ELECTRONICS AND SPACE DIVISION

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FINAL REPORT

NON-COOPERATIVE RENDEZVOUS RADAR SYSTEM

Prepared for:

NASA LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS

Contract No. NAS-9-13695

FINAL REPORT

Non-Cooperative

Rendezvous Radar

System

Prepared for:

NASA Lyndon B. Johnson
Space Center
Houston, TX

Contract No:

NAS-9-13695

Date: October 1974

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FORWARD

This final report is submitted to the National Aeronautics and Space Administration, Lyndon B. Johnson Space Center under Contract NAS-9-13695.

1.0 Introduction and Summary

Emerson Electric is pleased to submit this final report in accordance with contract NAS-9-13695. The purpose of this program was to provide NASA with a Fire Control Radar System for testing and evaluation at JSC. The Fire Control Radar System results from modifications of an Emerson Electric developed AN/APQ 153 Radar. The AN/APQ 153 was developed for the Northrop F5E aircraft and is presently in production.

Major modification was to include an angle tracking capability. The system was assembled and modified at Emerson. Acceptance testing was performed on June 26 and 27 and was shipped on June 28, 1974 ahead of the required delivery date of July 1, 1974. In accordance with the contract, final acceptance test at destination was completed August 23 at JSC.

2.0 Operational Description

The following defines the operation of the AN/APQ 153 baseline system and the modified angle tracking system.

2.1 Baseline AN/APQ 153 Fire Control Radar

The AN/APQ 153 (Shown in Figure 2.1) is a Search and Range Tracking Radar. The Radar provides stabilized search, automatic acquisition and target spotlight, and automatic target ranging with boresight steering in the missile mode for heads-down launch of the AIM-9 series missiles. Two gunnery modes are provided, dogfight (short range) and AA1/AA2 (long range). In the gunnery modes the radar automatically provides range rate outputs for targets within the sight lead angle computation envelope. (The Flight Line MTTR is minimized by built in test (BIT) for radar performance verification and suitcase flight line test set for fault isolation to one of five line replaceable units (LRU's). In order to accomplish the above tasks the radar employs:

Parabolic Dish Antenna

Double Integration, Split-Gate Range Tracker

Two-Axis Gimbal, Direct Electric Drive

Conical Scan for Boresight Steering

Non-Coherent, Ground Tunable X-Band Magnetron

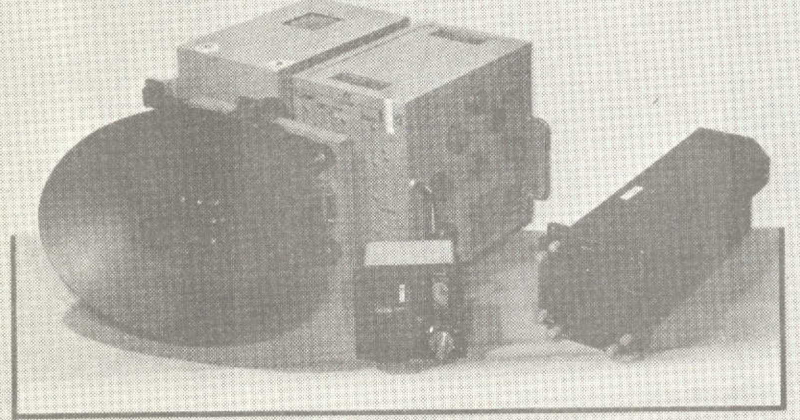
Fast Time Constant & Sensitivity Variation with Range

Direct View Storage Tube Display

BIT Target Generator

Solid State and Third Generation Electronics

ASTAR I-AN/APQ-153 FIRE CONTROL RADAR



- SEARCH AND RANGE TRACK WITH BORESIGHT STEERING
  - AIM-9 SERIES SIDEWINDER MISSILE
  - 20 MM CANNON

EMERSON SELECTED BY NORTHROP/USAF
CONTRACT GO-AHEAD DECEMBER 1970

WR-6351

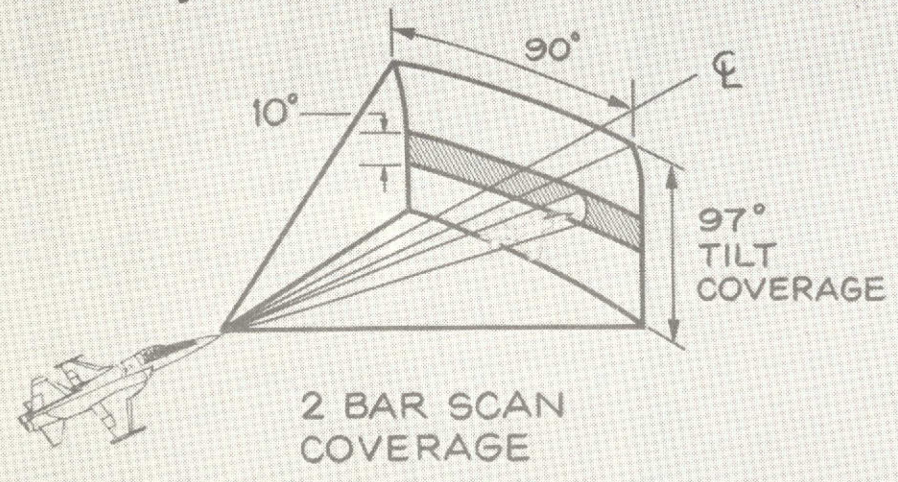
2.1 Baseline AN/APQ 153 Fire Control Radar - Continued

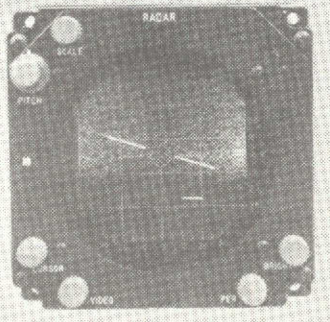
2.1.1 Search Mode

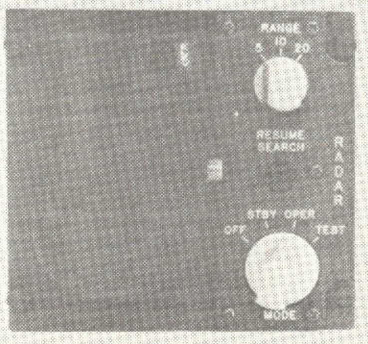
The AN/APQ 153 search consists of a 7° in elevation beamwidth which is stepped up 3° at the right azimuth limit and down 3° at the left azimuth limit providing a two bar scal coverage of 10° in elevation. This two bar 10° coverage can be adjusted ± 45° in elevation by the pilot. Azimuth search coverage is ± 45°. The search pattern is space stabilized for aircraft pitch and roll motion to allow searching a given volume of space and to prevent loss of the target and/or smearing of the display. Range search coverage extends to a maximum of 20 nautical miles. Antenna coverage and display are shown pictorially in Figure 2.2

The search display is a "B" type on a 5-inch direct view storage tube. Both neutral density and polarizing filters have been included in the indicator to obtain a high contrast ratio for operation in ambient light up to 10,000 foot lamperts. Electronic dimming (brightness control) is included to dim the display to less than one foot lambert for night operation. Antenna tilt angle relative to the aircraft longitudinal axis is displayed by a tilt cursor on the right vertical scale of the edge-lighted overlay. An attitude reference line is displayed by a split line on the display. The attitude reference line displays the pitch and roll attitude of the aircraft. A pitch trim control (PITCH) is provided so that the pilot may compensate the attitude reference line for sustained angles of attack. Target relative angle (horizontal) is given relative to the botton scale on the edge-lighted overlay. The edge-lighted overlay is divided into five equal segments to

AN/APQ-153 SEARCH MODE







- RANGE 20 NM
- DETECTION/RANGE $(P_{85}\ 2M^2)$ - 9-10 NM (8 NM MINIMUM)
- LOW ALTITUDE (F-4 OR F-104 TGT) - 3 NM
- ROLL AND PITCH STABILIZED

WR-6390

2.1.1 Search Mode - Continued

aid the pilot in estimating the target range. Display ranges of 5, 10, and 20 nautical miles can be selected by the pilot via the range select switch on the set control LRU.

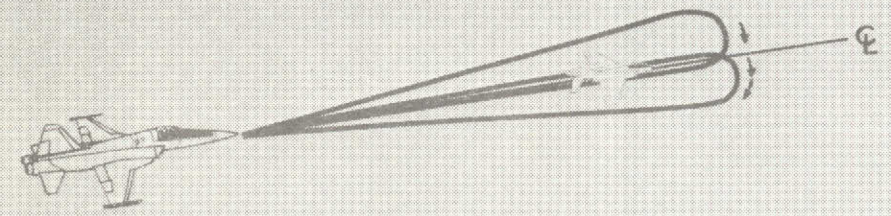
2.1.2 Boresight Missile Mode

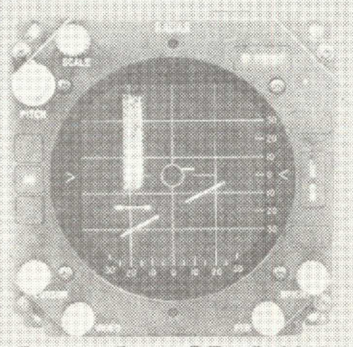
The missile mode as shown in Figure 2.3 enables the pilot to lock-on to targets out to 10 nautical miles and provides aircraft steering information to align the target and the acquisition envelope of the AIM-9 missile. Once the aircraft has been flown to bring the target within approximately 5° of the boresight axis using the search display, and target range is less than 10 NM, the pilot enters the boresight steering mode for heads-down missile attack. Acquisition is initiated by depressing the acquisition button on the set control. The antenna will align with boresight. 5 and 10 NM missile display ranges are provided. If in 20 NM search, the displayed range will automatically switch to 10 NM, and the range gate will automatically slew from 500 ft. outward to maximum range at 22,500 feet/second. Acquisition will be automatic if the acquisition button is not held down. Lock-on is inhibited while the acquisition button is depressed. After target lock-on has occurred the lock-on light will be illuminated target range and range rate will be provided to the signt and the gimbal will be conically lobed $\pm$ 2.5° at a 6 Hz rate to provide azimuth and elevation steering information. The steering information is presented on the steering bar on the display. The aircraft is flown toward the bar to align it within the $\pm$ 1° allowable aim error circle scribed on the overlay. Missile acquisition should occur any time the steering bar is within the allowable aim error circle and the in-range is illuminated steady. Targets may

2.1.2 Boresight Missile Mode - Continued

be rejected by depressing the acquisition button. The range gate will start its slew outward from the last tracking range.

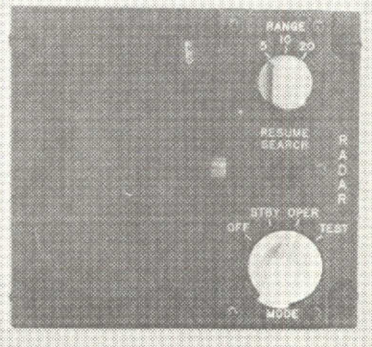
ACQUISITION MODE-MISSILE





RANGE - 5 OR 10 NM

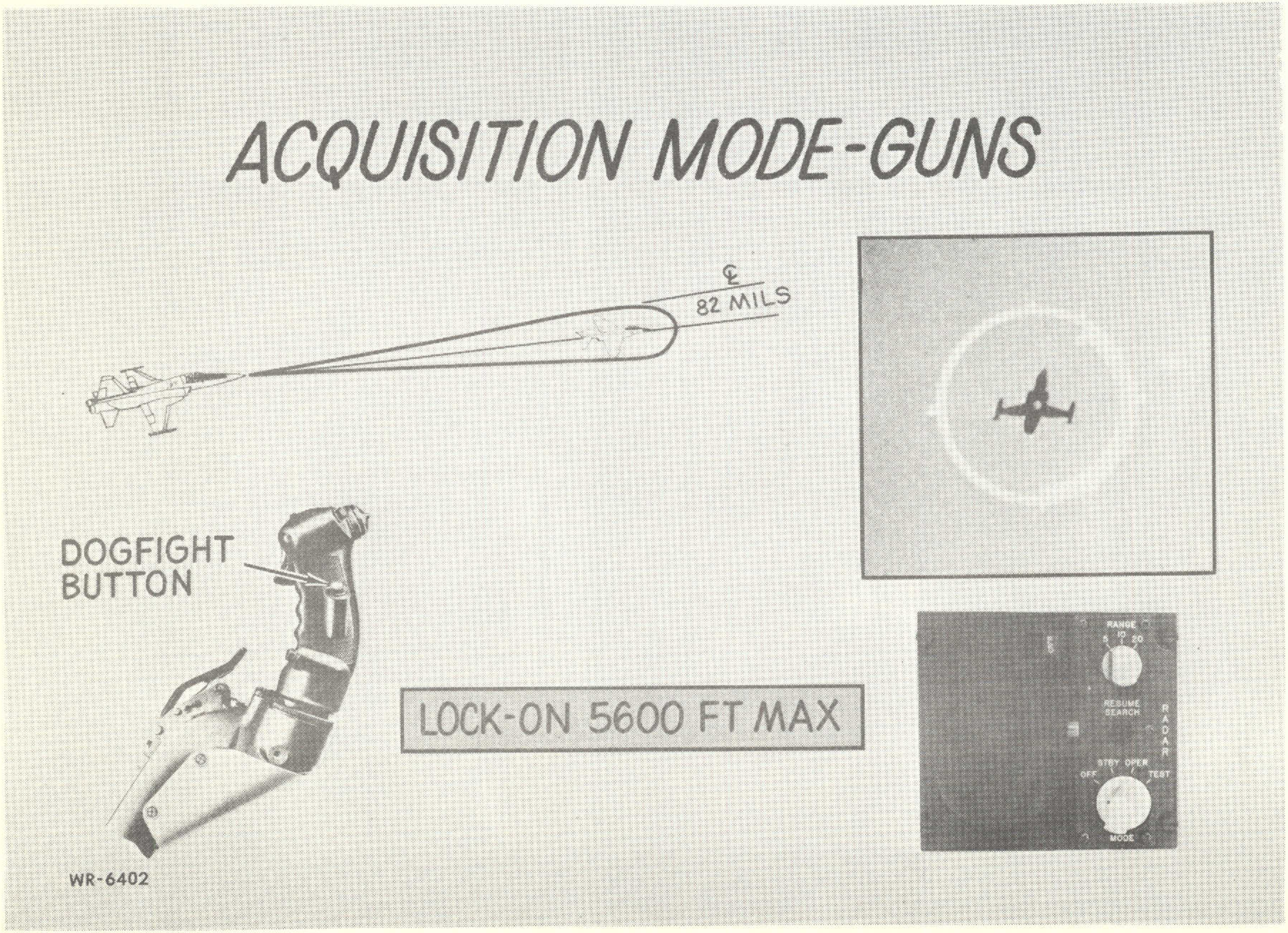
• LOCK-ON	6 NM ON $2M^2$ TARGET 10 NM MAX
• LOW ALTITUDE (F-4 OR F-104)	2 NM LOCK-ON
• ANGLE COVERAGE (AT 4 NM)	AZIMUTH 3° ELEVATION 4°
• INPUTS TO LCOSS	LOCK-ON RANGE RANGE RATE
• NIGHT CAPABILITY	



WR-6385

2.1.3 Air-To-Air Gunnery Modes

There are two air-to-air gunnery modes (see Figure 2.4) in the AN/APQ 153: Dogfight and AA1/AA2; both are external commands to the radar. The gunnery modes are heads-up and the radar automatically provides range and range rate information to the sight. Activation of a gunnery mode will cause the Radar Antenna to align to boresight in azimuth and 4.7° down in elevation. The range gate will automatically slew from 500 feet to 5,600 feet at 30,000 feet per second. Acquisition is automatic for the first target encountered. The angular coverage in the guns modes for a 2 square meter target at 4,000 feet range is $\pm$ 60 MILS in azimuth and 0 MILS to 165 MILS in elevation.


ACQUISITION MODE-GUNS
℄
82 MILS
DOGFIGHT
BUTTON
LOCK-ON 5600 FT MAX
RANGE
5 10 20
RESUME
SEARCH
RADAR
STBY OPER
OFF TEST
MODE
WR-6402

2.2.1 Standby - Continued

With the momentary depression of the Resume Search on the Set Control the ACQ SYM will pre-position to a present horizontal (left 20°) and mid-range position. Any subsequent TDC force application will drive the ACQ SYM in the corresponding directions. With the removal of force stimulus, the ACQ SYM will remain at the last position.

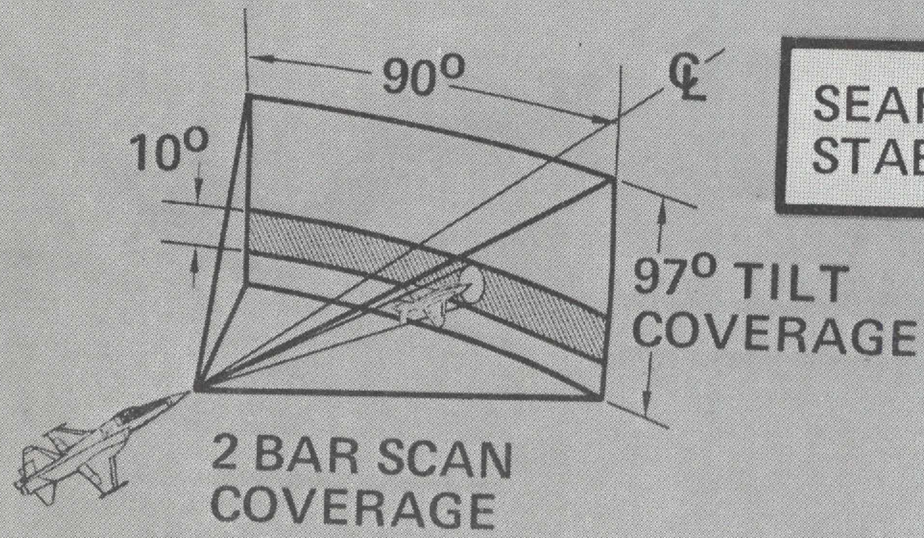
2.2.2 Operate

Search - The antenna will initiate a scan and search through its horizontal angle of ± 42.5° and the vertical two-bar controllable through an angle of + 45° to -35°. The horizontal and vertical coverage may be shortened due to gimbal limits that are a function of aircraft pitch and roll angles. The antenna scan is space stabilized. The antenna is commanded in elevation with the elevation control located on the Set Control. The antenna scans through a two-bar (±1.5°) elevation pattern as shown in Figure 2.5. The tilt cursor symbol indicates the antenna command referenced to the earth's horizon.

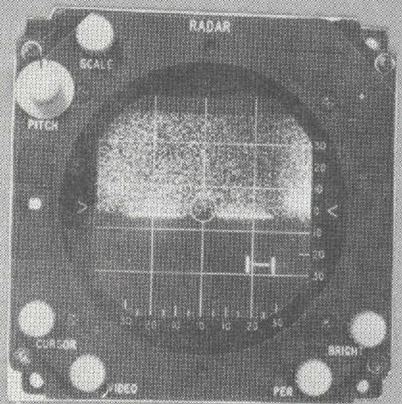
Acquisition

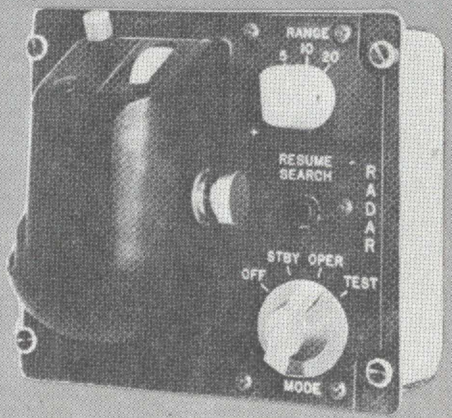
With a target displayed on the Indicator, as shown in Figure 2.6, the ACQ SYM is positioned over the target utilizing the TDC. With the acquisition switch on the Set Control depressed and held (Lock-on inhibited) the search pattern and slaves to the TDC will scan through a stabilized two-bar pattern (±5° AZ, ±1.5° EL) centered about the TDC horizontal position and Set Control Elevation control as shown in Figure (4). The indicator will display video only in an area subtended by the ACQ SYM width (10°) as shown in Figure 2.6.

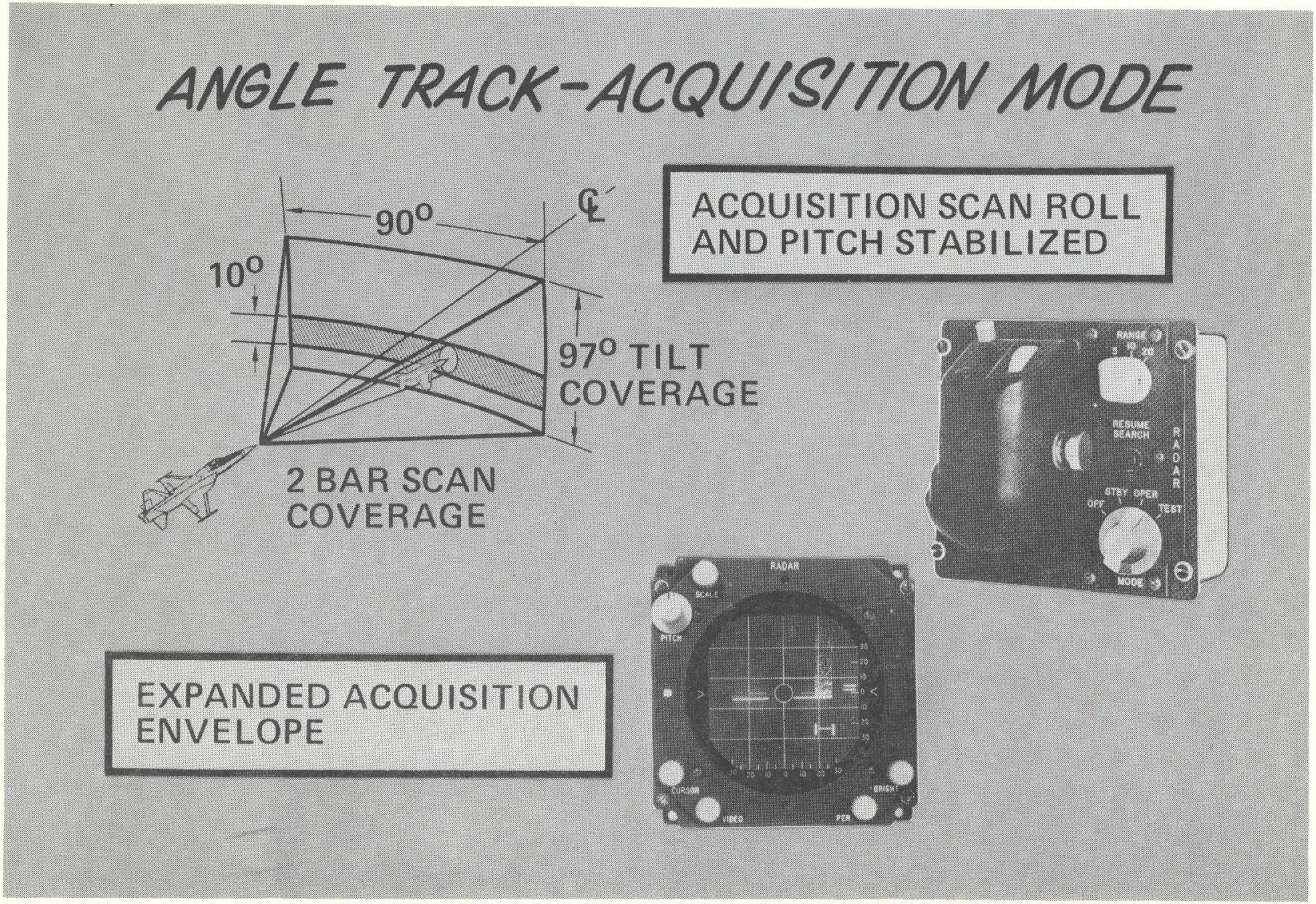
ANGLE TRACK SEARCH MODE



SEARCH SCAN POSITION
STABILIZED






ANGLE TRACK-ACQUISITION MODE
90°
℄
10°
97° TILT COVERAGE
2 BAR SCAN COVERAGE
ACQUISITION SCAN ROLL AND PITCH STABILIZED
RANGE
5 10 20
RESUME SEARCH
RADAR
OFF
STBY OPER
TEST
MODE
EXPANDED ACQUISITION ENVELOPE
RADAR
SCALE
PITCH
CURSOR
VIDEO
BRIGHT

Acquisition - Continued

The 10 degree ACQ SYM width corresponds to the antenna acquisition horizontal scan limits. Correspondingly, the video displayed within the 10 degrees correlates to the actual target horizontal position.

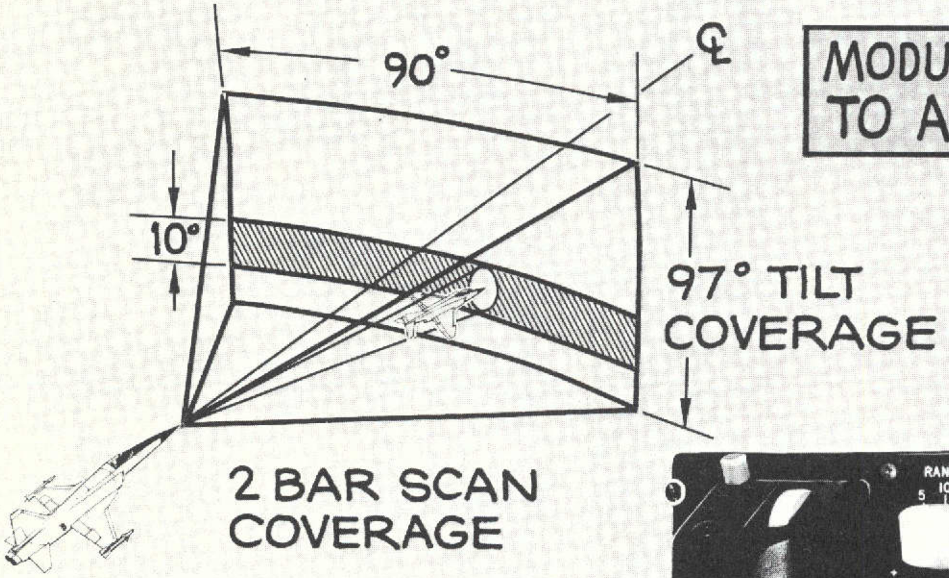
The range tracker will dither (triangular ramp) the acquisition gate through the range subtended by the vertical height of the ACQ SYM at a 5 Hz rate. The acquisition range interval corresponds to 3000 feet in the 5 mile range and 6000 feet in the 10 mile range. With 20 mile range selected, the system reverts to a 10 mile range during acquisition.

Track

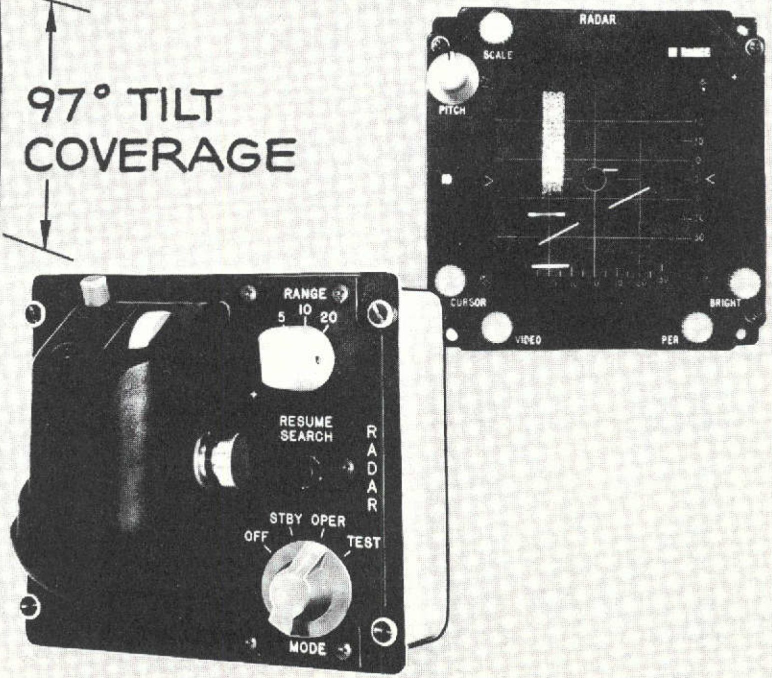
By releasing the ACQ switch (Lock-on enable) radar range and angle lockons will occur automatically (sufficient target strength). The antenna will start a 6 Hz conical scan about the target as shown in Figure 2.7. The 6 Hz conical scan will be demodulated and errors will drive the antenna servo.

After lockon, the ACQ SYM is removed from the indicator display. The video display and track gate will stow the -20° azimuth position. The AIM BAR will move over the entire face of the display following the antenna gimbals as it angle tracks "OFF" boresight and is not roll stabilized. The elevation AIM BAR position is a function of antenna elevation angle and of missile wing twist inputs. The AIM BAR position versus actual antenna position is provided throughout the antenna gimbal limits, but the scale factor near boresight is sufficient to allow reliable steering for AIM-9 missile lock-on. AIM BAR deflection is the angle shown in Figure 2.8.

ANGLE TRACK MODE



MODULAR MODIFICATIONS
TO AN/APQ-153



EXPANDED PURSUIT
ENVELOPE

WR-6451

Track - Continued

If the acquisition switch is released with no targets available, the TDC horizontal and range commands and the EL control are still controllable by the operator. The antenna will also maintain its space position independent of aircraft motion and without operator stimulus.

If during track, the target amplitude falls below a minimu threshold, the system will go into memory for $\approx$ 1.75 seconds. During memory, the range tracker and the angle tracker will follow the last rate signals. If the target reappears in $\leq$ 1.75 seconds, the system will revert to a full track. The antenna elevation position is the Set Control commanded position. The acquisition symbol position will return to the commanded position prior to track.

The initiation of Resume Search will break both the angle and range tracks. The antenna elevation position reverts to the Set Control position commands. The ACQ SYM will be positioned to the stow position.

The applications of dogfight stimulus (Guns and Acquisition or Dogfight) commands the system to a production AN/APQ 153 configuration.

2.2.3 Boresight Acquisition and Angle Track (BST)

The system mechanization is as follows:

Search

The system operations and functions are identical to the production AN/APQ 153. The Tilt Cursor Symbol position represents the commanded elevation with respect to the Aircraft body Axis. The ACQ SYM is also removed.

2.2.3 Boresight Acquisition and Angle Track (BST) - Continued

Acquisition

The system operations and functions are identical to the production AN/APQ 153.

Track

The initial track sequence is identical to the AN/APQ 153. However, after range lockon, the antenna will initiate a conical scan and proceed to angle track the target as in the OPERATE mechanization.

If during track, the target amplitude falls below a minimum threshold, the system will go into memory for 1.75 seconds. During memory, the range tracker and the angle tracker will follow the last rate signals. If the target reappears in ≤1.75 seconds, the system will revert to a full track.

The initiation of Resume Search will break both the angle and range tracks. The system returns to a full search mode. The antenna elevation position reverts to the Set Control position commands.

The application of dogfight stimulus (Guns and Acquisition or dogfight) commands the system to a Production AN/APQ 53 configuration.

2.2.4 Normal Missile Mode (MSL)

The system operation, mechanization and functions are identical to the production AN/APQ 153.

2.2.5 Test

Search - In the test mode, a normal stabilized search is performed. The display is a non-stabilized B sweep with the azimuth position derived from the gimbal azimuth and the El. Cursor displays the elevation gimbal position. A test target is generated @ 2000 feet range and is displayed for all azimuth angles.

Acquisition

Acquisition of the test target is performed by depression of the ACQ button. After lock-on to the test target the range tracker accuracy at 2000 feet is verified. Out of tolerance accuracy would illuminate the "FAIL" light on the indicator.

3.0 FUNCTIONAL CHARACTERISTICS/REQUIREMENTS

This section defines the performance of the Baseline AN/APQ 153 along with the performance of the system as modified. Also included are the requirements per contract.

3.1 AN/APQ 153 characteristics

The following summarizes the functional characteristics of the AN/APQ 153 along with predicted performance and measured data.

AN/APQ-153 PERFORMANCE

DETECTION RANGE (P_{85} CUMULATIVE PROBABILITY ,2M^2)	11 NAUTICAL MILES (8 NAUT. MI. MIN)
ACQUISITION (P_{85} CUMULATIVE PROBABILITY)	6 NAUTICAL MILES TYPICAL ON 2M^2 TARGET, 10 NAUTICAL MILES MAXIMUM
RANGE ACCURACY	SPEC $\pm$50 FEET, 500 FT. TO 1000 FT. $\pm$30 FEET, 1000 FT. to 2000 FT. $\pm$2.0%. 2000 FT. to 10 N MILES
RANGE RATE ACCURACY	SPEC $\pm$3% OR 10 FT/SEC
RANGE RATE MEMORY	1 TO 3 SECONDS (SET AT 1.7 SEC BY SPEC)
4 N MILE BORESIGHT STEERING COVERAGE (2M^2)	AZIMUTH 3° ELEVATION 4°
4000 FEET GUNNERY RANGING COVERAGE (>6000 FT ALT)	AZIMUTH $\pm$60 MILS (REF. ADL) ELEVATION 0 TO -165 MILS
SEARCH COVERAGE	AZIMUTH $\pm$45° ELEVATION 10° (POSITIONABLE OVER $\pm$45°)
LOW ALTITUDE (F4 OR F-104 TARGET)	2500 FT ALT: 3NM DET, 2NM LOCK-ON 1000 FT ALT: DOGFIGHT LOCK-ON AT 2700 FT.

AN/APQ-153 CHARACTERISTICS

TRANSMITTER	80 KW/80 W AVERAGE (60 W MIN)
DUTY CYCLE	2500 PPS @ 0.4 μSEC PULSE
FREQUENCY	9300 ±150 MC
ANTENNA	SIMPLE PARABOLA
GAIN	28 DB
SIDELOBES	21 DB (19 DB MIN)
BW	5.2^{o}AZ X 7.0^{o} EL
RECEIVER	LIN LOG
NOISE FIGURE	8 DB (9.5 DB MAX)
DISPLAY	DVST B SCAN + AUXILIARIES 1 TO 140 FT LAMBERTS ELECTRONIC CONTROL
TRACKER (RANGE)	ANALOG DOUBLE INTEGRATOR SPLITGATE
SEARCH COVERAGE	2 BAR SCAN, SPACE STABILIZED AZ $\pm 45^{o}$ EL 10^{o} POSITIONED FROM SET CONTROL
BIT	TRANSMITTER, AFC, POWER SUPPLIES — CONTINUOUS LOCK-ON SENSITIVITY, RANGE ACCURACY, ANTENNA POSITIONING — COMMANDED

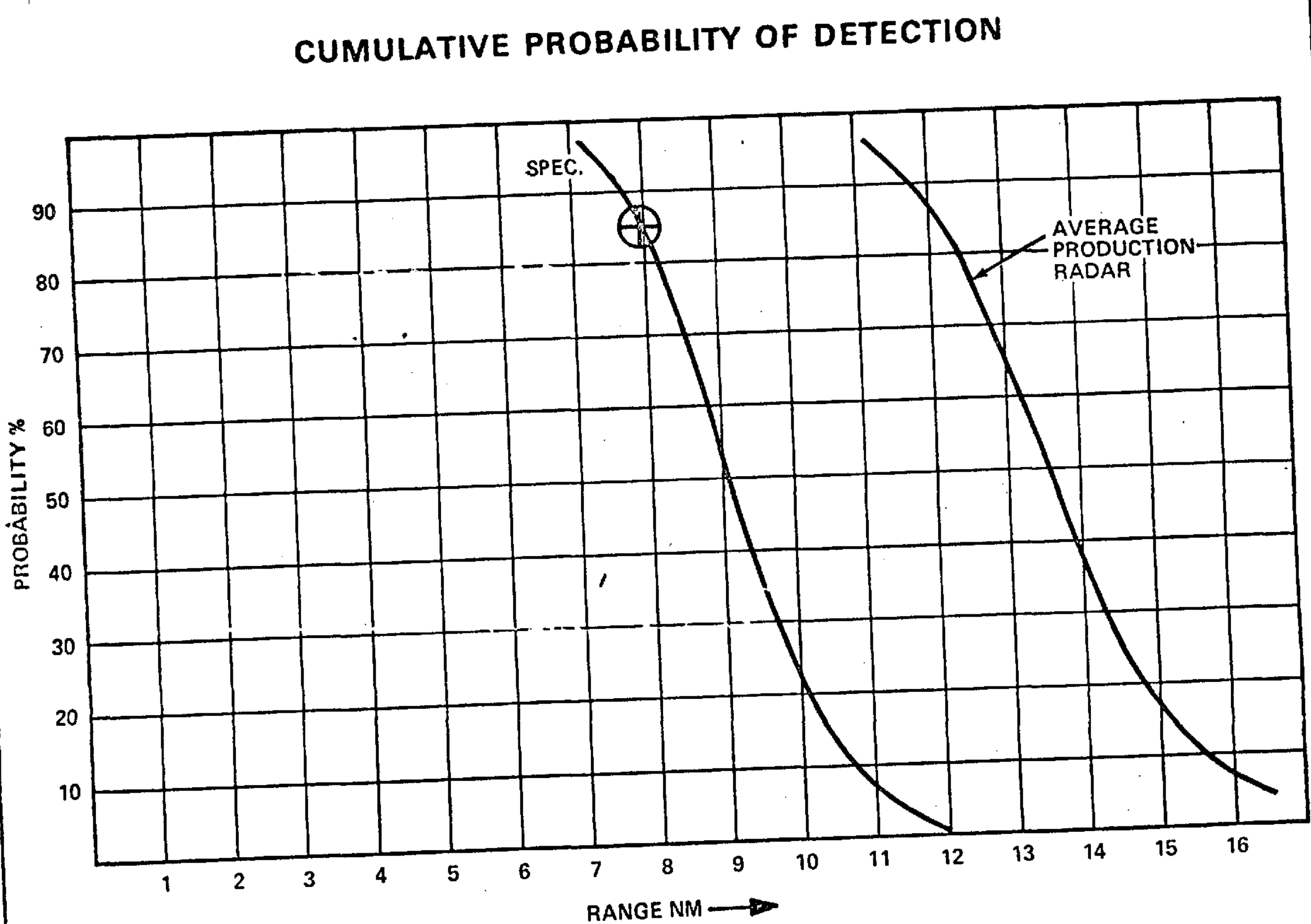
AN/APQ-153 PERFORMANCE SUMMARY

PARAMETER		SPEC	SYSTEM ACCEPTANCE TEST S/N 5 TO S/N 36 AVERAGE
DETECTION RANGE (P_{85}, $2M^2$)		> 8 N.M.	12 N.M.
SEARCH FRAME TIME		< 2.3 SEC.	2.03 SEC.
RF POWER @ LRU OUTPUT		> 45.7 W ave	72.8 W
XMTR SIDELOBES DOWN		> 8 DB	12.1 DB
NOISE FIGURE		< 9 DB	8.18 DB
MDS		< -97 DBM	-102.9 DBM
RCVR DYNAMIC RANGE		> 80 DB	83.8 DB
DISPLAY RANGE LINEARITY		±0.135"	±.008"
RANGE ACCURACY	600'	±50'	0.58'
	1000'	±30'	1.0'
	2000'	±40'	2.0'
	3000'	±60'	3.0'
	7500'	±150'	7.5'
	15000'	±300'	15.0'
	30000'	±600'	30.0'
	60000'	±1200'	60.0'
RANGE RATE ACCURACY	0	±10'/SEC.	0.01'/SEC.
CLOSING 1000'/SEC.		±30'/SEC.	5.0'/SEC.
CLOSING 2000'/SEC.		±60'/SEC.	10.0'/SEC.
CLOSING 3000'/SEC.		±90'/SEC.	15.0'/SEC.
OPENING 1000'/SEC.		±30'/SEC.	-5.0'/SEC.
ANTENNA VSWR		< 1.7:1	1.32:1

CUMULATIVE PROBABILITY OF DETECTION

THE CUMULATIVE PROBABILITY OF DETECTION FOR THE PRODUCTION RADAR IS SHOWN ON THE CHART BELOW. ALSO SHOWN IS THE SPECIFIED CUMULATIVE PROBABILITY OF DETECTION. THE CALCULATIONS ARE BASED ON MEASURED ANTENNA PATTERNS, RF POWER, NOISE FIGURES, AND TRANSMIT/RECEIVE LOSSES. ALLOWANCE WAS NOT MADE FOR FIELD DEGRADATION WHEREAS THE SPECIFIED CUMULATIVE PROBABILITY OF DETECTION ALLOWS 3 DB FOR FIELD DEGRADATION. A RADOME LOSS OF 2DB, 2-WAY IS INCLUDED IN ALL CASES. THE FOLLOWING NUMBERS WERE USED:

POWER	72.8	AVERAGE S/N 5 TO S/N 36
NOISE FIGURE	8.18	
LOSSES		
ATMOSPHERIC	.5 DB	
RADOME	2.0 DB	
ROTARY JOINTS	.54 DB	
WAVEGUIDE	.2 DB	
NON OPTIMUM BEAMSHAPE	1.0 DB	
NON OPTIMUM RECEIVER	.8 DB	
NON OPTIMUM INTEGRATOR	.9 DB	
	5.94	
TARGET	$2M^2$	
RANGE RATE	1000 FT/SEC	
FREQ.	9.3 GHz	
BW	3 MHz	
G (ANT)	28.0 DB	



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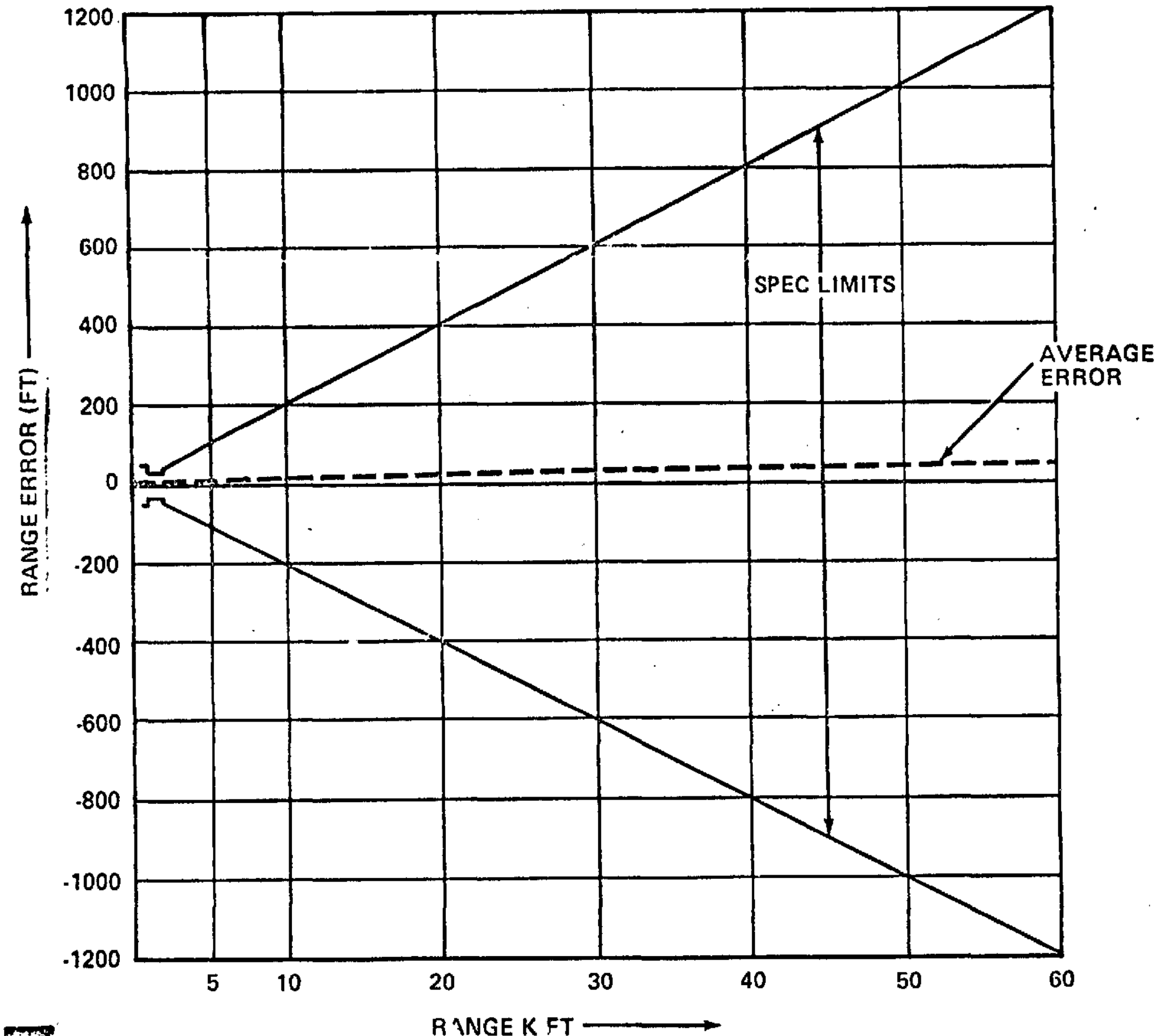
RANGE TRACKER MEASURED ERROR

THE CHART BELOW SHOWS THE AVERAGE MEASURED RANGE ERROR OF PRODUCTION RADARS S/N 5 TO S/N 36 AS A FUNCTION OF RANGE. ALSO SHOWN ARE THE SPECIFIED LIMITS OF ±2% OF RANGE FROM 2000 TO 60,000 FT. THE ABOVE DATA WAS TAKEN BY INJECTING A SIMULATED RANGE TARGET INTO THE SYSTEM AT RF.

RANGE TRACKER MEASURED ERROR



3.2 Modified System Characteristics

Tables I thru III below describe the performance characteristics of the modified system. These are in addition to the Baseline system performance.

SYSTEM PARAMETERS

TRANSMIT FREQUENCY		9.3 GHz
TRANSMIT BANDWIDTH (MECH. TUNABLE)		± 150 MHz
TRANSMIT POWER		65 KW - 100 KW (Peak)
PULSEWIDTH		0.4 μsec
PRF		2500 PPS
ANTENNA GAIN		28 DB
ANTENNA SIDELOBES PEAK		-20 DB
AZIMUTH BEAMWIDTH		5.2°
ELEVATION BEAMWIDTH		7.0°
AZ SEARCH RATE		85°/SEC
EL SEARCH RATE		85°/SEC
ELEVATION/AZIMUTH ACQ. RATE		42°/SEC
AZIMUTH GIMBAL LIMITS		±42.5°
ELEVATION GIMBAL LIMITS		+45° -35°
AZ CON SCAN	MSL Mode	4° P-P @ 6Hz
EL CON SCAN		5° P-P @ 6Hz
AZ CON SCAN	Angle Track	2.5° P-P @ 6Hz
EL CON SCAN		3.5° P-P @ 6Hz
RECEIVER NOISE FIGURE		8.0 DB Nominal, 9 DB max.
RECEIVER BANDWIDTH		3.0 MHz
RANGE GATE SEARCH (DOGFIGHT ACQUISITION)		30 KFT/SEC
RANGE GATE SEARCH (BA/AT ACQUISITION)		22.5 KFT/SEC (10 MILE RANGE)
		11.25 KFT/SEC (5 MILE RANGE)

TABLE 1

ANGLE TRACK PERFORMANCE

AIRCRAFT PARAMETERS

AXIS	RATE	ACCELERATION
ROLL	230°/SEC	500°/SEC^2
PITCH	40°/SEC	100°/SEC^2
YAW	50°/SEC	50°/SEC^2

STATIC ACCURACY

AZIMUTH $\pm$ 3 MILLIRADIANS (1 σ)

ELEVATION $\pm$ 3 MILLIRADIANS (1 σ)

DYNAMIC ACCURACY

AIRCRAFT MOTION - Maintain tracking (lockon) for aircraft rate and acceleration parameters above.

TARGET MOTION - Steady state target rate accuracy $\pm$ 5 milliradians - both axes - with angular rates of 30° -40°/SEC.

TABLE 2

SYSTEM PERFORMANCE

DETECTION RANGE (P_{85}CUM)	8 N. MILES (2 M^2 TARGET)
ACQUISITION RANGE (P_{85}CUM)	6 N. MILES (2 M^2 TARGET)
RANGE ACCURACY	50 FT. 500 FT TO 1000 FT. 30 FT. 1000 FT TO 2000 FT. ± 2% 2000 FT TO 10 N. MILES
RANGE RATE ACCURACY	± 3% OR 10 FT/SEC (WHICHEVER IS GREATER)
RANGE RATE MEMORY	APPLICABLE FOR 1.7 SECS
SEARCH COVERAGE	AZIMUTH ± 42.5° ELEVATION 10° (POSITIONABLE OVER +45° -35°)
ACQUISITION COVERAGE	AZIMUTH 15° (POSITIONABLE OVER ± 42.5) ELEVATION 10° (POSITIONABLE OVER +45° - 35°)
ANGLE RATE MEMORY	APPLICABLE FOR 1.7 SECS

TABLE 3

3.3 Requirements

An AN/APQ 153 Fire Control Radar System, modified for angle track, will be tested and evaluated at NASA/JSC to determine its possible application on the Space Shuttle as a rendezvous system. Evaluation will be made on the system performance parameters and with a view towards the growth potential of the system for space applications. The Shuttle rendezvous system must be capable of providing range, range rate and angular information of the target to the astronauts during rendezvous operations. The system will be required to operate in a non-cooperative (skin track) mode.

3.3.1 Non-Cooperative Mode

The system shall be capable of skin tracking a target having a radar cross section at 9.3 GHz of 1 square meter at ranges between 153 meters and 9,3 kilometers and of providing range, range rate, angle and angle rate information.

3.3.2 Antenna System

The antenna system shall have the capability of being designated to the target and provide automatic tracking after acquisition for non-cooperative operating modes. This is necessary to evaluate the systems target acquisition capabilities and angle tracking accuracies for Shuttle applications.

3.3.3 Self Test

The system shall have a self test capability that will exercise all major functions to permit determination of system readiness prior to usage.

3.3.4 Specifications

(a) Construction: Modular construction shall be used throughout to facilitate parts replacement and field maintenance.

(b) Test Points: Adequate test points shall be provided to permit isolation of any problem to a given replaceable module.

(c) Data Output: Analog signals for range, range rate, and angular information shall be provided.

(d) Cooling: Integral blowers, conduction and radiation.

(e) System weight: Minimum feasible, not to exceed 125 pounds.

(f) Mean Time Between Failures (MTBF): 100 hours minimum.

(g) Power: 28 VDC and 115 VAC, 400 Hz

3.3.5 Performance (Skin Tracking)

(a) Coverage

(1) Range: 153 meters to 9.3 kilometers

(2) Range Rate: 300 meters/second opening and 900 meters/second closing

(3) Angles (Az/El search): Forward sector: ± 45° Azimuth; +48.50, -38° in elevation.

(4) Angle Rates: ± 10 degrees/second

(b) Accuracy (sigma)

(1) Range: + 15 meters ± 1%, whichever is greater

(2) Range Rate: + 3 meters/second or + 2%, whichever is greater.

(3) Angles: ± 9 milliradians (MR)

(4) Angle Rates: ± 9 MR/second or ± 10% or tracking rate, whichever is greater.

(c) Target Cross Section: 1 square meter

(d) Acquisition Time: Less than 1 minute after target designation

4.0 HARDWARE DESCRIPTION

This section describes the AN/APQ 153 LRU's presently in production for the F5E. Also, modifications and addition are described in detail.

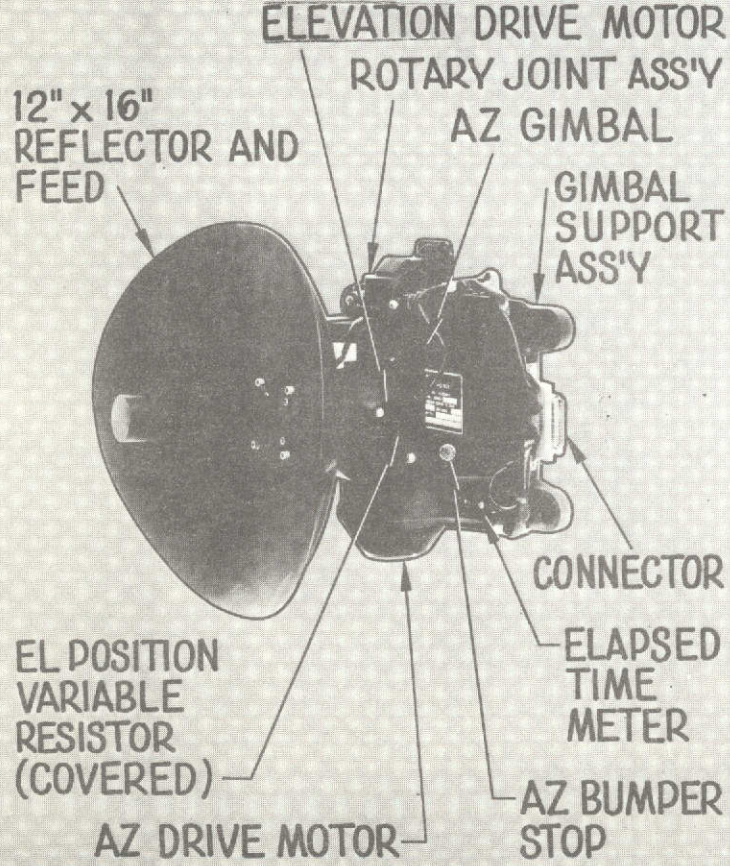
4.1 AN/APQ 153 Hardware

Following are descriptions of the present AN/APQ 153 LRU's.

4.1.1 ANTENNA AS 2736/APQ-153

The antenna LRU is a two axis gimbal, elevation on azimuth, with direct drive electric torque motors. The torque motors develope 450 inch ounces each and are an integral part of the gimbal. A potentiometer is attached to each motor shaft for position feedback to the servo drives in the processor. The high power two axis rotary joint is a single assembly. The rotary joint assembly is pressurized internally by the waveguide pressurization system in the Transmitter/Receiver LRU and to achieve minimum pressurized air leakage a carbon ring attached to a bellows against a polished steel ring is used for the Dynamic Seal in the rotary joint. The reflector/feed is a 12" X 16" epoxy resin, fiberglass reflector with a cutler feed. The feed is encased in a pressurized fiberglass radome. The antenna LRU is preboresighted to provide interchangeability at the flight line without the need for harmonization. To prevent damage to the LRU in the case of a hard landing with the radar in "OFF", the windings of the torque motors are shorted together to provide damping, and mechanical buffer stops are provided in both axes.

ANTENNA AS2736 CHARACTERISTICS



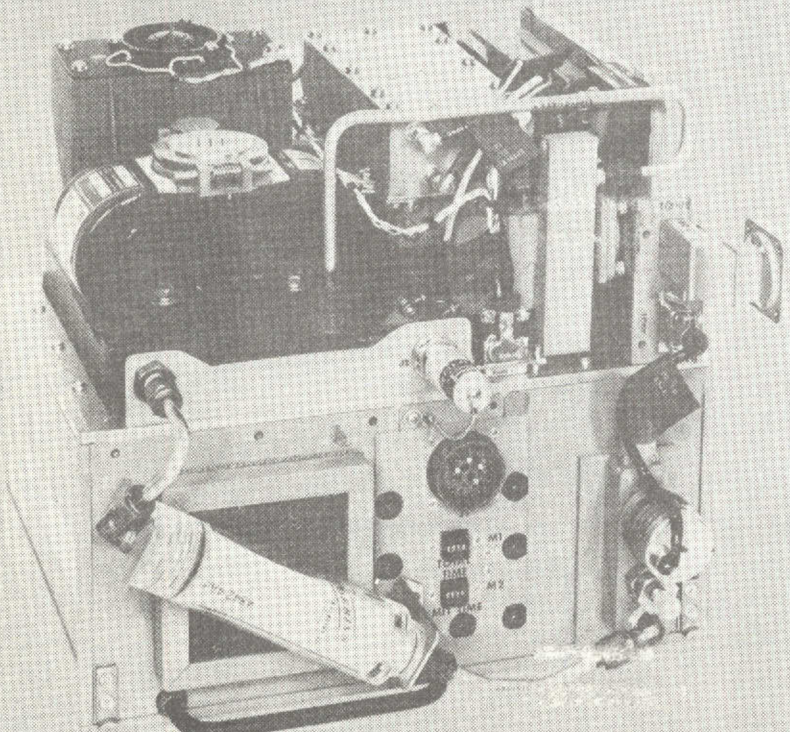
POLARIZATION	HORIZONTAL
GAIN	28DB RELATIVE TO ISOTROPIC RADIATOR
BEAMWIDTH	5.2° AZ - 7° ELEVATION
SIDELOBES	AT LEAST 19 DB BELOW PEAK OF MAIN BEAM - 21DB TYPICAL
FREQUENCY BANDWIDTH	9.150 GHz TO 9.450 GHz
MAXIMUM SCAN-VELOCITY CAPABILITY	2000°/SECOND
NORMAL SCAN VELOCITY	85 ± 5°/SECOND
FRAME TIME	LESS THAN 2.3 SECONDS
TURN AROUND TIME	LESS THAN 150 MS
STABILIZATION ACCURACY	±9 MILS
BORESIGHT STEERING-SCAN RATE	6 Hz

WR-6386

4.1.2 RECEIVER/TRANSMITTER RT1059/APQ-153

The Receiver/Transmitter LRU contains the microwave, receiver, AFC, BIT, magnetron and modulator. An RF Test Connector is provided external to the package for monitoring transmitter or injecting simulated received RF signals into the system while it is installed in the aircraft for fault isolating to the LRU using the radar test set. The desiccator on the front of the package is used for drying and filtering the pressurizing air from the external fuel stores pressurization system.

RECEIVER/TRANSMITTER-RT-1059



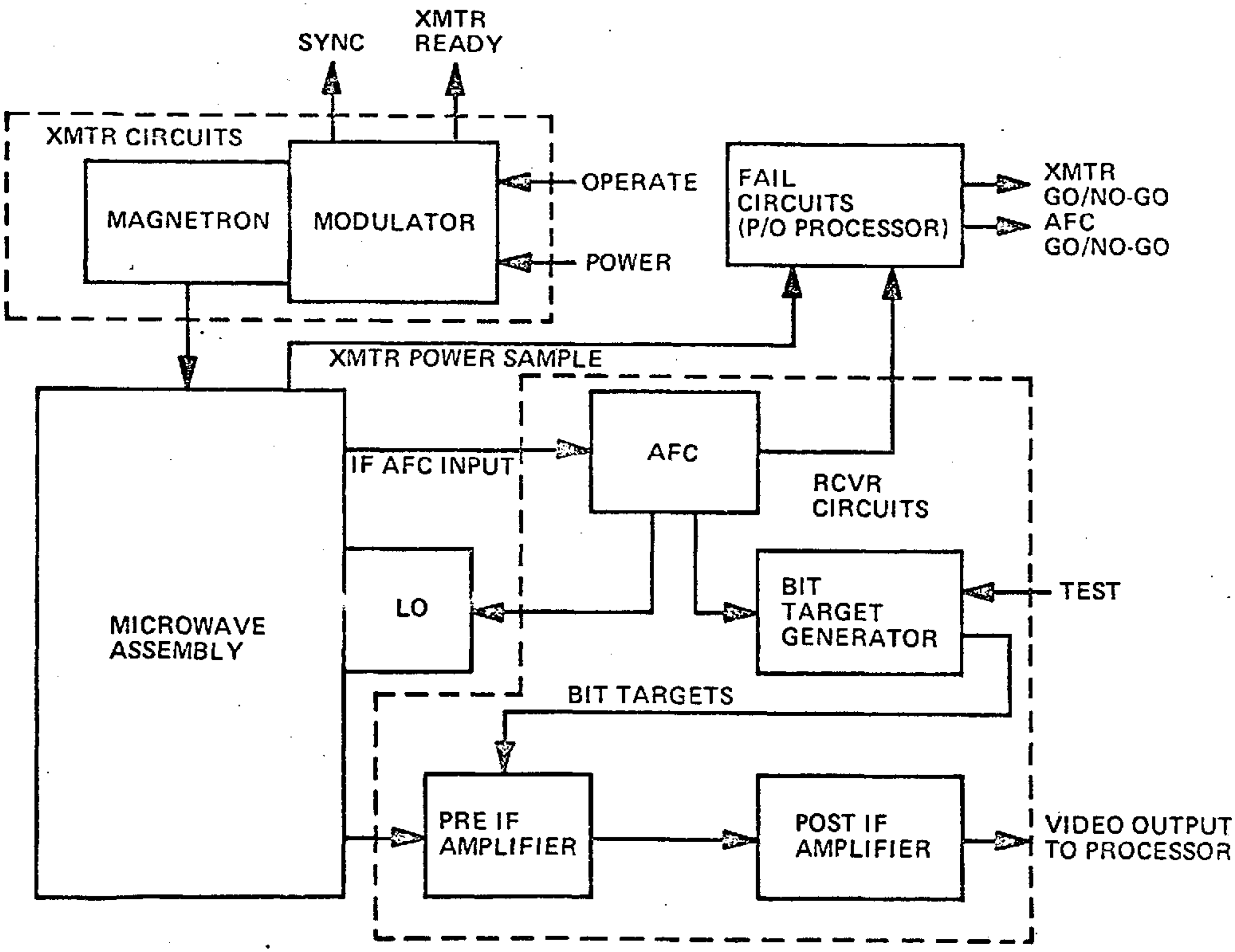
- WEIGHT - 41.7 POUNDS
- FREQUENCY - X-BAND 9300 ± 150 MHZ
- PEAK POWER - 80 KW (60 KW MINIMUM)
- DUTY CYCLE - 2500 PPS @ 0.4 μ SEC PULSE
- NOISE FIGURE - LESS THAN 9 DB
- ANTI-CLUTTER - FTC/BLC

WR-6343

RECEIVER/TRANSMITTER CHARACTERISTICS

TRANSMITTER	
PEAK POWER	60 KW MINIMUM AT MAGNETRON FLANGE
PRF	2500 ±50 Hz JITTERED
PULSE WIDTH	0.4 ±0.04 MICROSECONDS
PRF JITTER	± 100 Hz MINIMUM
JITTER RATE	50 Hz ±5 Hz
FREQUENCY	9.3 ±0.15 GHz GROUND TUNABLE
FREQUENCY PULLING	8 MHz MAXIMUM
SIDELOBE LEVEL	AT LEAST –8DB
TRANSMITTER LOSSES	LESS THAN 1 DB
RECEIVER	
IF FREQUENCY	60 MHz
NOISE FIGURE	9 DB INCLUDING RECEIVED LOSSES
BANDWIDTH	3 ±.3 MHz
MINIMUM DISCERNIBLE SIGNAL	AT LEAST –97 DBM
RECEIVER DYNAMIC RANGE	AT LEAST 80 DB
AFC ACCURACY	±150 KHz

RECEIVER-TRANSMITTER LRU BLOCK DIAGRAM

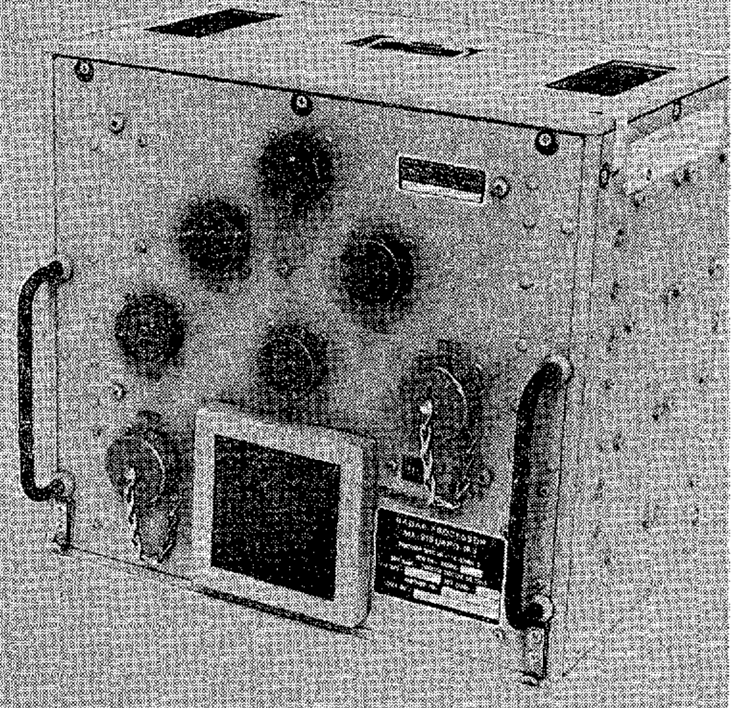


4.1.3 RADAR PROCESSOR MX9151/APQ-153

The Radar Processor contains the radar low voltage power supplies, Servo Search Programmer and Drives, the Indicator Auxiliary Electronics, the Range Tracker and the Built-in Test (BIT) Monitoring Circuits. Two System Electrical Test Connectors are provided for connection to the Radar Test Set used to isolate a fault down to the LRU level at the flight line.

RADAR PROCESSOR - MX-9151

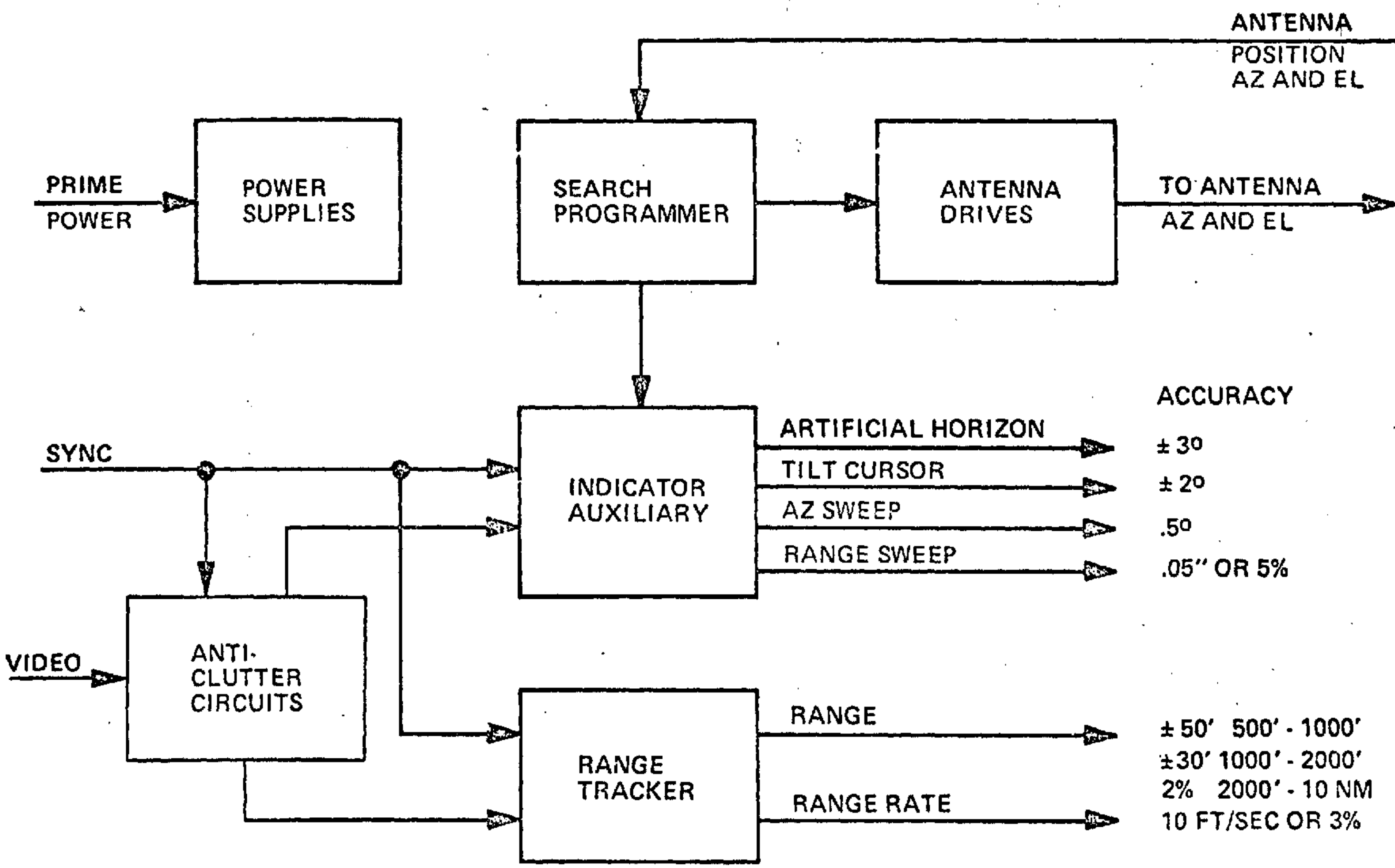
- RANGE ACCURACY
  - ± 50 FT - 500 TO 1000 FT
  - ± 30 FT - 1000 TO 2000 FT
  - ± 2% - 2000 FT TO 10 NM
- RATE ACCURACY
  - ± 3% OR ± 10 FT PER SEC
- RANGE RATE MEMORY
  - 1.7 SEC
- TRACKING RATE
  - 3000 FT PER SEC CLOSING
  - 1000 FT PER SEC OPENING



WEIGHT - 35 POUNDS

WR-6355

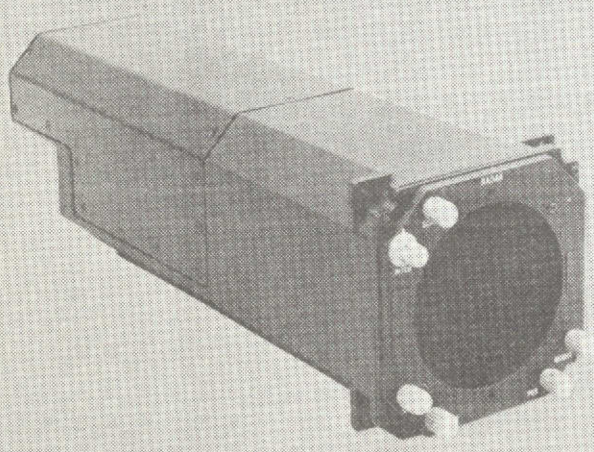
RADAR PROCESSOR BLOCK DIAGRAM



4.1.4 INDICATOR IP-1099/APQ-153

The indicator contains the 5-inch, 1800 feet lambert, direct view storage tube, the deflection amplifiers, the programmable high voltage power supply, the write gun bias supply, video amp, and DVST protection circuitry. The indicator electronics is housed in a one-piece precision casting with removable inspection cover. The edge lit panel on the front of the indicator is a white lighted panel which meets the requirements of MIL-L-27160B (3). Advisory lights are provided on the edge lit panel for range scale selected, radar lock-on, missile in-range functions, excess G for missile firing, and system built-in-test go/no go.

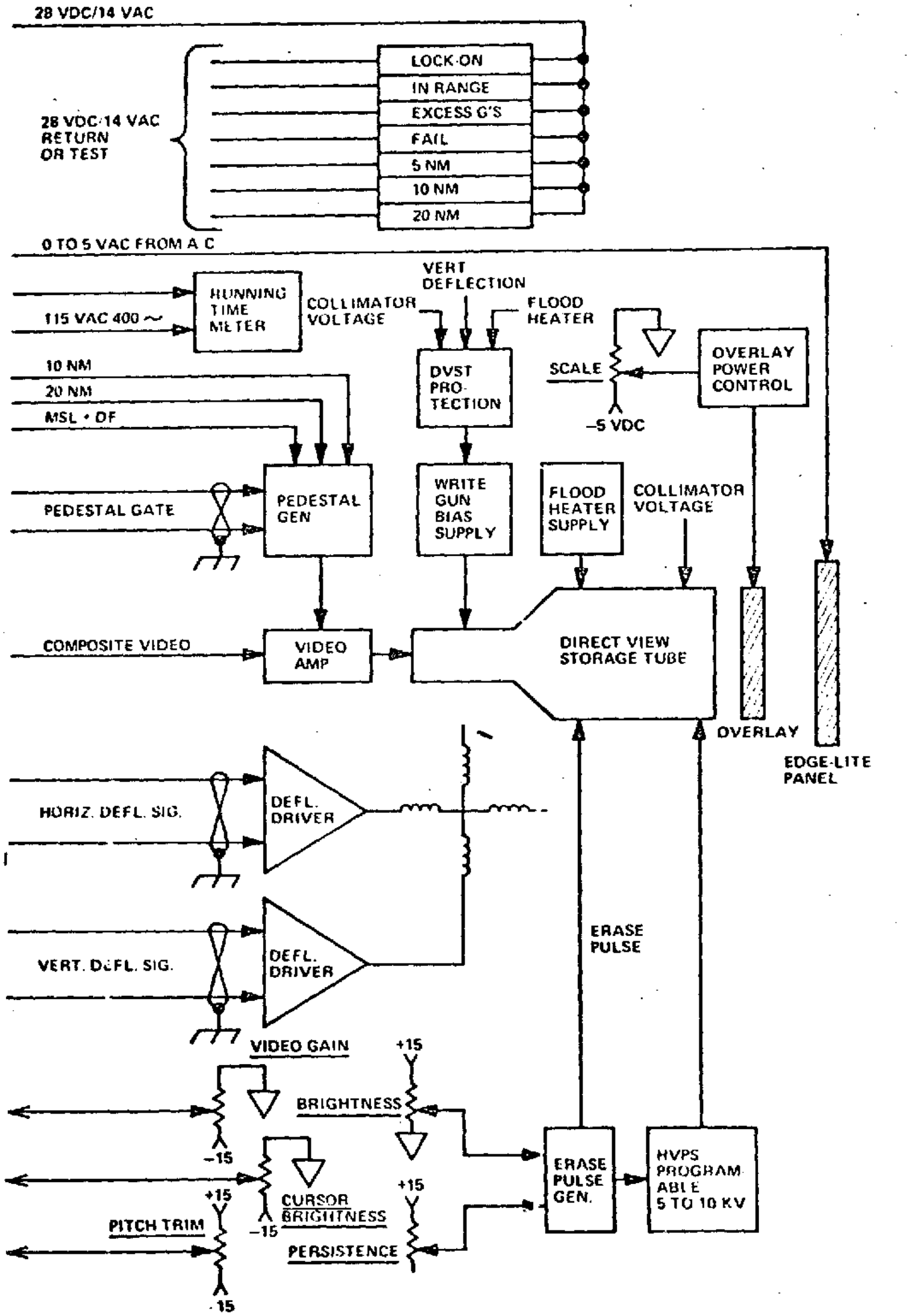
INDICATOR IP1099 CHARACTERISTICS



• LIGHT OUTPUT	1 TO 140 FT LAMBERTS, ADJUSTABLE FROM FRONT PANEL
• AZIMUTH ACCURACY	± 9 MILS
• RANGE LINEARITY	±.05 INCH OR ± 5 %
• CONTROLS	BRIGHTNESS, PERSISTENCE, VIDEO GAIN, SCALE BRIGHTNESS, PITCH TRIM, CURSOR INTENSITY
• FILTERS	CIRCULAR POLARIZER, AND NEUTRAL DENSITY
• PERSISTENCE	ADJUSTABLE 1 TO 2 SECONDS

WR-6394

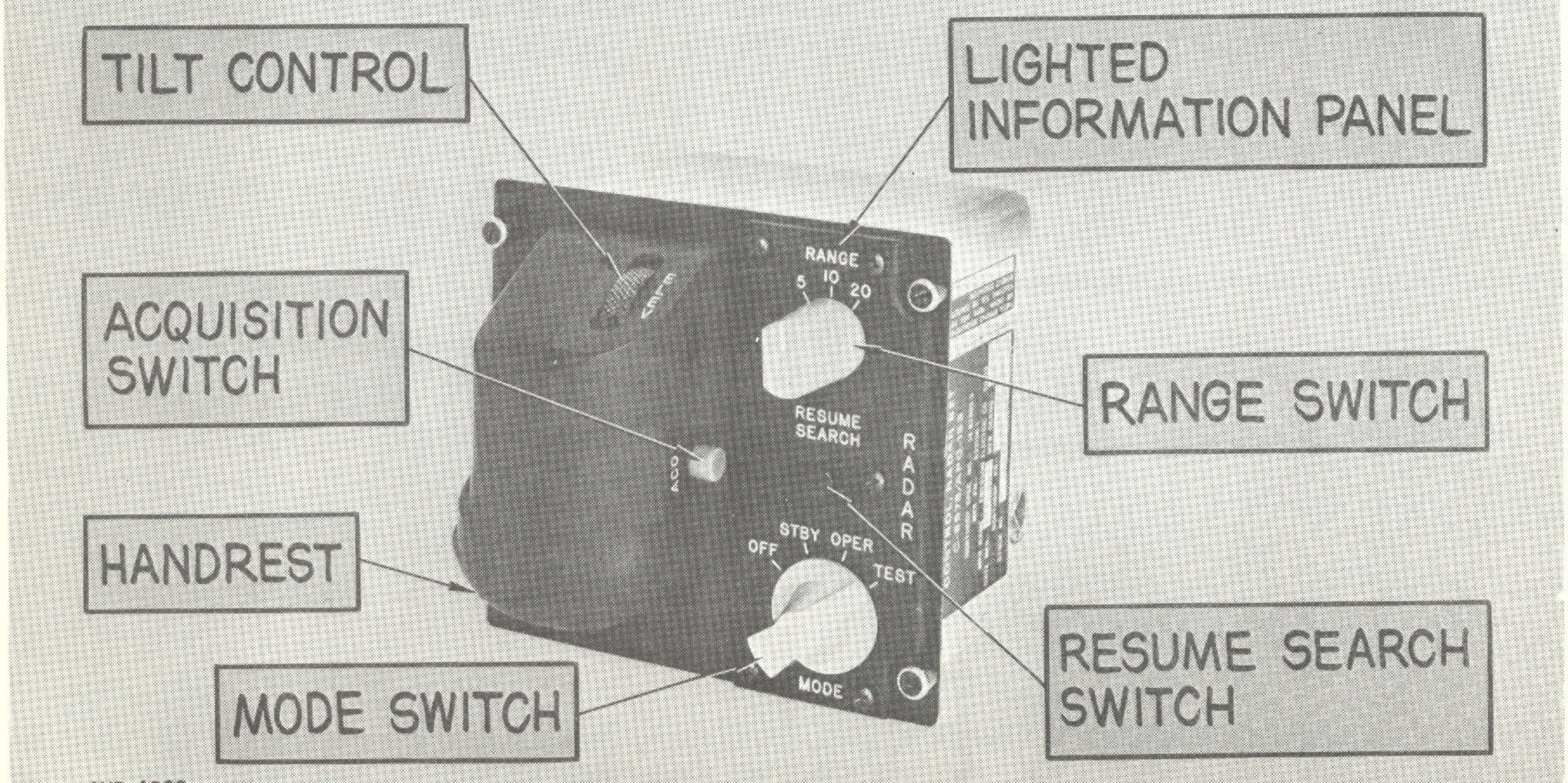
INDICATOR IP1099/APQ-153 BLOCK DIAGRAM



4.1.5 RADAR SET CONTROL C8978/APQ-153

The radar set contains radar mode select, range select, resume search, and missile acquisition switch functions and the elevation tilt control finger wheel.

RADAR SET CONTROL C8978



WR-6392

4.2 Hardware Modification

This section describes modifications to the AN/APQ 153 and Test Set to provide required performance for NASA.

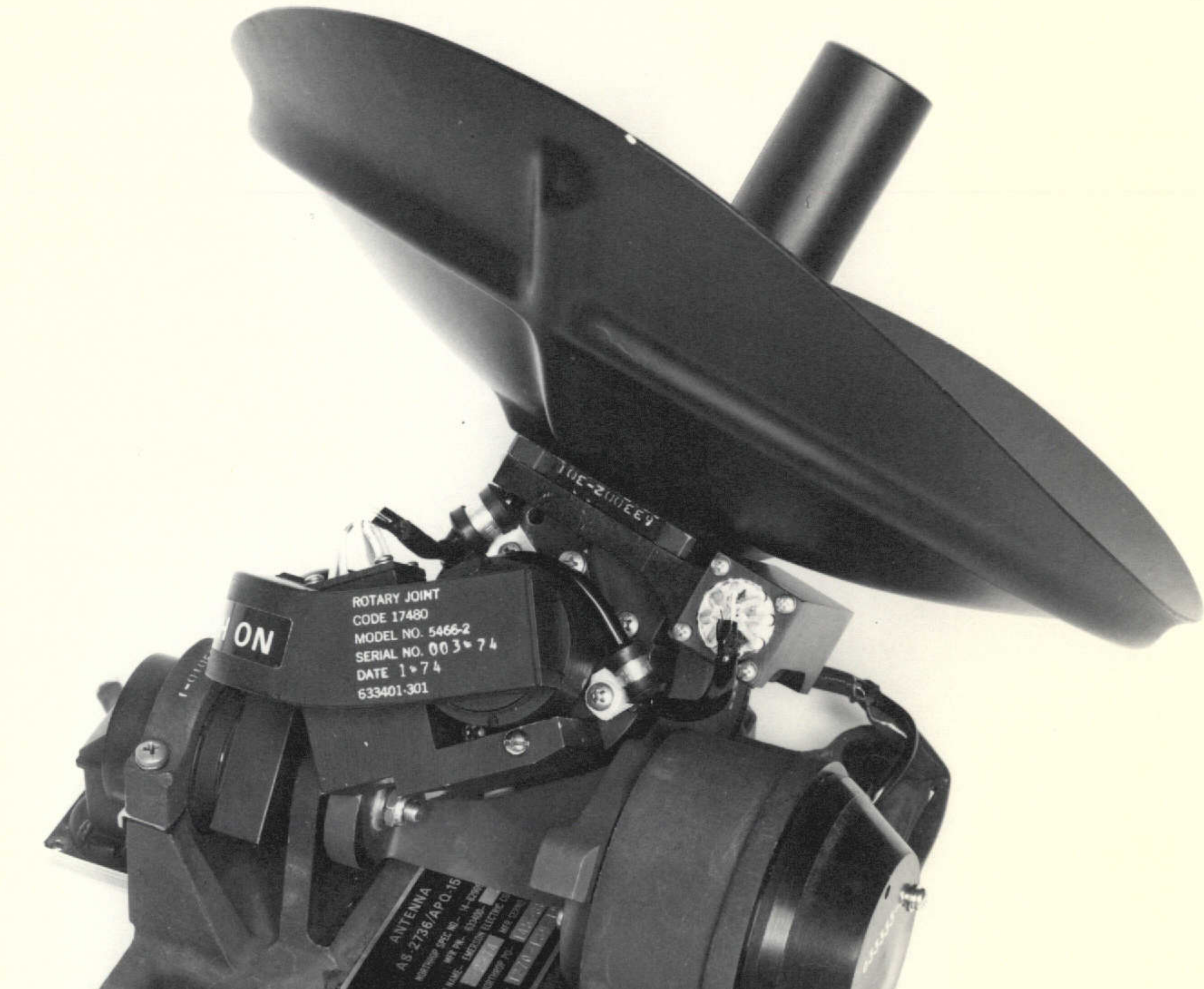
4.2.1 Antenna

Antenna modifications are shown in Figure 4.2.1. Two rate gyros were added to the antenna in the azimuth and elevation axis to provide sensing of ownship motion while angle tracking. The gyro motor excitation is 26 VAC, 400HZ and 26 VAC, 400HZ shifted 90° through two 1μf capacitors added on the antenna. Along with the capacitors, two 50 mhy inductors are included for amplitude scaling and phase correction of the 400HZ to the primary of the gyro pick-off windings. The outputs of each gyro secondary are used directly by the A1A16 angle tracker board in the Processor.

4.2.2 Set Control

The set control additions provided the pilot with a control for positioning the ACQ symbol in range and azimuth, and provide the processor with the corresponding analog voltages for the ACQ Symbol deflection circuitry. Three boards were added inside the set control chassis (656921, 656922, 656923) and an isometric transducer was added to the handrest as the pilot ACQ Symbol controller. Figure 4.2.2 shows the modified set control.

A new Mode switch to include the two new angle track modes was also added. The first mode, OPER, designates the off-boresight acquisition and angle track mode; the second operate mode, BST, provides boresight acquisition angle track operation; and the third mode, MSL, is identical to the AN/APQ 153 boresight acquisition, boresight steering mode.


ROTARY JOINT
CODE 17480
MODEL NO. 5466-2
SERIAL NO. 003-74
DATE 1-74
633401-301
ON
ANTENNA

4.2.2 Set Control - Continuted

Isometric Transducer - The isometric transducer is a strain gauge-type mechanism, which will provide analog signals proportional to force applied in the two axes corresponding to range and azimuth. Forward force positions the symbol to greater range, rear force to lesser range. Down and up for-e on the control positions right and left azimuth respectively. The analog voltages for both axes are then rooted to the 656923 board.

656923 Board - Circuitry on the 656923 board Figure 4.2.3 scales the analog signals from the isometric transducer and processes them to produce the following board outputs in each axes:

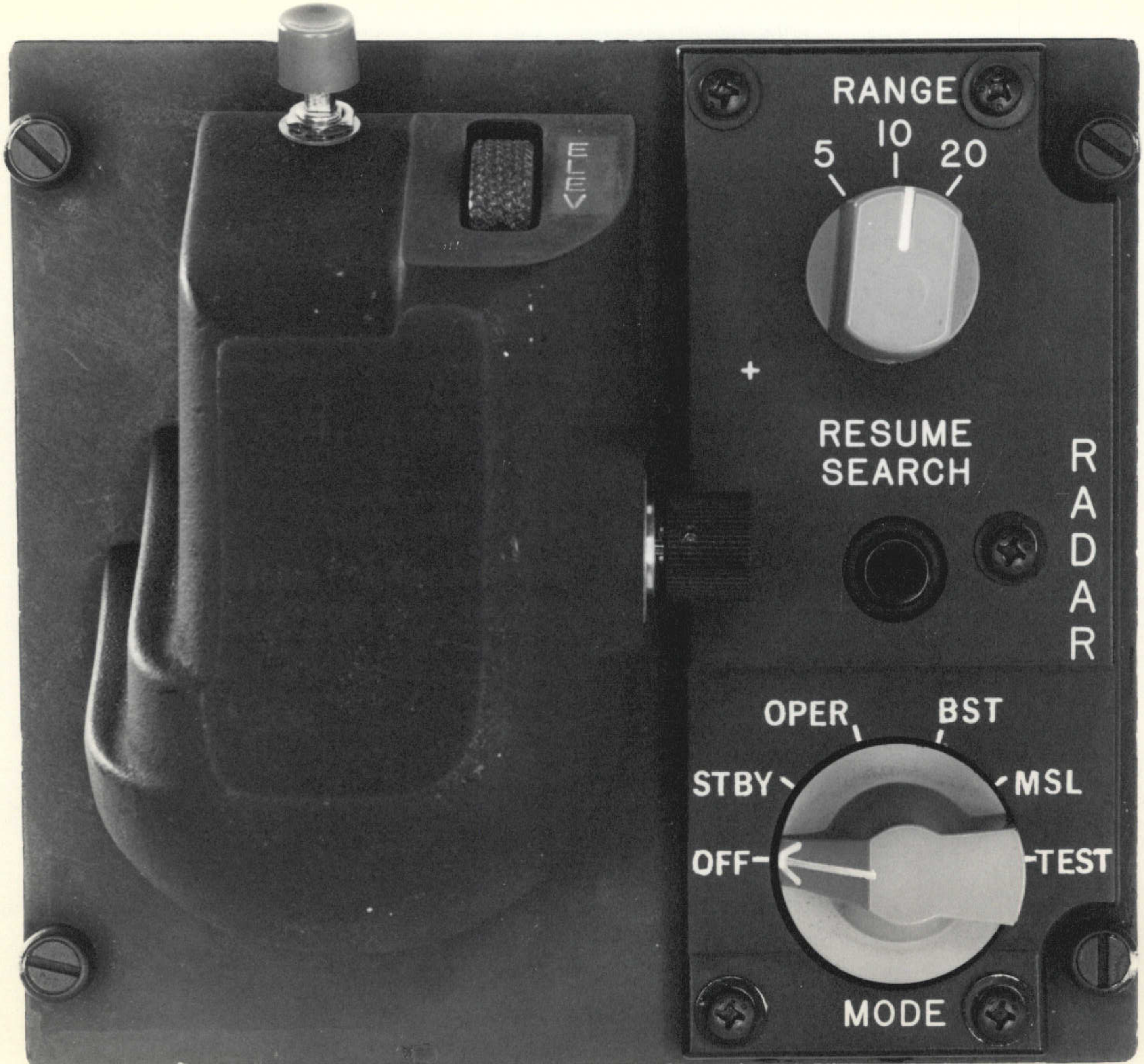
1. A free-running clock circuit exists in each axis, the frequency of which is increased in direct proportion to the absolute magnitude of the signal from the transducer. This then provides variable frequency clock pulses in each axis.

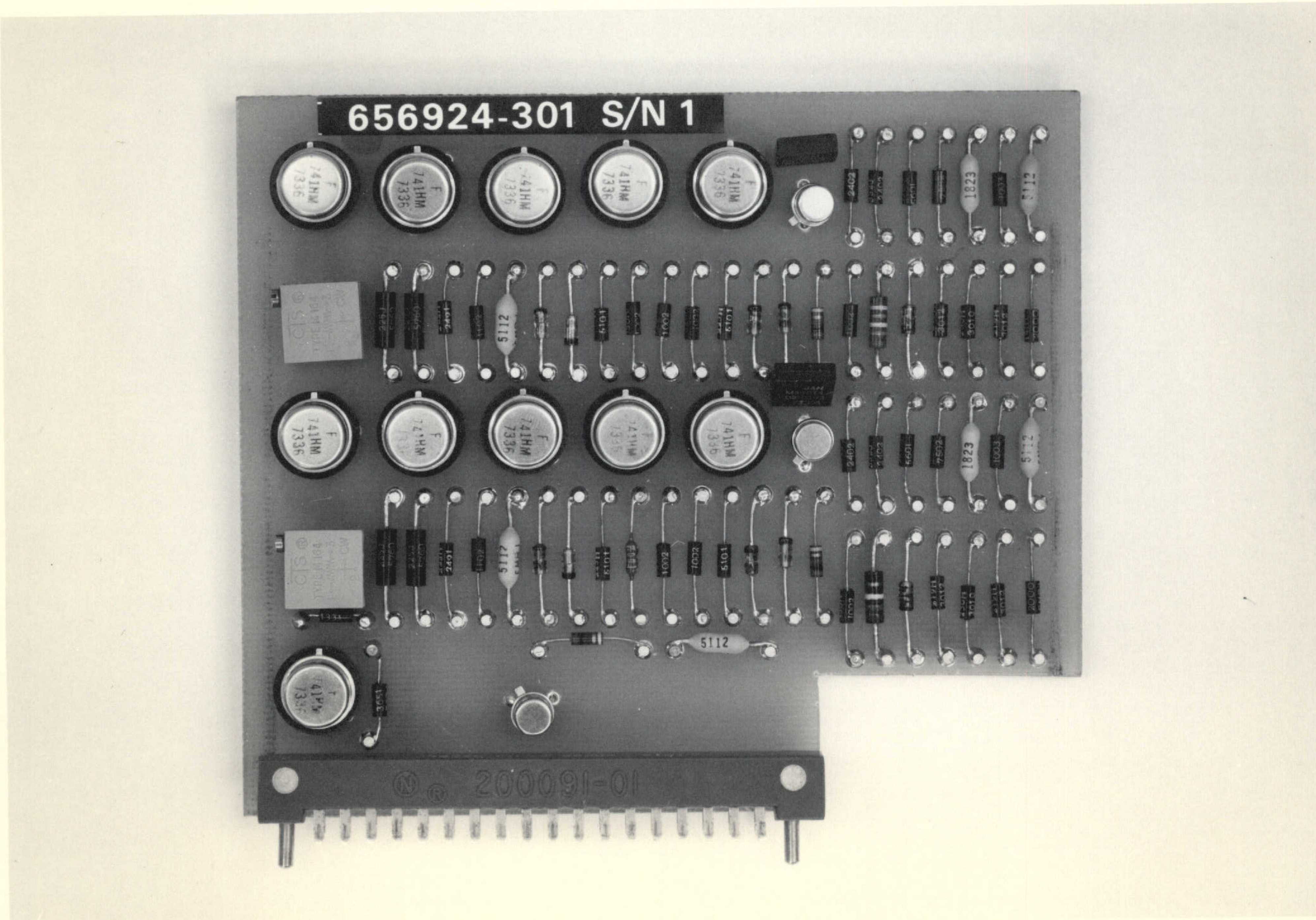
2. Circuitry also exists in each axis to provide polarity sensing of the transducer signal. This provides an UP/DN signal in each axis.

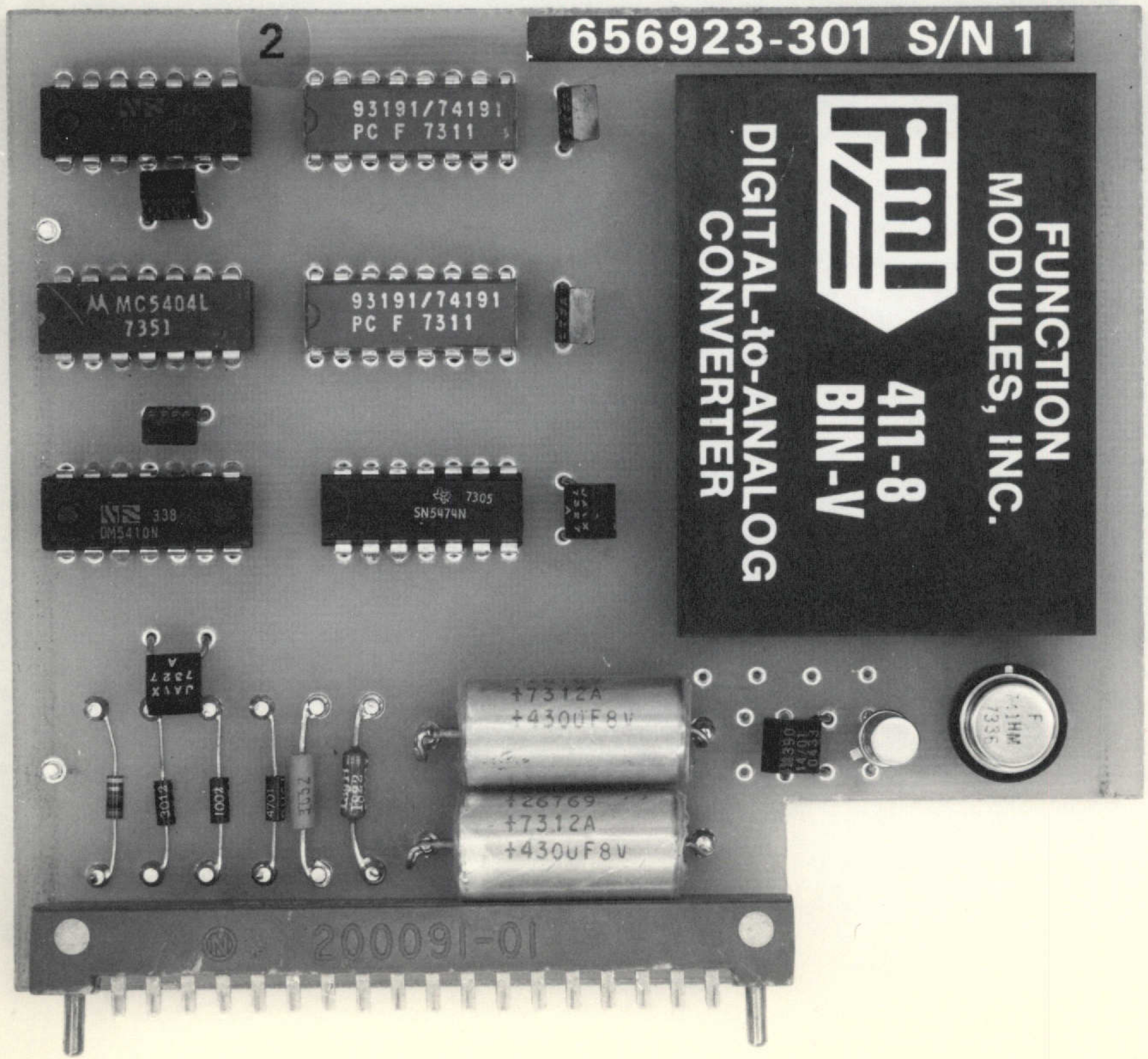
3. The final output is an indication that the magnitude of the transducer signal is above some pre-determined dead-zone about zero volts. This threshold circuit, then, provides an ENABLE command for each axis.

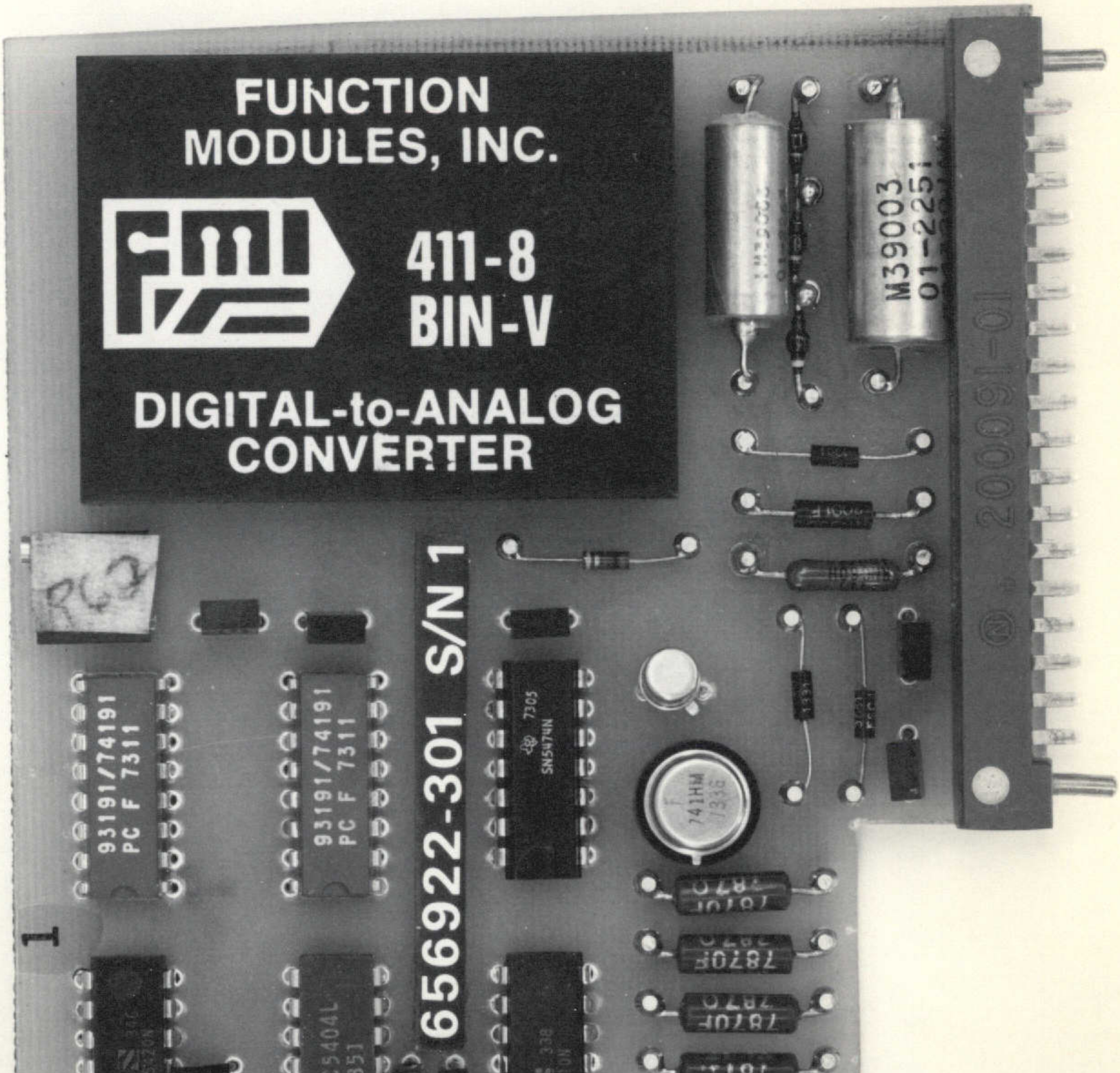
Thes outputs are then routed to the 656921 and 656922 boards.

656922 Board - The principal output of the 656922 board Figure 4.2.4 is a bipolar analog votage proportional to the desired azimuth position of the ACQ Symbol. The analog voltage is the direct output of an 8-Bit


ELEV
RANGE
5
10
20
RESUME
SEARCH
RADAR
OPER
BST
STBY
MSL
OFF
TEST
MODE


656924-301 S/N 1
200091-01


2
656923-301 S/N 1
93191/74191
PC F 7311
MC5404L
7351
DM5410N
SN5474N
FUNCTION MODULES, INC.
411-8
BIN-V
DIGITAL-to-ANALOG CONVERTER
+7312A
+430uF8V



FUNCTION
MODULES, INC.
411-8
BIN-V
DIGITAL-to-ANALOG
CONVERTER
656922-301 S/N 1

4.2.2 Set Control - Continued

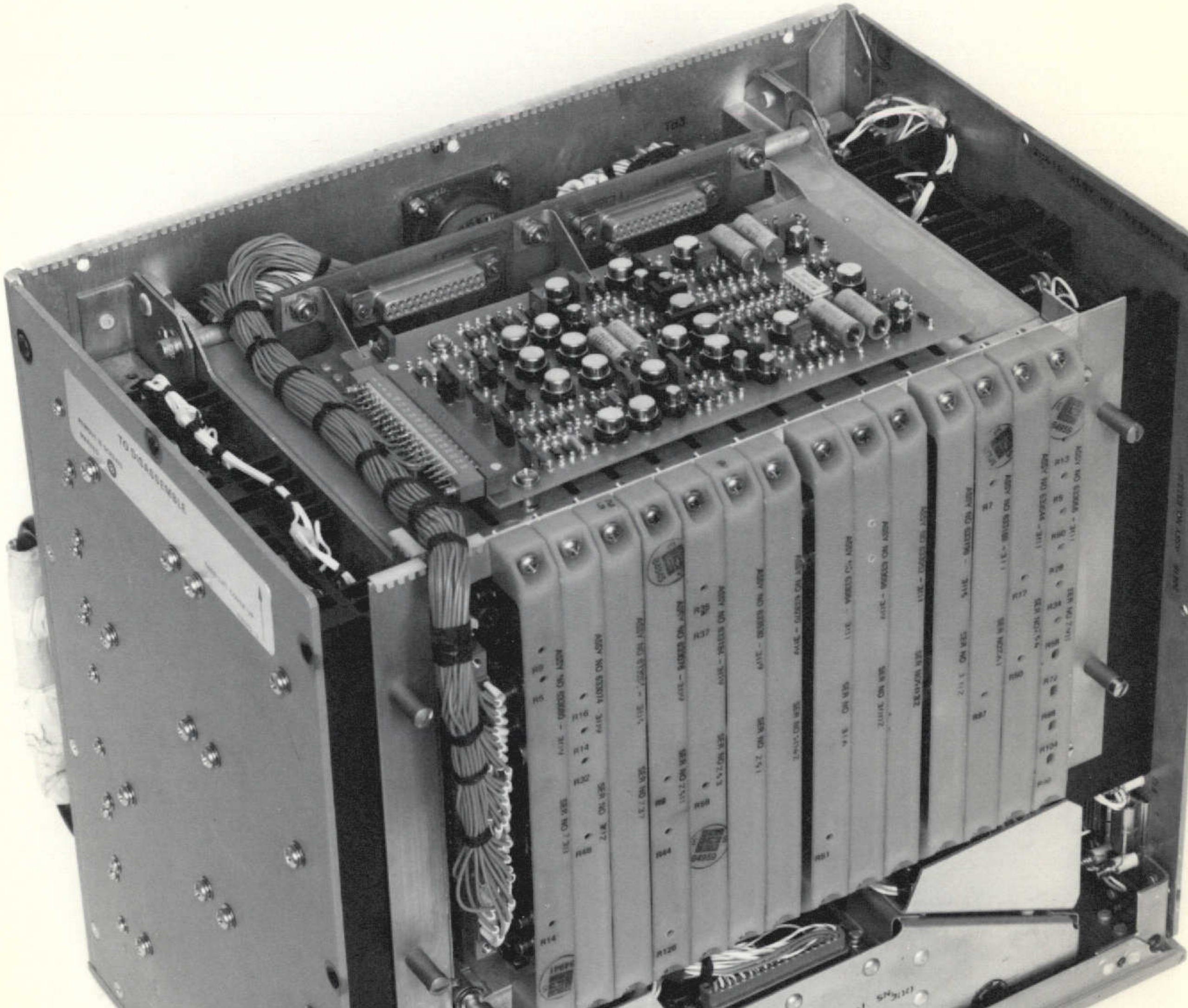
Digital-to-Analog Converter. The 8-Bit input to the D/A converter is the parallel output of two 4-Bit UP/DOWN Counters in cascade. The azimuth UP/DN command from the 656923 card, determines the direction of count. The azimuth ENABLE command allows the azimuth Clock pulses to sequence the counters in the direction determined by the UP/DN command. The clock and enable commands, also from the 656923 board, are first processed by appropriate logic which prevents a "fold-around" condition when the counters are both at a maximum (or minimum) count and would on the next count, if allowed, start back at minimum (or maximum). This circuitry, then, prohibits a sawtooth output from the D/A converter and discontinuities in ACQ Symbol positioning.

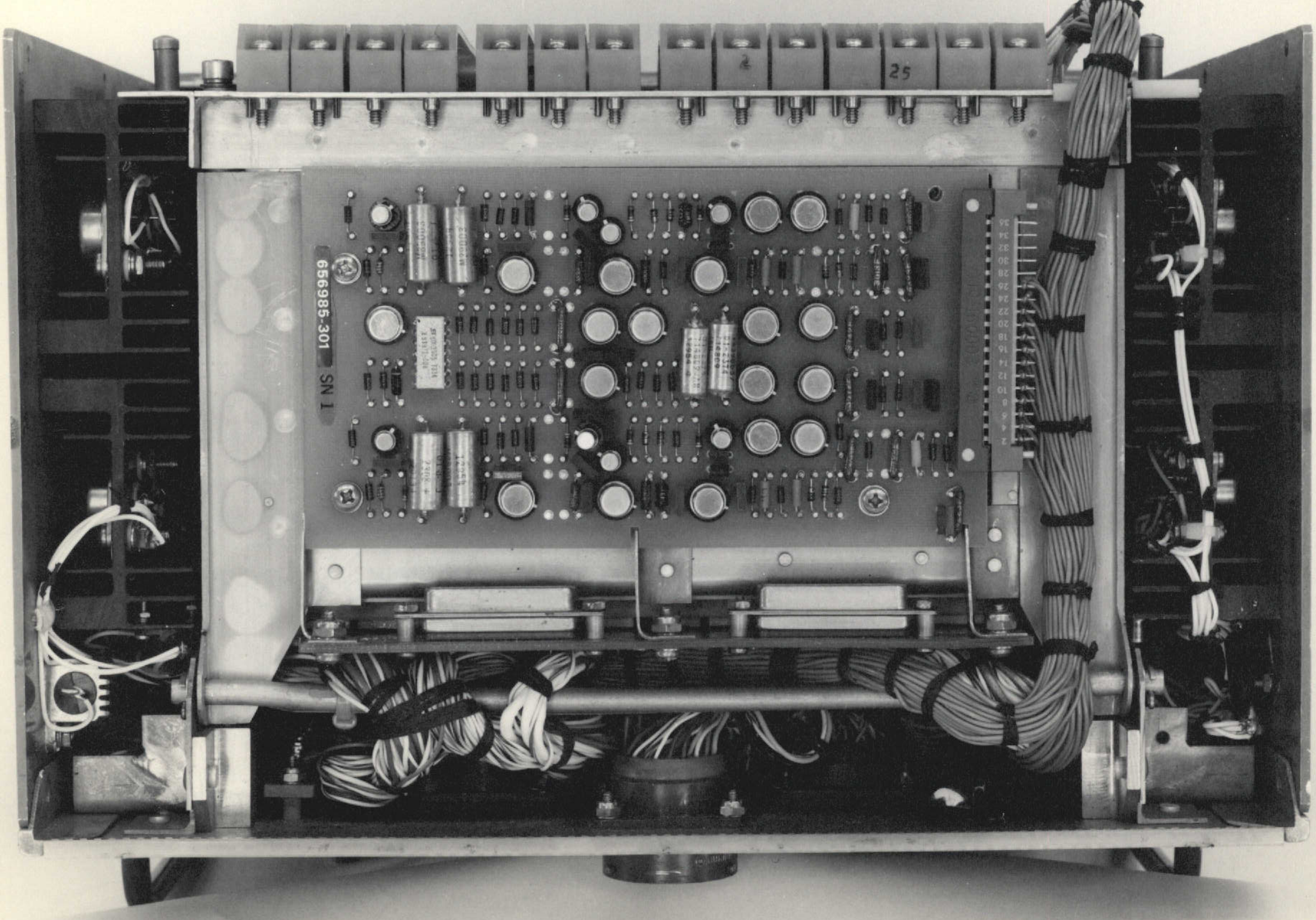
An ACQ Symbol preset circuit is also included to stow the symbol at a predetermined position whenever resume search is actuated.

656921 Board - The circuitry on the 656921 board Figure 4.2.5 is almost identical to the 656922 board. The principal output of this board is a negative unipolar voltage proportional to desired range positioning of the ACQ Symbol. The output of the symbol preset circuitry on the 656922 is also used by this board. In addition, a circuit for scaling the output swing of the D/A converter is included to adjust for either 5 or 10 mile radar mode select.

4.2.3 Processor

The following modifications to the processor along with additional circuit boards were done to provide added capability required by NASA


ASSY NO.


656985-301
SN 1

4.2.3 Processor - Continued

Two circuit boards A15 and A16 were added along with modifications to existing circuits. Modified processor is shown in Figure 4.2.6.

A16 (656986) Board - This added board is shown in Figure 4.2.7. In the angle track modes, the AN/APQ-153 AIM BAR steering commands are used as inputs for sensing target motion, while the gyro signals are used for cancelation of ownship motion. The gyro signals in each axis are 400HZ sine waves with amplitude proportional to gimbal rate. Direction of motion is indicated by a 0° or 180° phase. The 26 VAC, 400HZ gyro excitation signal is also brought into the board as a reference for full wave rectification of the gyro signals for each axis. The AN/APQ-153 AIM BAR commands are processed through appropriate networks and summed with the correct full-wave rectified gyro signal to become the input to the first integrator in each axis. The first integrator output is both the input to the second integrator and the angle rate command for that axis. The second integrator output is both the antenna gimbal position command used by the servo and the angle track AIM BAR command. Circuitry also exists on the board to maintain an output of the second integrator, in non-lock-on operation, which corresponds to present antenna position. Therefore, when lock-on occurs, no transients on the antenna command lines will occur. When the radar is angle tracking and loses the target for any reason, the target motion inputs are interrupted. In the absence of ownship motion, the second integrator then provides a rate memory to continue antenna drive at the last known target rates should the target be re-acquired before range tracker memory time-out.

4.2.3 Processor - Continued

Since the antenna commences a 6HZ conicalscan when locked-on to a target the demodulated gyro signals contain a 6HZ envelope. This 6Hz modulation appears on the second integrator output. The presence of this modulation requires stronger 6HZ commands to be summed in on the A1A6 board than in the non-angle track mode. This modulation required the addition of a six hertz notch filter in each AIM BAR signal in order to maintain an acceptable cursor presentation.

Range Tracker Modifications - A2 Circuit Card: Circuitry added to the A1A2 card both switches between the two track gate generation methods, and generates the error signal for positioning the gate in the OPER mode. The generation method for the AN/APQ-153 baseline system is used in the BST or MSL modes. A slowly varying ramp is compared to an identical ramp generated every PRF. At their "intersection" point in each PRF, the track gate is generated. In the OPER mode, the line representing the current source for driving the slow ramp is interrupted. In its place, an error signal is provided. The error signal is generated by comparing the unipolar negative voltage from the Set Control with the positive radar range voltage. This error signal causes the track gate to be generated at the center of the position chosen by the pilot for the ACQ Symbol range. In addition, a 5HZ triangular wave is also generated and summed in with the error signal to cause the dither of the track gate necessary to cover the total range subtended by the symbol.

A3 Circuit Card: A modification was added to allow range tracker operation with CW target returns. The baseline AN/APQ-153 Test mode operation required turning off (RCVR DUMP) the receiver pre-amp during

4.2.3 Processor - Continued

the pilots ground pre-flight tests to block heavy incoming clutter, but allow the BIT target to come through.

This procedure was modified for the operation modes to OPER, BST, and MSL. A logic line was brought out from the A1A3 card which, when held at logic "1" external of the system, provides receiver dumping during the range gate selected. By using the $\overline{Q}$ output of a .4µsec one-shot external to the system, the receiver can be turned on at any time during the range gate to allow a burst of the CW target through the receiver, thus simulating a discrete target return.

Antenna Search Programmer and Servo Modifications - A5 Circuit Board: The baseline AN/APQ-153 circuitry was modified to provide the mini-scan which occurs when in the OPER mode, the ACQ button is actuated, and not locked-on. The normal $\pm 42.5°$ scan at 85°/sec is generated by feeding a square wave into an integrator to produce the azimuth command triangular wave. The integrator's triangular output is sensed, and at predetermined levels, triggers the change in polarity of the input. The input square wave is then scaled and used as the elevation two-bar scan.

When mini-scan conditions exist, circuitry is switched in to change the pre-determined levels to those corresponding to $\pm 5°$. The scan rate is also cut in half to 42,5°/sec.

Additional circuitry also exists to sum in the bipolar voltage from the Set Control as a bias corresponding to the desired azimuth position of the ACQ Symbol. The result is a two bar mini-scan corresponding to the azimuth area inside the ACQ Symbol.

4.2.3 Processor - Continued

A6 Circuit Card: When locked-on to a target in any of the three operating modes, the antenna commences conical scan at a 6HZ rate. In the AN/APQ-153 baseline mode, MSL, the scan coverage is 5° elevation and 4° azimuth. The 6HZ antenna commands are generate and summed in on the A6 board. The circuit was modified to provide 3.5° elevation and 2.5° azimuth conical scan coverage when the OPER or BST angle track modes are selected.

The boresight steering or steering error circuitry is also contained on this board. For angle tracking the gain of the last stage in each axis was reduced by a factor of two (2) to create a greater range before saturation due to target acceleration. The remaining modification to this card was to allow adjustment of the gain of the boresight steering circuit to allow for the one-way transmission when using a CW target. A line is provided, that when grounded, doubles the gain.

Display Modifications - A7 Circuit Board: When in the MSL mode, the AIM BAR position is commanded by the boresight steering error output of the A1A6 board. Due to the gain of the last stage on the A1A6 board being cut in half for angle tracking purposes, a compensating change in gain of two (2) was made in each axis on this board, where the normal AN/APQ-153 AIM BAR is generated.

Circuitry on this board also sums in on the AIM BAR the aircraft wing twist input. Since the angle track AIM BAR is shaped prior to being sent to this board, the wing twist input must be sent to the shaping circuitry on the A15 board also. Therefore, circuitry was

4.2.3 Processor - Continued

added to switch out the wing twist input on the A7 board, and send it instead to the A15 board when OPER or BST are selected.

A8 Circuit Board: In the search mode, the Indicator B-scan horizontal deflection is a scaled version of the antenna stabilized azimuth command. In AN/APQ-153 system operation, any target acquisition mode interrupts this input to the deflection circuitry, allowing the Jizzled B-sweep to be generated. This circuit operation is desired in the BST or MSL modes. However, circuitry had to be added to delay the signal interruption in the OPER mode until full target lock-on occurred.

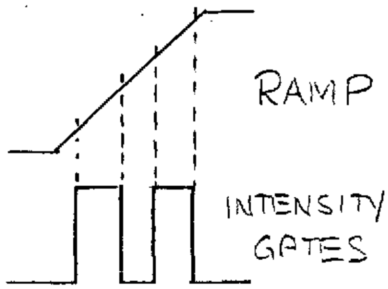
A9 Circuit Board: The actual circuitry for controlling the Jizzle B-sweep generation is contained on this board. Appropriate logic signals had to be brought in from the A15 board, as well as interruption of others, to delay the Jizzle Sweep in OPER until full target lock-on occurs.

ACQ Symbol Generation - Generation of the ACQ Symbol involved modifications to two (2) existing Processor boards, as well as circuitry on the new A15 board.

A7 Board: The existing cursors on the AN/APQ-153 are created by generating and processing a precision voltage ramp. The end result of the processing is a vertical deflection, a horizontal deflection, and an intensity gate(s) for each cursor. The intensity gate(s) are used by the indicator for proper synchronization of cursor writing. These gates are generated by feeding the pre-processed ramp into comparators with pre-set levels.

4.2.3 <u>Processor</u> - Continued

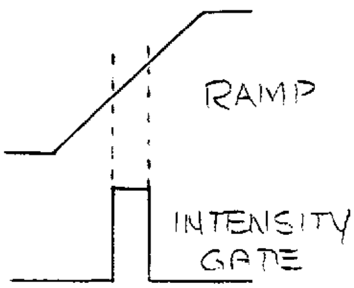
This new ACQ symbol is generated in this same manner. The deflections are obtained by appropriate processing of two successive ramps. The intensity gates are identical to those used for the TILT or AIM BAR cursor.



ATTITUDE CURSOR (— —)

HORIZONTAL DEFL. = (RAMP)·(COS ROLL ANGLE) + DC BIASES

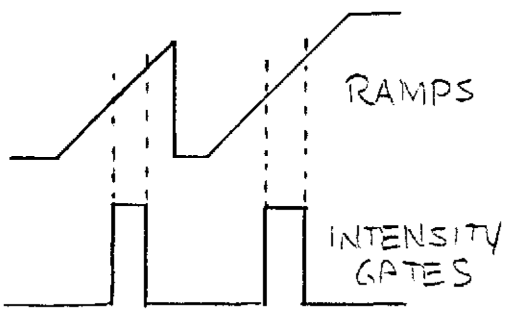
VERTICAL DEFL. = (RAMP)·(SIN ROLL ANGLE) + DC BIASES



TILT OR AIM BAR CURSOR (—)

HORIZONTAL DEFL. = (RAMP) + DC BIASES

VERTICAL DEFL = DC BIASES



ACQ SYMBOL CURSOR (/ /)

HORIZONTAL DEFL. = DC BIASES.

VERTICAL DEFL. = RAMPS + DC BIASES

4.2.3 Processor - Continued

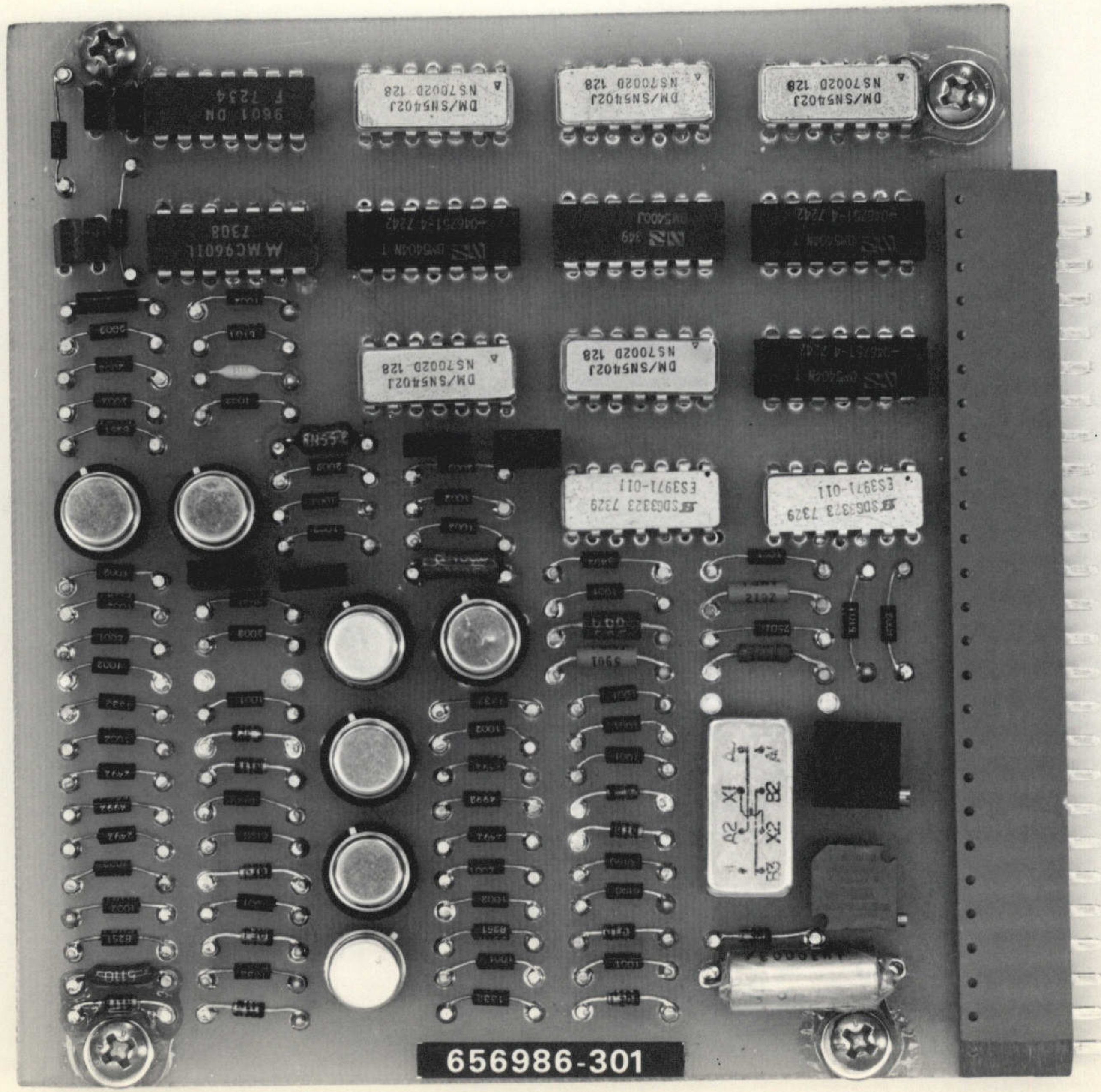
The appropriate circuitry for ACQ Symbol processing of the ramps is included on the A15 board.

A15 Board: This added board is shown in Figure 4.2.8. On this board, the analog positioning voltages for the ACQ Symbol are processed. The vertical deflection (or RANGE) is a combination of the two precision ramps, a unipolar voltage from the Set Control that is scaled appropriately, and a bias to allow the unipolar voltage to cause bipolar swing of the deflection output.

The horizontal deflection (or AZIMUTH) is a combination of the bipolar positioning voltage from the Set Control that is also scaled appropriately, and a specific + and - bias voltage, respectively, during each vertical deflection ramp. The + and - voltage spreads the bars of the ACQ Symbol ±5 degrees about the center.

In addition, circuitry on the A15 board generates the new TILT + AB + ACQ SYM time share gate which signals the start of the precision ramp(s) on the A1A7 card. A pulse from the A8 signals the time slot for the ACQ Symbol. The circuitry on the A15 "chop" this one pulse into two ramps to be generated, and through appropriate logic, combines the ACQ Symbol time share gate with that for the TILT or AIM BAR. The deflection signals are then used by the A8 Multiplexer Board.

A8 Board: The A8 board of the AN/APQ-153 contains circuitry that generates both the B-scan horizontal deflection and the vertical sweep occuring each PRF. In addition, through decoding circuitry, every 32nd sweep is "stolen" and a cursor, alternately the Attitude Cursor and the Tilt or Aim Bar, are written instead. Since another time slot


656986-301

4.2.3 Processor - Continued

was needed for the ACQ Symbol a decoding circuit modification was incorporated to create the ACQ Symbol time share gate. Circuitry was also added to sum in the ACQ Symbol deflections to the Composite Deflection Signals already generated.

Mode Switching and Logic Modifications - The A15 board contains the majority of mode control logic additions. The baseline AN/APQ 153 radar modes and performance was maintained while adding the two new angle track functions. The following list contains the function switching involved.

1. ACQ Symbol Generation (A15): Acquisition symbol to be generated only in OPER mode, not locked-on, not in Dogfight.

2. Jizzle Sweep Generation (A8, A9): Jizzled B-sweep to be generated in MSL or BST when acquisition button actuated, or when Dogfight actuated, or when in OPER and locked-on.

3. Angle Track Loop: Antenna commands to be switched from search programmer (A5) card to angle track (A16) card when in OPER or BST and locked-on, and not in Dogfight.

4. Antenna Search Pattern (A1A5): Antenna azimuth search ($\pm 42.5°$) to be changed to $\pm 5°$ about center of ACQ Symbol center when in OPER and acquisition button actuated, but not locked-on. Search rate also switched from 85°/sec to 42.5°/sec.

5. Track Gate Generation (A2, A12, A13, A14): Range gate to strobe as in AN/APQ-153 when MSL or MST selected. When OPER selected and Acquisition switch actuated, gate to be generated at center position

4.2.3 Processor - Continued

of ACQ Symbol and dithered in magnitude to coincide with range subtended by symbol.

6. Aim Bar Commands (A6, A7, A15, A16): When in MSL and acquisition switch actuated and locked-on, Aim Bar position to be commanded by boresight steering commands on A6 board. When in OPER or BST and locked-on, Aim Bar to represent, on a non-linear scale, antenna gimbal position. Boresight steering commands then used as input to A16 Angle Track board.

7. CW Target Operation (A3): To allow radar operation with CW target source, modified receiver dump circuits.

In addition to the above changes, following modifications were made were made to allow for use of lengthend cables (60 feet).

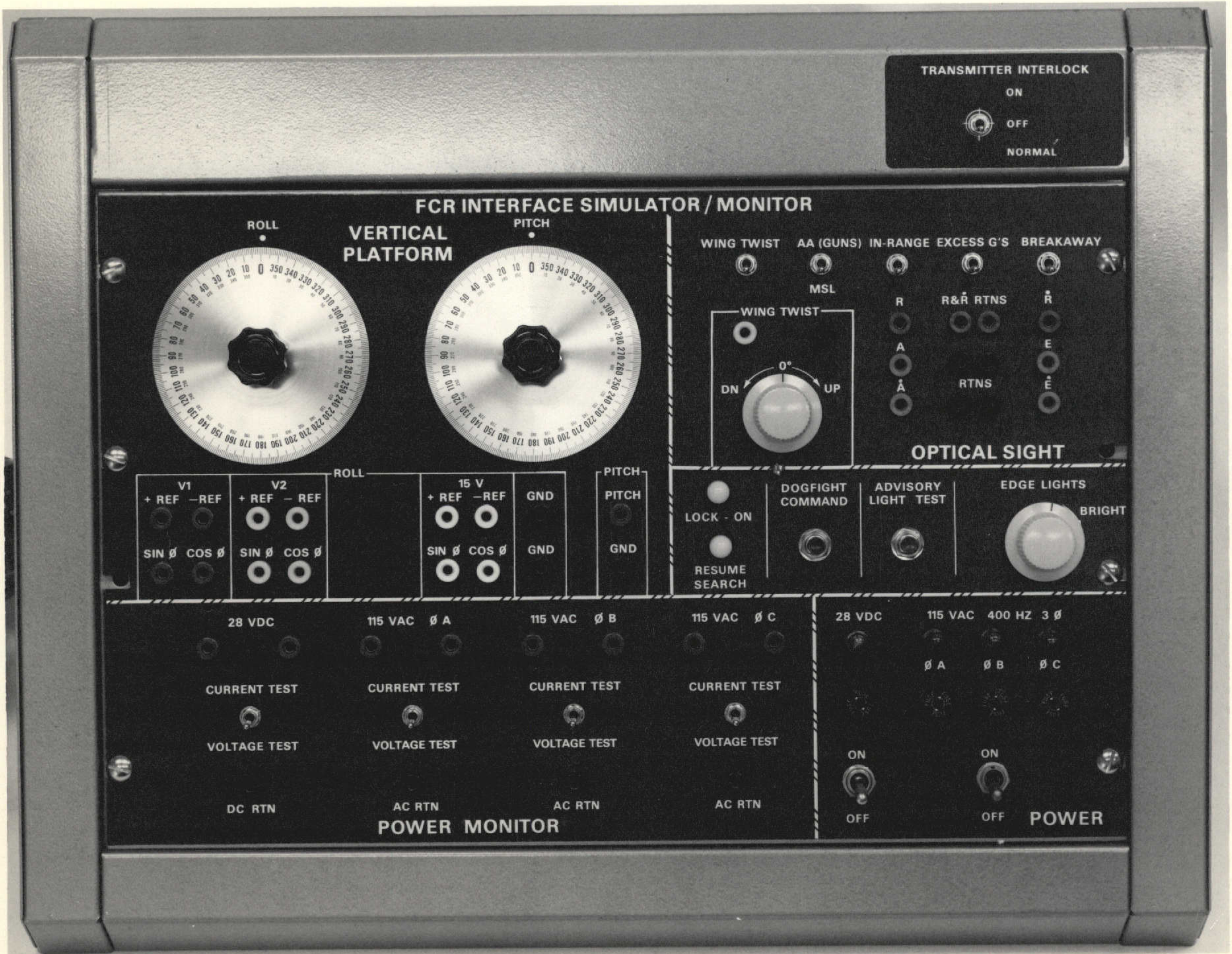
Receiver Video: Changed R6 on 656972-A1A2 board for impedance matching to prevent "ringing" on video line. Change R6 to 100Ω. Changing R6 provided too great a DC load to receiver, so had to add a 47μf capacitor (C20) in series with R6.

Transmit Sample Pulse: Upon comparing standard AN/APQ-153 cable to long cable, found approximately one-half volt drop in transmit sample pulse, causing FAIL light to illuminate. Therefore, lowered threshold on 656973-A1A8 BIT board by one-half volt.

Antenna Position Signals: Due to the long cables, the noise on the antenna position potentiometer signals to the 656976 board increased. Capacitors C47 and C48 were changed from .01μf to .1μf to alleviate this problem.

4.2.4 Aircraft Simulator Panel

The aircraft simulator panel used to control power and switching of Radar system is shown in Figure 4.2.9 additional test points were included on the front panel per NASA request along with a switching function to allow operation with the transmitter off.


TRANSMITTER INTERLOCK
ON
OFF
NORMAL
FCR INTERFACE SIMULATOR / MONITOR
ROLL
VERTICAL PLATFORM
PITCH
WING TWIST
AA (GUNS)
IN-RANGE
EXCESS G'S
BREAKAWAY
MSL
WING TWIST
R
R&Ṙ RTNS
Ṙ
A
E
Ȧ
Ė
RTNS
0°
DN
UP
OPTICAL SIGHT
V1
+ REF
−REF
SIN Ø
COS Ø
V2
+ REF
− REF
SIN Ø
COS Ø
ROLL
15 V
+ REF
−REF
SIN Ø
COS Ø
GND
GND
PITCH
PITCH
GND
LOCK - ON
RESUME SEARCH
DOGFIGHT COMMAND
ADVISORY LIGHT TEST
EDGE LIGHTS
BRIGHT
28 VDC
115 VAC Ø A
115 VAC Ø B
115 VAC Ø C
CURRENT TEST
VOLTAGE TEST
DC RTN
AC RTN
POWER MONITOR
28 VDC
115 VAC 400 HZ 3 Ø
Ø A
Ø B
Ø C
ON
OFF
POWER

5.0 Proposed Modifications/Additions

The following changes have been proposed to provide additional techniques for radar evaluation.

5.1 Range Rate Accuracy

In order to provide a higher range rate accuracy, the following are proposed system changes consistant with NASA applications.

1. Reduction of range rate limits from 3000 fps (closing) to 150 fps and from 1000 fps (opening) to 100 fps.

2. Reduction of Range Trucker bandwidth from 2Hz to 0.5Hz.

3. Reduction of acceleration error constant from $60/sec^2$ to $10/sec^2$.

Present spec (ATP) calls for accuracy better than 10 fps. Since no systems to date have been rejected for range rate accuracy, the 10 fps could be considered a 3 sigma value. With the above changes, the modifications would provide an accuracy of 3 fps (3σ).

Above changes would allow the scale factor to be increased to 100 mv/ft/sec as compared to 5 mv/ft/sec. The reduces the error contributions by a factor of 20 for those resulting from voltage offsets, etc. For example, a 20mv offset in the rate channel was an error of 4 fps, is now 0.2 fps. Noise contribution is reduced by bandwidth reduction. Further accuracy is attained by trimming the slope on the range ramps generator. Presently, small range variations on the slope result in rate errors at the close in ranges, however, the magnitude is small compared to the present accuracy requirement of 10 fps.

5.2 Frequency Agility

Addition of the frequency agility option will improve signal to clutter ratio, provide ECCM, increase detection range, reduce STAE (Second Time Around Echo) and reduce target fade and glint. All this will be accomplished with the present LRU envelope; the only LRU impacted is the receiver-transmitter. The weight of the LRU will increase by approximately 3 lbs.

System Operation and Performance

The operational performance of this pulse radar can be improved by the use of frequency agility where the transmitted frequency is changed on a pulse-to-pulse basis. The principal effect of varying the transmit frequency to separate pulse frequencies for a series of pulses during the time the radar beam scans a target is to reduce the correlation between various undesired radar returns such as clutter. Targets will appear more uniform to the pilot. The probability of detection will also increase as shown in Figure 5.2.1 for a two square meter target. Frequency agility will also improve angle tracking performance for the angle track option as the accuracy of a tracking system to determine the deviation of the target axis from the antenna axis is affected by target glint and fading, refraction errors in radomes and variations in the propagation media. These sources of angular resolution error can be averaged down by rapid variation as the transmission frequency. The peak-to-peak frequency excursion is 100 MHz at an agility rate of 85 Hz. Performance of frequency agility in rain is shown in Figure 5.2.4.

Hardware Description

Frequency agility is mechanized in the receiver transmitter LRU as shown in Figure 5.2.2. The present 6543 magnetron is replaced with an agile

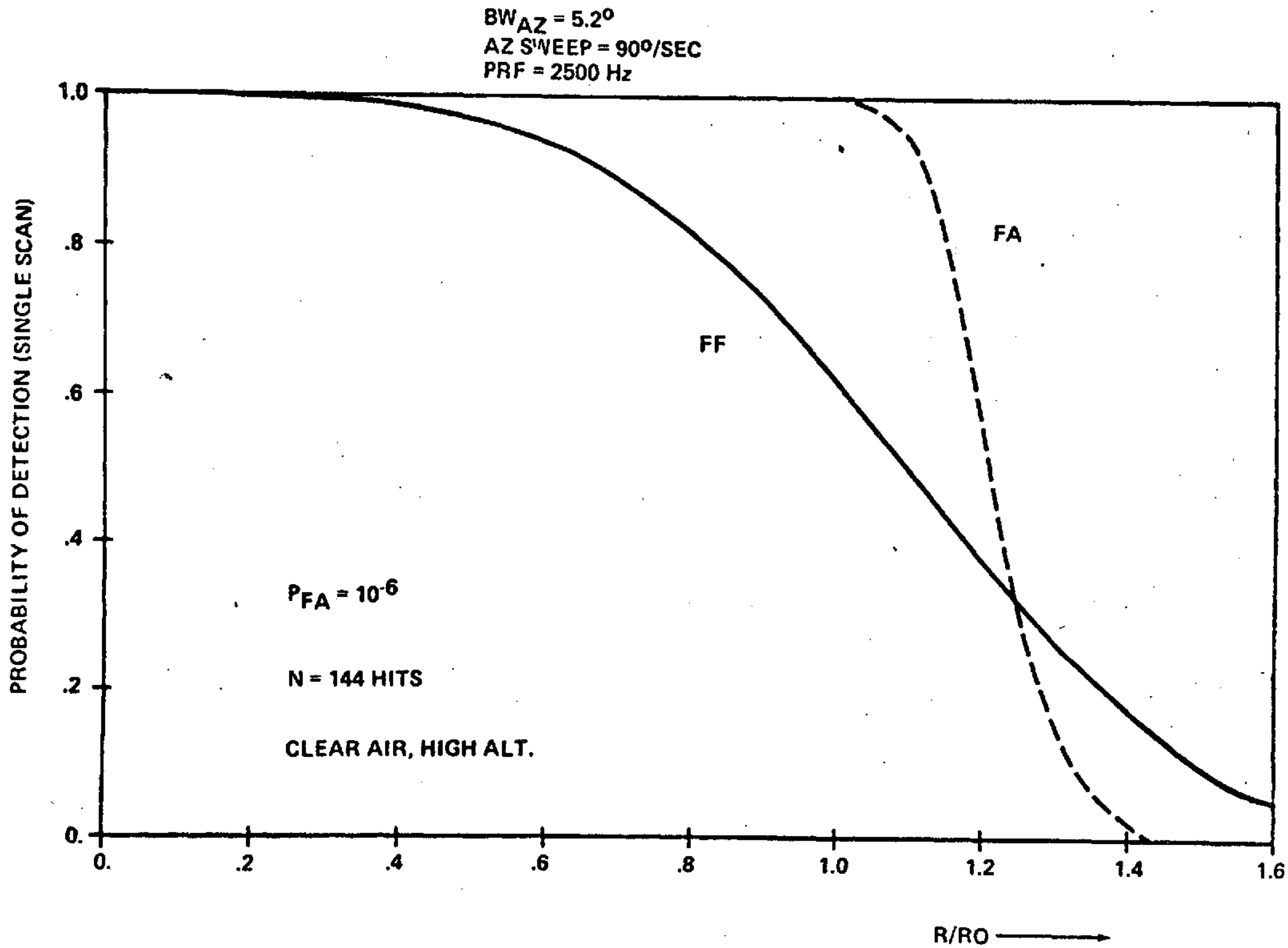


FIGURE 5.2.1 FREQUENCY AGILITY DETECTION RANGE

5.2 Hardware Description

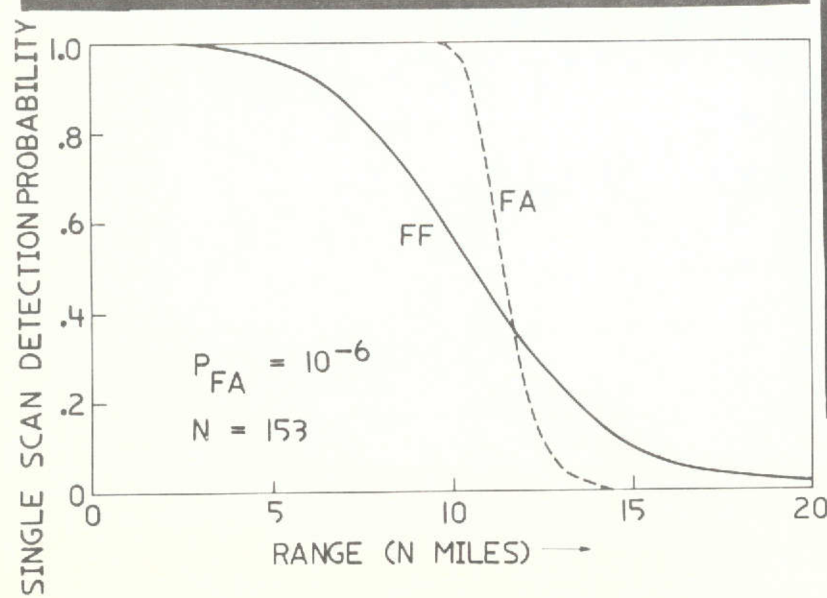
magnetron which has the same high voltage and RF interface with the modulator as the present magnetron.

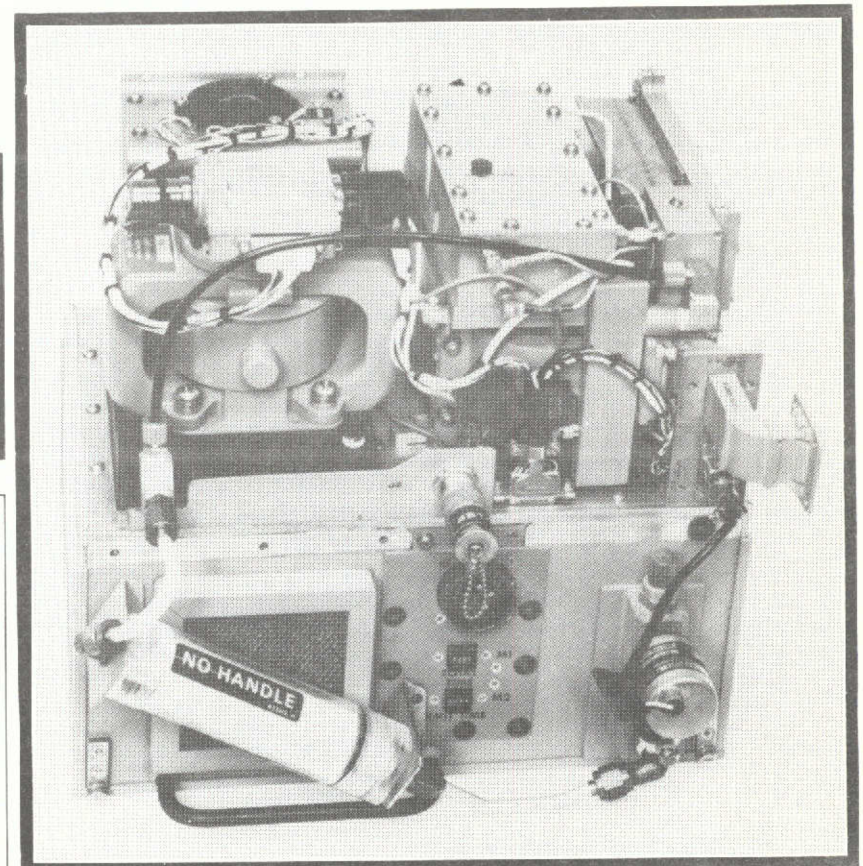
Several techniques are presently utilized in mechanized frequency agility in a coaxial magnetron. Two are considered for this application. The first technique is to dither a tuning plunger. The second technique is to drive an expanding ring at the agile rate to vary the cavity dimensions. In either case, a PM (Permanent Magnet) resolver is attached to the motor shaft to provide a readout voltage proportional to the transmitter frequency. This output is used in the coarse AFC loop.

The frequency agility technique requires that on a pulse-to-pulse basis the transmitter frequency be separated by an amount greater than the receiver bandwidth (3 MHz). This requires the transmitter output to be frequency modulated. The frequency modulation and agile rate are determined to be 100 MHz and 85 Hz respectively. Since the transmitter frequency is changed on a pulse-to-pulse basis, the AFC local oscillator (LO) must track the varying transmitter frequency. A block diagram of the frequency agility system is shown in Figure 5.2.4. The AFC loop is required to sample the transmitted RF frequency during the transmit pulse and then to generate a local oscillator frequency separated from the transmitter frequency by the system IF. As the transmitter frequency changes from pulse to pulse, the tracking local oscillator stabilizes to the transmitter frequency before the transmitter pulse is turned off. That stabilized frequency must be maintained over the interpulse period at least for a length of time corresponding to the maximum range of 20 NM. The AFC consists of a coarse and a fine tuning drive resolver output, which is proportional to frequency, as the feedback for the coarse loop. The local

FREQUENCY AGILITY GROWTH

- ANTI–JAMMING
- NARROW & SPOT JAMMING
- ALL WEATHER
- CONSISTENT DETECTIONS





HARDWARE IN TEST

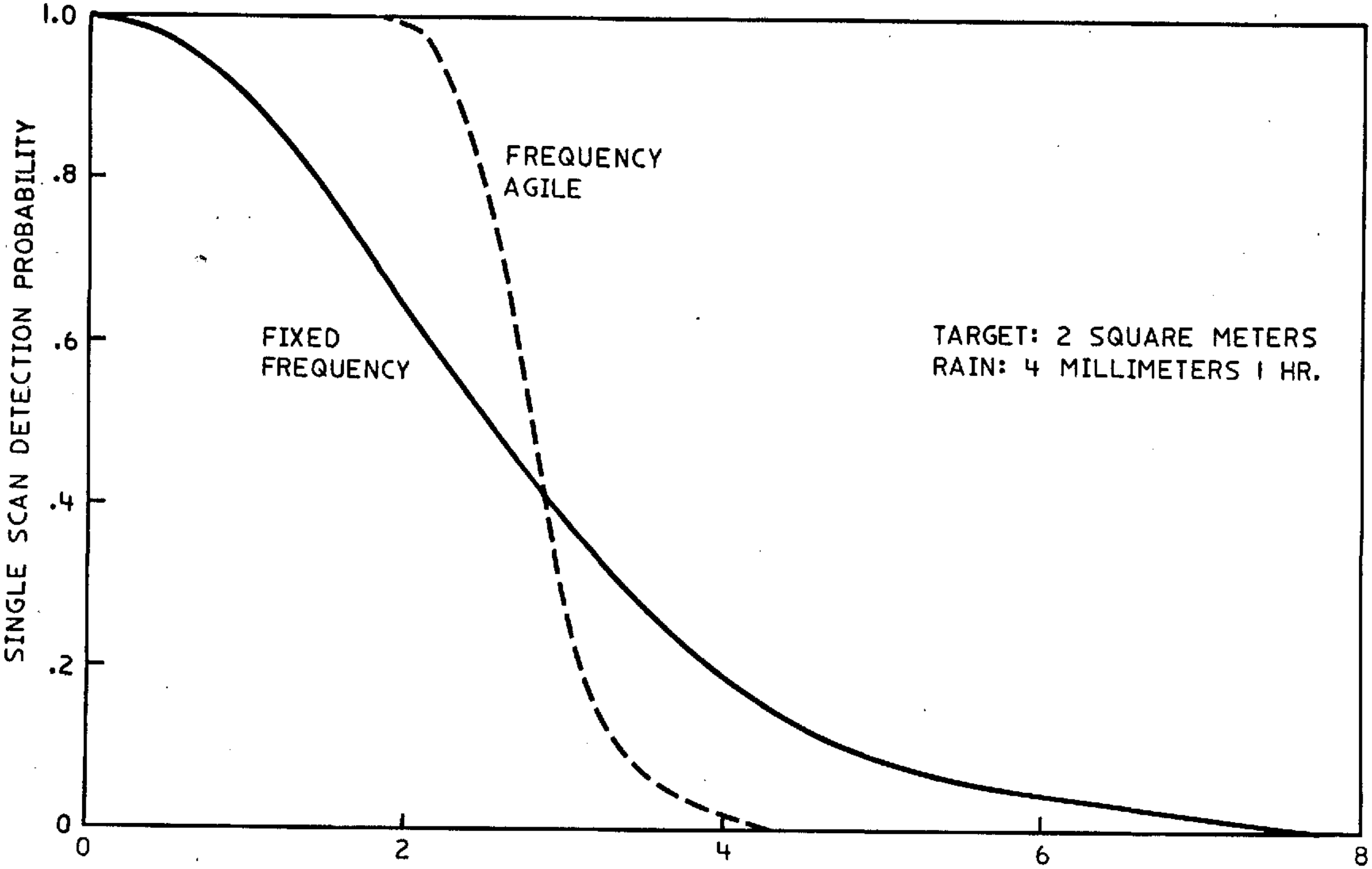
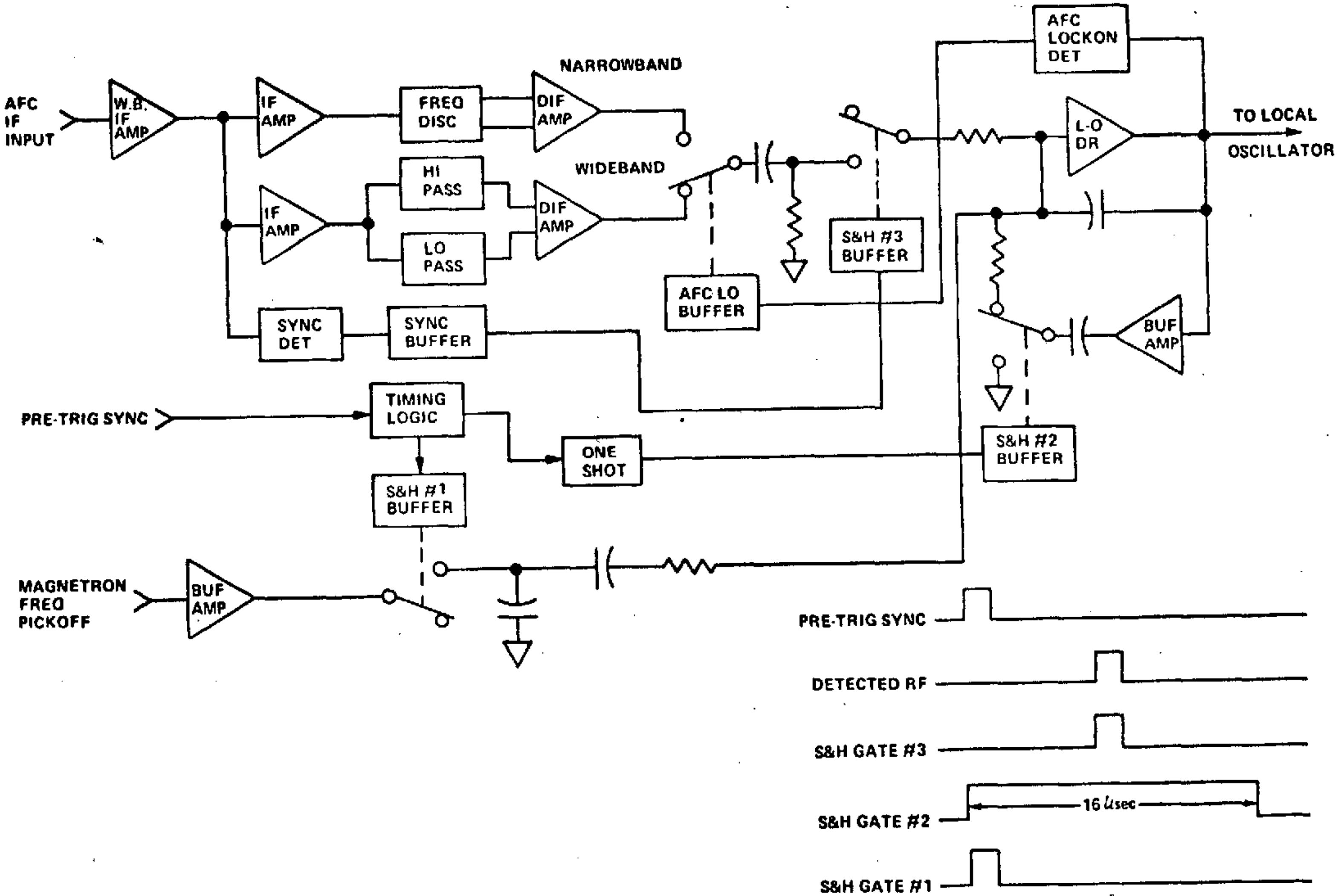


FIGURE 5.2.3
PERFORMANCE IMPROVEMENT IN RAIN



AFC IF INPUT
W.B. IF AMP
IF AMP
FREQ DISC
DIF AMP
NARROWBAND
IF AMP
HI PASS
LO PASS
DIF AMP
WIDEBAND
AFC LOCKON DET
L-O DR
TO LOCAL OSCILLATOR
S&H #3 BUFFER
AFC LO BUFFER
SYNC DET
SYNC BUFFER
BUF AMP
PRE-TRIG SYNC
TIMING LOGIC
ONE SHOT
S&H #2 BUFFER
S&H #1 BUFFER
MAGNETRON FREQ PICKOFF
BUF AMP
PRE-TRIG SYNC
DETECTED RF
S&H GATE #3
S&H GATE #2
16 usec
S&H GATE #1

FIGURE 5.2.4

5.2 Hardware Description

oscillator frequency is controlled using the resolver pickoff as the feedback to tune the LO each time the system sync pulse occurs. Since the system sync pulse occurs approximately 8 microseconds before the transmitted pulse, the coarse AFC loop has 8 microseconds to settle to within the coarse pickoff frequency. Upon the occurrence of the transmitted pulse the AFC fine loop then samples the transmit frequency and closes the fine loop aroung the local oscillator to maintain the local oscillator within the IF separation. This frequency of the local oscillator is then held for a time corresponding to 20 NM range.

In addition to requiring a new agile magnetron, the frequency agility modification also requires a new local oscillator and the above-described AFC circuits. The new local oscillator must have a tuning range compatible with the agile magnetron. A unit with the same physical dimensions as the present LO is installed in the same location. The receiver module contains the AFC circuits. With the addition of frequency agility an additional circuit board is required in the receiver module. To accomodate this, the height of the module is increased approximately 1/2 inch. This allows the installation of the new AFC circuits which require two printed circuit boards to replace the existing single AFC board. The additional height of the receiver module, however, does not require an increase in the overall receiver-transmitter LRU envelope.

5.3 Flat Plate Antenna

The option of adding a slotted flat plate array to the AN/APQ-153 will significantly increase its performance. This option can be added independent of, or with, any combination of the offered option. It has the highest performance-to-cost ratio of any addition.

5.3 Flat Plate Antenna

System Performance - Range performance of the system is increased by 3 db for return signal power of 0.75 db in range. This is the result of an increase in one way gain of 1.5 db over the parabolic deflector. In addition, the peak sidelobes are reduced 5 db minimum and the 90° lobes are virtually non-existent. The array performance is listed in the table below.

Form Factor - elliptical

Aperture Dimensions - 12 x 19.5 inches max.

Center Frequency - 9300 MHz

Bandwidth - $\pm$ 150 MHz

Polarization - Horizontal

Antenna Gain - 29.5 db minimum

Half Power Beam Width - 4.7° nominal E Plane (Azimuth)
7.7° nominal H Plane (Elevation)

Sidelobe - Lower than -24 db

VSWR - 1.5 max.

Peak Power - 160 KW

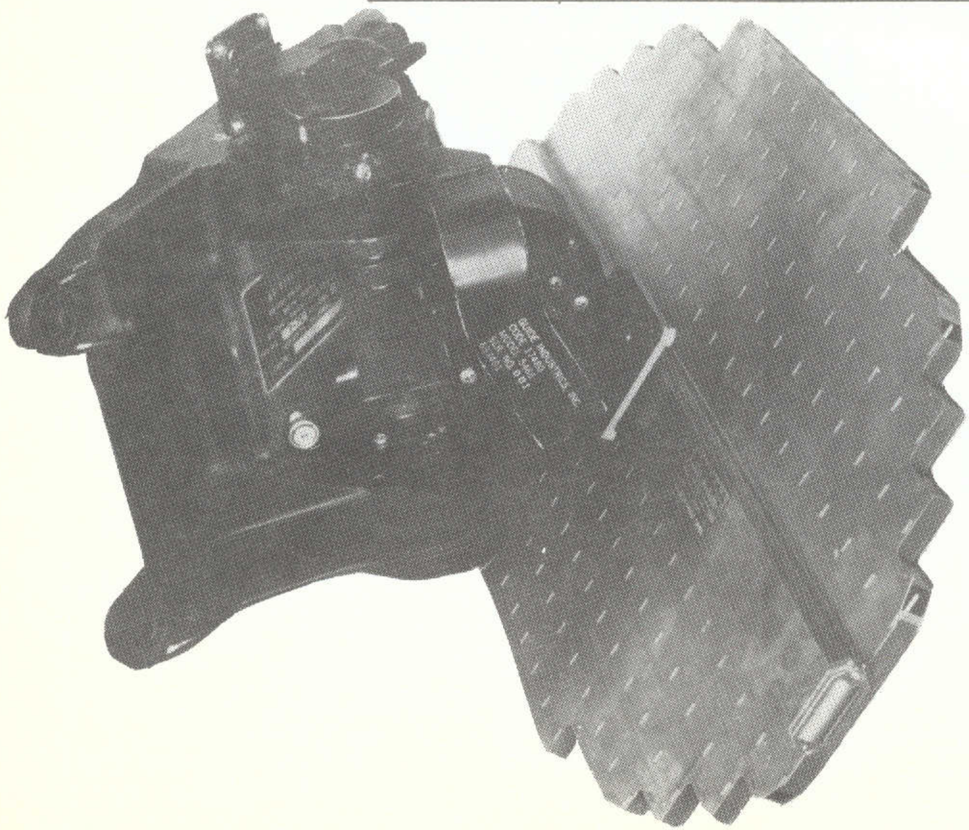
Altitude - 50,000 ft. max.

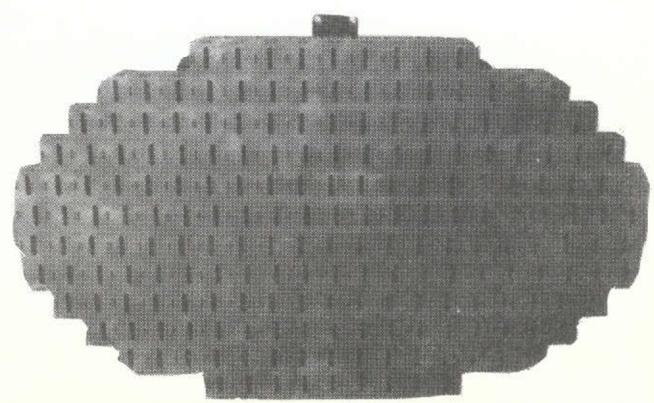
Weight - less than 24 oz.

Hardware Description - The flat plate antenna as shown mounted on the gimbal in Figure 5.3.1 consists of a two-dimensional array of slots regularly spaced on a plane aperture. These slots are excited by a network of parallel waveguides which also provide structural rigidity for the antenna. The feed system couples energy into each of the parallel aperture waveguides. The given aperture distribution is synthesized by adjustment of the feed system coupling and the radiating slot coupling. A 30 db modified Taylor distribution will be used to obtain the necessary low sidelobe structure. A characteristic of the flat plate is the high

FLAT PLATE ANTENNA

PROTOTYPE FOR F-5E/F CONFIGURATION
DEVELOPED
FLIGHT TEST IN PROGRESS





BASIC/IMPROVED RADAR COMPARISON

ANTENNA PARAMETER	PARABOLA	FLAT PLATE
ANTENNA GAIN	28 DB	29.5 DB
SIDELOBES	-19 DB	-24.0 DB
DOWNLOBE	-28 DB	-45.0 DB

The Flat Plate results in 19% more detection and lock-on range, significant reduction in ground clutter at low altitudes, and elimination of altitude line lockon or transfer.

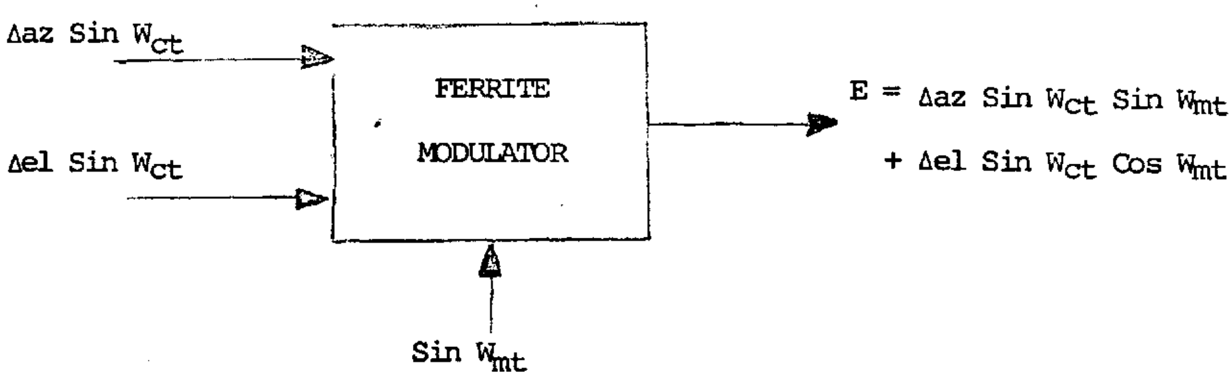
5.3 Flat Plate Antenna

aperture efficiency obtainable, which shows up in the increase in gain. The input power will be split and routed to each end of the coupling waveguide. The array is designed to operate with an input power of up to 160 KW peak at an altitude of 50,000 ft. To eliminate high power breakdown, the feed line will be pressurized. The antenna array and its feed is a single aluminum dip-brazed assembly. The antenna array is fabricated from two precision plates and a series of divider strips. The strips are parallel and form the narrow walls of the radiating waveguide.

5.4 Single Channel Monopulse Angle Tracker

Monopulse angle tracking capability applied to the APQ-153 will provide a significant improvement in angle tracking accuracy. The technique described here provides the benefits of monpulse while retaining the existing simplicity of the basic APQ-153. The block diagram in Figure 1 illustrates the technique.

A conventional 2-axis monopulse antenna (flat plate) and a mating monopulse comparator comprise the antenna portion of the system. The azimuth and elevation error signals, Δaz and Δel are coupled to a ferrite modulator which combines these signals as shown below.



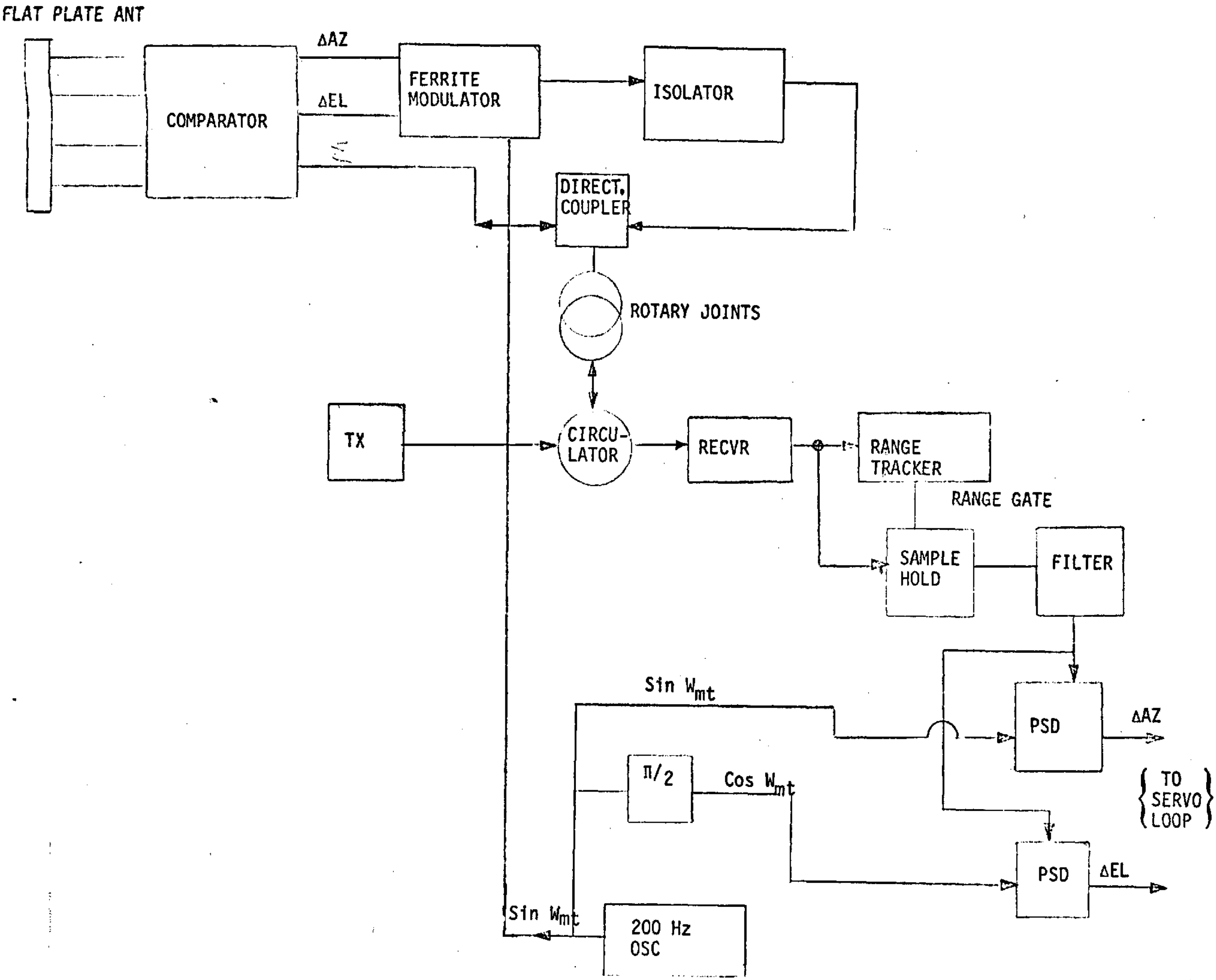


FIGURE 5.4.1 BLOCK DIAGRAM

5.4 Single Channel Monopulse Angle Tracker

The output is a double sideband, suppressed carrier signal whose envelope phase is determined by $\tan^{-1}\left(\frac{\Delta az}{\Delta el}\right)$.

Since the carrier is a pulse train envelope, recovery is accomplished by use of a range gate, sample and hold, and filter. The PSD reference is the original modulating signal - Sin W_{mt} and its quatrature, Cos W_{mt}. The modulating frequency will be roughly 200 Hz. This is a compromise value consistent with system dynamic response, and PRF values.

When performing an air-ground ranging function it is desirable to roll stabilize the system. This can easily be accomplished by utilizing both Δaz and Δel data. For 0° roll, only el information is used in the ranging function. If the roll angle is 90°, Δaz, is used instead. For intermediate roll angles, the vector sum of Δaz and Δel is used.

This processing is most easily accomplished by phase shifting the PSD references as a function of roll angle. Output is accepted only from the Δel channel. At 0° roll the reference is at 0° also. For 90° roll angle the reference is shifted 90° and the PSD now responds to Δaz only. For intermediate angles the PSD output becomes equivalent to the combination of Δaz and Δel corresponding to a vertical cut through the antenna pattern, which is the desired response.

This system retains all the benefits of a full monopulse system, without the need for multiple rotary joints, parallel receiver channels, etc.

APPENDIX

A.1 FLIGHT TEST DATA

A.2 SERVO ANALYSIS

A.3 ACCEPTANCE TEST PROCEDURE

A.1 FLIGHT TEST DATA

Following data summary is a result of Northrop/Emerson/Air Force flight test during 1974.

FLIGHT TESTS CONDUCTED SEPTEMBER 11, 1974

- TESTS AT HIGH, MEDIUM, AND LOW ALTITUDES WITH HORIZONTALLY POLARIZED FLAT PLATE ANTENNA AND FREQUENCY AGILITY:
    - MAXIMUM DETECTION RANGE
    - ALTITUDE LINE REDUCTION
    - HAT SECTION
    - GROUND CLUTTER
    - STAE
- MISSILE DOGFIGHT MODE
- OFF-BORESIGHT TARGET ACQUISITION AND ANGLE TRACK
    - WITHIN THE RADAR SEARCH VOLUME
    - VARIOUS ROLL MANEUVERS
    - LOS RATE MANEUVERS
    - HIGH G RATES
- 30 FLIGHTS TOTAL
- 4 USAF/JTF FLIGHTS

REDUCED PILOT WORKLOAD AND IMPROVED TACTICAL FLEXIBILITY-FLIGHT TEST RESULTS (SEPTEMBER 11, 1974)

ITEM EVALUATED	RESULTS SATISFY PERFORMANCE OBJECTIVES
MISSILE MODE HEAD DOWN STEERING	YES
BORESIGHT STEERING WITH ANGLE TRACK	YES
OFF-BORESIGHT ACQUISITION	YES
RADAR COVERAGE IN GUN MODE WITH ANGLE TRACK	YES
D/F GUNS, D/F MISSILE AND RESUME SEARCH SWITCH ON STICK GRIP	YES

BASIC/IMPROVED RADAR COMPARISON OF DETECTION AND LOCK-ON RANGES AGAINST A CO-ALTITUDE T-38 TARGET

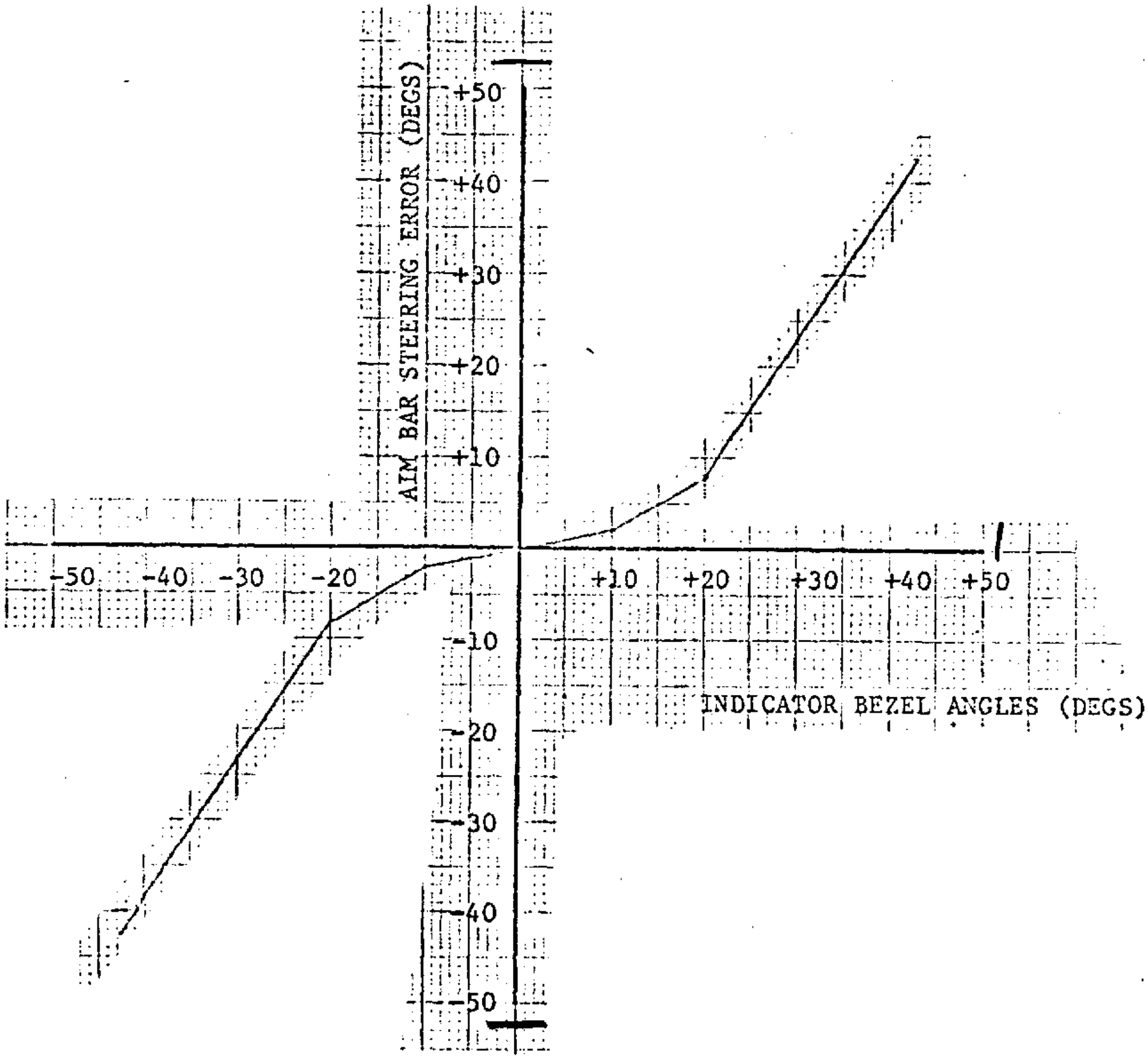
		BASIC RADAR		IMPROVED RADAR	
ALTITUDE (AGL)		SPEC	FLIGHT TEST, AUGUST 1974	MINIMUM EXPECTED	FLIGHT TEST, AUGUST 1974
20,000 FEET					
	DETECTION	8 N.M.	8-2/3 N.M.	9 N.M.	10-1/2 N.M.
	LOCK-ON	4 N.M.	5-1/2 N.M.	6 N.M.	7-1/2 N.M.
12,500 FEET					
	DETECTION		6 N.M.		9 N.M.
	LOCK-ON		4 N.M.		6 N.M.
2,500 FEET					
	DETECTION	2 N.M.	2-1/2 N.M.	3 N.M.	4-1/2 N.M.
	LOCK-ON	1-1/3 N.M.	1-3/4 N.M.	2 N.M.	3-1/4 N.M.

DETECTION - RANGE FLIGHT TEST RESULTS (CO-ALTITUDE TESTS ONLY) (SEPTEMBER 11, 1974)

TEST CONDITIONS	TEST RESULTS N.M. RANGE	BLIP SCAN %	RESULTS SATISFY PERFORMANCE OBJECTIVES
30,000 FT MSL AT 18,000 FT AGL AND 27,500 FT AGL OVER MOUNTAIN AND DESERT TERRAIN	9.25	90	YES (8 N.M.)
	12.0	10	
15,000 FT MSL AT 12,500 FT AGL OVER DESERT TERRAIN	8.0	90	YES
	9.5	10	
5,000 FT MSL AT 2,500 FT AGL OVER DESERT TERRAIN	3.5	90	YES (2.2 N.M.)
	5.0	10	

CLUTTER - FLIGHT TEST RESULTS (SEPTEMBER 11, 1974)

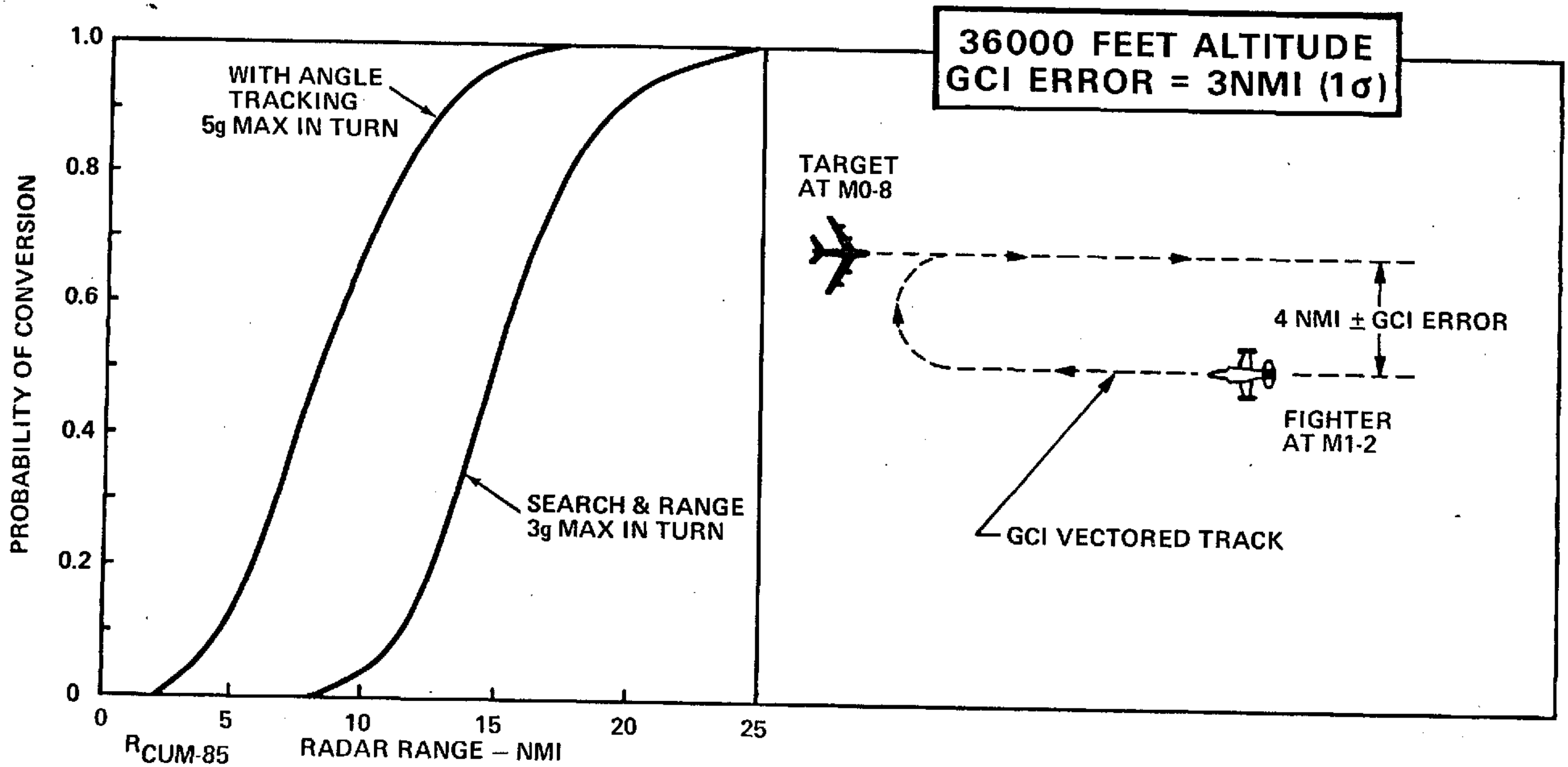
TEST CONDITIONS	TEST RESULTS	RESULTS SATISFY PERFORMANCE OBJECTIVES
MEDIUM AND HIGH ALTITUDE (15 & 30 K FT)	STAE IS NEARLY ELIMINATED. IT DOES NOT INTERFERE WITH TARGET DETECTION OR TRACKING IN THE 90% BLIP SCAN RANGE ENVELOPE.	YES
2,500 FT AGL AND ABOVE	ALTITUDE LINE IS VISIBLE BUT DOES NOT LIMIT TARGET DETECTION, ACQUISITION OR TRACKING OVER LAND.	YES
2,500 FT AGL AND ABOVE	SIDELOBES ARE BARELY VISIBLE AND DO NOT INTERFERE WITH DETECTION OR TRACKING.	YES


AIM BAR STEERING ERROR (DEGS)
+50
+40
+30
+20
+10
-10
-20
-30
-40
-50
-50
-40
-30
-20
+10
+20
+30
+40
+50
INDICATOR BEZEL ANGLES (DEGS)

TARGET FADE - FLIGHT TEST RESULTS
(CO-ALTITUDE TESTS ONLY)
(SEPTEMBER 11, 1974)

TEST CONDITIONS	TEST RESULTS	RESULTS SATISFY PERFORMANCE OBJECTIVES
30,000 FT MSL AT 27,500 FT AGL OVER DESERT TERRAIN	NO TARGET LOSS IN SEARCH OR TRACK WITH T-38 AT 9-1/2 N.M. OR LESS	YES ($\geq$ 8 N.M.)
30,000 FT MSL AT 18,000 FT AGL AVERAGE OVER MOUNTAIN TERRAIN	NO TARGET LOSS IN SEARCH WITH A T-38 AT 8 N.M. OR LESS	YES ($\geq$ 8 N.M.)
15,000 FT MSL AT 12,500 FT AGL OVER DESERT TERRAIN	LESS THAN 10% TARGET LOSS WITH T-38 AT 5 N.M. OR LESS	NO ($\geq$ 6 N.M.)
5,000 FT MSL AT 2,500 FT AGL OVER DESERT TERRAIN	LESS THAN 10% TARGET LOSS WITH T-38 AT 2.5 N.M.	YES ($\geq$ 2.2 N.M.)

PROBABILITY OF CONVERSION FOR SIDEWINDER, GUN ATTACK FOR CO-ALTITUDE TARGETS WITHIN SEARCH COVERAGE



A.2 SERVO ANALYSIS

This report addresses the correlation of measured and theoretical angle-track characteristics. Test results were measured on the brassboard configuration of the AN/APQ-153 as modified for angle track.

INTRODUCTION

The inclusion of angle track into the APQ-153 was accomplished by establishing a set of requirements, analyzing the existing system and establishing theoretical modifications necessary to incorporate angle track, design and breadboard the modifications, test the modifications and obtain pertinent performance data, correlate the analysis with test results.

Each of these tasks are discussed in the following paragraphs.

REQUIREMENTS

The basic requirements are:

1. Maintain target track in aircraft environment.

	ANGLE (Degrees)	RATE (Degrees/Sec)	ACCELERATION (Degrees/Sec^2)
ROLL	360	230	500
PITCH	360	40	100
YAW	360	50	50

2. Maintain static tracking accuracy of 3 mr (1σ).
3. Maintain tracking accuracy of 5 mr for tracking rates of 30 to 60 degrees/second.

With these major requirements in mind the system analysis was conducted. The following analysis is a brief outline of that analysis. Further chronological occurrences and results are available upon request.

ANALYSIS

After considering alternate approaches to rate stabilization (ref. "Alternate Approaches for Space Stabilization of APQ-153 Antenna in Track Mode", 14 June 1973), the approach shown in Figure 1 was choosen with the associated constants shown in Table I. Using the polynominal factor routine (ref: "Computer Aided Analysis and Design of Linear Control for APQ-153", 16 July 1973) developed during this RPA program the track response (transfer function) was determined to be:

$$\frac{\theta_T}{\theta_S} = \frac{(\frac{S}{2.5}+1)(\frac{S}{2.5}+1)(\frac{S}{40}+1)(\frac{S}{71}+1)(\frac{S^2}{240^2}+\frac{2(.4)S}{240}+1)}{(\frac{S}{2.5}+1)(\frac{S}{16}+1)(\frac{S}{560}+1)(\frac{S^2}{3.4^2}+\frac{2(.99)S}{104}+1)(\frac{S^2}{104^2}+\frac{2(.99)S}{104}+1)(\frac{S^2}{99^2}+\frac{2(.3)S}{99}+1)(\frac{S^2}{240^2}+\frac{2(.5)S}{240}+1)} \quad (1)$$

The computer output used to obtain equation #1 is shown in Table II. Several gain variations are also presented in Table II for future reference.

The response to a disturbance (a/c) input was determined to be:

$$\frac{\theta_T}{\theta_D} = \frac{S^3\ (\frac{S}{40}+1)}{290\ (\frac{S}{16}+1)(\frac{S^2}{3.4^2}+\frac{2(.6)S}{3.4}+1)(\frac{S}{104}+1)(\frac{S^2}{100^2}+\frac{2(.3)S}{100}+1)} \quad (2)$$

A straight line approximation of equation 2 is shown in Figure 2.

The deviation allowing determination of equation 2 is shown in Appendix A.

CIRCUIT MODIFICATION

With the above analysis and resulting equations, the circuits of Figure 3 were designed and breadboarded as modification to the existing APQ-153 to incorporate angle track. These circuits resulted from the above equations and the desire to retain the existing circuitry of the 058 card.

TEST DATA

With the system in full operation with the large torque motor in azimuth the following data was taken.

1. Frequency responses
2. Acquisition transients and static tracking accuracy
3. Track errors caused by antenna base motion

Each data item is expanded below.

1. FREQUENCY RESPONSES

The following frequency responses were taken

1.1 Closed position loop both azimuth and elevation

Data - Table III

Plot - Figures 4 and 5

1.2 Closed rate loop (az and el)

Data - Table IV

Plot - Figures 6 and 7

1.3 Closed track loop (az and el)

Two sets of responses were obtained for 2 sets of gains (low rate feedback gain and high rate feedback gain)

LOW RATE GAIN

Data - Tables V, VI

Plot - Figure 8

HIGH RATE GAIN

Data - Tables VII, VIII

Plot - Figures 9 and 10

2. ACQUISITION TRANSIENTS AND STATIC TRACK ACCURACY

With the antenna in the mini-search mode, multiple acquisitions of the same target were obtained and appear in Figures 11 and 12. An expanded time trace for acquisition appears in Figure 13.

The measured results are as follows:

ELEVATION

1. Mini-search amplitude - 3 degrees
2. 6 Hz scan with 2.7 degrees (P-P) amplitude
3. Track Loop .5 Hz natural frequency
   .5 damping ratio
4. Tracking ripple - less than .5 degrees (P-P)
5. Settling Time (from initiate track to less than .5° of steady state (track) - approximately 2.0 seconds

AZIMUTH

1. Mini-search amplitude - 10°
2. 6 Hz scan with 2.4° (P-P) amplitude
3. Track Loop - .5 Hz natural frequency
   .5 damping ratio
4. Tracking ripple - less than .5° (P-P)
5. Settling time - approximately 2.0 seconds

The track error (PSD output) for both azimuth and elevation are shown on the traces of Figure 14.

3. TRACK ERRORS FROM BASE MOTION

The system maintained track on this fixed target to within ±2.0° with rate table driving at a distorted sinusoid yielding maximum rates of 100°/sec and maximum accelerations of 214°/sec^2. These above maximum rates and accelerations of the antenna base are calculated on the basis of obtaining the Fourier Series of the table motion.

The table motion was measured using the rate gyro output from the phase sensitive detector. The picture of Figure 15 was recorded and noted to have a maximum rate of 100°/sec for negative peak and 82°/sec for the positive peak. Approximating this curve by the following:

$$
\begin{aligned}
y &= (1.25)\,t \quad \text{for } 0 \le t \le .8 \\
y &= -(.6)\,t + 1.48 \quad \text{for } .8 < t \le 3.8 \qquad (3) \\
y &= (.667)\,t - 3.33 \quad \text{for } 3.8 < t \le 5
\end{aligned}
$$

A computer program was used to obtain the following Fourier Series representation of the rate in degrees/second.

$$\dot{\theta} = 5 + 10 \sin wt + -7 \sin 3\,wt - 5 \sin 4\,wt + 1.7 \sin 6\,wt + 71 \cos wt + 10 \cos 2\,wt - 3.2 \cos 3\,wt - 2.6 \cos 4\,wt \tag{4}$$

where

$$w = 1.25$$

Equation 4 uses only the most significant terms.

Differentiating equation 4 and substituting w = 1.25 yields:

$$\theta = 214°/\text{sec}^2$$

The trace of azimuth error and antenna pot are shown in Figure 16 for the conditions stated above. The trace of Figure 17 shows the same traces for a rate table decrease of approximately half the frequency.

CORRELATION OF ANALYSIS AND TEST RESULTS

Antenna Track Response

From measured frequency response data the following simplified expression was derived

$$\frac{\theta_T}{\theta_S} = \frac{(1 + .32\,S)}{\left[\frac{S^2}{3.14^2} + \frac{2(.5)S}{3.14} + 1\right]} \tag{5}$$

And the corresponding error equation is

$$\frac{\theta_\varepsilon}{\theta_S} = \frac{S^2}{10\left[\frac{S^2}{3.14^2} + \frac{2(.5)S}{3.14} + 1\right]} \tag{6}$$

For θ_S = unit step = $\frac{1}{S}$

$$\theta_\varepsilon = \frac{S}{10\ [\frac{S^2}{3.14^2} + \frac{2(.5)S}{3.14} = L]} \tag{7}$$

The inverse transform of equation 7 is:

$$\theta_\varepsilon(t) = e^{-at}\ [\cos bt - \frac{a}{b} \sin bt] \tag{8}$$

Equation 8 is obtained in the following manner:

$$L^{-1}\ [\frac{1}{(S + a)^2 + b^2}] = (\frac{1}{b})\ e^{-at} \sin bt \tag{9}$$

and

$$L^{-1}\ [\frac{S + a}{(S + a)^2 + b^2}] = e^{-at} \cos bt \tag{10}$$

Rewriting 7 we obtain

$$L^{-1}\ [\frac{S + a - a}{(S + a)^2 + b^2}] = L^{-1}\ [\frac{S + a}{(S + a)^2 + b^2}] + L^{-1}\ [\frac{-a}{(S + a)^2 + b^2}] \tag{11}$$

From equation 11 we obtain equation 4, where

$$\left.\begin{array}{l} a = 1.6 \\ \text{and} \\ a^2 + b^2 = 10 \\ \text{then} \\ b = 2.7 \end{array}\right\} \tag{12}$$

Therefore we have

$$\theta_\varepsilon(t) = e^{-1.6t} [\cos (2.7 t) - .6 \sin (2.7 t)] \tag{13}$$

which is the track error response to a step. Figure 18 is a plot of equation 13.

The error response to a ramp is

$$\theta_\varepsilon = \frac{1}{10 \left(\frac{S^2}{3.14^2} + \frac{2(.5)S}{3.14} + 1\right)} \tag{14}$$

and

$$\theta_\varepsilon(t) = \frac{e^{-\frac{\alpha}{2} t} \sin \left[\left(\beta - \frac{\alpha^2}{4}\right)^{1/2} t\right]}{\left(\beta - \frac{\alpha^2}{4}\right)^{1/2}} \tag{15}$$

where

$$\begin{aligned} \alpha &= 3.14 \\ \beta &= 10 \end{aligned} \tag{16}$$

$$\theta_\varepsilon(t) = \frac{e^{-1.6t} \sin 2.7 t}{2.7} \tag{17}$$

Figure 19 is a plot of equation 17.

The error response to an acceleration is:

$$\theta_\varepsilon = \frac{1}{10 S \left(\frac{S^2}{3.14^2} + \frac{2(.5)S}{3.14} + 1\right)} \tag{18}$$

where

$$\theta_{\varepsilon}(t) = \frac{1}{\beta} - \frac{e^{-\frac{\alpha}{2}t}}{(\beta)^{1/2}\, b} \quad \sin\,[bt + \tan^{-1}\,(\frac{4\beta}{\alpha^2} - 1)^{1/2}] \qquad (19)$$

for

$$\theta_{\varepsilon} = \frac{1}{S\ (S^2 + \alpha\, S + \beta)} = \frac{1}{S\ (S^2 + 3.2\ S + 10)} \qquad (20)$$

where

$$b = (\beta - \frac{\alpha^2}{4})^{1/2} = 2.7 \quad ; \qquad \alpha = 2a$$

Equation 19 becomes

$$\theta_{\varepsilon}(t) = \frac{1}{10} - \frac{e^{-1.6t}}{(\sqrt{10})\ (2.7)} \quad \sin\,(2.7\ t + \tan^{-1}\ 1.7) \qquad (21)$$

The plot of equation 21 is shown on Figure 20.

ANTENNA DISTURBANCE RESPONSE

The disturbance response can be approximated in the region of interest by the expression:

$$\frac{\theta_T}{\theta_D} = \frac{S^3}{290\ (\frac{S}{16} + 1)\ (\frac{S^2}{3.14^2} + \frac{2(.5)S}{3.14} + 1)} \qquad (22)$$

Applying an acceleration of 290 rad/sec^2 yields

$$\therefore\ \theta_T = [\frac{1}{(\frac{S}{16} + 1)\ (\frac{S^2}{3.14^2} + \frac{2(.5)S}{3.14} + 1)}] \qquad (23)$$

$$\theta_T(t) = \frac{T\ \omega^2\ e^{-\frac{t}{T}}}{(1 - 2\ \zeta\ T\ \omega + T^2\ \omega^2)} + \frac{\omega\ e^{-\zeta\omega t}\ \sin\ (\omega\sqrt{1 - \zeta^2}\ t - \psi)}{[(1 - \zeta^2)\ (1 - 2\ \zeta\ T\ \omega + T^2\ \omega^2)]^{1/2}} \tag{24}$$

where

$$\psi = \tan^{-1}\ (\frac{T\ \omega\ \sqrt{1 - \zeta^2})}{1 - T\ \zeta\ \omega} \tag{25}$$

Applying a rate of 290 rad/sec yields:

$$\theta_T = \frac{S}{(\frac{S}{16} + 1)\ (\frac{S^2}{3.14^2} + \frac{2(.5)S}{3.14} + 1)} \tag{26}$$

$$\theta_T(t) = \frac{-\omega^2\ e^{-t/T}}{(1 - 2\ T\ \zeta\ \omega + T^2\ \omega^2)} + \frac{\omega^2\ e^{-\zeta\omega t}\ \sin\ (\omega\sqrt{1 - \zeta^2}\ t + \psi)}{[(1 - \zeta^2)\ (1 - 2\ T\ \zeta\ \omega + T^2\ \ ^2)]^{1/2}} \tag{27}$$

where

$$\psi = \tan^{-1}\ (\frac{T\ \omega\ \sqrt{1 - \zeta^2}}{1 - T\ \zeta\ \omega}) - \tan^{-1}\ (\frac{\sqrt{1 - \zeta^2}}{-\zeta}) \tag{28}$$

Applying a step of 290 rad yields

$$\theta_T = \frac{S^2}{(\frac{S}{16} + 1)\ (\frac{S^2}{3.14^2} + \frac{2(.5)S}{3.14} + 1)} \tag{29}$$

$$\theta_T(t) = \frac{\omega^2 e^{-t/T}}{T (1 - 2 T \zeta \omega + T^2 \omega^2)} + \frac{\omega^3 e^{-\zeta\omega t} \sin(\omega \sqrt{1 - \zeta^2}\, t - \psi)}{[(1 - \zeta^2)(1 - 2 T \zeta \omega + T^2 \omega^2)]^{1/2}} \quad (30)$$

where

$$\psi = \tan^{-1}\left(\frac{T \omega \sqrt{1 - \zeta^2}}{1 - T \zeta \omega}\right) - 2 \tan^{-1}\left(\frac{\sqrt{1 - \zeta^2}}{-\zeta}\right) \quad (31)$$

Applying a jerk of 290 rad/sec^3 yields:

$$\theta_T = \frac{1}{(S)(1 + T S)(1 + \frac{2 \zeta S}{\omega} + \frac{S^2}{\omega})} \quad (32)$$

$$\theta_T(t) = 1. - \frac{T^2 \omega^2 e^{-t/T}}{(1 - 2 T \zeta \omega + T^2 \omega^2)} + \frac{e^{-\zeta\omega t} \sin(\omega \sqrt{1 - \zeta^2}\, t + \psi)}{[(1 - \zeta^2)(1 - 2 \zeta T \omega + T^2 \omega^2)]^{\frac{1}{2}}} \quad (33)$$

where

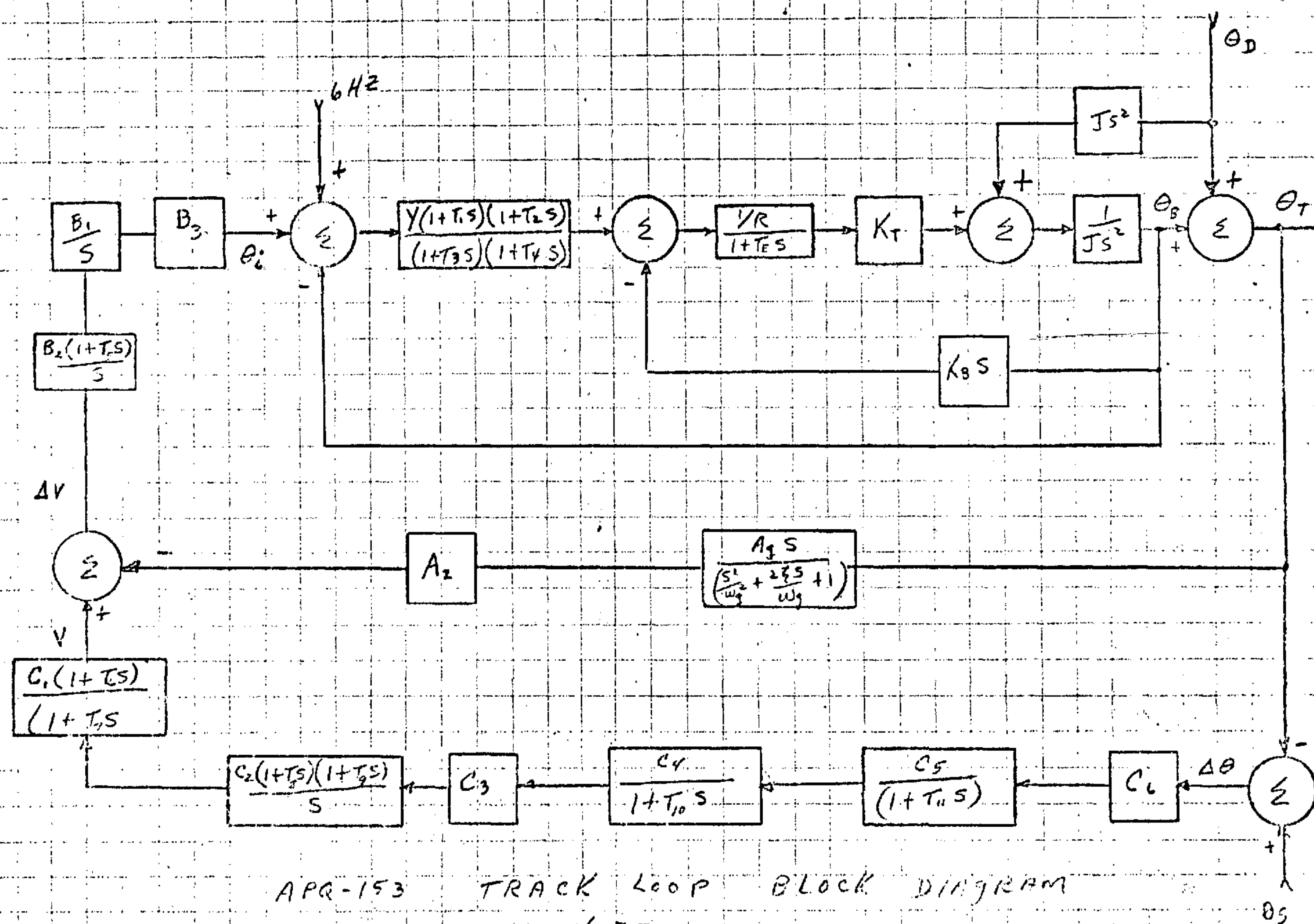
$$\psi = \tan^{-1}\left(\frac{T \omega \sqrt{1 - \zeta^2}}{1 - T \zeta \omega}\right) + \tan^{-1}\left(\frac{\sqrt{1 - \zeta^2}}{-\zeta}\right) \quad (34)$$

The response to a unit input of jerk, acceleration, rate and angle are shown in Figures 21, 22, 23, and 24 respectively. The plotted data and calculations appear in Table X.

RESULTS

The actual test results (track and rate table disturbance) and the response curves of Figures 18 thru 24 indicate that the requirements can be met. The flight test will obviously be the final proof.

D. Ringkamp



APQ-153 TRACK LOOP BLOCK DIAGRAM

10-4-73 DVR

FIGURE #1

TABLE I

Table of constants

$J = 2$ in oz sec^2

$K_B = .34$ V/rad/sec

$K_T = 48$ in oz/amp

$T_E = .0035$ sec

$T_M = .34$ sec $= \dfrac{RJ}{K_T K_B}$

$Y = 800$ V/V

$R = 2.8$ ohms

$T_1 = .4$ sec

$T_2 = .025$ sec

$T_3 = 1.0$ sec

$T_4 = .002$ sec

$B_1 = 20.$ V/V

$B_2 = 7.$ V/V

$C_1 = 2.0$ V/V

$C_2 = 3.0$ V/V

$C_3 = .85$ V/V

$C_4 = .67$ V/V

$C_5 = 2.0$ V/V

$C_6 = 2.9$ V/rad

$B_3 = (B_4)(B_5)(B_6) = 1/11.4 = .089$ rad/

$B_4 = \frac{1}{2.15}$ V/V gain in pot feedback

$B_5 = .093$ V/° pot sensitivity

$B_6 = 57.3$ °/rad

$T_5 = .014$ sec

$T_6 = .1$ sec

$T_7 = .01$ sec

$T_8 = 2.0$ sec

$T_9 = .22$ sec

$T_{10} = .088$ sec

$T_{11} = .22$ sec

$A_g = .8$ v/rad/sec

$A_1 = 3.0$ V/V

$\omega_g = 240.$ rad/sec

$\zeta = .4$

```
ØK
IRU POLY
```

TABLE II

```
 INPUT K1  8.6

 INPUT COEFFICIENTS ØF G1(S) NUMERATØR (CONSTANT TERM FIRST)
1.

 INPUT COEFFICIENTS ØF G1(S) DENOMINATØR (CONSTANT TERM FIRST)
0. 1. .0035

 INPUT A1  .35

 INPUT COEFFICIENTS ØF H1(S) NUMERATØR (CONSTANT TERM FIRST)
1.

 INPUT COEFFICIENTS ØF H1(S) DENØMINATØR (CONSTANT TERM FIRST)
1.

 ----- ØPEN LØØP TRANSFER FUNCTIØN NUMERATØR G(S)H1(S) -----

3.01( 1.00 )


     ***    *** DEGENERATE PØLYNØMIAL ***    ***

 ----- ØPEN LØØP TRANSFER FUNCTIØN DENØMINATØR G(S)H1(S) -----

1.00( .00350 S↑2 + 1.00 S)


          REAL RØØTS
             0.0000E+00
          -285.7143

 ----- CLØSED LØØP TRANSFER FUNCTION NUMERATØR G(S)/(1+G(S)H1(S)) -----

24.57( 1.00 )


     ***    *** DEGENERATE PØLYNØMIAL ***    ***

 ----- CLØSED LØØP TRANSFER FUNCTIØN DENØMINATØR G(S)/(1+G(S)H1(S)) ----

8.60( .00116 S↑2 + .332 S + 1.00 )


          REAL RØØTS
             -3.0424
          -282.6719


 DØ YØU WANT MØRE YES ØR NØ   YES
```

```
INPUT K2  800.

INPUT COEFFICIENTS OF G2(S) NUMERATOR (CONSTANT TERM FIRST)
1. .4255 .01

INPUT COEFFICIENTS OF G2(S) DENOMINATOR (CONSTANT TERM FIRST)
0. 1. 1. .002

INPUT A2  1.

INPUT COEFFICIENTS OF H2(S) NUMERATOR (CONSTANT TERM FIRST)
1.

INPUT COEFFICIENTS OF H2(S) DENOMINATOR (CONSTANT TERM FIRST)
1.

----- OPEN LOOP TRANSFER FUNCTION NUMERATOR G(S)H2(S) -----

19657.( .01000 S↑2 + .425 S + 1.00 )


        REAL ROOTS
          -2.4967
         -40.0533

----- OPEN LOOP TRANSFER FUNCTION DENOMINATOR G(S)H2(S) -----

1.00( 2.000E-05 S↑5 + .0157 S↑4 + 2.88 S↑3 + 11.46 S↑2 + 8.60 S)


        REAL ROOTS
           0.0000E+00
          -1.0020
          -3.0424
        -232.6719
        -498.9980

----- CLOSED LOOP TRANSFER FUNCTION NUMERATOR G(S)/(1+G(S)H2(S)) -----

19657.( .01000 S↑2 + .425 S + 1.00 )


        REAL ROOTS
          -2.4967
         -40.0533

----- CLOSED LOOP TRANSFER FUNCTION DENOMINATOR G(S)/(1+G(S)H2(S)) ----

19657.( 1.017E-09 S↑5 + 7.994E-07 S↑4 + .000147 S↑3 + .0106 S↑2
 + .426 S + 1.00 )


        REAL ROOTS
          -2.4974
         -;41.9207
           -5.5842E+02

        COMPLEX ROOTS               OMEGA        ZETA
    -41.4406 +/-J   56.9959       70.4637      -0.5881
```

```
PRO POLY

 INPUT K1  19657.

 INPUT COEFFICIENTS OF G1(S) NUMERATOR (CONSTANT TERM FIRST)
1. .4255 .01

 INPUT COEFFICIENTS OF G1(S) DENOMINATOR (CONSTANT TERM FIRST)
0. 8.6 11.46 2.88 .0157 2.0E-5  .

 INPUT A1   1.

 INPUT COEFFICIENTS OF H1(S) NUMERATOR (CONSTANT TERM FIRST)
1.

 INPUT COEFFICIENTS OF H1(S) DENOMINATOR (CONSTANT TERM FIRST)
1.


 ----- OPEN LOOP TRANSFER FUNCTION NUMERATOR G(S)H1(S) -----

19657.( .01000 S↑2 + .426 S + 1.00 )



          REAL ROOTS
            -2.4967
           -40.0533

 ----- OPEN LOOP TRANSFER FUNCTION DENOMINATOR G(S)H1(S) -----

1.00( 2.000E-05 S↑5 + .0157 S↑4 + 2.88 S↑3 + 11.46 S↑2 + 8.60 S)



          REAL ROOTS
             0.0000E+00
            -1.0008
            -3.0510
          -282.5979
          -498.3504

 ----- CLOSED LOOP TRANSFER FUNCTION NUMERATOR G(S)/(1+G(S)H1(S)) -----

19657.( .01000 S↑2 + .426 S + 1.00 )



          REAL ROOTS
            -2.4967
           -40.0533

 ----- CLOSED LOOP TRANSFER FUNCTION DENOMINATOR G(S)/(1+G(S)H1(S)) ----

19657.( 1.017E-09 S↑5 + 7.987E-07 S↑4 + .000147 S↑3 + .0106 S↑2
 + .426 S + 1.00 )



          REAL ROOTS
            -2.4974
          -141.4903
            -5.5791E+02

          COMPLEX ROOTS              OMEGA          ZETA
```

```
 DO YOU WANT MORE YES OR NO   YES

 INPUT K2  12.2

 INPUT COEFFICIENTS OF G2(S) NUMERATOR (CONSTANT TERM FIRST)
1. .014

 INPUT COEFFICIENTS OF G2(S) DENOMINATOR (CONSTANT TERM FIRST)
0. 0. 1.

 INPUT A2  2.4

 INPUT COEFFICIENTS OF H2(S) NUMERATOR (CONSTANT TERM FIRST)
0. 1.

 INPUT COEFFICIENTS OF H2(S) DENOMINATOR (CONSTANT TERM FIRST)
1. .0033 17.4E-6


 ----- OPEN LOOP TRANSFER FUNCTION NUMERATOR G(S)H2(S) -----

1.00( 80.58 S↑4 + 9184.2 S↑3 + 252957. S↑2 + 575557. S)


          REAL ROOTS
             0.0000E+00
            -2.4967
           -40.0533
           -71.4286

 ----- OPEN LOOP TRANSFER FUNCTION DENOMINATOR G(S)H2(S) -----

1.00( 3.430E-10 S↑9 + 3.392E-07 S↑8 + .000122 S↑7 + .0288 S↑6
 + 3.71 S↑5 + 236.0 S↑4 + 8437.5 S↑3 + 19657. S↑2)


          REAL ROOTS
             0.0000E+00
             0.0000E+00
            -2.4974
          -141.4903
            -5.5791E+02

          COMPLEX ROOTS            OMEGA       ZETA
      -41.5509 +/-J  57.0869     70.6073    -0.5885
      -94.8276 +/-J 220.1795    239.7317    -0.3956

 ----- CLOSED LOOP TRANSFER FUNCTION NUMERATOR G(S)/(1+G(S)H2(S)) -----

99923.( 2.436E-09 S↑5 + 7.397E-07 S↑4 + .000200 S↑3 + .0174 S↑2
 + .443 S + 1.00 )


          REAL ROOTS
            -2.4967
           -40.0533
           -71.4286

          COMPLEX ROOTS            OMEGA       ZETA
      -94.8276 +/-J 220.1795    239.7317    -0.3956
```

```
----- CLOSED LOOP TRANSFER FUNCTION DENOMINATOR G(S)/(1+G(S)H2(S)) ----

1.00( 1.450E-10 S↑9 + 1.413E-07 S↑8 + 5.080E-05 S↑7 + .0120 S↑6
 + 1.55 S↑5 + 131.9 S↑4 + 7342.4 S↑3 + 113589. S↑2 + 239815. S)


          REAL ROOTS
             0.0000E+00
            -2.4966
           -18.9731
          -109.1581
            -5.6136E+02

          COMPLEX ROOTS             ØMEGA        ZETA
     -27.3574 +/-J  96.6600   100.4569     -0.2723
    -113.9772 +/-J 208.5010   237.6204     -0.4797

 DØ YØU WANT MØRE YES ØR NØ   YES

 INPUT K3  24.

 INPUT CØEFFICIENTS ØF G3(S) NUMERATØR (CONSTANT TERM FIRST)
1. .4

 INPUT CØEFFICIENTS ØF G3(S) DENØMINATØR (CØNSTANT TERM FIRST)
0. 1. .01

 INPUT A3  1.

 INPUT CØEFFICIENTS ØF H3(S) NUMERATØR (CØNSTANT TERM FIRST)
1.

 INPUT CØEFFICIENTS ØF H3(S) DENØMINATØR (CØNSTANT TERM FIRST)
1.

 ----- ØPEN LØØP TRANSFER FUNCTIØN NUMERATØR G(S)H3(S) -----

2.398E+06( 9.744E-10 S↑6 + 2.983E-07 S↑5 + 8.036E-05 S↑4 + .00717 S↑3
 + .195 S↑2 + .843 S + 1.00 )


          REAL RØØTS
            -2.4966
            -2.5000
           -40.0533
           -71.4236

          CØMPLEX RØØTS             ØMEGA        ZETA
     -94.8276 +/-J 220.1795   239.7317     -0.3956
```

```
----- OPEN LOOP TRANSFER FUNCTION DENOMINATOR G(S)H3(S) -----

1.00( 1.450E-12 S↑11 + 1.558E-09 S↑10 + 6.493E-07 S↑9 + .000171 S↑8
 + .0275 S↑7 + 2.87 S↑6 + 205.3 S↑5 + 8473.3 S↑4 + 115987. S↑3
 + 239815. S↑2)


          REAL ROOTS
              0.0000E+00
              0.0000E+00
            -2.4966
           -18.9731
          -100.0001
          -109.1580
            -5.6136E+02

          COMPLEX ROOTS             OMEGA       ZETA
     -27.3574 +/-J  96.6600      100.4569     -0.2723
    -113.9772 +/-J 208.5010      237.6204     -0.4797

 ----- CLOSED LOOP TRANSFER FUNCTION NUMERATOR G(S)/(1+G(S)H3(S)) -----

2.398E+06( 9.744E-10 S↑6 + 2.983E-07 S↑5 + 8.086E-05 S↑4 + .00717 S↑3
 + .195 S↑2 + .843 S + 1.00 )


          REAL ROOTS
            -2.4966
            -2.5000
           -40.0533
           -71.4286

          COMPLEX ROOTS             OMEGA       ZETA
     -94.8276 +/-J 220.1795      239.7317     -0.3956

 ----- CLOSED LOOP TRANSFER FUNCTION DENOMINATOR G(S)/(1+G(S)H3(S)) ----

2.398E+06( 6.046E-19 S↑11 + 6.498E-16 S↑10 + 2.703E-13 S↑9 + 7.126E-11 S
↑8
 + 1.146E-08 S↑7 + 1.196E-06 S↑6 + 8.592E-05 S↑5 + .00362 S↑4 + .0555 S↑
3
 + .295 S↑2 + .843 S + 1.00 )


          REAL ROOTS
            -2.4966
           -16.1110
            -5.6138E+02

          COMPLEX ROOTS             OMEGA       ZETA
      -2.1149 +/-J   2.7609        3.4778     -0.6081
    -104.0444 +/-J   6.2323      104.2339     -0.9982
     -27.2063 +/-J  95.5715       99.3685     -0.2738
    -113.9672 +/-J 208.4693      237.5378     -0.4797

 DO YOU WANT MORE YES OR NO    NO
```

```
INPUT K3  24.

INPUT COEFFICIENTS OF G3(S) NUMERATOR (CONSTANT TERM FIRST)
1. .5

INPUT COEFFICIENTS OF G3(S) DENOMINATOR (CONSTANT TERM FIRST)
0. 1. .01

INPUT A3  1.

INPUT COEFFICIENTS OF H3(S) NUMERATOR (CONSTANT TERM FIRST)
1.

INPUT COEFFICIENTS OF H3(S) DENOMINATOR (CONSTANT TERM FIRST)
1.

----- OPEN LOOP TRANSFER FUNCTION NUMERATOR G(S)H3(S) -----

2.398E+06( 1.218E-09 S^6 + 3.723E-07 S^5 + .000101 S^4 + .00891 S^3
 + .239 S^2 + .943 S + 1.00 )


         REAL ROOTS
           -2.0000
           -2.4967
          -40.0533
          -71.4286

         COMPLEX ROOTS           OMEGA        ZETA
     -94.8276 +/-J 220.1795   239.7316     -0.3956

----- OPEN LOOP TRANSFER FUNCTION DENOMINATOR G(S)H3(S) -----

1.00( 1.450E-12 S^11 + 1.558E-09 S^10 + 6.493E-07 S^9 + .000171 S^8
 + .0275 S^7 + 2.87 S^6 + 205.3 S^5 + 8478.3 S^4 + 115987. S^3
 + 239815. S^2)


         REAL ROOTS
            0.0000E+00
            0.0000E+00
           -2.4966
          -18.9731
         -100.0001
         -109.1580
           -5.6136E+02

         COMPLEX ROOTS           OMEGA        ZETA
     -27.3574 +/-J  96.6600   100.4569     -0.2723
    -113.9772 +/-J 208.5010   237.6204     -0.4797

----- CLOSED LOOP TRANSFER FUNCTION NUMERATOR G(S)/(1+G(S)H3(S)) -----

2.398E+06( 1.218E-09 S^6 + 3.723E-07 S^5 + .000101 S^4 + .00891 S^3
 + .239 S^2 + .943 S + 1.00 )


         REAL ROOTS
           -2.0000
           -2.4967
          -40.0533
          -71.4286

         COMPLEX ROOTS           OMEGA        ZETA
     -94.8276 +/-J 220.1795   239.7316     -0.3956

----- CLOSED LOOP TRANSFER FUNCTION DENOMINATOR G(S)/(1+G(S)H3(S)) -----

2.398E+06( 6.046E-19 S^11 + 6.496E-16 S^10 + 2.708E-13 S^9 + 7.126E-11 S^8
 + 1.146E-08 S^7 + 1.196E-06 S^6 + 8.599E-05 S^5 + .00364 S^4 + .0573 S^3
 + .339 S^2 + .943 S + 1.00 )


         REAL ROOTS
           -2.4965
          -14.8335
           -5.6139E+02

         COMPLEX ROOTS           OMEGA        ZETA
      -2.9389 +/-J   2.1427     3.6371     -0.8080
    -103.9074 +/-J   7.4331   104.1729     -0.9975
     -27.1577 +/-J  95.2916    99.0860     -0.2741
    -113.9646 +/-J 208.4614   237.5796     -0.4797

DO YOU WANT MORE YES OR NO   NO

OK
TIM
SRU'S USED = 25
CONNECT TIME = 00:08
```

REPEAT
TRACK
ACC.

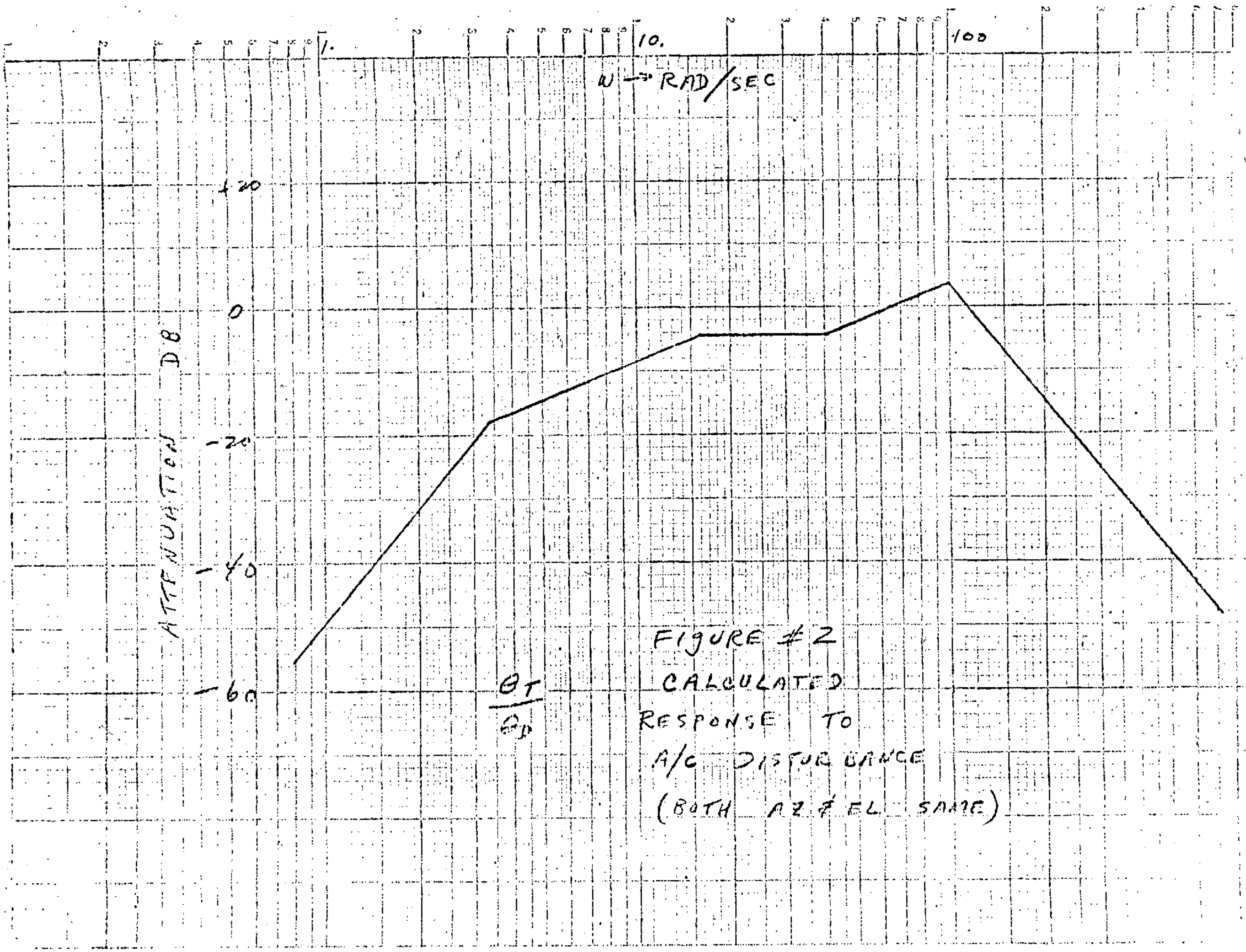
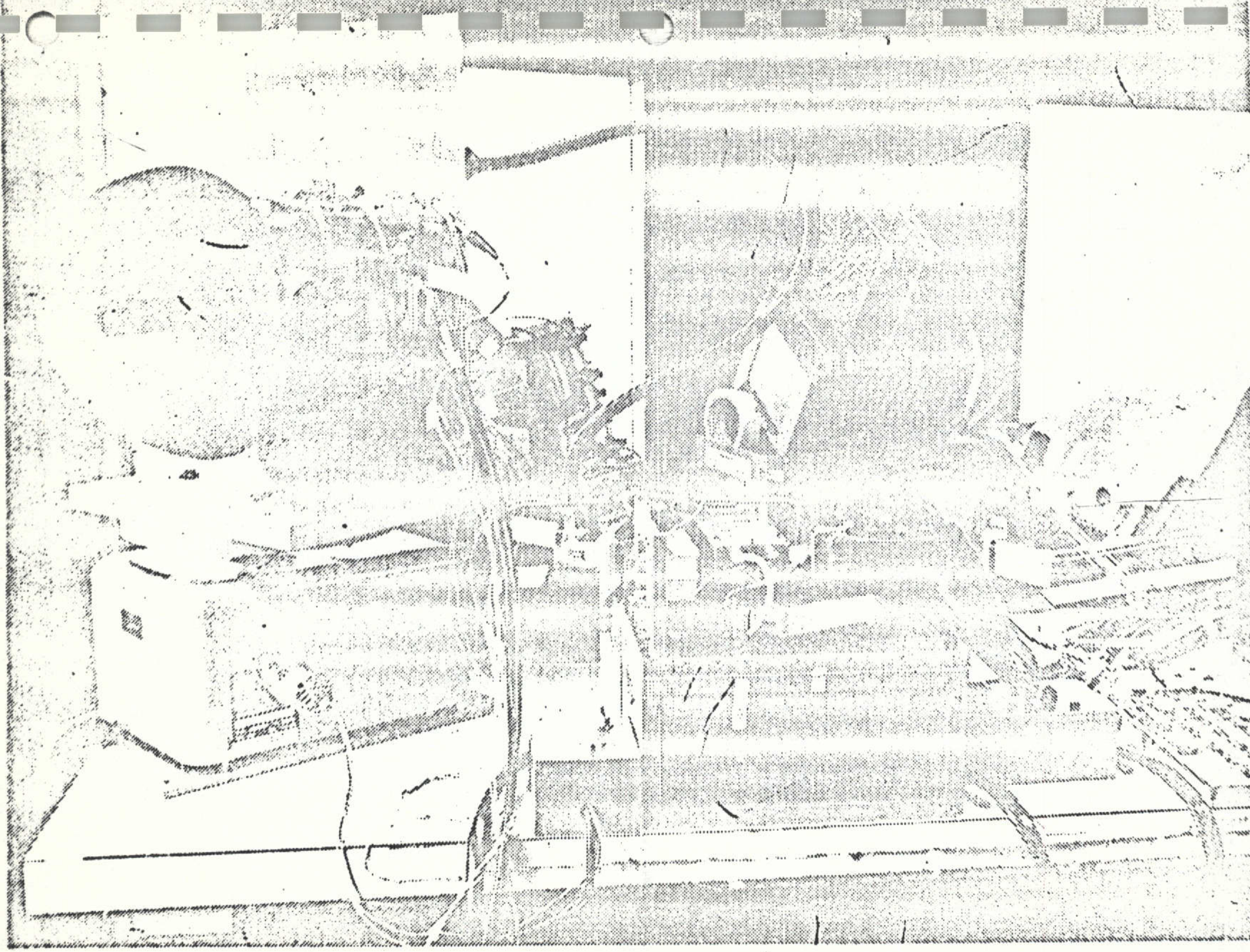


FIGURE #2
CALCULATED
RESPONSE TO
A/C DISTURBANCE
(BOTH AZ & EL SAME)



TEST BENCH
FOR ANGLE TRACK IN PENTHOUSE
SEPT 1973

TABLE III

POSITION LOOP RESPONSE (.2V INPUT VOLTAGE)
(INPUT AT 10K OUTPUT AT POT)

	AZ				EL			
f	AMPL	NORM AMPL	db	ϕ	AMPL	NORM AMPL	db	ϕ
1	.06	1.	0	+175	.061	1.0	0	+167
2	.06	1.	0	+124	.058	-1.05	0	+164
3	.06	1.	0	+174	.058	-1.05	0	+164
5	.065	1.1	.9	+171	.064	+1.05	0	+163
6	.07	1.15	1.2	+170	–			
7	.074	1.23	1.8	+166	.064	1.05	0	+164
8	.078	1.3	2.3	+163	.075	1.23	1.8	+158
9	.088	1.46	1.2	+158	.08	1.31	2.4	+154
10	.064	1.1	.9	+154	.085	1.39	2.9	+149
11	.08	1.32	2.4	+161	.091	1.49	3.5	+144
12	.09	1.5	3.5	+158	.098	1.62	4.2	+136
13	.1	1.67	4.5	+148	.078	1.28	2.1	+111
14	.1	1.67	4.5	+135	.08	1.31	2.4	+139
15	.09	1.5	3.5	+115	.1	1.64	4.3	+129
16	.09	1.5	3.5	+126	.11	1.8	5.1	+118
17	.09	1.5	3.5	+ 98	.11	1.80	5.1	+105
18	–				.105	1.73	4.8	+ 92
20	.05	-1.2	-1.8	+40	.09	1.47	3.3	+ 71
25	.025	-2.4	-7.6	+21	.04	-1.52	-3.6	+ 41

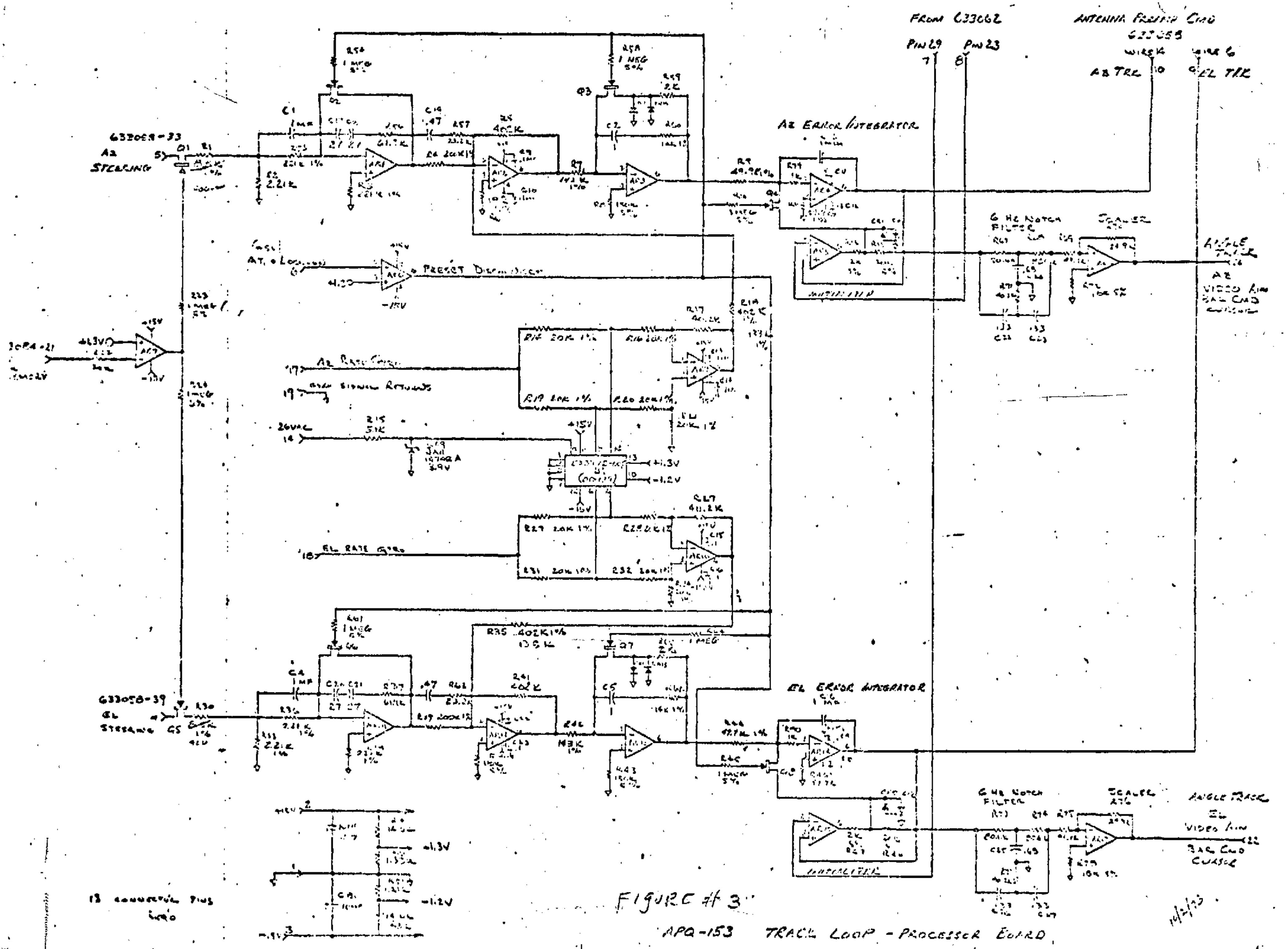
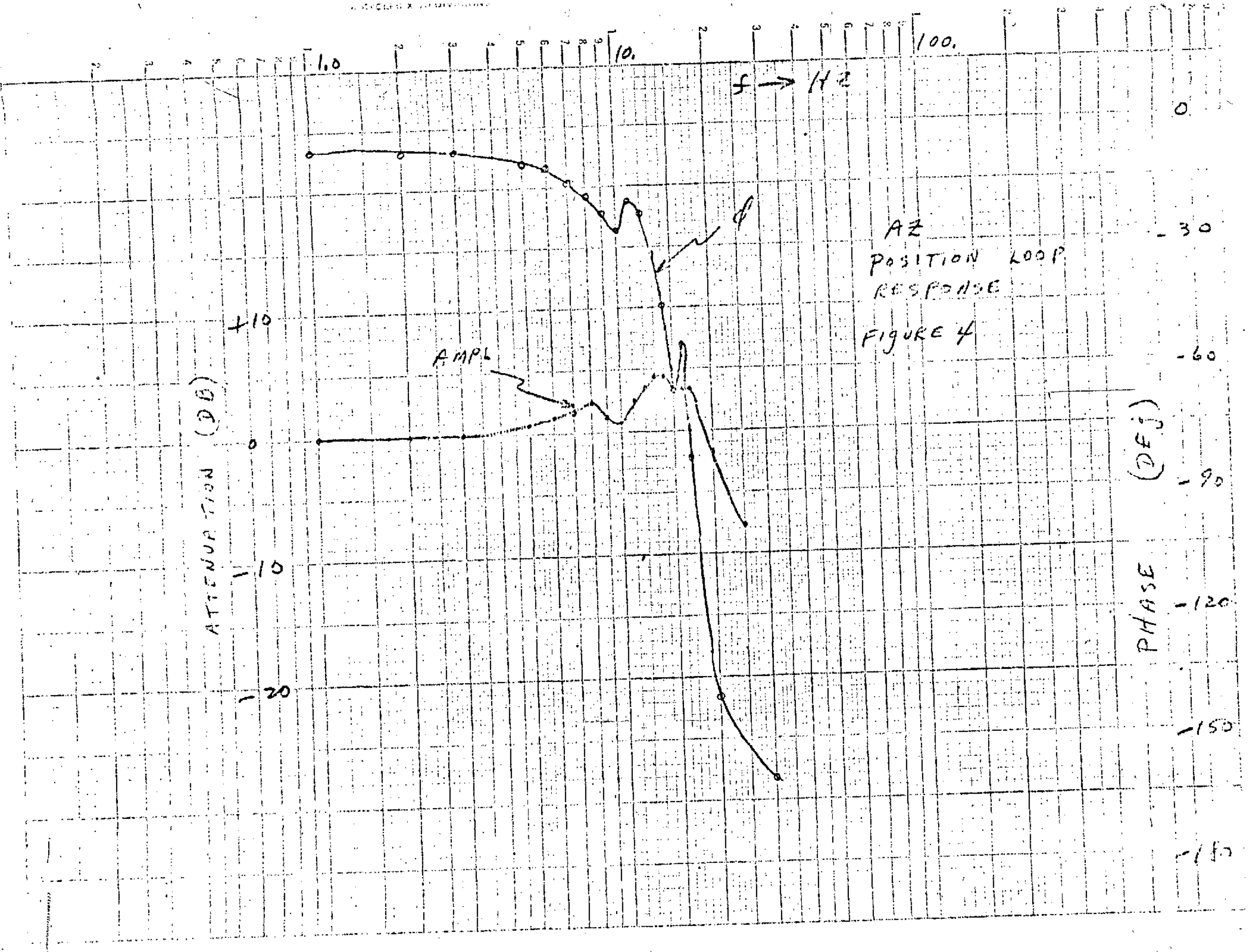


FIGURE # 3

APQ-153 TRACK LOOP - PROCESSOR BOARD



1.0
10.
100.
f → HZ
AZ
POSITION LOOP
RESPONSE
FIGURE 4
φ
AMPL
+10
0
-10
-20
ATTENUATION (DB)
0
-30
-60
-90
-120
-150
-180
PHASE (DEG)

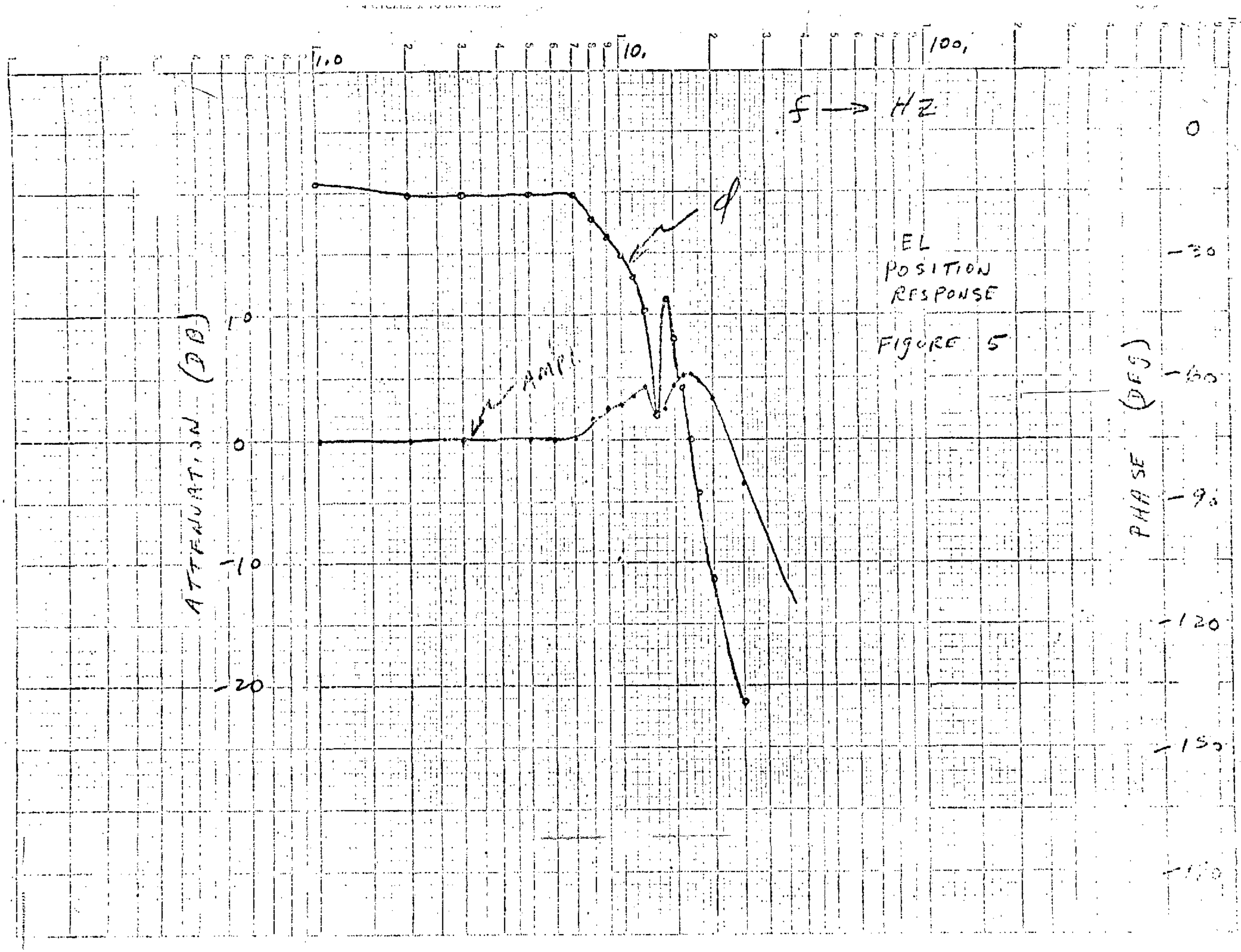
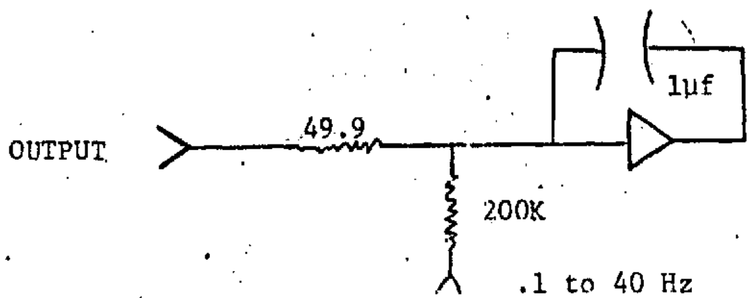

1.0
10.
100.
f → HZ
EL
POSITION
RESPONSE
FIGURE 5
ATTENUATION (DB)
10
0
-10
-20
AMPL
φ
PHASE (DEG)
0
-30
-60
-90
-120
-150

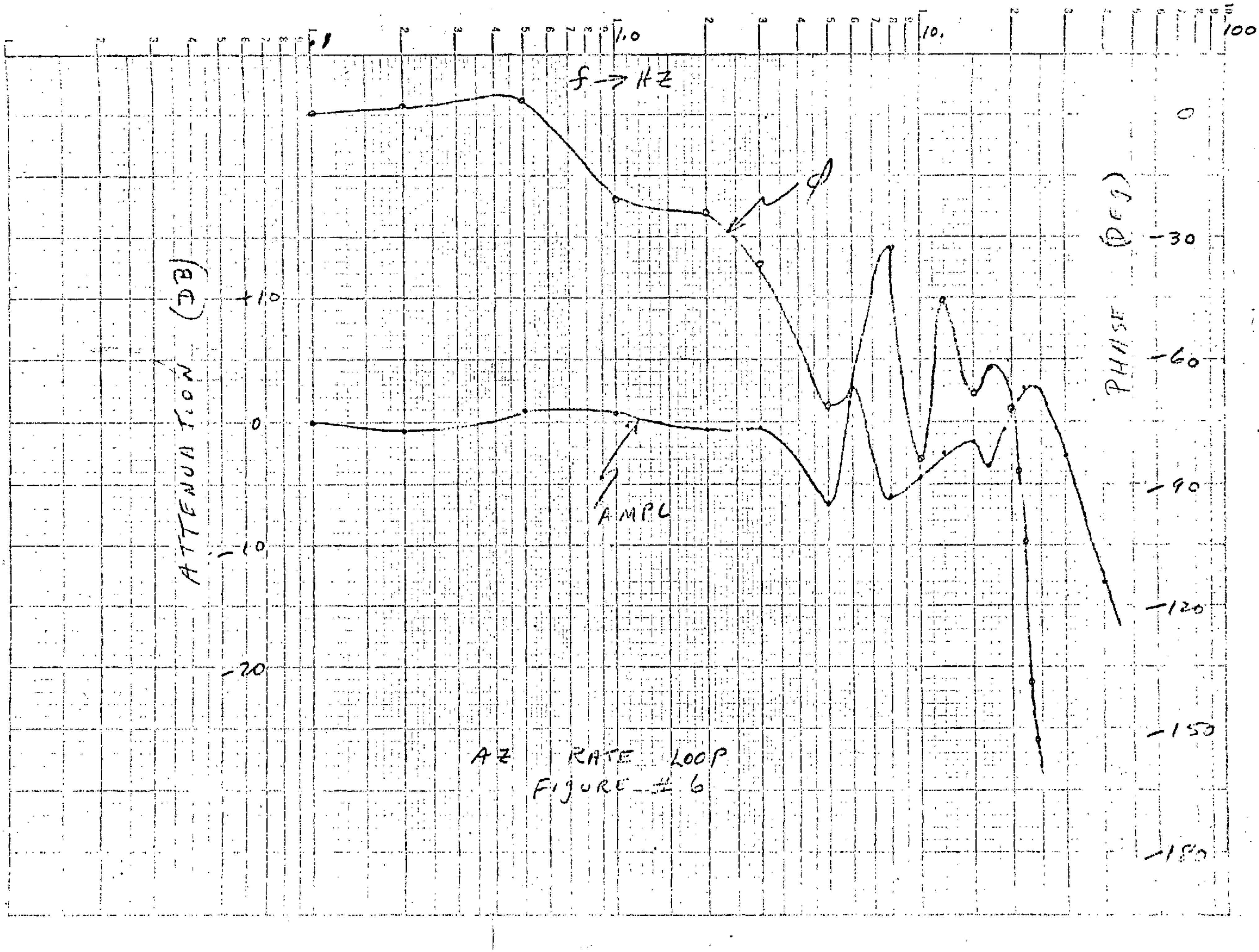
TABLE IV

RATE LOOP RESPONSE DATA

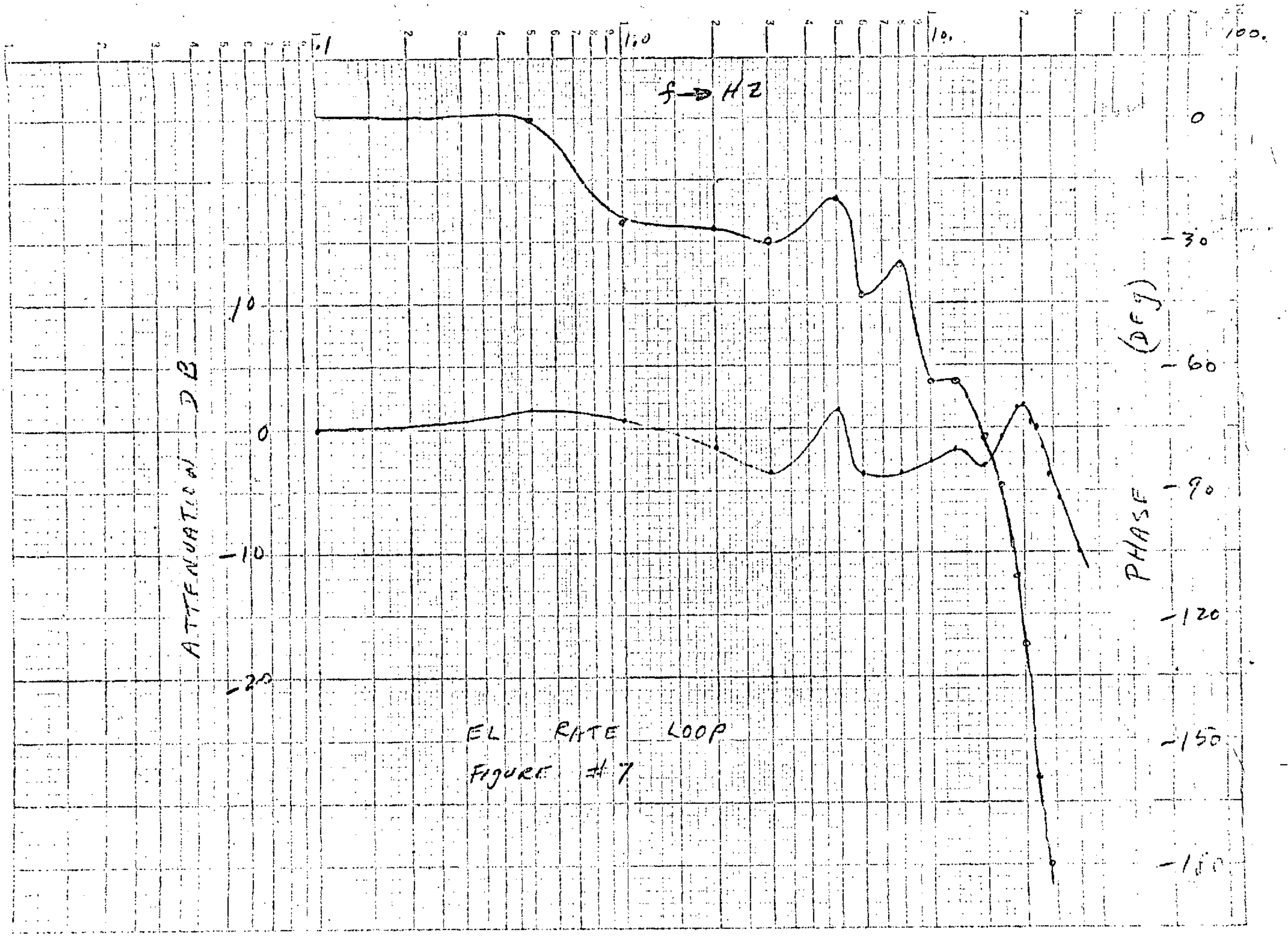
	AZ				EL			
f	AMPL	NORM AMPL	db	φ	AMPL	NORM AMPL	db	φ
.1	.138	1.0	0	-179	.124	1.	0	-129
.2	.128	-1.07	-.6	-177				
.5	.154	1.12	1.0	-176	.140	1.13	1.06	-179
1.0	.150	1.09	.75	+159	.138	1.11	.83	+155
2.0	.128	-1.07	-.6	+156	.104	-1.2	-1.6	+153
3.0	.131	-1.05	-.4	+143	.08	-1.55	-3.8	+150
5.0	.064	-2.16	-6.7	+109	.105	-1.18	1.4	+161
6.0	.190	1.38	2.8	- 68	.19	1.53	-3.8	+137
8.0	.068	-2.0	-6	+147	.084	-1.48	-3.4	+144
10.0	.081	-1.7	-4.6	+106	.09	-1.38	-2.8	+116
12.0	.099	-1.39	-2.5	+134	.101	-1.23	-1.8	+116
15.0	.112	-1.22	-1.7	+112	.088	-1.42	-3.0	+103
17.0	.094	-1.47	-3.3	+118	.114	-1.1	- .83	+ 91
19.0	.128	-1.08	- .67		.149	1.2	1.6	+ 69
20.0	.154	1.12	1.0	+108	.154	1.24	1.9	+ 53
21.0	.169	1.22	1.7	+ 93	.129	1.04	.35	+138
22.0	.190	1.38	2.8	+ 76	.124	0	0	+ 21
23.0	.19	1.38	2.8	+ 40	.104	-1.2	-1.6	+ 6
24.0	.19	1.38	2.8	+ 27	.079	-1.57	-3.9	0.0
26.0	.16	1.15	1.2		.065	-1.9	-5.6	- 4
28.0	.13	-1.06	- .5	- 12				
30.0	.10	-1.38	-2.8	- 19	.04	-3.1	-10.	- 7
40.0	.03	-4.6	-13.0	- 37				



.1 to 40 Hz

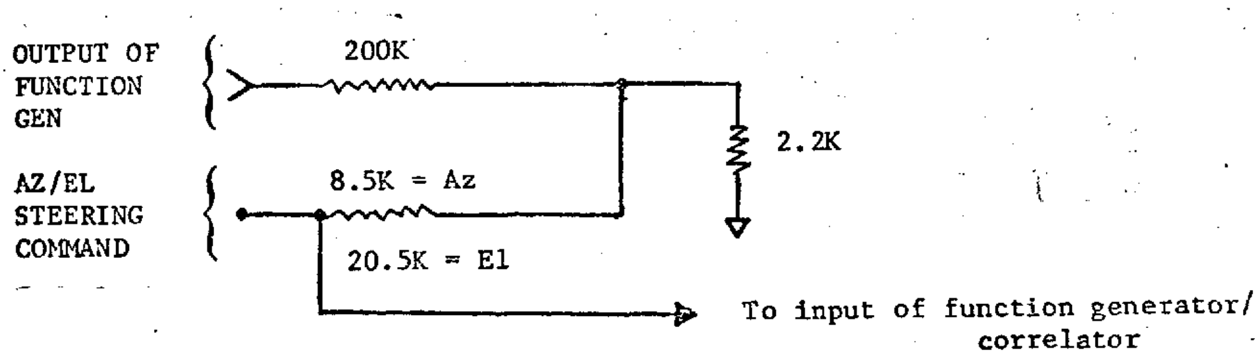


f → HZ
ATTENUATION (DB)
PHASE (DEG)
φ
AMPL
+10
0
-10
-20
0
-30
-60
-90
-120
-150
-180
.1
1.0
10.
100
AZ RATE LOOP
FIGURE # 6



EL RATE LOOP
FIGURE #7

	EL			AZ		
f	AMPL	DB	ϕ	AMPL	DB	ϕ
.05	.41		+179°	.2		+179°
.1	.48	1.3	+174	.21		+176°
.2	.74	5.1	+137	.24	1.6	+171°
.3	.58	2.9	+104	.29	3.2	+159
.4	.24		+ 63	.34	4.6	+134
.5	.18		+ 54	.30	3.5	+108
.7	.11		+ 29	.22	1.0	+ 65
1.0	.06		+ 12	.10	-6	+ 38
2.0	.01		- 8	.01	-23	- 13



CLOSED LOOP FREQUENCY RESPONSE

SYSTEM LOCKED ON TOWER

RATE FEEDBACK RESISTORS 402K EACH CHANNEL

	EL			AZ		
f	AMPL	DB	φ	AMPL	DB	φ
.05	.156		+172	.0017		+ 62
.1	.18	1.2	+174	.008		+ 7.2
.2	.195	1.9	+168	.014		− 32
.3	.234	3.5	+149	.019		− 77
.4	.25	4.1	+136	.038		−106
.5	.28	5.1	+ 99	.041		−143
.7	.21	2.6	+ 32	.084		+109
1.0	.09	4.9	+ 6	.018		+127
2.0	.01	−23	− 18	.009		+ 14

AZ READINGS, WHICH ARE MEASURE OF CROSS TALK, ARE ONLY APPROXIMATE AND ARE NOT ACCURATELY REPEATIBLE

WITH EL = 8.5K

The following response was obtained with input into El channel only.

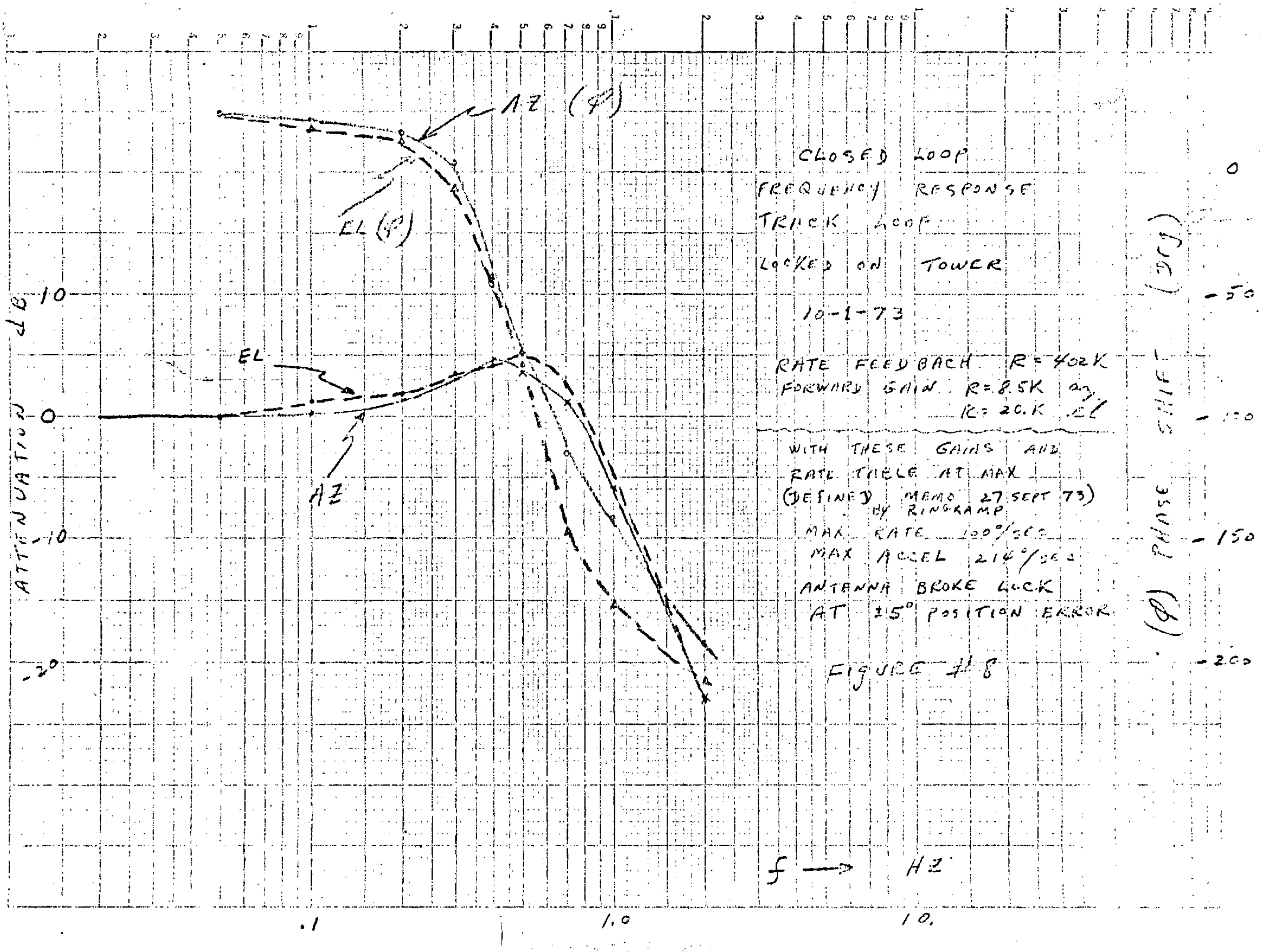

AZ (φ)
EL (φ)
EL
AZ
CLOSED LOOP
FREQUENCY RESPONSE
TRACK LOOP
LOCKED ON TOWER
10-1-73
RATE FEEDBACK R = 402K
FORWARD GAIN R = 8.5K az
R = 20.K EL
WITH THESE GAINS AND
RATE TABLE AT MAX
(DEFINED MEMO 27 SEPT 73)
BY RINGKAMP
MAX RATE 100°/SEC
MAX ACCEL 214°/SEC
ANTENNA BROKE LOCK
AT ±5° POSITION ERROR
f → HZ
ATTENUATION dB
10
0
-10
-20
PHASE SHIFT (φ) (DEG)
0
-50
-100
-150
-200
.1
1.0
10.

FIGURE #8

TABLE VII

TRACK LOOP RESPONSE DATA

INPUT INTO AZ					CROSS COUPLING INTO EL			
f	AMPL	NORM AMPL	db	φ	AMPL	NORM AMPL	db	φ
.1	.49	1.0	0.	+177.	.04	-12.3	-22	+145
.2	.54	1.1	.1	+171	.143	- 3.4	-10	+115
.3	.58	1.18	1.4	+163	.19	- 2.6	- 8.3	+ 89
.4	.68	1.38	2.8	+154	.19	- 2.6	- 8.3	+ 43
.5	.758	1.57	3.9	+132	.19	- 2.6	- 8.3	+ 44
.6	.614	1.25	1.95	+109	.19	- 2.6	- 8.3	+ 4
.7	.54	1.1	.1	+ 93	.19	- 2.6	- 8.3	- 27
1.0	.287	-1.71	-4.7	+ 81	.19	- 2.6	- 8.3	- 57
2.0	.154	-3.18	-10.	+ 54	.11	- 4.5	-13.	-100
3.0	.057	-8.6	-18.6	+ 47	.07	- 7.	-17.	-120

.1 - 2.0 Hz

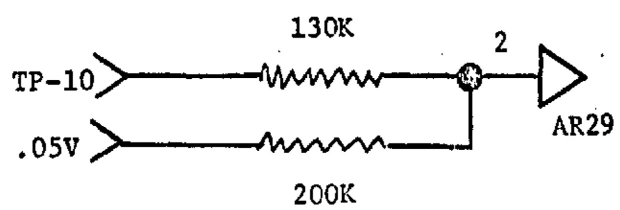
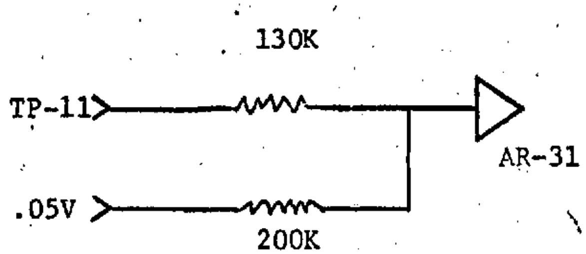


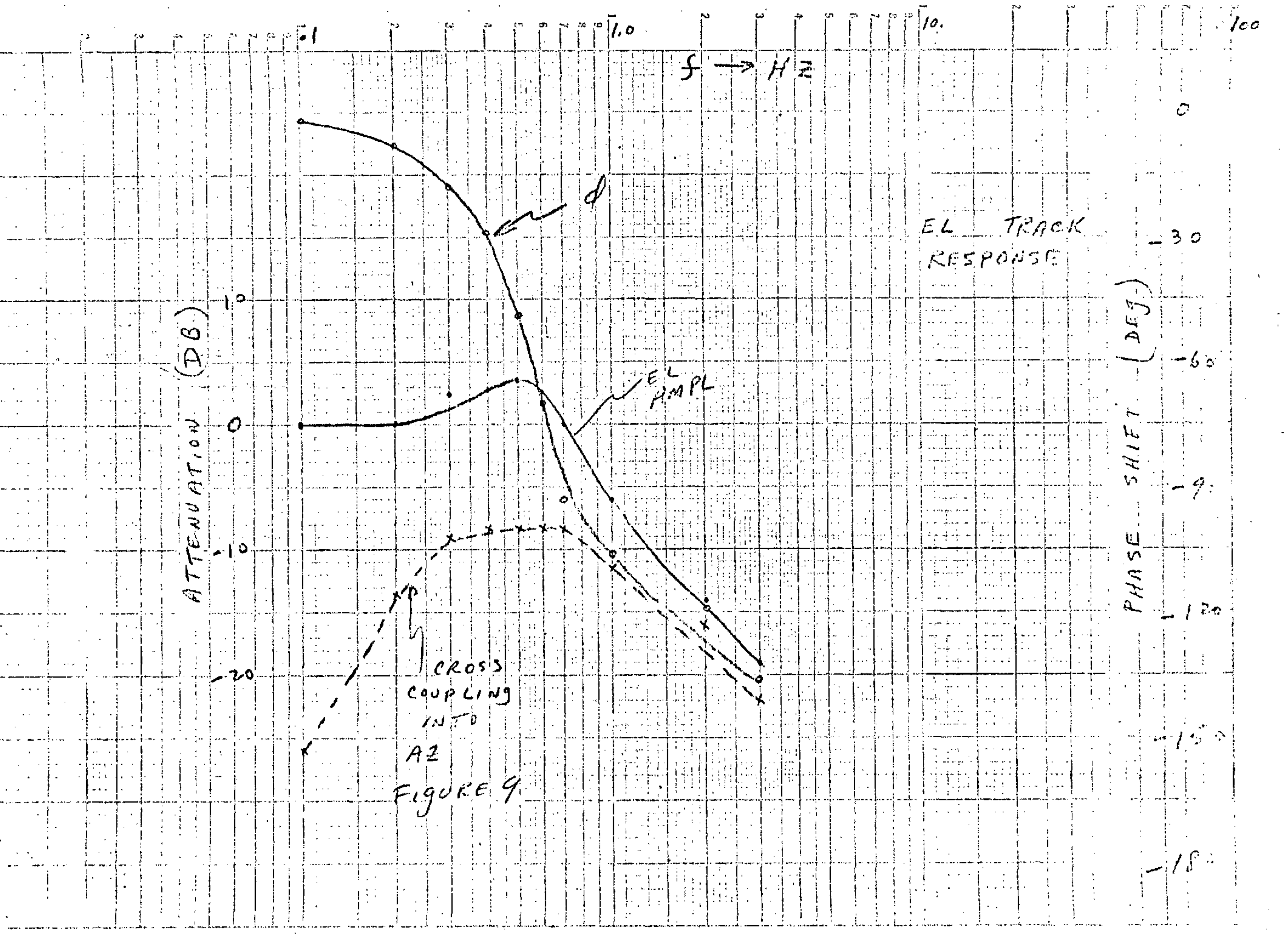
TABLE VIII

TRACK LOOP RESPONSE DATA

	INPUT INTO EL				CROSS COUPLING INTO AZ			
f	AMPL	NORM AMPL	db	ϕ	AMPL	NORM AMPL	db	ϕ
.1	.5	1.0	0	+178	.024	-21.	-26	- 28
.2	.55	1.1	.1	+172	.105	- 4.8	-13.6	- 77
.3	.654	1.31	2.3	+162	.18	- 2.8	- 9	-103
.4	.68	1.36	2.7	+151	.19	- 2.6	- 8.3	-132
.5	.757	1.52	3.6	+131	.19	- 2.6	- 8.3	-162
.6	.68	1.36	2.7	+110	.19	- 2.6	- 8.3	+162
.7	.51	1.0	0	+ 87	.19	- 2.6	- 8.3	+129
1.0	.25	-2.0	-6	+ 74	.13	- 3.8	-11.5	+ 96
2.0	.10	-5.0	-14	+ 61	.08	- 6.2	-16	+ 79
3.0	.054	-9.3	-19	+ 44	.04	-12.5	-22	+ 54

.1 - 3.0 Hz





f → HZ
d
EL TRACK RESPONSE
EL AMPL
CROSS COUPLING INTO AZ
ATTENUATION (DB)
PHASE SHIFT (DEG)

FIGURE 9

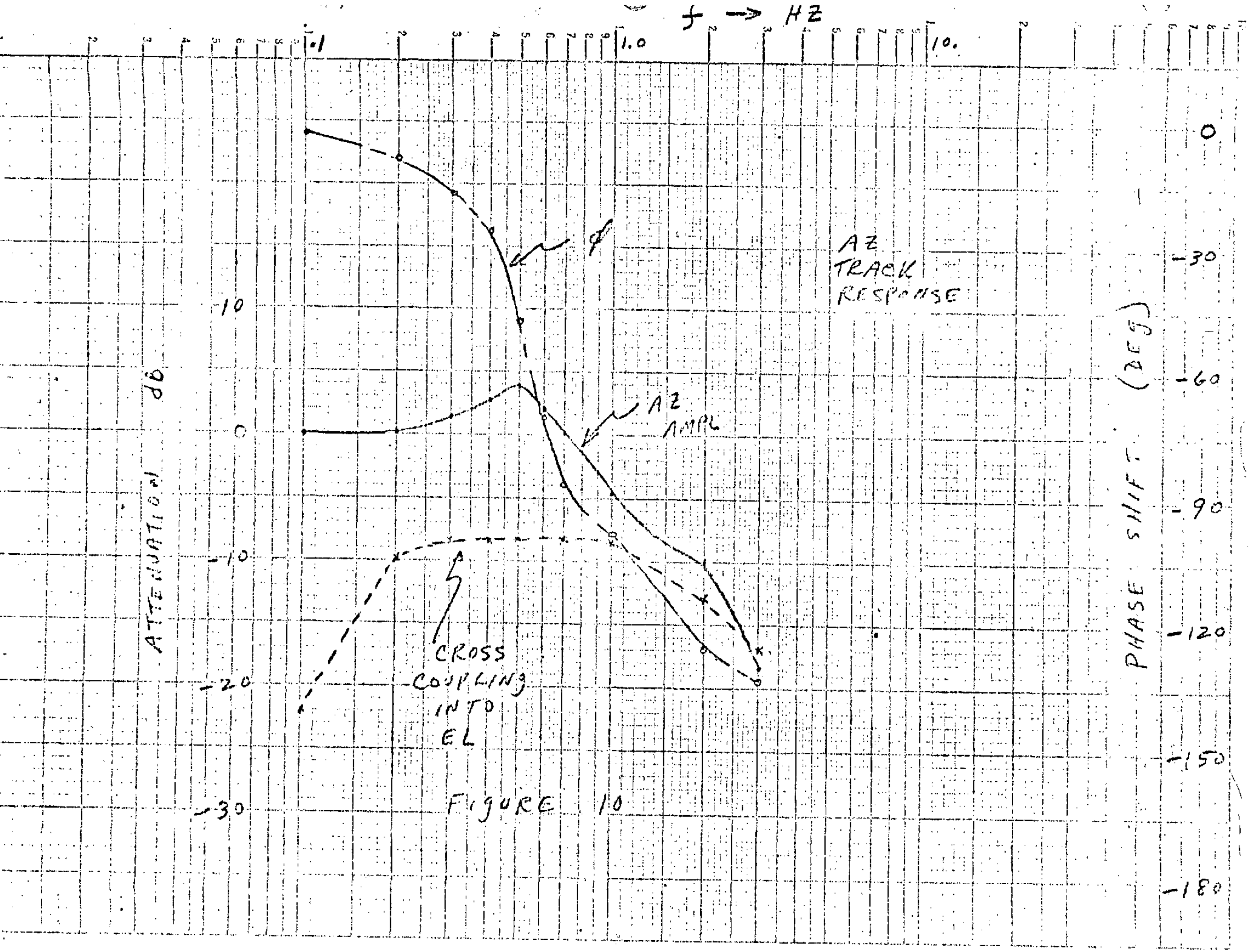

f → HZ
.1
1.0
10.
AZ
TRACK
RESPONSE
AZ
AMPL
CROSS
COUPLING
INTO
EL
ATTENUATION dB
PHASE SHIFT (DEG)
10
0
-10
-20
-30
0
-30
-60
-90
-120
-150
-180

FIGURE 10

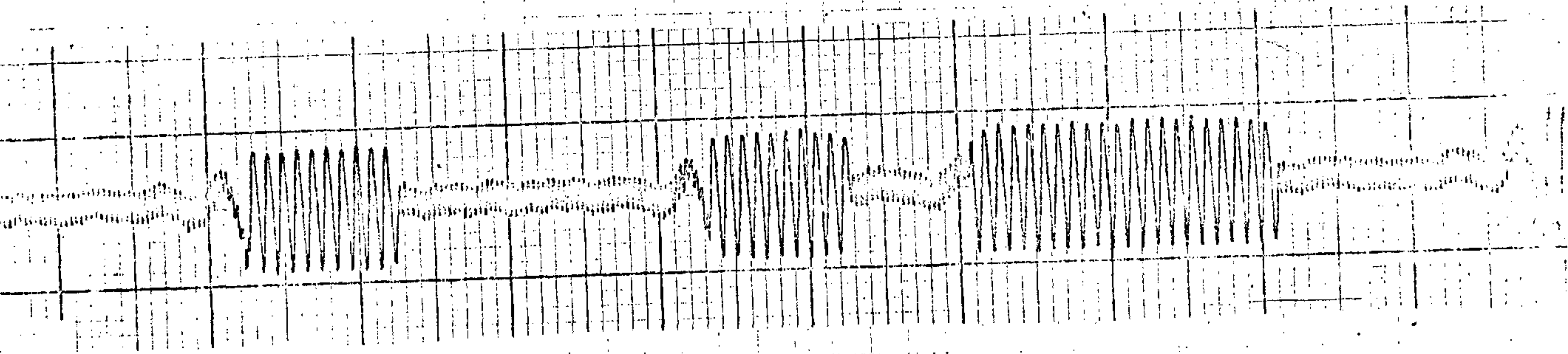


FIGURE. # 11

AZIMUTH - MINI-SEARCH / ACQ / TRACK

SCALING .2 IN/SEC .1V / DIV

(MULTIPLE ACQUISITIONS SAME TARGET)
TOWER

AZ POT OUTPUT (.093 V/1°)

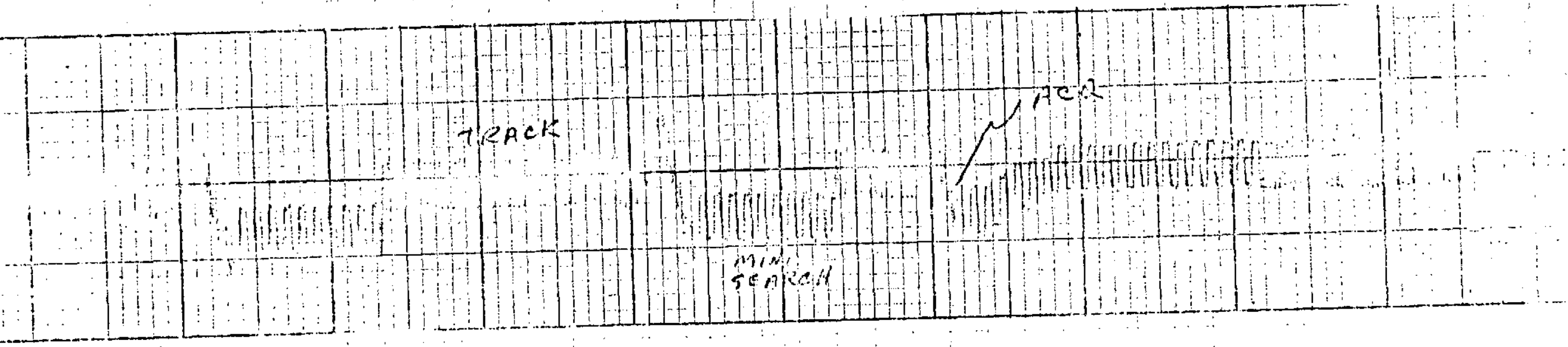


FIGURE # 12

ELEVATION MINI-SEARCH/ACR/TRACK

SCALING .2 IN/SEC .1V/DIV

MULTIPLE ACQUISITIONS SAME TARGET
TOWER

EL POT OUTPUT (.093V/1°)

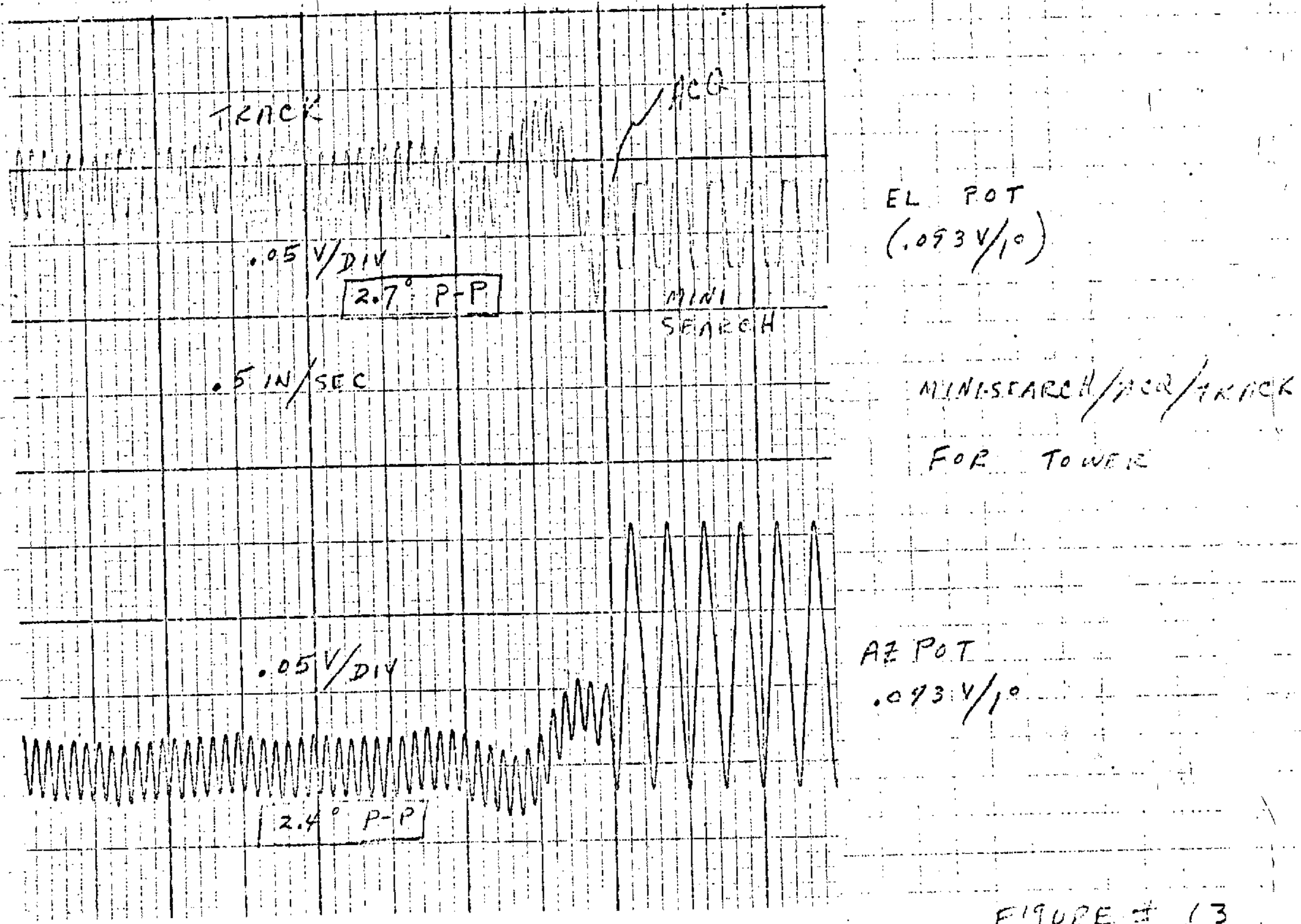

TRACK
ACQ
.05 V/DIV
2.7° P-P
MINI SEARCH
.5 IN/SEC
.05 V/DIV
2.4° P-P
EL POT
(.093 V/1°)
MINISEARCH/ACQ/TRACK
FOR TOWER
AZ POT
.093 V/1°

FIGURE # 13

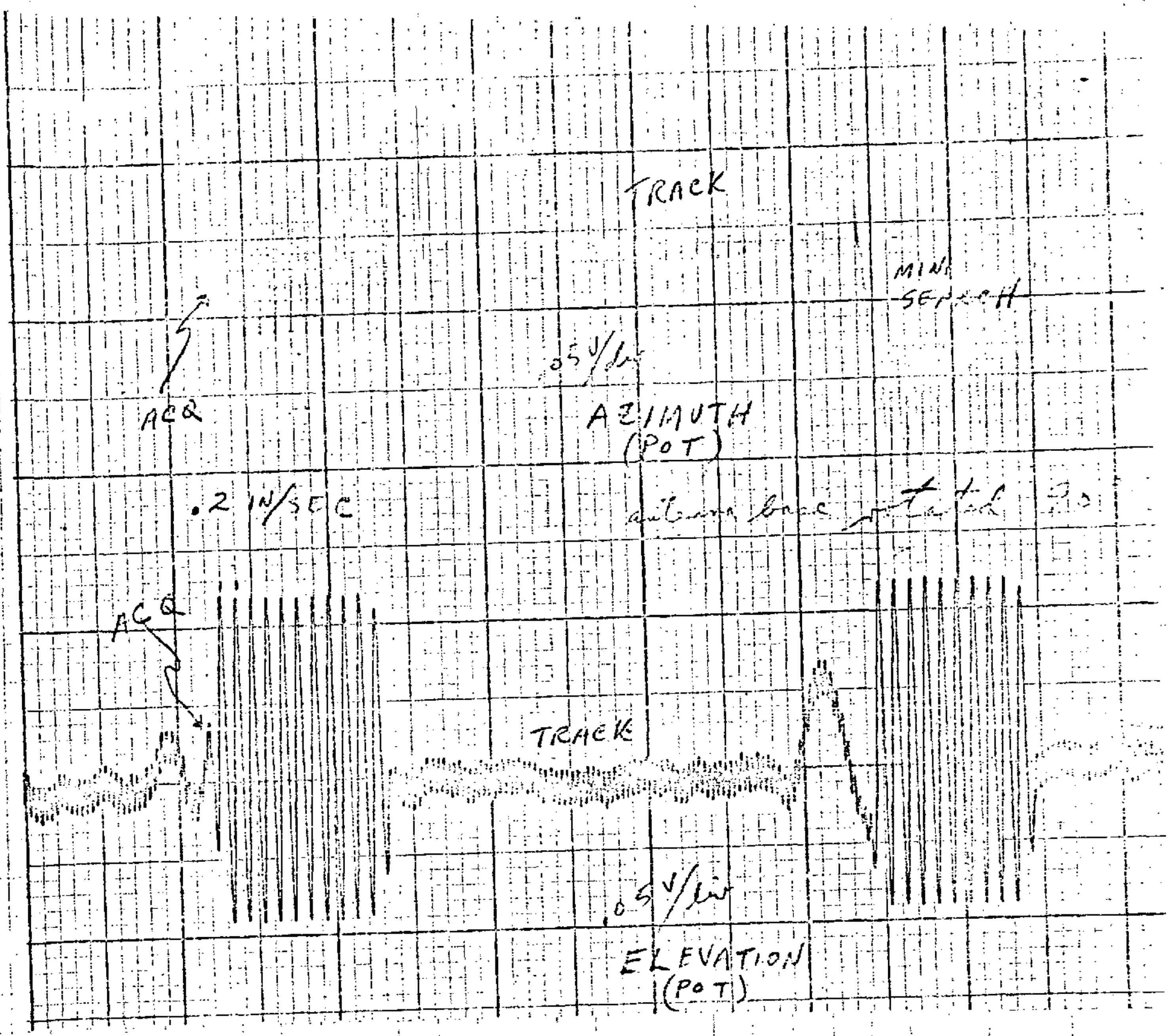


FIGURE 13A

MULTIPLE ACQUISITIONS OF TOWER
WITH ANTENNA BASE ROLLED 90°

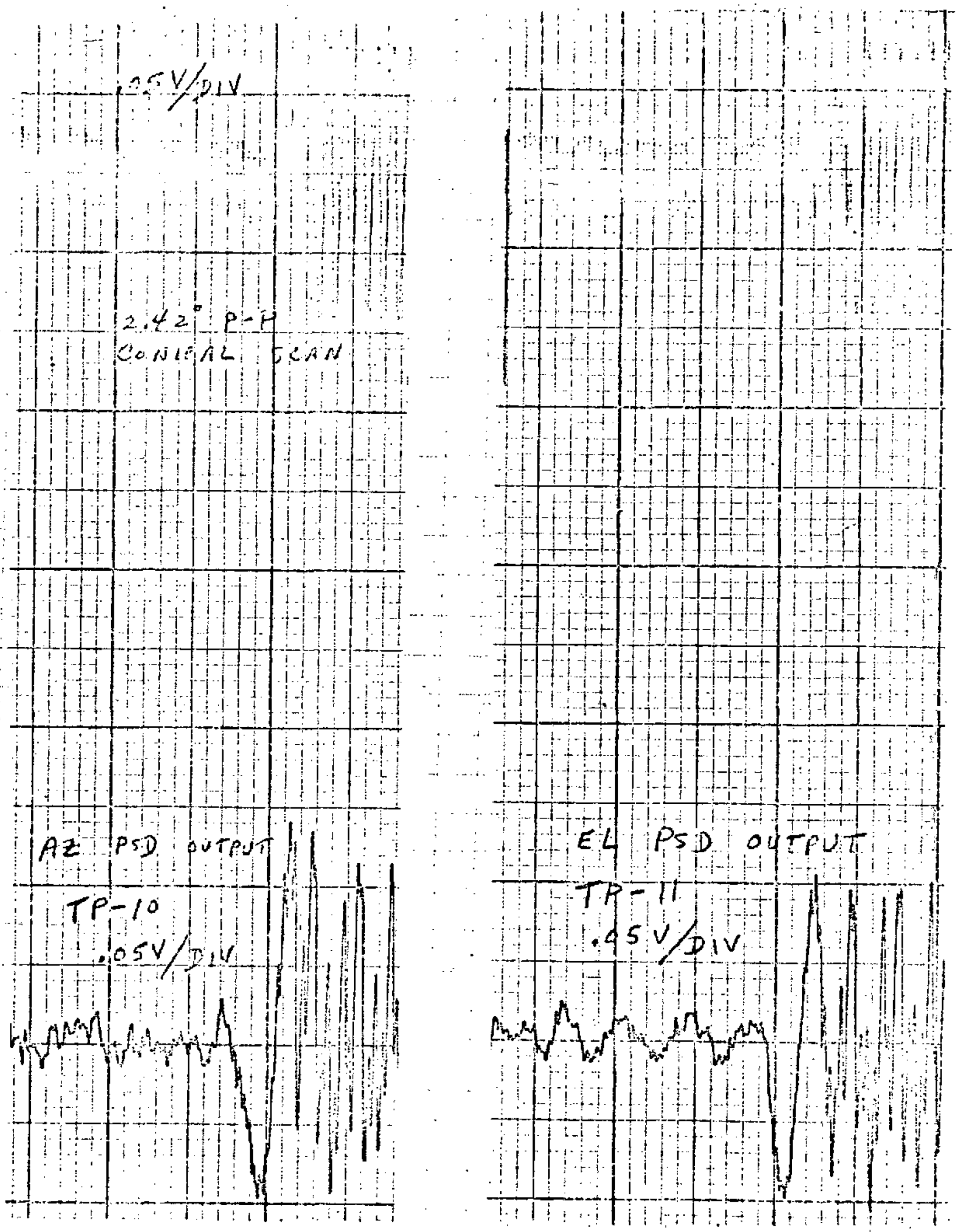


FIGURE #14

PSD OUTPUTS DURING MINISEARCH/ACQ/TRACK OF A TOWER

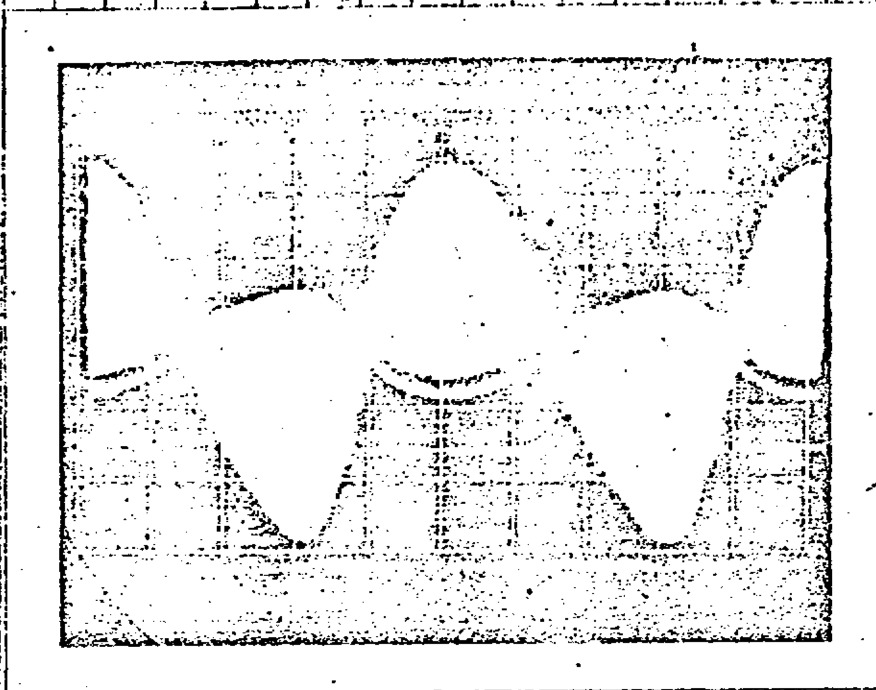


FIGURE #3 15

Rate gyro output of PSD (AZ)
gyro scale factor 14 mv/1°
scale .5 V/div and 1 sec/div

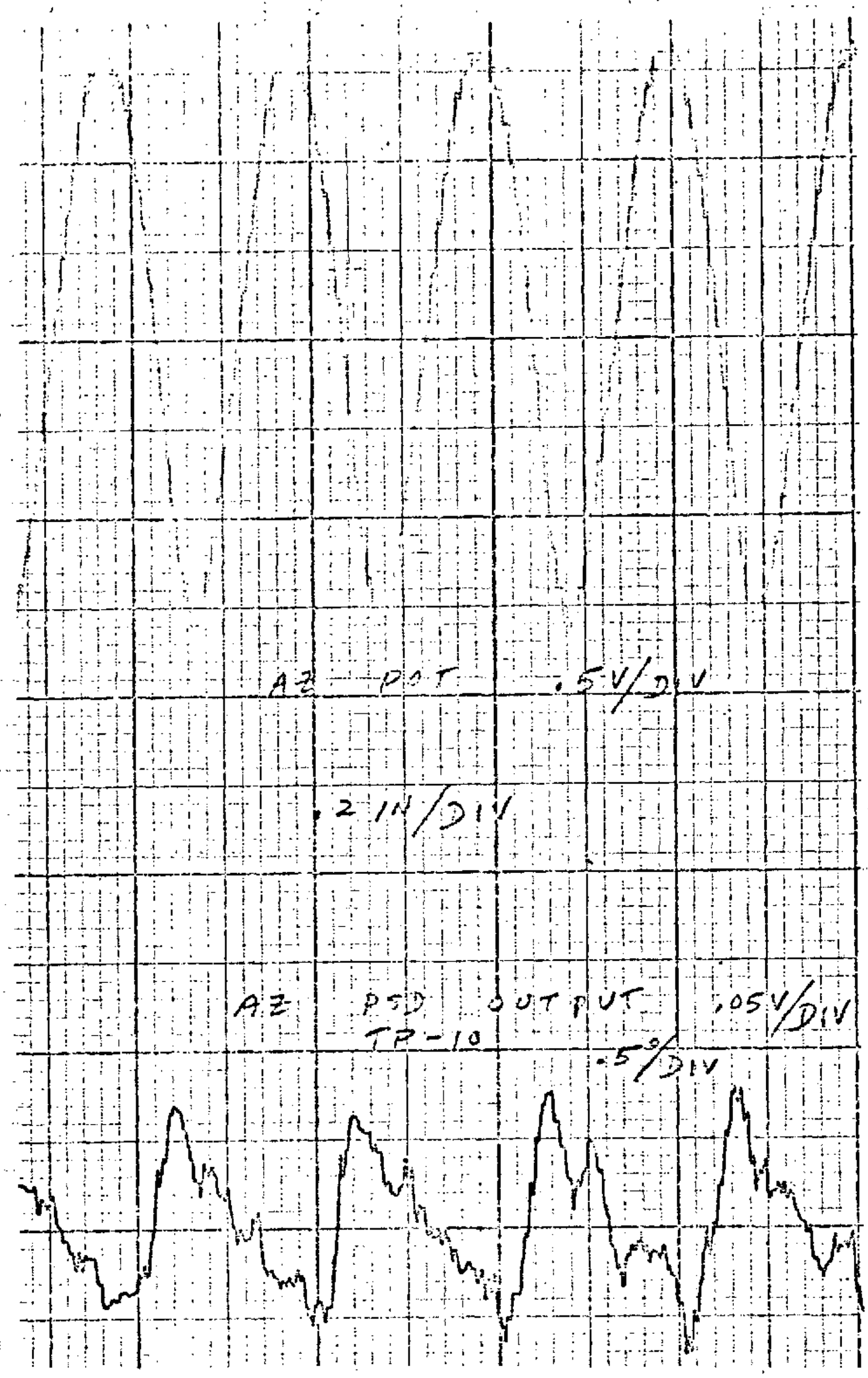


FIGURE # 16

TARGET TRACK WITH RATE TABLE MOTION

CONICAL SCAN
AMPLITUDE
MEASUREMENTS

2.6V P-P -AZ
3.4V P-P -EL

SCALE FACTOR
.093 V/°

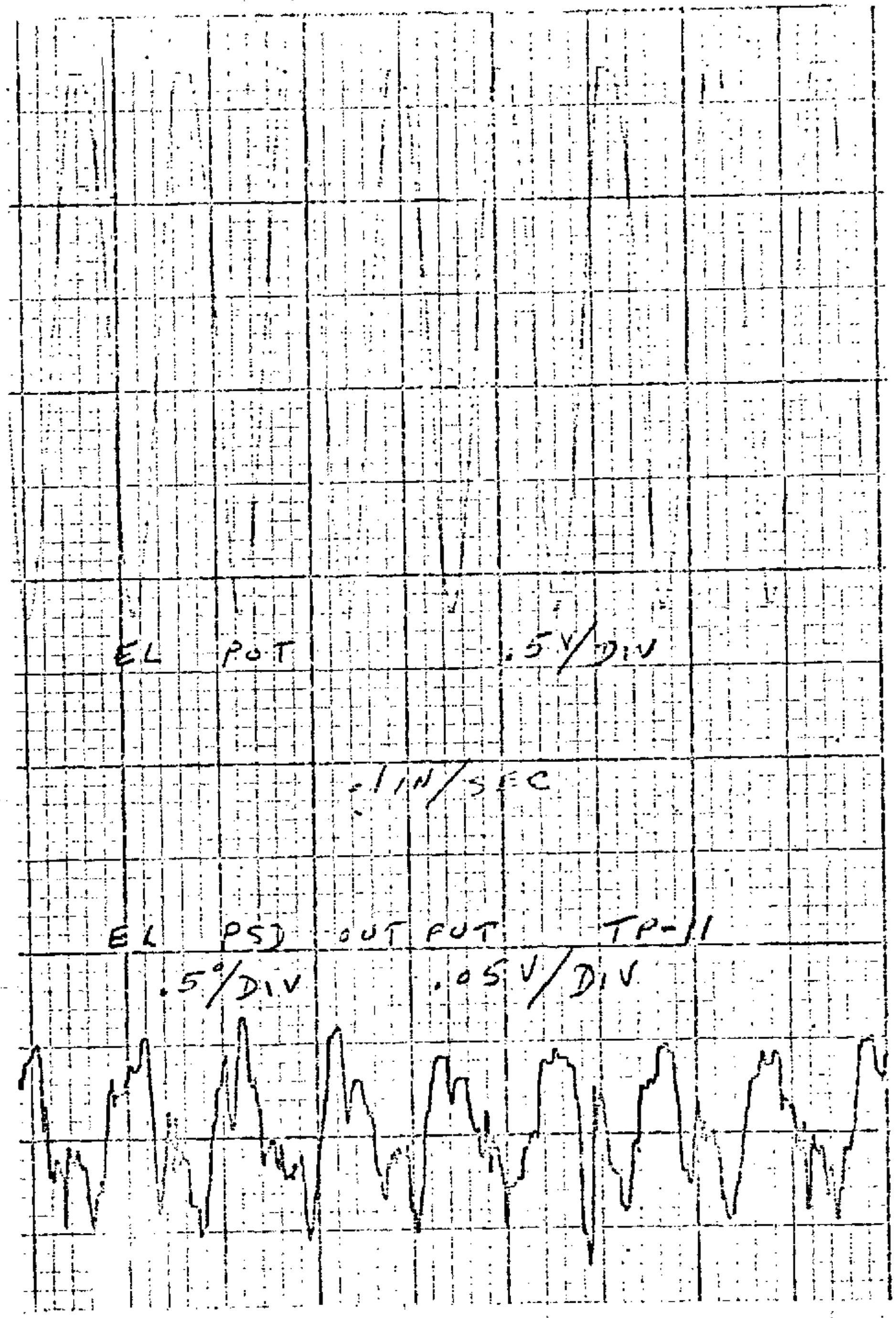


FIGURE 16A
ELEVATION ERROR TRACE
FOR RATE TABLE AT MAX (100°/SEC & 214°/SEC²)
(ANTENNA BASE ROTATED 90°, IN ROLL)

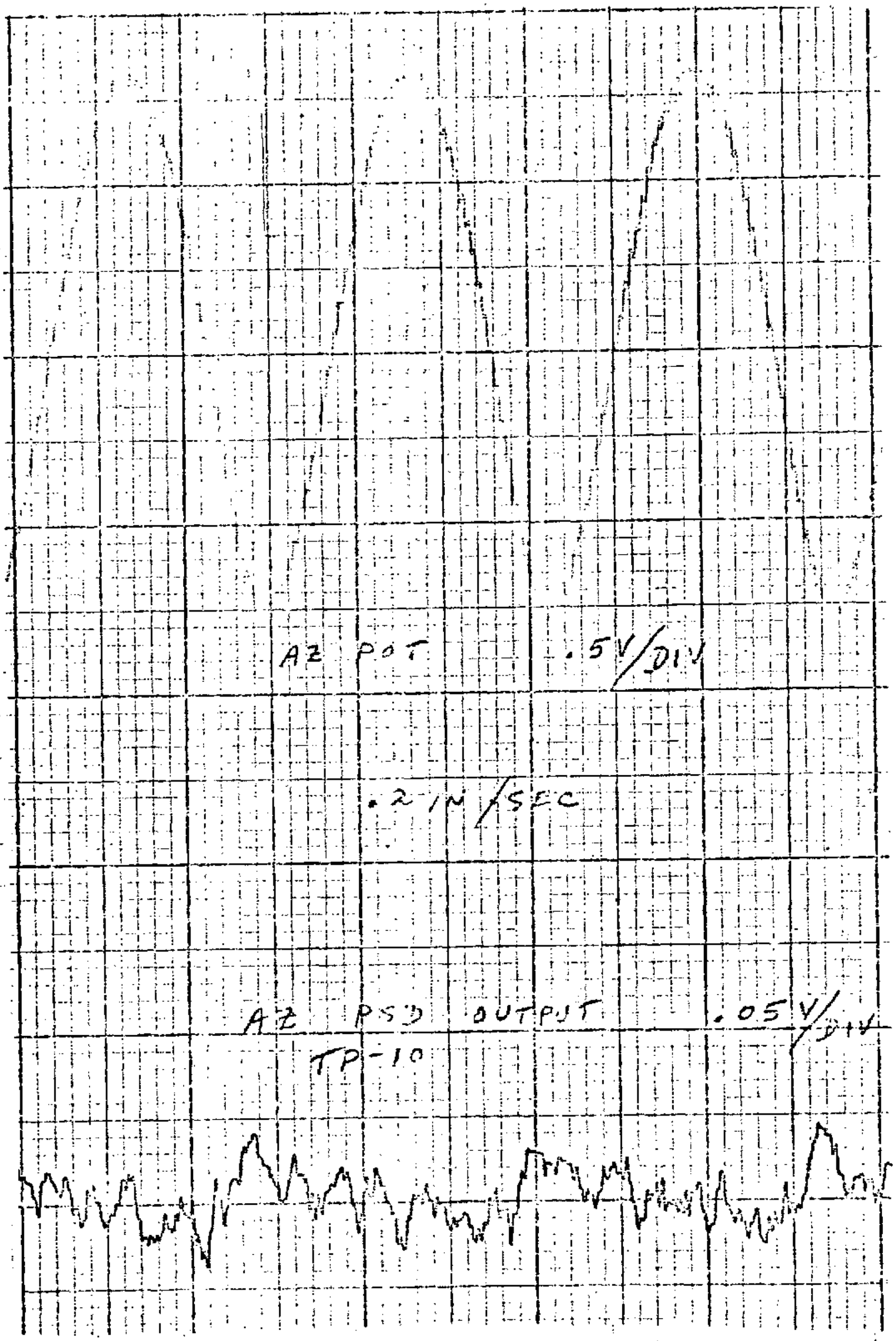


FIGURE #17
TARGET TRACK WITH RATE TABLE MOTION

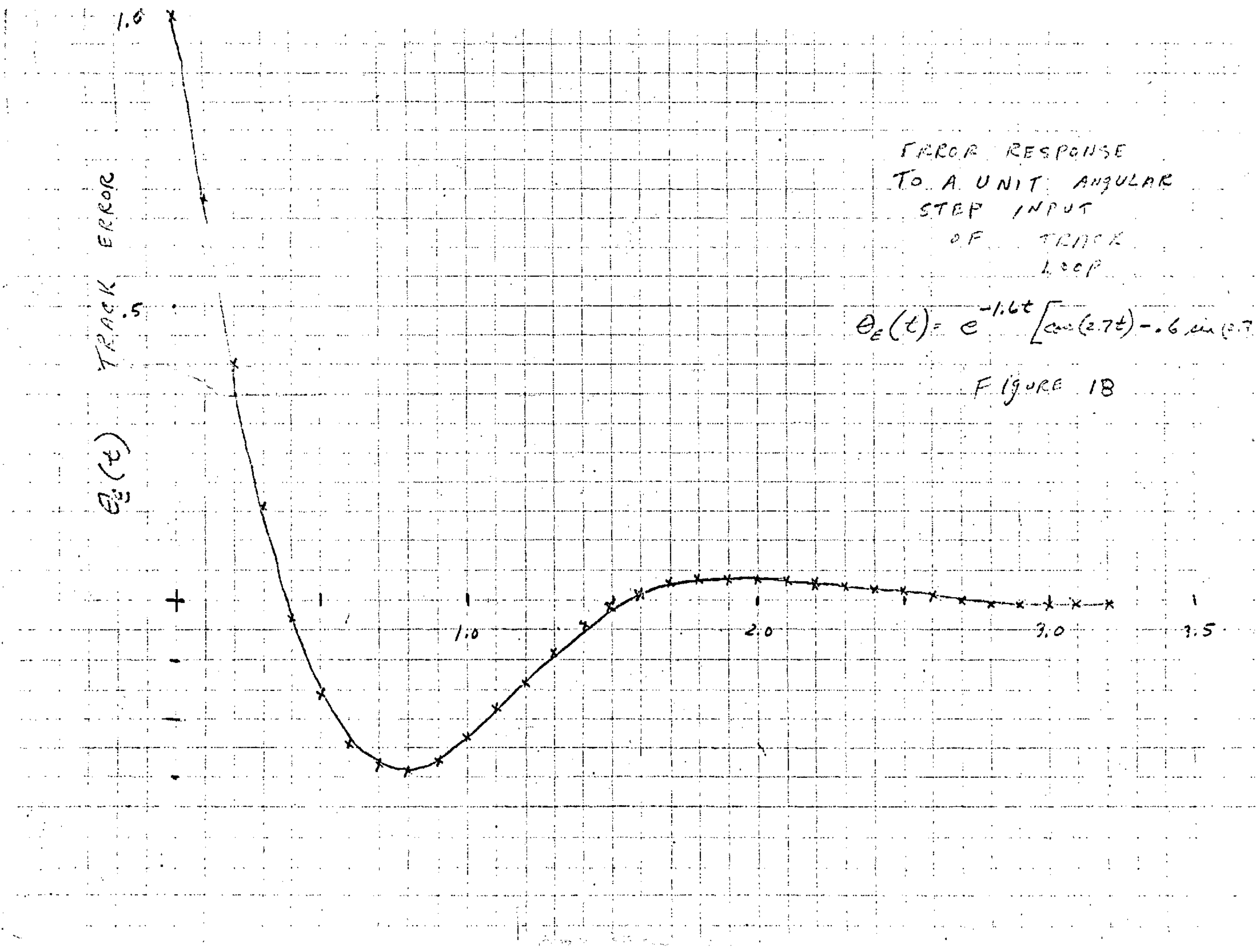
TABLE IX

```
TYP
$FREEIN
C
B=2.7
A=1.6
BB=A*A+B*B
AB=A/B
TH=.1
T=-TH
CC=SQRT(1./A*BB/A-1.)
SQ=SQRT(BB)*B
TYPE,'     T              O'
10 T=T+TH
BT=B*T
AO=EXP(-A*T)*(COS(BT)-AB*SIN(BT))
BO=EXP(-A*T)*SIN(BT)
BO=BO/B
CO=1../BB-EXP(-A*T)/SQ*SIN(BT+ATAN(CC))
TYPE,T,AO,BO,CO
IF(T.GT.4.) GO TO 20
GO TO 10
20 CONTINUE

CONTINUE
END

OK
BYE

OFF AT 16:48   11-Oct-73
SRU'S USED = 23
CONNECT TIME = 00:04
```

RUN
FORTRAN: ULRTTT.F4
RUNNING

T	U		
0.000000	1.000000	0.000000	0.000000
0.1000000	0.6565789	0.8418279E-01	0.4470674E-02
0.2000000	0.4015862	0.1382738	0.1583122E-01
0.3000000	0.1610639	0.1659914	0.3124503E-01
0.4000000	-0.2705711E-01	0.1722406	0.4831341E-01
0.5000000	-0.1613988	0.1623781	0.6515625E-01
0.6000000	-0.2454570	0.1416405	0.8042713E-01
0.7000000	-0.2859740	0.1147400	0.9327980E-01
0.8000000	-0.2914862	0.8561319E-01	0.1033019
0.9000000	-0.2711188	0.5730499E-01	0.1104307
1.000000	-0.2336618	0.3195797E-01	0.1148626
1.100000	-0.1869268	0.1088036E-01	0.1169654
1.200000	-0.1373620	-0.5334785E-02	0.1172014
1.300000	-0.8988626E-01	-0.1666338E-01	0.1160618
1.400000	-0.4789673E-01	-0.2349646E-01	0.1140188
1.500000	-0.1340161E-01	-0.2649385E-01	0.1114906
1.600000	0.1276745E-01	-0.2645535E-01	0.1088213
1.700000	0.3070265E-01	-0.2421556E-01	0.1062728
1.800000	0.4115934E-01	-0.2056456E-01	0.1040251
1.900000	0.4531128E-01	-0.1619407E-01	0.1021837
2.000000	0.4453790E-01	-0.1166652E-01	0.1007914
2.100000	0.4025266E-01	-0.7403443E-02	0.9984146E-01
2.200000	0.3377557E-01	-0.3688842E-02	0.9929226E-01
2.300000	0.2624838E-01	-0.6830783E-03	0.9907995E-01
2.400000	0.1858800E-01	-0.1556664E-02	0.9913002E-01
2.500000	0.1147134E-01	0.3052904E-02	0.9936643E-01
2.600000	0.5344512E-02	0.3884155E-02	0.9971840E-01
2.700000	0.4486848E-03	0.4163028E-02	0.1001248
2.800000	-0.3143927E-02	0.4017476E-02	0.1005369
2.900000	-0.5489847E-02	0.3575897E-02	0.1009185
3.000000	-0.6734350E-02	0.2956278E-02	0.1012461
3.100000	-0.7075009E-02	0.2259178E-02	0.1015072
3.200000	-0.6730864E-02	0.1564099E-02	0.1016980
3.300000	-0.5918221E-02	0.9285992E-03	0.1018220
3.400000	-0.4833321E-02	0.3894950E-03	0.1018870
3.500000	-0.3641426E-02	-0.3453926E-04	0.1019038
3.600000	-0.2471486E-02	-0.3395637E-03	0.1018841
3.700000	-0.1415304E-02	-0.5326672E-03	0.1018396
3.800000	-0.5300300E-03	-0.6283549E-03	0.1017808
3.900000	0.1571247E-03	-0.6453039E-03	0.1017165
4.000000	0.6429648E-03	-0.6036600E-03	0.1016537
4.100000	0.9420013E-03	-0.5229506E-03	0.1015971

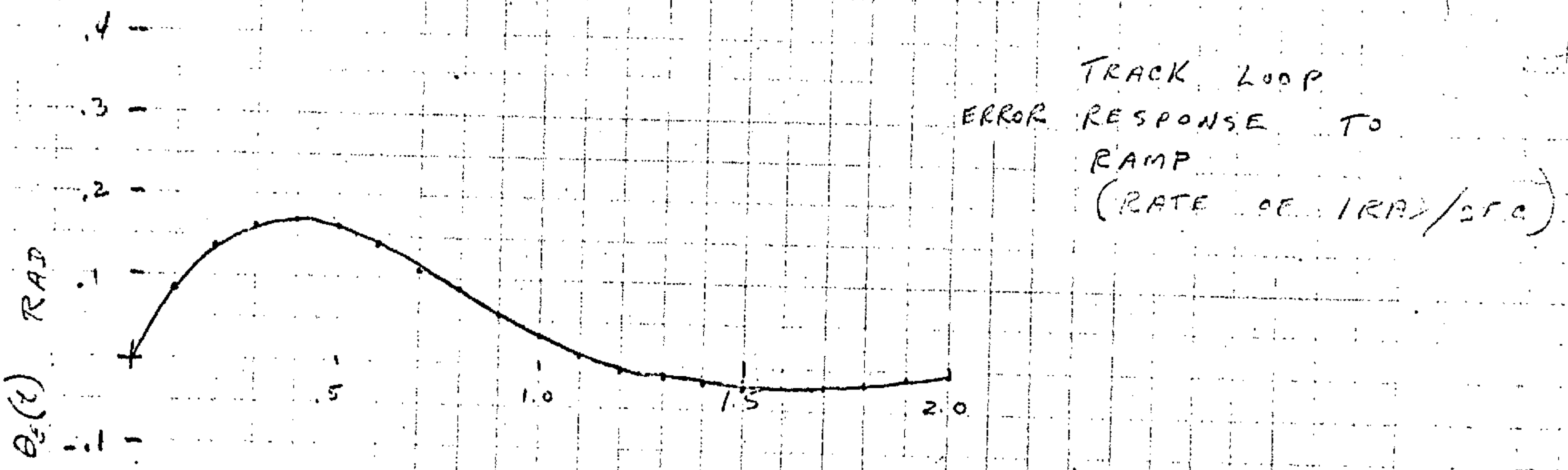
OK



ERROR RESPONSE TO A UNIT ANGULAR STEP INPUT OF TRACK LOOP

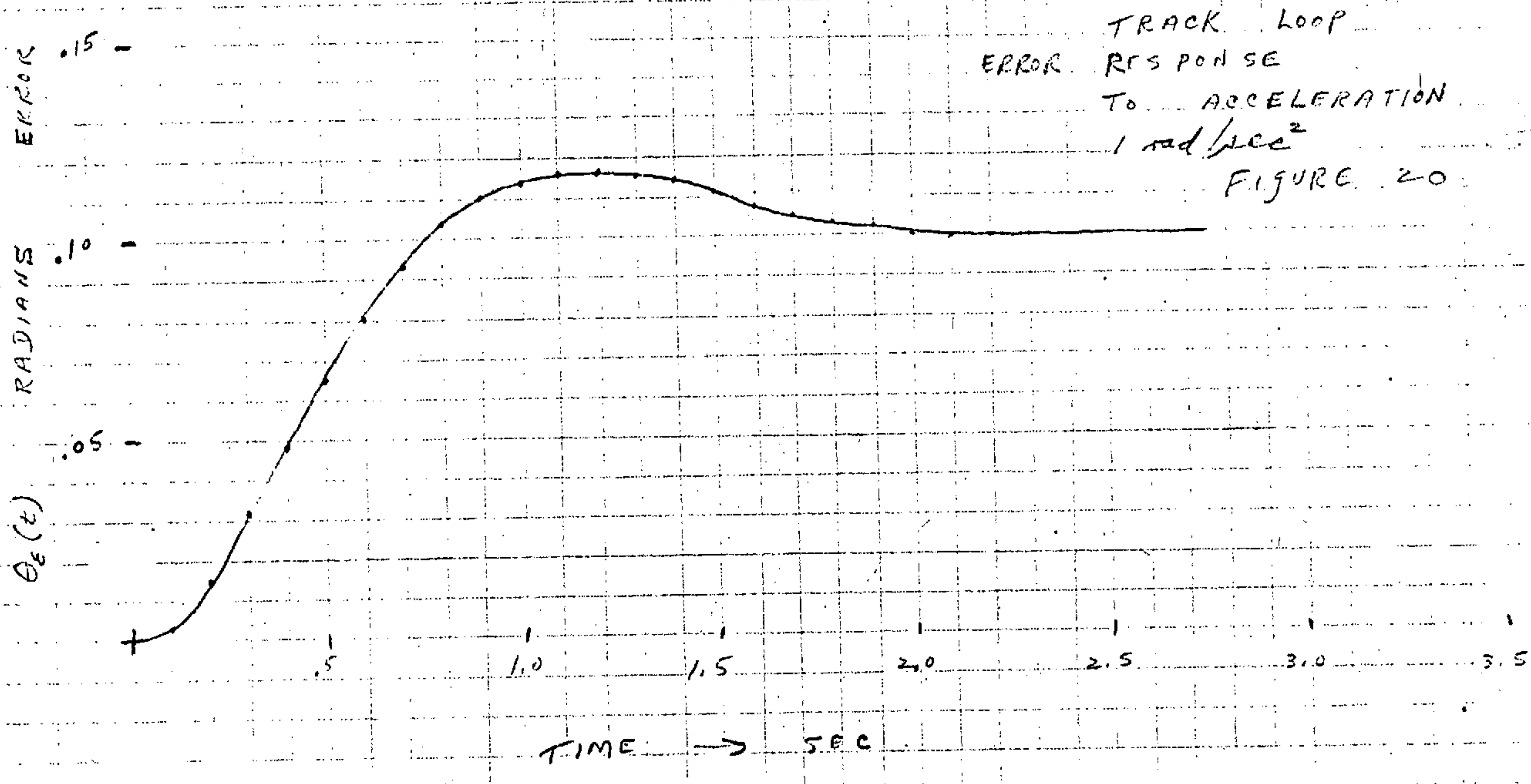
$\theta_E(t) = e^{-1.6t}[\cos(2.7t) - .6\sin(2.7$

FIGURE 18



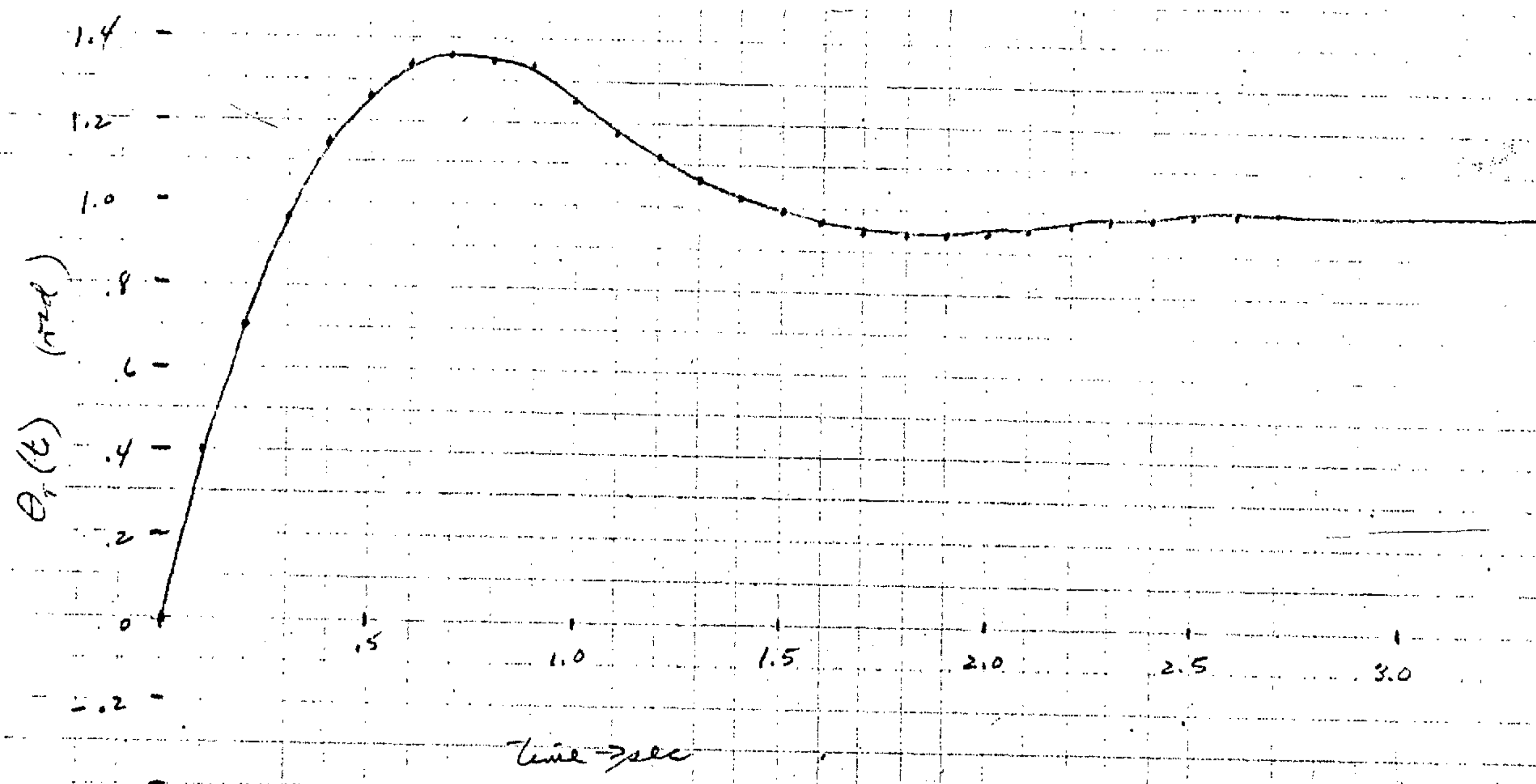
.4
.3
.2
.1
-.1
$\theta_e(t)$ RAD
.5
1.0
1.5
2.0
TRACK LOOP
ERROR RESPONSE TO
RAMP
(RATE OF 1RAD/SEC)

FIGURE #19

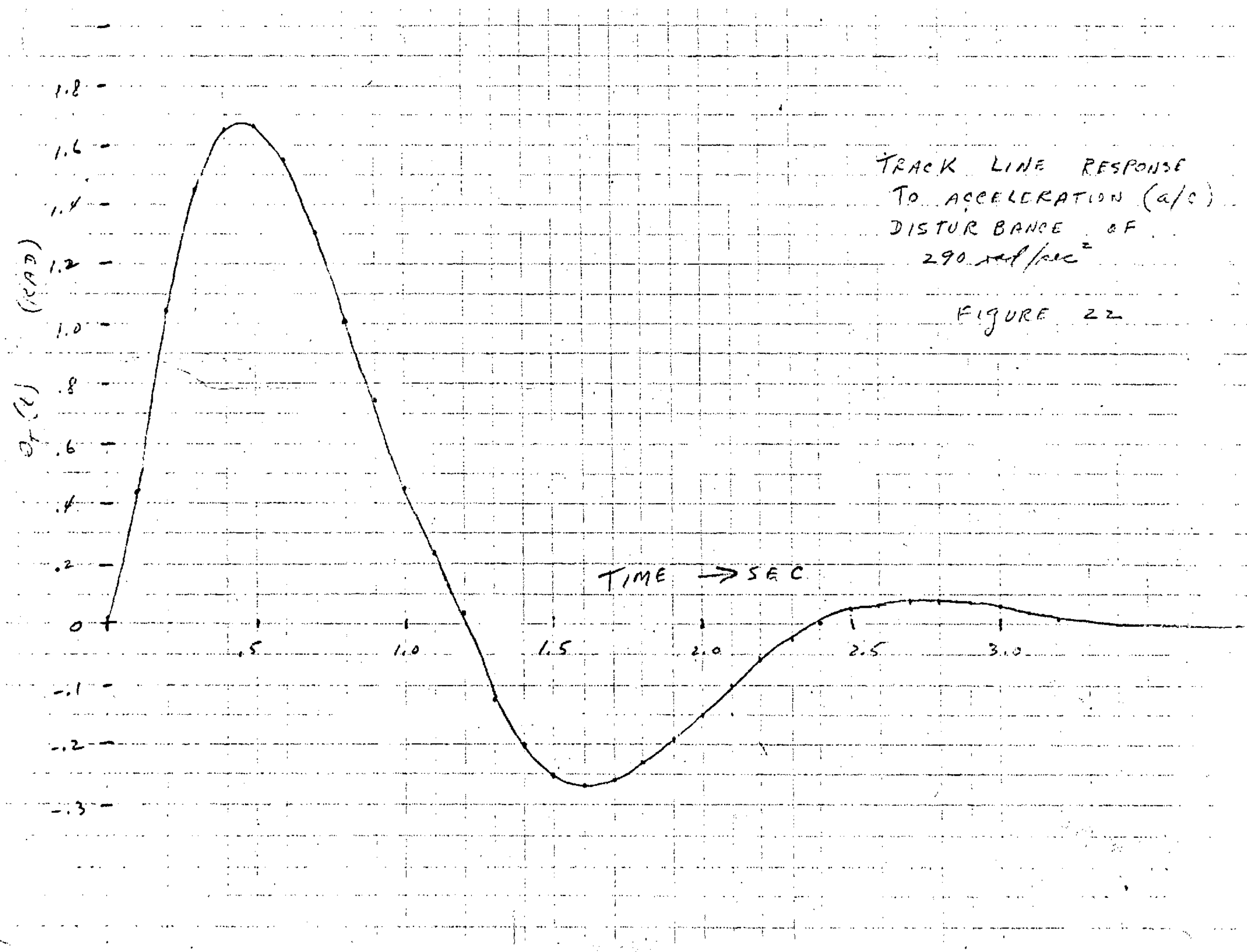


TRACK LOOP
ERROR RESPONSE
TO ACCELERATION
1 rad/sec²
$\Theta_E(t)$ RADIANS ERROR
.15
.10
.05
.5
1.0
1.5
2.0
2.5
3.0
3.5
TIME → SEC

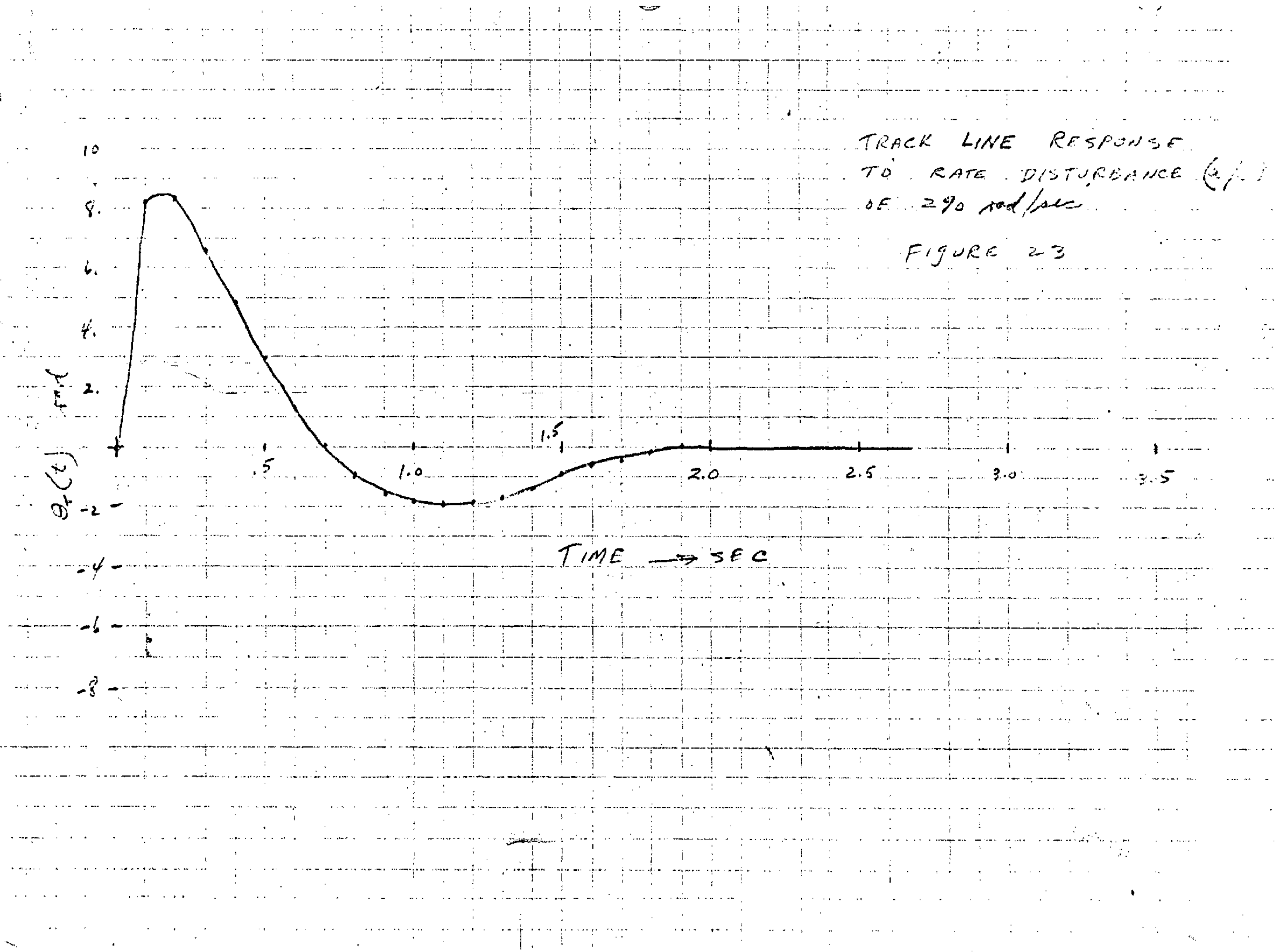
FIGURE 20

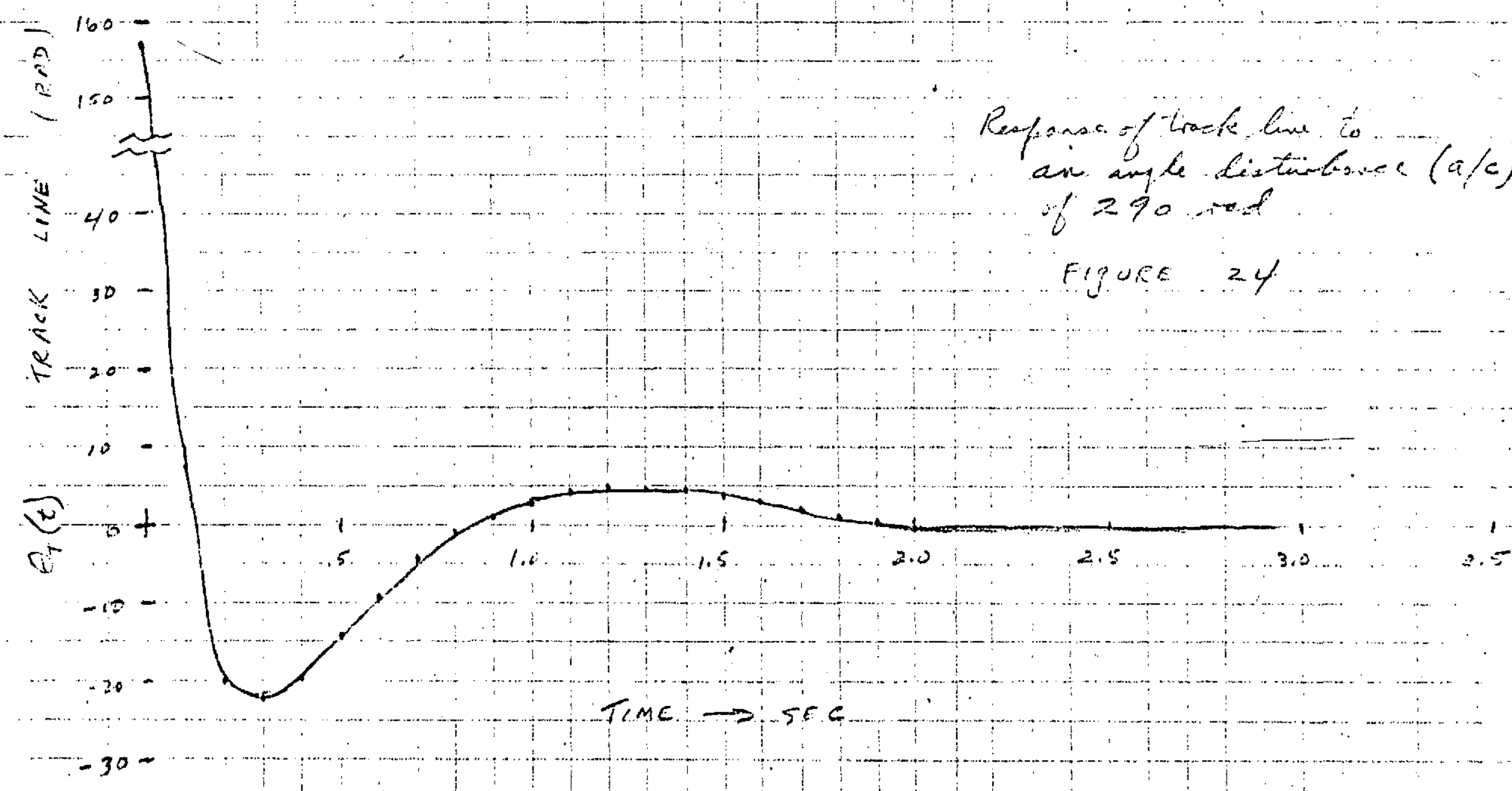


Response of track line
to jerk disturbance (a/c)
of 290 rad/sec^3
Figure # 21



TRACK LINE RESPONSE
TO ACCELERATION (a/c)
DISTURBANCE OF
290 rad/sec²
FIGURE 22
TIME → SEC
$\theta_T(t)$ (RAD)
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
-.1
-.2
-.3
.5
1.0
1.5
2.0
2.5
3.0


TRACK LINE RESPONSE
TO RATE DISTURBANCE
OF 2% rad/sec
FIGURE 23
TIME → SEC
10
8.
6.
4.
2.
-2
-4
-6
-8
.5
1.0
1.5
2.0
2.5
3.0
3.5



Response of track line to air angle disturbance (a/c) of 290 rad

FIGURE 24

```
FORTRAN  DERT.F4
RUNNING
                                                        TABLE I
     T      AO       BO.      CO       DO
ZZ =   0.8660254      D=      0.8422641     AD=      0.7947943
AZ=   -1.047198      BZ=      0.1862046     ZZ=      2.719370
PA=    0.8609330     PB=      0.1862046     PC=     -1.233462     PD=      2.280660
 T  AO  BO      0.000000     -0.7450581E-08   0.7450581E-08
CO=    0.000000       DO=    157.7536
 T  AO  BO      0.1000000     0.3933627        0.4366315
CO=    8.216711       DO=    7.663069
 T  AO  BO      0.2000000     0.7115671        1.040023
CO=    8.392498       DO=  -20.42967
 T  AO  BO      0.3000000     0.9641768        1.458350
CO=    6.779412       DO=  -22.64326
 T  AO  BO      0.4000000     1.150902         1.654641
CO=    4.822660       DO=  -19.00961
 T  AO  BO      0.5000000     1.274478         1.661811
CO=    2.946195       DO=  -14.08334
 T  AO  BO      0.6000000     1.341684         1.528115
CO=    1.319607       DO=  -9.166093
 T  AO  BO      0.7000000     1.362096         1.302308
CO=  0.1888130E-01    DO=  -4.777111
 T  AO  BO      0.8000000     1.346618         1.028077
CO=  -0.9332559       DO=  -1.164369
 T  AO  BO      0.9000000     1.306220         0.7414686
CO=  -1.550557        DO=   1.573619
 T  AO  BO      1.000000      1.251009         0.4696688
CO=  -1.871390        DO=   3.441946
 T  AO  BO      1.100000      1.189611         0.2320263
CO=  -1.948711        DO=   4.517975
 T  AO  BO      1.200000      1.128845         0.3880506E-01
CO=  -1.841650        DO=   4.924871
 T  AO  BO      1.300000      1.073641        -0.1056035
CO=  -1.608880        DO=   4.808798
 T  AO  BO      1.400000      1.027133        -0.2022339
CO=  -1.303811        DO=   4.320426
 T  AO  BO      1.500000      0.9908808       -0.2558517
CO=  -0.9715294       DO=   3.601068
 T  AO  BO      1.600000      0.9651633       -0.2735481
CO=  -0.6472559       DO=   2.773343
 T  AO  BO      1.700000      0.9492999       -0.2635181
CO=  -0.3560468       DO=   1.935921
 T  AO  BO      1.800000      0.9419664       -0.2340752
CO=  -0.1134317       DO=   1.161695
 T  AO  BO      1.900000      0.9414796       -0.1929218
CO=   0.7352301E-01   DO=   0.4986135
 T  AO  BO      2.000000      0.9460353       -0.1466675
CO=   0.2035973       DO= -0.2762662E-01
 T  AO  BO      2.100000      0.9538924       -0.1005687
CO=   0.2816781       DO= -0.4097366
 T  AO  BO      2.200000      0.9635017       -0.5845240E-01
CO=   0.3150778       DO= -0.6544679
 T  AO  BO      2.300000      0.9735846       -0.2278003E-01
CO=   0.3130339       DO= -0.7783554
 T  AO  BO      2.400000      0.9831673        0.5191136E-02
CO=   0.2852694       DO= -0.8035193
 T  AO  BO      2.500000      0.9915803        0.2518894E-01
CO=   0.2410456       DO= -0.7544665
 T  AO  BO      2.600000      0.9984328        0.3768373E-01
CO=   0.1885095       DO= -0.6553138
 T  AO  BO      2.700000      1.003570         0.4364879E-01
CO=   0.1343101       DO= -0.5278835
 T  AO  BO      2.800000      1.007024         0.4434316E-01
CO=   0.8344451E-01   DO= -0.3904905
 T  AO  BO      2.900000      1.008957         0.4112890E-01
CO=   0.3928307E-01   DO= -0.2573504
 T  AO  BO      3.000000      1.009617         0.3532906E-01
CO=   0.3725471E-02   DO= -0.1394907
 T  AO  BO      3.100000      1.009293         0.2812718E-01
CO=  -0.2256269E-01   DO= -0.4003868E-01
 T  AO  BO      3.200000      1.008276         0.2050549E-01
CO=  -0.3987312E-01   DO=  0.3524268E-01
 T  AO  BO      3.300000      1.006638         0.1321677E-01
CO=  -0.4917236E-01   DO=  0.8727943E-01
 T  AO  BO      3.400000      1.005214         0.6783000E-02
CO=  -0.5183892E-01   DO=  0.1179683
 T  AO  BO      3.500000      1.003590         0.1513745E-02
CO=  -0.4943615E-01   DO=  0.1304866
 T  AO  BO      3.600000      1.002103        -0.2462586E-02
CO=  -0.4353201E-01   DO=  0.1266803
 T  AO  BO      3.700000      1.000839        -0.5160700E-02
CO=  -0.3556549E-01   DO=  0.1165613
 T  AO  BO      3.800000      0.9998461       -0.6698610E-02
CO=  -0.2676096E-01   DO=  0.9792569E-01
 T  AO  BO      3.900000      0.9991334       -0.7259900E-02
CO=  -0.1808316E-01   DO=  0.7609359E-01
 T  AO  BO      4.000000      0.9986855       -0.7060646E-02
CO=  -0.1022623E-01   DO=  0.5375866E-01
 T  AO  BO      4.100000      0.9984687       -0.6322520E-02
CO=  -0.3628356E-02   DO=  0.3293085E-01
OK
```

```
OK
TYUNUNP
10$FREEIN
20C
30 W=3.14
40 Z=.5
50 A=1./16.
60 TH=.1
70 T=-TH
80 TYPE,'        T      AO       BO,       CO      DO'
90 ZZ=SQRT(1.-Z*Z)
100 D=1.-2.*A*W*Z+A*A*W*W
102 G=1.-2.*A*W*Z-A*A*W*W
110 SD=SQRT(D*(1.-Z*Z))
120 AZ=ATAN(-ZZ/Z)
130 BZ=ATAN(A*W*ZZ/(1.-A*Z*W)).
140 PA=BZ+AZ
141 PA=-PA
150 PB=BZ
160 PC=-BZ+AZ
170 PD=BZ-2.*AZ
180 WW=W*ZZ
182 TYPE,' ZZ =',ZZ,'D=',D,'AD=',SD
184 TYPE,' AZ=',AZ,'BZ=',BZ,'WW=',WW
186 TYPE,' PA=',PA,'PB=',PB,'PC=',PC,'PD=',PD
190 10 T=T+TH
200 EE=EXP(-Z*W*T)
210 EA=EXP(-T/A)
220 AO=1.-A*A*W*W*EA/D+EE*SIN(WW*T-PA)/SD
230 BO=A*W*W*EA/D+W*EE*SIN(WW*T-PB)/SD
240 CO=-W*W*EA/D+W*W*EE*SIN(WW*T-PC)/SD
250 DO=W*W/A*EA/D+A*W*W*EE*SIN(WW*T-PD)/SD
260 TYPE,'  T  AO  BO',T,AO,BO
270 TYPE,' CO=',CO,'  DO=',DO
280 IF(T.GT.4.) GO TO 20
290 GO TO 10
300 20CONTINUE
310 END

OK
REP

OK
BYE

OFF AT 09:57  15-Oct-73
SRU'S USED = 114
CONNECT TIME = 00:17
```

APPENDIX A

Appendix A presents the deviation of the track line response to an aircraft disturbance when the track line response to a target motion is known. Figure A-1 is a series of block diagrams showing the determination of the self stabilization term $\frac{\theta_D'}{\theta_D}$. Figure A-2 is a simplified overall loop block diagram of the track mode.

From Figure A-2, the tracking line (θ_T) response to a target input angle (θ_S) is written as:

$$\frac{\theta_T}{\theta_S} = \frac{G_1\ G_2\ G_3\ G_5\ G_6}{1 + G_2\ G_3\ H_1 + G_1\ G_2\ G_3\ H_2 + G_5\ G_1\ G_2\ G_3\ H_3 + G_6\ G_5\ G_1\ G_2\ G_3\ H_4} \qquad \text{(A-1)}$$

The response to a disturbance is:

$$\frac{\theta_T}{\theta_D'} = \left[\frac{1}{G_5\ G_6}\right] \left[\frac{\theta_i}{\theta_B}\right] \left[\frac{\theta_T}{\theta_S}\right] \qquad \text{(A-2)}$$

and

$$\frac{\theta_T}{\theta_D} = \left[\frac{\theta_D'}{\theta_D}\right] \left[\frac{\theta_T}{\theta_D'}\right] = \left[\frac{\theta_D'}{\theta_D}\right] \left[\frac{1}{G_5\ G_6}\right] \left[\frac{\theta_i}{\theta_B}\right] \left[\frac{\theta_T}{\theta_S}\right] \qquad \text{(A-3)}$$

where

$$\frac{\theta_D'}{\theta_D} = \frac{1 + G_2\ G_3\ H_1 + G_1\ G_2\ G_3\ H_2 - G_3\ G_4}{1 + G_2\ G_3\ H_1 + G_1\ G_2\ G_3\ H_2} \qquad \text{(A-4)}$$

where

$$\left.\begin{aligned} H_2 &= 1. & G_2 &= \frac{K_{T/R}}{1 + T_E\ S} \\ H_1 &= K_B\ S & G_1 &= \frac{Y\ (1 + T_1\ S)\ (1 + T_2\ S)}{(1 + T_3\ S)\ (1 + T_4\ S)} \end{aligned}\right\} \qquad \text{(A-5)}$$

$$G_3 = \frac{1}{JS^2}$$

$$G_4 = JS^2$$

Substituting into $\frac{\theta_D'}{\theta_D}$ we obtain

$$\frac{\theta_D'}{\theta_D} = \frac{\left[\frac{K_R}{(1 + T_E\ S)}\right] + \left[\frac{Y\ (1 + T_1\ S)\ (1 + T_2\ S)}{(1 + T_3\ S)\ (1 + T_4\ S)}\right]\ \left[\frac{K_R}{(1 + T_E\ S)}\right]\ \left[\frac{1}{JS^2}\right]}{1 + \frac{K_R\ K_B\ S}{JS^2\ (1 + T_E\ S)} + \frac{Y(1 + T_1\ S)\ (1 + T_2\ S)\ K_R}{JS^2\ (1 + T_3\ S)\ (1 + T_4\ S)\ (1 + T_E\ S)}} \qquad \text{(A-6)}$$

Further substitution yields

$$\frac{\theta_D'}{\theta_D} = \frac{(K_R\ K_B\ S)\ (1 + T_3\ S)\ (1 + T_3\ S) + K_R\ (1 + T_1\ S)\ (1 + T_2\ S)}{JS^2\ (1 + T_3\ S)\ (1 + T_4\ S)\ (1 + T_E\ S) + K_R\ K_B\ S\ (1 + T_3\ S)}$$

(A-7)

$$\overline{(1 + T_4\ S) + Y\ K_R\ (1 + T_1\ S)\ (1 + T_2\ S)}$$

where

$$(1 + T_3\ S)\ (1 + T_4\ S) = (1 + S)\ (1 + .002S) = 1 + S + .002S^2$$

$$(1 + T_1\ S)\ (1 + T_2\ S) + (1 + .4S)\ (1 + .025S) = 1 + .425S + .01S^2$$

$$(1 + T_E\ S)\ (1 + T_3\ S)\ (1 + T_4\ S) = 1 + S + .0055S^2 + 7^{-6}\ S^3 \qquad \text{(A-8)}$$

$$K_B\ K_R = \left(\frac{48}{2.8}\right)\ (.34) = (17.1)\ (.34) = 5.67$$

$$Y\ K_R = \frac{48}{2.8}\ (800) = 13700$$

Divide numerator and denominator of $\frac{\theta_D'}{\theta_D}$ by $Y\ K_R$

$$\frac{K_R\ K_B}{Y\ K_R} = \frac{K_B}{Y} = 4.25\backslash^{-4} \tag{A-9}$$

The numerator of equation A-7 is

$$NUM = 4.25\backslash^{-4} S\ (1 + S + .002S^2) + 1 + .425S + .01S^2$$

$$= 8.5\backslash^{-7} S^3 + .01S^2 + .4254S + 1 \tag{A-10}$$

$$= (\frac{S}{11700} + 1)\ (\frac{S}{2.5} + 1)\ (\frac{S}{40} + 1)$$

The denominator is

$$DEN = \frac{2S^2}{13700}\ (1 + S + .0055S^2 + 7\backslash^{-6} S^3) + 8.5\backslash^{-7} S^3 + .01S^2 + .4254S + 1$$

$$= 1.03\backslash^{-9} S^5 + 8.\backslash^{-7} S^4 + 1.46\backslash^{-4} S^3 + .01S^2 + .425 + 1 \tag{A-11}$$

$$= (\frac{S}{2.5} + 1)\ (\frac{S}{141} + 1)\ (\frac{S}{558} + 1)\ (\frac{S^2}{70^2} + \frac{2(.6)S}{70} + 1)$$

From Table II the track loop transfer function is

$$\frac{\theta_T}{\theta_S} = \frac{(\frac{S}{2.5} + 1)\ (\frac{S}{2.5} + 1)\ (\frac{S}{40} + 1)\ (\frac{S}{71} + 1)\ (\frac{S^2}{240^2} + \frac{2(.4)S}{240} + 1)}{(\frac{S}{2.5} + 1)\ (\frac{S}{16} + 1)(\frac{S}{561} + 1)(\frac{S^2}{3.5^2} + \frac{2(.6)S}{3.5} + 1)(\frac{S^2}{104^2} + \frac{2(.99)S}{104} + 1)}$$

(A-12)

$$\overline{(\frac{S^2}{100^2} + \frac{2(.27)S}{100} + 1)(\frac{S^2}{240^2} + \frac{2(.5)S}{240} + 1)}$$

Then with the aid of Figure A-3

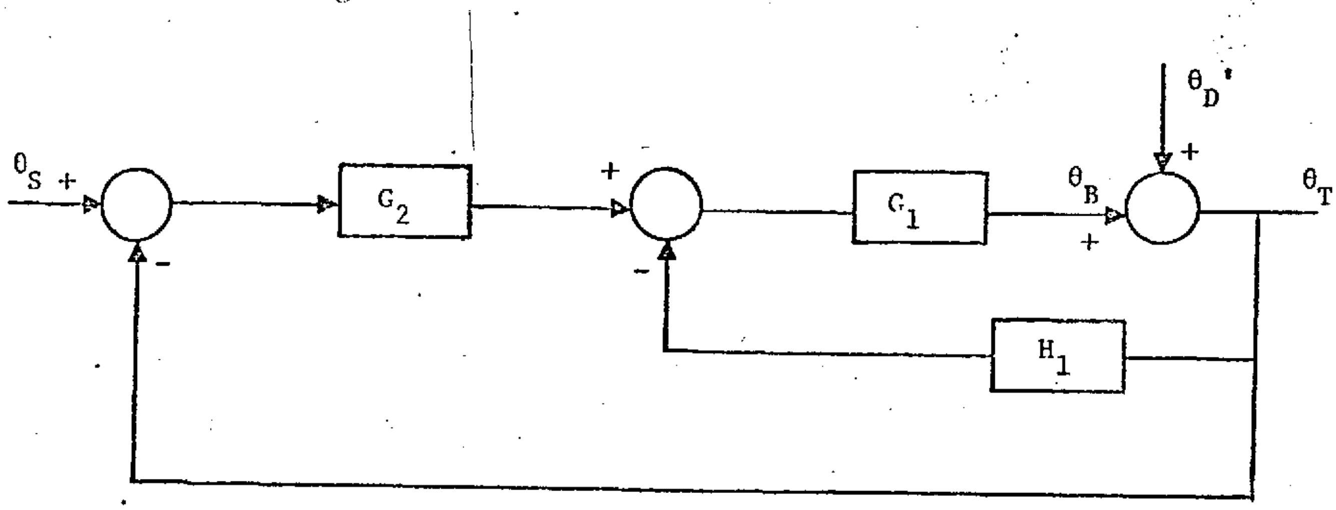


FIGURE A-3

The response to a disturbance is

$$\frac{\theta_T}{\theta_D'} = \left(\frac{1}{G_1 \; G_2}\right) \left(\frac{\theta_T}{\theta_S}\right) \tag{A-13}$$

where

$$G_2 = \frac{24 \; (1 + \frac{S}{2.5})}{S \; (1 + \frac{S}{100})} \tag{A-14}$$

and

$$G_1 = \left[\frac{(\frac{S}{2.5} + 1) \; (\frac{S}{40} + 1)}{(\frac{S}{2.5} + 1) \; (\frac{S}{141} + 1) \; (\frac{S}{560} + 1) \; (\frac{S^2}{70^2} + \frac{2(.6)}{70} + 1)}\right] \left[\frac{12.2 \; (1 + \frac{S}{70})}{S^2}\right] \tag{A-15}$$

Equation A-12 reduces to

$$\frac{\theta_T}{\theta_S} = \frac{(\frac{S}{2.5}+1)(\frac{S}{40}+1)(\frac{S}{71}+1)}{(\frac{S}{16}+1)(\frac{S^2}{3.5^2}+\frac{2(.6)S}{3.5}+1)(\frac{S}{104}+1)^2(\frac{S^2}{100^2}+\frac{2(.3)S}{100}+1)(\frac{S}{560}+1)} \tag{A-16}$$

Equation A-13 becomes

$$\frac{\theta_T}{\theta_D'} = \frac{S^3(\frac{S}{141}+1)(\frac{S}{560}+1)(\frac{S^2}{70^2}+\frac{2(.16)S}{70}+1)(\frac{S}{100}+1)(\frac{S}{2.5}+1)(\frac{S}{40}+1)(\frac{S}{71}+1)}{290(\frac{S}{16}+1)(\frac{S^2}{3.5^2}+\frac{2(.6)}{3.5}+1)(\frac{S}{104}+1)^2(\frac{S^2}{100^2}+\frac{2(3)S}{100}+1)(\frac{S}{560}+1)}$$

$$\overline{(290)(\frac{S}{2.5}+1)(\frac{S}{40}+1)(\frac{S}{70}+1)} \tag{A-17}$$

and reduces to

$$\frac{\theta_T}{\theta_D'} = \frac{S^3(\frac{S}{141}+1)(\frac{S^2}{70^2}+\frac{2(.6)S}{70}+1)}{290(\frac{S}{16}+1)(\frac{S^2}{3.5^2}+\frac{2(.6)}{3.5}+1)(\frac{S}{104}+1)(\frac{S^2}{100^2}+\frac{2(.3)S}{100}+1)} \tag{A-18}$$

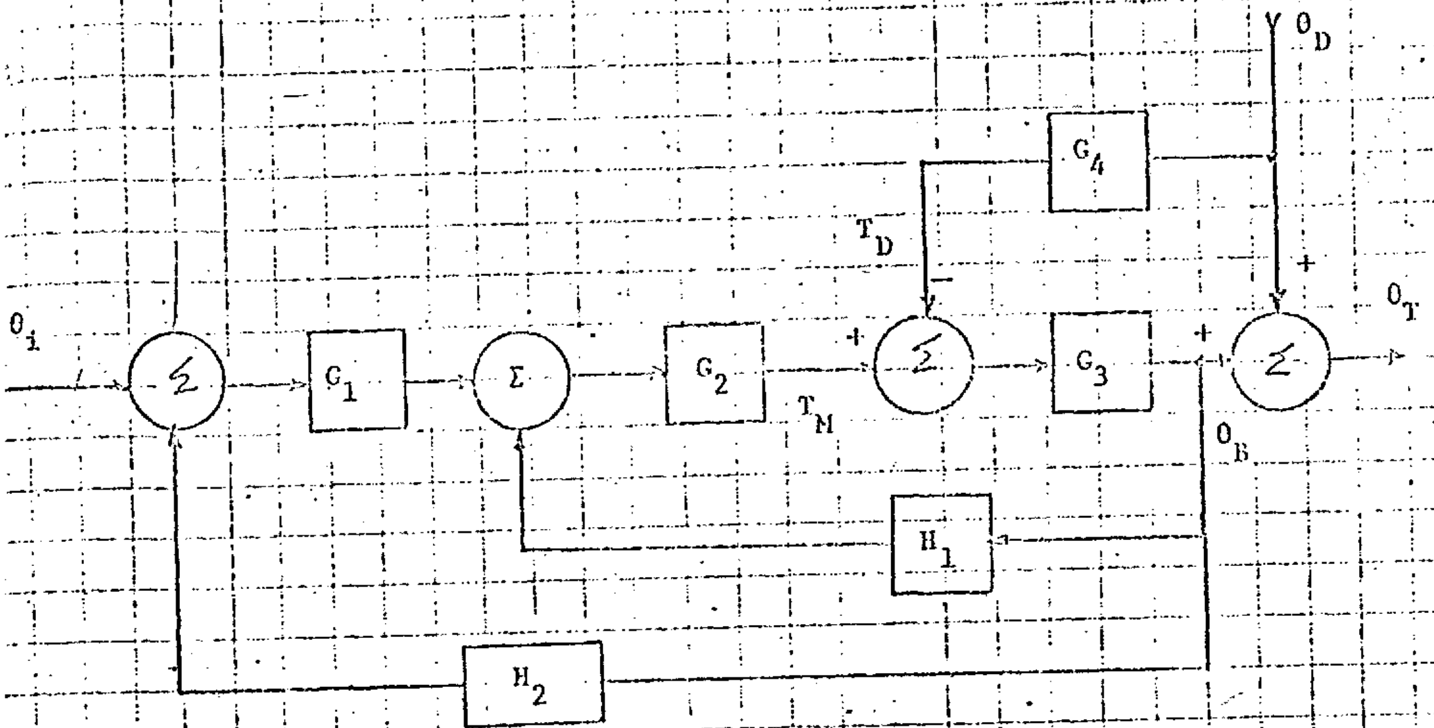
But the self stabilization terms is

$$\frac{\theta_D'}{\theta_D} = \frac{(\frac{S}{40}+1)}{(\frac{S}{141}+1)(\frac{S^2}{70^2}+\frac{2(.6)S}{70}+1)} \tag{A-19}$$

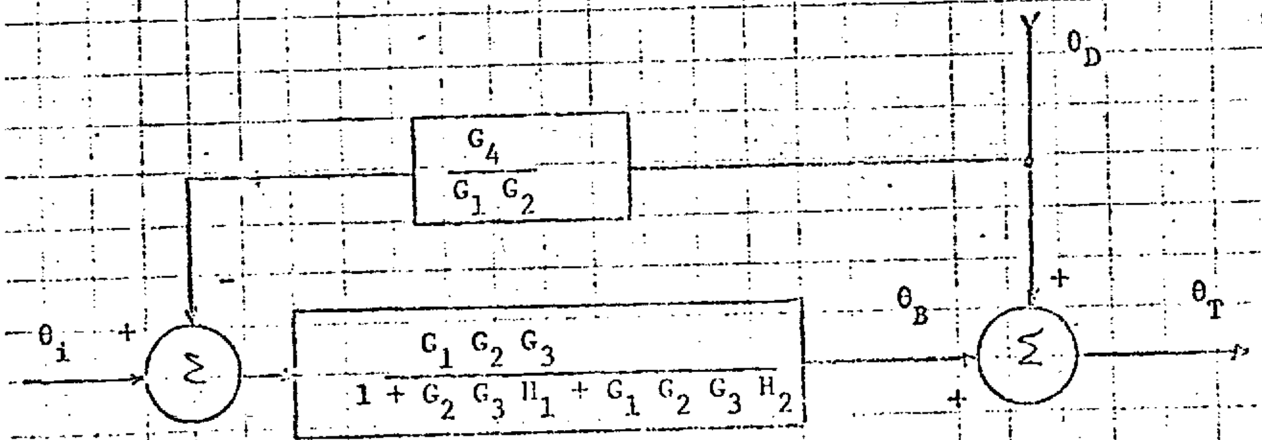
and finally

The response to an aircraft disturbance is

$$\frac{\theta_T}{\theta_D} = \frac{S^3 \left(\frac{S}{40} + 1\right)}{290 \left(\frac{S}{16} + 1\right)\left(\frac{S^2}{3.5^2} + \frac{2(.6)S}{3.5} + 1\right)\left(\frac{S}{104} + 1\right)\left(\frac{S^2}{100^2} + \frac{2(.3)S}{100} + 1\right)} \tag{A-20}$$

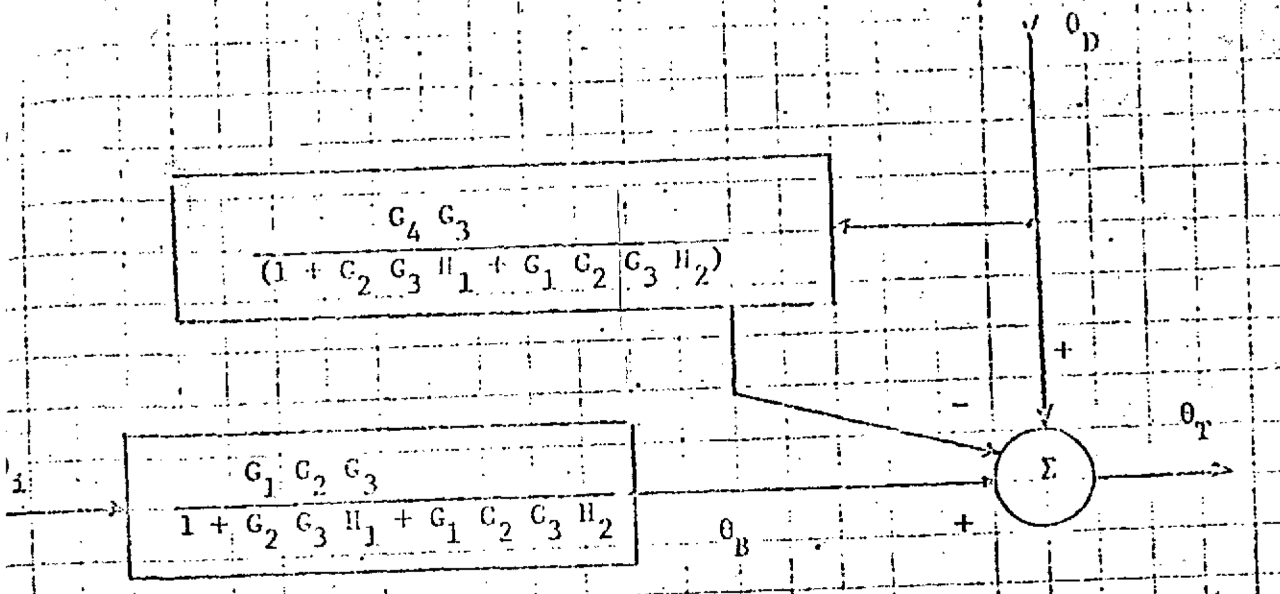


(A)

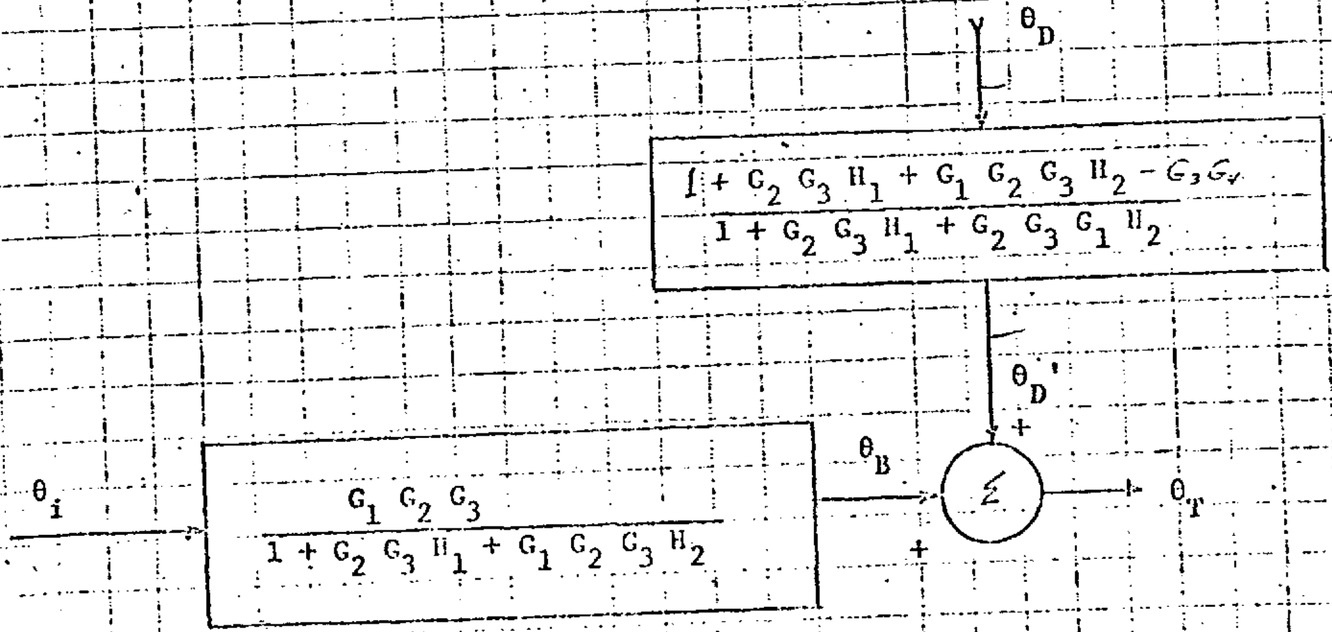


(B)

FIGURE A-1 SELF-STABILIZATION BLOCK DIAGRAMS



(C)



(D)

FIGURE A-1 (Cont)

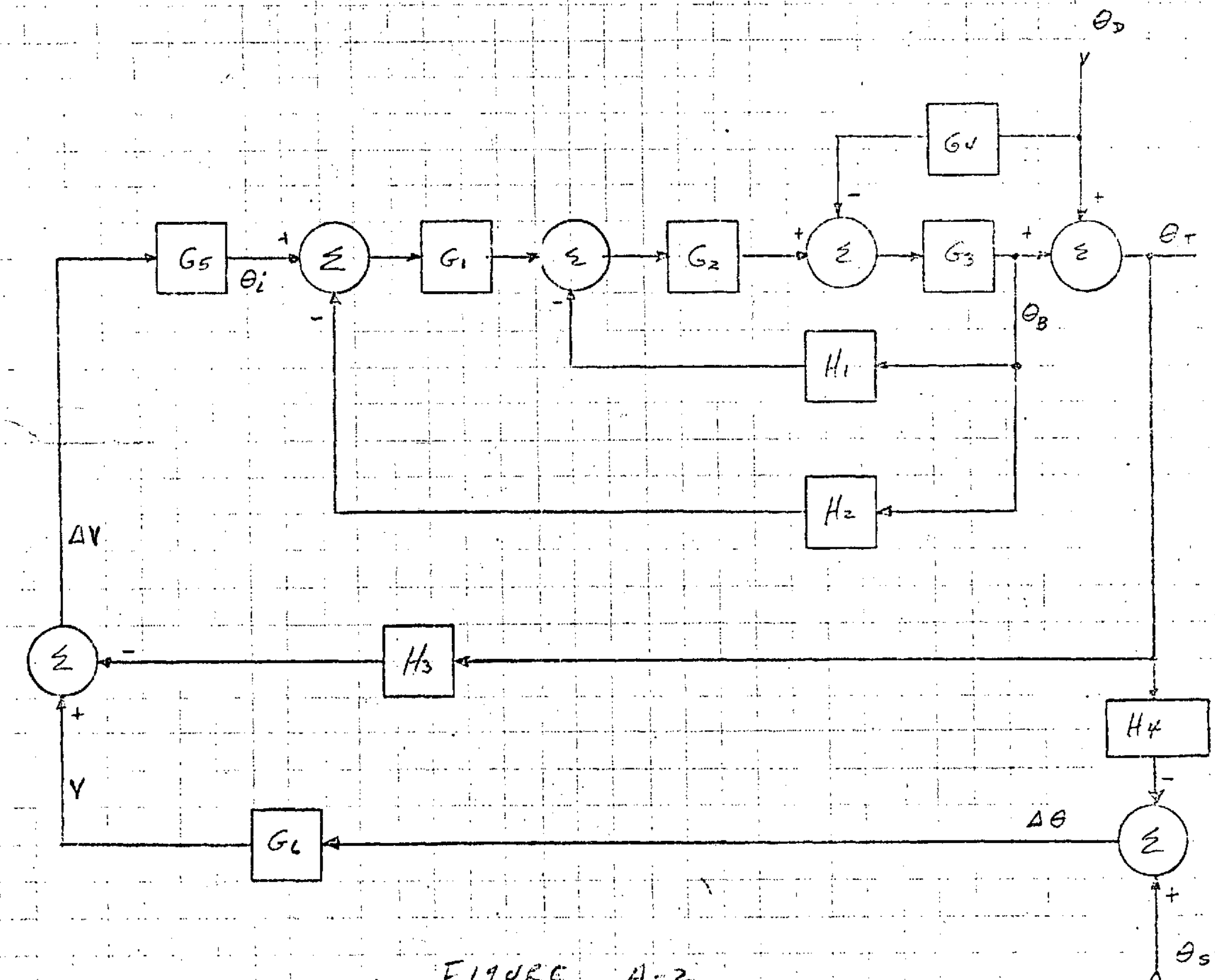

θ_D
G_4
G_5
θ_i
Σ
G_1
Σ
G_2
Σ
G_3
Σ
θ_T
θ_B
H_1
H_2
ΔV
Σ
H_3
H_4
Y
G_6
$\Delta\theta$
Σ
θ_S

FIGURE A-2

A.3 ACCEPTANCE TEST PROCEDURE

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

SHEET	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46						
REVISION																											

REVISION INDEX	SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	REVISION																									

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES: FRACTIONS ±1/64
ANGLES ±1°2°
3 PLACE DECIMALS ±.005
2 PLACE DECIMALS ±.01

CONTRACT NO.
NAS-9-13695

DRAWN D. Price 5-20-74

CHECK

PROJECT D. Price 5-20-74

APPROVED A. Kurtz 5/21/74

EMERSON
ELECTRONICS AND SPACE DIVISION
EMERSON ELECTRIC CO.
8100 FLORISSANT
ST. LOUIS, MISSOURI 63136

ACCEPTANCE TEST PROCEDURE (ATP) FOR AN/APQ-153 FIRE CONTROL RADAR MODIFIED FOR NASA

SIZE	CODE IDENT NO.	DRAWING NO.
A	20418	NAS-1000-1
SCALE: NONE		SHEET 1 OF 46

D FORM 468-A JULY 68

CONTENTS

1.0 SCOPE

This document is the Emerson Electric Company's Acceptance Test Procedure (ATP) for the AN/APQ-153 Fire Control Radar as modified for NASA per Contract NAS 9-13695.

2.0 APPLICABLE DOCUMENTS

Exhibit "A" Statement of Work, Pages 1-3 of Contract NAS 9-13695

3.0 TEST CONDITIONS AND EQUIPMENT

Unless specified otherwise, all acceptance testing of the APQ-153 Fire Control Radar, referred to as the FCR throughout this document, shall be conducted under the conditions delineated in this paragraph.

3.1 Environment - The acceptance testing of the FCR shall be conducted at a normal laboratory environment, designated as the Standard Environmental Conditions and shall be as follows:

Ambient Temperature: 20°C to 30°C
Barometric Pressure: 28" Hg. to 32" Hg.
Relative Humidity: Up to 90%

3.2 Input Power - The input power for acceptance testing the FCR shall be termed Standard Input Power and shall be 3 phase, 4 wire wye, 115 ± 2 rms, 400 ± 5 Hz., 1 Phase, p to 5.0 volts rms, 400 ± 5 Hz., 28 ± 1 volt dc.

3.3 Reject and Retest - When an item fails compliance with the requirements of this ATP during acceptance testing, further action shall be in accordance with Northrop procedures.

3.4 Warm-Up - The FCR shall pass any performance test in this ATP without requiring a warm-up time in excess of 5 minutes.

3.5 Visual Observation - All visual observation tests of the Indicator LRU performance shall be made at a distance of approximately 2 feet and an angle of 26° up from a line perpendicular to the Indicator front panel.

3.6 Unless specified otherwise, all functional performance acceptance testing of the FCR shall be conducted with all articles of the FCR interconnected with all articles of the Emerson System Test Bench, or equivalent, according to Figure 1 of this ATP.

3.7 Unless specified otherwise, all FCR acceptance testing shall be conducted at conditions simulated by the System Test Bench as follows:

Aircraft Roll Angle: 0°
Aircraft Pitch Angle: 0°
Aircraft Wing Twist: 0°

3.8 The following Special Test Equipment and Standard Test Equipment shall be used for AN/APQ-153 Acceptance tests. Standard Test Equipment Articles may be substituted by articles of equivalent capability and accuracy.

3.8.1 Special Test Equipment -

1 each Display Test Template Emerson Part No. 633332
1 each System Test Bench (STB)
consisting of 1 each of -

FCR Simulator/Monitor
Transmitter Breakout Box
Test Connector Breakout Box
System Cable Harness
Antenna Holding Fixture
Boresight Steering Signal Simulator

3.8.2 Standard Test Equipment

Recorder	Brush Model 280
Dummy Load (RF)	100 KW/100W or larger
Electronic Counter	Hewlett-Packard Mod 5245
Spectrum Analyzer	Tektronix 491
Power Meter	General Microwave 454A
Power Head	Narda 420A
Frequency Meter	HPX532B
Detector	HP 440A
Oscilloscope	Tektronix 545
Pulse Generator	HP 212
RF Generator	HP 620B
Isolator	Ferratec Model I-155-L
Voltmeter	John Fluke 887A
20 DB Attenuator	Enco A620N
Dynamic Range Simulator	Rutherford/CMC 301
BCD Display	Rutherford Electronic Co.
Microwave Amplifier	Alto Scientific 2008.0-12.4Q35
Directional Coupler 40 DB	Narda 1081
Directional Coupler 10 DB	HP X752C
Rotary Joint	X-Band
Flex Guide	X-Band
Standard Gain Horn	X-Band
Rate Table	Scientific Atlanta
Boresight Scope	

4.0 FCR PERFORMANCE TESTS

4.1 Initial Test Set Up, Turn On, and Power Supply Tests.

4.1.1 Connect the System Test Bench (STB), AN/APQ-153 Fire Control Radar (FCR) and Standard Test Equipment according to Figure 1. (All power control switches off.)

4.1.2 Record running time meter readings for each FCR LRU. Note: Receiver/Transmitter has 2 running time meters, Total and Xmit.

4.1.3 Make the following switch settings on the STB:

Switch or Control	Setting
Current Test/Voltage Test (4)	VOLTAGE TEST
Wing Twist Switch	DOWN
AA (Guns)/MSL	MSL
In-Range	DOWN
Excess G's	DOWN
Breakaway	DOWN
Wing Twist Dial	0
Roll	0°
Pitch	0°
Transmitter (On Indicator Holding Fixture)	OFF

4.1.5 Observe a watch, clock, or other timer to measure the time between system turn-on in the next step and illumination of the XMTR READY light on the STB Indicator Holding Fixture. The time will be between 3 and 5 minutes and should be recorded on the data sheet, paragraph 4.1.6. During the time out period, several other observations are made as directed in 4.1.6.

4.1.6 Place the MODE switch on the Set Control to STBY. Observe that the Antenna is pointed approximately straight ahead. Record. Observe FAIL light is not illuminated. Record.

Observe that after approximately 60 seconds the ARTIFICIAL HORIZON lines and TILT CURSOR (along right edge of the DVST) are displayed. Record.

Observe that the XMTR READY light on the Indicator Holding Fixture is illuminated after 3 to 5 minutes. Record.

4.1.7 Place the MODE switch on the Set Control to MSL Observe and record FAIL light lighted. Turn on TRANSMITTER SWITCH on the Indicator holding fixture. Observe that the antenna is searching a 2 bar elevation full azimuth pattern. Record.

Observe that a B-SCAN is displayed on the Indicator DVST. The range sweep will be sweeping back and forth in azimuth and the tilt cursor stepping slightly in elevation. Record.

4.1.8 Using the John Fluke 887A or equivalent meter, measure the FCR voltage at the J6/J7 Test Breakout Box as follows:

Voltage	J-7 Pin	J-7 Return	Value	Ripple Max
115VAC	A	W	115VAC ± 2VAC	
115VAC	B	W	115VAC ± 2 VAC	
115VAC	V	W	115VAC ± 2VAC	
28VDC	C	X	28VDC ± 1VDC	NA
+5VDC	Q	E	+5VDC ± 0.15VDC	50 MV
-5VDC	Y	E	-5VDC ± 0.15VDC	50 MV
+15VDC	P	E	+15VDC ± 0.23VDC	50 MV
-15VDC	D	E	-15VDC ± 0.23VDC	50 MV
+30VDC	N	E	+30VDC ± 0.9VDC	50 MV
+100VDC	T	E	+100VDC ± 3VDC	500 MV
+150VDC	U	E	+150VDC ± 4.5VDC	500 MV

4.2 Indicator Tests - With the FCR in MSL Mode, perform the visual observation tests of this paragraph.

4.2.1 Using the Display Test Template, verify that each segment of the Artificial Horizon Line is greater than 0.630" and less than 0.770". Verify the separation between the segments is greater than 0.630" and less than 0.770". Record.

4.2.2 Using the Display Test Template, verify that the Tilt Cursor length is less than 0.280" and greater than 0.220". Record.

4.2.3 Using the Display Test Template, verify the length of the B Sweep is less than 3.420" and greater than 3.320". Record.

4.2.4 Press the STB Advisory Light Test and observe the following FCR Indicator lights illuminate: Fail, Lock-on, In-Range, Excess G, 5 Mile, 10 Mile, and 20 Mile. Record.

4.2.4.1 Place the IN-RANGE switch on the STB in the UP position, observe the IN-RANGE light on the Indicator is illuminated. Record. Turn the switch to the DOWN position.

4.2.4.2 Place the BREAKAWAY switch on the STB in the UP position, observe the IN-RANGE light on the Indicator is flashing. Record. Return the switch to the DOWN position.

4.2.4.3 Place the EXCESS G's switch on the STB in the UP position, observe the EXCESS G's light on the Indicator is illuminated. Record. Return the switch to the DOWN position.

4.2.5 Vary the CURSOR Control on the Indicator front panel and observe that the intensity of the Horizon Line and Tilt Cursor vary. Record.

4.2.6 Vary the BRIGHTNESS control on the Indicator front panel from minimum to maximum and observe that DVST brightness varies.

4.2.7 Press the ACQ button on the Set Control. Observe the Range Gate sweeping from minimum to maximum range on the Indicator DVST. Vary the PER control on the Indicator front panel from minimum and maximum and observe that the persistance of the range sweep varies and increases with CW rotation of the PER control. Record. Press RESUME SEARCH button on the Set Control.

4.2.8 Vary the SCALE Control on the Indicator front panel and observe that the brightness of the edge lighted overlay varies. Record.

4.2.9 With the STB Pitch Control set for 0 degrees, and the STB Roll Control set for 0 degree, position the Artificial Horizon Line to 0 degree of Pitch on the Indicator display by adjusting the PITCH Control on the Indicator. Simulate +30 $\pm$3 degrees of A/C Roll Angle by the STB Roll Control and verify by visual observation that the Artificial Horizon Line on the Indicator is indicating a roll angle of +30 degrees. Record verification. Return STB simulated roll angle to 0 degrees and verify by visual observation that the Artificial Horizon on Indicator is indicating a roll angle of 0$\pm$2°. Record.

4.2.9.1 Pitch Zero - With the STB roll angle set for zero degrees and the STB Pitch angle set for zero degrees, set PITCH Control on Indicator to its zero mark and visually observe the Artificial Horizon Line on the Indicator is displayed at 0 $\pm$2°. Record.

4.2.9.2 Pitch Trim - With the STB Roll Control set to 0 degree and STB Pitch Control set to +20 degrees, verify the Indicator PITCH Control can be adjusted to position the Artificial Horizon Line to 0 degrees of Pitch Angle displayed on the Indicator. Record verification.

4.2.9.3 Set the STB PITCH Control to -20 degrees (+340°) and verify the Indicator PITCH Control can be adjusted to position the Artificial Horizon Line to 0 degrees of Pitch Angle displayed on the Indicator. Record verification. Return STB Pitch Control to 0 degrees.

4.2.10 Rotate the VIDEO control on the Indicator fully CCW to fully CW. Observe that there is no objectionable spoking on the "B" scan. Record.

4.3 Antenna Positioning Tests

4.3.1 Search Pattern Tests - Connect a 2 channel Brush Recorder to the Test Breakout Box as shown in Figure 2. Set the Brush Recorder sensitivity to 0.2 volts per division for the azimuth channel and 0.1 volts per division for the elevation channel with 0 volts at the center of the trace. Set paper speed to 100 MM per second. See PITCH Control on STB to 0°. Connect Voltmeter to ANT EL CMD J6-E on Test Connector.

4.3.2 Adjust the ELEV control on the Set Control so the voltmeter reads -0.5VDC and lower TILT CURSOR is at 0 $\pm$2°. Record. Turn on Brush Recorder and leave on sufficient time to record one full azimuth search frame.

Examine Brush Recording for Azimuth frame time, azimuth coverage, scan rate, and elevation step. The following information should be observed:

4.3.2.1 Azimuth Frame Time - The azimuth frame time is the time for the azimuth recorded voltage to repeat a value when reached traveling in the same direction and shall be less than 2.3 seconds. Record.

4.3.2.2 Azimuth Coverage - The maximum voltage excursions on the azimuth Brush Recording should be greater than 3.7 volts (18.5 division) each way from center. Record.

4.3.2.3 Scan Rate - Observe the linearity of the search trace between 2 maximums of opposite polarity on the trace. Draw a straight line between points 90% of the maximums recorded in 4.3.2.2. Observe that the recorded trace stays within .2 volts of the straight line. Record.

4.3.2.4. Elevation - The Elevation Brush Recording should be 0 volts $\pm$0.2 volts as the azimuth recording changes from plus to minus voltage and 0.3 $\pm$0.1 volts more negative than the 0 value as the azimuth voltage is changing from minus to plus. Record.

4.3.2.5 Tilt Symbol - Set Elevation Brush recorder sensitivity to .2 volts per division with 0 volts at center of trace. Set ELEV Control on Set Control for Voltmeter reading of -9.5VDC and upper TILT CURSOR at 30° up. Turn on Brush Recorder for sufficient time to see step on Elevation Brush recording. Observe that maximum excursion from 0 is -2.8 $\pm$ .26 volts. Record.

4.3.2.6 Repeat 4.3.2.5 with voltmeter reading of +9.5VDC and lower TILT CURSOR at 30° down. Observe that maximum excursion from 0 is +2.8 $\pm$ .26 volts. Record.

4.3.2.7 Repeat 4.3.2.5 with ELEV control positioned for antenna maximum down. Observe that maximum excursion is +2.8 volts or greater. Record.

4.3.2.8 Repeat 4.3.2.5 with ELEV control positioned for antenna maximum up. Observe that maximum excursion is -4 volts or greater. Record.

4.3.3 Stabilization - Set the ELEV control on the Set Control so the lower TILT CURSOR is at 0°. Set the ROLL control on the STB to 90°.

Set Brush Recorder sensitivities to 0.2 volts per division on Elevation Channel and 0.1 volts per division on the Azimuth Channel with 0 volts at center.

Turn on Brush Recorder long enough to observe a complete search frame on the Elevation Channel. Examine Brush Recording.

4.3.3.1 The Elevation recording should reach maximum excursion of at least plus 2.8 volts (14 div.) and minus 3.6 Volts (18 div).

4.3.3.2 The Azimuth recording should show a step of 0.3 ± 0.1 volts. Record. Return Roll to 0°.

4.3.4 Missile Stow - Set Brush Recorder sensitivity to 0.05 volt per division, both channels with 0 at center. Set paper speed to 10 MM per second.

Press ACQ button on Set Control. Turn on Brush Recorder for approximately 1 second.

Press DOGFIGHT button on STB. Turn on Brush Recorder for approximately 1 second.

4.3.4.1 Examine Brush Recordings. In Missile Acquisition (ACQ button pressed) both Azimuth and Elevation traces should be 0 ± 0.05 volt. Record.

4.3.4.2 Brush Recording after DOGFIGHT was pressed should show: Azimuth 0 ± 0.05 volt and elevation + 0.44 ± 0.07 volt. Record.

4.4 R.F. Output Tests

To perform the following RF Output Tests:

Frequency

Pulse Width

Power

PRF

connect the System Test Bench, Fire Control Radar and Standard Test Equipment according to Figure 3 (A) or (B) as stated in each specific test. Place the FCR in Operate, Search Mode and wait for transmitter to time out as indicated by the red Transmit Ready Light located on the STB. Turn Transmitter ON. Adjust oscilloscope to view RF pulse on the output of the crystal detector.

4.4.1 Frequency/PW/PRF - Use Figure 3 (A) for set up. Measure microwave frequency of 9.3 GHz ± 50 MHz. Frequency is measured by adjusting frequency meter to point where a dip in the amplitude of the detected RF pulse is noticed on Oscilloscope. Record frequency. Detune Frequency Meter setting so the detected RF pulse is not distorted. Measure and record RF pulse width at the 0.707 points. Measure and record System PRF as indicated on Electronic Counter connected to J6-$\bar{c}$ System Sync. Turn transmitter OFF. Pulse width should be 0.4 usec ± 0.04 u sec. PRF should be 2500 ± 175 PPS.

4.4.2 Power - Use Figure 3 (B) for set up. With the power meter on and zero set adjustment complete, set sensitivity switch to medium and range select to -10 DBM. Turn transmitter on and allow power meter to reach a steady reading. Measure RF power taking into account system test coupler plus cable and attenuator losses. Turn transmitter off. Average RF power = Power meter reading + coupler + attenuator + cable loss. Average power must be greater than +46.6 DBM.

4.4.3 Spectrum - Record Transmitter sidelobe levels at 9.15 GHz, 9.3 GHz, and 9.45 GHz from LRU test data sheets, para. 4.2.7 of Emerson QAS No. F5E-400-13.

4.4.4 Record Pulsewidth and RF power at 9.15GHz and 9.45 GHz from LRU test data sheets, para. 4.2.6 of Emerson QAS No. F5E-400-13.

4.4.5 AFC Tracking Test - Connect the FLUKE voltmeter to J6-D with J7-E as return. AFC voltage should read -4.5 ± 0.5 VDC. Record.

NOTE: The transmitter must be on at least 15 minutes before measurement.

4.5 DELETED

4.6 Target Tests - For the following Receiver input port tests connect the STB and FCR according to Figure 5.

MDS

Lock-on

CAUTION: DO NOT TRANSMIT AT ANY TIME DURING THIS SEQUENCE OF TESTS. Damage to the test equipment is possible. With STB transmitter Interlock Switch in OFF position, FCR in the operate, search mode.

4.6.1 MDS Measurement - Set output attenuator on H.P. 620 for -80 dBM power level and vary frequency of generator around 9.3 GHz to locate the system L.O. frequency and produce a simulated target on the scope. Peak frequency and set target range at approximately 8 miles. Switch H.P. 620 to CW and zero power set then back to internal pulse. Set the H.P. 620 pulse width to obtain a 0.4 ± 0.1 usec target pulse at the output of H.P. 620. Reduce target power with calibrated output attenuator and vary target in range until it is just discernible in the receiver noise displayed on the scope. Record attenuator setting in dBM down from 0 DBM and add loss of isolator, directional coupler and RF cables for MDS. MDS shall be at least -97 dBM. Adjust video control for optiumu noise point in the 8 to 10 NM range on the indicator display. Vary target power with calibrated output until a minimum detectable signal is observed on the display. Record attenuator setting in dBM down from 0 dBM and add loss of isolator, coupler, and cables. The reading should be at least -99 dBM.

4.6.1.1 Lock-On - Place the FCR in the missile mode (press and release ACQ button on Set Control). Slowly increase target strength with the H.P. 620 power attenuator until lock-on is obtained. Observe that lock-on occurs 5 ± 2 dB above the indicator display MDS measurement.

4.6.2 Dynamic Range - Record dynamic range from LRU test data sheet, para. 4.6.1 of Emerson QAS No. F5E-400-13.

4.6.3 Video Clipping - Press resume search button on Set Control. Turn the video control full CCW. Increase the target strength until an MDS target is again seen on the Indicator display.

4.6.4 DELETED

4.6.4.2 DF Lock-On - Momentarily press the DOGFIGHT button on STB. Observe that Lock-on occurs at following signal levels above display MDS measured in 4.6.1.

RANGE (FT)	SIGNAL LEVEL
5,000	26 ± 5 dB
3,000	31 ± 3 dB

NOTE: For all following tests, target level must be set above MDS or lock-on level at each test range depending on the purpose of the test.

4.6.5 Range - Initial Conditions - Select the 5 mile range scale located on the System Set control and simulate a radar target at 24,304 feet by dialing into Rutherford Simulator.

4.6.5.1 5 Mile Check - Observe the five mile range light on Indicator Display is illuminated. Record. Observe the 24,304 ft. target is displayed at the fourth bar from the bottom or 4 mile line ± .2 inches. Record.

4.6.5.2 10 Mile Check - Select the 10 mile range scale on System Set Control and observe the 10 mile range light on the Indicator is illuminated. Record. Observe the 24,304 foot target is displayed on the Indicator at the second bar from the bottom or 4 mile line ± .2 inches. Record.

4.6.5.3 20 Mile Check - Select the 20 mile range scale on the System Set Control and observe the 20 mile range light on the Indicator is illuminated. Record. Observe the 24,304 foot target is displayed at the first bar from the bottom or 4 mile line ± .2 inches. Record.

4.6.6 Display Linearity - For this test two range checks will be made at difference ranges for each FCR range scale.

4.6.6.1 Set the RANGE switch on the Set Control to 5. Set RANGE switch on the Dynamic Range Generator so that the target is aligned with the 1 mile line on the DVST scale Increase the Dynamic Range Generator RANGE by 18,228 ft. The target should appear within ±0.135 inches of the 4 mile line on the DVST scale. Record.

4.6.6.2 Set the RANGE switch on the Set Control to 10. Set the RANGE switches on the Dynamic Range Generator so that the target is aligned with the 2 mile line on the DVST scale. Increase the Dynamic Range Generator RANGE by 36456 ft. The target should appear within ±0.135 inches of the 8 mile line on the DVST scale. Record.

4.6.6.3 Set the RANGE switch on the Set Control to 20. Set the RANGE switches on the Dynamic Range Generator so that the target is aligned with the 4 mile line on the DVST scale. Increase the Dynamic Range Generator RANGE by 72912 ft. The target should appear within ±0.135 inches of the 16 mile line on the DVST scale. Record.

4.6.7 Jizzled Sweep - Set Dynamic Range Generator to 10,000 ft. Press reset on Dynamic Range Generator. Press and hold the ACQUISITION button on the Set Control. Observe the track gate sweeping from minimum to maximum range on the Indicator, and the Range Sweep Offset to the left and jizzled.

4.6.7.1 Release the ACQUISITION button and observe the track gate after lock-on. The track gate is displayed as two horizontal bars, one on each side of the jizzled sweep. Using the display test template, verify that the length of each bar is 0.125 ±.062 inches.

4.6.7.2 Using the display test template, verify that the width of the jizzled sweep is 0.4 ± 0.1 inches.

4.6.7.3 Using the display test template, verify that the center of the jizzled sweep is left 0.80 ± 0.13 inches.

4.6.8 Range Accuracy - Verify that the FCR will generate range voltages that are in tolerance for all specified ranges using a simulated target outlined in the following table. Press the FCR ACQ switch and lock-on to the simulated target at the following ranges and record the range voltage as monitored on the STB A/C Simulator using the Fluke 887A voltmeter.

NOTE: Verify zero range alignment as set up prior to Para. 4.6.5. Due to transmitter/receiver T/R limiter decay time, considerably higher target amplitudes may be required for lock-on at 600 feet.

Simulated Target Range	Range Voltage to be measured
600 feet	0.6 ± 0.050 VDC
1,000 feet	1.0 ± 0.050 VDC
2,000 feet	2.0 ± 0.050 VDC
3,000 feet	3.0 ± 0.060 VDC
7,500 feet	7.5 ± 0.150 VDC
15,000 feet	15.0 ± 0.300 VDC
30,000 feet	30.0 ± 0.600 VDC
60,000 feet	60.0 ± 1.200 VDC

4.6.9 Range Rate Accuracy - Verify that the FCR will generate range rate voltages that are in tolerance for all specified range rates using a simulated target outlined in the table below. Set Rutherford simulator to sweep in from 60,000 feet to 500 feet for all closing runs and 500 feet to 60,000 feet sweep out for the last opening run. Press the FCR ACQ switch and lock on to the simulated target and start sweep on Rutherford. Record the Range rate for each simulated target rate as monitored on the STB A/C Simulator using the Fluke 887A voltmeter.

Simulated Target Rate	Range Rate Voltage to be Measured
0 Rate	+0.0 ± 0.050 VDC
Closing 1000 Ft/Sec	+5.0 ± 0.150 VDC
Closing 2000 Ft/Sec	+10.0 ± 0.300 VDC
Closing 3000 Ft/Sec	+15.0 ± 0.450 VDC
Opening 1000 Ft/Sec	-5.0 ± 0.150 VDC

4.6.10 Memory - Verify that the FCR range rate memory mode will maintain the system in a "Lock-On" configuration with a constant target range rate and the range changing at that rate for 1.75 ± 0.1 seconds after target detection has been lost using the following procedure.

Set the Dynamic Range Generator RANGE for 10000 ft DECR, stop run to 1000 ft, velocity to 600/Ft/Sec, acceleration to 0. Set the Brush Recorder for 100 MM/Sec, Channel A sensitivity to 0.2 volts/division and Channel B sensitivity to 0.2 volts/division. Connect Channel A onput to the Range test jack J6-$\overline{D}$ AND Channel B to fade jack on Dynamic Range Generator. Lock the FCR onto the target in the Missile mode.

Turn on the Brush Recorder. Press START button on the Dynamic Range Generator. Set ZERO adjust on Channel A so trace is near left side. Depress and hold fade button on Dynamic Range Generator. After about 3 seconds turn off Brush Recorder. Examine Brush recording. Observe Channel A voltage at start of trace when Channel B shows approximately 0 volts. Observe Channel A when Channel B voltage increases. Channel A voltage should continue at a constant rate for 1.75 ± 0.1 seconds after Channel B voltage increases. Record time from start of Channel B increases to time Channel A voltage sweeps to left on recorder.

4.6.10.1 Press RESET button on Dynamic Range Generator. With Brush Recorder set as in previous test and FCR lock on target, turn on Brush Recorder and press START button on Range Generator. After ≈3 seconds, depress fade button on Dynamic Target Generator for approximately 1 second then release. Turn off Brush Recorder. Observe that Channel A trace stayed constant with ± 1 division during and after time Channel B trace went from 0 volts to ≈5 and back to 0 volts. Record.

4.6.11 Set range on dynamic range simulator to 7000 ft. Automatic Range Acquisition - Press DOGFIGHT button on STB. Set brush recorder chart speed to 200 MM/SEC. Allow recorder to run for approximately 1 second. Observe time for trace to run from minimum range (Right side of trace) to maximum dogfight range (left side of trace).

4.6.11.1 Leave Brush Recorder settings as in last step. Adjust Pen Position to center of trace. Connect Channel B to test connector J7-$\overline{E}$ (target lock-on). Set Range control on Dynamic Range Generator to 1000 ft. Set 620 Signal generator output to -25dbm. Press Resume Search button on Set Control. Turn on Brush Recorder. After approximately 1 second depress Dogfight button on STB. When Lock-On light on Indicator illuminates, turn off Brush Recorder. Examine Brush recording. Observe time from where Channel A stops strobing to time where Channel B goes to ≈5 volts. Record sum of above 2 tests to be less than .5 seconds.

4.6.12 Mode Tests - Press the RESUME SEARCH button on the Set Control.

4.6.12.1 Place the AA (Guns)/MSL switch on the STB to MSL. Set the RANGE on the CMC Range Generator to 6000 ft. Press and release the ACQ button on the SET CONTROL. Observe the LOCK-ON light on the Indicator is lighted. Observe the 10 mile range light on the Indicator is illuminated. Set the Range switch on Set Control to 5. Observe the 5 mile range light on Indicator is illuminated. Return Range switch to 20. Turn on Brush Recorder and zero channels A and B. Connect Channel A to J6-A, Azimuth Position and, Channel B to J6-B, Elevation Position. Set Channels A and B sensitivity to 50 MV/Division. Observe that the Antenna Position signals are centered about 0 $\pm$ 50 MV and the peak-to-peak reading of the elevation signal is 455 $\pm$ 45 MV and the Azimuth signal is 376 $\pm$ 38 MV. Record.

4.6.12.2 Place the AA (GUNS)/MSL switch on the STB to AA(BUNS). Observe that the LOCK-ON light extinguished and the range gate is strobing out on the Indicator DVST. Observe that the 5 Mile Range light on the Indicator is illuminated. Record.

4.6.12.3 Set the CMC Range Generator RANGE to 5200 ft. Observe that the LOCK-ON light on the Indicator illuminates. Record.

4.6.12.4 Place the AA(GUNS)/MSL switch on the STB to MSL. Observe that the LOCK-ON light remains illuminated and the AIM BAR is present on the Indicator. Record.

4.6.12.5 Set the CMC Range Generator RANGE to 70000 ft. DECR, STOP RUN to 1000 ft, velocity to 1000 ft/sec, accelerate to 0. Press and release the ACQ button on the Set Control. Observe that the Range Gate is strobing out on the Indicator DVST. Record.

4.6.12.6 Place the AA(GUNS)/MSL switch on the STB to AA(GUNS). Observe that the Range Gate is strobing out on the Indicator DVST.

4.6.12.7 Place the AA(GUNS)/MSL switch on the STB to MSL. Observe the Range Gate strobing out on the Indicator. Record.

4.6.12.8 Press the DOGFIGHT button on the STB. Observe the 5 mile light is illuminated and the Range Gate is strobing out. Record.

4.6.12.9 Press the ACQ button on the Set Control and observe that nothing changes. Record.

4.6.12.10 Press the RESUME SEARCH button on the Set Control. Observe the B SCAN on the Indicator DVST. Record.

4.6.12.11 Press the START BUTTON on the Range Generator. Press the ACQ button on the Set Control and observe that the FCR locks on to the target. Record.

4.6.12.12 Press and hold the ACQ button on the Set Control. Observe that the range gate breaks lock-on and starts strobing outward from the target to the maximum range. Release the ACQ button and observe that the FCR locks on to the target. Record. Press and hold FADE button on Dynamic Range Generator. Observe that FCR breaks lock-on and range sweep returns to minimum range and sweeps outward to maximum range.

4.6.12.13 Press the DOGFIGHT button on the STB. Observe that lock on is broken the Range Gate is strobing out from minimum range to about 1 mile. Observe that as the target range decreases below one mile, lock on is automatic. Record.

4.6.12.14 Press the DOGFIGHT button on the STB. Observe that lock on is broken, the Range Gate strobes out to about 1 mile, starts at minimum range, and reacquires the target. Record.

4.6.12.15 Press the ACQ button on the Set Control. Observe that lock on is broken, the Range Gate strobes out to about 1 mile, starts at minimum range, and reacquires the target. Record.

4.6.12.16 Press the RESUME SEARCH button on the Set Control. Place the AA(GUNS/MSL switch on the STB to AA(GUNS). Press the ACQ button on the Set Control. Observe that the FCR is locked on to the target. Record.

4.6.12.17 Press the ACQ button on the Set Control. Observe that lock on is broken, the Range Gate strobes out to about 1 mile, restrobes at minimum range, and reaquires the target. Record.

4.6.12.18 Press the DOGFIGHT button on the STB. Observe that lock on continues. Record.

4.6.12.19 Press the DOGFIGHT button on the STB. Observe that lock on is broken, the RANGE GATE strobes out to about 1 mile, starts at minimum range, and reacquires the target. Record.

4.6.12.20 Press the RESUME SEARCH button on the Set Control. Place the MODE switch on the Set Control to STBY. Observe no target video on the Indicator DVST. Record.

4.6.12.21 Press the DOGFIGHT button on the STB. Observe that target video reappears and the FCR locks on to the target. Record.

4.6.12.22 Press the RESUME SEARCH button. Observe that target video disappears and the antenna is pointed approximately straight ahead. Record.

4.6.13 Place the MODE switch on the Set Control in MSL . Place the AA(GUNS)/MSL switch on the STB in MSL. Press and release the ACQ button on the Set Control. After lockon, observe that the AIM BAR is inside the scribed circle on the center of the Indicator DVST and approximately 0.1 inches down. Record.

4.6.13.1 Place the WING TWIST switch on the STB up. Connect the FLUKE 887 meter to the WING TWIST jacks on the STB. Adjust the WING TWIST control for +5 volts. Observe that the AIM BAR is 0.9" ± 0.2" up from center. Record.

4.6.13.2 Adjust the WING TWIST control for -5 volts. Observe that the AIM BAR is 1.1" ± 0.2" down from center. Record.

4.6.13.3 For this test turn transmitter off and switch H.P. 620 output pulse to OFF. Connect the Boresight Steering Simulator as outlined in Figure 6. Disconnect Pulse Generator, Range Generator, and RF Generator. Adjust the range of the target displayed on the indicator for 5 miles with the FCR RANGE in the 10 mile range select position. Press the ACQ switch to place the FCR in the Missile Mode. Verify the range gate is locked onto the 5 mile target. Observe on the Indicator that the TILT CURSOR disappears and the AIM BAR is present. Verify the EL Phase control on Boresight Steering simulator positions the AIM BAR in the elevation axis about the Boresight Steering Circle. Record.

Verify the AZ Phase control on the Boresight Steering simulator positions the AIM BAR along the azimuth axis about the Boresight Steering Circle. Record. Press RESUME SEARCH.

4.6.13.4 Artificial Horizon and Tilt Cursor.

4.6.13.4.1 Set roll on the STB to 0° and EL control on set control to 0° EL. Set pitch control on STB to +20° and observe that the artificial horizon is at -20° on Indicator. Record.

4.6.13.4.2 Set pitch control on STB to -20° and observe that artificial horizon is at +20° on Indicator. Record.

4.6.13.4.3 Set roll to +30° and pitch to +20° on STB. Observe that the artificial horizon (center) is down 20° on Indicator and rolled 30° CCW.

4.6.13.4.4 Observe that the tilt cursor (center) is down 17.3° on Indicator.

4.6.13.4.5 Set Roll to -30° and pitch to -20° on the STB. Observe that the artificial horizon (center) is up at +20° and rolled 30° CW on Indicator.

4.6.13.4.6 Observe that the tilt cursor (center) is up 17.3° on the Indicator.

4.7 Disconnect all standard test equipment from system. BIT sequence - With the FCR in the OPERATE mode and transmitter ON, observe that the fail light from the indicator is not illuminated. Record.

4.7.1 Place the MODE Switch on the Set Control in the TEST position. Rotate the ELEV control on the Set Control so the TILT CURSOR is up about 20°. Press and hold the ACQ button on the Set Control. Observe that the TILT CURSOR moves to approximately 0°. Record. Measure Position Voltage at J6-B for -3V ± .3V. Record. Disconnect test connector breakout box 633224.

4.7.2 Release the ACQ button. Observe that the tracking gate strobes out on the INDICATOR DVST and locks on to the BIT target. the LOCK-ON light on the Indicator should be illuminated and the FAIL light not illuminated. Record.

4.7.3 Place the MODE switch to MSL . Set the AA(GUNS)/MSL Switch on the STB to AA(GUNS). Place the MODE Switch to TEST. Observe that the TILT CURSOR is down approximately five degrees.

4.7.4 Press the DOGFIGHT button on the STB. Observe that the TILT CURSOR is up about 20°. Observe that the tracking gate is strobing out on the Indicator DVST. Record.

4.7.5 Place the MODE switch on the Set Control to OFF.

4.8 Angle Lock-On Tests

4.8.1 Transmitter Interlock Tests - Connect Recorder as shown in Figure 2. Connect flexible waveguide between transmitter LRU and Antenna LRU. Remove 8 ft. cable between Processor J4 and Receiver/Transmitter J-1 and install 50 ft. cable.

4.8.1.1 Place TX switch on aircraft simulator to normal. Place FCR mode control switch to STBY. Adjust tilt cursor to 0°. After 5 minutes place mode switch to OPER. Note that ground return appears on Indicator along with cursors.

4.8.1.2 Place TX switch to OFF. Verify FAIL light illuminates on Indicator and Video and cursor disappear

4.8.1.3 Place TX switch to ON. Verify that after approximately 30 seconds, Indicator returns to Normal.

4.8.2 Angle Outputs - Connect Voltmeter to A on simulator.

4.8.2.1 Lock on to a target of opportunity.

4.8.2.2 Record Az position and measure (A) on Fluke for at least two readings at positive angles and two readings at negative angles. (Az position determined from center of Brush trace, DC + 6 Hz signal with scale factor of -0.093 VDC/degree)

4.8.2.3 Determine best straight line through data points and record angle output scale factor.

4.8.2.4 Connect voltmeter to El position (E) on simulator.

4.8.2.5 Repeat 4.8.2.2 above for Elevation.

4.8.2.6 Repeat 4.8.2.3 above for Elevation.

4.8.3 Squint Angle - Acquire a target near 0°, 0°.

Record amplitude of 6 Hz signals on J6-A and J6-B. Signals shall be approximately 90° out of phase.

4.8.4 Connect recorder channel A to Az rate output (A) on Aircraft simulator and Channel B to El rate output (E). Turn on rate table to maximum rate. Verify azimuth output approximately 2 VDC in both directions (+ DC for Right Azimuth Motion).

4.8.5 Repeat for El, but inject rate by moving table frame up and down. (+DC for up Antenna Motion).

4.9 MODE Tests

4.9.1 Turn the mode switch on the Set Control to OPER, and the Range switch to 5 NM. Momentarily depress the Resume Search button. Verify that the ACQ symbol is stowed on the display at approximately on half the height of the display and half the distance to the left.

4.9.2 Using the thumb-controlled TDC on the Set Control, move the ACQ symbol away from the stowed position. Momentarily depress Resume Search button on RSC and verify ACQ symbol is again located in the stowed position.

4.9.3 With the TDC again position the ACQ symbol at zero degrees azimuth and maximum visible range on the display. Switch Range switch to 10 NM. Verify that symbol is at vertically the same position on the display. Switch to 20 NM. Verify that symbol is now approximately at the center of the display.

4.9.4 Position the ACQ symbol at minimum range. Verify no change in position of the symbol as a function of the range selected.

4.9.5 Position the ACQ symbol half-way up the display and at maximum left azimuth on the display. Verify that the symbol is still visible on the display. Repeat test for maximum right azimuth.

4.9.6 Depress and hold ACQ button. Position the ACQ symbol in azimuth verify that antenna is positionable over entrie azimuth range and follows ACQ symbol position. Also verify that video is always displayed between the two ACQ symbol vertical bars.

4.9.7 Release ACQ button and momentarily depress Resume Search button.

4.9.8 Connect voltmeter across Range (R) and Range Return (RTN) test jacks on Simulator panel. Place system in 5 NM range mode. Set Meter to "+DC".

4.9.9 Depress and hold ACQ button. Position ACQ symbol to obtain following positions. At each point record voltage at 5 NM range and switch to "10 NM" range mode and record voltmeter reading.

4.9.9.1 1st Range Line on Overlay

4.9.9.2 2nd Range Line on Overlay

4.9.9.3 3rd Range Line on Overlay

4.9.9.4 4th Range Line on Overlay

4.9.9.5 Top of Display

4.9.10 Release ACQ button and momentarily depress Resume Search Button. Connect oscilloscope to Range (R) and range return (RTN) on simulator panel. Switch Set Control to 5 NM range.

4.9.11 Set oscilloscope for "AC". Using middle finger, depress and hold ACQ button. Measure the peak-to-peak dither on the range voltage.

4.9.12 While holding ACQ button, switch to 10 NM. Measure the dither voltage peak-to-peak, at the same positions on display as before.

4.9.13 Turn transmitter switch to "ON". Lock onto target of opportunity by depressing ACQ button and positioning ACQ symbols over target and release ACQ button. Verify Aim Bar follows target.

4.9.13.1 Release ACQ button and momentarily depress Resume Search button.

4.9.14 BST Operation

4.9.14.1 Place mode switch on Set Control to BST. Verify ACQ symbol disappears from indicator display.

4.9.14.2 Depress and hold ACQ button. Verify that acquisition display is identical to MSL acquisition display.

4.9.14.3 Release ACQ button and verify system reverts to MSL ACQ mode and display.

4.9.14.4 Momentarily depress Resume Search button on RSC. Again depress and hold ACQ button. Verify that with RSC range switch in 5 NM, the 5 NM light is illuminated on Indicator, and with switch in 10 NM or 20 NM, the 10 NM light is illuminated.

4.9.14.5 Lock-on to a target of opportunity by releasing ACQ button. Verify a lock-on display identical to that obtained in MSL.

4.9.15 OPER Tests

4.9.15.1 Momentarily depress Resume Search button on RSC. Verify ACQ symbol on Indicator display in stowed position.

4.9.15.2 Using thumb-controlled TDC, place ACQ symbol around a target of opportunity.

4.9.15.3 Depress and hold ACQ button. Verify that antenna is searching in azimuth the area inside the ACQ symbol on the video with target displayed inside the symbol bars.

4.9.15.4 Release ACQ button. Verify that system locks-on to target. Lock-on display should be identical to MSL lock-on display.

4.9.15.5 Depress and hold ACQ button. Antenna should return to two-bar scan within the ACQ symbol at previous position before lock-on. Target should still be visible in ACQ symbol.

4.9.15.6 Release ACQ button and verify system reacquires target. Turn VIDEO control on Indicator fully CCW. Verify that after approximately 1.7 seconds system reverts to Search Mode.

4.9.15.7 Using ACQ symbol and button, reacquire a target of opportunity. After target acquisition, momentarily depress DOGFIGHT button on simulator panel. Verify system reverts to DOGFIGHT display and mode.

4.10 Angle Rate Tests

4.10.1 Gyro Outputs - Connect recorder Channel A to J6-U. Place Mode select switch to OPER and momentarily depress Resume Search. Connect recorder channel B to J6-R. Adjust tilt cursor to 0° and pitch on simulator to 0°.

4.10.2 Record steady state DC output of Channel A (Do not include turn-around rates)

4.10.3 Adjust Roll to 90° on simulator. Record steady state DC output of Channel B (Do not include turn-around rates)

4.10.4 Stabilization Tests - Adjust Roll to 0° on simulator. Connect recorder channel A to J7-DD and Channel B to J7-EE - lock-on to a target of opportunity near center of display in azimuth.

4.10.5 Turn on Rate Table to minimum rate. Record maximum steady state DC voltage on Channel A of Recorder.

4.10.6 Turn Rate Table OFF. Move table in elevation by raising and lowering rear of table. Record maximum steady state DC voltage on Channel B of Recorder.

4.10.7 Turn system to OFF.

4.11 Boresight Tests

4.11.1 Tracking Accuracy - Set up system in Anechoic Chamber as shown in Figure 5. Do not install antenna on holding fixture. Do not connect RF output of signal generator to R/T LRU.

4.11.2 Connect Recorder Channel A to Test Jack A on simulator and Channel B to test jack E on simulator.

4.11.2.1 Connect output of 620 Signal Generator to standard gain horn.

4.11.2.2 Place standard gain horn on holding fixture 250 inches from antenna holding fixture.

4.11.3 Align target horn to pedestal with boresight scope at center of four antenna attaching points on holding fixture.

4.11.3.1 Attach antenna LRU to holding fixture. Remove antenna reflector and feed. Insert holding pins (.1875 dia. pins) in az and el gimbals.

4.11.3.2 Measure alignment difference between center of gimbal waveguide output and target. Record (0.25 inches at target equals 1 milliradian).

4.11.3.3 Align target horn to waveguide output. Attach reflector and feed to gimbals. Remove pins.

4.11.4 Turn TX interlock switch to OFF. Place mode switch to BST, and Range switch to 10 NM.

4.11.4.1 With oscilloscope connected to receiver output J6-$\overline{A}$, adjust 620 signal generator for a target with amplitude greater than -1.5 VDC and range near 80 microseconds.

4.11.4.2 Depress and release ACQ button to acquire target and lock-on. Verify lock-on light illuminates.

4.11.4.3 Record A and E outputs on recorder.

4.11.4.4 Connect Recorder Channel A to J7-DD (Az error) and Channel B (El error) to J7-EE.

4.11.4.5 Record voltages on Channel A and B.

4.11.5 Place Mode Select switch to OFF. Turn all equipment off, and disconnect system and test equipment.

4.12 Weigh the following components either separately or in combination:

R/T LRU
Processor LRU
Flexguide Assembly
Antenna LRU
Indicator LRU
Set Control LRU

Record total weight

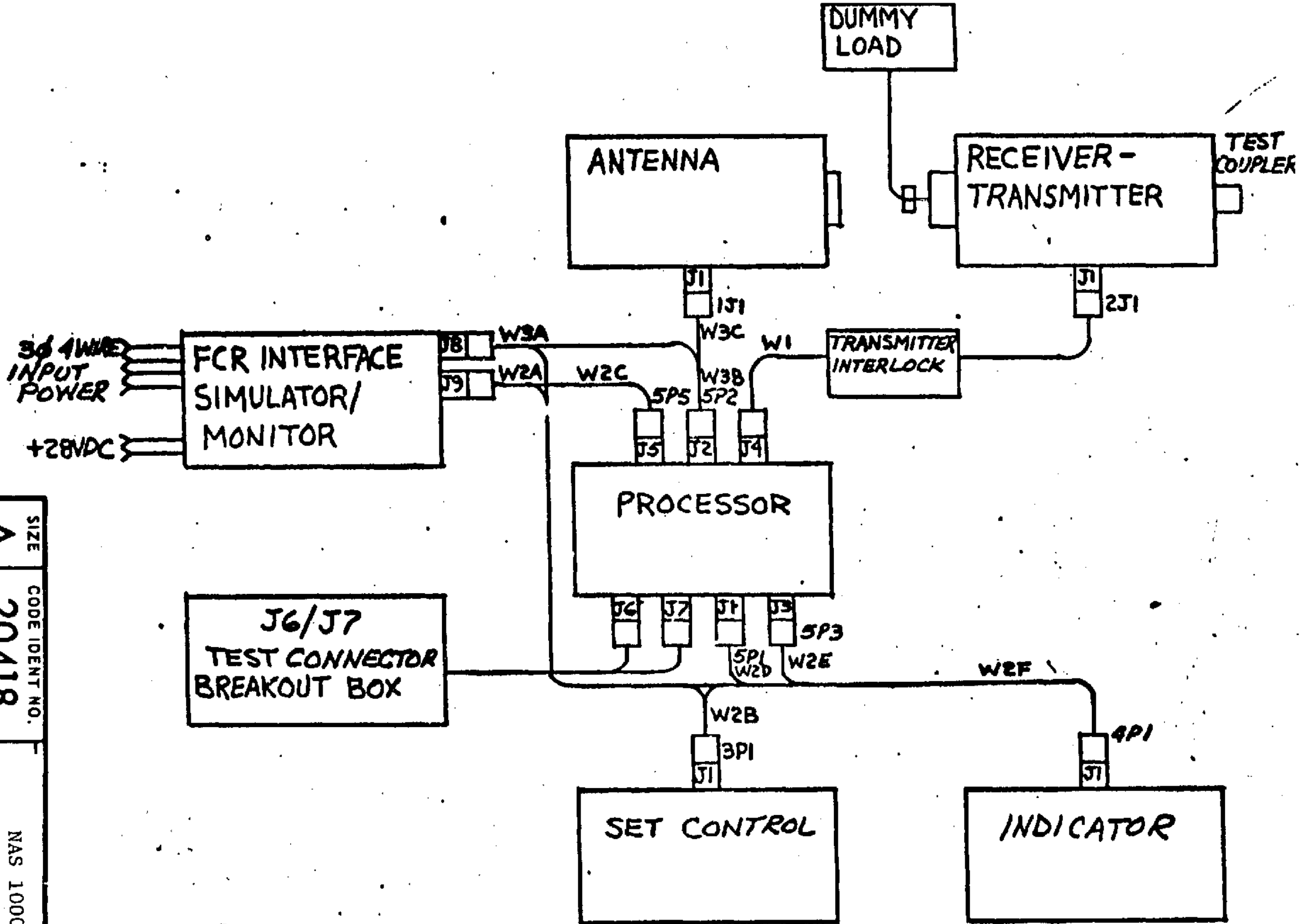


FIGURE 1
RADAR SYSTEM INTERCABLING WITH SYSTEM TEST BENCH FOR ACCEPTANCE TESTING

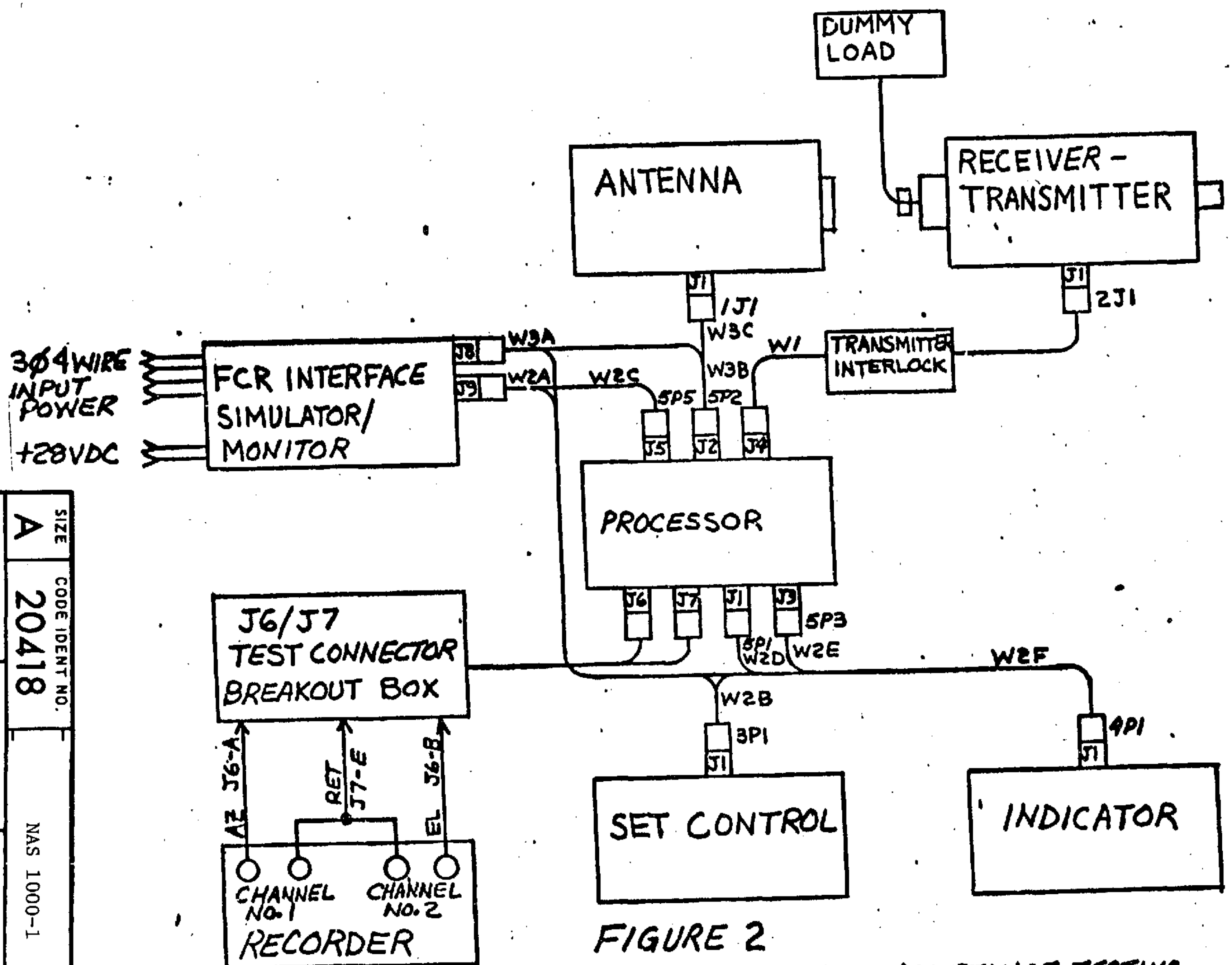


FIGURE 2
RADAR SYSTEM INTERCABLING WITH SYSTEM TEST BENCH FOR ACCEPTANCE TESTING

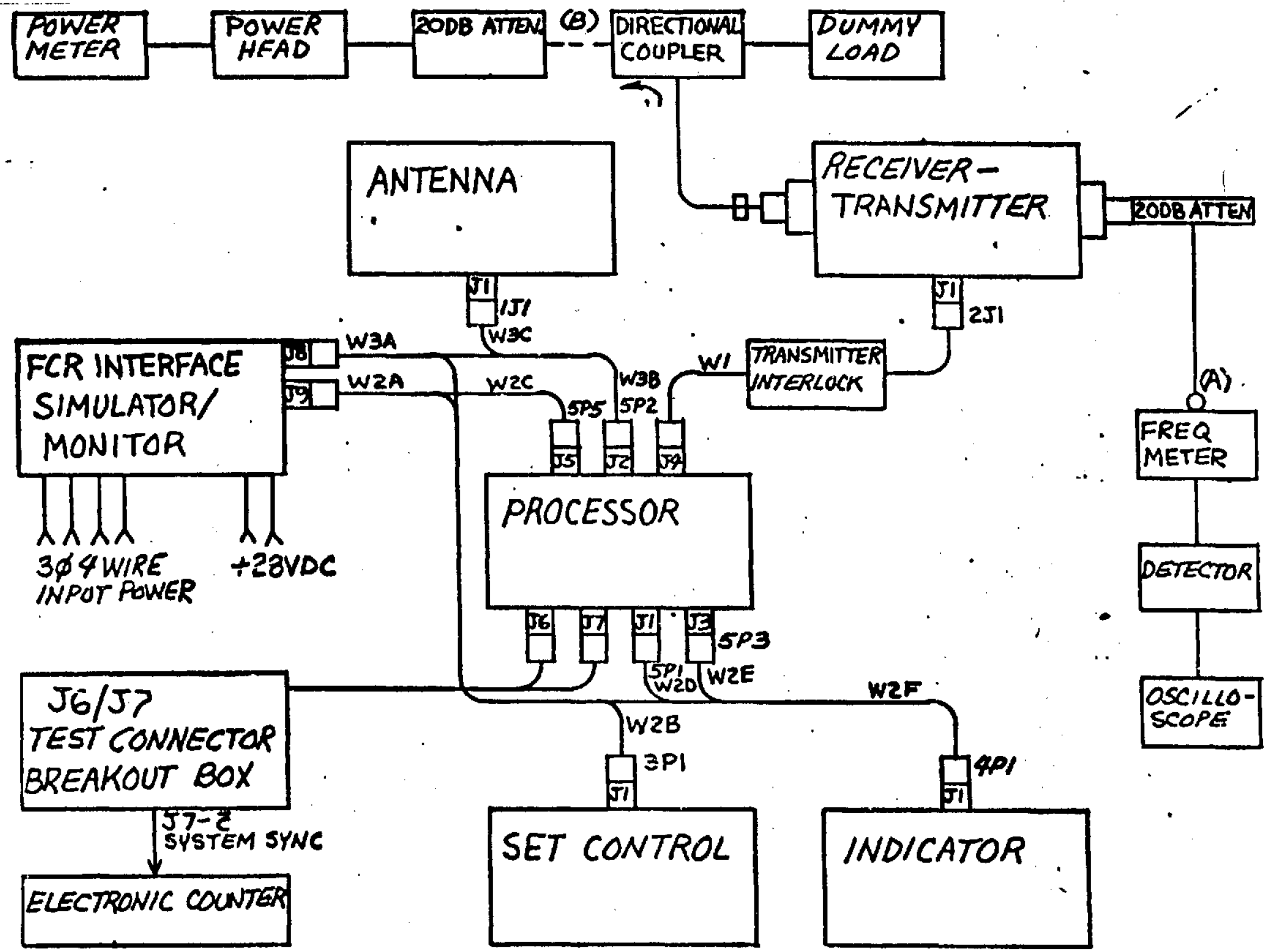


FIGURE 3

RADAR SYSTEM INTERCABLING WITH SYSTEM TEST BENCH FOR ACCEPTANCE TESTING

SD FORM 481-2 AUG 64 (2C)

SIZE	CODE IDENT NO.	
A	20418	NAS 1000-1
SCALE	REV	SHEET 28

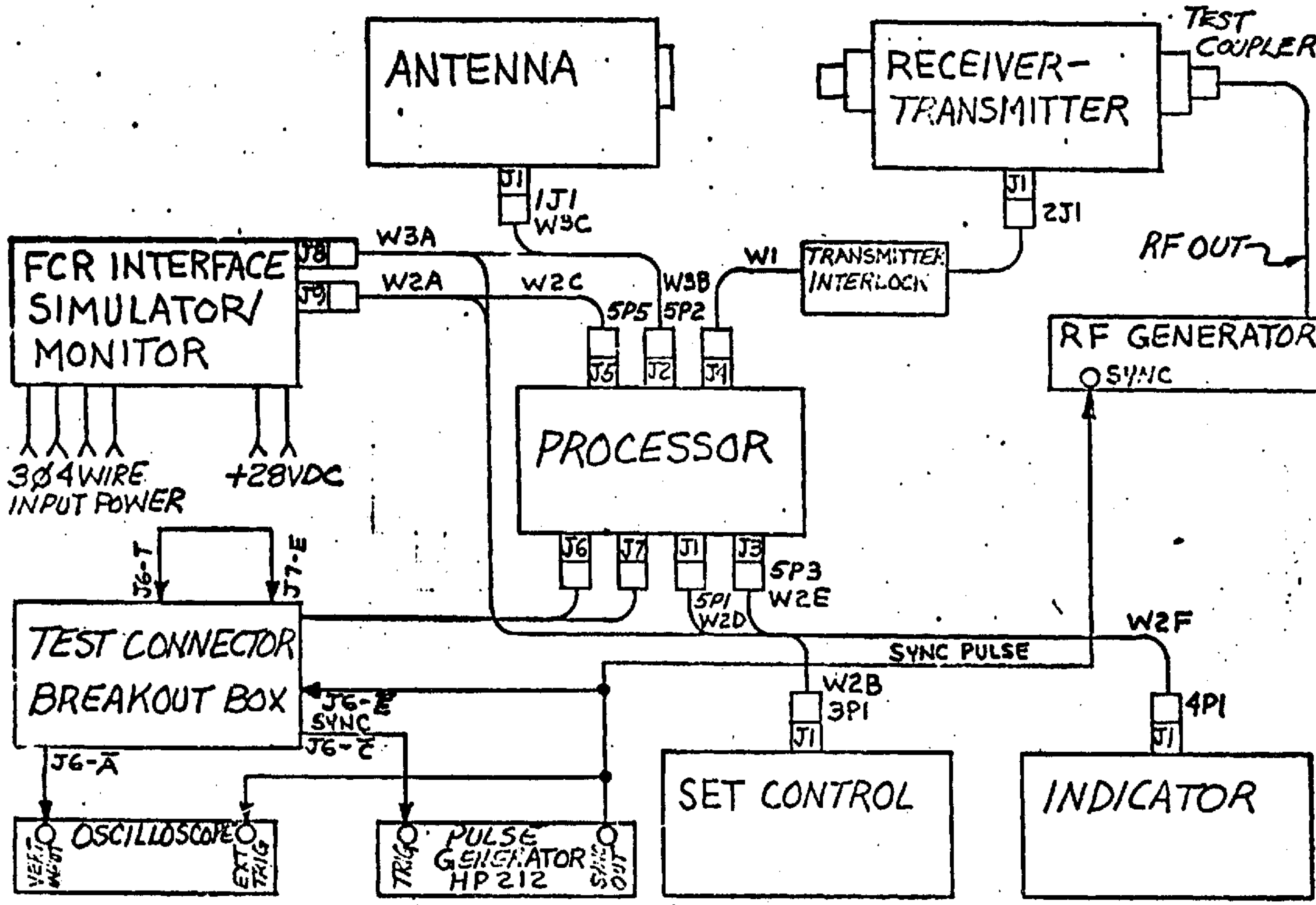


FIGURE 5

RADAR SYSTEM INTERCABLING WITH SYSTEM TEST BENCH FOR ACCEPTANCE TESTING

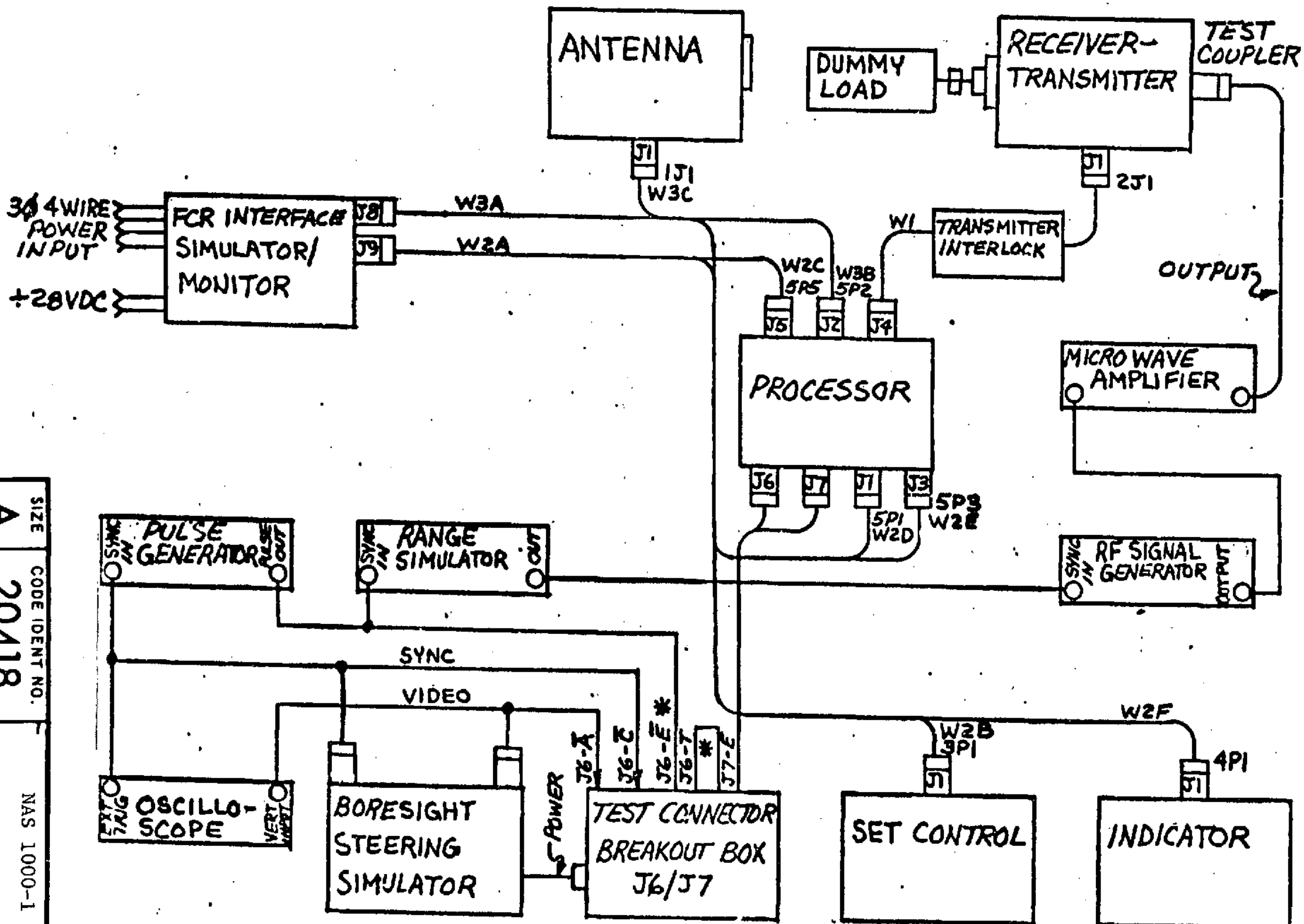


FIGURE 6

RADAR SYSTEM INTERCABLING WITH SYSTEM TEST BENCH FOR ACCEPTANCE TESTING

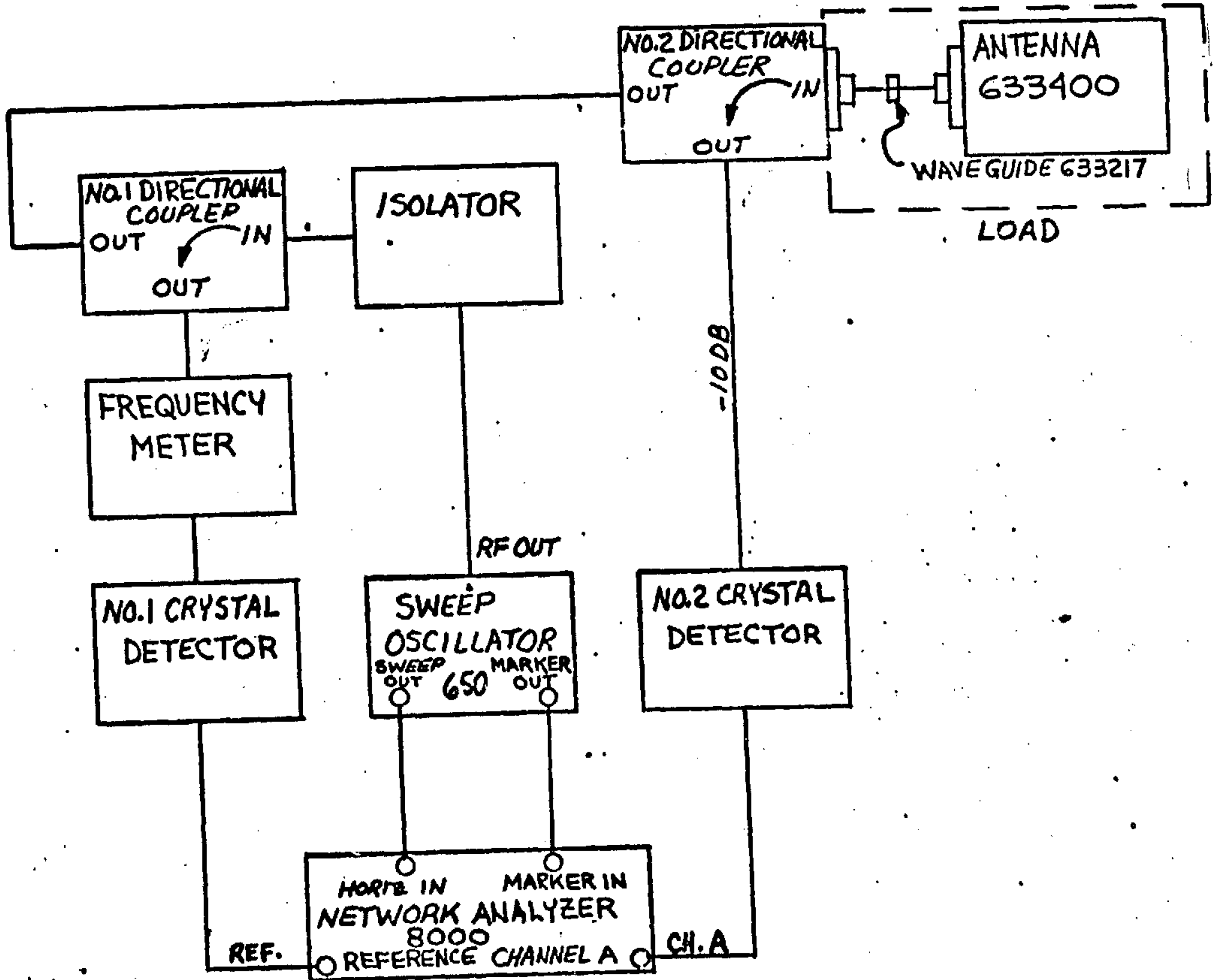


FIGURE 7
VSWR TEST SETUP

SD FORM 481-2 AUG 64 (2C)

SIZE	CODE IDENT NO.	
A	20418	NAS 1000-1
SCALE	REV	SHEET 31

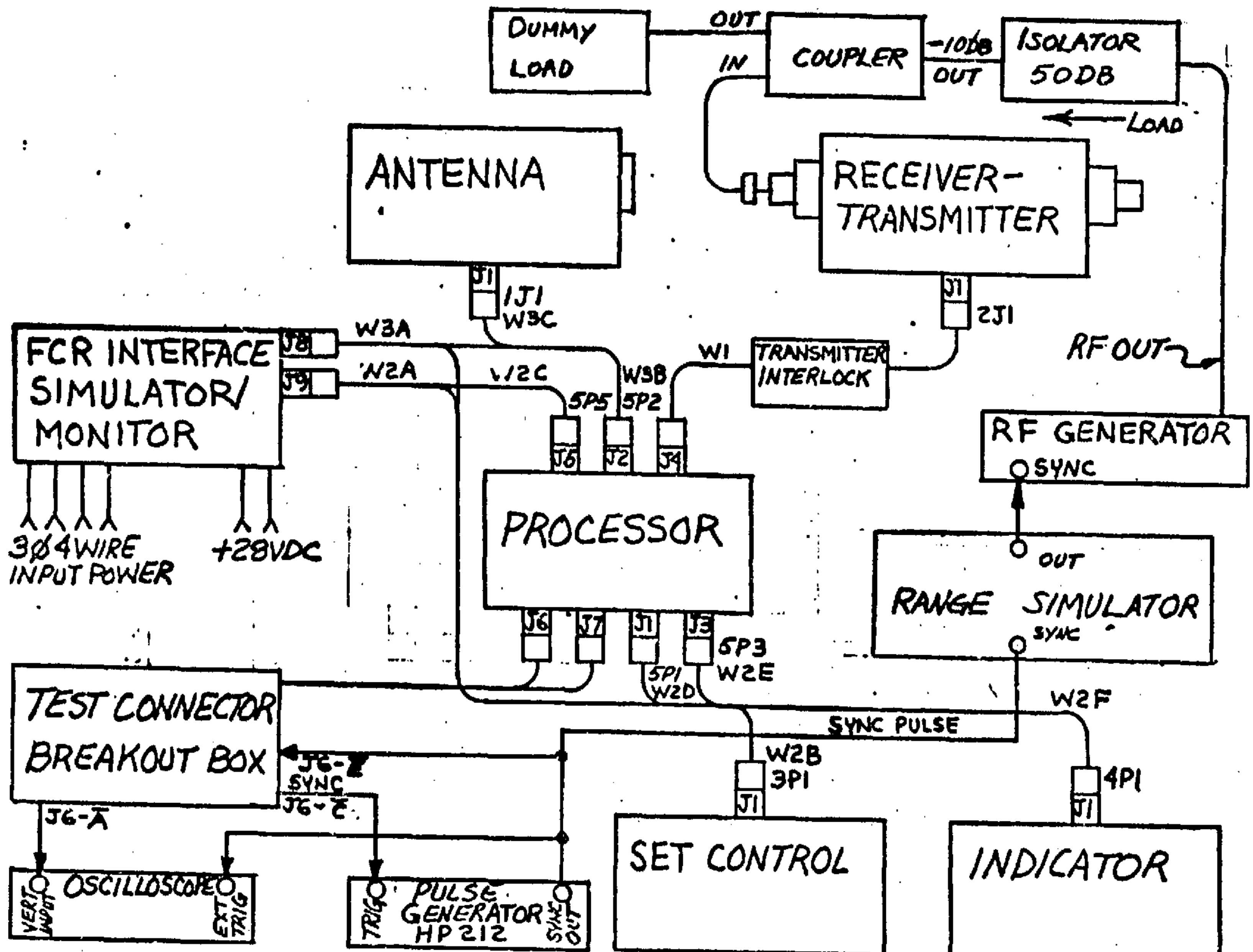


FIGURE 8

RADAR SYSTEM INTERCABLING WITH SYSTEM TEST BENCH FOR ACCEPTANCE TESTING

TEST WITNESS RECORD FOR ACCEPTANCE TEST MODIFIED FOR NASA FIRE CONTROL RADAR.

SYSTEM S/N ________________

TEST COMPLETED ON ________________

TEST PERFORMED BY ________________

EMERSON ENGINEERING ________________

EMERSON QUALITY ASSURANCE ________________

NASA TECHNICAL MONITOR ________________

5.0 DATA SHEETS

To be filled in as required by applicable paragraphs of Section 4 of these procedures.

TEST EQUIPMENT USED.

Instrument	MFR & Model	Next Calibration Due
Dummy Load		
Recorder		
Electronic Counter		
Microwave Amplifier		
Spectrum Analyzer		
Variable Attenuator		
Power Meter		
Power Head		
Directional Coupler 20 DB		
Frequency Meter (X Band)		
Detector		
Oscilloscope		
Pulse Generator		
RF Generator		
Voltmeter		
50 DB Isolator		
10 DB Directional Coupler		
Dynamic Range SImulator		
Target Simulator	633339-1 S/N -	
pressure Test Set		
System Test Bench		

LRU	S/N	Running Time Meter ATP Start	Running Time Meter ATP Complete
Processor			
Antenna			
Indicator			
XMTR/RCVR	TOTAL:		
	XMIT :		
Set Control		N/A	N/A

SIZE	CODE IDENT NO.	
A	20418	NAS 1000-1
SCALE	REV	SHEET 34

4.1.6	Antenna approximately straight ahead	______	Check
	Fail light not illuminated	______	Check
	ART. HORZ. and TILT CURSOR displayed	______	Check
	XMTR READY time	______	Seconds
4.1.7	Antenna searching full azimuth pattern:	______	Check
	FAIL light lighted	______	Check
	"B" scan displayed:	______	Check

4.1. 8	J-7 Pin	J-7 RTN	Measured Value		Measured	Ripple
	A	W 115 ± 2 vac	______	vac		
	B	W 115 ± 2 vac	______	vac		
	V	W 115 ± 2 vac	______	vac		
	C	X 28 ± 1 vdc	______	vdc		
	$\overline{Q}$	E +5 ± 0.15 vdc	______	vdc	<50 mv	______ Check
	Y	E -5 ± 0.15 vdc	______	vdc	<50 mv	______ Check
	$\overline{P}$	E +15 ± 0.23 vdc	______	vdc	<50 mv	______ Check
	D	E -15 ± 0.23 vdc	______	vdc	<50 mv	______ Check
	$\overline{N}$	E +30 ± 0.9 vdc	______	vdc	<50 mv	______ Check
	T	E +100 ± 3 vdc	______	vdc	<500 mv	______ Check
	U	E +150 ± 4.5 vdc	______	vdc	<500 mv	______ Check

4.2.1	Left Segment: 0.630" < L < 0.770"	______	Check
	Separation: 0.630" < L < 0.770"	______	Check
	Right Segment: 0.630" < L < 0.770"	______	Check
4.2.2	TILT CURSOR length: 0.220" < L < 0.280"	______	Check
4.2.3	"B" sweep length: 3.32 < L < 3.42	______	Check
4.2.4	Light	Illuminates	
	Fail	______	Check
	Lock-On	______	Check
	In-Range	______	Check
	Excess G's	______	Check

Applicable Paragraph	Data	ILLUMINATES	
4.2.4 Cont.	Light		
	5 mile	________	Check
	10 mile	________	Check
	20 mile	________	Check
4.2.4.1	In-Range Illuminated	________	Check
4.2.4.2	In-Range (flashing)	________	Check
4.2.4.3	Excess G's	________	Check
4.2.5	Art. HORZ. and TILT vary	________	Check
4.2.6	Brightness varies	________	Check
		________	Check
4.2.7	Persistance varies	________	Check
4.2.8	Brightness of overlay varies	________	Check
4.2.9	Observed Roll angle of 30 $\pm$ 3°	________	Check
	Observed Roll angle of 0 $\pm$ 2°	________	Check
4.2.9.1	Observed Pitch angle of 0° $\pm$ 2°	________	Check
4.2.9.2	Art. Horz. to 0°	________	Check
4.2.9.3	Art. HORZ. to 0°	________	Check
4.2.10	Objectionable spoking not present	________	Check
4.3.2.1	Azimuth frame time: $<$ 2.3 seconds	________	Seconds
4.3.2.2	Max. voltage excursions:	+ ________	Volts
	$> \pm$ 3.7 volts	- ________	Volts
4.3.2.3	Recorded trace within 0.2 volts of straight line	________	Check

Applicable Paragraph	Data		
4.3.2.4	Elevation recording for azimuth change from plus to minus: 0 ±0.2 volts	________	Volts
	minus to plus: 0.3 ±0.1 volts	________	Volts
4.3.2. 5	Max. excursion: -2.8 ±0.26 volts	________	Volts
4.3.2. 6	Max. excursion: +2.8 ±0.26 volts	________	Volts
4.3.2. 7	Max. excursion: > +2.8	________	Volts
4.3.2.12	Max. excursion: > -4 volts	________	Volts
4.3.3.1	Max. excursions: > 2.8 volts	________	Volts
	> -3.6 volts	________	Volts
4.3.3.2	Azimuth recording: 0.3 ± 0.1 volts	________	Volts
4.3.4.1	Azimuth recording: 0 ± 0.05 volts	________	Volts
	Elevation recording: 0 ± 0.05 volts	________	Volts
4.3.4.2	Azimuth recording: 0 ± 0.05 volts	________	Volts
	Elevation recording: 0.44 ± 0.07 volts	________	Volts
4.4.1	Frequency = 9.3 GHz ±.05 GHz	________	GHz
	Pulse Width = .4 ± .04 usec	________	usec
	PRF at J6-c̄ = 2500 ± 175 PPS	________	PPS
4.4.2	RF Power ≥ +46.6 DBM	________	DBM
4.4.3	Sidelobe levels > 8 DB down, from para. 4.2.7 of QAS No. F5E-400-13		
	9.15 GHz	________	DB down
	9.3 GHz	________	DB down
	9.45 GHz	________	DB down

Applicable Paragraph	Data		
4.4.4	From para. 4.2.6 of QAS No. F5E-400-13:		
	Pulse Width at 9.15 GHz	______	usec
	Pulse Width at 9.45 GHz	______	usec
	RF Power at 9.15 GHz	______	DBM
	RF Power at 9.45 GHz	______	DBM
4.4.5	AFC Voltage at J6-D -4.5 $\pm$.5 Volts	______	VDC
4.6.1	Receiver MDS: at least -97 dBM	______	DBM
	Indicator MDS: at least -99 dBM	______	DBM
4.6.1.1	Lock-On 5 $\pm$ 2 dB above Indicator MDS	______	dB
4.6.2	Dynamic Range, from para. 4.6.1 of QAS No. F5E-400-13 (> 80 dBM)	______	DBM
4.6.3	Video Control Functional	______	Check

Applicable Paragraph	Data		
4.6.5.1	5 mile Range light illuminated:	______	Check
	4 mile target properly displayed (±.2 inches)	______	Check
4.6.5.2	10 mile Range light illuminated:	______	Check
	4 mile target properly displayed (±.2 inches)	______	Check
4.6.5.3	20 mile Range light illuminated:	______	Check
	4 mile target properly displayed (±.2 inches)	______	Check
4.6.6.1	4 miles ± 0.135 inches	______	Inches
4.6.6.2	8 miles ± 0.135 inches	______	Inches
4.6.6.3	16 miles ± 0.135 inches	______	Inches
4.6.7	Jizzled sweep to left, and track gate sweeping min. to max range	______	Check
4.6.7.1	Track gate bars each 0.125 ±.062 inches		
	Left bar	______	Inches
	Right Bar	______	Inches
4.6.7.2	Jizzled sweep is 0.4 ±0.1 inches wide	______	Inches
4.6.7.3	Center of sweep is left 0.80 ±0.13 inches	______	Inches

Applicable Paragraph	Data		
4.6.8	Range	Range Voltage	
	600 ft. 0.6 ± 0.05 vdc	________	vdc
	1,000 ft. 1.0 ± 0.05 vdc	________	vdc
	2,000 ft. 2.0 ± 0.05 vdc	________	vdc
	3,000 ft. 3.0 ± 0.06 vdc	________	vdc
	7,500 ft. 7.5 ± 0.15 vdc	________	vdc
	15,000 ft. 15 ± 0.3 vdc	________	vdc
	30,000 ft. 30 ± 0.6 vdc	________	vdc
	60,000 ft. 60 ± 1.2 vdc	________	vdc
4.6.9	Target	Range Rate Voltage	
	0 ft./sec 0 ± 0.05 vdc	________	vdc
	closing 1000 ft/sec. +5 ± 0.15 vdc	________	vdc
	closing 2000 ft/sec. +10 ± 0.45 vdc	________	vdc
	closing 3000 ft/sec. +15 ± 0.45 vdc	________	vdc
	opening 1000 ft/sec. -5 ± 0.15 VDC	________	vdc
4.6.10	Memory time 1.75 ± 0.15 vdc	________	sec
4.6.10.1	Range Rate Voltage Constant	________	Check
4.6.11.1	Time ($<$ .5 sec)	________	Sec
4.6.12.1	Lock-On Light illuminated	________	Check
	10 Mile Range light illuminated:	________	Check
	5 Mile Range Light illuminated:	________	Check
	Az Antenna Position Center 0 ± 50mv	________	mv
	El Antenna Position Center 0 ± 50mv	________	mv
	Az Antenna Peak-to-Peak 376 ± 38 mv	________	mv
	El Antenna Peak-to-Peak 455 ± 45mv	________	mv
4.6.12.2	Lock-On Light extinguishes:	________	Check

4.6.12.2 cont. Target

	Range Gate Strobes Outward:	____	Check
	5 Mile Range Light illuminates:	____	Check
4.6.12.3	Lock-On light illuminates:	____	Check
4.6.12.4	Lock-On light remains illuminated:	____	Check
	AIM BAR displayed:	____	Check
4.6.12.5	Range gate strobing outward:	____	Check
4.6.12.6	Range gate strobing outward:	____	Check
4.6.12.7	Range gate strobing outward:	____	Check
4.6.12.8	5 mile light illuminated:	____	Check
	Range gate strobing outward:	____	Check
4.6.12.9	No change in conditions:	____	Check
4.6.12.10	"B" scan displayed:	____	Check
4.6.12.11	Lock-On light illuminates:	____	Check
4.6.12.12	Proper strobe and reacquisition observed: No lock-on while held, lock-on when released.	____	Check
4.6.12.13	Lock-on acquired:	____	Check
4.6.12.14	Lock-On reacquired:	____	Check
4.6.12.15	Lock-On reacquired:	____	Check
4.6.12.16	Lock-On acquired:	____	Check
4.6.12.17	Lock-On reacquired:	____	Check
4.6.12.18	Lock-On continues:	____	Check
4.6.12.19	Lock-On reacquired:	____	Check
4.6.12.20	No target video on Indicator:	____	Check
4.6.12.21	Target video appears:	____	Check
	Lock-On acquired:	____	Check
4.6.12.22	Target video disappears:	____	Check
	Antenna in proper position:		Check

Applicable Paragraph	Data		
4.6.13	AIM BAR in scribed circle	________	Check
4.6.13.1	AIM BAR up .9 ± 0.2 inches from center	________	Check
4.6.13.2	AIM BAR down 1.1 ± 0.2 inches from center	________	Check
4.6.13.3	Range Gate locked-on 5 mile target:	________	Check
	TILT CURSOR disappears	________	Check
	AIM BAR present	________	Check
	El. Phase control position AIM BAR:	________	Check
	AZ. Phase control position AIM BAR:	________	Check
4.6.13.4.1	Artificial Horizon at -20 ± 3°	________	Check
4.6.13.4.2	Artificial Horizon at +20 ± 3°	________	Check
4.6.13.4.3	Artificial Horizon at -20 ± 3°	________	Check
	Artificial Horizon CCW 30 ± 3°	________	Check
4.6.13.4.4	Tilt Cursor at -17.3 ± 3°	________	Check
4.6.13.4.5	Artificial Horizon at +20 ± 3°	________	Check
	Artificial Horizon CW 30 ± 3°	________	Check
4.6.13.4.6	Tilt Cursor at +17.3 ± 3°	________	Check
4.7	FAIL light OFF	________	Check
4.7.1	TILT CURSOR AT 0°	________	Check
	J6-B position voltage -3 ± .3V	________	Volts
4.7.2	Lock-On light illuminates	________	Check
	FAIL light extinguished	________	Check
4.7.3	TILT CURSOR Down ≈ 5°	________	Check
4.7.4	TILT CURSOR up 20°	________	Check
	Tracking Gate strobing outward:	________	Check

5.0 DATA SHEETS

Applicable Paragraph	Data		
4.8.1.1	Ground Return Video and Cursors Appear		______Check
4.8.1.2	Video and Cursors disappear		______Check
	FAIL light ON		______Check
4.8.1.3	Video and Cursors Appear		______Check
	FAIL light OFF		______Check
4.8.2.2		Recorder Angle	Voltage
	#1	________	______
	#2	________	______
	#3	________	______
	#4	________	______
4.8.2.3	Angle Scale Factor 0.1 ± 0.010 VDC/Degree		______VDC/Degree
4.8.2.5	#1	________	______
	#2	________	______
	#3	________	______
	#4	________	______
4.8.2.6	Angle Scale Factor -0.1 ± 0.010 VDC/Degree		______VDC/Degree
4.8.3	Az (J6A) .233 ± .05 VPP		______VPP
	El (J6B) .325 ± .05 VPP		______VPP
4.8.4	Az Rate Output		______Check
4.8.5	El Rate Output		______Check

Applicable Paragraphs	Data	
4.9.1	Symbols Stowed	______Check
4.9.2	Symbols Stowed	______Check
4.9.3	Symbol at same position	______Check
	Symbol at center of display	______Check
4.9.4	No Change in position	______Check
4.9.5	Symbol visible at left azimuth	______Check
	Symbol visible at Right Azimuth	______Check
4.9.6	Antenna positionable	______Check
	Video displayed between symbols	______Check
4.9.9.1	6.08 ± 0.30 VDC	______VDC
	12.16 ± 0.6 VDC	______VDC
4.9.9.2	12.16 ± 0.6	______VDC
	24.32 ± 1.2	______VDC
4.9.9.3	18.24 ± 0.90	______VDC
	36.48 ± 1.8	______VDC
4.9.9.4	24.32 ± 1.2	______VDC
	48.64 ± 2.4	______VDC
4.9.9.5	30.4 ± 1.5	______VDC
	60.8 ± 3.0	______VDC
4.9.11	$3.0 \pm .3$ V Peak-to-Peak	______VPP
4.9.12	$6.0 \pm .6$ V Peak-to-Peak	______VPP
4.9.13	Aim Bar follows target	______Check
4.9.14.1	ACQ symbols disappear	______Check
4.9.14.2	Same as MSL display	______Check

Applicable Paragraph	Data	
4.9.14.3	MSL ACQ display	______Check
4.9.14.4	5 NM Light	______Check
	10 NM Light	______Check
	10 NM Light	______Check
4.9.14.5	Lock-On Display	______Check
4.9.15.1	ACQ symbols stowed	______Check
4.9.15.3	Video displayed between symbols	______Check
4.9.15.4	Lock-On Display	______Check
4.9.15.5	2-Bar Scan	______Check
	Target displayed	______Check
4.9.15.6	System searches	______Check
4.9.15.7	System in DOGFIGHT Mode	______Check

Applicable Paragraph	Data		
4.10.2	2.15 ± .45 VDC		______VDC
4.10.3	2.15 ± .45 VDC		______VDC
4.10.5	Less than 1.0 VDC		______VDC
4.10.6	Less than 1.0 VDC		______VDC
4.11.3.2	Reference Only	AZ	______mr
	Reference Only	EL	______mr
4.11.4.2	Lock-On Light		______Check
4.11.4.3	0.050 VDC max	AZ	______VDC
	0.050 VDC max	EL	______VDC
4.11.4.4	0.25 VDC max	AZ	______VDC
	0.25 VDC max	EL	______VDC
4.12	System Weight less than 125 lbs		______lbs

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED
A	Correct ATP	6-26-74	DP

Revised Pages for Revision A.

SHEET	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
[redacted]ISION																		A	A		A

[redacted]EVISION [redacted]DEX	SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	REVISION				A																A		A		A	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TO[redacted]RANCES FRACTIONS ±1/64 AN[redacted]LES ±1/2° 1 P[redacted]E DECIMALS ±.005 2 PLACE DECIMALS ±.01

CONTRACT NO. NAS-9-13695

EMERSON ELECTRONICS AND SPACE DIVISION EMERSON ELECTRIC CO. 8100 FLORISSANT ST. LOUIS, MISSOURI

ACCEPTANCE TEST PROCEDURE (ATP) FOR AN/APQ-153 FIRE CONTROL RADAR MODIFIED FOR NASA

SIZE	CODE IDENT NO.	DRAWING NO.
A	20418	NAS-1000-1

SCALE: NONE SHEET 1 OF 46

3.0 TEST CONDITIONS AND EQUIPMENT

Unless specified otherwise, all acceptance testing of the APQ-153 Fire Control Radar, referred to as the FCR throughout this document, shall be conducted under the conditions delineated in this paragraph.

3.1 Environment - The acceptance testing of the FCR shall be conducted at a normal laboratory environment, designated as the Standard Environmental Conditions and shall be as follows:

Ambient Temperature: 20°C to 30°C
Barometric Pressure: 28" Hg. to 32" Hg.
Relative Humidity: Up to 90%

3.2 Input Power - The input power for acceptance testing the FCR shall be termed Standard Input Power and shall be 3 phase, 4 wire wye, 115 ± 2 rms, 400 ± 5 Hz., ~~1 Phase, p to 5.0 volts rms,~~ 400 ± 5 Hz., 28 ± 1 volt dc. A

3.3 Reject and Retest - When an item fails compliance with the requirements of this ATP during acceptance testing, further action shall be in accordance with Northrop procedures.

3.4 Warm-Up - The FCR shall pass any performance test in this ATP without requiring a warm-up time in excess of 5 minutes.

3.5 Visual Observation - All visual observation tests of the Indicator LRU performance shall be made at a distance of approximately 2 feet and an angle of 26° up from a line perpendicular to the Indicator front panel.

3.6 Unless specified otherwise, all functional performance acceptance testing of the FCR shall be conducted with all articles of the FCR interconnected with all articles of the Emerson System Test Bench, or equivalent, according to Figure 1 of this ATP.

3.7 Unless specified otherwise, all FCR acceptance testing shall be conducted at conditions simulated by the System Test Bench as follows:

Aircraft Roll Angle: 0°
Aircraft Pitch Angle: 0°
Aircraft Wing Twist: 0°

3.8 The following Special Test Equipment and Standard Test Equipment shall be used for AN/APQ-153 Acceptance tests. Standard Test Equipment Articles may be substituted by articles of equivalent capability and accuracy.

3.8.1 Special Test Equipment -

1 each Display Test Template Emerson Part No. 633332
1 each System Test Bench (STB)
consisting of 1 each of -

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4.8 Angle Lock-On Tests

4.8.1 Transmitter Interlock Tests - Connect Recorder as shown in Figure 2. Connect flexible waveguide between transmitter LRU and Antenna LRU. Remove 8 ft. cable between Processor J4 and Receiver/Transmitter J-1 and install 50 ft. cable.

4.8.1.1 Place TX switch on aircraft simulator to normal. Place FCR mode control switch to STBY. Adjust tilt cursor to 0°. After 5 minutes place mode switch to OPER. Note that ground return appears on Indicator along with cursors.

4.8.1.2 Place TX switch to OFF. Verify FAIL light illuminates on Indicator and Video and cursor disappear

4.8.1.3 Place TX switch to ON. Verify that after approximately 30 seconds, Indicator returns to Normal.

4.8.2 Angle Outputs - Connect Voltmeter to A on simulator.

4.8.2.1 Lock on to a target of opportunity.

4.8.2.2 Record Az position and measure (A) on Fluke for at least two readings at positive angles and two readings at negative angles. (Az position determined from center of Brush trace, DC + 6 Hz signal with scale factor of -0.093 VDC/degree)

4.8.2.3 Determine best straight line through data points and record angle output scale factor.

4.8.2.4 Connect voltmeter to El position (E) on simulator.

4.8.2.5 Repeat 4.8.2.2 above for Elevation.

4.8.2.6 Repeat 4.8.2.3 above for Elevation.

4.8.3 Squint Angle - Acquire a target near 0°, 0°.

Record amplitude of 6 Hz signals on J6-A and J6-B. Signals shall be approximately 90° out of phase.

~~4.8.4 Connect recorder channel A to Az rate output (A) on Aircraft simulator and Channel B to El rate output (E). Turn on rate table to maximum rate. Verify azimuth output approximately 2 VDC in both directions (+ DC for Right Azimuth Motion).~~

~~4.8.5 Repeat for El, but inject rate by moving table frame up and down. (+DC for up Antenna Motion).~~

Delete

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4.9.10 Release ACQ button and momentarily depress Resume Search Button. Connect oscilloscope to Range (R) and range return (RTN) on simulator panel. Switch Set Control to 5 NM range.

4.9.11 Set oscilloscope for "AC". Using middle finger, depress and hold ACQ button. Measure the peak-to-peak dither on the range voltage. 2.1 ± .2 V P-P

4.9.12 While holding ACQ button, switch to 10 NM. Measure the dither voltage peak-to-peak, at the same positions on display as before. 4.2 ± .2V P-P

4.9.13 Turn transmitter switch to "ON". Lock onto target of opportunity by depressing ACQ button and positioning ACQ symbols over target and release ACQ button. Verify Aim Bar follows target.

4.9.13.1 Release ACQ button and momentarily depress Resume Search button.

4.9.14 BST Operation

4.9.14.1 Place mode switch on Set Control to BST. Verify ACQ symbol disappears from indicator display.

4.9.14.2 Depress and hold ACQ button. Verify that acquisition display is identical to MSL acquisition display.

4.9.14.3 Release ACQ button and verify system reverts to MSL ACQ mode and display.

4.9.14.4 Momentarily depress Resume Search button on RSC. Again depress and hold ACQ button. Verify that with RSC range switch in 5 NM, the 5 NM light is illuminated on Indicator, and with switch in 10 NM or 20 NM, the 10 NM light is illuminated.

4.9.14.5 Lock-on to a target of opportunity by releasing ACQ button. Verify a lock-on display identical to that obtained in MSL.

4.9.15 OPER Tests

4.9.15.1 Momentarily depress Resume Search button on RSC. Verify ACQ symbol on Indicator display in stowed position.

4.9.15.2 Using thumb-controlled TDC, place ACQ symbol around a target of opportunity.

4.9.15.3 Depress and hold ACQ button. Verify that antenna is searching in azimuth the area inside the ACQ symbol on the video with target displayed inside the symbol bars.

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4.10 Angle Rate Tests

4.10.1 Gyro Outputs - Connect recorder Channel A to J6-U. Place Mode select switch to OPER and momentarily depress Resume Search. Connect recorder channel B to J6-R. Adjust tilt cursor to 0° and pitch on simulator to 0°.

4.10.2 Record steady state DC output of Channel A (Do not include turn-around rates) 1.55 ± .3 VDC

4.10.3 Adjust Roll to 90° on simulator. Record steady state DC output of Channel B (Do not include turn-around rates) 1.55 ± .3 VDC

4.10.4 Stabilization Tests - Adjust Roll to 0° on simulator. Connect recorder channel A to J7-DD and Channel B to J7-EE - lock-on to a target of opportunity near center of display in azimuth.

4.10.5 Turn on Rate Table to minimum rate. Record maximum steady state DC voltage on Channel A of Recorder.

4.10.6 Turn Rate Table OFF. Move table in elevation by raising and lowering rear of table. Record maximum steady state DC voltage on Channel B of Recorder.

4.10.7 Turn system to OFF.

4.11 Boresight Tests

4.11.1 Tracking Accuracy - Set up system in Anechoic Chamber as shown in Figure 5. Do not install antenna on holding fixture. Do not connect RF output of signal generator to R/T LRU.

4.11.2 Connect Recorder Channel A to Test Jack A on simulator and Channel B to test jack E on simulator. Connect jumper between J7-R and J7-E

4.11.2.1 Connect output of 620 Signal Generator to standard gain horn.

4.11.2.2 Place standard gain horn on target holding fixture 250 inches from antenna holding fixture.

4.11.3 Align target horn to pedestal with boresight scope at center of four antenna attaching points on holding fixture.

4.11.3.1 Attach antenna LRU to holding fixture. Remove antenna reflector and feed. Insert holding pins (.1875 dia. pins) in az and el gimbals.

4.11.3.2 Measure alignment difference between center of gimbal waveguide output and target. Record (0.25 inches at target equals 1 milliradian).

4.11.3.3 Align target horn to waveguide output. Attach reflector and feed to gimbals. Remove pins.

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5.0 DATA SHEETS

Applicable Paragraph	Data	Recorder Angle	Voltage / Check
4.8.1.1	Ground Return Video and Cursors Appear		______ Check
4.8.1.2	Video and Cursors disappear		______ Check
	FAIL light ON		______ Check
4.8.1.3	Video and Cursors Appear		______ Check
	FAIL light OFF		______ Check
4.8.2.2		Recorder Angle	Voltage
	#1	______	______
	#2	______	______
	#3	______	______
	#4	______	______
4.8.2.3	Angle Scale Factor 0.1 ± 0.010 VDC/Degree		______ VDC/Degree
4.8.2.5	#1	______	______
	#2	______	______
	#3	______	______
	#4	______	______
4.8.2.6	Angle Scale Factor -0.1 ± 0.010 VDC/Degree		______ VDC/Degree
4.8.3	Az (J6A) .233 ± .05 VPP		______ VPP
	El (J6B) .325 ± .05 VPP		______ VPP
~~4.8.4~~	~~Az Rate Output~~ Delete		______ Check
~~4.8.5~~	~~El Rate Output~~ Delete		______ Check

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SIZE	CODE IDENT NO.	
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Applicable Paragraphs	Data	
4.9.1	Symbols Stowed	______Check
4.9.2	Symbols Stowed	______Check
4.9.3	Symbol at same position	______Check
	Symbol at center of display	______Check
4.9.4	No Change in position	______Check
4.9.5	Symbol visible at left azimuth	______Check
	Symbol visible at Right Azimuth	______Check
4.9.6	Antenna positionable	______Check
	Video displayed between symbols	______Check
4.9.9.1	6.08 ± 0.30 VDC	______VDC
	12.16 ± 0.6 VDC	______VDC
4.9.9.2	12.16 ± 0.6	______VDC
	24.32 ± 1.2	______VDC
4.9.9.3	18.24 ± 0.90	______VDC
	36.48 ± 1.8	______VDC
4.9.9.4	24.32 ± 1.2	______VDC
	48.64 ± 2.4	______VDC
4.9.9.5	30.4 ± 1.5	______VDC
	60.8 ± 3.0	______VDC
4.9.11	3.0 ± .3 V Peak-to-Peak 2.1 ± .2	______VPP
4.9.12	~~6.0 ± .6 V Peak-to-Peak~~ 4.2 ± .2	______VPP
4.9.13	Aim Bar follows target	______Check
4.9.14.1	ACQ symbols disappear	______Check
4.9.14.2	Same as MSL display	______Check

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Applicable Paragraph	Data			
4.10.2	~~2.15 ± .45 VDC~~	1.55 ± .3		______VDC
4.10.3	~~2.15 ± .45 VDC~~	1.55 ± .3		______VDC
4.10.5	Less than 1.0 VDC			______VDC
4.10.6	Less than 1.0 VDC			______VDC
4.11.3.2	Reference Only		AZ	______mr
	Reference Only		EL	______mr
4.11.4.2	Lock-On Light			______Check
4.11.4.3	0.050 VDC max		AZ	______VDC
	0.050 VDC max		EL	______VDC
4.11.4.4	0.25 VDC max		AZ	______VDC
	0.25 VDC max		EL	______VDC
4.12	System Weight less than 125 lbs			______lbs

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DATA

D.1 DRAWING LIST

D.2 TECH ORDER LIST

D.3 ATP DATA

D.1 DRAWING LIST - NASA FIRE CONTROL RADAR

DRAWING NO.	TITLE	SHEET NO.	P/L	R/D
656900	System			
901	Interconnect	1-5		
902	Simulator Panel			
910	Antenna LRU	1, 2	X	
911	Nameplate			
912	Bracket			
913	Bracket			
914	Retainer			
920	Set Control LRU	1, 2	X	
921	Nameplate			
922	Circuit Board	1, 2	X	X
923	Circuit Board	1, 2	X	X
924	Circuit Board	1, 2	X	X
925	Bracket			
940	Indicator LRU			
941	Nameplate			
950	Receiver/Transmitter LRU			
951	Nameplate			
955	Flexguide			
960	Processor LRU	1, 2	X	(Wire List)
961	Nameplate			
962	Plate, Locater			
971	Circuit Board A1		X	
972	A2	1, 2	X	X
973	A3	1, 2	X	X
974	A4		X	
975	A5	1, 2	X	X
976	A6	1, 2	X	X
977	A7	1, 2	X	X
978	A8	1, 2	X	X
979	A9	1, 2	X	X
980	A10		X	
981	A11		X	
982	A12	1, 2	X	X
983	A13	1, 2	X	X
984	A14	1, 2	X	X
985	A15	1, 2	X	X
986	A16	1, 2	X	X
650990	Nameplate		X	
656991	Nameplate			

D.3 ACCEPTANCE TEST DATA

D.3

TILT/vw

MATERIAL INSPECTION AND RECEIVING REPORT

1. PROC. INSTRUMENT IDEN (CONTRACT)	NAS 9-13695
(ORDER) NO.	
6. INVOICE NO.	23719
DATE	
7. PAGE	1
OF	1
8. ACCEPTANCE POINT	D
2. SHIPMENT NO.	[illegible]
3. DATE SHIPPED	
4. B/L	
TCN	
5. DISCOUNT TERMS	Net 10 Days

9. PRIME CONTRACTOR CODE C20418
Emerson Electric Co.
8[illegible]00 Florissant Ave.
St. Louis, Mo. 63136

10. ADMINISTERED BY CODE

11. SHIPPED FROM (If other than 9) CODE FOB: D
See Block 9

12. PAYMENT WILL BE MADE BY CODE
NASA
Johnson Space Center
Houston, Texas 77058

13. SHIPPED TO CODE
Transportation Officer
Bldg. 420
NASA Lyndon B. Johnson Space Center, Texas

14. MARKED FOR CODE
Accountable Property Officer 807402
Purchase Request No. 3-102-009
Contract No. NAS 9-13695
For reissue to: Allen R. Cunningham EE6 14 113

15. ITEM NO.	16. STOCK/PART NO. DESCRIPTION (Indicate number of shipping containers - type of container - container number.)	17. QUANTITY SHIP/REC'D*	18. UNIT	19. UNIT PRICE	20. AMOUNT
1	656900-301 Emerson AN/APQ-153 Fire Control Radar, modified to include angle tracking capability.	1	ea.		
2	System Test Set consisting of: System Aircraft Simulator 1 ea. J6/J7 Breakout Box 1 ea. Holding Fixture 1 ea. System Interconnecting Cables 1 ea.	1	ea.		

21. PROCUREMENT QUALITY ASSURANCE

A. ORIGIN
☐ PQA ☐ ACCEPTANCE of listed items has been made by me or under my supervision and they conform to contract, except as noted herein or on supporting documents.

-25-74 Allen R. Cunningham
DATE — SIGNATURE OF AUTH GOVT REP
TYPED NAME AND OFFICE S2603A

B. DESTINATION
☐ PQA ☐ ACCEPTANCE of listed items has been made by me or under my supervision and they conform to contract, except as noted herein or on supporting documents.

DATE — SIGNATURE OF AUTH GOVT REP
TYPED NAME AND TITLE

22. RECEIVER'S USE
Quantities shown in column 17 were received in apparent good condition except as noted.

DATE — SIGNATURE OF AUTH GOVT REP
TYPED NAME AND OFFICE

*If quantity received by the Government is the same as quantity shipped, indicate by (✓) mark, if different, enter actual quantity received below quantity shipped and encircle.

23. CONTRACTOR USE ONLY

BILL NO.: 12
S/N 1

GROSS WEIGHT______ 6-27-74 [signature]
Date — Emerson Inspection

POM/EPO No. EPO-5658

Level: C/C

ELECTRONICS AND SPACE DIVISION
EMERSON ELECTRIC CO.
8100 FLORISSANT
ST. LOUIS, MISSOURI 63136
EMERSON

PLEASE REMIT TO P.O. BOX 14291 ST. LOUIS, MO. 63178

ED Form 810A-2 AUG. 68
DD FORM 250 OCT. 68

PREVIOUS EDITIONS ARE OBSOLETE.

MS 656900-301 S/N 1

6/27/74
6/27/74

DATA SHEETS

[illegible] filled in as required by applicable paragraphs of Section 4 of these procedures.

TEST EQUIPMENT USED.

Instrument	MFR & Model	Next Calibration Due
Dummy Load	[illegible] MODEL 3203	[illegible]
Recorder	[illegible] MODEL 290	9-?-74
Electronic Counter	N/A	N/A
Microwave Amplifier	N/A	N/A
Spectrum Analyzer	N/A	N/A
Variable Attenuator	N/A	N/A
Power Meter	N/A	N/A
Power Head	N/A	N/A
Directional Coupler 20 DB	N/A	N/A
Frequency Meter (X Band)	N/A	N/A
Detector	N/A	N/A
Oscilloscope	Tek [illegible]	9-12-74
Pulse Generator	N/A	N/A
RF Generator	HP 620	[illegible]
Voltmeter	[illegible] 4029	7-?-[illegible]
50 DB Isolator	[illegible] ASSOC. [illegible]	
10 DB Directional Coupler	H.P. MODEL [illegible]752C	[illegible]
Dynamic Range Simulator	SAK INDUSTRIES [illegible] DX219	8-25-74
Target Simulator	633339-1 S/N -	[illegible]
pressure Test Set	N/A	N/A
System Test Bench	N/A	N/A

6/27/74 Running Time Meter

LRU		S/N	ATP Start	ATP Complete
Processor	160		0054	0057 6/29
Antenna	148		0045	0050
Indicator	170		0036	0041
XMTR/RCVR	170	TOTAL:	[illegible]	0082
		XMIT :	[illegible]	0052
Set Control	072		N/A	N/A

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.1.6	Antenna approximately straight ahead	______	Check
	Fail light not illuminated	______	Check
	ART. HORZ. and TILT CURSOR displayed	______	Check
	XMTR READY time	______	Seconds
4.1.7	Antenna searching full azimuth pattern:	______	Check
	FAIL light lighted	______	Check
	"B" scan displayed:	______	Check

4.1.8

J-7 Pin	J-7 RTN	Measured Value		Measured Ripple	
A	W 115 ± 2 vac	[illegible] vac			
B	W 115 ± 2 vac	[illegible] vac			
V	W 115 ± 2 vac	[illegible] vac			
C	X 28 ± 1 vdc	[illegible] vdc			
$\overline{Q}$	E +5 ± 0.15 vdc	[illegible] vdc	<50 mv	✓	Check
Y	E -5 ± 0.15 vdc	-4.9[illegible] vdc	<50 mv	✓	Check
$\overline{P}$	E +15 ± 0.23 vdc	[illegible] vdc	<50 mv	✓	Check
D	E -15 ± 0.23 vdc	-15.033 vdc	<50 mv	✓	Check
$\overline{N}$	E +30 ± 0.9 vdc	[illegible] vdc	<50 mv	✓	Check
T	E +100 ± 3 vdc	[illegible] vdc	<500 mv	✓	Check
U	E +150 ± 4.5 vdc	+1[illegible] vdc	<500 mv	✓	Check

4.2.1	Left Segment: 0.630" < L < 0.770"	______	Check
	Separation: 0.630" < L < 0.770"	______	Check
	Right Segment: 0.630" < L < 0.770"	______	Check
4.2.2	TILT CURSOR length: 0.220" < L < 0.280"	______	Check
4.2.3	"B" sweep length: 3.32 < L < 3.42	______	Check
4.2.4	Light	Illuminates	
	Fail	______	Check
	Lock-On	______	Check
	In-Range	______	Check
	Excess G's	______	Check

Applicable Paragraph	Data	ILLUMINATES	
4.2.4 Cont.	Light		
	5 mile	✓	Check
	10 mile	✓	Check
	20 mile		Check
4.2.4.1	In-Range Illuminated		Check
4.2.4.2	In-Range (flashing)	✓	Check
4.2.4.3	Excess G's	✓	Check
4.2.5	Art. HORZ. and TILT vary	✓	Check
4.2.6	Brightness varies	✓	Check
		~~✓~~	~~Check~~
4.2.7	Persistance varies	✓	Check
4.2.8	Brightness of overlay varies	✓	Check
4.2.9	Observed Roll angle of 30 ± 3°	✓	Check
	Observed Roll angle of 0 ± 2°	✓	Check
4.2.9.1	Observed Pitch angle of 0° ± 2°	✓	Check
4.2.9.2	Art. Horz. to 0°	✓	Check
4.2.9.3	Art. HORZ. to 0°	✓	Check
4.2.10	Objectionable spoking not present	✓	Check
4.3.2.1	Azimuth frame time: < 2.3 seconds	[illegible]	Seconds
4.3.2.2	Max. voltage excursions:	+ [illegible]	Volts
	> ± 3.7 volts	- 3.40	Volts
4.3.2.3	Recorded trace within 0.2 volts of straight line	✓	Check

Applicable Paragraph	Data		
4.3.2.4	Elevation recording for azimuth change from plus to minus: 0 ±0.2 volts	.05	Volts
	minus to plus: 0.3 ±0.1 volts	.25	Volts
4.3.2.5	Max. excursion: -2.8 ±0.26 volts	-2.8	Volts
4.3.2.6	Max. excursion: +2.8 ±0.26 volts	+2.7	Volts
4.3.2.7	Max. excursion: > +2.8	2.9	Volts
4.3.2.12 ?	Max. excursion: > -4 volts	4.1	Volts
4.3.3.1	Max. excursions: > 2.8 volts	2.8	Volts
	> -3.6 volts	-3.65	Volts
4.3.3.2	Azimuth recording: 0.3 ± 0.1 volts	.3	Volts
4.3.4.1	Azimuth recording: 0 ± 0.05 volts	0	Volts
	Elevation recording: 0 ± 0.05 volts	0	Volts
4.3.4.2	Azimuth recording: 0 ± 0.05 volts	0	Volts
	Elevation recording: 0.44 ± 0.07 volts	.4	Volts
4.4.1	Frequency = 9.3 GHz ±.05 GHz	9.3	GHz
	Pulse Width = .4 ± .04 usec	.39	usec
	PRF at J6-$\bar{c}$ = 2500 ± 175 PPS	2513	PPS
4.4.2	RF Power ≥ +46.6 DBM	48.6	DBM
4.4.3	Sidelobe levels > 8 DB down, from para. 4.2.7 of QAS No. F5E-400-13		
	9.15 GHz	13	DB down
	9.3 GHz	12	DB down
	9.45 GHz	11	DB down

Applicable Paragraph	Data		
4.4.4	From para. 4.2.6 of QAS No. F5E-400-13:		
	Pulse Width at 9.15 GHz	0.39	usec
	Pulse Width at 9.45 GHz	0.39	usec
	RF Power at 9.15 GHz	48.8	DBM
	RF Power at 9.45 GHz	48.5	DBM
4.4.5	AFC Voltage at J6-D -4.5 ±.5 Volts	-4.43	VDC
4.6.1	Receiver MDS: at least -97 dBM	101.4	DBM
	Indicator MDS: at least -99 dBM	103.4	DBM
4.6.1.1	Lock-On 5 ± 2 dB above Indicator MDS	4	dB
4.6.2	Dynamic Range, from para. 4.6.1 of QAS No. F5E-400-13 (> 80 dBM)	81	DBM
4.6.3	Video Control Functional	✓	Check

Cable 4.2 db

Dir. Coupler 11.2 db

Settings on 620 88

88	86	84
11.2	11.2	11.2
4.2	4.2	4.2
103.4	101.4	99.4
Ind. MDS	Rec. MDS	

103.4
99.4
Lockon = 4 db below

Applicable Paragraph	Data		
4.6.5.1	5 mile Range light illuminated:	✓	Check
	4 mile target properly displayed (±.2 inches)	✓	Check
4.6.5.2	10 mile Range light illuminated:	✓	Check
	4 mile target properly displayed (±.2 inches)	✓	Check
4.6.5.3	20 mile Range light illuminated:		Check
	4 mile target properly displayed (±.2 inches)	✓	Check
4.6.6.1	4 miles ± 0.135 inches	.05	Inches
4.6.6.2	8 miles ± 0.135 inches	0	Inches
4.6.6.3	16 miles ± 0.135 inches	0	Inches
4.6.7	Jizzled sweep to left, and track gate sweeping min. to max range	✓	Check
4.6.7.1	Track gate bars each 0.125 ±.062 inches		
	Left bar	.12	Inches
	Right Bar	.11	Inches
4.6.7.2	Jizzled sweep is 0.4 ±0.1 inches wide	0.34	Inches
4.6.7.3	Center of sweep is left 0.80 ±0.13 inches	.8	Inches

4.6.12.2 cont. Target

	Range Gate Strobes Outward:	✓	Check
	5 Mile Range Light illuminates:	✓	Check
4.6.12.3	Lock-On light illuminates:	✓	Check
4.6.12.4	Lock-On light remains illuminated:	✓	Check
	AIM BAR displayed:	✓	Check
4.6.12.5	Range gate strobing outward:	✓	Check
4.6.12.6	Range gate strobing outward:	✓	Check
4.6.12.7	Range gate strobing outward:	✓	Check
4.6.12.8	5 mile light illuminated:	✓	Check
	Range gate strobing outward:	✓	Check
4.6.12.9	No change in conditions:	✓	Check
4.6.12.10	"B" scan displayed:	✓	Check
4.6.12.11	Lock-On light illuminates:	✓	Check
4.6.12.12	Proper strobe and reacquisition observed: No lock-on while held, lock-on when released.	✓	Check
4.6.12.13	Lock-on acquired:	✓	Check
4.6.12.14	Lock-On reacquired:	✓	Check
4.6.12.15	Lock-On reacquired:	✓	Check
4.6.12.16	Lock-On acquired:	✓	Check
4.6.12.17	Lock-On reacquired:	✓	Check
4.6.12.18	Lock-On continues:	✓	Check
4.6.12.19	Lock-On reacquired:	✓	Check
4.6.12.20	No target video on Indicator:		Check
4.6.12.21	Target video appears:	✓	Check
	Lock-On acquired:	✓	Check
4.6.12.22	Target video disappears:	✓	Check
	Antenna in proper position:	✓	Check

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SIZE	CODE IDENT NO.	
A	20413	NAS 1000-1
SCALE	REV	SHEET 41

Applicable Paragraph	Data		
4.6.13	AIM BAR in scribed circle	✓	Check
4.6.13.1	AIM BAR up .9 $\pm$ 0.2 inches from center 0.9	✓	Check
4.6.13.2	AIM BAR down 1.1 $\pm$ 0.2 inches from center 1.08	✓	Check
4.6.13.3	Range Gate locked-on 5 mile target:	✓	Check
	TILT CURSOR disappears	✓	Check
	AIM BAR present	✓	Check
	El. Phase control position AIM BAR:	✓	Check
	AZ. Phase control position AIM BAR:	✓	Check
4.6.13.4.1	Artificial Horizon at -20 $\pm$ 3°	✓	Check
4.6.13.4.2	Artificial Horizon at +20 $\pm$ 3°	✓	Check
4.6.13.4.3	Artificial Horizon at -20 $\pm$ 3°	✓	Check
	Artificial Horizon CCW 30 $\pm$ 3°	✓	Check
4.6.13.4.4	Tilt Cursor at -17.3 $\pm$ 3°	✓	Check
4.6.13.4.5	Artificial Horizon at +20 $\pm$ 3°	✓	Check
	Artificial Horizon CW 30 $\pm$ 3°	✓	Check
4.6.13.4.6	Tilt Cursor at +17.3 $\pm$ 3°	✓	Check
4.7	FAIL light OFF	✓	Check
4.7.1	TILT CURSOR AT 0°	✓	Check
	J6-B position voltage -3 $\pm$ .3V	3.02	Volts
4.7.2	Lock-On light illuminates	✓	Check
	FAIL light extinguished	✓	Check
4.7.3	TILT CURSOR Down $\approx$ 5°	✓	Check
4.7.4	TILT CURSOR up 20°	✓	Check
	Tracking Gate strobing outward:	✓	Check

5.0 DATA SHEETS

Applicable Paragraph	Data	Recorder Angle	Voltage
4.8.1.1	Ground Return Video and Cursors Appear		✓ Check
4.8.1.2	Video and Cursors disappear		✓ Check
	FAIL light ON		✓ Check
4.8.1.3	Video and Cursors Appear		✓ Check
	FAIL light OFF		✓ Check
4.8.2.2		Recorder Angle	Voltage
	#1 Az	31°	3.[illegible]
	#2 Az	12.3°	1.16
	#3 Az	14°	1.42
	#4 Az	22°	2.260
4.8.2.3	Angle Scale Factor 0.1 ± 0.010 VDC/Degree		.0996 VDC/Degree
4.8.2.5	#1 El	13.9°	1.374
	#2 El	5.1°	.496
	#3 El	8.1°	.795
	#4 El	15.5°	1.504
4.8.2.6	Angle Scale Factor -0.1 ± 0.010 VDC/Degree		.[illegible] VDC/Degree
4.8.3	Az (J6A) .233 ± .05 VPP		[illegible] VPP
	El (J6B) .325 ± .05 VPP		[illegible] VPP
~~4.8.4~~	~~Az Rate Output~~ Deleted		Check
~~4.8.5~~	~~El Rate Output~~ Delete		Check

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A	20418	NAS 1000-1
SCALE	REV 2	SHEET 43

Applicable Paragraphs	Data	
4.9.1	Symbols Stowed	✓ Check
4.9.2	Symbols Stowed	✓ Check
4.9.3	Symbol at same position	✓ Check
	Symbol at center of display	✓ Check
4.9.4	No Change in position	✓ Check
4.9.5	Symbol visible at left azimuth	✓ Check
	Symbol visible at Right Azimuth	✓ Check
4.9.6	Antenna positionable	✓ Check
	Video displayed between symbols	✓ Check
4.9.9.1	6.08 ± 0.30 VDC	6 VDC
	12.16 ± 0.6 VDC	12 VDC
4.9.9.2	12.16 ± 0.6	12 VDC
	24.32 ± 1.2	24 VDC
4.9.9.3	18.24 ± 0.90	18 VDC
	36.48 ± 1.8	36 VDC
4.9.9.4	24.32 ± 1.2	24 VDC
	48.64 ± 2.4	48 VDC
4.9.9.5	30.4 ± 1.5	30 VDC
	60.8 ± 3.0	[illegible] VDC
4.9.11	3.0 ± .3 V Peak-to-Peak	2.1 VPP
4.9.12	6.0 ±.6 V Peak-to-Peak	4.4 VPP
4.9.13	Aim Bar follows target	✓ Check
4.9.14.1	ACQ symbols disappear	✓ Check
4.9.14.2	Same as MSL display	✓ Check

Applicable Paragraph	Data	
4.9.14.3	MSL ACQ display	✓ Check
4.9.14.4	5 NM Light	✓ Check
	10 NM Light	✓ Check
	10 NM Light	✓ Check
4.9.14.5	Lock-On Display	✓ Check
4.9.15.1	ACQ symbols stowed	✓ Check
4.9.15.3	Video displayed between symbols	✓ Check
4.9.15.4	Lock-On Display	✓ Check
4.9.15.5	2-Bar Scan	✓ Check
	Target displayed	✓ Check
4.9.15.6	System searches	✓ Check
4.9.15.7	System in DOGFIGHT Mode	✓ Check

Procedure Changed

Applicable Paragraph	Data		
4.10.2	~~2.15 ± .45 VDC~~ 1.55 ± .3		1.55 VDC
4.10.3	~~2.15 ± .45 VDC~~ 1.55 ± .3		1.60 VDC
4.10.5	Less than 1.0 VDC		< .5 VDC
4.10.6	Less than 1.0 VDC		< .5 VDC
4.11.3.2	Reference Only	AZ	0 mr
	Reference Only	EL	+ .5 mr
4.11.4.2	Lock-On Light		✓ Check
4.11.4.3	0.050 VDC max	AZ	-.039 VDC
	0.050 VDC max	EL	-.043 VDC
4.11.4.4	0.25 VDC max	AZ	+.012 VDC
	0.25 VDC max	EL	+.017 VDC
4.12	System Weight less than 125 lbs		114.1 lbs

Sat Control	3.25
Waveguide	0.3
Antenna	17.25
Processor	36.8
Amplifier	41.5
Indicator.	15.0
Total	114.1 Lbs

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A	20418	NAS 1000-1
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