
CSCL 17I Unclas G3/17 09691

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
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 Introduction and Summary</td>
<td>1</td>
</tr>
<tr>
<td>2.0 Operational Description.</td>
<td>2</td>
</tr>
<tr>
<td>2.1 Baseline AN/APQ 153</td>
<td>2</td>
</tr>
<tr>
<td>2.2 Modified System for NASA.</td>
<td>7</td>
</tr>
<tr>
<td>3.0 Functional Characteristics</td>
<td>13</td>
</tr>
<tr>
<td>3.1 AN/APQ 153</td>
<td>13</td>
</tr>
<tr>
<td>3.2 Modified System</td>
<td>14</td>
</tr>
<tr>
<td>3.3 Requirements</td>
<td>18</td>
</tr>
<tr>
<td>4.0 Hardware Description</td>
<td>20</td>
</tr>
<tr>
<td>4.1 AN/APQ 153</td>
<td>20</td>
</tr>
<tr>
<td>4.2 Modifications for NASA.</td>
<td>30</td>
</tr>
<tr>
<td>5.0 Proposed Additions/Modifications</td>
<td>43</td>
</tr>
<tr>
<td>5.1 Range Tracker Improvement</td>
<td>43</td>
</tr>
<tr>
<td>5.2 Frequency Agility</td>
<td>44</td>
</tr>
<tr>
<td>5.3 Flat Plate Antenna</td>
<td>49</td>
</tr>
<tr>
<td>5.4 Single Channel, 2 Axis Monopulse</td>
<td>52</td>
</tr>
</tbody>
</table>

**APPENDIX:**

- A.1 Flight Test Data
- A.2 Servo Analysis
- A.3 ATP

**DATA:**

- D.1 Drawing List
- D.2 T.O. List
- D.3 ATP Test Data
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 AAL/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
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 bottom 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** ($A_0 2M^2$) - 9-10 NM (8 NM Minimum)
- **LOW ALTITUDE** (F-4 or F-104 TGT) - 3 NM
- **ROLL AND PITCH STABILIZED**
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 sight and the gimbal will be conically lobed + 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 + 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**

- **LOCK-ON**: 6 NM ON 2M² 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 LCROSS**: LOCK-ON RANGE, RANGE RATE
- **NIGHT CAPABILITY**

**RANGE**: 5 OR 10 NM
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 ±60 MILS in azimuth and 0 MILS to 165 MILS in elevation.
ACQUISITION MODE-GUNS

DOGFIGHT BUTTON

LOCK-ON 5600 FT MAX

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

97° TILT COVERAGE

2 BAR SCAN COVERAGE

10°
ANGLE TRACK-ACQUISITION MODE

ACQUISITION SCAN ROLL AND PITCH STABILIZED

2 BAR SCAN COVERAGE

97° TILT COVERAGE

EXPANDED ACQUISITION ENVELOPE
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

97° TILT COVERAGE

2 BAR SCAN COVERAGE

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 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 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 ($P_{85\text{Cumulative Probability}}$, $2\text{m}^2$) 11 NAUTICAL MILES (8 NAUT. MI. MIN)

ACQUISITION ($P_{85\text{Cumulative Probability}}$) 6 NAUTICAL MILES TYPICAL ON $2\text{m}^2$ 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 AZIMUTH $3^\circ$
ELEVATION $4^\circ$

4000 FEET GUNNERY RANGING AZIMUTH $\pm 60$ MILS (REF. ADL)
ELEVATION 0 TO -165 MILS

SEARCH COVERAGE AZIMUTH $\pm 45^\circ$
ELEVATION 10° (POSITIONABLE OVER $\pm 45^\circ$)

LOW ALTITUDE 2500 FT ALT: 3NM DET, 2NM LOCK-ON
1000 FT ALT: DOGFIGHT LOCK-ON AT 2700 FT.
## AN/APQ-153 CHARACTERISTICS

### TRANSMITTER
- **Power**: 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)
  - **Bandwidth (BW)**: 5.2° AZ X 7.0° EL

### RECEIVER
- **Noise Figure**: 8 DB (9.5 DB Max)
- **Display**: DVST
- **Tracker (Range)**: B Scan + Auxiliaries
  - Lin Log
- **Search Coverage**: 1 to 140 FT Lamberts Electronic Control

### Tracker (Range)
- **Analog**
  - Double Integrator
  - Splitgate

### Search Coverage
- 2 Bar Scan, Space Stabilized
  - AZ ±45°
  - EL 10° Positioned From Set Control

### BIT
- **Transmitter AFC Power Supplies**: Continuous
- **Lock-on Sensitivity Range Accuracy Antenna Positioning**: Commanded
<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SPEC</th>
<th>S/N 5 TO S/N 36 AVERAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DETECTION RANGE ($P_{85}, 2M^2$)</td>
<td>&gt; 8 N.M.</td>
<td>12 N.M.</td>
</tr>
<tr>
<td>SEARCH FRAME TIME</td>
<td>&lt; 2.3 SEC.</td>
<td>2.03 SEC.</td>
</tr>
<tr>
<td>RF POWER @ LRU OUTPUT</td>
<td>&gt; 45.7 W ave</td>
<td>72.8 W</td>
</tr>
<tr>
<td>XMTR SIDELOBES DOWN</td>
<td>&gt; 9 DB</td>
<td>12.1 DB</td>
</tr>
<tr>
<td>NOISE FIGURE</td>
<td>&lt; -97 DBM</td>
<td>8.18 DB</td>
</tr>
<tr>
<td>MDS</td>
<td>12.1 DB</td>
<td>-102.9 DBM</td>
</tr>
<tr>
<td>RCVR DYNAMIC RANGE</td>
<td>&gt; 80 DB</td>
<td>83.8 DB</td>
</tr>
<tr>
<td>DISPLAY RANGE LINEARITY</td>
<td>±0.135''</td>
<td>±.008''</td>
</tr>
<tr>
<td>RANGE ACCURACY 600'</td>
<td>±50'</td>
<td>0.58'</td>
</tr>
<tr>
<td>1000'</td>
<td>±30'</td>
<td>1.0'</td>
</tr>
<tr>
<td>2000'</td>
<td>±40'</td>
<td>2.0'</td>
</tr>
<tr>
<td>3000'</td>
<td>±60'</td>
<td>3.0'</td>
</tr>
<tr>
<td>7500'</td>
<td>±150'</td>
<td>7.5'</td>
</tr>
<tr>
<td>15000'</td>
<td>±300'</td>
<td>15.0'</td>
</tr>
<tr>
<td>30000'</td>
<td>±600'</td>
<td>30.0'</td>
</tr>
<tr>
<td>60000'</td>
<td>±1200'</td>
<td>60.0'</td>
</tr>
<tr>
<td>RANGE RATE ACCURACY 0</td>
<td>±10'/SEC.</td>
<td>0.01'/SEC.</td>
</tr>
<tr>
<td>CLOSING 1000'/SEC.</td>
<td>±30'/SEC.</td>
<td>5.0'/SEC.</td>
</tr>
<tr>
<td>CLOSING 2000'/SEC.</td>
<td>+60'/SEC.</td>
<td>10.0'/SEC.</td>
</tr>
<tr>
<td>CLOSING 3000'/SEC.</td>
<td>±90'/SEC.</td>
<td>15.0'/SEC.</td>
</tr>
<tr>
<td>OPENING 1000'/SEC.</td>
<td>±30'/SEC.</td>
<td>-5.0'/SEC.</td>
</tr>
<tr>
<td>ANTENNA VSWR</td>
<td>&lt;1.7:1</td>
<td>1.32:1</td>
</tr>
</tbody>
</table>
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 2 DB, 2-WAY IS INCLUDED IN ALL CASES. THE FOLLOWING NUMBERS WERE USED:

<table>
<thead>
<tr>
<th>POWER</th>
<th>72.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOISE FIGURE</td>
<td>8.18</td>
</tr>
<tr>
<td>AVERAGE S/N 5 TO S/N 36</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LOSSES</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ATMOSPHERIC</td>
<td>.5 DB</td>
</tr>
<tr>
<td>RADOME</td>
<td>2.0 DB</td>
</tr>
<tr>
<td>ROTARY JOINTS</td>
<td>.54 DB</td>
</tr>
<tr>
<td>WAVEGUIDE</td>
<td>.2 DB</td>
</tr>
<tr>
<td>NON OPTIMUM BEAMSHAPE</td>
<td>1.0 DB</td>
</tr>
<tr>
<td>NON OPTIMUM RECEIVER</td>
<td>.8 DB</td>
</tr>
<tr>
<td>NON OPTIMUM INTEGRATOR</td>
<td>.9 DB</td>
</tr>
<tr>
<td></td>
<td>5.94</td>
</tr>
<tr>
<td>TARGET</td>
<td>2 M^2</td>
</tr>
<tr>
<td>RANGE RATE</td>
<td>1000 FT/SEC</td>
</tr>
<tr>
<td>FREQ.</td>
<td>9.3 GHz</td>
</tr>
<tr>
<td>BW</td>
<td>3 MHz</td>
</tr>
<tr>
<td>G (ANT)</td>
<td>28.0 DB</td>
</tr>
</tbody>
</table>
CUMULATIVE PROBABILITY OF DETECTION

PROBABILITY %

RANGE NM

SPEC.

AVG. PRODUCTION RADAR

ELECTRONICS AND SPACE DIVISION
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.
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**

<table>
<thead>
<tr>
<th>Pulsewidth</th>
<th>PRF</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4 μsec</td>
<td>2500 PPS</td>
</tr>
</tbody>
</table>

**TRANSMIT POWER**

<table>
<thead>
<tr>
<th>Power Range</th>
<th>65 KW - 100 KW (Peak)</th>
</tr>
</thead>
</table>

**ANTENNA GAIN**
28 DB

**ANTENNA SIDELOBES PEAK**
-20 DB

**AZIMUTH BEAMWIDTH**
5.20

**ELEVATION BEAMWIDTH**
7.00

**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

<table>
<thead>
<tr>
<th>AXIS</th>
<th>RATE</th>
<th>ACCELERATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROLL</td>
<td>230°/SEC</td>
<td>500°/SEC²</td>
</tr>
<tr>
<td>PITCH</td>
<td>40°/SEC</td>
<td>100°/SEC²</td>
</tr>
<tr>
<td>YAW</td>
<td>50°/SEC</td>
<td>50°/SEC²</td>
</tr>
</tbody>
</table>

STATIC ACCURACY

AZIMUTH     ± 3 MILLIRADIANS (1 σ)
ELEVATION   ± 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 ± 5 milliradians - both axes - with angular rates of 30° - 40°/SEC.
### SYSTEM PERFORMANCE

<table>
<thead>
<tr>
<th>Description</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>DETECTION RANGE ($P_{85\text{Cum}}$)</td>
<td>8 N. MILES (2 m² TARGET)</td>
</tr>
<tr>
<td>ACQUISITION RANGE ($P_{85\text{Cum}}$)</td>
<td>6 N. MILES (2 m² TARGET)</td>
</tr>
<tr>
<td>RANGE ACCURACY</td>
<td>50 FT. 500 FT TO 1000 FT.</td>
</tr>
<tr>
<td></td>
<td>30 FT. 1000 FT TO 2000 FT.</td>
</tr>
<tr>
<td></td>
<td>± 2% 2000 FT TO 10 N. MILES</td>
</tr>
<tr>
<td>RANGE RATE ACCURACY</td>
<td>± 3% OR 10 FT/SEC (WHICHEVER IS GREATER)</td>
</tr>
<tr>
<td>RANGE RATE MEMORY</td>
<td>APPLICABLE FOR 1.7 SECS</td>
</tr>
<tr>
<td>SEARCH COVERAGE</td>
<td>AZIMUTH + 42.5°</td>
</tr>
<tr>
<td></td>
<td>ELEVATION 10° (POSITIONABLE OVER +45° - 35°)</td>
</tr>
<tr>
<td>ACQUISITION COVERAGE</td>
<td>AZIMUTH 15° (POSITIONABLE OVER +42.5)</td>
</tr>
<tr>
<td></td>
<td>ELEVATION 10° (POSITIONABLE OVER +45° - 35°)</td>
</tr>
<tr>
<td>ANGLE RATE MEMORY</td>
<td>APPLICABLE FOR 1.7 SECS</td>
</tr>
</tbody>
</table>

**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: $+45^\circ$ Azimuth; $+48.5^\circ$, $-38^\circ$ in elevation.

4. _Angle Rates:_ $\pm 10$ degrees/second

(b) _Accuracy (sigma)_

1. _Range:_ $\pm 15$ meters $\pm 1\%$, whichever is greater

2. _Range Rate:_ $\pm 3$ meters/second or $\pm 2\%$, whichever is greater.

3. _Angles:_ $\pm 9$ milliradians (MR)

4. _Angle Rates:_ $\pm 9$ MR/second or $\pm 10\%$ 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 develop 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

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polarization</td>
<td>Horizontal</td>
</tr>
<tr>
<td>Gain</td>
<td>28 dB relative to isotropic radiator</td>
</tr>
<tr>
<td>Beamwidth</td>
<td>5.2° AZ - 7° Elevation</td>
</tr>
<tr>
<td>Sidelobes</td>
<td>At least 19 dB below peak of main beam - 21 dB typical</td>
</tr>
<tr>
<td>Frequency Bandwidth</td>
<td>9.150 GHz to 9.450 GHz</td>
</tr>
<tr>
<td>Maximum Scan Velocity Capability</td>
<td>2000°/Second</td>
</tr>
<tr>
<td>Normal Scan Velocity</td>
<td>85 ± 5°/Second</td>
</tr>
<tr>
<td>Frame Time</td>
<td>Less than 2.3 seconds</td>
</tr>
<tr>
<td>Turn Around Time</td>
<td>Less than 150 ms</td>
</tr>
<tr>
<td>Stabilization Accuracy</td>
<td>± 9 mils</td>
</tr>
<tr>
<td>Boresight Steering Scan Rate</td>
<td>6 Hz</td>
</tr>
</tbody>
</table>

- **Diagram:**
  - Elevation Drive Motor
  - Rotary Joint Assy
  - Az Gimbal
  - Gimbal Support Assy
  - Connector
  - Az Drive Motor
  - Az Bumper Stop
  - Elapsed Time Meter
  - El Position Variable Resistor (Covered)
  - 12" x 16" Reflector and Feed
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
# RECEIVER/TRANSMITTER CHARACTERISTICS

<table>
<thead>
<tr>
<th>TRANSMITTER</th>
<th>receiver parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEAK POWER</td>
<td>60 kW minimum at magnetron flange</td>
</tr>
<tr>
<td>PRF</td>
<td>2500 ±50 Hz jittered</td>
</tr>
<tr>
<td>PULSE WIDTH</td>
<td>0.4 ±0.04 microseconds</td>
</tr>
<tr>
<td>PRF JITTER</td>
<td>±100 Hz minimum</td>
</tr>
<tr>
<td>JITTER RATE</td>
<td>50 Hz ±5 Hz</td>
</tr>
<tr>
<td>FREQUENCY</td>
<td>9.3 ±0.15 GHz ground tunable</td>
</tr>
<tr>
<td>FREQUENCY PULLING</td>
<td>8 MHz maximum</td>
</tr>
<tr>
<td>SIDELOBE LEVEL</td>
<td>at least -8dB</td>
</tr>
<tr>
<td>TRANSMITTER LOSSES</td>
<td>less than 1 dB</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RECEIVER</th>
<th>receiver parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>IF FREQUENCY</td>
<td>60 MHz</td>
</tr>
<tr>
<td>NOISE FIGURE</td>
<td>9 dB including received losses</td>
</tr>
<tr>
<td>BANDWIDTH</td>
<td>3 ±.3 MHz</td>
</tr>
<tr>
<td>MINIMUM DISCERNIBLE SIGNAL</td>
<td>at least -97 dBm</td>
</tr>
<tr>
<td>RECEIVER DYNAMIC RANGE</td>
<td>at least 80 dB</td>
</tr>
<tr>
<td>AFC ACCURACY</td>
<td>±150 kHz</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Range Accuracy</strong></td>
<td>± 50 ft - 500 to 1000 ft</td>
</tr>
<tr>
<td></td>
<td>± 30 ft - 1000 to 2000 ft</td>
</tr>
<tr>
<td></td>
<td>± 2% - 2000 ft to 10 nm</td>
</tr>
<tr>
<td><strong>Rate Accuracy</strong></td>
<td>± 3% or ± 10 ft per sec</td>
</tr>
<tr>
<td><strong>Range Rate Memory</strong></td>
<td>1.7 sec</td>
</tr>
<tr>
<td><strong>Tracking Rate</strong></td>
<td>3000 ft per sec closing</td>
</tr>
<tr>
<td></td>
<td>1000 ft per sec opening</td>
</tr>
</tbody>
</table>

**Weight:** 35 Pounds
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
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

- TILT CONTROL
- LIGHTED INFORMATION PANEL
- ACQUISITION SWITCH
- RANGE SWITCH
- HANDREST
- RESUME SEARCH SWITCH
- MODE SWITCH
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 AlA16 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.
4.2.2 Set Control - Continued

**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.

These 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 voltage proportional to the desired azimuth position of the ACQ Symbol. The analog voltage is the direct output of an 8-Bit
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
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 conical scan 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 AOQ 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 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 +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 ±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 generated 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.

**AOQ Symbol Generation** — Generation of the AOQ 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.
This new AOQ 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.

<table>
<thead>
<tr>
<th>Diagram</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Ramp Diagram" /></td>
<td><strong>ATTITUDE CURSOR (---)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>HORIZONTAL DEFL. = (RAMP) \cdot (\cos \text{ ROLL ANGLE}) + DC BIASES</strong></td>
</tr>
<tr>
<td></td>
<td><strong>VERTICAL DEFL. = (RAMP) \cdot (\sin \text{ ROLL ANGLE}) + DC BIASES</strong></td>
</tr>
<tr>
<td><img src="image" alt="Ramp Diagram" /></td>
<td><strong>TILT OR AIM BAR CURSOR (—)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>HORIZONTAL DEFL. = (RAMP) + DC BIASES</strong></td>
</tr>
<tr>
<td></td>
<td><strong>VERTICAL DEFL. = DC BIASES</strong></td>
</tr>
<tr>
<td><img src="image" alt="Ramp Diagram" /></td>
<td><strong>ACQ SYMBOL CURSOR (/ / /)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>HORIZONTAL DEFL. = DC BIASES.</strong></td>
</tr>
<tr>
<td></td>
<td><strong>VERTICAL DEFL. = RAMPS + DC BIASES</strong></td>
</tr>
</tbody>
</table>
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 occurring 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
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 (+42.5°)
   to be changed to +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 to allow for use of lengthened cables (60 feet).

Receiver Video: Changed R6 on 656972-AlA2 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-AlA8 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.
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 consistent 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 $60/\text{sec}^2$ to $10/\text{sec}^2$.

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 (3$\sigma$).

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 EOCM, 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
PROBABILITY OF DETECTION (SINGLE SCAN)

CLEAR AIR, HIGH ALT.

N = 144 HITS

PFA = 10^-6

BW = 5.2°
AZ SWEEP = 90°/SEC
PRF = 2500 Hz

PFA 10^-6

0.2 0.4 0.6 0.8 1.0

R/RO

PFA

FA

FF

0.1

0.3

0.5

0.7

0.9

1.1

1.3

1.5

1.7

1.9

2.1

2.3

2.5

2.7

2.9

3.1

3.3

3.5

3.7

3.9

4.1

4.3

4.5

4.7

4.9

5.1

5.3

5.5

5.7

5.9

6.1

6.3

6.5

6.7

6.9

7.1

7.3

7.5

7.7

7.9

8.1

8.3

8.5

8.7

8.9

9.1

9.3

9.5

9.7

9.9

1.0

R/RO

Figure 5.2.1 Probability of 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

\[ P_{FA} = 10^{-6} \]
\[ N = 153 \]

\[ \text{SINGLE SCAN DETECTION PROBABILITY} \]

\[ \text{RANGE (N MILES)} \]
FREQUENCY

J.

.8

- AGILE

a.6

2 SQUARE METERS

SQUARE METERS

F6

RAIN:

MILLIMETERS

I

HR.

w

w

w

z

2 4 6

0

2

4

6

8

SINGLE SCAN DETECTION PROBABILITY

FREQUENCY AGILE

FIXED FREQUENCY

TARGET: 2 SQUARE METERS
RAIN: 4 MILLIMETERS 1 HR.

PERFORMANCE IMPROVEMENT IN RAIN
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 around 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 accommodate 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** - ± 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
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 monopulse 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.

\[
E = \Delta az \sin W_{ct} \sin W_{mt} + \Delta el \sin W_{ct} \cos W_{mt}
\]
FLAT PLATE ANT

COMPARATOR

ΔAZ

ΔEL

FERRITE MODULATOR

ISOLATOR

DIRECT COUPLER

ROTARY JOINTS

TX CIRCULATOR

RECVR

RANGE TRACKER

RANGE GATE

SAMPLE HOLD

FILTER

Sin W_{mt}

Cos W_{mt}

π/2

200 Hz OSC

PSD

ΔAZ

ΔEL

SERVO LOOP

TO

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 \( \tan^{-1}\left(\frac{\Delta\text{az}}{\Delta\text{el}}\right) \).

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 - \( \sin W_{\text{int}} \) and its quadrature, \( \cos W_{\text{int}} \). 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 \( \Delta\text{az} \) and \( \Delta\text{el} \) data. For 0° roll, only \( \text{el} \) information is used in the ranging function. If the roll angle is 90°, \( \Delta\text{az} \), is used instead. For intermediate roll angles, the vector sum of \( \Delta\text{az} \) and \( \Delta\text{el} \) 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 \( \Delta\text{el} \) 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 \( \Delta\text{az} \) only. For intermediate angles the PSD output becomes equivalent to the combination of \( \Delta\text{az} \) and \( \Delta\text{el} \) 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-bore sight 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)

<table>
<thead>
<tr>
<th>ITEM EVALUATED</th>
<th>RESULTS SATISFY PERFORMANCE OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>MISSILE MODE HEAD DOWN STEERING</td>
<td>YES</td>
</tr>
<tr>
<td>BORESIGHT STEERING WITH ANGLE TRACK</td>
<td>YES</td>
</tr>
<tr>
<td>OFF-BORESIGHT ACQUISITION</td>
<td>YES</td>
</tr>
<tr>
<td>RADAR COVERAGE IN GUN MODE WITH ANGLE TRACK</td>
<td>YES</td>
</tr>
<tr>
<td>D/F GUNS, D/F MISSILE AND RESUME SEARCH SWITCH ON STICK GRIP</td>
<td>YES</td>
</tr>
</tbody>
</table>
### Basic/Improved Radar Comparison of Detection and Lock-on Ranges Against a Co-altitude T-38 Target

<table>
<thead>
<tr>
<th>Altitude (AGL)</th>
<th>Basic Radar</th>
<th>Improved Radar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Spec</td>
<td>Flight Test, August 1974</td>
</tr>
<tr>
<td>20,000 Feet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detection</td>
<td>8 N.M.</td>
<td>8-2/3 N.M.</td>
</tr>
<tr>
<td>Lock-on</td>
<td>4 N.M.</td>
<td>5-1/2 N.M.</td>
</tr>
<tr>
<td>12,500 Feet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detection</td>
<td>6 N.M.</td>
<td></td>
</tr>
<tr>
<td>Lock-on</td>
<td>4 N.M.</td>
<td></td>
</tr>
<tr>
<td>2,500 Feet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detection</td>
<td>2 N.M.</td>
<td>2-1/2 N.M.</td>
</tr>
<tr>
<td>Lock-on</td>
<td>1-1/3 N.M.</td>
<td>1-3/4 N.M.</td>
</tr>
</tbody>
</table>
# DETECTION - RANGE

## FLIGHT TEST RESULTS

*(CO-ALTITUDE TESTS ONLY)*

*(SEPTEMBER 11, 1974)*

<table>
<thead>
<tr>
<th>TEST CONDITIONS</th>
<th>N.M. RANGE</th>
<th>BLIP SCAN %</th>
<th>RESULTS SATISFY PERFORMANCE OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>30,000 FT MSL AT 18,000 FT AGL AND 27,500 FT AGL OVER MOUNTAIN AND DESERT TERRAIN</td>
<td>9.25</td>
<td>90</td>
<td>YES (8 N.M.)</td>
</tr>
<tr>
<td>15,000 FT MSL AT 12,500 FT AGL OVER DESERT TERRAIN</td>
<td>8.0</td>
<td>90</td>
<td>YES</td>
</tr>
<tr>
<td>5,000 FT MSL AT 2,500 FT AGL OVER DESERT TERRAIN</td>
<td>3.5</td>
<td>90</td>
<td>YES (2.2 N.M.)</td>
</tr>
</tbody>
</table>
## CLUTTER - FLIGHT TEST RESULTS
*(SEPTEMBER 11, 1974)*

<table>
<thead>
<tr>
<th>TEST CONDITIONS</th>
<th>TEST RESULTS</th>
<th>RESULTS SATISFY PERFORMANCE OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEDIUM AND HIGH ALTITUDE (15 &amp; 30 K FT)</td>
<td>STAE IS NEARLY ELIMINATED. IT DOES NOT INTERFERE WITH TARGET DETECTION OR TRACKING IN THE 90% BLIP SCAN RANGE ENVELOPE.</td>
<td>YES</td>
</tr>
<tr>
<td>2,500 FT AGL AND ABOVE</td>
<td>ALTITUDE LINE IS VISIBLE BUT DOES NOT LIMIT TARGET DETECTION, ACQUISITION OR TRACKING OVER LAND.</td>
<td>YES</td>
</tr>
<tr>
<td>2,500 FT AGL AND ABOVE</td>
<td>SIDELOBES ARE BARELY VISIBLE AND DO NOT INTERFERE WITH DETECTION OR TRACKING.</td>
<td>YES</td>
</tr>
</tbody>
</table>
# Target Fade - Flight Test Results

**Co-Altitude Tests Only**

*September 11, 1974*

<table>
<thead>
<tr>
<th>Test Conditions</th>
<th>Test Results</th>
<th>Results Satisfy Performance Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>30,000 FT MSL AT 27,500 FT AGL OVER DESERT TERRAIN</td>
<td>NO TARGET LOSS IN SEARCH OR TRACK WITH T-38 AT 9-1/2 N.M. OR LESS</td>
<td>YES (≥ 8 N.M.)</td>
</tr>
<tr>
<td>30,000 FT MSL AT 18,000 FT AGL AVERAGE OVER MOUNTAIN TERRAIN</td>
<td>NO TARGET LOSS IN SEARCH WITH A T-38 AT 8 N.M. OR LESS</td>
<td>YES (≥ 8 N.M.)</td>
</tr>
<tr>
<td>15,000 FT MSL AT 12,500 FT AGL OVER DESERT TERRAIN</td>
<td>LESS THAN 10% TARGET LOSS WITH T-38 AT 5 N.M. OR LESS</td>
<td>NO (≥ 6 N.M.)</td>
</tr>
<tr>
<td>5,000 FT MSL AT 2,500 FT AGL OVER DESERT TERRAIN</td>
<td>LESS THAN 10% TARGET LOSS WITH T-38 AT 2.5 N.M.</td>
<td>YES (≥ 2.2 N.M.)</td>
</tr>
</tbody>
</table>
PROBABILITY OF CONVERSION FOR SIDEWINDER, GUN ATTACK FOR CO-ALTITUDE TARGETS WITHIN SEARCH COVERAGE

36000 FEET ALTITUDE
GCI ERROR = 3NMI (1σ)

TARGET AT M0-8

SEARCH & RANGE
3g MAX IN TURN

SEARCH & RANGE
5g MAX IN TURN

4 NMI ± GCI ERROR

GCI VECTORED TRACK

FIGHTER AT M1-2

PROBABILITY OF CONVERSION

RADAR RANGE - NMI

RCUM-85
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.

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.

NOTICE

The data contained herein is proprietary to the Emerson Electric Co. of St. Louis, Missouri, and may not be disclosed in whole or in part for any purpose without the written permission of the company. If a contract is entered into whereby such data is used or disclosed to a third party, an agreement providing for the retention and confidentiality of such data shall be made in writing. No copies or other developments based on such data shall be made or disclosed to the customer and the customer agrees to immediately return all copies or other developments to the company.

ORIGINAL PAGE IS OF POOR QUALITY
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 chosen with the associated constants shown in Table I. Using the polynomial 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:

\[
\frac{\theta_T}{\theta_S} = \frac{(S + 1)(S + 1)(S + 1)(S + 1)(S^2 + 2.4S + 1)}{(S + 1)(S + 1)(S + 1)(S + 1)(S + 1)(S^2 + 2.4S + 1)}
\]

\[
\frac{S^2}{99^2 + 2(0.3)S + 1} \frac{S^2}{240^2 + 2(0.5)S + 1}
\]

(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:

\[
\frac{\theta_T}{\theta_D} = \frac{S^3(S + 1)}{290(S + 1)(S^2 + 2(0.6)S + 1)(S + 1)(S^2 + 2(0.3)S + 1)}
\]

(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°/sec². 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:

\[
y = (1.25) t \text{ for } 0 \leq t \leq .8
\]
\[
y = -(0.6) t + 1.48 \text{ for } .8 < t \leq 3.6 \tag{3}
\]
\[
y = (0.667) t - 3.33 \text{ for } 3.8 < t \leq 5
\]
A computer program was used to obtain the following Fourier Series representation of the rate in degrees/second.

\[
\theta = 5 + 10 \sin wt + 7 \sin 3wt - 5 \sin 4wt \\
+ 1.7 \sin 6wt + 71 \cos wt + 10 \cos 2wt \\
- 3.2 \cos 3wt - 2.6 \cos 4wt
\]  
(4)

where

\[ w = 1.25 \]

Equation 4 uses only the most significant terms.

Differentiating equation 4 and substituting \( w = 1.25 \) yields:

\[ \theta = 214^\circ/\text{sec}^2 \]

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

\[
\frac{\theta_T}{\theta_S} = \frac{(1 + 0.32 S)}{\left[ \frac{S^2}{3.14^2} + \frac{2(0.5)S}{3.14} + 1 \right]}
\]  
(5)

And the corresponding error equation is

\[
\frac{\theta_e}{\theta_S} = \frac{S^2}{10 \left[ \frac{S^2}{3.14^2} + \frac{2(0.5)S}{3.14} + 1 \right]}
\]  
(6)
For $S = \text{unit step} = \frac{1}{S}$

$$\theta_{c} = \frac{S}{10 \left[ \frac{S^2}{3.14^2} + \frac{2(0.5)S}{3.14} \right] = L}$$

The inverse transform of equation 7 is:

$$\theta_{c}(t) = e^{-at} \left[ \cos bt - \frac{a}{b} \sin bt \right]$$

(8)

Equation 8 is obtained in the following manner:

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

(9)

and

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

(10)

Rewriting 7 we obtain

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

(11)

From equation 11 we obtain equation 4, where

$$a = 1.6$$

and

$$a^2 + b^2 = 10$$

(12)

then

$$b = 2.7$$
Therefore we have

$$\theta_e(t) = e^{-1.6t} \left[ \cos(2.7t) - 0.6 \sin(2.7t) \right]$$

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

The error response to a ramp is

$$\theta_e(t) = \frac{1}{10 \left( \frac{s^2}{3.14^2} + \frac{2(0.5)s}{3.14} + 1 \right)}$$

and

$$\theta_e(t) = e^{-\frac{a}{2}t} \sin \left[ (\beta - \frac{a^2}{4})^{1/2} t \right]$$

where

$$a = 3.14$$

$$\beta = 10$$

$$\theta_e(t) = e^{-1.6t} \sin(2.7t)$$

Figure 19 is a plot of equation 17.

The error response to an acceleration is:

$$\theta_e = \frac{1}{10s \left( \frac{s^2}{3.14^2} + \frac{2(0.5)s}{3.14} + 1 \right)}$$
where

$$\theta(t) = \frac{1}{\beta} - \frac{e^{-\frac{\alpha}{2}t}}{(\beta^{1/2})b} \sin \left[ b t + \tan^{-1} \left( \frac{4\beta}{\alpha^2} - 1 \right)^{1/2} \right]$$  \hspace{1cm} (19)$$

for

$$\theta = \frac{1}{\beta} \frac{1}{S (S^2 + \alpha S + \beta)} = \frac{1}{S (S^2 + 3.2S + 10)}$$  \hspace{1cm} (20)$$

where

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

Equation 19 becomes

$$\theta(t) = \frac{1}{10} - \frac{e^{-1.6t}}{(\sqrt{10})(2.7)} \sin (2.7 \ t + \tan^{-1} \ 1.7)$$  \hspace{1cm} (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:

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

Applying an acceleration of 290 rad/sec^2 yields

$$\therefore \ \theta_T = \left[ \frac{1}{(\frac{S}{16} + 1) \ (\frac{S^2}{3.14^2} + \frac{2(.5)S}{3.14} + 1)} \right]$$  \hspace{1cm} (23)$$
\[ \theta_T(t) = \frac{T \omega e^{-t/T}}{(1 - 2 \zeta T \omega + T^2 \omega^2)} + \frac{\omega e^{-\zeta \omega t} \sin(\omega \sqrt{1 - \zeta^2} t - \psi)}{[(1 - \zeta^2) (1 - 2 \zeta T \omega + T^2 \omega^2)]^{1/2}} \]  

where

\[ \psi = \tan^{-1} \left( \frac{T \omega \sqrt{1 - \zeta^2}}{1 - T \zeta \omega} \right) \]  

Applying a rate of 290 rad/sec yields:

\[ \theta_T = \frac{S}{(\frac{S}{16} + 1) \left( \frac{S^2}{3.14^2} + \frac{2(0.5)S}{3.14} + 1 \right)} \]  

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

where

\[ \psi = \tan^{-1} \left( \frac{T \omega \sqrt{1 - \zeta^2}}{1 - T \zeta \omega} \right) - \tan^{-1} \left( \frac{\sqrt{1 - \zeta^2}}{-\zeta} \right) \]  

Applying a step of 290 rad yields

\[ \theta_T = \frac{S^2}{(\frac{S}{16} + 1) \left( \frac{S^2}{3.14^2} + \frac{2(0.5)S}{3.14} + 1 \right)} \]
\[
\theta_1(t) = \frac{\omega^2 e^{-t/T}}{T (1 - 2 T \zeta \omega + T^2 \omega^2)} + \frac{\omega^3 e^{-\zeta \omega t} \sin(\omega \sqrt{1 - \zeta^2 t - \psi})}{[(1 - \zeta^2) (1 - 2 T \zeta \omega + T^2 \omega^2)]^{1/2}}
\]  

where

\[
\psi = \tan^{-1} \left( \frac{T \omega \sqrt{1 - \zeta^2}}{1 - T \zeta \omega} \right) - 2 \tan^{-1} \left( \frac{\sqrt{1 - \zeta^2}}{-\zeta} \right)
\]

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

\[
\theta_T = \frac{1}{(S) (1 + T S) (1 + \frac{2 \zeta S}{\omega} + \frac{S^2}{\omega})}
\]

\[
\theta_1(t) = 1 - \frac{T^2 \omega^2 e^{-t/T}}{(1 - 2 T \zeta \omega + T^2 \omega^2)} + \frac{e^{-\zeta \omega t} \sin(\omega \sqrt{1 - \zeta^2 t + \psi})}{[(1 - \zeta^2) (1 - 2 \zeta T \omega + T^2 \omega^2)]^{1/2}}
\]

where

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

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
APR-153 TRACK LOOP BLOCK DIAGRAM

Figure 11
### Table I

**Table of Constants**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T$</td>
<td>$2$ in dy sec</td>
</tr>
<tr>
<td>$K_B$</td>
<td>$0.34$ V/rad/sec</td>
</tr>
<tr>
<td>$K_T$</td>
<td>$4.8$ in dy/amp</td>
</tr>
<tr>
<td>$T_{C_1}$</td>
<td>$1.0075$ sec</td>
</tr>
<tr>
<td>$T_{m}$</td>
<td>$0.34$ sec</td>
</tr>
<tr>
<td>$Y$</td>
<td>$800$ V</td>
</tr>
<tr>
<td>$R$</td>
<td>$2.8$ ohms</td>
</tr>
<tr>
<td>$T_1$</td>
<td>$1.4$ sec</td>
</tr>
<tr>
<td>$T_2$</td>
<td>$1.025$ sec</td>
</tr>
<tr>
<td>$T_3$</td>
<td>$1.0$ sec</td>
</tr>
<tr>
<td>$T_4$</td>
<td>$0.002$ sec</td>
</tr>
<tr>
<td>$B_1$</td>
<td>$20. V/V$</td>
</tr>
<tr>
<td>$B_2$</td>
<td>$7. V/V$</td>
</tr>
<tr>
<td>$B_3$</td>
<td>$2.15 V/V$</td>
</tr>
<tr>
<td>$B_4$</td>
<td>$1.093 V/V$</td>
</tr>
<tr>
<td>$B_5$</td>
<td>$0.85 V/V$</td>
</tr>
<tr>
<td>$B_6$</td>
<td>$2.9 V/rd$</td>
</tr>
<tr>
<td>$T_5$</td>
<td>$0.014$ sec</td>
</tr>
<tr>
<td>$T_6$</td>
<td>$0.1$ sec</td>
</tr>
<tr>
<td>$T_7$</td>
<td>$0.01$ sec</td>
</tr>
<tr>
<td>$T_8$</td>
<td>$2.0$ sec</td>
</tr>
<tr>
<td>$T_9$</td>
<td>$0.22$ sec</td>
</tr>
<tr>
<td>$T_{10}$</td>
<td>$0.088$ sec</td>
</tr>
<tr>
<td>$T_{11}$</td>
<td>$0.22$ sec</td>
</tr>
</tbody>
</table>

**Units**

$W_2 = 2.8$ V/rd/amp

$T = 0.014$ sec
INPUT K1 8.6

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

INPUT COEFFICIENTS OF G1(S) DENOMINATOR (CONSTANT TERM FIRST) 0. 1. 0.0035

INPUT A1 .35

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 (K(S)H1(S) -----

3.01( 1.00 )

*** *** DEGENERATE POLYNOMIAL *** ***

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

1.00( -0.0350 S^2 + 1.00 S)

REAL ROOTS
0.0000E+00
-285.7143

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

24.57( 1.00 )

*** *** DEGENERATE POLYNOMIAL *** ***

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

8.60( -0.0116 S^2 + .332 S + 1.00 )

REAL ROOTS
-3.0424
-282.6719

DO YOU WANT MORE YES OR NO YES
INPUT COEFFICIENTS OF \( P(S) \) NUMERATOR (CONSTANT TERM FIRST)
1. 1.425 5.00

INPUT COEFFICIENTS OF \( P(S) \) DENOMINATOR (CONSTANT TERM FIRST)
0. 1. 1. 0.002

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. \((0.01000 \, S^2 + 0.425 \, S + 1.00) \)

REAL ROOTS  
-2.4967
-40.0533

----- OPEN LOOP TRANSFER FUNCTION DENOMINATOR \( G(S)H2(S) \) -----  
1.00\((2.000E-05 \, S^5 + 0.0157 \, S^4 + 2.88 \, S^3 + 11.46 \, S^2 + 8.60 \, S) \)

REAL ROOTS  
0.0000E+00
-1.0020
-3.0424
-282.6719
-498.9980

----- CLOSED LOOP TRANSFER FUNCTION NUMERATOR \( \frac{G(S)}{1+G(S)H2(S)} \) -----  
19657. \((0.01000 \, S^2 + 0.425 \, S + 1.00) \)

REAL ROOTS  
-2.4967
-40.0533

----- CLOSED LOOP TRANSFER FUNCTION DENOMINATOR \( \frac{G(S)}{1+G(S)H2(S)} \) -----  
19657. \((1.017E-09 \, S^5 + 7.994E-07 \, S^4 + 0.00147 \, S^3 + 0.0106 \, S^2 + 0.426 \, S + 1.00) \)

REAL ROOTS  
-2.4974
-41.9267
-5.5842E+02

COMPLEX ROO'TS  IMEGA ZETA  
-41.4406 +j 56.9958 70.463 7  -6.5381
INP 1 1 -19657.

INP 1 COEFFICIENTS OF G(H) NUMERATOR (CONSTANT TERM FIRST)
1 - 4255 01

INP 1 COEFFICIENTS OF G(H) DENOMINATOR (CONSTANT TERM FIRST)
0 8 6 11.46 2.88 0157 2.0E5

INP 1 AL 1.

INP 1 COEFFICIENTS OF H1(H) NUMERATOR (CONSTANT TERM FIRST)
1.

INP 1 COEFFICIENTS OF H1(H) DENOMINATOR (CONSTANT TERM FIRST)
1.

----- OPEN LOOP TRANSFER FUNCTION NUMERATOR G(S)H(S) ----- 
19657 ( 01000 S2 + 426 S + 1.00 )

REAL ROOTS
-2.4967
-40.0533

----- OPEN LOOP TRANSFER FUNCTION DENOMINATOR G(S)H1(S) ----- 
1.000 2.000E-05 S5 + 0157 S4 + 2.88 S3 + 11.46 S2 + 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 S2 + 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 S5 + 7.987E-07 S4 + 000147 S3 + 0106 S2
+ 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 K? 12.2

INPUT COEFFICIENTS OF G2(S) NUMERATOR (CONSTANT TERM FIRST)
1. -0.014

INPUT COEFFICIENTS OF G2(S) DENOMINATOR (CONSTANT TERM FIRST)
0. 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 (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 (S)H2(S) ----- 
1.00( 3.43E-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
-41.5509 +/-J 57.0386
-94.8216 +/-J 220.1795

----- CLOSED LOOP TRANSFER FUNCTION NUMERATOR ((S)/(1+(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
-94.8216 +/-J 220.1795
-239.7317 -0.3956
CLOSED LOOP TRANSFER FUNCTION DENOMINATOR \( (S)/(1 + G(S)H(S)) \)

\[
1 \cdot 00 \times 1.450E-10 \cdot S^9 + 1.413E-07 \cdot S^8 + 5.040E-05 \cdot S^7 + 1.020 \cdot S^6
+ 1.55 \cdot S^5 + 131.9 \cdot S^4 + 7342.4 \cdot S^3 + 113889 \cdot S^2 + 239815 \cdot S
\]

REAL ROOTS

0.0000E+00
-2.4966
-13.9731
-109.1581
-5.6136E+02

COMPLEX ROOTS

\[
\Omega \quad \zeta
\]

-27.3574 +/- J 96.6600 100.4560 -0.2723
-113.9772 +/- J 203.5010 237.6204 -0.4797

DO YOU WANT MORE YES OR NO YES

INPUT K3 24.

INPUT COEFFICIENTS OF G3(S) NUMERATOR (CONSTANT TERM FIRST)

1.4

INPUT COEFFICIENTS OF G3(S) DENOMINATOR (CONSTANT TERM FIRST)

0.1

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 \( (S)/(S)H(S) \)

\[
2.398E+06 \cdot 9.744E-10 \cdot S^6 + 2.983E-07 \cdot S^5 + 8.086E-05 \cdot S^4 + 1.00717 \cdot S^3
+ 1.95 \cdot S^2 + 843 \cdot S + 1.00
\]

REAL ROOTS

-2.4966
-2.5000
-40.5533
-71.4236

COMPLEX ROOTS

\[
\Omega \quad \zeta
\]

-94.8276 +/- J 220.1795 239.7317 -0.3956
----- OPEN-LOOP TRANSFER FUNCTION DENOMINATOR G(s) -----
1.000 1.450E-12 s^11 + 1.558E-09 s^10 + 6.493E-07 s^9 + 0.00171 s^8  
+ 0.0275 s^7 + 2.87 s^6 + 205.3 s^5 + 8473.3 s^4 + 115977. s^3  
+ 239815. s^2

REAL ROOTS
  0.0000E+00  
  0.0000E+00  
  -2.4966  
  -18.9731  
  -100.0001  
  -109.1530  
  -5.6136E+02

COMPLEX ROOTS
  -27.3574 +/-J 9.66660 100.4569  -0.2723  
  -113.9772 +/-J 208.5010 237.6204  -0.4797

----- CLOSED LOOP TRANSFER FUNCTION NUMERATOR G(s)/(1+G(s)H(s)) -----
2.398E+06( 9.744E-10 s^6 + 2.983E-07 s^5 + 8.036E-05 s^4 + 0.00717 s^3  
+ 195 s^2 + 843 s + 1.00 )

REAL ROOTS
  -2.4966  
  -2.5000  
  -40.0533  
  -71.4286

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

----- CLOSED LOOP TRANSFER FUNCTION DENOMINATOR G(s)/(1+G(s)H(s)) -----
2.398E+06( 6.046E-19 s^11 + 6.493E-16 s^10 + 2.703E-13 s^9 + 7.126E-11 s^8  
+ 1.146E-08 s^7 + 1.966E-06 s^6 + 8.592E-05 s^5 + 0.00362 s^4 + 0.0555 s^3  
+ 0.295 s^2 + 843 s + 1.00 )

REAL ROOTS
  -2.4966  
  -16.1110  
  -5.6136E+02

COMPLEX ROOTS
  -2.1149 +/-J 2.7609 3.4778  -0.6031  
  -104.0444 +/-J 6.2323 104.2339  -0.2982  
  -27.2063 +/-J 95.5715 99.3685  -0.2738  
  -113.9672 +/-J 208.4693 237.5373  -0.4797

DO YOU WANT MORE YES OR NO  
  NO
INPUT A3 24.

INPUT COEFFICIENTS OF G3(S) NUMERATOR (CONSTANT TERM FIRST)

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>-2</td>
<td></td>
</tr>
<tr>
<td>-400</td>
<td></td>
</tr>
<tr>
<td>-71.4286</td>
<td></td>
</tr>
</tbody>
</table>

INPUT COEFFICIENTS OF G3(S) DENOMINATOR (CONSTANT TERM FIRST)

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

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

2.398E+06 (1.21E-09 s^6 + 3.72E-07 s^5 + 0.00101 s^4 + 0.0001 s^3 + 0.239 s^2 + 0.43 s + 1.00)

REAL ROOTS
-2.0000
-2.4967
-400.0000
-71.4286

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

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

1.00 (1.45E-12 s^11 + 1.55E-09 s^10 + 6.49E-07 s^9 + 0.00171 s^8 + 0.275 s^7 + 2.87 s^6 + 205.3 s^5 + 8418.3 s^4 + 115997. s^3 + 239815. s^2)

REAL ROOTS
0.00000E+00
-1.450E-12
-1.558E-09
-6.493E-07
-0.000171
-2.87
-205.3
-8418.3
-115997.
-239815.

COMPLEX ROOTS
-27.3574 +/-J 90.6600
100.4699
-0.2723

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

2.398E+06 (1.21E-09 s^6 + 3.72E-07 s^5 + 0.00101 s^4 + 0.0001 s^3 + 0.239 s^2 + 0.43 s + 1.00)

REAL ROOTS
-2.0000
-2.4967
-400.0000
-71.4286

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

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

2.398E+06 (6.49E-19 s^11 + 6.49E-16 s^10 + 6.49E-13 s^9 + 7.12E-11 s^8 + 1.14E-08 s^7 + 1.13E-06 s^6 + 2.59E-04 s^5 + 0.0034 s^4 + 0.0513 s^3 + 0.33 s^2 + 0.43 s + 1.00)

REAL ROOTS
-2.4967
-14.6395
-5.6139E+02

COMPLEX ROOTS
-2.0000 +/-J 2.1427
3.0371
-103.6074 +/-J 7.4331
104.1797
-0.9779
-27.1577 +/-J 95.2716
99.0009
-0.3741
-113.6646 +/-J 203.4614
237.5296
-0.4197

DO YOU WANT SOME YES OR NO NO
<table>
<thead>
<tr>
<th>$f$</th>
<th>$\text{AMPL}$</th>
<th>$\text{NORM AMPL}$</th>
<th>$\text{db}$</th>
<th>$\phi$</th>
<th>$\text{AMPL}$</th>
<th>$\text{NORM AMPL}$</th>
<th>$\text{db}$</th>
<th>$\phi$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.06</td>
<td>1.0</td>
<td>0</td>
<td>+175</td>
<td>0.061</td>
<td>1.0</td>
<td>0</td>
<td>+167</td>
</tr>
<tr>
<td>2</td>
<td>0.06</td>
<td>1.0</td>
<td>0</td>
<td>+124</td>
<td>0.058</td>
<td>-1.05</td>
<td>0</td>
<td>+164</td>
</tr>
<tr>
<td>3</td>
<td>0.08</td>
<td>1.0</td>
<td>0</td>
<td>+174</td>
<td>0.058</td>
<td>-1.05</td>
<td>0</td>
<td>+164</td>
</tr>
<tr>
<td>5</td>
<td>0.065</td>
<td>1.1</td>
<td>0.9</td>
<td>+171</td>
<td>0.064</td>
<td>+1.05</td>
<td>0</td>
<td>+163</td>
</tr>
<tr>
<td>6</td>
<td>0.07</td>
<td>1.15</td>
<td>1.2</td>
<td>+170</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>0.074</td>
<td>1.23</td>
<td>1.8</td>
<td>+166</td>
<td>0.064</td>
<td>1.05</td>
<td>0</td>
<td>+164</td>
</tr>
<tr>
<td>8</td>
<td>0.078</td>
<td>1.3</td>
<td>2.3</td>
<td>+163</td>
<td>0.075</td>
<td>1.23</td>
<td>1.8</td>
<td>+158</td>
</tr>
<tr>
<td>9</td>
<td>0.088</td>
<td>1.46</td>
<td>1.2</td>
<td>+158</td>
<td>0.08</td>
<td>1.31</td>
<td>2.4</td>
<td>+154</td>
</tr>
<tr>
<td>10</td>
<td>0.064</td>
<td>1.1</td>
<td>0.9</td>
<td>+154</td>
<td>0.085</td>
<td>1.39</td>
<td>2.9</td>
<td>+149</td>
</tr>
<tr>
<td>11</td>
<td>0.08</td>
<td>1.32</td>
<td>2.4</td>
<td>+161</td>
<td>0.091</td>
<td>1.49</td>
<td>3.5</td>
<td>+144</td>
</tr>
<tr>
<td>12</td>
<td>0.09</td>
<td>1.5</td>
<td>3.5</td>
<td>+158</td>
<td>0.098</td>
<td>1.62</td>
<td>4.2</td>
<td>+136</td>
</tr>
<tr>
<td>13</td>
<td>0.1</td>
<td>1.67</td>
<td>4.5</td>
<td>+148</td>
<td>0.078</td>
<td>1.28</td>
<td>2.1</td>
<td>+111</td>
</tr>
<tr>
<td>14</td>
<td>0.1</td>
<td>1.67</td>
<td>4.5</td>
<td>+135</td>
<td>0.08</td>
<td>1.31</td>
<td>2.4</td>
<td>+139</td>
</tr>
<tr>
<td>15</td>
<td>0.09</td>
<td>1.5</td>
<td>3.5</td>
<td>+115</td>
<td>0.1</td>
<td>1.64</td>
<td>4.3</td>
<td>+129</td>
</tr>
<tr>
<td>16</td>
<td>0.09</td>
<td>1.5</td>
<td>3.5</td>
<td>+126</td>
<td>0.11</td>
<td>1.8</td>
<td>5.1</td>
<td>+118</td>
</tr>
<tr>
<td>17</td>
<td>0.09</td>
<td>1.5</td>
<td>3.5</td>
<td>+98</td>
<td>0.11</td>
<td>1.80</td>
<td>5.1</td>
<td>+105</td>
</tr>
<tr>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.105</td>
<td>1.73</td>
<td>4.8</td>
<td>+92</td>
</tr>
<tr>
<td>20</td>
<td>0.05</td>
<td>-1.2</td>
<td>-1.8</td>
<td>+40</td>
<td>0.09</td>
<td>1.47</td>
<td>3.3</td>
<td>+71</td>
</tr>
<tr>
<td>25</td>
<td>0.025</td>
<td>-2.4</td>
<td>-7.6</td>
<td>+21</td>
<td>0.04</td>
<td>-1.52</td>
<td>-3.6</td>
<td>+41</td>
</tr>
</tbody>
</table>
Figure 4: AZ Position Loop Response
### TABLE IV
RATE LOOP RESPONSE DATA

<table>
<thead>
<tr>
<th>$f$</th>
<th>AMPL</th>
<th>NORM AMPL</th>
<th>db</th>
<th>$\phi$</th>
<th>AMPL</th>
<th>NORM AMPL</th>
<th>db</th>
<th>$\phi$</th>
</tr>
</thead>
<tbody>
<tr>
<td>.1</td>
<td>.138</td>
<td>1.0</td>
<td>0</td>
<td>-179</td>
<td>.124</td>
<td>1.0</td>
<td>0</td>
<td>-129</td>
</tr>
<tr>
<td>.2</td>
<td>.128</td>
<td>1.07</td>
<td>- .6</td>
<td>-177</td>
<td>.140</td>
<td>1.13</td>
<td>1.06</td>
<td>-179</td>
</tr>
<tr>
<td>.5</td>
<td>.154</td>
<td>1.12</td>
<td>1.0</td>
<td>-176</td>
<td>.138</td>
<td>1.11</td>
<td>.83</td>
<td>+155</td>
</tr>
<tr>
<td>1.0</td>
<td>.150</td>
<td>1.09</td>
<td>.75</td>
<td>+159</td>
<td>.104</td>
<td>-1.2</td>
<td>-1.6</td>
<td>+133</td>
</tr>
<tr>
<td>2.0</td>
<td>.128</td>
<td>-1.07</td>
<td>-.6</td>
<td>+156</td>
<td>.08</td>
<td>-1.55</td>
<td>-3.8</td>
<td>+150</td>
</tr>
<tr>
<td>3.0</td>
<td>.131</td>
<td>-1.05</td>
<td>-.4</td>
<td>+143</td>
<td>.105</td>
<td>-1.18</td>
<td>1.4</td>
<td>+161</td>
</tr>
<tr>
<td>5.0</td>
<td>.094</td>
<td>-2.16</td>
<td>-6.7</td>
<td>+109</td>
<td>.19</td>
<td>1.53</td>
<td>-3.8</td>
<td>+137</td>
</tr>
<tr>
<td>6.0</td>
<td>.190</td>
<td>1.38</td>
<td>2.8</td>
<td>-68</td>
<td>.084</td>
<td>-1.48</td>
<td>-3.4</td>
<td>+144</td>
</tr>
<tr>
<td>8.0</td>
<td>.081</td>
<td>-2.0</td>
<td>-6</td>
<td>+147</td>
<td>.09</td>
<td>-1.38</td>
<td>-2.8</td>
<td>+116</td>
</tr>
<tr>
<td>10.0</td>
<td>.081</td>
<td>-1.7</td>
<td>-4.6</td>
<td>+106</td>
<td>.101</td>
<td>-1.23</td>
<td>-1.8</td>
<td>+116</td>
</tr>
<tr>
<td>12.0</td>
<td>.099</td>
<td>-1.39</td>
<td>-2.5</td>
<td>+134</td>
<td>.088</td>
<td>-1.42</td>
<td>-3.0</td>
<td>+103</td>
</tr>
<tr>
<td>15.0</td>
<td>.112</td>
<td>-1.22</td>
<td>-1.7</td>
<td>+112</td>
<td>.114</td>
<td>-1.1</td>
<td>- .83</td>
<td>+ 91</td>
</tr>
<tr>
<td>17.0</td>
<td>.094</td>
<td>-1.47</td>
<td>-3.3</td>
<td>+118</td>
<td>.149</td>
<td>1.2</td>
<td>1.6</td>
<td>+ 69</td>
</tr>
<tr>
<td>19.0</td>
<td>.128</td>
<td>-1.08</td>
<td>- .67</td>
<td>+108</td>
<td>.154</td>
<td>1.24</td>
<td>1.9</td>
<td>+ 53</td>
</tr>
<tr>
<td>20.0</td>
<td>.154</td>
<td>1.12</td>
<td>1.0</td>
<td>+93</td>
<td>.129</td>
<td>1.04</td>
<td>.35</td>
<td>+138</td>
</tr>
<tr>
<td>21.0</td>
<td>.169</td>
<td>1.22</td>
<td>1.7</td>
<td>+93</td>
<td>.124</td>
<td>0</td>
<td>0</td>
<td>+ 21</td>
</tr>
<tr>
<td>22.0</td>
<td>.190</td>
<td>1.38</td>
<td>2.8</td>
<td>+76</td>
<td>.104</td>
<td>-1.2</td>
<td>-1.6</td>
<td>+ 6</td>
</tr>
<tr>
<td>23.0</td>
<td>.19</td>
<td>1.38</td>
<td>2.8</td>
<td>+40</td>
<td>.079</td>
<td>-1.57</td>
<td>-3.9</td>
<td>0.0</td>
</tr>
<tr>
<td>24.0</td>
<td>.19</td>
<td>1.38</td>
<td>2.8</td>
<td>+27</td>
<td>.065</td>
<td>-1.9</td>
<td>-5.6</td>
<td>- 4</td>
</tr>
<tr>
<td>26.0</td>
<td>.16</td>
<td>1.15</td>
<td>1.2</td>
<td>-12</td>
<td>.04</td>
<td>-3.1</td>
<td>-10.</td>
<td>- 7</td>
</tr>
<tr>
<td>28.0</td>
<td>.13</td>
<td>-1.06</td>
<td>- .5</td>
<td>-19</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30.0</td>
<td>.10</td>
<td>-1.38</td>
<td>-2.8</td>
<td>- 19</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40.0</td>
<td>.03</td>
<td>-4.6</td>
<td>-13.0</td>
<td>- 37</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Diagram:
- OUTPUT
- 49.9
- 1 mF
- 200K
- 1 to 40 Hz
### Table

<table>
<thead>
<tr>
<th>f</th>
<th>AMPL</th>
<th>DB</th>
<th>φ</th>
<th>AMPL</th>
<th>DB</th>
<th>φ</th>
</tr>
</thead>
<tbody>
<tr>
<td>.05</td>
<td>.41</td>
<td>+179°</td>
<td></td>
<td>.2</td>
<td>+179°</td>
<td></td>
</tr>
<tr>
<td>.1</td>
<td>.48</td>
<td>+174</td>
<td></td>
<td>.21</td>
<td>+176°</td>
<td></td>
</tr>
<tr>
<td>.2</td>
<td>.74</td>
<td>+137</td>
<td></td>
<td>.24</td>
<td>1.6</td>
<td>+171°</td>
</tr>
<tr>
<td>.3</td>
<td>.58</td>
<td>+104</td>
<td></td>
<td>.29</td>
<td>3.2</td>
<td>+159</td>
</tr>
<tr>
<td>.4</td>
<td>.24</td>
<td>+ 63</td>
<td></td>
<td>.34</td>
<td>4.6</td>
<td>+134</td>
</tr>
<tr>
<td>.5</td>
<td>.18</td>
<td>+ 54</td>
<td></td>
<td>.30</td>
<td>3.5</td>
<td>+108</td>
</tr>
<tr>
<td>.7</td>
<td>.11</td>
<td>+ 29</td>
<td></td>
<td>.22</td>
<td>1.0</td>
<td>+ 65</td>
</tr>
<tr>
<td>1.0</td>
<td>.06</td>
<td>+ 12</td>
<td></td>
<td>.10</td>
<td>-6</td>
<td>+ 38</td>
</tr>
<tr>
<td>2.0</td>
<td>.01</td>
<td>- 8</td>
<td></td>
<td>.01</td>
<td>-23</td>
<td>-13</td>
</tr>
</tbody>
</table>

### Diagram

- **OUTPUT OF 200K FUNCTION GEN**
- **AZ/EL STEERING COMMAND**
- **CLOSED LOOP FREQUENCY RESPONSE**
- **SYSTEM LOCKED ON TOWER**
- **RATE FEEDBACK RESISTORS 402K EACH CHANNEL**
<table>
<thead>
<tr>
<th>$f$</th>
<th>$	ext{AMPL}$</th>
<th>$	ext{DB}$</th>
<th>$\phi$</th>
<th>$\text{AMPL}$</th>
<th>$	ext{DB}$</th>
<th>$\phi$</th>
</tr>
</thead>
<tbody>
<tr>
<td>.05</td>
<td>.156</td>
<td></td>
<td>172</td>
<td>.0017</td>
<td></td>
<td>62</td>
</tr>
<tr>
<td>.1</td>
<td>.18</td>
<td>1.2</td>
<td>174</td>
<td>.008</td>
<td></td>
<td>7.2</td>
</tr>
<tr>
<td>.2</td>
<td>.195</td>
<td>1.9</td>
<td>168</td>
<td>.014</td>
<td></td>
<td>-32</td>
</tr>
<tr>
<td>.3</td>
<td>.234</td>
<td>3.5</td>
<td>149</td>
<td>.019</td>
<td></td>
<td>-77</td>
</tr>
<tr>
<td>.4</td>
<td>.25</td>
<td>4.1</td>
<td>136</td>
<td>.038</td>
<td></td>
<td>-106</td>
</tr>
<tr>
<td>.5</td>
<td>.28</td>
<td>5.1</td>
<td>99</td>
<td>.041</td>
<td></td>
<td>-143</td>
</tr>
<tr>
<td>.7</td>
<td>.21</td>
<td>2.6</td>
<td>32</td>
<td>.084</td>
<td></td>
<td>+109</td>
</tr>
<tr>
<td>1.0</td>
<td>.09</td>
<td>4.9</td>
<td>6</td>
<td>.018</td>
<td></td>
<td>+127</td>
</tr>
<tr>
<td>2.0</td>
<td>.01</td>
<td>-23</td>
<td>-18</td>
<td>.009</td>
<td></td>
<td>14</td>
</tr>
</tbody>
</table>

AZ readings, which are measure of cross talk, are only approximate and are not accurately repeatable with EL = 8.5K.

The following response was obtained with input into E1 channel only.
### TABLE VII

**TRACK LOOP RESPONSE DATA**

<table>
<thead>
<tr>
<th>f</th>
<th>AMPL</th>
<th>NORM AMPL</th>
<th>db</th>
<th>φ</th>
<th>Φ</th>
</tr>
</thead>
<tbody>
<tr>
<td>.1</td>
<td>.49</td>
<td>1.0</td>
<td>0.</td>
<td>+177.</td>
<td></td>
</tr>
<tr>
<td>.2</td>
<td>.54</td>
<td>1.1</td>
<td>.1</td>
<td>+171.</td>
<td></td>
</tr>
<tr>
<td>.3</td>
<td>.58</td>
<td>1.18</td>
<td>1.4</td>
<td>+163.</td>
<td></td>
</tr>
<tr>
<td>.4</td>
<td>.68</td>
<td>1.38</td>
<td>2.8</td>
<td>+154.</td>
<td></td>
</tr>
<tr>
<td>.5</td>
<td>.758</td>
<td>1.57</td>
<td>3.9</td>
<td>+132.</td>
<td></td>
</tr>
<tr>
<td>.6</td>
<td>.614</td>
<td>1.25</td>
<td>1.95</td>
<td>+109.</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>.54</td>
<td>1.1</td>
<td>.1</td>
<td>+ 93 .</td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>.287</td>
<td>-1.71</td>
<td>-4.7</td>
<td>+ 81 .</td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td>.154</td>
<td>-3.18</td>
<td>-10 .</td>
<td>+ 54</td>
<td></td>
</tr>
<tr>
<td>3.0</td>
<td>.057</td>
<td>-8.6</td>
<td>-18.6</td>
<td>+ 47</td>
<td></td>
</tr>
</tbody>
</table>

### Diagram

- TP-10
- 130K
- AR29
- 200K
- 0.05V
- 1 - 2.0 Hz

**Cross Coupling into EL**

<table>
<thead>
<tr>
<th>AMPL</th>
<th>NORM AMPL</th>
<th>db</th>
<th>φ</th>
</tr>
</thead>
<tbody>
<tr>
<td>.04</td>
<td>-12.3</td>
<td>-22</td>
<td>+145</td>
</tr>
<tr>
<td>.143</td>
<td>- 3.4</td>
<td>-10</td>
<td>+115</td>
</tr>
<tr>
<td>.19</td>
<td>- 2.6</td>
<td>- 8.3</td>
<td>+ 89</td>
</tr>
<tr>
<td>.19</td>
<td>- 2.6</td>
<td>- 8.3</td>
<td>+ 43</td>
</tr>
<tr>
<td>.19</td>
<td>- 2.6</td>
<td>- 8.3</td>
<td>+ 44</td>
</tr>
<tr>
<td>.19</td>
<td>- 2.6</td>
<td>- 8.3</td>
<td>+  4</td>
</tr>
<tr>
<td>.19</td>
<td>- 2.6</td>
<td>- 8.3</td>
<td>- 27</td>
</tr>
<tr>
<td>.19</td>
<td>- 2.6</td>
<td>- 8.3</td>
<td>- 57</td>
</tr>
<tr>
<td>.11</td>
<td>- 4.5</td>
<td>-13</td>
<td>-100</td>
</tr>
<tr>
<td>.07</td>
<td>-  7.</td>
<td>-17</td>
<td>-120</td>
</tr>
</tbody>
</table>
### TABLE VIII

**TRACK LOOP RESPONSE DATA**

<table>
<thead>
<tr>
<th>INPUT INTO EL</th>
<th>CROSS COUPLING INTO AZ</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>f</strong></td>
<td><strong>AMPL</strong></td>
</tr>
<tr>
<td>.1</td>
<td>.5</td>
</tr>
<tr>
<td>.2</td>
<td>.55</td>
</tr>
<tr>
<td>.3</td>
<td>.654</td>
</tr>
<tr>
<td>.4</td>
<td>.68</td>
</tr>
<tr>
<td>.5</td>
<td>.757</td>
</tr>
<tr>
<td>.6</td>
<td>.68</td>
</tr>
<tr>
<td>.7</td>
<td>.51</td>
</tr>
<tr>
<td>1.0</td>
<td>.25</td>
</tr>
<tr>
<td>2.0</td>
<td>.10</td>
</tr>
<tr>
<td>3.0</td>
<td>.054</td>
</tr>
</tbody>
</table>

---

130K

TP-11

.1 - 3.0 Hz

.05V

200K

AR-31
FIGURE # 11

AZIMUTH - MINI-SEARCH/ACQ/TRACK

SCALING .2 IN/SEC .1 V/DIV

(MULTIPLE ACQUISITIONS SAME TARGET)

HEL. POT. OUTPUT (.093 V/10)
FIGURE #12

**ELEVATION** MINI-SEARCH/ACQ/TRACK

**SCALING**: .2 IN/SEC .1V/DIV

**MULTIPLE ACQUISITIONS** SAME TARGET TOWER

**EL. POT OUTPUT**: (.093 V/1°)
Figure 13

- Track
- 0.05 V/Div
- 2.7° P-P

Elevator Pot (0.093 V/°)

Mini Search/Dec/Track
For Towing

Azimuth Pot (0.093 V/°)

MINI SEARCH / DEC / TRACK

For TOWING

FIGURE 13
Figure 13A

Multiple acquisitions of tower with antenna base rolled 90°.
Figure #3.15
Rate gyro output of P.S.D. (A/Z)
gyro scale factor 14mV/°
scale 0.5 V/div and 100°/div
FIGURE 416

TARSE TRACK WITH RATE TABLE MOTION
Figure 16A

Elevation Error Trace
For Rate Table at Max (100°/sec & 214°/sec)
(Antenna Base Rotated 90° in Roll)
FIGURE #17

TARGET TRACK WITH RATE TABLE MOTION

AZ POT .05 V/DIV

.2 IN/SEC

AZ PSD OUTPUT .05 V/DIV

TP-10
TYP
10SFREEE
20C
30 b=2.7  
40 A=1.6 
50 BB=A*A + b*b 
60 AB=A/B 
70 TH=.1 
80 T=-TH 
90 CC=SQRT(1./A*BB/TH-1.) 
100 SO=SQRT(BB)/B 
110 TYPE,T,U 
120 10 1=T+TH 
130 BT=b*T 
140 AO=EXP(-A*TH)*(CUST(BT)+AB*SIN(BT)) 
150 BO=EXP(-A*TH)*SIN(BT) 
160 BD=bD/B 
170 CD=1./BD-EXP(-A*TH)/SO*SIN(BT+ATAN(CC)) 
180 TYPE,T,AO,BO,CO 
190 IF(T.GT.4.) GO TO 20 
200 GO TO 10 
210 20 CONTINUE 
220 
230 CONTINUE 
240 END 
OK 
BYE 
OFF AT 16:48 11-Oct-73 
SRU'S USED = 23 
CONNECT TIME = 00:04
<table>
<thead>
<tr>
<th>T</th>
<th>U</th>
<th>V</th>
<th>W</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000000</td>
<td>0.000000</td>
<td>0.000000</td>
<td>0.000000</td>
<td>0.000000</td>
</tr>
<tr>
<td>0.100000</td>
<td>-0.4565789</td>
<td>0.6419279E-01</td>
<td>0.4706674E-02</td>
<td>0.1583122E-01</td>
</tr>
<tr>
<td>0.200000</td>
<td>-0.4915362</td>
<td>0.1382738</td>
<td>0.3124503E-01</td>
<td>0.4831341E-01</td>
</tr>
<tr>
<td>0.300000</td>
<td>-0.1610639</td>
<td>0.1659914</td>
<td>0.6515625E-01</td>
<td>0.6042713E-01</td>
</tr>
<tr>
<td>0.400000</td>
<td>-0.2705711E-01</td>
<td>0.1722406</td>
<td>0.9327980E-01</td>
<td>0.1033019</td>
</tr>
<tr>
<td>0.500000</td>
<td>-0.1613998</td>
<td>0.1623761</td>
<td>0.1104307</td>
<td>0.1148626</td>
</tr>
<tr>
<td>0.600000</td>
<td>-0.2454570</td>
<td>0.1461405</td>
<td>0.1147400</td>
<td>0.1162654</td>
</tr>
<tr>
<td>0.700000</td>
<td>-0.2859740</td>
<td>0.1147400</td>
<td>0.1162654</td>
<td>0.1162654</td>
</tr>
<tr>
<td>0.800000</td>
<td>-0.2914862</td>
<td>0.8563139E-01</td>
<td>0.1033019</td>
<td>0.1104307</td>
</tr>
<tr>
<td>0.900000</td>
<td>-0.2711188</td>
<td>0.5730499E-01</td>
<td>0.1033019</td>
<td>0.1104307</td>
</tr>
<tr>
<td>1.000000</td>
<td>-0.2336518</td>
<td>0.3195797E-01</td>
<td>0.1104307</td>
<td>0.1148626</td>
</tr>
<tr>
<td>1.100000</td>
<td>-0.1692682</td>
<td>0.1080361E-01</td>
<td>0.1104307</td>
<td>0.1148626</td>
</tr>
<tr>
<td>1.200000</td>
<td>-0.1373620</td>
<td>-0.5334795E-02</td>
<td>0.1104307</td>
<td>0.1172014</td>
</tr>
<tr>
<td>1.300000</td>
<td>-0.3986626E-01</td>
<td>-0.1666338E-01</td>
<td>0.1104307</td>
<td>0.1172014</td>
</tr>
<tr>
<td>1.400000</td>
<td>-0.4796731E-01</td>
<td>-0.2349646E-01</td>
<td>0.1140188</td>
<td>0.1172014</td>
</tr>
<tr>
<td>1.500000</td>
<td>-0.1340161E-01</td>
<td>-0.2649385E-01</td>
<td>0.1114906</td>
<td>0.1172014</td>
</tr>
<tr>
<td>1.600000</td>
<td>-0.1276745E-01</td>
<td>-0.2645359E-01</td>
<td>0.1082313</td>
<td>0.1172014</td>
</tr>
<tr>
<td>1.700000</td>
<td>-0.3070265E-01</td>
<td>-0.2421566E-01</td>
<td>0.1062728</td>
<td>0.1172014</td>
</tr>
<tr>
<td>1.800000</td>
<td>-0.4115934E-01</td>
<td>-0.2056456E-01</td>
<td>0.1040251</td>
<td>0.1172014</td>
</tr>
<tr>
<td>1.900000</td>
<td>-0.4531126E-01</td>
<td>-0.1615907E-01</td>
<td>0.1021387</td>
<td>0.1172014</td>
</tr>
<tr>
<td>2.000000</td>
<td>-0.4453790E-01</td>
<td>-0.1166352E-01</td>
<td>0.1007914</td>
<td>0.1172014</td>
</tr>
<tr>
<td>2.100000</td>
<td>-0.4025266E-01</td>
<td>-0.7403434E-02</td>
<td>0.0984146E-01</td>
<td>0.9929226E-01</td>
</tr>
<tr>
<td>2.200000</td>
<td>-0.3377557E-01</td>
<td>-0.3688642E-02</td>
<td>0.0992922E-01</td>
<td>0.9971840E-01</td>
</tr>
<tr>
<td>2.300000</td>
<td>-0.2624338E-01</td>
<td>-0.6830783E-03</td>
<td>0.0997184E-01</td>
<td>0.9971840E-01</td>
</tr>
<tr>
<td>2.400000</td>
<td>-0.1858000E-01</td>
<td>-0.1556664E-02</td>
<td>0.0997184E-01</td>
<td>0.9971840E-01</td>
</tr>
<tr>
<td>2.500000</td>
<td>-0.1147134E-01</td>
<td>-0.3053904E-02</td>
<td>0.0997184E-01</td>
<td>0.9971840E-01</td>
</tr>
<tr>
<td>2.600000</td>
<td>-0.5344512E-02</td>
<td>0.3384155E-02</td>
<td>0.9971840E-01</td>
<td>0.9971840E-01</td>
</tr>
<tr>
<td>2.700000</td>
<td>-0.4496848E-03</td>
<td>0.4163028E-02</td>
<td>0.101248</td>
<td>0.101248</td>
</tr>
<tr>
<td>2.800000</td>
<td>-0.3143276E-02</td>
<td>0.4017476E-02</td>
<td>0.1005369</td>
<td>0.1005369</td>
</tr>
<tr>
<td>2.900000</td>
<td>-0.5489347E-02</td>
<td>0.3575897E-02</td>
<td>0.1009185</td>
<td>0.1009185</td>
</tr>
<tr>
<td>3.000000</td>
<td>-0.6734350E-02</td>
<td>0.2956278E-02</td>
<td>0.1012461</td>
<td>0.1012461</td>
</tr>
<tr>
<td>3.100000</td>
<td>-0.7075009E-02</td>
<td>0.2259178E-02</td>
<td>0.1015072</td>
<td>0.1015072</td>
</tr>
<tr>
<td>3.200000</td>
<td>-0.6730364E-02</td>
<td>0.1564099E-02</td>
<td>0.1016980</td>
<td>0.1016980</td>
</tr>
<tr>
<td>3.300000</td>
<td>-0.5918221E-02</td>
<td>0.9235922E-03</td>
<td>0.1018220</td>
<td>0.1018220</td>
</tr>
<tr>
<td>3.400000</td>
<td>-0.4833321E-02</td>
<td>0.3849950E-03</td>
<td>0.1018370</td>
<td>0.1018370</td>
</tr>
<tr>
<td>3.500000</td>
<td>-0.3641426E-02</td>
<td>-0.3453928E-04</td>
<td>0.1019038</td>
<td>0.1019038</td>
</tr>
<tr>
<td>3.600000</td>
<td>-0.2471466E-02</td>
<td>-0.3395373E-03</td>
<td>0.101841</td>
<td>0.101841</td>
</tr>
<tr>
<td>3.700000</td>
<td>-0.1415304E-02</td>
<td>-0.5326672E-03</td>
<td>0.1018396</td>
<td>0.1018396</td>
</tr>
<tr>
<td>3.800000</td>
<td>-0.5303004E-03</td>
<td>-0.6283549E-03</td>
<td>0.1017808</td>
<td>0.1017808</td>
</tr>
<tr>
<td>3.900000</td>
<td>0.1571247E-03</td>
<td>-0.6453039E-03</td>
<td>0.1017165</td>
<td>0.1017165</td>
</tr>
<tr>
<td>4.000000</td>
<td>0.6429648E-03</td>
<td>-0.6036600E-03</td>
<td>0.1016937</td>
<td>0.1016937</td>
</tr>
<tr>
<td>4.100000</td>
<td>0.9426013E-03</td>
<td>-0.5229508E-03</td>
<td>0.1015971</td>
<td>0.1015971</td>
</tr>
</tbody>
</table>
ERROR RESPONSE
TO A UNIT ANGULAR
STEP INPUT
OF TYPICAL
LOOP

\[ \theta_e(t) = e^{-1.6t} \left[ \cos(2.7t) - 0.6 \sin(2.7t) \right] \]

FIGURE 1B
Figure #19

_TRACK LOOP ERROR RESPONSE TO RAMP (RATE OF 1 RAD/SEC)_
Figure 40

Track Loop
Error Response
To Acceleration
1 rad/sec^2

\[ \theta_e(t) \]

Time → Sec

Error
0.15 -
0.10 -
0.05 -

Rad/n
Figure 21: Response of track line to jerk disturbance (a/c) of 290 rad/sec^3.
TRACK LINE RESPONSE TO ACCELERATION (g/ℓ) DISTURBANCE OF 290.141/ℓsec²

Figure 22
Track Line Response
To Rate Disturbance (\(\theta_j\))
of 290 rad/sec

Figure 2.3
Response of track line to an angle distortion (a/c) of 290 deg.

Figure 24
TABLE I

<table>
<thead>
<tr>
<th>T</th>
<th>AU</th>
<th>ClI</th>
<th>CI</th>
<th>AU</th>
<th>ClI</th>
<th>CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>ClI</td>
<td>0.940490</td>
<td>0.024031</td>
<td>0.459058</td>
<td>0.104943</td>
<td>2.193701</td>
<td>-1.233467</td>
</tr>
<tr>
<td>PA</td>
<td>0.060710</td>
<td>0.016206</td>
<td>0.016206</td>
<td>0.104943</td>
<td>2.193701</td>
<td>-1.233467</td>
</tr>
<tr>
<td>AU</td>
<td>0.000000</td>
<td>0.000000</td>
<td>0.000000</td>
<td>0.104943</td>
<td>2.193701</td>
<td>-1.233467</td>
</tr>
<tr>
<td>ClI</td>
<td>0.000000</td>
<td>0.000000</td>
<td>0.000000</td>
<td>0.104943</td>
<td>2.193701</td>
<td>-1.233467</td>
</tr>
<tr>
<td>AU</td>
<td>0.356821</td>
<td>0.817381</td>
<td>0.356821</td>
<td>0.104943</td>
<td>2.193701</td>
<td>-1.233467</td>
</tr>
<tr>
<td>ClI</td>
<td>0.4366315</td>
<td>0.4366315</td>
<td>0.4366315</td>
<td>0.104943</td>
<td>2.193701</td>
<td>-1.233467</td>
</tr>
<tr>
<td>AU</td>
<td>1.663069</td>
<td>1.663069</td>
<td>1.663069</td>
<td>0.104943</td>
<td>2.193701</td>
<td>-1.233467</td>
</tr>
<tr>
<td>ClI</td>
<td>1.640392</td>
<td>1.640392</td>
<td>1.640392</td>
<td>0.104943</td>
<td>2.193701</td>
<td>-1.233467</td>
</tr>
<tr>
<td>AU</td>
<td>2.914673</td>
<td>2.914673</td>
<td>2.914673</td>
<td>0.104943</td>
<td>2.193701</td>
<td>-1.233467</td>
</tr>
<tr>
<td>ClI</td>
<td>2.250000</td>
<td>2.250000</td>
<td>2.250000</td>
<td>0.104943</td>
<td>2.193701</td>
<td>-1.233467</td>
</tr>
<tr>
<td>AU</td>
<td>2.193701</td>
<td>2.193701</td>
<td>2.193701</td>
<td>0.104943</td>
<td>2.193701</td>
<td>-1.233467</td>
</tr>
<tr>
<td>ClI</td>
<td>2.250000</td>
<td>2.250000</td>
<td>2.250000</td>
<td>0.104943</td>
<td>2.193701</td>
<td>-1.233467</td>
</tr>
<tr>
<td>AU</td>
<td>2.193701</td>
<td>2.193701</td>
<td>2.193701</td>
<td>0.104943</td>
<td>2.193701</td>
<td>-1.233467</td>
</tr>
<tr>
<td>ClI</td>
<td>2.250000</td>
<td>2.250000</td>
<td>2.250000</td>
<td>0.104943</td>
<td>2.193701</td>
<td>-1.233467</td>
</tr>
</tbody>
</table>
20C
30 I=3.14
40 Z=.5
50 A=1./16.
60 TH=.1
70 T=-TH
80 TYPE,- T AD BO, CU DU
90 ZZ=SQRT(1.-Z/Z)
100 D=1.-2.*A*Z+Z/A*A*Z
102 G=1.-2.*A*Z-Z/A*A*Z
110 SD=SQRT(D*(1.-Z/Z))
120 AZ=ATAN(-Z/Z)
130 BZ=ATAN(A*Z/ZZ*(1.-A*Z/Z))
140 PA=-PA
141 PA=-PA
145 PB=-BZ
150 PD=-BZ
160 PC=-BZ*AZ
170 PD=-BZ-2.*AZ
180 W1=1*ZZ
182 TYPE,- ZZ = , ZZ, D = , D, AD = , SD
184 TYPE,- AZ = , AZ, BZ = , BZ
186 TYPE,- PA = , PA, PB = , PB
190 TO T=1+TH
200 EE=EXP(-Z*W*T)
210 EA=EXP(-T/A)
220 AA=1.-A*Z*Z*GA/DD+EE*SI(K/T^T-PA)/SD
230 BD=A*Z*Z*GA/DD+EE*SI(K/T^T-PB)/SD
240 CU=-K*GA/DD+EE*SI(K/T^T-PC)/SD
250 DU=-K*GA/DD+EE*SI(K/T^T-PD)/SD
260 TYPE,- T AO BO, T, AO, BO
270 TYPE,- CU = , CU, DD = , DD
280 IF(T.GT.4.) GO TO 20
290 GO TO 10
300 20C CONTINUE
310 END

OK
REP
OK
BYE

OFF AT 09:57 15-Oct-73
SHUS 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 $\theta'_D$. Figure A-2 is a simplified overall loop block diagram of the track mode.

From Figure A-2, the tracking line ($\theta_T$) response to a target input angle ($\theta_S$) is written as:

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

The response to a disturbance is:

$$\frac{\theta_T}{\theta_D} = \left[ \frac{1}{G_5 G_6} \right] \left[ \frac{\theta_1}{\theta_S} \right] \left[ \frac{\theta_T}{\theta_S} \right]$$  \hspace{1cm} (A-2)

and

$$\frac{\theta_T}{\theta_D} = \left[ \frac{\theta_D'}{\theta_D} \right] \left[ \frac{\theta_T}{\theta_D} \right] = \left[ \frac{1}{G_5 G_6} \right] \left[ \frac{\theta_1}{\theta_D} \right] \left[ \frac{\theta_T}{\theta_D} \right]$$  \hspace{1cm} (A-3)

where

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

where

$$H_2 = 1, \hspace{2cm} H_1 = K_B S$$

$$G_2 = \frac{K_{T/R}}{1 + T_E S} \left( \frac{Y (1 + T_1 S) (1 + T_2 S)}{(1 + T_3 S) (1 + T_4 S)} \right)$$  \hspace{1cm} (A-5)
\[ G_3 = \frac{1}{JS^2} \]

\[ G_4 = JS^2 \]

Substituting into \( \frac{\theta_D'}{\theta_D} \) we obtain

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

Further substitution yields

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

\hspace{1cm} \hspace{1cm} \hspace{1cm} \hspace{1cm} \hspace{1cm} \hspace{1cm} \hspace{1cm} \hspace{1cm} \hspace{1cm} \hspace{1cm} (A-7)

where

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

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

\( (1 + T_E S)(1 + T_3 S)(1 + T_4 S) = 1 + S + .0055S^2 + .7S^3 \)  \hspace{1cm} (A-8)

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

\( Y K_R = \frac{48}{2.8} (800) = 13700 \)
Divide numerator and denominator of \( \frac{D}{D_0} \) by \( Y K_R \):

\[
\frac{K_R Q}{Y K_R} = \frac{K_R}{Y} = 4.25^{-4}
\]

(A-9)

The numerator of equation A-7 is:

\[
\text{NUM} = 4.25^{-4} S (1 + S + .002S^2) + 1 + .425S + .01S^2
\]

\[= 8.5^{-7} S^3 + .01S^2 + 4254S + 1 \]

(A-10)

\[
= \left( \frac{S}{11700} + 1 \right) \left( \frac{S}{2.5} + 1 \right) \left( \frac{S}{40} + 1 \right)
\]

The denominator is:

\[
\text{DEN} = \frac{25^2}{13700} (1 + S + .0055S^2 + 8.5^{-6}S^3) + 8.5^{-7} S^3 + .01S^2 + 4254S + 1
\]

\[= 1.03^{-9} S^5 + 8.5^{-7} S^4 + 1.46^{-4} S^3 + .01S^2 + .425 + 1 \]

(A-11)

\[
= \left( \frac{S}{2.5} + 1 \right) \left( \frac{S}{141} + 1 \right) \left( \frac{S}{558} + 1 \right) \left( \frac{S^2}{70^2} + \frac{2(.6)S}{70} + 1 \right)
\]

From TableII the track loop transfer function is:

\[
\frac{\theta_T}{\theta_S} = \frac{\left( \frac{S}{2.5} + 1 \right) \left( \frac{S}{2.5} + 1 \right) \left( \frac{S}{40} + 1 \right) \left( \frac{S}{71} + 1 \right) \left( \frac{S^2}{240^2} + \frac{2(.5)S}{240} + 1 \right)}{\left( \frac{S}{2.5} + 1 \right) \left( \frac{S}{16} + 1 \right) \left( \frac{S}{561} + 1 \right) \left( \frac{S^2}{3.5^2} + \frac{2(.6)S}{3.5} + 1 \right) \left( \frac{S^2}{104^2} + \frac{2(.99)S}{104} + 1 \right)}
\]

(A-12)

\[
\frac{\left( \frac{S^2}{100^2} + \frac{2(.27)S}{100} + 1 \right) \left( \frac{S^2}{240^2} + \frac{2(.5)S}{240} + 1 \right)}
\]
Then with the aid of Figure A-3

\[ \theta_D = \theta_T (A-13) \]

where

\[ G_2 = \frac{24 (1 + \frac{S}{2.5})}{S (1 + \frac{S}{100})} \]  

\[ G_1 = \left[ \frac{(\frac{S}{2.5} + 1) (\frac{S}{40} + 1)}{\frac{S}{141} + 1} \right] \frac{12.2 (1 + \frac{S}{70})}{S^2} \]  

and

The response to a disturbance is

\[ \theta_D = \left( \frac{1}{G_1 G_2} \right) \theta_T \]
Equation A-12 reduces to

\[
\frac{\theta_T}{\theta_S} = \frac{(S_{2.5} + 1)(S_{40} + 1)(S_{71} + 1)}{(S_{16} + 1)(S^2_{3.5} + 2(0.6)S_{104} + 1)(S_{100}^2 + 2(0.3)S_{100} + 1)(S_{560} + 1)}
\]  

(A-16)

Equation A-13 becomes

\[
\frac{\theta_T}{\theta_D} = \frac{s^3(S_{141} + 1)(S_{560} + 1)(S^2_{70} + 2(0.16)s_{70} + 1)(S_{100} + 1)(S_{2.5} + 1)(S_{40} + 1)(S_{71} + 1)}{290(S_{16} + 1)(S^2_{3.5} + 2(0.6) + 1)(S_{104} + 1)(S^2_{100} + 2(0.3)S_{100} + 1)(S_{560} + 1)}
\]  

(290)(S_{2.5} + 1)(S_{40} + 1)(S_{70} + 1)

(A-17)

and reduces to

\[
\frac{\theta_T}{\theta_D} = \frac{s^3(S_{141} + 1)(S^2_{70} + 2(0.6) + 1)}{290(S_{16} + 1)(S^2_{3.5} + 2(0.6) + 1)(S_{104} + 1)(S^2_{100} + 2(0.3)S_{100} + 1)}
\]  

(A-18)

But the self stabilization terms is

\[
\frac{\theta_D'}{\theta_D} = \frac{(S_{40} + 1)}{(S_{141} + 1)(S^2_{70} + 2(0.6)S_{70} + 1)}
\]  

(A-19)
and finally

The response to an aircraft disturbance is

$$\frac{\theta_T}{\theta_D} = \frac{s^3 \left( \frac{s}{40} + 1 \right)}{290 \left( \frac{s}{16} + 1 \right) \left( \frac{s^2}{3.5^2} + \frac{2(0.6)s}{3.5} + 1 \right) \left( \frac{s}{104} + 1 \right) \left( \frac{s^2}{100^2} + \frac{2(0.3)s}{100} + 1 \right)} \quad (A-20)$$
FIGURE A1 SELF-STABILIZATION BLOCK DIAGRAMS
\[ \frac{\theta_i}{1 + G_2 C_3 H_1 + G_1 G_2 C_3 H_2} \]

\[ \frac{\theta_B}{1 + G_2 C_3 H_1 + G_1 G_2 C_3 H_2} \]

\[ \frac{1 + G_2 G_3 H_1 + G_1 G_2 G_3 H_2 - G_3 C}{1 + G_2 G_3 H_1 + G_2 G_3 G_1 H_2} \]

\[ \frac{G_4 G_3}{(1 + G_2 G_3 H_1 + G_1 G_2 G_3 H_2)} \]

FIGURE A-1 (Cont)
Figure A.2
CONTENTS

1.0 SCOPE

2.0 APPLICABLE DOCUMENTS

3.0 TEST CONDITIONS AND EQUIPMENT

4.0 TESTING/PERFORMANCE

5.0 DATA SHEETS
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

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

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

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 DVS3) 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 DVS3. 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:

<table>
<thead>
<tr>
<th>Voltage</th>
<th>J-7 Pin</th>
<th>J-7 Return</th>
<th>Value</th>
<th>Ripple Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>115VAC</td>
<td>A</td>
<td>W</td>
<td>115VAC + 2VAC</td>
<td></td>
</tr>
<tr>
<td>115VAC</td>
<td>B</td>
<td>W</td>
<td>115VAC + 2VAC</td>
<td></td>
</tr>
<tr>
<td>115VAC</td>
<td>C</td>
<td>W</td>
<td>115VAC + 2VAC</td>
<td></td>
</tr>
<tr>
<td>28VDC</td>
<td>D</td>
<td>W</td>
<td>28VDC + 1VDC</td>
<td></td>
</tr>
<tr>
<td>+5VDC</td>
<td>E</td>
<td>E</td>
<td>+5VDC + 0.15VDC</td>
<td>50 mV</td>
</tr>
<tr>
<td>-5VDC</td>
<td>E</td>
<td>E</td>
<td>-5VDC + 0.15VDC</td>
<td>50 mV</td>
</tr>
<tr>
<td>+15VDC</td>
<td>F</td>
<td>E</td>
<td>+15VDC + 0.23VDC</td>
<td>50 mV</td>
</tr>
<tr>
<td>-15VDC</td>
<td>G</td>
<td>E</td>
<td>-15VDC + 0.23VDC</td>
<td>50 mV</td>
</tr>
<tr>
<td>+30VDC</td>
<td>H</td>
<td>E</td>
<td>+30VDC + 0.9VDC</td>
<td>50 mV</td>
</tr>
<tr>
<td>+100VDC</td>
<td>J</td>
<td>E</td>
<td>+100VDC + 3VDC</td>
<td>500 mV</td>
</tr>
<tr>
<td>+150VDC</td>
<td>K</td>
<td>E</td>
<td>+150VDC + 4.5VDC</td>
<td>500 mV</td>
</tr>
</tbody>
</table>

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 persistence 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 ° +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°. 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 °. 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 that the voltmeter reads -0.5VDC and lower TILT CURSOR is at 0° +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 maximum 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 ±0.2 volts as the azimuth recording changes from plus to minus voltage and 0.3 ±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 ±.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 ± .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--- System Sync. Turn transmitter OFF. Pulse width should be 0.4 usec ± 0.04 usec. 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 9.15 GHz 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.
4.6 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 optimum 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.

<table>
<thead>
<tr>
<th>RANGE (FT)</th>
<th>SIGNAL LEVEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>5,000</td>
<td>26 ± 5 dB</td>
</tr>
<tr>
<td>3,000</td>
<td>31 ± 3 dB</td>
</tr>
</tbody>
</table>

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 theDVST 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 ± 0.062 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.

<table>
<thead>
<tr>
<th>Simulated Target Range</th>
<th>Range Voltage to be measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>600 feet</td>
<td>0.6 ± 0.050 VDC</td>
</tr>
<tr>
<td>1,000 feet</td>
<td>1.0 ± 0.050 VDC</td>
</tr>
<tr>
<td>2,000 feet</td>
<td>2.0 ± 0.050 VDC</td>
</tr>
<tr>
<td>3,000 feet</td>
<td>3.0 ± 0.060 VDC</td>
</tr>
<tr>
<td>7,500 feet</td>
<td>7.5 ± 0.150 VDC</td>
</tr>
<tr>
<td>15,000 feet</td>
<td>15.0 ± 0.300 VDC</td>
</tr>
<tr>
<td>30,000 feet</td>
<td>30.0 ± 0.600 VDC</td>
</tr>
<tr>
<td>60,000 feet</td>
<td>60.0 ± 1.200 VDC</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Rate</th>
<th>Range Rate Voltage to be Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 Rate</td>
<td>+0.0 ± 0.050 VDC</td>
</tr>
<tr>
<td>Closing 1000 Ft/Sec</td>
<td>+5.0 ± 0.150 VDC</td>
</tr>
<tr>
<td>Closing 2000 Ft/Sec</td>
<td>+10.0 ± 0.300 VDC</td>
</tr>
<tr>
<td>Closing 3000 Ft/Sec</td>
<td>+15.0 ± 0.450 VDC</td>
</tr>
<tr>
<td>Opening 1000 Ft/Sec</td>
<td>-5.0 ± 0.150 VDC</td>
</tr>
</tbody>
</table>

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 output to the Range test jack J6-5 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 J7-5 (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 ± 50 MV and the peak-to-peak reading of the elevation signal is 455 ± 45 MV and the Azimuth signal is 376 ± 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-CN 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/PSL 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 reacquires 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 DOOfIGHT 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 I1SL. 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 entire 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-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 3

Radar system intercabling with system test bench for acceptance testing.
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
**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
### TEST EQUIPMENT USED

<table>
<thead>
<tr>
<th>Instrument</th>
<th>MFR &amp; Model</th>
<th>Next Calibration Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dummy Load</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recorder</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electronic Counter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microwave Amplifier</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spectrum Analyzer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable Attenuator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power Meter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power Head</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Directional Coupler 20 DB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency Meter (X Band)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detector</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oscilloscope</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulse Generator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RF Generator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voltmeter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50 DB Isolator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 DB Directional Coupler</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynamic Range Simulator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Target Simulator</td>
<td>633339-1 S/N</td>
<td></td>
</tr>
<tr>
<td>pressure Test Set</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System Test Bench</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>LRU</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Processor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antenna</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indicator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>XMTR/RCVR</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Set Control</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Running Time Meter

<table>
<thead>
<tr>
<th>S/N</th>
<th>ATP Start</th>
<th>ATP Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
4.1.6 Antenna approximately straight ahead
Fail light not illuminated
ART, HORIZ, and TILT CURSOR displayed
XHTR READY time

4.1.7 Antenna searching full azimuth pattern:
FAIL light lighted
"B" scan displayed:

4.1.8

<table>
<thead>
<tr>
<th>J-7 Pin</th>
<th>J-7 RTN</th>
<th>Measured Value</th>
<th>Measured Ripple</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>W 115 + 2 vac</td>
<td>vac</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>W 115 + 2 vac</td>
<td>vac</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>W 115 + 2 vac</td>
<td>vac</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>X 28 + 1 vdc</td>
<td>vdc</td>
<td></td>
</tr>
<tr>
<td>Q</td>
<td>E +5 + 0.15 vdc</td>
<td>vdc</td>
<td>&lt;50 mv</td>
</tr>
<tr>
<td>Y</td>
<td>E -5 + 0.15 vdc</td>
<td>vdc</td>
<td>&lt;50 mv</td>
</tr>
<tr>
<td>F</td>
<td>E +15 + 0.23 vdc</td>
<td>vdc</td>
<td>&lt;50 mv</td>
</tr>
<tr>
<td>D</td>
<td>E -15 + 0.23 vdc</td>
<td>vdc</td>
<td>&lt;50 mv</td>
</tr>
<tr>
<td>N</td>
<td>E +30 + 0.9 vdc</td>
<td>vdc</td>
<td>&lt;50 mv</td>
</tr>
<tr>
<td>T</td>
<td>E +100 + 3 vdc</td>
<td>vdc</td>
<td>&lt;500 mv</td>
</tr>
<tr>
<td>U</td>
<td>E +150 + 4.5 vdc</td>
<td>vdc</td>
<td>&lt;500 mv</td>
</tr>
</tbody>
</table>

4.2.1 Left Segment: 0.630" < L < 0.770"

Separation: 0.630" < L < 0.770"

Right Segment: 0.630" < L < 0.770"

4.2.2 TILT CURSOR length: 0.220" < L < 0.280"

4.2.3 "B" sweep length: 3.32" < L < 3.42"

4.2.4 Light
Fail
Lock-On
In-Range
Excess G's

Illuminates

Check
Check
Check
Check
Check
Check
Check
4.2.4 Cont. Light

4.2.4.1 In-Range Illuminated

4.2.4.2 In-Range (flashing)

4.2.4.3 Excess G's

4.2.5 Art. HORZ. and TILT vary

4.2.6 Brightness varies

4.2.7 Persistence varies

4.2.8 Brightness of overlay varies

4.2.9 Observed Roll angle of 30 + 3°

4.2.9.1 Observed Roll angle of 0 + 2°

4.2.9.2 Art. HORZ. to 0°

4.2.9.3 Art. HORZ. to 0°

4.2.10 Objectionable spoking not present

4.3.2.1 Azimuth frame time: < 2.3 seconds

4.3.2.2 Max. voltage excursions:

> 3.7 volts

= 3.7 volts

4.3.2.3 Recorded trace within 0.2 volts of straight line

ILLUMINATES

Check

Check

Check

Check

Check

Check

Check

Check

Check

Check

Check

Check

Check

Check

Check

Check

Check

Seconds

Volts

Volts

Check
4.3.2.4 Elevation recording for azimuth change from plus to minus: 0 +0.2 volts

minus to plus: 0.3 +0.1 volts

4.3.2.5 Max. excursion: -2.8 +0.26 volts

4.3.2.6 Max. excursion: +2.8 +0.26 volts

4.3.2.7 Max. excursion: > +2.8

4.3.2.12 Max. excursion: > -4 volts

4.3.3.1 Max. excursions: > 2.8 volts

> -3.6 volts

4.3.3.2 Azimuth recording: 0.3 ± 0.1 volts

4.3.4.1 Azimuth recording: 0 ± 0.05 volts

Elevation recording: 0 ± 0.05 volts

4.3.4.2 Azimuth recording: 0 ± 0.05 volts

Elevation recording: 0.44 ± 0.07 volts

4.4.1 Frequency = 9.3 GHz ±0.05 GHz

Pulse Width = .4 ± .04 usec

PRF at J6-c = 2500 ± 175 PPS

4.4.2 RF Power ≥ +46.6 DBM

4.4.3 Sidelobe levels ≥ 8 DB down, from para. 4.2.7 of QAS No. F5E-400-13

9.15 GHz

9.3 GHz

9.45 GHz
<table>
<thead>
<tr>
<th>Paragraph</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.4.4</td>
<td>From para. 4.2.6 of QAS No. F5E-400-13:</td>
</tr>
<tr>
<td></td>
<td>Pulse Width at 9.15 GHz</td>
</tr>
<tr>
<td></td>
<td>Pulse Width at 9.45 GHz</td>
</tr>
<tr>
<td></td>
<td>RF Power at 9.15 GHz</td>
</tr>
<tr>
<td></td>
<td>RF Power at 9.45 GHz</td>
</tr>
<tr>
<td>4.4.5</td>
<td>AFC Voltage at J6-D -4.5 ± .5 Volts</td>
</tr>
<tr>
<td>4.6.1</td>
<td>Receiver MDS: at least -97 dBM</td>
</tr>
<tr>
<td></td>
<td>Indicator MDS: at least -99 dBM</td>
</tr>
<tr>
<td>4.6.1.1</td>
<td>Lock-On 5 ± 2 dB above Indicator MDS</td>
</tr>
<tr>
<td>4.6.2</td>
<td>Dynamic Range, from para. 4.6.1 of QAS No. F5E-400-13 ( &gt; 80 dBM)</td>
</tr>
<tr>
<td>4.6.3</td>
<td>Video Control Functional</td>
</tr>
</tbody>
</table>
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 ± 0.062 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 Voltage

<table>
<thead>
<tr>
<th>Range</th>
<th>Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>600 ft.</td>
<td>0.6 ± 0.05 vdc</td>
</tr>
<tr>
<td>1,000 ft.</td>
<td>1.0 ± 0.05 vdc</td>
</tr>
<tr>
<td>2,000 ft.</td>
<td>2.0 ± 0.05 vdc</td>
</tr>
<tr>
<td>3,000 ft.</td>
<td>3.0 ± 0.06 vdc</td>
</tr>
<tr>
<td>7,500 ft.</td>
<td>7.5 ± 0.15 vdc</td>
</tr>
<tr>
<td>15,000 ft.</td>
<td>15 ± 0.3 vdc</td>
</tr>
<tr>
<td>30,000 ft.</td>
<td>30 ± 0.6 vdc</td>
</tr>
<tr>
<td>60,000 ft.</td>
<td>60 ± 1.2 vdc</td>
</tr>
</tbody>
</table>

#### 4.6.9 Target Range Rate Voltage

<table>
<thead>
<tr>
<th>Velocity</th>
<th>Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 ft./sec</td>
<td>0 ± 0.05 vdc</td>
</tr>
<tr>
<td>Closing 1000 ft/sec.</td>
<td>+5 ± 0.15 vdc</td>
</tr>
<tr>
<td>Closing 2000 ft/sec.</td>
<td>+10 ± 0.45 vdc</td>
</tr>
<tr>
<td>Closing 3000 ft/sec.</td>
<td>+15 ± 0.45 vdc</td>
</tr>
<tr>
<td>Opening 1000 ft/sec.</td>
<td>-5 ± 0.15 VDC</td>
</tr>
</tbody>
</table>

#### 4.6.10 Memory Time

<table>
<thead>
<tr>
<th>Time (sec)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.75 ± 0.15 vdc</td>
<td>sec</td>
</tr>
</tbody>
</table>

**4.6.10.1 Range Rate Voltage Constant Check**

**4.6.11.1 Time ( < .5 sec) Check**

**4.6.12.1 Lock-On Light illuminated Check**

**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: Check

No lock-on while held, lock-on when released.

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

4.6.12.22 Target video disappears: Check

Antenna in proper position: Check
<table>
<thead>
<tr>
<th>Applicable Paragraph</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.6.13</td>
<td>AIM BAR in scribed circle Check</td>
</tr>
<tr>
<td>4.6.13.1</td>
<td>AIM BAR up (0.9 \pm 0.2) inches from center Check</td>
</tr>
<tr>
<td>4.6.13.2</td>
<td>AIM BAR down (1.1 \pm 0.2) inches from center Check</td>
</tr>
<tr>
<td>4.6.13.3</td>
<td>Range Gate locked-on 5 mile target: Check</td>
</tr>
<tr>
<td></td>
<td>TILT CURSOR disappears Check</td>
</tr>
<tr>
<td></td>
<td>AIM BAR present Check</td>
</tr>
<tr>
<td></td>
<td>El. Phase control position AIM BAR: Check</td>
</tr>
<tr>
<td></td>
<td>AZ. Phase control position AIM BAR: Check</td>
</tr>
<tr>
<td>4.6.13.4.1</td>
<td>Artificial Horizon at (-20 \pm 3^\circ) Check</td>
</tr>
<tr>
<td>4.6.13.4.2</td>
<td>Artificial Horizon at (+20 \pm 3^\circ) Check</td>
</tr>
<tr>
<td>4.6.13.4.3</td>
<td>Artificial Horizon at (-20 \pm 3^\circ) Check</td>
</tr>
<tr>
<td></td>
<td>Artificial Horizon CCW (30 \pm 3^\circ) Check</td>
</tr>
<tr>
<td>4.6.13.4.4</td>
<td>Tilt Cursor at (-17.3 \pm 3^\circ) Check</td>
</tr>
<tr>
<td>4.6.13.4.5</td>
<td>Artificial Horizon at (+20 \pm 3^\circ) Check</td>
</tr>
<tr>
<td></td>
<td>Artificial Horizon CW (30 \pm 3^\circ) Check</td>
</tr>
<tr>
<td>4.6.13.4.6</td>
<td>Tilt Cursor at (+17.3 \pm 3^\circ) Check</td>
</tr>
<tr>
<td>4.7</td>
<td>FAIL light OFF Check</td>
</tr>
<tr>
<td>4.7.1</td>
<td>TILT CURSOR AT (0^\circ) Check</td>
</tr>
<tr>
<td></td>
<td>J6-B position voltage (-3 \pm 0.3) Volts</td>
</tr>
<tr>
<td>4.7.2</td>
<td>Lock-On light illuminates Check</td>
</tr>
<tr>
<td></td>
<td>FAIL light extinguished Check</td>
</tr>
<tr>
<td>4.7.3</td>
<td>TILT CURSOR Down (\approx 5^\circ) Check</td>
</tr>
<tr>
<td>4.7.4</td>
<td>TILT CURSOR up (20^\circ) Check</td>
</tr>
<tr>
<td></td>
<td>Tracking Gate strobing outward: Check</td>
</tr>
</tbody>
</table>
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 \( \pm \) 0.010 VDC/Degree VDC/Degree

4.8.2.5

| #1 | | |
| #2 | | |
| #3 | | |
| #4 | | |

4.8.2.6 Angle Scale Factor -0.1 \( \pm \) 0.010 VDC/Degree VDC/Degree

4.8.3 Az (J6A) .233 \( \pm \) .05 VPP
El (J6B) .325 \( \pm \) .05 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 ± .3 V Peak-to-Peak | VPP
4.9.12 6.0 ± .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

SIZE | CODE IDENT NO.
--- | ---
A | 20418

NAS 1000-1

SD FORM 481-2 AUG 64 (2C)
<table>
<thead>
<tr>
<th>Applicable Paragraph</th>
<th>Data</th>
<th>Check</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.9.14.3</td>
<td>MSL ACQ display</td>
<td></td>
</tr>
<tr>
<td>4.9.14.4</td>
<td>5 NM Light</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 NM Light</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 NM Light</td>
<td></td>
</tr>
<tr>
<td>4.9.14.5</td>
<td>Lock-On Display</td>
<td></td>
</tr>
<tr>
<td>4.9.15.1</td>
<td>ACQ symbols stowed</td>
<td></td>
</tr>
<tr>
<td>4.9.15.3</td>
<td>Video displayed between symbols</td>
<td></td>
</tr>
<tr>
<td>4.9.15.4</td>
<td>Lock-On Display</td>
<td></td>
</tr>
<tr>
<td>4.9.15.5</td>
<td>2-Bar Scan</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Target displayed</td>
<td></td>
</tr>
<tr>
<td>4.9.15.6</td>
<td>System searches</td>
<td></td>
</tr>
<tr>
<td>4.9.15.7</td>
<td>System in DOGFIGHT Mode</td>
<td></td>
</tr>
<tr>
<td>Applicable Paragraph</td>
<td>Data</td>
<td></td>
</tr>
<tr>
<td>----------------------</td>
<td>-------------------------------</td>
<td></td>
</tr>
<tr>
<td>4.10.2</td>
<td>2.15 ± .45 VDC</td>
<td></td>
</tr>
<tr>
<td>4.10.3</td>
<td>2.15 ± .45 VDC</td>
<td></td>
</tr>
<tr>
<td>4.10.5</td>
<td>Less than 1.0 VDC</td>
<td></td>
</tr>
<tr>
<td>4.10.6</td>
<td>Less than 1.0 VDC</td>
<td></td>
</tr>
<tr>
<td>4.11.3.2</td>
<td>Reference Only AZ mr</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reference Only EL mr</td>
<td></td>
</tr>
<tr>
<td>4.11.4.2</td>
<td>Lock-On Light Check</td>
<td></td>
</tr>
<tr>
<td>4.11.4.3</td>
<td>0.050 VDC max AZ VDC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.050 VDC max EL VDC</td>
<td></td>
</tr>
<tr>
<td>4.11.4.4</td>
<td>0.25 VDC max AZ VDC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.25 VDC max EL VDC</td>
<td></td>
</tr>
<tr>
<td>4.12</td>
<td>System Weight less than 125 lbs</td>
<td></td>
</tr>
</tbody>
</table>

```
<table>
<thead>
<tr>
<th>SIZE</th>
<th>CODE IDENT NO.</th>
<th>NAS 1000-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>20418</td>
<td></td>
</tr>
</tbody>
</table>

SD FORM 481-2 AUG 64 (2C)
**Revised Pages for Revision A.**

<table>
<thead>
<tr>
<th>LTR</th>
<th>DESCRIPTION</th>
<th>DATE</th>
<th>APPROVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Correct ATP</td>
<td>6-26-74</td>
<td>2/1</td>
</tr>
</tbody>
</table>

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

**EMERSON**

**NAS-9-13695**

**SCALE: NONE**

**NAS-1000-1**

**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., 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 -
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 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).
4.9.10 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. \( Z \pm .2 \, \text{V} \)

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. \( 4.7 \pm .2 \, \text{V} \)

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.
4.10 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 $\pm$ .3 V DC

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 $\pm$ .3 V DC

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 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.
5.0 DATA SHEETS

Applicable Paragraph

4.8.1.1 Ground Return Video and Cursors Appear

4.8.1.2 Video and Cursors disappear
FAIL light ON

4.8.1.3 Video and Cursors Appear
FAIL light OFF

4.8.2.2 Recorder Angle Voltage

4.8.2.3 Angle Scale Factor 0.1 ± 0.010 VDC/Degree

4.8.2.5 Angle Scale Factor

4.8.2.6 Angle Scale Factor -0.1 ± 0.010 VDC/Degree

4.8.3 Az (J6A) .233 ± .05 VPP
El (J6B) .325 ± .05 VPP

4.8.4 Az Rate Output

4.8.5 El Rate Output

<table>
<thead>
<tr>
<th>Recorder Angle</th>
<th>Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td></td>
</tr>
<tr>
<td>#2</td>
<td></td>
</tr>
<tr>
<td>#3</td>
<td></td>
</tr>
<tr>
<td>#4</td>
<td></td>
</tr>
<tr>
<td>#1</td>
<td></td>
</tr>
<tr>
<td>#2</td>
<td></td>
</tr>
<tr>
<td>#3</td>
<td></td>
</tr>
<tr>
<td>#4</td>
<td></td>
</tr>
<tr>
<td>#1</td>
<td></td>
</tr>
<tr>
<td>#2</td>
<td></td>
</tr>
<tr>
<td>#3</td>
<td></td>
</tr>
<tr>
<td>#4</td>
<td></td>
</tr>
</tbody>
</table>

PRECEDING PAGE BLANK NOT FILMED
<table>
<thead>
<tr>
<th>Paragraphs</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.9.1</td>
<td>Symbols Stowed</td>
</tr>
<tr>
<td>4.9.2</td>
<td>Symbols Stowed</td>
</tr>
<tr>
<td>4.9.3</td>
<td>Symbol at same position</td>
</tr>
<tr>
<td>4.9.4</td>
<td>No Change in position</td>
</tr>
<tr>
<td>4.9.5</td>
<td>Symbol visible at left azimuth</td>
</tr>
<tr>
<td>4.9.6</td>
<td>Antenna positionable</td>
</tr>
<tr>
<td>4.9.9.1</td>
<td>6.08 ± 0.30 VDC</td>
</tr>
<tr>
<td>4.9.9.2</td>
<td>12.16 ± 0.6 VDC</td>
</tr>
<tr>
<td>4.9.9.3</td>
<td>18.24 ± 0.90 VDC</td>
</tr>
<tr>
<td>4.9.9.4</td>
<td>24.32 ± 1.2 VDC</td>
</tr>
<tr>
<td>4.9.9.5</td>
<td>30.4 ± 1.5 VDC</td>
</tr>
<tr>
<td>4.9.11</td>
<td>30.4 ± 1.5 VDC</td>
</tr>
<tr>
<td>4.9.12</td>
<td>6.0 ± 0.6 VDC</td>
</tr>
<tr>
<td>4.9.13</td>
<td>Aim Bar follows target</td>
</tr>
<tr>
<td>4.9.14.1</td>
<td>ACQ symbols disappear</td>
</tr>
<tr>
<td>4.9.14.2</td>
<td>Same as MSL display</td>
</tr>
</tbody>
</table>
4.10.2  2.15 ± 0.45 VDC  1.55 ± 0.3
4.10.3  2.15 ± 0.45 VDC  1.55 ± 0.3
4.10.5  Less than 1.0 VDC
4.10.6  Less than 1.0 VDC
4.11.3.2  Reference Only  AZ
          Reference Only  EL
4.11.4.2  Lock-On Light
4.11.4.3  0.050 VDC max  AZ
          0.050 VDC max  EL
4.11.4.4  0.25 VDC max  AZ
          0.25 VDC max  EL
4.12     System Weight less than 125 lbs

PRECEDING PAGE BLANK NOT FILMED
DATA

D.1 DRAWING LIST

D.2 TECH ORDER LIST

D.3 ATP DATA
<table>
<thead>
<tr>
<th>DRAWING NO.</th>
<th>TITLE</th>
<th>SHEET NO.</th>
<th>P/L</th>
<th>R/D</th>
</tr>
</thead>
<tbody>
<tr>
<td>656900</td>
<td>System</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>901</td>
<td>Interconnect</td>
<td>1-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>902</td>
<td>Simulator Panel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>910</td>
<td>Antenna LRU</td>
<td>1, 2</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>911</td>
<td>Nameplate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>912</td>
<td>Bracket</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>913</td>
<td>Bracket</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>914</td>
<td>Retainer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>920</td>
<td>Set Control LRU</td>
<td>1, 2</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>921</td>
<td>Nameplate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>922</td>
<td>Circuit Board</td>
<td>1, 2</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>923</td>
<td>Circuit Board</td>
<td>1, 2</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>924</td>
<td>Circuit Board</td>
<td>1, 2</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>925</td>
<td>Bracket</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>940</td>
<td>Indicator LRU</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>941</td>
<td>Nameplate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>950</td>
<td>Receiver/Transmitter LRU</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>951</td>
<td>Nameplate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>955</td>
<td>Flexguide</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>960</td>
<td>Processor LRU</td>
<td>1, 2</td>
<td>X</td>
<td>(Wire List)</td>
</tr>
<tr>
<td>961</td>
<td>Nameplate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>962</td>
<td>Plate, Locator</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>971</td>
<td>Circuit Board A1</td>
<td>1, 2</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>972</td>
<td>A2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>973</td>
<td>A3</td>
<td>1, 2</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>974</td>
<td>A4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>975</td>
<td>A5</td>
<td>1, 2</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>976</td>
<td>A6</td>
<td>1, 2</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>977</td>
<td>A7</td>
<td>1, 2</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>978</td>
<td>A8</td>
<td>1, 2</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>979</td>
<td>A9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>980</td>
<td>A10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>981</td>
<td>A11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>982</td>
<td>A12</td>
<td>1, 2</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>983</td>
<td>A13</td>
<td>1, 2</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>984</td>
<td>A14</td>
<td>1, 2</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>985</td>
<td>A15</td>
<td>1, 2</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>986</td>
<td>A16</td>
<td>1, 2</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>650990</td>
<td>Nameplate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>656991</td>
<td>Nameplate</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
D.3 ACCEPTANCE TEST DATA
## MATERIAL INSPECTION AND RECEIVING REPORT

### SHIPMENT NO. 2

#### 1. PROCUREMENT IDENTIFICATION NO.

NAS 9-13695

#### 2. DATE SHIPPED


#### 3. BILL OF LADING NO.


#### 4. TON


#### 5. DISCOUNT TERMS

Net 10 Days

### PRIME CONTRACTOR

Emerson Electric Co.  
100 Florissant Ave.  
St. Louis, Mo. 63136

### SHIPPED FROM (if other than 2) CODE

See Block 9

### SHIPPED TO

Transportation Officer  
Bldg. 420  
NASA Lyndon B. Johnson Space Center, Texas

### FOB: CODE

D

### FOB: D

NASA Johnson Space Center  
Houston, Texas 77058

### 10. ADMINISTERED BY CODE

Accountable Property Officer 887402  
Purchase Request No. 3-102-009  
Contract No. NAS 9-13695  
For reissue to: Allen R. Cunningham EE6 14 113

### 11. STOCK/PART NO.

656900-301

### 12. DESCRIPTION

Emerson AN/APQ-153 Fire Control Radar, modified to include angle tracking capability.

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.

### PROCUREMENT QUALITY ASSURANCE

A. ORIGIN

B. DESTINATION

### 13. QUANTITY SHIP/REC'D

1 ea.

### 14. AMOUNT

1 ea.

### 15. QUANTITY SHIP/REC'D

1 ea.

### 16. UNIT PRICE

### 17. UNIT

### 18. UNIT

### 19. AMOUNT

### 20. AMOUNT

### 21. RECEIIVER'S USE

Quantities shown in column 17 were received in apparent good condition except as noted.

### 22. SIGNATURE OF AUTH GOVT REP

Allen R. Cunningham  
ST. LOUIS, MO. 63130

### 23. GROSS WEIGHT

### 24. PO/M/EPO No.

EPO-5658

### 25. LEVEL

C/C

### 26. ELECTRONICS AND SPACE DIVISION

Emerson Electric Co.  
100 Florissant  
ST. LOUIS, MISSOURI 63130

### 27. PREVIOUS EDITIONS ARE OBSOLETE.
I.

As required by applicable paragraphs of Section 4 of these procedures.

**TEST EQUIPMENT USED.**

<table>
<thead>
<tr>
<th>Instrument</th>
<th>MFR / Model</th>
<th>Next Calibration Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dummy Load</td>
<td></td>
<td>6-1-73</td>
</tr>
<tr>
<td>Recorder</td>
<td></td>
<td>9-1-73</td>
</tr>
<tr>
<td>Electronic Counter</td>
<td>N/A</td>
<td>6-1-73</td>
</tr>
<tr>
<td>Microwave Amplifier</td>
<td>N/A</td>
<td>6-1-73</td>
</tr>
<tr>
<td>Spectrum Analyzer</td>
<td>N/A</td>
<td>6-1-73</td>
</tr>
<tr>
<td>Variable Attenuator</td>
<td>N/A</td>
<td>6-1-73</td>
</tr>
<tr>
<td>Power Meter</td>
<td>N/A</td>
<td>6-1-73</td>
</tr>
<tr>
<td>Power Head</td>
<td></td>
<td>6-1-73</td>
</tr>
<tr>
<td>Directional Coupler 20 DB</td>
<td></td>
<td>6-1-73</td>
</tr>
<tr>
<td>Frequency Meter (X Band)</td>
<td>N/A</td>
<td>6-1-73</td>
</tr>
<tr>
<td>Detector</td>
<td>N/A</td>
<td>6-1-73</td>
</tr>
<tr>
<td>Oscilloscope</td>
<td></td>
<td>6-1-73</td>
</tr>
<tr>
<td>Pulse Generator</td>
<td></td>
<td>6-1-73</td>
</tr>
<tr>
<td>RF Generator</td>
<td></td>
<td>6-1-73</td>
</tr>
<tr>
<td>Voltmeter</td>
<td></td>
<td>6-1-73</td>
</tr>
<tr>
<td>50 DB Isolator</td>
<td></td>
<td>6-1-73</td>
</tr>
<tr>
<td>10 DB Directional Coupler</td>
<td></td>
<td>6-1-73</td>
</tr>
<tr>
<td>Dynamic Range Simulator</td>
<td>533339-1 S/N</td>
<td>6-26-73</td>
</tr>
<tr>
<td>Target Simulator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure Test Set</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System Test Bench</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Test Set Control of Processor, Antenna, Indicator, Xmit/RCVR, Set Control**

<table>
<thead>
<tr>
<th>Processor</th>
<th>Antenna</th>
<th>Indicator</th>
<th>Xmit/RCVR</th>
<th>Set Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>160</td>
<td>148</td>
<td>170</td>
<td>170</td>
<td>0.42</td>
</tr>
</tbody>
</table>

**PRECEDING PAGE BLANK NOT FILMED**
4.1.6 Antenna approximately straight ahead
Fail light not illuminated
ART, ESS, and TILT CURSOR displayed
XMTR READY time

4.1.7 Antenna searching full azimuth pattern:
FAIL light illuminated
"E" scan displayed:

4.1.8

<table>
<thead>
<tr>
<th>J-7 Pin</th>
<th>J-7 RTN</th>
<th>Measured Value</th>
<th>Measured Ripple</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>V 115 + 2 vac</td>
<td>115 vac</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>V 115 + 2 vac</td>
<td>115 vac</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>V 115 + 2 vac</td>
<td>115 vac</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>X 28 + 1 vdc</td>
<td>28 vdc</td>
<td></td>
</tr>
<tr>
<td>Q</td>
<td>E +5 ± 0.15 vdc</td>
<td>5.025 vdc</td>
<td>&lt;50 mv Check</td>
</tr>
<tr>
<td>Y</td>
<td>E -5 ± 0.15 vdc</td>
<td>4.975 vdc</td>
<td>&lt;50 mv Check</td>
</tr>
<tr>
<td>F</td>
<td>E +15 ± 0.23 vdc</td>
<td>15.003 vdc</td>
<td>&lt;50 mv Check</td>
</tr>
<tr>
<td>D</td>
<td>E -15 ± 0.23 vdc</td>
<td>14.997 vdc</td>
<td>&lt;50 mv Check</td>
</tr>
<tr>
<td>N</td>
<td>E +30 ± 0.9 vdc</td>
<td>30.023 vdc</td>
<td>&lt;50 mv Check</td>
</tr>
<tr>
<td>T</td>
<td>E +100 ± 3 vdc</td>
<td>101.023 vdc</td>
<td>&lt;500 mv Check</td>
</tr>
<tr>
<td>U</td>
<td>E +150 ± 4.5 vdc</td>
<td>151.025 vdc</td>
<td>&lt;500 mv Check</td>
</tr>
</tbody>
</table>

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 "H" sweep length: 3.32 < L < 3.42
Illuminates

4.2.4 Light
Fail
Check
Lock-On
Check
In-Range
Check
Excess G's
Check
<table>
<thead>
<tr>
<th>Applicable Paragraph</th>
<th>Data</th>
<th>ILLUMINATES</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.2.4 Cont. Light</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 mile</td>
<td>Check</td>
<td></td>
</tr>
<tr>
<td>10 mile</td>
<td>Check</td>
<td></td>
</tr>
<tr>
<td>20 mile</td>
<td>Check</td>
<td></td>
</tr>
<tr>
<td>4.2.4.1 In-Range Illuminated</td>
<td></td>
<td>Check</td>
</tr>
<tr>
<td>4.2.4.2 In-Range (flashing)</td>
<td></td>
<td>Check</td>
</tr>
<tr>
<td>4.2.4.3 Excess G's</td>
<td>Check</td>
<td></td>
</tr>
<tr>
<td>4.2.5 Art. HORZ. and TILT vary</td>
<td></td>
<td>Check</td>
</tr>
<tr>
<td>4.2.6 Brightness varies</td>
<td></td>
<td>Check</td>
</tr>
<tr>
<td>4.2.7 Persistance varies</td>
<td></td>
<td>Check</td>
</tr>
<tr>
<td>4.2.8 Brightness of overlay varies</td>
<td></td>
<td>Check</td>
</tr>
<tr>
<td>4.2.9 Observed Roll angle of $30^\circ \pm 3^\circ$</td>
<td></td>
<td>Check</td>
</tr>
<tr>
<td>4.2.9.1 Observed Pitch angle of $0^\circ \pm 2^\circ$</td>
<td></td>
<td>Check</td>
</tr>
<tr>
<td>4.2.9.2 Art. Horz. to $0^\circ$</td>
<td></td>
<td>Check</td>
</tr>
<tr>
<td>4.2.9.3 Art. HORZ. to $0^\circ$</td>
<td></td>
<td>Check</td>
</tr>
<tr>
<td>4.2.10 Objectionable spoking not present</td>
<td></td>
<td>Check</td>
</tr>
<tr>
<td>4.3.2.1 Azimuth frame time: $&lt; 2.3$ seconds</td>
<td>3.23</td>
<td>Seconds</td>
</tr>
<tr>
<td>4.3.2.2 Max. voltage excursions: $&gt; \pm 3.7$ volts</td>
<td>$+ 3.7$ $- 3.7$ Volts</td>
<td></td>
</tr>
<tr>
<td>4.3.2.3 Recorded trace within 0.2 volts of straight line</td>
<td></td>
<td>Check</td>
</tr>
<tr>
<td>Paragraph</td>
<td>Data</td>
<td>Volts</td>
</tr>
<tr>
<td>---------------</td>
<td>---------------------------------------------------------------------</td>
<td>----------</td>
</tr>
<tr>
<td>4.3.2.4</td>
<td>Elevation recording for azimuth change from plus to minus: 0 +0.2 volts minus to plus: 0.3 +0.1 volts</td>
<td>0.25</td>
</tr>
<tr>
<td>4.3.2.5</td>
<td>Max. excursion: -2.8 +0.26 volts</td>
<td>-2.8</td>
</tr>
<tr>
<td>4.3.2.6</td>
<td>Max. excursion: +2.8 +0.26 volts</td>
<td>2.8</td>
</tr>
<tr>
<td>4.3.2.7</td>
<td>Max. excursion: &gt; +2.8</td>
<td>2.8</td>
</tr>
<tr>
<td>4.3.2.12</td>
<td>Max. excursion: &gt; -4 volts</td>
<td>4.1</td>
</tr>
<tr>
<td>4.3.3.1</td>
<td>Max. excursions: &gt; +2.8</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-3.6</td>
</tr>
<tr>
<td>4.3.3.2</td>
<td>Azimuth recording: 0.3 + 0.1 volts</td>
<td>0.3</td>
</tr>
<tr>
<td>4.3.4.1</td>
<td>Azimuth recording: 0 + 0.05 volts</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Elevation recording: 0 + 0.05 volts</td>
<td>0</td>
</tr>
<tr>
<td>4.3.4.2</td>
<td>Azimuth recording: 0 + 0.05 volts</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Elevation recording: 0.44 + 0.07 volts</td>
<td>0.4</td>
</tr>
<tr>
<td>4.4.1</td>
<td>Frequency = 9.3 GHz +0.05 GHz</td>
<td>9.3</td>
</tr>
<tr>
<td></td>
<td>Pulse Width = .4 + .04 usec</td>
<td>.39</td>
</tr>
<tr>
<td></td>
<td>PRF at J6-6 = 2500 + 175 PPS</td>
<td>2513</td>
</tr>
<tr>
<td>4.4.2</td>
<td>RF Power ≥ 46.6 DBM</td>
<td>46.6</td>
</tr>
<tr>
<td>4.4.3</td>
<td>Sidelobe levels &gt; 8 DB down, from para. 4.2.7 of QAS No. F59-400-13</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>9.15 GHz</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>9.3 GHz</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>9.45 GHz</td>
<td></td>
</tr>
</tbody>
</table>
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: 46.8 DBM
- RF Power at 9.45 GHz: 46.5 DBM

4.4.5 AFC Voltage at J6-D: -4.5 ± 5 Volts

4.6.1 Receiver MDS: at least -97 dBM
Indicator MDS: at least -99 dBM

4.6.1.1 Lock-On 5 ± 2 dB above Indicator MDS

4.6.2 Dynamic Range, from para. 4.6.1 of QAS No. F5E-400-13 (> 80 dBM)

4.6.3 Video Control Functional

---

Cable 4.2 dB
Direction 11.2 dB
Summing on 610 88.2 dB

\[
\text{DBM} = 10 \log_{10} \left( \frac{P_1}{P_0} \right)
\]

\[
L_{\text{ref}} = 10 \log_{10} \left( \frac{P_2}{P_1} \right)
\]

\[
P_1 = 10 \log_{10} \left( \frac{V_1^2}{R_1} \right)
\]

\[
P_2 = 10 \log_{10} \left( \frac{V_2^2}{R_2} \right)
\]

---

SIZE CODE IDENT NO. A 20418
SCALE REV SHEET 1
<table>
<thead>
<tr>
<th>Applicable Paragraph</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.6.5.1</td>
<td>5 mile Range light illuminated: Check</td>
</tr>
<tr>
<td></td>
<td>4 mile target properly displayed (+.2 inches) Check</td>
</tr>
<tr>
<td>4.6.5.2</td>
<td>10 mile Range light illuminated: Check</td>
</tr>
<tr>
<td></td>
<td>4 mile target properly displayed (+.2 inches) Check</td>
</tr>
<tr>
<td>4.6.5.3</td>
<td>20 mile Range light illuminated: Check</td>
</tr>
<tr>
<td></td>
<td>4 mile target properly displayed (+.2 inches) Check</td>
</tr>
<tr>
<td>4.6.6.1</td>
<td>4 miles + 0.135 inches 0.05 Inches</td>
</tr>
<tr>
<td>4.6.6.2</td>
<td>8 miles + 0.135 inches 0 Inches</td>
</tr>
<tr>
<td>4.6.6.3</td>
<td>16 miles + 0.135 inches 0 Inches</td>
</tr>
<tr>
<td>4.6.7</td>
<td>Jizzled sweep to left, and track gate sweeping min. to max range Check</td>
</tr>
<tr>
<td>4.6.7.1</td>
<td>Track gate bars each 0.125 + 0.062 inches Left bar 1/2 Inches Right Bar 1/1 Inches</td>
</tr>
<tr>
<td>4.6.7.2</td>
<td>Jizzled sweep is 0.4 + 0.1 inches wide 3/4 Inches</td>
</tr>
<tr>
<td>4.6.7.3</td>
<td>Center of sweep is left 0.80 + 0.13 inches 8 Inches</td>
</tr>
</tbody>
</table>
4.6.12.2 cont. Target

Range Gate Strobe Outward:

5 Mile Range Light illuminates:  
Check

4.6.12.3  Lock-On light illuminates:  
Check

4.6.12.4  Lock-On light remains illuminated:

AIM BAR displayed:  
Check

4.6.12.5  Range gate strobing outward:

4.6.12.6  Range gate strobing outward:

4.6.12.7  Range gate strobing outward:

4.6.12.8  5 mile light illuminated:

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

4.6.12.22  Target video disappears:

Check

Antenna in proper position:  
Check

PRECEDING PAGE BLANK NOT FILMED

SIZE  CODE IDENT NO.  NAS 1000-1
A  20418

SCALE  REV  SHEET 41
Data

4.6.13 AIM BAR in scribed circle

4.6.13.1 AIM BAR up .9 ± 0.2 inches from center

4.6.13.2 AIM BAR down 1.1 ± 0.2 inches from center

4.6.13.3 Range Gate locked-on 5 mile target:

TILT CURSOR disappears

AIM BAR present

El. Phase control position AIM BAR:

AZ. Phase control position AIM BAR:

4.6.13.4.1 Artificial Horizon at -20 ± 3°

4.6.13.4.2 Artificial Horizon at +20 ± 3°

4.6.13.4.3 Artificial Horizon at -20 ± 3°

Artificial Horizon CCW 30 ± 3°

4.6.13.4.4 Tilt Cursor at -17.3 ± 3°

4.6.13.4.5 Artificial Horizon at +20 ± 3°

Artificial Horizon CW 30 ± 3°

4.6.13.4.6 Tilt Cursor at +17.3 ± 3°

4.7 FAIL light OFF

4.7.1 TILT CURSOR AT 0°

J6-B position voltage -3 ± .3V

4.7.2 Lock-On light illuminates

FAIL light extinguished

4.7.3 TILT CURSOR Down ± 5°

4.7.4 TILT CURSOR up 20°

Tracking Gate strobing outward:

Check

Check

Check

Check

Check

Check

Check

Check

Check

Check

Check

Check

Check

Vols
5.0 DATA SHEETS

<table>
<thead>
<tr>
<th>Applicable Paragraph</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.8.1.1</td>
<td>Ground Return Video and Cursors Appear</td>
</tr>
<tr>
<td>4.8.1.2</td>
<td>Video and Cursors disappear</td>
</tr>
<tr>
<td></td>
<td>FAIL light ON</td>
</tr>
<tr>
<td>4.8.1.3</td>
<td>Video and Cursors Appear</td>
</tr>
<tr>
<td></td>
<td>FAIL light OFF</td>
</tr>
<tr>
<td>4.8.2.2</td>
<td>Recorder Angle</td>
</tr>
<tr>
<td>#1</td>
<td>31°</td>
</tr>
<tr>
<td>#2</td>
<td>12.3°</td>
</tr>
<tr>
<td>#3</td>
<td>14°</td>
</tr>
<tr>
<td>#4</td>
<td>22°</td>
</tr>
<tr>
<td>4.8.2.3</td>
<td>Angle Scale Factor 0.1 ± 0.010 VDC/Degree</td>
</tr>
<tr>
<td>4.8.2.5</td>
<td>Angle Scale Factor -0.1 ± 0.010 VDC/Degree</td>
</tr>
<tr>
<td>4.8.3</td>
<td>Az (J6A) .233 ± .05 VPP</td>
</tr>
<tr>
<td></td>
<td>El (J6B) .325 ± .05 VPP</td>
</tr>
<tr>
<td>4.8.4</td>
<td>Az Rate Output</td>
</tr>
<tr>
<td></td>
<td>El Rate Output</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recorder Angle</th>
<th>Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>31°</td>
<td>3.832</td>
</tr>
<tr>
<td>12.3°</td>
<td>1.11</td>
</tr>
<tr>
<td>14°</td>
<td>1.14</td>
</tr>
<tr>
<td>22°</td>
<td>1.90</td>
</tr>
<tr>
<td>13.9°</td>
<td>1.374</td>
</tr>
<tr>
<td>5.1°</td>
<td>0.93</td>
</tr>
<tr>
<td>8.1°</td>
<td>0.75</td>
</tr>
<tr>
<td>15.5°</td>
<td>1.50</td>
</tr>
</tbody>
</table>

4.8.4 Az Rate Output  
4.8.5 El Rate Output  

---

SIZE CODE IDENT NO.  NAS 1000-1
A 20418
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 $6.08 \pm 0.30 \text{ VDC}$ | $6 \text{ VDC}$
$12.16 \pm 0.6 \text{ VDC}$ | $12 \text{ VDC}$
4.9.9.2 $12.16 \pm 0.6$ | $12 \text{ VDC}$
$24.32 \pm 1.2$ | $24 \text{ VDC}$
4.9.9.3 $18.24 \pm 0.90$ | $18 \text{ VDC}$
$36.48 \pm 1.8$ | $36 \text{ VDC}$
4.9.9.4 $24.32 \pm 1.2$ | $24 \text{ VDC}$
$48.64 \pm 2.4$ | $48 \text{ VDC}$
4.9.9.5 $30.4 \pm 1.5$ | $30 \text{ VDC}$
$60.8 \pm 3.0$ | $60 \text{ VDC}$
4.9.11 $3.0 \pm .3 \text{ V Peak-to-Peak}$ | $3.1 \text{ VPP}$
4.9.12 $6.0 \pm .6 \text{ V Peak-to-Peak}$ | $6.1 \text{ VPP}$
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
<table>
<thead>
<tr>
<th>Applicable Paragraph</th>
<th>Data</th>
<th>Check</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.9.14.3</td>
<td>MSL ACQ display</td>
<td>✓</td>
</tr>
<tr>
<td>4.9.14.4</td>
<td>5 NM Light</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>10 NM Light</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>10 NM Light</td>
<td>✓</td>
</tr>
<tr>
<td>4.9.14.5</td>
<td>Lock-On Display</td>
<td>✓</td>
</tr>
<tr>
<td>4.9.15.1</td>
<td>ACQ symbols stowed</td>
<td>✓</td>
</tr>
<tr>
<td>4.9.15.3</td>
<td>Video displayed between symbols</td>
<td>✓</td>
</tr>
<tr>
<td>4.9.15.4</td>
<td>Lock-On Display</td>
<td>✓</td>
</tr>
<tr>
<td>4.9.15.5</td>
<td>2-Bar Scan</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Target displayed</td>
<td>✓</td>
</tr>
<tr>
<td>4.9.15.6</td>
<td>System searches</td>
<td>✓</td>
</tr>
<tr>
<td>4.9.15.7</td>
<td>System in DOGFIGHT Mode</td>
<td>✓</td>
</tr>
<tr>
<td>Applicable Paragraph</td>
<td>Data</td>
<td></td>
</tr>
<tr>
<td>----------------------</td>
<td>------</td>
<td></td>
</tr>
<tr>
<td>4.10.2</td>
<td>$1.55 \pm 0.3$</td>
<td></td>
</tr>
<tr>
<td>4.10.3</td>
<td>$1.55 \pm 0.3$</td>
<td></td>
</tr>
<tr>
<td>4.10.5</td>
<td>Less than 1.0 VDC</td>
<td></td>
</tr>
<tr>
<td>4.10.6</td>
<td>Less than 1.0 VDC</td>
<td></td>
</tr>
<tr>
<td>4.11.3.2</td>
<td>Reference Only</td>
<td></td>
</tr>
<tr>
<td>4.11.3.2</td>
<td>Reference Only</td>
<td></td>
</tr>
<tr>
<td>4.11.4.2</td>
<td>Lock-On Light</td>
<td></td>
</tr>
<tr>
<td>4.11.4.3</td>
<td>0.050 VDC max</td>
<td></td>
</tr>
<tr>
<td>4.11.4.4</td>
<td>0.25 VDC max</td>
<td></td>
</tr>
<tr>
<td>4.12</td>
<td>System Weight less than 125 lbs</td>
<td></td>
</tr>
</tbody>
</table>

Set Control

Required

Antenna

Process

Indicator

Total: 114.1 lbs

### Notes

- 3.25
- 0.3
- 17.25
- 8.9
- 41.5
- 15.0

**Total:** 114.1 lbs