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COMBAT INFORMATION CENTER COMMUNICATIONS SYSTEM

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COMBAT INFORMATION CENTER COMMUNICATIONS SYSTEM

R. B. Lewis and D. J. McLaughlin

May 25, 1951

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ABSTRACT

A system has been devised for monitoring the radio circuits entering a modern shipboard Combat Information Center (CIC) as an alternative to the present system using loudspeakers. The background of noise from the speakers, with the attendant confusion and mental fatigue resulting therefrom, has been alleviated by use of a multichannel pocket receiver using hearing-aid-style earpieces. Complete mobility within the CIC is maintained, and coverage of several radio channels is possible for any officer in CIC with no audible noises to disturb other personnel.

The application of similar techniques is cited as a possible aid toward solving the problem of communication with flight-deck personnel under high ambient-noise-level conditions.

PROBLEM STATUS

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

AUTHORIZATION

NRL Problem R07-25R
RDB NR 507-250

Manuscript submitted for publication: April 3, 1951

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COMBAT INFORMATION CENTER COMMUNICATIONS SYSTEM

INTRODUCTION

This project was originated primarily as a means of reducing the noise level and improving the flexibility of communications in the Combat Information Center (CIC) of a modern warship. In the normal course of their duties, the Operations Officer, the CIC Officer, the Air Intercept Officer, the Gunnery Liaison Officer, and the Surface Plot Officer must maintain surveillance over certain radio circuits, but cannot be restricted by ordinary headphones. They find it necessary to move about to view various plots, displays, and operations, and have had to rely upon low-fidelity loudspeakers mounted overhead, each emitting a continual background of noise and interference between radio voice messages. With three or four radio circuits in operation, the cumulative noise level in CIC contributes to mental fatigue and increases the probability of errors in interpretation. Confusion can also occur as to the identity of the circuit over which a given message originated.

It was suggested that this undesirable situation might be alleviated by a communication system consisting of a small multichannel receiver worn in the shirt pocket, connected to a hearing-aid-style earpiece. A loop antenna worn about the neck would permit a reasonably constant signal pickup throughout the CIC from a field established by a large loop suspended from overhead and encircling the operating area. By means of a selector switch in his receiver, an officer can continuously monitor any of three channels at will, without being restricted by trailing cords or cumbersome equipment, in his movements about CIC.

Some thought was given to a similar system permitting a reply to be made over a miniature pocket transmitter, without returning to a specific position. It seemed evident that there was not an urgent requirement for such a scheme, the only benefit being a minor convenience for the user. Actually, the greatest utility of the CIC Communication System would be in its ability to provide a means of constantly monitoring selected circuits from any position in the CIC space without cumbersome restrictive equipment, without disturbing or confusing those who do not require the information thus provided.

PRELIMINARY INVESTIGATION OF FIELD CHARACTERISTICS

The original proposal for the system suggested the use of a small, constantly horizontal loop antenna for reception. To insure uniformly good coupling between receivers and transmitter, it was desirable to establish a field having a vertical magnetic component which is approximately uniform throughout the working area of the CIC. To find a design for a transmitting loop which would most nearly meet these conditions, a scale model of a steel chamber was constructed (Figure 1). Models of loops of several different dimensions were placed in the box at a height corresponding to 18 inches below the overhead of a CIC space 7 feet 6 inches high. Based upon the assumption that the full-scale system would be operated near

100 kc, the model loop was resonated at a frequency of one megacycle per second, thereby reducing the wavelength to the same scale as used for room dimensions. The antenna was fed by a Boonton Model 65-B Signal Generator. The test probe, a similarly scaled model of a ten-inch-diameter receiving loop, was tuned to 1 Mc and connected across an r-f voltmeter. The test probe was held in a horizontal position and moved diametrically across the box at a height corresponding to shoulder level while measurements were made of r-f voltage developed in the probe loop (Figure 1).

The optimum dimensions of the model loops were used as the basis for construction of full-scale loop radiators, and the results given by full-scale apparatus agree well with predictions made by the models.

The signal pickup of the receiving loop is due to the vertical component of magnetic field that enters the loop. As the receiving loop is passed directly under the side of the transmitting coil a signal null occurs (see Figure 2) because the vertical component of the field drops to zero. However, greater field strength in the proximity of the side of the transmitting loop causes an increase in signal to occur simultaneously with the decrease in the vertical component. The net result is a null which is noticeable over a very limited range of movement. This region of poor reception is limited further by the inherent action of the receiver circuit employed. In actual shipboard installations, a judicious planning of the loop to pass over normally inaccessible areas, such as those occupied by equipments, the number of locations where nulls would otherwise be encountered would be minimized.

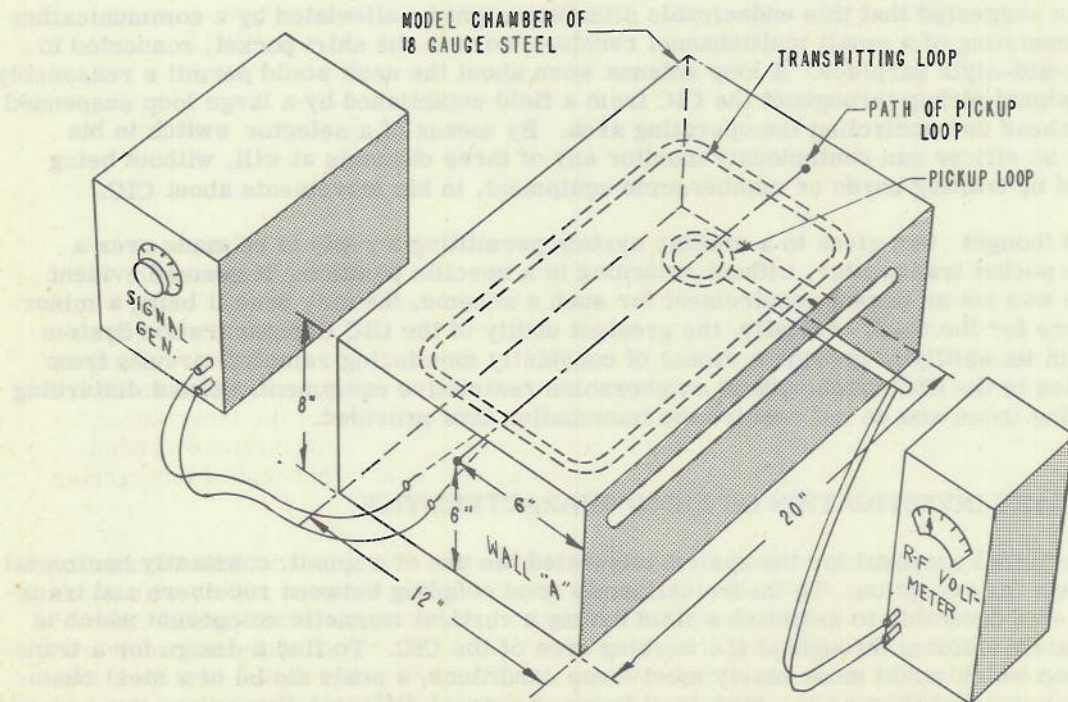


Figure 1 - Setup of apparatus for model field exploration

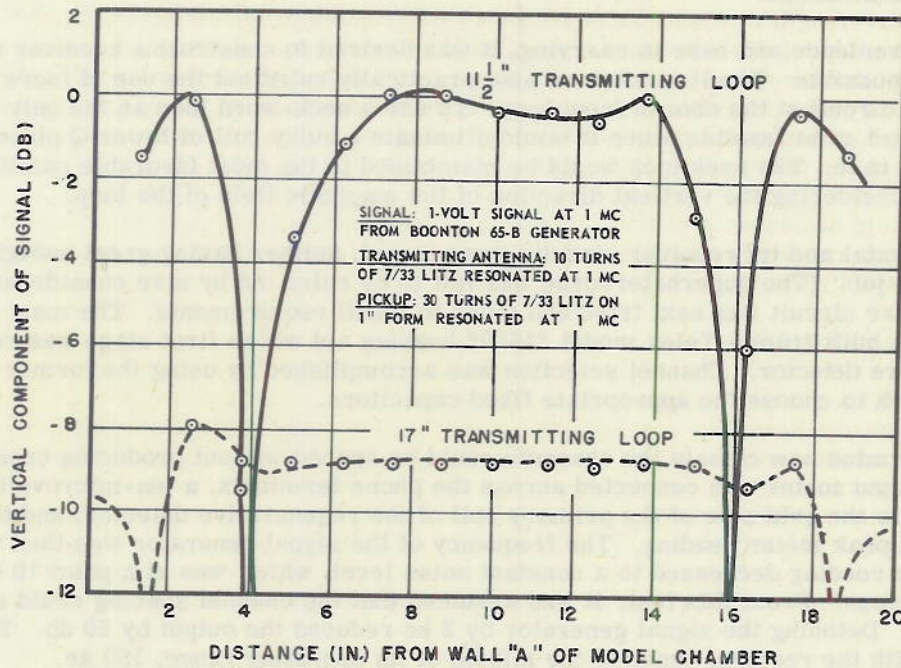


Figure 2 - Fields produced in model chamber by 11-1/2-inch and 17-inch model loops

CHOICE OF OPERATING FREQUENCY

Preliminary investigations showed that a field which is uniform and unidirectional can most nearly be approached by a loop antenna whose dimensions are comparable to those of the room. At frequencies of 100-200 kilocycles, the wavelength is great enough in comparison with room dimensions to avoid troublesome standing-wave effects. Furthermore, the probability of interference from other systems is reduced by working in the relatively little used low-frequency end of the spectrum. Frequencies lower than 100 kc involve serious problems in the design of small receivers owing to the size of the inductances and capacitances. Furthermore, voice transmission becomes difficult because of bandwidth requirements, the modulation bandwidth being an appreciable percent of the carrier frequency.

In normal use, relatively low power output (1 watt) will be employed. The attenuation of an enclosed space such as a CIC would undoubtedly be in the order of 100 db with doors closed; so there seems virtually no likelihood of this signal being detected outside the ship. Tests conducted on the USS MISSISSIPPI in November 1950 indicated that with the receivers worn in the CIC and operated as intended, no noise or interference could be detected, thus indicating that this system should be mutually compatible with other electronic systems aboard ship. These factors resulted in the choice of a 100- to 200-kc operating range for this system.

DESIGN OF RECEIVER

For convenience and ease in carrying, it was desired to construct a receiver as small and light as possible. The limitation on size practically ruled out the use of more than a single tuned circuit at the chosen frequency. To use a neck-worn loop as the only tuned circuit seemed most feasible since it would eliminate a bulky coil of lower Q placed inside the receiver case. The neck loop would be maintained in the most favorable position for reception, considering the vertical direction of the magnetic field of the loop.

Both crystal and trf receiver circuits were tested, neither having great enough selectivity for the job. (The superheterodyne was felt to be ruled out by size considerations.) A regenerative circuit was next tried and found to fulfill requirements. The most successful receiver was built from a Telex model "1550" hearing aid whose first stage was rebuilt as a regenerative detector. Channel selection was accomplished by using the former tone-control switch to choose the appropriate fixed capacitors.

To determine how closely the channels could be spaced without producing cross modulation, an output meter was connected across the phone terminals, a ten-microvolt signal was applied to the grid side of the primary coil of the regenerative detector, and the receiver was tuned to peak meter reading. The frequency of the signal generator was then varied until the meter reading decreased to a constant noise level, which was at a point 10 kc from center frequency. From this test, it was assumed that the channel spacing could safely be set at 20 kc. Detuning the signal generator by 2 kc reduced the output by 20 db. The test was made with the receiver tuned to the middle of its operating range, 150 kc.

Although the receivers have been successfully tested for multichannel operation, no attempt has been made to couple more than one transmitter to the large loop. No trouble is anticipated in doing this if very loose coupling of transmitter to loop is used.

The physical design of the receiving loop was found to be critical. A bunch-wound coil was too inefficient for good selectivity. A flat and flexible basket-weave coil of 7/33 litz wire was not only more convenient to wear, but possessed a relatively high Q factor. Presence of the operator's body within the loop did not noticeably affect receiver characteristics.

A circuit diagram of the receiver is shown in Figure 3. The indicated values of tuning capacitors resonate the receiver at 126, 153, and 176 kc. Figures 4a and 4b show completed receiver and loop in use.

EARPHONES

Several of the newest and lightest types of earphones were used with the receivers in this system. Figure 5 effectively demonstrates their size in comparison to a common type of heavier earphones. The two smaller units which were designed for use on one ear only were particularly light and convenient to use. Both fastened to the ear securely and gave complete freedom of movement of the head. The ear moulding gives considerably more attenuation to room noises and, if fitted with reasonable care, can be comfortable even though worn daily for several hours at a time. The other single earpiece is suitable where mouldings cannot be made or where attenuation to room noise in that ear is undesirable. This earset is also light and comfortable, but the coupling coefficient with the eardrum, although low compared to that of the ear moulding, is still sufficient for normal CIC use.

The third style of headphones is also convenient and not tiring. Each reproducer connects by a ball and socket joint to a tube which can be coupled to the ear canal as tightly

or loosely as desired. This feature also permits swinging one tube out of the way to permit using a handset. If required, separate circuits can feed each earphone, thus permitting two channels to be monitored simultaneously.

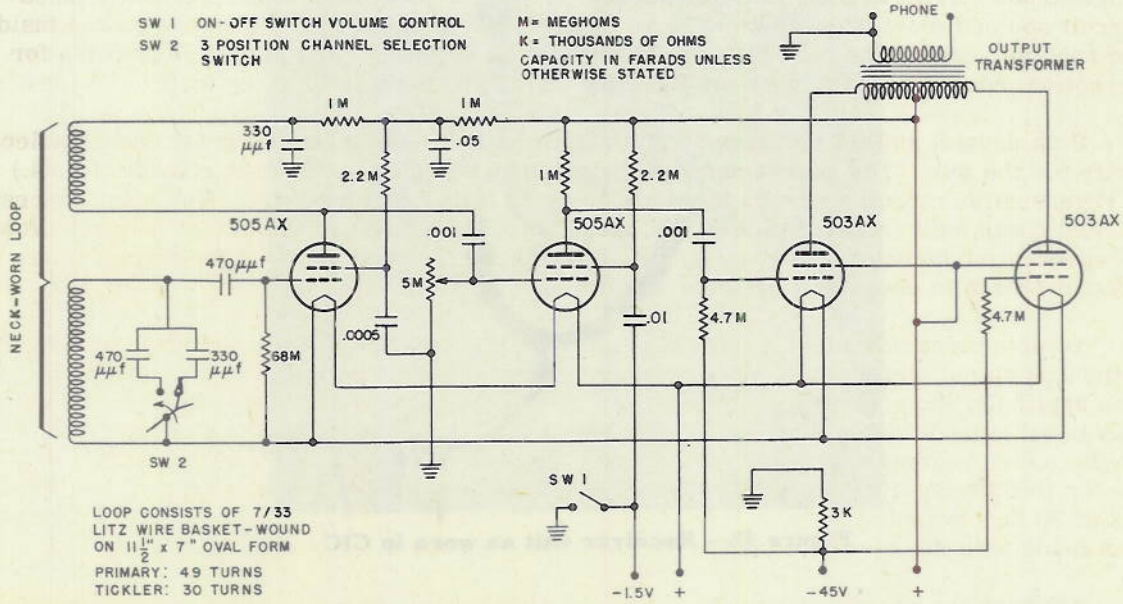


Figure 3 - Schematic diagram of regenerative receiver

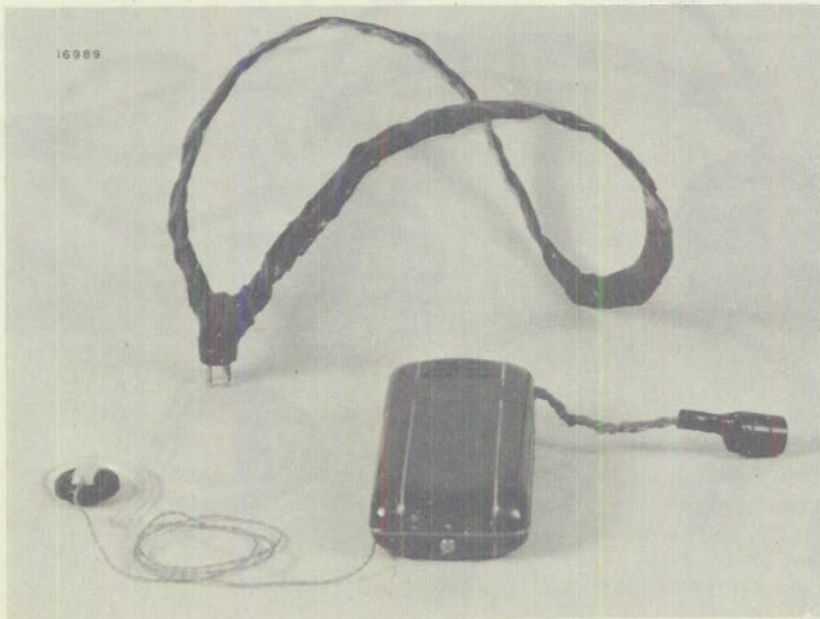


Figure 4a - Complete receiver unit

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Figure 4b - Receiver unit as worn in CIC



Figure 5 - Comparison of earpieces used in system compared to old type headphones

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DESIGN OF TRANSMITTER

Although the transmitter power need not exceed one watt for normal CIC operation, the experimental transmitter (Figures 6 and 7) was capable of seven watts output and 100 percent modulation. Flexibility in power output was felt to be desired to permit adjustment of the field intensity to the requirements dictated by a particular installation. The r-f power is made variable in five steps from less than one watt to seven watts by varying the screen voltage on the output tube. Values from zero power to the maximum power at each setting are obtainable in the antenna circuit by adjusting the coupling between the final plate coil and the antenna coil.

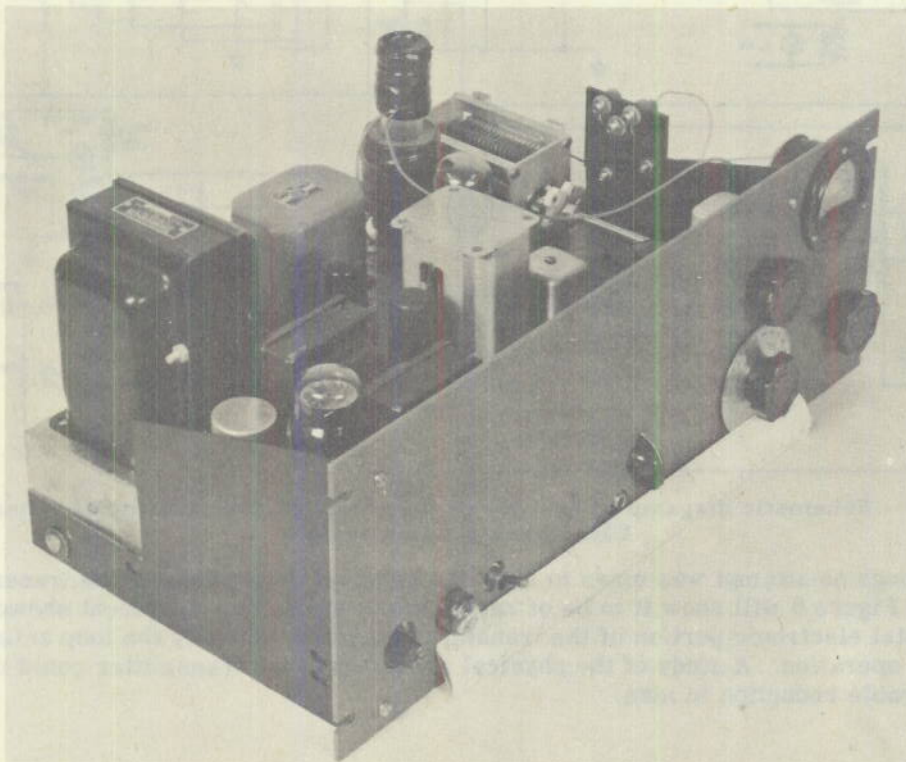


Figure 6 - Transmitter used in testing of CIC Communication system

An attempt to use the loop itself as the final tank was defeated by the unfavorable impedance match between the loop and the plate of the 6L6. The "shorted turn" effect of the shielded room resulted in so low a Q factor for the loop that it was not possible to load the 6L6 properly in this fashion. To overcome this effect and at the same time provide variable coupling, a link coil was used, and the loop circuit tuned with a series capacitor.

The transmitter tunes over the frequency range from 125-176 kc, which is sufficient to cover the frequency band tunable by the present input circuits of the receivers. The r-f section consists of a 6F6 oscillator followed by a 6L6 Class C amplifier. The modulator consists of a 6AG7 driving a 6N7 push-pull, class B, output stage. More than adequate gain is available for carbon microphone, sound-powered phone, and radio inputs. The audio section has a 3-db bandwidth from 150 cycles to 3000 cycles with a maximum output

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of 6.25 watts. The low ratio of carrier to modulating frequencies made it difficult to obtain greater bandwidth, but, subsequent intelligibility tests of the complete communication system indicated that wider bandwidth was unnecessary.

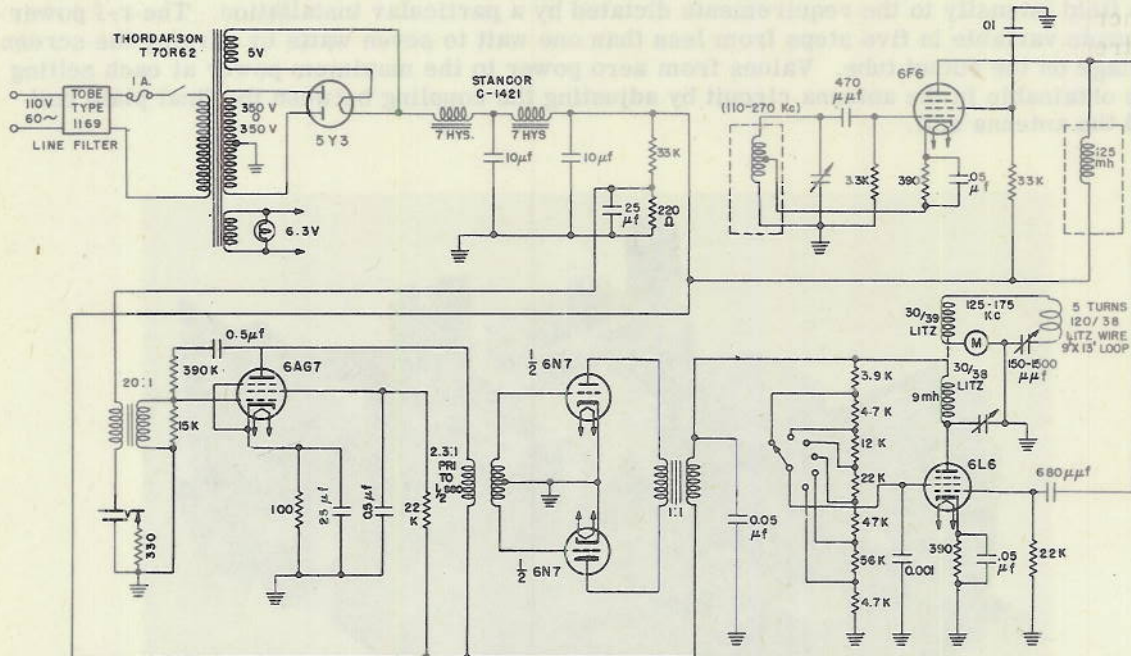


Figure 7 - Schematic diagram of low-power, low-frequency transmitter for use in CIC communication system

Even though no attempt was made to limit the physical dimensions of the transmitter, reference to Figure 6 will show it to be of rather small size. The equipment shown comprises the total electronic portion of the transmitting system and only the loop antenna is required for operation. A study of the physical assembly of the transmitter could result in a considerable reduction in size.

TRANSMITTING LOOP ANTENNA

The design of the transmitting loop was based upon work with the scale model, which showed that maximum field strength in the center of the room was achieved by making the loop dimensions about 55 percent of room dimensions. Five turns of 120/38 litz wire were bunch-wound on a 9- by 13-foot form for the 16- by 23-foot room. A 150-1500 microfarad series capacitor resonated the antenna over the 100-200 kc range. The loop was suspended 18 inches beneath the 8-1/2-foot ceiling. Figure 8 shows the experimental arrangement. A second loop of four turns on a 21- by 14-foot form was also suspended 18 inches under the ceiling for comparative tests.

TEST RESULTS

Using the 9- by 13-foot loop, with the transmitter adjusted to a power output of one watt and modulated 100 percent, the received audio signal was strong and uniform over most of

the working area of the room. The one exception was a sharp null whose locus was a line extending around the room directly under the loop. A larger antenna was tried for comparative results, and once again the null was observed, close enough to the wall, however, that it could safely be considered outside the operating area. Although the null line was thus moved closer to the wall, the signal strength was considerably reduced because of increased coupling with the metal wall. By quadrupling the power input, however, the field strength could be raised to provide adequate signal in the receiver.

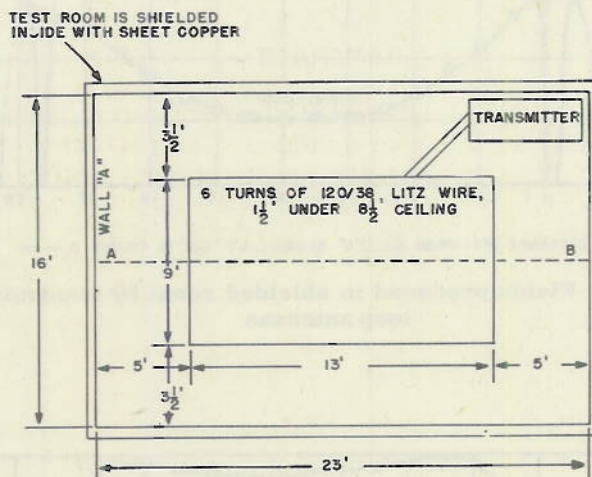


Figure 8 - Sketch of test room

To test the uniformity of the field, the transmitter and the 9- by 13-foot loop were energized and tuned to 150 kc and a receiving loop, with an r-f voltmeter connected in parallel, was resonated at this frequency. The loop was carried across the room along the line marked AB on Figure 8, at a height of five feet from the floor. The voltage as measured at one foot intervals is shown graphically in Figure 9. A second test was run using the 21- by 14-foot transmitting loop and these results are shown on the same figure. Finally, since the quantity of greatest interest is the relative uniformity of audio signal in the receiver, a test similar to the previous runs was carried out with an output meter across the phone terminals of the receiver, this giving the results as plotted in Figure 10. (The db reference for this figure is not the same as that shown in Figure 9.) By comparison with the previous measurements, a considerable amount of beneficial automatic gain control action on the part of the receiver can be observed.

APPLICATION TO OTHER FIELDS

Work to date demonstrates the practicality of this type of communication system for the intended purpose. Although developed primarily to combat noise levels within a CIC space, this system, or parts of it, could also be used to advantage in other fields.

One of the problems which may deserve consideration is that of the difficulty of communication with flight deck personnel of an aircraft carrier during take-off operations due to the very high noise levels present. Lack of communication with certain officers in direct charge of take-offs has had attention focused upon it by cases where the orders of the Commanding Officer could not be carried out because of his inability to attract the attention of the desired officer. In one incident the bull horn, sirens, and whistles were resorted to without avail.

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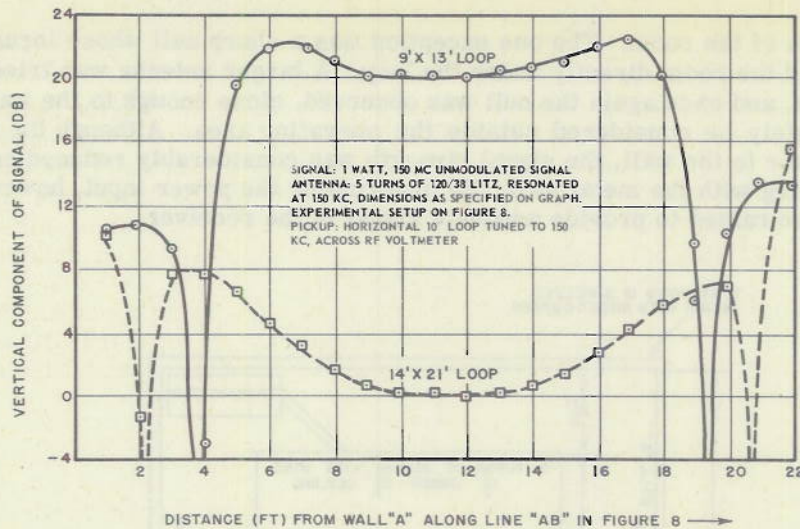


Figure 9 - Fields produced in shielded room by transmitting loop antennas

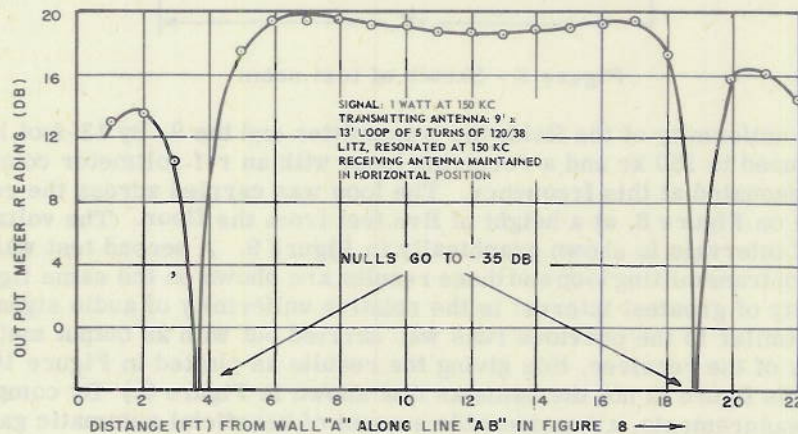


Figure 10 - Receiver output level as a function of position of receiver loop in room

A small receiver such as used in the CIC system, but employing microwaves and line-of-sight transmission, could receive signals beamed in a wearer's direction. To permit universal coverage, a small microwave transmitter, limited in angular coverage for security, could be fixed high on the mast to illuminate the entire deck. Voice intelligence might be impossible when sound levels exceeded 100 db, but it would still be possible to hear a suitable tone signal, coded for prearranged operations. In such a case the tone could momentarily drive the eardrum to an energy level above the pain threshold and thus gain the attention of the person receiving the tone despite the high noise level.

Significant progress toward successful design of such a flight deck communication system would be made by incorporation into it of the moulded type earpiece (Figure 5c) which gives an attenuation of 25-30 db to outside noises and is capable of the power required to reach the pain threshold.

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CONCLUSIONS

A system of communication using low radio frequencies in the region between 100 and 200 kc has been successfully built and tested. A loop suspended from overhead produces a vertically oriented field of reasonably constant strength over virtually the entire CIC area. The field thus produced can be picked up by a tuned loop worn about the neck and connected to a multichannel pocket-size receiver. Comfortable light-weight hearing-aid-type earpieces reproduce with good fidelity the signals with which the transmitter is modulated.

Since all the full-scale tests made so far have been made in a copper shielded room, further tests will be made to determine whether operation in a shipboard CIC will make any significant difference in the performance of the system. Scale-model tests in a steel box indicate that no difficulty is to be expected.

RECOMMENDATIONS

The receivers used in tests up to now have been redesigned hearing aids of about 1940 vintage. Further work on this project would be chiefly concerned with increasing the ruggedness of construction and accessibility for maintenance. The adoption of more modern techniques such as printed circuits could effect a considerable reduction in size and weight.

Further work on the transmitter might well involve design of a compact multichannel unit in which all the channels could operate simultaneously. Each channel could be provided with inputs to handle one, or the combined outputs of several radio circuits, the actual number being determined by the situation existing in an individual CIC. Definite power requirements must be determined by operational tests.

ACKNOWLEDGMENTS

Sincere appreciation is expressed to Dr. Aram Glorig of the Forest Glen section of Walter Reed Hospital, who was very helpful in obtaining hearing aids and earpieces, and provided for the fitting of several members of the Laboratory with ear mouldings. Valuable help was given by R. M. Roppel, who assisted in the development work in its early stages and made a large number of the test measurements. Also instrumental in the development of this system was R. B. Whiteley, who supplied technical information.

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CONCLUSIONS

A system of communication using low radio frequencies in the region between 100 and 300 kc has been successfully built and tested. A loop suspended from overhead provides a vertically oriented field of reasonably constant strength over a fairly large area. The field lines produced can be picked up by a tuned loop wire placed on the deck and connected to a multichannel pocket-size receiver. Considerable light-weight, low-type equipment is required with good fidelity the signals with which the transmitter is modulated.

Since all the full-scale tests made so far have been made in a copper shielded room, further tests will be made to determine whether operation in a shipboard CIC will make any significant difference in the performance of the system. Tests made in a steel box indicate that no difficulty is to be expected.

RECOMMENDATIONS

The receiver part is built up in two parts and has been redesigned having side of about 1000 cycles. Further work on this project would be highly concerned with increasing the ruggedness of construction and accessibility for maintenance. The design of more modern techniques such as printed circuit could effect a considerable reduction in size and weight.

Further work on the transmitter might well involve design of a compact multichannel unit in which all the channels could operate simultaneously. Each channel could be provided with means to handle one or the combined outputs of several radio channels, the actual number being determined by the attention of the operator. For this power requirements must be determined by operational tests.

ACKNOWLEDGMENTS

Many suggestions in regard to the design of the present transmitter section of Walter Reed Hospital, who was very helpful in obtaining bearing size and dimensions and provided for the design of several models of the laboratory with our assistance. Valuable help was given by M. M. Gopaul, who assisted in the development work in its early stages and made a large number of the test measurements. Also instrumental in the development of the system was E. M. Williams, who supplied technical information.

