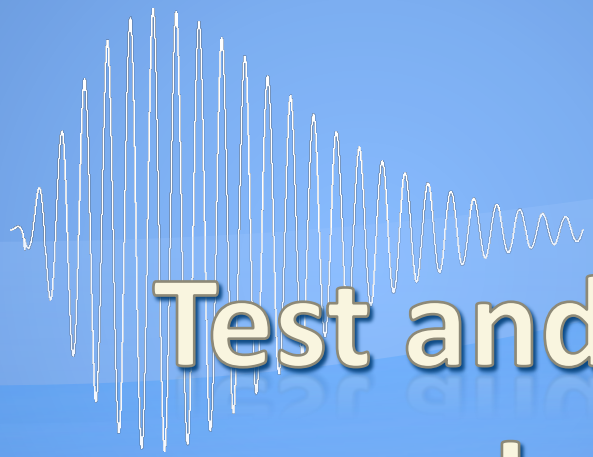

Test and Evaluation of a New eLoran Transmitter

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Introductory Thoughts

- eLoran will be implemented
- Need to cost effectively upgrade older transmitters
  - Lower purchase cost
  - Lower operation and maintenance costs
  - Must meet all eLoran signal requirements
- Alternative technology solutions should be investigated
- Historical Loran transmitters
  - Based upon so called half-cycle generators
  - Design approach has remained essentially the same
    - tube amplifiers (c1950) -> solid-state transmitters (1970s) -> new solid state transmitters (c2000)
- Recently, advances in AM broadcast technology appear to allow alternative system designs for high power transmitters
- Nautel proof-of-concept Loran transmitter
  - Derived from traditional EER AM band transmitters
  - Alion, in support of USCGA, conducted evaluation at CG LSU, Wildwood, NJ

LSU, Wildwood NJ

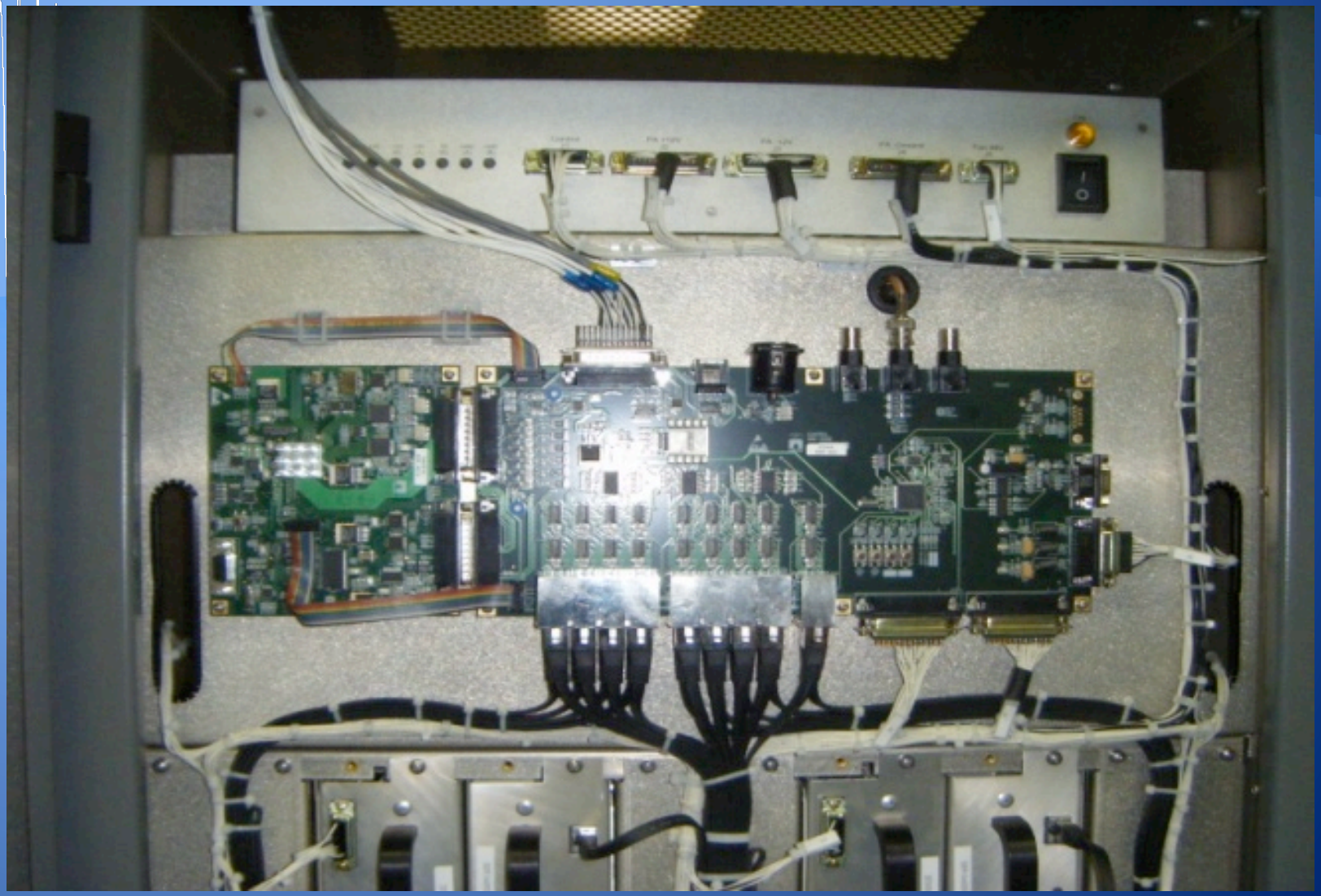
LSU Transmitter Deck

Nautel Transmitter

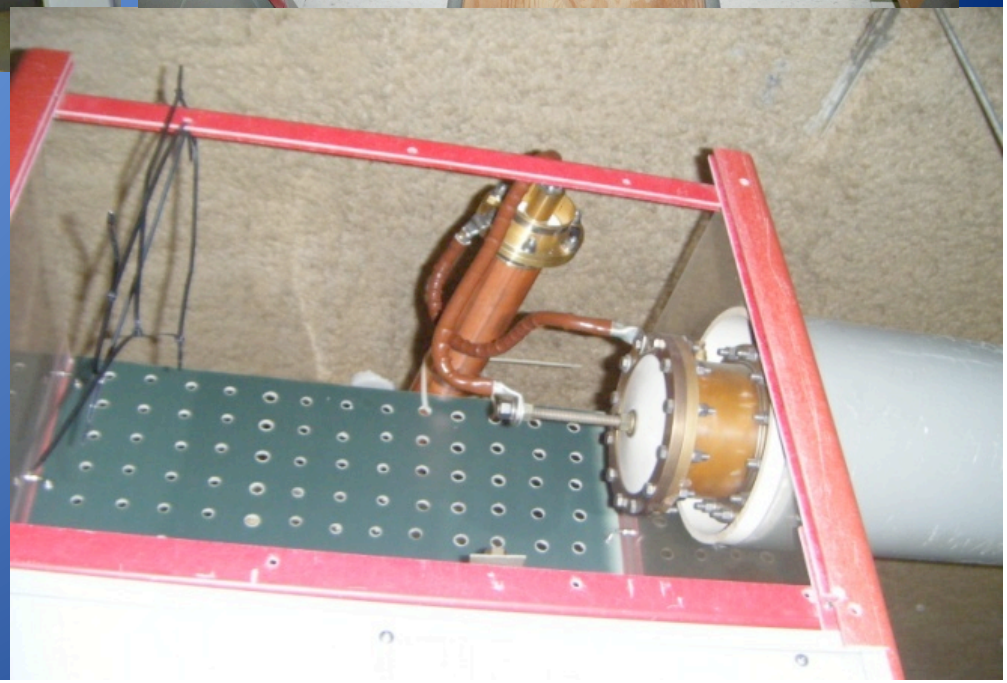
Front

Back

Nautel Transmitter



Transmitter Installation



Transmitter Evaluation

- Loran-C Tests
- eLoran Tests
- Future Concepts

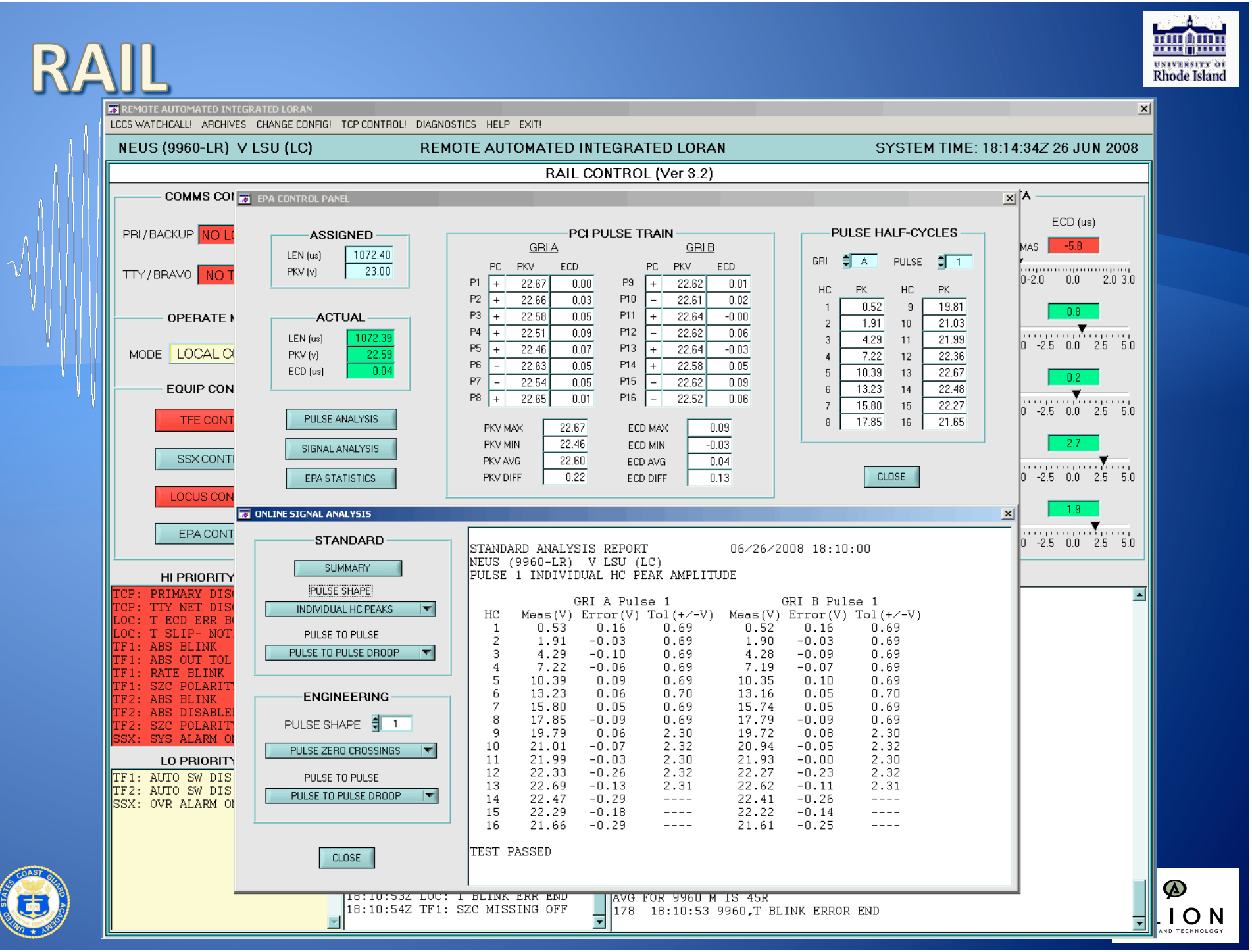
Loran-C Specifications

Specification	Notes
Pulse Leading Edge (specs 1, 2)	Attempts to measure how good the pulse shape is along the leading edge (from 0 to 65 µsec into the pulse) which is the most important part of the pulse for a receiver
1. Half-cycle Peak Amplitudes Ensemble Tolerance	Ensures that the average distance of the half-cycle peaks from the ideal amplitudes are less than 1% of the peak value
2. Half-cycle Peak Amplitudes Individual Tolerances	Ensures that the distance of any single half-cycle peak from the ideal amplitude does not exceed the threshold of 3% of the peak value for the first 8 half-cycles and 10% of the peak for the next 5 half-cycles.
3. Pulse Trailing Edge	Attempts to measure the current in the tail of the pulse to ensure that the pulse has been sufficiently attenuated in the tail. The current after 500 µsecs must be less than .14% of the peak value.
4. Zero-Crossing Times and Tolerances within Pulse	Ensures that the individual zero-crossing times are at strict 5usec intervals. The category 1 tolerances vary from ±1000ns to ±50ns depending upon which zero crossing it is. The reference point is the third zero crossing at 30 µsec.
5. Pulse-Group Phase Coding	Ensures that the transmitter is adhering to the correct plus-minus phase code sequence. This is currently a two group long sequence with different codes for master and secondary stations.
Uniformity of Pulses within Pulse Group (specs 6,7,8)	Ensures that the pulses within a group are uniform.
6. Pulse-to-Pulse Amplitude Tolerance	The amplitude of the smallest peak in the group must be within 5% of the amplitude of the largest peak for a single-rate station or within 10% for a dual-rate station.
7. Pulse-to-Pulse ECD Tolerance	This accounts for the pulse-to-pulse leading edge differences and the pulse-to-pulse zero-crossing differences. The ECD of any single pulse must not differ from the average of the ECD over all pulses in the PCI by more than 0.5 µsec for a single-rate station and by more than 0.7 µsec for a dual-rate station.
8. Pulse-to-Pulse Timing Tolerance	Ensures that the pulse spacing is uniformly 1000 usec with a tolerance of 25 ns for single-rate and 50ns for dual-rate. This is measured at the third zero-crossing and referenced to the first pulse of the group.
9. Spectrum	99% of the total energy must be within the 90-110 kHz band; no more than .5% above the band and no more than .5% below the band.

Loran-C Tests

Test #	Description	GRIs (Rates)	Xmtr	Load
1	Single Rate High	5930	Both	Simulator
2	Single Rate Low	9960	Both	Simulator
3	Dual Rate	5930/8970	Both	Simulator
4	Searchlight Dual Rate	9610-W/9940-Y	Both	Simulator
5	LSU Single Rate Low	9960-T	Nautel	Antenna
6	LSU Dual Rate	5030-M/9960-T	Nautel	Antenna

RAIL


REMOTE AUTOMATED INTEGRATED LORAN
LCCS WATCHCALL! ARCHIVES CHANGE CONFIG! TCP CONTROL! DIAGNOSTICS HELP EXIT!
NEUS (9960-LR) V LSU (LC)
REMOTE AUTOMATED INTEGRATED LORAN
SYSTEM TIME: 18:14:34Z 26 JUN 2008
RAIL CONTROL (Ver 3.2)
COMMS CO
PRI / BACKUP
TTY / BRAVO
OPERATE
MODE
LOCAL C
EQUIP CON
TFE CONT
SSX CONT
LOCUS CON
EPA CONT
HI PRIORITY
TCP: PRIMARY DIS
TCP: TTY NET DIS
LOC: T ECD ERR B
LOC: T SLIP- NOT
TF1: ABS BLINK
TF1: ABS OUT TOL
TF1: RATE BLINK
TF1: SZC POLARIT
TF2: ABS BLINK
TF2: ABS DISABLE
TF2: SZC POLARIT
SSX: SYS ALARM O
LO PRIORITY
TF1: AUTO SW DIS
TF2: AUTO SW DIS
SSX: OVR ALARM O
EPA CONTROL PANEL
ASSIGNED
LEN (us) 1072.40
PKV (v) 23.00
ACTUAL
LEN (us) 1072.39
PKV (v) 22.59
ECD (us) 0.04
PULSE ANALYSIS
SIGNAL ANALYSIS
EPA STATISTICS
PCI PULSE TRAIN
GRI A
GRI B
PC PKV ECD
P1 + 22.67 0.00
P2 + 22.66 0.03
P3 + 22.58 0.05
P4 + 22.51 0.09
P5 + 22.46 0.07
P6 - 22.63 0.05
P7 - 22.54 0.05
P8 + 22.65 0.01
P9 + 22.62 0.01
P10 - 22.61 0.02
P11 + 22.64 -0.00
P12 - 22.62 0.06
P13 + 22.64 -0.03
P14 + 22.58 0.05
P15 - 22.62 0.09
P16 - 22.52 0.06
PKV MAX 22.67
PKV MIN 22.46
PKV AVG 22.60
PKV DIFF 0.22
ECD MAX 0.09
ECD MIN -0.03
ECD AVG 0.04
ECD DIFF 0.13
PULSE HALF-CYCLES
GRI A PULSE 1
HC PK HC PK
1 0.52 9 19.81
2 1.91 10 21.03
3 4.29 11 21.99
4 7.22 12 22.36
5 10.39 13 22.67
6 13.23 14 22.48
7 15.80 15 22.27
8 17.85 16 21.65
CLOSE
ONLINE SIGNAL ANALYSIS
STANDARD
SUMMARY
PULSE SHAPE
INDIVIDUAL HC PEAKS
PULSE TO PULSE
PULSE TO PULSE DROOP
ENGINEERING
PULSE SHAPE 1
PULSE ZERO CROSSINGS
PULSE TO PULSE
PULSE TO PULSE DROOP
CLOSE
STANDARD ANALYSIS REPORT 06/26/2008 18:10:00
NEUS (9960-LR) V LSU (LC)
PULSE 1 INDIVIDUAL HC PEAK AMPLITUDE
GRI A Pulse 1 GRI B Pulse 1
HC Meas(V) Error(V) Tol(+/-V) Meas(V) Error(V) Tol(+/-V)
1 0.53 0.16 0.69 0.52 0.16 0.69
2 1.91 -0.03 0.69 1.90 -0.03 0.69
3 4.29 -0.10 0.69 4.28 -0.09 0.69
4 7.22 -0.06 0.69 7.19 -0.07 0.69
5 10.39 0.09 0.69 10.35 0.10 0.69
6 13.23 0.06 0.70 13.16 0.05 0.70
7 15.80 0.05 0.69 15.74 0.05 0.69
8 17.85 -0.09 0.69 17.79 -0.09 0.69
9 19.79 0.06 2.30 19.72 0.08 2.30
10 21.01 -0.07 2.32 20.94 -0.05 2.32
11 21.99 -0.03 2.30 21.93 -0.00 2.30
12 22.33 -0.26 2.32 22.27 -0.23 2.32
13 22.69 -0.13 2.31 22.62 -0.11 2.31
14 22.47 -0.29 ---- 22.41 -0.26 ----
15 22.29 -0.18 ---- 22.22 -0.14 ----
16 21.66 -0.29 ---- 21.61 -0.25 ----
TEST PASSED
ECD (us)
MAS -5.8
0.8
0.2
2.7
1.9
18:10:54Z TF1: SZC MISSING OFF
178 18:10:53 9960,T BLINK ERROR END

Loran-C RAIL Results

Transmitter	Test	Rate/GRI Measured	1. Half-cycle Peak Amplitudes Ensemble Tolerance		2. Half-cycle Peak Amplitudes Individual Tolerances	4. Zero-Crossing Times and Tolerances within Pulse	5. Pulse-Group Phase Coding	6. Pulse-to-Pulse Amplitude Tolerance		7. Pulse-to-Pulse ECD Tolerance		8. Pulse-to-Pulse Timing	
Nautel	1. Single Rate 5930	5930		0.39					0.22		0.05		-10.0
	2. Single Rate 9960	9960		0.40					0.25		0.06		-10.0
	3. Dual Rate-9960/5930	9960		0.39					0.28		0.06		-13.0
	3. Dual Rate-9960/5930	5930		0.39					0.21		0.05		-9.0
	4. Dual Rate-9940/9610	9940		0.39					0.25		0.08		-11.0
	4. Dual Rate-9940/9610	9610		0.38					0.25		0.08		-10.0
NSSX	1. 5930 single rate low	5930		0.74					1.24		0.02		10.0
	2. 9960 single low	9960		0.70					0.48		0.05		32.0
	3. Dual 5930/9960	5930		0.68					0.54		0.05		37.0
	3. Dual 5930/9960	9960		0.71					0.54		0.05		32.0
	4. Searchlight 9610/9940	9610		0.72					1.46		0.02		-12.0
	4. Searchlight 9610/9940	9940		0.73					0.54		0.01		10.0
Nautel	5. Single Rate 9960 - ON AIR	9960		0.39					0.21		0.05		-9.0
	6. Dual Rate 9960/5030 - ON AIR	9960		0.38					0.85		0.06		-9.0

Specification 4 Details

STANDARD ANALYSIS REPORT 06/26/2008 19:20:00
USWC (9940-LR) Y SEARCHLIGHT (SL)
PULSE 1 ZERO-CROSSINGS

	GRI A PULSE 1		GRI B PULSE 1			
0-XING	0-XING(US)	ERROR(NS)	0-XING(US)	ERROR(NS)	TOL(+/-NS)	
1	5.014	14	5.014	14	1000	
2	9.900	-100	9.900	-100	100	FAILED
3	14.895	-105	14.895	-105	75	FAILED
4	19.935	-65	19.935	-65	50	FAILED
5	24.983	-17	24.983	-17	50	
6	30.000	0	30.000	0	0	
7	35.008	8	35.009	9	50	
8	40.006	6	40.007	7	50	
9	45.011	11	45.011	11	50	
10	50.013	13	50.013	13	50	
11	55.023	23	55.023	23	50	
12	60.021	21	60.022	22	50	
13	65.018	18	65.018	18	760	
14	70.011	11	70.012	12	810	
15	75.015	15	75.016	16	860	
16	80.011	11	80.012	12	910	

*** TEST FAILED (SEE PARA. 2.A.3 OF THE SIGNAL SPECIFICATION)

Analysis Tool Issues

- Some questions and concerns about RAIL
  - Very little documentation
  - At times conflicting results observed
  - Does not measure all of the Loran-C specifications (3 and 9 are not measured)
  - Does not have the capability to do any eLoran specification measurements
- Some of the specifications themselves are not clearly defined from a testing perspective

LORDAC II Developed

- Replacement for the aging LORDAC
- Based on Matlab code running on a Windows PC with an A/D card running at 20 MHz
  - Samples two channels (Loran signal and MPT) at 20 Msps
  - Data capture started with a trigger signal from the TFE PCI strobe
  - Data is captured 1 PCI at a time and analyzed and optionally stored to disk
  - Multiple PCIs are captured in succession to allow for statistical analysis.
- Perform analysis of all specifications listed in Table 1 – including the spectrum occupancy and tail current
  - MPT signals used to locate each pulse and the pulse timing can be relative to the MPT rather than the first pulse. This corrects
  - Analysis is conducted on each pulse
  - Statistics computed based upon the entire batch of PCIs
  - Results written to a file as well as displayed on a GUI

LORDAC II Results

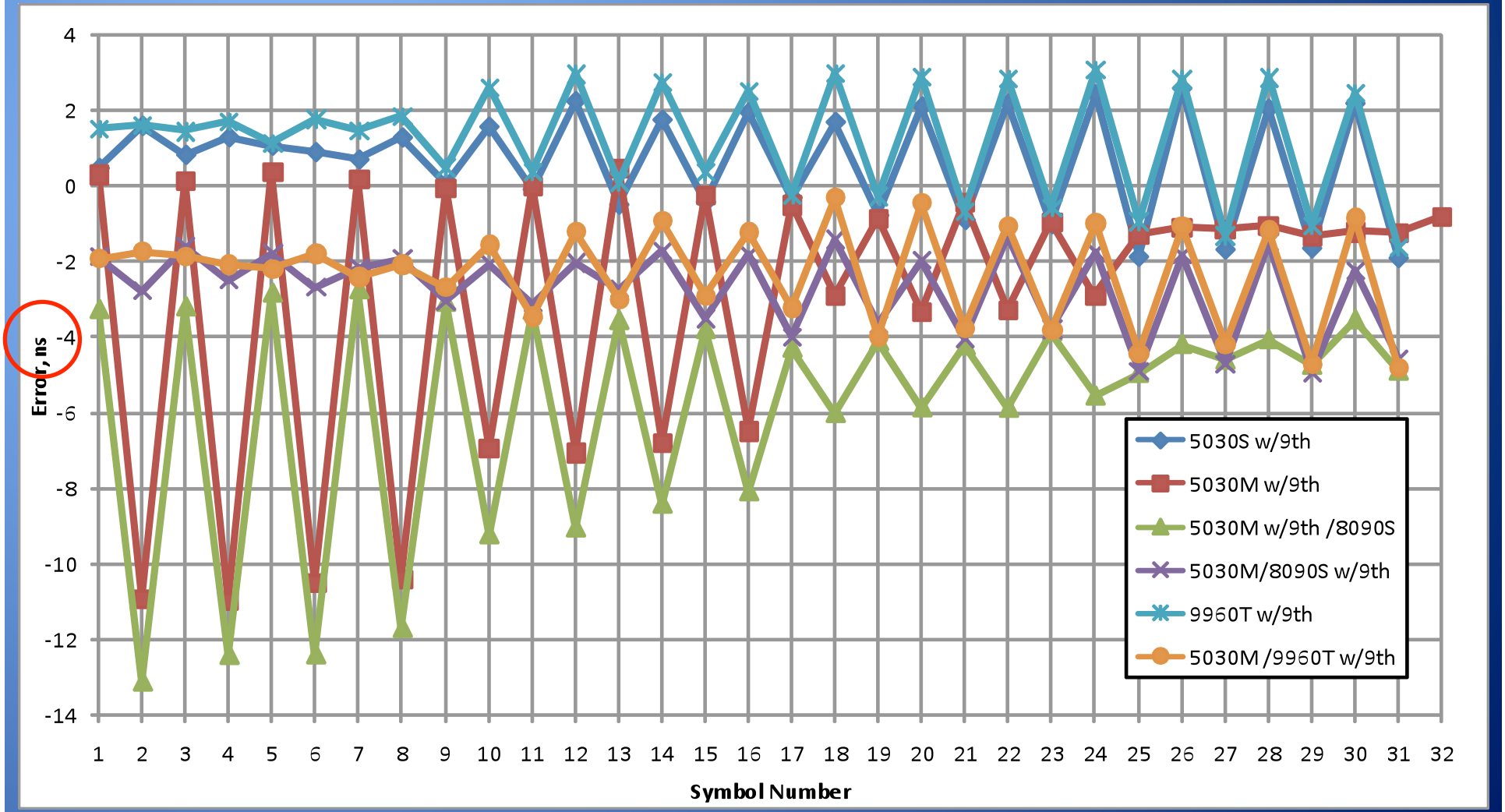
Transmitter	Test	Rate/GRI Measured	1. Half-cycle Peak Amplitudes Ensemble Tolerance	2. Half-cycle Peak Amplitudes Individual Tolerances	3. Pulse Trailing Edge	4. Zero-Crossing Times and Tolerances within Pulse	5. Pulse-Group Phase Coding	6. Pulse-to-Pulse Amplitude Tolerance	7. Pulse-to-Pulse ECD Tolerance	8. Pulse-to-Pulse Timing	9. Spectrum
Nautel	1. Single Rate 5930	5930	0.42		0.058			0.46	29.87	15.4	99.3
	2. Single Rate 9960	9960	0.38		0.039			0.65	29.94	7.6	99.3
	3. Dual Rate-9960/5930	9960	0.38		0.050			0.73	43.27	11.1	99.3
	3. Dual Rate-9960/5930	5930	0.39		0.054			0.73	29.88	10.7	99.3
	4. Dual Rate-9940/9610	9610	0.37		0.047			0.97	48.28	9.4	99.3
	4. Dual Rate-9940/9610	9940	0.38		0.059			1.48	53.63	8.2	99.3
NSSX	1. Single Rate 5930	5930	0.74		0.066			0.30	12.36	16.2	99.0
	2. Single Rate 9960	9960	1.21		0.075			0.62	12.14	7.8	99.1
	3. Dual Rate-9960/5930	9960	1.14		0.073			0.48	10.16	11.1	99.0
	3. Dual Rate-9960/5930	5930	1.17		0.065			0.62	13.97	27.8	99.1
	4. Dual Rate-9940/9610	9610	0.74		0.055			0.24	13.80	24.8	99.0
	4. Dual Rate-9940/9610	9940	0.72		0.049			0.36	9.08	19.6	99.1
Nautel	6. Dual Rate 9960/5030 - ON AIR	5030	0.36		0.068			0.42	15.27	16.1	99.3
	5. Single Rate 9960 - ON AIR	9960	0.43		0.059			0.73	24.61	15.8	99.3

eLoran Tests

- Primary change in the eLoran specification is the addition the LDC
- Tests to verify transmitter performance of this
- Test the generation of the 9th pulse through all 32 symbols on both Master and Secondary rates
- Procedure
  - Capture the sequential 9th pulses
  - Ensure that all 32 symbols were at the correct delay from the 8th pulse as per the LDC specification [4]
- Variety of rate combinations to see any transmitter variations.

Test #	Description	GRIs (Rates)	Load
1	Single Rate Secondary	5930-S with 9th pulse	Simulator
2	Single Rate Master	5030-M with 9th pulse	Simulator
3	Dual Rate	5030-M / 8090-S with 9th pulse	Simulator
4	Dual Rate	5030-M with 9th pulse / 8090-S	Simulator
5	Single Rate Secondary	9960-T with 9th pulse	Antenna
6	Dual Rate	5030-M / 9960-T with 9th pulse	Antenna

eLoran Results



eLoran Pulse Results

Test	Rate/GRI Measured	1. Half-cycle Peak Amplitudes Ensemble Tolerance		2. Half-cycle Peak Amplitudes Individual Tolerances	3. Pulse Trailing Edge		4. Zero-Crossing Times and Tolerances within Pulse	5. Pulse-Group Phase Coding	6. Pulse-to-Pulse Amplitude Tolerance		7. Pulse-to-Pulse ECD Tolerance		8. Pulse-to-Pulse Timing		9. Spectrum	
1. 5030S w/9th	5030		0.32			0.028				0.55		26.74		3.4		99.3
2. 5030M w/9th	5030		0.38			0.039				0.91		28.75		3.3		99.3
3. 5030M w/9th - 8090S	5030		0.34			0.028				0.69		27.29		2.9		99.3
4. 5030M - 8090S w/9th	8090		0.36			0.023				0.94		43.58		4.8		99.3
5. 9960T w/9th	9960		0.35			0.039				0.94		41.19		4.5		99.3
6. 5030M - 9960T w/9th	9960		0.35			0.026				1.12		41.76		4.5		99.3

Conclusions 1/2

- Prototype eLoran transmitter performed well
  - Met almost all existing specs
    - The one not met could be met with minor changes to the defined pulse shape
    - Production version of the transmitter is expected to have numerous improvements based upon what has been learned from the prototype
  - Was not impacted by dual-rating, having consistently good performance across all tests
  - Performed well on the eLoran tests (9th pulse modulation)
  - Successfully tested with a 10th pulse (a possible addition to the eLoran Specification)
  - Flexibility of the transmitter enabled us to test out some different concepts

Conclusions 2/2

- Advantages
  - Smaller footprint
  - High efficiency (currently about 60% with the production transmitter to be as high as 70-75%)
    - lower electrical load
    - very little heat generated so lower AC demand
- Further refinement needed for LORDAC II software as well as new transmitter testing procedures
  - Will be reported on in the future

Acknowledgements

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  - Alion
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  - Nautel

Questions?

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