COAST GUARD

The U.S. Coast Guard has been serving country and humanity since August 4, 1790. Originally entrusted with the enforcement of the young republic's anti-smuggling laws, the new fleet, consisting of ten small cutters, shortly went into action in the undeclared war with France.

The oldest continuous sea-going armed service of the United States, the Coast Guard is today our chief agency for promoting maritime safety and for maritime law enforcement. Its duties include extensive merchant marine and recreational boating safety programs, maintenance of a network of more than 40,000 navigation aids; search and rescue; oceanographic research, port security; ocean weather patrols; the International Ice Patrol. Additionally, the Coast Guard maintains its ships, aircraft and stations in a constant state of military readiness, prepared to operate as a part of the U.S. Navy in time of war or national emergency. In 1967 the Coast Guard was transferred from the Treasury Department to the new Department of Transportation where it has been the Department's major administration in the marine transportation and science areas.

The Coast Guard has come a long way since those first small cutters were launched almost 200 years ago. But its spirit is still summed up in its motto:

"SEMPER PARATUS--ALWAYS READY!"

UNITED STATES COAST GUARD

ELECTRONICS ENGINEERING CENTER

Wildwood, New Jersey

ELECTRONICS ENGINEERING CENTER

During World War II, the need arose for a Coast Guard engineering laboratory to assist in the testing and developing of a new electronic navigation system called Loran-A. Relative obscurity was required for this laboratory to avoid its disclosure to the enemy. Assateague Island, off the coast of Virginia, was therefore selected in 1943 as the first site for this "test station". After initial tests were completed and the Loran-A navigation system was placed into operation in the war zones, the need for secrecy diminished and the test station was relocated to available Coast Guard property near the Coast Guard Lifeboat Station at Fenwick Island, Selbyville, Delaware. This relocation also solved a difficult logistics and accessibility problem with Assateague Island. The Selbyville Station remained until 1948 when the need for more space and better "near ocean" antenna sites led to the establishment of the present facilities on the 392 acres of fastland in Lower Township, Cape May County, New Jersey.

Over the years, the Electronics Engineering Center has performed electronics engineering assignments involving not only the Loran-A and Loran-C Navigation Systems, but also Marine Radar Systems, Marine Radiobeacon Systems, loran and communications antenna designs, maintenance of loran and other navigation receivers, RACONS and Closed Circuit Television Systems. The results of all engineering work are reported to the Commandant, U. S. Coast Guard for use in making improvements and providing general engineering support for electronic aids to navigations system operated or controlled by the Coast Guard world-wide.

Each of the individual laboratory buildings at the Center house Coast Guard electronic navigation equipment in current use. The equipment is installed and maintained exactly like that in the field so engineering investigations will produce results that will work in the field.

Typical of the Loran-C transmitting antennas is the 625-foot tower located at the western end of the Center. On the platforms of the steel structure above the microwave laboratory are mounted antennas for each type of surface search radars in use by the Coast Guard. Two model antenna ranges, 1/20th and 1/100th scale, are used to conduct inexpensive tests of new or improved loran transmitting towers.

It is with much pleasure that we welcome you to this Engineering Center. It is our hope that through your visit with us you may become better acquainted with the United States Coast Guard and its engineering facilities.

The Commanding Officer
USCG EECEN

LORAN-C & LORAN-D SYSTEMS

OF

RADIONAVIGATION

TABLE OF CONTENTS

INTRODUCTION

Loran-C and D are pulsed, low-frequency (LF), hyperbolic radio aids-to-navigation. They derive their high accuracy from time difference measurements of the pulsed carrier and the inherent stability of LF propagation. The wide coverage areas are made possible by the low propagation losses of LF groundwaves and the resultant long baseline lengths (station-to-station separation). The Coast Guard now operates 8 Loran-C chains (including one on the east coast of the United States) using 31 transmitting stations to provide coverage over 12,000,000 square miles (see Figure 1).

Loran-D is a tactical extension of Loran-C. The theory of operation is the same, but the physical size of the ground stations is reduced for mobility, sacrificing radiated power and coverage area.

THEORY

Hyperbolic radio aids-to-navigation operate on the principle that the difference of time of arrival of signals from two stations, observed at a point in the coverage area, is a measure of the difference in distance from the point of observation to each of the stations (see Figure 2). The locus of all points having the same observed difference in distance to a pair of stations is a hyperbola and is a line of position (LOP). The intersection of two or more LOP's defines the position of the observer. The accuracy of hyperbolic radio aids-to-navigation depends on the observer's ability to measure the difference between the times of arrival of two signals (time difference or TD) and his knowledge of the propagation conditions so that the time differences can be converted to LOP's.

In identifying the proper frequency for a radio navigation system which will give wide coverage and high accuracy, various physical factors must be considered. The basic limitation on accuracy is the velocity of propagation of radio energy, approximately one foot per nanosecond (1 ft/ns). Thus for accuracies on the order of tens or hundreds of feet, measurements must be made to tens or hundreds of nanoseconds. Also the propagation conditions must be reliably predictable (mathematically or from survey) to tens or hundreds of nanoseconds.

Very Low Frequency (VLF) signals propagate primarily by skywave or the waveguide mode and predictability of this propagation suffers from the lack of real-time knowledge of ionospheric conditions. Low Frequency (LF) signals meet the requirements for time measurement accuracy and the ability to predict groundwave propagation conditions although they are subject to skywave interference at long ranges. Medium and High Frequency (MF and HF) signals meet the time measurement capabilities but suffer high propagation losses over land reducing their range. They also suffer loss of propagation predictability due to natural and man-made physical features whose size is a significant fraction of a wavelength. Higher frequency signals (VHF and above) are range limited to line-of-sight. Thus 100 kHz was chosen for Loran-C and D to take advantage of the stable propagation characteristics and long range of the LF band. Pulsed and coded signals are used to minimize the effects of skywave interference.

Skywaves are echoes of the transmitted pulses which are reflected from the ionosphere. Skywave conditions vary from day to night and in different parts of the world. A skywave may arrive at a receiver as little as 35 microseconds (us) or as much as 1000 us after the ground wave. In the first case, the skywave will overlap its own groundwave while in the second case the skywave will overlap the groundwave of the succeeding pulse. Either case will cause distortion of the received signal in the form of fading and pulse shape changes. Large positional errors would result if these conditions were not accounted for in the selection of the Loran-C/D signal format, and the design of the receivers.

The early arriving skywave can be overcome by making time of arrival measurements on the first part of the pulse. This ability is enhanced by the fast rising pulse, achieving high power prior to the arrival of skywaves (see Figure 3). The shape of the pulse also allows the receiver to identify one particular cycle of the 100 kHz carrier. This is essential to prevent whole cycle ambiguities in the time difference measurement and allows the high accuracy of the phase measurement system to be achieved.

To prevent the long delay skywaves from affecting the time difference measurement, the phase of the 100 kHz carrier is changed in each pulse of a group in accordance with a predetermined pattern. The phase codes for Loran-C and D are shown in Table II. Additionally, the phase code is different for the master and secondary signals so that automatic receivers may use the code for master and secondary station identification.

Ranges of 800 to 1200 nautical miles (nm) are typical (250 to 400 nm for Loran-D) depending on transmitter power, receiver sensitivity and losses over the signal path. Variations in propagation losses and velocity increase with distance from the transmitters. These errors and those introduced by receivers will normally result in position variations of 50 to 200 feet at 200 to 500 nm. increasing to 500 feet at 1000 nm.

OPERATION

Loran-C and D chains are comprised of a master transmitting station, two or more secondary transmitting stations and, if necessary, system area monitor (SAM) stations. The transmitting stations are located such that the signals from the master and at least two secondary stations can be received throughout the desired coverage area. For convenience, the master station is designated by the letter "M" and the secondary stations are designated X, Y, Z, W, based on the order in which they transmit. Thus a particular master-secondary pair and the TD which it produces can be referred to by the letter designations of both stations or just that of the secondary (e.g. MX time difference or TDX).

All transmitting stations are equipped with Cesium Beam frequency standards. The high stability and accuracy of these standards permit each station to derive its own time of transmission (ToT) without reference to another station. This is called the '"free-running" mode of operation.

The current objective for control of a Loran-C or D chain is to maintain constant the observed TD of each master-secondary pair at a particular point in the coverage area. Frequency offsets in the Cesium standards and changes in propagation conditions can cause the observed TD to vary. Therefore, one or more SAM stations with precision receiving equipment are established in the coverage area to continuously monitor the TD's of the master-secondary pairs. In some cases a transmitting station is suitably located and performs the SAM function. A control TD is established through calibration (see System Calibration). When the observed TD varies from the control TD by one-half of the prescribed control tolerance, the SAM directs a change in the timing of the secondary station to eliminate the error. The control tolerance is plus or minus 200 ns or less for precision chains. If the observed TD differs from the control TD by more than the control tolerance, "blink" is ordered to advise users that the TD is unusable. Blink is described in the next section.

New equipment is being developed which is expected to permit reduction of the control tolerance to plus or minus 40 ns. Consideration is being given to control by maintaining the ToT of the secondary station constant with respect to the ToT of the master station and performing all monitoring from transmitting station sites.

The Loran-C system as it operates today has maintained a record of 99.7% availability, not including scheduled off-air maintenance which reduces that figure to 99%. New equipment is presently being developed which will permit on-air maintenance, and also improve the system availability, with a goal of better than 99.7%, including all interruptions to service.

SIGNAL FORMAT

The transmitting stations of a Loran-C or D chain transmit groups of pulses at a specified group repetition interval (GRI) (see Figure 3a). For each chain a minimum GRI is selected of sufficient length so that it contains time for transmission of the pulse group from each station (10 milliseconds for the master and 8 milliseconds for each secondary) plus time between each pulse group so that signals from 2 or more stations cannot overlap in time anywhere in the coverage area. The minimum GRI is therefore a direct function of the number of stations and the distance between them. A GRI for the chain is then selected so that adjacent chains do not cause mutual (cross-rate) interference. Possible values for GRI are listed in Table I. The GRI is defined to begin coincident with the start of the first pulse of the master group.

Loran-C pulses and pulse groups: Each station transmits one pulse group per GRI. The master pulse group consists of eight pulses spaced 1000 microseconds apart, and a ninth pulse 2000 microseconds after the eighth. Secondary pulse groups contain eight pulses spaced 1000 microseconds apart. Eight pulses, rather than one, are used so that more signal energy is available at the receiver, improving signficantly the signal to noise ratio without having to increase the peak transmitted power capability of the transmitters. The master's ninth pulse is used for visual identification of the master and for blink. Blink is accomplished by turning the ninth pulse on and off in a specified code as shown in Table III. The secondary station of the unusable pair also blinks by turning its first two pulses on and off.

Loran-D pulses and pulse groups: During a GRI each station transmits a pulse group comprised of 16 pulses spaced 500 microseconds apart. When the TD of a master-secondary pair is unusable, only the secondary blinks by turning its first four pulses on and off.

SYSTEM CALIBRATION

When a Loran-C or D chain is established (or when a secondary is added) and periodically thereafter, a chain calibration is conducted. The purpose of the calibration is to record the Loran time differences at a number of known geographical points in the coverage area. This information is then used to:

a. verify the initial chain synchronization to ensure that the chain performs as advertised.

b. establish the control time differences, which are then used as the reference for measuring chain performance.

c. ensure the accuracy of the control time differences.

d. provide survey data for accurate charting and for use in determining surface conductivities, which are utilized by users requiring the best possible geodetic positioning accuracies.

In performing a calibration, an effort is made to distribute the monitor sites uniformly over the coverage area. Each site is visited for a minimum period of four hours, during which time the Loran signals are monitored precisely and the average value for the period is determined. The transmitting stations and the station for which the control time difference(s) are to be established are also required to monitor precisely. The geographic location of the monitor site (if not already known) is determined at the same time by use of satellite positioning, or at a later time by first-order survey. The calibration data is then reduced to establish or check the control time differences, and to estimate surface conductivities throughout the coverage area. The results are reported in "Chain Calibration Reports".

USER EQUIPMENTS

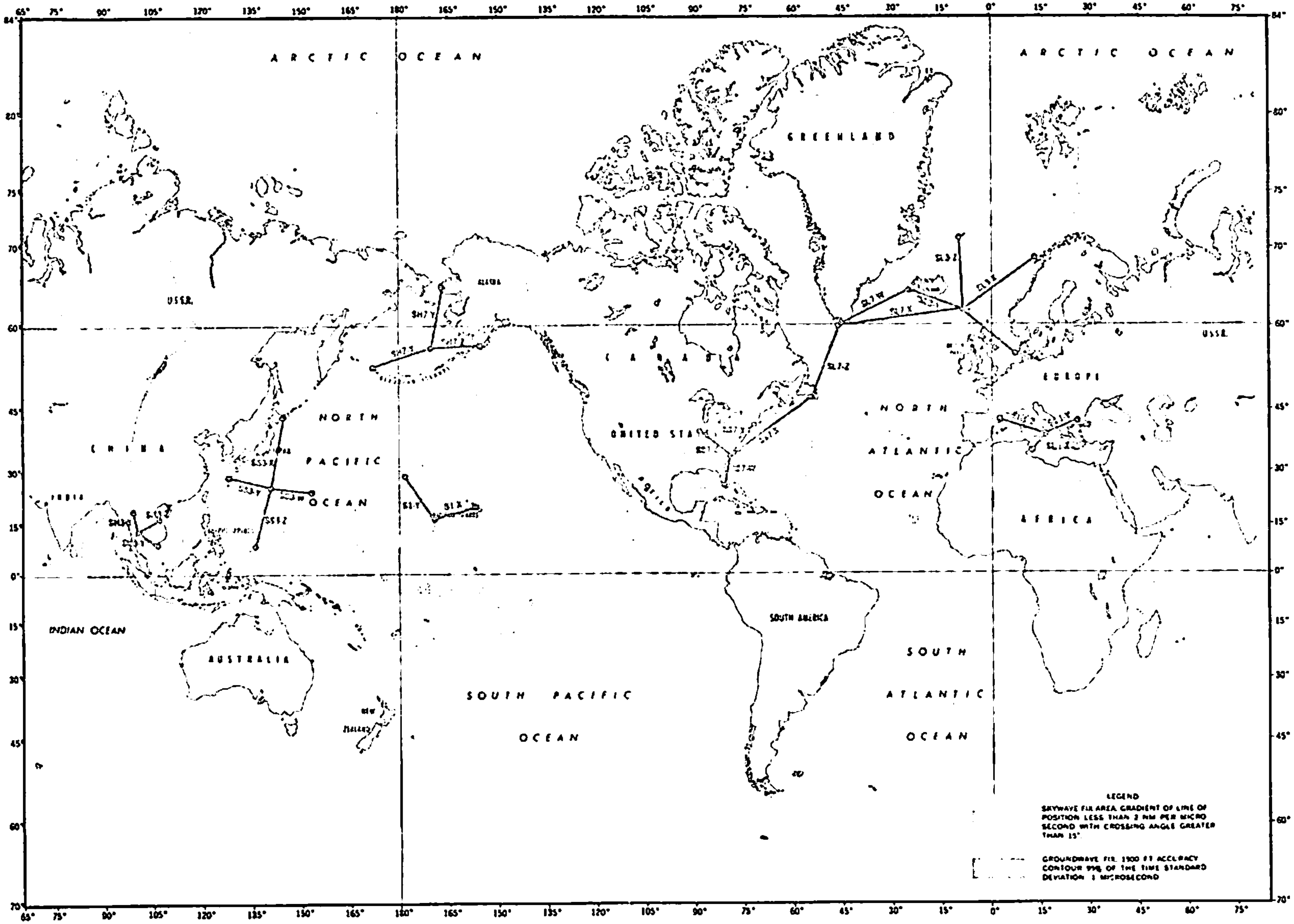
Loran-C and D user equipments can be classed in two general categories: receivers and information displays. Although the information processing is separated for discussion, it may be performed along with the signal processing in a single unit.

Receivers must perform two functions, signal acquisition and time difference or time-of-arrival measurement. Signal acquisition may be manual, partially automated or automatic. The time measurement may be manual or automatic, tracking the pulse envelope or the carrier phase of the received signal. Coast Guard published information on the Loran-C and D system is based on the performance of automatic phase-tracking receivers. This type of receiver is capable of signficantly greater accuracy and range of operation (factors of 10 and 2 respectively) than those receivers which are limited to pulse envelope measurement or manual phase-tracking. Automatic receivers may track the master and one, two or more secondary stations, presenting the output in either time-of-arrival (rho-rho) form or time difference form. Rho-rho in combination with a stable frequency source permits use of the Loran-C and D system in areas where hyperbolic information is not available. Rho-rho operation from Loran-C also makes it possible to accurately determine universal time (UTC) with very high precision (±5 usec, 2 sigma).

Time difference information can be plotted directly on a Loran chart. Over small areas a plotting sheet with straight line approximations of the grid can be used for maneuvering to return to a previously recorded position. This concept can be used with automatic computation and real time display to show vessel movement in restricted waters or for aircraft terminal-area navigation.

Some receiver-computer combinations can compute the coordinate transformation to latitude and longitude, UTM, and/or along-track and cross-track coordinate systems, from the measured data. In one system for aircraft a three-dimensional computation of real-time position is made by providing digital pressure altitude to the computer.

Many of the Loran-C receivers available today were built for military use, are quite sophisticated and hence expensive ($15,000 and up). Recently, however, the Coast Guard contracted for the development of two low-cost ($1000 - $3000) Loran-C receivers which meet Coast Guard specifications. Contracts have been awarded to Teledyne Systems Co. and Litcom Division of Litton Industries and are expected to be successfully completed by 1 July 1972. There are several other receivers on the market which have been developed for civil use. At least one of them was based on the Coast Guard specification and costs approximately $3000.



Prepared by
U.S. Naval Oceanographic Office—1972

FIGURE 1 LORAN-C COVERAGE DIAGRAM

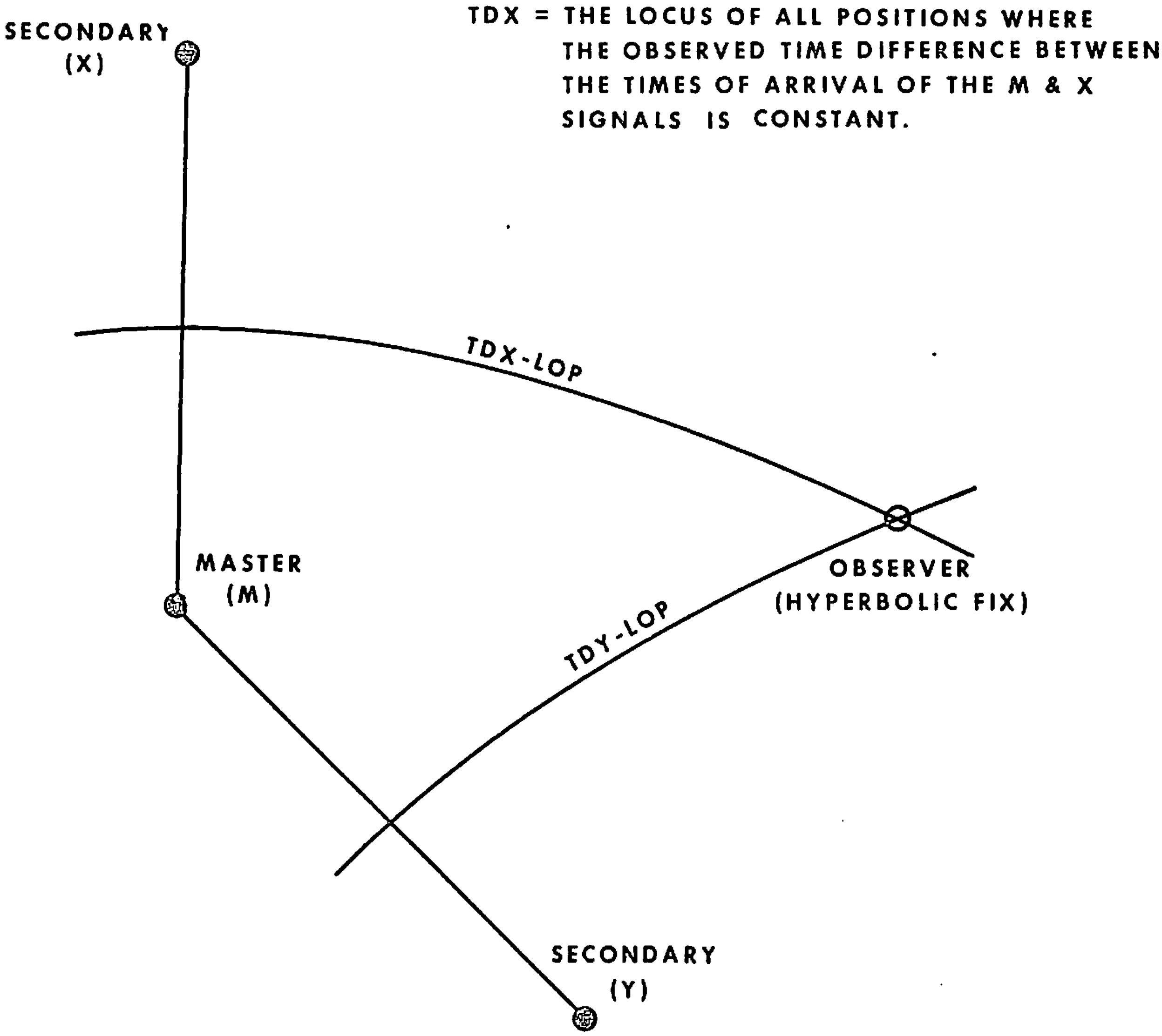
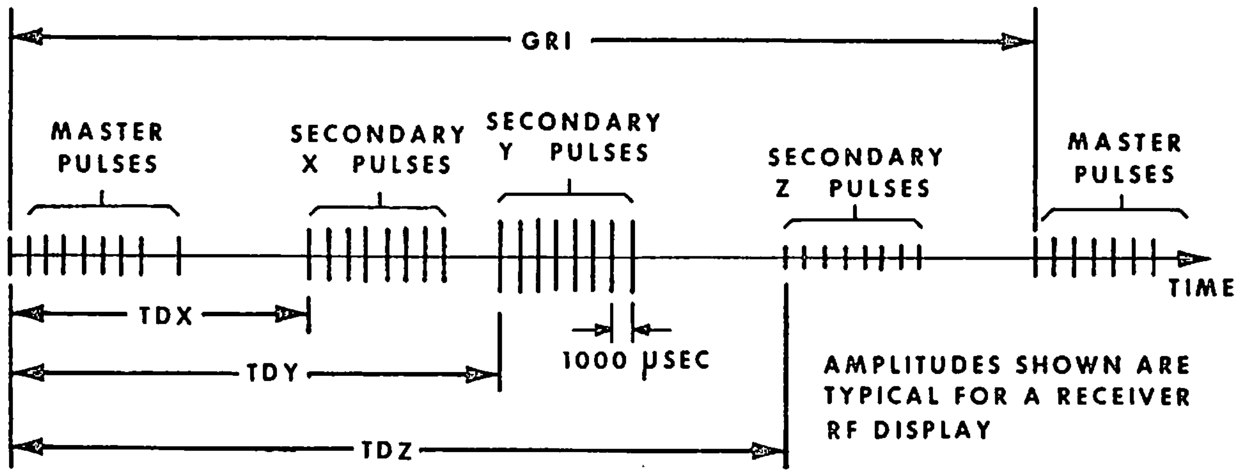
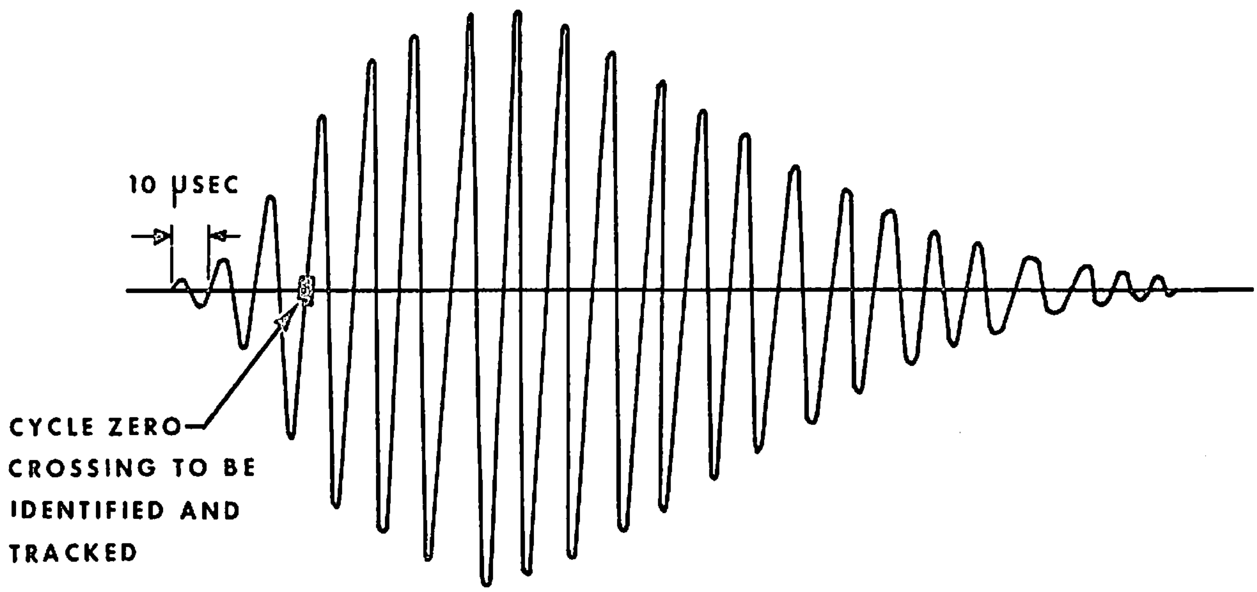


FIGURE 2 HYPERBOLIC FIX GEOMETRY



3a- EXAMPLE OF RECEIVED LORAN-C SIGNAL



3b-LORAN-C PULSE

FIGURE 3 LORAN-C SIGNAL FORMAT

TABLE I

GROUP REPETITION INTERVALS

(GRI IN MICROSECONDS)

SPECIFIC GRI	BASIC GRI				
	SS	SL	SH	S	L
0	100,000	80,000	60,000	50,000	40,000
1	99,900	79,900	59,900	49,900	39,900
2	99,800	79,800	59,800	49,800	39,800
3	99,700	79,700	59,700	49,700	39,700
4	99,600	79,600	59,600	49,600	39,600
5	99,500	79,500	59,500	49,500	39,500
6	99,400	79,400	59,400	49,400	39,400
7	99,300	79,300	59,300	49,300	39,300

NOTE: THE DESIGNATION OF A CHAIN GRI IS A COMBINATION OF THE IDENTIFICATION OF THE BASIC AND SPECIFIC GRI. FOR EXAMPLE, SL-7 DESIGNATES A CHAIN HAVING A GRI OF 79,300 μSEC

TABLE II
PHASE CODE

	MASTER	EACH SECONDARY
LORAN-C		
A GRI	++--+-+- +	+++++--+
B GRI	+--+++++ -	+-+-++--
LORAN-D		
A GRI	++++-+--++-++--+	+++-+++++-----++
B GRI	++-+-++-+-+-+++-	++--++-+++++-+--
C GRI	+-+----++---++--	+-+++-+-++-+-++-
D GRI	+-----+++++++-++	+--++---+-+----+

NOTE: (+) INDICATES ZERO DEGREE CARRIER PHASE

(–) INDICATES 180° CARRIER PHASE

LORAN-C INTERVALS A & B ALTERNATE IN TIME

LORAN-D INTERVALS OCCUR SEQUENTIALLY A,B,C,D, REPEATING IN THAT ORDER

TABLE III
LORAN-C BLINK CODE

MASTER STATION NINTH PULSE :

UNUSABLE TD(S)	ON-OFF PATTERN
NONE	▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬
X	▬ ▬▬ ▬ ▬
Y	▬ ▬▬ ▬ ▬ ▬
Z	▬ ▬▬ ▬ ▬ ▬ ▬
W	▬ ▬▬ ▬ ▬ ▬ ▬ ▬
XY	▬ ▬▬ ▬ ▬ ▬ ▬
XZ	▬ ▬▬ ▬ ▬ ▬ ▬ ▬
XW	▬ ▬▬ ▬ ▬ ▬ ▬ ▬ ▬
YZ	▬ ▬▬ ▬ ▬ ▬ ▬ ▬ ▬
YW	▬ ▬▬ ▬ ▬ ▬ ▬ ▬ ▬ ▬
ZW	▬ ▬▬ ▬ ▬ ▬ ▬ ▬ ▬ ▬ ▬
XYZ	▬ ▬▬ ▬ ▬ ▬ ▬ ▬ ▬ ▬
XYW	▬ ▬▬ ▬ ▬ ▬ ▬ ▬ ▬ ▬ ▬
XZW	▬ ▬▬ ▬ ▬ ▬ ▬ ▬ ▬ ▬ ▬ ▬
YZW	▬ ▬▬ ▬ ▬ ▬ ▬ ▬ ▬ ▬ ▬ ▬ ▬
XYZW	▬ ▬▬ ▬ ▬ ▬ ▬ ▬ ▬ ▬ ▬ ▬ ▬ ▬

SECONDARY STATION FIRST TWO PULSES:

TURNED ON (BLINKED) FOR APPROXIMATELY 0.25 SECONDS EVERY 4.0 SECONDS. ALL SECONDARIES USE SAME CODE.

Appendix A

Loran-C Data Sheets

GENERAL SPECIFICATIONS FOR DATA SHEETS

1. The latitude, longitude and baseline lengths listed herein were furnished by the U.S. Naval Oceanographic Office and are based upon Mercury Datum, Fischer Spheroid using the following parameters:

a. Signal propagation constant: Use the velocity of light in free space as 2.997942 x 10^8 meters/sec and an index of refraction of 1.000338 at the surface for standard atmosphere.

b. Phase of the ground wave: As described by Johler, Kellar and Walters in NBS Circular 573.

c. Conductivity, Sigma = 5.0 mhos/meter (seawater). Baseline electrical distance computations are made assuming a smooth all sea-water transmission path between stations.

d. Permittivity of the earth, esu:

e_2 = 80 for seawater

e. Altitude in meters:

$h_2 = 0$

f. Parameter associated with the vertical lapse of the permittivity of the atmosphere:

a = 0.75

g. Frequency:

100 kHz.

h. Fischer Spheroid:

equatorial radius (a).............6,378,166.000 meters

polar radius (b)..................6,356,784.283 meters

Flattening, F = (a-b)/a...........1/298.3

2. Inquiries pertaining to the Loran-C system should be addressed to:

Commandant (WAN-3)
U. S. Coast Guard
400 Seventh St., SW
Washington, D.C. 20590

LORAN-C DATA SHEET

U.S. EAST COAST CHAIN - RATE SS7 (99,300 μsec.)

1 October 1971

STATION	COORDINATES: LATITUDE & LONGITUDE	STATION FUNCTION	CODING DELAY & BASELINE LENGTH	MAJOR EQUIPMENT: FREQUENCY STANDARDS	MAJOR EQUIPMENT: LORAN-C EQUIPMENT	MAJOR EQUIPMENT: XMTING ANTENNA	RADIATED PEAK POWER	REMARKS
CAROLINA BEACH, N. CAROLINA	34-03-46.36N 77-54-46.19W	Master		Cesium/ URQ-11	FPN-41 (Tmr) FPN-42 (Xmtr)	TIP	1.0 MW	Transmissions synchronized to UTC. Exercises operational control of chain.
JUPITER, FLORIDA	27-01-59.09N 80-06-52.92W	W Secondary	11,000 μs 2695.48 μs	Cesium/ URQ-11	FPN-41 (Tmr) FPN-42 (Xmtr)	625 ft Tower	400 KW	
CAPE RACE, NEWFOUNDLAND	46-46-31.96N 53-10-28.51W	X Secondary	28,000 μs 8389.56 μs	Cesium/ URQ-14	FPN-46 (Tmr) FPN-45 (Xmtr)	1350 ft Tower	2.0 MW	Host nation manned. Double-rated to NORLANT chain (SL7Z).
NANTUCKET, MASSACHUSETTS	41-15-11.93N 69-58-38.76W	Y Secondary	49,000 μs 3541.27 μs	Cesium/ URQ-11	FPN-41 (Tmr) FPN-42 (Xmtr)	625 ft Tower	400 KW	
DANA, INDIANA	39-51-07.70N 87-29-11.19W	Z Secondary	65,000 μs 3560.68 μs	Cesium/ URQ-14	FPN-46 (Tmr) FPN-44 (Xmtr)	625 ft Tower	400 KW	
Electronic Engineering Center, Wildwood, N.J.	38-56-58.34N 74-52-01.10W	T Secondary	82,000 μs 2026.19 μs	Cesium URQ-11/14	FPN-38, FPN-41 & FPN-46 (Tmrs) FPN-39, FPN-42 & FPN-44 (Xmtrs)	625 ft Tower	200 KW to 400 KW	Experimental station. Not normally on air.
BERMUDA ISLAND U.K.	32-15-53.53N 64-52-34.54W	System Monitor		URQ-14	FPN-43 (Tmr)			Control for X & Y.
WARNER ROBINS, GEORGIA	32-37-28.88N 83-36-15.41W	System Monitor		5C/5P	SPN-30 (Rcvr)			Control for W & Z.

LORAN-C DATA SHEET

15 February 1972

MEDITERRANEAN SEA CHAIN - RATE SL1 (79,900 μsec)

STATION	COORDINATES: LATITUDE & LONGITUDE	STATION FUNCTION	CODING DELAY & BASELINE LENGTH	MAJOR EQUIPMENT: FREQUENCY STANDARDS	MAJOR EQUIPMENT: LORAN-C EQUIPMENT	MAJOR EQUIPMENT: XMTING ANTENNA	RADIATED PEAK POWER	REMARKS
SIMERI CRICHI, ITALY	38-52-19.89N 16-43-09.28E	Master		Cesium/ URQ-14	FPN-38 (Tmr) FPN-39 (Xmtr)	625 ft Tower	250 KW	Temporarily synchronized to UTC.
LAMPEDUSA, ITALY	35-31-12 N 12-31-24 E Approx.	X Secondary	11,000 μs 1757.12 μs	Cesium/ URQ-14	FPN-46 (Tmr) FPN-44 (Xmtr)	625 ft Tower	400 KW	Proposed station, not on air. See Note 1.
TARGABARUN, TURKEY	40-58-19.88N 27-52-04.56E	Y Secondary	29,000 μs 3273.28 μs	Cesium/ URQ-14	FPN-38 (Tmr) FPN-39 (Xmtr)	625 ft Tower	250 KW	
ESTARTIT, SPAIN	42-03-36.13N 03-12-19.68E	Z Secondary	47,000 μs 3999.68 μs	Cesium/ URQ-14	FPN-38 (Tmr) FPN-39 (Xmtr) FPN-54 (Tmr)	625 ft Tower	250 KW	
RHODES, GREECE	36-25-20.66N 28-09-31.92E	System Monitor		W-542 Com. Osc.	SPN-30 (Rcvr)			Control for X & Y. Commercial power: 380/220v, 3Ø, 50 Hz.
SARDINIA, ITALY	39-10-51.26N 09-09-35.02E	System Monitor			SPN-29 (Rcvr)			Control for Z.

Note 1: Lampedusa is the proposed replacement for the Matratin, Libya station which was disestablished in May 1970. Lampedusa may be on air for testing in the summer of 1972 using the system constants shown above.

LORAN-C DATA SHEET

1 October 1971

NORWEGIAN SEA CHAIN - SL3 (79,700 μsec.)

STATION	COORDINATES: LATITUDE & LONGITUDE	STATION FUNCTION	CODING DELAY & BASELINE LENGTH	MAJOR EQUIPMENT: FREQUENCY STANDARDS	MAJOR EQUIPMENT: LORAN-C EQUIPMENT	MAJOR EQUIPMENT: XMTING ANTENNA	RADIATED PEAK POWER	REMARKS
EJDE, FAROE ISLANDS	62-17-59.64N 07-04-26.55W	Master		Cesium/ URQ-11	FPN-46 (Tmr) FPN-44 (Xmtr) 50 Hz.	625 ft Tower	400 KW	Host nation manned. Transmissions synchronized to UTC. Double-rated to NORLANT (SL7X).
BØ, NORWAY	68-38-06.55N 14-27-48.46E	X Secondary	11,000 μs 4048.16 μs	Cesium/ URQ-14	FPN-38 (Tmr) FPN-39 (Xmtr) 50 Hz.	625 ft Tower	250 KW	Host nation manned. Control for Z.
SYLT, GERMANY	54-48-29.24N 08-17-36.82E	W Secondary	26,000 μs 4065.69 μs	Cesium/ URQ-11	FPN-41 (Tmr) FPN-42 (Xmtr) 50 Hz.	625 ft Tower	400 KW	
SANDUR, ICELAND	64-54-26.07N 23-55-20.41W	Y Secondary	46,000 μs 2944.47 μs	Cesium/ URQ-11	FPN-46 (Tmr) FPN-45 (Xmtr)	1350 ft Tower	1.5 MW	Host nation manned. Double-rated to NORLANT chain (SL7W).
JAN MAYEN, NORWAY	70-54-51.63N 08-43-56.57W	Z Secondary	60,000 μs 3216.20 μs	Cesium/ URQ-14	FPN-38 (Tmr) FPN-39 (Xmtr)	625 ft Tower	250 KW	Host nation manned. Control for X.
SHETLAND IS., U.K.	60-26-25.27N 01-18-05.22W(1) 60-26-17.49N 01-18-19.08W(2)	System Monitor		URQ-14	FPN-46 (Tmr)			Chain Operational Control Officer. Control for W & Y.

LORAN-C DATA SHEET

1 October 1971

NORTH ATLANTIC CHAIN - RATE SL7 (79,300 μsec.)

STATION	COORDINATES LATITUDE & LONGITUDE	STATION FUNCTION	CODING DELAY & BASELINE LENGTH	MAJOR EQUIPMENT FREQUENCY STANDARDS	MAJOR EQUIPMENT LORAN-C EQUIPMENT	MAJOR EQUIPMENT XMTING ANTENNA	RADIATED PEAK POWER	REMARKS
ANGISSOQ, GREENLAND	59-59-17.19N 45-10-27.47W	Master		Cesium/ URQ-11	FPN-46 (Tmr) FPN-45 (Xmtr) 50 Hz.	625 ft Tower	500 KW	Host nation manned.
SANDUR, ICELAND	64-54-26.07N 23-55-20.41W	W Secondary	11,000 μs 4068.07 μs	Cesium/ URQ-11	FPN-46 (Tmr) FPN-45 (Xmtr)	1350 ft Tower	1.5 MW	Host nation manned. Double-rated to Norwegian Sea Chain (SL3Y)
EJDE, FAROE ISLANDS	62-17-59.64N 07-04-26.55W	X Secondary	21,000 μs 6803.77 μs	Cesium/ URQ-11	FPN-46 (Tmr) FPN-44 (Xmtr)	625 ft Tower	400 KW	Host nation manned. Double-rated to Norwegian Sea Chain (SL3M).
CAPE RACE, NEWFOUNDLAND	46-46-31.88N 53-10-29.16W	Z Secondary	43,000 μs 5212.24 μs	Cesium/ URQ-14	FPN-46 (Tmr) FPN-45 (Xmtr)	1350 ft Tower	2.0 KW	Host nation manned. Double rated to U.S. East Coast Chain (SS7X).
KEFLAVIK, ICELAND	See Note 1.	System Monitor		URQ-14	SPN-30 (Rcvr)			Control for W & X. Exercises operational control of NORLANT chain.
ST. ANTHONY, NEWFOUNDLAND	See Note 1.	System Monitor			SPN-29 (Rcvr)			Host nation manned. Control for Z.

Note 1: Monitor stations physically relocated. Positions given on old data sheets no longer valid. System control established using correlated numbers. New geodetic positions not determined.

LORAN-C DATA SHEET

1 October 1971

NORTH PACIFIC CHAIN - RATE SH7 (59,300 μs.)

STATION	COORDINATES	STATION FUNCTION	CODING DELAY & BASELINE LENGTH	MAJOR EQUIPMENT			RADIATED PEAK POWER	REMARKS
	LATITUDE & LONGITUDE			FREQUENCY STANDARDS	LORAN-C EQUIPMENT	XMTING ANTENNA		
ST. PAUL, PRIBILOFF IS. ALASKA	57-09-11.11N 170-14-56.91W	Master		Cesium/ URQ-11	FPN-41 (Tmr) FPN-42 (Xmtr)	625 ft Tower	400 KW	Controls X, Y & Z.
ATTU, ALASKA	52-49-46.70N 173-10-54.58E	X Secondary	11,000 μs 3875.30 μs	Cesium/ URQ-11	FPN-41 (Tmr) FPN-42 (Xmtr)	625 ft Tower	400 KW	
PORT CLARENCE, ALASKA	65-14-41.12N 166-53-10.61W	Y Secondary	28,000 μs 3069.07 μs	Cesium/ URQ-11	FPN-41 (Tmr) FPN-42 (Xmtr)	1350 ft Tower	1.8 MW	
SITKINAK, ALASKA	56-32-21.02N 154-07-43.13W	Z Secondary	42,000 μs 3284.39 μs	Cesium/ URQ-11	FPN-41 (Tmr) FPN-42 (Xmtr)	625 ft Tower	400 KW	

LORAN-C DATA SHEET

1 October 1971

CENTRAL PACIFIC CHAIN - RATE S1 (49,900 μsec)

STATION	COORDINATES	STATION FUNCTION	CODING DELAY & BASELINE LENGTH	MAJOR EQUIPMENT			RADIATED PEAK POWER	REMARKS
	LATITUDE & LONGITUDE			FREQUENCY STANDARDS	LORAN-C EQUIPMENT	XMTING ANTENNA		
JOHNSTON IS.	16-44-43.85N 169-30-32.36W	Master		Cesium/ URQ-11	FPN-41 (Tmr) FPN-42 (Xmtr)	625 ft Tower	400 KW	Transmissions synchronized to UTC.
UPOLO POINT, HAWAII	20-14-50.27N 155-53-08.95W	X Secondary	11,000 μs 4972.44 μs	Cesium/ URQ-14	FPN-41 (Tmr) FPN-42 (Xmtr)	625 ft Tower	400 KW	
KURE, MIDWAY ISLANDS	28-23-40.66N 178-17-29.94W	Y Secondary	29,000 μs 5253.02 μs	Cesium/ URQ-11	FPN-41 (Tmr) FPN-42 (Xmtr)	625 ft Tower	400 KW	
FRENCH FRIGATE SHOALS	23-52-05.23N 166-17-19.60W	System Monitor		5C/5P Com. Osc.	SPN-29 (Rcvr)			Controls X & Y.

LORAN-C DATA SHEET

1 October 1971

NORTHWEST PACIFIC CHAIN - RATE SS3 (99,700 μs)

STATION	COORDINATES LATITUDE & LONGITUDE	STATION FUNCTION	CODING DELAY & BASELINE LENGTH	MAJOR EQUIPMENT FREQUENCY STANDARDS	LORAN-C EQUIPMENT	XMTING ANTENNA	RADIATED PEAK POWER	REMARKS
IWO JIMA, BONIN ISLANDS	24-48-04.22N 141-19-28.71E	Master		Cesium/ URQ-11	FPN-46 (Tmr) FPN-45 (Xmtr)	1350 ft Tower	3.0 MW	Transmissions synchronized to UTC.
MARCUS ISLAND	24-17-07.79N 153-58-51.20E	W Secondary	11,000 μs 4283.94 μs	Cesium/ URQ-11	FPN-46 (Tmr) FPN-45 (Xmtr)	1350 ft Tower	3.0 MW	
HOKKAIDO, JAPAN	42-44-33.40N 143-43-04.82E	X Secondary	30,000 μs 6684.70 μs	Cesium/ URQ-11	FPN-46 (Tmr) FPN-44 (Xmtr)	625 ft Tower	400 KW	
GESASHI, OKINAWA	26-36-21.45N 128-08-53.76E	Y Secondary	55,000 μs 4463.34 μs	Cesium/ URQ-11	FPN-46 (Tmr) FPN-44 (Xmtr)	625 ft Tower	400 KW	
YAP, CAROLINE IS.	09-32-45.84N 138-09-54.93E	Z Secondary	75,000 μs 5746.78 μs	Cesium/ URQ-14	FPN-46 (Tmr) FPN-45 (Xmtr)	1000 ft Tower	3.0 MW	
SAIPAN, MARIANA IS.	15-07-47-07N 145-41-37.62E	System Monitor			SPN-30 (Rcvr)			Controls W & Z.
FUCHU, JAPAN	See Note 1.	System Monitor		Cesium	SPN-30 (Rcvr)			Controls X & Y. Time Service Monitor.
	Note 1: System control established using correlated numbers. Precise geodetic data unknown.							

LORAN-C DATA SHEET

1 October 1971

SOUTHEAST ASIA CHAIN - RATE SH3 (59,700 μsec)

STATION	COORDINATES	STATION FUNCTION	CODING DELAY & BASELINE LENGTH	MAJOR EQUIPMENT			RADIATED PEAK POWER	REMARKS
	LATITUDE & LONGITUDE			FREQUENCY STANDARDS	LORAN-C EQUIPMENT	XMTING ANTENNA		
SATTAHIP, THAILAND	12-37-05.00N 100-57-38.15E	Master		Cesium/ URQ-14	FPN-46 (Tmr) FPN-44 (Xmtr)	625 ft Tower	400 KW	
LAMPANG, THAILAND	18-19-30.98N 99-22-50.15E	X Secondary	11,000 μs 2182.87 μs	Cesium/ URQ-14	FPN-46 (Tmr) FPN-44 (Xmtr)	625 ft Tower	400 KW	
CON SON, RVN	08-43-17.69N 106-37-59.12E	Y Secondary	27,000 μs 2522.12 μs	Cesium/ URQ-14	FPN-46 (Tmr) FPN-44 (Xmtr)	625 ft Tower	400 KW	
TAN MY, RVN	16-32-41.03N 107-38-37.23E	Z Secondary	41,000 μs 2807.30 μs	Cesium/ URQ-14	FPN-46 (Tmr) FPN-44 (Xmtr)	625 ft Tower	400 KW	ATLS Station.
UDORN, THAILAND	17-22-37.08N 102-47-15.37E	System Monitor		URQ-14	FPN-46 (Tmr)			Controls X, Y & Z.

LORAN-C DATA SHEET

RUSSIAN CHAIN

15 February 1972

STATION	COORDINATES	STATION FUNCTION	CODING DELAY & BASELINE LENGTH	MAJOR EQUIPMENT			RADIATED PEAK POWER	REMARKS
	LATITUDE & LONGITUDE			FREQUENCY STANDARDS	LORAN-C EQUIPMENT	XMTING ANTENNA		
ORIOL, USSR	36-05- N 52-56- E	Master						Master function presumed because of central location.
PETROZAVODSK, USSR	61-48- N 34-19- E							
BARANOVITCHI, USSR	53-08- N 26-01- E							
SIMFEROPOL, USSR	44-58- N 34-02- E							
KUIBYCHEV, USSR	53-11- N 49-46- E							
	Note: The above information appeared in the International Frequency Registration Board's Weekly Circular 914 dated 30 June 1970. The USSR notified the ITU/IFRB of their intention to implement a pulsed (20P9) radionavigation system on 100 kHz. This data sheet will be updated upon receipt of additional information.							

APPENDIX B

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