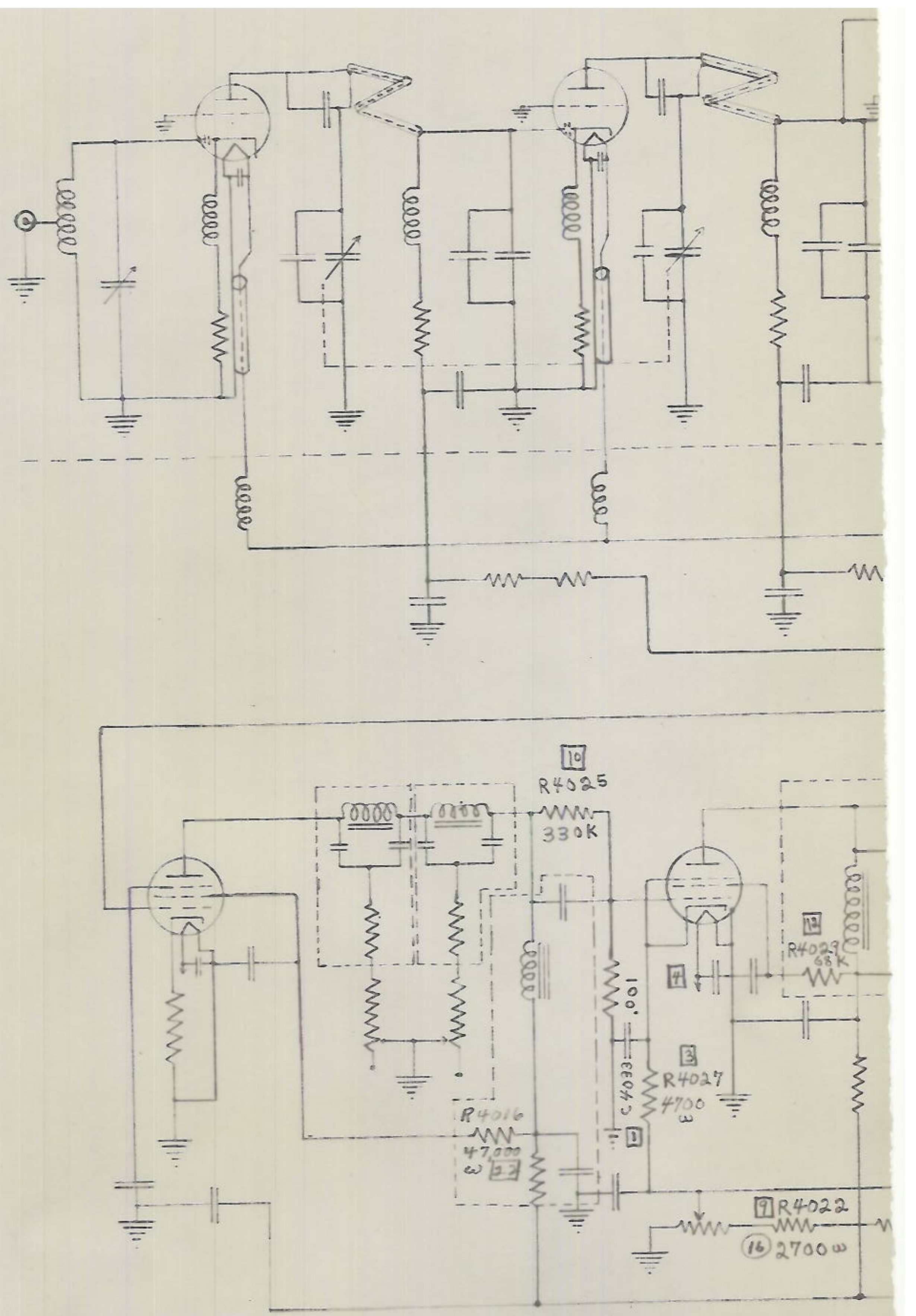
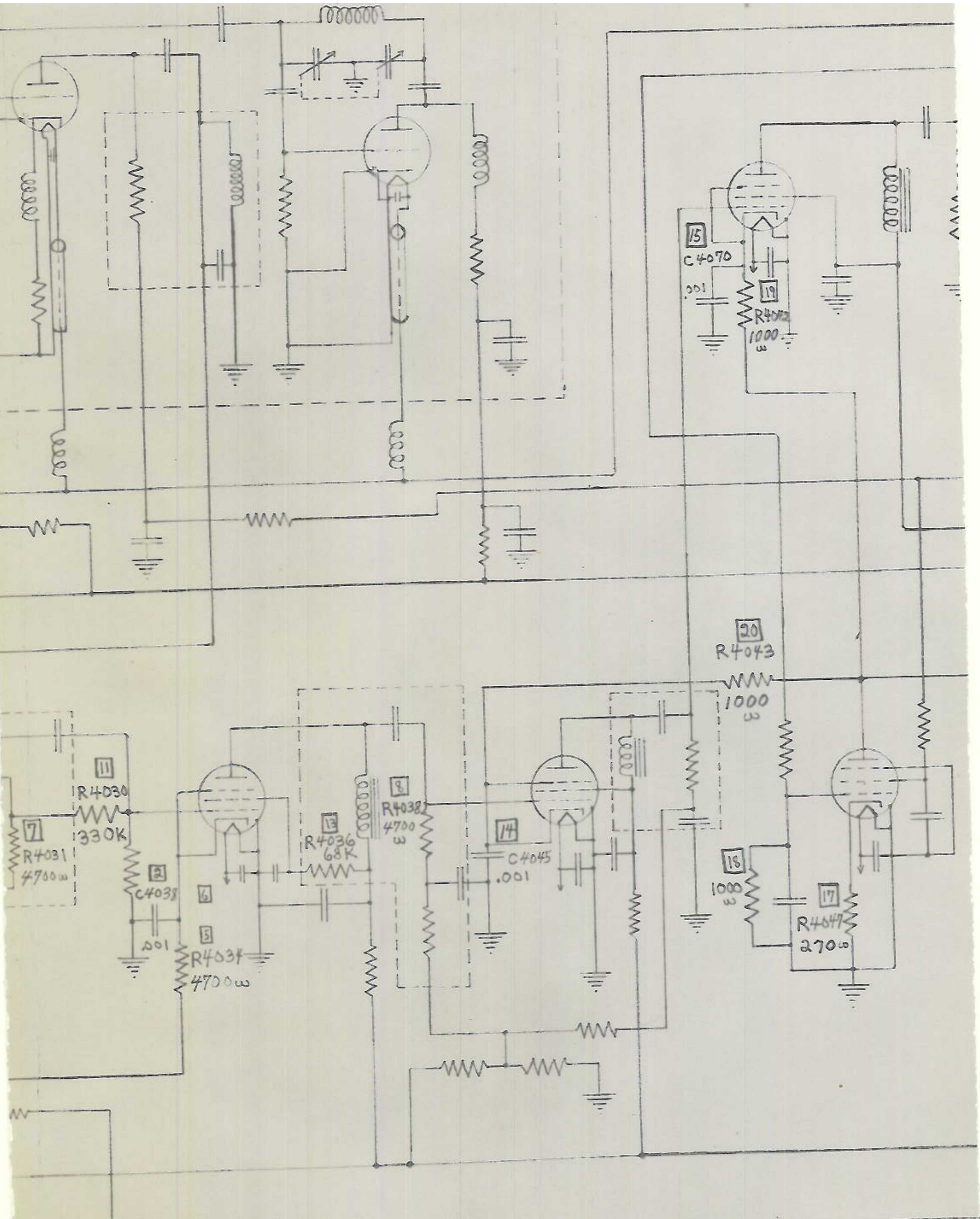


PLATE 22

DECLASSIFIED

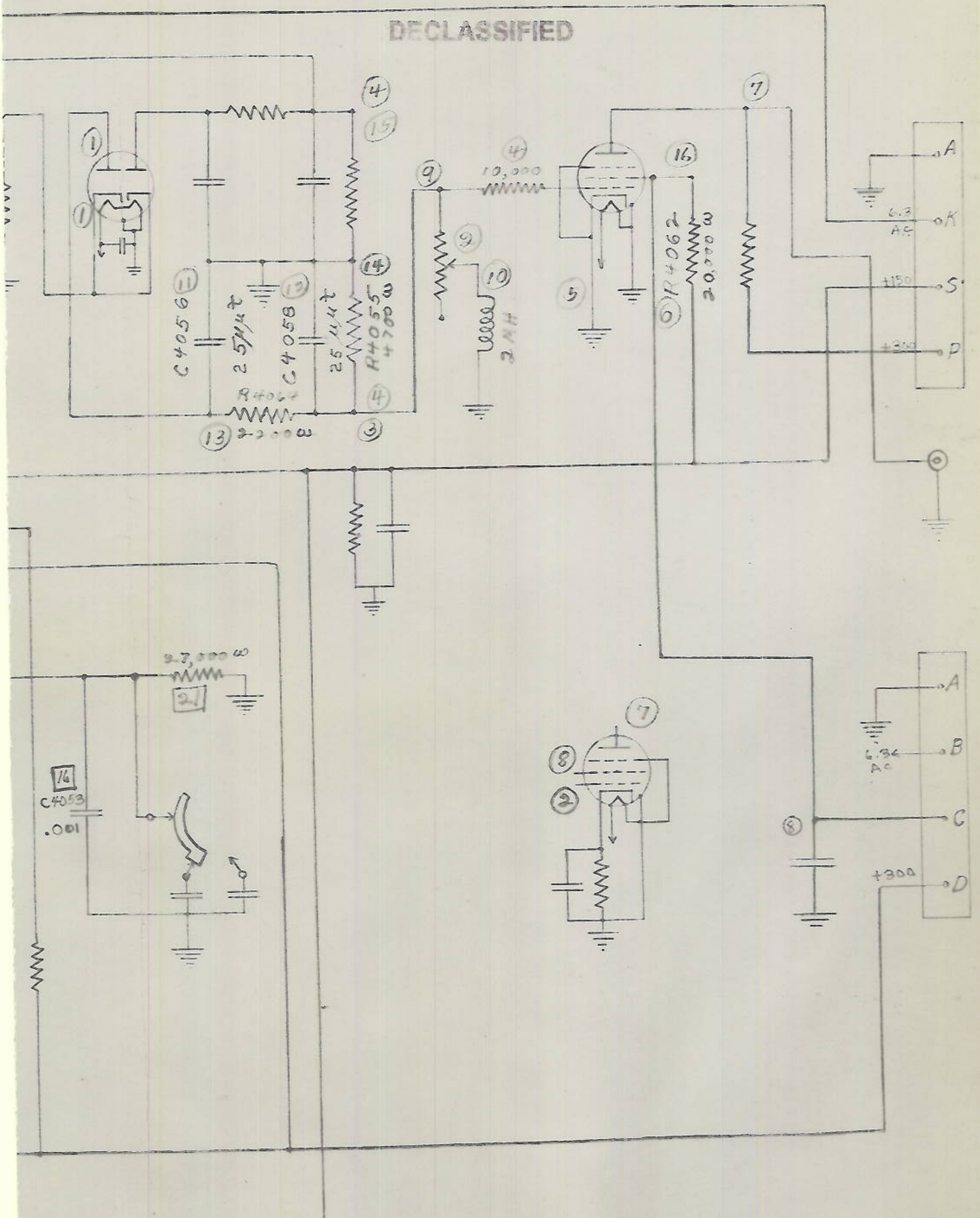


SCHEMATIC DIAGRAM
CG46ACQ RECEIVER
WITH FIELD CHANGES



☐ DENOTES CHANGES IN ACCORDANCE WITH TABLE 2.

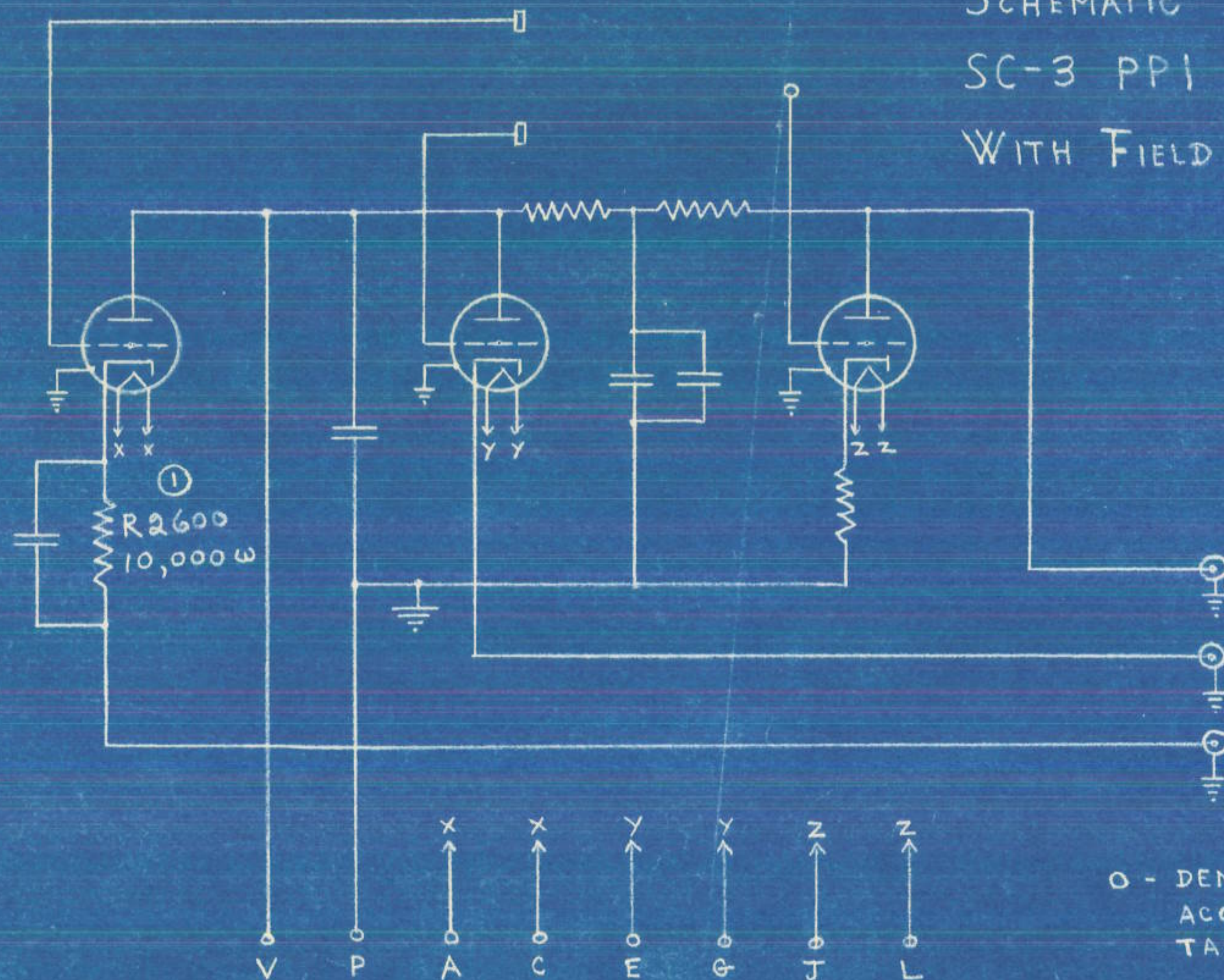
☐ · DENOTES CHA[NGES IN ACCORDANCE] WITH TABLE 3



NGES IN ACCORDANCE

PLATE 23

Schematic Diagram
SC-3 PPI Coupling Unit
With Field Change



O - DENOTES CHANGE IN ACCORDANCE WITH TABLE 1.

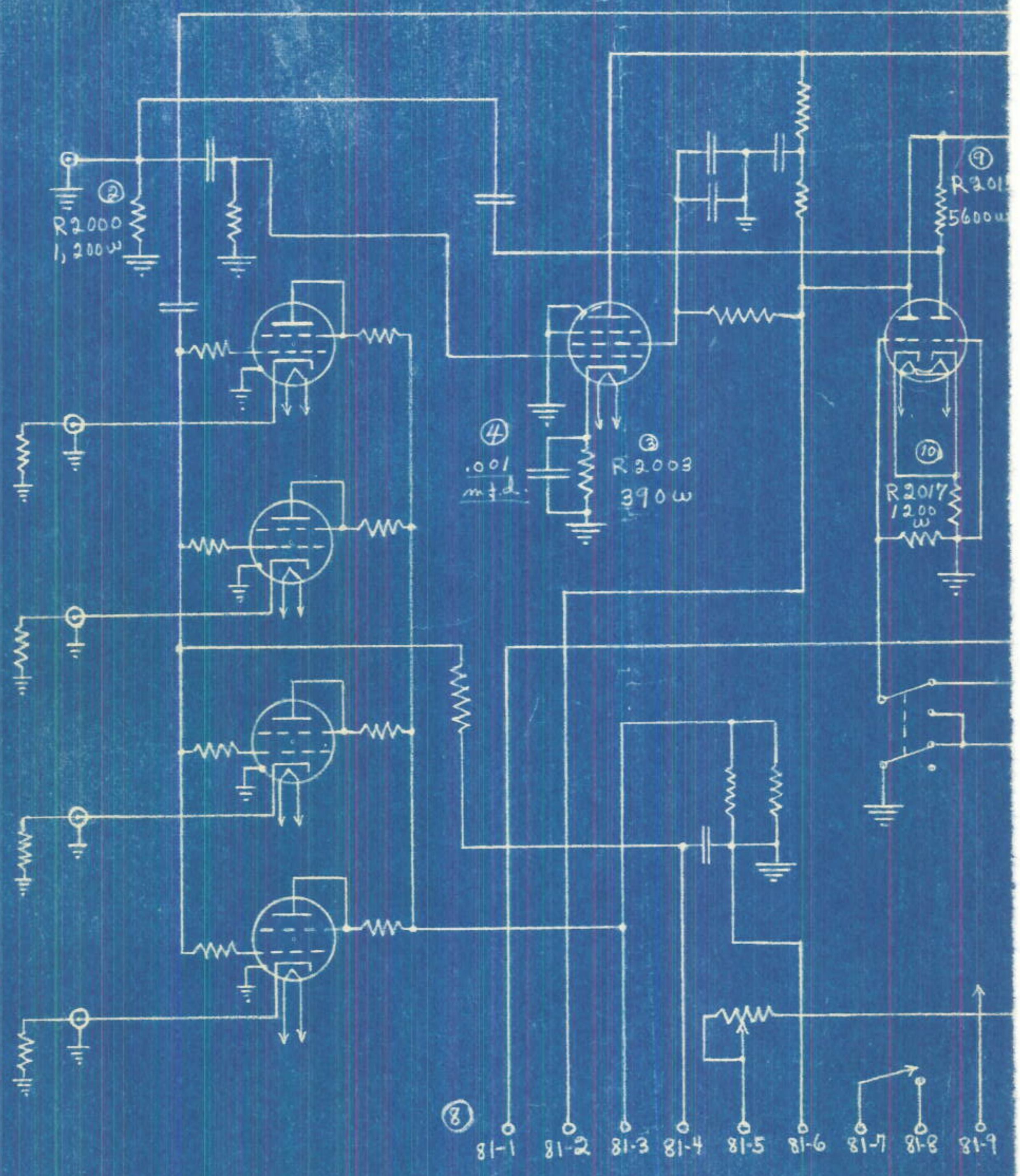
DECLASSIFIED

DECLASSIFIED

PLATE 24

U. S. NAVAL RESEARCH LABORATORY WASHINGTON 20, D. C.		SCALE	
B'LD'G.	PHONE	DR'WN.	
		CH'K'D.	
ROOM	DATE	APPR'V'D.	UNLESS OTHERWISE SPECIFIED, TOLERANCES ARE ±

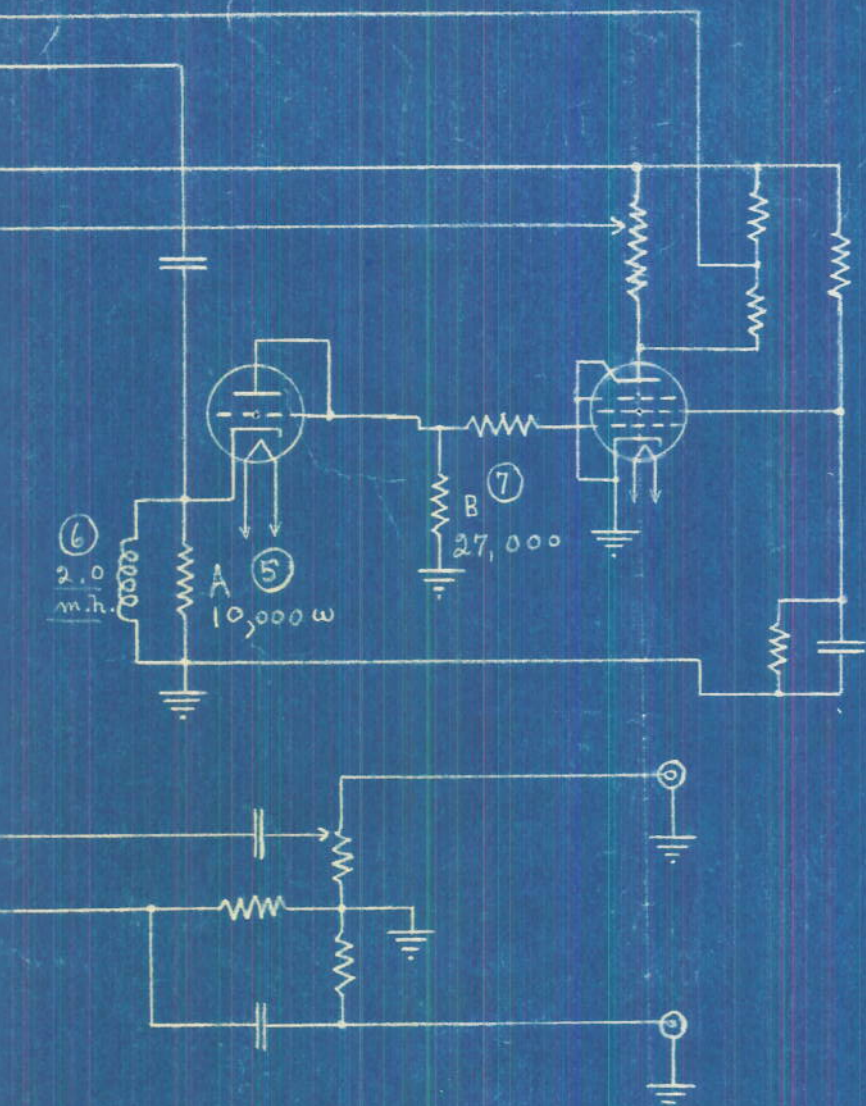
SHEET OF



SCHEMATIC DIAGRAM SC-3 PPI V

WITH FIELD CHANGES

U. S. NAVAL RESEARCH LABOR	
WASHINGTON 20, D. C.	
B'LD'G.	PHONE
ROOM	DATE



O - DENOTES CHANGE IN ACCORDANCE WITH TABLE 1

A - DIAGRAM # WW-7351160 (C) - R2022
IN PPI - R2027

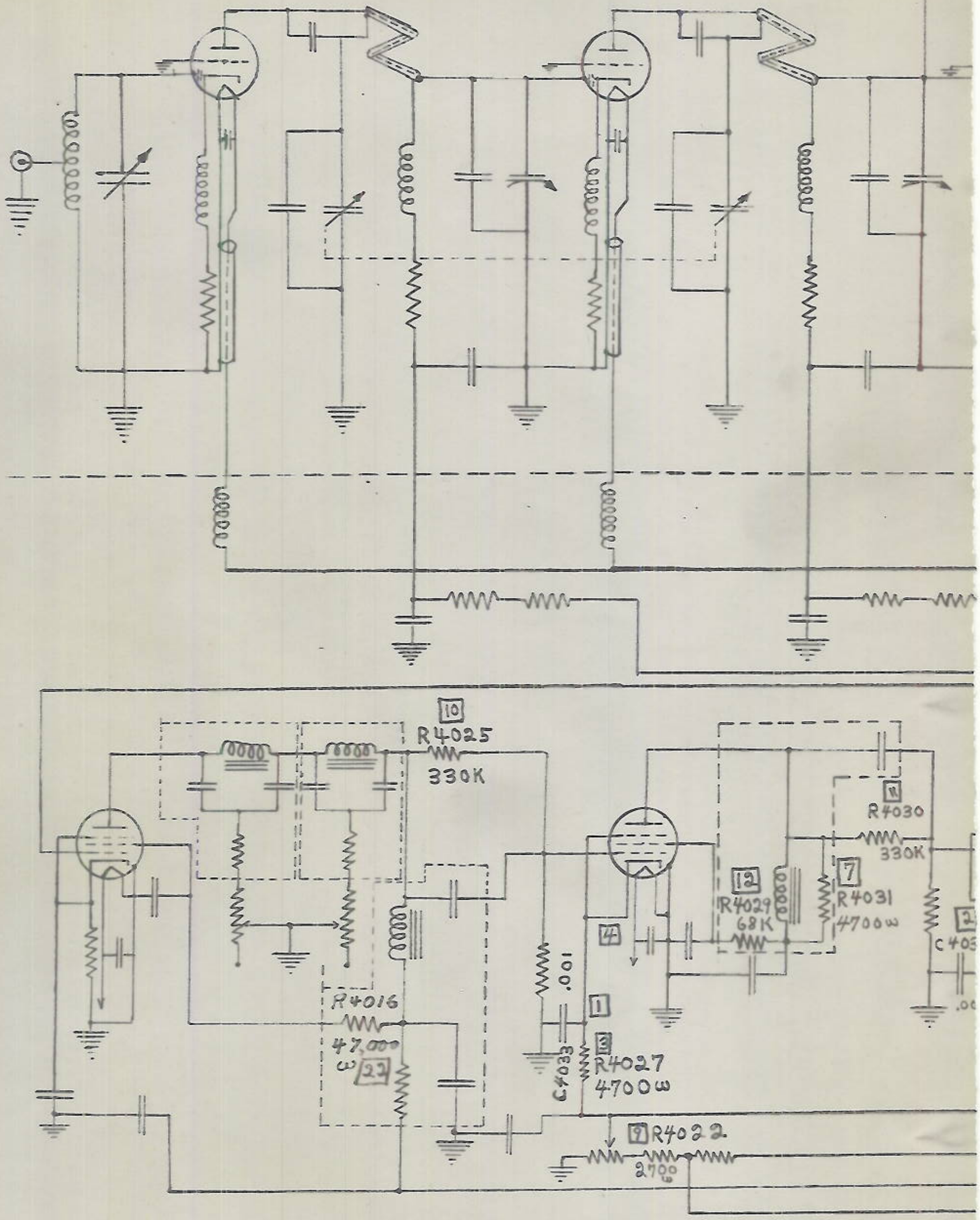
B - DIAGRAM # WW-7351160 (C) - R2027
IN PPI - R2022

IDEO UNIT

PLATE 25

ATORY	SCALE	
	DR'WN.	
	CH'K'D.	
	APPR'V'D.	UNLESS OTHERWISE SPECIFIED, TOLERANCES ARE ±

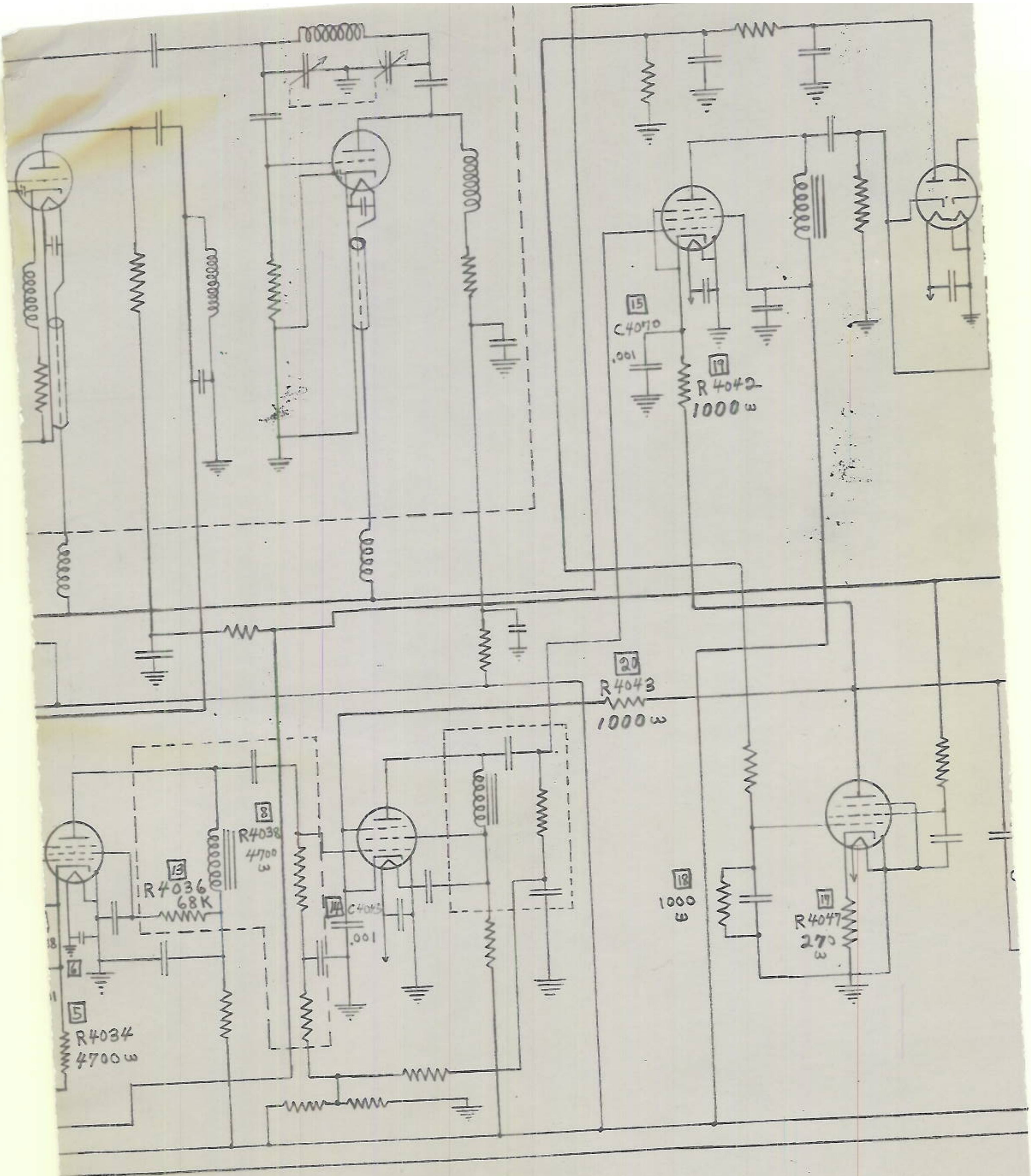
SHEET OF



Schematic Diagram

Revised CG46ACQ Receive

(1)



☐ - DENOTES CHANGE IN ACCORDANCE WITH TABLE 3.

R

②

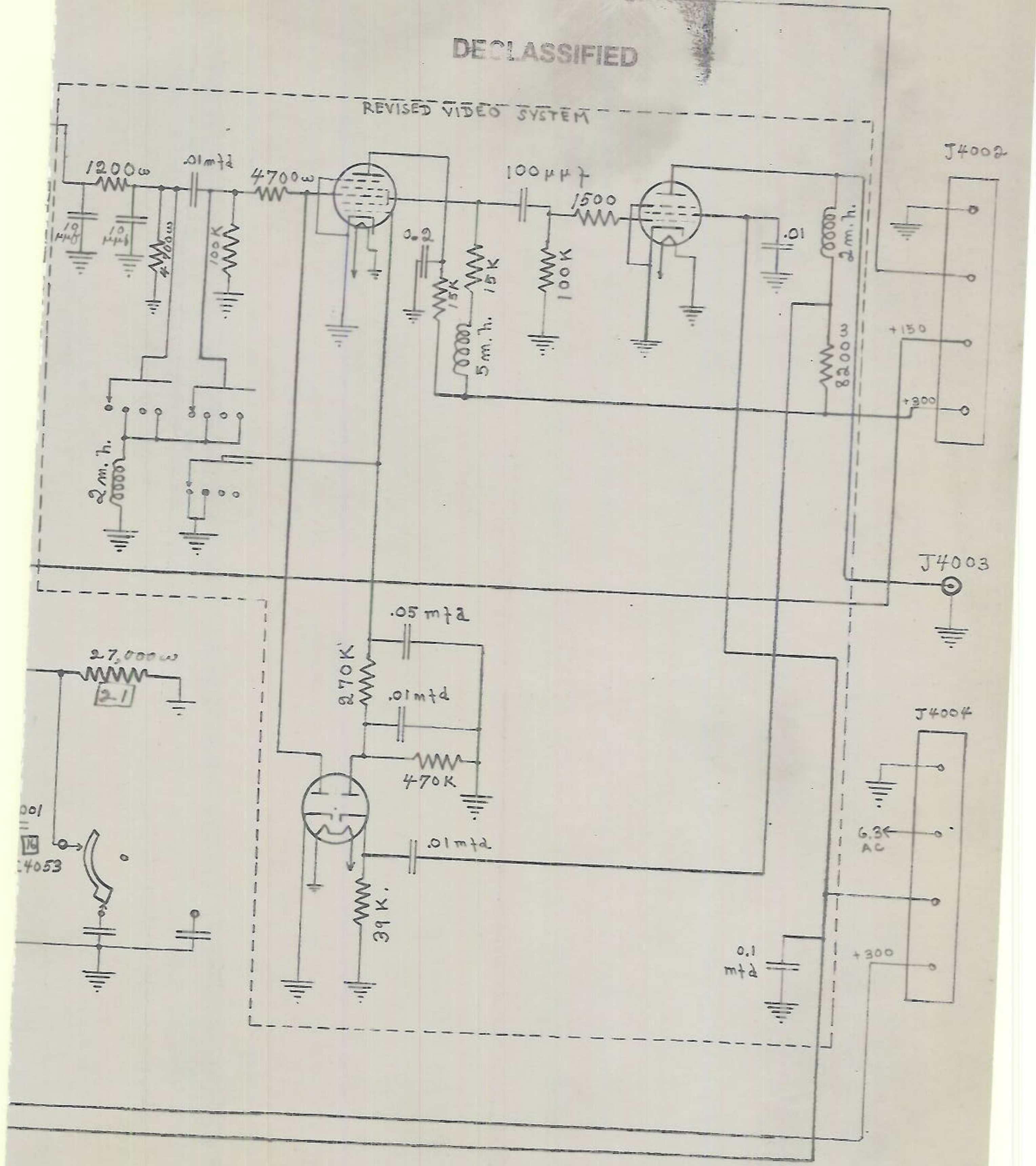
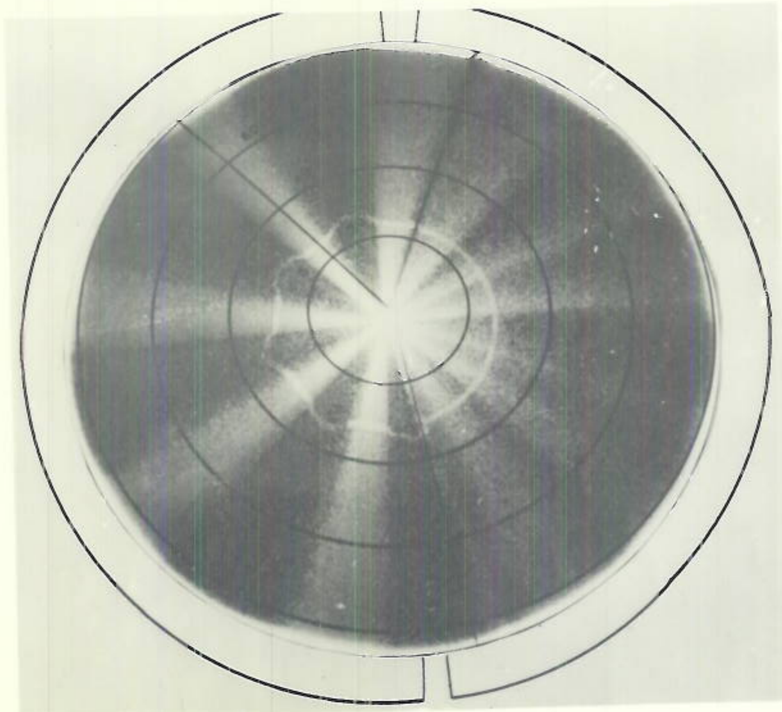

REVISED VIDEO SYSTEM
1200ω
.01mfd
4700ω
100μμf
1500
J4002
10 μμf
10 μμf
4700ω
100K
0.2
15K
15K
100K
.01
2m.h.
5m.h.
8200ω
+150
+300
2m.h.
J4003
.05 mfd
270K
.01mfd
470K
27,000ω
2.1
.01mfd
39K.
J4004
6.3 AC
0.1 mfd
+300
4053

PLATE 26

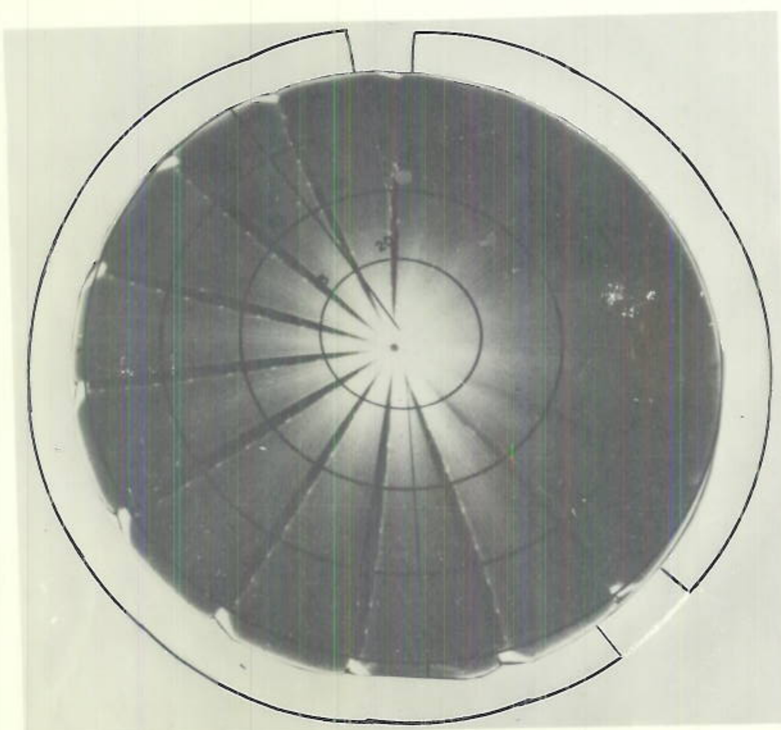
F T C
OUT



F T C
IN

8 μ V 62 CYCLE JAMMING
VIDEO OPERATIVE

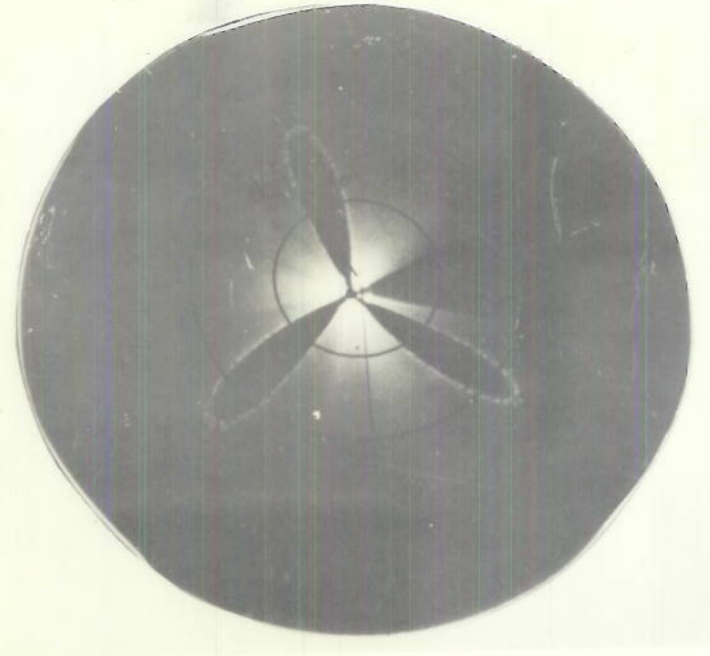
F T C
OUT



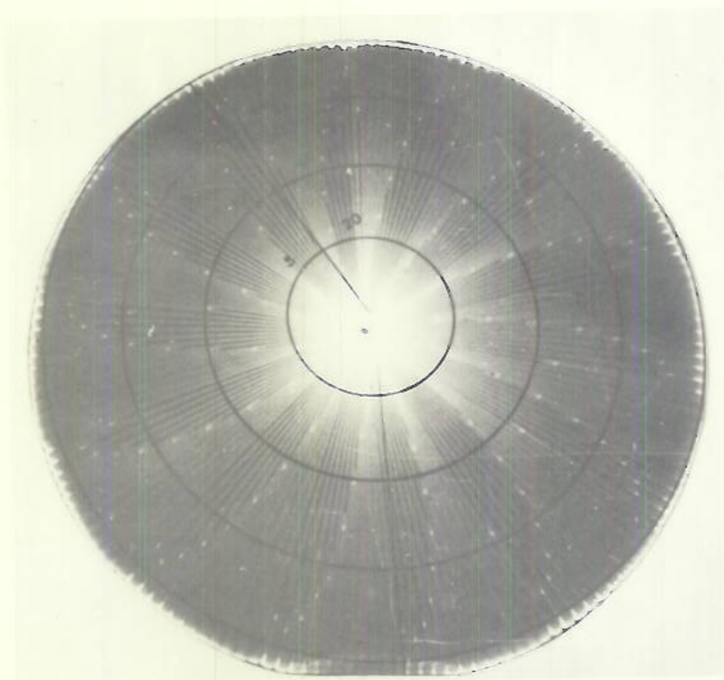
F T C
IN

1 MV.. 65 CYCLE JAMMING
VIDEO DISCONNECTED

SC-3 PPI IN THE PRESENCE OF LOW FREQUENCY JAMMING

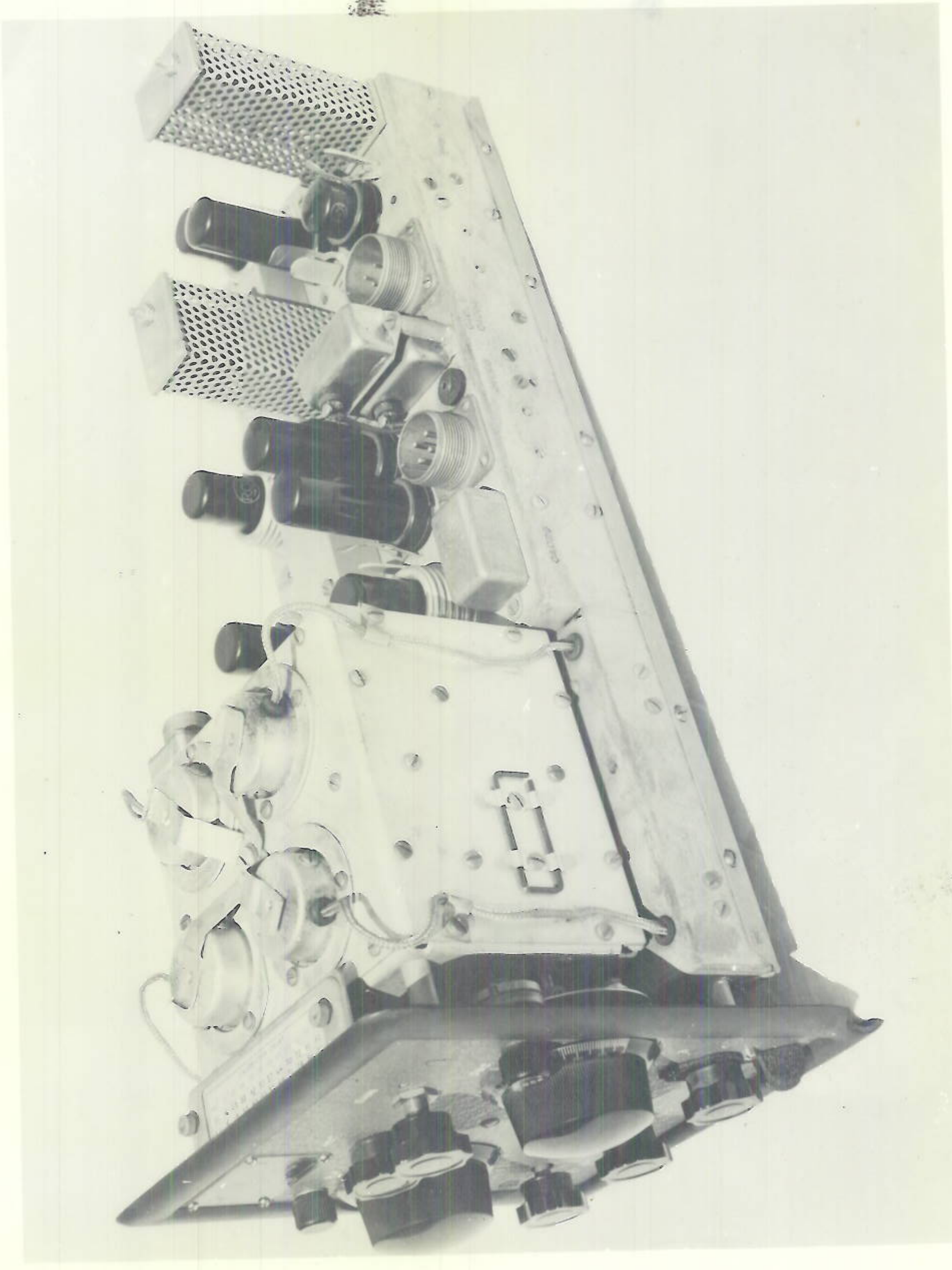


15 µV 61 CYCLE JAMMING
VIDEO DISCONNECTED

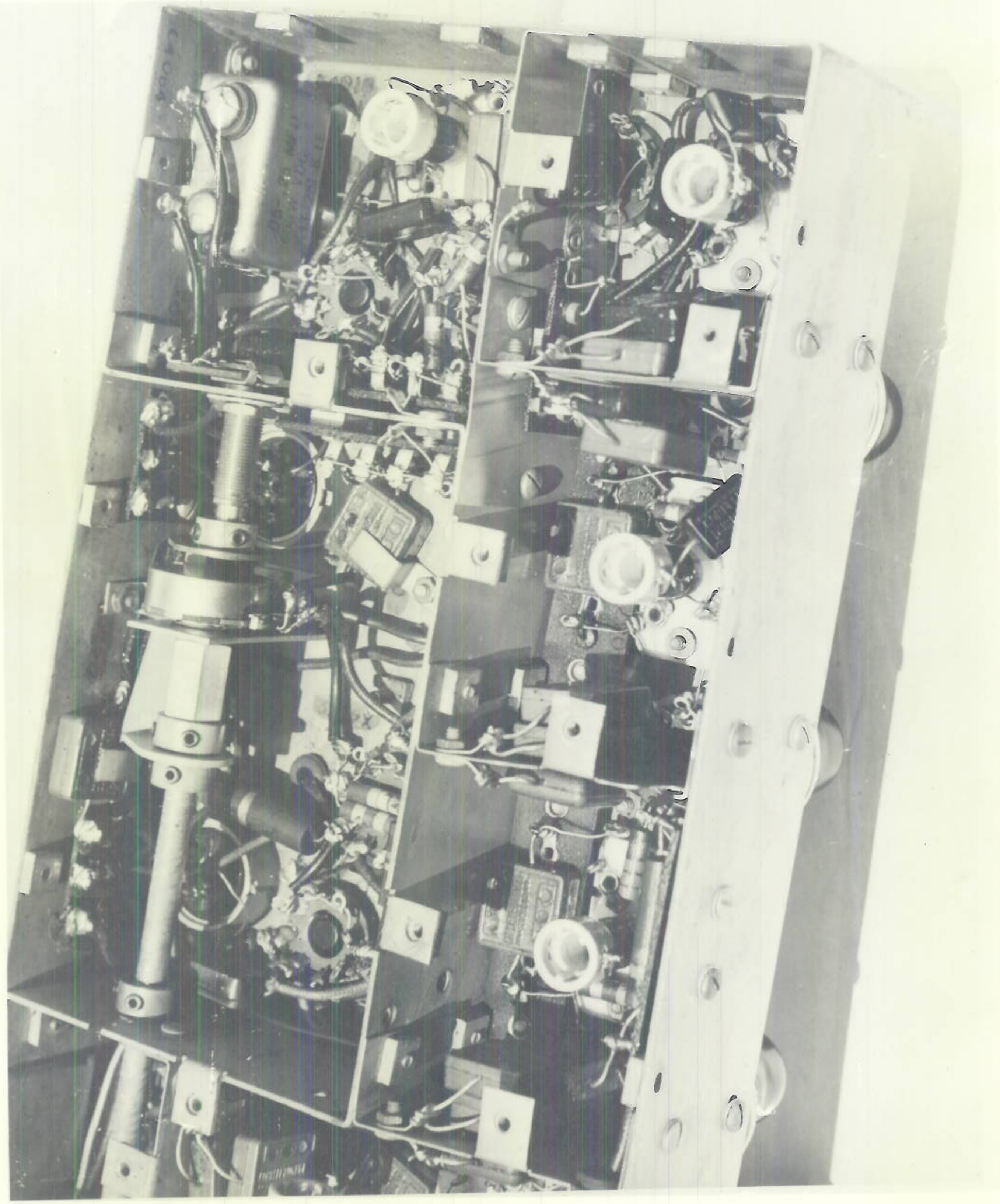


100 µV 35 CYCLE JAMMING
VIDEO DISCONNECTED

SC-3 PPI IN THE PRESENCE OF LOW FREQUENCY JAMMING

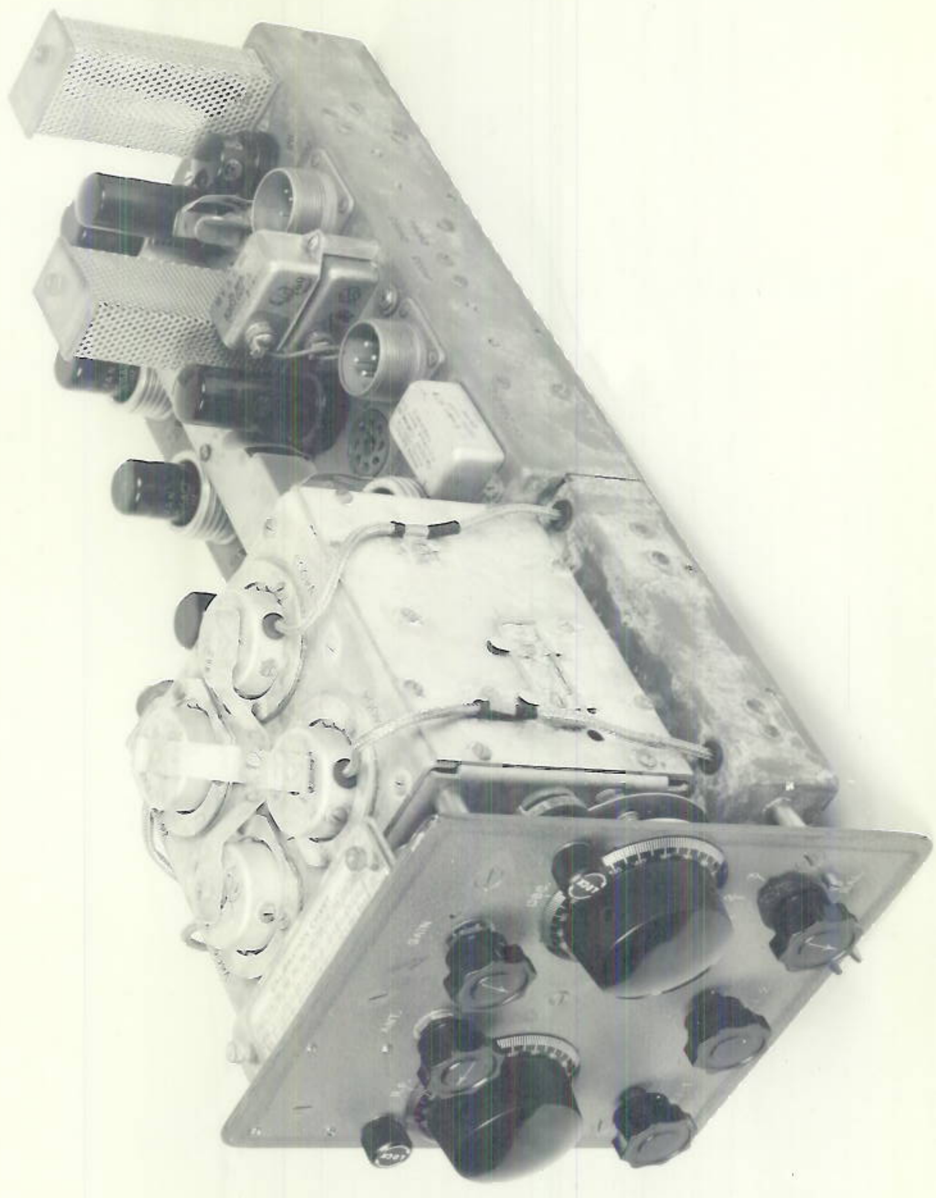


CG46ACQ RECEIVER



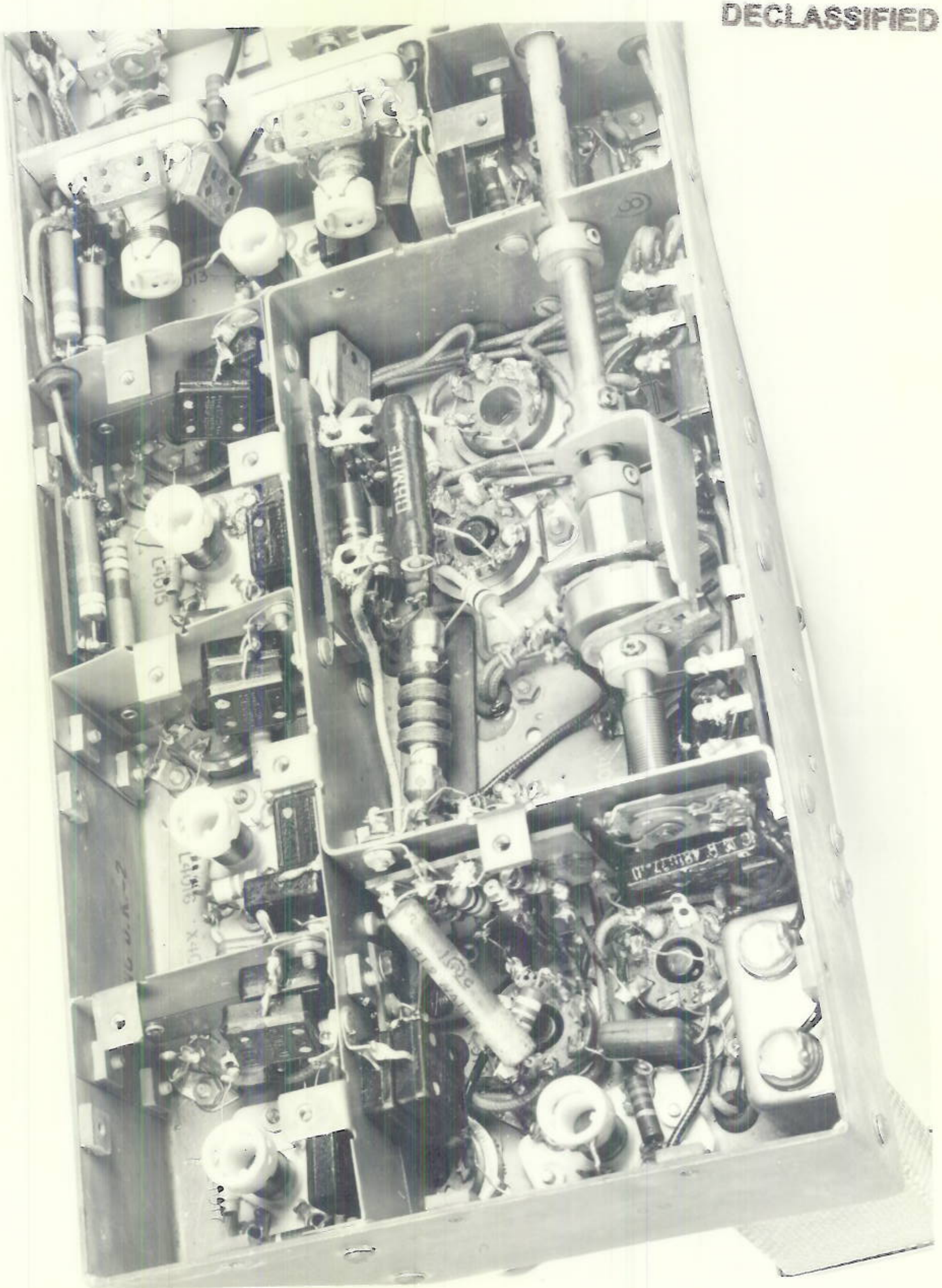
CG46ACQ

PLATE 30



CG46ACQ RECEIVER WITH FIELD CHANGES

DECLASSIFIED



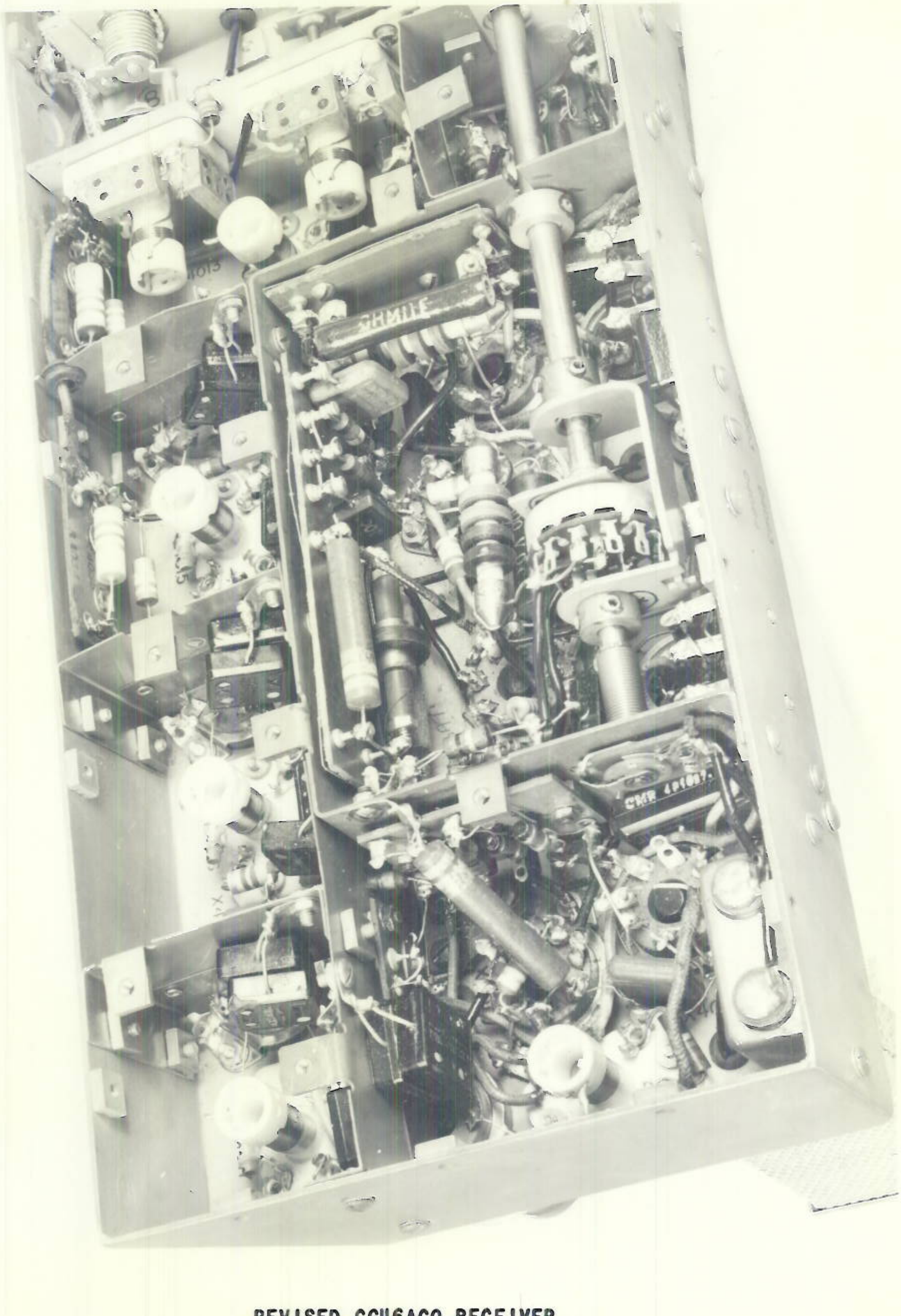
CG46ACQ RECEIVER WITH FIELD CHANGES

CONFIDENTIAL

DECLASSIFIED

REVISED CG46ACQ RECEIVER

DECLASSIFIED



REVISED CG46ACQ RECEIVER

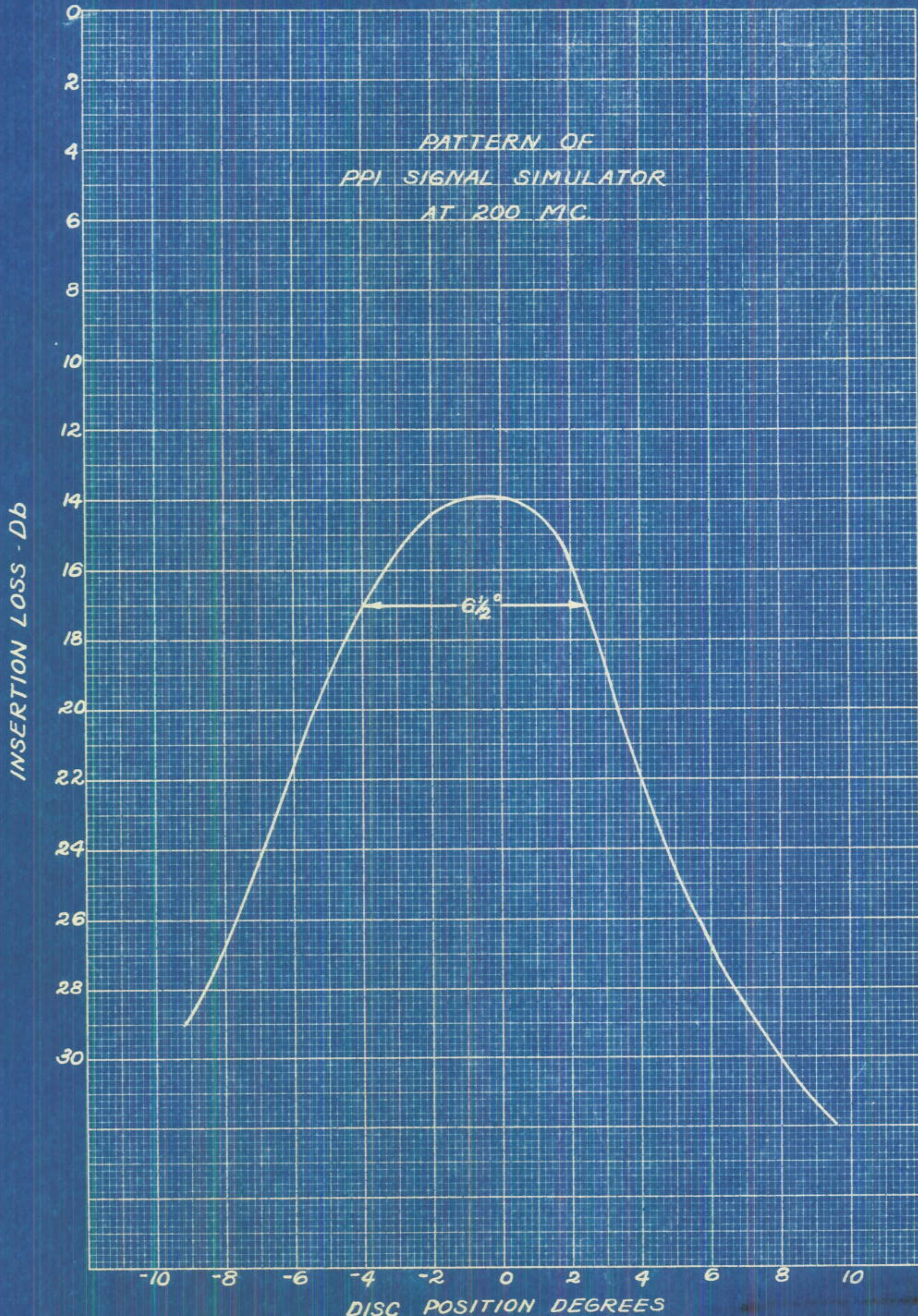
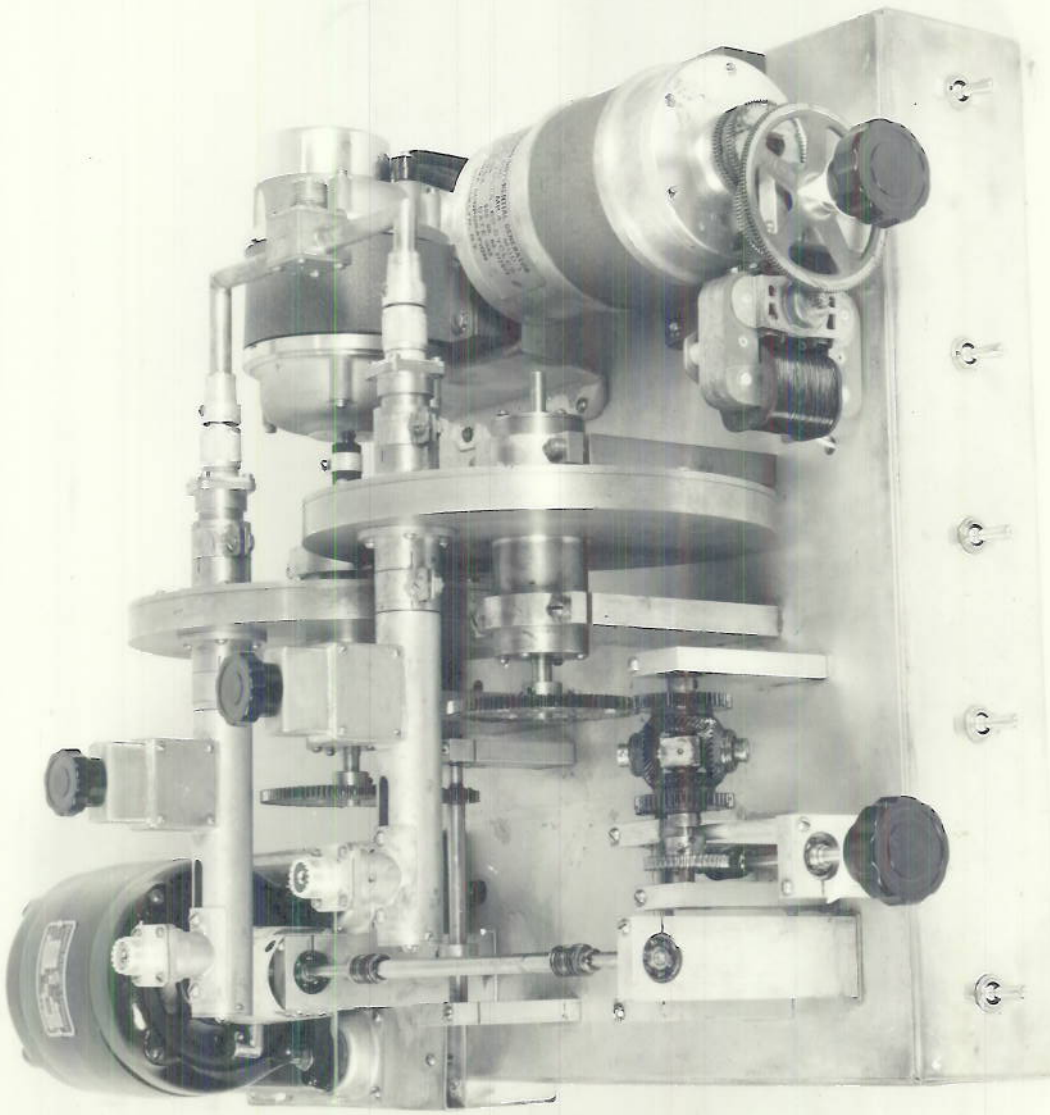
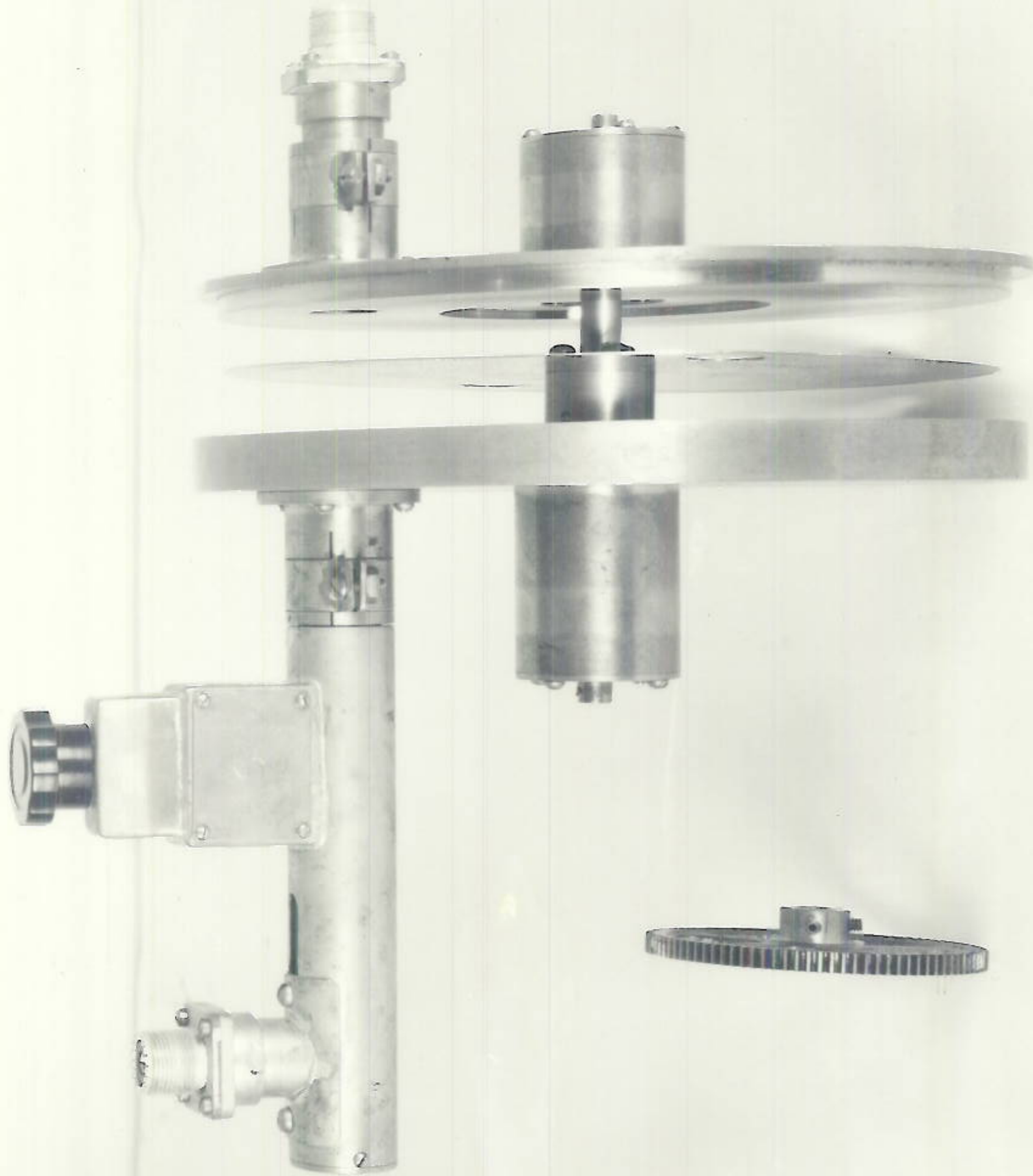

PATTERN OF
PPI SIGNAL SIMULATOR
AT 200 MC.
INSERTION LOSS - Db
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
6½°
-10
-8
-6
-4
-2
0
2
4
6
8
10
DISC POSITION DEGREES

PLATE 35



PPI SIGNAL SIMULATOR   GENERAL VIEW



SHUTTER TYPE SIGNAL CHOPPER EXPLODED VIEW.

PARTS OF SHUTTER TYPE SIGNAL CHOPPER

COUPLING LOOPS FOR SHUTTER TYPE SIGNAL CHOPPER

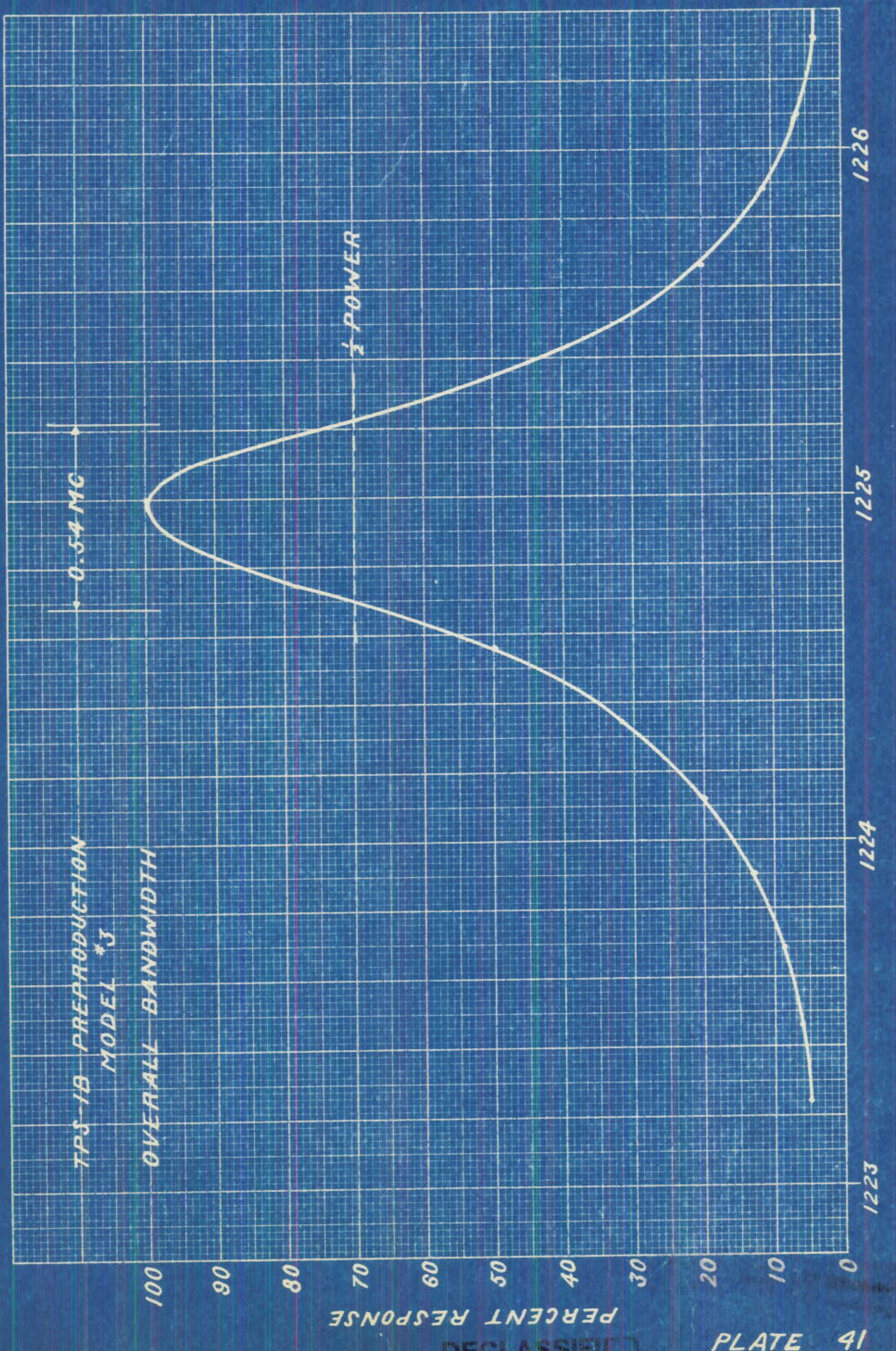
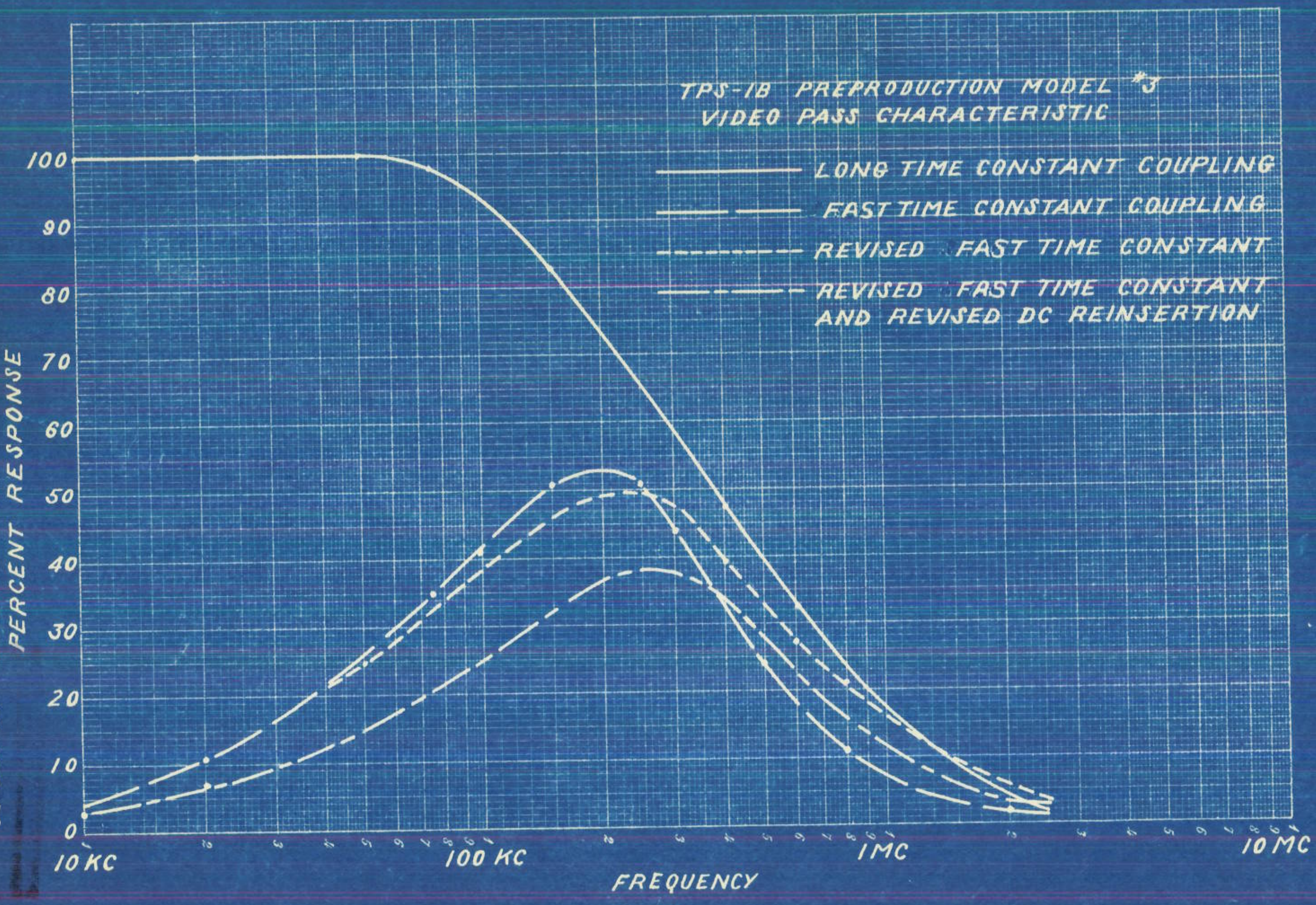

TPS-1B PREPRODUCTION
MODEL #3
OVERALL BANDWIDTH
0.54 MC
½ POWER
FREQUENCY - MC
1223
1224
1225
1226
PERCENT RESPONSE
100
90
80
70
60
50
40
30
20
10
0

PLATE 41



DECLASSIFIED

DECLASSIFIED

PLATE 42

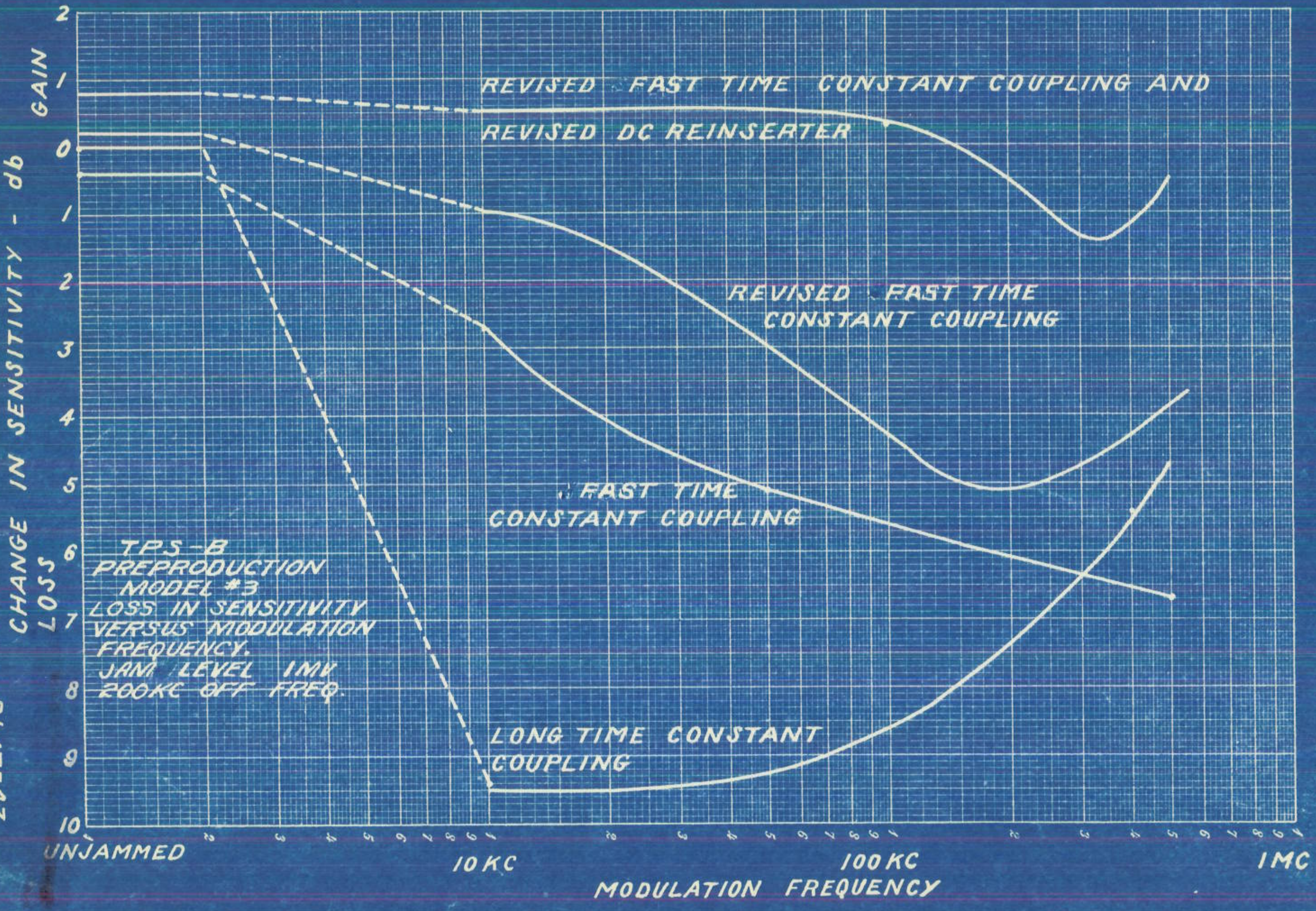
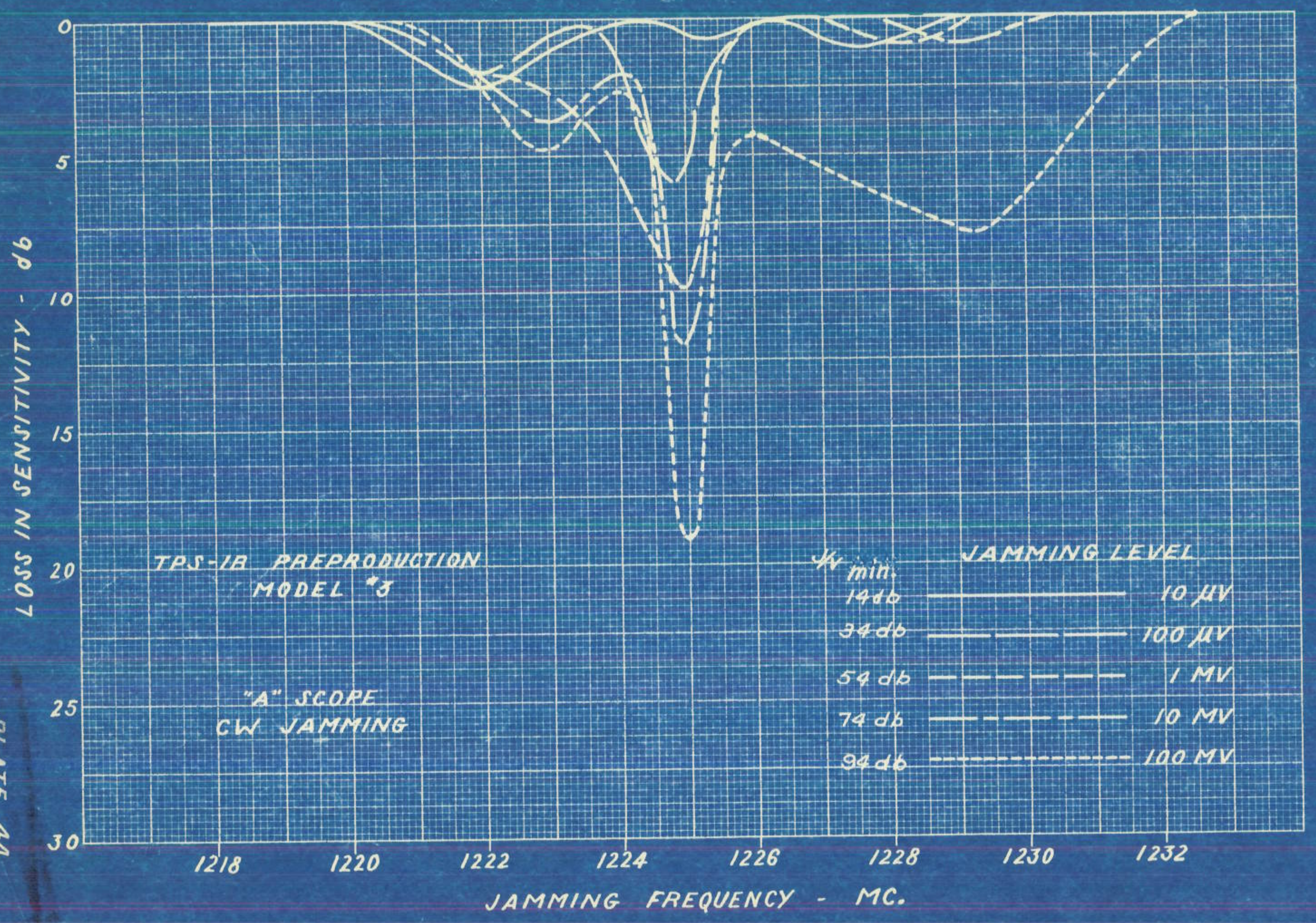

REVISED FAST TIME CONSTANT COUPLING AND
REVISED DC REINSERTER
REVISED FAST TIME
CONSTANT COUPLING
FAST TIME
CONSTANT COUPLING
LONG TIME CONSTANT
COUPLING
TPS-B
PREPRODUCTION
MODEL #3
LOSS IN SENSITIVITY
VERSUS MODULATION
FREQUENCY.
JAM LEVEL 1MV
200KC OFF FREQ.
CHANGE IN SENSITIVITY - db
GAIN
LOSS
2
1
0
1
2
3
4
5
6
7
8
9
10
UNJAMMED
10 KC
100 KC
1 MC
MODULATION FREQUENCY

PLATE 43



DECLASSIFIED

PLATE 44

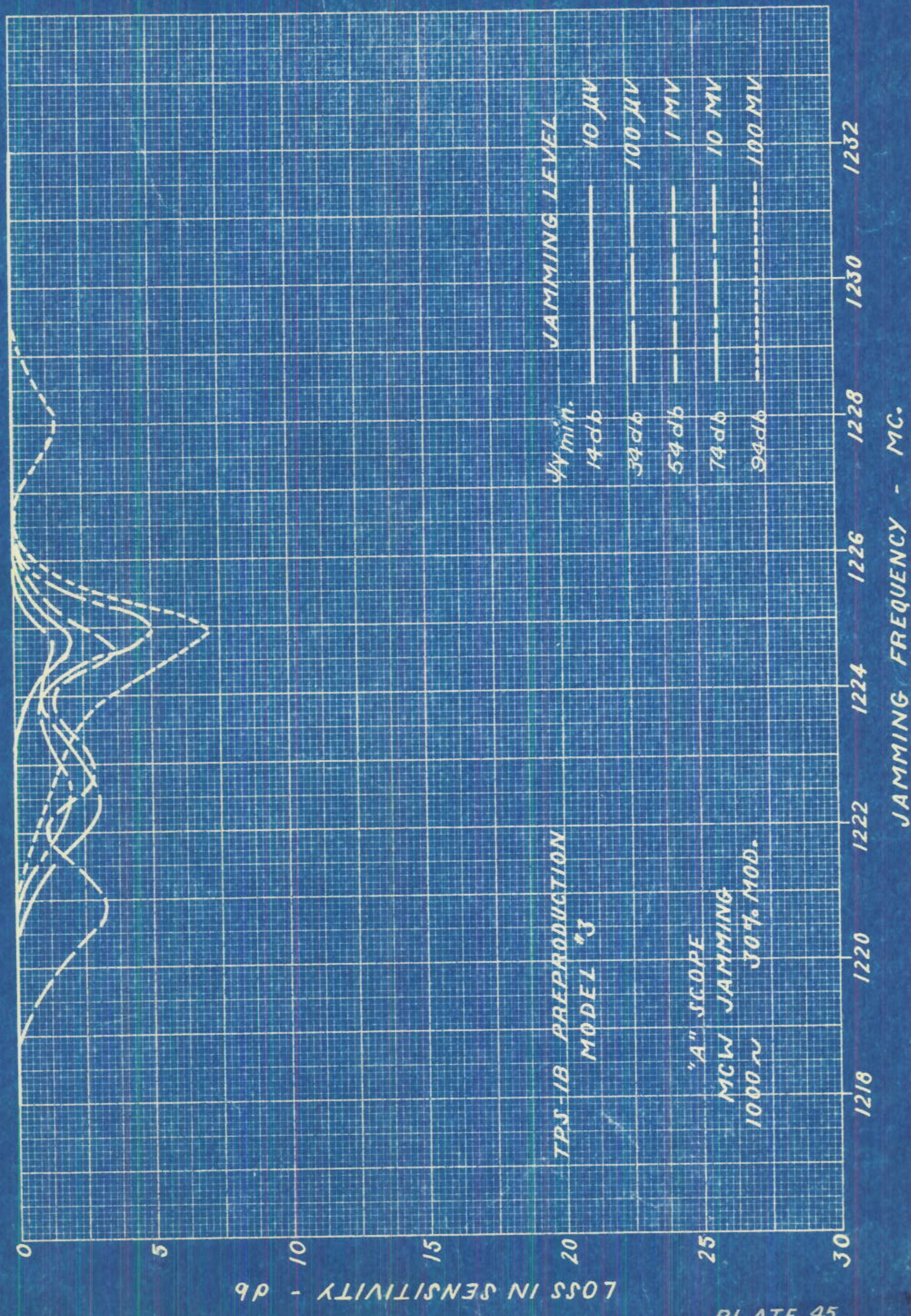
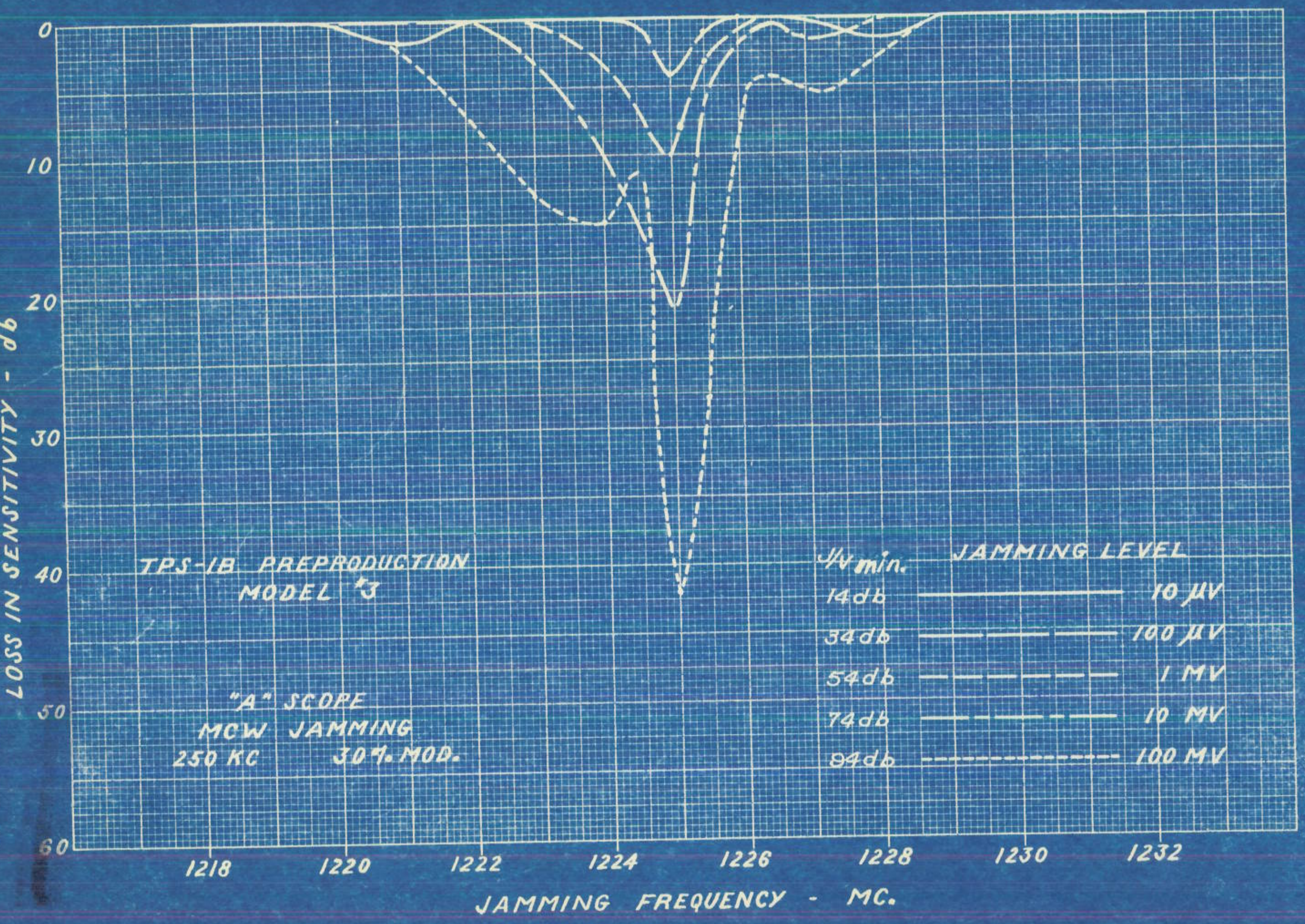

TPS-1B PREPRODUCTION
MODEL #3
"A" SCOPE
MCW JAMMING
1000 ~ 30% MOD.
JAMMING LEVEL
1/4 min.
14 db — 10 μV
34 db — 100 μV
54 db — 1 MV
74 db — 10 MV
94 db — 100 MV
1218
1220
1222
1224
1226
1228
1230
1232
JAMMING FREQUENCY - MC.
0
5
10
15
20
25
30
LOSS IN SENSITIVITY - db

PLATE 45



DECLASSIFIED

PLATE 46

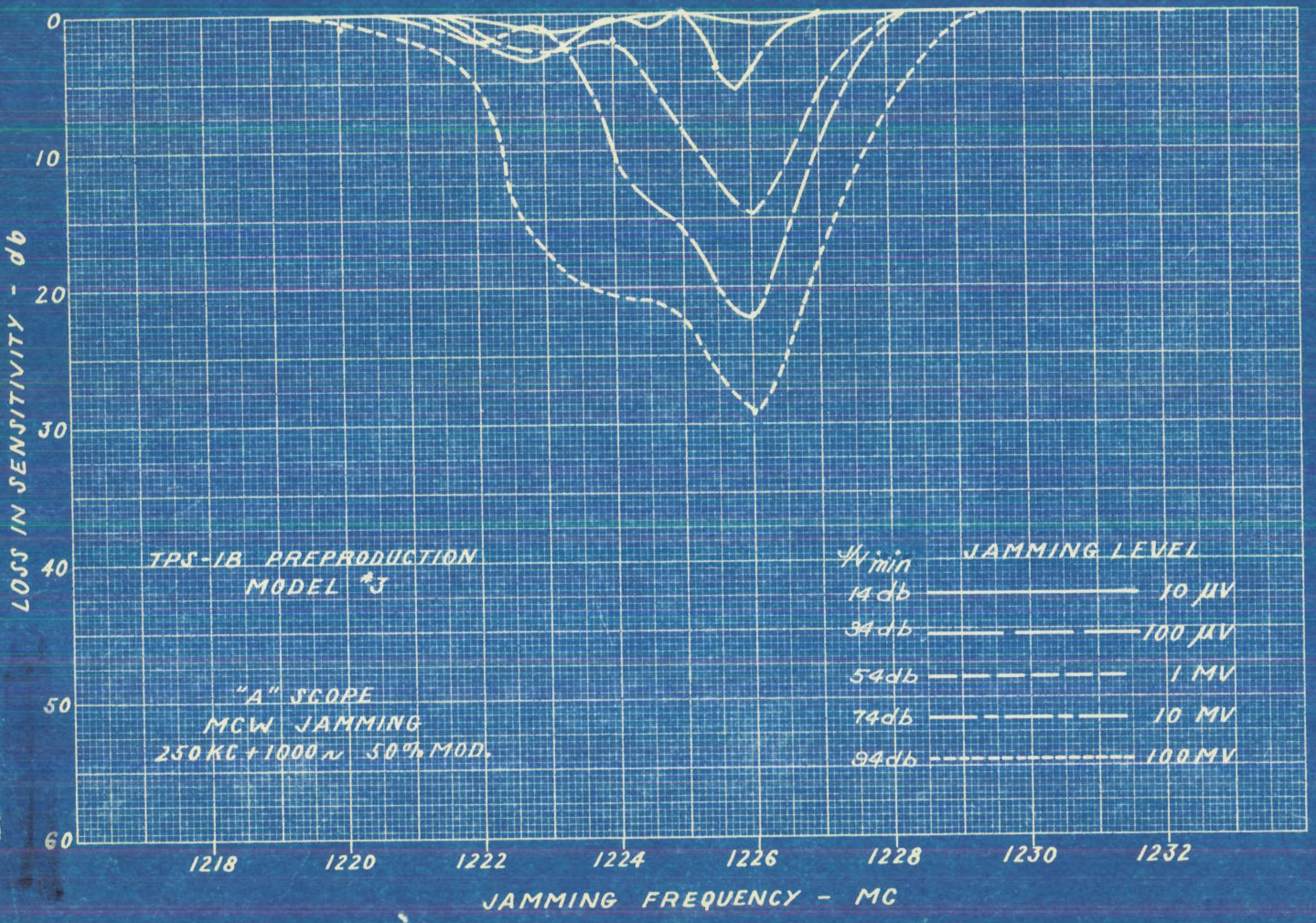
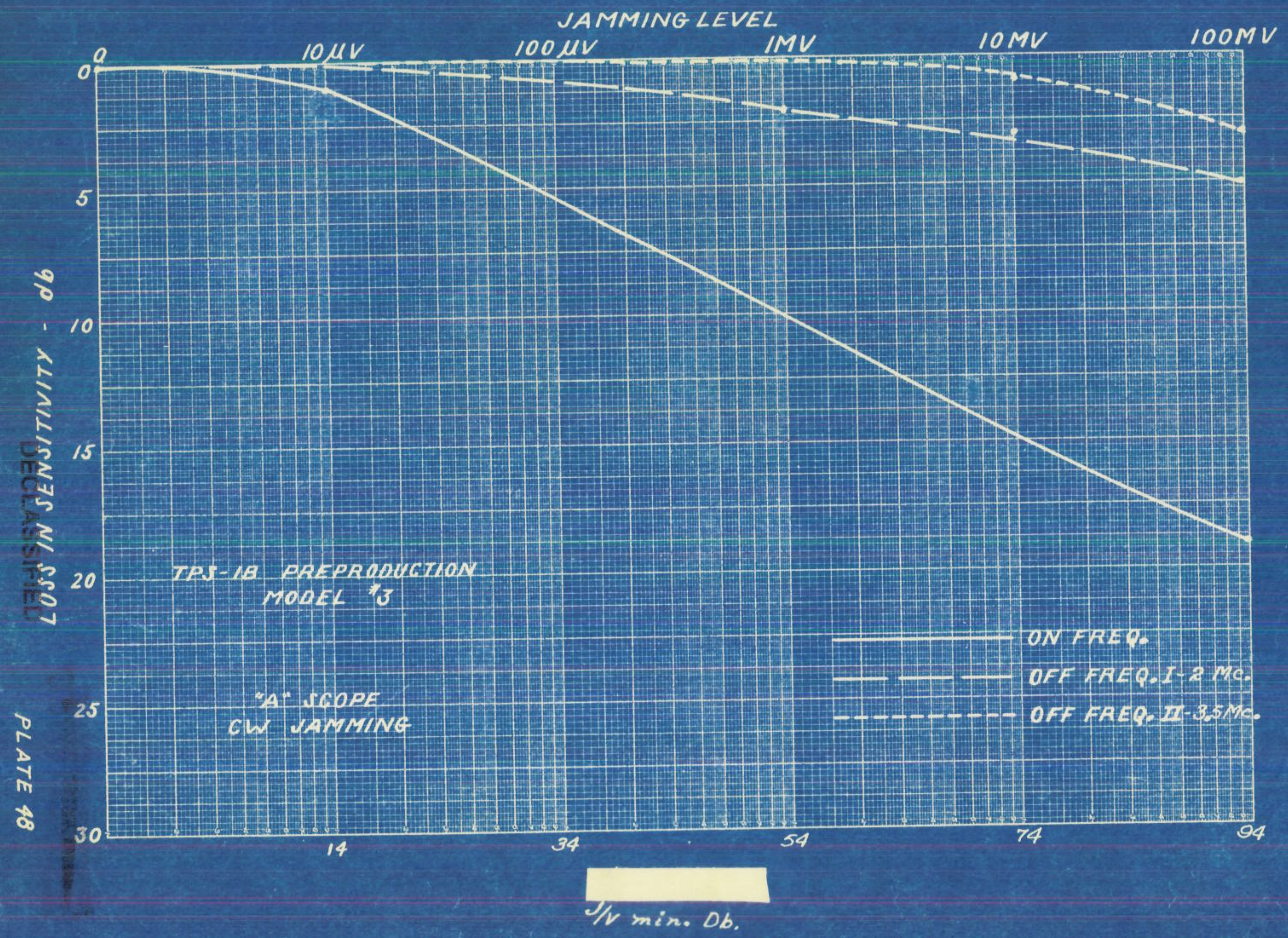


PLATE 47

DECLASSIFIED



DECLASSIFIED

PLATE 48

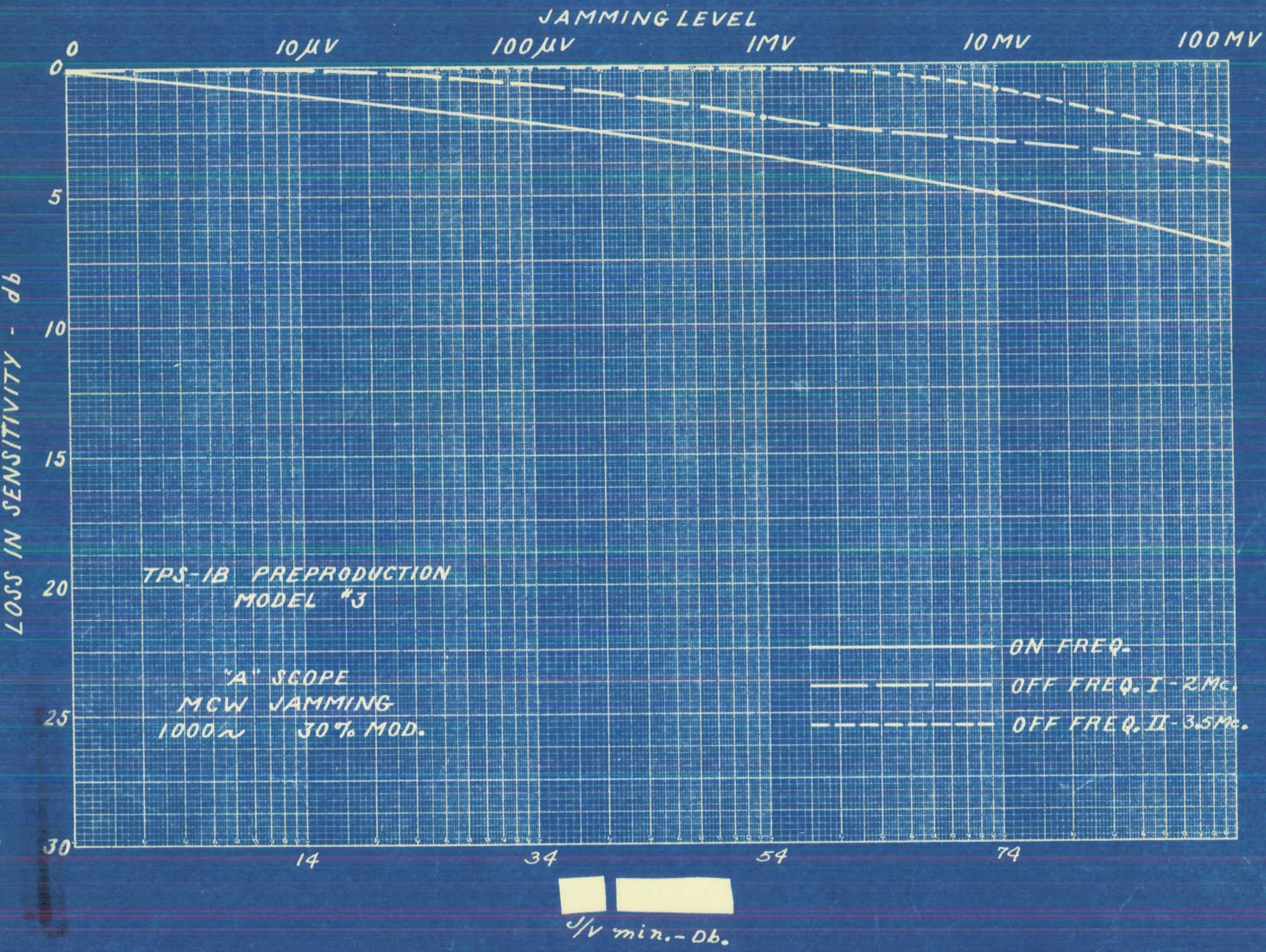


PLATE 49

DECLASSIFIED

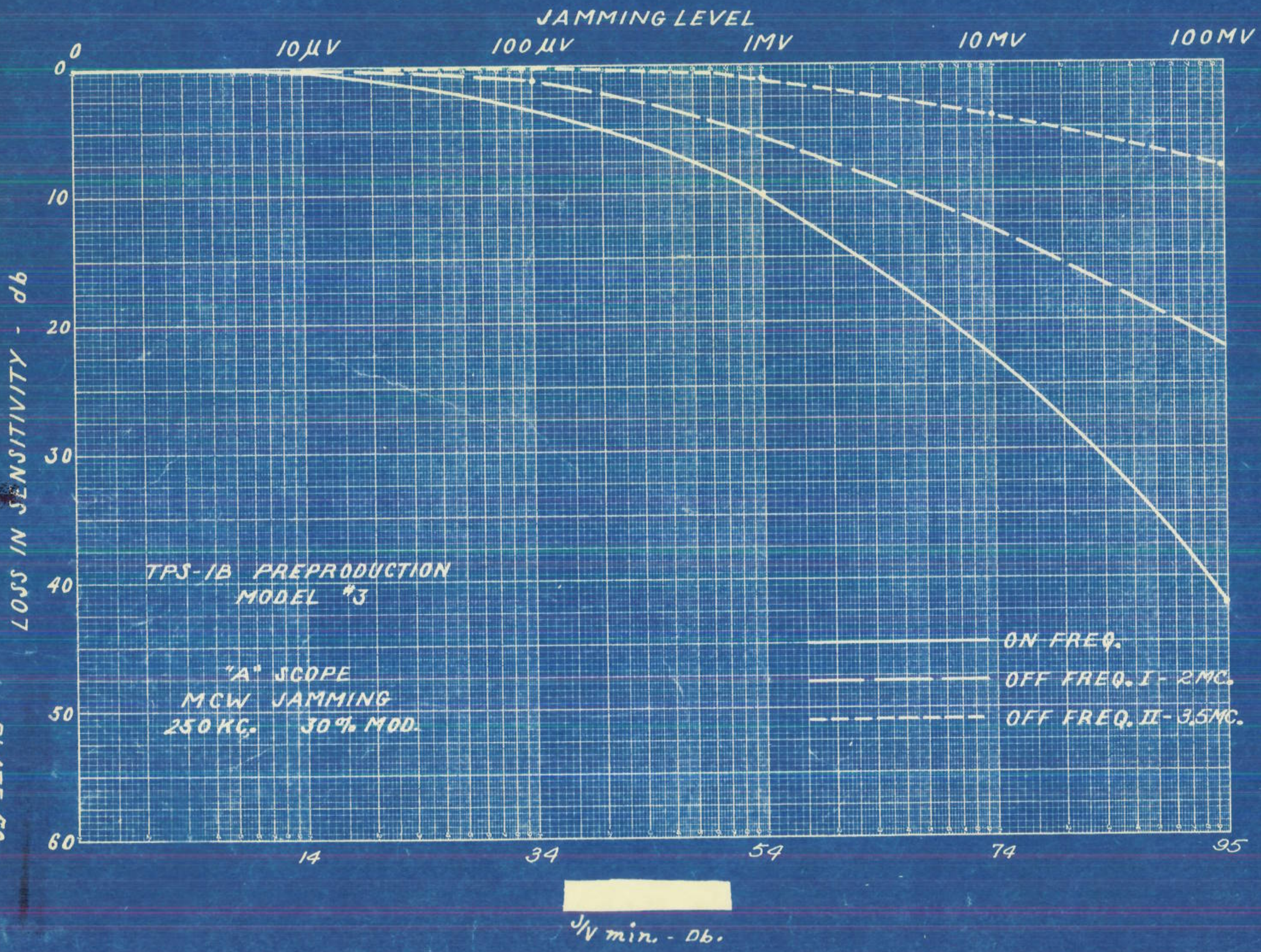


PLATE 50

DECLASSIFIED

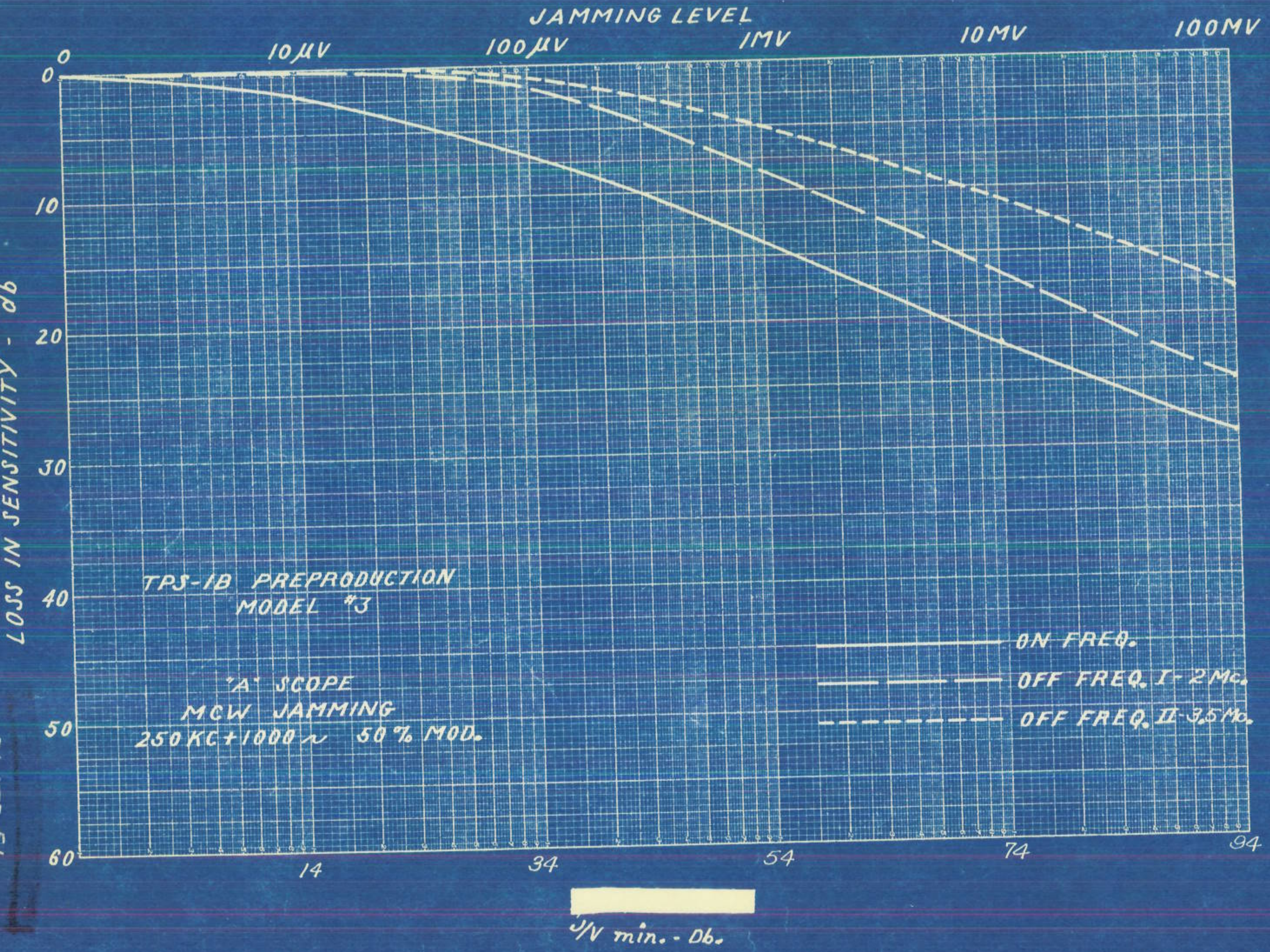
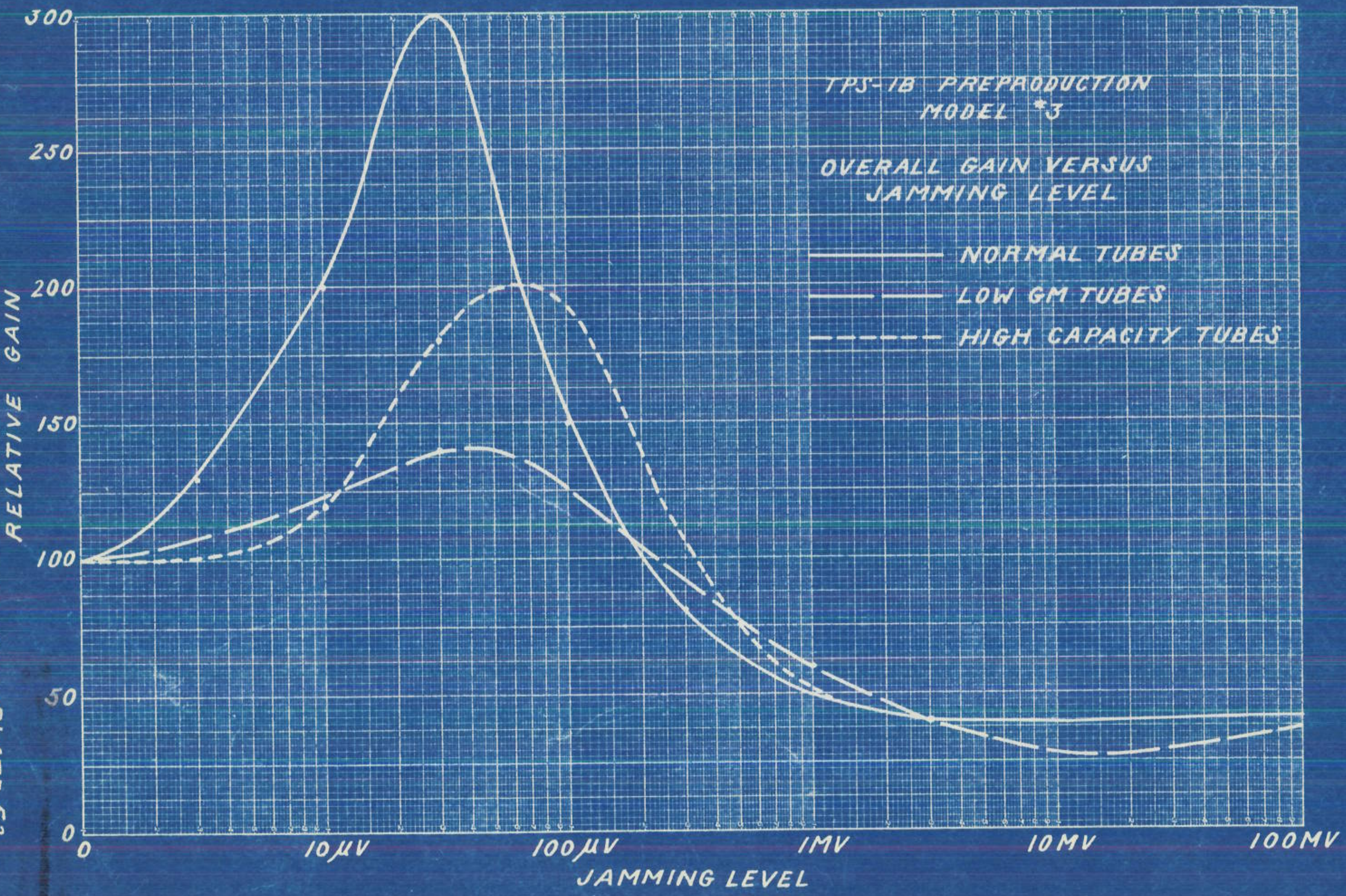
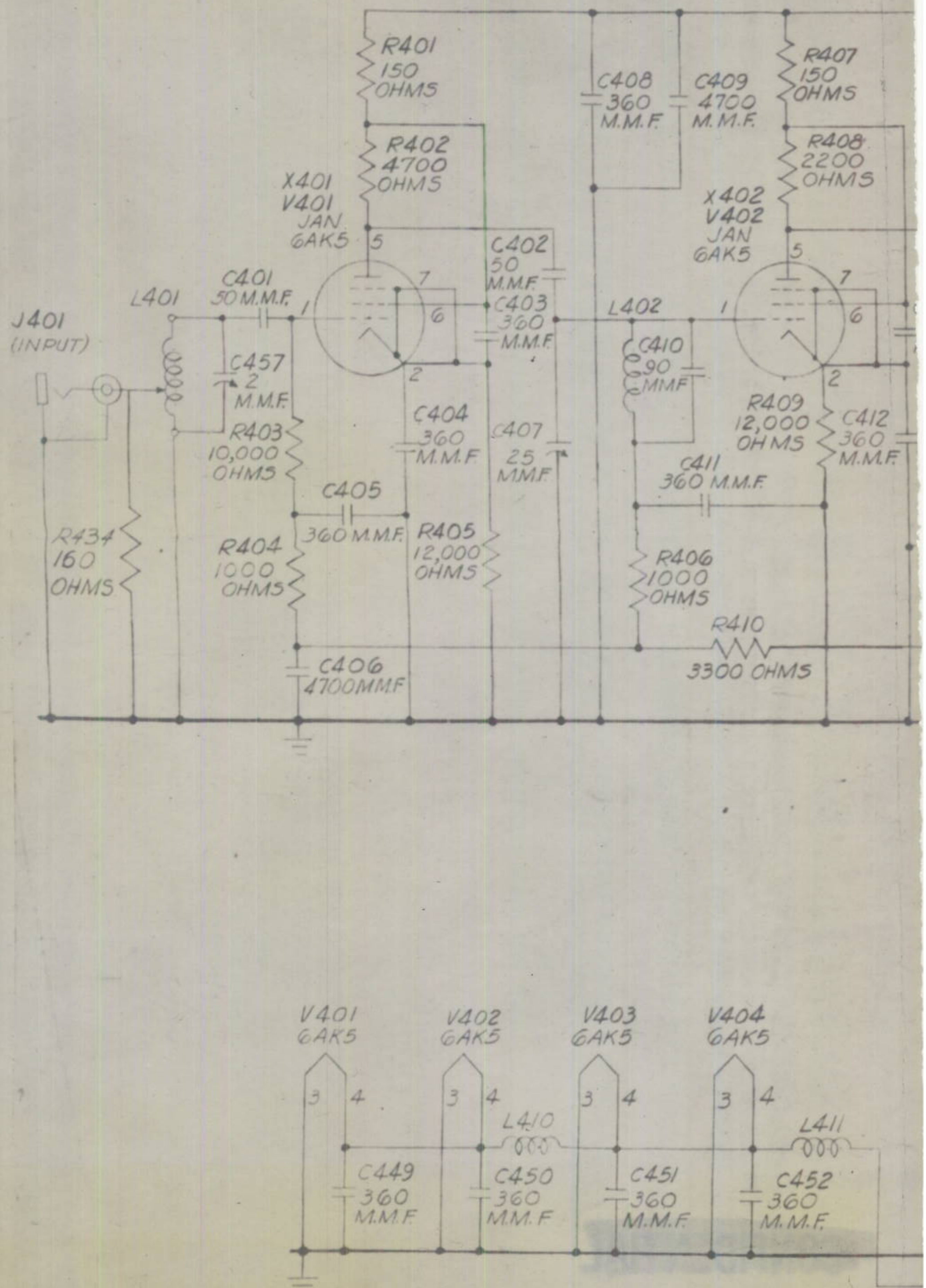

JAMMING LEVEL
0
10 µV
100 µV
1MV
10MV
100MV
LOSS IN SENSITIVITY - db
0
10
20
30
40
50
60
14
34
54
74
94
J/V min. - Db.
TPS-1B PREPRODUCTION
MODEL #3
"A" SCOPE
MCW JAMMING
250 KC + 1000 ~ 50 % MOD.
ON FREQ.
OFF FREQ. I - 2 Mc.
OFF FREQ. II - 3.5 Mc.

PLATE 51

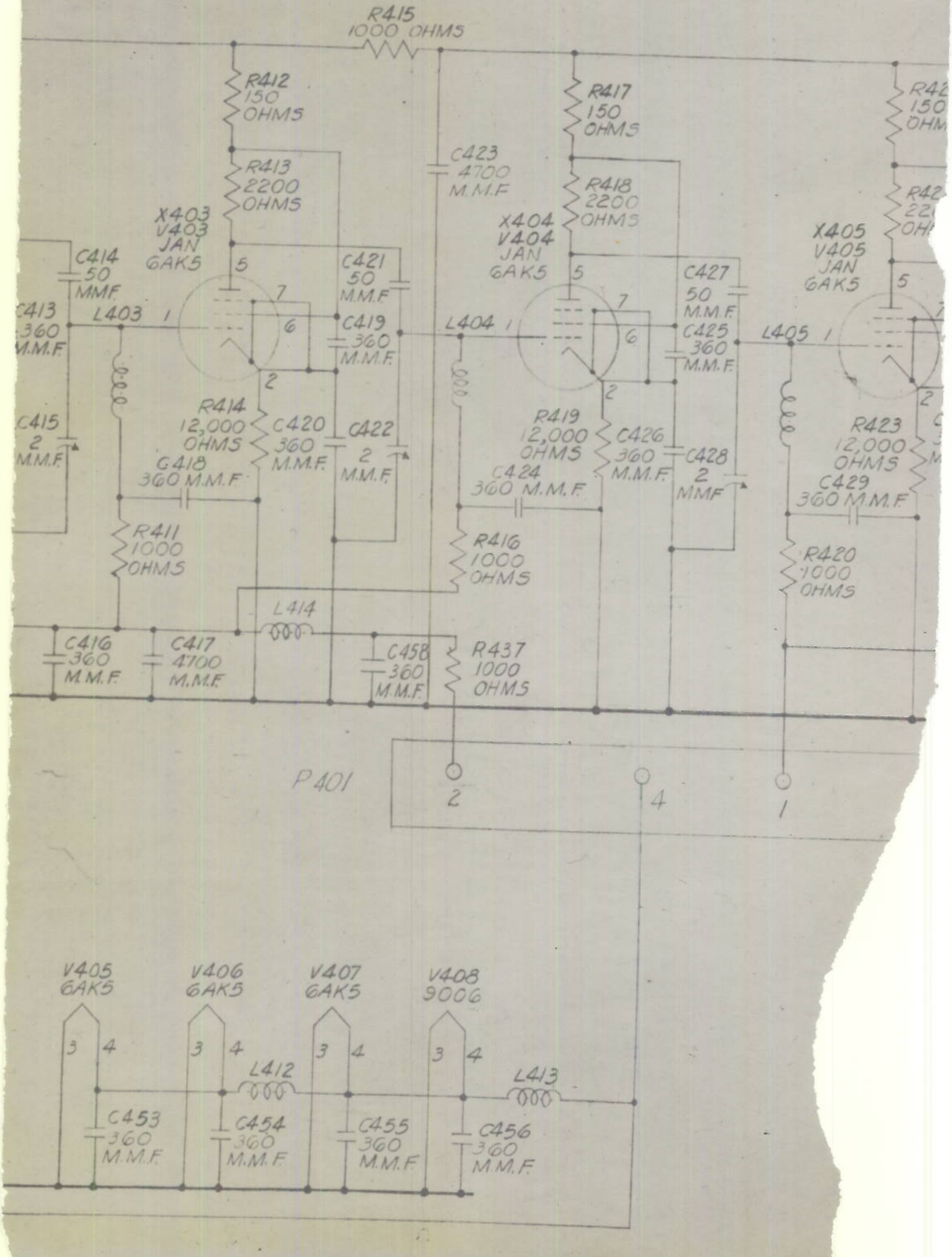


TPS-1B PREPRODUCTION
MODEL #3
OVERALL GAIN VERSUS
JAMMING LEVEL
NORMAL TUBES
LOW GM TUBES
HIGH CAPACITY TUBES
RELATIVE GAIN
300
250
200
150
100
50
0
0
10µV
100µV
1MV
10MV
100MV
JAMMING LEVEL

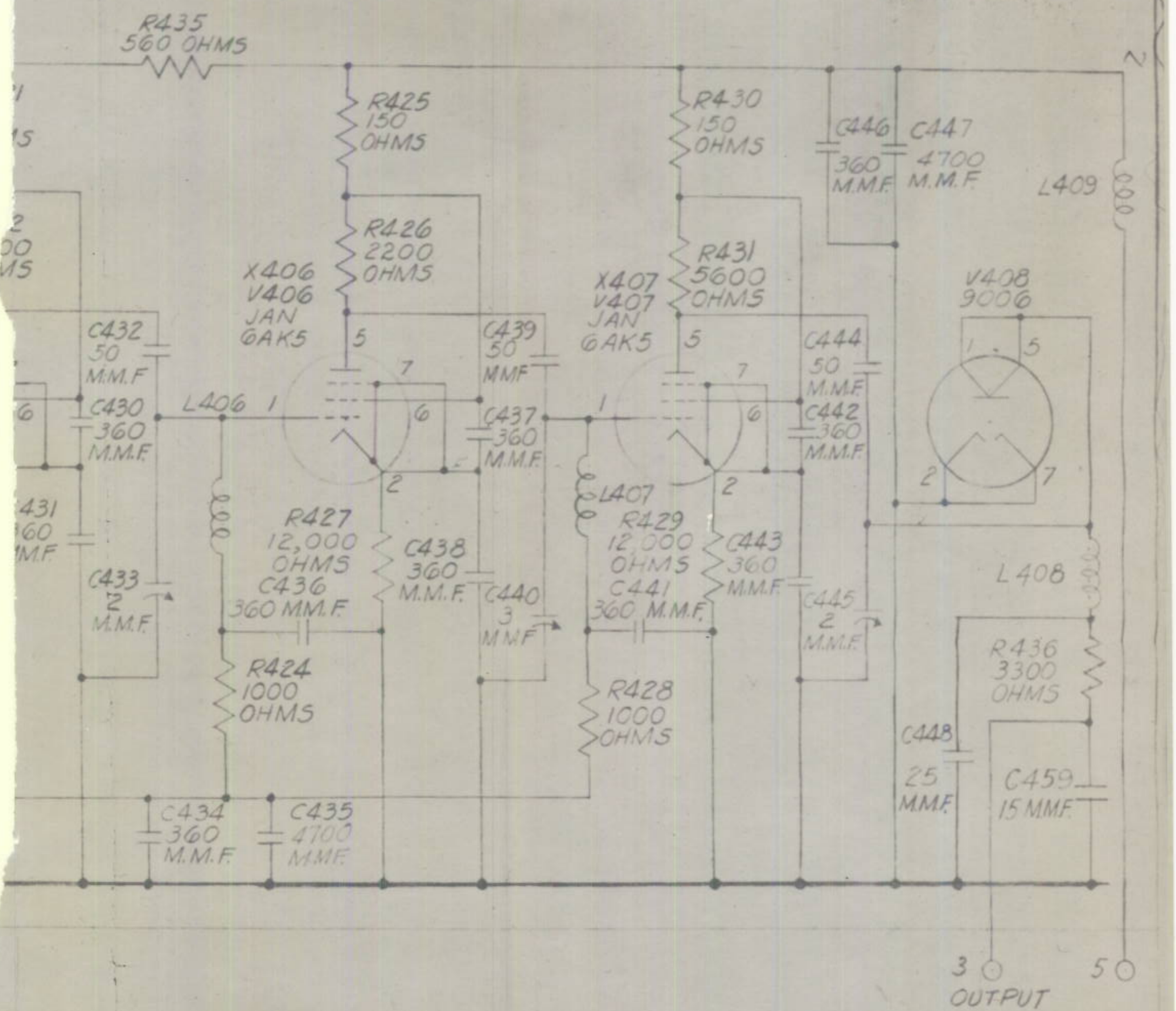
PLATE 52



R401
150
OHMS
C408
360
M.M.F.
C409
4700
M.M.F.
R407
150
OHMS
R402
4700
OHMS
R408
2200
OHMS
X401
V401
JAN
6AK5
X402
V402
JAN
6AK5
C402
50
M.M.F.
C401
50 M.M.F.
L401
C403
360
M.M.F.
L402
J401
(INPUT)
C457
2
M.M.F.
C410
90
MMF
R403
10,000
OHMS
C404
360
M.M.F.
C407
25
M.M.F.
R409
12,000
OHMS
C412
360
M.M.F.
C411
360 M.M.F.
C405
360 M.M.F.
R434
160
OHMS
R404
1000
OHMS
R405
12,000
OHMS
R406
1000
OHMS
R410
3300 OHMS
C406
4700MMF
V401
6AK5
V402
6AK5
V403
6AK5
V404
6AK5
L410
L411
C449
360
M.M.F.
C450
360
M.M.F
C451
360
M.M.F.
C452
360
M.M.F.

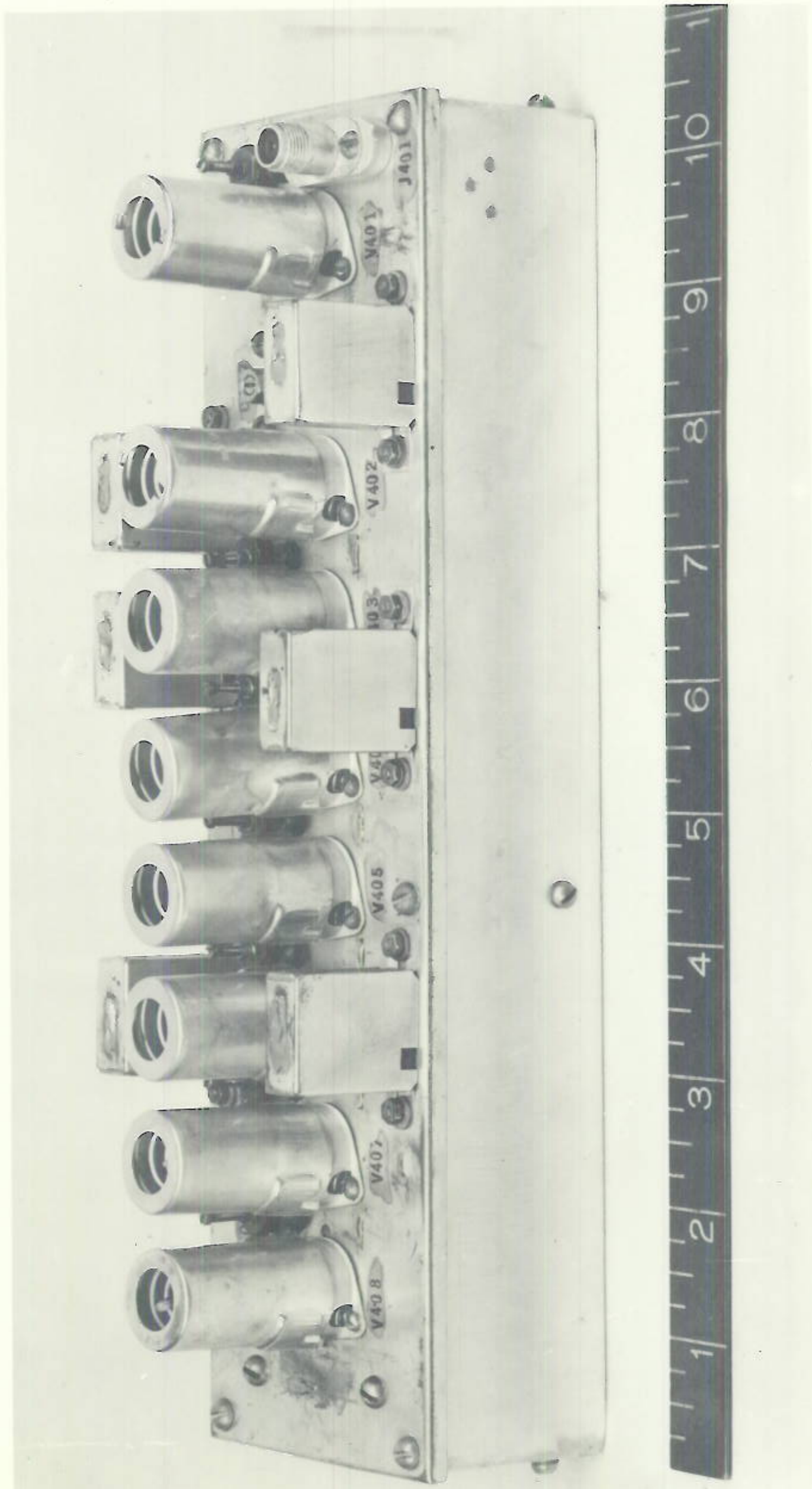


R415
1000 OHMS
R412
150
OHMS
R413
2200
OHMS
X403
V403
JAN
6AK5
C414
50
MMF
C413
360
M.M.F.
L403
C421
50
M.M.F.
C419
360
M.M.F.
C423
4700
M.M.F.
R417
150
OHMS
R418
2200
OHMS
X404
V404
JAN
6AK5
C427
50
M.M.F.
C425
360
M.M.F.
L404
X405
V405
JAN
6AK5
L405
C415
2
M.M.F.
R414
12,000
OHMS
C420
360
M.M.F.
C422
2
M.M.F.
C418
360 M.M.F.
R419
12,000
OHMS
C426
360
M.M.F.
C428
2
MMF
C424
360 M.M.F.
R423
12,000
OHMS
C429
360 M.M.F.
R411
1000
OHMS
R416
1000
OHMS
R420
1000
OHMS
L414
C416
360
M.M.F.
C417
4700
M.M.F.
C458
360
M.M.F.
R437
1000
OHMS
P401
2
4
1
V405
6AK5
V406
6AK5
V407
6AK5
V408
9006
L412
L413
C453
360
M.M.F.
C454
360
M.M.F.
C455
360
M.M.F.
C456
360
M.M.F.

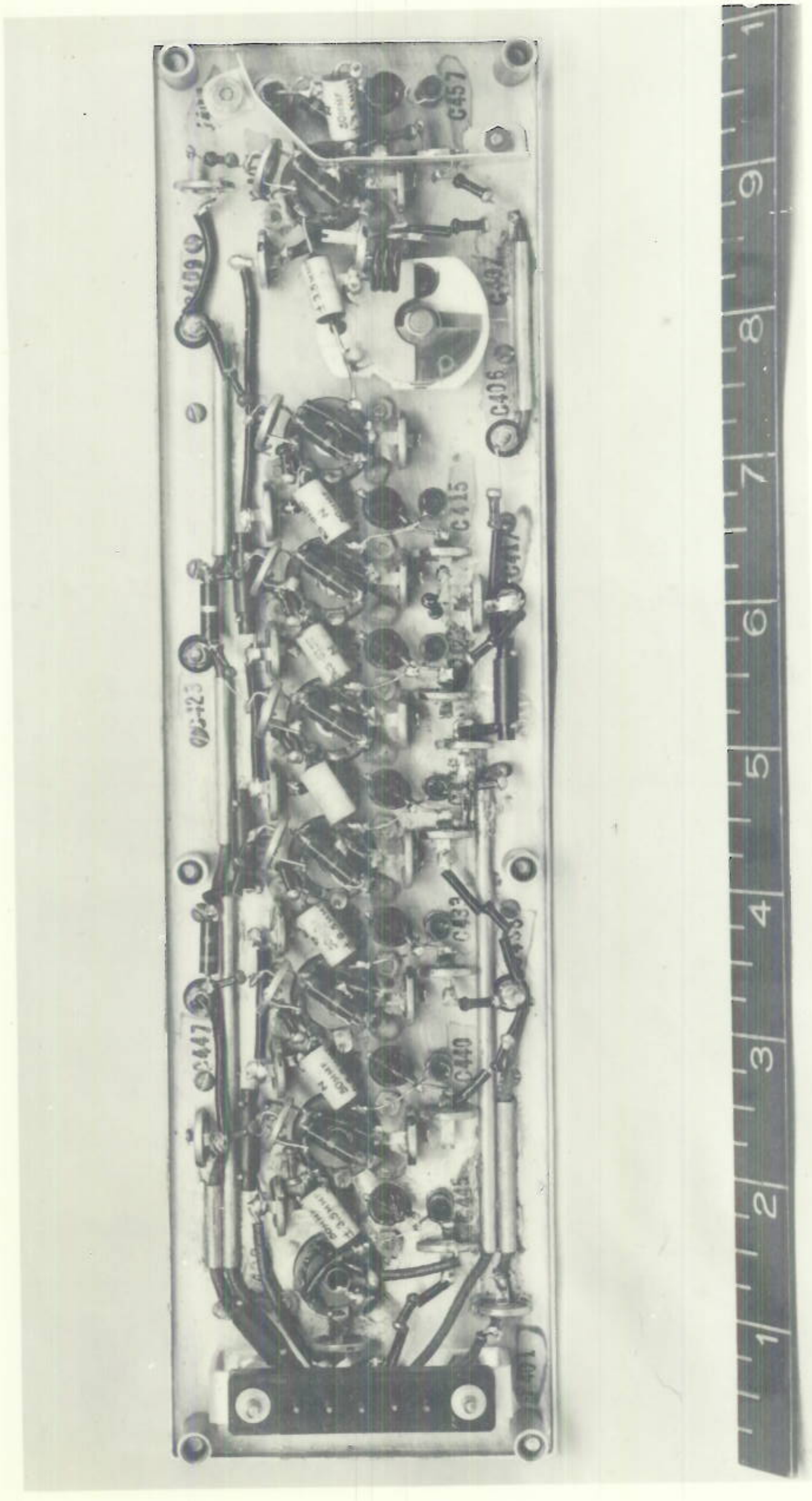


AN/TPS-1B
I.F. AMPLIFIER
SCHEMATIC

PLATE 55



AN/TPS-1B IF AMPLIFIER   TOP VIEW



AN/TPS-1B IF AMPLIFIER   BOTTOM VIEW

CONFIDENTIAL

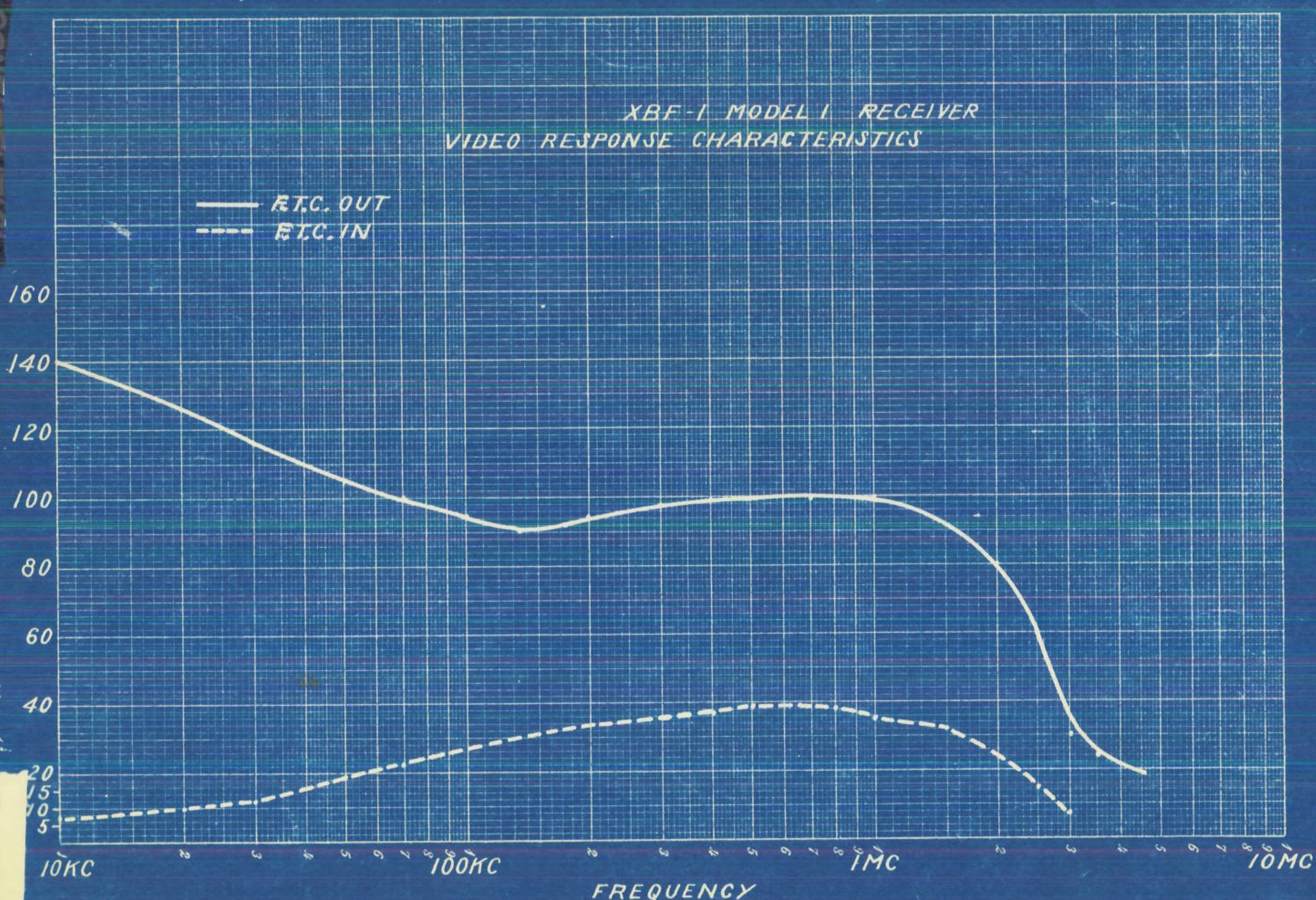


PLATE 58

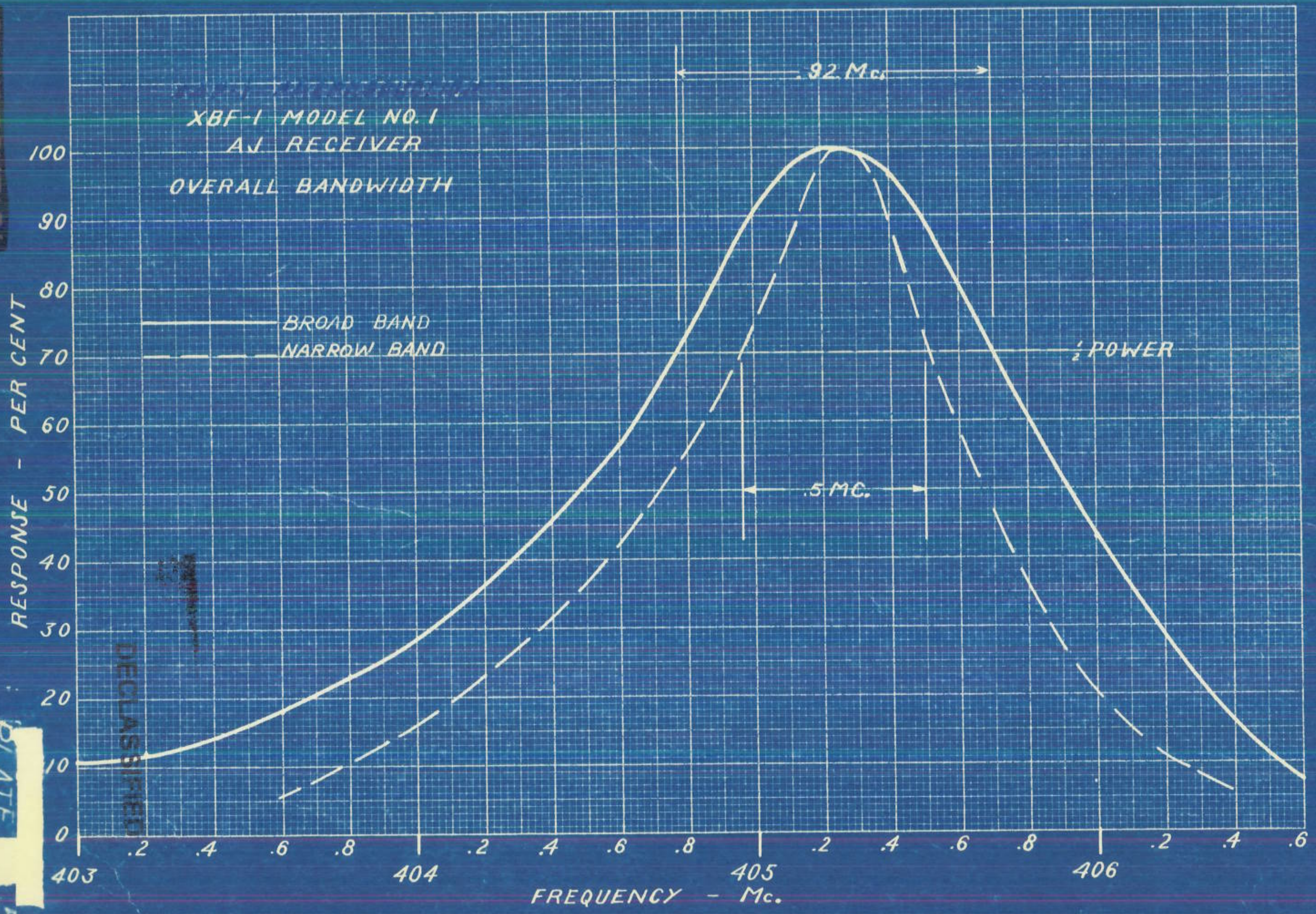

XBF-1 MODEL NO. 1
AJ RECEIVER
OVERALL BANDWIDTH
BROAD BAND
NARROW BAND
.92 Mc.
.5 MC.
½ POWER
100
90
80
70
60
50
40
30
20
10
0
RESPONSE - PER CENT
403
.2
.4
.6
.8
404
405
406
FREQUENCY - Mc.

PLATE 59

[redacted]

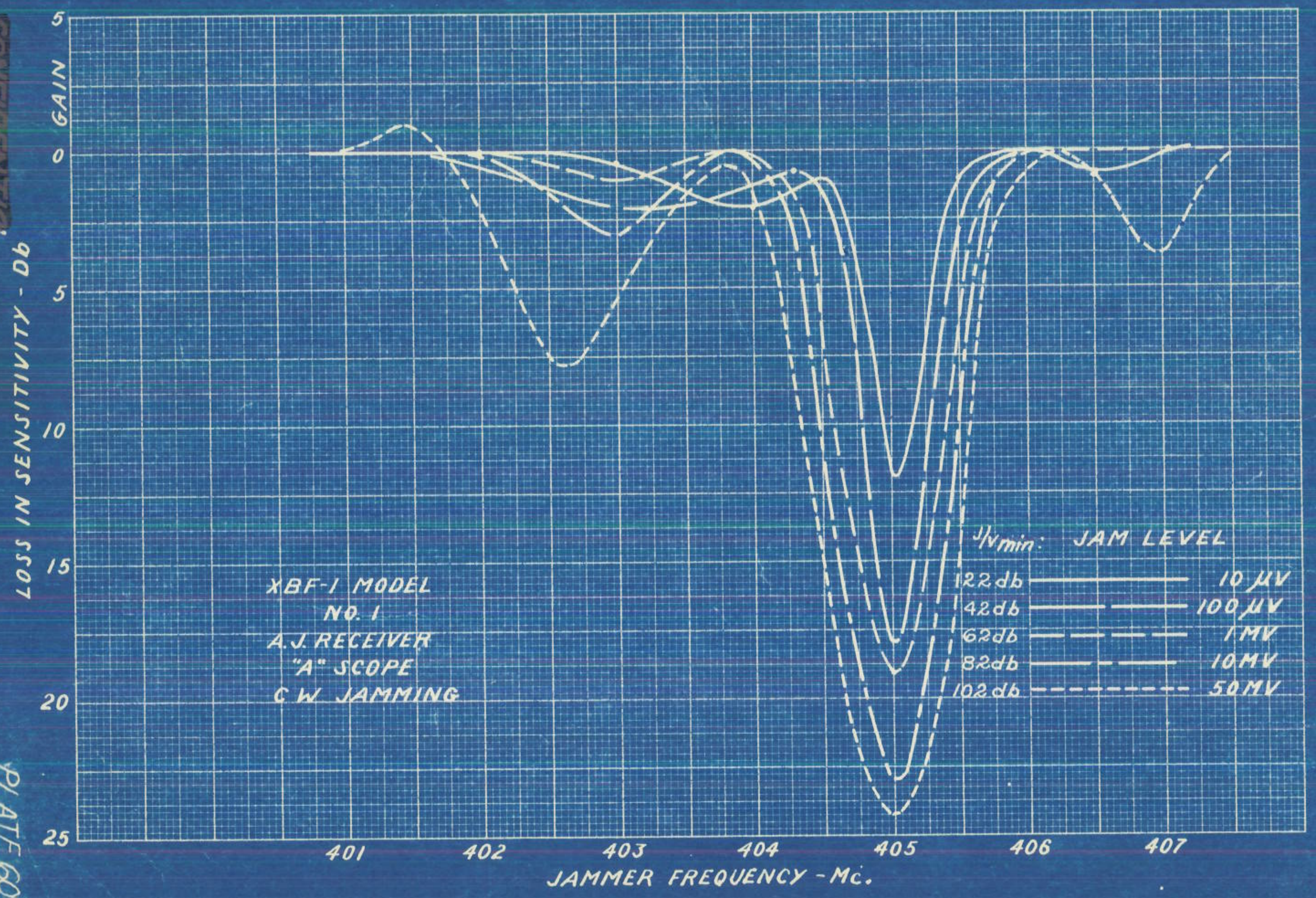
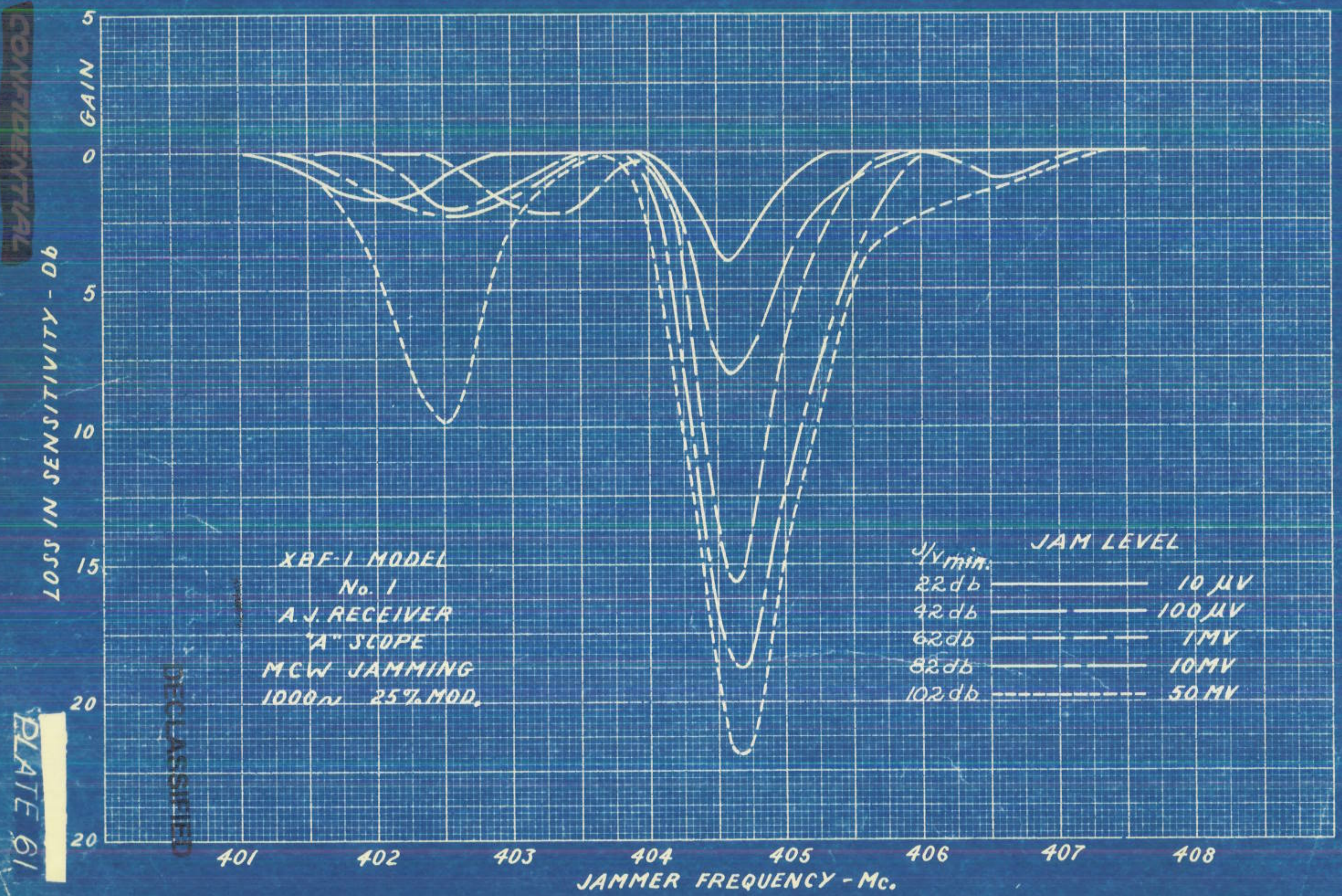


PLATE 60



LOSS IN SENSITIVITY - Db
GAIN
5
0
5
10
15
20
20
401
402
403
404
405
406
407
408
JAMMER FREQUENCY - Mc.
XBF-1 MODEL
No. 1
A.J. RECEIVER
"A" SCOPE
MCW JAMMING
1000~ 25% MOD.
J/Vmin.
JAM LEVEL
22db 10 μV
42db 100 μV
62db 1MV
82db 10MV
102db 50MV

PLATE 61

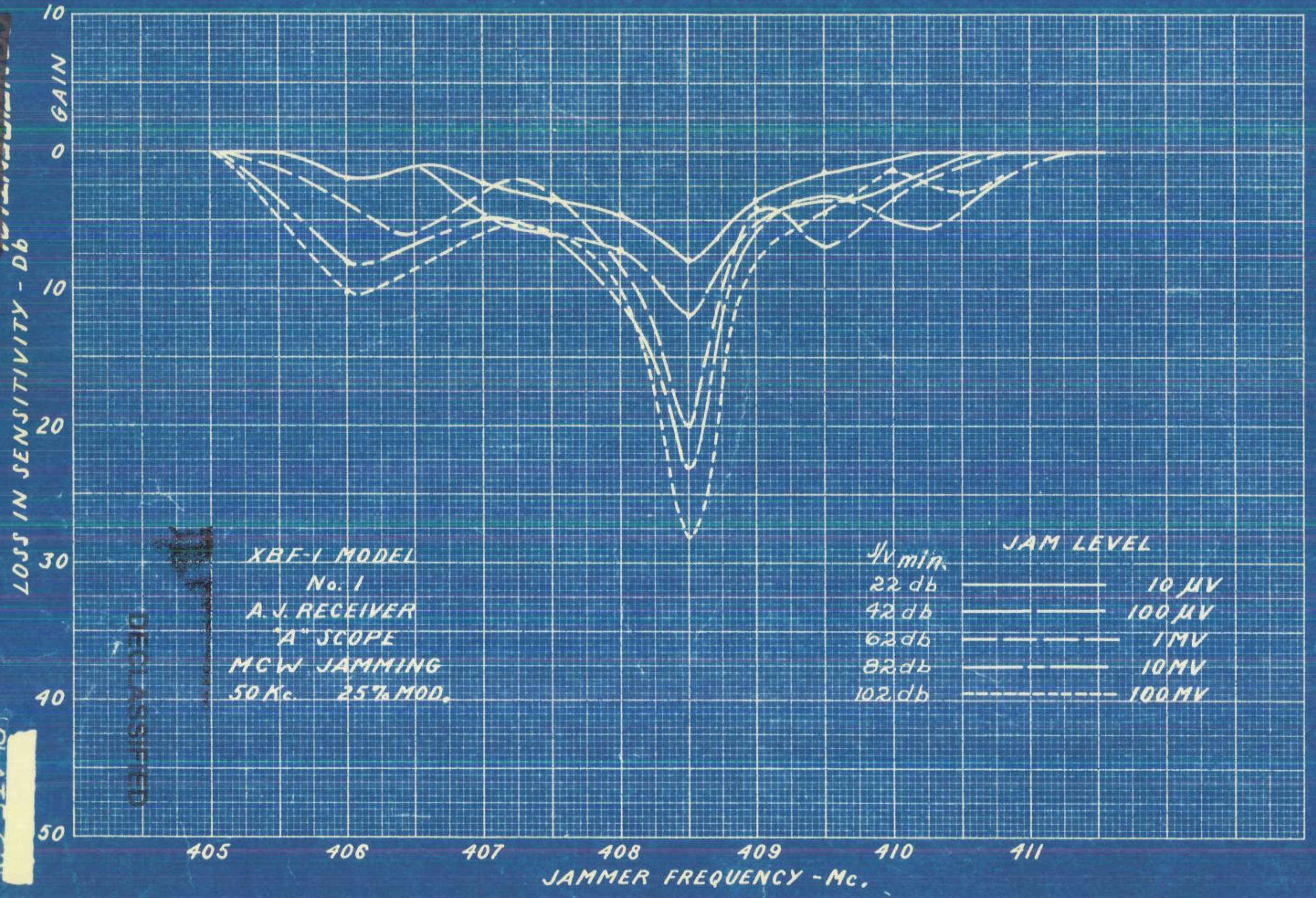

10
GAIN
0
10
20
30
40
50
LOSS IN SENSITIVITY - Db
405
406
407
408
409
410
411
JAMMER FREQUENCY - Mc.
XBF-1 MODEL
No. 1
A.J. RECEIVER
"A" SCOPE
MCW JAMMING
50 Kc. 25% MOD.
S/N min.
22 db
42 db
62 db
82 db
102 db
JAM LEVEL
10 µV
100 µV
1 MV
10 MV
100 MV

PLATE 62

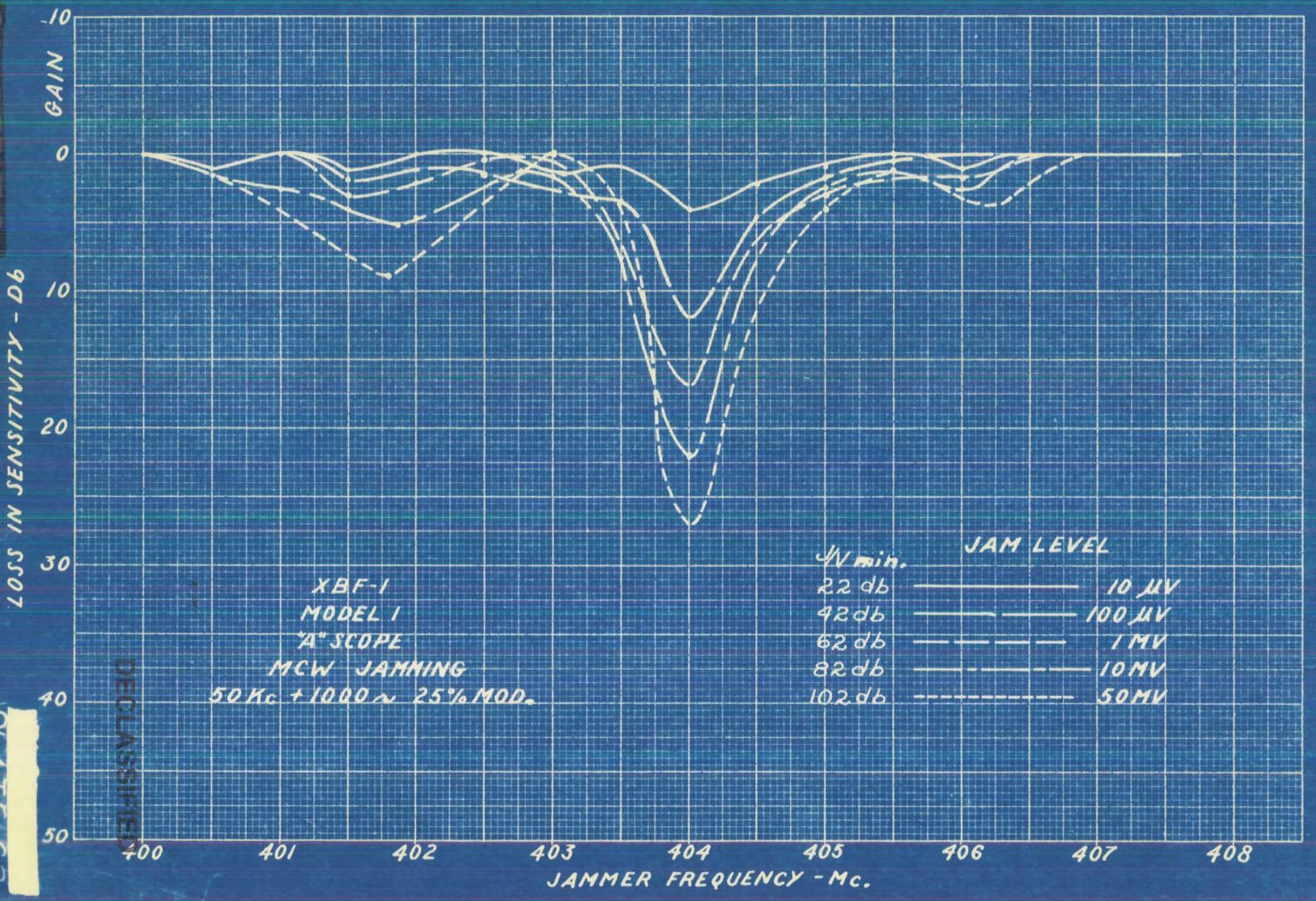
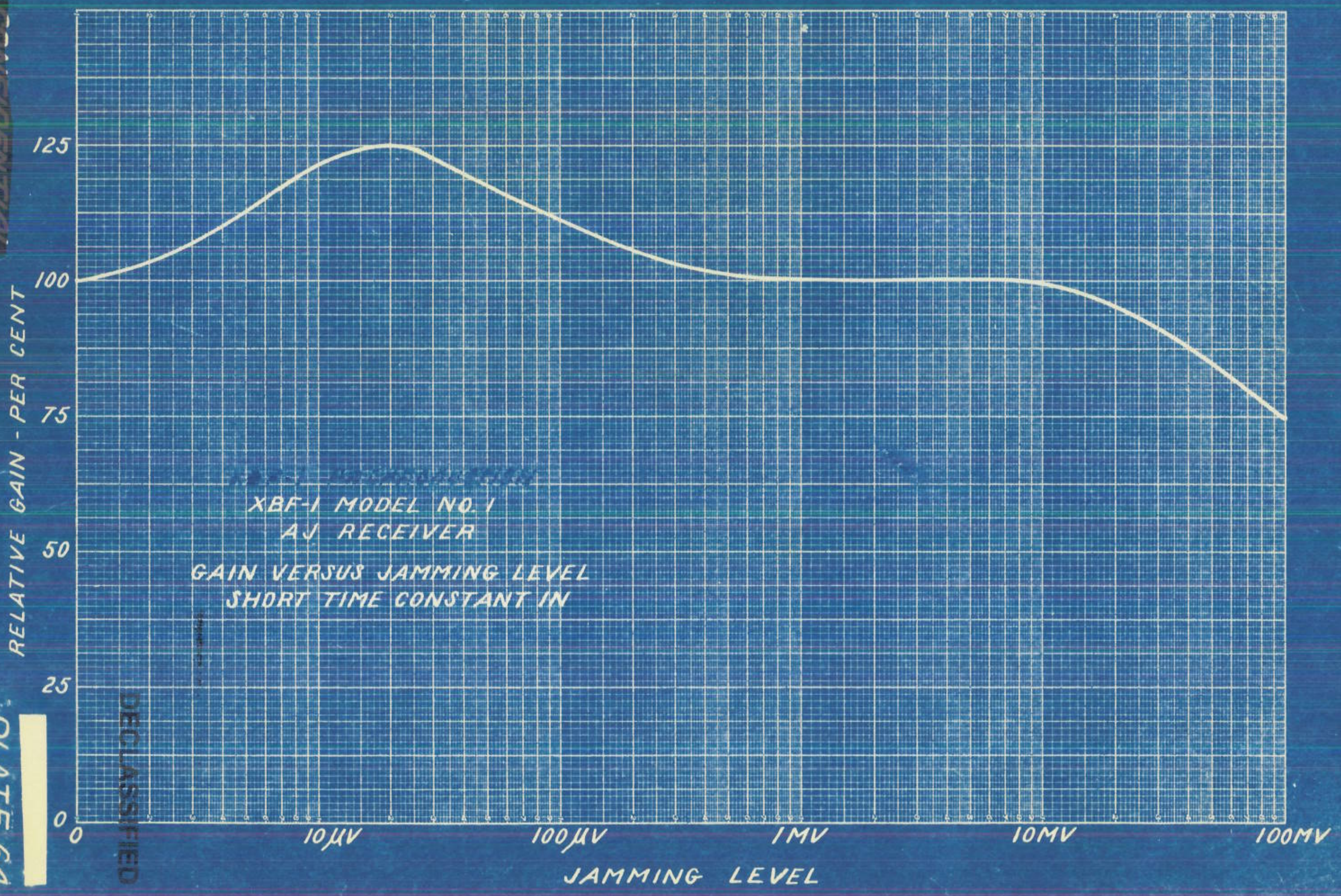
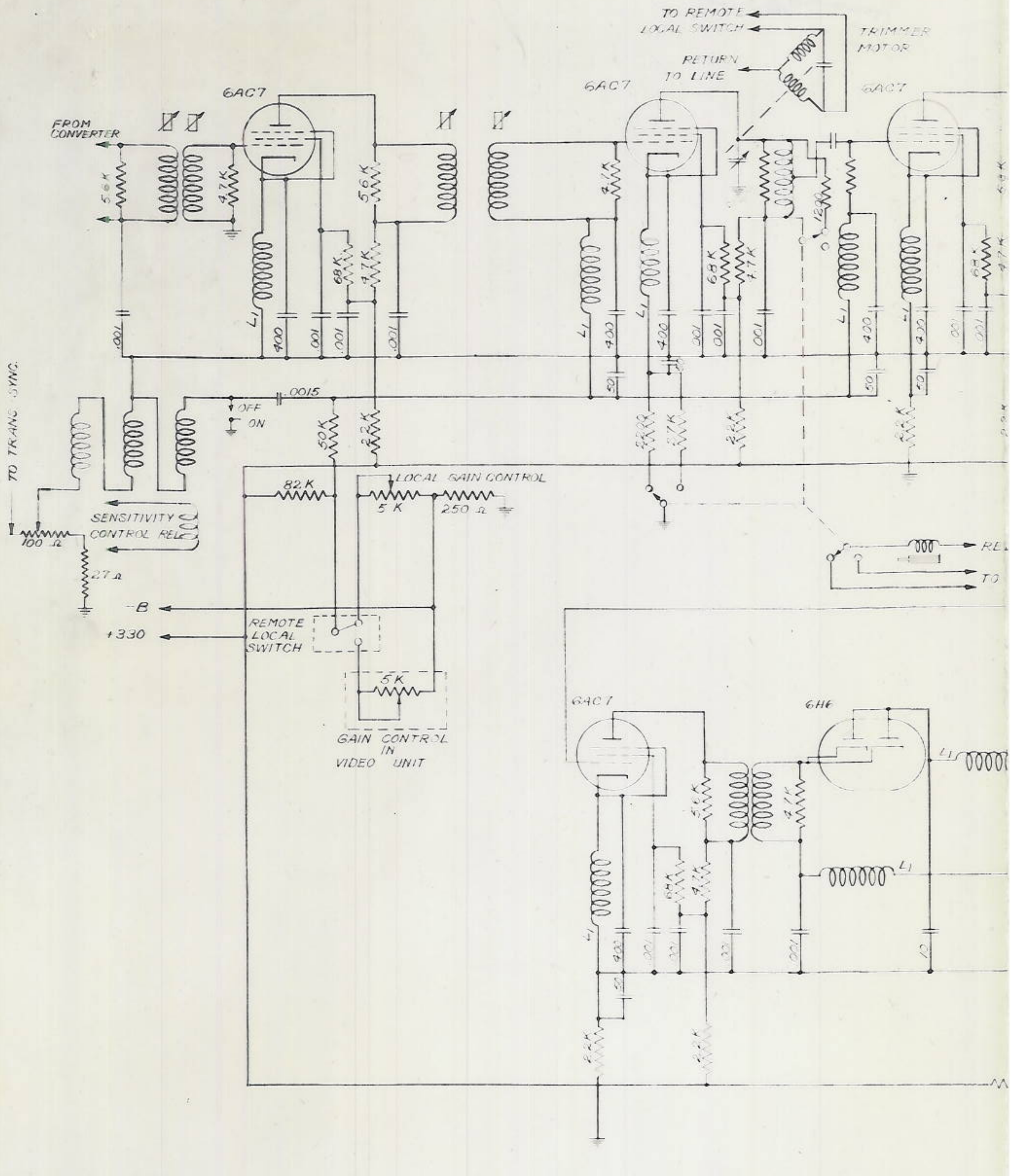

GAIN
LOSS IN SENSITIVITY - Db
10
0
10
20
30
40
50
400
401
402
403
404
405
406
407
408
JAMMER FREQUENCY - Mc.
XBF-1
MODEL I
"A" SCOPE
MCW JAMMING
50 Kc + 1000 ~ 25% MOD.
JAM LEVEL
S/N min.
22 db 10 µV
42 db 100 µV
62 db 1 MV
82 db 10 MV
102 db 50 MV

PLATE 63



DECLASSIFIED

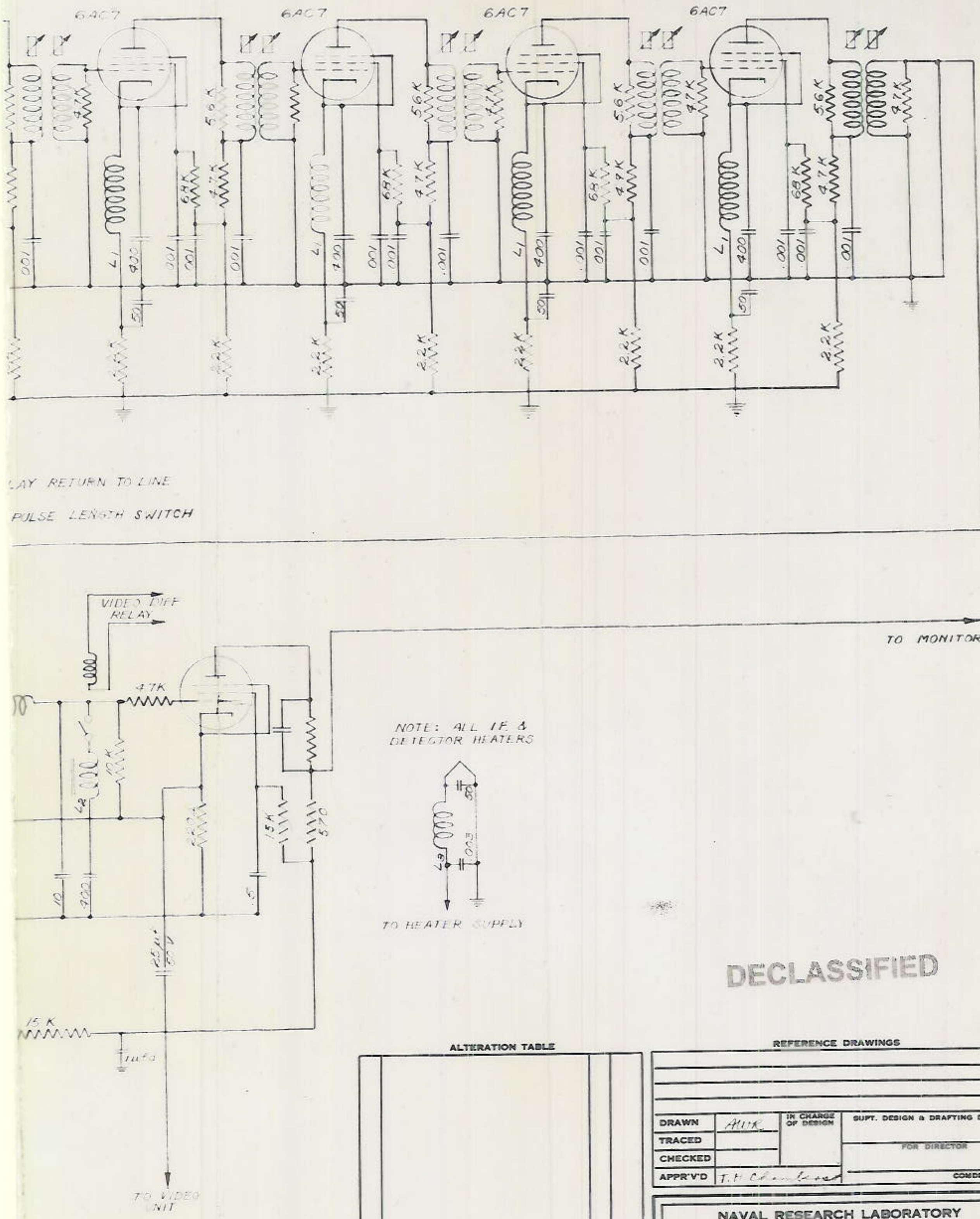
PLATE 64



L_1 - SELF RESONANT CHOKE 30 MC 1 MEG
½ W RESISTOR FULL #36 ENAMEL.

L_2 - VIDEO DIFFERENTIATION FILTER RESONANT AT 1 MC WITH 30 μμf POTTED.

L_3 - SELF RESONANT CHOKE 30 MC
1 MEG, ½ W RESISTOR #26 ENAMEL.



ALTERATION TABLE

SYMBOLS AND THEIR EQUIVALENT TOLERANCES (UNLESS OTHERWISE NOTED)

SYMBOL 1	± .0005	SYMBOL 3	± .0050
SYMBOL 2	± .0010	SYMBOL 3½	± .0100
SYMBOL 2½	± .0030	SYMBOL 4	± .0250
SYMBOL 5			

REFERENCE DRAWINGS

DRAWN	AWK.	IN CHARGE OF DESIGN	SUPT. DESIGN & DRAFTING DIVISION
TRACED			FOR DIRECTOR
CHECKED			
APPR'V'D	T. H. Chamberlain		COMDR. U.S.N.

NAVAL RESEARCH LABORATORY
WASHINGTON 20. D. C.

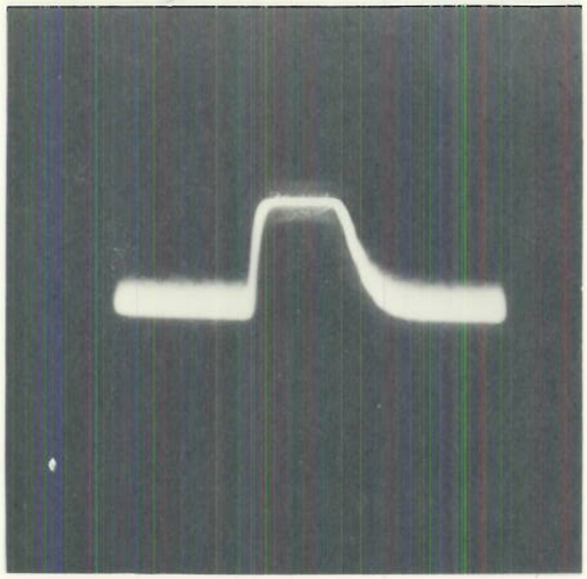
RECEIVER MODEL #1
FOR
XBF-1 EQUIPMENT

SCHEMATIC DIAGRAM

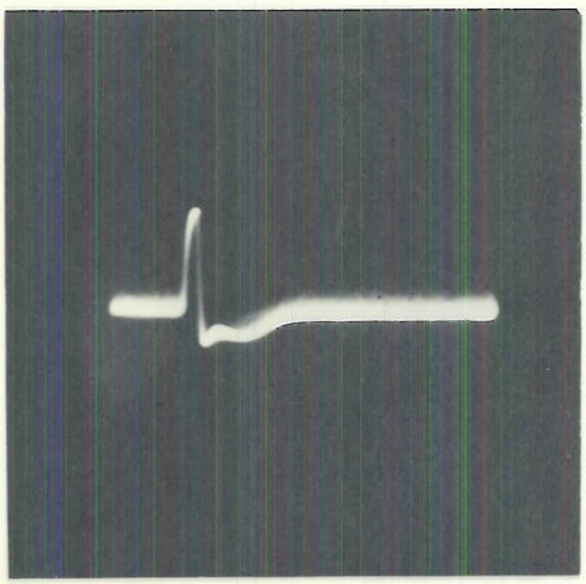
SCALE DATE

RA 46F 349A

PLATE 65 SHEET

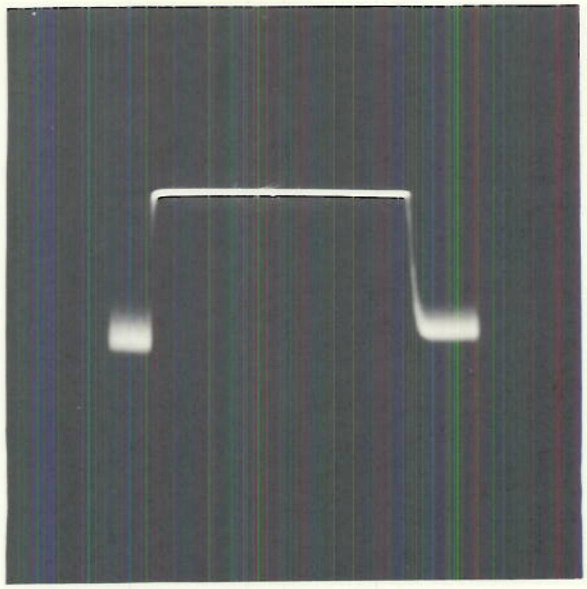


5 μ SEC PULSE 25μ SEC SWEEP FTC OUT

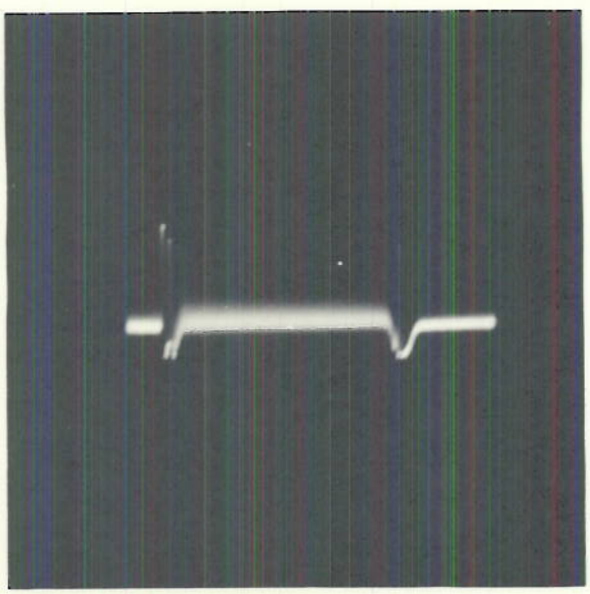


5 μ SEC PULSE 25μ SEC SWEEP FTC IN

RECOVERY OF XBF-1
RECEIVER TO 50 MV PULSE

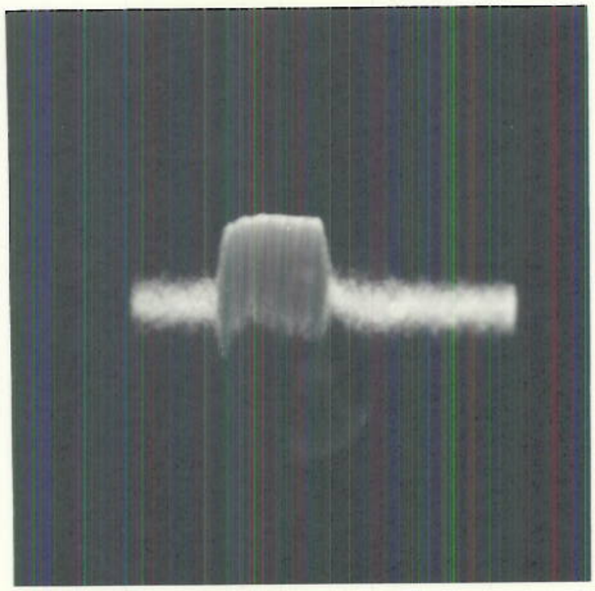


30μSEC PULSE 50μSEC SWEEP FTC OUT

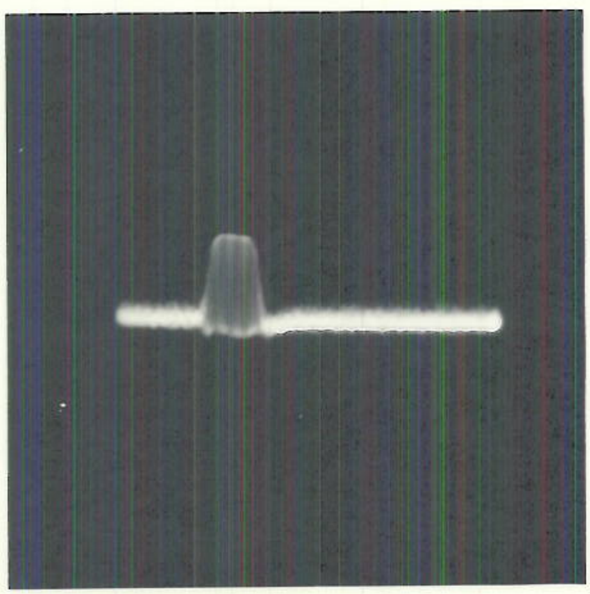


30μSEC PULSE 50μSEC SWEEP FTC IN

RECOVERY OF XBF-1
RECEIVER TO 50 MV PULSE.

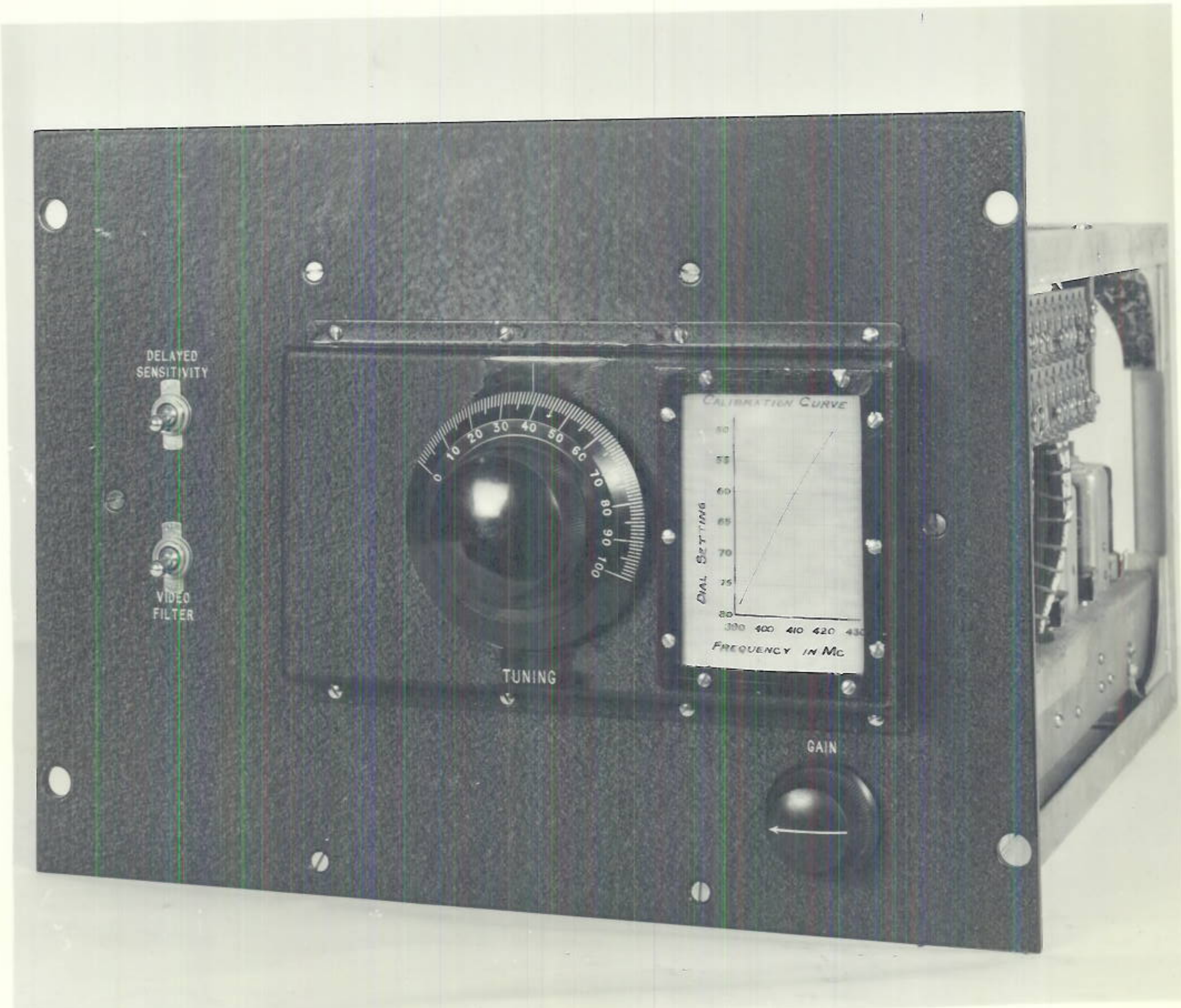


5μ SEC PULSE 15μ SEC SWEEP FTC IN 1 MC BEAT NOTE

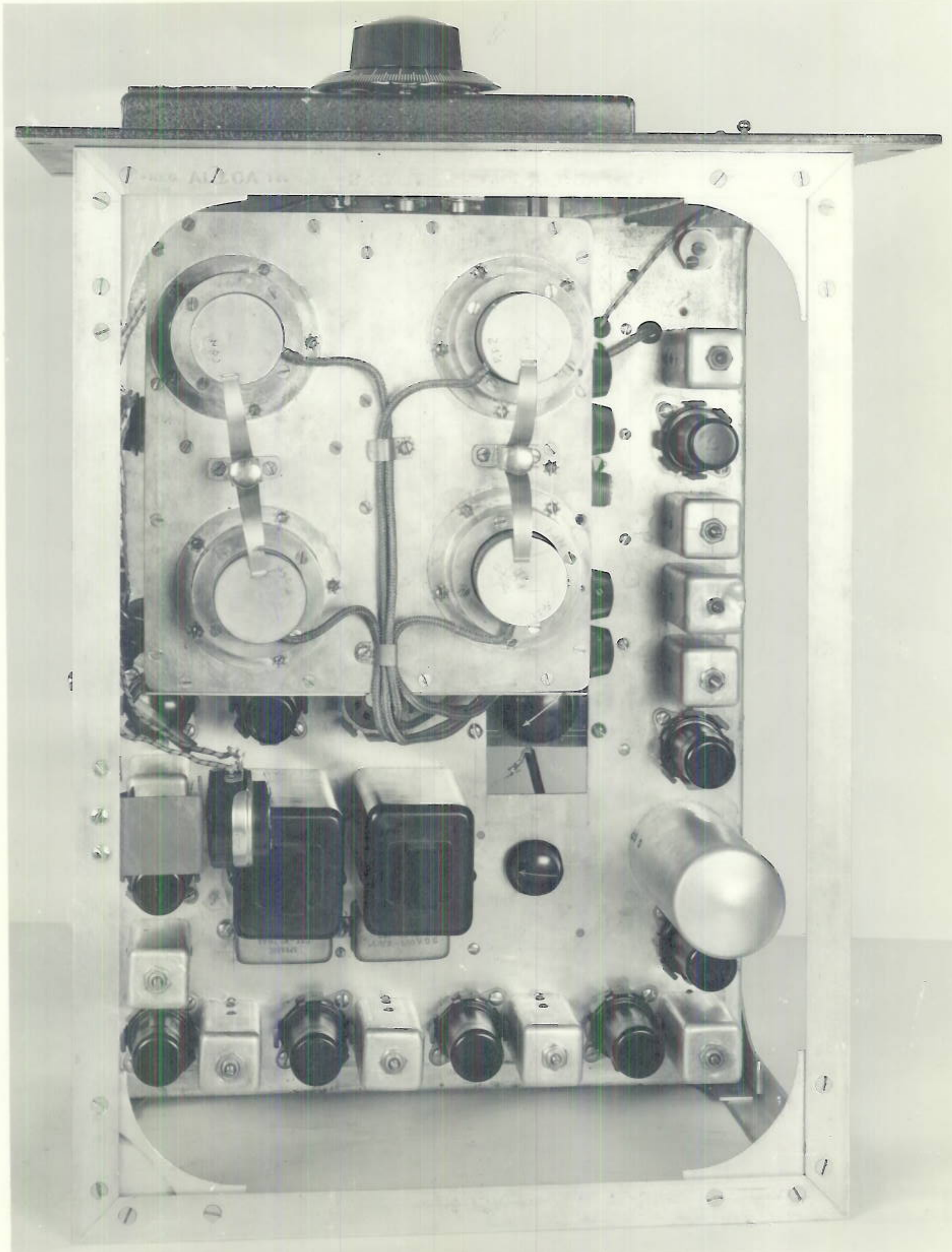


2μ SEC PULSE 15μ SEC SWEEP FTC IN 1.5 MC BEAT NOTE

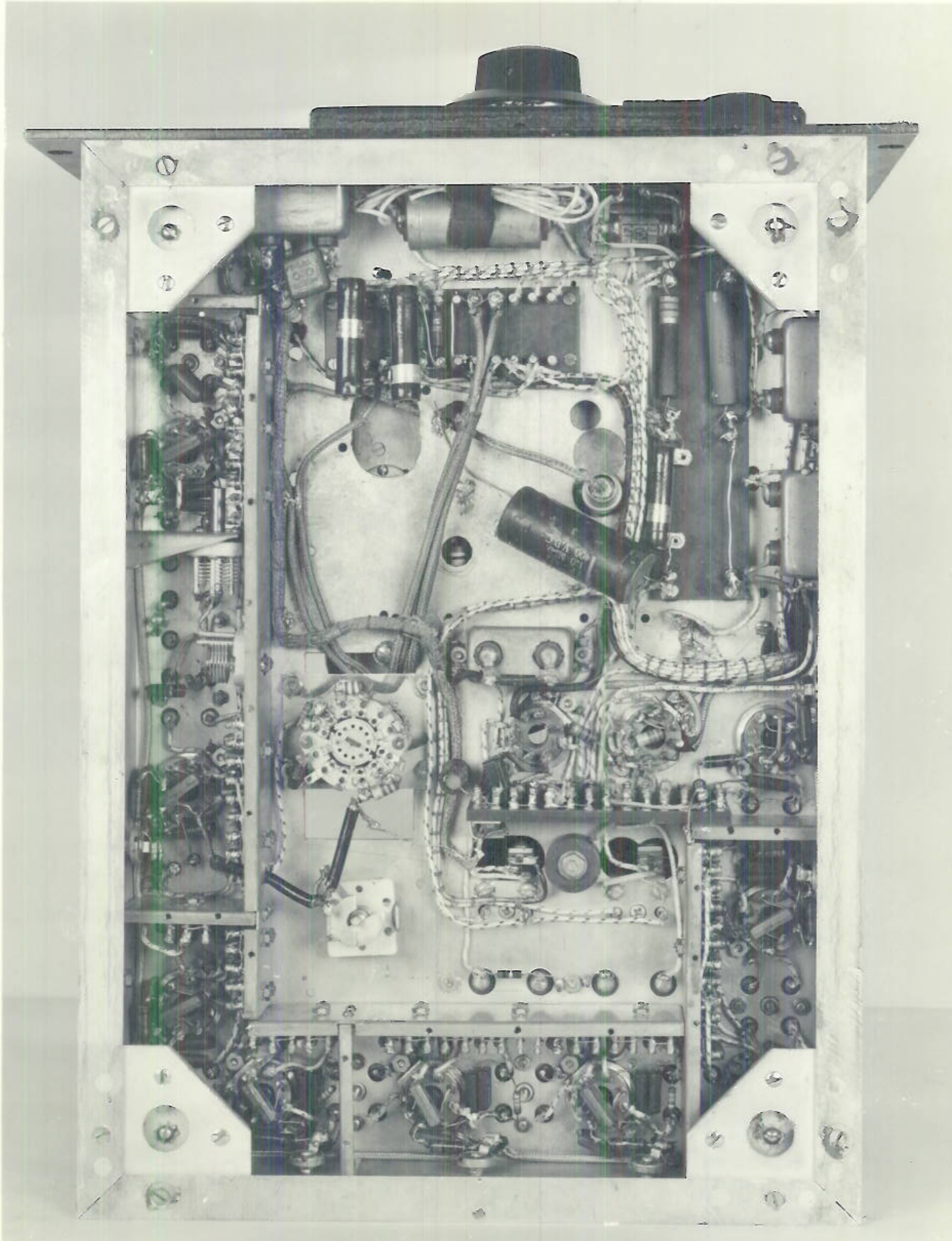
DETECTOR OUTPUT IN THE PRESENCE OF
OFF FREQUENCY JAMMING.
XBF-1 RECEIVER 10μV PULSE
10 MV CW JAMMING



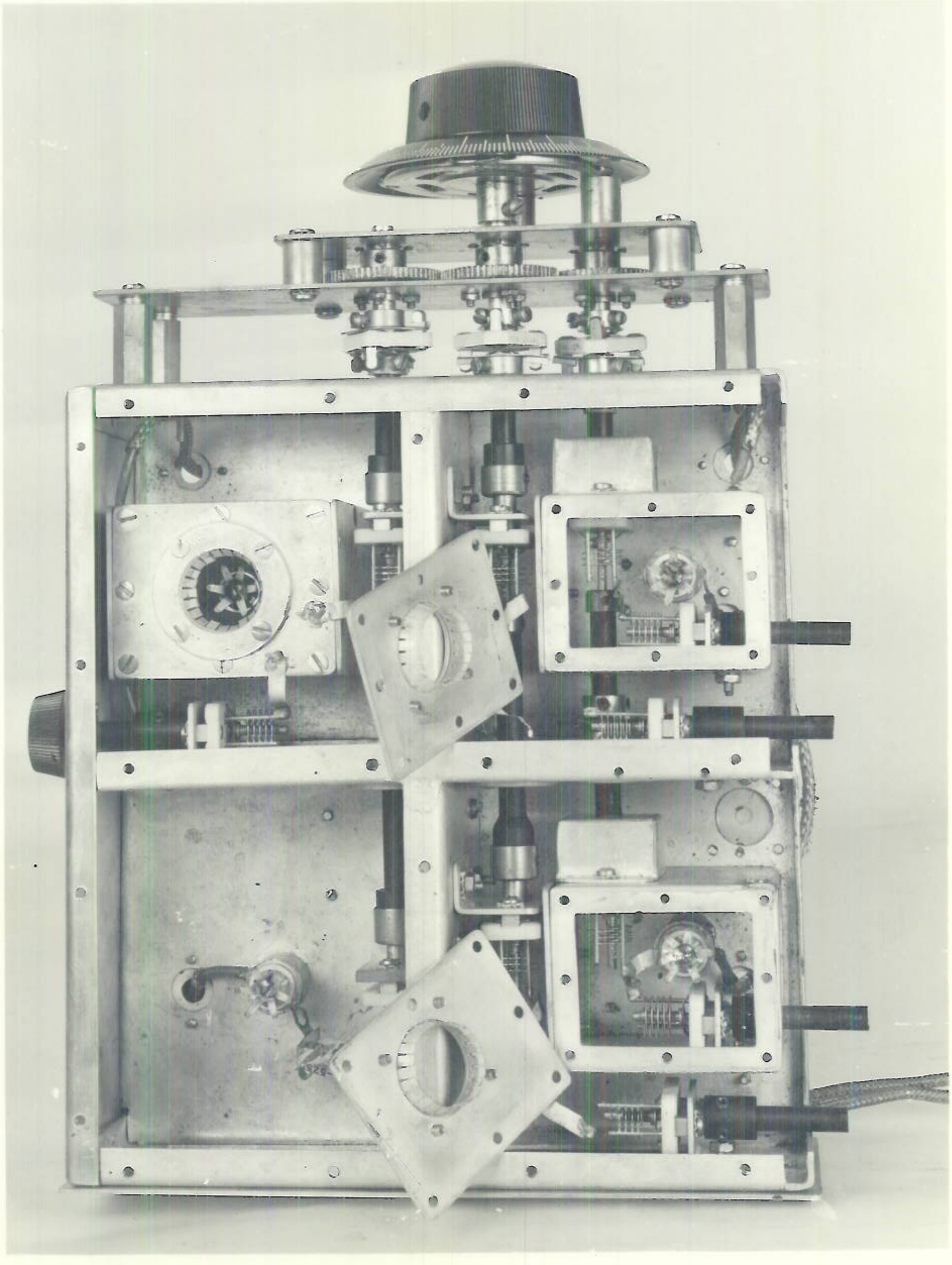
XBF-1 MODEL NO.1 RECEIVER FRONT VIEW



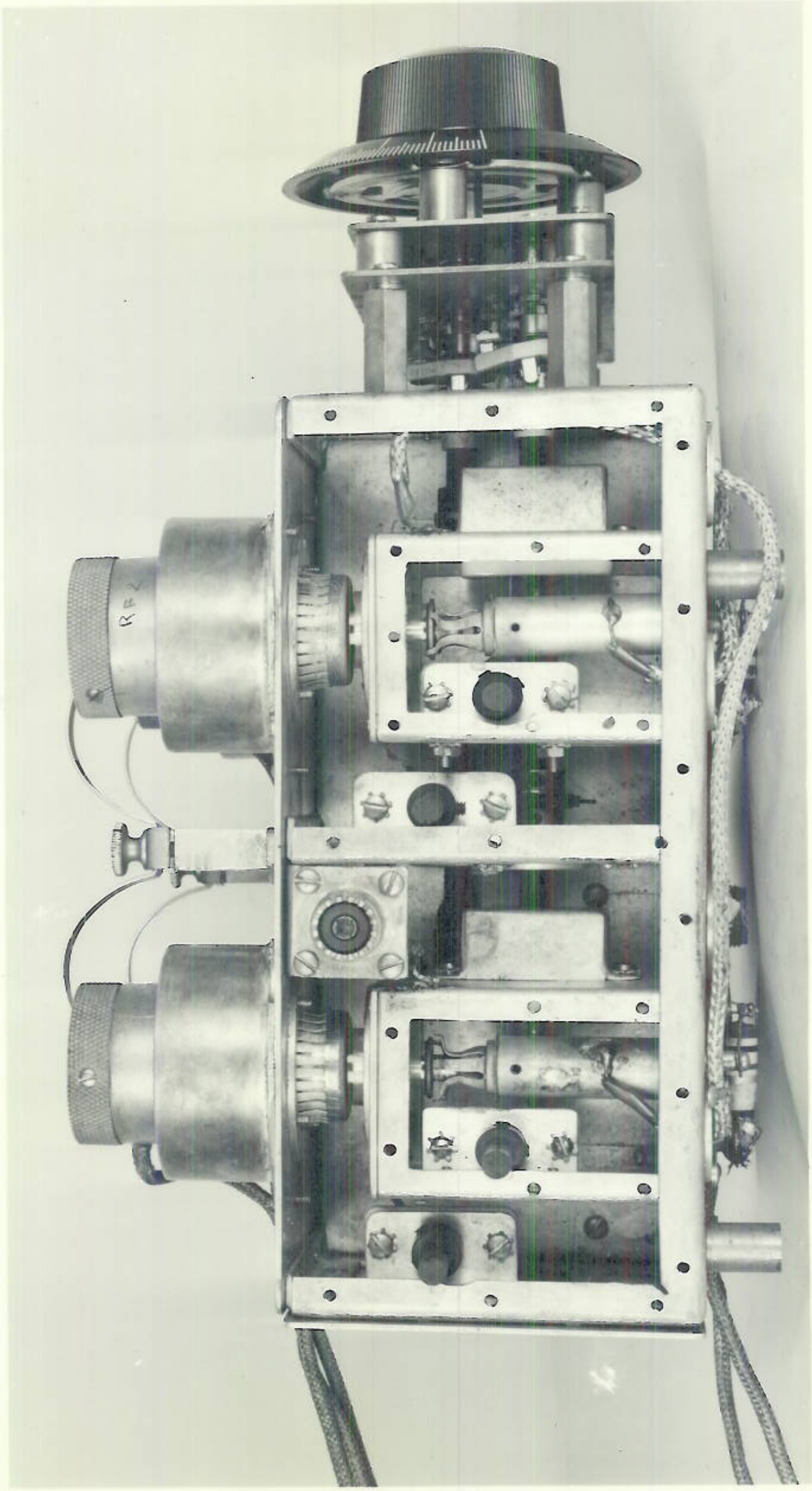
XBF-1 MODEL NO.1 RECEIVER—TOP VIEW



XBF-1 MODEL NO.1 RECEIVER   BOTTOM VIEW

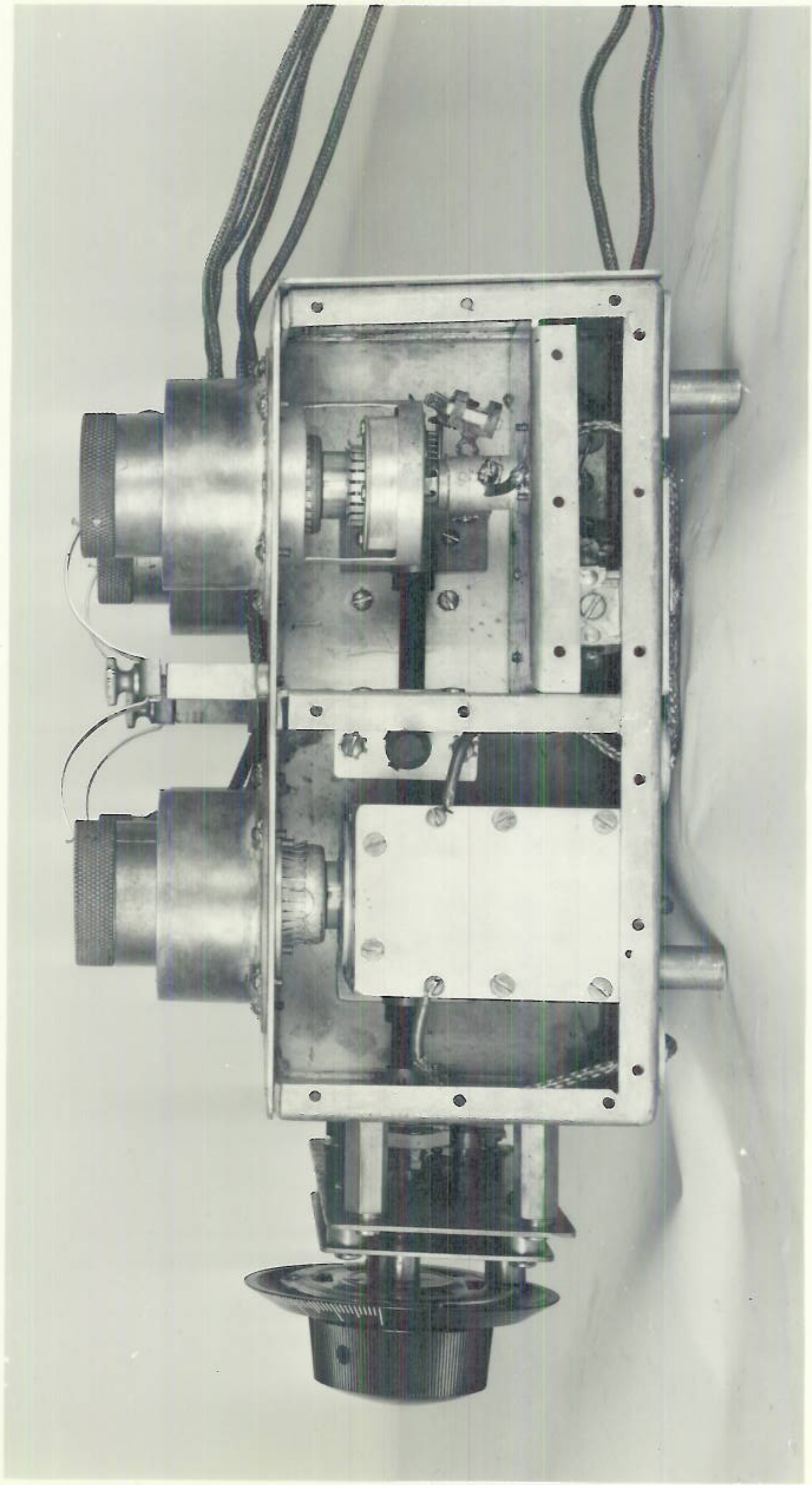


XBF-I PREAMPLIFIER UNIT TOP VIEW - DISASSEMBLED



XBF-1 PREAMPLIFIER UNIT   RIGHT SIDE VIEW - DISASSEMBLED

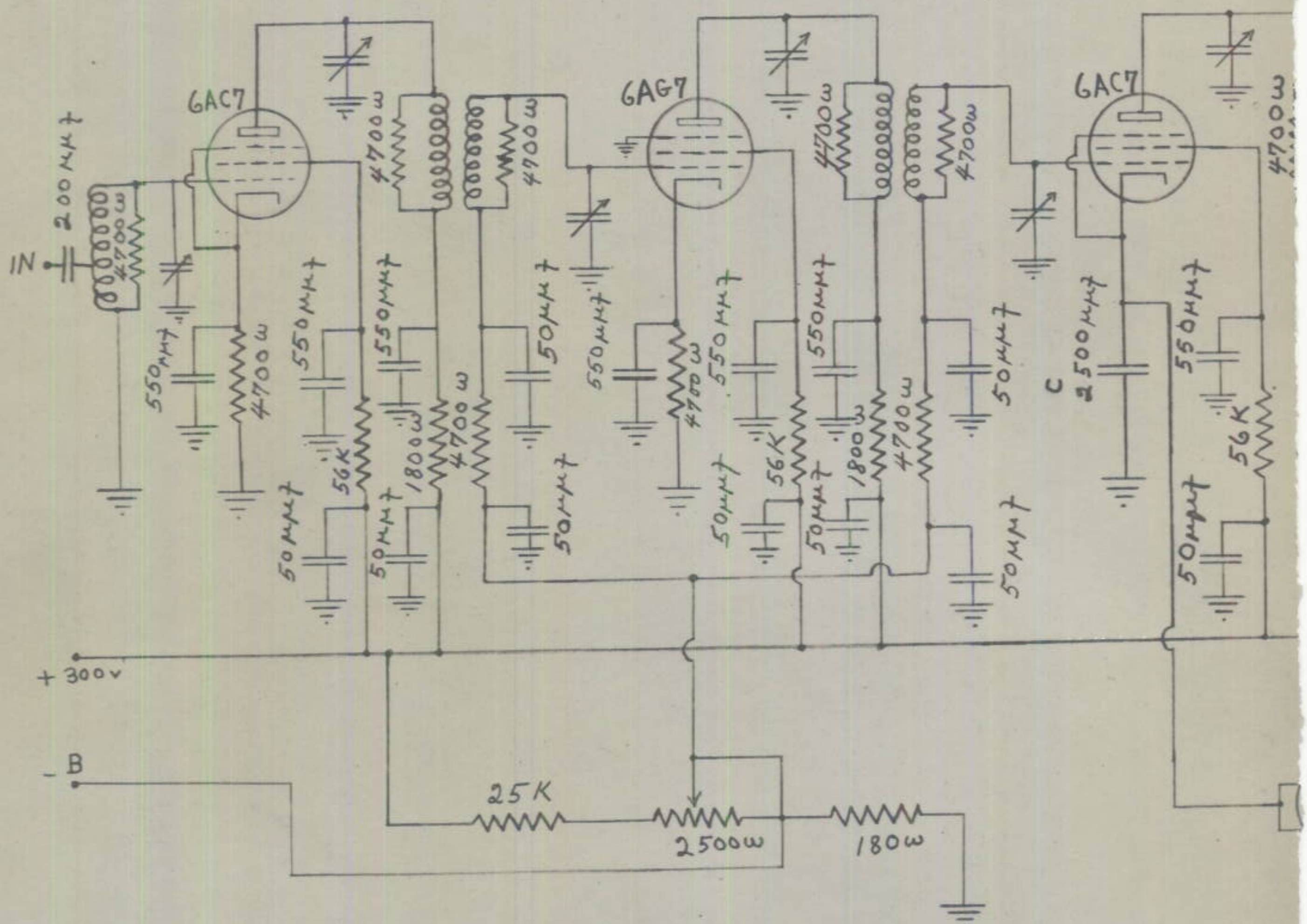
DECLASSIFIED



XBF-1 PREAMPLIFIER UNIT   LEFT SIDE VIEW - DISASSEMBLED

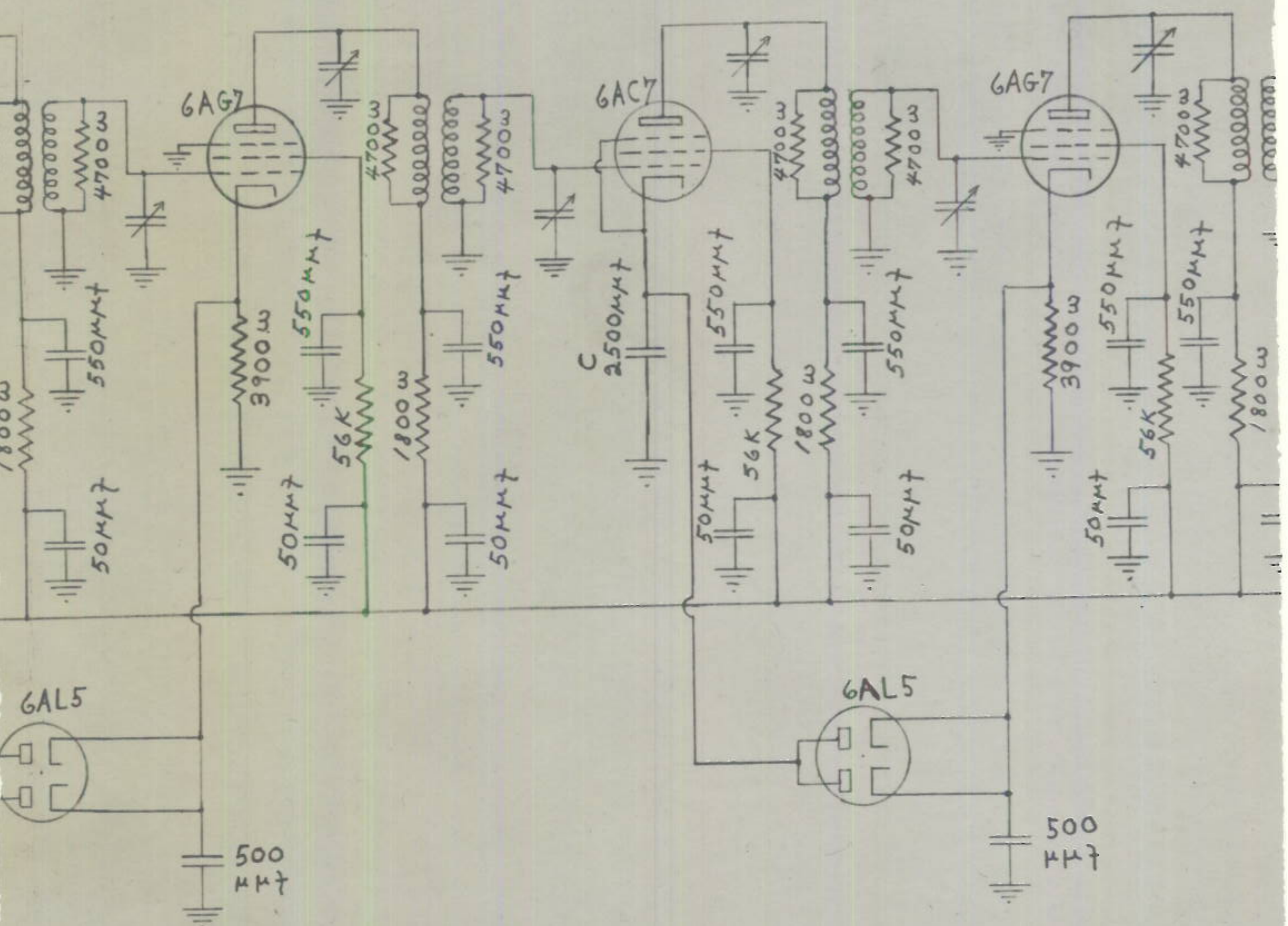
CONFIDENTIAL

DECLASSIFIED


6AC7
6AG7
6AC7
IN
200 μμf
4700 ω
550 μμf
50 μμf
56K
1800 ω
C
2500 μμf
+ 300v
- B
25K
2500ω
180ω

XBF-1 Model No. 2

A-J Receiver



Legend

L1 30 M.C. SELF RESONANT CHOKE

L2 VIDEO FILTER RESONANT AT 1 MC WITH 30 μμf

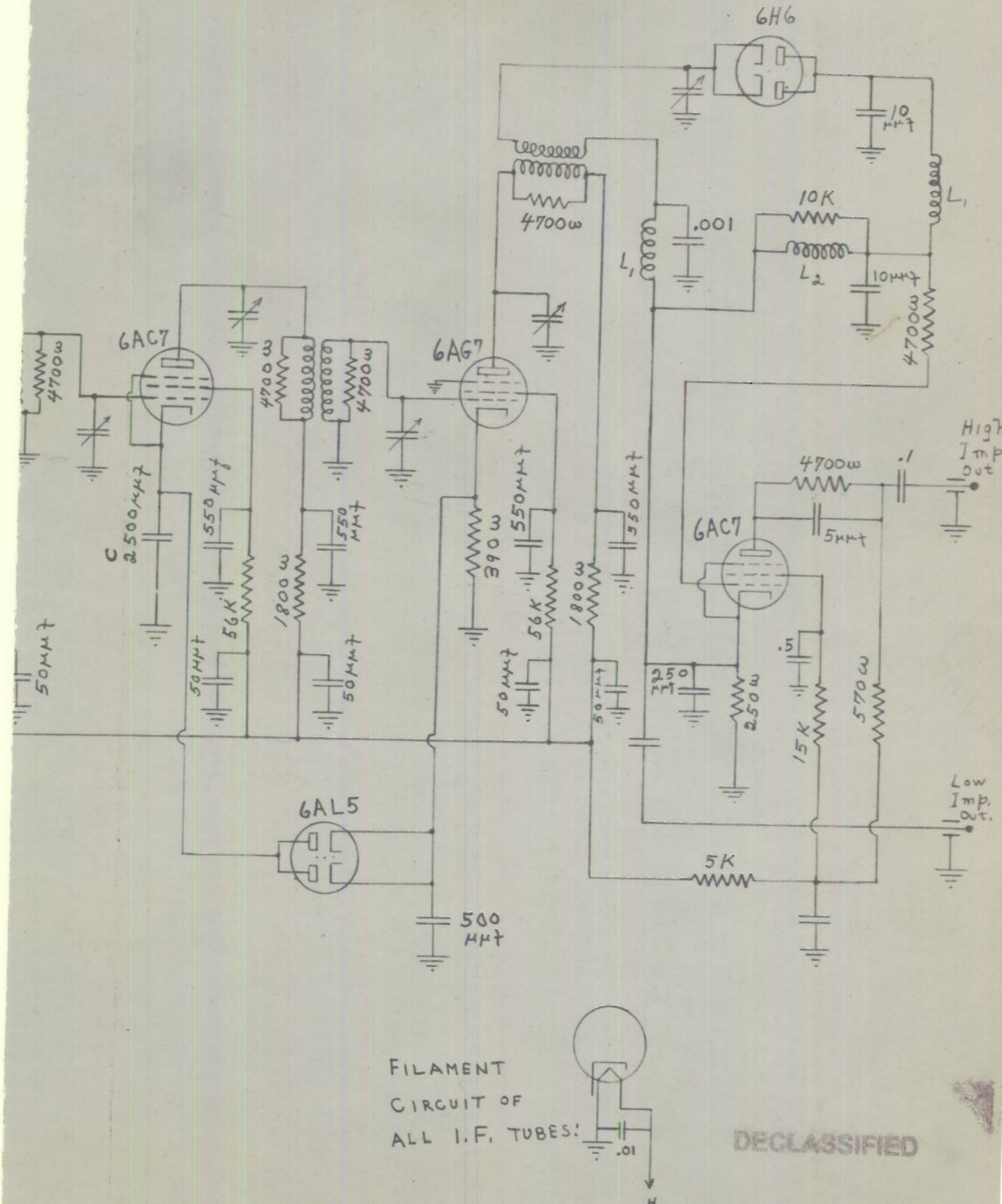

6H6
10 μμf
L1
10K
.001
L2
10μμf
4700ω
4700ω
6AC7
6AG7
C 2500μμf
550μμf
56K
1800ω
50μμf
390ω
250 μμf
250ω
.5
15K
570ω
4700ω
.1
5μμf
High Imp. Out.
Low Imp. Out.
5K
6AL5
500 μμf
FILAMENT CIRCUIT OF ALL I.F. TUBES:
.01
H

PLATE 75

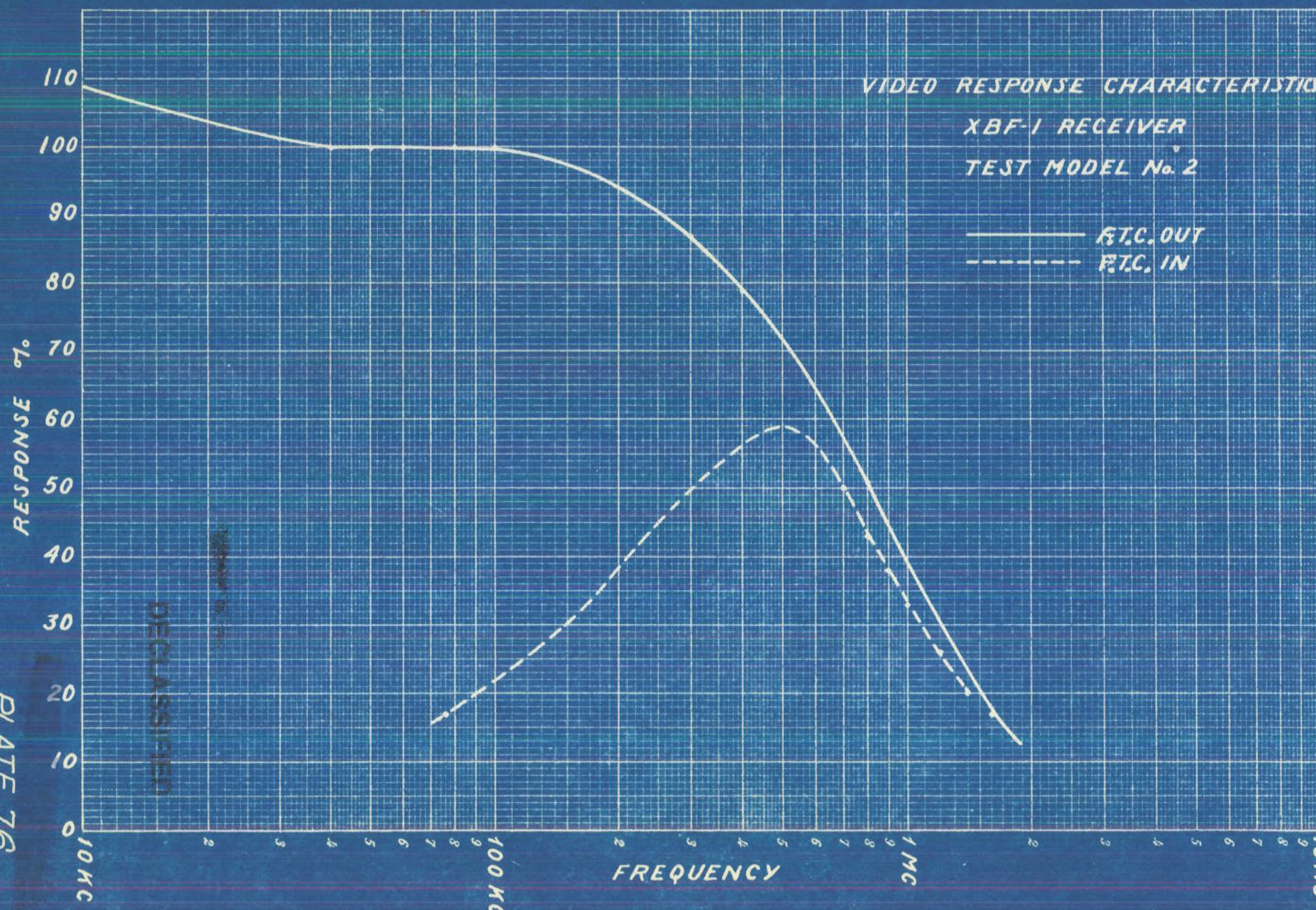

VIDEO RESPONSE CHARACTERISTIC
XBF-1 RECEIVER
TEST MODEL No. 2
F.T.C. OUT
F.T.C. IN
RESPONSE %
110
100
90
80
70
60
50
40
30
20
10
0
FREQUENCY
10 KC
100 KC
1 MC
10 MC

PLATE 76

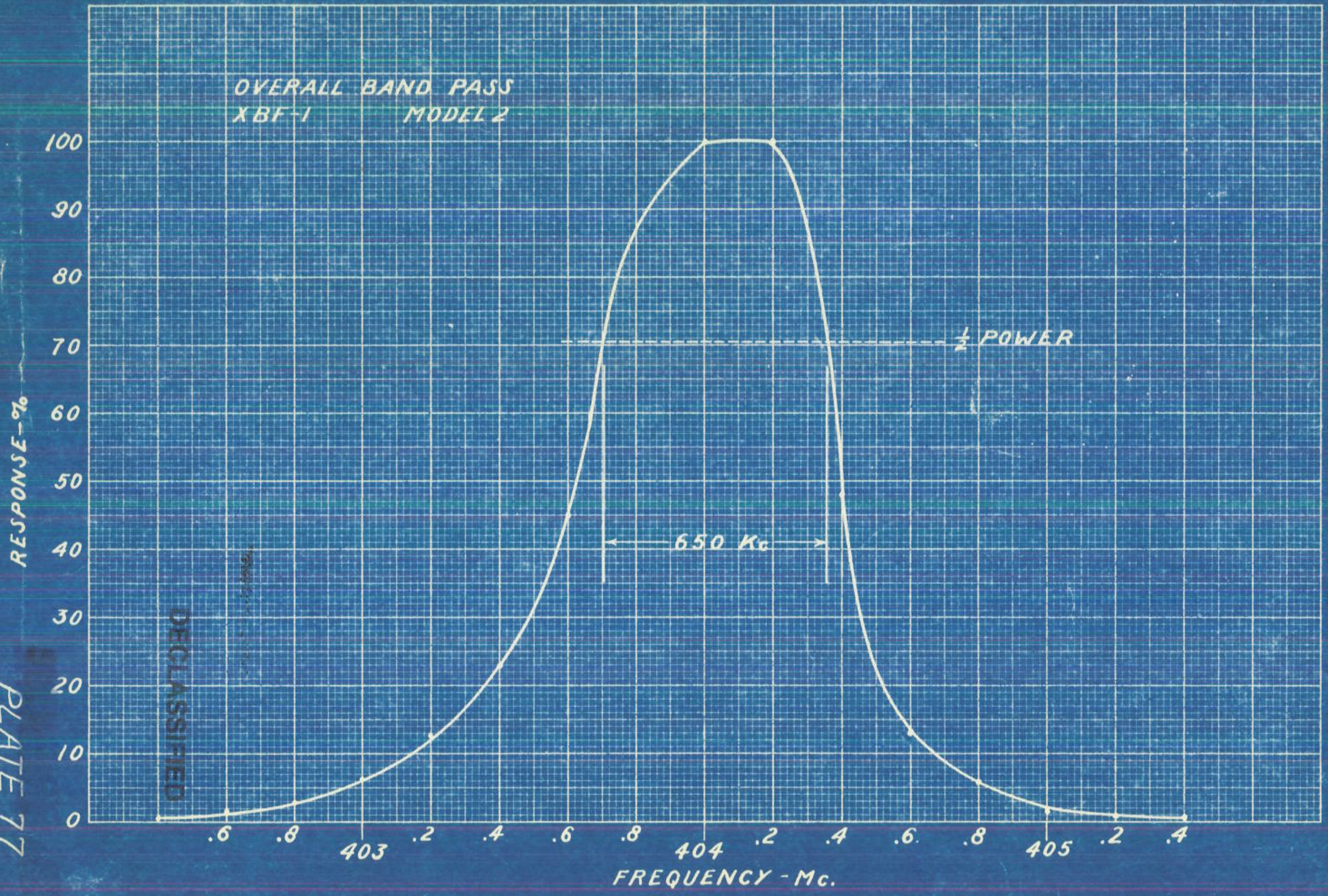

OVERALL BAND PASS
XBF-1 MODEL 2
RESPONSE-%
100
90
80
70
60
50
40
30
20
10
0
½ POWER
650 Kc
.6
.8
403
.2
.4
.6
.8
404
.2
.4
.6
.8
405
.2
.4
FREQUENCY - Mc.

PLATE 77

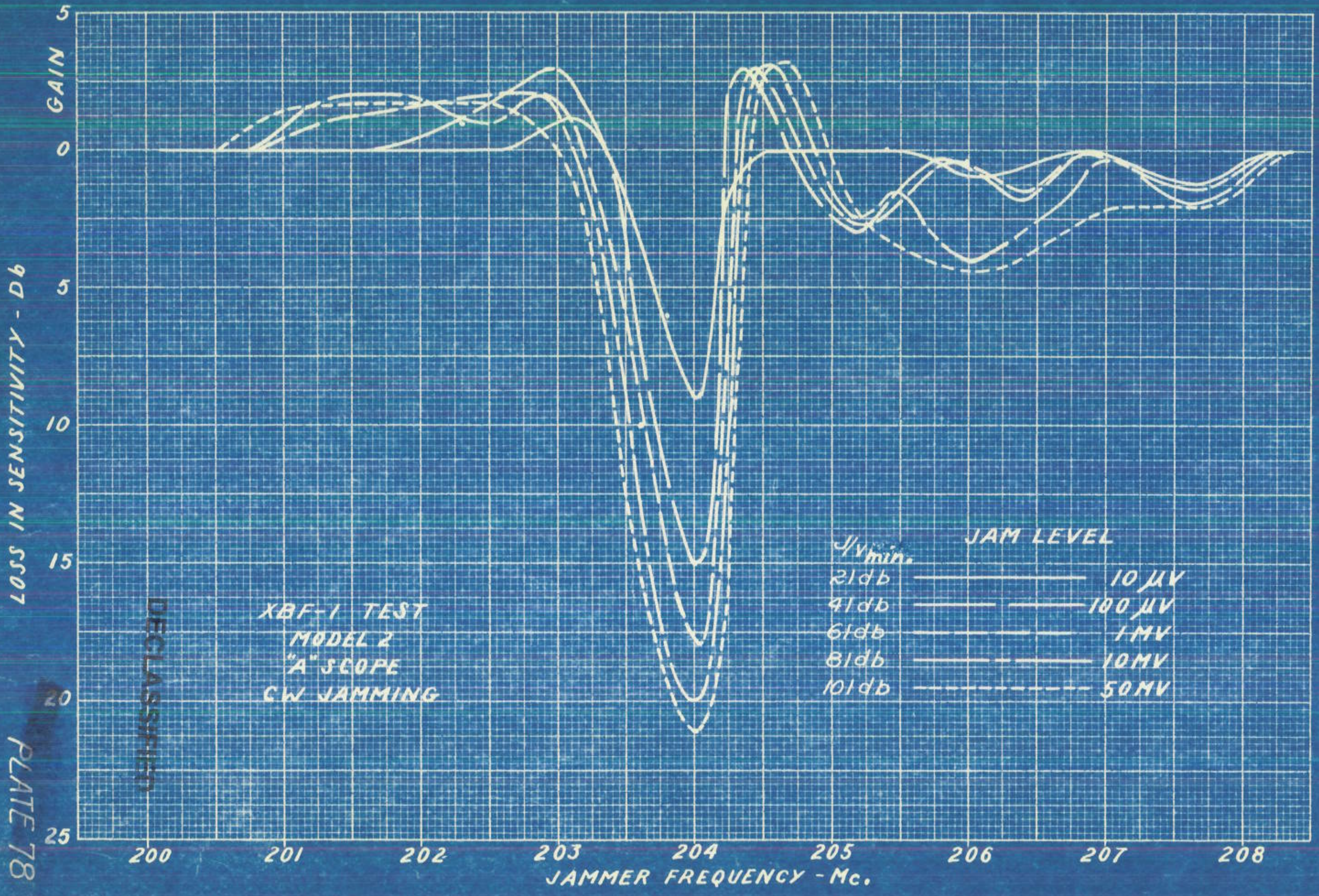
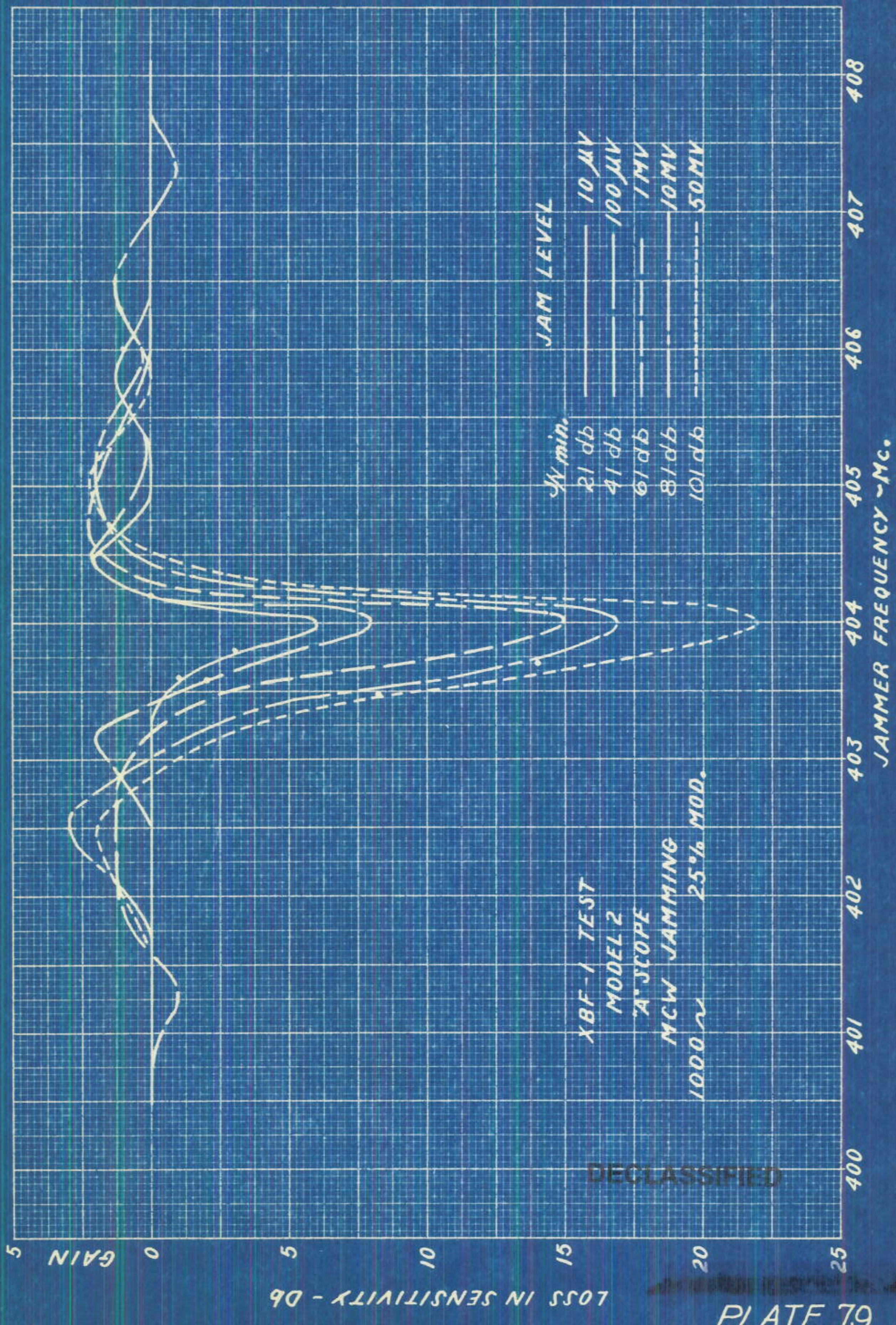


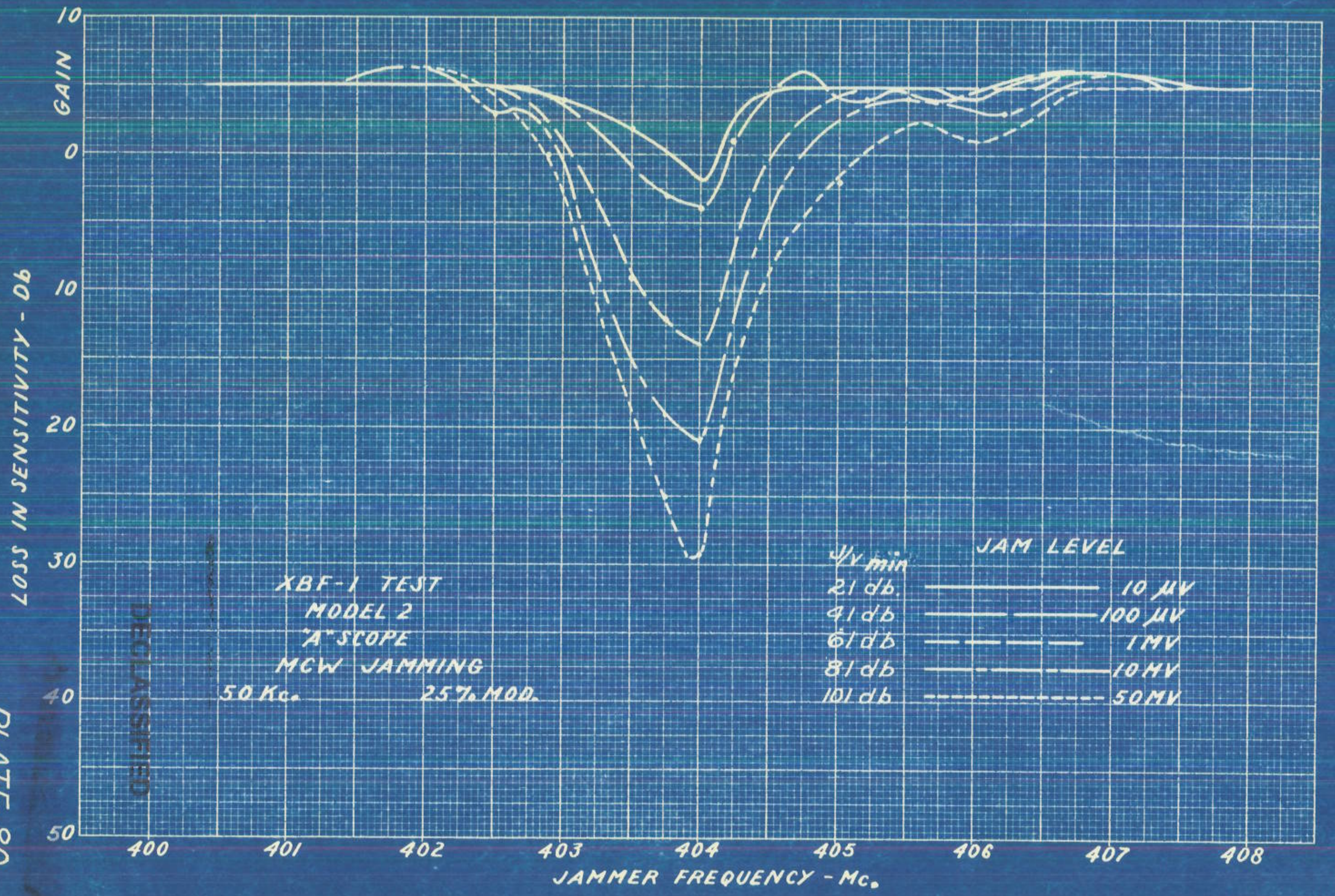
PLATE 78

DECLASSIFIED



[redacted]

PLATE 79



DECLASSIFIED

PLATE 80

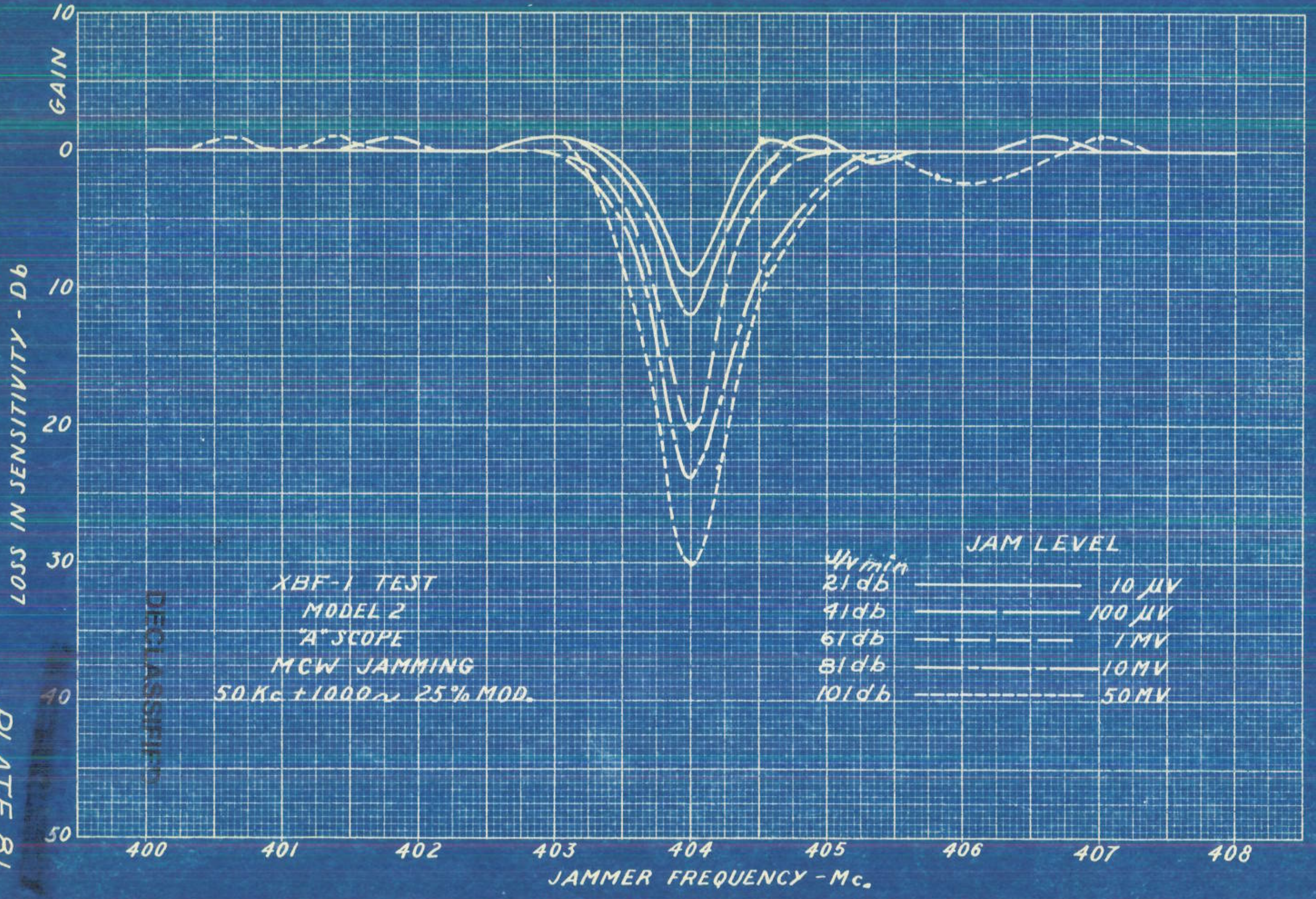
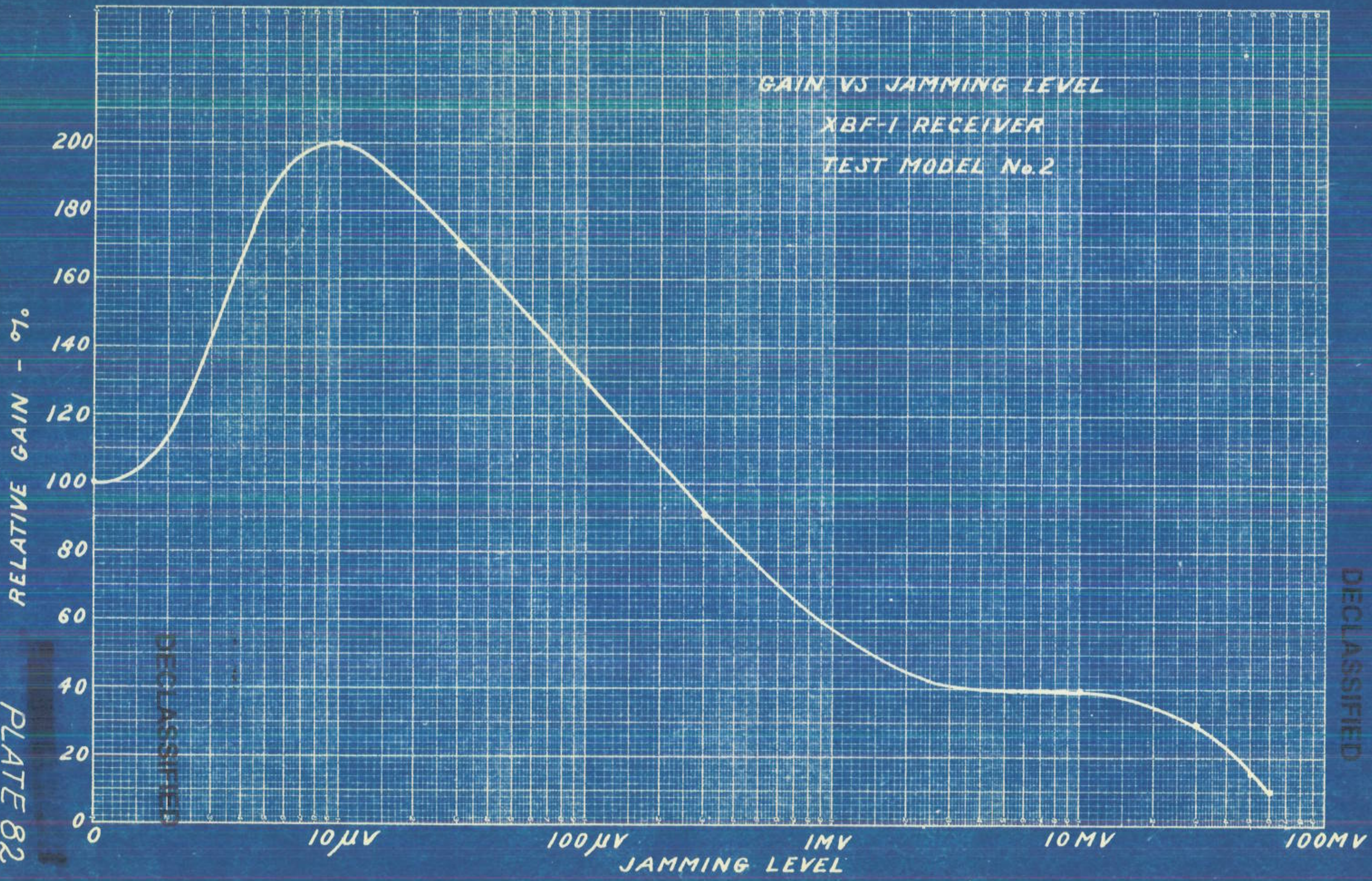


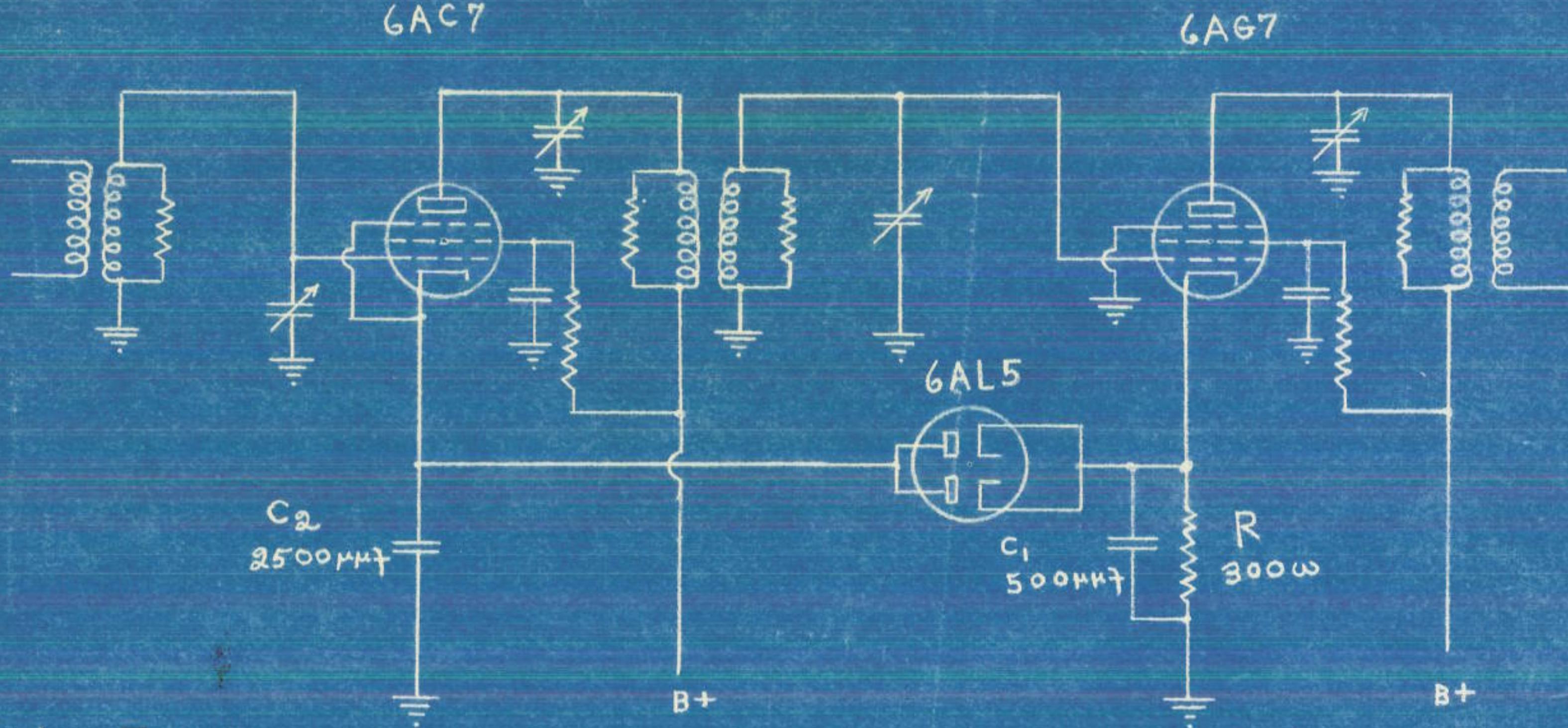
PLATE 81

DECLASSIFIED



[redacted]

PLATE 82



DECLASSIFIED

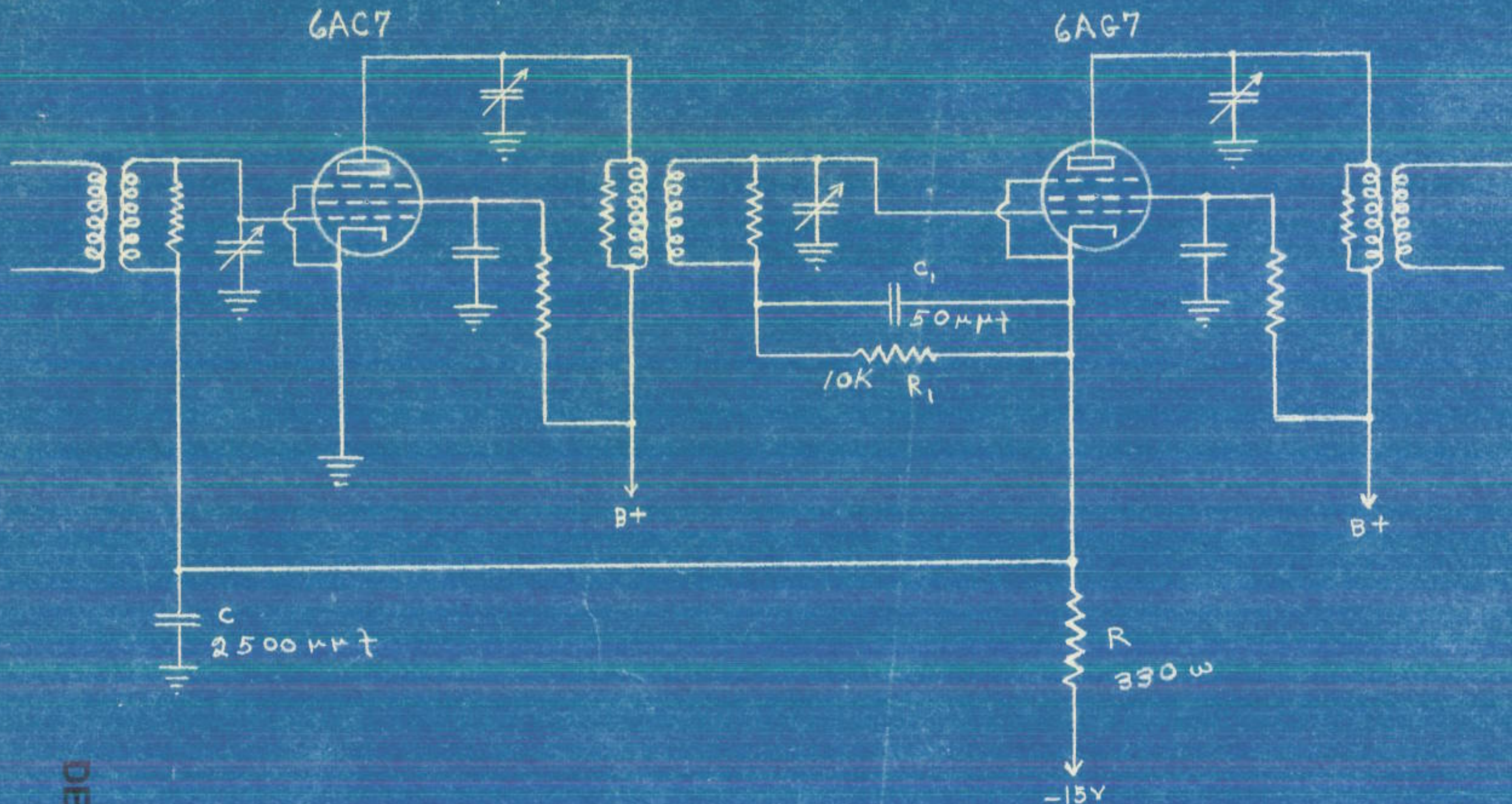
PLATE 83

[redacted]

Two stages of
I. F. amplification using
amplified back bias
with diode feedback tube

U. S. NAVAL RESEARCH LABORATORY WASHINGTON 20, D. C.		SCALE	
		DR'WN.	
B'LD'G.	PHONE	CH'K'D.	
ROOM	DATE	APPR'V'D.	UNLESS OTHERWISE SPECIFIED, TOLERANCES ARE ±

SHEET OF

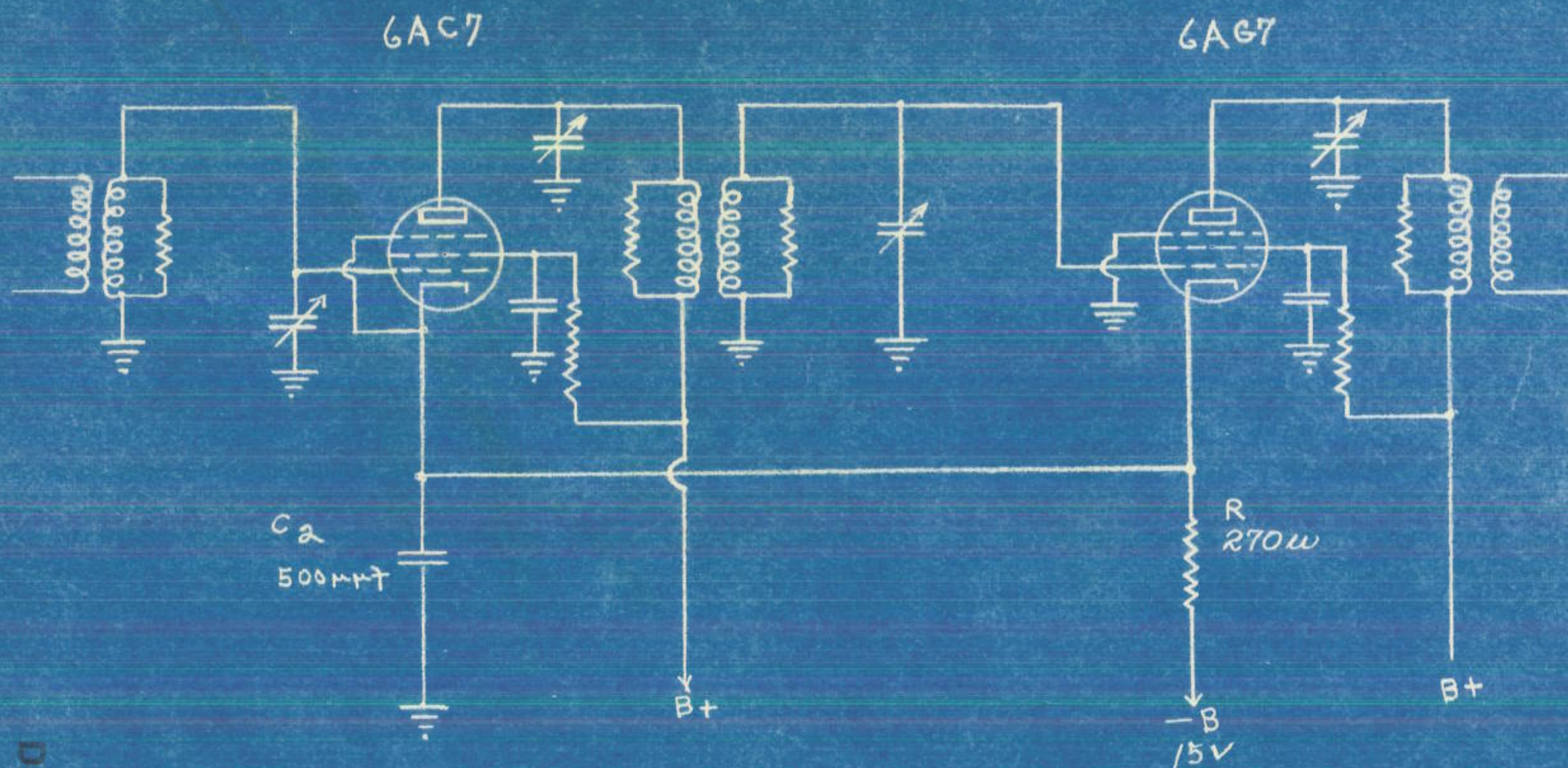


TWO STAGES OF
I.F. AMPLIFICATION USING
AMPLIFIED BACK BIAS
WITH GRID DETECTOR

PLATE 84

U. S. NAVAL RESEARCH LABORATORY WASHINGTON 20. D. C.		SCALE	
B'LD'G.	PHONE	DR'WN.	
ROOM	DATE	CH'K'D.	
		APPR'V'D.	UNLESS OTHERWISE SPECIFIED, TOLERANCES ARE ±

SHEET OF



TWO STAGES OF
I. F. AMPLIFICATION USING
AMPLIFIED BACK BIAS
WITH COMMON CATHODE
CIRCUIT.

PLATE 85

U. S. NAVAL RESEARCH LABORATORY		SCALE	
WASHINGTON 20, D. C.		DR'WN.	
B'LD'G.	PHONE	CH'K'D.	
ROOM	DATE	APPR'V'D.	UNLESS OTHERWISE SPECIFIED, TOLERANCES ARE ±

SHEET OF