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NRL Report 5209

UNCLASSIFIED

LOW-FREQUENCY AIRBORNE SONAR SYSTEMS

[UNCLASSIFIED TITLE]

C. L. Maskaleris and J. J. Yagelowich

Airborne Sonar Branch
Sound Division

October 31, 1958

U. S. NAVAL RESEARCH LABORATORY
Washington, D.C.

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FINAL REPORT ON LOMASS SYSTEMS

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ABSTRACT

The LOMASS project is a high-performance low-frequency sonar system to be carried by a helicopter. Such an ASW combination offers great potential for obtaining high area coverage.

The program is divided into three phases. LOMASS I is a simplified echo-ranging system which serves as a basis for the other two phases. LOMASS II uses the basic LOMASS I system with the addition of a high-power driver and transducer. LOMASS III is a new system which uses an acoustic Luneberg lens to obtain preformed beams for scanning operation rather than the searchlight operation used in the first two phases. Each phase uses new and improved signal-processing techniques.

Tests were performed to determine the spectral level and radiation pattern of noise radiated into the water by a Sikorsky HR2S helicopter. These tests, though incomplete, do indicate a high noise operating background which places a severe restriction on expected sonar range. More tests need to be performed to gain a better picture of the radiated, helicopter noise.

Little trouble is encountered in handling large arrays (6 ft x 8 ft x 3 ft) from a helicopter.

No echo-ranging data was obtained because insufficient time was available to work the difficulties out of the system and to exploit all noise-reduction schemes.

Field tests were performed with only the LOMASS I system.

Some components of LOMASS II and III were started and a few of these items were tested. To improve these two phases, various noise-reduction schemes have been suggested. A concentrated helicopter-noise-analysis program is needed to provide a more complete description of the sonar operating environment.

PROBLEM STATUS

This is a final report on this problem. The problem was closed on July 1, 1958.

AUTHORIZATION

NRL Problem S05-11
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LOW-FREQUENCY AIRBORNE SONAR SYSTEMS
[Unclassified Title]

INTRODUCTION

The LOMASS problem is an outgrowth of the original problem known as the Long Range Airship Search and Classification Sonar Program (1). Early in 1953, it became evident to NRL that there was a good possibility of developing a high-performance low-frequency sonar system capable of being carried by aircraft such as blimps, seaplanes, or helicopters. Such an ASW combination offers great potential for obtaining high area coverage at low cost. A helicopter system was proposed, because of the encouraging results of tests conducted off the New Jersey coast during the Spring of 1955, and because of the poor hovering capabilities of a blimp. This system was called the Low-Frequency Mobile Active Sonar System (LOMASS).

This program was divided into three phases. LOMASS I is a simplified version of the blimp system using an improved transducer training design. LOMASS II uses the basic LOMASS I system with the addition of a high-power driver and transducer. LOMASS III is a new system which uses an acoustic Luneberg lens to obtain preformed beams for scanning operation rather than the searchlight operation used in the first two phases. Each phase uses new and improved signal-processing techniques. The conclusion of the LOMASS I program due to unavailability of funds automatically concludes the LOMASS II and III programs.

HELICOPTER NOISE MEASUREMENTS

An HR2S helicopter, No. 138420, was made available to NRL for the installation of LOMASS, an active sonar operating at 2.3 kc. Measurements of the noise the helicopter transmits into the water had been previously made by the U.S. Navy Underwater Sound Laboratory, Fort Trumbull, New London, Conn. (2).

The New London tests used a hydrophone mounted on the bottom of Long Island Sound (Fisher's Island Test Facility) in approximately 120 ft of water. An HSS-1 and an HR2S helicopter, No. 138419, made a series of runs at various hovering heights and forward speeds to give information on noise of hover versus altitude and noise at various forward speeds versus altitude. Some of the results of the New London tests are listed in Table 1.

It was felt by NRL that some of these tests should be repeated, and that some new tests should be made in order to get a more complete picture of the noise environment in which the LOMASS system would be expected to operate.

Because of the difficulty experienced at Fisher's Island in precisely stationing the helicopter over a buoy, it was decided to lower a hydrophone from the HR2S helicopter into the water. One additional piece of information was desired and that was the directionality of noise from the helicopter. If the noise proved to be very directional, then perhaps an acoustic screen over the transducer, fabricated of compliant tubes, would help reduce the effect of the helicopter noise, and consequently increase the detection capabilities of the system.

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Table 1
New London Noise-Measurement Results
Using the HR2S Helicopter

Helicopter Hovering Altitude (ft)	Transducer Depth (ft)	Spectrum Level 2.3 kc in a 1-Cycle Band and Referred to 1 dyne/cm² (db)
50	120	-17
	50	-11*
25	120	-18
	50	-12*

*Calculated from the 120-ft value

Noise-Measuring Equipment

The mode of operation chosen was to use a transducer having a variable-width null in its directional response directed vertically upward toward the helicopter. A comparison of the results of a transducer having a sharp null with those of one having a broad null would give some indication as to the directionality of noise.

A $\lambda/2$ doublet or dipole of two elements has a fairly sharp null at bearings along the axis of the doublet. By adding a compliant-tubing baffle off one end of the doublet, as in Fig. 1a, the response in the baffle direction is further reduced by the loss due to the baffle. The initial null is now broadened considerably as shown by the beam pattern. To get a sharp null, the outputs of a doublet above the plane of compliant tubes were connected in phase opposition (see Fig. 1b). Figure 1c shows the beam pattern when these two upper elements are in phase addition.

These hydrophone signals are amplified by a transistor amplifier having an adjustable gain to account for various conditions, and a bandwidth including hydrophones of 200 cycles. The output impedance has been kept low because of the long cable into which the signals were fed. The equipment in the helicopter consisted of a GR 1551 battery-operated noise-level meter and a GR 1231P-5 filter. The filter was used to take noise measurements in a 50-cycle band.

Figure 2 is a photograph of the array installed in the helicopter. The compliant baffle was made collapsible so that the noise array could be lowered through a hatch in the helicopter fuselage. Figure 3 shows the array extended and about to enter the water.

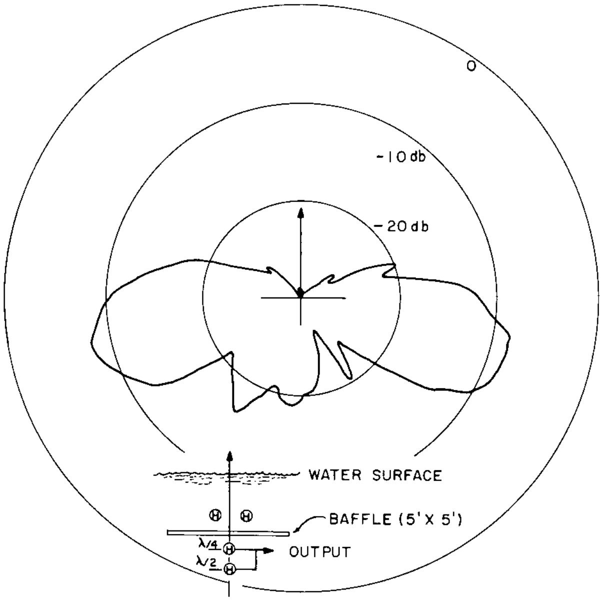

Fig. 1a - Vertical beam pattern noise array (broad null) 2.3 kc

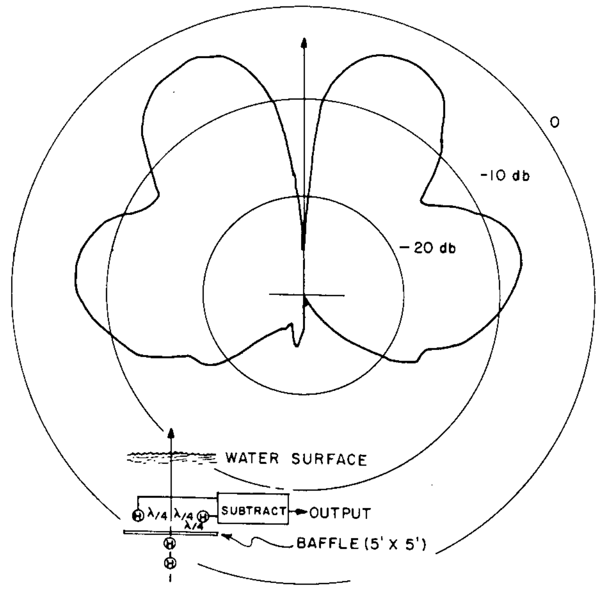

Fig. 1b - Vertical beam pattern noise array (sharp null) 2.3 kc

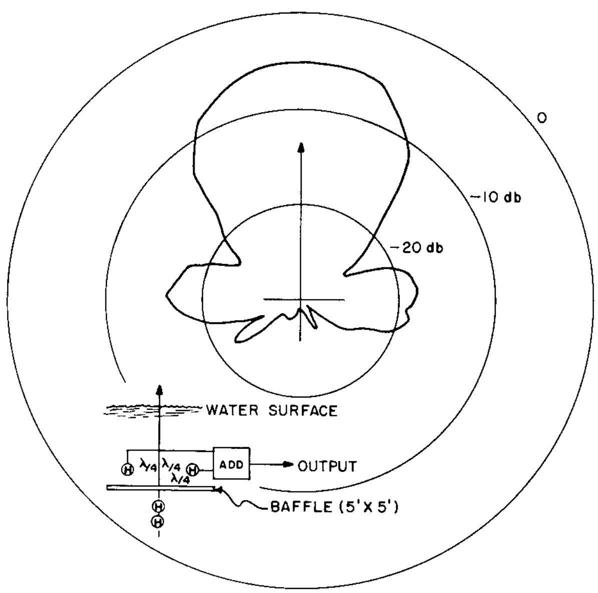

Fig. 1c - Vertical beam pattern noise array 2.3 kc

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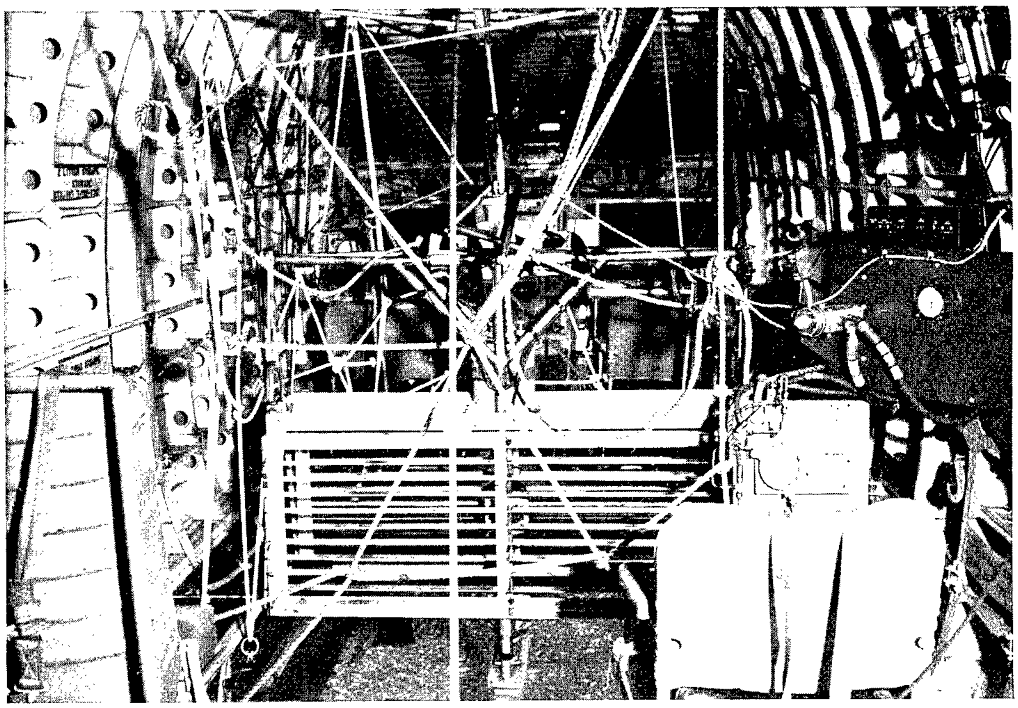

Fig. 2 - Noise array installed in helicopter

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Fig. 3 - Noise array extended and about to enter water

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Noise Measurements and Results

For each beam pattern, runs were made at a hovering height of 35 ft with the noise array at a depth of 50 ft and 75 ft in 180 ft of water with the array depth maintained by a float. These tests were made in Long Island Sound near Eatons Point. The 180-ft figure is in question because during one of the test runs to check out the equipment with the array at a depth of 100 ft in this same spot in the Sound, the array came up with mud on it. One further limitation on this test site is that the "hole" isn't very large, so there is a good possibility that some reflection from the bottom and sides of the "hole" were encountered.

Table 2 lists the NRL spectrum-level results of the runs and it can be seen that the 50-ft and 75-ft results agree as to the correction between them for spherical spreading. However, the results do not shed too much light on the directionality part of the measurement. The photograph of the hovering conditions, Fig. 4, clearly shows the size of the disturbed water surface. This distance covers at least 150 ft in diameter or about 60 wavelengths at 2.3 kc. If this 150 ft can be considered as the active area of noise generation in the water, then operating depths of 50 and 75 ft are certainly in the Fresnel zone. A check of this requires an operating depth of 200 ft or more. Since test flights were made from the Sikorsky plant at Stratford, Connecticut, the nearest deep water in the Atlantic is about 150 miles from shore and this distance is beyond the practical range of the HR2S helicopter. Deep-water noise tests were planned to be made later from Key West.

Table 2
NRL HR2S Noise-Measurement Results

Noise Array Beam Pattern	Transducer Depth (ft)	Spectrum Level 2.3 kc in a 1-Cycle Band and Referred to 1 dyne/cm² (db)
Fig. 1a (Broad Null)	75	-1
Fig. 1c	75	-5
	75	AVE-3
Fig. 1a (Broad Null)	50	-3
Fig. 1c	50	+3
	50	AVE 0
Fig. 1b (Sharp Null)	75	+10
Fig. 1b (Sharp Null)	50	+11

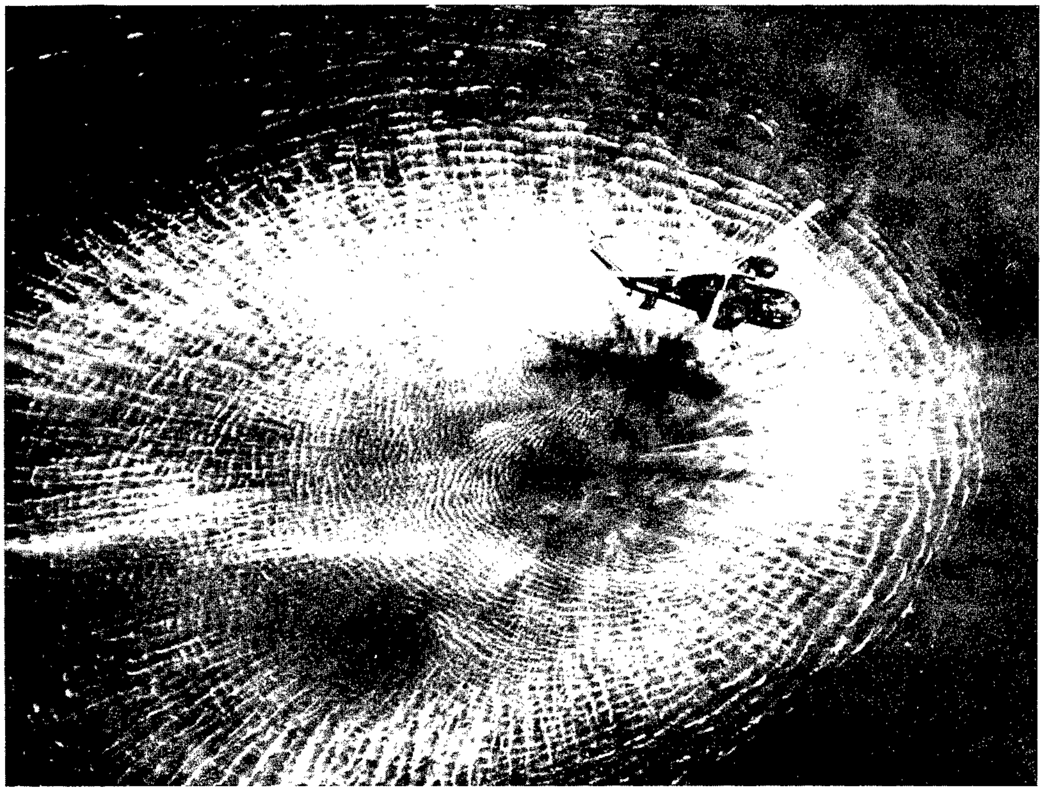

Fig. 4 - Water surface disturbed by helicopter

Until deep-water tests can be made, the initial results have limited reliability because of the experimental limitations. However, these results do indicate a very high noise level from an HR2S, which seriously limits the expected sonar range. Of the two results, the NRL figure is higher than the New London by 12 db, and this difference has not been resolved. Two different helicopters were used in the tests, but Sikorsky engineering personnel believe that the difference in the noise output from the two ships would not account for the large difference in noise level encountered.

TRANSDUCER HANDLING TESTS

The next phase of the program was to determine the feasibility of launching and retrieving a transducer array of the size, shape, and weight used in the LOMASS I system. A dummy array, 8 ft high x 6 ft wide x 3 ft deep, was used to develop the proper handling technique. A model No. 5200 winch, with 300 ft of special sonar cable, was used to raise and lower the transducer. The hoist operator handled the controls of the hydraulically operated winch and the crew chief and one stack operator helped guide and seat the array into the helicopter. The launching and retrieving of the array was fairly simple and no difficulties were encountered once the technique was mastered.

A cable angle pickoff device was used to feed information through a coupler to the autopilot system to hover the helicopter automatically during the dunking. Sikorsky Aircraft personnel modified a coupler from an HSS-AN/AQS-4 system for this purpose. However, even after considerable effort was spent, this device was not reliable, and it was decided to make flights with the pilot hovering the helicopter rather than further delay the program.

LOMASS I TESTS

The LOMASS system was installed in the HR2S helicopter at Stratford, Connecticut, and tests were conducted in Long Island Sound during the latter part of August and the month of September 1957. The system had been thoroughly checked at NRL before shipment to Stratford.

Lomass I Equipment

A block diagram of the equipment is shown in Fig. 5. The installation is shown in Figs. 6, 7, 8, 9, and 10. Figure 6 shows rack 1 which contained the Reyer-oscillator, the intercommunication system (ICS), the forward receiver, the operator's console, the aft receiver, the driver, and the preamplifier battery power supplies. The operator's console in Fig. 6 includes:

1. controls for power,
2. receiver gains and TVG's,
3. preamplifier gain and TVG,
4. forward A-scan and aft A-scan displays,
5. compass indicator to show true bearing of the transducer, and
6. training switch for selecting training with or without maintenance of true bearing.

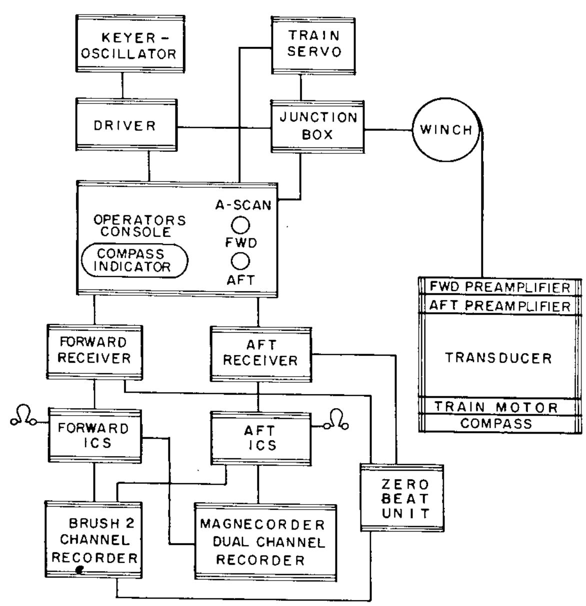

Fig. 5 - Block diagram of LOMASS I system

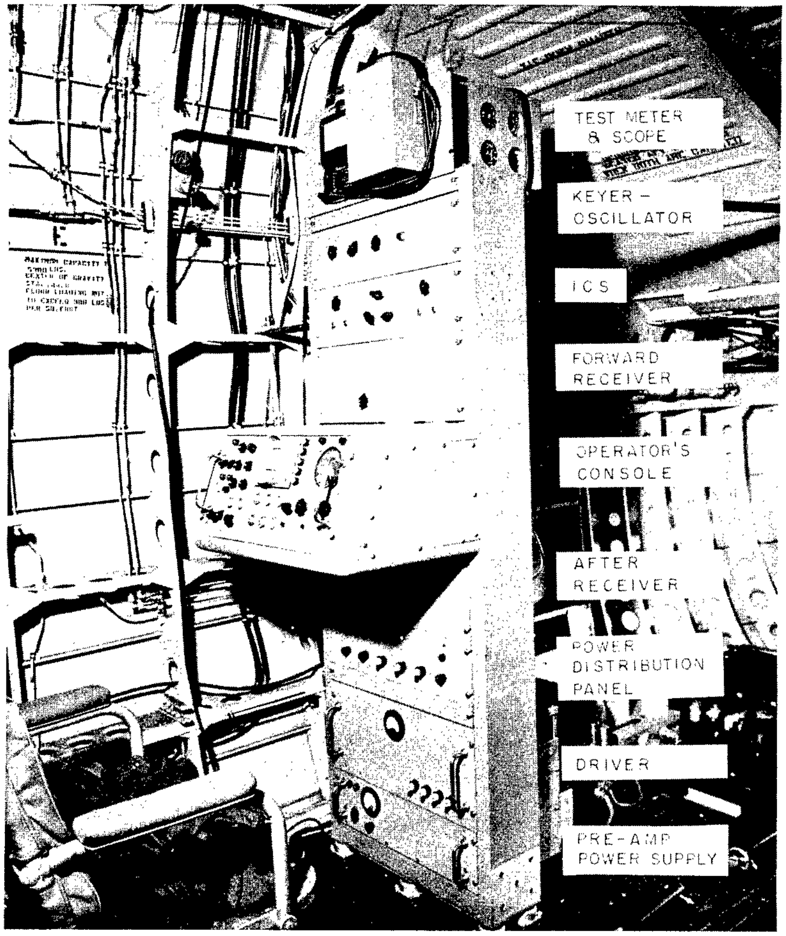

Fig. 6 - Rack I installation

Figure 7 shows rack 2 which contained the recording equipment consisting of a two-channel Magnecorder tape recorder and a two-channel Brush paper recorder. Also in rack 2 were the zero-beat unit (a new signal-processing display), the ICS unit for the rack 2 operator, and the train servo system for the maintenance of true bearing. Figure 8 shows the power supply unit. Figure 9 shows the model No. 5200 winch installation. Figure 10 shows the LOMASS I installation when one looks through the open front doors toward the rear of the helicopter. The dummy transducer is shown in the housed position in the helicopter.

The transducer, Fig. 11, contained two cylinders, one mounted in each upper corner of the frame. In these containers were the underwater electronics which were composed of the preamplifiers for the forward and after beams of the transducer, the transducer transfer relays, and the train and compass junction boxes and amplifier. The training motor was mounted in the lower right-hand corner of the transducer frame with a flux-gate compass mounted in a container on the training housing. Figure 12 shows the training motor and compass box.

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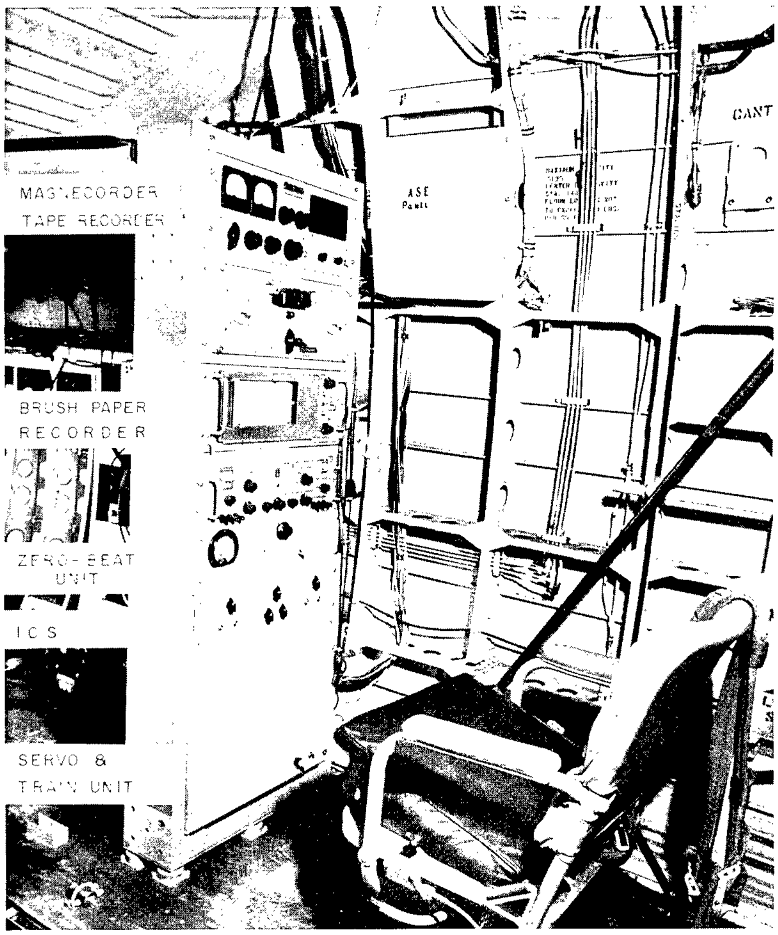

Fig. 7 - Rack II installation

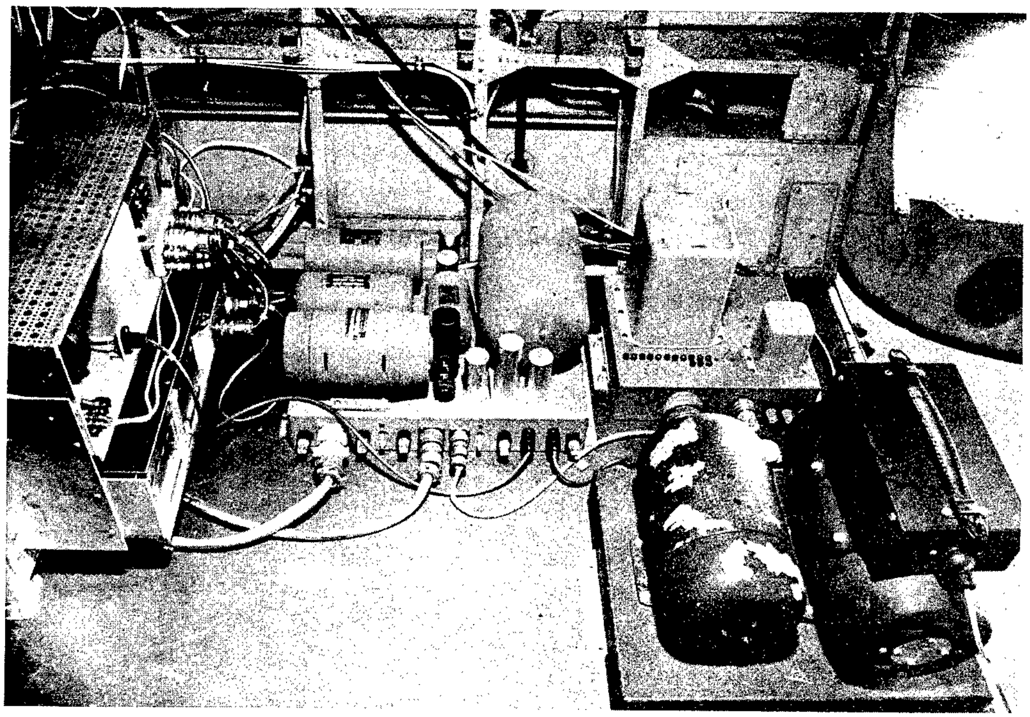

Fig. 8 - Power supply installation

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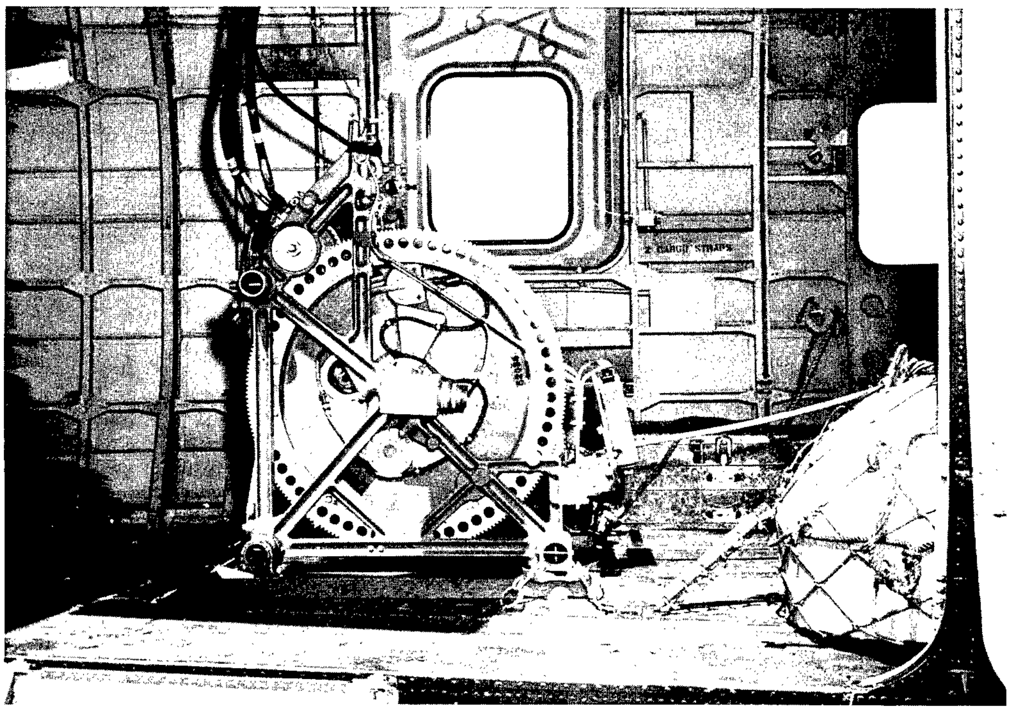

Fig. 9 - Model No. 5200 winch installation

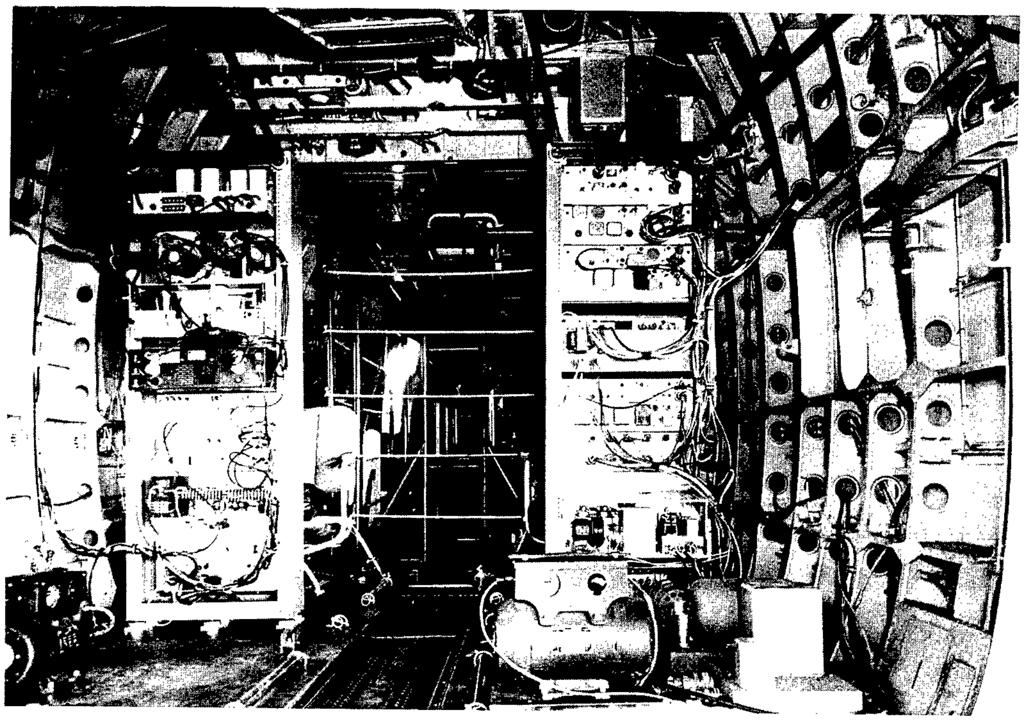

Fig. 10 - View of LOMASS I installation through open front doors of helicopter

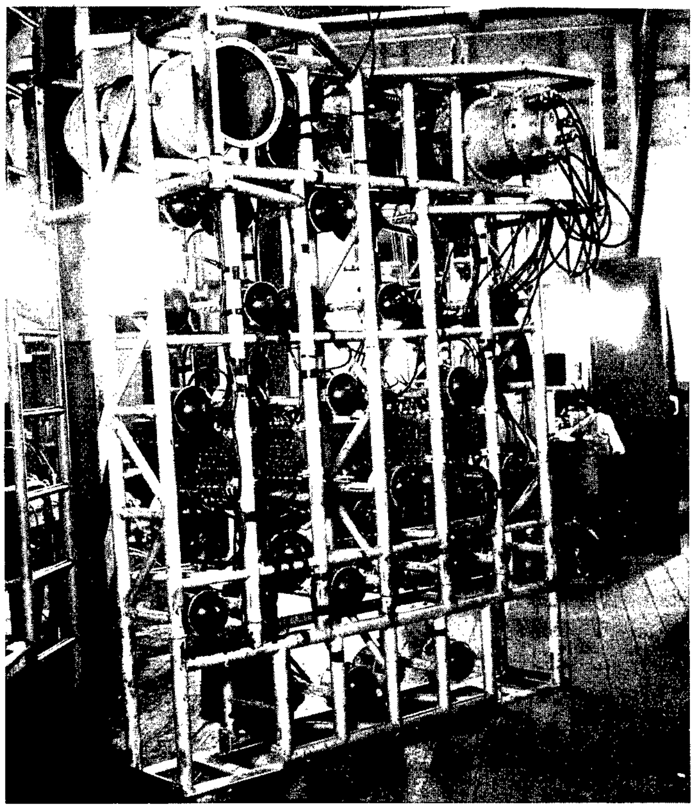

Fig. 11 - Transducer

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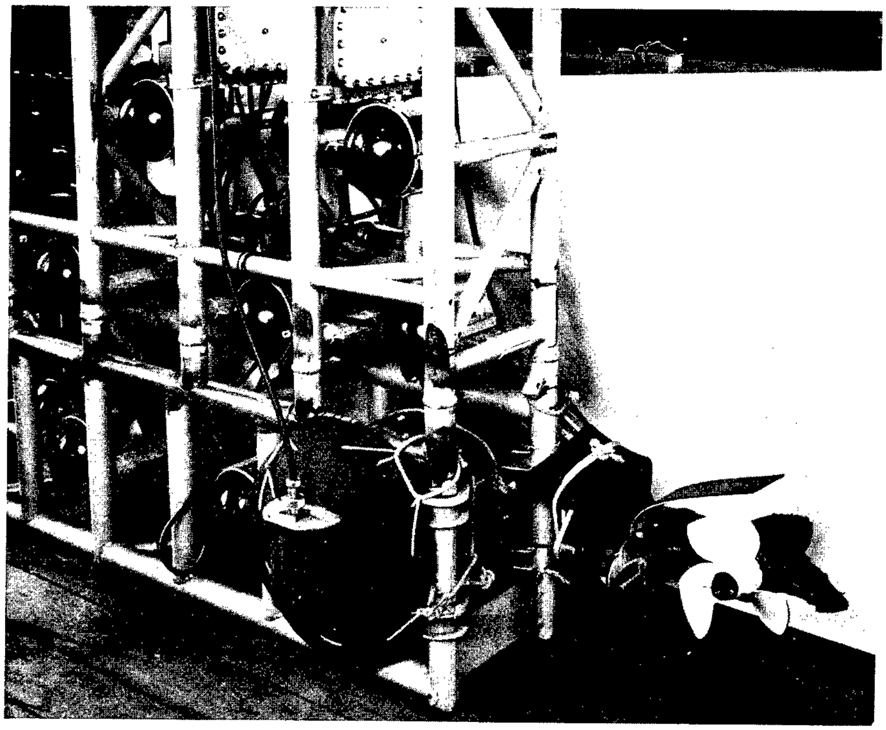

Fig. 12 - Training motor and compass box

Noise Tests With LOMASS I System

From the data obtained from the noise measurements, the noise radiated by the helicopter into the water was known to be very high. Further noise measurements were made using the LOMASS I system. A spectrum level of -6 to -12 db was obtained at 50 ft compared with 0 db using the noise-measuring array. These tests were made in the same area off Eatons Point, Long Island, as in the noise array tests.

Next, a test was performed to see if the noise was transmitted down the cable and picked up by the transducer. The measurements were made in air, not in water, and the LOMASS I system was used to determine noise levels. The LOMASS helicopter hovered over the field and the transducer was lowered to just above the ground and readings taken. The transducer was then placed on the ground and readings taken as the helicopter hovered directly over the transducer. All the cable was let out and the helicopter flew the cable length (about 200 ft) away from the transducer and landed. The noise level dropped over 40 db. Another HR2S helicopter flew over the transducer and readings were taken. While this helicopter hovered directly over the transducer, the readings were the same as measured when the LOMASS helicopter was hovering over the transducer. To make sure no noise was being transmitted by the LOMASS helicopter, which had its engine running to furnish power for the LOMASS I system, an external power unit was connected to the helicopter to supply the necessary power and the helicopter engines were stopped. The other HR2S helicopter again hovered directly over the transducer and the readings again were the same as those measured when the power was supplied by the LOMASS helicopter. This showed that the noise generated by the helicopter was picked up by the transducer and was not generated by vibrations down the cable.

Two flights were made off New London, Connecticut, in The Race, the entrance to Long Island Sound from the Atlantic Ocean. The water depth in this area is over 300 ft but there is a strong current flowing except during slack and ebb tide. These flights took place Sept. 26, 1957, but no new results were obtained. On the first flight no readings were made because the current was too swift. The coupler did not work on these flights and the pilot could not hover satisfactorily. On the second flight, readings were made at 50 ft and 100 ft. These readings did not indicate a lesser noise level than measured off Eatons Point. Upon returning to Stratford, the main cable junction box on the transducer was found to have water in it.

Noise Reduction

Several attempts were made to reduce the radiated helicopter noise. First, sound-absorbing material was fastened underneath the main rotor gear box. It was thought that the noise generated by the main rotor gear box was projected through the hole in the fuselage and into the water. In a previous test by Sikorsky, a noise reduction of 3 db was measured inside the fuselage of a helicopter by installing sound-absorbing material under the main rotor gear box. A flight was made to check this theory but no difference was noted in the level of noise radiated by the helicopter into the water. Next, a baffle of compliant tubing was mounted on top of the transducer frame. The tubes covered an area of only 4 x 6 ft, which is very small considering the wavelength, the transducer size, and the disturbed water area under a hovering helicopter. However, on the first flight to check the baffle, a reduction in noise of 6 db was noted compared to the previous flight without the baffle. Further work to verify this was not successful.

Transducer Training

No transducer training problem was encountered in this system. A 1-hp electric motor geared down to drive an outboard motor strut and propeller (Fig. 12) supplied ample power to train the transducer under all conditions encountered during the evaluation. The train servo system held the transducer on a heading with an error of plus or minus five degrees.

LOMASS I Operations

Because of limited flight time, low source level, high noise background, and transducer leakage, no echo-ranging data could be obtained. Whenever echo ranging was attempted, reverberations could not be heard above the noise. Trouble with the transducer array because of a shorted element and water in the element-cable junction boxes prevented echo ranging several times. A total of only 11 flights were made. Only during 2 flights did the coupler system work satisfactorily. This small number of flights did not provide enough operating time to get the faults out of the system. The maximum on-station time for any one flight was 45 minutes which did not allow time for making many in-flight adjustments.

Summary of Tests

From the limited number of flights made, the following conclusions are presented:

1. The LOMASS I system can be carried and operated from an HR2S helicopter.

2. The launching and retrieving of a transducer the size, weight, and shape of the LOMASS I transducer can be accomplished readily with proper training of the personnel.

3. The transducer training problem encountered in the airship system has been eliminated by employing a larger, more powerful motor and a new train servo system.

4. The noise background of an HR2S helicopter is very high and a baffle constructed of compliant tubing seems to offer a partial solution in reducing noise.

5. No echo-ranging data was obtained because insufficient time was available to perfect the system and exploit all noise-reduction schemes or make the LOMASS II conversion.

SYSTEM COMPARISONS AND IMPROVEMENTS

System Comparisons

Table 3 is a comparison of the various NRL airborne systems. To complete the comparison, all of the echo-ranging parameters are included as well as the predicted range. Most of these values are measured with the exceptions being the source level I_0 for columns c and d. The helicopter spectral noise level referred to is at a depth of 50 ft.

Table 3
Comparison of Various NRL Airborne Systems

Measurement Criteria \ Systems	a Original Airship System M-2	b Present LOMASS I System on HR2S	c Proposed LOMASS II System on HR2S	d Proposed LOMASS II on HR2S with Noise Reduction*
Source Level, I_o (db)	109	101	122	122
Target Strength, T (db)	20	20	20	20
Receiving Directivity, Δ_r (db)	17	-	-	-
Recognition Differential, $-\delta$ (db)	15	15	15	15
Noise, Sea-State 2 in a 1-kc Band, -N (db)	14	-	-	-
Noise,† HR2S in a 1-kc Band, -N (db)	-	-13	-13	-13
Noise Reduction* (db)	-	-	-	30
Total Allowable Loss (db)	175	123	144	174
Predicted Range (10^3 yd) Good Condition	28	1.4	4	28
Poor Condition	10			10

*Helicopter background noise reduced 10 db by a transducer baffle, 12 db by 200-ft transducer depth, and 8 db by helicopter quieting or a total of 30 db.

†Noise level = 0 db (for a 1-cycle band) - 17 db (due to vertical transducer rejection) + 30 db (due to correction from 1 cycle to 1 kc).

Column a is a list of the parameters of the airship system and for its allowed loss the predicted range is between 10 and 28 thousand yards. Column b covers the present HR2S LOMASS I system. There is no listed value for directivity index because it does not enter into the calculation of the received noise background. Since the high spectral level of the radiated noise of the HR2S is much higher than sea-state 2 noise, the received background noise is determined only by the helicopter radiated noise and the vertical beam pattern of the transducer, assuming the noise field is directional. If the vertical transducer response is reduced in comparison to the horizontal response, then any noise from the helicopter will be reduced accordingly. The sensitivity of the transducer to a signal will then depend on the horizontal response but the sensitivity of the transducer to noise (the helicopter source) will be reduced by the lowered vertical response. In the case of the LOMASS I array, this reduction amounts to 17 db (this is the same as the directivity index only by coincidence) so that although the spectrum level is 0 db at a 50-ft depth, the vertical pattern reduces this level to an effective value of -17 db.

LOMASS II Developments

One method of increasing range is to increase power. Column c, LOMASS II, is the same as b except that the LOMASS I array is replaced with a proposed Gulton array which will have an expected acoustic output power of 2 kw. The framework for the array is completed and awaits final testing of the Gulton elements. These elements are being tested individually to provide better matching by selection of elements. Enough elements have been received and tested to make one array.

In order to obtain high acoustic output power from the proposed Gulton transducer array, it is necessary to investigate new driver techniques. Conventional electronic-signal-power generating methods are too large and too heavy to be used in a helicopter.

A number of driver developments have been produced which could be used experimentally. A gas turbine driving a 400-cycle generator with 0.25-percent speed control has been delivered by the AiResearch Corporation (3). A 2-kc synchronous generator could be used with this machine. The frequency multiplier which multiplies 400 cycles to 2 kc has been delivered and tested at power levels to 21 kw. Higher power tests are planned. The combination of the gas turbine and frequency multiplier should give a driver capable of 25 kva with 5-cps frequency stability. A feasibility study of a monopropellent-asynchronous generator driver has been completed by the AMF division of Sunstrand Turbo and results are published (4).

Improvements

The predicted ranges for LOMASS I and II systems illustrates the serious limitations of the high-noise background of the helicopter and the low-output power of the LOMASS I array. To double the range, it is necessary to increase the allowed loss by at least 12 db (assuming spherical spreading), and two ways of obtaining this increase are to increase power, as was stated, and to reduce the background noise. Table 3 uses the spectrum level at a 50-ft depth. Due to spherical spreading, noise level can be reduced 12 db by operating the transducer at a 200-ft depth.

Additional noise reduction may result by supporting the transducer with a float and moving the helicopter away from the transducer. It is necessary to keep the helicopter in the null response of the transducer. This method requires a longer support cable. No float problem is advanced since the transducer was floated in the blimp system.

Some additional noise reduction can be obtained by baffling the transducer but this has the limitation of handling techniques for a baffle large enough to warrant its use.

There may be other methods which could be thought of if a more accurate description of the radiated noise pattern could be obtained. This certainly deserves more investigation.

Sikorsky personnel have worked on schemes to reduce the noise of the helicopter and in one exhaust baffle and oil-cooler baffle test, they succeeded in reducing the noise radiated into the air by about 8 db. Further tests were planned.

Column d includes all of these possible improvements to indicate the potential of the system under actual operating conditions since sea-state 2 is more of an ideal situation for helicopter operation than a realistic one. As can be seen from the table, these improvements give predicted ranges near those of the airship system.

It is possible to obtain longer ranges by using more sophisticated detecting devices such as the "NRL Spectrum Stretcher," which has shown in laboratory tests to have a recognition differential of -24 db (referred to a 1-kc bandwidth) against noise, 13 db better than the figures used here.

LOMASS III Developments

While the LOMASS I was being developed and field tested, preliminary design work was being done on the LOMASS III scanning system. A laboratory test model of the compliant tube receiving lens, 5 ft in diameter (Fig. 13) was constructed and tested with encouraging results. Satisfactory beam patterns have been obtained and it is believed that a model suitable for sea use can now be built.

The Luneberg lens is comprised of a group of transducers arranged in a circle about a special core material as shown in Fig. 13. At this point, it is necessary to explain the operation of the lens and to list some of the differences between other scanning systems and that used with the lens. Conventional scanning arrays use complex phase addition devices to form the beam and some arrays require as many of these devices as there are beams. In contrast, the output from each lens hydrophone is a beam associated with that hydrophone. No phase networks are used and the beam is rotated by switching to the adjacent hydrophone. The operation of the lens* depends on the core material having an index of

*For a complete explanation of the theory and operation of Luneberg lenses, see Refs. 5-7 refraction (hence, the sound velocity) which varies with radius. A sound ray entering the lens (Fig. 14) off the axis is bent toward the axis by the action of the core, and emerges from the opposite side at the axis. A bundle of sound rays having the diameter of the lens will be focussed to a point on the opposite face of the lens. By placing a hydrophone at this point, a gain is achieved, and, for the main lobe, a beam pattern (Figs. 15 and 16) is formed similar to that of a circular piston having the same diameter as the lens. Some internal reflections have been measured and are believed to be caused by the cement used in the construction of the lens. For this reason, the front to back ratio is not as high as is possible.

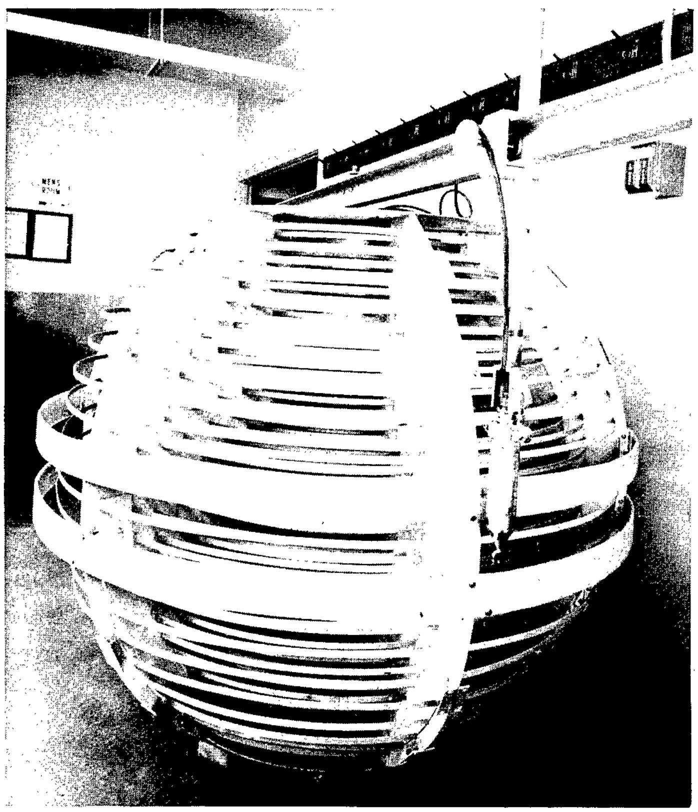

Fig. 13 - Compliant tube receiving lens with mounted hydrophone

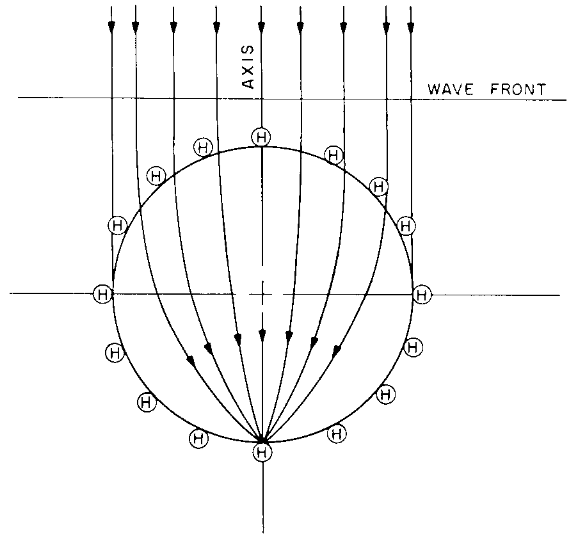

Fig. 14 - Ray diagram of lens operation

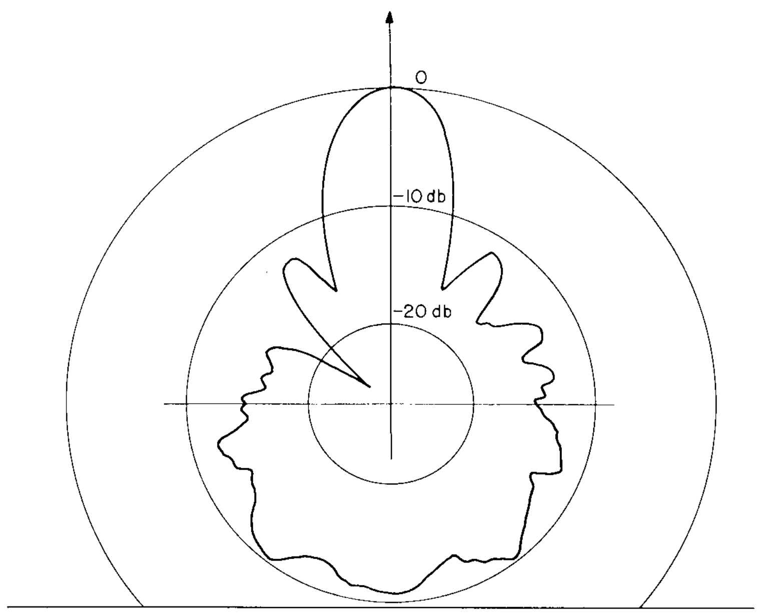

Fig. 15 - 2.3-kc lens pattern with omnidirectional hydrophone

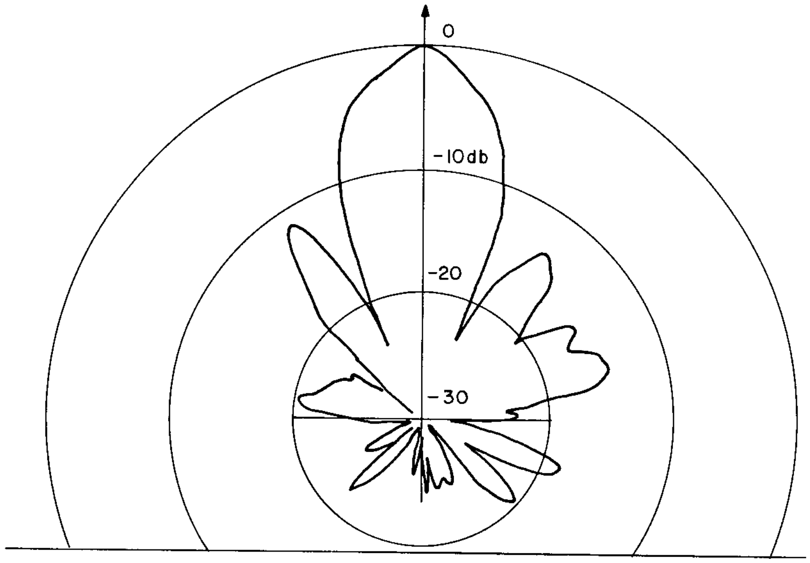

Fig. 16 - 2.3-kc lens pattern with directional hydrophone

Thus the lens has preformed beams and two operational modes are available. First, of course, these preformed beams allow continuous monitoring of all beams. The second type, the intended use of the lens, consists of a sequential output from all beams. This process is called scanned, preformed beams. Compared to preformed-beam operation there may be a loss incurred in scanning depending on the scanning rate but this is supplimented by omnidirectional coverage. Both the conventional scanning array and the scanned, preformed beams of the lens suffer the same scanning loss. The main advantages of the lens are its simplicity of beam formation and the availability of preformed beams. All of the foregoing discussion has in mind beam formation for the normal sonar operation of target detection. For precise bearing information within a particular beam, it is necessary to be able to obtain phase-sensitive operation.

Information for high bearing resolution within the beam can be obtained from the lens by comparing the phase of two adjacent hydrophones. The bearing of the target will be a function of the phase difference. Figure 17 is a plot of experimental results showing this phase difference with respect to mechanical rotation. On this same figure is also shown the theoretical phase difference for the same hydrophones without the lens. The lens phase difference appears to be quite nonlinear but in the useable portion (between the 3-db downpoints) the error is small. Perhaps this could be corrected by modifying the cathode-ray-tube display sweep voltage.

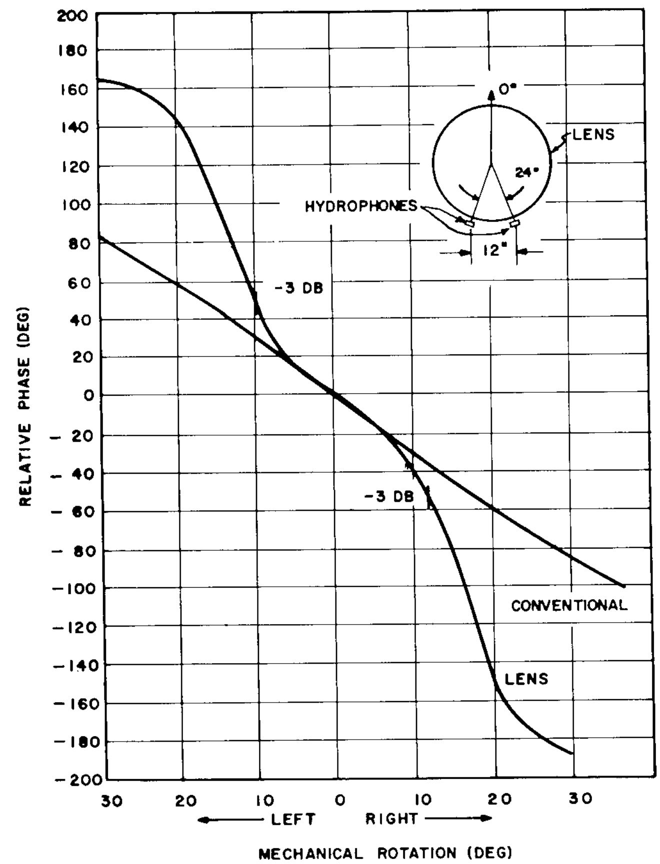

Fig. 17 - Lens phase test

Scanning switches for this system have been obtained and considerable work has been done on a matrix display. A preliminary display model has been tested with good results.

The development work on the LOMASS III was approximately 25 percent complete.

RECOMMENDATIONS AND COMMENT

Noise measurements of the radiated noise into the water from an HR2S have shown that the reference of sea-state 2 noise is misleading and gives a false picture of the sonar system's operating environment. A more accurate noise level is some 30 to 40 db higher than sea-state 2. A level this high places a severe restriction on the range expected from a sonar system. Means must be found to circumvent this limitation and this requires more information about the radiated noise from the helicopter. The helicopter designers can attack the problem by analyzing the noise producers and reducing their effect by the use of baffles and similar devices. The sonar engineer can attack the problem by learning more about the noise radiation pattern, by building better transducers, and using underwater acoustic baffles.

In one experiment to reduce the noise coupled to the water, fire-fighting foam was spread over the surface of the water. A loudspeaker was suspended about 12 in. above the water and a hydrophone was placed about 12 in. below the surface. A 2.5-kc signal was fed into the speaker to give an indication on the monitored hydrophone output at least 20 db above the ambient noise level. The addition of about 2 in. of foam reduced the hydrophone output to the ambient level. One advantage of this noise-reduction scheme is that it reduces the amount of noise that enters the water and consequently would greatly reduce any noise scattering in the water medium or reflections from the bottom. However, in an experiment conducted at NRL, a helicopter hovering over the foam blew it away from the surface immediately below the helicopter. It may be possible to develop a foam which would not blow away. If this can be done there is still the problem of generating and placing the foam on the surface from a helicopter at a small cost in weight.

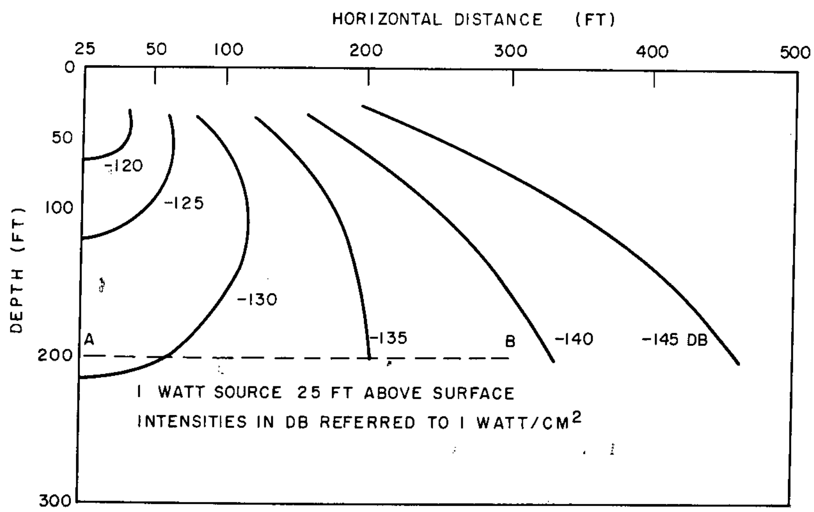

Fig. 18 - Iso-intensity lines versus range and depth for a simple source above an air-water interface.

Some theoretical work on the radiation pattern from a sound source at a point above an air-water interface indicates that the intensity level drops off fast enough in a horizontal direction to be useable for noise reduction (see Fig. 18). Point A on one end of the dashed line, is the theoretical intensity at a depth of 200 ft immediately below the helicopter and point B, at the other end of the dashed line, is the intensity at a 200-ft depth and 300 ft horizontally from the helicopter. A difference of about 10 db is indicated. A point source is assumed, as well as ray theory, but some recent measurements by NEL, at a higher frequency, have verified in a general way the results of the above work. The noise measurements conducted by the U.S. Navy Underwater Sound Laboratory contained the necessary data to check this theory, but the data was never analyzed for this type of information. A current promising approach to this noise problem is the replacement of the conventional reciprocating engine with a gas turbine. The radiated engine noise should be at higher frequencies, and the sonar environment may be closer to the ideal of sea-state 2. However, this assumes that most of the noise comes from the engine, which has not been proven. A more complete picture is needed to account for noise contributions from helicopter components such as rotor blades, drive shafts, gear boxes, and the downwash illustrated in Fig. 5. It is recommended that a continuing detailed noise-measurement program be maintained on all aircraft considered for ASW, and that standards be established for all ASW aircraft noise measurements.

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