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Loran C Monitor Collocation Tests

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February 1987

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16. Abstract

The Federal Aviation Administration (FAA) and other segments of the aviation community are becoming increasingly aware of the potential of Loran C navigation for use in en route flight and, more recently, for nonprecision approach operations. As part of an overall response to user's requirements, the FAA is planning to implement a network of approximately 100 Loran C monitors within the United States. These monitors will be designed to provide current status of Loran C stations for use by the aviation community. This information is necessary for conducting consistently reliable Loran C nonprecision approaches. For economic and logistical reasons, consideration is being given to collocating the planned Loran C monitors at existing very high frequency omnidirectional range tactical air navigation (VORTAC) sites. The purpose of this test was to perform an initial investigation of VORTAC/Loran C monitor collocation and VORTAC/remote communication air-to-ground (RCAG)/Loran C monitor collocation. The test results indicate that a Loran C monitor can be collocated at a VORTAC/RCAG site. The preferred monitor site locations are on top of the Tactical Air Navigation (TACAN) detector pole or remote from the VOR (250 feet from the VOR).

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EXECUTIVE SUMMARY

The Federal Aviation Administration (FAA) and other segments of the aviation community are becoming increasingly aware of the potential of Loran C navigation for use in en route flight and, more recently, for nonprecision approach operations. As part of an overall response to user's requirements, the FAA is planning to implement a network of approximately 100 Loran C monitors within the United States. These monitors will be designed to provide current status of Loran C stations for use by the aviation community. This information is necessary for conducting consistently reliable Loran C nonprecision approaches. For economic and logistical reasons, consideration is being given to collocating the planned Loran C monitors at existing very high frequency omnidirectional range tactical air navigation (VORTAC) sites. The purpose of this test was to perform an initial investigation of VORTAC/Loran C monitor collocation and VORTAC/remote communication air-to-ground (RCAG)/ Loran C monitor collocation. The test results indicate that a Loran C monitor can be collocated at a VORTAC/RCAG site. The preferred monitor antenna site locations are on top of the tactical air navigation (TACAN) detector pole or remote from the VOR (250 feet from the VOR).

INTRODUCTION

OBJECTIVE.

The objective of this project was to determine if a Loran C monitor could be collocated at a very high frequency omnidirectional range tactical air navigation (VORTAC) site.

BACKGROUND.

The Federal Aviation Administration (FAA) will install Loran C monitors at 102 locations across the United States to support Loran C nonprecision approaches. Loran C has been included in the National Airspace System (NAS) Plan. The monitor specifications are described in item 1 "Related Documentation."

In the interest of economics, the FAA plans to consolidate the location of airways navigation and communication facilities at a common site. For example, it is intended to collocate remote communication air-to-ground (RCAG) and very high frequency omnidirectional ranging (VOR) distance measuring equipment (DME) locations.

The purpose of the Loran C monitors are: to respond to the increasing use of Loran C by continuously monitoring Loran C signals and provide advisories on signal status to assure safe nonprecision approach operations. The monitor receives Loran signals from a single chain of stations and compares measured time differences (TD's) with expected TD's for the geographic position of the monitor. In the event observed TD's or signal-to-noise ratios (SNR's) exceed specified limits or other monitored parameters, such as blink or loss of signal occur, an alarm signal shall be sent to the Air Traffic Control Point (ATCP) and to the Remote Monitoring Subsystem (RMS) to advise Loran C users in the vicinity. The monitors will furnish TD correction values for nonprecision approaches. The TD correction values are necessary to resolve seasonal TD variations and reduce airborne receiver coordinate conversion biases.

RELATED DOCUMENTATION.

1. Loran C Monitor Specification, FAA-E-2762.

2. Luciani, V. J., NAFEC Range Instrumentation Systems, Report FAA-NA-79-32, February 1980.

3. VORTAC Siting Criteria, Handbook 67000.11.

4. United States Flight Inspection Manual, OP8200.1.

EQUIPMENT AND DATA COLLECTION

GROUND EQUIPMENT.

The Experimental VORTAC Facility located at building 196 is described herein. The FA-9969 VOR, reference figure 1, is a completely solid-state system providing identification and azimuth navigation information to aircraft. A ground transmitter radiates continuous wave signals on 1 of 40 channels between 108 and 112 megahertz (MHz) or 1 of 120 channels between 112 and 118 MHz. The assigned VOR frequency for the facility is 111.65 MHz and the tactical air navigation (TACAN) channel is 53Y. A cardioid antenna pattern rotates 30 times per second generating a 30-hertz (Hz) amplitude modulated (AM) signal to airborne receivers with a phase angle proportional to the aircraft bearing from north. A 30-Hz frequency modulated (FM) reference signal is also radiated omnidirec- tionally on a 9960 Hz subcarrier. The airborne receiver determines bearing as a function of phase difference between the detected FM and AM 30-Hz signals.

The VOR monitor utilizes a microcomputer design and, in conjunction with ground check equipment, performs all VOR monitoring functions. If a discrepancy occurs in the monitored parameters, the monitor shuts down the VOR transmitter. The VOR monitor unit is redundant, containing two identical and independent monitors. During executive monitoring, 1 of 16 antennas (typically at 90° or 270° radials in a conventional VOR station) is selected and designated by the monitor as the executive antenna. For these tests monitor number 1 and the 270° radial antenna were selected.

The radio frequency (RF) signal from the executive antenna is routed to the RF level detector which provides an RF level output that is proportional to the VOR carrier and is routed to the VOR monitor.

Monitor executive and ground check data were collected from the FA-9969 equipment during the test. The VOR monitor was used to determine the VOR functioned properly during all phases of test. The data included the following parameters:

VOR Monitor Ground Check Data

Parameter	Units
Azimuth error	Degrees
Duantal error	Degrees
Octantal error	Degrees
Quadrantal error	Degrees

VOR Monitor Executive Data

AZ angle	Degrees
30 Hz mod.	Percent
9960 Hz dev.	Percent
Field intensity	-
Ident	-

The Extended Area Instrumentation Radar (EAIR) was used to provide reference data to determine bearing error for orbital and radial flights. Detailed information concerning the EAIR is presented in item 2 Related Documentation.

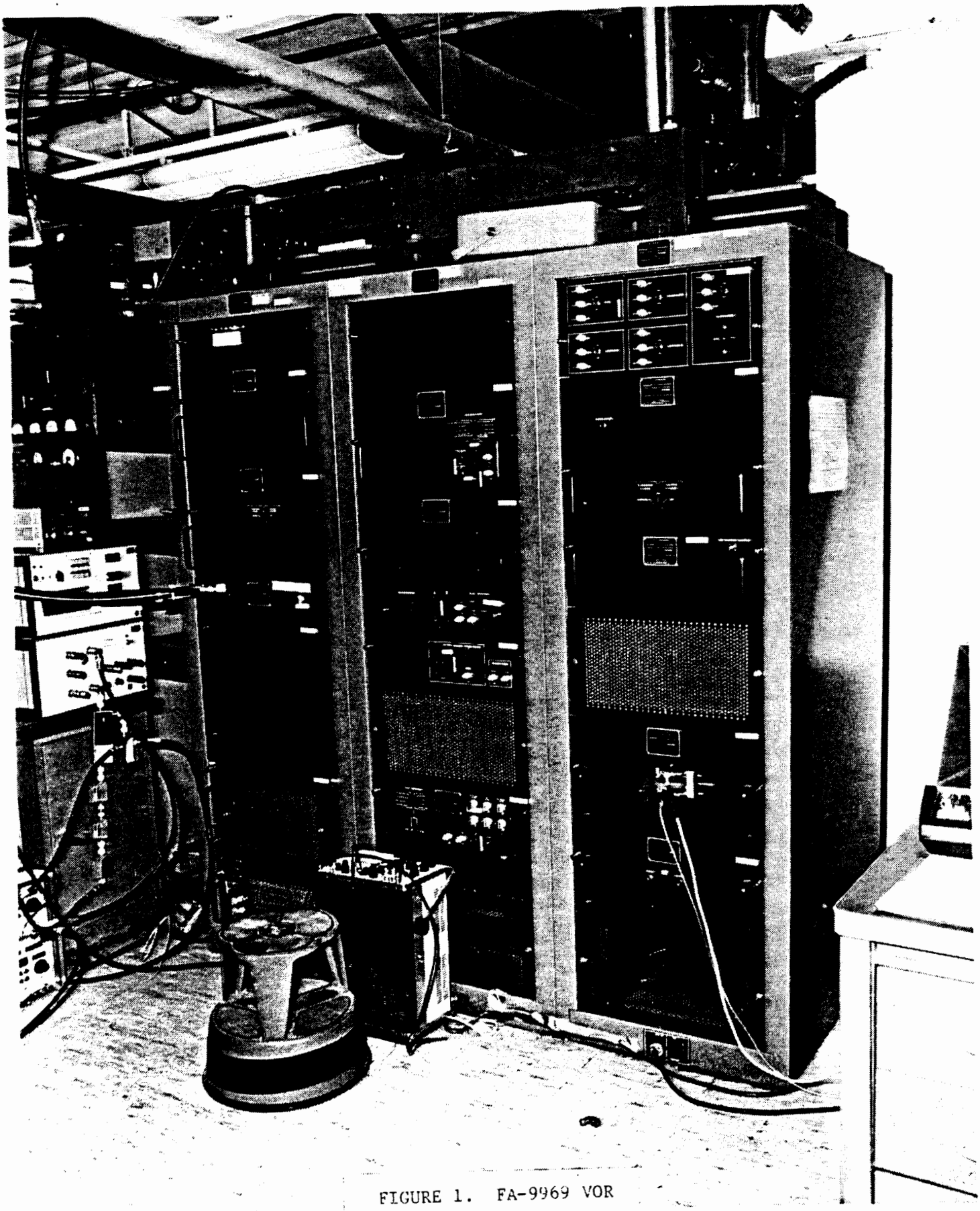

FIGURE 1. FA-9969 VOR

A Northstar 7000 Loran C receiver was used as the monitor receiver. A Northstar 7000 peripheral interface unit provided a 132-byte word every 3 seconds to an RS-232 serial port of a Zenith 152 personal computer (PC). The information was displayed on a monitor screen and recorded on a disk. A block diagram of the test equipment is shown in figure 2. Data reduction and plotting were accomplished post-test using a Hewlett Packard (HP) 1000 computer located in the Flight Operations building.

The following Loran C parameters were collected from the Loran C receiver during the ground and flight tests: master and secondary station TD's and SNR's for the dedicated triad MXY and any alarm indications.

The RCAG installation contains 24 communications receiver/transmitter units operating on the assigned VHF and UHF frequencies listed in table 1 (see figure 3).

TABLE 1. RCAG FREQUENCIES

VHF MHz	UHF MHz
118.025	267.575
118.425	268.15
118.725	268.625
119.225	298.95
119.825	299.35
120.375	299.85
121.275	363.725
123.725	365.35
126.375	366.35
127.375	373.85
128.625	374.75
132.425	377.05

Each transmitter radiates power at 10 watts. There are two antenna poles, one for receive and one for transmit. Each antenna pole has six radiating elements. Each radiating element is interfaced to four receivers or transmitters through frequency combiners. The antennas are mounted on two fiberglass poles aligned with the VORTAC 270° (receiver antennas) and 90° radial (transmit antennas) approximately 70 feet from the center of the VOR and 30 feet high. The pole located on the 270° radial is shown in figure 4. The poles can be raised and lowered as required.

AIRBORNE EQUIPMENT.

Flight tests at the VORTAC site with the Loran C monitor antenna installed at different locations were accomplished using an FAA Convair 580 aircraft equipped with a flight inspection rack. The flight inspection console consisted of one

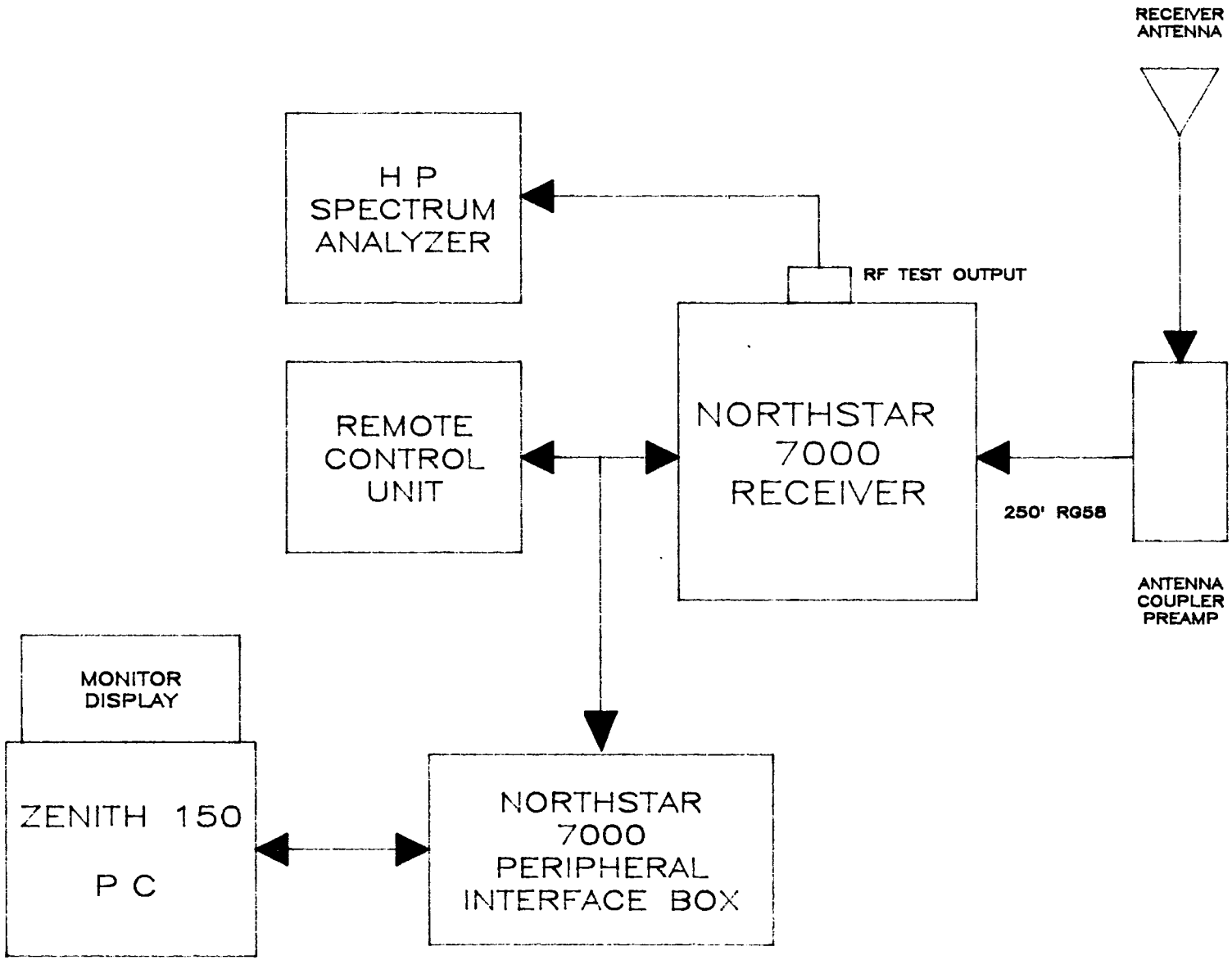

FIGURE 2. LORAN C TEST UNIT

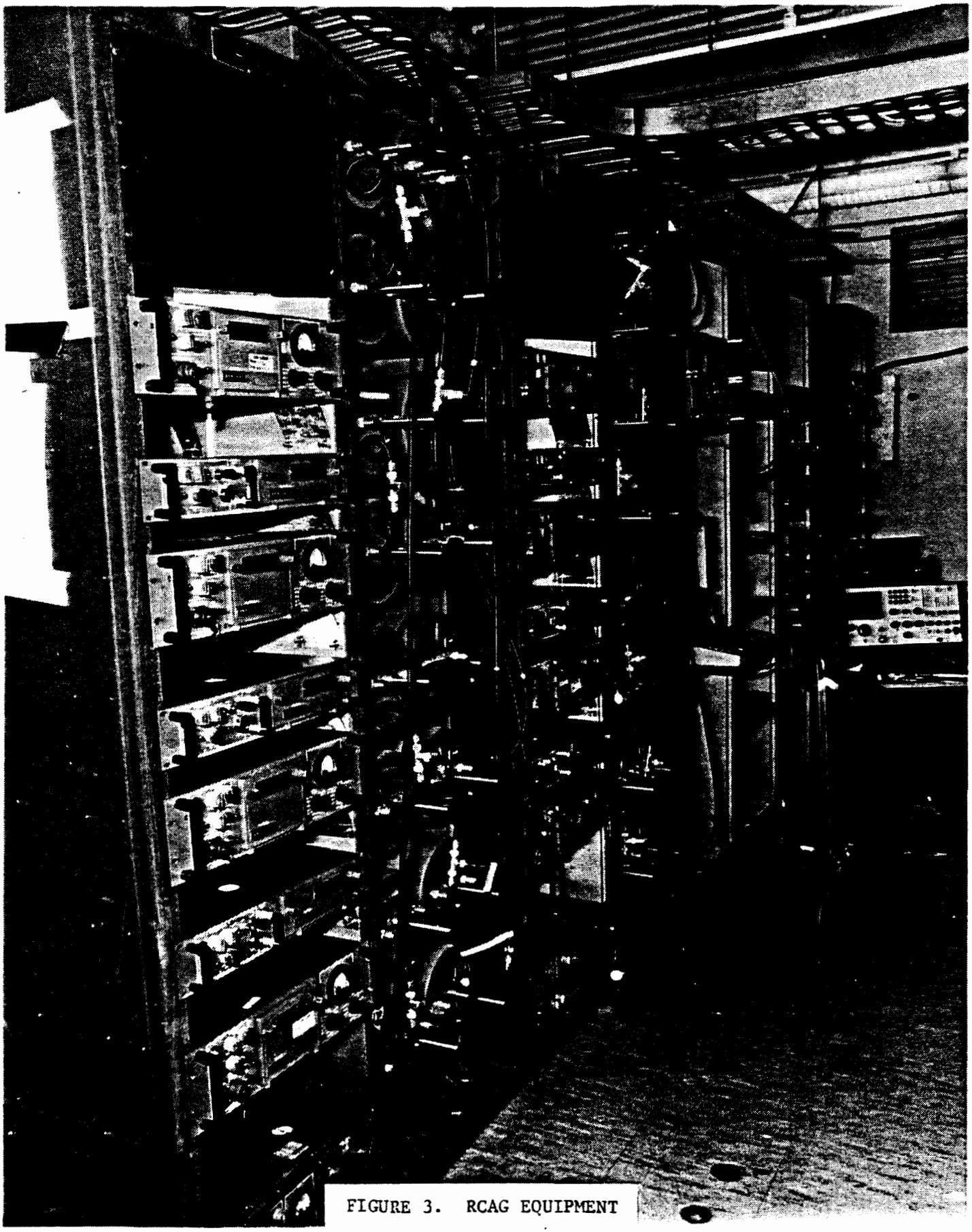

FIGURE 3. RCAG EQUIPMENT

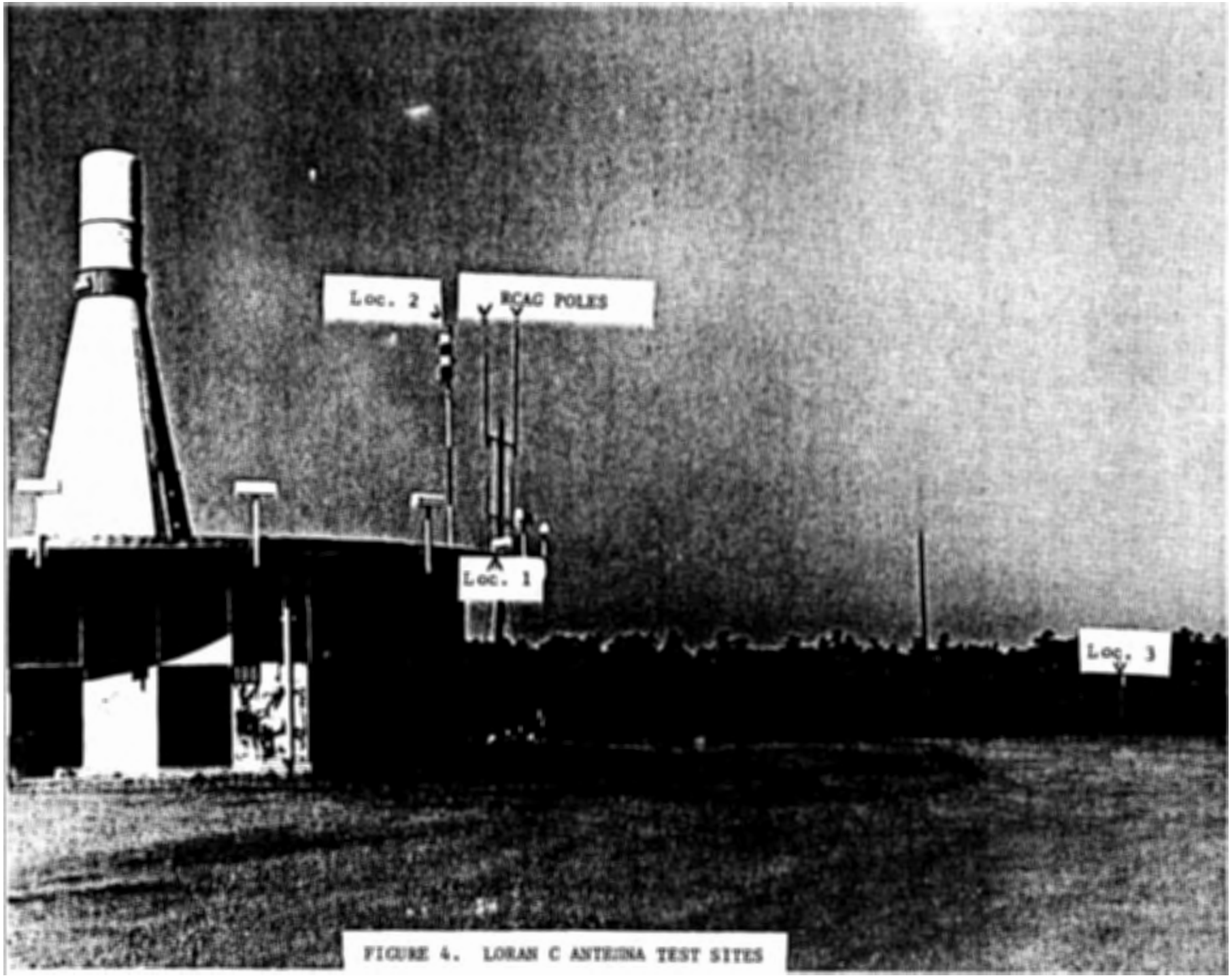

FIGURE 4. LORAN C ANTENNA TEST SITES

VOR receiver, an analog data recorder, and other related subunits. Bearing position reference for all flight testing was obtained from EAIR. Coordination for all testing was accomplished via a very high frequency (VHF) communications link.

VOR site parameters were measured with the flight inspection system and recorded manually on a strip chart recorder. Data collected included VOR course deviation, field strength, Automatic Gain Control (AGC), and modulation levels.

TEST PROCEDURES

GROUND.

The Loran C antenna was tested at three locations on the 270° radial at the VOR site (see figure 4). Location number 1, figure 5, was at the edge of the VOR counterpoise. Location number 2, figure 6, was at the top of the TACAN detector pole, 20 feet from the counterpoise and 37 feet high. Location number 3, figure 7, was a pole 5 feet high, mounted in the ground on the 270° radial, 250 feet from the VOR.

Tests were conducted at the three antenna sites with the VOR energized and deenergized. Loran C data were collected every 3 seconds for 5 minutes duration with the VOR energized, and for 5 minutes duration with the VOR deenergized over a 1-hour interval at each of the three Loran C antenna locations. This provided six 5-minute intervals with the VOR energized, and six 5-minute intervals with the VOR deenergized. Recordings were taken from the Loran C receiver and comparisons were made with the Loran C data for the condition when the VOR was energized and deenergized. The receiver control display unit was used to monitor station Y SNR.

VOR monitor and ground check data were recorded during the tests to observe any VOR abnormalities. The Loran C receiver RF spectrum was monitored with a spectrum analyzer (model number HP 8566A) for interference between 80 to 120 kHz.

VOR monitor and ground check data were recorded with the Loran C antenna in place at the three locations. The data was compared between each of the three locations to determine the effects of the antenna on VOR performance. Baseline VOR data were also recorded without the Loran C antenna installed.

Tests were conducted at the three antenna locations with the VOR system energized and the RCAG antenna poles raised. The 24 VHF communication transmitters were keyed with no modulation for six 5-minute intervals. After each 5-minute interval, the receiver/transmitters were operated in a quiescent mode without keying for 5 minutes. Loran C TD and SNR data were recorded over each 5-minute interval. The data were plotted and statistically analyzed to determine any interference effects.

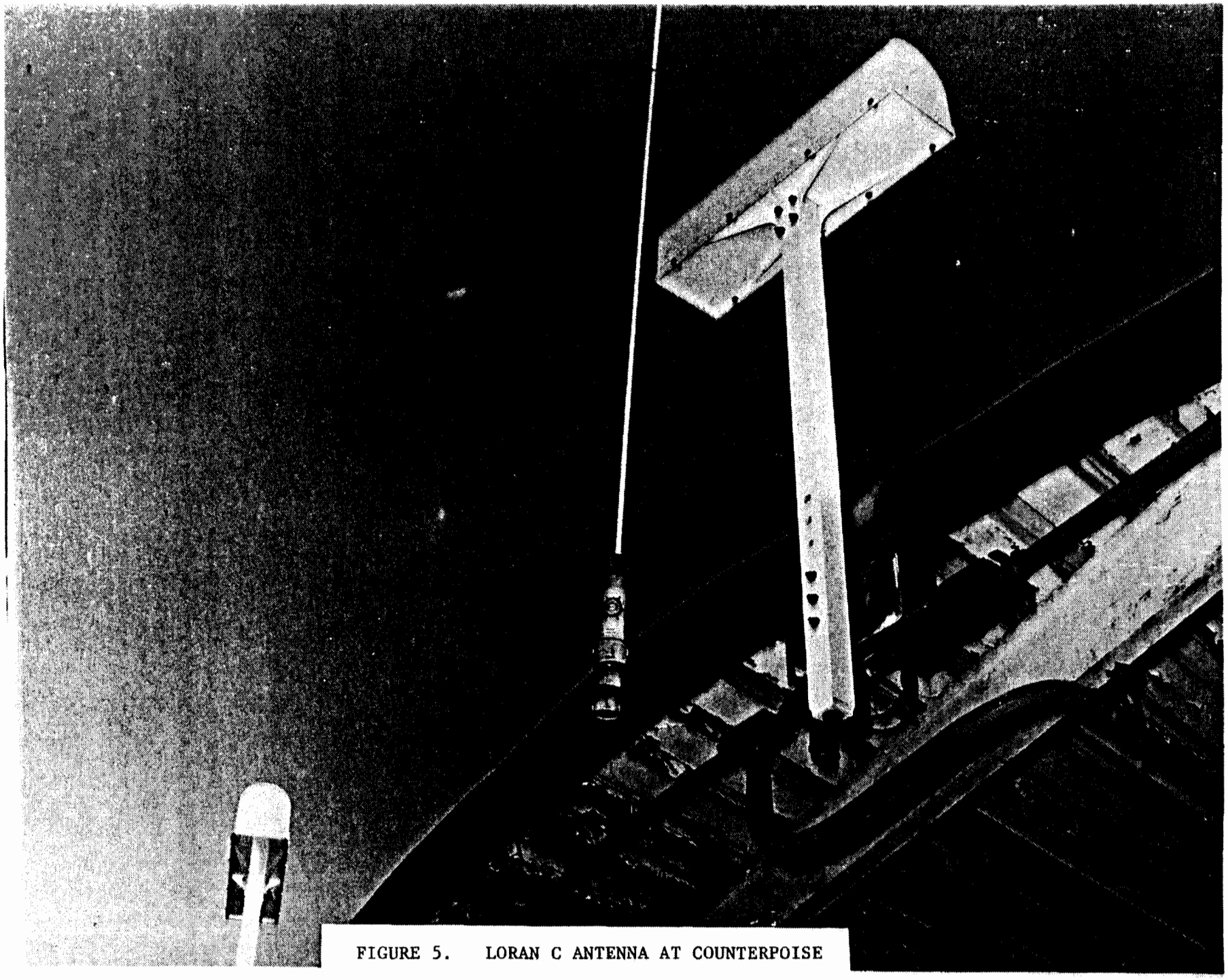

FIGURE 5. LORAN C ANTENNA AT COUNTERPOISE

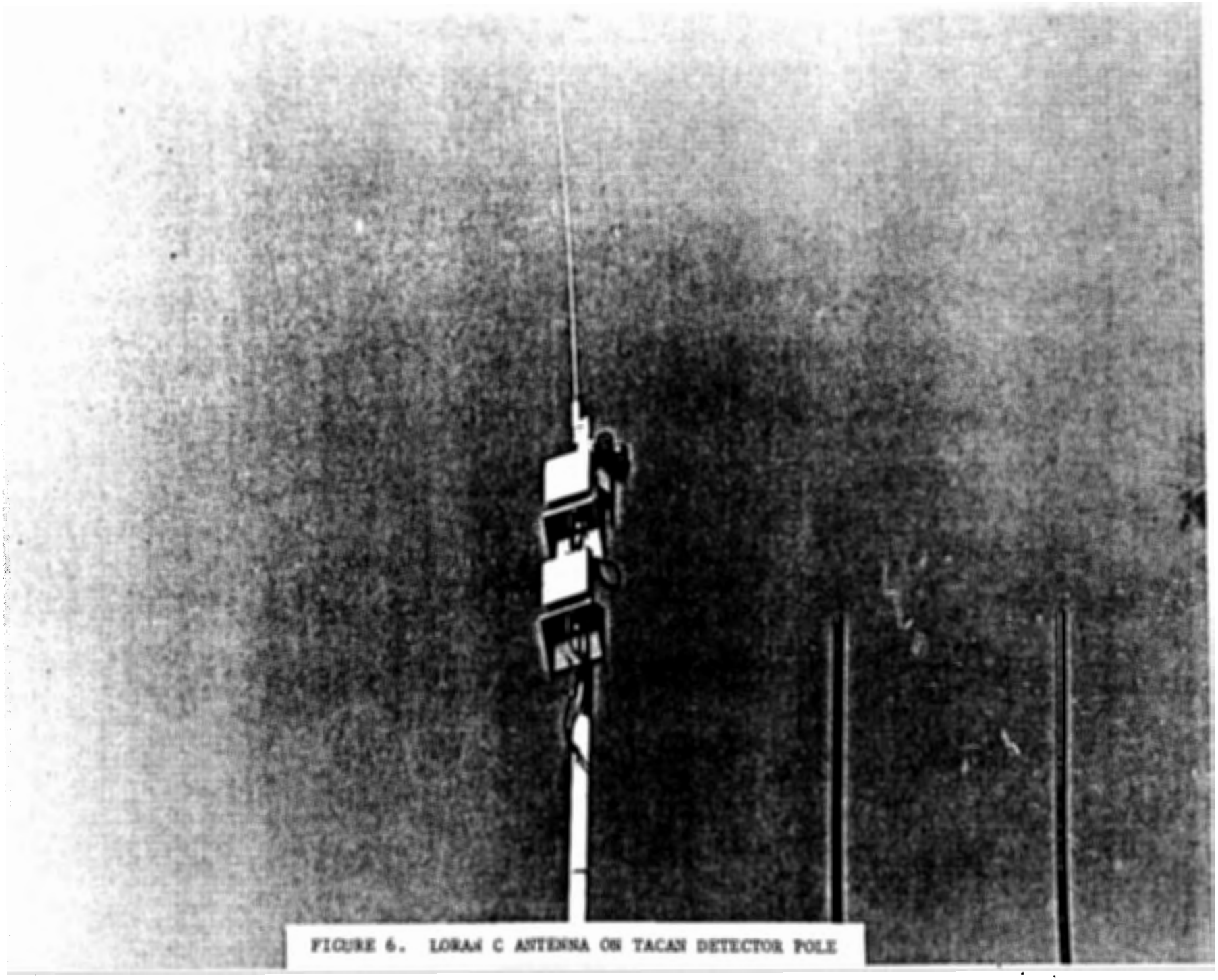

FIGURE 6. LORAN C ANTENNA ON TACAN DETECTOR POLE

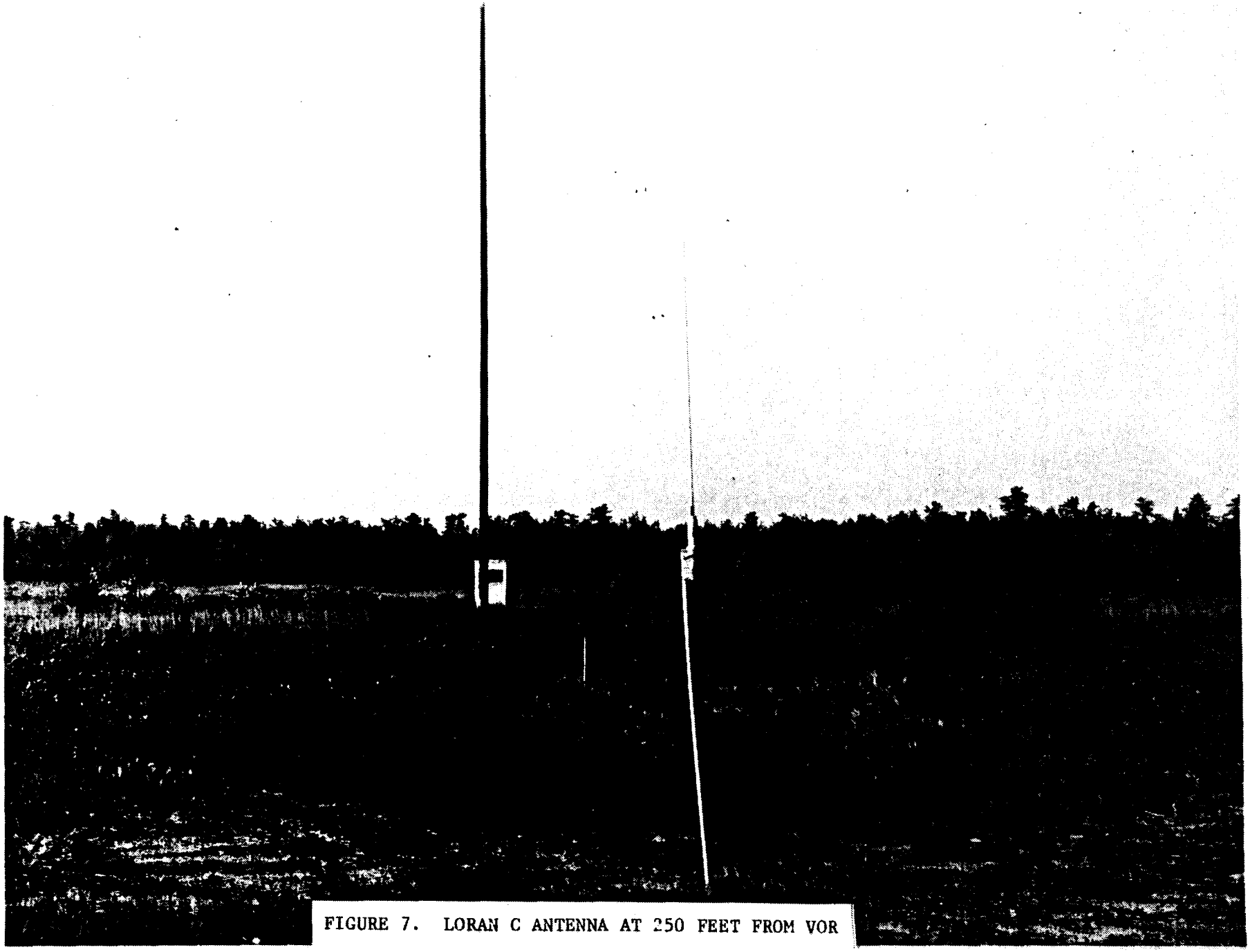

FIGURE 7. LORAN C ANTENNA AT 250 FEET FROM VOR

AIRBORNE.

A series of four flight checks were flown at the test VORTAC. An initial test was made with the VORTAC operating in its normal mode (without the Loran C antenna installed). This test is considered a control for the three tests involving installing the Loran C monitor antenna at the different locations specified in the ground test procedures at the VORTAC site. For all tests the RCAG antenna pole was left in the upright position. In order to maintain consistency with the number of test Loran C antenna locations, flight tests are listed as follows:

Test	
1	VORTAC energized mode, Loran antenna at location No. 1
2	VORTAC energized mode, Loran antenna at location No. 2
3	VORTAC energized mode, Loran antenna at location No. 3
4	Control test, VORTAC energized, no Loran antenna.

Test 4 was flown first in order to insure that the VORTAC site was operating within the tolerances described in the Vortac Siting Criteria (Related Documentation item 3) and the United States Flight Inspection Manual (Related Documentation item 4). Each test was identical, consisting of one complete inbound and outbound radial of 270° (site reference valid) and one complete 15-mile orbit. All flight testing was accomplished at an altitude of approximately 2000 feet above mean sea level (m.s.l.). Data collection included analog recordings of the course deviation indicator (CDI) and signal strength.

Loran C monitor, VOR monitor, and ground check data were recorded during the flight tests.

TEST RESULTS AND ANALYSIS

GROUND.

VOR MONITOR DATA. These are presented in appendix A. VOR monitor data with the RCAG off was recorded without a Loran C antenna installed, reference figure A-1; for the Loran C antenna installed at the three test locations, reference figures A-2 to A-4. The installation of the Loran C antenna did not cause the monitor to alarm. The Loran C antenna was installed on the 270° radial for all three antenna locations. No significant difference in VOR monitor azimuth error was observed with or without the Loran C antenna installed at locations 2 (TACAN detector pole) and 3 (250 feet from the VOR). However, a 0.4° increase in azimuth error at the 270° radial was observed when the Loran C antenna was located on the counterpoise.

VOR monitor data with the RCAG on (transmitter keyed) was recorded without a Loran C antenna installed, reference figure A-5; for the Loran C antenna installed at the three test locations, reference figures A-6 through A-8. The data were recorded twice in figures A-6 through A-8. The installation of the Loran C antenna with the RCAG on (transmitter keyed) did not cause the monitor to alarm. No significant difference in VOR monitor azimuth error were observed at locations 2 (TACAN detector) and 3 (250 feet from the VOR). However, a 0.4° reduction in azimuth error at the 270° radial was observed when the Loran C antenna was located on the counterpoise.

SPECTRUM ANALYZER DATA. These are presented in appendix B. Figures B-2 and B-4 are plots of the RF input spectrum of the Loran C receiver with the VOR off and RCAG deenergized at antenna locations 2 and 3. Figures B-1, B-3, and B-5 are plots of the RF input spectrum of the Loran C receiver with the VOR on and the RCAG deenergized at antenna locations 2 and 3. Figures B-6, B-8, and B-10 are plots of the RF input spectrum of the Loran C receiver with the VOR on and the RCAG off (RCAG energized but transmitters not keyed) at the three antenna locations. Figures B-7, B-9, and B-11 are plots of the RF input spectrum of the Loran C receiver with the VOR and the RCAG on (transmitter keyed) at the three antenna locations. Large amplitude, narrow bandwidth signals at approximately 77.5, 88, 112, 137, and 143 kilohertz (kHz), which are low frequency (LF) communication transmitters, can be seen on some of the plots. Figures B-1 (VOR on), B-6 (RCAG off), and B-7 (RCAG on) with the Loran C antenna at the counterpoise indicate a reduction of 5 to 8 decibels (dB) of the Loran C spectrum when compared to locations 2 (TACAN detector pole) and 3 (250 feet from the VOR). At location 2 (TACAN detector pole) the RF spectrum between 50 to 87 kHz and 120 to 145 kHz was noticeably different than the spectrum at locations 1 (counterpoise) and 3 (250 feet from the VOR). The measured spectrum, which is nearly out of the Loran C band, except for the LF content (87 kHz), is wide band, approximately 20 kHz. The cause of the near out of the Loran C band energy levels is unknown. The near out of the Loran C band spectrum was higher on the day the RCAG equipment was energized (reference figures B-8 (RCAG energized, transmitters not keyed) and B-9 (RCAG transmitter keyed). The RCAG antennas were mounted close to the detector pole and could possibly have affected the spectrum. This phenomena was not noticed at locations 1 (the counterpoise) or 3 (250 feet from the VOR).

LORAN C MONITOR TEST DATA PLOTS. These are presented in appendix C. Change in TD's, SNR's, and ECD's are referenced to a 1-hour average plotted for the signals received from each transmitter. The preferred triad for the Northeast Chain 9960 GRI at the Technical Center is MXY.

Signals were received at times from all the Loran C transmitters in the GRI 9960 chain. Typical SNR's for the transmitters as measured at the Technical Center are listed in table 2. Stations M, X, and Y are the only signals continuously received with a measured SNR greater than 0 dB. Therefore, the discussion of the test results will only be concerned with transmitters M, X, and Y.

TABLE 2. 9960 GRI LORAN C TRANSMITTERS TYPICAL SNR'S MEASURED AT THE TECHNICAL CENTER

Station	SNR dB
M*	7
W	-
X*	7
Y*	4
Z	-15

*Preferred Triad

Figures C-1 through C-9 are plots of the Loran C monitor data with the Loran C antenna at the three locations for the VOR cycled on and off for 5-minute intervals over a 1-hour period. At all three antenna locations there appeared to be no relationship between signal perturbations and cycling on and off of the VOR. At the counterpoise there were two occasions where perturbations in ECD and SNR occurred coincidentally for stations M, X, and Y. The cause of these perturbations is unknown. Mean and standard deviations (1 sigma) of the parameters were computed for the aggregate of the VOR off cycles and VOR on cycles, respectively. Mean +2 sigma values were arithmetically computed for the off and on cycles. The mean +2 sigma differences in the parameters between the on and off cycles for the data shown in figures C-1 through C-9 were calculated and are presented in table 3. The differences were small and did not affect the operation of the monitor receiver.

Figures C-10 through C-18 are plots of the monitor data with the Loran C antenna at the three locations with the VOR on and the RCAG cycled on (transmitters keyed) and off. At all three antenna locations there appeared to be no relationship between signal perturbations and cycling on and off of the RCAG. There were occasions where perturbations in envelope-to-cycle discrepancy (ECD) or SNR occurred at the three locations, but the occurrences were not coincidental with cycling on or off the RCAG equipment. The cause of these perturbations is unknown. Statistics as previously described are presented in table 4. The differences were small and did not affect the operation of the monitor receiver.

Figures C-19 through C-20 are plots of the monitor data with the Loran C antenna at the counterpoise. The VOR and the RCAG were off. The data indicate the quality of the site without interference from the VOR or RCAG. The TD's for stations X and Y are stable. Random fluctuations and a bias shift are evident in the SNR measurements for stations M, X, and Y.

AIRBORNE.

Orbital flight test data with the VOR energized for the Loran C antenna installed at the three test locations and the Loran C antenna removed are presented in figure 8. The orbits were 15 miles in radius and were flown counterclockwise at 2000 feet above m.s.l. Field Strength (AGC) and azimuth error (Related Documentation item 4) were plotted versus EAIR position reference. The field strength was essentially constant, approximately 8 milliamps, for all orbits. There were no disturbances to the VOR field strength attributable to the placement of the Loran C antenna at any location.

The azimuth error exceeded tolerances at several radials, with or without the Loran C antenna installed. The placement of the Loran C antenna appeared to make no difference in the characteristic azimuth error pattern. The percentage of modulation (30 Hz variable) exceeded tolerance (± 2 percent) between 80° to 110° azimuth. The variation exceeded the criteria by 3 percent in the worst case for all tests.

Inbound and outbound 270° radial flights were conducted at 2000 feet above m.s.l. Field strength (AGC) and course error as previously described are presented in figure 9. No unusual characteristics or perturbations were noted in the field strength data. The radial course error plots are inconclusive because of the characteristics of the site and the test flight altitude.

TABLE 3. DIFFERENCE STATISTICS FOR VOR CYCLED ON/OFF (MEAN +2 SIGMA)

	M	X	Y
Location 1 (Counterpoise)			
TD (Microseconds)	0	0	0.02
SNR (dB)	0.02	0.09	0.02
ECD (Microseconds)	0.29	0.02	0.12
Location 2 (TACAN Detector Pole)			
TD (Microseconds)	0	0	0.01
SNR (dB)	0.22	0.16	0.06
ECD (Microseconds)	0.15	0.33	0.05
Location 3 (Far Field)			
TD (Microseconds)	0	0.01	0.015
SNR (dB)	0.12	0.02	0.07
ECD (Microseconds)	0.20	0.12	0

TABLE 4. DIFFERENCE STATISTICS FOR RCAG CYCLED ON/OFF (MEAN +2 SIGMA)

	M	X	Y
Location 1 (Counterpoise)			
TD (Microseconds)	0	0	0.01
SNR (dB)	0.16	0.03	0.10
ECD (Microseconds)	0.30	0	0.20
Location 2 (TACAN Detector Pole)			
TD (Microseconds)	0	0.02	0
SNR (dB)	0.03	0.10	0.10
ECD (Microseconds)	0.50	0.30	0.23
Location 3 (Far Field)			
TD (Microseconds)	0	0.01	0.01
SNR (dB)	0.30	0.30	0.20
ECD (Microseconds)	0.80	0.10	0.44

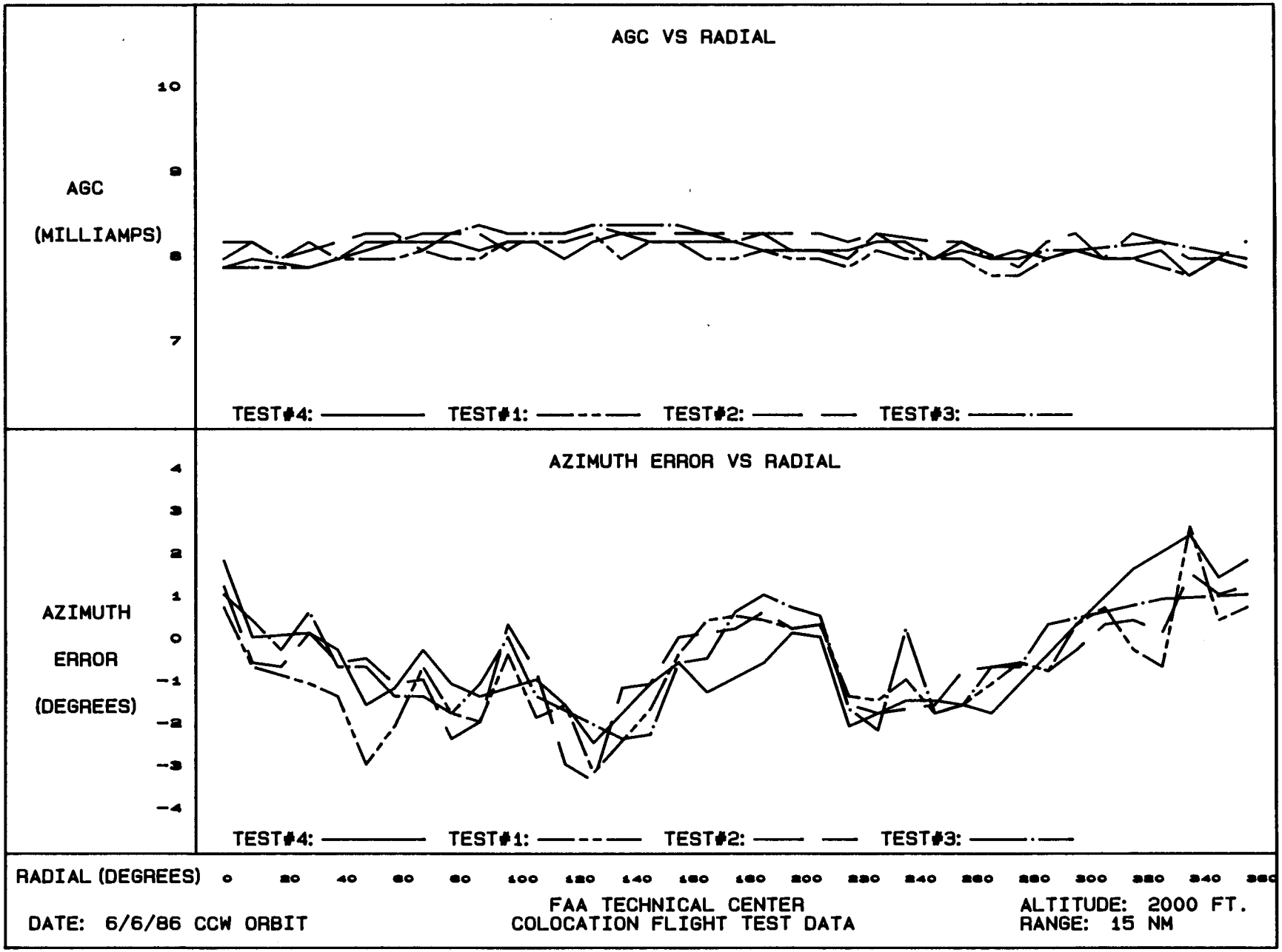

FIGURE 8. ORBITAL FLIGHT TEST DATA

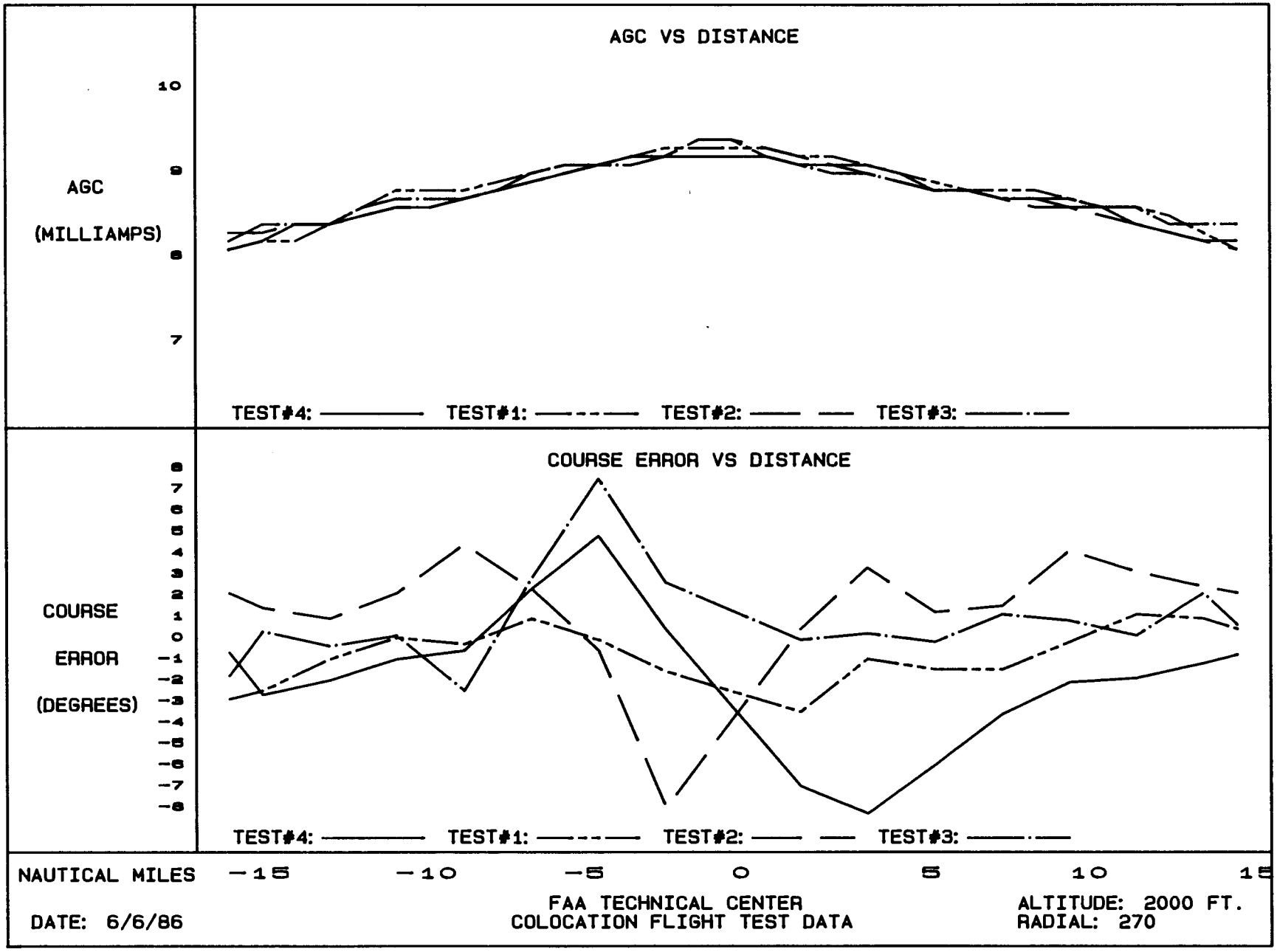

FIGURE 9. RADIAL FLIGHT TEST DATA

CONCLUSIONS

1. Location 1 (Counterpoise). The very high frequency omnidirectional radio range (VOR) monitor data indicate that the Loran C antenna, when located at the counterpoise, may have a small effect on the monitor detector (0.4°); however, no effect could be determined in flight check because of the precision of the airborne measurement. The Loran C spectrum appeared to be reduced between 5 and 8 decibel (dB) at the counterpoise when compared to the signal at the tactical air navigation (TACAN) detector pole and the far field location. For these reasons it is recommended that a Loran C monitor antenna not be located on the counterpoise even though the Loran C receiver operated satisfactorily.

2. Location 2 (TACAN Detector Pole). The VOR monitor data and the flight check data were not affected by the placement of the Loran C antenna on the TACAN detector pole. Broad bandwidth energy above and below the Loran C band of 90 to 110 kHz were observed on the spectrum analyzer during the cycled on and off remote communications air/ground (RCAG) tests.

The broad band signals had no apparent effect on the operation of the Loran C monitor. The Loran C monitor operated satisfactorily for all test conditions. The TACAN detector pole can be considered as an installation site for a Loran C monitor antenna.

3. Location 3 (250 feet from the VOR). Location 3 appeared to be satisfactory with respect to VOR monitor data, spectrum data, Loran C monitor data, and flight check data. As far as collocation interference, it is the best location when compared to the other two locations. Site terrains and security restrictions may not permit consideration of this location for all very high frequency omnidirectional range tactical air navigation (VORTAC)/RCAG sites.

4. Locations 2 (TACAN Detector Pole and 3 (250 feet from the VOR). These are considered as acceptable sites for a Loran C monitor antenna.

APPENDIX A

VOR MONITOR DATA

Figure		Page
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A-7	VOR Monitor Data - Loran C Antenna at Location 2 (TACAN Detector Pole), RCAG On	A-7
A-8	VOR Monitor Data - Loran C Antenna at Location 3 (250 feet from the VOR), RCAG On	A-8

F G R O U N D C H E C K D A T A TEST FILED 86/06/09 10:16:36

VOR MON1

AZIMUTH	ERROR	AZIMUTH	ERROR
0.00	1.68	22.50	1.46
45.00	1.31	67.50	1.82
90.00	1.02	112.50	1.68
135.00	1.12	157.50	.76
180.00	.97	202.50	.69
225.00	.76	247.50	1.49
270.00	1.49	292.50	.68
315.00	.66	337.50	.80

QUANTAL ERROR	AMPL	.27	DEG
	PHASE	35.9	DEG
QUADRANTAL ERROR	AMPL	.23	DEG
	PHASE	318.0	DEG
OCTANTAL ERROR	AMPL	.16	DEG
	PHASE	105.4	DEG
INDEX		1.14	DEG

FIGURE A-1. VOR MONITOR DATA - NO LORAN C ANTENNA

F G R O U N D C H E C K D A T A TEST FILED 86/06/09 11:36:33

VOR MON1

AZIMUTH	ERROR	AZIMUTH	ERROR
0.00	1.58	22.50	1.28
45.00	1.04	67.50	1.81
90.00	.89	112.50	1.59
135.00	1.17	157.50	.75
180.00	.93	202.50	.68
225.00	.75	247.50	1.42
270.00	1.91	292.50	.69
315.00	.66	337.50	.87

DUANTAL ERROR	AMPL	.16	DEG
	PHASE	46.4	DEG
QUADRANTAL ERROR	AMPL	.23	DEG
	PHASE	297.8	DEG
OCTANTAL ERROR	AMPL	.22	DEG
	PHASE	109.9	DEG
INDEX		1.12	DEG

FIGURE A-2. VOR MONITOR DATA - LORAN C ANTENNA AT LOCATION 1 (COUNTERPOISE)

F G R O U N D C H E C K D A T A TEST FILED 86/06/09 12:07:22

VOR MON1

AZIMUTH	ERROR	AZIMUTH	ERROR
0.00	1.91	22.50	1.54
45.00	1.27	67.50	1.73
90.00	.96	112.50	1.42
135.00	1.20	157.50	.79
180.00	.92	202.50	.72
225.00	.80	247.50	1.47
270.00	1.56	292.50	.60
315.00	.61	337.50	.85

QUANTAL ERROR	AMPL	.26	DEG
	PHASE	46.3	DEG
QUADRANTAL ERROR	AMPL	.20	DEG
	PHASE	337.9	DEG
OCTANTAL ERROR	AMPL	.19	DEG
	PHASE	110.9	DEG
INDEX		1.14	DEG

FIGURE A-3. VOR MONITOR DATA - LORAN C ANTENNA AT LOCATION 2 (TACAN DETECTOR POLE)

F GROUND CHECK DATA TEST FILED 86/06/09 12:46:35

VOR MON1

AZIMUTH	ERROR	AZIMUTH	ERROR
0.00	1.60	22.50	1.24
45.00	1.04	67.50	1.74
90.00	.74	112.50	1.44
135.00	1.22	157.50	.50
180.00	.90	202.50	.72
225.00	.75	247.50	1.42
270.00	1.60	292.50	.51
315.00	.57	337.50	.80

DUANTAL ERROR	AMPL	.17	DEG
	PHASE	42.9	DEG
QUADRANTAL ERROR	AMPL	.21	DEG
	PHASE	319.1	DEG
OCTANTAL ERROR	AMPL	.17	DEG
	PHASE	113.6	DEG
INDEX		1.04	DEG

FIGURE A-4. VOR MONITOR DATA - LORAN C ANTENNA AT LOCATION 3 (FAR FIELD)

F G R O U N D C H E C K D A T A TEST FILED 86/05/28 10:51:57

VOR MON1

AZIMUTH	ERROR	AZIMUTH	ERROR
0.00	1.95	22.50	1.22
45.00	1.09	67.50	1.83
90.00	1.01	112.50	2.01
135.00	1.26	157.50	.94
180.00	.84	202.50	.47
225.00	1.18	247.50	1.86
270.00	1.52	292.50	.84
315.00	.67	337.50	1.02

DUANTAL ERROR	AMPL	.18	DEG
	PHASE	39.1	DEG
QUADRANTAL ERROR	AMPL	.24	DEG
	PHASE	292.7	DEG
OCTANTAL ERROR	AMPL	.19	DEG
	PHASE	134.8	DEG
INDEX		1.23	DEG

FIGURE A-5. VOR MONITOR DATA - NO LORAN C ANTENNA, RCAG ON

F G R O U N D C H E C K D A T A TEST FILED 86/05/28 11:04:07

VOR MON1

AZIMUTH	ERROR	AZIMUTH	ERROR
0.00	1.99	22.50	1.29
45.00	1.14	67.50	1.82
90.00	1.07	112.50	1.93
135.00	1.23	157.50	.95
180.00	.82	202.50	.52
225.00	1.16	247.50	1.86
270.00	1.16	292.50	.67
315.00	.67	337.50	.84

DUANTAL ERROR	AMPL	.24	DEG
	PHASE	26.5	DEG
QUADRANTAL ERROR	AMPL	.22	DEG
	PHASE	311.9	DEG
OCTANTAL ERROR	AMPL	.16	DEG
	PHASE	141.7	DEG
INDEX		1.19	DEG

F G R O U N D C H E C K D A T A TEST FILED 86/05/28 11:07:57

VOR MON1

AZIMUTH	ERROR	AZIMUTH	ERROR
0.00	1.67	22.50	1.28
45.00	1.15	67.50	1.83
90.00	1.03	112.50	1.97
135.00	1.28	157.50	.97
180.00	.85	202.50	.46
225.00	1.14	247.50	1.90
270.00	1.16	292.50	.77
315.00	.36	337.50	.96

DUANTAL ERROR	AMPL	.24	DEG
	PHASE	13.1	DEG
QUADRANTAL ERROR	AMPL	.25	DEG
	PHASE	306.4	DEG
OCTANTAL ERROR	AMPL	.17	DEG
	PHASE	146.6	DEG
INDEX		1.17	DEG

FIGURE A-6. VOR MONITOR DATA - LORAN C ANTENNA AT LOCATION 1 (COUNTERPOISE), RCAG ON

F G R O U N D C H E C K D A T A TEST FILED 86/05/28 12:15:50

VOR MON1

AZIMUTH	ERROR	AZIMUTH	ERROR
0.00	1.92	22.50	1.45
45.00	1.23	67.50	1.84
90.00	1.01	112.50	1.75
135.00	1.23	157.50	.95
180.00	.87	202.50	.60
225.00	1.11	247.50	1.97
270.00	1.59	292.50	.53
315.00	.72	337.50	.88

DUANTAL ERROR	AMPL	.19	DEG
	PHASE	38.7	DEG
QUADRANTAL ERROR	AMPL	.26	DEG
	PHASE	319.9	DEG
OCTANTAL ERROR	AMPL	.21	DEG
	PHASE	140.0	DEG
INDEX		1.22	DEG

F G R O U N D C H E C K D A T A TEST FILED 86/05/28 12:20:35

VOR MON1

AZIMUTH	ERROR	AZIMUTH	ERROR
0.00	1.95	22.50	1.48
45.00	1.31	67.50	1.94
90.00	1.03	112.50	1.76
135.00	1.19	157.50	.97
180.00	.86	202.50	.60
225.00	1.04	247.50	1.95
270.00	1.55	292.50	.63
315.00	.45	337.50	.90

DUANTAL ERROR	AMPL	.23	DEG
	PHASE	33.9	DEG
QUADRANTAL ERROR	AMPL	.29	DEG
	PHASE	323.6	DEG
OCTANTAL ERROR	AMPL	.23	DEG
	PHASE	132.7	DEG
INDEX		1.22	DEG

FIGURE A-7. VOR MONITOR DATA - LORAN C ANTENNA AT LOCATION 2 (TACAN DETECTOR POLE), RCAG ON

F G R O U N D C H E C K D A T A TEST FILED 86/05/28 12:26:52

VOR MON1

AZIMUTH	ERROR	AZIMUTH	ERROR
0.00	1.94	22.50	1.51
45.00	1.29	67.50	1.88
90.00	1.03	112.50	1.73
135.00	1.22	157.50	.96
180.00	.87	202.50	.64
225.00	1.09	247.50	1.98
270.00	1.58	292.50	.60
315.00	.45	337.50	.91

DUANTAL ERROR	AMPL	.21	DEG
	PHASE	33.6	DEG
QUADRANTAL ERROR	AMPL	.29	DEG
	PHASE	326.2	DEG
OCTANTAL ERROR	AMPL	.23	DEG
	PHASE	132.4	DEG
INDEX		1.23	DEG

F G R O U N D C H E C K D A T A TEST FILED 86/05/28 12:49:21

VOR MON1

AZIMUTH	ERROR	AZIMUTH	ERROR
0.00	1.92	22.50	1.47
45.00	1.31	67.50	1.84
90.00	.97	112.50	1.68
135.00	1.46	157.50	.90
180.00	.81	202.50	.63
225.00	1.05	247.50	1.95
270.00	1.62	292.50	.43
315.00	.38	337.50	.71

DUANTAL ERROR	AMPL	.23	DEG
	PHASE	19.3	DEG
QUADRANTAL ERROR	AMPL	.31	DEG
	PHASE	325.6	DEG
OCTANTAL ERROR	AMPL	.20	DEG
	PHASE	136.8	DEG
INDEX		1.19	DEG

FIGURE A-8. VOR MONITOR DATA - LORAN C ANTENNA AT LOCATION 3 (250 FEET FROM THE VOR), RCAG ON

APPENDIX B

SPECTRUM ANALYZER DATA

Figure		Page
B-1	VOR On, Loran C Antenna at Location 1 (Counterpoise)	B-1
B-2	VOR Off, Loran C Antenna at Location 2 (TACAN Detector Pole)	B-2
B-3	VOR On, Loran C Antenna at Location 2 (TACAN Detector Pole)	B-3
B-4	VOR Off, Loran C Antenna at Location 3 (250 Feet from the VOR)	B-4
B-5	VOR On, Loran C Antenna at Location 3 (250 feet from the VOR)	B-5
B-6	RCAG Off, Loran C Antenna at Location 1 (Counterpoise)	B-6
B-7	RCAG On, Loran C Antenna at Location 1 (Counterpoise)	B-7
B-8	RCAG Off, Loran C Antenna at Location 2 (TACAN Detector Pole)	B-8
B-9	RCAG On, Loran C Antenna at Location 2 (TACAN Detector Pole)	B-9
B-10	RCAG Off, Loran C Antenna at Location 3 (250 Feet from the VOR)	B-10
B-11	RCAG On, Loran C Antenna at Location 3 (250 Feet from the VOR)	B-11

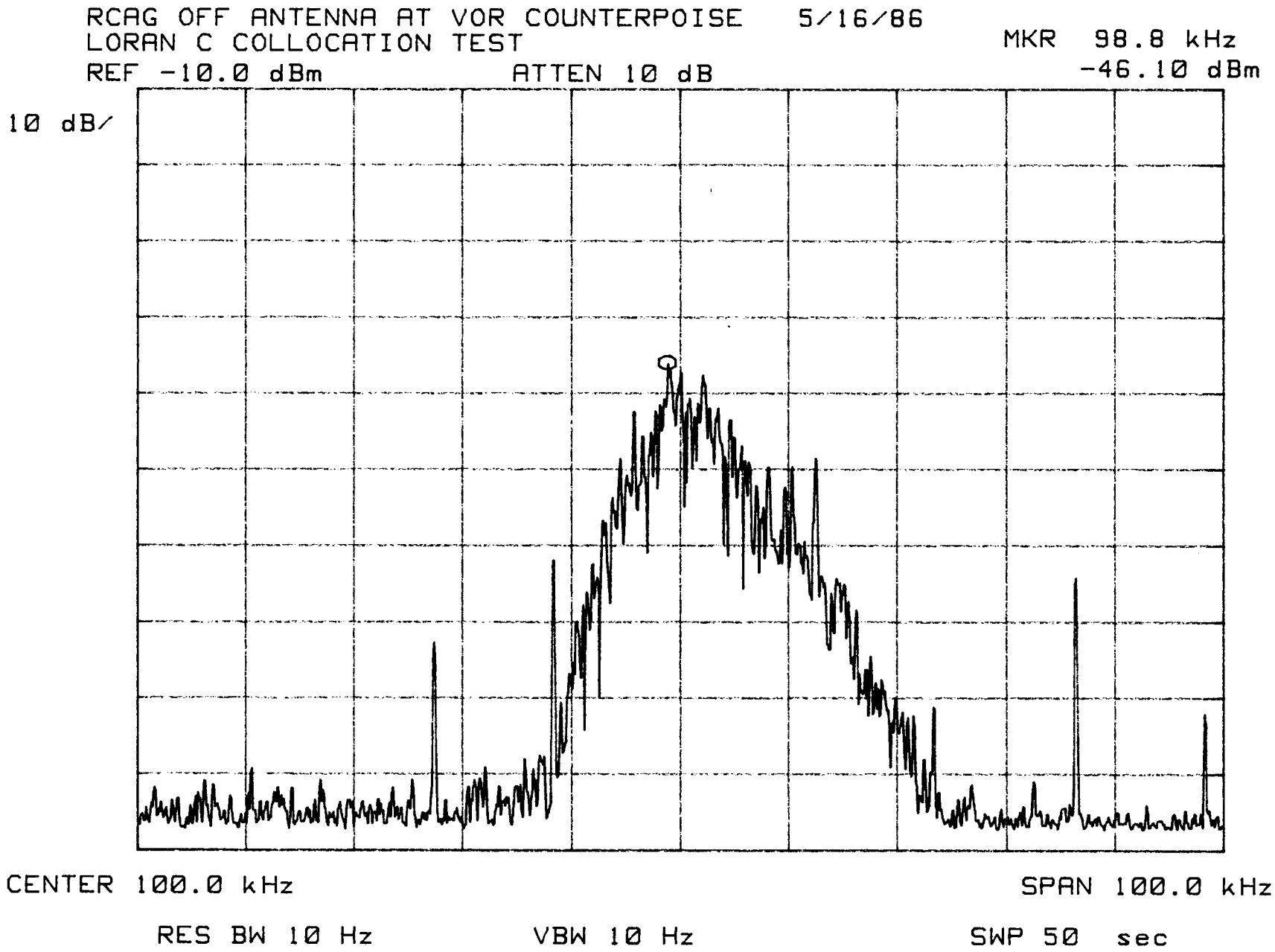


FIGURE B-1. VOR ON, LORAN C ANTENNA AT LOCATION 1 (COUNTERPOISE)

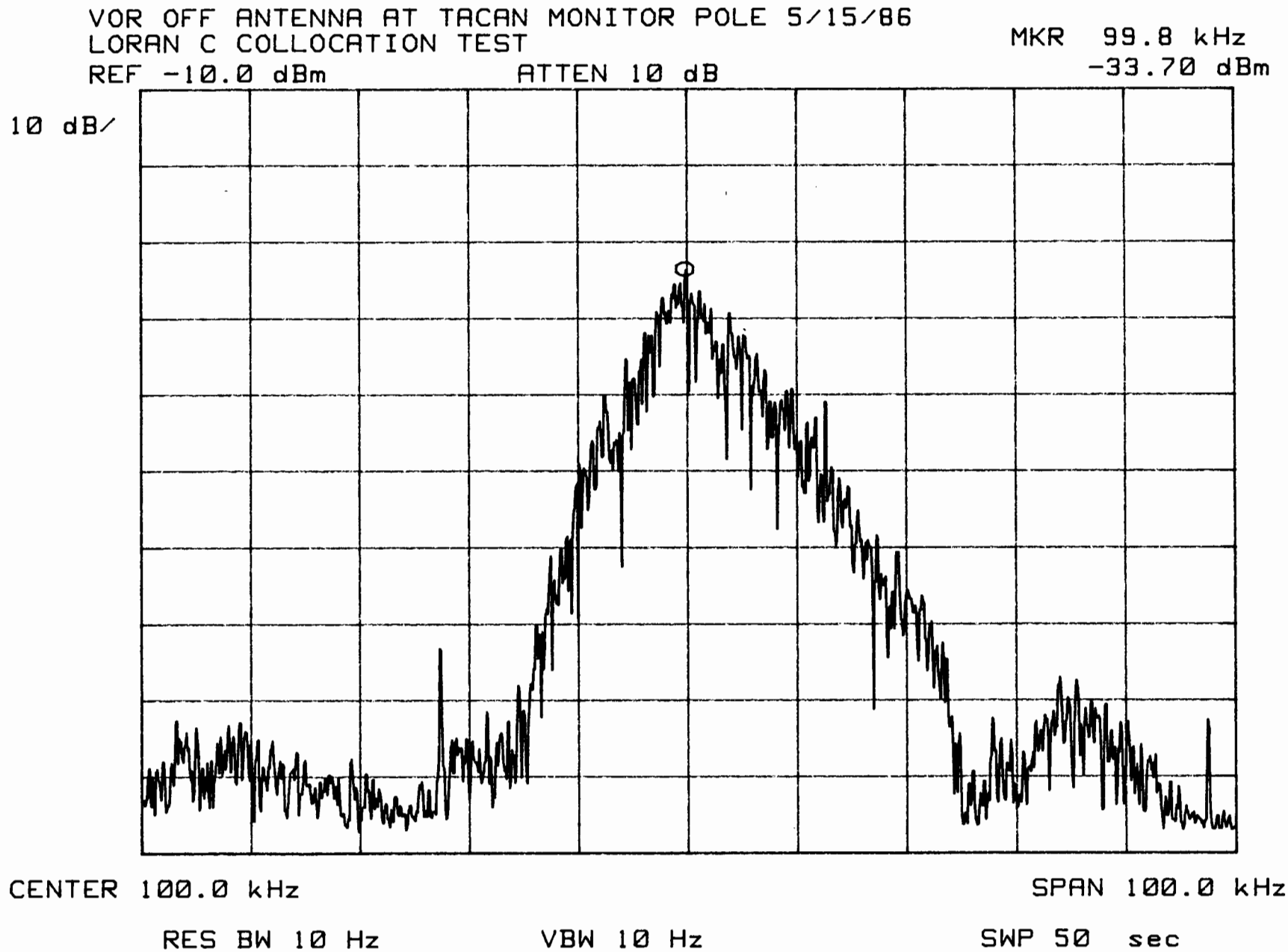


FIGURE B-2. VOR OFF, LORAN C ANTENNA AT LOCATION 2 (TACAN DETECTOR POLE)

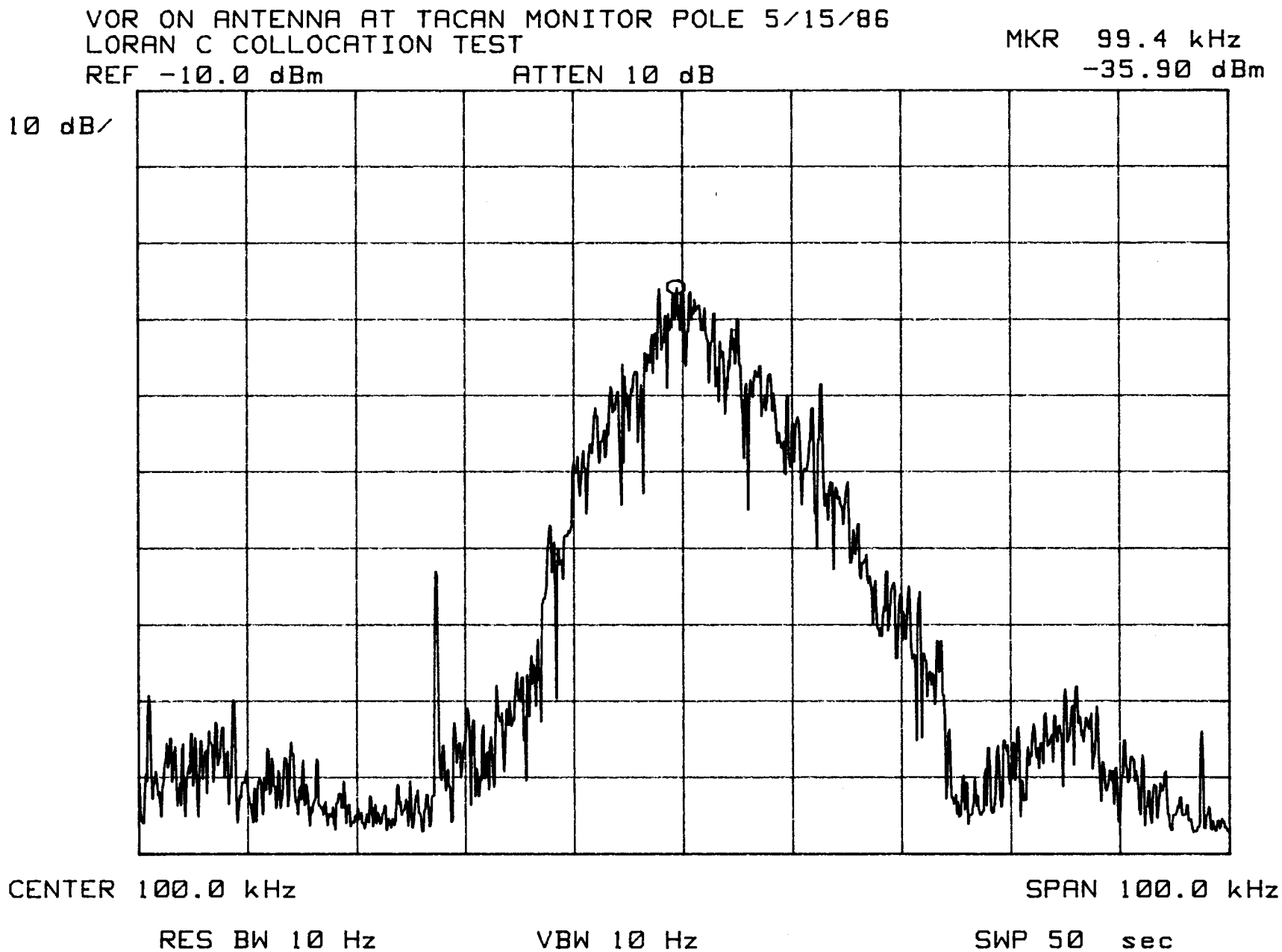


FIGURE B-3. VOR ON, LORAN C ANTENNA AT LOCATION 2 (TACAN DETECTOR POLE)

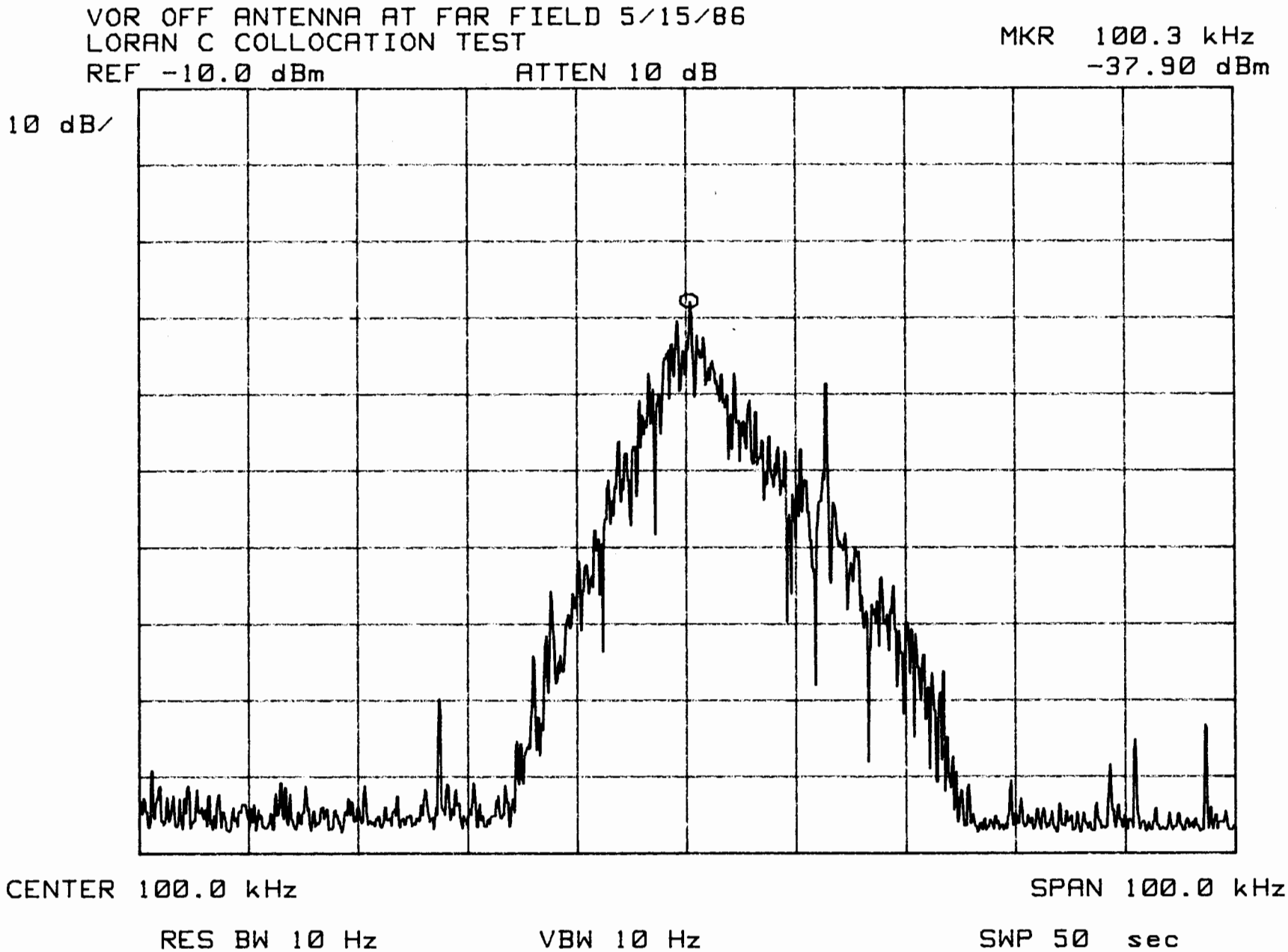


FIGURE B-4. VOR OFF, LORAN C ANTENNA AT LOCATION 3 (250 FEET FROM THE VOR)

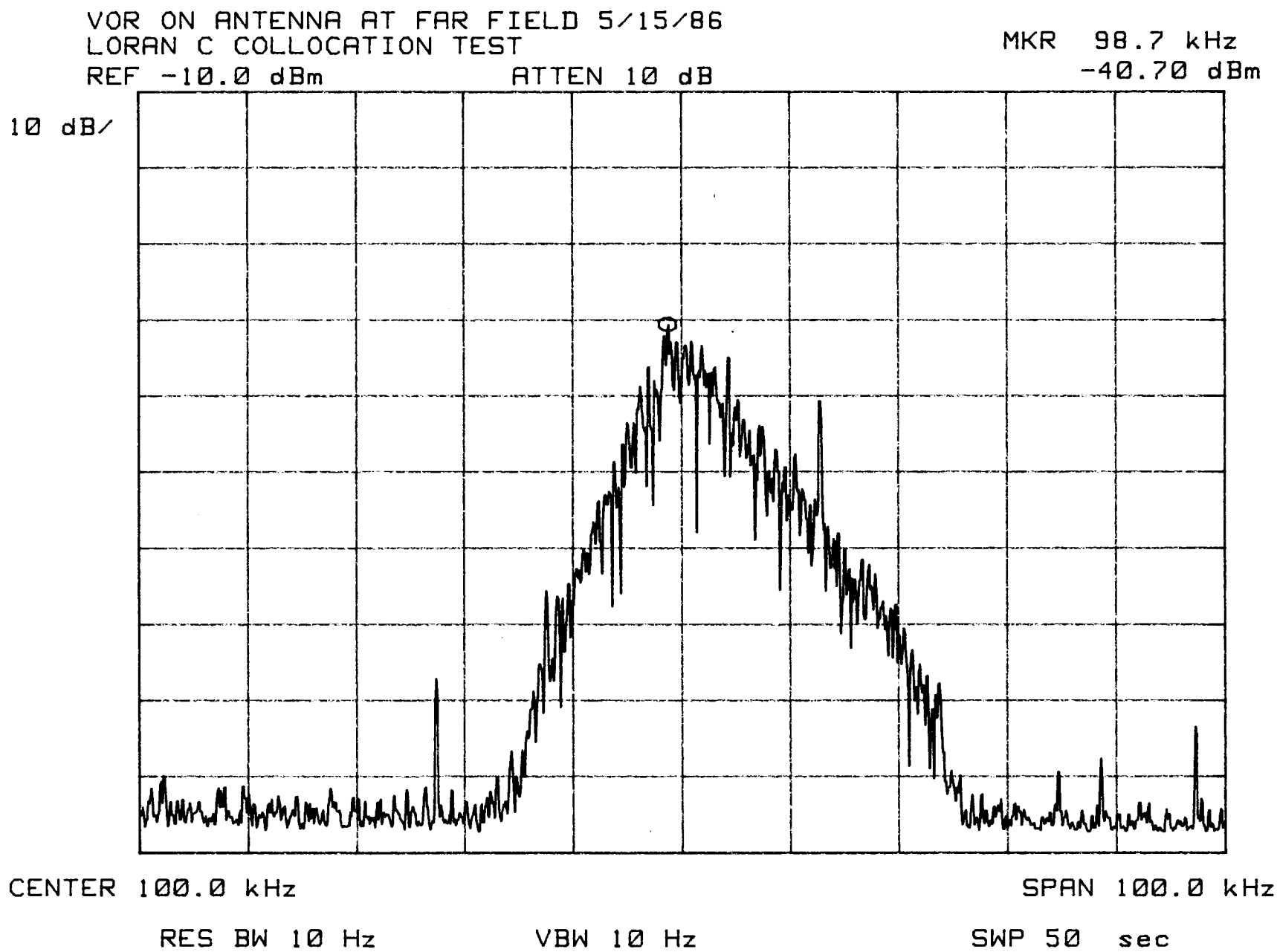


FIGURE B-5. VOR ON, LORAN C ANTENNA AT LOCATION 3 (250 FEET FROM THE VOR)

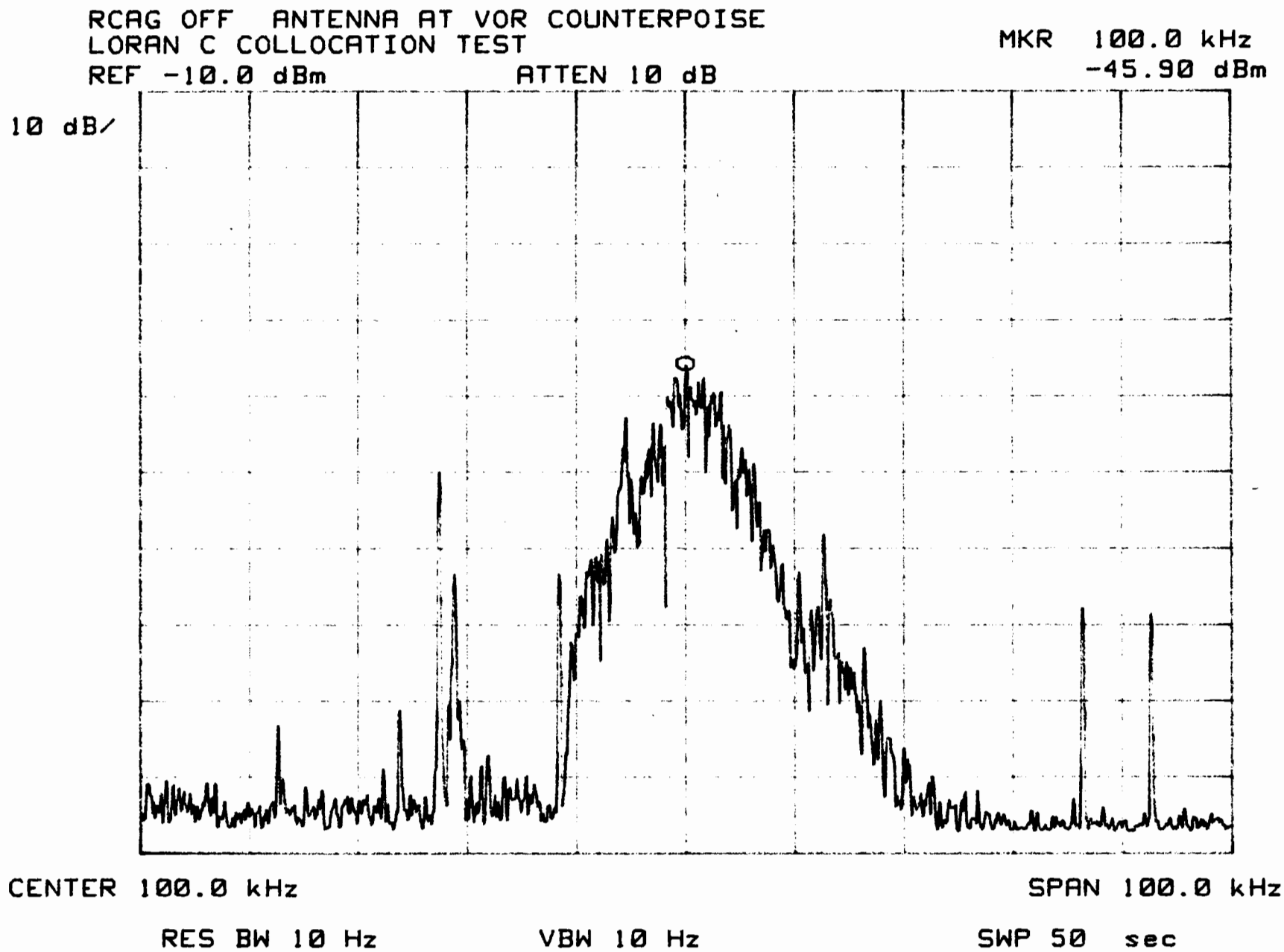


FIGURE B-6. RCAG OFF, LORAN C ANTENNA AT LOCATION 1 (COUNTERPOISE)

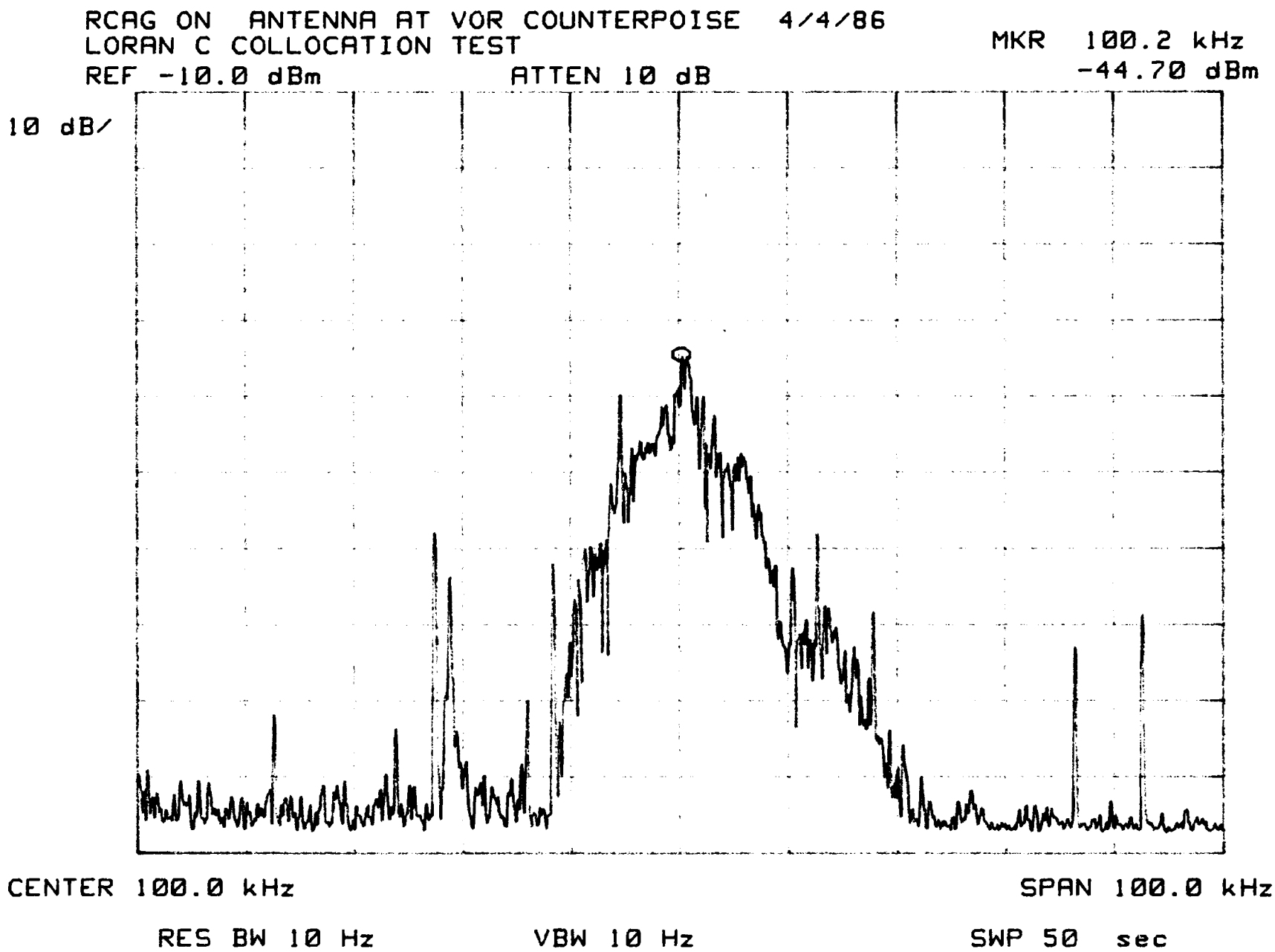


FIGURE B-7. RCAG ON, LORAN C ANTENNA AT LOCATION 1 (COUNTERPOISE)

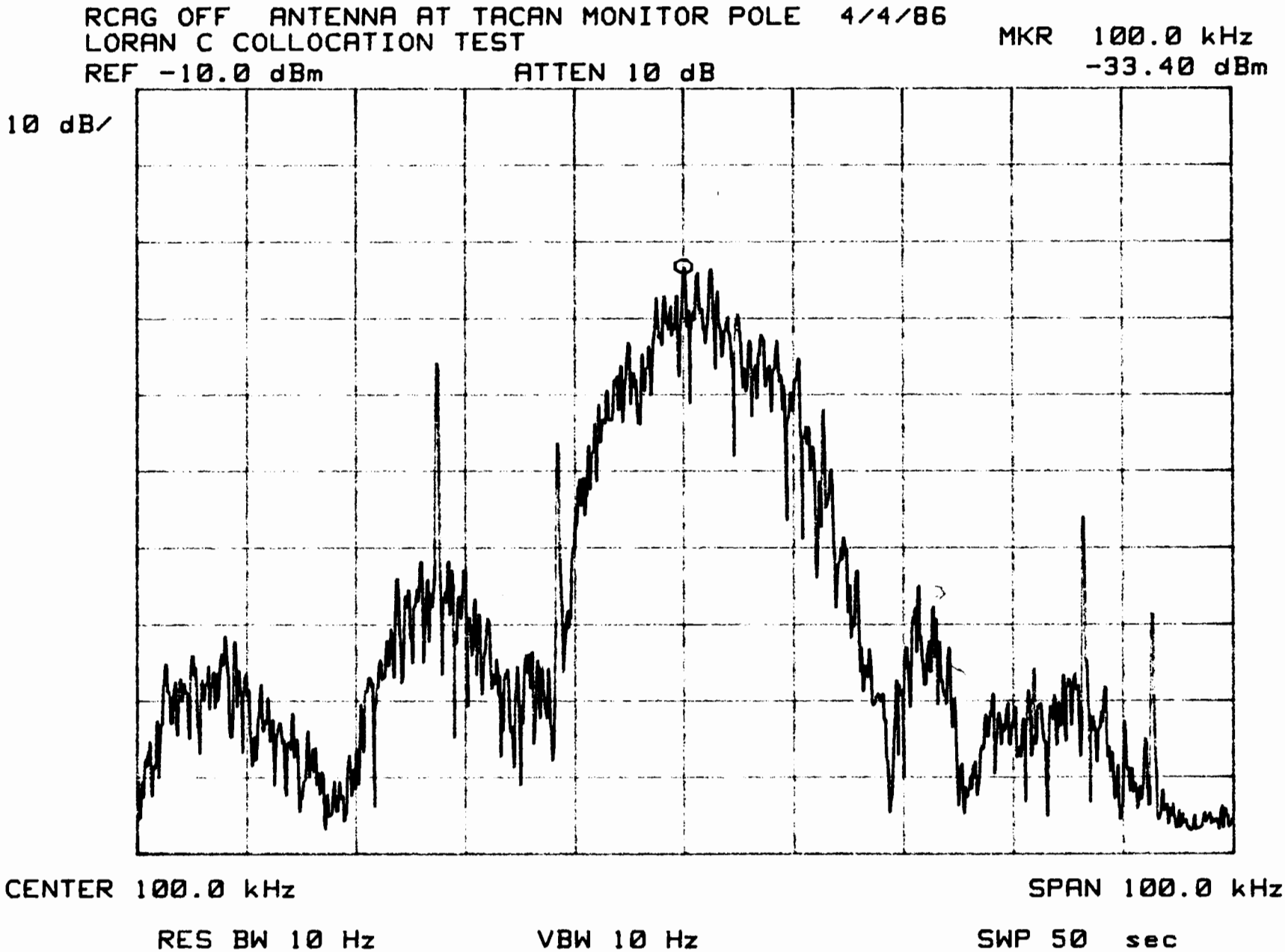


FIGURE B-8. RCAG OFF, LORAN C ANTENNA AT LOCATION 2 (TACAN DETECTOR POLE)

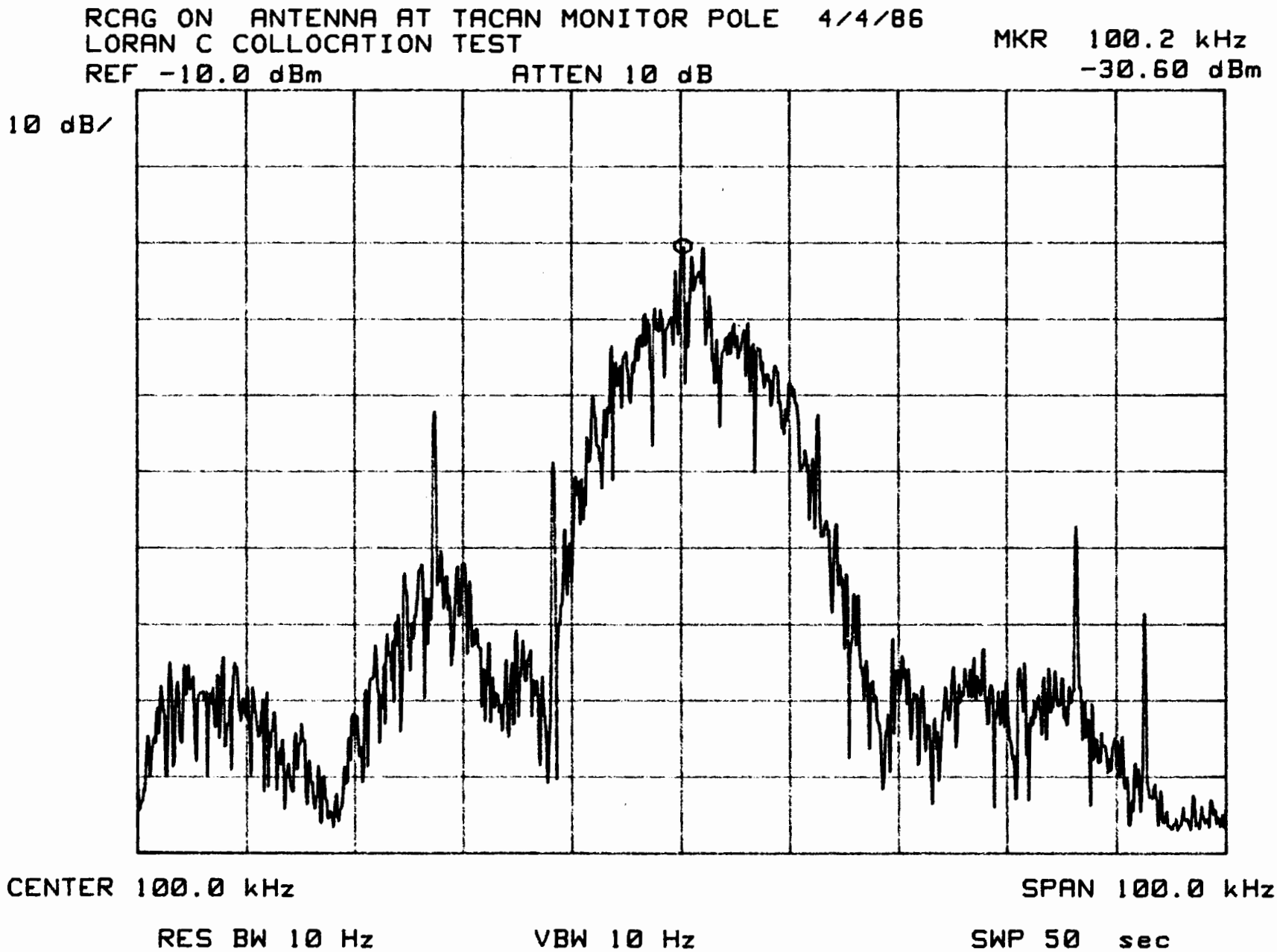


FIGURE B-9. RCAG ON, LORAN C ANTENNA AT LOCATION 2 (TACAN DETECTOR POLE)

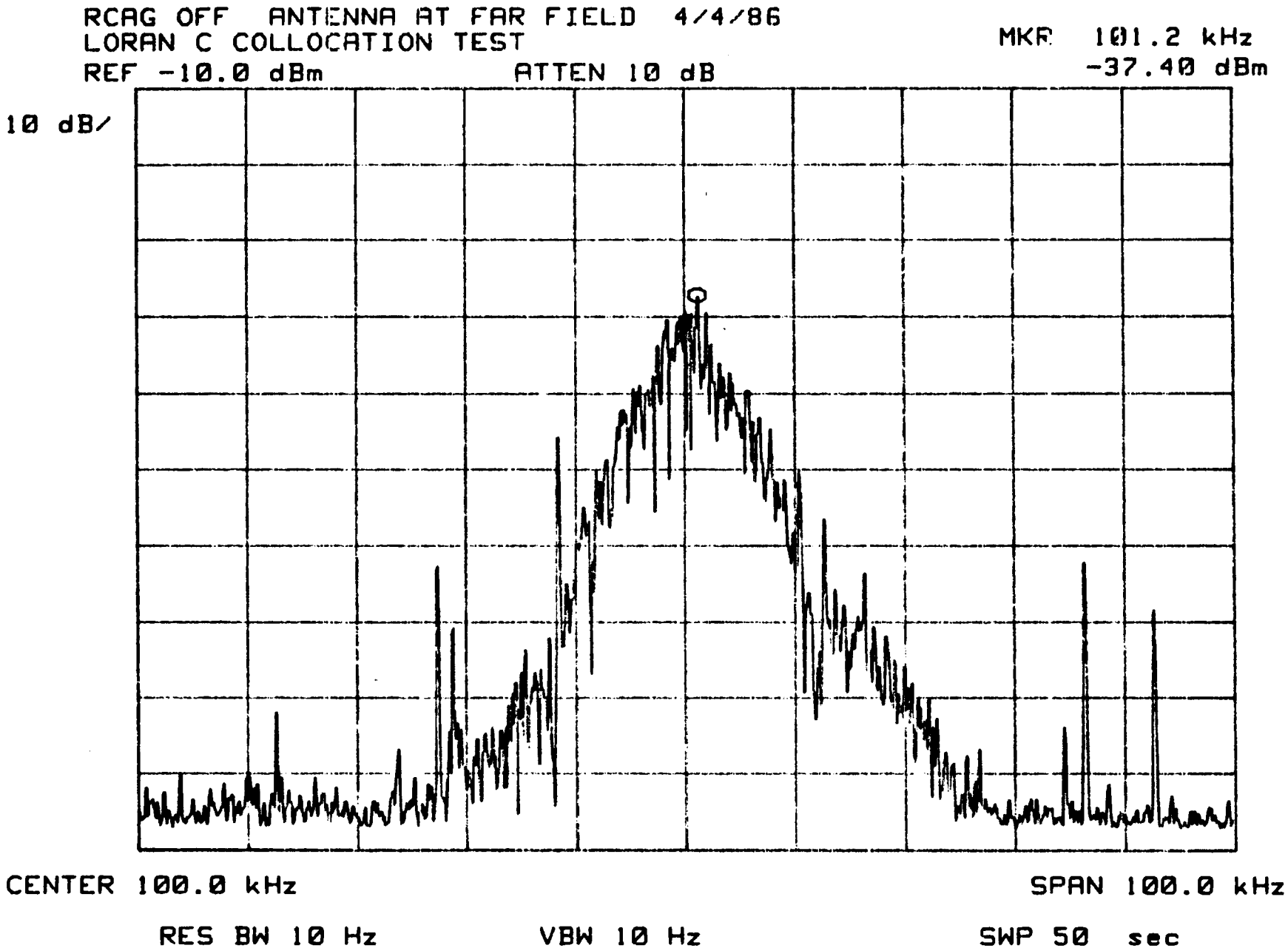


FIGURE B-10. RCAG OFF, LORAN C ANTENNA AT LOCATION 3 (250 FEET FROM THE VOR)

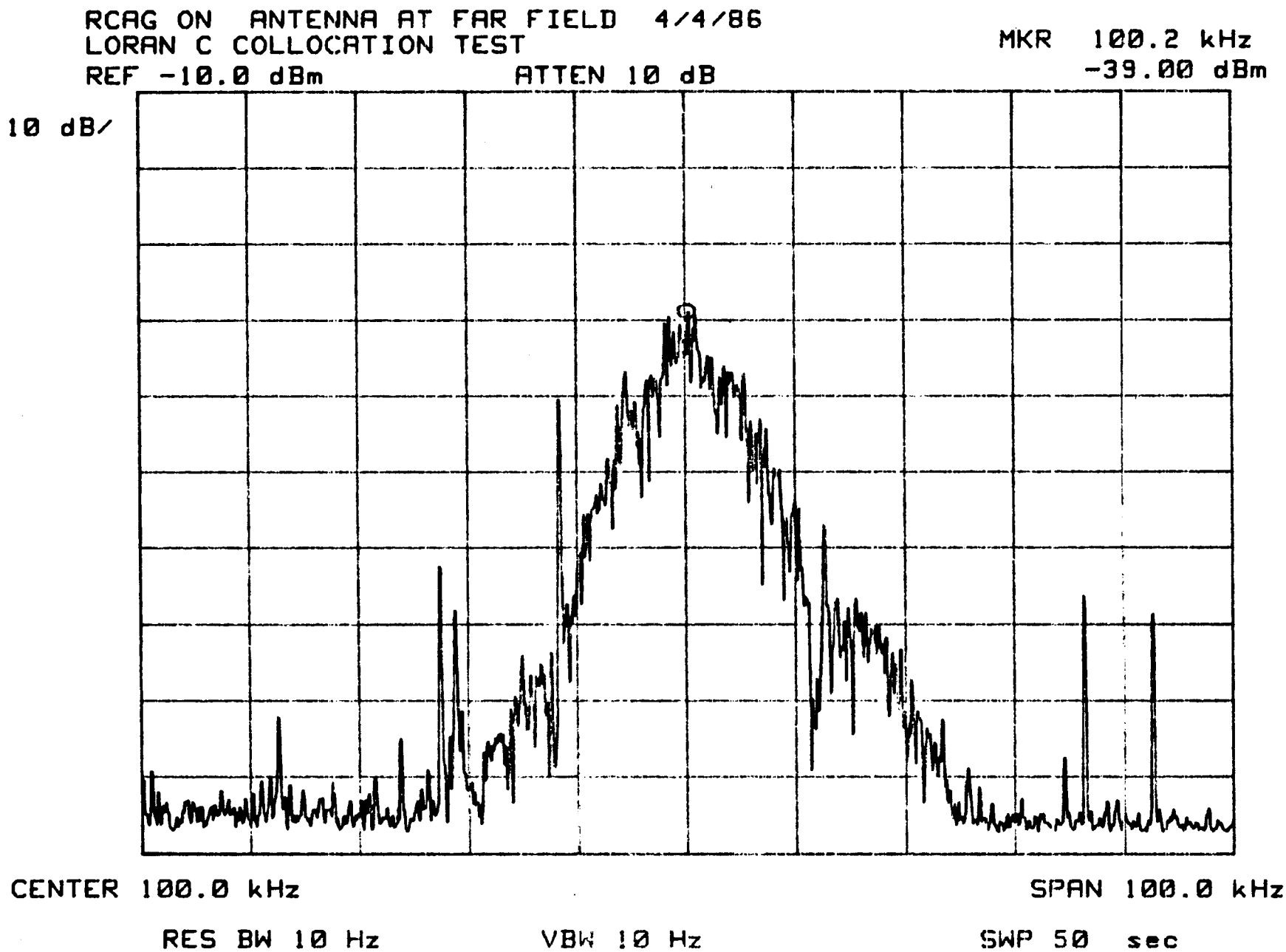


FIGURE B-11. RCAG ON, LORAN C ANTENNA AT LOCATION 3 (250 FEET FROM THE VOR)

APPENDIX C

LORAN C MONITOR TEST DATA PLOTS

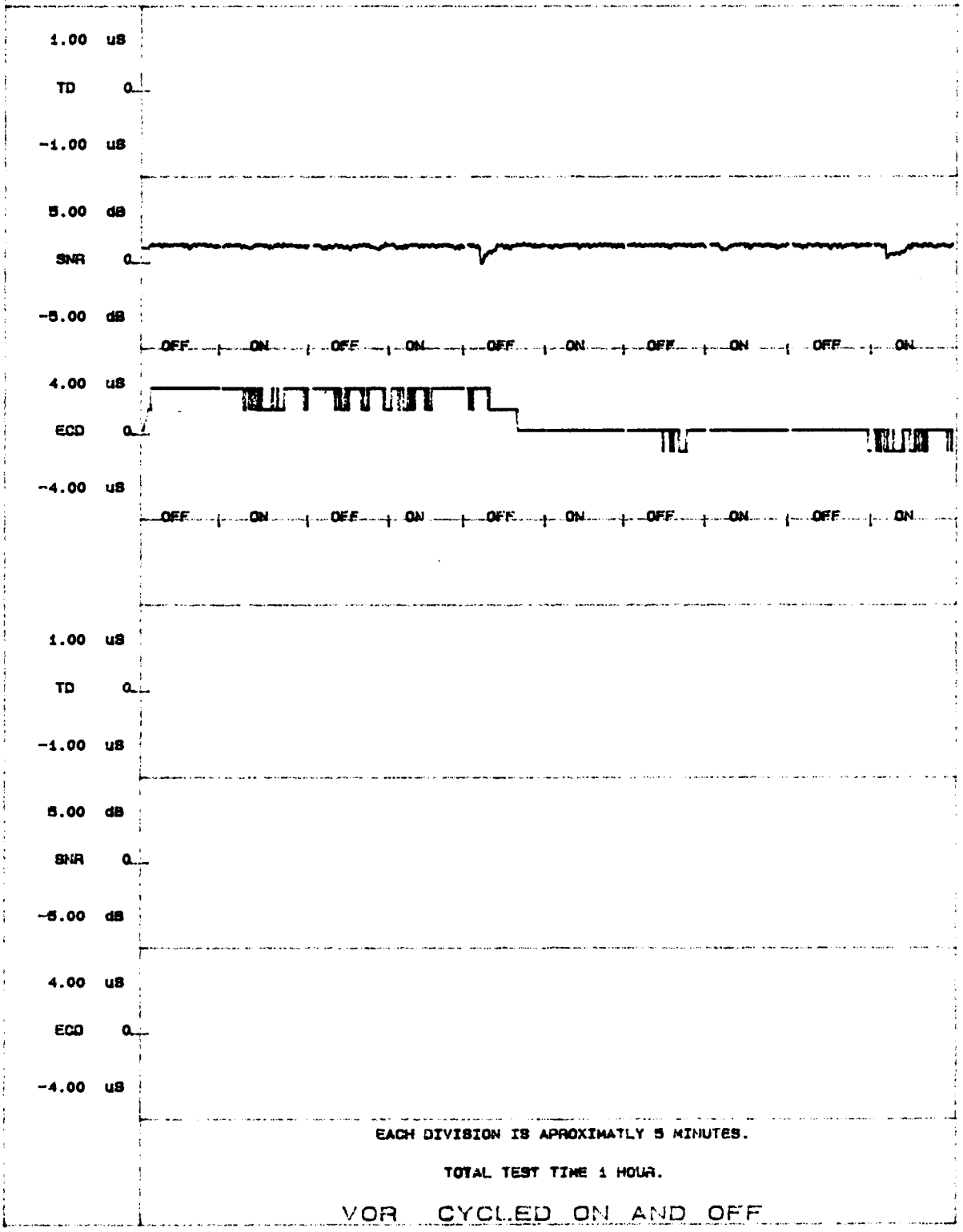
LORAN-C CO-LOCATION TEST

GRAPH VALUES = ACTUAL DATA - QUIESCENT MEAN VALUE.

QUIESCENT MEAN VALUES
TD 0000000 uS
SNR 3.71240 dB
ECD 1.76949 uS

DATA COLLECTION DATE 05-14-88

STATION M ANT. LOCATION COUNTER POISE



EACH DIVISION IS APROXIMATLY 5 MINUTES.

TOTAL TEST TIME 1 HOUR.

VOR CYCLED ON AND OFF

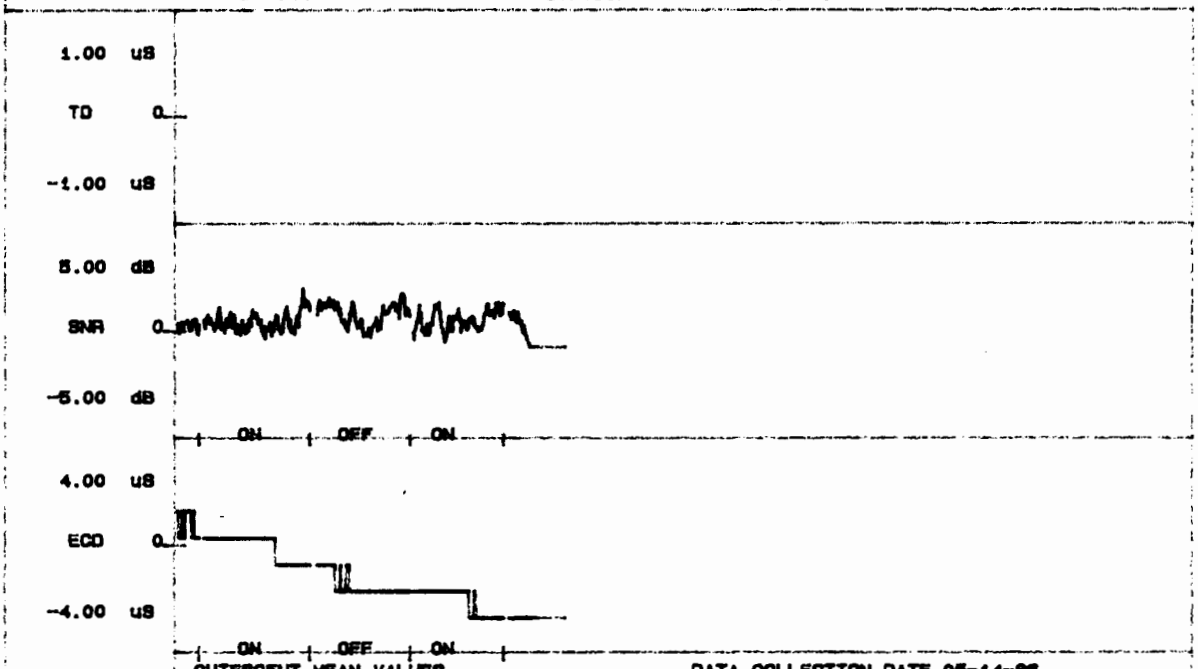
LORAN-C CO-LOCATION TEST

GRAPH VALUES = ACTUAL DATA - QUIESCENT MEAN VALUE.

QUIESCENT MEAN VALUES
TD 11.16554 uS
SNR -17.1002 dB
ECD -.31579 uS

DATA COLLECTION DATE 05-14-86

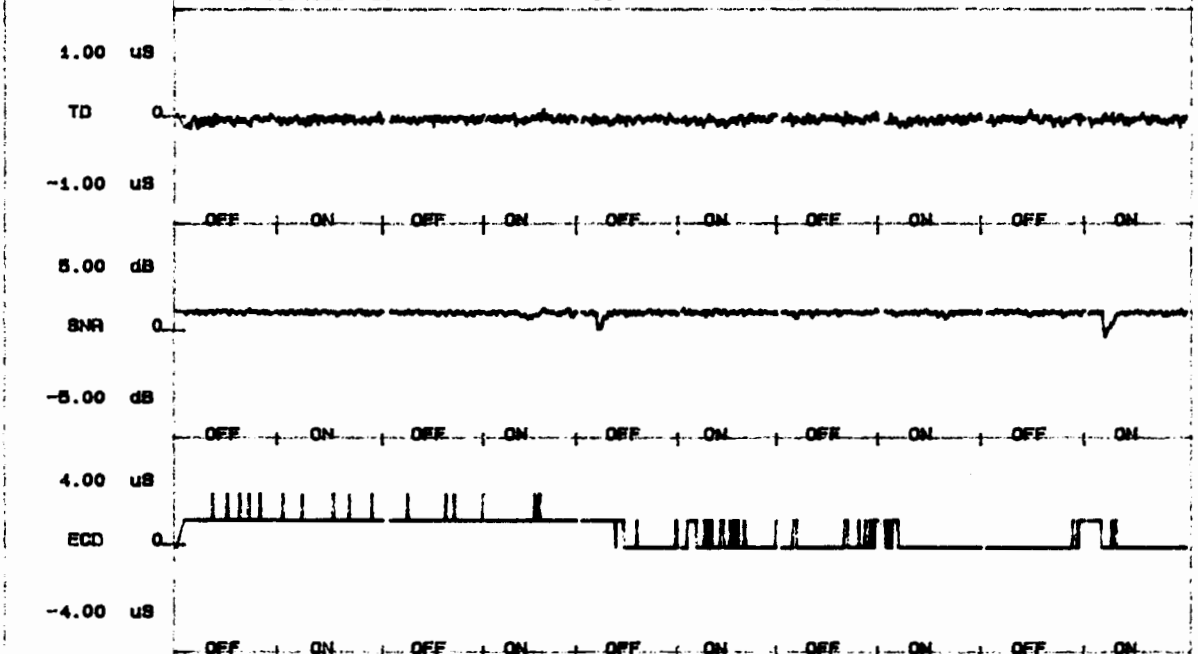
STATION W ANT. LOCATION COUNTER POISE



QUIESCENT MEAN VALUES
TD -2.94930 uS
SNR 3.26745 dB
ECD 3.04396 uS

DATA COLLECTION DATE 05-14-86

STATION X ANT. LOCATION COUNTER POISE



EACH DIVISION IS APROXIMATLY 5 MINUTES.

TOTAL TEST TIME 1 HOUR.

VOR CYCLED ON AND OFF

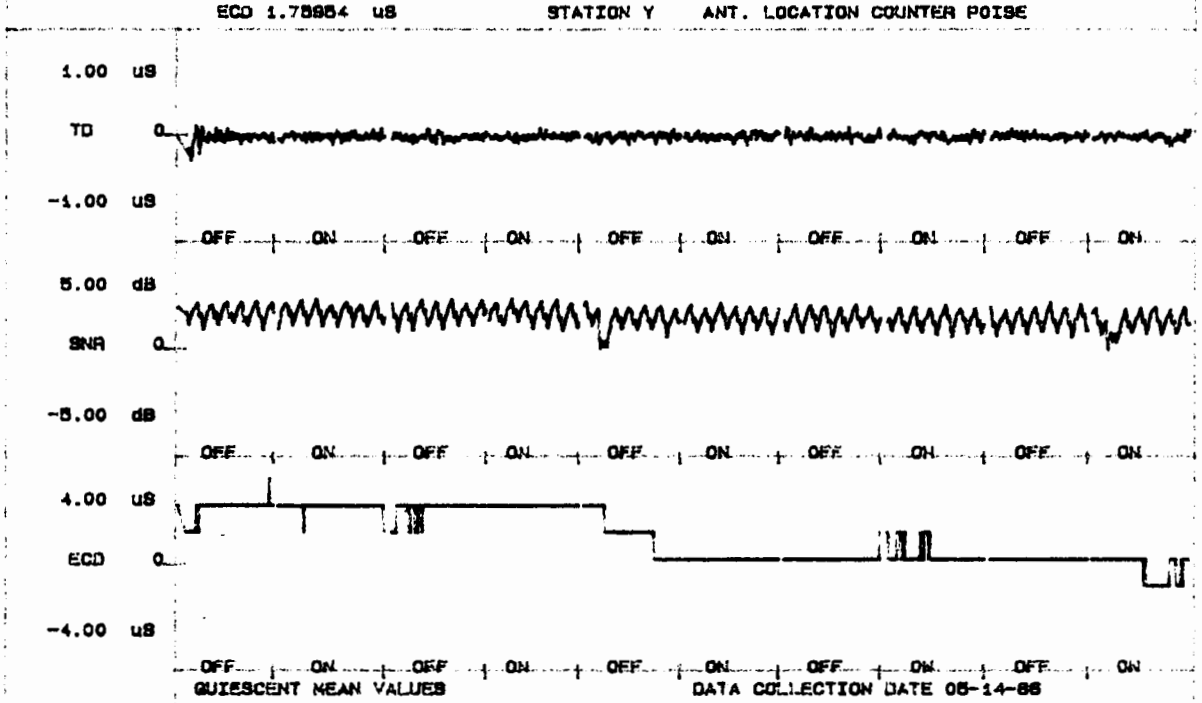
LORAN-C CO-LOCATION TEST

GRAPH VALUES = ACTUAL DATA - QUIESCENT MEAN VALUE.

QUIESCENT MEAN VALUES
TD -.49411 uS
SNR 2.30784 dB
ECD 1.75954 uS

DATA COLLECTION DATE 06-14-86

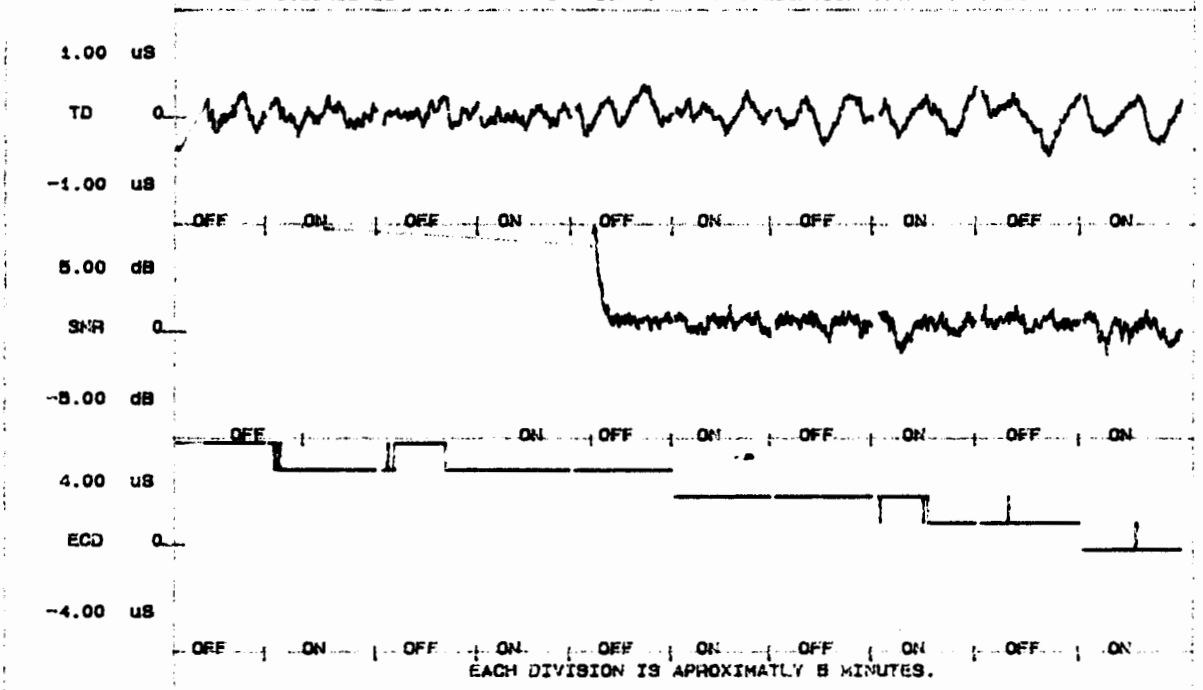
STATION Y ANT. LOCATION COUNTER POISE



QUIESCENT MEAN VALUES
TD 1.34209 uS
SNR -16.3476 dB
ECD -3.86433 uS

DATA COLLECTION DATE 06-14-86

STATION Z ANT. LOCATION COUNTER POISE



EACH DIVISION IS APROXIMATLY 5 MINUTES.

TOTAL TEST TIME 1 HOUR.

VOR CYCLED ON AND OFF

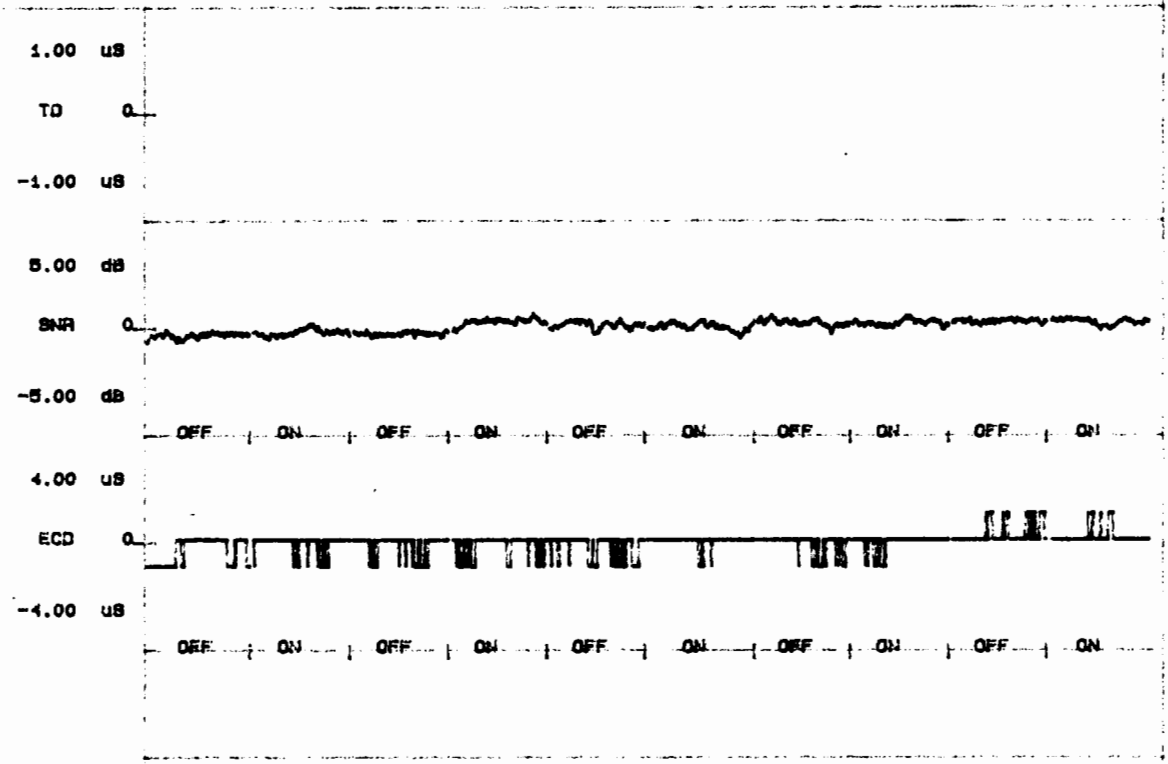
LORAN-C CO-LOCATION TEST

GRAPH VALUES = ACTUAL DATA - QUIESCENT MEAN VALUE.

QUIESCENT MEAN VALUES
TD 0000000 uS
SNR 3.09461 dB
ECD 1.82101 uS

DATA COLLECTION DATE 05-15-86

STATION M ANT. LOCATION TACAN MONITOR POLE



EACH DIVISION IS APROXIMATLY 5 MINUTES.

TOTAL TEST TIME 1 HOUR.

VOR CYCLED ON AND OFF

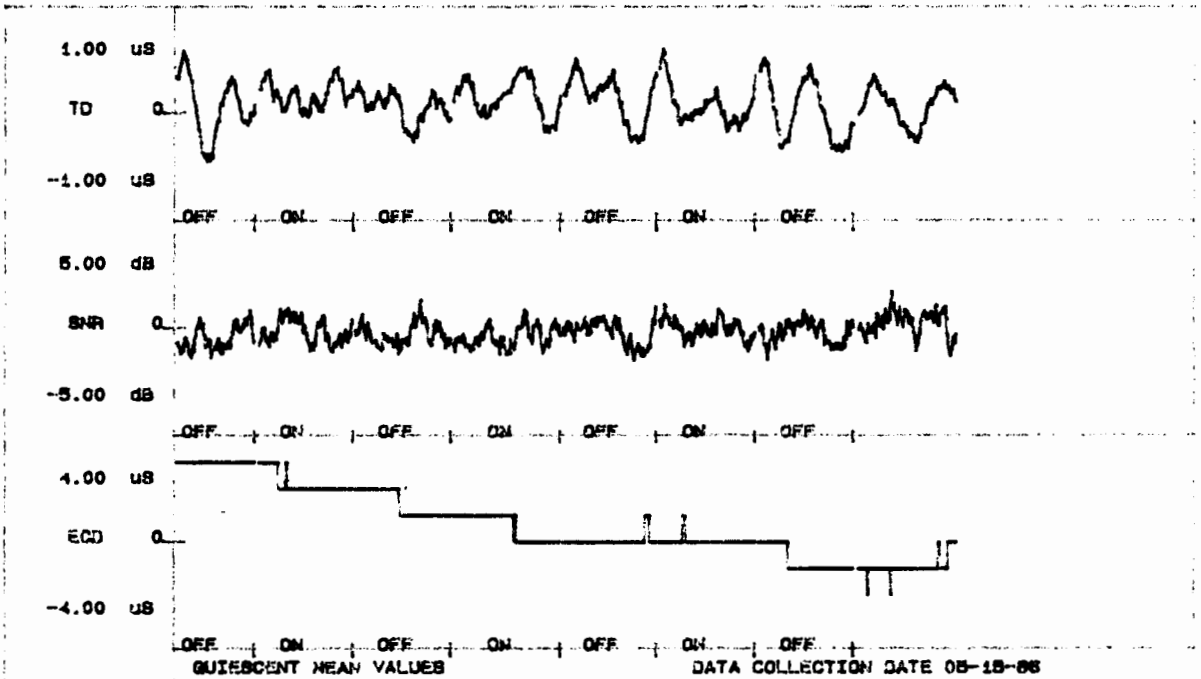
LORAN-C CO-LOCATION TEST

GRAPH VALUES = ACTUAL DATA - QUIESCENT MEAN VALUE.

QUIESCENT MEAN VALUES
TD 1.13202 uS
SNR -16.2535 dB
ECD -3.03885 uS

DATA COLLECTION DATE 05-15-86

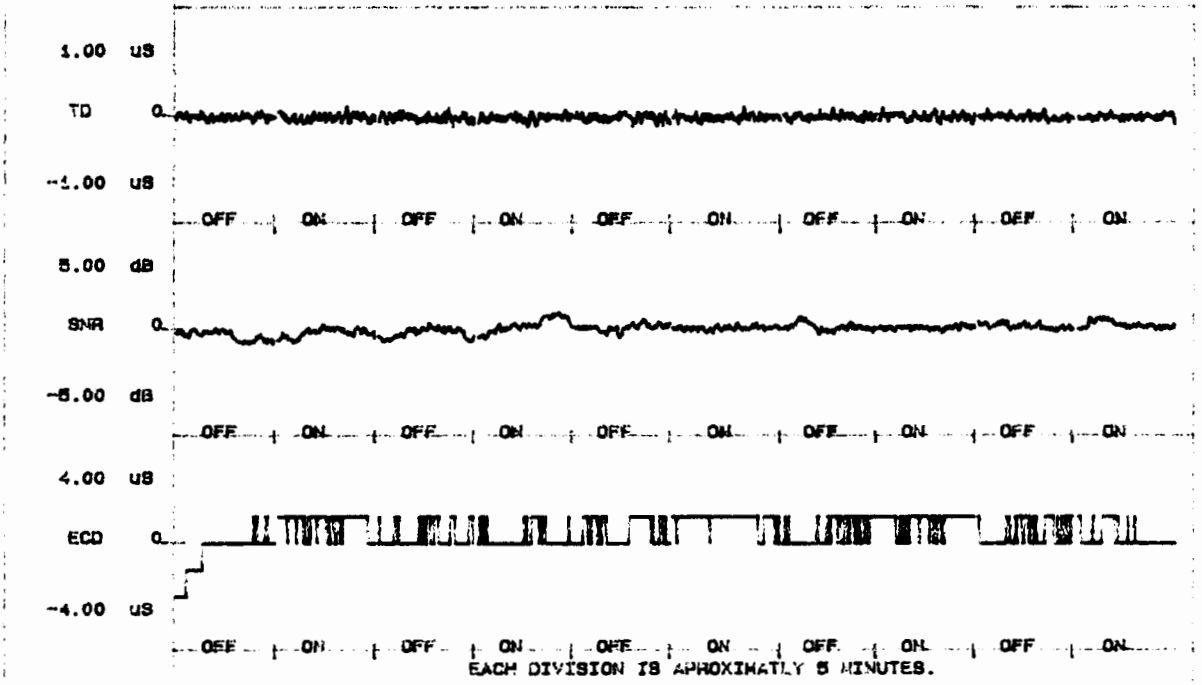
STATION W ANT. LOCATION TACAN MONITOR POLE



QUIESCENT MEAN VALUES
TD -2.91743 uS
SNR 2.78671 dB
ECD 2.98143 uS

DATA COLLECTION DATE 05-15-86

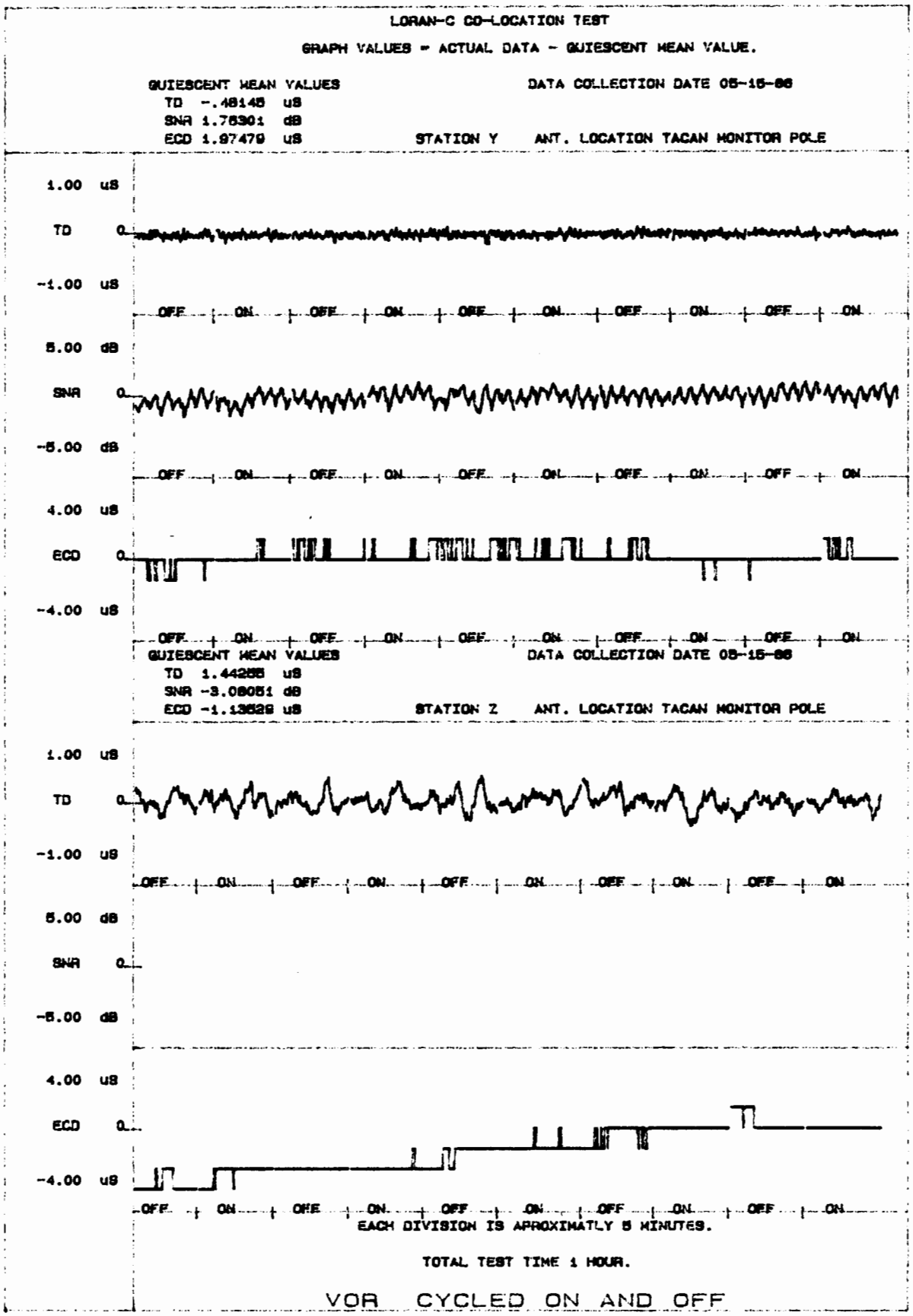
STATION X ANT. LOCATION TACAN MONITOR POLE



EACH DIVISION IS APROXIMATLY 5 MINUTES.

TOTAL TEST TIME 1 HOUR.

VOR CYCLED ON AND OFF


LORAN-C CO-LOCATION TEST
GRAPH VALUES = ACTUAL DATA - QUIESCENT MEAN VALUE.
QUIESCENT MEAN VALUES
TD -.48145 uS
SNR 1.76301 dB
ECD 1.97479 uS
DATA COLLECTION DATE 05-15-86
STATION Y ANT. LOCATION TACAN MONITOR POLE
1.00 uS
TD 0
-1.00 uS
OFF ON OFF ON OFF ON OFF ON OFF ON
5.00 dB
SNR 0
-5.00 dB
OFF ON OFF ON OFF ON OFF ON OFF ON
4.00 uS
ECD 0
-4.00 uS
OFF ON OFF ON OFF ON OFF ON OFF ON
QUIESCENT MEAN VALUES
TD 1.44255 uS
SNR -3.08051 dB
ECD -1.13529 uS
DATA COLLECTION DATE 05-15-86
STATION Z ANT. LOCATION TACAN MONITOR POLE
1.00 uS
TD 0
-1.00 uS
OFF ON OFF ON OFF ON OFF ON OFF ON
5.00 dB
SNR 0
-5.00 dB
4.00 uS
ECD 0
-4.00 uS
OFF ON OFF ON OFF ON OFF ON OFF ON
EACH DIVISION IS APROXIMATLY 5 MINUTES.
TOTAL TEST TIME 1 HOUR.
VOR CYCLED ON AND OFF

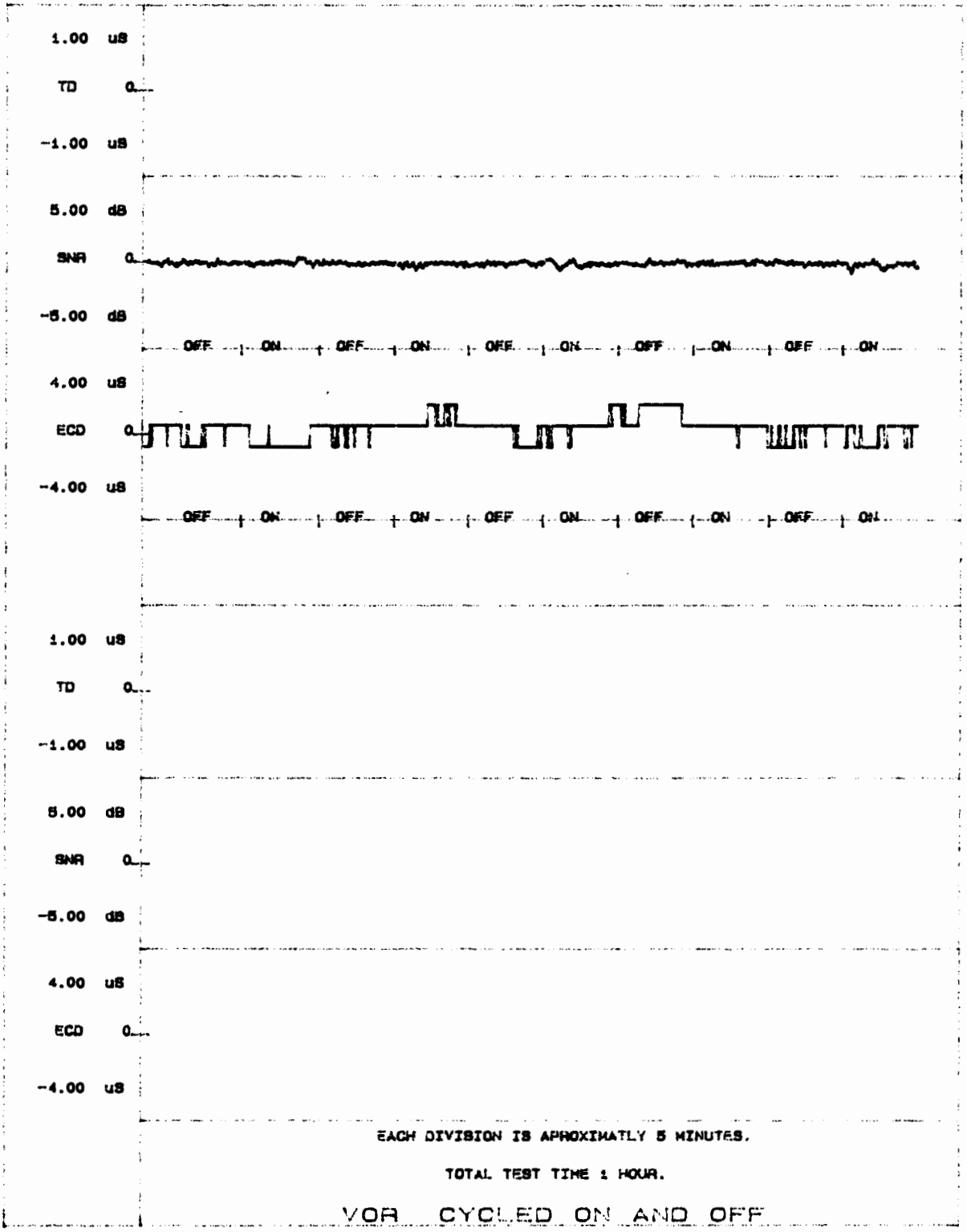
LORAN-C CO-LOCATION TEST

GRAPH VALUES = ACTUAL DATA - QUIESCENT MEAN VALUE.

QUIESCENT MEAN VALUES
TD 0000000 uS
SNR 2.90300 dB
ECD .52374 uS

DATA COLLECTION DATE 05-15-86

STATION M ANT. LOCATION FAR FIELD



EACH DIVISION IS APROXIMATLY 5 MINUTES.

TOTAL TEST TIME 1 HOUR.

VOR CYCLED ON AND OFF

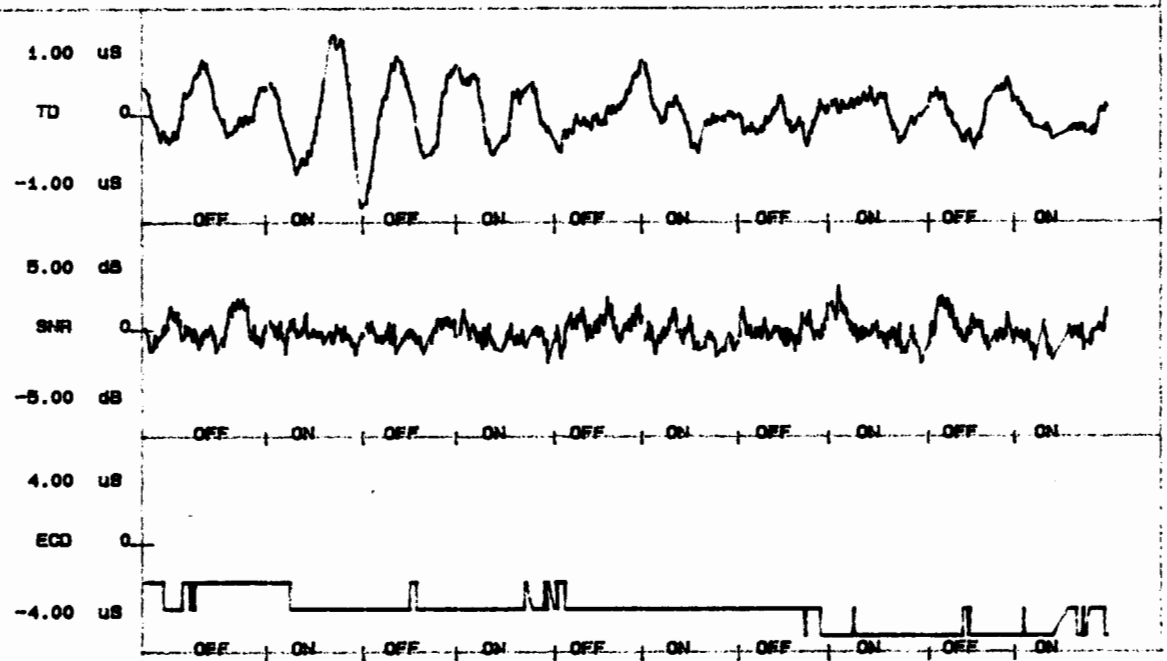
LORAN-C CO-LOCATION TEST

GRAPH VALUES = ACTUAL DATA - QUIESCENT MEAN VALUE.

QUIESCENT MEAN VALUES
TD .31121 uS
SNR -16.7702 dB
ECD -.63363 uS

DATA COLLECTION DATE 05-15-86

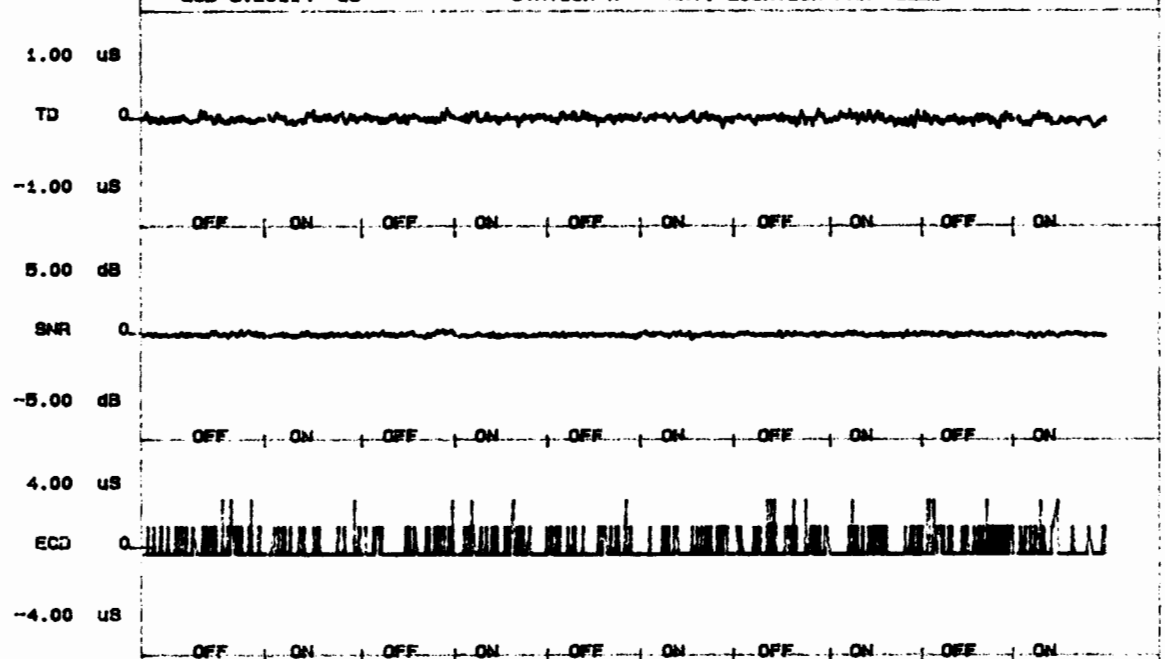
STATION W ANT. LOCATION FAR FIELD



QUIESCENT MEAN VALUES
TD -3.70245 uS
SNR 4.24026 dB
ECD 3.20114 uS

DATA COLLECTION DATE 05-15-86

STATION X ANT. LOCATION FAR FIELD



EACH DIVISION IS APROXIMATLY 6 MINUTES.

TOTAL TEST TIME 1 HOUR.

VOR CYCLED ON AND OFF

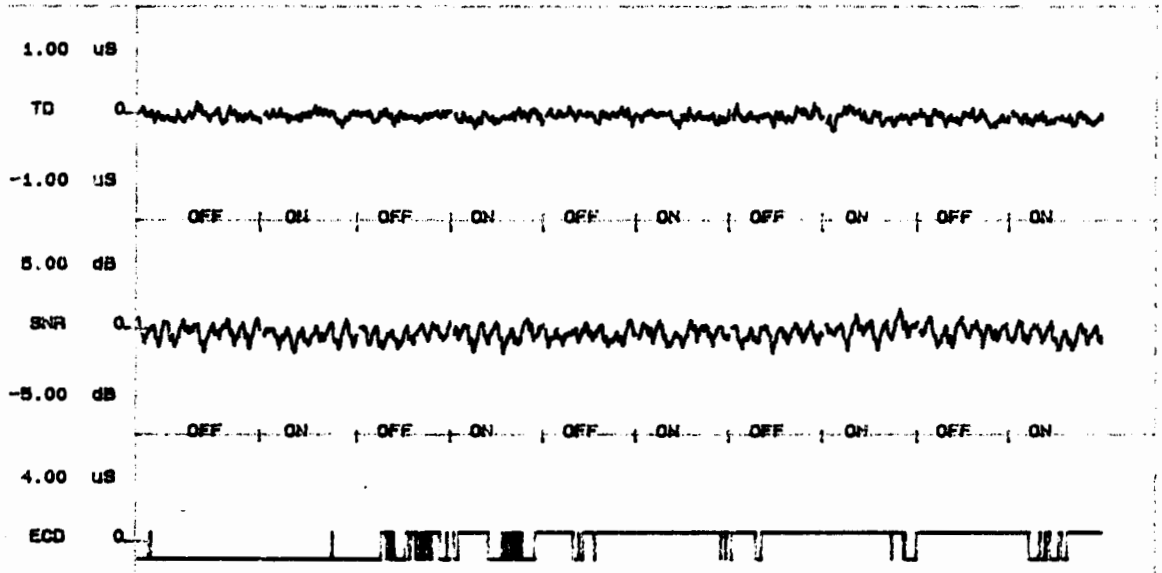
LORAN-C CO-LOCATION TEST

GRAPH VALUES = ACTUAL DATA - QUIESCENT MEAN VALUE.

QUIESCENT MEAN VALUES
TD .92392 uS
SNR .15991 dB
ECD -.39141 uS

DATA COLLECTION DATE 05-15-86

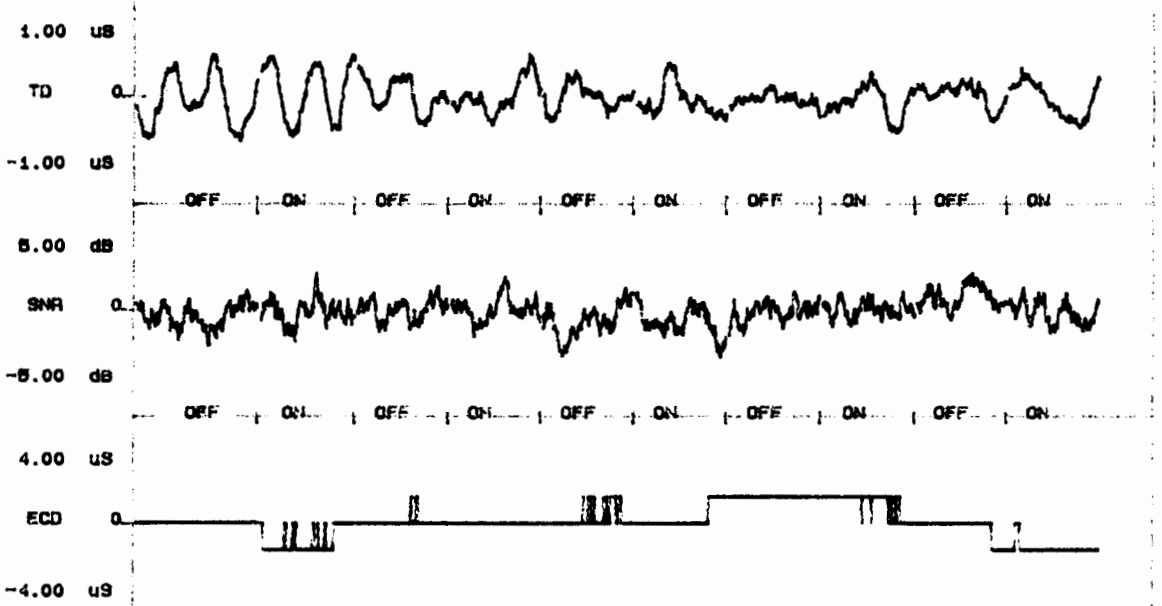
STATION Y ANT. LOCATION FAR FIELD



QUIESCENT MEAN VALUES
TD 3.43959 uS
SNR -14.9862 dB
ECD -1.08098 uS

DATA COLLECTION DATE 05-15-86

STATION Z ANT. LOCATION FAR FIELD



EACH DIVISION IS APROXIMATLY 5 MINUTES.

TOTAL TEST TIME 1 HOUR.

VOR CYCLED ON AND OFF

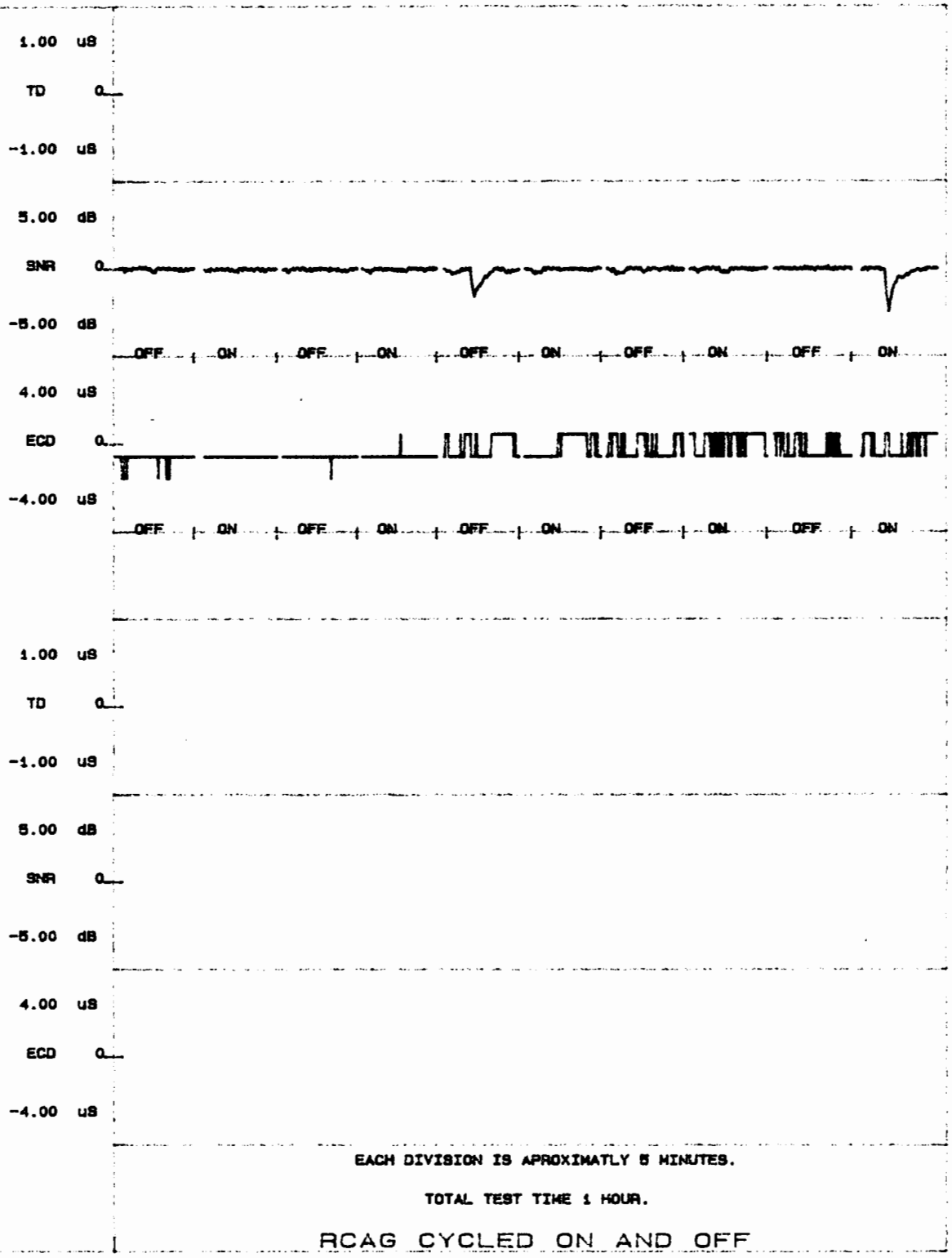
LORAN-C CO-LOCATION TEST

GRAPH VALUES = ACTUAL DATA - QUIESCENT MEAN VALUE.

QUIESCENT MEAN VALUES
TD 0000000 uS
SNR 4.75534 dB
ECD 1.51452 uS

DATA COLLECTION DATE 05-16-86

STATION M ANT. LOCATION COUNTER POISE



EACH DIVISION IS APROXIMATLY 5 MINUTES.

TOTAL TEST TIME 1 HOUR.

RCAG CYCLED ON AND OFF

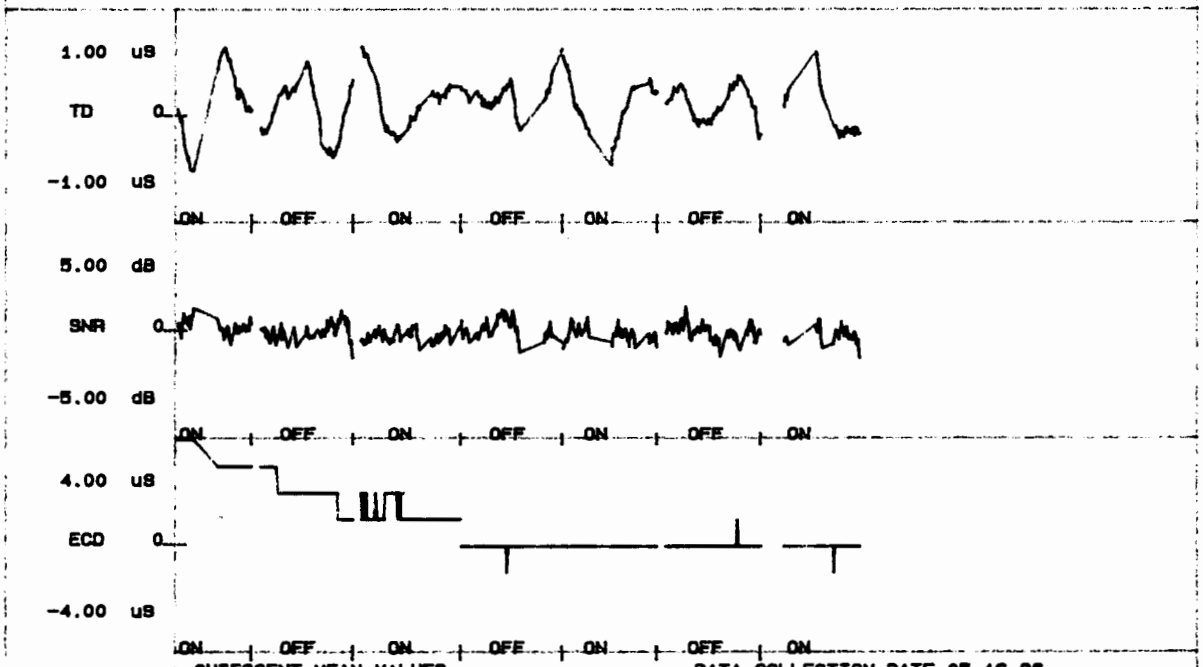
LORAN-C CO-LOCATION TEST

GRAPH VALUES = ACTUAL DATA - QUIESCENT MEAN VALUE.

QUIESCENT MEAN VALUES
TD 1.11214 uS
SNR -17.0185 dB
ECD -3.97880 uS

DATA COLLECTION DATE 05-16-86

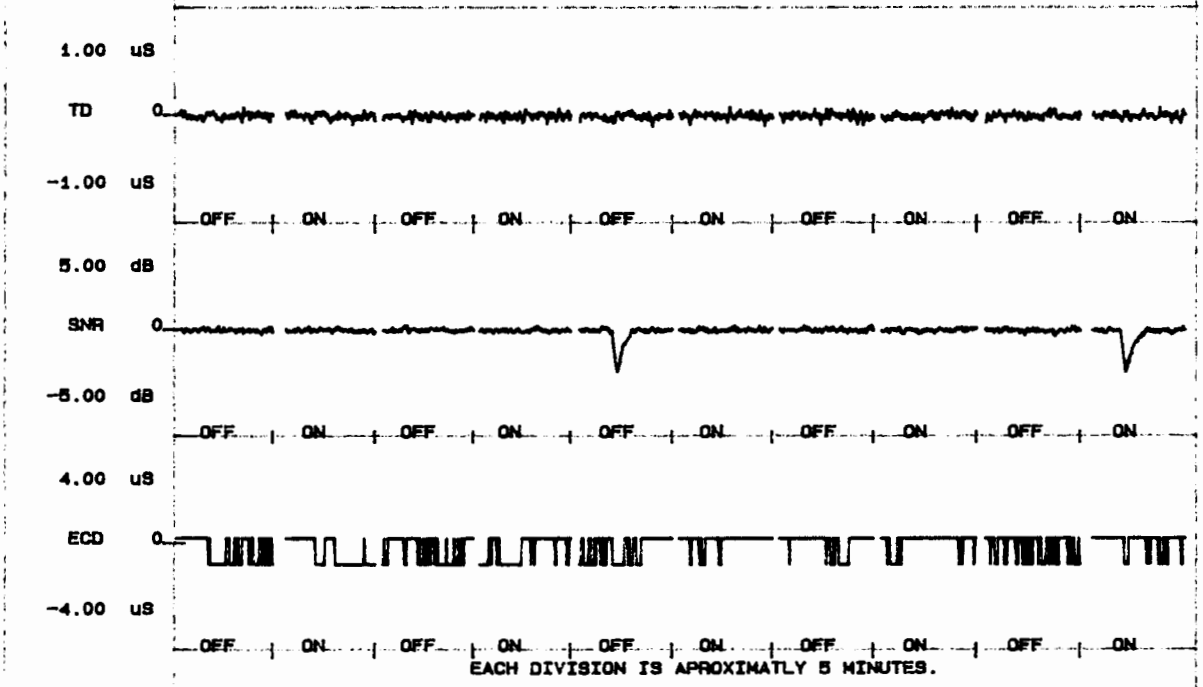
STATION W ANT. LOCATION COUNTER POISE



QUIESCENT MEAN VALUES
TD -2.98967 uS
SNR 4.18687 dB
ECD 2.77759 uS

DATA COLLECTION DATE 05-16-86

STATION X ANT. LOCATION COUNTER POISE



EACH DIVISION IS APROXIMATLY 5 MINUTES.

TOTAL TEST TIME 1 HOUR.

RCAG CYCLED ON AND OFF

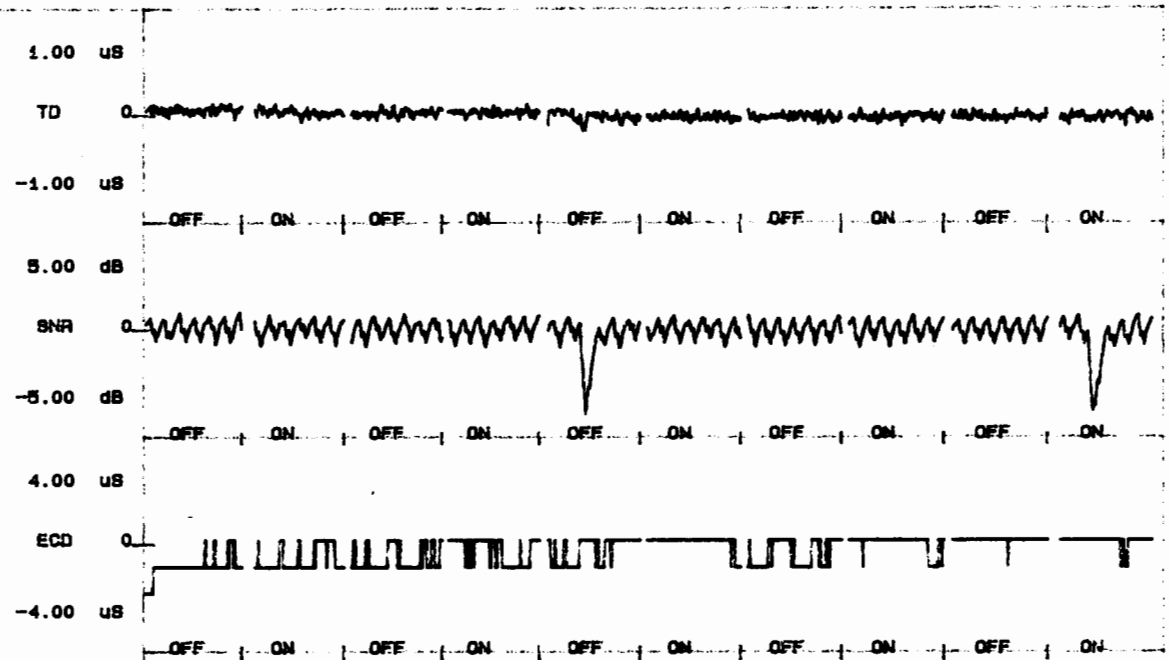
LORAN-C CO-LOCATION TEST

GRAPH VALUES = ACTUAL DATA - QUIESCENT MEAN VALUE.

QUIESCENT MEAN VALUES
TD -.63516 uS
SNR 3.89297 dB
ECD 1.78755 uS

DATA COLLECTION DATE 05-16-86

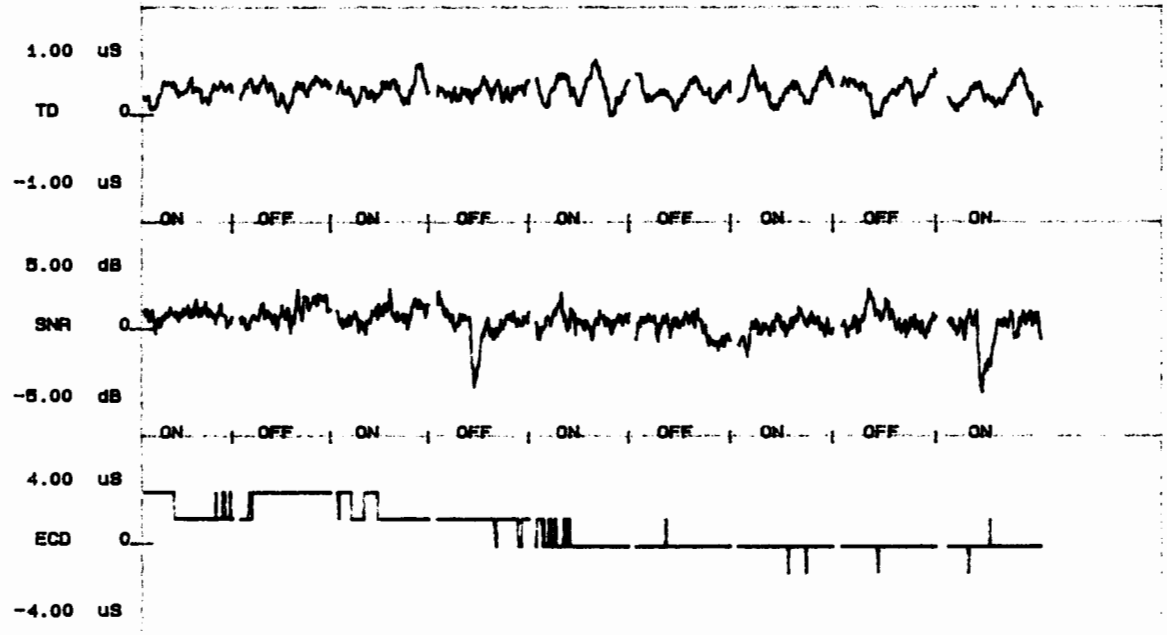
STATION Y ANT. LOCATION COUNTER POISE



QUIESCENT MEAN VALUES
TD 1.136011 uS
SNR -12.6053 dB
ECD -3.94421 uS

DATA COLLECTION DATE 05-16-86

STATION Z ANT. LOCATION COUNTER POISE



EACH DIVISION IS APROXIMATLY 5 MINUTES.

TOTAL TEST TIME 1 HOUR.

RCAG CYCLED ON AND OFF

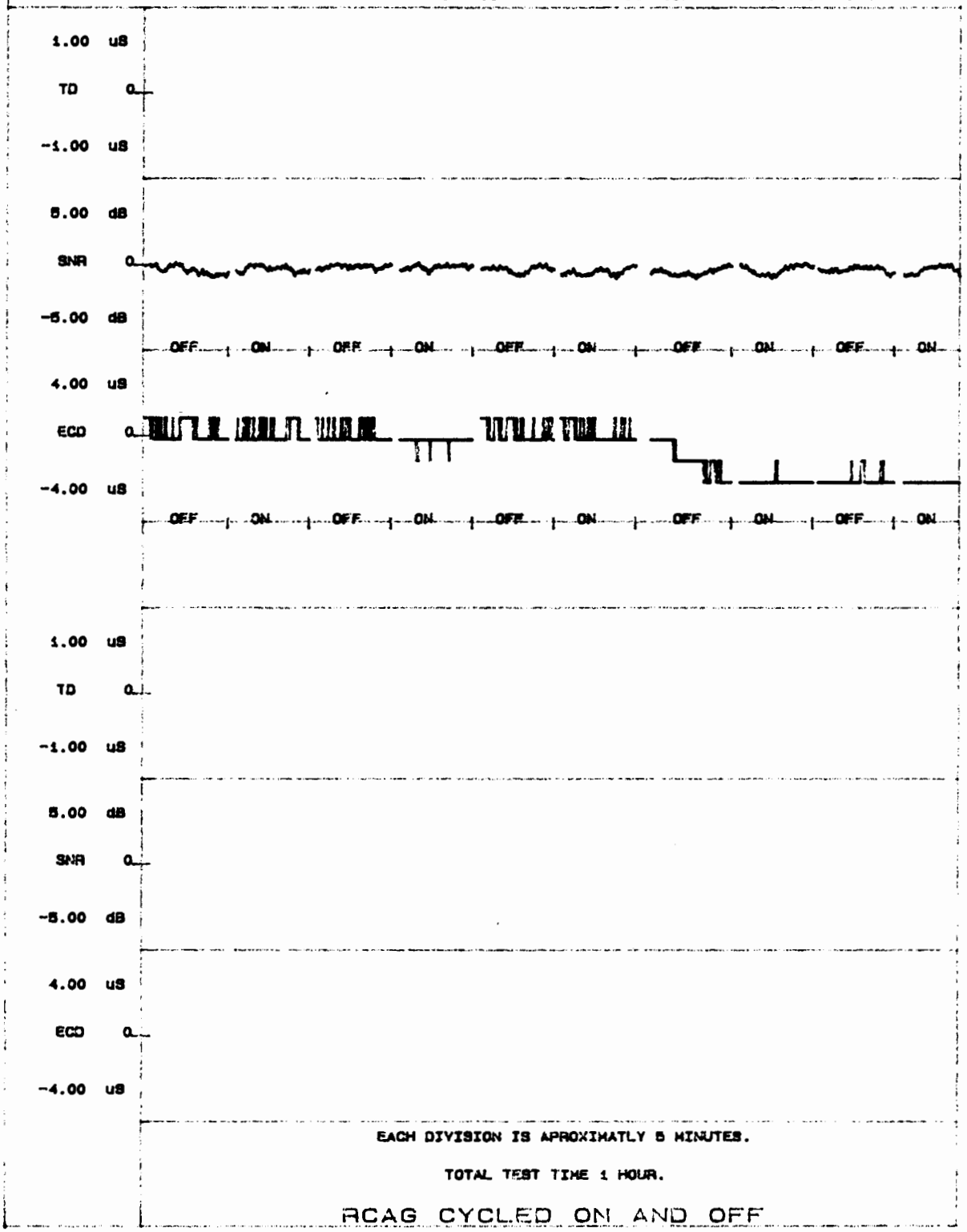
LORAN-C CO-LOCATION TEST

GRAPH VALUES - ACTUAL DATA - QUIESCENT MEAN VALUE.

QUIESCENT MEAN VALUES
TD 0000000 uS
SNR 4.11309 dB
ECD .11638 uS

DATA COLLECTION DATE 04-03-86

STATION M ANT. LOCATION TACAN MONITOR POLE



EACH DIVISION IS APROXIMATLY 5 MINUTES.

TOTAL TEST TIME 1 HOUR.

RCAG CYCLED ON AND OFF

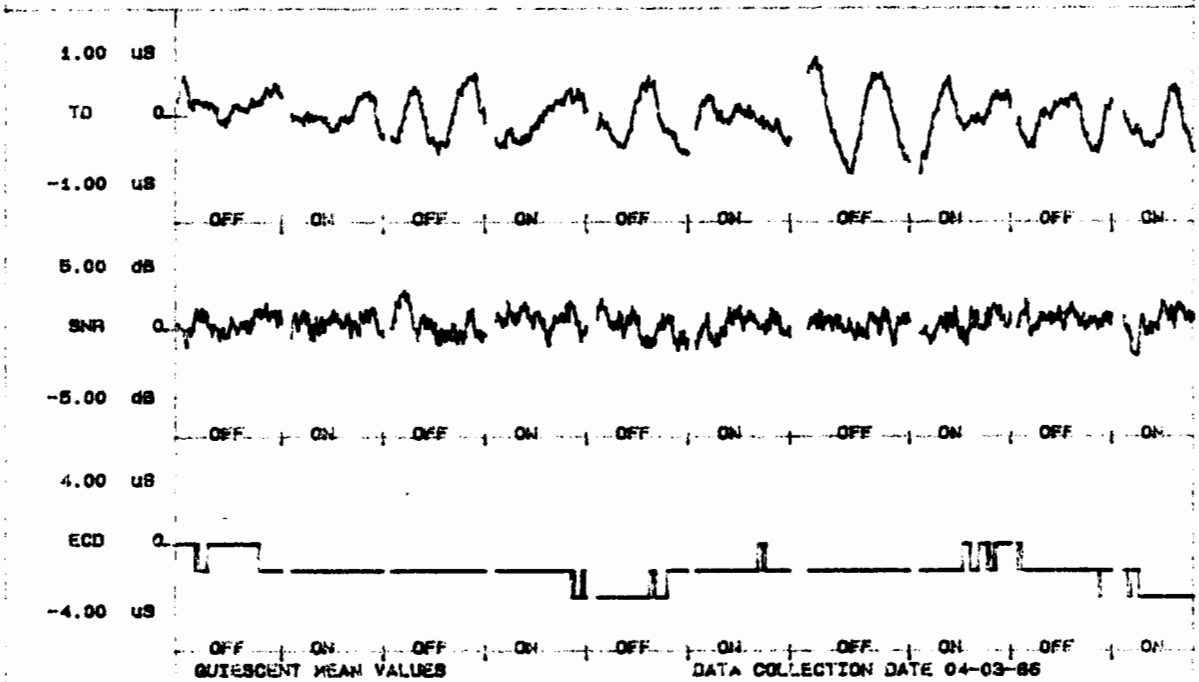
LORAN-C CO-LOCATION TEST

GRAPH VALUES = ACTUAL DATA - QUIESCENT MEAN VALUE.

QUIESCENT MEAN VALUES
TD 1.10670 uS
SNR -16.4034 dB
ECD -2.06366 uS

DATA COLLECTION DATE 04-03-86

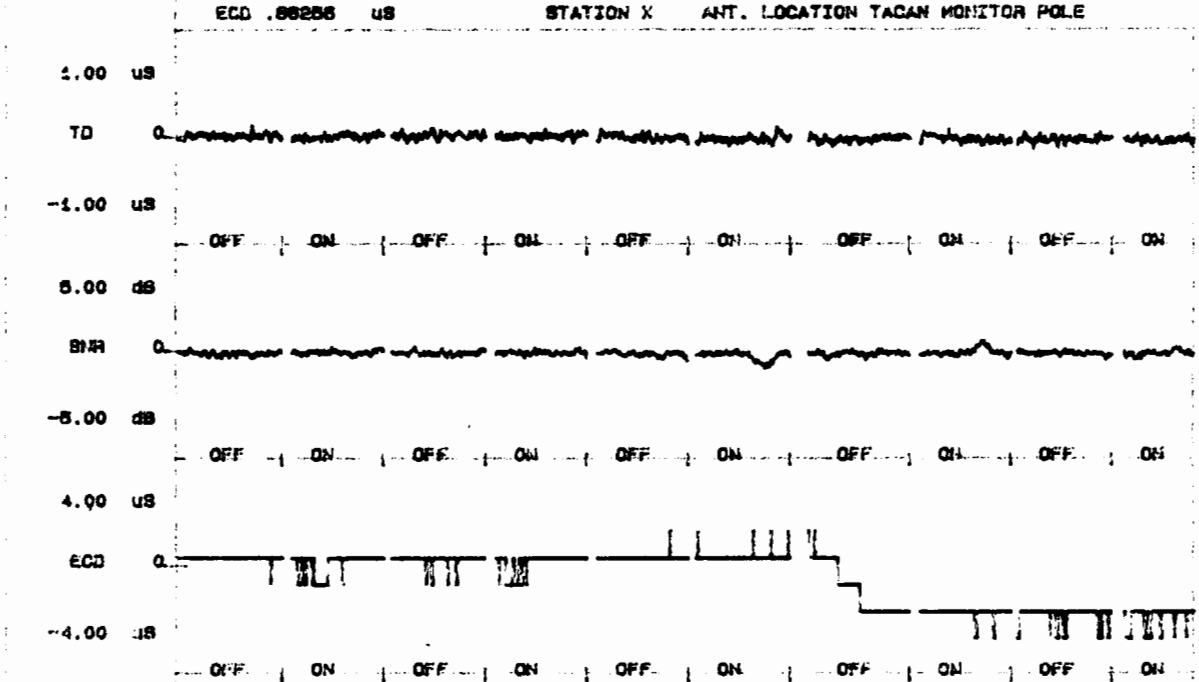
STATION W ANT. LOCATION TACAN MONITOR POLE



QUIESCENT MEAN VALUES
TD -2.91566 uS
SNR 3.58464 dB
ECD .86256 uS

DATA COLLECTION DATE 04-03-86

STATION X ANT. LOCATION TACAN MONITOR POLE



EACH DIVISION IS APROXIMATLY 5 MINUTES.

TOTAL TEST TIME 1 HOUR.

RCAG CYCLED ON AND OFF

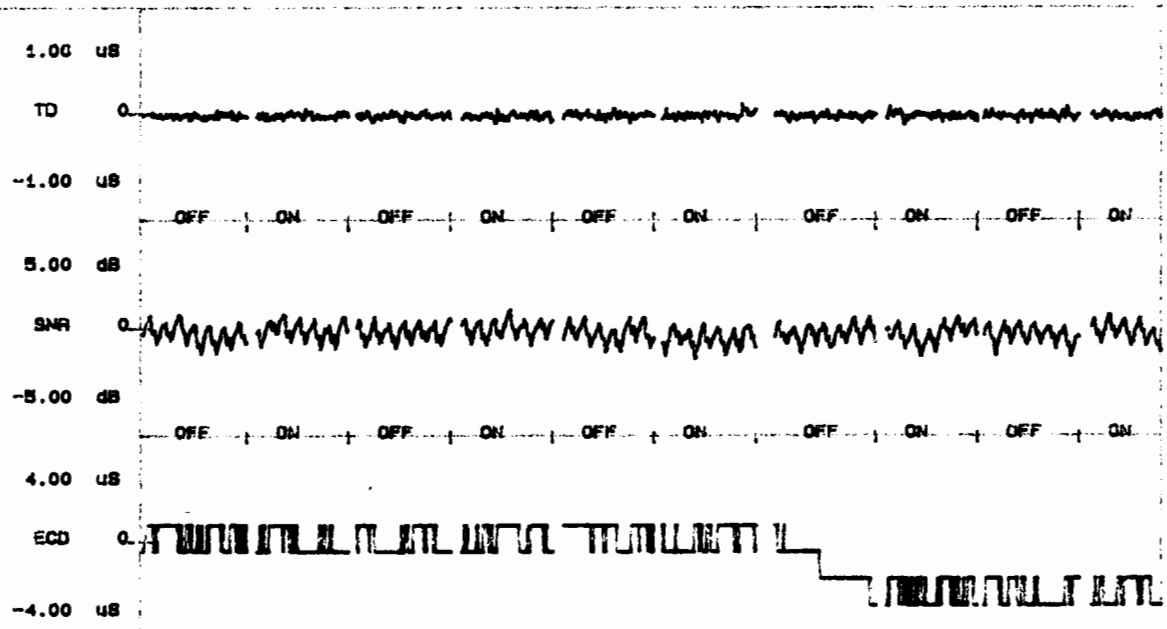
LORAN-C CO-LOCATION TEST

GRAPH VALUES = ACTUAL DATA - QUIESCENT MEAN VALUE.

QUIESCENT MEAN VALUES
TD -.47540 uS
SNR 2.94403 dB
ECD .31589 uS

DATA COLLECTION DATE 04-03-86

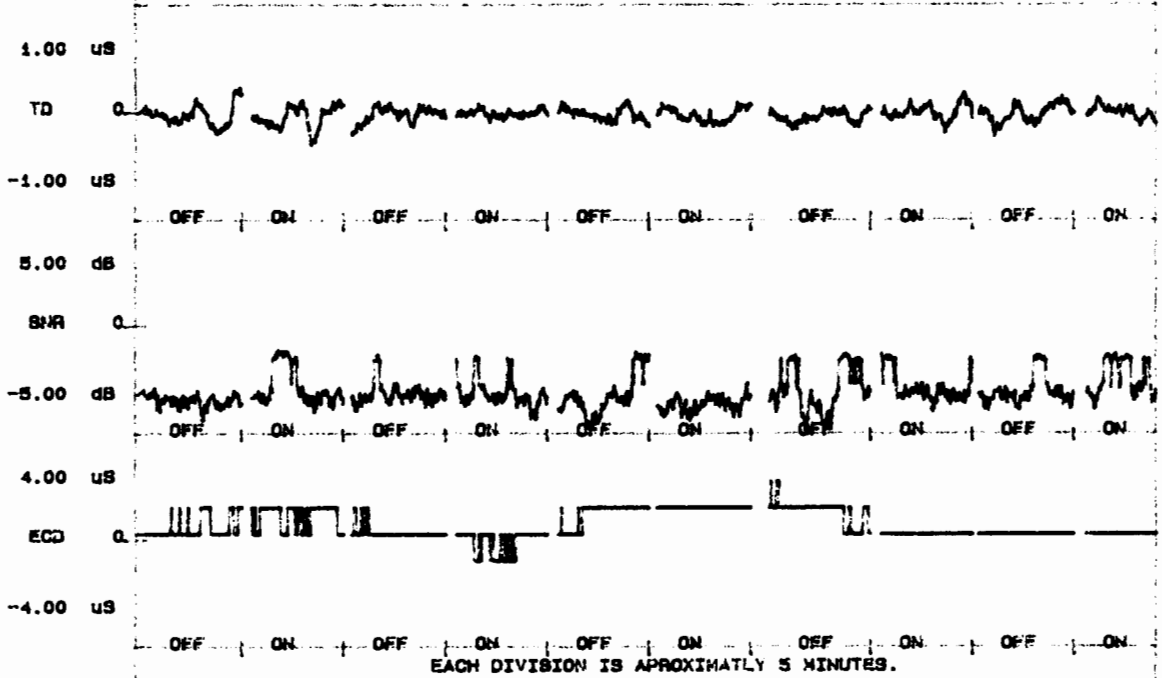
STATION Y ANT. LOCATION TACAN MONITOR POLE



QUIESCENT MEAN VALUES
TD 1.41402 uS
SNR -7.44600 dB
ECD -3.28420 uS

DATA COLLECTION DATE 04-03-86

STATION Z ANT. LOCATION TACAN MONITOR POLE



EACH DIVISION IS APROXIMATLY 5 MINUTES.

TOTAL TEST TIME 1 HOUR.

RCAG CYCLED ON AND OFF

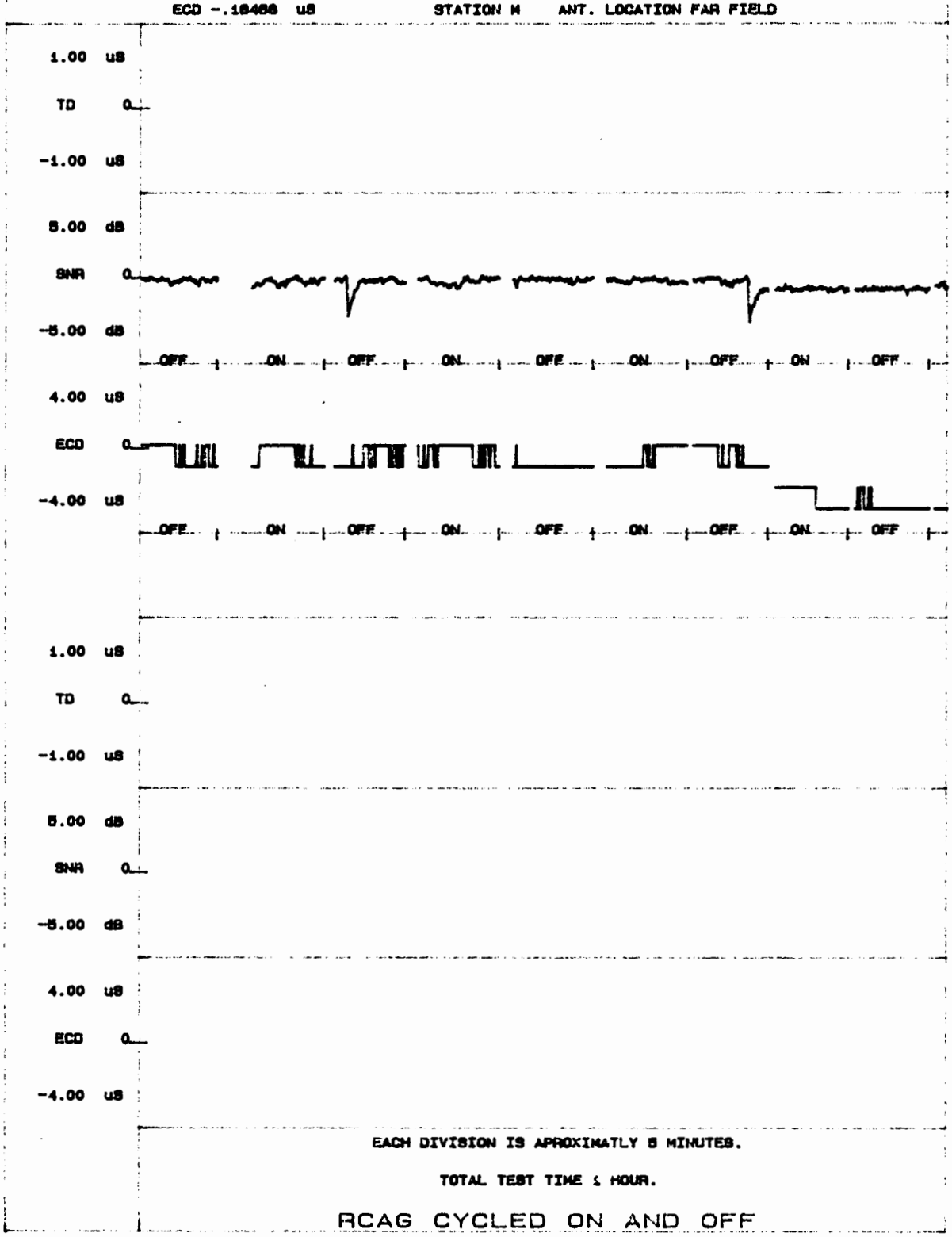
LORAN-C CO-LOCATION TEST

GRAPH VALUES = ACTUAL DATA - QUIESCENT MEAN VALUE.

QUIESCENT MEAN VALUES
TD uS
SNR 3.50319 dB
ECD -.18468 uS

DATA COLLECTION DATE 04-04-86

STATION M ANT. LOCATION FAR FIELD



EACH DIVISION IS APROXIMATLY 5 MINUTES.

TOTAL TEST TIME 1 HOUR.

RCAG CYCLED ON AND OFF

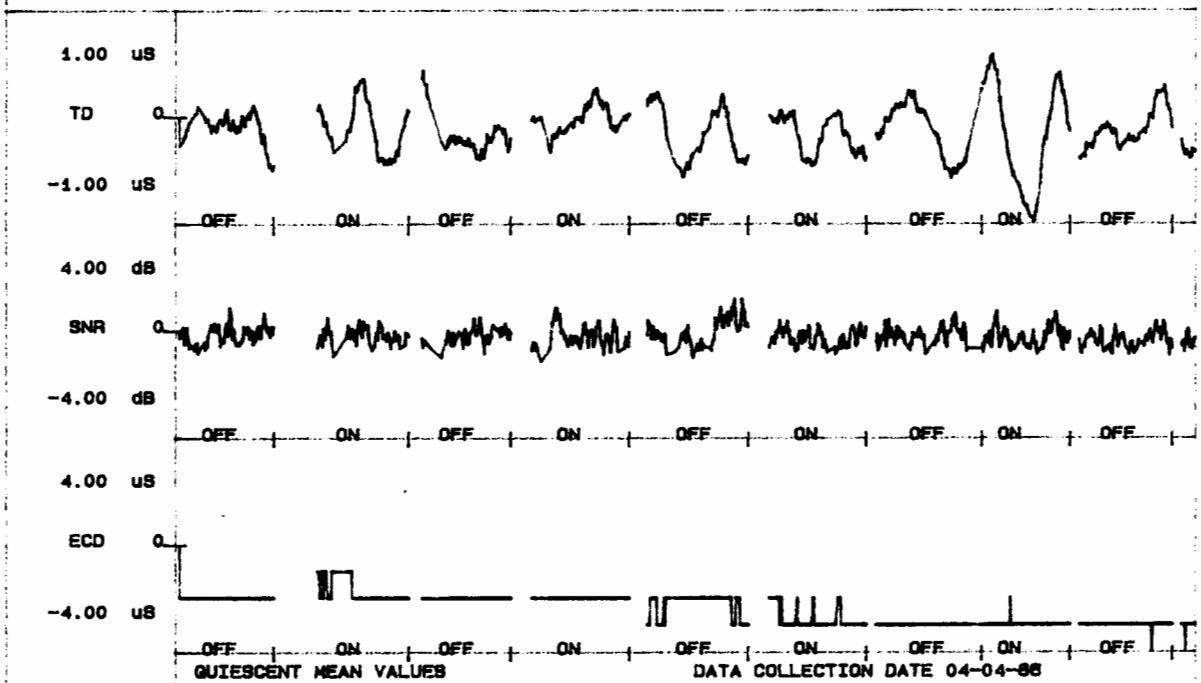
LORAN-C CO-LOCATION TEST

GRAPH VALUES = ACTUAL DATA - QUIESCENT MEAN VALUE.

QUIESCENT MEAN VALUES
TD .66852 uS
SNR -16.8604 dB
ECD -1.06690 uS

DATA COLLECTION DATE 04-04-86

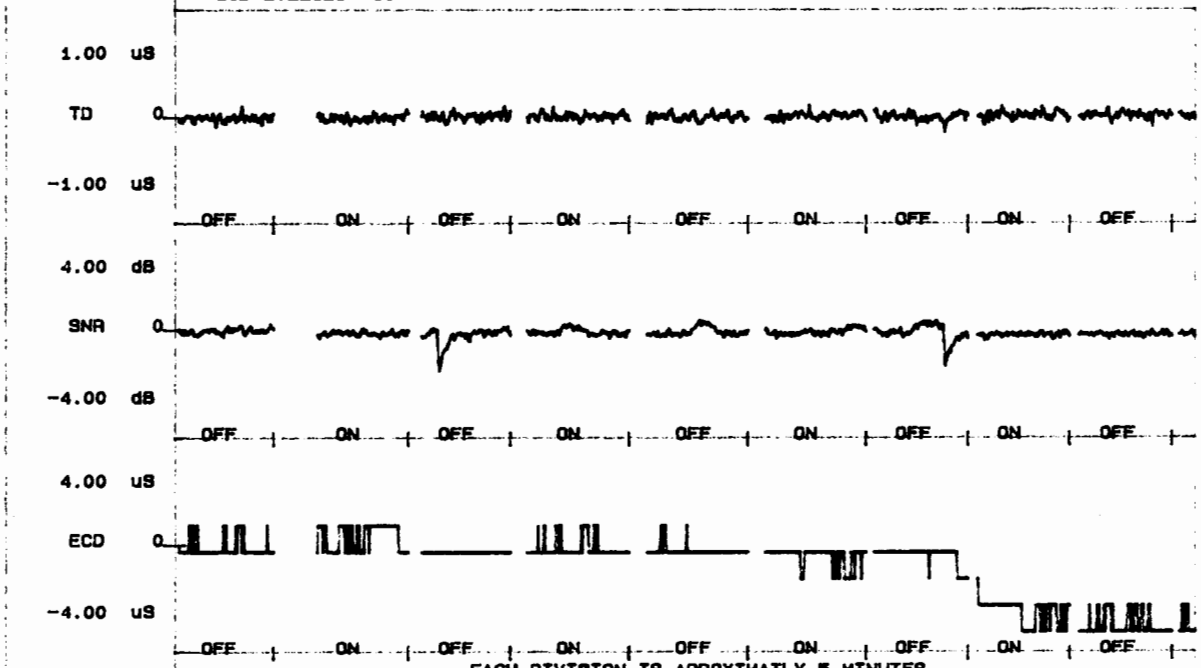
STATION W ANT. LOCATION FAR FIELD



QUIESCENT MEAN VALUES
TD -3.65900 uS
SNR 4.36496 dB
ECD 2.22128 uS

DATA COLLECTION DATE 04-04-86

STATION X ANT. LOCATION FAR FIELD



EACH DIVISION IS APROXIMATLY 5 MINUTES.

TOTAL TEST TIME 1 HOUR.

RCAG CYCLED ON AND OFF

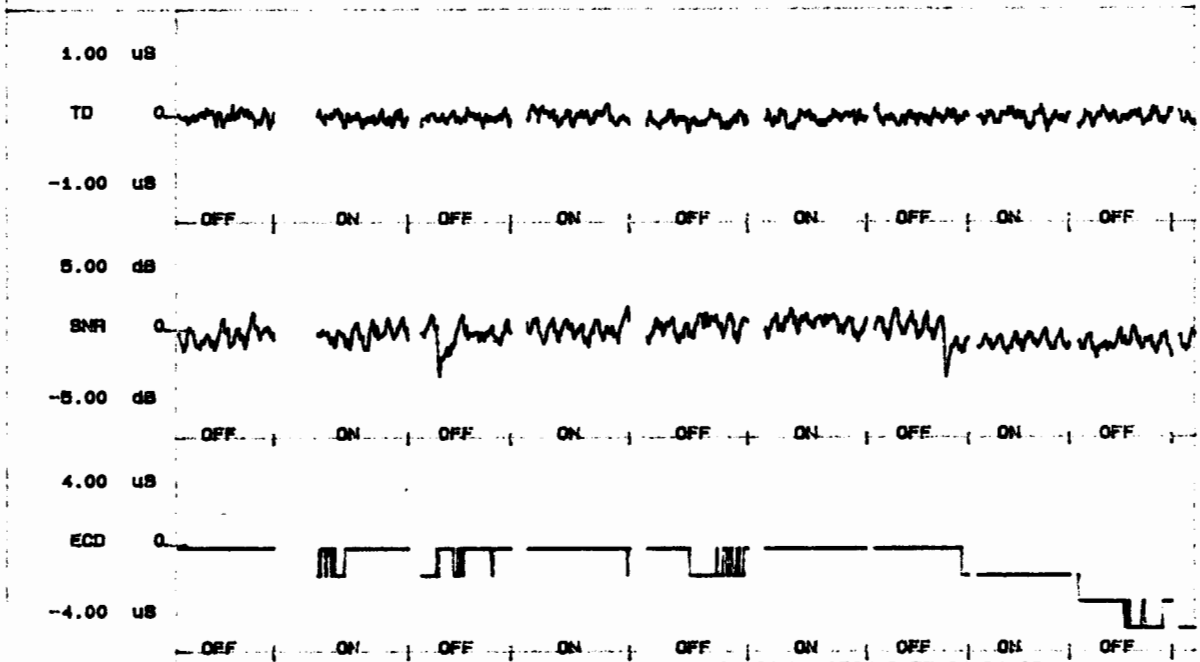
LORAN-C CO-LOCATION TEST

GRAPH VALUES = ACTUAL DATA - QUIESCENT MEAN VALUE.

QUIESCENT MEAN VALUES
TD .37260 uS
SNR -1.46370 dB
ECD -.90553 uS

DATA COLLECTION DATE 04-04-86

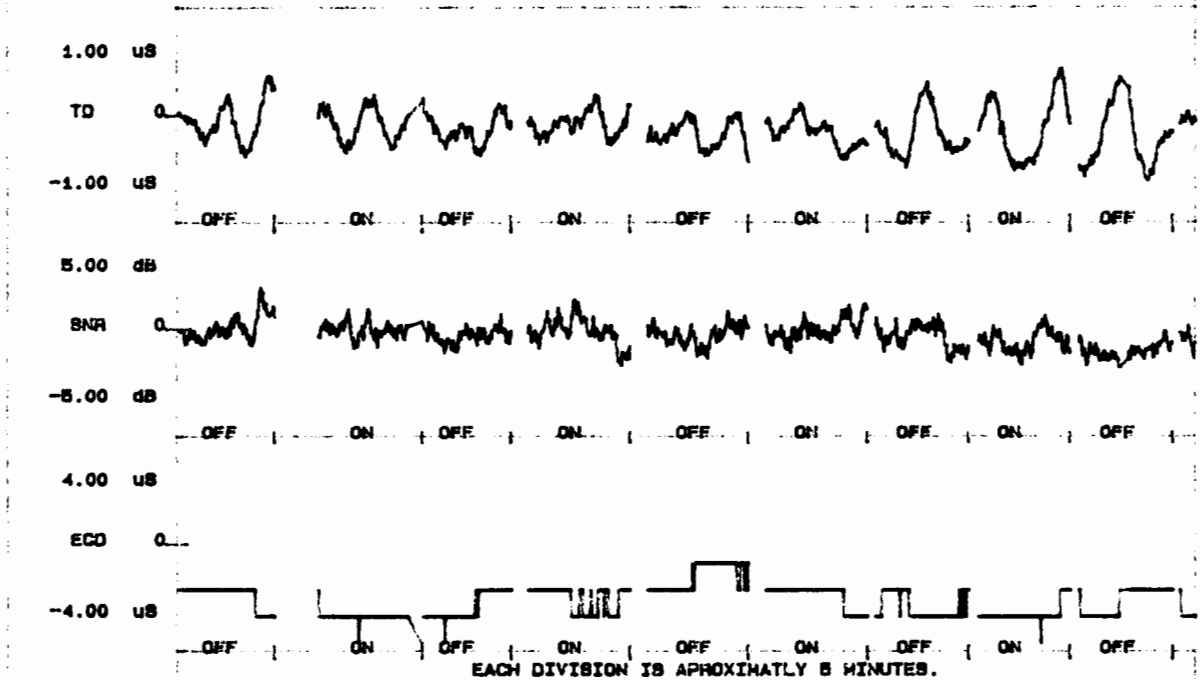
STATION Y ANT. LOCATION FAR FIELD



QUIESCENT MEAN VALUES
TD 3.02820 uS
SNR -15.6233 dB
ECD -1.34014 uS

DATA COLLECTION DATE 04-04-86

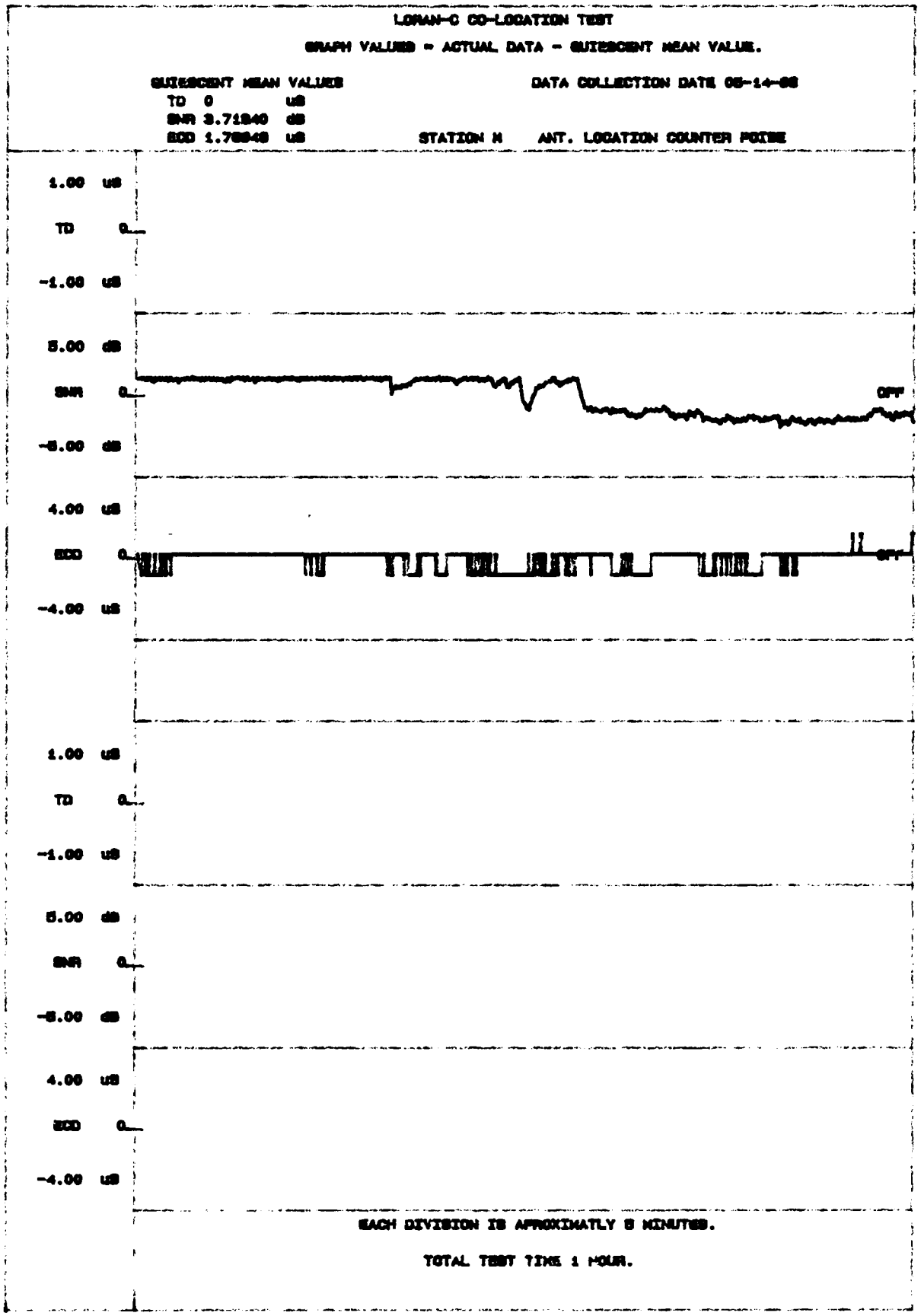
STATION Z ANT. LOCATION FAR FIELD



EACH DIVISION IS APROXIMATLY 5 MINUTES.

TOTAL TEST TIME 1 HOUR.

RCAG CYCLED ON AND OFF


LORAN-C CO-LOCATION TEST
GRAPH VALUES = ACTUAL DATA - QUIESCENT MEAN VALUE.
QUIESCENT MEAN VALUES
TD 0 uS
SNR 3.71840 dB
ECD 1.76848 uS
DATA COLLECTION DATE 05-14-88
STATION M
ANT. LOCATION COUNTER POINE
1.00 uS
TD 0
-1.00 uS
5.00 dB
SNR 0
-5.00 dB
OFF
4.00 uS
ECD 0
-4.00 uS
OFF
1.00 uS
TD 0
-1.00 uS
5.00 dB
SNR 0
-5.00 dB
4.00 uS
ECD 0
-4.00 uS
EACH DIVISION IS APPROXIMATLY 5 MINUTES.
TOTAL TEST TIME 1 HOUR.

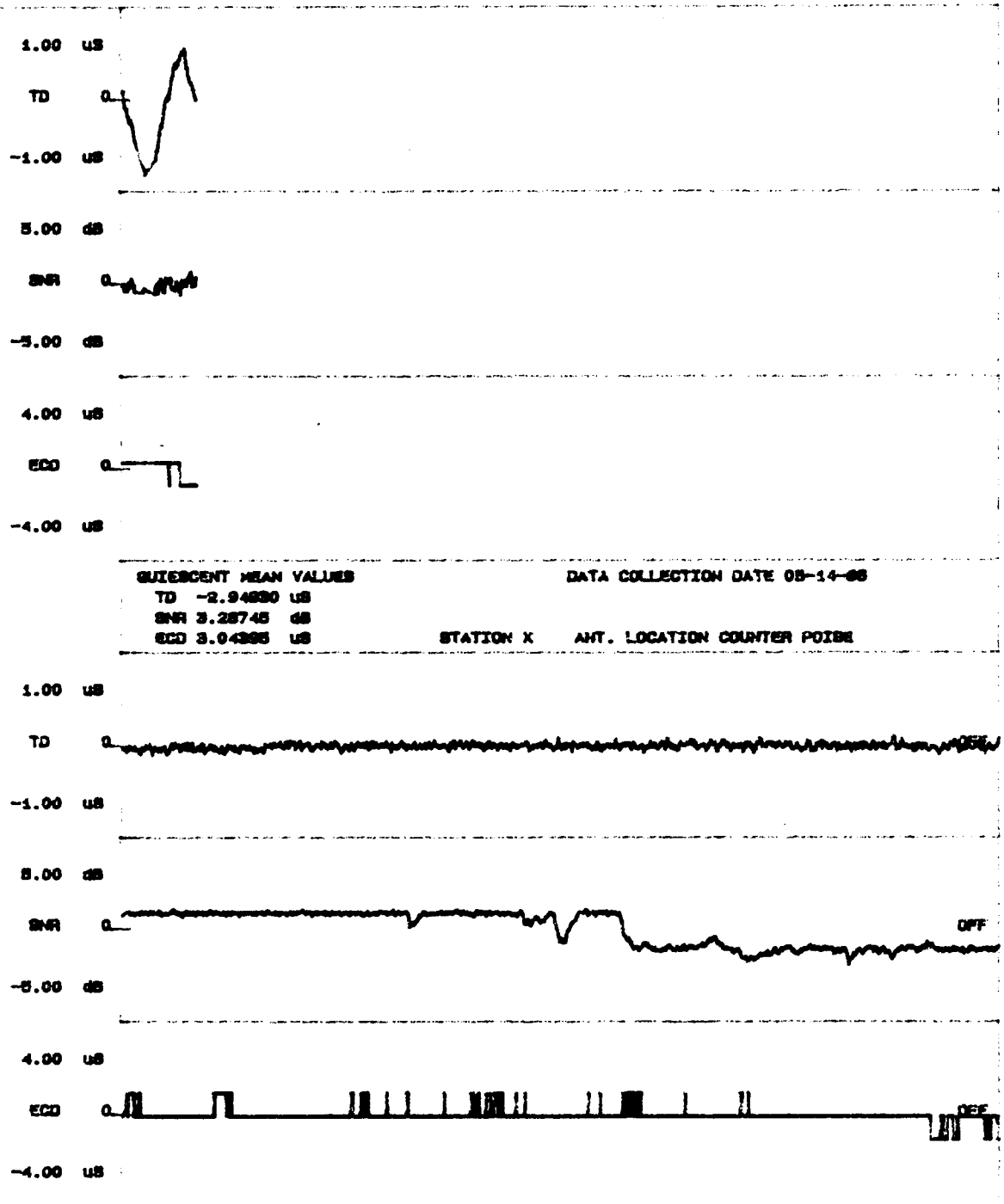
LORAN-C CO-LOCATION TEST

GRAPH VALUES = ACTUAL DATA - QUIESCENT MEAN VALUE.

QUIESCENT MEAN VALUES
TD 11.18554 uS
SNR -17.1002 dB
ECD -.31579 uS

DATA COLLECTION DATE 05-14-86

STATION W ANT. LOCATION COUNTER POISE



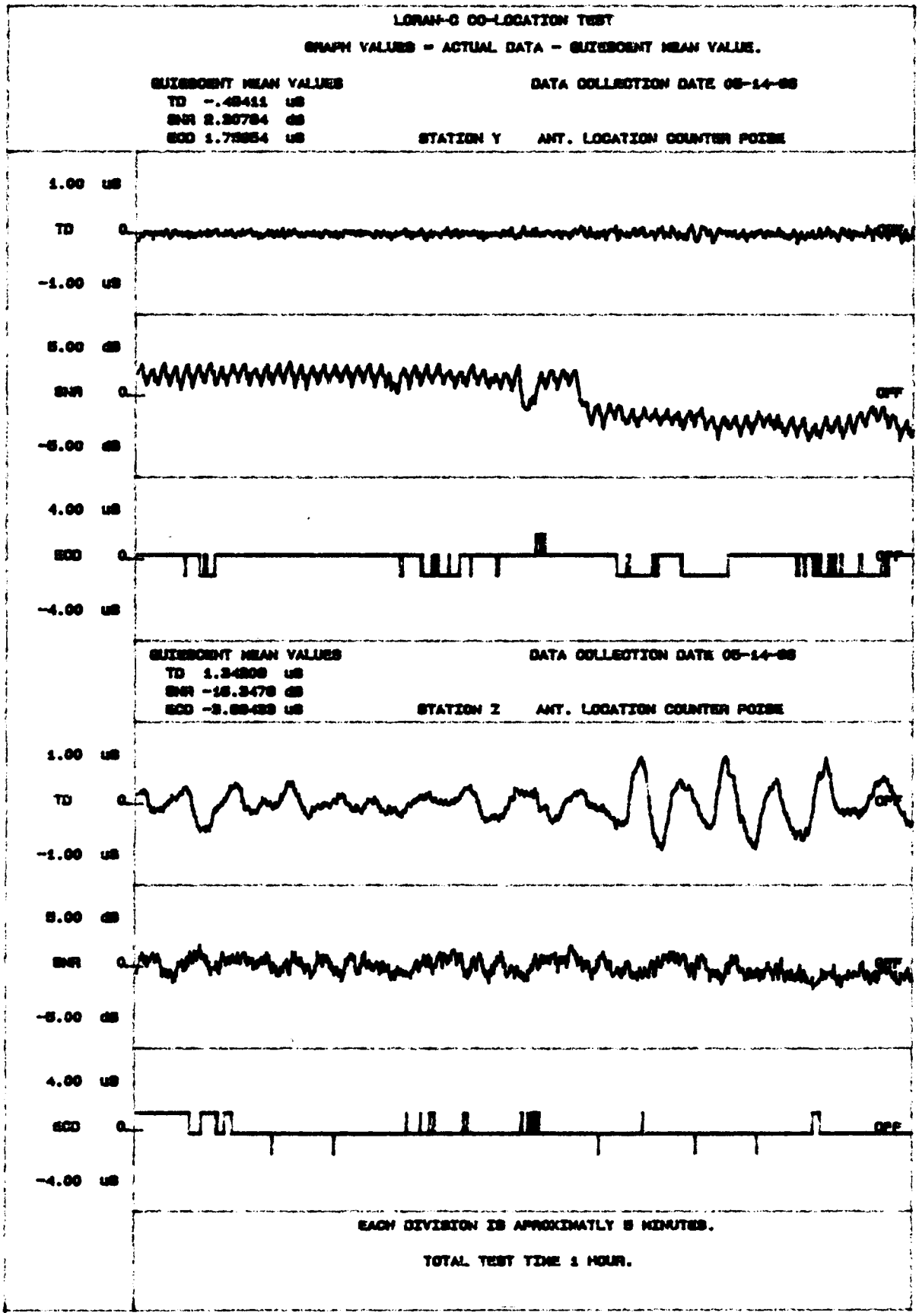
QUIESCENT MEAN VALUES
TD -2.94630 uS
SNR 3.28745 dB
ECD 3.04386 uS

DATA COLLECTION DATE 05-14-86

STATION X ANT. LOCATION COUNTER POISE

EACH DIVISION IS APROXIMATLY 5 MINUTES.

TOTAL TEST TIME 1 HOUR.


LORAN-C CO-LOCATION TEST
GRAPH VALUES = ACTUAL DATA - QUIESCENT MEAN VALUE.
QUIESCENT MEAN VALUES
TD -.49411 uS
SNR 2.20784 dB
SCD 1.73854 uS
DATA COLLECTION DATE 05-14-88
STATION Y
ANT. LOCATION COUNTER POISE
1.00 uS
TD
0
-1.00 uS
5.00 dB
SNR
0
-5.00 dB
4.00 uS
SCD
0
-4.00 uS
OFF
QUIESCENT MEAN VALUES
TD 1.34808 uS
SNR -16.3478 dB
SCD -3.69429 uS
DATA COLLECTION DATE 05-14-88
STATION Z
ANT. LOCATION COUNTER POISE
1.00 uS
TD
0
-1.00 uS
5.00 dB
SNR
0
-5.00 dB
4.00 uS
SCD
0
-4.00 uS
OFF
EACH DIVISION IS APPROXIMATLY 5 MINUTES.
TOTAL TEST TIME 1 HOUR.