Department of the Interior
U.S. Geological Survey

Integrated GPS, Range-range and Hyperbolic Loran C Marine Navigation System for Use on IBM AT or Compatible Microcomputer.

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1.0.0 Introduction

During 1987 and 1988 the U.S. Geological Survey has been using an integrated navigation system developed primarily for use in its mapping operations of the U.S. Exclusive Economic Zone.

1.1.0

The bottom mapping system GLORIA, developed by the British Institute of Oceanographic Sciences (IOS), requires that the towing vessel travel predominately straight tracklines with course changes of less than one degree per five minutes. To properly process and mosaic the bottom image data required that the data be collected along straight preplanned rhumb lines. These requirements led to the development of a real time graphical steering display taking inputs from both the Global Positioning System (GPS) and hyperbolic Loran C (**LO**ng **RA**nge Navigation). As the operations area included Hawaii, the need for range-range Loran C navigation became apparent. The RHORHO system in use today is a product of software evolution. RHORHO provides integrated GPS, Navy Navigation Satellite System (NNSS), range-range and hyperbolic Loran C navigation, two real time graphical steering displays, one quality control text display and complete data acquisition capability of up to 12 serial data inputs.

2.0.0 Software

The RHORHO software is currently inplemented on an IBM AT compatible computer running under the MS-DOS 3.2 operating system. The RHORHO system software is written entirely in the C language and compiled under the Microsoft 5.0 C Compiler. There are 20 C language source files that contain about 150 functions. The four executable files that are invoked by the RHORHO system; RS232.EXE, REOPEN.EXE, RHO.EXE and MN.EXE, occupy about 270 Kbytes of disk space. The minimum memory required to operate the system is approximately 250 Kbytes; however, the compiler requires a minimum of 640 Kbytes. The RS232 program configures the Arnet RS-232 serial multiport to the specific serial devices to which it will communicate. REOPEN performs about the same function as RS232 except that REOPEN is invoked while RHORHO system is running and RS232 executes before the RHORHO system is loaded. RHO is the actual navigation program and controls the invocation of all other programs and functions. The MN program controls survey line selection, deletion and modification as well as navigation sensor selection. MN provides a menu driven user interface for convenience.

3.0.0 Hardware Components.

The IBM AT compatible computer uses the Intel 80286 microprocessor with the Intel 80287 math coprocessor to run the RHORHO software under the MS-DOS 3.2 operating system. A 30 megabyte hard-disk drive is installed in the system but a much smaller (10 Mbyte) hard disk would do the job as the hard disk is only used to store the RHORHO software, survey line file (LINEFILE) and the navigation parameter file (NAVFILE) all of which occupy less than 500 Kbytes. All data is logged on the high density 1.2 Mbyte floppy disk drive. To provide the three video displays (two enhanced graphics and one monochrome text), one generic Enhanced Graphics Adapter (EGA) and one generic monochrome video adapter were added to the motherboard. The second EGA display located on the bridge is a duplicate of the first and is driven by a video amplifier. The amplifier was required to drive the long cable run, about 250 feet from the lab to the ship's bridge. The three monitors used were two generic EGA monitors for the graphical steering displays and one generic monochrome monitor for the quality control text display. The ARNET serial multiport interface is an intelligent serial interface that has an onboard 80186 microprocessor. This board is compatible with the MS-DOS operating system and the C language compiler.

4.0.0 Navigation Sensors.

The primary navigation sensors used on the R/V FARNELLA were the Trimble 4000A GPS receiver, the Northstar 7000 Loran C Receiver, the Racal Decca MNS2000 NNSS receiver and the ship's gyro and speed log. The speed log and gyro data were serially passed to the RHORHO system through an interface built by the British IOS. Other sensors have been used on different vessels, see appendix A for the list of Navigation equipment that can be accommodated. To perform the range-range Loran C computations requires that the Loran C receiver use an external precision frequency standard. Several different types of reference frequency standards were used. The rubidium frequency standards used were the Effratom FRT and FRK-L/LN. The cesium frequency standards used were the HP5062C and the HP5061B.

5.0.0 Hyperbolic Loran C Navigation.

Loran C is a 100 kHz pulse modulated radio-navigation aid. The first Loran system (Loran-A) developed near the end of World War II at the Massachusetts Institute of Technology was improved by the Department of Defense in the 1950's and has become known today as Loran C. It is a passive non-saturable system used in land, air and marine navigation. The U.S. Coast Guard states the accuracy of Loran C at 0.25 nautical miles. At the time of development of Loran C the limited availability and high cost of precision frequency standards dictated that Loran evolve as a time-difference system. To measure differences between two received signals requires a relatively simple and inexpensive timing source. To measure ranges directly requires a very stable timing source such as a cesium or rubidium atomic frequency reference standard. Although the Loran C system was designed and is operated as a hyperbolic system, the advanced development of precision frequency standards has made the range-range mode more attractive.

5.1.0 Time Difference.

The difference in the arrival times of a Loran C master signal and a secondary signal is called a time difference (TD). The locus of points having the same observed TD defines a hyperbolic line of position (LOP). Figure 1 shows the geometry of a typical hyperbolic fix.

5.2.0 Hyperbolic Gradient.

For a given master secondary pair a family of hyperbola separated by a constant value can be plotted. The hyperbolas in Figures 2 and 3 are all separated by 10 microseconds. The distance between these hyperbolas at the baseline represents about 1852 meters. Notice that the distance between successive hyperbolas increases as one moves towards the baseline extensions or away from the baseline. This change in the accuracy of a hyperbolic LOP that occurs relative to the position of the Loran C stations is known as the gradient. Figure 2 illustrates the intersection of two pairs of time difference pairs. Notice that even though both time difference pairs are separated by 10 microseconds, each pair represents a different spatial distance depending on the observers location relative to the transmitting stations. Based on the larger spatial separation between the two "X" time differences in Figure 2, one would assume that the observer was closer to the X station baseline extension than the Y station baseline extension. The reduction in accuracy of hyperbolic LOP's in areas with high gradients is the major weakness of time-difference or hyperbolic navigation.

5.3.0 Crossing Angles

The angle between intersecting lines of position is called the crossing angle. When the crossing angle is less than about 30 degrees the resulting position solution will probably be in error. This is due to the fact that a small error in the observed TD will cause the point of intersection to vary much more than the intersection point of a pair of TD's with a higher crossing angle. This fact is common to any ranging positioning system. Hyperbolic Loran C is further limited by this fact because the reception of 3 stations is required to define 2 LOP's. Direct ranging navigation systems provide one LOP per station.

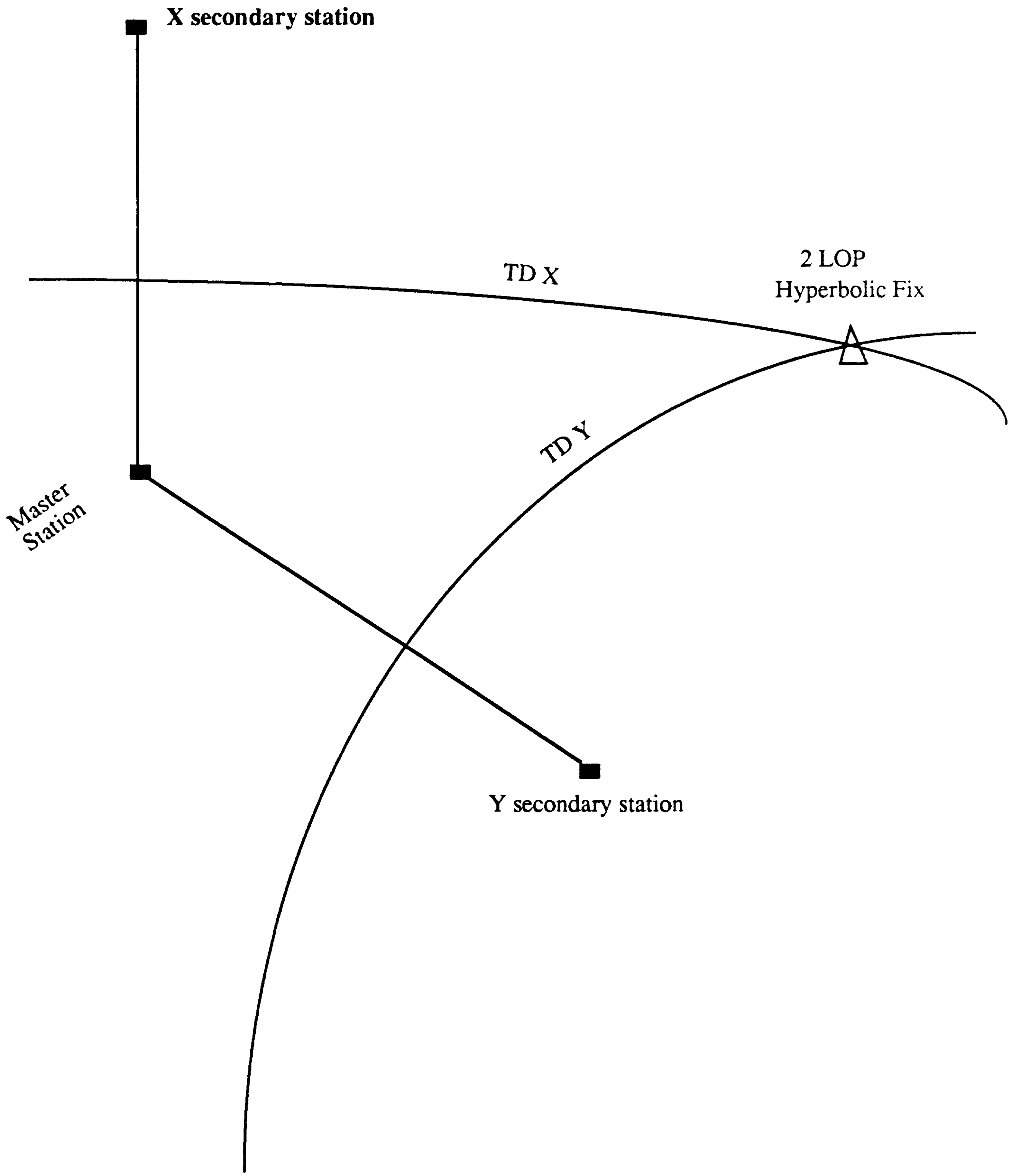

Figure 1. Typical Hyperbolic Fix Geometry

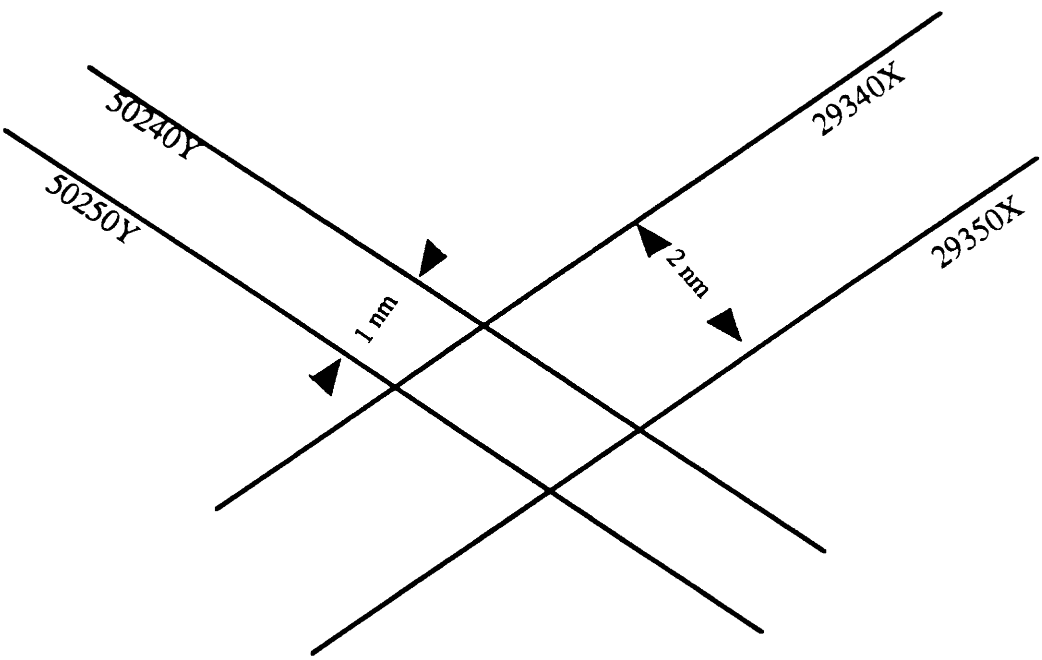

Figure 2. Hyperbolic Gradients
and Crossing Angles

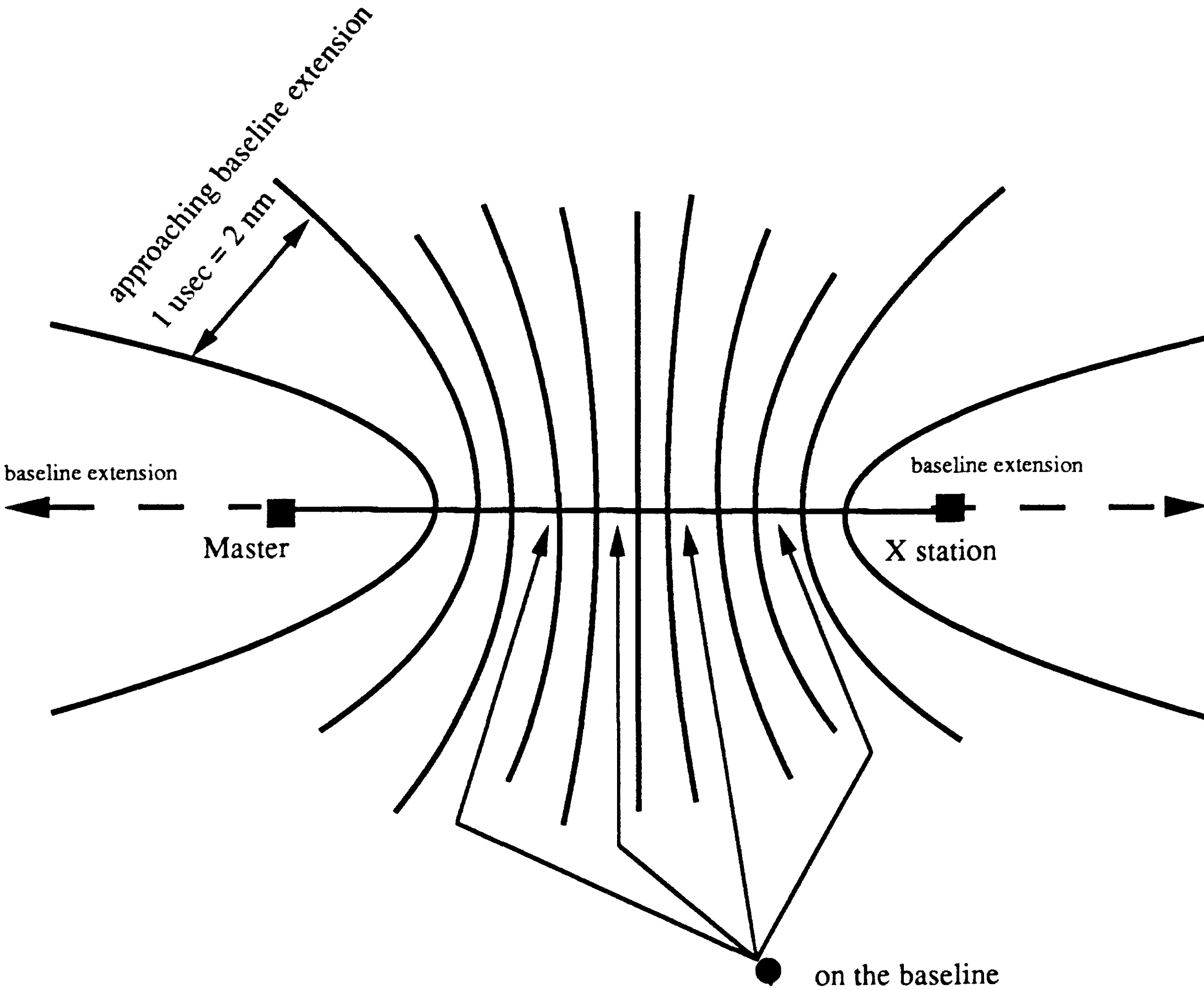

Figure 3. Hyberbolic Gradients

6.0.0 Global Positioning System.

The Global Positioning System (GPS) is an ultra-high-frequency satellite based radio navigation system currently under development by the U.S. Air Force. When complete the GPS will employ a constellation of 21 satellites (with three broadcasting spares) operating in 12 hour orbits at an altitude of 20,000 km. At that time, the GPS will globally provide precise three dimensional positioning, heading, velocity and time 24 hours a day. While the GPS is presently incomplete, most areas of the earth are provided GPS coverage at least several hours a day. Military users of GPS will be able to get positions accurate to less than 10 meters; however, the signals available to civilian users will only allow accuracy of approximately 100 meters.

6.1.0 The GPS Fix.

The position solution provided by the Trimble 4000A is a least squares fit of two or more pseudoranges measured by the receiver. The solution is very similar to land based ranging systems in that the ranges are measured to each GPS satellite. When four or more satellites are being tracked, a three-dimensional solution and precise timing information is provided. When three or more satellites are being tracked, a three-dimensional solution is provided assuming a fixed altitude. When two satellites are tracked, the receiver provides a two-dimensional solution when both the altitude and frequency offset are fixed. The two satellite solution requires the use of an external frequency reference standard. The precise ephemeris data for each satellite is known and broadcast by all of the other satellites in view of the receiver antenna.

7.0.0 Range-Range Loran C.

The RHORHO system adds a range-range Loran C option to the suite of navigation tools. Range-range (sometimes called rho-rho) is a method of using circular versus hyperbolic lines of position to solve the navigation equations.

7.1.0

Loran receivers typically measure the relative arrival times of the transmitted signals from each Loran station. TD values are then computed by subtracting the observed times of arrival of the master from the time of arrival of a secondary station and adding the emission delay for the secondary station. (Emission delay is the time delay due to the baseline length of the master and secondary pair plus the coding delay for the secondary station).

7.2.0

To compute a TD, one must know the relative arrival times of the signals from master station and from the secondary station (1). Since these two signals generally arrive within a few microseconds of each other, one can see that for hyperbolic navigation there is no need for a very stable timing source and in fact most commercial Loran C receivers use an ordinary crystal oscillator.

(1) TD_X = TOA_secondary - TOA_master

where:

TD_X = Time Difference between Stations X and Master
TOA = Time of Arrival of each signal

7.3.0

If the Loran signal contained information about the time each signal left the transmitter and if both the transmitter clock and receiver clock were exactly in synchronization, then ranges to each station would always be available and no calibration phase would be required. Unfortunately, this is not the case. The Loran C receiver has no information about when the signals left the transmitter and so can only measure the relative changes between the arrival of two successive signals. If, however, the location of the receiver can be determined initially, then the ranges to each station can be computed. If also the receiver uses a very stable timing source that drifts very little over time, then the changes in the initial measured values can be tracked long after the receiver's initial location was determined. Then it follows that any change in receiver location should result in a relative change in the arrival times of each station's signal. For example, as the receiver moves closer to the master station then one would expect to see the TOA of the master decrease (2).

(2) TOA_master = Rho_master_0 + Delta_Rho_master

where:

Rho_master_0 = initial range to master station
Delta_Rho_master = the change in Rho_master_0

7.4.0

The equation for a TD value can also be expressed using ranges instead of times of arrival (3). All values are expressed in units of time unless otherwise noted.

(3) TD_X = (Rho_X + Emission_Delay_X + ASF_X) - (Rho_master + ASF_master)

where:

Rho_X = range to X station
Rho_master = range to master station
Emission_Delay_X = Coding Delay + Baseline length
ASF_X = Additional Secondary Factor - station X
ASF_master = Additional Secondary Factor - master

The Additional Secondary Phase Correction is the timing correction required by the non-conformity of the propagation velocity over various conductive media. See section 7.11.0.

7.5.0

To compute a range to a station using a measured TD equation (3) can be solved for Rho_X (4).

(4) Rho_X = TD_X + Rho_master - Emission_Delay_X - ASF_X + ASF_master

7.6.0

The TD X value in equation 4 is available from the receiver. The emission delay for each Loran C chain is also available and published by the U.S. Coast Guard as are the ASF corrections. This leaves Rho_master which must be computed by comparing the current TOA_master to the initial TOA_master_0 as in (5).

(5) Rho_master = (TOA_master_0 - TOA_master) + Rho_master_0

where:

Rho_master = Current range to master
TOA_master_0 = TOA_master at initial time 0
TOA_master = Current master_TOA

Rho_master_0 = Range to master at initial time 0

7.7.0

The above computations are repeated for each slave in the Loran C chain and the lines of position are reduced to a fix by a non-weighted least squares routine.

7.8.0

The key and primary weakness of the range-range method of navigation using Loran C lies in accurately knowing the initial location of the vessel. It is easily seen from (4) that an error in the initial computed range to the master station will result in a direct error in the successive range computations. It is therefore very important to initialize the RHORHO system using only high quality position information.

7.9.0

Traditionally, this initialization has been performed at a dock or anchorage of which the position is accurately known. The RHORHO system allows initialization in two ways. First, the traditional dock location may be easily entered as the reference position as in the traditional case. Secondly, the reference position may come directly and automatically from the GPS receiver. This second feature provides the ability to initialize the RHORHO system dynamically whenever GPS is available and also eliminates any long term clock drift errors that would eventually build up if the system were not initialized periodically.

7.10.0

The traditional method of dock initialization works well until the onboard clock and the transmitter clock drifted out of synchronization. In the worst case, temporary failure of the onboard clock in the traditional mode terminates navigation until the vessels position may again be accurately determined and the re-synchronization process repeated. In the best case, a cumulative error occurs as a result in the differences between the onboard and transmitter clocks since these systems were not usually reinitialized after leaving the dock. A frequency offset between two atomic standards of one part in 2 X 10^{11} causes a range measurement error of about 150 m / days since calibration (S.T. Grant, 1973). The traditional method of using range-range Loran C usually involves one or two days of clock drift error rating. This is not necessary with the U.S.G.S RHORHO system because the clock drift error is eliminated by periodic initialization using GPS after the vessel has left the dock or anchorage.

7.11.0

An error inherent to all terrestrial radio navigation systems including RHORHO is the uncertainty in the propagation velocities of the Loran C signal as it travels over different media with varying electrical conductivities. As mentioned above the Coast Guard publishes tables of ASF corrections for both Loran C ranges and TD's for various geographical locations. Many commercial receivers account for the ASF corrections by storing these values in a look-up table and applying the appropriate correction for the receiver's current location. The ASF tables are very large and most receivers only provide a coarse grid of ASF values to save memory. Some Loran C chains have had very extensive ASF tables produced, especially those heavily used by the U.S. Coast Guard. However, the ASF corrections for other chains are sparse and less accurate. By using the GPS to correct the measured Loran C ranges, the RHORHO system can compute a "pseudo ASF" correction. If one accepts the GPS position as accurate, then any difference between the Loran C measured ranges and the ranges predicted by the GPS position must be a sum of receiver error, propagation anamoly and clock drift. These differences are usually stable except during periods of ionospheric scintillation. The RHORHO system computes and applies these corrections to the measured Loran C ranges to improve the RHORHO solution quality during and after the GPS episode.

7.12.0

One principal advantage of RHORHO over hyperbolic navigation is stronger position geometry over a larger area owing to the circular versus hyperbolic lines of position (LOP). Further, a circular LOP is defined by measuring a range from one station whereas a hyperbolic LOP requires measuring the signals from two stations. This permits RHORHO navigation while receiving only two Loran stations as opposed to the minimum of three stations required in the hyperbolic mode. With RHORHO, any combination of two or more station ranges may be used to compute a fix. The range-range service area is much greater than the hyperbolic service area for the same Loran C chain. Additionally, by stepping the trackpoint of the Loran C signal to a point that produces a higher signal to noise ratio, the range-range coverage area is even further extended. It is not necessary to use the Loran C master station in a given fix as in the hyperbolic method. This allows more flexibility in the selection of stations with the best geometry.

References

Grant, S.T: Rho-rho Loran-C for offshore surveys, The Canadian Surveyor, Vol. 26, No. 2, June 1972.

Grant, S.T.: Rho-rho Loran-C combined with Satellite Navigation for Offshore Surveys, International Hydrographic Review, 1973.

National Ocean Survey Technical Report NOS: Formulas for Positioning at Sea by Circular, Hyperbolic and Astronomic Methods.

RHORHO Loran C Users Manual

United States Geological Survey

August 1988

1.0.0 Introduction.

The purpose of this manual is to describe the operation and principles of the RHORHO system.

1.1.0

RHORHO (rho is the Greek letter used to represent range) is an alternate way to navigate using Loran C ranges instead of time difference (TD) values. Typically Loran C receivers measure the difference in the arrival time of the master Loran C transmitter signal and two or more secondary station signals. Each time difference value defines a hyperbolic line of position (LOP). Two lines of position that intersect define a fix.

1.2.0

RHORHO computes a fix by using circular instead of hyperbolic LOP's. Circular LOP's are not affected by hyperbolic gradients and generally extend the Loran C service area. Ranges are obtained from the receiver indirectly. The Northstar 7000 receiver provides the TD values of two secondary stations and a "master time of arrival" value. The TD values are just the difference in time that the master and each secondary signal was received at the ship's antenna. The receiver has no way of telling when the master signal was transmitted from the master station, so the TOA value represents the relative arrival time after the front edge of the signal has been located. Changes in the TOA value indicate a change in the range to the master station.

1.3.0

By knowing one's position very accurately at any given time, one can compute what the theoretical ranges should be to all of the Loran C stations in the chain. As the location of the receiver is altered, the time of arrival of the master station signal and all of the time-difference values will begin to change proportionally. The change in the time difference values and the TOA of the master station signal can be used to compute new ranges to each station.

1.4.0

With three ranges to three stations there is more than enough information to compute a fix. The RHORHO system uses an unweighted least squares adjustment algorithm to solve for position. The algorithm will iterate a maximum of 20 times or until the adjustments to the initial position estimate are less than two meters.

1.5.0

For compatibility, the RHORHO latitude and longitude are put back into the original receiver output format and can be passed via the serial port to two external computers. This method allows the RHORHO system to operate transparently within other navigation systems. On the R/V FARNELLA, the RHORHO output is passed to the British IOS data logging system. No IOS software revisions were necessary because the RHORHO data is identical in format to the raw NS7000 hyperbolic data.

2.0.0 Pre-Startup

To start the RHORHO program you need to know a few things first. Have the best estimate of your current position handy. Also take a look at the stations in the Loran C chain that you are operating in. The program initially assigns the first two valid secondary stations that it can receive as the slaves to be used. This may not be the best choice. You can override the initial selection (see Appendix B, System Commands). The best choices for three stations would be if they were all 120 degrees apart in azimuth to your location. As this almost never occurs, choose the stations that give ranges intersecting at angles as close to this as possible. If you are using two stations (e.g. master and slave X used twice) then of course you want to pick two stations whose ranges will intersect as close to 90 degrees as possible. Also make sure that there is a floppy diskette in drive A. (That's the top one). The diskette should already be formatted but the program will sense if it's not and prompt you for instructions. If formatting is required this will take 2 or 3 minutes. It is best to have all of the diskettes preformatted so that no data is lost while waiting for the floppy disk to be formatted. The floppy diskettes typically hold about 5 days worth of navigation data.

2.1.0 Startup

To begin the program type RHORHO. After 10-15 seconds the system will prompt for the current latitude and longitude. Enter the most accurate information available to you or you may just press return to use the last position known to the RHORHO system.

2.2.0 Refining the RHORHO Initial Solution.

Initially, the RHORHO system will compute the range corrections necessary to make the measured ranges converge on the initial position that you supplied at start up. If the initial location was accurate and the receiver is providing valid TD measurements then the solution should be reasonably accurate. There are however a few things that should be done after first starting the program. First check your slave station selection as mentioned in the previous section. If the difference in azimuths between the master and either of the slaves is close to zero or 180 degrees select another secondary station. Realize that there are many variables to each situation and that hard and fast rules don't work here. But a guideline to shoot for... select stations that are no less than 30 degrees apart in azimuth relative to your position. Choose stations that have signal to noise ratios above 200.

3.0.0 Cycle Selection.

The NS7000 attempts to track the third cycle of the each Loran station signal. If the receiver determines that the improper cycle is being tracked it will select another cycle to track. The cycles are separated in time by 10 microseconds (3000m). Once the RHORHO system has computed biases, cycle steps can cause huge errors. The NS7000 has a Command 50 that is supposed to disable the automatic cycle selection feature of the receiver. However, this command loses its effect whenever the signal-to-noise ratios drop below some threshold value. To help eliminate this problem, the RHORHO command CYCLE ON/OFF was added. When the program detects a change in TD values that would produce a speed value greater than 150 m/sec, the bias for that TD is adjusted to reflect the nearest 10 microsecond increment. For example, given the proper TD value of 11010.6 followed by an errant value of 11020.8, the RHORHO program will add -10.0 microseconds to the current bias. The effect of this is to remove only the 10 microsecond cycle slip while leaving the small delta TD (0.2 in this case) that is due to change in position.

4.0.0 Using GPS to Improve the RHORHO Solution.

The best way to improve the RHORHO position solution is to use the GPS receiver to provide position information that allows the RHORHO system to compute very accurately the range biases. This is simply done by typing "CALIBRATE ON" followed by a carriage return. The GPS port value at the bottom of the screen will be highlighted to indicate that the calibration process has been started. The highlighted area will stay illuminated until "CALIBRATE OFF" followed by a carriage return has been typed indicating that the GPS calibration process is over. It is best to perform the GPS calibration during a 4 satellite episode with low Horizontal Dilution of Precision (HDOP). When the situation calls for it however, satisfactory results can be obtained by using two and three satellite constellations. Generally, allow the calibration cycle to run for 5 or 6 GPS fixes (about 1 to 1.5 minutes). After this time the GPS biases should be near zero and the biases in use should be changing by less than 1 microsecond each GPS cycle. Do not allow the GPS calibration period to overlap the end of a GPS episode. Plan to execute the calibration well before the end of the GPS episode when the satellites are of sufficient elevation. Occasionally, the low elevation and signal to noise ratios of a setting GPS satellite will introduce an erroneous pseudorange that results in a positional error. If the calibration process is invoked when this error occurs, the RHORHO system will bear the same positional error.

4.1.0

As the GPS fixes are integrated into the RHORHO system, the two bias values on the text display will begin to change. The BIAS IN USE value represents the total difference between the uncorrected Loran C measured range and the range predicted by the GPS position. The GPS BIAS value is the difference between the ranges predicted by the last GPS position and the corrected ranges (measured plus most recent bias). After the first GPS position report both the BIAS IN USE and the GPS BIAS value will be equal because the GPS calibration software attempts to correct any difference between the ranges predicted by the GPS position and the ranges measured by the Loran C receiver. Subsequent GPS position reports should cause the GPS BIAS to drop near zero. This is because there should be very little difference in the corrected RHORHO system position and the GPS position which means that the further range biases should be very small.

5.0.0 Setting Options on the NS7000 Receiver.

There are a few helpful commands that allow smoother operation of the NS7000 receiver. These commands are listed briefly here and in detail in the NS7000 manual. Once underway and before GPS calibration, force the NS7000 to track the TD values you plan to use during the survey. TD forcing is done by pressing the CMD key followed by the Command 43 (FORCE LAT/LON PAIR) followed by pressing the ENTer key on the NS7000 control head. After the receiver is locked on the proper cycle (or even if it is not) use Command 50 (HOLD/RELEASE STATION) to inhibit further automatic cycle selection adjustment. Once the cycle lock command has been issued, do not release it. The GPS biases will adjust to the cycle selection. If a different cycle is tracked later the biases will be in error by the amount of the cycle selection change (increments of 10 microseconds).

5.1.0

Familiarize yourself with Command 50. It should always be used. Unfortunately, the NS7000 will occasionally drop the Command 50 request. This will happen when the receiver temporarily loses the master signal or when the signal to noise values drop below -20db (64 in the numeric format). If this occurs and the cycle actually steps (indicated by a change in TD or master TOA greater than 10 microseconds) then RHORHO will need to be reinitialized using the "init" command. Refer to the display line labeled "Delta" in the hyperbolic box. This line represents the change in the master TOA and TD's since reference time. See also Signal to Noise Ratios and Cycle Selection.

6.0.0 Signal to Noise Ratios.

To increase the signal-to-noise ratio (SNR) of weak stations, the NS7000 Command 20 (STEP TRACK POINT 10 USEC) can be used. By forcing the receiver to step 10 microseconds along the Loran C pulse, the SNR's can be increased. This is due to the fact that the NS7000 normally tracks the third cycle of the pulse, a relatively weak part of the Loran signal. This is done to prevent skywave interference. By tracking a later cycle in the pulse with a higher amplitude, the SNR's can be increased by 2 or 3 fold. This technique also seems to aid the cycle lock facility (Command 50) of the NS7000 receiver.

6.1.0

Note that stepping the track point should only be done when GPS is available. Performing the cycle step (Command 20) will cause errors in the TD values which must be biased out. The only reliable way to do this is with GPS. The whole point of this exercise is to force the NS7000 to stay locked on the master and secondary stations by causing the SNR values to increase.

6.2.0

Note that the RHORHO command CYCLE OFF should be issued before the track point stepping procedure is started. Only step the signal enough to get SNR's > 250. It is possible to step the cycle too far which will cause SNR's to fall. The best method is to select the signal to be cycle stepped on the top line of the NS7000 display. Then issue Command 20 and step +10 microseconds. Now display the SNR values for this station by pressing the NS7000 SNR key. The SNR value is heavily filtered and will change only gradually. Once you have the SNR's where you want them, issue Command 50 on the NS7000 control head and HOLD -ALL- stations.

7.0.0 Data Logging.

There are six data files logged on the 1.2 Mbyte floppy disk. The data files are: COM.LOG, PRINTER.LOG, GPS.LOG, RHO.LOG and HYP.LOG.

7.1.0 COM.LOG.

COM.LOG Format <DDDHHMMSS0 Text message>

where DDD = day of year
HH = hour
MM = minute
SS = second
0 = tenth of second

sample output:

090 20:11:58 Console command: gps on
090 20:18:04 Console command: gps off
090 21:12:35 MNS2000: TRANSIT FIX

7.1.1

The COM.LOG file contains all of the dialogue between the RHORHO system and the operator. Commands (successful or not) are logged here. System start-ups and shutdowns are time stamped and recorded.

7.2.0 PRINTER.LOG.

PRINTER.LOG Format <DDDHHMMSS0 Text Message>
where DDD = day of year
HH = hour
MM = minute
SS = second
0 = tenth of second

sample output:

090 20:11:58 Console command: gps on
090 20:18:04 Command Response: GPS calibration will begin next fix.
090 21:12:35 MNS2000: TRANSIT FIX

7.2.1

In the event that the printer is not available or out of paper, a disk file named PRINTER.LOG is created that contains all of the messages that would have been sent to the printer.

7.3.0 GPS.LOG.

GPS.LOG Format <DDDHHMMSS0 sdd.ddddd sddd.ddddd GPS#>
where DDD = day of year
HH = hour
MM = minute
SS = second
0 = tenth of second
s = sign + = North or East; - = South or West
d = decimal degrees of latitude or longitude
# = Number of Space Vehicles used in fix

sample output:

0902003470 22.79824 -153.65083 GPS2
0902004020 22.79792 -153.65038 GPS2
0902005020 22.79672 -153.64834 GPS2

7.3.1

The GPS.LOG file contains the time and position of the GPS fixes. Appended to the record is the GPS label and number of space vehicles used in the fix. These positions are recorded every minute when the GPS receiver is actively solving.

7.4.0 RHO.LOG.

RHO.LOG Format <DDDHHMMSS0 sdd.ddddd sddd.ddddd RHO>
where DDD = day of year
HH = hour
MM = minute
SS = second
0 = tenth of second
s = sign + = North or East; - = South or West
d = decimal degrees of latitude or longitude

sample output:

0902004000 22.79791 -153.65041 RHO
0902006000 22.79544 -153.64594 RHO
0902008000 22.79286 -153.64116 RHO

7.4.1

The RHO.LOG file contains all of the positions that were successfully computed by the RHORHO system using the range-range algorithm. These positions are logged every two minutes.

7.5.0 HYP.LOG

HYP.LOG Format <DDDHHMMSS0 sdd.ddddd sddd.ddddd HYP >
where DDD = day of year
HH = hour
MM = minute
SS = second
0 = tenth of second
s = sign + = North or East; - = South or West
d = decimal degrees of latitude or longitude

sample output:

```
0902004000  22.58117 -153.90533 HYP
0902006000  22.57900 -153.90083 HYP
0902008000  22.57733 -153.89517 HYP
```

7.5.1

The HYP.LOG file contains all of the positions that were successfully computed by the NS7000 receiver using its hyperbolic algorithm. These positions are logged every two minutes.

7.6.0

The navigator's responsibility is to insure that the system has adequate space available on the logging high density diskette. The free disk space is indicated in the upper right hand corner of the text display. Please note that this value only changes in increments of 1024 bytes (that's the number of bytes in 1 cluster). Change the diskette when there are less than 5000 bytes available on the diskette. The program will highlight the disk free space as a warning to change the diskette.

7.7.0

To change the diskette in drive A type "change diskette" and press return. The program will first close all files then instruct you to remove and replace the diskette in drive A. At this time remove the diskette in drive A and replace it with a new High Density (HD) diskette. Then press return. If the diskette is already formatted, the program will reopen new logfiles on the new diskette and continue the previous operations. If the diskette is not yet formatted the program will issue a DOS format request. The FORMAT program will prompt you to insert disk in drive A and then press return, but you have already put the new disk in so you can just press return to start the formatting. The HD format will take about 2-3 minutes to complete. The most efficient method of handling the disk changes is to format all of the diskettes before they are needed. Make sure the diskettes are formatted in a high density floppy drive. This will provide 1.2 Mbytes of disk space whereas the low density format will only provide 360 kb of storage.

8.0.0 Data Transmission - Output Lines.

There are three data transmission lines output from the RHORHO program. They are GPS to FARNAV system, RHO to FARNAV system and RHO to the ABC system. These data lines are automatically controlled as long as the RHORHO system is running.

8.1.0 Data Transmission - Input Lines.

There are five input data transmission lines. GPS, Hyperbolic Loran C, the ship's Gyrocompass via the ABC system level A, the ship's speed log via the ABC system level A and the MNS2000 bridge satnav receiver.

9.0.0 Quick Start Instructions.

1. Format enough floppy diskettes to last the length of your survey. One disk lasts 4-5 days.

2. Insert a formatted floppy disk for data logging into Drive A.

3. Type RHORHO and press return.

4. Enter best estimate of position.

5. Select desired slaves <type "slaves x y" for example>.

6. Calibrate to GPS <type "GPS on">

7. Type CYCLE ON and use command 50 on NS7000.

10.0.0 Installation Instructions.

To install the RHORHO system software on your system, insert the diskette labeled INSTALL into Drive A. Type INSTALL and press return. The INSTALL program creates a directory called C:\NAV. RHORHO is a batch file that invokes the executable programs in the proper sequence. Be sure that the MS-DOS PATH variable contains an entry for the \NAV directory. INSTALL will copy everything required for the RHORHO system to the \NAV directory. The INSTALL batch file will create the directory \NAV\SOURCE. Then INSTALL will copy the C language source code and include files to the \NAV\SOURCE directory. Additionally, the batch files required for compiling all of the source code and linking the object modules are copied into the \NAV\SOURCE directory.

11.0.0 The Graphics Display.

The real time graphics display is illustrated in Figure A.1. The graphics display contains vital steering information for the bridge and science labs. The video display is divided into three sections. The top section contains graphics text providing a navigational information and quantitative description of where the vessel is relative to the survey line. The middle section shows the spatial relation and orientation of the ship relative to the survey trackline. The lower portion of the screen displays the width of the displayed area in meters as well as some function key definitions for the operator.

11.1.0 The Top Section of the Graphics Display First Column.

There are three columns with four rows in this section. The first column contains the latitude, longitude, time and survey line respectively. The latitude and longitude are displayed in degrees and decimal minutes followed by the letter of the appropriate hemisphere. The time is displayed as a 3 digit day of year field followed by one space which is followed by the hour, minute and second all separated by colons. The day of year and time values are referenced to Universal Time (UT). The fourth row of the first column contains the name of the survey trackline currently in use preceded by the abbreviation "LIN: ". The line name may be six alphanumeric characters or less. Line names that are longer will be truncated to six characters.

11.2.0 The Top Section of the Graphics Display Second Column.

The second column of this section displays the three orthogonal trackline distances and the speed over ground respectively. The top three values represent the distance to the end of track, the cross track error and the distance along the track, respectively. All distances are displayed in units of meters. Negative values have the following meanings: negative "END" is the parallel distance that the vessel has traveled beyond the end of the survey line, negative "CRO" is the perpendicular cross track error to the left of the survey line, negative "ALO" is the parallel distance that the vessel must travel before reaching the start of line. Positive values have the following meanings: positive "END" is the parallel distance to the endpoint of the survey line , positive "CRO" is the perpendicular cross track error to the right of the survey line, positive "ALO" is the parallel distance the vessel has traveled along the survey line. The fourth row in the second column preceded by the abbreviation "SOG: " is the computed speed over ground and is displayed in knots. This value is computed using position data from the navigation sensor in use. Speed over ground is computed by looking at changes in position every 30 seconds and dividing distance traveled by time elapsed. The 30 second values are then filtered using a linear weighted filter which applies greater values to the most recent speeds computed.

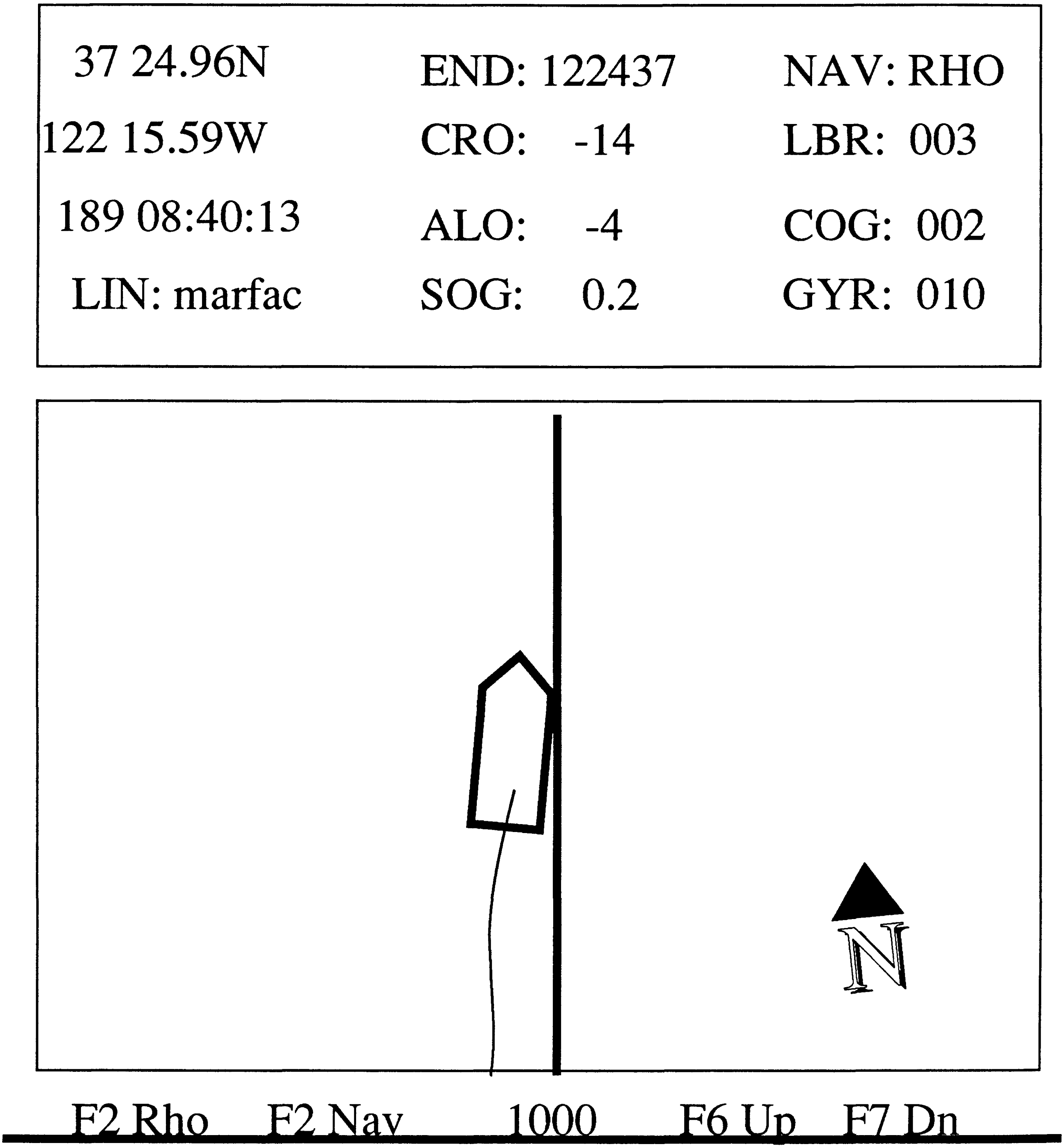

Figure A4. Typical Graphics Display

11.3.0 The Top Section of the Graphics Display Third Column.

The third column of this section displays the current navigation sensor, the bearing of the survey line, the course over ground and the ship's gyro. The current navigation sensor is preceded by "NAV: " and may be any of the following abbreviations: GPS, RHO or HYP indicating GPS, range-range Loran C or hyperbolic Loran C respectively. The navigation sensor is selected in the main menu (See Main Menu Section 14.0.0). Course over ground, speed over ground as well as all trackline parameters are computed based on data from the current navigation sensor. (The selected navigation sensor has no effect on data logging or transmission of data to other optional systems.) The bearing of the survey line "LBR: " is the computed rhumbline bearing from the starting coordinates to the ending coordinates in degrees clockwise from north. The course over ground "COG: " is computed much like speed over ground and again is based on data from the current navigation sensor only. The ship's gyro "GYR: " is the heading of the ship as reported by the gyrocompass.

11.4.0 The Middle Section of the Graphics Display.

The middle section of the graphics display is where the values in the top of the display are animated. The survey line is always represented by the vertical line in the center of the display. The spatial orientation of the survey line is indicated by the north arrow and the large letter "N" in the lower right hand corner of the display. The survey line is always vertical on the display but the north arrow will rotate to point to true north. The vessel is indicated by the pointed polygon drawn at the proper location on the video display. As the vessel moves along the desired trackline a line of historical track points are plotted on the screen. Up to 50 points are stored in the historical track array to graphically display vessel motion. As the vessel moves toward the the top or bottom of the screen the viewing area is automatically shifted along the trackline in the proper direction so that the vessel is always in view on the screen. As the vessel moves toward the left or right of the track the viewing area is automatically scaled up so the the ship and the survey trackline are both always in view. The real width of the viewing display can also be set manually (see next section).

11.5.0 The Bottom Section of the Graphics Display.

The bottom line of the graphics display shows the width of the current viewing area in meters. The width is bounded by left and right dimension arrows. The height of the viewing area is scaled proportionally to the width. In the left hand side of this section are function key definitions to remind the user how to get back to the text and main menu display. The "F1 Rho" label tells the user that pressing F1 will restore the text rhorho display. The "F2 Nav" label tells the user that pressing the F2 key will display the Main Menu for selecting navigation sensors and survey lines. To the right side of the screen are function key definitions for the F6 and F7 keys. The "F6 Up" label tells the user that the width of the screen can be increased by pressing the F6 key. Each time the F6 key is pressed the video screen increases in width by 500 meters. The "F7 Dn" label tells the user that the width of the screen can be decreased by pressing the F7 key. Whenever the F7 key is pressed the width of the screen is scaled down to the smallest width (in multiples of 500 meters) that will allow the vessel and the survey line to be displayed simultaneously.

12.0.0 The Text Display.

When two video adapters are used as in the U.S.G.S. system, the monographic video display will always show the text display. In a system that employs only one monitor (or one adapter) the text display will be the first dislay that the user sees. The F1 key can then be used to toggle between the graphics display and the text display. The RHORHO system text display is divided into three sections also. The top section displays the values related to the range-range solution. The middle section displays data related to the hyperbolic solution. The lower section displays reference position and system status information.

12.1.0 The Text Display Top Section.

The top section of the RHORHO system text display will be discussed as five rows and four data columns. The first column displays the range-range solution for latitude, longitude, the time of the fix, speed over ground and course over ground. The latitude and longitude are displayed in degrees and decimal minutes followed by the letter of the appropriate hemisphere. The time is displayed as a 3 digit day of year followed by one space which is followed by the hour, minute and second all separated by colons. The speed and course over ground (displayed in knots and degrees respectively) are not necessarily related to the range-range solution but rather to the currently selected navigation device. The next three columns provide information about the ranges used to compute the fix. The second column always provides information about the master station ranges. Columns three and four provide data about the two secondary stations selected by the user. In some instances the user may select the same secondary station for both slaves providing a two line of position fix. In this case, both columns three and four would contain exactly the same information. The first row of columns 2-4 contain the range in meters to the master station and the selected secondary stations respectively. The second row of columns 2-4 display the azimuth from the ships current location to the master and two secondary stations, respectively. Azimuths are displayed in degrees measured clockwise from north. The azimuths to the stations are provided so that the user can select stations that are separated by 30 degrees or more of relative azimuth whenever possible. The third row of columns 2-4 displays the residual in meters from the last least squares range-range solution. The residual values are intended as a quality control information to be used in the selection of optional secondary stations. Generally, the residuals should be less than 400 meters. The fourth row of columns 2-4 contains information about the GPS bias currently in use. The GPS bias, displayed in microseconds, is the difference between the Loran C ranges predicted by the current range-range position and the ranges predicted by the current GPS position. These biases will change when the GPS is used to improve the range-range position solution (see section 4.0.0 Using GPS to Improve the RHORHO Solution). The fifth row of columns 2-4 shows the bias currently in use in units of microseconds. This value represents the total bias that is being added to the measured ranges to force the solution to converge on the desired location. Initially the RHORHO system computes the initial range biases to all stations in the given chain based on the reference position entered at start up. The difference between the initially measured ranges and the computed ranges becomes the initial bias in use value. Later by using GPS or by manually adjusting the biases, the "bias in use" values will change. The difference between the two fields "bias in use" and "GPS bias" is that "bias in use" represents the total amount that is being added to the measured ranges and "GPS bias" is the the difference between the corrected ranges and the ranges predicted by the current GPS position. During the first cycle of a GPS calibration, both the "GPS bias" and the "bias in use" values would be the same because the measured ranges have not yet been corrected. On subsequent cycles during a GPS calibration, the "GPS bias" should be close to zero because the measured ranges have now been corrected by the initial GPS bias. A fifth column provides labels and units for the preceding three columns.

12.2.0 The Text Display Middle Section.

The middle section of the RHORHO system text display contains information about the hyperbolic Loran C receiver and measurements. The first column contains the latitude, longitude and time of fix respectively in the same format as the section above. The next three columns like the range-range section pertain to the master and two secondary stations selected by the user. Columns 2-4 of the first row contain the master time of arrival and the two secondary station time differences respectively. These values are all displayed in microseconds. The value in columns 2-4 of row 2 of this section display the scaled signal to noise ratios of each signal as reported by the Northstar 7000 Loran C receiver. The signal to noise ratios are displayed so that the user can see the effect of stepping the Loran C trackpoint (see section 6.0.0 Signal to Noise Ratios). Column 2 has a value in row three that represents the change in the arrival time of the master signal since the system was first initialized. This value is displayed in microseconds and is provided as a quality control aid.

12.3.0 The Text Display Bottom Section.

The bottom display section is divided into three separate boxes that contain data about the reference position, system status and communication status, respectively.

12.3.1 Bottom Section - Reference Position.

The left box contains the reference position used to compute the initial "bias in use" values. When a GPS calibration episode occurs, this value will be updated to the most recent GPS position and time. The intent of this box is to inform the user of the time since initialization and/or GPS calibration.

12.3.2 Bottom Section - System Status Messages.

The middle box in the bottom section is used to display system status information. Following is a list of possible messages that may appear in this area.

Printer OFF
Computing GPS Range Biases
Last Cycle Slip [999] 000 00:00:00
Line Graphics On

12.3.3 Bottom Section - Status Message Printer OFF.

The "Printer OFF" message is displayed whenever the printer is off-line, out of paper, turned off or disconnected. Should the printer be reenabled a "PRINTER ON" command will remove the "Printer OFF" message and restore printer operations. (See next section on Issuing Commands).

12.3.4 Bottom Section - Status Message Computing GPS Range Biases.

Whenever the "CALIBRATE ON" command has been issued, this message will be displayed and new GPS range biases will be computed. In addition to this message the value in the right hand box of the bottom section labeled "GPS " will be highlighted. This message will be removed whenever the command "CALIBRATE OFF" is issued.

12.3.5 Bottom Section - Status Message Last Cycle Slip.

The "Last Cycle Slip" message is an indication that the automatic cycle slip compensation routines have been invoked by the command "CYCLE ON". The first value following the message is the number of cycle slips that have occurred since the "CYCLE ON" command was issued. The next value is the day of year and time (UT) of the last occurrence of a cycle slip. (See section on Cycle Selection and Signal to Noise). The automatic cycle slip compensation is disabled whenever a change in secondary stations is made or whenever the user enters the Main

Menu.

12.3.6 Bottom Section - Status Message Line Graphics On.

The "Line Graphics On" message will appear on the monographic text display whenever the EGA graphics monitor is in the graphics mode (F1). When in the graphics mode, the command window will appear on the monographic video display instead of the EGA display. (See next section on Issuing Commands).

12.3.7 Bottom Section - Communications.

The right hand side of the bottom section is a display of all of the input queues for the various RS-232 devices. The abbreviations "GPS", "HYP", "GYR" and "MNS" represent the GPS, Hyperbolic Loran C, ship's gyro interface and Racal Decca NNSS receiver , respectively. The values following these abbreviations represent the number of characters waiting to be input for each port.

13.0.0 Issuing Commands to the RHORHO system.

Appendix A lists in short form all of the available commands that can be used to make the RHORHO system perform specialized functions. The following sections elaborate on the action of each command. The method of entering all commands follows the same pattern. To begin entering a command just start typing. When the first character of the command is received, a command window will be opened at the top of the text display. If the line graphics display is currently on, then the command window will open on the monographic monitor, otherwise the window will always open on the EGA monitor. Some commands require an associated value for example "print nav 30". The command part "print nav" expects to be followed by a numeric argument. In this case the argument is the number of minutes between navigation printouts. While some error checking is performed, it is safer to learn the commands or refer to the "HELP" command for assistance.

13.1.0 Command AUTO TIME ON/OFF.

This command enables or disables the function that allow the Loran C receiver to set the RHORHO system time. The default state of this command is enabled. It is important to maintain the proper time on the Loran C receiver as this is the time that the system will be set to. Note that the Loran C receiver time is set to midnight every time the Loran C receiver power is cycled on and off.

13.2.0 Command CHANGE DISKETTE.

The CHANGE DISKETTE command is used when the logging diskette becomes saturated. The disk space available is always indicated on the text display in the upper right hand corner preceded by the words "Disk Space". This area will be highlighted in red whenever the disk space available drops below 5000 bytes. At this time (or at any time that's convenient) type the command CHANGE DISKETTE and press return. The system will close all the files on the current diskette and prompt the user to insert the new diskette and press enter when ready. Note that although the system can detect an unformatted diskette and actually format it, it is much better to preformat all diskettes before the start of the survey to prevent any loss of data while waiting for the diskette to format. The system will then reopen all the data logging files and resume operations.

13.3.0 Command CLEAR.

The CLEAR command clears the text display and redraws it. Occasionally the text screen may contain some garbage that can be erased by the CLEAR command.

13.4.0 Command CYCLE ON/OFF.

This command is used to enable or disable the cycle slip compensation feature of the RHORHO system. To enable type CYCLE ON. To disable type CYCLE OFF. The CYCLE ON command is always disabled when the Main system menu is entered or whenever secondary stations are re-selected.

13.5.0 Command DEBUG ON/OFF.

The DEBUG ON/OFF command is used to turn the debugging facilities of the program ON and OFF. This command should only be used for software problem diagnosis. The default state of this command is OFF.

13.6.0 Command EP ON/OFF.

This command enables or disables the printing of the estimated position from the Racal Decca NNSS receiver on the line printer. This command is sometimes used when there is no other reliable information available to initialize the RHORHO system with. By typing "EP ON" and pressing return the estimated position will be reported on the line printer.

13.7.0 Command FIX #.

The FIX # command is used to set the interval in seconds between successive range-range computations. The # is entered in seconds. The default value for FIX is 6 seconds.

13.8.0 Command CALIBRATE ON/OFF.

This command enables or disables the GPS range bias computation routines used to improve the range-range solution. After this command is invoked, the status message "Computing GPS Range Biases" will be reported in the lower portion of the text display indicating that the range biases are now being computed and applied to the range-range solution. To end the calibration period, type CALIBRATION OFF and press return. This command has two modes. If the command is entered in lower case (i.e. "calibrate on") then the command works silently. If the command is entered in uppercase, the results of the calibration procedure will be reported on the line printer. (See also Section 4.0.0 Using GPS to Improve the RHORHO Solution.)

13.9.0 Command HELP.

The HELP command lists all of the RHORHO system commands. This command has two modes. If entered in lower case (i.e. help) then the commands will be listed on the video text display. If the command is entered in upper case (i.e. HELP) then the commands will be listed on the line printer.

13.10.0 Command INIT.

The command "INIT" is used to reinitialize the RHORHO system. Following this command the user will be prompted to enter the current latitude and longitude. All previous biases will be cleared and recomputed to the new position. All filters are reset. This command should only be used when the system does not respond to GPS calibration and is obviously malfunctioning.

13.11.0 Command PRINT NAV #.

The PRINT NAV command is used to set the printer output interval when the line graphics mode is invoked. The default value is set at 5 minutes. Whenever the line graphics display is active, a printer report of time, position, latitude, longitude, line name, navigation sensor and orthogonal track distances will occur.

13.12.0 Command REFRESH #.

The REFRESH # command is used to set the interval between successive graphics screen refreshes in seconds. The # should be entered in seconds. The default value for REFRESH is 10 seconds.

13.13.0 Command QUIT.

The quit command kills the RHORHO system and returns controls to the operating system.

13.14.0 Command SET BIAS.

This command allows the user to manually modify the Loran C range biases in use. This command should only be used if GPS or other position information is not available and as a last resort. After the SET BIAS command has been issued, the system prompts for the master bias in microseconds. The user can keep the current bias in use by pressing return or enter another value. The same procedure is followed for each of the secondary stations.

13.15.0 Command SET FILTERS ON/OFF.

The SET FILTERS ON/OFF command used to set the range filters on and off. The ranges are smoothed by a weighted linear filter to remove some of the Loran C signal jitter. The normal state of the filters is ON and should probably remain that way.

13.16.0 Command SLAVES A B.

The two secondary stations to be used in the fix can be selected by use of the command SLAVES A B where A and B represent the letter (W,X,Y,Z) of the Loran secondary stations. To select stations X and Y one would type "SLAVES X Y" and press return. The text display would then display range and time-difference data for the two secondary stations X and Y. The range-range solution will now use the newly selected station ranges with the appropriate biases.

13.17.0 Command SYSTEM <MS-DOS COMMAND> .

The SYSTEM command is used to invoke an MS-DOS command or program while operating the RHORHO system. A typical example of using the SYSTEM command to set the system date would be as follows: " SYSTEM DATE ". Any legal MS-DOS command can be issued, however due to the limitations of the current operating system true concurrent operations are not possible. What this means is that the RHORHO system is actually suspended until the completion of the MS-DOS command. This is acceptable for operations that take only one or two minutes. The serial multiplexor will continue to buffer incoming data up to 2 kbytes. After that time the data buffers will be dumped and loss of data will occur.

14.0.0 Main Navigation Menu.

The Main Menu can be invoked by pressing the F2 key while using either the graphics screen or the text screen. The Menu can also be entered while not actively running the RHORHO system by typing "MN" and pressing return. This mode is useful for entering survey line coordinates prior to the beginning of the actual survey. The functions provided by the Menu program are the selection, modification, deletion and addition of survey lines and also selection of navigation sensors. The user selects options by using the arrow keys to position the highlight bar over the selection desired and pressing return to activate that selection.

14.1.0 Selecting a Survey Line.

To select a survey line, position the highlight bar over the "Select a Survey Line" field using the arrow keys then press return. The current contents of the survey LINEFILE will be displayed beginning at the first record in the file. The Home key will position the pointer at the first record in the line file and the "End" key will position the pointer at the last record in the LINEFILE. The "PgDn" and "PgUp" keys can be used to position the pointer down or up by 10 records. Position the highlight bar over the desired survey line and press return. The Selection routine will return control to the Main Menu and the contents of the window at the bottom of the menu will now be updated to indicate your last selection. When control is returned to the navigation screen, the new survey line will be employed.

14.2.0 Adding a Survey Line.

The survey lines are added to the LINEFILE by positioning the pointer over the "Add a Survey Line" selection and pressing return. A window will open at the lower portion of the screen with labels for "LINENAME", "Starting Lat", "Starting Lon", "Ending Lat", "Ending Lon". Fill in ALL of the fields before pressing return. As each field is filled in, use the arrow keys to select the next field to be filled in. The Line Name field can be up to six characters (or numbers) long. The latitude and longitude should be entered in degree and decimal minutes. Don't forget to use the proper sign for the appropriate hemisphere. For example, a west longitude would be entered as -122 09.8. The Home key takes on a special function within the Add Survey Line routines. When the Home key is pressed and the cursor is located in a latitude or longitude field, the system will enter the "current" latitude or longitude depending on which data is expected. The "current" latitude or longitude is the last position that was recorded by the RHORHO system before the Menu was invoked. After all the fields have been properly entered, press the return key. If there were errant entries the system will beep and the user will be required to reenter the data correctly. If the system accepts the data as entered there will be no beep and the record will be recorded. The survey line entry form will again be displayed and the user may continue to enter line coordinates or exit the entry procedure by pressing the F1 "Esc" keys.

14.4.0 Changing Coordinates of an Existing Survey Line.

The coordinates or line names of previously entered survey lines may be modified using the "Change Coordinates " selection. Select this option by positioning the highlight bar over the "Change Coordinates of Existing Survey Line" using the arrow keys and press return. A window will open showing a page full of survey lines from the LINEFILE. To select a survey line to modify, use the arrow keys to position the highlight bar over the desired line and press return. Another window similar to the "Add a Survey Line" window will open at the bottom of the screen. The data entry fields in this window will contain the data values of the survey line that was selected from the previous window. Any of the data fields may be modified. The "Home" key has the same effect here as in the "Add a Survey Line" selection which is to enter the current latitude or longitude depending on where the cursor is located. Do not press return until ALL of the fields are correct. Use the arrow or TAB keys to move the cursor from field to field. Once all of the data has been entered correctly, this window will disappear and control will return to the window that selects a line for modification. The user at this point may select another line for modification or return to the Main Menu by pressing either the F1 or Esc keys.

14.5.0 Deleting Survey Lines.

To delete records from the LINEFILE position the highlight bar over the "Delete Survey Line" option using the arrow keys and press return. The selection type window (similar to "Select..." and "Change..." windows) will open. To delete a line position the highlight bar over the desired line and press return. The line will then be deleted and the LINEFILE updated. The user may then delete more lines or return to the main menu by pressing either the F1 or Esc keys.

14.6.0 Selecting the Navigation Sensor.

The current navigation sensor can be selected by positioning the highlight bar over the selection "Navigation Sensor" using the arrow keys and pressing return. A window containing all of the possible navigation sensors will open. Select the desired sensor by positioning the highlight bar over that sensor and pressing return. The window will close and control will be returned to the Main Menu. The status window at the bottom of the Menu screen will reflect the navigation sensor selection.

RHORHO System Commands

auto time on/off	Enable/Disable automatic system time updates by NS7000
calibrate on/off	Begin/End the GPS calibration.
Calibrate on	Begin the GPS calibration & print.
change diskette	Replace diskette in drive A. This should be done when disk space is less than 5000 bytes.
clear	Clear the video screen & redraw
cycle on/off	Enable automatic cycle slip compensation by RHORHO system.
ep on/off	Print estimated position as computed MNS2000 NNSS receiver.
F1 (function key)	Toggle between text & graphics displays
F2 (function key)	Toggle between current display and System Menu.
F5 (function key)	Clear the Graphics Display.
F6 (function key)	Scale Graphics Display Up 500m.
F7 (function key)	Scale Graphics Display Down.
F8 (function key)	Mark Current Position.
fix #	Set # seconds between rhorho fix computations

help	Display this list.
init	Initialize all biases and reference position.
print nav #	Set # minutes between navigation printouts.
quit	End the RHORHO program and return to DOS.
refresh #	Set # seconds between graphics refresh.
set bias	Manually set station biases
slaves <x y>	Select a pair of slaves.

Advanced System Commands

debug	Print debugging information.
set filter <on/off>	Set range filters on or off.
system <DOS command>	Execute a DOS command without leaving RHORHO system.