

Navy Department - Office of Research and Inventions

UNCLASSIFIED
DECLASSIFIED

NAVAL RESEARCH LABORATORY
Washington, D.C.

DECLASSIFIED: By authority of
JOD DIR 5200.9
Date
Entered by
NRL Code

SHIP-SHORE RADIO DIVISION - SEARCH RADAR SECTION

10 July 1945

DECLASSIFIED by NRL Contract
Declassification Team

Date: 9 SEP 2014

Reviewer's name(s): A. THOMPSON,
P. HANNA

Declassification authority: NAVY DECLASS
MAY 11/DEC 2012, OF SERIES

A STUDY OF PROCEDURES AND
EQUIPMENT USED FOR SETTING
RADAR "SPOT JAMMERS" ON FREQUENCY

By K. M. Watson

- Report R-2543 -

DISTRIBUTION STATEMENT A APPLIES. * * *

Further distribution authorized by
UNLIMITED only.

FR-2543

Approved by:

R.C. Guthrie - Head, Search Radar Section

L.A. Gebhard

Supt. Ship-Shore Radio Division

Rear Adm. A.H. Van Keuren, USN (Ret.)
Director, Naval Research Laboratory

Preliminary Pages ... a-c
Numbered Pages 20
Plates 4
Distribution List ... d-e

Navy Department - Office of Research and Inventions

UNCLASSIFIED

DECLASSIFIED

NAVAL RESEARCH LABORATORY
Washington, D.C.

LIBRARY
NAVAL RESEARCH LABORATORY

SHIP-SHORE RADIO DIVISION - SEARCH RADAR SECTION

10 July 1945

A STUDY OF PROCEDURES AND
EQUIPMENT USED FOR SETTING
RADAR "SPOT JAMMERS" ON FREQUENCY

By K. M. Watson

- Report R-2543 -

DECLASSIFIED: By authority of

DOD DIR 5200.9

Cite Authority

Date

Entered by

NRL Code

Archie A. Raymond 2028

Approved by:

R.C. Guthrie - Head, Search Radar Section

L.A. Gebhard

Rear Adm. A.H. Van Keuren, USN (Ret.)

Supt. Ship-Shore Radio Division

Director, Naval Research Laboratory

Preliminary Pages ... a-c
Numbered Pages 20
Plates 4
Distribution List ... d-e

NRL Problem S411.1R-S

-a-

DECLASSIFIED

~~CONFIDENTIAL~~
CLASSIFICATION CHANGE BY AUTHORITY OF [unclear] REFERENCE AUTHORITY [unclear] (DATE) [unclear]
Signature of Custodian [unclear]

5431
Juryon

UNCLASSIFIED

DECLASSIFIED

ABSTRACT

In order to determine the most effective methods of setting a noise-modulated jamming transmitter to a radar frequency, and the consistency with which an operator can set on frequency well, tests were conducted in the laboratory using actual jammers (TDY, etc.) with a simulated radar system, at frequencies between 100 and 1000 megacycles. Further information was obtained under operational conditions, using actual radar equipments, at the NRL Chesapeake Bay Annex.

It was found that unless experienced operators use great care in setting on frequency, and unless they possess, in addition to the intercept receiver, at least the equivalent of an APA-6 pulse analyzer or RDK-1 panoramic adaptor (in good condition), that the consistency of setting on frequency for a number of trials is quite poor and that the loss in jamming effectiveness may be equivalent to a serious reduction in jamming power. This may be as much as 20 decibels in extreme cases, with 8 decibels as the statistically determined "expected" loss. Eight decibels represents a reduction to about one-sixth of the maximum or "attainable" effective power, while 20 decibels represents a reduction to one percent of the maximum.

It was also found that the best results with present available equipment are obtained by using a pulse analyzer, such as the AN/APA-6 or SPA-1, with an intercept receiver whose bandwidth is approximately equal to the bandwidth of the radar receiver to be jammed. In general, there is no significant difference in the suitability of the APR-1 receiver (2-Mc bandwidth) and the APR-4 (0.25-Mc bandwidth). However, the APR-4 cannot be used in the narrow-band condition (0.25 Mc) with a panoramic adaptor. The method of setting on frequency which is most rapid as well as most effective is: (a) set the jammer to the correct frequency as well as is possible with the APR-1 (or equivalent) receiver using the panoramic adaptor; (b) make any further tuning adjustment of the jammer necessary to increase the amplitude of the noise as seen on the pulse analyzer (the intercept receiver having been initially tuned to the exact frequency of the enemy radar).

These experiments were conducted before the Model RDO Receiver, Model RDJ Pulse Analyzer, and Model RDP Panoramic Adaptor became available; however, the conclusions reached are equally applicable to these equipments, with the RDO considered to be approximately equivalent to the APR-1.

-b-

DECLASSIFIED

DECLASSIFIED

TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT	-b-
INTRODUCTION	1
OPERATIONAL TESTS FROM TILGHMAN ISLAND	2
LABORATORY TEST OF SETTING-ON-FREQUENCY METHODS	4
SIGNIFICANCE OF THE DATA	7
ADVANTAGE OF "LOOK-THROUGH" RECEIVERS	9
CONCLUSIONS	9
RECOMMENDATIONS	10
TABLE 1. Jamming Effectiveness Levels Measured During an Operational Test	11
TABLE 2. TDY Transmitter Operated Against SA Receiver (.9 Mc bandwidth) at 190 Mc	12
TABLE 3. TDY Operated Against Laboratory Receiver Set at $\frac{1}{4}$ Mc Bandwidth - 200 Mc	13
TABLE 4. TDY Operated Against Laboratory Receiver Set at 1.54 Mc Bandwidth - 200 Mc	14
TABLE 5. TDY Operated Against Mark 5 Receiver (1.7 Mc Bandwidth) 400 Mc	14
TABLE 6. "Rug" Operated Against SA Receiver (.9 Mc Bandwidth) at 190 Mc	15
TABLE 7. "Rug" Operated Against Laboratory Receiver Set at $\frac{1}{4}$ Mc Bandwidth - 200 Mc	16
TABLE 8. SPT-6 Operated Against Mk 5 Receiver (1.7 Mc Bandwidth) at 400 Mc	17
TABLE 9. SPT-6 Operated Against an APR-1 Receiver at 400 Mc	17
TABLE 10. Tabulated Averages for TDY Transmitter With Standard Deviation of Data	18
TABLE 11. Tabulated Averages for "Rug" Transmitter with Standard Deviations of Data	19
TABLE 12. Tabulated Average for SPT-6 Transmitter	20
TABLE 13. Tabulated Averages for All Tests in Laboratory With All Transmitters	20
PLATE 1. Block Diagram of Simulated Radar System	
PLATE 2. Jamming Spectra of TDY at 200 Mc	
PLATE 3. Performance Comparison of Several Intercept-Receiver and Indicator Combinations for Setting on Frequency	
PLATE 4. Jamming-Effectiveness Spectrum of "Rug" (AN/APQ-2) at 200 Mc	

DECLASSIFIED



DECLASSIFIED

INTRODUCTION.

1. Considerable work has been done at this laboratory to develop methods and techniques for determining the effectiveness of a radar-jamming transmitter. Using these techniques it is now possible to make quantitative measurements, and to determine "minimum jamming ranges" for various ship types. However, it became apparent after a few jamming transmitters had been subjected to these tests that the results could not be evaluated properly without taking into account the accuracy with which the jammer can be set "on frequency".

Objects of the Study.

1-1. The first object of the present study, therefore, was to determine quantitatively how much loss in "jamming effectiveness" may result in typical operational cases due to error in setting exactly on frequency. This determination was desired in order to establish the importance (or lack of it) of the setting-on-frequency problem. The second object was to compare the relative efficacies of various auxiliary equipments and methods used in tuning jammers to an enemy radar frequency. This comparison was intended (a) to establish a basis for determining the method of setting on frequency to be employed in future studies at this laboratory of jamming-transmitter performance, and (b) to provide information applicable to operational use of radar-jamming transmitters.

Experimental Procedure

1-2. With these objects in view, two sets of experiments were conducted. One of these was an operational test at the NRL Chesapeake Bay Annex with the jamming transmitters mounted on a tower 18,000 yards from the station. Enough trials were made of setting on frequency with a particular jammer operating against one radar to give an idea of the statistical spread of jamming effectiveness. The other test was conducted in the laboratory with a simulated radar system to determine the most effective method available for setting on frequency. It was resolved into the twofold problem of the APR-1 receiver vs. the APR-4 receiver, and APA-6 (pulse analyzer) vs. RDK-1 (panoramic adaptor).

1-2-1. Both the APA-6 and the RDK-1 can be used with either the APR-1 or the APR-4; however, when the optional 0.25-Mc i-f bandwidth is used in the APR-4, the RDK-1 has very poor response. The APR-1 receiver nominally has 2-Mc bandwidth (points 6 db from peak); a measurement indicated nearly a 2-Mc bandwidth for the two APR-1's available, but only 1-Mc bandwidth if points "3 db down" are used for measurement. This latter definition of bandwidth will be used in the present report, so the APR-1 bandwidth will be considered as 1 Mc. The APR-4 has very nearly its specified bandwidth of 0.25 Mc with the bandwidth switch on the "narrow" position.

1-2-2. The decision between the APR-1 and the APR-4 is thus one between wide- and narrow-band receivers for setting on frequency. (The report listed as reference (a) described a method for reducing the APR-1 bandwidth to 0.25 Mc on the assumption that this was preferable to 2 Mc.)

DECLASSIFIED

Use of the RDK-1 panoramic adaptor provided an effective receiver bandwidth of 50 kc. The choice between RDK-1 and APA-6 was a choice between using a relatively accurate method of adjusting the frequency of maximum jammer power output to the radar frequency, or using a type "A" presentation to view the jammer modulation as it would be seen on the victim radar. In view of the many variable factors involved, one could expect no general, simple answer to the proposed problem. The most effective means of setting on frequency might be expected to vary with the radar-receiver bandwidth, the particular jammer used, and the loading of the jammer by the antenna at the particular frequency of operation (this includes the effect of the electrical length of the line coupling the transmitter to the antenna).

Authorization and References

1-3. The work on this problem was conducted under the authorization of NRL Problem S411.1R-S which calls for determination of the jamming effectiveness of various transmitters. Pertinent references are listed below:

- (a) Radio Research Laboratory Report 411-148, dated 10 January 1945, "Conversion of AN/APR-1 for Reduced Bandwidth and Sensitivity".
- (b) NRL Secret Report R-2423, dated 16 December 1944: "Performance Tests and Modifications of the Model TDY Radar Jamming Transmitter".
- (c) NRL Secret Report R-2498, now in preparation: "Dependence of the Effectiveness of Clipped Noise Jamming on Receiver Bandwidth".
- (d) S.O. Rice: "The Mathematical Analysis of Random Noise," B.S.T.J., July 1944 and January 1945.

OPERATIONAL TESTS FROM TILGHMAN ISLAND.

2. In October 1944, a series of operational tests was conducted at the NRL Chesapeake Bay Annex for the purpose of determining the consistency with which a jamming transmitter could be set on frequency. The transmitters were mounted on a 100-foot tower on Tilghman Island at a range of 18,000 yards from the radars at the station. The transmitters AN/APQ-2 ("Rug") and AN/APT-2 ("Dina") with the AM-18/APT ("Dina" Amplifier) were operated against the SC-2 radar (200 Mc). The XBH and AN/APT-3 ("Mandrel") jamming transmitters, were operated against the captured Japanese 100-Mc air-search radar (Mark 1, Model 1, Modification 1).

2-1. Jamming effectiveness was read by means of a pulsed signal generator at the radar (method described in report of reference (b)). The signal-generator pulse was attenuated until it was just lost in the jamming signal. According to the usual procedure at this laboratory the

strength of this signal relative to the strength of a standard-target echo, expressed in decibels, was taken as a measure of the jamming effectiveness, for the tests at 200 Mc. However, as the standard target was not visible with the Japanese radar, the effectiveness readings in this case were expressed in decibels with respect to an arbitrary level. (Since the dial on which the decibel readings were taken reads negative values, it should be noted that the smaller the numerical value of an effectiveness reading, the greater will be the strength of an echo which can be jammed.)

2-2. It was proposed to repeat each test a sufficient number of times to demonstrate the expected deviations from an "on frequency" adjustment of the jammers. Due to shortage of time, less data was obtained than was desired; however, that which was obtained -- recorded in Table 1 -- shows a surprisingly large spread of jamming-effectiveness levels.

2-3. The quantity σ' used here is not the conventional "standard deviation" of statistics, but is defined as

$$[\sigma']^2 = \sum_{n=1}^N \frac{(X_{\max} - X_n)^2}{N}$$

where the X_n 's are the individual effectiveness readings of the set and X_{\max} is the highest of the readings. The justification for this definition is that jammer settings which are either too high or too low in frequency will give only effectiveness readings which are below optimum. The set of data thus tends to "fold back over itself" at the optimum value, presumably clustering about the level X_{\max} rather than about the average, X . The value of σ' for all the data considered together is

$$\sigma'_{\text{total}} = 8.9 \text{ decibels}$$

where

$$[\sigma']^2 = \sum_{i=1}^M \frac{[\sigma'_i]^2}{M}$$

with the (σ'_i) 's as the (σ') 's of the individual tests.

2-4. The jamming transmitters were set on frequency in these tests by means of the APR-1 receiver, both with earphones and with the RDK-1 panoramic adaptor. The signal to the APR-1 was picked up by an intercept antenna near the transmitter antenna. The range in values of jamming effectiveness is probably larger than would be expected under ideal conditions. Some reasons for this are that the RDK-1 was found to be so poorly aligned during these tests that it was nearly useless, that many

DECLASSIFIED

of the operators were not well experienced either in the use of the jammers or with procedure of setting on frequency, and that the jamming equipment was operated unprotected on a 100-foot tower in cold weather.

2-5. The importance of these results - the "expected" 8-db loss - lies in the indication of the amount of jamming power which may be lost unless exceeding care is taken by well-trained operators. A ratio of 10/1 lost in jamming-effectiveness (power ratio - i.e., 10 db) is very difficult to make up in increased jammer power output. It was because of the somewhat disturbing results observed in these operational tests -- the wide variation in jamming effectiveness in successive trials under similar conditions -- that the laboratory study described in the following paragraphs was made.

LABORATORY TEST OF SETTING-ON-FREQUENCY METHODS

3. To conduct these tests a simulated radar system was set up in a shielded laboratory room as shown in Plate 1. A pulsed signal generator was fed through a decoupling network into a receiver whose output could be viewed on a servo-scope. A variable delay control on the signal generator made it possible to set its pulse any place on the sweep of the scope. Also coupled to the receiver was a line leading to an adjacent shielded room which contained the jammer and search receiver for setting on frequency. The line from the "simulated radar" receiver was coupled to the jammer output through an attenuator and was also connected to the search receiver (while jamming effectiveness readings were being taken, the search receiver was disconnected because of extraneous radiations which were picked up and fed back to the "radar" receiver).

3-1. After the search receiver had been tuned to the signal-generator frequency, the jamming transmitter was set on frequency by means of the RDK-1 or the APA-6. There was little uncertainty in adjusting the jammer with the RDK-1, because the peak of the jamming-signal spectrum could be set exactly on the signal-generator frequency with very little difficulty. However, when the APA-6 was used, considerable judgment and skill were required to determine the frequency setting which gave the "best appearing" noise -- i.e., that which resulted in maximum jamming effectiveness.

3-2. When the jamming transmitter was set to frequency, the "effectiveness" was read by turning down the attenuator on the signal generator until its "echo" was just lost in the jamming signal. The decibel reading on the signal-generator attenuator at the setting for which the echo was just lost was taken as the measure of jamming effectiveness. This procedure is described more fully in the report listed as reference (b).

Service Equipments Used in Tests

3-3. The transmitters tested against receivers of various bandwidths were the TDY, the "Rug" (APQ-2), the "Dina" (APT-1), and the SPT-6.

DECLASSIFIED

The data were taken by two observers. When their respective results are the same, the data is presented lumped together; when their results vary, these are presented separately. The tests included comparison of jamming effectiveness when the setting-on-frequency adjustment was made using the APR-1 with the APA-6, the APR-1 with the RDK-1, and the APR-4 with the APA-6.

Tests with TDY

3-4. The TDY (with the 5J30 tube) was operated against the Model SA radar receiver (200 Mc) using the APR-4 with the APA-6, the APR-1 with the APA-6, and the APR-1 with the RDK-1. During the first four trials testing the APR-1 with the APA-6, the operators had not learned how to use the APA-6 properly, so these readings are not as good as would otherwise have been expected. Enough readings were taken to indicate the statistical spread of the settings. σ is here the usual "standard deviation".

$$\sigma^2 = \frac{N}{\sum_{i=1}^N} \frac{(X_i - \bar{X})^2}{N}$$

where N is the number of readings, the X_i are the individual readings, and \bar{X} is the average of all X_i . The data are presented in Table 5.

3-4-1. A "jamming-effectiveness spectrum" of the TDY vs. the SA receiver was plotted by tuning the SA receiver to various frequencies about the center of the spectrum and taking effectiveness readings. At each setting of the SA receiver, the signal generator was retuned to the new receiver center frequency. This curve is shown in Plate 2, Figure 2, with the original center frequency (peak of the power spectrum) indicated by the abscissa zero. A comparison of the power spectrum as seen on the RDK-1 and the "jamming-effectiveness spectrum" was made by tuning the transmitter by incremental steps and taking jamming-effectiveness readings at each setting. The power spectrum is a free-hand drawing of the spectrum as it appeared on the RDK-1. These two spectra are represented superimposed in Plate 2, Figure 1.

3-4-2. The TDY (with the 5J30 tube) was operated against a special, variable-bandwidth receiver made at the Laboratory. The results are presented in Table 3 for a receiver bandwidth setting of 0.25 Mc. In Table 4 are the effectiveness comparisons for a bandwidth setting of 1.54 Mc. The frequency was about 210 Mc for these tests.

3-4-3. With a 5J29 tube in the TDY, a test was made against the Mark 5 (400-Mc experimental) radar receiver. The data of the two operators is presented in Table 5. The difference between the readings of the two operators was probably due to a difference in judgment as to what was the best setting on the APA-6. It is interesting to note that, whereas the effectiveness readings are nearly the same for the different methods

of setting on frequency, that the frequency settings were one-quarter to one-half megacycle different when the jammer was set to frequency by the APR-1/APA-6 than when the APR-1/RDK-1 combination was used.

Tests With AN/APQ-2 ("Rug")

3-5. Employing the three proposed methods of setting a jammer to frequency, the "Rug" (APQ-2) was operated against the SA receiver and against the variable-bandwidth laboratory receiver set at 0.25-Mc bandwidth. This data is presented in Tables 6 and 7, respectively. A considerable number of readings were taken, and the standard deviations have been calculated (see Table 11) to indicate the rather remarkable consistency of the readings.

3-5-1. To demonstrate the effect of radar-receiver bandwidth, curves were plotted giving jamming effectiveness vs. receiver bandwidth. The jamming effectiveness is plotted in decibels relative to the readings taken when the jammer was set on frequency by means of the APR-1 and APA-6. This gives a direct comparison of the various means of setting on frequency. Each point is the average of three readings. More readings were not considered necessary because of the consistency of the data taken. This curve is given in Plate 3. It is apparent that the APR-1/APA-6 combination is, on the whole, better than the other combinations.

3-5-2. A jamming effectiveness spectrum was plotted using the laboratory receiver set at 1-Mc bandwidth (Plate 4). The peak of the power spectrum fell at abscissa zero on the graph, or at the minimum on the curve. The gain of 16 db by tuning the transmitter to one side of the radar frequency shows the undependability of the RDK-1 under some conditions.

3-5-3. The particular "Rug" used in these experiments had loading coils in both the plate and grid lines to reduce its frequency as it was operating within 10-15 Mc of the lower limit of its tuning range. The frequency was about 200 Mc during all of the tests involving the "Rug".

Tests with AN/APT-1 ("Dina")

3-6. The "Dina" (APT-1) transmitter was operated against the laboratory receiver set at a 1-Mc bandwidth. The effectiveness of setting on by means of both the APA-6 and the RDK-1, with the APR-1, was compared. No significant difference was noted. This was probably to be expected, as the "Dina" has no "carrier" and its modulation is about the same at different parts of its spectrum.

Tests with AN/SPT-6.

3-7. The SPT-6 was operated against the Mark 5 receiver (bandwidth 1.7 Mc) and against an APR-1 receiver (bandwidth 1 Mc). There was very little difference in the jamming levels for the various methods of setting on frequency. The data are shown in Table 8.

DECLASSIFIED

SIGNIFICANCE OF THE DATA

4. At the outset it was stated that one could not be assured of finding one method of setting on frequency which would under all conditions be superior to the others. This indeed appears to be the case, for the results do not seem to be entirely consistent. In addition to the variable factors mentioned at the beginning, the training of the operator appears to be important as well as the amount of care exercised in setting on frequency. It is felt, however, that several conclusions can be drawn which will be of importance in developing spot-jamming techniques.

4-1. The much greater consistency with which the transmitter could be set to frequency in the laboratory than during the operational tests described in paragraph 2 indicates the advantage of using a panoramic adaptor and/or pulse analyzer in good operating condition--this is exceedingly important, for a large proportion of RDK-1's are so poorly aligned as to be nearly valueless. (It is hoped that panoramic adaptors recently made available--Model RDP--will prove more satisfactory.) The value of σ for 156 of the readings taken in the laboratory was only 1.5 db (see Table 12), which indicates good consistency in setting on frequency. Such dependability should be important from an operational standpoint.

4-2. The overall comparison of the methods considered for setting on frequency can best be obtained from the tabulated averages. In Tables 9, 10 and 11 these are given with corresponding values of σ for the TDY, Rug, and SPT-6 respectively. These are computed for the tests against individual receivers and are totalled to give the average for each jamming transmitter. In Table 12 are the average for all tests of each means of setting on frequency.

4-2-1. An examination on Tables 9 and 10 indicates that the APR-4/ APA-6, with the APR-4 set for "narrow band" operation is probably somewhat preferable when the jamming transmitter is operated against a narrow-band radar receiver, whereas the APR-1/ APA-6 is probably better for operating against a wide-band receiver. These relative advantages are not of a very large order of magnitude. The overall average shows an advantage of 1.7 db in favor of the APR-1, however.

4-2-2. A more definite answer is given in the comparison between the APA-6 and the RDK-1. In almost no cases was the jamming more effective when adjusted by means of the RDK-1 than when adjusted by means of the APA-6; however, for certain conditions the results obtained using the RDK-1 were equal to those with the APA-6. But under some conditions definitely better results were obtained with the APA-6 than with the RDK-1. An examination of the individual readings in Tables 2 to 8, inclusive, shows the difficulty of predicting under what conditions the APA-6 will be appreciably more effective. Such things as small changes in transmitter loading, which distort the output spectrum, are likely to make changes in the jamming effectiveness of the signal. However, the 5.7-db advantage in favor of the APA-6 over the RDK-1 shown in

DECLASSIFIED

Table 12 for the 91 and 84 readings considered indicates a significant advantage in the use of the APA-6.

4-2-3. The standard deviation is greatest with the use of the APR-1/ APA-6 combination. This is probably due to the facts (a) that the peak of the power spectrum can be set very consistently to the radar frequency with the RDK-1 and (b) that because of the narrower bandwidth of the APR-4, the transmitter frequency will be more consistently set to the same value with the APR-4/APA-6 than with the APR-1/APA-6. In view of these facts, the greater effectiveness of the APR-1 with the APA-6 seems a bit surprising until we analyze the nature of the jamming signal in terms of its ability to obscure an echo. It appears that there is very little correlation between the jamming-effectiveness spectrum and the power spectrum of a jamming transmitter. The use of the panoramic adaptor results in setting the maximum-power portion of the jamming signal on the radar frequency, whereas it is possible with the pulse analyzer to set the maximum-jamming-effectiveness portion of the spectrum "on" the radar frequency. (See Plate 2.)

4-3. The reason for the lack of correlation between the power and jamming-effectiveness spectra seems to be due to the nature of the noise output of the jamming transmitters in use. To obtain high sideband energy in the transmitter output the modulation is not true noise, but is clipped to form randomly occurring pulses of random widths. Clipping, however, greatly reduces the effectiveness of the noise for obscuring an echo. The term "screening ratio" is used to indicate the ratio of r-f power in the jamming signal to peak power in an echo that is considered to be just obscured by the jamming signal. Measurements of the screening ratio indicates that the receivers of bandwidth comparable to the bandwidth of the jamming signal, values as high as 100/1 will be had for extremely clipped noise, whereas the value is about 1/1 for unclipped noise if the power of the cw carrier is subtracted from the total jammer power output. If, however, the bandwidth of the receiver being jammed is much narrower than the bandwidth of the jamming signal, the statistical distribution of the clipped noise after passage through the receiver i.f., approaches that of unclipped noise, (i.e., a normal distribution -- see reference (d)). In this case the screening ratio is again unity, if only the jamming signal power in the radar receiver channel is considered. (A report on an investigation of the screening ratio as a function of clipping level and radar receiver bandwidth is in the process of preparation at this Laboratory - reference (c)).

4-3-1. In many cases for the tests under consideration, when the radar receiver was tuned to the center frequency of the jamming signal, the noise appeared on the scope to be very dense, having a definite line of clipping on both the top and bottom. A weak echo could be seen "riding on top" of the noise. However, when the receiver was tuned to one side of the center frequency (as seen on the panoramic adaptor) the noise appeared much less dense, having gaps in it and being considerably less definitely clipped. The echo was thus lost "down within the noise"

instead of remaining visible above the clipping level. Plate 2 shows jamming-effectiveness spectra plotted about the center frequency indicated by the RDK-1, and also a comparison of: (a) an effectiveness spectrum and (b) voltage spectrum as seen on the RDK-1.

4-3-2. On the basis of the above argument, one would expect the jamming effectiveness to be best when the jamming transmitter is set on frequency with a receiver whose bandwidth is the same as that of the radar receiver being jammed (if the APA-6 is used). This assumes, of course, that the receiver being used to set the jammer on frequency can be accurately tuned to the radar frequency itself. The results of the tests indicate that this is the case, but that the proper receiver bandwidth is not so important as is the advantage of the APA-6 (or any other equipment giving a similar presentation) over the RDK-1.

ADVANTAGE OF "LOOK-THROUGH" RECEIVERS

5. An attempt was made to evaluate the advantage of being able to "look through" the jamming signal so as to be able to observe both the jamming and the echo simultaneously on the APA-6 and RDK-1. No increase in jamming effectiveness was observed, but "setting on" with the RDK-1 was somewhat simpler when the radar signal appeared simultaneously with the jamming. It is believed that there would have been considerable advantage in being able to see the radar pip and the jamming simultaneously on the APA-6 if it had not been for the fact that the input to the receiver from extraneous radiation (when the jamming signal into the APR-1 was reduced enough that the signal generator echo could be seen) was so great that it was impossible to learn anything by tuning the receiver through the jamming and signal-generator signals, because the motion of the hand in tuning changed the signal strength by such a large amount. With better shielding of the receiver the advantage of being able to look through the jamming signal would probably be demonstrable. Further work on this subject is being done in connection with another project at this laboratory.

CONCLUSIONS

6. Neither the APR-1 nor the APR-4 can, in general, be considered better than the other as a receiver for setting a jammer on frequency. If most of the radar receivers against which it is planned to operate have less than 0.5- to 0.75-Mc bandwidth, the APR-4 will probably be most satisfactory. It is a far more important consideration that the APA-6 (or similar equipment) be used instead of the RDK-1 or other panoramic adaptor for final adjustments. However, the adjustment to frequency can be done with considerably more ease and in much less time with the RDK-1 (or equivalent) which suggests the advantage of making a preliminary setting with the RDK-1 and then making improvements in the setting as indicated by the APA-6 presentation.

6-1. In general, the RDK, RDK-1, and RDP panoramic adaptors have widely varying gain for different frequencies within their sweep widths.

As this means that the spectrum received will probably be badly distorted, care must be taken to use only the portion of the sweep at which the gain varies least with signal frequency. Thus the panoramic adaptor is used for setting on frequency, the radar signal should be set so that it appears in this "best" portion of the sweep, and then the transmitter should be adjusted until its spectrum appears at the same place on the panoramic adaptor.

6-2. The operational tests indicated that trained operators and some method of viewing the jamming signal on a scope are necessary for dependable performance. Lacking these, the jamming effectiveness can be expected to be as much as 20 db below optimum on some occasions (as observed during the operational tests. See Table 1).

RECOMMENDATIONS.

7. The recommended procedure for setting a radar "spot jammer" on frequency is to employ both panoramic adaptor and a pulse analyzer with the radar-intercept receiver. The transmitter should first be set to frequency using the panoramic adaptor, as this results in easiest and quickest adjustment. Then, if any further adjustment gives better appearing "grass" on the scope of the pulse analyzer, this latter setting should be used. Experience will indicate what is the best appearing "grass". This is decidedly not the "most dense" noise, but rather the signal which has the greatest amplitude and which seems to be least clipped. It is suggested that the RCM training courses teach operators to recognize the most effective types of noise signals.

TABLE 1

JAMMING EFFECTIVENESS LEVELS MEASURED DURING AN OPERATIONAL TEST

Jamming Effectiveness Level in Db
With Respect to an Arbitrary Zero Level

Radar System Jammed:	200 Mc		100 Mc	
	SC-2 Radar		Japanese Radar	
Jamming Transmitter Employed:	"Rug"	"Dina"	XBH	Mandrel
Individual Readings:	-35	-24	-43	-59
	-34.5	-41	-39	-60.5
	-32	-43	-52	-52
	-31	-23	-52	-51
	-36	-23	-40	-41
	-34		-44	-44
	-32		-50	-47
			-44	
			-46	
			-46	
		-47		
		-46		
Value of σ' expressed in db:	3	12.1	7.5	9.7

Overall value of $\sigma' = 8.0$ db

DECLASSIFIED

TABLE 2

TDY Transmitter Operated Against SA Receiver
(.9 Mc bandwidth) at 190 Mc

Equipment used to set on frequency:	APR-1/APA-6	APR-1/RDK-1	APR-4/APA-6
Individual Effective- ness readings expressed in db relative to an arbitrary level:	-21	-22	-22
	-20	-21	-24
	-22	-20	-23
	-20	-22	-21
	-18	-23	-24
	-16	-21	-23
	-15	-20	-22
	*16	-22	-20
	-18		-19
Average levels for each column:	-18.4	-21.4	-22

DECLASSIFIED

TABLE 3

EDY Operated Against Laboratory Receiver Set
at $\frac{1}{4}$ Mc Bandwidth - 200 Mc

Equipment used to set on frequency:	APR-1/APA-6	APR-1/RDK-1	APR-4/APA-6	
Individual effectiveness readings expressed in db	-25	-24	-24	Test #1
	-23	-23	-22	
	-22	-21	-22	
	-42	-41	-37	Test #2
	-37	-42	-36	
	-37	-36	-38	
	-25	-28	-22	Test #3
	-21	-30	-22	
	-30	-28	-22	
	-22			
	-38	-33	-35	Test #4
	-41	-34	-36	
	-43	-35	-36	
Average Levels:	-31.2	-31.3	-29.4	

Readings of the various tests above are with respect to different zero levels, so cannot be directly compared.

TABLE 4

TDY Operated Against Laboratory Receiver Set
at 1.54 Mc Bandwidth - 200 Mc

Equipment used to set on frequency:	APR-1/APA-6	APR-1/RDK-1	APR-4/APA-6
Individual effective- ness readings expressed in db with respect to an arbitrary level.	-30	-30	-32
	-28	-31	-33
	-26	-31	-29
	-26		
	-28		
Average levels:	-27.6	-30.3	-31.3

TABLE 5

TDY Operated Against Mark 5 Receiver (1.7 Mc Bandwidth) 400 Mc

Equipment used to set on frequency:	APR-1/APA-6	APR-1/RDK-1	APR-4/APA-6
	-22	-24	-26 Operator #1
	-22	-25	-27
	-21	-25	-26
	-26	-24	-24 Operator #2
	-26	-23	-25
	-23	-25	-24
Average for Operator #1	-21.7	-24.7	-26.3
Average for Operator #2	-25.0	-24.0	-24.7

DECLASSIFIED

TABLE 6

"Rug" Operated Against SA Receiver
(.9 Mc Bandwidth) at 190 Mc

Equipment Used to set on frequency:	APR-1/APA-6	APR-1/RDK-1	APR-4/APA-6
Individual Effective- ness levels expressed in db with respect to an arbitrary zero level :	-27	-31	-26
	-24	-33	-23
	-26	-29	-24
	-26	-33	-24
	-26	-32	-26
	-26	-31	-23
	-23	-34	-26
	-26	-36	-26
	-27	-32	-24
Average level :	-25.7	-32.3	-24.7

DECLASSIFIED

TABLE 7

"Rug" Operated Against Laboratory Receiver Set
at $\frac{1}{4}$ Mc Bandwidth - 200 Mc

Equipment Used to set on frequency:	APR-1/APA-6	APR-1/RDK-1	APR-4/APA-6
Individual effectiveness levels expressed in db with respect to an arbitrary zero level:	-32	-40	-28
	-30	-39	-31
	-34	-40	-28
	-34	-39	-31
	-34	-40	-32
	-35	-40	-31
	-35	-36	-33
	-33	-37	-32
	-32	-35	-31
Average levels:	-33.2	-38.4	-30.8

DECLASSIFIED

TABLE 8

SPT-6 Operated Against Mk 5 Receiver
(1.7 Mc Bandwidth) at 400 Mc

Equipment used to set on frequency:	APR-1/APA-6	APR-1/RDK-1
Individual effectiveness readings expressed in db:	-19	-17
	-15	-19
	-16	-17
	-15	
Average levels:	-16.2	-17.7

TABLE 9

SPT-6 Operated Against an APR-1 Receiver at 400 Mc

Equipment Used to set on frequency:	APR-1/APA-6	APR-1/RDK-1	APR-4/APA-6
Individual effectiveness readings expressed in db:	-18	-19	-15
	-16	-18	-18
	-19	-18	-19
	-18		
Average levels:	-17.1	-18.0	-17.3

DECLASSIFIED

TABLE 10

Tabulated Averages for TDY Transmitter With Standard Deviation of Data

Receiver Jammed	Rec. Band- width (Mc)	APR-1/APA-6			APR-1/RDK-1			APR-4/APA-6		
		Ave. db	No. of trials	σ	Ave. db	No. of trials	σ	Ave. db	No. of trials	σ
SA	.9	-18.4	9	2.32	-21.4	8	.99	-22	9	1.63
Mk 5 Operation #1	1.7	-21.7	3	.47	-24.7	3	.47	-26.3	3	.47
Mk 5 Operation #2	1.7	-25.0	3	1.41	-24.0	3	.82	-24.7	3	.62
Laboratory Receiver	.25	-31.2	13	2.53	-31.3	12	1.41	-29.4	12	.66
Laboratory Receiver	1.54	-27.6	5	1.48	-30.3	3	.60	-31.3	3	1.70
Total:		-25.7	33	2.12	-27.0	29	1.10	-26.6	29	1.14

DECLASSIFIED

TABLE 11

Tabulated Averages for "Rug" Transmitter With Standard Deviations of Data

Receiver Jammed	Rec. Bandwidth (Mc)	APR-1/APA-6			APR-1/RDK-1			APR-4/APA-6		
		Ave. db level	No. of Trials	σ	Ave. db level	No. of Trials	σ	Ave. db levels	No. of Trials	σ
SA	.9	-25.7	9	1.25	-32.3	9	1.89	-24.7	9	1.25
Laboratory Receiver	.25	-33.2	9	1.57	-38.4	9	1.83	-30.8	9	1.62
Total of tests against Laboratory Receiver from Plate 5	--	-23.6	33		-33.9	31		-27.8	31	
Total Average		-25.6	51		-34.4	49		-27.8	49	

DECLASSIFIED

TABLE 12

Tabulated Average for SPT-6 Transmitter

Receiver	Receiver Bandwidth	APR-1/APA-6	APR-1/RDX-1	APR-4/APA-6
		level	level	level
		trials	trials	trials
Mk 5	1.7	-16.2	-17.7	
		3	3	
		1.65	.94	
APR-1	1.0	-17.8	-18.3	-17.3
		4	3	3
		1.09	.48	1.70
Total Average	--	-17.1	-18.0	-17.3
		7	6	3

TABLE 13

Tabulated Averages for All Tests in Laboratory With All Transmitters

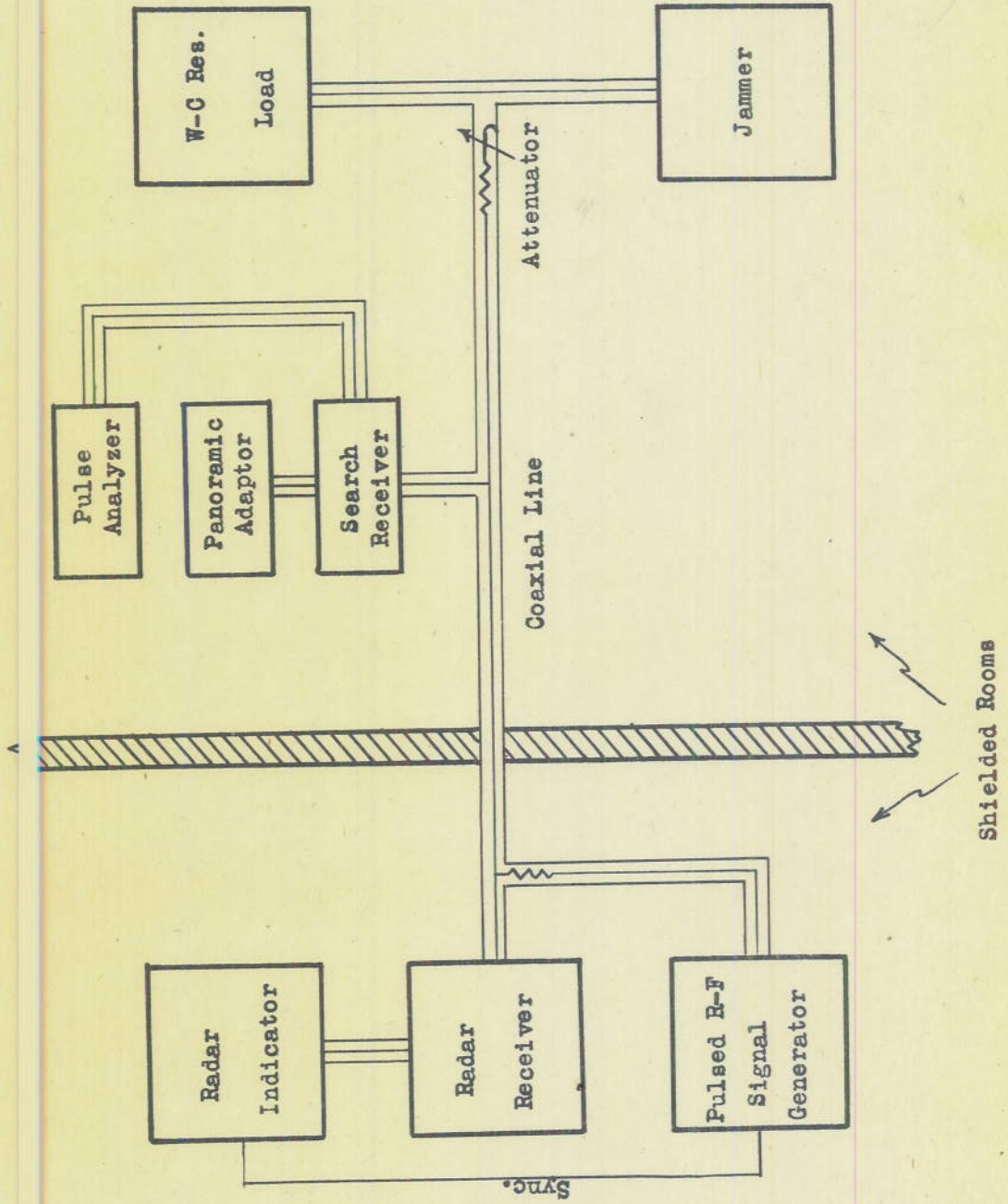
Methods of setting on frequency	Ave. db level	No. of trials in Ave.	σ db	No. of trials used in computing σ
APR-1/APA-6	-25.1	91	1.88	51
APR-1/RDX-1	-30.8	84	1.37	54
APR-4/APA-6	-26.8	81	1.29	51

Overall value of $\sigma = \sigma_t = 1.53$ db.

(All totalled values of σ defined by $\sigma_t^2 = \frac{\sum_{i=1}^M \sigma_i^2}{M}$, where the σ_i 's are the values of σ for individual sets of data, and M is the number of such sets.)

DECLASSIFIED

Simulated Radar System



DECLASSIFIED

DECLASSIFIED

JAMMING SPECTRA OF TDY AT 200 MC

Figure 2

Jamming Effectiveness Spectrum
At 200 Mc of TDY Operated Against
the SA Radar Receiver

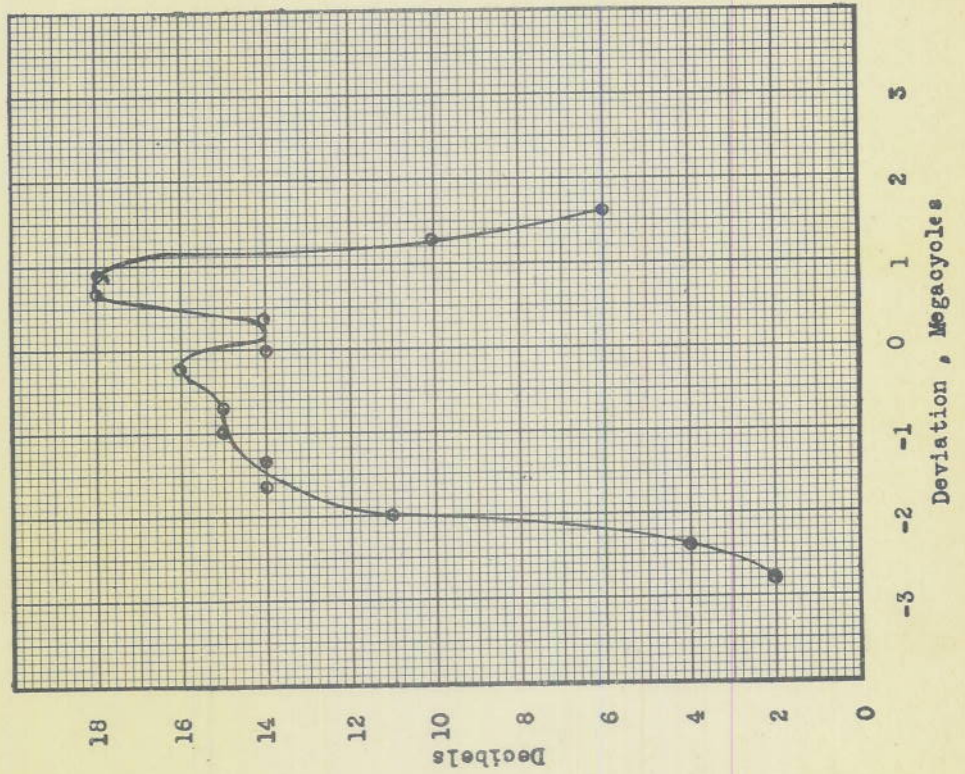
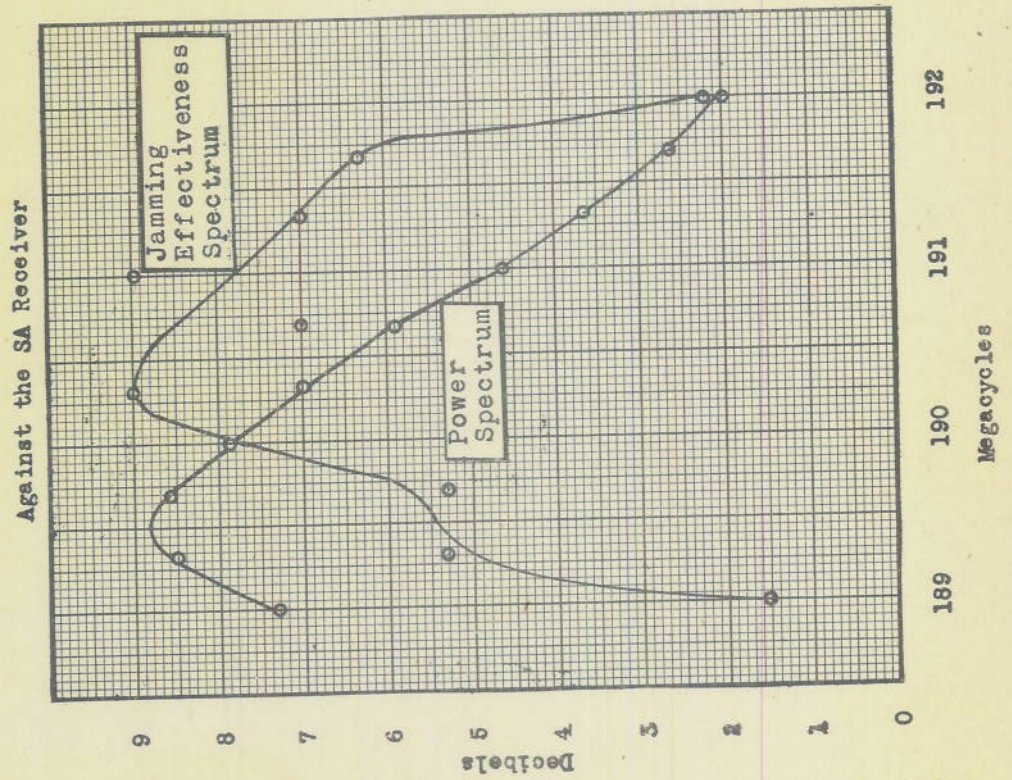


Figure 1

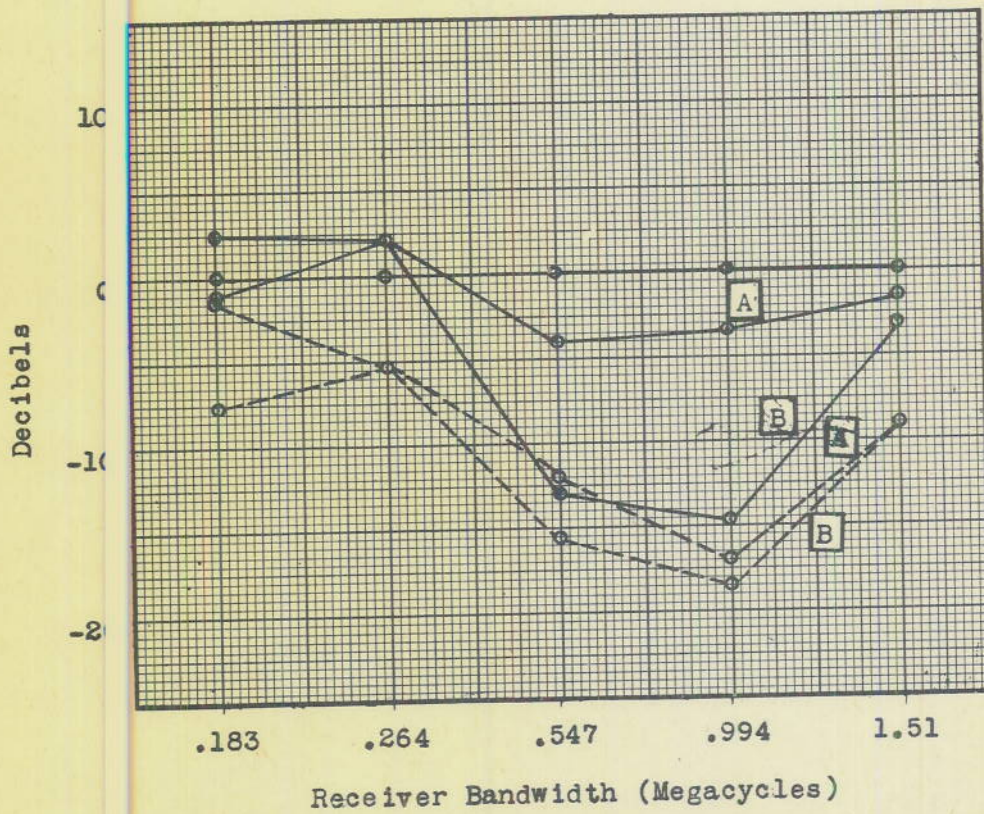
Comparison of Jamming Effectiveness
and Power Spectra of the TDY Operated
Against the SA Receiver



DECLASSIFIED

PERFORMANCE COMPARISON OF SEVERAL INTERCEPT-RECEIVER AND
INDICATOR COMBINATIONS FOR SETTING ON FREQUENCY

Jamming Effectiveness in Db Relative to
APR-1/APA-6 Settings, vs. Radar-Receiver Bandwidth



- Jammer set to frequency by means of APR-4/APA-6
- - - Jammer set to frequency by means of APR-1/RDK-1
- A Operator #1
- B Operator #2

