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VHF Omnirange Test (VOT) System Reliability Tests

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This report documents the results of a 5000-hour reliability test conducted to investigate the performance of a prototype very high frequency (VHF) omnirange test (VOT) system. Some deficiencies were uncovered with respect to the monitor alarm system.

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EXECUTIVE SUMMARY

This report documents the results of a 5000-hour reliability test conducted to investigate the performance of a prototype very high frequency (VHF) omnirange test (VOT) system. Some deficiencies were uncovered with respect to the monitor alarm system. The alarm system does not monitor the signal at the final output stage of the VOT transmitter. It is possible to interrupt the signal at certain points in the circuit without being detected by the monitor.

INTRODUCTION

OBJECTIVE.

The purpose of this project is to conduct performance and reliability tests on the very high frequency (VHF) omnirange test (VOT) system developed by AMAF Industries, Inc.

BACKGROUND.

The Federal Aviation Administration (FAA) is in the process of replacing existing tube type VOT systems with new solid-state equipment. In support of this effort, the Program Engineering and Maintenance Service Division, APM-420, has a current contract, DTFA01-81-Y-20587, with AMAF Industries Inc., to develop a VOT prototype.

APM-420 requested a reliability test be conducted on the prototype VOT system (FA 00049-01) at the FAA Technical Center. Test measurements were conducted for over 5000 hours at periodic intervals for 7 months to determine performance and stability.

The VOT system generates a test signal for VOR receivers. It is composed of an exciter, which generates the necessary low-powered radio frequency signal, and a power amplifier to drive an antenna. The system also includes an antenna detector (to monitor the antenna output and a remote computer), interfaced via telephone lines, to control and monitor VOT system status. The remote monitor was not tested because of an issue concerning the availability of telecommunication lines to connect the remote control unit to the VOT system. The VOT system is exempt from the remote maintenance monitoring (RMM) requirement. Photographs of the VOT and a system block diagram are shown in appendix A.

RELATED DOCUMENTATION.

1. VORTAC, VOR/DME, VOR Equipment, Instruction Book, TI-68820.2, March 1983.

2. Operating Procedures for the VHF Omnirange Test (VOT) System, AMAF Industries Incorporated, September 1985.

3. VOR Test Facility (VOT) OA P 8200.1, Chg 37, 5/17/82.

4. Beauregard, Norman, VHF Omnirange (VOT) System Test and Evaluation Project Plan, FAA Technical Center, Technical Note DOT/FAA/CT-TN86/7, April 1986.

5. United States Standard Flight Inspection Manual, OAP 8200.1, Chg 4, August 10, 1964.

TEST RESULTS

The tests to verify that the VOT equipment met specifications were conducted at the FAA Technical Center, building 301. An Alford loop VOR antenna was mounted on the roof of the building. Approximately 50 feet of RG 214 cable connected the antenna to the equipment under test. A Convair 580 (N-91) aircraft was used for ground testing on the ramp and a flight check.

The VOT was set up and aligned in accordance with the manufacturers instructions (Related Documentation item No. 2). Checks were made to determine if the equipment met all specifications.

GROUND TESTS.

Ground tests using a Technical Center Convair 580 aircraft were conducted. A VOR flight inspection system consisting of an FA 65.3A Bendix VOR receiver and oscillograph were used to record data. Recordings were made to provide graphic data for analysis of signal intensity and station performance. The ground and flight checks included recording the 30 hertz (Hz) and 9960 Hz modulation levels, course alignment (course deviation indicator (CDI)), sensing (to/from indicator), flag alarm current in microamps, signal strength (automatic gain control (AGC)) in millivolts, and station identification (ID).

The ground testing was completed in approximately 2 hours. The ground test data are presented in table 1. The measurement points located on the taxiway Bravo are identified in figure 1. The distance from the VOT antenna is listed in table 1 for each measurement point. The AGC of the FA 65.3A Bendix VOR receiver, which provided an indication of the measured VOT signal strength, is scaled in microvolts and presented in column 3 of table 1.

The percent modulation of the reference (REF) signal, the variable (VAR) signal and the 9960 Hz signal indicated 30 percent throughout the test at all locations. These signals were within specifications of 30 percent ± 5 percent, required in Related Documentation item No. 5. The flag alarm current was never less than 285 microamps, which is above the minimum value of 240 microamps as specified in OAP 8200.1. The omnibearing selector (OBS) on the flight inspection data collection equipment rack was set to 0° for all test locations. The course sensitivity (CS) data in column 8 of table 1 was obtained by rotating the OBS for a total CDI deflection of ± 150 microamps. The CDI deflection was recorded and scaled in degrees. The course sensitivity was within the specification of 20° $\pm 2°$ per OAP 8200.1 for all test locations.

FLIGHT TESTS.

Flight tests were conducted at 40° and 310° inbound and outbound radials at 2,000 feet mean sea level (m.s.l.). The data are presented in table 2. All data were within tolerance as described in OAP 8200.1 for the 10-mile length inbound and outbound radials.

RELIABILITY TESTS.

The VOR reliability tests were conducted from March 25 to October 1986. A total of 5120 hours of testing was accumulated. A sample of the data recorded for the month of August is presented in table 3. The output power was

TABLE 1. VOR GROUND TEST DATA

Measurement Location	Distance to VOT Antenna (feet)	AGC Microvolts	REF Percent Modulation	VAR Percent Modulation	9960 Hz Percent Modulation	Flag Microamps	CDI Deflection (deg) for +150 Microamps
1	400	1000	30	30	30	285	20.75
2	1000	1000	30	30	30	285	20.75
3	1900	1000	30	30	30	290	20.5
4	3550	110	30	30	30	290	20.5
5	4940	82	30	30	30	290	20.25
6	6600	25	30	30	30	285	20.0
7	8525	18	30	30	30	290	20.0
8	1500	1000	30	30	30	290	20.25

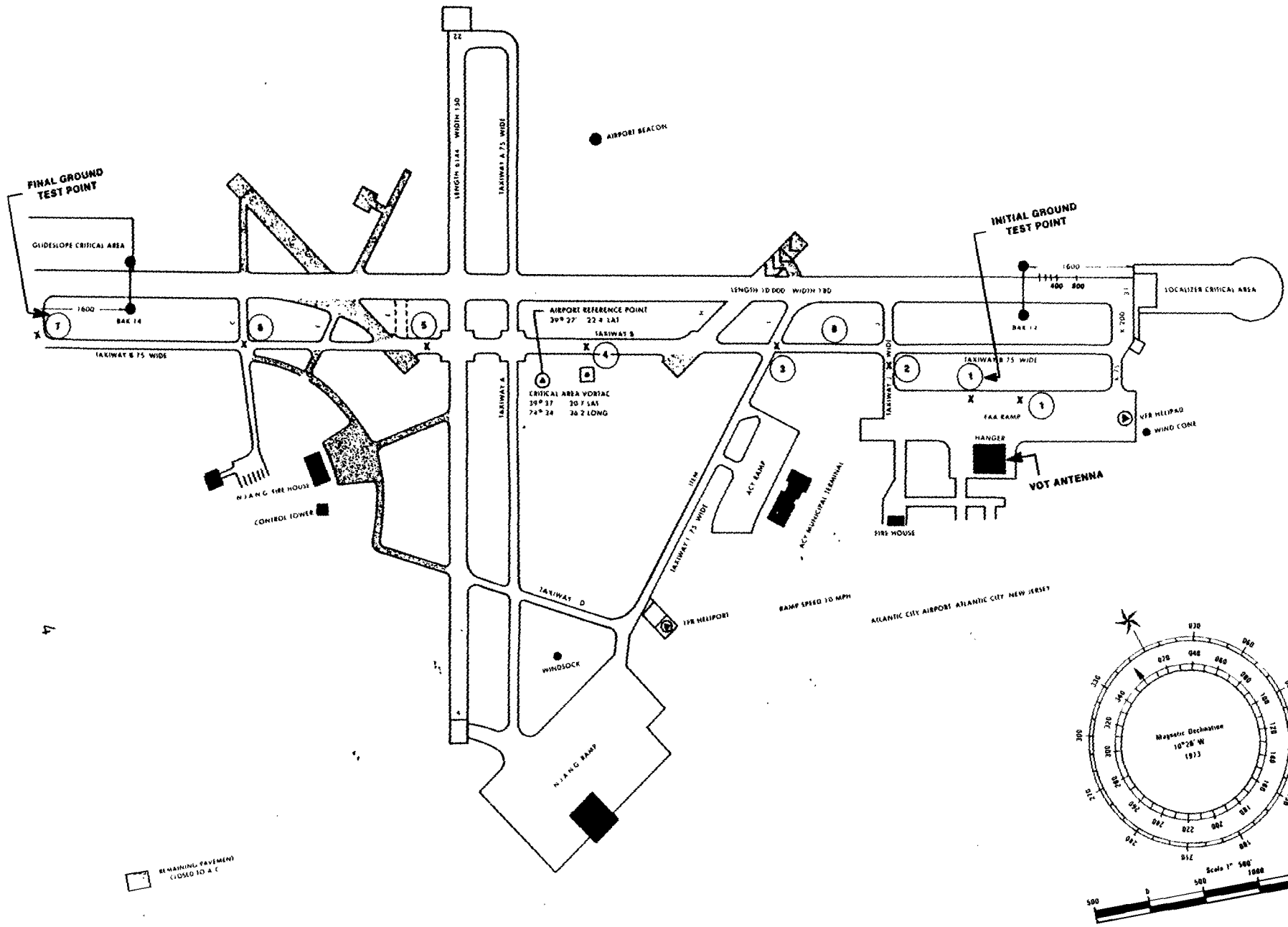

FIGURE 1. GROUND TEST MEASUREMENT LOCATIONS

TABLE 2. VOT FLIGHT TEST DATA

	310° Radial					40° Radial				
Mile Mark	CDI Degrees	AGC Microamps	Flag Microamps	REF Percent Modulation	VAR Percent Modulation	CDI Degrees	AGC Microamps	Flag Microamps	REF Percent Modulation	VAR Percent Modulation
10	0	25	280	30	30	0	11	280	30	29
9	0	32	280	30	30	0.25L	11	280	30	29
8	0	32	280	30	30	0	12.5	280	30	29
7	0	40	280	30	30	0	15	280	30	29
6	0	46.5	280	30	30	0	16.5	280	30	29
5	0	39	280	30	30	0.25L	16.5	280	30	29
4	0	32	280	30	30	0.25L	19.5	280	30	29
3	0.5L	100	280	30	30	0	46.5	280	30	30
2	0.5L	100	280	30	30	0	80.0	280	30	30
1	0.25L	>100	280	30	30	0	>100	280	30	31
1	0	>100	280	30	30	0	>100	280	30	31
2	0.5L	100	280	30	30	0	>100	280	30	31
3	0	65	280	30	30	0	>100	280	30	31
4	0.25L	46.5	280	30	30	0	32.0	280	30	30
5	0	32	280	30	30	0	65	280	30	31
6	0	40	280	30	30	0	65	280	30	31
7	0	32	280	30	30	0	65	280	30	30
8	0.25L	25	280	30	30	0	65	280	30	30
9	0	25	280	30	30	0	46.5	280	30	30
10	0	23.5	280	30	30	0	32	280	30	30

TABLE 3. VOT RELIABILITY TEST

Month August

Total Hours 3896

Date	Power (Watts)	1020 Hz Modulation (Volts)	9960 Hz Modulation (Volts)	30Hz VAR Modulation (Volts)	MOD RF Percent Modulation	Carrier (Volts)	Composite (Volts)	Comments
1	2	8.2	7.5	7	30	0.3	5	
2								
3								
4	2	8.2	7.5	7	30	0.3	5	3224 Hrs
5	2	8.2	7.5	7	30	0.3	5	
6	2	8.2	7.5	7	30	0.3	5	
7	2	8.2	7.5	7	30	0.3	5	
8	2	8.2	7.5	7	30	0.3	5	
9								
10								
11	2	8.2	7.5	7	30	0.3	5	3992 Hrs
12	2	8.2	7.5	7	30	0.3	5	
13	2	8.2	7.5	7	30	0.3	5	
14	2	8.2	7.5	7	30	0.3	5	
15	2	8.2	7.5	7	30	0.3	5	
16								
17								
18	2	8.2	7.5	7	30	0.3	5	3560 Hrs
19	2	8.2	7.5	7	30	0.3	5	
20	2	8.2	7.5	7	30	0.3	5	
21	2	8.2	7.5	7	30	0.3	5	
22	2	8.2	7.5	7	30	0.3	5	
23								
24								
25	2	8.2	7.5	7	30	0.3	5	3728 Hrs
26	2	8.2	7.5	7	30	0.3	5	
27	2	8.2	7.5	7	30	0.3	5	
28	2	8.2	7.5	7	30	0.3	5	
29	2	8.2	7.5	7	30	0.3	5	
30								
31								

initially set at 2 watts and was measured using a Bird throughline model FA-5114D wattmeter. The 9960 Hz signal, the reference signal, and the 30 Hz variable signal modulation levels were initially set for 30 percent. The ID modulation level was set for 8 percent. The front panel course selector was set for 0°. All VOT front panel monitored voltage levels, as determined by the set up procedure, were recorded initially and daily. The readings were consistent without variation for the duration of the tests. The daily readings were transmitted to APM-420 monthly.

TEST ANOMALIES.

During the reliability tests two equipment failures occurred. On April 17, 1986, after 573 hours of testing, the power amplifier fault light alarm occurred causing the VOT to shut down. The unit could not be reset for 1/2 hour. The cause of the fault could not be determined. It is believed a thermal sensor (TS1) located in the power amplifier was activated causing the power amplifier monitor to indicate an alarm. The fault could not be replicated and did not reoccur for the duration of the reliability tests.

On May 16, 1986, at the beginning of ground tests after 320 hours of testing, the 30 Hz variable signal could not be received by the aircraft flight inspection equipment. The VOT did not indicate any alarm conditions. An intermittant connection to the front panel variable modulation selection switch was found to be the cause of the lack of 30 Hz variable signal. Further investigation revealed the VOT monitor system was not adequate to properly detect all possible failures. It is possible to turn off the modulated signals from the transmitter via front panel switches without being detected by the monitor. The radio frequency (RF) power monitor shut down the unit when power was reduced by 50 percent using the rear panel control.

In addition, the modulation system limits are not constant and are a function of the front panel switch settings. Front panel switches permit settings of +189.95° for course, 0 to 49 percent for 9960 Hz and 30 Hz variable modulation levels, 0 to 19 percent modulation for 1020 Hz identification signal, and 0 to 39 percent modulation level for voice. This permits setting false courses with excess modulation levels. The monitor does not detect these conditions. Alarm limits should be built into the system to detect nonstandard settings input from the front panel. Any switch settings which generate a nonstandard signal should alarm the system. False courses or false modulation levels could be set from the front panel with no alarm indication.

CONCLUSIONS

1. The ground tests indicated that for the Alford loop antenna used and location on top of the flight operations building, the ground check point should be between 6,000 and 8,000 feet from the very high frequency omnirange test (VOT) antenna.

2. The flight check indicated the useful range of the VOT was in excess of 10 miles.

3. The monitor logic does not detect all combinations of failures and permits insertion of improper operating parameters such as course and modulation levels.

4. Failures occurred after 320 and 573 hours of testing. The VOT was operated without any recurrent failures for 4,547 hours. The cause of the first failure could not be positively identified. It was thought the failure was caused by the activation of a thermal sensor in the power amplifier. The design of the power amplifier should be closely reviewed before the VOT is placed in the field.

APPENDIX

PHOTOGRAPHS OF THE VOT AND A SYSTEM BLOCK DIAGRAM

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A-4	VOT Block Diagram	A-4

FIGURE A-1. VOT SYSTEM

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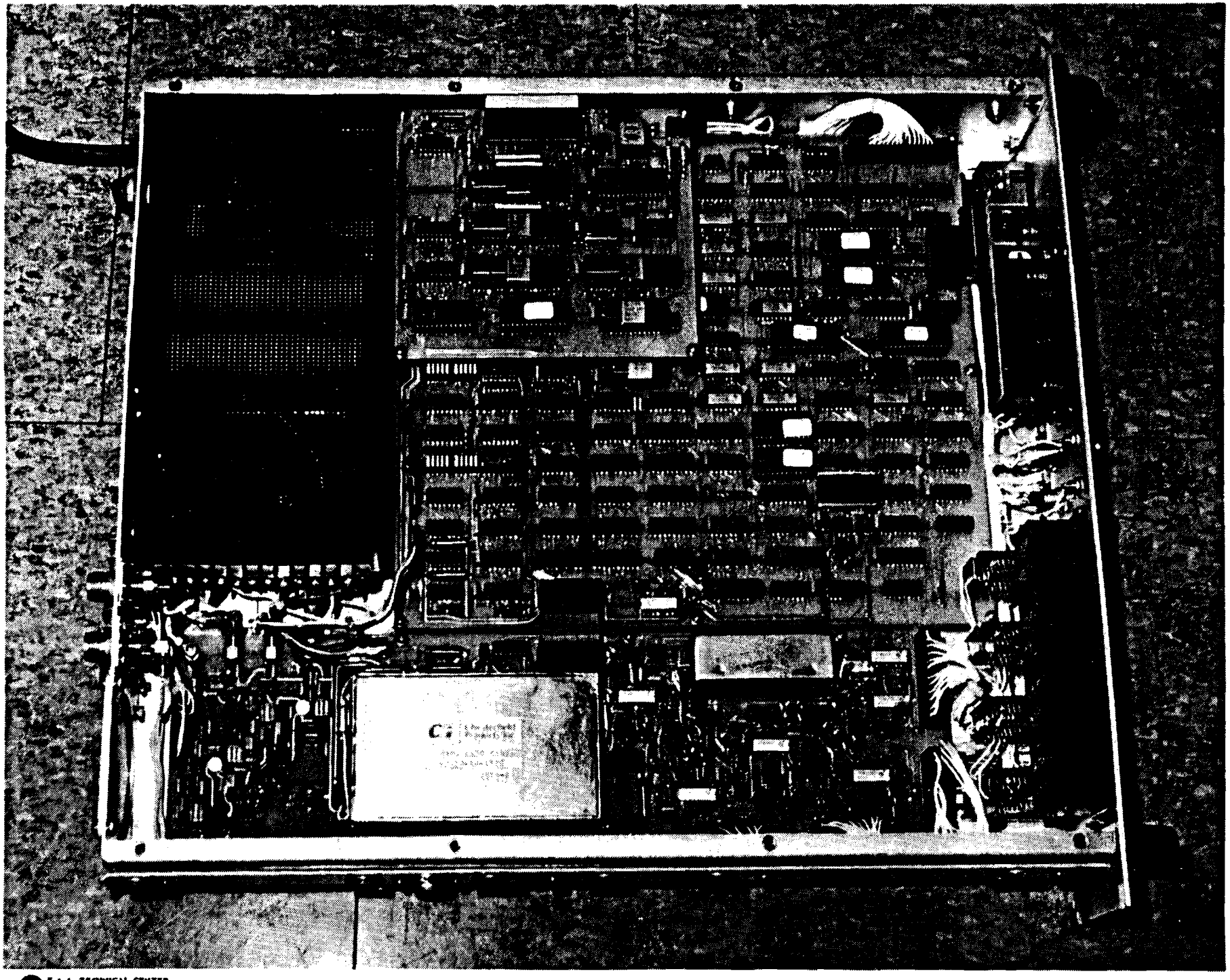

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FIGURE A-2. VOT EXCITER (COVER REMOVED)

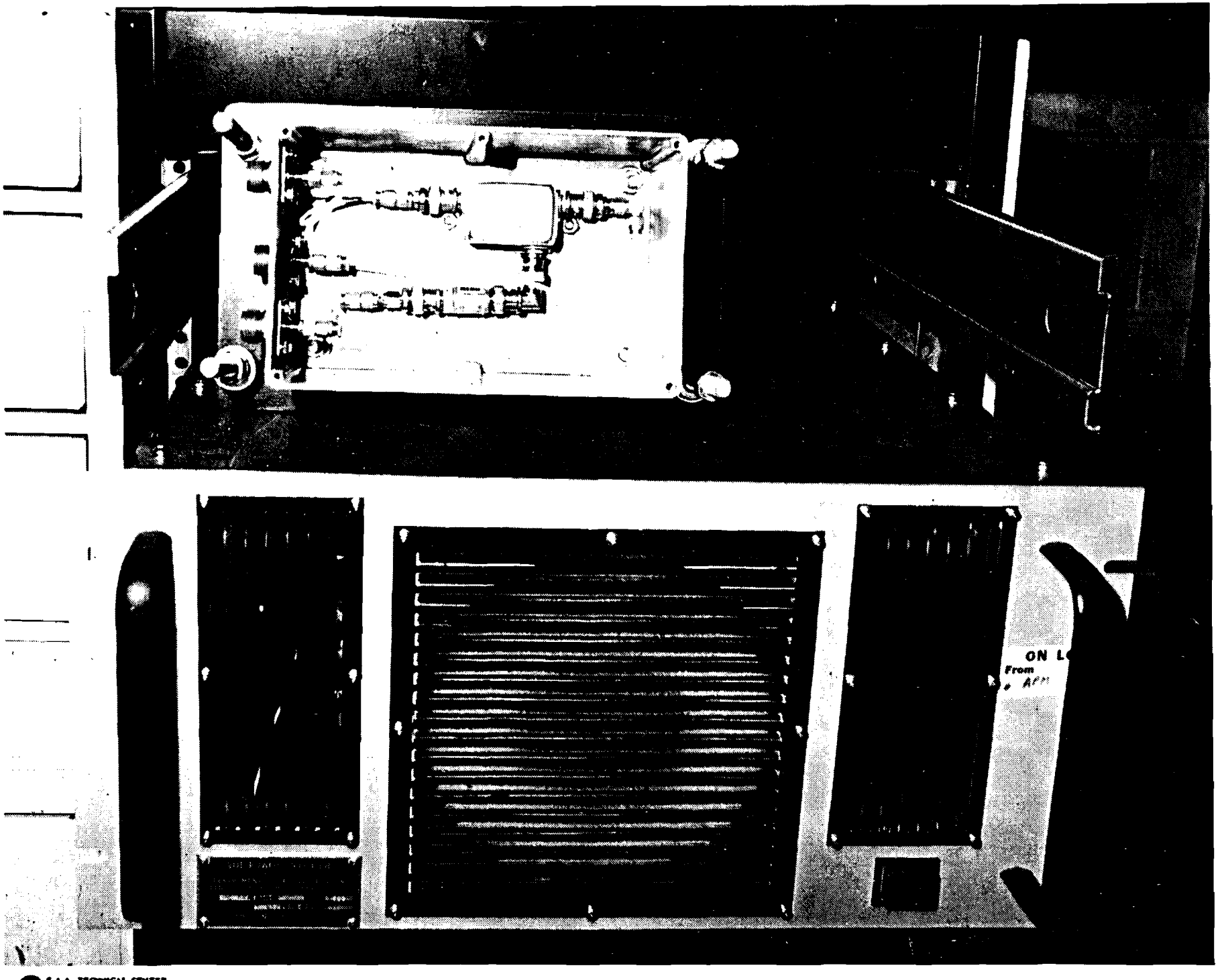

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FIGURE A-3. VOT RF DETECTOR (COVER REMOVED)

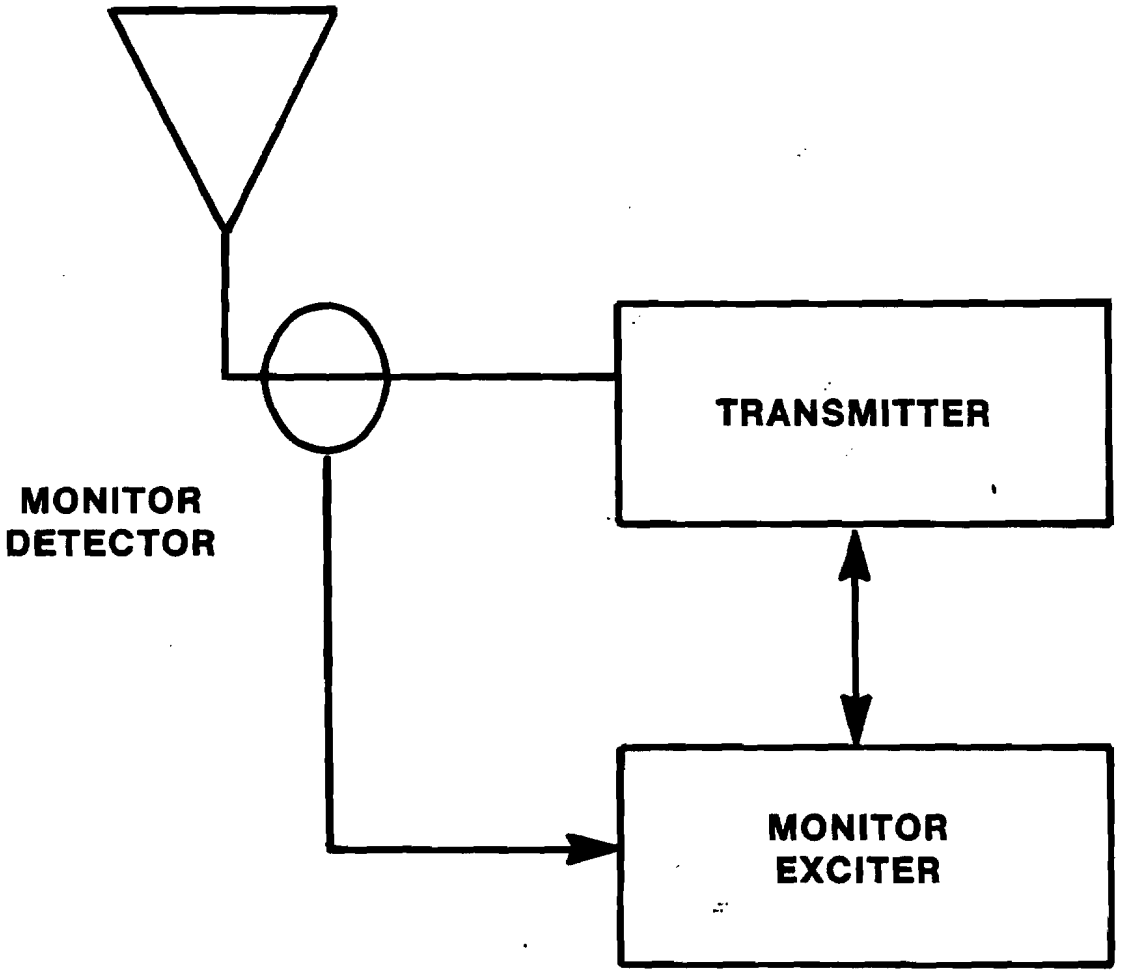

FIGURE A-4. VOT BLOCK DIAGRAM