Test and Evaluation of a New eLoran Transmitter

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Abstract

In 2001, the Volpe National Transportation Systems Center completed an evaluation of the Global Positioning System's (GPS) vulnerabilities and their potential impacts to transportation systems in the United States. One of the recommendations of this study was for the operation of backup system(s) to GPS; Loran-C was identified as one possible backup system. This recommendation has taken a further step forward with the request in the President's FY09 budget to continue to operate the Loran-C system and upgrade it to enhanced Loran or eLoran capabilities. Looking to the future, there will always be the desire to cost effectively run the system to meet the accuracy, availability, continuity and integrity requirements of eLoran. As such, alternative technology solutions to generating the signals should be investigated.

Historically, Loran transmitters in the United States have been based upon so called half-cycle generators, a system design approach that provided the high power/high current needs of Loran. This design approach has remained the same during the technology transition from tube amplifiers (circa 1950), through the first round of solid-state transmitters (late 1970s), to the new solid state transmitters (c 2000). In recent years, advances in AM broadcast technology appear to allow alternative system designs for high power transmitters; of interest for eLoran is how to leverage these improvements.

Toward the goal of testing high power AM transmitters for eLoran, Nautel, a US/Canadian manufacturer of AM transmitters, has developed a proof-of-concept Loran transmitter derived from traditional EER AM band transmitters. Alion Science & Technology, in support of the U.S. Coast Guard Academy, has leased one of these new transmitters for testing at the Loran Support Unit in order to determine whether the transmitter meets both the existing Loran signal specification and the draft eLoran specification.

As part of the test and evaluation, the authors have realized that the existing Loran transmitter test procedures to verify operation against the Signal Specification are based on 1950's methodology. Just as transmitters and receivers have been updated to the digital world, the transmitter test procedures can be rewritten to use digital signal processing concepts that were not possible when the procedures were originally developed. In addition, the test procedures are revised to include statistical data analysis and support for eLoran and advanced signaling concepts. This paper describes the transmitter itself, the new test procedures developed to test the transmitter against the Loran and eLoran specifications, and the results of the transmitter testing.

Keywords

eLoran, transmitter, LDC, Loran specification

Introduction

Loran (Long Range Navigation) is a land-based radio navigation system that has been used for more than 30 years and provides position, navigation and timing (PNT) information to users throughout the Continental United States and other parts of the World. Recently the U.S. Department of Homeland Security announced that eLoran will be implemented as a land-based, independent back-up system for PNT systems in the event of GPS outage or disruption.

In 2001, the Volpe National Transportation Systems Center completed an evaluation of the Global Positioning System's (GPS) vulnerabilities and their potential impacts to transportation systems in the United States [1]. One of the recommendations of this study was for the operation of backup system(s) to GPS; Loran-C was identified as one possible backup system. With the recent announcement in the President's FY09 budget to operate and upgrade the Loran-C system to enhanced Loran or eLoran capabilities, a path must be established which enables the Coast Guard to cost effectively upgrade older transmitter technology to meet the accuracy, availability, continuity and integrity requirements of eLoran. In order to satisfy this new goal, Loran transmitters must become cheaper to purchase and have lower operation and maintenance costs, while meeting all eLoran signal requirements. As such, alternative technology solutions to generating the signals should be investigated.

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Nautel Transmitter

Nautel, Inc. has developed a prototype eLoran transmitter. The manufacturer's claims for the system under test are:

> "The technology being demonstrated is extremely easy to deploy and uses Class D amplification with Nautel's patent pending regenerative antenna damping to achieve superior efficiency. This efficient operation means cooling requirements are dramatically reduced. In addition accurate pulse timing and flexible modulation schemes permit the support of advanced applications for Loran. Soft fail power amplifiers with a passive reserve ensure continuous operation. This technology is designed for an extended life under normal operation."

Additional information on the transmitter is contained in Nautel's paper presented at this same conference.

Transmitter Installation

The prototype transmitter, leased from Nautel by Alion Science & Technology was installed at the Coast Guard Loran Support Unit (LSU) in May 2008. The transmitter, with ~50kW radiated power into the 625' TLM antenna, consists of two 21" rack cabinets (see Figure 1). The left-hand cabinet contains the power amplifiers and control board, while the right-hand cabinet contains the tuning coil, harmonic filter and antenna feed. A close-up is shown in Figure 3. There are sixteen active power amplifiers and two spares (inserted into the rack but not connected) and two tail "nibblers" (located in the lower right-hand corner) which provide the final attenuation in the tail of the Loran pulse. The back of the transmitter cabinet is shown in Figure 5 where the coupling coils can be seen. The control board (Figure 4) is the interface to the existing TFE (time and frequency equipment) and controls which amplifiers fire when. The existing Megapulse transmitter can be seen in the background of Figure 1 and in Figure 2 for size comparisons.

Figure 1: Nautel transmitter.

Figure 2: MegaPulse Transmitter.

Installing the transmitter was a fairly simple operation that took less than one day. Once the cabinets were moved into position and wired into the 3-phase power and ground connection, the antenna connection was the only major job remaining. Approximately 25’ of 3 $^{1}/_{8}$” copper hard line was run from the top of the transmitter to the connection point of the antenna switch (the existing MegaPulse transmitter was disconnected from the switch to allow the Nautel transmitter to be connected). The elbow is not soldered on; hose clamps are all that is needed for this install (Figure 6 and Figure 7). The existing TFE system was connected to the control board using a single multi-function cable (contains wires for the MPT HI, MPT LO, Phase Set HI, Phase Set LO, Phase Reset HI, Phase Reset LO, and the 5MHz clock).

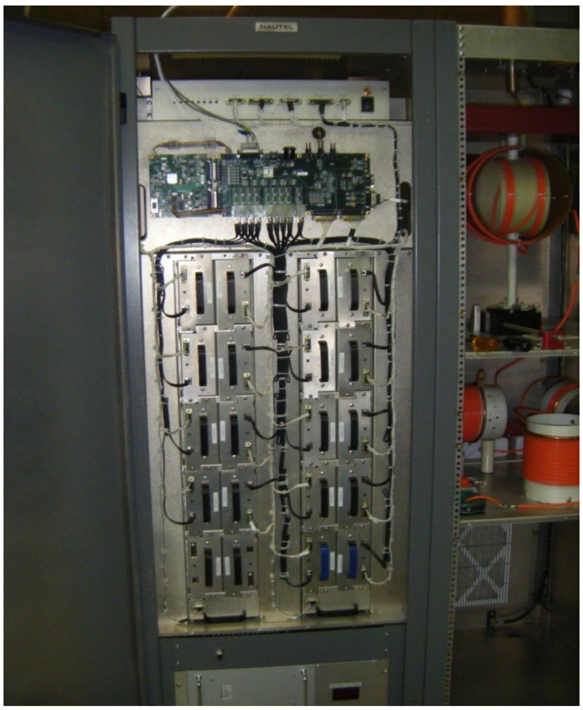

Figure 3: The Nautel transmitter. The control board is at the top and the 20 amplifiers are paired up below.

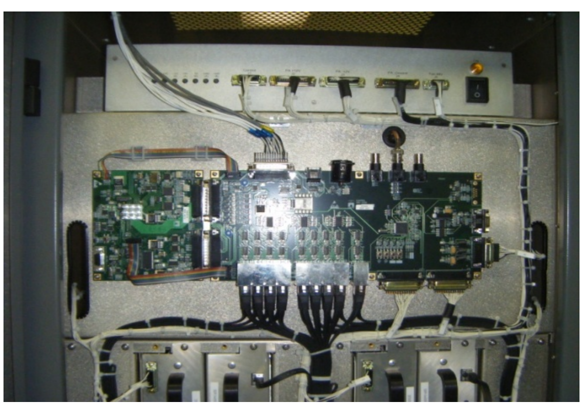

Figure 4: The control board is controlled by LSU’s TFE input on the top of the board.

Figure 5: Back side of the transmitter rack showing the coupling coils.

Figure 6: Tim Hardy of Nautel installing the 90˚elbow.

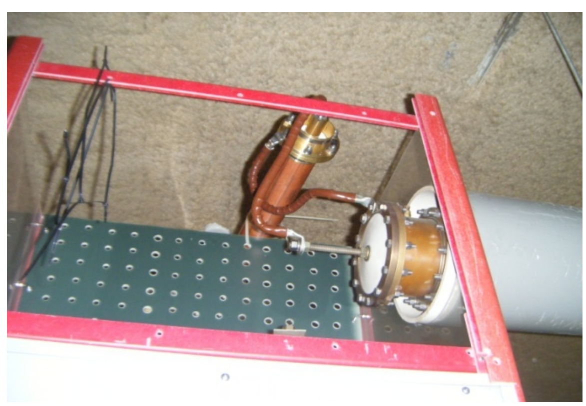

Figure 7: Large gauge straps go from the conductor and ground to the antenna switch input.

Transmitter Evaluation

A test plan was developed and executed by Alion and LSU personnel to determine whether this transmitter meets both the existing Loran signal specification and the draft eLoran specification as well as determine if future concepts (such as 10th pulse) are possible. In order to meet this goal of determining if the transmitter could meet all current and potential future requirements, a series of tests were specified in a phased manner. First, tests were run to compare the transmitter to the current Loran-C specifications and then tests were run to compare the transmitter to evolving eLoran specifications. Finally, some tests of advanced concepts were run; these are reported on in our companion paper. In each case, the transmitter was tested into the antenna simulator first to ensure proper operation prior to transmitting on-air (into the antenna).

Loran-C Tests

The first series of tests were to see if the transmitter could meet the all of the requirements of the existing Category 1 Loran-C signal transmitter specifications as per the 1994 Signal Specification [2]. The specifications are summarized in Table 1 for a Category 1 transmitter (newer solid-state systems; Category 2 was for the older tube-type transmitters). Some additional requirements such as Blink and dual-rate blanking are also addressed in [2] but are not really a measure of the transmitter's performance and were not addressed. The first set of tests were conducted using LSU's antenna load simulator, or dummy load, and then a second set of tests was performed with LSU's full-size Loran tower on-air. In all cases, the waveform transmit cycle was triggered by LSUs Time and Frequency Equipment (TFE).

Table 1: Loran Specifications Summarized.

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.

A series of tests with different rate configurations was selected to assess performance under different conditions. The transmitter was run with single GRI rates both slow (9960) and fast (5930) rates and then dual rates (two GRIs) with two different configurations (one "easy" and one that is difficult for the existing transmitter, LorSta Searchlight). All of the specific rates were chosen based upon what rates that LSU could set up on the RAIL system and what rates were authorized for transmission. The tests run are listed in Table 2.

Table 2: Transmitter Loran-C Tests.

Test #	Description	GRIs (Rates)	Transmitter	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

For each of these tests the existing monitoring system (RAIL) was used to assess the performance. The RAIL or Remote Automated Integrated Loran system integrates command and control functions at a Loran station and provides the remote interface for all commands, alarms and data to the Loran Consolidated Control System (LCCS). RAIL is a custom-built software application developed at the Loran Support Unit (LSU) using a Windows-based operating system and first used in 2000[3]. The RAIL system allows a variety of measurements to be made and assesses whether the transmitter is meeting the Loran-C Specifications. Of the specifications listed in Table 1, Pulse Trailing Edge and Spectrum are not measured by RAIL. One other drawback of RAIL is that there is no easy electronic output of test results. Each specification must be examined in a separate screen and then printed or captured from the screen as an image. An example screen capture is shown in Figure 8.

Figure 8: Sample RAIL screen capture showing individual half-cycle peak amplitudes.

Loran-C Results

The results of running the Nautel transmitter through the series of tests listed in Table 2 and compared to the specifications listed in Table 1 are summarized in Figure 9. Pass is indicated by green and fail by red. For the specifications for which a single numerical result is possible, these values are included in the table for each test.

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
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
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

Figure 9: Nautel Transmitter Test Results. Specification 1 and 6 values are percents. Specification 7 is in µsec. Specification 8 is in ns.

As can be seen the Nautel transmitter performed well and passed all specifications on all tests except for Specification 4 (Zero-Crossing Times). For Specification 1, the half-cycle amplitude tolerances remained the same across all tests and within the specified tolerance of 1%. For Specification 6, the pulse-to-pulse amplitude tolerance, again the results were consistent across all tests and well within the specified tolerances of 5 or 10% since the worst case is less than a 1% variation. For Specification 7 the ECD variations again are uniformly low across all tests with the worst case variation being 0.08 µsec compared to the tolerance value of 0.5 or 0.7 µsec. For Specification 8, the pulse-to pulse timing was also consistently low across all tests and well within the 25ns tolerance. For Specification 4, more detail is shown in Figure 10. The results shown in this figure for the 9940 Rate of the Searchlight dual-rate test are typical of the results on all of the tests; it is the 2nd, 3rd, and 4th zero-crossings that are not within tolerance by small amounts. However, it can be seen that the tolerances range considerably while the results for the Nautel transmitter are consistently low, mostly in the 10-20ns range, even where the tolerances are as much as 1000ns! It is not clear why the tolerances were set at these values other than perhaps that is what other transmitters could meet, or even that this specification has meaning for a receiver. However, the shape and characteristics of the Nautel pulse can be altered very easily through the serial port interface and can be better tuned to the antenna characteristics to enable this specification to be met (the zero-crossing values are affected by the impedance characteristics of the antenna). The production version of the transmitter is planned to have a feedback loop to enable auto-tuning of the pulse shape parameters as the antenna characteristics change due to events such as ice loading.

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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)
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Figure 10: Details on Zero-crossing test results.

For comparison purposes the results for the existing NSSX transmitter on tests 1-4 are shown in Figure 11. As can be seen, the NSSX passes almost all specifications on all tests.

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
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

Figure 11: NSSX results for tests 1-4.

LORDAC II

The testing conducted with RAIL raised some questions and concerns about the measurement tool. First of all, there is very little documentation on how the tool was constructed and how it performs the measurements leading to low confidence on some of the measurements. At times conflicting results were observed. In addition, RAIL does not measure all of the Loran-C specifications (3 and 9 are not measured) and it does not have the capability to do any eLoran specification measurements. Furthermore, some of the specifications themselves are not clearly defined from a testing perspective. In many cases it would make more sense to do statistical testing rather than relying on the results from a single pulse or a single group of pulses, but this is not defined in the Loran-C Specification.

To address these concerns, we developed a new test tool, which we called LORDAC II as a replacement for the aging LORDAC (an existing stand-alone test tool which was the precursor to RAIL). LORDAC II is based on Matlab code running on a Windows PC with an A/D card running at 20 MHz. The system samples two channels (channel 1 being the transmitted Loran waveform and channel 2 being the MPT signals into the transmitter) at 20 Msps.

Table 1 – including the spectrum occupancy and tail current. Since the MPT signals are also captured simultaneously with the Loran signal they can be used to locate each pulse and the pulse timing can be relative to the MPT rather than the first pulse. This corrects a long-standing problem with RAIL and LORDAC where if the first pulse is off, the entire test is skewed. The analysis is conducted on each pulse and then statistics computed based upon the entire batch of PCIs. The results are written to a file as well as displayed on a GUI.

Loran-C Tests

All of the tests described in Table 2 were also analyzed using LORDAC II. These results are summarized in Figure 12 for both transmitters. The

Software Design

Data capture is started with a trigger signal from the TFE PCI strobe. This guarantees that the first pulse captured will be pulse 1 of Group A. 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. The code is written to perform analysis of all specifications listed in

results are similar to those using RAIL (in terms of PASS – FAIL except that the NSSX transmitter seems to fail the Specification 1 on some tests and is close to failing on the others. It should be noted though that an exhaustive analysis of the performance of the LORDAC II has not been done yet. The LORDAC II measures the tail current (Specification 3) which is met by both transmitters on all tests and the spectral occupancy which is also met by both transmitters on all tests though the Nautel transmitter has slightly more energy in-band than the NSSX (99.3% vs 99.1%). As a slight modification (improvement perhaps) of specification 7 and 8, LORDAC II calculates the standard deviation of the measurements across the PCI and displays those instead of looking at the individual ECD and third-zero crossing variations.

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

Figure 12: LORDAC II results for both transmitters. Specifications 1, 3, 6, and 9 are in %. Specification 7, 8 are standard deviations, in ns.

Developing the LORDAC II software has raised additional questions as to how the transmitter assessments should be done. Some of the specifications may not be meaningful to the performance of a receiver in the field and maybe should be dropped. Other specifications need to be tighter and have greater clarity; for example the spectral occupancy specification as written could allow a transmitter to have large out-of-band harmonics that although technically within the specification could cause interference. Also the measurement could be defined various ways – instantaneous spectrum, averaged spectrum, etc. These finer points of the assessment tool will be addressed in a future work.

eLoran Tests

The main transmitter change in the eLoran specification is the addition of the Loran Data Channel (LDC) on the 9th (and possibly 10th) pulses. A series of tests was executed to verify transmitter performance of this. The requirement was to test the generation of the 9th pulse through all 32 symbols on both Master and Secondary rates. The test procedure was to capture the sequential 9th pulses and ensure that all 32 symbols were at the correct delay from the 8th pulse as per the LDC specification [4]. Again a variety of rate combinations were selected to enable us to see any transmitter variations. The specific tests are listed in Table 3; in the tests with 9th pulse on the Master rate, there were actually 10 pulses transmitted since the Master's 9th pulse was added at 2000us after the 8th pulse in addition to the modulated LDC 9th pulse. Results are only available for the Nautel transmitter as the TFE system connected to the NSSX was an old version that had incorrect values for the 9th pulse symbol positions. This test will be re-run once this is corrected.

Table 3: Transmitter eLoran Tests.

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

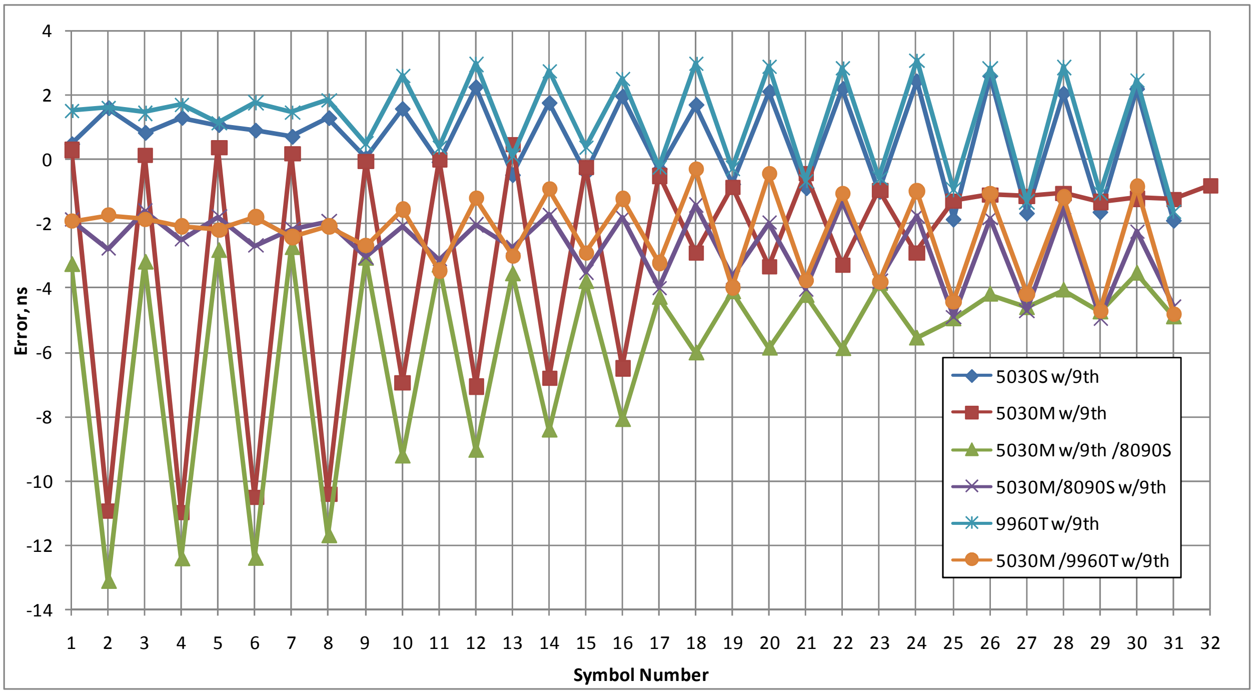

Figure 13: Error in the symbol times.

In Figure 13 the error (in ns) is the actual symbol time relative to the ideal symbol time where the actual times are relative to the 8th pulse. In all tests the Nautel transmitter performed well; the worst-case error was about 13 nanoseconds. The worst case error and largest variations occurred when the LDC pulse was added to the Master. When the LDC pulse was added to the secondary, the variation in the errors was much less (on the order of 4ns rather than 10ns). In all cases, whether the transmitter was running single rate or dual rate, the results were about the same. Also, there was no difference between the antenna simulator results and the antenna results. It should be noted that some of this "error" may be due to the measurement system. It does appear that there are some slight biases in the measurements perhaps due to slight errors in the 8th pulse time measurement. In the future, the timing should probably be measured relative to the MPT. Also, at present there is no specification defined for the symbol performance; this will need to be addressed in the eLoran specification.

Conclusions

This prototype eLoran transmitter from Nautel, which was developed and delivered in a very short time, performed well, meeting almost all existing specifications; the one not met could be met with minor changes to the defined pulse shape. The production version of the transmitter is expected to have numerous improvements based upon what has been learned from the prototype. The prototype transmitter was not impacted by dual-rating, having consistently good performance across all tests. The transmitter also performed well on the eLoran tests (9th pulse modulation) and was successfully tested with a 10th pulse (a possible addition to the eLoran Specification). In addition the flexibility of the transmitter enabled us to test out some different concepts for possible future eLoran implementation.

The footprint of this new transmitter is considerably smaller than the existing transmitter which makes housing it easier and cheaper. In addition, although not tested at LSU, the manufacturer reports the efficiency to be currently about 60% with the production transmitter to be as high as 70-75% -- which results in a much lower electrical load. Also since the efficiency is high, there is very little heat generated meaning that the A/C requirement is much less leading to further cost reductions for both installation and operation. All of this adds up to a package with many advantages for efficient and cost-effective eLoran operation.

Additional details on the development of the LORDAC II software, the development and implementation of algorithms and test procedures, as well as suggestions for changes in transmitter testing procedures will be reported on in the future.

Disclaimer

The views expressed herein are those of the authors and are not to be construed as official or reflecting the views of the U.S. Coast Guard, Federal Aviation Administration, Department of Transportation or Department of Homeland Security or any other person or organization.

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