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REPORT NO. R-2099

DATE 2 December 1943

FR-2099

SUBJECT

Effects on Shipboard HF DF,
Radar and Homing Performance
Installing of their Antennas on a Common Mast

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ANACOSTIA STATION

WASHINGTON, D. C.

DEC 20 1943

To: Bureau of Ships

Subject: Naval Research Laboratory Report No. R-2099 dated 2 December 1943 - Report on "Effects on Shipboard HF DF, Radar and Homing Performance Installing of their Antennas on a Common Mast." - Forwarding of.

Ref: Bureau of Ships conf. ltr. 184(928-1) of 31 July 1943.

1. Enclosure 1 is forwarded herewith for the Bureau's information and files.

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NAVY DEPARTMENT

Report of

Effects on Shipboard HF DF, Radar and Homing Performance Installing of their Antennas on a Common Mast.

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D.C.

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OBJECT OF TEST

1. The object of the tests was to determine the practicality of operating high frequency direction finder, search radar and aircraft homing equipment on a vessel with the respective antennas all mounted on a common mast.

ABSTRACT OF TEST

2-2. This report covers a preliminary investigation made under simulated conditions to determine the practicability of carrying the antenna structure of a Model DAQ high frequency direction finder as well as the antenna structures of various models of search radar equipments or aircraft homing equipments on a common mast in naval vessels. The results indicate that such action is practical, within limits, provided certain nominal impairment of the absolute accuracy of the high frequency direction finder would be acceptable in service operation. Three factors are involved in the problem, namely, (1) the effects of the installation of, and more particularly the rotation of, the radar or homing antennas in proximity to the Model DAQ loops, (2) the effects of the mast on the radar or homing beams and, (3) the practicability of supporting the required weight of the several antennas on a standard mast without additional stiffening. Under (1) it was determined that the installation and rotation of both Model SL and SA radar antennas mounted on platforms aft and forward of a mast and spaced 15 feet and 26 feet, respectively, below the base of the DAQ loop mounted atop the mast (measured from loop base to radar antenna platforms) caused variations in deviation of the direction finder up to a maximum of 15°, with an average value of approximately 6° chargeable to each radar antenna when these antennas are rotated. These extreme deviations, however, cover a narrow frequency band (less than 1 megacycle) in the 14-15 megacycle spectrum with the 50 feet mast employed in the test. Similarly, in the same frequency region, pronounced "blurring" or lack of bearing definitions exist. At other frequencies the effects are inappreciable. Under (2) it was determined that the effects of the mast on the radar or homing beams appeared negligible. Similarly, interferences from the pulse frequencies of the radar antennas due to their proximity to the DAQ loops are not believed to be serious. No attempt was made to determine the practicability of supporting the required weight on a standard mast, inasmuch as this is a ship construction problem and the weights of the respective antennas involved are known.

CONCLUSIONS

3-1 It is concluded:

3-1.1 That the operation of a Model DAQ Direction finder and Model SA and SL radar antennas (or others of comparable size) as well as Models YE or YG homing antennas, all mounted on a common mast, is

[redacted]

practicable provided a reduction in direction finder accuracy over a portion of the frequency band would be acceptable and provided that the spacings indicated by plate 6 of this report are not reduced below the limits shown.

3-1.2 That the interpretation of the effects of the specific radar and homing antennas mentioned can be applied for other types of similar dimensions, the overall dimensions rather than the pulse rates, being the determining factors.

3-1.3 That it might prove possible to eventually develop a system employing forms of collectors, such as small continuously rotating loops, that would reduce the weight to be carried by the mast and thereby ameliorate the necessity of mast stiffening. Such systems have not as yet been developed to a point permitting of immediate production, could not be adopted as a modification of the DAQ equipments and would not eliminate the necessity for top of mast mounting of the direction finder collectors.

RECOMMENDATIONS

4-1 It is recommended:

4-1.1 That, should it be considered that the limitations in direction finder accuracy indicated by this report appear reasonably acceptable to the operating forces, and mechanical considerations such as mast loading permit, a trial installation be made in a suitable naval vessel to determine the performance obtainable under practical installation and operating conditions.

METHODS OF TEST

5-1 Because of the fact that tests under the subject problem had, of necessity, to be simulated, two lines of approach were followed:

5-1.1 To determine the effects of mounting radar or homing antennas on platforms rather than atop and concentric with a mast, which action results in the mast being in the beams at certain angles of rotation, A copper cylinder, eight inches in diameter and ten feet long was employed to simulate a mast section. This was placed in the beam of the various radar and homing devices tested, and measurements made to determine any change in the patterns of these antennas resulting from the interposition of this dummy mast.

5-1.2 To determine the effects of the mounting and most particularly the rotation of radar and homing antennas on the performance of a Model DAQ equipment, a 50 foot steel mast of a diameter similar to that employed in destroyers and destroyer escorts was erected in a clear field location. A Model DAR loop was mounted atop and concentric with this mast and copper "mock-ups" of the radar antennas were mounted on this mast at the heights and in the position shown by plate 6 of this report. These "mock-ups" were equal in size to the antennas involved and of approximately similar configuration. Copper sheeting was used on the "mock-up" support to simulate the metallic platforms that would be employed in naval vessels.

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5-2 At the time these tests were conducted, the Model DAQ equipment was not available so that a Model DAR loop was employed and both the Model DAR and a British Type FH-4 receiver were used with this loop.

5-3 No tests were made to determine absolute deviations resulting from the proximity of the radar antennas to the direction finder antenna inasmuch as such deviations would be amenable to removal by suitable calibration. All tests were conducted on the premise of determining changes in deviation resulting from movement of the radar and homing antennas and the degree of blurring existing throughout the frequency spectrum, it having been previously determined that the location employed with the direction finder antenna mounted atop the mast in the absence of any other antennas produced satisfactory results with a minimum of blurring or other adverse factors.

5-4 In order to conserve time and to reduce the number of variables, no attempt was made to mount a simulated homing antenna on the mast together with simulated SA and SL radar antennas inasmuch as the YE or YG homing antennas are so much smaller in area that their effects would be negligible with respect to the larger radar units.

5-5 For transmissions a small field transmitter was employed radiating substantially pure vertically polarized waves. This was located at distances in excess of one wave length from the direction finder. Tests were made with incremental variations in frequency in small steps and both a DAR and a British Type FH-4 receiver arranged in such manner as to permit their rapid switching to the loops, the FH-4 equipment being valuable to indicate out of phase components in the loops and permit more accurate observations to be made under conditions of bad blurring.

ACCURACY OF TEST

6-1 It is impossible to estimate the absolute accuracy of the results in view of the many variables involved, but it is believed that the results are sufficiently accurate to indicate the desirability of effecting a trial installation with reasonable expectation of success. It will be realized that the 50 foot mast employed in the tests is shorter than the mast that would be involved in naval vessels, and consequently the frequencies at which effects of the radar antennas on the direction finder might be expected will differ in actual installations, the critical frequencies probably being lower in view of the fact that actual masts will probably exceed 50 foot in height. Some question may exist as to the effects of employing solid copper in lieu of lattice steel in the radar antenna "mockups" but it is believed that the actual radar antennas will probably be less harmful than the copper "mockups" in view of their lower conductivity. However the most important factor contributing to the impossibility of obtaining data of sufficiently rigorous representative accuracy that could be expected to be duplicable

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in actual installations involves the multiplicity of variable phase conditions existing when two or more radar or homing antennas are rotated in proximity to a direction finder loop with determinate variations in the frequency of transmission. This introduces so many variables that only maximum effects can be ascertained and these may not be expected to be duplicable with respect to actual frequencies.

RESULTS OF TEST

7-1 Effects of Rotation of Radar Antennas on Model DAQ High Frequency Direction Finder Accuracy.

7-1.1 Model SA Radar
Plates 1, 2 and 3 indicate the variation in bearing accuracy of the direction finder due to rotation of a Model SA radar antenna with transmissions arriving at what would be approximately on the beam and close to the stern of a vessel, observations being made with both a Model DAR and FH-4 receiver. During these tests the Model SL Radar antenna was secured for a forward beam projection. Plate 1 indicates that (under the conditions of test employing a 50 ft. mast) no effects on the direction finder were noted below 8 megacycles. Nominal effects (deviations not in excess of 2.5°) were noted in the region of nine megacycles and above sixteen megacycles. The most serious effects occur between 14 and 15 megacycles where bearing variations of approximately 6° were noted. Plates 2 and 3 illustrate a study made of these variations in the critical frequency region between 13 and 15.5 megacycles. These plates show data obtained with both a DAR and an FH-4 receiver and while it will be noted that exact duplication of results was not obtained, the agreement is considered excellent for the different types of observations particularly in view of the fact that in this critical region the blurring or minimum width is such as to make readings of extreme bearing accuracy difficult. In general this survey would indicate that a maximum bearing deviation of 6° might be expected in this critical region of the frequency spectrum, the exact deviation varying rapidly with small changes in frequency.

7-1.2 Model SG or SL Radar
Plates 4 and 5 indicate the variation in bearings resulting from rotation of an SL radar antenna with the Model SA antenna secured for an athwortship beam direction. These plates indicate that rotation of the SL antenna produced negligible effects (less than 1°) up to approximately 13.75 megacycles and above 14.5 megacycles. Plate 5 covers a more meticulous survey made in the 13 to 15 megacycle region which showed the presence of a maximum bearing shift of 6° at approximately 14 megacycles, this shift being very critical with respect to frequency.

7-1.3 Both Radars
While as noted above, rotation of either the SA or SL radar antennas with the other antenna secured resulted in maximum bearing shifts in the order of 6°, the effects of rotating both simultaneously cannot

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be said to add up algebraically in any particular orderly manner. This appeared to be due to the random phase conditions existing at the Model DAQ loops from radiations from the respective radar antennas. These effects vary with such rapidity as to render quantitative analysis difficult. However, it was noted that deviations as high as 15° were observed for certain critical angles of the two radar antennas with respect to the direction of signal arrival and the DAQ loops.

8. EFFECTS OF MAST ON RADAR OPERATION

8-1.1 Air Search Radar
Tests with a ten foot long eight inch diameter copper tube (simulating a mast) placed in front of a Model SC-2 radar antenna at such a distance as to provide for just rotational clearance indicated no appreciable change in the field pattern of the radar beam when directed at the mast.

8-2 Surface Search Radar
Facilities did not permit of actual test of a simulated mast in the beam of an SL or SG radar antenna but it is understood from tests made by the forces afloat that a few blind spots and other spurious effects are encountered when these antennas are so located that the beam projects through a mast. However, it is also understood that certain destroyers have been able to obtain considerable utility from their Model SG radar equipments when installed in a manner similar to that shown for an SL Radar on Plate 6. In addition sufficient success has been obtained by the Pearl Harbor Navy Yard in the use of a small special mast shield to substantially reduce the spurious reflections and the blind spot sector to warrant the assumption that relatively satisfactory performance could be obtained with the SL or SG radar antennas mounted forward of a mast.

8-3 YG Homing Equipment
Tests conducted by placing a twelve inch diameter ten foot copper tube (simulating a mast) six feet in front of and directly in line with the principal radiation pattern of a Model YG Homing antenna indicated that an aircraft flying at various distances up to 80 miles on a homing course (as well as on other courses) could not detect any difference in the pattern when the simulated mast was in place or removed.

8-4 Pulse Interference Effects from Radar Antennas
While opportunity has not permitted definite tests to be made with respect to the interferences resulting from radar operation with the antennas in close proximity to the high frequency direction finder loops, such tests as have been made to date indicate that the pulse components from the radar transmissions under the conditions of antenna mounting indicated by plate 6 should cause little interference, with the possible exception of one or two very narrow frequency bands.

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9. EFFECTS OF COMBINED DIRECTION FINDER AND RADAR ANTENNA INSTALLATION ON MAST LOADING

9-1 As noted above, no investigations were made with respect to the effects of the additional weight that a common mast would have to carry to permit of the combined installation of a Model DAQ loop and two or more radar or homing antennas. This is believed to be a ship installation problem and not within the province of this Laboratory as a matter of radio investigation. However, it is believed that the weight involved in such combined installations including the weight of a 15 foot mast extension and a Model DAQ loop mounted thereon would impose loading, possibly beyond the designed limits of the mast involved. It has been proposed and it is considered practical to develop a small mast head assembly to be employed in lieu of the rather heavy Model DAQ loop assembly which would contain a small continuously rotating loop tuned by selsyn devices and coupled to a conventional receiving equipment, automatic bearing indications being obtained by employing simple scanning and triggering circuits capable of simultaneously operating any reasonable number of remotely located automatic bearing indicators. Such a system would have the advantage of lighter weight and would preclude the necessity of providing critical radio frequency circuits such as matched feeders, goniometers, etc., between the direction finder collectors and the radio receiver but, on the other hand, the development of such a system has not progressed beyond the rudimentary stage so that it is believed that a year or more would be required to consummate the development and obtain production of finished equipment embodying such principles and suitable for shipboard installation.

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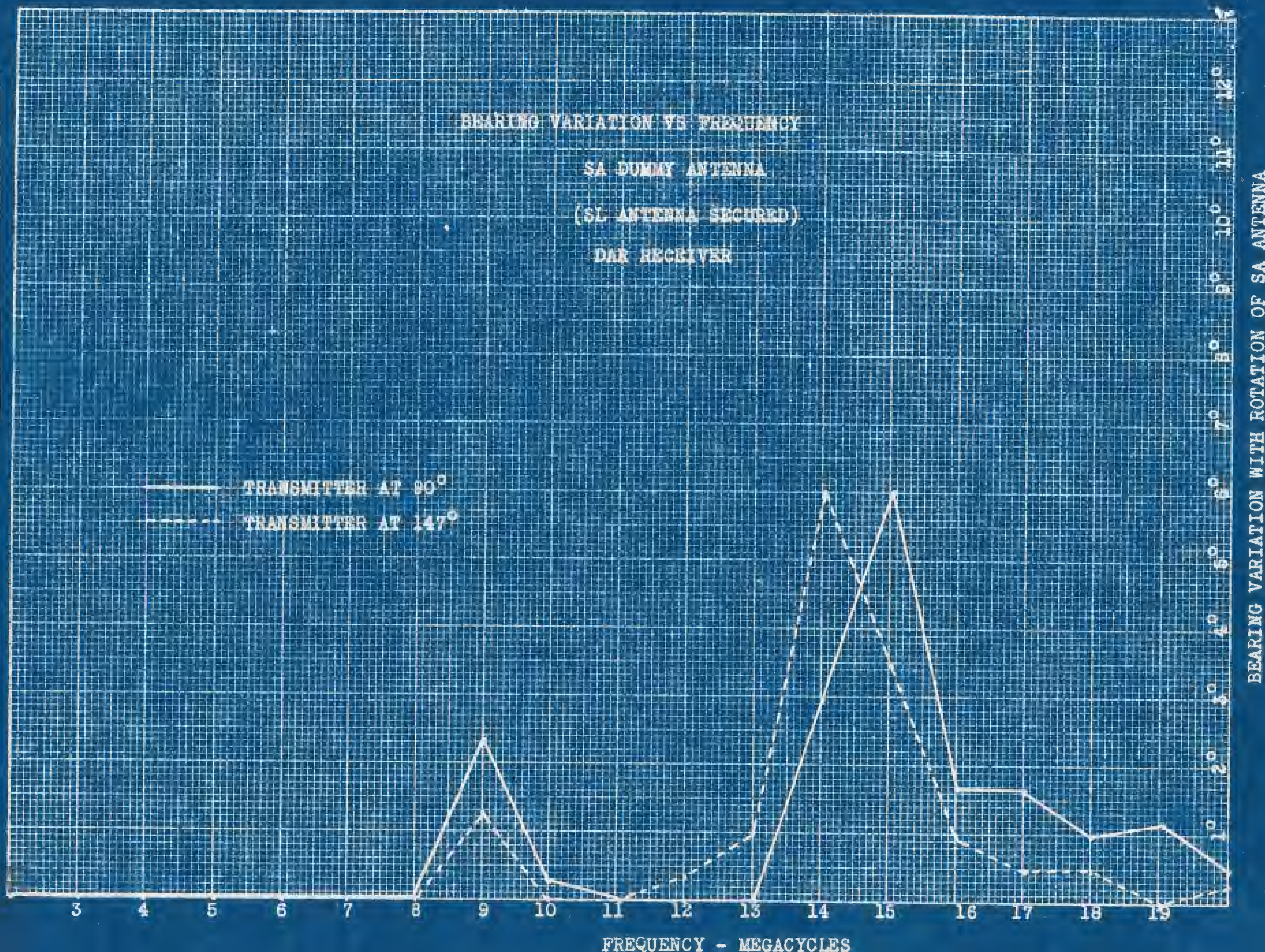

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PLATE I

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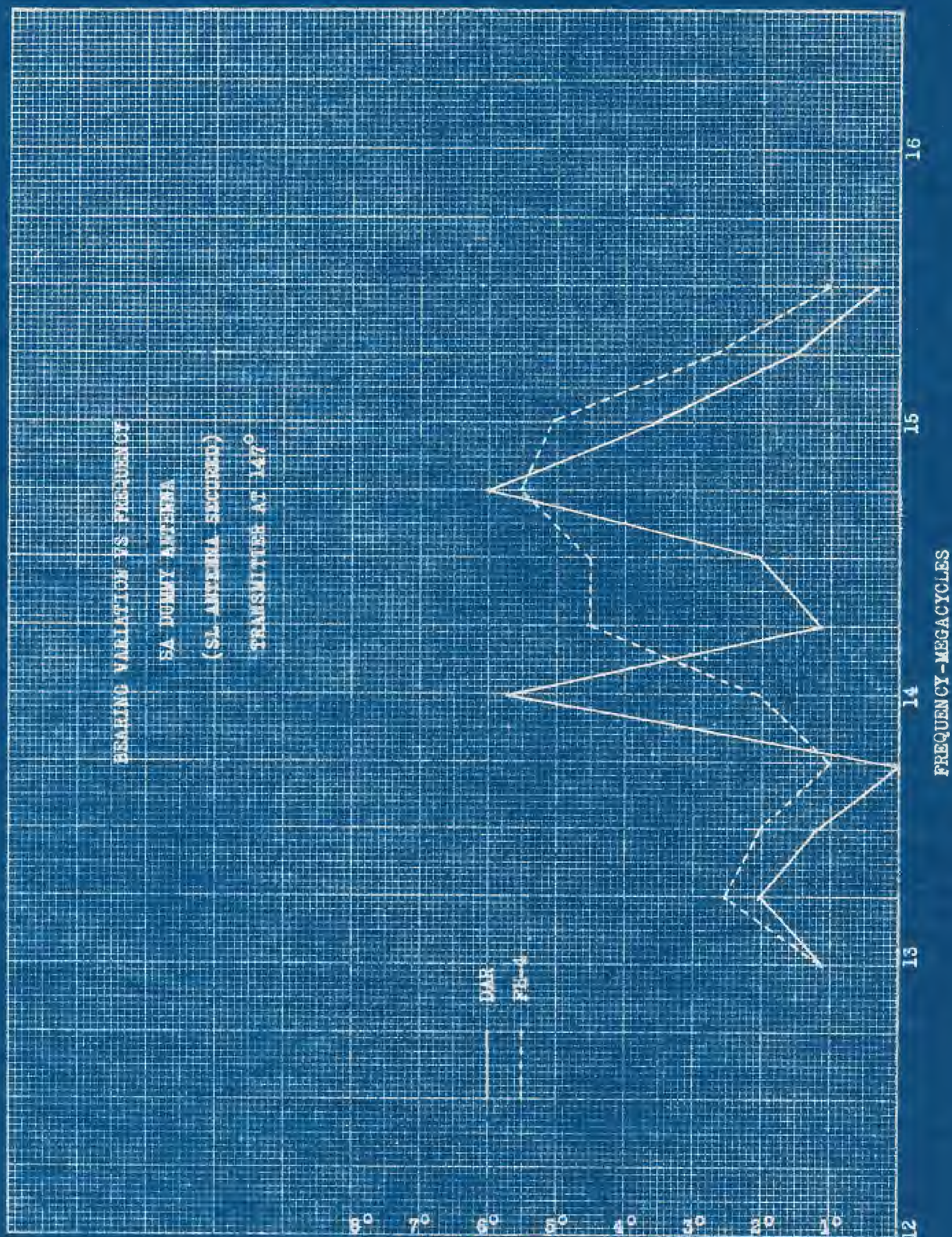

BEARING VARIATION WITH ROTATION OF SA ANTENNA

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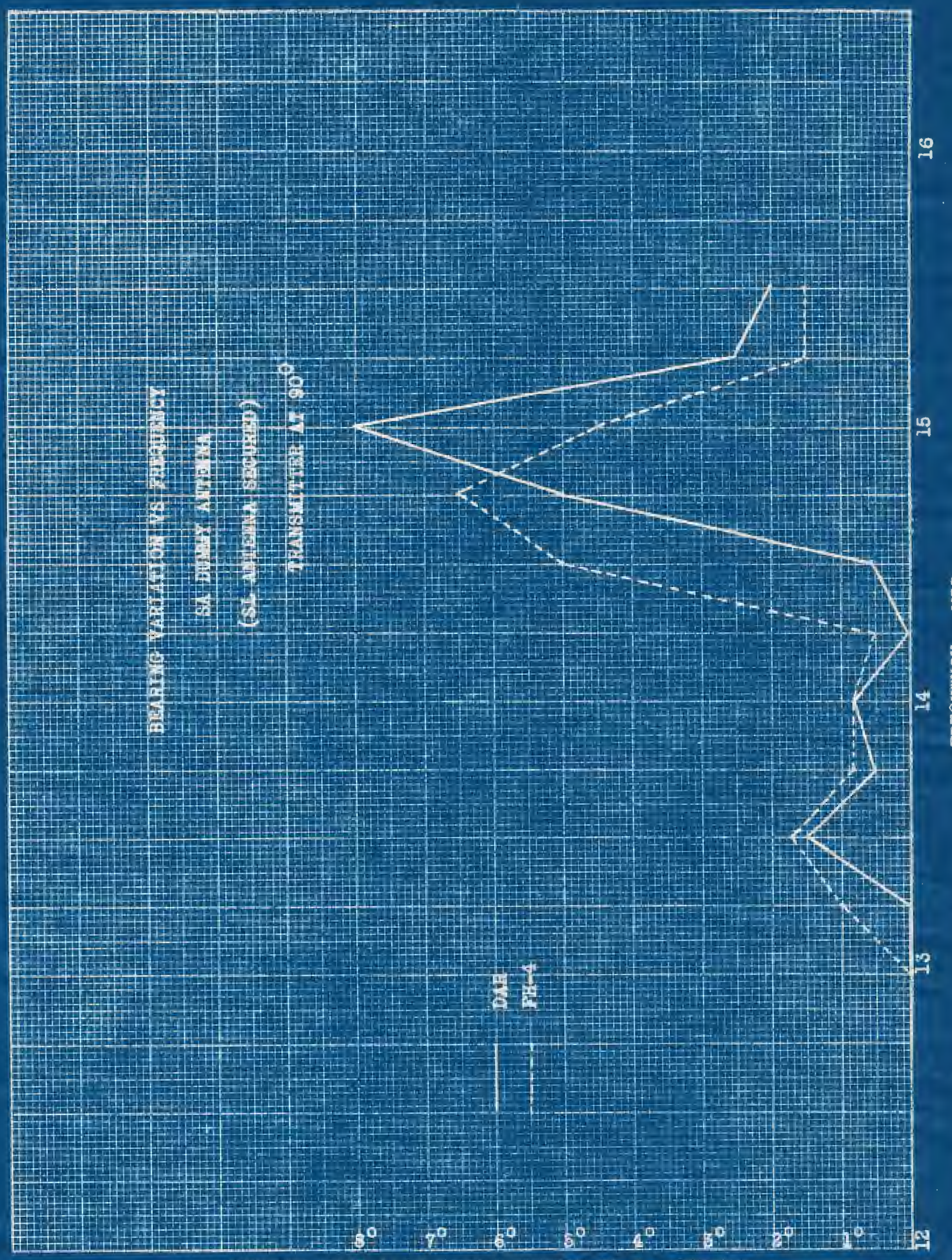

BEARING VARIATION WITH ROTATION OF SA ANTENNA

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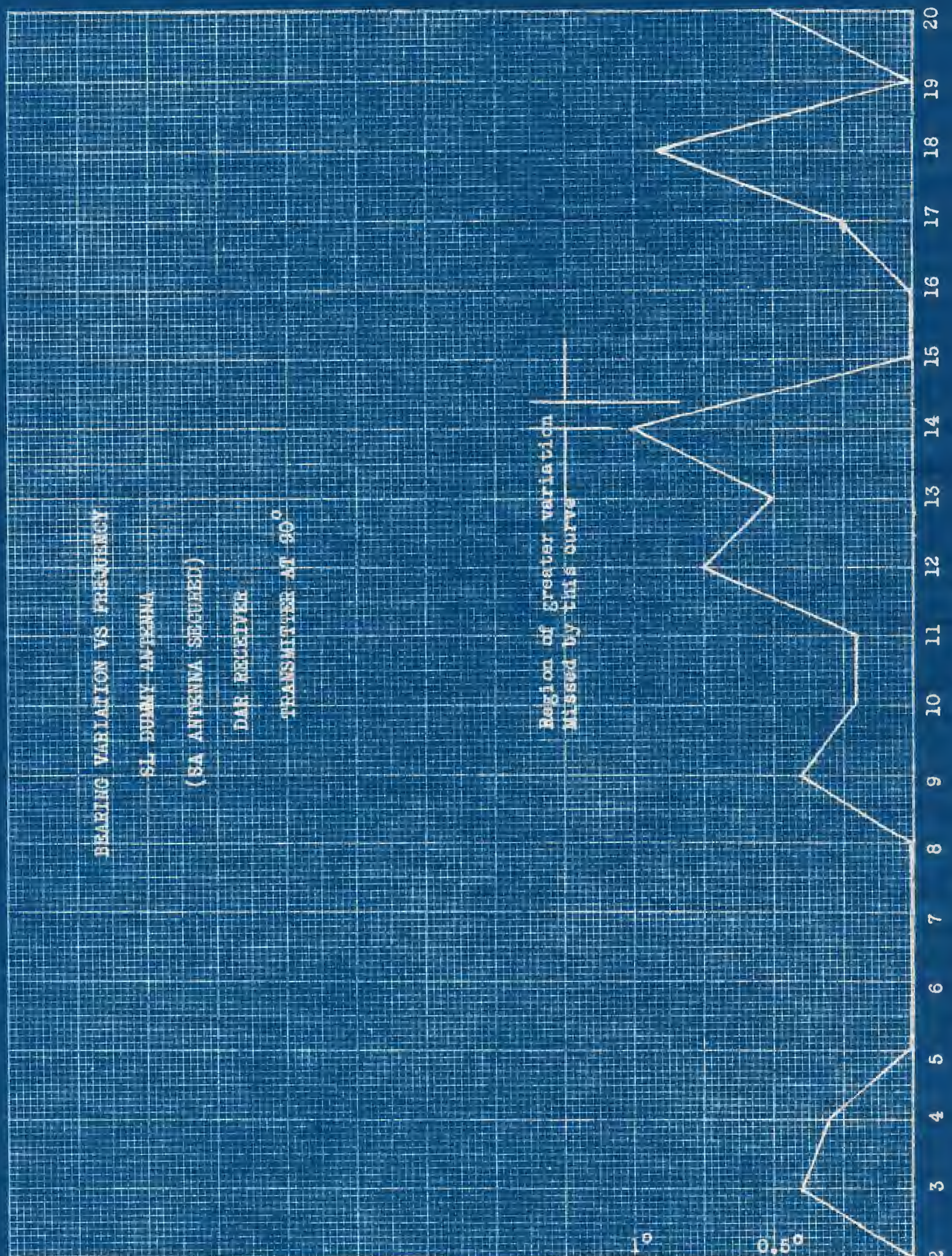
PLATE 3 [redacted] R-2099



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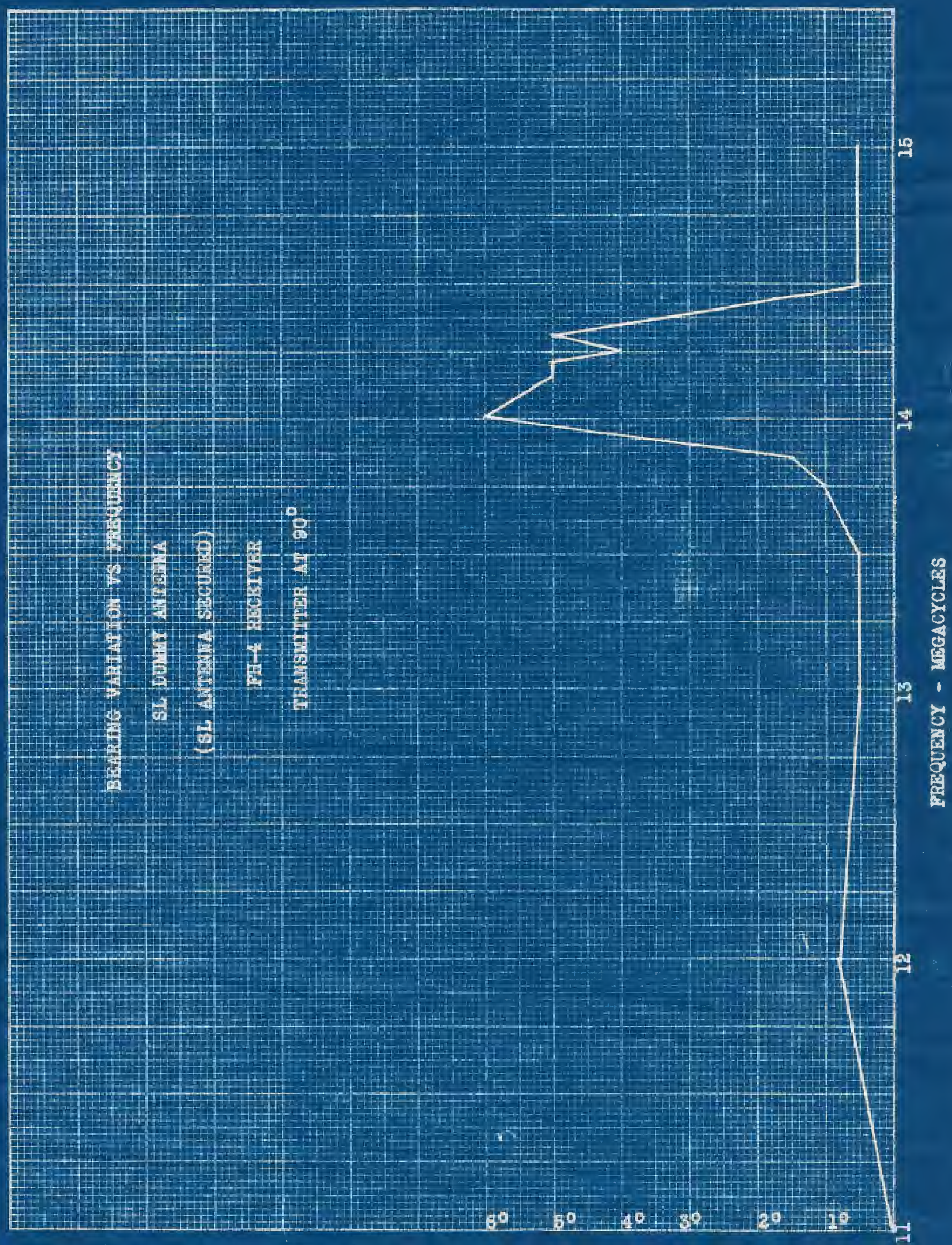

BEARING VARIATION WITH ROTATION OF SL ANTENNA

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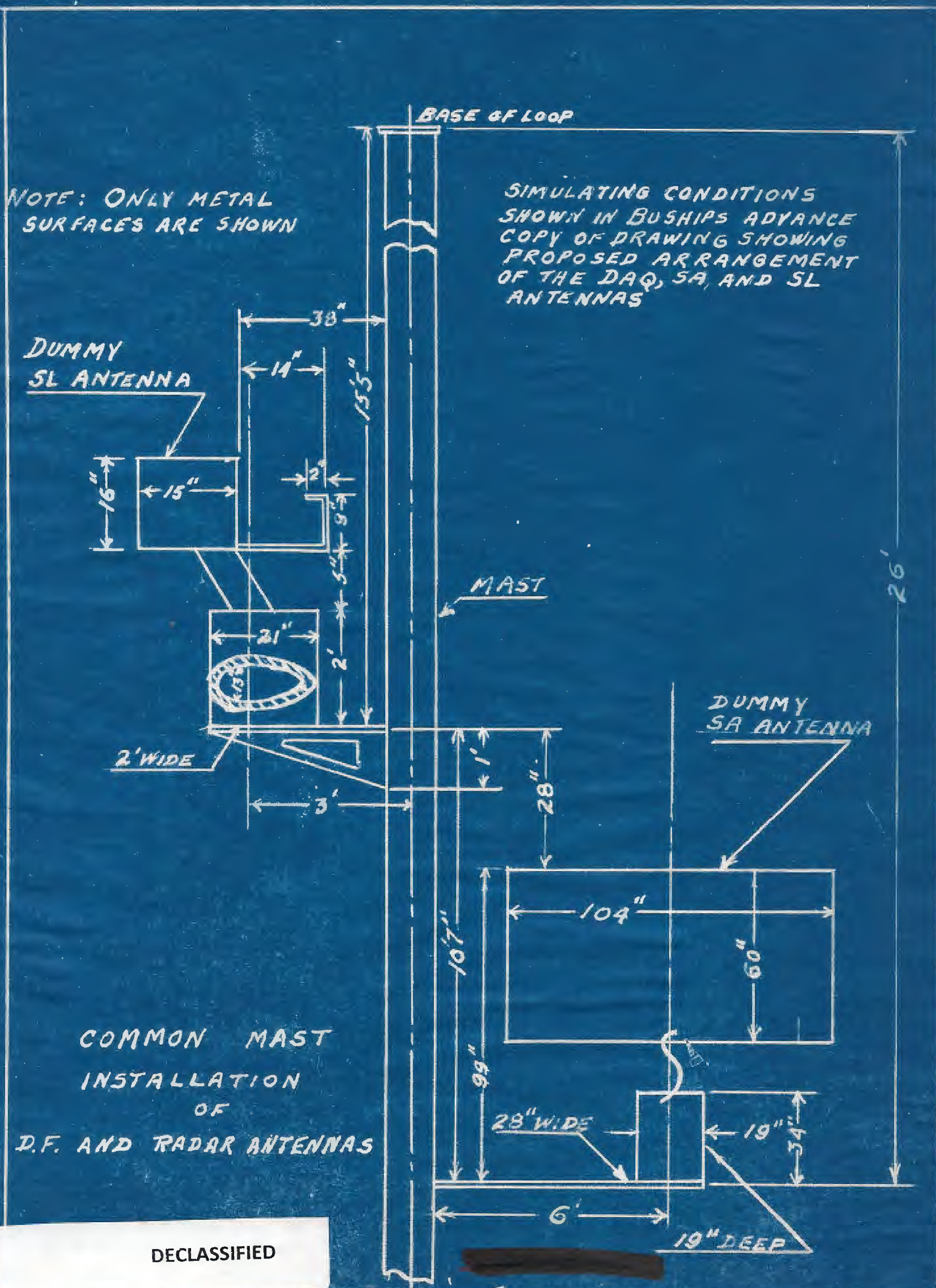
EXPERIMENTAL FIELD INSTALLATION



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R-2099 PLATE 6