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DOT/TSC LORSTA NANTUCKET TEST REPORT

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PROJECT MEMORANDUM

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PREFACE

This report presents the results of LORAN-C field measurements made in the vicinity of LORSTA Nantucket on 9 to 12 August 1983. Using an ensemble of test equipment with semi-automatic control, TSC engineers determined the following:

a. Frequency signature for both transmitters:

(1) Spectrum - 99 percent energy in-band.

(2) Harmonics (relative to the 100 kHz peak) - 39 dB at 200 kHz, -50 dB from 300 to 1200 kHz, all others were below the background noise level.

(3) Spurious emissions - bands of emissions centered at 615 kHz and 1.1 MHz.

b. Time domain signature:

(1) Use of the Hewlett Packard 5180A waveform analyzer to establish the time domains signature of LORAN-C stations is feasible and has been achieved.

(2) The AN/FPN-42 LORAN-C transmitters at LORSTA Nantucket meet or exceed the emission standards of COMDTINST M16562.4 except for the zero crossings in a pulse from transmitter 23.

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1. INTRODUCTION

Measurements of the LORAN-C signal radiated by LORSTA Nantucket were carried out by members of an engineering test team from DOT/TSC, with the cooperation of station personnel, during the period 9 to 12 August 1983. The principal objective of the trip was to gather sufficient data to ensure that the Hewlett Packard 5180A waveform analyzer was adequate for use as a measurement standard to establish LORSTA time domain signal characteristics. A secondary objective was to document the frequency signature of LORSTA Nantucket. Both objectives were achieved and are documented in this report.

2. STATION DESCRIPTION

LORSTA Nantucket is a dual rated station operating on group repetition interval (GRI) 9960 and GRI 5930. It is equipped with an AN/FPN-42, tube-type LORAN-C transmitter. The antenna is a 625-foot monopole. The rated peak output power is 250 kW. During the period when these tests were made, all aspects of LORSTA Nantucket transmitter operations were in accordance with the normal operating specifications for that station.

3. OBSERVATION SITES

Measurements were made at the station transmitter and operations buildings, and four other sites which are indicated in Figure 3-1. The sensor at the transmitter building was a spare Pearson current transformer mounted next to the standard sampling transformer. The transformer output had been unbalanced and the station had no documentation regarding what had been done. A visual inspection of the transformer was performed, but it was not possible to determine if a balun had been introduced into the output circuit because the transformer is housed inside the antenna coupler enclosure. To make this determination would require shuting down the transmitters. Data from the transmitter building were therefore not used in this report. Frequency domain data were collected at all test sites. Time domain data on LORAN-C pulse shape were taken only at sites 1, 2, and 3 since beyond a one-half mile radial distance from the antenna it was observed that the system and ambient noise level was equal or greater than the first half cycle peak of the observed LORAN-C pulse. The flat terrain in the vicinity of LORSTA Nantucket permitted us to sight the transmitting antenna at all measurement locations; this eliminated the requirement to use an antenna rotor for maximizing the signal.

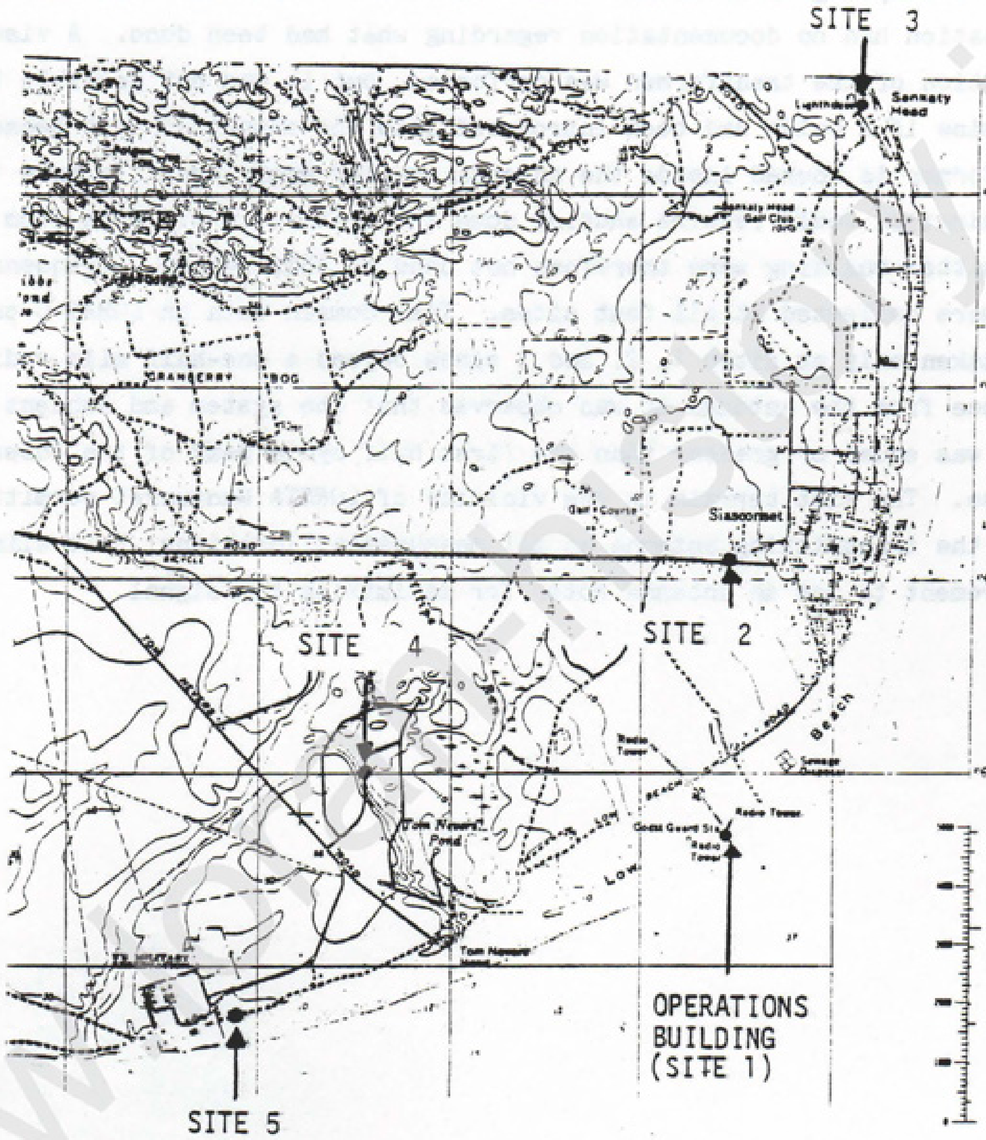

FIGURE 3-1. TEST SITE LOCATIONS--NANTUCKET

4. FREQUENCY DOMAIN MEASUREMENTS AND RESULTS

Frequency domain measurements were made using a calibrated, Coast Guard furnished, Austron 2021L loop antenna terminated with a matching filter as the sensor. The signal was analyzed by a Hewlett Packard 3585A spectrum analyzer, controlled by a Tektronix 4052 graphics computer. Calculations of in-band power are automatically performed using the Tektronix 4052 after completion of a spectrum sampling sequence. Harmonic measurements were made using the HP 3585A in the manual mode. The analyzer intermediate frequency (IF) output was examined for characteristic LORAN-C pulse group patterns using an oscilloscope triggered in synchronism with a local group repetition interval (GRI). A 100 kHz notch rejection filter, also provided by the Coast Guard, was used to protect the high amplitude carrier level from overloading the analyzer circuits during harmonic measurements. Scans of the adjacent band energy were also made and results are documented with photographs when appropriate. These procedures are documented in the DOT/TSC LORSTA Seneca Test Report (DOT/TSC CG-337-PM-83-29). A diagram of the equipment interconnection is shown in Figure 4-1.

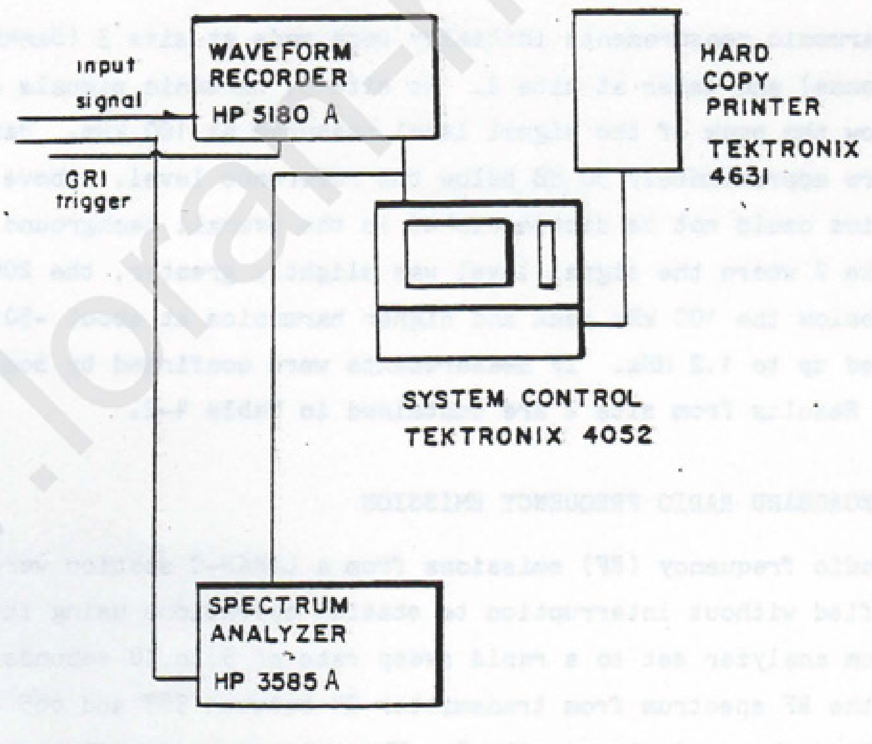

FIGURE 4-1. EQUIPMENT USED FOR COLLECTION AND STORAGE OF FREQUENCY AND TIME DOMAIN MEASUREMENTS AT LORSTA NANTUCKET

4.1 SPECTRUM EVALUATION

The spectrum in the frequency range 76 kHz to 124 kHz of each of the two transmitters (23 and 24) at Nantucket was distinctly different. However, as was the case at LORSTA Seneca, the observed spectrum was virtually identical at each site. Representative spectrum envelopes observed at Sankaty Head lighthouse (site 3) are shown in Figures 4-2 and 4-3. The radiated LORAN-C signal from the Nantucket transmitters was in most cases found to be very close to, or within, the specification for LORAN-C signals which requires that 99 percent of the power be within the frequency limits of 90 to 110 kHz. The out-of-band power was unequally distributed. In most cases, about two-thirds of the residual power was distributed below 90 kHz, leaving an average one-third of the out-of-band power above 110 kHz. Transmitter 23 radiated a slightly greater percentage of power out-of-band as compared to transmitter 24. Spectrum measurements for transmitter 23 were taken at site 4, but a computer malfunction rendered the data unusable. Table 4-1 presents a summary of the measurements with the computed in-band and out-of-band power distributions.

4.2 HARMONIC RADIATION SIGNAL LEVELS

Harmonic measurements initially were made at site 3 (Sankaty Head lighthouse) and later at site 2. At site 3, harmonic signals at 200 kHz were 35 dB below the peak of the signal level measured at 100 kHz. Harmonics above 200 kHz were approximately 50 dB below the reference level. Above 800 kHz, harmonics could not be distinguished in the overall background noise level. At map site 2 where the signal level was slightly greater, the 200 kHz harmonic was 39 dB below the 100 kHz peak and higher harmonics at about -50 dB could be observed up to 1.2 MHz. IF measurements were confirmed by scanning the entire band. Results from site 2 are contained in Table 4-2.

4.3 BROADBAND RADIO FREQUENCY EMISSION

Radio frequency (RF) emissions from a LORAN-C station were conclusively identified without interruption to station operations using the HP 3585A spectrum analyzer set to a rapid sweep rate of 5 to 10 seconds. Figure 4-4 shows the RF spectrum from transmitter 24 between 565 and 665 kHz, centered on 615 kHz as observed at map site 2. The extensive distribution of spectrum

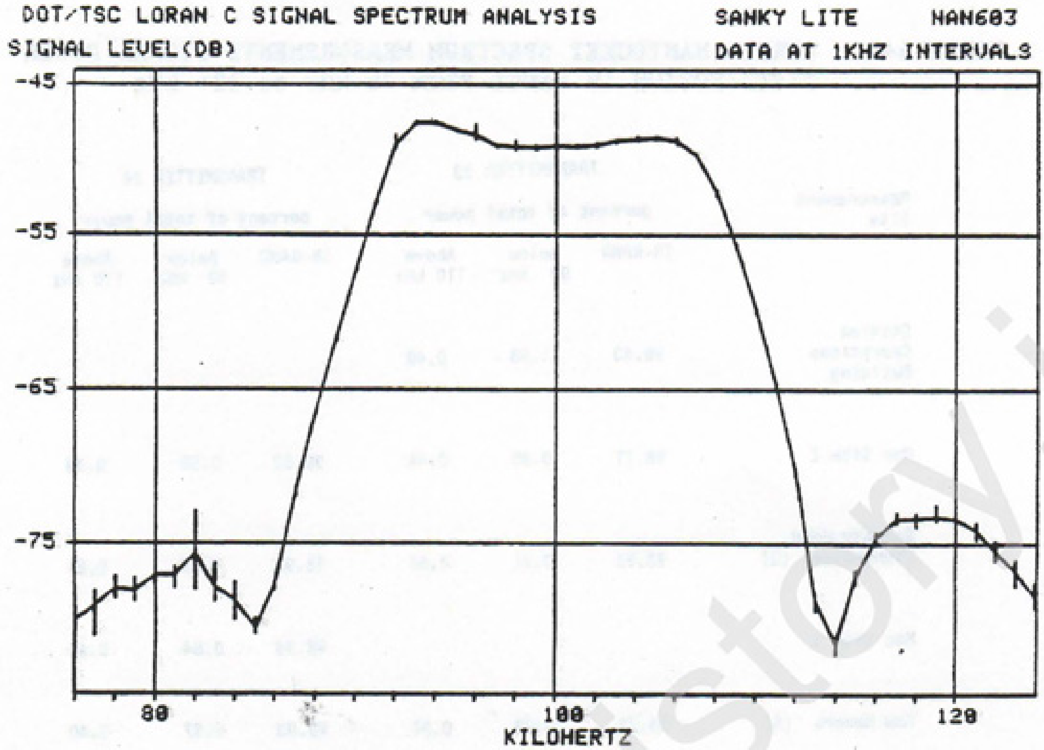

FIGURE 4-2. LORSTA NANTUCKET TRANSMITTER 23 SIGNAL FREQUENCY SPECTRUM MEASURED AT SANKATY HEAD LIGHTHOUSE

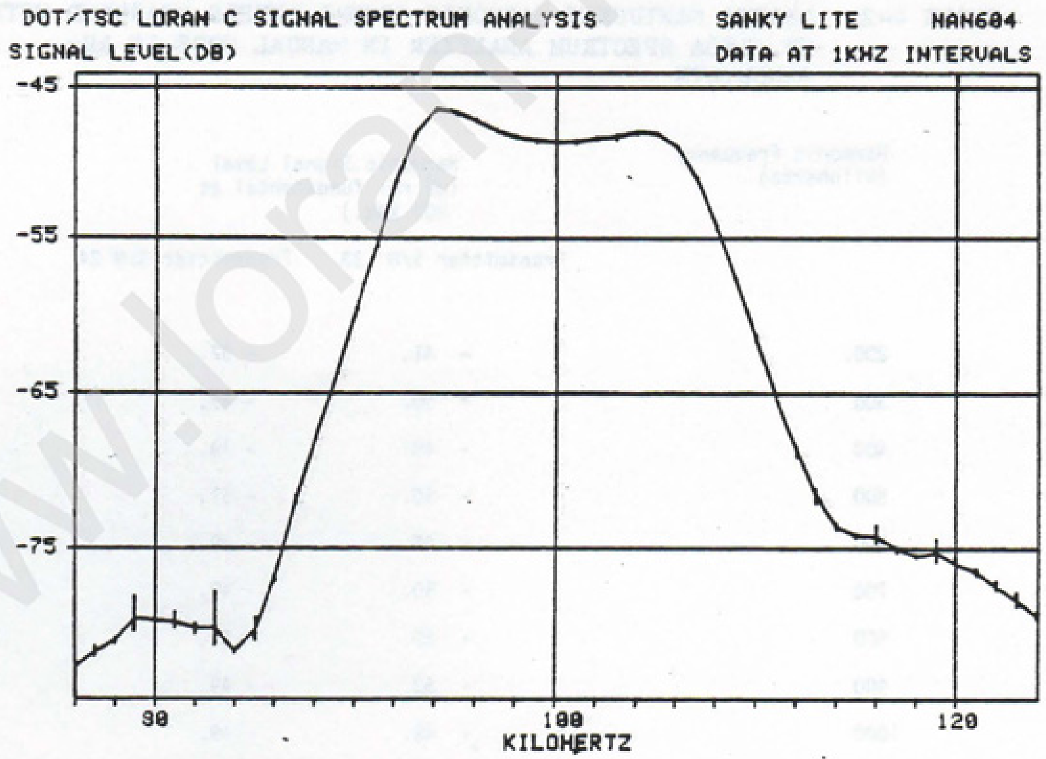

FIGURE 4-3. LORSTA NANTUCKET TRANSMITTER 24 SIGNAL FREQUENCY SPECTRUM MEASURED AT SANKATY HEAD LIGHTHOUSE

TABLE 4-1. LORSTA NANTUCKET SPECTRUM MEASUREMENTS SIGNAL POWER DISTRIBUTION IN RANGE FROM 76 kHz to 124 kHz

Measurement Site	TRANSMITTER 23 percent of total power			TRANSMITTER 24 percent of total power		
	IN-BAND	Below 90 kHz	Above 110 kHz	IN-BAND	Below 90 kHz	Above 110 kHz
Station Operations Building	98.43	1.08	0.49			
Map Site 2	98.71	0.85	0.44	99.02	0.59	0.39
Sankaty Head Lighthouse (3)	98.53	0.91	0.56	98.92	0.57	0.51
Map Site 4				98.93	0.64	0.43
Tom Nevers (5)	98.71	0.78	0.51	99.03	0.57	0.40

TABLE 4-2. LORSTA NANTUCKET HARMONIC SIGNAL LEVELS MEASURED WITH HP 5180A SPECTRUM ANALYZER IN MANUAL MODE 10 kHz BANDWIDTH

Harmonic Frequency (kilohertz)	Harmonic Signal Level (dB re: fundamental at 100 kHz.)	
	Transmitter S/N 23	Transmitter S/N 24
200.	- 41.	- 37.
300	- 50.	- 49.
400	- 48.	- 49.
500	- 50.	- 51.
600	- 45.	- 49.
700	- 50.	- 49.
800	- 50.	- 55.
900	- 53.	- 49.
1000	- 48.	- 49.
1100	- 42.	- 45.
1200	- 47.	- 51.

components, between 605 and 625 kHz above the general background ambient level, is due to the local LORAN-C transmissions. It can be recognized by the striated structure which is a unique consequence of the dual rated pulse group sequence spread in time by the higher scan rate. The peak levels represent a signal which is 40 dB down from the 100 kHz peak. Continued observation disclosed that this spurious emission varied over approximately a 6 dB range at a rate apparently related to the difference in the station's two GRI values. Figure 4-5 presents a wider spectrum from 750 kHz to 1250 kHz for transmitter 24. LORAN-C emission is evident throughout this range. Transmitter 23 demonstrated similar performance for the spectrum from 750 kHz to 1250 kHz and is shown in Figure 4-6. This broadband emission was not present at LORSTA Seneca and may be unique to the AN/FPN-42 transmitter.

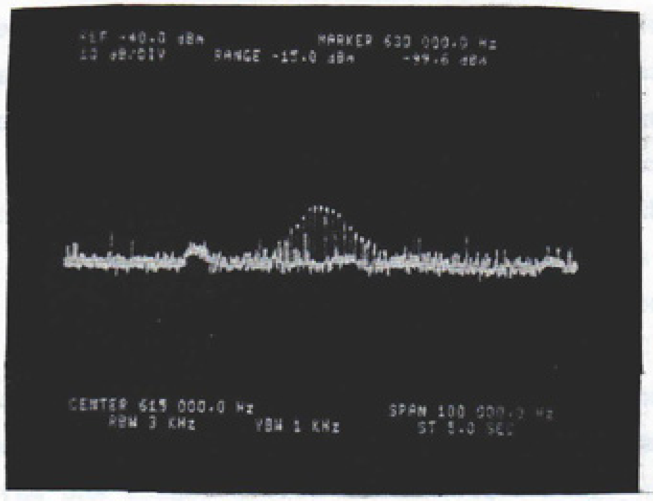

FIGURE 4-4. RADIO FREQUENCY SPECTRUM BETWEEN 565 kHz AND 665 kHz AS OBSERVED AT TEST SITE 2. LORSTA NANTUCKET USING TRANSMITTER 24

FIGURE 4-5. RADIO FREQUENCY SPECTRUM BETWEEN 750 kHz AND 1250 kHz AS OBSERVED AT TEST SITE 2. LORSTA NANTUCKET USING TRANSMITTER 24

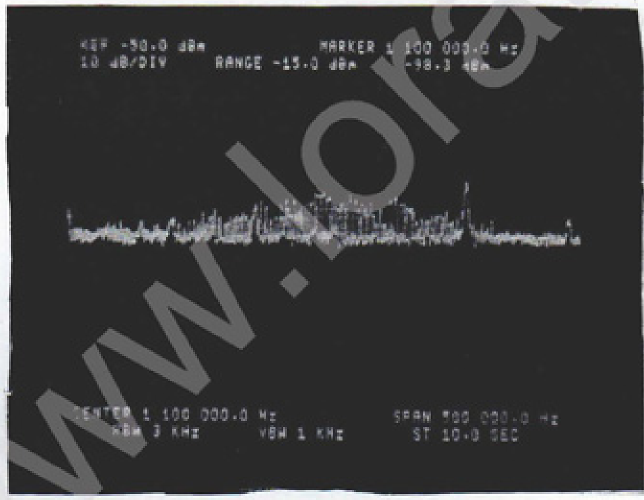

FIGURE 4-6. RADIO FREQUENCY SPECTRUM BETWEEN 750 kHz AND 1250 kHz AS OBSERVED AT TEST SITE 2. LORSTA NANTUCKET USING TRANSMITTER 23

5. TIME DOMAIN MEASUREMENTS AND RESULTS

5.1 EQUIPMENT DESCRIPTION

The HP 5180A waveform recorder was used to sample an input signal at selected intervals and the sampled signal level was converted to an equivalent digital value and stored in the HP 5180A's memory. The sample window is 10 nsec wide and the closest sample spacing is 50 nsec. Samples at LORSTA Nantucket were taken with a sample interval of 200 nsec. This provided 25 samples per half cycle and an excellent reconstruction of the pulse signal for subsequent analysis. The HP 5180A has a data storage capacity of 16,384 locations. This makes it possible, when using the 200 nsec sample interval, to collect a total of four sequential LORAN-C pulses. The initiation of the sample sequence (which continues until the assigned memory capacity has been filled) can be initiated by the signal itself through an internal trigger level set or, as was used in these tests, by an external trigger. A trigger was derived from the cross rate blankers and adjusted in time to initiate a storage cycle starting with pulses 1, 3, or 5, for either phase code. The trigger circuit also permits sample selection of a desired GRI. Sampling was done on the first GRI after crossover of the two rates. This procedure ensures that pulses from the appropriate rate are sampled. Overlapping samples, pulses 3-6, were taken to permit evaluation of pulse spacing from pulse 4 to pulse 5. Using the Tektronix 4052 data terminal, waveform data were transferred to tape storage for later analysis. Figure 5-1 is a diagram of the equipment interconnection.

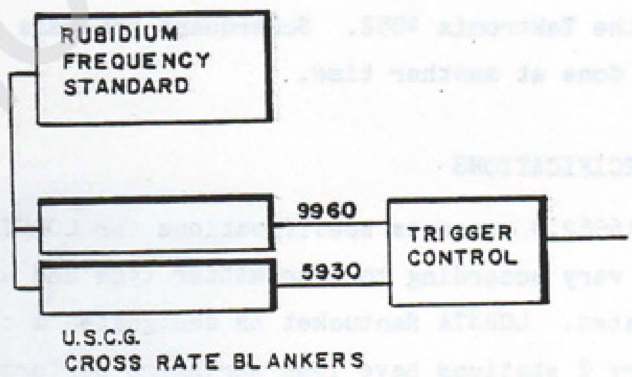

FIGURE 5-1. EQUIPMENT USED TO GENERATE GRI SYNCHRONIZED TRIGGER FOR TIME DOMAIN MEASUREMENTS.

5.2 WAVEFORM ANALYSIS

The pulse samples were analyzed with a special processing program written for the Tektronix 4052. After collecting data on a pulse, the program reviews the data and provides an estimated zero signal level, adjusts the input signal values to this reference, converts the digital storage values to actual volts and provides the plot shown in Figure 5-2. The maximum, or peak value, of the pulse is found by the processing program. The storage location of the peak value is given, together with the position of the maximum peak values. The program then proceeds to identify the 30 microsecond zero crossing, locates five zero crossings below the 30 microsecond point and six above it, establishes the exact relative time, by interpolation, of each crossing and tabulates the results in the terminal display shown in Figure 5-3. Zero crossing offset is reformatted into a curve as shown in Figure 5-4. The tolerance established for zero crossings at LORSTA Nantucket is superimposed with the curve offset as a dotted line. The program then computes an effective envelope to cycle difference (ECD) using the standard Coast Guard algorithm established in EECEN Interim Report No. 1, Project W0899-A4. A sample of the results of this analysis is shown in Figure 5-5, where three successive estimates are printed together with the predicted pulse peak based on the ECD value and the RMS ensemble error in percent of the individual half cycle peaks compared to the approximation. Three values are printed to show the convergence values. (The Coast Guard algorithm is an iterative program and the ECD value is established when two successive approximations have a difference of less than 0.1 microsecond.) The waveform analysis program previously discussed permits on-site, "real-time" evaluation of ECD and zero crossings, using the entire 32 kbyte memory of the Tektronix 4052. Subsequent analysis of pulse spacing, droop, etc., are done at another time.

5.3 WAVEFORM SPECIFICATIONS

COMDTINST M16562.4 presents specifications for LORSTA performance. Time domain standards vary according to transmitter type and whether the station is single or dual rated. LORSTA Nantucket is designated a category 2, dual rated station. Category 2 stations have less stringent performance requirements. The pulse evaluations in the following sections will identify tolerance for LORSTA Nantucket.

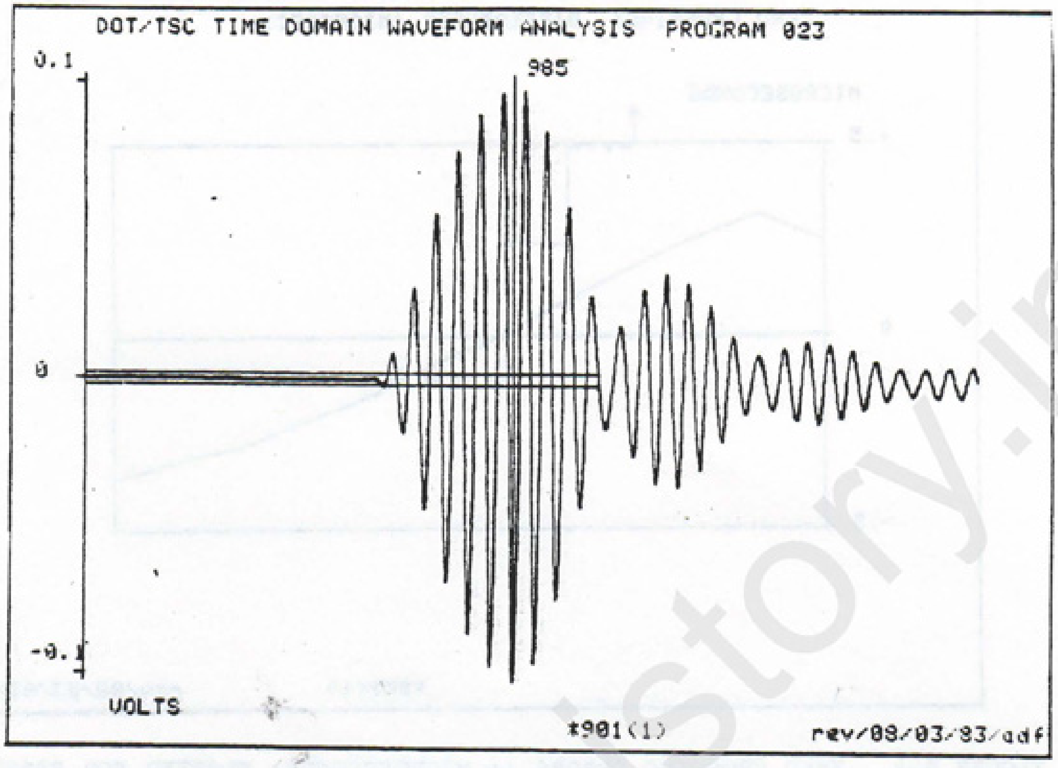

FIGURE 5-2. COMPUTER-GENERATED PLOT OF DIGITIZED LORAN-C PULSE AS COLLECTED AND STORED BY HP 5180A WAVEFORM ANALYZER

DOT/TSC TIME DOMAIN WAVEFORM ANALYSIS PROGRAM 023

ZERO CROSSINGS

REGISTER INDEX	TIME(MICRO SEC) (#6 SET TO 30 MICROSEC)
694.2353	4.7538
718.8679	9.6803
744.1887	14.7444
769.5766	19.8220
795.0063	24.9080
820.4665	30.0000
845.8013	35.0671
871.2273	40.1522
896.5609	45.2189
921.8791	50.2825
947.0646	55.3196
972.3197	60.3706

SCAN AT 200 NSEC INTERVALS

*901(1) rev/08/03/83/adf

FIGURE 5-3. COMPUTER DISPLAY OF ON-LINE COMPUTATION OF LORAN-C ZERO CROSSING TIMES RELATIVE TO THE REFERENCE TRACK POINT AT 30 MICROSECONDS

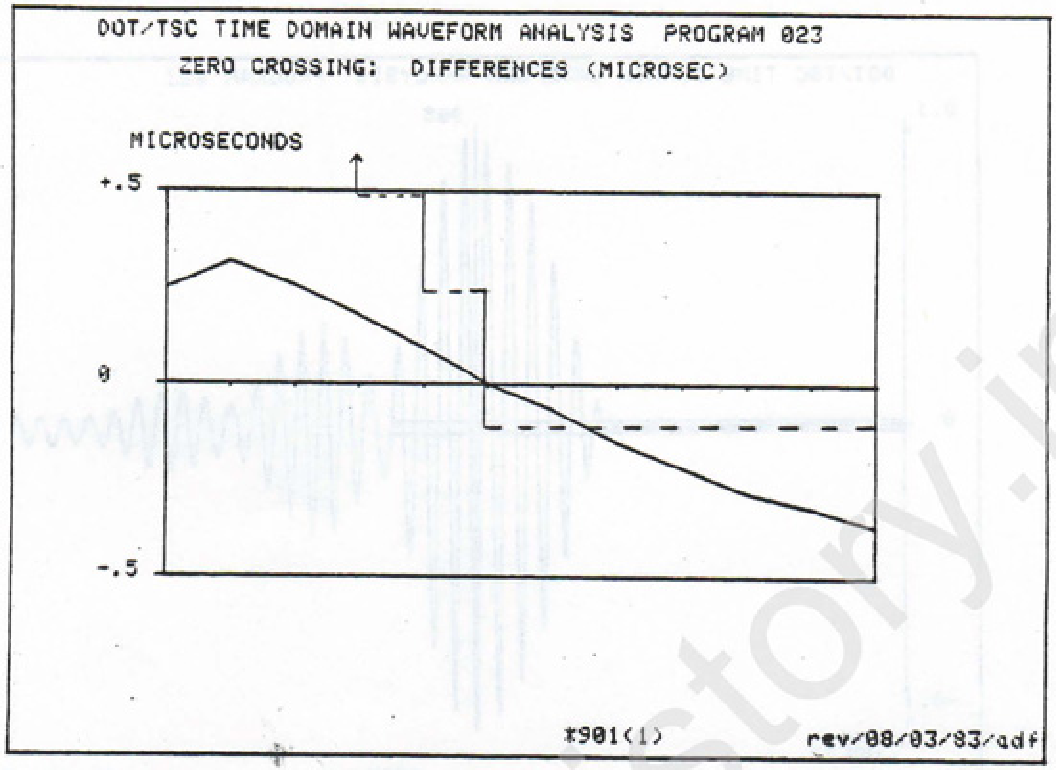

FIGURE 5-4. ZERO CROSSING ERRORS (± MICROSECONDS) PLOTTED FOR FIRST ELEVEN HALF CYCLE INTERVALS. U.S.C.G. TOLERANCES FOR LORSTA NANTUCKET ARE INDICATED BY DASHED LINE

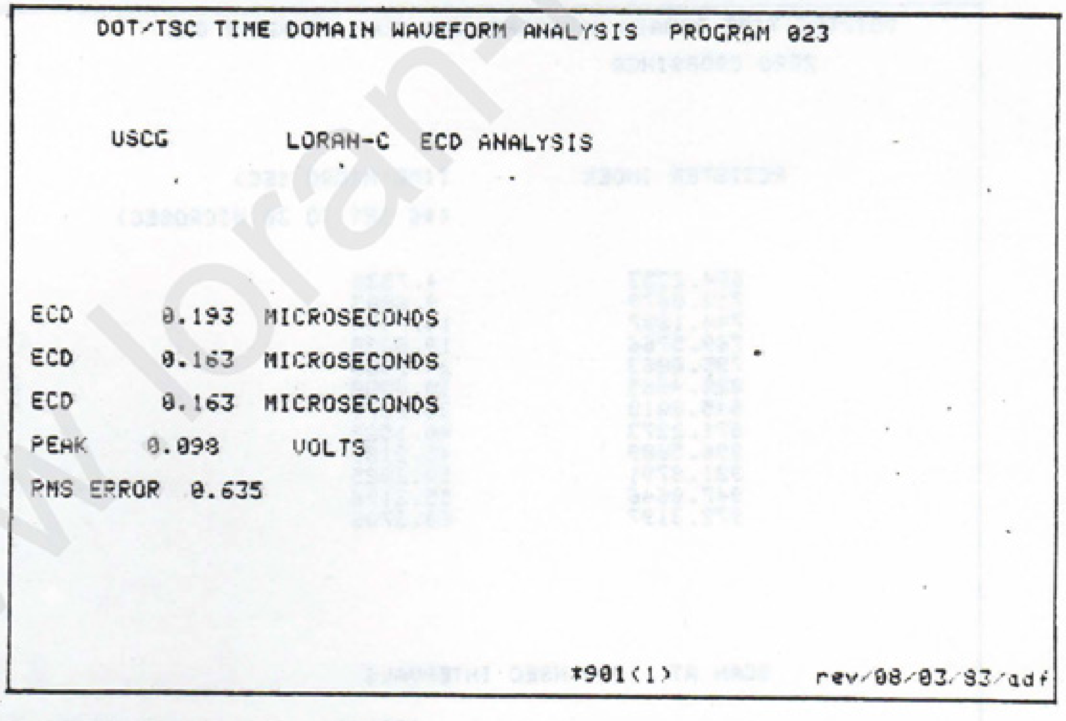

FIGURE 5-5. COMPUTER DISPLAY OF ON-LINE COMPUTATION OF LORAN-C PULSE ECD (ENVELOPE TO CYCLE DELAY) IN MICROSECONDS, COMPUTED PULSE PEAK VALUE (VOLTS) AND THE COMPOSITE RMS ERROR OF THE FIRST EIGHT HALF CYCLE PEAKS (IN PERCENT)

5.4 PULSE WAVEFORM EVALUATION

The majority of the pulse evaluation data collected was obtained from a direct signal connection to the signal output BNC jack on a AN/FPN-60 signal analysis rack. This ensured that a strong, noise-free signal was used. The signal analyzed by the station envelope pulse analyzer was obtained from the same signal splitter in the AN/FPN-60 equipment. Measurements also were made using a loop antenna or a dipole antenna at sites where there was sufficient signal strength. Table 5-1 lists the data collected and analyzed for this report. Each pulse was subjected to the analysis routine described in section 5.2 and compared with the specifications of COMDTINST M16562.4. Results will be presented in the order addressed in COMDTINST M16562.4.

TABLE 5-1. DISTRIBUTION OF PULSE WAVEFORM RECORDS COLLECTED AT LORSTA NANTUCKET FOR TIME DOMAIN ANALYSIS

Site	Signal Source	Transmitter	GRI	Phase Code	Pulse #
Operations Building	Direct connection to signal test point	23	9960	A	1 2 3 4 5 6 7 8
		23	9960	B	1 2 3 4 5 6 - -
		23	5930	A	1 2 3 4 5 6 7 8
		23	5930	B	- - - - 5 6 7 8
Operations Building	Austron Loop	23	5930	A	1 2 3 - 5 6 7 8
		23	5930	B	1 2 3 4 5 6 7 8
Map Site #2	Austron Loop	24	9960	A	1 2 3 4 - - - -
		23	9960	B	- - - - - 6 - 8
	Dipole	23	9960	B	1 2 3 4 5 6 7 8

5.4.1 Half-Cycle-Peak Amplitudes (Ensemble Tolerance ≤ 0.01)

For data collected on the first pulse in each group using the direct connected test signal, it was found that none of the averages exceeded 0.01 and all were within specifications. For data collected using the loop antenna, ensemble averages were 0.016 and 0.014. Loop antenna measurements at map site 2 have an ensemble average of 0.017. All field measurements were found to be outside the allowed limits. This may be due in part to the intrusion of external noise and reradiated signals with a consequent effect on calculations. The ensemble results using data obtained by the HP 5180A were checked against that obtained by station personnel using the same waveform and a differential plug-in. Differences were less than 1 percent.

5.4.2 Pulse Trailing Edge (The trailing edge must be equal to or less than 0.016 of the peak value at times greater than 500 microseconds.)

The analog-to-digital quantitization of the input signal to the recorder into 1024 levels centered on zero provides a maximum dynamic range capability of 54 dB. The presence of system background noise reduces this to about 48 dB. The specification of the trailing edge requires that the signal amplitude by -57 dB relative to the pulse peak after time t=500 microseconds. In view of the system limitations, it is not possible at present to directly monitor the trailing edge at t=500 microseconds. Examination of pulse records obtained from the AN/FPN-60 test point showed that the trailing edge disappeared into the system ambient noise level at t=400 microseconds. A logarithmic plot of the successive cycle amplitudes in the range t=250 to t=375 microseconds indicated an envelope decay rate of approximately 0.2 dB/microsecond. This rate, if sustained, would reduce the signal amplitude to the -57 dB level at a time between t=475 and t=550 microseconds. The Nantucket pulses appear to meet the standard.

5.4.3 Zero Crossing Times and Tolerances within a Pulse (Times vary with cycle number prior to the standard zero crossing, then must be plus or minus 100 nsec for successive cycles to the 60 microsecond point where the zero crossings must conform to 100 kHz ± kHz.)

Information was collected on over 50 individual pulses using transmitters 23 and 24 for phase codes A and B. For zero crossings prior to t=30 microseconds, i.e., 5, 10, 15, 20, and 25, all crossings were found to be well within tolerance. Transmitter 23 exhibited a linearly increasing time delay which, at t=60 was in excess of 300 nsec. Effective pulse frequencies were found to lie in range of 97.2 to 98.8 kHz for positive pulses. Negative code pulses were 0.1 to 0.4 percent higher in frequency than adjacent positive code pulses in the same group. At times beyond 35 microseconds, all transmitter 23 pulses exceeded zero crossing and frequency tolerances. Transmitter 24 was within tolerance for zero crossings and frequency. Table 5-2 presents this information for a representative pulse group.

5.4.4 Uniformity of Pulses within a Group

5.4.4.1 Pulse-to-Pulse Amplitude Tolerance (The amplitude of the smallest pulse in a group cannot differ from the amplitude of the largest pulse in the same group by more than 20 percent.) - As has previously been discussed, measurements for all pulses in a group were accomplished by taking three pulse group samples. Calculations of pulse droop for both rates and for both transmitters resulted in an effective droop of less than 5 percent, which means that the Nantucket transmitters meet the more stringent droop requirements of a single rated category 1 station.

5.4.4.2 Pulse-to-Pulse ECD Tolerance (Each pulse must be within 1.5 microsecond of the average of all pulses.) - Analysis of the pulse groups showed that the deviation of the ECD values from the average of all pulses was not more than 0.6 microsecond, comfortably within the 1.5-microsecond tolerance. The distribution of the ECD values about the average caused considerable concern. Table 5-3 shows the ECD data for transmitter 23 on phase code A, rate 5930. There is a 1.1 microsecond ECD offset between the average of positive and negative pulses. This offset was not confirmed by either the envelope pulse analyzer (EPA) or from data obtained from an oscilloscope using a differential amplifier. Use of the half cycle peak values determined by the EPA and oscilloscope did, however, give identical results when manually inserted into the Tektronic 4052 ECD program as when computed using station equipment. After much discussion and selective sampling, it was hypothesized that the offset existed and that it was related to the crossover position of the two rates. Measurements by the EPA and the oscilloscope reflect an "average" value while that of the HP 5180A was a record of one pulse group taken at a time when the transmitter was stressed. Observations of the pulse train were taken at a "random" point in the interval and the hypothesis was confirmed in that the ECD offset between positive and

TABLE 5-2. TIME DOMAIN PULSE ANALYSIS LORSTA NANTUCKET. TRANSMITTER 23; SIGNAL SOURCE: AUSTRON LOOP; SITE: TRANSMITTER OPERATIONS BUILDING; GRI 5930; PHASE CODE B

Pulse Number	Phase Code.	ECD (microseconds)	Signal peak (volts) computed	Signal peak (volts) measured	Effective carrier frequency (kHz)	RMS error (%) of first eight half-cycle peaks	Offset from standard zero crossing (microseconds)
1	+	.64	.093	.099	99.1020	1.61	0
2	-	-.435	.092	.0978	99.3878	1.649	.136
3	+	+.805	.091	.0982	98.905	1.68	.052
4	-	-.817	.091	.0984	99.3832	1.88	.124
5	+	+1.042	.087	.094	99.0805	1.722	.078
6	+	+1.112	.086	.0931	99.1120	1.631	.130
7	-	-.542	.086	.931	99.5012	1.85	.070
8	-	-.500	.086	.929	99.5177	1.826	.115

TABLE 5-3. COMPUTED ECD VALUES LORSTA NANTUCKET. TRANSMITTER 23; SIGNAL SOURCE: AUSTRON LOOP; SITE: OPERATIONS BUILDING; GRI 5930; PHASE CODE A

Pulse #	Phase Code	Computed ECD (microseconds)
1	+	.572
2	+	.993
3	+	1.168
-	+	
5	+	.757
6	-	-.939
7	-	-.496
8	+	.766

negative pulses disappeared. The random sampling was done by triggering the HP 5180A somewhere during the pulse sequence. The sampling technique was not reproducible; thus, it was considered undesirable for routine use since the analysis of the pulse train mandates controlled triggering.

5.4.4.3 <u>Pulse-to-Pulse Timing Tolerance</u> (Successive pulses must satisfy the standard (N-1)(1000) $\pm$ 100 nsec + C, where C = 0 for positive phase coded pulses and $|C| \leq 150$ nsec for negatively phase-coded pulses.) - The LORSTA Nantucket transmitters satisfied this requirement. Table 5-4 shows representative results for transmitter 23 on rate 9960. The mean offset of negative phase code pulses, C, was less than 100 nsec. Group-to-group offset throughout the interval was not measured due to the large number of observations which would have been required. The AN/FPN-54 cycle compensation servo loop was not hunting, implying a net balance between positively and negatively coded pulses.

TABLE 5-4. PULSE-TO-PULSE TIMING ERROR (MICROSECONDS) LORSTA NANTUCKET. TRANSMITTER 23, GRI 9960, CODE A

Pulse #	Phase Code	Pulse to Pulse timing error. (microseconds)
1	+	0
2	+	.014
3	+	.023
4	+	.032
5	+	.020
6	-	.082
7	-	.088
8	+	.024

6. DISCUSSION OF OBSERVATIONS AND RESULTS

6.1 FREQUENCY DOMAIN

6.1.1 Spectrum

When rounded to the nearest 1 percent, the spectrum of the AN/FPN-42 LORAN-C transmitters at Nantucket proved to meet Coast Guard requirements for radiated energy in-band. As was observed previously at LORSTA Seneca, there is no significant variation in results between sites when LORAN-C signals are sufficiently above background noise levels. It appears that the adjustment of transmitter 24 is slightly better than that of transmitter 23 since its spectrum is closer to the standard. Station personnel were very interested in the results of our observations. They cannot monitor spectrum performance because they do not have the necessary test equipment.

6.1.2 Harmonics

The performance of both transmitters was quite similar. Harmonics did not roll-off in the same fashion as observed at LORSTA Seneca; however, it can be noted that the third and higher harmonics were partially masked by background noise at Sankaty Head lighthouse which is located 1.8 miles from the station and unidentifiable beyond 800 kHz.

6.1.3 Spurious Emissions

The bands of LORAN-C emissions between 605 to 625 kHz and between 800 and 1200 kHz were considered spurious and no attempt was made to use the energy information as part of the in-band spectrum computations. Since the emissions are only 40 dB down from the peak, they can interfere with broadcast band radio stations. Interference was confirmed by tuning a car radio through the broadcast band. Characteristic LORAN-C "clicking" was clearly discernable. Station personnel were aware of the emissions, but did not have any identified procedure to control or reduce them.

6.2 TIME DOMAIN MEASUREMENTS AND RESULTS

6.2.1 HP 5180A Waveform Analyzer Capabilities

Two characteristics of the HP 5180A which have significant effect on making LORAN-C measurements will be briefly discussed.

6.2.1.1 Retrigger Time - The HP 5180A requires that samples be initiated no more often than every 5 msec. This limitation precludes partitioning the memory into eight sections and sampling each LORAN-C pulse in a group with triggers set at 1 msec. Selection of 200 nsec sampling intervals and taking four samples in a pulse group was therefore established as a compromise between obtaining maximum samples on the pulse and establishing a manageable rate between taking samples of pulse groups.

6.2.1.2 Signal Input - As noted in section 5.4.2, the maximum effective dynamic range of the HP 5180A when centered on 0.0 is 54 dB. The minimum input range for the analyzer is 100 mV peak. Care must be exercised in selection of the sensor to ensure that the signal has low noise and at least a 200 mV peak-to-peak amplitude. The noise on the signal from the AN/FPN-60, after passing through the RG-58 transmission line and attenuator, was sufficiently low that readings could be made. Experiments were conducted using a broadband amplifier with a 50 ohm output impedance inserted between the test jack and the HP 5180A. This experiment produced no discernable difference. The offset between positively and negatively phase-coded pulses caused consternation because it clouded the issue on whether the signal-to-noise margin was adequate for the sampling procedure in use.

6.2.2 Waveform Analysis

The 32 kbyte memory limitation of the Tektronix 4052 was a dominant factor throughout the development of the sampling and analysis programs used with the HP 5180A. It was not possible to write a program to analyze all aspects of the LORAN-C pulse with the available memory space. The ECD, the pulse ensemble error, the standard sampling point identification and zero crossing determination parameters selected for on-site analysis were considered the most critical in ensuring that the sampled data were good. Identification of the first half cycle posed a special problem. Figure 6-1 shows a representative pulse from transmitter 23.

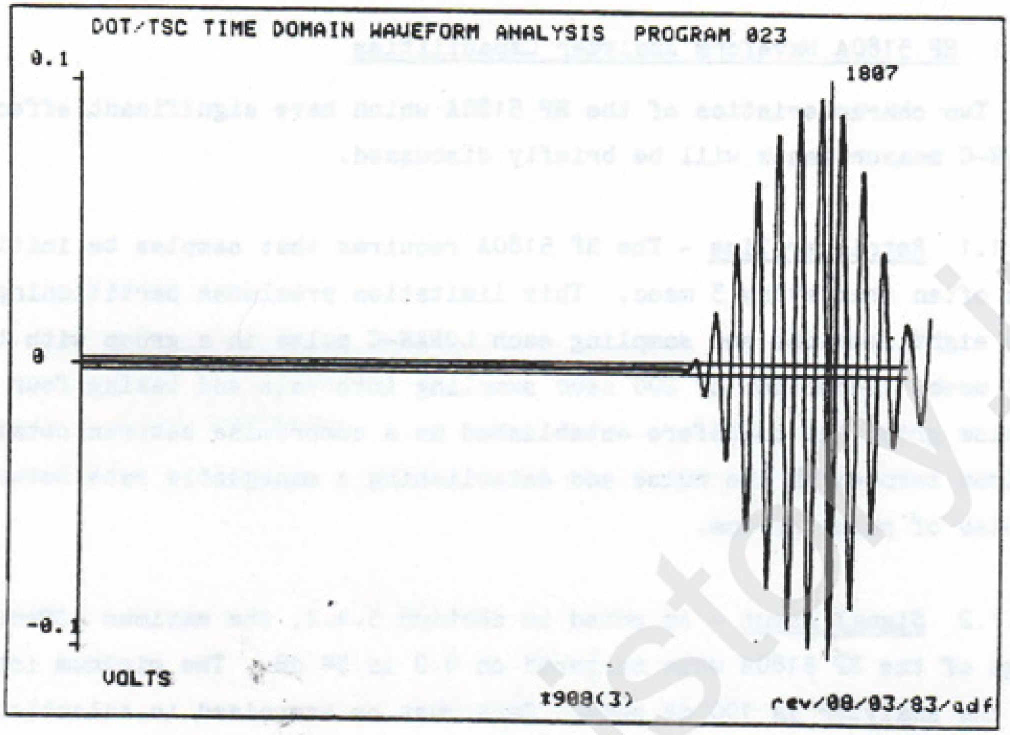

FIGURE 6-1. LORSTA NANTUCKET: TRANSMITTER 23, GRI 5930, CODE A, PULSE 6

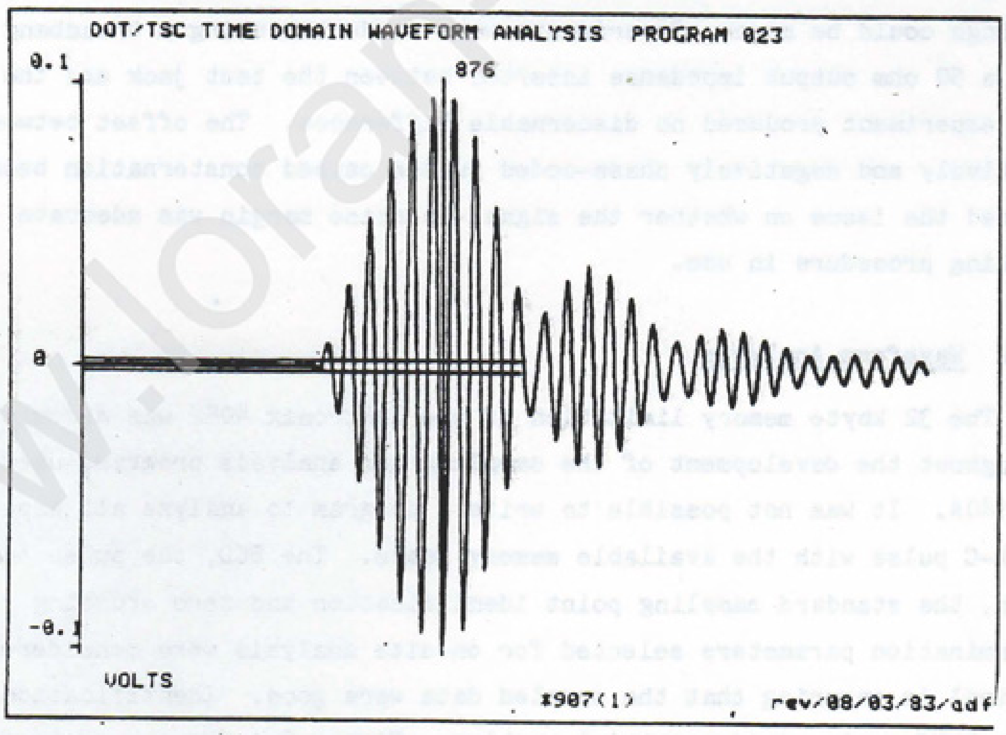

FIGURE 6-2. LORSTA NANTUCKET: TRANSMITTER 23, GRI 5930, CODE B, PULSE 5

Inspection shows that there are 14 half cycles before the pulse peaks. Figure 6-2 shows a pulse with only 13 effective half cycles. Operator interaction is used to advise the Tektronix 4052 of the correct number of half cycles to be used to establish the standard sampling point. Incorrect cycle selection normally produces an ECD value greater than ±2.5 microseconds. Creation of a more sophisticated sampling point identification program would have required dropping some other pulse analysis parameter.

6.2.3 Pulse Waveform Evaluation

Evaluation of station performance is straightforward but time consuming due to the large amount of data which are available and which must be used for analysis. The storage medium for the Tektronix 4052 is a reel-to-reel cassette which holds a nominal 300 kbytes of data. Partitioning requirements, etc., are such that an entire cassette is used for each time domain sample. This presents a logistics challenge in that 20 cassettes are needed for time domain data collection etc., where only one cassette is needed for all frequency domain measurements and analysis.

6.2.4 Sampling Time

Selection of the sample time with respect to GRI crossover at a dual-rated station is important. For a station such as LORSTA Nantucket, with resident GRIs of 9960 and 5930, the rate difference of 40,300 microseconds produces pulse overlap every few GRIs. The first GRI after rate coincidence was selected for sampling because it ensures an unambiguous sample. During the field trip to Nantucket, our sample trigger could be moved integer numbers of GRI, but was reset with a pulse derived from overlap of the two, 10 msec local intervals generated by the GCF-W-541A-B LORAN cross rate blankers. Since then, the circuit has been modified to lock-out a GRI coincidence reset pulse for approximately 5 seconds. This modified circuit permits the selection of any one of the approximately 50 different GRI for use as a pulse sample. The circuit has also had a separate counter added which generates 16 pulses, coincident with the blanker GRI, initiated by GRI crossover. Thus, change from the existing sample GRI can be made, if desired.

7. SUMMARY AND FINDINGS

7.1 SUMMARY

This report presents the results of LORAN-C field measurements made in the vicinity of LORSTA Nantucket on 9 to 12 August 1983. The measurements were made with the principal objective of gathering sufficient data to ensure that the HP 5180A waveform recorder was adequate for use as a measurement standard to establish LORSTA time domain signal characteristics. A secondary objective was to document the frequency domain signature of LORSTA Nantucket. The report presents data in two sections, one for frequency domain signature and one for time domain signature.

7.2 FINDINGS

7.2.1 Frequency Domain

o Computations of percentage of in-band power for five sites showed an overall average value of power in-band of 98.8 percent for transmitter 23 and 99.0 percent for transmitter 24. Out-of-band power was unevenly distributed, with approximately two-thirds below 90 kHz and one-third above 110 kHz.

o Harmonic content from both transmitters was similar. The second harmonic was approximately 39 dB down from the peak, while the third through twelfth harmonics were approximately 50 dB down from the peak. No harmonics were discernable above background noise above 800 kHz at Sankaty Head lighthouse, a distance of 1.8 miles from the LORSTA.

o Spurious emissions were identified from each transmitter in two discrete bands. The emissions caused interference in the broadcast band in the vicinity of the LORSTA.

7.2.2 Time Domain

o Data obtained by the HP 5180A waveform analyzer was adequate to determine the time domain characteristics of a LORSTA signal.

- Comparison of ECD computations performed by LORSTA equipment and the DOT/TSC computer program executed on the Tektronix 4052 showed no significant difference.
- Pulses radiated by LORSTA Nantucket met or exceeded requirements of COMDT-INST M16562.4, except for the zero crossings and the effective carrier frequency of transmitter 23 beyond the standard 30 microsecond sampling point.