eLoran 101

Introduction to System and Signal

Presented By

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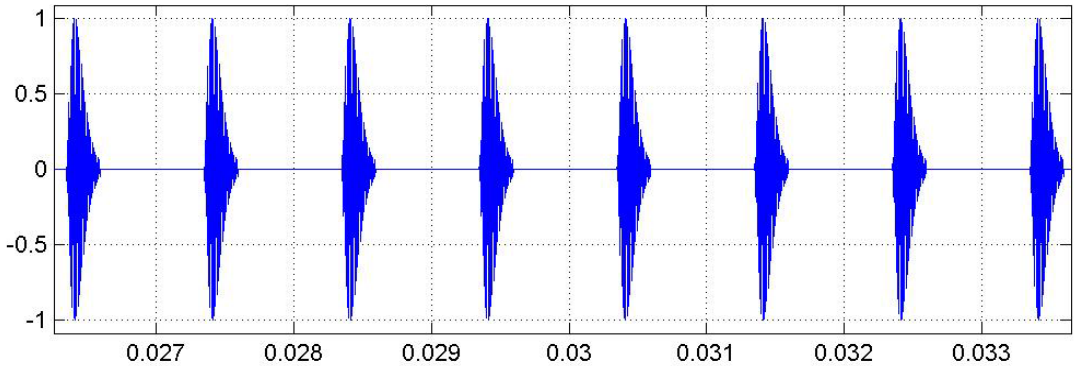
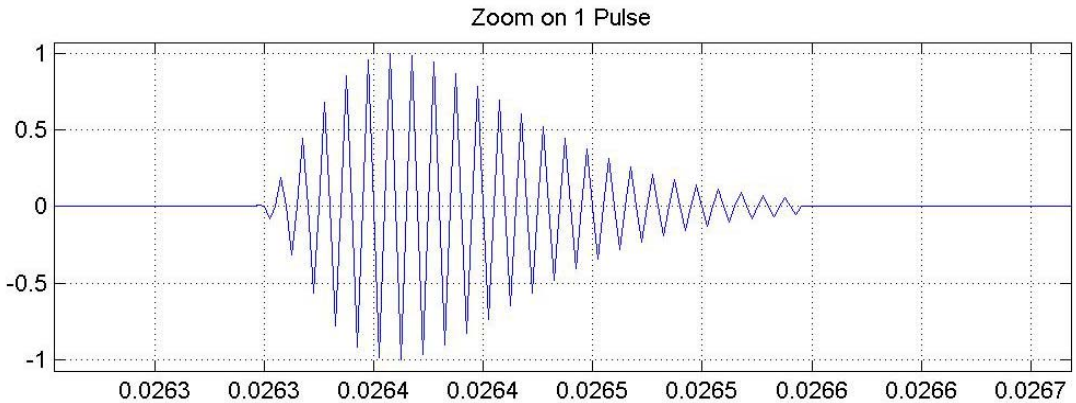
Outline

- Loran-C Signal and Definitions
- The Legacy USer Community
- Rationale for eLoran
- eLoran System and Signal
- Status of Major Loran Systems

Loran-C Signal Structure

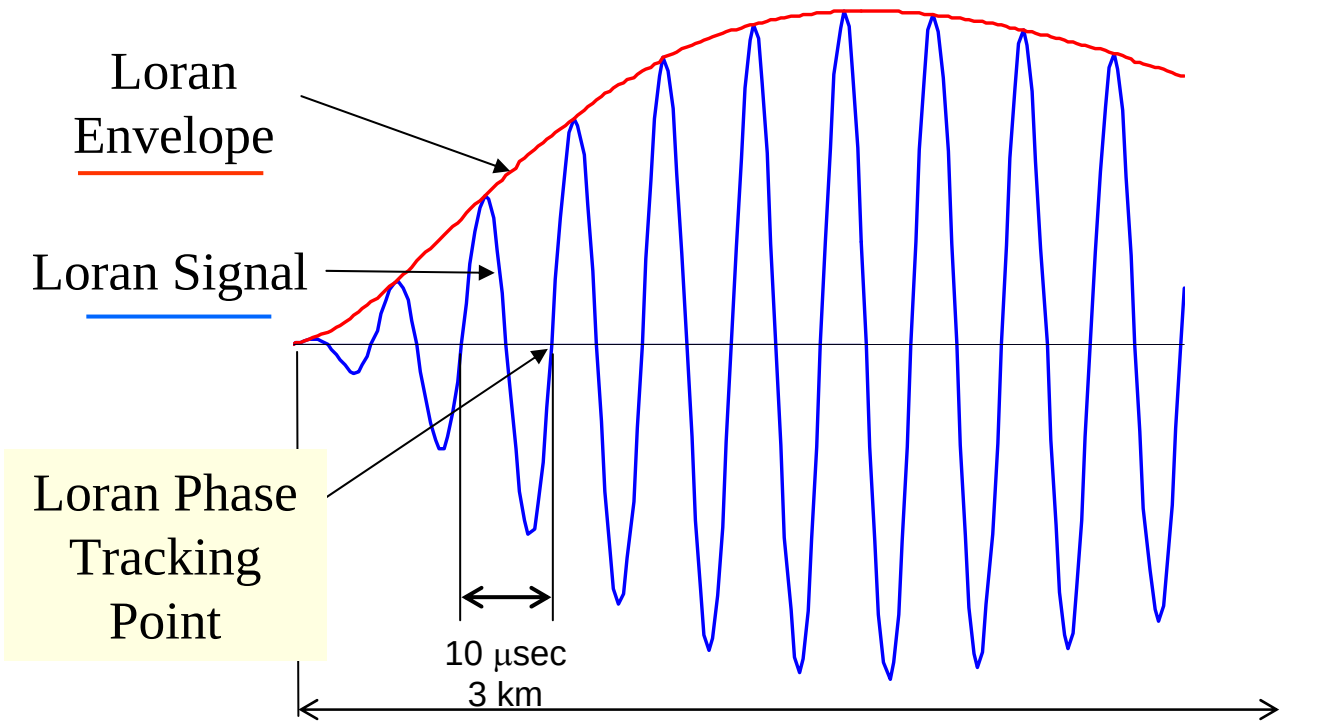
Standard Group of Eight Pulses with 1msec Spacing





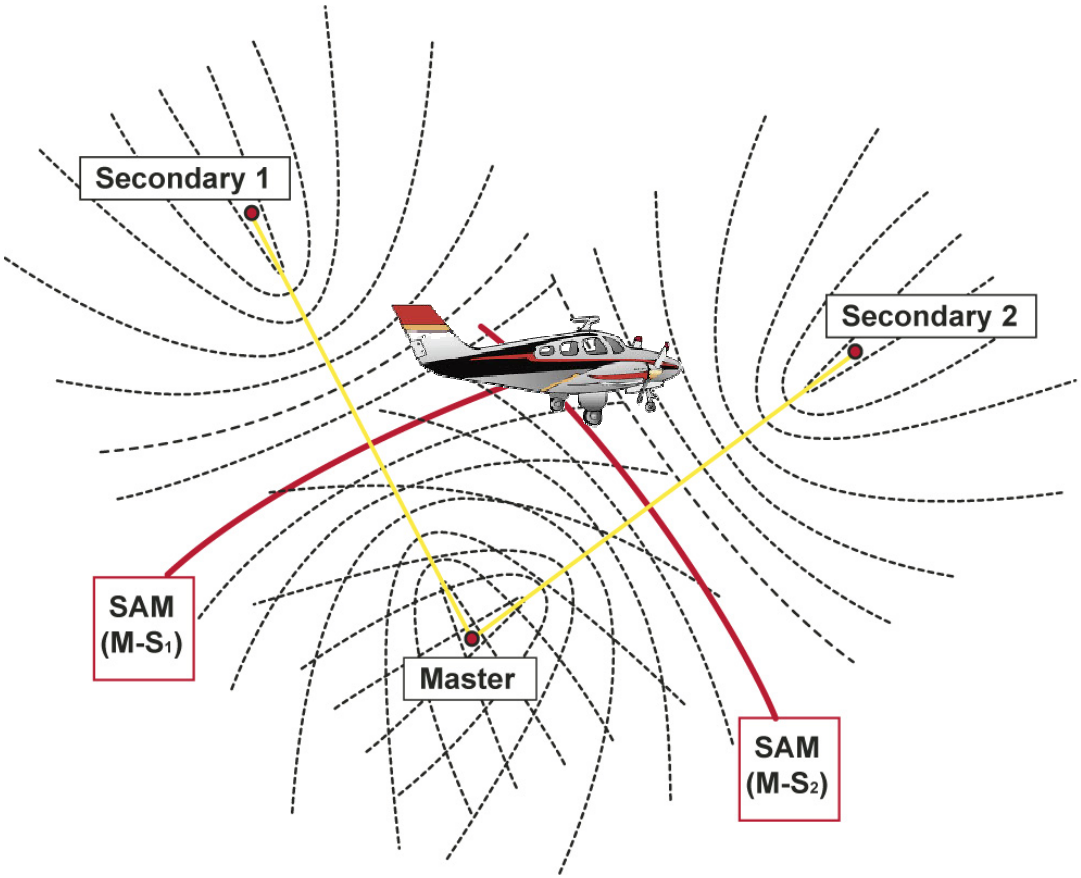
Loran is a LF (100kHz) pulsed phased radionavigation system

Loran-C Signal Structure (cont.)



~65μsec Rise Time, Graceful Degradation of Trail

Loran-C System Concept



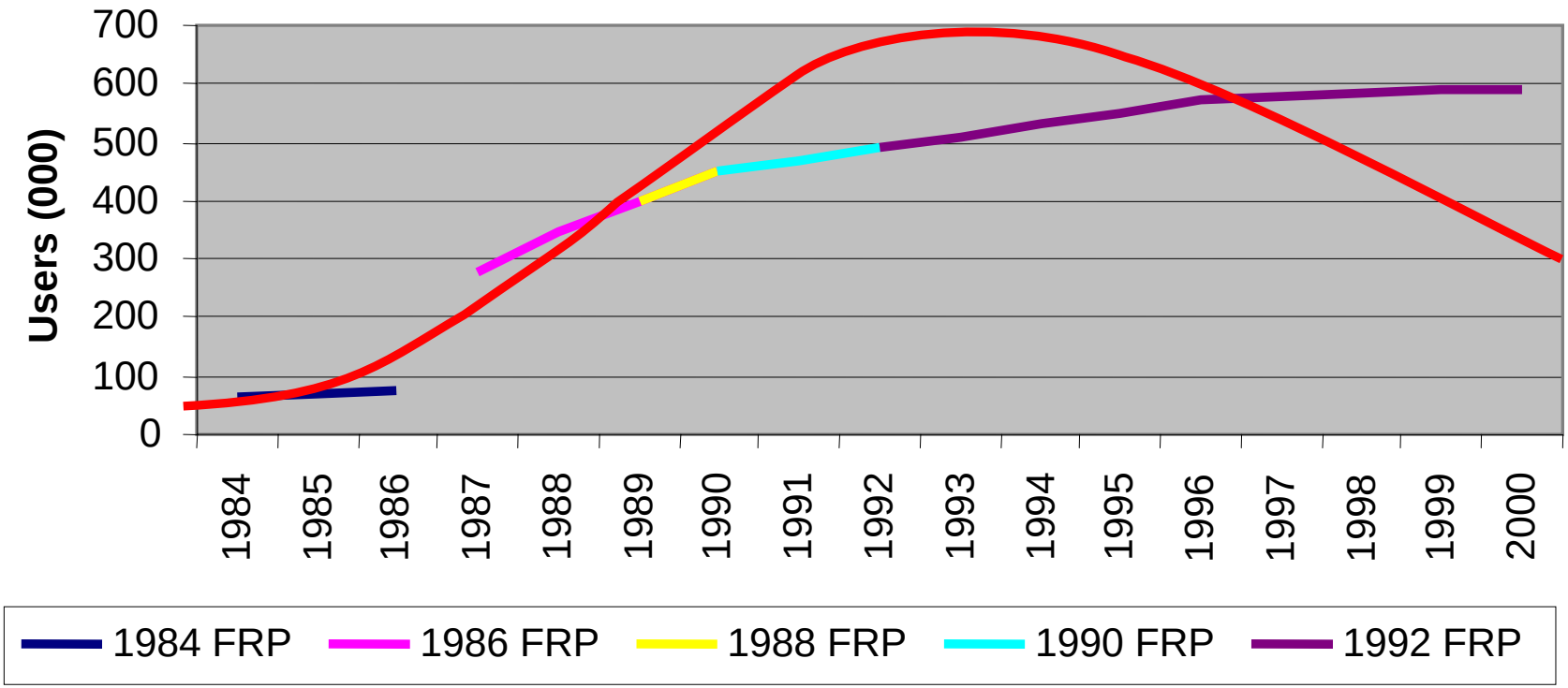
Legacy Signal in Space Characteristics

- Accuracy
  - Predictable — .25nm (460m)
  - Repeatable — 60-300 ft (18-90m)
- Availability — 99.7%
- Coverage — Regional, Wide Area
- Dimension — 2D + Time
- System Capacity — Unlimited
- System Type — Area Navigation

Legacy User Community

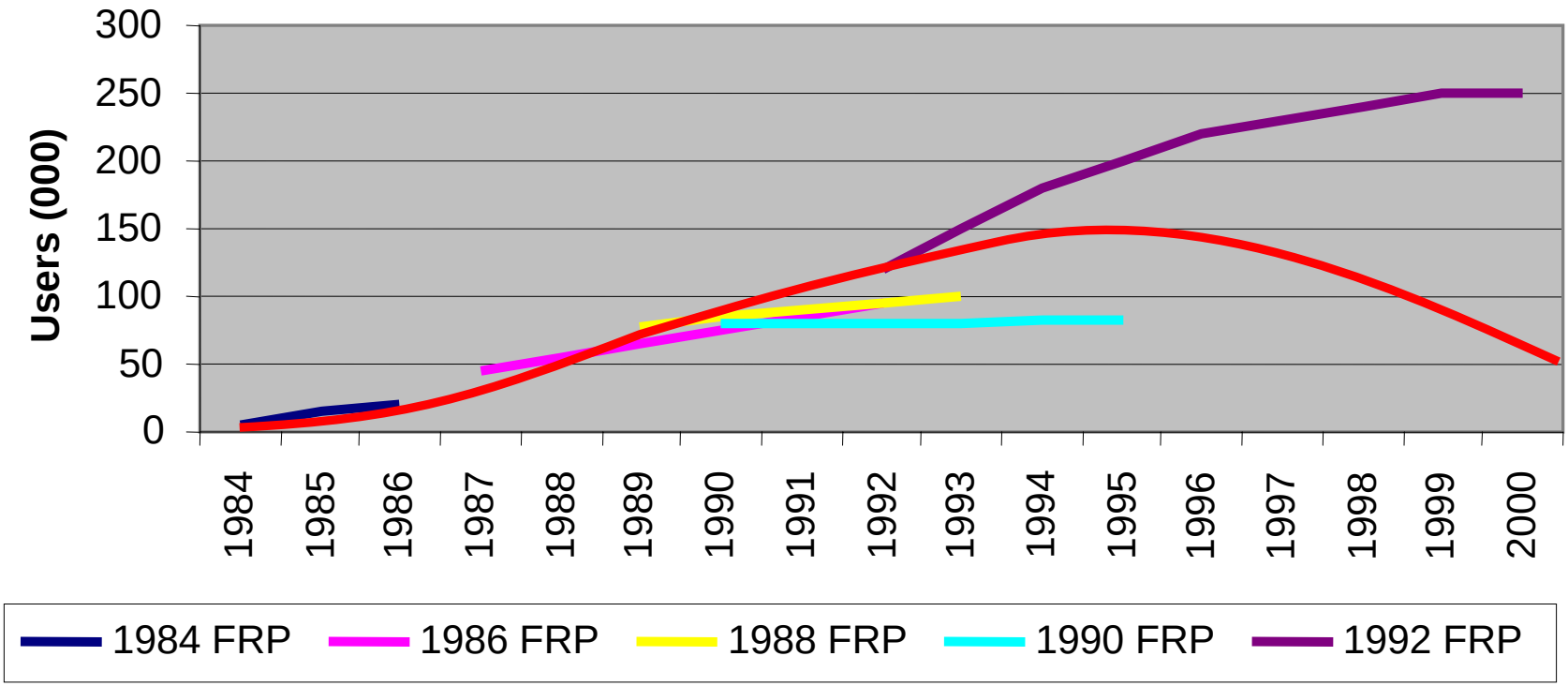
- No Mandatory Carriage Requirement
- Approved Aviation Navaid for US En-Route Environment
- The Last Commercial Legacy Marine Receiver was the Furuno LC90 and is no Longer Available

US FRP Projections of Maritime Users



FRP = Federal Radionavigation Plan

US FRP Projections of Aviation Users



FRP = Federal Radionavigation Plan

Early Aviation Certification Efforts

- The First FAA Approved IFR Non Precision Approach was Flown in November 1985
- Receiver Manufacturers Began to Look to Certification
- Effort Failed Technically due to Significant Concerns on Availability/Continuity
  - Triads
  - Momentaries
  - Atmospheric Noise
- Efforts Effectively Ended as FAA Promoted Transition to Satellite Navigation (Sole Means) as Cornerstone of Future Air Traffic Management System

Rationale for eLoran

"GPS provides many benefits to civilian users. It is subject, however, to interference and other disruptions that can have harmful consequences. Adequate independent backup systems or procedures should be used for critical applications."

Source: Volpe Presentation to RIN, November 2002

GPS Vulnerability Mitigation

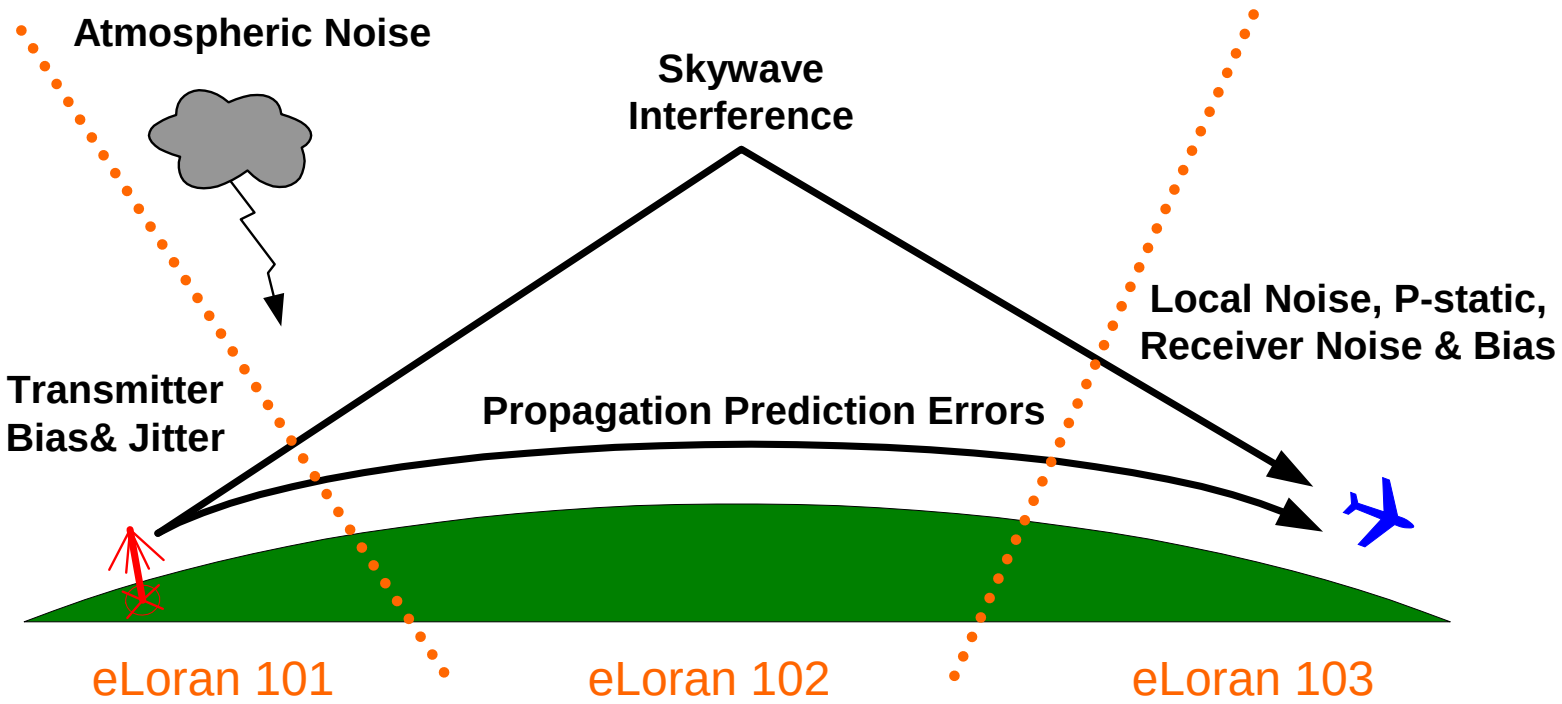
Redundant, Back-up or Contingency Systems

- Redundant: Seamless Transition in Process and Procedures-No Change in Operations Tempo
- Back-up: Some Change in Process and Procedures Due to Difference Performance Capabilities of Systems-Ops Tempo Reduced
- Contingency: Cease/Complete Operation in a Safe Manner-Ops Severely Reduced

Definitions for the Performance Capabilities

- Accuracy: The Degree of Conformance Between the Estimated, Measured, or Desired Position, Velocity and/or Time and the True Position, Velocity-Time.
- Integrity: The Ability to Provide Timely Warning to users when the System Should not be used
- Availability: The ability of the System to Provide Usable Service within a Specified Coverage
- Continuity: The Capability of the Total System to be available for the Duration of a Phase of Operation, Presuming that the System was Available at the Beginning of that Phase of Operation.

Integrity Hazards (From Sherman Lo)



Legacy vs E Loran Characteristics

	Accuracy	Availability	Integrity	Continuity
Current Definition of Capability (US FRP)*	**0.25 nm (463 m)**	**0.997**	**10 second alarm/ 25m error**	**0.997**
FAA NPA (RNP 0.3) Requirements**	**0.16 nm (307 m)**	**0.999 – 0.9999**	**0.9999999 (1×10^{-7})**	**0.999 - 0.9999 over 150 sec**
US Coast Guard HEA Requirements	**0.004 - 0.01 nm (8 – 20 m)**	**0.997 - 0.999**	**10 sec alarm 25m error (3×10^{-5})**	**0.9985 – 0.9997 over 3 hours**

*** Includes Stratum 1 timing and Frequency Capability**

****Non-Precision Approach Required Navigation Performance**

System & Signal Demands: Continuity

- Major Factor for Loran in Timing Application
- Switch to TOT Control
- UPS System
- Fast Coupler Switch

System & Signal Demands: Integrity

- The Major Factor for Loran in Aviation Applications
- Extensive Signal Monitoring on Site-
  - ABS - Automatic Blink System
  - RAIL - Remote Automated Integrated Loran
- Data Channel
- Blank not Blink
- Tighter Automatic Blink Parameters

System & Signal Demands: Availability

- Solid State Transmitters
- UPS System
- Improved Lightning Protection
- Switch to TOT Control
- Coordinated Maintenance Periods
- Time Transfer via Loran to Augment GPS Synchronization

System & Signal Demands: Accuracy

- Major Factor for Loran in Precision Maritime Application
- Improved Timing and Frequency Equipment Capability
- Improved Transmitted Pulse Characteristics
- Means of ASF Compensation Including Differential
- Elimination of LPAs
- SAM Conversion to Propagation + Common View Loran Timing Monitors

eLoran System of the Future

Timing and Frequency Equipment (TFE)

- System utilizes three cesiums (all HP5071) to compute a local timescale that is steered to UTC(USNO) via GPS (<15ns)
- Kalman filter models clocks and predicts clock performance when measurement data isn't available
- Three clock timescale provides real-time clock fault monitoring as well as superior stability.
- Automatic Blink System (ABS) monitors the transmitted signal for out-of-tolerance conditions through RF feedback and is critical for LORAN's HMI performance for integrity protection
- Blink is initiated in hardware based on programmable rule set
  - - Phase of transmitted signal vs local TOC estimate
  - - Phase error in transmitted pulses
  - - Lack of RF return from transmitter
  - - Time step in cesium standard

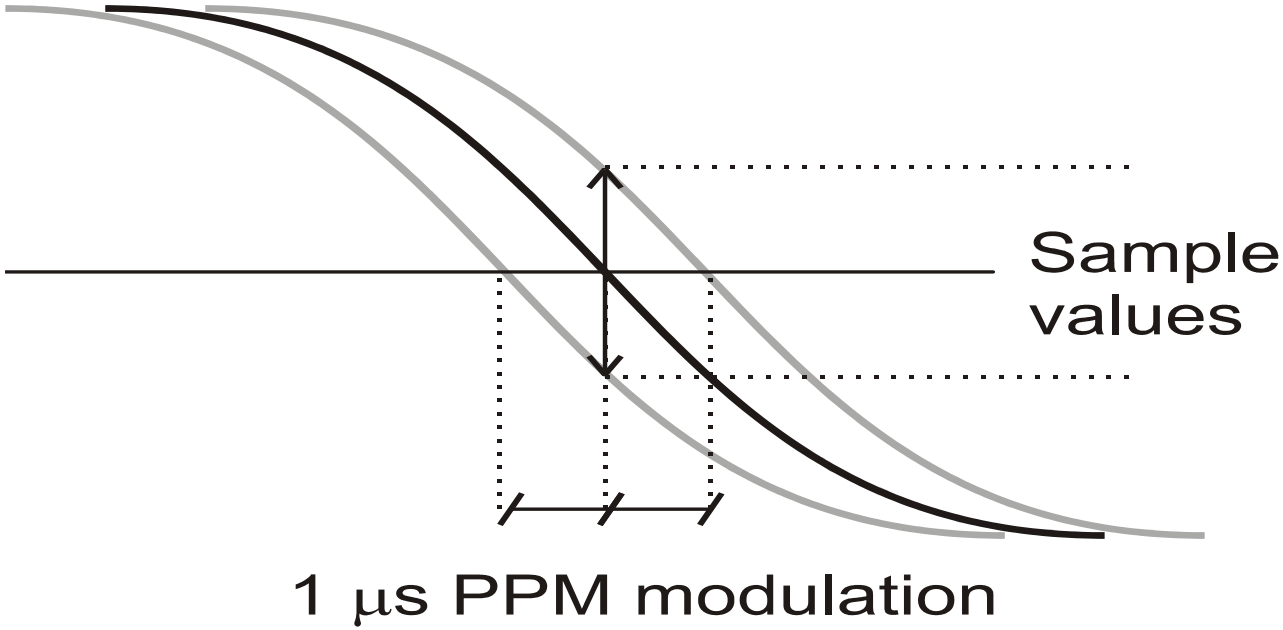
Transmitter and Coupler

- Redesigned Transmitter Control System
  - Reduce Phase Jitter by Control of Individual Pulses Versus Group Control
  - Robust Envelope Control from Dynamically Reassigning Power Units During Outage Due to Failure of Maintenance.
- Fast Coupler Switch Allows for Sub 3 Second Switchover
- Built in Signal Analyzer Used in Redundancy and Failure Analysis Decisions

Data Channel

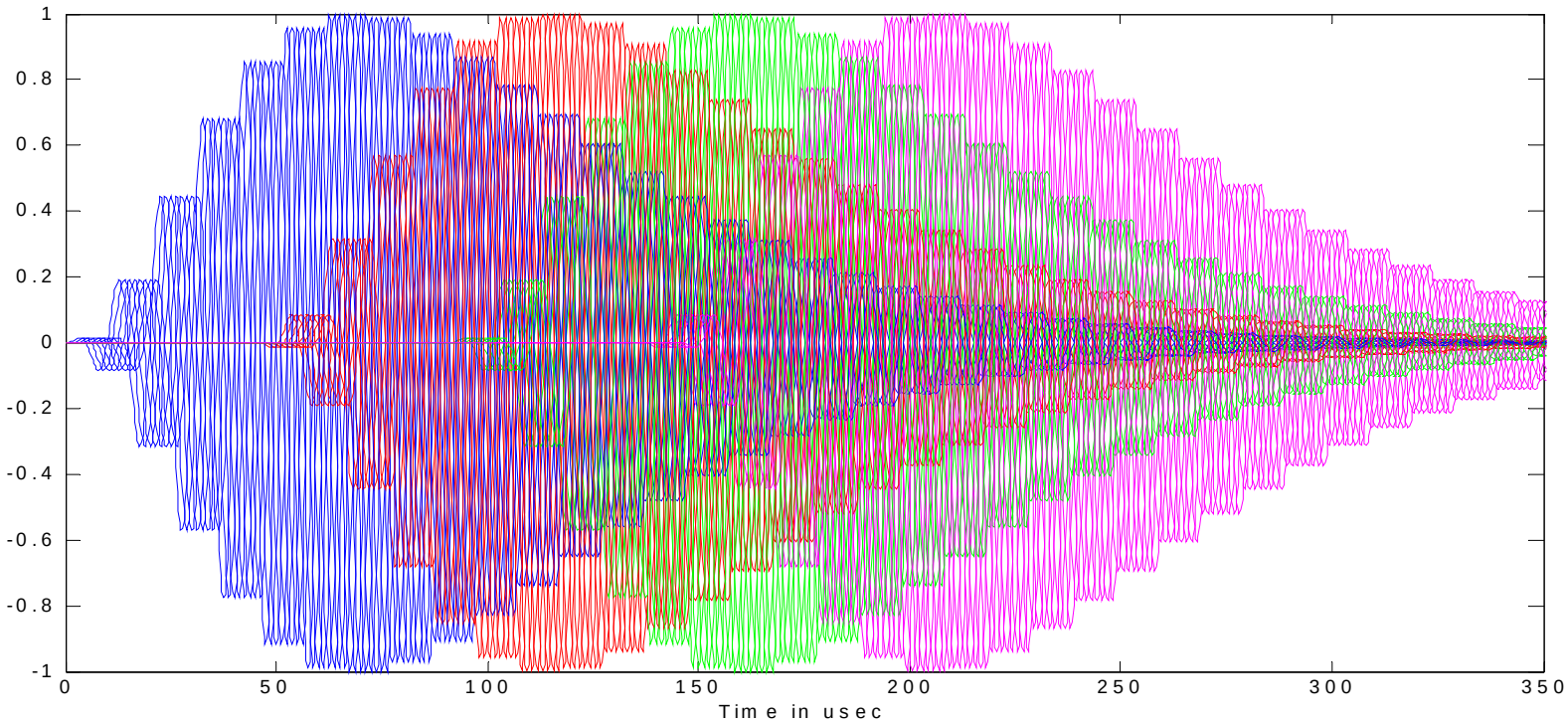
- Data Channel is an Important Component of eLoran. Two of Three Investigated Techniques will Likely be Used in the Future
  - Eurofix (Tristate Pulse Position Modulation)
  - Ninth Pulse (32 State Pulse Position Modulation)
- Data Channel and Cost Data Message Types Include
  - Differential GNSS
  - Differential Loran
  - UTC Information
  - Unique Station ID, Info.
  - Integrity
  - Short Message Service (SMS)
- The Two Data Channel Methods are Compatible.

Data Channel – Eurofix



Data channel by 3-level 1 us pulse position modulation
(1 us advance, prompt or 1 us delay)
Last 6 of 8 pulses modulated (balanced each GRI) results in 7-bit symbols

Data Channel – 5th Pulse



9th pulse Pulse Position Modulation (PPM)
32 state PPM, 5 bits/GRI (3 bits phase, 2 bits envelope & phase)

eLoran Status of Major Loran-C Systems

	N. America	FERNS	Europe
Time of Transmission	Planned Migration	No	Yes
UPS & Fast Coupler Switch	Yes	No UPS Sw in Japan/Korea	Switch- not France UPS Sylt
UTC Synch	In Process w/ new TFE	Capability at Niijima	No
Cs Steering	In Process w/ new TFE	Capability at Niijima	No
SSX SSX TCS	In Process – TCS w/ NSSX	Russia TTX Niijima TCS	No TCS
ABS	In Process w/ new TFE	No	No
Data Channel	Transmit Yes No RSIM	Trial in Korea/Rus No RSIM	Eurofix at 4 stations

Questions?