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MINIMUM PERFORMANCE STANDARDS FOR MARINE eLORAN RECEIVING EQUIPMENT

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Developed by
RTCM Special Committee 127

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- the International Electrotechnical Commission (IEC)
- the International Organization for Standardization (ISO)
- the European Telecommunication Standards Institute (ETSI)

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Enhanced Long Range Navigation System (eLoran) Receiver equipment – Performance standards

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Enhanced Long Range Navigation System (eLoran) Receiver equipment – Performance standards

1 Scope

This document details the RTCM's recommended minimum performance standards for eLoran shipborne receiver equipment, based on IMO Resolution A.115(22), A.818(19), A.915(22) and A.1046(27) requirements. A description of the eLoran system is provided in the Enhanced Loran (eLoran) Definition Document Version 1.0, 16 October 2007 and an eLoran Signal-in-Space specification is provided in *Enhanced Loran (eLoran)* LORIPP/LORAPP Draft Specification of the eLoran System, Rev. 4.0. That specification is based on information contained in *Loran's Capability to Mitigate the Impact of a GPS Outage on GPS Position, Navigation, and Time Applications*; Prepared for the Federal Aviation Administration, Vice President for Technical Operations, Navigation Services Directorate, dated 31 March 2004. This receiver standard applies to phases of the voyage for harbor entrances, harbor approaches and coastal waters with a high volume of traffic and/or significant degree of risk.

Since V2.0 of this standard, methods of testing and required test results are considered in a separate document.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

- Enhanced Loran (eLoran) Definition Document Version 1.0, 16 October 2007
- *Enhanced Loran (eLoran)* LORIPP/LORAPP Draft Specification of the eLoran System, Rev. 4.0
- *Loran's Capability to Mitigate the Impact of a GPS Outage on GPS Position, Navigation, and Time Applications*; Prepared for the Federal Aviation Administration, Vice President for Technical Operations, Navigation Services Directorate; dated 31 March 2004
- IEC 60721-3-6:1987, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Ship environment*
- IEC 60945, *Maritime navigation and radiocommunication equipment and systems – General requirements – Methods of testing and required test results*

- IEC 61162 (all parts), *Maritime navigation and radiocommunication equipment and systems – Digital interfaces*
- IEC 61108-1 *Maritime navigation and radiocommunication equipment and systems –Global navigation satellite systems (GNSS)*
- IMO resolution A.818 (19):1995, Performance Standards for Shipborne LORAN-C and CHAYKA Receivers
- IMO Resolution A.529(13):1983 , *Accuracy standards for navigation*
- IMO Resolution A.694(17):1991, *General requirements for shipborne radio equipment forming part of the Global maritime distress and safety system (GMDSS) and for electronic navigational aids*
- IMO Resolution A.915(22):2002, *Revised Maritime Policy And Requirements For A Future Global Navigation Satellite System (GNSS)*
- IMO Resolution A.1046(27):2011, *Worldwide radionavigation system*
- IMO Resolution MSC.112(73):2000, *Performance standards for shipborne global positioning system (GPS) receiver equipment*
- IMO Resolution MSC.114(73):2000, *Performance standards for shipborne DGPS and DGLONASS maritime radio beacon receiver equipment*
- ITU-R Recommendation M.589-2*, *Technical characteristics of methods of data transmission and interference protection for radionavigation services in the frequency bands between 70 and 130 kHz*
- *NMEA 0183 rev 4 Standard for Interfacing Marine Electronic Devices.*
- *NMEA 2000 Standard for Interfacing Marine Electronic Devices.*

3 Terms, definitions, and abbreviations

For the purposes of this document, all terms, definitions and abbreviations used to describe the eLoran system are the same as those used in the normative reference of the LORIPP/LORAPP Draft Specification of the eLoran System, Rev. 3.0. The terms, definition, and abbreviations for a ship borne receiver are the same as those used in normative reference of IEC 61108-1 Maritime navigation and Radiocommunication equipment and systems – Global navigation satellite systems (GNSS). The terms, definition, and abbreviations for shipborne receiver testing are the same as those used in normative reference of IEC 60945, *Maritime navigation and radiocommunication equipment and systems – General requirements – Methods of testing and required test results.*

3.1 GNSS and eLoran terms, definitions and abbreviations

Due to the differences between GNSS receivers and eLoran receivers in some cases it is required to modify the terms, definition, and abbreviations. Discussions of these modifications are explained in the following sections with appropriate references and more detailed information as applicable in the appendices for a shipborne receiver are the same as those used in the normative references.

3.1.1 Terms

Several terms are taken directly from the normative references or other documents for ease in understanding this MPS and to avoid confusion. Also several "terms" refer to the service provider's[1] retransmission of the pulse.

3.1.1.1 eLoran System

eLoran is the latest in the long-standing and proven series of low-frequency, LOng-RAnge Navigation (LORAN) systems, one that takes full advantage of 21st century technology. It is a positioning, navigation, and timing (PNT) service for use by many modes of transport and in other applications. It is a PNT system operating at an assigned frequency of 100 kHz, utilizing pulses from widely spaced transmitting stations in which the receiver's position is determined by the measurement of the times of arrival (TOA) of these pulses.

eLoran is an independent, dissimilar, complement to Global Navigation Satellite Systems (GNSS). It allows GNSS users to retain the safety, security, and economic benefits of GNSS, even when their satellite services are disrupted.

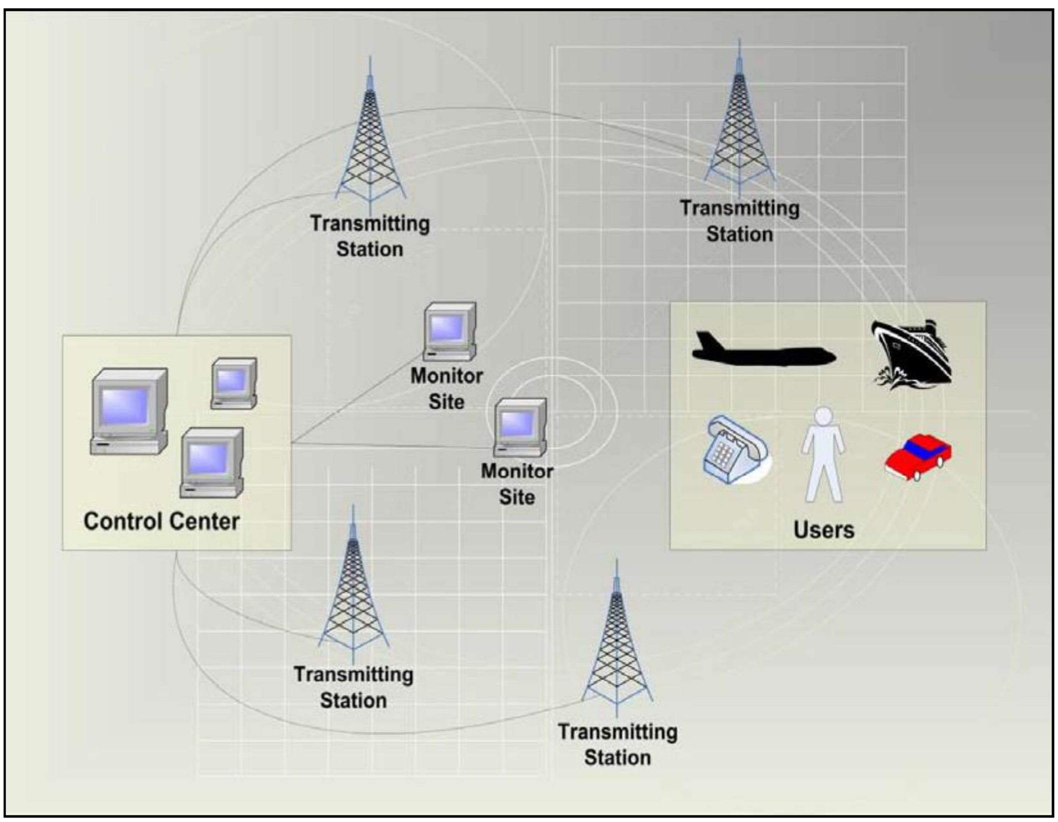

Figure 3.1 - A high level view of the eLoran System.

[1] The "Service Provider" is the organization that is responsible for transmission, monitoring, and control of the eLoran pulse.

3.1.1.2 eLoran Pulse

The pulse and specifically referenced points or parameters of the pulse are identified in Figure 3.2.

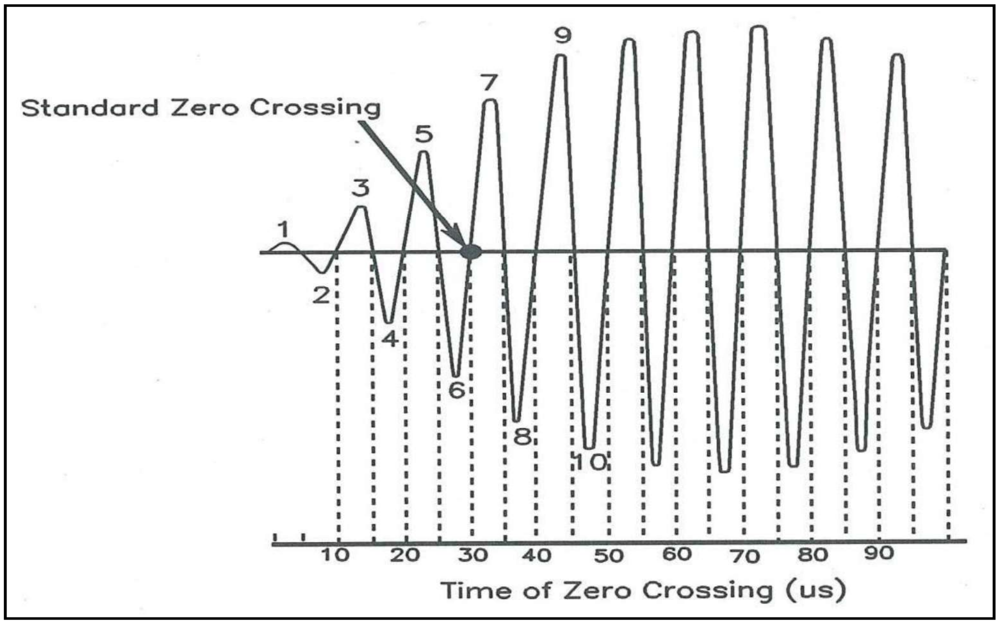

Figure 3.2 The eLoran Pulse.

3.1.1.3 Loran Data Channel

The Loran Data Channel (LDC) allows the eLoran system to meet higher position accuracy and time synchronization applications. Regardless of the type of communication scheme[2] used, the LDC shall convey corrections, warnings, and signal integrity information to the user's receiver via the eLoran transmission. The data transmitted may not be needed or provided for all applications but will include at a minimum:

- The identity of the station[3];
- The identity of the monitor site[4];
- Absolute time based on the Coordinated Universal Time (UTC) scale; leap-second offsets between eLoran system time and UTC;
- Warnings of anomalous radio propagation conditions including early skywaves;
- Warnings of signal failures, aimed at maximizing the integrity of the system;

[2] Refer to regional specific signal specification for type of the data communication scheme
[3] Changes in almanac information (e.g., Station location) will be accomplished so that it will not create an HMI situation.
[4] Changes in almanac information (e.g., Station location) will be accomplished so that it will not create an HMI situation

- Differential eLoran corrections, to maximize accuracy for maritime and timing users; and

The data transmitted may not be needed or provided for all applications but may include:

- Differential GNSS corrections:
- Almanac message on changes of Loran transmitting and differential monitor sites;
- Messages that allow users to authenticate the eLoran transmissions;
- Official-use only messages;
- Messages to inform users that another station is transmitting but it is transmitting improperly (a 'tattle tale').
- Messages that explain to eLoran users why a certain signal is being blinked. (e.g., Master blink)

3.1.1.4 Additional Secondary Phase Factor Grid

The data developed during a measurement survey of Harbor Entrance and Approach (HEA), or modeled by computer software and calibrated with measurements. This grid (or ASF map) information and data will be developed and given to the receiver manufacturer by the service provider. This grid data is used along with the differential-Loran data to provide the accuracy required for HEA. Appendices at the end of this document present information on how to use ASF data, and it's publication format.

More information on the data and composition of this grid is found in Enhanced Loran (eLoran) LORIPP/LORAPP Draft Specification of the eLoran System, Rev. 4.0.

3.1.1.5 eLoran Receiving Equipment

A device, using a nominal antenna, which processes eLoran signals.

3.1.1.6 Nominal eLoran Antenna

The nominal antenna for a receiver shall be specified by the manufacturer. In carrying out the specific test procedures, the signal levels at the space coupling node shall be related to the field strength in proportion to the effective height of the nominal antenna.

eLoran antennas are normally designed as active devices, comprising the actual antenna element(s), a bandpass filter to suppress signals outside the Loran band, and an amplifier. The combination of the bandpass filter and amplifier is also sometimes referred to as the 'antenna coupler'. Both E-field and H-field antennas are used in eLoran, each having its merits and limitations.

3.1.1.6.1 H-field Antenna

An H-Field eLoran antenna is typically realized using several ferrite-loaded loop antenna elements. A single loop has a figure-eight antenna pattern in the horizontal plane. The phase response of an ideal loop is constant over the range of azimuths corresponding to each lobe of the figure-eight pattern, with a 180 degree phase transition between the two lobes. In order to obtain an omnidirectional characteristic, signals from two or more loop antenna elements need to be combined. This may be accomplished either in hardware, or in software. If the antenna outputs are combined in software a two-channel receiver architecture is required. In either case some calibration and additional signal processing has to be performed to achieve a truly omnidirectional antenna pattern.

Parasitic coupling between the channels and between the antenna and the carrying platform causes heading-dependent errors, which need to be calibrated out after installation. This calibration may require the rotation (yaw) of the vessel.

Due to their immunity to precipitation static and the fact that no grounding is required, H-Field antennas are suitable mainly for aviation use.

3.1.1.6.2 E-Field Antenna

An eLoran E-Field antenna senses the electric field component of the vertically polarized radiated electromagnetic field. It is typically a monopole antenna, consisting of a short vertical conductor, and the associated filter and amplifier. A vertical monopole antenna has an omnidirectional pattern in the horizontal plane. Since the antenna consists of only one element, a single-channel receiver architecture is used to process the output signal.

E-Field antennas are preferred aboard ship over H-Field antennas, as they provide improved signal-to-noise ratio (SNR) performance compared to H-Field, in addition to not requiring calibration to take into account parasitic coupling with the vessel's superstructure.

3.1.1.7 Legacy Loran-C Receiver

The legacy Loran-C receiver is typically chain-based, which cannot use signals from different GRIs. However later versions developed after the chain-to-chain timing tolerances were minimized did allow from some cross chain position fixing capability. The legacy receiver does not significantly benefit from the changes made to create the eLoran system and derives no benefit from the eLoran Data Channel.

3.1.1.8 All-in-View

eLoran uses the Time of Arrival (TOA) of signals (relative to UTC) from individual transmitting stations to determine position. In an eLoran receiver, each transmitter may contribute a range to the position solution.

3.1.1.9 Error Budget

The amount of signal generation errors, propagation factor errors, and receiver processing induced effects that would degrade the position fix beyond acceptable application limits.

3.1.1.10 2drms

The 2drms (twice distance root mean square) statistical error refers to the radius of a circle, centered at the true position that contains at least 95 percent of the measured or estimated positions. The actually probability level of 2-drms varies between approximately 95% and 98% depending on the eccentricity of the position distribution ellipse. Assuming a circular distribution of errors the positioning error at the 95th percentile is 1.7308×2drms.

3.1.2 Definitions

Several definitions like the “Terms” are taken directly from the nominative references and other documents for ease in understanding this MPS and to avoid confusion.

3.1.2.1 Acquisition

Acquisition is defined as the processing of eLoran signals to obtain a position fix within the required accuracies. The Time to Fix (TTF) for a specified mode is defined as the time needed from “power on” to process eLoran signals to obtain a position fix within the required accuracy of that mode.

3.1.2.2 Time to Reacquisition Fix (TTRF)

Time to Reacquisition Fix for a specified mode is defined as the time needed, beginning from restoration of a lost signal to nominal state, to obtain a position fix within the required accuracy of that mode.

3.1.2.1 Accuracy[5]

Accuracy is the degree of conformance between the estimated, measured, or desired position or the velocity of a platform at a given time and its true position or velocity. Radionavigation performance accuracy is usually presented as a statistical measure of system error. Accuracy is a statistical measure of performance; therefore, a statement of the accuracy of a navigation system is meaningless unless it includes a statement of the uncertainty in position that

[5] *Loran's Capability to Mitigate the Impact of a GPS Outage on GPS Position, Navigation, and Time Applications*; Prepared for the Federal Aviation Administration, Vice President for Technical Operations, Navigation Services Directorate; dated March 2004

applies. Accuracy can be specified in terms of one or more of the following definitions:

- *Predictable.* The accuracy of a position in relation to the geographic or geodetic coordinates of Earth.
- *Repeatable*. The accuracy with which a user can return to a position whose coordinates have been measured at a previous time with the same navigation system.
- *Relative.* The accuracy with which a user can measure position relative to that of another user of the same navigation system at the same time.

Another factor related to accuracy is fix dimension, which gives "accuracy" in more than one measurement axis. The term *fix dimension* defines whether the navigation system accuracy is a linear, one-dimensional line-of-position or a two- or three-dimensional position fix. The ability of the system to derive a fourth dimension (e.g. time) from the navigation signals is also included. A vital factor is a system's ability to limit fix ambiguity. System ambiguity exists when the navigation system identifies two or more possible positions of the user, with the same set of measurements, with no indication of which is the most likely correct position. The potential for system ambiguities should be identified with provision for users to identify and resolve them.

3.1.2.2 Integrity[6]

Integrity is defined as the ability of a system to provide timely warnings to users when the system should not be used for navigation.

3.1.2.3 Availability[7]

Availability is the ability of the system to provide the required function and performance at the initiation of the intended operation. Availability is also an indication of the system's ability to provide usable service within the specified coverage area. Signal availability is the percentage of time that navigational signals transmitted from external sources are available for use. Availability is a function of the technical capabilities of the transmitter and receiver, as well as the effects of propagation.

Availability can be also be used as a sanity check on the tuning of the Integrity Monitor. An integrity monitor that always indicates "do not use" provides 100% integrity, but 0% availability.

3.1.2.4 Continuity[8]

Continuity is defined as the capability of the total system (comprising all elements necessary to maintain a user's position within the defined space) to perform its

[6] The "Service Provider" is the organization that is responsible for transmission, monitoring, and control of the eLoran pulse.
[7] Same as footnote 6
[8] Same as footnote 6

function without nonscheduled interruptions during the intended operation. The continuity risk is the probability that the system will be unintentionally interrupted, and not provide guidance information for the intended operation. More specifically, continuity is the probability that the system will be available for the duration of a phase of operation, presuming that the system was available at the beginning of that phase of operation.

3.1.2.5 Coverage[9]

Coverage is the result of the preceding four factors. Coverage is the geographic area where the application-specific radionavigation system requirements (e.g., RNP 0.3 or HEA) for integrity, accuracy, availability, and continuity parameters are satisfied at the same time. System geometry, signal power levels, receiver sensitivity, atmospheric noise conditions, and other factors that affect signal availability influence coverage.

3.1.2.6 Time and Frequency[10]

Frequency Accuracy: Maximum long-term deviation from the definition of the second without external calibration. This is measured as the frequency difference from a recognized and maintained source.[11]

Frequency Stability: Change in frequency over a given time interval.

Timing Accuracy: Absolute offset in time from a recognized and maintained time source of UTC[12] .

3.1.2.7 Performance Parameters Interrelationship[13]

In many instances, the characteristics of the eLoran system affect all or some of the performance parameters (e.g., the signal-to-noise ratio [SNR] affects accuracy and integrity). Also, a characteristic may affect different parameters in different ways; for example the earlier mentioned effect on availability of an integrity monitor that is "too strict". In addition, the impact of a performance parameter and system characteristic may differ from user community to user community. These interrelationships and other possible interrelationships among performance factors, system characteristics, and user applications are optimized to meet the application's requirements for shipborne receivers.

3.1.2.8 Phase Factors

An eLoran receiver takes Time of Arrival (TOA) measurements of the Loran signals. For the purpose of positioning, the TOA measurement is converted to a pseudorange by multiplication with the speed of light (*c*). Since the Loran signals

[9] Same as footnote 6
[10] Same as foot note 6
[11] For example, these sources could be the U.S. Naval Observatory (USNO), National Institute Standard and Technology (NIST), or Bureau International des Poids et Mesures (BIPM).
[12] *UTC.* The international atomic time as based on cesium-133 with leap seconds added for variable earth rotation. For example, these sources could be the U.S. Naval Observatory (USNO), National Institute Standard and Technology (NIST), or Bureau International des Poids et Mesures (BIPM).
[13] Same as footnote 6

propagate through air and over a conducting surface, the propagation speed is lower than the speed of light in vacuum. The Time of Arrival needs to be corrected to compensate for the delay due to the lower propagation speed. Refer to Figure 3.3 for an illustration of the definitions below and their relationship. Appendix D also contains additional information on the various phase factors.

3.1.2.8.1 Primary Phase Factor

The primary phase factor (PF) accounts for the fact that the Loran signals propagate through the earth's atmosphere as opposed to in free space (vacuum). The speed of light in atmosphere used is V_{pf}= 299691162 m/s which corresponds to an index of refraction of approximately 1.000338.

The lower propagation speed is compensated for by a primary factor delay in the TOA processing. This is incorporated in Equation 3.1.

3.1.2.8.2 Secondary Phase Factor

The sea-water secondary phase factor (SF), reflects the fact that the Loran ground wave is further retarded when traveling over seawater as opposed to through the atmosphere. Appendix D.1 contains equations for computing Secondary Factor and Primary Factor.

$$p = PF+SF \qquad \text{Equation 3.1}$$

3.1.2.8.3 Additional Secondary Phase Factor (nominal)

The Additional Secondary Phase Factor (ASF), accounts for the additional delay caused by signal propagation over land and elevated terrain when compared to the delay experienced over sea-water. Depending on the receiver's location, signals from some eLoran transmitters may have traveled hundreds of kilometers over land and must be corrected to account for the additional delay imparted by the non-seawater portion of the signal path. An ASF is the cumulative delay the signal experiences when traveling over sections of land with different ground conductivity.

The eLoran service provider publishes ASFs for a geographic area of interest (e.g. a Harbor Entrance and Approach area, or Coastal Voyage Phase). ASFs are published in grid form, and they are a function of geographic location within the grid, for each eLoran transmitter.

The user receiver shall use equation 3.1 to compensate for PF and SF delays in addition to the ASF delay. ASFs are provided in microseconds. Even with the corrections, there are still residual errors. ASF values are determined at locations between published grid elements through interpolation, as described in the Appendices.

Should the eLoran service provider offer ASF measurement error bound data, this should be employed by the receiver manufacturer in the computation of HPL.

A recommended service provider ASF data format is presented in Appendix D.

3.1.2.8.4 Differential-Loran Corrections

In order to provide the highest possible eLoran accuracy, the maritime service provider installs a differential-Loran (DLoran) Reference Station in a static location close to the area of interest. This Reference Station calculates differential-Loran corrections and broadcasts them through the Loran Data Channel of one or more eLoran transmitters within range. The differential correction compensates for any temporal variations in Primary Factor, Secondary Factor and Additionally Secondary Factor delays, as well as possible errors in transmitter UTC synchronisation. Differential-Loran corrections are provided in units of microseconds. The difference between the location of the differential Reference Station and the location of the user equipment can result in errors due to a phenomenon known as “spatial decorrelation”.

The differential data format may be found in the signal specification published by the service provider.

3.1.2.8.5 Time of Arrival Processing

The received Time of Arrival of an eLoran transmitter’s signal converts to a pseudorange measurement according to Equation 3.3

$$PR = TOA*c - p - (ASF + \delta)*1\times10^{-6}*c \qquad \text{Equation 3.2}$$

Where,

PR	=	Pseudo range in meters
TOA	=	Time of Arrival in seconds
c	=	speed of light in vacuum
p	=	phase delay in metres (Equation 3.1); PF+SF
ASF	=	published ASF in microseconds (equation 3.2)
δ	=	differential eLoran corrections in microseconds,

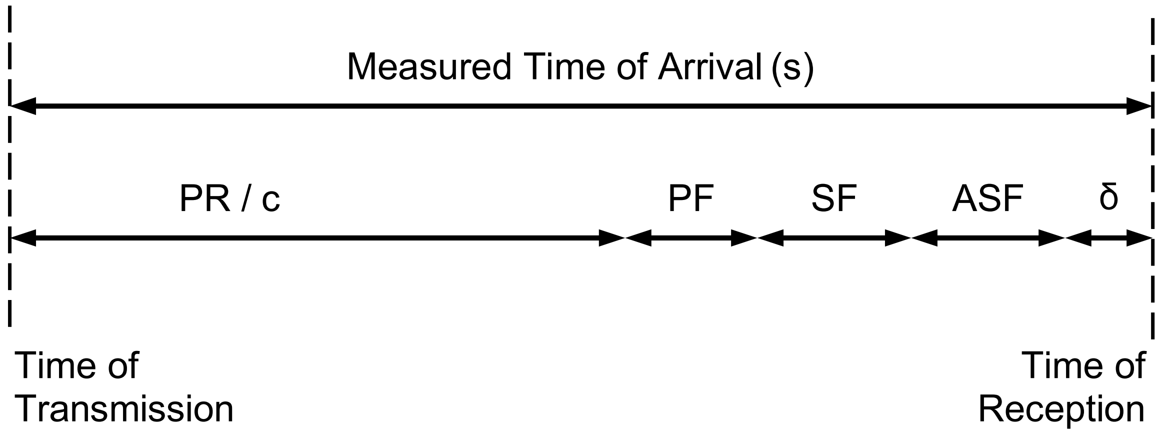

Figure 3.3 - Components and factors affecting measured time of arrival.

3.1.2.9 Standard Zero Crossing

Referring to Figure 3.2 the Standard Zero Crossing (SZC) is the positive zero crossing at the point 30 microseconds into a positively phase coded pulse on the antenna-current waveform. This zero crossing is phase-locked to the eLoran station's cesium time reference. The standard zero crossing is used as a timing reference for measurement of eLoran signal specifications.

3.1.2.10 Envelope to Cycle Difference

The Envelope to Cycle Difference (ECD) has both a near-field value as well as a far-field value. The difference is that one is measured at the ground return on the base of the transmitting antenna and the other determined at the user location; see Figure 3.4.

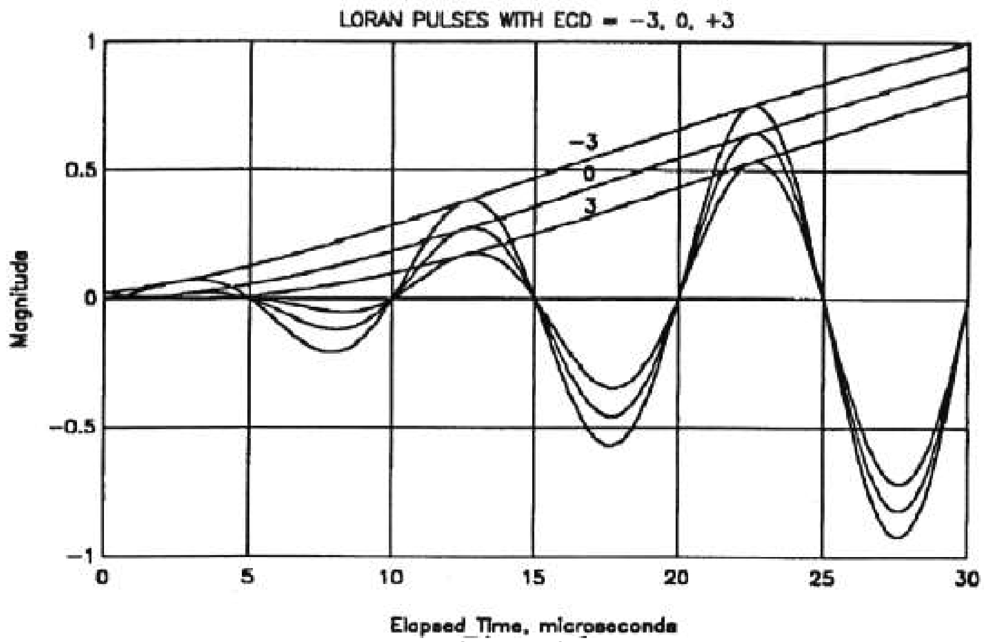

Figure 3.4 - eLoran pulses with ECD's of -3, 0 and +3 microseconds.

3.1.2.10.1 Envelope to Cycle Difference at the Transmitter

This effective shift in time position of the envelope ahead or behind the standard sampling point (at the transmitter) is known as Envelope-to Cycle Difference (ECD).

An ECD = 0 is mathematically defined as the signal condition occurring when the 25 microsecond point of the eLoran pulse envelope is in time coincidence with the third negative going zero crossing of the 100 kHz RF carrier for a positive phase-coded signal. ECD is positive when the 25 microsecond point of the eLoran pulse envelope lags the reference zero crossing, and ECD is negative when the 25 microsecond point of the eLoran pulse envelope leads the reference zero crossing. The ECD magnitude is the amount of lag or lead, in microseconds.

3.1.2.10.2 Far-field Envelope to Cycle Difference

Conceptually, the leading envelope of a local radio frequency (RF) field will be fit to the same ideal eLoran envelope equation with a similar cost function as used in the transmitter antenna current algorithm. In the actual receiver, the RF signal is digitized after the signal has been processed by some known frequency response. The eLoran receiver must determine the far-field ECD for each signal and calibrate this measurement so that it matches the standard ECD measurement as seen Figure 3.4. Whatever algorithm is used at this point, the receiver's algorithm must give the same answer as would have been obtained if the local RF field had been available. (Note that the same should be true of SNR and ASF in addition to ECD).

Note: There are two methods for calibrating the algorithm:

1. Software simulation where pulses of various ECDs and phase modulation conditions are filtered by a model of the RF front end and the user receiver ECD algorithm calculation is compared to the model.

2. Hardware simulation where pulses of various ECDs and phase modulation conditions are generated and used as input to the receiver.

3.1.2.11 Time of Arrival

The time of arrival of the pulse group from a transmitting station is the time of occurrence of the electric field of the standard zero crossing of the 1st pulse, in a pulse group at the receiving antenna, with respect to the local receiver clock.

3.1.2.12 Nominal Antenna

The nominal antenna for a receiver shall be specified by the manufacturer. In carrying out the specific test procedures, the signal levels at the space coupling node shall be related to the field strength in proportion to the effective height of the nominal antenna.

3.1.2.13 Blink

An indication of out-of-tolerance (OOT) at a transmitting station will occur for one of the following reasons:

- Time of emission is out of tolerance
- ECD out of tolerance
- Improper phase code or GRI
- Master or secondary station operating at less than one half of specified output power

When an OOT situation exists, it is indicated by the OOT eLoran signal being turned off. If the signal is returned to a non-OOT condition before 10 seconds, then it returns on-air without any other indication. If it does not, it will stay off air for a minimum of 10 seconds and come back on air "blinking"[14]. Blink is a repetitive on-off pattern (approximately 0.25 second on, 3.75 seconds off) of the first two pulses of the secondary signal which indicates that the eLoran signal is unusable. Blink continues until the out-of-tolerance condition no longer exists.

3.1.2.14 Atmospheric Noise

In the low-frequency portion of the radio spectrum considerable atmospheric noise can be present. This noise is generated by the occurrence of lightning throughout the world. It has been well established that a background noise level representing

[14] Blinking is the method that is used to indicate that the Loran-C and eLoran signals are out-of-tolerance.

the sum of distant storms and bursts from more local storms can characterize such noise. The international standards body, International Telecommunication Union - Radiocommunication Spectrum (ITU-R), has produced an extensive, empirically-based set of predictions of both these components. Receivers may use receiver non-linear processing algorithms that can detect, and can mitigate, the effects of the noise bursts (e.g. lightning).

3.1.2.15 Crossrate Interference

Each eLoran transmitter uses the same RF spectrum as all the others and they transmit at times that periodically conflict with one another. This means normal receiver frequency filters will pass signals from neighboring GRIs whose time of arrival will cause them to occasionally overlap, and interfere with, signals from local stations. This is referred to as cross-rate interference (CRI) and it causes variations in signal measurements that affect alarm detection, cycle selection, and other calculations. Crossrate interference can be mitigated by processing techniques such as cancellation or blanking. Receivers may use different techniques to mitigate cross-rate interference.

3.1.2.16 Transmitter Blanking

An eLoran transmitter can operate in two chains with two GRIs (dual-rate). On regular intervals dual-rated stations may need to broadcast pulses on both rates at the same time. If this happens the eLoran transmitter gives priority to broadcast pulses of one of the rates and blanks the transmission of the pulses in the other rate. The eLoran service provider shall provide information on the blanking regime of each dual-rated transmitter (priority or alternate, partial blanking and guard times), so that the receiver may properly deal with blanked pulses.

3.1.2.17 Skywave

Skywaves (see Figure 3.5), in the context of eLoran, are reflections of the signal from the ionosphere. From the stand point of navigation, this signal is an interference source and cannot be used for precise navigation. The reflection can occur at different heights and strengths resulting in variations in the delay and received amplitude for a given location. For a given reflection height, the delay and strength relative to the groundwave is a function of the distance from the user to the transmission source.

Under nominal conditions, the nighttime ionospheric environment results in a skywave that is stronger than in the daytime. The nighttime ionosphere also tends to have a higher ionosphere reflection height for eLoran resulting in a greater delay relative to the groundwave than typical daytime skywave.

While always present, skywaves typically do not affect the eLoran position fix. Receivers shall be able to function under typical day time and night time occurrence of skywave.

"Early skywave" is skywave with delays of roughly 37 µsec or less relative to the ground wave. Early skywave can be problematic as it is close to the tracking point of the groundwave. Early skywaves generally occur during the day time and are induced by severe solar weather activity. Under conditions of adverse solar weather, the ionosphere can be disturbed enough to lower the ionospheric reflection height and strengthen the reflection for the eLoran signal. This can create problems for signals traveling over long paths. Since the disturbed ionosphere is caused by solar activity, the reflection region must be illuminated by the sun. The effect is particularly strong at high geomagnetic latitudes.

The difficulty with early skywave versus typical skywave is that it is more difficult for a receiver to disregard, mitigate or detect. For example, receivers on moving platforms may not be able to easily discern errors caused by early skywave from platform movement. Hence, the eLoran system requires some means to be aware of early skywave or its effects through monitoring.

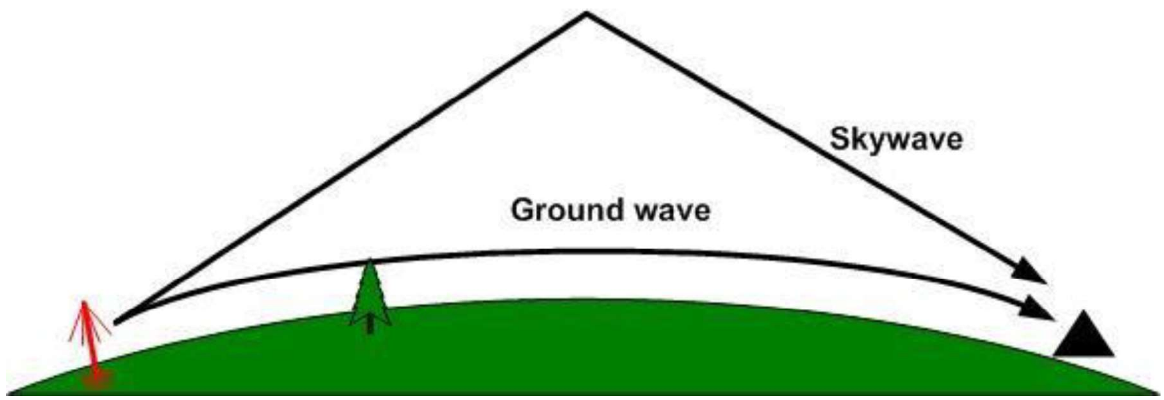

Figure 3.5 Skywave.

3.1.2.17.1 Skywave Processing (User Receiver)

The receiver has algorithms or processing that mitigates the presence of skywave error in the local service. It may exclude the use of signals with significant errors caused by skywave. Alternatively, a receiver may dynamically adjust the location of the tracking point in the eLoran pulse to balance high signal strength (by tracking later in the pulse envelope) with skywave rejection (by tracking earlier). This dynamic process shall not alter the TOA that is determined.

3.1.2.17.2 Skywave Warning (Service Provider)

A skywave warning may be provided by service providers to indicate the possibility of early skywave in a specified geographic region and transmitted signal. The details of this warning shall be as specified by the service provider. See LORIPP/LORAPP Draft Specification of the eLoran System, Rev. 4.0[15] for the

[15] This system has yet to be developed

eLoran System for further details. If provided, the warning shall be part of the transmitted LDC message, and provision has been made for the broadcast of an early skywave alarm in the DLoran data sentence structure.

3.1.2.18 Interference

Interference is a man-made source of radio frequency energy which has sufficient energy to adversely affect the performance of an eLoran receiver. Interference may be synchronous, near synchronous, or non-synchronous. Synchronous and near synchronous interfering signals of sufficient amplitude will cause increases in the mean error of the TOAs at the receiving set. Non-synchronous interfering signals will increase the standard deviation (jitter) of the receiver TOAs. Generally, eLoran receiving equipment is more sensitive to synchronous and near synchronous interfering signals because these signals are at carrier frequencies very near the "comb filter" frequency responses of the eLoran receiver (i.e. the eLoran spectral lines of stations in one chain). At these frequencies interference will cause problems when its level is so great compared to the desired eLoran signals that it causes the signal tracking in the receiver to operate improperly. The effects of high level signals, whether synchronous or non-synchronous, can usually be most easily reduced with notch filters.

- In-Band Interference - interference whose carrier frequency lies in the band 90-110 kHz.
- Near-Band Interference - interference whose carrier frequency lies in the frequency bands 70-90 kHz and 110-130 kHz.
- Out-of-Band Interference - interference whose carrier frequency lies in the frequency bands below 70 kHz or above 130 kHz.
- Synchronous Interference - near-band interference whose carrier frequency (fc) is determined by $f_c = N/2\,GRI$, where N = 1, 2, 3....
- Near-Synchronous Interference - near-band interference whose carrier frequency (fc) satisfies the relationship $|f_c - N/2GRI| < f_b$ where f_b is the tracking bandwidth of the receiver (related to response time)

3.1.2.18.1 Continuous Wave Interference

Continuous wave interference (CWI) is interference from man-made sources that are intentionally radiated in or near the eLoran band. It results in additional noise and interference on the eLoran signal. Throughout the world, in the bands 70 to 90 kHz and 110 to 130 kHz, there are broadcast stations which operate with keyed CW, modulated CW and FSK modulation schemes. Generally, no more than two interfering frequencies are transmitted from any one station at any one time. The radiated power may be as great as 100 kW. These interfering signals may adversely affect eLoran receiver performance simply due to their extremely high level.

3.1.2.18.2 Interference (Other)

Man-made interference can also result from inadvertent transmissions from human activities. Examples of such interference include power line carriers and emission from automobile engines and switch-mode power supplies.

3.1.2.19 Field Strength

RMS Field Strength value in volts per meter of the envelope at the standard zero crossing.

3.1.2.20 Signal to Noise Ratio

Signal to noise ratio (SNR) is the ratio of the root mean square (RMS) amplitude, of the envelope, of the eLoran pulse, at the standard zero crossing point, to the RMS value of the noise present at that time.

It is recognized that measuring signal and noise in the context of a receiver inherently requires some amount of processing. It is also recognized that this processing is not limited to, but may include, different forms of signal averaging and different amounts of filtering prior to a signal measurement or a noise measurement. It is also recognized that SNR measurements are heavily influenced by the design of the receive antenna, the analog front end, and a receiver's digital filters. This document attempts to standardize the definition of SNR in an attempt to reduce the variability of reported SNR values, between various receivers.

With regard to an SNR measurement, signal level shall be normalized to a level equal to that of a single eLoran pulse.

With regard to an SNR measurement, noise level shall be measured at a point where there are no tracked eLoran stations, and any averaging that has been performed, must be accurately compensated for.

The noise measurement shall be taken after interference mitigation including, but not limited to CWI, impulse noise, crossrate mitigation, and notch filtering.

With regard to receiver filtering distorting the shape of the eLoran pulse envelope, SNR shall be reported in a manner after the description of ECD in section 3.1.2.10.1. That is, whatever filtering or processing is performed by the receiver, the SNR shall be equivalent to that of the local RF field at the sky-connection node, if such an observation were available. Calibration of SNR-reporting algorithms can be performed in the same way as for ECD.

3.1.3 Abbreviations

Several abbreviations, like the definitions, are taken directly from the nominative references for ease in understanding this MPS and to avoid confusion.

- ASF: Additional phase Secondary factor

- CWI: Continuous Wave Interference
- ECD: Envelope to Cycle Difference
- eLoran: Enhanced Loran
- EUT: Equipment under test
- TD: Time Difference
- TOA: Time of Arrival
- COG: Course over Ground
- GPS: Global Positioning System
- GNSS: Global Navigation Satellite System
- GRI: Group Repetition Interval
- HAL: Horizontal Alert Limit
- HEA: Harbor Entrance and Approach
- HDOP: Horizontal Dilution Of Precision
- HMI: Hazardously Misleading Information
- HPL: Horizontal Protection Level
- HSC: High Speed Craft
- PCI: Phase Code Interval
- PDOP: Position Dilution Of Precision
- PF: Primary phase Factor
- RAIM: Receiver Autonomous Integrity Monitor
- RMS: Root Mean Square
- SDME: Speed and Distance Measuring Equipment
- SF: Secondary phase Factor
- SNR: Signal to Noise Ratio
- SOG: Speed Over Ground
- SGR: Skywave to Groundwave Ratio
- SIR: Signal to Interference Ratio
- TTFF: Time To First Fix
- USNO: United States Naval Observatory
- UTC: Universal Time Coordinated
- 2drms: Twice distance root mean square