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A SURFACE RADAR INTERCEPT SYSTEM

[UNCLASSIFIED TITLE]

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W. E. Withrow

Countermeasures Branch
Radio Division

August 5, 1959

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A BUOY-MOUNTED RADAR INTERCEPT AND WARNING SYSTEM FOR SUBMARINES

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ABSTRACT

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A crystal-video ECM receiving system to provide warning of approaching aircraft has been designed for installation in a radio-communication buoy which is towed from a submerged submarine. The antenna is omnidirectional and responds to radar signals from 2,500 to 10,000 Mc. The system is pressurized for 500 pounds per square inch. Sensitivity of the system is sufficient for about 80-percent radar line-of-sight operation with high-power radars. Sea trials under typical operating conditions were consistent for two antenna heads of different mechanical design. Ranges up to 77 miles were measured for an aircraft altitude of 5000 feet. For visual signal analysis, an improved terminal amplifier would be desirable.

PROBLEM STATUS

This is an interim report on one phase of the problem; work on this and other phases is continuing

AUTHORIZATION

NRL Problem R01-15
Project NE 021-500
BuShips No. S-1812

Manuscript submitted June 3, 1959.

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The NRL electronics buoy

A BUOY-MOUNTED RADAR INTERCEPT AND WARNING SYSTEM FOR SUBMARINES

[[redacted] Title]

INTRODUCTION

The NRL experimental electronic buoy is essentially a communications device for submerged submarines. It is designed for launching and operation while the submarine is at any operating depth. The buoy contains three separate antenna systems, one for vlf, one for hf, and one for ECM. This report covers the ECM system only.

The ECM system was initially conceived as an instantaneous warning of area radar activity when the buoy broaches the surface. The omnidirectional antenna array contains three antenna elements which are part of a crystal-video receiving system. The detected signal is fed to the submerged submarine through a 600-foot transmission line which also serves as the buoy tow cable. At the present time, this system requires the three antennas in the buoy to be time shared: this is accomplished by remote switching from the submarine.

To perform the warning function completely, it would be necessary to cover the frequency range from P-through X-band. Single antennas are at present incapable of such a wide frequency coverage. The antenna element utilized in the present experimental effort is a spiral which can be made to operate over a four-to-one frequency band. An omnidirectional antenna utilizing three spiral antenna elements has been designed to cover the S- and X-bands in order to prove out the system.

Other factors peculiar to the system are pressurization of the antenna and transmission of the ECM information over the long transmission line. Problems connected with each of these have been solved, and a complete system has been evaluated under typical operating conditions.

ECM SYSTEM

The ECM system is shown in Fig. 1. It is a wide-open crystal-video system consisting of an antenna head, a preamplifier, 600 feet of transmission line, line switches, and a terminal amplifier.

The antenna (Fig. 2) is an around-the-mast assembly of three spiral antenna elements with the beam of each element elevated 22 degrees above the horizon for improved hemispheric coverage. The crystal holder is integral with the antenna-element housing. Signals from the three elements are combined in parallel and fed to the preamplifier through a short length of coaxial cable.

The two-stage video preamplifier circuit (Fig. 3) is an RC – coupled common-emitter circuit with slight degeneration in the emitter. A cathode-follower stage is required to drive the 600 feet of transmission line. Power for the preamplifier is taken from the terminal amplifier high-voltage supply and is carried in common with the signal on the transmission line.

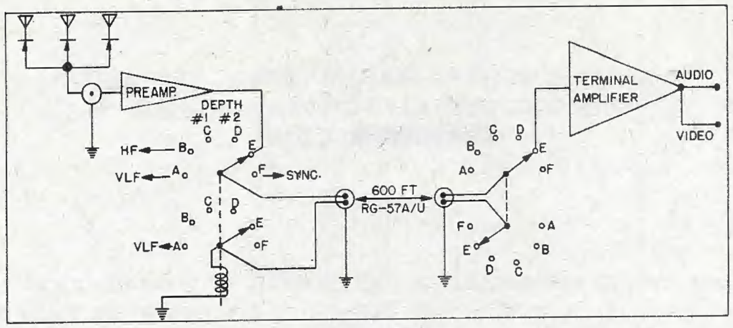
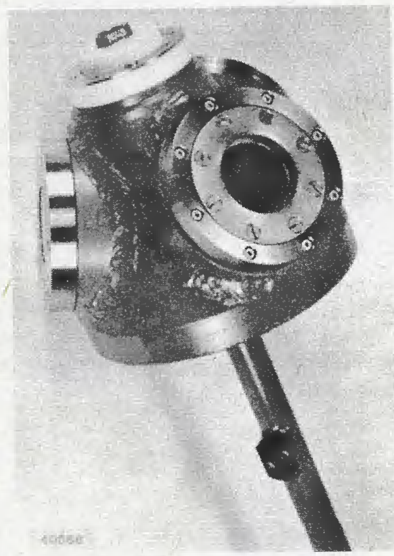


Fig. 1 - ECM system

Fig. 2 - Antenna mast number 1, used on USS BARRACUDA (35 pounds)



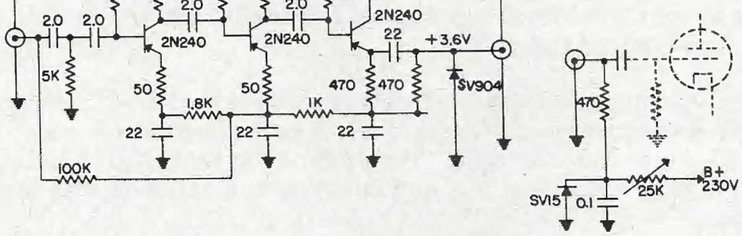


Fig. 3 - Video preamplifier

The zener diodes at each end of the transmission line serve two purposes. They form a two-stage voltage regulator for the preamplifier, and they reduce the switching transients which appear on the ECM line. Voltages up to 150 volts were observed during switching prior to the use of the diodes.

The preamplifier characteristic is shown in Fig. 4. The overall voltage gain, including the diode loading, is 35 db. The bandwidth is one megacycle. With a normal tangent-signal detector sensitivity of -50 to -55 dbm, the dynamic range is greater than 20 db. The tangent-signal sensitivity of the amplifier itself is ten microvolts, which is much less than the detector noise output.

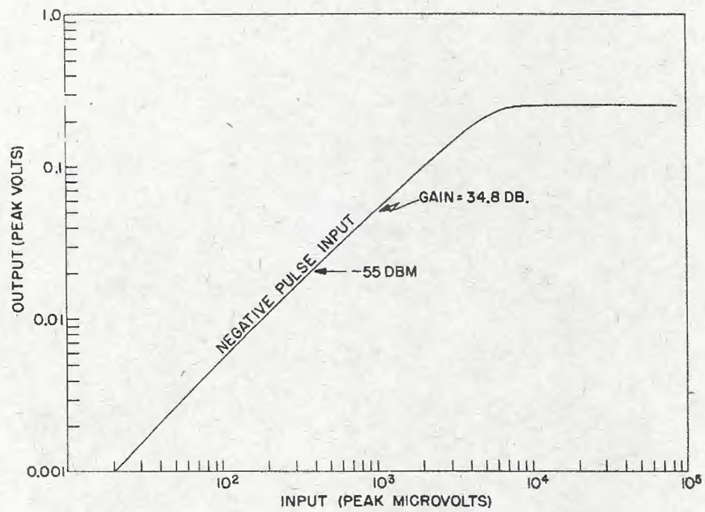


Fig. 4 - Preamplifier characteristic

The preamplifier is mounted in 1-1/2 x 3/4 x 3 inch shielded case with Microdot input and output connectors. It may therefore be conveniently located at the buoy end of the line. Two locations were used during the sea trials. It was located within the antenna head (Fig. 2) on the first trials and in the buoy housing during the second trials.

A switch is shown at each end of the transmission line in Fig. 1. The ECM system uses one conductor of the two-conductor cable, RG-57A/U. The switch disconnects the ECM system when other services are being used.

The terminal amplifier is a model R-467 (XB-3)/ALR crystal-video receiver with the input circuit modified to supply power to the preamplifier. The receiver has a video gain of 80 db, which proved excessive during tests, and a bandwidth of 1.2 Mc. Optimum operation of the amplifier was with 30-db video attenuation. The low-frequency response of this particular amplifier, which is rather poor (40 -percent droop in 10 microseconds), should be improved for signal-analysis purposes. The video attenuation is provided by a 60-db, six-step attenuator which controls the overall gain of the receiver. Three audio outputs and one video output are provided. Individual audio gain controls are used.

PRESSURIZATION

The antenna system is designed for a pressure of 500 pounds per square inch. This is accomplished by means of glass windows and O-ring seals. Figs. 5 and 6 show the antenna arrangement used during the second sea trials. Two O-rings are used for each window, one to seal the window in the removable element assembly and a second to seal the assembly in the pressure housing. The window size is determined from both electronic and mechanical considerations. For a pressure of 500 pounds per square inch, the minimum thickness for a 2-1/2-inch window is 0.555 inch. One wavelength in 7740 Pyrex glass is 0.592 inch at 3.2 centimeters (X-band). The window was therefore made 0.592 inch thick and was measured for loss in both S- and X-bands. The total window attenuation was found to be about one decibel.

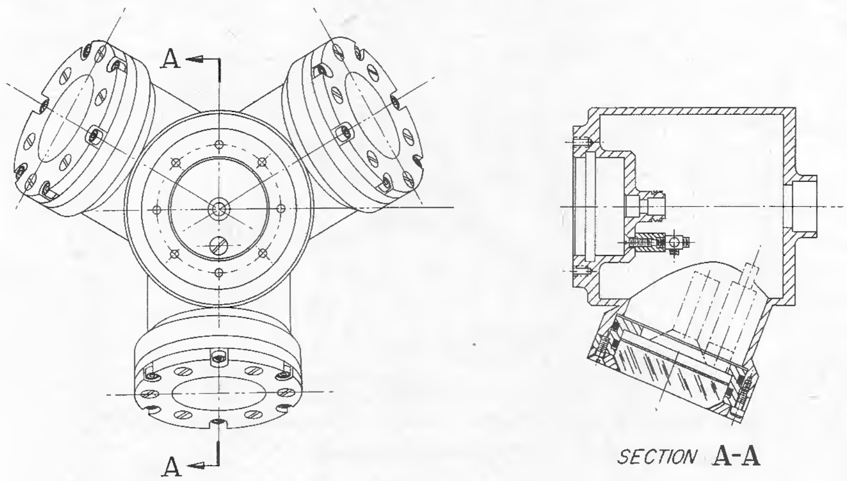


Fig. 5 - Antenna mast number 2, sectional assembly

SEA TRIALS

The ECM system has undergone two sea trials with only slight differences in components. The first installation was on the USS BARRACUDA on Oct. 6, 7, and 8, 1958. For these runs an antenna mast and a three-element ECM antenna assembly (Fig. 2) weighing 35 pounds was used. The second installation was on the USS HARDHEAD on Jan. 14, 1959. For the second trial an antenna unit (Fig. 6) weighing 15 pounds was used. The antenna elements within the second unit were the same as on the first trials.

The field trials were conducted in Long Island Sound in water of sufficient depth for the submarines to operate submerged. The ECM trials consisted of intercept-range runs working with an AN/APS-20E radar. The aircraft was controlled by means of the buoy communications system. Each run consisted of an outbound and inbound leg. This allowed the operator to determine the point at which the outbound signal was lost and the point of acquisition in an inbound run. Runs were conducted at altitudes of 500, 1500, and 5000 feet. The data for all runs are summarized in Table 1 and on Figs. 7, 8 and 9. The buoy antenna was 2-1/2 feet above the surface.

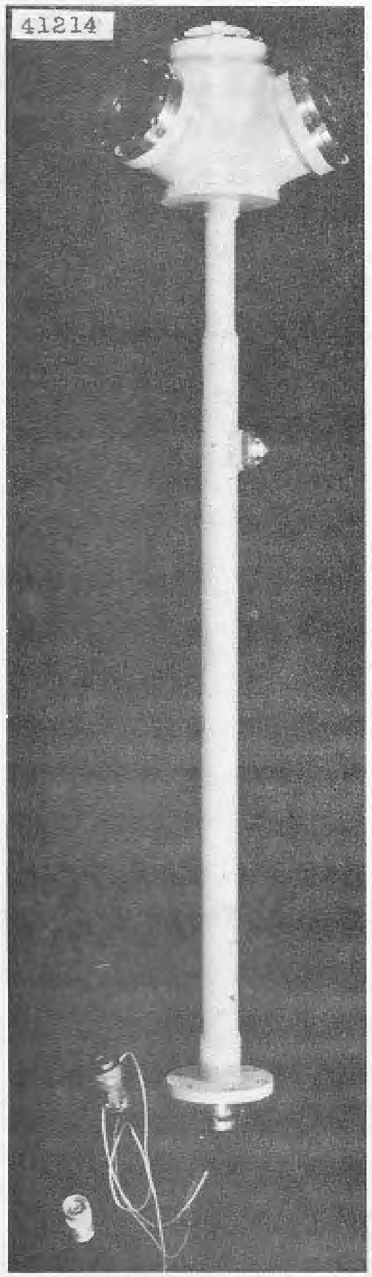


Fig. 6 - Antenna mast number 2, used on USS HARDHEAD (15 pounds)

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Table 1
Summary of Radar Intercept Data Using
Buoy-Mounted ECM Equipment

Aircraft Altitude (ft)	Intercept Range (Nautical Miles)			
	USS BARRACUDA (Oct. 6, 7, 8, 1958)		USS HARDHEAD (Jan. 14, 1959)	
	Out	In	Out	In
500	24	23	30	25
1500	32	32	40	37
5000	79	77	78	38

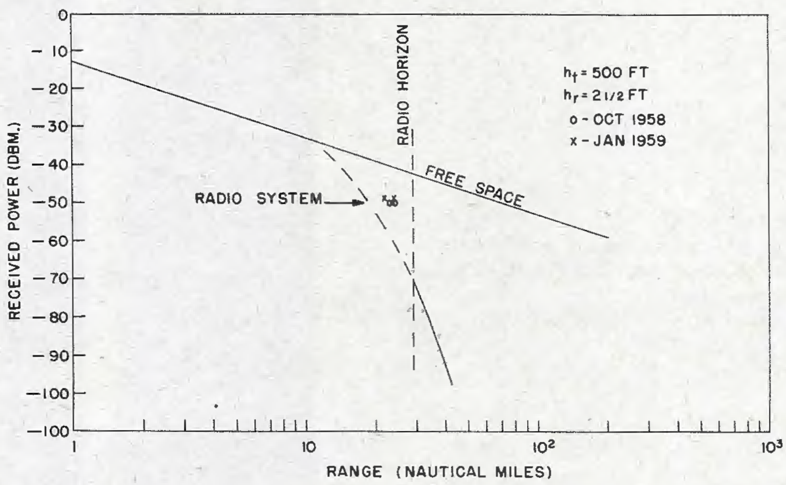

Fig. 7 - Received power vs range for wide-open crystal-video receiver and AN/APS-20E radar at a altitude of 500 feet

On the 5000-foot altitude run of Jan. 14, the communications failed at about 44 miles, the last contact on the out bound leg. The range beyound this point was determined by stop-watch and plane speed. The short acquisition range is the range reported on the inbound leg when communications were re-established and is therefore not a true maximum acquisition range. The signal had been acquired prior to this communication contact.

The data of Table 1 are plotted on Figs. 7, 8 and 9. These curves allow a comparison to be made between the theoretical and measured ranges. The curves show the expected received power from the radar for a given range. The point marked Radio System is located at a level of -50 dbm, which is the normal tangent-signal sensitivity of a crystal-video receiver having unity antenna gain. It was to be expected that the measured ranges would exceed the theoretical, since tangent-signal sensitivity is a visual measure, and the tests were run using audible threshold. Visual signal analysis would therefore be feasible at somewhat less than the indicated measured ranges.

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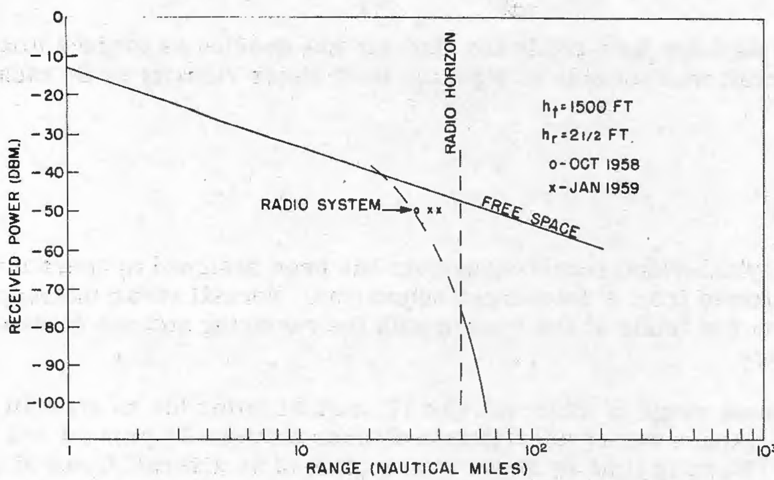

Fig. 8 - Received power vs range for wide-open crystal-video receiver and AN/APS-20E radar at altitude of 1500 feet

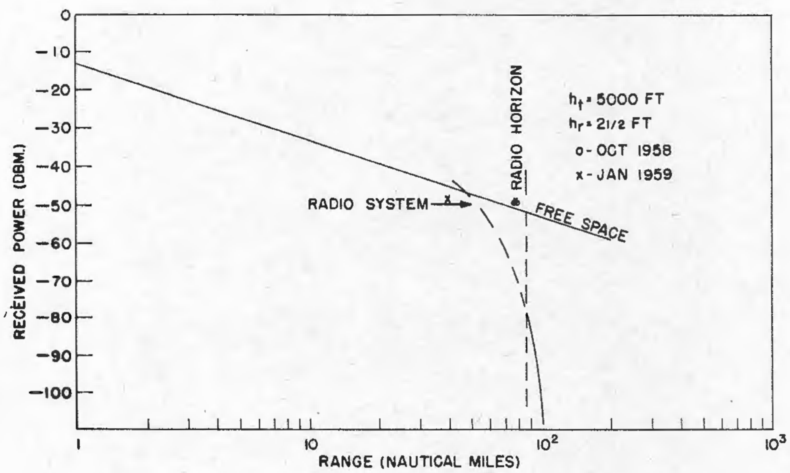

Fig. 9 - Received power vs range for wide-open crystal-video receiver and AN/APS-20E radar at altitude of 5000 feet

The measured ranges are seen to be slightly short of the radar horizon for each altitude. Warning time varies according to altitude. For a 180-knot aircraft speed, the warning times would range from 9 to 25 minutes. This is considerably better than visual warning. Visual warning has been reported for an aircraft altitude of 500 feet and speed of 155 knots.* The average warning time was 1.4 minutes.

*J. M. Hood, Jr., "A Field Study of Periscope Search for Aircraft," NEL Report 813 [redacted], Nov. 29, 1957.

[redacted]

During the October field trials the aircraft was queried as to the ability to sight the buoy. The aircraft was not able to sight the buoy either visually or by radar from a range of 500 feet.

CONCLUSIONS

An ECM crystal-video receiving system has been designed to operate with a buoy which is being towed from a submerged submarine. Normal radar intercept ranges have been obtained on sea trials of the system with the reveiving antenna elevated 2-1/2 feet above the surface.

The maximum range of intercept was 77 nautical miles for an aircraft altitude of 5000 feet. Intercept ranges varied according to altitude between 75 percent and 90 percent of the radio horizon. Warning time by radar interception of an aircraft flying at 500 feet is nine minutes. This compares with a visual-intercept warning of 1.4 minutes.

* * *