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# ANTENNA-MULTICOUPLER SYSTEM FOR USMC COMMUNICATION CONTROL VEHICLE

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# ANTENNA-MULTICOUPLER SYSTEM FOR USMC COMMUNICATION CONTROL VEHICLE

L. G. Robbins and E. H. Flath, Jr.

December 19, 1951

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R. B. Meyer, Head, Communication Branch  
L. A. Gebhard, Superintendent, Radio Division II



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## ABSTRACT

At the request of the U. S. Marine Corps two antenna-multicoupler units have been developed, one for the frequency range 2-8 Mc and the other for the frequency range 28-48 Mc, which provide means for reducing the number of communication antennas required on a communication control tank. The 2-8 Mc multicoupler unit will permit simultaneous operation of two transmitter and/or receiver equipments on a single antenna with provisions for time-sharing a third transmitter-receiver equipment on this same antenna. The 28-48 Mc multicoupler unit permits simultaneous operation of two transmitter-receiver equipments on one antenna, one circuit covering the 28-38 Mc band and the other the 40-48 Mc band. These units have performed satisfactorily both in the laboratory and in a field installation on a communication control tank. They provide a more desirable load for the transmitting equipment than the regular whip antenna, resulting in a greater transfer of r-f power from the transmitter to the antenna system and hence a substantial increase in signal strength. These units contribute only a nominal loss in the communication system, and permit operation into a relatively wide range of antenna impedances. For optimum performance the 28-48 Mc unit should be used with the broadband antenna described herein.

Other considerations involved auxiliary impedance-matching circuits for receiver protection and bandpass filters for attenuation of harmonics and interfering signals in existing transmitting and receiving equipment. The basic problem therefore resolved itself into four parts, viz, reduction of the number of antennas, antenna design, multicoupler design, and systems operations.

## PROBLEM STATUS

This is a final report on one phase of the problem; work is continuing on other phases.

## AUTHORIZATION

NRL Problem R09-32  
RDB Projects NE 021-005, and NE 021-019  
BuShips S706.2R-C

Manuscript submitted September 26, 1951

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ANTENNA-MULTICOUPLER SYSTEM FOR  
USMC COMMUNICATION CONTROL VEHICLE

## INTRODUCTION

The U. S. Marine Corps has a requirement for a special communication control tank for observing and controlling military operations in the combat area. Such a tank must provide several communication channels in addition to those required by a regular combat tank. Furthermore, it is essential that the silhouette and general appearance of the special tank be similar to that of a regular tank so that an enemy observer cannot readily distinguish one from the other. It has been established by the Marine Corps that the communication control tank must carry eight transmitter-receiver equipments in order to provide the necessary communication channels. When this tank is equipped with eight antennas, the similarity of appearance between it and a regular tank is destroyed. Combat activities prevent the use of dummy antennas on the regular tanks. Hence the only alternative is to reduce the number of antennas on the special tank to a practical minimum by use of antenna-multicoupler systems and by switching and time-sharing techniques.

The radio equipments presently employed on the communication control tank are:

- 1 - Radio Transmitting and Receiving Equipment TCS-2-12 Mc
- 1 - Radio Set BC-287-2-12 Mc
- 1 - Radio Set AN/GRC-9-2-12 Mc
- 1 - Radio Set SCR-508-A-20-28 Mc
- 1 - Radio Set SCR-608-A-28-38 Mc
- 1 - Radio Set SCR-300-A-40-48 Mc
- 2 - Radio Set SCR-522-115-156 Mc

It was considered feasible<sup>1</sup> to carry these eight channels on four antennas by using two antenna-multicoupler equipments and a simple switching arrangement. By agreement, the operating range of the TCS, BC-287, and AN/GRC-9 equipments was to be restricted to 2-8 Mc in order to simplify multicoupler design.

The eight communication channels would than be made available by the following grouping of equipment:

<sup>1</sup> Conference report, NRL Serial S-3910-47/51, 7 February 1951

- (a) Three equipments, 2-8 Mc, operating into a single 18-ft whip antenna through a multicoupler unit and a switching system which would provide two simultaneous channels and a third channel on a time-sharing basis.
- (b) One equipment, 20-28 Mc, operating into its regular whip antenna.
- (c) Two equipments, 28-38 Mc and 40-48 Mc, operating simultaneously into a single broadband antenna through a multicoupler unit.
- (d) Two equipments, 115-156 Mc, sharing operating time on one whip antenna through an r-f switch.

To implement this proposed system it was necessary to develop the two antenna-multicoupler units (2-8 Mc and 28-48 Mc), and a broadband antenna for the 28-48 Mc band. In addition, due to the limitations of some of the above communication equipments, certain systems problems were encountered. Investigation of these problems resulted in the development of auxiliary impedance-matching units for use with some of the receivers and with the SCR-300-A equipment. Sufficient investigation of interference on several channels was made to prove the need for using bandpass filters with some of these equipments.

Since the Marine Corps representatives requested a workable system for installation within a relatively short time, the developmental work was held to a minimum. It is believed that had more time been available for study, a considerably improved system could have been produced.

The research and development work on experimental models of the multicoupler units, the broadband antenna, and the receiver impedance-matching units are discussed. Field measurements and results of actual operation with this experimental equipment installed on a communication control tank at Camp Lejeune, N. C., are discussed also. These field trials resulted in the verification of certain predictions regarding systems operation which were made in the laboratory.

## PART I - COMPONENTS OF ANTENNA-MULTICOUPLER SYSTEM

### 2-8 Mc MULTICOUPLER

The basic design considerations to be resolved in the 2-8 Mc multicoupler system were as follows:

- (a) It must provide for simultaneous operation of two transmitters and/or receivers on a single whip antenna over a 4 to 1 (2-8 Mc) frequency range.
- (b) It must provide a means for time-sharing a third transmitter and/or receiver equipment with one of the other two by a simple switching arrangement.
- (c) It must be capable of operating into an antenna load having a relatively high capacitive reactance.
- (d) It must provide as low a loss as practicable.
- (e) It must be compact and relatively simple in design.

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As indicated by Marine Corps representatives, the antenna normally employed with the 2-8 Mc communication equipment is an 18-ft whip with a short feeder line to the transmitting equipment. Such an antenna is less than a quarter wavelength at all frequencies in the 2-8 Mc band and its reactive characteristic is capacitive. By calculation, this capacitive reactance was found to vary from about 1000 ohms at 2 Mc to about 200 ohms at 8 Mc. The multicoupler was designed<sup>2</sup> to operate into an antenna load having these characteristics.

Transmitters No. 1 and No. 2 of the 2-8 Mc antenna-multicoupler system (Figure 1, simplified diagram) operate on frequencies  $f_1$  and  $f_2$ , respectively, and parallel circuits  $L_1-C_1$  and  $L_2-C_2$  are tuned to resonance at frequencies  $f_1$  and  $f_2$ , respectively. If frequency  $f_2$  is not too close to  $f_1$  then the equivalent series resistance and reactance of circuit  $L_2-C_2$  will be small at  $f_1$ . The equivalent series resistance of circuit  $L_1-C_1$  will be high at resonance frequency  $f_1$ . Hence, transmitter No. 1 will deliver power to the antenna load ( $R_1 - j/\omega C_3$ ) if the reactance of the antenna is not too great. The effective reactance of the antenna is reduced by series inductance  $L_3$ . In practice, inductance  $L_3$  should be adjusted to resonate the antenna at the mean frequency between  $f_1$  and  $f_2$ . This makes it possible to feed the antenna efficiently at both frequencies and still provide the necessary isolation between the transmitters. With proper design of the circuit elements this multicoupler can be used with transmitters and/or receivers. It is basically limited to two equipments; however, a third channel, at frequency  $f_3$ , is provided on a time-sharing basis. This is accomplished by inserting another parallel resonant circuit in series with circuit  $L_1-C_1$  and resonating this circuit at  $f_3$ . The third transmitter or receiver is switched into the system in place of transmitter or receiver No. 1 by means of a suitable switching arrangement.

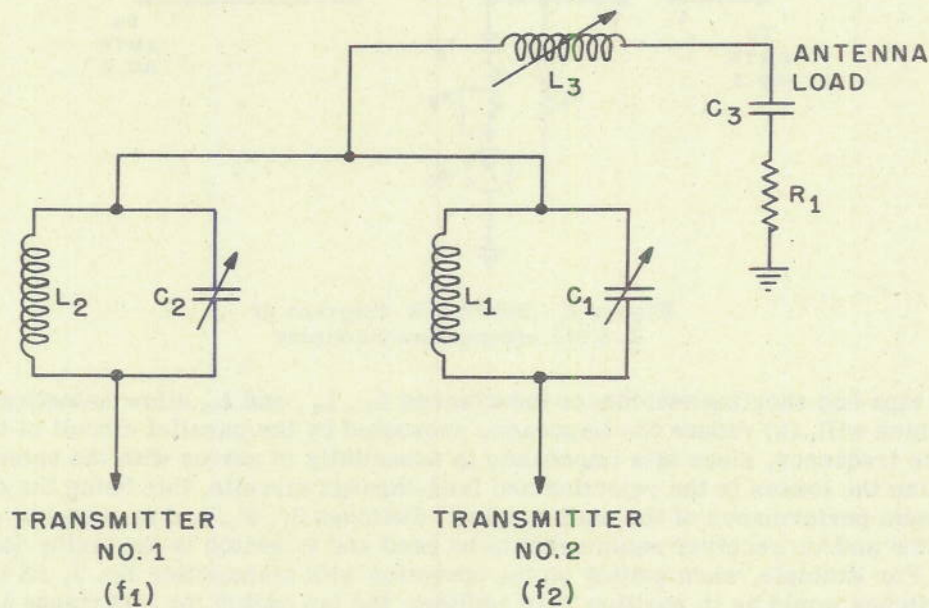


Figure 1 - Simplified schematic diagram of 2-8 Mc antenna-multicoupler system

<sup>2</sup> NRL ltr C-3910-118/51, to BuShips Code 833, 10 July 1951

The parallel-tuned circuits in the actual 2-8 Mc antenna multicoupler for three equipments (Figure 2) furnish the necessary isolation between the transmitter-receiver equipments. Circuit No. 1 is resonant to the operating frequency, say for example, 2 Mc, of transmitter No. 1. Hence circuit No. 1 offers a high impedance to energy at 2 Mc flowing toward transmitter-receiver No. 3, thus electrically isolating equipments No. 1 and No. 3. Likewise circuits No. 2 and No. 3 are resonated to the operating frequencies of transmitters No. 2 and No. 3, respectively, isolating equipments No. 2 and No. 3. Since circuit No. 3 is considerably off resonance at 2 Mc it affords a relatively low impedance path to the antenna for the energy from transmitter No. 1. The same action takes place with the other operating transmitter, thus permitting two equipments to operate simultaneously.

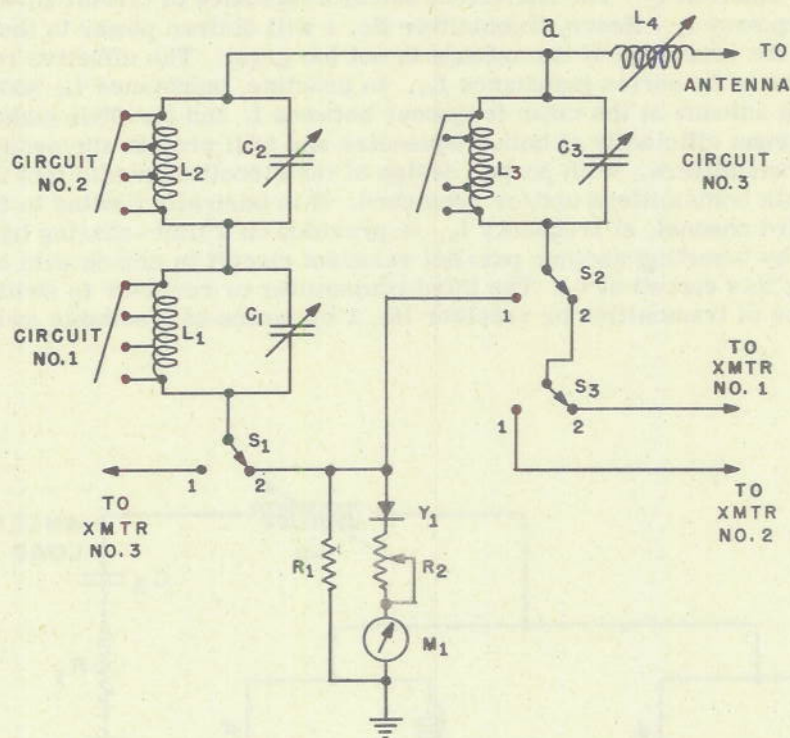


Figure 2 - Schematic diagram of 2-8 Mc antenna multicoupler

The taps and shorting switches on inductances  $L_1$ ,  $L_2$ , and  $L_3$  allow selection of inductance values which will, (a) reduce the impedance presented by the parallel circuit at the off-resonance frequency, since this impedance is essentially in series with the antenna, and (b) equalize the losses in the rejection and feed-through circuits, this being the condition for optimum performance of the multicoupler. Switches  $S_1$ ,  $S_2$ , and  $S_3$  serve to select the transmitter and/or receiver equipments to be used and to switch in the tuning-indicator circuit. For example, when setting up for operation with transmitter No. 1, all three of these switches would be in position 2; in addition, the tap switch for inductance  $L_2$  would be closed, shorting out  $L_2$ . The antenna loading coil  $L_4$  would be set at a previously calibrated setting so as to resonate the antenna at the mean of frequencies  $f_1$ ,  $f_2$ , and  $f_3$ . Circuit No. 3 would be set for the operating frequency of transmitter No. 3. Then with transmitter No. 1 energized, circuit No. 1 is tuned until a minimum reading is obtained

on the tuning-indicator meter  $M_1$ . This is the condition for optimum isolation between transmitters No. 1 and No. 3. When tuning the system for transmitter No. 3, switches  $S_1$  and  $S_2$  would be in position 1, and inductance  $L_2$  would be shorted out. Circuit No. 3 would then be adjusted for a minimum reading on the tuning-indicator meter.

The antenna loading inductance  $L_4$  is capable of resonating an 18-ft whip antenna over the range from 2.8-8 Mc. Its purpose is to lower the voltage at point "a" (Figure 2) which reduces the losses in the rejection circuits, and thus aids in equalizing the losses in the rejection and feed-through circuits. It lowers the Q of the antenna circuit which is advantageous in tuning the system.

The tuning indicator consists of crystal rectifier  $Y_1$  and microammeter  $M_1$  in series between the tuned circuits and ground. Resistor  $R_1$  serves to protect the detector circuit from overload and potentiometer  $R_2$  is used to vary the sensitivity of the detector circuit for fine tuning.

The experimental model multicoupler was constructed as compactly and as light in weight as practicable. The weight is 29 pounds and the over-all dimensions are: height, 13 inches; width, 13 inches; depth,  $12\frac{1}{2}$  inches. It is of interest to note that if the frequency range were changed from 2-8 Mc to 3-9 Mc, the dimensions of the unit could be reduced to about 11 x 11 x 11 inches, which would reduce the volume by 30 percent with a corresponding decrease in weight.

#### LABORATORY PERFORMANCE OF 2-8 Mc MULTICOUPLER

The 2-8 Mc multicoupler was operated with three communications equipments, Models TCS, BC-191, and AN/GRC-9, using a dummy load to simulate an 18-ft whip antenna. The performance factor of the multicoupler system in percent is defined as 100 times the ratio of the antenna power when the transmitter feeds the antenna through the multicoupler to the antenna power when the transmitter feeds directly into the antenna, the input power into the transmitter power amplifier being the same value for both measurements. It is obvious that this performance factor includes the performance of the antenna tuning circuits in the transmitter and thus could vary from transmitter to transmitter. The input impedance to the multicoupler circuit is a more desirable load for the transmitter than the regular antenna impedance. Thus if the efficiency of the multicoupler circuits is higher than the antenna matching circuits in the transmitter, it is possible for the performance factor of the multicoupler system to be greater than 100 percent (Figure 3).

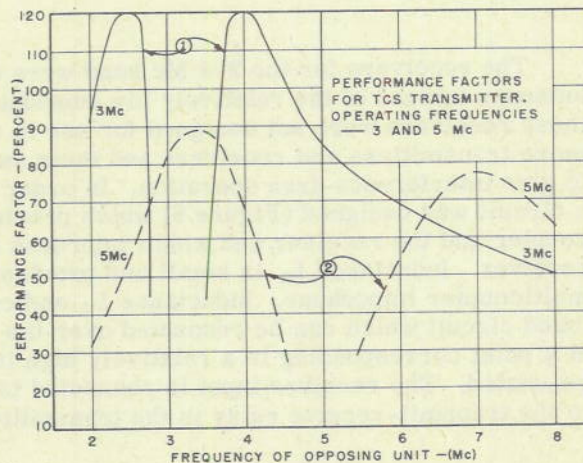


Figure 3 - Performance factors for TCS transmitter. Operating frequencies—3 and 5 Mc.

The multicoupler-system performance factor was measured for the three transmitting equipments indicated above as a function of the frequency separation between the two operating channels. In Figure 3, curve (1) gives this factor when the TCS transmitter and its associated multicoupler circuit were operated at 3.0 Mc. The second transmitter and its associated multicoupler circuit were operated over the frequency range 2-8 Mc, and the performance factor is plotted as a function of this operating frequency. The performance factor attains a maximum value of 120 percent at 2.5 and 4.0 Mc, and decreases rapidly for close spacing of operating frequencies. Curve (2) in Figure 3 shows the performance factor as a function of the operating frequency of the other multicoupler circuit when the TCS transmitter and its multicoupler circuit were operating at 5 Mc. Figures 4 and 5 show the performance factor when using BC-191 and AN/GRC-9 transmitters.

Multicoupler performance factors of 50 percent and 25 percent correspond to insertion losses of 3 and 6 db, respectively. It is evident that the insertion loss due to the multicoupler will be less than 3 db if reasonable precautions are taken in the selection of the operating frequencies, and should be less than 6 db in the general case.

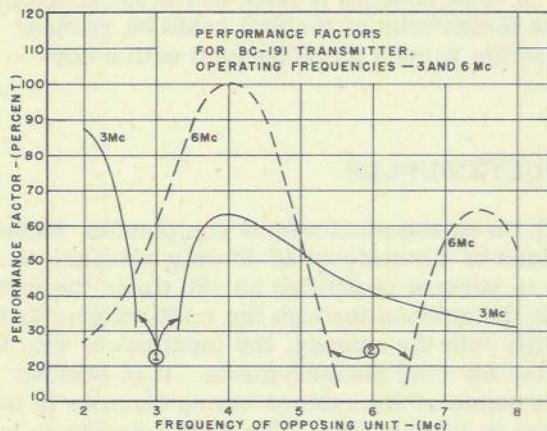


Figure 4 - Performance factors for BC-191 transmitter. Operating frequencies—3 and 6 Mc.

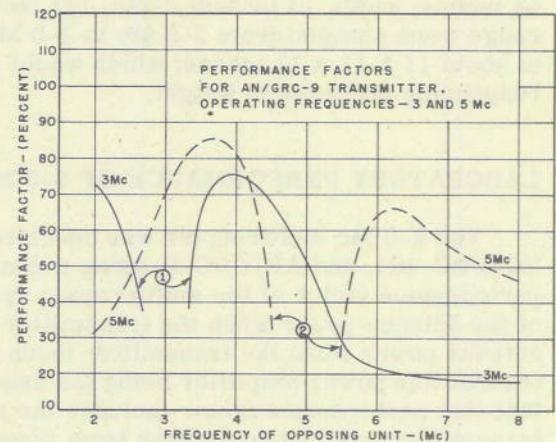


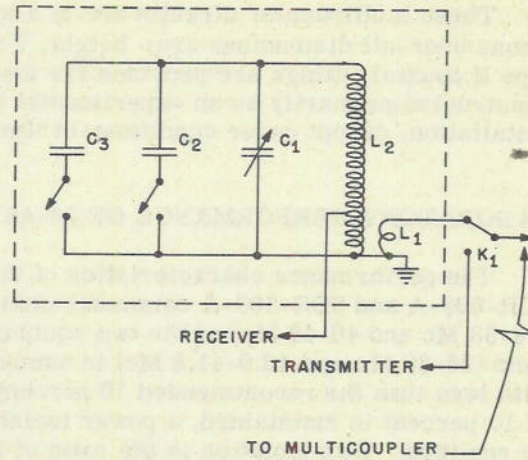
Figure 5 - Performance factors for AN/GRC-9 transmitter. Operating frequencies—3 and 5 Mc.

The receivers for the 2-8 Mc band were designed for use with high-impedance antennas instead of the relatively low impedance of the multicoupler system. In addition these receivers were not designed for use in a communication network in which one or more transmitters and receivers and their associated closely spaced antennas would have to give interference-free operation. In order to partially overcome these deficiencies, a circuit was designed (Figure 6) which provides impedance matching between the multicoupler and the receiver and which improves the isolation between the transmitter and receiver. Inductance  $L_1$  is small and provides a relatively low impedance to match the multicoupler impedance. Inductance  $L_2$  and capacitors  $C_1$ ,  $C_2$ , and  $C_3$  form a parallel-tuned circuit which can be resonated over the range 2-8 Mc. Inductance  $L_2$  is tapped at a point corresponding to a relatively high impedance when the parallel circuit is resonated. The receiver input is connected to this high-impedance point. Switch  $K_1$  is the transmit-receive relay in the transmitter.

28-48 Mc MULTICOUPLER

The 28-48 Mc multicoupler (Figure 7) was designed for use with a broadband antenna. This multicoupler provides for simultaneous operation into a single antenna of one transmitter or receiver operating in the 28-38 Mc band and one transmitter or receiver operating in the 40-48 Mc band. It consists of two essentially identical sections; each section contains: (a) a parallel resonant circuit ( $L_1 - C_1$  in section 1 and  $L_2 - C_2$  in section 2); (b) a coupling capacitor ( $C_3$  and  $C_4$  for sections 1 and 2, respectively) between the inner conductor of the antenna-transmission line and the parallel circuit, and; (c) a tuning-indicator circuit. The inner conductors of the 50-ohm coaxial feed lines are connected to inductances  $L_1$  and  $L_2$  at points slightly above ground. When the parallel circuits are tuned to resonance this tap corresponds to 50 ohms on the resistance curve for the circuits, thereby matching the 50-ohm characteristic impedance of the feed lines to the transmitters or receivers.

The tuning indicators are directional couplers connected in series with the transmitter feed line and are designed to indicate the relative magnitude of the energy reflected from the tuned circuit back toward the transmitter. The object when tuning the unit is to adjust the variable capacitors ( $C_1$  or  $C_2$ ) until a minimum reading is obtained on meter  $M_1$ . Under these conditions the reflected energy on the transmitter feed line is of negligible magnitude and the transmitter is operating into essentially a 50-ohm resistive load. The coupling capacitors ( $C_3$  and  $C_4$ ) are small (3 to  $4\mu\mu\text{f}$ ) and since they are in series between the tuned circuits, they provide a high impedance path and the required isolation between the transmitters.



NOTE:

$K_1$  IS TRANSMIT-RECEIVE RELAY IN TRANSMITTER

Figure 6 - Schematic diagram of matching unit for receivers with high-input impedance

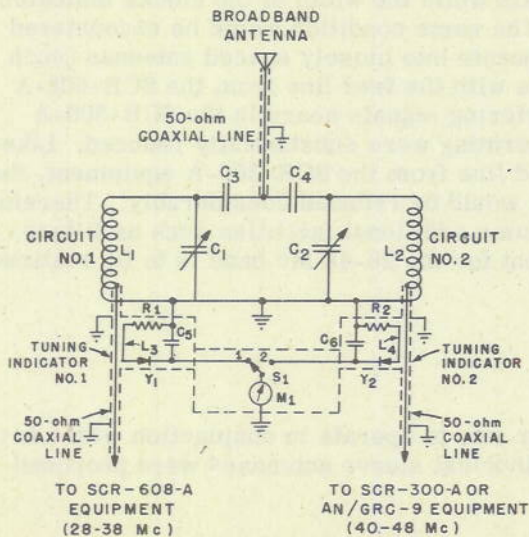


Figure 7 - Schematic diagram of 28-48 Mc antenna multicoupler

These multicoupler circuits are in a self-contained unit which weighs 10 pounds and whose over-all dimensions are: height, 7 inches; width, 8 inches; depth, 7 inches. Standard type N coaxial fittings are provided for the coaxial feed lines and the antenna line. It was constructed primarily as an experimental model and is not sufficiently rugged for a field installation, except under conditions of limited maneuvers.

#### LABORATORY PERFORMANCE OF 28-48 Mc MULTICOUPLER

The performance characteristics of this multicoupler unit were determined using SCR-608-A and SCR-300-A communications equipments. Since the frequency ranges (28-38 Mc and 40-48 Mc) of the two equipments do not overlap, there is only a narrow band (36-38 Mc and 40.0-41.8 Mc) in which it would be possible to operate the equipments with less than the recommended 10 percent channel separation. When a channel separation of 10 percent is maintained, a power isolation ratio of at least 200 to 1 or about 23 db can be realized. This isolation is the ratio of the power into a 50-ohm resistive antenna load at the operating frequency to the power at that same frequency appearing at the 50-ohm terminated input terminal of the other tuned circuit. Since this latter input terminal is normally connected to the output circuit of the transmitter or the input circuit of the receiver, the terminating impedance is not 50 ohms at this off-resonance frequency. Hence the isolation will generally be greater than 23 db. As the channel separation increases, the isolation increases and conversely, as the channel separation decreases, the isolation decreases.

When a 50-ohm resistive antenna load is used and the multicoupler circuits are properly adjusted for operation, the impedance presented at the input of the 28-38 Mc and 40-48 Mc sections varies from 46 to 58 ohms and 54 to 74 ohms, respectively, over the frequency range. Therefore, a much more desirable antenna load is presented to the transmitters than when they are feeding the regular whip-type antenna.

During the course of this investigation it was found that a considerable number of interfering signals would be present in this system due to transmitter harmonics and spurious responses in the receivers. The possible number and intensity of interfering signals heard in the SCR-300-A receiver when the SCR-608-A transmitter is operating (both equipments connected to the multicoupler) are shown in Figure 8. The height of the plotted blocks indicates the relative strength of the interfering signals while the width of the blocks indicates the frequency spread of the interfering signals. The same condition would be encountered in any installation in which several equipments operate into closely spaced antennas (such as on a tank). By using a low-pass filter in series with the feed line from the SCR-608-A equipment, the number and strength of these interfering signals heard in the SCR-300-A receiver when the SCR-608-A transmitter was operating were substantially reduced. Likewise, if a high-pass filter were inserted in the feed line from the SCR-300-A equipment, the interference resulting in the SCR-608-A receiver would be reduced considerably. Therefore, it appears that it would be necessary to provide some additional facilities such as filters, if interference-free operation in existing equipment for the 28-48 Mc band is to be realized either with or without the use of multicouplers.

#### ANTENNA DESIGN

It was agreed<sup>3</sup> that the 28-48 Mc multicoupler was to operate in conjunction with a broad-band sleeve-type antenna. Several designs of cylindrical sleeve antennas<sup>4</sup> were proposed

<sup>3</sup> Op. cit., footnote 1

<sup>4</sup> NRL ltr S-3910-68/51, Serial 8521, to BuShips Code 833, 2 April 1951

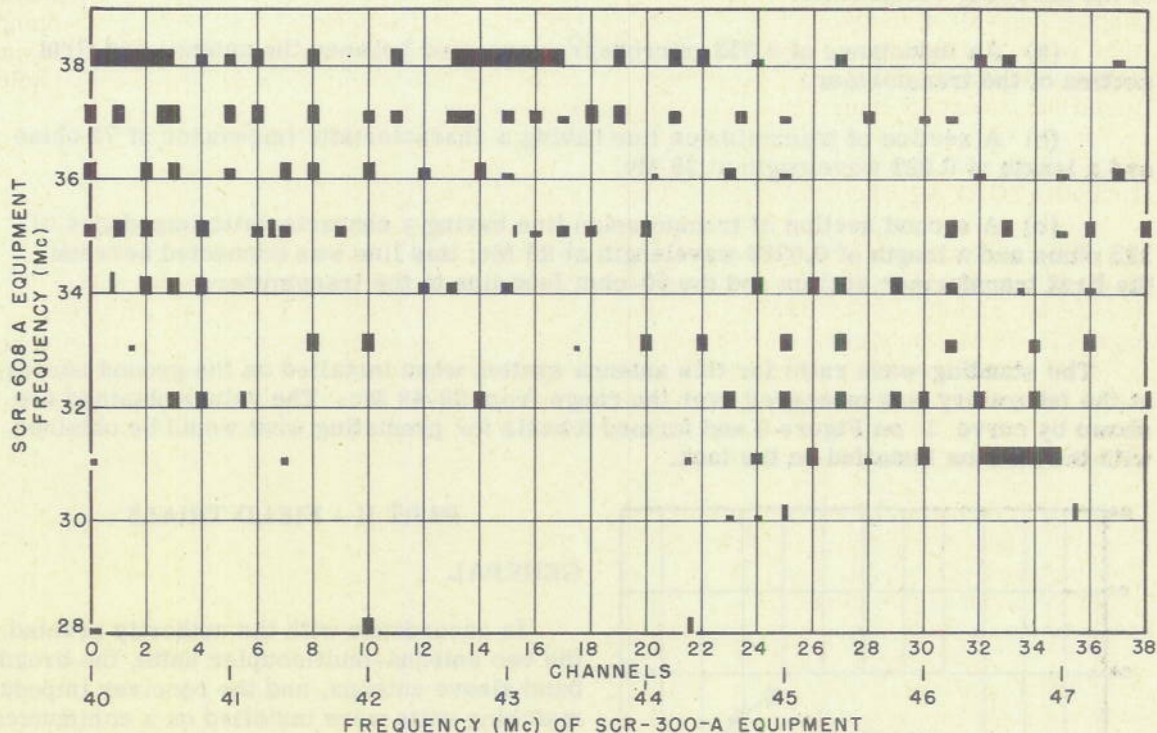


Figure 8 - Possible interference points  
(SCR-608-A transmitting and SCR-300-A receiving)

for the tank installation. The antenna selected by Marine Corps representatives on the basis of physical considerations consisted of a sleeve 5.72 inches in diameter and 3.57 feet long, with an upper-radiating section 0.72 inch in diameter and 3.57 feet long, thus making an over-all length of 7.14 feet. An antenna of these dimensions when used with the proper matching transformer will maintain a standing-wave ratio greater than 0.3 over the 28 to 48 Mc range. This standing-wave ratio is satisfactory for multicoupler operation, but may not be realized in all tank installations. Antenna-impedance measurements were made at the laboratory using an infinite ground screen; but a tank and its surroundings may present a much different ground system. In addition, coupling between the sleeve antenna and the tank structure and other antennas will affect its impedance; however, by proper placement of the antenna and redesign of the matching transformer after installation, these effects can be minimized and comparable results should be obtained.

Due to mechanical considerations, the above design was modified when the antenna for the field trials was constructed. To allow the use of standard-diameter aluminum tubing, the diameter of the sleeve section was increased to 6 inches and the diameter of the upper-radiator section was increased to 0.75 inch. Both the sleeve and the upper-radiator sections retained the 3.57-ft length and thus maintained the 7.14-ft over-all length for the antenna. A suitable feed-through insulator for mounting the upper-radiator section on the sleeve section was constructed of mycalex. The base of the sleeve section was provided with a flange to permit mounting the antenna in a vertical position on a deck.

After making these changes in the antenna, it was necessary to redesign the matching transformer. This transformer was made up of sections of transmission line which were available instead of using line of optimum impedance. The resulting transformer consisted

of the following components:

- (a) An inductance of 0.353 microhenry connected between the antenna and first section of the transformer.
- (b) A section of transmission line having a characteristic impedance of 75 ohms and a length of 0.022 wavelength at 28 Mc.
- (c) A second section of transmission line having a characteristic impedance of 125 ohms and a length of 0.0789 wavelength at 28 Mc; this line was connected between the first transformer section and the 50-ohm feed line to the transmitter.

The standing-wave ratio for this antenna system when installed on the ground screen at the laboratory was measured over the range from 28-48 Mc. The values obtained are shown by curve 1 on Figure 9 and formed a basis for predicting what would be obtained with the antenna installed on the tank.

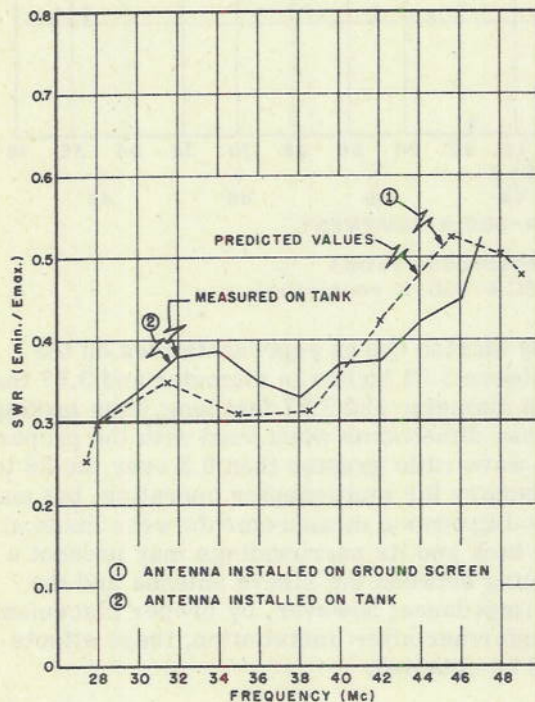


Figure 9 - Voltage standing-wave ratio of broadband-sleeve antenna system for 28 to 48 Mc

of signal strengths when using the sleeve antenna and the multicoupler with signal strengths when using the regular whip antenna without the multicoupler.

(f) Demonstration of simultaneous operation of two transmitter and/or receiver equipments with the multicouplers.

<sup>5</sup> CMC ltr AC-11-bjw, to CG FMF At, 2 May 1951

## PART II - FIELD TRIALS

### GENERAL

In accordance with the authority granted,<sup>5</sup> the two antenna-multicoupler units, the broadband-sleeve antenna, and the receiver impedance-matching units were installed on a communication control tank at Camp Lejeune, N. C., on June 5, 1951 for operational evaluation. This evaluation procedure was divided into seven parts as follows:

(a) Measurement of impedance of the sleeve antenna when installed on the tank.

(b) Measurement of antenna patterns with the four proposed antennas using the multicouplers.

(c) Measurement of antenna patterns using the eight regular whip antennas without the multicouplers.

(d) Comparison of signal strengths in the 2-8 Mc band for the 18-ft whip antenna with and without the multicoupler.

(e) Comparison, in the 28-48 Mc band,

(g) Instruction of Marine Corps personnel in operation of the multicoupler equipment.

The scope of this project did not permit going into extensive systems operations. However, a few instances of interference due to transmitter harmonic frequencies or spurious responses in the receiving equipment were demonstrated and were shown to be present with or without the multicoupler equipment.

#### ORIGINAL INSTALLATION ON COMMUNICATION CONTROL TANK

The communication control tank with the eight whip antennas installed is shown in Figure 10. Figure 11 is an outline plan view of the tank showing the relative locations and lengths of these antennas; the arrangements of the associated transmitter-receiver equipments inside the tank is shown also. Radio frequency cable RG-8/U was used for interconnections to the antennas on all equipments operating at 20 Mc and above, while unshielded line was used on the equipments operating below 12 Mc. It will be observed that this arrangement permitted use of relatively short lengths of interconnecting line to all of the antennas except in the case of the SCR-522 equipments where the antenna lines were about 12 feet in length.

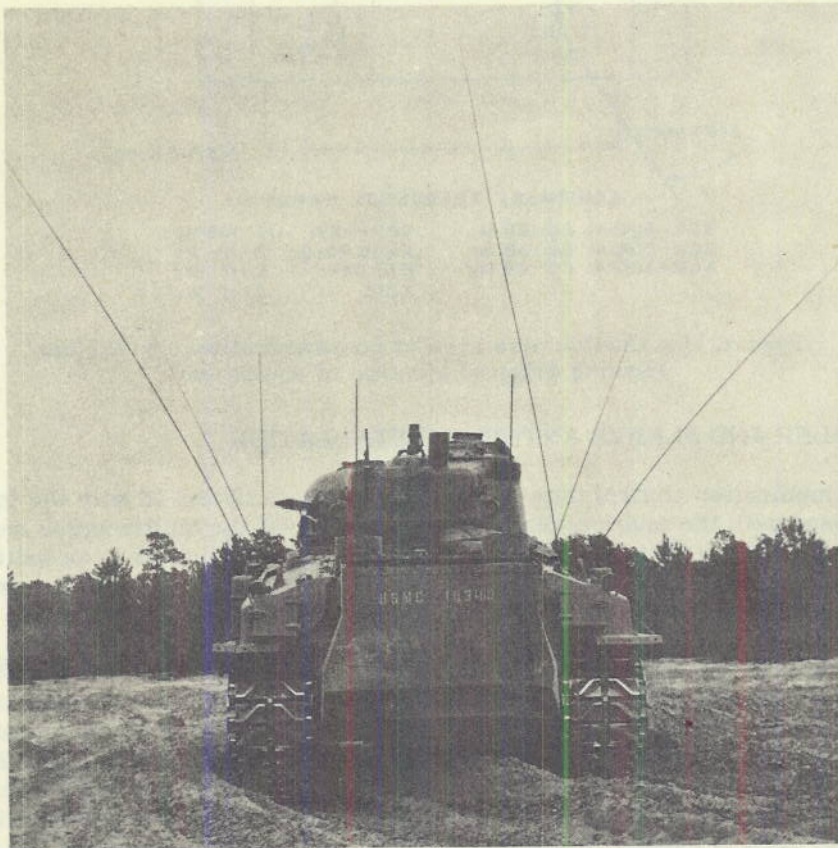


Figure 10 - Communication control tank with eight whip antennas

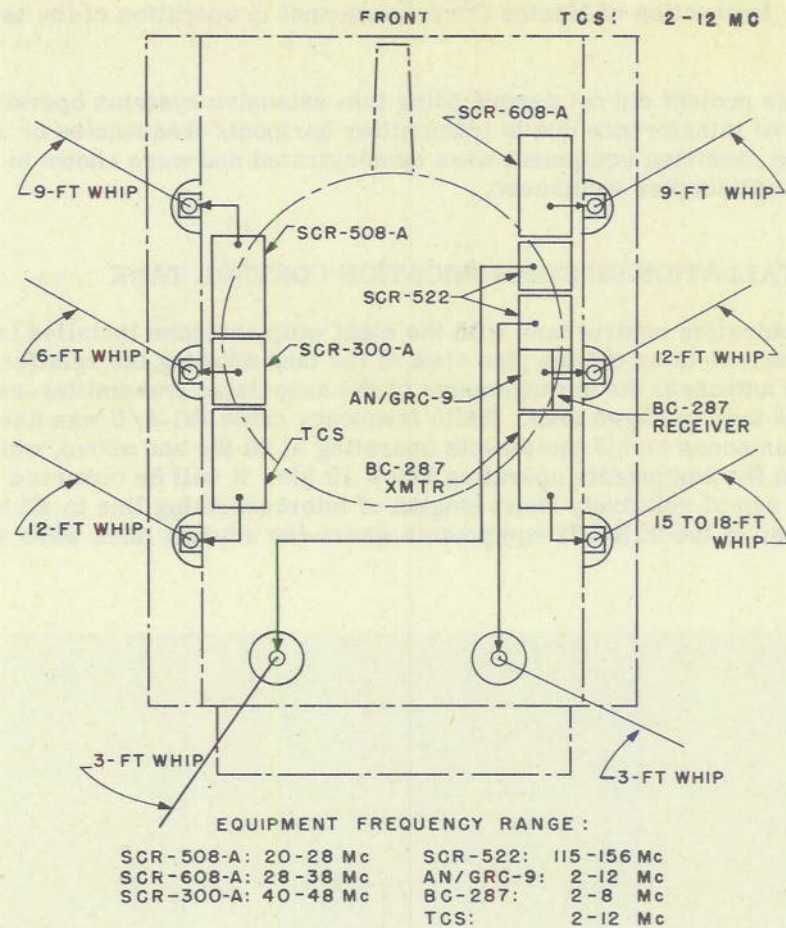


Figure 11 - Outline plan view of communication control tank showing original location of equipment

#### MULTICOUPLER AND SLEEVE ANTENNA INSTALLATION

The communication control tank is shown in Figures 12 and 13 with the four-antenna installation used with the multicoupler system. A view of the multicoupler units as they were installed for the field trials is shown in Figure 14. Figure 15 is an outline plan view of the tank showing the relative location of these four antennas and also the arrangement of the transmitter-receiver equipment and the multicouplers inside the tank.

In order to provide space for the multicoupler units, one of the two SCR-522 (vhf) equipments was removed and the 2-8 Mc multicoupler was secured in that space. The 28-48 Mc multicoupler was fastened to the top of the 2-8 Mc multicoupler case. The interconnections between the SCR-300-A and SCR-608-A equipments and the 28-48 Mc multicoupler were made with RG-8/U (50-ohm) coaxial line. The coaxial line normally used to connect the displaced SCR-522 equipment to the 3-ft whip antenna (left rear corner of vehicle) was used to connect the output terminal of this multicoupler to the sleeve antenna.



Figure 12 - Communication control tank with four-antenna installation, right side view



Figure 13 - Communication control tank with four-antenna installation, rear view

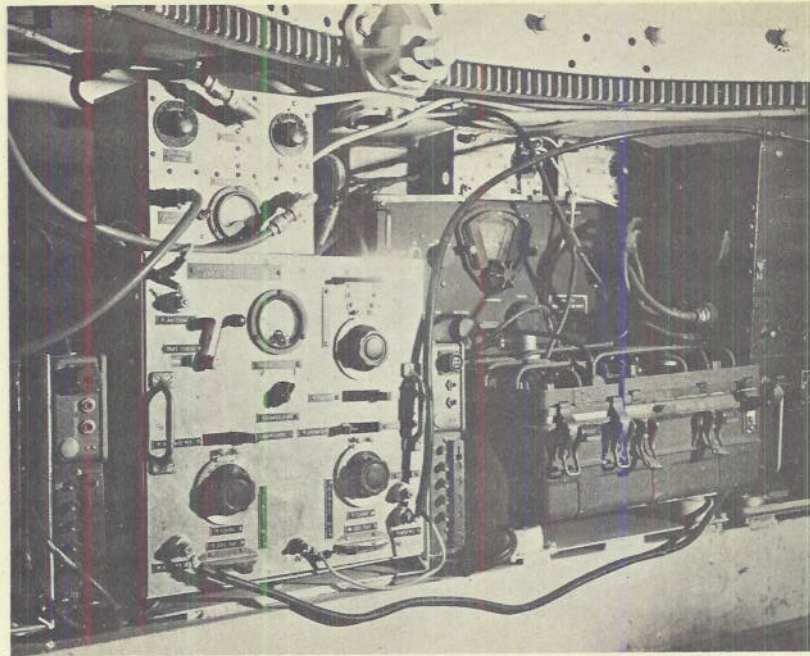


Figure 14 - Antenna-multicoupler units installed in communication control tank for field trials

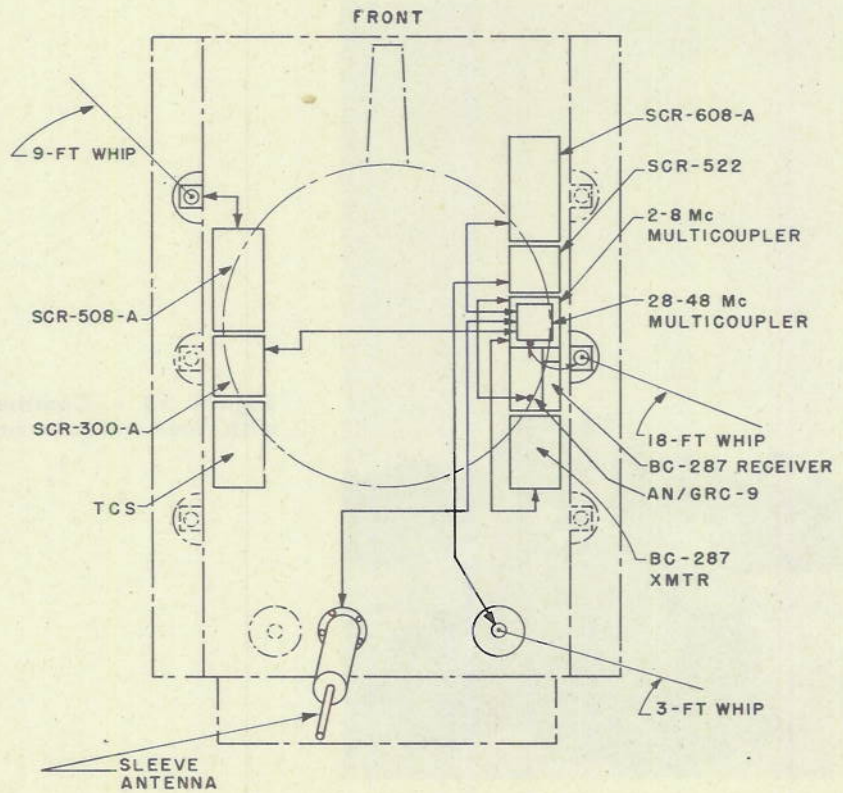


Figure 15 - Outline plan view of communication control tank showing arrangement of equipment during field trials

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The BC-287 and AN/GRC-9 equipments were adjacent to each other and to the location selected for the multicoupler, thus permitting the use of short interconnecting cables between equipments and to the base of the 18-ft whip antenna. Radio frequency cable RG-63/U (125-ohm characteristic impedance) was used for these interconnections. The receiver impedance-matching units were installed on top of the receiver for the BC-287 equipment resulting in reasonably short interconnecting leads for this receiver and the AN/GRC-9 receiver.

The location of the TCS equipment made it impractical for the purpose of this project to connect this equipment to the 2-8 Mc multicoupler in order to demonstrate its use on a time-sharing basis as provided for in the multicoupler.

The base of the sleeve antenna was secured to the top rear deck of the vehicle by means of cap screws tapped into a steel plate which was welded to the deck. It was therefore unnecessary to drill any additional holes in the skin of the vehicle.

Should this antenna multicoupler system be adopted for use in this type of communication control tank, a rearrangement of equipment would be necessary in order to simplify the interconnections between units. Figure 16 shows a proposed arrangement which would require a minimum length for all interconnecting cables.

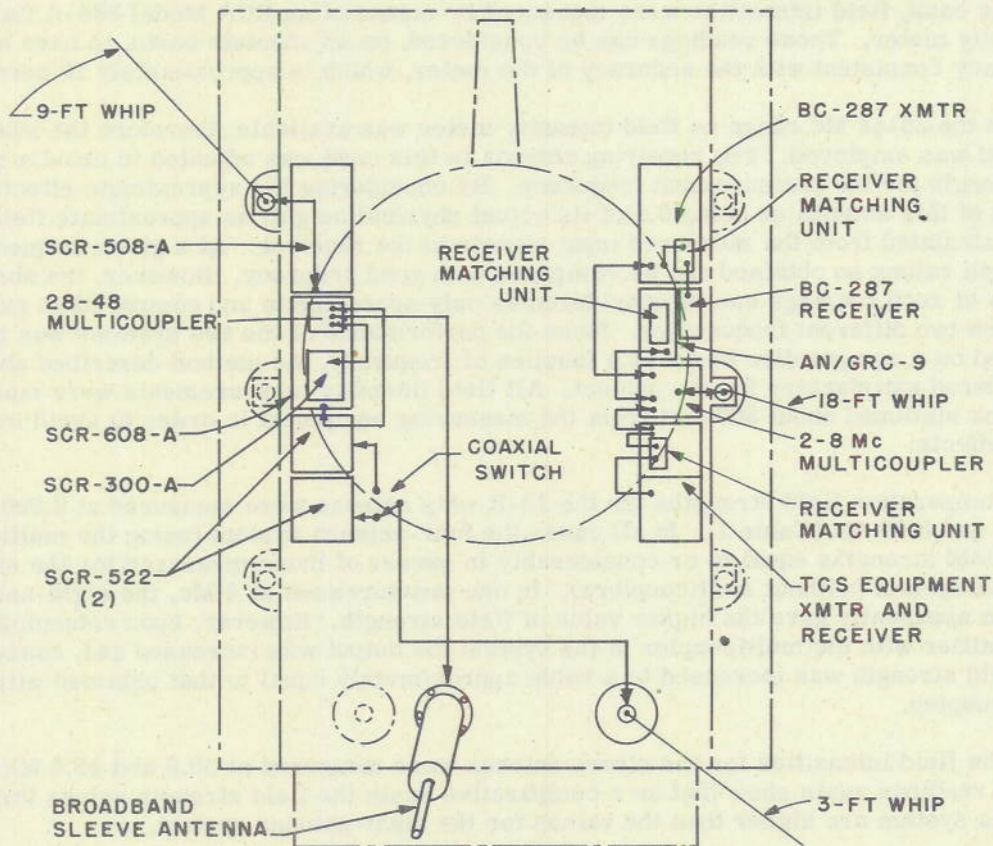


Figure 16 - Outline plan view of communication control tank showing proposed arrangement of equipment for final installation

## MEASUREMENTS AND RESULTS

### Sleeve Antenna Impedance

Measurements of the impedance of the sleeve antenna as installed on the tank were made at 1 Mc intervals in the 28-48 Mc band using a General Radio Type 916-A r-f bridge. Convenience and a-c power requirements necessitated connection of the antenna to the bridge through 23 feet of 50-ohm line.

Curve (2), Figure 9 shows the standing-wave ratio as a function of frequency as calculated from the impedance measurements. It will be noted that the standing-wave ratio is in general nearer unity for the tank installation than for the laboratory installation. This is probably due to an increase in the antenna resistance caused by higher ground losses. Since the standing-wave ratio was greater than 0.3 over the 28-48 Mc band, the antenna was considered satisfactory without further design work or alteration.

### Field Intensity

In order to provide a comparison between the tank communication systems using the multicoupler units (four antennas) and the original installation (eight antennas), field intensity measurements were made on the tank driving range at Camp Lejeune. In the 2-8 Mc band, field intensities were measured by means of an RCA Model 308-A field intensity meter. These readings can be considered, on an absolute basis, to have an accuracy consistent with the accuracy of the meter, which is approximately 10 percent.

In the 28-48 Mc range no field intensity meter was available; therefore the substitution method was employed. The receiving antenna in this case was adjusted to about a quarter wavelength for the measurement frequency. By considering the approximate effective height of this antenna as being 0.6 of its actual physical height, an approximate field strength was calculated from the measured input signals to the receiver. At a given frequency, field strength values so obtained can be compared with good accuracy. However, the absolute values of such readings can be considered as only approximate and compared as such between two different frequencies. Since the performance of the two systems was to be considered on a comparative basis as a function of frequency, the method described above was considered satisfactory for the project. All field intensity measurements were made with the tank stationed about 500 feet from the measuring equipment in order to avoid induction field effects.

Comparative field strengths for the 18-ft whip antenna were measured at 2.090, 4.015, 5.950, and 8.00 Mc (Table 1). In all cases, the four-antenna system (using the multicouplers) gave field strengths equal to or considerably in excess of those measured for the eight-antenna system (without multicouplers). In one measurement at 8 Mc, the eight-antenna system apparently gave the higher value of field strength. However, upon returning the transmitter with the multicoupler in the system the output was increased and, consequently, the field strength was increased to a value approximately equal to that obtained without the multicoupler.

The field intensities for the sleeve antenna were measured at 30.6 and 45.6 Mc (Table 1). These readings again show that on a comparative basis the field strength values for the four-antenna system are higher than the values for the eight-antenna system.

TABLE 1  
Field Strength Data

Frequency (Mc)	Equipment Used	Field Strength with Multicoupler in Circuit ( $\mu\text{v}/\text{m}$ )	Field Strength without Multicoupler ( $\mu\text{v}/\text{m}$ )
18-foot Whip Antenna			
2.090	BC-287	21,700†	14,600†
2.090	BC-287	21,700 †	15,600 †*
4.015	BC-287	96,300	57,300
5.950	AN/GRC-9	39,500	9,150
5.950	AN/GRC-9	32,400	9,620*
8.00	AN/GRC-9	13,600	25,000
8.00	AN/GRC-9	25,100*	
		Sleeve Antenna	9-foot Whip Antenna
30.6	SCR-608-A	58,200	23,300
45.6	SCR-300-A	3,357	2,640

† Transmitter operated at one-half power  
\* Transmitter retuned for higher output

It should be emphasized that this gain in field strength is achieved as a result of the ability of the multicoupler to match the impedance of the transmitter output circuits to the antenna impedance. By thus matching the system, the output power of the transmitter, and consequently the power radiated from the antenna, is increased.

Radiation Patterns

Radiation patterns were measured in the horizontal plane for several communication frequencies used by the Marine Corps. In order to compare the directional characteristics and hence the coverage capabilities of these antennas, measurements were made at the same frequency for both the four- and eight-antenna systems wherever possible. The communication control tank described circles at its minimum turning radius, which was 30 feet, while a continuous recording of the field strength was being made at a distance of about 500 feet. An Esterline-Angus Model AW (5 ma, dc) recorder was used. Relative bearings at 0, 90, 180, 270, and 360 degrees were observed at the tank and then signaled to the recording station. These bearings were recorded on the radiation pattern chart. Since the tank turned at essentially a constant rate, intermediate relative bearing points were interpolated on the chart. The field intensity at relative bearing 0, which corresponds to the tank bearing when heading toward the recording equipment, was measured and from this the field intensity at all other bearings was determined. During these pattern measurements no attempt was

made to adjust the transmitting equipment for optimum performance. The only requirement was for adequate radiated power to obtain a satisfactory signal at the recording equipment. The important parameter here is the shape of the pattern. A study of these radiation patterns (Figures 17, 18, 19, and 20) will show that the four-antenna system has better omnidirectional coverage than the eight-antenna system in the 28-48 Mc band. The patterns in the 2-8 Mc band for the four-antenna system are essentially omnidirectional. No pattern measurements were made for the eight-antenna system in this frequency range and consequently no direct comparisons are possible. In general, the coupling between electrically short antennas, which is the case in the 2-8 Mc band, affects the pattern for only very narrow frequency bands. The probability of this coupling affecting the antenna pattern increases as the number of antennas increases, but it should not seriously affect the eight-antenna system. One of the obvious advantages of the four-antenna system is the general improvement in antenna patterns.

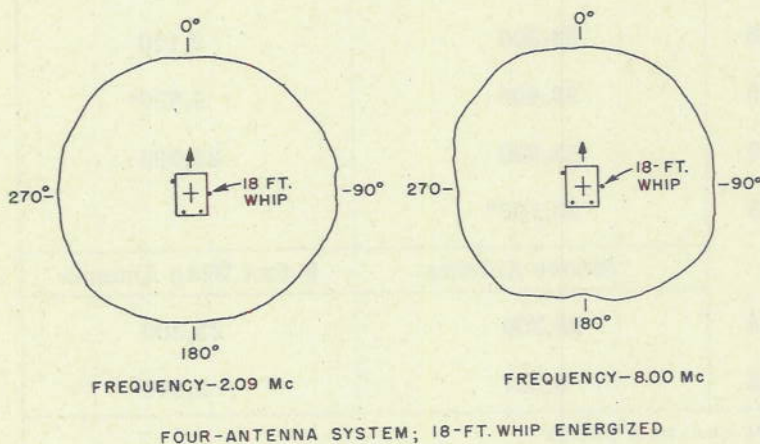


Figure 17 - Radiation patterns for communication control tank

Figure 18 - Radiation patterns for communication control tank

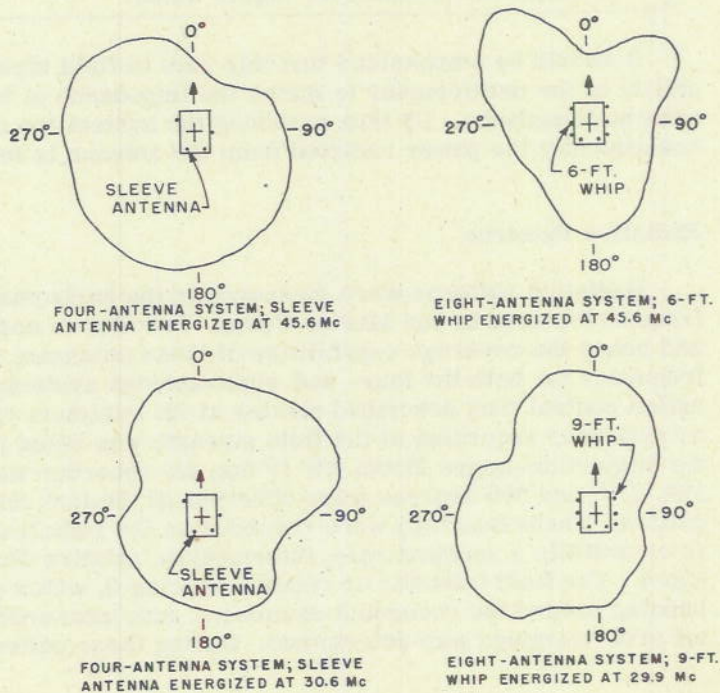
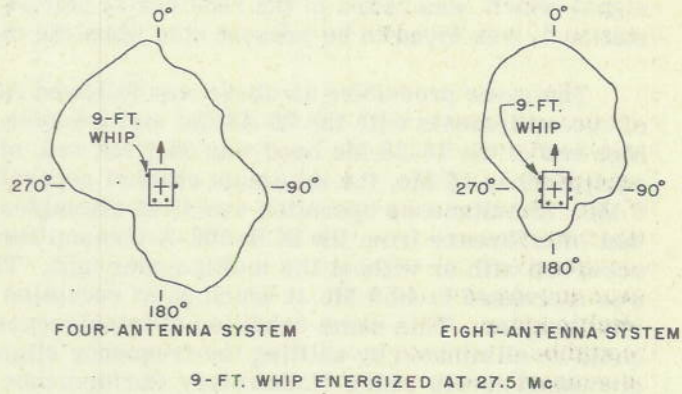


Figure 19 - Radiation patterns for communication control tank



9- FT. WHIP ENERGIZED AT 27.5 Mc

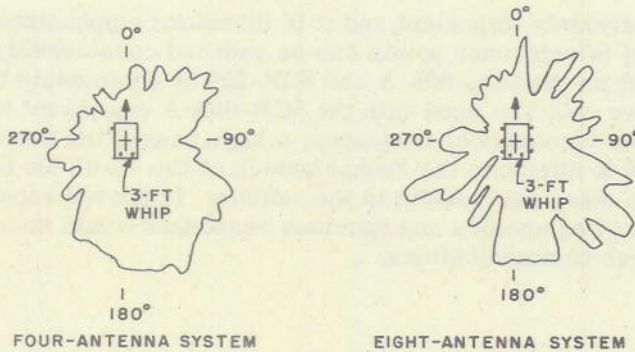


Figure 20 - Radiation patterns for communication control tank

3- FT. WHIP ENERGIZED AT 142.56 Mc

**Simultaneous Operation**

Two communication circuits were set up, one in the vehicle (station 1) and the other at a point about 1 mile away (station 2), in order to demonstrate simultaneous operation of two transmitter and/or receiver equipments through the multicoupler units. The channels used in the 2-8 Mc band were 2090 kc ( $f_1$ ) and 2792 kc ( $f_2$ ) for one test, and 6475 kc ( $f_3$ ) and 7995 kc ( $f_4$ ) for another test. The communication circuits were operated as follows:

- (a) Station 1 transmitting on  $f_1$  and receiving on  $f_2$ ,  
 Station 2 receiving on  $f_1$  and transmitting on  $f_2$ ;
- (b) Station 1 transmitting on  $f_1$  and  $f_2$ ,  
 Station 2 receiving on  $f_1$  and  $f_2$ ;
- (c) Station 1 receiving on  $f_1$  and  $f_2$ ,  
 Station 2 transmitting on  $f_1$  and  $f_2$ .

This same procedure was followed using channels  $f_3$  and  $f_4$ . In no case did interference occur between channels as a result of using the multicoupler units. However, an interfering

signal which was heard in the receiver at station 2 when channel  $f_1$  was transmitting at station 1, was found to be present also when the multicoupler was not used.

The same procedure as above was followed in demonstrating simultaneous operation of two equipments with the 28-48 Mc multicoupler. The only available channel near the high end of the 28-38 Mc band was 35.1 Mc and, since the lower limit of the SCR-300-A equipment is 40 Mc, the minimum channel separation that could be obtained was about 5 Mc. Simultaneous operation was first attempted at 35.1 Mc and 40.1 Mc. It was found that interference from the SCR-608-A transmitter blocked the SCR-300-A receiver. This occurred with or without the multicoupler unit. The frequency of the SCR-300-A equipment was increased to 40.6 Mc at which point reception was interference free with or without the multicoupler. This same condition of interference was found on some other channels and could be eliminated by shifting the frequency slightly. This condition of interference is discussed herein under "Laboratory Performance of the 28-48 Mc Multicoupler" and is illustrated in Figure 8.

The problem of interference is extremely important, and it is therefore emphasized again that the number and magnitude of interference points can be reduced considerably through the use of filters in the lines from the SCR-608-A and SCR-300-A equipments to the multicoupler unit. A low-pass filter could be used with the SCR-608-A equipment to attenuate the harmonics of the 28-38 Mc fundamental frequency; a high-pass filter could be used with the SCR-300-A equipment to attenuate the subharmonics of the 40-48 Mc band. These considerations can be applied to other equipments in the vehicle. Improved receiver and transmitter design for elimination of harmonics and spurious responses would do a great deal in obtaining interference-free communications.

#### GENERAL OBSERVATIONS

The field tests conducted at Camp Lejeune were planned to give Marine Corps personnel the necessary minimum amount of training for the successful operation of the multicouplers, transmitters, and receivers as a system. This training will be useful to the Marine Corps personnel in conducting further operational tests which are planned for the near future. The tests permitted the multicouplers, transmitters, and receivers to be tuned in a manner consistent with that which would be expected in actual practice, and thus gave the Marine Corps personnel an opportunity to study the equipment. One Marine Corps radio operator commented that after he was familiar with the multicoupler system, he found it considerably easier to tune and obtain normal transmitter output than when tuning the transmitters without the multicouplers.

During the field trials, several problems arose which were beyond the scope of the project, the more important of which was the presence of cross-channel interference due to limitations in the transmitting and receiver equipment used in the tank. The field trials clearly demonstrated the need for a system engineering study of radio equipment used by the Marine Corps in any system requiring closely spaced transmitting and receiving equipment and associated antennas.

The Marine Corps observers considered it essential to reduce the physical size of the sleeve antenna, and if possible, to use a whip. It should be emphasized that the work on this problem to date was done as an interim measure and that it should be possible to reduce the physical size of both the sleeve antenna and the multicoupler unit through a more complete investigation of the problem.

## CONCLUSIONS

(a) The field strength or the efficiency of the transmitter antenna system was equal to or greater in both the 2-8 Mc and the 28-48 Mc bands when using the four-antenna system with multicouplers as compared to the original eight-antenna system.

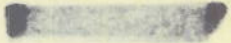
(b) The four-antenna system with multicouplers had better omnidirectional radiation patterns in the 28-48 Mc band than the original eight-antenna system.

(c) Simultaneous operation of the radio equipments in the 2-8 Mc band and the 28-48 Mc band could be obtained without increasing the amount of interference which is inherent in the equipments used in the system.

## RECOMMENDATION

It is recommended that the Marine Corps study the results of these field trials together with the operational tests planned by the Marine Corps at Camp Lejeune and then determine if further research and development work on this problem is justified.

\* \* \*



(a) The test results show that the efficiency of the transmitter system was equal to or better than that of the receiver system when using the test equipment. The test results also show that the efficiency of the receiver system was equal to or better than that of the transmitter system when using the test equipment.

(b) The test results show that the efficiency of the transmitter system was equal to or better than that of the receiver system when using the test equipment. The test results also show that the efficiency of the receiver system was equal to or better than that of the transmitter system when using the test equipment.

(c) The test results show that the efficiency of the transmitter system was equal to or better than that of the receiver system when using the test equipment. The test results also show that the efficiency of the receiver system was equal to or better than that of the transmitter system when using the test equipment.

RECOMMENDATIONS

It is recommended that the test results be used to guide the design of the transmitter and receiver systems. The test results show that the efficiency of the transmitter system was equal to or better than that of the receiver system when using the test equipment. The test results also show that the efficiency of the receiver system was equal to or better than that of the transmitter system when using the test equipment.

