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WILD GOOSE ASSOCIATION

RADIONAVIGATION JOURNAL

1976

FILE COPY

for the best . . . .

international navigation corporation

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EDITORIAL

The JOURNAL is now an established institution – well nearly so! Your response to last year's edition was heartening. All copies were sent to members or sold by April. But, we need your response. There were requests for help in last year's JOURNAL, specifically, the Loran Associated Business and Membership List sections. Although we suspect that we are less than perfect, there were no reports of erroneous information, misspelling, or requests to add information.

Now we are looking for even more member participation in determining the content of the JOURNAL. If you have an idea for an article of general interest, even if you don't desire to write it, please tell us. We are, of course, always looking for contributors, and although we cannot pay you for writing, there is no "page charge" if your material is published.

We have made a major publication policy decision this year, which we think will be helpful to our members and friends, and will improve the stature of the WGA. Enclosed with your JOURNAL is a copy of WGA Pub. #I/76, entitled "Loran-C System Characterization". You will recognize it as the Loran-C System Description published last year. It has been corrected for errors, which were pointed out and is the first of a series of publications on Loran-C, which are yet to come. It is our plan to publish the "WGA Pub. # " series on various aspects of Loran-C. We will maintain a stock of these Pubs even though the stock of a particular year's JOURNAL becomes depleted. The Pubs will be up-dated only as significant factors change or errors are discovered. Next year, Pub. #2/77 will be the Loran-C Receiver Characterization contained in this year's JOURNAL. Our thought is that a Pub on Coordinate Conversion and Guidance Algorithms would be appropriate; also one on Propagation would be very useful. Your ideas are very much of interest to us. Please speak-up.

Once again, I must recognize the indefatigable Bahar Uttam, for his efforts to create the 76 JOURNAL. Bahar has borne the brunt of the work load since I was transferred from Boston in the middle of putting it all together. Many thanks also to John Hanna of DMAHC and Gil Nelson of Simrad, Inc. for their help in gathering and correcting chain and chart data.

BILL ROLAND
Editor

U.S. House of Representatives
Committee on
Merchant Marine and Fisheries
Room 1334, Longworth House Office Building
Washington, D.C. 20515

August 2, 1976

FOREWORD

In the two years since Loran-C was designated as the national radio-navigation system for the Coastal Confluence Zone of the United States, excellent progress has been made toward achieving the expanded and improved signal coverage prescribed in the plan. Further, significant progress has been made with regard to user equipments from both cost and technical performance viewpoints. Most gratifying to me, however, is the way the potential marine users have been accepting the system, together with the way that a whole new set of potential applications has evolved in such diverse areas as urban vehicle location, forestry management, and general aviation. This is certainly in keeping with the goal of having one government-provided system to meet the needs of as many user categories as possible.

I congratulate the Wild Goose Association for its efforts on behalf of Loran, as typified by this publication, and I look forward to a continuation of the kind of cooperation among the Congress, the Department of Transportation and other government agencies, and the Loran community, which has made possible the progress of the past years.

Sincerely,

Mario Biaggi

MARIO BIAGGI, CHAIRMAN
Subcommittee on Coast Guard
and Navigation

MB:FHem

CONTENTS

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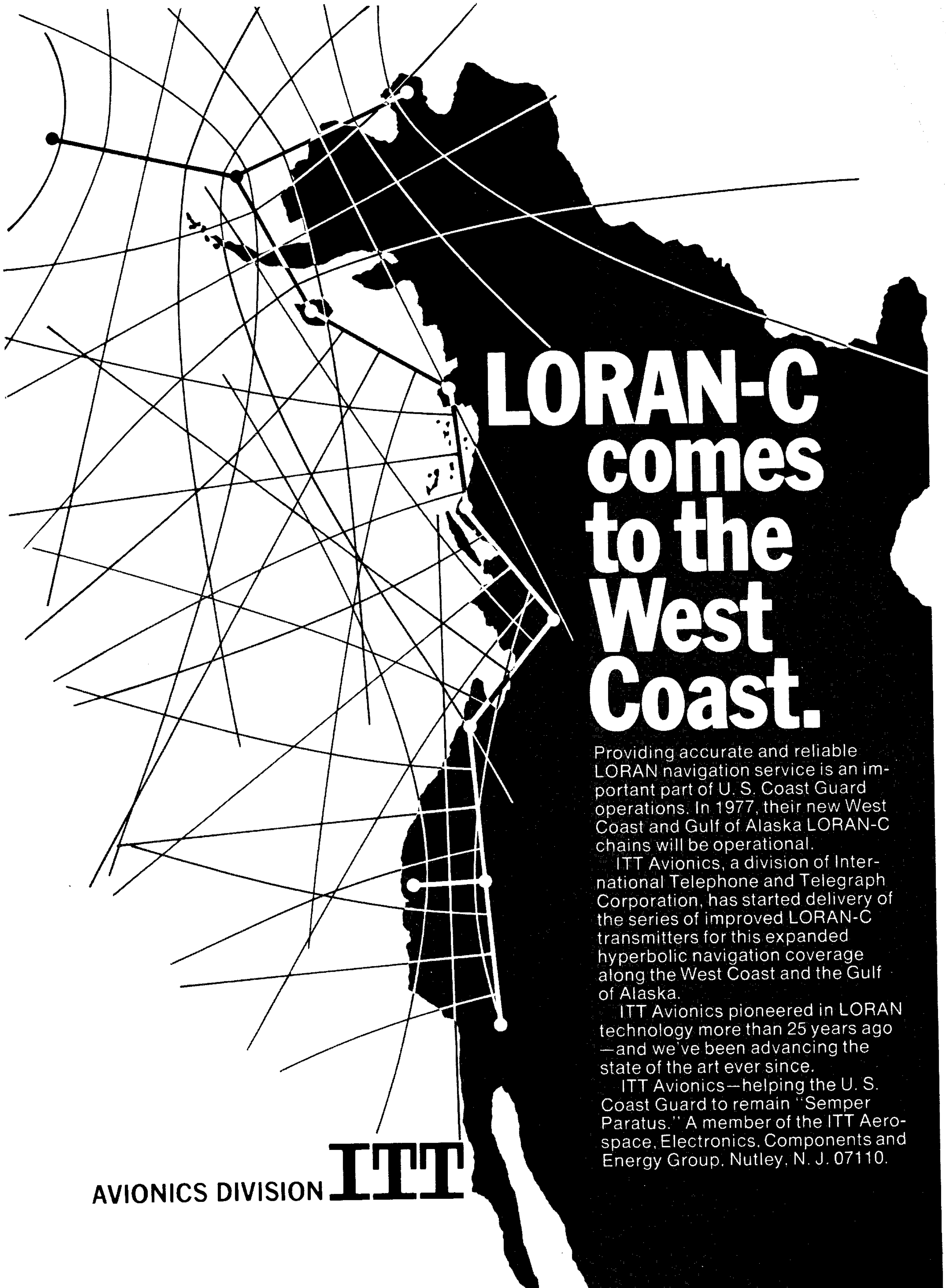

LORAN-C comes to the West Coast.

Providing accurate and reliable LORAN navigation service is an important part of U. S. Coast Guard operations. In 1977, their new West Coast and Gulf of Alaska LORAN-C chains will be operational.

ITT Avionics, a division of International Telephone and Telegraph Corporation, has started delivery of the series of improved LORAN-C transmitters for this expanded hyperbolic navigation coverage along the West Coast and the Gulf of Alaska.

ITT Avionics pioneered in LORAN technology more than 25 years ago —and we've been advancing the state of the art ever since.

ITT Avionics—helping the U. S. Coast Guard to remain "Semper Paratus." A member of the ITT Aerospace, Electronics, Components and Energy Group, Nutley, N. J. 07110.

AVIONICS DIVISION ITT

PRESIDENT'S PAGE

Loran-C implementation progress and new implementation initiatives for commercial application during 1975 and 1976 have been exciting, and it is gratifying to see the effective contributions of the Wild Goose Association and its individual members to this progress and to these new initiatives. Loran-C headline actions and events for 1976 include:

- USCG West Coast Loran-C implementation nears completion. Operational date is January 1977.
- USCG St. Mary's River Loran-C Project develops convincing proof that Loran-C can be useful for Harbor and Estuary Navigation applications.
- Iceland, Norway, Canada, Mexico, and Venezuela are among nations to consider Loran-C and its potential to satisfy their national navigation requirements.
- DOT creates Loran-C Applications Project under the Assistant Secretary for Systems Development and Technology.
- State and Federal agencies study economic utility of Loran-C for various terrestrial and/or airborne area navigation applications.

The WGA, as an organization, is attempting to address itself to the membership needs and to the new initiatives wherever it can be effective and supportive. For instance,

- Useful Loran-C data is published or up-dated in this Journal.
- Loran-C System Characterization has been prepared by WGA committee.
- WGA has worked to initiate and support preparatory actions to address the goal to eliminate interference between Loran-C and other authorized services in the 90-110 KHz band during the 1979 General World Administrative Radio Conference.
- Loran-C receiver description, in laymen's language, is being prepared by WGA committee.
- WGA expanded newsletter is keeping membership advised of Loran-C news and actions by your Board of Directors and WGA committees.

I think the WGA continues to serve its constitutional Aims and Purposes well but there is no doubt it could do even better. Toward this end, I urge you to support our new President, John Beukers, and the new Board of Directors during the coming year.

Jim VanEtten, President 1974-1976

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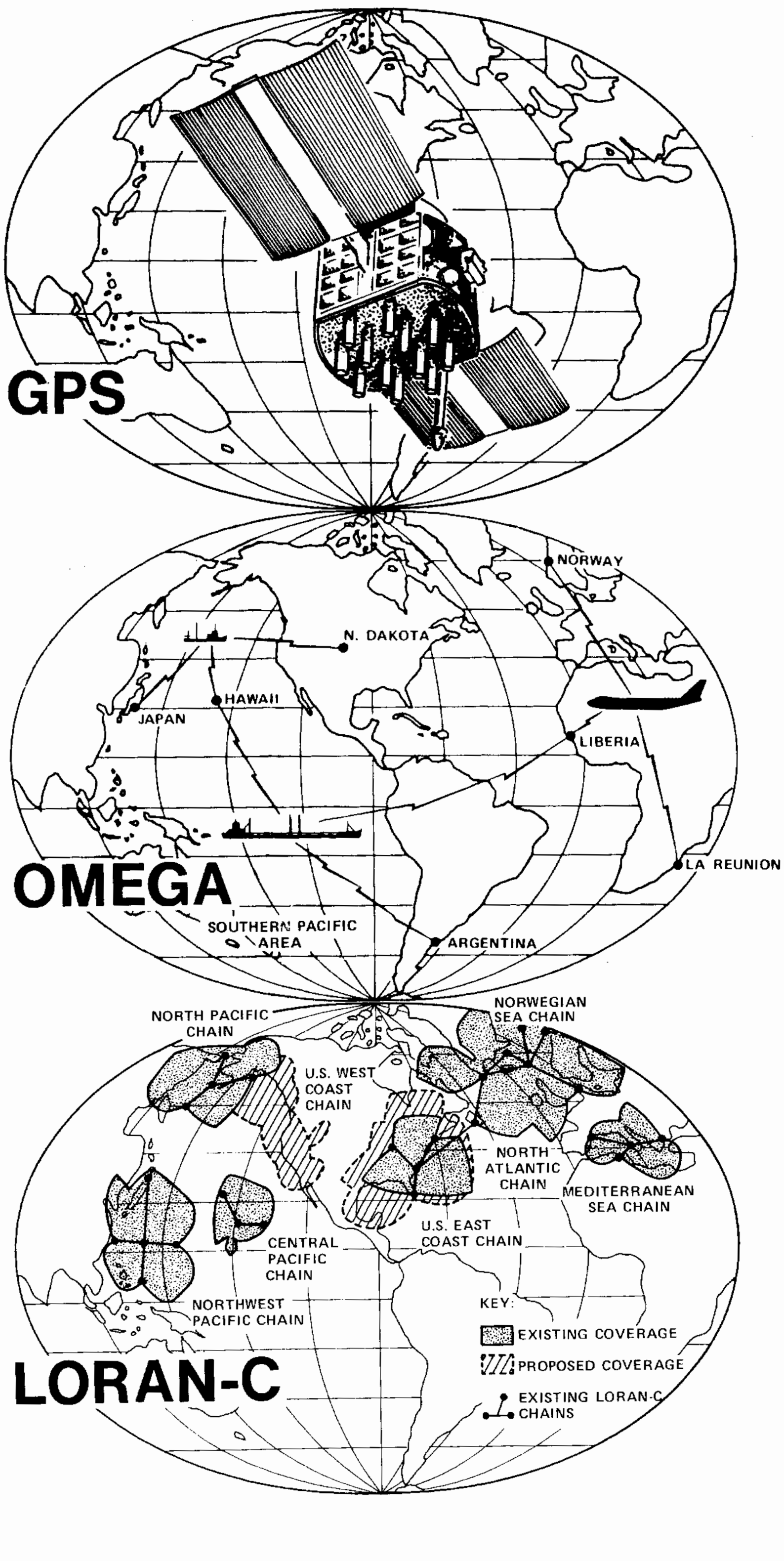

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LORAN-C RECEIVING SETS

FUNCTIONS, CHARACTERIZATION, AND SPECIFICATION

The comparative description and operation of Loran-C Receiving Sets has been a source of confusion to users since the first Loran-C receiving sets came on the market. Such phrases as "envelope tracking", "automatic tracking", "cycle selection", and "automatic acquisition" are often used, but seldom defined.

We propose here a set of definitions and standard phrases for the description of functions and characterization of Loran-C receiving sets and a standard form for the specification of Loran-C receiving sets. We do not expect that this proposal will stand as is, because of the limited participation in its preparation. However, we do expect that it will be used as a "straw man" to be developed into a set of industry standards, accepted and published by the Wild Goose Association.

This proposal does not attempt to set standards beyond the function of a numerical display (visual or electrical) of the time parameters of the received Loran-C signals. The functions of analysis of signal parameters, coordinate conversion, and display of navigation and guidance information is left to another standard.

In the description of functions, we have attempted to generalize, and in so doing, have considered operations and decisions performed by humans and those performed by electronic circuits as being functionally equivalent. This eases the problems of definition, but causes the definitions to ignore many other intelligent functions performed by humans. Suggestions which claify wordings in this area will be particularly welcome.

This standard is divided in four parts:

1. Definition of receiving sets functions. This discusses the generalized functions without addressing particular circuit implementations, but does identify set characterizations by degree of operator participation in those functions.

2. Signal processing alternatives. This attempts to identify the characteristics of a number of circuit implementations of set functions without discussing comparative merits and demerits.

3. Performance Testing and Claims. This is an attempt to outline the format, and define the terms and test procedures, for the specifications claimed by manufacturers.

4. Receiving Set Specifications. A recommended Loran-C specification sheet is presented.

1.0 RECEIVING SET FUNCTIONS

There are four major functional states through which any receiver must pass in order to obtain information suitable for navigation. Since it is possible to conceive a receiving set which is not useful for navigation, and therefore, does not enter these functional states, it is first necessary to define a Loran-C receiving set.

1.1 DEFINITION

A Loran-C Receiving Set is a device which receives radio waves from one or more Loran-C transmitting stations, processes those signals to measure time parameters of the signals and displays the results of the measurements for use in navigation or position determination.

1.1.1 In clarification, the word "device" is considered to include an antenna, interconnecting cables, antenna coupler, and one or more interconnected units in which processing, measurement and display occur. Further, the "device" may be a portion of a more general device which includes the Loran-C Receiving Set as only a portion of its total functional capability. A device claimed to be a Loran-C receiving set, which does not include all these elements, must include that fact in its description.

1.1.2 "Receives radio waves" means that either (or both) the E-field or H-field of the electromagnetic waves are converted to electrical signals for processing. The description of a set should clearly state the type of antenna being used.

1.1.3 Loran-C Transmitting Station and its transmitted signal are defined in the Loran-C System Characterization, WGA publication No. 1/1976.

1.1.4 "Processing those signals to measure time parameters" includes such circuit processes as analog signal filtering, amplification, cross correlation, and digital processing of sampled signals.

1.1.5 "Display" includes not only visual numerical displays, but electrical signals, which are representative of information which might have been visually displayed. This generalized definition is used to accommodate Loran-C receiving sets, which do not display time parameters as a normal function, but perform coordinate conversions processes.

1.2 LORAN-C RECEIVING SET FUNCTIONAL STATES

All receiving sets, by virtue of the information to be derived from Loran-C signals for navigation must enter each of four functional states for each of the station's signals to be used. A functional state is the setting of certain control conditions to accomplish a certain action within the set. The four functional states are:

Initialization

Acquisition

Pulse Group Time Reference Identification

Tracking

1.2.1 INITIALIZATION

Initialization is the process of providing to the set all a-priori knowledge of the signals to be tracked and of adjusting the set to minimize the effects of interference. Initialization may include GRI selection, estimates of secondary time difference, estimates of expected envelope-to-cycle difference, adjustment of interference filters, setting of clipping levels and/or the determination to search for the strongest signal. In any case, the unique characteristics of initialization are that it is accomplished by a force external to the set, is prerequisite to any following states, and provides to the set the identification of the signals to be ultimately processed and tracked for navigation information.

Initialization may be accomplished by the operator or by devices outside the Loran-C Receiving Set. Whether the set provides estimates of time parameters by deriving the best chain and secondaries and predicting time differences, or these are done by the operator, all sets require initialization and there is an infinite variety of levels of automation. Therefore, no standard nomenclature or set type identification is related to initialization procedures. However, the parameters to be initialized are categorized in the paragraphs below.

1.2.1.1 RATES

A set which requires that all signals be on the same chain rate is called a "single rate" set. Equipment whose rate selection is factory or shop set is a fixed rate set. If signals may be on two rates, it would be called a "dual rate" set. Sets which are more generalized are "multi-rate" sets.

1.2.1.2 TIME REFERENCE

Receiving sets most commonly utilize the master station for time reference initialization on any rate which is tracked. This provides a time location for secondary search, even if time information from the master is not to be used. Set timing would be considered "master referenced". If, however, an external clock is needed to provide a time reference, or the set must be continually in operation to maintain its own time reference, then that it requires "clock referenced" initialization, must be noted.

1.2.1.3 STATIONS AND PAIRS

Sets may track any number of stations from one to the total number of signals available, although eight is a practical maximum without losing too many samples to overlapping signals. The result of tracking is a "time of arrival" (TOA) measurement or a "time difference" (TD) measurement. One station must be tracked for each TOA measurement and two for each TD measurement. Note that tracking three stations would permit up to three TD's to be measured, and of those three, one is totally redundant. Therefore, a set may be described as tracking a number of stations, number of non-redundant pairs, a whole chain or a number of cross-chain (between stations of different chains) pairs.

Summarizing the initialization descriptors applied to sets:

RATES	TIME REFERENCE	NUMBERS & KINDS OF STATIONS OR PAIRS	MEASUREMENT PROCESS
Fixed rate Single rate Dual Rate Multi-Rate	Master Referenced Clock Referenced	X Stations Y Stations Z Cross-Chain Pairs Whole Chain	Time of Arrival (TOA) Time Difference (TD)

TABLE 1.2.1 INITIALIZATION DESCRIPTORS

Examples:

A) The most common receiver is:

A single-rate, master-referenced, two-pair, time difference set.

B) The Micrologic 1000 is:

A single-rate, master-referenced, whole chain, time difference set.

C) The Austron 5000 is:

A multi-rate, clock-referenced, eight station, time of arrival set.

1.2.2 ACQUISITION

1.2.2 Acquisition is the process of searching for and locating, approximately in time, the signals identified during initialization. Generally, a set will locate the signals from each station in time slots, called "intervals", which repeat at the group repetition interval. Each interval must be identified to associate it with the display. Generally, the master is the set time reference in a TD set and is not displayed. The secondary intervals are identified A and B in a two pair set or W,X,Y, and Z in a whole chain set.

1.2.2.1 SEARCH

The mechanization of search is very much dependent on the automation and displays built into the set. In a manual search, the received signals are displayed on an oscilloscope and cross-correlation is performed by the operator. For automatic search, there is no oscilloscope. The set samples the received signals, compares the samples with the known characteristics of the signal, and recognizes a good match. Because Loran-C is designed to operate when signal-to-noise ratios are low, often the set will have narrowbanding circuits to minimize the effects of noise on the search process. However, narrowbanding circuits may adversely effect the next functional state, and so are switched out of the process after search is completed.

1.2.2.2 MANUAL SEARCH

There are two general forms of manual search, pulse alignment and phase code. In manual pulse alignment, the detected master signal is displayed and identified by its ninth pulse, and the pulse group moved to the left edge marker of the oscilloscope. In manual phase code search, the signals are phase decoded and displayed in eight overlapping 1000 μs sweeps on the oscilloscope. When the master signals are properly placed, all signals on the oscilloscope appear to overlap exactly. Similar steps are used to find the secondary stations' signals. These search methods are not generally operable to the lowest advertised signal-to-noise ratios in Loran-C coverage.

1.2.2.3 AUTOMATIC SEARCH

Automatic search invariably operates on the phase code of the signals and cross-correlates an approximation of the known signals with the received signals. Generally, automatic search will operate at lower signal-to-noise ratios than manual search, and can be designed to search much more quickly by multipoint search for master (simultaneous cross correlation in several intervals) and limited range search for secondaries. (Secondary search only over the range of TD's known to be the minimum to maximum possible for the desired secondary). When the correlation reaches a certain value, after assuring that no false locks have occurred on secondary signals, acquisition is complete.

1.2.2.4 SPECIAL CASES OF ACQUISITION

The acquisition process includes search for all signals called for in initialization. However, because the signals are sequential, and speed of acquisition is dependent on signal-to-noise ratio, some signals may be acquired before others. The set may then permit the signal processing to go to the next functional state on the acquired signals before acquisition is complete on the most difficult signals. This is called 'segmented acquisition'. When segmented acquisition is used, it permits the operator to change initialization on one of the secondaries and repeat acquisition in that interval without disturbing the functional states of other intervals. This function is appropriate when operating in regions of a chain where the best secondaries change due to geometric considerations, and is called 'Alternate Secondary Acquisition'. If the time sequence of intervals may be reversed without adverse effects, this is 'Inverted Sequence Secondary Acquisition'.

1.2.2.5 ACQUISITION SUMMARY

The specification should identify these acquisition features:

Acquisition Function

Automatic Acquisition

Manual Acquisition, Pulse Alignment or Phase Code

Search Features

Narrow Band Search

Multipoint Master Search

Maximum Signal Strength Search

Secondary Correlation Master Search Check

Acquisition Features

Segmented Acquisition

Alternate Secondary Acquisition

Inverted Sequence Secondary Acquisition

1.2.3 PULSE GROUP TIME REFERENCE (PGTR) IDENTIFICATION

PGTR Identification is the process of assuring that the receiver is operating on the groundwave of the signals, and then adjusting the receiver timing for a specified time relationship to the PGTR. The following discussions address only the PGTR, which relates to the first pulse in a group. Sets which process all eight pulses in a group, combine all data into quantities which can be related to the first pulse. "Multipulse processing" is used to improve the SNR of the data, but does not add new data. Assuring operation of the groundwave, sometimes called guard sampling or groundwave location, operates on the principle that the groundwave signal from a station always arrives at a receiver before the skywave, because of the longer skywave path. Therefore, the earliest arriving signal from a station must be the groundwave. It is necessary to find the groundwave because its timing (and therefore its position locating qualities) are stable, while the skywave is not. The "specified time relationship" to the PGTR is a design factor chosen in manufacture. All sets have a time reference for each signal, (internal timing trigger or sampling strobe) which is related directly to the readout. That time reference must have the same relationship to each signals' PGTR for the readout to be correct.

1.2.3.1 GROUNDWAVE LOCATION

The PGTR Identification process presumes that acquisition has located the signals, but with only a gross estimate of the time relationship to the PTGR. Typically, skywaves, although delayed with respect to groundwaves, are much larger in amplitude and, therefore, are more likely to be located in the acquisition process. Groundwave location looks ahead (earlier in time) of the receivers time reference, usually 30 to 60 μs, for signals. If signals are found, the receiver timing is advanced and the process repeated. This continues until no signals are found at two or more successive locations. More than one test is made after no signals is detected to account for the possibility of the groundwave and skywave signals summing out-of-phase and creating a null which might otherwise be presumed to be the start of the groundwave. In a manual receiver, the operator must move the receiver timing and increase the signal gain while observing the oscilloscope to assure tracking on the groundwave.

1.2.3.2 CYCLE SELECTION

Adjusting the set's time reference to the specified time relationship with the PGTR is the most critical and difficult to achieve. The PGTR is defined in terms of an RF cycle zero crossing, which can be identified by the first and second derivatives of the envelope at the PGTR (called cycle selection). A set is not required to identify the PGTR, but may use some other time reference point defined by the envelope shape and a cycle zero crossing. The same time reference point must, of course, be used on the signals from all stations.

The use of envelope shape to adjust the set's time reference is complex, because of the many factors which effect the shape, and because slight distortions may result in considerable change of the first and second derivatives. The shape of the transmitted signal is accurately specified and reasonably well maintained. However dispersion in the propagation medium alters the shape. Then the bandpass and notch filters used on the set's input circuits cause further distortion. With care in the design, these factors can be accommodated.

1.2.3.2.1 ENVELOPE TRACKING SETS

Envelope tracking sets use non-coherent detection of the envelope and compare the envelope slope of the leading edge of the master and secondary signals using either the first pulse of each group or the mean slope of eight pulses. In either case, the slope is dependent on skywave conditions, receiver gain settings and the design trade-offs of narrowbanding the front end for reducing noise effects and wide banding to reduce slope distortions. The set's time reference is used to trigger the oscilloscope. The timing and gain are adjusted to overlay the leading edges of master and secondary pulses to complete PGTR Identification.

1.2.3.2.2 CYCLE TRACKING SETS

Cycle tracking sets use coherent detection or directly sampled RF, which permits operation below 0 dB SNR and the use of statistical processing of sampled signals. The received signals may be processed in an "envelope deriver" circuit, which alters the pulse envelope so that it passes through zero amplitude at a point near the PGTR. The set then samples this derived envelope waveform to find the zero point of the derived envelope. Alternatively, the set may take sequential samples of envelope amplitude and compute the ratio of these samples. Either technique operates to generate an envelope error signal, which goes to zero when the signal sampling, and hence the receiver timing reference is properly placed. The set must be so designed that envelope distortions caused by propagation dispersion or by the set's front end filters will not shift the zero point by more than 5 μs. When the envelope error signal is zero, the nearest cycle zero crossing of proper direction is selected as the tracking point. This is called "cycle selection".

1.2.3.3 PGTR IDENTIFICATION SUMMARY

The PGTR Identification features which should be specified are:

Groundwave Location Process

- Guard Sampling
- Sequential Sampling
- Step Intervals in μs

Cycle Selection

- Derived Envelope, Delay and Add
- Derived Envelope, Derive and Add
- Derived Envelope, Derive and Add
- Ratio Sampling
- Envelope Shape Comparison (Manual Only)

1.2.4 TRACKING

Tracking is the process of maintaining a constant time relationship between the set's time reference and the PGTR for each signal being tracked. Tracking in a manual set amounts simply to the operator adjusting the controls to maintain alignment of the master and secondary pulses. He must cease tracking to obtain a reading. In an automatic tracking set, circuits within the equipment automatically adjust the time reference and up-date the display to provide continuous readings.

1.2.4.1 ALARMS

While tracking, automatic sets generally provide auxiliary functions to advise the operator of undesirable signal conditions. If a station goes off air, the set would be expected to indicate "lost signal" or "low SNR". Problems at transmitting stations are indicated by the transmitter turning the first and second pulses on and off, or blinking. This could be indicated by a "blink alarm".

1.2.4.1.1 ENVELOPE ERROR ALARMS

When a set is tracking automatically, the question arises as to the meaning of "envelope error" and what indication or action should be initiated by the set. Each manufacturer has opted for a design which he believes best serves the navigator.

The design question is: When a set has been properly initialized, acquisition and PGTR Identification have been completed and the set is automatically tracking, what action should be taken when the envelope error exceeds the level at which the set would change cycle selection, if it were still in the PGTR Identification mode.

a. If the conditions are as described, no action is necessary, as only noise or a fault in the receiver must have caused the envelope error to increase.

b. If PGTR Identification occurred in noisy conditions, the wrong cycle may have been selected, and therefore, the set should be allowed to jump 10 μs.

c. If a station was momentarily off air, the set may have drifted 10 μs or more off and the set should be allowed to cycle select.

Possible alarm indications are:

envelope error

envelope jump

station has been off-air (history alarm)

Summary of tracking features to be specified:

Automatic Cycle Tracking

Automatic Envelope Tracking

Manual Envelope Tracking

Lost Signal Alarm

Low Signal-to-Noise Ratio Alarm

Blink Alarm

Automatic Cycle Selection While in Track

Inhibited Cycle Selection While in Track

Envelope Error Alarm

Envelope Jump Alarm

SNR History Alarm

2.0 RECEIVING SET SIGNAL PROCESSING

In this section, circuit implementations of the various set functions are examined to point out some of the more esoteric design considerations. To facilitate the discussions, the set is divided into functional elements coinciding with the following paragraphs. This is indicated pictorially below:

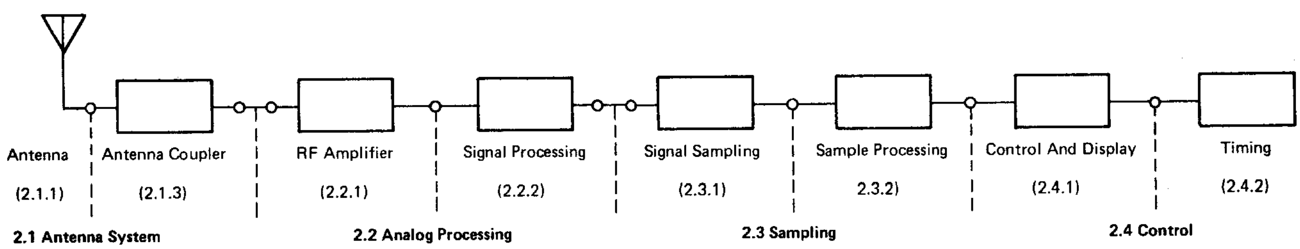


FIGURE 2-0

2.1 ANTENNA SYSTEM

The antenna and coupler have three distinct functions to perform; coupling to the electromagnetic field, bandpass filtering, and matching to the receiver. Both elements are integrally involved in each of the functions. One cannot be fully described without the other.

2.1.1 COUPLING TO THE ELECTROMAGNETIC FIELD

The received Loran-C groundwave signal is vertically polarized and so must be the receiving antenna. Further, the antenna must have a uniform phase pattern in the horizontal plane. These conditions are necessary if the antenna phase characteristic is not to be a part of the navigation computations! The simplest antenna to meet these requirements is a vertical whip (E-field antenna) over an infinite flat conducting plane. The infinite flat conducting plane is difficult to achieve on most moving vehicles and so compromise is necessary. A vertical whip mounted above a surface which is conductive and whose structure is flat compared to the antenna (25% the antenna height), and having no significant masses of grounded surfaces above it, will reasonably fill the bill. For the most part, land based vehicles' and ships' requirements can be satisfied by a well placed whip. However, aircraft run into a third factor, noise from precipitation static and static discharge. There are two solutions; low profile, semi-conducting surface E field antennas, and loop antennas. Well placed E field antennas can minimize the problem satisfactorily. A belly mounted flat plate antenna has proven successful, as well as a short vertical height (8" to 12") antenna with a long (4' to 8') horizontal top loading section have proven reasonably successful. These antennas should not be near the nose or tail of the aircraft. The so-called "tail-cap" antenna has been particularly unsuccessful because of its proximity to static discharge points and its badly distorted gain and phase patterns.

Loop antennas (H-field) are good alternative solutions for precipitation static and static discharge noise as well as for small physical size. Loops are also easier to construct, as a ground plane is not needed. However, these advantages must be traded off against their sensitivity to vehicle skin currents, which requires a surface survey to locate the optimum antenna placement. Also, since loop antennas do not have uniform phase patterns, phase corrections dependent on the relative bearing of the transmitted stations must be applied when processing the signals.

2.1.1.1 ANTENNA EFFECTIVENESS

Antenna effectiveness (AE) is a measure of the antenna ability to couple energy into the receiver. For E-field antennas, the measure is the product of the effective height (h_e) and the antenna capacitance (C_A).

$$AE = h_e C_A$$

h_e is in meters

C_A is in picofarads

For H-field antennas

$$AE = h_e / L_A$$

h_e is in meters

L_A is in microhenries

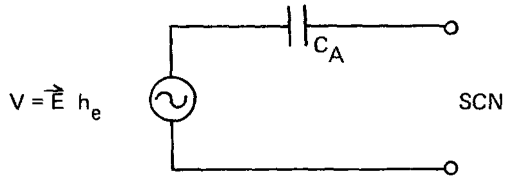
The antenna effectiveness can be seriously degraded by long cable runs between the antenna and coupler. Therefore, in installation design, minimum separation of the units should be required. To reduce the chance of such installation errors, some manufacturers offer integral antenna/coupler units.

2.1.2 SPACE COUPLING NODE (SCN)

The SCN is the electrical point of connection from the antenna to the antenna coupler. Its significance is as a connection point for simulated signals used in testing the receiver.

2.1.2.1 SIMULATED ANTENNAS

Simulated antennas are used to insert signals into the Loran-C receiver at the SCN. The simulated antennas is a lumped circuit equivalent of the receiving antenna. Since the antennas are extremely small compared to a wavelength, and radiation resistance is an insignificant part of the antenna impedence; the simulated antenna is a simple Thevenin or Norton equivalent. For an E-field antenna, the Thevenin equivalent is used:



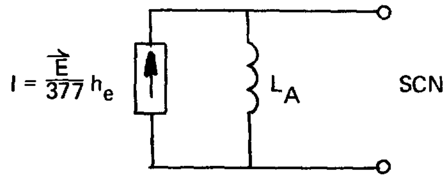
E = field strength in microvolts per meter

h_e = effective height of the antenna in meters

C_A = capacitance of the antenna as seen looking in at the SCN.

FIGURE 2.1.2 A EQUIVALENT E-FIELD ANTENNA

For an H field antenna, the Norton equivalent is used:



E and h_e are as described in Figure 2.1.2A

L_A = inductance of the antenna as seen looking in at the SCN

FIGURE 2.1.2B EQUIVALENT H-FIELD ANTENNA

If interconnecting cable is used in an installation, it should be considered as a part of the antenna and connected between the simulated antenna and the SCN.

2.1.3 ANTENNA COUPLER

The antenna coupler matches the antenna impedance, provides bandlimiting and gain, and matches the cable connecting the coupler output to the receiver. The coupler may also provide for insertion of standard signals for set calibration.

2.1.3.1 ANTENNA MATCHING

There are two general types of antenna matching: tuned coupling and broadband coupling. Tuned coupling utilizes the antenna impedance to provide a reactance element of a bandpass limited circuit and is designed to maximize energy transfer from the antenna. Braodband coupling does not derive any significant bandpass limiting from the antenna reactance. This generally requires that gain be provided in the coupler, and permits using the same antenna for receiving other services in other bands.

2.1.3.2 BANDPASS LIMITING

If tuned coupling is used, the coupling circuit becomes a part of the set's overall bandpass characteristic. The coupler must, on installation, be adjusted for the reactance of the actual antenna installed. No tuning adjustments are required on braodband coupled circuits. However, in both cases, band-limiting is required in the Loran-C signal path for noise reduction and elimination of out-of-band signals. In most designs, most of the bandpass limiting is done in the antenna coupler, with some final tuned circuits, in some cases with switched Q, in the receiver. The switched Q circuit permits narrowband RF for the search mode, and wideband for PGTR Identification and tracking. Typical search bandwidths are 4 to 8 kHz. Manual receivers generally use a 10 to 16 kHz RF bandwidth, and for accurate PGTR Identification 22 to 30 kHz is the usual range of values. The exact bandwidth chosen depends on the SNR design goal, number of poles in the filter, and trade-offs of the cost of the filter versus costs of processing sampled data.

2.1.3.3 COUPLER GAIN

Amplification may be provided in the coupler for a number of purposes. With broadband coupling, amplification is a must, to assure adequate signal levels at the receiver. Amplifiers can increase signal levels to make up for use of antennas with a very low effective height, and to bring signal levels above the noise pick-up on the cables from the coupler to the receiver. Gain can also make up for losses in this cable. Amplifiers designed for low output impedance can also match the cable impedance to the receiver, assuring maximum power transfer and minimum reflections, which can cause carrier phase measurement errors.

The requirements on the coupler amplifier are very stringent. Generally, amplifiers are specified to operate over an 80 to 120 dB dynamic range depending on application with the lowest level signals on the order of 0.1 to 10 μvolts at the SCN. These requirements must be met in temperature, pressure, vibration, and humidity environments of exposed locations on aircraft, ships, or land vehicles.

2.1.3.4 COUPLER OUTPUT MATCHING

In a coupler with no gain element, the antenna output is transformer-coupled to the transmission line. Although design decisions may vary, generally when no gain is provided by the coupler, balanced shielded cable is used between the coupler and receiver to minimize pick up of stray signals. Also a fairly large antenna is required to assure adequate signal levels.

Antenna coupler systems have been designed in which the antenna connects directly to the receiver. These have not been particularly successful, because of the difficulty of getting a good antenna site near the receiver or the alternative high losses of directly connecting an antenna to a transmission line to get away from the receiver.

In a coupler with gain, the amplifier is designed with an output to match the transmission line, and with sufficient gain to overcome the noise and losses of the transmission line. Power for the amplifier is sometime provided on the signal cable, by providing a signal splitting scheme on the coupler output. This reduces the number of cables required, but adds to the complexity of a signal splitter.

2.2. ANALOG SIGNAL PROCESSING

In this section, Loran-C peculiar design considerations are discussed. Those that are common to more generalized design, are not covered. As digital signal processing devices and techniques have come to the fore recently, a designer has increasingly had the option to go analog or digital in his design. Because a digital design may be confused with the smapling processes in the following section, perhaps this section should be described as concerned with those signal processing functions which could be, but are not necessarily, implemented with linear networks. The function of the Analog Signal Processing section is to provide for bandpass filtering, interference filtering, processing the envelope shape for cycle identification, providing a narrowband signal for use in the acquisition process, and to amplify the signals for sampling.

2.2.1 RF AMPLIFICATION

There are two basic design types for the analog signal processing. The types differ by virtue of the two different amplifier types: linear and hard limited. With linear amplifiers, filtering is done at low level ahead of the amplifier. The amplifier has a wide range automatic gain control which adjusts the gain in each interval such that the amplifier output is the same amplitude for all stations' signals. Envelope shape processing is done at high level, so that there are two outputs, an envelope and a cycle channel for sampling. A modification of this amplifier type is the clipped linear amplifier, which operates linearly over the expected signal ranges. but limits high amplitude signals such as atmospheric noise bursts or crossing rate Loran-C signals.

The alternative type of amplification is the hard limiting amplifier. In this case, all linear processing must be done at low level. Two hard limited RF amplifiers are then required to make envelope and cycle signals available for the sampling process. The amplifier then amplifies the signal and limits the amplitude until the output has a squarewave shape with the polarity equal to the instantaneous polarity of the input waveform.

In both types of amplifier, the overriding requirement is that delay through the amplifier not vary with received signal amplitude or agc setting. In general, this means a very wide-band amplifier (10 MHz to 100 MHz), with very low internal noise.

2.2.2 SIGNAL PROCESSING

The signal processing circuits are essentially filters which minimize the effects of interference and noise, shape the envelope appropriately, and minimize unwanted distortions. The bandpass limiting circuits are designed so that when their effects are considered with the filtering in the antenna coupler, the exact bandpass is achieved which minimizes atmospheric noise, while maintaining the envelope shape undistorted for good cycle selection, and maintaining an overall linear phase shift characteristic over the passband for good timing accuracy. Narrowband switching of the filters is provided to gain SNR during search, at the expense of envelope shape. This envelope distortion is of no consequence during search.

2.2.2.1 INTERFERENCE FILTERS

Interference filters are narrowband rejection filters (notch filters) for reduction of the effects of near-band signals, which can adversely effect the operation of the set. The number of notch filters is a design decision which must be based on interference known to exist in the operating area, the receiver bandpass characteristic, and any sampled signal processes which have interference rejection capabilities. Interference effects can be classed in two general types – high level signals which cause the receiver circuits to act non-linearly, and signals which are coherent with the spectrum of the sampled data process (cross-correlation), called "synchronous interference". High level continuous signals must be reduced by filtering the analog signal, ahead of the active stages. In the case of high level atmostpheric noise bursts and crossing rate Loran-C signals, a form of limiting is most effective. Synchronous interference can be handled by either notch filters or changing the cross correlation process to eliminate the synchronism, or both.

2.2.2.2 ENVELOPE DERIVER

The envelope deriver is a circuit, which modifies the shape of the pulse envelope to cause its amplitude to go through zero at the point on the leading edge where a cycle zero crossing is to be tracked. It is a circuit peculiar to cycle tracking Loran-C sets. The implementation may use the RF signal directly, or the envelope may be coherently detected and then derived. To visualize the circuit's operation, one particular implementation is described and then others described in comparison.

First, a waveform representing the pulse envelope and that same waveform delayed and amplified are pictured in Figure 2.2.2.2.A.

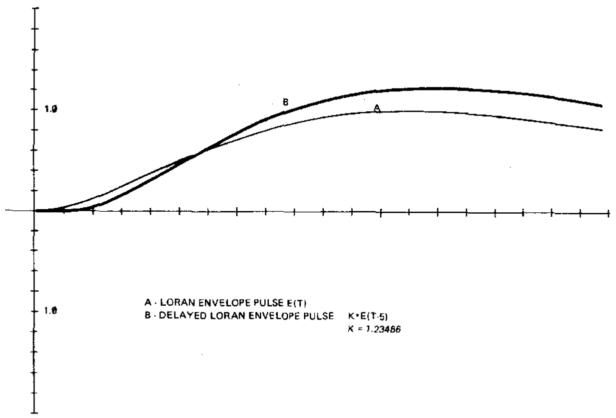


FIGURE 2.2.2.2A PULSE ENVELOPE AS DETECTED, AND DELAYED AND AMPLIFIED.

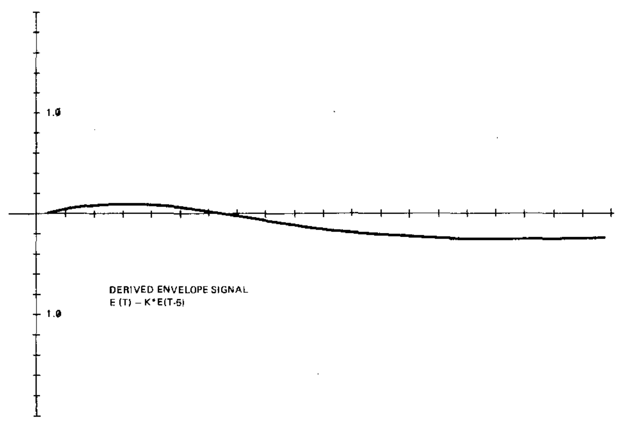


FIGURE 2.2.2.2B DERIVED ENVELOPE

The algebraic difference, which is the derived envelope, is shown in Figure 2.2.2.2B. This is called a delay and add deriver. The derived envelope is sampled (called the envelope error sample) and the timing circuits then adjusted, based on the sign and amplitude of the sample, to move the sampling time toward t_d, reducing the sample amplitude (hence, envelope error) to zero. When the envelope error is zero, the cycle zero crossing nearest t_d is identified as the tracking point.

A variation of the delay and add deriver is the sample difference deriver. Imagine that the pulse envelope in Figure 2.2.2.2A is sampled at two points separated by an amount equal to the delay, and that the first sample is amplified and subtracted from the second sample. As this pair of samples is moved over the pulse envelope, the circuit response sample difference would be the same as Figure 2.2.2.2B, where the ordinate is the sample pair position. This implementation has the advantage over the delay and add deriver in that the delay line is not needed.

The delay and add deriver can also be implemented at RF, which eliminates the need for coherent detection. Figures 2.2.2.2C and D depict the RF waveforms when the delay is exactly 5 μs. This is an extremely handy delay, as 5μs inverts the phase of the carrier, which is equivalent to changing the algebraic sign of the envelope. Summing the pulse and the delayed and amplified pulse gives a RF pulse with a derived envelope shape. Of particular significance is the carrier phase inversion which occurs after the zero crossing of the derived RF pulse envelope.

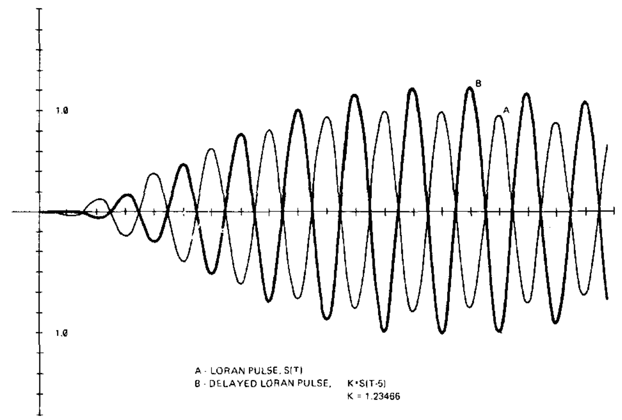


FIGURE 2.2.2.2C RF PULSE AND THE DELAYED AND AMPLIFIED RF PULSE

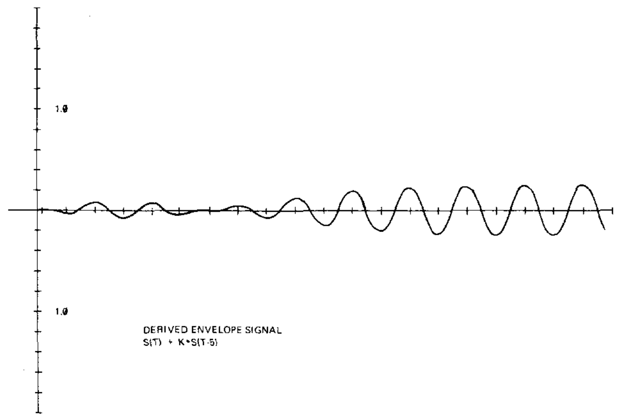


FIGURE 2.2.2.2D DERIVED RF PULSE

As with the pulse envelope deriver, a sample difference deriver can be implemented on the RF pulse. Samples can only be taken at the peaks of the RF cycles, so again, a 5 μs delay is very handy. Two samples are taken 5μs apart and added; the result is an envelope error curve similar to Figure 2.2.2.2D, except values are defined only at the peaks of each half cycle.

Another class of envelope deriver is the derivative adder. The implementation is quite similar to the delay and add envelope deriver. The difference is that the first dirivative of the pulse envelope is added to the pulse, rather than the delayed envelope, as in Figure 2.2.2.2E, with the resultant derived envelope shown in Figure 2.2.2.2F.

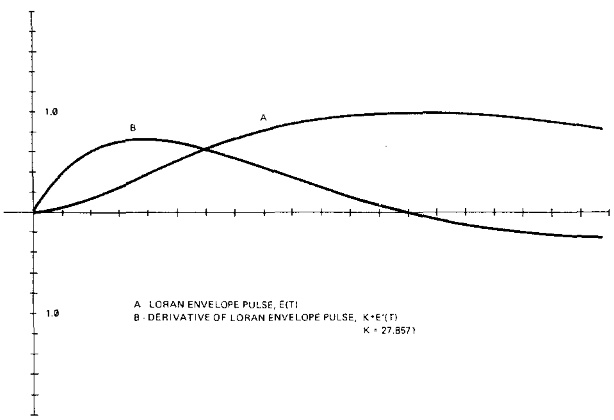


FIGURE 2.2.2.E PULSE ENVELOPE AND ITS FIRST DERIVATIVE

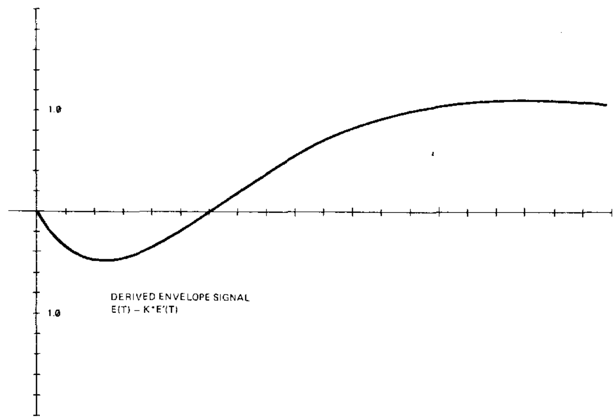


FIGURE 2.2.2.2F DERIVED ENVELOPE

This class of envelope deriver can also be implemented at RF, as shown in the following Figures.

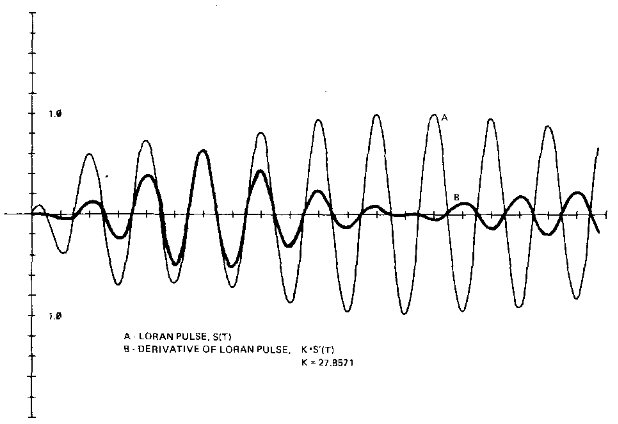


FIGURE 2.2.2.2G RF PULSE AND
ITS FIRST DERIVATIVE

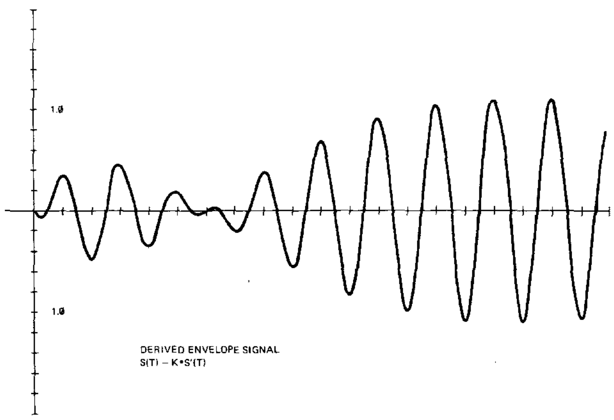


FIGURE 2.2.2.2H DERIVED
RF PULSE

There is no equivalent sample difference deriver.

2.2.2.3 ENVELOPE DERIVER CIRCUIT IMPLEMENTATIONS

The classical Loran-C receiving set was implemented using a linear RF amplifier, coherent detector and an envelope deriver. Detection and the deriver operated at high level, because low level operation was not possible with the circuit devices available.

One of the first advances beyond this "classical" receiver was the development of sample and hold circuits which were fast enough to track the signal and had sufficiently narrow aperature time to permit sampling the peaks. This made the sample difference deriver possible, eliminating the need for coherent detection.

With the development of very fast solid state devices, it became possible to build hard limiting amplifiers, which eliminate the need for the automatic gain control necessary in linear amplifiers.

In order to implement the cycle identification function using hard limiting amplifiers, it is necessary to generate the derived RF pulse at low level and amplify it separately from the cycle channel. This requires a derivative circuit with a very wide dynamic range, and a second hard limiting amplifier. Then to detect the zero crossing of the derived envelope, the receiver sampling is designed to look for the RF phase inversion associated with that zero crossing.

The envelope deriver, RF amplifier, and cycle identification function remain the most controversial aspects of Loran-C receiving set function and performance specification. The performance weakness is in the correct cycle selection. Under adverse propagation conditions, the cycle selection function may select the wrong cycle, causing unacceptable navigation errors.

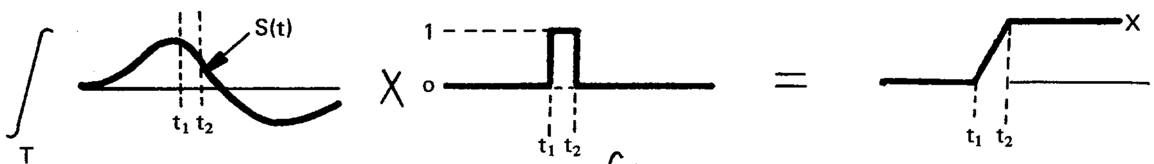
To minimize errors, designs have tended toward very long sample averaging times to improve estimates and reduce noise effects. This results in longer time to complete cycle selection, which also may be unacceptable performance. Some more recent development efforts have included the use of multiple samples of the RF. In linear receivers, multiple samples of the RF pulse permits use of a curve fitting alogorithm to estimate the PGTR and to identify a particular cycle. Multiple sampling can in either type of receiver permit estimates of most likely correct cycle, which tends to reduce errors and the time to complete cycle selection.

2.3 SAMPLING

The purpose of sampling the received signal is to separate groundwave signal information from skywave information by sampling the pulse before skywave arrives, and to obtain a limited number of discrete samples for signal processing.

2.3.1 SINGLE SAMPLING

Signal sampling is the process of observing the state of the signal at a particular instant of time. It may also be considered observing the average state of the signal over a time interval which starts and ends at particular times. In mathematical terms, sampling can be thought of as multiplying the signal by a sampling signal which is zero except during the sampling time when it is equal to one, and integrating the result:



$$X = \int_{t_1}^{t_2} S(t)dt$$

FIGURE 2.3.1. A SAMPLING

Signal sampling of an analog signal is generally mechanized in a sample and hold circuit which charges a capacitor. With a proper size capacitor and appropriate time constant, a series of samples can be summed or averaged in a sample and hold circuit. Alternatively, an analog to digital converter could be used to convert individual samples, and the samples summed and averaged digitally. The point is that samples may be statistically processed easily.

Signal sampling of a digital signal (e.g., a hard limited RF signal) can be mechanized in a counter in which a "one" level at the time of the clock (sampling) pulse causes the counter to count up, and a zero causes no count or count down one. The sum of samples is the digital number in the counter, and average value is the number divided by the number of clock pulses. The sampling can also be looked on as a one bit analog to digital conversion and digital summing. It can be shown that the average value of the number in such a counter is a function of the signal amplitude and the signal-to-noise ratio at the sample time. This provides an easily mechanized digital integrator for averaging samples.

The process of sampling a particular point of each of a series of pulses and averaging those samples provides a statistical estimate of the amplitude of the pulse at the point. That estimate has a signal-to-noise ratio, improved over the SNR of any individual sample by a factor equal to the square root of the number of samples. This feature of sample averaging is the characteristic which permits operating Loran-C receivers at very low SNR. In general, signal samples are taken to determine the presence of the Loran-C pulses, to determine the correct PGTR Identification, and to track the selected RF cycle.

2.3.2 SAMPLE PROCESSING

2.3.2.1 Determination of signal presence or of signal-to-noise ratio is accomplished by sampling the envelope, or the peak of an RF cycle, of each pulse and averaging the samples. In actual practice, the samples are multiplied by the phase code before averaging so that determination of proper code alignment is accomplished. Sampling is averaged over a sufficient number of pulses so that detection of the presence of pulses may be accomplished at the lowest SNR specified for the Loran-C receiving set. When the sample average exceeds a certain value, which may be a constant or variable as a function of number of samples, detection is considered to have occurred.

2.3.2.2 Correct PGTR Identification is accomplished by sampling either the derived envelope, the RF derived envelope, or by sample difference deriver. In all cases, samples are taken over many pulses to assure a good estimate of the derived envelope amplitude. If the estimate is reasonably close to zero, PGTR Identification is presumed correct. A positive amplitude estimate means the estimate is early in time and should be later, in multiples of 10 μs, and a negative estimate means it is late in time. (Note the signs may be reversed depending on design.) Again, a threshold value is set for the average, and if that threshold is exceeded, the condition exists.

2.3.2.4 Tracking the selected RF cycle zero crossing is accomplished by sampling at the estimated time of the selected RF zero crossing and averaging. If the amplitude estimate is zero, then the sample is presumed to be at the zero crossing and is usable as the receiver's time reference for computing time of arrival or time difference. If the estimate is positive, the sample is early in time, and the set's timing circuits are automatically corrected to bring the sample to the zero crossing. If the estimate is late, the sample is late and the set's timing circuits are automatically corrected to bring the sample to the zero crossing. (Note the signs may be reversed depending on design.) Generally, no threshold decisions are associated with tracking. Each sample or group of eight samples is applied to correct the sample time position.

2.3.2.5 There may be other sampling for other purposes in the set, such as guard sampling, blink sampling, or skywave tracking. The operation of the sampling circuits and the data processing is similar to the circuits described.

2.4 CONTROL

The control portion of a Loran-C receiving set is essentially everything other than the signal handling circuits. Each of the functional states of the receiver is set by the control section; decisions based on sample averages exceeding or not exceeding thresholds are made in this section; tracking and time measurement is done in this section. It is the purpose of the control section to provide the means of entering data and setting control device states to cause the Loran-C receiving set to step sequentially through its functional states, requiring and receiving data as needed, displaying information required by the operator, until all intervals are in the track mode, appropriate time of arrival or time difference information is displayed, and all alarm circuits are ready for activation.

2.4.1 CONTROL AND DISPLAY

2.4.1.1 INITIALIZATION CONTROLS

Manual input devices, or electrical interface circuits must be provided to enter initialization data. Typical data are:

a. Chain Identification, GRI in tens of microseconds

b. Secondary Identification, coding delay or initial TD in microseconds

c. Interference filter tuning. Usually a tuning control and display to search for interference and one or more notch filter controls are provided.

d. Control device(s) which initiate or re-initiate the mode sequence for any or all intervals.

e. Secondary interval time reference. This is usually the starting point for secondary search.

2.4.2.1 ACQUISITION CONTROLS AND DISPLAYS

During acquisition, operator participation is not generally required, except when the set is designed for manual acquisition. In either manual or automatic acquisition, a display is generally used to indicate completion of acquisition in each interval. Controls and displays are:

a. "Interval select" control which determines the interval (M, A, B, X, Y, all, etc.) in which the controls have effect, and for which displays have meaning.

b. "Slew" or "drift" control which moves the selected interval at a certain rate either later in time (+) or earlier in time (-). Movement continues as long as the control is operated.

c. "Step" control which moves the selected interval a specific number of microseconds. Movement occurs once for each time the control is operated.

d. Both the "slew" and "step" controls usually clear the averaging and integrating circuits associated with the interval(s) moved.

e. An indicator lamp is usually provided to indicate acquisition is completed in each interval. It usually indicates presence of a signal by integrating a number of samples of the signals and turning the lamp on (or off) when the threshold is exceeded.

f. In some cases, the display of TOA or TD will be active at this point to give an indication of the time measures, assuring the operator of acquisition of the proper signals.

2.4.1.3 PGTR IDENTIFICATION, CONTROLS AND DISPLAY

PGTR Identification may begin immediately upon completing search for signals in each interval, or operator action may be required to initiate the process.

a. A "mode" control may be set to groundwave location or cycle identification, or automatic cycle selection or a similar function title. As the operator may manually slew or step the samples through the pulses, checking first for groundwaves and then for correct cycle selection.

b. A set of display lights or a meter may be used for indicating signal level (or SNR) and envelope error.

c. When the conditions for PGTR Identification are satisfied, the mode control would be set to "operate" or "track" or "normal".

d. In a fully automatic set, the above operations would be automatically completed, perhaps, with an indication of the present state of each interval. When the conditions for PGTR Identification are satisfied in all intervals, the indication of "operate", "track", or "normal" would come on (or go off).

2.4.1.4 TRACK CONTROLS AND DISPLAYS

Normally, no controls are necessary in the track mode, except those controls necessary to revert to other modes, or to clear alarm states. The displays may include:

a. TOA or TD for each interval

b. Signal level, SNR, or lost signal for each interval

c. Blink for each interval

d. Envelope error, for each interval

e. Lost signal history, for each interval.

The number of actual displays may be made less by "ORing" alarms, and requiring the operator to sort them out with the mode switch and/or interval switch. The display of interest is a numerical representation of TOA or TD. If the display is visual, there may be one set of display devices which alternatively or selectively display the TOA or TD for each interval, or there may be separate (continuous) displays for each interval. If the display is electrical, the manufacturer should state design to an interface standard, i.e., RS-232, MILSTD 188., IEEE 488, and state the coding used, i.e., BCD, ASCII, BOUDOT. If the interface is special, proprietary, or for some reason works only with certain equipment, this fact should be clearly stated.

2.4.2 TIMING

There are two basic types of timing systems: a single clock source and divider which is gated, cleared, and/or reset to provide all gate timing and triggers in the set, and the multiple clock systems with one clock for each interval.

The only feature of significance is the oscillator stability. It is generally agreed that an oscillator stability of one part in 10^5 is the maximum frequency error which can be tolerated, although there is potential for less accurate oscillators, at lower cost.

3.0 PERFORMANCE TESTING AND CLAIMS

In this section, a series of standard tests is described for stating claims relative to a particular Loran-C receiving set. The tests described can provide a level of comparitive performance under which receiving sets can be compared. These are by no means a complete set of tests, and should an operator require particular performance of a set, the conditions should be specified to the manufacture.

A Loran-C Receiving Set is tested by disconnecting the antenna at the SCN, and substituting a simulated antenna as described in paragraph 2.1.1. Signals simulating actual reception conditions are then fed in at the SCN and the set performance observed under standard sets of conditions.

In the following paragraphs, we describe the measures of performance, the test set-up, definitions of signal, noise and interference level, and then tabulate standard tests for computing the measures of performance.

3.1 MEASURES OF PERFORMANCE

Of most significance to the navigator is the accuracy of readout. There are two measures of performance: mean error and standard deviation of readout. For purposes of this specification, the readout is the time parameter (TOA or TD) of the signals, and not position derived from those readouts. Where more than one readout is observable, all or the one with the greatest error is to be reported. The computation of any claimed performance is to be based on no less than 20 independent observations of the readout. The error (E_i) of any given observation is the algebraic difference of the time parameter of the signal at the SCN (T_i) and the observed time parameter (O_i)

(3.1.1.)

The mean error is

$$E_M = \frac{1}{N} \sum_{i=1}^{N} E_i$$

(3.1.2)

and the standard deviation is

$$\sigma E_M = \left[\sum_{i=1}^{N} (E_i - E_M)^2 \right]^{1/2}$$

(3.1.3)

Another performance measure is the "time to track" (TT). This is of significance to the navigator in that it measures the utility of the set. This parameter has difficulty in use in that, when data is collected and a receiver indicates it is in track but there is a cycle selection error, is the data to be used without regard to erroneous cycle selection, is it to be discarded completely, or can it be logically integrated into the data? The solution presented here is that:

a. an experiment begins when acquisition begins on any signal.

b. the experiment ends with an indication of track for all signals from the receiver.

c. the "time-to-track" (TT) is the average time-to-track of all the experiments.

d. the probability of correct cycle selection (Pc) is the ratio of the number of cycle selections ending with correct cycle selection (Nc) to the total number of cycle selections (N). Note that the number of cycle selections is the number of stations tracked times the number of experiments.

$$Pc = Nc/N \qquad (3.1.4)$$

The measure of performance is then

$$TT/Pc$$

written as two numbers separated by a slant mark.

3.2 TEST SET-UP

The test set-up is indicated in Figure 3.2A. Each signal simulator and its output calibration are discussed in the following paragraphs.

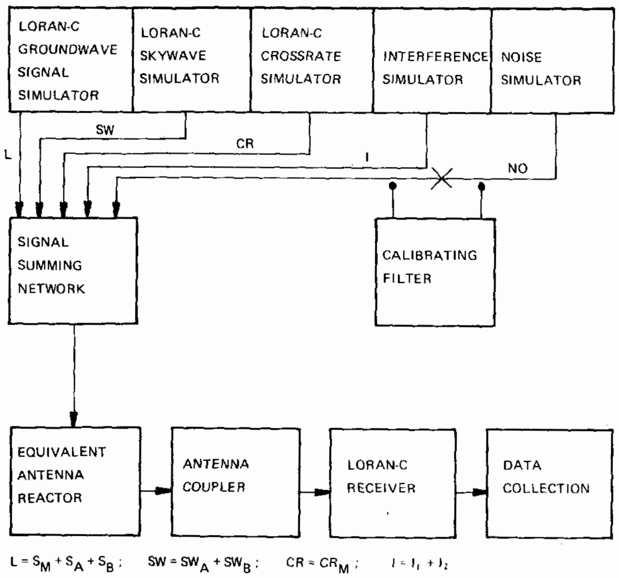


FIGURE 3.2.A LORAN-C RECEIVING SET PERFORMANCE MEASUREMENT TEST SET-UP

Note: Subscripted signals are defined in Table 3.3.A.

3.2.1 SIGNAL SUMMING NETWORK AND EQUIVALENT ANTENNA REACTOR

The signal summing network linearly combines the outputs of each simulator and generates an output which is the equivalent source voltage or current for the Equivalent Antenna Reactor (C_A or L_A), as defined in Section 2.1.

The field strength E described in Section 2.1 is usually expressed in microvolts per meter or in dB above 1 μv per meter and is the sum of the simulated signals (all are functions of time).

The gain constant of the summing network for each simulator is:

$K_L = \frac{Vin}{L}$ when only the Loran-C groundwave simulator has an output signal

$K_{SW} = \frac{Vin}{SW}$ for the skywave simulator

and similarly for each other simulator. With reasonable design all K's are equal, and the signal levels called for in the following tests can be equated to the individual simulator outputs:

$$L = \frac{Vin}{K_L} = \frac{Eh_e}{K_L}$$

for the Loran-C groundwave simulator has an output signal (3.2.1.1)

Groundwave Simulator. Similar equations can be derived for SW, CR, I and N.

3.2.2 LORAN-C GROUNDWAVE SIGNAL SIMULATOR

This is a Loran-C signal generator capable of outputing Loran-C signals, as defined in the Loran-C System Characterization (WGA pub No. 1/76) for one or more Loran-C chains. The timing, amplitude, and ECD of each pulse group is adjustable over a range sufficient to permit generation of the signals required to perform the desired tests. The definitions of timing, amplitude, and ECD are also contained in the Loran-C System Characterization.

3.2.3 LORAN-C SKYWAVE SIGNAL SIMULATOR

This device is capable of generating Loran-C signals identical to those generated by the groundwave simulator but delayed in time and increased in amplitude over a range sufficient to permit generation of the signals required to perform the desired tests.

3.2.4 LORAN-C CROSSRATE SIMULATOR

This is a device identical to the Loran-C groundwave signal simulator operated on a rate not to be tracked for navigation by the receiver. In practice, each of these Loran-C signal simulators is identical, with a common frequency standard input. A total of two simulators is all that are required, one for the groundwave and one for either skywave or crossrate signal.

3.2.5 LORAN-C INTERFERENCE SIMULATOR

The interference simulator is a single frequency oscillator with a range of frequency and output level sufficient to permit generation of the signals required to perform the desired tests. Additionally, the test requiring frequency setting to within 0.01Hz necessitates that the oscillator frequency be synthesized.

3.2.6 LORAN-C NOISE SIMULATOR

3.2.6 The noise simulator is a "pink" noise source. That is, the power spectral density of the noise is required to be constant within ± dB from 20 kHz to 200 kHz. The output level is defined such that the output level N_C required to produce the Vin equivalent to 1.0 μV per meter, as measured with an RMS voltmeter, when the calibrating filter is in circuit, is the initial reference level. N_C is then corrected for the center frequency attenuation of the calibrating filter to obtain the calibrated reference level N_o. That is, when the level N_o is observed at the noise simulator output, and the calibrating filter is out of the circuit, the defined noise level at the antenna is lμV/meter, and noise levels are referenced to N_o.

3.2.7 CALIBRATING FILTER

The calibrating filter is a single pole resonant bandpass circuit with a center frequency of approximately 100 kHz and skirts that fall off at 6 dB/octave. The Q is such that the 3 dB points on the bandpass are at 90 and 110 kHz. Its use is in calibrating the power spectral density of the noise simulator.

3.3 TEST PROCEDURES

The tests described are designed for a single rate, two secondary, time difference receiver. If the set being tested is capable of more secondaries of cross rate time differences, or of TOA measurement, the same signal levels and range of time differences of signals should be used, and appropriate observations made. On single pair sets, the tests should be sequentially conducted, first using the conditions for interval A, then for interval B, and only the worst case data claimed for each condition.

3.3.1 THE TEST PROCEDURES ARE:

a. For each test to be performed, set the output levels of each simulator according to the Table 3.3.A. Note that levels are expressed as dB above 1 μv per meter.

b. Operate the receiver so as to initialize it, acquire, cycle select and track on all signals.

c. Record the time from commencement of acquisition on the last signal. Record whether the cycle selection was correct on each signal. For each acquisition gate, there will be three cycle selections, in a two TD set.

d. Repeat steps b and c not less than 10 times. Compute the average time to track and the ratio of number of correct cycle selections to the total number of cycle selections.

e. After the tenth acquisition cycle, allow the set to continue operating in the track mode. If cycle selection is incorrect on any signal, use the receiver operating procedures to assure that all TOA's and TD's are within 5 μs of the correct values.

f. Observe and record each TOA or TD for each interval. Repeat the observations at time intervals sufficiently longer that the time constant of the displayed parameter that the samples are independent. Take a total of 20 or more observations and compute the mean error and standard deviation in paragraph 3.1.

3.3.2 TEST #1, REFERENCE STANDARD

This test is intended to set an upper bound on claimed performance and to provide a reference for comparison with the results of succeeding tests.

3.3.3 TEST #2 DYNAMIC RANGE OF AMPLITUDE AND TIME DIFFERENCE

This test is intended to show the performance of the set under extreme signal amplitude and time difference. The signal level extremes are moderate in that they do not represent the absolute worst case, but do cover a reasonable range. The TD extremes are those which reasonably represent the limits of chain design. The test also calls for operation at high ambient temperature. The test may be conducted without the high temperature in which case that fact should be stated in the claim.

3.3.4 TEST #3 DYNAMIC RANGE OF AMPLITUDE AND TIME DIFFERENCE

This test sets different TD limits than test #2 and tests those conditions which cannot be set in that test. The test also calls for operation at low ambient temperature. The test may be conducted without low temperatures in which case that fact should be stated in the claim.

3.3.5 TEST #4 AND TEST #5 SKYWAVE EFFECTS

These tests subject the receiver to typical daytime and nighttime skywaves. The effects, if any, will be increased probability of selecting the wrong cycle, and an increased mean TOA or TD error.

3.3.6 TEST #6 CROSSRATE EFFECTS

This test is expected to show any sensitivity to crossrate interference. Since the U.S. Coastal Confluence Zone (CCZ) Loran-C implementation will create areas of high crossrate interference, good performance is required in these tests. The effect, if any, is expected to be increased standard deviation of error.

3.3.7 TEST #7 LOW SNR PERFORMANCE

This test determines the performance of the set at the lowest SNR's planned for the CCZ Loran-C implementation. The most significant effect, if any, will be the inability to properly cycle select.

3.3.8 TEST #8 ACCELERATION TEST

This test is generally reserved for airborne Loran-C Receiving Sets. It is intended to demonstrate a net capability in a maneuvering condition. The expected effects are high standard deviation and possible change of cycle selection.

3.3.9 TEST #9 AND TEST #10 INTERFERENCE EFFECTS

These tests are intended to determine the effects of high level non-synchronous interference and low level synchronous interference. The levels are such that the interference filters must be reasonably effective or interference will saturate the set. The effects may be as serious as a lost signal indication, or there may be, as a minimum, an increase of the mean error.

4.0 LORAN-C RECEIVING SET SPECIFICATION

The form below outlines the data to be presented on a Loran-C Receiving Set specification sheet. The references are to paragraphs in this characterization.

4.1 FUNCTIONAL DESCRIPTION:

4.1.1 INITIALIZATION DESCRIPTORS (Table 1.2.1)

Rates

Time Reference

Numbers and Kinds of Stations or Pairs

Measurement Process

4.1.2 ACQUISITION DESCRIPTORS (Para. 1.2.2.5)

Acquisition Function

Search Features

Acquisition Features

4.1.3 PGTR IDENTIFICATION DESCRIPTORS (Para. 1.2.3.3)

Groundwave Location Process

Cycle Selection

4.1.4 TRACKING DESCRIPTORS (Para. 1.2.4)

Automatic/Manual

Alarms

4.2 CIRCUIT DESCRIPTION

4.2.1 ANTENNA AND COUPLER DESCRIPTORS (Para. 2.1)

Integral with Coupler, or User Supplied

E-Field or H-Field

Designed Antenna Reactance (C_A or L_A)

Bandpass and Skirt Slope

Coupling, Broadband or Tuned

Amplification Provided

Output Impedance, Balanced or Unbalanced

ANALOG SIGNAL PROCESSING (Para. 2.2)

Linear or Hardlimiting

Overall System Bandpass, Number of Poles

Search Bandpass

Interference Filters, Number, Depth in dB, Width at 6 dB

RF or Envelope Sampling

Deriver Type

DISPLAY TYPE

Visual and/or Electrical Readout

Electrical Readout Standard, R5232, MILSTD 188, IEEE 488 and Code, BCD, ASCII, BAUDOT.

4.3 PERFORMANCE (Para. 3.0)

For each of the best conditions described in paragragh 3.0, for which a performance claim is to be made, state the test number and name, the mean error and standard deviation of the TOA or TD for each station or pair tracked, and the mean time-to-track.

For example:

Test #3 Dynamic Range:	Mean TD Error	0.05 μs
	Standard Deviation	0.11 μs
	Time-To-Track	4.2 min/1.0

Notes for Table 3.3.A.

All signal levels are in decibles above one microvolt per meter (dB/μV/m)

All GRI are in standard four digit notation.

All TD's are in milliseconds, ± 20 nanoseconds

Skywave delays are in microseconds, ± 20 nanoseconds

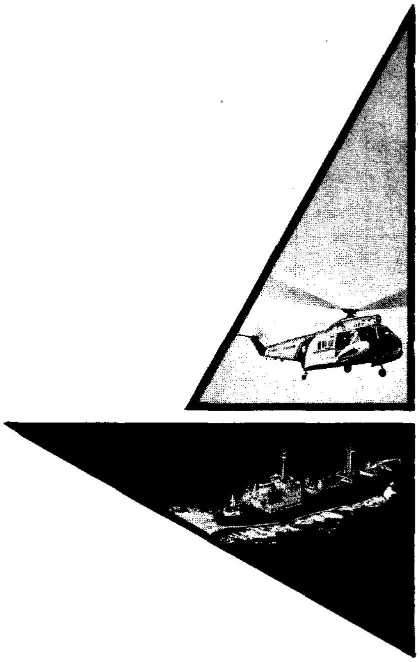
Frequency F1 is in kilohertz, ± 100 Hz

Frequency F2 is in kilohertz. Add 0.02 Hz to the stated frequency. Actual frequency is F2 + 0.02 Hz, ± 0.01 Hz.

In test #8, TDA, dTDA/dt, TDB, and dTDB/dt are initial values only.

PERFORMANCE TEST TITLE / TEST PARAMETERS		TEST # 1 REFERENCE STANDARD	TEST # 2 DYNAMIC RANGE	TEST # 3 DYNAMIC RANGE	TEST # 4 SKYWAVE EFFECTS	TEST # 5 SKYWAVE EFFECTS	TEST # 6 CROSSRATE EFFECTS	TEST # 7 LOW SNR PERFORMANCE	TEST # 8 ACCELERATION TEST	TEST # 9 INTERFERENCE EFFECTS	TEST # 10 INTERFERENCE EFFECTS
AIR TEMPERATURE (*C)		20	50	0	20	20	20	20	20	20	20
POWER LINE (% NOM.)		100	100	100	100	100	100	100	100	100	100
S_M/GRI		60/9930	60/9930	60/9930	60/9930	60/9930	90/9930	30/9930	60/9930	90/9930	90/9930
S_A/TDA		60/20	110/20	30/11	60/20	60/20	60/20	30/20	60/20	60/20	60/20
S_B/TDB		60/60	30/29.5	110/89.7	60/60	60/60	30/60	30/60	30/60	30/60	30/60
SW_A/TA					66/35	74/50					
SW_B/TB					66/37.5	74/52.5					
CR_A/GRI							90/9990				
$N_o + N$		40	40	40	40	40	40	40	40	40	40
I_1/F_1										70/70	70/130
I_2/F_2										40/110	40/40
dTDA/dt	d^2TDA/dt^2								-1.0/0.03		
dTDB/dt	d^2TDB/dt^2								-1.0/0.03		

TABLE 3.3A TEST CONDITIONS



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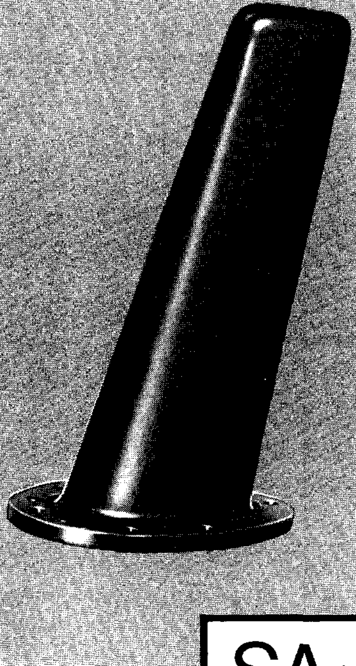

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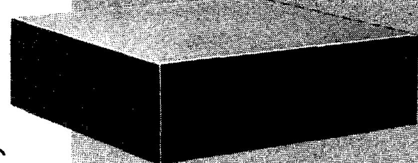

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LORAN AND OMEGA CHART AVAILABILITIES

On the following pages we have attempted to present data on available charts, including areas covered and sources of information. We strongly suggest that if you have a continuing need for charts that you obtain the indicated chart catalogs for the areas of interest.

The chart data is presented in tabular form. Table #1 is a list of nautical charts of U.S. waters printed by the National Ocean Survey. Table #2 is a list of charts known to be published by other nations. Table #3 is a list of world-wide charts printed by the U.S. Defense Mapping Agency Hydrographic Center (DMAHC). Table #4 lists world-wide aviation charts prepared by the U.S. Defense Mapping Agency, Aerospace Center (DMAAC). Table #5 is a list of loran and Omega tables which are prepared by the DMAHC.

ORDERING INFORMATION:

NATIONAL OCEAN SURVEY:

National Ocean Survey and Defense Mapping Agency Aerospace Center charts may be ordered from the nearest N.O.S. sales agent or from:

DISTRIBUTION DIVISION (C-44)
NATIONAL OCEAN SURVEY
RIVERDALE, MD. 20840

Nautical Chart Catalogs are available from the same source, at no charge:

CHART NO.	CATALOG TITLE
1.	Atlantic and Gulf Coasts, including Puerto Rico and the Virgin Islands
2.	Pacific Coast, including Hawaii, Guam, and the Samoa Islands
3.	Alaska
4.	Great Lakes and Adjacent Waterways

Also, a quarterly subscription to 'Dates of Latest Editions, Nautical Charts' is available. This list indicates the lines-of-position available on each chart edition.

DEFENSE MAPPING AGENCY HYDROGRAPHIC CENTER:

Requests for DMAHC charts should be directed to either of the DMAHC Depots:

DEFENSE MAPPING AGENCY
HYDROGRAPHIC CENTER DEPOT
CLEARFIELD, UTAH 84016
TEL: 801-773-3254

DEFENSE MAPPING AGENCY
HYDROGRAPHIC CENTER DEPOT
5801 TABOR AVENUE
PHILADELPHIA, PA. 19120
TEL: 215-697-4262

A Catalog of Nautical Charts is available at no charge (Publication No. 1-N-A). This catalog lists regional catalogs available at nominal charge, and lists DMAHC and British Admiralty Charts sales agents.

CANADIAN HYDROGRAPHIC SERVICE:

HYDROGRAPHIC CHART DISTRIBUTION OFFICE
MARINE SCIENCES DIRECTORATE
DEPARTMENT OF THE ENVIRONMENT
OTTAWA, ONTARIO, CANADA K1A OE6

ICELANDIC HYDROGRAPHIC SERVICE:

SJÓMAELINGAR ISLANDS
PÓSTHÓLF 7094
SELJAVEGI 32
REYKJAVIK, ICELAND

NORWEGIAN HYDROGRAPHIC OFFICE:

NORGES SJØKARTVERK
KLUBBT 1, P.O. BOX 60,
4001 STAVANGER, NORWAY

GERMAN HYDROGRAPHIC INSTITUTE:

DEUTSCHES HYDROGRAPHISHES INSTITUTE (D.I.H.)
BERNHARD - NOCHT STR. 78
2000 HAMBURG 4,
GERMANY

Some three dozen charts are reportedly available from D.I.H. for waters between Iceland, Norway, and Great Britain. (Possibly charts for U.S. waters as well). We have not determined the exact areas and availability.

TABLE #1
NATIONAL OCEAN SURVEY CHARTS
WITH LORAN-C OVERLAYS

Old Chart #	New Chart #	Title	Scale	Proposed NOAA(NOS) Issue Date
70	13006	West Quoddy Head to N.Y.	1:675,000	
71	13009	Gulf of Maine & Georges Bank	1:500,000	
77	12260	Chesapeake Bay-Northern Part	1:197,250	9/75
78	12220	Chesapeake Bay-Southern Part	1:200,000	Avail.
243	13279	Ipswich Bay to Gloucester Harbor	1:20,000	Avail.
246	13270	Boston Harbor	1:2500	Avail.
612	13204	Georges Bank	1:220,000	9/75
1000	13003	Cape Sable to Cape Hatteras	1:1:200,000	11/75
1001	11009	Cape Hatteras to Straits of Florida	1:1,200,000	11/75
1002	11013	Straits of Florida and approaches	1:1,200,000	9/75
1003	11006	Gulf Coast-Key West to Mississippi River	1:875,000	2/76
1007	411	Gulf of Mexico	1:2,160,000	1/76
1050	11352	New Orleans to Calcasieu River, East Section	1:175,000	9/75
1051	11345	New Orleans to Calcasieu River, West Section	1:175,000	4/76
1106	13260	Bay of Fundy to Cape Cod	1:378,838	11/75
1107	13200	Georges Bank-Nantucket Shoals	1:400,000	2/76
1108	12300	Approaches to N.Y., Nantucket Shoals	1:400,000	Avail.
1109	12200	Cape May to Cape Hatteras	1:416,944	Avail.
1110	11520	Cape Hatteras to Charleston	1:432,720	Avail.
1111	11480	Charleston Lt. to Cape Canaveral	1:449,659	Avail.

Table #1 continued

Old Chart #	New Chart #	Title	Scale
1112	11460	Cape Canaveral to Key West	1:446,940
1114	11400	Tampa Bay to Cape San Blas	1:456,394
1115	11360	Cape St. George to Mississippi River	1:456,394
1116	11340	Mississippi River to Galveston	1:458,596
1117	11300	Galveston to Rio Grande	1:460,732
1201	13325	Quaddy Narrows to Petit Manon I.	1:80,000
1204	13288	Monhegan Island to Cape Elizabeth	1:80,000
1205	13286	Cape Elizabeth to Portsmouth	1:80,000
1206	13278	Portsmouth to Cape Ann	1:80,000
1207	13267	Massachusetts Bay	1:80,000
1208	13246	Cape Cod Bay	1:80,000
1209	13237	Nantucket South and approaches	1:80,000
1210	13218	Martha's Vineyard to Block Island	1:80,000
1211	13205	Block Island Sound and approaches	1:80,000
1212	12354	Long Island Sound-Eastern Part	1:80,000
1213	12363	Long Island Sound-Western Part	1:80,000
1215	12326	Approaches to N.Y.- Fire Isl. Lt. to Sea Girt Lt.	1:80,000
1216	12323	Sea Girt to Little Egg Inlet	1:80,000
1217	12318	Little Egg Inlet to Hereford Inlet	1:80,000
1218	12304	Delaware Bay	1:80,000
1219	12214	Cape May to Fenwick Isl. Lt.	1:80,000
1220	12211	Fenwick Isl. Lt. to Chincoteaque Inlet	1:80,000
1221	12210	Chincoteaque Inlet to Gt. Machipongo Inlet	1:80,000
1222	12221	Chesapeake Bay Entrance	1:80,000
1223	12225	Chesapeake Bay-Wolf Trap to Smith Point	1:80,000
1224	12230	Smith Point to Cove Point	1:80,000
1225	12263	Cove Point to Sandy Point	1:80,000
1226	12273	Sandy Point to Head of Bay	1:80,000
1227	12207	Cape Henry to Currituck Beach Lt.	1:80,000
1229	12204	Currituck Beach Lt. to Wimble Shoals	1:80,000
1231	11548	Pamlico Sound-Western Part	1:80,000
1232	11555	Cape Hatteras-Wimble Shoals to Oracoke Inlet	1:80,000
1233	11544	Portsmouth Island to Beaufort	1:80,000
1234	11543	Cape Lookout to New River	1:80,000
1236	11536	Approaches to Cape Fear River	1:80,000
1238	11531	Winyah B. Entrance to Isle of Palms	1:80,000
1239	11521	Charleston Harbor and approaches	1:80,000
1241	11509	Tybee Island to Doboy Sound	1:80,000
1242	11502	Doboy Sound to Fernandina	1:80,000
1245	11484	Ponce de Leon Inlet to Cape Kennedy	1:80,000
1246	11476	Cape Canaveral to Bethel Shoal	1:80,000
1247	11474	Bethel Shoal to Jupiter Inlet	1:80,000
1256	11424	Lemon Bay to Passage Key Inlet	1:80,000
1257	11412	Tampa Bay & St. Joseph's Sound	1:80,000
1258	11409	Anclote Keys to Crystal River	1:80,000
1261	11405	Apalachee Bay	1:80,000
1262	11401	Apalachicola Bay to Cap San Blas	1:80,000
1263	11389	St. Joseph & St. Andrew Bay	1:80,000
1264	11388	Choctawhatchee Bay	1:80,000
1265	11382	Pensacola Bay and approaches	1:80,000
1266	11376	Mobile Bay	1:80,000
1267	11373	Mississippi Sound and approaches	1:80,000

Table #1 continued

Old Chart #	New Chart #	Title	Scale	Proposed NOAA(NOS) Issue Date
1268	11371	Lake Borgne and approaches	1:80,000	3/76
1269	11369	Lakes Pontchartrain & Maurepas	1:80,000	2/76
1270	11363	Chandeleur & Breton Sounds	1:80,000	12/75
1271	11364	Mississippi River-Venice to New Orleans	1:80,000	5/76
1272	11361	Mississippi River Delta	1:80,000	10/75
1273	11358	Barataria Bay and approaches	1:80,000	10/75
1274	11357	Timbalier & Terrebonne Bays	1:80,000	12/75
1275	11356	Isles Dernieres to Point au Fer	1:80,000	2/76
1276	11351	Point au Fer to Marsh Island	1:80,000	12/75
1278	11344	Rollover Bayou to Calcasieu Pass	1:80,000	11/75
1279	11341	Calcasieu Pass to Sabine Pass	1:80,000	6/76
1282	11323	Approaches to Galveston Bay	1:80,000	5/76
1283	11321	San Luis Pass to E. Matagorda Bay	1:80,000	2/76
1284	11316	Matagorda Bay and approaches	1:80,000	3/76
1288	11301	Southern Part of Laguna Madre	1:80,000	2/76
4000	540	Hawaiian Archipelago	1:3,121,170	4/76
4102	19004	Hawaiian Islands	1:600,000	4/76
4116	19340	Hawaii to Oahu	1:250,000	10/75
4172	19401	French Frigate Shoals	1:80,000	9/75
4174	19441	Maro Reef	1:80,000	4/76
4179	19010	Hawaiian Islands-Southern Part	1:675,000	12/75
4183	19022	Laysan Island to Kure Island	1:642,271	11/75
4185	19480	Midway Islands and approaches	1:180,000	6/76
5002	18020	San Diego to Point St. George	1:1,412,349	6/76
5142	18746	San Pedro Channel	1:80,000	6/76
6300	18400	Strait of Georgia & Strait of Juan de Fuca	1:200,000	6/76
6401	18440	Admiralty Inlet and Puget Sound	1:150,000	6/76
8054	17425	Portland Canal-North of Hattie Island	1:80,000	5/76
8502	16013	Cape St. Elias to Shumagin Islands	1:969,761	6/76
8528	16683	Point Elrington to Cape Resurrection	1:81,436	10/75
8703	16549	Cold Bay and approaches, Alaska Pen.	1:80,000	6/76
8802	16011	Alaska Pen. & Aleutian Isl. to Sequan Pass	1:1,023,188	8/75
8833	16363	Port Moller & Herendeen Bay	1:80,000	10/75
8860	16520	Unimak & Akutan Passes and approaches	1:300,000	12/75
8861	16500	Unalaska Island to Amukta Island	1:300,000	8/75
8864	16440	Rat Islands-Semisop. Isl. to Buldir Isl.	1:300,000	5/76
8865	16420	Near Islands-Buldir Isl. to Attu Isl.	1:300,000	6/76
9052	16322	Bristol Bay-Nushagak B. and approaches	1:100,000	Avail.
9102	16012	Aleutian Isl.-Amutka Isl. to Attu Isl.	1:1,126,321	3/76
9198	16421	Near Isl.-Ingenstrem Rocks to Attu Isl.	1:160,000	
9302	16006	Bering Sea-Eastern Part	1:1,534,000	5/76
9380	16200	Norton Sound	1:400,000	12/75
LSO		Great Lakes-General Chart (Polyconic P.)	1:1,500,000	12/75
LS7	14901	Lake Michigan (Polyconic P.)	1:500,000	12/75
LS7M		Lake Michigan (Mercator P.)	1:500,000	
NOS9		Lake Superior (Polyconic P.)	1:600,000	
	14500	Great Lakes-Lake Champlain to Lake of the Woods	1:1,500,000	
	14900	Lake Michigan	1:500,000	
	97026	Asia-Phillipine Sea (Ryukyn Is) inc Daito Juna	1:983,500	

TABLE #2

Chart #	Title	Scale	British Admiralty Issue Date	Canadian Hydro Serv Issue Date	Icelandic Hydro Serv Issue Date	Norwegian Hydro Office Issue Date	Price Code
245	Scotland to Iceland		Avail.				
4102	Western approaches to Br. Isles	1:3,500,000					
L8005	Georges Bank	1:300,000		Avail.			C$2.00
20C	Iceland-Jan Mayen	1:200,000			Avail.		I.K.475
25C	Iceland-Austurhluti	1:750,000			Avail.		I.K.475
26C	Iceland-Vesturhluti	1:750,000			Avail.		I.K.475
56C	Iceland-Kolbeinsey	1:200,000			Avail.		I.K.475
306	Skagerrak vestre blad	1:350,000				Avail.	
307	Utsira to Kinn	1:350,000				Avail.	
308	Kinn to Trondheimsleden	1:350,000				Avail.	
309	Smøla to Vegg	1:350,000				Avail.	
311	Stott to Andenes	1:350,000				Avail.	
310	Lekaand Sklima to Vestfjorden	1:350,000				Avail.	
321	Andenes to Grøtsund	1:200,000				Avail.	
552	Vesteralen—Vest Finnmark-Bjørnøya	1:700,000				Avail.	NKr20.00
554	Bjørnøya-Spitsbergen	1:700,000				Avail.	
555	Barentshavet, nordvestlige del	1:700,000				Avail.	
557	Haltenbanken-Vesteralen	1:700,000				Avail.	NKr20.00
558	Vikingbanken-Haltenbanken	1:700,000				Avail.	NKr20.00
559	Birdshøen, nordre blad	1:800,000				Avail.	NKr20.00
560	Nordsjøen, søre blad	1:800,000				Avail.	NKr20.00

TABLE #3

CHARTS PUBLISHED BY THE DEFENSE MAPPING AGENCY, HYDROGRAPHIC CENTER

Chart #	Former #		Scale
19009	HO/BC 4744	Hawaiian Islands	1:1,030,000
28031	HO/BC 2056	Tampico to Progreso (Mexico-East Coast)	1:1,023,400
42720		Mys Litskiy to Mys Bd'shoy Gorodetskiy	1:200,000
51014		Cabo de Sao Vicente to Beddouza including Strait of Gibraltar	1:898,500
52000	HO/BC 3915	Gibraltar to Cabo de San Antonio & Cap Tenes	1:778,800
52010	HO/BC 3916	Cabo de Palos & Cap Tenes to Sardegna including the Balearic Islands	1:757,900
52020	HO/BC 3920	Tunis to Surt including Sicily and Malta	1:798,700
53000	HO/BC 3917	Barcelona to Roma including Island of Corsica	1:713,400
53020	HO/BC 3918	Tyrrhenian Sea including Sardegna (Sardinia) and Sicilia (Sicily)	1:754,330

54000	BC 3919	Adriatic Sea	1:713,400
54010	BC 3921	Malta to Kriti (Crete) including the Ionian Sea	1:768,500
54020	BC 3923	Aegean Sea (Greece-Turkey)	1:768,450
54030	BC 3924	Antalya Korfezi to Al Iskandariyah including Cyrpus	1:817,600
56000	BC 3925	Tubrug to Al Iskandariyah including Kriti and the Dhodhekanisos	1:817,600
56020	BC 3926	Ras at Barq to Tubruq (Libya)	1:817,600
71028	HO/BC 5501	Pulau Bintan to Mui Bai Bung	1:1,091,700
91006	HO/BC 14706	Philippines – Central Part	1:1,068,000
91011	HO/BC 14705	Philippines – Northern Part	1:1,031,800
92006	HO/BC 14707	Philippines – Southern Part	1:1,089,900
94002	HO/BC 5495	Shen Ch'uan Chiang to San-Men Wan including Taiwan to Iwo Jima	1:985,600
94028	HO/BC 5494	San-Men to Korea Strait	1:927,700
94033	HO/BC 5993	Northern Part of Yellow Sea	1:864,700
95016	HO/BC 3320	Korea Strait to Mys Nizmennyy	1:852,800
96039		Approaches to Vladivostok (U.S.S.R. & Korea)	1:291,360
97021	HO/BC 5492	South Coast of Honshu including Shikoku & Kyushu	1:925,200
97026	HO/BC 5499	Nansei (Ryukyu Islands) Shoto including Daito Jima	1:983,500
7400 Series		Loran-C Plotting Charts	1:2,188,800
7500 Series		Omega Position Plotting Charts (contains Trinidad)	1:2188,800
7600 Series		Omega Position Plotting Charts (contains Liberia)	1:2188,800
7700 Series		Omega Position Plotting Charts (contains Liberia)	1:2188,800
7800-7900 Series		Loran-C Plotting Charts	1:2,187,400

TABLE #4

Charts published by the Defense Mapping Agency, Aerospace Center. The area coverage charts are used with the permission of DMAAC.

Chart #	Title	Scale
	GLOBAL LORAN CHARTS	1:5,000,000
GLC-1,3,6,7,8,9,10 Loran-A GLC-C-1,3,4,6,7,8,9,10,11,13 Loran-C	See Figure 3 for areas covered	
	USAF LORAN-C NAVIGATION CHARTS	1:3,000,000
LCC-1A,2A,3A,4A	North Polar Region See Figure 4 for areas covered	
	USAF LORAN NAVIGATION CHARTS	1:2,000,000
LJC-6,7,15,16	Loran-A North Polar Region, Alaska, and Bering Sea	
	USAF CONSOL-LORAN NAVIGATION CHART	1:2,000,000
CJC-9	Consol & Loran-A, North Sea Area	

TABLE #5

Loran-A and Loran-C Rate Tables and Omega Lattice and Propagation Correction Tables published by Defense Mapping Agency, Hydrographic Center.

LORAN RATE TABLES

INDIVIDUAL LORAN-A TABLES ($.70)

Pub. No.	Title
221 (103)	North Atlantic (Rate 1L6)
221 (104)	North Atlantic (Rate 1L7)
221 (105)	North Atlantic (Rate 1L2)
221 (106)	North Atlantic (Rate 1L3)
221 (107)	North Atlantic (Rate 1H1)
221 (108)	West Indies (Rate 3L2)
221 (109)	West Indies (Rate 3L3)
221 (110)	North Atlantic (Rate 1L0)
221 (111)	North Atlantic (Rate 1L1)
221 (112)	Denmark Strait (Rate 1L5)
221 (113)	Denmark Strait (Rate 1L4)
221 (114)	East Coast U.S. (Rate 3H7) Changed to 3L1 June 1973)
221 (117)	North Atlantic (Rate 1H2)
221 (118)	North Atlantic (Rate 1H3)
221 (119)	North Atlantic (Rate 3H5)
221 (120)	North Atlantic (Rate 3H4)
221 (121)	North Atlantic (Rate 3H6)
221 (122)	North Sea (Rate 1S1) (Intermittent use only)
221 (123)	North Sea (Rate 1S2) (Intermittent use only)
221 (124)	West Portugal (Rate 1S5)
221 (125)	Azores (Rate 1S6)
221 (126)	Azores (Rate 1S7)
221 (127)	Gulf of Mexico (Rate 3H0)
221 (128)	Gulf of Mexico (Rate 3H1)
221 (129)	Gulf of Mexico (Rate 3H2)
221 (130)	Gulf of Mexico (Rate 3H3)

Pub. No.	Title
221 (131)	Southeast U.S.A. (Rate 3L5)
221 (132)	Gulf of Maine (Rate 1H7)
221 (133)	Bay of Biscay (Rate 1H5)
221 (201)	South Japan (Rate 2S7)
221 (202)	South Japan (Rate 2H6)
221 (203)	South Japan (Rate 2H7)
221 (204)	Central Pacific (Rate 2L7)
221 (205)	Asiatic Area (Rate 2H4)
221 (206)	Asiatic Area (Rate 2H3)
221 (207)	Asiatic Area (Rate 1L6)
221 (208)	Asiatic Area (Rate 1L7)
221 (209)	Central Pacific (Rate 2L6)
221 (210)	Central Pacific (Rate 1H2)
221 (211)	Central Pacific (Rate 1H1)
221 (213)	Central Pacific (Rate 2L5)
221 (214)	West Coast U.S. (Rate 1H5)
221 (215)	West Coast U.S. (Rate 1H6)
221 (216)	West Coast U.S. (Rate 2H4) (Changed to 1L0 May 1971)
221 (217)	West Coast U.S. (Rate 1L1)
221 (218)	Japanese Area (Rate 2S3)
221 (219)	Japanese Area (Rate 2S4)
221 (220)	West Japan (Rate 2S5)
221 (221)	West Japan (Rate 2S6)
221 (222)	South Pacific (Rate 2L1)
221 (223)	South Pacific (Rate 2L2)
221 (224)	South Pacific (Rate 2L3)
221 (225)	East Japan (Rate 2S1)
221 (226)	East Japan (Rate 2S2)
221 (227)	North Pacific (Rate 1L2)
221 (228)	North Pacific (Rate 1L3)
221 (229)	North Pacific (Rate 1L7)
221 (230)	North Pacific (Rate 1L6)
221 (231)	Philippine Sea (Rate 2H5)
221 (232)	West Coast U.S. (Rate 2H1) (Changed to 1H4 May 1971)
221 (233)	South Japan (Rate 2S0)
221 (234)	West Coast Canada (Rate 1L4)
221 (235)	West Coast Canada (Rate 1L5)

LORAN-C TABLES ($2.25)

Pub. No.	Title
221 (1001)	East Coast U.S.A. (Pair 9930-W)
221 (1002)	East Coast U.S.A. (Pair 9930-Y)
221 (1003)	Mediterranean Sea (Pair 7990-X)
221 (1004)	Mediterranean Sea (Pair 7990-Y)
221 (1005)	Norwegian Sea (Pair 7970-X)
221 (1006)	Norwegian Sea (Pair 7970-Y)
221 (1007)	Norwegian Sea (Pair 7970-Z)
221 (1008)	Mediterranean Sea (Pair 7990-Z)
221 (1009)	North Sea (Pair 7970-W)
221 (1010)	North Atlantic (Pair 7930-W)
221 (1011)	North Atlantic (Pair 7930-X)
221 (1012)	North Atlantic (Pair 7930-Z)
221 (1013)	East Coast U.S.A. (Pair 9930-X)
221 (1014)	Eastern U.S.A. (Pair 9930-Z)
221 (2001)	North Pacific (Pair 5930-Z)
221 (2002)	North Pacific (Pair 5930-X)
221 (2003)	Central Pacific (Pair 4990-X)
221 (2004)	Central Pacific (Pair 4990-Y)
221 (2005)	North Pacific (Pair 5930-Y)
221 (2006)	Northwest Pacific (Pair 9970-W)
221 (2007)	Northwest Pacific (Pair 9970-X)
221 (2008)	Northwest Pacific (Pair 9970-Y)
221 (2009)	Northwest Pacific (Pair 9970-Z)
221 (2018)	West Coast, U.S.A. (Pair 9940-X) Avail. July, 1976
221 (2019)	West Coast, U.S.A. (Pair 9940-Y) Avail. July, 1976

AUXILIARY LORAN TABLES AND DIAGRAMS

Chart No.	Title	Price	Scale
5130	Loran-C Coverage Diagram	3.00	1:45,000,000
5131	Loran-A Coverage Diagram	3.00	1:45,000,000
16 or 55 (March 1976)	Omega Coverage Diagram	2.45	1:58,500,000
5148	Loran Interpolator Diagram	1.50	
5179	Omega Linear Interpolator	1.50	

Code N.O. 7300/7400 Code N.O. 730

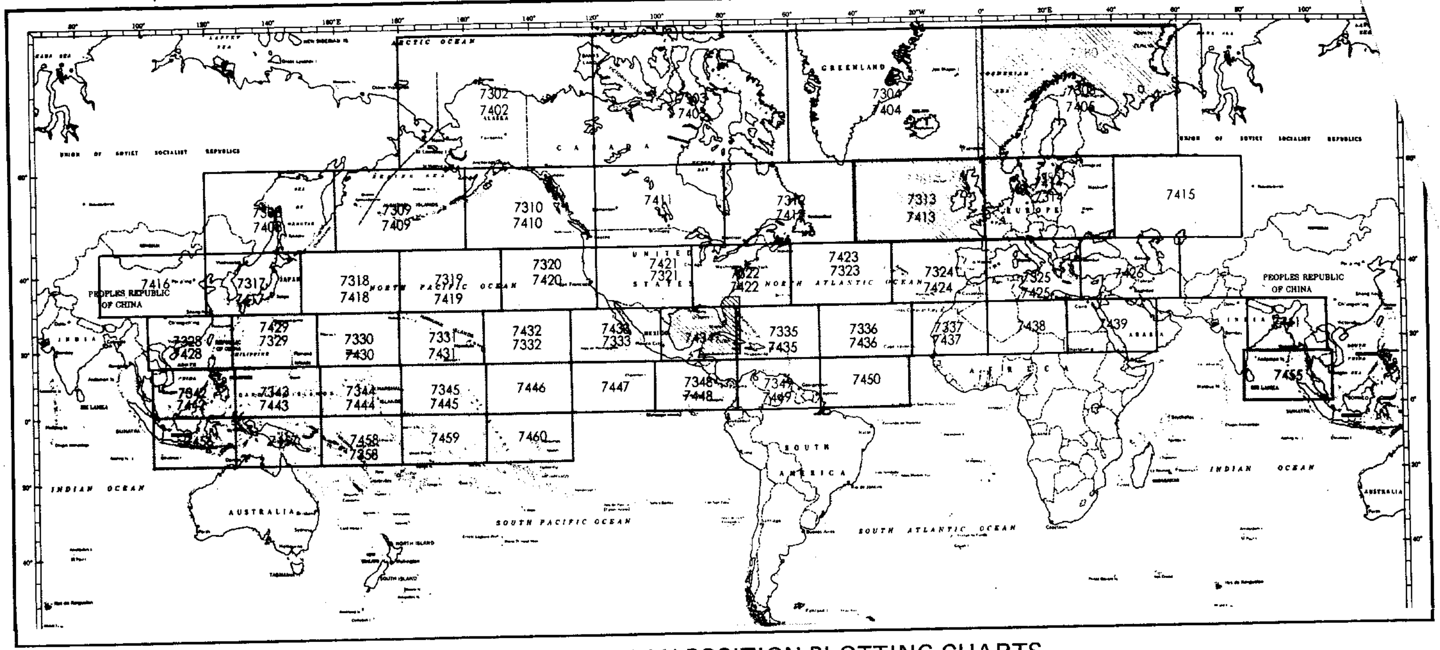

FIGURE 1 - LORAN POSITION PLOTTING CHARTS

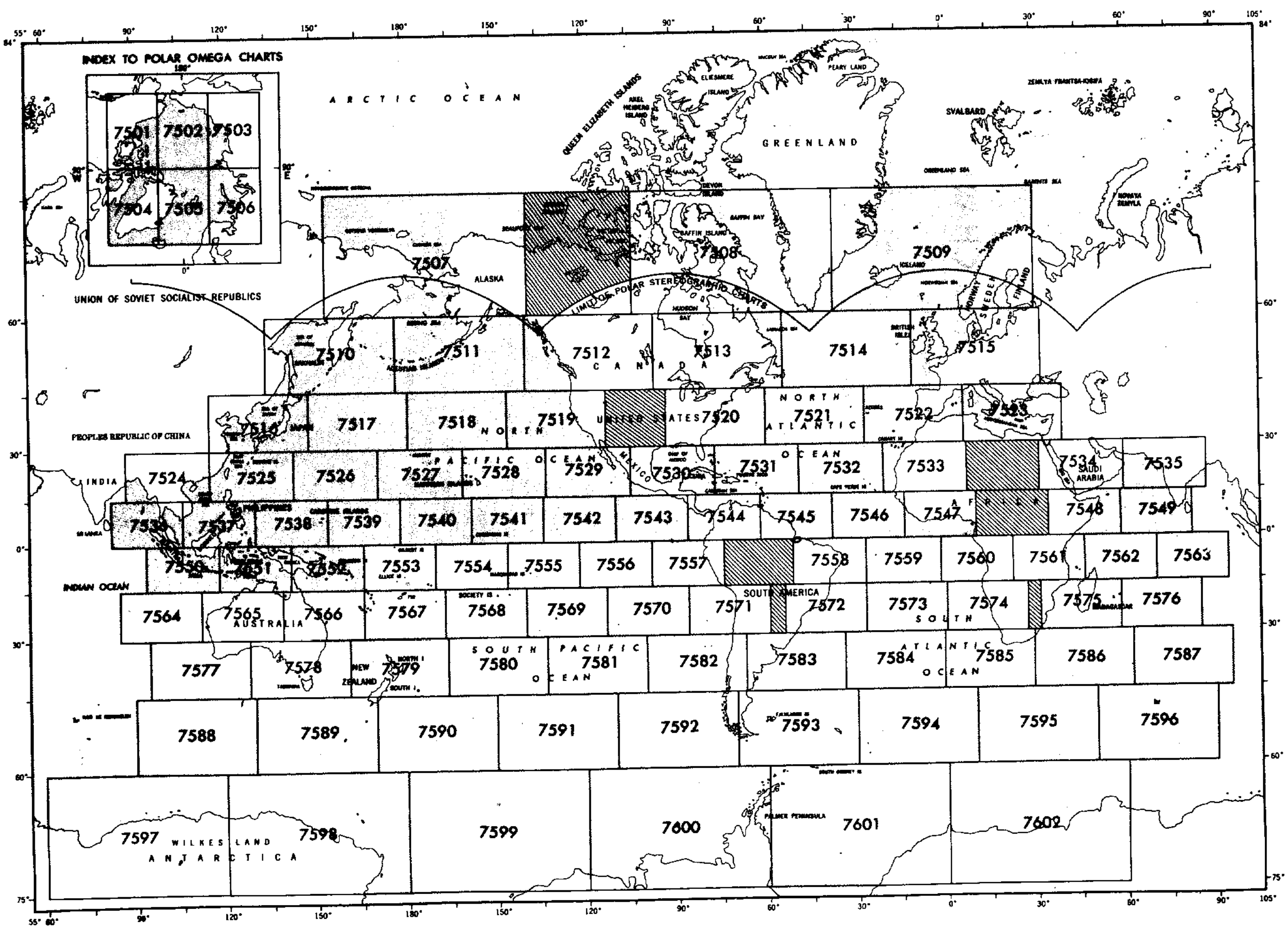

FIGURE 2 - OMEGA POSITION PLOTTING CHARTS

CURRENT AS OF 1 MARCH 1974

DEFENSE MAPPING AGENCY HYDROGRAPHIC CENTER

7501-7552 Completed - Remainder of series not scheduled for production. Entire 7500 series to be discontinued when Omega Trinidad is removed from service.

LORAN-C RELIABILITY DIAGRAMS

5592	Mediterranean Sea	7790-X, 7790-Y, 7790-Z	1:5,093,677
5593	Norwegian Sea	7970-W, 7970-X, 7970-Y, 7970-Z	1:5,000,000
5594	East Coast U.S.A.	9930-W, 9930-X, 9930-Y, 9930-Z	1:5,000,000
5595	North Pacific	5930-X, 5930-Y, 5930-Z	1:5,000,000
5596	Central Pacific	4990-X, 4990-Y	1:5,000,000
5597	Northwest Pacific	9970-W, 9970-X, 9970-Y, 9970-Z	1:5,000,000
5598	North Atlantic	7930-W, 7930-X, 7930-Z	1:5,000,000

SPECIFICATIONS FOR OMEGA
(Revised 12 January 1976)

1. Transmitting Station Locations:

Station Letter	Location	Latitude	Longitude
A	Aldra, Norway	66°25′12.″39N	13°08′12.″65E
G (Temporary)	Trinidad	10°42′06.″2N	61°38′20.″3W
B	Monrovia, Liberia	6°18′19.″39N	10°39′44.″21W
C	Haiku, Oahu, Hawaii	21°24′16.″9N	157°49′52.″7W
D	La Moure, North Dakota	46°21′57.″20N	98°20′08.″77W
E	La Reunion I., France	20°58′26.″47S	55°17′24.″25E
F	Golfo Nuevo, Argentina	43°03′12.″53S	65°11′27.″69W
G	South Pacific Area	(proposed)	
H	Tsushima, Japan	34°36′53.″26N	129°27′12.″49E

2. Transmitter Position Datum: Mercury Datum

3. Datum Reference Spheroid:

   Fischer (1960)

   Equatorial Radius (a) = 6,378,166 meters
   Polar Radius (b) = 6,356,784.283 meters
   Flattening (a-b)/a = 1/298.3

4. Synchronization:

   Coordinated Universal Time (UTC)

5. Frequencies:

   10.2 kHz (λ = 29,468.087 meters)
   11 1/3 kHz (λ = 26,521,279 meters)
   13.6 kHz (λ = 22,101.066 meters)
   3.4 kHz (Difference frequency: 13.6 - 10.2)

6. Propagation Velocity:

Free space (group) velocity	c = 299, 793 km/sec
Nominal charted (phase) velocity	v = 300, 574 km/sec
Nominal ratio	$\frac{c}{v}$ = 0.9974

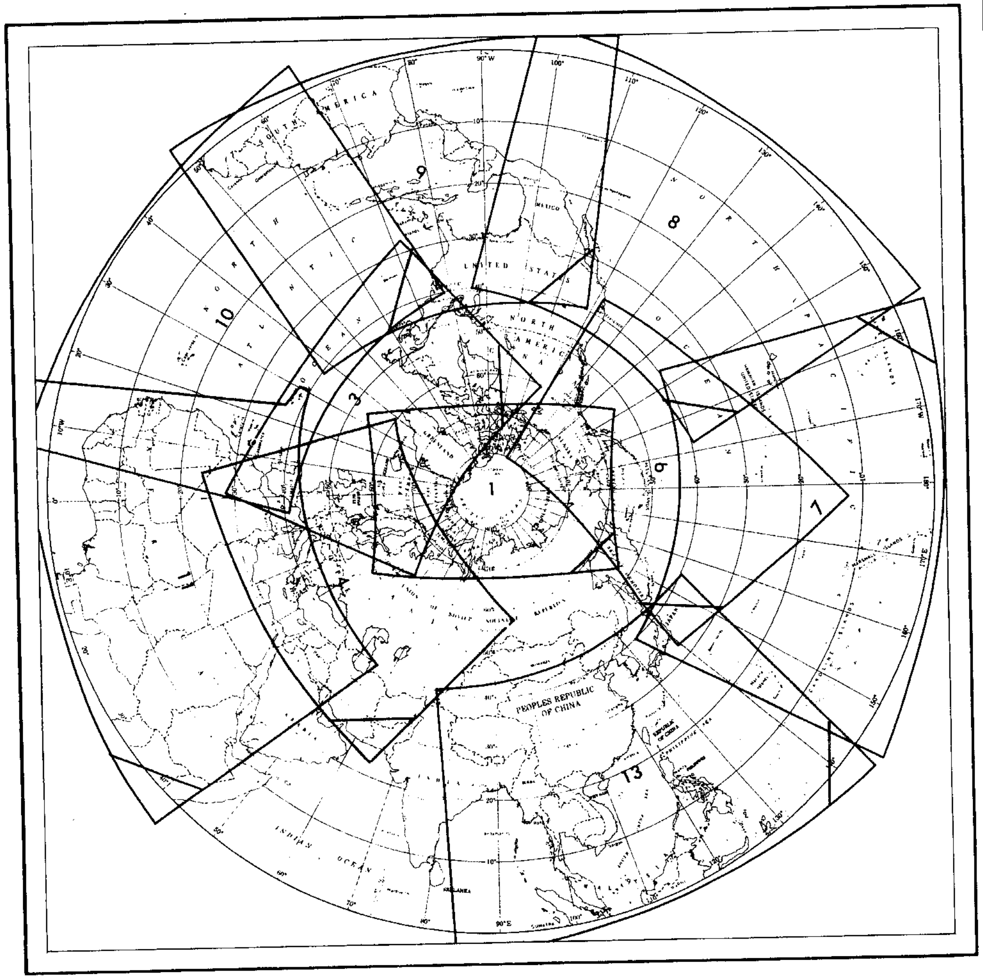

FIGURE 3 - GLOBAL LORAN NAVIGATION CHARTS

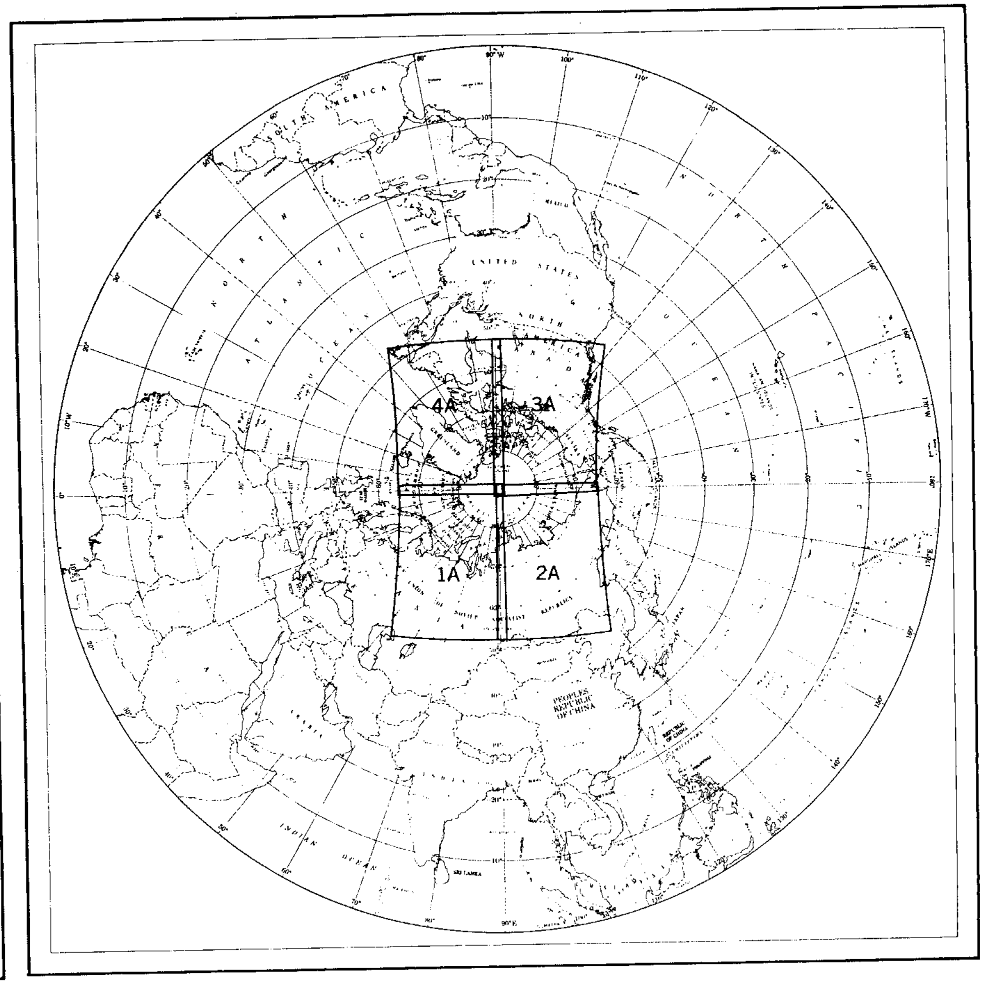

FIGURE 4 - USAF LORAN C NAVIGATION CHARTS

7. Hyperbolic Lattice (Minimum/Maximum Lane Counts):

A fictitious coding delay (minimum lane count) must be inserted in the lattice computations to provide a 10.2 kHz lane count of 900 lanes on the perpendicular bisector of the baseline. The purpose is to impose an orderly lane counting system for chart portrayal. This makes the quantity B + D, baseline distance plus minimum lane count, a constant equal to 900, 1000, 1200, and 300 for 10.2, 11 1/3, 13.6, and 3.4 kHz respectively for all Omega pairs. The minimum lane count will be read on the great circle baseline extension behind the first designated station of a station pair. A maximum lane count equal to twice the baseline length plus the minimum lane count, will be read on the baseline extension behind the second designated station.

Pair	Baseline Length (B) Meters	Baseline Length (B) *Wavelengths	*Minimum Lane Count	*Maximum Lane Count
A-G (Temp)	8,244,153.29	279.7655	620.2345	1179.7655
A-B	6,919,722.68	234.8209	665.1791	1134.8209
A-C	10,236,895.48	347.3892	552.6108	1247.3892
A-D	6,222,437.95	211.1585	688.8415	1111.1585
A-E	10,309,445.92	349.8512	550.1488	1249.8512
A-F	13,820,081.25	468.9847	431.0153	1368.9847
A-G				
A-H	7,578,862.15	257.1888	642.8112	1157.1888
G (Temp) -C	10,217,543.49	346.7325	553.2675	1246.7325
B-C	15,305,978.41	519.4086	380.5914	1419.4086
G (Temp) -D	5,255,330.06	178.3397	721.6603	1078.3397
B-D	9,327,981.64	316.5452	583.4548	1216.5452
G (Temp) -E	13,221,742.06	448.6800	451.3200	1348.6800
B-E	7,806,944.02	264.9288	635.0712	1164.9288
G (Temp) -F	5,963,134.21	202.3590	697.6410	1102.3590
B-F	7,743,457.11	262.7743	637.2257	1162.7743
B-G				
G (Temp) -H	14,855,234.91	504.1126	395.8874	1404.1126
B-H	13,849,194.31	469.9726	430.0274	1369.9726
C-D	5,992,070.99	203.3410	696.6590	1103.3410
C-E	16,599,728.31	563.3120	336.6880	1463.3120
C-F	11,811,246.71	400.8148	499.1851	1300.8148
C-G				
C-H	7,152,188.38	242.7096	657.2904	1142.7096
D-E	16,318,394.47	553.7650	346.2350	1453.7650
D-F	10,432,155.03	354.0154	545.9846	1254.0154
D-G				
D-H	9,842,096.76	333.9917	566.0083	1233.9917
E-F	10,674,895.82	362.2528	537.7472	1262.2528
E-G				
E-H	9,957,474.49	337.9070	562.0930	1237.9070
F-G				
F-H	18,441,400.55	625.8092	274.1908	1525.8092
G-H				

*Frequency of 10.2 kHz

OMEGA LATTICE TABLES

H.O. Pub. No.	Area of Coverage	Area
224 (100) A-D	North Polar	00
224 (100) A-H	North Polar	00
*224 (100) B-C	North Polar	00
**224 (100) B-C	North Polar	00
*224 (100) B-D	North Polar	00
*224 (100) B-H	North Polar	00
**224 (100) B-H	North Polar	00
224 (100) C-H	North Polar	00
*224 (101) A-B	Northern Europe	01
224 (101) A-C	Northern Europe	01
224 (101) A-D	Northern Europe	01
224 (101) A-E	Northern Europe	01
224 (101) A-H	Northern Europe	01
*224 (101) B-C	Northern Europe	01
*224 (101) B-D	Northern Europe	01
**224 (101) B-D	Northern Europe	01
*224 (101) B-E	Northern Europe	01
*224 (101) B-H	Northern Europe	01
**224 (101) B-H	Northern Europe	01
224 (101) C-D	Northern Europe	01
224 (101) C-E	Northern Europe	01
*224 (102) A-B	Central U.S.S.R.	02
**224 (102) A-B	Central U.S.S.R.	02
224 (102) A-C	Central U.S.S.R.	02
224 (102) A-D	Central U.S.S.R.	02
224 (102) A-E	Central U.S.S.R.	02
*224 (102) B-C	Central U.S.S.R.	02
**224 (102) B-C	Central U.S.S.R.	02
224 (102) D-E	Central U.S.S.R.	02
224 (102) D-H	Central U.S.S.R.	02
**224 (103) A-B	Eastern U.S.S.R.	03
224 (103) A-C	Eastern U.S.S.R.	03
224 (103) A-D	Eastern U.S.S.R.	03
224 (103) A-H	Eastern U.S.S.R.	03
*224 (103) B-C	Eastern U.S.S.R.	03
**224 (103) B-C	Eastern U.S.S.R.	03
*224 (103) B-H	Eastern U.S.S.R.	03
224 (103) C-D	Eastern U.S.S.R.	03
224 (103) C-H	Eastern U.S.S.R.	03
224 (103) D-H	Eastern U.S.S.R.	03
**224 (104) A-B	Alaska	04
224 (104) A-C	Alaska	04
224 (104) A-D	Alaska	04
224 (104) A-H	Alaska	04
**224 (104) B-C	Alaska	04
**224 (104) B-H	Alaska	04
224 (104) C-D	Alaska	04
224 (104) C-H	Alaska	04
224 (104) D-H	Alaska	04
*224 (105) A-B	Canada	05
**224 (105) A-B	Canada	05
224 (105) A-C	Canada	05
224 (105) A-D	Canada	05
*224 (105) B-C	Canada	05
**224 (105) B-C	Canada	05
*224 (105) B-D	Canada	05
**224 (105) B-D	Canada	05
*224 (105) B-F	Canada	05
*224 (105) B-H	Canada	05
**224 (105) B-H	Canada	05
224 (105) C-D	Canada	05
224 (105) C-H	Canada	05
224 (105) D-H	Canada	05
*224 (106) A-B	Greenland	06
**224 (106) A-B	Greenland	06
224 (106) A-C	Greenland	06
224 (106) A-D	Greenland	06
*224 (106) B-C	Greenland	06
**224 (106) B-C	Greenland	06
*224 (106) B-D	Greenland	06
**224 (106) B-D	Greenland	06
*224 (106) B-E	Greenland	06
*224 (106) B-F	Greenland	06
*224 (106) B-H	Greenland	06
**224 (106) B-H	Greenland	06
*224 (107) A-B	Mediterranean	07
**224 (107) A-B	Mediterranean	07
224 (107) A-D	Mediterranean	07
224 (107) A-E	Mediterranean	07
**224 (107) B-C	Mediterranean	07
*224 (107) B-D	Mediterranean	07
**224 (107) B-D	Mediterranean	07
*224 (107) B-E	Mediterranean	07
*224 (107) B-H	Mediterranean	07
224 (107) D-E	Mediterranean	07
224 (107) E-H	Mediterranean	07
*224 (108) A-B	Asia	08
224 (108) A-C	Asia	08
224 (108) A-E	Asia	08
224 (108) A-H	Asia	08
*224 (108) B-E	Asia	08
*224 (108) B-H	Asia	08
224 (108) C-E	Asia	08
224 (108) E-H	Asia	08
224 (109) A-C	Northwest Pacific	09
224 (109) A-E	Northwest Pacific	09
224 (109) C-D	Northwest Pacific	09
224 (109) C-E	Northwest Pacific	09
224 (109) C-H	Northwest Pacific	09
224 (109) D-H	Northwest Pacific	09
224 (109) E-H	Northwest Pacific	09
**224 (110) A-B	Central Pacific	10
224 (110) A-C	Central Pacific	10
224 (110) C-D	Central Pacific	10
224 (110) C-H	Central Pacific	10
224 (110) D-F	Central Pacific	10
224 (110) D-H	Central Pacific	10
224 (110) F-H	Central Pacific	10
*224 (111) A-B	North America	11
**224 (111) A-B	North America	11
224 (111) A-C	North America	11
224 (111) A-F	North America	11
*224 (111) B-C	North America	11
**224 (111) B-C	North America	11
*224 (111) B-D	North America	11
**224 (111) B-D	North America	11
*224 (111) B-F	North America	11
**224 (111) B-F	North America	11
*224 (111) B-H	North America	11
224 (111) C-D	North America	11
224 (111) C-F	North America	11
*224 (112) A-B	North Atlantic	12
**224 (112) A-B	North Atlantic	12
224 (112) A-C	North Atlantic	12
224 (112) A-D	North Atlantic	12
224 (112) A-E	North Atlantic	12

OMEGA PROPAGATION TABLES - 10.2 kHz

H.O. Pub. No.	Area of Coverage	Area
224 (100-C) A	North Polar	00
*224 (100-C) B	North Polar	00
**224 (100-C) B	North Polar	00
224 (100-C) C	North Polar	00
224 (100-C) D	North Polar	00
224 (100-C) H	North Polar	00
224 (101-C) A	Northern Europe	01
*224 (101-C) B	Northern Europe	01
**224 (101-C) B	Northern Europe	01
224 (101-C) C	Northern Europe	01
224 (101-C) D	Northern Europe	01
224 (101-C) E	Northern Europe	01
224 (101-C) H	Northern Europe	01
224 (102-C) A	Central U.S.S.R.	02
*224 (102-C) B	Central U.S.S.R.	02
**224 (102-C) B	Central U.S.S.R.	02
224 (102-C) C	Central U.S.S.R.	02
224 (102-C) D	Central U.S.S.R.	02
224 (102-C) E	Central U.S.S.R.	02
224 (102-C) H	Central U.S.S.R.	02
224 (103-C) A	Eastern U.S.S.R.	03
**224 (103-C) B	Eastern U.S.S.R.	03
224 (103-C) C	Eastern U.S.S.R.	03
224 (103-C) D	Eastern U.S.S.R.	03
224 (103-C) H	Eastern U.S.S.R.	03
224 (104-C) A	Alaska	04
**224 (104-C) B	Alaska	04
224 (104-C) C	Alaska	04
224 (104-C) D	Alaska	04
224 (104-C) H	Alaska	04
224 (105-C) A	Canada	05
*224 (105-C) B	Canada	05
**224 (105-C) B	Canada	05
224 (105-C) C	Canada	05
224 (105-C) D	Canada	05
224 (105-C) F	Canada	05
224 (105-C) H	Canada	05
224 (106-C) A	Greenland	06
*224 (106-C) B	Greenland	06
**224 (106-C) B	Greenland	06
224 (106-C) C	Greenland	06
224 (106-C) D	Greenland	06
224 (106-C) E	Greenland	06
224 (106-C) F	Greenland	06
224 (106-C) H	Mediterranean	07
224 (107-C) A	Mediterranean	07
*224 (107-C) B	Mediterranean	07
**224 (107-C) B	Mediterranean	07
224 (107-C) D	Mediterranean	07
224 (107-C) E	Mediterranean	07
224 (107-C) F	Mediterranean	07
224 (107-C) H	Mediterranean	07
224 (108-C) A	Asia	08
*224 (108-C) B	Asia	08
224 (108-C) C	Asia	08
224 (108-C) E	Asia	08
224 (108-C) H	Asia	08
224 (109-C) A	Northwest Pacific	09
224 (109-C) C	Northwest Pacific	09
224 (109-C) D	Northwest Pacific	09
224 (109-C) E	Northwest Pacific	09
224 (109-C) H	Northwest Pacific	09

H.O. Pub. No.	Area of Coverage	Area
224 (112) A-F	North Atlantic	12
*224 (112) B-C	North Atlantic	12
**224 (112) B-C	North Atlantic	12
*224 (112) B-D	North Atlantic	12
**224 (112) B-D	North Atlantic	12
*224 (112) B-E	North Atlantic	12
*224 (112) B-F	North Atlantic	12
224 (112) D-E	North Atlantic	12
224 (112) D-F	North Atlantic	12
*224 (113) A-B	Africa	13
224 (113) A-F	Africa	13
*224 (113) B-E	Africa	13
*224 (113) B-F	Africa	13
*224 (113) B-H	Africa	13
224 (113) E-F	Africa	13
*224 (114) A-B	Indian Ocean	14
224 (114) A-E	Indian Ocean	14
*224 (114) B-F	Indian Ocean	14
*224 (114) B-H	Indian Ocean	14
224 (114) E-H	Indian Ocean	14
224 (115) C-E	Australia	15
224 (115) C-F	Australia	15
224 (115) C-H	Australia	15
224 (115) E-F	Australia	15
**224 (116) B-C	South Pacific	16
224 (116) C-F	South Pacific	16
224 (116) C-H	(Avail. June 76)	16
224 (116) D-F	South Pacific	16
224 (116) D-H	(Avail. June 76)	16
224 (116) F-H	(Avail. June 76)	16
*224 (117) A-B	East Pacific	17
**224 (117) A-B	East Pacific	17
*224 (117) B-C	East Pacific	17
**224 (117) B-C	East Pacific	17
*224 (117) B-D	East Pacific	17
*224 (117) B-F	East Pacific	17
224 (117) C-F	East Pacific	17
224 (117) D-F	East Pacific	17
*224 (118) A-B	South Atlantic	18
**224 (118) A-B	South Atlantic	18
224 (118) A-C	South Atlantic	18
*224 (118) A-F	South Atlantic	18
*224 (118) B-D	South Atlantic	18
*224 (118) B-E	South Atlantic	18
*224 (118) B-F	South Atlantic	18
**224 (118) B-F	South Atlantic	18
224 (118) D-E	South Atlantic	18
224 (118) D-F	South Atlantic	18
224 (118) E-F	South Atlantic	18
*224 (119) B-E		19
*224 (119) B-F		19
**224 (119) B-F		19
224 (119) E-F		19
224 (121) C-H	Victoria Land	21
224 (121) E-F	Victoria Land	21
224 (121) E-H	Victoria Land	21
**224 (122) B-C	Ross Sea	22
*224 (123) B-C		
*224 (123) B-D		
*224 (123) B-E		
224 (123) C-F		
*224 (124) B-E		
*224 (124) B-F		
**224 (124) B-F		
224 (124) E-F		

H.O. Pub. No.	Area of Coverage	Area
224 (110-C) A	Central Pacific	10
**224 (110-C) B	Central Pacific	10
224 (110-C) C	Central Pacific	10
224 (110-C) D	Central Pacific	10
224 (110-C) F	Central Pacific	10
224 (110-C) H	Central Pacific	10
224 (111-C) A	North America	11
*224 (111-C) B	North America	11
**224 (111-C) B	North America	11
224 (111-C) C	North America	11
224 (111-C) D	North America	11
224 (111-C) F	North America	11
224 (111-C) H	North America	11
224 (112-C) A	North Atlantic	12
*224 (112-C) B	North Atlantic	12
**224 (112-C) Bb	North Atlantic	12
224 (112-C) C	North Atlantic	12
224 (112-C) D	North Atlantic	12
224 (112-C) E	North Atlantic	12
224 (112-C) F	North Atlantic	12
224 (113-C) A	Africa	13
*224 (113-C) B	Africa	13
224 (113-C) E	Africa	13
224 (113-C) F	Africa	13
224 (113-C) H	Africa	13
224 (114-C) A	Indian Ocean	14
*224 (114-C) B	Indian Ocean	14
224 (114-C) E	Indian Ocean	14
224 (114-C) F	Indian Ocean	14
224 (114-C) H	Indian Ocean	14
224 (115-C) C	Australia	15
224 (115-C) E	Australia	15
224 (115-C) H	Australia	15
224 (116-C) C	South Pacific	16
224 (116-C) D	South Pacific	16
224 (116-C) F	South Pacific	16
224 (116-C) H	South Pacific	16
*224 (117-C) B	East Pacific	17
**224 (117-C) B	East Pacific	17
224 (117-C) C	East Pacific	17
224 (117-C) D	East Pacific	17
224 (117-C) F	East Pacific	17
224 (118-C) A	South Atlantic	18
*224 (118-C) B	South Atlantic	18
**224 (118-C) B	South Atlantic	18
224 (118-C) C	South Atlantic	18
224 (118-C) D	South Atlantic	18
224 (118-C) E	South Atlantic	18
224 (118-C) F	South Atlantic	18
224 (119-C) E	(Avail. June 76)	19
224 (119-C) F	(Avail. June 76)	19
224 (120-C) E	(Avail. June 76)	20
224 (121-C) E	(Avail. June 76)	21
224 (121-C) F	(Avail. June 76)	21
*224 (123-C) B		23
224 (123-C) C		23
224 (123-C) D		23
224 (123-C) E	(Avail. June 76)	23
224 (123-C) F		23
*224 (124-C) B	(Avail. June 76)	24
224 (124-C) E	(Avail. July 76)	24
224 (124-C) F	(Avail. July 76)	24

H.O. Pub. No.	Area of Coverage	Area
224 (201-C) A	Northern Europe	01
*224 (201-C) B	Northern Europe	01
**224 (201-C) B	Northern Europe	01
224 (201-C) C	Northern Europe	01
224 (201-C) D	Northern Europe	01
224 (201-C) H	Northern Europe	01
*224 (202-C) B	Central U.S.S.R.	02
224 (202-C) H	Central U.S.S.R.	02
224 (204-C) A	Alaska	04
**224 (204-C) B	Alaska	04
224 (204-C) C	Alaska	04
224 (204-C) D	Alaska	04
224 (204-C) H	Alaska	04
224 (205-C) A	Canada	05
*224 (205-C) B	Canada	05
**224 (205-C) B	Canada	05
224 (205-C) C	Canada	05
224 (205-C) D	Canada	05
224 (205-C) H	Canada	05
224 (206-C) A	Greenland	06
*224 (206-C) B	Greenland	06
**224 (206-C) B	Greenland	06
224 (206-C) C	Greenland	06
224 (206-C) D	Greenland	06
224 (206-C) H	Greenland	06
224 (207-C) A	Mediterranean	07
*224 (207-C) B	Mediterranean	07
224 (207-C) D	Mediterranean	07
224 (207-C) F	Mediterranean	07
224 (207-C) H	Mediterranean	07
*224 (208-C) B	Asia	08
224 (208-C) H	Asia	08
224 (209-C) A	Northwest Pacific	09
224 (209-C) C	Northwest Pacific	09
224 (209-C) D	Northwest Pacific	09
224 (209-C) H	Northwest Pacific	09
224 (210-C) A	Central Pacific	10
**224 (210-C) B	Central Pacific	10
224 (210-C) C	Central Pacific	10
224 (210-C) D	Central Pacific	10
224 (210-C) F	Central Pacific	10
224 (210-C) H	Central Pacific	10
224 (211-C) A	North America	11
*224 (211-C) B	North America	11
**224 (211-C) B	North America	11
224 (211-C) C	North America	11
224 (211-C) D	North America	11
224 (211-C) F	North America	11
224 (211-C) H	North America	11
224 (212-C) A	North Atlantic	12
*224 (212-C) B	North Atlantic	12
**224 (212-C) B	North Atlantic	12
224 (212-C) C	North Atlantic	12
224 (212-C) D	North Atlantic	12
224 (212-C) F	North Atlantic	12
*224 (213-C) B	Africa	13
224 (213-C) F	Africa	13
224 (213-C) H	Africa	13
224 (214-C) A	Indian Ocean	14
*224 (214-C) B	Indian Ocean	14
224 (214-C) H	Indian Ocean	14
224 (215-C) C	Australia	15
224 (215-C) H	Australia	15

H.O. Pub. No.	Area of Coverage	Area
224 (216-C) C	South Pacific	16
224 (216-C) D	South Pacific	16
224 (216-C) F	South Pacific	16
224 (216-C) H	South Pacific	16
*224 (217-C) B	East Pacific	17
**224 (217-C) B	East Pacific	17
224 (217-C) C	East Pacific	17
224 (217-C) D	East Pacific	17
224 (217-C) F	East Pacific	17

H.O. Pub. No.	Area of Coverage	Area
224 (218-C) A	South Atlantic	18
*224 (218-C) B	South Atlantic	18
**224 (218-C) B	South Atlantic	18
224 (218-C) D	South Atlantic	18
224 (218-C) F	South Atlantic	18

* Omega Liberia
** Omega Trinidad

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7621	7653	7686
7622	7654	7694
7623	7655	7695
7624	7656	7696
7625	7657	7697
7633	7658	7698
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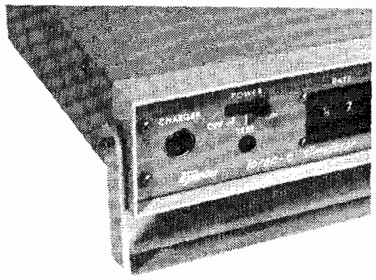

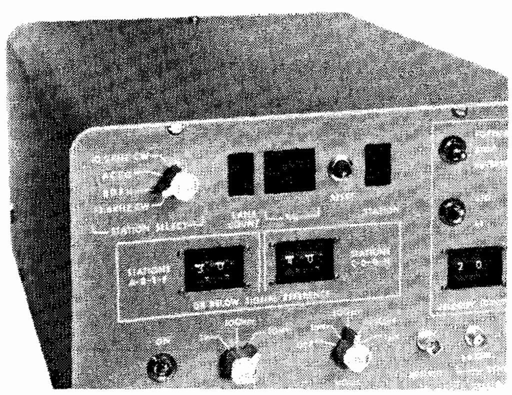

LORAN CHAIN DATA

The information on loran chains is provided primarily to indicate coverage areas. The information on U.S. Coast Guard chains is sufficient for use as the data base in a computerized solution for latitude and longitude from time differences. The information on the U.S.S.R. chains is based on derived information. Before use is made of these systems for navigation, the data should be confirmed and refined.

Privately owned chains are presently in operation in the Gulf of Mexico and Java Sea and planned for operation in the North Sea, Celtic Sea and Hudson's Bay. The USCG and USAF have installed chains utilizing this same low power commercial equipment, to cover respectively, the St. Mary's River and Southwestern, Southeastern and Central European test ranges.

The information on planned chains is tentative and must be confirmed with the owner or operator before use is made of the information. In particular, site locations are not confirmed. The names of towns indicate only general areas. Where a latitude and longitude are given, the site location is determined, but the final survey may not have been made.

General Specifications and Notes

The latitude, longitude, and baseline lengths listed herein were furnished by the Defense Mapping Agency, Hydrographic Center and are based upon Mercury Datum 1960 (center of mass), Fischer spheroid. Appropriate geodetic satellite shifts have been made to relate these coordinates to the center of the earth. The latitudes and longitudes are listed in units of degrees, minutes and seconds.

The following parameters were used in the computations:

a. Signal propogation: Use the velocity of light in free space as 2.997942 (10^8) meters/second and an index of refraction of 1.000338 at the surface for standard atmosphere.

b. Phase of the groundwave: As described in NBS Circular 573.

c. Conductivity: Sigma = 5.0 mhos/meter (seawater). Baseline electrical distance computations were made assuming a smooth, all seawater 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. Spheriod: Fischer 1960 (equatorial radius (a) = 6,378,166.000 meters, polar radius (b) = 6,356,784.283 meters, flattening (f) = (a-b)/a = 1/298.3).

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

Commandant (G-WAN-3/73)
U.S. Coast Guard
Washington, D.C. 20590

The information contained in the following pages supersedes the information contained in the "Loran-C User Handbook" published by the Coast Guard (CG-462) August 1974.

U.S. East Coast Chain - Rate 9930 (SS7)

Station	Coordinates Latitude & Longitude	Station Function	Coding Delay & Baseline Length	Radiated Peak Power
Carolina Beach, NC	34-03-45.96N 77-54-46.76W	Master	- - -	700 kW
Jupiter, Florida	27-01-58.42N 80-06-53.52W	W Secondary	11.000μs 2695.51μs	300 kW
Cape Race, Newfoundland	46-46-32.09N 53-10-28.16W	X Secondary	28,000μs 8389.65μs	1.8MW
Nantucket, Massachusetts	41-15-11.84N 69-58-39.09W	Y Secondary	49,000μs 3541.31μs	300 kW
Dana, Indiana	39-51-07.46N 87-29-12.14W	Z Secondary	65,000μs 3560.71μs	400 kW
Electronics Engineering Center Wildwood, NJ	38-56-58.13N 74-52-01.57W	T Secondary	82,000μs 2026.19μs	200 to 400 kW

West Canadian Chain (operational 1/77) - Rate 5990 (SH1)

Station	Coordinates Latitude & Longitude	Station Function	Coding Delay & Baseline Length	Radiated Peak Power
Williams Lake BC, Canada	51-57-58.70N 122-22-02.50W	Master	- - -	400 kW
Shoal Cove, Alaska	55-26-20.68N 131-15-19.69W	X Secondary	11,000μs 2343.58μs	1.0 MW
George, Washington	47-03-47.90N 119-44-39.38W	Y Secondary	27,000μs 1927.37μs	2.0 MW

Southeast US Chain(Test) - Rate 3970 (L3) USAF, Loran-C/D

Station Name	Location	Function Power	Coding Delay & Baseline Length	
Ft. McClellan, Alabama	33-44- 85-56-	M		
Kisatchie, Louisiana	31-05-42N 92-34-06W	X	11,000μs 1798.82μs	
Raiford, Florida	30-05-15 82-11-43	Y	25,000μs 2304.00μs	

Norwegian Sea Chain - Rate 7970 (SL3)

Station	Coordinates Latitude & Longitude	Station Function	Coding Delay & Baseline Length	Radiated Peak Power
Ejde, Faroe Islands	62-17-59.61N 07-04-26.71W	Master	- - -	400 kW
Bo, Norway	68-38-06.09N 14-27-47.00E	X Secondary	11,000μs 4048.10μs	200 kW
Sylt, Germany	54-48-29.72N 08-17-36.33E	W Secondary	26,000μs 4065.64μs	300 kW
Sandur, Iceland	64-54-26.52N 23-55-21.75W	Y Secondary	46,000μs 2944.53μs	1.8 MW
Jan Mayen, Norway	70-54-52.55N 08-43-58.69W	Z Secondary	60,000μs 3216.30μs	200 kW

Eastern USSR Chain - Rate 5000 (SO)

Station	Coordinates Latitude & Longitude	Station Function	Coding Delay & Baseline Length	Radiated Peak Power
Okhotsk				
Vladivostok				
Kamchatka Penninsula				

North Pacific Chain (reconfigured 1/77) - Rate 9990 (SS1)

Station	Coordinates Latitude & Longitude	Station Function	Coding Delay & Baseline Length	Radiated Peak Power
St. Paul Is., Pribiloff Is., Alaska	57-09-09.80N 170-14-59.84W	Master	- - -	300 kW
Attu, Alaska	52-49-44.96N 173-10-52.31E	X Secondary	11,000μs 3875.32μs	300 kW
Port Clarence, Alaska	65-14-40.06N 166-53-14.47W	Y Secondary	29,000μs 3069.09μs	1.0 MW
Narrow Cape, Alaska	57-26-20.48N 152-22-11.98W	Z Secondary	43,000μs 3590.06μs	400 kW

Gulf of Mexico Chain (operational 7/78)

Station	Approximate Latitude & Longitude	Station Function	Coding Delay & Baseline Length	Radiated Peak Power
Malone, Florida	30-59-38N 85-10-11W	Master	- - -	1.0 MW
Grangeville, Louisina	30-43-34N 90-49-41W	W Secondary	11,000μs	1.0 MW
Raymondville, Texas	26-31-54N 97-49-58W	X Secondary	23,000μs	400 kW
Jupiter, Florida	27-01-58.42N 80-06-53.52W	Y Secondary	41,000μs	300 kW
Carolina Beach, N. Carolina	34-03-45.96N 77-54-46.76W	Z Secondary	59,000μs	350 kW

North Atlantic Chain - Rate 7930 (SL7)

Station	Coordinates Latitude & Longitude	Station Function	Coding Delay & Baseline Length	Radiated Peak Power
Angissoq, Greenland	59-59-17.19N 45-10-27.47W	Master	- - -	1.0 MW
Sandur, Iceland	64-54-26.52N 23-55-21.75W	W Secondary	11,000μs 4068.03μs	1.8 MW
Ejde, Faroe Islands	62-17-59.61N 07-04-26.17W	X Secondary	21,000μs 6803.76μs	400 kW
Cape Race, Newfoundland	46-46-32.09N 53-10-28.16W	Z Secondary	43,000μs 5212.19μs	1.8 MW

Northwest Pacific Chain - Rate 9970 (SS3)

Station	Coordinates Latitude & Longitude	Station Function	Coding Delay & Baseline Length	Radiated Peak Power
Iwo Jima, Bonin Is.	24-48-04.01N 141-19-29.01E	Master	- - -	1.8 MW
Marcus Is.	24-17-07.59N 153-58-51.50E	W Secondary	11,000μs 4283.94μs	1.8 MW
Hokkaido, Japan	42-44-36.88N 143-43-09.06E	X Secondary	30,000μs 6685.11μs	400 kW
Gesashi, Okinawa, Jap.	26-36-24.91N 128-08-56.21E	Y Secondary	55,000μ 4463.18μs	400 kW
Yap, Caroline Is.	09-32-45.63N 138-09-55.23E	Z Secondary	75,000μ 5746.78μs	1.5 MW

Great Lakes Chain (operational 2/80) - Rate 9960 (SS4)

Station	Approximate Latitude & Longitude	Station Function	Coding Delay & Baseline Length	Radiated Peak Power
Dana, Indiana	39-51-07.46N 87-29-12.14W	Master	- - -	400 kW
Malone, Florida	30-59-38N 85-10-11W	W Secondary	11,000μs	1.0 MW
Seneca, New York	42-42-53N 76-49-35W	X Secondary	28,000μs	1.0 MW
Int. Falls, Minnesota		Y	44,000μs	1.0 MW

Utah (RPV Test) Chain - Rate 4970 (S3), USAF, Loran-D

Station Name	Location	Function Power	Coding Delay Baseline Length	
Little Mountain, Utah	41-14-46.584N 112-13-26.33W	M 125W		
Montello, Nevada	41-16-44.336N 114-09-22-662W	X 125W	11,000μs 541.76μs	
Nephi, Utah	39-44-21.896N 111-51-58.159W	Y 125W	25,000μs 568.77μs	

Mediterranean Sea Chain - Rate 7990 (SL1)

Station	Coordinates Latitude & Longitude	Station Function	Coding Delay & Baseline Length	Radiated Peak Power
Simeri Crichi, Italy	38-52-20.52N 16-43-05.96E	Master	- - -	200 kW
Lampedusa, Italy	35-31-20.80N 12-31-29.96E	X Secondary	11,000μs 1755.98μs	400 kW
Kargabarun, Turkey	40-58-20.87N 27-52-01.52E	Y Secondary	29,000μs 3273.31μs	200 kW
Estartit, Spain	42-03-36.40N 03-12-15.90E	Z Secondary	47,000μs 3999.70μs	200 kW

Gulf of Alaska Chain (operational 1/77) - Rate 7960 (SL4)

Station	Coordinates Latitude & Longitude	Station Function	Coding Delay & Baseline Length	Radiated Peak Power
Tok, Alaska	63-19-42.70N 142-48-33.30W	Master	- - -	1.0 MW
Narrow Cape, Alaska	57-26-20.48N 152-22-11.98W	X Secondary	11,000μs 2804.40μs	400 kW
Shoal Cove, Alaska	55-26-20.68N 131-15-19.69W	Y Secondary	26,000μs 3651.18μs	1.0 MW

North Pacific Chain - Rate 5930 (SH7)

Station	Coordinates Latitude & Longitude	Station Function	Coding Delay & Baseline Length	Radiated Peak Power
St. Paul, Pribiloff Is. Alaska	57-09-09.80N 170-14-59.84W	Master	- - -	300 kW
Attu, Alaska	52-49-44.96N 173-10-52.31E	X Secondary	11,000μs 3875.32μs	300 kW
Port Clarence, Alaska	65-14-40.06N 166-53-14.47W	Y Secondary	28,000μs 3069.09μ	1.0 MW
Sitkinak, Alaska	56-32-20.09N 154-07-46.17W	Z Secondary	42,000μs 3284.41μs	300 kW

Western USSR Chain - Rate 8000 (SLO)

Station	Coordinates Latitude & Longitude	Station Function	Coding Delay Baseline Length	Radiated Peak Power
Oriol	53-56N 36-05E	Master	- - -	500 kW
Petrovavodesk	61-48N 34-19E	W Secondary	10,000μs	500 kW
Kuibychev	53-11N 49-46E	X Secondary	25,000μs	500 kW
Simferopol	44-58N 32-02E	Y Secondary	50,000μs	500 kW
Baranovichi	53-08N 26-01E	Z Secondary	65,000μs	500 kW

St. Mary's River Chain - Rate 4970

Station	Coordinates Latitude & Longitude	Station Function	Coding Delay & Baseline Length	Radiated Peak Power
Gordon Lake, Canada	46-24.5353 83-51.9768	Master	- - -	100 W
Pickford, Michigan	46-03.8813 84-21.7117	X Secondary	11000.045μs 221.652μs	100 W
Drummond Island, Michigan	45-57.2326 83-37.2904	Y Secondary	21999.988μs US 220.332μs US	100 W
Dennis, Canada	46-36.7668 84-26.9115	Z Secondary	32999.988μs 227.934μs	100 W

Fort Hood Chain - Rate 4970 (S3), US Army, Loran-D

Station Name	Location	Function Power	Coding Delay Baseline Length	
Summerville, Texas	30-20-11.966N 96-32-32.826W	Master 150 W	- - - - - -	
Canyon Lake, Texas	29-54-22.512N 98-13-40.627W	X Sec. 150 W	11,000μs	
Navarro Mill Dam, Texas	31-57-36.960N 96-41-18.163W	Y Sec. 150 W	23,000μs	

Central European Chain - Rate 3970 (L3), USAF, Loran-D

Station Name	Location	Function Power	Coding Delay & Baseline Length	
Baumholder, Germany	49-36-18.813N 07-19-38.277E	Master 5 kW	- - - - - -	
Hokes Mook, Germany	53-39-13.867N 08-43-46.508E	X Sec. 5 kW	11,000μs	
Eching, Germany	48-15-48.929N 11-37-49.263E	Y Sec. 5 kW	25,000μs	

U.S. West Coast Chain (operational 1/77) - Rate 9940 (SS6)

Station	Coordinates Latitude & Longitude	Station Function	Coding Delay & Baseline Length	Radiated Peak Power
Fallon, Nevada	39-33-06.38N 118-49-56.20W	Master	- - -	400 kW
George, Washington	47-03-47.90N 119-44-39.38W	W Secondary	11,000μs 2796.92μs	2.0 MW
Middletown, California	38-46-56.76N 122-29-44.30W	X Secondary	27,000μs 1094.50μs	400 kW
Searchlight, Nevada	35-19-18.11N 114-48-17.35W	Y Secondary	40,000μs 1967.28μs	1.0 MW

Gulf of Mexico - Rate 4864 - Industrial Radiolocation Service

Station Name	Location	Function Power	Coding Delay Baseline Length	
Perry, Louisiana	29-56-02.416N 92-09-22.019W	Master 200W		
Triumph, Louisiana	29-20-27.564N 89-27-59.844W	X Sec. 100W		
San Louis Pass, Texas	29-05-52.747N 95-06-30.133W	Y Sec. 100W		

U.S. East Coast Chain (reconfigured 7/78) - Rate 5930 (SH7)

Station	Approximate Latitude & Longitude	Station Function	Coding Delay & Baseline Length	Radiated Peak Power
Seneca, New York	42-42-53N 76-49-35W	Master	- - -	1.0 MW
Caribou, Maine	46-48-27.90N 67-55-37.97W	W Secondary	11,000μs	700 KW
Nantucket, Massachusetts	41-15-11.84N 69-58-39.09W	X Secondary	25,000μs	300 KW
Carolina Beach, N. Carolina	34-03-45.96N 77-54-46.76W	Y Secondary	39,000μs	350 KW

Central Pacific Chain - Rate 4990 (S1)

Station	Coordinates Latitude & Longitude	Station Function	Coding Delay & Baseline Length	Radiated Peak Power
Johnston Is.	16-44-43.90N 169-30-31.20W	Master	- - -	300 kW
Upolo Pt., Hawaii	20-14-49.10N 155-53-09.70W	X Secondary	11,000μs 4972.23μs	300 kW
Kure, Hawaii	28-23-41.70N 178-17-30.20W	Y Secondary	29,000μs 5253.17μs	300 kW

RECENT LORAN RELATED PAPERS

One of the objectives of this Journal is to provide a forum for dissemination of state-of-art concepts of the loran system. In order to achieve this objective, the editorial committee has compiled a list of papers published in various journals and conferences over the past year. Every effort has been made to make this list complete and if we have missed any, we apologize. We urge members to send us the abstract of papers they may have recently published or that may be of value to the community.

RADIO NAVIGATION IN NORTH AMERICA . . . THE NEXT 25 YEARS, J. M. Beukers; Navigation: Journal of the Institute of Navigation, Vol. 22, No. 1, Spring 1975

On May 16th of this year the Secretary of the Department of Transportation authorized the announcement of the selection of Loran-C as the radio navigation system to serve the coastal confluence region. He also instructed that the national plan for navigation be amended to reflect this decision, thereby ending a long period of uncertainty in U.S. policy relating to radio navigational aids. The decision will permit firm plans to be made by both users and manufacturers to derive the best cost benefits from the various radio navigation systems now sponsored by the federal government. This paper explores the impact of the decisions to provide for the co-existence of Loran-C and Omega hyperbolic systems with an orderly phase-out of the Loran-A network. The paper also discusses the current VORTAC and VLF LF beacon systems in relation to the availability of hyperbolic systems having extensive coverage. A comparison of costs and accuracy of the various systems is provided. A bibliography of reference material is included.

LOW COST NAVIGATION PROCESSING FOR LORAN-C AND OMEGA, J. F. Delorme and A. R. Tuppen; Navigation: Journal of the Institute of Navigation, Vol. 22, No. 2, Summer 1975

Investigations and development of a Loran feasibility model, which were conducted to determine the impact of microcomputer concepts on performance and cost of radio navigation equipment, have demonstrated that the performance requirements for both austere and sophisticated Loran-C or Omega users can be satisfied within the economic value to these users. Continuing development of MOS/LSI semiconductor technology has provided microcomputer sets, central processor units and compatible semiconductor memories whose architecture is in accordance with the requirements for radio navigation processing. The result of this feasibility demonstration was a microcomputer configuration which served as a base for consideration of a low cost Omega navigator and a combined Loran/Omega navigator. The resultant configurations for these navigators has the potential to satisfy user cost objectives for either Loran-C or Omega navigation equipment, and a combined Loran/Omega navigator. Further, it is clearly demonstrated that mechanization of navigator functions such as conversion to latitude and longitude, and steering can be provided at minimal cost to the user.

ADVANCES IN LOW-FREQUENCY RADIO NAVIGATION METHODS, Patrick H. Garrett; IEEE Transactions on Aerospace and Electronic Systems, Vol. AES-11, No. 4, July 1975

Advances in the analysis and design of low-frequency radio navigation systems are presented in four sections detailing system design, propagation, receivers and processors, and error analyses. Emphasis is on the short-baseline case where radial accuracies of 114 feet are possible for non-line-of-sight operation to ranges of 50 miles from transmitters. Possible future applications for LF include an efficient solution for commercial ground transportation management, remotely piloted vehicle navigation, and cruise missile guidance. An error budget and experimental results are included plus a countermeasure analysis.

MEDIUM ACCURACY, LOW-COST NAVIGATION: LORAN-C VERSUS THE ALTERNATIVES, J.P. Van Etten; presented at the 30th Technical Meeting of the Avionics Panel, Advisory Group for Aerospace Research and Development, Sandefjord, Norway, September 1975

There are a number of candidate navigation systems which have been proposed to provide medium or high accuracy navigation for particular segments of the user community. The user community is very diverse; it encompasses commercial, scientific and governmental interests and marine, airborne, and terrestrial applications. Evaluating the alternative systems for broad, economical application at the national level is difficult since different users have different specific requirements and different specific cost goals. An individual user is primarily interested in an economical solution for his specific navigation problem; a user nation is interested in an economical solution to the national navigation problem, and the international community is understandably grateful when the individual national interests produce a consensus.

Loran-C is now recognized as a leading candidate system to satisfy national and multi-national requirements for medium and high accuracy navigation. For over a decade and a half, it has satisfied certain high accuracy requirements of the U.S. Department of Defense. In the last several years, technology advancements have made it possible for the user with limited resources to also satisfy his requirements with Loran-C at a price that he can afford. Consequently, and after extensive evaluation, the United States Government selected Loran-C as the national system to satisfy commercial marine requirements within the coastal confluence region of the U.S. At about the same time and on the other side of the globe, the USSR appears to be implementing a Loran-C system to satisfy their national requirements.

This paper compares the fundamentals of the Loran-C system with the fundamentals of alternative navigation systems to provide a simple but clear perspective regarding the operational merit, the universal applicability, and the economy of Loran-C. It is hoped that it will serve to clarify the basis for the developing consensus toward Loran-C on the national and international level.

UNEXPLOITED POTENTIALS OF LORAN-C, R. H. Doherty and J. L. Johler; Navigation: Journal of the Institute of Navigation, Vol. 22, No. 4, Winter 1975-76

Current Loran-C radio navigation equipment has demonstrated a repeatable precision index of less than 0.01 μs/km. Thus, two colocated receivers measuring the same time difference will deviate less than this amount as to the standard deviation of their measured time difference. It is therefore concluded that operation of Loran-C in a differential mode is a feasible technique for such practical matters as collision avoidance, instrument landing systems, air traffic control, precise location of surface vessels used out of sight of land in underwater exploration, and ground based vehicle location in the non-urban environment. By differential operation mode, we mean that two vehicles can determine their distance apart, their rate of closing or separation, and indeed their direction of relative motion, if the measured time difference information on each vehicle is relayed between vehicles.

Loran-C can be compared quantitatively with other systems such as Omega operating in a differential mode. A comparison of Loran-C data with the Beukers-Nard Omega data reveals a possible 20 to 100 accuracy improvement factor if we use Loran-C instead of Omega in the 0 to 700 km differential separation range. We conclude that the fundamental reason for part of the improvement is the reciprocal phase measurement improvement with frequency. The remainder of the improvement is a consequence of the greater stability of the pulsed ground wave propagation mechanism of Loran-C as compared with the single frequency ionospheric waves of Omega. Frequencies greater than 100 kHz would give greater improvement with a loss of range or coverage area.

We have found that Loran-C is an excellent propagation measuring device for the detection and identification of effects of irregular, inhomogeneous terrain in the spatial domain, and the study of meteorological variations in the time domain. Furthermore, the Loran-C skywave signal can be used as a D-region diagnostic to study particle precipitation events and D-region variations with latitude, season and solar zenith angle.

We make the observation from our Loran-C studies that the first prerequisite to a capability for prediction of propagation phenomena is the ability to separate, identify, and understand the physical nature of the observed radio measurements. This prediction capability is essential to the successful operation of radio navigation systems in both the normal and the differential mode of operation.

EM FIELDS IN NONUNIFORM MULTILAYERED STRUCTURES – STEADY STATE AND LORAN-C PULSE EXCITATION, E. Bahar; Proceedings of the Seventh Annual Precise Time and Time Interval (PTTI) Applications and Planning Meeting, Greenbelt, Maryland, December 1975

The steady-state electromagnetic field response from nonuniform layered models of the earth's crust are used to compute the transient response due to LORAN C pulse excitations. Using a full wave approach, the electromagnetic fields are expressed completely in terms of a continuous spectrum of vertically polarized waves (the radiation term) and a discrete set of vertically polarized surface waves (the waveguide modes of the structure). Thus the scattered radiation fields and surface waves due to incident plane waves are computed. The full wave solutions satisfy the reciprocity relationships in electromagnetic theory.

These investigations are relevant to problems of navigation since it is possible to facilitate the derivation of the LORAN grid corrections due to ground effects if the propagation delays of the LORAN pulses can be related to the LORAN pulse distortions. Thus in this work analytical expressions are derived for the propagation delays due to ground effects (compared with the smooth perfectly conducting case) and the dependence of the distortions of the received signal upon the ground parameters along the propagation path is determined for different excitations.

This approach could also be used to determine the effects of a nonuniform stratified model of the ionosphere upon satellite navigation signals.

PATH DELAY CORRECTIONS FOR LORAN SIGNALS, Ronald G. Roll; Proceedings of the Seventh Annual Precise Time and Time Interval (PTTI) Applications, Greenbelt, Maryland, December 1975

In November 1973, an experiment was initiated to explore the possibility that measurements of the Loran pulse location relative to the phase of the carrier could be used to infer path delay corrections. The Applied Physics Laboratory was joined in this effort by the U.S. Naval Observatory and the Defense Mapping Agency. Measurement of the transit time of the Loran-C wave between a site at the U.S. Naval Observatory and 10 field sites were made in the summer of 1975. The instrumentation and the results of the test are described along with statistical estimates of the precision of measurement and of the quality of the data. The precise nature of the transmitted signal and the precision of time recovery is inferred from the data. Status of the development of a path delay correction is also described.

SATELLITE NAVIGATION IN HYDROGRAPHY, R. M. Eaton, D. E. Wells, N. Stuifbergen; The International Hydrographic Review, Vol. LIII, No. 1, January 1976

Satellite Navigation ("Navsat") is a remarkable development in positioning that gives a dozen or more good fixes per day, anywhere in the world. The accuracy of the ship's position from a good pass is from 60 - 600 m, depending on how well the ship's course and speed is measured. For stationary receivers, this positioning accuracy improves to about 20 m.

Navsat's great value to hydrography is that the fix is virtually free of systematic position errors. Navsat is extremely useful in offshore surveys as a complementary partner to a high resolution, continuous system which has systematic biasses or which accumulates error with time; we describe integration with rho-rho (range measuring) Loran-C, and Doppler Sonar. The continuous system feeds accurate course and speed to Navsat, which in turn provides a control network of intermittent, bias-free fixes. By bridging a number of satellite fixes the combined system means out random errors and improves on the single-pass accuracy of Navsat.

Navsat has many auxiliary applications. It is used to resolve the cycle ambiguity in low frequency radio aids; to calibrate both marine survey positioning systems and radio aids to navigation; to position the transmitters for the radio aids; to position offshore drilling rigs; and as a geodetic instrument capable of establishing shore control to 1 m accuracy.

The "Datum Shift" between a Navsat position and a position from the local geodetic control often causes confusion. We outline the reason for the difference, and give algorithms for computing it.

LORAN-C AND THE YACHTSMAN, David T. Haiship; presented at the New England Sailing Yacht Symposium, New London, Connecticut, January 1976

After considerable study and review, the Secretary of Transportation selected Loran-C as the government provided radionavigation system for the coastal confluence zone (CCZ) of the United States. This decision was announced publicly on 16 May 1974. Under the National Plan for Navigation (NPN) it is stated, among other items, that the Department of Transportation National Navigation Policy is to "coordinate the planning for facility implementation and deployment in the interest of electromagnetic frequency conservation, overall economics, and avoidance of unnecessary duplication." Therefore, plans have been announced to phase out Loran-A gradually as Loran-C service is provided or improved in any existing Loran-A service area.

INSHORE NAVIGATIONAL SYSTEM CONCEPTUAL ADVANCES, S. Feldman; Navigation: Journal of the Institute of Navigation, Vol. 23, No. 1, Spring 1976

The U.S. Navy, through a contract with MYSTECH ASSOCIATES, INC., has developed an advanced proto-type navigational system called MATCH-NAV, which utilizes a mini-computer to provide automated ownship geographic position in inshore, coastal navigation situations. Conceptual development of MATCH-NAV has demonstrated the capability to provide ownship position display on digitized nautical charts, with overlay of the chart data on a radar

Plan Position Indicator (PPI). Future plans include utilization of the MATCH-NAV concept in design of a completely automated Ownship Position Display having stored nautical chart capability, which can accept navigational data inputs from such ship's sensors as Loran-C, Omega, radar and other precision electronic navigation systems, including satellite systems. The goal – to provide continuous, accurate, real-time visual display of ship's position in restricted coastal waters.

This paper discusses the MATCH-NAV concept and its potential applications in future inshore navigation.

A LORAN-C PRECISION GUIDANCE SYSTEM, John R. Stoltz; Proceedings of the 8th Annual Offshore Technology Conference, Houston, Texas, May 1976

The United States Coast Guard is implementing a feasibility demonstration of LORAN C to perform precision guidance of ore carriers on the St. Marys River. A special four-station LORAN C chain has been erected to provide optimal hyperbolic LORAN C coverage for the 60-mile river channel. The required navigation accuracies are in the 25 to 50 feet range. Teledyne will modify the TDN 6000 LORAN C system design to become the St. Marys Precision Guidance System. This paper presents the results of a test where a preliminary configuration of this Precision Guidance System was evaluated in the Hampton, Virginia area using Raydist to monitor the system. The test demonstrates that with optimal filtering of the data and the addition of a real time grid calibration the required navigation accuracies can be achieved.

LORAN-C IMPLEMENTATION IN THE COASTAL CONFLUENCE ZONE, Francis W. Mooney; Proceedings of the 8th Annual Offshore Technology Conference, Houston, Texas, May 1976

The Secretary of the Department of Transportation announced the selection of Loran-C as the U.S. Government sponsored radio navigation system to serve the Coastal Confluence Zone (CCZ) on May 16, 1974. This paper provides information concerning the implementation of Loran-C in the CCZ. It will address chain configurations/reconfigurations (as appropriate), coverage, accuracies and operational schedules. The expanded Loran-C grid will permit navigation fixes to 1/4 NM or better 95% of the time throughout the CCZ and use of the signals in a repeatable mode will permit returning to within 100 ft of a previously determined position throughout much of the CCZ. Detailed information concerning Loran-C coverage characteristics in the Gulf of Mexico and the Western Coast of North America will be discussed, including representative examples of near shore accuracies. A status report on the West Coast/U.S. Canadian/ Gulf of Alaska stations, scheduled to become operational January 1, 1977 will be made during the presentation.

TRADE-OFFS IN LORAN-C RECEIVERS, Barry P. Kane, Proceedings of the 8th Annual Offshore Technology Conference, Houston, Texas, May 1976

This paper will compare various classes of Loran-C receivers with respect to both price and operating characteristics. It includes a short discussion of the Loran-C system, and then sets out to provide the prospective receiver purchaser with some guidelines to use for evaluation of the commercial market. This should allow the user to optimize his selection of a receiver. In order to avoid endorsing or rejecting specific manufacturers' products, only classes of receivers will be discussed, not particular makes and models.

NEW DEVELOPMENTS IN LORAN-C RECEIVERS FOR EXTENDED-RANGE NAVIGATION, Friedhelm K. Sender; Proceedings of the 8th Annual Offshore Technology Conference, Houston, Texas, May 1976

ABSTRACT
Loran-C employing low-frequency groundwave signals is the most stable and accurate radionavigation system. Current electronic equipment has achieved repeatable accuracies in time-difference measurement with a precision-index of less than 0.1 microsecond. This corresponds to a 15 m error along the baseline gradient of 6.27 microseconds per kilometer. Technically Loran-C is a complicated system developed by highly skilled engineers and maintained by well trained electronics technicians. Modern semi and fully automatic Loran-C receivers, however, allow that they can be employed even by the novice boatman. This simple implementation precludes that operational areas are marginal and limited to the standard range of existing Loran-C network. This is becoming true in the total US-coastal confluence zone after completion of the current Loran-C improvement and expansion plan.

But what can be done if you need a navigation system of comperative precision off this marginal area as many survey ships demand it in deep sea regions far off the coastal zone to discover and exploit new fields of earth resources?

This paper will deal with the technical problems of special equipment and improvements on existing Loran-C receivers to expand the operating range of Loran-C considerably.

A LORAN-C AIRBORNE NAVIGATOR, Robert H. Cassis, Jr.; Proceedings of the 8th Annual Offshore Technology Conference, Houston, Texas, May 1976

A Loran-C Airborne Navigator for use in Coast Guard helicopters is described. Cockpit mounted, the device weighs only 12 pounds, uses LSI circuitry extensively and includes a microcomputer and a completely automatic Loran-C receiver. The navigator generates steering information relative to a trackline defined by up to nine operator entered waypoints.

The Coast Guard is conducting an extensive laboratory and operational flight evaluation program. Many test scenarios are similiar to offshore helicopter operations. Results to date indicate the receiver will perform satisfactorily in the Coastal Confluence Zone Loran-C system. Flight testing on prototype systems indicates that navigation accuracy better than 190 meters is probable and rendezvous to within 10 meters have been accomplished.

4-D NAVIGATION USING INTEGRATED STRAPDOWN INERTIAL/DIFFERENTIAL LORAN, Rodney D. Wierenga; Proceedings of the IEEE National Aerospace and Electronics Conference, June 1975

This paper describes a four-dimensional terminal area navigation, control, and display system that uses strapdown inertial sensors combined with differential Loran to accurately determine aircraft position, velocity, attitude and heading. The functional and hardware requirements of the system are given. A unique integration filter is defined which combines the strapdown inertial and differential Loran data. The four-dimensional path generation technique that is used is briefly described as is the hybrid computer and cockpit simulator being used to evaluate the system.

KALMAN FILTER DESIGN AND PERFORMANCE FOR AN OPERATIONAL F-4 LORAN INERTIAL WEAPON DELIVERY SYSTEM, Michael W. Bird, Rodney D. Wierenga and John V. TenCate, National Aerospace and Electronics Conference, June 1976

ABSTRACT

This paper describes the design, implementation and performance of a Kalman filter technique which is an integral part of the AN/ARN-101(V) Digital Modular Avionics System that was recently flight tested at Eglin Air Force Base. The AN/ARN-101(V) system, which will be installed in USAF F-4E and RF-4C aircraft to improve their air to ground weapon delivery and airborne reconnaissance capabilities, utilizes the Kalman filter to sub-optimally combine Loran and inertial navigation information. This paper briefly develops the Kalman filter equations and describes the special Loran/inertial Kalman filter features unique to the AN/ARN-101(V) system, including in-flight INS alignment, Loran jammer detection, and adaptation to time varying Loran characteristics. Also described is the filter implementation, including floating point software, memory and timing requirements, and special programming techniques. The paper concludes with Kalman filter performance data provided by a hybrid computer evaluation of the filter using the actual AN/ARN-101(V) hardware and operational flight program.

The following papers were presented at the **Institute of Navigation National Marine Meeting**, Cockeysville, Maryland, October 1975. They are also contained in the conference proceedings.

AN ADAPTIVE α, β TRACKING ALGORITHM, Ron Hatch

ARTIC ICE NAVIGATION AND TRACKING, David D. Wasilew and John Vivian

OMEGA NAVIGATION SYSTEM STATUS AND FUTURE PLANS, Thomas P. Nolan, Neal F. Herbert

IMPACT OF LORAN-C DECISION ON OREGON MARINE INTERESTS, Daniel A. Panshin

LORAN-C IN THE EYES OF THE GERMAN HYDROGRAPHIC INSTITUTE (DHI), Uave Hammerschmidt

LORAN-C NAVIGATION CHARTS FOR THE COASTAL CONFLUENCE ZONE, Walter B. Ferm

LORAN-C EXPANSION IN THE COASTAL CONFLUENCE ZONE, Francis W. Mooney

PROGRESS REPORT ON THE GETTYSBURG WORKSHOP SIXTEEN MONTHS LATER, J. F. Culbertson

LORAN-C REPLACEMENT EQUIPMENT (LRE), G. R. Goodman and R. P. Oswitt

THE LORAN-C GROUND STATION, Harold T. Sherman and Vernon L. Johnson

CALCULATOR ASSISTED LORAN-C CONTROLLER FOR TIME DIFFERENCE ERROR CONTROL, J. T. Doherty and D. A. Feldman

AUTOMATED LORAN-C CHAIN DEVELOPMENT UTILIZING A FLEXIBLE MINICOMPUTER WITH REAL-TIME EXECUTIVE SOFTWARE, S. P. Plusch, M. F. Dean

THE COAST GUARD TWO PULSE LORAN-C COMMUNICATIONS SYSTEM, D. A. Feldman, M. A. Letts, R. J. Wenzel

OPTIMAL ELEMENT SITING FOR SHORT BASELINE SURFACE POSITIONING SYSTEMS, J. J. Fee

CALIBRATION OF REFERENCE TIME ERRORS IN DIRECT-RANGING LORAN-C NAVIGATION, Bahar J. Uttam, Thorgeir Palsson

SIGNAL PROCESSING IN SPERRY LORAN-D, Barry Brenin

THE AN/BRN-5 LORAN RECEIVER, W. N. Dean, D. P. Roth

The following papers were presented at the **Fourth Annual Technical Symposium of the Wild Goose Association,** Cockeysville, Maryland, October 1975. They are also contained in the conference proceedings.

A REPORT ON POTENTIAL FEDERAL AGENCY TERRESTRIAL USES OF LORAN-C, William F. Cass

LORAN-C: A COMMON REFERENCE SYSTEM FOR ACCIDENT DETECTION AND LOCATION, Joseph Stephany

THE ACCURACY OF WIND FINDING USING THE LORAN-C NAVIGATION SYSTEM, P. Ryder

ON THE ANALYSIS AND MINIMIZATION OF MUTUAL INTERFERENCE OF LORAN-C CHAINS, Donald A. Feldman, Paul Pakos, Cyrus Potts

VELOCITY AIDING AND ALTERNATIVES FOR LORAN-C RECEIVERS, Ed Bregstone

LORAN-C MINICHAIN ON THE ST. MARY'S RIVER, B. P. Kane

USER EQUIPMENT FOR ST. MARY'S RIVER LORAN-C MINICHAIN, David L. Olsen

LORAN CALIBRATION BY PREDICTION, Lloyd Burch, Robert Doherty, Ralph Johler

THE AN/ARN-101 LORAN-C NAVIGATION SYSTEM, Arthur E. Gaunt, Donald L. Gray

LORAN-D AND ELECTRONIC COUNTERMEASURES, Larry Drayer

THE AIRBORNE USE OF LORAN-C IN THE CARIBBEAN, Robert H. Wehr, Winner of the Best Paper Award 1975

LORAN-C USAGE IN LAND-BASED PLATFORMS, L. P. Tuttle and W. K. Vogeler

LORAN-C SEISMIC SURVEY IN BRISTOL BAY, ALASKA, John R. Stoltz

THE GLOBTIK SUN INCIDENT: A CASE FOR MARINE TRACK MAINTENANCE, Roger Hassard

LORAN-C PHASE CODE AND RATE MANIPULATION FOR REDUCED CROSS CHAIN INTERFERENCE, William F. Roland, Winner of the Best Paper Award 1974

APPLICATION OF LORAN-C TO LAND NAVIGATION
(Vehicle Monitoring, Dispatch and Site Registration)

(A study completed for the U.S. Department of Transportation by the Traffic Records Project Office, DMV State of NY and Polhemus Navigation Sciences, Inc. Burlington, VT)

A study has been completed for DOT which identifies the operational, economic and social benefits which could be realized from utilization of Loran-C by state and local governments.

The report identifies requirements for at least 14,000 receivers for public-sector users within the State of New York assuming that performance of receiver equipment meets specified repeatable accuracy criteria, control-display features of the hardware are compatible with intended use of the equipment, installation constraints can be met, and price of fully automatic equipment is in the $800 price range for quantity purchases.

The report analyzes the operational, technical, economic, and social factors which suggest that adoption of the Loran-C radionavigation system for terrestrial positioning would be cost effective. Technical parameters considered included problems peculiar to terrestrial positioning, such as the effects of power lines and local changes in ground conductivity. Operational, economic and social benefits related data were obtained through extensive interviews with representatives of local government, state agencies, and private industry.

Significant interest was generated among quite diverse user groups. Three categories were defined: automatic vehicle monitoring, in which the position of a vehicle, fleet of vehicles or even an individual such as a dismounted police officer, is monitored continuously from a remote location; dispatch, in which a vehicle (for example, an ambulance) or all elements of an emergency services team is directed to go to a specified location; site registration, which includes such things as traffic accident reporting, the correlation of highway engineering data, development of improved environmental protection and pollution control data and the correlation of demographic and geographic data bases.

Performance desires were found to be generally within the capabilities of the system, although differential corrections may prove useful for some applications.

The study phase of the project is complete. Field evaluation of Loran-C equipment applied to the various public sector user groups is planned to start in November of this year and may extend over a period of 2 to 3 years. Sponsors for the Conceptual Study were National Highway Traffic Safety Administration, Federal Highways Administration and the Office of the Assistant Secretary of Transportation for Systems Technology. The newly formed Loran-C Project Office, managed by Commander Bill Mohin, USCG, provided technical inputs.

Authors of the report are Dr. Fred Raab and W. L. Polhemus of Polhemus Navigation Sciences and C. Mosher, M. Abrams and J. Murdoch of the TRPO, Department of Motor Vehicles, State of New York.

Copies of the report may be obtained from Cmdr. Bill Mohin, Loran-C Project Office, DOT, Washingtin, D.C. or from Polhemus Navigation Sciences, Inc., Box 1011, Burlington, VT.

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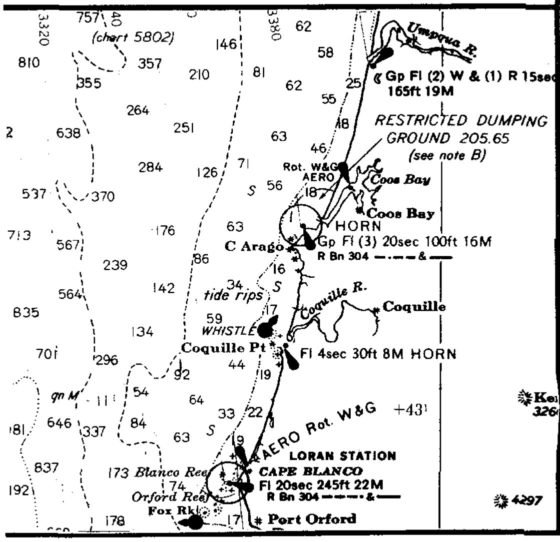
The NEW Morrow LAA-1850 Automatic, Convertible Loran

The LAA-1850 Automatic Aquisition, Automatic Tracking Loran A is designed to simplify Loran navigation for the operator. Clean, clearly marked controls make for easy operation. The brilliant, ½" Digital Readout Display and bright 3" CRT are recessed from the front of the set making auxiliary external hoods unnecessary. Plug-in printed circuit boards, including NEW plug-in module power supply and hinged front panel provide easy access to all parts for fast, easy and less costly maintenance. Solid state design using reliable CMOS integrated circuits and crystal controlled receiver maintain accurate readings even in harsh signal conditions. This unit operates both as an automatic or manual Loran, making it a truly versatile performer.

LAA-1850



Features

☐ **Convertible to Loran C** — The LAA-1850 is completely convertible to Loran C and when converted will feature true cycle match display and tracking.

☐ **Automatic Aquisition** — the automatic aquisition circuits of this unit search through even the noisiest conditions and lock in on the station signal automatically.

☐ **Search ATC light** — a front panel light indicates when the Loran has acquired the selected station signals.

☐ **Automatic Tracking Control** — the automatic tracking feature gives continuous update readings with the vessel's course.

☐ **Automatic Gain Control** — gain is automatically maintained on ATC mode.

☐ **Automatic Frequency Control** — this feature locks to the signal frequency, maintaining signal accuracy.

☐ **Bright CRT and Digital one tenth microsecond Readout Display** — the large (½"/12.7 mm high) digital readout display is an adaptation of readouts developed for aircraft instrumentation where quick readability is a must. Both the CRT and the digital readout display employ circular polarized filters allowing high readability up to 20 feet away from the unit on a sunny day. In addition, the CRT and digital readout have separate intensity controls for day time or night time use.

☐ **Additional Features** — Stable one tenth microsecond readout. High resolution to one tenth microsecond gives position fix to 50 feet or less, permitting pinpointing of best fishing spots from day to day. All units are wired with an interface socket compatible with the Morrow RDR-6 Remote Readout, auto pilots and XY plotters. Low power consumption of 24 watts. Rugged cast aluminum panel frame, epoxy coated cabinet and corrosion treated chassis parts. Compact size allows mounting almost anywhere.

The Morrow LAA-1850 automatic Loran is a commercial quality unit, yet handsomely compatible with pleasure boat gear; and is 100% American designed, engineered and manufactured.

All specifications subject to change without notice.

LORAN ASSOCIATED BUSINESSES

The following is a list of businesses which relate to Loran interests. Every effort was made to ensure that no one was left off the list, however the response to our newsletter request for company names, contacts, and brief descriptors was poor. When no response was received, we attempted to get the information by letter or phone. If this was unsuccessful, we named a WGA member employed by the company as a contact and then made up as good a descriptor as possible within our knowledge. Anyone desiring to add, change, or delete a listing in the next edition of the Journal should contact the Editor as soon as possible.

Advanced Technology Systems
2425 Wilson Blvd.
Arlington, VA 22906

Aerospace Systems, Inc.
One Vine Brook Park, Suite 202
Burlington, MA 10803
John Zvara, 617-272-7517
Analysis, computer simulation and flight test of navigation, guidance, control and display systems.

Amecom Div. Litton Systems Inc.
5115 Calvert Road
College Park, MD 20720
Norman C. Dickerson, 301-864-5600
Development and manufacture of electronic systems including radionavigation transmitting and receiving systems.

Analytical Systems Engineering Corp.
Old Concord Road
Burlington, MA 01803
Hank Hilbun, 617-272-7910
Provide systems engineering services in the fields of communication and navigation.

Austron, Inc.
1915 Kramer Lane
Austin, TX 78758

Aviation Electric Co. Ltd.
200 Laurentian Blvd.
Montreal, P.Q.
D. Garbutt

Bendix Corporation
Navigation and Control Division
Teterboro, NJ 07608
L. Ranch

Beukers Laboratories, Inc.
30 Orville Drive
Bohemia, NY 11716
John M. Beukers, 516-567-5100
Development and manufacture of radiosonde and radionavigation specializing in retransmission and remote tracking.

Cambridge Engineering
P.O. Box 66
Cambridge, VT 05444
Martin C. Poppe, Jr., 802-644-5196
Electronic Systems, consultation and development.

Canadian Marconi Co.
Marine and Land Communication Div.
2442 Trenton Avenue
Montreal 301, P.Q. Canada

Collins Radio Company
Dallas, TX 75207
Fred J. Spencer, 214-690-5193
Manufacture and sales of airborne radio equipment, including the AN/APN - 199 Loran-C receiver.

Communications Associates, Inc.
200 McKay Road
Huntington Station, NY 10801
Gerald A. Gutman, 516-271-0800
Manufacture and sales of marine communications and navigation systems.

CRDL
P.O. Box 1056
Boulder, CO 80302
Robert Doherty
Consultants in radiowave propagation.

Computing Devices Company of Canada
P.O. Box 8508
Ottawa, Ontario, Canada
Sale of loran and Decca Navigator systems.

Dahl Loran Service
46 No. Water Street
New Bedford, MA 02740
Harold Dahl, 617-997-7961
Loran sales and service for vessels and aircraft, consultant for users and manufacturers.

Decca Survey Systems, Inc.
P.O. Box 22397
Houston, TX 77027
C.D. Paget-Clarke, 713-783-8220
Radionavigation services for hydrographic survey.

Digital Marine Electronics Corporation
Civil Air Terminal
Bedford, MA 01730
Charles J. Malaquias, Jr., 617-274-7130
Manufacturer and distributors of fully automatic Loran-A and Loran-C receivers.

EDO-AIRE
Division of EDO Corporation
216 Passaic Avenue
Fairfield, NJ 07006
Dick Pasciati, 201-228-1880
Aircraft Flight and Engine Instruments, Flight Control Systems, loran, VOR/DME/ILS Ground Nav Aids, R-Nav, Solid-State Chronometers.

E-Systems, Inc.
P.O. Box 6030
Dallas, TX 75222
Johnnie Walker, 617-861-9050
Intelligence/Recce, command/control, electronic warfare, communications, guidance, controls and navigation, aircraft overhaul and modification.

EPSCO, Inc.
411 Providence Highway
Westwood, MA 02090
Bernard Ambroseno, 617-329-1500
Manufacture of electronic systems including Loran-C receivers, simulators, and guidance devices.

Electro-Nav, Inc.
1201 Corbin Street
Elizabeth Marine Terminal
Elizabeth, NJ 07201
Sales, service and installation of marine electronic systems.

Robert L. Frank
16500 North Park Drive, Apt. 720
Southfield MI 48075
Tele: 313-559-8208
Electronic systems consultant.

Gem Marine Products, Inc.
356 South Boulevard
Lake City, SC 29560
L. Haynes, 803-394-3565

G. E. - TEMPO
816 State Street
Santa Barbara, CA 93102

Griffith Marine Navigation Inc.
134 North Avenue
New Rochelle, NY 10801
Ray Yturraspe, 212-828-5524
Sales, service and installation for VHF radio telephone, radar, depth sounders, loran, Omega wind and speed instruments and autopilots.

HPL Engineering
49 Cleopatra Drive
Ottawa, Ontario, Canada
C.B. Jefferies
Radionavigation system studies and equipment sales.

Hartman Division of ATO Inc.
360 Wolfhill Road
Huntington Station, NY 11746
Robert Romandetto
Development and production of electronic systems.

Integra
P.O. Box 455
Cupertino, CA 95014
Werner Schuerch, 408-252-1495
Consulting services, development and manufacturing of special navigation equipment.

Internav Inc.
65 Wiggins Ave.
Bedford, MA 01730
John Currie, 617-275-2970
Development and manufacture of radionavigation, monitor, survey, and timing receivers for Loran-C.

ITT Avionics Div.
100 Kingsland Road/390 Washington Ave.
Clifton, NJ 07014 /Nutley, NJ 07110
James Van Etten
Development and manufacture of electronic systems including radionavigation transmitting and receiving systems.

Krupp Atlas-Electronick
Div. of Krupp International Inc.
P.O. Box 58218
Houston, TX 77058

Lear Siegler, Inc.
Instrument Division
4141 Eastern Ave., SE
Grand Rapids, MI 49508
H.R. Walton, 616-241-8651
Designs and builds complex modular digital avionics systems to solve navigation, weapon delivery and reconnaissance problems.

The Magnavox Company
Fort Wayne, IN 46802
W.N. Dean, Sr., Staff Engineer
Manufacturers of AN/BRN-5 Loran Receiver for Poseidon/Trident Submarines, AN/FRQ-17 transmitter control set (Clarinet Pilgrim) R-1663/UR digital data receiver.

Megapulse, Inc.
8 Preston Ct.
Bedford, MA 01730
Edward L. McGann, 617-275-2010
Development and manufacture of Loran-C and D transmitting equipment.

Micrologic, Inc.
9436 Irondale Ave.
Chatsworth, CA 01311
Calvin Culver, 213-998-1216
Manufacturer of commercial marine Loran-C receivers, featuring automatic operation with direct ranging and secondary only operation.

MIECO, Division of Polarad Electronics Corp.
109 Beaver Court
Cockeysville, MD 21030
S.R. Berger, 301-667-4660
Manufacturer of Loran-A and C receivers, Omega receivers, and telephone and voice scramblers.

MITRE Corporation
P.O. Box 208
Bedford, MA 01730

Morrow Electronics-International, Inc.
P.O. Box 7064
4740 Ridge Drive NE
Salem, OR 97303
Robert D. Morrow, Jr., 503-393-2550
Manufacturers of Loran-A and C receivers with manual and automatic tracking.

Nautical Electronics Company, Inc.
7095 Milford Industrial Road
Baltimore, MD 21208
David A. Hutzler, 301-484-3284
Manufacturers of Loran-A and C cycle matching receivers.

Navigation Systems, Inc.
884 Monard Drive
Silver Spring, MD 20910
Carl Andren
Development and manufacture of airborne and marine radionavigation equipment including Loran-C.

Offshore Navigation Inc.
P.O. Box 23504
Harahan, LA 70183
Bill Marchall
Radionavigation services for hydrographic survey.

Plessey Radar Ltd.
Addlestone
Weybridge, Surrey KT152PW
England
A.M. Patrick, Weybridge 47282
Manufacture and sales of marine communications navigation and radar systems.

Polhemus Navigation Sciences, Inc.
P.O. Box 1011
Burlington, VT 05444
William L. Polhemus, 802-863-5595
Consultant in navigation and guidance systems design

Redifon Limited
P.O. Box 451
Carlton House
Lower Regent Street
London SW1Y4LS England
W. Blanchard, Tele: 01-874-7281
Manufacturer and sales of marine communications and navigation systems.

Satellite Positioning Corp.
6614 Hornwood Drive
Houston, TX 77036

Simrad, AS
P.O. Box 6114
Etterstand
Oslo 6 Norway
Manufacture and sales of marine electronic systems.

Singer-Kearfott
150 Totowa Road
Wayne, NJ 07470
Development and manufacture of navigation and guidance systems.

Spears Associates, Inc.
188 Needham Street
Newton, MA 02164
M.F. Spears, 617-965-2800
ELF/VLF/LF communications and navigation techniques for extremely sensitive reception.

Sperry Gyroscope
Great Neck, NY 11020
Dalton Szelle

Sperry Systems Management
Marcus Road
Great Neck, NY 11020
Design and management of electronics systems.

SRD Labs
645 McGlincey Lane
Cambell, CA 95008
Bruce G. Gato, 408-371-2666
Manufacturers of manual, tracking and fully automatic Loran-A and C receivers primarily for fishboat, workboat and pleasure craft industry.

Telcom, Inc.
8027 Leesburg Pike
Vienna, VA 22180
L.P. Tuttle,
Specializing in low-cost Loran-C receivers, telecommunications systems and engineering consulting services, nationally and internationally.

Teledyne Systems Company
19601 Nordhope Street
Northridge, CA 01324
L. Speelman, 213-886-2211, Ext. 22080
Development and manufacture of communication, navigation, and data processing electronics systems.

The Analytic Sciences Corporation
6 Jacob Way
Reading, MA 01867
James L. O'Hare, 617-944-6850
Applied research in navigation, guidance, and control, in defense, space and public systems.

Tracor, Incorporated
65000 Tracor Lane
Austin, TX 78721
Harry L. Thomas, 512-926-2800
Development and manufacture of electronic systems for navigation and frequency measurement.

TRW, Inc.
3 New England Executive Park
Burlington, MA 01803
B.H. Evans
Electronic system design and management.

Watkins Associates
P.O. Box 205
North Dayton Station
Dayton, OH 45404
Billy J. Watkins, 513-236-2330
Provides representative/marketing consultant services to avionics companies interested in DOD programs.

Western Geophysical
Box 2469
Houston, TX 77001
Radionavigation services for hydrographic survey

Revised July, 1975

CONSTITUTION

ARTICLE I

NAME

The name of this association shall be the "Wild Goose Association".

ARTICLE II

AIMS AND PURPOSES

The Wild Goose Association is formed to provide an organization for individuals who have a common interest in loran and who wish to foster and preserve the art of loran, to promote the exchange of ideas and information in the field of loran, to recognize the advances and contributions to loran, to document the history of loran, and to commemorate fittingly the memory of fellow Wild Geese.

ARTICLE III

COMPOSITION OR NATURE

The Association shall be composed of individuals meeting the membership requirements and shall not be used for the dissemination of partisan principles, nor for the promotion of the candidacy of any person seeking public office or preferment, nor for promotion of any commercial enterprise.

ARTICLE IV

MEMBERSHIP

SECTION 1. MEMBERSHIP. There shall be two (2) classes of membership, Regular and Honorary; and the members shall be divided between such classes according to their respective eligibilities as defined in Sections 2 and 3 of this Article. Membership shall be on annual or lifetime basis.

SECTION 2. REGULAR MEMBER. Any individual who has made or is making a significant contribution to loran is eligible for membership. Application shall be presented to the Board of Directors, which shall approve or reject the same by a majority vote of those present.

SECTION 3. HONORARY MEMBER. Honorary membership may be awarded by unanimous approval of the Board of Directors to an individual who has made an outstanding contribution to loran.

ARTICLE V

MEMBERSHIP FEES

SECTION 1. INITIATION FEES AND ANNUAL DUES. In order to provide funds for operating the Association, Dues and Fees may be established to cover the expenses.

SECTION 2. Fees and Dues will be established by the By-Laws to this Constitution.

ARTICLE VI

OFFICERS AND DIRECTORS

SECTION 1. OFFICERS. The officers of the Association shall be President, Vice-President, Secretary, and Treasurer. All officers shall be dues-paying members of the Association.

SECTION 2. ELECTED OFFICERS. The President shall be elected by the Membership of the Association to serve for a period of one (1) year and thereafter until his successor is duly chosen. No person may be elected to the office of President for more than two (2) consecutive terms.

SECTION 3. APPOINTED OFFICERS. The Vice-President, Secretary, and Treasurer shall be appointed by the elected President. The appointments shall be made from among the elected Directors of the Association, and they shall serve for a period of one (1) year and thereafter until their successors have been chosen for the new presidential term.

SECTION 4. ELECTED DIRECTORS. There shall be twelve (12) elected Directors and they shall be elected for a period of three (3) years. One-third (1/3) of the total membership of elected Directors shall be elected each year. The initial Directors shall be designated as one (1) year, two (2) year, and three (3) year Directors, to allow for the election of one-third (1/3) of the Directors each year. Term of office to be served by the initial groups of Directors shall be determined by drawing lots by the founding Directors. All Directors shall be dues-paying members of the Association.

SECTION 5. VOTING. All Regular Members of the Association shall exercise the right of voting. Voting will be by mail, and the annual election will be held as prescribed in the By-Laws.

SECTION 6. VACANCIES

a. Vacancies occurring among elected officials between the time of the annual election and the start of the term of office shall be filled by the candidate or candidates for the office next in line according to votes received.

b. Vacancies occurring among elected officials after the start of the term of office shall be appointed by the Board of Directors.

ARTICLE VII

BOARD OF DIRECTORS

SECTION 1. COMPOSITION. The Board of Directors shall be composed of the President of the Association, the twelve (12) elected Directors of the Association, and the Immediate Past President of the Association.

SECTION 2. POWERS. The administrative authority of the Association shall be vested in the Board of Directors.

ARTICLE VIII

ANNUAL CONVENTION

The Convention shall be held annually at a time and place fixed by the Board of Directors and in accordance with the By-Laws.

ARTICLE IX

STANDING COMMITTEES

The Association may provide by its By-Laws for such Standing Committees as may be deemed necessary. The President, annually, shall appoint the Chairman of each Committee.

ARTICLE X

SPECIAL COMMITTEES

Either the Association's Membership, duly assembled, or the Board of Directors or President may create special Committees and define their respective powers and duties.

ARTICLE XI

DISCIPLINE

SECTION 1. ACTION, HOW TAKEN. The Board of Directors, after notice and a proper hearing, may by majority vote suspend or revoke the membership privileges of any Member.

SECTION 2. CAUSES FOR ACTIONS. Any member of the Association may be suspended or expelled for misconduct reflecting unfavorably upon the Association.

ARTICLE XII

AMENDMENTS

SECTION 1. The Constitution may be amended by two-thirds vote of the members voting.

SECTION 2. Proposed changes will be placed on a Ballot and mailed to the membership after approval by the Board of Directors.

ARTICLE XIII

AWARDS

Awards for significant contributions in furtherance of the aims and purposes of the Wild Goose Association may be authorized by appropriate provision in the By-Laws.

ARTICLE XIV

REGIONAL CLUBS

Regional clubs in furtherance of the aims and purposes of the Wild Goose Association may be organized as authorized by appropriate provision in the By-Laws.

ARTICLE XV

PUBLICATIONS

Publications that serve to further the aims and purposes of the Wild Goose Association may be organized as authorized by appropriate provision in the By-Laws.

BY-LAWS

ARTICLE I

OFFICERS

SECTION 1. THE PRESIDENT. The President shall exercise the powers and perform the duties assigned to him by the Constitution and By-Laws and be the Chief Executive Officer of the Association and Chairman of the Board of Directors, as such, subject to the Constitution and By-Laws, he shall generally supervise the management of its affairs. He shall have full power to enforce the provisions of the Constitution, By-Laws, and the will of the Annual Convention. He shall preside at the Annual Convention. He shall appoint all necessary committees and shall perform such other duties as are usually incident to the office.

SECTION 2. VICE PRESIDENT. The Vice President shall preside in the absence or disability of the President. The duties of the Vice President shall be such as may be assigned by the President.

SECTION 3. THE SECRETARY. The Secretary shall keep a record of the proceedings of the Board of Directors, of annual meetings of the Association, and of all other matters of which a record shall be ordered by the President, the Board of Directors, or the Association. He shall perform such other duties as may be assigned to him by the Constitution and By-Laws of the Association, the President and the Board of Directors, and shall perform such other duties as are usually incident to the office.

SECTION 4. THE TREASURER. The Treasurer shall collect and disburse all funds of the Association and be the custodian of such funds. He shall keep regular accounts in the books belonging to the Association. He shall make annual reports at each National Convention upon the condition of the Treasury and at such other times as shall be required by the Board of Directors or by the President. He shall perform such other duties as may be assigned to him by the Constitution and the By-Laws of the Association, and shall perform such other duties as are usually incident to the office.

ARTICLE II

BOARD OF DIRECTORS

SECTION 1. MEETINGS. The Board of Directors shall meet at such times and places as shall be designated by the President. The Secretary shall call a special meeting upon the written request of five (5) or more members of the Board. The Secretary shall notify all directors of all meetings in advance.

SECTION 2. QUORUM. Seven (7) members shall constitute a quorum of the Board of Directors. Absent members of the Board of Directors shall be counted as present at meetings, but only as to those matters with respect to which the vote, in writing, of such absent members, is received by the Secretary of the Association prior to the meeting.

SECTION 3. POWERS. In addition to such powers as are specifically conferred upon it by the Constitution or any By-Laws, the Board of Directors shall be responsible for the general management of the affairs of the Association, and may make such regulations as it deems advisable, not inconsistent with the Constitution and By-Laws. It shall keep a record of its proceedings in minute books which shall be maintained at the office of the Secretary.

SECTION 4. REMOVAL. A Director may be removed from office for lack of participation in the affairs of the Board upon an affirmative vote of two-thirds (2/3) of the members of the Board of Directors.

ARTICLE III

STANDING COMMITTEES

SECTION 1. AUTHORIZED COMMITTEES. The Standing Committees of the Association shall be as follows:

- Awards Committee
- Constitution Committee
- Convention Committee
- Executive Committee
- Historical Committee
- Membership Committee
- Nominating and Election Committee

SECTION 2. CHAIRMEN OF STANDING COMMITTEES. The President shall appoint the chairman of each committee from among the membership. Members of the Board of Directors should be selected for chairmen of committees where they can be effective; however, their selection is not mandatory unless specifically required by these By-Laws.

SECTION 3. MEETINGS. Each Standing Committee shall hold meetings at such times as may be specified, after due notice to its members, by its Chairman, by the President of the Association, or upon the request in writing of a majority of its members.

SECTION 4. REPORTS. Each Standing Committee shall keep a record of its proceedings and shall make a written report of its activities to the Secretary of the Association.

SECTION 5. REMOVAL. Any member of a Standing Committee may be removed from office (except members of the Executive Committee), by the Committee Chairman with the concurrence of the President, or by the written request of two-thirds (2/3) of the committee members.

SECTION 6. DUTIES. Each Standing Committee shall be charged with the duties assigned to it by the Constitution and By-Laws of the Association or by the President or Board of Directors and shall perform such other duties as are usually incident to committees of its particular function. Any question which may arise as to the jurisdiction of a Committee shall be determined by the President.

SECTION 7. APPROPRIATIONS. The Chairman of any Committee may make application to the Executive Committee for appropriation of funds for the work of such Committee. No committee shall have authority to incur any indebtedness or pecuniary obligation for which the Association shall be responsible except to the extent previously authorized by the Board of Directors, or by the Executive Committee.

ARTICLE IV

NOMINATING AND ELECTION COMMITTEE

SECTION 1. CHAIRMAN. The chairman shall be a member of the Board of Directors.

SECTION 2. MEMBERSHIP. The chairman shall appoint an even number of members, not less than two (2) nor more than six (6), to serve on the Committee.

SECTION 3. NOMINATIONS. Nominations to any office to become vacant may be made in writing by any member of the Association, provided it is accompanied by a short biographical sketch of the person to be nominated, suitable for release to the general membership and a complete but concise justification for nomination.

SECTION 4. SELECTION.

a. The Nominating and Election Committee shall solicit and review all nominations and shall select not less than two (2) nor more than five (5) candidates for President, and not less than eight (8) nor more than twelve (12) candidates for the Board of Directors.

b. The Chairman of the Committee shall submit the Nominating and Election Committee nominations to the President of the Association for Board of Directors action not later than 1 April of each year.

c. The Board of Directors shall act upon the recommendations of the Nominating and Election Committee and may add candidates.

SECTION 5. ELECTIONS.

a. Ballots will allow write-in votes for all offices. Ballots will be mailed to the membership between the first (1) and thirty-first (31) of May and only those ballots received in the Association mail box by 1400 on the thirtieth (30) of June shall be counted. Ballots will be returned in the ballot envelopes provided, and they shall not be opened prior to close of the election on thirty (30) June, and then only at such time and place as there are three (3) members of the Nominating and Election Committee present.

b. Results of the election will be provided to the Secretary of the Association not later than fifteen (15) July. Results shall show each candidate and the number of votes received.

c. The Nominating and Elections Committee shall establish the validity of ballots and shall exercise the discretion necessary to resolve voting discrepancies. Offices will be filled by candidates receiving the largest number of votes.

d. Immediately after counting, the ballots will be delivered to the Secretary. The ballots will remain in the Secretary's jurisdiction for possible recount until after the next Annual Convention, at which time they will be destroyed.

ARTICLE V

EXECUTIVE COMMITTEE

SECTION 1. CHAIRMAN. President of the Wild Goose Association.

SECTION 2. MEMBERSHIP. The Executive Committee shall be composed of the President, Vice President, Secretary, and Treasurer.

SECTION 3. The Executive Committee shall be responsible for the business affairs of the Association. They shall insure that the resolutions of the Board are properly administered and that actions requiring authorization between meetings of the Board of Directors are authenticated and approved.

ARTICLE VI

CONVENTION COMMITTEE

SECTION 1. CHAIRMAN. The Chairman shall be any member of the Association.

SECTION 2. MEMBERSHIP. The Chairman shall appoint an even number of members, not less than two (2) nor more than six (6), to serve on the Committee.

SECTION 3. DUTIES. The Convention Committee shall plan and conduct an annual convention in September or October of each calendar year at a place and date approved by the Board of Directors. Installation of all officers shall take place at this convention.

ARTICLE VII

MEMBERSHIP FEES

SECTION 1. INITIATION FEES AND ANNUAL DUES. Regular membership fees and dues shall be paid on the following basis:

a. Initiation Fee $10.00. This includes dues for the first year.

b. Annual Dues. $7.50 per year.

c. Honorary Members shall be exempt from Initiation Fees and Annual Dues.

d. Regular Life Memberships shall be $100.00. No initiation fee is required in case of Life Membership.

ARTICLE VIII

AMENDMENTS

SECTION 1. The By-Laws may be amended with the concurrence of two-thirds (2/3) of the members of the Board of Directors.

SECTION 2. Members of the Board will be provided a copy of all proposed changes and given thirty (30) days after date of mailing to respond. Yeas and Nays shall be recorded by the Secretary, including each member's vote.

ARTICLE IX

AWARDS COMMITTEE

SECTION 1. CHAIRMAN. The Chairman shall be any member of the Association.

SECTION 2. MEMBERSHIP. The Chairman shall appoint an even number of members, not less than two (2) nor more than six (6), to serve on the committee.

SECTION 3. DUTIES. The Awards Committee shall be responsible for administering the Awards Program of the Association in accordance with the Constitution and By-Laws. The Committee will prepare a report describing the authorized awards and detailing criterial and procedures for nomination and selection. After approval by the Board of Directors, this report will be distributed to the membership.

ARTICLE X

CONSTITUTION COMMITTEE

SECTION 1. CHAIRMAN. The Chairman shall be any member of the association.

SECTION 2. MEMBERSHIP. The Chairman shall appoint an even number of members, not less than two (2) nor more than six (6), to serve on the Committee.

SECTION 3. DUTIES. The Constitution Committee shall be responsible for proper preparation and administration of proposed changes to the Constitution for presentation to the membership, and proposed changes to the By-Laws for presentation to the Board of Directors. Further, the Constitution Committee will prepare a report detailing procedures for forming Regional Clubs and providing a sample club Charter and Constitution. After approval by the Board of Directors, this report will be distributed to the membership.

ARTICLE XI

AWARDS

SECTION 1. The following non-monetary awards are authorized to further the aims and purposes of the Wild Goose Association:

Medal of Merit:

To be awarded to a person or persons for a particular contribution of outstanding value to the development or fostering of loran. This award shall normally be given only after the exceptional nature of the contribution is clearly recognized.

Paper Award:

To be awarded to a member of the Wild Goose Association for the best paper published on the general subject of loran.

Service Award:

This award will be given to members who distinguish themselves by service to the Wild Goose Association.

President's Award:

To be awarded to the person, persons, or organization as designated by the President of the Association with consent of the Board of Directors. The Award shall be presented at the annual banquet.

ARTICLE XII

REGIONAL CLUBS

SECTION 1. Regional Clubs shall be chartered by the Board of Directors to further the aims and purposes of the Wild Goose Association.

SECTION 2. The area of jurisdiction for each club shall be appropriately designated. All Association members in the designated jurisdiction will be eligible for club membership.

SECTION 3. Regular members who desire to form a club shall make application for a charter to the Constitution Committee in accordance with the current procedures *established by the Committee.* The Chairman of the Constitution Committee shall forward the application and proposed Club Constitution with the Committee's recommendations to the Board of Directors for action. When approved by the Board of Directors, the President of the Association shall issue the Charter. The Charter shall be retained by the Club until such time as the Club may become inactive, at which time the Charter will be returned to the Association.

SECTION 4. Each Regional Club shall upon issue of the Charter be provided with funds from the Association in the amount of $1.00 per Club member for the purpose of partially defraying the Club operating expenses. Such funds shall be further provided to each active Regional Club on April 1 upon application to and certification by the Membership Committee of the Association as to the current status of membership.

ARTICLE XIII

RADIONAVIGATION JOURNAL

SECTION 1. PURPOSE. To provide to the membership of the Wild Goose Association and to the loran community at large a compendium of current Association and loran information and related topics. It is intended that the Journal will be updated and published annually, closely following the annual elections (approximately July of each year), to provide to the membership an annual report of the significant activities, accomplishments, and objectives of the Association. It is further intended that the Journal will serve the interest of the loran community by providing a compendium of loran information and reference data deemed to be of interest to the Community at large.

SECTION 2. JOURNAL COMMITTEE. A special committee shall be constituted to effect the compilation, editing and publication of the Journal. The President of the Association shall annually appoint the Editor of the Journal, who will serve as Chairman of the Committee. The Editor shall appoint not less than two (2) nor more than six (6) members to serve on the Committee.

SECTION 3. FINANCE. The Journal is intended to be financially self-supporting through the sale of advertising space and copies of the Journal to the loran community at large. The Editor of the Journal may make application to the Executive Committee for the funds necessary to publish a specific issue of the Journal and may make application to the Treasurer for the funds necessary for the administration of the Journal Committee (i.e.: mailings, telephone, etc.). Such application shall be supported by a detailed budget. The Committee shall not have authority to incur any indebtedness or pecuniary obligation for which the Association shall be responsible except to the extent previously authorized by the Executive Committee, or by the Board of Directors.

SECTION 4. CONTENTS. Prior to final editing and publication, the Chairman of the Committee shall submit to *the Executive Committee for approval a detailed* listing of the contents of the forthcoming issue.

SECTION 5. DISTRIBUTION. At publication, a copy of the Journal shall be provided to each member of the Association at no cost. Copies shall be made available for sale to the loran community at large at prices to be determined by the Chairman of the Committee and approved by the Executive Committee, or Board of Directors.

WGA MEMBERSHIP LIST

We have attempted to compile a WGA Membership List and the member's affiliation. To those members included in this list without an affiliation, we apologize. We do not know their current affiliation and would urge them to contact the editorial or membership committee to provide the pertinent information. There are also a number of members listed herein who have not paid their current dues – we urge them to do so.

Roald Aarset
Simrad, as
Frank Abate
Republic Electronics
Ray Abraczinskas
Lear Siegler, Inc.
John V. Adams
ITT Avionics Div.
Col. Michael H. Alexander
US Air Force
Bernard Ambroseno
Epsco Inc.
Duncan Amos
White Fish Authority
Gordon R. Anderson
Electronic Communications Inc.
Carl Andren
Navigation Systems Inc.
Capt. Edward J. Ard
US Coast Guard
William S. Arnold
Watkins-Johnson
Donald W. Baake
Teledyne Systems Co.
Christian Bachman
ASEC
Tom Baine
Offshore Navigation Inc.
Robert L. Baker
James H. Ball
Lear Siegler Inc.
Charles J. Baltzer
Austron Inc.
Ian T. Band
SC Labs
Peter F. Barry
Hartman Systems
Donald E. Bartlett
Sperry Gyroscope Div.
Robert P. Bartlett
Epsco Inc.
George E. Basset
US Coast Guard
Dr. Charles C. Bates
US Coast Guard
William R. Bazzarre
John W. Beakes
Amecom
William J. Becker
US Air Force
Thurman C. Becker
G. R. Begley
Melvin Benjamin
Amecom
LCOL John F. Beran
US Air Force
Larry Berberich

John M. Beukers
Beukers Labs Inc.
CDR James A. Blake
US Coast Guard
Wally Blanchard
Redifon Telecommunications Ltd.
Emmanuel E. Bliamptis
US Air Force
Murray Block
ITT Avionics Div.
J. Bode
Austron Inc.
Eugene J. Boyle Jr.
MITRE Corp.
C. Lawrence Bradley
The Analytic Sciences Corp.
Evan W. Branson
ITT Avionics Div.
Dan Breedon
Ed Bregstone
US Coast Guard
Barry Brenin
Sperry
William E. Brennan
Teledyne Systems Co.
Kenneth E. Briggs
EDO-AIRE
Earl Brown
Canadian Center for Inland Waters
Herb Brown
Internav Inc.
Michael Brown
Amecom
Keith Bruhl
Beukers Labs Inc.
Loren E. Brunner
US Coast Guard (ret)
Gilbert A. Buccola
US Air Force
Lloyd B. Burch
CRPL Inc.
Lawrence Burke
Spears
Richard E. Burke, Jr.
US Coast Guard
John G. Busharis
ITT Avionics Div.
John G. Busharis
Bjorn Carlsen
Simrad Inc.
Carl O. Carlson
C. S. Carney
Communications Assoc. Inc.
LCDR David Carter
US Coast Guard
LCDR Robert H. Cassis, Jr.
US Coast Guard

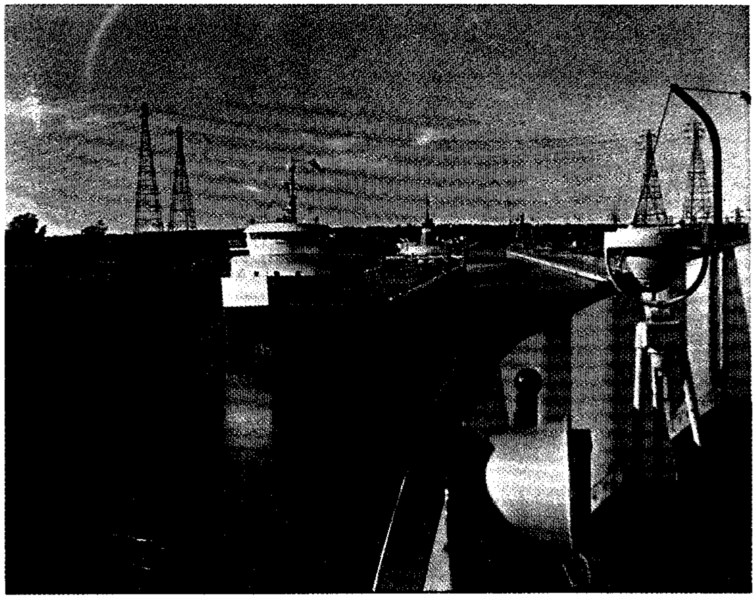
James Castanias
Sperry
Hardy M. Caton
Tracor Inc.
Frederick J. Chambers
Teledyne Systems Co.
James T. Chapman
Griffith Marine
John M. Cawley
Arthur D. Little Inc.
Peter Chappell
Mel Chaskin
US Air Force
Kenon T. Chism
US Coast Guard
David A. Clayton
Offshore Nav. Inc.
CAPT G. L. Cline
James M. Cloeren
Austron Inc.
Dr. L. V. Cockroft
DOT
John L. Coco
US Air Force
Melvin S. Cohn
Michael G. Coleman
Tom Collins
Collins Marine
RADM Peter V. Colman
Boeing Co.
Gerald Cook
US Army
John G. Courtney
Duncan Cox
Charles Stark Draper Labs Inc.
Eugene Cronin
Sperry
Maj. Richard G. Cronquist
US Air Force
Lylton F. Crossley
CAPT James F. Culbertson
US Coast Guard
Dr. Calvin Culver
Micrologic Inc.
Paul M. Cunningham
Vought Systems
Charles Cusack
John Currie
Internav
Donald B. Daniel
Thomas E. Daniels
US Army
James DaRold
Lowell Davis
Amecom
Harry Davis
Consultant

Martin C. Day
Amecom Div.
Walter N. Dean
Magnavox Inc.
Herbert Deich
MDH Ind.
John J. Del Giorno
US Coast Guard
John A. DeLisio
Lear Siegler Instrument Div.
Louis L. Demlow
M. Diamond
ITT Avionics
Norman C. Dickerson Jr.
Amecom Div.
Charles Dilger
Angelo Dimitriou
Lear Siegler Instrument Div.
LT James T. Doherty
US Coast Guard
Robert H. Doherty
Consultant
Paul R. Donavan
Dare Electronics
Joseph L. Drayer
Tracor Inc.
CAPT J. E. Driscoll
US Air Force
Merton S. DuBois
US Army
CDR Robert F. Dugan
US Coast Guard
Edward Durbin
Kaiser Aerospace and Electronics Co.
R. M. Eaton
Bedford Institute
Thomas H. Eggers
Albert M. Eichin
Bernard T. Ellis Jr.
ITT Avionics Div.
Robert W. Elsner
Lear Siegler Astronautics Div.
Charles J. England
Institute of Telecommunications Sciences
Harold E. Englert
Harold Erdley
Teledyne
Donald B. Erisman
US Coast Guard
Bowman H. Evans
TRW Systems Div.
MAJ C. J. Ewald
US Air Force
M. H. Fakharzadeh
Boeing
CAPT William R. Fearn
US Coast Guard
Leo F. Fehlner
Applied Physics Lab
Donald Feldman
US Coast Guard
Charles F. Feltham
Dynell Electronics Corp.

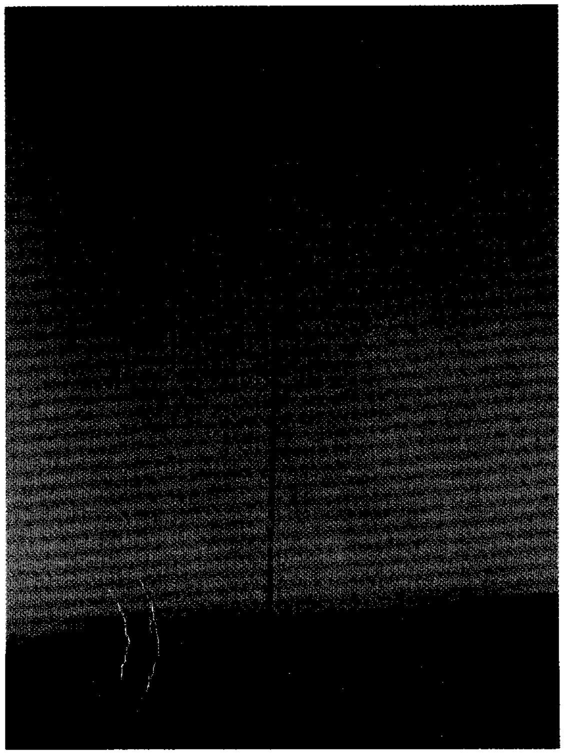
LCDR Walter B. Ferm
US Coast Guard
D. D. Fitzgerald
William G. Fitzsimmons
Lloyd D. Ford
MITRE Corp.
Bruce Francis
Austron Inc.
Robert L. Francisco
Epsco Inc.
Aaron Frank
ITT Avionics
Robert L. Frank
Consultant
Wilbert Frantz
CDR Warren J. Frederick
Megapulse Inc.
Dr. Ronald J. Fredericks
Lear Siegler Instrument Div.
John D. Freitag
Data Systems Div.
John E. French
RCA
Dr. Karl Frudenfeld
Global Nav. Inc.
Eugene O. Frye
Ron Von Gaasbeck
Digicon Geophysical
William J. Garmany
ITT Avionics Div.
John I. Geiling
Amecom
Dan Gentry
Aerospace Systems Inc.
Andrew Georgia
Singer-Kearfott Div.
Hal Gershanoff
Epsco Inc.
Thomas Gilmartin
US Coast Guard
I. Ginsburg
John J. Del Giorno
US Coast Guard
Robert Goddard
Internav Inc.
Arnold Goldman
Hartman Systems
Russel Good
Boston Elec. Ltd.
LCDR Gil R. Goodman
US Coast Guard
Robert V. Gould
Sperry Systems Management Div.
Dennis J. Granato
DMA Hydrographic Center
S. T. Grant
Bedford Institute
John D. Gratrelis
CDC
Gordon T. Graves
Donald G. Gray
Lear Siegler Inc.

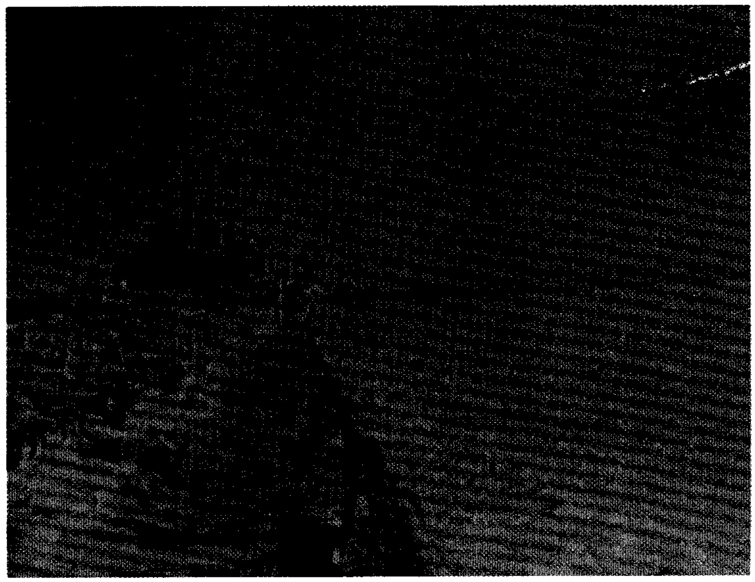
James A. Graydon
US Air Force
Marianne Grosszko
Charles W. Gruber
ITT Avionics Div.
Gerald A. Gutman
Communications Associates Inc.
Fred Hahn, Jr.
DMAHC
David T. Haislip
US Coast Guard
Robert Hall
Ultrasystems Inc.
Harry Halamandaris
Teledyne Systems Co.
Arthur S. Hanby Jr.
University of Delaware
John E. Hanna
DMA Hydrographic Center
Robert C. Hanson
R. C. Hanson, Inc.
MAJ James A. Harden
US Air Force
James C. Harris
Lear Siegler, Inc.
LCDR Roger W. Hassard
US Coast Guard
Jim Haynes
Gemtronics Inc.
Neal I. Heenan
MITRE Corp.
Gifford Hefley
Joseph Heinen
ITT Avionics Div.
James W. Henderson
ASEC
CAPT Harold T. Hendrickson
US Coast Guard (ret)
LCOL R. H. Herr
US Air Force
CAPT R. I. Hetherington
Royal Canadian Forces
Lloyd D. Higginbotham
US Air Force
William H. Hilbun III
ASEC
John Hird
Nav. Systems Inc.
David C. Hiser
Sperry Rand Corp.
George R. Hitchcock
David E. Hoagland
Hewlett Packard Corp.
Charles Hoffman
Amecom
G. H. Hoffman
EDO-AIRE
Richard F. Hoffman
Maganavox Corp.
Robert J. Holden
Digicon Inc.
Harold Holland
HWH Electronics Corp.

The problems of navigation on the Great Lakes are ▷ amply demonstrated in this picture of two ore carriers passing at the entrance to locks.



The U.S. Air Force Loran-D program is symbolized in this 400 foot quick erecting tower, near Alexandria, Louisiana.
▽





△
Great Lakes ore carrier in ice. Loran-C is a part of the U.S. Coast Guard effort to keep the lakes open to shipping throughout the year.

The MV DRACO uses Loran-C for accurate position fixing. She is one of many similar hydrographic and geological survey vessels. ◁