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REPORT NO. 2260

DATE 30 May 1944

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SUBJECT

Report on additional jamming tests made at

Naval Research Laboratory
Chesapeake Bay Annex

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SEARCH RADAR SECTION

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Problem S411.1R-S.

Radio Division, U.S. Naval Research Laboratory

Navy Department

Report on

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Additional Jamming Tests

Made at the

Naval Research Laboratory

Chesapeake Bay Annex

Naval Research Laboratory

Anacostia Station

Washington, D. C.

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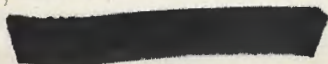
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1. ABSTRACT.

Jamming tests were performed at the Chesapeake Bay Annex of the Naval Research Laboratory on the USS San Jacinto (CVL-30), the USS Quincy (CA-71) and the USS Croatan (CVE-25). A summary of the results obtained is as follows:

Jammer	Ship	Ship Aspect	Radar	Jammer Ant. Gain over Dipole (db)	Jammer Ant. Height (ft)	Minimum Jam. Range (yds.)
Carpet	OVL	Bow	FD	0	80	20,000
	CVE	Bow	FD	8	78	8,400
	CVE	Stern	"Hot Dog"	8	78	6,000
Rug	CVL	Bow	SC-2	0	11	6,100
	CA			No Results		
CXFR	CA			No Results		
	CVE	Bow	"Hot Dog"	0	86	7,000
	CVE	Stern	FD	0	86	7,300

In most cases a monitor receiver was used to set the jammer on frequency. Of those available the AN/APR-1 receiver proved the most satisfactory, but because of several spurious responses, it might be very confusing to an inexperienced operator.

1-1. Conclusions. The results of these tests show the minimum ranges at which the ships involved will be screened by jammers operating under similar conditions. The Carpet, when used with the corner reflector antenna, will effectively screen a CVE from the FD to a range of 8,400 yards. When it is used with a dipole antenna it will screen a CVL from the FD to 20,000 yards. The Rug, when mounted only 11 feet above sea level, will screen a CVL from the SC-2 to a range of 6,100 yards. The CXFR will screen a CVE from the FD to a range of 7,300 yards and from an equipment simulating a German Wurzburg to a range of 7,000 yards. These ranges, however, should not be taken as the optimum ranges for the particular jammer. Only in a very few cases was it possible to repeat a run and in that way check the previous values.

2. INTRODUCTION.

Operational tests of three types of jammers were carried out at the Chesapeake Bay Annex of the Naval Research Laboratory. The jammers were tested for the purpose of determining their effectiveness when used to screen ships. All observations of the jamming were made on the radars located at the annex. These tests were made in conjunction with the propagation tests conducted by the Consultant Section of this laboratory. Previous tests have been reported in reference (e).

2-1. Authorization and References. Authorization for these tests is to be found in Bureau of Ships letter of reference (a) assigning problem S411.1R-S. Additional references pertinent to this problem are listed as references (b) to (e).

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- (a) BuShips ltr S-S67-5(920), S-920-06218 to NRL dated 8 November 1943.
- (b) RRL report number 411-TR13 Division 15 dated 4 February 1944 "Report on Field Tests of L-105 Jamming Signal Generator Against the Mark 8 Fire-Control Radar at Chesapeake Bay Annex January 29-31, 1944".
- (c) NRL ltr S-S67-5/RCM(361) Serial 2785 dated 31 March 1944 "Interim Report on Radar Chick NRL problem Request S-135R-S".
- (d) NRL report number R-2291 "The Modification and Test of the Model CXFR Jamming Transmitter".
- (e) NRL report number R-2234 dated 21 February 1944 "Jamming Tests at Naval Research Laboratory, Chesapeake Bay Annex, 13-14 January 1944".

3. EQUIPMENT USED.

3-1. Carpet. The Carpet or AN/APT-2 is a noise modulated, triode oscillator jammer covering a frequency range from 425 Mc to 710 Mc. The measured power output at 700 mc with $1\frac{1}{2}$ ft. of AN/RG-8U cable is $1\frac{1}{2}$ to 2 watts. At 425 Mc the power output is 7 to $7\frac{1}{2}$ watts. It is designed primarily for use in aircraft.

3-2. Rug. The Rug or AN/APQ-2 was used as a noise modulated, triode oscillator jammer covering a frequency range from 200 Mc to 550 Mc. Its rated power output is between 10 and 20 watts up to 500 Mc. It is designed primarily for use in aircraft.

3-3. L105. The L105 is a klystron jammer which was designed by RRL. It covers the 10 cm. range and is described in the report of reference (b).

3-4. CXFR. The CXFR is a noise modulated jammer employing the ZP579 magnetron. Its frequency is variable from 350 Mc to 750 Mc. The power output is approximately 70 watts, and the bandwidth is about 5 Mc.

3-5. RDA. The RDA is an experimental heterodyne search receiver with a frequency range of 50 Mc. to 700 Mc.

3-6. ARD. The ARD is a search receiver ranging from 80 Mc to 3000 Mc. It consists of a tuned detector followed by a video amplifier.

3-7. CUO. The CUO is an RF converter unit to be used with an ordinary standard broadcast receiver. Three of these converters cover the frequency range 50 Mc to 700 Mc.

3-8. AN/APR-1. The APR-1 is a standard heterodyne search receiver, and by the use of two r.f. heads it covers the range from 80 Mc. to 1000 Mc.

3-9. AN/APA-6. The APA-6 or pulse analyzer is a servoscope to be used with the APR-1. The radar repetition frequency is read on a meter.

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3-10. RDK. The RDK is a panoramic adapter which can be used with a receiver of 30 mc. I.F. During these tests it was used with the APR-1. The frequency sweep is 1.5 Mc on each side of the center frequency.

4. DESCRIPTION OF TESTS.

4-1. Tests on the USS San Jacinto (CVL-30). Radar countermeasures tests were conducted on the USS San Jacinto (CVL-30) 31 January 1944 at the Chesapeake Bay Annex. These tests included two self screening runs made by the ship and a run made with the jammers operating on a YP boat at the same range as the CVL.

4-1-1. Tests of Carpet. Two self screening runs were made by the CVL against the Mark 4 or FD (690 Mc) radar using an APT-2 (Carpet) jammer. These runs were made radially with the station, and the approximate minimum jamming in each case was 20,000 yards.

4-1-1-1. The APT-2 antenna which consisted of a balanced dipole on a 3 x 3 foot aluminum ground plane was mounted on the forward rail of the 24 inch spotlight platform on top of the "Island". The height above sea level was about 80 feet. The antenna was fed by 15 feet of RG-8U cable. The jammer was set on frequency by an RCV receiver. The 800 cycle power for the carpet was supplied by a converter operating from two 15 amp. 26 volt copper oxide rectifiers. The carpet was located on the searchlight platform and was exposed to the weather.

4-1-1-2. The 800 cycle power supply was one of the chief causes of trouble throughout the test. As the voltage of this rather unstable power supply changed the frequency of the APT-2 also changed. Therefore, it became necessary to check the frequency of the Carpet frequently with the RCV. After the range to the station was less than 14,000 yards, the FD signal could not be received on the RCV due to the "break through" interference from the SC-2 radar. This interference was noted throughout the entire tuning range of the RCV and it increased as the range to the station decreased. However, as the interference became excessive after the minimum jamming range had been determined, it did not affect the results of the test.

4-1-1-3. The power output of the APT-2 at the time of the test is not known although it had been measured on 22 January 1944. At that time the output at 700 Mc and with $1\frac{1}{2}$ feet of antenna cable was $1\frac{1}{2}$ to 2 watts. The additional length of antenna cable used in the test would cause a power loss of 1 db.; therefore, the power output at the time of the test can be estimated to be between 1.3 and 1.6 watts. The bandwidth of the carpet at this frequency is approximately 1 Mc. The height of the FD antenna is 132 feet above sea level.

4-1-1-4. The jamming fluctuated considerably throughout the test but this variation was undoubtedly due to the unstable power supply. Had the frequency been more constant the minimum range might have been reduced somewhat.

4-1-2. Tests of L105. The screening of the CVL from the Mark 8 fire control S band radar was performed by the Radio Research Laboratory L105 klystron jammer operating on the YP-564 (a 75 ft. converted yacht). The

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results of these tests have been fully discussed in the report of reference (b).

4-1-3. Tests of Rug. The screening of the CVL from the SC-2 (200 Mc) search radar was performed with the Rug or APQ-2 operating on the YP-564.

4-1-3-1. The Rug power supply had been constructed specially to work on 110 volts 60 cycles A.C. This was supplied by the ship's power. In spite of the fact that this voltage varied from 90 to 105 volts due to the overload on the system, very good jamming was accomplished most of the time. The regular Rug antenna consisting of a balanced semi-broadband dipole backed by a small ground plane was mounted 11 feet above sea level. This antenna was fed by 25 feet of PT-5 cable. The power output was estimated to be 20 watts and the bandwidth 1 Mc. The SC-2 horizontally polarized antenna at the station was 105 feet above sea level. The ARD and CUO converters were to be used as monitoring receivers. These proved impracticable, however, as the noise level on the YP-564 was much too high. The jammers were set on frequency by means of an absorption wavemeter.

4-1-3-2. During the first run the YP-564 was stationed 2800 yards from the station and the CVL made a radial run toward the station on the same bearing as the YP-564. The jamming came on when the carrier was at 23,000 yards. Previously the carrier echo had been observed as having a signal to noise ratio of four to one. The jamming made it impossible to see the echo at any time. The SC-2 receiver used was one of recent design and employed some anti-jamming features which were used in an attempt to decrease the effect of the jamming. The noise modulated jamming was decreased only slightly by these a-j circuits, however, and it was still very effective. The noise output of the rug appeared to be modulated with 60 cycles as a beating was noticed on the radar screen due to the difference in frequency of the a-c supply on board ship and that on the shore. When the CVL was at 12,000 yards the modulation went off for a short time due to a loose connection in the modulator. At this range the carrier was visible occasionally through the C.W. jamming. The run continued until the CVL was 5,200 yards from the station. At that time the jamming was still complete. Due to the shallow water, however, the carrier was forced to change its bearing with respect to the station if it were to come closer. With the radar trained on the maximum jamming signal the CVL changed its bearing 16° and was not observed at any time although it was continuously approaching the station. When the SC-2 antenna was trained on the CVL, which was 16° off the bearing of the YP-564 and at a range of 4500 yards, the CVL echo was clearly observed through the decreased jamming. It became apparent that a cross-over point could not be obtained with the YP-564 stationed so close to the radar station.

4-1-3-3. Due to the failure of the first run to obtain the desired information a second run was made. The CVL and YP-564 were located 9700 yards from the station and the jammer was turned on. Complete screening was observed. The run continued with both ships closing range together. At a range of 6100 yards the CVL echo was barely visible. This represented the minimum jamming range for a self-screened CVL with the jammer height at 11 feet above sea level.

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4-1-3-4. An attempt was made to jam the SK (200 Mc) search radar but this failed as this particular equipment was adjusted at too low a frequency for the Rug tuning range. Jamming was observed, but it was not satisfactory.

4-1-3-5. During the jamming of the SC-2 some attempts were made to determine how accurately the bearing of the jamming signal could be determined. By observing the two bearings at which the signal fades but as the antenna is rotated, the bearing can be determined as accurately as that of an ordinary target. The maximum signal method has practically the same accuracy and can be used as a check.

4-1-3-6. As noted in paragraph 4-1-3-1, the rug antenna was 11 feet above sea level. Had this antenna been mounted on the CVL at a greater height, the jamming signal would have been increased as the square of the ratio of the new height over the old.

4-1-4. Window Tests. Window was dropped at 1500 ft. altitude over the CVL to determine the number of dipoles required to simulate the CVL. The trials were made at three frequencies: 200 Mc, 700 Mc and 3000 Mc, using the SK, FD and SG radars respectively. The Window used was Naval Window types CAFJ - 10271 (282) for SK, CAFJ - 10270 (081) for FD, and CAFJ - 10270 (017) for SG. A unit of Window is that number of dipoles that will give an echo comparable in magnitude to the echo from a medium bomber. One unit at 200 Mc contains 50 dipoles $28\frac{1}{2}$ " long. One unit at 700 Mc contains 3200 dipoles $8\frac{1}{4}$ " long. One unit at 3000 Mc contains 32,000 dipoles. Quantities used in the trials were 1, 2, and 4 units at 200 Mc and at 700 Mc, and $\frac{1}{2}$, 1, and 2 units were used at 3,000 Mc.

The CVL was stationed at about 10,000 yards, broadside to the radar installations. At 200 Mc 4 units, or 200 dipoles simulates the CVL. At 700 Mc quantities tried were all too small. It is estimated that 8 to 16 units will be required, i.e. about 25,000 to 50,000 dipoles. At 3000 Mc 8 to 16 units will be required, i.e. 250,000 to 500,000 dipoles. Further tests are planned.

4-2. Tests on the USS Quincy (CA-71). Radar countermeasures tests were conducted on the USS Quincy 11 February 1944 at the Chesapeake Bay Annex. The main purpose of these tests was to obtain operation data on the CXFR jammer.

4-2-1. CXFR Tests. The tests on the CXFR did not prove successful as the equipment failed to operate properly. As a result of this failure, additional work was done at this laboratory on the CXFR. This work is discussed in the report of reference (d).

4-2-2. Rug Tests. The Rug was to operate against the SC-2 to determine its effectiveness. These tests were unsuccessful also as the Rug did not perform satisfactorily.

4-2-3. Window Tests. The window tests scheduled had to be cancelled due to bad weather conditions. These tests were to determine the correct package size to screen a CA.

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4-3. Tests on the USS Croatan (CVE-25). Radar countermeasures tests were conducted on the USS Croatan (CVE-25) 20 March 1944 at the Chesapeake Bay Annex. All of the jamming equipment was installed on the CVE. The main object of the test was to determine the effectiveness of the CXFR. Due to the bad weather conditions, the testing time was decreased to one-half the scheduled time. As the countermeasures tests were of secondary importance compared to the propagation tests, only two jamming events were completed.

4-3-1. Scope of Tests. The installation and operation of only two jamming equipments will be discussed in this report. These are the Carpet and the CXFR. The Rig had been installed but was not used in the test. Three 100 Mc jammers called "chicks" were also installed but these have been described in the letter report of reference (c).

4-3-2. CXFR Tests. The tests made on the CXFR consisted of two jamming runs. One of these runs was against the "Hot Dog" (560 Mc simulated German Würzburg equipment) and the other was against the FD. The test against the FD was a range run for the purpose of determining the maximum range at which the signal could be received.

4-3-2-1. The CXFR was installed on the flight deck. Approximately 70 feet of AN/RG-17U (7/8" solid coaxial) cable ran to the antenna mounted on a platform above the bridge. The height of this antenna was 86 feet above sea level. Two antennas were used to cover the frequency range of the CXFR. The low frequency one is designated as CAKZ-66AHM and the high frequency one as CAKZ-66AHN. These antennas are semi-broadband balanced dipoles backed by a small ground plane. The CXFR was protected from the weather by a tarpaulin. In order to maintain a stable voltage supply a separate generator on the ship was operated and its 440 volts were transformed to 110 volts at the load.

4-3-2-2. The first self screening run was against the "Hot Dog". The CXFR was turned on at 18,000 yards and complete jamming was observed. At 13,000 yards the jamming went off due to a temporary power failure on board ship. When the range was 11,000 the jamming came back on and complete jamming was observed to 7,000 yards. At this point the echo began breaking through. At 6,000 yards the CVE echo was seen easily through the jamming.

4-3-2-3. The CXFR was set on frequency by using the APR-1 as a listen through receiver. The APA-6 and RDK may be used as auxiliary indicators with the APR-1. Although some jamming is observed when the CXFR is off frequency as much as 3 or 4 Mc, effective jamming is not present until the carrier is within at least one megacycle of the radar frequency. The frequency can be set accurately by the proper use of the APR-1, but as there are several false signal points, care should be taken to distinguish between them and to select the proper one. The frequency calibration chart on the CXFR was used to set the approximate tuning. Then the responses were noted on the APR-1. There are four responses near the proper frequency. The lowest response is the correct reading. The second response is 15 Mc. higher and is caused by the second harmonic

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of the jammer heterodyning with the second harmonic in the local oscillator. A third response 45 Mc higher than the first represents the image of the second response. A fourth response 60 Mc higher than the first is the image of the first. Frequently this image can be tuned sharper than the true frequency; therefore, it is sometimes more accurate to check the frequency of this image and subtract twice the intermediate frequency than it is to read the true frequency directly. The peak of each response can be noted conveniently by the meter on the APR-1 or by the response shown on the APA-6 or RDK. A panoramic receiver with a large frequency swing would be very beneficial in setting the frequency.

4-3-2-4. The second jamming run using the CXFR was against the FD. The run started at twelve thousand yards, and readings were taken of the jamming level by a pulsed signal generator as the ship increased range. Each reading was taken by decreasing the amplitude of the signal generator voltage until this simulated echo was just screened in the jamming. The signal generator readings were then compared with readings taken of the CVE echo at an earlier time in the absence of jamming. These results are shown as plate 1. This curve shows the range over which the CVE will be screened. The curves cross at 7300 yards. At ranges closer than this the CVE echo is larger than the jamming signal. Zero db. corresponds to the signal returned from a standard target constructed near the Chesapeake Bay Station. The signal generator is referred to this standard target frequently during each run.

4-3-3. Carpet Tests. Tests on the Carpet were similar to those performed on the CXFR. The first of the two runs was against the FD; the second was a range run on the "Hot Dog",

4-3-3-1. The Carpet was installed on the open bridge. Fifteen feet of PT-5 coaxial cable extended to the antenna which was located 78 feet above sea level. The antenna used was of new design and consisted of a balanced dipole backed by a corner reflector. The gain of this antenna over an ordinary dipole is 8 db. The 400 cycle power was supplied from an M-G set operating from 110 volts a.c.

4-3-3-2. The jamming of the FD by the Carpet began when the CVE was at 15,000 yards. At this range the CVE was completely screened. After one power interruption the test continued. At 8400 yards the CVE echo was beginning to break through the jamming. This distance can be taken as the minimum jamming range.

4-3-3-3. The range run of the Carpet was made against the "Hot Dog". Readings were taken similar to those described in paragraph 4-3-2-4. The results are shown as plate 2. The minimum jamming range as indicated by this curve is 6,000 yards. At relatively short ranges from the radar, the jamming signal should decrease as the 4th power of the distance. The curvature shown at the greater range is probably due to the curvature of the earth effectively decreasing the height of the sending antenna.

4-3-4. Comparison of Carpet and CXFR. The effectiveness of the Carpet and CXFR appears to be almost equal from the data on minimum jamming ranges. It should be noted, however, that the Carpet antenna has a

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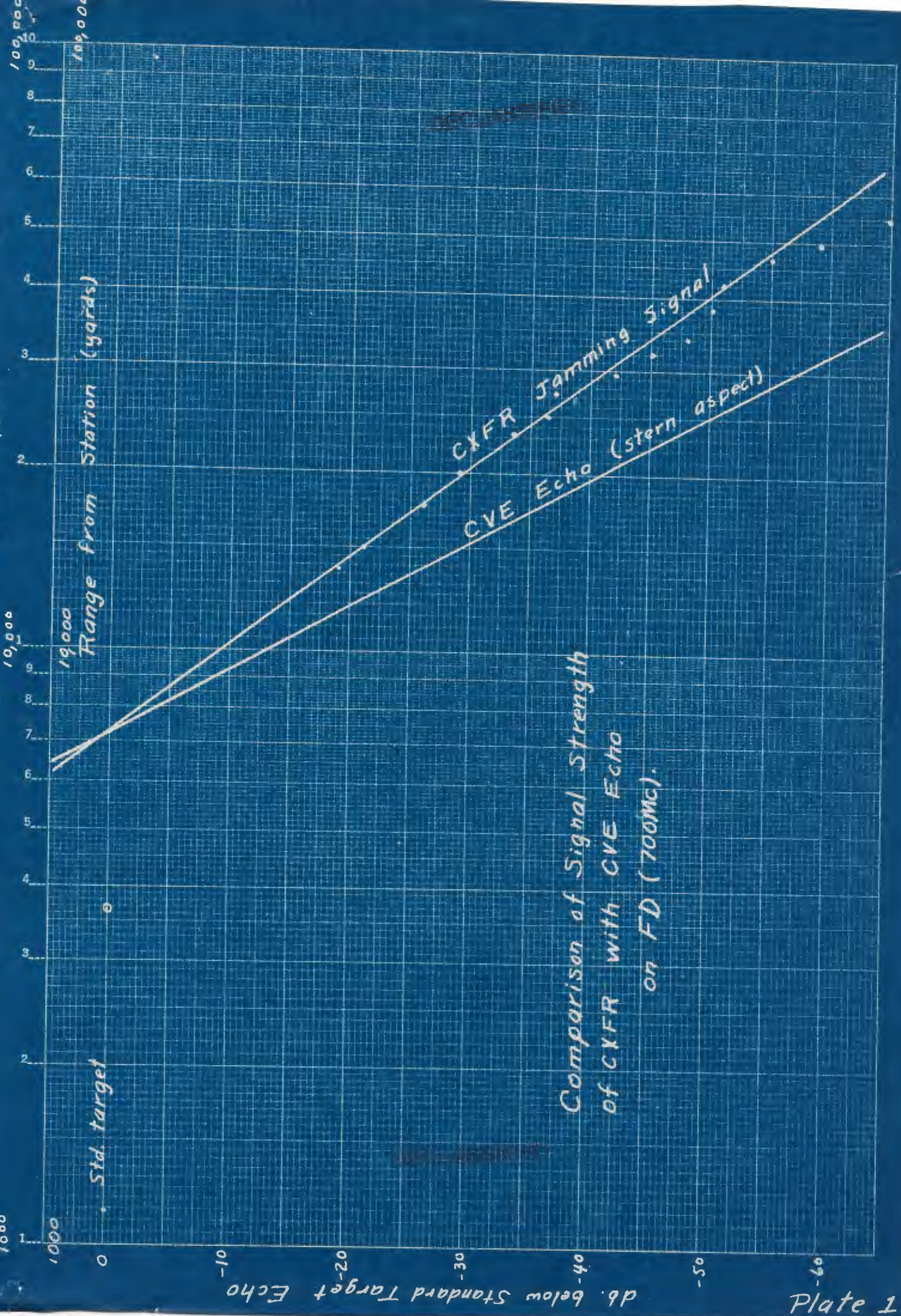
gain of nearly 8 db over the CXFR antenna. Also the Carpet has a much more narrow bandwidth. When these two considerations are made, it is easily understood why the effective jamming of the Carpet compares favorably with the CXFR in spite of the large difference in power outputs.

4-3-5. Window Tests. The window tests scheduled for this ship had to be cancelled due to bad weather conditions. The tests were intended to determine the correct package size to screen a CVE.

5. CONCLUSIONS.

The results of these tests show the minimum ranges at which the ships involved will be screened by jammers operating under similar conditions. The Carpet, when used with the corner reflector antenna, will effectively screen a CVE from the FD to a range of 8,400 yards. When it is used with a dipole antenna it will screen a CVL from the FD to 20,000 yards. The Rug, when mounted only 11 feet above sea level, will screen a CVL from the SC-2 to a range of 6,100 yards. The CXFR will screen a CVE from the FD to a range of 7,300 yards and from an equipment simulating a German Warzburg to a range of 7,000 yards. These ranges, however, should not be taken as the optimum ranges for the particular jammer. Only in a very few cases was it possible to repeat a run and in that way check the previous values.

Range from Station in Yards



Comparison of Signal Strength
of CXFR with CVE Echo
on FD (700mc).

Range from Station in yards

100,000
10
9
8
7
6
5
4
3
2
1

100,000
10
9
8
7
6
5
4
3
2
1

Range from Station (yards)

10,000
9
8
7
6
5
4
3
2
1

1,000
1000

Standard Target Echo db below

2 at 10

std. target

CARPET Jamming Signal
CVE Echo (stern aspect)

Comparison of Signal Strength
of Carpet with CVE Echo
on "Hot Dog" (560 Mc)

1000
1000

0

-10

-20

-30

-40