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31 December 1946

A STUDY OF VARIOUS LOOP
COUPLING METHODS

By S. V. Fratianni

Report R-2872

RESTRICTED

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NRL Problem 31082.1R-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 Marc Island Coupling Units were designed to be used with the CM 66097 loops, EQ Loop series, and the RAK Receiver series. Functionally, the units couple the low-inductance loop antenna 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 Marc Island Couplers were tested at WNL 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 EQ Coupling Unit (CM 6736) with the CM 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 Marc Island Coupling Units have faults that should be remedied. The present condition of these units is unsatisfactory for Navy 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 Marc Island and CM 47367 Coupling Unit (Reference 4).
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**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 CM 60077 Loop, used with the so-called Mare Island Coupling Unit; the Type CM 60077 Loop and CM 47367 Coupling Unit; and the 60077 Loop with ZEL transformer input direct to the grid of the first receiver tube, with ganged tuning by the receiver variable capacitor. The RA 6XK 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 due to the request of reference (2). Test procedures outlined herein were modified, but the shipboard test conducted by Consultant compared the CM 47367 Unit and the Mare Island Coupling Unit constructed by USW USN, December 1944, after which those 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 USW USN, December 1944, will be called Unit A. The unit manufactured by B.H.M.I. will be called Unit B. For further clarification, see plates 2 to 8 inclusive. While those 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 reduction 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 antenna reception but rather with the usefulness of the 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 6AX Receiver, CM 47367 Coupling Unit, and CM 60077 Loop was measured in a shielded room for an output range of 15 to 35 millivolts. The measurements were made at a standard output of 6 millivolts 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 (CIM 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 CIM-47367 Coupling Unit varied from 33 microvolts per meter at 15 kilocycles to 31 microvolts per meter at 25 kilocycles. These data indicate that the present standard CIM 66097 system using the CIM-47367 Coupling Unit is about 13: decibels at 15 kilocycles and about 6 decibels at 25 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 CIM 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 DQ Loop, of higher Q value than a standard DQ Loop, was used with the Mare Island Coupling Unit B and the RA-50085 Coupling Unit (Reference 5). The use of the DQ Loop improved the overall performance of the Mare Island Coupling Unit B by approximately five decibels. Using the DQ 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 CIM 66097 loop (Reference Plate 1). However, this rewound DQ 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 1 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 Concor, reference (6), where the excessive length of coaxial cable from the coupling unit to the receiver prevented exciting 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 may be 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 Mere Island Coupling Unit has a frequency range of 16 to 25 kilocycles. Unit A frequency coverage lies between 15 and 25 kilocycles, Unit B between 15 and 33 kilocycles.

9. A preliminary investigation of the Coupling Unit B was made using the coupler in a system simulating actual service conditions. The RCA Loop, G8W 66097, was connected to the input of Unit B, and the output of Unit B was introduced into the antenna input of a standard BAK Receiver. The G8W 66097 loop was loosely coupled to the output of a signal generator set at a frequency tunable by the coupler and the receiver. At any 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 Mere Island Coupling Unit B to oscillate. This instability probably resulted mainly from the wiring layout which caused plate output energy to feed back to the grid input through excessive grid to plate stray capacitance (Reference Plates 2, G to H). Both units (the Mere Island Coupling Unit B and the BAK 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 size 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 A probably would not have oscillated if precautions were taken in the cabling.

INSTALLATION OF MARIS ISLAND COUPLING UNITS

10. When attempts were made to wire either Mere Island Coupling Unit into working order, difficulty was encountered. The power for the Coupling Unit is obtained from the BAK 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 RTK 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 bars 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 606-6 tube. Further, the electrical wiring should have been such that all components would have been placed on approved fungus proof terminal boards and properly numbered 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 load. 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 safeguard 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 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 657 tube and the emission 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.
15. Reference 4, dated 11 August 1945, was received by the Receiver Section of NRL on 18 March 1945.

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

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 ORM 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 RCA Receiver first radio frequency amplifier. However, the RCA 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 antenna to RCA Receivers (Reference Paragraph 8). However, the new Modified RCA Receiver (Reference 8) 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 new 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 base.

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 RBL for his assistance in the completion of this phase of the problem.
REFERENCES

1. BuShips ltr. Section 9266, Ser. No. 1646 (9250) of 3/24/45 to NHL.


5. National Electric Machine Shops, Inc., Instruction book (NA 504 257A) Instructions for Installation, Operation and Maintenance of Type GPKE95 Loop Coupling Unit - Frequency Range 15 to 75 Kilocycles - For use with Model RAE curly receiving equipment.

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

DECIBEL SCALE

RELATIVE ONLY

FREQUENCY (Kilocycles)

15 17 19 21 23 25 26 27 28 30 32 34 36

MICROVOLTS PER METER AT LOOP CENTER IN AIR

UNIT 3

UNIT 2

UNIT 1

LC LOOP - RA 5008G UNIT

LC LOOP - FA10084 UNIT INTO GRID

R-2672 PLATE 1

RESTRICTED
BOTTOM VIEW OF CHASSIS
MARE ISLAND COUPLING UNIT
UNIT A
TOP PERSPECTIVE VIEW
MARE ISLAND COUPLING UNIT
UNIT B

RESTRICTED
FRONT VIEW
WARE ISLAND COUPLING UNIT
UNIT B
Distribution
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RADIO DIVISION II - RECEIVER SECTION

31 December 1946

SUBMERGED VLF RECEPTION
A STUDY OF VARIOUS LOOP COUPLING METHODS

By S. V. Fratianni

- Report R-2872

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* * *

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