AD-A096 292 RADAR EVALUATION SQUADRON (TECHNICAL) (1954TH) HILL --ETC F/G 17/7
FINAL ACCEPTANCE TESTING OF THE TEXAS INSTRUMENTS (TI) ASR-8/MT--ETC(U)
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DEPARTMENT OF THE AIR FORCE
1954TH RADAR EVALUATION SQUADRON (TECHNICAL) (AFCS)
HILL AIR FORCE BASE, UTAH 84056

REPLY TO ATTN OF: DVX

15 Oct[redacted]980

SUBJECT: Final Acceptance Testing of the Texas Instruments (TI) ASR-8/MTD (AN/GPN-25) at Tolicha Peak, NV.

TO: See Distribution

1. INTRODUCTION. Final acceptance testing of the ASR-8/MTD (AN/GPN-25) was accomplished at Tolicha Peak, NV from 25 through 29 August 1980. This testing was done to supplement the earlier acceptance testing performed from 24 June through 7 July 1980.

2. AUTHORITY. The authority for this final acceptance test is contained in Eglin Armament and Development Center message R191400Z Aug 80, Subject: Site Acceptance Test AN/GPN-25 Gap Filler Radar, Contract No. F08635-78-C-0270.

3. EVALUATION PERSONNEL. AFCC evaluation personnel conducting final acceptance testing were:

Mr Lee R. Bishop, 1954 RADES, Scientific Analyst
SMS Noel H. Benner, 1866 FCS, Radar Technician

4. OBJECTIVES. The objectives of the final acceptance testing were twofold:

a. Determine the operational subclutter visibility (SCV) of the Lincoln Laboratories developed Moving Target Detector (MTD) as implemented by Texas Instruments Corporation (TI) in the ASR-8.

b. Verify radar maximum-detection range in a noise-only environment.

5. SUMMARY:

a. The SCV measurements were performed by superimposing an injected test target 0.6 microseconds in duration and 16 azimuth change pulses (ACPs) in width over a fixed block of actual clutter. The amplitude of the test signal was increased until it was just below the limit level at the input to the analog-to-digital (A/D) converter. Using RF attenuation, the ground clutter signal was matched in amplitude to the injected test-target signal in the IF strip. The injected signal was then decreased in amplitude in 1 dB steps relative to the clutter and the number of target detections in a 10-scan interval were manually counted at the output of the MTD (Video Display Unit). The test was repeated 11 times at each test target signal level for channel A and ten times for channel B, giving scan counts at each test target power level of 110 and 100 respectively. SCV was defined to be the difference in power level between the test target and clutter signal where an average single-scan probability of detection (SSPD) of 50 percent occurred. The SCV investigation is included as Attachment 1.

b. The maximum MTD detection range in a noise-only environment was determined by flying nine nose-on active beam penetrations with a T-38 (2.6 dBsm radar cross section) aircraft flying on a 274° T radial towards the radar. The antenna was raised to a 4.0° true tilt to eliminate the possibility of multipath and clutter influences, and to assure a beam threshold penetration. A false alarm rate of 1/filter/scan was established. Data were collected manually at the site video display terminal and from computer printouts in the Nellis AFB Range Control Center. Tracking data from the 9 tracks (radar hits and misses) were grouped into statistically independent 3-NM cells, and the SSPD for the center of each independent 3-NM cell was computed as the number of radar hits in the cell divided by the number of antenna scans in the cell. A third order polynomial was fitted to the probability of detection points of each 3-NM cell and the detection range was taken as the range at which SSPD reached 75 percent. The test data are included as Attachment 2. The final product of this test is a verified radar coverage indicator (RCI) which is included as Attachment 3.

6. CONCLUSIONS:

a. The measured operational SCV for channel A was 41.54 dB with 90-percent confidence limits of 41.03 and 42.17 dB. The corresponding SCV for channel B was 40.81 dB with 90-percent confidence limits of 40.31 and 41.35 dB. The SCV for channel A was measured with a Doppler offset of 634 Hz. This offset placed the test signal at the peak of filter 4 for the 1266 PRF and at the peak of filter 5 for the 1050 PRF. The channel B measurement was made with a Doppler offset of 570 Hz which placed the test signal between filter peaks on both PRFs. Hence the Channel B SCV was approximately 0.7 dB lower. The actual operational SCV should be a value somewhere between 41.54 and 40.81 or approximately 41.2 dB.

b. During the SCV testing, Doppler filters were successively removed to determine which filters were producing scan modulation clutter. Doppler filters 1 and 7 produced approximately 95 percent of the scan modulation false targets from the MTD.

c. The measured 75-percent SSPD detection range with a 2.6 dBsm aircraft at a true altitude of 16,300 feet and an active beam antenna tilt of 4.0° T was 47.1 NM. After adjusting for power and noise figure deviations from specified values, this equates to an on main-beam axis 75-percent SSPD range of 68.27 NM.

d. This investigation indicates that, different implementation techniques notwithstanding, the TI implemented MTD is the equal in SCV and range performance of the original Lincoln Laboratories MTD.

7. RECOMMENDATIONS. Based on the results of the final acceptance testing, it is recommended that the bandpass of Doppler filters 1 and 7 be reshaped. Also, the bandpass of the zero velocity filter should be widened to encompass the frequency range lost by the reshaping of filters 1 and 7.

LEE R. BISHOP, GS-12, ~~DAFC~~
Scientific Analyst

3 Atch
1. Subclutter Visibility Investigation
2. Detection in a Noise-Only Environment Investigation
3. Radar Coverage Indicators
   A. Active Beam
   B. Composite Beam

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ATTACHMENT 1

SUBCLUTTER VISIBILITY INVESTIGATION

PURPOSE:

To determine the operational subclutter visibility (SCV) of the Texas Instruments (TI) implemented ASR-8/MTD (AN/GPN-25) system with actual clutter and a scanning antenna and compare this figure to that achieved by the Lincoln Laboratories prototype MTD.

RATIONALE:

At the 50-percent single-scan probability of detection (SSPD) point, where subclutter visibility is normally defined, there is an approximate 0.8 dB average difference in signal-to-noise ratio between jet aircraft return signals and nonfluctuating target signals. Thus an SCV measurement over actual clutter with a nonfluctuating target, as would be obtained from a signal generator, will give a good estimate of MTD performance against actual aircraft over clutter. The nonfluctuating-signal-over-clutter method of SCV measurement was used by Lincoln Laboratories to measure MTD performance, and has also been successfully used by the 1954th RADES to measure SCV on foreign and US moving target indicator systems.

INVESTIGATION METHOD:

The method of investigation consisted of selecting a patch of ground clutter larger in size than a radar resolution cell and capable of producing limiting at the analog-to-digital (A/D) converter.

The method of investigation was based on superimposing an injected test target, one pulse width deep and a beamwidth wide with a predetermined Doppler offset, over a patch of ground clutter. As the strength of the injected test target was decreased with respect to the clutter, SSPD was determined. A "window" was placed over the clutter patch so that the TI-990 terminal (video display unit) could display only declared targets over the clutter. The probability of detection was computed as the number of declared targets over the clutter patch divided by the total number of antenna scans over the clutter patch.

Because antenna scan modulation from Doppler filters 1 and 7 produced false targets from some clutter patches, it was necessary to select a clutter patch free of scan modulation returns so that the only detections counted were those from the superimposed test target. There were several patches of clutter that were (a) larger than a radar resolution cell (one pulse width times the horizontal beamwidth) and (b) of sufficient strength to produce limiting at the A/D converter input. A clutter patch at an azimuth of 23°T and 27.5 NM in range was chosen for the test.

INVESTIGATION CONFIGURATION:

A functional diagram of the test setup for the SCV measurement is shown in Figure 1-A. The following discussion addresses Figure 1-A. The 0.6 microsecond IF test pulse injected into the MTD linear IF amplifier was adjusted (using the variable attenuator on the IF signal generator) to a point just below limit level as viewed on an oscilloscope connected to test point 2, the A/D converter input.

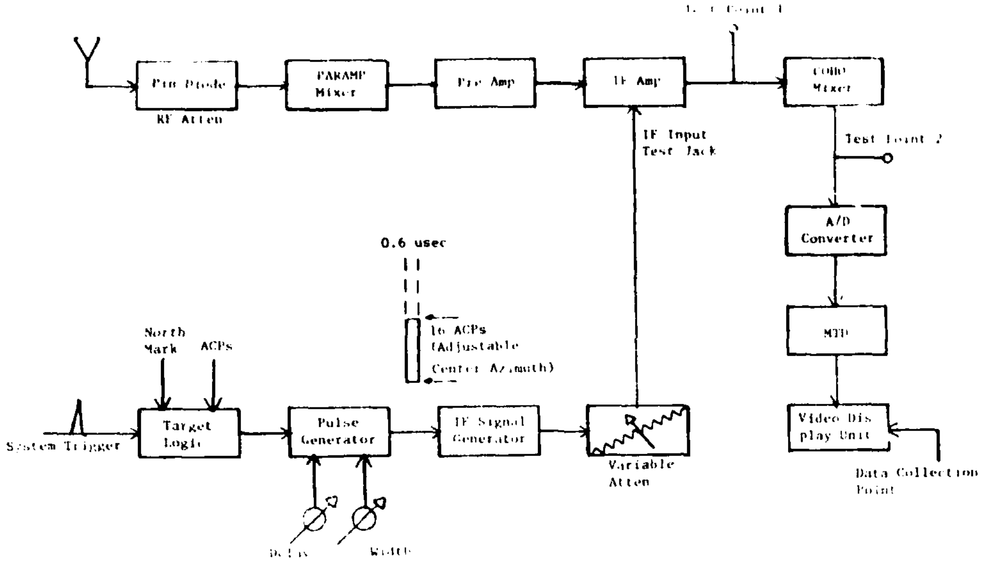


Figure 1-A   Test Setup for the SCV Measurement

This IF attenuator setting became the test reference level. Next, an oscilloscope was connected to the IF amplifier output (test point 1) and gated in range and azimuth to display only the selected clutter and the injected test target. The bias on the PIN-diode attenuators was adjusted until the average IF clutter amplitude equaled the injected test signal in amplitude. The test target was then superimposed in range and azimuth over the clutter and the test was started. Starting at a point where the injected test signal was 20 dB below the clutter reference value, the injected test signal was decreased in 1-dB steps from its reference value. The number of targets declared over the clutter in a 10-scan interval were manually counted at the TI-990 video display unit.

DATA COLLECTION:

Hit/scan data in 1-dB increments were collected at the TI-990 video display unit over 10-scan intervals and manually recorded. The SCV test for channel A of the radar was repeated 11 times, that for channel B, 10 times. The data sheets showing the clutter-to-signal levels that encompassed the 50-percent single-scan probability of detection points are shown in Tables 1-A and 1-B.

Test Date: 28 August 1980   Test Target Doppler Offset: 634 Hz

Clutter Azimuth: 23° T   Clutter Range: 27.5 NM

Clutter-To-Signal Ratio (dB)	Test Number 1	2	3	4	5	6	7	8	9	10	11	Total Count	Single-Scan Prob of Det (%)
40	9	10	9	7	7	8	9	10	7	7	5	88	80.0
41	8	6	3	8	5	5	6	3	9	7	5	65	59.1
42	6	4	3	3	4	5	6	5	6	4	2	48	43.6

Table 1-A   SCV Recording Sheet for Channel A

Test Date: 27 August 1980 Test Target Doppler Offset: 540 Hz

Clutter Azimuth: 23° T Clutter Range: 27.5 NM

Clutter-To-Signal Ratio (dB)	Test Number 1	2	3	4	5	6	7	8	9	10	Total Count	Single-Scan Prob of Det (%)
40	6	5	5	6	8	6	7	7	5	9	64	64
41	3	5	3	5	2	6	5	6	5	7	47	47
42	2	5	3	5	2	3	1	4	3	4	32	32

Table 1-B SCV Recording Sheet for Channel B

DATA ANALYSIS:

Second order polynomials were fitted to the three ordered pairs of SSPD and clutter-to-signal ratio points taken from each data sheet.

The polynomial fitted to the channel A data is

$$SSPD = 0.0288258x^2 - 2.54572x + 56.5082$$

The polynomial fitted to the channel B data is

$$SSPD = 0.0117602x^2 - 1.12434x + 26.7979$$

The x for both polynomials is clutter-to-signal ratio in dB. The average SCV for each channel was determined by solving the fitted quadratic equations for the value of clutter-to-signal ratio that produced a 50-percent SSPD. Next, exact 90-percent confidence limits ($\alpha = 0.10$) for a proportion in terms of the percentage points of the 'F' distribution, were computed. These confidence limits were converted from percentages to dB by solving the fitted quadratic equations for the values of clutter-to-signal ratio that produced the confidence-limit percentages. Figures 1-B and 1-C are plots of the reduced channel A and B SCV data.

The average SCV for channel A was measured as 41.54 dB with 90-percent confidence limits of 41.03 and 42.17 dB. The average SCV for channel B was measured as 40.81 dB with 90-percent confidence limits of 40.31 and 41.35 dB.

The channel A SCV is slightly higher than that of channel B because the test target Doppler offset used in the channel A experiment was chosen to place the test target at the peak of Doppler filter 4 on the 1266 PRF and Doppler filter 5 on the 1050 PRF. It is therefore an optimal value. The channel B Doppler offset was chosen to place the test target between filter peaks on both PRFs and is a pessimal value. The actual SCV for targets with Doppler frequencies falling in the range of filters 2 through 6 between the peaks of filters 1 and 7 will be approximately the average of 41.53 and 40.81 or 41.2 dB. This 41.2 dB SCV figure agrees well with theoretical considerations. During the detection performance investigation, it was determined that a signal-to-noise ratio of approximately 5.8 dB is required to produce a 50-percent SSPD. The linear dynamic range of the MTD receiver has a theoretical upper limit of 48 dB. This 48 dB minus 5.8 dB is approximately 42.2 dB and an upper limit for SCV. The average of the two measured SCV values is within a dB of the upper limit.

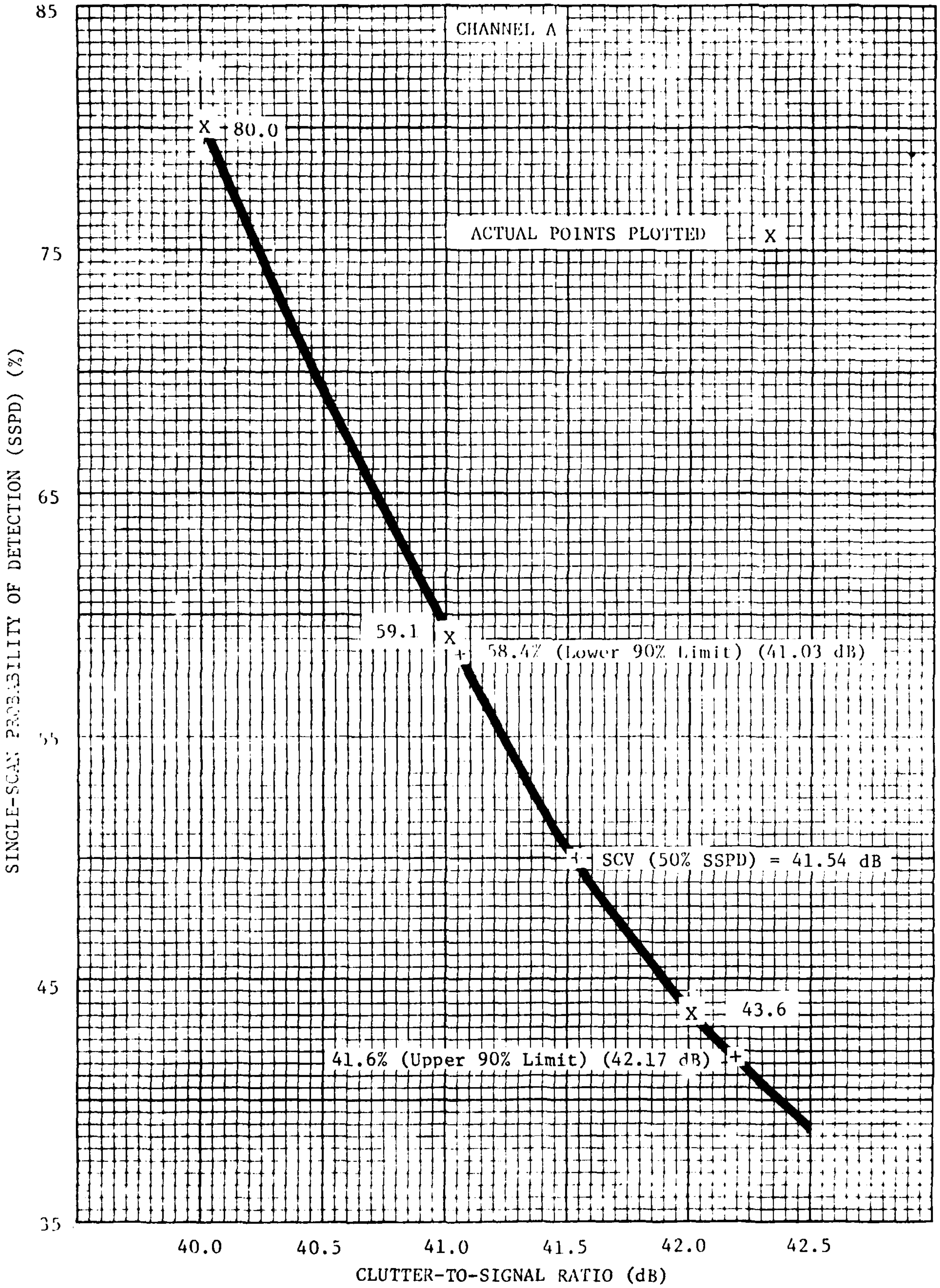


Figure 1-B Measured Subclutter Visibility for SSPD = 0.5

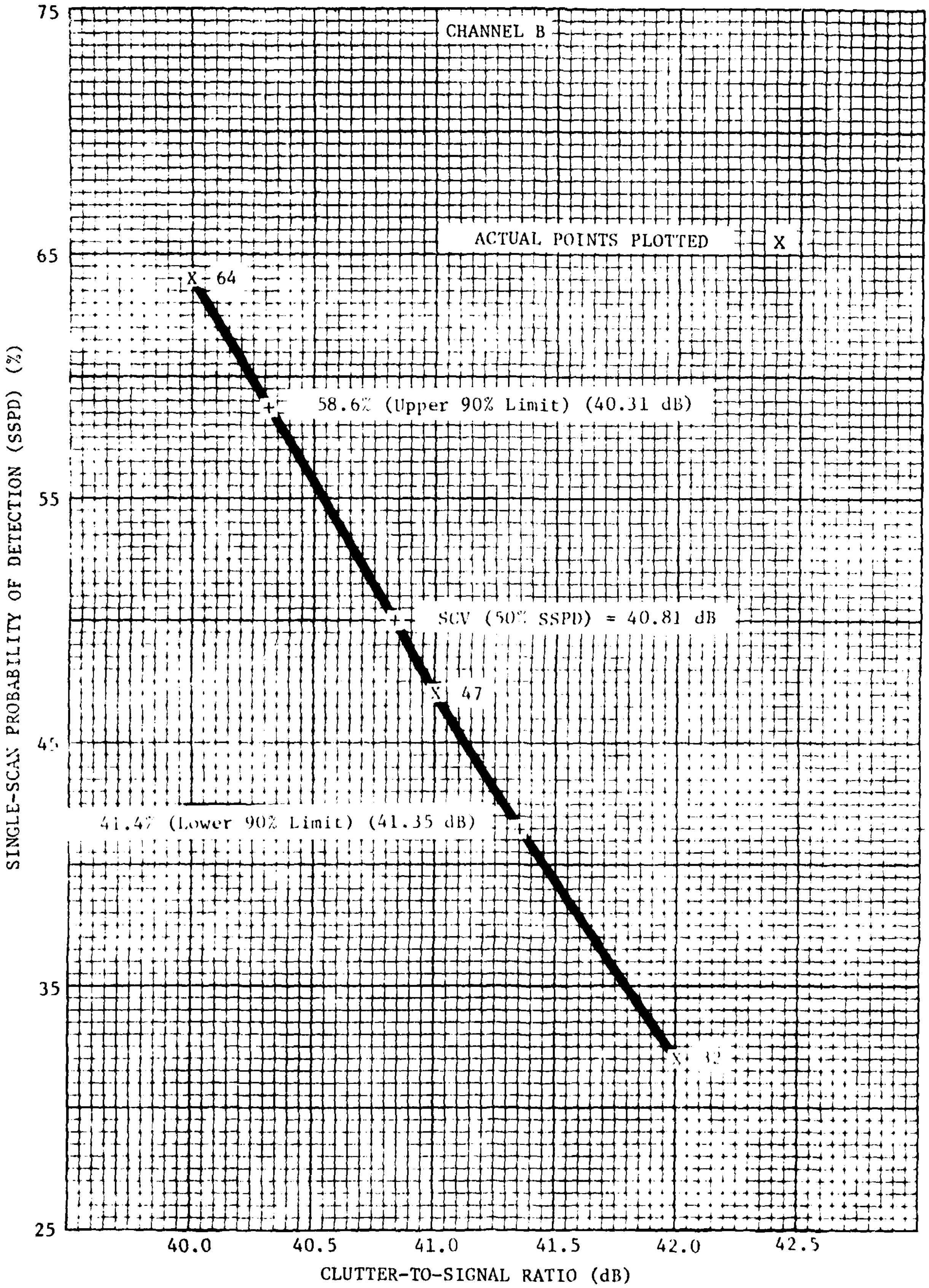


Figure 1-C Measured Subclutter Visibility for SSPD = 0.5

While selecting the clutter patch for the SCV experiment, approximately 61 false targets per scan from clutter were counted on the PPI scope. This figure excludes cars and noise false alarms. Removing filters 1 and 7 reduced the scan modulation false target count to approximately three per scan, a reduction of approximately 95 percent.

CONCLUSIONS:

This investigation was an unqualified success. It proves that the TI implemented MTD is equal in performance to the Lincoln Laboratories developed MTD. The measured average SCV of 41.2 dB for the TI MTD matches the Lincoln Laboratories expected SCV value of 41.2 dB reported in FAA report RD-76-190 dated 8 March 1977.

This investigation also showed that a useful reduction in false alarms caused by scan modulation should be possible by changing the shapes of filters 0, 1, and 7.

ATTACHMENT 2

DETECTION IN A NOISE-ONLY ENVIRONMENT INVESTIGATION

PURPOSE:

This investigation was designed to determine the maximum detection range of the ASR-8/MTD (AN/GPN-25) against a 1M^2 (0 dBsm) target on beam axis and provide data to empirically develop a radar coverage indicator (RCI).

RATIONALE:

Because the free-space beam pattern of the ASR-8 antenna is well known, the radar cross section (RCS) detection capability for an entire lobe contour can be determined by repeatedly penetrating the beam at one point in space. Flight results from one RCS can be translated to any other RCS by manipulating the radar range equation. By elevating the radar beam and properly selecting an aircraft altitude, it is possible to reduce the effects of clutter return and multipath propagation, thereby creating a system-noise-limited detection environment.

Radar range computations for a new system can be refined by measuring the signal-to-noise ratio (SNR) required to produce a given single-scan probability of detection (SSPD). By injecting IF test targets the size of a radar resolution cell at a known SNR and counting final target declarations, it is possible to combine all signal processing losses, except antenna pattern and target fluctuation losses into one measurement.

INVESTIGATION METHOD:

The investigation consisted of flying nine nose-on beam penetrations with a T-38 aircraft on a 274° T radial from the radar at an altitude of approximately 16,300 ft MSL. The 274° radial was chosen to provide a flight path with winds that would minimize aircraft crab angle. The antenna was raised to a true active-beam tilt of 4.0 degrees to reduce clutter/multipath influences to a negligible level and bring target detection range well within the 60 NM range limits of the radar.

The adjusted flight data were then compared with theoretical predictions refined with measured single-scan probability of detection (SSPD) data as a function of signal-to-noise ratio (SNR).

The SNR required to determine an SSPD was measured by counting MTD target declarations from an injected IF test target 0.6 microsecond deep and 16 ACPs wide with a known SNR. SSPD for a given SNR was computed by dividing the number of declared targets by the number of injected targets.

INVESTIGATION CONFIGURATION:

The normal radar configuration was modified to receive active beam data only. The passive beam data were not used. The antenna tilt was adjusted for a true active-beam tilt of 4.0 degrees. All range azimuth gating (RAG) was removed. The flight data were collected from radar channel A. The false alarm rate due to noise was set for 1/filter/scan for Doppler filters 1-7 and 2/scan for the zero velocity filter with the receiver connected to the radar antenna and the transmitter off. Transmitter power, noise figure, and false alarm rate were checked before and after flights. The equipment configuration used to determine the SNR required to produce a given probability of detection is the same as was used for the SCV investigation.

DATA COLLECTION:

Channel A active-beam flight data were collected from the TI-990 video display unit at the site and from computer printouts of radar-only and radar reinforced data at the Nellis Range Control Center. As the Nellis data were more complete, only these data were used for the final data reduction. Hit/miss data from the nine tracks were combined over the range interval from 59 to 44 NM and grouped into 3-NM cells. These data are shown in Table 2-A. The SSPD value for the center of each 3-NM cell was computed as Total Hits/(Total Hits + Total Misses).

	Range (NM)				
	44-47	47-50	50-53	53-56	56-59
Total Hits	41	33	23	21	16
Total Misses	8	17	26	32	29
Total Scans	49	50	49	53	45
SSPD (%)	83.7	66.0	46.9	39.6	35.6

Table 2-A Combined Radar Tracking Data

The SNR required to produce a specified SSPD was determined from data manually collected from the TI-990 video display unit at the Tolicha Peak radar site. The IF amplifier noise level was determined using a CW noise power test. This value represented a 0-dB SNR. A single 1 resolution cell target per scan was injected at SNRs of 5, 6, 7, and 8 dB. MTD declared targets were counted over a 10-scan interval. The test was repeated 5 times at each SNR. The data counts are shown in *Table 2-B along with the average SSPD associated with each* SNR.

	10-Scan Target Counts						
SNR (dB)	1	2	3	4	5	Totals	SSPD%
5	2	2	3	3	2	12	24.0
6	7	6	5	6	6	30	60.0
7	6	7	5	8	6	32	64.0
8	8	8	8	8	8	40	80.0

Table 2-B Data Count for the Signal Processing Loss Investigation

DATA ANALYSIS

The reduced flight data shown in Table 2-A were converted to an SSPD curve by fitting third order polynomials to the computed SSPD points plotted in the center of their respective range cells. The polynomial used to describe the SSPD range between 30 and 42.7 percent is

$$SSPD = -0.004938x^3 + 0.994709x^2 - 66.27037x + 1496.109983$$

The polynomial used to describe the SSPD range between 42.7 and 80 percent is

$$SSPD = 0.105514x^3 - 15.375097x^2 + 739.668554x - 11679.76371$$

The x for both polynomials is range in NM.

Detection range was determined by solving the latter polynomial for the range that produced a 75-percent SSPD (47.1 NM). The smoothed probability of detection curve is shown in Figure 2-A.

To convert the 47.1 NM range to a 0 dBsm on-axis range, it is necessary to account for antenna tilt and aircraft flight level, aircraft radar cross section, and radar deviation from normal operating parameters.

The antenna tilt was 4.0° T during the evaluation and the aircraft altitude was 16,300 ft MSL. With an exponentially modeled atmosphere RCI background, centered at a 7100 foot focal-point elevation, 47.1 NM and 16,300 feet intersect at an angle of 1.55° above the horizontal or 2.45° below the nose of the active beam.

The antenna pattern shows the antenna gain to be 4.7 dB down at a -2.45° angle. Thus the antenna gain at the average lobe penetration point was 33.8 minus 4.7 or 29.1 dB.

The radar range equation can be written as

$$\text{Range (NM)} = K x \log^{-1} (\textit{One-Way Antenna Gain in dB/20})$$

Knowing range (47.1 NM) and the one way antenna pattern gain (29.1 dB) it is possible to solve for K. The resulting K can be used to solve for the range at any other antenna gain. The K yielded by 47.1 NM and 29.1 dB of antenna gain is 1.65204. The on-beam-axis antenna gain is 33.8 dB; therefore the on-axis range for the evaluation aircraft equals 1.65204 times $\log^{-1}(33.8/20)$ or 80.91 NM. Because on-axis range desired is that for a 0 dBsm ($1M^2$) target and the evaluation aircraft was a 2.6 dBsm target, the 80.91 NM range must be adjusted by -2.6 dB. The 0 dBsm on-axis range is computed as

$$\text{0 dBsm Range} = 80.91 x \log^{-1}(-2.6/40)$$

or 69.66 NM. This range figure must be reduced by another -0.35 dB to account for the fact that during flights the transmitter was 0.45 dB above specifications and the receiver noise figure was 0.1dB below specifications. Thus

$$\text{Range} = 69.66 x \log^{-1}(-0.35/40)$$

or 68.27 NM. Therefore, the on-axis range for a 0 dBsm target is approximately 68 NM. This empirically verified 68 NM figure was used in constructing the ASR-8/MTD (AN/GPN-25) radar coverage indicators that are included as Attachments 3A and 3B to this report. The composite pattern (atch 3B) is based on the active transmit pattern (upper feedhorn) and the passive receive pattern (lower feedhorn).

The SSPD as a function of SNR data was analyzed by fitting a second order polynomial to the data presented in Table 2-B. The polynomial used is

$$SSPD = -0.0500147x^2 + 8.22193x - 2.59861$$

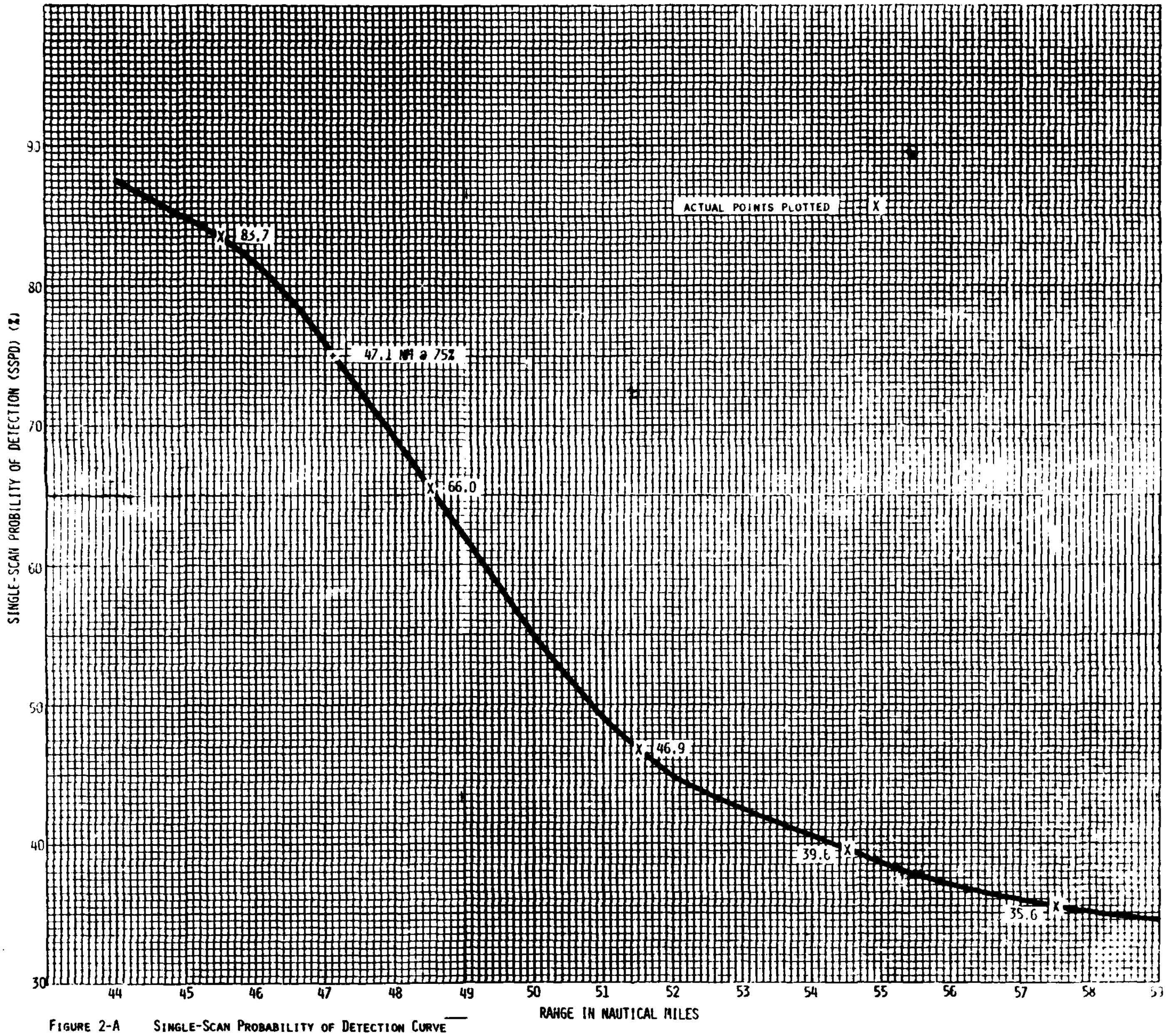


FIGURE 2-A SINGLE-SCAN PROBABILITY OF DETECTION CURVE

where x is SNR in dB. This polynomial was solved to find the SNR that produced a 75-percent SSPD (7.44 dB). This 7.44 dB SNR figure is for a non-fluctuating target and includes A/D converter loss, CFAR loss, MTD improvement factor, and range straddling loss. It does not include Doppler straddling loss (0.4dB) because it was made with the test target centered on a Doppler filter peak. The second order polynomial and the data points from Table 2-B are shown plotted in Figure 2-B. This 7.44 dB figure was used to refine the radar range calculations shown in Table 2-C. The notation used in this table is that of L.V. Blake, except where otherwise noted.

Range Factors	Decibel Values	Plus (+) dB	Minus (-) dB
Pt (KW)	+10log 1400.0	31.46	
PW (usec)	+10log 0.6		2.20
Gt	Gt (dB)	33.80	
Gr	Gr (dB)	33.80	
σ (m^2)	+10log 1.0	0.00	
f (MHz)	-20log 2800.0		68.94
T_s (^oK) (a)	-10log 596.0		27.75
V_o (b)	$-V_o$ (dB)		7.44
L_t	$-L_t$ (dB)		1.19
L_p	$-L_p$ (dB)		1.60
L_{ds}	$-L_{ds}$ (dB)		0.40
L_{ft}	$-L_{ft}$ (dB)		0.80
L_x	$-L_x$ (dB)		0.41
L_α	$-L_\alpha$ (dB)		1.31
Range Equation Constant		+40log 1.292	4.45
Totals:		+103.51	-112.04

Max Range = 100xlog^{-1} (103.51+(-112.04)/40) = 61.20 NM

(a) Assumes antenna temperature of 80° K and 17 feet of tower waveguide.
(b) Measured

Table 2-C MTD Range Calculations

The symbols used in Table 2-C are defined as follows:

Pt ----------------------- Transmitted signal power (at antenna terminals)
PW ----------------------- Pulse width
Gt ----------------------- Transmitting-antenna gain
Gr ----------------------- Receiving-antenna gain
σ ----------------------- Radar target cross section
f ----------------------- Frequency
T_s ----------------------- Receiving system noise temperature
V_o ----------------------- Visibility factor
L_t ----------------------- Transmitting loss factor
L_p ----------------------- Antenna-pattern loss factor
L_{ds} ----------------------- Doppler straddling loss
L_{ft} ----------------------- Fluctuating (jet aircraft) loss relative to a non-fluctuating signal
L_x ----------------------- 10log (20/22) to account for loss of every 11th pulse
L_α -----------------------Atmospheric absorption loss

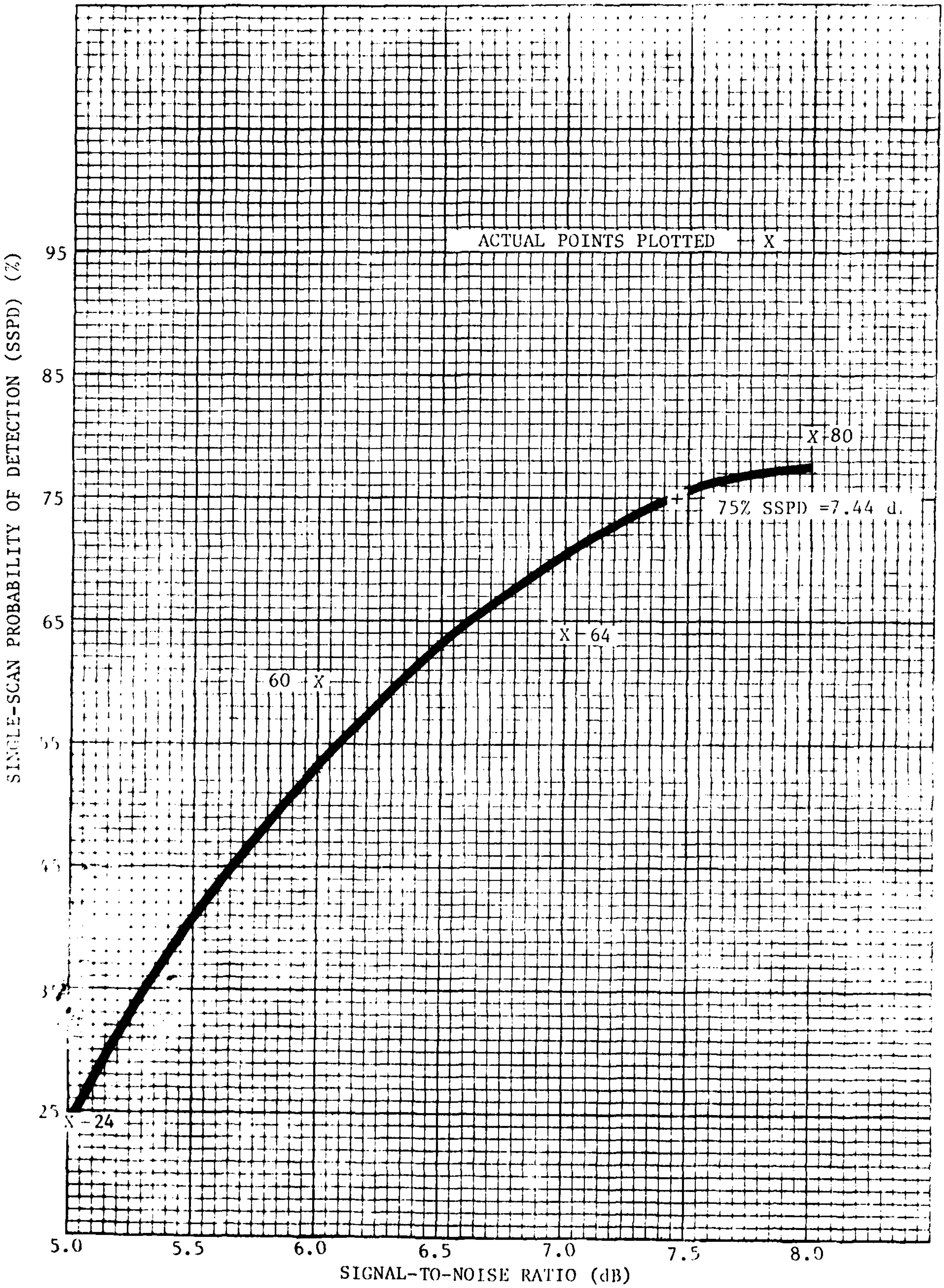


Figure 2-B SSPD as a Function of SNR

The predicted 0 dBsm on-axis theoretical range for the ASR-8/MTD (AN/GPN-25) is 61.2 NM or approximately 61 NM, 1.9 dB shorter than the 68 NM range indicated by the flight data.

CONCLUSIONS:

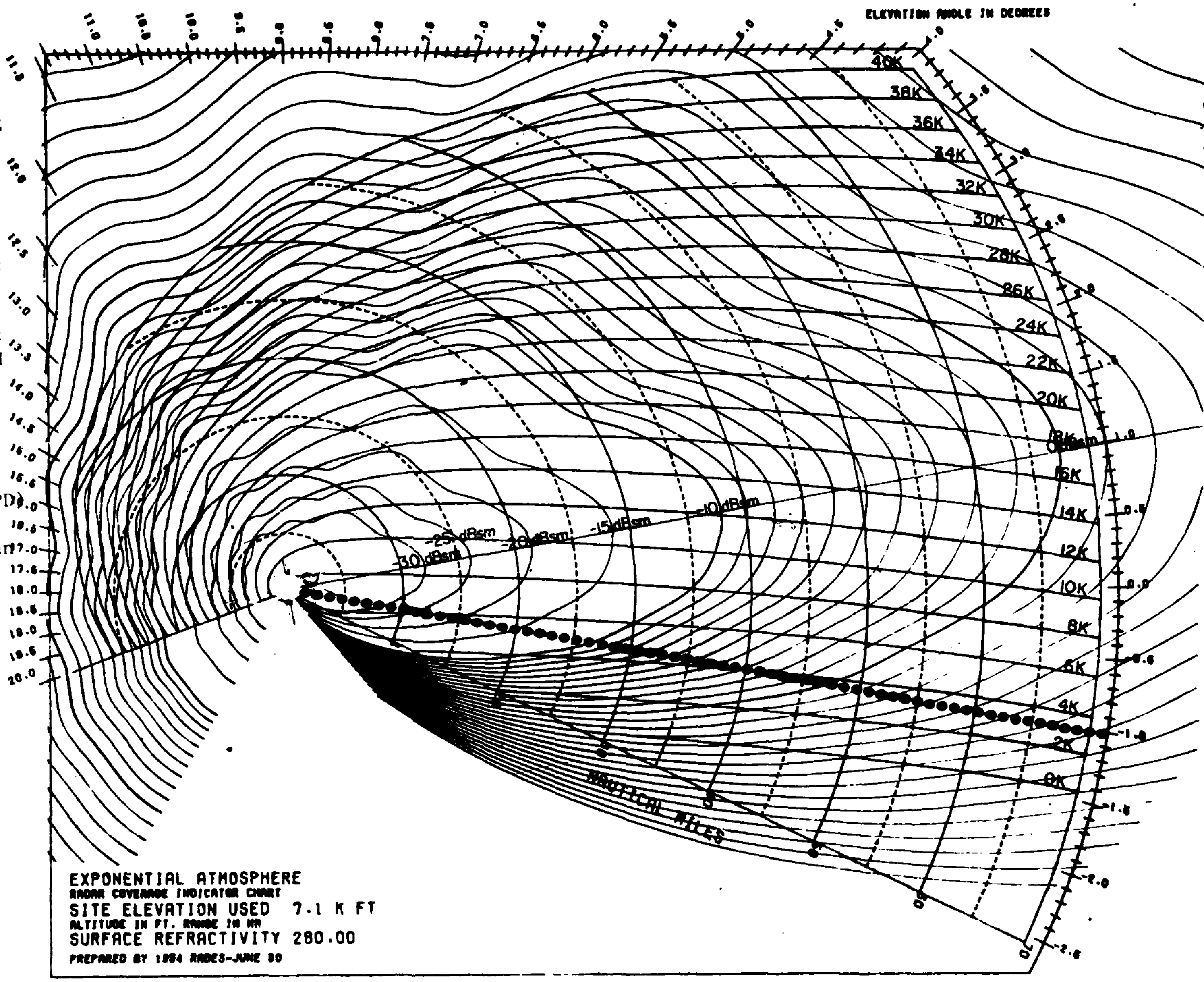
This phase of the evaluation was a complete success. It has demonstrated that the TI implemented MTD has an on-axis range capability of 68 NM for a 75-percent SSPD against a 0 dBsm ($1M^2$) jet aircraft target. This figure, based on actual flight results, agrees to within 1.9 dB of refined range calculations.

The Tolicha Peak ASR-8/MTD (AN/GPN-25) with a true tilt of 1.0 ° should provide maximum range (60 NM) detections for all 0 dBsm targets above 8000 ft MSL.

The solid center line on each pattern represents the pointing angle of the nose of the active pattern. The lower dashed line represents the lower one-way 3-dB pointing angle of the active pattern.

AN/GPN-25 (Active Pattern)

Peak Power	1.4 MW
Pulse Width	0.6 μsec
Noise Figure	2.0 dB
Frequency	2.8 GHz
PRF	1050/1266 Hz
Antenna Speed	12.8 RPM
Horizontal Beam Width	1.35°
Receive Line Loss	2.4 dB
Transmit Line Loss	1.2 dB
Pattern Loss	1.6 dB
Other System Losses	9.1 dB
0 dBsm Reference Range	(75% SSPD) 68 NM
False Alarm Rate	1/Filter/Scan

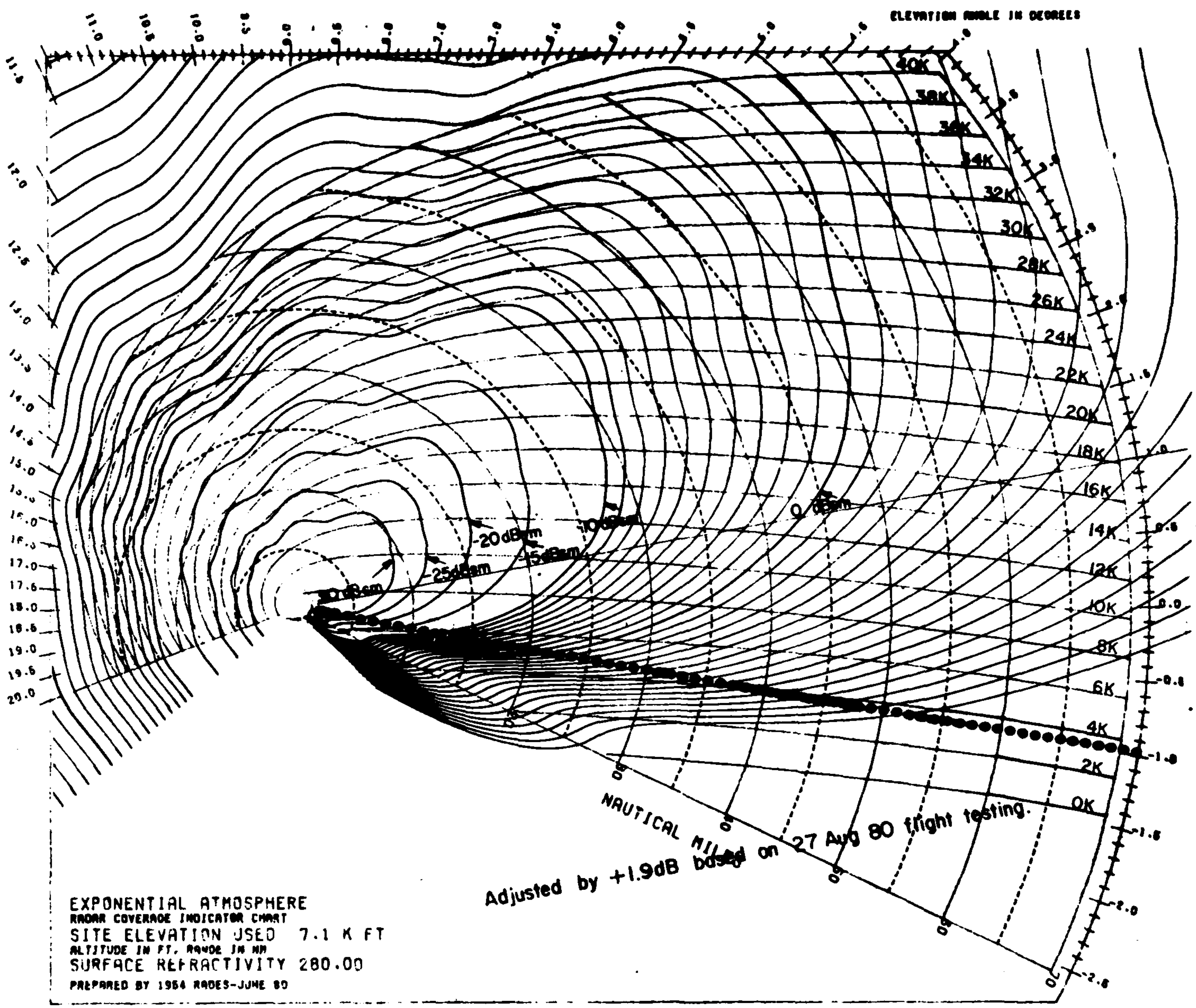


Adjusted by +1.9 dB based on 27 Aug 80 flight testing.

ATCH 3A

The solid center line on each pattern represents the pointing angle of the nose of the active pattern. The lower dashed line represents the lower one-way 3-dB pointing angle of the active pattern.

AN/GPN-25 (Composite Pattern)



Adjusted by +1.9 dB based on 27 Aug 80 flight testing.

ATCH 3B

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