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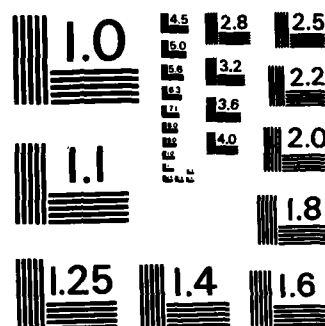
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Airport Surface Detection Equipment (ASDE)-3 Improvements Test and Evaluation

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August 1982

Final Report

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12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Systems Research and Development Service Washington, D.C. 20590			
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16. Abstract The Airport Surface Detection Equipment (ASDE)-3 radar test bed at the Federal Aviation Administration (FAA) Technical Center was installed and evaluated in 1980. Resulting from these tests, it was noted that additional information was required prior to the issuance of the procurement specification. Specifically, the three objectives were: (1) an investigation of anomalous elongation of target returns from F-106 aircraft; (2) to determine if there is an improvement in system performance when oversized waveguide is installed in lieu of standard Ku waveguide; and (3) a comparison of linear vertical, linear horizontal, and right hand circular antenna feed polarizations with respect to clear weather target imaging performance. This report documents the evaluation conducted and the results of this evaluation. The results indicated that: (1) the target elongation is generated by intermediate frequency (IF) amplifier saturation; (2) oversize waveguide improves system performance and should be utilized for long radiofrequency (RF) runs; and (3) linear polarization improves clear weather target imaging and should be provided to the controller as an option.			
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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				
teaspoon	teaspoons	5	milliliters	ml
Thsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cup	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 Heights and Measures, Price \$2.25, SD Catalog No. C13.10/286.

Approximate Conversions from Metric Measures

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

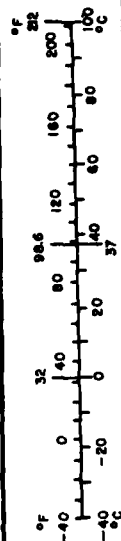


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INTRODUCTION

PURPOSE.

The purpose of the system improvements tests performed on the Airport Surface Detection Equipment (ASDE)-3 System located at the Federal Aviation Administration (FAA) Technical Center, Atlantic City Airport, N.J., was to provide additional information for the ASDE-3 procurement specification. The three specific objectives were: (1) an investigation of the anomalous elongation of target returns from F-106 aircraft; (2) installation of oversize waveguide (WR-187) to provide less signal attenuation and investigation of subsequent system performance compared to that achieved using the ASDE-3 standard (WR-62) waveguide; and (3) determination of the relative merits of linear vertical, linear horizontal, and right hand circular antenna feed polarizations with respect to target imaging performance.

BACKGROUND.

The ASDE-2 now used at several major airports has been operational for the past 20 years. Being a vacuum tube design, it has had a maintenance problem with tube failures, resulting in a mean time between failures (MTBF) rate of approximately 200 hours. In addition, the radar is nearly useless in heavy rain due to backscatter from rain droplets, resulting in a white-out and absorption of signals at its emitted frequency by the rain.

In order to correct the above deficiencies, the Transportation Systems Center (TSC), under FAA Systems Research and Development Service (SRDS) sponsorship, issued a contract with engineering specification (DOT-TSC-1373) to Cardion Electronics for development of the ASDE-3 engineering model and display enhancement unit (DEU). Upon completion, the system was shipped to the FAA Technical Center for engineering evaluation by TSC and operational evaluation by the FAA.

These tests were completed on May 30, 1980. During the engineering tests, the time frame available did not allow the evaluation of oversize waveguide, linear polarizations, and, as was discovered, a target elongation problem with F-106 aircraft. The three tests were performed during fiscal year 1981.

SYSTEM DESCRIPTION.

The ASDE-3 radar uses a solid-state design. Several new features have been added to provide a state of the art and more reliable airport surface detection system. The new features are:

1. The antenna is designed for continuous focus from near to far field.
2. A rotating radome of a smaller cross section than a conventional radome provides a constant radiofrequency (RF) window for the antenna beam and also sheds precipitation, reducing losses due to radome coating by rain, snow, or ice.
3. A new pedestal with belt drives reduces noise.
4. A traveling wave tube (TWT) is used to provide a wide band RF power amplifier for use with the frequency agility feature.

5. The pulse repetition frequency (PRF) is selectable at 13, 16, and 20 kilohertz (kHz), staggered or fixed.
6. Transmitter frequency agility is available, as well as several fixed frequencies from 15.7 to 16.2 gigahertz (GHz).
7. A DEU is part of the system. This unit provides airport mapping and target enhancement between the map boundary lines. The background may be reduced or eliminated while not affecting the enhanced targets. The display of the ASDE-3 is an analog scan converted television (TV) with 1,225 scan lines per frame.
8. The antenna has an inverted cosecant radiation pattern to provide a constant signal-to-noise plus clutter ratio.

This radar operates in the frequency range of 15.7 to 16.2 GHz with a pulse width of 36 nanoseconds (ns), a peak power of 10 kilowatts (kW), and a maximum range of 18,000 feet. It has three fixed PRF's of 13, 16, and 20 kHz. The selected PRF may also be staggered. In addition to the variable PRF, the carrier frequency may be varied in thirteen 30 megahertz (MHz) steps or any combination thereof. These features reduce or eliminate second time around targets, amplitude variations of small targets, and clutter due to precipitation. The sensitivity time control (STC) is programmable so each site can have its own unique STC curve.

The antenna system is circularly polarized with an azimuth beam width of 0.25° . The elevation main beamwidth is between 1.6° and 2.0° at the half-power points, with secondary beam cosecant to the 1.5 power shaping from -2° to -4° and cosecant shaping from -4° to 31° . The antenna and radome rotate at 62 revolutions per minute (rpm). The output video passes through the DEU to the high resolution analog scan converter and then to the New Bright Radar Indicator Tower Equipment (NU-BRITE) display.

Range and XY offset are continuously variable at the scan converter or the remote display control unit. A block diagram of the system is shown in figure 1.

Shown operating in conjunction with, but not part of, the ASDE-3 system are a data acquisition system (DAS) and a Hewlett-Packard (HP)-9825A calculator system. The DAS, under the control of software in the HP-9825A calculator, used as an engineering tool during the evaluation, performs high-speed digital sampling and temporary storage of the analog radar video within a preset window up to 500 feet square in range and azimuth. The calculator then stores the video data along with time and remarks on a 10.5 inch, 9-track digital magnetic tape. These data are later reduced off-line with the calculator.

DISCUSSION

GENERAL.

The tests performed consisted of: (1) an investigation of anomalous elongation of target returns from F-106 aircraft; (2) installation and evaluation of oversize waveguide; and (3) determination of the relative merits of linear versus circular antenna feed polarizations.

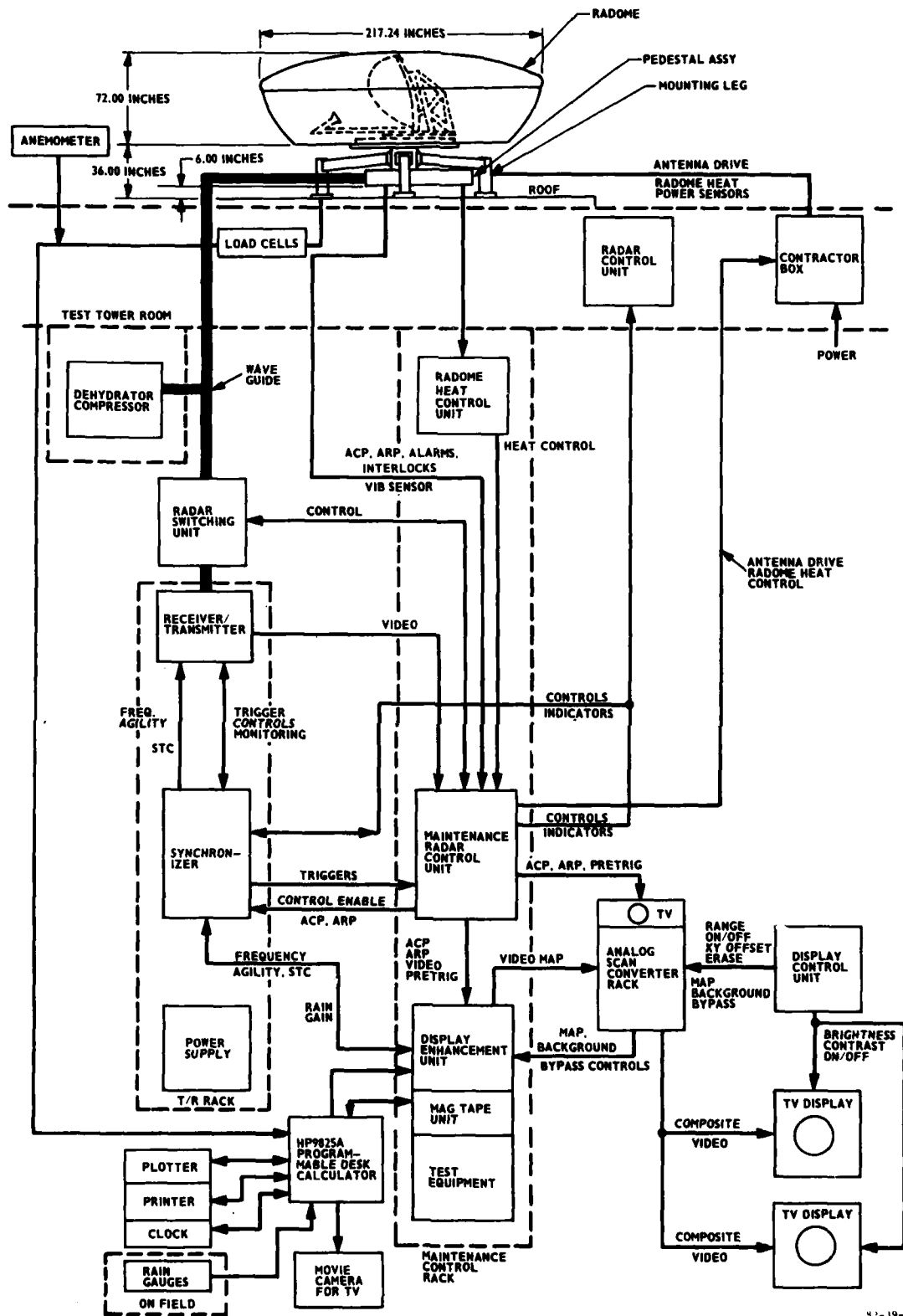


FIGURE 1. BLOCK DIAGRAM, ASDE-3 SYSTEM

In addition to these tests, three additional tasks were to be performed: (1) to provide contractor support in the investigation of system adaptive sensitivity (rain gain), and thresholding as a function of the rain intensity (this portion of the tests was cancelled by TSC due to lack of contract funds); (2) investigation of improved DEU map generation (this item was later deleted by SRDS); and (3) perform pedestal/rotodome noise and integrity checks. The noise tests were not completed due to test equipment failure. Three integrity checks over a period of 1 year revealed two broken bell washers in the rotodome floor. Based on the negligible deterioration, a semiannual integrity check and rotodome preventative maintenance schedule is recommended.

F-106 TARGET SIGNAL ANALYSIS.

An elongation in range of target echoes from F-106 aircraft (as well as several other aircraft types and supply vans at the FAA Technical Center) is experienced with the ASDE-3 system (figure 2). The tests performed to isolate the causes of this problem and to provide possible solutions for correcting them are described in the following sections.

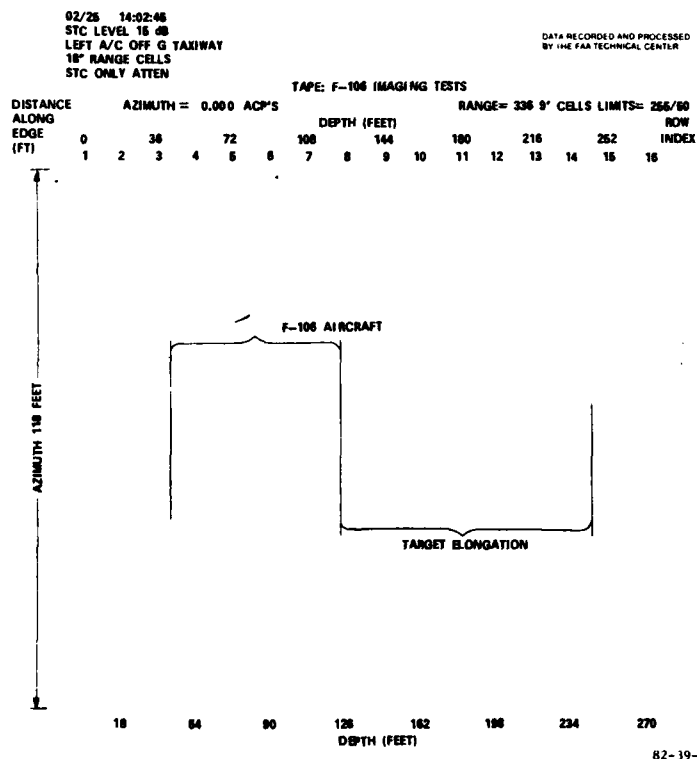


FIGURE 2. F-106 AIRCRAFT WITH TARGET ELONGATION

TEST PROCEDURES. To quantify the target signal elongation, the range extent of F-106 aircraft echoes and point targets were measured as a function of their radar cross section (signal strength). To calibrate and perform this test, the DAS provided with the ASDE-3 test bed was utilized to collect small aircraft signal

strength data at the airport municipal ramp as well as F-106 and point target signal elongation data as a function of target strength.

The small aircraft testing was done to establish the analog-to-digital (A/D) converter count at which a small aircraft was barely detectable on the ASDE-3 system NU-BRITE display. This count was then used as the system minimum discernible signal (MDS) level for subsequent analysis of the F-106 and point targets. Two samples of F-106 aircraft, positioned at slightly different orientations and located on the Air National Guard ramp, and two of the strongest obtainable point targets were used for the data samples. With the DAS window superimposed on the targets and the receiver at full sensitivity using a +7.3 volts (V) fixed STC level, the receiver input was attenuated in 3 dB (point targets 6 dB) steps from zero attenuation to the target MDS Level. At each increment, the size of the target was recorded using the DAS.

Two tests were performed to determine the receiver response in deep saturation since an external point target with an amplitude greater than 36 dB could not be found: (1) the ASDE-3 receiver check pulse was fed into the receiver RF input, and (2) signal generator pulses at the receiver intermediate frequency (IF) were fed directly into the IF amplifier. In each case, the pulse elongation was measured at the receiver video output as a function of the signal strength in dB above MDS. The detected waveforms at the inputs were matched to each other as closely as possible.

RESULTS. The results of the F-106 and point target measurements are shown in figure 3. From these it is concluded that:

1. For a point target, the width of the pulse at the video output (MDS level of +1.5 V) will vary directly with the input pulse amplitude from 0 feet to approximately 90 feet with a 36 dB higher signal level.
2. The aircraft, depending on their orientation with the ASDE-3, may reflect as a point target for up to 27 dB or more above the MDS level before the rest of the aircraft becomes visible. The increase in target length from that point becomes nonlinear as the several portions of the aircraft reflect in differing amounts with a resulting variation in the return pulse waveshape. The length of the F-106 aircraft is 70 feet.

Figure 4 shows a comparison of the response of the whole receiver chain versus the IF only. Projecting the linear portion of the curves to 45 dB above MDS and measuring the difference between the projections and actual crossings, shows an increase in signal width of approximately 85 feet for the IF amplifier and 105 feet for the whole receiving chain. This value is the target elongation due to deep receiver saturation (primarily in the IF stage), and accounts for the balance of the elongation shown in figure 3.

The target and its observed elongation, then, depend on the transmitted pulse shape, the target dimensions, and, primarily, on slow receiver recovery from saturation.

Figure 5 is a comparison of F-106 target elongation and small aircraft MDS level, and indicates that a maximum of 27 dB of attenuation (STC) was used to reduce the observed F-106 target elongation before it degraded the presentation of a typical small aircraft target to a minimum discernible signal in clear weather.

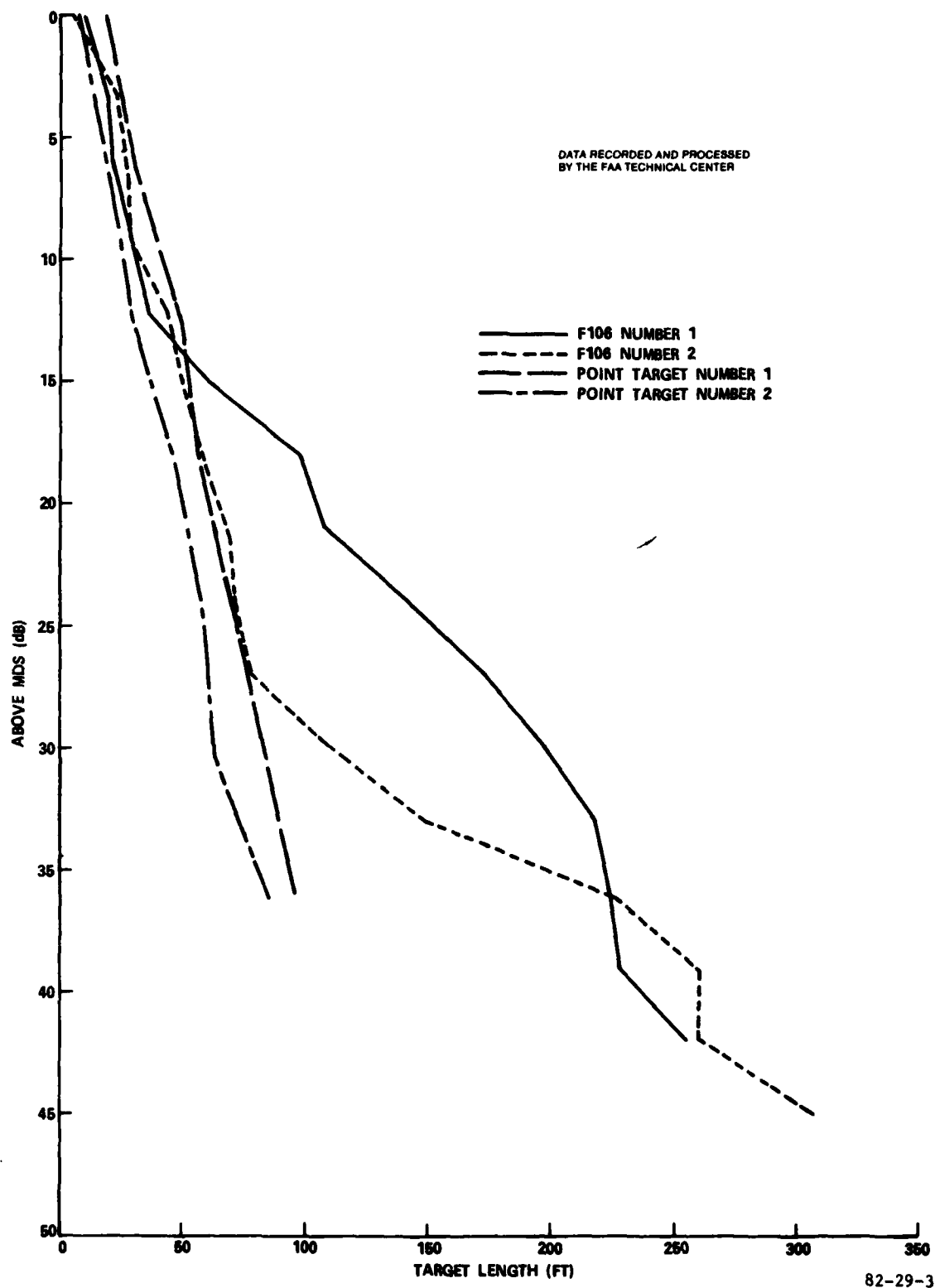


FIGURE 3. ASDE-3 RADAR POINT TARGET AND F-106 AIRCRAFT COMPARISON

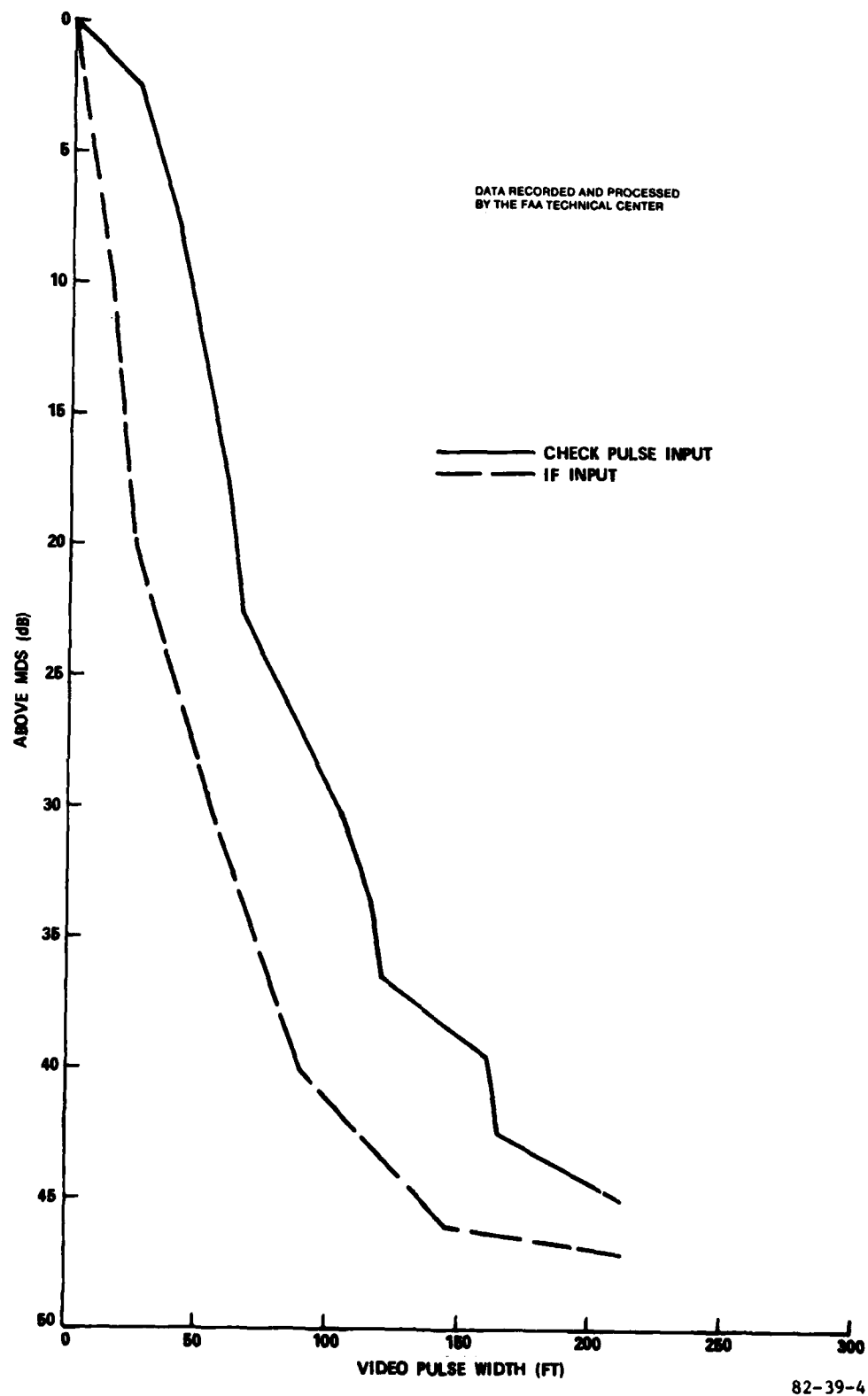
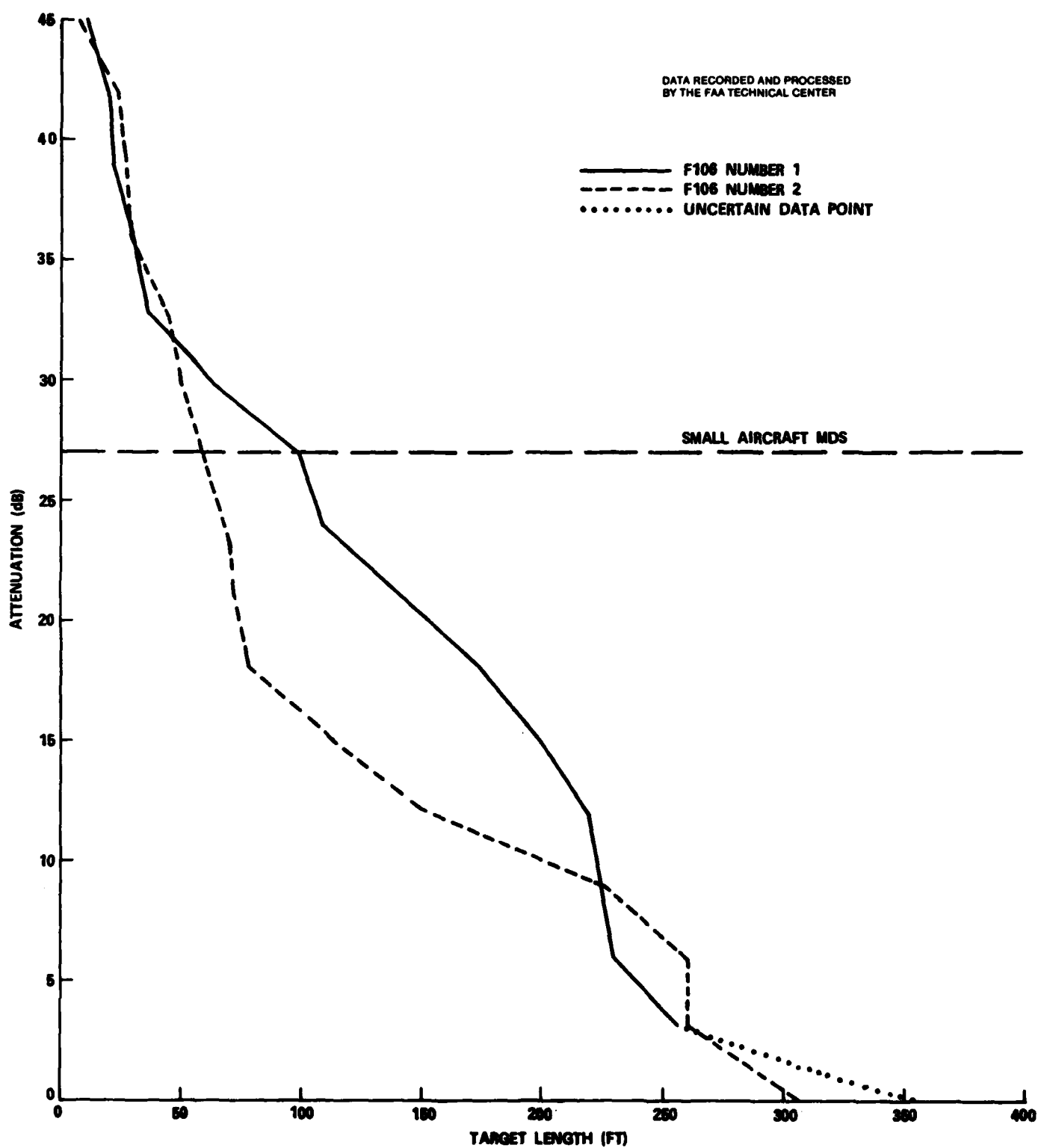


FIGURE 4. ASDE-3 RADAR TARGET SIZE ELONGATION, RECEIVER TESTS



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FIGURE 5. ASDE-3 RADAR F-106 ELONGATION

INVESTIGATION OF OVERSIZE WAVEGUIDE.

This test series was designed to determine the relative merits of oversize waveguide (C-band, WR-187) versus the standard waveguide (K_u, WR-62) which was installed with the ASDE-3 system. The primary goal was to determine if oversize waveguide would significantly decrease signal losses which are caused by long runs of the standard waveguide. Secondly, it was to be determined if there were any deleterious effects, such as waveguide multimoding, caused by operating with the oversize waveguide.

TEST PROCEDURE. The oversize waveguide with mode suppressors and transitions was installed parallel to the existing standard waveguide. A precision RF attenuator was inserted at the front-end of the ASDE-3 receiver.

For the first series of tests, three separate targets were used. Target No. 1 was a taxiway light at a range of 2,830 feet, target No. 2 was an RF reflector at a range of 5,100 feet, and target No. 3 was an RF reflector at a range of 8,600 feet.

Return video was recorded from each target at three transmitter frequencies; low, mid, and high corresponding to 15.75, 16.00, and 16.20 GHz, respectively, using the standard waveguide. The tests were then repeated with the oversize waveguide. The tests were conducted twice and were each completed within 1 day to maintain similar weather conditions.

The second series of tests were conducted with an RF signal generator and an RF power meter. The waveguide runs were disconnected from the ASDE-3 and onsite insertion loss tests were performed on the standard and oversize waveguides at frequencies of 15.75, 16.00, and 16.20 GHz. During both of the test series, the system display was monitored for evidence of rings due to multimoding within the oversize waveguide (reference 1).

TEST RESULTS. A signal gain of greater than 6 dB (7 dB per 100-foot run) was realized with the oversize waveguide in both series of tests. Results of these tests are shown in table 1. The system test values are the average of all three targets for the two tests.

A multimode ring was barely detectable (figure 6) at 420 feet in range, at 15.75 GHz only, while operating with the standard receiver sensitivity time control curve.

TABLE 1. OVERSIZE VERSUS STANDARD WAVEGUIDE ATTENUATION IMPROVEMENT

System Test			Insertion Loss Test	
Frequency GHz	Gain (dB)	Improvement per 100 ft (dB)	Gain (dB)	Improvement per 100 ft (dB)
15.75	6.24	7.34	7.73	9.09
16.00	5.93	6.98	7.59	8.93
16.20	6.19	7.28	7.57	8.91

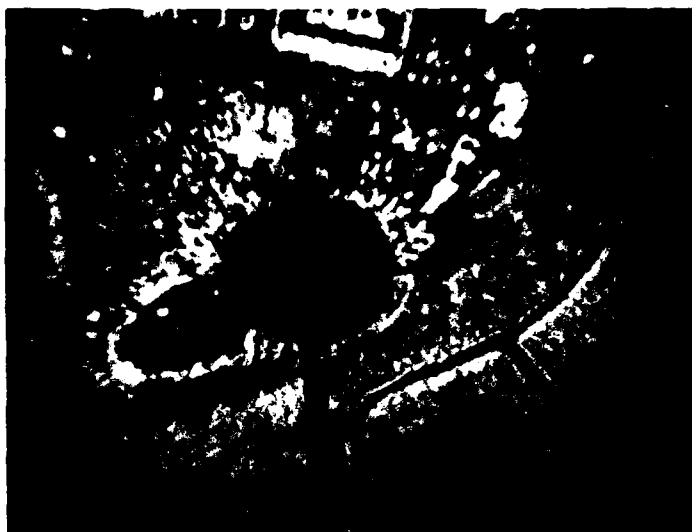


FIGURE 6. OVERSIZE WAVEGUIDE TESTS — MULTIMODE RING

ASDE-3 ANTENNA POLARIZATION TESTS.

The ASDE-3 normally radiates right hand circularly polarized signals in order to reduce precipitation clutter. In this test, the relative merits of linear and circular antenna feed polarizations, with respect to target imaging in clear weather, were investigated.

TEST PROCEDURES. The test involved the replacement of the right hand circularly polarized feed horn with vertically and horizontally polarized horns and data collection in each mode. Upon completion, the circularly polarized horn was reinstalled and data retaken for repeatability. Upon installation at the approximate focus location, each feed horn was focused by moving it in small increments. Using dynamic focusing, the TSC antenna plot program was utilized to find the deepest first null of the antenna pattern. The plot program utilizes the DAS for generating a window 5.5° wide and 54 feet deep. Located in this window was a Hewlett-Packard K_u band signal generator tuned to 16.0 GHz feeding a 2-foot parabolic dish, with a feed capable of linear and circular polarizations. With the radar transmitter off, the signal strength within the window was recorded as the radar antenna swept past the window.

The program recorded ten scans and plotted the resulting antenna radiation pattern average. When the optimum focus was found, three antenna patterns were made at frequencies of 15.75, 16.0, and 16.2 GHz (corresponding to the transmitter low, midband, and high frequencies). The patterns were plotted at ASDE test pads 1 and 2, corresponding to distances of 500 and 5,100 feet, respectively.

The first series of tests on fixed target imaging was then performed at several ranges. The targets used were two reflectors on pad 2, one reflector on pad 3 (8,600-foot range), and four towers (approximately 10-foot crosssection) at building 70, averaging 8,450 feet from the ASDE. A TSC "IMAGE" data collection program (all programs named are listed in reference 2) was used to form a window around each target, collect 15 samples of each target, and record these along with time and remarks on a digital magnetic tape. The data were collected with: PRF stagger off and fixed frequency at midband, PRF stagger off and frequency agility, PRF stagger on and fixed frequency at midband, and PRF stagger on and frequency agility.

A second program called "IMAGER" was used for partial data reduction by integrating the data over five PRF pulses and printing out each window numerically (signal strength A/D count from 0 to 255), as well as a dot printout (such as figure 2). The signal strength in A/D counts and signal width (at MDS level) in feet were manually extracted, and the signal strength average ($\bar{X}$) and standard deviation (σ) taken of each 15-sample grouping. An imaging quality coefficient (η) was derived from these data where

$$\eta = \frac{\text{signal strength}}{\text{target width}}$$

Obviously, a high η will result in a brighter, sharper target.

The second test series on moving target imaging was performed using linear horizontal and right hand circular polarizations. The test site was the FAA Technical Center ramp. The target, a Ford Fairmont station wagon, was moved radially toward the ASDE site over the exact same course for each polarization. A TSC program "TRACKER" was used for this test. The TRACKER program is similar to the image program with two primary differences: (1) the number of samples to be taken is variable (in this case, set to 120), and (2) the window is movable via the keyboard input and is, thereby, kept in track with the moving target. The target video signal strength in A/D counts and receiver input level in dB were plotted versus the range.

RESULTS. Figures 7, 8, and 9 show the antenna patterns for linear vertical, linear horizontal, and right hand circular polarizations at frequencies of 15.75, 16.0, and 16.2 GHz, respectively. The corresponding antenna beam widths for pads 1 and 2 are shown in tables 2 and 3.

From these data it is seen that the three horns provided approximately the same patterns at the 5,100-foot range, with the horizontally polarized beam width being sharpest at 0.24° and circularly polarized beam width broadest at 0.27°. At that 500-foot range, the beam width provided by horizontal and circular polarizations increased to 0.45° and 0.68°, respectively. This is due to the antenna defocusing in near field and within the design specifications. The broader azimuth beam shape obtained using circular polarization is attributed to the matching of the circular polarization feed horn to the reflector by the contractor during development of the ASDE-3 antenna system. The linear polarization feedhorns were spares from other project work at the Technical Center and, as a result, were not optimized for operation with the ASDE-3 reflector. The slight variations of the vertically polarized horn across the band in tables 2 and 3 might be attributed to misalignment in the vertical plane (as a temporary mount was improvised), or to the radiation pattern of the horn, which was unknown.

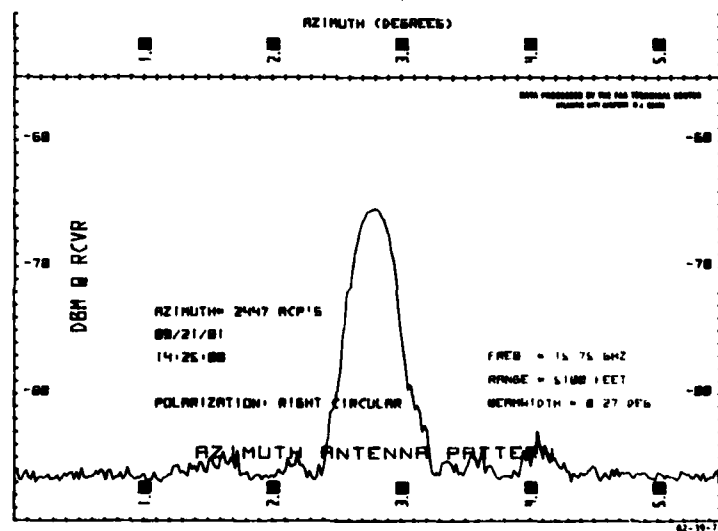
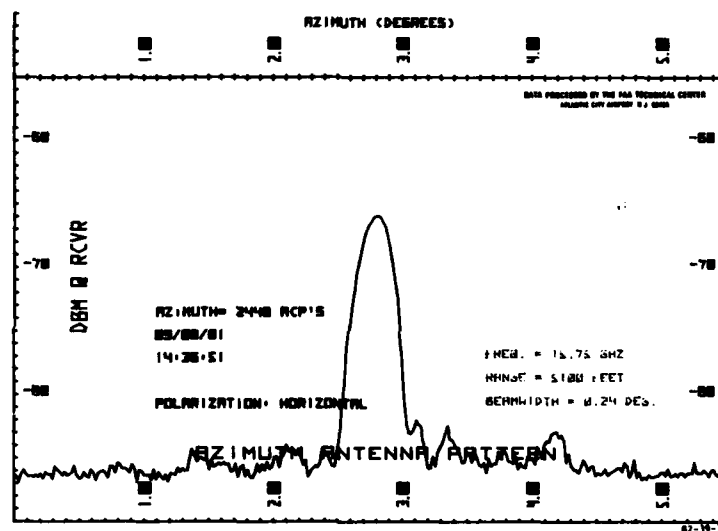
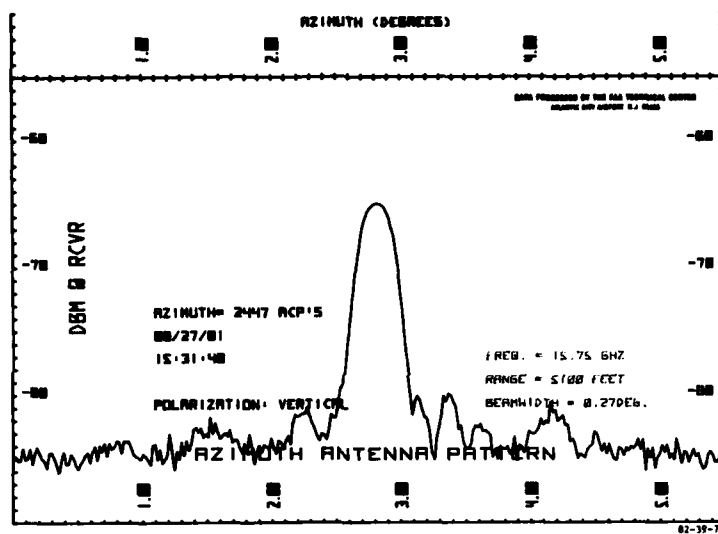


FIGURE 7. AZIMUTH ANTENNA PATTERNS — 15.75 GHz

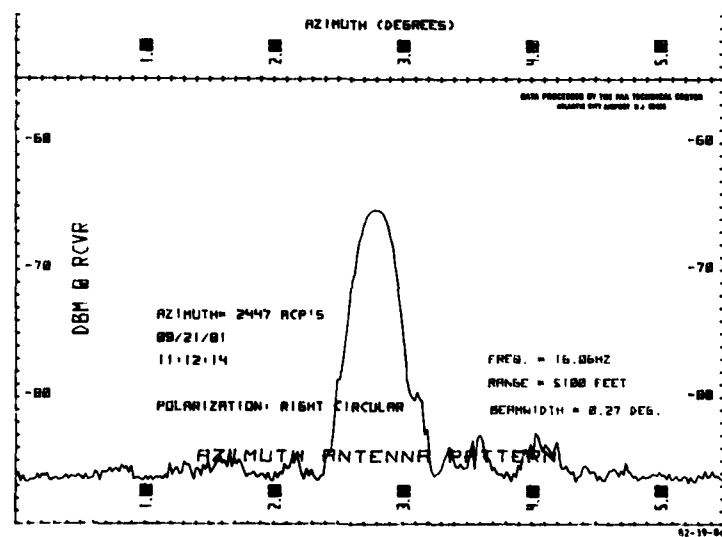
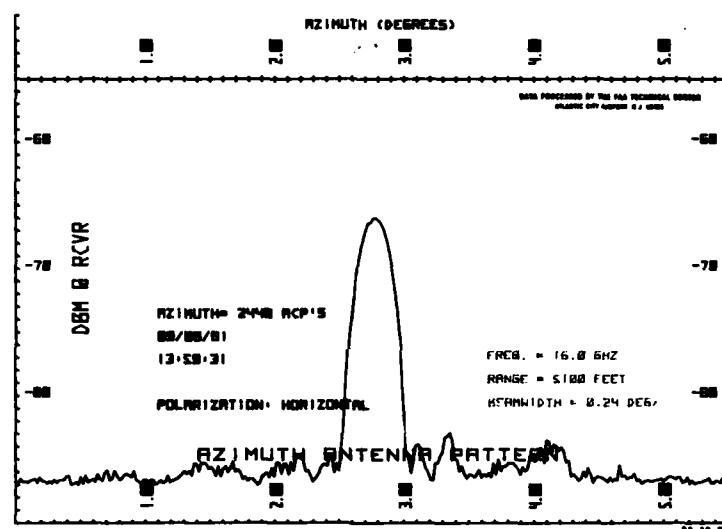
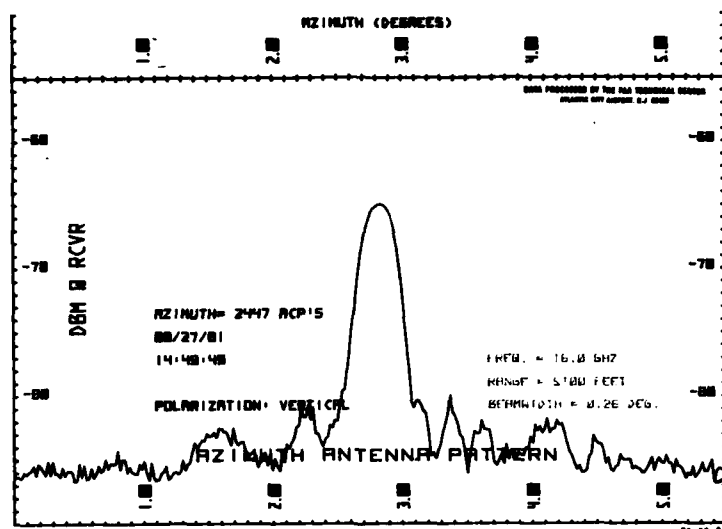


FIGURE 8. AZIMUTH ANTENNA PATTERNS — 16.00 GHz

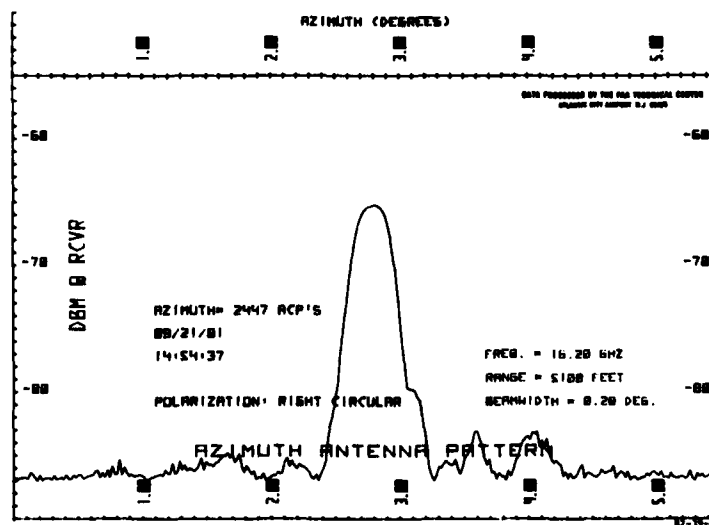
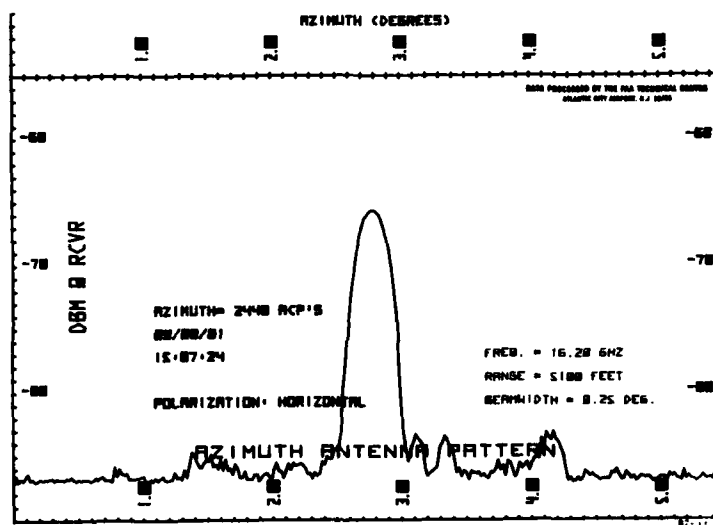
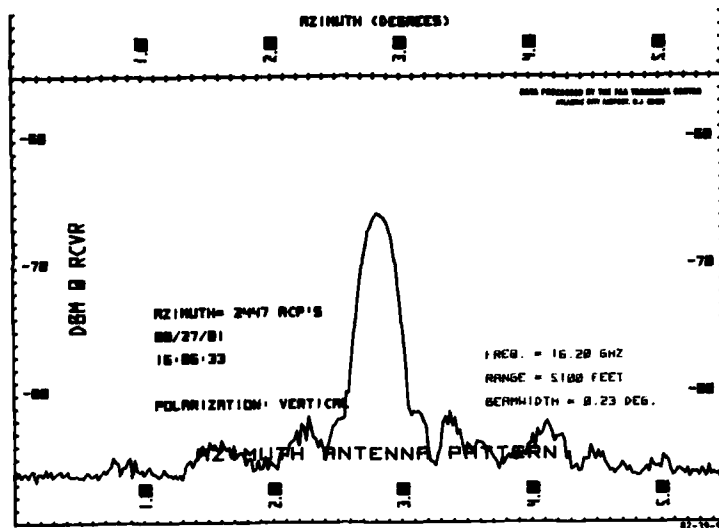


FIGURE 9. AZIMUTH ANTENNA PATTERNS — 16.20 GHz

TABLE 2. ASDE-3 ANTENNA BEAM WIDTH IN DEGREES AT PAD 1 (500 FEET)

<u>Frequency (GHz)</u>	<u>Vertical Polarizations</u>	<u>Horizontal Polarizations</u>	<u>Circular Polarizations</u>
15.75	0.46	0.44	0.68
16.00	0.49	0.47	0.68
16.20	0.51	0.45	0.69

TABLE 3. ASDE-3 ANTENNA BEAM WIDTH IN DEGREES AT PAD 2 (5,100 FEET)

<u>Frequency (GHz)</u>	<u>Vertical Polarizations</u>	<u>Horizontal Polarizations</u>	<u>Circular Polarizations</u>
15.75	0.27	0.24	0.27
16.00	0.26	0.24	0.27
16.20	0.23	0.25	0.28

Table 4 shows the averages for target signal strength, 1-sigma dispersion, and the imaging quality coefficient for the four combinations of PRF stagger and frequency settings. The results indicate that there is very little difference between PRF stagger on or off. There also appears to be no difference between fixed frequency and frequency agility operation; however, any rapid changes in the frequency agility made would be masked by the computer integration of the data in the window. Taking the overall average of η for the three polarizations shows 3.94 for vertical polarization, 3.93 for horizontal polarization, and 3.81 for circular polarization, showing only slightly better imaging for the linear polarizations.

The results of the moving target test are shown in figures 10 through 13, plots of target signal strength with respect to range. The plots were made with horizontal and circular polarizations for the fixed frequency and frequency agility modes. The salient features of the plots are irregular signal strength of the circularly polarized runs for both fixed frequency and frequency agility, and broad nulls at 6,900 feet in the horizontally polarized runs. The worse-case null depth shown is equivalent to a change in target signal strength of 13 dB.

TABLE 4. FIXED TARGET SIGNAL STRENGTH — AVERAGES OF SEVEN TARGETS AND IMAGING QUALITY COEFFICIENTS

PRF Stagger Off			PRF Stagger On		
<u>Polarization</u>		<u>Fixed Frequency</u>	<u>Frequency Agility</u>	<u>Fixed Frequency</u>	<u>Frequency Agility</u>
Vertical	$\bar{X}$		188.7	182.9	191.5
	σ		10.04	9.50	8.00
	η		4.01	3.90	3.93
Horizontal	$\bar{X}$	209.6	200.9	210.5	204.1
	σ	4.26	9.44	4.63	6.79
	η	4.03	3.92	3.91	3.87
Righthand Circular	$\bar{X}$	185.0	188.9	182.2	186.3
	σ	12.34	8.99	10.46	10.73
	η	3.89	3.82	3.83	3.71

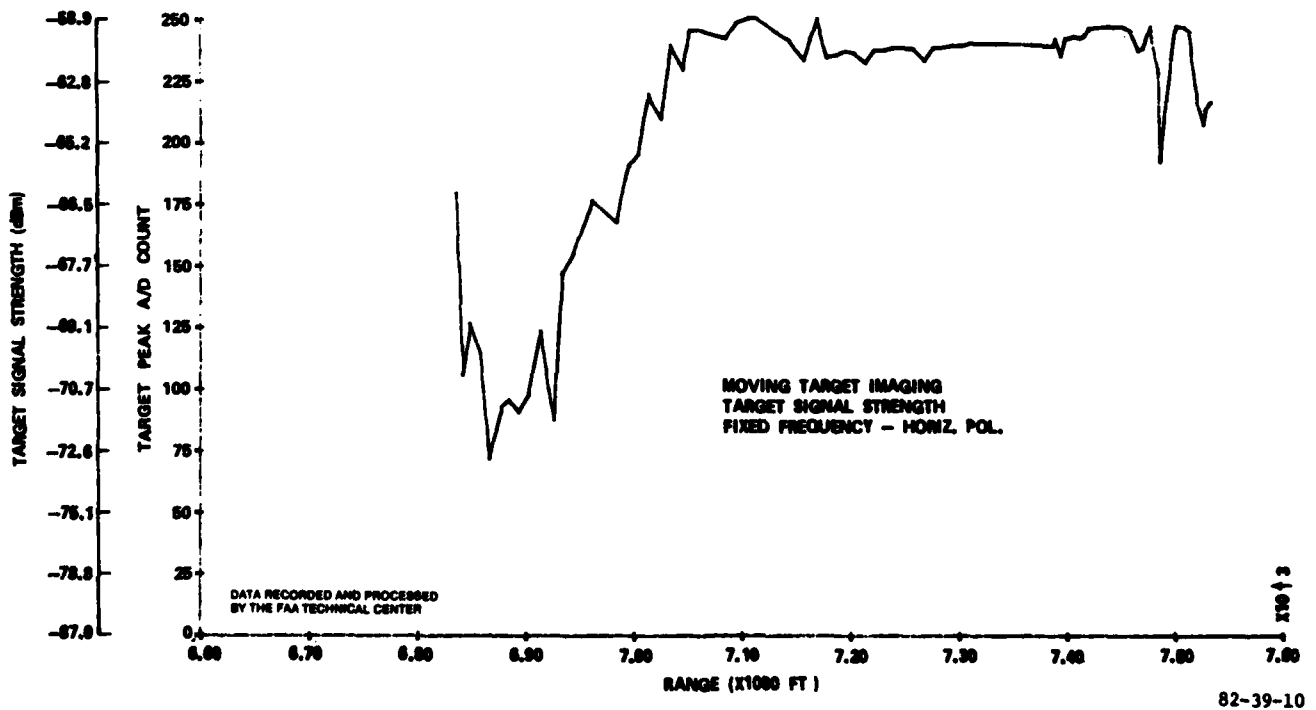


FIGURE 10. MOVING TARGET IMAGING — TARGET SIGNAL STRENGTH, FIXED FREQUENCY, HORIZONTAL POLARIZATION

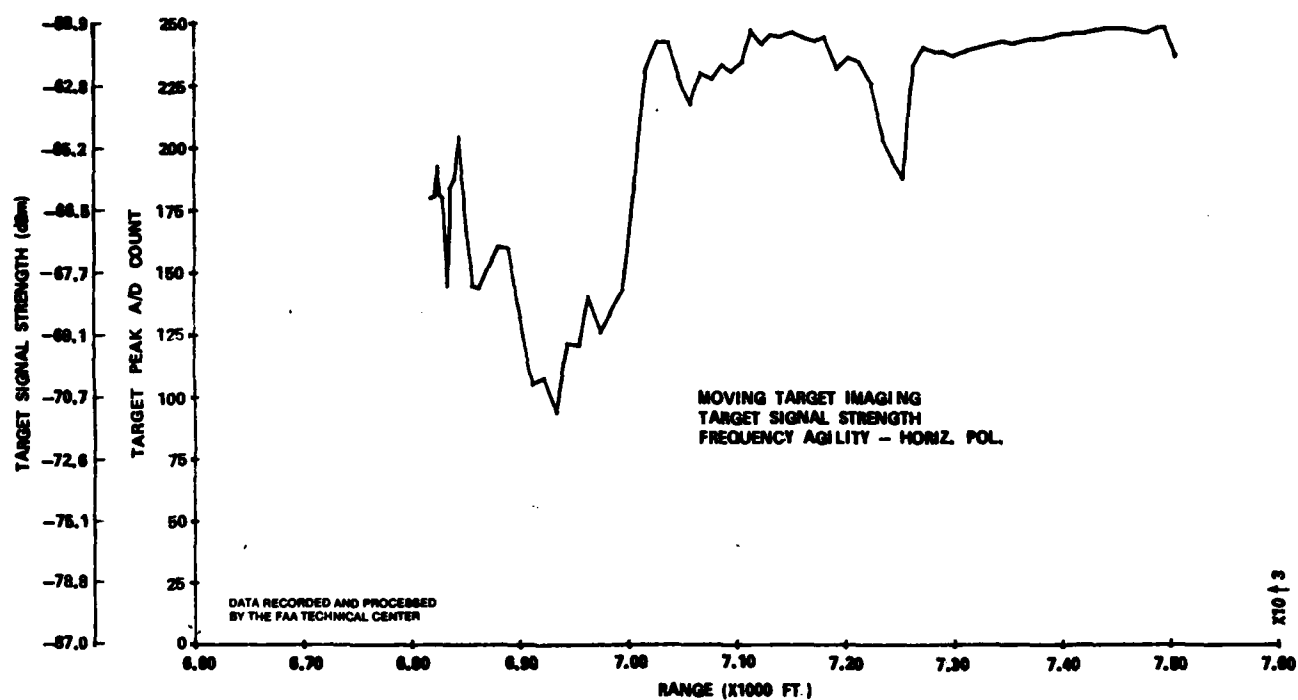


FIGURE 11. MOVING TARGET IMAGING — TARGET SIGNAL STRENGTH, FREQUENCY AGILITY, HORIZONTAL POLARIZATION

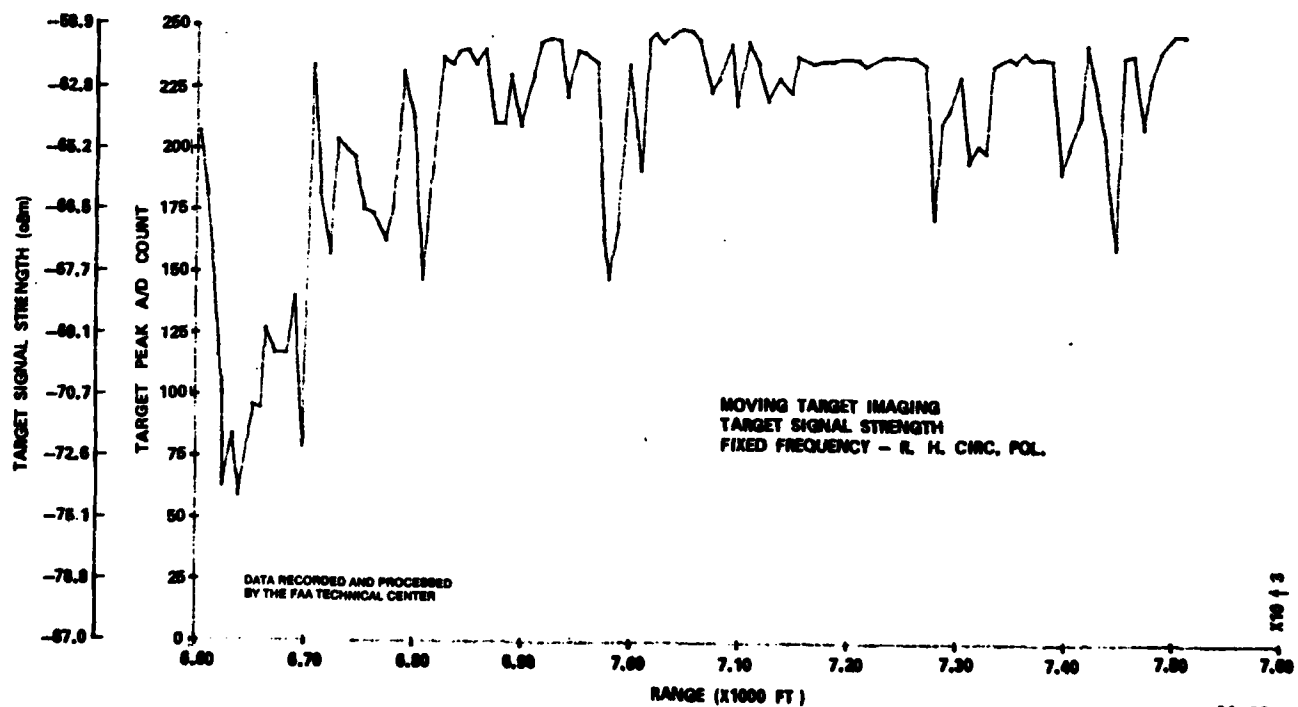


FIGURE 12. MOVING TARGET IMAGING — TARGET SIGNAL STRENGTH, FIXED FREQUENCY, RIGHT HAND CIRCULAR POLARIZATION

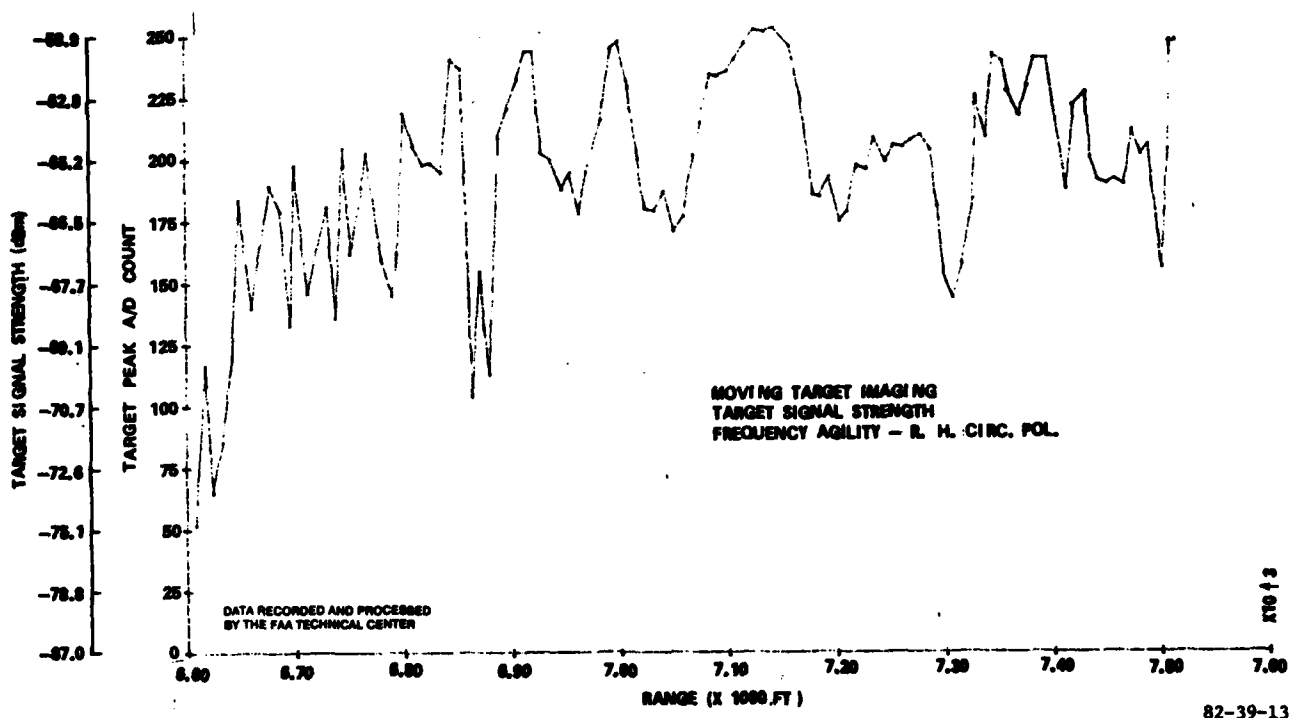


FIGURE 13. MOVING TARGET IMAGING — TARGET SIGNAL STRENGTH, FREQUENCY AGILITY, RIGHT HAND CIRCULAR POLARIZATION

A reduction in signal strength also occurs at ranges less than 6,800 feet and was due to signal shadowing by a tree line. The signal null with horizontal polarization is due to cancellation effects between the incident (in-phase) and reflected (out-of-phase) rays. The location of the null is derived as follows:

$$\Psi_{(n)} = \sin^{-1} \left(\frac{984n}{2hf} \right) \quad (\text{reference 3})$$

Where n is 1 for the first null, h is the ASDE-3 antenna height in feet, and f is the transmitter frequency in MHz. In this case, the null elevation is 0.0158° . Then the target height (H_t) can be calculated at the 6,900-foot range by: $H_t = 6900 \tan \Psi = 1.9$ feet above ground, the height of the target vehicle radiator. This null does not appear in the circularly polarized case due to the following reasons. Upon reflection from a symmetrical target, circularly polarized signals change from right hand polarization to left hand polarization and vice versa. Therefore, signals which are reflected an even number of times from ground and target are accepted by the transmitting antenna. However, signals which are reflected an odd number of times (such as from target only), arrive at the antenna with the wrong polarization and are rejected. Since the vehicle reflecting

surfaces were not symmetrical reflectors (i.e., flat sheets or spherical), both direct (incident) and ground reflected signals contained orthogonal components complicating the analysis for symmetrical targets. Also, the vertical and horizontal components are reflected by different amounts. The net effect of these factors was a lack of deep nulls such as experienced with horizontal linear polarization.

Although a moving target test using vertical polarization was not performed, it is expected that the results would be similar to those obtained using horizontal polarization. Since horizontal and vertical polarization reflection coefficients differ from each other at low grazing angles, primarily at Brewster's angle, it was resolved to calculate the reflection coefficients. With an average land assumed

with a relative permittivity (ϵ_{r2}) of 15, a conductivity (σ_2) of $0.03 \frac{\text{mho-m}}{\text{m}^2}$ and with the frequency f in MHz, the coefficient of reflection squared is

$$n^{-2} = \epsilon_{r2} - \frac{j 1.8 \times 10^4}{f} = 15 - j 0.034 \quad (\text{reference 4})$$

and to all intents and purposes equals 15. The coefficient of reflection for horizontal polarization is

$$R_H = \frac{\sin \Psi - \sqrt{n^{-2} - \cos^2 \Psi}}{\sin \Psi + \sqrt{n^{-2} - \cos^2 \Psi}}$$

and for vertical polarization is

$$R_V = \frac{n^{-2} \sin \Psi - \sqrt{n^{-2} - \cos^2 \Psi}}{n^{-2} \sin \Psi + \sqrt{n^{-2} - \cos^2 \Psi}} \quad (\text{reference 4})$$

where $\sin \Psi$ is the grazing angle or 0.9166° . Solving the above equations yield,

$$R_H = -0.9915 \text{ and } R_V = -0.8795.$$

From this, it is inferred that the composite of incident and reflected waves in vertical polarization would differ from those experienced with horizontal polarization by approximately 10 percent. The comparative magnitude and phase of the reflection coefficients for horizontal and vertical polarizations are available in the literature (reference 5).

SUMMARY OF RESULTS

1. The F-106 target elongation increases to approximately 100 feet at 45 dB above MDS, and is primarily due to receiver saturation, i.e., slow IF recovery.
2. A maximum of 27 dB of RF STC attenuation was used to decrease the depth of IF saturation (and decrease the size of the F-106 target tails) before a typical small aircraft target degraded to the MDS level in clear weather.
3. An average 7 dB of signal improvement per 100 feet of waveguide would be realized when K_u (WR-62) was replaced by oversized (WR-187) waveguide.
4. Oversize (WR-17) waveguide with multimode suppressors installed produced barely perceptible "ringing" at a range of 420 feet (only at the frequency of 15.75 GHz).
5. Linearly polarized feed horns installed on the ASDE-3 antenna provided a slightly narrower antenna beam width than the circularly polarized feed horn, particularly at shorter ranges.
6. On moving targets, horizontally polarized signals provide better imaging and more stable returns from scan to scan. Deeper signal nulls, however, may occur with linear polarization at various locations on the field, depending on the height and the size of the target as well as the type and roughness of the reflecting surface.
7. The received target signal level obtained during the moving target polarization testing was above the MDS level at all ranges with both polarizations.

CONCLUSIONS

1. The Airport Surface Detection Equipment (ASDE)-3 receiver provides a significant amount of target elongation when it is saturated by strong targets.
2. Oversized waveguide provides improved ASDE-3 performance over standard K_u waveguide for long waveguide runs.
3. Linearly polarized ASDE-3 signals provide better clear weather imaging as well as a 3 decibel (dB) gain over circularly polarized signals.

RECOMMENDATIONS

1. To minimize target elongation, the following actions are proposed:
 - a. Design the intermediate frequency (IF) amplifier to provide faster recovery from saturation.

b. Limit the receiver input signal to values that do not cause excessive elongation (keeping in mind that the receiver dynamic range is 20 decibels (dB) and New Brite Radar Indicator Tower Equipment (NU-BRITE) display is less than that).

c. Desensitize the receiver by the use of sensitivity time control (STC) to reduce the radar cross-section of strong targets. Care must be taken in this case not to provide excessive attenuation which would render small targets invisible in rain.

2. For long waveguide runs, WR-62 should be replaced by WR-187 waveguide with the appropriate multimode suppressors.

3. Both linear and circular antenna polarization capabilities should be incorporated in the system. This option should be remotely controllable by the controller at his discretion.

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