RAYDIST FOR SHALLOW-WATER HYDROGRAPHY

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FOREWORD

In the development of improved methods in the conduct of shallow-water hydrography in civil works construction and maintenance, the Corps of Engineers in 1946 *became interested in radio-locator equipment, « Raydist », manufactured by the Hastings Instrument Company, Inc., Hampton, Virginia, and investigated by the Norfolk Engineer District. The favorable results of the investigation led to more extended tests by the Norfolk District, the results of which are given here.*

Raydist is a continuous-wave system which depends upon the measurement of the relative phase between continuous wave signals. The system is based on the counting of interference patterns of electromagnetic radiations. Errors in the system result only from variations in the frequency of a single transmitter, from uncertainty in phase determination, or from radio propagation phenomena.

The Type E Raydist system purchased by the Norfolk Engineer District consists of three fixed radio-relay units or stations and one set of recording or indicating apparatus. The equipment for each fixed relay station includes a receiver, a constant output amplifier, and a radio transmitter. They are arranged compactly in double units, each equipped with a collapsible whip antenna. To set up a relay station for operation it is only necessary to place the units at the desired location and extend the whip antenna. The power supply is normally two 6-volt storage batteries, but 115-volt A. C. supplies are easily adapted. The mobile transmitter is a continuous-wave transmitter with a power output of 10 watts. It transmits an unmodulated signal on 1.738 Mc, which is the measuring frequency used in this system. The reference transmitter is a simple continuous-wave transmitter conveniently located so that it can be readily received by each of the relay stations. The indicating station may be installed in the moving object or the indicating and recording may be done at a fixed location.

For convenience in hydrographic surveying, the indicating station for the Norfolk District equipment was installed on the Survey Boat *Pocahontas*. (See Figure 1). In addition to the pair of synchro-indicators located with the master station receiving and phase measuring unit, another pair was located in the pilot house in full view of the boat operator. Both pairs of synchro-indicators at all times show the hyperbolic co-ordinates of the mobile transmitter with respect to the three shore-based relay stations. Another important feature of this particular installation was a specially designed inter-connection between the Raydist equipment and the supersonic echo-sounder equipment installed in the Survey Boat *Pocahontas*. This inter-connection causes a mark to be made on the depth-finder recorder chart, by means of electrical contacts, for each one-eighth, one-fourth, and one-half of a revolution of the syncro-indicator of the Raydist system, which ever is desirable while working. (See Figure 2). The shore-based relay stations are designed to operate from a 6-volt, 200-ampere-hour storage battery, while the mobile transmitter is designed to operate either from a 6-volt, light-weight battery or from 110-volt A. C., 60-cycle external source of power with provision for switching power sources without loss of continuity of operation. The master receiving, indicating, and recording station is designed for operation from 110-volt A. C., 60-cycle source of power. The system has a working range of 20 miles between base-line relay stations with an allowable tolerance of error in both position and distance measurements of 1 foot per mile at a working range between 3 and 20 miles, and a fixed tolerance of 3 feet at a working range between one-quarter mile and 3 miles.

In order to indicate the position of the mobile transmitter it is necessary that all three relay stations be placed in operation. The signal transmitted by the mobile transmitter is received at each of the three relay stations. The reference transmitter transmits a continuous-wave signal which is also received by each of the three relay stations, and heterodynes with the mobile transmitter signal. The heterodyne signals are each transmitted to the indicating station, where the phase relationships are continuously inter-compared. The position of the mobile transmitter with respect to each of the relay stations is thus determined by these phase relationships. If the mobile transmitter moves in such a manner that the difference in distance from each of the two relay stations remains constant, no difference in the phase of the two received will be recorded. This type of path is a hyperbola with the receivers at the foci. At any particular instant the indicator dial indicates on which hyperbolic line of position the mobile transmitter is located. By the use of the third fixed relay station at another location, a second system of hyperbolae is formed in space, referenced to a second base line, one end of which is identical to one end of the first base line. This second system of hyperbolae furnishes a means of determining the position of the mobile transmitter in a two-dimensional system.

Exacting field tests, incorporated in the specifications for the Raydist apparatus purchased, were based on Unites States Coast and Geodetic Survey control positions of first, second, and third order accuracies with supplementary stations established, where necessary, to fix the test locations with large intersection angles and also to avoid overland paths of the radio beams.

In order to have theoretical comparative data for use in testing the Raydist apparatus, certain fixed buoys and beacons were instrumentally located within the triangle bounded by three selected control stations. The purpose of the tests was to obtain two measurements of position and two measurements of distance on each of three different days. Each measurement was required to be within the allowable tolerance of error. The tests were carried on intermittently between August 24 and October 20, 1950, with varying results. The earlier tests, while indicating good repeatability in the readings, were definitely affected by overland paths and local interference. There was also some indication of lack of transmitting power when

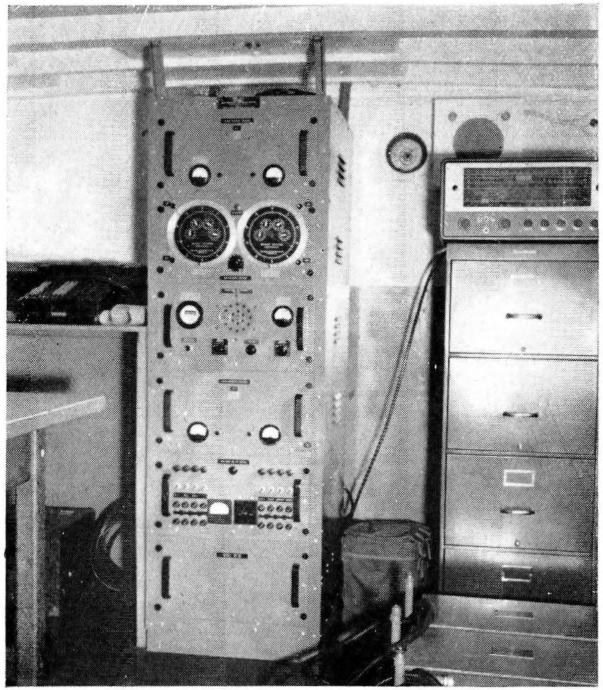

Fig. 1

Interior of raydist - equipped *Pocahontas* showing master recording station.

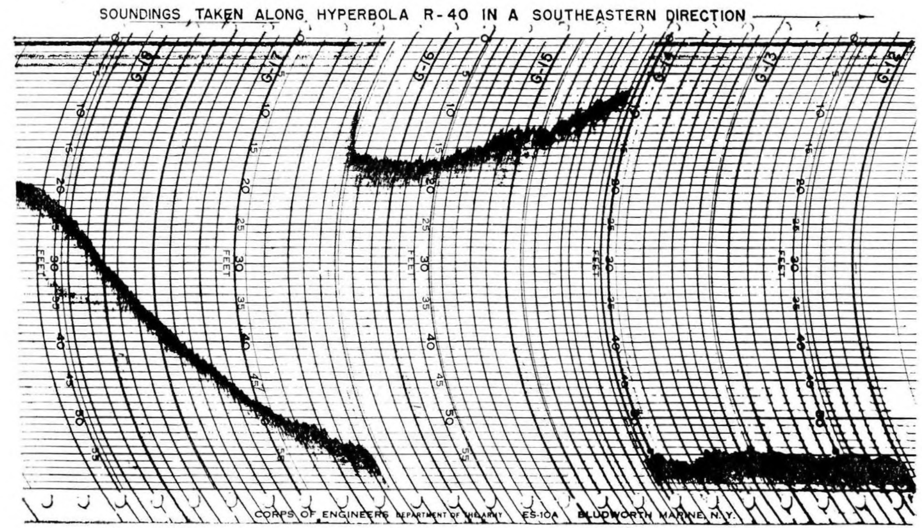

Fig. 2

Section of supersonic echo-sounder chart showing raydist markings at 1/8 hyperbola intervals.

working at the 20-mile design limits of the system with portable whip antennae. Later operations with larger antennae resulted in more satisfactory signals. And careful selection of survey control stations permitted a series of satisfactory performance tests.

In testing the accuracy of the position measurements, a comparison was made between the measured and the theoretical hyperbolae readings in half wave lengths converted to feet along the base lines of the system. Typical of the accuracy obtained with the apparatus under favorable conditions is the result of a test performed while working with base lines 4 to 5 miles in length. The results are shown in Table I.

Table I. — *Results of Position Checks*
Raydist Test of October 18, 1950
East Base Line Buoy

Computed Hyperbola Reading	Field Hyperbola Reading	Indicated Error in Hyperbolae	Indicated Error in Feet	Allowable Error in Feet
R 29.986	R 29.982	— .004	— 1.13	4.60
G 22.352	G 22.351	— .001	— .28	4.95
R 29.986	R 29.984	— .002	— .57	4.60
G 22.352	G 22.351	— .001	— .28	4.95
R 29.986	R 29.982	— .004	— 1.13	4.60
G 22.352	G 22.347	— .005	— 1.41	4.95
R 29.986	R 29.972	— .014	— 3.96	4.60
G 22.352	G 22.336	— .016	— 4.53	4.95
R 29.986	R 29.980	— .006	— 1.70	
G 22.352	G 22.339	— .013	— 3.68	
R 29.986	R 29.970	— .016	— 4.53	
G 22.352	G 26.336	— .016	— 4.53	

* Raydist readings from R base line ; ** Raydist readings from G base line.

An exemple of performance in the measurement of base line lengths is shown in Table II, giving results of a test measurement of a base line 3 miles long.

Table II. *Base Line Measurement. Raydist Test of August* 25, 1950.

Field Reading		Mesured Length of Base in Hyperbolae	Mesured Length of Base in Feet	Computed Length of Base in Feet	Indicated Error in Feet	Allowable Error in Feet
Ft. Wool Ecc.	Sub					
51.089	0.51	51.038	14436.59	14433.63	2.96	3.00
51.087	.059	51.028	14433.76	14433.63	0.13	3.00
51.088	.055	51.033	14435.18	14433.63	1.55	3.00

In conducting a base line measurement test, it is necessary to carry the mobile transmitter behind each station to obtain readings for computing the base length. Measurement of a base line 14 miles in length with the apparatus during another test showed results, as determined by eight readings, of 1 foot in 6,568 feet. Table III.

Table III. *Base Line Measurement. Raydist Test of September 27,* 1950.

Field Reading		Mesured Length of Base in Hyperbolae	Mesured Length of Base in Feet	Computed Length of Base in Feet	Indicated Error in Feet	Allowable Error in Feet
Plantation Light CE Ecc.	New Point Comfort Lt. CE Ecc.					
255.041	0.27	255.014	72,133.184	72,122.201	10.983	13.66

Further tests were conducted using the Raydist apparatus to determine positions within a working range of from 7 to 12 miles. Although the apparatus showed some indications of having insufficient power at the outer limits of the specified 20-mile working range, satisfactory operation was achieved by placing the reference transmitter within the triangular area bounded by the control base lines. Subsequently, telescopic antennae approximately 30 feet in lenght were installed to replace the whip antennae originally furnished. As a result, the power output was increased and the operation of the apparatus improved to the extent that it is now entirely satisfactory. Table IV shows the results of a typical position measurement subsequent to installation of the longer antennae. The working range was approximately 12 miles at the observation point.

Table IV. *Position Check Fishnet Buoy S74N. March* 6, 1951

Computed Hyperbola Reading	Field Hyperbola Reading	Indicated Error in Hyperbola	Indicated Error in Ft. on Base line	Allowable Error in Ft. on Base line
R 142.519	R 142.520	+ .001	+ .28	13.66
G 209.590	G 209.550	— .040	— 11.31	15.31

The results of this position measurement were within the allowable error of 1 foot per mile as fixed by the three control points and were well within working limits of good hydrographic surveying.

Several operation tests were conducted to demonstrate the operating dependability of the apparatus and to familiarize the survey personnel of the Norfolk District with the Raydist system. One of these operations was to make a hydrographic survey of the established dumping ground in Hampton Roads. After careful selection of three control stations which would not involve overland paths or local interference, and which would provide hyperbolic intersections approximately at right angles, a hyperbolic tracking chart was prepared on the scale : 1 inch = 300 feet. A complete hydrographic survey was made and maps prepared of an area covering 1 1/2 square miles during two days operation, as compared to the seven to eight days which would have been required using customary methods. Other demonstrations of the practicability of the Raydist system were the completion of a check survey of the dumping ground for York Spit Channel and location of buoys. Results of these operations were considered to be very satisfactory.

The application of Raydist to the hydrographic surveying program of the Norfolk District is in its infancy. It is proposed to use the apparatus for contract dredging work and hydrographic condition surveys of all channels in the District to which it can be adapted. Miscellaneous surveys and wreck locations are also planned.

The major task in preparing for the use of the Raydist equipment is the computation of plotting points and the plotting of Raydist charts to cover the various channels in the Norfolk District. Considerable work is in progress assembling available control data and planning additional control necessary for preparation of the Charts.

Plotting points for the hyperbolic lines can be computed by any of the mathematical formulae available for the solution of the conic equation. The Norfolk

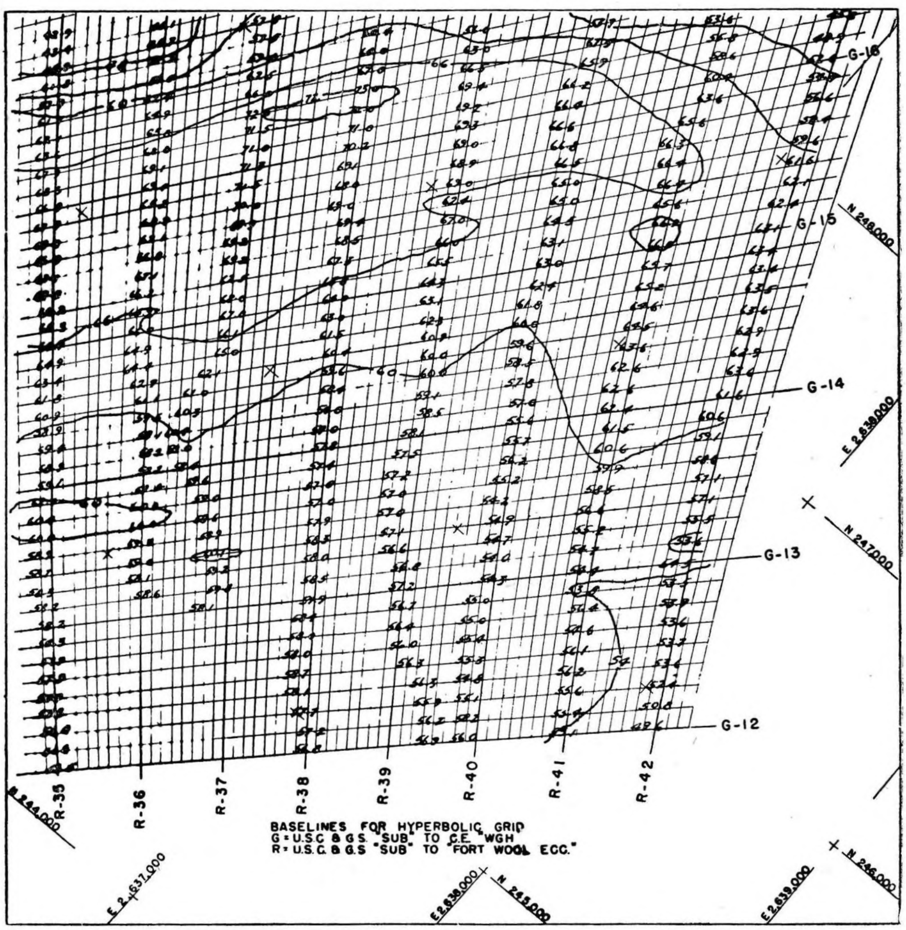

Fig. 3

Section of raydist chart showing results of hydrographic survey

District has prepared a standard form for solution of the equations by use of the polar equation. After the points are plotted, the curve is drawn through them with a spline. When the numbered hyperbolae are completed, the spaces between them are divided into eight parts and intermediate curves drawn. The hyperbolae originating from one base are numbered R and those originating from the other base G as a manner of distinction. (See figure 3).

The first step in the field procedure of a hydrographic survey by the Raydist method is to set up the three relay stations on the three control points by which the Raydist chart is controlled, and locate the reference transmitter at some convenient location near the area to be surveyed. The mobile transmitter is then placed on some permanent point which has been computed into the system and is conveniently located near the area to be surveyed. The supersonic echo-sounder is put into operation and the survey is commenced. It is customary to steer the boat along one system of hyperbolic lines and obtain one-eighth interval fixes along the line to simplify the plotting of the soundings. It is also practical to pick off the soundings and plot the map at a drafting table located on the boat while the survey is in progress.

Although the preparatory work for hydrographic surveys in the Norfolk District entails considerable study and the establishment of additional control, as well as the computation and plotting of Raydist charts for all channels in the District to which Raydist is adaptable, the saving in time to the field and office force outweighs the additional cost of the preparatory work, as well as the original cost of the Raydist apparatus. Furthermore, the accuracy of hydrographic surveys will be greatly improved over the customary methods of sounding on ranges from base lines or of cutting in the survey boat by transit angles or sextants, both of which are slow, cumbersome, and sometimes of doubtful accuracy. Hydrographic surveying by Raydist will be possible during foggy or otherwise unfavorable weather when it would be impossible to locate the survey boat by sight, thereby resulting in an improvement in the over-all efficiency of the survey organization and economy in operation.