



SYSTEMS MANAGEMENT STANDARD

SAE9990™/2

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Transmitted Enhanced Loran (eLoran) Signal Standard for 9th Pulse Modulation

RATIONALE

A data channel is a fundamental part of eLoran. This document provides technical descriptions of the ninth pulse modulation data channel waveform, specifications, and explanations.

FOREWORD

Long-Range Navigation (LORAN) is an internationally-recognized Positioning, Navigation, and Timing (PNT) system used by many modes of transport and in other applications. eLoran is the latest in the longstanding series of low-frequency (LF) systems that takes full advantage of state-of-the-art hardware and software technologies that provide a data channel and time of transmission capability not implemented in legacy LORAN systems.

1. SCOPE

This eLoran transmitted signal standard provides technical descriptions of the data channel using ninth pulse modulation techniques. The eLoran transmitted signal standard, to which this data channel technique applies, is part of the SAE9990 family of standards covering data channels, receiver specifications, and recommended practices for eLoran.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 References

Loran Data Channel Communications using 9th Pulse Modulation, Version 1.3 (MOD 1), Dr. Benjamin Peterson, Ken Dykstra, LT. Dave Lown, LT. Kevin Shmihluk.

2.2 Acronyms

ASF	Additional Secondary Factor
ED	Emission Delay
eLoran	Enhanced Loran
FEC	Forward Error Correcting

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GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRI	Group Repetition Interval
LAT	Latitude
LF	Low Frequency
LON	Longitude
LORAN	Long-Range Navigation
PCI	Phase-Code Interval
PNT	Positioning, Navigation, and Timing
RS	Reed-Solomon
TDMA	Time Division Multiple Access
TOT	Time of Transmission
UTC	Coordinated Universal Time

3. ELORAN SIGNALS

SAE9990 provides technical descriptions of the waveform, specifications of the transmitted Enhanced Loran (eLoran) signal. The information contained in this document is only addressing the ninth pulse data channel technique but a brief understanding of how multiple eLoran transmitting stations are sequenced is provided here for completeness and clarity.

All eLoran transmitters broadcast the same signal shape modulated onto the same carrier frequency of 100 kilohertz (kHz). To prevent the signals of neighboring transmitters known as a group from overlapping, eLoran shall use a Time Division Multiple Access (TDMA) scheme as shown in Figure 1. This scheme allocates a time slot for each transmitter to broadcast. The time slot shall repeat with a fixed repetition interval known as the Group Repetition Interval (GRI). The TDMA scheme guarantees that the signals from transmitter stations sharing a common GRI do not overlap anywhere in the coverage area.

The Emission Delay (ED) of a transmitter is the difference between the start of transmitter n 's time slot and the start of the first transmitter's time slot as shown in Figure 1. The time slot shall be long enough to transmit all eLoran timing and data channel pulses. Time slot length, ED, as well as the selection of the GRI, are subject to the number of timing and data channel pulses for each transmitter. The transmitter locations, and the baseline length between them are determined during the eLoran system configuration, which is outside the scope of this standard.

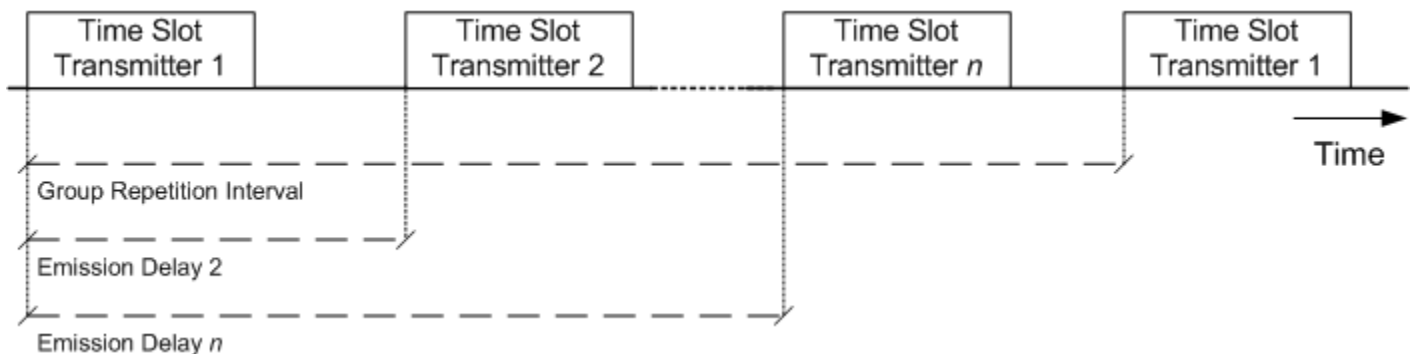


Figure 1 - GRI and ED of an eLoran system

An eLoran group shall have at least eight pulses and may have more pulses depending on how the data channel is implemented. All pulses in a group shall be transmitted sequentially with a fixed start time for each of the pulses and a variable start time for each of the data channel pulses — depending on the data content they carry.

4. DATA CHANNEL STRUCTURE

4.1. Ninth-Pulse Modulation

The ninth-pulse modulation scheme was chosen for its negligible impact on the transmitted eLoran signals that provide PNT functionality. In this data modulation scheme, an additional pulse is inserted in time following the eighth pulse of the LORAN pulse group. Thirty-two state pulse-position modulation is used to change the time delay of this pulse from the zero-symbol offset. In this manner, the data transfer rate is five bits per GRI. The phase code of the 9th pulse is the same as the phase code of the last navigation pulse.

The zero-symbol offset is 1000 microseconds after the eighth navigation pulse. The remaining 31 symbols are positioned in time a specific number of microseconds later in relationship to the zero symbol. The ideal delays are given by the formula:

$$d_i = 1.25 \bmod(i, 8) + 50.625 \text{ floor}(i/8) \quad (\text{Eq. 1})$$

As depicted in Table 1, the delays are the ideal values shifted to coincide with the ticks of a 5MHz clock. Table 1 lists the symbol i and corresponding time delay d_i with respect to the zero symbol. The 5 MHz clock rate reflected in Table 1 need not be viewed as a limiting implementation technique.

Table 1 - Symbol delays from zero-symbol offset (μs)

$i = [0, 7]$		$i = [8, 15]$		$i = [16, 23]$		$i = [24, 31]$	
0	0.0	8	50.6	16	101.2	24	151.8
1	1.2	9	51.8	17	102.6	25	153.2
2	2.6	10	53.2	18	103.8	26	154.4
3	3.8	11	54.4	19	105.0	27	155.6
4	5.0	12	55.6	20	106.2	28	156.8
5	6.2	13	56.8	21	107.6	29	158.2
6	7.6	14	58.2	22	108.8	30	159.4
7	8.8	15	59.4	23	110.0	31	160.6

4.1.1 Messages

All messages are 120 bits in length and consist of three components: a 4-bit type, a 41-bit payload, and a 75-bit parity component, as shown in Table 2. The messages are transmitted 5 bits/GRI. The time length of the messages is 24 GRI (maximum of approximately 2.4 seconds).

Table 2 - eLoran data channel message components

Section	Type	Payload	Parity
Length (bits)	4	41	75
Bit Assignment	0...3	4...44	45...119

4.1.2 Type Component

Table 3 shows the most recent list of proposed message types. All message types may not currently be in use.

Table 3 - eLoran data channel message types

Number	Type code	Description
0	0000	Reference Site Phase Correction
1	0001	Almanac (further divided into sub-messages)
2	0010	Message for government use-only
3	0011	Message for government use only
4 - 14	0100 thru 1110	Undefined
15	1111	Station Identification and Time-of-Day

4.1.3 Payload Component

NOTE 1: For bit-level details on the message payloads, see the message payload tables later in this document.

NOTE 2: The differential phase correction bit assignment has changed in this document.

4.1.3.1 Type 0: Differential Phase Correction

This message contains the Additional Secondary Factor (ASF) Phase correction data from Differential Reference Sites. The purpose of this message is to mitigate the temporal component of the ASF. The correction is given relative to a published nominal value. It is expressed as a 2s complement number (2ns resolution). The total correction used for navigation is the sum of the transmitted correction and offsets determined by calibration. The format of this message has been changed.

4.1.3.2 Type 1: Almanac

This message contains system-wide almanac data to enable automatic updating in receiver systems. It is used to pass updated system information to the end user. This message is divided into sub-types according to the information content.

- **Sub-type 0:** Reference Station List: This message is used to communicate which reference station corrections are being sent from a specific eLoran transmitting station, and to indicate the status of the eLoran data channel broadcast from other eLoran stations.
- **Sub-type 1:** Reference Station Latitude: This message contains the latitude of a reference station whose corrections are being sent from this transmitter. A useful formula is the conversion from a 26-bit binary to decimal latitude:

$$LAT_{decimal} = LAT_{binary} \cdot 180^\circ / (2^{26}) = (2.682209015 \times 10^{-6}) LAT_{binary} \quad (\text{Eq. 2})$$

where LAT_{binary} is the latitude expressed in a 26-bit binary, 2's complement integer.

- **Sub-type 2:** Reference Station Longitude: This message contains the longitude of a reference station whose corrections are being sent from this transmitter. A useful formula is the conversion from a 26-bit binary to decimal longitude:

$$LON_{decimal} = LON_{binary} \times 360^\circ / (2^{26}) = (5.364418030 \times 10^{-6}) LON_{binary} \quad (\text{Eq. 3})$$

where LON_{binary} is the longitude expressed in a 26-bit binary, 2's complement integer.

- **Sub-types 3 through 6:** Reference Station Correction List: These messages contain the signal ID codes for the corrections from a particular reference station. Sub-type 3 contains the codes for signals 1 through 3, sub-type 4 contains the codes for signals 4 through 6, etc.
- **Sub-types 7 through 10:** Reference Station Nominal Value List: These messages contain the nominal ASF values that a particular differential reference site associates with the corrections it calculates. Sub-type 7 contains the nominal values for signals 1 through 3, sub-type 8 contains the nominal values for signals 4 through 6, etc.