



SYSTEMS MANAGEMENT STANDARD

SAE9990™/1

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Transmitted Enhanced Loran (eLoran) Signal Standard for Tri-State Pulse Position Modulation

RATIONALE

A fundamental component of eLoran is a data channel. This document defines the tri-state pulse position modulation 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 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 a data channel based on the tri-state pulse position modulation technique. 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 International Telecommunication Union (ITU)

Available from ITU Publications, sales@itu.int, tel: 41-22-730-6141 <https://www.itu.int/en/publications/Pages/default.aspx>.

2.1.1.1 ITU Radio Regulations Articles

ITU-R M.589-3 Technical Characteristics of Methods of Data Transmission and Interference Protection for Radionavigation Services in the Frequency Bands Between 70 and 130 kHz

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2.2 Acronyms

3s-PPM	Tri-State Pulse Position Modulation
CRC	Cyclic Redundancy Check
ED	Emission Delay
eLoran	Enhanced Loran
FEC	Forward Error Correction
GLONASS	Global Orbiting Navigation Satellite System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRI	Group Repetition Interval
IOD	Issue of Data
ITU	International Telecommunication Union
LDC	Loran Data Channel
PCI	Phase-Code Interval
PNT	Positioning, Navigation, and Timing
PRC	Pseudo-Range Correction
PRN	Pseudo-Random Noise
RRC	Range-Rate Correction
TDMA	Time Division Multiple Access
TOD	T _b of Navigation Data
UDRE	User Differential Range Error
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 tri-state pulse position modulation 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.

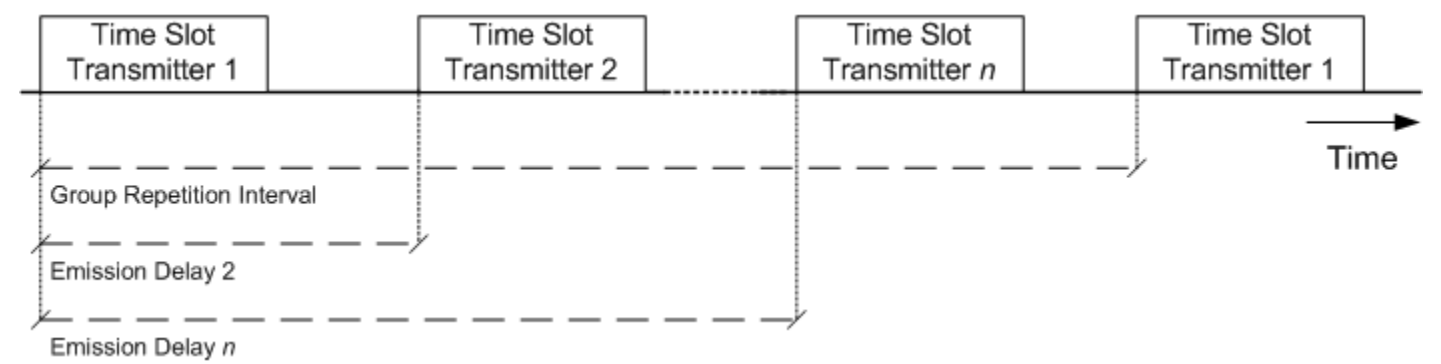


Figure 1 - GRI and ED of an eLoran system

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

The structure given in Table 1 is used for the tri-state pulse position modulation (3s-PPM) data service using eLoran transmissions in the frequency band 90 to 110 kHz.

Table 1 - Structure for signal specification

1	Physical layer	eLoran signal specification	SAE9990/1
2	Modulation/demodulation layer	Description of the 3s-PPM	Section 4.1
3	Forward error correction (FEC) layer	Description of the FEC algorithm	Section 4.2
4	Message coding layer	Description of the message coding algorithm	Section 4.3

4.1 Modulation/Demodulation Layer

These definitions give the modulation of the eLoran signal to enable data transmissions. The definitions include the low level modulation type, the modulation strategy to minimize devaluation of eLoran use for positioning, and the relation between modulation patterns and other data representations.

4.1.1 Pulse Modulation

4.1.1.1 Timing

A 3s-PPM shall be applied to pulses three to eight of each pulse group. The modulation shall consist of a time-shift of 1 μs of the pulse transmission, with respect to an unmodulated pulse. The three possible states of the modulation are given in Table 2.

Table 2 - States of the modulation

Pulse state	Transmission time minus time of reference pulse (μs)	Indication
Advanced pulse	-1	-
Prompt pulse	0	0
Delayed pulse	+1	+

4.1.1.2 Modulation Balance

The number of advanced and delayed pulses of one channel in one pulse group shall be equal. The modulation of six pulses in one pulse group results in 141 possible balanced patterns (see Table 3), of which 128 patterns shall represent valid data, one pattern shall indicate no data transmission and 12 patterns shall be not used.

Table 3 - Modulation pattern combination

Modulation pattern combination			Example	Number of combinations
6 x zero (0)	0 x plus (+)	0 x minus (-)	0 0 0 0 0 0	1
4 x zero	1 x plus	1 x minus	00 + 0 - 0	30
2 x zero	2 x plus	2 x minus	0 + - + 0 -	90
0 x zero	3 x plus	3 x minus	+ + - - - +	20
Total =				141

4.1.1.3 Timing Accuracy

The timing accuracy of the modulated signal shall conform to the same timing accuracy requirements as for the unmodulated signal.

4.1.1.4 Modulation Patterns

4.1.1.4.1 Pattern/Data Translation

Each of the 128 valid modulation patterns shall uniquely represent a 7-bit binary block of data, as shown in Table 4.

4.1.1.4.2 No Data Transmission Pattern

The pattern "000000" shall be used to indicate that no data is being transmitted.

4.1.1.4.3 Message Structure

One 3s-PPM message shall consist of 30 consecutive pulse groups.

4.1.1.4.4 Blanking

A blanked pulse group shall be considered to have been transmitted for modulation purposes.

4.2 FEC Layer

4.2.1 A systematic Reed-Solomon (RS) (30,10) 2^7 -ary code shall be applied to all messages. All messages shall consist of 30 symbols, each symbol representing a 7-bit element. Of these symbols, 10 shall be data and 20 shall be RS parity.

4.2.2 Primitive Polynomial

The symbols shall be elements of the Galois field GF(128), constructed using the primitive polynomial:

$$p(x) = x^7 + x^3 + 1$$

(Eq. 1)