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NAVAL RESEARCH LA

REPORT

31 December 1946

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A STUDY OF [illegible]
COUPLING [illegible]

[illegible] S. V. Prabhavi

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RADIO DIVISION II - RECEIVER SECTION

31 December 1946

SUPERHETERODYNE RECEPTION
A STUDY OF VARIOUS IMAGE
COUPLING DEVICES

By G. V. Fratianni

- Report R-2872

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* * *

Approved by:

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Preliminary Pages	a-c
Numbered Pages	7
Plates	8
Distribution List	6

NRL Problem S1083.1R-C

ABSTRACT

This problem provides for research to yield more effective submerged reception, the present phase relating to the attainment of the best energy transfer from the collecting loop to the receiver. Various coupling units available to the service have been studied. While the study of couplings is the prime consideration, it was found desirable to include the limitations of the various couplers and their usefulness to the Navy.

The Mare Island Coupling Units were designed to be used with the CNM 66097 loops, EQ loop series, and the RAK Receiver Series. Functionally, the units couple the low-inductance loop antennae to the RAK Receiver Antenna input, over a nominal frequency range of 15 to 35 kilocycles. The Coupling Units each contain a step-up transformer with its secondary tuned to the desired frequency by a variable capacitor. The signal is then amplified through a pentode tube and cabled into the antenna input of the RAK Receiver.

The two Mare Island Couplers were tested at NRL under shielded room conditions. Analysis indicated that both units are similar electrically, but do not cover the same frequency range. The electrical tests indicated that the overall performance was not as good as the system using the NRL Coupling Unit (CNM 47367) with the CNM 66097 loop, and more inferior when compared to the new system using this loop with an input transformer in a modified Model RAK Receiver (Reference 3).

Mechanically, both Mare Island Coupling Units have faults that should be remedied. The present condition of these units is unsatisfactory for Naval use.

This report contains electrical and mechanical information, such as, sensitivity comparisons of various coupling methods, operating characteristics, and mechanical and electrical recommendations.

This report also contains comments on a letter, "Results of Submerged Reception Tests", that compares two loop positions and the Mare Island and CNM 47367 Coupling Unit (Reference 4).

TABLE OF CONTENTS

	Page
ABSTRACT	-b-
INTRODUCTION	1
ELECTRICAL ANALYSIS	1
INSTALLATION DIFFICULTIES OF THE MARE ISLAND COUPLING UNITS	3
MECHANICAL INSPECTION OF COUPLING UNIT A	4
MECHANICAL INSPECTION OF COUPLING UNIT B	4
COMMENTS ON REPORT "RESULTS OF SUBMERGED RECEPTION TESTS"	5
CONCLUSIONS	5
RECOMMENDATIONS	5
ACKNOWLEDGEMENTS	6
REFERENCES	7

PLATE 1 - Graph Showing Overall Sensitivity Characteristics of Various Coupling Unit Methods.

PLATE 2 - Circuit Wiring Diagram of Unit B.

PLATE 3 - Photograph Showing Top Perspective View of Unit A.

PLATE 4 - Photograph Showing Front View of Unit A.

PLATE 5 - Photograph Showing Chassis Bottom View of Unit A.

PLATE 6 - Photograph Showing Top Perspective View of Unit B.

PLATE 7 - Photograph Showing Front View of Unit B.

PLATE 8 - Photograph Showing Chassis Bottom View of Unit B.

INTRODUCTION

1. This report depicts the relative efficiency of several loop input circuits which are, or have been, used for submerged reception. This includes: the older RA 60085 Coupling Unit, used with the loop taken from the Model DQ direction finder; the Type CBM 66097 Loop, used with the so-called Mare Island Coupling Unit; the Type CBM 66097 Loop and CBM 47367 Coupling Unit; and the 66097 Loop with NRL transformer input direct to the grid of the first receiver tube, with ganged tuning by the receiver variable capacitor. The Model RAK receiver was used for all. The Mare Island units are presumed to be war-produced emergency units to meet a then unfilled need. Their inclusion in the problem was a result of the request of reference (2). Test procedures outlined therein were modified, but the shipboard test conducted by Comsublant compared the CBM 47367 Unit and the Mare Island Coupling Unit constructed by USN USL, December 1944, after which these units were shipped to NRL in December 1945, for Laboratory tests. The report on these shipboard tests (Reference 4) was received at NRL in March 1946.

2. The two Mare Island units do not have type designations or serial numbers. For this reason, letter identification will be given to each in this report. The unit constructed by USN USL, December 1944, will be called Unit A. The unit manufactured by N.Y.M.I. will be called Unit B. For further clarification, see pieces 2 to 8 inclusive. While these coupling units were not designed to meet Navy specifications and it appears unnecessary to place them in production, they are discussed at some length herein to inform the Bureau regarding changes required if redesign to specifications were required.

ELECTRICAL ANALYSIS

3. All electrical investigations reported on herein were performed on the coupling units with the loop in air. Because of simplicity and convenience, the air measurements were preferred to sea water measurements. If the investigations had been conducted with the loop in sea water, it is believed that results obtained would have been relatively similar to the measurements obtained in air. For this phase of the problem, the investigation was not concerned with the mode of submerged reception but rather with the usefulness of one coupling system as compared to another.

4. Operational analysis indicated that both Mare Island Coupling Units perform electrically the same. The overall sensitivity of the combination of RAK Receiver, CBM 47367 Coupling Unit, and CBM 66097 Loop was measured in a shielded room for the entire range of 12 to 28 Kilocycles. The measurements were made at a standard output of 6 milliwatts into 600 ohms, with a 20 db signal-to-noise ratio. The Regeneration Control on the Receiver was adjusted for Standard Oscillation. A signal generator fed a properly terminated transmission line. The resultant field energized the Loop. The line constants having been experimentally determined, the induced field strength in space at the loop center, and the induced voltage in the loop were computed.

5. The sensitivity of the overall system (CNM 66097 Loop, Mare Island Coupling Unit B, and RAK Receiver) varied from 163 microvolts per meter at 15 Kilocycles to 79 microvolts per meter at 30 Kilocycles. At 25 Kilocycles the sensitivity value was 102 microvolts per meter (Reference Plate 1). The overall sensitivity using the CNM-47367 Coupling Unit varied from 38 microvolts per meter at 15 Kilocycles to 31 microvolts per meter at 30 Kilocycles. The overall sensitivity using the modified Model RAK Receiver (incorporating NRL transformer design, reference 3), varied from 12.2 microvolts per meter at 15 Kilocycles to 8.2 microvolts per meter at 25 Kilocycles. These data indicate that the present standard CNM 66097 system, using the CNM-47367 Coupling Unit, is about 13 decibels at 15 Kilocycles and about 6 decibels at 30 Kilocycles better than the system using the Mare Island Coupling Units. When the comparison is carried further, it is found that the NRL proposed system using the modified Model RAK Receiver and CNM 66097 Loop is about 23 decibels at 15 Kilocycles and about 21 decibels at 25 Kilocycles better than the system using the Mare Island Coupling Units. Proposed in reference (3), this system modification is understood to be in process of adoption.

6. For purposes of further comparison, a rewound Model DO Loop, of higher Q value than a standard DO Loop, was used with the Mare Island Coupling Unit B and the RA-50085 Coupling Unit (Reference 5). The use of the DO Loop improved the overall performance of the Mare Island Coupling Unit B by approximately five decibels. Using the DO Loop with the RA-50085 Coupling Unit, the overall performance was about three decibels short of being as good as the NRL modified RAK Receiver. The output of the RA-50085 Coupling Unit was then introduced directly into the first radio frequency amplifier grid of the RAK Receiver. The result obtained in overall performance was nearly as good as the NRL Modified RAK Receiver with the CNM 66097 loop (Reference Plate 1). However, this rewound DO loop, while essentially matching the inductance of a DQ loop, is believed to have a definitely superior Q. Unfortunately, no Model DQ loop was available for comparison. The use of a DQ loop might very possibly have raised the DQ Loop curves of Plate I by a factor of two, or 6 decibels.

7. This Laboratory has found it difficult to evaluate the wartime success in using submerged reception in the Fleet. Adequate official reports have not been found. Most unofficial comments indicate that little use was made of underwater loop reception, largely because the ranges attained were quite inadequate. The reasons given for this lack of success are many, ranging from lack of understanding of the requirements for submerged reception to conditions such as were found on the Conner, reference (6), where the excessive length of coaxial cable from the coupling unit to the receiver prevented resonating the receiver input circuit, and to report of weak signals near a high power station. It appears that the general level of performance attained in submerged reception has been consistently poor, compared to the best that computation and experiment offer. Whatever the causes have been it is undoubtedly possible to improve conditions by careful overhaul of existing installations and adequate training of the new personnel involved.

8. The curves shown on Plate 1 indicate that neither Mare Island Coupling Unit has a frequency range of 15 to 35 Kilocycles. Unit A frequency coverage lies between 15 and 25 Kilocycles, Unit B between 15 and 32 Kilocycles.

9. A preliminary investigation of the Mare Island Coupling Unit B was made using the coupler in a system simulating that of service conditions. The RCA Loop, GMM 66097, was connected to the input of Unit B, and the output of Unit B was introduced into the antenna input of a standard RAK Receiver. The GMM 66097 loop was loosely coupled to the output of a signal generator set at a frequency tunable by the coupler and the receiver. At low values of gain, the Coupling Unit B seemed to operate normally. At higher values of gain, the system became unstable and uncontrollable. Readjustment of the receiver or the coupler tuning controls did not remedy this condition. Readjustment to a lower value of gain setting was necessary to restore initial control. Therefore, increasing the voltage on the screen of the amplifier tube (increasing sensitivity control) caused the Mare Island Coupling Unit B to oscillate. This instability probably resulted mainly from the wiring layout which caused plate output energy to be fed back to the grid input through excessive grid to plate stray capacitance (Reference Plates 2, 6 to 8). Both units (the Mare Island Coupling Unit B and the RAK Receiver) are normally independently tuned to the same frequency. Because free and self-sustained oscillations took place in the coupling unit at higher gain settings, the plate impedance was varied by detuning the receiver over an appreciable frequency range. This receiver detuning was conducted because it was hoped that the oscillations would cease. However, the detuning was carried on to a frequency where it was believed that a strong input signal at the loop resonant frequency would have been still audible at the output of the receiver. This procedure did not stop the self-sustained oscillations of the coupler. The fact that this detuning was great enough to destroy the sensitivity of the system and that the oscillations had not terminated indicated that the electric coupling between the grid and plate electrodes of the tube was excessive. The amount of detuning necessary to stop oscillations of a circuit depends upon the gain of the tube and the capacitance between grid and plate electrodes. This implies that if the electric coupling were reduced, less detuning of the receiver would have been necessary to stop oscillation. However, the electric coupling should have been kept to a minimum so that self-sustained oscillations in the coupling unit would have been impossible. For identical conditions of equipment arrangement, the Coupling Unit A did not oscillate with high gain, presumably because the carelessly done wiring was not cabled (Reference Plates 2 to 5). This indicated that Coupling Unit B probably would not have oscillated if precautions were taken in the cabling.

INSTALLATION DIFFICULTIES OF THE MARE ISLAND COUPLING UNITS

10. When attempts were made to wire either Mare Island Coupling Unit into working order, difficulty was encountered. The power for the Coupling Units is obtained from the RAK Receiver terminals or Power Pack terminals, and no provisions were made in either unit for the power cable. If the

coupling unit had to be installed in the Fleet, appropriate holes in the Receiver or Power Pack would have to be made by the radio technician.

11. The Coupling Unit A is cumbersome. Insufficient thought was applied to mechanical design. The RAK antenna input cable continuously unfastened from its mounting standoff insulator in the Coupling Unit upon handling of the equipment.

12. Neither of the Coupling Units has provisions for mounting. Holes would have to be drilled in the back of the cabinet when installed.

MECHANICAL INSPECTION OF COUPLING UNIT A

13. Upon inspection of this unit, it was observed that there were numerous undesirable features in the design that did not conform with the standards expected in naval equipment. For example, the dial plate of the variable capacitor should have been provided with a clamp to prevent accidental change of setting (Reference Plates 3 to 5 inclusive); the controls should have been labeled to properly identify them as to their function; it would have been desirable to include mounting brackets to facilitate installation and maintenance; knurled captive thumb screws to secure chassis to cabinet would have been superior to the use of self tapping screws: cable connections to the unit should have been made through proper jacks and plugs, and a tube clamp assembled to the chassis for the 6C6-Gt. tube. Further, the electrical wiring should have been such that all components would have been placed on approved fungus proof terminal boards and properly number designated for immediate identification with no more than three connections made at a terminal. The wiring lead lengths should have been long enough so that no lead would have been excessively long permitting a possible source of added coupling, or too short, allowing stress to exist in the lead. The method of grounding components and circuit points should have been made directly to the chassis in the shortest practicable distance, and the soldering of all components and all electrical circuit leads to terminals should have been such as to insure the electrical connection by making at least two turns around the terminal before the application of the solder. Further, the transformer should have incorporated a rust proof shield to safe guard against physical injury and stray field coupling.

MECHANICAL INSPECTION OF COUPLING UNIT B

14. Upon inspection of this unit, it was discovered that there were undesirable features in the design of a nature similar to Unit A, but less numerous, that did not conform with the standards expected in naval equipment. These are, briefly, the methods of grounding circuit points and components, the use of self tapping screws to secure chassis to cabinet, the undesignated components, not mounted on approved terminal boards for immediate circuit identification, the absence of a tube clamp for the 6J7 tube and the omission of suitable brackets attached to the cabinet to facilitate installation and maintenance. Further, it would have been desirable if the design of the resonating capacitor was such as to minimize the possible physical damage to the rotor plates that could occur when the dial is set on 100 divisions and the chassis is removed from the cabinet.

COMMENTS ON REPORT "RESULTS OF SUBMERGED RECEPTION TESTS"

15. Reference 4, dated 11 August 1945, was received by the Receiver Section of NRL on 18 March 1946.

16. The letter states that reception with the Mare Island design (Unit A) was very poor as compared to the RCA Coupling Unit CNM 47367, on USS Conger.

17. Analysis of the data obtained from this letter indicates that the operators were confronted with difficulties in obtaining the correct information. The supporting data were not sufficient to make an accurate study of the comparison of the two coupling methods employed in the tests. Too many variables were changed simultaneously, so that a number of the readings taken were useless. The remainder of the data are not very apparent, but with careful study, it could be interpreted that the Coupling Unit CNM 47367 had been more successful than the Mare Island Coupling Unit. This conclusion conforms with the findings of this report.

CONCLUSIONS

18. It is concluded, both from a standpoint of electrical performance and mechanical construction, that the Mare Island Coupling Units are unsatisfactory for Naval use.

19. The electrical design of the Mare Island Coupling Units should have been such that the circuit would secure more efficient utilization of the signal picked up from the antenna system by making the signal-to-noise ratio as large as possible. The design of the amplifier should have been such that it would have been as good as or better than the RAK Receiver first radio frequency amplifier. However, the RAK Receiver sensitivity is high enough so that the signal-to-noise ratio is the limiting factor and not the gain; the additional amplifier in the Coupling Unit is superfluous.

20. From the results of the data shown on Plate 1, it is concluded that the Navy had a good system of coupling loop antennae to RAK Receivers (Reference Paragraph 6). However, the NRL Modified RAK Receiver (Reference 3) has advantages over this system. These are simplicity, elimination of cost for a coupling unit, and the reduction in the number of controls for the radio operator. Aside from these the NRL modified design conserves needed space in the radio room of a submarine.

RECOMMENDATIONS

21. If the Mare Island Coupling Units are to be used, the following changes are recommended:

(a) Mechanical

1. That the units contain brackets for mounting.

2. That all components be mounted on terminal boards and properly number designated for immediate identification.

3. That the wiring be properly cabled and a color code wiring system be used in the circuit.

4. That captive thumb screws be used to secure chassis in cabinet.

5. That Coupling Unit A have incorporated with the variable capacitor dial plate a clamp to prevent accidental change of setting.

6. That all controls of Coupling Unit A be properly labeled as to function.

7. That Navy approved tube clamps be used with the amplifier tubes.

8. That Coupling Unit A have jacks incorporated for incoming cables.

9. That all lead lengths and soldered connections be properly made to prevent electrical failure due to mechanical vibration.

10. That instructions as to theory, operation and maintenance be supplied with the units.

11. That a direct ground system be used in the circuit wiring.

12. That a shield be used with the transformers to prevent stray field coupling and mechanical damage.

13. That all metal and bakelite be treated against moisture and fungus growth.

14. That the Coupling Unit B resonating capacitor be protected against damage when chassis is not enclosed in cabinet.

(b) **Electrical**

1. That the amplifier wiring be cabled to keep the grid to plate capacitance at a minimum.

2. That the amplifier by-pass condensers be soldered directly at tube socket lugs.

3. That the amplifier circuit be redesigned for optimum signal-to-noise ratio performance.

4. That the transformer be redesigned for a greater coefficient of coupling.

ACKNOWLEDGMENTS

An acknowledgment is made to Mr. Warren B. Burgess (Radio Engineering Consultant) of the Receiver Section of NRL for his assistance in the completion of this phase of the problem.

REFERENCES

1. BuShips ltr. Section 9250, Ser. No. 1646 (9250) of 3/24/45 to NRL.

2. BuShips ltr. Section 9250, Ser. No. 92 of 3/18/45 to Comsubplant.

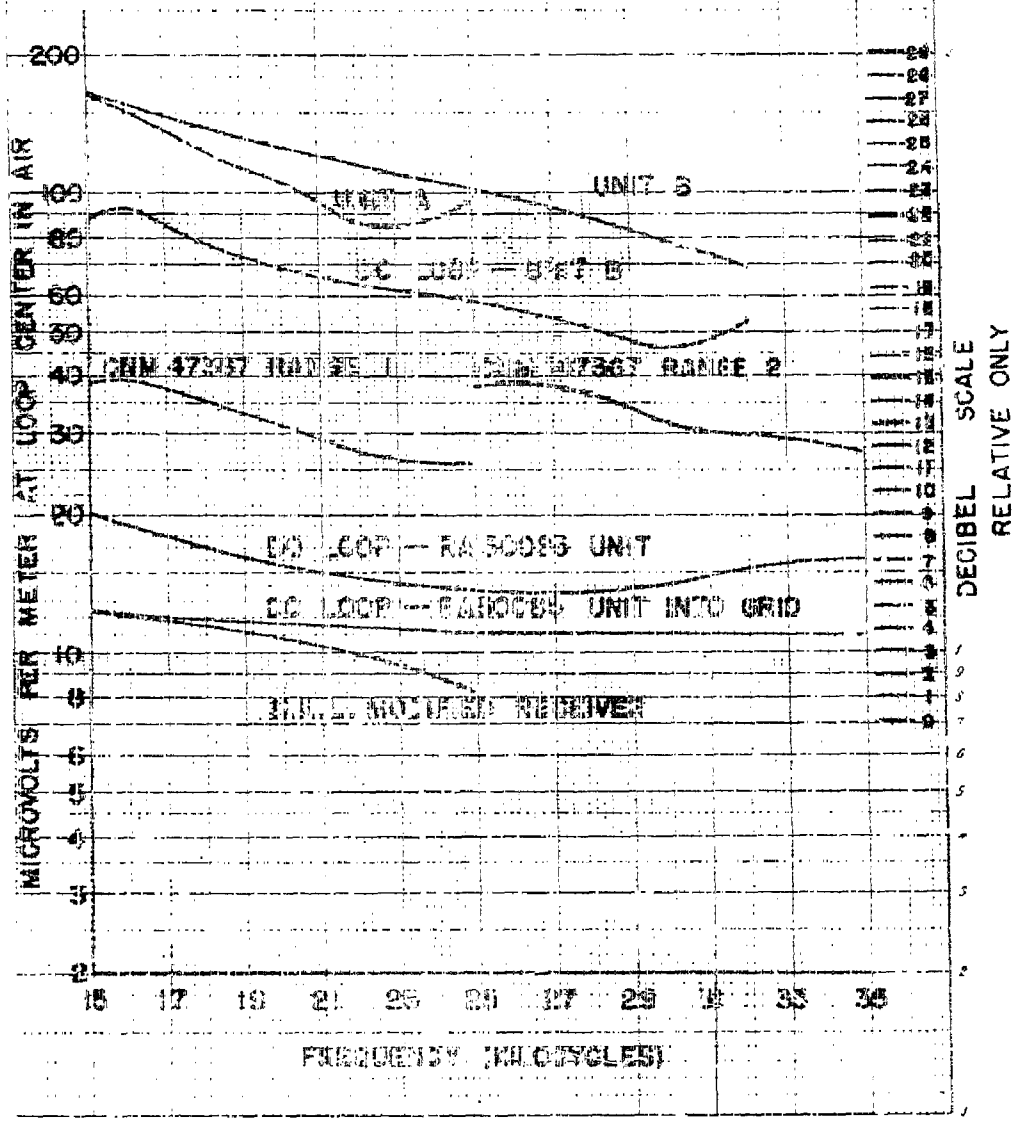
3. NRL ltr. C-SS/7 (1223:SVF) C-1220-38/46 of 11 March 1946 to BuShips - Interim Report on Problem S1083.1R-C.

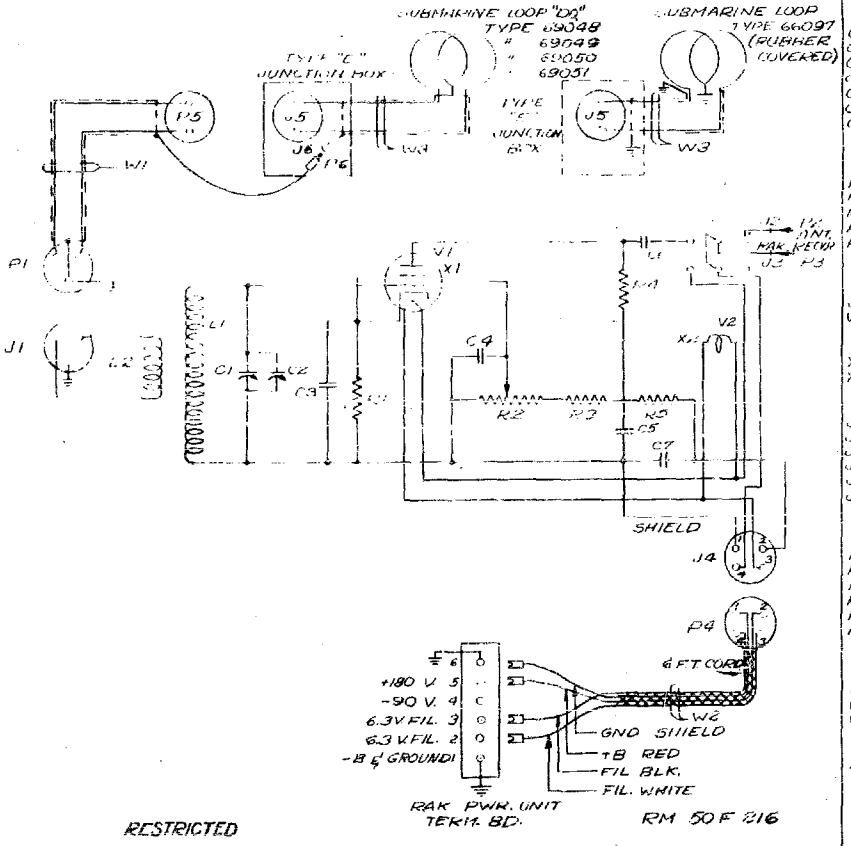
4. Comsubplant ltr. S3477/S57 of 11 August 1945 to the Chief of the Bureau of Ships - Results of Submerged Reception Tests.

5. National Electric Machine Shops, Inc., Instruction book (RA 50A 257 A) Instructions for Installation, Operation and Maintenance of Type CH 50085 Loop Coupling Unit - Frequency Range 15 to 35 Kilocycles - For use with Model RAK Series Receiving Equipment.

6. NRL ltr. C-SS/7 (358) C-350-176/45 of 21 May 1945 to BuShips.

OVERALL SENSITIVITY CHARACTERISTICS
OF
COUPLING UNIT SYSTEMS
MICROVOLTS PER METER AT LOOP CENTER
IN AIR VS. FREQUENCY





L1 - 2500 T #33 SSE COP. WIRE ½" DIA. X ½" WIDE 125 MH
L2 - 100 T #30 SCE COP. WIRE ¾" DIA. X ⅛" WIDE

C1 - .001 μf VAR. CAP
C2 - .00025 μf VAR. CAP. TRIMMER MIN. CAP. .000015 μf
C3 - .5 μf FIXED CAP. 400 V.
C4 - .5 " " " "
C5 - .5 " " " "
C6 - .001 " " " "
C7 - .5 " " " "

R1 - 1000 Ω, ½ W. RESISTOR
R2 - 50 M Ω POTENTIOMETER
R3 - 50 M Ω, ½ W. RESISTOR, LIMITING
R4 - 100 M Ω, " "
R5 - 10 M Ω, " "

V1 - TYPE 6J7 VACUUM TUBE
V2 - PILOT LAMP, 6V BLUE BEAD, BAYONET BASE

X1 - OCTAL SOCKET
X2 SOCKET FOR PILOT LAMP WITH BULLS EYE

J1 JACK, AMPHENOL, PC-3F
J2 - JACK, TYPE 49120
J3 JACK, " "
J4 - JACK, AMPHENOL, PC-4F
J5 - JACK, " " PC-2F
J6 - G-R BANANA JACK, MOUNTED IN "E" BOX

P1 PLUG, AMPHENOL MC-3M
P2 - PLUG PART OF TYPE 49120 PATCH CORD
P3 - PLUG " " " "
P4 - PLUG AMPHENOL MC-4M
P5 - PLUG " MC-2M
P6 - GR BANANA PLUG, FOR GROUNDING SHIELD

W1 - CABLE 6 FT, ANT., COUPLER TO JUNC. BOX, MIC CABLE
W2 - CABLE 6 FT. POWER TO RAK PWR. UNIT, 4 COND. MIC "
W3 - CABLE 325 K PART OF LOOP ASSEMBLY

S1 - TOGGLE SWITCH D.P.D.T.

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PLATE 2

TOP PERSPECTIVE VIEW
HARE ISLAND COUPLING UNIT
UNIT 4

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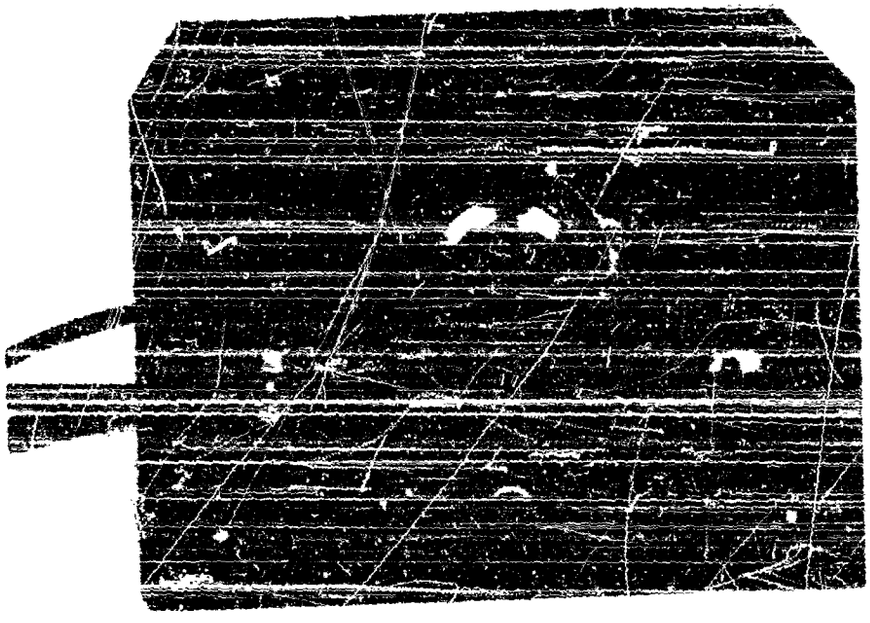
PLATE 3



FRONT VIEW
MARE ISLAND COUPLING UNIT
UNIT A

PLATE 4

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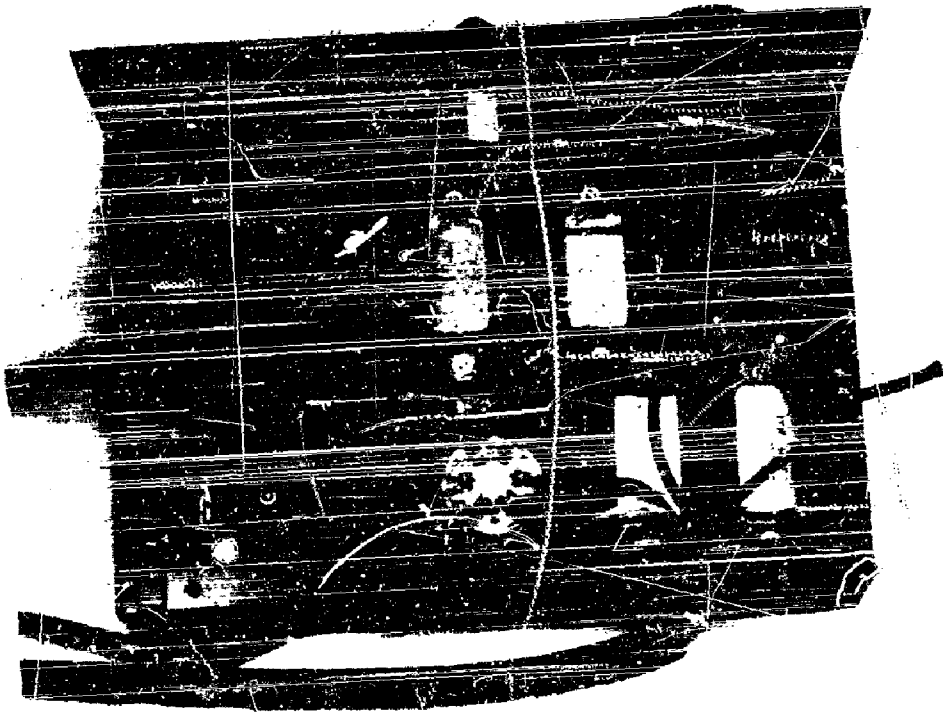

BOTTOM VIEW OF CHASSIS
MARE ISLAND COUPLING UNIT
UNIT A

PLATE 5

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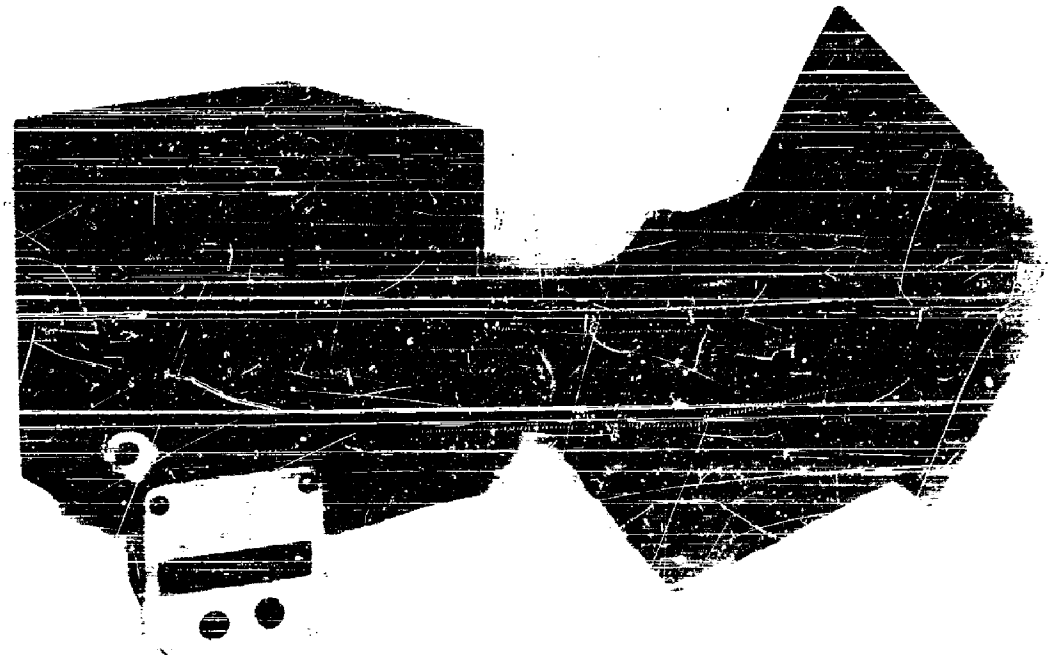

TOP PERSPECTIVE VIEW
MARE ISLAND COUPLING UNIT
UNIT B

FRONT VIEW
MARE ISLAND COUPLING UNIT
UNIT B

PLATE 7

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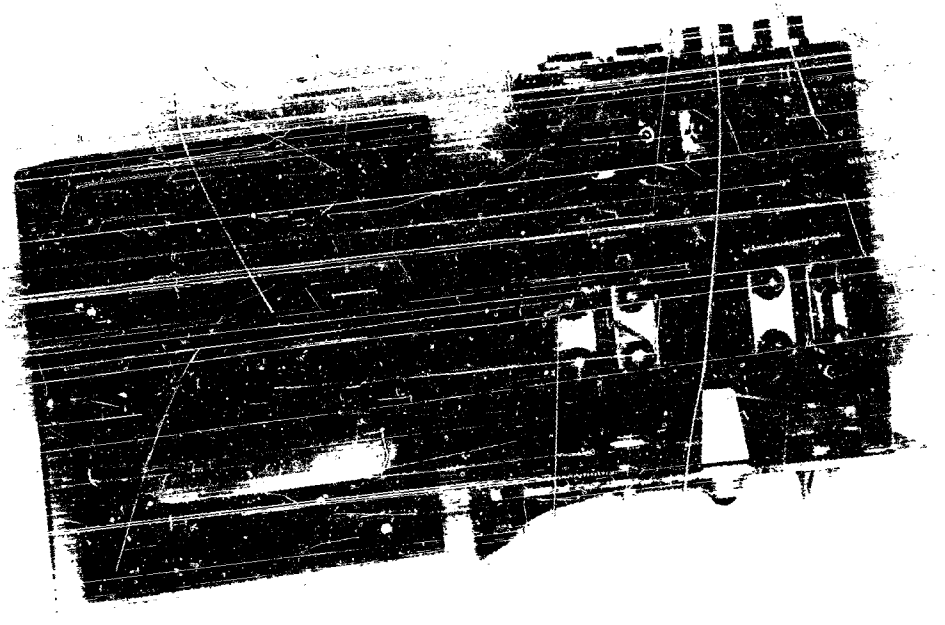

BOTTOM VIEW OF CHASSIS
MARE ISLAND COUPLING UNIT
UNIT B

PLATE 8

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RADIO DIVISION II - RECEIVER SECTION

31 December 1946

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SUBMERGED VLF RECEPTION
A STUDY OF VARIOUS LOOP COUPLING METHODS

By S. V. Fratianni

- Report R-2872

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Director, Naval Research Laboratory

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