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"OPERATIONAL EVALUATION OF THE AN/BRN-7 OMEGA RECEIVER IN SUBMARINES"

OPTEVFOR

Meritum Probatur

FINAL REPORT ON PROJECT 0/S170
PREPARED AND SUBMITTED BY
COMMANDER OPERATIONAL TEST AND EVALUATION FORCE

DEPARTMENT OF THE NAVY
Commander Operational Test and Evaluation Force
Norfolk, Virginia 23511

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3930 (O/S170)
Ser 460
2 June 1972

From: Commander Operational Test and Evaluation Force
To: Chief of Naval Operations

Subj: Final Report on Project O/S170, "Operational Evaluation of the AN/ARN-99 OMEGA Receiver in Submarines"; submission of

Ref: (a) CNO ltr ser 4036P982 of 7 May 1971 (NOTAL)
(b) COMOPTEVFOR 042345Z FEB 72 (NOTAL)
(c) COMOPTEVFOR ltr ser 454 of 1 June 1972

1. The final report on Project O/S170, entitled "Operational Evaluation of the AN/ARN-99 OMEGA Receiver in Submarines"; is forwarded.

2. By reference (a), the Chief of Naval Operations assigned Project O/S170 to COMOPTEVFOR for prosecution. A Preliminary Report on this project was submitted by reference (b). The AN/ARN-99 has been redesignated the AN/BRN-7 for use in submarines.

3. Extracts from this report, together with a request for termination of this project were forwarded by reference (c). Unless otherwise directed, this report is considered to terminate the prosecution of this project.

4. Commands and agencies within the Department of Defense desiring copies of this report should submit their request to the Defense Documentation Center, Cameron Station, Alexandria, Virginia 22314.

M. D. CARMODY

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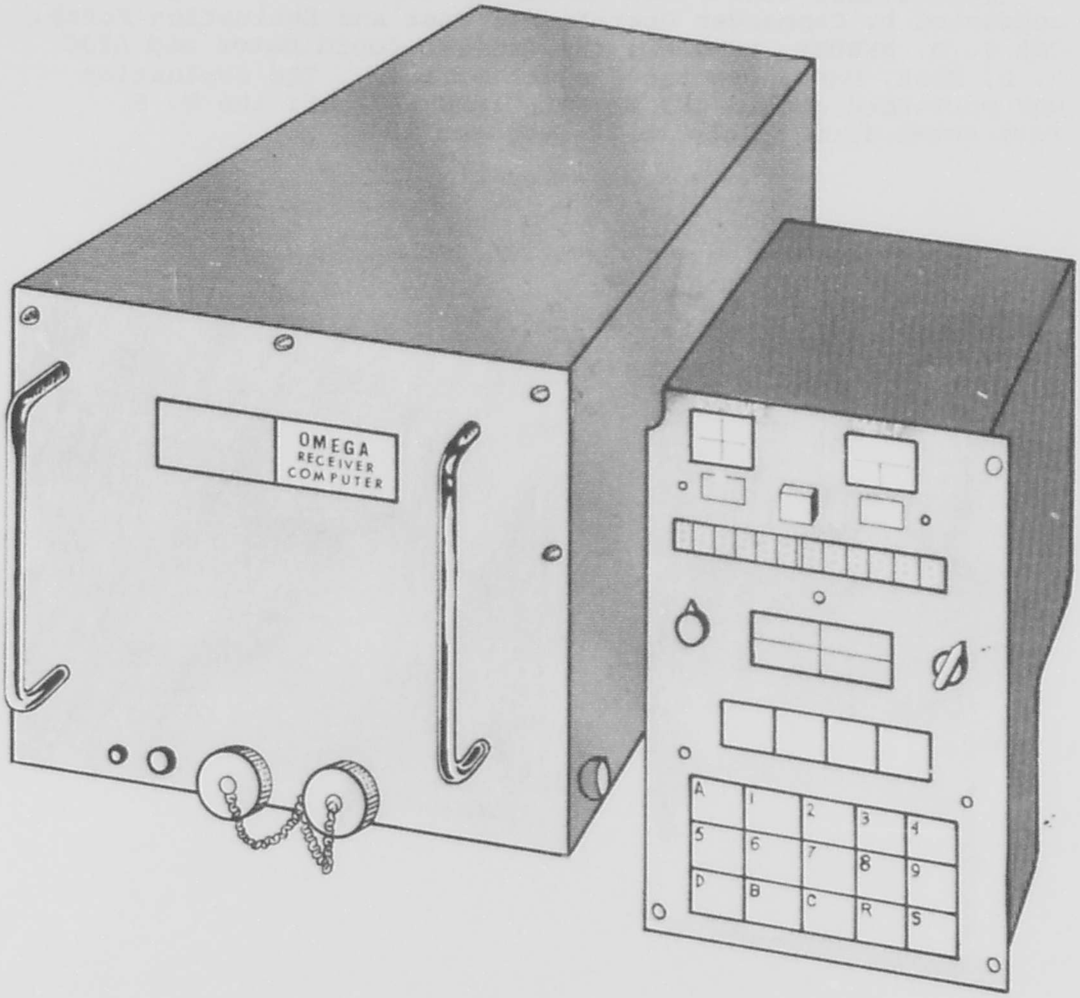
ABSTRACT



The AN/BRN-7 OMEGA Navigation Set was designed for aircraft and modified for submarine use. This receiver is primarily designed to supply the submarine with instantaneous navigation information within 1-2nm when operating in the OMEGA signal environment. Additionally, the BRN-7 provides a dead reckoning capability when no OMEGA signals are received or during submerged submarine operations.

This project was conducted to evaluate the AN/BRN-7 OMEGA Navigation Set in a submarine operational environment in order to determine its suitability for service use. It was found that the accuracy and reliability of the AN/BRN-7 are within the operational criteria required for submarines.

Operational tests were under the supervision of and were conducted by Commander Operational Test and Evaluation Force. CDR J. D. HENDRY, USN, was the Project Coordinator and LTJG R. D. ROSE, USNR, was the Project Officer. The evaluation was performed aboard USS BERGALL (SSN 667) off the U. S. East Coast from 7 July to 10 December 1971.

List of Acronyms, Abbreviations and Definitions

Ao	Operational Availability
BITE	Built In Test Equipment
CEP	Circular Error Probable
DR	Dead Reckoning
DRAI	Dead Reckoning Analyzer Indicator
LOP	Line Of Position
NCTR	"Number Count" - the number of OMEGA navigational inputs to the receiver from each frequency and each station
PM	Planned Maintenance
RDVU	Rendezvous
SID	Sudden Ionosphere Disturbances
SINS	Shipboard Inertial Navigation System
SYNC	Synchronization

List of References

(a) NAVELECSYSCOM Memo Ser 74-0465221 of 1 Feb 1972; "Redesignation of AN/ARN-99 (XN-1) as Receiving Set, OMEGA, AN/BRN-7 (XN-1)".

(b) COMOPTEVFOR ltr ser 569 of 23 May 1967; First Partial Report on Project O/C2, "Conduct Operational Evaluation of OMEGA Navigation Receivers AN/ARN-88 (XN-1), AN/SRN-12 (XN-1) and AN/WRN-3 (XN-1)". (AN/SRN-12 OPEVAL only)

(c) COMOPTEVFOR ltr ser 480 of 21 May 1968; Second Partial Report on Project O/C2, "Conduct an Operational Evaluation of OMEGA Navigation Receiver AN/ARN-88 (XN-1), AN/SRN-12 (XN-1) and AN/WRN-3 (XN-1)". (AN/WRN-3 OPEVAL only)

(d) USAF Report of 10 February 1971; "OMEGA Feasibility Flight Test RC-135C Final Report" (U), by Major Carl A. LEAVER.

(e) Canadian Marconi Company, Montreal, Canada; "Design and Performance of CMA Computerized Airborne OMEGA Receiver".

(f) Naval Air Test Center, Technical Report NO. WST-25R-71 of 22 March 1971; "Final Report Technical Evaluation of Advanced Development Model of Airborne OMEGA Navigation Set AN/ARN-99 (XN-1)".

(g) CNO ltr ser 4036P982 of 7 May 1971; "Operational Evaluation of the AN/ARN-99 OMEGA Navigation Set in Submarines".

(h) COMOPTEVFOR Confidential msg 0423452 Feb 1972; "Preliminary Report O/S170, Evaluation of the AN/ARN-99 (XN-1) OMEGA receiver in Submarines" (NOTAL).

(i) NAVELECSYSCOM ltr ser 547-0571 of 25 June 1971; "Maintenance Concept for OPEVAL of the AN/ARN-99 OMEGA Receiver".

(j) NAVAL OCEANOGRAPHIC OFFICE, msg 061933Z Mar 1972; "Information for Ships with OMEGA Navigation Equipment" (NOTAL).

Section 1

Purpose of the Project

101. Purpose. The purpose of this project was to conduct shipboard testing of the AN/ARN-99 (XN-1) OMEGA Navigational Receiver, to determine its suitability for service use in the submarine environment. The AN/ARN-99 was redesignated the AN/BRN-7 by reference (a).

102. Limitation of Scope. The BRN-7 evaluated during this project was a prototype model designed for use as an airborne navigation receiver. Table 1-1 indicates the eight OMEGA stations (A thru D are in operation, E. thru H are planned) required for worldwide navigational coverage. Stations transmit consecutive OMEGA signals on 10.3, 11.33, and 13.6 KHz. Figure 1-1 shows the OMEGA transmission format for all eight stations. All of the four stations operating during this evaluation were limited to the indicated present power output. Reception of at least three OMEGA stations is required by the BRN-7 for accurate navigation, thereby limiting the BRN-7's area of operation. The purpose of this evaluation did not include the following:

a. A complete investigation of the OMEGA area coverage for submarines.

b. Investigation of unpredictable VLF (Very Low Frequency) propagation effects that can degrade OMEGA navigational accuracy. These as identified in OMEGA literature, are SIDs (Sudden Ionosphere Disturbances) or other anomalous propagation phenomena (transition effect, thunderstorms, and others). SID's, occuring as often as once a month, can induce OMEGA propagation error, while the other propagation phenomena occur at random and usually cause less error effects.

103. Tests Performed. This project was divided into the following general areas: Navigational Accuracy, Operational Uses, Materiel Suitability and Human Factors.

Tests 0-1 and 0-3B, (Navigational accuracy) To determine the absolute accuracy of the BRN-7 receiver in port and at sea for both surfaced and submerged operations. Determine the relative accuracy for two OMEGA receivers.

Table 1-1

OMEGA Station Status

LOCATION	DESIGNATION	ANTENNA TYPE	PRESENT POWER	FULL POWER DATE (ESTIMATED)
NORWAY (ALDRA)*	A	VALLEY SPAN	1.25 KW	10 KW NOVEMBER 73
TRINIDAD	B	VALLEY SPAN	900 WATTS	10 KW NOVEMBER 73
HAWAII (HAIKU)	C	VALLEY SPAN	1.95 KW	10 KW DECEMBER 72
NEW YORK (FOREST PORT)	D	TOWER	250 WATTS	TO BE DECOMMISSIONED
NORTH DAKOTA (LAMOUR)	D	TOWER		10 KW MAY 72
LA REUNION ISLAND	E	TOWER		10 KW MARCH 74
ARGENTINA (PORTO MADRYN)	F	TOWER		10 KW SPRING 73
AUSTRALIA	G	TOWER		10 KW FALL 74
JAPAN (TSUSHIMA ISLAND)	H	VALLEY SPAN		10 KW DECEMBER 73

*NORWAY NOT PRESENTLY TRANSMITTING ON 11.3 kHz

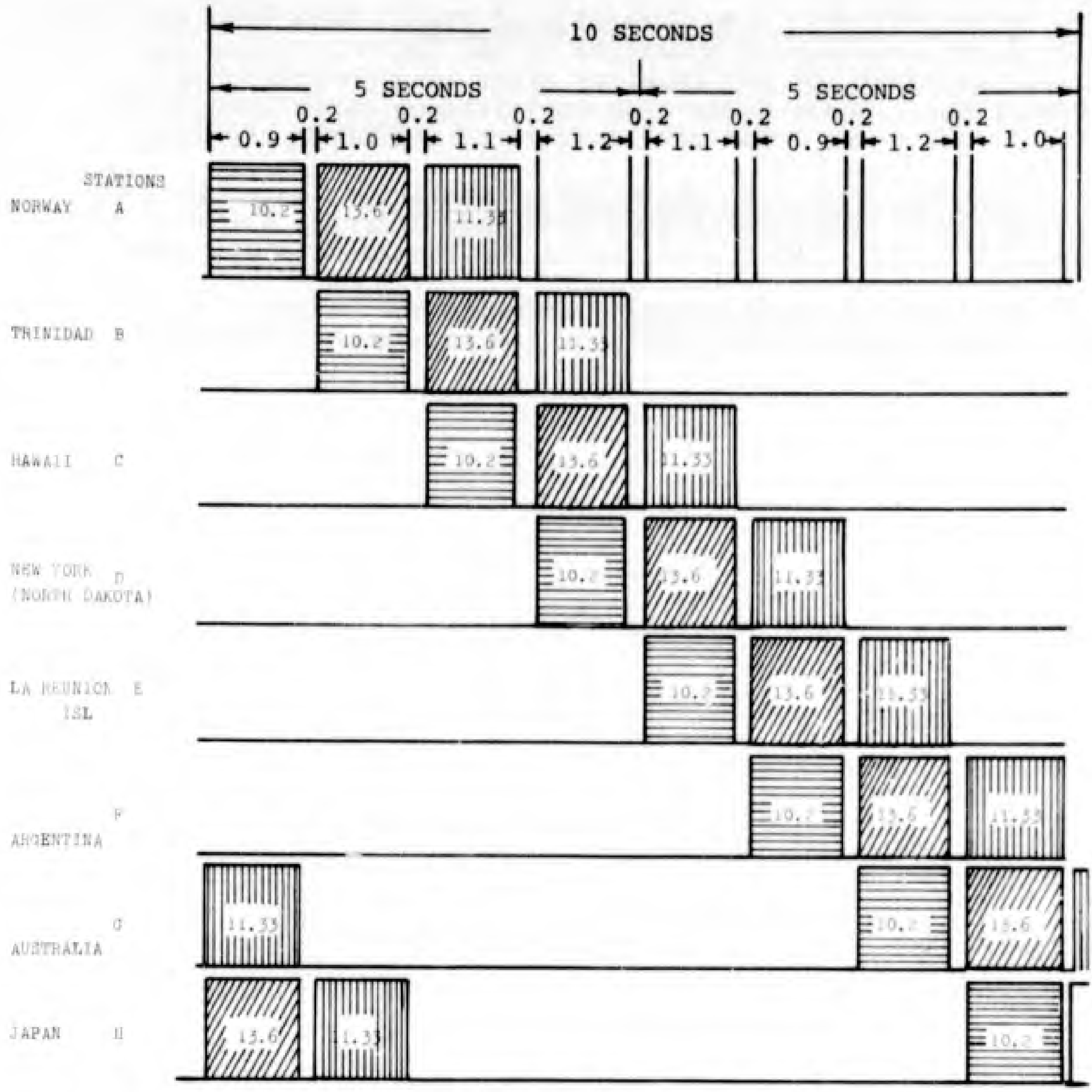


Figure 1-1

OME^A Transmission Format

Test O-2, O-4, O-5, (Operational Uses) Determine the speed and depth envelope of operation of the BRN-7. Insure the update capability of the receiver after long periods of DR operations. Investigate area surveillance capability using the "Ten Pre-set Positions" feature of the OMEGA receiver.

Test M-1 thru M-6, (Materiel Suitability) Determine the Reliability, Maintainability, and other Materiel Suitability factors for the BRN-7 receiver in the submarine environment.

Test H-1 (Human Factors) Determine the compatibilty of the OMEGA receiver with operator and maintenance personnel.

Section 2

Description of Materiel

201. General. The worldwide OMEGA Navigation System will consist of eight OMEGA stations operating in the VLF portion of the frequency spectrum. This OMEGA system, developed in response to Specific Operational Requirement 34-01, is a hyperbolic radio navigation system, similar to Loran. Navigational fixes are established by intersecting local hyperbolic LOP's (lines of position) derived from measurements of the phase difference between the signals received from several OMEGA stations. The BRN-7 selects one station as a master OMEGA station (based on relative signal strength), and determines LOP's between that master station and any other OMEGA station that can be received in that area. A minimum of two LOP's from three OMEGA stations are required to define an OMEGA position. LOP fixes are corrected for predictable propagation effects by the OMEGA computer, then converted to latitude/longitude coordinates and displayed on the OMEGA Control-Indicator panel.

202. Description of Equipment. The BRN-7 consists of the Submarine Interface Box, Receiver-Computer, and Control-Indicator. A block diagram is shown in figure 2-1. OMEGA signals are received by the submarine on either the floating wire or loop antennas and supplied to the OMEGA antenna coupler via the ship's CU-1441/BRR Antenna Coupler. The OMEGA antenna coupler conditions the incoming OMEGA signals for the Receiver-Computer input circuit. The receiver strip in the Receiver-Computer must be capable of maintaining phase stability over a wide range of signal levels. This allows received signals to be processed in the BRN-7 computer to obtain sine and cosine phase data. Phase data is converted into digital form for SYNC (synchronization) with a known OMEGA transmission format (used to stabilize the reference oscillator) in the Receiver-Computer. Circuitry within the computer section will then process this information along with current ship's velocity and heading data and preprogrammed navigational data to compute present position. After completing the computation, the result is supplied to the OMEGA Control-Indicator unit. This unit contains circuits which process the computer outputs and enable the computed navigational data to be displayed on the front panel. This display information, including latitude and longitude, appears on 12 alpha-numeric light indicators located just below the Panel Test button shown in

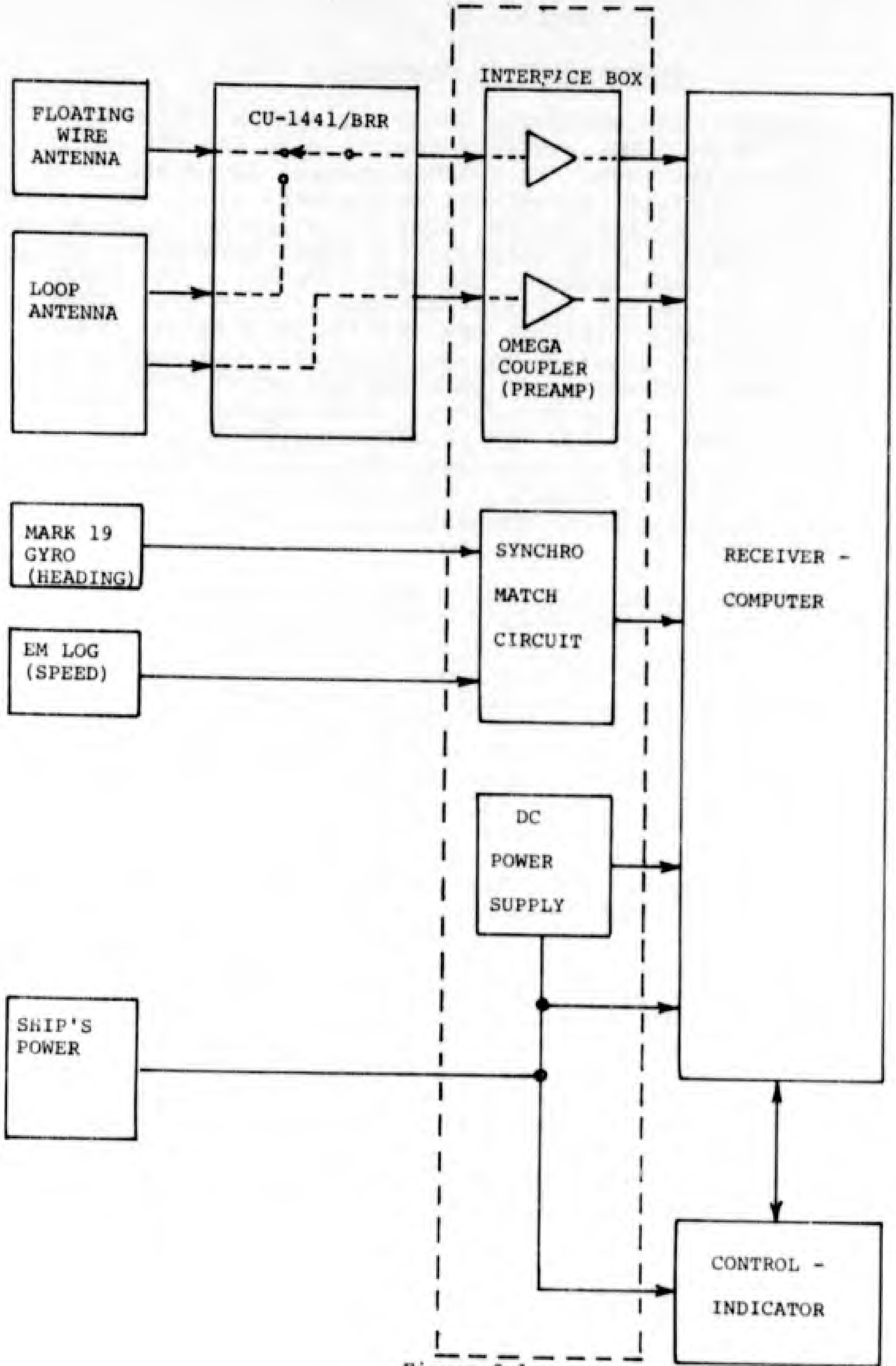


Figure 2-1

AN/BRN-7(XN-1) Block Diagram

Figure 2-3. The BRN-7 up-dates the displays at a maximum rate of once per second. The operator can insert up-dated information to alter the preprogrammed plan through the Control-Indicator panel. The physical characteristics of the equipment are listed in Table 2-1.

a. OMEGA Submarine Interface Box. Enclosed in the OMEGA Submarine Interface Box is an OMEGA loop antenna coupler, 28 VDC power supply, synchro matching circuitry (for ship's heading and speed inputs), and various terminal boards and fuses.

(1) Orthogonal Loop Antenna Coupler. The Orthogonal Loop Antenna Coupler as part of the BRN-7 set provides a means of coupling the received OMEGA signals from the floating wire or orthogonal loop antenna via the ship's CU-1441 Antenna Coupler to the Receiver-Computer. The orthogonal loop antenna coupler contains preamplifier and filter circuits that adjust signal level and quality to a value compatible with the Receiver-Computer.

(2) 28VDC Power Supply. This power supply provides +28 volts to the precision oscillator oven heaters and to panel lights on the Control-Indicator unit.

(3) Synchro Matching Circuitry. This synchro circuitry consists of a step-down transformer which reduces Mark 19 Gyrocompass heading input (115 volts, 400 Hz) to a value (26 volt, 400 Hz) compatible with the BRN-7 Receiver-Computer.

b. OMEGA Receiver-Computer. The Receiver-Computer consists of 13 modules and is divided into three sections: receiver, computer, and power supply.

(1) Receiver Section. The receiver section amplifies, filters, correlates (i.e., extracts sine and cosine phase information) and converts the received OMEGA signals to digital form for the computer. The receiver also contains an antenna switching matrix that automatically selects the best loop, or combination of loops of the orthogonal loop antenna to be used in a particular situation.

(2) Computer Section. The computer is a general purpose, internally programmed, single-address, fixed-point fractional binary machine. It uses a non-volatile destructive readout, random-access, magnetic core memory. A complete read and restore memory cycle operation requires 2 microseconds

Table 2-1

Physical Characteristics of the BRN-7

OMEGA Navigation Set BRN-7	Dimensions (inches)			Weight (lbs.)
	Length	Width	Height	
Submarine Interface Box	8.2	7.4	7.5	5
OMEGA Receiver-Computer	22.0	10.1	7.6	50
OMEGA Control-Indicator	7.0	5.75	9.0	8

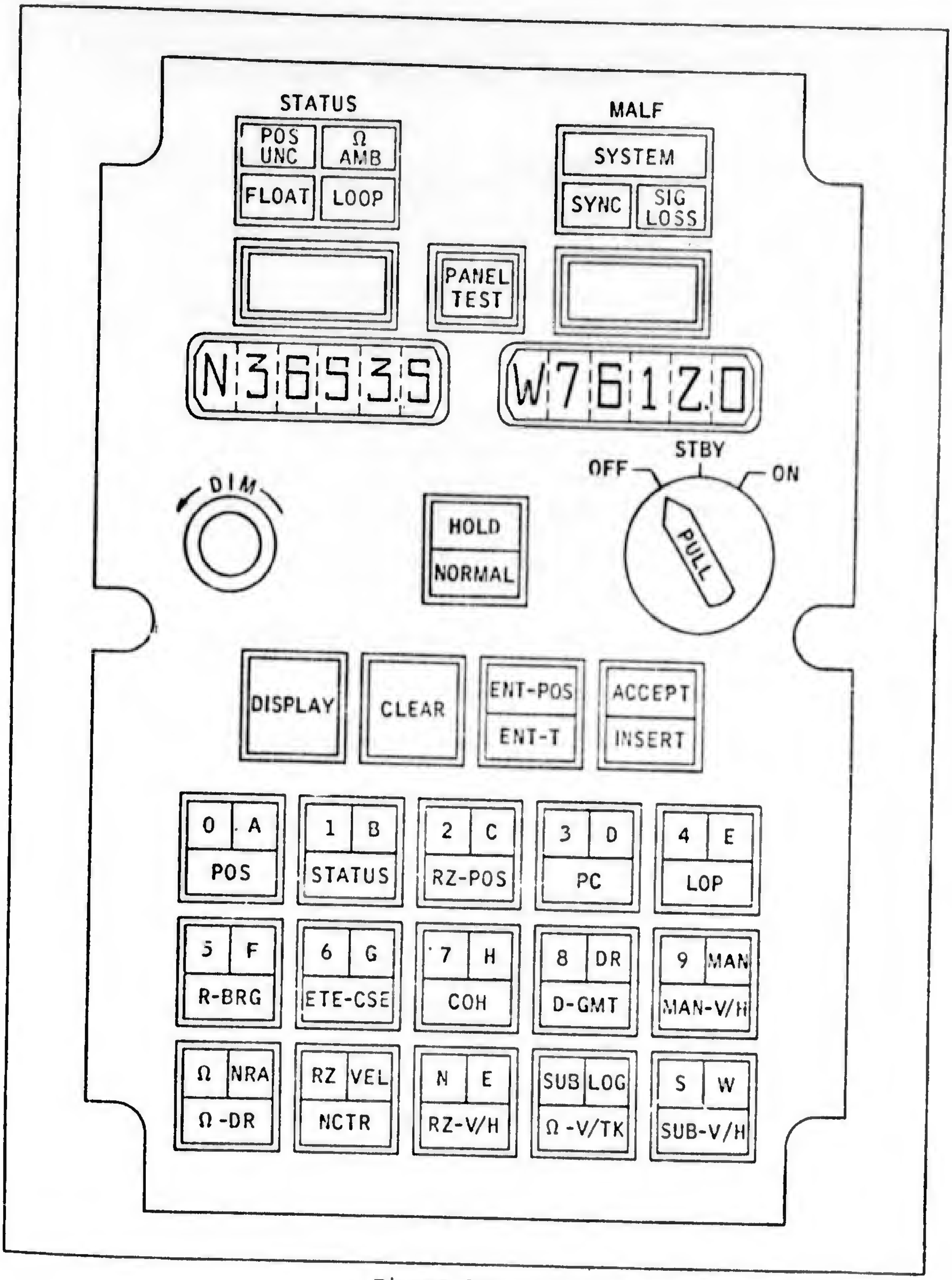


Figure 2-2

BRN-7 Control-Indicator Panel

to complete. Extensive use of multifunctional microelectronic arrays as the basic circuit building blocks provide a significant reduction in size, weight, and power requirements over previous systems.

(3) Power Supply Section. The Power Supply converts the ship's primary AC power to regulated DC, and provides protection from voltage variations and overloads. The power supply utilizes 115v RMS, 400 Hz, single phase power and must withstand voltage variations within the limits set by MIL-STD704A, Category E. The power supply also provides logic signals to the computer for orderly turn-on and turn-off sequences to prevent memory loss. The average input power is approximately 200 watts.

c. Control-Indicator. The BRN-7 computer is controlled by the operator through the Control-Indicator. The Control-Indicator is of modular design and places a maximum of dependence on the computer, not only to reduce the requirements for switches and displays, but to simplify the operating procedures. Indicator outputs can be modified at any time by entering new computer software program changes.

d. Memory Augmentor Unit. The Memory Augmentor Unit is a maintenance test box which can be connected to two adaptor plugs on the Receiver-Computer face. This unit has 13 functional switch test positions and 8 voltage test terminals. Checks can be performed on each Receiver-Computer module unit, part of the Control-Indicator Unit and the sychro matching transformer in the OMEGA Interface Box. The augmentor unit is supplemented by BITE (Built In Test Equipment) which is activated when the BRN-7 is turned ON and performs checks to see if the computer is sequencing through the program properly. If the computer fails the BITE test, a Power Malfunction Indicator on the Receiver-Computer is activated. Correct computer sequencing is also checked when the set is on by activating the Control-Indicator Panel Test switch. During this test all Control-Indicator panel lights are energized to check for failed lights.

e. ECCM. The Kalman Statistical Filter accepts various external data and makes corrections to the system "state" giving the BRN-7 computer the capability for real-time onboard error analysis. This technique of error analysis is used to refine the displayed information of the BRN-7. In an ECCM environment the Kalman Filter will reject signals that are being jammed. If jamming is sufficient to preclude

OMEGA signal update, the receiver is designed to continue in a DR mode of operation.

204. Equipment Availability. The BRN-7 receiver used for this OPEVAL is a prototype produced for the Navy by Northrop Corporation, Hawthorne, California. The estimated cost for a production set is $40,000 to $45,000.

Section 3

Previously Known Data

301. Previous Work. A series of VLF propagation studies, conducted by the Naval Research Laboratory during the period 1955-1957, indicated that dual frequency CW phase measurement in the 10-14KHz band was theoretically feasible. These studies led to the initiation of the OMEGA Navigation System development program in 1958. Technical tests conducted during the next year using VLF transmitters and laboratory model receivers verified the predictability of phase propagation values and established the validity of the techniques for navigation purposes. By 1961, technical testing by NELC (Naval Electronics Laboratory Center) and NRL (Naval Research Laboratory) demonstrated OMEGA airborne reception at ranges of up to 6,300 miles, shipboard fix accuracies of 0.7 miles, and submerged submarine VLF reception at antenna depths of 24 feet. In 1961-1962, using experimental transmitters and laboratory model receivers, the OMEGA Navigation System was evaluated under CNO Project C/S21. The results of this evaluation indicated that OMEGA provided a practical means of navigation for ships, aircraft and submarines. Several OMEGA navigation receivers were then developed and evaluated as different OMEGA transmitting stations became operational.

302. Previous Evaluations. Shipboard AN/SRN-12 OMEGA receivers were evaluated in CNO Project O/C2. Reference (b) reported navigational accuracies of 1 to 2nm and relative accuracies of approximately 0.3nm, meeting the design requirements of the system for surface ships. The submarine AN/WRN-3 OMEGA navigation receiver (later designated AN/BRN-4) was evaluated in 1968. Reference (c) recommended that design problems be corrected and the equipment undergo another OPEVAL. However, due to the many materiel problems encountered with this receiver the project was terminated. Several tests and evaluations of OMEGA airborne receivers have been conducted as indicated below:

a. OMEGA feasibility flight tests were conducted by the USAF as reported in reference (d). In many areas of the Northern Hemisphere OMEGA accuracies were investigated using the Mark III and AN/ARN-99 (XN-1) OMEGA receivers in comparison tests. The reported average accuracy was 2.49nm day and 2.66nm night. Areas with better known propagation prediction plus good station geometry gave accuracies of 0.9 to 1.4nm.

b. Reference (e) reported OMEGA navigational accuracies using the CMA-719 OMEGA Computer Receiver were on the order of 0.5 to 1nm in the Alaska and Norway areas.

303. ARN-99 Evaluations. Technical Evaluation of the ARN-99 (XN-1) OMEGA Receiver in P-3 aircraft was conducted by NATC in July-August 1970. Reference (f) reported OMEGA navigational accuracy within 2.0nm can be achieved in a favorable signal environment. An OPEVAL (O/V91) of the ARN-99 (XN-2) OMEGA Receiver began in Jan 1971. Further development and testing is now required before the project can be completed. NAVELECSYSCOM installed and tested the ARN-99 (XN-1) OMEGA receiver in the USS BERGALL (SSN 667) in the spring of 1971. No technical report was published on this installation or testing.

Section 4

Conduct of Tests, Results, and Discussions

401. General Approach

a. The OPEVAL of the BRN-7 OMEGA receiver was assigned to COMOPTEVFOR in May 1971. Actual testing commenced in July 1971 aboard BERGALL and project operations were completed in December 1971.

b. Due to ship schedule restraints imposed by other higher priority projects, Test 0-3A (OMEGA Sub to Ship Rendezvous) was not conducted. However, relative OMEGA data (aircraft to submarine) was obtained and is reported as part of this project.

402. Acceptance Criteria. The acceptance criteria established by reference (g) for the BRN-7 OMEGA Receiver are:

a. Operational Criteria. Achieve a daytime navigational accuracy of 1nm RMS and night time accuracy of 2nm RMS when compared to absolute positioning. Relative accuracy when comparing two OMEGA equipped units should be 0.25 to 0.5nm RMS.

b. Materiel Suitability Criteria.

(1) MTBF (Mean-Time-Between-Failure) of 1000 hrs with a 90% confidence level.

(2) MTFL (Mean-Time-To Fault-Locate) of 10 minutes.

(3) MTTR (Mean-Time-To-Repair) of 30 minutes.

(4) A_o (Operation Availability) of 0.98.

c. General. Other specifications were considered as criteria for the BRN-7 Receiver.

(1) When operating in good OMEGA coverage areas the receiver must be capable of providing a usable fix in less than 10 minutes after a period of up to 30 hours without signals, aided only by a DR position that is known only within 35 miles accuracy.

(2) The receiver must function in such a manner that constant operator attention is not required while exposed to signals.

(3) Minimum effort should be required to obtain a latitude/longitude position.

(4) The BRN-7 receiver must be compatible with the orthogonal loop and floating wire antennas using the CU-1441 multicoupler.

403. Chronological History of Events.

Sep 1970 - Oct 1970	Preliminary installation and check-out of the BRN-7 aboard BERGALL at New London, Conn.
Nov 1970	BRN-7 removed for modifications.
Jan 1971	Equipment re-installed and checked.
May 1971	Equipment modified with Interface Box by NAVELEX.
Jun 1971	Technical tests conducted in BERGALL by NAVELEX (no report published).
7 Jul 1971	BRN-7 certified ready for OPEVAL by NAVELEX.
7 Jul 1971	OPEVAL commenced.
7 Jul 1971 - 23 Jul 1971	Test 0-4, OMEGA DR Test, conducted.
Aug 1971	BERGALL in port. No equipment Operations during this period.
7 Sep 1971 - 9 Sep 1971	Test 0-4 OMEGA DR, and 0-5, Area Surveillance conducted aboard BERGALL.
21 Sep 1971 - 22 Sep 1971	Operational Test 0-1A, In port Accuracy Test was conducted.
23 Sep 1971 - 25 Sep 1971	Conducted operational Tests 0-4, OMEGA DR, 0-5, Area Surveillance, 0-2, Speed and Depth Test, and 0-1B, At-Sea Accuracy Test.

28 Sep 1971 - - - - - - - BERGALL conducted operational Test 0-3B Air to Ship OMEGA Rendezvous, with OMEGA equipped P-3 of AIRTEVRON ONE.

30 Sep 1971 - - - - - - - BERGALL conducted operational Test 0-1A, Inport Accuracy Test.

10 Dec 1971 - - - - - - - Project operations complete.

404. Test 0-1A, Inport Accuracy

a. Test Objective. The objective of this test was to establish the inport accuracy of the BRN-7.

b. Description of Test. While operating on normal ship's power dockside, OMEGA and SINS (Ship Inertial Navigation System) positions were recorded in two different geographic locations. OMEGA receiver update rates from each of the four operating stations were recorded for both inport locations. Actual inport positions were determined from current additions of Naval Oceanographic Charts CS456 and CS546.

c. Data Analysis. The OMEGA mean and RMS position error from dockside position were determined for both geographic locations. Data analysis included computing the accuracy values for day versus night OMEGA positions to determine any difference in navigational accuracy. One-sigma probability contour ellipse plots (showing OMEGA major and minor axis shift) are shown for both locations. The inport static drift rate of SINS was found to be almost non-existant and therefore was not analyzed as part of the test results.

d. Results and Discussion. The following OMEGA inport accuracy figures were obtained:

(1) The RMS error from actual position was 0.83nm (sample size 51). There was no significant difference in RMS error for Fort Lauderdale and Cape Kennedy and the data were combined to obtain the overall inport RMS error.

(2) The RMS error referenced to the true position was 0.75nm for daytime and 0.94nm for night observations. At 0.05 significance level there was a significant difference in the CEP and mean bias values between day and night.

Since 100 percent of the data had errors less than two miles and 73 percent of the data had errors less than one mile, the data was grouped for presentation as being operationally representative.

(3) The mean error bias referenced to actual position was 0.68nm in the direction of true North. The mean error bias was the same for both Fort Lauderdale and Cape Kennedy. Figure 4-1 shows the Latitude and Longitude Error Distribution versus Frequency of Repetition for the combined inport data.

(4) The CEP about the mean was .37nm. The CEP's for Fort Lauderdale and Cape Kennedy were found to be not significantly different and the data were combined to obtain the overall inport CEP. Figure 4-2 and 4-3 show the one-sigma constant probability ellipse for Cape Kennedy and Fort Lauderdale. These are presented to demonstrate the elliptical nature of the error distribution which can occur as a function of station strength. This phenomenon can be explained as follows: as one of the OMEGA Stations being utilized for navigational information decreases in strength relative to the other stations, the variance of the weak station LOP, along the stronger LOP, will increase. This increase in variance causes the elliptical distribution of error. The angular displacement of this ellipse approximately parallels the actual LOPs.

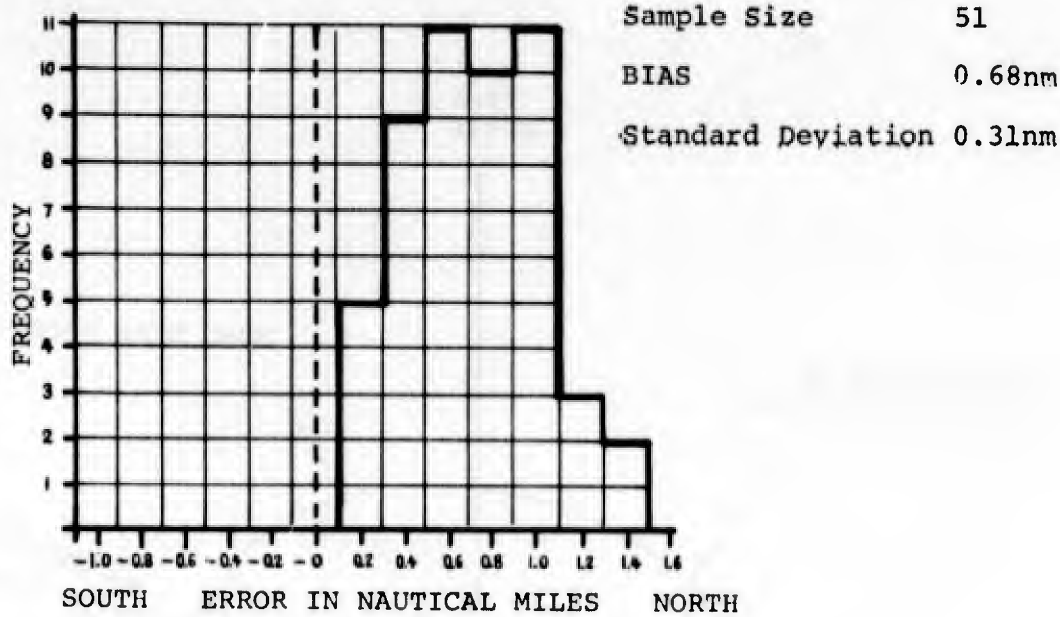
405. Test 0-1B, Accuracy Test At-Sea

a. Test Objective. The objective of this test was to establish the at-sea accuracy of the BRN-7 for surfaced, periscope depth and submerged operations.

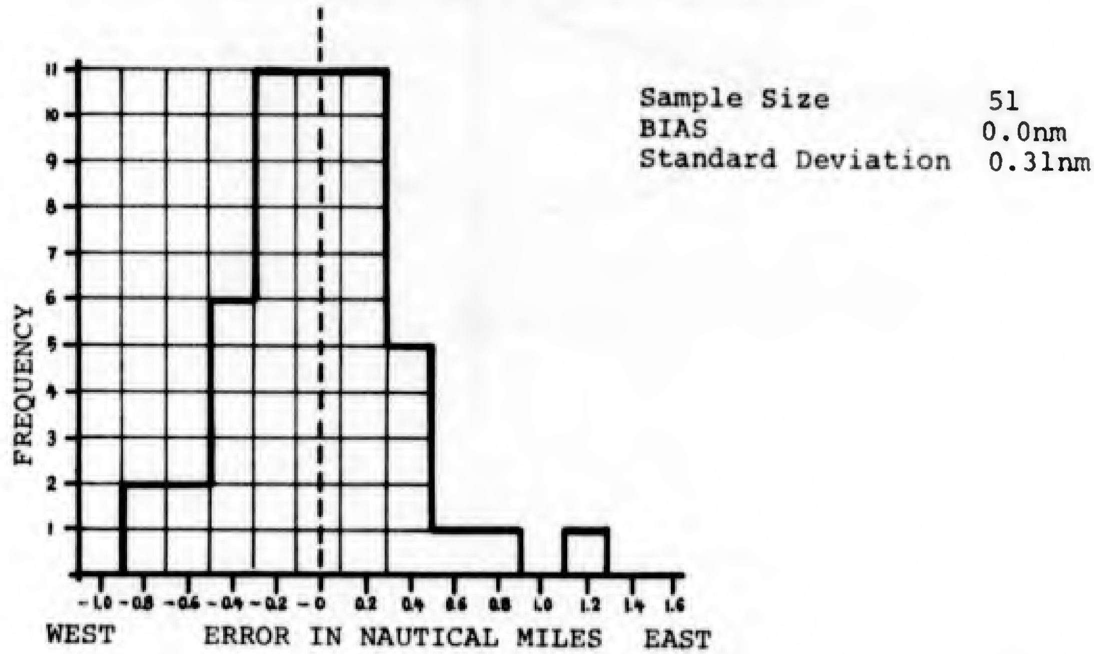
b. Description of Test

(1) OMEGA positions (latitude/longitude) and NCTR update rate were recorded while a precise underwater tracking plot (accuracy about 20 meters) was made of BERGALL on an AUTEC range. During the tracking period OMEGA position and NCTR data for both the VLF loop and RG-374 Floating Wire Antenna were obtained. Two 180 degree turns were made to observe any directional effects of the antennas.

(2) In addition, for two months, BERGALL recorded OMEGA positions concurrently with other shipboard navigation equipment (SRN-9, SINS, visual sightings) during transits along the eastern seaboard and operations off the south-eastern Florida coast.



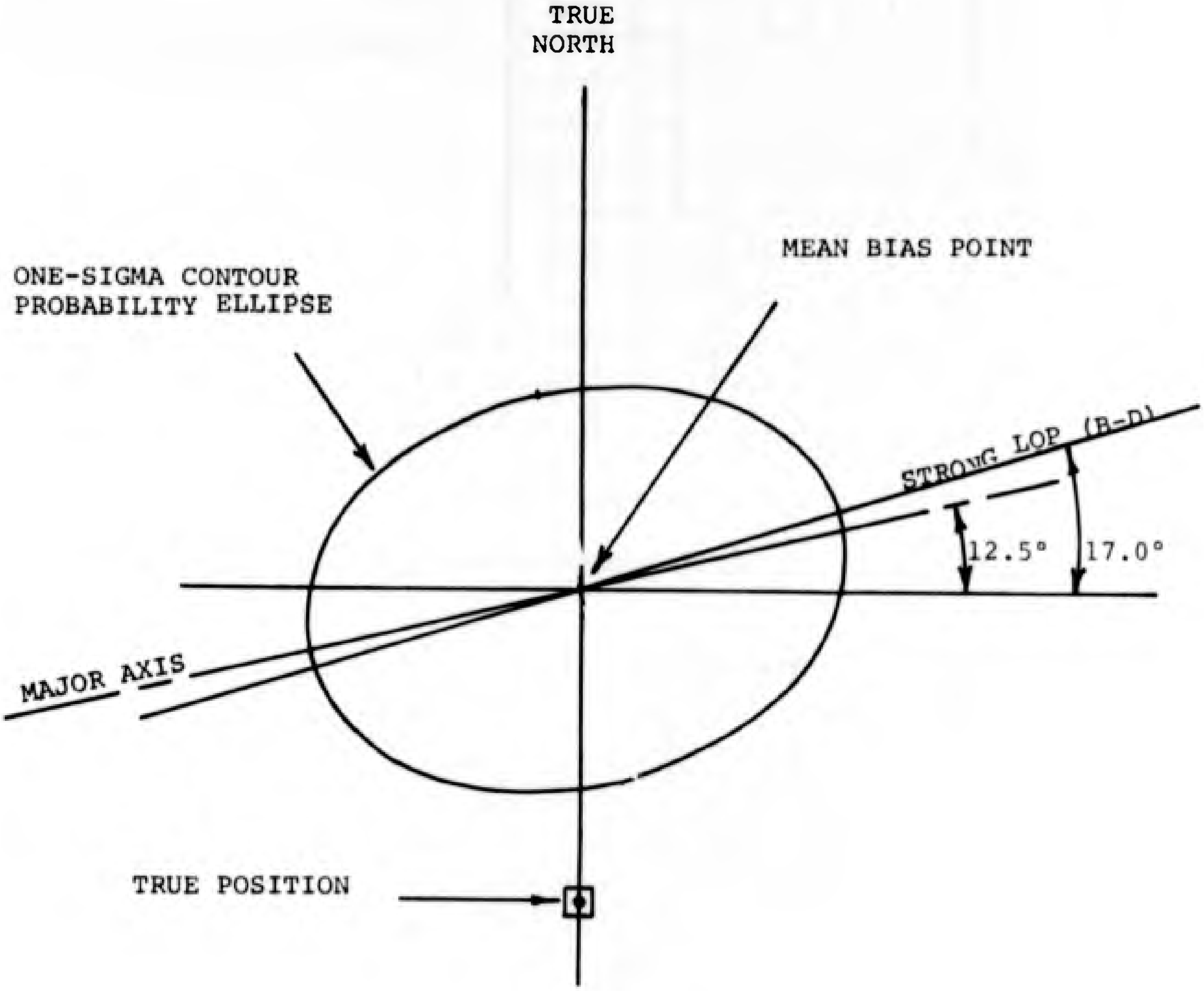
DISTRIBUTION OF LATITUDE ERRORS FOR INPORT DATA



DISTRIBUTION OF LONGITUDE ERRORS FOR INPORT DATA

Figure 4-1

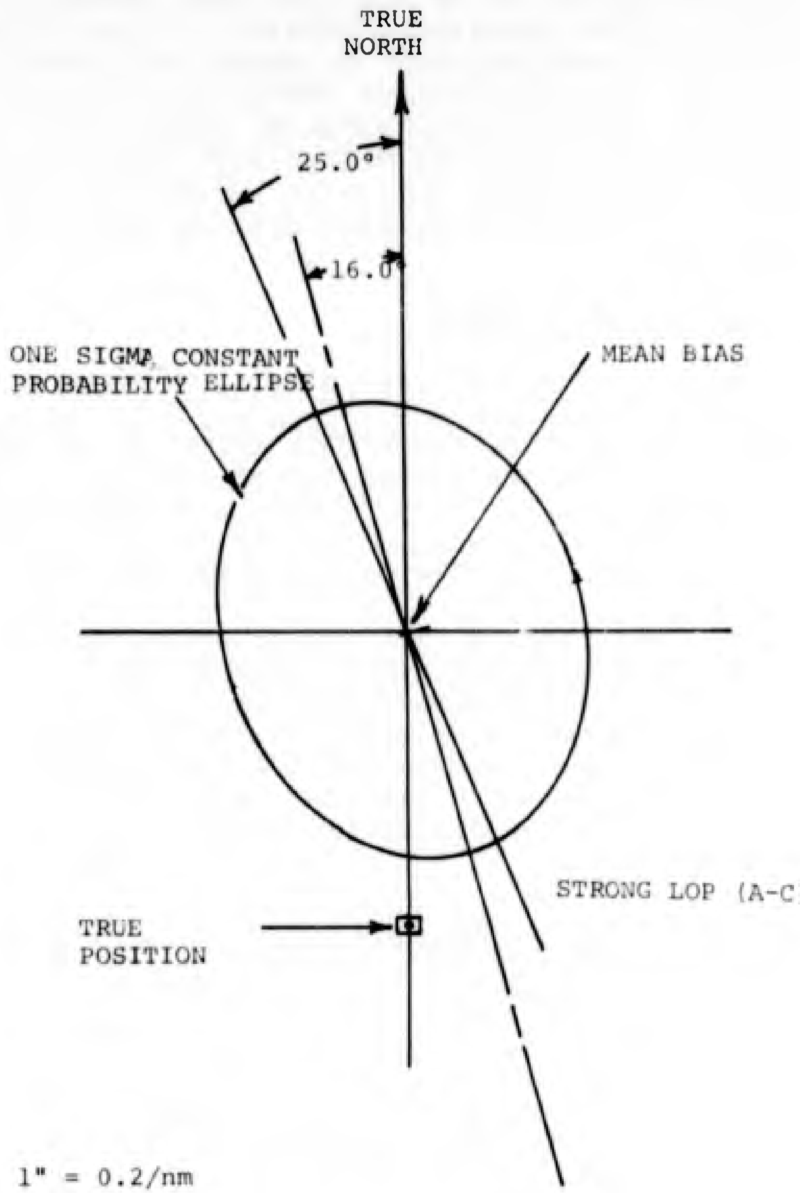
Distribution of OMEGA Errors For Inport Data
Cape Kennedy and Ft. Lauderdale



SCALE: 1" = 0.2 nm

Figure 4-2

Probability Ellipse for Inport Data at Cape Kennedy



Scale: 1" = 0.2/nm

Figure 4-3

Probabilty Ellipse for Inport Data

at Ft. Lauderdale

c. Data Analysis. Using the range tracking data plots, RMS, mean and CEP values about the mean were determined and compared with the OMEGA derived positions. These values for both antennas were then compared to assess any differences in antenna accuracy. A comparison of OMEGA update rates, using NCTR numbers, was made for both antenna types during the range test. RMS values were also determined for OMEGA data which used shipboard navigational fixes as a reference. The RMS values for three shipboard reference systems used were analyzed for differences.

d. Results and Discussion

(1) The RMS error referenced to true position (range data) was 0.39nm and the CEP was 0.30nm for the OMEGA at-sea data. No significant differences were noted in the absolute error biases, CEP's, or RMS values for the errors generated by OMEGA coupled to the VLF loop or RG-374 Floating Wire Antenna. There were 10 observations with the VLF Loop and 11 observations with the RG-374 Floating Wire Antenna.

(2) The OMEGA update rate is higher for the VLF loop antenna than for the RG-374 Floating Wire Antenna. Signal reception from weaker stations C and D was the most affected by switching the antennas. It was not possible to record NCTR numbers, used in determining update rates, simultaneously for both antenna. However, to reduce the time difference effect on update rate, two consecutive one hour periods for each antenna were used.

(3) No effect was noted on update rate when making a turn using the VLF loop antenna. However, a decrease in update rate of about 10 percent was noted for all received stations when making a turn with the RG-374 wire antenna.

(4) The RMS values for OMEGA at-sea errors when compared with SINS were less than two nautical miles. During this period the SRN-9 was used to groom, or slowly reduce, the SINS errors allowing a more accurate navigation reference system to be used. Other at-sea comparisons shown in Table 4-1 indicate that SINS was not the most accurate reference.

Table 4-1

OMEGA Errors Using Shipboard References

	SRN-9 NAVSAT	SINS	VISUAL
OMEGA RMS Errors	0.80nm	1.85 nm	0.95nm
Data Sample Size	22	247	13

406. Test 0-2, Speed and Depth Range

a. Test Objective. This test was to determine the maximum submarine speed and depth range at which usable OMEGA navigational information could be obtained.

b. Description of Test. Maximum speed and depth ranges were determined for both the VLF loop and floating wire antenna. Different keel depths and antenna lengths for the floating wire were set and ships speed slowly increased in discrete increments until the OMEGA signals were lost. This procedure was repeated for the loop antenna.

c. Data Analysis. Subjective comparisons were made of the OMEGA and SINS fixes for each signal loss point at both speed and depth extremities.

d. Results and Discussion

(1) With the VLF loop antenna fully raised, a keel depth of 80 feet was found to be the maximum depth for OMEGA signal reception and navigation. At this keel depth the loop antenna was submerged to about 15 feet in low sea states. No decrease in signal strength was observed for increasing speed to near structural limits of the loop antenna.

(2) Using the RG-374 Floating Wire "Speed-Depth Versus Cable Length Guide," it was found that OMEGA signals could be received as long as sufficient length of cable was extended to just reach the surface. The O/S170 Preliminary Report, reference (h), provides the signal loss data points with corresponding antenna lengths, keel depth and ship speed. They are not shown here again due to the required classification. During this test it was readily observed that the

13.6 kHz OMEGA signals were the first of the three OMEGA frequencies to deteriorate in strength. The loss of this signal then caused OMEGA errors to increase and also illuminated the BRN-7 signal loss light.

407. Test 0-3B, OMEGA Aircraft to Ship Rendezvous and Relative Accuracy Test. (Test 0-3A not conducted)

a. Test Objective. This test was conducted to evaluate the Moving RDVU (Rendezvous) feature of the airborne ARN-99 in conducting at-sea RDVU and to obtain relative OMEGA Mark-on-Top accuracy data.

b. Description of Test. To conduct rendezvous, BERGALL's OMEGA position/PIM (Plan of Intended Movement) was inserted into the Moving RDVU feature of the P-3 ARN-99 equipped aircraft. After a 30 minute flight period the intercept solution (range/bearing to RDVU point) was displayed on the airborne OMEGA receiver. This RDVU intercept bearing was then followed to as near zero range point as possible. Seven aircraft to submarine rendezvous were achieved. Upon reaching the RDVU position indicated by the ARN-99, that rendezvous run was considered complete and aircraft heading was adjusted to overfly the submarine to achieve a visual low altitude Mark-on-Top position (latitude and longitude). OMEGA positions were recorded for both the aircraft and submarine at Mark-on-Top and RDVU positions.

c. Data Analysis. Aircraft OMEGA RDVU positions were compared to the submarine OMEGA position and to the SINS positions. RMS radial errors for OMEGA data points were determined.

d. Results and Discussion

(1) Six OMEGA RDVU's were achieved using the airborne ARN-99 feature with a computed RMS radial error of 0.66nm when compared to the submarine OMEGA positions. One of the seven RDVU runs was aborted due to ambiguity indications on the ARN-99 receiver. Based on the shipboard SINS the RMS radial error for the airborne OMEGA receiver was 0.80nm. The submarine OMEGA receiver had an RMS radial error of 0.52nm.

(2) Seven OMEGA relative fixes (aircraft to submarine Mark-on-Top data points) had an RMS radial error value of 0.41nm. Using SINS as a reference the RMS radial error of OMEGA to SINS for the aircraft was 0.80nm and 0.74nm for the submarine.

408. Test 0-4, OMEGA DR Navigation.

a. Test Objectives. The objective of this test was to determine the usefulness of the BRN-7 Dead Reckoning Navigational Mode.

b. Description of Test. By design, OMEGA signals (when available) update the DR position generated by the ship's Mark 19 Gyrocompass and EM log (heading and speed) inputs to the BRN-7. When no OMEGA signals are available this DR function provides the receiver with an OMEGA Lane Tracking capability and usable DR information.

(1) Results of DR navigation runs 1 thru 5 are shown in Table 4-2. These runs were conducted during submerged operations with no OMEGA signal updates. Just prior to signal reception the BRN-7 DR position was recorded. An OMEGA fix was obtained and compared to the DR position. The difference in these two positions is the DR radial error.

(2) In runs 6 thru 26, shown in Table 4-2, large fix errors of about 35nm were manually inserted into the BRN-7. The time required for the BRN-7 to correct its position error was recorded as automatic update time.

Table 4-2

Automatic Update Rate Times

DR Runs	Automatic Update Time Minutes	DR Radial Error NM	NCTR* NCTR MAX X100 A	B	C	D	Total Test Time Hours
1	5	8.5	12	74	67	40	7.2
2	3	3.0	18	42	59	36	3.3
3	4	13.0	33	98	50	50	9.4
4	2	15.0	35	51	74	25	3.5
5	57	8.5	10	42	21	18	7.4
Manually Inserted Error Runs							
6-11	5(AVE)	35.0	14	46	69	32	(AVE)
12-21	7(AVE)	35.0	11	72	51	21	(AVE
22-26	No Update	36.5	12	45	66	34	(AVE)

* NCTR update rate for 10.2KHz shown only.

c. Data Analysis. Position error was then compared with the measured position update time. Update time was defined as the time signals were received by the BRN-7 until all adverse status indicators were extinguished and OMEGA position error was reduced to less than 2nm.

d. Results and Discussion.

(1) The BRN-7 was found to be capable of automatically updating when its DR position error was not greater than 35nm and when operating in good OMEGA signal environments. It was observed that good OMEGA coverage existed when three frequencies from two stations and two frequencies from a third station were updating at least 20 percent of the maximum rate (1 update each 30 seconds) per frequency per station. In light to moderate currents OMEGA DR should maintain a DR position capable of automatically updating the BRN-7 after about a 9 hour period. If DR radial position error is greater than 35nm, manual position updating may be required using a position with less radial position error. Although set and drift can be inserted into the BRN-7 it is slowly decayed to zero. If long periods of known set and drift are encountered, the position used to initialize the receiver should be modified by this set and drift.

(2) Time required for automatic OMEGA updating (time required to resolve OMEGA position) varied from 3.5 minutes to about 1 hour or no update at all in poor signal coverage areas. Poor OMEGA coverage occurred when operating within 360nm of the New York OMEGA Station. The reason for poor OMEGA coverage was due to weak signals from Hawaii and Norway in this area and because the BRN-7 computer is preprogrammed to disallow any OMEGA station when the receiver is within 360nm of that station. In Table 4-2, DR runs 1 thru 5 show the BRN-7 automatic update time as related to DR radial error. DR runs 6 thru 26 show the average time for automatic update when large radial errors were manually inserted. Runs 6 thru 11 were grouped because they were recorded when station C was being used as a master station by the receiver, while Tests 12 thru 21 used station B as a master station. The update times for all of these large inserted error runs were within the 10 minutes maximum allowed. Runs 22 thru 26 were grouped because inserted radial errors of 36.5nm were used during these runs and as a result no automatic update was achieved.

(3) The BRN-7 DR mode accuracies were within the accuracy of DRAI (Dead Reckoning Analyzer Indicator) and proved to be very useful. Over a 6 month period BERGALL operated the BRN-7 DR Mode as a DR Analyzer and found it to be an invaluable aid to submarine navigation (See Annex A).

409. Test O-5, Area Surveillance Test

a. Test Objective. The objective was to determine the accuracy and usefulness of the "Ten Pre-set Positions" feature in both the DR and OMEGA mode of operation.

b. Description of Test. Pre-set waypoints (latitude/longitude) were inserted into the OMEGA computer, with the waypoints being at least 5nm apart along a planned transit route of the submarine. The range/bearing to each waypoint, in succession, was displayed to the OMEGA operator who recommended courses to the navigator. These courses were then followed by the submarine until zero or near zero range to the waypoint was indicated by the BRN-7. This procedure was followed to pass through 14 pre-set waypoints in the DR mode and 9 pre-set waypoints in the OMEGA mode. Error determinations were made using SINS.

c. Data Analysis. RMS, and CEP about the mean values were computed for both the DR and OMEGA waypoint runs. During data reduction a SINS bias of 1.75nm in longitude was removed before determining the BRN-7 errors for the OMEGA waypoint run. No SINS bias was removed from the BRN-7 DR waypoint test because the OMEGA DR position was initialized with the SINS position prior to the start of this test.

d. Results and Discussion

(1) In the BRN-7 DR mode, waypoint zero-range data had an RMS error from the SINS position of 0.44nm and the CEP about the mean of 0.29nm. The run track covered a transit distance of 85nm during which 14 DR waypoint data points were recorded. When all ten pre-set positions had been filled, the remaining 4 waypoints were inserted as earlier waypoints were passed.

(2) Using the OMEGA mode, waypoint zero-range data had an RMS error from the SINS position of 1.98nm after the longitude bias was removed and a CEP about the Mean of 0.69nm.

For most of the 9 waypoints of this run, the exact zero-range point was not achieved because of position variance caused by the BRN-7 updating each 30 seconds with new OMEGA positions. Figure 4-4 indicates the SINS and OMEGA track covered by the submarine. The total transit distance for this test was 50nm.

410. Test M-1, Reliability.

a. Test Objective. The purpose of this test was to determine the reliability of the BRN-7 in the operating environment.

b. Description of Test. The equipment was operated as much as possible during the OPEVAL period. Observations of equipment operation were made and recorded. Data to compute the system MTBF were collected.

c. Data Analysis. The MTBF was computed by dividing the total full operating time in hours by the number of critical/major failures. The lower one-sided 90 percent confidence limit for the true MTBF was computed and compared to the acceptance criteria.

d. Results and Discussion. Based on 2936 hours of operating time with no critical/major failures the computed MTBF of the BRN-7 is at least 1280 hours at the 90 percent confidence level. This 1280 hours meets the acceptance criteria of 1000 hours. The following materiel problems were encountered during the evaluation period:

(1) On one occasion all the BRN-7 power supply fuses blew, several power supply diodes shorted and the AC line filters shorted. The BRN-7 is designed to store the master program in the computer upon any shutdown, which it did successfully in this case. It was determined that the failure was caused by a large overvoltage on the 115 volt, 400 Hz AC supply and was therefore not considered a BRN-7 failure. Prior to this overvoltage failure a voltage variation test was performed as outlined in test M-4B. Although the voltage was varied to the extremities of the shipboard regulators, this was not sufficient to test for an overvoltage of this magnitude.

(2) A partial equipment failure occurred when one of the two loops comprising the submarine Orthogonal Loop Antenna was found to be shorted to ground. This caused very weak signals from that loop to the BRN-7. Although the Orthogonal

OMEGA Pre-set Way points

	Latitude	Longitude
1.	24° 27.0	77° 33.5
2.	24° 24.0	77° 35.0
3.	24° 21.2	77° 32.0
4.	24° 17.5	77° 28.0
5.	24° 15.0	77° 30.0
6.	24° 16.4	77° 33.0
7.	24° 21.2	77° 32.0
8.	24° 25.4	77° 31.0

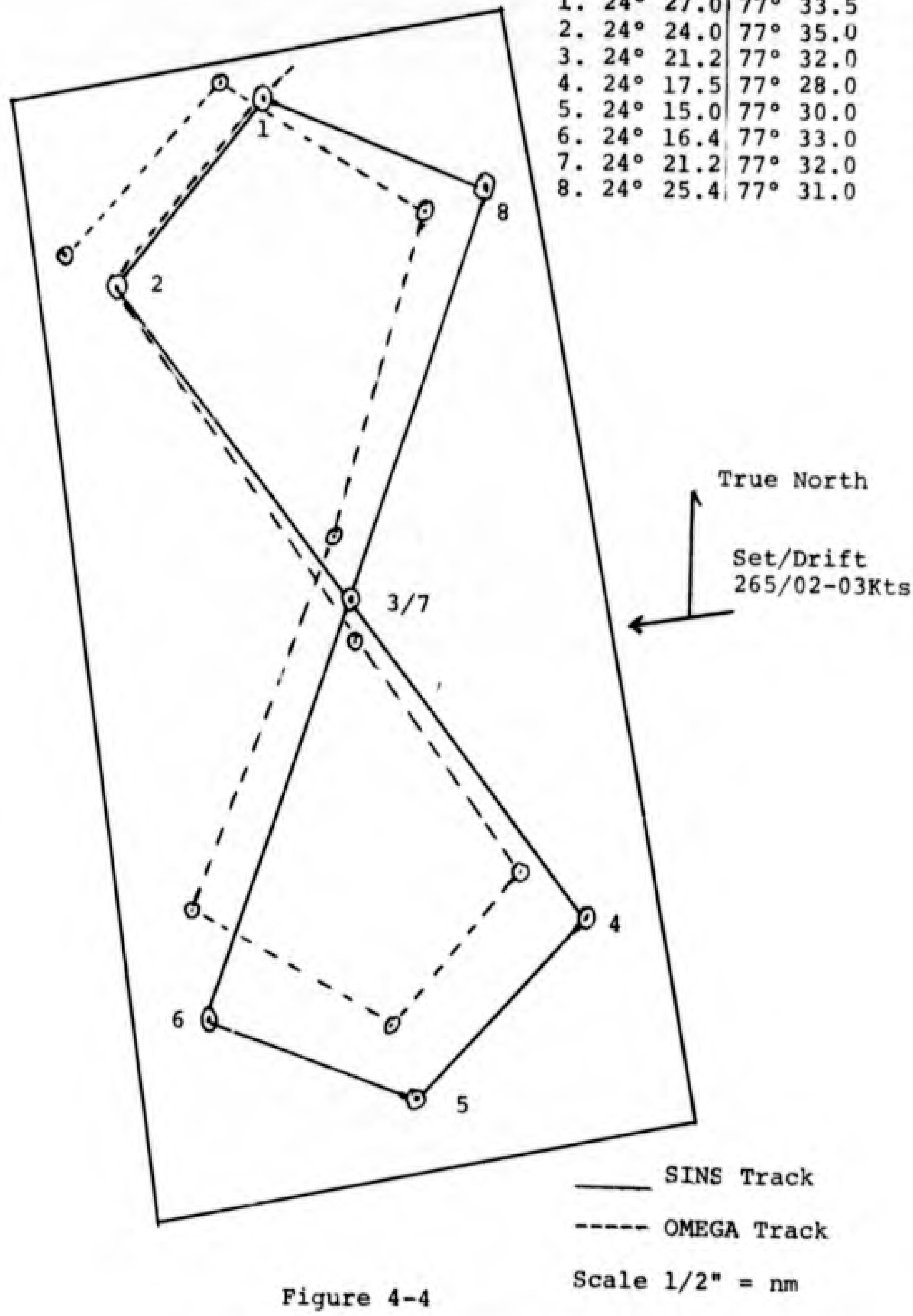


Figure 4-4

Area Surveillance with OMEGA Signals

Loop Antenna is also used for communications, this reduced signal effect was not observed on any other submarine equipment. Indications of the shorted loop were first noticed when monitoring BRN-7 signal status from each OMEGA station during turns. An analysis of the shorted loop indicated the cause to be torn insulation at one of the conduit connectors. This damage occurred as a result of disassembly during routine PM (planned maintenance) checks.

(3) Several minor failures occurred on the BRN-7 control panel in the form of push-button switches developing intermittent contacts. This problem caused the display panel to clear, requiring the display or insertion sequence to be repeated.

411. Test M-2, Maintainability

a. Test Objective. The objective of this test was to determine the maintainability of the BRN-7 by Navy technicians and to determine the total effort in men, time and materials necessary to keep the receiver in an acceptable operating condition.

b. Description of Test. This test consisted of collecting data necessary to compute MTTR (Mean-Time-to-Repair), MTFL (Mean-Time-to-Fault-Locate), and MSI (Maintenance Support Index), noting man-hours required to perform necessary maintenance. During this test observations on adequacy of the BITE (Built In Test Equipment) and Memory Augmentor Unit as maintenance aids were made.

c. Data Analysis. Due to no failures of the BRN-7 during this evaluation no MTTR or MTFL data was recorded. However, observations (made by the Project Officer) of Navy electronic technicians conducting fault location and modular replacement procedures at a one week factory school were made.

d. Results and Discussions

(1) Using a maintenance concept of fault location and modular replacement based on a complete set of replaceable spares, the established materiel criteria, MTFL of 10 minutes and MTTR of 30 minutes, are considered realistic.

(2) The time to fault locate using the Memory Augmentor Unit is 3 to 4 minutes. The Memory Augmentor Unit is used only as a fault location device to the failed stage or assembly

level of the BRN-7 Receiver-Computer. The BITE for checking computer sequencing is activated by the Panel Test switch on the Control-Indicator panel. This self-test sequencing requires about 5 seconds to complete. If improper computer sequencing or a Control-Indicator malfunction occurrs a Power Malfunction indicator will be activated. The same BITE test is performed when turning the BRN-7 from OFF to ON.

(3) Replaceable assemblies are also contained in the Control-Indicator unit and are checked in part by the BRN-7 BITE feature. The display panel also serves as a check for the BRN-7 Control-Indicator Using the procedures outlined in the Operator and Maintenance Manual, faulty assemblies can be located in about 3 to 4 minutes.

(4) The BRN-7 Interface Box contains no replaceable assemblies and its fault location procedures are outlined in the Operator and Maintenance Manual. These procedures consist of checking various fuses, reference voltages and the DC power supply current meter. Some fault location procedures can also be performed by checking various indications on the Control-Indicator panel. These checks, for the most part, will serve to fault locate to either the failed DC power supply, Orthogonal Loop Antenna Coupler or the Synchro Matching Transformer. Time to fault locate for the Interface Box is about 10 minutes.

(5) The BRN-7 BITE and Memory Augmentor unit seem to be adequate as fault locating features for the Receiver-Computer and Control-Indicator units. Fault locations for the Interface Box only, to the stage level, is inadequate. The function of the Interface Box, should be incorporated into the Receiver-Computer and included as part of the fault locating function of the Memory Augmentor Unit. Although the BRN-7 is designed to be VAST (Versatile Avionics Shop Test) compatible, no test of this compatibility was possible because VAST equipment for the BRN-7 has not been developed.

(6) Since no corrective or preventive maintenance was required on the BRN-7 the Maintenance Support Index was not computed.

412. <u>Test M-3, Availability</u>.

a. <u>Test Objective</u>. The purpose of this test was to determine the probability that the BRN-7 will be operationally ready, when needed at any point in time.

b. Description of Test. This test consisted of collecting, throughout the evaluation, necessary maintenance data to compute Availability. The time required to commence operation from a cold start and time to resume full operation after a power failure was recorded.

c. Data Analysis. Operational availability is defined as Demand Usage Time/Demand Usage Time + Downtime and was computed.

d. Results and Discussion.

(1) The operational availability of the BRN-7 is 100 percent. The BRN-7 requires no preventive maintenance that precludes total system operation.

(2) The time to start from a cold start condition was less than three minutes.

(3) The time to resume full operation after restoring power was about three minutes. No computer reprogramming was required either after a power failure or after the ship's overvoltage casualty.

413. Test M-4A, Compatibility (Physical Environment).

a. Purpose. The purpose of this test was to determine the compatibility of the BRN-7 with its physical environment.

b. Description of Test. Observations were made throughout the evaluation of the effects of vibration, sharp turns, large up/down angles and torpedo impulse firings on the operation of the BRN-7.

c. Data Analysis. Remarks from the data sheets and observations were used to subjectively assess the physical compatibility of the BRN-7 to the submarine environment.

d. Results and Discussion. No detrimental effects to BRN-7 operation were noted due to torpedo impulse firings or extremes in either maneuver or environment. During the evaluation over 100 torpedo impulse firings occurred and the equipment was exposed to many sharp turns, dives/climbs, and speed changes. The BRN-7 equipment was located in a relatively open area so that overheating was not a problem.

414. Test M-4B, Compatibility (Electrical and Electronic Interference)

a. Purpose. The purpose of this test was to investigate whether interference exists between the BRN-7 and other electrical and electronic systems in the operational environment, and the extent of such interference.

b. Description of Test.

(1) Sources of mutual interference with the BRN-7 were investigated with particular attention given to VLF/LF receivers/transmitters and all 60 Hz or 400 Hz equipment operating near the BRN-7.

(2) Line power interruptions and voltage variations above and below the normal operating voltage were observed for any adverse effects on the BRN-7.

(3) Particular attention was given to interference when operating hand tools in the vicinity of the VLF loop antenna or when in vicinity of other 60 Hz and 400 Hz power lines.

c. Data Analysis. Remarks from the data sheets and observations were used to subjectively assess the electrical and electronic compatibility of the BRN-7 with the shipboard environment.

d. Results and Discussion

(1) No mutual interference effect was observed between the BRN-7 and other shipboard equipment. Installation of the BRN-7 aboard BERGALL is near other navigation equipment: SRN-9 (including the teletype printout), DRAI and LORAN. No adverse effects on the BRN-7 were observed during normal submarine communication transmission/reception periods.

(2) No detrimental effects were noted during power line interruptions or voltage variations. A line voltage variation test was performed in which the BRN-7 line voltage was lowered 5 percent and raised 3 percent (maximum limits of the shipboard regulators) for 2 minutes at each limit. The 28 VDC power supply varied $\pm$ 0.2 volts with the changes in line voltage. No effect in BRN-7 equipment operation was noted during this test.

(3) Sixty Hertz interference was noted during a yard period when electrical hand tools were operated within 10 to 20 feet of the VLF loop antenna. This interference

was noted as an increase in noise on the signal to noise status indicators of the BRN-7. The OMEGA signal update rate, although adversely effected, was not degraded to the extent that OMEGA inport positioning was precluded.

415. Test M-4C, Compatibility (Functional).

a. Test Objective. The purpose of this test was to assess the interface compatibility between the BRN-7 and other submarine systems with which it must operate.

b. Description of Test. The BRN-7 and its interface equipment were observed for proper operation to insure functional compatibility.

c. Data Analysis. Quantitative and subjective data were used to assess the effects of functional compatibility on the performance of the BRN-7 OMEGA Set.

d. Results and Discussion.

(1) The submarine rate-aid inputs (MK 19 Gyrocompass for heading and EM Log for speed) were compatible with the BRN-7 and were sufficient to provide heading and speed information necessary for DR positioning.

(2) The submarine CU-1441 Antenna Coupler, modified for the BRN-7, did provide adequate coupling for OMEGA signals in the areas covered. During this evaluation the VLF loop could not be used with the BRN-7 during communication periods. A CU-1441 limitation does not allow joint usage of this antenna for both the submarine's communication center and the OMEGA signals.

416. Test M-5, Supportability.

a. Test Objective. The objective of this test was to assess the supportability of the BRN-7 in its operational environment.

b. Description of Test. This test consisted of assessing the actual method of logistic support available and exhibited during the evaluation with specific comments on supportability related to:

(1) Adequacy of repair parts on board.

(2) Adequacy of the approved on-board BRN-7 spare parts allowance list.

(3) Repair parts provided that did not appear on the allowance list.

c. Data Analysis. Supportability and adequacy of spare parts were subjectively assessed during the evaluation as no failures occurred.

d. Results and Discussion. The List of Replaceable Assemblies was found to be inadequate. The BRN-7 employs modular construction for rapid replacement of defective assemblies. Reference (i) defines the Maintenance Concept used during this evaluation for isolation and replacement of the failed assemblies listed in the List of Replaceable Assemblies. This list was found inadequate due to a lack of in-line filters which failed when a ship's over-voltage casualty occurred. With the low assembly failure rate, a complete set of replaceable assemblies may not be required. High risk assemblies should be identified (based on long term usage) and only these items carried on board.

417. Test M-6, Technical Documentation

a. Test Objective. The objective of this test was to evaluate the adequacy of technical documentation provided with the BRN-7 set.

b. Description of Test. Technical documentation assessment questionnaires were filled in by personnel using the Operator and Maintenance Manual during the evaluation.

c. Data Analysis. Questionnaires were reviewed and comments obtained from them were used in the Technical Documentation assessment.

d. Results and Discussion. Two ship's company Electronic Technicians (ET-1 and ET-3) attended the factory school and performed most of the operator/maintenance procedures required.

(1) Both ET's stated that the operator portion of the BRN-7 Operator and Maintenance Handbook was satisfactory.

(2) Both ET's stated that the maintenance portion of the handbook was lacking complete modular functional diagrams. BERGALL's comment letter (Annex A) stated that a complete set

of detailed electrical schematics of the BRN-7 are needed to further assist technicians in the required trouble-shooting procedures and equipment repairs.

418. Test H-1, Human Engineering, Personnel and Training.

a. Test Objective

(1) The Human Engineering test was to assess the adequacy with which the BRN-7 has been designed and installed to facilitate its operation and maintenance by the assigned personnel.

(2) To determine the capability of assigned personnel to operate and maintain the BRN-7, and assess the training received.

b. Description of Test

(1) Whenever possible the Project Officer observed the operator/maintenance technicians perform their duties, and questioned them on what he observed or was told to be possible discrepancies. Discrepancies in design and installation of the equipment were compared to the Human Engineering Design Criteria for Military System (Military Standard 1472), Equipment and Facilities. Also, subjective comments were used from the Human Engineering Questionnaire completed by operator/maintenance personnel.

(2) The Project Officer's observations of personnel and adequacy of training required for operation and maintenance of the BRN-7 on board the submarine were made.

c. Data Analysis. Human Factors Engineering and Training Evaluation Questionnaires were analyzed to compile the following subjective comments.

d. Results and Discussions

(1) The BRN-7 Interface Box Unit was temporarily installed behind the Receiver Computer unit with one mounting support. This unit can be subjected to movement and possible electrical shortage during fuse removal/replacement or during extreme ship movements.

(2) Both ET's agree that no increase in personnel allowance for operation or maintenance of the BRN-7 is considered necessary. This equipment did add an additional

maintainance responsibility to the ship's ET force. However, with a high MTBF and no requirement for preventive maintenance, no additonal personnel allowance should be required.

(3) Both ET's who attended the factory school stated that it was satisfactory. The school was conducted at Northrop Corporation, Hawthorne, California for 5 days. Approximately 50 percent of this time was spent in operating and module fault location/replacement in the BRN-7 Receiver-Computer and Control-Indicator. The ET-1 stated that his general experience with the Navy would have enabled him to satisfactorily maintain this equipment without factory school training. It is the Project Officer's opinion that some formal schooling is required for at least one of the maintenance/operator personnel aboard each ship.

SECTION 5

OPERATIONAL APPLICATIONS

501. By design, the accuracy of the OMEGA transmission system is approximately 1 to 2 nautical miles and when fully operational should provide world wide coverage. The BRN-7 set has the ability to provide acceptable fixes within the design accuracies of the OMEGA system.

502. With the present limited OMEGA system (4 stations operating at reduced power) the Florida Coast is considered a good OMEGA signal area. A trained BRN-7 operator can tell, by means of NCTR, signal/noise ratio and PC (Position Variance) indicators, when good OMEGA navigational accuracies for an area are achievable.

503. Receiver geographic location, as related to the OMEGA stations being used, has an effect on position accuracy. Position 1 in Figure 5-1 indicates LOP crossing angles of about 90 degrees while position 2 has LOP's that are almost parallel. In position 2 station B is not used in updating the BRN-7 because it would cause inaccuracies and therefore is disallowed by the BRN-7 when within 360nm of the station. Position variances and OMEGA errors will be greater in position 2 than position 1 due to this receiver/station LOP geometry.

504. During trailing wire operations (Test 0-2, Speed and Depth Range) it was observed that as depth was slowly increased, position variance and OMEGA errors (para 4-6 d) also increased. To insure better DR accuracy when diving, using the trailing wire antenna, all OMEGA stations should be disallowed (i.e. shift to the DR mode) prior to reaching depths at which OMEGA inputs introduce errors. If allowed the BRN-7 will retain these errors until updated by manual or OMEGA updating methods.

505. Observations made during surfaced operations in NRA (No Rate Aiding) mode indicated an increase in position variance and OMEGA errors. However, BRN-7 navigation can be continued in this mode with acceptable accuracy even if shipboard heading and speed inputs are removed.

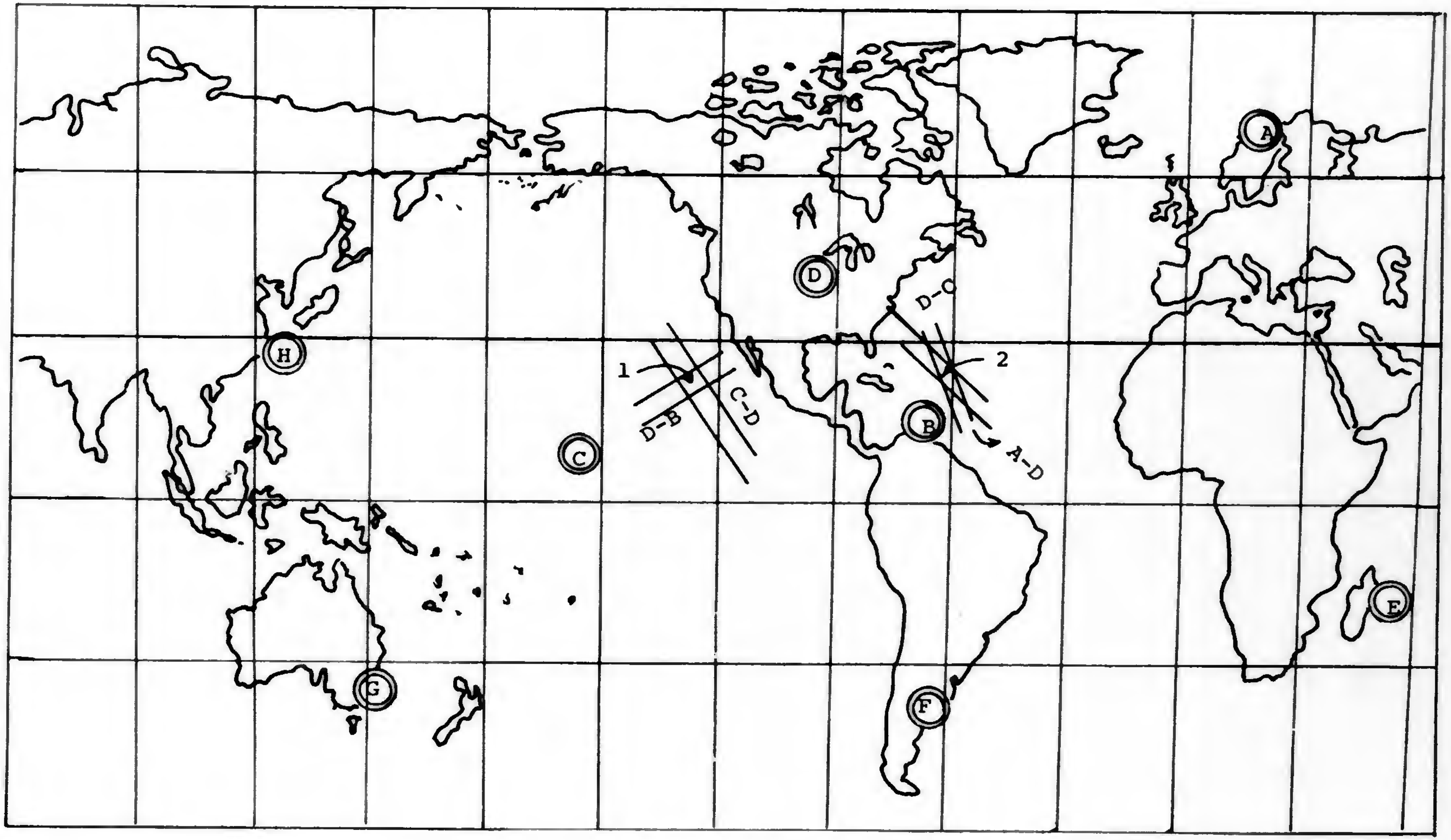


Figure 5-1

OMEGA LOP Crossing Angles

506. On two different occasions while conducting OMEGA accuracy tests, errors of 8 to 10nm were recorded for two periods of 1 1/2 to 2 hours each. During these periods the BRN-7 had no abnormal status indications. NCTR ("Number Counts" of OMEGA inputs per station to the receiver) continued to increase at a constant rate. A few periods of BRN-7 navigational error over a 6 month period were also reported in BERGALL's comment letter (Annex A). This same type position shift has been reported by NATC and AIRTEVRON ONE during OPEVAL of the AN/ARN-99 Receiver in P-3 aircraft. The U. S. Naval Oceanographic Office, by reference (j), reported that while the OMEGA transmitting system is in its testing stage, inaccuracies in position fixes and changes in station transmitting periods will continue to occur until the system becomes fully operational. Therefore prudent navigation dicatates that positioning information derived at present from OMEGA should not be relied on without reference to other navigational positioning. A possible reason for these present inaccuracies is that in OMEGA navigation, using LOP's from two or more stations, there are positions 8 to 9nm from the true position that satisy all the ambiguity and lane resolution requirements. If one or more transmitted frequencies has a shift, or drift in frequency, either at the OMEGA station or at the receiver site, these errors may occur. This frequency shift may not be indicated by a normal BRN-7 status indicator or by a decrease in signal strength at the receiver. When more OMEGA stations become operational, this temporary inaccuracy problem should not exist with the BRN-7 or ARN-99 airborne receiver because of their ability to select the best OMEGA stations from several available at any point in time.

Section 6

Conclusions

601. It is concluded that:

a. Navigational accuracy of the AN/BRN-7 OMEGA receiver is within operational criteria (1-2nm RMS absolute accuracy) when operated in good OMEGA coverage areas. (404d and 405 d (1), (4))

b. Relative error between two OMEGA receivers meets the operational criteria and can be less than the absolute error for either of the two systems. (407(1) and (2))

c. There is no operationally significant difference between the day/night accuracy. (404 d (2))

d. Although less sensitive than the Orthogonal Loop Antenna, the RG-374 Trailing Wire Antenna provides usable OMEGA signals for BRN-7 OMEGA navigation near the speed and depth limits established by the "Speed-Depth Versus Cable Length Guide". (405 (1), (2), (3) and 406 (1), (2))

e. The Orthogonal Loop provides usable OMEGA signals to the BRN-7 receiver to an antenna depth of about 15 feet. (406 d, (1))

f. The DR feature of the BRN-7 receiver is capable of providing usable fix information for automatic updating after long periods of time (9 hours in light to moderate currents) in a good OMEGA signal environment. (408 d (1) and (2))

g. The DR mode and Pre-set feature of the receiver are desirable features for the BRN-7. (408 d (1), (2), (3) and 409 (1), (2).

h. The Materiel Reliability of the BRN-7 set is satisfactory (410 d)

i. The Materiel Reliability of the BRN-7 Control-Indicator Panel switches is unsatisfactory. (410 d (3))

j. The Maintainability of the BRN-7 Receiver-Computer and Control-Indicator is satisfactory. (411 d (1), (2), (3), (5))

k. The Maintainability of the BRN-7 Interface Box is unsatisfactory. (411 (4), (5))

l. The Operational Availability of the BRN-7 receiver is satisfactory. (412 (1) (2) (3))

m. The compatibility with the shipboard CU-1441 antenna coupler is unsatisfactory. All other aspects of compatibility are satisfactory. (413 d, 414 d and 415 d)

n. The supportability for the BRN-7 is satisfactory. (416 d)

o. The Technical Documentation for the BRN-7 is unsatisfactory. (417 d (2))

Section 7

Recommendations

701. Commander Operational Test and Evaluation Force recommends that:

a. The AN/ARN-99 (XN-1) redesignated AN/BRN-7 (XN-1) be accepted for service use in submarines.

b. For considerations of operation and maintainability of the BRN-7, the developing agency should correct the following:

(1) Eliminate the restriction which precludes joint usage of the CU-1441 coupler with the ship's communication center and limits the BRN-7 automatic update capability.

(2) Correct the relatively short life of control switches on the BRN-7 Control-Indicator Panel.

(3) Expand Technical Documentation to include complete modular diagrams.

c. For consideration of supportability and maintainability of the BRN-7 the developing agency should investigate the following for action:

(1) The high risk assemblies be identified and supplied for spare part supportability of the BRN-7 based on long term usage.

(2) The functions of the BRN-7 Interface Box be incorporated into the Receiver-Computer group and included in maintenance checks of the BITE and/or Memory Augmentor Unit.

Annex A

USS BERGALL Comments Letter

USS BERGALL (SSN 667)
CARE OF FLEET POST OFFICE
NEW YORK, NEW YORK 09501

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Ser: C4
20 JAN 1972

From: Commanding Officer, USS BERGALL (SSN667)
To: Commander Operational Test and Evaluation Force

Subj: Project Plan O/S 170 (OMEGA, AN/ARN-99) OPEVAL (U)

Encl: (1) Evaluation Material Log (Data Sheet M-1, 8 July to 20 October 1971)

1. The OMEGA (AN/ARN-99) OPEVAL was conducted aboard BERGALL during the period July - December 1971. During this period the OMEGA Navigation System proved to be an acceptable, independent navigation system for use in submarines. Acceptable fix accurracies are obtainable within the time limitations imposed by operational committments. In addition to reliable fix information the system's employment as a dead reckoning analyzer is an invaluable aid to submerged navigation.

2. The reliability of the OMEGA System with regard to the frequency and extent of necessary corrective maintenance appears to be excellent. Only one major system failure occurred during OPEVAL, the cause of which was probably external to the OMEGA system. Repair of minor malfunctions and routine preventive maintenance were completed without incident. The inclusion in technical manuals of detailed electrical schematics of the OMEGA Systems is needed, however, to further assist technicians in required trouble shooting and equipment repairs, should they become necessary.

3. As demonstrated during this OPEVAL, confidence in the reliability of OMEGA fix information is generally high, especially when it is compared with other information available to the SSN Navigator. At times, the OMEGA system has been utilized as the only source of fix information prior to continuing high speed submerged transits in restricted waters.

4. Two operational problems that have appeared during this OPEVAL should be the subject of further investigation.

a. At infrequent intervals the OMEGA System appeared to exhibit fix accuracy degradation with increased signal exposure time. The system would indicate "position uncertain" even with good indicated signal strength, and the degeneration of fix accuracy did not appear to be accompanied by a decrease in indicated signal strength.

b. At very infrequent intervals the OMEGA system has locked on to a position fix 4 to 10 miles in error. Indicated signal strength was good and indicated fix accuracy was less than 0.5 NM. During these times, the reason for the fix error could not

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readily be discovered. This condition would last for about a 4 hour period.

c. Possible causes for these two problems are the quality of station transmission, possible antenna directionality, amount of mast exposure, or actual signal strength less than indicated signal strength. It is felt that the solution of these two problems would greatly enhance the value of the OMEGA system even though it presently operates as a highly satisfactory Navigation System.

5. BERGALL has requested that the ARN 99 system be retained on board for further evaluation. It is recommended that the problems mentioned above be the subject of further investigation by BERGALL when the power output and number of transmitting stations is increased.

B. F. Tally

B. F. TALLY

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COMSUBDEVGRU TWO (less encl)
NAVELEX (PME 119) (Less encl)

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13. ABSTRACT

The AN/BRN-7 OMEGA Navigation Set was designed for aircraft and modified for submarine use. This receiver is primarily designed to supply the submarine with instantaneous navigation information within 1-2 NM when operating in the OMEGA signal environment. Additional BRN-7 provides a dead reckoning capability when no OMEGA signal received or during submerged submarine

This project was conducted to evaluate the AN/BRN-7 OMEGA Navigation Set in a submarine operational environment in order to determine its suitability for service use. It was found that the accuracy and reliability of the AN/BRN-7 are within the operational criteria required for submarines.

Operational tests were under the supervision of and were conducted by Commander Operational Test and Evaluation Force. CDR J. D. HENDRY, USN, was the Project Supervisor and LTJG R. D. ROSE, USNR, was the Project Officer. The evaluation was performed aboard USS BERGALL (SSN 667) off the U. S. Southeast and East Coast from 7 July to 10 December 1971.

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