WIRE DRAG OPERATIONS USING RAYDIST " T "

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ABSTRACT

This paper describes a two-month wire drag project using Raydist " T ", a new passive form of the Raydist radiolocation system. Operations were conducted in the lower Chesapeake Bay by the *Rude* and *Heck*, wire drag vessels of the National Ocean Survey (NOS) (formerly U.S. Coast and Geodetic Survey).

Raydist DR-S has been in regular use by the *Rude* and *Heck* for nearly four years. The only modifications required to convert existing DR-S shipboard installations for Raydist " T " operations were accomplished by module substitution in the DR-S Navigators. Shipboard CW transmitters, needed for range-range operation, were not employed.

The ground network and shipboard equipment are described, and the method of conducting wire drag operations using Raydist " T " is discussed. Results of the two-month project are presented, along with a comparison of the operational and performance characteristics of Raydist " T " with those of the range-range and 3-station hyperbolic forms of Raydist.

INTRODUCTION

The wire drag survey has been used for more than 60 years by the National Ocean Survey to complement conventional hydrographic surveying techniques. Wire drag is the only completely positive means of detecting and recording the location of submerged obstacles which extend over an area too small to assure their detection by standard hydrographic surveying methods. Wire drag data is used mainly to supplement hydrographic survey information in the preparation of navigational charts. Wire drag operations are conducted over a wide range of depths, from 2 metres to more than 100 metres.

The *Rude* and *Heck* (figure 1) are the only vessels of their kind in the United States. They are designed especially for this one purpose and are combined under the command of one officer. Each of the two 28 metre, 220 ton vessels has a complement of two commissioned officers and a crew of eight. The vessels are tasked with projects from the Canadian to the Mexican border, keeping them away from their home base, the Atlantic Marine Center at Norfolk, Virginia, most of the time.

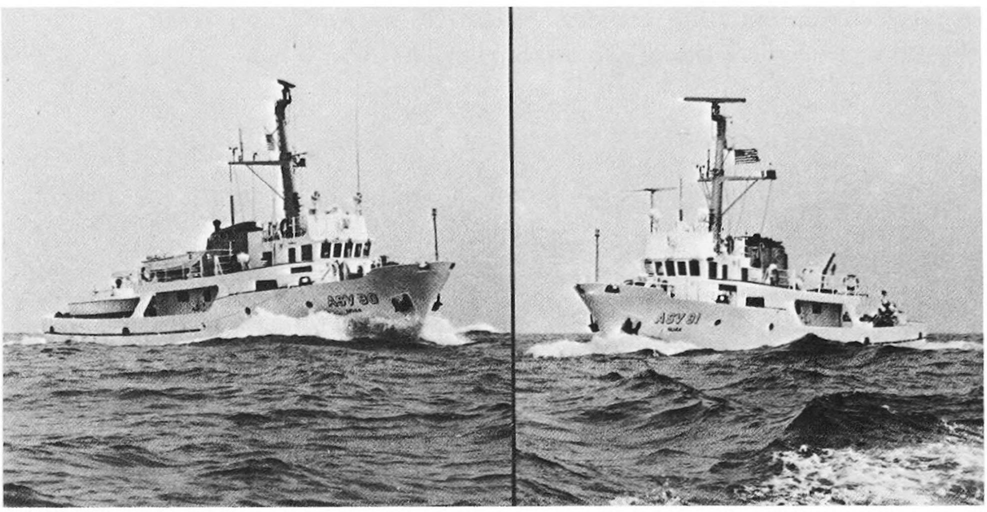

FIG. 1. — The NOAA wire drag vessels *Rude* and *Heck*.

The principal means of detecting wrecks and obstructions is to drag a one quarter inch stainless steel wire suspended from surface buoys to a predetermined depth. Upon snagging an object, the surface buoys form a " V ". The apex of the " V " indicates the location of the obstruction as shown in figure 2.

Raydist has been used for navigational control by the *Rude* and *Heck* since 1967. The vessels acquired the modern Raydist DR-S system shortly after its introduction in that year. Although the same hardware elements are used to implement both the DR-S and Raydist " T " systems, there are important differences in system deployment.

Raydist DR-S uses two shore stations and a CW Transmitter on each vessel. The quantity measured is distance (range) from the using vessel to each shore station, resulting in a circular coordinate geometry. Up to four vessels or aircraft can be served by a single pair of shore stations. Each CW Transmitter operates at a slightly different frequency (about 100 Hz intervals).

Raydist " T " uses four shore stations and no mobile transmitters. An unlimited number of users can operate within a single network without mutual interference. The quantity measured is *difference* in distance from the user to each base-station pair, producing a hyperbolic coordinate geometry.

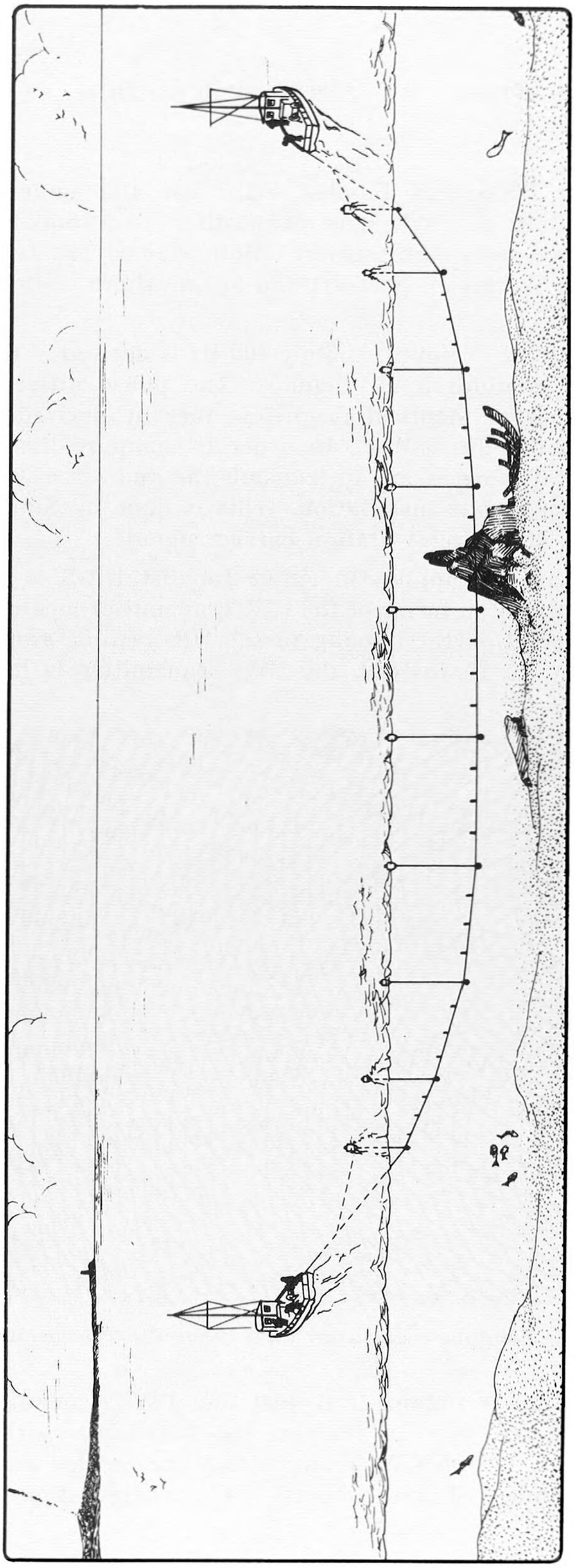

FIG. 2. — Wire drag construction diagram.

RAYDIST " T " SYSTEM DESCRIPTION

Both Raydist DR-S and Raydist " T " use the same principle of operation. To obtain a single line of position, continuous signals are broadcast from two radio transmitters. Both signals are received at the mobile installation (vessel or aircraft) and at one shore station, designated the "relay station ".

An audio beat tone of approximately 400 Hz is derived at each receiving point by suitably combining the signals. The phase difference between the two audio tones of identical frequency thereby derived contains the necessary coordinate information. In order to compare the phase of the two audio signals, it is necessary to transmit the audio tone derived at the relay station to the mobile installation. This is done by Single Side Band (SSB) modulation of the relay station carrier signal.

The above principle applies to either Raydist DR-S or Raydist "T". The systems differ only in terms of the CW Transmitter location. If the CW Transmitter is located on the moving vessel, DR-S (range-range) operation results (see figure 3). If, instead, the CW Transmitter is located ashore,

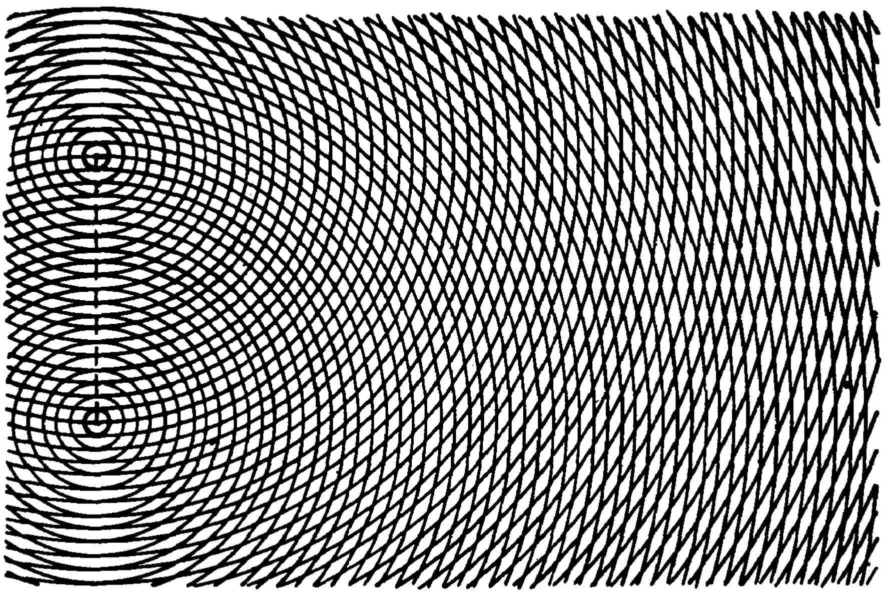

FIG. 3. — Coordinate geometry, DR-S (Range-Range) operation.

hyperbolic operation is obtained. If just one CW Transmitter is placed ashore, along with the two relay stations, the 3-station hyperbolic geometry of figure 4 results. If two CW Transmitters are located ashore, the two independent baselines of the Raydist "T" configuration are obtained (figure 5).

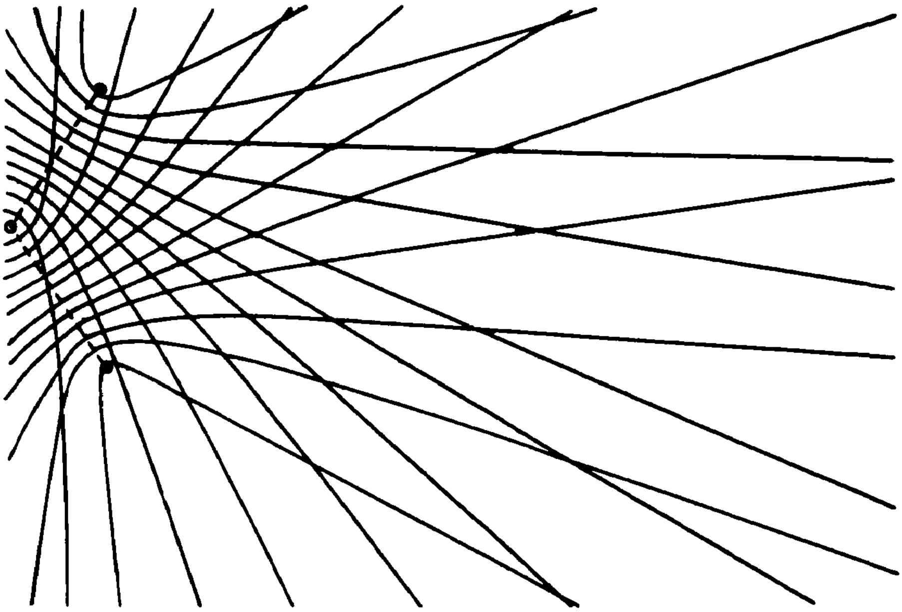

FIG. 4. — Coordinate geometry, 3-station hyperbolic operation.

The circular coordinate geometry of DR-S Raydist exhibits little accuracy degradation due to geometric dilution, even at offshore distances several times the baseline length. In contrast, the three-station hyperbolic geometry results in poor intersection angles between Red and Green lines-of-position even at moderate distances offshore. This " geometric dilution " effect is a major cause of inaccuracy when the three-station hyperbolic arrangement is used.

Geometric dilution can be greatly reduced if a fourth station is added. Each family of hyperbolas is defined by an independent station pair, resulting in excellent intersection angles throughout a very large coverage area.

The cost of acquiring and operating an additional CW station for Raydist " T " operation can be readily justified for survey projects of extensive areas or of irregular shorelines. With the expanded coverage, shore station relocation is virtually eliminated as the need for control moves about the project area. Thus, the benefits of accuracy, expanded coverage, and control versatility are achieved.

A Raydist " T " network has been installed in the lower Chesapeake Bay under sponsorship of the State of Virginia. Figure 5 depicts the station locations and resulting hyperbolic pattern, showing every 100th lane. The Red baseline is formed by stations at Seashore State Park and Palmer, Virginia and is 44.4 nautical miles long. The Green baseline is formed by stations at Day's Point and Saxis, Virginia, and has a length of 67.4 nautical miles. The areas worked by the *Rude* and *Heck* are cross-hatched in Figure 6. During the project, the *Rude* and *Heck* operated out of the Little Creek Amphibious Base (Norfolk) and the Atlantic Marine Center (Norfolk) (also shown in figure 6).

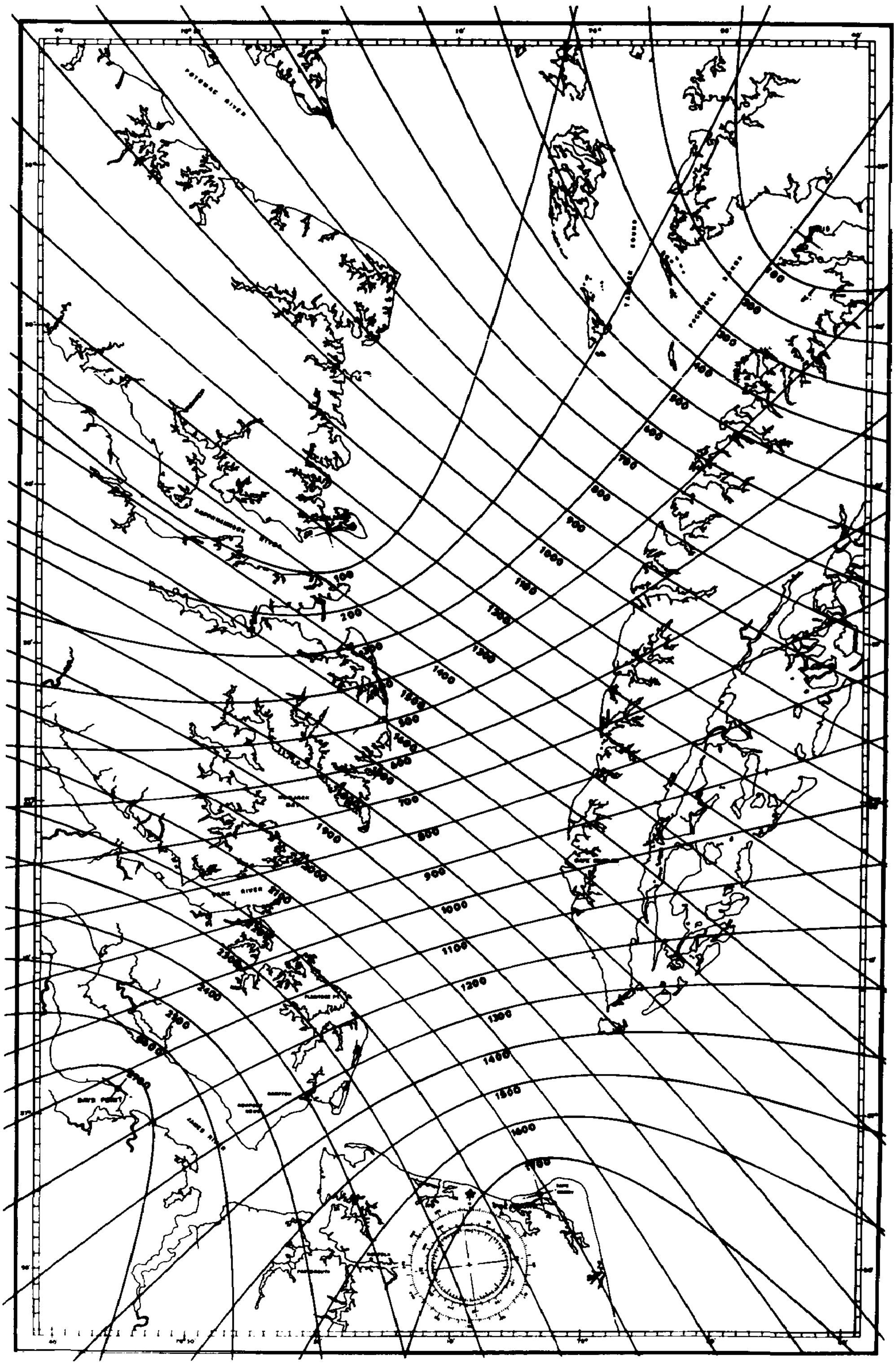

FIG. 5. — Coordinate geometry, Raydist " T " operation.

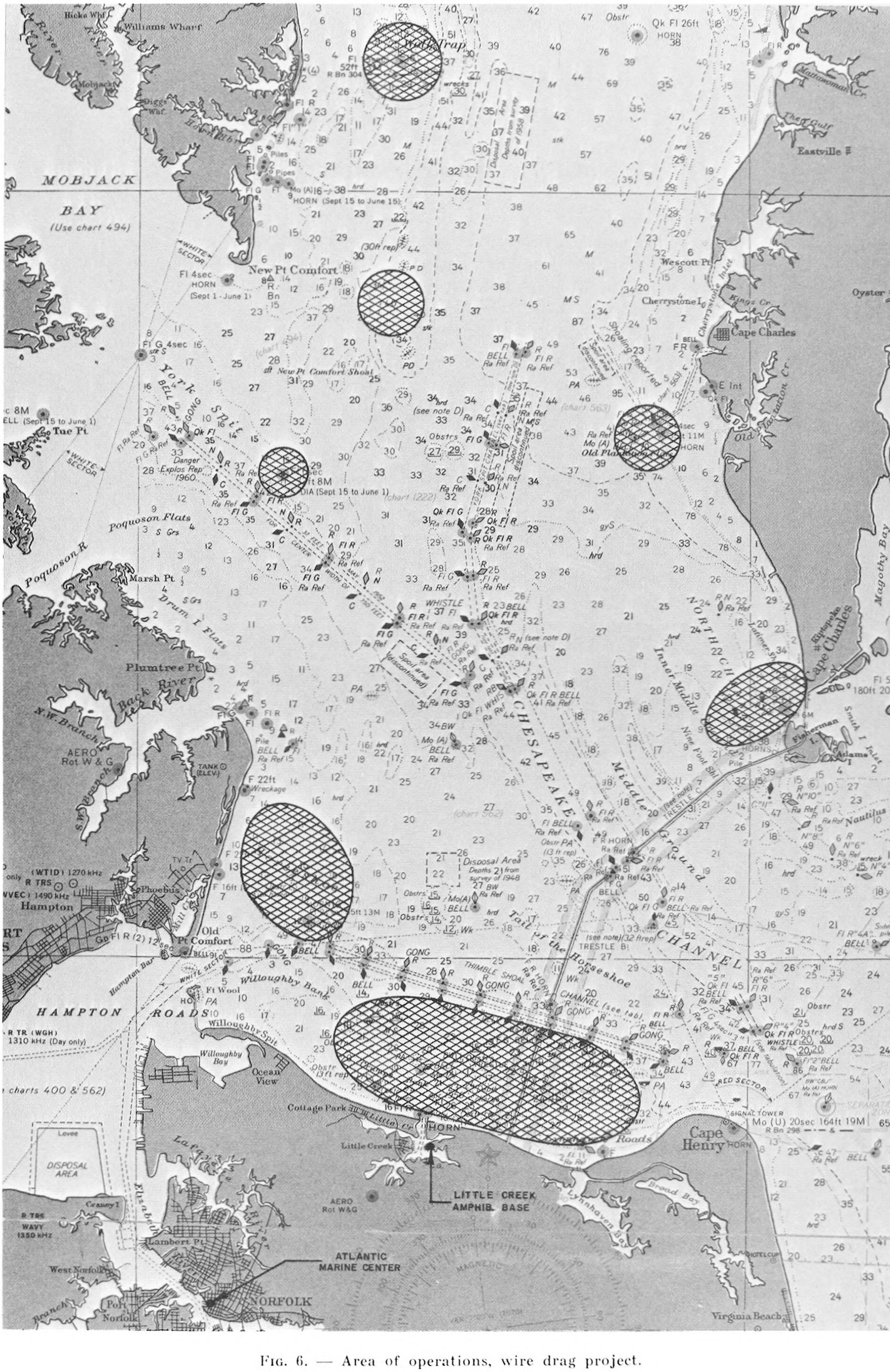

Fig. 6. — Area of operations, wire drag project.

RAYDIST " T " MOBILE INSTALLATIONS

Raydist shipboard installations on the *Rude* and *Heck* consisted of a Raydist Navigator, antenna installation and Strip Chart Recorder, all of which were elements of a Raydist DR-S system installed in 1967.

FIG. 7. — Raydist Navigator.

The Raydist Navigator receives signals from the 4 stations of the " T " network, processing them to provide a visual display of the Red and Green Raydist coordinates (See figure 7). For operation in the "T" Mode, the DR-S Receiver Module in the Navigator was replaced by a Raydist " T " Receiver Module.

During range-range operation, a 10 metre telescoping aluminum whip antenna is used to achieve sufficient radiation from the shipboard CW Transmitter. For convenience, this same antenna was used during the temporary Raydist " T " project. Permanent Raydist " T " installations employ a whip antenna only 1 metre high (See figure 8), which includes a built-in transistor amplifier for impedance matching.

The 2-channel Strip Chart Recorder produced a printed analog recording of vessel position during each operation. The Strip Chart Recorder generates 2 sawtooth patterns, corresponding to the Red and Green Raydist coordinates. A typical sawtooth recording is shown in figure 9. The " uphill " or " downhill " slope of the sawtooth ramps indicates increasing or decreasing coordinate values, respectively. The sawtooth flyback occurs at each whole lane transition. The Strip Chart is accessible for penciled annotations, providing a means of noting events during an operation. The Strip Chart Recording is quite useful for verifying proper system operation and confirming the vessel's progress.

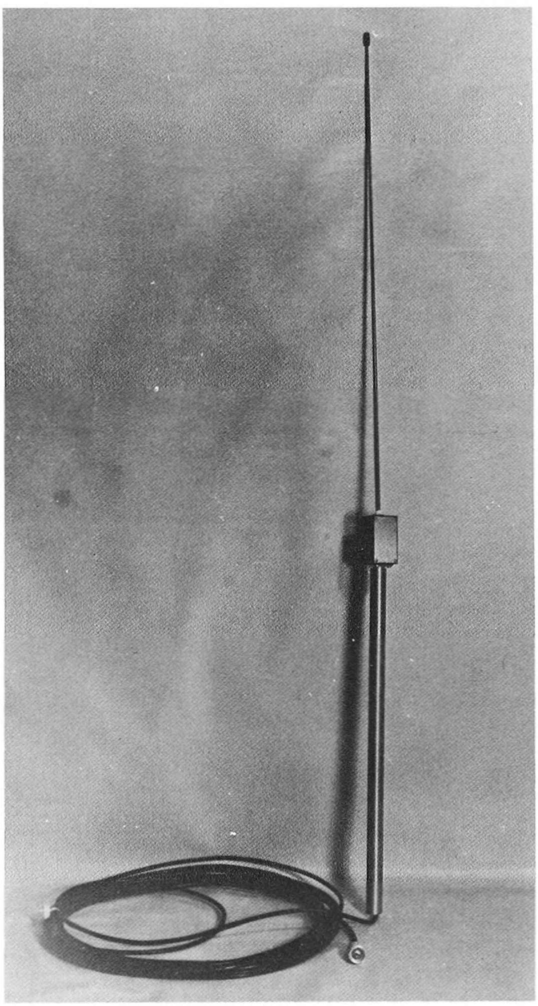

FIG. 8. — Raydist " T " voltage probe antenna.

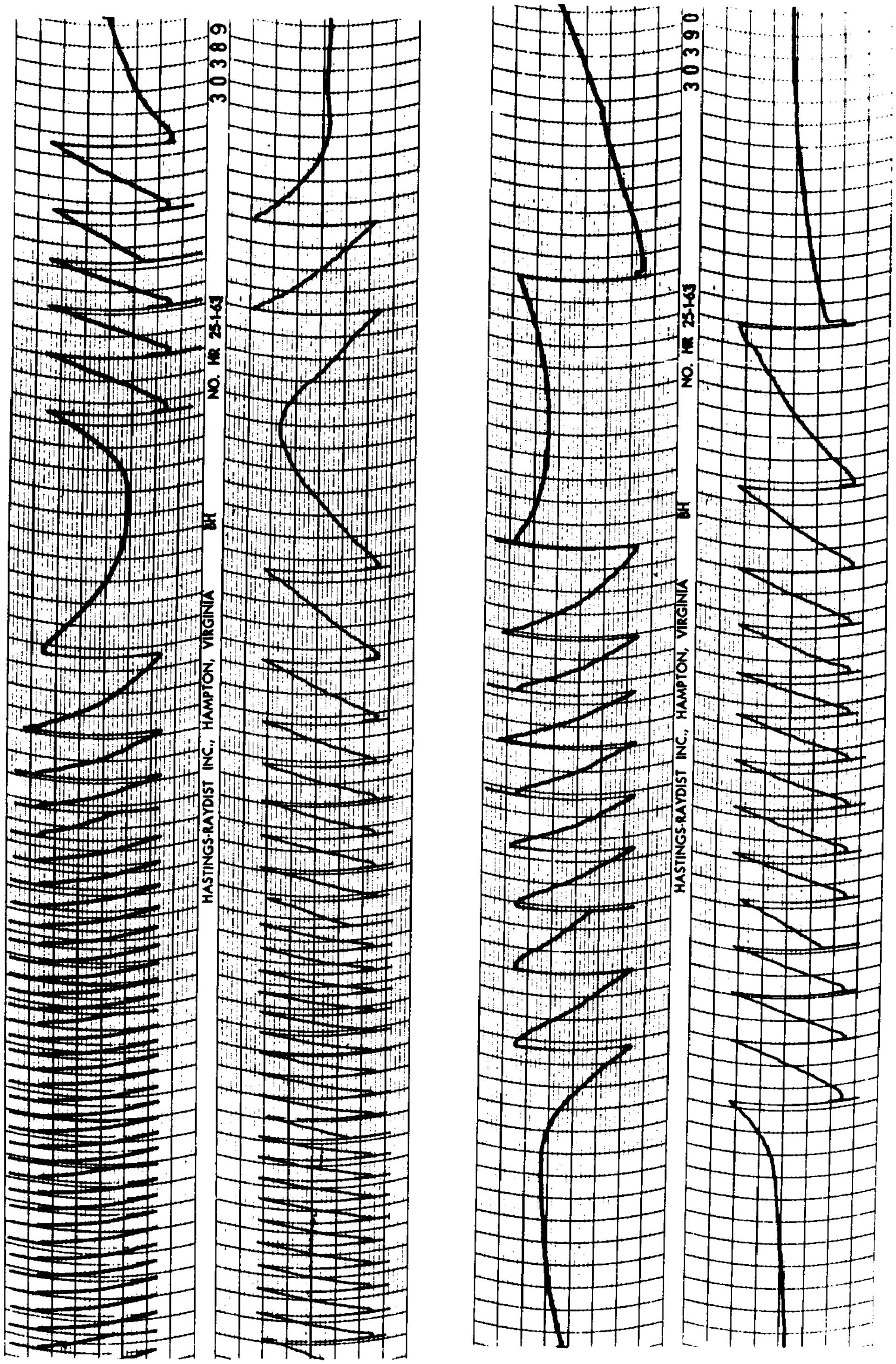

FIG. 9. — Typical strip chart recording.

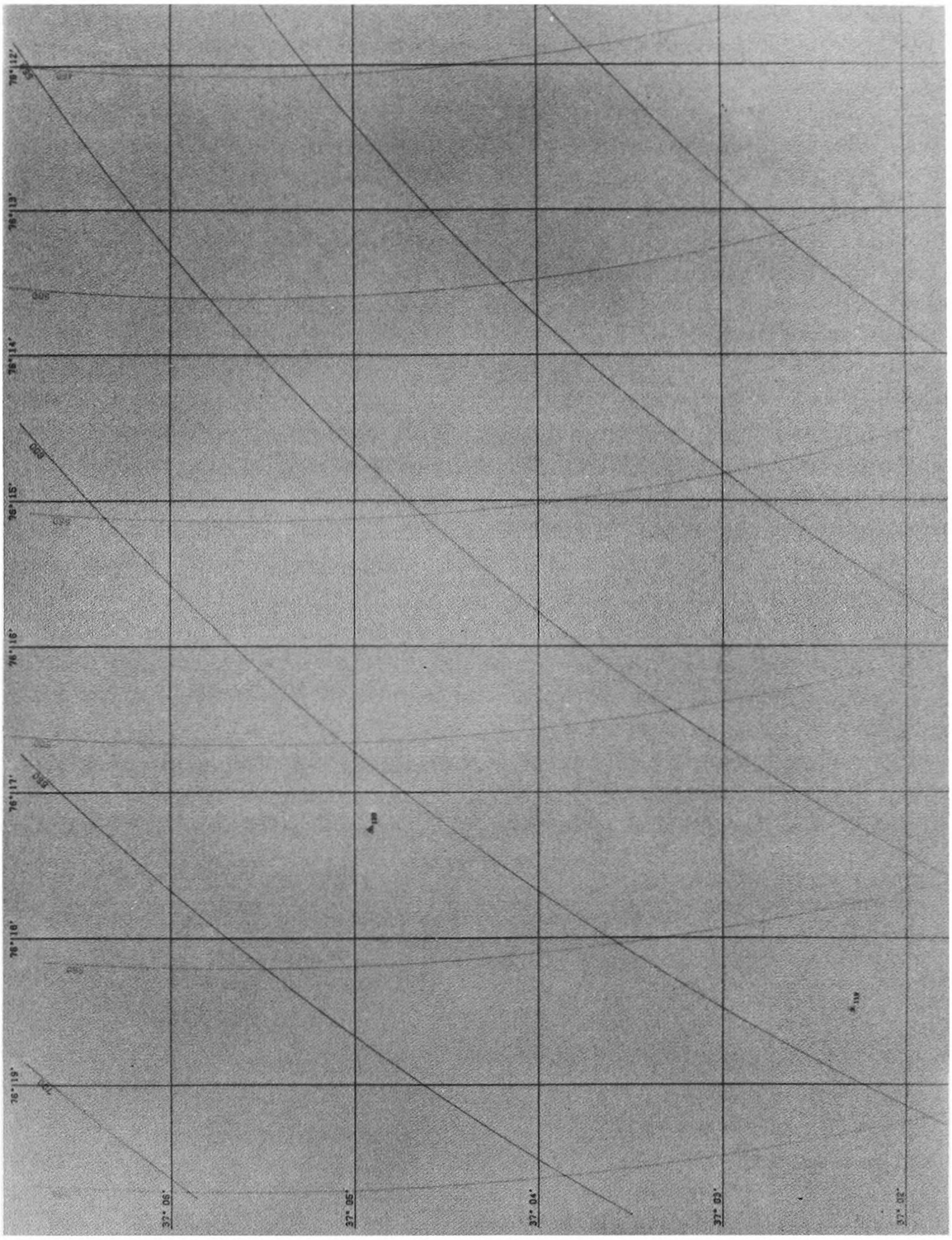

Fig. 10. — Typical navigational boat sheet.

BOAT SHEET PREPARATION

Navigational boat sheets for the Raydist " T " operation were prepared at the computing facility of the Atlantic Marine Center (NOAA) in Norfolk, Virginia. This facility utilizes an IBM 1130 computer coupled with a Calcomp 618 flatbed plotter to produce charts of the type shown in figure 10. It is customary to prepare the boat sheets at twice the scale of the local navigation charts. In other words, if the local chart is scaled to 1/20 000 boat sheets will be 1/10 000. Thus, when data is transferred from the boat sheets at some future date, the possibility of introducing inaccuracies due to insufficient resolution is virtually eliminated. The computing and chart plotting facility is shown in figure 11.

Information printed on each boat sheet includes a latitude/longitude grid and Raydist Red and Green coordinate geometry. In addition, selected navigation markers in the area of operation and specific hazards to navigation are shown.

The basic parameters supplied to the IBM 1130 in order to preppare the desired boat sheet are as follows :

(a) RAYDIST PARAMETERS.
   (1) Base Station coordinates in latitude and longitude;
   (2) Red and Green position measurement frequencies.

(b) CHART PARAMETERS.
   (1) Latitude and longitude values defining the coverage area;
   (2) Chart scale;
   (3) Raydist line intervals to be plotted.

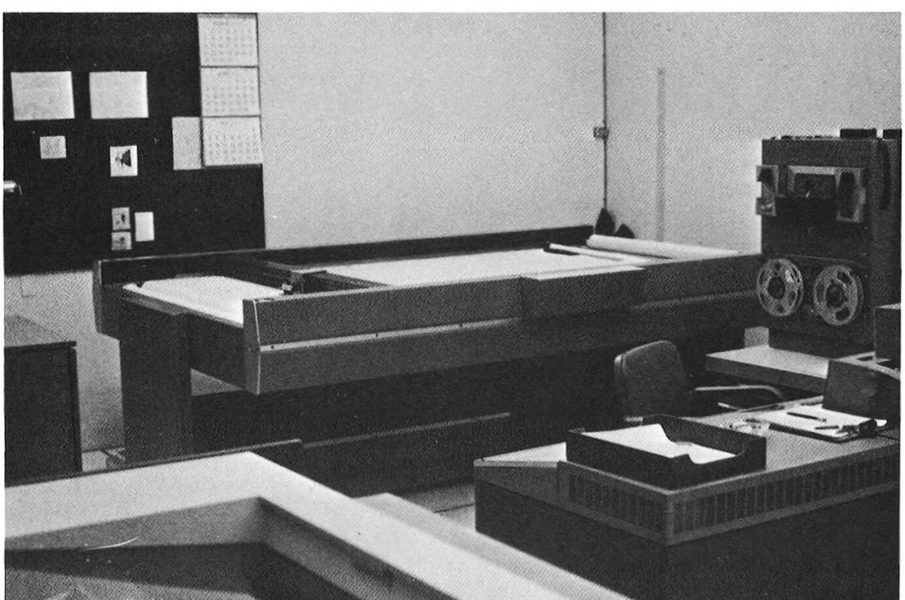

FIG. 11. — Computing and plotting facility, Atlantic Marine Center.

Each ship operator maintains a continuous record of his track made good using the boat sheet prepared as described above. Prior to the wire drag operation, lines representing the desired track are laid out on the boat sheets for each vessel. Each ship then navigates independently, changing her course and speed based on Raydist information. Vessel position is read and plotted every five minutes by the survey officer. He may choose to take readings more frequently, as necessary, to maintain his vessel on course within desired accuracy limits. Fixes are plotted, using 11-point dividers to interpolate between lines-of-position printed on the boat sheet.

CALIBRATION AND CLOSURE TECHNIQUES

Systematic Raydist calibration procedures have been developed to assure highest possible accuracy during wire drag operations. Fine calibration is accomplished underway, since dockside calibration is subject to several sources of uncertainty. Exact dockside position of the vessel can vary enough to introduce unacceptable error. Also, the position and orientation of other nearby vessels and cranes can vary from one day to the next or even from hour to hour, causing errors of several metres.

The combined effect of all causes of dockside error will not exceed a few tenths of a lane. It is therefore practical to set the whole number portion of initial Raydist coordinates at dockside. Fractional lane count is then established while underway using optical techniques. Fine calibration is done in the morning, prior to the start of drag operations, and again after the day's work is done. A discrepancy of as much as 0.10 lane (about 5 metres) between morning and evening readings is acceptable, and can easily be accounted for in terms of changing weather conditions and the normal diurnal variation of radio propagation velocity. Differing vessel orientation during morning and evening readings can also produce a slight error if the effective center of radio reception on the vessel is imprecisely known, or if individuals taking the readings do not stand at exactly the right spot.

Fine calibration is accomplished as near to the actual working area as practical. Morning and evening readings are averaged, and weighted corrections are applied to all fixes.

Three techniques are available for accomplishing fine calibration. One consists of running a range determined by two objects and indicating a " mark " when a predetermined sextant angle is obtained between the range and a known object ashore. This method is illustrated in figure 12.

A second approach is the so-called " circle calibrations " method. The ship circles a fixed object at a constant radius. When the object bears from the ship on the same bearing as a Raydist line is known to cut through the object, a reading is taken. Gyro error, followup error and eccentricity of the observed position with respect to the receiving antenna position are canceled by averaging the readings taken from reciprocal bearings. This

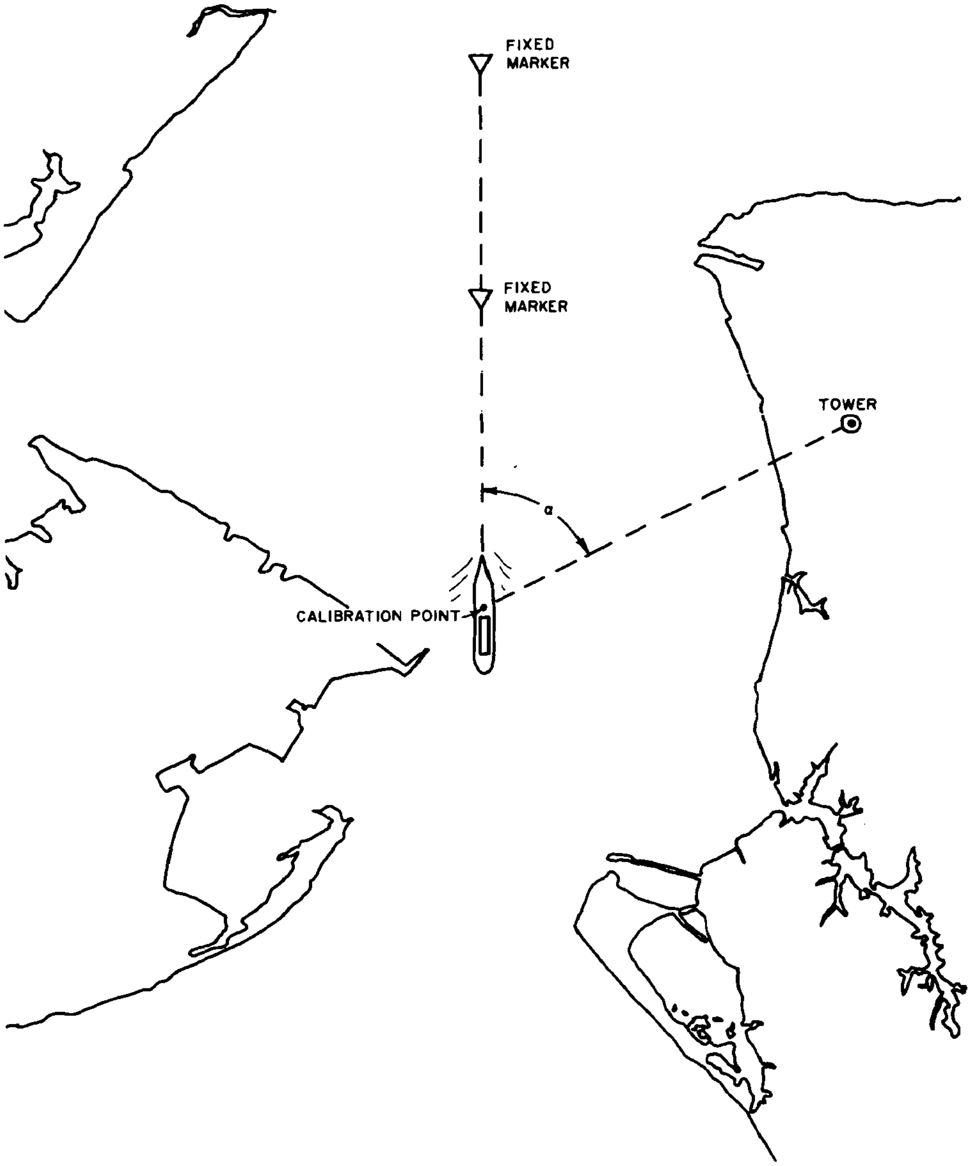

FIG. 12. — Diagram of range calibration procedure.

method is useful in the lower Chesapeake Bay since lighthouses at distances of 8 kilometres, 44 kilometres and 92 kilometres from Norfolk are available for use as calibration objects.

A third method, that of three-point fixes with check angles, is frequently employed and can also be used for checking orientation errors. Fixes can be taken at regular intervals of ship's heading, say every 20°, to verify if ship's relative heading to an incoming signal has any effect on the resultant Raydist readings. Any of these methods will produce results reliable to ± 0.10 lane (about 5 metres).

WIRE DRAG OPERATIONS

The wire drag operation is conducted at a speed of about 2 knots. Each vessel is independently controlled to maintain position along a preplotted line. Thus, each vessel is independently controlling position lateral to the prepared plot. One of the vessels, the " guide " ship, simply maintains a planned speed along the track without regard to position relative to the other vessel. The second vessel is required to adjust along-track position so as to stay abeam of the guide ship, speeding up or slowing down slightly as required.

The buoys which suspend the drag wire are under constant observation for indication of a " hang ", the condition of having snagged an object. When a " hang " occurs, it is necessary to determine as accurately as possible the coordinates of the obstacle, be it a wreck, shoal, or other form of debris. Location of the hang is determined by recording the Raydist coordinates of each vessel and the bearing of each vessel to the apex of the " V " which marks the location of the hang.

Scuba divers are then dispatched to swim along the ground wire until the snag is located. The obstruction is investigated and its exact depth measured by divers using a lead line. Since the ship fixing the snag position may be as much as 1 500 metres from the snag, divers position a marker buoy at the snag and the vessels proceed to pick up the drag; that is, free the drag wire from the obstacle. One of the vessels is then stationed directly over the object and Raydist readings are again recorded. Care is taken to station the ship's antenna directly over the object to assure the highest possible accuracy. The Raydist readings are later converted to latitude and longitude and the find is radioed to the Rockville office of the National Ocean Survey for use in chart preparation, and to the Coast Guard for inclusion in local Notice to Mariners broadcasts.

In wire drag operations, the only sensor used is the wire itself. Other devices such as bottom profilers, fathometers or sidelooking sonars, although on board the *Rude* and *Heck* for preliminary investigation, leave open the possibility that an object of very small extent, such as a mast or pinnacle rock, can remain undetected. The ability to pass a wire through an area without hanging on something is the only method of determining with absolute certainty that an area is clear.

In terms of mission objectives, wire drag projects generally fall into one of two categories :

1. A search for individual shipwrecks, the position of which or the very existence of which is doubtful.
2. Clearing a specific area for deep draft vessels, referred to as an "area sweep ".

The two months of operations in the Chesapeake Bay using Raydist " T " were of the first type, and produced four ship wrecks, two sunken barges, three old fashioned ship's anchors, the wreck of a twin engine aircraft and miscellaneous clumps, piles, and junk.

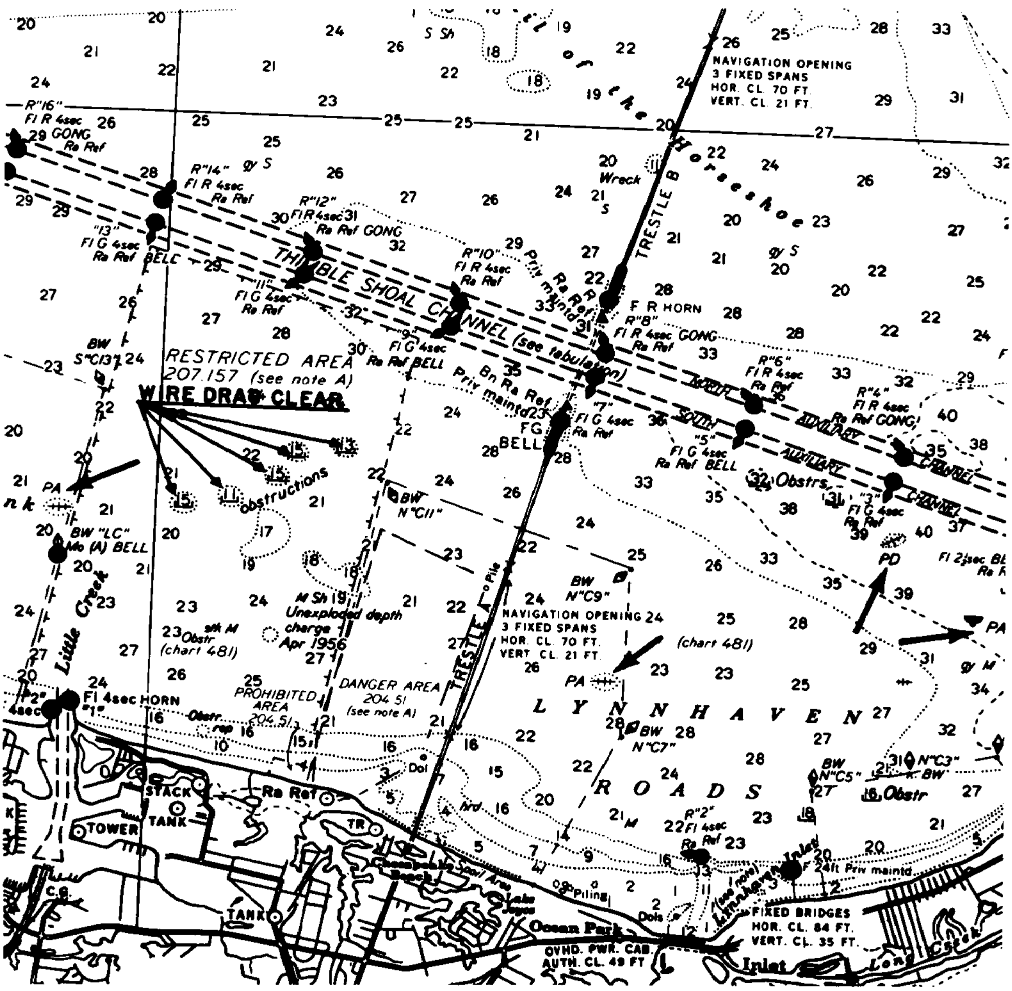

FIG. 13. — Navigational chart, showing wire drag symbols.

The symbols PA and PD shown on the chart in figure 13 indicate the " Position Approximate " and " Position Doubtful " of a submerged obstacle. After a wire drag operation has been completed, the chart can be corrected, if necessary, by either deleting the indicated shipwreck or correcting its position. In addition, a number underlined with a special symbol is added to the chart under the wreck to indicate that the area has been cleared by a wire drag vessel for the number of feet indicated. Such a " wire drag clear " symbol is the surest indication that the particular area is safe for navigation to the indicated depth.

Vessel separation during wire drag operations will vary from a minimum of about 600 metres to a maximum of about 2 500 metres. It is interesting to compare the spacing used during wire drag operations with the separation between parallel lines in a conventional hydrographic survey. To develop a channel, a maximum spacing of 50 metres is normal using conventional methods. Even with such close spacing, an obstruction could be overlooked. The greater efficiency of wire drag operations is obvious.

FACTORS AFFECTING RADIOLOCATION PERFORMANCE

Large metallic objects in or near the operating area can affect the performance of any radiolocation system. The size and geometry of such objects, as well as the radio frequency used, will determine the extent of such effects. Errors due to fixed objects, such as permanent towers, metal buildings or fixed bridges, will be repeatable, allowing full system accuracy to be restored by calibration if desired.

The fact that range-range operation involves radio transmission from each vessel introduces the risk of one vessel disrupting the operation of others by being relatively much closer to a shore station. For example, if the ratio of distances from each of two vessels to a particular shore station exceeds 22/1, it is possible that Raydist operation on the more distant vessel will be impaired. With Raydist " T ", this effect is absent, allowing multi-party operations to proceed without concern for the relative location of vessels within the network.

The question naturally arises, "What about interaction of the *Rude* and *Heck* with each other ? " During drag operations, vessel separation is always sufficient to avoid any measurable effect. However, errors as large as 6 metres have been observed when the two vessels have come alongside each other to transfer material or personnel. On one occasion, when range-range Raydist was being used, actual physical contact of the two ships during transfer of personnel caused the Raydist Navigator on one vessel to lose several lanes. During such a maneuver, the Quartermaster Surveyor will closely observe the Raydist dials and Strip Chart Recorder, allowing proper lane count to be easily restored if a loss does occur.

CONCLUSIONS

Although the circular geometry of range-range Raydist is more convenient that the hyperbolic geometry of Raydist "T", the latter provides the major advantages of improved stability and lower operating cost.

A chain of permanent Raydist " T " networks can eliminate the cost to each user of transmitting equipment and its deployment. This has been discussed in detail by HASTINGS *et al* (*). Also, equipment which is moved from place to place is repeatedly subjected to vibration and shock.

(*) " Precision Low Cost Marine Navigation. A regional Approach " by Charles E. HASTINGS, A. Clifford BARKER and Joseph T. BRADBURY, A Symposium Paper Presented at the RTCM Assembly Meeting, April 26-28, 1971, Montreal, Canada.

This treatment can cause minor frequency shifts and misalignments which reduce power output and degrade performance. With range-range operation, one of the radio transmitting sites is aboard the vessel itself, providing a much less stable environment than a fixed ground site.

Raydist " T " also corrects the major performance drawback of standard 3-station hyperbolic systems; namely, extreme accuracy degradation due to geometric dilution.

The Raydist " T " system performed well throughout the two-month operation. The only system downtime occurred when the station at Seashore State Park, Virginia was vandalized. Monitoring equipment at the Hastings-Raydist facility in Hampton, Virginia showed the loss of signal, and operation was restored within 24 hours. The only instance of lane loss during the two-month Raydist " T " operation in the Chesapeake Bay happened during a period of severe precipitation static while operating off the Virginia Capes. Closure error, as determined by system calibration before and after each operation, was consistently equal to or better than that of range-range Raydist.