AD NUMBER:	AD0321515
CLASSIFICATION CHANGES	
TO:	Unclassified
FROM:	Confidential
LIMITATION CHANGES	
TO:	Approved for public release; distribution is unlimited.
FROM:	Distribution authorized to U.S. Government Agencies only; Administrative/Operational Use; 13 Jan 1961. Other requests shall be referred to US Naval Research Laboratory, Washington, DC 20374.
AUTHORITY	
U per USNRL ltr dtd 8 Dec 1978; ST-A per USNRL ltr dtd 14 Dec 1978	

UNCLASSIFIED

AD 321515

CLASSIFICATION CHANGED
TO: UNCLASSIFIED
FROM CONFIDENTIAL
AUTHORITY:

USNRL Ltr, 8 Dec 78

UNCLASSIFIED

[redacted]

AD 321 515

Reproduced by the

ARMED SERVICES TECHNICAL INFORMATION AGENCY
ARLINGTON HALL STATION
ARLINGTON 12, VIRGINIA

[redacted]

[redacted]

NRL Report 5586

A SUBMARINE COMMUNICATION BUOY SYSTEM

[UNCLASSIFIED TITLE]

K. L. Leidy and H. D. Cubbage

Communications Branch
Radio Division

January 13, 1961

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

[redacted]

[redacted]

CONTENTS

Abstract	ii
Problem Status	ii
Authorization	ii
INTRODUCTION	1
CONTROL SYSTEM	1
BUOY AND ANTENNA SYSTEMS	6
ECM, VLF, and HF Facility	6
HF, UHF, IFF, and VLF Facility	8
WINCH-NEST ASSEMBLY	9
CONTROLLERS	13
Radio Room	13
Main Controller (Sonar Room)	15
Auxiliary Controller	15
APPROXIMATE RANGES	15
BUOY AND CABLE BEHAVIOR IN VARIOUS SEA STATES	15
OPERATION OF THE SYSTEM	20
EXPERIENCES	20
CONCLUSION	21
ACKNOWLEDGMENT	22
REFERENCES	22

[redacted]

ABSTRACT
[Confidential]

The system described in this report is intended to fill a long-standing requirement of the submarine service for a means of communication while submerged. It consists of an assembly which includes a towable buoy, tow-signal cable, winch-nest assembly, and controls. The towable buoy, which supports the communication antennas, may be released and retrieved while under way at all operating depths. At these depths it provides vlf, hf, uhf, IFF, and ECM services and a flashing marker light, as well as loran and lf reception in strong signal areas.

The system requires a minimum of hull penetration for installation. It has been in operation on the USS HARDHEAD more than 18 months and has been used in many exercises at sea. In addition to regular submarine communications service, it has been used for research purposes by the Laboratory. Although experimental in nature, it has provided much useful information and experience for future buoy systems.

PROBLEM STATUS

This is an interim report; work on the problem is continuing.

AUTHORIZATION

NRL Problem R01-15
Project SF 006-03-02, Task 7461
BuShips No. S-1812

Manuscript submitted November 29, 1960.

A SUBMARINE COMMUNICATION BUOY SYSTEM
[Unclassified Title]

INTRODUCTION

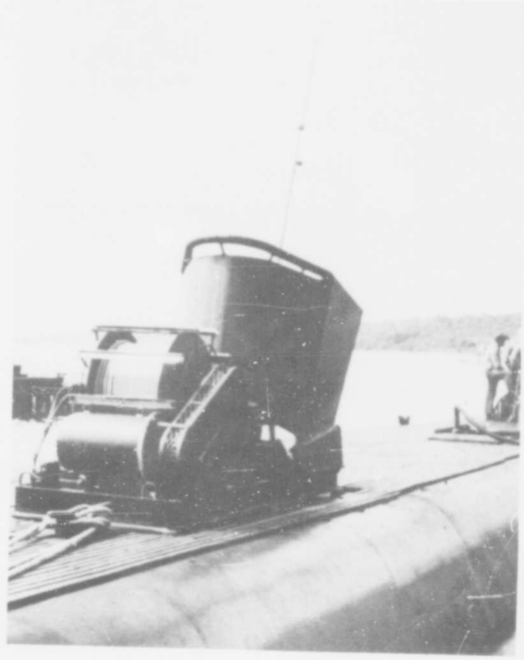
The submarine service has long needed a means of communication while submerged. Detection, location, and tracking of enemy submarines are accomplished effectively by another submarine operating at or near the depth of the enemy submarine. If it is necessary for the submarine to surface in order to communicate with surface ships or aircraft, the contact will likely be lost. It is also desirable to be able to receive orders, intelligence, etc., while submerged and hidden. If vlf is used for this purpose, the buoy and submarine may be completely submerged and retain communication without disclosing their position. This is very desirable in enemy waters.

Communications from a submerged submarine has been the objective of many investigations at the Naval Research Laboratory over the years, dating back to the 1920's. From these investigations, the limitations and capabilities of underwater radio wave propagation have been established and reported. The most severe limitation is the attenuation of radio waves in sea water.

Some acoustic methods of communication are in use but their ranges are limited. The idea of raising antennas to the surface by means of buoys has been suggested and expanded to include buoys, floating wires, planing devices, etc. A remote television camera has also been proposed and demonstrated for use as a buoy-mounted periscope. The buoy idea was recognized as feasible but it was not until a towable body was demonstrated that interest was aroused in the project (1). An experimental system was then devised to include various communication services, to permit launching and retrieving of the communication buoy from a deeply submerged submarine, and to provide a haul-down mechanism along with the necessary controls and indicators.

CONTROL SYSTEM

The system is as shown in Figs. 1 and 2. It consists of a winch-nest assembly, buoy, tow-signal cable, and controls. Inside the submarine, in the sonar room, is the main controller (Fig. 3). It has push buttons for various means of operation, tension and cable indicators, and safety devices. In the radio room, essentially in parallel with the controller, is an auxiliary controller. This has tension and cable indicators and a single buoy up-down switch so that the radio operator may control the buoy at the surface to compensate for various sea states, changes in depth and speed of the submarine, etc. Also in the radio room is a coaxial switch to permit selection of the various services in the ASW mode (Fig. 4). When used with the vlf facilities, a signal control unit is used to select the various services (Fig. 5). It features a synchronous stepping switch which permits selection of the desired band and includes an indicator for depth. A multiplexing system will be installed in the future which will allow the services to be used simultaneously.

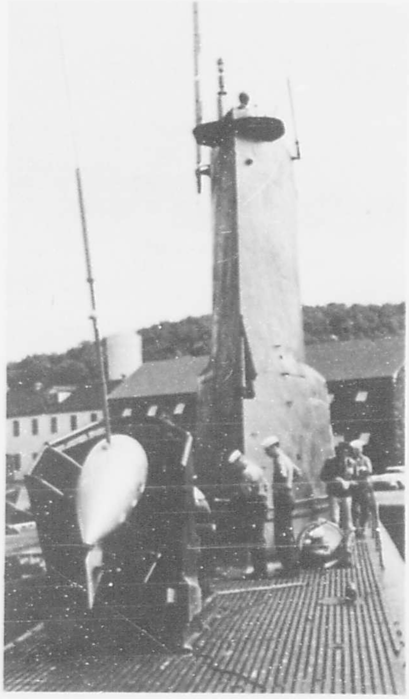


(a)

(b)

Fig. 1 - ASW buoy communication system

(c)



(d)

Fig. 1 (Continued) - ASW buoy communication system

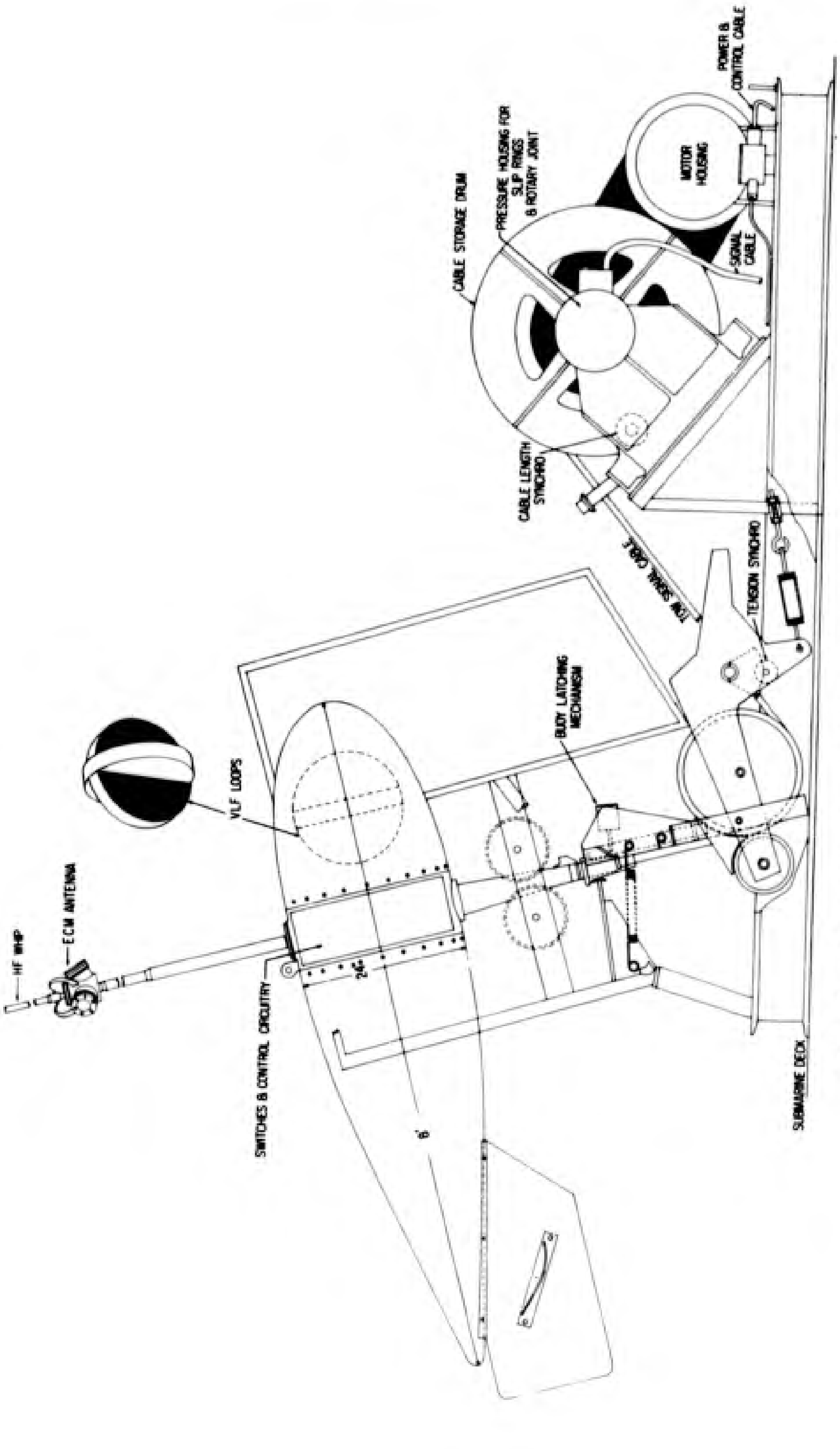


Fig. 2 - Schematic drawing of communication buoy system

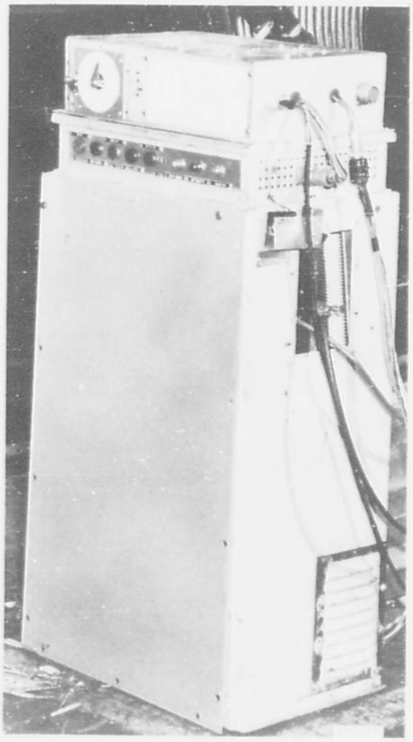


Fig. 3 - Main winch controller

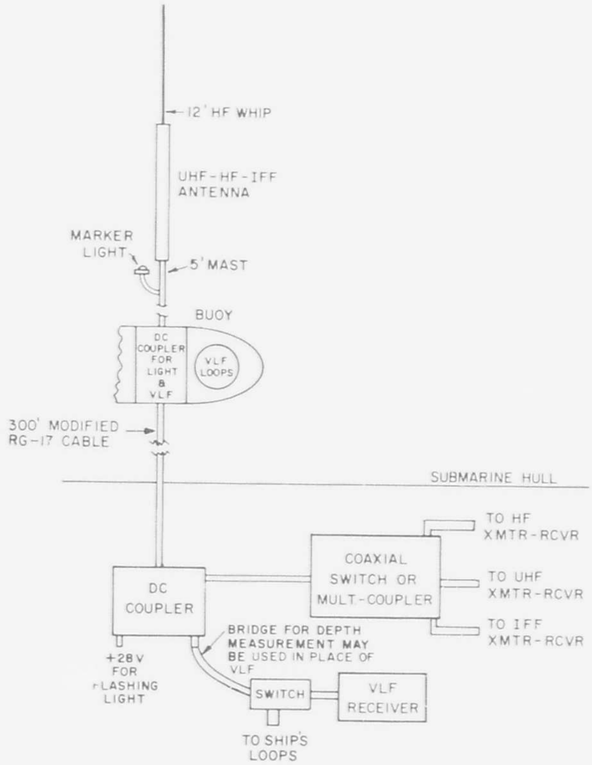


Fig. 4 - Block diagram of ASW mode

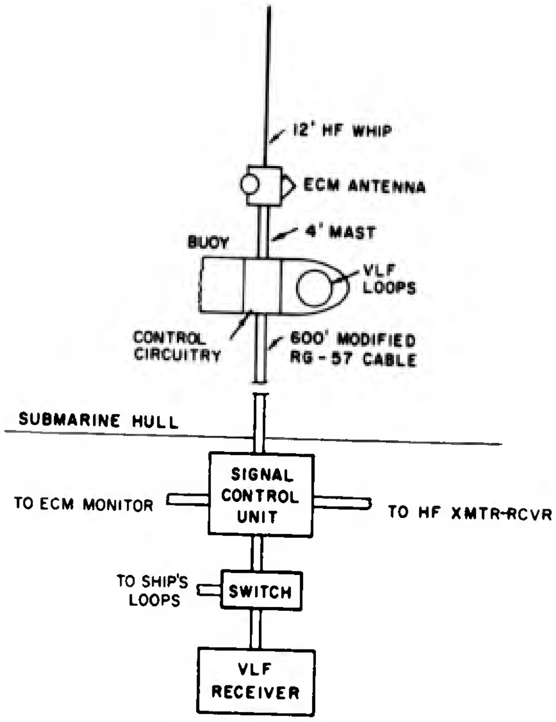


Fig. 5 - Block diagram of vlf mode

BUOY AND ANTENNA SYSTEMS

The buoy is 8 feet long and 24 inches in diameter (Figs. 1 and 2). The nominal reserve buoyancy is 600 pounds. Its weight out of water is 350 pounds. The center section of the buoy is stainless steel, while the front and rear sections are fiberglass, with O-ring seals between sections. The nose section contains crossed vlf loops, together with their associated circuitry.

A sealed tube extending through the metal center section contains the necessary switches and other control circuitry for the antennas. If the fiberglass should leak for any reason, the sealed tube prevents damage to the control circuitry and the antennas. In the ASW configuration, it contains a dc coupling circuit (Fig. 6) which permits dc and low frequency ac to be picked off the center conductor without interference to the rf circuit. This coupler is used to power the flashing light and to carry vlf signals.

Two configurations have been used with the buoy, a combined ECM, vlf, and hf facility and another which includes hf, uhf, IFF, vlf, and a flashing light. The system has evolved through various designs to meet research needs and to obtain the desired communications services of the submarine. Further services may be incorporated in the future. However, each service must be considered in terms of the additional weight and complexity required.

ECM, VLF, and HF Facility

The vlf, as previously mentioned, consists of two crossed loops mounted in the nose section of the buoy, together with their associated circuitry. The loops are approximately 15 inches in diameter and provide reception equal to or better than the standard 317 loops. Their design is based upon principles described in previous NRL Reports (2-6).

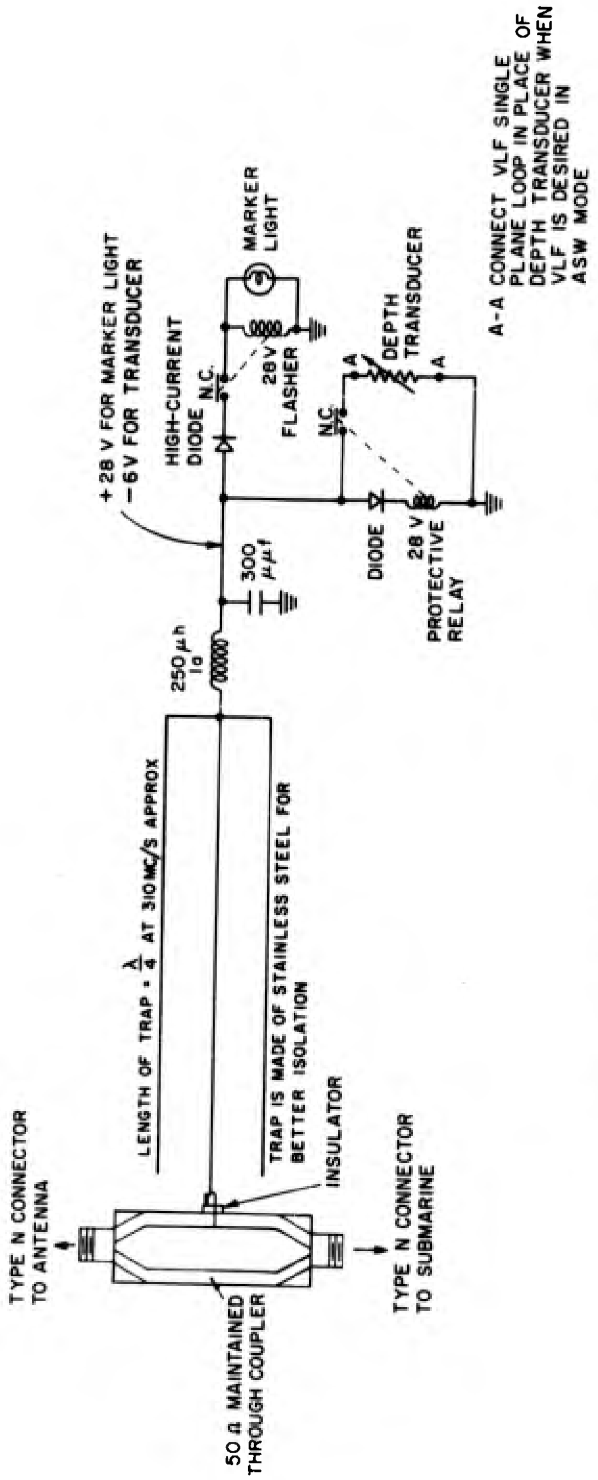


Fig. 6 – Buoy dc coupling circuit for use in ASW mode

Fig. 7 - HF antenna mounted on top of ECM antenna

The ECM antenna is actually several antennas in parallel in a "wide open" system. It provides coverage from 1000 to 10,000 Mc/s and may be monitored either aurally or visually, using an oscilloscope. The range from 2500 to 10,000 Mc/s is covered by three printed spiral antennas (7) mounted at equal distances around the mast, as shown in Fig. 7. Three "scimitar" antennas (also shown in Fig. 2), capacitively coupled to the whip, provide 1000-2500 Mc/s reception. The head also includes a transistorized amplifier to increase the signal level and to provide a low-impedance source to feed the transmission line. It will be more fully described in a forthcoming NRL Report. Typical ranges are shown in Fig. 8.

The hf antenna consists of a 12-foot whip, mounted on top of the ECM antenna section (Fig. 7). It is effectively a longer whip, fed off ground. Its characteristics are similar to that of a standard whip, with some improvement noted due to the off-base feed.

HF, UHF, IFF, and VLF Facility

The uhf, hf, and IFF antenna* has been reported previously (1,8). Typical ranges are shown in Fig. 9. One of the vlf loops is also used in this configuration as a single plane loop; it is coupled to the transmission line by the previously mentioned dc coupler. (The vlf is so low in frequency as to appear essentially dc to the coupling circuit.) This does not provide the omnidirectionality of crossed loops but it is not too great a limitation since the pattern is a figure eight with a fairly sharp null. Also, in most cases, the heading of the submarine could be changed if necessary to bring a more favorable part of the

*Patent application filed.

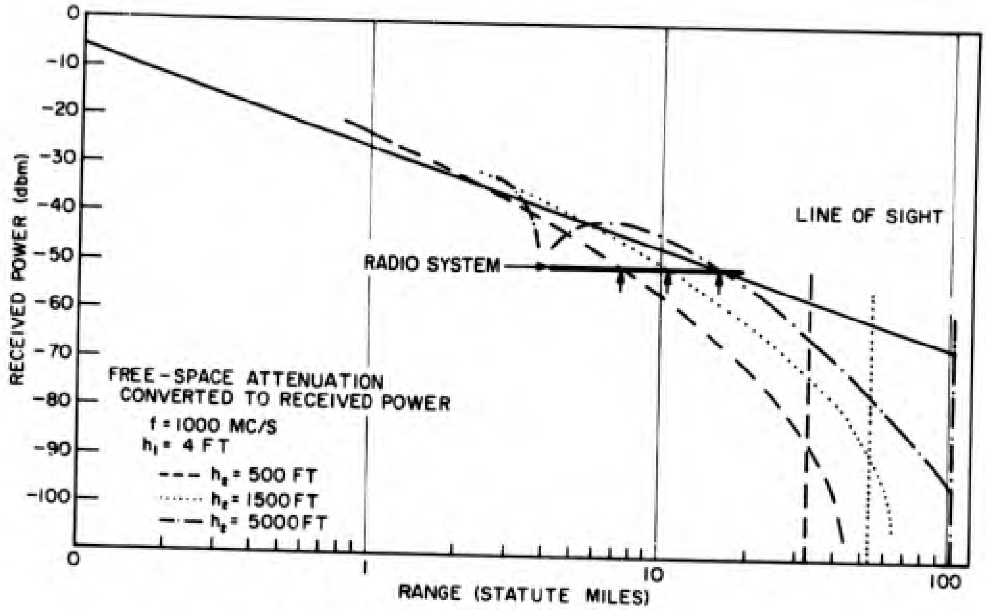


Fig. 8 - ECM reception ranges

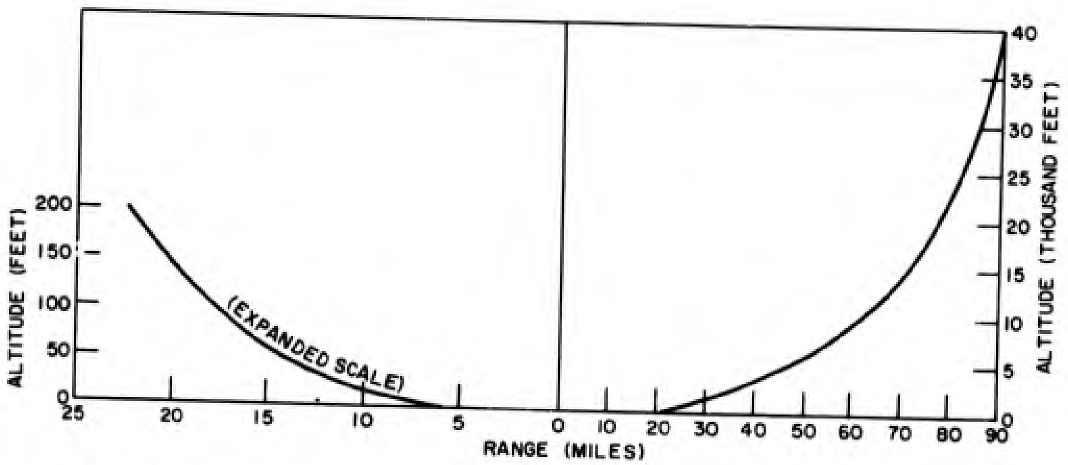


Fig. 9 - UHF communications range versus receiver height

antenna pattern into use. The horizontal patterns of all services used with the buoy are omnidirectional, with the exception of the vlf in the ASW configuration, as previously mentioned.

WINCH-NEST ASSEMBLY

The winch and nest are shown in Fig. 1. The assembly is palletized for convenient installation on the deck of a submarine. The overall size of the entire system on the deck is approximately 10-1/2 × 4-1/2 feet, and the highest point of the nest is approximately 6 feet above the deck.

The arms of the nest are curved so as to make the buoy position itself correctly in the nest. Directly under the nest is a latching arrangement which permits the tension in the tow cable to be reduced while the buoy is in the nest (Fig. 10). No auxiliary power is required for the latch. It is engaged by increasing the cable tension to a specified point (approximately 1000 pounds) and then slacking the cable. This allows a spring-loaded bar (shown in Fig. 10(b)) to automatically latch the buoy. To unlatch the buoy, the tension must be increased beyond the latching point, as shown in Fig. 10(c) (approximately 1200 pounds), causing the dashpot to operate. The dashpot (shown in actuated position) provides a time delay sufficient to allow the buoy to clear the nest before releasing the spring-loaded latch.

Between the nest and the cable drum is a series of rollers mounted on a spring-loaded arm. Also mounted on this arm is a synchro transmitter which gives cable tension information (see Fig. 2).

Two types of cable are used with the system. A modified RG-17/U cable is used with the hf, uhf, IFF, and vlf Facility. Its rf characteristics are similar to those of standard RG-17/U cable. However, its center conductor is constructed of standard copperweld wire, with a breaking strength of approximately 4500 pounds. This stranded center conductor also makes the cable much more flexible than standard RG-17/U cable. A diagram of the cable is shown in Fig. 11.

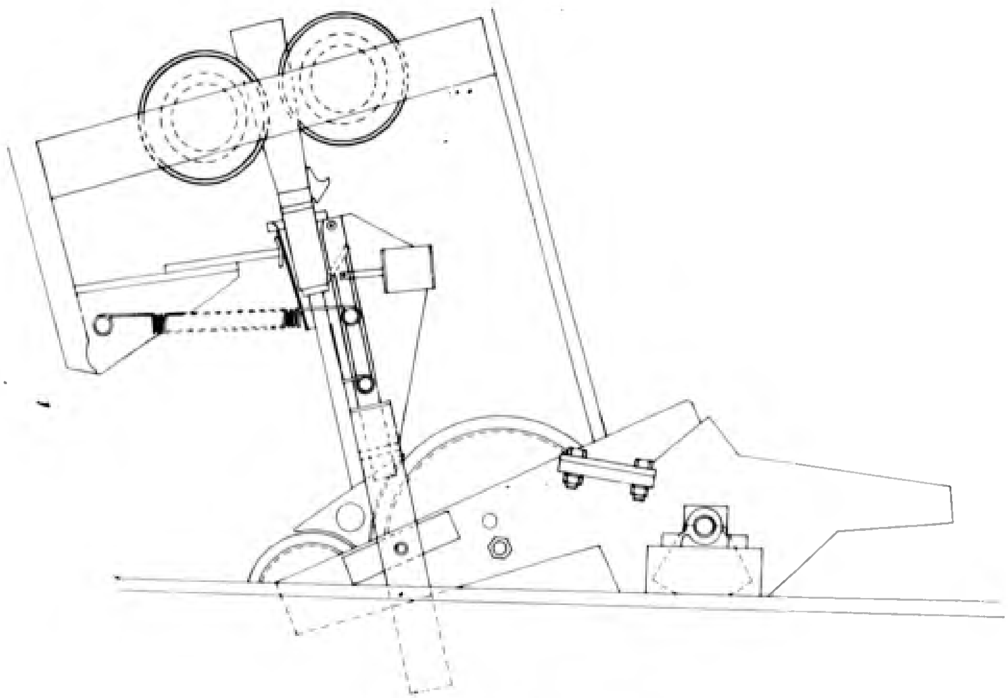
A stainless steel basket-weave shield is placed over the outside of the cable for protection and added strength. It was originally intended to use the shield as a load-bearing member but difficulty was experienced in loading the shield and center conductor evenly. The shield is now used only as a reserve member in case of breakage of the center conductor. The weight of the modified cable is 0.57 lb/ft in air and 0.28 lb/ft in water.

For the ECM, vlf, and hf facility, a modified RG-57/U cable has been used. A diagram of this cable is shown in Fig. 12. A stainless steel basket-weave shield, with a breaking strength of approximately 4000 pounds, is placed over the outside of standard RG-57/U cable. The electrical characteristics remain unchanged. This cable has performed satisfactorily in electrical tests. However, the outside shield is vulnerable to abrasion, and the two conductors have a shorter life than a single conductor due to the greater flexing and twisting action and smaller size. The weight of the cable is 0.28 lb/ft in air and 0.13 lb/ft in water.

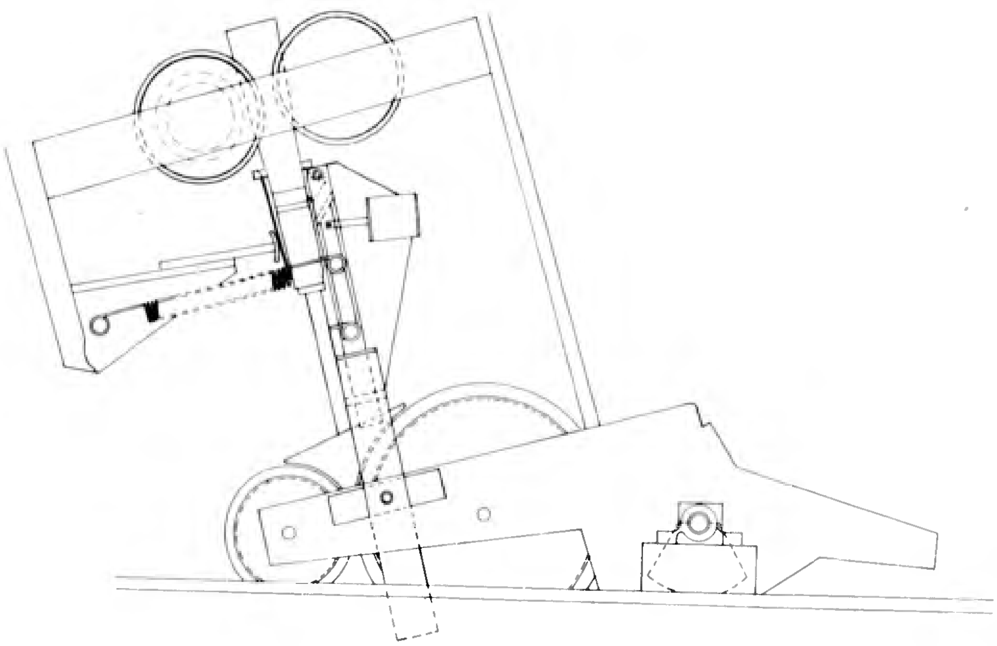
The drum is equipped with a level wind mechanism to properly lay the cable. It may be easily changed for various sizes of cable diameters. The drum has a storage capacity of approximately 1000 feet of 1-inch cable and proportionately more for smaller cables.

Also, on the drum is a synchro transmitter which provides cable length information. For coaxial cable, a coaxial rotary joint may be used on the winch shaft, and for multiconductor cable, a slip ring assembly is used. Locations are shown in Fig. 2.

The drum is driven by a 250-vdc, reversible, 6-hp motor equipped with an electric brake. As now used, the reel-in speed is about 100 ft/min under 600- to 800-pound tension, with reel-out speed of 110 to 125 ft/min depending on tension. When the motor is not energized the brake is locked, holding the drum through the shock-absorbing springs provided within the drum.

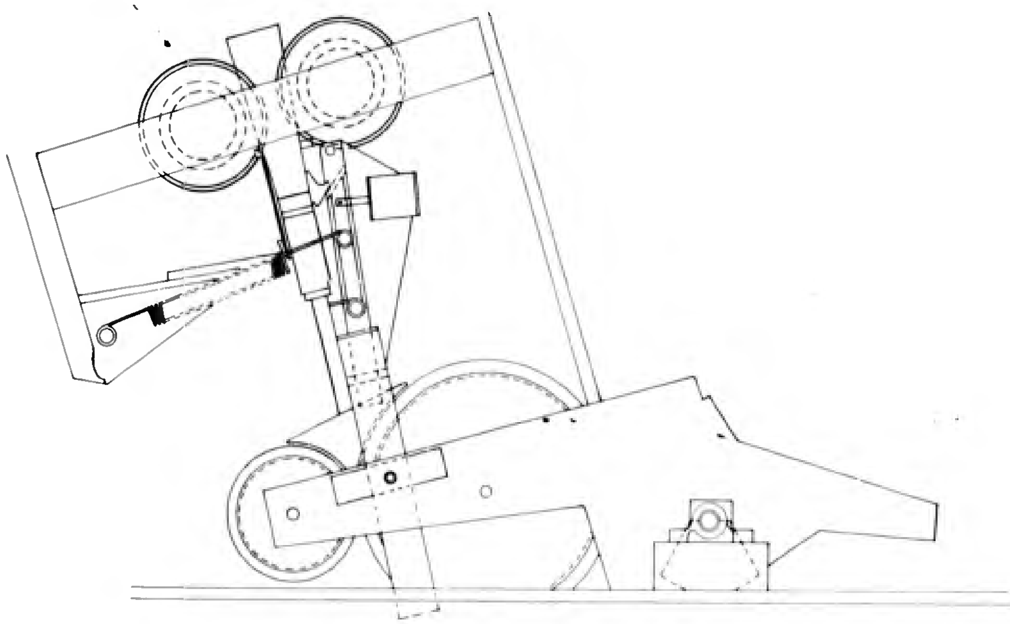


(a) Buoy entering nest

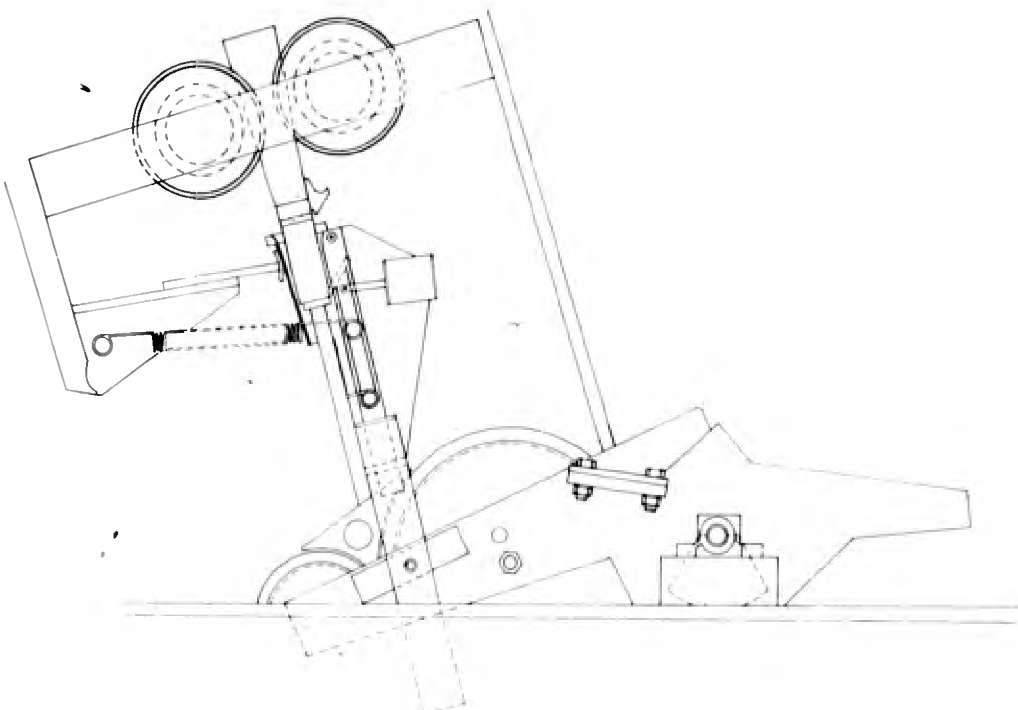


(b) Buoy in latching position

Fig. 10 - Buoy latching mechanism



(c) Latch released–dashpot activated



(d) Buoy leaving nest

Fig. 10 (Continued) – Buoy latching mechanism

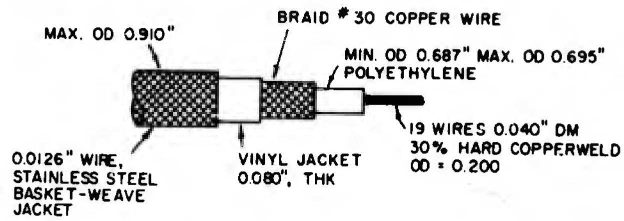


Fig. 11 - Modified RG-17/U tow signal cable

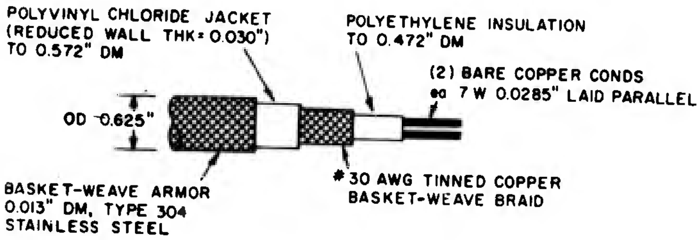


Fig. 12 - Modified RG-57/U tow signal cable

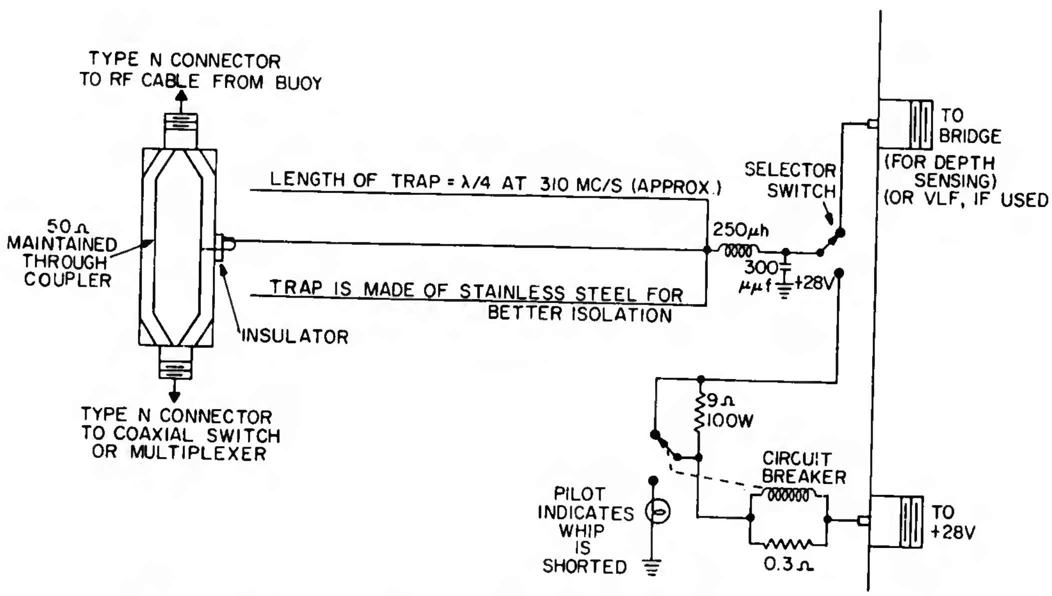


Fig. 13 - Radio room dc coupling circuit for use in ASW mode

CONTROLLERS

Radio Room

The power connections are made through an antihosing, waterproof cable to the controller in the submarine. The rf connections to the winch are made using either RG-17/U or RG-57/U cable (see Figs. 4 and 13 for the ASW mode, and Figs. 5, 14, and 15 for the vlf mode). The rf switches and controls are located in the radio room. Also in the radio room is an auxiliary buoy control unit to allow the radio operator to adjust the buoy on the surface. (Schematics of main and auxiliary controllers are shown in Fig. 16.) A depth gauge may also be provided to give the depth of the buoy below the surface. Synchro receivers show the cable tension and length of cable out.

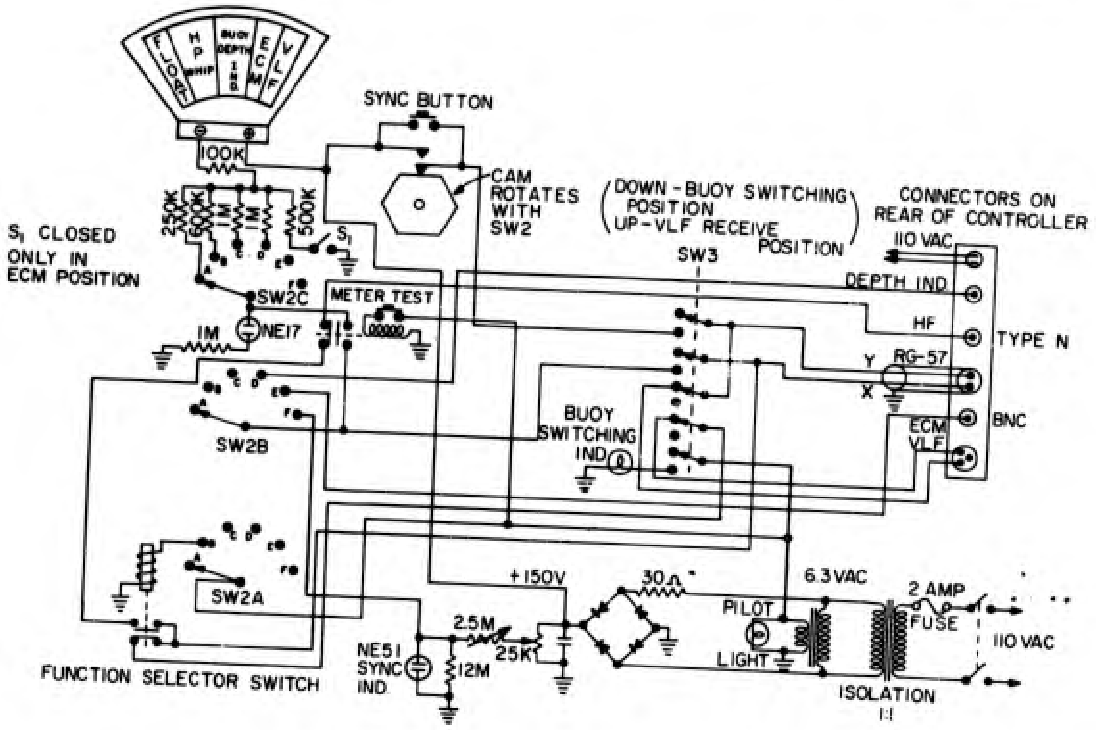


Fig. 14 – VLF mode buoy controller

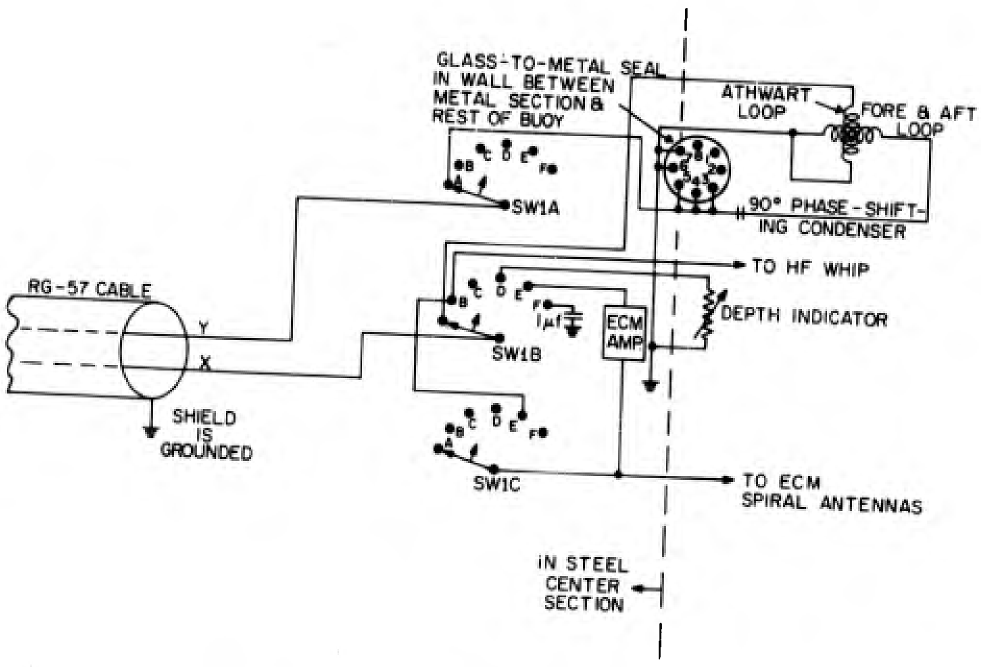


Fig. 15 – VLF mode buoy control circuitry

Main Controller (Sonar Room)

The main controller (Figs. 3 and 16) is in the sonar section of the submarine. It has Inch Up, Inch Down, Auto Up, Auto Down, and Stop buttons. Three pilot lights indicate whether the buoy is in either of the automatic positions and whether it is going up or down.

The auto buttons are locking positions on the control relays, by means of which the winch will continue to run until the Stop button is pushed. To prevent accidentally pulling the buoy into the nest with the Auto Down button, a safety switch is incorporated which de-energizes the motor when the buoy is approximately 25 feet from the nest.

The controller has cable and tension indicators and a tension release switch, which is used to slacken the cable after the buoy is latched. The tension release runs the motor for a set time to partially unwind the springs in the drum and so decrease the tension in the cable.

Auxiliary Controller

The auxiliary controller is in parallel with the main control unit. It provides cable and tension indicators and a buoy up-down switch. It permits the radioman to adjust the buoy attitude on the surface and to compensate for speed and depth changes of the submarine (Fig. 16).

APPROXIMATE RANGES

The approximate ranges of the various services are as follows:

vlf (reception only)	See Fig. 17
hf	To 6000 miles, dependent on atmospheric conditions (if a network of stations is available)
ECM	See Fig. 8
uhf	See Fig. 9
IFF	See Fig. 18

BUOY AND CABLE BEHAVIOR IN VARIOUS SEA STATES

In perfectly calm water the buoy and cable assume configurations such as shown in Figs. 19 and 20. As the speed is increased the buoy and cable move further behind the towpoint as shown. These configurations may be calculated to a satisfactory degree of accuracy using methods developed at the David Taylor Model Basin. However, as waves develop and become larger, it becomes more difficult to predict the configuration of the cable. The method of adjusting the buoy in this case is to release more cable, allowing the buoy to rise to the top of the waves. The shape of the cable is a taut catenary. In the trough of the waves the buoy follows the wave, allowing the catenary to become slack. It is thus essentially a wave-following buoy.

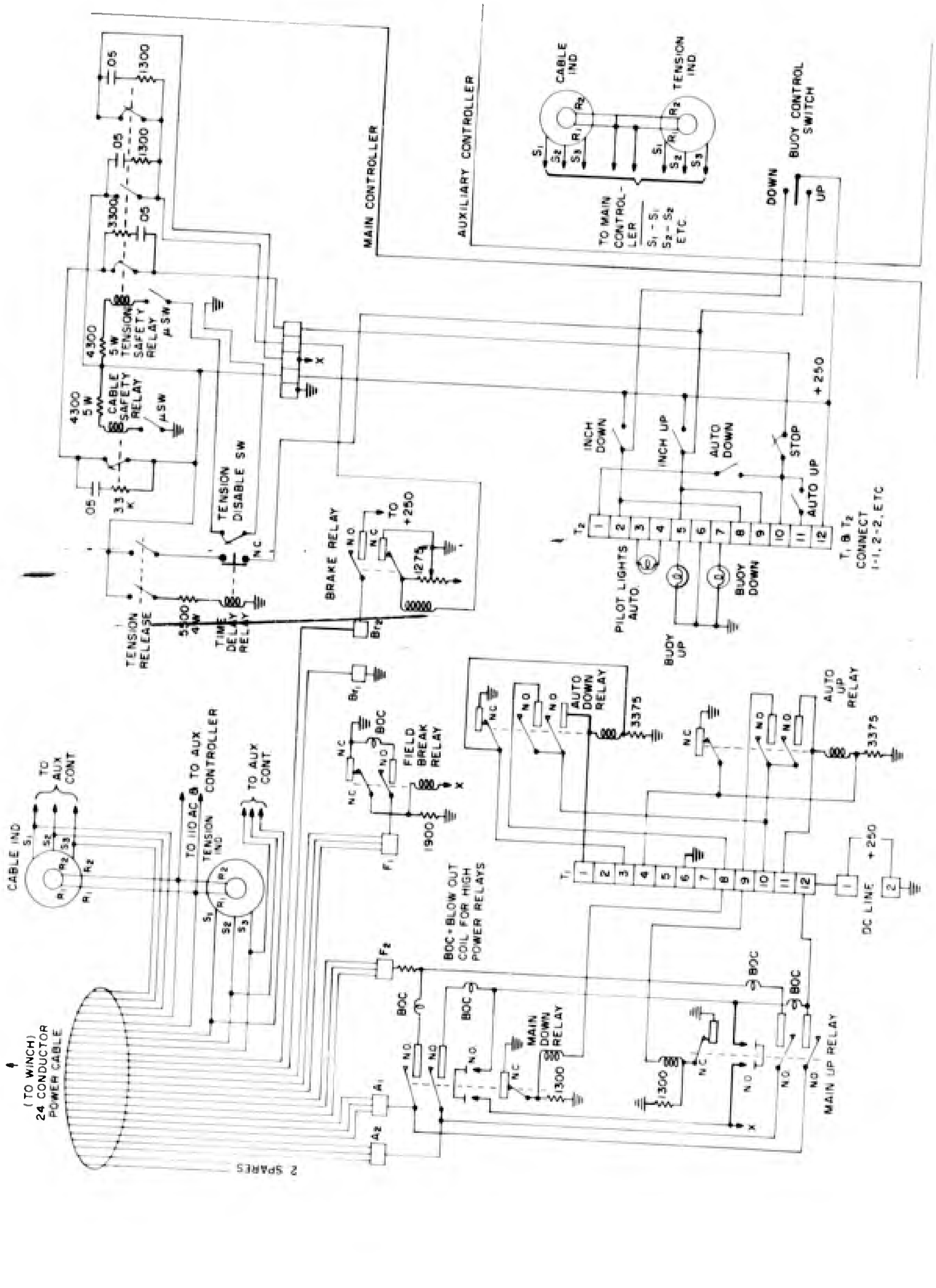


Fig. 16 - Main and auxiliary controller schematics

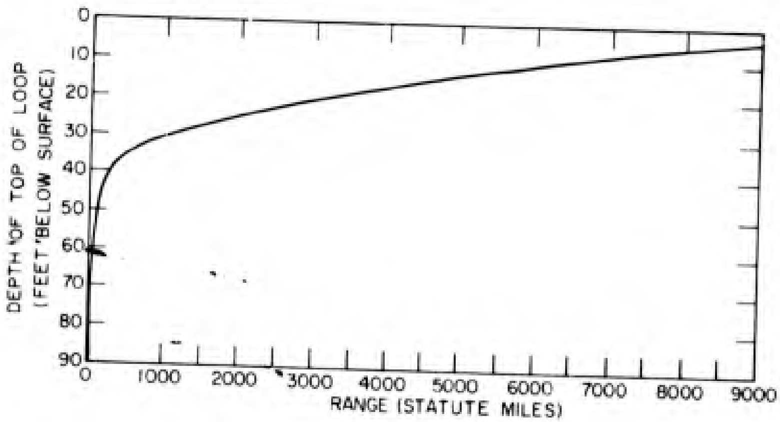


Fig. 17 – Representative values of vlf reception range versus loop depth

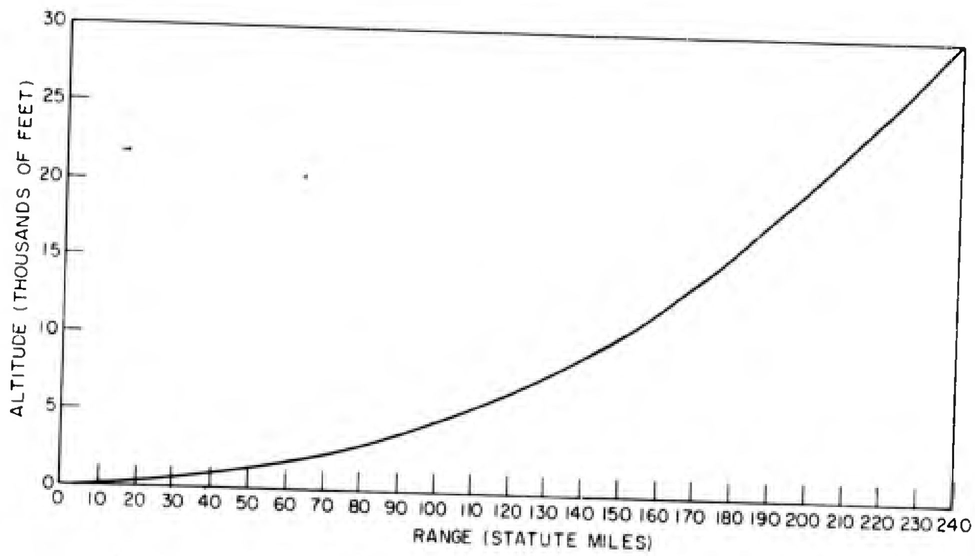


Fig. 18 – Approximate range of IFF antenna (essentially line of sight) in ASW mode

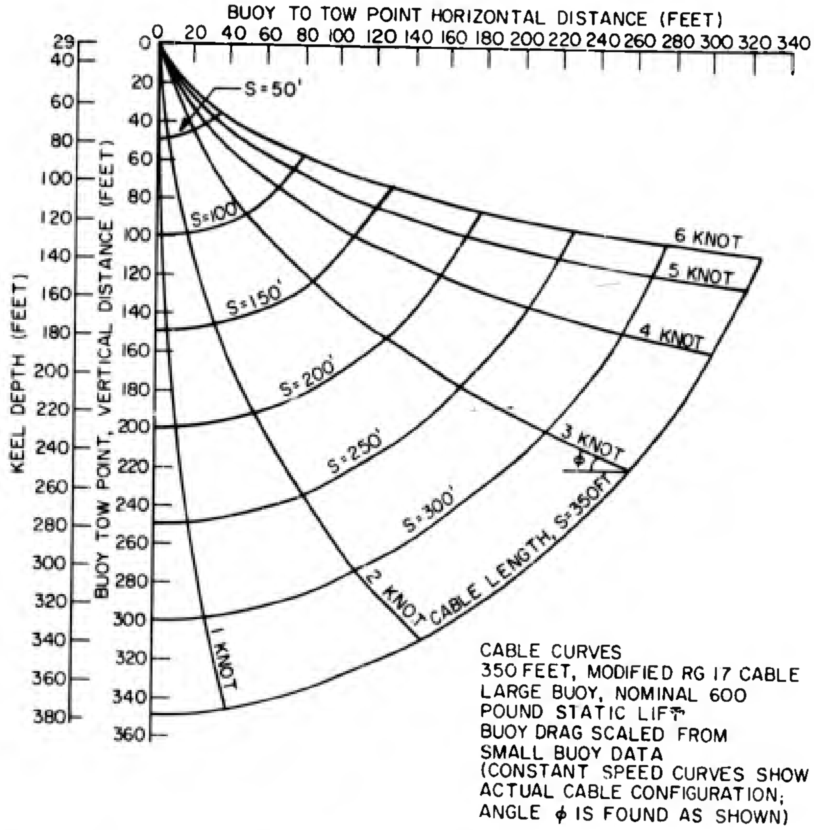


Fig. 19 – Modified RG-17/U cable configuration chart

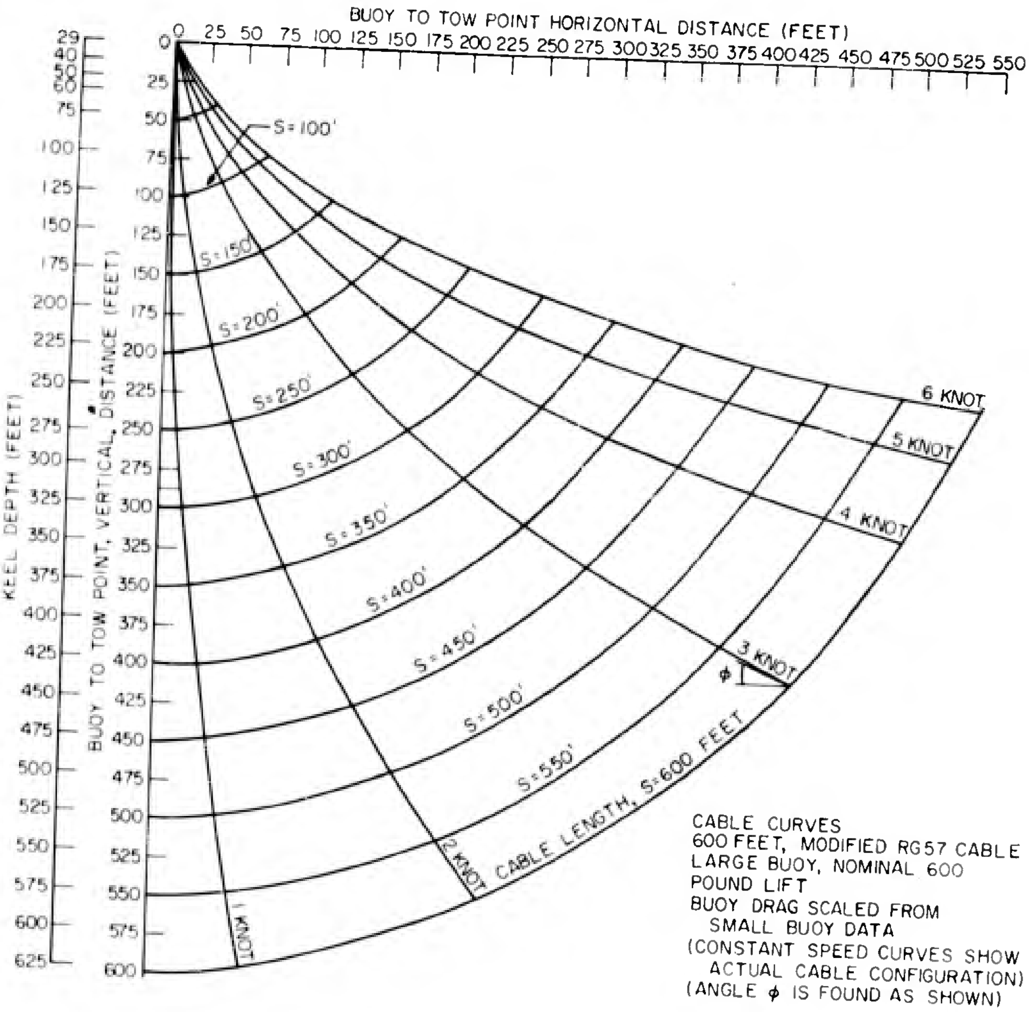


Fig. 20 – Modified RG-57/U cable configuration chart

It is also possible to design a buoy to cut through the waves by adjusting the maximum cable length to the trough of the waves. However, this requires much longer masts for the antennas to keep them above water and adversely affects the buoy's stability. Therefore, the design was for wave-following action.

In the tow-cable configuration charts, given in Figs. 19 and 20, the curves at the various speeds give the actual cable configurations, subject to the assumptions made in their calculations. Interpolations may be made between the given conditions to obtain points which are not directly on the curves. It can be seen that the charts give all the necessary information, such as speed, depth, distance behind the towpoint, length of cable, and the angle of the cable at the submarine for the buoy with the tow cables presently in use. The angle of the curves to the horizontal at any point is the actual angle of the cable to the submarine for that particular speed and depth.

OPERATION OF THE SYSTEM

Under conditions requiring communication from a submarine at all depths below periscope, the communication buoy is released from the nest. Upon release, the operator may consult the cable curves shown in Figs. 19 and 20 to determine the approximate amount of cable to be released. As an example, assume that the submarine is at a keel depth of 210 feet making a speed of 3 knots. From Fig. 19 it is determined that approximately 250 feet of cable is required. It requires about 2 minutes to release this amount of cable. During this time the operator observes the cable tension indicator for an indication of a change in tension, since the tension will decrease when the buoy reaches the surface. While the buoy is approaching the surface the radio operator, by means of an rf coaxial switch in the radio room, transfers the radio transmitting and receiving equipment from the ship's antennas to the buoy antenna. The radio operator can also tell immediately when the buoy reaches the surface since his hf receiver will receive radio signals, or interference, characteristic of an antenna in air. During use of the buoy antenna for communication the radio operator adjusts, by means of the auxiliary controller, the cable length to insure optimum sea-following characteristics of the buoy-cable system. This adjustment is normally made once for a given sea state; however, if the depth or speed of the submarine changes appreciably, a readjustment will be required. Following completion of communication, the buoy may be nested or allowed to stream if additional use is anticipated in a reasonable time. The nesting of the buoy is accomplished by the main controller operator and requires about 3 minutes to haul in 300 feet of cable. When the buoy reaches the nest, which is indicated by the cable length indicator returning to zero and also by a sharp increase in cable tension as the buoy engages the nest, the operator "inches" the buoy in by means of the Inch Down switch until the tension indicates 1100 pounds. Next, the operator momentarily depresses the Inch Up switch which allows the buoy-hold-down latch to engage a hook on the buoy. Following this, the operator depresses the tension release button which, by means of a time-control switch, operates the winch so as to remove most of the tension from the cable.

The buoy may be nested and released at submarine speeds from 1 to 5 knots; however, speeds of 3 to 4 knots appear optimum for this system. The buoy achieves its greatest vertical stability when it is towed with the body just beneath the surface. The mast in this condition is quite steady and provides a stable support for the antenna. The degree of stability and wave-following ability is at a minimum at periscope depth because of the short length of cable required. However, when the buoy is observed from a surface vessel with the submarine running deep, the towing characteristic may be better appreciated. While on the surface, the visible target nature of the buoy appears to be about the same as an attack periscope. As a radar target it should appear about the same as a periscope; however, in all test radar runs by search-radar-equipped aircraft, the buoy has not been picked up on the aircraft radar.

The system has been used satisfactorily in sea states 3 and 4. At higher sea states the system remains useful; however, the antenna is "shorted" from time to time by the wave action, making it necessary to repeat some parts of messages.

EXPERIENCES

The system described in this report is the current configuration which has been evolved over the past eighteen months by noting deficiencies and taking corrective measures, both as to mechanical and electrical features and to changes in performance capabilities, to better meet the needs of the operating submarine.

Over the eighteen-month period, trouble-free periods of operation of the system have varied from a few hours up to about 3 months. The early malfunctions were caused by leakage of sea water into outboard components. The probability of this type of failure has been greatly reduced by providing means of vacuum checking all O-ring seals after assembly. One failure occurred as a result of cable snarl on the winch drum. Reccurrence of this type of failure has been avoided by operator skill aboard the USS HARDHEAD; however, future systems should incorporate features to avoid cable snarl.

On at least two occasions the buoy leaked after a week or more of operation. This was caused by the bolts, holding compression type O-ring seals, working loose as a result of vibrations. Also, it is believed that this deficiency was responsible for the only complete buoy loss which occurred during a North Atlantic storm in which sea state 9 was observed. This has been corrected by providing cylinder type O-ring seals and other means to insure the locking of the bolts in position. The failure that occurred after 70 or 80 days of operation was caused by parting of the center conductor due to fatigue, which was in turn caused by excessive cable flexing. Corrective measures taken for this deficiency consist of adding a spring arrangement at the point of attachment to the buoy to limit the degree of flexing, and the procurement of a tow cable with a stranded center conductor capable of withstanding more flexing. In addition, a mechanical latching system was added to the nest assembly to eliminate stress on the cable while the buoy is carried in a nested position.

The feasibility of streaming and retrieving a buoy from a submerged submarine has been well demonstrated in that it has been accomplished well over one hundred times with the submarine at various speeds, depths, and turn and dive aspects. The system has enabled the USS HARDHEAD to accomplish two-way communication at depths in excess of 300 feet. On hf test transmissions from the USS HARDHEAD at 300 feet keel depth, radio signals were monitored 6000 miles away. VLF signals have been received by the USS HARDHEAD at keel depth of 400 feet from all of the major vlf transmitting stations over ranges of many thousands of miles. Aircraft and surface ship coordination with submerged submarines has been accomplished by the buoy communication system. The USS HARDHEAD, while using the buoy in an exercise, was able to transfer a sonar contact to another submarine. The use of the buoy system to receive loran signals while submerged has aided the navigator on many occasions.

An incident that furnished the radio operator of the USS HARDHEAD amusement revealed in a simple way the impact of communication from a submerged submarine. During a night exercise with a destroyer, in which radio communication had been in process for several hours, the following exchange of message occurred:

> USS HARDHEAD – "I am at 150 feet coming to periscope depth."
>
> Destroyer – Long pause – "Say again."
>
> USS HARDHEAD – "I am at 150 feet coming to periscope depth."
>
> Destroyer – Pause – "Roger?"

CONCLUSION

A system has been developed which incorporates numerous communication services, with the feasibility of adding such other services as may be deemed necessary for the accomplishment of the submarine's mission. With presently available cables and equipment, a passive system may be used for keel depths of 350 to 700 feet with a moderately sized buoy, dependent upon services desired. As the desired frequency increases, it is necessary to either decrease the keel depth and length of cable or go to an active system embodying amplifiers, etc., in the buoy. If a low-loss cable becomes available, e.g., less than half that of existing polyethylene cables, a passive system could be used to a much greater depth, with its concurrent reliability and low cost as compared to an active system.

ACKNOWLEDGMENT

The system represents a joint effort, and acknowledgment is made to F. S. Shanahan and R. K. Chaimson for mechanical design, to S. V. Fratianni for the vlf portion of this system, and to W. E. Withrow for the ECM portion of this system. In addition, thanks and appreciation are due the officers and men of ComSubDevGru Two and the USS HARDHEAD for assistance during the installation and sea investigations.

REFERENCES

1. Leidy, K.L., and Cubbage, H.D., "A Towable Electronic Communications Buoy," NRL Report 5075 (Secret Report, Unclassified Title), Jan. 24, 1958
2. Norgorden, O., "The Submerged Reception of Radio Frequency Signals," NRL Report R-1669 (Unclassified), Dec. 2, 1940
3. Fratianni, S.V., "Submerged VLF Reception – A Study of Various Loop Coupling Methods," NRL Report R-2872 (Unclassified), Dec. 31, 1946
4. Fratianni, S.V., "Theory and Design of Resonant Transformer-Coupled Loop-Antenna Input Systems for VLF Reception," NRL Report R-3281 (Unclassified), Apr. 28, 1948
5. Fratianni, S.V., "The Equivalent Selectivity of Transformer-Coupled Loop-Antenna Input Circuits," NRL Report R-3464 (Unclassified), May 13, 1949
6. Toth, E., and Fratianni, S.V., "Underwater Loop Reception Phenomena and Techniques," NRL Report 3605 (Confidential Report, Unclassified Title), Jan. 12, 1950
7. Withrow, W.E., "A Surface Radar Intercept System," NRL Report 5353 (Confidential Report, Unclassified Title), Aug. 5, 1959
8. Leidy, K. L., "Buoy Antenna Characteristics," NRL Memo Report 987 (Confidential Report, Unclassified Title), Oct. 22, 1959

* * *

UNCLASSIFIED

UNCLASSIFIED