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TEST AND EVALUATION OF THE AIRPORT SURVEILLANCE RADAR PERFORMANCE MONITOR

Domenick L. Offi

SEPTEMBER 1978

FINAL REPORT

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16. Abstract

A radar performance monitor developed by Westinghouse to operate with Federal Aviation Administration (FAA) Airport Surveillance Radar Systems was tested at the National Aviation Facilities Experimental Center (NAFEC). Tests were made to determine compliance with design specifications and to evaluate its capabilities and limitations.

The equipment as originally designed and configured did not function satisfactorily when operated with the NAFEC Airport Surveillance Radar (ASR-5) due to instabilities inherent in the ASR-5 model. Subsequent tests conducted in the NAFEC ASR-7 testbed demonstrated a capability to satisfactorily monitor normal video figure-of-merit following some reconfiguration, but indicated incompatibilities with regard to radar moving target indicator (MTI) performance. It is recommended that future monitor development consider design changes discussed in this report.

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METRIC CONVERSION FACTORS

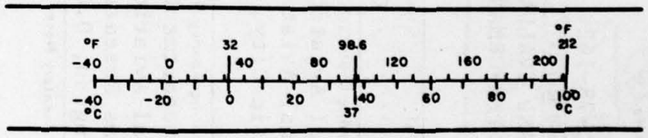
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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INTRODUCTION

PURPOSE.

The purpose of this project was to evaluate an automatic radar performance monitor (RPM) developed for use with Airport Surveillance Radar (ASR) systems. The evaluation determined the effectiveness of the device as a reliable tool for assuring continuous satisfactory performance of the ASR systems.

BACKGROUND.

The need to provide performance assurance of Federal Aviation Administration (FAA) radars has long been recognized. A radar performance analyzer (RPA), developed by Sperry Microwave Electronics, saw only limited use in the field during the early 1960's because of poor reliability and performance.

With the advent of the National Airspace System (NAS), the need for performance assurance was reemphasized. A design philosophy study, conducted by Operations Research, Inc., recommended that the RPA monitor concept form the basis for a new model. A 1968 National Aviation Facilities Experimental Center (NAFEC) evaluation determined causes for poor RPA performance and recommended a new design which ultimately led to the development of a system by Westinghouse Corp. (contract No. DOT-FA71WA-2570), which is the subject of this report.

DESCRIPTION OF EQUIPMENT.

The Westinghouse RPM consists of equipment shown in the functional diagram in figure 1. All of the units are contained in the cabinet depicted in figure 2. The cabinet is normally located in proximity to the radar system, except for four external antennas and an azimuth sensing device. These are located on the radar antenna platform and interconnected with the RPM. Figure 3 is a photograph of one antenna which is a half-wave dipole with a circular reflector. The dipole is covered by a cylindrical radome as seen in the photograph.

The azimuth sensor device, pictured in figure 4, consists of a stationary pickup unit mounted on the drive motor assembly and five permanent magnets fastened to the rotating portion of the radar antenna. As the antenna rotates, the magnets generate pulses in the pickup unit (one per quadrant plus a north mark reference) which are sent to the RPM for timing purposes.

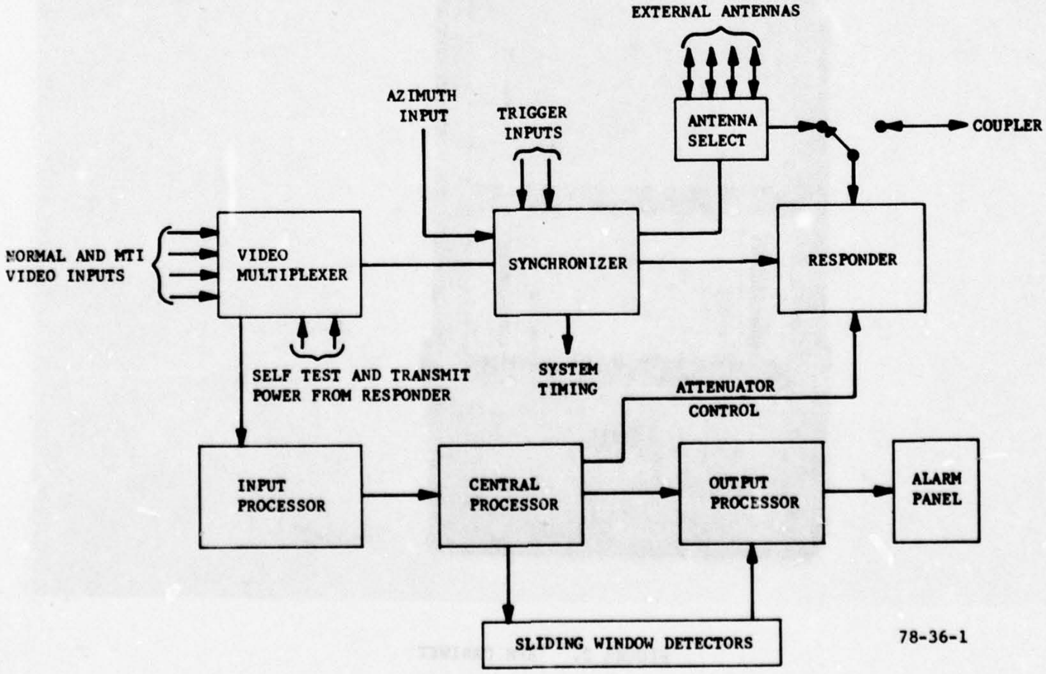

FIGURE 1. RPM FUNCTIONAL DIAGRAM

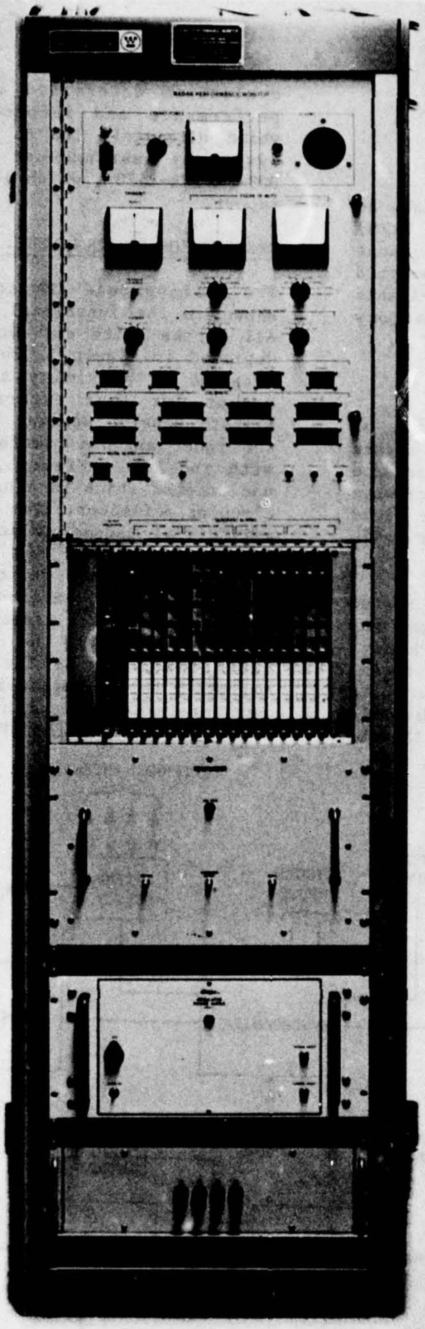

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FIGURE 2. RPM CABINET

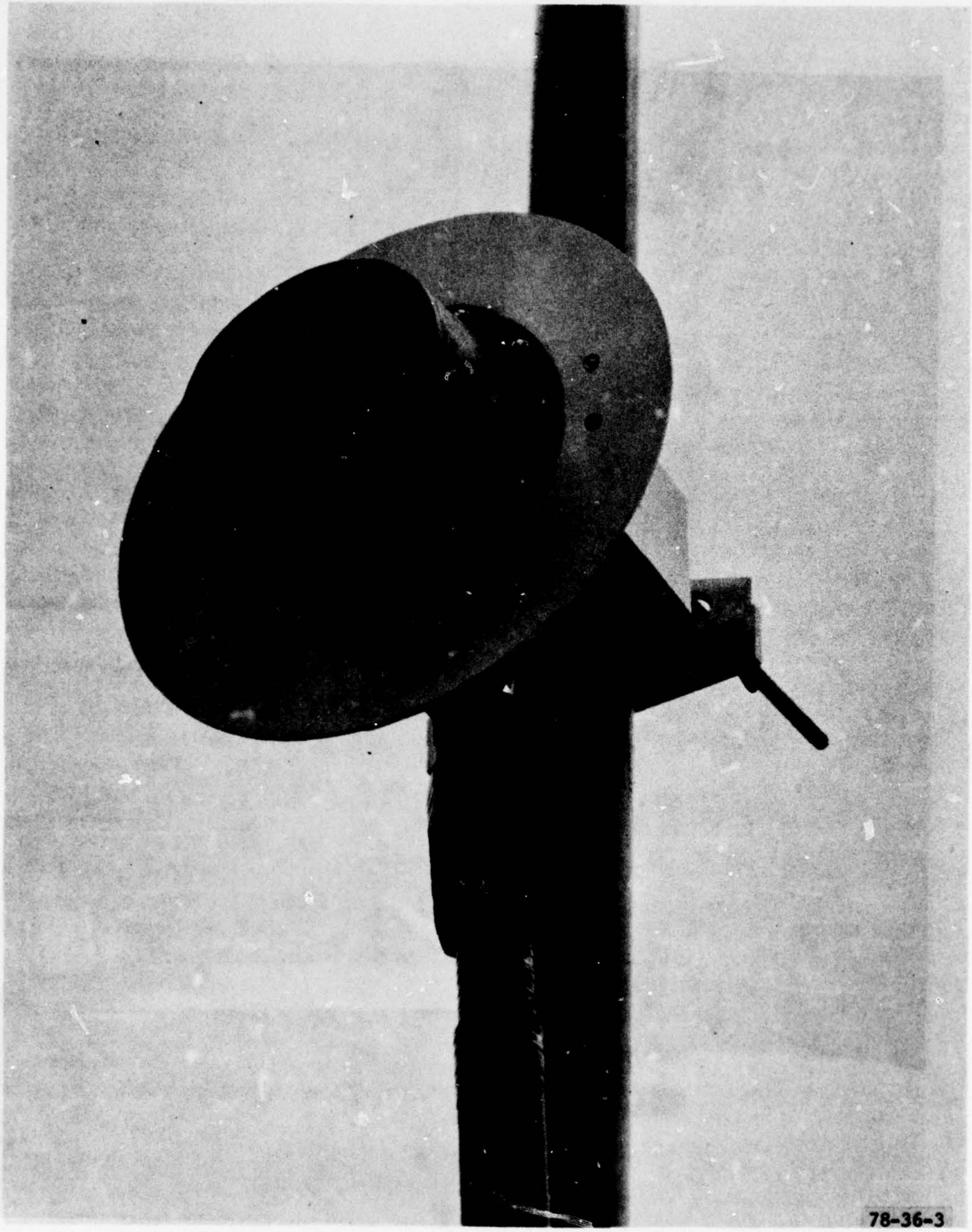


FIGURE 3 RPM ANTENNA

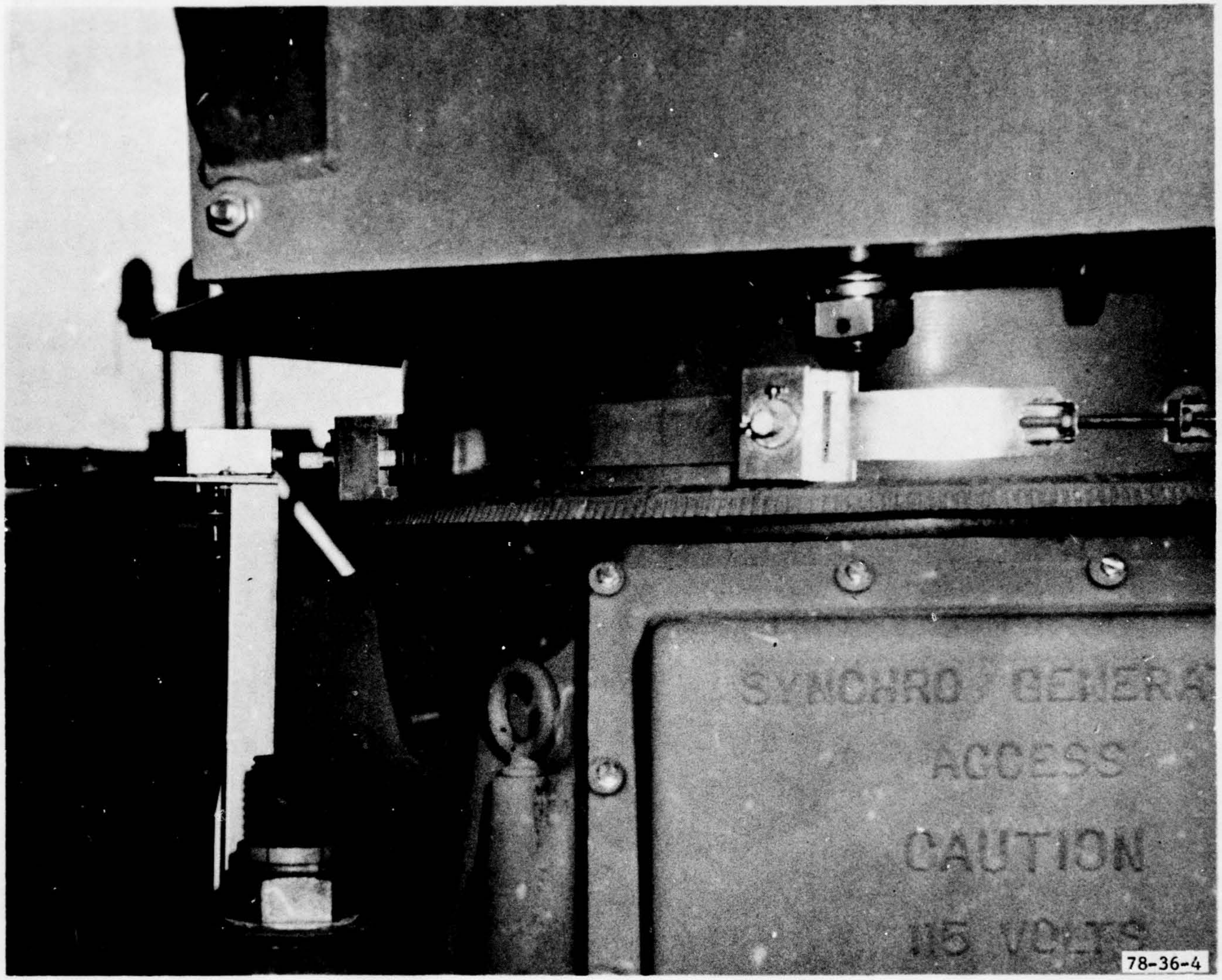


FIGURE 4. AZIMUTH SENSOR DEVICE

OPERATION.

The RPM generates audible and visible alarms when the radar's overall figure-of-merit (FOM), which is a function of both transmitter power output and receiver sensitivity, degrades below certain preset tolerances. Alarm criteria will also respond to changes in normal or moving target indicator (MTI) video root-mean-square (rms) noise levels, as well as to certain catastrophic (fast alarm) conditions.

Referring to figure 1, operation of the RPM is as follows: (1) the transmitted radar pulses received from either the external antennas or from the selected radar channel's directional coupler are fed into the responder; (2) the S-band (2.7 to 2.9 gigahertz (GHz)) signals are down-converted to 30 megahertz (MHz) and applied to a delay line network which generates a train of pulses; (3) the selected range azimuth gated pulses (one MTI and one normal set per quadrant) are then up-converted to the original frequency, sent through an electrically controlled variable attenuator, and retransmitted to the radar via the antennas or coupler; and (4) the signals then appear in the radar video outputs which are fed into the RPM video multiplexer along with the transmit power, self-test, and responder test signals generated in the responder.

Amplitude of the test signals is dependent on the responder's variable attenuator value which is automatically controlled by the central processor to maintain a constant, preset signal-to-noise ratio (SNR) at the radar video output. The processor evaluates the combined radar transmit power level and receiver sensitivity and generates attenuator correction voltages proportional to changes in either value. This error voltage is thus a measure of the radar degradation. Sixteen independent FOM computations are made (one for each quadrant for both MTI and normal, and for separate 2-decibel (dB) and 3-dB threshold values) producing raw alarm output pulses. The raw alarms are applied to 16 sliding window detector (SWD) units which produce output alarms when raw alarms (m) are present in a given window length (n). The m/n criteria are individually selectable for each SWD to minimize the statistical sampling error.

In addition to the FOM measurements, the RPM also evaluates the RMS value of the MTI and normal video baseline noise to produce output alarms corresponding to changes above or below preset thresholds. The RPM also senses catastrophic system failures through the use of fast reaction alarm thresholds and by direct connection to transmitter high-voltage circuity.

Self-testing is accomplished by internally generated signals which activate alarms if either the responder or the computation circuitry malfunctions within prescribed limits.

More detailed circuit descriptions and operational characteristics are found in report No. FAA-RD-76-121, "Radar Performance Monitor."

DISCUSSION

GENERAL

The RPM was delivered to the NAFEC Terminal Facility for Automated System Testing (TFAST) and interconnected first with the ASR-5 and then with the ASR-7 of that facility. Postinstallation tests were performed to determine adherence to design specifications. The equipment was then relocated to the Terminal Radar Beacon Test Facility (TRBTF) and tested to evaluate its capabilities and limitations.

INSTALLATION IN THE TFAST.

The RPM cabinet was physically located directly between the two radar channels and interconnected with the dual-channel Airport Surveillance Radar (ASR-5). The dipole antennas and azimuth sensor were installed on the antenna platform. Since the NAFEC ASR-5 antenna platform is larger than and different from the standard FAA ASR configuration, the dipole antennas were mounted on portable wooden structures which were placed at 12-foot distances from the radar antenna vertical axis, simulating a standard installation. The four antennas were spaced at about 90° intervals, one per quadrant.

Interface with the single-channel ASR-7 was accomplished by disconnecting the video trigger and radiofrequency (RF) cables from the two ASR-5 channels and reconnecting one set of video and trigger cables to the ASR-7 via a specially constructed distribution panel. The RF cable was connected to a cross-guide coupler located in a section of waveguide common to the ASR-7.

POSTINSTALLATION TESTS.

ASR-5 TESTS AND INVESTIGATION. A comprehensive procedure was developed by the contractor for feasibility demonstration and acceptance tests involving the ASR-5. Calibration, adjustments, and preliminary tests made upon completion of the installation revealed unforeseen problems which precluded completion of planned tests. An investigation was performed to discover reasons for the problems, and the results obtained were used to guide the course of further testing. Data were obtained from the two ASR-5 channels, the single-channel ASR-7 at the TFAST, the ASR-7 at the TRBTF, and also from the commissioned Atlantic City ASR-4 for comparison.

Results showed that problems were due primarily to changes in receiver gain occurring for a number of reasons, but mainly because of instabilities inherent in the vacuum-tube-equipped, analog MTI systems such as the ASR-4 and ASR-5. The solid-state ASR-7 with digital MTI circuitry appeared to be much more stable, as indicated by chart-recorded samples of gated MTI video from the three radars illustrating amplitude variation as a function of time.

The ASR-4 MTI baseline noise also appeared to have a "spikey" characteristic evident in the chart recordings which affected calibration of the RPM. Oscilloscope photographs of ASR-5 and ASR-7 MTI videos clearly reveal the difference in distribution between the two and show baseline clipping of the ASR-5 inherent in its video circuitry.

ASR-7 TESTS. A feasibility test of the RPM capability to function with the ASR-7 proved successful. This factor, coupled with previously described results, led to a decision to complete the RPM tests with the ASR-7.

A continuous check was maintained on radar performance to assure optimum levels of operation. A power meter was used to measure average power; a signal generator to measure sensitivity; a noise figure indicator to check noise figure; and the MTI and normal rms noise levels, video levels, and direct current (d.c.) levels were checked periodically. Parameters at the start of the test were described as follows, with the radar operating into its dummy load.

1. MTI sensitivity: -107 decibels per one milliwatt (dBm)

2. MTI video level: 2 volts (V)

3. MTI rms noise level: 24 millivolts (mV)

4. Normal sensitivity: -109 dBm

5. Normal video level: 2 V

6. Normal rms noise level: 21 mV

7. Transmitter power output: +56 dB average

8. Pulse Repetition Frequency (PRF): unstaggered, 1,200 pulses per second (pps).

The receiver RF gain control was calibrated in 1-dB steps from position 1 (0 attenuation) to position 6 (maximum attenuation) for use in FOM degradation tests.

The RPM was calibrated and adjusted to work with the established inputs, and two Esterline-Angus chart recorders were implemented to record selected data such as FOM and rms noise analog excursions (paralleling the front panel meters). An output alarm signal latching indicator was employed to indicate presence or absence of alarm events during unattended operation. Front-panel settings and selectable SWD thresholds were as follows:

1. MTI and Normal SNR: 3.0

2. Feedback: 1/2

3. Antenna/coupler mode: coupler

4. SWD thresholds (m/n) which were the same for all 2-dB and 3-dB alarms: (a) Q1 = 100/200 (b) Q2 = 50/100 (c) Q3 = 25/50 (d) Q4 = 13/25

5. MTI and normal noise scans: 6

6. Normal target range: 620 microseconds (μs)

7. MTI target ranges: 300 μs for all quadrants.

After a 3-hour period of unattended operation, results were as follows:

1. Average scan-to-scan FOM excursion on chart recorder strips was less than ±1 dB.

2. No alarm lamps were activated, and none were latched on during the period.

3. Radar parameters were unchanged from start.

A series of tests to determine compliance with specifications was then initiated. Tests and their results were as follows:

1. Receiver sensitivity degradation.

Sensitivity was decreased by 1 dB, by 3 dB, then by 4 dB, while noting corresponding changes on the FOM front-panel meter and chart recorder, SWD raw alarm count, and activation, if any, of alarm indicators. With 1-dB degradation, there were no alarms; 3-dB reduction triggered all 2-dB alarms intermittently; 4-dB reduction activated the 2-dB alarms continuously and the 3-dB alarms intermittently.

2. Transmitter degradation.

Transmitter high voltage was deceased in steps corresponding to 2-dB and 3-dB average power reduction as indicated on the HP-432A power meter. Corresponding changes in recorded data were noted, with 2-dB and 3-dB FOM alarms activated consistently.

3. Fast alarm tests.

A combination of receiver degradation and transmitter power reduction levels totaling 5 dB, 6 dB, 7 dB, and 8 dB were deployed while noting the number of scans required to activate the normal and MTI fast alarms. At 7-dB and 8-dB reductions, alarms occurred as programed in the RPM logic (n consecutive 3-dB raw alarms); in this case, 16 consecutive alarms, totaling 4 or 5 scans. Reset (no alarms) occurred in one scan.

4. RMS noise alarm tests.

With the chart recorders reading MTI and normal rms noise measured by the RPM, the radar MTI and normal receiver gains were varied ±2 dB, then ±3 dB from nominal. At ±2 dB, the alarms were triggered ON and OFF intermittently at a one-scan rate. At ±3 dB, the alarms remained ON consistently. Chart recordings indicated correlation with alarm events, with the ±3-dB setting shown as ±2.7 dB on the recording.

5. Transmitter high-voltage OFF alarm.

The alarm was activated upon turn-OFF of transmitter high voltage and was reset when the high voltage was restored.

6 Internal monitor alarms tests.

With the front-panel calibrate switch set to a nominal or minimum error as indicated on the normal FOM meter, test points TP-97 and TP-98 on the range synchronizer unit were jumpered. This placed the internal monitor error voltage near the 0.5-dB threshold. The calibrate setting was increased 0.5 dB, activating the internal monitor alarm. Decreasing the calibrate setting by 0.5 dB reset the alarm. Normal operation was then restored.

7. Sensitivity time control (STC) compatibility.

With the STC-4 curve selected, 30-dB attenuation was present in the receiver at a range of 300 μs (range of the monitor MTI test targets). To demonstrate the capability to function with STC, the quadrant 1 target was recalibrated to nominal performance.

8. Azimuth positioning agility.

The azimuth positioning of the quadrant 1 signal was varied by internal RPM adjustments. Maximum range of adjustment from nominal was +10° to -5° for a total of 15°.

9. Radar directional coupler interface.

The RPM was switched from coupler mode of RF input to antenna mode, requiring recalibration for proper operation.

10. Radar channel switching test.

This was exercised with the dual-channel ASR-5 during preliminary tests. Recalibration was required for proper operation. After the transmitter high voltage was activated, the responder AFC locked into the second frequency in less than 10 seconds when switching from one channel to the other.

11. 72-Hour reliability test.

The RPM was required to operate continuously without failure for a 72-hour period. The test for record began with the start of ASR-7 tests (previously described) and was completed satisfactorily. In addition to chart recordings of FOM excursions, etc., independent measurements were made on a continuous basis during round-the-clock operation commencing at *about the 36-hour mark.* ***Measurements included*** **FOM raw alarm counts for all 16 SWD's, plus a narrative log containing remarks and notations of normal and MTI sensitivity, average power output, normal and MTI rms noise levels and d.c. levels. Some noise figure readings were also made to supplement sensitivity readings, and a check was made on MTI clock long-term frequency stability during a portion of the data run.**

Results showed that in every case where the RPM alarms (FOM and rms noise) were activated, the problem was traceable to the radar or to some situation which caused apparent alarm conditions. Some of the situations included the following:

a. Switching from dummy load to antenna mode caused a drop in MTI noise level of approximately 2 dB and normal level of 6 dB. This required recalibration of the system.

b. Changing video loading reflected in slight shifts in RPM input video levels causing rms alarms. This occurred when ASR-7 videos were connected to a plan position indicator (PPI) for a short period of time.

c. The ASR-7 MTI clock stability indicated some time interval change over a period of time

(as much as 150 nanoseconds) causing changes in MTI FOM readings and, in some cases, activating alarms.

d. Weather clutter appearing in the radar returns began to cause increases in raw alarm counts. The radar antenna was switched from linear polarization (LP) to circular polarization (CP) to reduce the clutter, but this required some slight recalibration of the RPM transmitter power adjustments.

During the 72-hour period, there were no transmitter high-voltage OFF alarms, no internal monitor alarms, and no fast alarms.

Figure 5 is a graph of the Q1 FOM raw alarms for approximately 36 hours and is included to show an example of the results previously discussed.

INSTALLATION IN THE TRBTF.

Additional testing at the TFAST became difficult to accomplish because heavy facility utilization precluded uninterruptable operation required for most tests. Attempts were made to conduct some limited tests with the ASR-7 and later with the ASR-5, but little success was achieved because of various problems including some unresolved RPM hardware difficulties. The RPM was subsequently relocated to the TRBTF for completion of planned evaluation.

Interconnection with the ASR-7 at that facility was accomplished without difficulty. Figure 6 shows the installation of the RPM antennas, two of which are visible on the ASR-7 antenna platform. The array of cylindrical objects surrounding the platform are portions of an experimental electonically scanned beacon antenna. The RPM cabinet was located in close proximity to the ASR-7 and connected to the radar and to its external antennas and azimuth sensing device.

POSTINSTALLATION RETESTS.

The RPM was calibrated and adjusted according to procedures established by the contractor. Methods and equipment utilized during previous tests were implemented, and abbreviated tests were repeated to ensure operation according to specification. Chart recordings of MTI and normal FOM excursions were made with the radar operating first into its dummy load, then into the antenna.

In dummy-load operation, FOM alarms remained within ±1 dB of nominal for normal and MTI. In the antenna, the alarm count was slightly higher from scan to scan. Previously unresolved equipment problems were no longer in evidence.

EVALUATION.

Tests were performed to corroborate earlier results, to investigate reasons for apparent alarm conditions, and to evaluate the capabilities and limitations of the RPM operating in conjunction with the ASR-7.

PROBLEM INVESTIGATION.

1. RMS Noise Level Change - Previous tests indicated that the RPM rms noise calibration required readjustment when the radar channel being monitored was switched from dummy load to the antenna mode of operation. Similar results were obtained during subsequent tests at the TRBTF, with the MTI video baseline noise reduced by about 1 dB and the normal video noise by about 6 dB, as indicated by calibration settings. Figure 7 shows two oscilloscope photos of range-gated MTI and normal video appearing at a test point in the RPM under the two operation conditions. The reduction is caused by bottom clipping of the baseline noise due to change in video duty cycle present only when the transmitter is ON and connected to the antenna. RMS levels are equal in both cases with the transmitter OFF.

2. Video Load Change - RMS noise alarms occurred as a result of changing video loads. A test was performed to determine the amount of change in rms noise reading in the RPM for a given change in MTI and normal video input levels.

An attenuator was placed in each video line and the RPM was calibrated. The attenuators were then switched from 0 to 3 dB in steps while observing the change in rms noise on the RPM front-panel meter. Results showed that for the normal video, the rms noise dropped 0.5 dB, 1 dB, and 2 dB for video drops of 1 dB, 2 dB, and 3 dB, respectively. For the MTI video, similar results were obtained but with much less reduction in noise, which dropped a maximum of 0.2 dB.

3. MTI Clock Stability - ASR-7 MTI clock rate at the TFAST varied with time, causing drift in position of RPM sampling gates relative to MTI range cells, leading to cusping loss. Similar measurements made at the TRBTF over a period of several days showed pulse repetition period variation from a low of 748.4 s to a high of 750.2 s with the period remaining stable most of the time. Extremes appeared to be due to ambient temperature changes occurring in the radar equipment van. Figure 8 shows oscilloscope photos illustrating positional drift of sampling gates as a function of clock rate change. Changes are

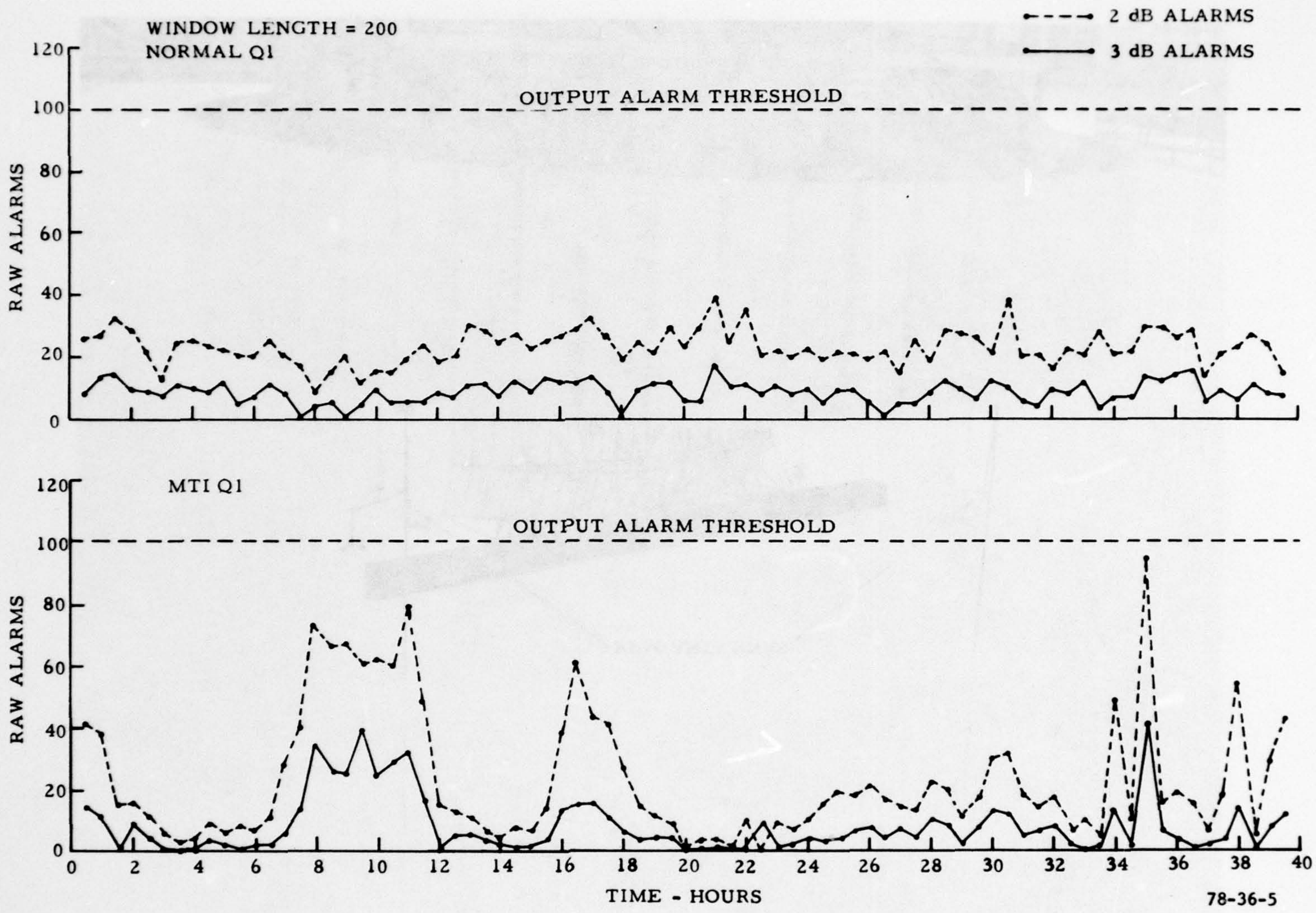


FIGURE 5. ARS-7 72 HOUR TEST DATA

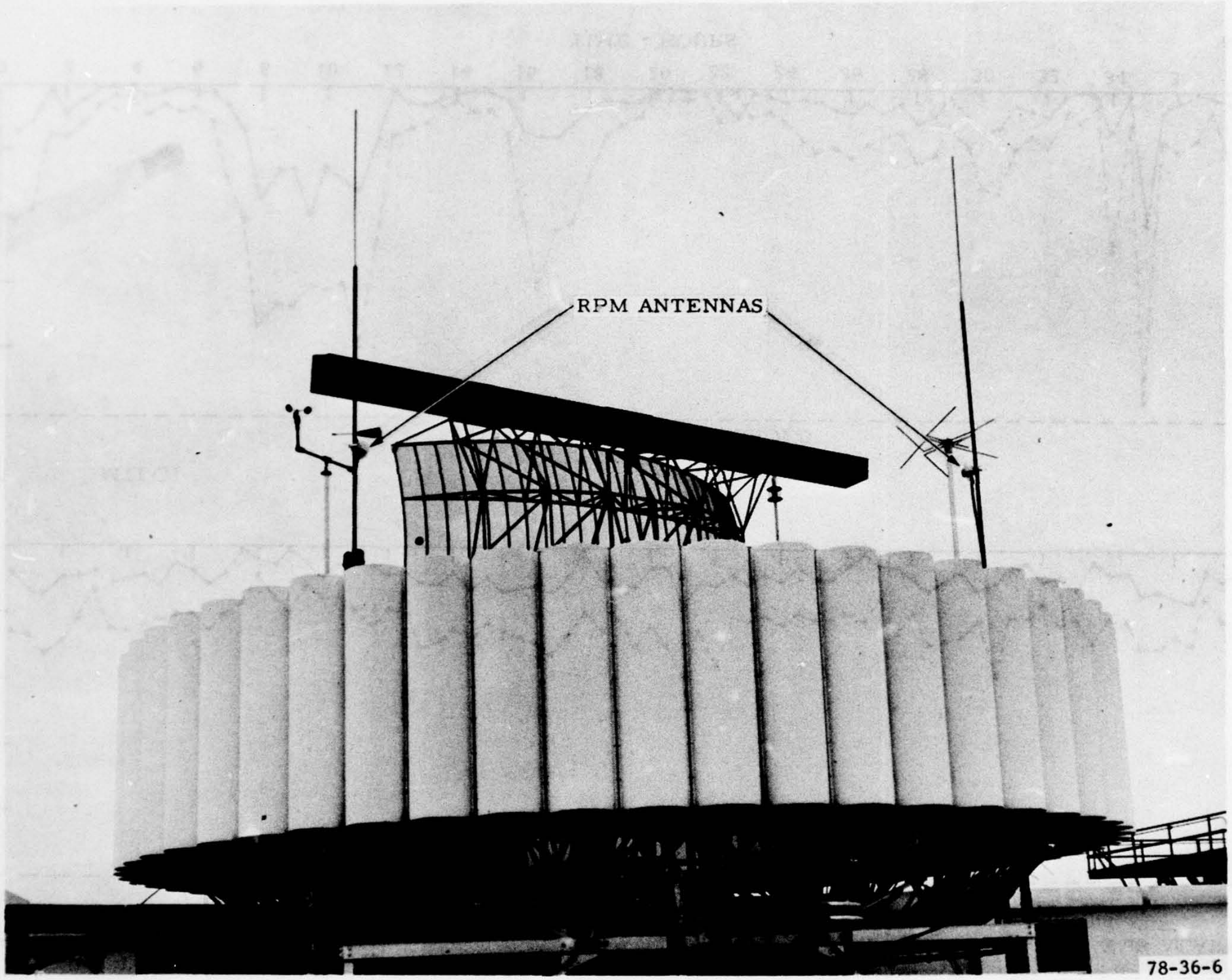
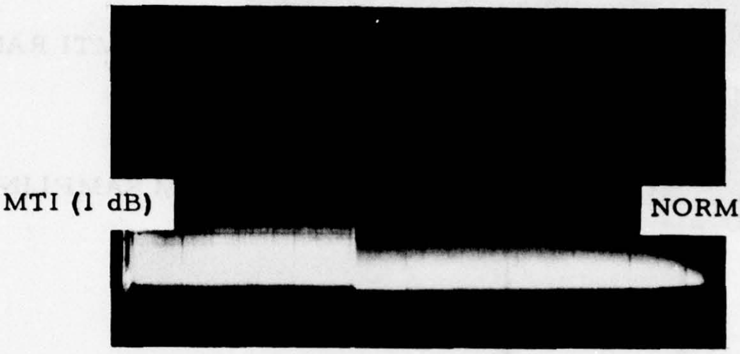
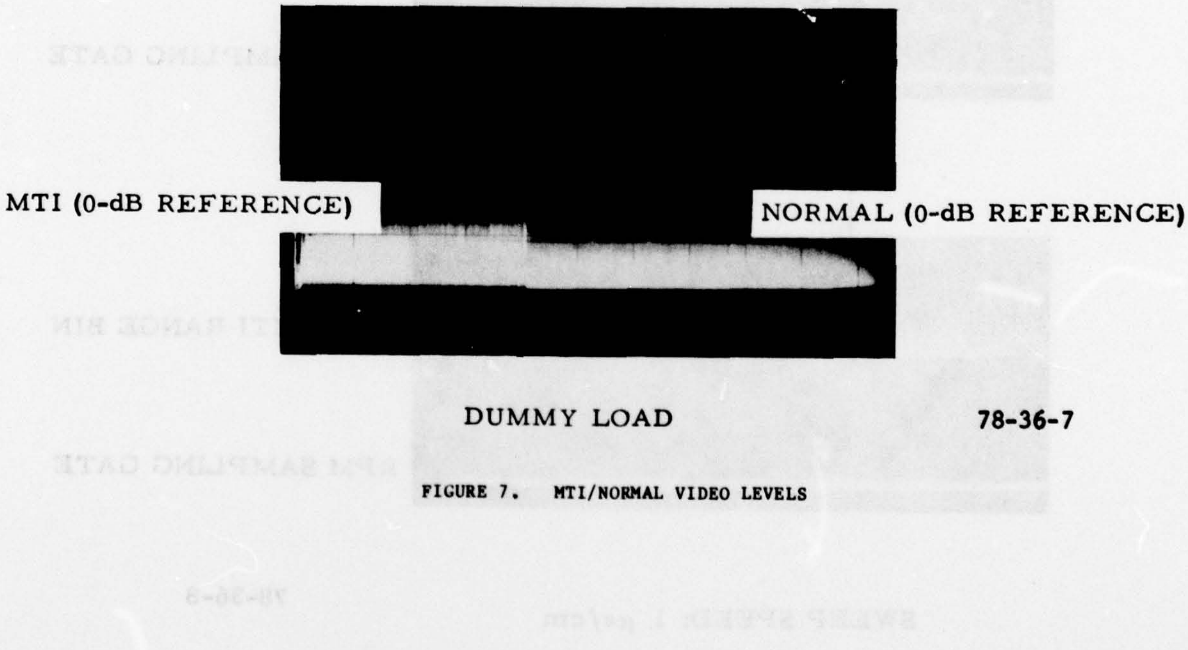


FIGURE 6. RPM ANTENNAS ON ASR-7 ANTENNA PLATFORM



ANTENNA



DUMMY LOAD

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FIGURE 7. MTI/NORMAL VIDEO LEVELS

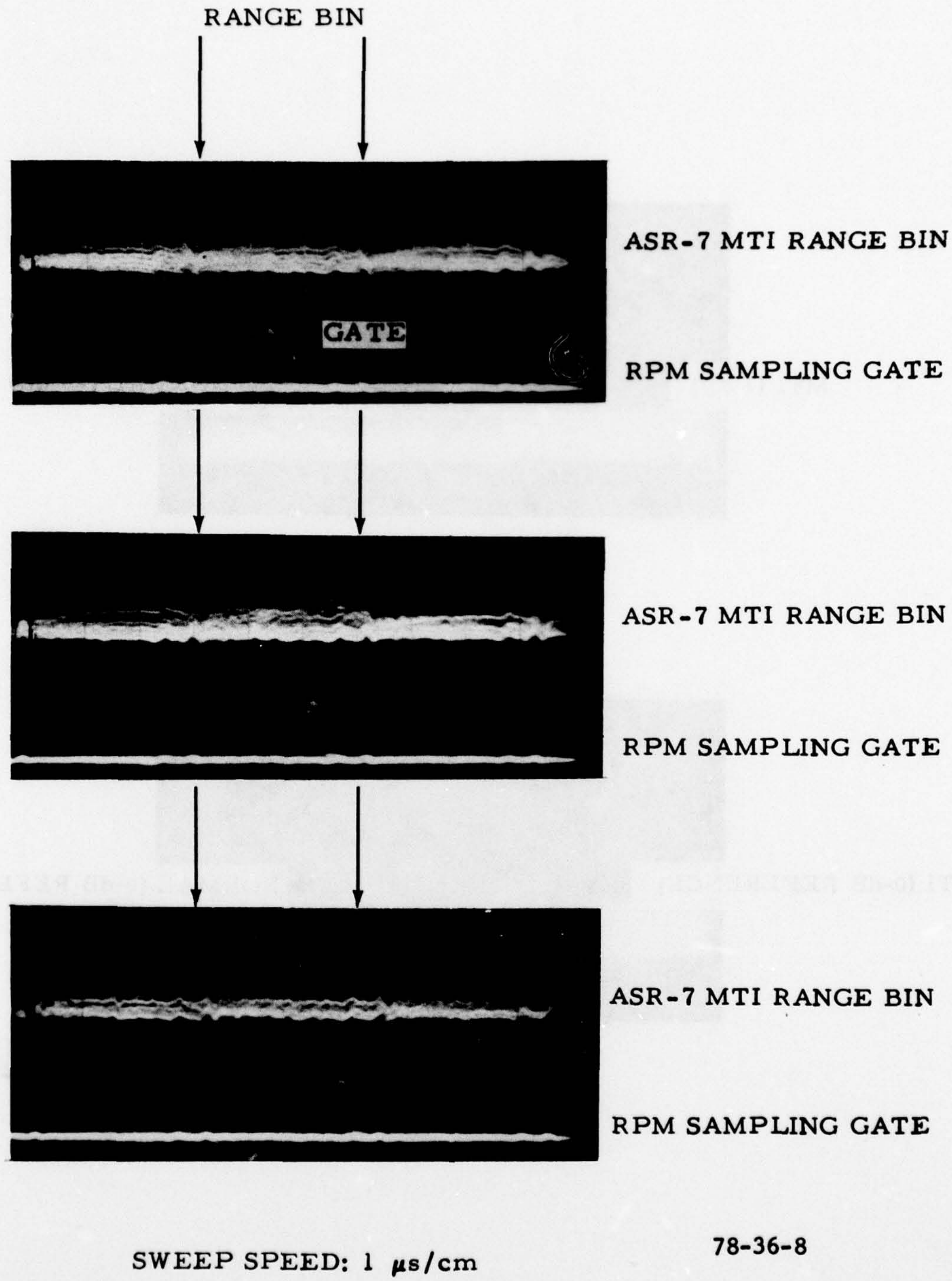

FIGURE 8. SAMPLING GATE DRIFT

fractionally related. (Sampling gates are located at some fraction of the total radar period.)

FOM SHORT-TERM STABILITY. The RPM was reconfigured to feed all four quadrant raw alarms into one SWD, thus simplifying the data collection procedures and quadrupling the data rate. The radar and RPM were adjusted for optimum performance and allowed to stabilize. The resultant MTI and normal 2-dB and 3-dB raw alarms were then recorded at both 6- and 15-minute intervals. The procedure was performed with the radar operating into its load, then into the antenna. A sample of the resultant data is shown in figure 9. In no case did the raw alarm rate approach the SWD 100-count threshold. Weather conditions were clear for the antenna operational mode with some pulse interference present during the 15-minute test.

RADAR VARIABLE PARAMETER EFFECTS. All previous data were recorded at both sites with the radar system under test in a fixed mode with respect to certain variable operational parameters.

These parameters include MTI and normal log/FTC, MTI and normal video enhancers, MTI canceler settings, and RF/cross-sectional sensitivity (CSS) and gain control. In addition, the transmitter PRF, is selectable from any one of six frequencies plus a stagger sequence.

Since the RPM is not adaptive, operational radar changes require recalibration of the RPM to preclude generation of false alarms. Tests were conducted to determine the change from nominal calibration resulting from radar changes. MTI and normal 2-dB and 3-dB FOM readings, MTI and normal rms meter readings, and transmitter power readings were all noted and recorded, with the radar sequenced through various parameter settings in 10-minute time intervals. All of the aforementioned parameters were varied except the RF/CSS and gain control, the effects of which were directly predictable in terms of receiver sensitivity reduction and test target positions (position on the CSS curve). The PRF changes were made while operating the RPM in the coupler/operate and antenna/operate modes in order to note the external antenna effects. The remaining tests were made with the radar system in the dummy load to eliminate external variables.

Results showed that with MTI and normal log/FTC, there was a small, insignificant decrease in the 2-dB and 3-dB FOM raw alarm counts, but there was a 13-dB decrease in the MTI rms noise and a 3-dB increase in the normal rms noise, both of which caused output alarms for undetermined reasons. Similar results were obtained with the MTI and normal enhancers employed, except that the FOM raw alarms showed a slight increase.

Changes in MTI canceler settings did not cause any significant RPM changes, while PRF affected transmitter power readings sufficiently to cause output alarms.

ENVIRONMENTAL EFFECTS AND DESIGN DEFICIENCIES. During the course of testing, the following effects were noted and recorded:

1. With the radar and monitor in the antenna/operate mode, snow and ice coating on the monitor antennas caused variations in FOM readings of ±3 dB from quadrant to quadrant. Under the same conditions, strong gusty winds caused buffeting of the monitor antennas, resulting in very erratic FOM and power readings.

2. With the system operating either as above or in the coupler/operate mode, weather clutter, anomalous propagation (AP), and pulse interference caused changes in FOM, rms, and internal monitor raw alarm counts, all resulting in false output alarms.

3. The RPM design does not consider MTI cancellation ratio (CR) and subclutter visibility (SCV) performance. During tests in the TRBTF, the ASR-7 experienced a coherent oscillator (COHO) failure which was not detected by the RPM, resulting in complete noncancellation of the ground clutter.

Attempts were made to monitor tactical SCV by setting one or more test targets at ranges which coincided with normal video ground clutter areas and rating changes in MTI FOM readings for those particular quadrants. Difficulty was encountered in calibration of those targets, and extreme variations in FOM readings subsequently obtained were not correlated to actual MTI performance measurements.

4. No provision was made in the RPM design to automatically determine the radar's azimuth pulse generator (APG) problems, other than to detect the test target shift on the display.

RAW ALARM DISTIBUTION. The statistical nature of the radar performance monitoring problem necessitated incorportation of SWD's in the RPM to achieve a measure of performance with an acceptable false alarm rate. Both the alarm count, m, and the window length, n, of the SWD units were individually adjustable from 1 to 200 for each unit.

In order to determine the optimum m/n, it was necessary to know the raw alarm distribution

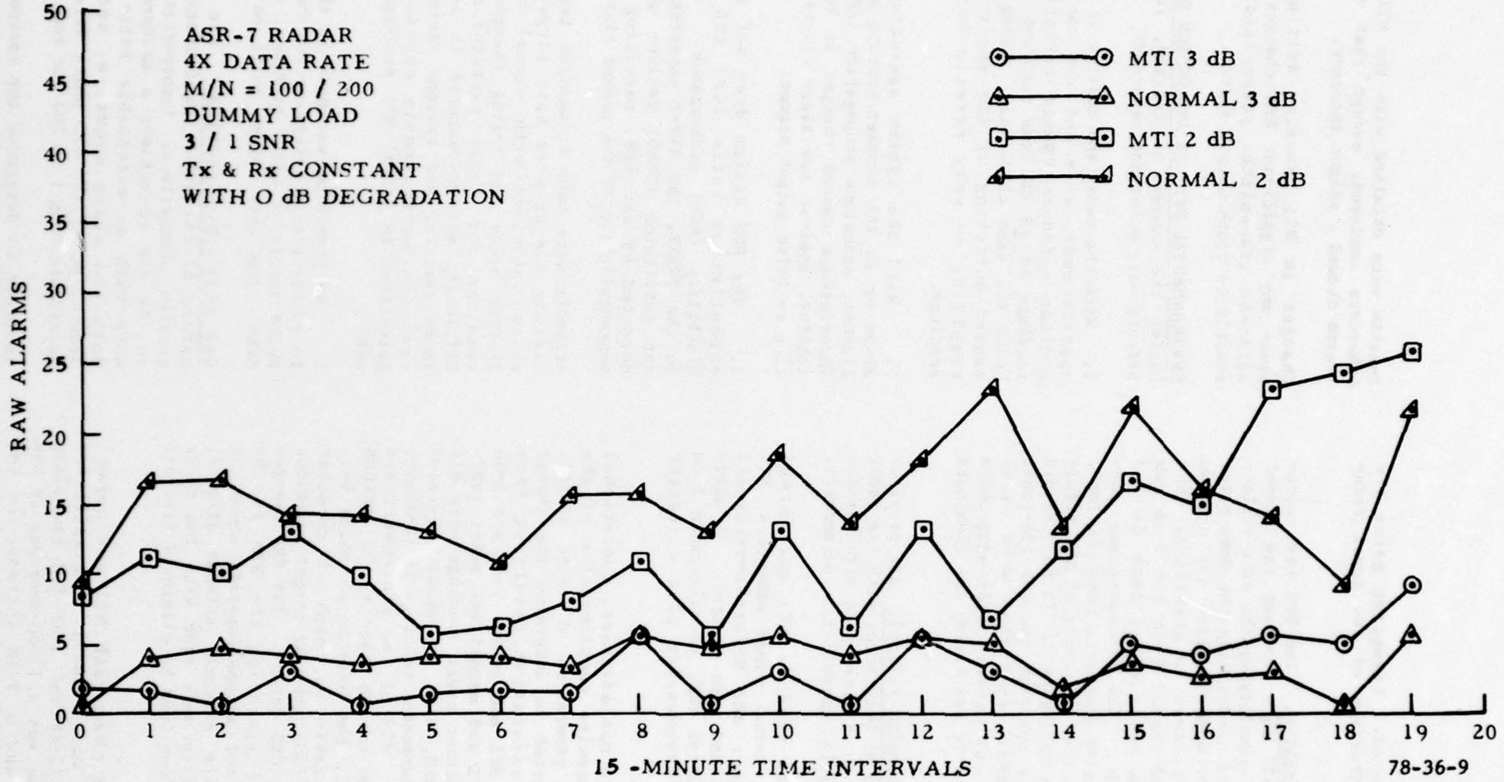

FIGURE 9. FOM SHORT-TERM STABILITY TEST RESULTS

as a function of radar FOM degradation. The data, in turn, were analyzed by the Radar Section, ARD-243, for a solution to this problem.

The data were obtained with the radar operating in the dummy load, to eliminate environmental factors, and the RPM in the test mode. The four quadrants were combined to quadruple the data rate, and the systems were optimized and allowed to stabilize. Other conditions during the tests were as noted on the data plots discussed below.

The radar FOM was degraded by reducing receiver sensitivity in calibrated decibel steps and by lowering transmitter power in 0.5-dB increments. The tests were performed for receiver and transmitter reduction separately and in combination. The RPM raw alarm counts were then recorded as single readings every 10 minutes on an average of six readings every 10 minutes.

Figure 10 depicts a typical data plot and illustrates the MTI and normal 2-dB and 3-dB FOM raw alarm distributions as a function of receiver degradation.

Analysis of all the data by ARD-243 led to a decision to employ a 75/150 SWD setting for remaining tests.

LONG-TERM STABILITY. Efforts were made to conduct a long-term stability test of the RPM to determine frequency of false alarm occurrences.

Because of all the previously discussed environmental factors and design deficiencies, in addition to various testbed and instrumentation problems, many interruptions were encountered before a minimally satisfactory RPM/ radar test setup was configured. Although the final configuration was not completely satisfactory because of unresolved MTI difficulties (cusping loss), data collection continued on a limited basis until higher priority work forced termination of the project.

Analysis of previous data by ARD-243 indicated that with SWD set to 75/150, the monitor would provide acceptable false alarm rates for both MTI and normal. In order to determine probability of false alarms (Pfa) more accurately in a short period of time (30 days), it was necessary to degrade the radar by 2 dB to place performance near threshold. The radar was operated online, and external environmental effects plus RPM antenna problems previously discussed were negated by modifying the RPM/radar interface as illustrated in figure 11. As shown in the illustration, the RPM input and output paths were separated, thus enabling the test targets to be inserted into the receiver through a gating unit with external signal returns gated off during the time of test target insertion.

During unattended operation, the data were recorded photographically with a special arrangement wherein each RPM output alarm caused the camera shutter to trip. A second camera set up to photograph a PPI was also tripped simultaneously to record radar video. Chart recordings of the receiver noise figure and transmitter power were also made simultaneously, and the MTI clock stability was also recorded with a digital counter/printer. All of the supporting data were examined to determine possible causes for the recorded output alarms.

Data collection during regular working hours was accomplished by observation and manual means.

The test was conducted for a total of nearly 700 hours of actual running time with many interruptions of varying lengths for reasons previously described. During the test, there were a total of three normal FOM 3-dB alarms, and one normal rms alarm, all of which could not be correlated with an apparent alarm condition. MTI alarm data were not considered because of design problems. True alarm capability of the RPM was exercised periodically during the test, with results in each case showing RPM alarmed with 4-dB degradation. This test and all further efforts were subsequently suspended, and it was therefore not determined what the false alarm rate would be with no deterioration.

SUMMARY OF RESULTS

1. RPM/ASR-5 tests could not be completed because of inherent radar instabilities.

2. Tests of the ASR-7 characteristics showed the system to be much more stable than the ASR-5.

3. RPM tests were subsequently performed in the ASR-7 testbed with the following results:

    a. RPM functioned satisfactorily according to feasibility and acceptance test procedures.

    b. Additional problems encountered were traceable to design philosophy; i.e., RPM antennas, RPM nonadaptability, and external environmental causes.

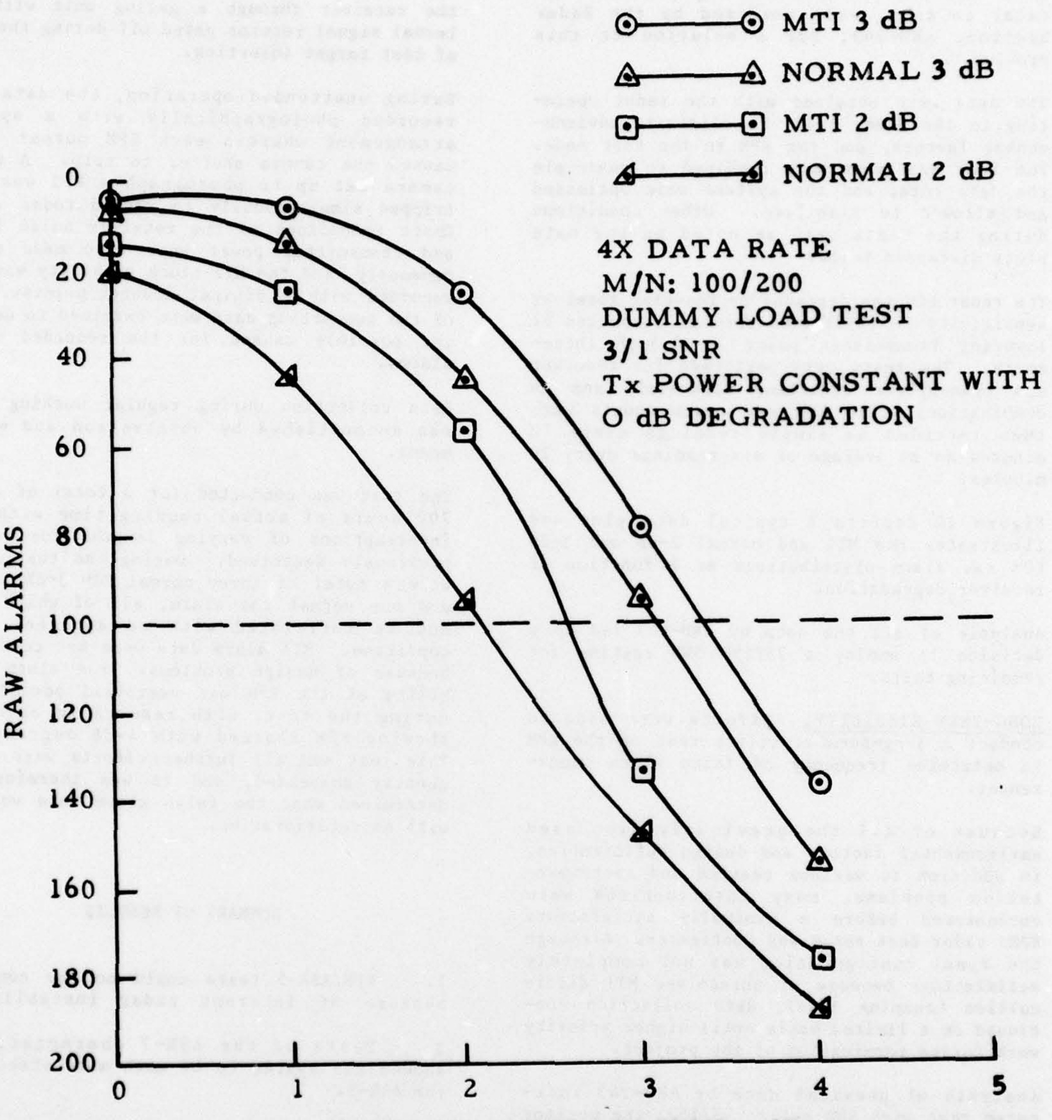

FIGURE 10. FOM RAW ALARM DISTRIBUTION

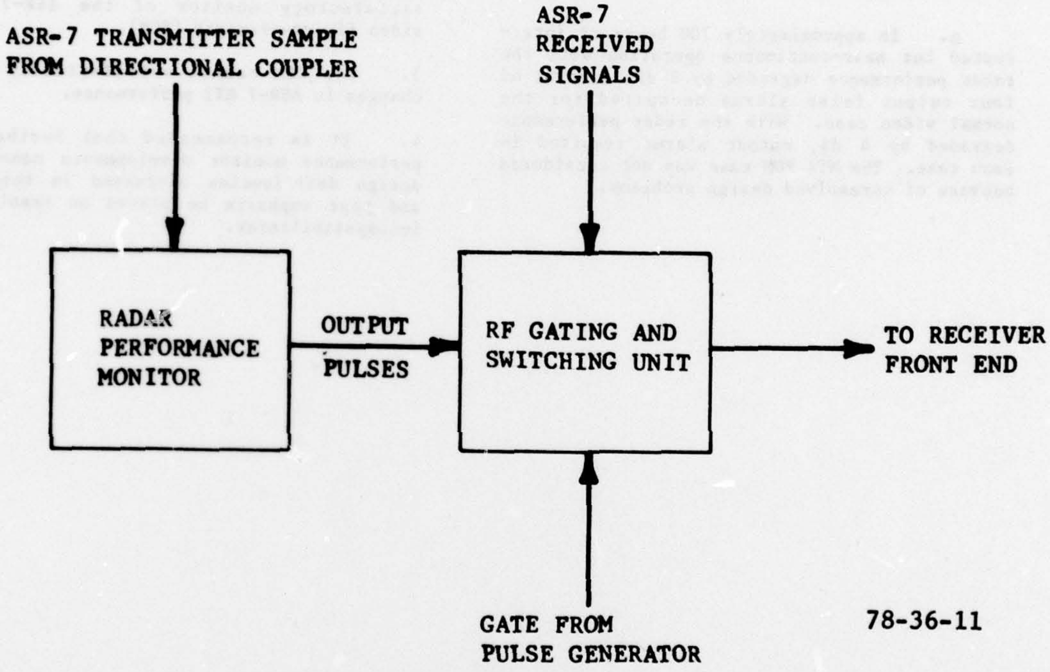

FIGURE 11. MODIFIED RPM/RADAR INTERFACE

c. RPM exhibited good short-term stability.

d. ASR-7 digital MTI design caused RPM sampling problems due to cusping loss.

e. ASR-7 coherent oscillator failure which occurred during stability test was not detected because the RPM was not designed to measure CR or SCV.

f. Optimum SWD setting for 0.5 and 0.2 false alarms per year for the MTI and normal FOM was 75/150.

g. In approximately 700 hours of interrupted but near-continuous operation with the radar performance degraded by 2 dB, a total of four output false alarms occcurred for the normal video case. With the radar performance degraded by 4 dB, output alarms resulted in each case. The MTI FOM case was not considered because of unresolved design problems.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the efforts described herein, it is concluded and recommended that:

1. The Westinghouse Radar Performance Monitor (RPM) as presently designed and configured cannot be used to monitor the performance of FAA terminal radars earlier than the ASR-7 models.

2. With some reconfiguration and changes in design philosophy, it can be employed as a satisfactory monitor of the ASR-7 normal video figure-of-merit (FOM).

3. The RPM cannot satisfactorily monitor changes in ASR-7 MTI performance.

4. It is recommended that further radar performance monitor developments consider the design deficiencies discussed in this report and that emphasis be placed on resolving MTI incompatibilities.