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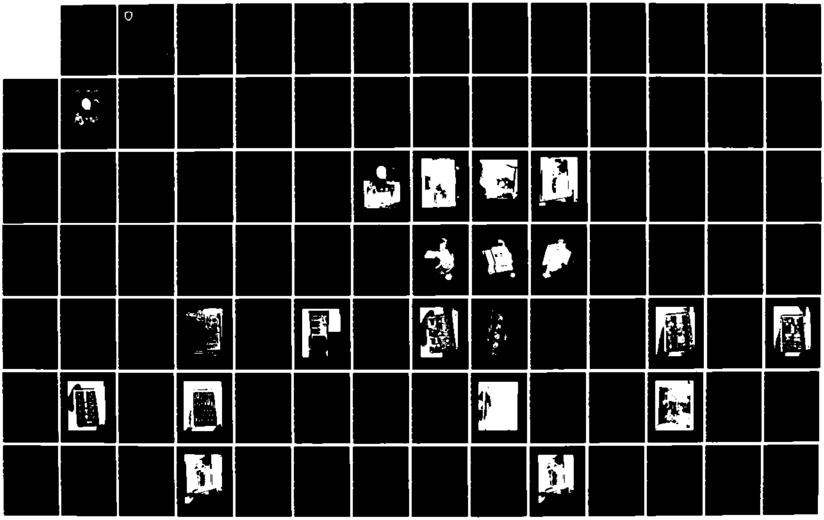

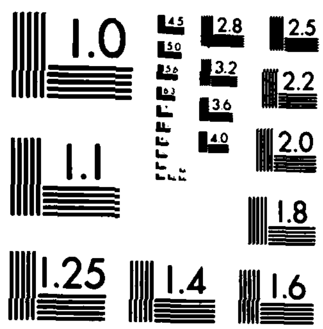
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RDI TASK FINAL REPORT

OF

HAWK VELOCIMETER

BERNARD ST. LOUIS

MATERIEL TESTING DIRECTORATE

US ARMY ABERDEEN PROVING GROUND
ABERDEEN PROVING GROUND, MD 21005

SEPTEMBER 1983

Period Covered:
April 1981 through August 1983

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
The Research and Development of Instrumentation Program at Aberdeen Proving Ground for the fiscal year 1983 is outlined in TECOM Project No. 5-CO-APO-DFW-203, entitled Direct Fire Weapons Instrumentation. This program has several subprojects including the subject of this report, HAWK Velocimeter. The design, development, and testing of the system was accomplished by the Materiel Testing Directorate of Aberdeen Proving Ground and the Contractor, Raytheon Co. Certain GFE components have been supplied by US Army Missile Command,

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ABSTRACT

The Research and Development of Instrumentation (RDI) Program at Aberdeen Proving Ground (APG) for the fiscal year 1983 is outlined in TECOM Project No. 5-CO-APO-DFW-203, entitled Direct Fire Weapons Instrumentation. This program has several subprojects including the subject of this report, HAWK Velocimeter. The design, development, and testing of the system was accomplished by the Materiel Testing Directorate of APG and the contractor, Raytheon Co. Certain GFE components have been supplied by US Army Missile Command, Huntsville, AL. A description of the hardware and software used in the HAWK Doppler Velocimeter is included in this report.

FOREWORD

The Materiel Testing Directorate (MTD) of Aberdeen Proving Ground (APG) was responsible for the development and integration of equipments into the HAWK Velocimeters to improve performance and provide maintainability and supportability for the next 10 to 15 years.

Raytheon Co. performed the integration of the transmitter and high voltage power supply and the design, integration, and testing of the receiver, signal and data processor, antenna positioning, and powe. distribution systems.

SECTION 1. BODY

1. BACKGROUND

For a great number of years, the need to know inflight performance of projectiles has been a major factor in the design and development of ammunition and projectiles. Of great importance to range, accuracy, and penetration of projectiles is the velocity and drag of the projectile in its trajectory.

First measurements of muzzle velocity were made by break screens, velocity coils, and field sky screens. Later measurements were made by the use of the radar chronograph and now by the use of tracking radars. A number of systems have been used over the past 20 years, including pulse radar systems. However, pulse radar systems are adversely affected by ground clutter so that only projectiles fired at higher elevations could be tracked.

In 1965-1966 US Army Test and Evaluation Command (TECOM) had a few AN/MPQ-33 HAWK Low Power Illuminators, a continuous wave (CW) radar used in the HAWK Missile Air Defense System, modified to track projectiles and produce a doppler shifted radar return which was directly proportional to the projectile velocity. These systems provided the proving grounds with not only muzzle velocity, but because of their tracking capability, produced a continuous record of the projectile flight to or near impact. The success of these systems prompted TECOM to modify an additional 13 low power illuminators to perform as velocimeters. These modifications were accomplished in 1970 and 1971. Though these systems served the proving grounds well for many years in ammunition and projectile testing, the systems had been replaced in the HAWK Air Defense System by the high power illuminator, and the low power illuminator transmitter, receiver, tracking systems, and power supplies were phased out of the depot inventories and the velocimeters became obsolete due to lack of replacement component parts.

Fortunately, the US Army Missile Command (MICOM) began a Product Improvement Program in 1975 to replace the magnetron-based transmitter and its associated high voltage power supply in the Improved Continuous Wave Acquisition Radar (ICWAR) with a highly reliable klystron transmitter and newly designed high voltage power supply. Because the pedestals and trailers for the ICWAR and the LPI are so closely the same, the ICWAR transmitter was well suited for installation in the velocimeter.

In 1980, the Velocimeter Improvement Program was begun and in 1981, the remaining vacuum tube circuitry throughout the velocimeter was scheduled to be replaced with solid state circuitry.

2. OBJECTIVES

a. To assure maintainability and supportability for the next 10 to 15 years.

b. To increase the antenna tracking rate.

c. To increase the output power and receiver sensitivity to provide greater tracking range.

d. To repair and refurbish antennas, pedestal, trailer, and leveling jacks.

3. DETAILS

3.1 Hardware Environment

The velocimeter consists of five major subsystems and will be addressed in this order:

a. Transmitter.

b. Receiver.

c. Signal data processor.

d. Antenna positioning.

e. Power distribution.

3.1.1 Transmitter

The transmitter is composed of two units, the master oscillator power amplifier (MOPA) and the high voltage power supply (HVPS). Because of the cooling requirements of these items and the higher voltages used in the new transmitter the MOPA has been installed within the Radar Set Group (RSG) as opposed to the old transmitter which, along with its associated electronics chassis, was located directly behind the transmit antenna. The transmitted RF energy is now routed via waveguide and azimuth and elevation rotary couplers to the antenna feed. No liquid cooling is required for the MOPA so the liquid coolant pump, reservoir, and coolant lines have been removed. The air plenum within the RSG has been modified by removing the heaters within the plenum and installing baffles to direct the air flow as required for proper cooling of the various chassis. A complete description of the transmitter is provided in Section 3 of the Annex to this report, pages A-29 to A-70.

3.1.2 Receiver

A totally new receiver design has been developed. Only the cassegrain lens, mutating scanner, and the saturable reactor have been retained from the original configuration. The new receiver is of homodyne design and is located along with the new solid state doppler amplifier and spin motor speed control, directly behind the receiver feed. The doppler frequency is the difference frequency between the transmitted frequency reference and the doppler shifted returned frequency. This signal is then amplified by the doppler amplifier and is routed to the signal data processor via a coaxial cable through the pedestal and azimuth rotary coupler. A complete description of the receiver's subsystem is provided in the Annex, Section 4, pages A-71 to A-85.

3.1.3 Signal Data Processor

The signal data processor (SDP) is located in the upper right section of the RSG and contains some ten modules, controls, display, and test points.

There are three functional groups within the SDP. The first is the Doppler Tracking Unit which provides the radar the capability of tracking targets with velocity between 100 and 10,000 fps and provides the polar error from the scanner motor to the antenna control system. The second group is the AZ/EL Position Readout or data interface. These modules process and store antenna position and error data and provide both analog an digital interfaces for transmission of corrected azimuth and elevation data to off trailer systems. A complete description of the SDP is furnished in the Annex to the report, Section 5, pages A-86 to A-136.

3.1.4 Antenna Control System

The fourth major subsystem is the Antenna Control System, the primary function being positioning the antenna so that the target or projectile will be in or near the center of the radar transmitted beam throughout the trajectory of the projectile. In addition, antenna pointing, search patterns, bird bath and analog and digital outputs of antenna elevation and azimuth position are available. A detailed description of the Antenna Control group is included in Section 7, pages A-140 to A-156 of the Annex.

3.1.5 Power Distribution System

The power distribution system accepts the 416 V, 400 Hz 3-phase primary power and generates and distributes AC and DC power to all units of the velocimeter. The power distribution system is discussed in the Annex, Section 8, pages A-157 to A-159.

3.1.6 Low Voltage Power Supply

To accommodate the new circuitry in the receiver and SDP, low voltage DC power supplies were added. These include 5 V at 20 A and two +15 V 5 A supplies. They are located where the old 250 V and +100 V supplies were located. Description of the low voltage can be found in Section 6, pages A-137 to A-139 of the Annex to this report.

3.1.7 Software

The software of the velocimeter controls the function of the Z8002 central processor and is burned into the Erasable Programmable Read Only Memories (EPROM) of Module ZCPU. There are 14K bytes of code and approximately 0.7K bytes of data tables. 7.5K bytes of Random Access Memory (RAM) are required. A complete description of the software is included in the Annex to this report, Section 9, pages A-160 to A-180.

3.1.8 Radar Interface

The present capability of the velocimeter allows for local, terminal, and off-trailer control of the radar. Wideband and reconstituted doppler and azimuth and elevation history data are provided as outputs. A complete description of the system interfaces is provided in the Annex, Section 10, pages A-181 to A-183.

3.2 Acceptance Testing Procedures

Preshipment acceptance, testing of the improved velocimeter was accomplished at the contractor's facilities at Bedford, MA. An acceptance test procedure was closely followed and testing was conducted on each radar subsystem followed by integrated testing on target simulators and targets of opportunity; i.e., aircraft, both jet and propeller, and helicopters. These tests were performed by Raytheon Co. engineers and were observed by Raytheon quality control personnel, representatives of Defense Contract Audit Agency and the contracting officer's representative.

3.2.1 Transmitter

Preshipment acceptance testing of the transmitter included complete checkout of the high voltage power supply (HVPS) utilizing the built-in test equipment (BITE) built into the HVPS. These checks are made with the radar in standby mode; the radar is then placed in the radiate mode to complete checkout of the HVPS and the master oscillator power amplifier (MOPA). During initial installation and test, the power amplifier tube is tuned for maximum output, the master oscillator tube is checked for frequency (f_0), and the radar power output is checked. The arc detectors are checked to assure proper operation to protect the MOPA in the event of an arc in the RF transmission wave guide and couplers.

3.2.2 Receiver

Preshipment testing of the receiver is performed to determine noise figure and sensitivity of the radar receiver. All receiver tests are performed according to the Radar Acceptance Test Procedure.

3.2.3 Signal Data Processor

Preshipment acceptance testing is performed on the signal data processor according to the Velocimeter Acceptance Test Procedure and includes upper and lower sweep limit adjust, stonewall adjust, upper and lower sweep limit test, and lock-and-lock hold test. Remote operation tests are performed according to a mission scenario by use of a terminal.

3.2.4 Antenna Positioning

Antenna positioning is tested by use of the remote terminal and is included in the tests performed in 3.2.3. Further, antenna positioning can be accomplished by use of the antenna positioning handwheels when the radar is in the local mode of operation. Antenna positioning tests include upper and lower limit switch tests, actual antenna position tests compared to reported position, and to drift and jitter.

3.2.5 Power Distribution

Power distribution is tested in accordance with the Velocimeter Acceptance Test Procedure. All voltages developed within the low voltage power supply (LVPS) have overvoltage protection devices to protect the various chassis served by this supply.

3.2.6 Contractor Acceptance Testing

A copy of the Velocimeter Acceptance Test Procedure is included as Appendix B.

4. GOVERNMENT ACCEPTANCE TEST

4.1 Government Acceptance Testing

Government acceptance testing of the velocimeter was conducted at the user's proving ground by Raytheon engineers and Government personnel. Contractual requirements are that the velocimeter will acquire and track a 30 caliber projectile fired into, and parallel with, the radar beam for a period of 10 seconds.

Normally, to keep a 30 caliber projectile in the air for 10 seconds requires that the weapon be fired at approximately a 45° angle to the horizontal. This provides a problem for a gunner to fire into the very narrow (1.3°) beam width in azimuth and elevation as he has no target at which to shoot. To solve this problem, an observer was placed off to one side of the radar and another to the rear to observe the weapon pointing angle and to direct the gunner to move up/down or left/right. Normally a quantity of 20 rounds was fired with a minimum of 15 being fired into the beam and tracked. All projectiles which were acquired, were tracked for greater than 10 seconds, usually 14 to 15 seconds, and were tracked to heavy clutter or ground impact.

4.2 Radiation Hazard Report

A copy of nonionizing radiation study is enclosed as Appendix C.

5. SUMMARY OF RESULTS

All radars which have been delivered to the various proving grounds have performed well. Some problems have been encountered with the master oscillator tubes and this problem has been under study by the contractor. Some tubes have been reworked with some success and tubes have been procured from another vendor for testing and installation in delivered systems. The master oscillator tube problem appears to be under control at this time. Some HVPS cooling problems were observed with the initial Government-furnished equipment (GFE) power supplies. Rerouting of cooling air and changing of ducting has remedied this problem. The contractor has been very supportive of the fielded equipment and though some systems have been in use for over 2 years, the contractor has supported this equipment in retrofit and failure at no cost to the Government.

6. CONCLUSIONS

a. Because the modifications to the velocimeters were accomplished using as many components as possible from the existing improved continuous wave acquisition radar (ICWAR) from the HAWK Air Defense System, maintainability and supportability will be assured for many years.

b. Digital Control of the radar antenna positioning and data processing system greatly enhance the operation, control and confidence testing of the system. Further, the systems can be readily adapted for use with sophisticated data processing systems.

c. Mean time between failures of the velocimeters is greatly increased.

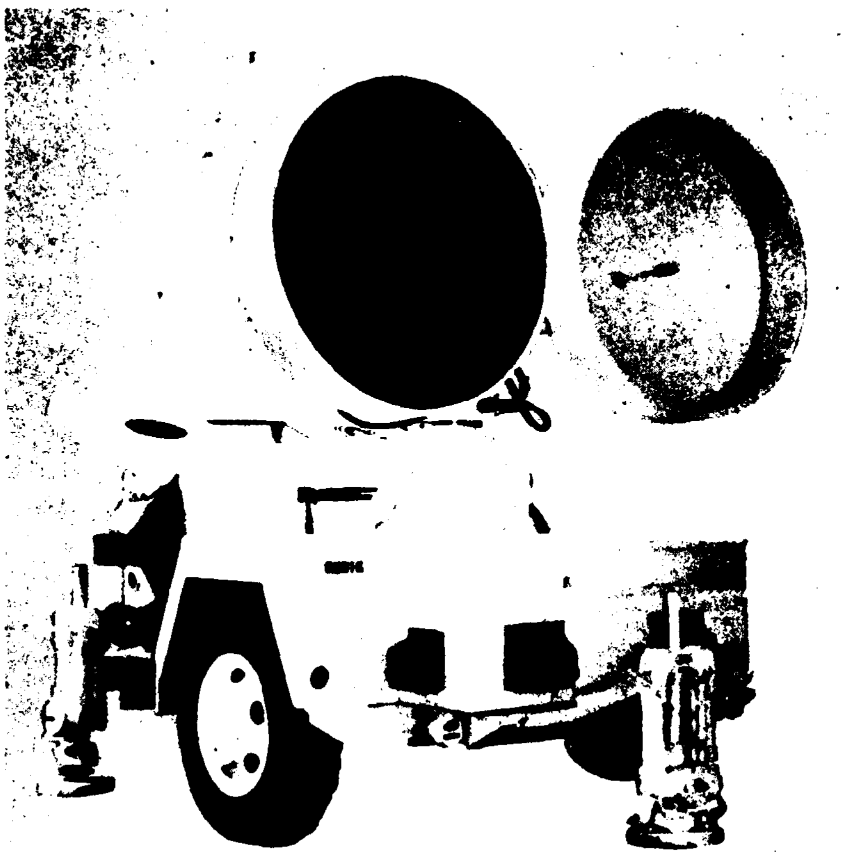
7. RECOMMENDATIONS

a. Software development should be accelerated to permit in-depth processing of the doppler signal by the ADAPT systems.

b. Yuma and Dugway Proving Grounds have no data processing hardware and software designed to process the velocimeter outputs. A coordinated effort should begin immediately to develop a system which could be utilized by both these proving grounds. It must be noted that both YPG and DPG are extensive users of the Digital Equipment PDP-11 Computers and peripheral equipment; therefore, system development should be directed toward utilization of this equipment.

APPENDIX A - ANNEX

VELOCIMETER



OPERATIONAL AND MAINTENANCE MANUAL

RAYTHEON

RAYTHEON COMPANY
MISSILE SYSTEMS DIVISION

OPERATIONAL AND MAINTENANCE MANUAL

FOR

VELOCIMETER RADAR SET

(PRODUCT IMPROVEMENT CONFIGURATION)

Prepared for

U.S. Army Test and Evaluation Command

APG, Maryland

Prepared by

Raytheon Company

Missile Systems Division

Bedford, Massachusetts

WARNING FOR RADIO-FREQUENCY RADIATION HAZARD

Radio-frequency (rf) radiation from radar antennas and associated equipment is a potential hazard to personnel. Rf radiation is not cumulative but it can be hazardous. It heats the body tissues, and, if the radiation intensity is sufficiently high, will permanently damage the tissue. This damage is not immediately apparent.

Precautions should be taken to insure that personnel are not exposed to rf radiations of hazardous intensity levels. Personnel who must be within the hazardous distances for the radars should be instructed not to place themselves on the radiating side of the antenna, and to never look into a transmitting horn or open waveguide which is connected to an energized transmitter.

Personnel are prohibited from entering areas where they may be exposed to levels of rf radiation above 10 milliwatts per square centimeter (10 mw/cm^2). This level, though not considered hazardous, is stipulated by AR 40-583 as the maximum permissible exposure level for personnel.

A power intensity of at least 10 mw/cm^2 is present along the axis of the radar's transmitted beam, for the distance listed below. This distance is based on calculations and actual measurements and may be used as a guide to prevent radio-frequency radiation injury. Radiation intensity rapidly diminishes as the distance is increased.

ANTENNA	DISTANCE
Improved Velocimeter Radar (non-scanning)	74 m (243 ft)

No radiation hazard exists at radar ground level if the radar is not depressed below zero degrees elevation. When at all possible during maintenance, however, place the antenna at a high elevation. Personnel are restricted from the area atop the radar or other elevated locations in front of the antennas when radiating.

Personnel may move in and around the velocimeter to zero range at ground level provided they are below the horizontal center line of the antennas. There is no height restriction to either side or rear of the antennas.

The above information is applicable to typical velocimeter sites. The services of the U.S. Army Environmental Hygiene Agency are available, in accordance with the provisions of AR 40-583 for the evaluation of potential radiofrequency hazard at sites where unusual operating or site conditions may exist.

WARNING DANGEROUS VOLTAGE

is used in the operation of this equipment

DEATH ON CONTACT

may result if personnel fail to observe safety precautions

Never work on electronic equipment unless there is another person nearby who is familiar with the operation and hazards of the equipment and who is competent in administering first aid. When the technician is aided by operators, he must warn them about dangerous areas.

Whenever possible, the power supply to the equipment must be shut off before beginning work on the equipment. Take particular care to ground every capacitor likely to hold a dangerous potential. When working inside the equipment, after the power has been turned off, always ground every part before touching it.

Use extreme caution when operating equipment protected by interlocks. Insure that interlocks (doors, panels, and drawers) are functioning properly. Be careful not to contact high-voltage connections when installing or operating this equipment.

Whenever the nature of the operation permits, keep one hand away from the equipment to reduce the hazard of current flowing through the vital organs of the body.

WARNING

> Do not be misled by the term "low voltage". Potentials as low as 50 volts may cause death under adverse conditions.

For artificial respiration, refer to FM 21-11.

EXTREMELY DANGEROUS POTENTIALS

greater than 500 volts exist in the following units:

High Voltage Power Supply

Amplifier-Oscillator Group

MECHANICAL HAZARD

When performing maintenance procedures in the vicinity of the antenna, insure that the antenna **PEDESTAL SAFETY SWITCH**, located on the pedestal base, is in the **SAFE** position.

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LIST OF TABLES

1. INTRODUCTION

1.1 Scope

This manual supplements, and in certain instances supersedes, existing U.S. Army Technical Manuals (TM) for Radar Set AN/MPQ-33, FSN 1430-00-714-3313, in order to reflect the conversion of the HAWK Low Power Illuminator to a Velocimeter Configuration. As such, this addendum to the formal TM's contains the documentation package for the operation, assembly, maintenance and operation of the HAWK Velocimeter System.

1.2 Technical Manual Reference

The following TM publications pertain to the HAWK CW Illuminator Radar Set:

TM 9-1430-504-20	Schematics for Radar Set AN/MPQ-33 (Organizational Maintenance Manual)
TM 9-1430-504-34/1	Units of Radar Set AN/MPQ-33 Tested at CW/Pulse Console (Direct and General Maintenance Manual)
TM 9-1430-504-12/2	Organizational Maintenance Manual: Functional Theory and Schematics for Radar Set AN/MPQ-33
TM 9-1430-504-34	Field Maintenance Radar Set AN/MPQ-33
TM 9-1430-504-15P/1	Organization, DS, GS, and Depot Maintenance Repair Parts and Special Tools List for Radar Set AN/MPQ-33 (XO-3)

TM 9-1430-504-12/1	Check Procedures for CW Illuminator Radar Set AN/MPQ-33 (Operator and Organizational Maintenance Manual)
TM 9-1430-504-15P/2	Operator, ORG, DS, GS and Depot Maintenance Repair Parts and Special Tools List Illustration Supplement for Radar Set AN/MPQ-33 (XO-3)
TM 9-1430-504-12	Operator and Organizational Maintenance Manual Radar Set AN/MPQ-33

Detailed information regarding the operation and maintenance of retained AN/MPQ-33 components and parts may be found in the above references. The discussion in this manual summarizes the operation of the new subassemblies.

In addition, the following TM's are to be referenced for maintenance and parts detail on new High Voltage Power Supply (FSN 1430-01-043-6648) and the Oscillator Amplifier (FSN 1430-01-043-8427).

TM 9-1430-1528-24P	Organization, Direct Support, and General Support Maintenance Repair Parts and Special Tools Including Depot Maintenance Repair Parts and Special Tools (Radar Set AN/MPQ-55 Improved CW Acquisition)
TM 9-1430-1528-34-2	Direct and General Support Maintenance Manual (Radar Set AN/MPQ-55)

2. BASIC THEORY OF OPERATION

2.1 Functional Description (Figures 2-1 through 2-4)

The Velocimeter radar provides inflight ballistic trajectory parameters on a wide range of projectiles by illuminating the desired targets with continuous-wave, X-Band, RF energy. The system will acquire, lock-on and track the target, thereby providing radial speed, wideband doppler spectrum return and azimuth and elevation data.

Basically the Velocimeter consists of five major functional systems:

1) Transmitter
2) Receiver
3) Signal Data Processor
4) Antenna Positioning
5) Power Distribution

Its interfaces are compatible with both analog and digital data recording or processing systems in three modes as follows:

1) **Local** - The radar is a stand-alone system providing analog wideband, narrowband and DC doppler data and DC Azimuth and Elevation Data in real time under control of the operator at the radar.
2) **Terminal Remote** - All radar functions specified in Local Mode and readout of stored corrected digital Azimuth and Elevation Data are controlled from a standard RS-232C terminal. Wideband doppler and timing signals are sent over coaxial lines as applicable.
3) **Data Acquisition System Remote** - The radar is controllable from, and provides, the same data as specified above to an off-trailer data acquisition system over a standard RS-232C interface, supplemented by coaxial lines as appropriate for wideband doppler and timing signals. In this mode, the radar behaves as if it were a peripheral to the Data Acquisition System.

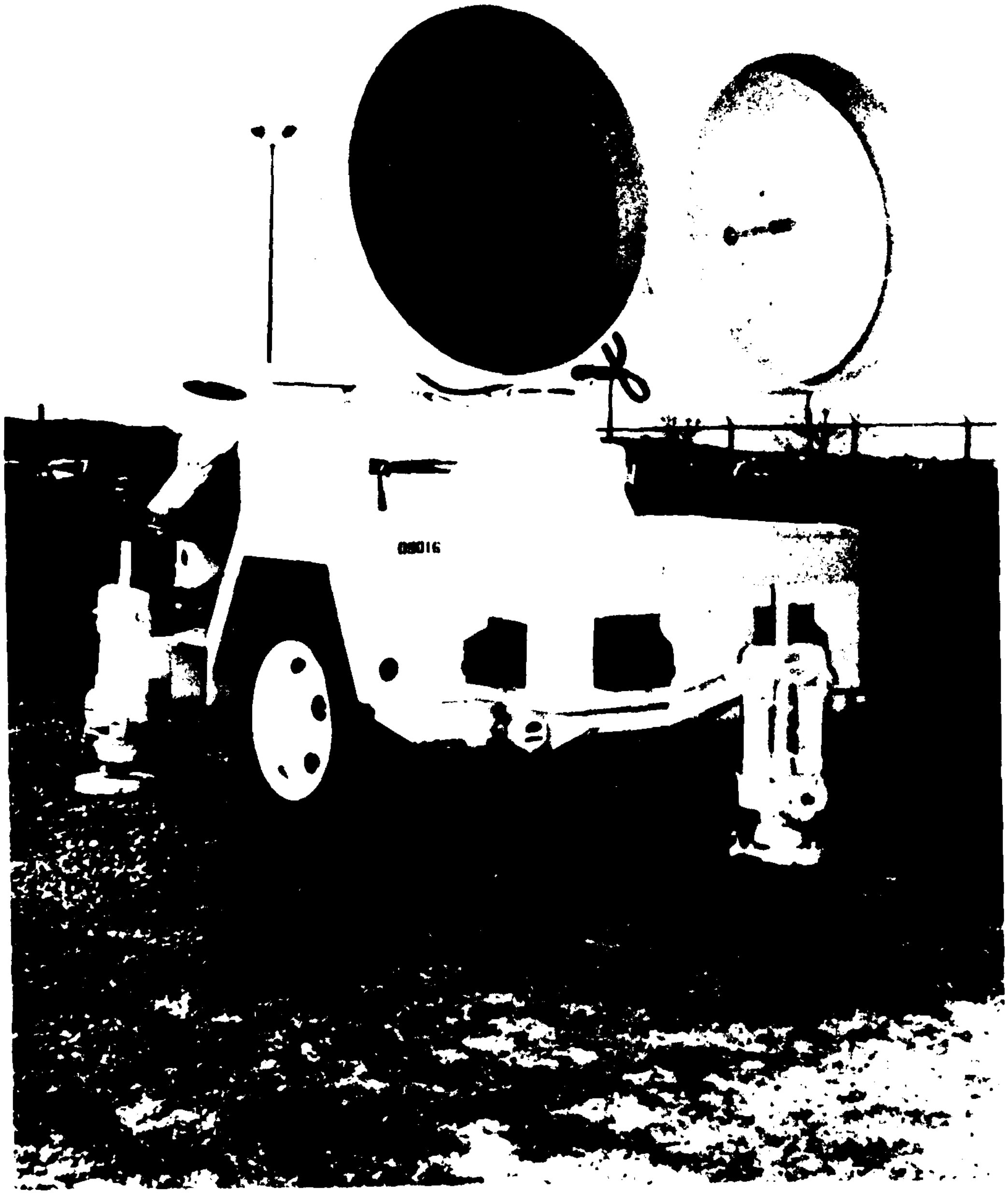

Figure 2-1 - Velocimeter Radar

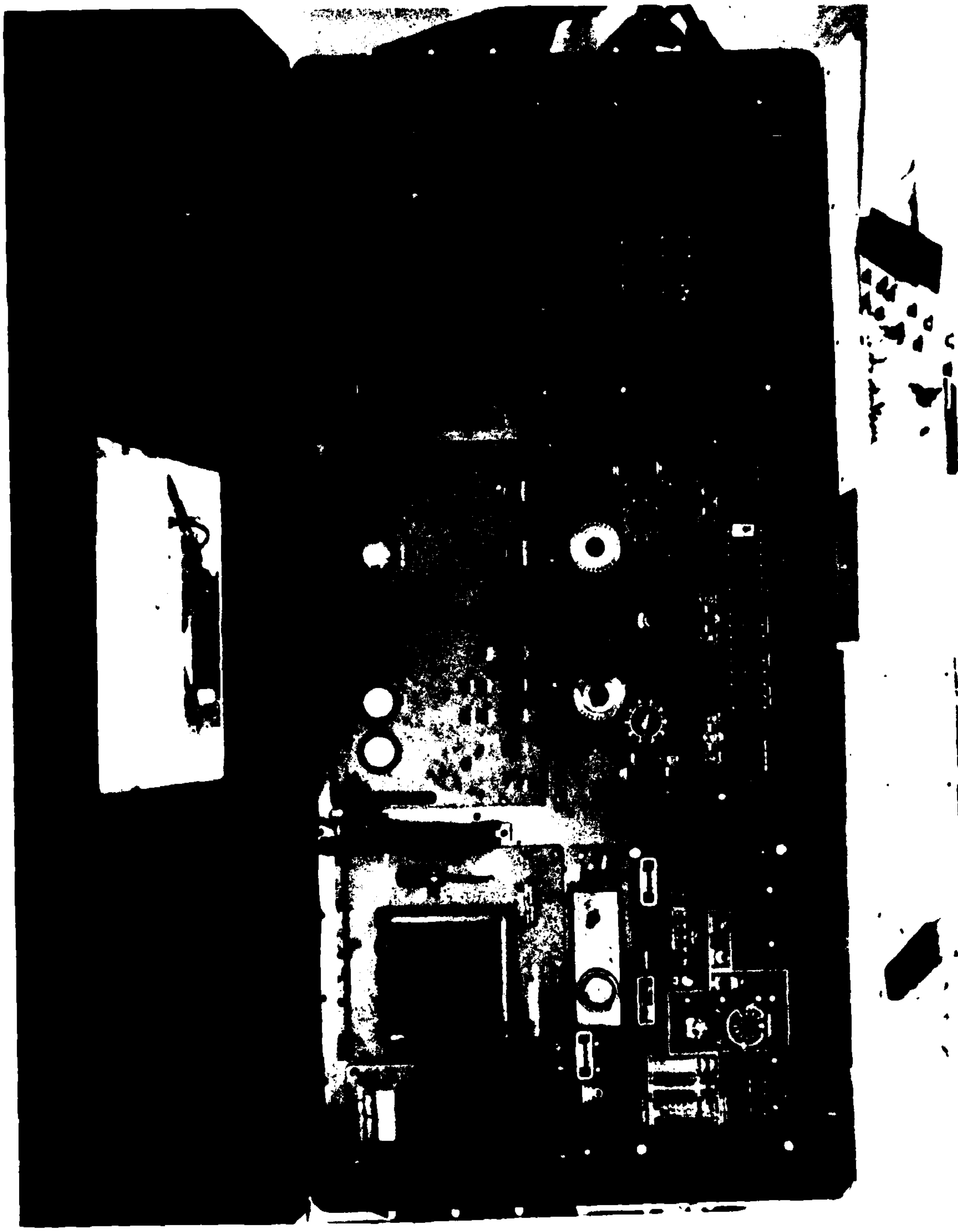

Figure 2-2 - Radar Set Group (RSG)

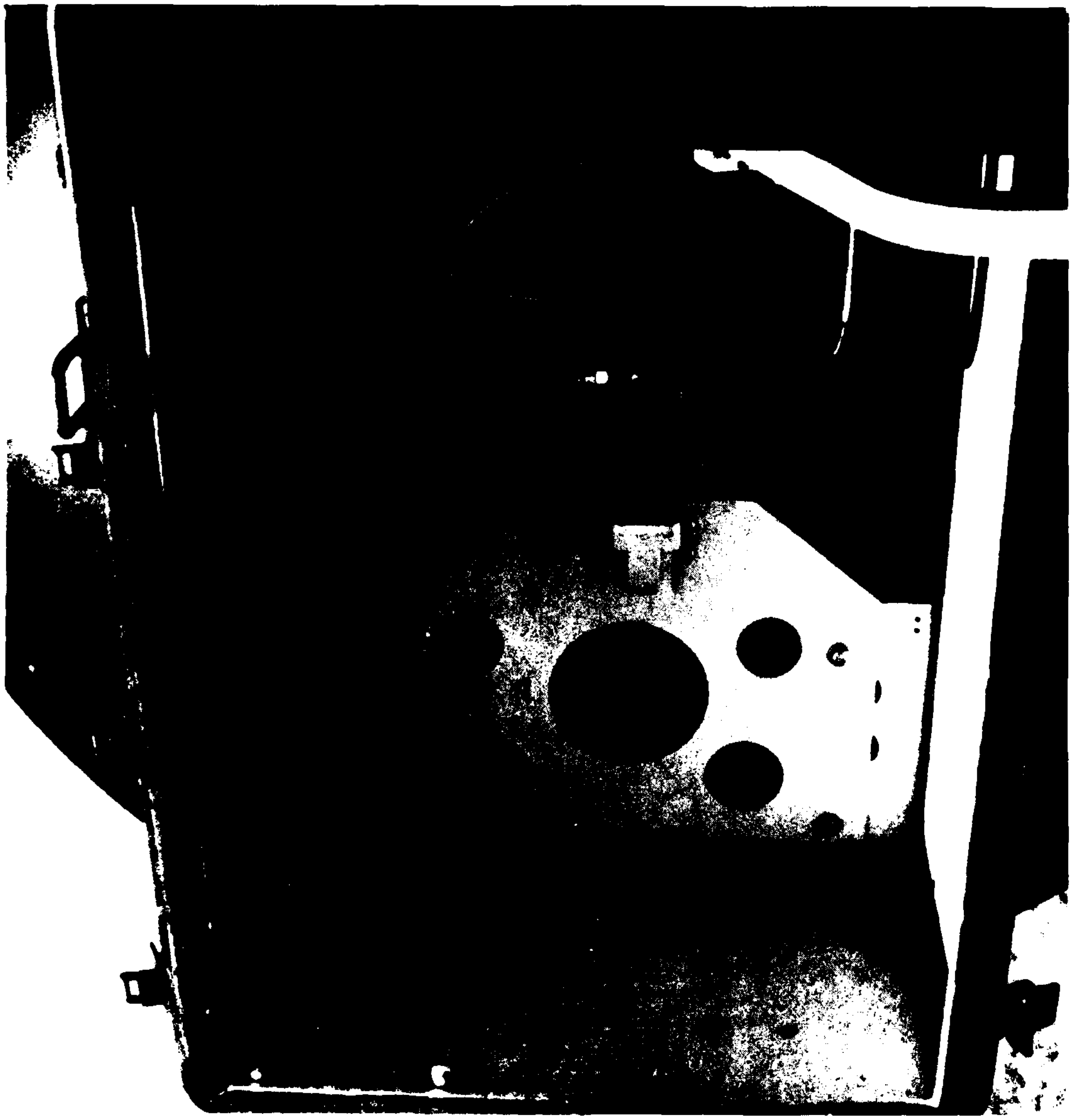

Figure 2-3 - Transmitter Antenna Group

Figure 2-4 - Receiver Antenna Group

2.2 Transmitter System

The illuminating RF energy is generated by the transmitting system and propagated by the transmitter antenna. The transmitted energy is unmodulated.

A sample of the transmitted RF energy is coupled to the receiver to provide a coherent reference for processing target return energy.

The transmitter design which is installed in the velocimeter systems is a derivative of the ICWAR design fielded by the U.S. Army for the Improved HAWK air defense system. Two of the three major subassemblies that compromise the ICWAR transmitter, the High Voltage Power Supply (HVPS) and the Microwave Assembly, form the basis for the velocimeter transmitter.

The transmitter design facilitates field replacement of modular units by incorporating Built-In Test Equipment (BITE) functions in the radar. Functions that are critical to the operation of the transmitter are identified and monitored by BITE on a continuous basis. Manually operated BITE functions are incorporated to identify failures of the transmitter on a modular basis. These modular assemblies are replaceable in the field.

2.3 Receiver System

The Velocimeter receiver is a CW homodyne design utilizing a GAS FET X-band amplifier, a high power mixer, followed by low noise amplification. The receiver system detects and amplifies target (projectile) reflected energy collected by the receiving antenna. The process enables the detection of any doppler shift of the transmitter RF signal caused by the target's radial velocity relative to the location of the radar sensor. The Receiver Antenna is a simple Cassegrain configuration, with a mechanical nutating scanner as the feedhorn to develop angle error modulation for positioning of the antennas while continuously tracking a target.

2.4 Signal Data Processor

The Signal Data Processor contains the solid state modules that are identified with the doppler tracking, antenna control and Azimuth/Elevation Readout subsystems.

The Doppler Tracking module (DTUP) analyzes the composite signal from the receiver for acceptable target radial speed data. If acceptable criteria is present in the form of target data, the phase lock loop maintains frequency track while the antenna-positioning system is activated in the auto-track mode. The memory and search modes of operation for the antennas are controlled by the DTUL module.

The Antenna Control Amplifiers and the Tracking Filter circuits condition the antenna directional information from the signal processor and other position information for application to the Amplidyne Control.

A microprocessor controlled AZ/EL Data Interface Unit acquires, processes, and stores antenna position and error data, and provides analog and digital interfaces for transmission of corrected AZ/EL Data to off-trailer systems. The AZ/EL Data Interface Unit is of new, modern solid state design using digital technology with high reliability and is capable of interfacing data processing equipment through serial data lines. Provision has been made for remote control of the radar by means of ASCII character commands.

ASCII Command and Data interfaces are compatible with EIA standard RS-232C for the purpose of interfacing commercial data processing equipment.

2.5 Antenna Positioning System

The antenna positioning system contains two servo loops and drive motors for positioning the antenna in both azimuth and elevation. The antennas can be positioned by servo handwheels on the illuminator, or by command from the Remote computer terminal. The system contains a nutating drive motor which causes the main lobe antenna to scan conically. The conical scan produces amplitude modulation of the target tracking video. The amplitude modulation is indicative of the distance the target is from the electrical axis of the receiver antenna. The phase relationship between the amplitude modulation and the nutating scanner reference signal determines in which quadrant the target is located. This information allows the antenna positioning system to keep the target close to the electrical axis of the receiver antenna during the automatic tracking mode of operation.

2.6 Power Distribution System

The power distribution system receives ac power from an engine generator. Using this as the primary power source, the system generates and distributes ac and dc power to other systems in the CW Velocimeter Radar.

2.7 Velocimeter Radar Characteristics

Table 2-1 lists certain characteristics of the Velocimeter radar for reference purposes.

TABLE 2-1
HAWK VELOCIMETER RADAR CHARACTERISTICS AND REFERENCE DATA

Velocimeter Parameter	Typical Value
Power Requirements	_______KW 416 Vac, 3 phase, 400 Hz
Physical	
Length	4.4 meters
Width	2.4 meters
Height	3.1 meters
Weight	Less than 2270 kg.
Transmitter	
Radiated Power (delivered to antenna)	400 watts
Duty Cycle	Continuous
Modulation	None
Frequency	Specified, single frequency within ± 5 MHz of designation in a ±, 125 MHz Band
AM Noise (SSB) (3-200 kHz)	-127 dBc/kHz
FM Noise (SSB) (3-200 kHz)	0.26 Hz (rms)/kHz
Antennas	
Transmit	
Size (diameter)	1.2 meters
Polarization	Vertical
Gain	38.5 dB
Beamwidth	NMT 34 MIL
Receive	
Size (diameter)	1.2 meters
Polarization	Vertical
Gain	38.5 dB
Beamwidth	NMT 34 MIL
Combined	
Slew rate (AZ & EL)	NLT 500 MIL/sec
Tracking Rate	
Azimuth	NLT 426 MIL/sec
Elevation	NLT 426 MIL/sec

TABLE 2-1 (Cont.)

Velocimeter Parameter	Typical Value
Azimuth Coverage	Continuous 6400 MILS
Elevation Coverage	
Maximum	Electrical 1584 MIL Mechanical 1600 MIL
Minimum	Electrical -144 MIL Mechanical -178 MIL
Average Sidelobe ($\pm 20^{\circ}$ About Peak of Beam)	-37.5 dB
Receiver	
Noise Figure	11 dB (DSB)
RF Frequency	X-band
RF Bandwidth	A $\pm$ 125 MHz
Conical Scan Modulation	"M" Hz $\pm$ 1 Hz
Doppler Bandwidth	2-200 kHz
DTUP Bandwidth	900 Hz
DTUP Acquisition Time	$\leq$ 100 msec.
Clutter Rejection	$\geq$ 120 dB
Target Radial Speed Coverage (Approach or recede)	
Maximum	3048 meters/sec
Minimum	30.5 meters/sec
Target Acceleration Coverage (with S/N $\geq$, 20 dB)	Up to 762 meters/sec/sec

3. TRANSMITTING SYSTEM

3.1 General

The transmitting system generates the microwave energy to illuminate the target. The RF generation circuits are designed around a master oscillator and power amplifier concept. The low level, highly stable reference frequency is generated by the oscillator and the power amplifier increases the power to the level required for the range of the radar. The rotary joint connects the RF energy from the transmitter to the rotating antenna assembly. The antenna consists of two separate reflectors, one for the transmitting antenna and the other for the receiving antenna. Between the two reflectors, there is sufficient RF isolation so that the transmitter signal leakage into the receiver does not degrade the detection of the target return signal.

Peripheral circuits include RF detectors and a microwave test panel for performance monitoring, fault isolation, and arc detection.

3.2 General Block Theory

The functional diagram of Figure 3-1 of the Velocimeter Transmitter depicts the MO-PA Klystron chain for low noise, high power generation, for the Continuous Wave (CW) transmitter carrier. The two major assemblies are indicated: the High Voltage Power Supply (HVPS) and the Microwave Assembly (Amplifier - oscillator). To facilitate maintenance, these assemblies include individual Built-In-Test Equipment (BITE) and are separately mounted on drawer slides within the Radar Set Group (RSG). Also shown is the Control-Indicator Panel which contains control indicators for the transmitter Microwave Assembly.

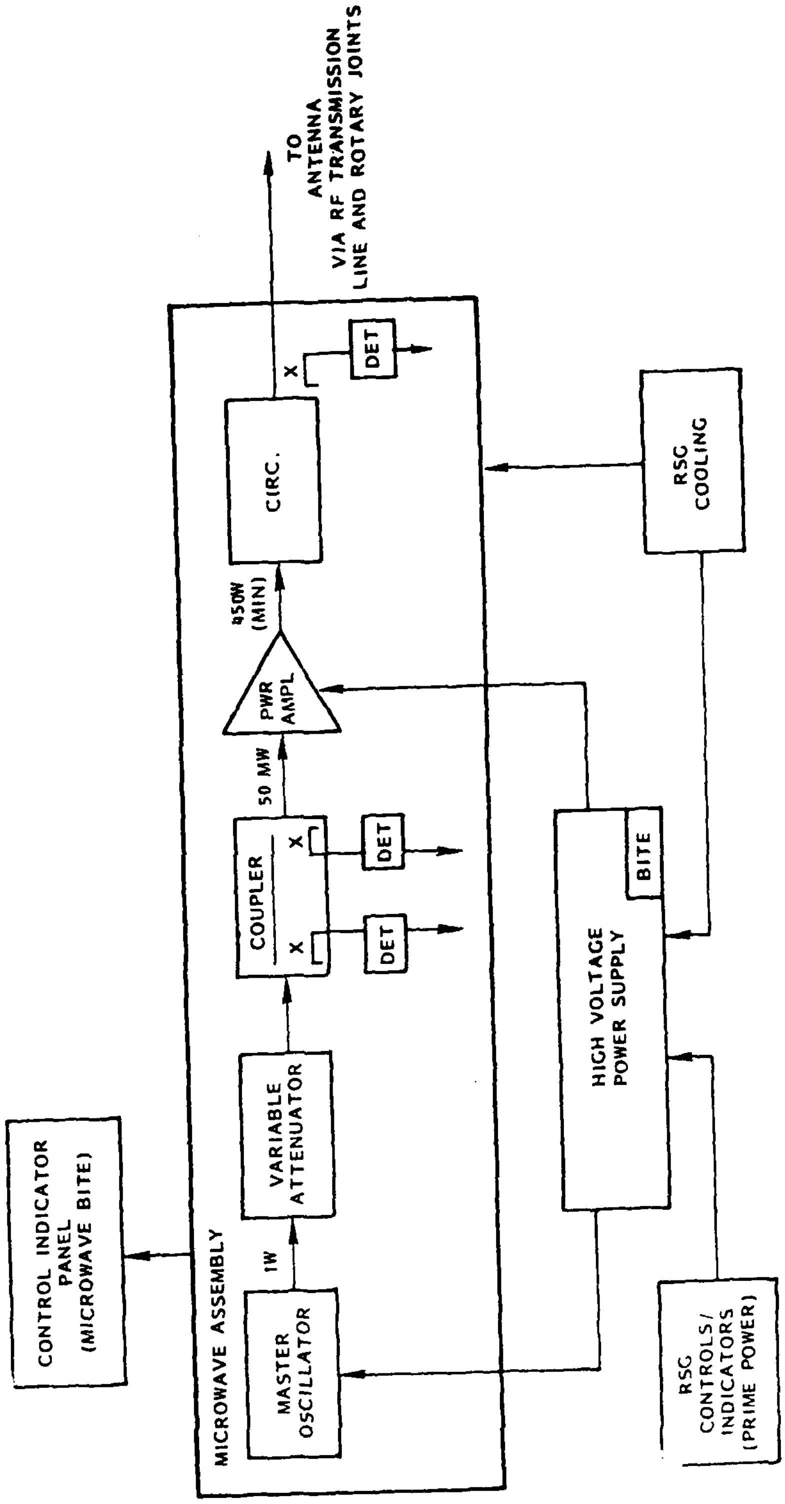

Figure 3-1 - Transmitter Functional Block Diagram

3.3 Microwave Assembly

3.3.1 General

The Microwave assembly provides the RF energy that constitutes the transmitter output for the radar system by means of generating the fundamental X-Band carrier via the Master oscillator (MO) and amplification through the Power Amplifier (PA) klystron. The block diagram Figure 3-2 depicts the microwave signal flow through the microwave assembly. The fundamental microwave energy is generated by the MO and fed via an undirectional isolator, variable and fixed attenuator filter, and directional coupler to the power amplifier. The variable attenuator is accessible at the front panel and is used to adjust the input power level of the signal into the PA klystron. The power into the PA and the power reflected back from the PA input are sampled by a dual directional coupler. The microwave power is then detected by calibrated crystal detectors for tuning and BITE monitoring.

From the PA klystron, the microwave energy is fed through a high power circulator and a directional coupler to the output port of the microwave assembly. The high power circulator presents an optimum voltage standing wave ratio (VSWR) match to the PA output and prevents the reflection of microwave energy into the PA, thus preventing tube damage. The directional coupler provides a sample of the output energy to be detected and measured for PA tube cavity alignment and BITE purposes. After leaving the microwave deck, the RF energy reaches the transmitting antenna via the rotary joints and interconnecting waveguide components.

A sketch of the modified microwave assembly is included as Figure 3-3.

3.3.2 Master Oscillator

The Master Oscillator (MO) is a fixed frequency, ultra low noise, two cavity klystron oscillator, followed by a stabilizing cavity. The Q of the combined assembly, shown in Figure 3-4, is well in excess of 25,000 which contributes to the low FM noise performance. The frequency of the oscillator is pre-set at the factory and is not a field adjustment. The oscillator is turned on or off by energizing or de-energizing the high voltage power supply which drives it.

3.3.3 Power Amplifier

The Power Amplifier is a tuneable, air cooled, permanent magnet focused, four cavity klystron which is used to amplify the Master Oscillator output to the required level for spatial transmission by the radar's antenna. A photo of the tube is shown in Figure 3-5. The PA amplifies the 50 mwatt MO supplied, X-Band carrier to a 450 W minimum level.

3.3.4 High Power Circulator

A high power circulator is employed in series with the PA tube to prevent reflected microwave energy and sustained arcs from traveling back to the PA tube output port. The circulator is shown in Figure 3-6.

3.3.5 Microwave Power Profile (Figure 3-7)

This diagram shows the microwave power run from the Power Amplifier output to the transmitting feed. Shown here are the calculated RF losses throughout the run. The high power waveguide construction is of WR 90 OFHC copper, heavy wall, and has a chromate conversion finish. All flanges are 8 hole CPR. This waveguide run is constructed to provide minimum loss.

3.3.6 Control Indicator Panel/Microwave BITE

The Control Indicator Panel/Microwave BITE (Figure 3-8) provides proper monitoring of the PA Drive power, and PA Output power of the Microwave Assembly. The values are displayed on the BITE Monitor meter. A second function is the Tune Function where panel indicators are used to tune the PA Tube to its proper operating point. The monitoring devices are standard RF crystal detectors which are calibrated for specific BITE signal outputs.

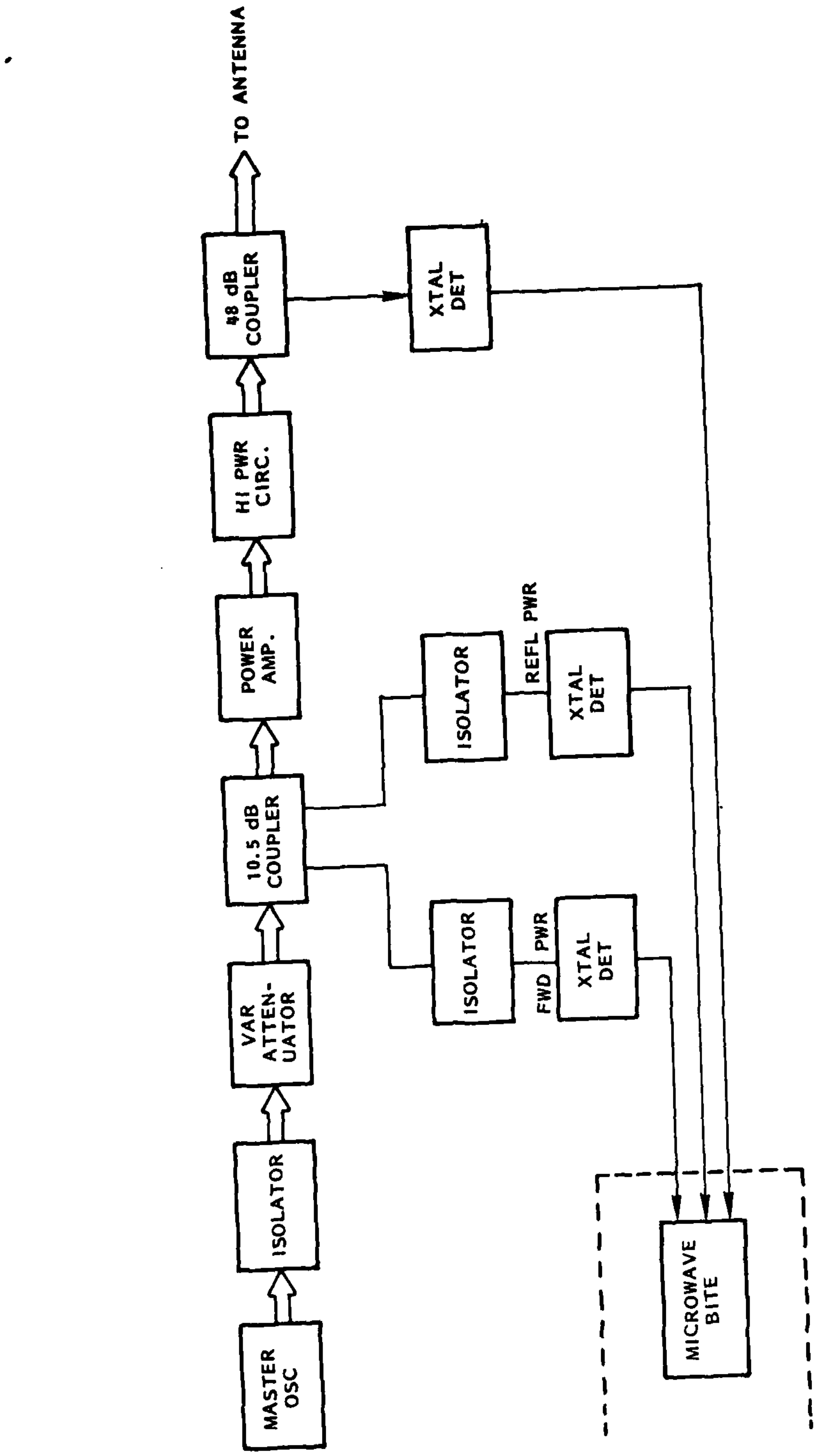

Figure 3-2 - Microwave Block Diagram

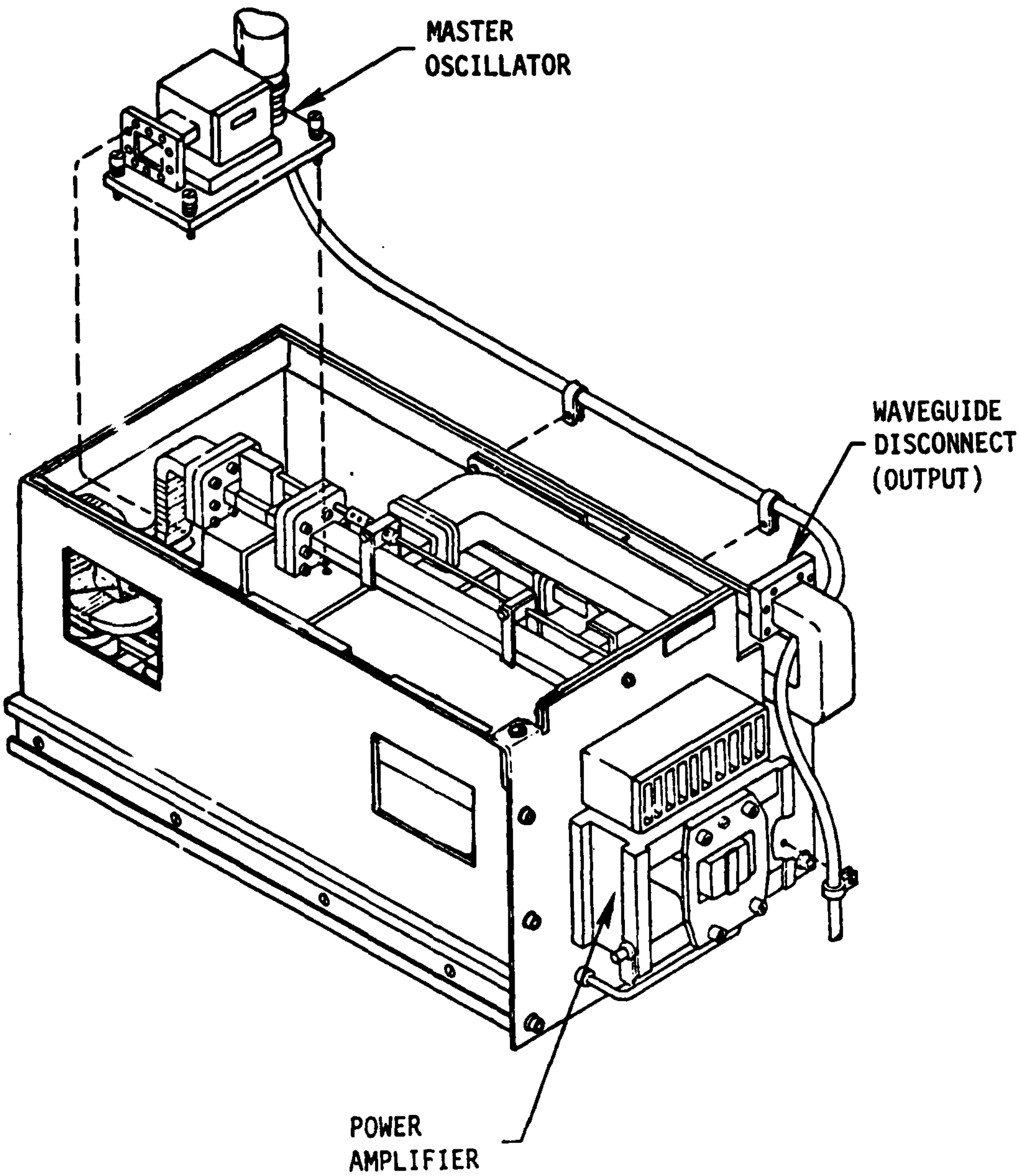

Figure 3-3 - Microwave Assembly

Figure 3-4 - Master Oscillator Klystron

Figure 3-5 - Power Amplifier Klystron

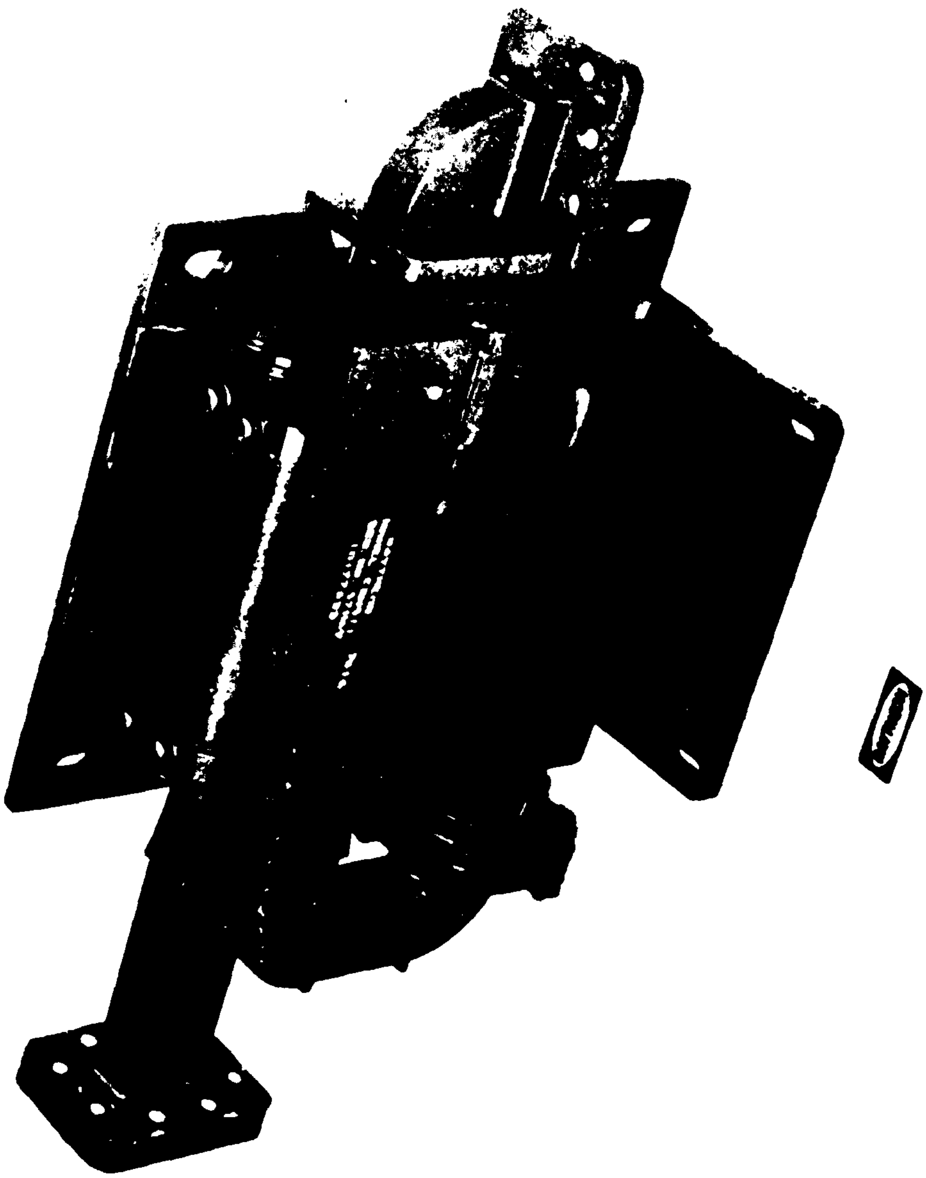

Figure 3-6 - High Power Circulator

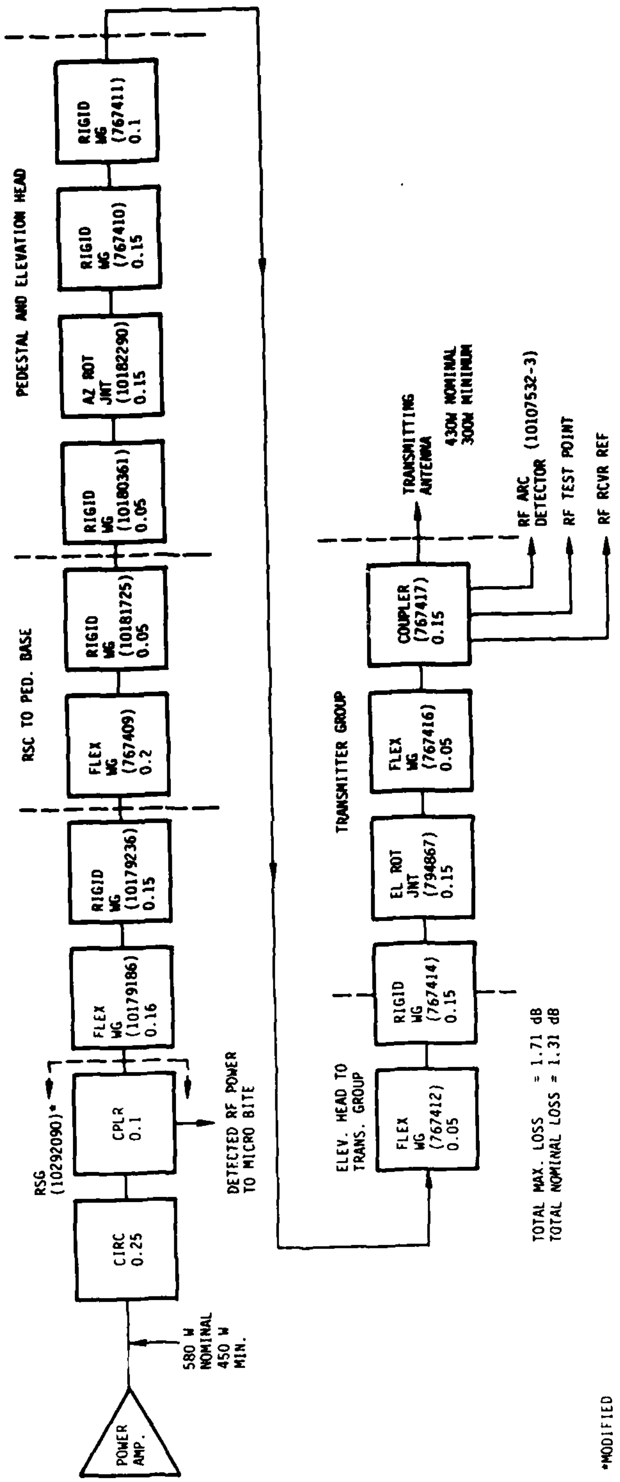

Figure 3-7 - Microwave Power Profile

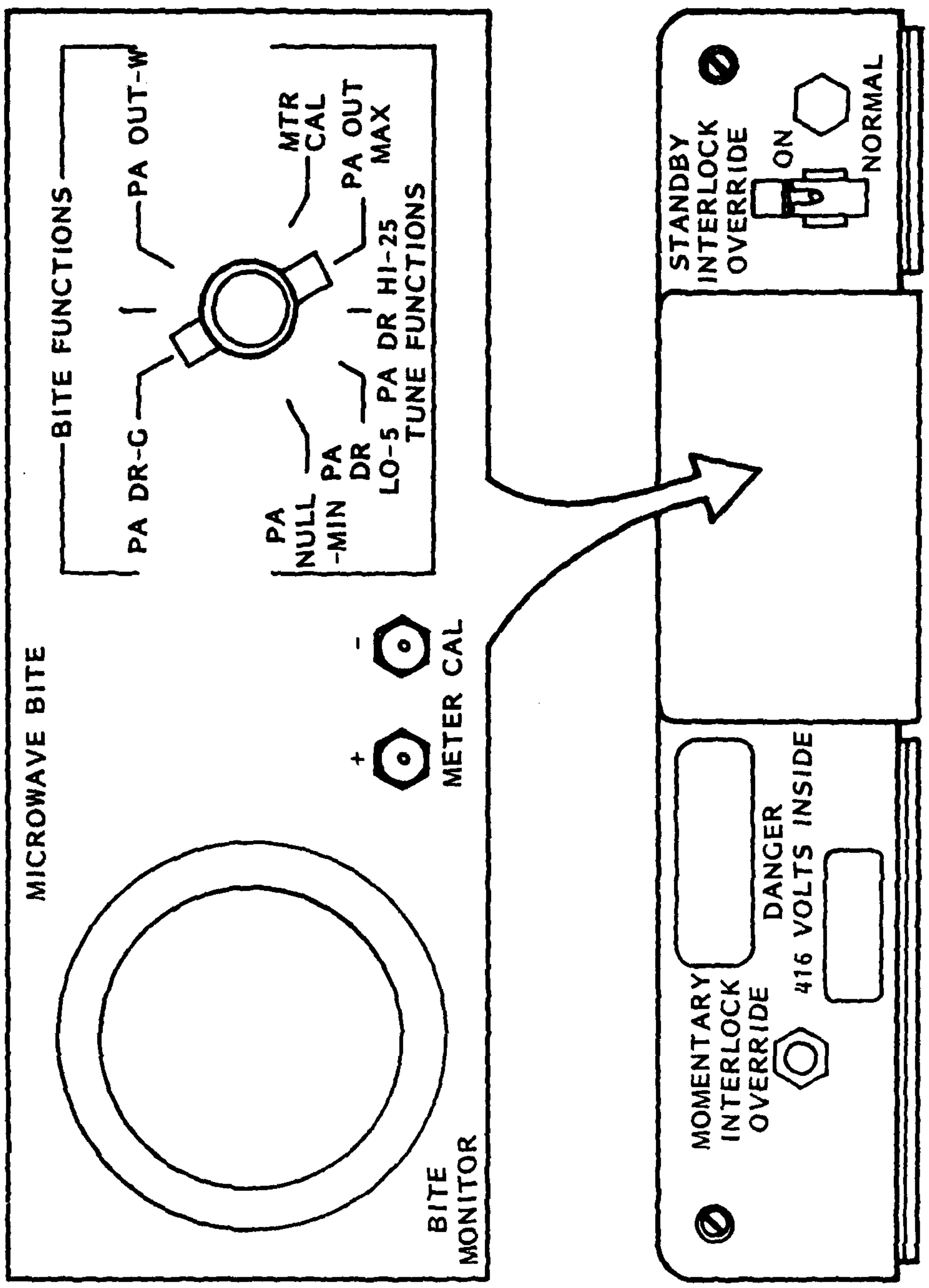

Figure 3-8 - Microwave Bite Panel

The PA Drive BITE function measures the input to the PA Tube, the PA Null Function measures the reflected power from the PA Tube, and the PA Output BITE Function measures the PA Tube output. These three BITE Functions are used for fault isolation. Faults on the Microwave Assembly including the MO klystron, attenuator, and PA klystron plus control indicator panel/microwave BITE and external (wiring) faults, can be found.

3.4 High Voltage Power Supply (HVPS)

3.4.1 General

The High Voltage Power Supply is an air-cooled, series tube, regulated supply which develops the required filament and beam voltages for the Master Oscillator and Power Amplifier klystron tubes. The supply is a 400 Hz series regulation type utilizing both passive and active ripple (noise) degeneration. Five series regulator tubes are used to equally share the current drawn by the Master Oscillator and Power Amplifier tubes at a fraction of their capability. In this way, the High Voltage Power Supply will still operate within specification even if two regulator tubes fail. The result is an increase in the tactical mean time between failures (MTBF) since the immediate replacement of a defective tube is not essential to continued specified radar operation.

The block diagram for the HVPS is shown in Figure 3-9. The blocks out-lined in a heavy black border indicate the replaceable modules or components at the radar. The blocks made with narrow lines indicate components that are chassis mounted.

Specifications for the HVPS are contained within the U.S. Army Missile Command Specification, MIS-23758. input power is determined by the power supply and its load (MO and PA Tubes). The supply draws approximately 3 kW from a prime power source of 416 Vac, 3 phase, 400 Hz.

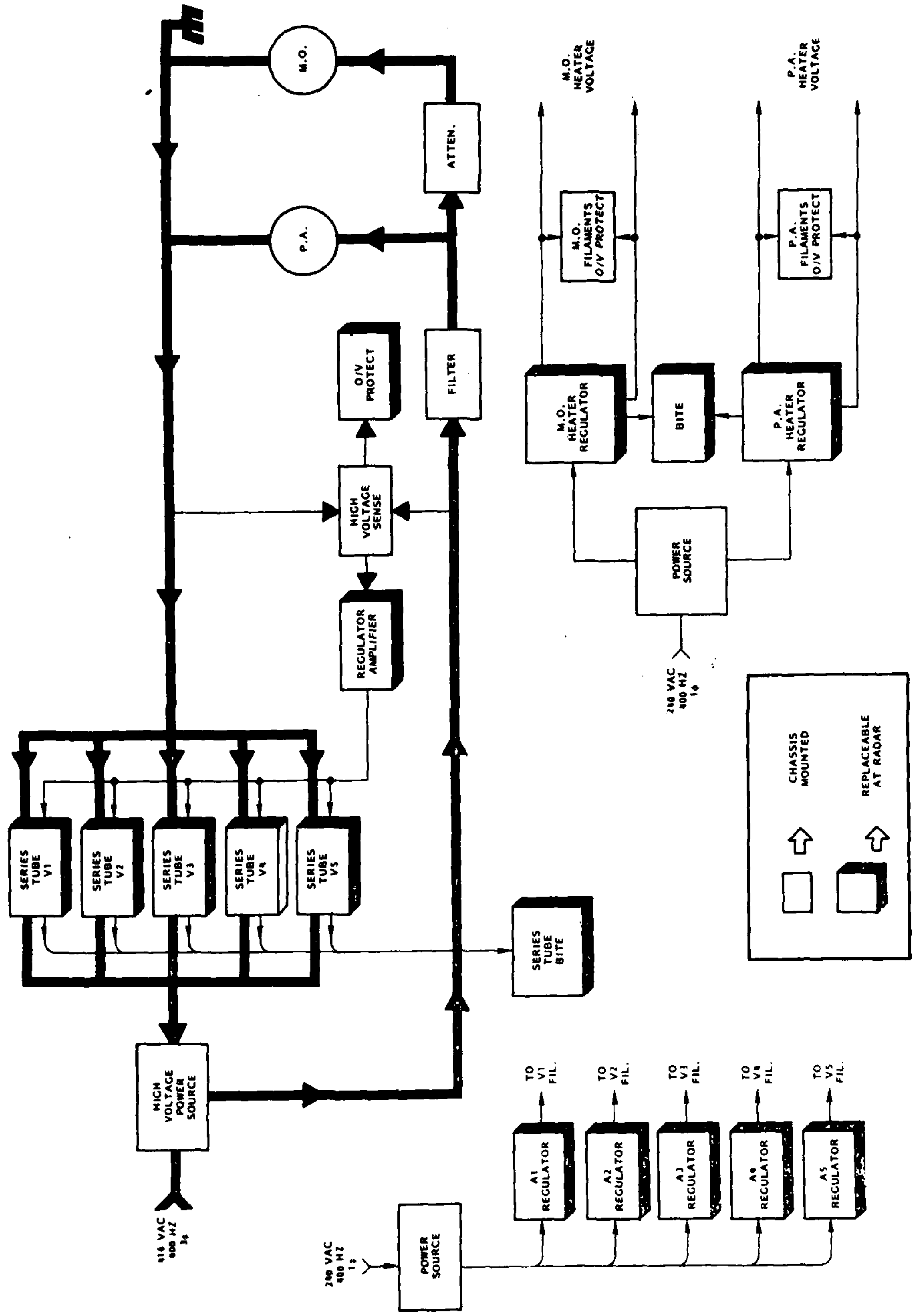

Figure 3-9 - HVPS Block Diagram

3.4.2 Description

The (HVPS) is a negative output, high voltage, low noise, dual output power supply containing two auxiliary filament power supplies, each floating at the potential of a high voltage output.

The high voltage source consists of a three phase delta to Y step-up transformer, full wave rectifier block, and a two stage LC filter, an active series regulator using five triodes in parallel, a regulator amplifier, and voltage sensing circuitry. There is a two stage LC filter before the PA output and a resistor capacitor section which drops the PA output voltage for the MO output. There is also an RC filter before the MO output. The O/V (Over Voltage) protection circuitry operates when the PA voltage reaches a preselected maximum. There is a series tube BITE card plus HV BITE, BITE meter and series tube and O/V lamps.

The series tube regulator section contains a power source and the five series tube regulators. The power source is a transformer which has a winding for each regulator. Each winding goes to a full wave bridge rectifier with a capacitor load and then to the regulator. In addition, there is a center tap winding with three full wave rectifier circuits with capacitor loads. This supplies voltages to the BITE and to the regulator amplifier. The five identical series tube regulator cards provide filament voltages to the series tubes.

The MO and PA heater regulator section contains a power source, a MO heater regulator, a PA heater regulator, O/V Protection, and BITE. The two auxiliary filament outputs are supplied from a separate single phase step down high voltage isolated transformer. Each of the two secondaries is rectified, capacitively filtered and series regulated. The common of each regulator is then tied to its respective high voltage output capacitor. All outputs including the filaments are overvoltage protected. The regulator cards are identical to the series tube regulation cards, but the external connections are different. The BITE circuitry monitors the filament current using isolation transformers. This circuitry is at low voltage.

The resistor of the RC filter is used as a combination filter and voltage dropping resistor for the low output voltage. Its value is pre-set by the MO CURR switch to compensate for a known load current. The lower output voltage is sampled by a resistive divider network at the junction of R59 and R61 and compared to a precision reference voltage at the junction of R66 and R67. The difference voltage is amplified by A10-AR2 and displayed on the HVPS front panel meter. The M.O. H.V. ADJUST potentiometer R45 is adjusted for a front panel meter zero (center scale) reading. Once this has been set, the higher of the two output voltages will also be correct since the lower voltage output current was known and compensated for by the step variable resistor of the RC filter. The active series regulator is used for ripple degeneration, as a means of adjusting high voltage, and automatic compensation for input line voltage changes. The regulator consists of five triodes (V1 thru V5) in parallel as the series pass element, a feedback amplifier A9 and a capacitive, variable resistor sampling network that terminates in R45. The high voltage is sensed and compared to a preci-ion reference on the A9 module. Any attempted change in the output voltage is sensed, amplified, and used to cause corresponding compensating change in voltage across the five triodes, therefore, keeping the output high voltage constant.

The HVPS has various BITE functions built in for operational status checks. The majority of these are simply voltages that are sensed through a current limiting resistor which is connected to ground through the front panel meter.

Various functions and appropriate readings are displayed on the front panel of the HVPS. The more complex BITE functions are explained in their respective following sections.

3.4.3 HVPS Specifications

The input power is determined by the power supply and its load (MO and PA Tubes). The MO beam voltage is set to 4.35 kV and the PA beam voltage follows. Actual PA beam current depends on the tube, but the MO beam current is set to the value specified on each tube. The PA and MO beam ripple and regulation are measured during HVPS testing along with PA and MO filament ripple. The MO and PA beam ripple must be maintained at the Table 3-1 levels in order to meet the transmitter noise requirement.

The PA and MO filament voltages are determined by external connections to the standard Filament Regulator module. These maximum filament current values are the values where the Filament Regulator modules must start current limiting. These maximum filament currents are set using external connections. The PA and MO filament regulation and ripple are measured during Filament Regulator module testing. The ripple must be maintained at the Table 3-1 levels in order to meet the transmitter noise requirements.

TABLE 3-1

HIGH VOLTAGE POWER SUPPLY SPECIFICATION SUMMARY

Input Power: (416 V 3ϕ 400 Hz)	3.06 kW
Output:	
PA Beam Voltage	5.35 kV
MO Beam Voltage	4.35 kV
PA Beam Current	365 max
MO Beam Current	28 - 35 mA
PA Beam Regulation	NMT ± 2% (Line and Load)
MO Beam Regulation	NMT ± 0.5% (Line and Load)
PA Beam Ripple	250 μV
MO Beam Ripple	50 μV
PA Filament Voltage	5.2 V
MO Filament Voltage	6.3 V
PA Filament Current	4.5 A max
MO Filament Current	1.5 A max
PA Filament Regulation	NMT ± 2% (Line and Load)
MO Filament Regulation	NMT ± 2% (Line and Load)
PA Filament Ripple	0.1 MV, 3-100 KHz
MO Filament Ripple	0.1 MV, 3-100 KHz

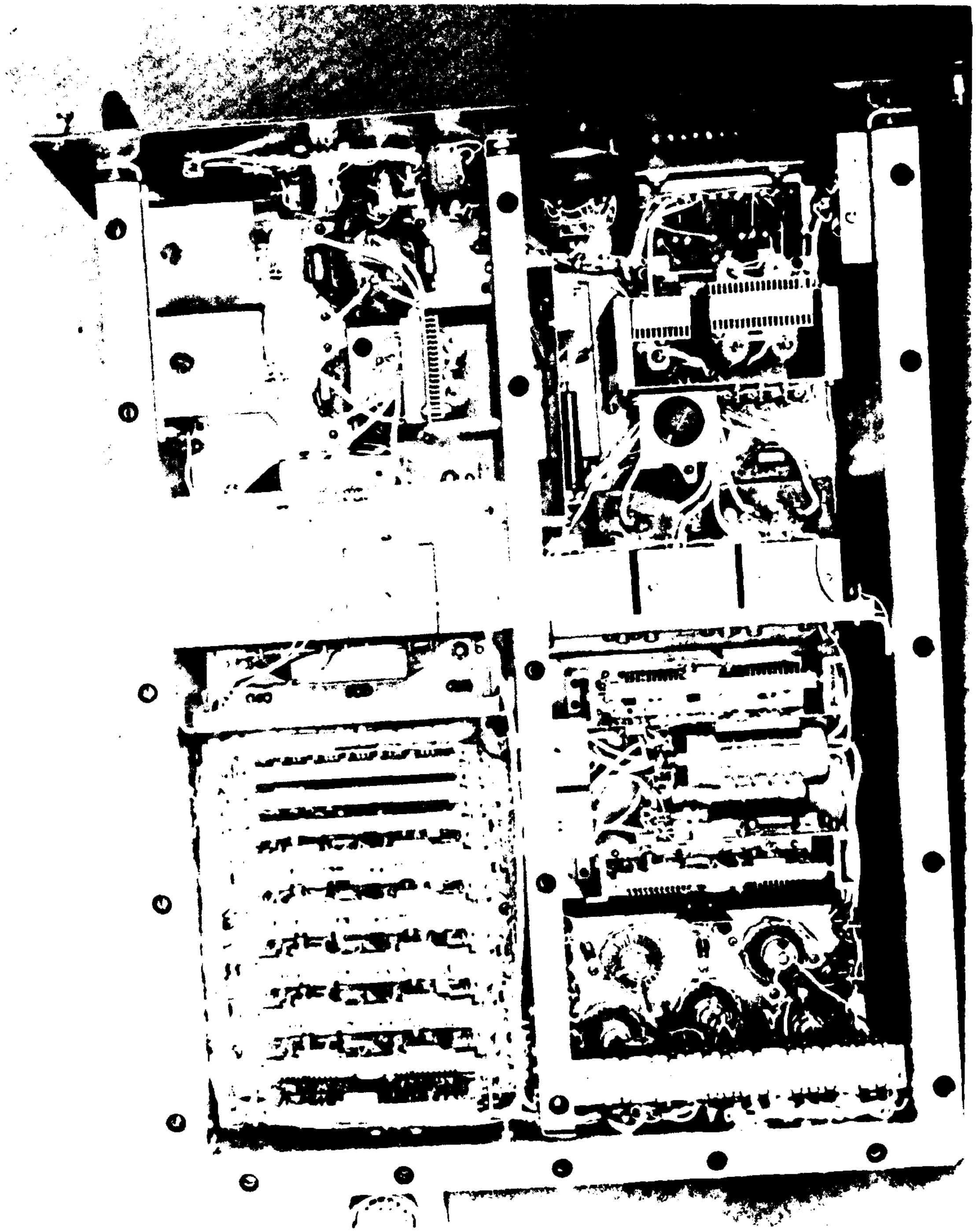

Figure 3-10 - HVPS - Top View

3.4.4 HVPS Detail

The high voltage power supply is divided into five sections because of electrical, thermal, and structural considerations. The upper left hand section, high voltage input, has high ripple and must be electrically isolated from the other circuitry. The lower left and lower right have the most stringent thermal requirements, and isolating them enables more efficient use of the cooling air. In addition, the cross members and top that provide electrical and thermal isolation contribute to the structural strength of the unit. The fifth section is located below the upper left hand section with the modules. It is shown in Figure 3-11.

The upper left hand section is the HV input, which contains the HV transformer, rectifiers block, LC filter, spark gap, voltage divider, and ARC network. The upper right section in the HV output contains the PA output, LC filters, and divider network, MO output attenuation resistors, RC filter, divider network and current control, plus the meter drive reference voltage circuit, regulator divider network, and the ripple sensing circuit. The maximum voltage is minus 5350 Vdc, the PA output voltage.

The lower right hand section contains the series regulator tubes and associated resistors, the MO and PA filament regulator cards, and their O/V protection cards. The HV output connectors J2 and J3 are located at the rear of this section. The lower left section contains the series tube regulator modules (A1-A5), the regulator amplifier (A9), series tube BITE (A8), BITE monitoring network (A11), O/V protection and meter drive (A10) cards, and the resistor for the function meter site. This is the only section without high voltage. There is one more section of the power supply that is shown in Figure 3-11.

3.4.5 HVPS Subsection Detail (Figure 3-11)

This section, which is located below the circuit modules, is a low voltage section which supplies minus 65 Vdc, plus 20 Vdc and plus 5 Vdc. It contains a transformer, five large capacitors with full wave bridges mounted to them, and a circuit board containing six diodes and three capacitors. The transformer has five pairs of taps that go to the five caps and full wave bridge rectifiers which provide 13 Vdc to the series tube filament regulator modules. The transformer has three pairs of taps plus a center tap which form three fullwave center tap rectifiers which produce minus 65 Vdc, plus 20 Vdc, and plus 5 Vdc unregulated to various points on the HVPS.

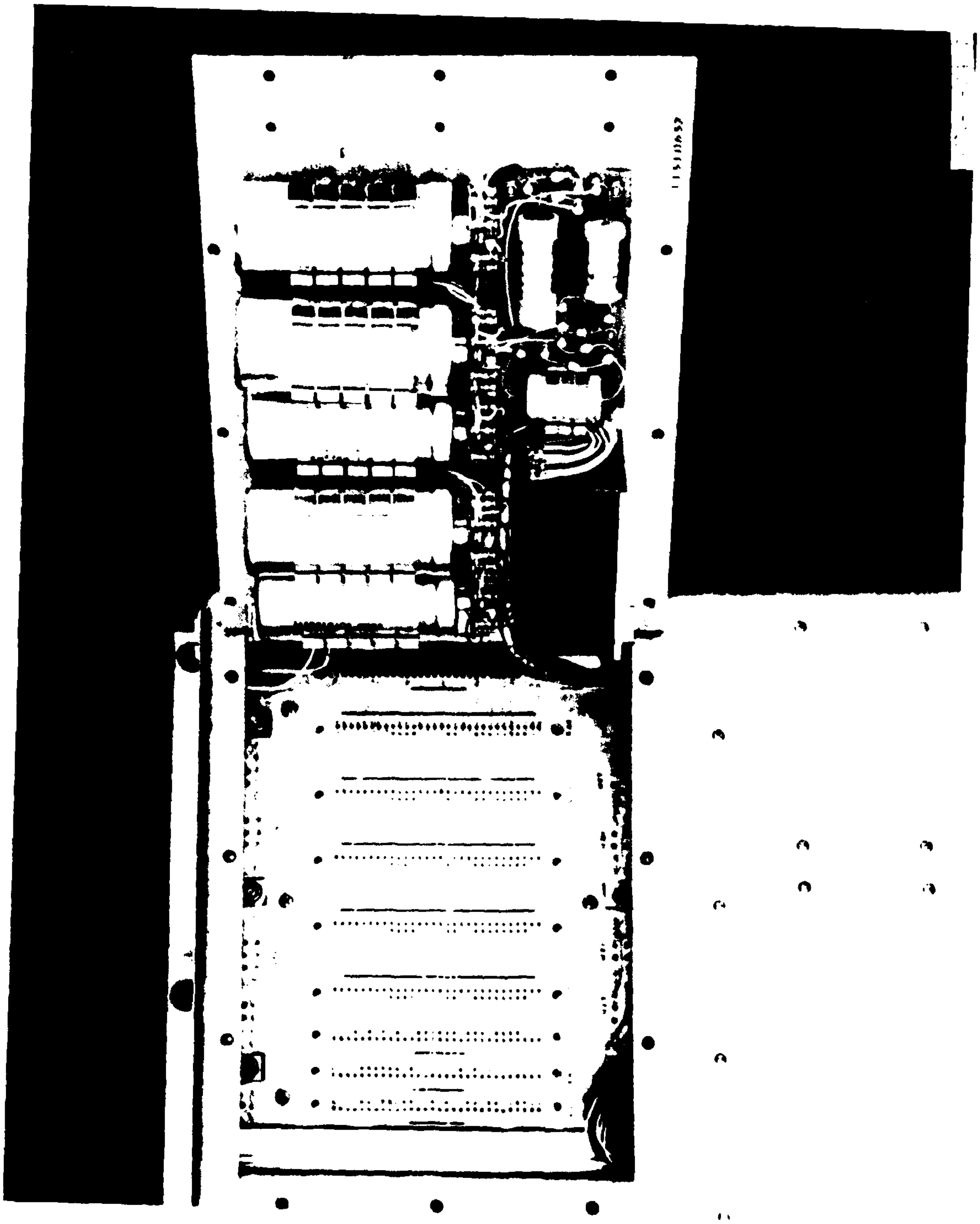

Figure 3-11 - HVPS - Subsection Detail

3.4.6 Filament Regulator Module (Figures 3-12 and 3-13)

The filament voltage regulator is a plug-in, direct current series regulator with built in current limiting and is capable of providing two output voltages and three current limit points. Output voltage and current limiting are determined by the prewiring of its mating connector. Seven regulators are used to regulate the filament voltages of the power amplifier tube, master oscillator tube, and five high voltage series regulator tubes in the high voltage power supply.

Input voltage to the regulator is nominally 13 Vdc. Output voltage is 5.2 or 6.2 Vdc. The lower voltage is programmed by shorting pins 43, 44, 45, and 46 in the module's mating connector. Output voltage is sampled by dividers R4, R5, and R6. It is compared to the adjustable reference voltage source, and the difference is amplified by Q4 and sent to the base of Q1. Q1 and Q2 constitute a Darlington Amplifier which is used as the regulator series pass element. Base drive of Q1 is provided by a constant current source. If the output current reaches the preprogrammed limit, the constant current source is shut-off and the output voltage decreases. This constant current capability limits surge current at turn-on and provides overload and temporary short circuit protection.

3.4.7 Series Regulator Tubes (Figure 3-14)

The five series regulator tubes are high frequency triodes with forced air radiator cooling. They are replaceable at the radar level by the removal of three screws. Each tube has its own Filament Regulator module. These modules provide 6.15 Vdc plus or minus 2 percent to the filaments of the tubes. By keeping the filaments within 2 percent of 6.15 Vdc instead of 5 percent the tube life expectancy is increased. The other tube specifications are shown in Table 3-2. The tubes will typically operate at a plate voltage of 1400 Vdc, a plate current of 75 mA, a grid voltage of minus 20 Vdc, a heater current of 1.3 A, and a heater voltage of 6.15 Vdc.

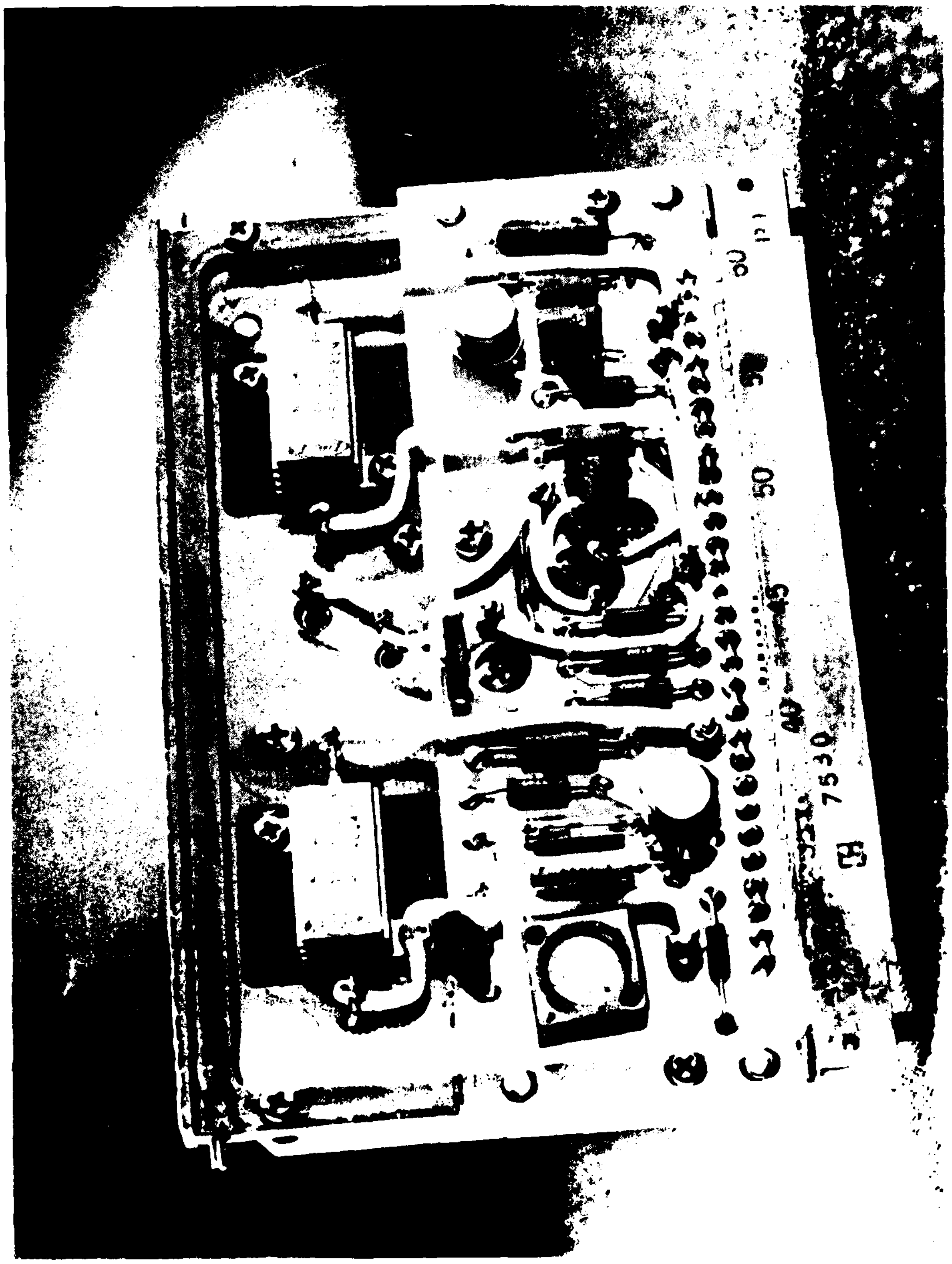

Figure 3-13 - HVPS Filament Regulator Module

Figure 3-14 - Series Regulator Tubes

TABLE 3-2

SERIES TUBE SPECIFICATIONS

Heater Voltage	6.15 Vdc ±2%
Plate Voltage (Max)	4 kVdc
Grid Voltage (Max)	-150 Vdc
Plate Current (Max)	150 mA
Grid Dissipation (Avg)	1.5 W
Plate Dissipation (Avg) (Forced Air Cooling)	320 W
Heater Current (Typ)	1.3 A

The supply is capable of operating with one or two series tubes not functioning. Under these conditions the plate current increases 25 percent and 66 percent respectively. The current through each tube is monitored by the Series Tube BITE module which turns on a Fault Lamp if the current drops below 40 mA. The Series Tubes are protected by a spark gap which fires when the voltage across the tubes reaches 3000 Vdc. The Function Select Switch has a position that monitors the voltage across the Series Tubes.

3.4.8 Feedback Amplifier Module (Figures 3-15 and 3-16)

The Feedback Amplifier Module is a high gain differential amplifier used in the main regulator of the High Voltage Power Supply. The output of the HVPS is sampled and filtered and fed into a differential high gain amplifier where it is compared to a minus 6.2 Vdc reference voltage. The difference is amplified, filtered, amplified again and filtered. The output goes to the grids of the Series Tubes. The voltage regulators take the HVPS basic plus 20 Vdc and minus 65 Vdc voltages and convert them to the values needed in the Feedback Amplifier.

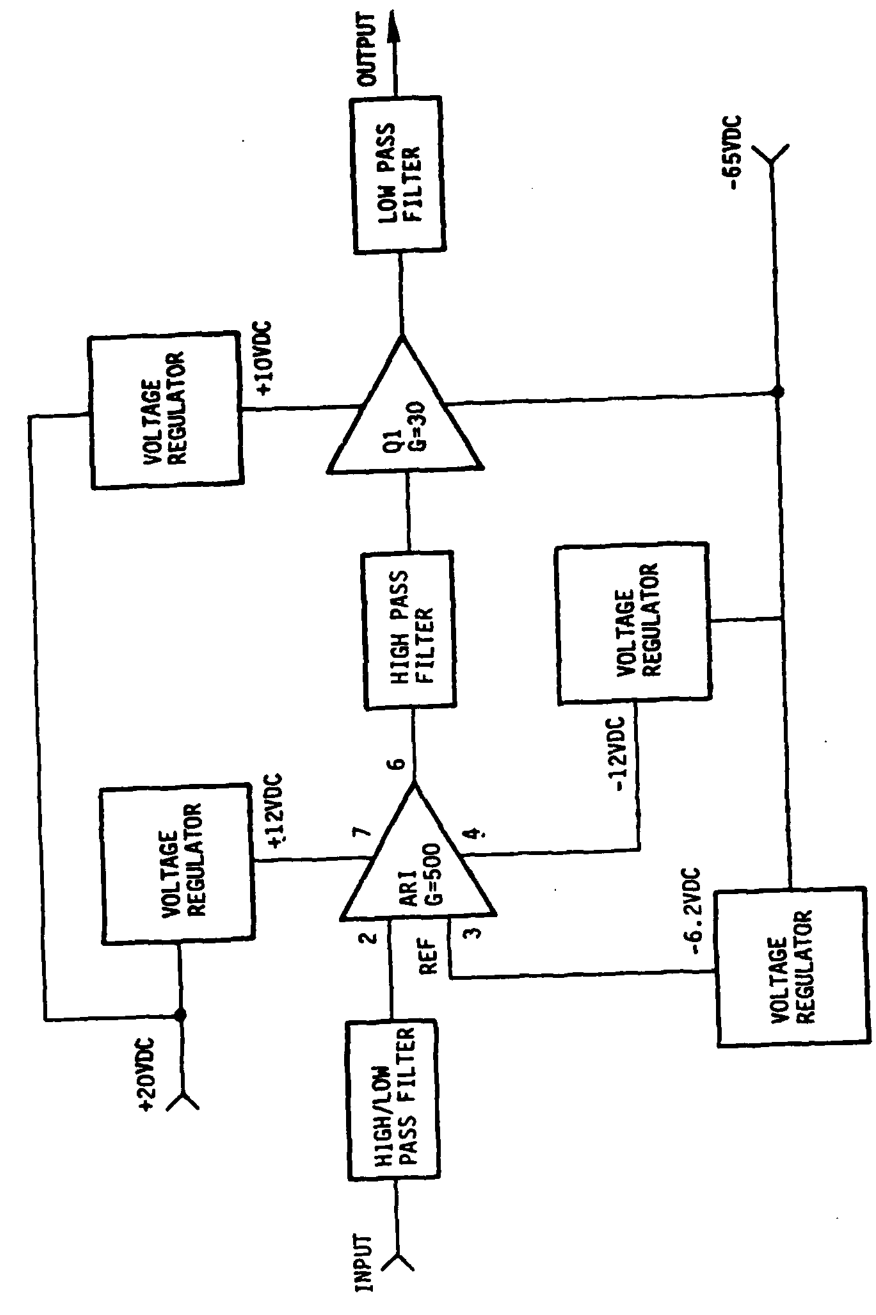

Figure 3-15 - Feedback Amplifier Module Block Diagram

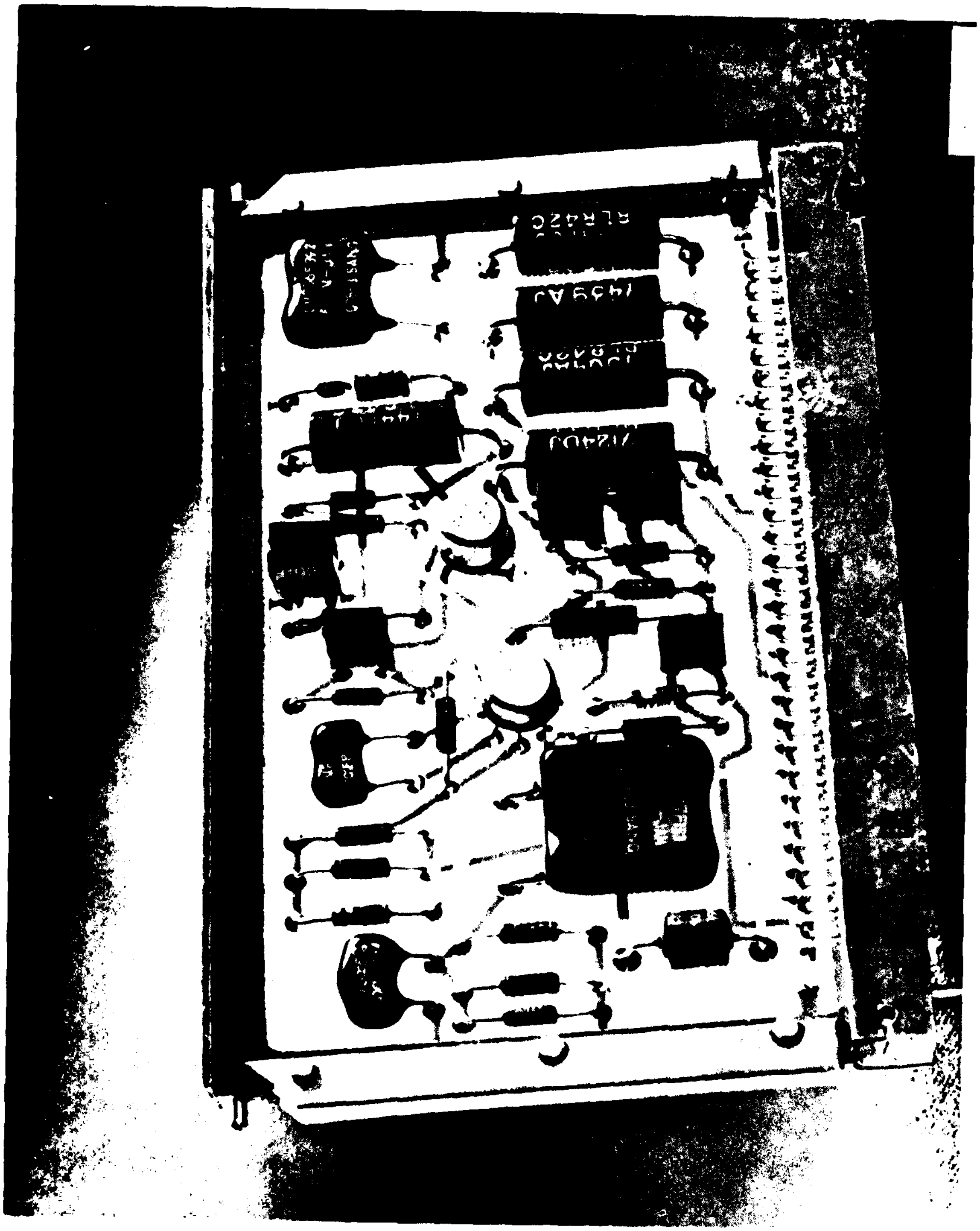

Figure 3-16 - Feedback Amplifier Module

3.4.9 Overvoltage Protection and Meter Drive Module (Figures 3-17 and 3-18)

The Overvoltage Protection and Meter Drive module contains an overvoltage protection comparator that latches the overvoltage relay, when an overvoltage occurs, plus the meter drive differential amplifier.

When a sample of the PA output voltage exceeds a set limit, the output of AR1 increases, turning on Q1, which activates K1. When the contacts of K1 close, the O/V Lamp illuminates and the Overvoltage Interlock is opened, sending the Radar back to standby and removing high voltage from the HVPS.

The meter drive is a high gain differential amplifier which measures the difference between a sample of the MO output voltage and a temperature compensated reference voltage. This difference should register between 0 and plus 1 on the Function Meter when the MO Output is 4350 plus or minus 43 Vdc. There is a built-in-drift compensation called Null Adjust that is used to zero the meter before each reading.

3.4.10 Series Tube BITE Module (Figures 3-19 and 3-20)

The main components of the Series Tube BITE Module are the comparator Q1 and the lamp driver Q2. The voltage regulator creates a reference voltage 2.7 Vdc which does to the emitter of Q1. When the input voltage is 2.7 Vdc or greater Q1 doesn't conduct and Q2 is "off". As the input voltage to the base of Q1 decreases (Series Tube Current decreases) Q1 starts to conduct. As current through Q1 becomes larger, the voltage at the base of Q2 increases. When the voltage at the base of Q2 is large enough Q2 comes "on" allowing the lamp to illuminate. The other four circuits for the other Series Tubes are exactly the same. The diode CR1 and the other four diodes are tied through the LAMP TEST switch to ground. When the switch is closed, all the lamps illuminate.

3.4.11 BITE Monitoring Network Module (Figures 3-21 and 3-22)

The BITE Monitoring Network Module contains five voltage dividers clamped to a reference voltage. These protect the function meter if one of the Series Tube filament voltages becomes unregulated. The PA and MO filament current monitoring circuitries are also located on this module.

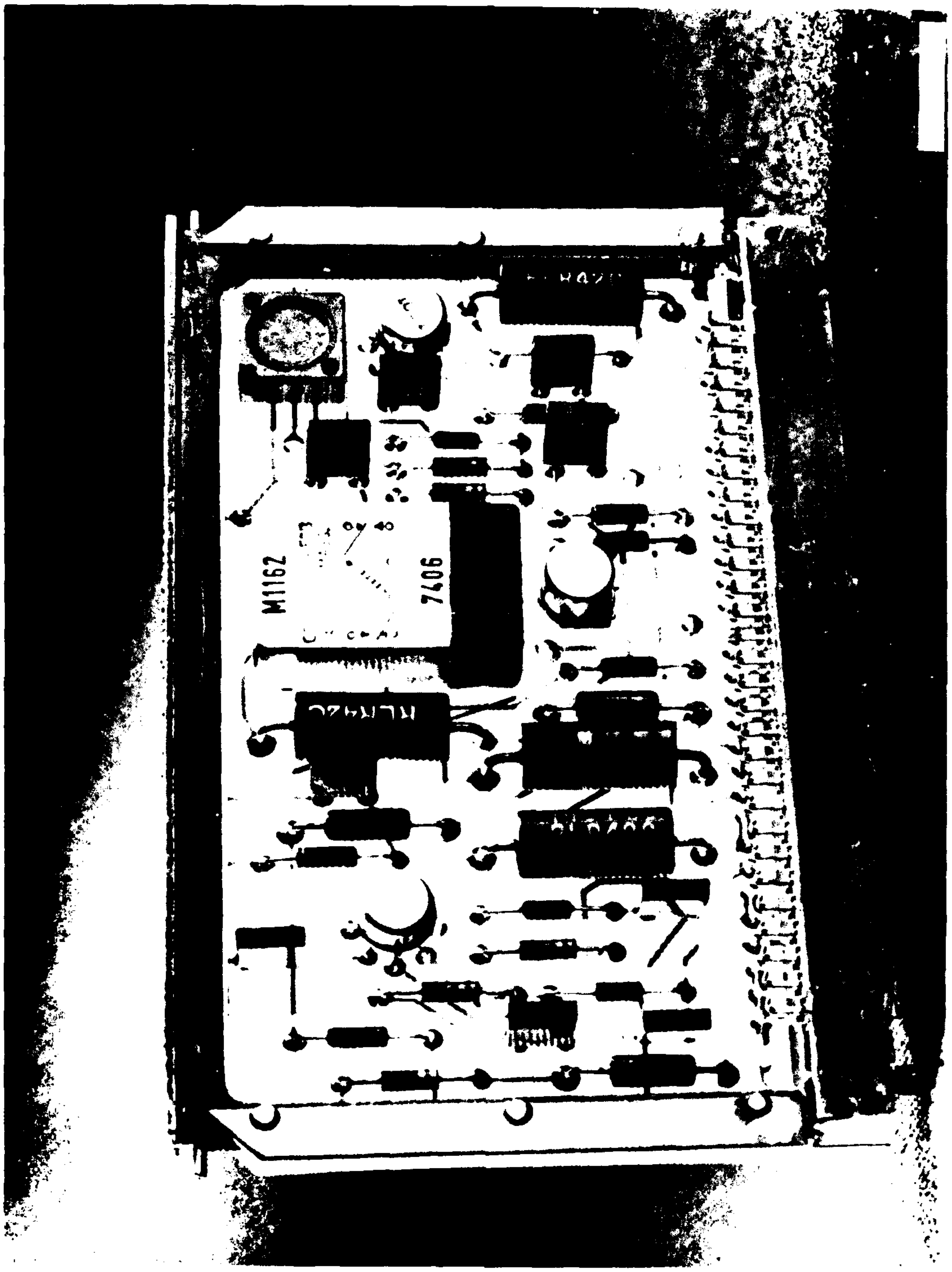

Figure 3-18 - Overvoltage Protection Module

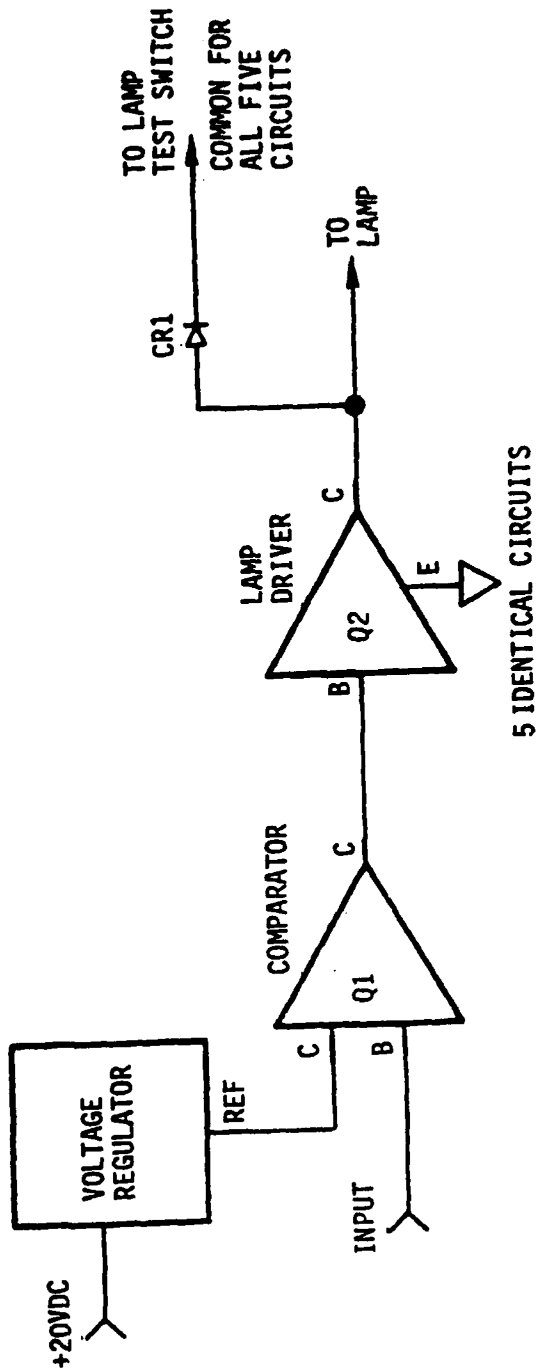

Figure 3-19 - Series Tube BITE Module Block Diagram

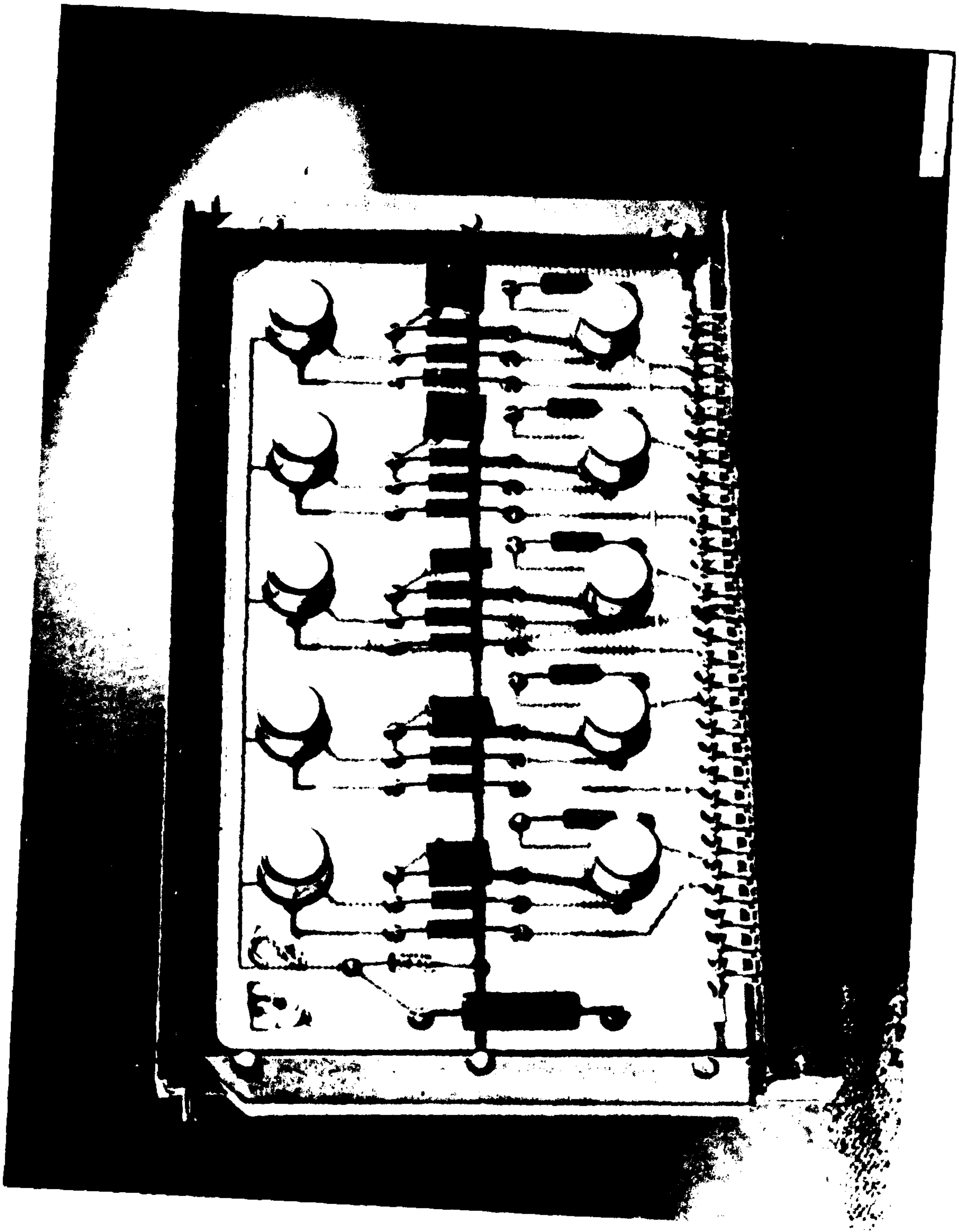

Figure 3-20 - Series BITE Module

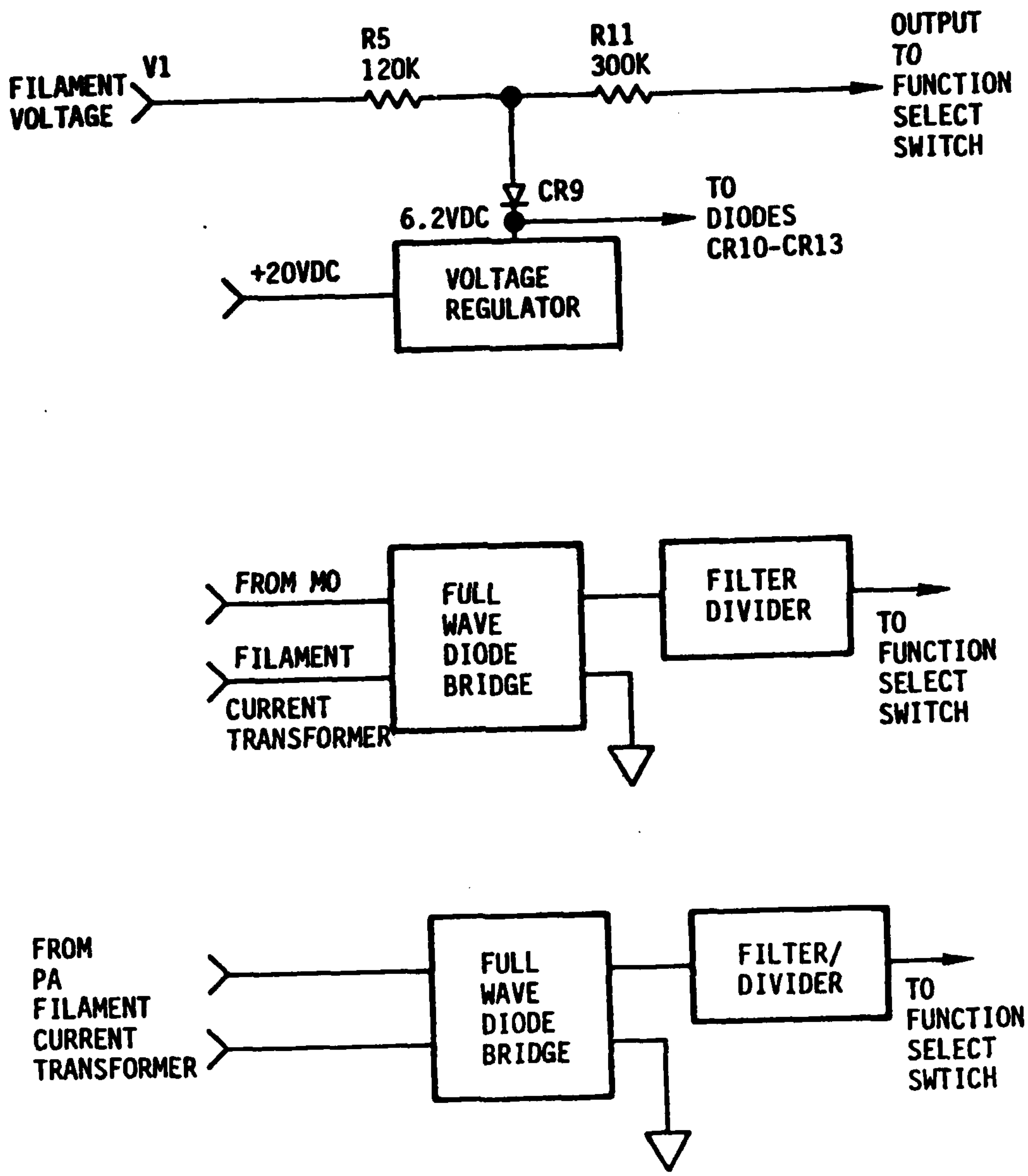

Figure 3-21 - BITE Monitoring Network Module Block Diagram

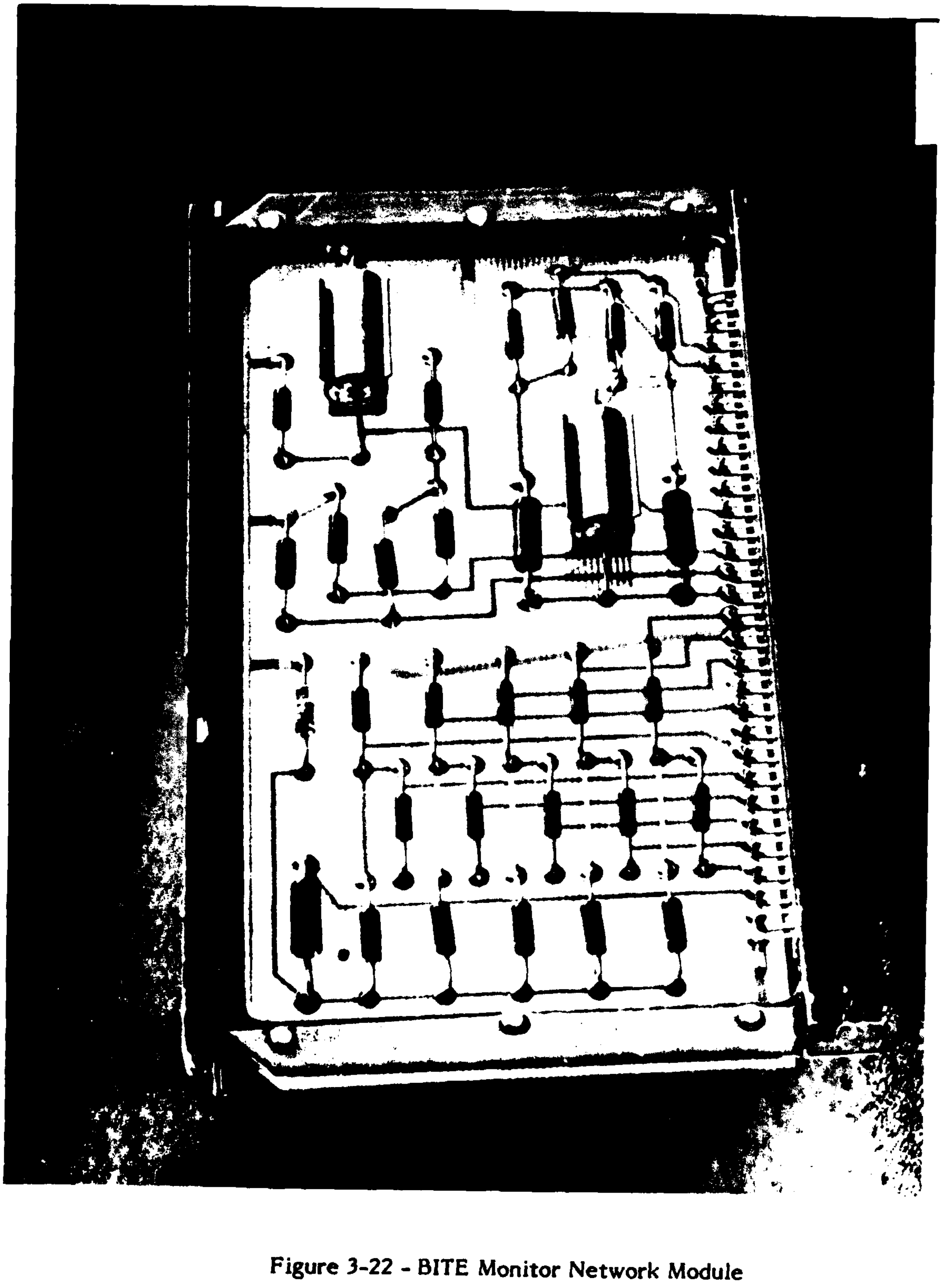

Figure 3-22 - BITE Monitor Network Module

The V1 filament voltage input to the R5/R11 divider network is reduced by the R11 (R5 plus R11) ratio because the external load between R11 and ground is only 1.2K. The voltage at the junction of R5 and R11 can't be greater than 6.8 Vdc, so if the filament voltage is larger than 9.5 Vdc, the voltage at the junction of R5 and R11 remains at 6.8 Vdc. If the filament voltage drops below 6.8 Vdc, the junction voltage drops by the same ratio. There are five identical divider and diode circuits, one for each Series Tube.

The input current to the MO and PA Filament Regulator modules is sampled using two current transformers. The outputs of these two current transformers are sent to the BITE Monitoring Network module. The current transformers isolate the BITE Monitoring Network module from the high voltage of the PA and MO Filament Regulator modules. The ac voltages into the BITE Monitoring Network module are converted to dc voltages by the fullwave diode bridges and filters. They are then sent to the Function Select Switch.

3.4.12 MO Filament Protector (Figure 3-23)

The MO Filament Protector module provides unregulated 13 Vdc to the MO Filament Regulator module and the overvoltage protection for the MO Filaments. The fullwave bridge transforms the ac input to 13 Vdc, which is used on this module and the MO Filament Regulator/Module. The overvoltage protection circuitry takes the regulated MO Filament voltage and divides it to a lower level. It is then compared to a reference voltage. If it is larger than the reference voltage the SCR is fired removing the voltage from the MO filaments. Under normal circumstances the MO Filament Regulator will current limit and the fuse will not blow.

3.4.13 PA Filament Protector (Figure 3-24)

The PA Filament Protector module provides unregulated 13 Vdc to the PA Filament Regulator module and the overvoltage protection for the PA Filaments. The fullwave bridge transforms the ac input to 13 Vdc, which is used on this module and the PA Filament Regulator Module. The overvoltage protection circuitry takes the regulated PA filament voltage and divides it to a lower level. It is then compared to a reference voltage. If it is larger than the reference voltage, the SCR is fired, removing the voltage from the PA filaments. This protects the PA tube from a short across the Filament Regulator Module pass transistor. When the SCR fires, high current is drawn and F1 blows.

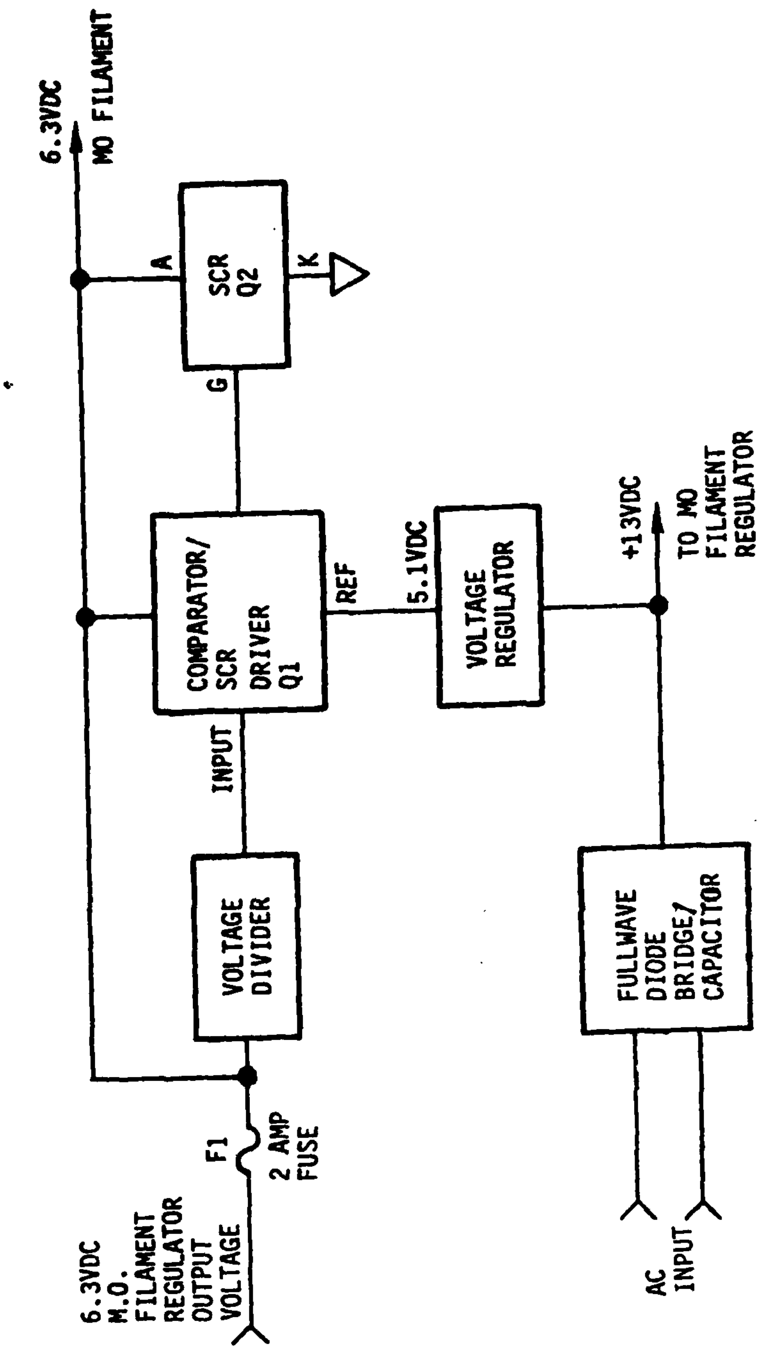

Figure 3-23 - MO Filament Protector Block Diagram

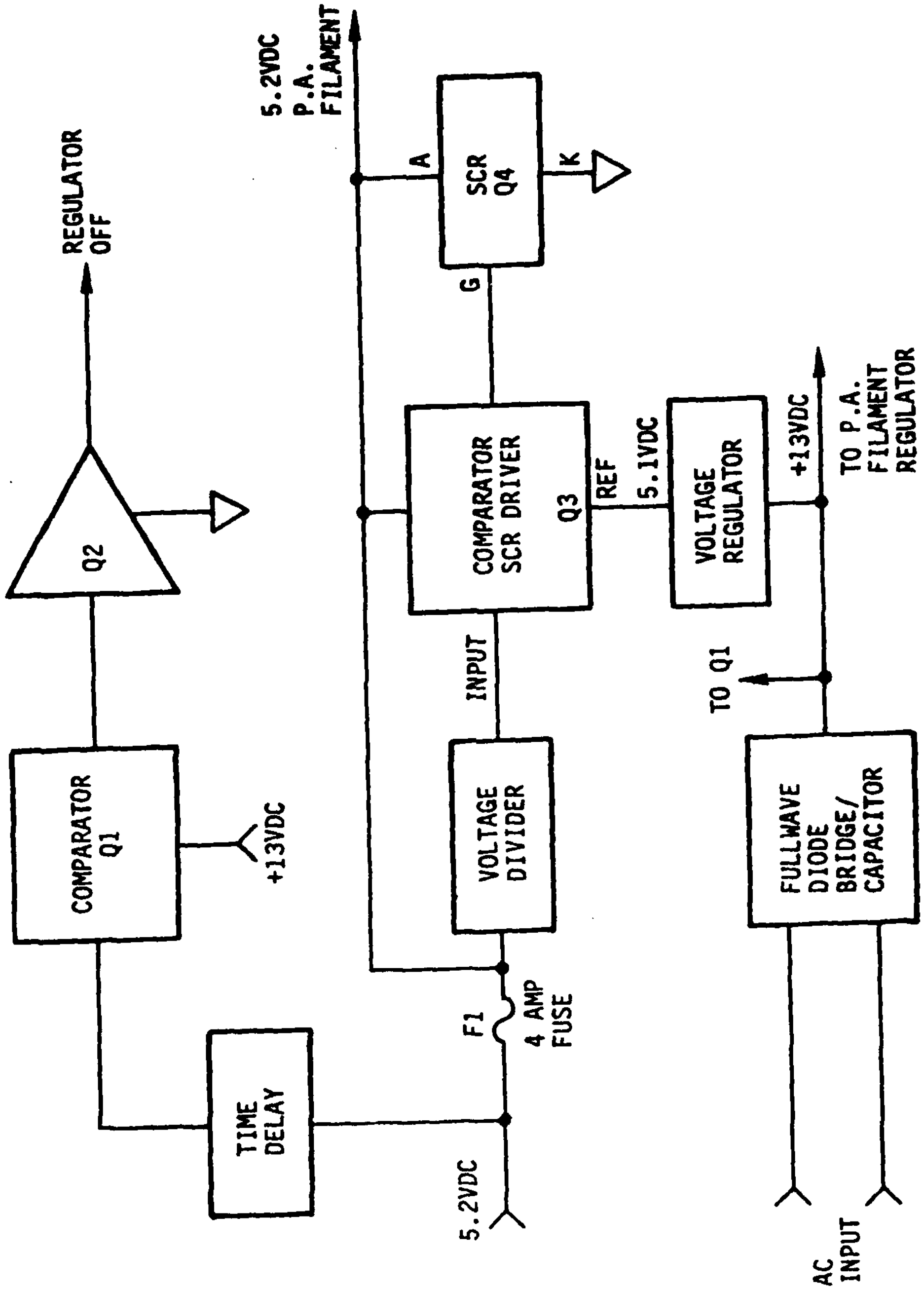

Figure 3-24 - PA Filament Protector Module Block Diagram

If a short occurs, the PA voltage regulator will current limit. The Regulator Off circuitry which is sampling the PA Filament Regulator output will notice the drop in voltage, and after a time delay, the comparator Q1 will turn-off Q2 shutting off the PA Filament Regulator Module.

3.4.14 HVPS Front Panel (Figure 3-25)

The Function Select switch on the HVPS front panel enables the Function Meter to monitor 10 functions normally and 8 more using the function extent pushbutton. The O/V Fault Lamp is tested using the Function Select switch and the Meter zero pushbutton.

The first 8 positions are used with the radar in Standby (Table 3-3). The first two voltages minus 65 Vdc and 20 Vdc are generated in the HVPS and used throughout the supply. Positions 2-7 are self explanatory. Position 8 does not use the meter. An artificial overvoltage is provided to the Over-voltage Protection and Meter Drive module while the supply still in Standby.

The last 3 positions are used with the radar in Radiate. Position 9 measures voltage across the series tubes. Position 10 checks MO output voltage. The meter is zeroed to compensate for drift before the reading is checked. Position 11 checks PA output voltage, and 11D checks ripple on the PA output.

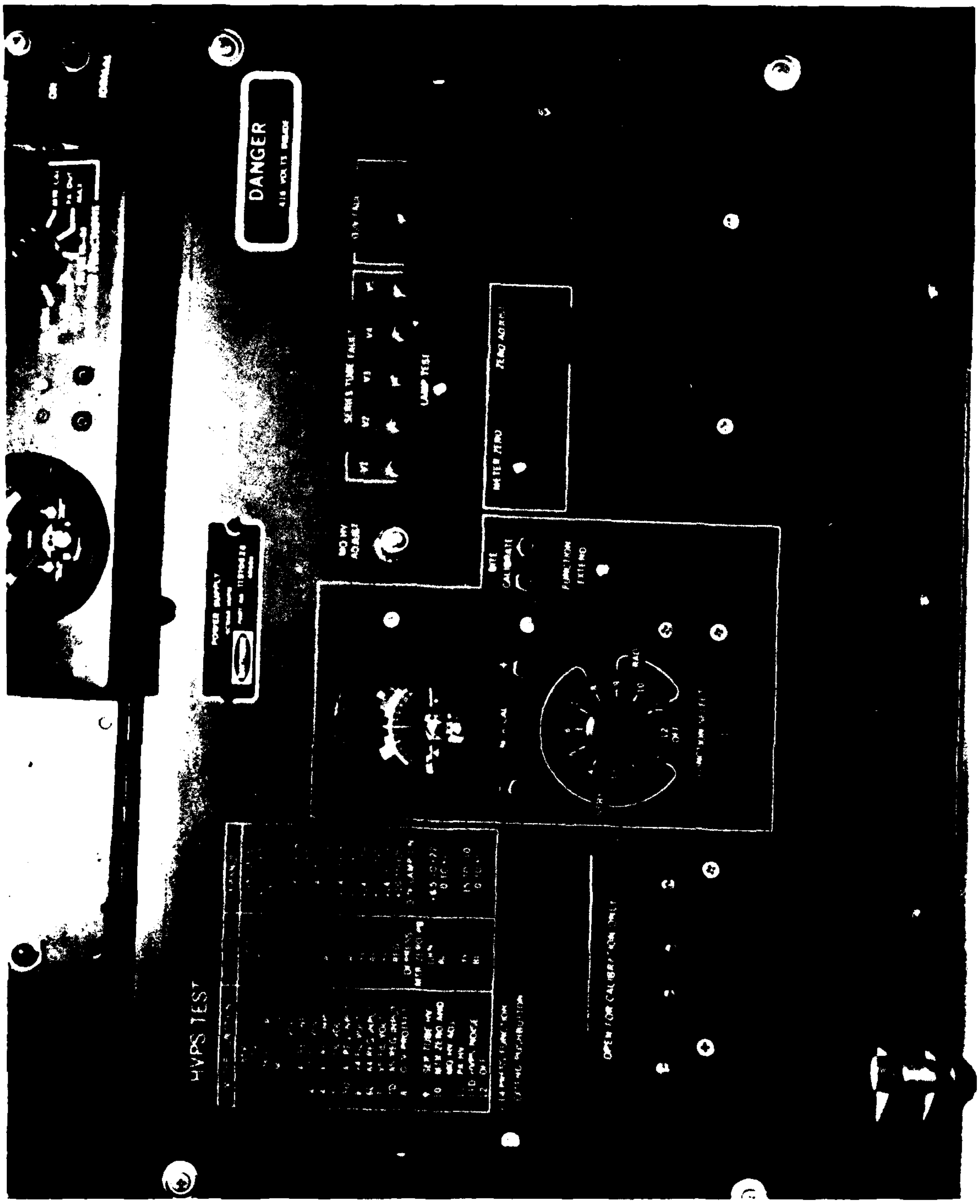

Figure 3-25 - HVPS Front Panel

TABLE 3-3

HVPS FUNCTION SELECT SWITCH AND METER BITE TESTS

Function Select Switch Position	Switch Function	Meter Range (Color)	Comments
1	-65 Vdc	-15 to 5 (grn)	
1D	+20 Vdc	+10 to +20 (red)	Press and Hold Function Extend Pushbutton for D's.
2	PA Fil Cur	-15 to -5 (grn)	
2D	MO Fil Cur	-15 to -5 (grn)	
3-7	V1-V5 Fil Volt	+14 to +16 (yel)	Regulator Tubes
3D-7D	A1-A5 Reg input	+10 to +20 (red)	Fil Voltage.
8	O/V Protect	None	Press Meter Zero Pushbutton O/V Fault Lamp
9	Series Tube HV	+6.5 to 22 (grn)	
10	MTR Zero and MO HV ADJ	0 to +1 (blu)	Press and Hold Meter Zero Push-button. Adjust Zero Adjust for 0 to +1. Release Meter Zero Push-button. Adjust MO HV Adjust for 0 to +1
11	PA HV	-15 to -10 (yel)	
11D	HVPS Noise	0 to +1 (blu)	
12	OFF		

3.5 Arc Detection

Protection of the Power Amplifier Klystron from damage by the possible occurance of microwave arcs in the RF transmission line that goes from the RSG Console to the transmitter antenna feed is provided by the simultaneous monitoring of power along the line. Arcing can be caused by many factors. One common example is contamination (moisture, loose hardware, metal filing, etc.) in the waveguide. Another is improper transmitter tuning. Presence of an arc in the waveguide inbalances the antenna and the RSG arc detection signals. Arc detection circuits sense this inbalance and place the radar in standby removing the beam high voltage from the MO and PA tubes. This interruption should be long enough to allow the air in the vicinity of the arc to deionize. After a few seconds, it may be possible to manually return the radar to radiate. If this is not possible (radar again goes to standby), troubleshooting and repair action is indicated. Presence of ionization will also return the radar to standby. A short wait should allow the ionization to clear itself.

The arc detection module (Figure 3-26) contains the comparator circuits that monitor the RF detectors placed at the output of the Power Amplifier and at a position just prior to the antenna. A waveguide arc near the antenna, or between the RSG and the antenna, decreases the antenna arc detector signal. While the PA is still producing RF, the arc detector circuit sees a mismatch and activates a relay which in turn interrupts the radiate interlock system.

This interruption places the radar in standby. An arc sometimes clears its own cause preventing another arc when power returns. The dc level of the antenna arc detector diode and the dc level of the PA arc detector diode are normally equal. These two signals are compared in the dual voltage comparator. When an arc occurs, the RF power at the arc detection diodes is unequal. This causes an imbalance in the arc detector circuit resulting in activation This causes an imbalance in the arc detector circuit resulting in activation of the relay circuit. With RF power shut off, there is not output from either arc detector diode. This returns the arc detector circuit to a balanced condition, however, the relay circuit is of a latching design and must be reset via the switch on the CIP Panel before making any attempt to restore the radar to radiate. (Figure 3-27).

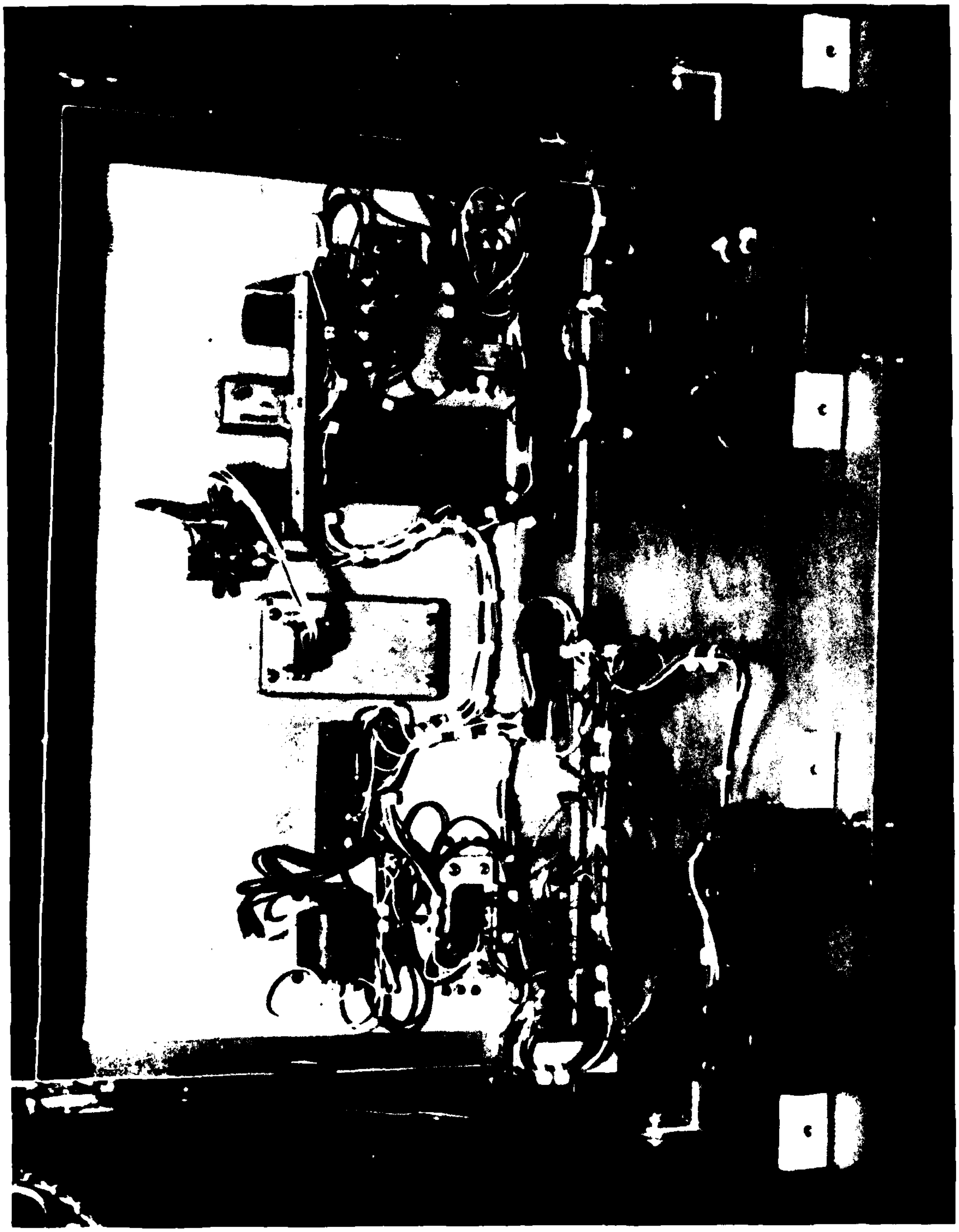

Figure 3-26 - Arc Detection Module

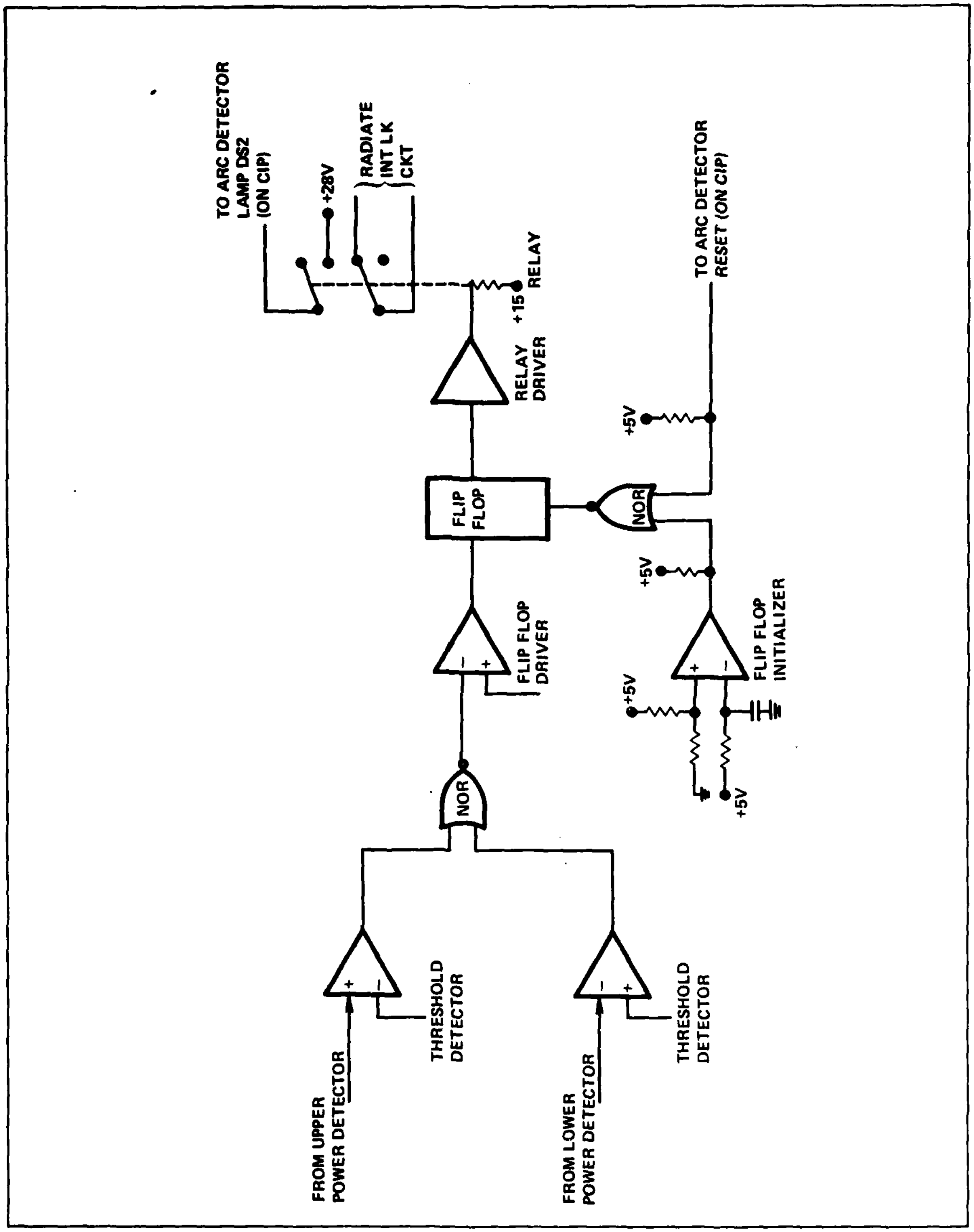

Figure 3-27 - Arc Detection Block Diagram

4. THEORY OF OPERATION FOR RECEIVER

4.1 General

The receiver consists of two major units and the receiving antenna. The two major units are the RF microwave receiver and the doppler amplifier. The receiving antenna is a parabolic reflector cassegrain lens along with a nutating scanner.

The receiver accepts microwave energy reflected from objects in the transmitted beam. This energy consists of signals reflected from targets having radial speed and also from fixed objects. The receiver discriminates between the two and applies the information from the moving targets to the Signal Data Processor. This information consists of the target doppler frequency shift, and antenna position error amplitude modulation.

The receiver uses a wide dynamic range, low-noise FET preamplifier at microwave frequencies followed by a mixer and a Doppler Amplifier. This mixer uses Schottky Diodes and receives its local oscillator input from the highly stable low noise transmitter's reference output.

The environment in which this receiver is intended to operate is characterized by extreme levels of localized point clutter, sudden jumps in target input level, presence of significant blast overpressures, target cross-sections ranging from 2.43 x 10^{-5} $meter^2$ (5.54 mm U.S. Rifle) to 0.1 $meter^2$ (8 inch shell, side aspect, approximate) at initial ranges as close as 30 meters for the large caliber weapons, with obscuring of targets by explosive particulate clutter generated by muzzle blast and low speed doppler anomalies created by discarding sabots and kick plates.

The use of a mechanically and electrically isolated wide range FET preamplifier/Schottky mixer combination allows the dynamic ranges produced by this environment to be handled linearly, protects the system from microphonics generated by blast, provides a noise performance capability for tracking extremely small cross-section projectiles to maximum ranges, and protects the system inputs from the effects of ground loops.

The Receiver gain is divided between the RF and video sections of the signal path. The RF gain desensitizes the Receiver to low frequency 1/F noise generated in the mixer and video preamplifier, and to ground loops and EMR.

The overall gain of this Receiver is predicated upon the signal level necessary to place the receiver's amplified front end noise equal to the level of the feedthrough LO signal (VCO) in a 1 KHz bandwidth at the output of the up-conversion mixer in the Doppler Tracking Unit (DTUP).

A functional block diagram is shown in Figure 4-1.

4.2 Receiving Antenna

The receiving antenna reflector receives microwave energy reflected from the target and directs it toward the receiving horn. This energy contains the target echo with attendant doppler information. The energy is focused by the antenna reflector and fed to the nutating scanner. The nutating scanner has two functions. The primary function is to provide transition of the reflected energy from free space to waveguide. The secondary function is to produce conical scanning of the receiver sensitivity pattern. This conical scanning puts antenna position error modulation on the target echo (Figure 4-2).

The amount of target energy coupled to the receiving horn is at a maximum when the target is on the peak of the sensitivity pattern of the receiving antenna. The shape of the sensitivity pattern is determined by the antenna reflector. Rotation of the sensitivity pattern about the electrical axis of the receiving reflector is a result of the reflector construction and the rotation of the receiving horn. The rotation of the sensitivity pattern is at "M" frequency and produces amplitude modulation of the target echo when the target is off the electrical axis of the reflector. The main lobe of the receiving antenna has a minimum 36 db gain and a beamwidth of 32 mils at half power points (Figure 4-3).

The "M" frequency rotation of the receiving horn is produced by the nutating scanner motor. The motor speed is controlled by the motor speed control servo loop. The motor also rotates a reference generator. The reference generator not only develops an error signal for the speed control servo loop but also supplies reference generator output signals which are coupled to the antenna positioning system. The reference generator output signals provide a reference for determining the phase and the amplitude of the antenna position error modulation carried on the target echo.

Table 4-1 identifies the typical RF inputs to the receiver.

The reflected target echo with doppler and antenna position error modulation is coupled through the nutating scanner to the RF Microwave Receiver.

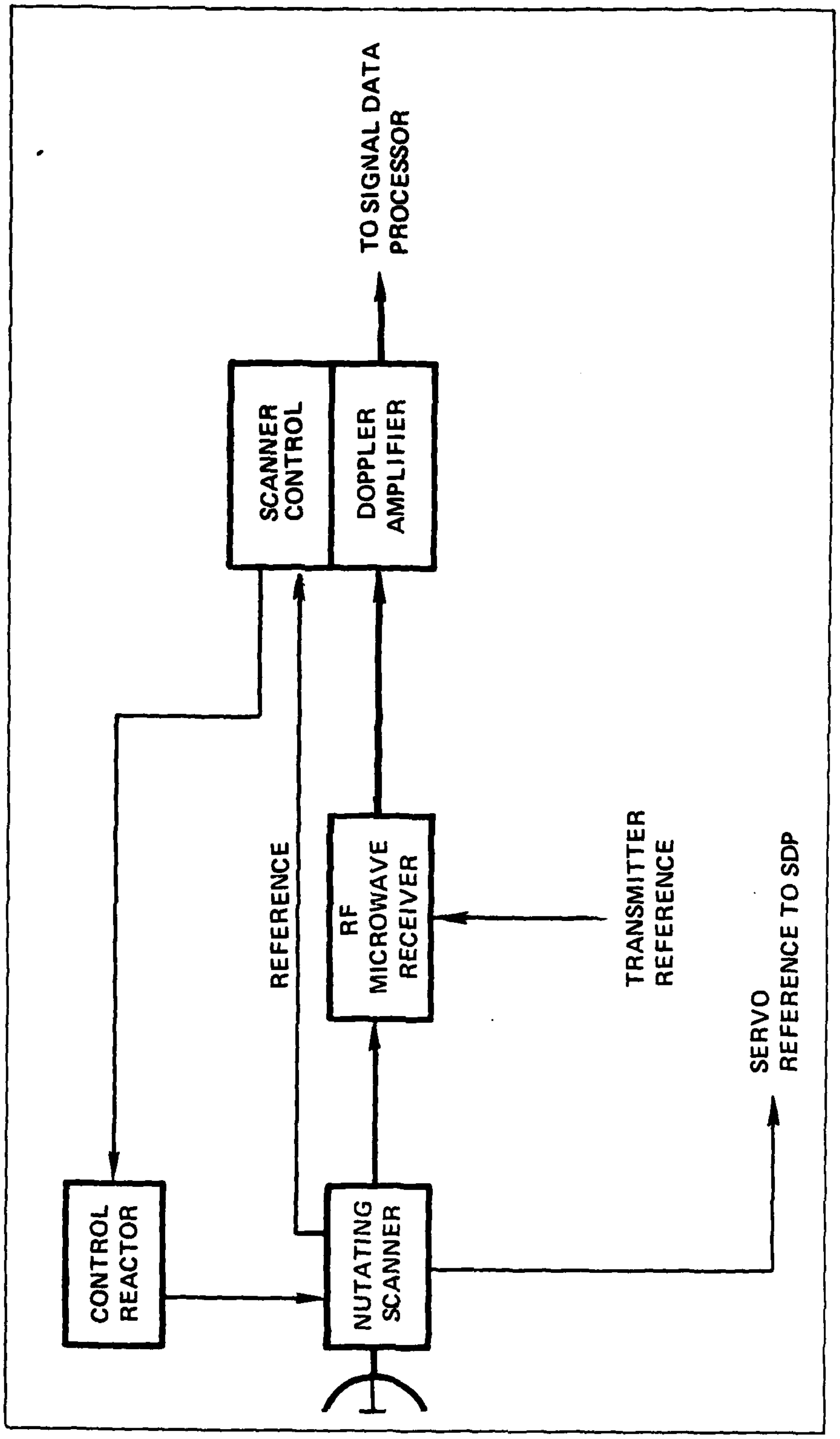

Figure 4-1 - Receiver Block Diagram

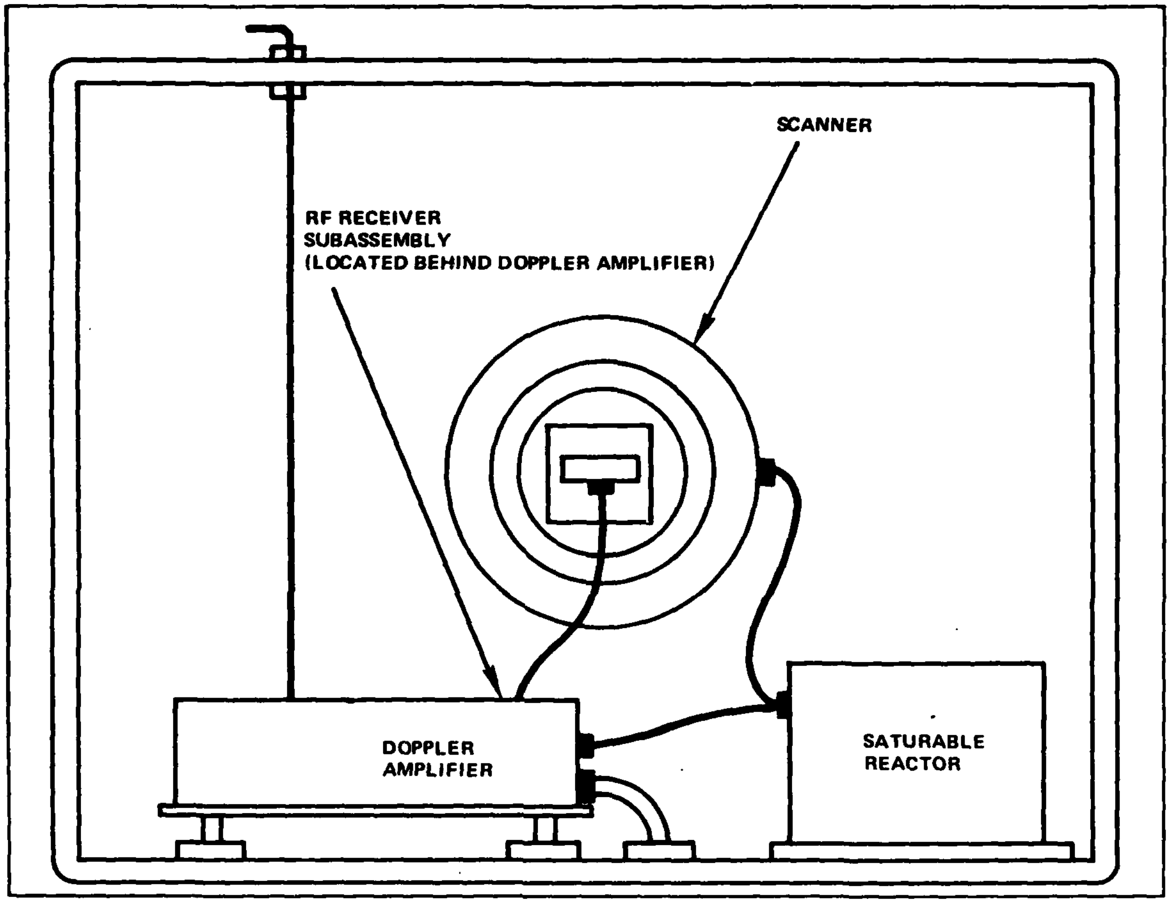

Figure 4-2 - Receiver Antenna Box

Figure 4-3 - Receiving Antenna Group

TABLE 4-1
RECEIVER RF INPUTS

Maximum (operating) feedthru level	≤ -4dBm
NOTE: P_T = 400W = 56 dBm P_C/P_T = -60db	
Typical (operating) feedthru level	≤ -14dBm
Maximum (non-operating) feedthru level	≤ +30dBm
Maximum target level	≤ -40dBm
Transmitter Intentional Modulation (coding, ranging)	None
Minimum Discernible Signal (MDS)	-133 dBm/KHz*
NOTE: Thermal Noise Floor using NF = 11 dB	
Transmitter Reference Input	+20 dBm ± 2 db
Transmitter Frequency Range	A ± 125 MHz
*Measurement bandwidth	

4.3 RF Microwave Receiver (Figure 4-4)

The RF Microwave Receiver accepts signal inputs from the receiving antenna system and the transmitter reference output. After amplification of the received energy, these inputs are coupled to a balanced Schottky barrier mixer assembly where they are heterodyned with a sample of the transmitted RF carrier to produce doppler outputs. This conversion to baseband video allows the information on the microwave signals to be amplified effectively without the use of a local oscillator. The resultant video signals represent doppler frequency shift information (return echo) from moving targets. The signal contains the modulation of the original microwave carrier.

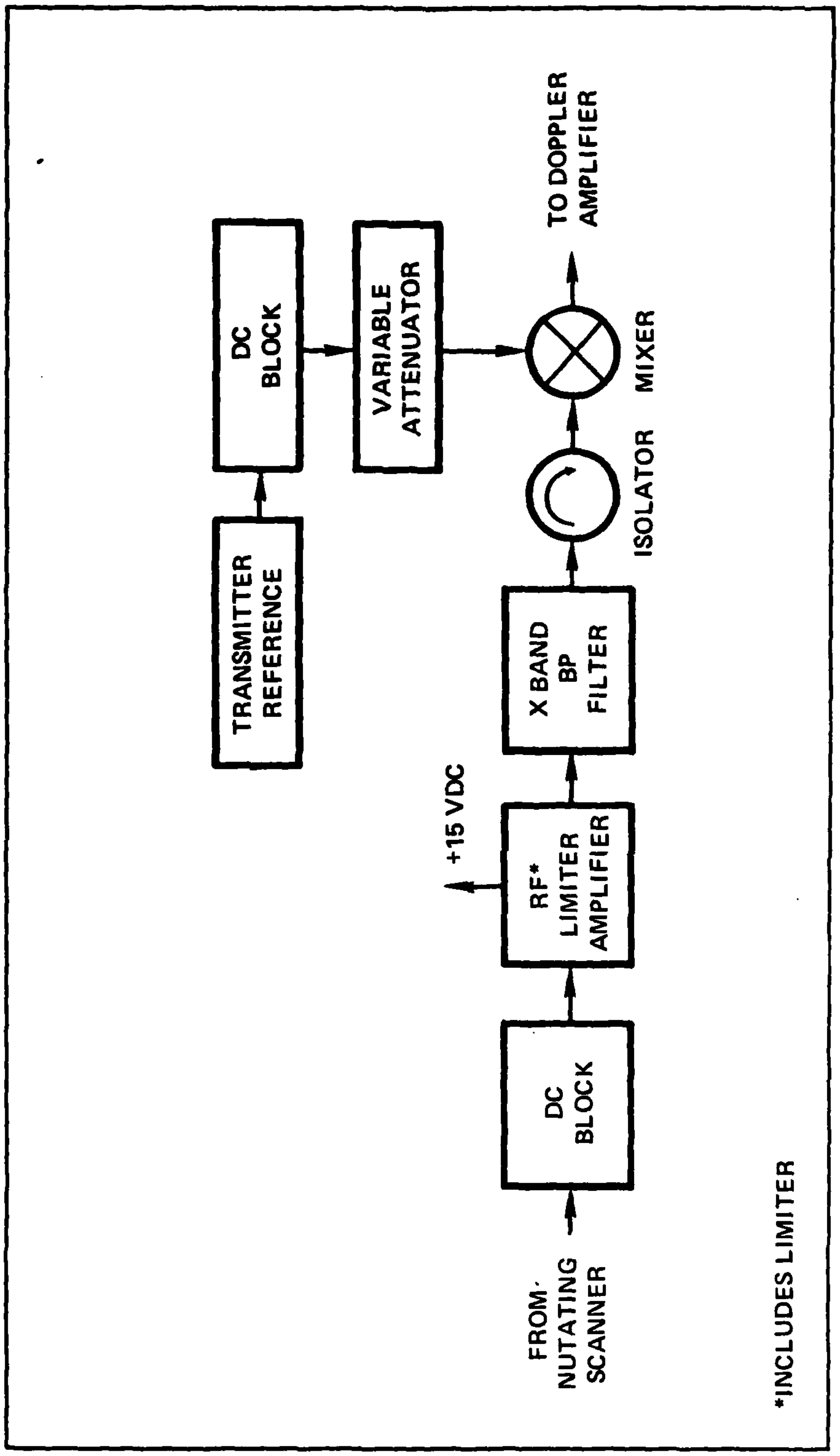

Figure 4-4 - RF Microwave Receiver Block Diagram

The Gas FET (RF) amplifier (Specifications listed in Table 4-2) has sufficient amplification and low noise characteristics to establish the basic noise figure for the receiver.

TABLE 4-2
LIMITER/GAS FET AMPLIFIER CHARACTERISTICS

Operating Frequency Range:	2.5% at X-Band
Power Gain (S21):	24 ± 2 dB
Noise Figure:	5.5 dB maximum
VSWR-Input, Small Signal:	2:1 maximum
VSWR-Output:	2:1 maximum
Maximum Signal Level, Small Signal:	-14 dBm
Maximum Signal Without Degradation:	+20 dBm
Stability:	Unconditional
Spurious Signals:	Below noise in a 300 Hz bandwidth across the operating frequency range
Voltage Breakdown of DC Block:	150 VDC minimum, inside & outside
Power:	+15 VDC 250 MA maximum
RF Connectors:	SMA male

Note: Specifications assume that the input and output are terminated in 50 ohms, except for the stability requirement which is independent of termination, temperature, frequency, etc.

The received energy is coupled from the scanner through an X-Band bandpass filter, which provides attenuation to out-of-band microwave signals, to the RF amplifier.

The receiver RF amplifier is protected by a limiter which is transparent to small signals, but prevents damage from high level inputs. The inside/outside DC blocks provide immunity to ground loop currents. The RF preamplifier output is coupled to the high power mixer that has as the local oscillator a direct sample of the transmitted energy.

4.4 Doppler Amplifier

4.4.1 General (Figure 4-6)

The Doppler Amplifier increases the signal strength of the doppler outputs from the RF microwave receiver. The output of the doppler amplifier is applied to the SDP which extracts target radial speed and antenna position error information from the doppler signal.

The doppler signal is frequency-dependent upon target radial speeds, and is amplitude-modulated at the scan frequency rate with an amplitude and phase representing the amount and direction of target error off the antenna electrical axis.

Each doppler signal contains its own antenna position error amplitude modulation. If more than one moving target reflects energy to the receiver, a doppler signal is produced for each target. The doppler signal or signals are coupled out of the RF amplifier to the doppler amplifier.

Figure 4-5 is a block diagram of the Doppler Amplifier. After a low noise amplification stage, a bandpass filter attenuates undesirable reflected energy. The low end frequency shaping acts as a clutter filter. This action provides for discrimination between the reflected energy from targets having radial speed and reflected energy from objects having little or no radial speed. An object that has no radial speed is fixed or is a moving target that is maintaining a constant range from the illuminator. In either case the radar echo from the object has little or no doppler shift and therefore is not an ac signal within the acceptable doppler band.

The video preamplifier is designed without the usual input transformer for impedance transformation to reduce sensitivity to ground loops and EMR. The follow-on gain stages amplify the doppler returns to a level consistant with tape recording levels and with the DTUP tracking design. Automatic gain control (AGC) is employed in these amplifiers to provide linear operation.

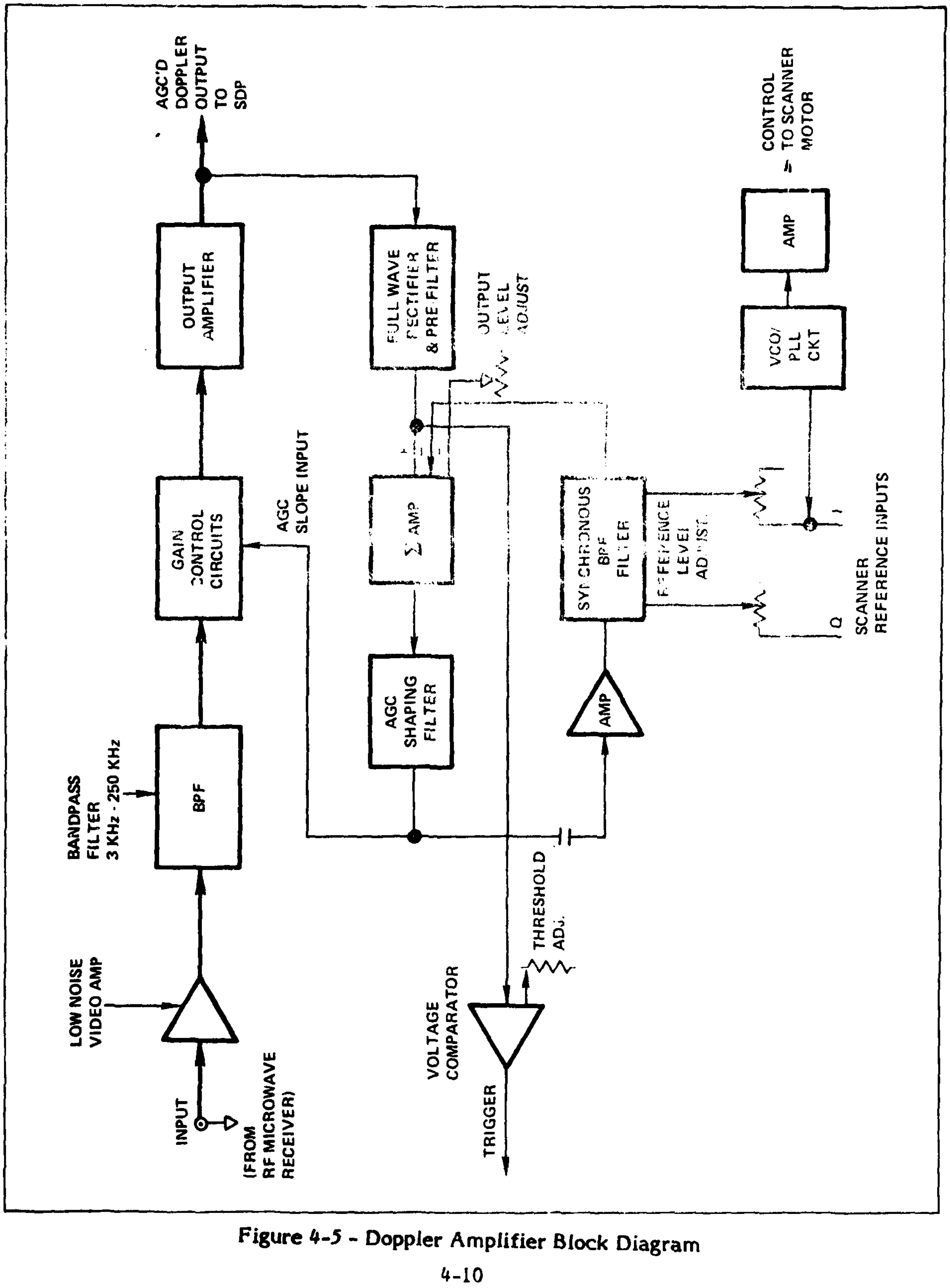

Figure 4-5 - Doppler Amplifier Block Diagram

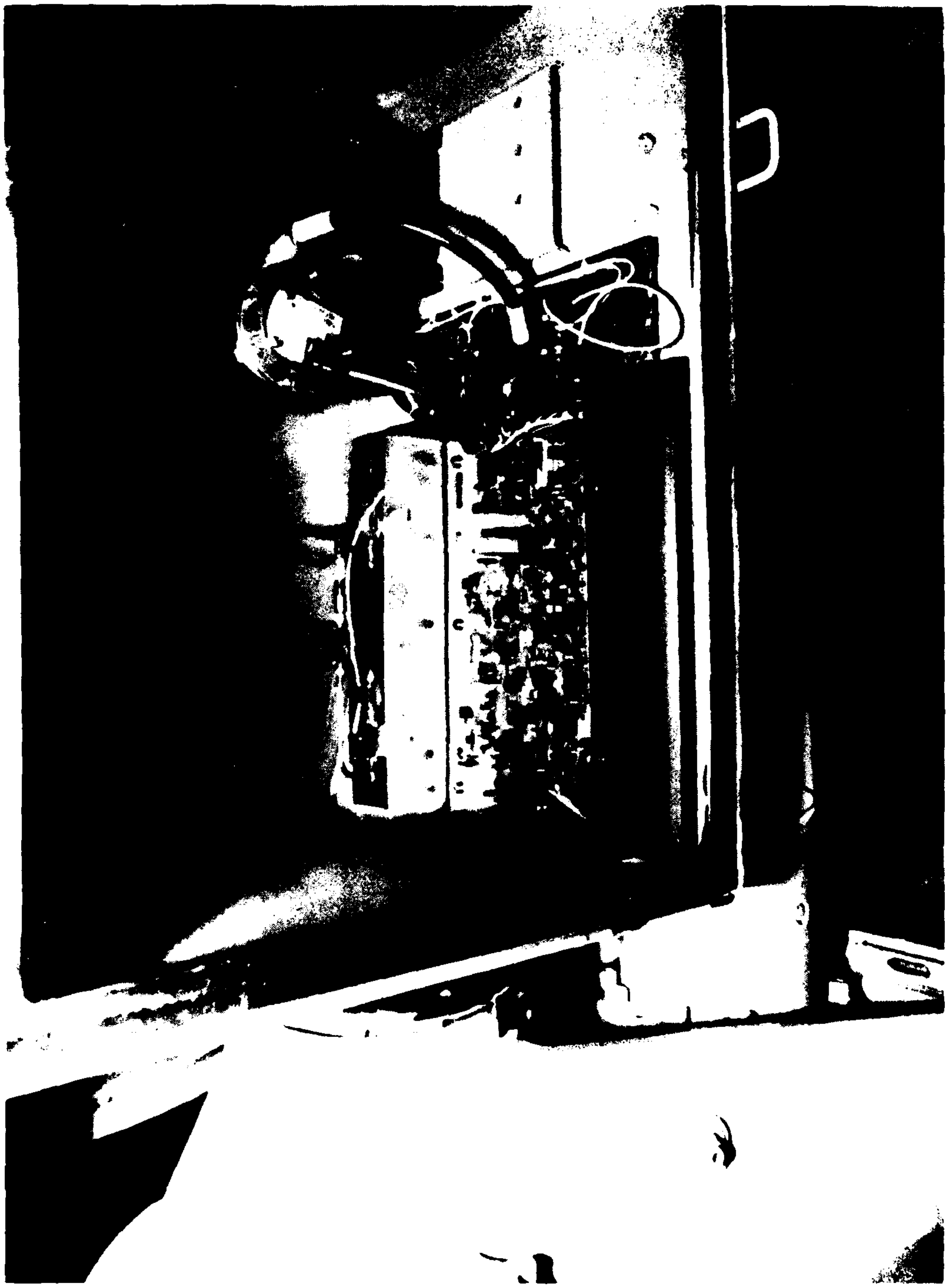

Figure 4-6 - Doppler Amplifier Subassembly

The AGC circuit maintains the output of the doppler amplifier constant under varying input signal strength. The circuit also prevents limiting action of the amplifier which would affect the peaks of the scan frequency amplitude modulation of the doppler signal. The result of such limiting would be a degradation of the scan frequency amplitude modulation which contains information concerning target position off the antenna electrical axis.

Table 4-3 lists the electrical parameters for the Doppler Amplifier.

TABLE 4-3
DOPPLER AMPLIFIER CHARACTERISTICS

Gain:	88 ± 5 dB
Frequency Coverage:	2 - 200 KHz (Figure 4.7)
AGC Linear Range:	> 60 dB
AGC Response (τc):	800 ± 100 Hz
Nominal Noise Output: (Background)	80 ± 40 mVrms
Maximum Signal (handling): (1db compression point)	TBDL
Minimum Signal:	TBDL
Normalized Signal Level:	600 MV P-P
Input Impedance:	50 Ω
Output Impedance:	50 Ω
+15 V Current Drain	125 mA
-15 V Current Drain	125 mA

4.4.2 Doppler Amplifier Design Detail

The low noise video amplifier consists of a matched NPN transistor pair and a low noise operational amplifier. This stage provides approximately 26 dB of gain, with a noise input voltage of less than 2 nanovolts per square root hertz. Hence, this amplification stage assures that the receiver noise figure established by the RF Microwave Receiver is not degraded by video (doppler) gain circuits.

The bandpass filter limits the frequency response of the receiving system. The lower 3 dB point is approximately 3 KHz, with the upper 3 dB point set at 250 KHz. The low end has a shaping factor of 5 while the upper filter end is a single pole design. (See Figure 4-7).

The gain control circuits consist of a number of amplification stages the operation of which is based on the transconductance multiplier effect. As a stage, its input is low impedance, its output is high impedance, and the circuit(s) responds to input current, and its output signal is current. This design is capable of producing current gain of from -60 to +60 db.

The output amplifier is a low noise operational amplifier. The current output from the gain control circuit is applied to the inverting input of this amplifier. The result is that this amplifier converts the signal current from the AGC circuit to output voltage.

A full-wave rectifier generates a dc voltage proportional to the output signal level. This dc voltage is utilized in the summing amplifier and AGC shaping filter to generate the control voltage for the gain control circuit.

The AGC frequency response is determined by a bandpass filter whose center frequency is synchronized to the scan reference frequency. A fixed 26 db ac amplifier drives the filter. The amplifier and filter form a feedback network around the summing amplifier and the result is that the composite AGC open loop frequency response has a zero, or notch, at the scan reference frequency. This type of AGC response is required if the conscan A.M. on the incoming signal is to be preserved; otherwise this modulation will be removed.

4.4.3 Nutating Scanner Control Loop

Included on the same Doppler Amplifier board is the control electronics for the receiving antenna's nutating scanner.

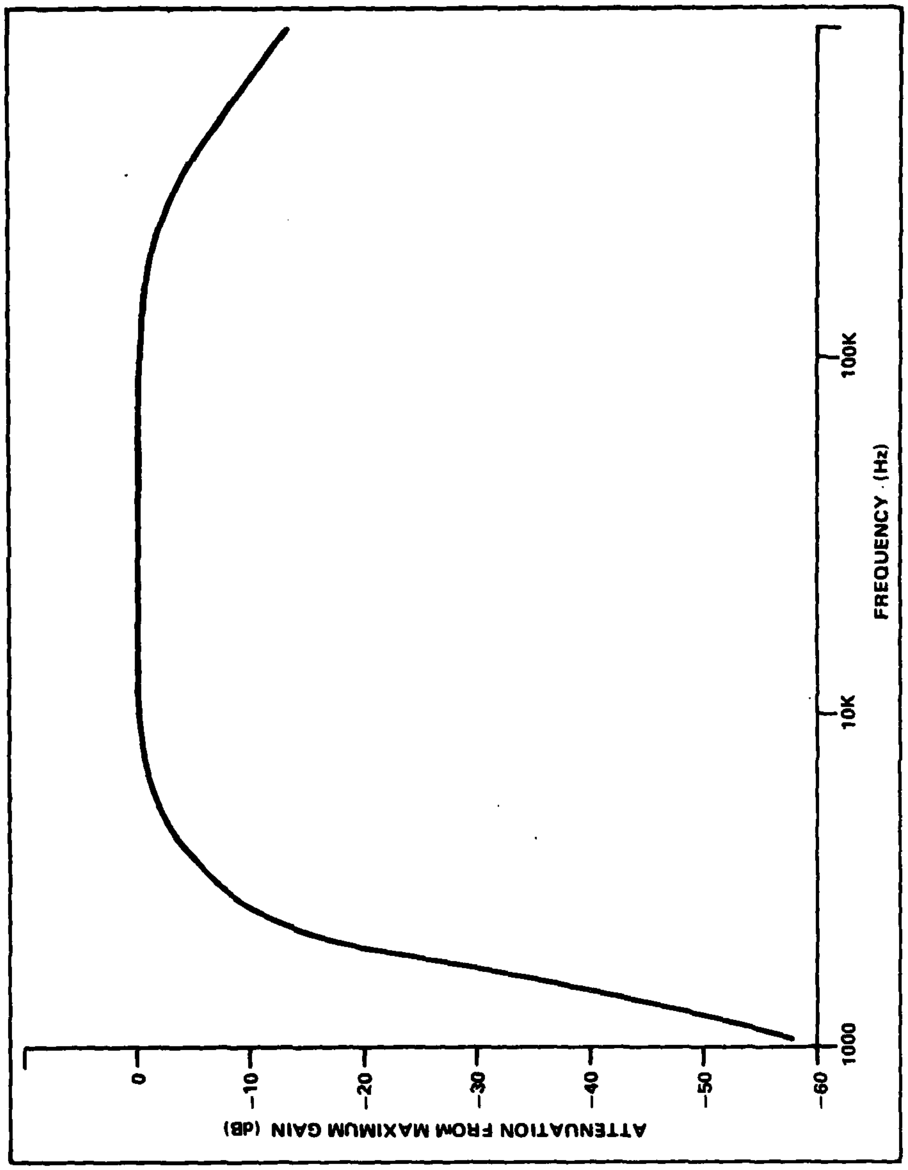

Figure 4-7 - Doppler Amplifier Response

The speed control servo loop consists of nutating scanner motor-generator assemblies B1 and G1, the speed control circuitry, and the nutating scanner saturable reactor L1. An output from reference generator G1 is used to detect changes in the motor speed. The saturable reactor is a controlled variable impedance in series with the ac power to the scanner motor and thus can control motor speed. Operation of the servo loop is as follows: when power is applied, the motor speed command voltage control circuitry allows maximum current through the saturable reactor. This applies maximum ac to the motor windings and the motor begins to accelerate. The reference generator output is an ac voltage whose amplitude and frequency are dependent on motor speed. This generator output voltage is applied to the control electronics comprised of a reference voltage controlled oscillator (VCO set to "M" frequency), a phase lock loop (PLL) that closes around the reference VCO and the reference generator output and the result error voltage that is sensed, amplified and fed to the saturable reactor. Thus the VCO/PLL circuitry senses the scanner reference frequency, compares it to a VCO reference and sends out a control voltage to the reactor to maintain the desired motor speed (rpm) of the scanner.

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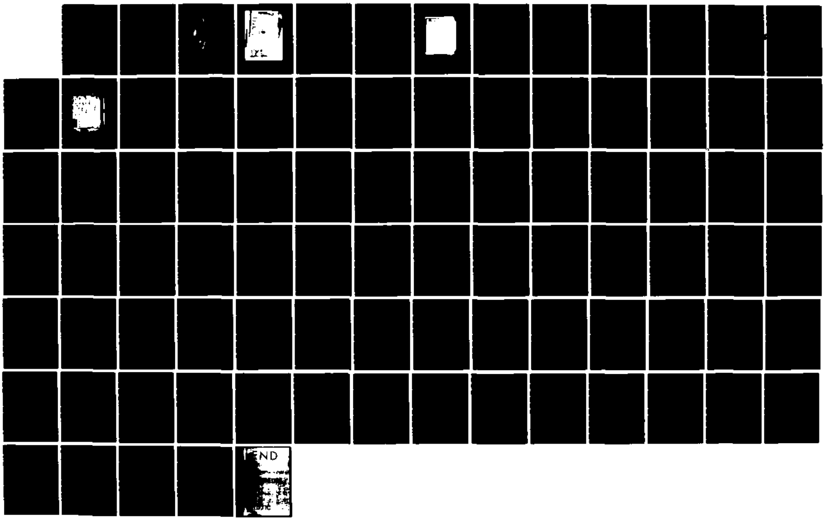

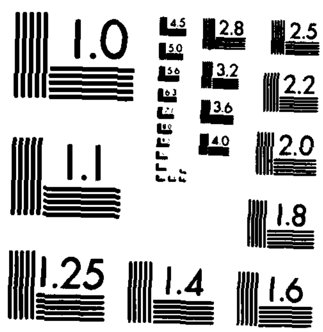
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6.3

5. SIGNAL DATA PROCESSOR

5.1 General Description

The Signal Data Processor (SDP) Unit contains the solid state modules that comprise the Doppler Tracking Unit, AZ/EL Position Readout and antenna control subsystems. Figure 5-1 and 5-2 depicts the unit module content. Figure 5-3 shows a block diagram of the SDP. The three functional groups are discussed in detail by module in subsequent sections. In general:

a) **Doppler Tracking Unit** - The solid state doppler tracking unit (DTUP) provides the capability of processing the doppler return from projectiles traveling at velocities between 30 and 3,000 meters per second. The DTUP also provides the Polar error signal to the antenna control modules.

b) **AZ/EL Position Readout (Data Interface)** - The AZ/EL Data Interface modules acquire, process and store antenna position and error data, and provide analog and digital interfaces for transmission of corrected AZ/EL Data to off-trailer systems.

c) **Antenna Control** - These modules condition the antenna directional information from the signal data processor and other position information for application to the amplidyne control. Although these modules are located within the SDP Unit, discussion of the antenna control system is covered in a separate section, namely 7.0.

5.2 Display Controller (ZDIS) (Figure 5-5)

The front panel of the SDP in addition to control and signal inputs and outputs provides a digital display of radial velocity. The velocity display is used also as a BITE display for setting the main loop VCO and as a pre-mission preset display for setting upper and lower sweep limits. The lower sweep limit operates as an adjustable stonewall and may be disabled by operating in Lock Hold mode. This provides an opportunity to limit the acquisition sweep to a very narrow window, but switches to the stonewall setting

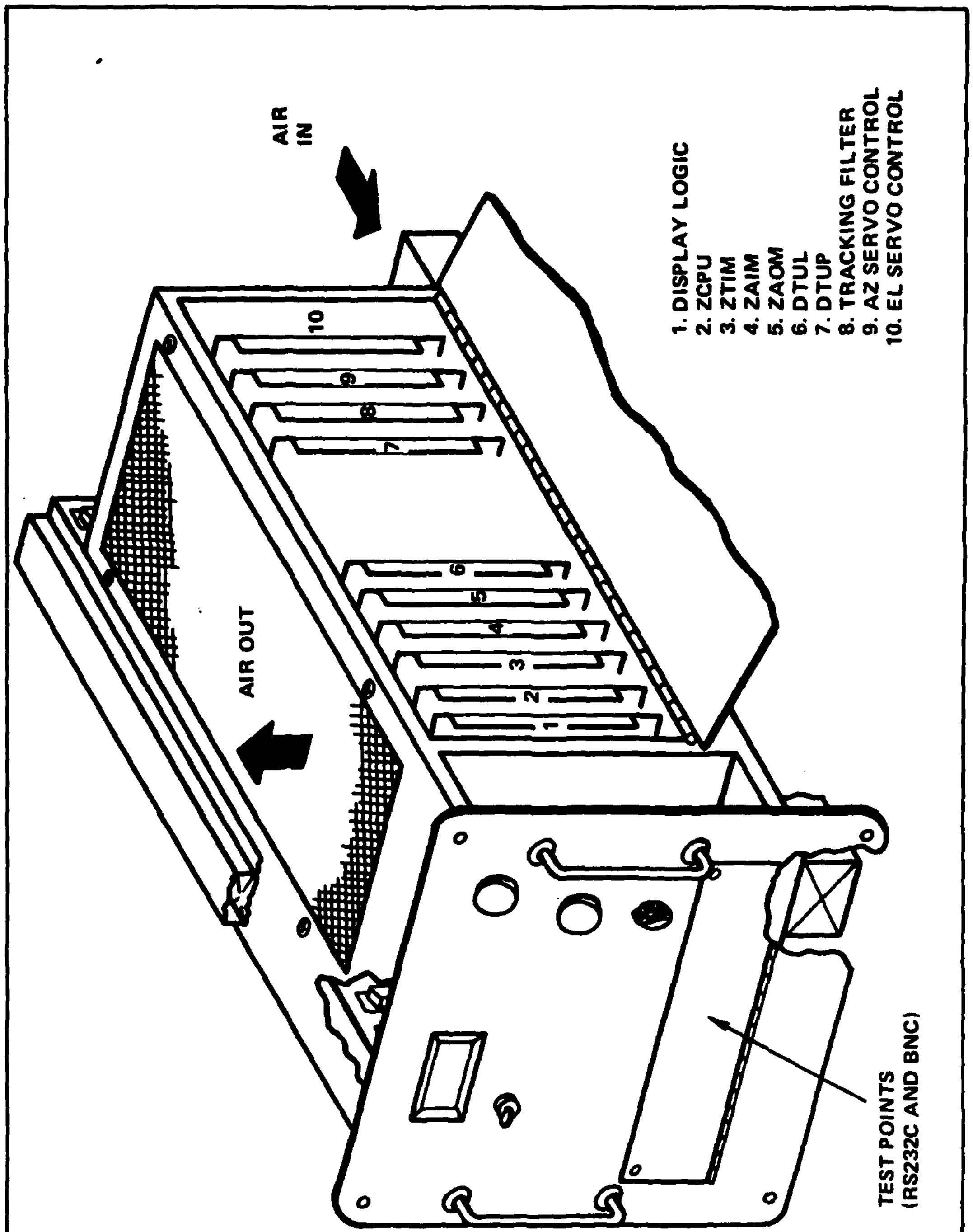


Figure 5-1 - Signal Data Processor

5-2

Figure 5-2 - SDP Chassis

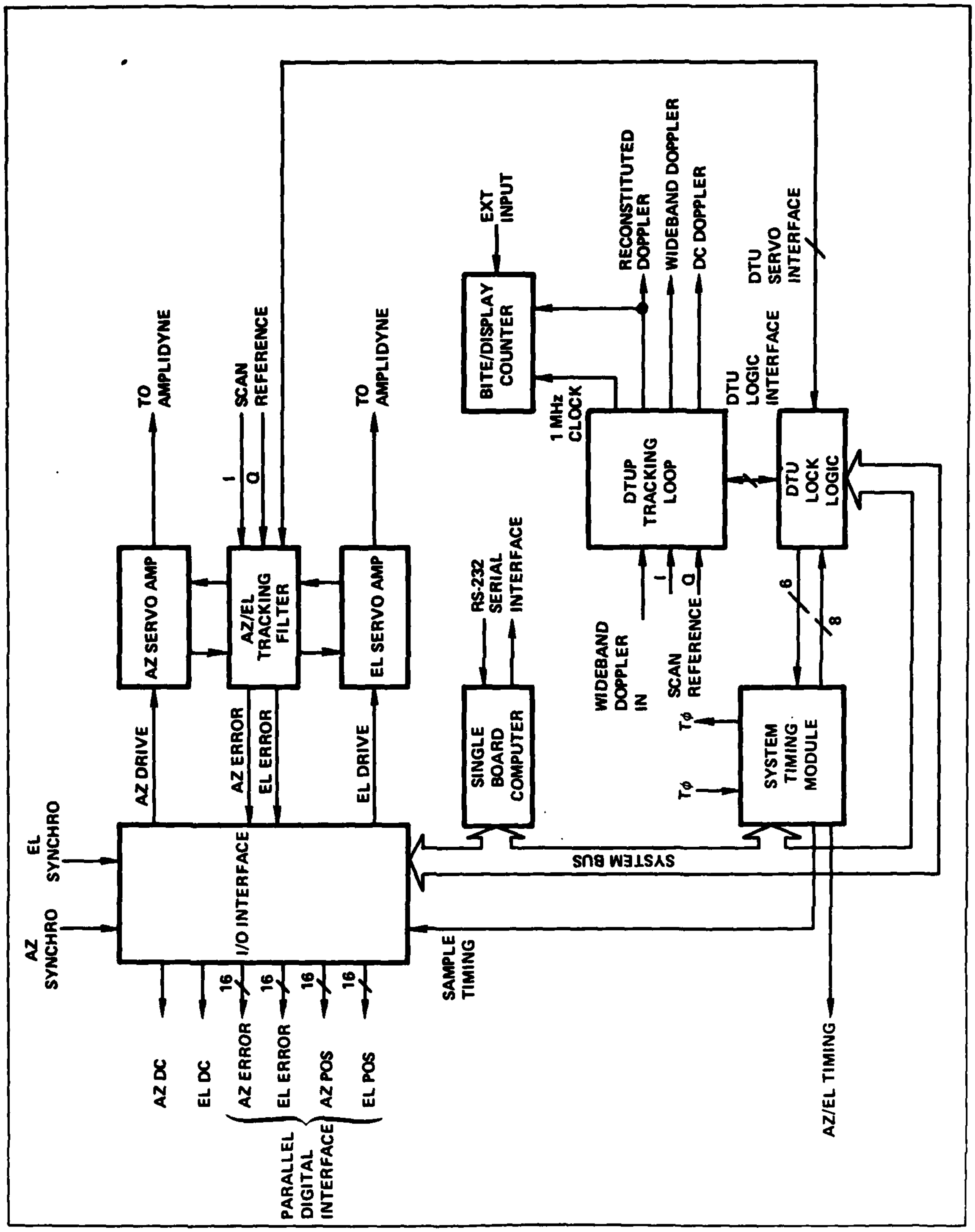


Figure 5-3 - SDP Block Diagram

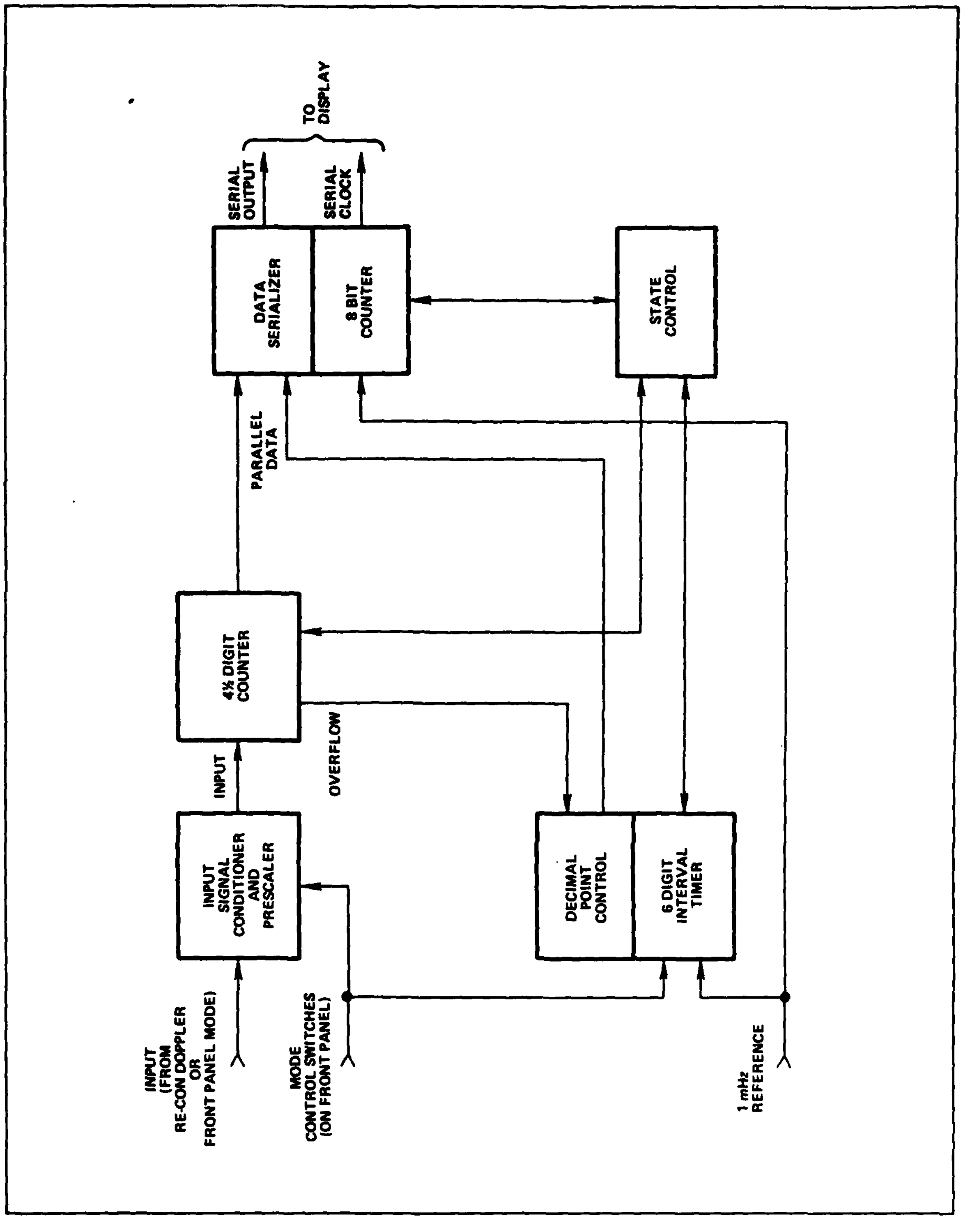


Figure 5-4 - ZDIS Block Diagram

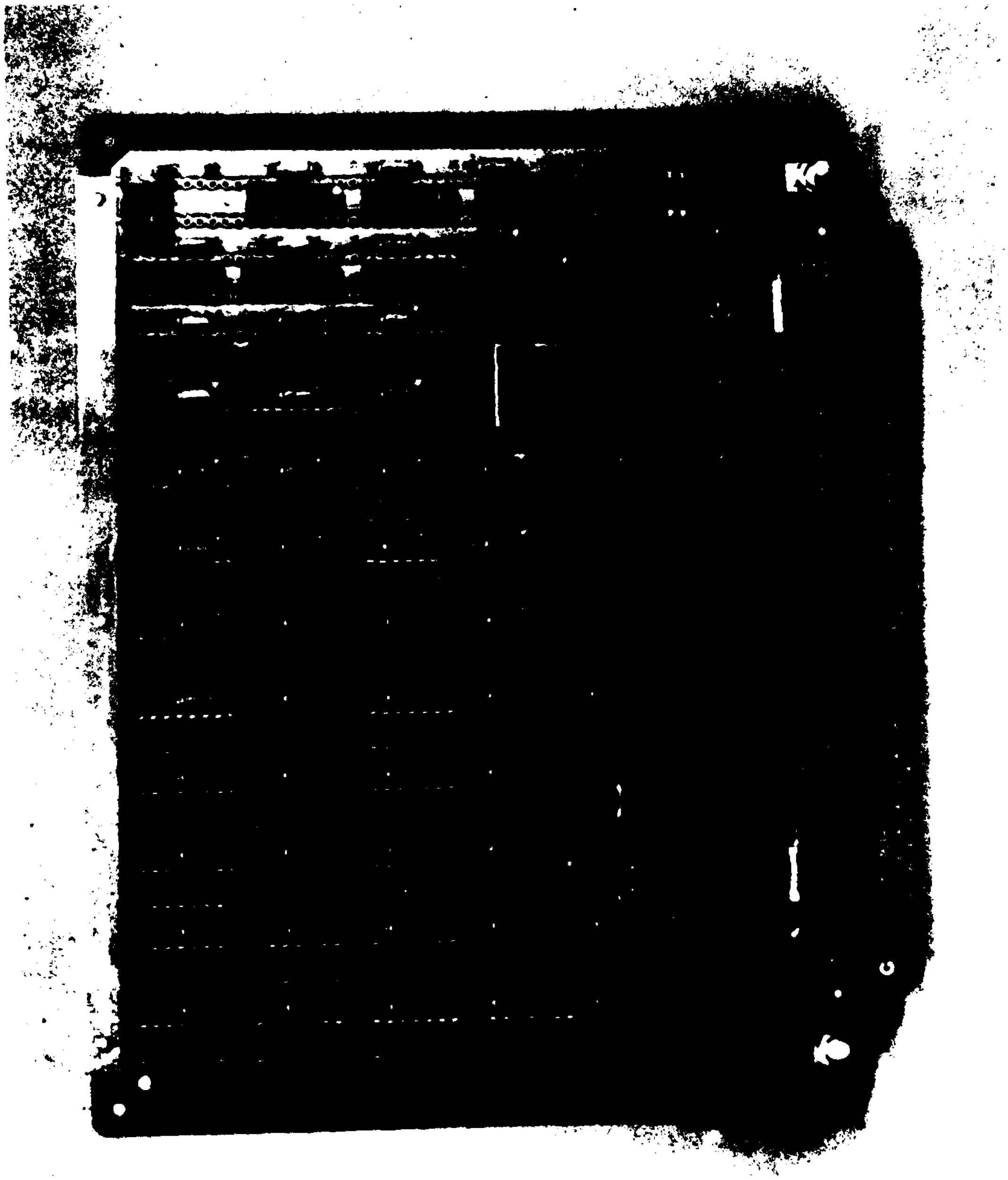


Figure 5-5 - Timing Generator

to permit tracking below the sweep limit after the loop is locked. If the loop should lose lock in this mode, resweep will not be triggered.

The frequency counter for the display obtains its input from the reconstituted doppler. The reconstituted doppler signal is generated by mixing the output of VCO-1 with the 1 MHz reference oscillator. When this doppler frequency is divided by a factor, the resultant frequency, when counted, can read directly in meters/seconds, and be displayed on a 7-segment digital readout. A 100 millisecond update rate will provide velocity to the nearest 10 meters/second, uncompensated for transmitter frequency.

These displays are for BITE and monitoring purposes only and are not intended to be used for direct reading of high precision data the Display Controller module (ZDIS) contains two distinct circuits, the frequency meter and the VCO2 generator. Figure 5-4 depicts the block diagram.

5.2.1 Frequency Meter

The basic purpose of the ZDIS frequency meter is conversion of an input signal from frequency to a display formatted serial data stream. This is accomplished in the straightforward manner of counting the number of clock transitions on the input over a period of time, then encoding and transmitting the resultant count. In ZDIS, this implies two states of operation. In state 0, a conditioned and prescaled input (PLOD-O) is clocked into a 4-1/2 digit BCD counter chain while another counter, based on an external 1 MHz reference (CLK1-1) measures the time interval. In state 1, the final count is converted to 7-segment code and packed with a start bit and decimal points into a serial stream with the use of a bit counter and data selectors.

The input signal (CNTRIN) is preconditioned with a threshold detector and Schmitt trigger to provide clean transitions for 500 mv P.P. sinusoids.
This is accomplished by applying a hysteresis feed-back on the threshold. Capacitive coupling is used at the input to remove any DC bias. An additional low-pass cut is provided at about 1.5 MHz to improve the rejection of both noise pickup and the upper side-band of the DTUP reconstituted doppler. The TTL level signal developed from this signal is then prescaled to provide the input to the 4-1/2 digit counter. A ÷ prescaler is used for direct external frequency measurement, ÷ 7 for doppler kilofeet per second, and ÷23 for doppler kilometers per second. This prescaling allows for a reasonable update rate

(<1 sec) at the front panel display. The approximation of 23/7 kilofeet per second per kilometer per second is accurate to better than .2%.

At low frequencies, the above is sufficient to describe the counting operation of ZDIS. To provide a more useful tool, especially in direct external measurement, decade scaling was provided to frequency measurements up to 2 MHz. When the 4-1/2 digit counter overflows (> 19999), a value of 2000 is synchronously loaded, and the decimal point position is shifted right. In addition, within 10 microseconds, the least significant decade of the interval timer is effectively removed from the chain, dividing the remaining time interval by ten. This provides for operation up to 200 KHz, with a resolution of 10 Hz. If overflow again occurs, the operation is repeated, providing for operation up to 2 MHz. Additional overflows are considered beyond the range of the device and result in blanking of both the digits and decimal points of the display.

When the interval is completed, an output pulse (EOIX-0) signals the end of counting and a transition to State 1. During State 1, both the interval timer and 4-1/2 digit counter clocks are inhibited. State 1 consists of 256 periods of the 1 MHz reference. These 256 periods are divided into 64 bit periods of 4 microseconds each. One bit of data is made available at the start of each bit period and remains valid for the entire period (excludidng propagation delays). A positive clock (LODC-1) is provided during the second microsecond of each bit frame (25% duty cycle over State 1).

The 64 bit periods are further subdivided into 8 byte periods of 8 bit periods each. As shown in Table 5-1, logic zero data is transmitted during the first byte period and the first seven bit periods of the second byte period. During the last bit period of the second byte period, a start bit (logic one) is transmitted to synchronize the transmission with reception by the display controller at the front panel. During byte periods 2, 3, 4 and 5, seven-segment data for each digit is transmitted during the last seven bit periods. The first bit period of each byte period is reserved for the half digit (HDIG) and the decimal points DPT2, DPT3, and DPT4 respectively. To terminate the transmission, logic zero data is transmitted during the last two byte periods. The display segments are shown in Figure 5-6. It should be noted that, if the display is blanked, only the start bit is transmitted, with logic zeroes replacing all segments of byte periods 2, 3, 4 and 5.

After the last bit is transmitted, an output pulse (EOIX-0) signals the end of transmissions, resetting and re-enabling the counters of State ϕ and disabling the output of State 1. The whole process will then repeat.

TABLE 5-1
SEGMENT TRANSMISSION

	BYTE PERIOD							
BIT PERIOD	0	1	2	3	4	5	6	7
0	null	null	HDIG	DPT2	DPT3	DPT4	null	null
1	null	null	1a	2a	3a	4a	null	null
2	null	null	1b	2b	3b	4b	null	null
3	null	null	1c	2c	3c	4c	null	null
4	null	null	1d	2d	3d	4d	null	null
5	null	null	1e	2e	3e	4e	null	null
6	null	null	1f	2f	3f	4f	null	null
7	null	start bit	1g	2g	3g	4g	null	null

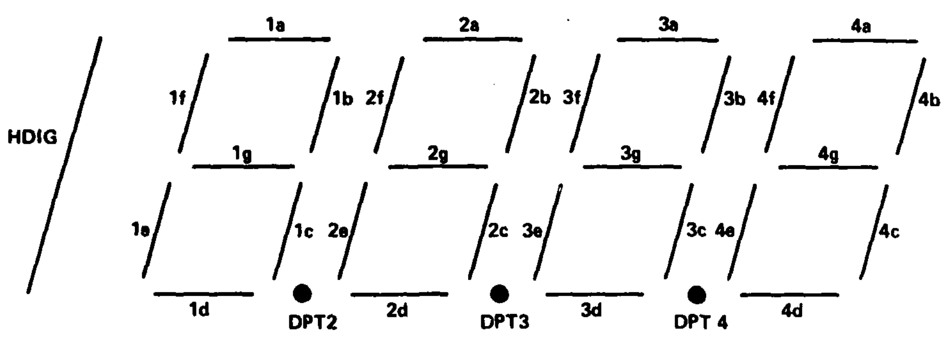


Figure 5-6 - Display Segments

5.2.1.1 Inputs

a) P1-72 CNTRIN - Selected input frequency source. Input impedance >2KΩ capacitively coupled. Minimum level: 500mV P.P. sinewave.

b) P1-101 DDIS-1 - Doppler disable. TTL level. When active (high) will blank the numeric portion of the display for doppler km/sec and kft/sec (external direct frequency measurement is still active). Used in the Velocimeter to blank the display during sweep.

c) P1-100 EDIR-0 - External direct. TTL level, active low. When active, indicates that an external frequency measurement is to be made. Note: EDIR-0 and UMPS-0 cannot both be active.

d) P1-44 KMPS-0 - Kilometers per second. TTL level, active low. When active, indicates that a doppler km/sec measurement is to be made. Note: KMPS-0 and EDIR-0 cannot both be active.

e) P1-50 CLK1-1 - 1 MHz reference. TTL clock. Nominally 50% duty cycle. The counter accuracy is nearly equivalent to the accuracy of this reference for direct external measurements.

5.2.1.2 Outputs

a) P1-46 LCDC-1 - TTL positive clock. See description.

b) P1-47 LCDR-0 - Grounded to +5 V return for shield on LCDC-1.

c) P1-48 LCDD-1 - TTL level, active high. See description.

5.2.2 VCO2 Generator

The basic purpose of the ZDIS VCO2 generator in the generation of the variable, but stable, frequency reference used to force a re-sweep in the Doppler Tracking Unit. Basically, the circuit is a digitally controlled voltage to frequency converter. In use, the input voltage (LSLSET) will be switched between the front panel lower sweep and the stonewall limit on module DTUL.

As shown in Figure 5-7, the input voltage is applied to a lo-bit A/D converter, set up to less than one LSB change during a conversion, the input is through a low pass filter with a time constant of 18 msec. The digital output of the A/D(1) is summed with a bias to form the frequency divisor on the feedback leg of a phase-locked loop.

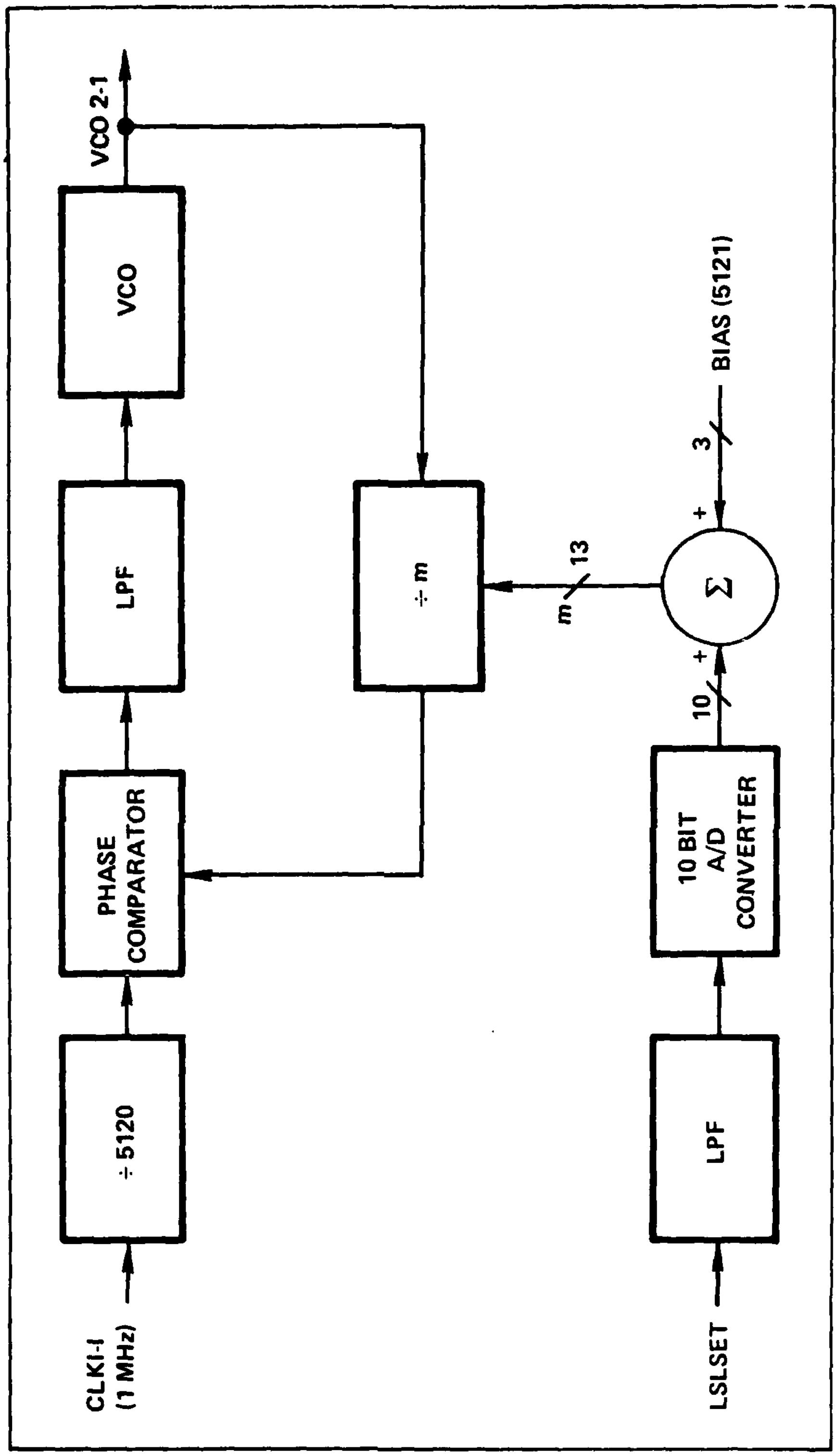


Figure 5-7 - ZDIS VCO2 Generator Block Diagram

The phase comparator in Figure 5-7 provides an error signal when it detects a phase difference between the two input signals. This signal, filtered, is used to drive the Voltage Controlled Oscillator (VCO). The filter time constant is set at 1.7 msec. The two counters (5120 and m) reduce the input frequency by the appropriate factors. Thus (in frequency):

$$\frac{VCO2}{m} = \frac{1\ MHz}{5120}$$

OR

$$VCOZ = 1\ MHz\ \frac{m}{5120} = 1\ MHz\ \frac{L+5121}{5120}$$

The range of frequencies available at VCOZ is then from 1000195.31 Hz (L=0) to 1200000.00 Hz (L=1023) in steps of 195.31 Hz.

5.2.2.1 Inputs

a) P1-50 CLK1-1 - Frequency reference 1 MHz at TTL levels.

b) P1-70 LSLSET - Input setting. Nominally 0 to 10 Vdc relative to +15 return. Should not exceed range of -0.5 V to +15 V, although some voltage protection is provided.

5.2.2.2 Outputs

a) P1-96 VCO2CK - VCOZ output at TTL levels (buffered).

b) P1-97 VCO2RT - VCOZ return. Tied on board to +5 V return for use as a shield for VCO2CK.

5.2.2.3 Adjustments

The A/D converter is adjustable per manufacturer's recommendations in both gain (R14) and offset (R14). These are factory preset for correct operation.

The VCO operating range is adjustable (R12). At room temperature, the range is approximately 900 KHz to 1300 KHz. This allows for range drift over temperature. The range is factory preset for correct operation.

WARNING

Do not attempt to adjust R12, R14 or R15. Complex factory procedures are required to insure correct operation.

5.3 Doppler Tracking Unit (DTUP and DTUL) (Figure 5-8)

5.3.1 Function

The primary function of the Doppler Tracking modules (DTUP and DTUL) is to frequency scan the conditioned output spectrum from the Doppler Amplifier, acquire and track target doppler signals for the purpose of extracting polar error. This error signal is applied to the antenna servos, closing the antenna tracking loop.

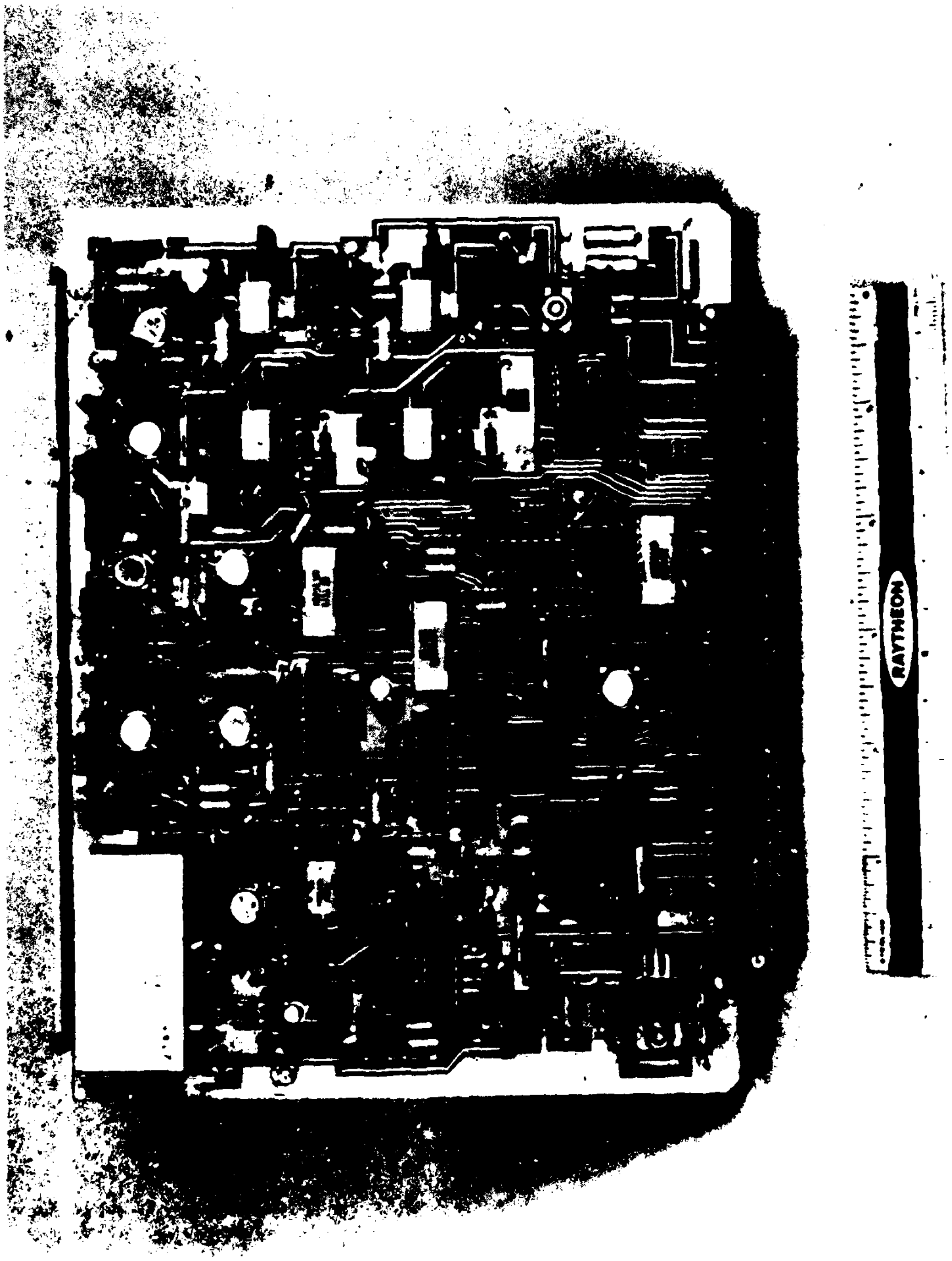


Figure 5-8 - DTUP Module

The doppler tracking feature is accomplished via two modules, the phase lock loop, narrowband tracking filter, detection circuits, and AM detector are located on the Doppler Tracking Module (DTUP), while control logic is contained on a second module designated as DTUL.

Precise measurement of speed may be obtained by using a Fast Fourier Transform processor off trailer, if desired, and a wideband doppler output is provided for that purpose.

For monitoring purposes, a dc Doppler signal is provided which may be calibrated using the upper sweep limit adjustment and the front panel speed display. However, this is not a high accuracy method and should not be used for data taking purposes.

5.3.2 Theory Of Operation (Figure 5-9)

The doppler tracker design is based on a double conversion phase locked loop. Wideband doppler from the doppler amplifier is mixed with the output of VCO-1. Prior to acquisition, VCO-1 is swept from the upper sweep limit to the lower sweep limit by pulsing U6 to the upper sweep limit position, and then closing the phase locked loop through the sweep filter. This causes the loop to be driven toward the minimum frequency of VCO-1, approximately 40 KHz below the 1 MHz IF frequency. If a target exists with doppler, f_d, then the band pass filter will produce a 1 MHz output at a VCO frequency of f_x + 1 MHz which is amplified, limited and applied to a phase detector where it is compared with a 1 MHz reference oscillator. If the output of the phase detector is consistent with a coherent input signal, a DC error voltage will be generated by the phase detector and the loop will attempt to lock. The detector at the output of the IF amplifier provides drive to a fast AGC amplifier which has a notch in its frequency response at the spin motor frequency. Detection of a rise in AGC voltage above noise background trips a threshold comparator which, through the DTUL circuitry causes UG to switch the precharged track filter into the loop, causing a significant reduction in frequency tracking error, closing the loop through a longer time constant. The loop is capable of tracking targets with more than 75 g's acceleration with minimum frequency error because the maximum loop gain operates in a 0.3 Hz bandwidth while the unity gain response of the loop is flattened out to approximately 6 KHz.

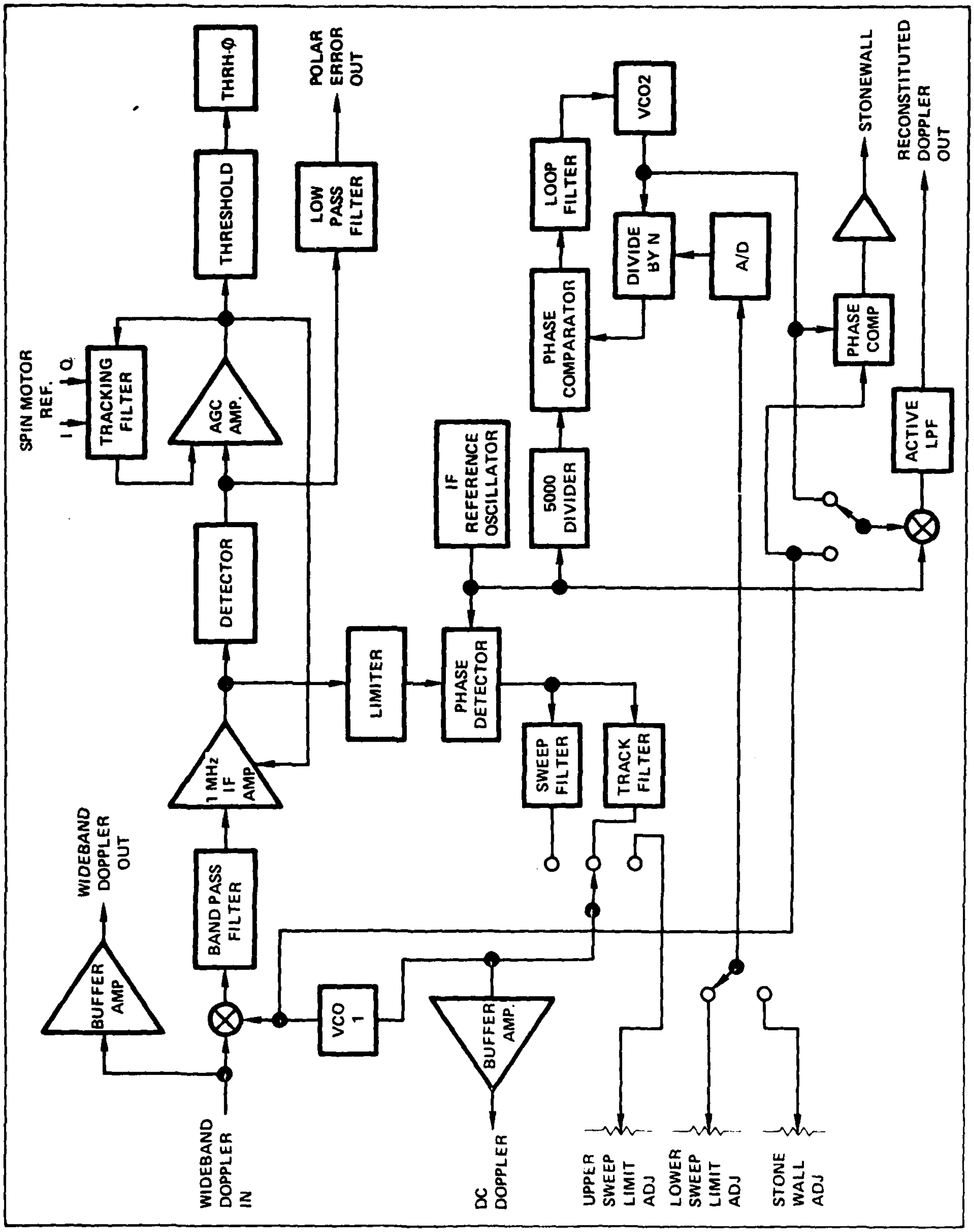


Figure 5-9 - Doppler Tracker Unit Block Diagram

The stonewall and lower sweep limit are generated by a phase locked loop synthesizer consisting of a divide by 5000 counter, a phase comparator, VCOZ and a divide by N counter, programmed by an Analog to Digital converter driven by lower sweep limit and stonewall adjustment potentiometers.

If there are no targets, VCO-1 sweeps downward, driving a phase comparator. When VCO-1 matches VCO-2, a phase comparator produces the stonewall output which triggers a one-shot in DTUL which switches U6 to the upper sweep limit, recycling the sweep.

VCO-1 and the reference oscillator are mixed and filtered to produce reconstituted doppler which drives the front panel display through the ZDIS circuits. When sweep limits are adjusted, either VCO-1 or VCO-2 is selectively applied to the reconstituted doppler in order to provide a display of the sweep limit speeds which may then be precisely set by the operator.

When the loop is locked, AM detection of the IF amplifier output prior to the limiter provides polar error output.

Intelligence on the IF signal in the form of "M" frequency amplitude modulation, is extracted by an AM detection circuit and applied to the antenna positioning system as radar positioning error.

5.3.3 DTU Phased Locked Loop

5.3.3.1 General

The Doppler Tracking Unit Phase Locked Loop (DTUP), under digital control, detects and tracks the conditioned doppler output signal from the doppler amplifier and supplies polar error information and a coherent target indication to the antenna positioning system and signal processor respectively.

5.3.3.2 Inputs

a) **Doppler Signal (DOPPIN)** - The doppler signal is at a frequency dependent upon target radial velocity and is amplitude-modulated at the nutating scan frequency with an amplitude and phase representing the amount and direction of target error off the antenna electrical axis. The signal is obtained from the doppler amplifier which conditions it to a level of 150 rms.

b) **Upper Sweep Limit (USLARM)** - The upper sweep limit signal is front panel adjustable, 0 to 12 Vdc. It sets the maximum velocity at which the DTU will acquire a target.

c) **Lower Sweep Limit (LSLARM)** - The lower sweep limit signal is front panel adjustable, 0 to 12 Vdc. It sets the minimum velocity at which the DTU will acquire a target and track in auto mode prior to system lock.

d) **Nutating Scan Motor I&Q Phase References (SPINPI&Q)** - The nutating scan motor I&Q Phase reference signals originate in the nutating scan motor reference generator. They are quadrature sine wave signals at a level of 30 V pk-pk.

e) **VCO-2 Output Frequency (VCO2)** - The output signal VCO 2 is the reference signal for the lower sweep limit and/or stonewall frequencies. It is a TTL level signal at a frequency determined by the front panel lower sweep adjust pot or by the DTUP module stonewall adjust pot. The frequency is selected by the multiplexer controls.

5.3.3.3 Outputs

a) **Wideband Doppler (WBDOPP)** - The doppler input is amplified to a level of 1.0 V pk-pk into a 50 ohm load.

b) **dc Doppler (DCDOPP)** - The dc doppler signal is a dc level signal that is proportional to the doppler frequency and is approximately 0 to 7 volts into 51 K ohms.

c) **Clock Signal (CLK1-0)** - The clock signal is a 1.0 MHz TTL signal from the DTUP Phase-Locked loop reference oscillator.

d) **Polar Error Out (POLERR)** - The polar error out signal is the detected AM modulation at the nutating scan frequency that is present on the doppler signal and contains the target error information.

e) **Threshold Signal (THRH-0)** - The threshold signal is a dc level signal which changes state (0 V or 12 V) upon the detection of a rise in the DTUP AGC voltage above a preset level.

f) **Stonewall/Lower Sweep Limit Signal (STNW-1)** - The stonewall/lower sweep limit signal is a D.C. level signal which changes state, 0 V or 12 V when the phase-locked loop frequency and the preset stonewall or lower sweep limit frequencies coincide. The selection of the stonewall or lower sweep limit frequency is controlled by the LSLA/Stonewall multiplexers.

g) **Reconstituted Doppler (REDOPP)** - The reconstituted doppler signal is the reconstituted frequency of one of the four (4) following signals:

- Doppler signal
- Upper sweep limit
- Lower sweep limit
- Stonewall frequency

The signal is filtered and sent to the display control module (ZDIS) for display on the front panel.

h) **Lower Sweep Limit/Stonewall Set Signal (LSLSET)** - The lower sweep limit/stonewall set signal is a 0 to 12 Vdc adjustable signal that controls the frequency of VCO-2. The selection of the stonewall or lower sweep limit frequency is controlled by the LSLA/Stonewall multiplexer.

5.3.3.4 Multiplexer Controls

The multiplexer control signals control three (3) DTUP multiplexers as follows:

a) Input signals FPOP-O, LPLK-6 and SWPR-3 control the filter/USLA multiplexer, U6. This multiplexer controls the phased-lock loop circuitry as illustrated in the following truth table (Table 5-2).
Signal FPOP-O is front panel originated and when it is a logic "1", VCO-1 in U5, is operator adjustable to the desired upper sweep limit. With FPOP-O a logic "O", a sweep restart at the upper sweep limit, is initiated by the SWPR-3 logic "1" pulse while LPLK-6 determines which filter (sweep or track) will be in the loop.

TABLE 5-2

TRUTH TABLE #1

FPOP-O	LPKL-6	SWPR-3	OUT
0	0	0	Track LPF
0	0	1	Sweep Restart
0	1	0	Sweep LPF
0	1	1	Sweep Restart
1	0	0	Front
1	0	1	Panel
1	1	0	Upper Sweep
1	1	0	Limit
1	1	1	Adjust

b) Input signals swen-H and the on-module stonewall select switch control the LSLA/Stonewall muultiplexer, U23. This multiplexer controls the frequency of VCO-2. As illustrated in the following truth table (Table 5-3).

When the stonewall select switch is activated, logic "0", the output frequency of VCO-2 will always be at the stonewall frequency which is adjustable by a 10 turn edge mounted potentiometer on the DTUP. With the stonewall select switch deactivated, logic "1", the output frequency of VCO-2 can be either the stonewall frequency or the lower sweep limit. The lower sweep limit frequency is commanded only when SWEN-H is commanded logic "1". The lower sweep limit is operator adjustable from the front panel.

TABLE 5-3

TRUTH TABLE #2

No Connection	Stonewall Select Switch	SWEN-4	Out
1	0	0	Stonewall Freq.
1	0	1	Stonewall Freq.
1	1	0	Stonewall Freq.
1	1	1	Lower Sweep Limit Freq

c) Input signal FPLS-0 controls the doppler/sweep limit multiplexer, U25. This multiplexer controls which VCO output frequency will be applied to the redopp balanced modulator as illustrated in the following truth table (Table 5-4).

The frequency outputs of VCO-2 and VCO-1 are inputted to the redopp balanced modulator for display on the front panel LCO during adjust and tracking operations.

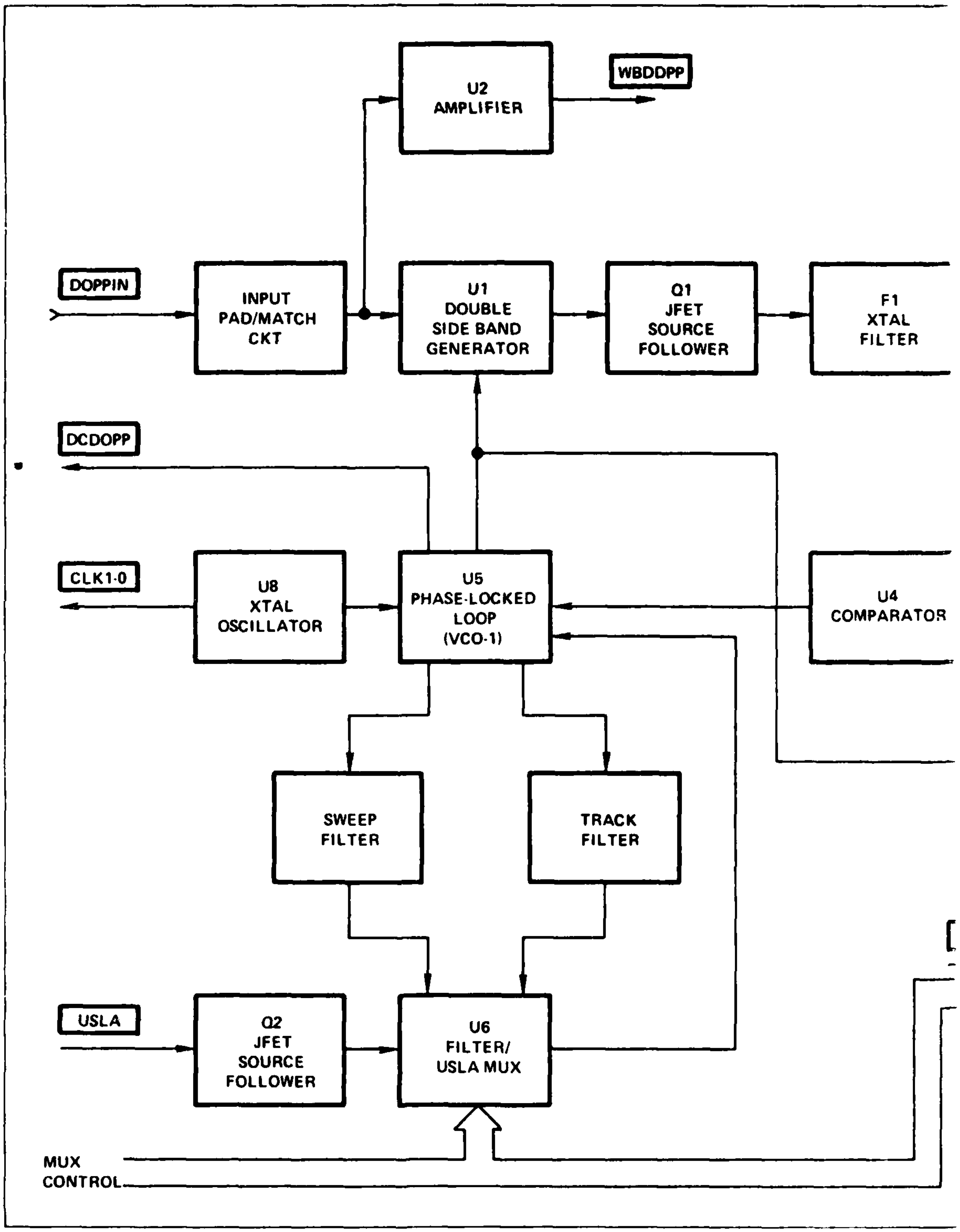
TABLE 5-4

TRUTH TABLE #3

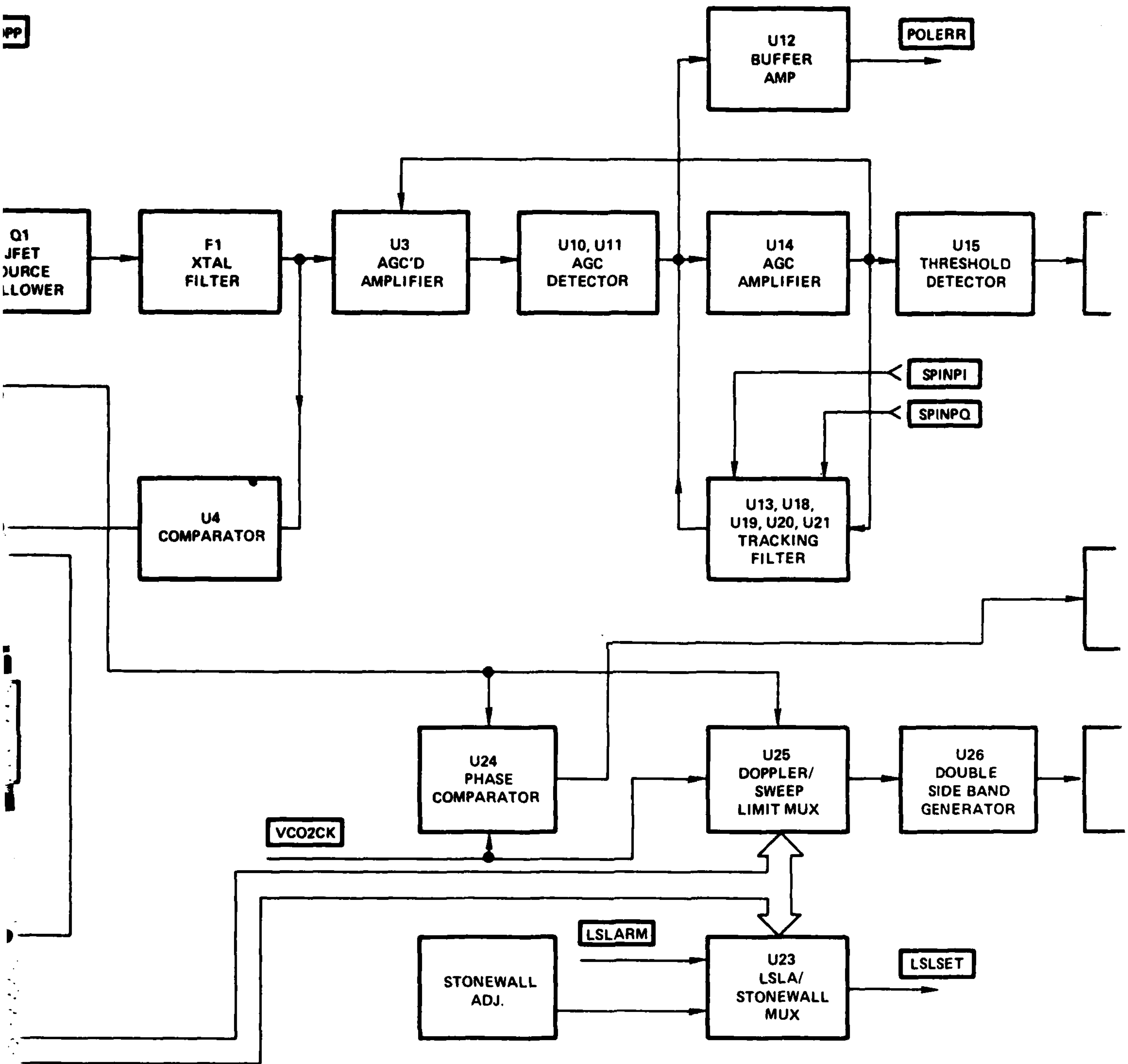
No Connection	FPLS-0	No Connection	Out
1	0	1	VCO-2
1	1	1	VCO-1

5.3.3.5 Circuit Description of DTUP

A block diagram of the DTUP is contained in Figure 5-10.



U2
AMPLIFIER
WBDDPP
DOPPIN
INPUT
PAD/MATCH
CKT
U1
DOUBLE
SIDE BAND
GENERATOR
Q1
JFET
SOURCE
FOLLOWER
F1
XTAL
FILTER
DCDOPP
CLK1·0
U8
XTAL
OSCILLATOR
U5
PHASE-LOCKED
LOOP
(VCO-1)
U4
COMPARATOR
SWEEP
FILTER
TRACK
FILTER
USLA
Q2
JFET
SOURCE
FOLLOWER
U6
FILTER/
USLA MUX
MUX
CONTROL



Figure

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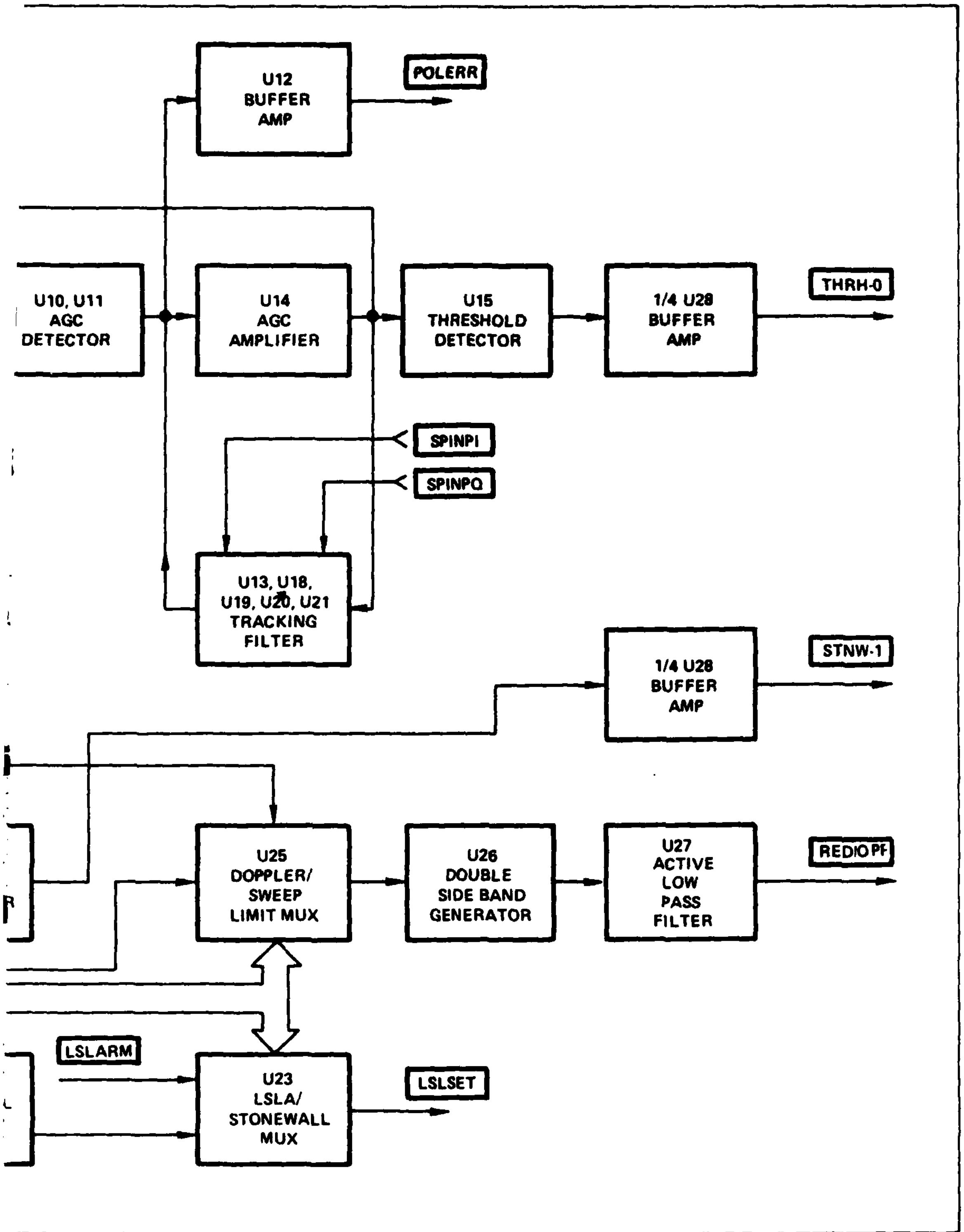

Figure 5-10 - DTUP Detail

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5.3.3.5.1 Phase-Locked Loop Circuitry

The phase-locked loop consists of the following circuitry:

- Input Pad/Match Circuit
- Balanced Modulator (U1)
- JFET Source Follower (Q1)
- Crystal Filter (F1)
- AGC Amplifier (U3)
- Comparator (U4)
- Phase-Locked Loop (U5)
- Crystal Oscillator (U8)
- Sweep Filter
- Track Filter
- Filter/USLA Multiplexer (U6)

a) **Input Pad/Match Circuit** - This is a symmetrical T-section attenuator designed for 50 ohm input and output impedance with an attenuation of -6.62 dB. This sets the 150 mv rms doppler signal to 70 mv rms at the input of the balanced modulator and provides isolation from the doppler amplifier.

b) **Balanced Modulator (U1)** -, The balanced modulator mixes the doppler signal with the phase-locked loop voltage controlled oscillator VCO-1. The resultant signal is a suppressed carrier double side band signal at the sum and difference frequencies of the two inputs. The carrier, VCO-1, is suppressed approximately 35 dB below the output of the two sidebands. To obtain this suppression the VCO-1 signal level to U1 is conditioned to 60 mv rms. The 70 mv rms doppler signal level from the input circuit insures small signal linear operation of U1.

c) **JFET Source Follower (Q1) and Crystal Filter (F1)** - Crystal Filter (F1) is a 1.0 MHz center frequency, 900 Hz bandwidth filter with source and load impedances of 500 ohms. The JFET source follower matches the approximate 4k output impedance of the balanced modulator circuit with the 500 ohms source impedance of the filter. F1's 1.0 MHz center frequency was selected so as to pass the lower sideband and reject any carrier and upper sideband frequencies contained in the output signal of U1.

d) **AGC Amplifier (U3)** - The AGC amplifier amplifies the 1.0 MHz signal from F1 to a level such that the target information can be detected. The response of this amplifier is fast enough to attenuate AM modulation other than the nutating scan frequency. The output level of the 1.0 MHz signal is controlled to a level of 1.0 V pk-pk. This output is also fed to comparator U4.

e) **Comparator U4** - The comparator circuit is configured as a zero crossing detector. With a non-coherent signal out from U3, this circuit produces a 0 - 12 V pk-pk sawtooth output signal at approximately 5 MHz. When a coherent signal is applied, U4's output becomes a 0 to 12 V pk-pk square wave at the signal frequency. The input level to U4 is conditioned to 0.2 V pk-pk and is AC coupled from U3.

f) **Phase-Lock Loop (U5)** - The phase-lock loop is a CMOS device containing two phase comparators, a voltage-controlled oscillator (VCO-1), source follower and zener diode. The comparators have two common signal inputs, PCAin and PCBin. A TTL 1.0 MHz crystal oscillator signal is ac coupled to PCAin from U8 while the comparator output is directly coupled to the PCBin. The output of phase comparator 2 is coupled to the VCO-1 frequency control input via either a sweep or track filter network. The choice of filter is controlled, by Filter/USLA MUX (U6).

The presence of a high level, high frequency signal into PCBin allows VCO-1 to be driven to its upper sweep limit frequency by placing a DC voltage (USLARM) into the VCO-1 frequency control input via U6. This voltage level will decay to zero in a time period determined by the RC constant of the filter controlled by U6. This voltage decay causes the VCO-1 output frequency to sweep from the upper sweep limit downward. VCO-1 sweep limits are from approximately 1.250 MHz @ +12 Vdc to 950 KHz @ 0 Vdc.

To initiate the search mode of operation, the VCO-1 frequency control input is switched via U6 from the USLARM DC level to the sweep filter to cause VCO-1 to sweep. The lower sweep limit is determined by LSLARM.

If a target at doppler frequency fd exists, then when the frequency of VCO-1 passes through 1MHz+fd, a coherent signal will be present at the input to U4. This signal will cause U4 to input a 1 MHz square wave to PCBin and the output of phase comparator 2 will be a voltage such as to control the frequency of VCO-1 to close the loop on frequency fd. Upon establishment of loop closure, the tracking filter is switched into the VCO-1 loop via U6 to reduce frequency tracking error by utilizing a larger RC time constant filter.

g) **AGC and Detection Circuitry** - The AGC and detection circuitry consists of the following:

- AGC Detector (U10, U11)
- AGC Summing Amplifier (U14)
- Nutating Scan Tracking Filter (U13, U18, U19, U20, U21)
- Polar Error Out Amplifier (U12)

h) **AGC Detector** - The AGC Detector is a full-wave rectifier and averaging filter. Its output is an AM signal at the frequency of the modulator envelope of the input signal with a DC offset-proportional to the input signals carrier level.

The DC offset of this circuit is adjustable to set the no signal gain of the AGC amplifier U3.

i) **AGC Summing Amplifier** - This circuit sums and amplifies the AGC detected signal and the output from the nutating scan tracking filter. The frequency response of this circuit's output to the AGC amplifier contains a notch at the nutating scan frequency, thus allowing a fast AGC time constant to be implemented without affecting scan modulation.

j) **Nutating Scan Tracking Filter**

k) **Polar Error Out Amplifier** - The polar error out amplifier is a phase compensated amplifier. Phase compensation is necessary to provide the antenna positioning system with accurate polar error information. This circuit is AC coupled to the AGC detector to remove the DC offset voltage. The output level is adjusted to 3 V pk-pk for 50% AM modulation on the doppler signal.

5.3.3.5.2 Control Circuitry (Figure 5-10)

The control circuitry consists of the following:

- Threshold Detector (U15)
- REDOPP Balanced Modulator (U26)
- Active Low Pass Filter (U27)
- Phase Comparator (U24)
- Doppler/Sweep Limit Multiplexer (U25)
- LSLA/Stonewall Multiplexer (U23)

a) **Threshold Detector (U15)** - The threshold detector is a voltage comparator that is triggered by the AGC DC voltage that is generated by the presence of a coherent signal in the 1.0 MHz filter (F1). The output signal of this circuit is the input to the logic circuitry that switches the phase-locked loop sweep and track filters.

The trip level of the comparator is adjusted with the radar in Bird Bath and is set to obtain a pause lock rate of approximately one per 8 to 12 seconds.

b) **REDOPP Balanced Modulator (U26)** - The REDOPP balanced modulator mixes the 1 MHz phase-locked loop reference oscillator with one of the following signals:

- Phase-locked loop VCO-1
- VCO-2

The output of the balanced modulator is 1.0 MHz minus VCO-1 or VCO-2 and dependant upon the multiplexer controls will be one of the following frequencies:

- Upper sweep limit
- Doppler
- Lower sweep limit
- Stonewall

The REDOPP balanced modulator output is filtered by the active low pass filter (U27) which has a cut-off frequency of 150 MHz. This output is sent to the ZDIS module and is displayed on the front panel LCD.

c) **Phase Comparator (U24)** - The phase comparator circuitry is a phase-locked loop CMOS device described earlier. For this application the device is connected to utilize only one of its internal phase comparators.

The signal inputs to this circuit are the phased-locked loop VCO-1 and VCO-2. VCO-2, depending upon the state of the LSLA/Stonewall Mux (U23), can be either the lower sweep limit or stone-wall reference frequency. As VCO-1 is varied in frequency, either sweeping or tracking a target doppler, when

APPENDIX B - VELOCIMETER ACCEPTANCE TEST PROCEDURE

ACCEPTANCE TEST PROCEDURE

VELOCIMETER

PRODUCT IMPROVEMENT CONFIGURATION

RADAR S/N:

DATE:

PARAGRAPH	TEXT	INITIAL

1.0 **Procedure**

The following document contains the electrical parameters to be tested regarding the acceptance test of the Modernized Velocimeter radar.

In addition to the tests described herein, the radar shall perform a tracking mission using targets of opportunity at the Raytheon Company facility and shall be capable of tracking a target as described in the contract at the user's facility.

2.0 **Modes Of Operation**

2.1.1 **OFF**

All circuit breakers are in the "OFF" position. All indicator lights are extinguished.

2.1.2 **STANDBY**

MAIN POWER and LVPS circuit breaker is in the "ON" position. The STANDBY push button is depressed and held until the cooling air pressure has been built up (10 sec. maximum). Blower is operating.

All STANDBY interlocks are closed. RADAR INTERLOCK indicator light is not illuminated. EQUIPMENT TIME indicator is running. STANDBY indicator light is illuminated. Low voltage power supplies are energized. Signal processing and receiver circuits are energized.

PARAGRAPH	TEXT	INITIAL
2.1.3	RADIATE READY	
	FILAMENT circuit breaker are in the "ON" position. All radiate interlocks are closed. RADIATE READY indicator light illuminates when the filaments have stabilized at their operating temperature (about 5 min). STANDBY indicator light extinguishes.	
2.1.4	FALSE RADIATE	
	This mode of operating allows the "checkout" of the certain portions of the radar without RF power being generated in the MO/PA assembly. When in the RADIATE READY mode, press the RADIATE push button. The RADIATE indicator light illuminates the RADIATE READY light shall extinguish. Antenna control electronics is now energized. The H.V. "ON" light shall remain extinguished.	
2.1.5	RADIATE	
	When the system is in the FALSE RADIATE mode, press the STANDBY push button first. The system will then return to the RADIATE READY mode. When in the RADIATE READY mode, switch the BEAM POWER circuit breaker to the "ON" position and press the RADIATE push button. The RADIATE READY indicator ligh shall extinguish and the RADIATE and	

PARAGRAPH	TEXT	INITIAL
2.1.5 Cont.	H.V. ON indicator lights shall illuminate. Microwave power is now being applied to the transmitting antenna and all transmitter and receiving circuits are energized. The RADIATE TIME indicator shall be running.	
2.2	Hazards to Personnel	

The following precautions should be observed to insure safety to personnel:

a) Extreme care should be used at all times when primary power is connected to the radar. Even when the MAIN POWER circuit breaker is "OFF", 416V 400 Hz, 3 phase power is present at a number of terminals and connectors.

b) Do not work on or about the antenna unless the AMPLIDYNE circuit breakers are "OFF" and the antenna safety switch is in the SAFE position. Be sure the antenna area is clear of personnel and equipment before activating the antenna.

c) Under conditions of high ambient temperature, the temperature of the exhausted cooling air may reach +85°C (185°F). Exposure of unprotected skin to air of this temperature should be avoided.

PARAGRAPH	TEXT	INITIAL
2.2 Cont.	d) During the RADIATE mode, several components such as the HVPS Regulator Tubes and the Power Amplifier Tube will reach a temperature that will cause severe skin burns upon contact. Therefore, the radar should be returned to the STANDBY mode for at least 5 minutes after operation by pressing the STANDBY push button and switching the FILAMENTS circuit breaker to the "OFF" position before attempting to replace the Regulator Tubes or the Power Amplifier Tube.	
	e) After removal and replacement of the MO/PA assembly, make sure that all eight (8) screws of the disconnecting flange are properly fastened to prevent RF leakage.	
	f) Do not become exposed or cause others to be exposed to either direct or indirect RF radiation emanating from the radar antenna. This document specifies that the test of RADIATE functions be performed with a microwave dummy load attached to the transmitter antenna feed waveguide. In those instances where tests are performed with the antenna radiating RF energy, the following applies:	

PARAGRAPH	TEXT	INITIAL
2.2 Cont.	The power output of the antenna is hazardous to personnel for a distance of 75 meters. For all tests and adjustment performed in full RADIATE	

1) Do not energized to radiate until the antenna has been set to an elevation which is not occupied by personnel and/or equipment/material capable of reflecting RF energy, AND

2) Action has been taken to emplace appropriate radiation HAZARD signs, along the periphery of a corridor 5 to 7 meters wide at the RADAR by 16 to 20 meters wide at a distance of 75 meters from the Transmitting Antenna. (The designated azimuth should bisect the corridor):

g) Do not work on any power supply or disconnect cables while the radar is operating.

2.3 Hazards to Equipment

The following precautions should be observed to prevent damage to equipment:

PARAGRAPH	TEXT	INITIAL

2.3 Cont.

a) When shutting down the radar, first press the STANDBY push button to put radar in the RADIATE READY mode, then place the FILAMENTS circuit breaker in the "OFF" position and finally press the "OFF" push button.

NOTE: In an emergency, go directly to "OFF".

b) Before energizing the radar, insure that all interlocks are secure. Accidential opening of an interlock will cause the radar to turn off.

c) Before connecting or disconnecting units, insure the radar is in the "OFF" mode.

3.0 Equipment Tests

The following sections contain test requirements related to the correct functioning of the assemblies at the system level. To verify the electrical characteristics of each separate assembly, refer to the appropriate assembly Test Requirements Specification. Before subjecting the radar to the test described in the following sections, a continuity check, in accordance with the interconnection drawing, shall be performed to assure the application of power will not result in damage to the radar.

PARAGRAPH	TEXT	INITIAL

3.1 **Initial Setup**

a) Insure that the radar is level (with wheels off the ground).

b) Insure that the radar is properly grounded.

c) Open the air intake on the back of the RSG.

d) Open the air intake at the base of the Receiver Group.

e) Open the air outlet on the left hand side of the RSG.

f) Open the air outlet on the right hand side of the RSG.

g) Open the air inlet and exhaust ports on the Amplidyne case.

h) Open the RSG door.

i) Disengage the antenna elevation and azimuth stow locks.

3.1.1 **Normal Switch Positions**

Unless otherwise specified, switches and controls shall be in positions as specified in Table I:

3.1.2 **Meter Calibration**

During the tests of this paragraph, no prime power shall be applied to the radar.

TABLE I

NORMAL SWITCH POSITIONS

Location	Control	Positions
Back of Antenna Pedestal	Antenna Safety Switch	SAFE
Fuze and Control Panel	MAIN POWER Circuit Breaker	OFF
	FILAMENTS Circuit Breaker	OFF
	BEAM POWER Circuit Breaker	OFF
	AZ AMPLIDYNE Circuit Breaker	OFF
	EL AMPLIDYNE Circuit Breaker	OFF
	LVPS Circuit Breaker	OFF
	AZIMUTH Handwheel	Zero Mils
	ELEVATION Handwheel	Zero Mils
	VOLUME Control	CCW
Control Indicator Panel	LOCAL-REMOTE Switch	LOCAL
High Voltage Power Supply	FUNCTION SELECT Switch	OFF
Subjunction Distribution Box	STANDBY INTERLOCK OVERRIDE Switch	NORMAL
Microwave BITE Panel	BITE/TUNE FUNCTIONS Switch	MTR CAL (STBY)
Signal Data Processor	MODE Switch	MANUAL
	DISPLAY Switch	kHz
Low Voltage Power Supply	BITE Select	MTR CAL
Pedestal Rear Compartment	S2	UP
	S3	OFF

PARAGRAPH	TEXT	INITIAL
3.1.2 Cont.	All external test equipment must therefore be provided with external AC power and cannot be plugged into any of the convenience outlets of the radar. Perform the following tests:	

Connect the DC Voltage Source (see Figure 1) to the METER CAL (+) and (-) jacks of the MICROWAVE BITE panel meter. Place the BITE/TUNE FUNCTIONS switch in the MTR CAL position.

Figure 1 - DC Voltage Source

Adjust the output voltage of the DC Voltage source for a 12.50 ± 0.01 Vdc indication of the voltmeter. Verify that the BITE MONITOR meter indicates 25 ± 1.0 μA.

Disconnect the DC Voltage Source from the MICROWAVE BIT METER CAL jacks and connect the DC Voltage Source to the MTR CAL jacks of the High Voltage Power Supply (HVPS). With the FUNCTION SELECT switch in the OFF position verify that the meter reads 25 ± 1.0 μA. Disconnect the DC Voltage Source from the HVPS MTR CAL jacks.

PARAGRAPH	TEXT	INITIAL
3.1.2 Cont.	Connect the DC Voltage Source to the MTR CAL jacks of the Low Voltage Power Supply (LVPS). With the BITE SELECT switch in the MTR CAL position verify that the meter reads center scale (25 ± 1.0 μA). Disconnect the DC Voltage Source from the LVPS MTR CAL jacks.	
3.2	<u>Standby Operation</u>	
3.2.1	<u>Main Power Application</u>	
	Connect the 416 ± 21 V, 400 ± 20 Hz, 3 phase power to the main power input connector J1 location on the left hand cable panel of the RSG. Put the MAIN POWER circuit breaker in the "ON" position. Observe that the LINE VOLTAGE meter indicates in the green area. If not, adjust the input voltage for a red line indication. Record readings of the RADIATE TIME and EQUIPMENT TIME indicators.	
3.2.2	<u>Standby</u>	
	Press and hold the STANDBY push button for 10 seconds maximum. Observe that the STANDBY lamp illuminates.	
3.2.3	<u>RSG Cooling</u>	
	RSG blower operation is evidenced by air flow out of the left and right exhaust ports and out of the front exhaust port.	

PARAGRAPH	TEXT	INITIAL

3.2.4 **Convenience Outlets**

With the AC Multimeter, measure the voltage at convenience outlets J2 and J3 on the FCP and at the convenience outlets J7 located behind the pedestal rear access door. The output voltage shall be:

J2	100 to 130 Vrms
J3	100 to 130 Vrms
J4	100 to 130 Vrms

3.2.5 **Low Voltage Power Supply Checks**

Make sure that the LV PWR SUPS circuit breaker is in the ON position.

Place LVPS front panel meter switch in the following positions and observe meter indicates in the yellow area.

a) +5.0 V
b) +15.0 V
c) -15.0 V

3.2.6 **Standby Interlocks**

a) Press and hold the MOMENTARY INTERLOCK OVERRIDE push button. Open the FCP. Radar shall remain in the STANDBY mode. Release the MOMENTARY INTERLOCK OVERRIDE push button. The STANDBY indicator lamp shall extinguish.

PARAGRAPH		TEXT	INITIAL
3.2.6 Cont.		Place the STANDBY INTERLOCK OVERRIDE switch in the "ON" position. Press and hold the STANDBY push button for 10 seconds maximum. The STANDBY INTERLOCK OVERRIDE and STANDBY indicator lamps shall illuminate.	
		Close the FCP and observe that the STANDBY INTERLOCK OVERRIDE indicator lamp remains illuminated.	
		Place the STANDBY INTERLOCK OVERRIDE switch in the "NORMAL" position. The STANDBY INTERLOCK OVERRIDE indicator lamp shall extinguish.	
	b)	Repeat 3.2.6 a) for the CIP.	
	c)	Repeat 3.2.6 a) for the 90, 28 Vdc POWER SUPPLY DRAWER.	
	d)	Pull out the LOW VOLTAGE POWER SUPPLY drawer. Repeat 4.2.6. a) for the cover of the LOW VOLTAGE POWER SUPPLY.	
		After completion of this test, secure the cover and close the power supply drawer.	
	e)	Repeat 3.2.6 a) for the MICROWAVE BITE Panel.	
	f)	Place the STANDARD INTERLOCK OVERRIDE switch in the "ON" position. Close the air intake cover on the rear of the RSG. The radar shall switch off and the STANDBY and RADAR INTERLOCK OVERRIDE indicator lamps shall extinguish. Set the STANDBY INTERLOCK OVERRIDE switch	

PARAGRAPH	TEXT		INITIAL
3.2.6 Cont.		to NORMAL and open the air intake cover on the RSG. Return the radar to the STANDBY mode.	
	g)	Repeat 3.2.6 f) for the air exhaust cover on the right hand side of the RSG.	
	h)	Repeat 3.2.6 f) for the air exhaust cover on the left hand side of the RSG.	
	i)	Repeat 3.2.6 f) while pushing the lever of switch 4S8 on the radar set group front door.	
	j)	Place STANDBY INTERLOCK OVERRIDE to ON. Open the HVPS drawer. The RADAR INTERLOCK OVERRIDE and STANDBY lamps shall extinguish. Remove HVPS cover. Latch (manually depress and rotate plunger clockwise) switch S5. Depress and hold S7 on the rear of HVPS. Return the radar to STANDBY. Press and release S5 and observe that the radar goes to off. Release switch S7. Replace the HVPS cover, close the HVPS drawer and return the radar to STANDBY.	
	k)	Perform the following tests with the Radar OFF. Open the MO/PA drawer door. Disconnect The MO power cable from the bulkhead connector on the partition between the FCP area and the MO/PA drawer area. Push the STANDBY button and observe that the radar does come on but goes to off when the button is released. Reconnect the MO power cable and return the Radar to the STANDBY mode.	

PARAGRAPH	TEXT	INITIAL

3.2.6 Cont.

1) Return radar to OFF. Disconnect the PA power cable from the bulkhead connector. Push the STANDBY button and observe that the Radar does come ON but goes to off when the button is released. Reconnect the PA power cable and return the Radar to the STANDBY mode. Close the MO/PA drawer door.

3.3 Radiate Ready Operation

Place the MAIN POWER, the FILAMENTS and the LVPS circuit breakers in the "ON" position. Push the STANDBY button and at the same time start a stopwatch. Observe that the STANDBY light comes on. After approximately five minutes the STANDBY light extinguishes and the RADIATE READY light illuminates. Stop the stopwatch and observe that the elapsed time is greater than 3 and less than 7 minutes.

3.3.1 High Voltage Power Supply Checks

Observe that all SERIES TUBE FAULT lamps on the HVPS illuminates.

3.3.1.1 Standby Functions

Set the FUNCTION SELECT switch to position 1 through 7 and for each position depress the FUNCTION EXTEND push button as specified in Table II. For each step, observe that the HVPS BITE meter indication is as specified in Table II.

TABLE II

STANDBY FUNCTIONS - POSITIONS 1 THROUGH 7

Step	FUNCTION SELECT Switch Position	FUNCTION EXTEND Pushbutton	HVPS BITE Meter Indication
1	1	-	Lower Green
2	1	Depressed	Red
3	2	-	Lower Green
4	2	Depressed	Lower Green
5	3	-	Upper Yellow
6	3	Depressed	Red
7	4	-	Upper Yellow
8	4	Depressed	Red
9	5	-	Upper Yellow
10	5	Depressed	Red
11	6	-	Upper Yellow
12	6	Depressed	Red
13	7	-	Upper Yellow
14	7	Depressed	Red

Place the FUNCTION SELECT switch to position 8.
Depress the METER ZERO pushbutton.
Observe that the O/V FAULT lamp illuminates.
Radar to OFF.

PARAGRAPH	TEXT	INITIAL

3.3.2 Servo Checks

3.3.2.1 Azimuth Polarity

Open the SCD drawer and open the backplane access door.

Connect a zero center DC voltmeter to pins 34 (+) and 30 (ground) of the XA10 connector. Manually turn the pedestal clockwise (CW) in Azimuth. Observe that the meter indicates a positive polarity.

3.3.2.2 Elevation Polarity

Connect the zero center DC voltmeter to pins 34 (+) and 30 (ground) of the XA11 connector. Manually move the antenna's from horizontal to a bird bath position and observe that the meter indicates a positive polarity.

3.3.2.3 Lower Mechanical Stop

Manually move the antennas down to the mechanical stop.

Observe that the antenna position reads -178 ± 20 mils on the vertical position ring.

3.3.2.4 Upper Mechanical Stop

Manually move the antennas up to the mechanical stop.

Observe that the antenna position reads +1600 ± 20 mils on the vertical position ring.

PARAGRAPH	TEXT	INITIAL

3.3.2.5 **Lower Electrical Stop**

Remove the Radar Set Group connector from radar console (J1). Connect an ohm meter between pins f and k of the cable connector. Manually move the antennas to approximately zero mils with safety key "ON" and then slowly move it down until the ohm meter swtiches to indicate 600 ohms.

Observe that the reading on the vertical position ring is 36 ± 20 mils less negative than that observed for test 3.3.2.3.

With key "OFF", monitor f and k and ohmeter shall switch at 0 ± 20 mils.

3.3.2.6 **Upper Electrical Stop**

Manually move the antennas to approximately 1300 mils and then slowly move on up until the ohm meter switches to indicate 600 ohms.

Observe that the reading on the vertical positon ring is 36 ± 20 mils less positive than that observed for test 3.3.2.4.

Reconnect the connector J1 to the radar console.

3.3.2.7 **Azimuth Control Transmitter**

Stow the antennas in azimuth facing the rear of the trailer. In the rear of the antenna pedestal adjust the azimuth synchro cluster to the hair line position. Open the Fuze and Control Panel and connect an AC voltmeter between pins S1 and S3 of

PARAGRAPH	TEXT	INITIAL
3.3.2.7 Cont.	the Azimuth Control Transmitter. With the meter on the 2.5 V scale adjust the handwheel for a null indication on the meter. Observe that the handwheel scale indicates 0 ± 7 mils.	
3.3.2.8	Elevation Control Transmitter Stow the antennas in elevation at zero mils. Connect the AC voltmeter between pins S1 and S3 of the Elevation Control Transmitter. With the meter on the 2.5 V scale adjust the handwheel for a null indication on the meter. Observe that the handwheel scale indicates 0 ± 7 mils.	
3.3.2.9	Elevation Synchro Null Open the SCD drawer and open the backplane access door. Connect a center reading AC voltmeter between pins 48 (+) and 55 (ground) of the El Servo Controller (XA11) Module Connector. Observe that the meter reads 0 ± 0.1.	
3.3.2.10	Azimuth Synchro Null Connect the center reading AC voltmeter between pins 48 (+) and 55 (ground of the AZ Servo Controller (XA10) module connector. Observe that the meter reads 0 ± 0.1. In the rear of the pedestal push S2 and observe that the pedestal meter reads zero. Remove the AC voltmeter.	

PARAGRAPH	TEXT	INITIAL

3.4 **False Radiate**

When in the RADIATE READY mode depress the RADIATE push button. The RADIATE light shall illuminate and the RADIATE READY light shall extinguish. The HV ON light shall remain extinguished. The BEAMPOWER and the AMPLIDYNES circuit breaker should remain in the "OFF" position.

3.4.1 **Spin Frequency**

Connect Spin Ref out to Counter in BNC connector on Signal Data Processor front panel. Observe LCD Display reads M ± 2 Hz.

3.4.2 **Servo Checks**

Unstow the Elevation and Azimuth stow locks. Switch the SAFETY SWITCH in the rear of the pedestal to the OPERATE position.

3.4.2.1 **Azimuth Field Current**

Observe that the AZ SERVO FIELD CURRENT meter of the Control Indicator Panel (CIP) yields an on-scale reading.

3.4.2.2 **Elevation Field Current**

Observe that the EL SERVO FIELD CURRENT meter of the CIP yields an on-scale reading.

PARAGRAPH	TEXT	INITIAL

3.4.3 **Antenna Tests**

Manually move the antennas to a zero reading on the antenna elevation position ring and to a zero reading on the azimuth position ring.

Observe the EL SERVO FIELD CURRENT meter on the CIP reads zero center scale ± 2 μA.

Observe the AZ SERVO FIELD CURRENT meter on the CIP reads zero center scale ± 2 μA. CLEAR PERSONNEL AND EQUIPMENT FROM ANTENNA AND TOP OF THE RADAR SET GROUP.

Momentarily lift the AZ AMPLIDYNE circuit breaker and observe that the antenna's are stable in azimuth.

Momentarily lift the EL AMPLIDYNE circuit breaker and observe that the antenna's are stable in elevation.

Switch the AZ and EL AMPLIDYNE circuit breakers to "ON".

3.4.3.1 **Azimuth Manual Positioning**

Rotate the azimuth handwheel on the FCP CCW and then CW and observe that the antenna's follow smoothly in azimuth. Rotate the handwheel through a full 6400 mils and observe that the antenna's make a complete revolution.

PARAGRAPH	TEXT	INITIAL

3.4.3.2 **Elevation Manual Positioning**

Rotate the elevation handwheel on the FCP CCW and then CW and obsere that the antenna follows smoothly in elevation.

Rotate the handwheel and observe that the antenna's can be positioned in elevation from -100 to +1520 mils.

3.4.4 **Receiver Checks**

3.4.4.1 **Doppler Amplifier Noise**

Put the radar in Standby with the LVPS circuit breaker ON.

Open the Receiver Group door.

Disconnect the input cable plug W3P1 from J2 on the Doppler Amplifier.

Connect a cable from a signal generator (HP606 or equivalent) through a 100 dB (50 Ω) step attenuator to J2 on the Doppler Amplifier.

Put maximum attenuation in both the signal generator and 50 Ω attenuator.

Open the Signal Processor drawer and disconnect plug 4A12W1P5 from J4 on the Signal Processor. Connect an adapter cable with 50 Ω load to plug 4A12W1P4-6. Connect the other end of the cable to a TRMS Voltmeter (HP 3400 or equivalent).

Short the AGC in the Doppler Amplifier and observe that the ACVM indicates 80 $\pm$ 40 mVrms.

PARAGRAPH	TEXT	INITIAL

3.4.4.2 **Receiver Gain**

Adjust the output of the signal generator for 50 kHz at 500 mVrms into the attenuator. While monitoring the ACVM, decrease the attenuator until the ACVM indicates 500 mVrms.

The attenuator shall indicate 65 $\pm$ 10 dB attenuation.

3.4.4.3 **Receiver AGC Range (Dynamic Range)**

Unshort the AGC in the Doppler Amplifier and connect a DVM to the AGC test point. Disconnect the ACVM from the adapter cable and attach an oscilloscope and 50 Ω load . While observing the oscilloscope, decrease the attenuation until slight distortion is seen on the output signal. The attenuator shall indicate 17 $\pm$ 2 dB. Record the AGC voltage for reference.

Remove the oscilloscope.

While monitoring the AGC voltage decrease the signal level until the AGC is approximately -0.5 Vdc. The attenuator indicates 95 $\pm$ 5 dB.

3.4.4.4 **Doppler Bandwidth**

With the AGC shorted and a 50 kHz applied to the input of the Doppler Amplifier via a 50 Ω step attenuator, monitor the output of the Doppler Amplifier on a oscilloscope. Set the attenuator and signal generator for a convenient level (600 mV pk-pk) on the oscilloscope.

PARAGRAPH	TEXT	INITIAL
3.4.4.4 Cont.	Remove 3 dB from the step attenuator and change the Signal Generator Frequency to approximately 5 kHz and note that signal on scope is at the same amplitude as the 50 kHz setting.	
	Next change the Signal Generator Frequency to approximately 200 kHz and note that signal on scope is at the same amplitude as the 50 kHz setting.	
3.4.4.6	<u>Doppler AGC Kick</u>	
	Adjust signal generator for 50 kHz and 0 dBm signal level. Set attenuator for 20 dB.	
	Remove the back cover on the Signal Processor and connect an oscilloscope to XA...PIN.. (AGC). Observe that the oscilloscope signal is approximately 0 V. Increase the attenuator by another 40 dB (60 dB total) and observe no change in oscilloscope signal. Increase the attenuator an additional 10 dB (70 dB total) and observe oscilloscope signal is now approximately +5.0 V. Remove the 10 dB from the attenuator (60 dB total) and the oscilloscope signal will return to 0 V.	
	Disconnect the test equipment and connect all cables.	
3.5	<u>Radiate</u>	
	When operating outside, point the antenna to an elevation of approximately 200 mils. Do not point the antenna at buildings or obstructions that can reflect the radar energy.	

PARAGRAPH	TEXT	INITIAL
3.5 Cont.	When operating inside a building remove the antenna feed from the transmitting antenna and connect the dummy RF load with 8 sockethead screws. Make sure that the antenna is set and stowed for an elevation of zero mils. Leave the EL and AZ AMPLIDYNE cirucit breakers "OFF". Place the BEAM POWER circuit breaker in the "ON" position. When the radar is in the RADIATE READY mode depress the RADIATE push button. The RADIATE READY light shall extinguish and the HV ON and the RADIATE lights shall illuminate.	
3.5.1	High Voltage Power Supply	
	Observe that all the SERIES TUBE FAULT and the O/V FAULT lamps have extinguished. Press the LAMP TEST button and observe that all lamps illuminate. Release the LAMP TEST push button. Place the FUNCTION SELECT switch in position 9. Observe that the BITE meter indicates within +6.5 to +22 μA. Place the FUNCTION SELECT switch in positon 10. Press and hold the METER ZERO push button. Observe that the BITE meter indicates in the blue area.	

PARAGRAPH	TEXT	INITIAL

3.5.1 Cont. If the BITE meter indication is not as specified, rotate the ZERO ADJUST until the desired indication is obtained. Release the METER ZERO push button. Observe that the BITE meter indicates in the blue area.

If the BITE meter indication is not as specified rotate the MO AV ADJUST until the desired indication is obtained.

Place the FUNCTION SELECT switch in position 11. Observe that the BITE meter indicates in the lower yellow area. Depress the FUNCTION EXTEND push button. Observe that the BITE meter indicates in the blue area. Release the FUNCTION EXTEND push button and place the FUNCTION SELECT switch in position 12.

3.5.2 MO/PA Assembly

For the following tests the radar should be in the RADIATE mode. Perform the following tests in the order listed.

3.5.2.1 Tuning

This procedure should be followed after changing the power amplifier tube, the MO/PA assembly or the MO tube. The microwave BITE meter monitors all the following tuning functions. Set the

PARAGRAPH	TEXT	INITIAL
3.5.2.1 Cont	microwave TUNE FUNCTION select switch to PA DR LO. Adjust the MO OUT ADJ with a suitable screwdriver until the meter indicates 30 μA. Remove the tuning tool PN 10182378 from the MO/PA assembly door, insert the tool in cavity tuning screw No. 1 and turn fully CCW to the stop. Repeat for cavity tunign screws No. 2, No. 3 and No. 4. Set the microwave TUNE FUNCTIONS select to PA NULL. Beginning with cavity tuning screw No. 1, trun each tuning screw one half turn clockwise. Repeat turning each tuning screw one half turn clockwise until the meter dips to a minimum. Adjust tuning screw No. 1 for a minimum indication of the meter. Increase the MO OUT ADJ if necessary to obtain a clear minimum. Set the TUNE FUNCTIONS select swtich to PA DR LO and adjust the MO OUT ADJ for an indication of 5 μ A. Set the TUNE FUNCTIONS select switch to PA OUT and turn cavity tuning screws No. 2, No. 3 and No. 4, for a maximum indication on the meter. Continue adjustment of these screws until the maximum meter indication is obtained. Turn cavity turning screw No. 3 one turn counterclockwise. Set the TUNE FUNCTIONS select swtich to PA DR HI and turn the MO OUT ADJ unti the meter indicates 25 μA. Set the TUNE FUNCTIONS switch to PA OUT and turn the cavity tuning screws No. 3 and No. 4 for a maximum indication in the white area of the meter. Replace the tuning tool in its holder.	

PARAGRAPH	TEXT	INITIAL

3.5.2.2 **Tuning Verification**

Place the BITE FUNCTIONS switch in the PA DR position. Observe that the meter indicates in the green area.

Place the BITE FUNCTIONS switch in the PA OUT position. Observe that the meter indicates in the white area. Close the MO/PA assembly door.

3.5.3 **Transmitter Power**

Radar to STANDBY.

Connect a power meter to the TEST connector of the Tranmsitter Group. Radar to RADIATE. Observe that the power meter output power greater than 300 W. Radar to STANDBY. Disconnect the power meter.

3.5.4 **Transmitter Frequency**

Connect a frequency meter to the TEST connector of the Transmitter Group. Radar to RADIATE. Observe that the frequency meter indicates a frequency listed on the MO tube $\pm$ 10 MHz. Radar to STANDBY. Disconnect the frequency meter.

3.5.5 **Arc Protection Circuit**

Radar to RADIATE.

Open the Transmitter Group door. Disconnect the cable connected to the group detector in the Transmitter Group and observe that the radar returns to the RADIATE READY mode. Reconnect the cable to

PARAGRAPH	TEXT	INITIAL
3.5.5 Cont.	the detector, remove all test equipment from the Transmitter Group and close the Transmitter Group compartment. On the CIP observe that the ARC FAILURE light is illuminated. Push the RADIATE FAILURES RESET button and the ARC FAILURE light shall extinguish. Momentarily press the RADIATE push button and observe that the radar goes in the radiate mode.	
3.5.6	Transmitter Reference Level Using an RF power meter, measure the X-Band power input to the Microwave Receiver by disconnecting the reference cable at the receiver termination and apply cable ending to proper power sensor. Power should be 100 ± 10 mW.	
3.5.6.1	Receiver Noise Disconnect Antenna Feed Cable and connect Noise Source ( ). Attach 28 V power to Noise Source. Connect Doppler Amplifier output to Spectrum Analyzer. Short the AGC in the Doppler Amplifier and observe output spectrum from 0 - 200 kHz. Turn on 28 V Power Supply and observe noise rise. Rise shall be greater than 8 dB which will indicate a system noise figure of 10 dB.	

PARAGRAPH	TEXT	INITIAL

3.5.7 Signal Data Processor - LOCAL

The following test are to be conducted in the Local Mode.

3.5.7.1 Upper Sweep Limit Adjust

a) Rotate the front panel mode swtich to the upper sweep limit adjust position. Observe that the LCD will be activated and a number will appear on the display.
b) Rotate the display function swtich to KFT/s. Observe that the LCD will display KFT/S to indicate the units for the number on the display.
c) Rotate the upper sweep limit adjust control to set the desired upper sweep limit as indicated on the LCD. Rotating the control CCW will lower the upper sweep limit and rotating the control CW will raise the upper sweep limit. Adjust the control for an upper sweep limit of approximately 5 KFT/S.

3.5.7.2 Lower Sweep Limit Adjust

a) Rotate the front panel mode switch to the lower sweep limit adjust position.
b) Rotate the lower sweep limit adjust control to set the desired lower sweep limit as indicated on the LCD. Rotating the control CCW will lower the lower

PARAGRAPH	TEXT	INITIAL
3.5.7.2 Cont.	sweep limit and rotating the control CW will raise the lower sweep limit. Adjust the control for a lower sweep limit of approximately 0.5 KFT/S.	
3.5.7.3	Stone Wall Adjust	
	a) Flip up the stone wall select switch on the edge of the DTUP. Stonewall will now be displayed on the LCD.	
	b) With a screw driver, adjust the Stonewall adjust potentiometer on the edge of the DTUP. Adjust the potentiometer for a Stonewall of 0.25 KFT/S.	
	c) Flip down the Stonewall select switch to the lower sweep limit position. Observe LCD again displays the lower sweep limit.	
3.5.7.4	Upper Sweep Limit Test	
	a) With a Signal Generator inject a -20 dBm, 50 kHz signal at the input to the Doppler Amplifier.	
	b) Rotate the front panel mode switch to the manual position. Observe that the LCD will go blank except for the KFT/S units notation.	
	c) Rotate the front panel mode switch to the auto position. Observe that the LCD will display the word "LOCK" and approximately 2.50 KFT/S (50 kHz).	

PARAGRAPH	TEXT		INITIAL
3.5.7.4 Cont.	d)	Remove the injected 50 kHz singal by disconnecting or shutting off the Signal Generator. Observe that the word "MEMORY" will appear for approximately 5 seconds and the display speed will vary as the DTUP is reswept. At the end of the five second the display will go blank to signify Bird Bath.	
	e)	Reset the Signal Generator to 150 khz and inject the signal to the Doppler Amplifier input. Observe that display remains blank.	
	f)	Slowly decrease the frequency of the Signal Generator toward 100 kHz (the upper sweep limit). Observe that when approximately 100 kHz or approximately 5 KFT/S is reached the display will activate and a "LOCK" will be displayed along with approximately 5.00 KFT/S. Lowering or raising the frequency further will result in the DTUP tracking the signal as displayed on the LCD. Disconnect Signal Generator to terminate test.	
3.5.7.5	Lower Sweep Limit Test/Stonewall		
	a)	With the front panel mode switch in the "AUTO" position inject a 5 kHz, -20 dBM, signal with the Signal Generator at the input of the Doppler Amplifer. Observe LCD remains blank.	

PARAGRAPH	TEXT		INITIAL
3.5.7.5 Cont.	b)	Slowly increase the frequency of Signal Generator towards 10 kHz (The Lower Sweep Limit). Observe that when approximately 10 kHz or 0.5 KFT/S is reached the display will activate and a "LOCK" will be displayed along with approximately 0.500 KFT/S. Raising the frequency further will result in the DTUP tracking the signal as displayed on the LCD.	
	c)	With the DTUP locked and tracking the Signal Generator. Slowly decrease the frequency toward 5 kHz (Stonewall). Observe that the DTUP will track the signal below 10 kHz (0.500 KGT/S the Lower Sweep Limit) unti 5 kHz or approximately 0.250 KFT/S is reached. Observe that the LCD will display "MEMORY" and the speed will vary as the DTUP is reswept. At the end of 5 seconds the display will go blank to signify Bird Bath.	
3.5.7.6	Lock Hold Tests		
	a)	With the front panel mode switch in the auto position inject a 50 kHz, -20 dBm signal with the Signal Generator at the input of the Doppler Amplifier. Observe LCD displays "LOCK" and approximately 2.500 KFT/S.	

PARAGRAPH	TEXT	INITIAL
3.5.7.6 Cont.	b) Rotate the mode switch to the hold position. Observe that the word LOCK remains.	
	c) Remove the injected 50 kHz signal by disconnecting or shutting OFF the Signal Generator. Observe that the display will remain activated and the speed will slowly drift down to Stonewall (0.200 KFT/S). Rotate the Mode Switch to auto. Observe that the word memory is now added to the display.	
3.5.8	Signal Data Processor - Remote Operation	

This Radar contains a computer and software burned in to ROMS that controls and commands the multiple functions of the system, therefore to demonstrate the sytem capability, a mission scenario of a typical mission will be shown and a demonstration of the command set available to the user from a terminal will be demonstrated.

Switch LOCAL/REMOTE switch to REMOTE. Type in the following:

```
GL.AR
LH 20
LN 30
BB 50
AP 400  400
AT 100  50
RT 20  20
FI 100
```

PARAGRAPH	TEXT	INITIAL
3.5.8 Cont.	All commands are set for mission. On the GO command the system will go into operation. Observe the following:	

Antenna position will start a search pattern about the point AZ-400 mils EL 400 mils and after 20 seconds will stop searching.

On SDP Front Panel indicator observe following

at	20 sec	LOCK indicator
	30 sec	MEMORY
	32.5 sec	Blank
	37.5 sec	Antenna goes into Bird Bath position (BB).

Real Time Terminated

TYPE

SS.f ALL

RESPONSE

SRC LD REM

will be the first line and as functions are excuted they will be displayed on the terminal

TYPE

AE ALL

PARAGRAPH	TEXT	INITIAL
3.5.8 Cont.	RESPONSE	

400 400.0

and rest of antenna positions for mission.

First column is sample number, second is AZ position and third is EL position.

The following is the command set that will be individually demonstrated.

GL.options

Purpose
Set a global option which will be assumed to be on each succeeding command

Options
A,E,R

Parameters
No parametes are allowed.

LC.options

Purpose
Resets (turns off) a global option.

Options
A,E,R, if from the terminal.
E,R only if sent from the ADP.

Parameters
No parameters are allowed.

AE.options type

Purpose
A,E,R
R options is ignored on a dumpl of buffer data. In that case, any real-time activity terminated.

Parameters

Type-A or ALL		Display all valid buffer entries from the last mission.
	TO	Display position at last mission time zero.
	n	Display buffer entries 0,1,...,n. (0.le.n.le.1023)
	none or null	Display current position.

SS.options type

Purpose
Displays radar status bytes.

Options
A,E,R,F
R option is ignored on a dump of buffer data. In that case, any real-time activity is terminated.
F option will force output to be mnemonic instead of hexadecimal.

Parameters
Type (see AE command)

AD.options mode

Purpose
Initiates real time. This command will ARM data collection and initiate search.

Options
A,E,R
Roption is ignored. Any real-time activity is terminated prior to its re-activation.

Parameters
Mode LH Send a lock hold command to the radar at initiation.
LN Send a lock normal ocmmand to the radar at intiation.
LD Send a lock disable command to the radar at initiation.
None Send the same command that was sent on the previous mission initiation on this initiation.

GO.options mode

Purpose
Initiates real time. This command will arm data collection and initiate search.
This command differs from AD in that only the internal timer data collection sync pusles are allowed and the software will inject an artifical time zero pulse.

Options
A,E,R
R option is ignored. Any real-time activity is terminated prior to its re-activation.

Parameters
Mode (see AD command)

SN.options source

Purpose
To define the source of data collections sync pulses that will be used for succeeding missions.

Options

A,E,R

Parameters

Source- IT Internal interval timer.
SY External TTL signal.

TO.options source

Purpose

To define the source of the time zero pulse that will be used for succeeding missions.

Options

A,E,R

Parameters

Source- AN Analog input threshold detection.
SY The first external sync pulse. (SO)
DI An external TTL signal.
SW Software injected TØ.

BB.options time

Purpose

To generate a birdbath command to the radar.

Options

A,E,R

Parameters

If no parameter is present, the command is sent immediately.
If a parameter is present, the execution will be deferred until 'time' seconds into succeeding missions.

LH.options time

Purpose

To generate a lock hold command to the radar.

Options

A,E,R

Parameters

(See BB command.)

LN.options time

Purpose

To generate a lock normal command to the radar.

Options

A,E,R

Parameters

(See BB command.)

LD.options time

Purpose

To generate a lock disable command to the radar.

Options

A,E,R

Parameters

(See BB command.)

AP.options az el

Purpose

To move the radar to acquisition position.

Options

A,E,R,N,H,P

The N option, if used, allows the setting of the data base to be used on succeeding missions, but will not move the radar into position.

The H option allows the setting to be the current radar pointing angle.

The P option makes parameters relative rather than absolute.

AT.options az el rot

Purpose

To define the search pattern parameters that will be used for acquisition on succeeding missions.

Options

A,E,R,0,1,2

Option 0 sets the search pattern to a single point.

Option 1 sets the search pattern to be a non-reiterative spiral.

Option 2 sets the search pattern to be a reiterative spiral.

Parameters

az The semiaxis in mils in the azimuth dimension.

el The semiaxis in mils in the elevation dimension.

rot If this parameter is non-zero, the semiaxis of the pattern will be rotated by this quantity. (in mils)

RT.options az el rot

Purpose

To define the search pattern parameters that will be used for re-acquisition on succeeding missions.

Options

A,E,R,0,1,2

(See AT command.)

Parameters

(See AT command.)

FT.options fi bi

Purpose
To define time frame interval that will be used for succeeding missions.

Options
A,E,R

Parameters
fi-The frame interval in milliseconds.(10.le.fi.lt.1001)
bi-The bias interval in milliseconds.(0.le.bi.lt.1001).
This is the time between the reception of the time zero input and the acceptance of any frame interval inputs.

PC.options npc

Purpose
To set the pcm codec multiplier that will be usd on succeeding missions.

Options
A,E,R

Parameters
npc-The number of pcm codec frames that will be issued during each frame interval.(3.le.npc.le.32, but if npc.se.16, npc must be even).

FT.options ftargv ftargf

Purpose
To set the false target doppler frequency.

Options
A,E,R

Parameter
ftargv-The assumed target velocity in meters/second.(1.le.ftargv.le.3050)
If E option is used, input is in feet/second.
ftargv-The assumed rf transmission frequency that will be used to determine the doppler frequency, (MHz) (8000.le.ftargf.le.12000).

PARAGRAPH	TEXT	INITIAL
3.6	Radar Off Trailer Panel	
3.6.1	DC Doppler	

Connect a DVM to J8 on the off trailer panel. Connect a signal generator to the Doppler input plug J4-6 on the signal processor drawer. Adjust the output of the signal generator for 200 mVrms. Adjust the signal generator for the following frequencies, allow the DTUP to lock on the signal, and observe the DVM for corresponding reading as seen below.

Frequency	DVM Indication
3 kHz	
10 kHz	
30 kHz	
60 kHz	
100 kHz	
130 kHz	
160 kHz	
200 kHz	

Disconnect DVM from J8.

3.6.2 Wide Band Doppler

Connect an oscilloscope to plug J6 on off trailer panel.

PARAGRAPH	TEXT	INITIAL
3.6.2 Cont.	Adjust the signal generator for a frequency of 100 kHz and observe that the oscilloscope displays a 100 kHz signal 1 Volt Peak to Peak with no visible distortion. Disconnect Oscilloscope from J6.	
3.6.3	<u>Reconstitued Doppler</u>	
	Connect a frequency counter to J7 on the off trailer panel. With the signal still adjusted for 100 kHz, observe that the frequency counter indicates 100 kHz. Change the frequency of the signal generator to 10 kHz and observe the frequency counter indicates 10 kHz. Disconnect the frequency counter from J7.	
3.6.4	<u>AZ DC Error</u>	
	Disconnect the signal generator from J4-6 and connect a HP 606 or equivalent to J4-6 on the signal processor. Adjust the frequency to 50 kHz and the output amplitude to 200 mVrms. Set the signal generator to "M" frequency and connect it to the external modulation input on the HP 606. Adjust the amplitude for approximately 30 percent modulation. Assure the radar is in LOCAL with both Azimuth and Elevation Amplidyne circuit breakers to OFF. Allow the DTUP to lock on the 50 kHz signal. Set the swtich on the rear of the Control Indicator Panel to cross coupling.	

PARAGRAPH	TEXT	INITIAL

3.6.4 Cont. Observe the Azimuth and Elevation meters on the Control Indicator Panel and adjust the signal generator for a slow beat frequency around "M" frequency (meters will move slowly across the dial and return).

Connect an oscilloscope to J16 on the off trailer panel and observe a "M" frequency sine wave changing slowly in amplitude.

3.6.6 Elevation DC Error

Disconnect the oscilloscope from J16 and connect it to J17 on the off trailer panel.

Observe a "M" frequency sine wave changing slowly in amplitude.

Disconnect the HP 606 form J4-6 on the signal processor and reattach cable 4A12W1P6 to J4.

3.6.7 Radar Operation Status

Connect a DVM to J14 on the off trailer panel.

With the radar in remote, position the antenna to the following azimuth positions and observe the DVM for the following indications.

Azimuth Position	DVM
0.0 mils	
+500 mils	
-500 mils	

PARAGRAPH	TEXT	INITIAL

3.6.8 **Elevation DC**

Connect the DVM to J15 on the off trailer panel.

With the radar in remote, position the antenna to the following elevation positions and observe the DVM for the following indications:

Elevation Position	DVM
0.0 mils	
50 mils	
100 mils	
300 mils	

Disconnect the DVM from J15.

3.6.9 **Analog Bipolar TØ**

Adjust a pulse generator for a 10 μsec pulse width with a repetition rate of 1 second. Adjust the output for a positive pulse amplitude of 0 to 5 V peak.

Connect the output of the pulse generator to J12 on the off trailer panel.

Put the radar in remote operation and type into the computer the following:

```
GL.AR
TØ ƀ AN
AD ƀ LD
SS.F ƀ TØ
```

PARAGRAPH	TEXT	INITIAL

3.6.9 Cont. The computer screen should show the following print out if Bi Polar input is functioning

```
| 1 ƀ ƀ Number > 0
| ƀ ƀ ............ ANA
```

A number greater than zero will appear to the right of 1 on the first line and the letters ANA will appear part way across the screen on the second line. All other following tests will be shown as above and can be read as explained above.

Test is over. Type BB into the computer.

3.6.10 Digital In

Disconnect the pulse generator from J12. Using the same pusle width and repetition rate, adjust the output for a negative pulse going from +5 V to 0 V.

Connect the output of the pulse generator to J10 on the off trailer panel.

Type into the computer the following:

```
| GL.AR
| TØ ƀ DI
| AD ƀ LD
| SS.F ƀ TØ
```

The computer screen should show the following print out if Digital In is functioning.

PARAGRAPH	TEXT	INITIAL

3.6.10 Cont.

| 1 ƀ ƀ Number > 0
| ....TØ

Test is over type BB into computer.

3.6.11 Digital Outs

With the pulse generator still connected to J10, adjust an oscilloscope to trigger on a negative going pulse and connect it to J5 on the off trailer panel.

While observing the scope for a triggering pulse, type the following into the computer:

|AD ƀ LD
|SS.F ƀ TØ

The computer screen should show the same output as the previous test and a pulse should have appeared on the oscilloscope.

Test is over. Type BB into computer.

Disconnect the scope from J5.

3.6.12 Digital Sync. Input

Disconnect pulse

PARAGRAPH	TEXT	INITIAL
3.6.12 Cont.	The computer screen should show the following print out if the Digital Sync Input is functioning.	

|1 b̸b̸ Number > 0
|.................FRM

3.6.13	Digital Sync Out	

Connect an oscilloscope to J4 on the off trailer panel and observe a positive going output pulse approximately 100 μsec duration at a repetition rate of 1 sec.

Change the repetition rate of the pusle generator and observe that the Digital Sync Output as seen on the scope varies with pulse generator.

Test over. Type BB into computer.

RADAR CONFIGURATION SUMMARY

Radar Serial No.:
Proving Ground:
Contract:
Date of PAT:
HVPS S/N:
Microwave Assembly S/N:
+90 V, +28 Vdc PS S/N:
LVPS S/N:
SDP S/N:

-DTUL S/N:
-DTUP S/N:
-ZDIS S/N:
-ZTIM S/N:
-ZCPU S/N:
-ZAOM S/N:
-AZIM S/N:
-STRF S/N:
-SAEC (A9) S/N:
-SAEC (A10) S/N:

Dop. Amplifier S/N:
RF Micro Receiver S/N:
Scanner S/N:
Saturable Reactor S/N:
Amplidyne AZ S/N:
Amplidyne EL S/N:
Equipment Time*:
Radiate Time*:
Data of Shipment:

*At time of shimpment from Bedford Labs.

DEPARTMENT OF THE ARMY
U.S. ARMY ENVIRONMENTAL HYGIENE AGENCY
ABERDEEN PROVING GROUND, MARYLAND 21010

Mr. Hicks/cvc/AUTOVON
584-3932

REPLY TO
ATTENTION OF

HSHB-RL-M/WP

7 MAR 1984

SUBJECT: Nonionizing Radiation Protection Study No. 24-42-0703-84, AN/MPQ-33 (Modified) Velocimeter, Yuma Proving Ground, Arizona, 7-8 December 1983

Commander
US Army Materiel Development
and Readiness Command
ATTN: DRCSG
5001 Eisenhower Avenue
Alexandria, VA 22333

1. AUTHORITY. Letter, STEYP-SAF, Yuma Proving Ground (YPG), 6 October 1983, subject: Request for Technical Assistance, Microwave Evaluation, with indorsements thereto.

2. REFERENCES. See Inclosure for a listing of references.

3. PURPOSE. To evaluate the potential microwave radiation hazards associated with the modified AN/MPQ-33 Velocimeter Radar in use at YPG, and to make recommendations to prevent needless exposure of personnel to such radiation.

4. GENERAL.

a. Background. This study was requested by the Safety Office, YPG, coincident with two studies (references 5 and 6, Inclosure) being conducted at this facility. The study was coordinated by Mr. E. Matzkanin, Chief, Safety Office, who accompanied the survey officers during the study. Mr. C. Hicks and Mr. B. Roberts conducted the study for the US Army Environmental Hygiene Agency.

b. Briefings. Briefings were held with Mr. E. Matzkanin; and SP4 M. Turchen and SP4 P. Wyman, Preventive Medicine (PVNTMED) Activity, YPG.

c. Instrumentation.

(1) Narda Model 8603 Broadband Isotropic Radiation Monitor.

(2) Raham Model 3 Broadband Isotropic Radiation Monitor.

5. FINDINGS AND DISCUSSION.

a. General. The AN/MPQ-33 is a HAWK System Lower Power Illuminator (LPI) Radar which is widely used as a velocimeter at various DA installations. There are three of these radars on the YPG inventory. Two of them have been modified and were in use. A third was at the manufacturer's plant being modified. The principle modification to the system which has an impact on radiation protection control is the increase in transmitter power. A radiation protection program (RPP) had always been a requirement for the LPI and an acceptable RPP was in use at YPG. The two radars that were studied are denoted unit #2 and unit #4. Both were in use at the time of the study and measurements were conducted in and out of the main beam. Power density levels of approximately 200 mW/cm² were measured at both radars.

b. System Description. The modified LPI velocimeter radar is a trailer mounted unit using a 1.2 m diameter parabola antenna which can be articulated a full 360° in azimuth and from -10° to +90° in elevation. The system is mounted close enough to the ground to permit personnel to be exposed to the main beam at the highest power density levels. The transmitter power of the system had been increased to a reported maximum of 400 W average (reference 7, Inclosure). Radiated power density measurements made during this study indicated that the transmitter power was close to 500 W. Maintenance personnel who were familiar with the system verified that the manufacturer was reporting a transmitter power level of 485 W for the modification. This higher transmitter level was consistent with the measurements of this study. System parameters of the modified LPI are summarized in Table 1.

TABLE 1. SYSTEM PARAMETERS AN/MPQ-33 (MODIFIED)

1. Frequency	I band
2. Power	485 W (average); 450 W at Feed (-0.3 dB loss)
3. Antenna	1.2 m diameter prime fed parabola,
4. Gain	39.2 dB @ 60% efficiency

c. Hazard Analysis and Radiation Measurement. Based on the system parameters outlined in Table 1, the modified AN/MPQ-33 is able to produce hazardous power density levels to a range of 55 m. This analysis is detailed in Table 2. Main beam power density measurements were made on both systems, and these are listed also in Table 2. There was good agreement between the measured and analytical levels, as indicated in Table 2. No detectable leakage levels in excess of 0.05 mW/cm² were found around the waveguide or transmitter components of either system.

TABLE 2. AN/MPQ-33 (MODIFIED) ANALYSIS AND MEASUREMENT

Analyzed Power Density Levels vs Range	Measured Power Density Level: Unit #2 (Δ dB)* mW/cm² at Range (± dB)	Unit #4 (Δ dB) mW/cm² at Range (± dB)
198 mW/cm² at 12 m	195 at 11 m (-0.1 dB)*	190 at 8 m (-0.2 dB)
100 mW/cm² at 17.4 m	110 at 16 m (-0.1 dB)	160 at 12 m (-0.9 dB)
50 mW/cm² at 25 m	50 at 26 m (+0.4 dB)	100 at 16 m (-0.8 dB)
10 mW/cm² at 55 m	10 at 52 m (-0.4 dB)	50 at 26 m (+0.4 dB)
5 mW/cm² at 78 m		10 at 58 m (+0.3 dB)

* Δ dB = Difference between measured and expected level (dB); ie 10 log (195/198).

d. Hazard Evaluation and RPP. As indicated in Table 2, the modified AN/MPQ-33 radar is able to produce hazardous and potentially hazardous power density levels in the main beam. The range of control for the system should extend to 55 m. An effective RPP for the radar should include all of the following program elements as a minimum. The RPP for these radars at YPG did address all of these elements. Current documentation of the RPP had been delayed pending the outcome of the US Army Environmental Hygiene Agency study. The RPP referred to in paragraph 7 of this report should include the following:

(1) Inventory the modified AN/MPQ-33 as a potentially hazardous microwave source.

(2) Prohibit personnel occupancy of the main beam to a range of 55 m. Note: As necessary, the following positive measures should be taken to prevent accidental intrusion of personnel or misdirection of the beam:

(a) Locate the system at least 55 m from potentially occupied test stands, structures, etc.

(b) Provide adequate warning at paths or roadways that intersect the main beam (choose warning signs, lights, alarms, and/or barricades, as appropriate).

(c) Specify prohibited azimuth and elevation zones where applicable. Such limits should be marked at local and remote control panels.

(d) Prohibit all nonessential free space radiation.

(3) Provide initial and routine safety briefings for all appropriate personnel on the hazards associated with the system and the RPP which is specified for control.

(4) Publish the Standing Operating Procedures (SOP) for control of the potential hazards. Post the SOP in the work place associated with maintenance and/or operation of the radar.

6. CONCLUSION. These are potentially hazardous microwave power levels associated with the modified AN/MPQ-33 radars. The RPP used at YPG was providing adequate control of the radiation hazard. Implementation of the following recommendation will assure that the RPP meets all applicable requirements of AR 40-583.

7. RECOMMENDATION. Document the RPP used at YPG to control the AN/MPQ-33 radiation hazard (paragraph 6f, AR 40-583).

FOR THE COMMANDER:

for Alexander L. Doherty, LTC

1 Incl
as

JOSEPH T. WHITLAW, JR
Colonel, MSC
Director, Radiation and
Environmental Sciences

CF:

HQDA (DASG-PSP)
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Comdt, AHS (HSHA-IPM)
Cdr, YPG (2 cy)
Cdr, WBAMC (PVNTMED Actv)
Cdr, MEDDAC, Ft Huachuca (PVNTMED Actv) (2 cy)

APPENDIX D - ABBREVIATIONS

A	=	ampere
ACPU	=	Central processing unit
ADC	=	analog to digital converter
ADJ	=	adjust
ADP	=	Automatic Data Processing
AE	=	azimuth and elevation
AGC	=	automatic gain control
AM	=	amplitude modulation
AMP	=	amperes
AMPL	=	amplitude
AP	=	acquisition positioning
Avg	=	average
AZ	=	azimuth
BB	=	birdbath
BITE	=	built in test equipment
Blu	=	blue
C	=	centigrade
Cal	=	calibrate
CFM	=	cubic ft per minute
CIP	=	control indicator panel
Circ	=	circulator
CKT	=	circuit
CLK	=	clock
CM	=	centimeter
CONTRIN	=	counter input
CTC	=	counter timer controller
CW	=	continuous wave
DAC	=	digital to analog converter
dB	=	decibel
DC	=	direct current
DCDOPP	=	direct current doppler
DDIS	=	doppler disable
DET	=	detector
DOPPIN	=	doppler input
DPT	=	decimal point
DR	=	drive
DTUL	=	doppler tracking unit lock logic
DTUP	=	doppler tracking unit module
EDIR	=	external direct
El	=	elevation
EMR	=	electro magnetic radiation
EPRDM	=	erasable programmable read only memory
Ext	=	external
fd	=	frequency of doppler
FET	=	field effect transistor
FT	=	fast Fourier transform
Fil	=	filament
FM	=	frequency modulation
FSS	=	function select switch
Ft	=	feet
Fwd	=	forward
G	=	gain

Grn = green
HADIG = half digit
HV = high voltage
HVPS = high voltage power supply
Hz = Hertz
I&Q = inphase and quadrature
ICWAR = improved continuous wave acquisition radar
IF = intermediate frequency
INT = interrupt
INTLK = interlock
I/O = input/output
Inv = invertor
Kg = kilograms
KHz = kilohertz
KMPS = kilometers per second
KVDC = kilovolts direct current
KW = kilowatt
LC = inductive capacitive
LO = local oscillator
LPI = low power illuminator
LSB = least significant bit
LSL = lower sweep limit
LSLSET = lower sweep limit set
LV = low voltage
LVPS = low voltage power supply
M = meter
MA = milliamp
MDS = minimum discernable signal
MHz = megahertz
Mil = miliradian
Min = minimum
MO = master oscillator
MOPA = master amplifier power amplifier
MTBF = mean time between failures
Mtr = meter
MUX = multiplexor
MW = milliwatt
NLT = not less than
NMT = not more than
OSC = oscillator
O/V = over voltage
PA = power amplifier
Pk-Pk = peak to peak
PLL phase locked loop
POLERR = polar error
P-P = peak to peak
PROM = programmable read only memory
PWR = power
Q = transconductance
R = resistor
Rad = radians
RAM = random access memory
RC = resistive capacitive
Ref = reference

Reg	=	regulator
RF	=	radio frequency
RMS	=	root mean squared
ROM	=	read only memory
RPM	=	revolutions per minute
RSG	=	radar set group
SCR	=	silicon controlled rectifier
SDP	=	signal data processor
Sec	=	second
SS	=	system status
Swp	=	sweep
Sync	=	synchronized
Tach	=	tachometer
Tzero	=	time zero
T 0	=	time zero
TP	=	test point
TTL	=	transistor transistor logic
TTY	=	teletype
Typ	=	typical
U	=	upper sweep limit
V	=	volt
VAC	=	volts alternating current
VCO	=	voltage controlled oscillator
VDC	=	volts direct current
VRMS	=	volts root mean squared
VSWR	=	voltage standing wave ratio
W	=	watts
WBDOPP	=	wideband doppler
WG	=	waveguide
XTAL	=	crystal
X,Y&Z	=	cross range, elevation and distance
Yel	=	yellow
ZADM	=	analog output module
ZAIM	=	analog input module
ZAOM	=	analog output module
ZCPU	=	central processing unit
ZDIS	=	display controller module
ZTIM	=	timing module

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