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Volume I

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LARK SP-1M RADAR EQUIPMENT

NRL PROTOTYPE FOR ANA/MPQ-5 AND ANA/SPQ-2 RADARS

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LARK SP-1M RADAR EQUIPMENT

NRL PROTOTYPE FOR ANA/MPQ-5 AND ANA/SPQ-2 RADARS

February 1950

Approved by:

W. C. Hodgson, Head, Control Systems Section
P. A. Waterman, Head, Equipment Research Branch
A. S. Locke, Division Consultant for Missile Guidance
Dr. R. M. Page, Superintendent, Radio Division III



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FOREWORD

When the Naval Research Laboratory undertook the development of a mobile ground facility for guidance and performance analysis of guided missiles, it was recognized that the basic elements of such a system could be uniformly applicable to several different types of guidance and to different types of missiles. The development of the Lark SP-1M guidance equipment has demonstrated that with appropriate objectives at the time of project inception, one apparatus can be built to serve successfully a multiplicity of guidance systems without compromising the apparatus for any one function and without significant complication beyond that required to perform any one function well. The resulting potentially wide application in the missile guidance field has given the equipment unusually high utility as a research tool.

The equipment bears the name "Lark" because its development was financed from Lark missile funds. Termination of Lark missile development does not decrease the usefulness of the guidance project to other missiles. In fact, much of the technology of missile guidance that originated in this project has already found its way into other missiles thereby losing its identity of origin. It is anticipated that the same process will continue with increasing benefit to the National effort on missile guidance as the Lark SP-1M equipment, and other equipments manufactured to its pattern, find sustained application in the study of missile guidance.

This report describes the Lark SP-1M and its development. When the project was initially undertaken a primary requirement for the equipment was that it be capable of providing the guidance intelligence necessary for beam rider flight of the Lark missile. This was to be accomplished without compromise of the search and fighter control capabilities of the SP Radar. In its present form, the Lark SP-1M Radar equipment is designed to serve as surface instrumentation for general purpose use in the control and evaluation of short range anti-aircraft guided missiles, having performance capabilities up to and including those of the V-2 rocket. It may be used for either beam-rider or command missile guidance; for the automatic tracking of target and/or missile; for the recording of control station and missile performance data; and for conventional fighter-direction and search operations. The equipment comprises two twelve-ton trailers which contain receiving, transmitting, communications, data recording and associated equipment; and auxiliary trailers that provide power and general service facilities.

Field evaluation of the Lark SP-1M Radar has been accomplished in conjunction with the flight test, in aircraft and missiles, of air-borne automatic missile guidance equipment. These tests have demonstrated consistently reliable performance of the Lark SP-1M equipment.

The Radar is the prototype of the ANA/MPQ-5 (mobile) and the ANA/SPQ-2 (shipborne) missile guiding radars currently being constructed commercially for service application.

The design, development, performance and physical description of the Lark SP-1M radar are contained in this two-volume report. Volume I principally includes theoretical materials, design considerations and procedures, the physical characteristics and performance of the major units, and installation and operation instructions. Volume II provides supplementary data, parts lists, cabling sheets, and schematic wiring diagrams.

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Mr. Peter Waterman, Head, Equipment Research Branch and Mr. A. S. Locke, Division Consultant and Project Chairman, directed the design, development, and evaluation of the Lark SP-1M radar system.

The following committee directed the planning, preparation, and review of this two-volume report: W. C. Hodgson (Chairman), G. Bailey, L. F. Gilchrist, M. S. McVay, K. G. Miles, E. W. Peterkin, J. W. Titus and C. F. White.

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Radio Division III, NRL

PROBLEM STATUS

This is an interim report on problems R05-04R and R05-16D.
Work continues on these problems.

AUTHORIZATION

NRL Problem R05-04R (NO 049-205)
NRL Problem R05-16D (NL 480-041)
(BuAer A-156)

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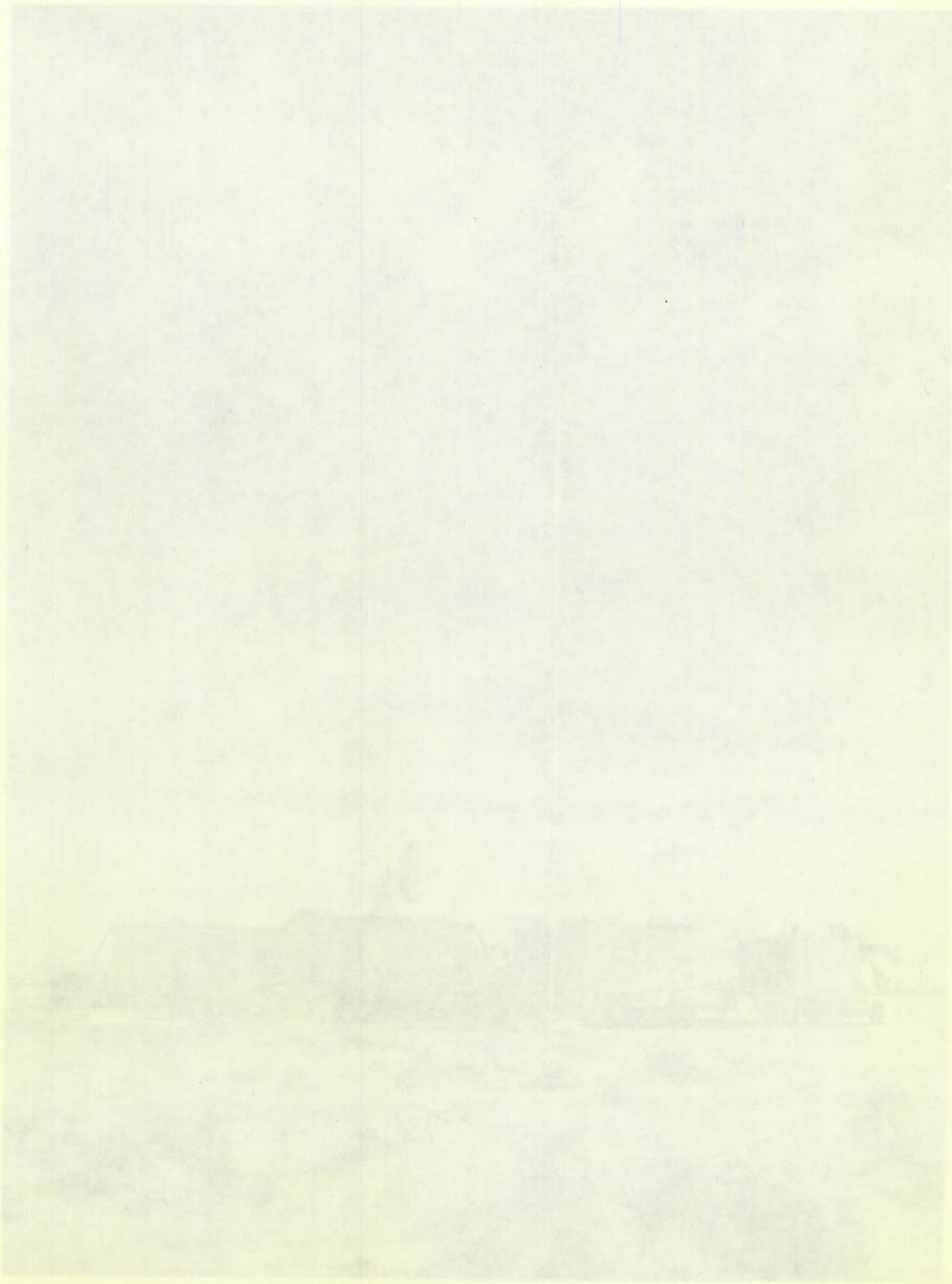
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Frontispiece. Lark 3P-1M Surface Control Station

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Frontispiece. Lark SP-1M Surface Control Station

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SECTION I

INTRODUCTION AND GENERAL DESCRIPTION

1. INTRODUCTION

a. General. - This report, published in two volumes, describes in Volume I the design, performance, and theory of operation of the Lark SP-1M Radar. Also included are general operating instructions and information relating to the construction and use of the equipment. Cabling, wiring, and parts and spare parts data including photographs showing parts locations are supplied as supplementary data in Volume II. The Lark SP-1M is an automatic target-tracking and missile-guiding surface radar. The radar was developed principally for beam-rider guidance of the Lark subsonic antiaircraft missile. However, the system may be used as a guidance control signal source for both beam-rider (Wasp) and command (Hornet) type systems. Engineering development of the radar system was accomplished by the Naval Research Laboratory under Problems A-156R-C (36R05-16D) sponsored by the Bureau of Aeronautics, O(A)-126R-S (36R05-05R), and O(A)-121R-S (36R05-04R) co-sponsored by the Bureaus of Aeronautics and Ordnance. Overall views of the Lark SP-1M equipment are shown in figures 1-1 and 1-2.

Problem 36R05-16D, Project Lark, requests the modification of an SP shipborne radar, and the development of a beam-rider receiver, to afford radar beam control of the Lark missile. Problem 36R05-05R, Project Wasp, requests the development and test of a system for control of a guided missile by means of a radar beam modulated at different frequencies in different lobes. The basic requirements of the Lark and Wasp projects are the same. Components developed under the Lark project are therefore being used to implement Project Wasp. Problem 36R05-04R, Project Hornet, requests the development and test of a system for command control of a guided missile by automatic transmission of control data by a fire control radar system. Hornet differs from Wasp in that Hornet requires radar tracking of both target and missile and the generation and transmission of guidance intelligence to the missile from the launching station.

The guidance system for the Lark missile will consist of a shipborne automatic tracking radar, which transmits information in the radar

beam suitable for interpretation by a missile flying in the beam so that the missile can fly under control to the target; a missile or missiles containing suitable control equipment to guide the missile along the tracking beam; and a homing and computing mechanism in the missile automatically functioning at a predetermined range from the target to transfer control of the missile flight from the surface radar to the homing radar. The homing radar guides the missile on a collision rather than a beam-riding course. To accomplish the objectives of this project, numerous investigations and tests are being conducted. These principally include: tactical considerations; spectrum analyses of frequencies contained in trajectories of interest; servo bandwidth requirements; propagation of electromagnetic waves through propellant gases; reflection, attenuation, and modulation of the control line; noise dispersion; receiver design and construction; missile flight stability; airframe response characteristics; autopilot and control response characteristics; and specifications for and studies related to alternate control systems. Procedures, techniques, and instrumentation have been developed for testing and evaluation of the system. The progress of these studies is detailed in the reports listed in the bibliography, paragraph 3. This report will treat in detail only the surface radar equipment.

Although specifically covering the Lark SP-1M, the material in this report applies in general also to the Lark SP, the AN/MPQ-5 and the AN/SPQ-2 Radars. The Lark SP is the shipborne counterpart of the vehicle-mounted Lark SP-1M built by the Naval Research Laboratory. The Bureau of Aeronautics has contracted with the Pilotless Plane Division of Fairchild Engine and Airplane Corporation for the construction of two vehicle-mounted AN/MPQ-5 Radars. The NRL-built Lark SP-1M is the prototype radar for the AN/MPQ-5. The Fairchild Corporation is manufacturing for the Bureau of Ships the shipborne AN/SPQ-2 Radar for which the NRL-built Lark SP is the prototype. The radars are all functionally identical, the principal differences being in the inclusion of correction for own ship's course, a stable element, and a third (cross level) antenna axis in the Lark SP and the AN/SPQ-2 Radars. These differences are described in detail in section IV of this report.

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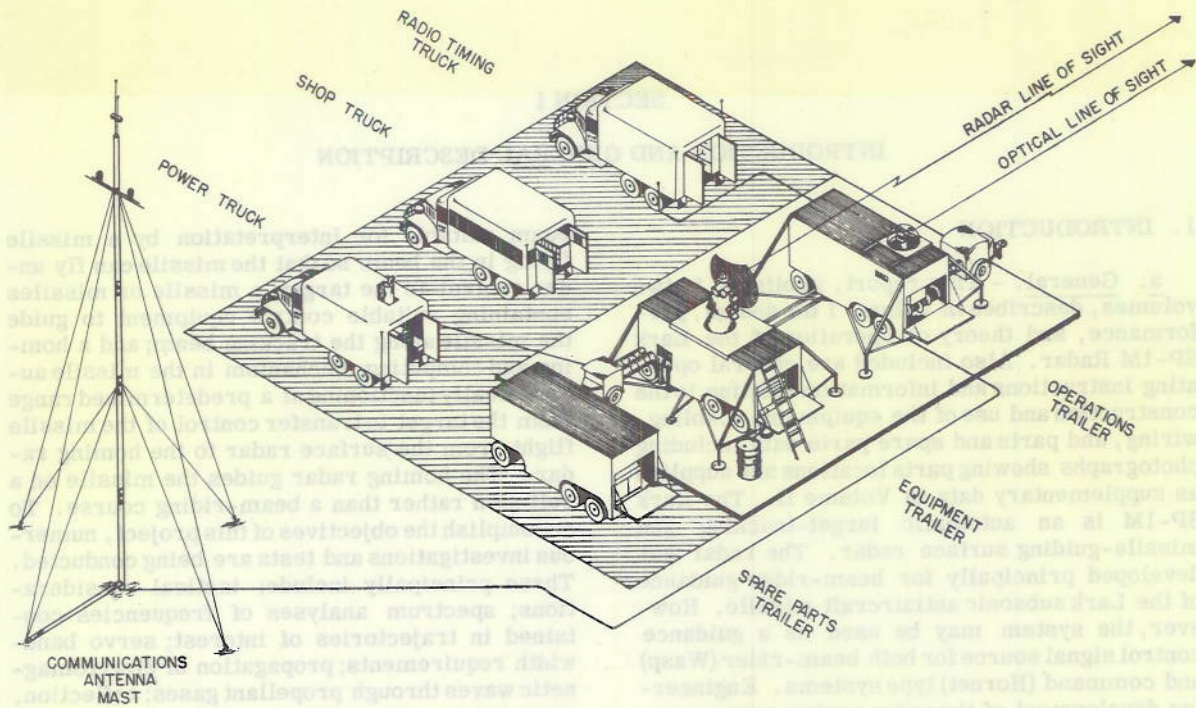


Figure 1-1. Lark SP-1M Field Arrangement

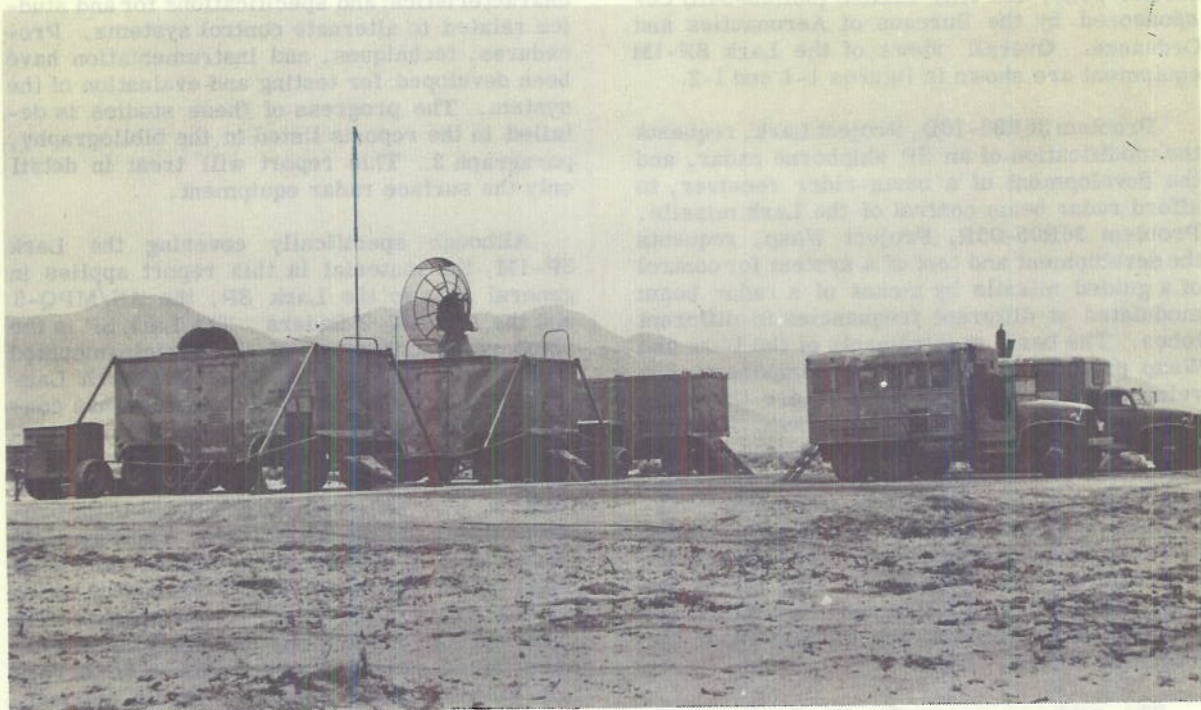


Figure 1-2. Lark SP-1M Equipment at N.O.T.S. Inyokern

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b. Initial Lark Guidance Specifications. - Bureau of Aeronautics specifications require that control of the missile be effective over a range of 90,000 yards and to an altitude of at least 40,000 feet. The Lark missile is intended to attack an approaching enemy aircraft capable of making a speed of 300 knots and capable of executing 3g turns. Two versions of the missile are under development: XSAM-N-2 Lark (KAQ-1), designed and manufactured by the Fairchild Pilotless Plane Division; and XSAM-N-4 Lark (KAY-1), designed and manufactured by the Consolidated-Vultee Aircraft Co. The target is assumed to have a minimum radar area of three square meters.

The requirements indicated above place certain restrictions upon the performance of the surface radar to be used. Moreover the initial time limitation suggested modification of an existing radar, rather than the design and construction of a new one. The radar must be capable of detecting and automatically tracking a target to 45 nautical miles in range. It must be provided with stabilization against roll and pitch, and with facilities for transmitting coordinate information to the missile using the regular radar transmitter. A further restriction is that the normal functions of the radar should not be adversely affected by the new application. A study of existing shipborne radars indicated that the SP fighter direction and search radar would give the desired detection range; that provision for stabilization had been incorporated in the mount; that this radar was installed on naval carrier vessels; and that it was practicable to modify the SP so as to provide the required automatic tracking and missile guidance functions without sacrifice of any of the original functions of the radar. Another factor favoring the selection of the SP was the existence of the SP-1M mobile counterpart which could be modified for field test application. For these reasons, although the required modifications were extensive, the SP and SP-1M radars were selected for use in the Lark program.

c. Design Considerations. - The performance requirements for the ground radar, listed in the preceding paragraph, have been expanded in the actual design of the Lark SP-1M radar to permit broader application of the equipment than the problem specifications require. Because the development of missile guidance equipment by the Department of Defense is progressing rapidly, it was considered that the design of a guidance system for the Lark missile should anticipate some of the future requirements of an operational anti-aircraft missile guidance system. It would be desirable, for example, that the SP and SP-1M equipments be modified so as

to be adaptable for command as well as for beam-riding guidance. Such an extension in usefulness of the equipment would mainly require provision for automatic tracking of the missile as well as of the target. Missile tracking was further desirable so that data on missile range and position with respect to radar line of sight could be obtained and recorded. The need for measurement of target and missile positions and rates and of the time relation between data recorded at the Lark SP-1M and that recorded by other field test activities, and the need for a record of the mode of operation being applied at various times and of communications between the operators of all ground equipment, have made it desirable to include a complete data taking and recording section. Optical tracking of target or missile, with provision for control of antenna position from an optical tracking stand, was also considered desirable. A computer that would generate simulated target courses and rates, thus permitting displacement of the radar antenna as a function of theoretical target motion, would be useful in field test operations, as a substitute for real targets and to permit repetition of identical runs for comparison purposes. It was believed also that it would be feasible and desirable to design the radar for broader and more stringent tactical application than was prescribed by the initial problem specification. Performance of the tracking servos is now predicated upon supersonic target and missile speeds. Minimum radar performance requirements for angle tracking were determined by expected tactical target maneuvers. Minimum requirements for range tracking were determined by expected tactical missile velocity capabilities, since the missile will normally be moving directly away from the tracking radar, and be capable of greater speed than the target. Since naval carrier vessels already are equipped with the SP radar, an important design consideration was to minimize the difficulty of modifying these equipments for automatic tracking and missile guidance with the components developed in connection with this redesign. This consideration made it desirable that the chassis of the two systems be as nearly interchangeable as possible and that cabling and other changes, to convert an SP radar into a Lark SP, be minimized.

Many of the physical components of the original SP and SP-1M equipments were unsuitable for the missile guidance purposes. The original systems used a spark gap modulator for keying the transmitter. This modulator was unsuitable for pulse-time modulation for missile reference use and was replaced with a hydrogen thyratron modulator. The original SP-1M antenna mount was found to be statically unbalanced and was modified. The SP-1M equipment trailer, which

was not sufficiently rigid, was further stabilized. The original nutator (scanner) was replaced with a redesigned nutator taken from an SCR-615B radar equipment. Antenna polarization was changed from horizontal to vertical to take advantage of the resulting reduced direct surface reflection (an important factor in using the radar for control) and to simplify the design of the missile antennas. The beam crossover (two way) was changed from its original 0.45 db down to approximately three db down with a two-degree squint angle. This crossover point had been determined as optimum by a theoretical analysis. (See this section, paragraph 3.) The Lark missile has an effective radar cross section of about 0.07 square meters area at tail aspect. For command guidance, and for field test of beam- rider guidance, it is desirable to track the missile out to its maximum range. It is therefore necessary that the missile carry a beacon. The beacon is operated at a frequency slightly different from the S-band SP transmission frequency so that a missile beacon receiver is provided. In addition, a missile range unit and

coordinate detector are required to allow simultaneous tracking of both the target echo and the missile beacon signals.

Modifications of the SP and SP-1M have been extensive. The operational usefulness of the radars as search and fighter director equipments has not been compromised by the inclusion in their signal transmission of the intelligence required for missile guidance. On the contrary, the original radars have been appreciably improved by the addition of automatic tracking circuits and the redesign and addition of improved radar and servo circuitry. The system, as now constituted, not only supplies missile guidance intelligence to an airborne receiver, but also provides instrumentation for the recording of data useful to the analysis of missile flight performance and of guidance control.

Table 1-1 summarizes the minimum design requirements for the Lark SP-1M Radar. The requirements for the Lark SP are identical except for the inclusion of stabilization quantities.

TABLE 1-1
MINIMUM PERFORMANCE AND REQUIREMENTS

Function	Lark SP-1M
CONTROL OF EQUIPMENT	Complete control from radar console
TRANSMITTER	
Peak Power	700 kw
Pulse Repetition Rate	Controllable 350-850 pps (nominal 576 pps)
Pulse Length	1 microsecond
ANTENNA	
Gain	2900 x
Beam Width	3°
First Side-Lobe (two way)	21 db down
Squint Angle	2°
Crossover (two way)	3 db down
Dish Diameter	8 feet
Search Scan	6 revolutions per minute
Nutator Scan	24 cycles per second
RECEIVER (TARGET AND MISSILE)	
Noise Factor	Less than 15 db
Gain (i-f stages)	140 db

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TABLE 1-1

MINIMUM PERFORMANCE AND REQUIREMENTS (Continued)

Function	Lark SP-1M	Lark SP-1M	Function
RECEIVER (TARGET AND MISSILE) (Continued)			
Bandwidth		2.2 Mc	
AGC		7 stages	
I-f Gating		Provided	
AFC (Missile)		Provided	
AFC (Target)		Provided	
RANGE UNITS (TARGET AND MISSILE)			
Maximum		Dials calibrated to 100,000 yds	
Minimum		300 yds	
Accuracy of Timing Circuit		± 10 yds (with calibration ± 5 yds)	
Automatic Range Following		Max. error + 5 yds outgoing 750 yds/sec ² (3000 knots steady state error 5 yds)	
Handcrank Gear Ratio		250 yds/rev	
Position Slew Rate		10,000 yds/sec	
Max. Range Rate for Tracking		4500 knots	
Range Synchro Transmission		1000 yds/rev and 100,000 yds/rev (alternate speeds require gear substitution)	
Bandwidth		Selectable, 12 or 1.2 radians/sec	
OPTICAL TRACKING STAND (TARGET ACQUISITION AND OPTICAL MONITORING STATION)			
Number of Axes		Two	
Error for Bearing and Elevation Input		0.1° at $10^\circ/\text{sec}$ ($\epsilon = \frac{\dot{\theta}}{100}$)	
Field of View		± 3°	
Position, Rate, and Slew Control of Antenna Mount		Bearing and elevation	
Position Control		3° per handwheel revolution (no zero freq. stiffness)	
PPI UNIT			
Sweep Ranges		(4, 20, 50, 100, and 200 miles)	
Sweep Markers		(1, 5, 10, 20, and 50 miles)	
Hand-crank Following Error		$\epsilon = \frac{\dot{\theta}}{24}$	
ANTENNA PEDESTAL			
Mount Position Synchro Transmission		(Train - 1 speed and 36 speed; Elevation - 2 speed and 36 speed)	
Slew Velocity-Elevation and Bearing		36°/sec	
Tracking Accuracy (Automatic in Elevation)		$\epsilon = \frac{\dot{\theta}_{in}}{100} + \frac{\ddot{\theta}_{in}}{10}$ (approx) independent of elevation angle	

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TABLE 1-1

MINIMUM PERFORMANCE AND REQUIREMENTS (Continued)

Function	Lark SP-1M	Lark SP-1M	Function
ANTENNA PEDESTAL (Continued)			
Tracking Accuracy (Automatic in Horizontal Plane)		$\epsilon = \left(\frac{\dot{\theta}_{in}}{100} + \frac{\ddot{\theta}_{in}}{10} \right) \cdot (\secant \text{ of elevation angle})$	approx
Tracking Bandwidth (Automatic in Horizontal Plane)		3.3 rad/sec	
Radial rms Error (Small Targets)		1 mil	
DATA RECORDING UNIT			
Synchro Following Error		Static $\pm 0.2^\circ$	
Missile and Target "R" scope		Provided	
Sound Recorder		Provided	
POWER SOURCES AND REQUIREMENTS			
		Either self-contained or external 110v, 3-phase, 60-cycle 10.38 kva to 20 kva	
COMMUNICATIONS EQUIPMENT			
		VHF, MHF, phone intercom	
HEIGHT FINDING (TARGET)			
		Provision for	
VENTILATION, HEATING, AND COOLING			
Blowers		Where required	
Refrigerating Units		2 external 2-ton units	
Heating Units		Provision for	
SPARE PARTS			
		100% of essential parts	
OPERATING PERSONNEL			
		Maximum 5, Minimum 2	
TEST EQUIPMENT			
		Supplied where necessary	
MODES OF OPERATION			
		Automatic (in 3 coordinates for target or missile); Manual (at console and at telescope); Computer (target motion simulator)	

2. BRIEF DESCRIPTION

a. General. - The Lark SP-1M radar beam is conically scanned at 24 cycles per second. For beam rider guidance purposes, the beam

may be pulse-time modulated at the scanning frequency. For command guidance the beam may be modulated by signals derived from pitch and yaw missile errors measured at the radar. Guidance intelligence needed to maintain the

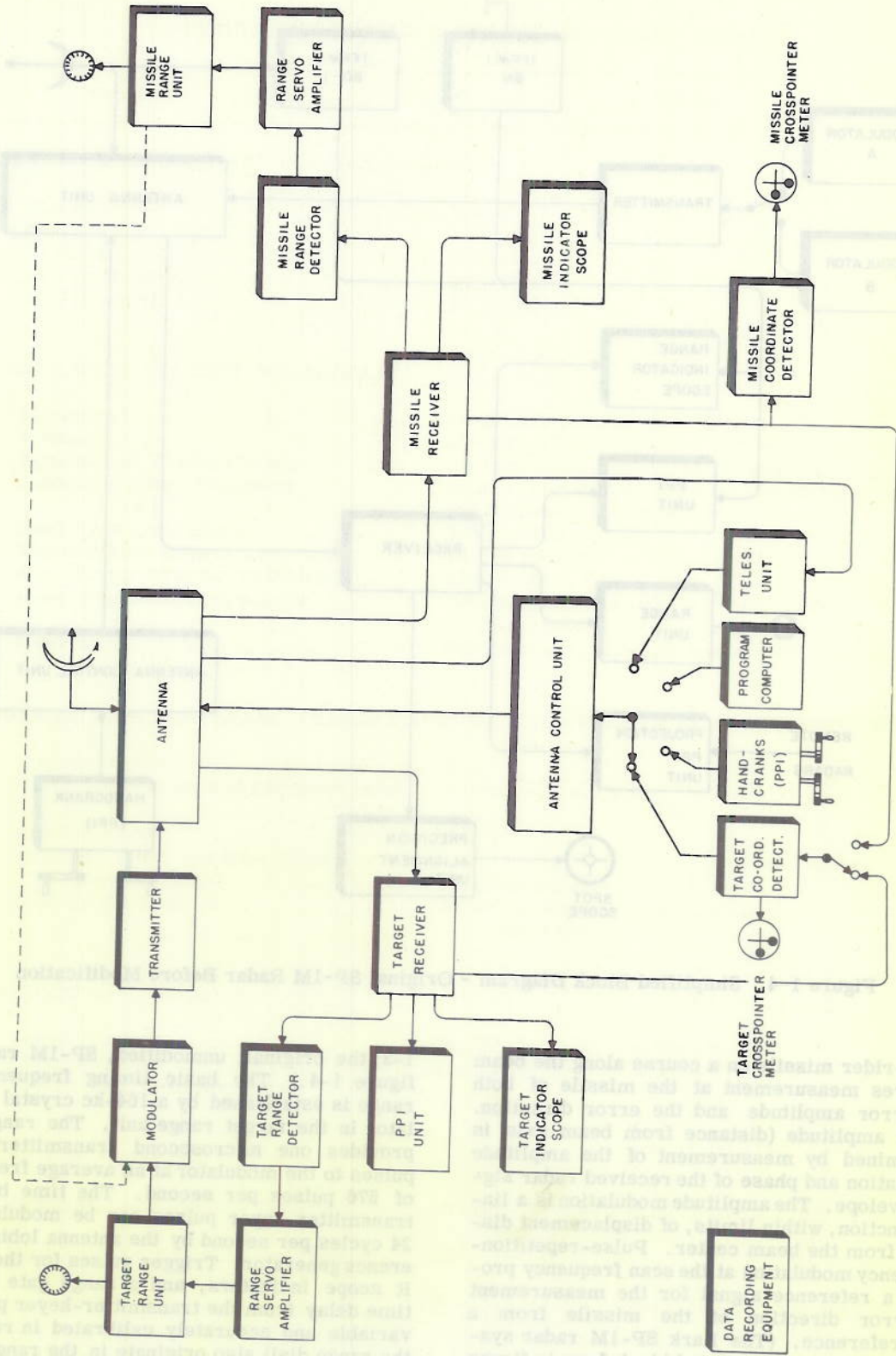


Figure 1-3. Simplified Block Diagram - Lark SP-1M Radar

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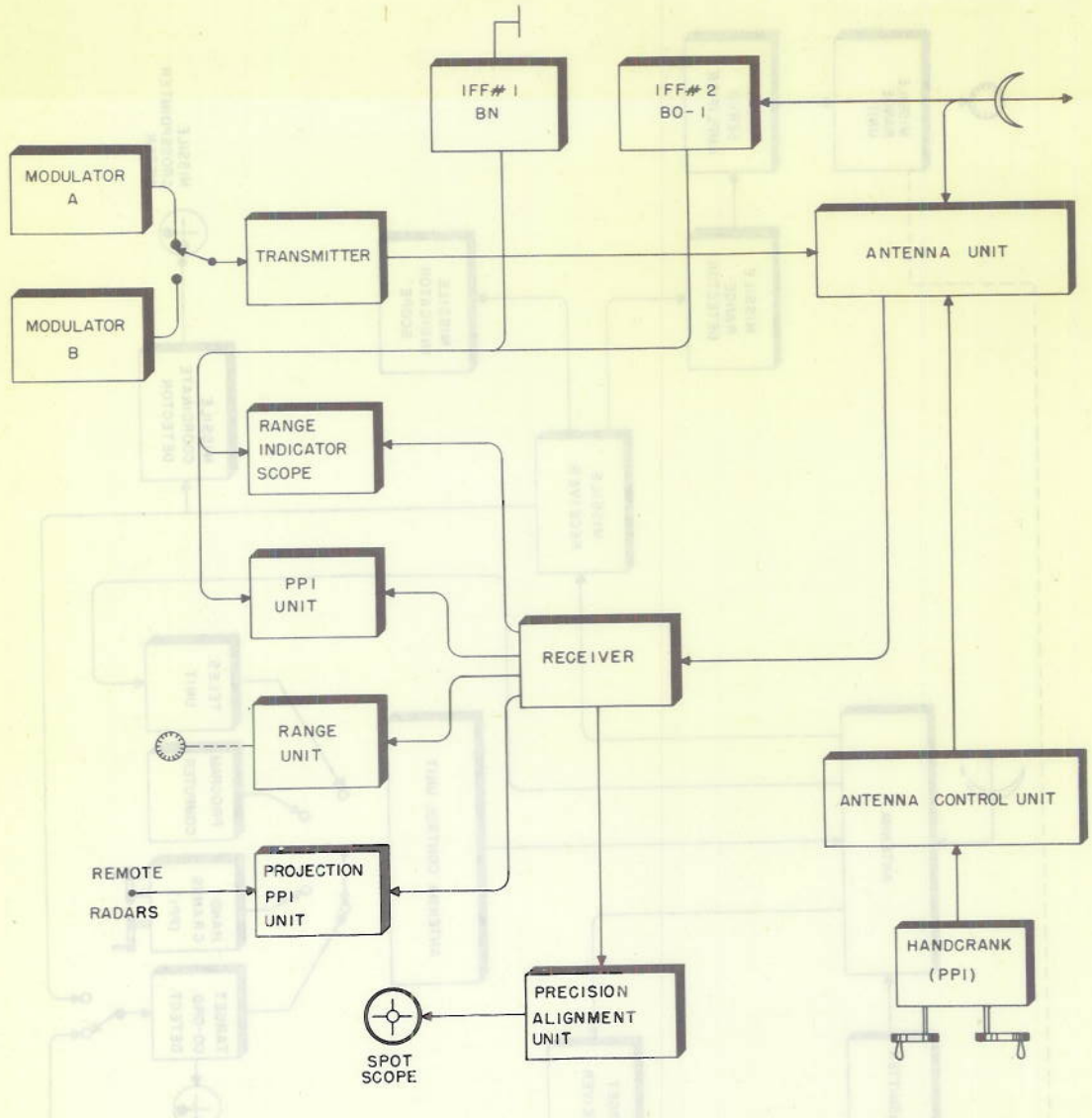


Figure 1-4. Simplified Block Diagram - Original SP-1M Radar Before Modification

beam-rider missile on a course along the beam requires measurement at the missile of both the error amplitude and the error direction. Error amplitude (distance from beam axis) is determined by measurement of the amplitude modulation and phase of the received radar signal envelope. The amplitude modulation is a linear function, within limits, of displacement distance from the beam center. Pulse-repetition-frequency modulation at the scan frequency provides a reference signal for the measurement of error direction of the missile from a zero reference. (The Lark SP-1M radar system is shown in abbreviated block form in figure

1-3; the original, unmodified, SP-1M radar in figure 1-4.) The basic timing frequency for range is established by a 164-kc crystal oscillator in the target range unit. The range unit provides one microsecond transmitter-keyer pulses to the modulator at an average frequency of 576 pulses per second. The time between transmitter-keyer pulses can be modulated at 24 cycles per second by the antenna lobing reference generator. Trigger pulses for the A and R scope indicators, and a range gate (whose time delay from the transmitter-keyer pulse is variable and accurately calibrated in range on the range dial) also originate in the range unit.

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The transmitter-keyer pulse triggers the hydrogen thyratron modulator which in turn keys the magnetron at approximately 576 pps. The r-f energy is transmitted through wave-guide, TR circuits, ATR circuits, and to the antenna which is nutated at 24 cycles. Energy reflected from the target impinges on the antenna, passes to the target receiver where it is amplified and demodulated to give video pulses. The pulses are separated into two channels, gated and ungated video. The ungated video serves to present all objects within the antenna beamwidth on the PPI scope and the target A and R scopes. The gated video contains only those echo pulses which occur at the same time as the range gate. The gated video pulses are supplied to the range and coordinate detectors which produce error signals for driving the range, train, and elevation servos and for operating the cross-pointer meters. Since the frequency of the beacon reply signal from the missile differs from the radar frequency by approximately 55 to 105 megacycles, the beacon signals are not received by the target receiver. Consequently, a separate beacon local oscillator and receiver channel is provided to convert the beacon signal to the 30-megacycle intermediate frequency. The signal passes through i-f and video channels which are identical to those in the target receiver. Ungated video is displayed on the missile A and R scopes while gated video is again supplied to

range and coordinate detectors. The missile range and coordinate detectors are identical to those in the target channel. The train and elevation error signals from the coordinate detectors are used to operate cross-pointer meters or, depending on the mode of operation, may be used to control the antenna for automatic tracking of the missile. The range error signal operates the range servo system of the missile range unit. The output of either the missile or the target receiver may be used to control the antenna. The target and missile ranging systems are identical, except for the inclusion of a height finding potentiometer in the target range unit. Normally the target range unit supplies the 164-kc timing signal to the missile range unit, and the transmitter keyer pulse output from the missile range unit is not used.

b. Major Units. - The major units of the Lark SP-1M radar equipment (figures 1-1 and 1-2) are listed in table 1-2 and each is briefly described in the following subparagraphs. Principal dimensions of the mobile units are given in table 1-3. The NRL unit number (column one) in table 1-2 indicates the first digits of the numerical series of reference symbols used for component designation in that unit; for example, R3301 would be a resistor in the D-c Servo Amplifier Unit, Unit 3300. The test equipment supplied is listed in table 1-4.

TABLE 1-2

MAJOR UNITS

NRL Unit No.	Name of Unit	Location*	Army-Navy Designation
100T	Target Receiver Unit	OT	
100M	Missile Receiver Unit	OT	
300M	Missile Range Unit	OT	
300T	Target Range Unit	OT	
500	Main Power Unit	OT	CG-20ACQ (Navy, Modified)
600	Synchronizer and Missile Coordinate Detector Unit	OT	
700	Auxiliary Power Unit	OT	
800	PPI Unit	OT	
900	High Voltage Power Unit	OT	CDY-20 ACP (Navy, Modified)
1000T	Target Indicator Unit	OT	
1000M	Missile Indicator Unit	OT	
1200	Target and Manual Coordinate Detector Unit	OT	
1300	Target and Missile Range Detector and Servo Amplifier Unit	OT	
1400	Power Control Unit	OT	
1500	System Control Switching Unit	OT	

*ET = Equipment Trailer OT = Operations Trailer

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TABLE 1-2

MAJOR UNITS (Continued)

NRL Unit No.	Name of Unit	Location*	Army-Navy Designation
1600	Handcrank Servo Amplifier Unit and Telescope Servo Preamplifier Unit	OT	
1700	Target Local Oscillator Preamplifier Unit	ET	
1800	Telescope Final Amplifier Unit and Telescope Amplifier Power Unit	OT	
2000	Transmitter	ET	
2300	Hydrogen Thyatron Modulator Unit	ET	
2400	D-c Motor Generator and Power Filter	ET	
2500	Modulator Induction Regulator Unit	ET	
2600	Handcrank Isolation Relay Unit	OT	
2700	Reference Voltage Distribution Unit	OT	
2800	Missile Cross-pointer Meter Unit	OT	
2900	D-c Voltage Regulator	OT	
3000	Antenna Unit	ET	
3200	Antenna Control Unit	ET	
3300	D-c Servo Amplifier Unit	ET	
3400	D-c Servo Amplifier Power Unit	ET	
3500	D-c Servo Equalizer Unit	ET	
3600	Synchro Capacitor Unit	ET	
3800	Simulated Target Programmer	OT	
4200	Missile Oscillator Preamplifier Power Supply	ET	
4300	Missile Oscillator Preamplifier Unit	ET	
4400	Standing Wave Amplifier	ET	
4700	Echo Box	ET	
4900	Power Distribution Panel	ET	
5000	15-kw Gasoline Engine Alternator	ET	
5100	Cable Panel, Equipment Trailer	ET	
5150	Cable Panel, Operations Trailer	OT	
5300	Power Unit PE137		
5400	Dehumidifier Units		CAJH-10306 (Navy, Modified)
6200	Keep-alive Power Supply	ET	
6300	D-c Relay Box	ET	
7100	Equipment Trailer	ET	CAHU-10301 (Navy, Modified)
7200	Operations Trailer	OT	CAHU-10302 (Navy, Modified)
7300	Spare Parts Trailer		CAHU-10305 (Navy, Modified)
8100	Dial Box Unit	OT	
8200	Camera Control Unit	OT	
8400	Time Comparator Unit	OT	
8500	Remote Range Indicator Unit	OT	
8600	Commutator Unit	OT	
9100	Telescope Unit	OT	
	Sound Recorder	OT	Model B-AVE
4850	Radio Equipment (Communications) VHF	OT	Model TCS-12 (Navy)
4850	Radio Equipment (Communications) VHF (4 channels)	OT	Model SCR-624A (Army)
4850	Telephone Switchboard	OT	Model BD-72B (Army)

*ET = Equipment Trailer OT = Operations Trailer

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TABLE 1-3

OVERALL DIMENSIONS AND WEIGHTS OF MOBILE EQUIPMENT

Name of Unit	Length	Width	Height	Weight (Approx)
Equipment Trailer	20'	8'	10' 6"	12 tons
Operations Trailer	20'	8'	11' 2"	12 tons
Power Truck	13' 6"	7' 6"	9'	8 tons
Machine Shop Truck	13' 6"	7' 6"	9'	8 tons
No. 1 Dehumidifier Trailer	7' 8"	6' 2"	5' 2"	1 ton
No. 2 Dehumidifier Trailer	7' 8"	6' 2"	5' 2"	1 ton
Spare Parts Trailer	20'	7' 11"	10' 3"	12 tons

TABLE 1-4

TEST EQUIPMENT

Type Designation	Name of Unit	Instruction Book	Supplier
TS-155B/UP	UHF Signal Generator Equipment	TM 11-2657B	Boonton Radio Corp.
256D (Dumont) CPF60057 (Navy)	Oscilloscope Portable Vacuum Tube Tester	----	Dumont Precision Apparatus Co.
IE-36 (Army)	Test Equipment (for SCR-624)	AN 08-401E36-2	Bendix Radio Corp.
----- CTO 600-77 (Navy)	Junior Voltohmyst Volt-ohm-milliammeter	----- NavAer 08-508-6 May 1944	Radio Corp. of America Triplett Elec. Inst. Co.
-----	Sixteenth Harmonic Frequency Multiplier	-----	NRL
-----	Range Unit Bridge Adjuster	-----	NRL
FG9	Frequency Standard Unit	-----	Reeves-Hoffman
-----	Nutator Phasing Unit (Strobolux and Keyer)	-----	NRL
Mk 2 Mod 3 224A (Dumont)	Synchro Test Unit	-----	Ford Inst. Co.
-----	Oscilloscope	-----	Dumont
-----	A-c Voltmeter	-----	Ballantine
65A (Hewlett- Packard)	High Frequency Signal Generator	-----	Hewlett-Packard
-----	Recorder	-----	Brush

1). Equipment Trailer, Unit 7100. (See figures 1-5 and 1-6.) - The Lark SP-1M Equipment Trailer, Unit 7100, is a modified Navy Type CAHU-10301 trailer. Figure 1-6 is a

cutaway perspective drawing of the Equipment Trailer. This trailer principally contains equipment associated with the transmission of the radar signal and with the antenna servo drive sys-

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TABLE 1-3
OVERALL DIMENSIONS AND WEIGHTS OF MOBILE EQUIPMENT

Name	Length	Width	Height	Weight (Approx)
Equipment Trailer, Unit 7100 (See Figures 1-6 and 1-6)	30'	8'	8'	12 tons
Equipment Trailer, Unit 7100 (See Figure 1-6)	30'	8'	8'	12 tons
Equipment Trailer, Unit 7100 (See Figure 1-6)	30'	8'	8'	12 tons
Equipment Trailer, Unit 7100 (See Figure 1-6)	30'	8'	8'	12 tons
Equipment Trailer, Unit 7100 (See Figure 1-6)	30'	8'	8'	12 tons
Equipment Trailer, Unit 7100 (See Figure 1-6)	30'	8'	8'	12 tons
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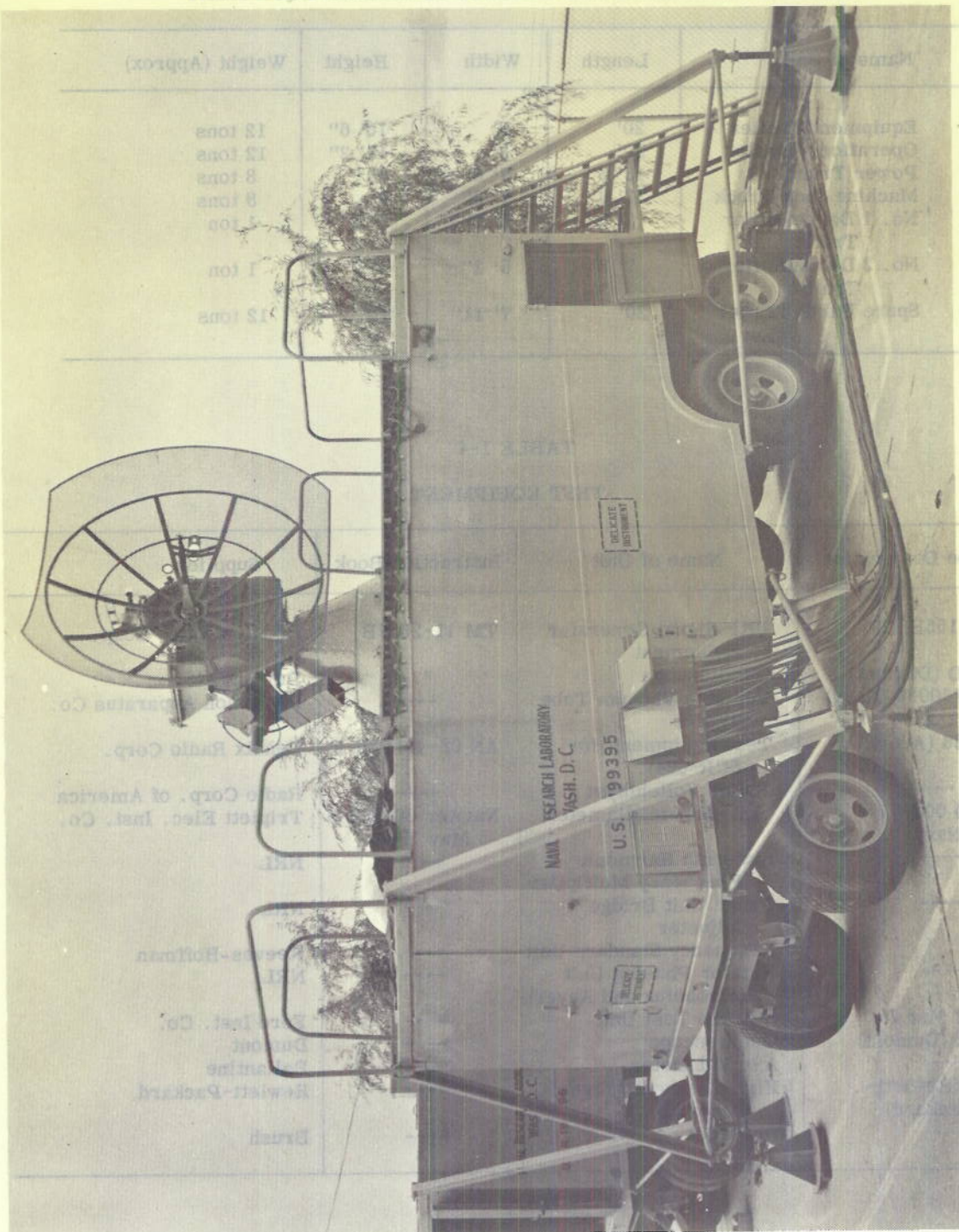


Figure 1-5. Equipment Trailer - Exterior

1. Equipment Trailer, Unit 7100 (See Figures 1-6 and 1-6) - The Lark 8F-1M Equipment Trailer, Unit 7100, is a modified Navy Type CAHU-10301 trailer. Figure 1-6 is a cutaway perspective drawing of the Equipment Trailer. This trailer principally contains equipment associated with the transmission of the radar signal and with the antenna servo drive system.

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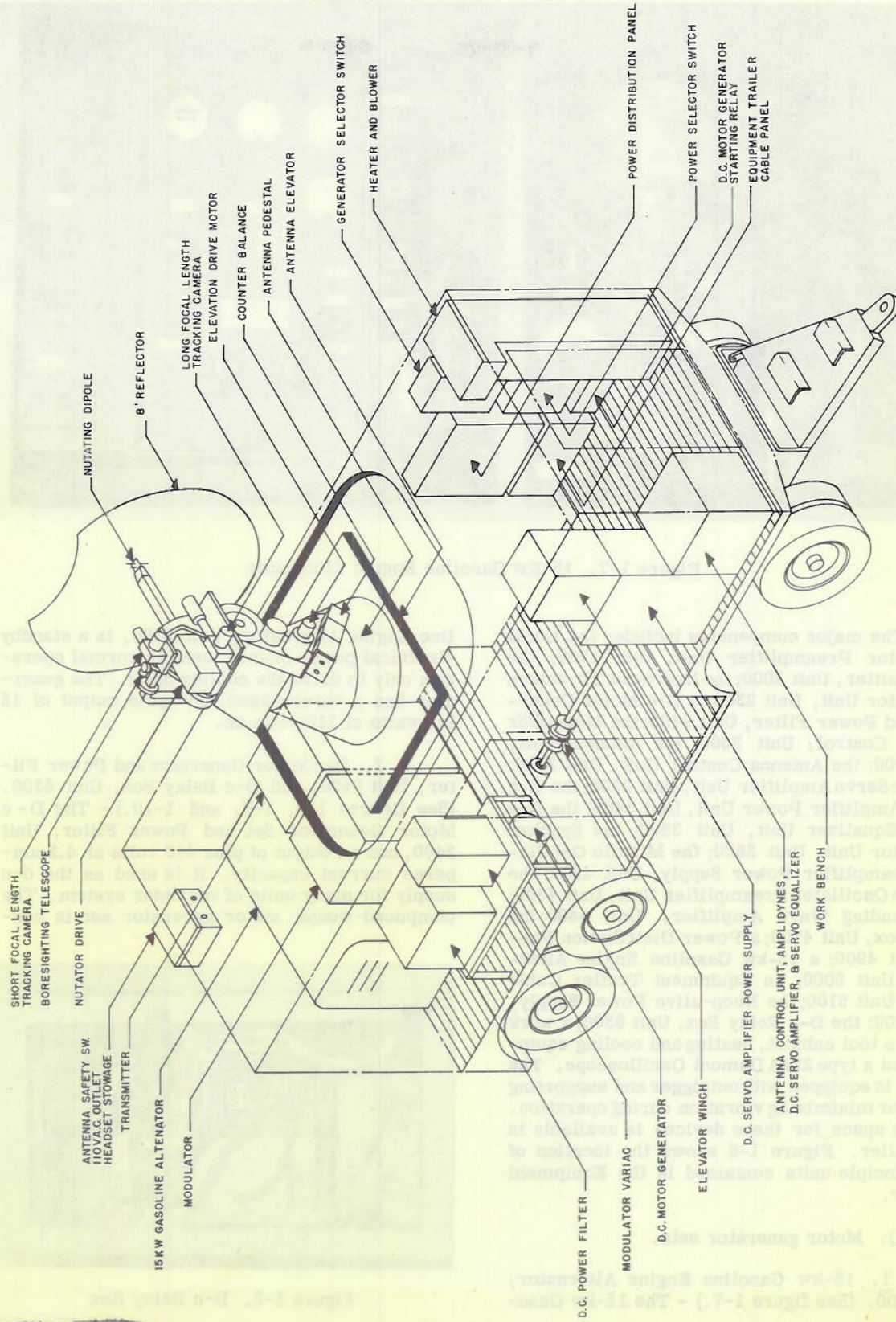


Figure 1-6. Equipment Trailer - Location of Equipment

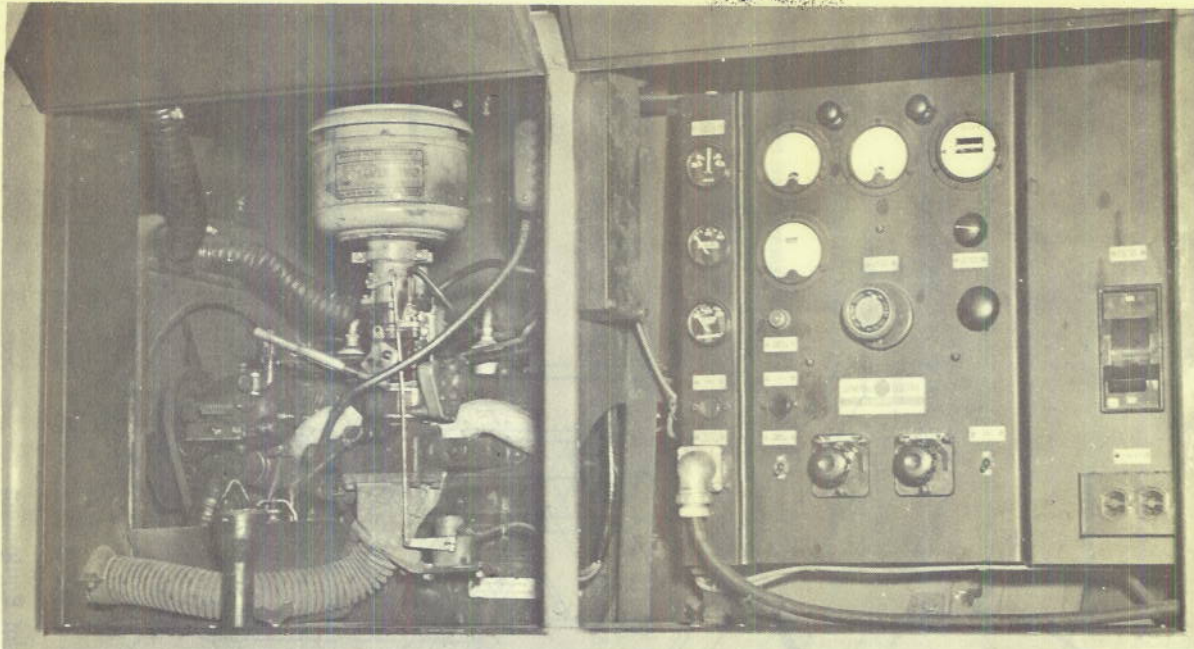


Figure 1-7. 15-Kw Gasoline Engine Alternator

tem. The major components include: the Local Oscillator Preamplifier Unit, Unit 1700; the Transmitter, Unit 2000; the Hydrogen Thyatron Modulator Unit, Unit 2300; a D-c Motor Generator and Power Filter, Unit 2400; the Modulator Variac Control, Unit 2500; the Antenna Unit, Unit 3000; the Antenna Control Unit, Unit 3200; the D-c Servo Amplifier Unit, Unit 3300; the D-c Servo Amplifier Power Unit, Unit 3400; the D-c Servo Equalizer Unit, Unit 3500; the Synchro Capacitor Unit, Unit 3600; the Missile Oscillator Preamplifier Power Supply, Unit 4200; the Missile Oscillator Preamplifier Unit, Unit 4300; the Standing Wave Amplifier, Unit 4400; the Echo Box, Unit 4700; a Power Distribution Panel, Unit 4900; a 15-kw Gasoline Engine Alternator, Unit 5000; an Equipment Trailer Cable Panel, Unit 5100; the Keep-alive Power Supply, Unit 6200; the D-c Relay Box, Unit 6300; a work bench, a tool cabinet, heating and cooling equipment and a type 224A Dumont Oscilloscope. The trailer is equipped with outrigger and supporting jacks for minimizing vibration during operation. Storage space for these devices is available in the trailer. Figure 1-6 shows the location of the principle units contained in the Equipment Trailer.

a). Motor generator sets.

1. 15-kw Gasoline Engine Alternator, Unit 5000. (See figure 1-7.) - The 15-kw Gaso-

line Engine Alternator, Unit 5000, is a standby electrical power source, used in normal operation only to drive the cooling units. The generator has a three-phase, 60-cycle output of 15 kilowatts at 110 volts ac.

2. D-c Motor Generator and Power Filter, Unit 2400, and D-c Relay Box, Unit 6300. (See figures 1-8, 1-9, and 1-10.) - The D-c Motor Generator Set and Power Filter, Unit 2400, has an output of plus 440 volts at 4.2 amperes current capacity. It is used as the d-c supply for many units of the radar system. The compound-wound motor generator set is con-

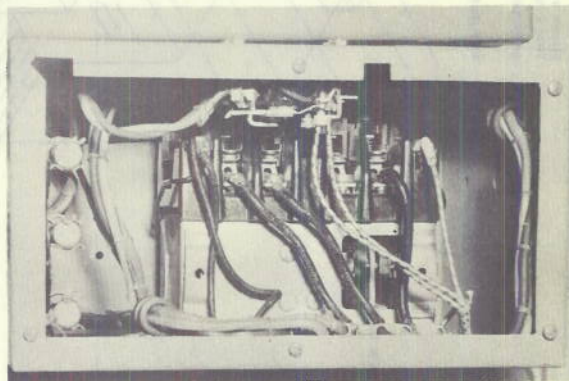


Figure 1-8. D-c Relay Box

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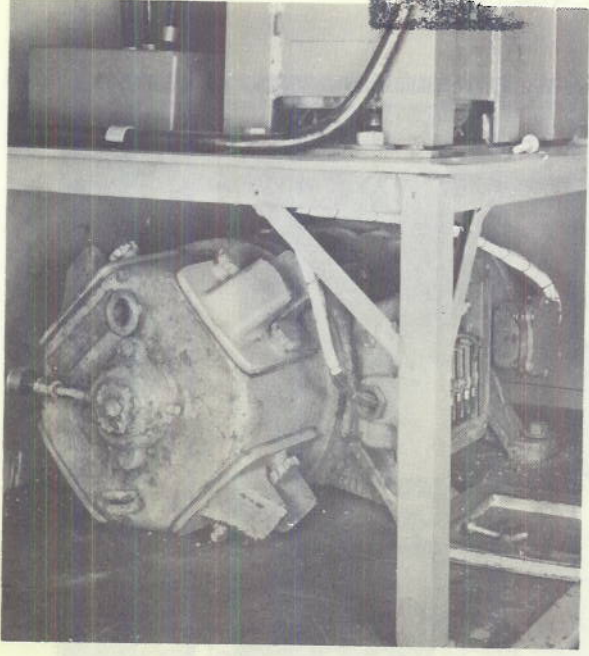


Figure 1-9. D-c Motor Generator

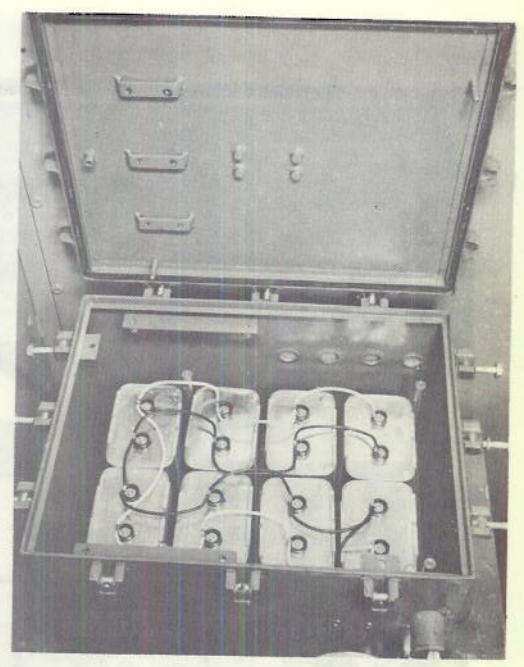


Figure 1-10. Power Filter Capacitors

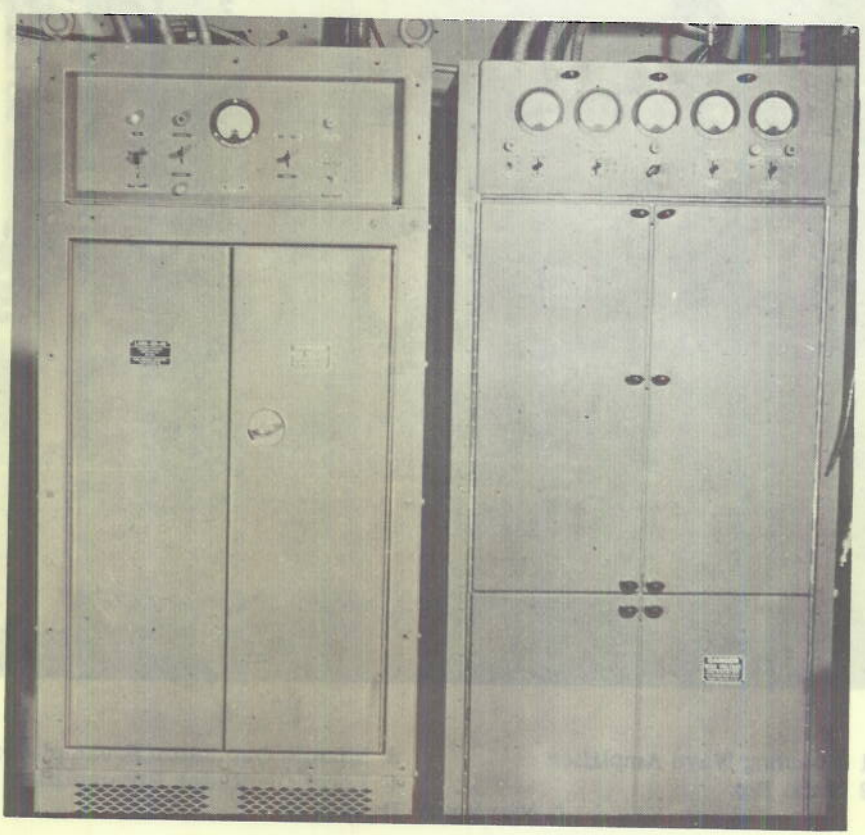
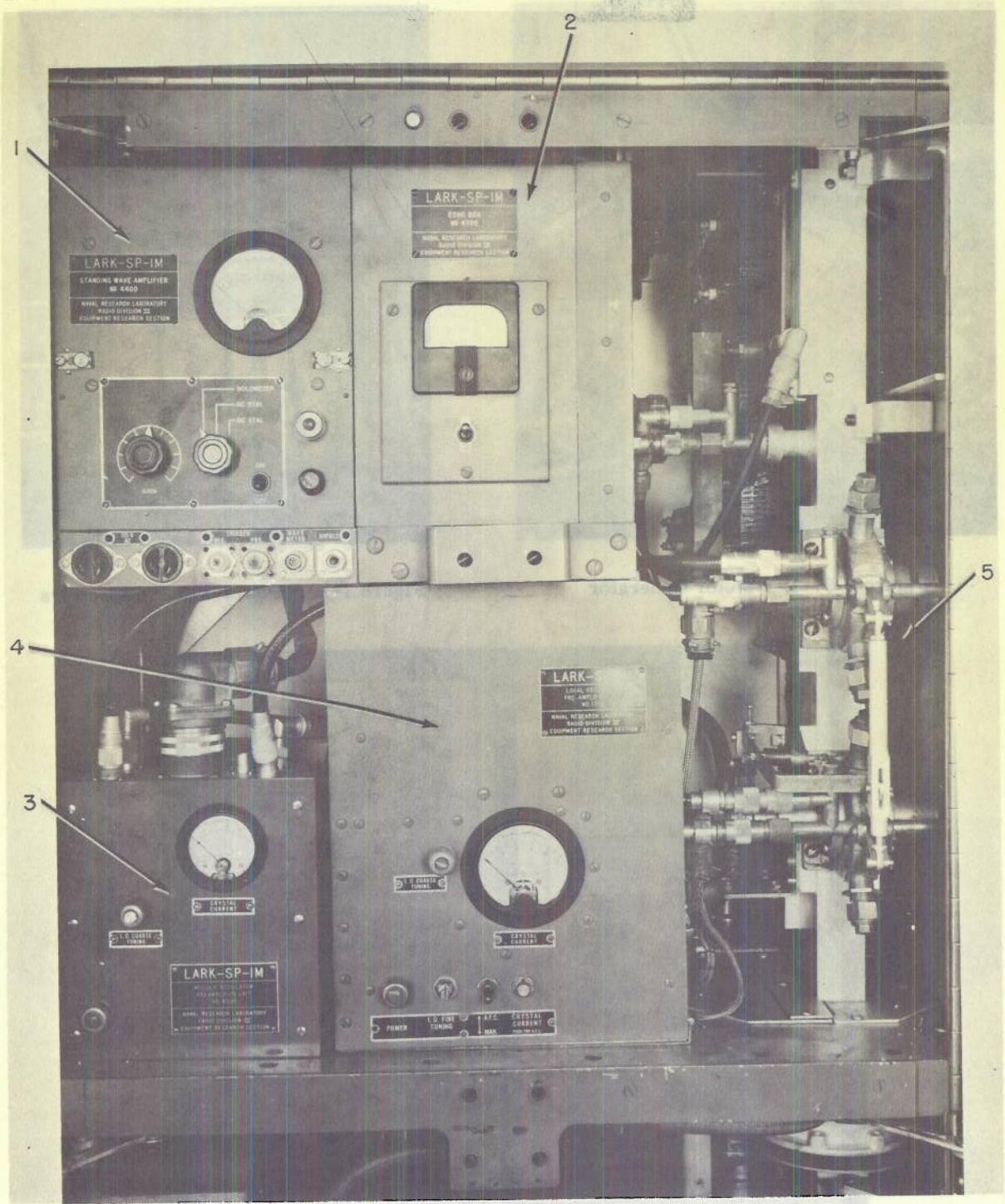


Figure 1-11. Hydrogen Thyatron Modulator (Left) and Transmitter

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- 1 Standing Wave Amplifier
- 2 Echo Box
- 3 Missile Oscillator Preamplifier
- 4 Local Oscillator Preamplifier
- 5 Waveguide Duplexers

Figure 1-12. Components in Transmitter Cabinet

trolled from a Relay Box Unit 6300, which contains the required relays for starting, running, and stopping the unit. A power filter is provided to remove brush and other noise in the motor generator output. This unit contains about 200 microfarads of capacitor filtering.

b). Transmitter section. (See figure 1-11.)

1. Missile Oscillator Preamplifier Power Supply, Unit 4200. - The Missile Oscillator Preamplifier Power Supply, Unit 4200, consists of a four-tube voltage regulator which provides the following regulated d-c voltages; plus 300, minus 150 and minus 250 volts. The preamplifier power supply derives its positive and negative d-c inputs from units 2400 and 500 respectively.

2. Missile Oscillator Preamplifier, Unit 4300. (See figure 1-12.) - The signal input to the Missile Oscillator Preamplifier, Unit 4300, is the 30-megacycle i-f signal from the converter in the antenna waveguide. A second input to this unit is an automatic frequency control voltage from the Missile Receiver, Unit 100M. The preamplifier unit increases the i-f signal

level for transmission via coaxial cable to the missile receiver located in the operations trailer. This unit contains the 2K-28 klystron local oscillator for the missile channel converter.

3. Target Local Oscillator Preamplifier, Unit 1700. (See figure 1-12.) - The Local Oscillator Preamplifier, Unit 1700, amplifies at intermediate frequency, an input signal derived from the crystal mixer in the wave guide. Three stages of i-f gain are applied. The output is fed via coaxial cable to the Target Receiver, Unit 100T, in the operations trailer. The 2K-28 klystron local oscillator for the target channel converter and automatic frequency control circuits are also contained in this unit.

4. Echo Box, Unit 4700. (See figure 1-12.) - The Echo Box, Unit 4700, is a tuneable resonant cavity which returns energy to the receiver after excitation by the transmitted pulse. The echo box is used for system alignment and tune-up; it may also be used as a wave meter.

5. Standing Wave Amplifier, Unit 4400. (See figure 1-12.) - The Standing Wave Amplifier is a vacuum-tube detector and amplifier which is used for making standing wave ratio

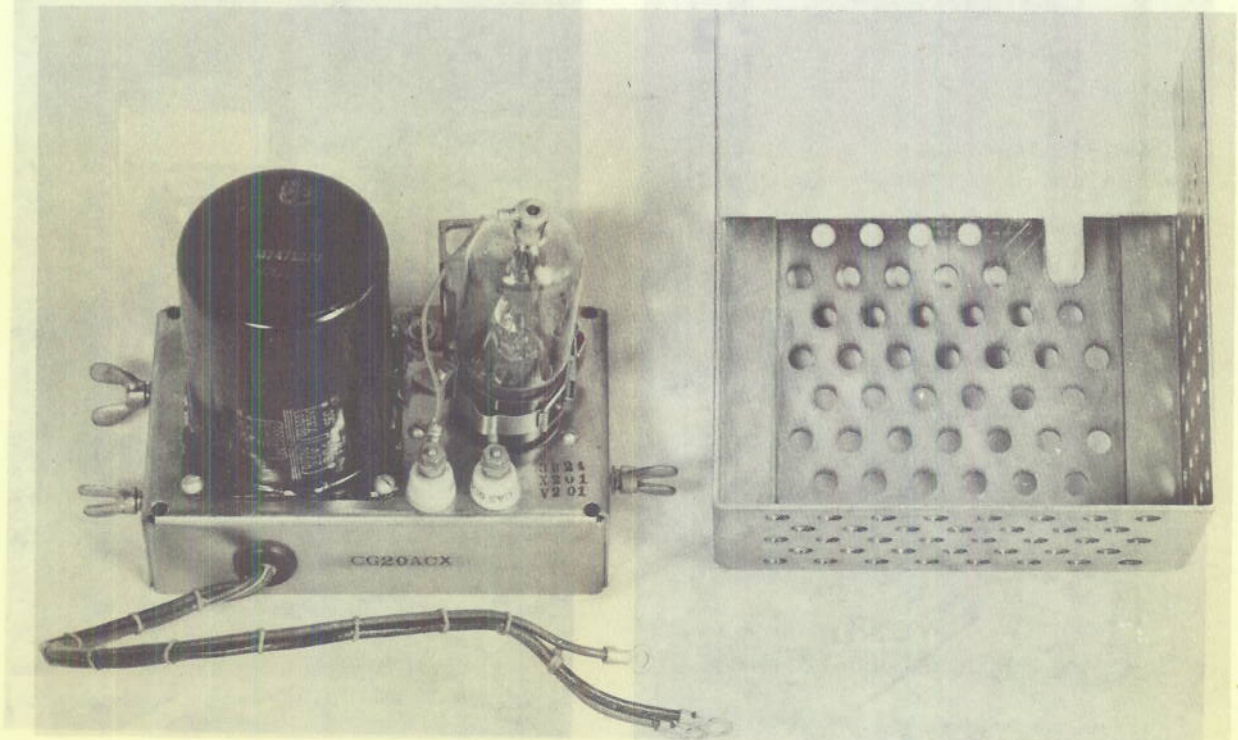


Figure 1-13. Keep-alive Power Supply - Cover Removed

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measurements. Its input is a signal picked up by a movable probe in the output waveguide.

6. Keep-alive Power Supply, Unit 6200. (See figure 1-13.) - The Keep-alive Power Supply, Unit 6200, is located in the top section of the transmitter cabinet. It provides 900-volts dc to pre-ionize the missile and target TR tubes.

7. Hydrogen Thyatron Modulator Unit, Unit 2300. (See figure 1-14.) - Pulse modulation of the transmitted signal is effected by the Hydrogen Thyatron Modulator, Unit 2300. The unit receives a pulse-time modulated synchronizing pulse from the range unit. This pulse is shaped and used to trigger a pair of hydrogen

thyatron tubes connected in series across the usual pulse forming delay line. The modulator supplies transmitter keying pulses of about one microsecond duration and at about 8000 volts. These pulses are sent to the transmitter via a high voltage coaxial cable.

8. Modulator Induction Regulator, Unit 2500 (See figure 1-15) - The Modulator Induction Regulator controls the primary voltage to the high-voltage power transformer in the Hydrogen Thyatron Modulator, Unit 2300.

9. Transmitter, Unit 2000. (See figure 1-16.) - The Transmitter, Unit 2000, is keyed by the pulses from the modulator, unit 2300. The keying pulses are received at the transmitter at a level of about 8000 volts, are stepped up in the pulse transformer to about 22,000 volts, and are used to fire the magnetron.

c). Antenna Unit and Servo Drive Section. - The Lark SP and Lark SP-1M radars are both equipped with an 8-foot antenna reflector dish.

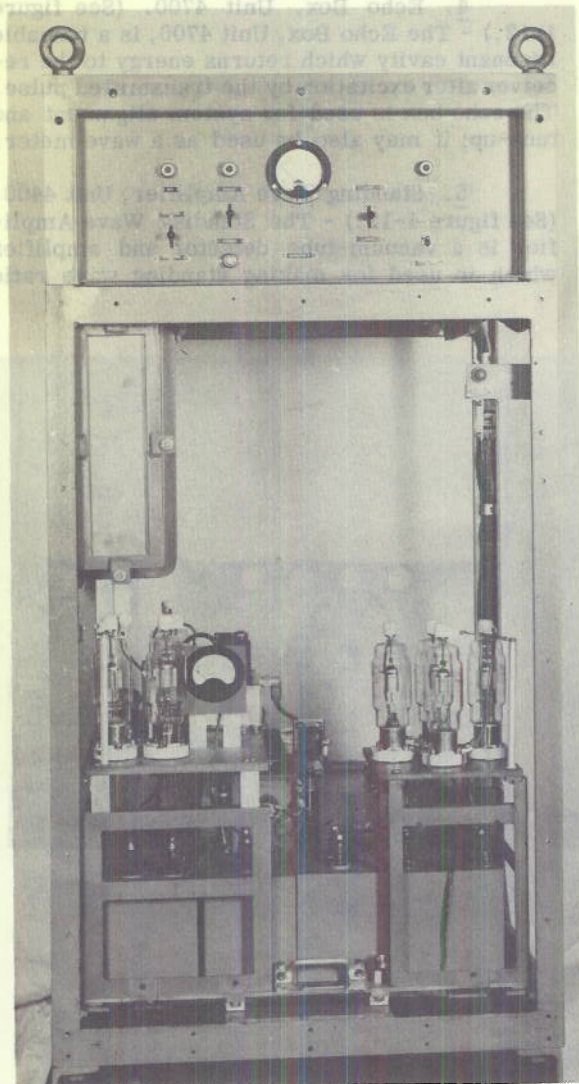


Figure 1-14. Hydrogen Thyatron Modulator Unit - Covers Removed

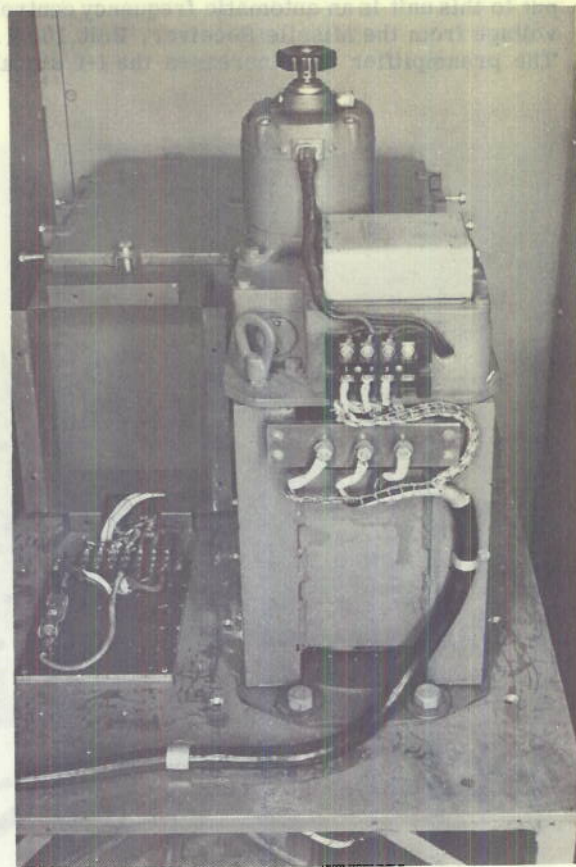


Figure 1-15. Modulator Induction Regulator

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The Lark SP-1M dish is truncated at the top and bottom to facilitate trailer stowing. (See figures 1-17 and 1-18.) Additional sections to complete the circular periphery of the dish are added when the radar is in use. Antenna position intelligence is transmitted by 1-speed and 36-speed synchro generators for train and by 2-speed and 36-speed synchro generators for elevation. Additional 36-speed train and elevation synchros are provided for transmission of data to the Data Recording Unit, Unit 8100. The antenna can be slewed in elevation and train at 36 degrees per second; the servo transmission bandwidth in train and elevation is 12 radians per second for handcrank input.

1. Antenna Unit, Unit 3000. (See figures 1-17 and 1-18.) - The Antenna Unit, Unit 3000, is mounted on an elevator platform located in the Equipment Trailer. The unit consists of the

mount proper and its drive motors, synchros, and tachometers; an 8-foot reflector, a nutating mechanism, an offset boresighting telescope, and two tracking cameras. The unit may be raised for use, or lowered for stowage and transport, by the elevator mechanism.

2. Antenna Control Unit, Unit 3200. - The Antenna Control Unit consists of a console containing the train and elevation amplidynes (figure 1-19), relays, indicator lamps, and elevator controls, together with the d-c servo amplifier, the d-c servo amplifier power unit, and d-c servo equalizer unit.

a. D-c Servo Amplifier, Unit 3300. (See figure 1-20.) - The Servo Amplifier is located in the antenna control unit console. Its function is to receive d-c control signals from the Target and Manual Coordinate Detector Unit,

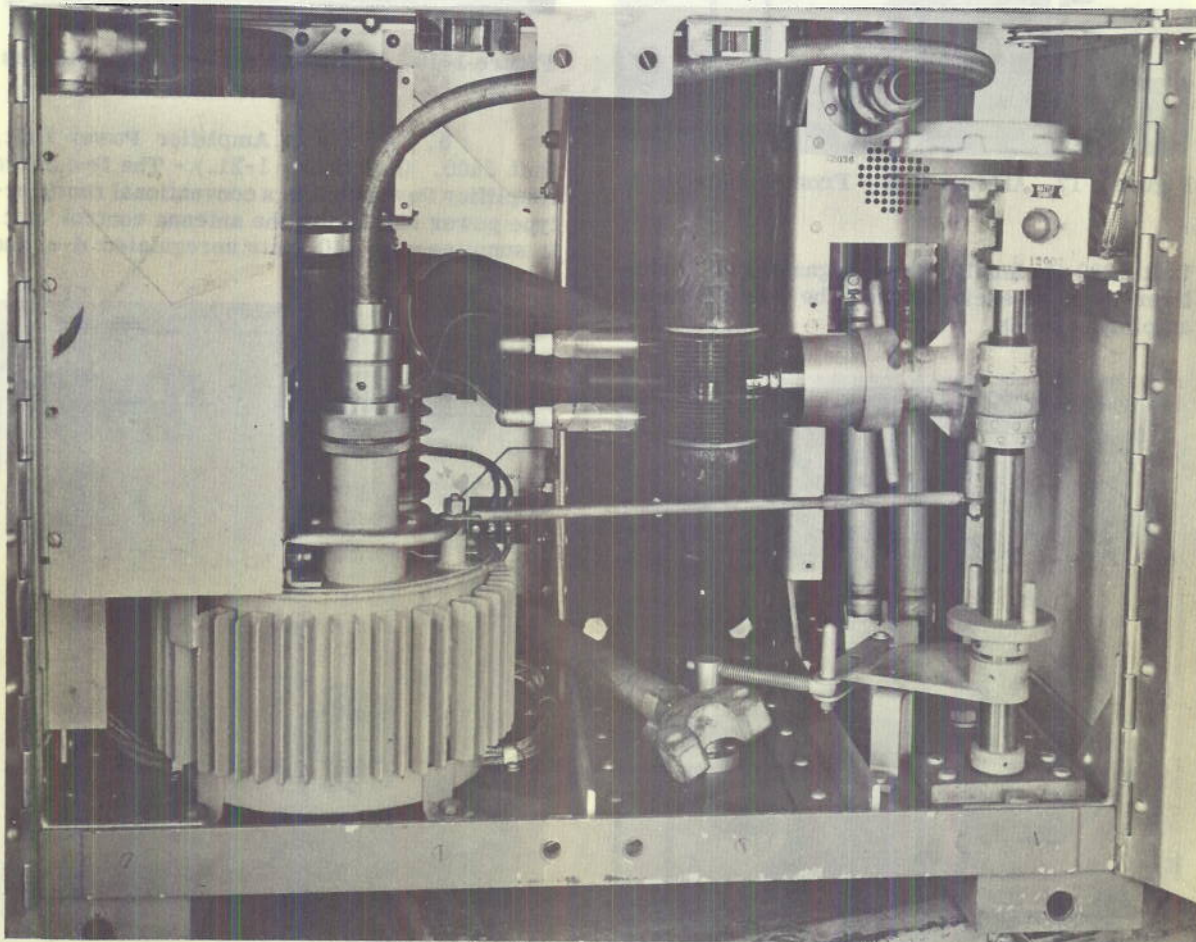


Figure 1-16. Transmitter - Covers Removed, Showing Magnetron

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Figure 1-17. Antenna Unit - Front Oblique View

Unit 1200, to amplify these signals, and to deliver them as excitation for the antenna-drive amplidyne fields.



Figure 1-18. Antenna Unit - Rear View

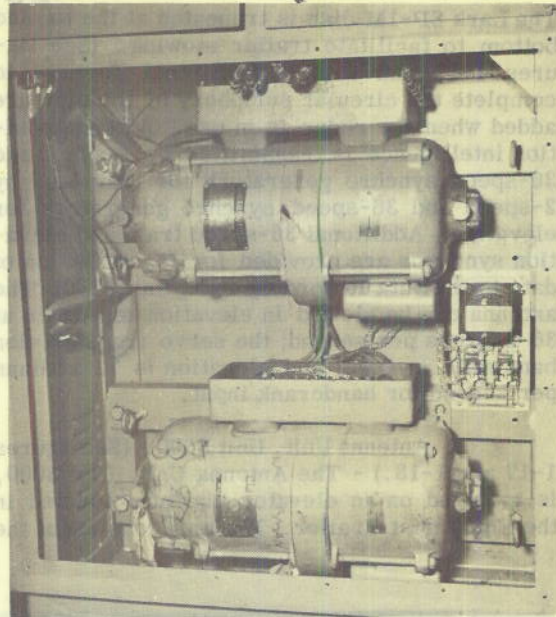


Figure 1-19. Train and Elevation Amplidyne

b. D-c Servo Amplifier Power Unit, Unit 3400. (See figure 1-21.) - The D-c Servo Amplifier Power Unit is a conventional rectifier-type power supply for the antenna control unit. It supplies plus 540 volts unregulated d-c; and

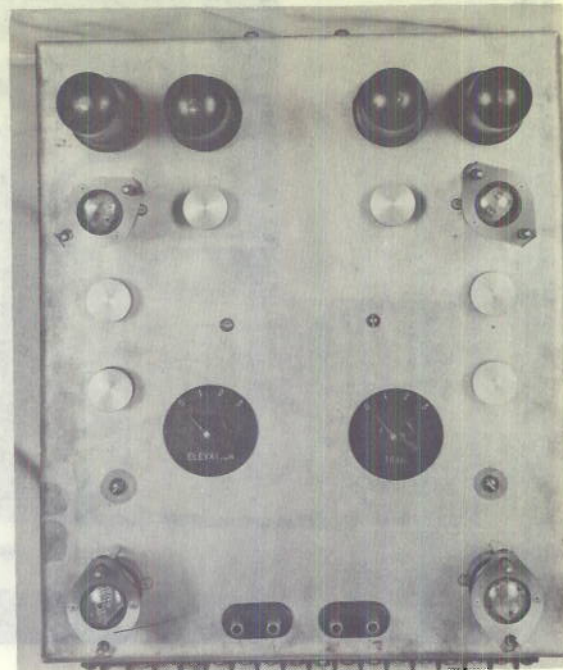


Figure 1-20. D-c Servo Amplifier

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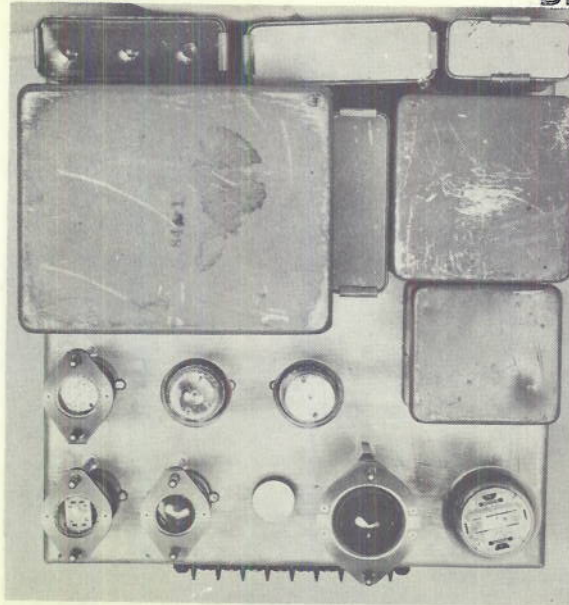


Figure 1-21. D-c Servo Amplifier Power Unit

plus 200 volts and minus 150 volts of regulated dc.

c. D-c Servo Equalizer Unit, Unit 3500. (See figure 1-22.) - The D-c Servo Equalizer Unit is located in the antenna control unit console. It consists of resistance-capacitance

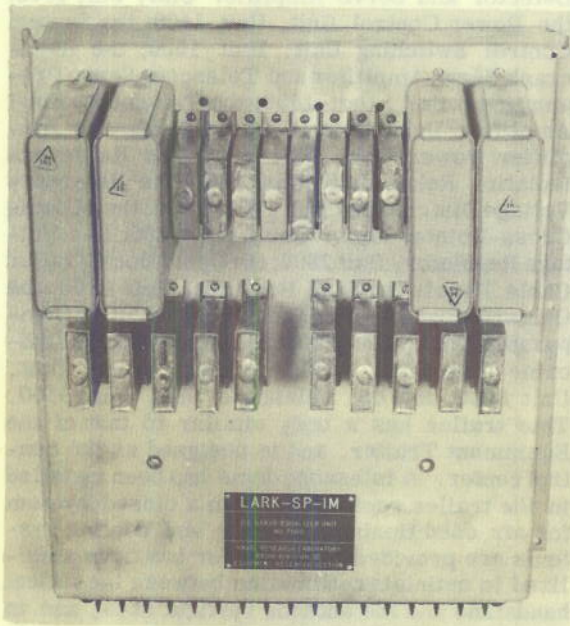


Figure 1-22. D-c Servo Equalizer Unit

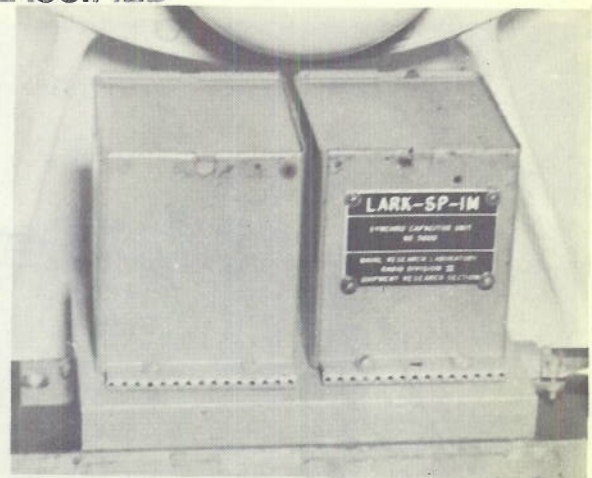


Figure 1-23. Synchro-capacitor Unit

networks which in conjunction with associated equipment control the transmission characteristics of the antenna unit drive servos.

3. Synchro-Capacitor Unit, Unit 3600. (See figure 1-23.) - The Synchro-Capacitor Unit

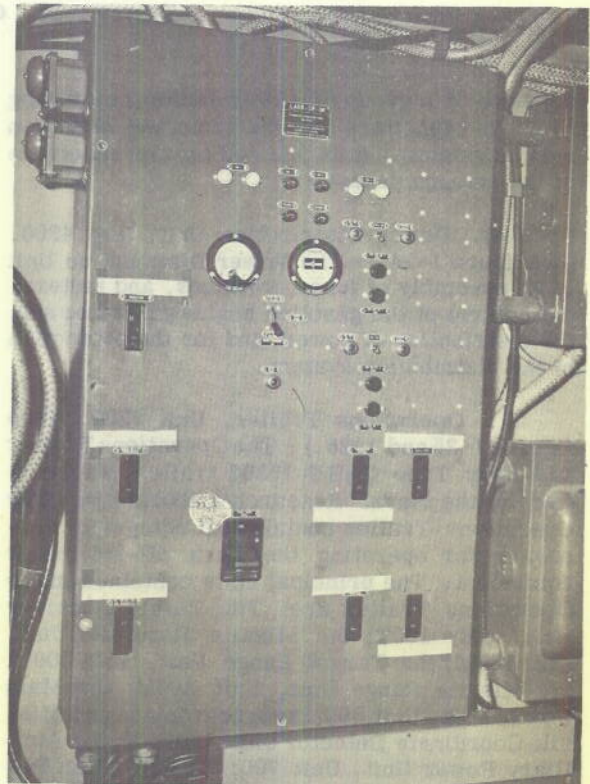


Figure 1-24. Power Distribution Panel

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Figure 1-25. Operations Trailer

consists of a group of power-factor correcting synchro capacitors for the train and elevation servo systems. It is located on the underside of the antenna pedestal.

d). Power Distribution Unit, Unit 4900. (See figure 1-24.) - The Power Distribution Unit is an assembly of fuses, switches, and meters, for control of the gasoline engine generator set, for distribution of power, and for the protection of the distribution system.

2). Operations Trailer, Unit 7200. (See figures 1-25 and 1-26.) - The Operations Trailer is a Navy Type CAHU-10302 trailer, as modified by the Naval Research Laboratory. The Operations Trailer contains all equipment necessary for operating the Lark SP-1M radar equipment. The principal units contained in the Operations Trailer are: The Target Receiver Unit, Unit 100T; the Missile Receiver Unit, Unit 100M; the Target Range Unit, Unit 300T; the Missile Range Unit, Unit 300M; the Main Power Unit, Unit 500; the Synchronizer and Missile Coordinate Detector Unit, Unit 600; the Auxiliary Power Unit, Unit 700; the PPI (Plan Position Indicator) Unit, Unit 800; the High-Voltage Power Unit, Unit 900; the Missile Indicator Unit, Unit 1000M; the Target Indicator Unit, Unit

1000T; the Target and Manual Coordinate Detector Unit, Unit 1200; the Target and Missile Range Detector and Servo Amplifier Unit, Unit 1300; the Power Control Unit, Unit 1400; the System Control Switching Unit, Unit 1500; the Handcrank Servo Amplifier and Telescope Servo Pre-amplifier Unit, Unit 1600; the Telescope Final Amplifier Unit, Unit 1800; the Telescope Amplifier Power Unit, Unit 1800; the Handcrank Isolation Relay Unit, Unit 2600; the Reference Voltage Distribution Unit, Unit 2700; the Missile Cross-Pointer Meter Unit, Unit 2800; D-c Voltage Regulator, Unit 2900; the Operations Trailer Cable Panel; the Dial Box Unit, Unit 8100; the Camera Control Unit, Unit 8200; the Time Comparator Unit, Unit 8400; the Remote Range Indicator Unit, Unit 8500; the Commutator Unit, Unit 8600; and the Telescope Unit, Unit 9100. This trailer has a body similar to that of the Equipment Trailer, and is designed as the control center. A telescope dome has been installed in the trailer roof to maintain a closed system for air conditioning. Heating and cooling systems are provided. The trailer has been stabilized to maintain collimation between the optical handstand and the antenna vertical axes, and to minimize vibration when the equipment is in operation. The location of the principal components is shown in figure 1-26.

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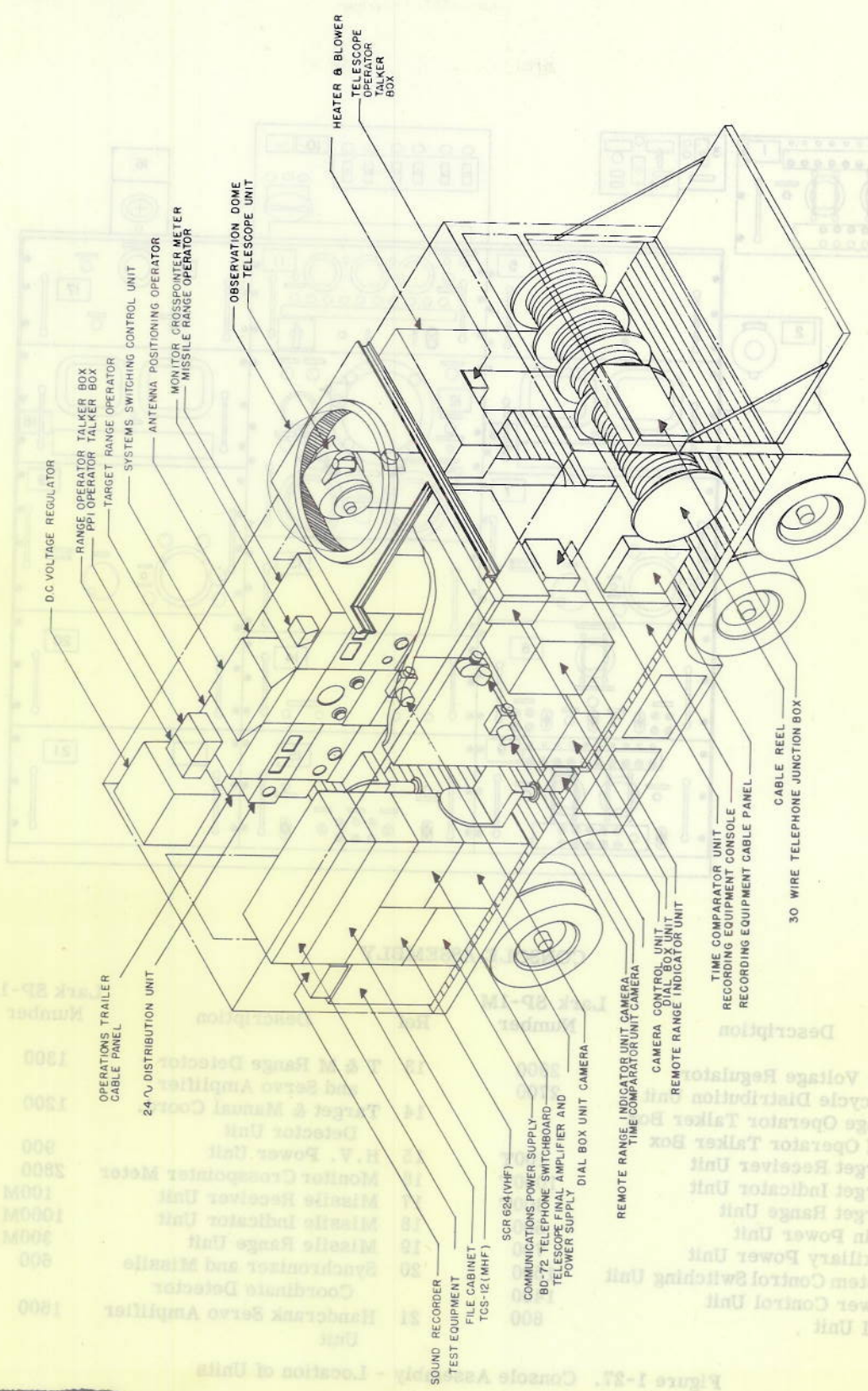
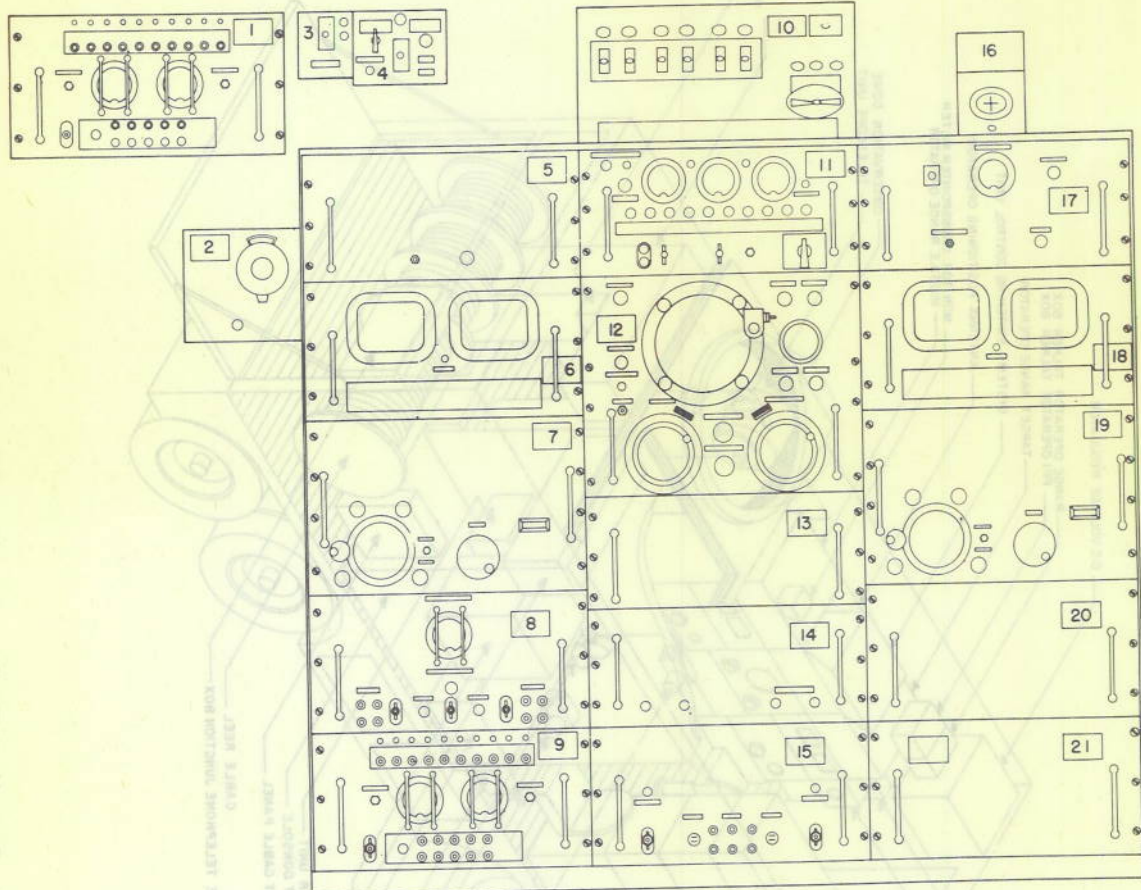


Figure 1-26. Operations Trailer - Location of Equipment

Ref	Description
1	D-c Voltage Regulator
2	24-cycle Distribution Unit
3	Range Operator Talker Box
4	PPI Operator Talker Box
5	Target Receiver Unit
6	Target Indicator Unit
7	Target Range Unit
8	Main Power Unit
9	Auxiliary Power Unit
10	System Control Switching Unit
11	Power Control Unit
12	PPI Unit

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CONSOLE ASSEMBLY

Ref	Description	Lark SP-1M Number	Ref	Description	Lark SP-1M Number
1	D-c Voltage Regulator	2900	13	T & M Range Detector - and Servo Amplifier	1300
2	24-cycle Distribution Unit	2700	14	Target & Manual Coord. Detector Unit	1200
3	Range Operator Talker Box		15	H. V. Power Unit	900
4	PPI Operator Talker Box	100T	16	Monitor Crosspointer Meter	2800
5	Target Receiver Unit	1000T	17	Missile Receiver Unit	100M
6	Target Indicator Unit	300T	18	Missile Indicator Unit	1000M
7	Target Range Unit	500	19	Missile Range Unit	300M
8	Main Power Unit	700	20	Synchronizer and Missile Coordinate Detector	600
9	Auxiliary Power Unit	1500	21	Handcrank Servo Amplifier Unit	1600
10	System Control Switching Unit	1400			
11	Power Control Unit	800			
12	PPI Unit				

Figure 1-27. Console Assembly - Location of Units

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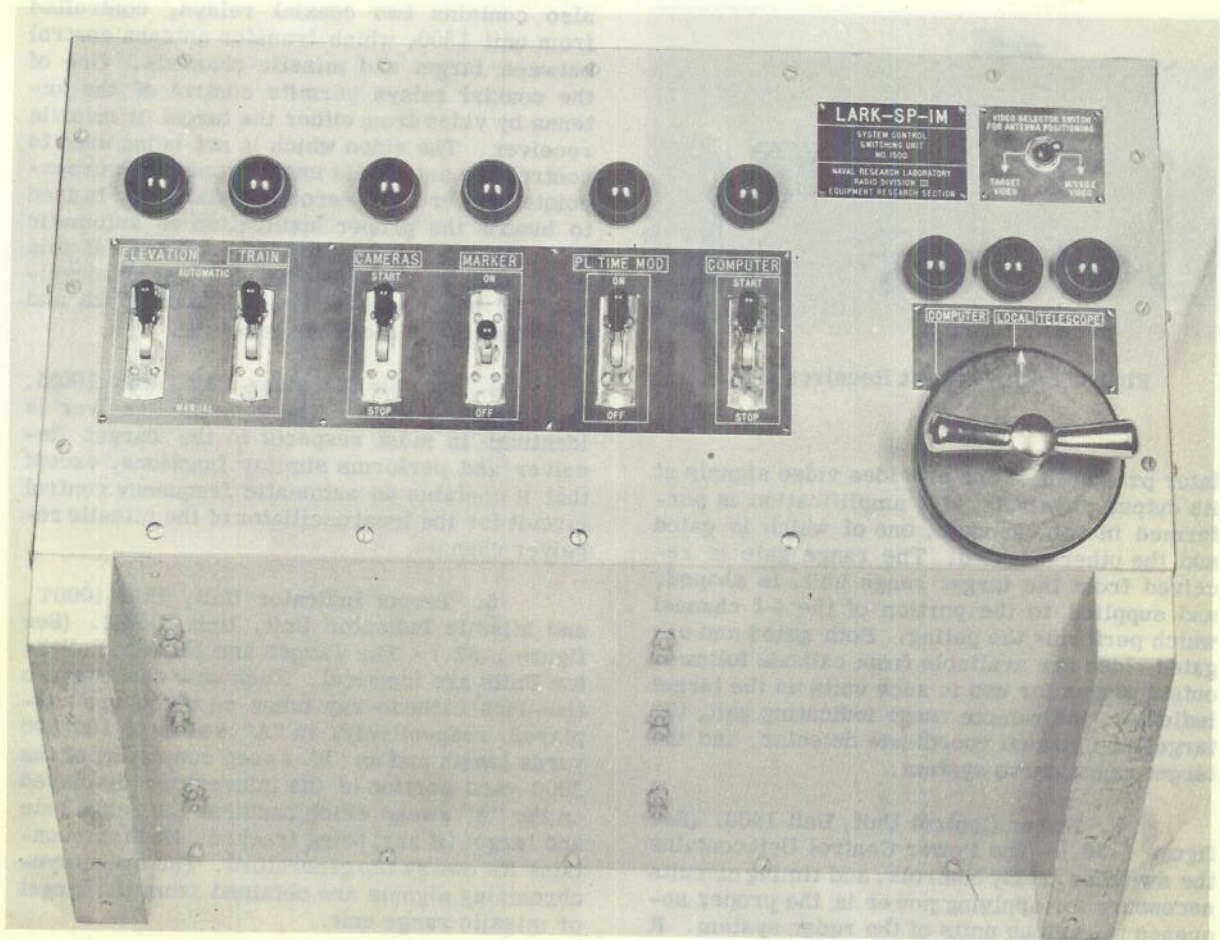


Figure 1-28. System Control Switching Unit

a). Console assembly. (See figure 1-27.) - A normal complement of three operators at the console assembly controls the operation of the radar equipment. These operators are Target Range, Missile Range, and PPI operators. Elements of the console are described in the following subparagraphs and their location is shown in figure 1-27.

1. System Control Switching Unit, Unit 1500. (See figure 1-28.) - The System Control Switching Unit is located above the center bay of the console assembly. Through selector switches, this unit permits the operators to select any of the several modes of operation. The principal modes of tracking operation are: manual through handcranks on the operating console, or hand controls on the telescope unit; automatic radar tracking of either missile or target; and computer, by introduction of simulated target or missile course through a computing de-

vice. (The computer, which is used for test purposes, causes automatic displacement of the radar beam at tactically expected rates, as if the beam were actually tracking a target.) Switches are provided for local, computer, or telescope operation, and for automatic tracking in train or elevation or both; for starting and stopping cameras in the data recording unit; for causing a marker to be placed on the recording film; and for turning on and off the pulse-time modulation. Switch positions are indicated by lights located on the switching unit and in the data recording section. When the equipment is operating in "telescope," the Handcrank Isolation Relay Unit, Unit 2600, disconnects the error signal input to the manual coordinate detectors in unit 1200.

2. Target Receiver Unit, Unit 100T. (See figure 1-29.) - The Target Receiver amplifies and detects the i-f signal from the target oscil-

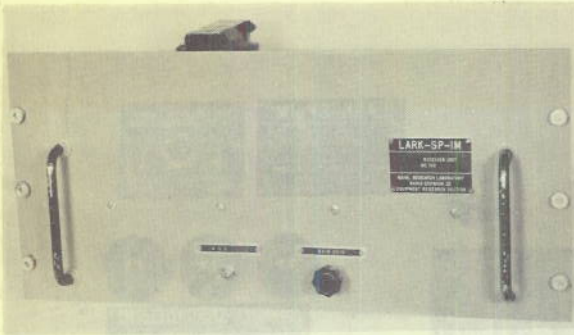


Figure 1-29. Target Receiver Unit

lator preamplifier and provides video signals at its output terminals. I-f amplification is performed in two channels, one of which is gated and the other ungated. The range gate is received from the target range unit, is shaped, and supplied to the portion of the i-f channel which performs the gating. Both gated and ungated video are available from cathode follower output stages for use in such units as the target indicator, the remote range indicating unit, the target and manual coordinate detector, and the target range servo system.

3. Power Control Unit, Unit 1400. (See figure 1-30.) - The Power Control Unit contains the switches, relay controls, and timing circuits necessary for applying power in the proper sequence to various units of the radar system. It

also contains two coaxial relays, controlled from unit 1500, which transfer antenna control between target and missile channels. One of the coaxial relays permits control of the antenna by video from either the target or missile receiver. The video which is not being used to control the antenna is used to operate a cross-pointer meter. The second coaxial relay is used to insure the proper application of automatic gain control voltages to the receivers. If this relay were not provided, the AGC voltage developed by one receiver would interact with and vary the gain of the other receiver.

4. Missile Receiver Unit, Unit 100M. (See figure 1-31.) - The Missile Receiver is identical in most respects to the Target Receiver and performs similar functions, except that it contains an automatic frequency control circuit for the local oscillator of the missile receiver channel.

5. Target Indicator Unit, Unit 1000T, and Missile Indicator Unit, Unit 1000M. (See figure 1-32.) - The Target and Missile Indicator Units are identical. Each unit contains two five-inch cathode-ray tubes on which are displayed, respectively, an "A" sweep of 100,000 yards length and an "R" sweep consisting of the 2000-yard portion of the information displayed on the "A" sweep which contains the range gate and target (if any) being tracked. Each unit contains its own sweep generators. The sweep synchronizing signals are obtained from the target or missile range unit.

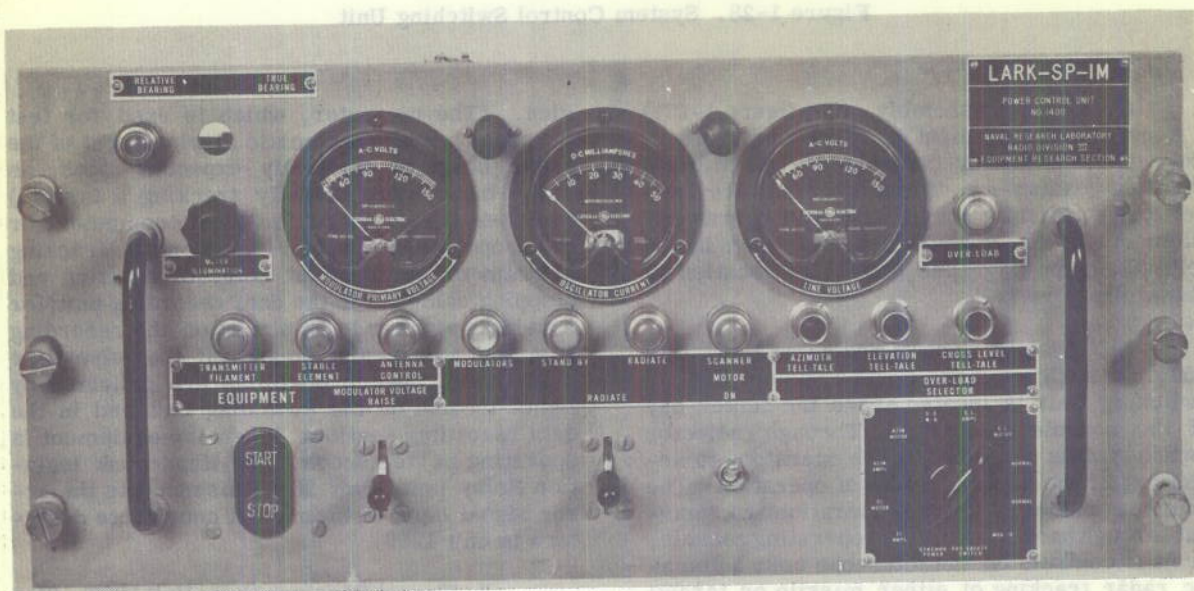


Figure 1-30. Power Control Unit

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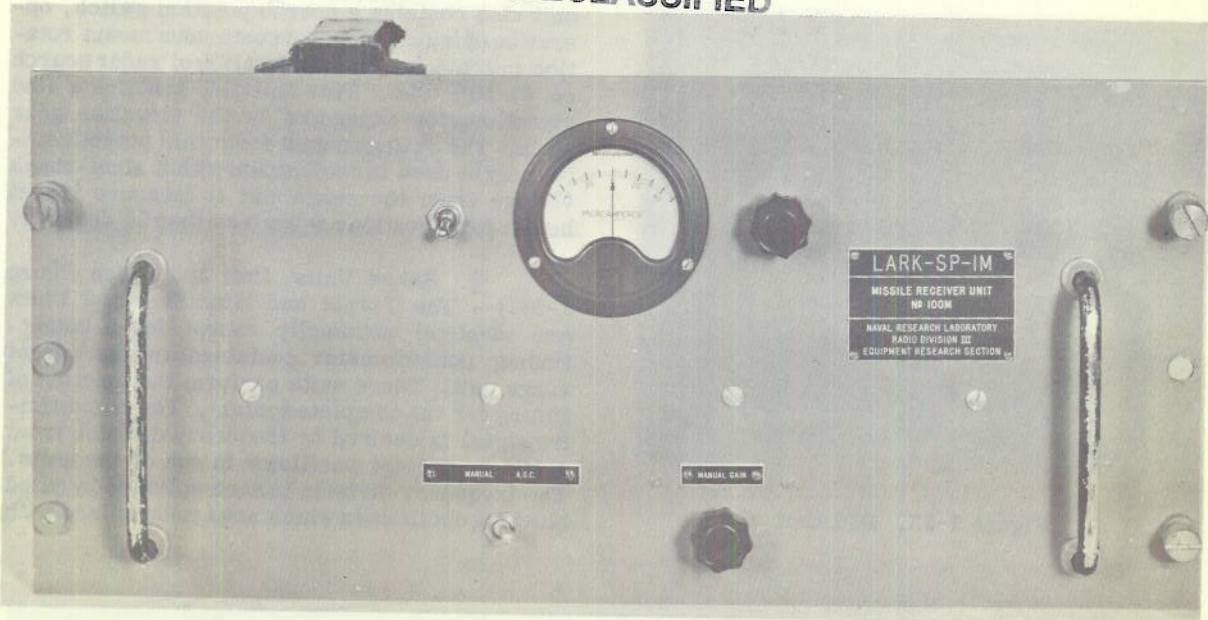


Figure 1-31. Missile Receiver Unit

6. PPI (Plan Position Indicator) Unit, Unit 800. (See figure 1-33.) - The Plan Position Indicator Unit, in addition to the PPI tube, provides handcranks for manual control of the antenna position in train and in elevation. Each

handcrank assembly includes a servo motor and tachometer generator. In automatic operation, each servo motor drives its handcrank to keep it in position with the antenna mount. Graduated dials indicate the ordered mount position. The

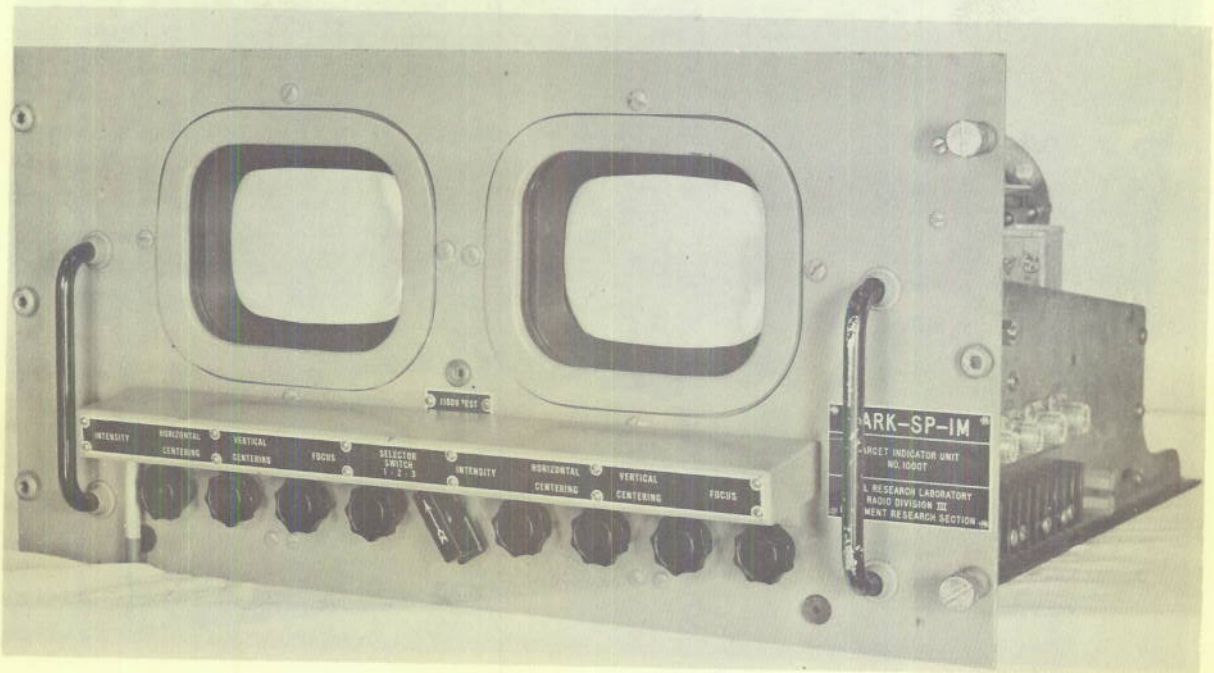


Figure 1-32. Target Indicator Unit

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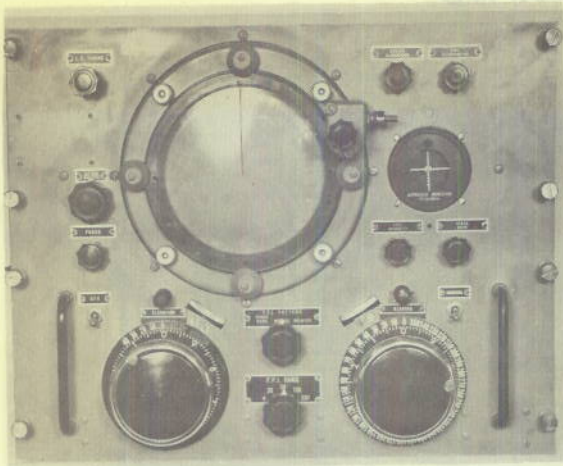


Figure 1-33. PPI Unit

unit also contains a search position switch, operation of which provides continuous mount rotation in train for the presentation of radar search on the PPI tube. This unit also contains a sine potentiometer connected to the elevation gear train. The voltage output from this potentiometer may be used in conjunction with a slant-range voltage from the range unit to measure target height for elevation angles less than 30 degrees.

7. Range Units, Unit 300. (See figure 1-34.) - The Target and Missile Range Units are identical physically except for a height-finding potentiometer contained in the target range unit. These units perform the function of timing for the complete system. The basic timing signal is derived by frequency division from a 164-kc crystal oscillator in one of the units. The frequency division is accomplished by gated blocking oscillators which are synchronized with

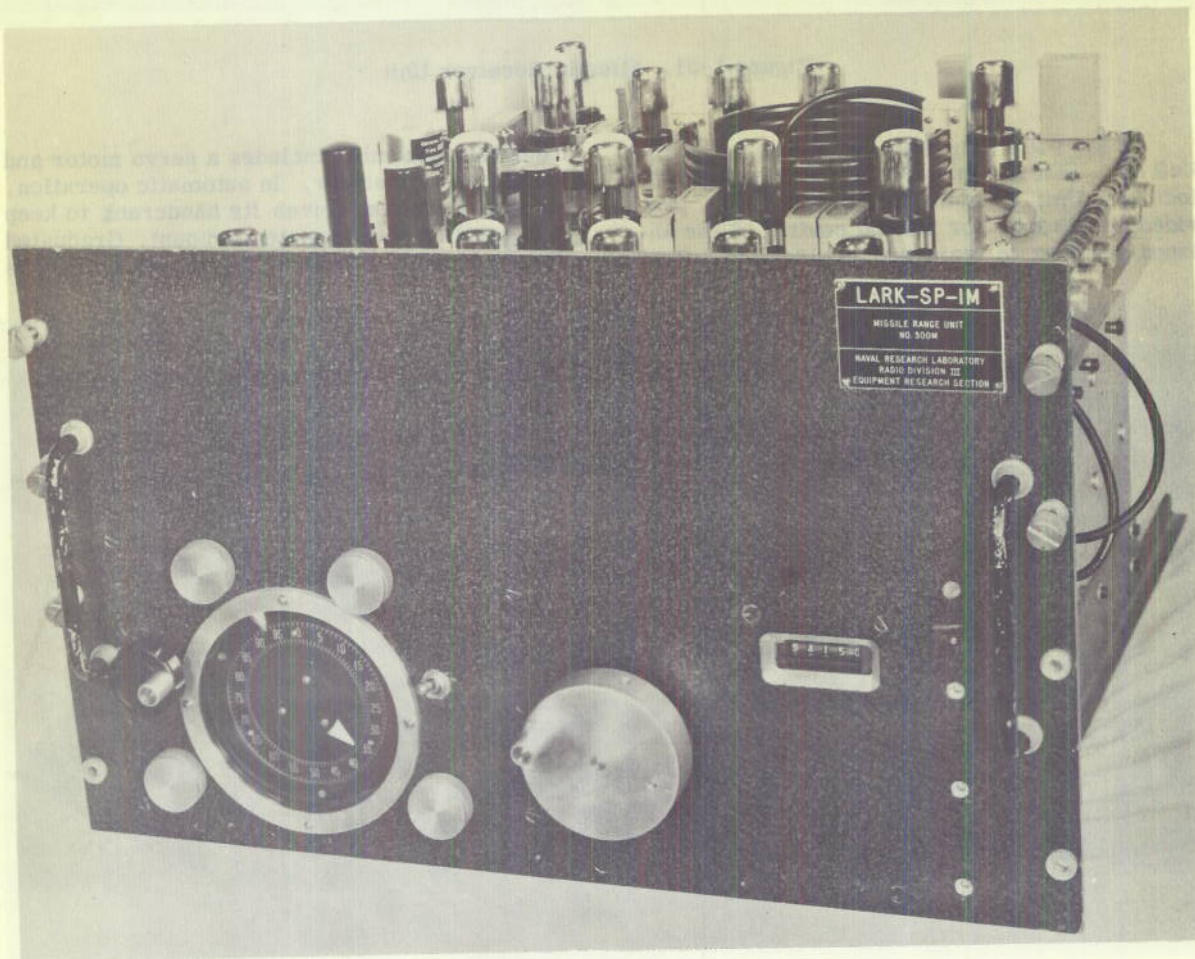


Figure 1-34. Missile Range Unit

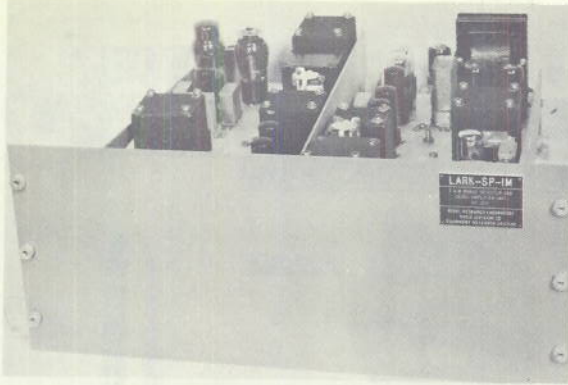


Figure 1-35. T and M Range Detector and Servo Amplifier Unit

the output of the crystal oscillator. Pulses are provided for timing the modulator and the indicator units and phase-shifted pulses are provided for the gating circuits. The mechanical section of the range unit contains the motors, gearing, and tachometers for the range servo system. A height-finding potentiometer is installed in the target range unit. This potentiometer has a voltage output directly proportional to the target range. As described in the pre-

ceding paragraph, this voltage may be used to compute the target height.

8. Target and Missile Range Detector and Servo Amplifier, Unit 1300. (See figure 1-35.) - The Target and Missile Range Detector and Servo Amplifier contains a range detector which receives gated video and the range gate from the receiver. These inputs are arranged so that they feed circuits providing a d-c output voltage which is proportional to the difference between the actual target range and the indicated range, and of a polarity which indicates whether the displacement direction is positive or negative. This voltage is applied to a balanced modulator producing a modulated 60-cycle carrier which is fed into a servo amplifier, amplified, and used to drive the range servo motors located in the mechanical section of unit 300. Two identical chassis are contained in the unit, one for missile and another for target tracking.

9. Main Power Unit, Unit 500. (See figure 1-36.) - The Main Power Unit is a rectifier type power supply which provides minus 440 volts dc to the regulators of the Auxiliary Power Unit, Unit 700.

10. Auxiliary Power Unit, Unit 700. (See figure 1-37.) - The Auxiliary Power Unit

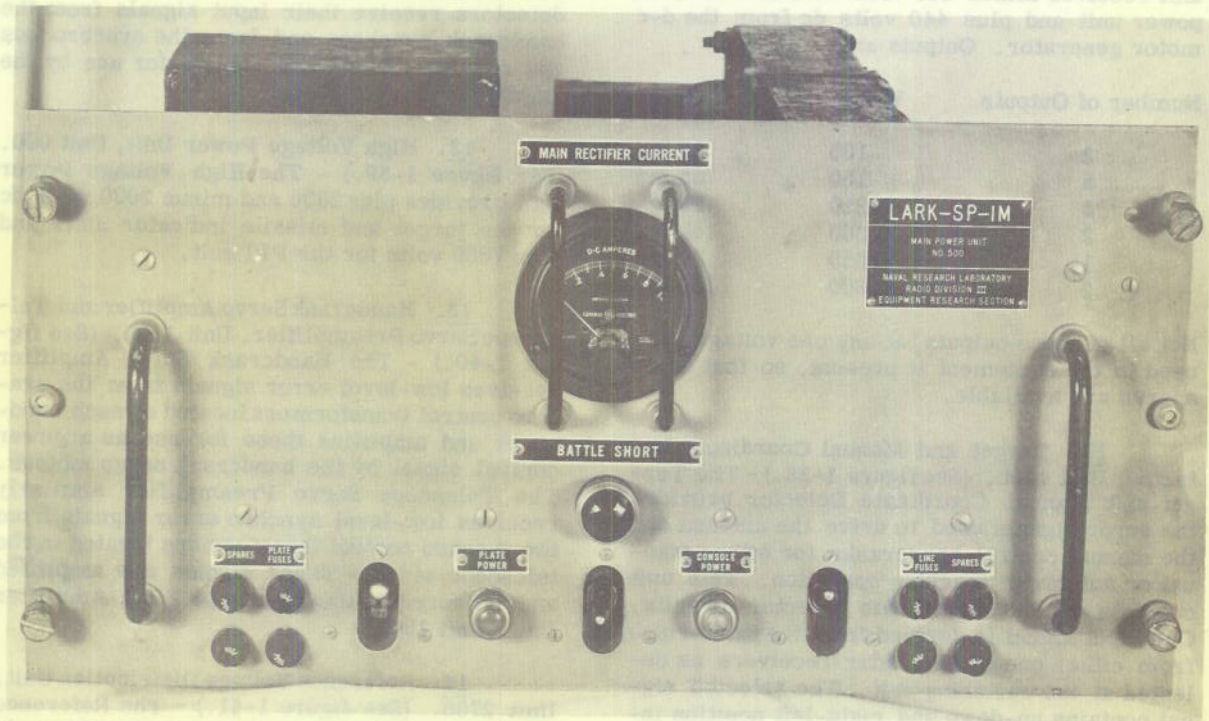


Figure 1-36. Main Power Unit

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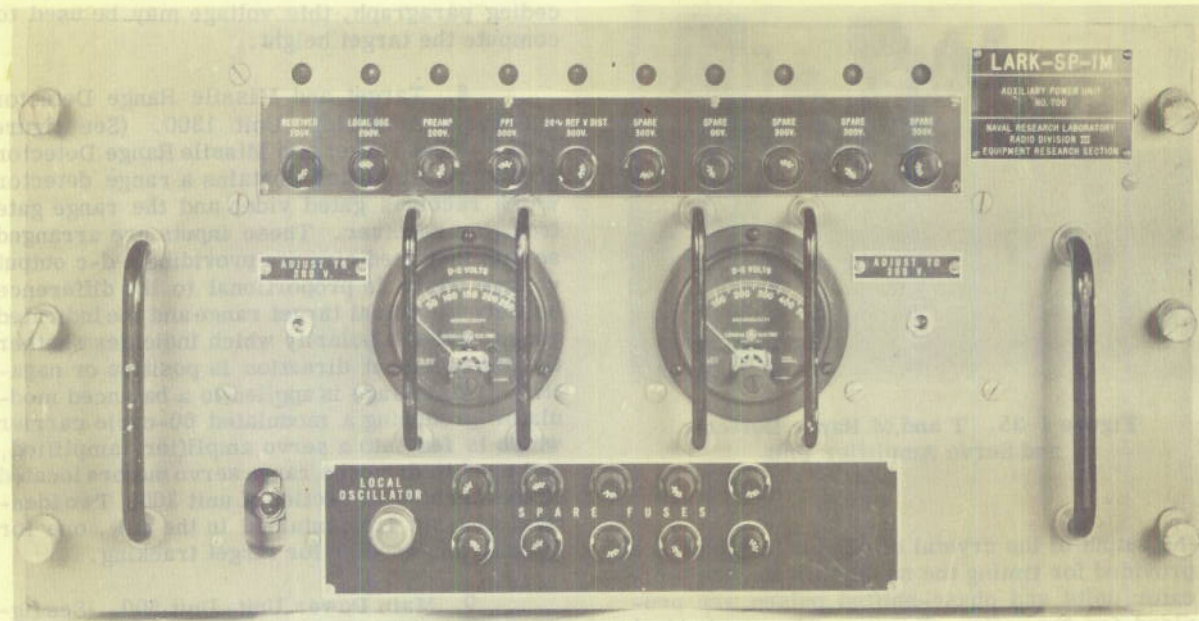


Figure 1-37. Auxiliary Power Unit

is a voltage regulator which provides regulated d-c voltages to elements of the system. The unit receives minus 440 volts dc from the main power unit and plus 440 volts dc from the d-c motor generator. Outputs are:

Number of Outputs	Voltages	Current
2	-105	35 ma
5	-150	35 ma
3	-210	35 ma
2	+200	150 ma
1	+250	30 ma
2	+300	350 ma

Not all of these outputs, at any one voltage, are used in the equipment at present, so that some spares are available.

11. Target and Manual Coordinate Detector, Unit 1200. (See figure 1-38.) - The Target and Manual Coordinate Detector provides the error signals used to drive the antenna and the manual control handcranks for either manual or automatic tracking operation. This unit consists of four coordinate detector circuits. One input signal is derived from the gated video from either one of the radar receivers as selected at the switching unit. The selected signal contains up-down and right-left position intelligence. The other input signal is derived from the two-phase, 24-cycle reference gener-

ator at the antenna. From these inputs two d-c voltages are generated for use as train and elevation control signals. The manual coordinate detectors receive their input signals from the handcrank synchros and from the synchro bus and develop d-c control signals for use by the amplidyne drive system.

12. High Voltage Power Unit, Unit 900. (See figure 1-39.) - The High Voltage Power Unit provides plus 2000 and minus 2000 volts dc for the target and missile indicator units and plus 7000 volts for the PPI unit.

13. Handcrank Servo Amplifier and Telescope Servo Preamplifier, Unit 1600. (See figure 1-40.) - The Handcrank Servo Amplifier receives low-level error signals from the synchro control transformers located at each handcrank and amplifies these for use as a power control signal by the handcrank servo motors. The Telescope Servo Preamplifier similarly receives low-level synchro error signals from the synchro control transformers located in the telescope stand. These signals are amplified and delivered to the Telescope Final Amplifier Unit, Unit 1800.

14. Reference Voltage Distribution Unit, Unit 2700. (See figure 1-41.) - The Reference Voltage Distribution Unit derives its 24-cycle input signal from the reference generator in the

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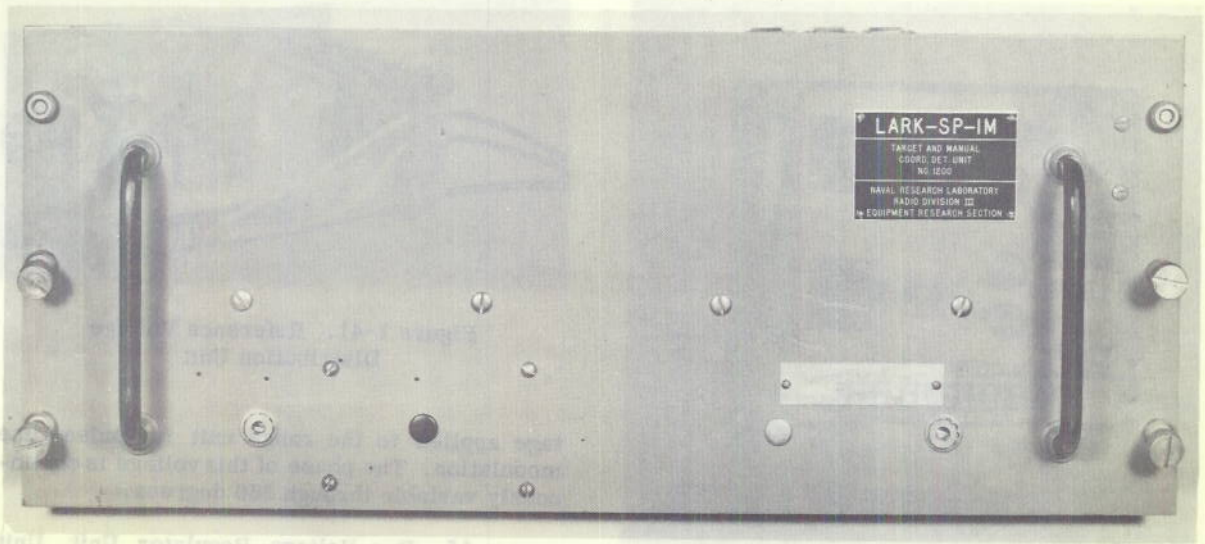


Figure 1-38. Target and Manual Coordinate Detector Unit

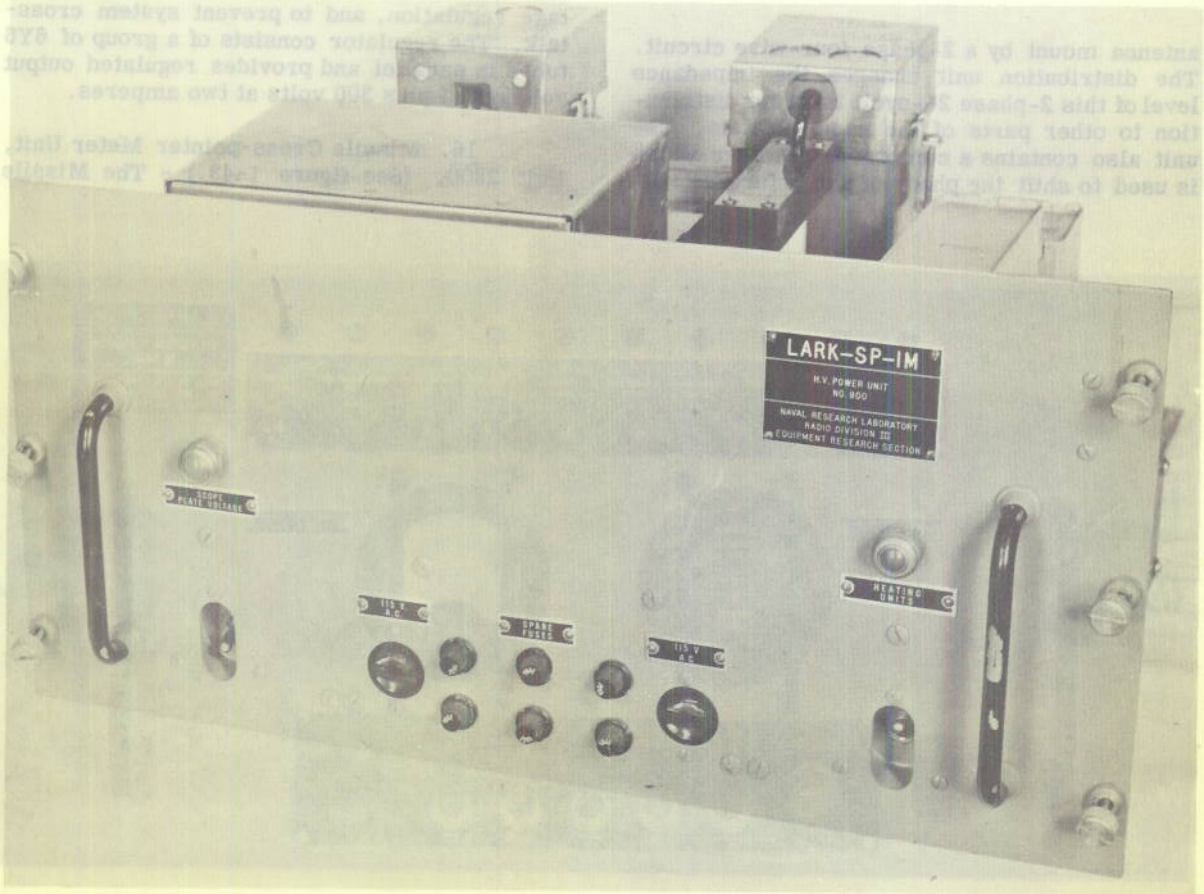


Figure 1-39. H-v Power Unit

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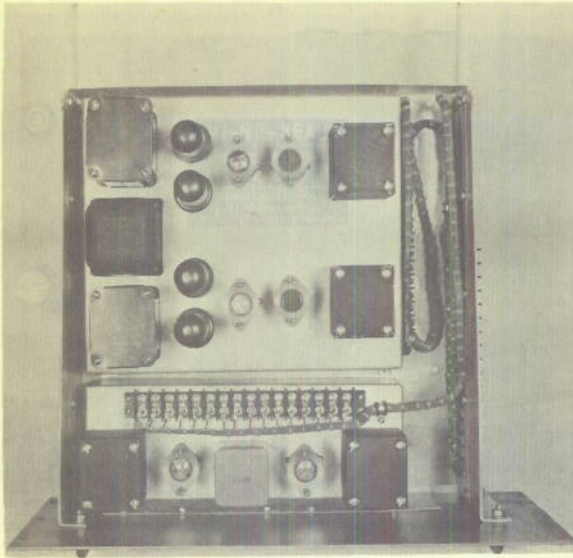


Figure 1-40. Handcrank Servo Amplifier (Upper Chassis) and Telescope Servo Preamplifier

antenna mount by a 2-phase four-wire circuit. The distribution unit changes the impedance level of this 2-phase 24-cycle input for distribution to other parts of the radar system. The unit also contains a component resolver which is used to shift the phase of the reference vol-

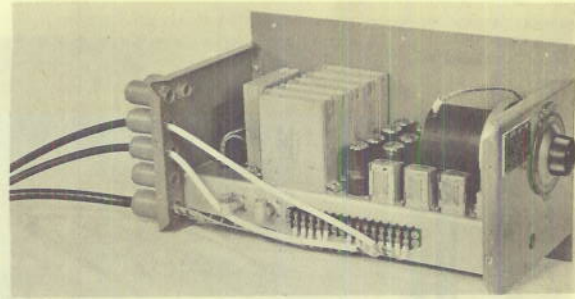


Figure 1-41. Reference Voltage Distribution Unit

tage applied to the range unit for pulse-time modulation. The phase of this voltage is continuously variable through 360 degrees.

15. D-c Voltage Regulator Unit, Unit 2900. (See figure 1-42.) - The D-c Voltage Regulator Unit is designed to remove generator ripple from the voltage derived from the D-c Motor Generator Set; Unit 2400, to provide voltage regulation, and to prevent system cross-talk. The regulator consists of a group of 6Y6 tubes in parallel and provides regulated output voltages of plus 300 volts at two amperes.

16. Missile Cross-pointer Meter Unit, Unit 2800. (See figure 1-43.) - The Missile

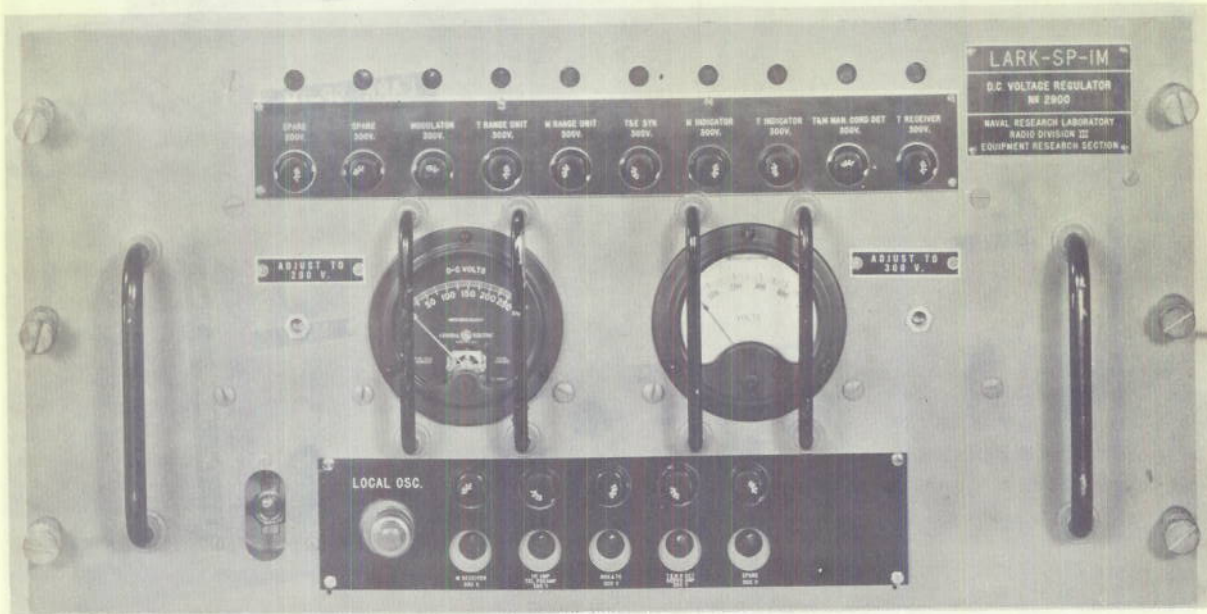


Figure 1-42. D-c Voltage Regulator

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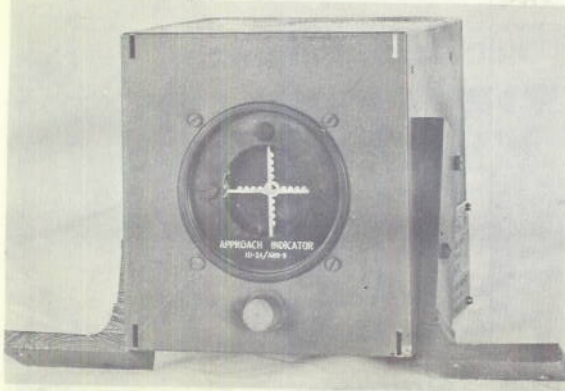


Figure 1-43. Missile Cross-pointer Meter

Cross-pointer Meter is located at the top of the right bay of the operations console. Its function is to indicate the elevation and train error for either the missile or the target depending on the mode of operation. The unit derives its error signals from the Synchronizer and Missile Coordinate Detector Unit, Unit 600.

17. Synchronizer and Missile Coordinate Detector Unit, Unit 600. - The Synchronizer and

Missile Coordinate Detector Unit contains four synchronizing circuits which act as a switching unit between fine and coarse control, and prevent false zeroing of the synchros of the antenna mount, the handcrank, and the telescope manual controls. For the elevation channel, coarse and fine speeds are two and thirty-six, respectively; for the train channel, they are one and thirty-six. When the displacement between antenna position and handcrank position and between antenna position and telescope position is in excess of 2-1/2 degrees, the synchronizer unit causes these elements to realign at coarse speed; for errors less than 2-1/2 degrees, alignment is accomplished at fine speed. The missile coordinate detector, contained in this unit, delivers error signals to the Missile Cross-pointer Meter, Unit 2800.

b). Optical tracking equipment. - The optical tracking equipment consists of the Telescope Unit, Unit 9100, the Telescope Servo Pre-amplifier, part of Unit 1600 described in paragraph 2 b 2) a), the Telescope Final Amplifier, Unit 1800, and the Telescope Amplifier Power Unit, Unit 1800.

1. Telescope Unit, Unit 9100. (See figures 1-44 and 1-45.) - The Telescope Unit is a

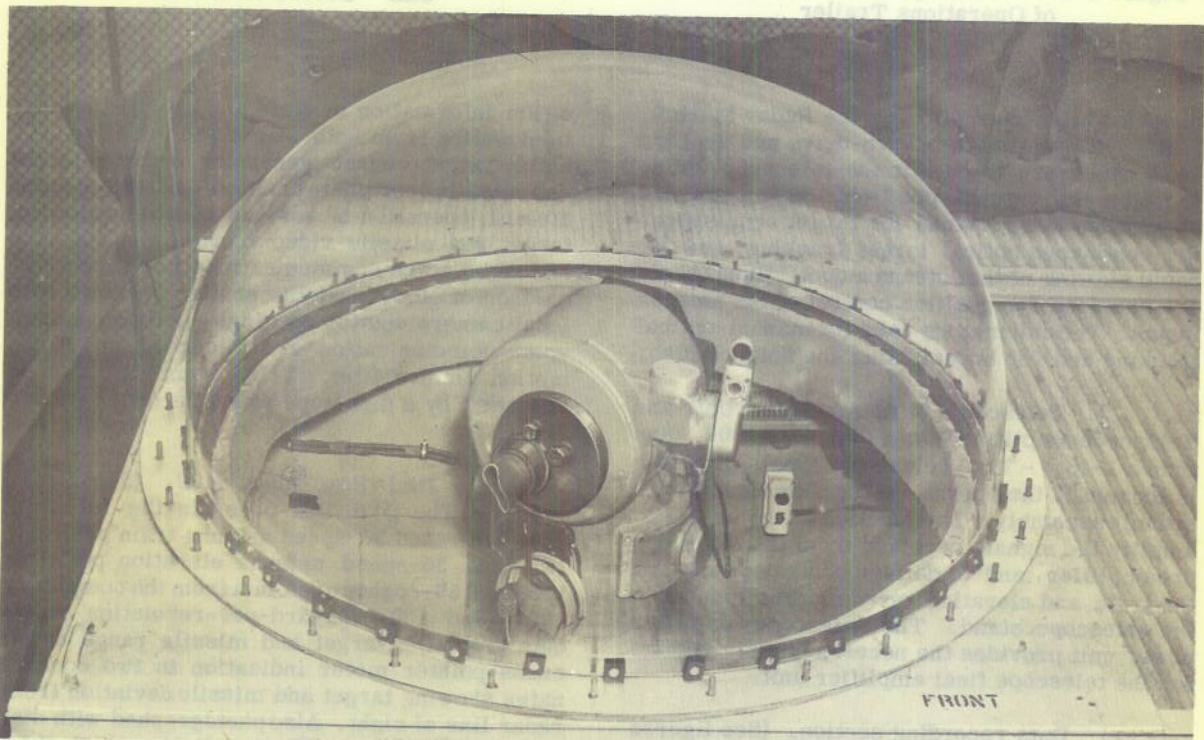


Figure 1-44. Telescope Dome - Showing Telescope Unit

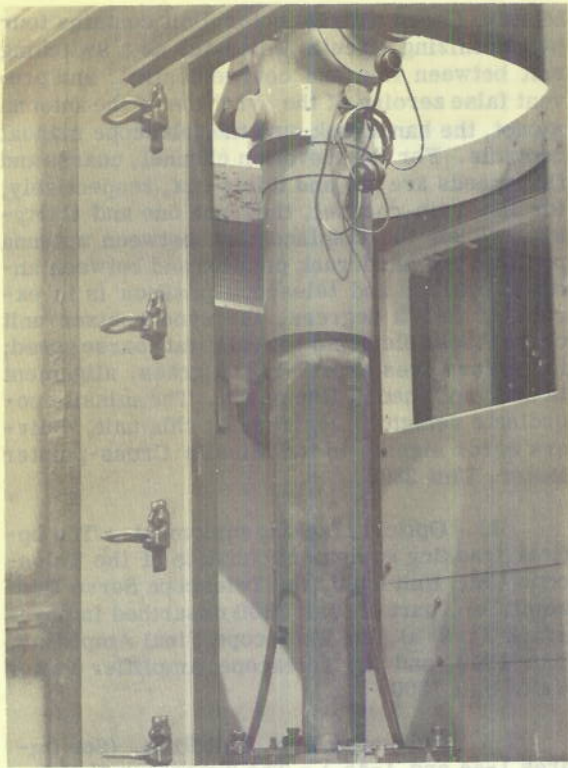


Figure 1-45. Telescope Unit Through Door of Operations Trailer

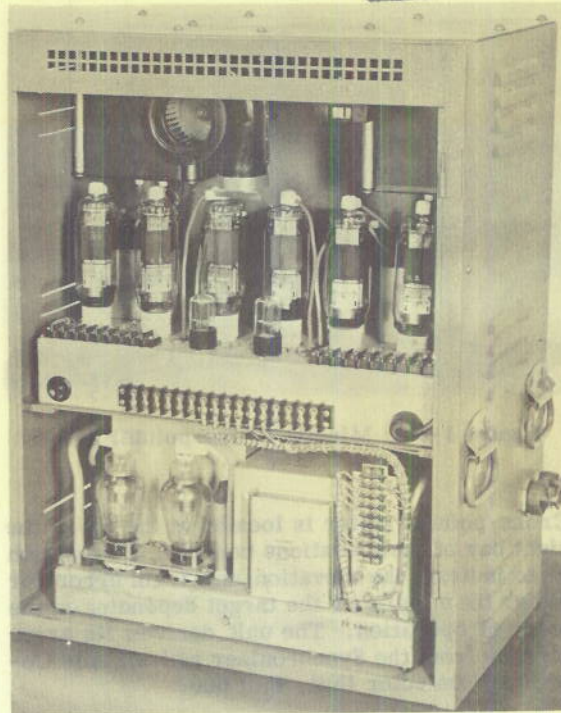


Figure 1-46. Telescope Final Amplifier Unit (Top) and Telescope Amplifier Power Unit - Covers Removed

modified telescope unit from the Radar Mark 7, Mod 1. It contains the servo-drive and synchro units necessary to permit the telescope optics to follow the antenna position. Slew sight and slew knobs are provided for target acquisition, for continuous optical target tracking, and for rapid slewing of the antenna mount. Handwheels are provided for position control of the antenna mount. The unit may be used for manual-optical tracking and for boresighting the antenna dish.

2. Telescope Final Amplifier Unit and Telescope Amplifier Power Unit, Unit 1800. (See figure 1-46.) - The Telescope Final Amplifier is located in the Operations Trailer opposite the console assembly. The function of the unit is to amplify the signals received from the telescope preamplifier, and to deliver control power for the train and elevation servo motors located in the telescope stand. The telescope amplifier power unit provides the necessary plate voltage for the telescope final amplifier unit.

c). Data recording section. (See figures 1-47 and 1-48.) - The recording equipment for the Lark SP-1M radar is arranged to record the following general data: antenna present po-

sition information in train and elevation; range information from both target and missile range units; target-course generator outputs; target and missile coordinate position on cross-pointer meters; operation of various control switches; target and missile video signals; all telephone and radio voice communications; and time comparison of cine-theodolite shutter openings with local camera shutter openings. All data except voice communication are recorded on 16mm motion picture film. Voice communication is recorded by a disk-type sound recorder (figure 1-49).

1. Dial Box, Unit 8100. (See figure 1-50.) - The Dial Box presents the following data: one- and 36-speed antenna train position, two- and 36-speed antenna elevation position; two- and 36-speed range data from the computer, 1000- and 100,000-yard-per-revolution range data from the target and missile range units; cross-pointer meter indication in two coordinates showing target and missile deviation from radar line of sight. Also photographed with dial indications are six indicator lights which show switch positions on the System Control Switching Unit, Unit 1500, as follows: automatic eleva-

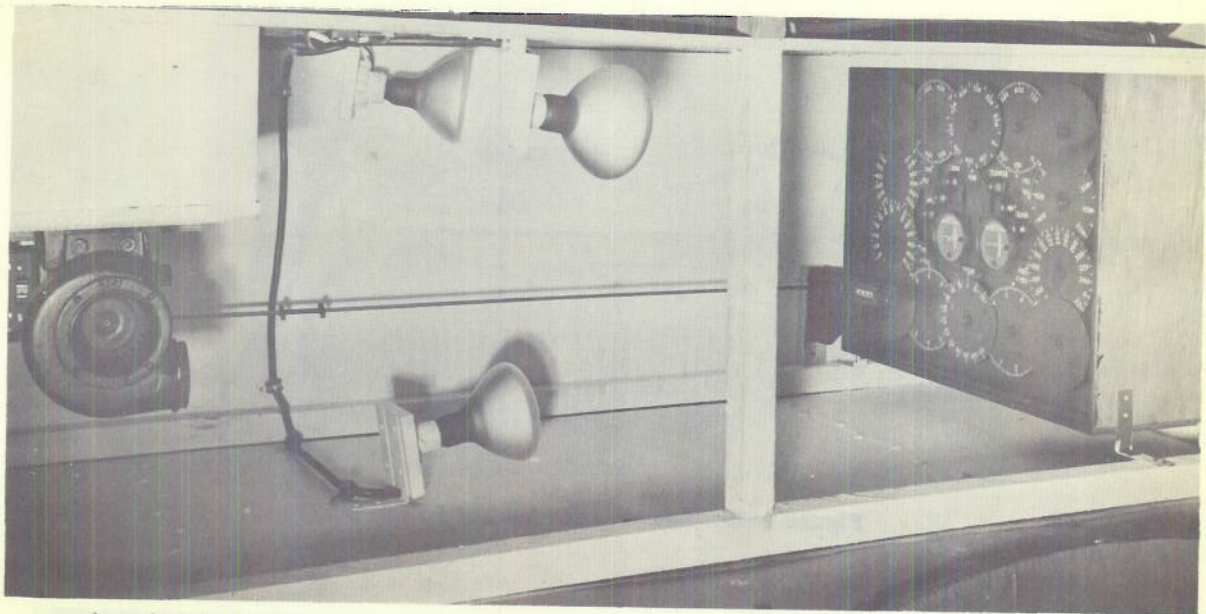


Figure 1-47. Data Recording Section - Showing Dial Box Unit, Photoflood Lamps, and Blower

tion; automatic train; pulse-time modulation; computer time motor; computer, local, and telescope. These data are recorded by a single 16mm motion picture camera synchronized with the tracking cameras by unit 8200.

2. Camera Control Unit, Unit 8200. (See figure 1-51.) - The operation of all cameras is controlled from the Camera Control Unit. All camera shutters are rotated by self-synchro-

nous motors supplied with power from this unit. The unit triggers all synchronizing flag lights. These lights are mounted in each camera so that, when the lights are energized at the beginning of a run, the film will be fogged for a period of five seconds. A synchronization point for all film is provided in this manner. Indicator lights in this unit will show continuity in flag light circuits by means of a bulb in series with each camera circuit. The unit includes a run-

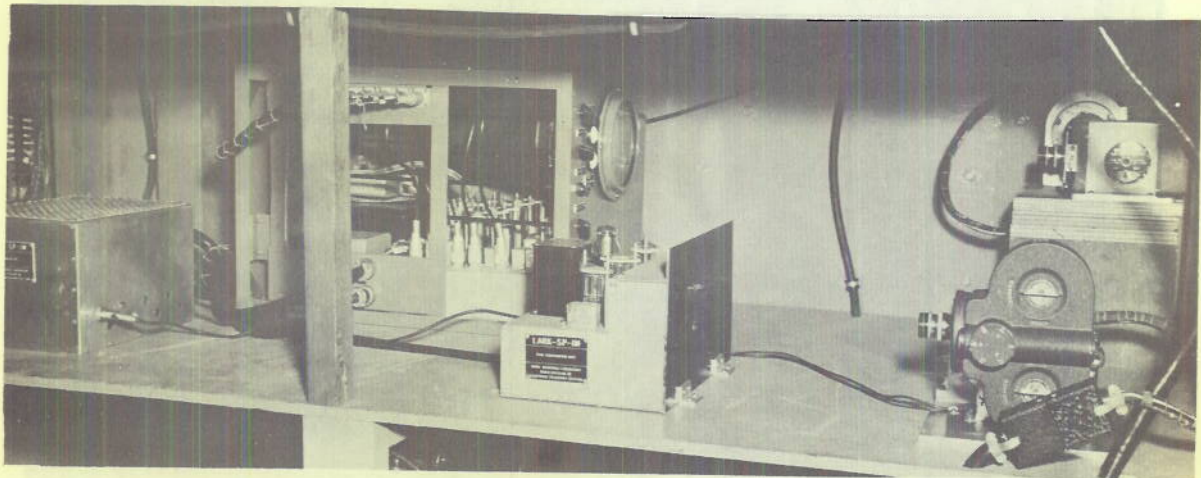


Figure 1-48. Data Recording Section - Showing Cameras, Time Comparator, and Remote Range Indicator

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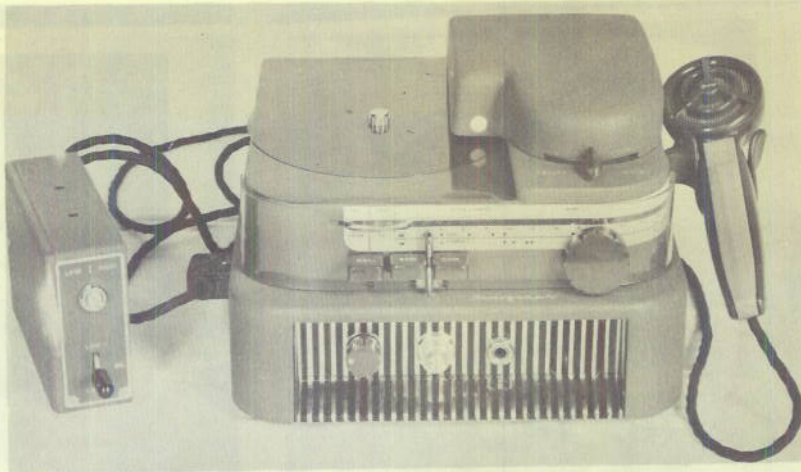


Figure 1-49. Sound Recorder and Switch Box

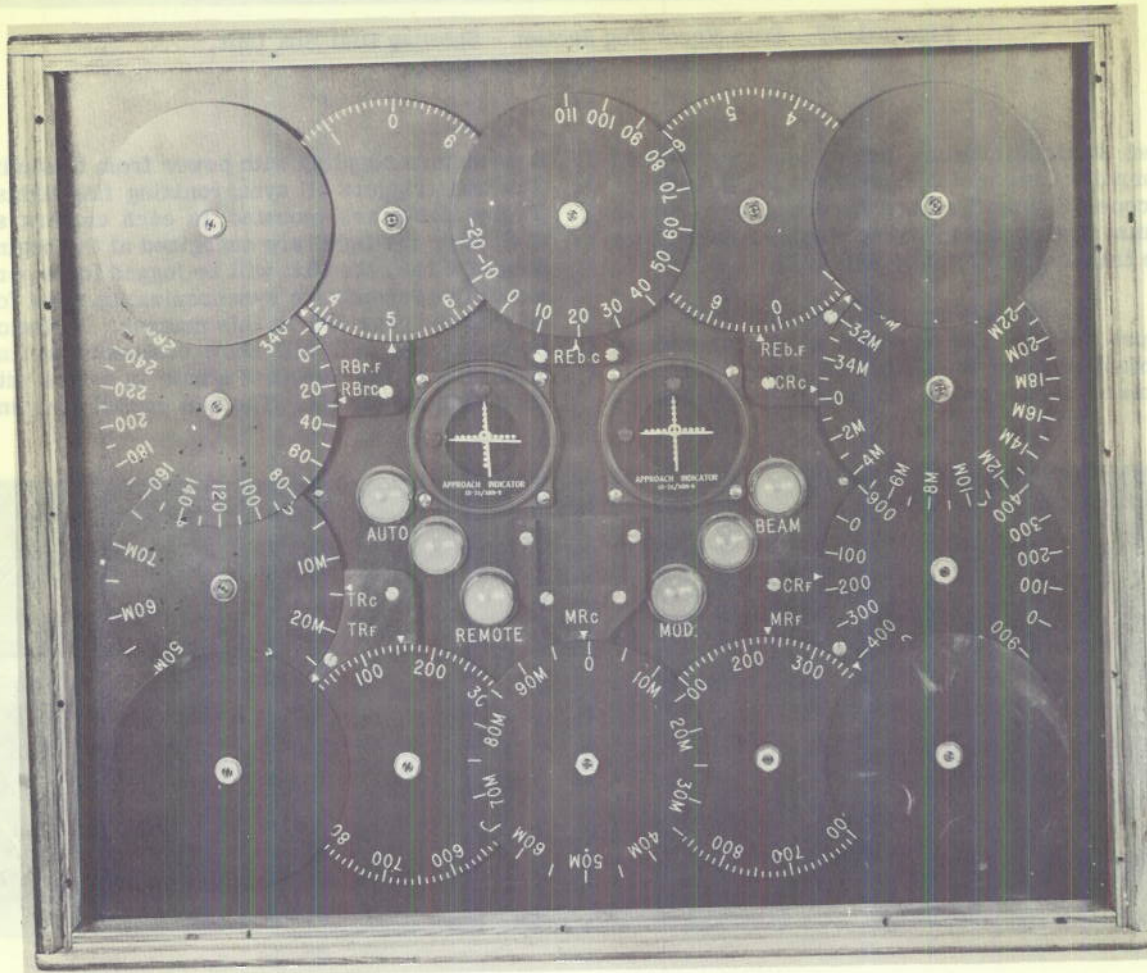


Figure 1-50. Dial Box Unit

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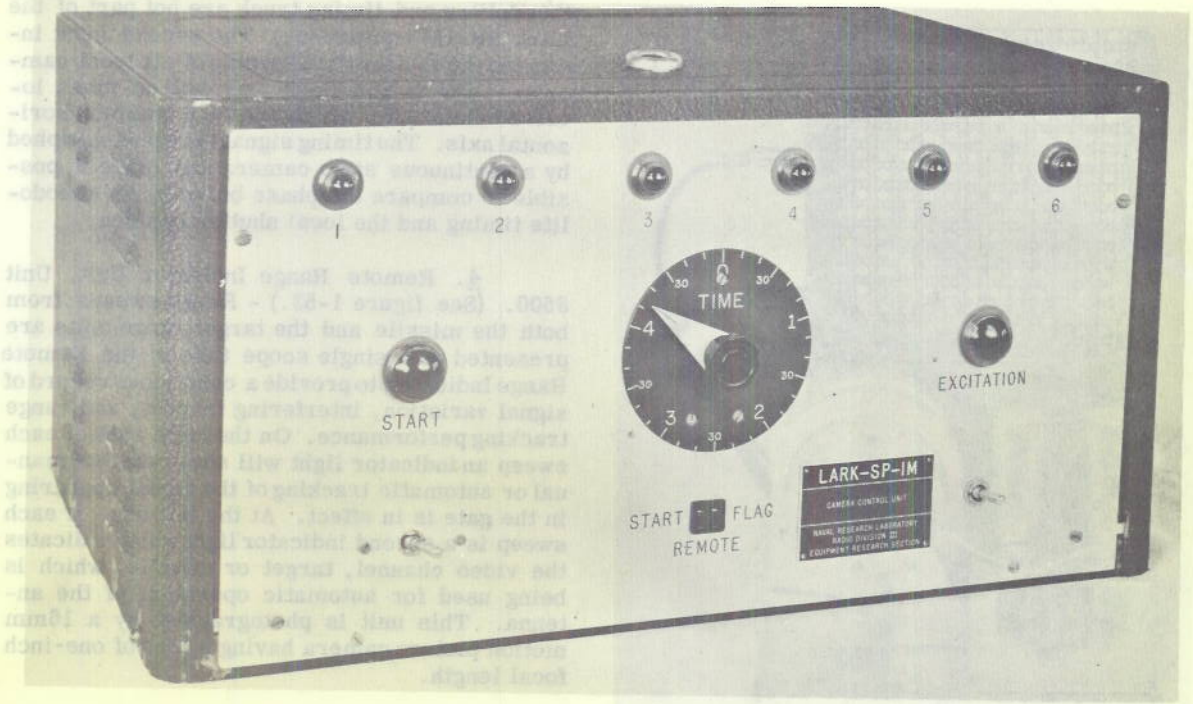


Figure 1-51. Camera Control Unit

time clock which is mounted on the front panel, to indicate the length of camera runs. A synchronous motor contained in this unit drives through a gear box a 7G synchro generator which in turn supplies power to 5G synchro motors driving the camera shutters. Various shutter speeds may be selected by changing the gear box ratio. Camera operation may be started either locally or by a remote control switch located on the System Control Switching Unit, Unit 1500.

3. Time Comparator Unit, Unit 8400.
(See figure 1-52.) - Two input timing signals

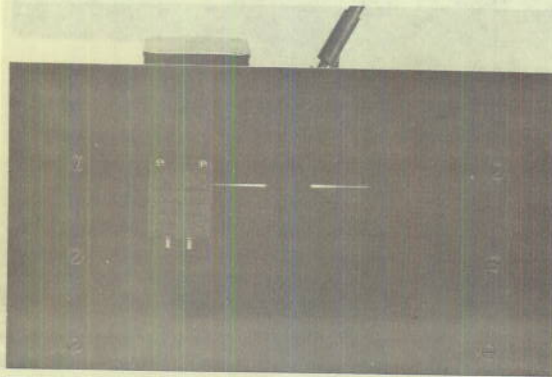


Figure 1-52. Time Comparator Unit

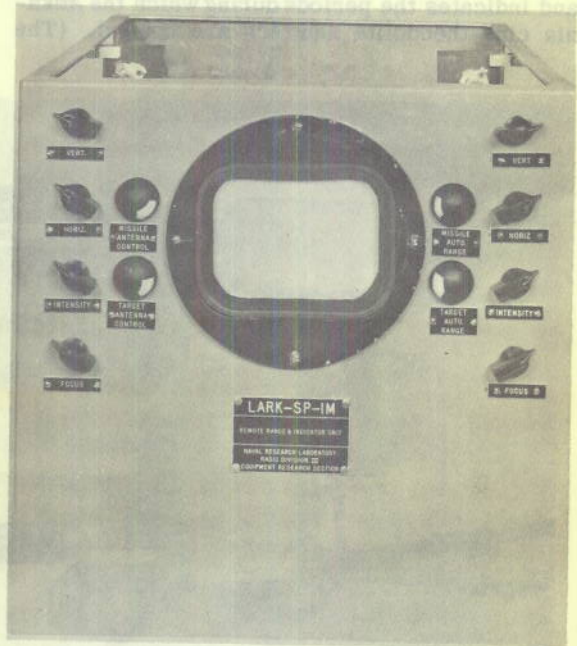


Figure 1-53. Remote Range Indicator Unit

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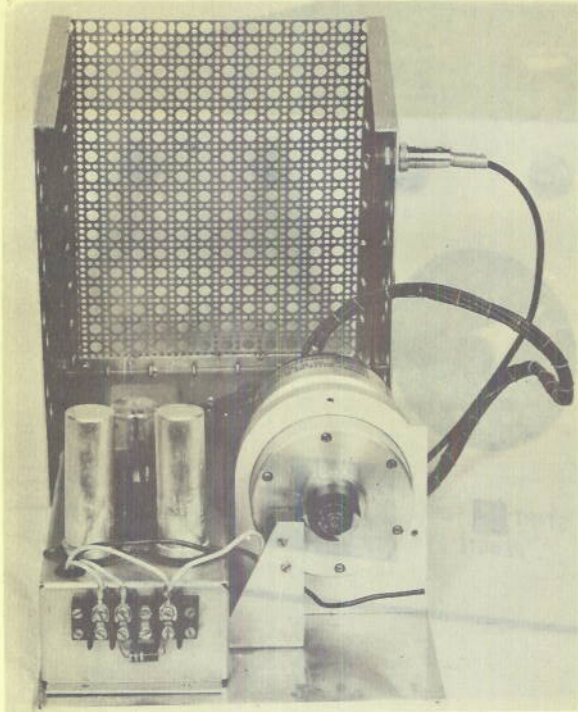


Figure 1-54. Commutator Unit - Cover Lifted

are received by the Time Comparator Unit. One of these originates at the test-range timing truck and indicates the periods during which the Askania cine-theodolite shutters are opened. (The

theodolites and timing truck are not part of the Lark SP-1M equipment.) The second input indicates the shutter time opening of all local cameras. The inputs flash strobotron tubes located behind slits which are on a common horizontal axis. The timing signals are photographed by a continuous strip camera and make it possible to compare the phase between the theodolite timing and the local shutter opening.

4. Remote Range Indicator Unit, Unit 8500. (See figure 1-53.) - Range sweeps from both the missile and the target range units are presented on a single scope tube in the Remote Range Indicator to provide a continuous record of signal variation, interfering targets, and range tracking performance. On the right side of each sweep an indicator light will show whether manual or automatic tracking of the signal appearing in the gate is in effect. At the left edge of each sweep is a second indicator light which indicates the video channel, target or missile, which is being used for automatic operation of the antenna. This unit is photographed by a 16mm motion picture camera having a lens of one-inch focal length.

5. Commutator Unit, Unit 8600. (See figure 1-54.) - The Commutator Unit consists of a commutator driven by a synchro motor to provide a timing pulse for the time comparator unit. The pulse is synchronous with the opening of all motion picture camera shutters.

6. Tracking cameras. (See figures 1-55 and 1-56.) - Two tracking cameras are located

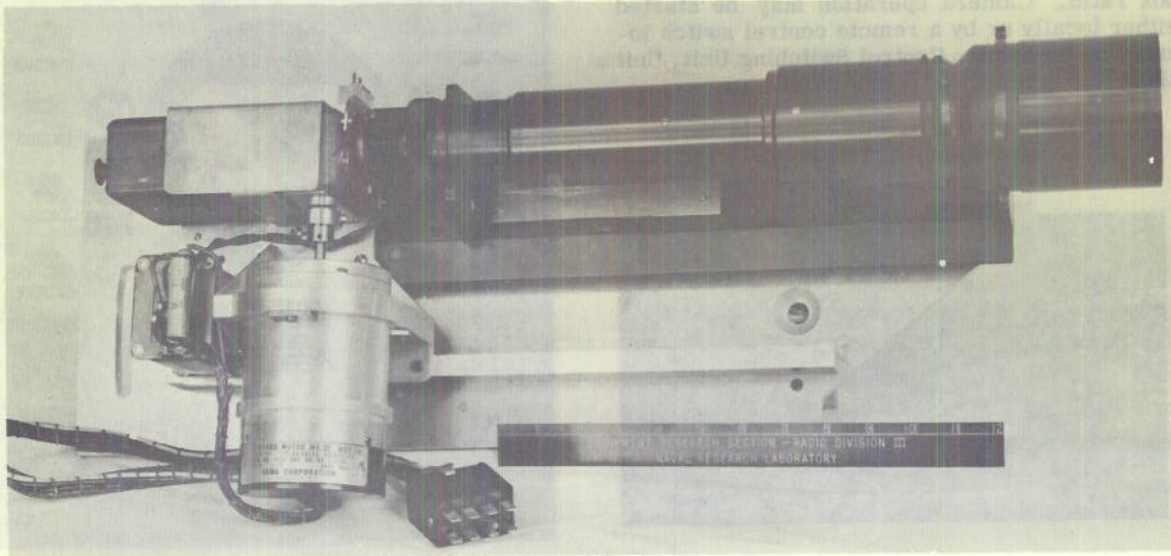


Figure 1-55. Main Tracking Camera - Unmounted

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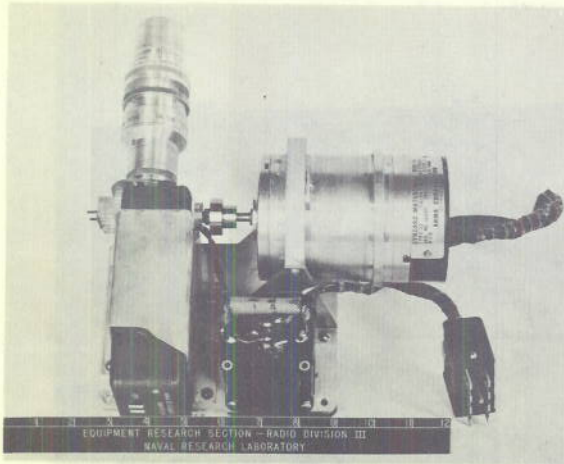


Figure 1-56. Auxiliary Tracking Camera - Unmounted

on the antenna dish. Both are 16mm cameras. One of these is equipped with a lens of 6-inch focal length to record a wide area about the target. The second camera may be equipped with a 10-, 15-, or 21-inch focal length lens to permit the recording of long-range target tracking.

d). Communications Section, Unit 4850. (See figure 1-57.) - The Communications Section consists of a telephone switchboard BD-72B; a medium-high-frequency radio equipment, TCS-12; and a very-high-frequency radio equipment SCR-624A; together with selector control units. The telephone switchboard, BD-72B, will connect all operators to provide individual or conference-type communication. Radio Equipment TCS-12 consists of a radio receiver and transmitter, operating in the 1.5- to 12-mega-cycle band. Radio Equipment SCR-624A con-

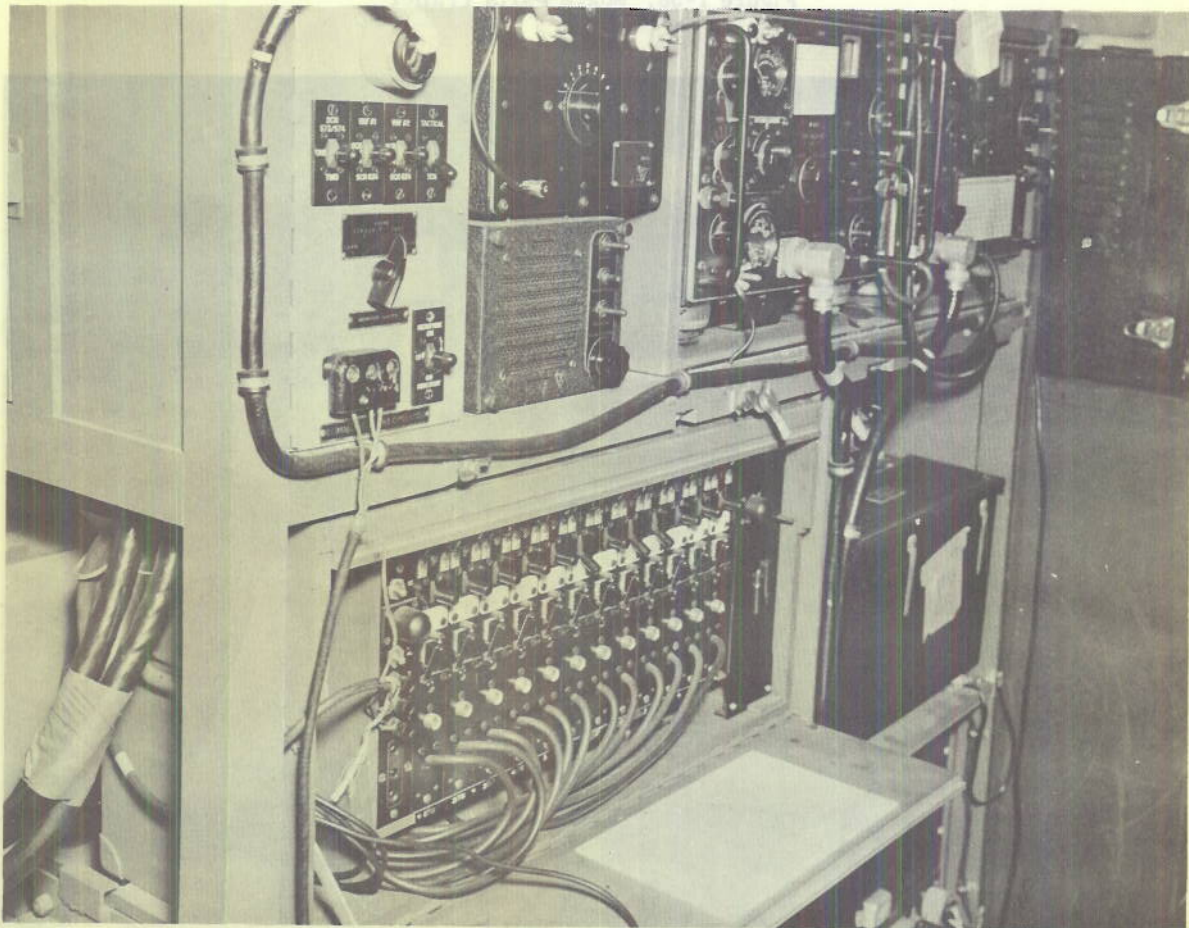


Figure 1-57. Communications Section

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Figure 1-58. Spare Parts Trailer

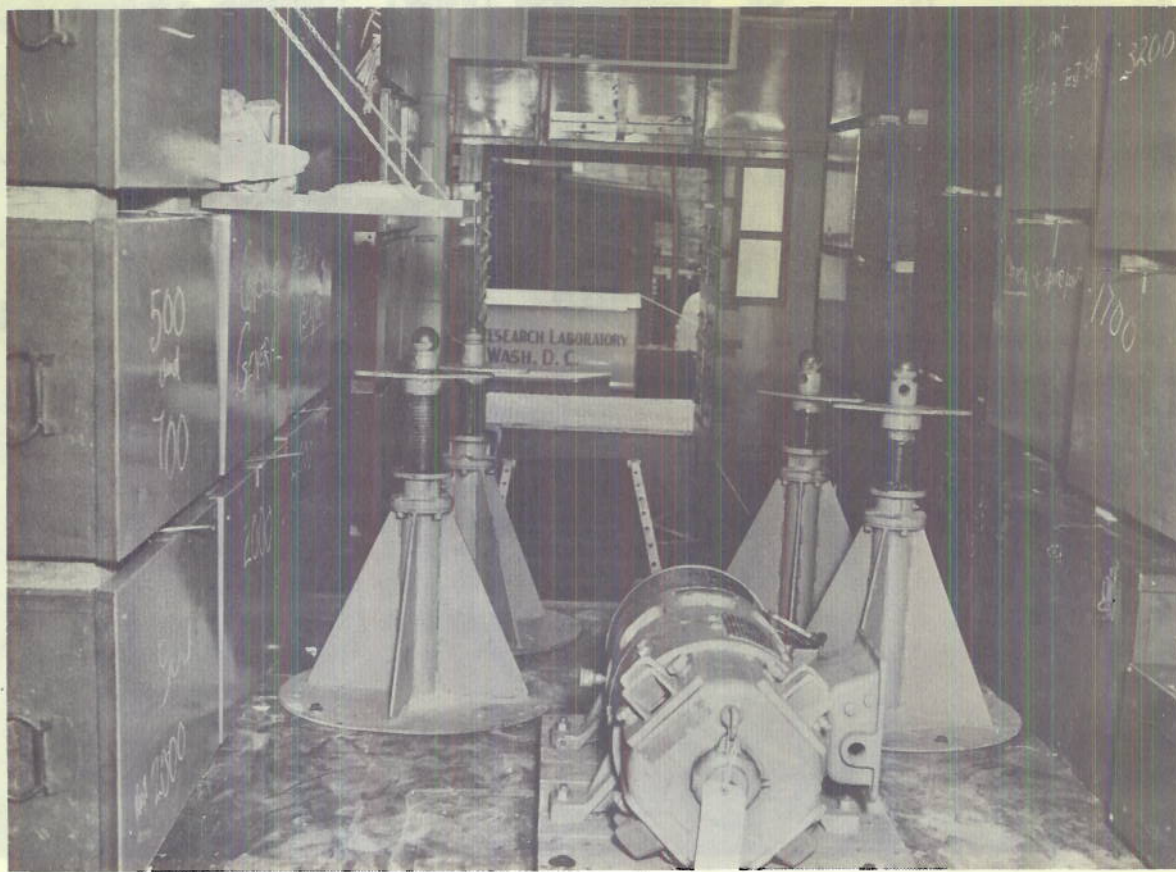


Figure 1-59. Spare Parts Trailer - Interior View

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sists of a four-channel VHF transmitter and receiver, operating in the 100- to 156-megacycle band. Both are used for communication with aircraft and control centers. All speech received or transmitted via the radio equipment is introduced into the telephone switchboard and can be monitored by all operators and recorded on a sound recording instrument. This equipment is located so as to be under control of the operators at the console assembly.

3). Spare Parts Trailer, Unit 7300. (See figures 1-58 and 1-59.) - The Spare Parts Trailer, Unit 7300, is a modified Navy Type CAHU-10305 trailer. This trailer is similar to the Operations and Equipment Trailers. It contains a complete set of spare parts for maintenance of the Lark SP-1M system. The parts are stowed in metal boxes racked in shelves along the sides of the trailer. A diagram showing the location of all parts is supplied.

4). Dehumidifier Units, Unit 5400. (See figure 1-60.) - The Dehumidifier Units are modified Navy Type CAHJ-10306 dehumidifiers. These two units are transportable air conditioning systems which connect with flexible ducts to the Operations and Equipment Trailers. When in use, they reduce operating temperature and humidity, and thus minimize equipment failures and personnel fatigue. Each unit consists of a York refrigerating unit of two-ton capacity driven by a five-horsepower, 220-volt, 60-cycle, three-phase motor. Transformers permit operation on either a 110-volt or 220-volt, 60-cycle, three-phase supply.

5). Power Unit, PE137, Unit 5300. (See figure 1-61.) - This unit consists of the power unit PE137-A mounted on a type CCKW353 (Army) truck. This unit can supply all current required for the operation of the Lark SP-1M system. Power unit PE137-A is a portable,

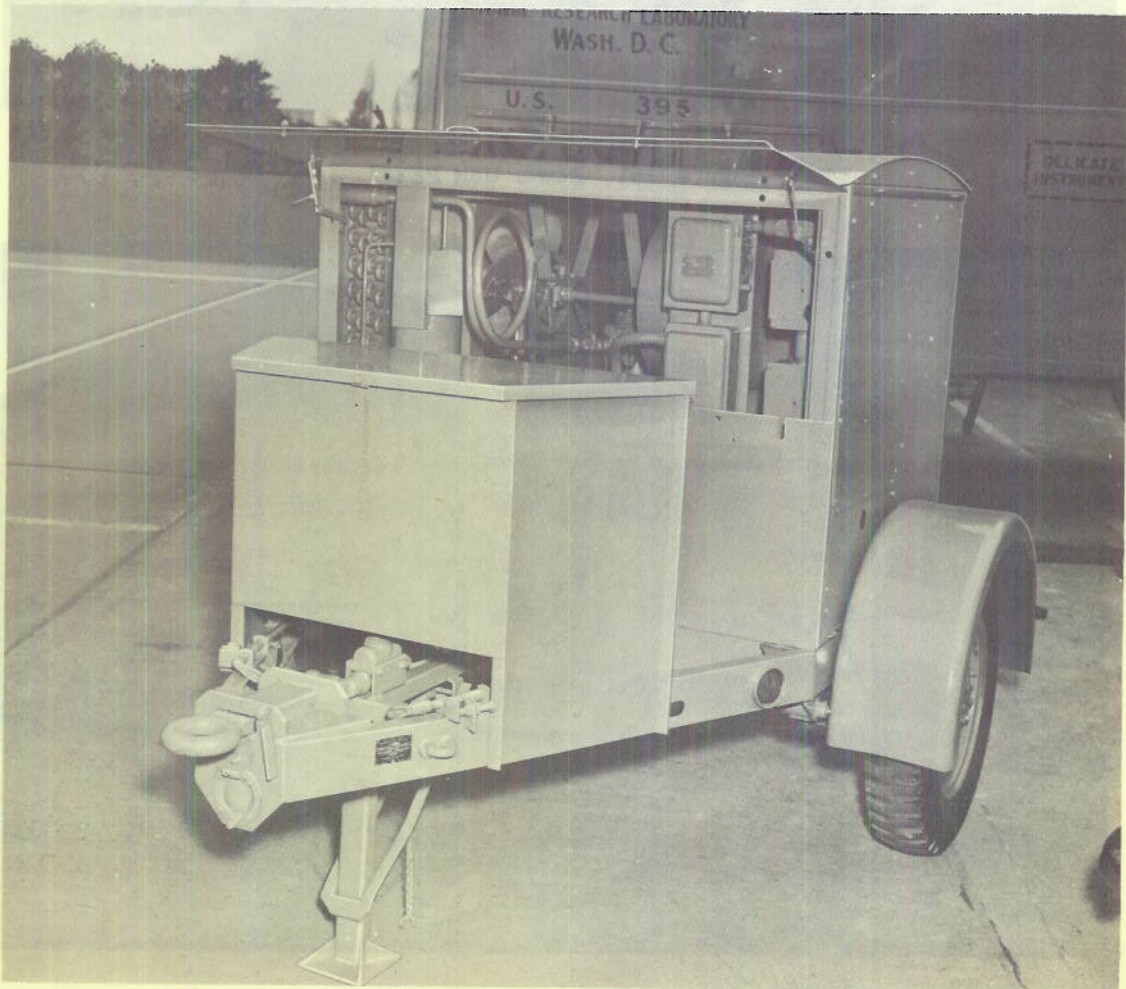


Figure 1-60. Dehumidifier Unit

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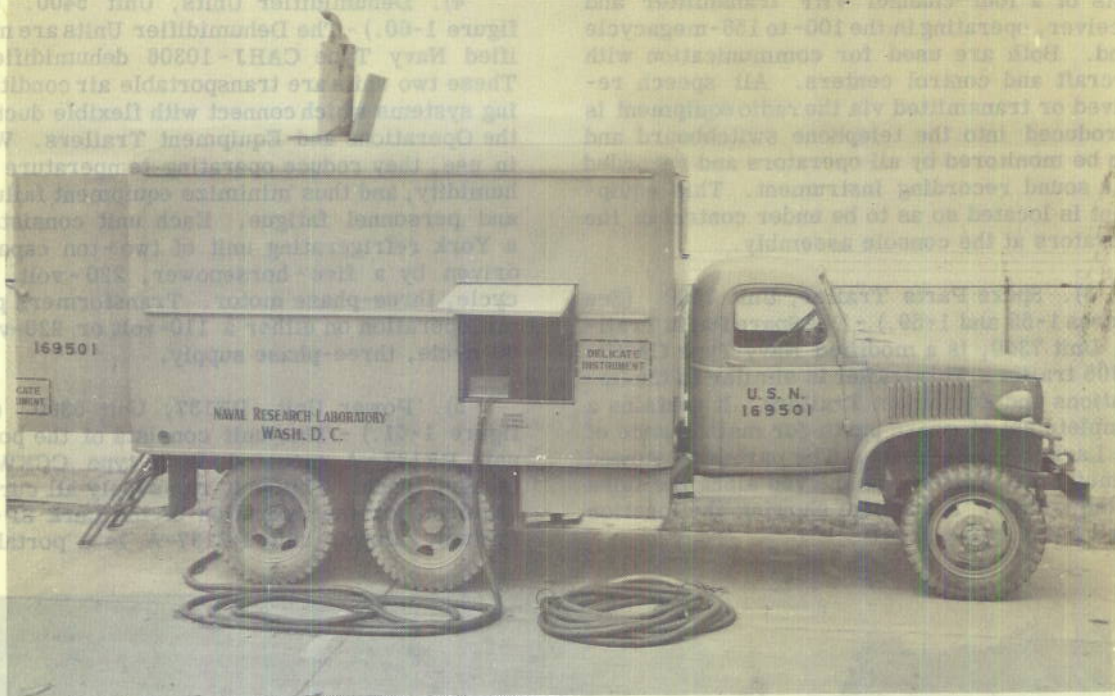


Figure 1-61. Power Unit PE137



Figure 1-62. Machine Shop Truck

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self-contained, gasoline electric power plant consisting of a four-cylinder gasoline engine connected to an alternating current generator. The a-c generator is a three-phase, four-wire generator of the revolving field type, rated at 120/208 volts, 60 cycles, 900 rpm, 31.3 kva at 80 percent power factor. A transformer bank converts the output of the generator to a three-wire, three-phase supply.

receives and demodulates station timing signals (used by cine-theodolite and other range timing equipment). In the Lark SP-1M equipment, these timing signals are recorded in the Time Comparator Unit, Unit 8400, together with locally originated timing signals, for reference in data recording and analysis.

6). Machine Shop and Timing Trucks. - Field installation of the Lark SP-1M will normally include, in addition to the trailers and major units already described, a mobile machine-shop facility and a timing and communications truck. The machine-shop truck is shown in figure 1-62. The timing and communications truck, supplied by the test-station,

c. Test Equipment. - Test equipment supplied with the Lark SP-1M is listed in table 1-4. All of the equipment except the Range Unit Bridge Adjuster, the Frequency Standard Unit and the Nutator Phasing Unit is available commercially. Instruction books for most of the standard test equipment are available from the equipment manufacturer and are identified by number in table 1-4. The standard test equipment is shown in figures 1-63 through 1-69. The three NRL equipments are described briefly below:

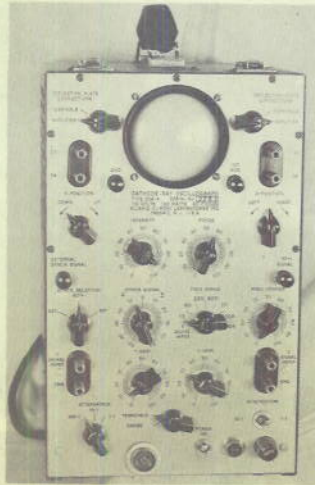


Figure 1-63. Oscilloscope - Dumont Type 224A



Figure 1-65. Portable Vacuum Tube Tester



Figure 1-64. Volt-ohm-milliammeter

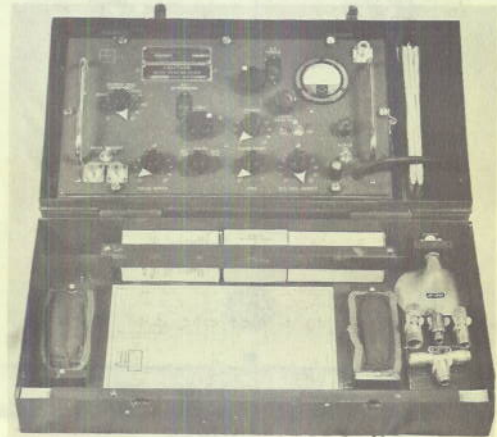


Figure 1-66. Signal Generator TS-155B/UP

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Figure 1-67. Synchro Test Unit Mk 2 Mod 3

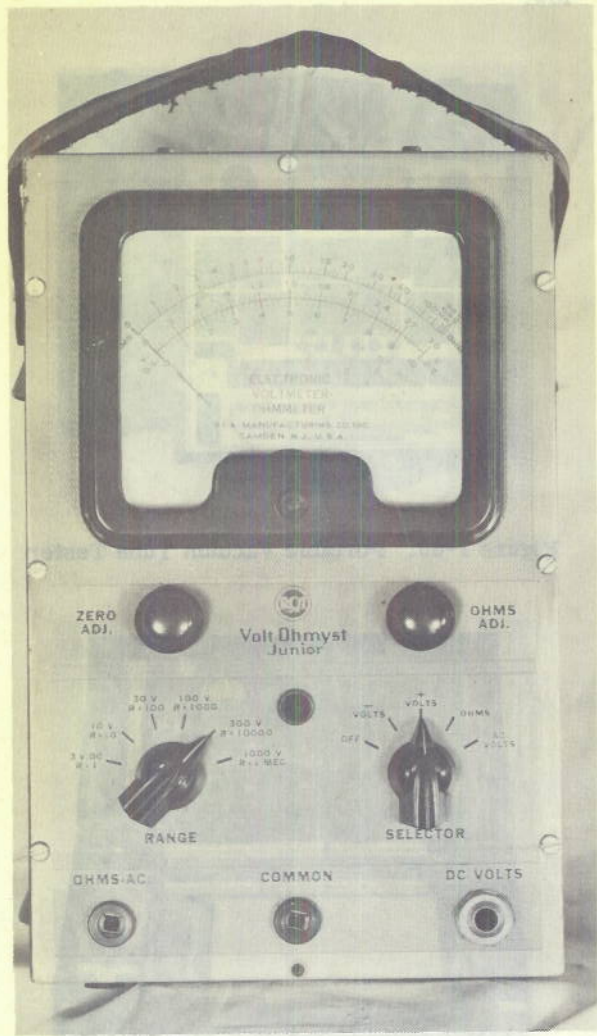


Figure 1-68. Volt Ohmyst Junior - RCA



Figure 1-69. Test Set 1E-36 (Army) - For SCR-624A

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Figure 1-70. Range Unit Bridge Adjuster

1). Range Unit Bridge Adjuster. (See figure 1-70.) - The Range Unit Bridge Adjuster is a variable impedance device designed for coupling an oscilloscope to various terminals in the range units without loading the circuit whose wave-form is being observed. It consists of cathode followers and a probe device.

2). Nutator Phasing Unit. (See figure 1-71.) - The Nutator Phasing Unit receives a 24-cycle signal from the reference generator. This signal is differentiated, and amplified, then used to key a General Radio Company "Strobolux" which in turn is used to illuminate the end of the nutating antenna. By means of this equipment it is possible to adjust the phase of the 24-

cycle modulation voltage relative to nutator position.

3). Frequency Standard Unit (Type FG-9 Frequency Generator). (See figure 1-72.) - The frequency standard unit is supplied to set, or to check, the 24 cps nutator scan rate, and the nominal 576 cps pulse repetition rate. Input to the unit is 115 volts ac at 75 watts, and outputs are 24 cps at 42 to 45 volts rms, and 576 cps at 45 to 53 volts rms.

4). Sixteenth Harmonic Frequency Multiplier. - The Sixteenth Harmonic Frequency Multiplier generates calibration pulses, spaced 62.5 yards apart in radar range, from the 164 kc timing wave in the range unit. It is used to check cyclic error in the Range Unit.

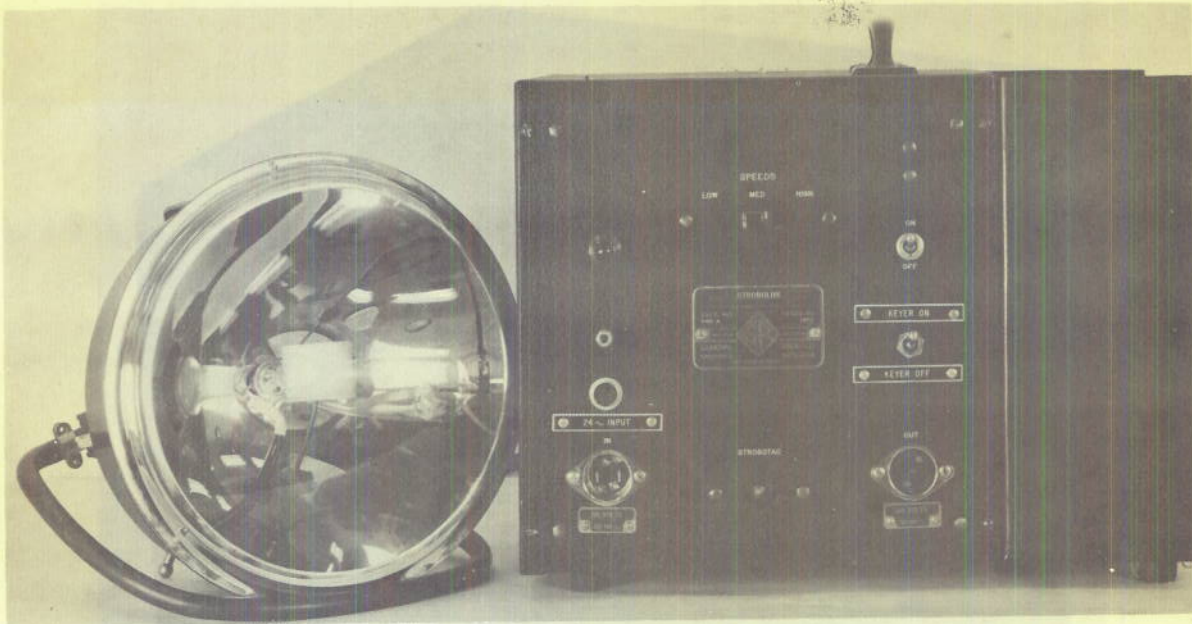


Figure 1-71. Nutator Phasing Unit

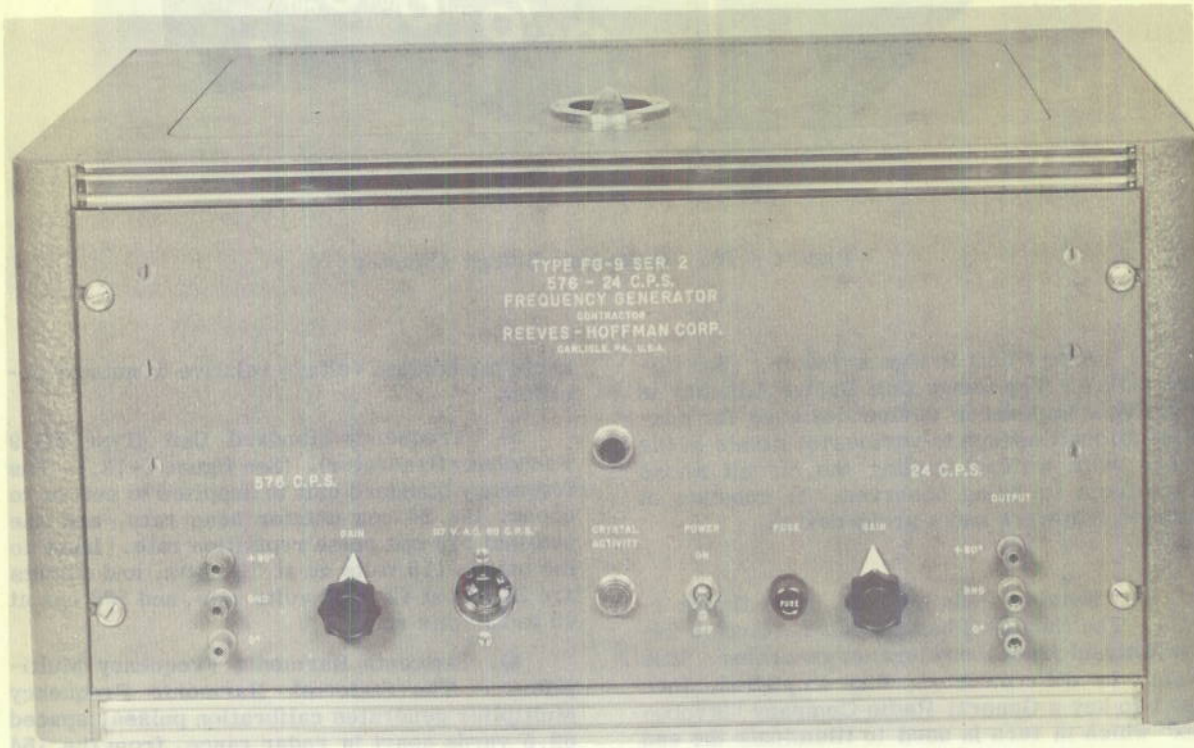


Figure 1-72. Frequency Standard Unit

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SECTION II
SYSTEM INTEGRATION

1. INTRODUCTION

a. Scope of Section. - This section contains a general discussion of the operation of the Lark SP-1M radar. Details of design and operation of individual units are not included here, but may be found in section III of this report. Three types of signals will be discussed in some detail. These are: (1) radar signals, (2) servo signals, and (3) synchronizing signals. Other voltages and currents will not be discussed. The paths of these signals are shown by distinctive lines on the functional block diagram, figure 2-1.

b. Basic Principles. - The fundamental principles of operation of the radar portion of the system are basically the same as those of any pulse radar system. Pulses of radio frequency energy are radiated from a highly directional antenna. Upon striking an object, some of the radiated energy is reflected back to the source of the pulses. The elapsed time between the transmission of the pulse and the return of the echo is a measure of the distance or range of the reflecting object. The angular position of the object is commonly determined by means of the directional antenna.

The Lark SP-1M radar performs three operations not included in the ordinary radar system. These are: (1) the automatic tracking in train, elevation, and range of a missile or target, (2) the provision of a radar beam containing intelligence which may be used to guide a missile along the beam, and (3) the simultaneous and independent automatic tracking in range of two "targets" which are not too widely separated in train or elevation. The latter function is made possible by almost complete duality in receiving, indicating, and range tracking circuits. Since the duality does not extend to the antenna, dual train and elevation tracking is not possible; however, a means is provided for continuously monitoring (within limits) the displacement from the radar beam of the second object being tracked in range. These three functions will be discussed briefly, before the signal path is traced through the equipment.

1). Automatic Train and Elevation Tracking. - Automatic tracking of a target in train and elevation is accomplished as follows: the radiated

beam is caused to describe a conical scan which results in amplitude modulation of the echo pulses received from any target which is displaced from the scan axis. The resulting amplitude modulated video pulses from the receiver, after selection by the range gate and clamping for the entire repetition period at nearly peak level, are supplied to coordinate detectors. In the coordinate detectors, separate comparison of the clamped video with each phase of a two-phase reference voltage takes place, and two d-c error voltages are developed -- one for each phase of the reference voltage. One of these d-c voltages is a function of the train component of target displacement, the other of the elevation component. The magnitude of the error voltage is a function of the magnitude of the target displacement and the polarity represents the sense or direction of the displacement. These voltages, through amplifiers and an amplidyne drive, are used to control the movement of the antenna in train and elevation. The antenna is driven in such a direction as to reduce the error voltages to zero. Since this process is continuous, the antenna automatically aligns itself so that the scan axis passes through the target (provided the antenna is initially aligned so that the target is within the beam). The target may be any object which produces a reflection or it may be a missile which contains a receiver and transmitter to produce a beacon signal. The frequency of the beacon signal must be different from but near the frequency of the radar transmitter.

2). Automatic Range Tracking. - Automatic range tracking is accomplished by using a servo-controlled delay circuit to produce a range gate. The time delay between the gate and the transmitter pulse is proportional to the range of the target. The range gate, which is of very short duration (1 microsecond) compared to the total repetition period, controls or gates one output of the receiver so that only the signal occurring during the gate is passed. The gated output of the receiver (in addition to its use in the train and elevation tracking circuits) is applied to a range detector which develops an error voltage which is proportional to the time difference between the target signal and the gate. The error voltage, after amplification, drives a servo motor which by varying the gate delay reduces the error voltage to zero.

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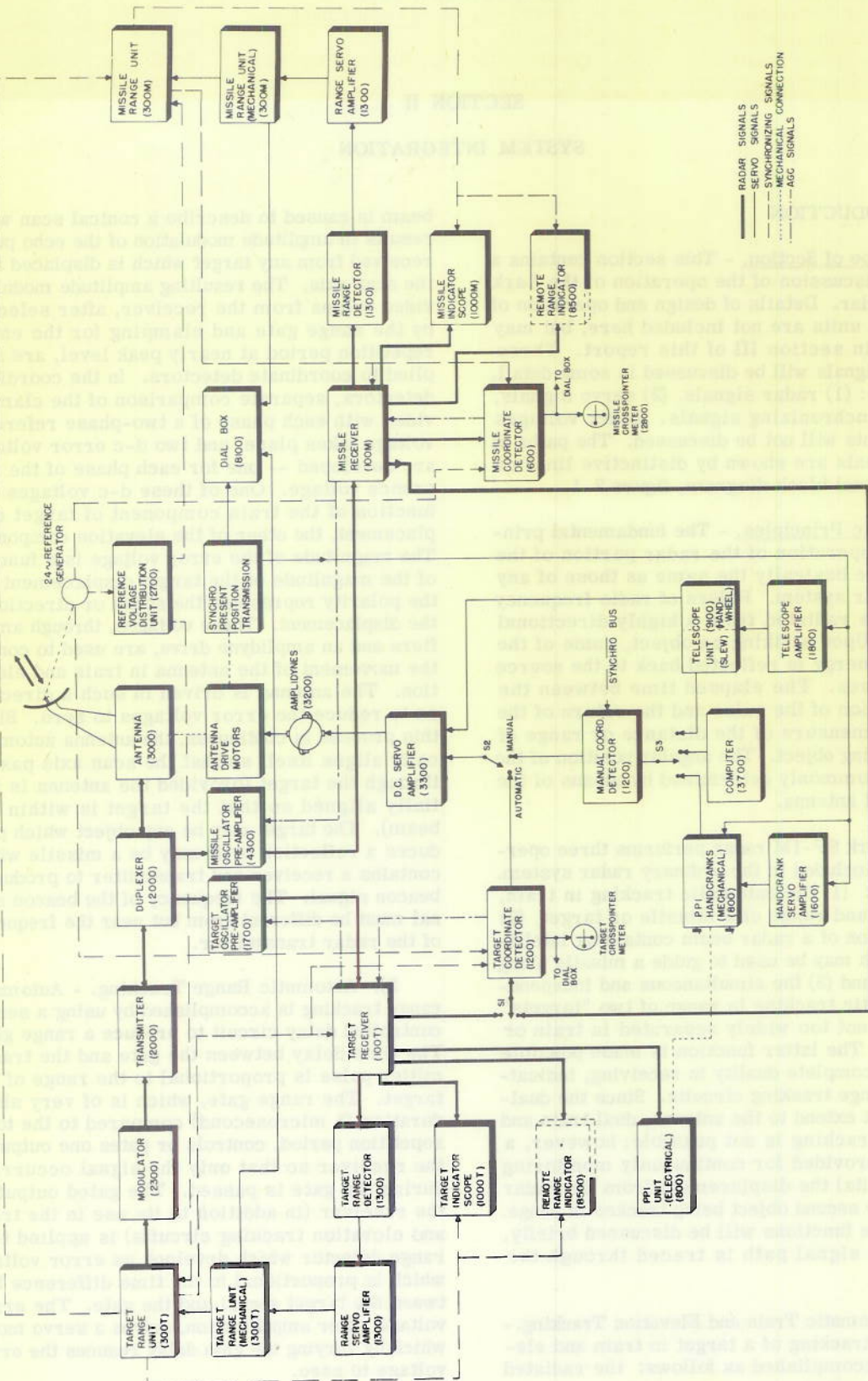


Figure 2-1. Lark SP-1M Radar - Functional Block Diagram

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3). Missile Guidance. - Guidance of a missile along the radar beam is accomplished by placing a receiver connected to a coordinate detector in a missile and using the error voltages developed to control flaps on the missile so as to move it to the center of the beam. When the missile is displaced from the center line of the conical scan, the pulses received are amplitude modulated in proportion to the amount of angular displacement. Frequency, or pulse-time, modulation of the repetition rate in phase synchronization with the movement of the nutator is used to give the missile-borne receiver the direction of the displacement. Any deviation develops an error voltage which will act to bring the missile back to the center of the beam. The beam may be held stationary or it may be moved to maneuver the missile in any desired manner within the ability of the missile to respond.

Because of the fact that the radar can simultaneously and independently track two targets in range, it may be used equally well for command guidance. That is, a target and a missile may be tracked and the path of the missile determined by use of a computer at the radar; command signals are then sent by means of the radar beam to place the missile on the desired collision course.

4). Dual Channel Functions. - Examination of figure 2-1 will show an almost complete duality of the target and missile channels as traced from the duplexer of unit 2000. There are two exceptions: (1) the PPI unit gives a presentation of the output of the target receiver only; (2) the target coordinate detector of unit 1200 is used to supply automatic drive to the antenna from either the target or missile receiver. That is, if a missile beacon is being tracked automatically, the output of the missile receiver can be supplied through the target coordinate detector to the antenna drive system. The duality of the system is summarized in the following chart:

<u>Target Channel</u>	<u>Missile Channel</u>
1. Target Oscillator Preamplifier, Unit 1700	1. Missile Oscillator Preamplifier, Unit 4300
2. Target Receiver, Unit 100T	2. Missile Receiver, Unit 100M
3. Target Indicator, Unit 1000T	3. Missile Indicator, Unit 1000M
4. Target Coordinate Detector, part of Unit 1200	4. Missile Coordinate Detector, part of Unit 600

<u>Target Channel</u>	<u>Missile Channel</u>
5. Half of Remote Range Indicator Presentation	5. Half of Remote Range Indicator Presentation
6. PPI Unit, Unit 800	6. Not present in missile channel
7. One chassis of Range Error Detector and Servo Amplifier, Unit 1300	7. One chassis of Range Error Detector and Servo Amplifier
8. Target Range Unit, Unit 300T	8. Missile Range Unit, Unit 300M (the missile range unit is slave to the target range unit insofar as the standard frequency is concerned)

2. TIMING SYSTEM

a. Target Range Unit, Unit 300T. - The Target Range Unit, Unit 300T, is the heart of the entire radar system. The unit performs three fundamental functions: it develops the pulse which keys the transmitter, it supplies gates or gate triggers to various portions of the system to permit or to prevent signals from passing through at a given time, and it supplies pulses to initiate sweep circuits throughout the equipment. In addition, the range unit contains components of the range servo system which will be discussed later in paragraph 4.

The target range unit contains a crystal oscillator having a frequency of 164,000 kc or period of approximately 6.1 microseconds. As will be explained in the detailed discussion of section III, this frequency leads to a slight, constant percentage error in the indicated range but has the advantage that it may be readily checked against the standard frequency transmissions of radio station WWV of the National Bureau of Standards. The output of the crystal oscillator is shaped into pulses and divided down to the mean pulse repetition rate of 576 pps in a series of blocking oscillators. The blocking oscillators are of the coincidence type and maintain the output in phase synchronization with the original 164-kc signal. A blocking oscillator also effects the 24-cps pulse-time modulation of the repetition rate. Truly sinusoidal pulse-time modulation of the repetition rate is, of course, incompatible with the synchronization of the output pulses with the crystal oscillator, for the syn-

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chronization requires that the output pulse move along the time axis in discrete steps which are integral multiples of 6.1 microseconds. This fact is of no practical consequence because of the great disparity of the frequencies involved.

The repetition rate of 576 pps gives a maximum range of about 140 miles without PTM. The crystal oscillator, through the frequency dividers and through fixed and variable delay circuits, controls and synchronizes the timing of the entire system. Important functions of the output of this section of the range unit are: the modulator trigger, the range gate trigger (delayed by servo-controlled variable delay circuits), and indicator triggers bearing various time relationships to the modulator trigger. Functions of the modulator and indicator trigger or keyer pulses are conventional. The delayed pulses, through the gating circuits (which are physically located in the receiver unit), perform more diverse functions:

- Control initiation of the range or R sweep.
- Initiate the range gate for range tracking.
- Control the gating of receiver i-f stages for elimination of unwanted signals and noise.
- Control the full - repetition - period clamping of gated video signals which are used to develop the 24-cycle voltage for train and elevation tracking and to develop the automatic gain control voltage.

b. Missile Range Unit. - The timing circuits of the missile range unit duplicate in every way those of the target range unit, except that usually this unit is slave to the target unit crystal oscillator. The modulator trigger output of this unit is not used.

3. RADAR SYSTEM

a. Hydrogen Thyatron Modulator, Unit 2300. - The input pulse to the Hydrogen Thyatron Modulator, Unit 2300, is fed into a pulse-shaper amplifier and is used to trigger the hydrogen thyatrons. The triggered thyatrons discharge an artificial transmission line developing high amplitude negative pulses. These pulses are used to key the transmitter.

b. Transmitter, Unit 2000. - The Lark SP-1M Transmitter, Unit 2000, consists of a magnetron coupled to the antenna by means of a waveguide. The plate of the magnetron is grounded, and the tube is made to oscillate by driving the cathode with the negative pulses developed in the modulator.

The power output of the tube is limited by the amount of power the plate is capable of dissipating as heat. By reducing the length of time that the tube oscillates, the peak power can be

increased. The peak power output of the magnetron exceeds 500 kilowatts but the duration of each pulse is approximately one microsecond.

c. Duplexer. - In common with many radar systems, the Lark SP-1M uses the same antenna structures for both transmission and reception. To protect the receiver from overload during a transmission pulse, a duplexer switch is used. Gaseous discharge tubes used in conjunction with the electrical equivalent of quarter-wave transmission lines act as the switch. During transmission the gaseous tubes ionize. This action effectively shorts the input of both the target and the missile receivers and the power output of the transmitter travels out the waveguide and is radiated from the antenna. Since, during reception, the power level is so low that the tubes do not ionize, the power picked up by the antenna is transferred to the receivers and at the same time the circuit to the transmitter is effectively short-circuited by another unfired gas tube.

When the radar is turned off and no voltages are present to operate the duplexers, nearby radar sets could damage the crystal input to the receivers. To prevent this, mechanical shutters close the openings from the waveguide to the input of the receivers.

d. Antenna Assembly, Unit 3000. - The power traveling through the waveguide past the duplexer strikes a dipole antenna and reflector at the end of the waveguide. The energy is radiated from this antenna to the surface of a metal parabolic reflector. The resulting transmitted energy is a beam which is highly directional but much too wide for accurate target location. Accuracy of target location is greatly improved during actual target tracking by nutating the waveguide feed and dipole antenna in front of the parabolic reflector. In this motion, the dipole antenna describes a small circle about the focus of the paraboloid reflector (without changing its angle of polarization) and, in consequence, the radiated beam describes a cone about the axis of the reflector which remains fixed relative to the rotation. This is shown diagrammatically in figure 2-2. The axis of the reflector passes through the center of the circle in figure 2-2. This line is also the axis of rotation of the radiated beam or lobe. A target anywhere along this line will reflect the same amount of energy, regardless of the instantaneous position of the lobe. If the target moves from the center toward T in the diagram, more energy will be reflected when the beam position is near T than when it is near T + 180 degrees. The result is amplitude modulation of the reflected signal at the frequency of nutation. The magnitude of the resulting modulation will depend upon how far the target has

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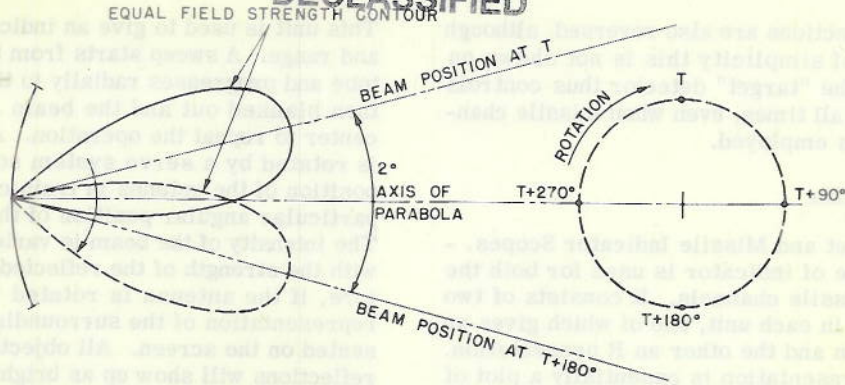


Figure 2-2. Rotation of Radiated Beam

moved from the center of the circle. A target at T will, of course, produce a modulation of the same magnitude as it would at T + 180 degrees, but the phase of the modulation would be reversed. Similarly, targets located at other points on the circle will produce modulation proportionately displaced in phase from that produced at T. If, therefore, the position of the nutator is known at the instant the modulation reaches its maximum, then the direction of target displacement can be determined. This is accomplished as follows: the motor which drives the nutator at 24 cycles per second also drives a two-phase generator, the output of which -- also at 24 cycles per second -- bears a fixed phase relationship to the instantaneous position of the nutator. Thus each point in a cycle of the generator output voltage corresponds to an instantaneous position of the radar beam in space. For example, position T on figure 2-2 may correspond to zero generator voltage (of one phase). Then T + 90 degrees may be the peak positive voltage, T + 180 degrees would again be zero voltage and T + 270 degrees would be the peak negative voltage. This 24-cycle reference voltage is supplied through an amplifier to the target coordinate detectors where, as will be explained later, d-c error voltages for driving the antenna are developed by comparison of the reference voltage with the amplitude modulated echo pulses received from the target. The 24-cycle reference voltage is also supplied through a phase shifter and amplifier to the range unit for frequency modulation of the repetition rate and to telemetering equipment.

e. Local Oscillator Preamplifier and Receiver. - The reflected signal from a target is received by the antenna and is passed through the duplexer and local oscillator preamplifier into the target receiver. The target receiver is tuned to the radar frequency by changing the

local oscillator frequency to obtain the desired intermediate frequency. The oscillator is of the reflex klystron type. Coarse tuning is accomplished by varying the size of the cavity surrounding part of the klystron tube. Fine tuning is accomplished by varying the voltage on the klystron repeller plate. Automatic frequency control is accomplished in the receiver by beating the transmitted signal with the local oscillator signal. The output is applied to an i-f amplifier which in turn supplies the input signal to a discriminator. The output of the discriminator controls the voltage applied to the repeller plate of the local oscillator klystron so that the required intermediate frequency is produced.

Following the crystal mixer and oscillator are a number of intermediate-frequency amplifier stages arranged to amplify in two channels. One of these channels is ungated and the other is gated by the gate received from the range unit so that only the signal occurring during the gate is amplified. Each i-f channel feeds a second detector which is followed by video amplifiers and cathode followers as necessary. Outputs from the target receiver are sent to the target range detector (gated), the PPI unit (ungated), the target indicator scope (ungated), the remote range indicator (ungated), and the target coordinate detector (gated). The range gate, properly shaped and delayed, is supplied to the range detector and target coordinate detector and to the indicators. Automatic gain control of several of the i-f and one of the video stages is provided, utilizing a voltage produced from the gated video signal in the coordinate detector unit. If missile-channel tracking of the antenna in train and elevation is used, the target receiver output to the target coordinate detector is switched to the missile coordinate detector and the target detector receives its input from the missile receiver.

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The AGC connections are also reversed, although for the sake of simplicity this is not shown on figure 2-1. The "target" detector thus controls the antenna at all times, even when missile channel tracking is employed.

f Indicators.

1). Target and Missile Indicator Scopes. - The same type of indicator is used for both the target and missile channels. It consists of two oscilloscopes in each unit, one of which gives an A presentation and the other an R presentation. The type A presentation is essentially a plot of target range against target amplitude (though not true target amplitude since AGC is used). In this type of presentation, the entire range covered, from transmitter pulse to 100,000 yards, is presented along the horizontal trace and the transmitter pulse and echo pulses are shown as vertical pips. The horizontal distance between the transmitter pulse and the echo pip is a measure of the range to the target. The A-scope sweep is initiated by a trigger from the range unit. The output of the receiver produces the vertical deflection. The sweep trigger precedes the transmitter trigger by an amount sufficient to allow the transmitter pulse to be shown on the indicator screen.

The R-type presentation also shows range on the horizontal axis against target amplitude on the vertical. However, the R sweep displays only an expanded 2000-yard (12.2-microsecond) segment of the range covered by the A scope. The sweep trigger is derived from the delay circuits that determine the position of the range gate, as described above, and the sweep is therefore controlled by the range tracking circuits, manual or automatic. The sweep trigger is timed to occur about six microseconds before the range gate. Hence, the range gate, which is displayed on the R scope so as to produce a downward deflection or notch in the trace, always appears at about the center of the screen. The expanded R sweep facilitates precise ranging on target or missile echoes or the placing of a selected echo in the range gate for automatic tracking.

These A and R indicators show range only and not train or elevation.

2). Remote Range Indicator. - The function and operation of the remote range indicator will be discussed in connection with the data recording equipment, paragraph 8 of this section. It is essentially an R presentation of both target and missile signals on a double-gun oscilloscope.

3). PPI Unit, Unit 800. - Another output of the receiver is applied to the PPI Unit, Unit 800.

This unit is used to give an indication of bearing and range. A sweep starts from the center of the tube and progresses radially to the outside. It is then blanked out and the beam returned to the center to repeat the operation. A deflecting coil is rotated by a servo system so that any given position of the antenna in train corresponds to a particular angular position of the radial sweep. The intensity of the beam is varied in accordance with the strength of the reflected signal. Therefore, if the antenna is rotated continuously, a representation of the surroundings will be presented on the screen. All objects which produce reflections will show up as bright spots. The intensity of the spot will depend upon the strength of the reflected signal.

Range is represented by the distance from the center of the tube screen to the edge. The scale can be varied by changing the sweep time while keeping the sweep length constant. If the sweep time is reduced, the range is decreased. A system is provided for initiating the PPI sweep at the same time as the target R sweep. This condition is used for minute examination of the area surrounding a long range target and is called "delayed trigger" operation.

One limitation of the PPI is that it does not give an indication of elevation. If the elevation of the antenna is zero, the PPI gives a picture of all targets in a horizontal plane. If the elevation is not zero, targets will be shown which lie in a cone-shaped surface having an included angle of 180 degrees minus twice the elevation angle of the antenna.

Handwheels and components of a servo system for control of the antenna in manual tracking and search are located in the PPI Unit. These portions of the PPI Unit will be described in paragraph 5 below.

4. RANGE TRACKING SYSTEM

The target range detector compares the gated output of the receiver with the range gate and develops a d-c signal proportional to the time displacement of the video from the gate. The polarity of the output signal indicates whether the video is early or late and the amplitude is proportional to the magnitude of the displacement. (The source of the range gate is the target range unit, via shaping and delay circuits in the receiver.) The d-c output of the target range detector is applied to a balanced modulator which produces a 60-cycle suppressed-carrier-type servo signal. This signal is amplified and used to operate the tracking motor of the target range unit. The motor shifts the position (in time) of the range gate to coincide with the position of the video and

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moves the range counter and dial. The range of the target, in yards, can be read from the counter and dial. Tachometer feedback around motor and amplifier is employed and means are provided for slewing and manual tracking in range. The range unit must, of course, be set to the approximate range of the target before automatic tracking can commence. This is done by positioning the video signal in the gate with the slew and manual controls, as observed on the R scope of the target indicator unit, and then throwing a switch to the AUTOMATIC position.

5. TRAIN AND ELEVATION TRACKING SYSTEM

a. Target Coordinate Detector. - If the position of switch S1 (figure 2-1) is correct, the target receiver will supply an input to the target coordinate detector. There is also a two-phase input from the 24-cycle reference generator which is operated by the antenna drive motor. The outputs obtained are two d-c voltages, representing X and Y components. The polarity of the X and Y components shows the particular quadrant in which the target is located.

The component voltages are fed to a cross-pointer meter unit. This unit consists of two zero-center meters whose pointers, with zero deflection, are at right angles to each other and cross at the center of the face of the instrument. Within limits, the indications of the cross-pointer meter show the position of the target with respect to the axis of the transmitted beam. A similar meter is contained in the dial box.

b. Antenna Positioning. - The train and elevation angles of the antenna are varied by means of d-c motors and gear trains. The advantage of using d-c motors is that the large amount of power required can easily be supplied by use of amplidynes. The antenna can turn continuously in train but is limited to approximately 90 degrees in elevation. Limit switches are provided to prevent damage to the gear train or motor at maximum elevation.

The train and elevation motors require considerable power to move the antenna at the desired rate. Since vacuum tube amplifiers are not practical for this purpose amplidynes are used to supply the required d-c power. The amplidyne is a special type of motor generator whose d-c output power is a function of the field excitation and whose response to changes in field excitation is rapid. The source of power controlled is the a-c power used to drive the motor generator. Because of the method of connecting the field coils with respect to the armature, only a few watts applied to the field coils can control several hundred watts of d-c output power. The

polarity of the output can be reversed by reversing the polarity of the voltage applied to the field.

A d-c amplifier is used to supply the d-c power required for the field coils of the amplidyne.

c. Automatic Tracking. - When the output of the target coordinate detector is supplied through switch S2 to the d-c amplifier, the amplidynes, and the antenna drive motors, the radar tracks the target automatically. Any misalignment between the beam and the target will set up error voltages which will drive the elevation or train motor in such a direction as to reduce the voltage to zero.

The one-microsecond range gate selects the target echo to be tracked in train and elevation as well as in range as previously described in paragraph 4. When the range indicator is set to the approximate range of the target, the return signal occurs simultaneously with the range gate and is applied to the coordinate detector to provide train and elevation error signals while signals not occurring during the range gate are blocked and do not affect the automatic tracking circuits. If, however, two targets are within the gate, there is a possibility that the radar will track the one having the stronger echo provided the velocities of the two targets are approximately equal.

The output of the missile receiver may be fed into the target coordinate detector through switch S1 on figure 2-1, so that the radar may automatically track the missile. This operation is identical to that using the target channel except that the PPI does not properly display the tracked missile.

d. Manual Tracking - Telescope. - When S3 on figure 2-1 is at the telescope position, the antenna can be controlled from the telescope. Error signals developed by operating the slew sight or the telescope handwheels are applied through the manual coordinate detector, the servo amplifiers and amplidynes or through the servo amplifiers and the amplidynes to the antenna drive motors which move the antenna in such a direction as to reduce the error signal. The difference in voltages developed by synchro generators mechanically connected to the antenna drive motors and synchro control transformers connected to the telescope drive motors is applied through the telescope amplifier to drive the telescope until it points to the same angular position as the antenna. In this way, if the crosshairs of the telescope are centered on the target, the center of the radar beam will also be on the target, neglecting parallax. This method of operation is limited to

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relatively short distances because of the optical limitations of the telescope.

There are two methods of training the telescope on the target. One method is to use an open slew sight. The slew sight is connected to two potentiometers whose axes of rotation are mutually perpendicular. If the slew sight is held on the target, voltages are developed which are combined with the 60-cycle reference voltage in the manual detector to develop error voltages. These are applied through the servo amplifiers and amplidyne to drive the antenna in train or elevation until the error voltages are zero.

The second method of training the telescope is to use the handwheels on the side of the telescope column to develop error signals to bring the antenna on target. These handwheels turn tachometer generators which are connected in parallel with the train or elevation feedback tachometers on the antenna mount. The telescope handwheels thus provide direct position control of the antenna mount through the amplidyne drive system. The movement of the telescope itself is effected through synchro transmission from the antenna. The telescope tachometers are switched out when control from the telescope handwheels is not desired.

e. Manual Tracking - PPI. - If switch S3 (figure 2-1) is thrown to the PPI position, the antenna can be moved in train or elevation by use of the handwheels on the front of the PPI unit. The position of the target may be observed on the PPI screen or on the target or the missile indicator scopes.

In this mode of operation the handcranks drive control transformers which develop voltages that are combined with the 60-cycle reference voltages in the manual detector to develop d-c error voltages for driving the antenna.

f. Handcrank Amplifiers and Telescope Amplifiers. - When the antenna is tracking automatically or when it is rotating continuously, it is desirable that the handwheels on the PPI unit and the optics of the telescope unit follow the antenna. This is accomplished by the use of the synchro present position transmission as shown in figure 2-1. Synchro generators, mechanically coupled to the antenna drive motors, are electrically connected to control transformers which are geared to the handcranks of the PPI unit and to the telescope column and elevation prisms so that error voltages are developed if the handcranks and telescope are not aligned with the antenna. The error voltages are amplified and supplied to the motors which drive the handcranks and telescope. In this way the telescope and handcranks are al-

ways kept in alignment with the antenna so that control may be rapidly transferred from automatic to manual or telescope without development of large error voltages.

g. Synchro Motors, Synchro Generators and Control Transformers. - When a synchro motor is driven by a synchro generator, the rotors will be perfectly aligned if one assumes zero load on the motor. (This load includes all friction.) The position of zero angular error between generator and motor is also the position of zero torque. When the angular error is 90 degrees, the torque tending to reduce the error is at maximum. In any practical system there will be a load on the motor and hence an angular error. One method of reducing this error is to use a gear train so that several revolutions of the motor are required to give one revolution of the output shaft. The error is reduced in proportion to the gear ratio. A 36-speed synchro, for example, should have 1/36th the angular error of a 1-speed synchro, neglecting added friction and backlash in the gears. A 36-speed synchro develops considerably greater torque for a small angular error, say 1° , than a 1- or 2-speed synchro develops for the same angular error. A serious defect is that the synchro motor can lock in at 36 different positions with respect to the output shaft. Thus the output information supplied from the motor can be greatly out of alignment with the input information unless the angular error is kept very small (less than approximately 10 degrees).

In the Lark SP-1M this problem is solved by using a built-in vacuum tube voltmeter which constantly measures the error voltage. When the error voltage is large (corresponding to more than approximately 2.5 degrees), the 1-speed synchro is connected. When the error becomes smaller than 2.5 degrees, the plate current through the voltmeter tube changes so that the 36-speed synchro is switched in and the error is reduced to a few minutes of angle. Switching from 1-speed to 36-speed synchros at an error voltage corresponding to 2.5 degrees rather than 10 degrees removes the possibility of the system locking in 10 degrees out of alignment. The shift from 1-speed or 2-speed to 36-speed and back again is entirely a function of the magnitude of the error voltage.

A 1-speed synchro is used on the train motor and a 2-speed synchro is used on the elevation motor since the elevation travel of the antenna is only 90 degrees. The system can be locked in the 36-speed position if desired.

The range unit uses 1000 yd./rev. and 100,000 yd./rev. synchros for coarse and fine range.

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The synchro generator and motor are fundamentally alike. They differ only in application. Because the synchro generator is always mechanically driven its bearings can have more friction than synchro motors. Further, the generator does not require a damper to prevent oscillations. Synchros are built and tested. Those which have the lower friction bearings have dampers added and are used for motors, the others are used for generators.

Control transformers differ from synchros in that the output is a voltage whose amplitude and phase depends upon the rotor position and upon the voltage applied to the stator. The impedance of the stator and the rotor windings are high enough to be used with vacuum tube amplifiers. The rotor of a control transformer is always mechanically driven so that dampers are never required.

h. Tachometer Feedback. - Tachometer feedback, although not shown on the block diagram (figure 2-1), is employed in all servos of the Lark SP-1M system. D-c tachometers are employed in the train and elevation antenna drive servos and in the range servo (although the latter uses an a-c motor and amplifier). A-c tachometers are used in the telescope and handcrank servos. (The d-c tachometers coupled to the telescope handwheels are connected in parallel with the antenna tachometers and operate directly on the antenna drive servos.) The feedback voltage developed by any of these tachometers is proportional to the velocity of the output member -- the greater the velocity the greater the voltage developed. Since the feedback voltage is applied so as to oppose the motion causing it, the effect is to make the system more responsive to sudden changes in velocity: for example, sudden removal of the input signal when the system is moving at constant velocity results, because the input signal and the feedback signal act in opposition to each other, in full application of the feedback voltage to the input, bringing the system quickly to a stop. Conversely, if the system is at a standstill, sudden application of an input signal results in high starting torque, since the feedback voltage does not develop until the system gets under way. Tachometer feedback thus counteracts the inertia of elements and other system forces -- usually of the motor and gearing -- within and outside its loop.

6. COMPUTER OPERATION

Use of a computer makes it possible to synthesize any desired course and repeat it any desired number of times. If S2 is placed in MANUAL position and S3 in COMPUTER position the antenna, and hence the radar beam, can be made to

follow any desired straight line course within the response characteristics of the system. Any desired straight line course corresponding to an imaginary target can be set into the computer and a beam riding missile launched into the beam. By comparing the tracking camera record, the dial box record, and the computer course, the deviation of the missile from the theoretical course can be determined. This information, together with data which may be telemetered from the missile, makes possible a complete study of the performance of beam riding missiles. The theoretical course can be used to check the performance of the radar system itself and to compare its actual performance against that predicted by the design calculations.

7. BEACON OPERATION

Because of its small size and unfavorable aspect, a missile produces an echo which is quite weak when moving away from the radar at a considerable distance. As an aid in tracking the missile, a receiver tuned to the radar frequency is installed in the missile. The output of this receiver is used to trigger a transmitter inside the missile which sends out a pulse that is picked up by the radar. The beacon transmitter is tuned to a frequency different from that of the radar transmitter and is received at the radar by a separate receiving system (the missile receiver and related units). In this way a pulse striking the missile produces, in effect, a much stronger signal for use at the radar than would be possible from the reflection alone, thus allowing the missile to be tracked to a greater distance. This arrangement also provides other advantages: (1) it permits automatic tracking of a missile as it leaves the launcher. Unless the missile is tracked automatically from the launcher, the early part of the flight record may be lost. Without a beacon the radar may get a stronger reflection from the launcher than from the missile and thus remain locked on the launcher. (2) Because of the greater strength of the beacon signal and because of its frequency, there is much less probability of extraneous reflections from the ground or other sources causing the radar to lose the missile. The echo signal and the beacon signal may be received and observed or recorded simultaneously. By comparing the two signals an indication is obtained of the amount of noise developed in the beacon receiver and transmitter.

The receiver in the missile is connected to a coordinate detector which develops error voltages if the beam and missile are not aligned. The error voltages are used to control flaps on the missile so that it will follow the center of the beam where the error voltages are zero. If the beam is moved, error voltages will be de-

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veloped and the missile will again align itself with the beam. In this way the beam can be held on a target and the missile will follow the beam to the target.

8. DATA RECORDING EQUIPMENT

a. General. - To make possible the use of the Lark SP-1M radar as a test instrument, a complete data recording system is included in the equipment. The data recording system is made up of six units. They are: the camera control unit, the antenna tracking cameras, the dial box, the remote range indicator, the time comparator, and the sound recorder.

b. Cameras. - Correlation of the data requires that all cameras used operate at the same speed. This requirement is satisfied by driving a synchro generator with an a-c motor and using the output of the synchro generator to drive synchro motors which in turn drive the cameras. All of the cameras thus run in synchronism and the data obtained may be compared frame by frame. To provide a reference point for correlation at the beginning of each film, a small lamp is mounted inside each camera in such a way that it momentarily fogs the film when the camera start switch is thrown. A time delay relay extinguishes the lamps in all cameras simultaneously. All the motion-picture cameras normally operate at 10 frames per second and the continuous-strip camera used for the time comparator operates at an equivalent rate. This rate is chosen on the basis of missile flight time and the advantage of using 50-foot film magazines in the cameras. The cameras can be operated at 10, 20, or 30 frames per second by changing the gear ratio in the camera control unit.

Two 16-mm motion-picture tracking cameras are mounted on the antenna reflector. One has a 6-inch lens and the other a 21-inch telephoto lens. Both cameras have crosshairs which are photographed along with the target or missile. The cameras are aligned in such a way that when the object is in the center of the crosshairs it is also in the center of the radar beam.

c. Dial Box. - A cross check on the antenna tracking cameras can be obtained by comparing the reading of the target and missile cross-pointer meters in the dial box with the antenna tracking film. These meters are in series with those on the output of the target and missile coordinate detector and indicate the position of the target or missile with respect to the center of the radar beam.

The dial box shows additional information. Dials mounted on synchro motor shafts give a continuous record of 2-speed and 36-speed antenna elevation and 1-speed and 36-speed antenna

train angles. These synchros are controlled by other synchros mounted on the antenna elevation and train motors.

In the same way, other dials show coarse and fine range as transmitted by both the target and missile range units, so that the ranges of both the target and the missile are continuously recorded.

The range as supplied by the computer is recorded by two dials and their associated synchros. Additional spare dials and synchros are provided to display any additional information, if necessary.

The position of switches S1, S2, and S3 is recorded at all times by the use of indicator lights on the front of the dial box. When any of these switches is in any given position, the indicator light corresponding to this position is turned on.

A counter is provided on which the run number can be shown and photographed along with the other data.

d. Remote Range Indicator Unit, Unit 8500. - The Remote Range Indicator Unit, Unit 8500, shows the position of the returned signal from either the target or missile in the range gate. Any interfering signal within the gate will be recorded. This information may be very useful in the interpretation of irregularities recorded on any other portion of the data recording equipment. The height of the pulse gives an indication of its strength. Four indicator lights are on the front of the remote range indicator. Two of them are used to show the position switch S1 (figure 2-1). The other two lights indicate whether the system is using the automatic target or the automatic missile signal.

A camera records the data shown by the remote range indicator unit.

e. Time Comparator. - A synchro motor is used to drive a commutator which supplies one pulse per revolution to the input of an amplifier. This pulse marks the opening of the camera shutters. The output of the amplifier is connected to a strobotron which flashes each time a pulse is applied to the amplifier input. The flash of light passes through a slit and produces a well-defined image on the film in the continuous strip camera. A duplicate amplifier and strobotron is connected to the output of a receiver which picks up theodolite timing signals. Flashes from this source are photographed on the same film beside those derived from the commutator. This arrangement makes possible the correlation of the theodolite camera records and any of the radar records.

f. Sound Recorder. - A sound recorder is connected to the communications equipment so that all communications by radio, telephone, or intercommunication system are recorded.

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SECTION III

DESIGN AND DEVELOPMENT OF MAJOR SUBASSEMBLIES

Subsection 3-1. Lark SP-1M Range System

1. INTRODUCTION

The ranging system of the Lark SP-1M equipment is designed so that targets of much higher speed than the Lark missile may be automatically tracked in range. At a target speed of 3000 knots or an acceleration of 750 yards per second per second, the automatic range-tracking error is approximately plus or minus five yards and is independent of target range. The system is capable of operation from 0 to 90,000 yards with the automatic tracking error less than the reset error. A slewing speed of 10,000 yards per second is available. Manual range tracking may be accomplished by throwing a switch on the panel of the range unit to the slew position and turning the manual handwheel. The range indication appears as dial and counter displays, and the range gate and target echo (or missile beacon signal) being tracked are displayed on the indicator oscilloscopes. In addition, timing outputs are provided to key the transmitter and the A and R scopes, and to generate several range gates for display and tracking purposes. Provision is made also for 24-cycle pulse-time modulation of the repetition frequency to transmit guidance intelligence to the Lark missile. The basic units of the ranging system of the Lark SP-1M equipment are the Range Unit, Unit 300, and the Range Error Detector and Servo Amplifier, Unit 1300. Two separate range systems are used in the equipment, one for target and the other for missile ranging. Each system consists of a separate range unit and one of two identical chassis of the Range Error Detector and Servo Amplifier. The two systems are for the most part identical and the discussion in this sub-section, unless otherwise indicated, will apply to both. The units are shown in the photographs (figures 3-1 through 3-6), the block diagrams (figures 3-7 and 3-8), and the schematic diagrams (figures 3-9 and 3-10). Reference should be made to these illustrations throughout the following discussion.

2. SPECIFICATIONS

The requirements for the range system to be used in the surface control radar of the Lark system are briefly as follows:

a. Overall Range System. - The automatic range tracking servo system must have a frequency response flat within plus or minus three db to an angular frequency of 12.2 radians per second as detailed in the appendix, paragraph 6 of this subsection. The maximum range error must be less than plus or minus 10 yards, plus or minus zero per cent of the range. The range unit must be capable of continuous operation from 0 to 90,000 yards with automatic tracking error to be kept less than the reset error. Provisions are to be made for slewing the range servo at a maximum speed of 10,000 yards per second with dynamic braking for quick stopping. Range information is to be transmitted at speeds of 1,000 yards per revolution and 100,000 yards per revolution. Special testing and calibrating equipment, where necessary, must be provided with the range unit. Mechanical arrangements are to be made to include range transmission from a potentiometer to retain the present height finding features of the SP-1M radar. The range rate of the missile is expected to be about 560 knots with an acceleration of 100 yards per second, per second. The range unit is to be designed so that it is capable of tracking either the target or the missile with a suitable safety factor.

b. Range Unit, Unit 300. - The inputs required by the Range Unit, Unit 300, are plus 300 volts dc, 115 volts ac, and 115 volts ac from the synchro bus. The 24-cycle sine-wave output from the lobing generator is required at a maximum amplitude of 35 volts rms for 100 per cent pulse-time modulation and at an amplitude of 15 volts for 20 per cent pulse-time modulation. The system is usually operated at about 20 per cent pulse-time modulation. The required outputs from the range unit are as follows: an A-scope keying pulse of 0.5-microsecond duration at an amplitude of 30 volts, a transmitter keying pulse of 0.5-microsecond duration at an amplitude of 30 volts, an R-sweep trigger of 0.5-microsecond duration at an amplitude of 30 volts, a range-gate trigger of one-microsecond duration at an amplitude of 20 volts. All of these pulses are positive triangular blocking-oscillator outputs and appear across 70-ohm impedances. In the case of the missile range unit, a 164-kilocycle

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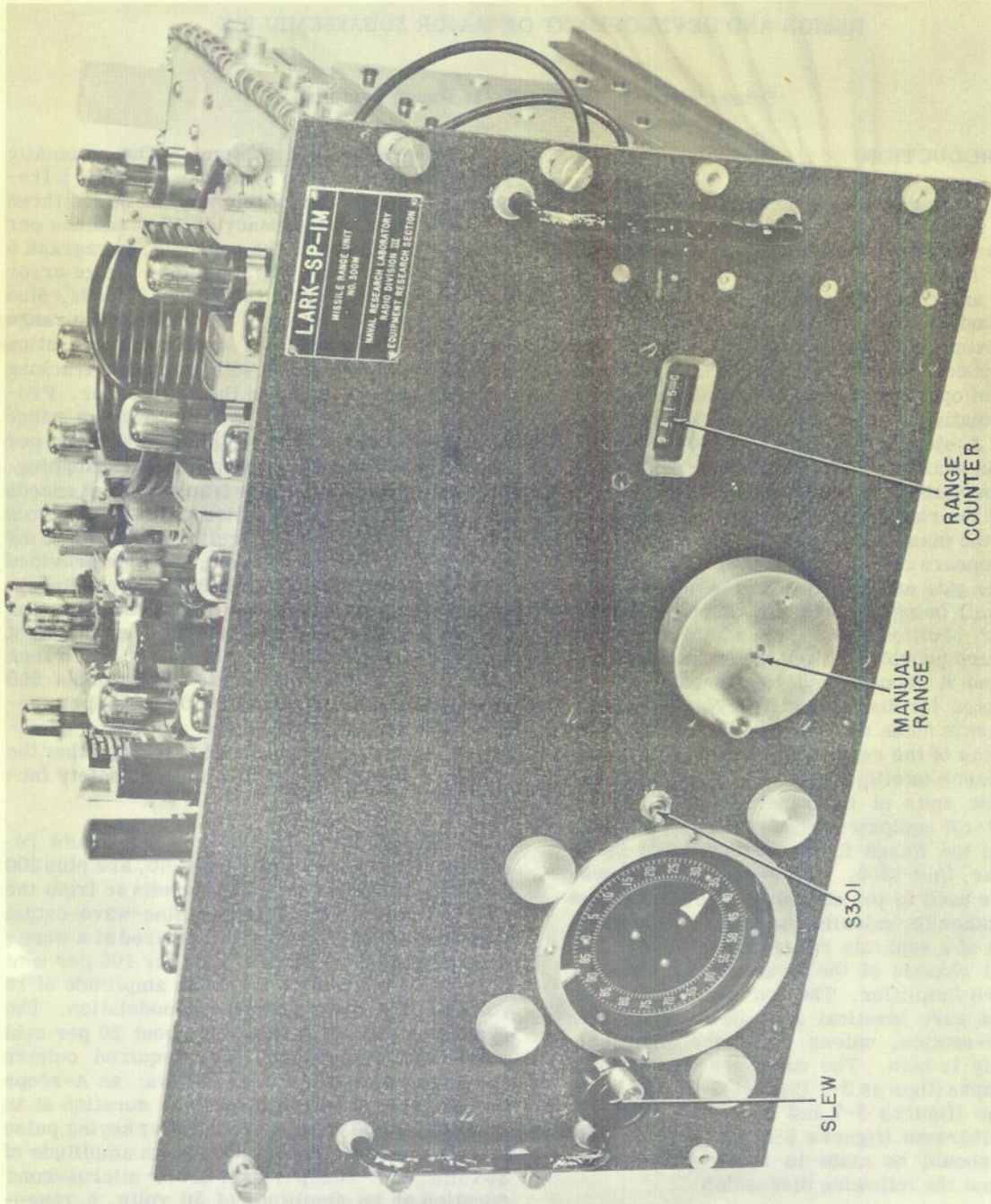


Figure 3-1. Range Unit - Front View

gate trigger of one-microsecond duration at an amplitude of 30 volts. All of these pulses are positive triangular blocking-oscillator outputs and repeat every 70-80 microseconds. In the case of the antenna range unit, a 144-kilocycle

2. SPECIFICATIONS
 The requirements for the range system to be used in the antenna control of the Lark system are briefly as follows:

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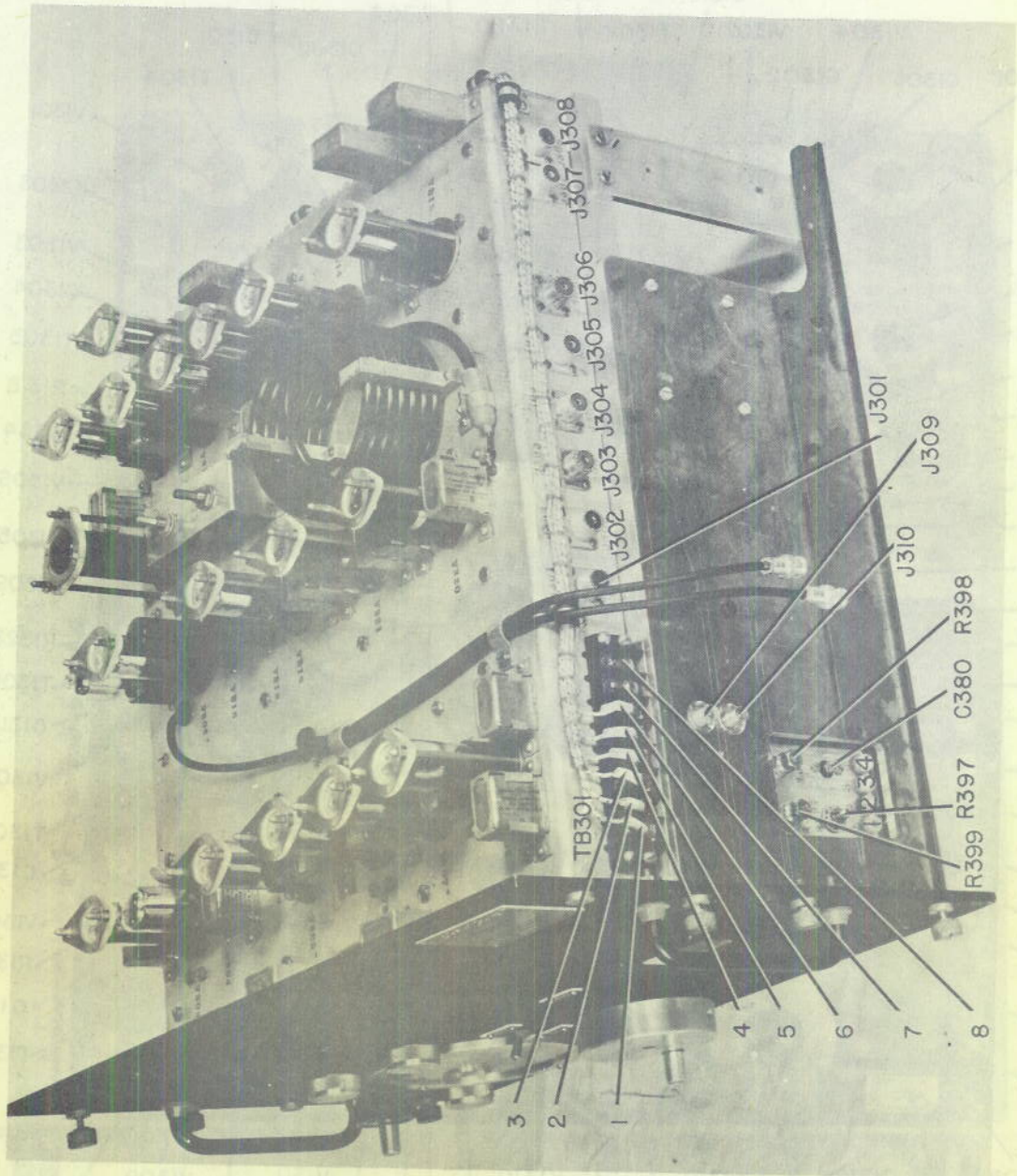


Figure 3-2. Range Unit - Right Side View

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Figure 3-3 - Range Error Detector and Servo Amplifier - Top View

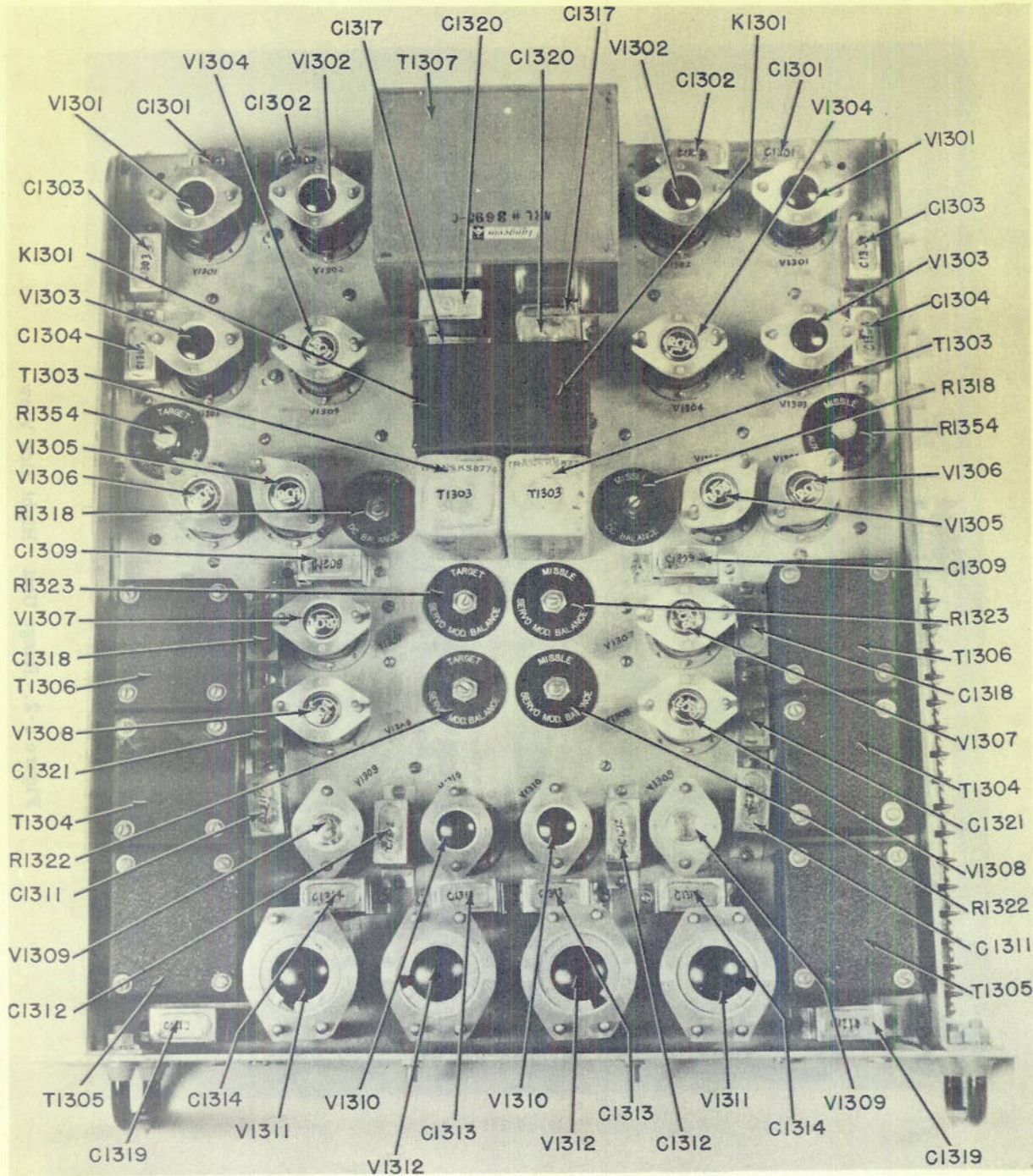


Figure 3-3. Range Error Detector and Servo Amplifier - Top View

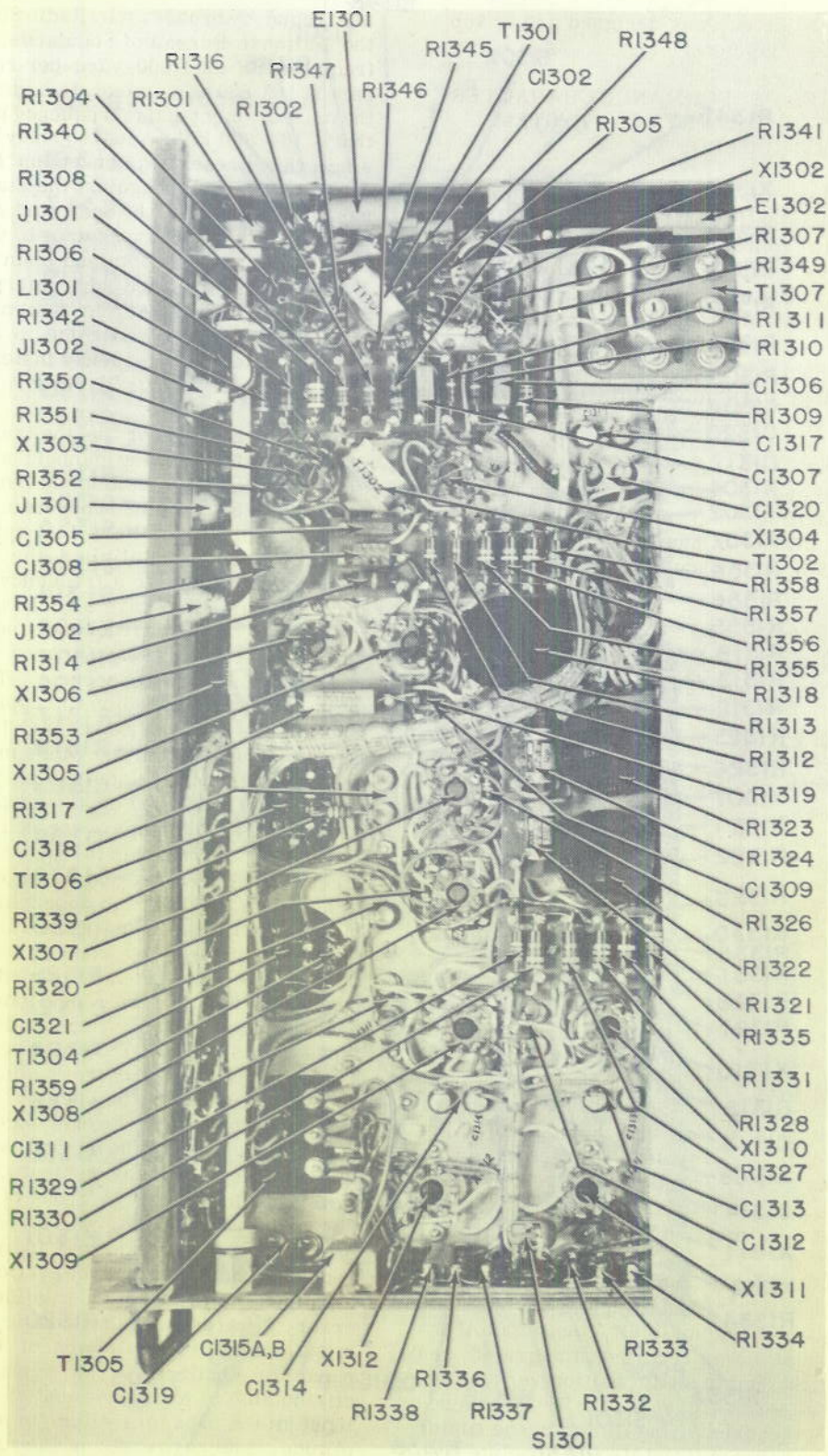


Figure 3-4. Left Half of Range Error Detector and Servo Amplifier - Bottom View

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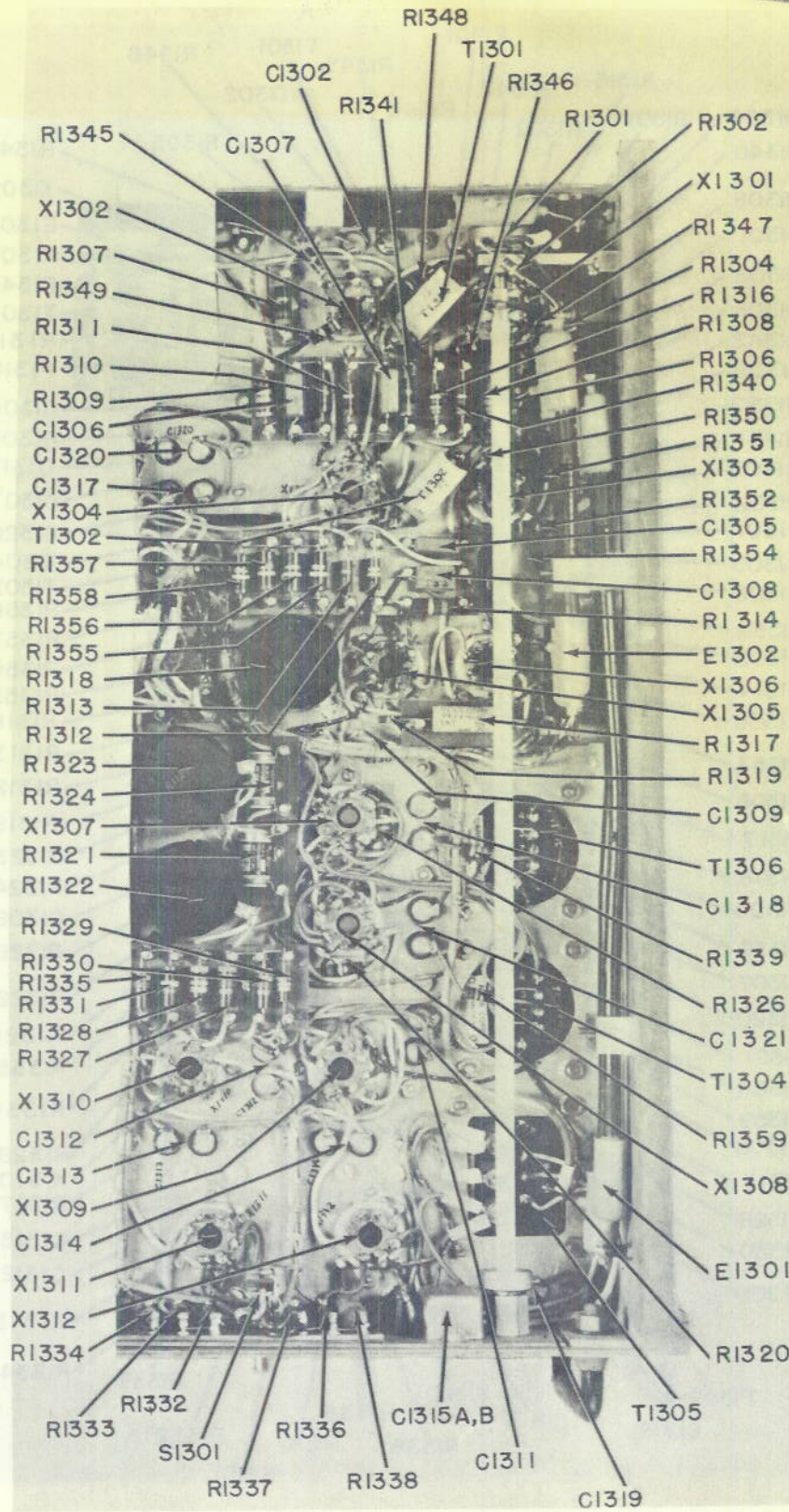


Figure 3-5. Right Half of Range Error Detector and Servo Amplifier - Bottom View

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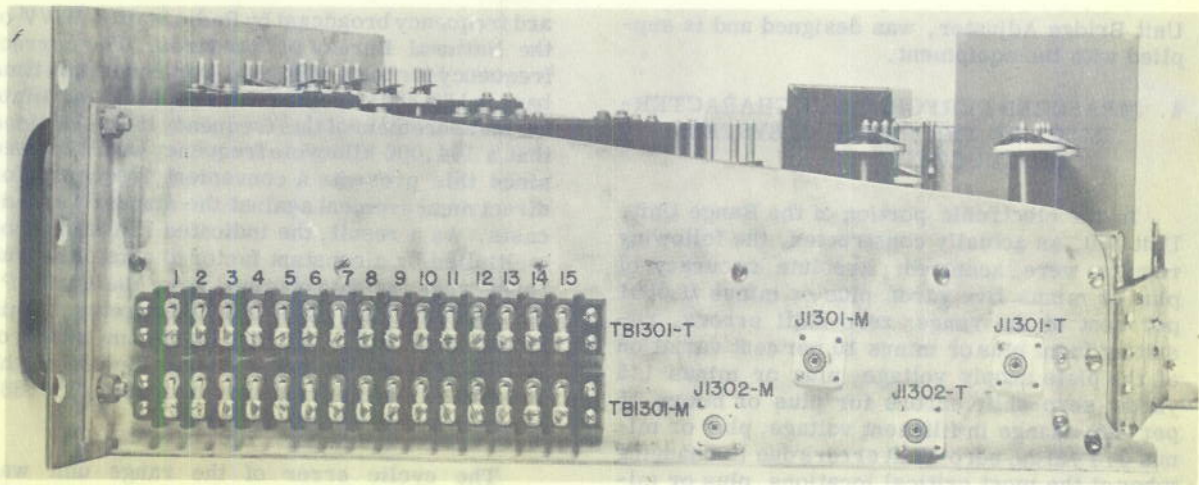


Figure 3-6. Range Error Detector and Servo Amplifier - Right Side View

sine-wave voltage from the target range unit is required or the reverse procedure can be used, that is, the missile range unit can supply the 164-kilocycle voltage to the target range unit. In addition, a repetition rate synchronizing pulse is mutually interchanged between the units so that the repetition rates of the two range units will remain the same.

c. Range Error Detector and Servo Amplifier, Unit 1300. - The Range Error Detector and Servo Amplifier, Unit 1300, requires the following inputs: A video signal from the receiver at an amplitude of 10 volts positive across a 70-ohm impedance, a gate of an amplitude of 30 volts positive across 70 ohms with a delay from the i-f gating pulse equal to cable and video delay plus one-half the gate width, and the 115-volt a-c synchro-bus signal plus the remote range designation from a remote synchro. In addition, plus 300 volts dc at 200 ma and minus 210 volts dc at 20 ma are required. The outputs of the Range Error Detector and Servo Amplifier, Unit 1300, are as follows: a 60-cycle voltage at 25 volts rms per yard error, approximately linear to 125 volts rms (five yards error), and a 60-cycle voltage at an amplitude between 0 and 125 volts rms to operate the slew system.

3. DESIGN CONSIDERATIONS

In view of the specifications set forth in the preceding paragraph for the Lark SP-1M ranging system, it was felt that no available range unit employed in fire control equipment was adequate. In general, range unit error is composed of a cyclic component and a percentage of indicated range component. The Meacham range

unit of the Mark 12 radar has an accuracy of plus or minus 15 yards, plus or minus one tenth of one percent of the indicated range. The 15-yard error is independent of range and represents a cyclic error in the 360-degree phase-shift capacitor. This cyclic error is a percentage of the range increment represented by one revolution of the phase-shift capacitor or one cycle of the driving voltage. In the Meacham unit, the range increment is 2,000 yards and the error is plus or minus 0.75 per cent of this interval. By careful alignment of the capacitor driving circuits, the error can be reduced to 0.5 per cent. By doubling the driving frequency, cyclic errors can be reduced to plus or minus five yards at any indicated range. The one tenth of one per cent error of the Meacham unit is caused by frequency instability in the keyed L-C oscillator. Since the tank circuit in this unit is enclosed in a temperature controlled oven, there is slight chance of any substantial improvement in this characteristic. If the time base has a stability of plus or minus 0.005 per cent, then these measures would reduce the error to a usable degree. Stability of this order can be obtained easily with a crystal oscillator. Accordingly, in the present system, a free-running crystal oscillator was employed as a time base at double the frequency of the Meacham unit. Phase-locked timing pulses are obtained from the time-base oscillator by a divider system. The divider system used permits pulse-time modulation of the pulse repetition frequency without any possibility of phase instability between the timing pulses and the time-base oscillator. To achieve the required accuracy of adjustment of the driver circuits of the phase-shift capacitor, a special test unit, the Range

Unit Bridge Adjuster, was designed and is supplied with the equipment.

4. MEASURED PERFORMANCE CHARACTERISTICS OF THE PHYSICAL SYSTEM CONSTRUCTED

In the electronic portion of the Range Unit, Unit 300, as actually constructed, the following results were achieved: absolute accuracy of plus or minus five yards plus or minus 0.0001 per cent of the range; zero-shift errors, resulting from plus or minus 10 per cent variation of the plate supply voltage, plus or minus 1.5 yards; zero-shift errors for plus or minus 15 per cent change in filament voltage, plus or minus 3.5 yards; zero-shift errors due to changing tubes at the most critical locations, plus or minus 12 yards. The factor of plus or minus 0.0001 per cent of range represents a grinding tolerance for the crystal employed. A frequency stability of plus or minus 0.001 per cent over long periods of time should be obtained giving a calibrated accuracy of plus or minus six yards at 100,000 yards.

Bench tests of the Range Error Detector and Servo Amplifier, Unit 1300, lead to the following conclusions: the range error detector delivers a d-c output voltage of plus or minus five volts per yard error across an impedance of 1,000 ohms. The servo amplifier delivers an output of 25 volts rms per yard error, linear out to 125 volts (five yards error). Figure 3-30 shows plots of the calculated, and of the actually obtained, frequency response for the range servo system. The dashed curve indicates that the measured response is flat within zero to minus two db from a low angular frequency out to an angular frequency of 12.2 radians per second. Beyond 12.2 radians per second, the response starts to drop and eventually reaches asymptotic slopes, first, of six db per octave and then of 12 db per octave. The solid curve is the calculated response from the supplied design expressions of the system. For more detailed information on the servo system refer to paragraph 6 of this subsection. The measured performance of the range servo amplifier system was arrived at as follows: a simulated echo, obtained from a signal generator, was position-modulated with a constant-amplitude, variable-frequency sine wave and applied to the radar input. With the radar tracking this echo automatically, the output of the track tachometer was recorded, integrated, and used to plot the motor shaft position versus frequency as shown on figure 3-30. The frequency stability of the crystal oscillator in the timing portion of the range unit and also the absolute frequency of the crystal were determined by comparison of the oscillator frequency with a stand-

ard frequency broadcast by Radio Station WWV of the National Bureau of Standards. The correct frequency for the 1,000-yard-per-revolution time base is 163,880 kilocycles. In order to facilitate the measurement of this frequency it was decided that a 164,000 kilocycle frequency would be used since this presents a convenient frequency for direct measurement against the standard broadcasts. As a result, the indicated range must be multiplied by a constant factor to obtain the true range when the data obtained from the Lark SP-1M systems are used and interpreted. This factor is 0.9927. At the maximum range of 100,000 yards, the error due to the use of the 164,000 kilocycle frequency instead of 163,880 kilocycles will be plus 73 yards.

The cyclic error of the range unit was checked in the following manner: a 164-kilocycle sine-wave signal was obtained from the cathode follower, V316 in the range unit, and was applied to a small auxiliary test unit containing a multiplier which multiplied the 164-kilocycle frequency 16 times to a frequency of 2624 kilocycles. This sine-wave signal was then shaped into pips of the same frequency and of very short duration. The pips were spaced 62.5 yards in range (0.76218 microseconds). The 2624 kilocycle pips were placed on the upper vertical deflection plate of a servoscope. The range-gate trigger derived from the range unit was placed on the lower vertical deflection plate. Thus a pattern was displayed on the scope in which the 62.5-yard spaced pips were in the upward direction and the range-gate trigger in a downward direction. The range-gate trigger was then aligned with the first pip appearing on the scope by a manual adjustment of the range handwheel. At this point the range counter was read. Further manual adjustment was made of the range handwheel to align the range-gate trigger with each successive 62.5-yard pulse. At each of these points the range counter was again read. The difference between the readings of the range counter should have then been 62.5 yards. Any deviation from this yardage was cyclic error. For a description of the method used in the field, for cyclic error measurements, refer to section V of this report. A group of approximately 25 such measurements was made on two pieces of equipment. A statistical analysis of the data recorded indicated that the cyclic error was plus or minus four yards. Of this four yards cyclic error, 2 yards are attributable to mechanical misalignment of the plates of the phase-shift capacitor (built in). The remaining error is attributable to maladjustment of the four-phase input to the capacitor either in phase or in amplitude. The zero error of the range timing unit was observed with the same test set-up as for the measurement of cyclic error. This was ac-

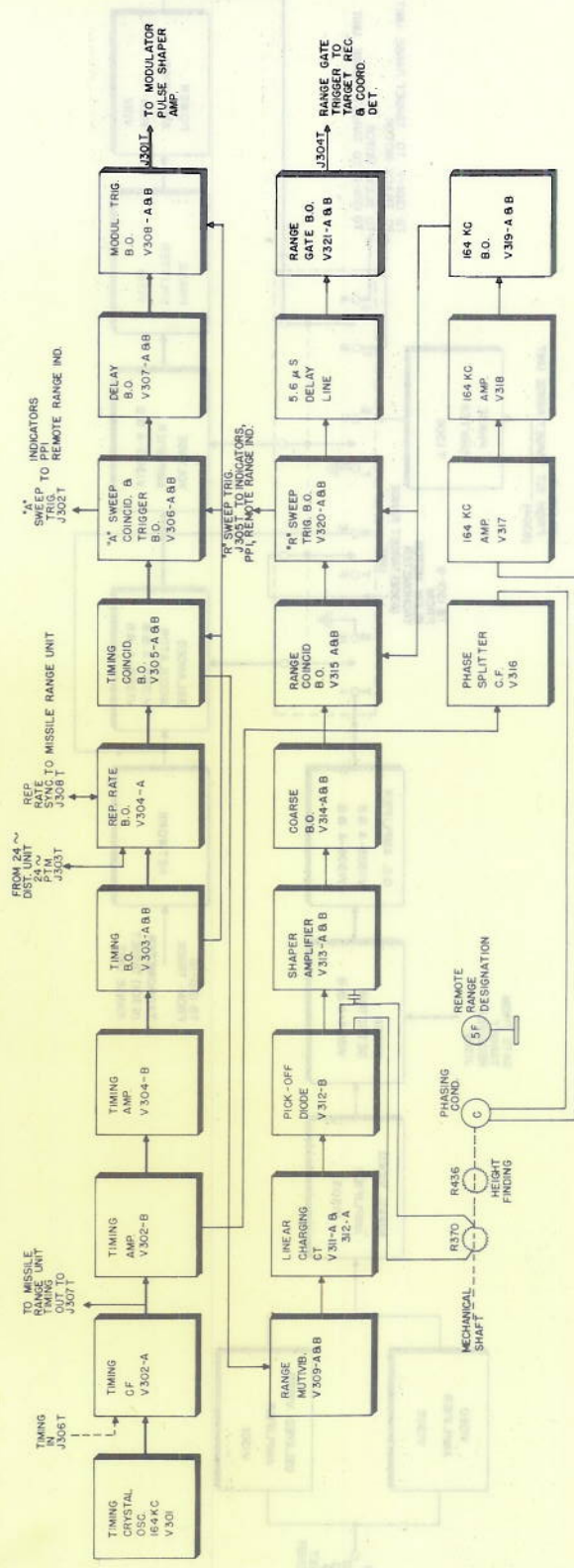


Figure 3-7. Range Unit - Block Diagram

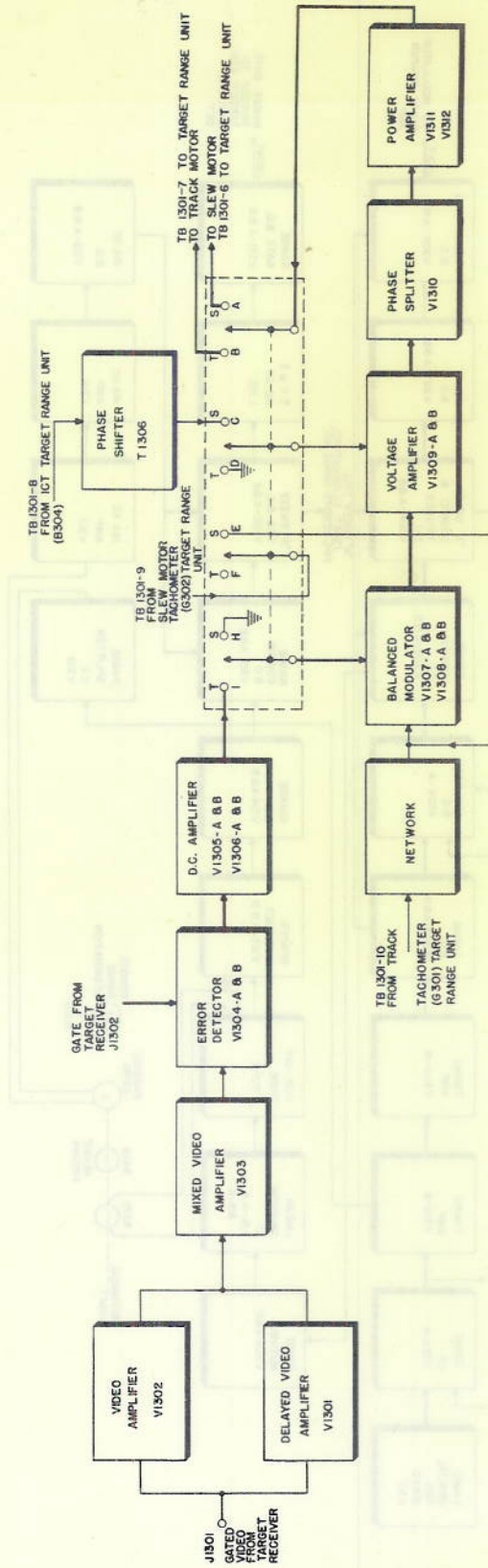


Figure 3-8. Range Error Detector and Servo Amplifier - Block Diagram

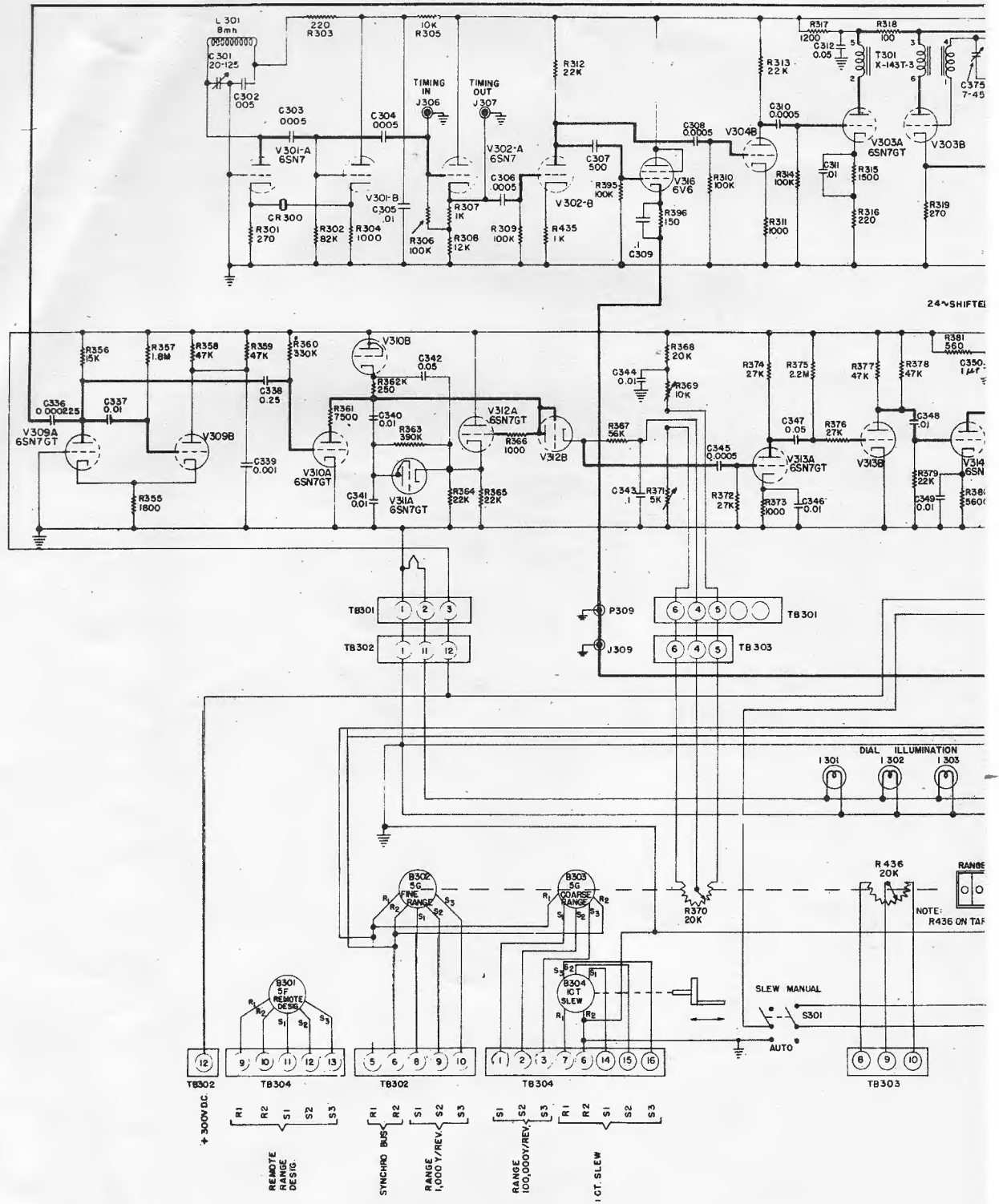
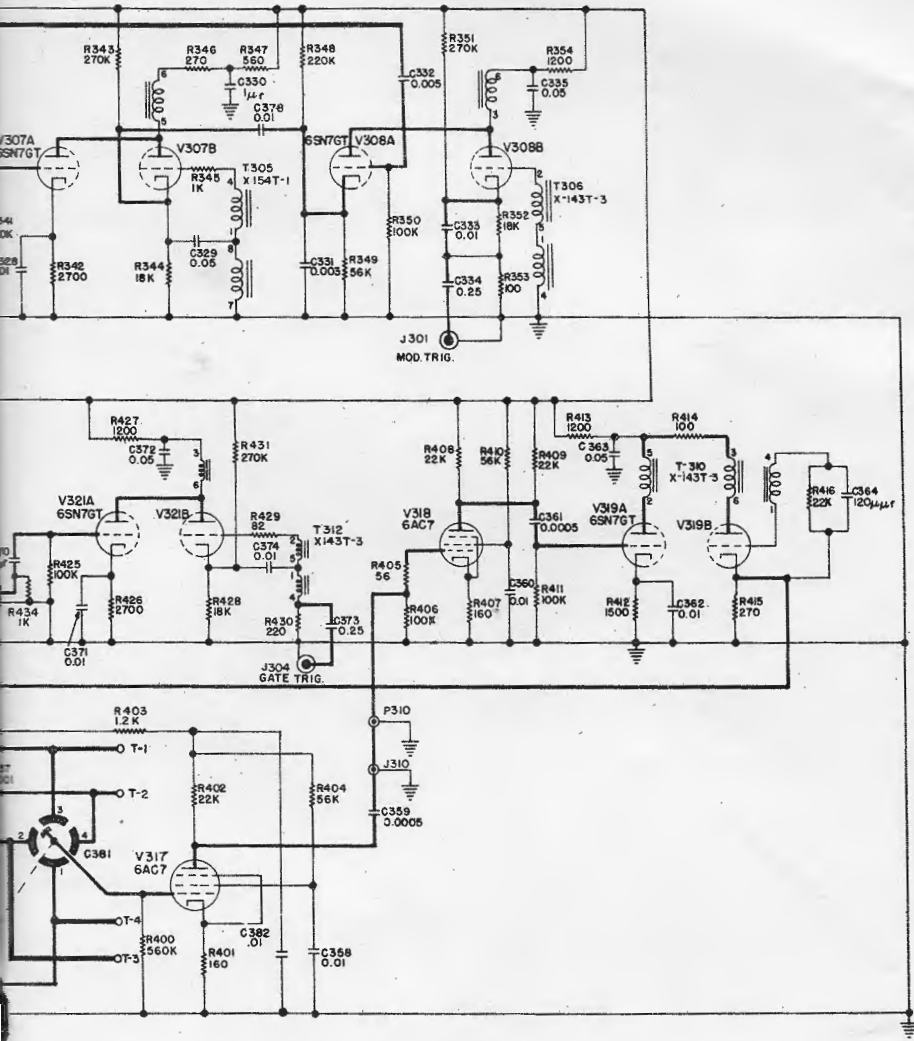


Figure 3-9. Target or Missile Range Unit - Schematic Diagram

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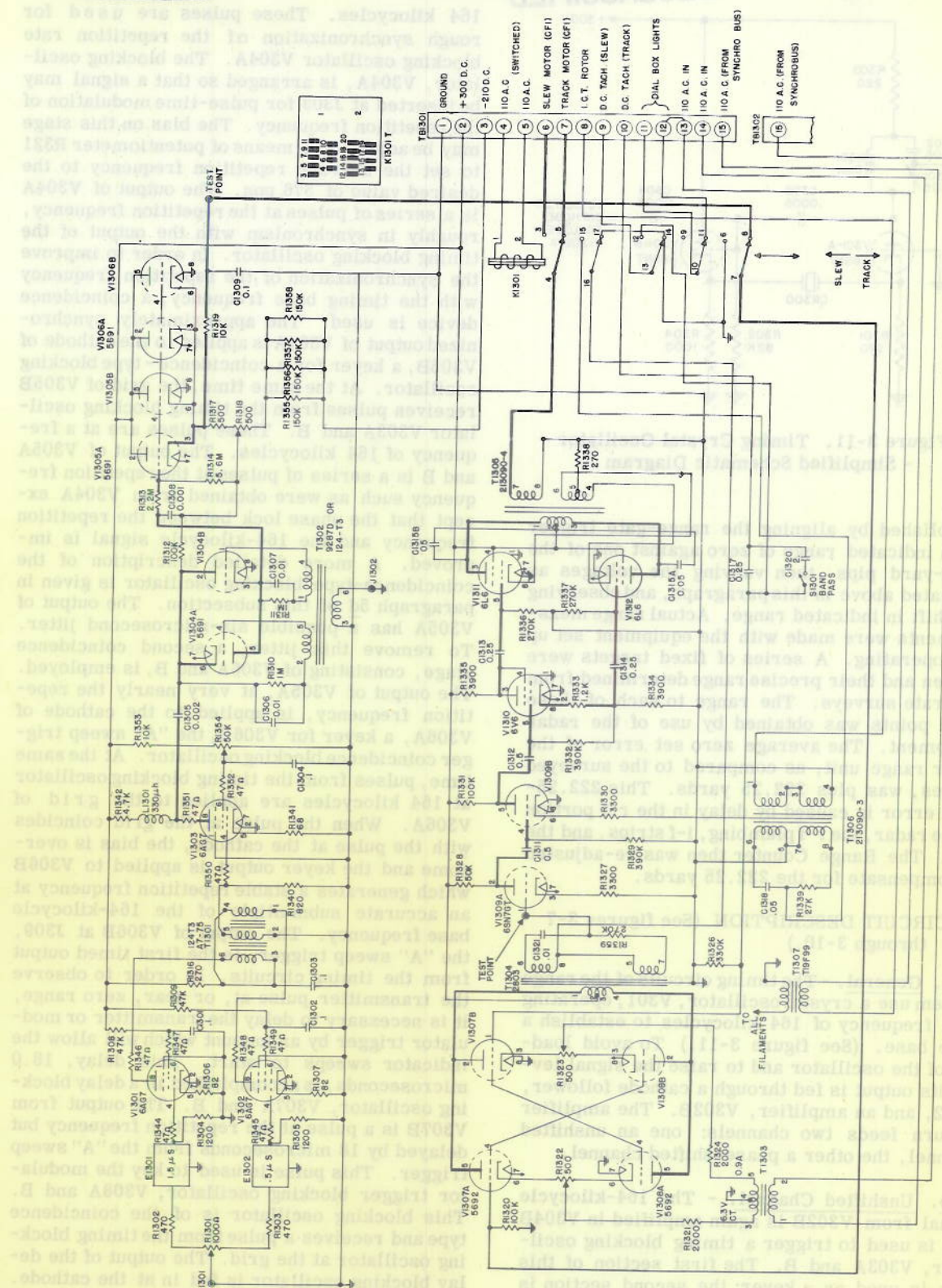


Figure 3-10. Target and Missile Range Error Detector and Servo Amplifier - Schematic Diagram

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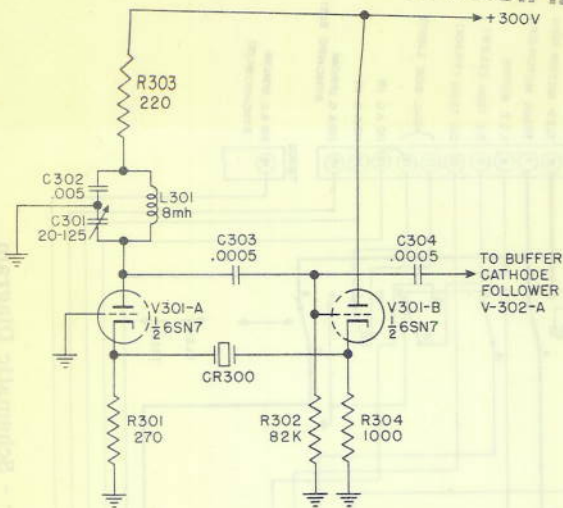


Figure 3-11. Timing Crystal Oscillator -
- Simplified Schematic Diagram

completed by aligning the range-gate trigger at an indicated range of zero against one of the 62.5-yard pips, then varying the voltages as indicated above in this paragraph, and observing the shift in indicated range. Actual range measurements were made with the equipment set up and operating. A series of fixed targets were chosen and their precise range determined from accurate surveys. The range to each of these fixed points was obtained by use of the radar equipment. The average zero set error of the radar range unit, as compared to the surveyed ranges, was plus 222.25 yards. This 222.25-yard error is caused by delay in the r-f portion of the radar, the r-f plumbing, i-f strips, and the like. The Range Counter then was re-adjusted to compensate for the 222.25 yards.

5. CIRCUIT DESCRIPTION (See figures 3-7 through 3-10.)

a. **General.** - The timing circuits of the range system use a crystal oscillator, V301, operating at a frequency of 164 kilocycles to establish a time base. (See figure 3-11.) To avoid loading of the oscillator and to raise the signal level, its output is fed through a cathode follower, V302, and an amplifier, V302B. The amplifier in turn feeds two channels: one an unshifted channel, the other a phase-shifted channel.

b. **Unshifted Channel.** - The 164-kilocycle signal from V302B is again amplified in V304B and is used to trigger a timing blocking oscillator, V303A and B. The first section of this tube is used as a keyer; the second section is the blocking oscillator proper. The output of V303B is a series of pulses at a frequency of

164 kilocycles. These pulses are used for rough synchronization of the repetition rate blocking oscillator V304A. The blocking oscillator, V304A, is arranged so that a signal may be inserted at J303 for pulse-time modulation of the repetition frequency. The bias on this stage may be adjusted by means of potentiometer R321 to set the average repetition frequency to the desired value of 576 pps. The output of V304A is a series of pulses at the repetition frequency, roughly in synchronism with the output of the timing blocking oscillator. In order to improve the synchronization of the repetition frequency with the timing base frequency, a coincidence device is used. The approximately synchronized output of V304A is applied to the cathode of V305B, a keyer for a coincidence-type blocking oscillator. At the same time, the grid of V305B receives pulses from the timing blocking oscillator V303A and B. These pulses are at a frequency of 164 kilocycles. The output of V305A and B is a series of pulses at the repetition frequency such as were obtained from V304A except that the phase lock between the repetition frequency and the 164-kilocycle signal is improved. A more detailed description of the coincidence-type blocking oscillator is given in paragraph 5d of this subsection. The output of V305A has a possible six-microsecond jitter. To remove this jitter, a second coincidence stage, consisting of V306A and B, is employed. The output of V305A, at very nearly the repetition frequency, is applied to the cathode of V306A, a keyer for V306B, the "A" sweep trigger coincidence blocking oscillator. At the same time, pulses from the timing blocking oscillator at 164 kilocycles are applied to the grid of V306A. When the pulse at the grid coincides with the pulse at the cathode, the bias is overcome and the keyer output is applied to V306B which generates a stable repetition frequency at an accurate submultiple of the 164-kilocycle base frequency. The output of V306B at J309, the "A" sweep trigger, is the first timed output from the timing circuits. In order to observe the transmitter pulse at, or near, zero range, it is necessary to delay the transmitter or modulator trigger by an amount which will allow the indicator sweeps to start. This delay, 18.0 microseconds, is accomplished in a delay blocking oscillator, V307A and B. The output from V307B is a pulse at the repetition frequency but delayed by 18 microseconds from the "A" sweep trigger. This pulse is used to key the modulator trigger blocking oscillator, V308A and B. This blocking oscillator is of the coincidence type and receives a pulse from the timing blocking oscillator at the grid. The output of the delay blocking oscillator is fed in at the cathode. When the two pulses coincide the modulator trigger is obtained at J312.

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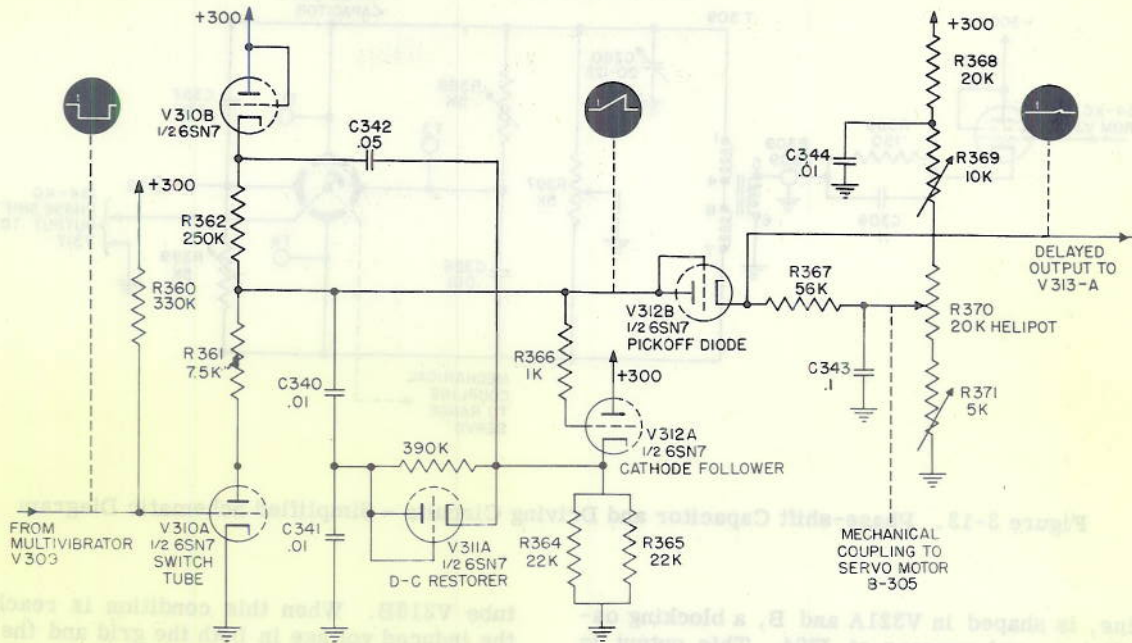


Figure 3-12. Linear Charging Circuit - Simplified Schematic Diagram

c. Phase Shifted Channel. - The output of V305B, in addition to being applied to the next coincidence stage, is used to key the range multivibrator, V309A and B. This multivibrator generates a square wave of a length equal to the maximum range desired for the unit, in this case 100,000 yards. V310A and B, V311A, and V312 (figure 3-12) comprise a linear charging circuit or sawtooth generator. The sawtooth generator circuit is keyed by the aforementioned square wave from the multivibrator, V309A and B. The sawtooth output of this circuit is kept linear, within plus or minus one per cent by feedback through a cathode follower to the capacitor charging circuit. V312B is a pickoff diode which conducts at a point dependent on the setting of the coarse range helipot contained in the mechanical portion of the range unit. The linearity of the helipot must be at least as good as that of the sawtooth generator. The point of conduction of V312B is determined by the position of the helipot. This wave shape is fed to V313A and B, a shaper amplifier. The shaped output from V313A and B is used to key a blocking oscillator V314A and B. V302B, the amplifier for the 164-kilocycle sine wave, has two outputs. In addition to keying V304B, an output is also applied to V316, a cathode follower, for driving the phase-splitting network.

(See figure 3-13.) The output of the phase-splitting network provides voltages at phases of 0, 90, 180, and 270 degrees to the phase-shift capacitor which is constructed so that the output obtained from its rotor is a voltage of constant amplitude and of continuously variable phase. This voltage is applied to V317 and V318, cascaded amplifiers for the 164-kilocycle sine-wave voltage. The output of V318 is applied to V319A and B, a blocking oscillator similar to V303A and B. V319A and B has a pulse output which is applied to the first coincidence blocking oscillator, V315A and B. The output of V319A and B is the same as that of V303A and B except that in the case of V319A and B the pulses are continuously variable in time. V314A and B mentioned above are used to supply one input to V315A and B. An output of V315A and B can occur only when the output from V314A and B and V319A and B are coincidental. The pulses from V315A and B, however, can have a time jitter of six microseconds. V315A and B applies a signal to V320A and B. Another input to V320A and B is the output of V319A and B. The operation of V320A and B is the same as the operation of the above mentioned V315A and B, however, without time jitter. V320A and B has two signal outputs. One is at J305, the R-sweep trigger; the other, delayed by a 5.6-microsecond delay

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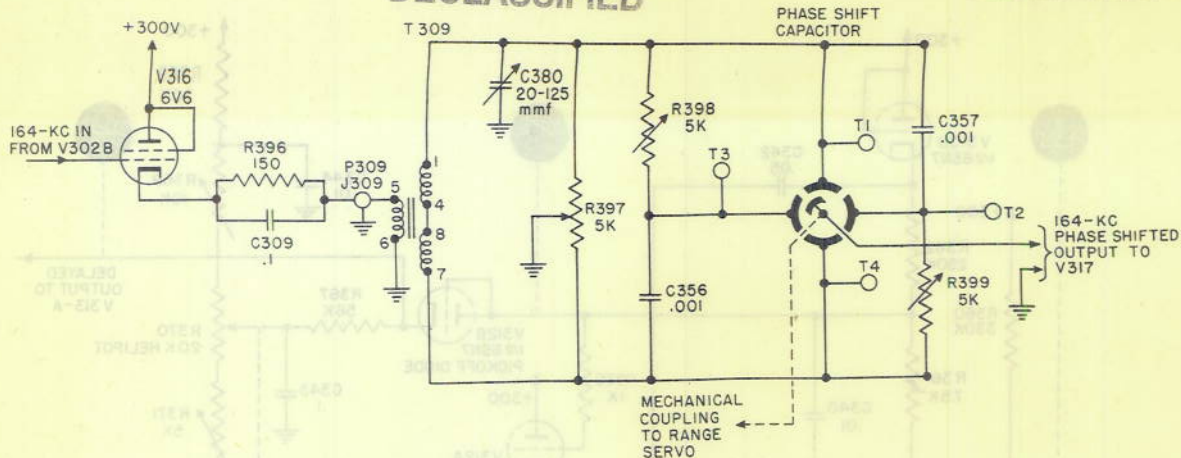


Figure 3-13. Phase-shift Capacitor and Driving Circuits - Simplified Schematic Diagram

line, is shaped in V321A and B, a blocking oscillator, and appears at J304. This output is the range-gate trigger. The phase-shift capacitor and the helipot mentioned above are contained in the mechanical section of the range unit and are geared to the synchro system, a slewing motor, and the automatic tracking drive motor. (Refer to the range servo block diagram, figure 3-14, and the mechanical schematic, figure 3-15.) The gearing ratio between the phase-shift capacitor and helipot is ten to one. The ratio would be a hundred to one, or a thousand yards to a hundred thousand yards, except for the fact that the helipot is a ten-turn device.

d. Coincidence Blocking Oscillator. (See figure 3-16.) - The operation of the circuit of V315A and B may be taken as typical of the coincidence blocking oscillators used in the range system of the Lark SP-1M. When V315A is caused to conduct by the coincidence of the pulses on its grid and on its cathode, current is caused to flow through the winding of transformer T308, connected in the plate circuit of V315B. Voltages are induced in the grid and cathode windings of this transformer. The voltage induced in the cathode winding has a polarity such that the cathode potential goes positive with respect to ground. The voltage induced in the grid winding has a polarity such that the grid end of this winding goes positive with respect to the cathode return through C355. The voltages thus induced are sufficient to raise the grid potential above cut-off and so cause additional current to flow through the plate winding. This process produces a regenerative action that continues until further increase of the grid potential no longer increases the plate current through the

tube V315B. When this condition is reached, the induced voltage in both the grid and the cathode windings drops to zero and as a result the tube tends to resume its quiescent cut-off condition. However, as soon as the plate current begins to decrease, the field in the transformer core which was caused by the plate current flowing through the transformer winding collapses so that voltages of opposite polarity are induced in the other windings. This action tends to drive the tube rapidly to cut-off. The third factor tending to drive the tube to cut-off is the charge build-up on C355 during the time the grid conducts. This charge causes the grid to drop below cut-off as soon as the plate current begins to decrease. The entire cycle of driving the grid potential from below cut-off to conduction and back below cut-off occupies a time interval of about 15 microseconds. This time interval of 15 microseconds is determined largely by the size of condenser C355. During this time, the grid potential is driven from about minus 20 volts to about plus 125 volts with respect to ground, and then below minus 20 volts. The output of V315B is taken across a plate load resistor, R391, and applied to the next coincidence stage which operates in a similar manner.

e. Range Error Detector. (See figures 3-8, 3-10, and 3-14.) - The range error detector of unit 1300 develops a differential d-c output voltage dependent upon the position of the gated video within the range gate. The gated video supplied to the range error detector is divided into two channels. The simple solution to the problem would be to delay and amplify the video in one channel and amplify, but not delay, in the other channel. This method suffers from the

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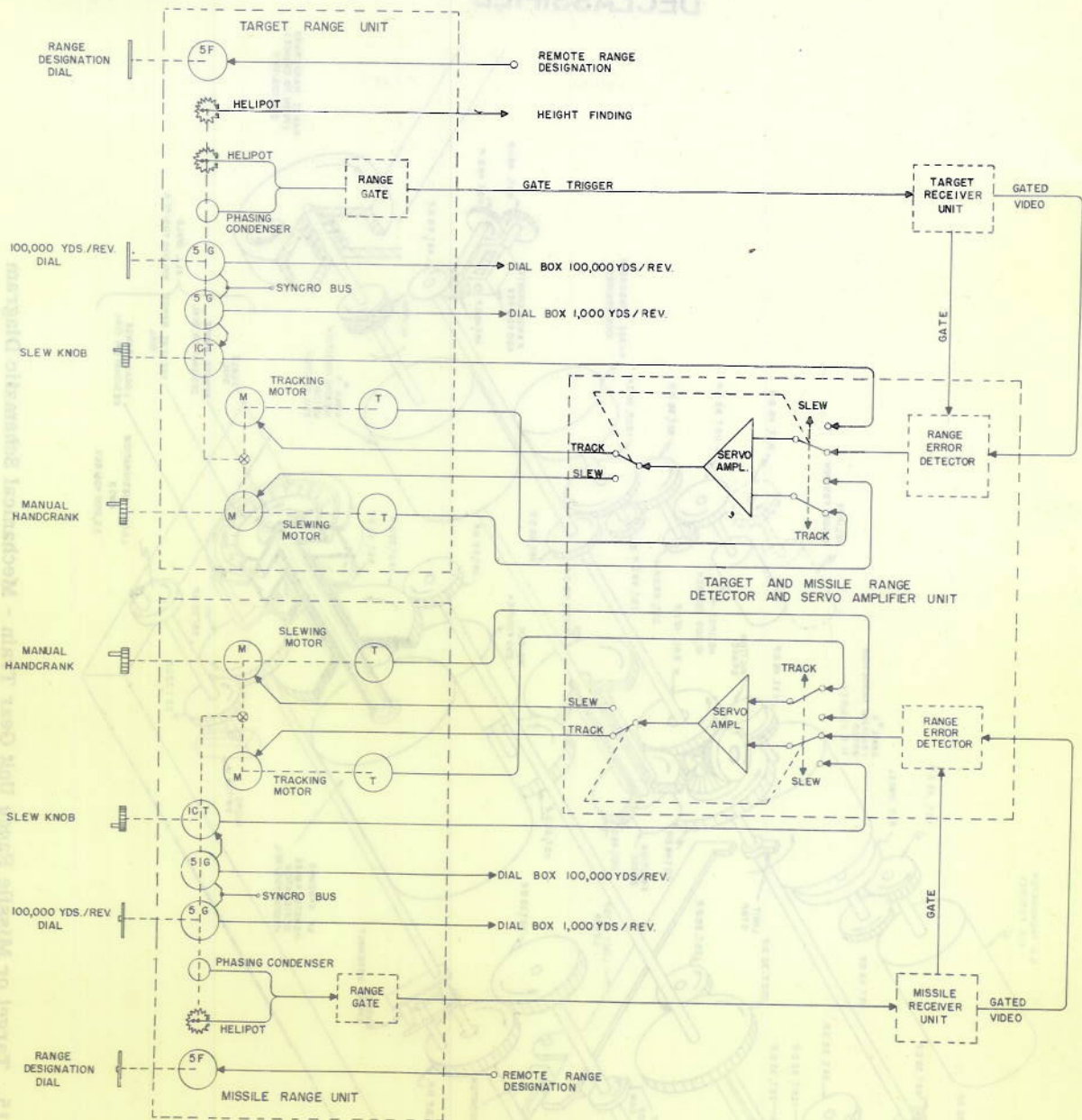


Figure 3-14. Range Servo System - Block Diagram

fact that the delay line used in the delayed channel restricts the band pass characteristics of this channel resulting in difficulties with noise balance in the error detector. To overcome this difficulty and keep the bandwidths the same, a fixed delay is introduced in each channel. (See figure 3-17.) Therefore, one channel has a delay of 1.5 microseconds and the other a delay of 0.5 microsecond. One video pulse is de-

layed by a time interval equal to its length plus 0.5 microsecond (total delay, 1.5 microsecond) and amplified; this, and the video that has been delayed only 0.5 microsecond, are mixed so that they appear as immediately adjacent pulses of opposite polarities. These are applied to an electronic switch (figure 3-18) which is caused to conduct by the application of the range gate. The resultant d-c voltage is amplified and this

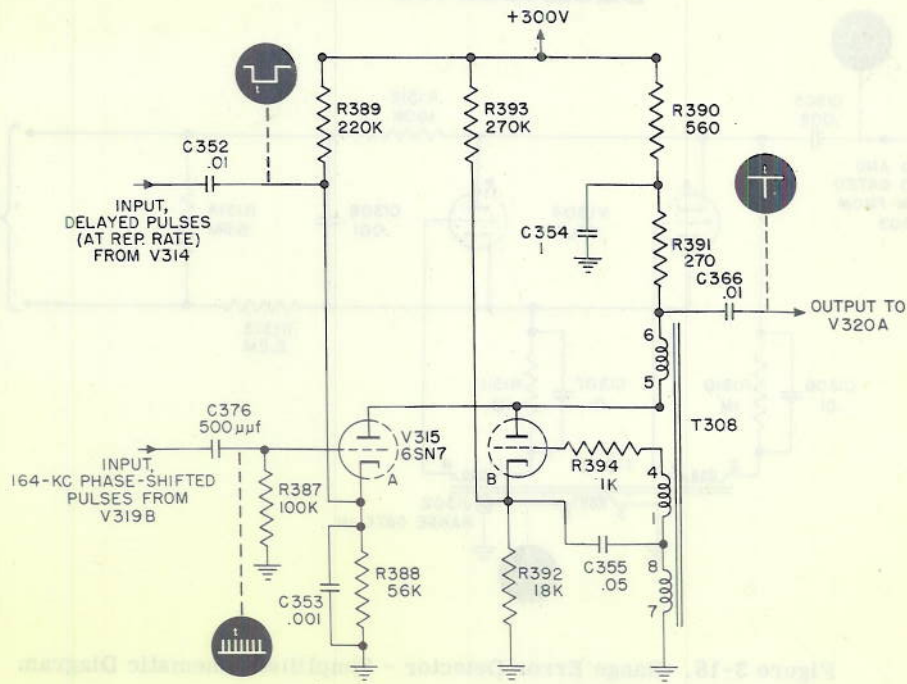


Figure 3-16. Coincidence Blocking Oscillator - Simplified Schematic Diagram

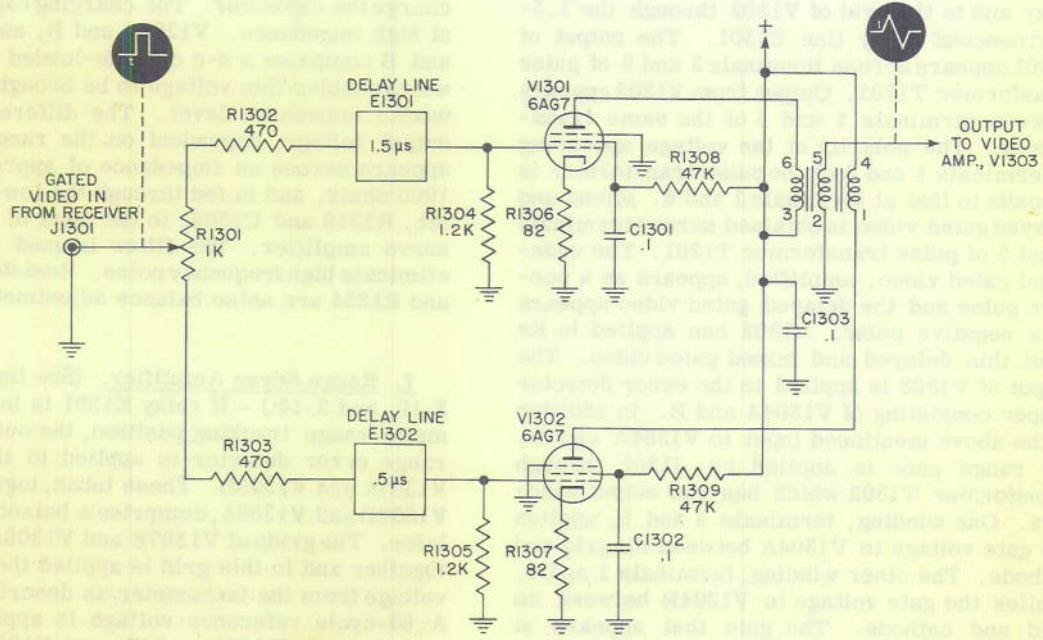


Figure 3-17. Delay and Mixing Circuits - Range Error Detector and Servo Amplifier

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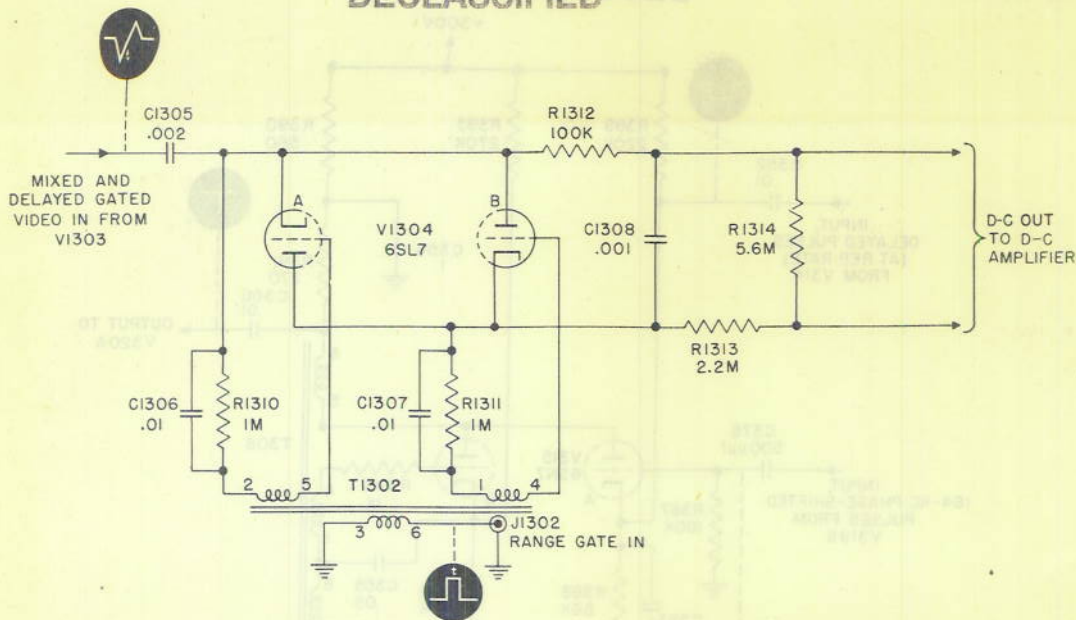


Figure 3-18. Range Error Detector - Simplified Schematic Diagram

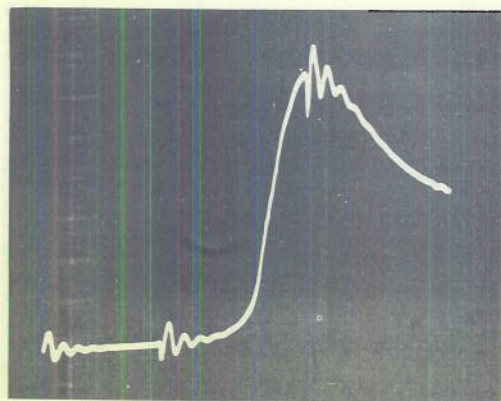
is the output voltage from the range error detector. Gated video is applied to J1301 of the Range Error Detector and Servo Amplifier, Unit 1300. V1301 and V1302 are video amplifiers. The gated video input from J1301 is applied to the grid of V1301 with a 0.5-microsecond delay and to the grid of V1302 through the 1.5-microsecond delay line Z1301. The output of V1301 appears across terminals 3 and 6 of pulse transformer T1301. Output from V1302 appears between terminals 1 and 4 of the same transformer. The polarity of the voltage appearing at terminals 1 and 4 of the pulse transformer is opposite to that at terminals 3 and 6. Mixed and delayed gated video is obtained across terminals 2 and 5 of pulse transformer T1301. The undelayed gated video, amplified, appears as a positive pulse and the delayed gated video appears as a negative pulse. V1303 has applied to its input this delayed and mixed gated video. The output of V1303 is applied to the error detector proper consisting of V1304A and B. In addition to the above mentioned input to V1304A and B, the range gate is applied to J1302 through transformer T1302 which has two output windings. One winding, terminals 2 and 5, applies the gate voltage to V1304A between its grid and cathode. The other winding, terminals 1 and 4, applies the gate voltage to V1304B between its grid and cathode. The gate that appears at J1302 has been delayed half the gate width from the gate as displayed on the R sweep. This delay is accomplished in the receiver chassis.

Capacitors C1305 and C1308 are caused to be charged in either a positive or negative direction dependent upon the position of the gated video in the gate, with respect to time. This is accomplished by causing one of the two switch tubes, V1304A or V1304B, to conduct and so charge the capacitor. The charging capacitor is at high impedance. V1305A and B, and V1306A and B comprise a d-c cathode-loaded amplifier which enables this voltage to be brought out at a usable impedance level. The differential d-c output voltage, dependent on the range error, appears across an impedance of approximately 1000 ohms, and is fed through the low-pass filter, R1319 and C1309, to the input of the range servo amplifier. The filter is used mainly to eliminate high frequency noise. Resistors R1301 and R1354 are noise balance adjustments.

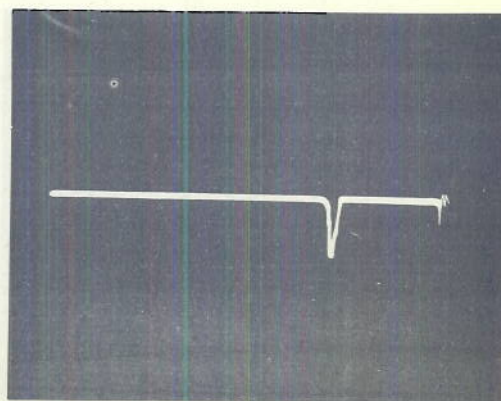
f. Range Servo Amplifier. (See figures 3-8, 3-10, and 3-14.) - If relay K1301 is in the automatic range tracking position, the output of the range error detector is applied to the grid of V1307A and V1308B. These tubes, together with V1307B and V1308A, comprise a balanced modulator. The grids of V1307B and V1308A are tied together and to this grid is applied the feedback voltage from the tachometer as described later. A 60-cycle reference voltage is applied to the cathodes of V1307A and B, and V1308A and B through T1303. This a-c voltage appears between terminals 1 and 4 of T1304. Its amplitude

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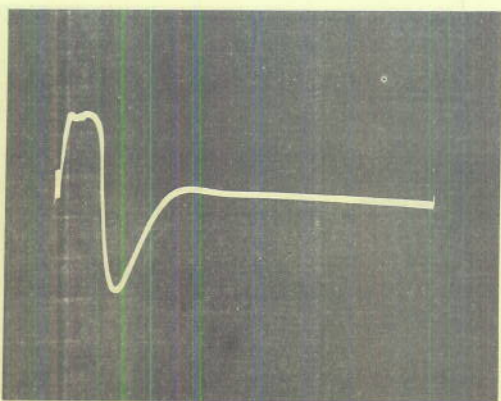
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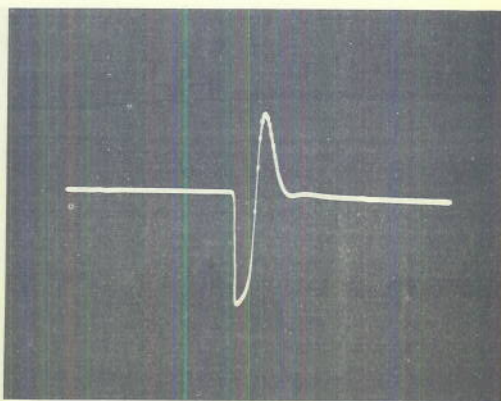
V305-6 - Sweep: 20 microseconds



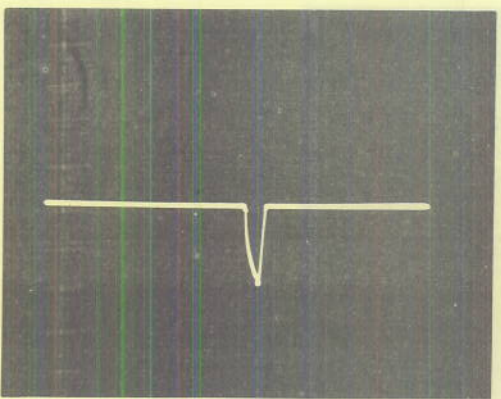
J302 - Sweep: 20 microseconds



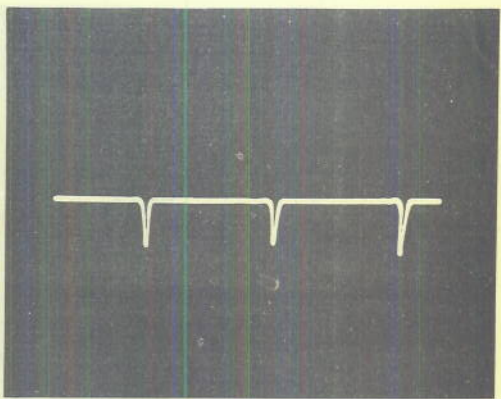
V308-2 - Sweep: 20 microseconds



V308-5 - Sweep: 20 microseconds



J301 - Sweep: 20 microseconds

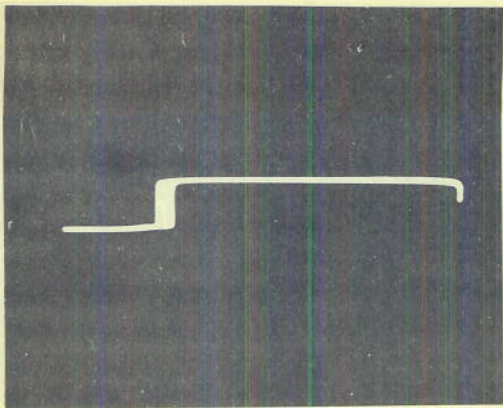


V303-6 and V319-6 - Sweep: 20 microseconds

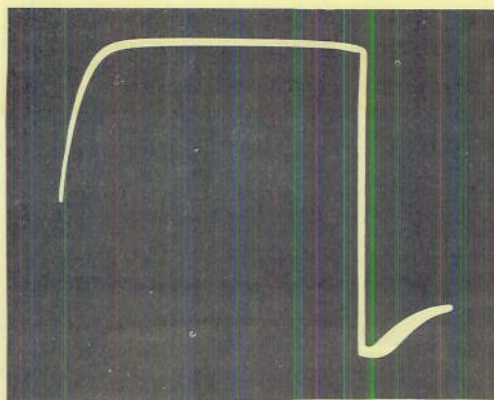
Figure 3-19. (Sheet 1 of 5 sheets) Range Unit Wave Shapes

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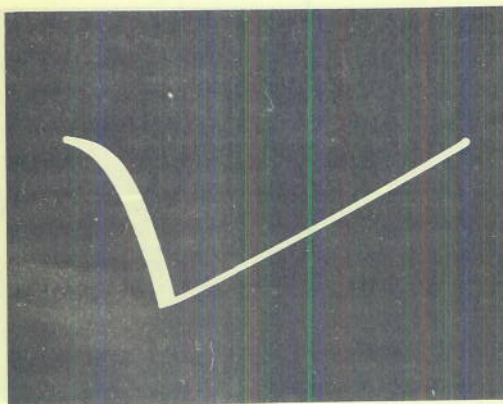
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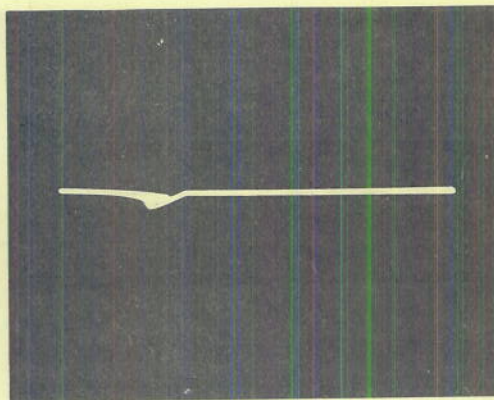
V309-2 - Sweep: 1000 microseconds



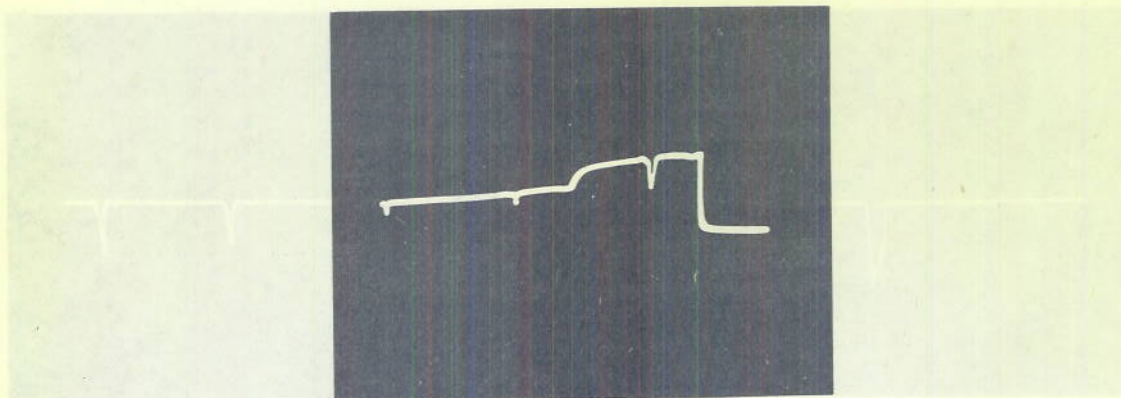
V309-5 - Sweep: 1000 microseconds



V312-4 and 5 - Sweep: 1000 microseconds



V312-6 - Sweep: 1000 microseconds



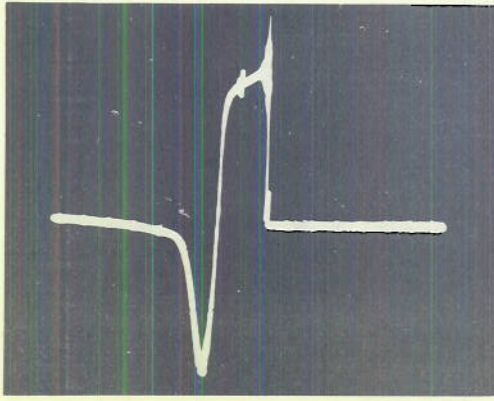
V315-3 - Sweep: 20 microseconds

Figure 3-19. (Sheet 2 of 5 sheets) Range Unit Wave Shapes

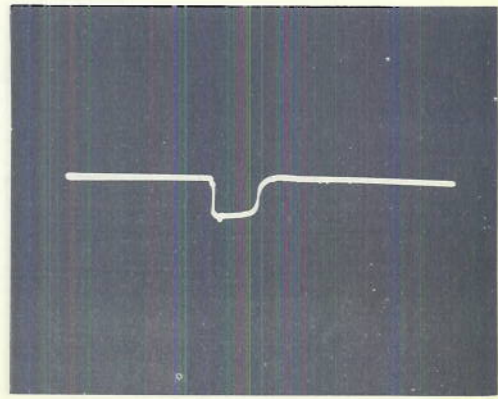
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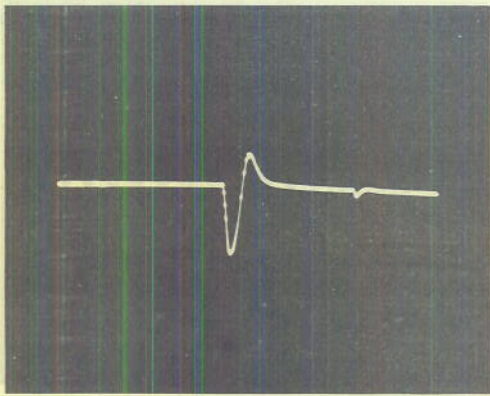
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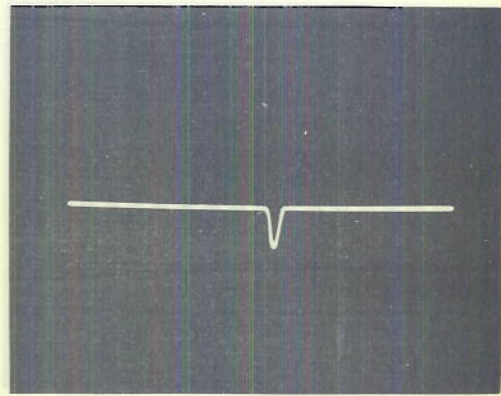
V315-5 - Sweep: 20 microseconds



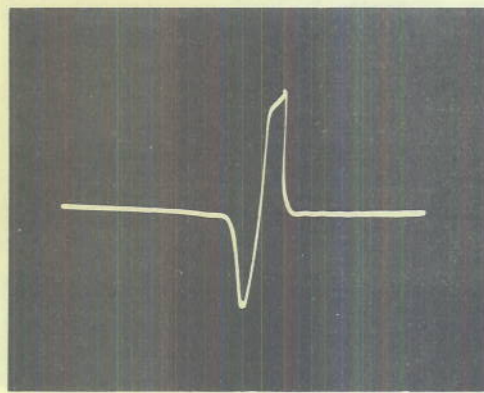
V320-3 - Sweep: 20 microseconds



V320-2 and 5 - Sweep: 20 microseconds



J305 - Sweep: 20 microseconds



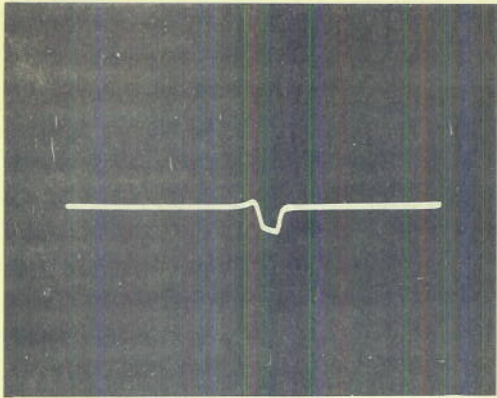
V321-2 and 5 - Sweep: 20 microseconds

Figure 3-19. (Sheet 3 of 5 sheets) Range Unit Wave Shapes

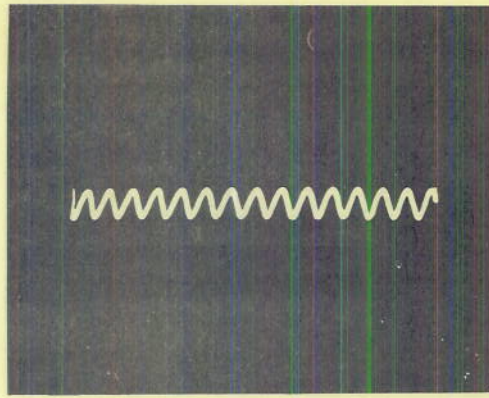
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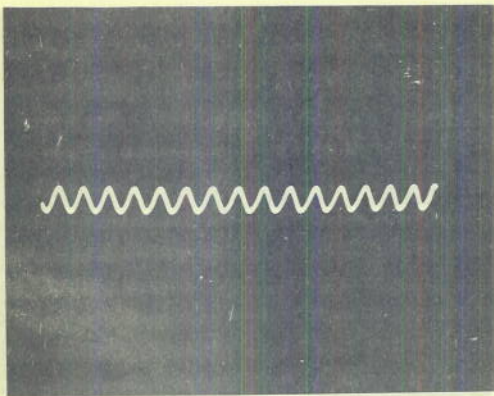
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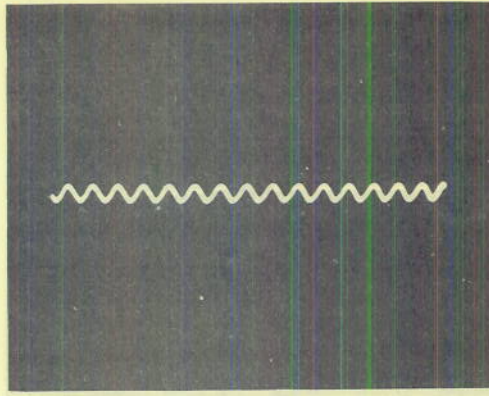
J304 - Sweep: 20 microseconds



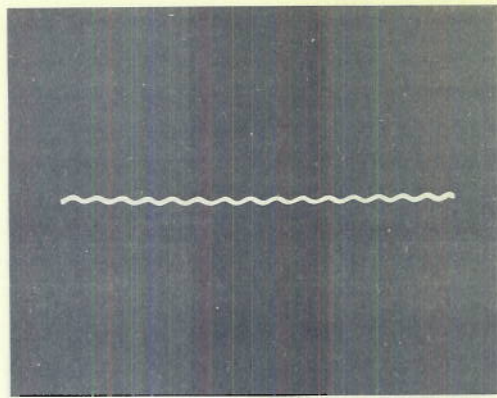
V301-4 - Sweep: 20 microseconds



V302-3 - Sweep: 100 microseconds



V316-4 - Sweep: 100 microseconds

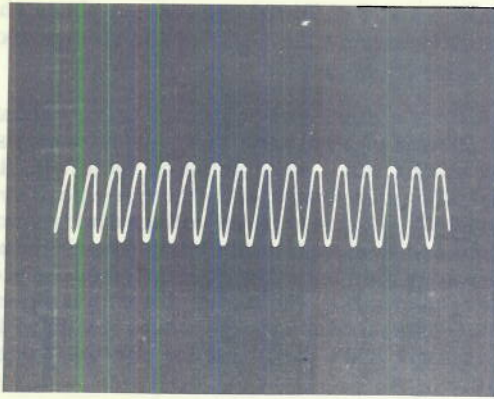


V317-8 - Sweep: 100 microseconds

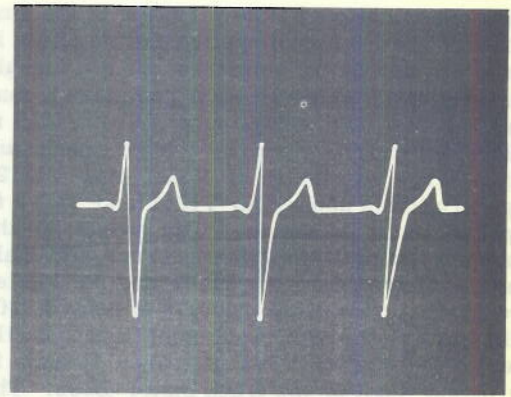
Figure 3-19. (Sheet 4 of 5 sheets) Range Unit Wave Shapes

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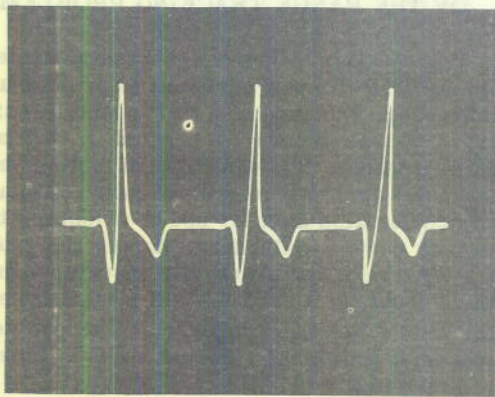
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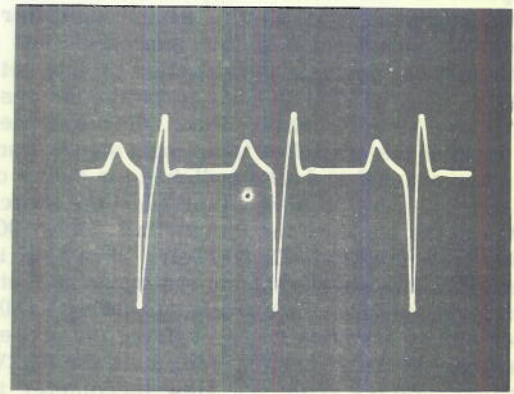
V318-8 - Sweep: 100 microseconds



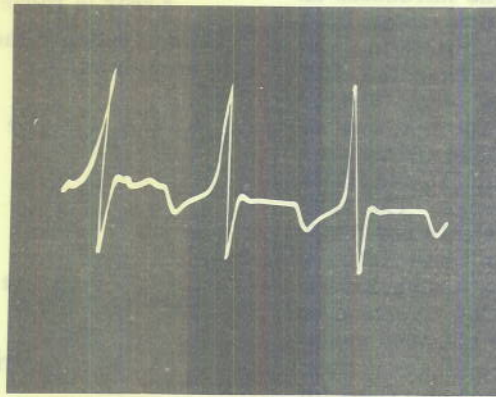
V319-2 - Sweep: 20 microseconds



V319-5 - Sweep: 20 microseconds



V303-5 - Sweep: 20 microseconds



V303-2 - Sweep: 20 microseconds

Figure 3-19. (Sheet 5 of 5 sheets) Range Unit Wave Shapes

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is caused to change by the variation in the amplitude of the d-c signal applied and its phase is caused to vary by the polarity of the d-c signal. The circuits of V1309A and B comprise a conventional cascaded voltage amplifier. V1310 is a phase splitting tube which drives the push-pull output stage consisting of V1311 and V1312. Degeneration is applied to V1311 and V1312 to improve their operation. The output of the range servo amplifier appears across terminals 2 and 8 of transformer T1305 and is applied through the appropriate contacts of relay K1301 to the track motor B305 via terminal 6 of TB1301. The d-c tachometer G301 is geared directly to the output shaft of the track motor B305. The voltage generated by G301 is applied to terminal 10 of TB1301, and from there goes to the grid of V1307B and V1308A through the high-pass network consisting of C1317 and R1326. The response of this network determines the bandwidth characteristic of the servo amplifier. (Refer to paragraph 6 of this subsection for a mathematical analysis of the action of this network.) Relay K1301 is used to switch the system from slew to track. This relay switches the input of the amplifier to an input signal from the slew channel and also switches the output of the amplifier to the slew motor when the switch S301 (on the panel of the Range Unit, Unit 300) is in SLEW position. Conversely, when S301 is at AUTO., the relay connects the inputs and outputs for automatic range tracking. Relay K1301 also applies feedback voltages from the proper sources. When the switch S301 is in the SLEW position, voltage from the slew tachometer is connected to the amplifier input and, in the AUTO. position, feedback voltage from the track tachometer is connected to the input. Slewing is accomplished by displacing the rotor of the 1CT control transformer, B304. This introduces an error signal which causes the slew motor B306 to drive the 5G synchro generator B303 to a position where the output voltage from the 1CT control transformer rotor is at zero. Voltage from the control transformer rotor is applied between terminals 1 and 4 of T1306 and appears across its terminals 5 and 8. C1318 and R1339 comprise a phase-shifting network. The voltage from the junction point of C1318 and R1339 is applied through a contact on relay K1301 to terminal 8 on T1304. When the switch S301 is at AUTO., terminal 8 of T1304 is grounded through relay K1301. Thus the balanced modulator is not used for the signal voltage on slew. The slew system has a d-c tachometer G302 for feedback voltage. The slew tachometer voltage is applied through a voltage divider composed of R432 and R433 to the grid of V1307B and the grid of V1308A; thus mixing of the feedback voltage and the signal voltage is obtained in transformer T1304. R1359 and C1321 connected across ter-

minals 6 and 7 of T1304 comprise a phase shift network to correct the phase of the voltage from the balanced modulator.

S302 is a microswitch located in the mechanical portion of the range unit. It is used as a limit switch, and, when actuated by a cam (located on a gear connected to the one-speed synchro B303), disconnects the voltage divider from ground and thus applies the full feedback voltage to the amplifier and slows the speed of the slew motor, preventing the motor from driving into the mechanical stop at high speed. Switch S302 is actuated 8000 yards before the mechanical stops.

g. Range System, Wave Shapes. - Wave shapes at significant test points in the range unit are shown in the five sheets of figure 3-19.

6. APPENDIX: MATHEMATICAL ANALYSIS OF THE RANGE TRACKING PROBLEM

a. Introduction. - The range tracking system of the Lark SP-1M was designed to provide automatic range tracking of a high speed missile flying a course known to present a difficult tracking problem. The equations of motion were derived and analyzed to provide range rate and range acceleration data for use in computing the necessary servo bandwidth to handle the problem. With information on the required bandwidth at hand the servo system was designed.

b. The Tracking Problem. - The problem is presented graphically in figure 3-20. Conditions imposed are:

$$\text{Target speed: } S_n = 3000K$$

$$\text{Range at crossover: } R_o = 4000 \text{ yds.}$$

$$\text{Elevation angle at crossover: } \phi_o = 60^\circ$$

$$\text{Error in range (max.): } E_R = \pm 5 \text{ yds.}$$

The derivation of the equation of motion for range is as follows:

$$R = \left[(R_h)^2 + H^2 \right]^{1/2} \quad (1)$$

$$H = \text{Target Altitude.}$$

$$R_h = \text{Horizontal Range}$$

But

$$R_h^2 = R_{ho}^2 + (S_n t)^2 \quad \text{where} \quad (2)$$

$$S_n t = \text{Target Speed} \times \text{Time.}$$

The equation for range as a function of time is:

$$R = \left[R_{ho}^2 + (S_n t)^2 + H^2 \right]^{1/2} \quad (3)$$

This function is plotted as figure 3-21.

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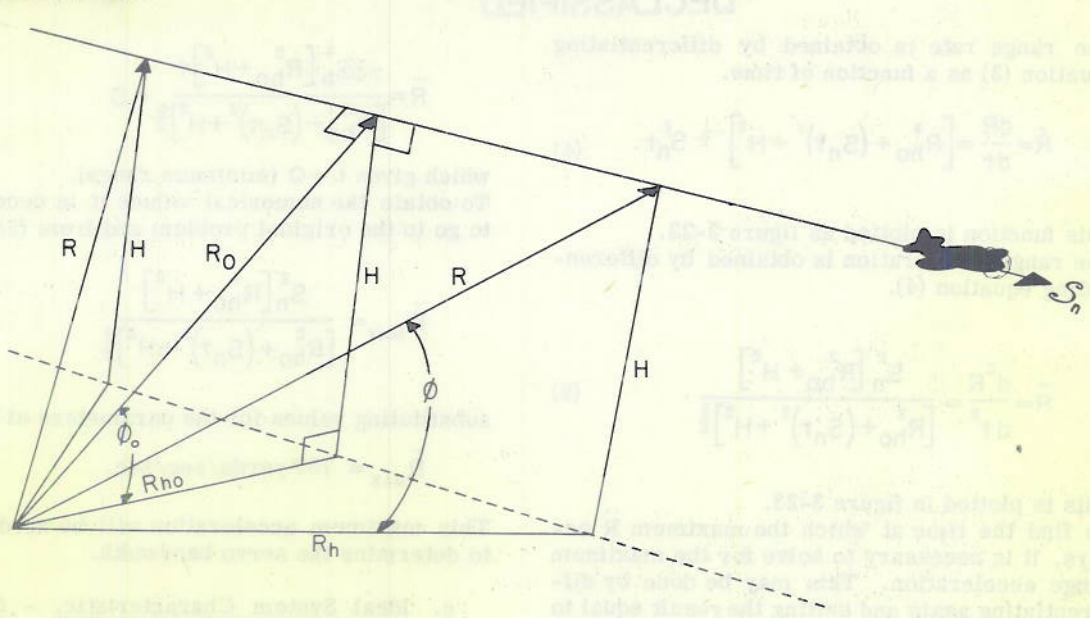


Figure 3-20. Range Tracking Problem

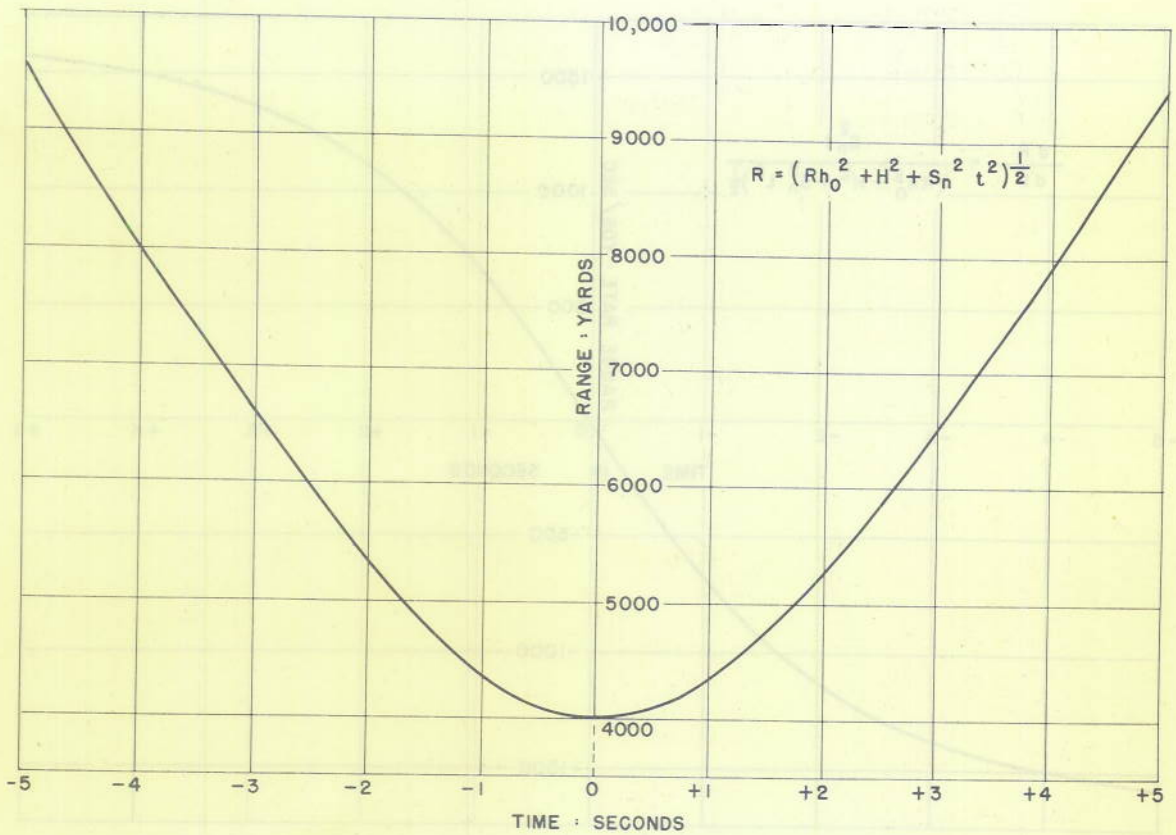


Figure 3-21. Range as a Function of Time

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The range rate is obtained by differentiating equation (3) as a function of time.

$$\dot{R} = \frac{dR}{dt} = [R_{ho}^2 + (S_n t)^2 + H^2]^{-\frac{1}{2}} S_n^2 t \quad (4)$$

This function is plotted as figure 3-22. The range acceleration is obtained by differentiating equation (4).

$$\ddot{R} = \frac{d^2R}{dt^2} = \frac{S_n^2 [R_{ho}^2 + H^2]}{[R_{ho}^2 + (S_n t)^2 + H^2]^{\frac{3}{2}}} \quad (5)$$

This is plotted in figure 3-23. To find the time at which the maximum \ddot{R} occurs, it is necessary to solve for the maximum range acceleration. This may be done by differentiating again and setting the result equal to zero, and then solving for the value as follows:

$$\ddot{\ddot{R}} = \frac{-3S_n^4 [R_{ho}^2 + H^2] t}{[R_{ho}^2 + (S_n t)^2 + H^2]^{\frac{5}{2}}} = 0 \quad (6)$$

which gives $t = 0$ (minimum range). To obtain the numerical values it is necessary to go to the original problem and from (5)

$$\ddot{R}_{MAX} = \frac{S_n^2 [R_{ho}^2 + H^2]}{[R_{ho}^2 + (S_n t)^2 + H^2]^{\frac{3}{2}}} \quad (7)$$

substituting values for the parameters at $t = 0$

$$\ddot{R}_{MAX} = 750 \text{ yards/sec/sec.} \quad (8)$$

This maximum acceleration will be used later to determine the servo bandwidth.

c. Ideal System Characteristic. - Of the several transmission characteristics which

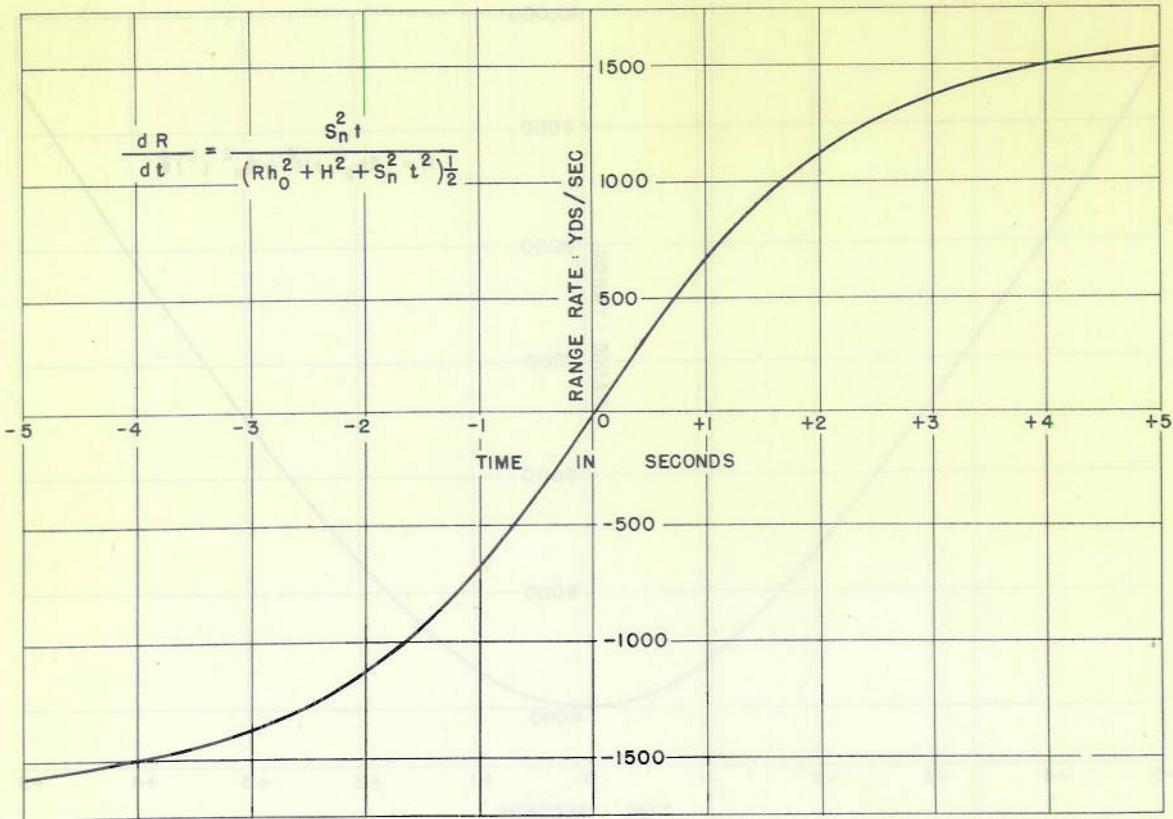


Figure 3-22. Range Rate as a Function of Time

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could be used to solve the range servo problem, one was chosen which would make a compromise between maximum error, type of error, and required servo bandwidth. The characteristic allows the given target (figure 3-20) to be tracked with zero velocity error, low acceleration error, and rather easily attainable bandwidth. The 40-20 decibel per decade transmission characteristic was used. This characteristic is so named because the open loop response drops from maximum gain near zero frequency at a rate of 40 decibels per frequency decade and breaks into a rate of 20 decibels per frequency decade in the region where the open loop gain is crossing unity. Figure 3-24 shows the synthesis of such a characteristic with the transmission expressions for the component parts expressed in operational form.

The total transmission characteristic, μ , is given as:

$$\mu = \frac{\omega_2^2}{p^2} \left(\frac{\omega_2 + p}{\omega_2} \right) \quad (9)$$

In closing the loop, commonly used feedback

amplifier terminology applies, as shown in figure 3-25, that is:

$$\frac{R_{OUT}}{R_{IN}} = \frac{\mu}{1 - \mu\beta} \quad (10)$$

where $\beta = -1$

$$\text{So } \frac{R_{OUT}}{R_{IN}} = \frac{\mu}{1 + \mu} \quad (11)$$

Substituting

$$\frac{R_{OUT}}{R_{IN}} = \frac{\frac{\omega_2^2}{p^2} \left(\frac{\omega_2 + p}{\omega_2} \right)}{1 + \frac{\omega_2^2}{p^2} \left(\frac{\omega_2 + p}{\omega_2} \right)} \quad (12)$$

This is the desired closed loop response provided that the components have ideal characteristics. (See figure 3-26.)

d. Bandwidth Considerations. - A typical servo system is shown diagrammatically in fig-

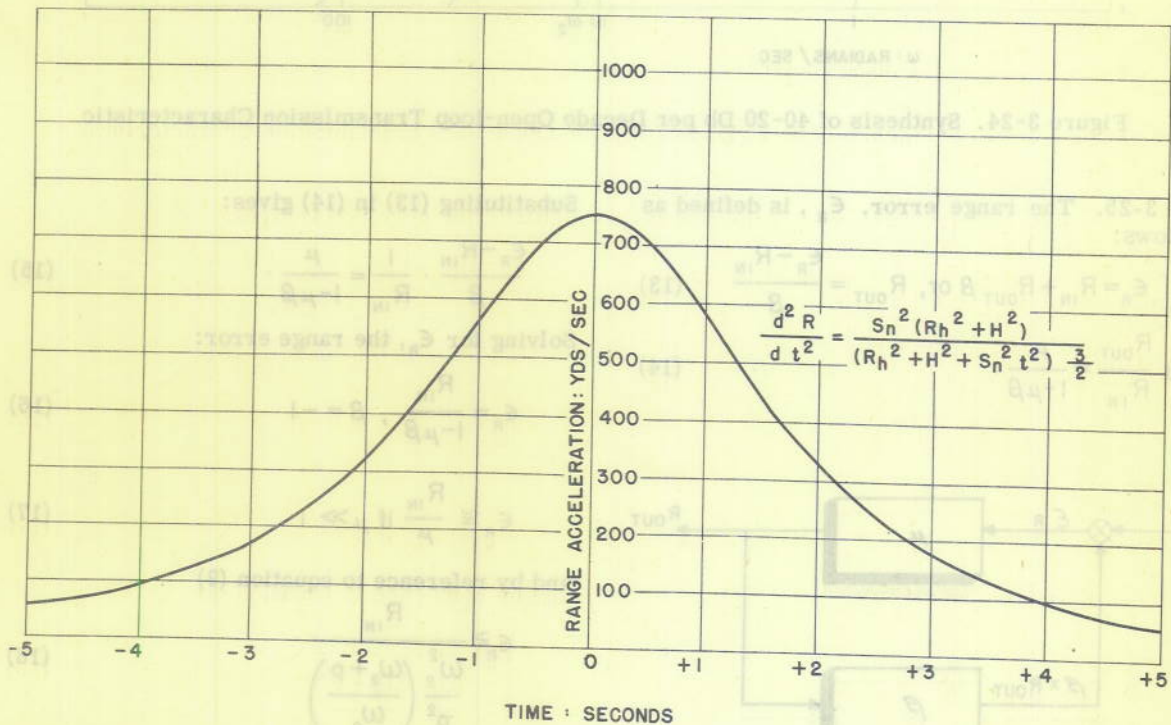


Figure 3-23. Range Acceleration as a Function of Time

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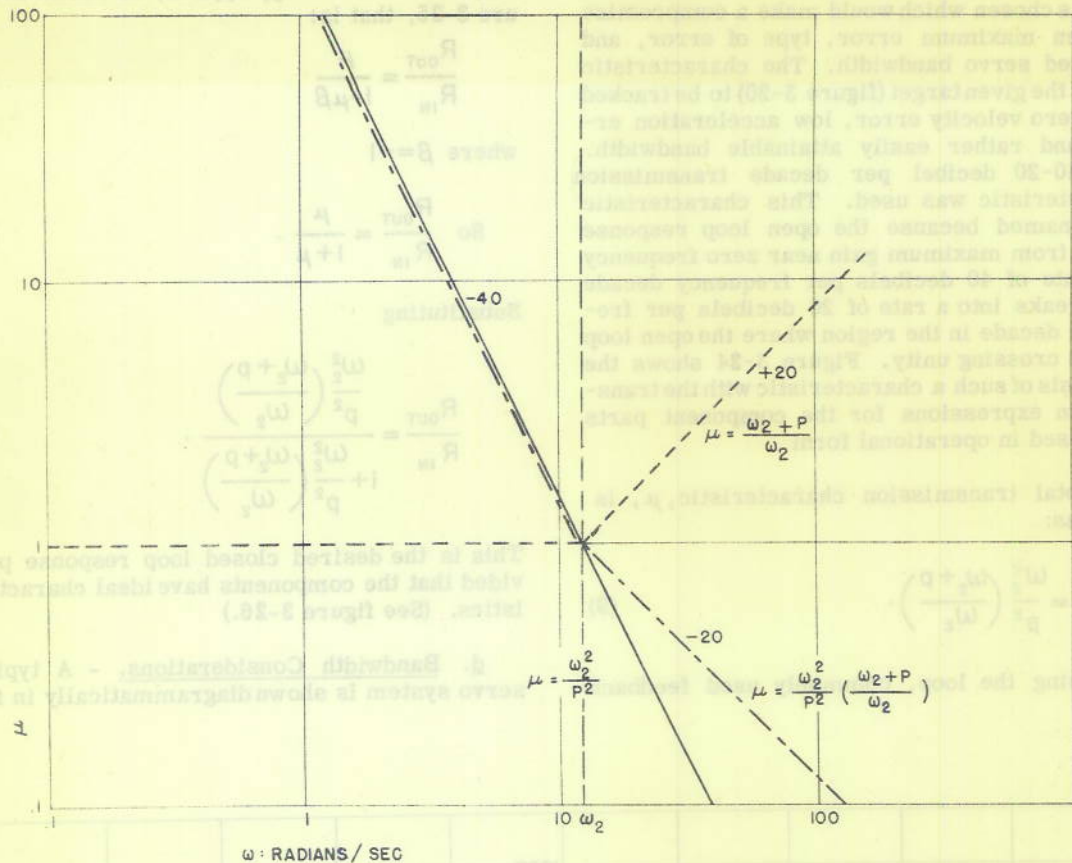


Figure 3-24. Synthesis of 40-20 Db per Decade Open-loop Transmission Characteristic

Figure 3-25. The range error, ϵ_R , is defined as follows:

$$\epsilon_R = R_{IN} + R_{OUT} \beta \text{ or, } R_{OUT} = \frac{\epsilon_R - R_{IN}}{\beta} \quad (13)$$

and $\frac{R_{OUT}}{R_{IN}} = \frac{\mu}{1 - \mu\beta} \quad (14)$

Substituting (13) in (14) gives:

$$\frac{\epsilon_R - R_{IN}}{\beta} \cdot \frac{1}{R_{IN}} = \frac{\mu}{1 - \mu\beta} \quad (15)$$

Solving for ϵ_R , the range error:

$$\epsilon_R = \frac{R_{IN}}{1 - \mu\beta}, \beta = -1 \quad (16)$$

$$\epsilon_R \approx \frac{R_{IN}}{\mu} \text{ if } \mu \gg 1 \quad (17)$$

and by reference to equation (9)

$$\epsilon_R \approx \frac{R_{IN}}{\frac{\omega_2^2}{p^2} \left(\frac{\omega_2 + p}{\omega_2} \right)} \quad (18)$$

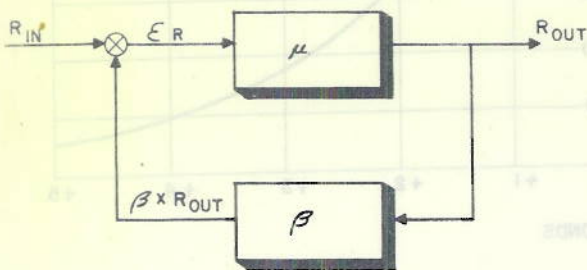


Figure 3-25. Simple Servo System - Diagram

For low angular frequencies, $\omega \ll \omega_2, \frac{\omega_2 + p}{\omega_2} \rightarrow 1$

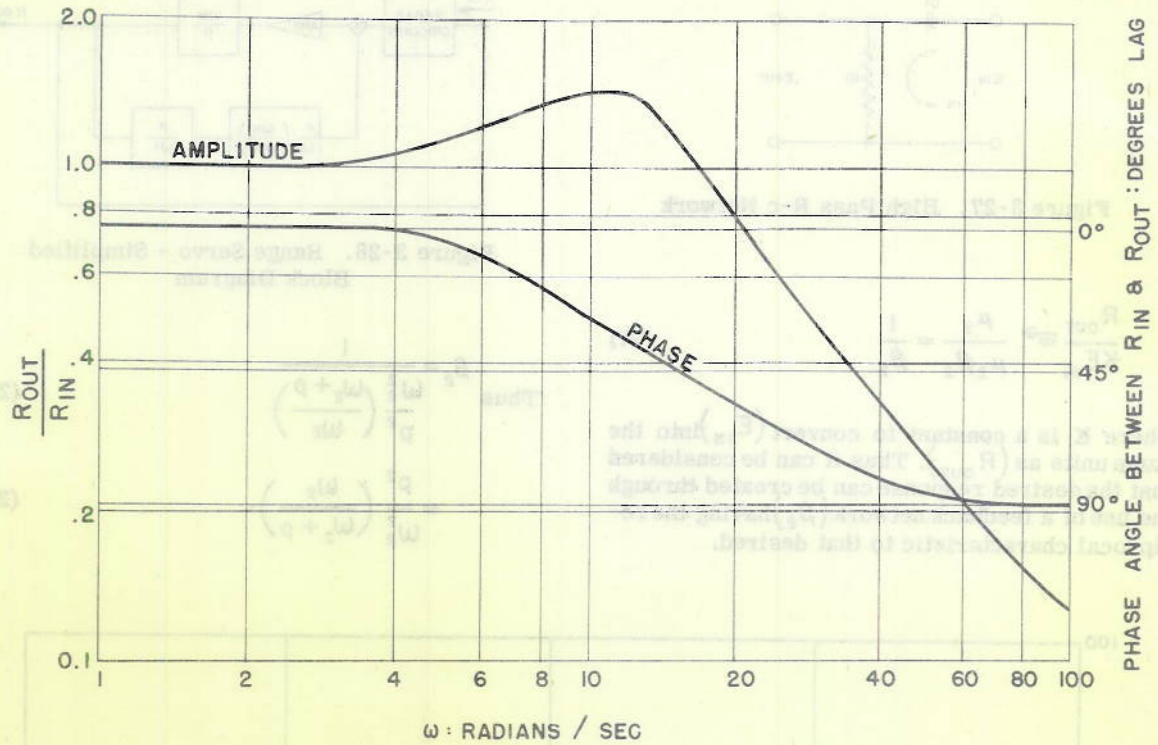


Figure 3-26. Closed-loop Gain and Phase Characteristics

$$\epsilon_R \approx \frac{R_{IN}}{\left(\frac{\omega_2^2}{p^2}\right)} \quad (19)$$

In the operational notation

$$p^2 = \frac{d^2}{dt^2}, \quad \epsilon_R = \frac{\ddot{R}_{IN}}{\omega_2^2} \quad (20)$$

Substituting the maximum acceleration of 750 yds per second per second into (20) gives

$$\epsilon_R = \frac{750}{\omega_2^2} \quad (21)$$

where, from the specifications, $\epsilon_R = \pm 5$ yards

$$\omega_2^2 = \frac{750}{5} = 150 \quad (22)$$

or $\omega_2 = 12.2$ radians per second. (23)

Thus the maximum angular frequency component of target motion which must be passed by the

servo system in order to track the given target with an error of ± 5 yards maximum is 12.2 radians per second. The closed loop servo system must then be flat from a very low angular frequency out to an angular frequency of 12.2 radians per second.

e. Component Design. - From equation (9) the desired total open loop transmission characteristic is given as

$$\mu = \frac{\omega_2^2}{p^2} \left(\frac{\omega_2 + p}{\omega_2} \right) \quad (24)$$

To mechanize the above into a servo system it is reasonable for the initial design considerations to take advantage of the following relationships.

$$\frac{R_{OUT}}{KE_{IN}} = \frac{\mu_2}{1 + \mu_2 \beta_2} \quad (25)$$

and if $\mu_2 \beta_2 \gg 1$ then (26)

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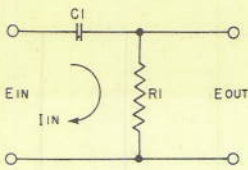


Figure 3-27. High Pass R-c Network

$$\frac{R_{OUT}}{KE_{IN}} \Rightarrow \frac{\mu_2}{\mu_2 \beta_2} = \frac{1}{\beta_2} \quad (27)$$

where K is a constant to convert (E_{IN}) into the same units as (R_{OUT}). Thus it can be considered that the desired response can be created through the use of a feedback network (β_2) having the reciprocal characteristic to that desired.

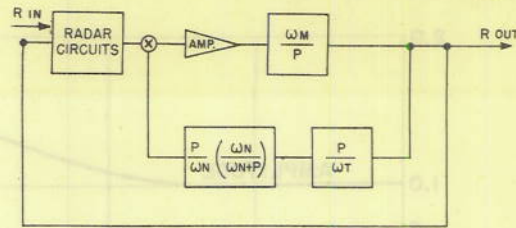


Figure 3-28. Range Servo - Simplified Block Diagram

$$\text{Thus } \beta_2 = \frac{1}{\frac{\omega_2^2}{p^2} \left(\frac{\omega_2 + p}{\omega_2} \right)} \quad (28)$$

$$= \frac{p^2}{\omega_2^2} \left(\frac{\omega_2}{\omega_2 + p} \right) \quad (29)$$

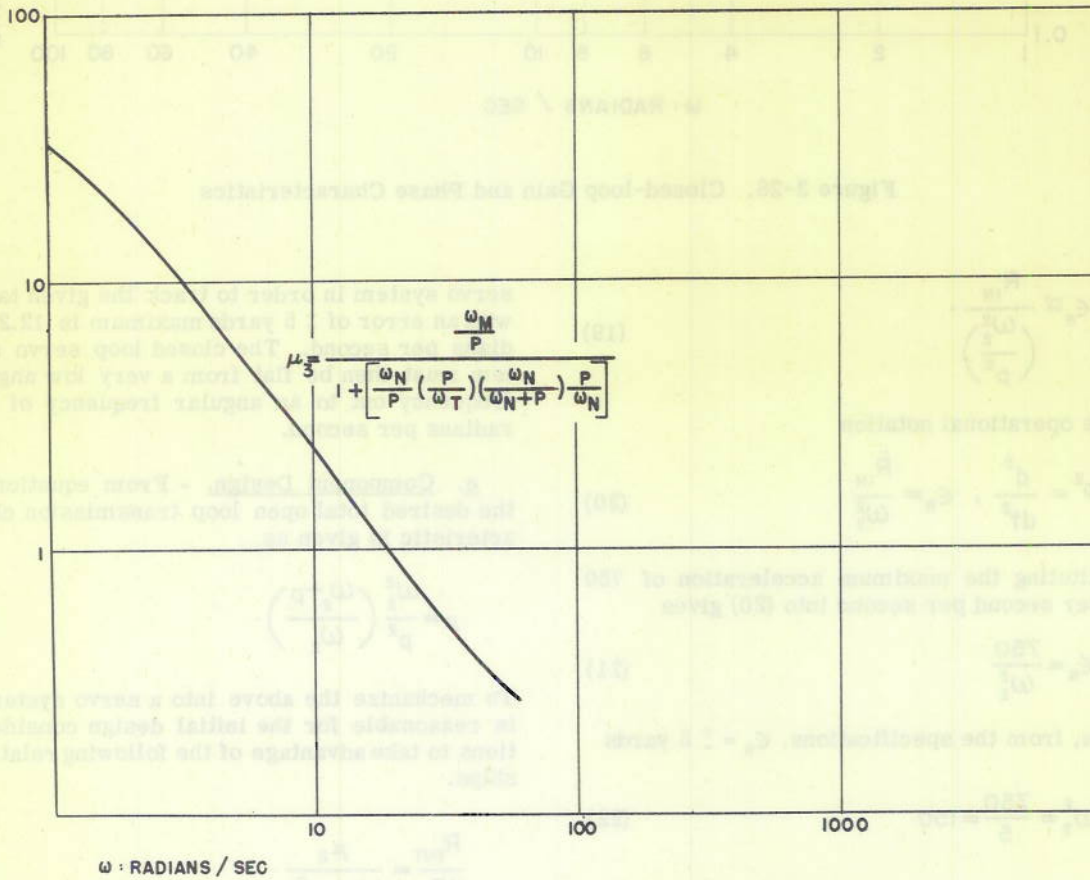


Figure 3-29. Tracking Loop Gain - Open Loop Characteristics

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A tachometer is used for $\frac{p}{\omega_T}$ and a high-pass RC network for

$$\frac{p}{\omega_2} \left(\frac{\omega_2}{\omega_2 + p} \right) \quad (30)$$

where $\omega_2 = \frac{1}{R_1 C_1}$. (31)

If ω_T is adjusted to be equal to ω_2 then

$$\frac{R_{OUT}}{R_{IN}} \Rightarrow \frac{1}{\beta_2} = \frac{1}{\frac{p^2}{\omega_2^2} \left(\frac{\omega_2}{\omega_2 + p} \right)} \quad (32)$$

or $\frac{R_{OUT}}{KE_{IN}} = \frac{R_{OUT}}{R_{IN}} = \frac{\omega_2^2}{p^2} \left(\frac{\omega_2 + p}{\omega_2} \right)$.

To leave the problem for a moment, the high-pass feedback network (figure 3-27) may be analyzed as follows:

$$I_{IN} = \frac{E_{IN}}{Z} = \frac{E_{IN}}{R_1 + \frac{1}{pC_1}} \quad (33)$$

$$E_{OUT} = I_{IN} R_1 \quad (34)$$

$$\frac{E_{OUT}}{E_{IN}} = \frac{R_1}{R_1 + \frac{1}{pC_1}} = \frac{pC_1 R_1}{pC_1 R_1 + 1} \quad (35)$$

Let $\omega_2 = \frac{1}{C_1 R_1}$ (36)

$$\frac{E_{OUT}}{E_{IN}} = \frac{p}{\omega_2} \frac{1}{\frac{p}{\omega_2} + 1} = \frac{p}{\omega_2} \left(\frac{\omega_2}{\omega_2 + p} \right) \quad (37)$$

Returning to the servo problem, for the complete closed loop form

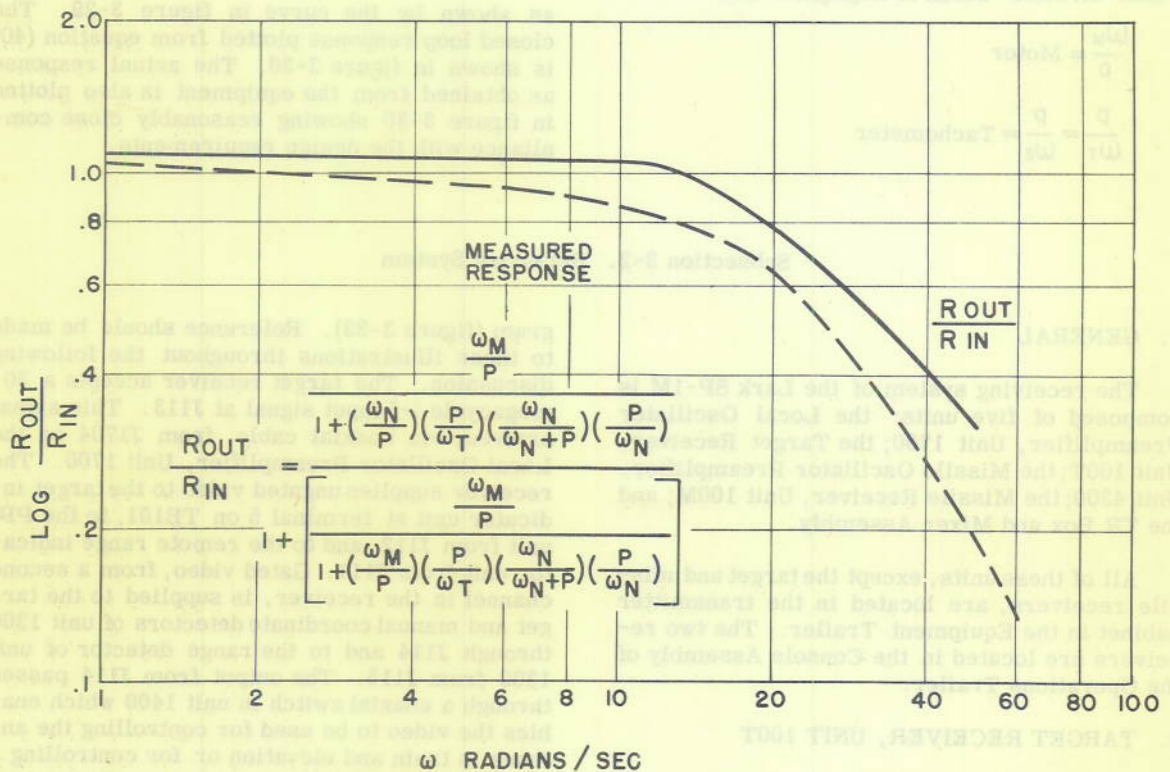


Figure 3-30. Closed-loop Response as Calculated and as Actually Measured

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$$\frac{R_{OUT}}{R_{IN}} = \frac{\frac{R_{OUT}}{KE_{IN}}}{1 + \left(\frac{R_{OUT}}{KE_{IN}}\right)}, \beta = -1 \quad (38)$$

substitute from equation (32)

$$\frac{R_{OUT}}{R_{IN}} = \frac{\frac{\omega_2^2 (\omega_2 + p)}{p^2}}{1 + \frac{\omega_2^2 (\omega_2 + p)}{p^2}} \quad (39)$$

thus satisfying equation (12).

This expression is plotted in figure 3-26 both in amplitude and in phase. In the actual case when real components are employed, the statement that $\mu_2 \beta_2 \gg 1$ (equations (26) and (27)) is not strictly correct. Equation (12) is true only if the servo motor has no losses or is able to run on zero voltage. An analysis of the servo when these factors are taken into account follows.

Writing the loop expression for the system shown in figure 3-28 where contribution of the "radar circuits" block is negligible and:

$$\frac{\omega_M}{p} = \text{Motor}$$

$$\frac{p}{\omega_T} = \frac{p}{\omega_2} = \text{Tachometer}$$

$$\frac{p}{\omega_N} \left(\frac{\omega_N}{\omega_N + p} \right) = \frac{p}{\omega_2} \left(\frac{\omega_2}{\omega_2 + p} \right) = \text{Network}$$

$$\frac{R_{OUT}}{R_{IN}} = \frac{\frac{\omega_M}{p}}{1 + \left(\frac{p}{\omega_N}\right) \left(\frac{\omega_N}{\omega_N + p}\right) \left(\frac{p}{\omega_T}\right) \left(\frac{\omega_M}{p}\right)} \cdot (40)$$

$$1 + \frac{\omega_M}{p} \left(\frac{p}{\omega_N}\right) \left(\frac{\omega_N}{\omega_N + p}\right) \left(\frac{p}{\omega_T}\right) \left(\frac{\omega_M}{p}\right)$$

Thus equation (12) has been modified by the use of practical components to equation (40).

The tracking loop gain, as accomplished by an internal feedback amplifier, is

$$\mu_3 = \frac{\frac{\omega_M}{p}}{1 + \left(\frac{\omega_M}{p}\right) \left(\frac{\omega_N}{\omega_N + p}\right) \left(\frac{p}{\omega_T}\right) \left(\frac{p}{\omega_N}\right)} \quad (41)$$

as shown by the curve in figure 3-29. The closed loop response plotted from equation (40) is shown in figure 3-30. The actual response as obtained from the equipment is also plotted in figure 3-30 showing reasonably close compliance with the design requirements.

Subsection 3-2. Receiving System

1. GENERAL

The receiving system of the Lark SP-1M is composed of five units: the Local Oscillator Preamplifier, Unit 1700; the Target Receiver, Unit 100T; the Missile Oscillator Preamplifier, Unit 4300; the Missile Receiver, Unit 100M; and the TR Box and Mixer Assembly.

All of these units, except the target and missile receivers, are located in the transmitter cabinet in the Equipment Trailer. The two receivers are located in the Console Assembly of the Operations Trailer.

2. TARGET RECEIVER, UNIT 100T

a. Introduction. - The target receiver unit is shown in the photograph (figure 3-31) the block diagram (figure 3-32), and the schematic dia-

gram (figure 3-33). Reference should be made to these illustrations throughout the following discussion. The target receiver accepts a 30-megacycle i-f input signal at J113. This signal arrives, via coaxial cable, from J1704 on the Local Oscillator Preamplifier, Unit 1700. The receiver supplies ungated video to the target indicator unit at terminal 5 on TB101, to the PPI unit from J112, and to the remote range indicator unit from J111. Gated video, from a second channel in the receiver, is supplied to the target and manual coordinate detectors of unit 1200 through J114 and to the range detector of unit 1300 from J115. The output from J114 passes through a coaxial switch in unit 1400 which enables the video to be used for controlling the antenna in train and elevation or for controlling a monitor cross-pointer meter. Auxiliary circuits within the receiver are used to shape the gate and supply it to various portions of the sys-

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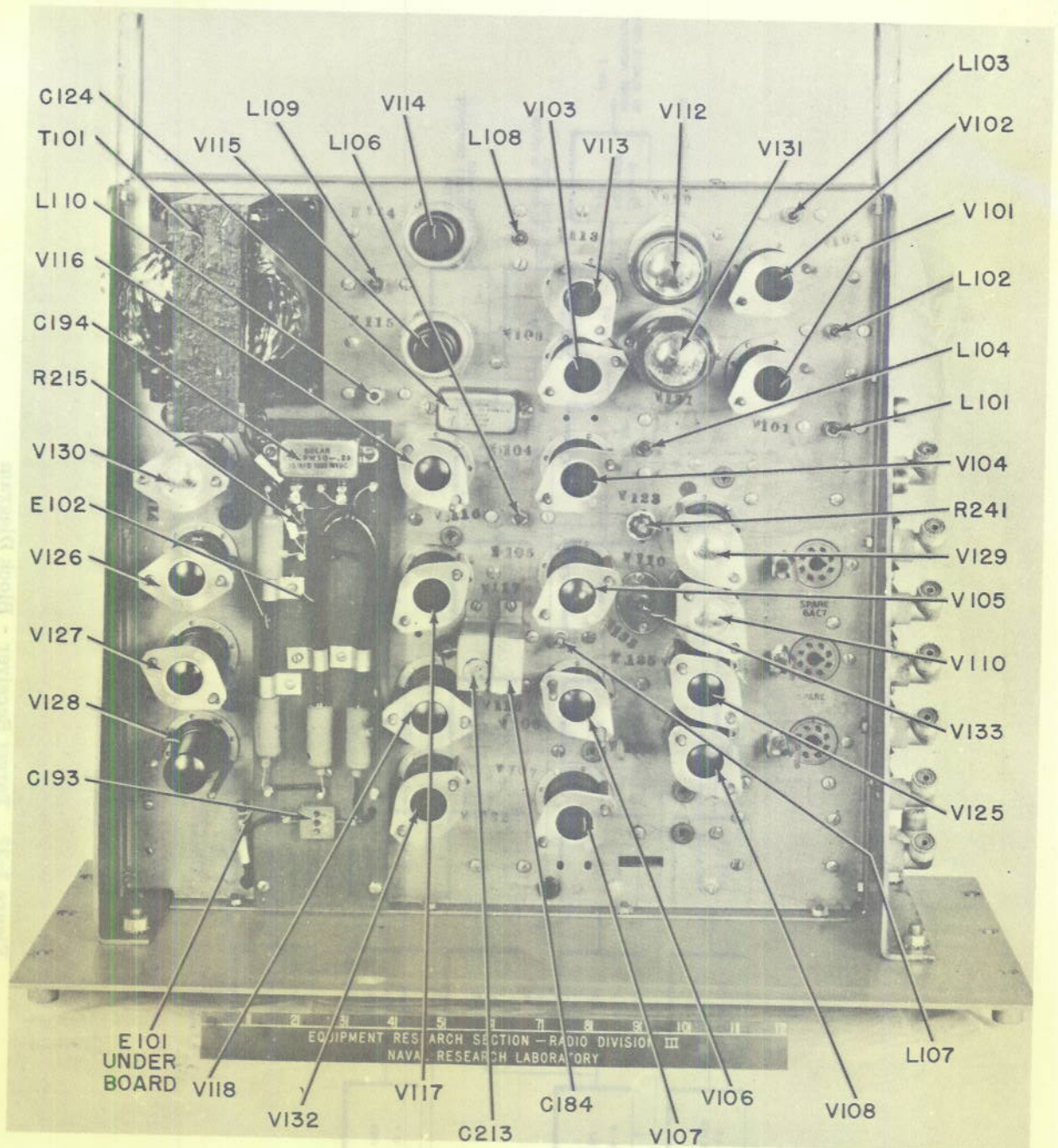


Figure 3-31. Target Receiver -Top View

tem. The gate for this purpose is received from the range unit at J117 and is applied to a shaper and to amplifiers and cathode followers which produce the following outputs: a negative gate at J118 for the A- and R-scope gate presentation of the Target Indicator Unit, Unit 1000T; a similar negative gate at J119 to the Remote Range

Indicator, Unit 8500, in the data recording section; and a positive gate, delayed one microsecond, at J120 to the range detector circuit of the T and M Range Detector and Servo Amplifier, Unit 1300. In addition the receiver is supplied with an automatic gain control signal from the pulse spreader circuits in either the T and M

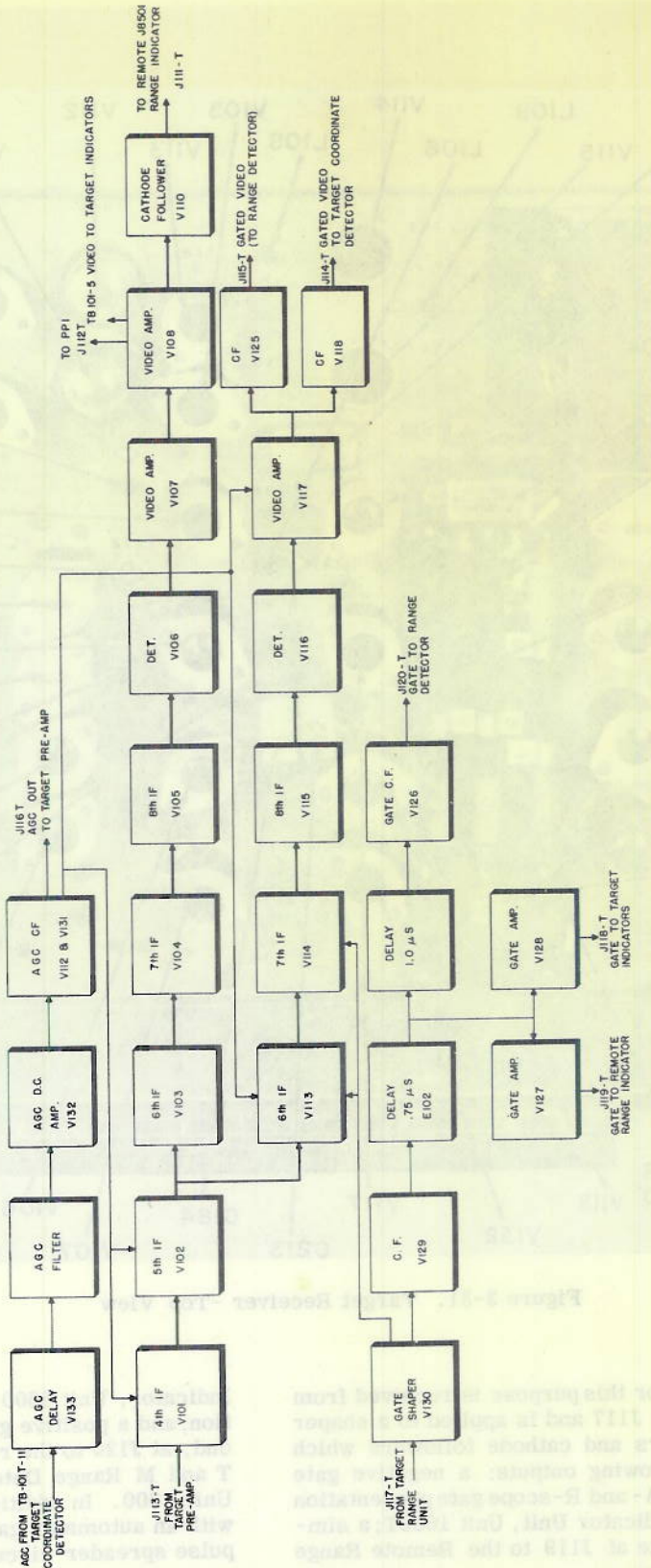


Figure 3-32. Target Receiver - Block Diagram

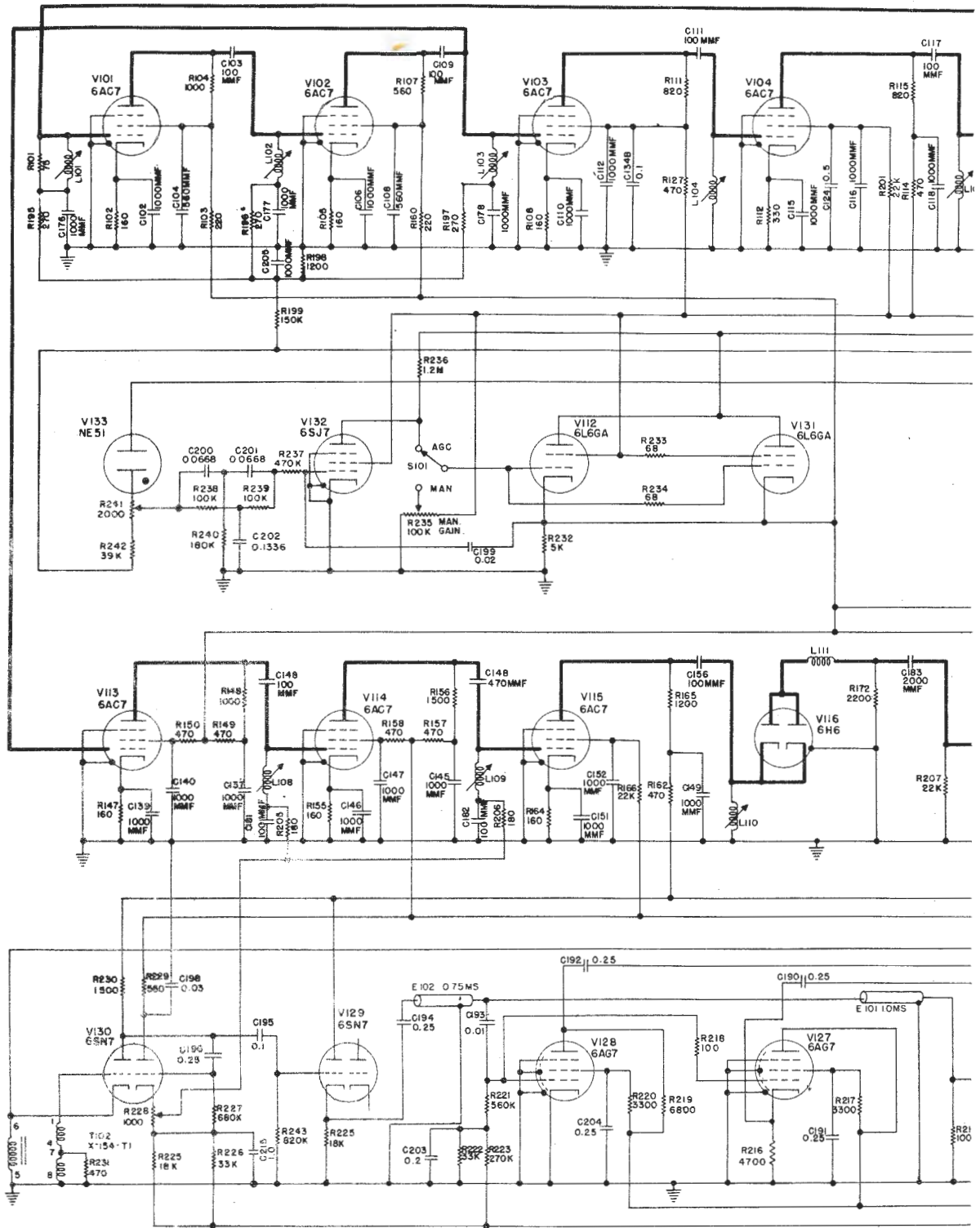
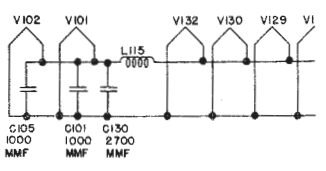
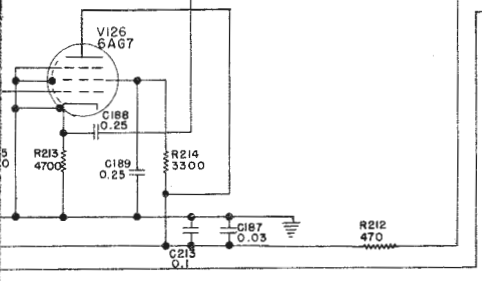
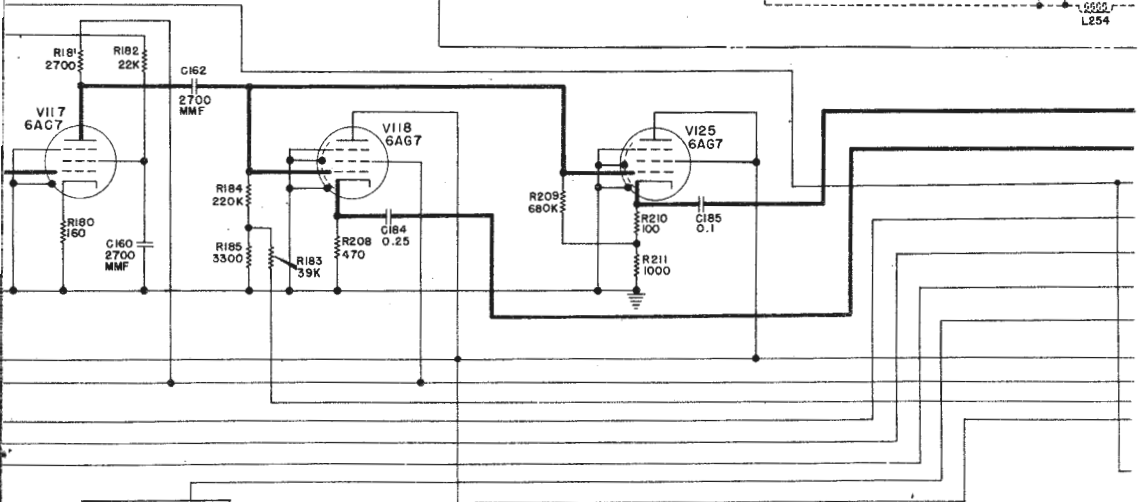
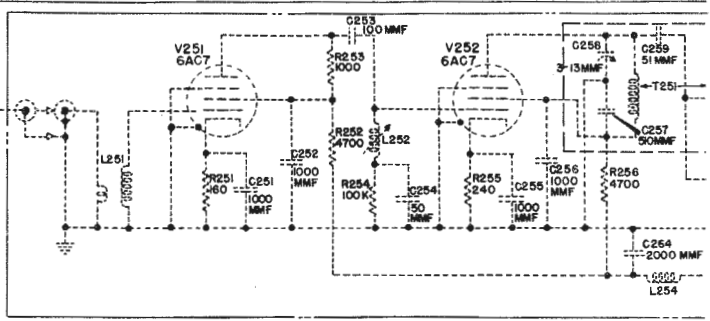
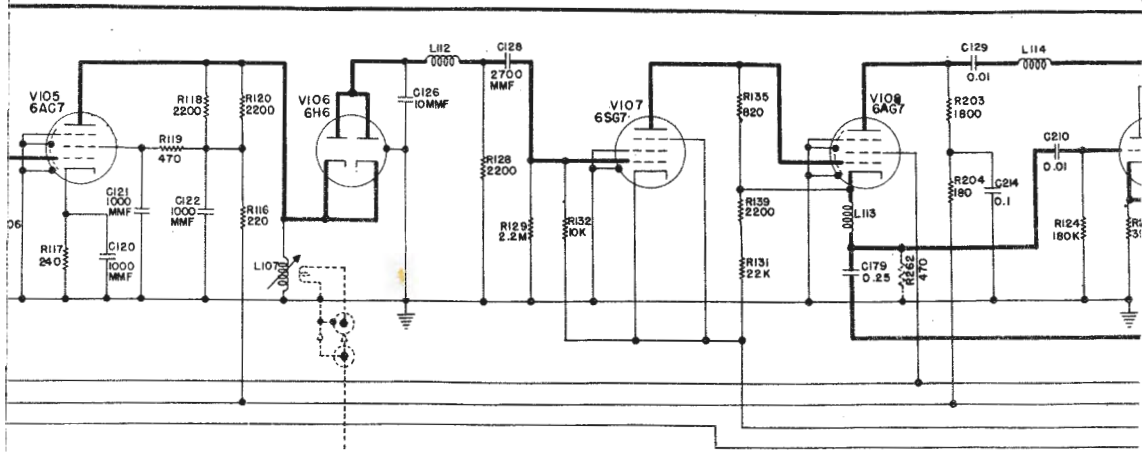
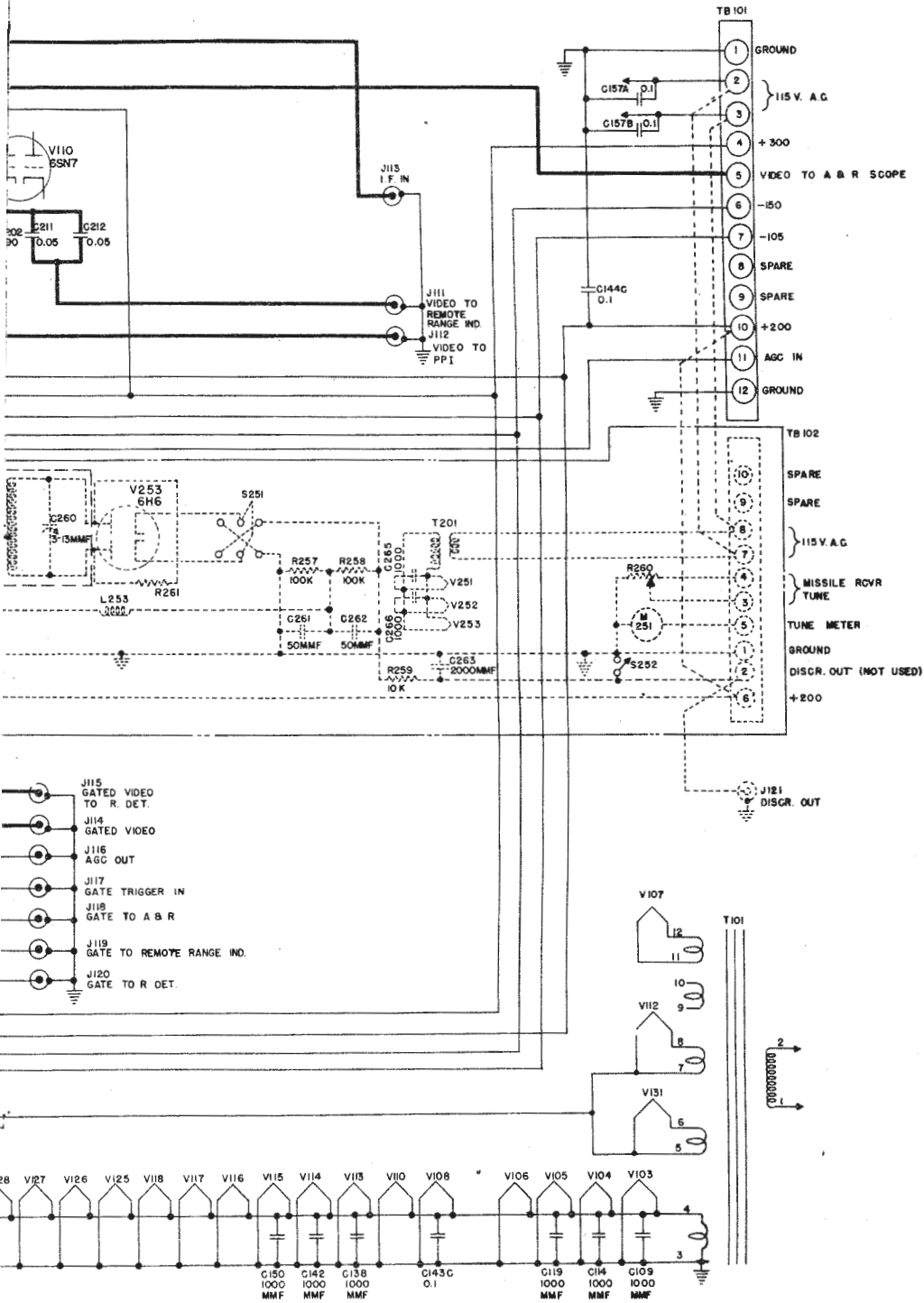


Figure 3-33. Target or Missile Receiver Unit - Schematic Diagram





Coordinate Detector or Synchronizer and Missile Coordinate Detector Units, Units 1200 and 600, respectively. The selection of the AGC source is accomplished by the operation of a coaxial relay for switching the gated video to insure that the automatic gain control signal is applied to the proper receiver. The automatic gain control signal is applied at terminal 11 of TB101.

b. Specifications. - The specified intermediate-frequency gain of the receiver unit is approximately 90 db in either the gated or the ungated channel. The gated video outputs are at a level of plus five volts. The ungated video supplied to the A and R scopes of the target indicator is at a level of about 70 volts and is negative. Ungated video is supplied to the remote range indicator at about a five-volt level. The automatic gain control circuits are designed to attenuate all incidental signal modulation between zero frequency and an angular frequency of 40 radians per second. Almost complete removal of the incidental modulation at near zero frequency is accomplished and at 40 radians per second, the AGC system reduces the incidental modulation by a factor of two. The automatic gain control circuits will provide sufficient control to maintain the receiver output flat within plus or minus three db for an input signal variation between noise level and 100 db above noise. The gate shaping circuits improve the shape of the gate so that it is reasonably square for presentation upon the oscilloscopes associated with the system.

c. Design Considerations. - The intermediate-frequency amplifier stages in the receiver unit, with minor exceptions, are the same as those in the receiver unit of the original SP-1M radar. The grid circuits of the first two stages in the ungated channel and the first three stages in the gated channel have been modified to include approximately one volt of fixed bias. Since a receiver input signal 100 db above noise develops an automatic gain control voltage which will reduce the plate and screen voltages of the controlled i-f stages to approximately 50 volts, the original cathode biasing system allowed the first few stages of the receiver to overload, an effect virtually eliminated by the fixed bias. The ungated video amplifier is the same as in the original SP-1M receiver with the exception that V110, a type 6SN7 tube, has been added as a cathode follower to supply ungated video to the Remote Range Indicator, Unit 8500. The gated video amplifier has been modified to apply automatic gain control voltage to the first video amplifier stage, V117. In addition, V125, a type 6AG7 tube, has been added to supply gated video to the range error detector circuit in unit 1300.

The video amplifier stages are of standard design. The first gate-shaper stage is of unique design in that a pulse is applied at a positive polarity to the cathode of a triode. This cathode is returned to ground through the primary winding of a pulse transformer. Two secondary windings on this transformer are series connected and feed the grid of the stage. The secondary of the pulse transformer is polarized so that the grid is driven rapidly negative upon the arrival of the pulse. The tube is thus driven very rapidly into the cut-off plate current region and a rectangular pulse is generated at the plate. V130, a type 6SN7 tube, performs this function.

d. Measured Performance. - The design requirements set up in paragraph 2c. of this subsection have been met with respect to the gated and ungated video outputs for the receiver. The ungated video output to the A and R scopes at terminal 5 of TB101 is negative and at an amplitude of about 70 volts. The video output from J112 to the PPI Unit, Unit 8500, is unaltered from that of the original SP-1M radar and remains at a level of about 12 volts. The ungated video output to the Remote Range Indicator, Unit 8500, at J111 is at a level of about five volts positive. The gated video output to the coordinate detector circuits at J114 is at a level of plus five volts. The gated video to the range detector is at an amplitude of plus five volts. Gate voltage at an amplitude of about 15 volts positive is available at J118 for application to the A and R scopes, and at J119 for application to the remote range indicator. Gate voltage is also available at an amplitude of about 30 volts at J120 for the range detector. This particular gate output has been delayed by approximately one microsecond to obtain the correct position for triggering the range switch of the range error detector described in subsection 3-1 of this report.

e. Circuit Description. (See figure 3-33.) - The i-f signal from the target oscillator pre-amplifier is applied via coaxial cable at J113. J113 is connected to the grid of V101, the first i-f amplifier, which in turn feeds V102, the second i-f amplifier. The output of V102 is fed into two channels: one an ungated i-f channel, the other a gated channel. The ungated channel is composed of V103, V104, V105, and V106, the latter being the ungated detector stage. Video amplification is provided in two stages, V107 and V108, type 6SG7 and 6AG7 tubes respectively. V108 is arranged to provide an output at terminal 5 for use in the target indicator and the cathode output is available at J112 for use in the PPI unit. A fixed bias of one volt is applied to the grids of the first three i-f stages, V101, V102, and V103. This bias is derived from the

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minus 150-volt supply by the use of a divider composed of R199 and R198. The junction point of these two resistors feeds into three decoupling circuits each of which is connected to a grid on each of the first three i-f amplifier stages. These i-f stages in the original SP-1M radar were cathode biased and the plate and screen voltages of these stages were varied in accordance with the automatic gain control signal. As the plate and screen voltages were reduced to a very low value, say 50 volts, in the presence of a strong signal a very small plate current flowed, and consequently almost no bias was developed in the cathode resistors. This lack of bias made the controlled stages easy to overload. The minus one-volt fixed bias of the present equipment overcomes this difficulty. The output of V102, in addition to being fed to the ungated channel, is supplied to the gated i-f channel which is composed of V113, V114, V115, and V116, the latter being the gated channel detector. Video amplification is provided in three stages, V117, V118, and V125. V118 is a cathode follower which feeds gated video to the coaxial jack J114 for use in units 600 and 1200. V125 is also a cathode follower of the same design in which the output is available at J115 for use in unit 1300. Gating is accomplished in V114 and V115. The gate is applied to the grid return of these stages through decoupling circuits composed of R205 and C181, and R206 and C182. Gate voltage is received from the range unit at J117 and applied to the cathode of V130, a type 6SN7 tube, which acts as gate shaper and cathode follower. One half of V130 is used for gate shaping and has in its grid circuit two windings of pulse transformer T102 connected in series aiding. The gate signal from the range unit is applied to a single winding of the same pulse transformer in the cathode circuit of V130. The positive gate pulse from the range unit drives the cathode positive, tending to cut off the plate current flow in the tube. Voltages induced in the series connected secondary windings of the pulse transformer drive the grid in a negative direction and thus hasten plate current cut-off. The pulse is shaped by the clipping which takes place during plate current cut-off. The shaped pulse is developed across the 1500-ohm plate resistor R230. The output of this shaper is applied to the second half of V130, a cathode follower for gating the i-f channel of the receiver. This is accomplished in the following manner: plate current flows through half of V130 through R229, R228, and the parallel combination of R225 and R226, to the minus 150-volt input. The setting of the arm of R228 allows a cut-off bias to be applied to the grids of the i-f stages V114 and V115. When a pulse is applied at the grid of the cathode follower, through C196, the tube conducts and raises the

potential at the arm of potentiometer R228. This potential rise overcomes the cut-off bias on the grids of the V114 and V115 and allows these tubes to amplify the applied i-f signal. The gate signal from the gate shaper V130 is also applied through C195 to another cathode follower, V129, which drives the 0.75-microsecond delay line, E102. This delay line takes up incidental delays in the process of gating the receiver. The output of the delay line is amplified in V128 and V127, at the plates of which suitable gates are available for displaying upon the cathode-ray tubes of the target and the remote range indicator units. The output of the delay line E102 is also series connected to a second delay line, E101, which provides a one-microsecond delay. E101 feeds V126, a type 6AG7 cathode follower which delivers the gate, to J120, the gate output for the range detector. The automatic gain control circuits in the receiver are composed of the delay bias neon tube, V133, a d-c amplifier, V132, and a cathode follower consisting of V112 and V131 connected in parallel. An automatic gain control signal is received at terminal 11 of TB101 from the pulse spreader in either unit 600 or unit 1200, depending upon the position of the video selector switch on the system control switching unit. This automatic gain control signal is passed through a network composed of V133, R241, a 2000-ohm potentiometer, and R242, a 39,000-ohm resistor which returns to the minus 150-volt supply. The network provides a delay bias which prevents the application of automatic gain control voltage from reducing the receiver gain in the presence of very weak signals. Output from the network is taken from the arm of potentiometer R241. A parallel-T network, composed of R238, R239, and R240, and C200, C201, and C202, is used to shape the gain control characteristic versus frequency. The gain control characteristic versus frequency is given on figure 3-34. The signal received from the parallel-T network is amplified in the d-c amplifier, V132, and is applied through switch S101, to the grids of the parallel connected cathode follower V131 and V112, type 6L6GA tubes. To reduce the open loop gain to unity before the loop phase shift reaches 180 degrees a feedback signal for stabilization is taken from the cathodes of V131 and V112 and is applied through C199 and R237, a 470,000-ohm resistor, to the grid of V132. Operation of S101 to the manual position allows the gain of the receiver to be controlled manually by variation of the potentiometer R235. The output of the automatic gain control cathode follower, V131 and V112, controls the gain of V101, V102, and V113 by variation of plate and screen voltage, and of V117 by variation of screen voltage alone. The output is also connected to J116 for use in controlling the gain of the preamplifier of Unit 1700.

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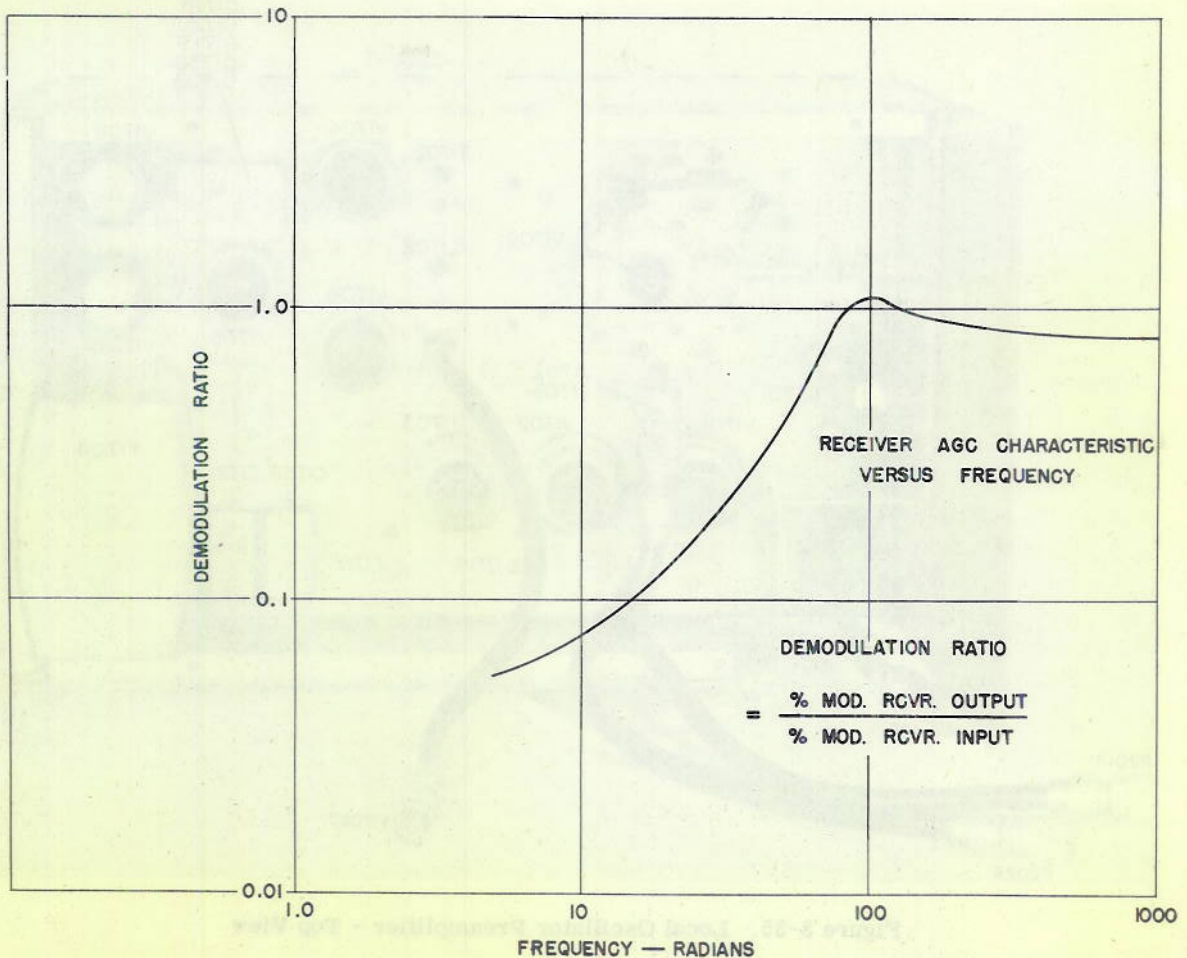


Figure 3-34. Receiver Automatic Gain Control Characteristic Versus Frequency

3. LOCAL OSCILLATOR PREAMPLIFIER UNIT, UNIT 1700, AND TR BOX AND MIXER ASSEMBLY

a. Introduction. - The r-f energy reflected from the target is mixed in the receiver crystal with the local oscillator signal which is 30 megacycles lower than the transmitted frequency. The resultant signal is then amplified in a conventional three-stage i-f amplifier. Through another crystal a small portion of the transmitter r-f energy is mixed with the local oscillator signal. This output is fed into the automatic frequency control circuit. The local oscillator preamplifier unit is shown in the photograph (figure 3-35) and the schematic diagrams (figures 3-36 and 3-51.) Reference should be made to these illustrations throughout the following discussion.

b. Specifications. - The target TR box and mixer assembly and the local oscillator preamplifier units are modified units of the SP-1M radar equipment. The modifications include provisions for automatic gain control and provisions for operating the missile receiver input from the TR box and mixer assembly. The three-stage intermediate-frequency amplifier included in the unit must be capable of providing sufficient output to drive the main receiver unit without overloading within itself.

c. Design Considerations. - Since the local oscillator preamplifier unit is essentially the same as that provided in the original SP-1M radar, no design discussion is given here. It was necessary, however, to modify the grid circuit of each of the three intermediate-frequency amplifier stages to provide a one-volt fixed bias to

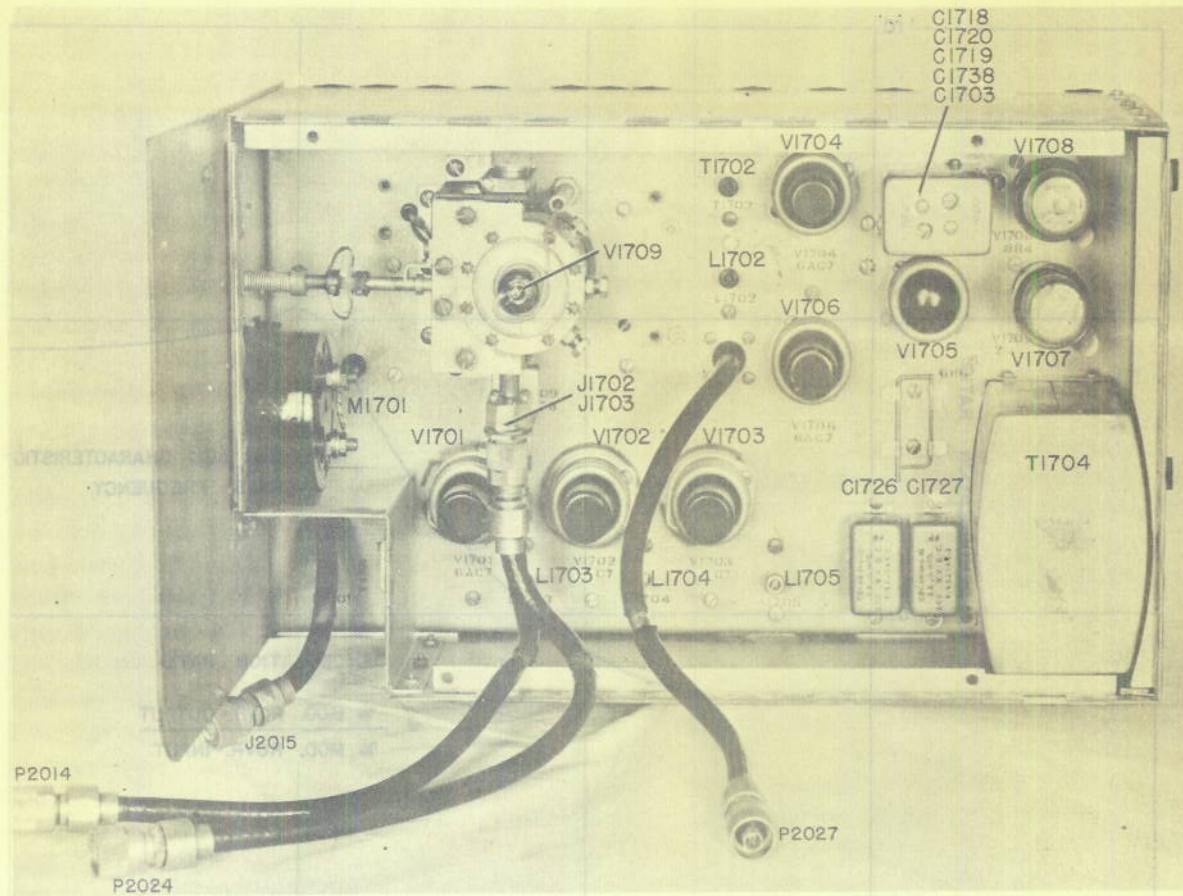


Figure 3-35. Local Oscillator Preamplifier - Top View

prevent overloading of these stages in the presence of strong signals. The change from the cathode bias of the original SP-1M receiver was made for the reasons given in the discussion of the target receiver proper in paragraph 2 of this subsection. This change has made it possible to pass through the three-stage i-f amplifier a signal whose intensity varied from noise level to 100 db above noise level without overloading.

d. Circuit Description. (See figure 3-36.)

1). Local Oscillator. - Local oscillator V1709 is a type 2K28 temperature-compensated, reflex-type, McNally klystron tube. In this tube, the electrons emitted from the cathode are acted upon by the field in the resonant cavity through which they pass and are arranged in bunches. Upon leaving this cavity, they approach a negative reflector plate which repels them back through the cavity where they give up energy to the field, thus sustaining oscillation. Coarse

tuning is adjusted by four tuning screws in a cavity of the McNally tube, one of which is adjustable from the front panel. Variation of the d-c reflector potential of the McNally tube provides fine tuning of the local oscillator over a range of a few megacycles. The output of the local oscillator is coupled to the signal and the automatic-frequency-control mixers.

2). Signal and AFC Mixers. - The signal mixer unit comprises a crystal detector, CR-2005, mounted in a coupling assembly through which it receives signals from the TR cavity. A coupling device introduces the correct amount of local oscillator signal.

Signal current in the walls of the TR cavity excites current in the coaxial line leading to the crystal. The TR cavity is coupled to the waveguide by means of a coupling slot whose size and shape are such as to match the impedance of the TR cavity to that of the waveguide. A length of short-circuited coaxial line next to the coupling

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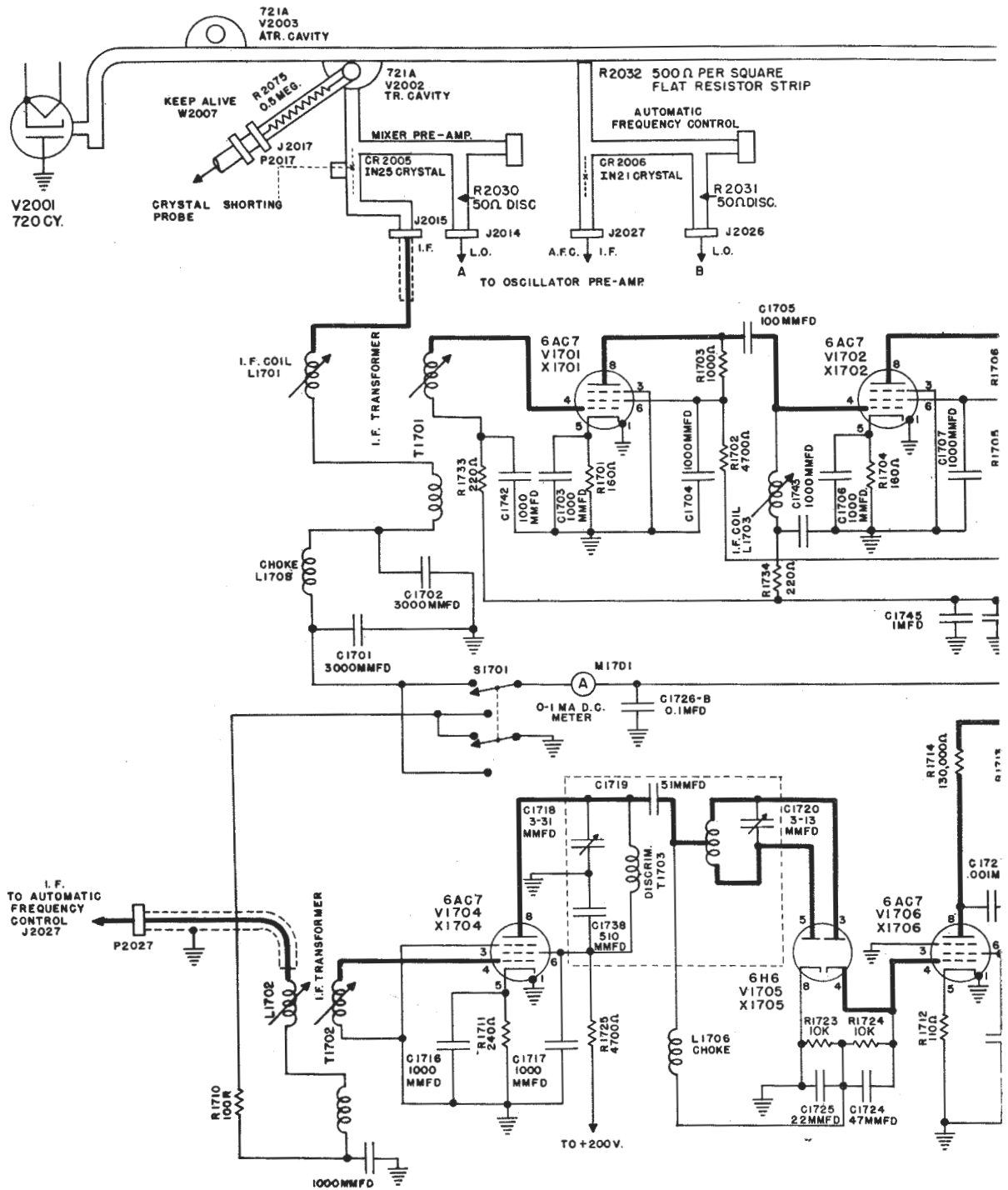
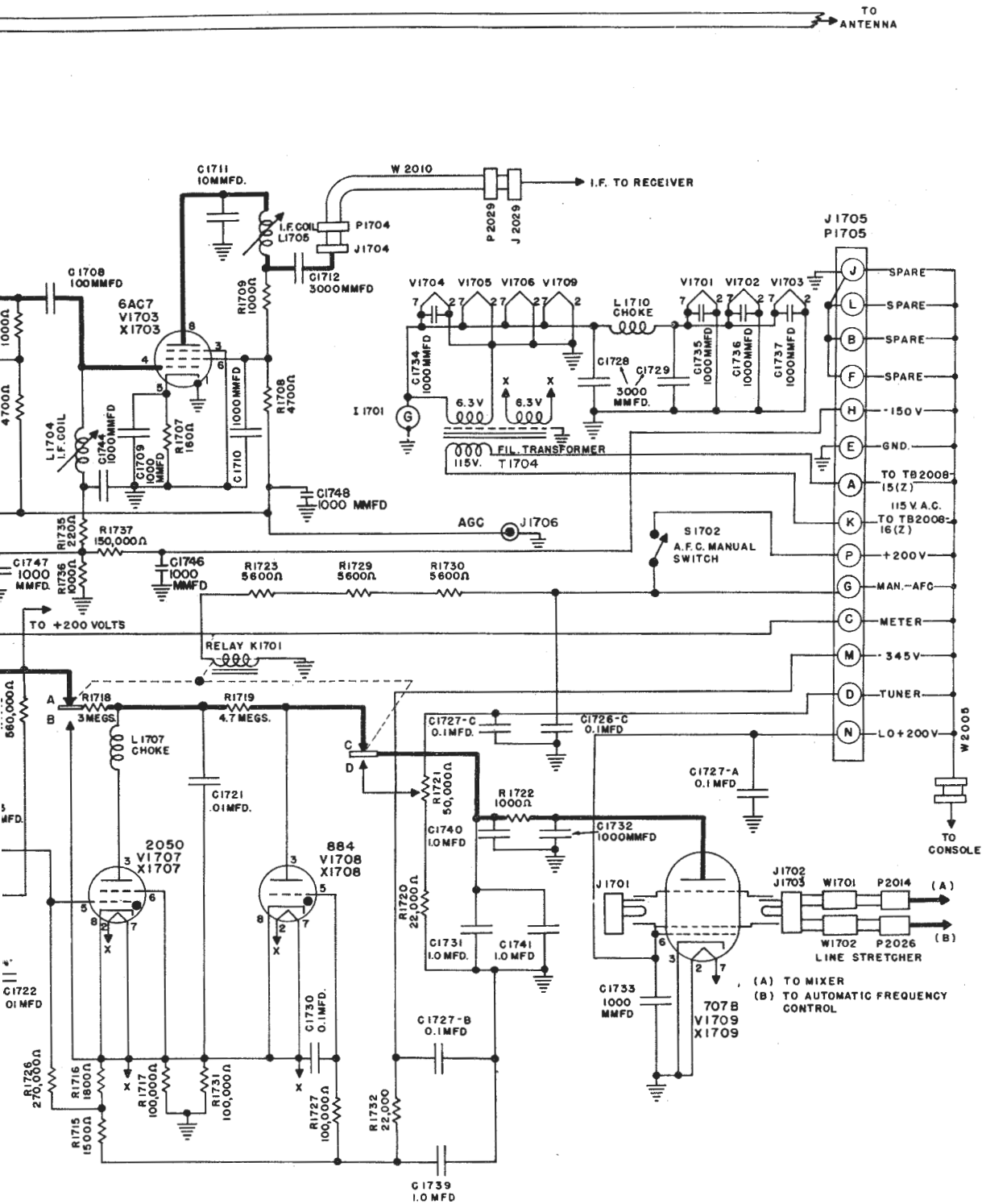


Figure 3-36. Local Oscillator Preamplifier - Schematic Diagram

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windows serves as a stub-support for the center conductor of the crystal coupling device and aids in obtaining the proper impedance match.

Two small cylinders mounted on the center conductor between the coupling window and the crystal unit are harmonic chokes to prevent damage to the crystal by harmonics generated in the magnetron and not sufficiently attenuated by the TR cavity.

Mounted on the side of the coaxial cable leading to the crystal is an adjustable probe which varies the capacity coupling between the local oscillator and the crystal. This coupling must be as loose as possible, since signals coming from the TR cavity to the crystal will also be coupled into the local oscillator and lost. Normal crystal current should be 0.4 to 0.5 milliamperes.

The crystal itself is a small rectifier unit serving as an ordinary diode. When voltages of two different frequencies, f_1 (the signal) and f_2 (the local oscillator), are applied to such a rectifier, the output current will consist of a direct-current component and frequencies of f_1 , f_2 , $f_1 + f_2$, $f_1 - f_2$, $2f_1$, $2f_2$, etc. The component $f_1 - f_2$ is the intermediate frequency and appears at J1704. The components f_1 , f_2 , $f_1 + f_2$, etc., are rejected by the tuned circuits of the i-f amplifier because they are much higher than the 30-megacycle intermediate-frequency $f_1 - f_2$. The d-c component is filtered out in the preamplifier and indicated on a crystal-current meter, M1701. Since the signals received are of small power, most of the current indicated by the crystal-current meter is derived from the local oscillator signal.

The automatic frequency control mixer is mounted above the duplexer section and is similar in construction to the signal mixer. A signal of intermediate frequency is provided by combining the transmitter signal with some of the local oscillator output. The output of this mixer is applied to a discriminator which develops a voltage for automatic control of the local oscillator frequency.

The AFC mixer is coupled to the main waveguide through a reflection type attenuator instead of through a TR cavity. The attenuator reduces the transmitter pulse to the received level. Since the attenuation is large (about 60 db), this method eliminates the possibility of the automatic-frequency control circuit locking on an interfering or jamming signal unless these signals, at the automatic-frequency control mixer, are as strong as those from the magne-

tron. A resistor strip of 500 ohms per square inch further attenuates the harmonics generated by the magnetron, at the same time varying slightly the cut-off frequency of the input cavity so that the S-sub-G-band signal is increased.

3). Automatic Frequency Control Circuits. (See figure 3-36.) - Operation of the automatic-frequency control (AFC) circuit includes two separate functions: the action of V1708 which provides automatic-frequency control search only when the automatic-frequency control is not controlling the local oscillator frequency; and the action of the AFC circuit proper which consists of V1704, V1705, V1706, and V1707.

If the preamplifier is in operation but the local oscillator (LO) repeller voltage has been adjusted manually to give zero local oscillator output and the unit is switched to AFC operation, no intermediate-frequency signal will appear at either J1704 or J2029 and there will be no possibility for the AFC to tune the local oscillator properly. Without V1708 it would be necessary to tune the local oscillator manually to give the correct intermediate frequency as determined by the appearance of signals on the indicator scopes before switching on the AFC.

At the time of switching from manual to AFC operation, the plate of V1708 is at cathode potential (minus 250 volts). This potential, which is also the potential applied to the local oscillator repeller or reflector electrode, then rises slowly toward minus 200 volts as capacitors C1731, C1740 and C1741 in parallel charge through resistors R1719 and R1718. The rising repeller voltage sweeps the local oscillator frequency downward through one of its modes. If the AFC fails to tune in the transmitter signal, this potential will rise to about minus 100 volts at which time V1708 fires, discharging the three parallel capacitors so that the plate of V1708 drops again to about minus 200 volts. The cycle repeats as long as the AFC does not tune in the transmitter signal during the sweep. The sawtooth voltage applied to the local oscillator repeller is sufficient to vary the local oscillator frequency through one mode of oscillation. Capacitor C1730 tends to keep the grid-to-cathode potential of V1708 (about minus 15 volts) constant for the transient conditions which prevail when the tube fires.

If the local oscillator has been adjusted properly, it will tune in transmitter pulses at the AFC input cable P2027 when the repeller voltage is between minus 120 and minus 150 volts. These pulses are amplified by V1704 and applied to the discriminator circuit.

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The discriminator is adjusted so that its output pulses are positive for intermediate frequencies less than 30 megacycles or negative for frequencies greater than 30 megacycles. Trimmer C1720 is adjusted so that during AFC operation signals on the indicator scopes are at maximum. Under these conditions, the output from the discriminator will be negative pulses of small amplitude. These pulses are amplified by V1706 and appear at the grid of V1707 as positive pulses which trigger V1707 if their magnitude is of the order of seven volts.

Note that the repeller voltage constantly tends to decrease to minus 200 volts but is prevented from doing so by the firing of either V1708 during search or V1707 during actual AFC operation.

The effect of an increasingly positive repeller voltage (voltage becoming less negative) on the pulse output from the discriminator is as follows: (a) An increase in the positive direction of repeller voltage reduces the local oscillator frequency. (b) The reduction in local oscillator frequency raises the intermediate frequency, since the local oscillator is tuned below the transmitter frequency. Hence the i-f is constantly tending to increase. (c) The tendency for the i-f to increase above 30 megacycles produces a negative pulse output from the discriminator. (The discriminator is adjusted so that its curve of output voltage versus frequency has the positive peak on the left for frequency increasing from left to right and a frequency difference between peaks of about 3.5 megacycles. C1720 is adjusted so that the correct i-f frequency is approximately at the crossover of the discriminator characteristic.) (d) The discriminator output, after polarity inversion in V1706, causes V1707 to fire, restraining the tendency of the repeller voltage to increase. The net result is a frequency control similar in principle to the "hit-or-miss" speed governor often used on gasoline engines.

In actual AFC operation, V1708 is inoperative and could be removed from the circuit while V1707 controls the repeller voltage in accordance with information supplied by the discriminator. V1707 is biased at minus nine volts which is sufficient to keep this tube from firing under practically all conditions of anode potential. When this tube is fired by a positive pulse on its grid, the potential at the junction of R1718, R1719, and L1707 drops to a value more negative than the cathode potential of V1707 due to the resonant effect of L1707 and C1721. However, the overshoot is a transient condition and the upper point of C1721 is at a potential of about minus 250 volts when V1707 deionizes and

C1721 begins to charge toward minus 200 volts through R1718. L1707 restricts the discharge current of C1721 to a value within the peak current rating of V1707.

The potential at the junction of R1718, R1719, and L1707 varies as a sawtooth, the frequency of which is fixed by the rate at which V1707 is fired. The lower effective potential of this sawtooth is about minus 250 volts: the maximum value depends upon the time between those pulses which are of sufficient magnitude to fire V1707. The maximum rate of firing is the transmitter repetition rate and when this sawtooth voltage is filtered by R1719, C1731, and C1740 and C1741, the lower limit of the repeller voltage is obtained. The upper limit of the repeller voltage will be obtained when V1707 does not fire at all, in which case V1708 will conduct when the repeller reaches minus 100 volts. The normal repeller voltage required to tune the receiver correctly is between these two extremes. The rate at which V1707 is triggered will adjust itself so that this voltage is obtained when the sawtooth is averaged by the filter. This rate will be approximately 30 cycles per second and the average rate for short time intervals will be constant unless the transmitter or local oscillator frequencies vary.

The gain of the AFC channel is limited by the necessity for attenuation of the harmonics of the local oscillator and magnetron. If the gain were greater than optimum, the second harmonic of the local oscillator would lock in with the second harmonic of the magnetron, resulting in a fifteen megacycle intermediate frequency. Under these conditions the AFC would be of little use to the radar system. The gain of the AFC channel is set at optimum and is about 20 db.

4. MISSILE RECEIVER UNIT, UNIT 100M. (See figure 3-37.)

a. Introduction. - The Missile Receiver, Unit 100M, is identical to the target receiver with the exception that it contains a small additional chassis which performs the limiting and discriminating functions required for the operation of the missile AFC. This additional chassis, called the discriminator unit, contains two limiters, a discriminator circuit, a tuning indicator meter and tuning control, and a switch for manual or AFC operation.

b. Specifications. - The bandwidth of the missile receiver is 2.2 megacycles, or only that required to pass a one-microsecond pulse with good fidelity. Consequently, the frequency of the local oscillator in the Missile Oscillator

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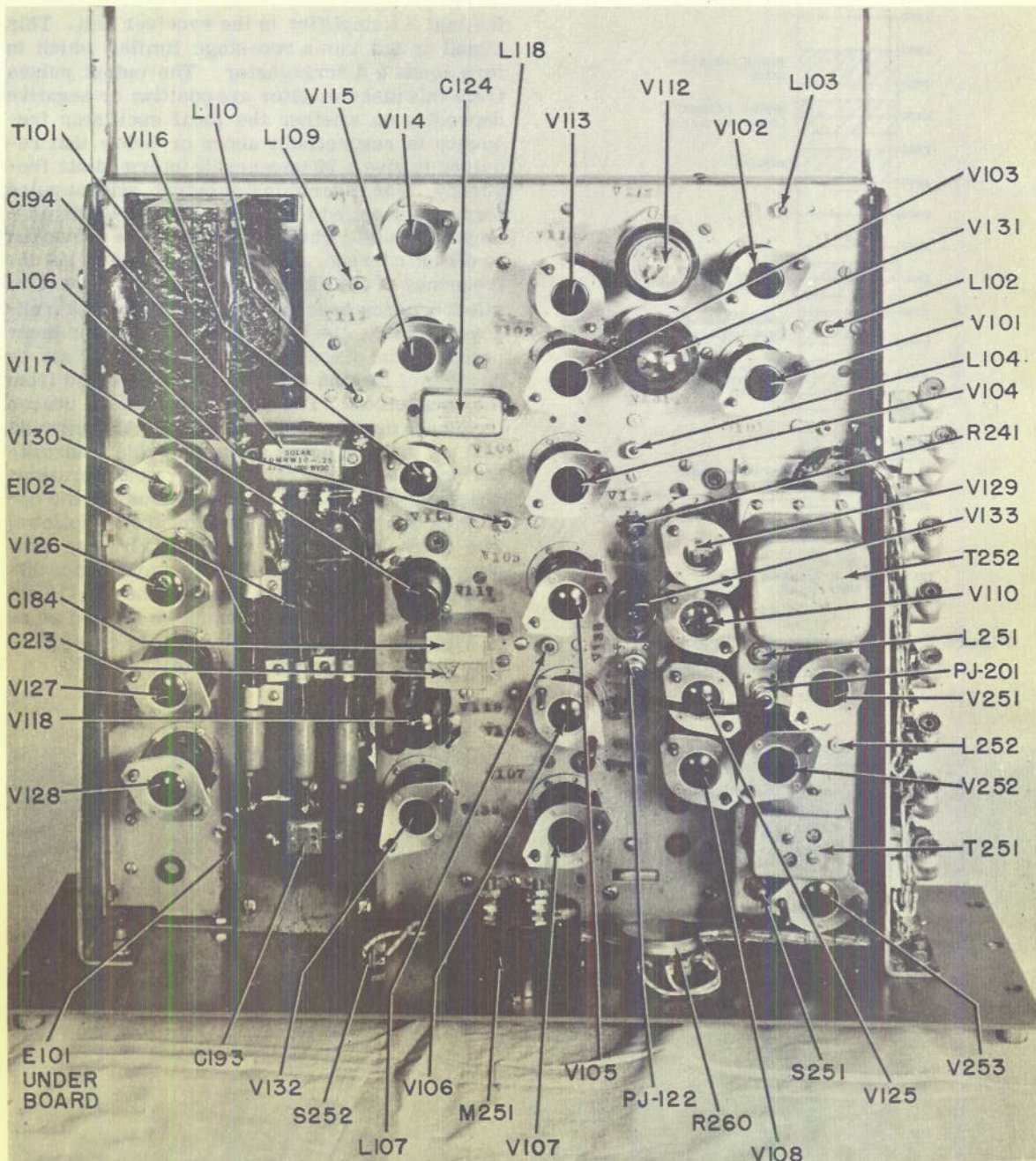


Figure 3-37. Missile Receiver - Top View With AFC Chassis in Place

Preamplifier Unit, Unit 4300, must be maintained within plus or minus 200 kilocycles of the correct frequency in order to avoid losing the beacon signal from the missile. This need is met by the addition of a small chassis to the target receiver unit. The chassis contains the limiter and discriminator circuits necessary for the automatic-frequency control.

c. Design Considerations. - With the exception of the discriminator chassis, the missile receiver unit is identical to the target receiver unit discussed in paragraph 2 of this subsection. Hence, the following discussion applies only to the discriminator chassis. The missile AFC circuits were designed in the following manner: A small signal is derived from the output coil of

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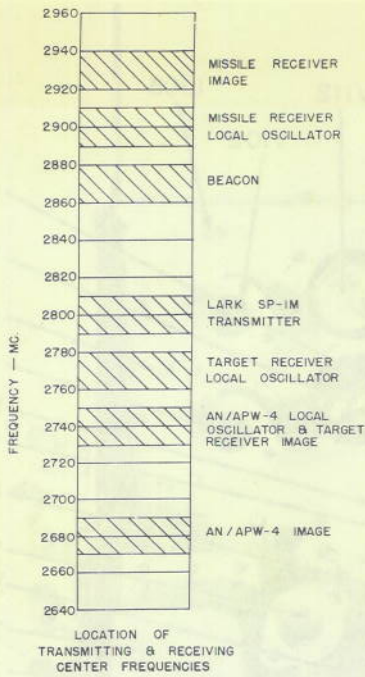


Figure 3-38. Location of Transmitting and Receiving Frequencies

the last i-f amplifier in the receiver unit. This signal is fed into a two-stage limiter which in turn feeds a discriminator. The output pulses from this discriminator are positive or negative depending on whether the local oscillator frequency is respectively above or below that required to give a 30-megacycle intermediate frequency. The discriminator output, still in pulse form, is supplied to the missile oscillator preamplifier unit, where the pulses are converted to direct current, amplified, and used to set the frequency of the 2K28 McNally tube. The missile frequency beacon is approximately 75 megacycles above the frequency of the radar magnetron. The discriminator circuit must not be capable of locking onto the signal received from the magnetron. The proper choice of beacon frequency must be made so that the AFC circuits will not lock on echos from the pulse transmitted by the magnetron. Other considerations governing the choice of frequencies for the operation of the complete system are as follows: The Lark beam-rider receiver klystron frequency must be located so as to avoid image difficulties with the beacon signal. The SP-1M receiver klystron frequency must be located so as to avoid image troubles, etc. These considerations are shown graphically on figure 3-38.

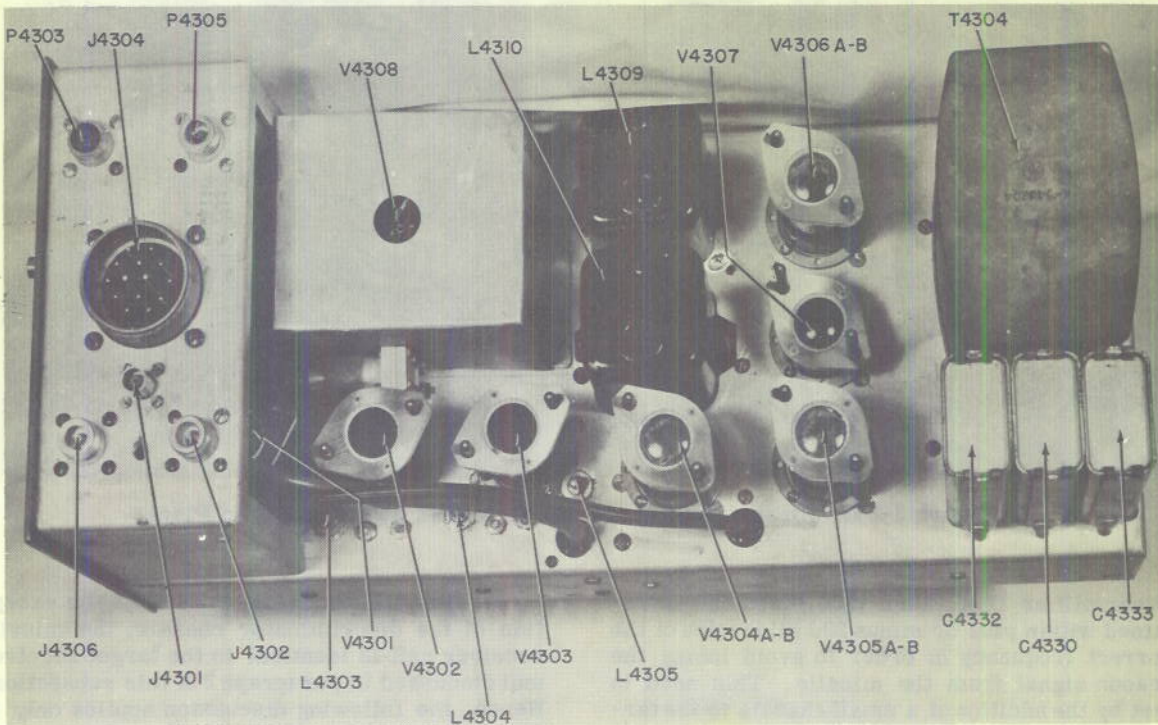


Figure 3-39. Missile Oscillator Preamplifier Unit - Top View

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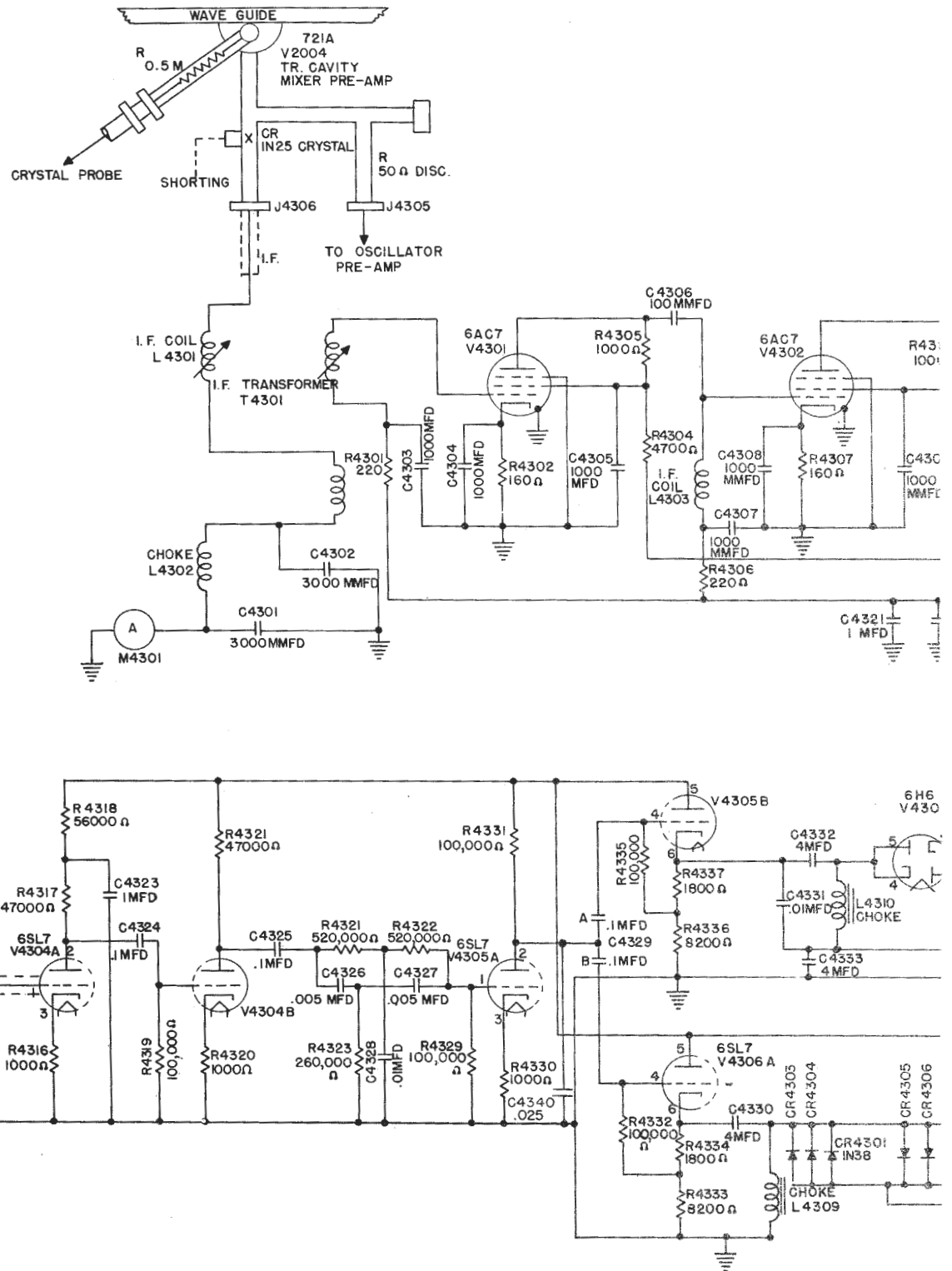
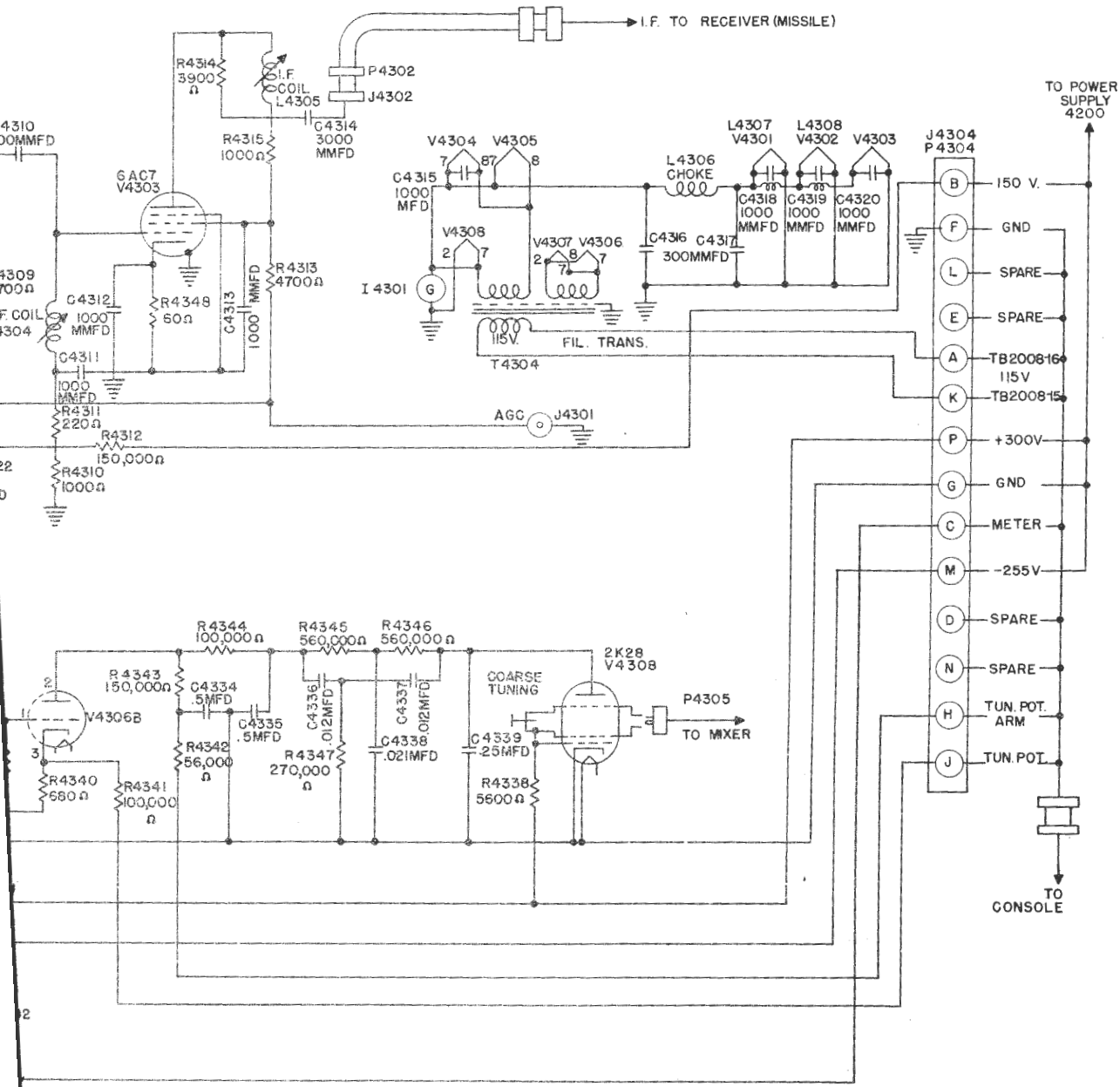


Figure 3-40. Missile Oscillator Preamplifier - Schematic Diagram





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d. Circuit Description. (See figure 3-33.) - The circuit description given in paragraph 2 of this subsection for the target receiver unit applies to the missile receiver except for the discriminator chassis. The discriminator chassis schematic is shown in dashed lines in figure 3-33. Components in solid lines are common to both target and missile receivers. A discussion of the discriminator chassis follows. A partially limited intermediate-frequency signal is link-coupled from L107, the ungated intermediate-frequency output coil, to the grid of V251, a type 6AC7 tube. The plate of V251 is coupled by a single tuned coil to the grid of V252, another 6AC7. V252 is a limiter-driver stage for V253, a type 6H6 discriminator. The output of this discriminator is a positive or a negative pulse depending upon the relative relationship of the beacon signal and the beacon local oscillator. Switch S251 allows polarity reversal to permit operation of the beacon local oscillator either above or below the proper frequency. The discriminator output appears at terminal 2 of TB102 and at J121. Switch S252 is provided so that the output of the discriminator may be shorted for manual tuning. Meter M251 indicates the departure of the tuning of the klystron from the proper center frequency. This meter is connected to circuits in the missile oscillator preamplifier unit described in paragraph 5 below. The potentiometer R260 is provided for manual tuning of the missile klystron.

5. MISSILE OSCILLATOR PREAMPLIFIER UNIT, UNIT 4300

a. Introduction. (See figures 3-39 and 3-40.) - The i-f energy received from the beacon in the missile is mixed with a local oscillator signal in the receiver crystal. The local oscillator which is separate from that described in paragraph 3 of this subsection, is operated 30 megacycles higher than the beacon transmitter frequency. The missile TR cavity is identical to the target TR cavity described in paragraph 3d above except that it is placed at a different point along the wave guide. The mixed signal is then amplified in a conventional three-stage i-f amplifier such as that contained in the local oscillator preamplifier unit described in paragraph 3 of this subsection. AFC circuits are provided to control the frequency of the klystron. A 2K28 klystron local oscillator tube, V4308, is used in a circuit similar to that used in the local oscillator preamplifier unit and the discussion of this circuit in paragraph 3 of this subsection applies equally to the missile oscillator preamplifier unit.

b. Design Considerations. - The automatic frequency control circuits in the missile oscil-

lator preamplifier unit are entirely different from those used in unit 1700. The AFC signal is received from the discriminator chassis in the Missile Receiver, Unit 100M. This signal consists of positive or negative pulses, the polarity depending upon the relationship between the frequencies of the beacon and the beacon receiver klystron signals. The AFC pulses are amplified in video amplifier stages having a poor frequency response. Passage through these stages spreads the pulses. The pulse-spread video is then rectified, amplified in a d-c amplifier, and applied to the repeller of the klystron local oscillator to control its frequency.

c. Circuit Description. (See figure 3-40.) - The i-f signal is coupled into the unit from the crystal mixer via J4306. The input circuit composed of L4301 and T4301 couple the input signal at 30 megacycles into the grid of a three-stage amplifier, consisting of 6AC7 tubes V4301, V4302, and V4303 and their associated circuits. L4302, M4301, and the associated by-pass condensers, C4301 and C4302, are a filtering and metering circuit for the rectified crystal current. Coil L4305 couples the signal from the plate of V4303, the last i-f amplifier, into the coaxial jack J4302 from whence the signal is sent to the Missile Receiver, Unit 100M. The plate and screen voltage for the three i-f stages V4301, V4302, and V4303, is obtained from the AGC input jack J4301 and varies in accordance with the signal level. The automatic-frequency control portion of the circuit is composed of V4304, V4305, V4306, V4307, and V4308. The AFC signal, a positive or negative pulse, is coupled into the unit at P4303. V4304A and B are video amplifiers and are not conventional in that their plate load impedances are too high to give pulse shape reproduction. This deterioration of the pulse shape is intentional and is provided to give a measure of pulse spreading or energy increase. R4321, R4322, R4323, and C4326, C4327, and C4328 comprise a parallel-T network whose null frequency is centered on 60 cycles. This network is used to attenuate any 60-cycle hum which has been picked up in the process of transferring the AFC signal from the missile receiver into the missile oscillator preamplifier. V4305A is an additional video amplifier used to raise the level of the signal. V4305B is a cathode follower used to drive the signal rectifier, V4307, a 6H6 tube. V4306B is a conventional direct-current amplifier used to feed the rectified voltage to the repeller plate of the klystron V4308. The parallel-T network, R4345, R4346, R4347, C4336, C4337, and C4338, is used in the coupling circuit to the klystron repeller to reject any 24-cycle amplitude modulation of the direct current. The 24-cycle component is a result of the nutation of the an-

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tenna and, though useful in other portions of the circuit, it would lead to instability in the 2K28 output. In addition, V4306A, a cathode follower, is used to feed signal to the rectifier composed of CR4303, CR4304, CR4305, CR4306, CR4301, and CR4302. The rectifier feeds the tuning meter in the Missile Receiver, Unit 100M, to indi-

cate the relative frequencies of the 2K28 and the beacon signals. The cathode voltage of V4306B is varied by the tuning potentiometer located in the missile receiver unit. Leads from this potentiometer arrive in the missile oscillator pre-amplifier unit at terminals H and J of J4304. The potentiometer is provided for manual tuning.

Subsection 3-3. Transmitting System

1. GENERAL (See figure 3-41.)

The transmitting system consists of the Transmitter, Unit 2000, the Hydrogen Thyatron Modulator, Unit 2300, and the Induction Regulator, Unit 2500. The transmitter cabinet contains in addition to the transmitter, six units which are not part of the transmitting system proper: The Local Oscillator Preamplifier, Unit 1700, the Missile Oscillator Preamplifier Power Supply, Unit 4200, the Missile Oscillator Preamplifier, Unit 4300, the Standing Wave Amplifier, Unit 4400, the Echo Box, Unit 4700, and the Keep-alive Power Supply, Unit 6200. Units 1700, 4200, and 4300 are components of the receiving system and are discussed in paragraph 2 of this section. All other units in the transmitter cabinet are discussed in this paragraph.

The Lark SP-1M transmitting system performs the functions of a conventional radar transmitter. Pulses from the Range Unit, Unit 300, are employed to key the hydrogen thyatron modulator. High voltage pulses generated in the modulator are applied through a pulse transformer with a three-to-one voltage step-up ratio to the magnetron at the Transmitter, Unit 2000 where they are converted to radio-frequency pulses and supplied to the antenna through the duplexer and waveguide assemblies. The Induction Regulator, Unit 2500, regulates the high voltage supply to the hydrogen thyatron modulator.

2. TRANSMITTER, UNIT 2000

a. Introduction. - The transmitter consists of a magnetron, a pulse transformer, a duplexer assembly, and metering and control circuits. The unit is shown in the photographs (figures 3-42, 3-43, and 3-44), the block diagram (figure 3-45), and the schematic diagram (figure 3-46). Reference should be made to these illustrations throughout the following discussion.

b. Magnetron. - Radio frequency power is generated by a transit time magnetron oscillator with internally tuned circuits. In addition to

plate voltage, the magnetron must be supplied with a strong magnetic field (produced by a permanent magnet) parallel to the axis of the cathode. Since the anode of the magnetron is grounded, excitation is applied by driving the cathode highly negative. (See figure 3-46.) Negative pulse excitation at the repetition rate is supplied to the magnetron cathode by the modulator through pulse transformer T2001. The radio-frequency output of the magnetron comes through a 50-ohm coaxial line (with a 1-5/8 inch outside diameter) which is capacitively coupled to the waveguide through the magnetron coupling circuit as shown in figure 3-47.

c. Magnetron Coupling Unit. - The coupling unit mechanically supports the magnetron in the magnetic field and transforms its output from the coaxial to the waveguide mode. Transition from the coaxial line mode to the rectangular waveguide mode is accomplished by gradually flaring the outer conductor of the coaxial line to form the bottom wall of the waveguide. The exact shape in the transition region determines the efficiency of transformation and consequently the impedance match of the magnetron to the waveguide. This type of transition is accomplished by the doorknob converter. Probable distribution of the electrical field in this transition region is shown in figure 3-47. The impedance matching diaphragms are used to correct the line mismatch to the magnetron.

d. Waveguide Transmission Line. (See figure 3-48.) - Power is transmitted from the magnetron oscillator to the antenna and the received signal is returned from the antenna by means of a waveguide transmission line consisting of various types of guide couplers and converters. The waveguide is rectangular tubing 1-1/2 by 3 inches outside dimensions with 0.080 inch wall thickness (RG-48/U). The power is transmitted along the guide by an electromagnetic field whose electric field (E) is parallel to the narrow dimension of the guide. This is known as the TE₀₁ mode of transmission. The current flow is on the inner surface of the tubing parallel to the run of the guide along its broad

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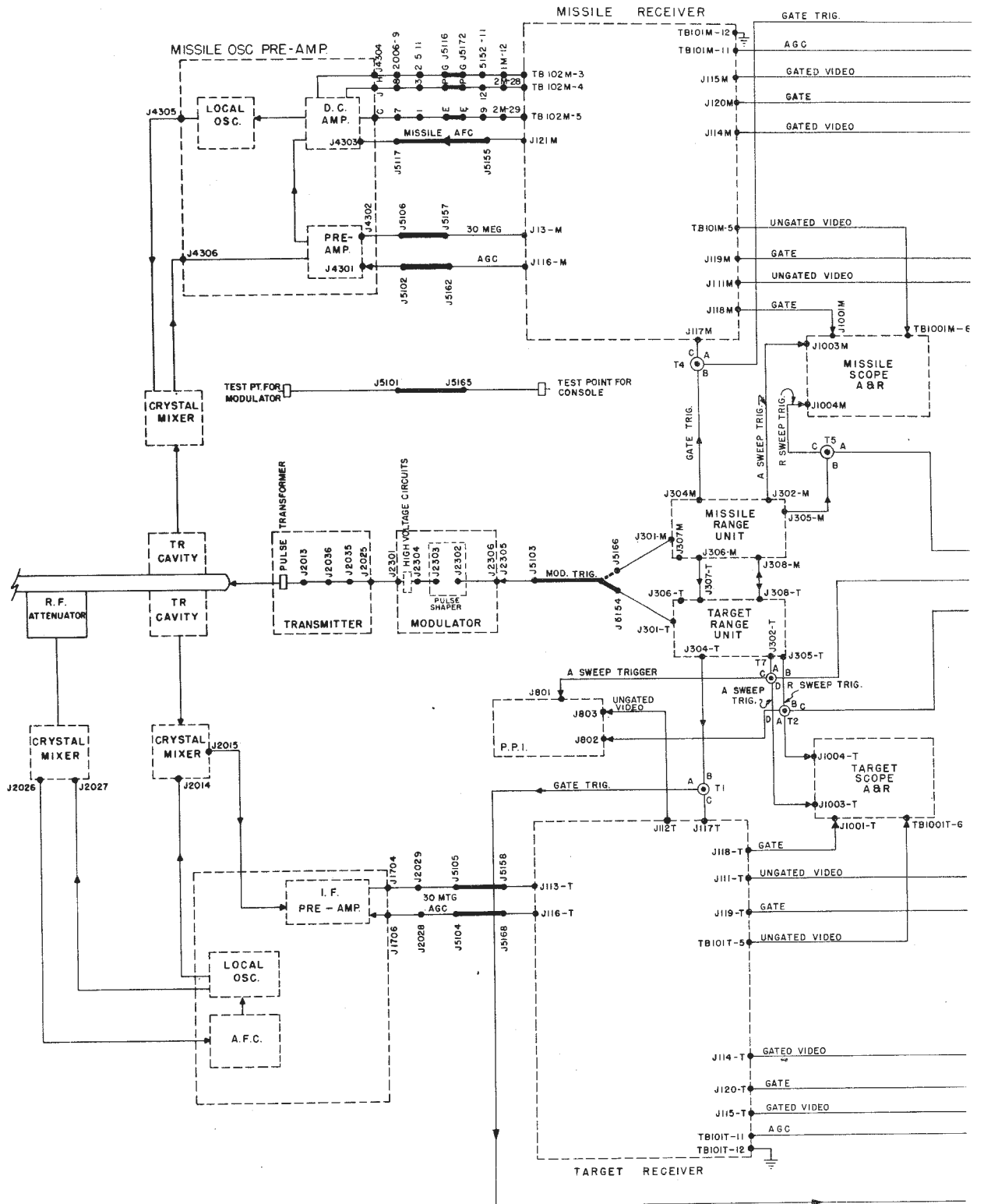
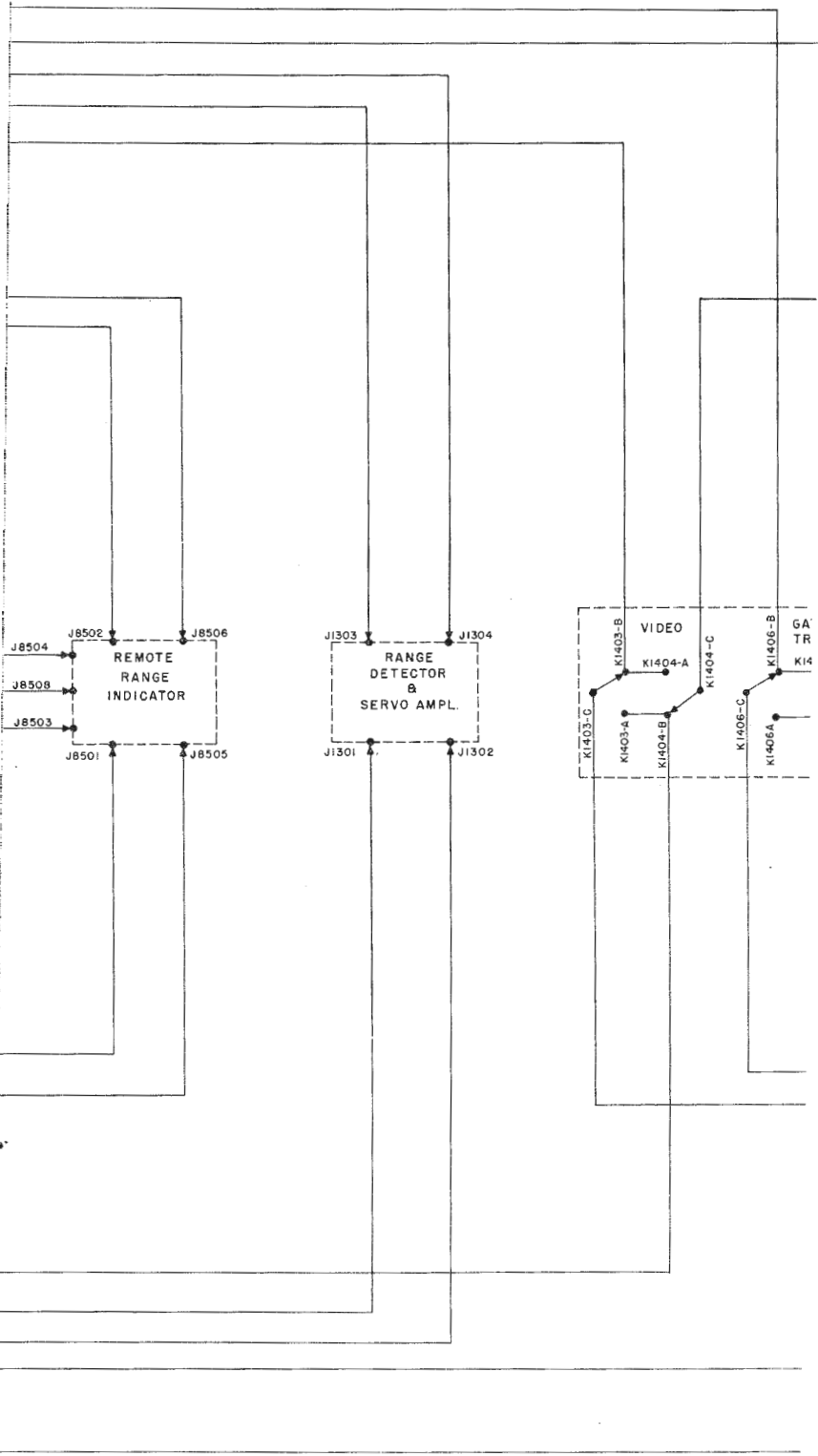
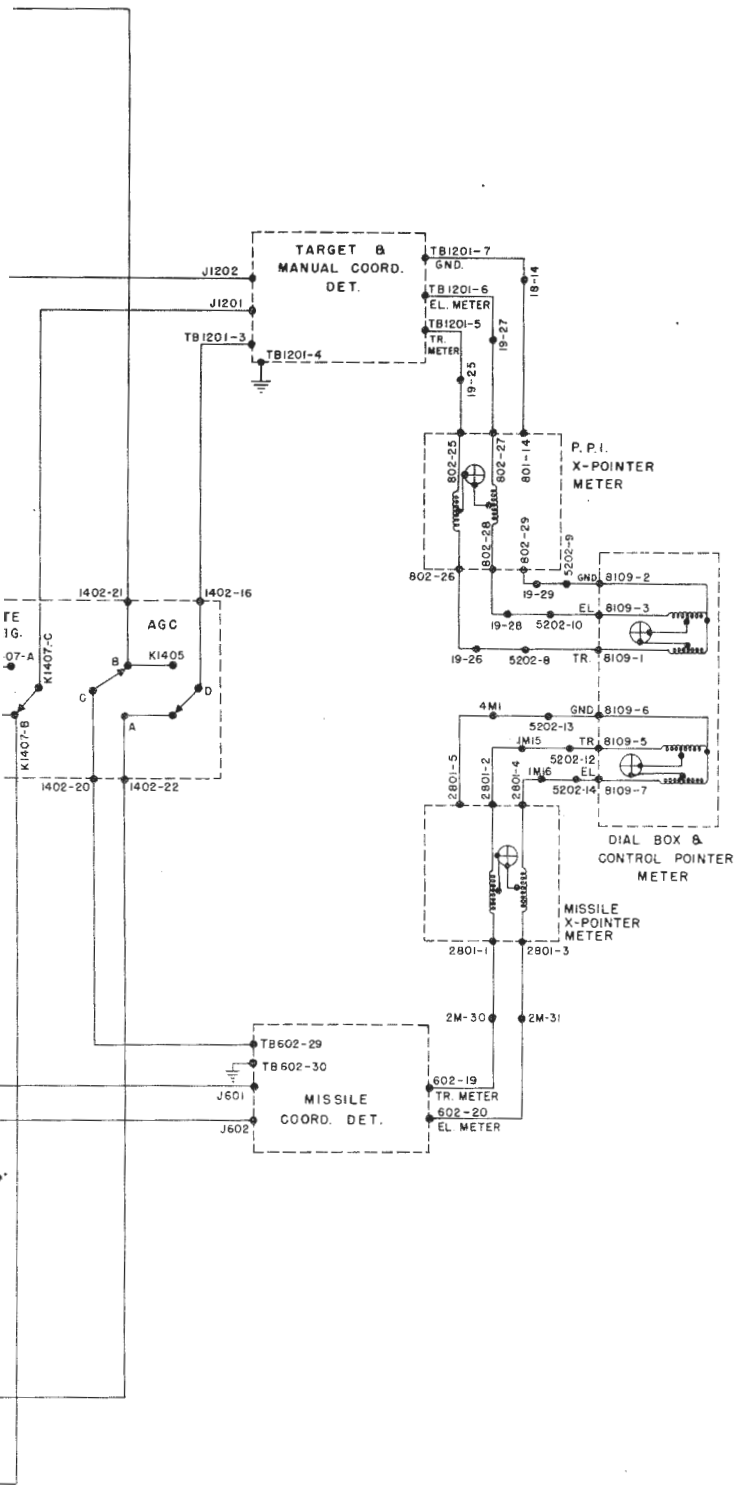


Figure 3-41. Radar Transmitting and Receiving System - Interconnection Diagram





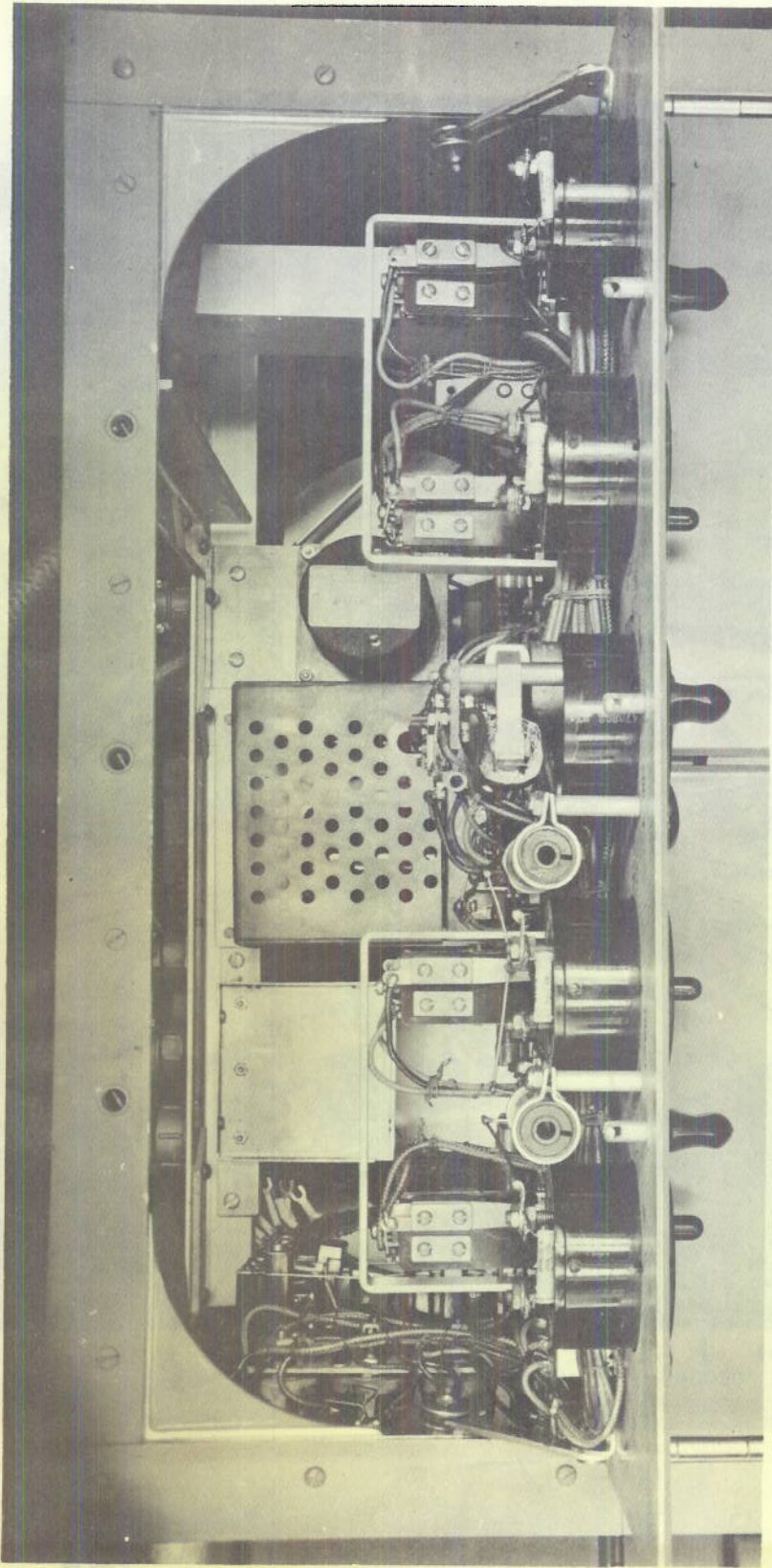


Figure 3-42. Transmitter - Top Section With Meter Panel Open - Front View

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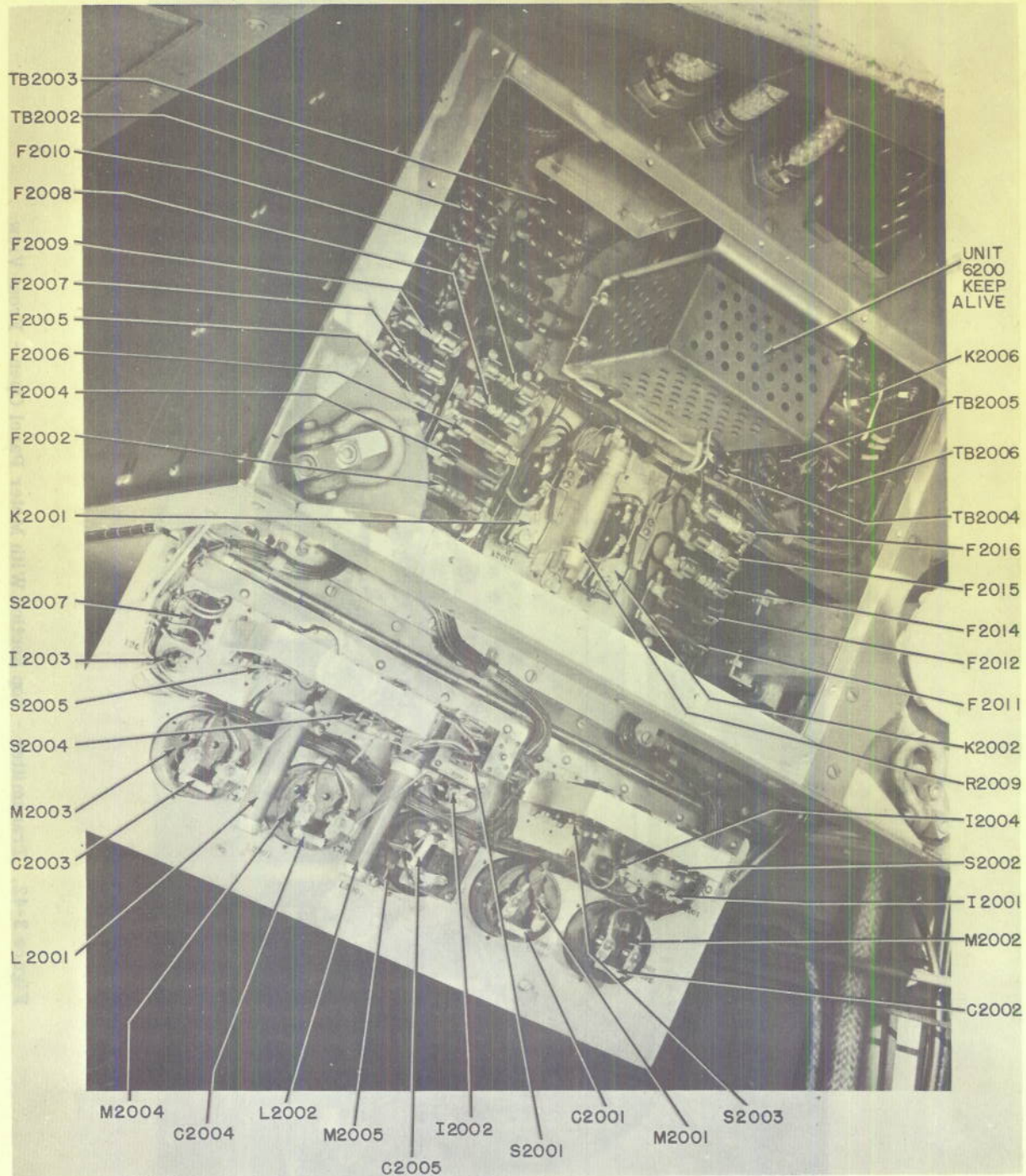


Figure 3-43. Transmitter - Top Section With Top Panel Dropped Showing Keep-alive Power Supply

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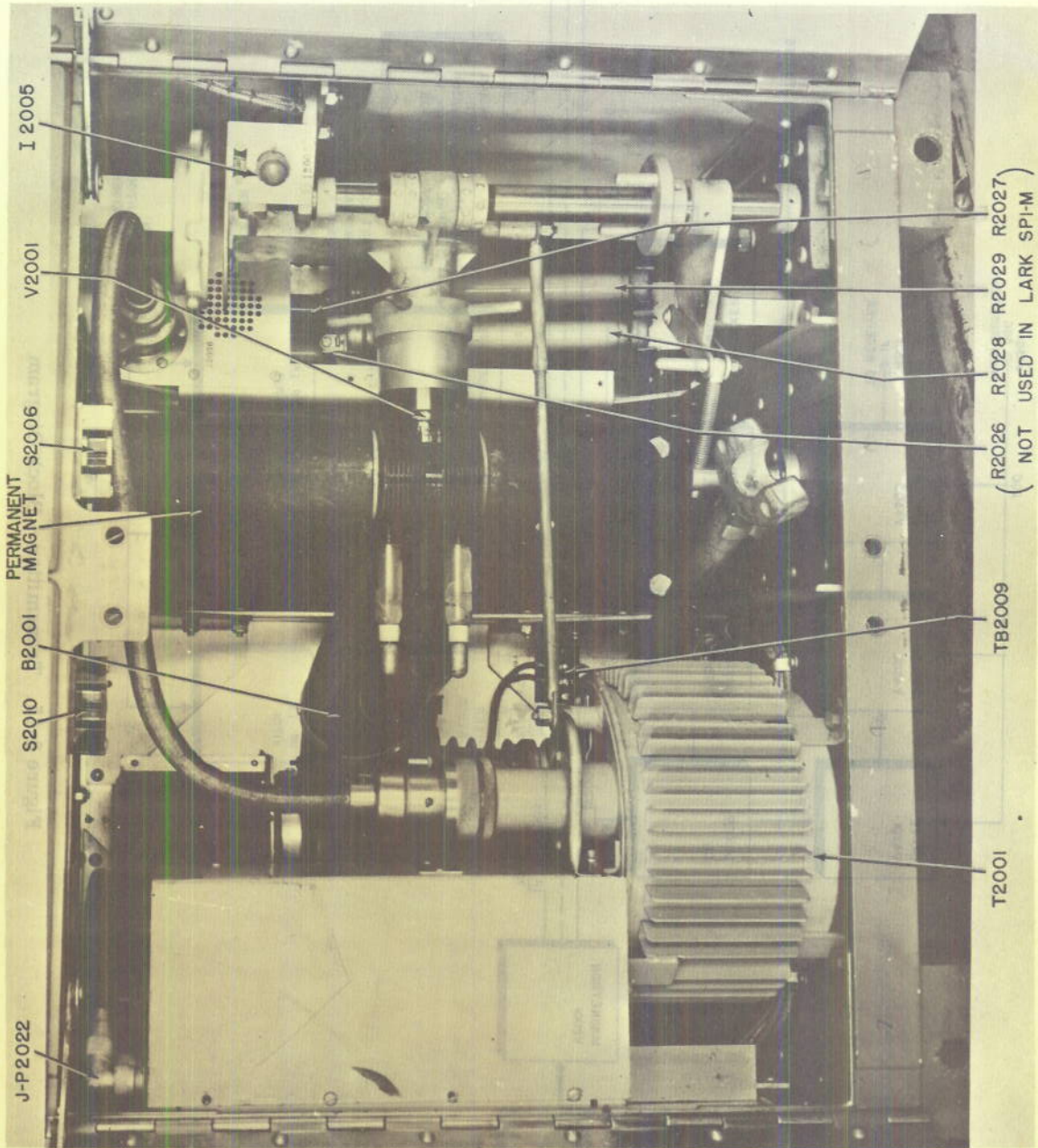
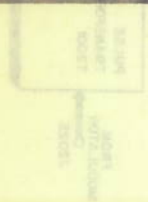
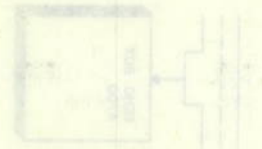


Figure 3-44. Transmitter - Bottom Section - Front View

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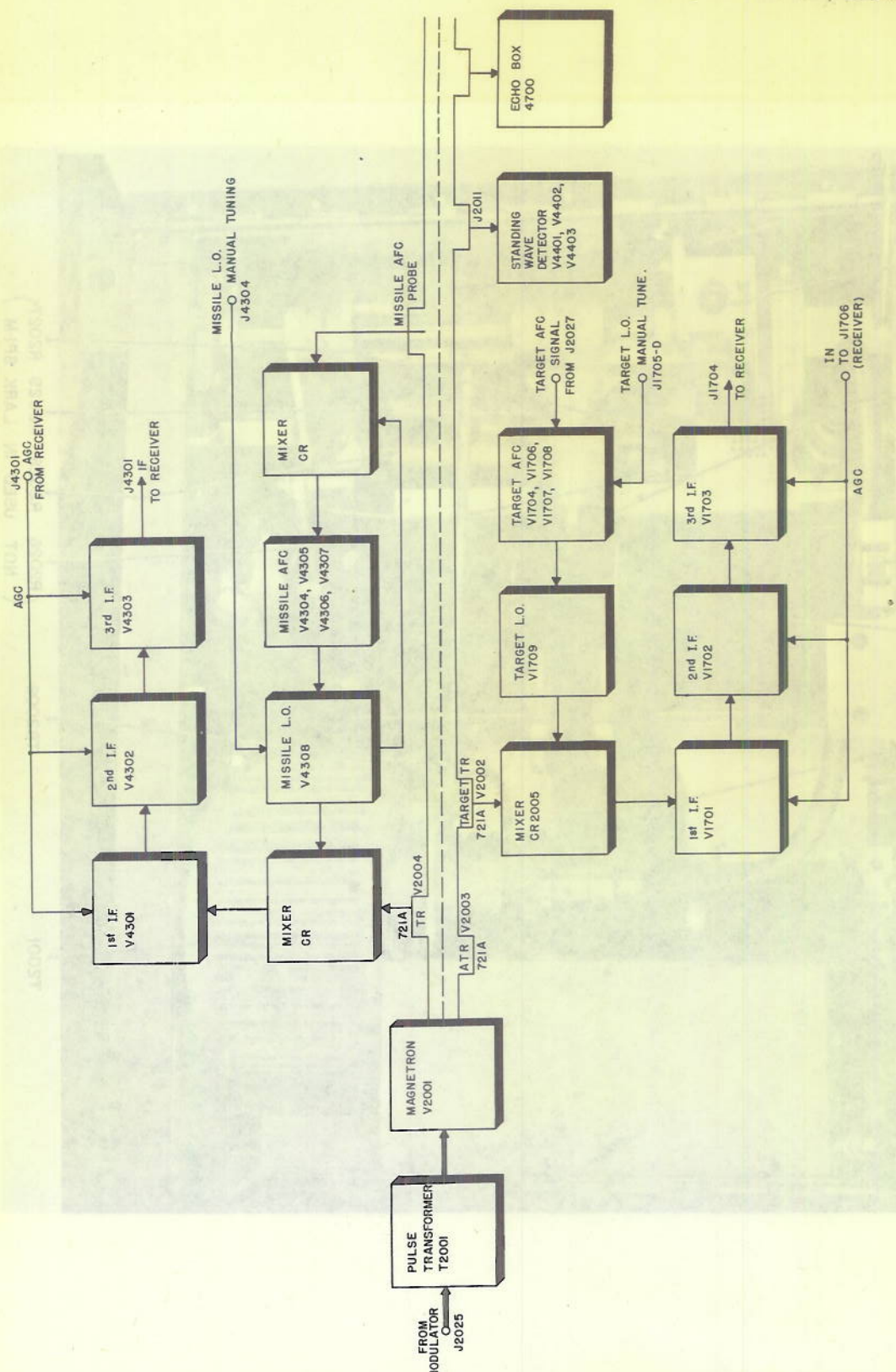


Figure 3-45. Transmitter - Block Diagram

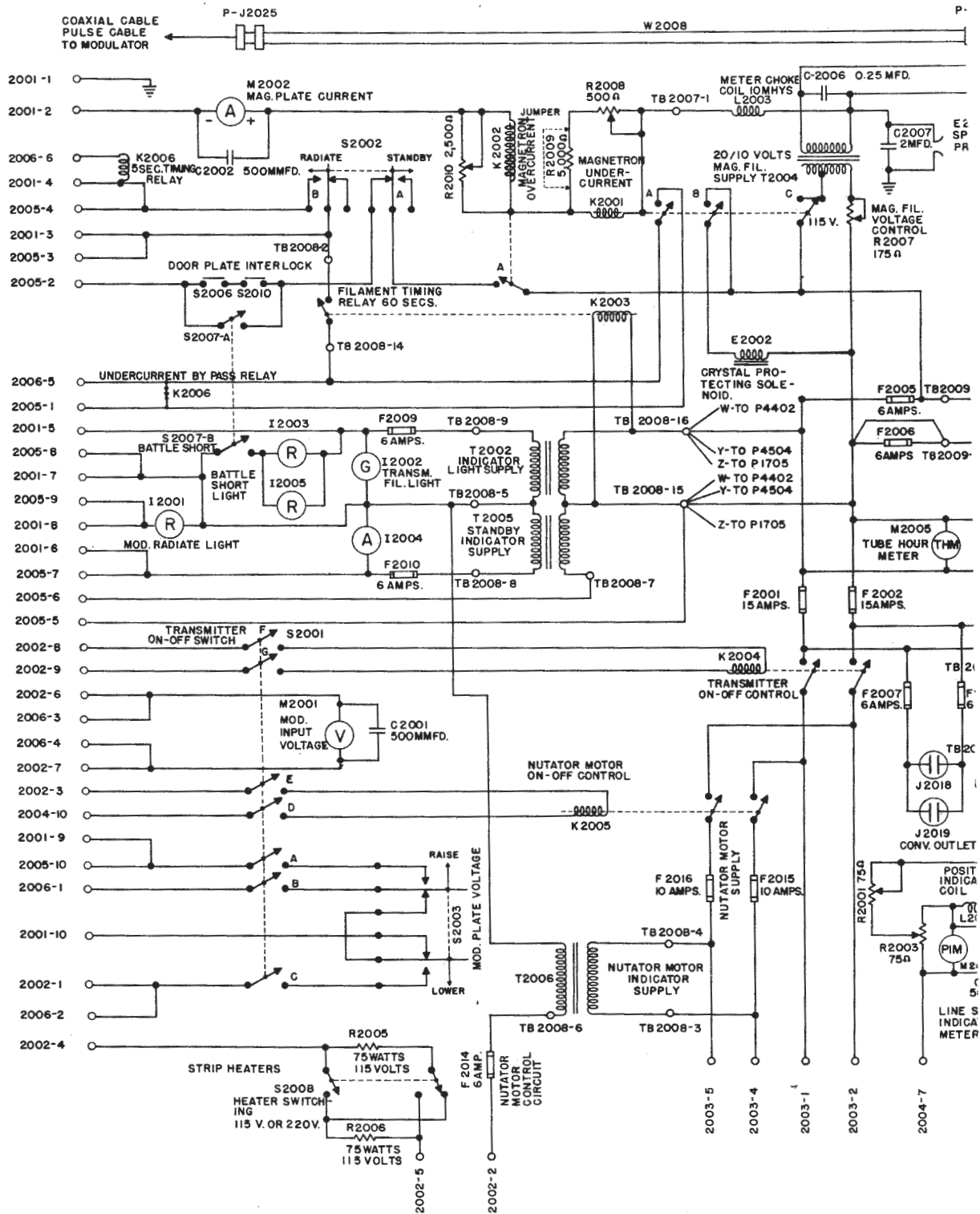
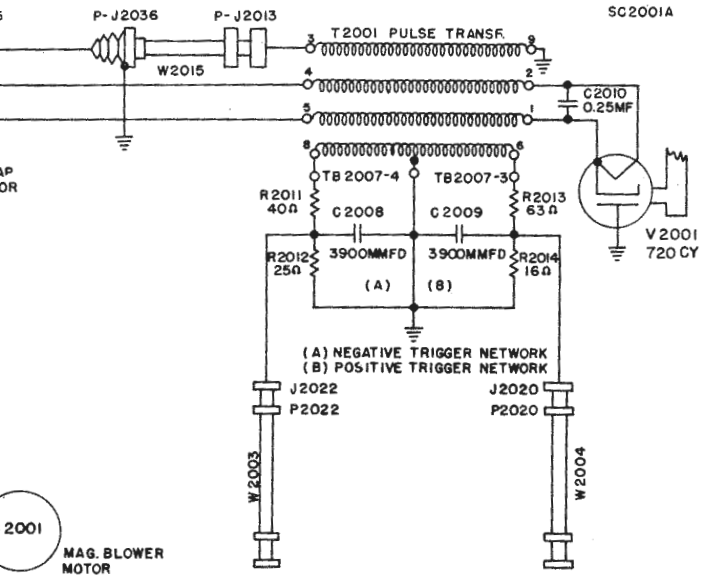
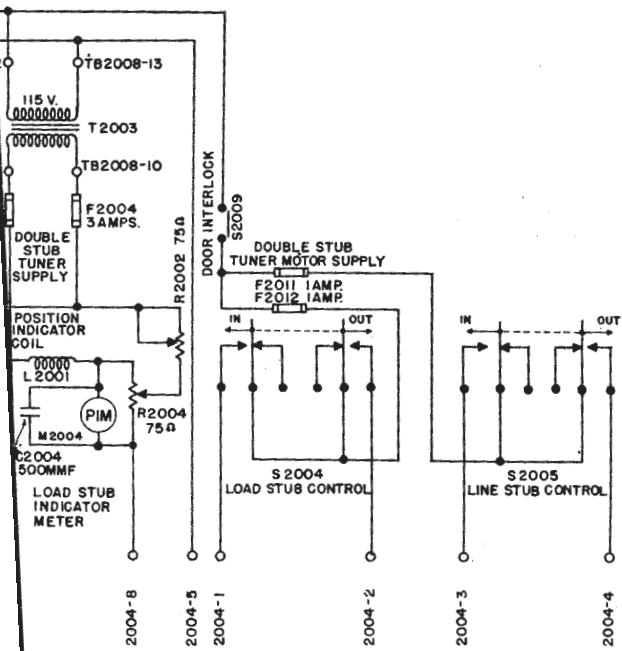


Figure 3-46. Transmitter - Schematic Diagram



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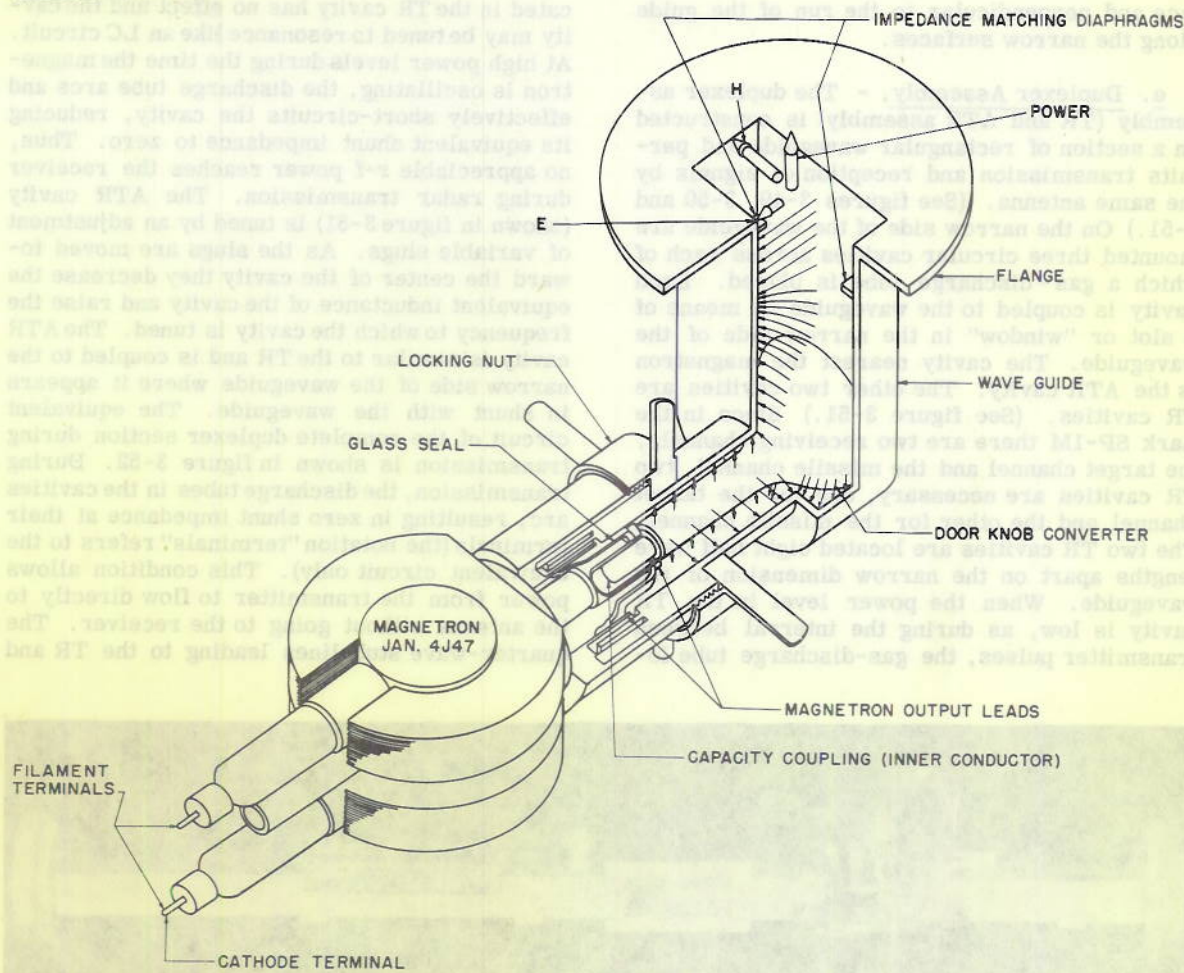


Figure 3-47. Magnetron Coupling Circuit

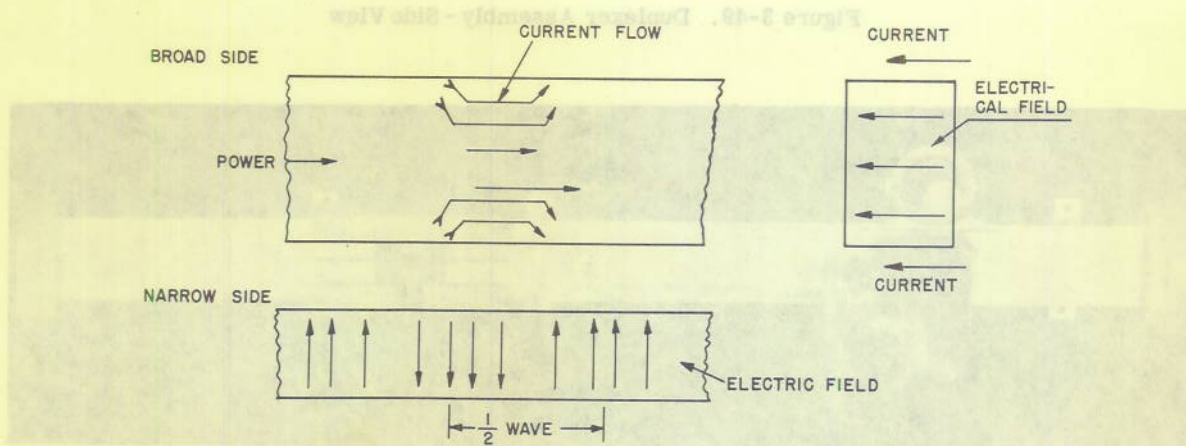


Figure 3-48. TE₀₁ Waveguide Mode

face and perpendicular to the run of the guide along the narrow surfaces.

e. Duplexer Assembly. - The duplexer assembly (TR and ATR assembly) is constructed on a section of rectangular waveguide and permits transmission and reception of signals by the same antenna. (See figures 3-49, 3-50 and 3-51.) On the narrow side of the waveguide are mounted three circular cavities across each of which a gas-discharge tube is placed. Each cavity is coupled to the waveguide by means of a slot or "window" in the narrow side of the waveguide. The cavity nearest the magnetron is the ATR cavity. The other two cavities are TR cavities. (See figure 3-51.) Since in the Lark SP-1M there are two receiving channels, the target channel and the missile channel, two TR cavities are necessary, one for the target channel and the other for the missile channel. The two TR cavities are located eight half wave lengths apart on the narrow dimension of the waveguide. When the power level in the TR cavity is low, as during the interval between transmitter pulses, the gas-discharge tube lo-

cated in the TR cavity has no effect and the cavity may be tuned to resonance like an LC circuit. At high power levels during the time the magnetron is oscillating, the discharge tube arcs and effectively short-circuits the cavity, reducing its equivalent shunt impedance to zero. Thus, no appreciable r-f power reaches the receiver during radar transmission. The ATR cavity (shown in figure 3-51) is tuned by an adjustment of variable slugs. As the slugs are moved toward the center of the cavity they decrease the equivalent inductance of the cavity and raise the frequency to which the cavity is tuned. The ATR cavity is similar to the TR and is coupled to the narrow side of the waveguide where it appears in shunt with the waveguide. The equivalent circuit of the complete duplexer section during transmission is shown in figure 3-52. During transmission, the discharge tubes in the cavities arc, resulting in zero shunt impedance at their terminals (the notation "terminals" refers to the equivalent circuit only). This condition allows power from the transmitter to flow directly to the antenna without going to the receiver. The quarter-wave stub lines leading to the TR and

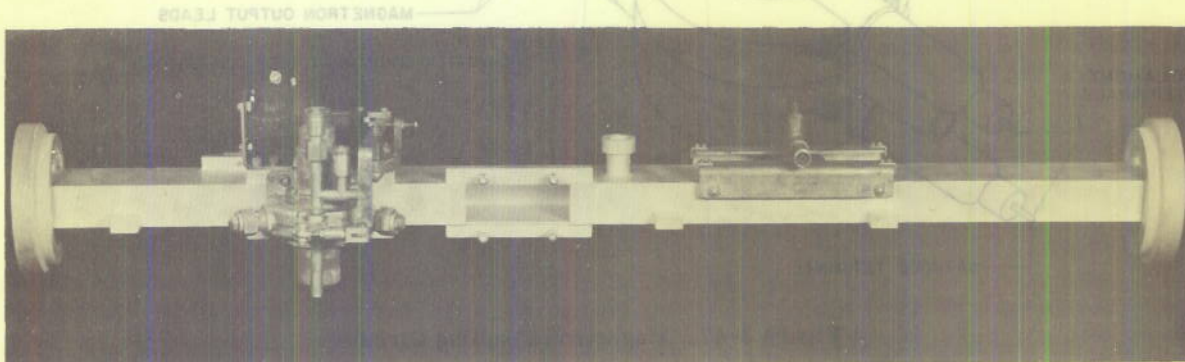


Figure 3-49. Duplexer Assembly - Side View

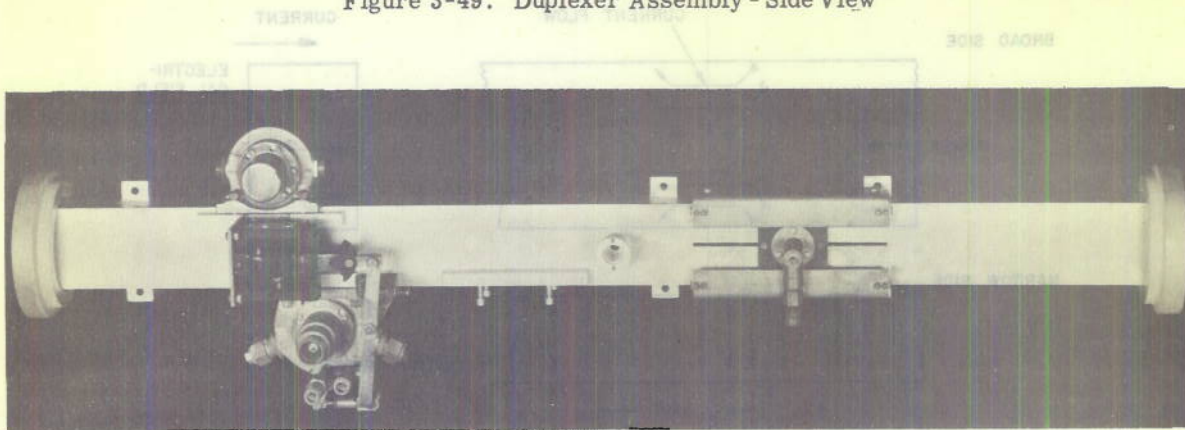


Figure 3-50. Duplexer Assembly - Front View

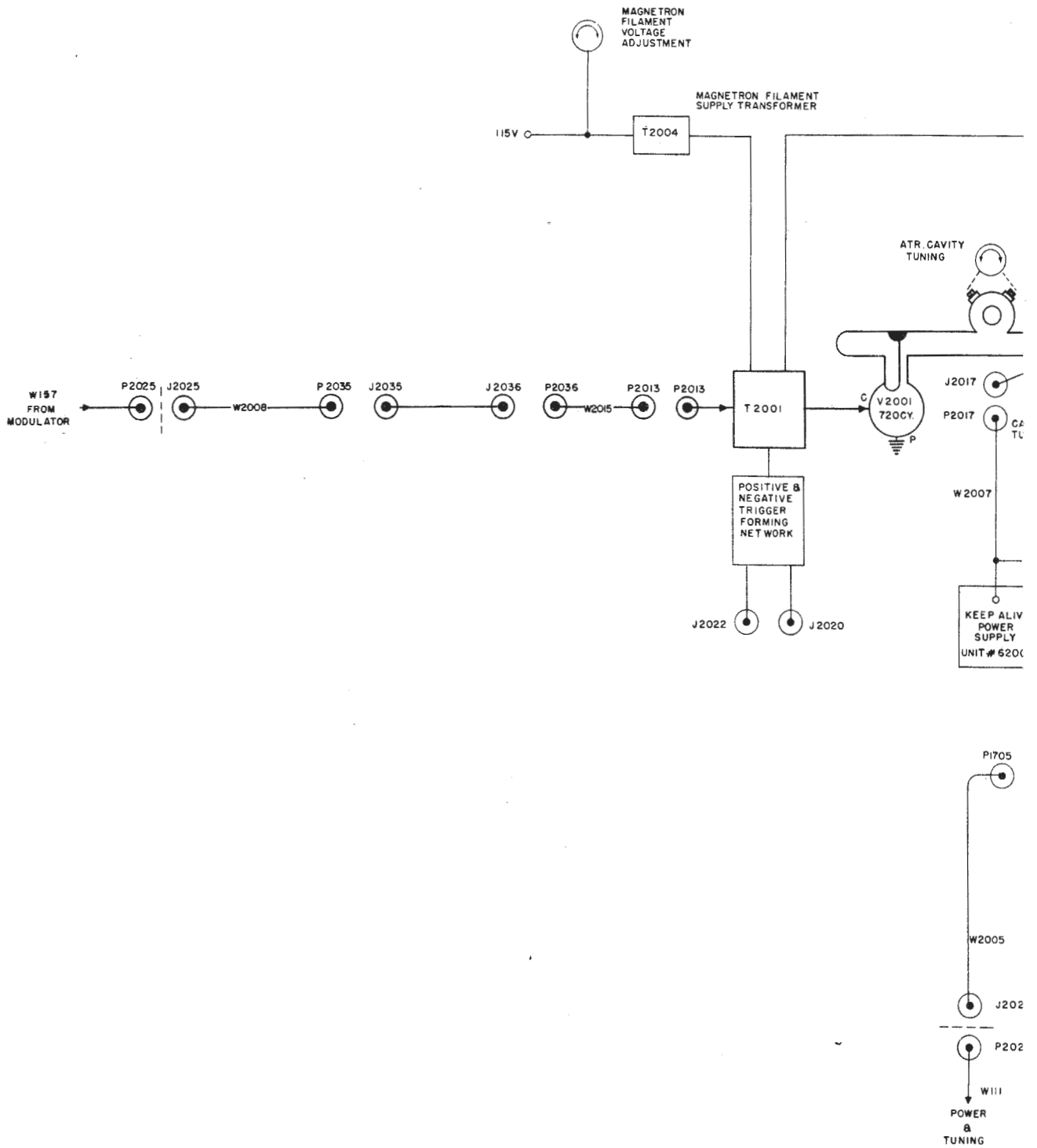
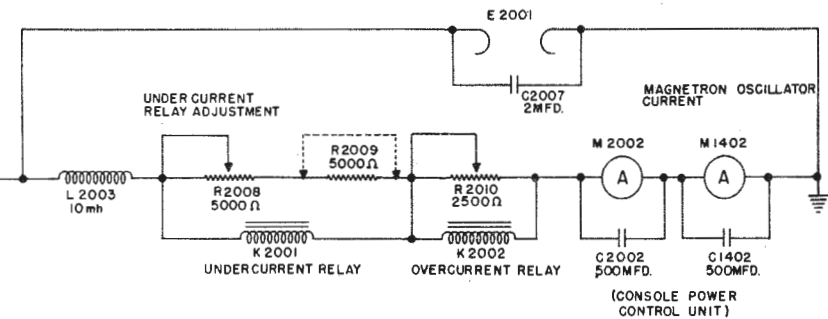
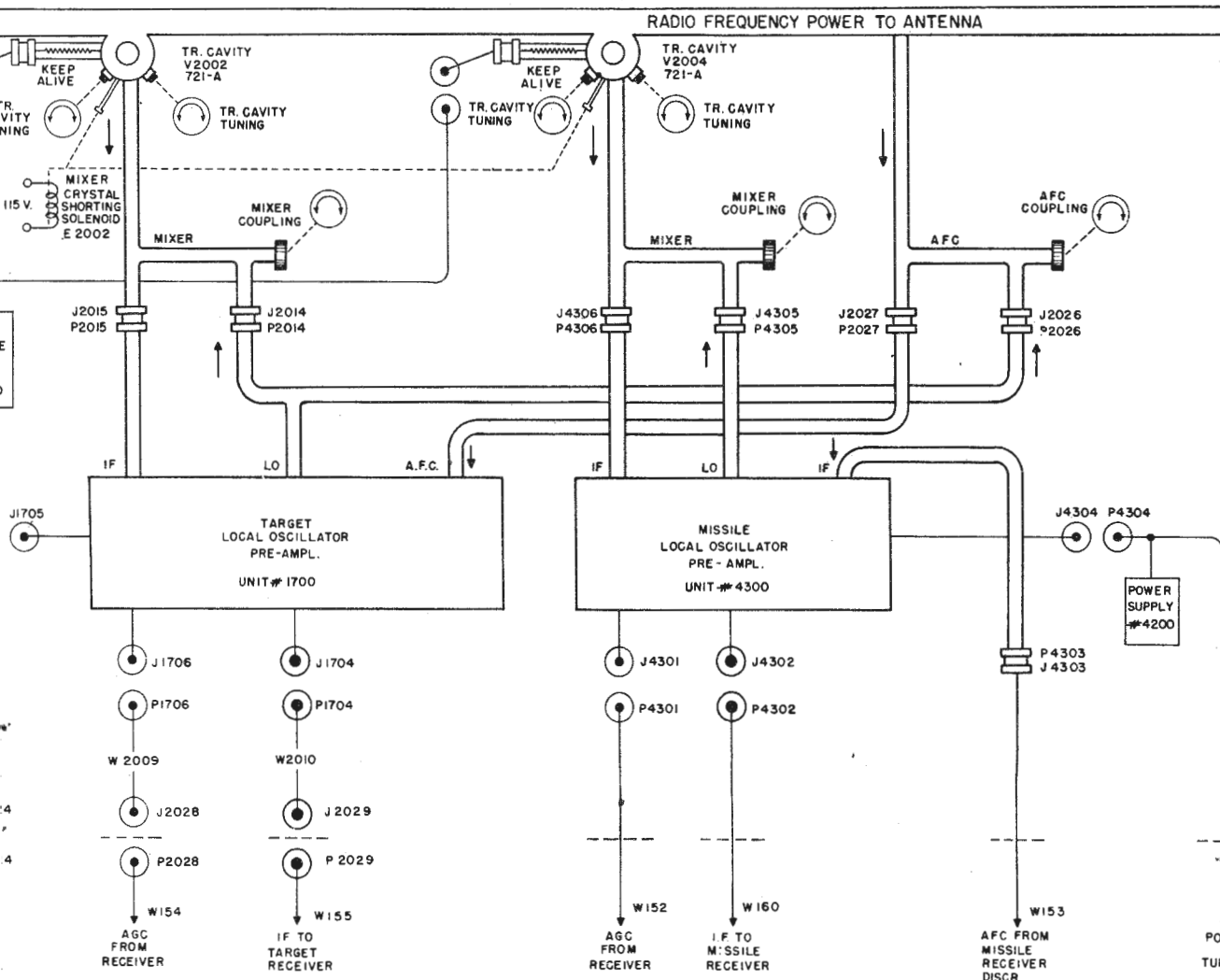


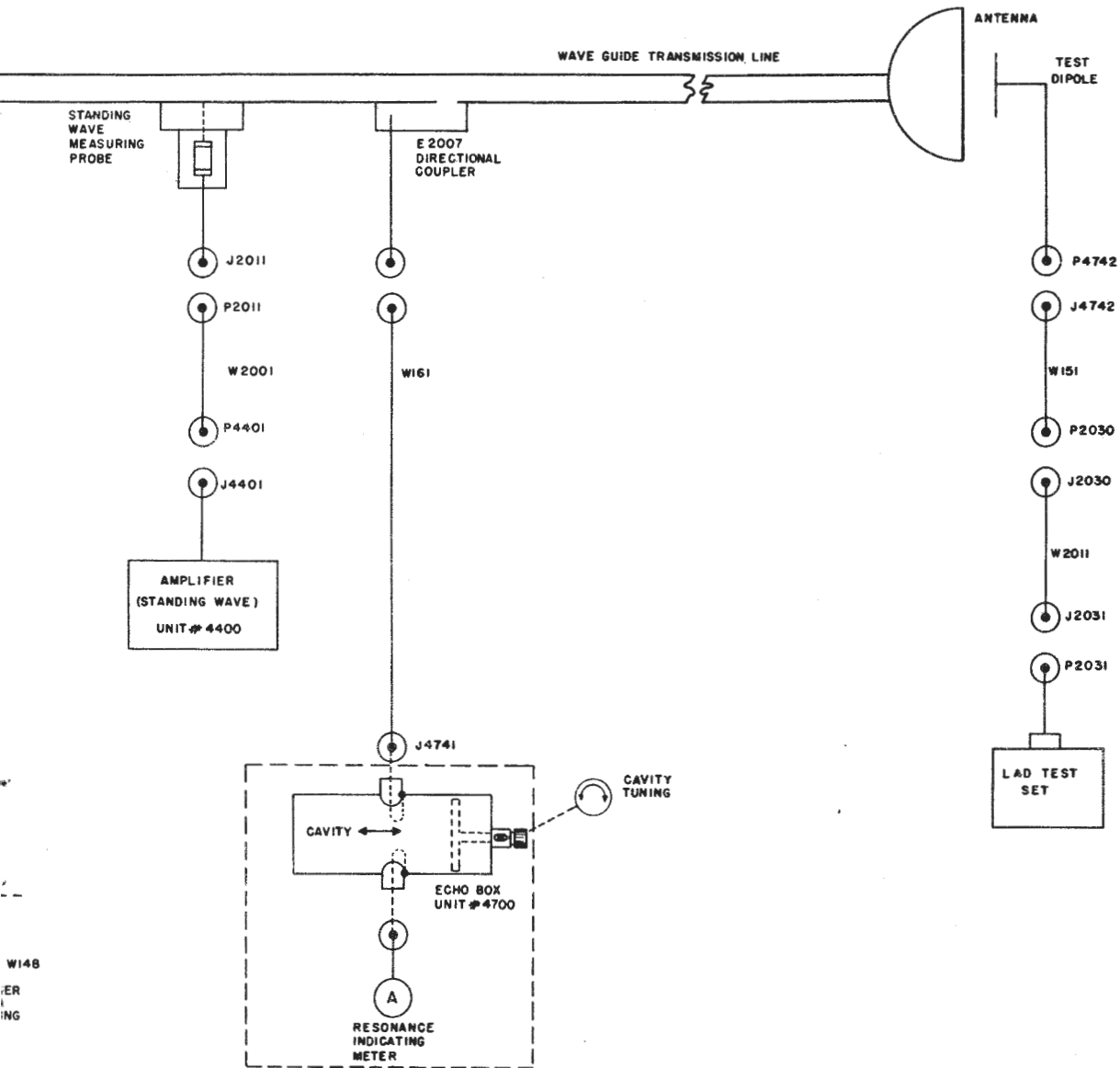
Figure 3-51. Transmitter Waveguide - Schematic Diagram



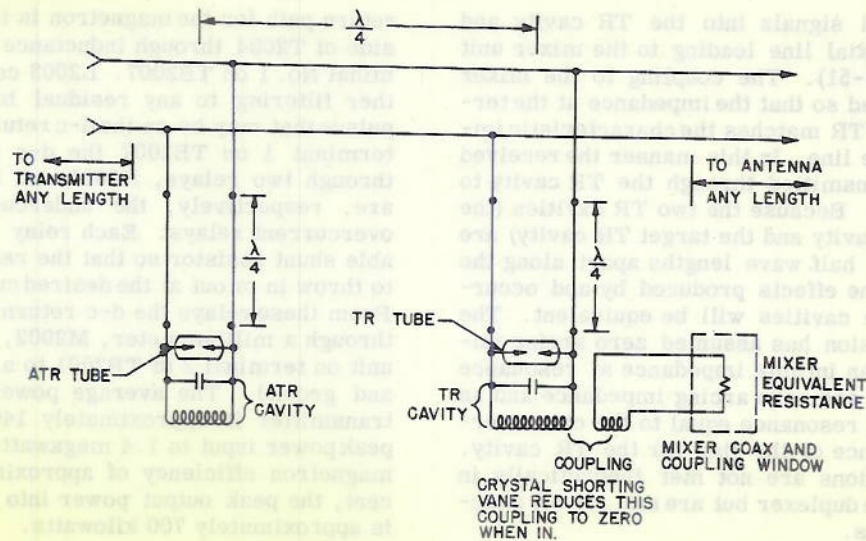
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(NOTE: LINE LENGTH NOT DIMENSIONED SHOULD BE CONSIDERED ZERO.)

Figure 3-52. Duplexer Equivalent Circuit - During Transmission

ATR circuits present a high impedance across the main line and do not effect the operation of the transmitter. The short circuit created by the gas tube across the TR effectively reduces the coupling between the main line and the receiver loop to such a small value that a negligible fraction of the transmitted power reaches the receivers (for the TR cavity, approximately one ten-millionth of the transmitted power gets into the receiver). The action during reception

is different. The ATR now presents an open circuit at its terminals which produces a short circuit at the junction with the main line one-quarter wave length away. A new equivalent circuit for the receiving condition only is shown in figure 3-53. The impedance at the TR junction created by the ATR is infinite and therefore leaves the TR effectively connected directly across the line. The coupling aperture in the side of the TR cavity and waveguide also cou-

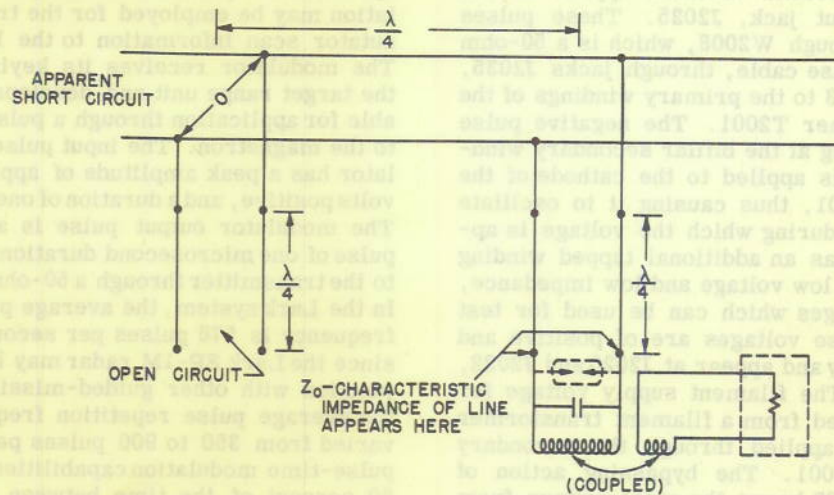


Figure 3-53. Duplexer Equivalent Circuit - During Reception

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ples received signals into the TR cavity and thence to coaxial line leading to the mixer unit (see figure 3-51). The coupling to the mixer unit is adjusted so that the impedance at the terminals of the TR matches the characteristic impedance of the line. In this manner the received energy is transmitted through the TR cavity to the receiver. Because the two TR cavities (the missile TR cavity and the target TR cavity) are located eight half wave lengths apart along the waveguide, the effects produced by and occurring at these cavities will be equivalent. The above discussion has assumed zero arcing impedance and an infinite impedance at resonance for the ATR, and zero arcing impedance and an impedance at resonance equal to the characteristic impedance of the line for the TR cavity. These conditions are not met theoretically in the waveguide duplexer but are met for all practical purposes.

The target and missile channel crystal mixer circuits are discussed in subsection 3-2, under the receiving system, and will not be described here.

In addition to the protection afforded the receiving circuits by the TR and ATR circuits described above, a shorting vane in the TR cavity closes the coupling windows when the Lark SP-1M is not in operation to prevent damage to the crystal from nearby radar equipments. The shorting vane is removed from the coupling windows by means of a solenoid actuated by magnetron undercurrent relay K2001.

f. Signal Flow. (See figure 3-46.) - High-voltage negative pulses coming from the modulator at approximately nine kilovolts amplitude and one microsecond duration appear at the transmitter input jack, J2025. These pulses are coupled through W2008, which is a 50-ohm high-voltage pulse cable, through jacks J2035, J2036, and J2013 to the primary windings of the pulse transformer T2001. The negative pulse voltage appearing at the bifilar secondary windings of T2001 is applied to the cathode of the magnetron V2001, thus causing it to oscillate for the period during which the voltage is applied. T2001 has an additional tapped winding to bring out, at low voltage and low impedance, two-pulse voltages which can be used for test purposes. These voltages are of positive and negative polarity and appear at J2020 and J2022, respectively. The filament supply voltage for V2001 is obtained from a filament transformer T2004 and is applied through the secondary windings of T2001. The bypassing action of C2006 and C2007 keeps the pulse voltage from affecting this transformer. E2001 is a spark-protector gap for transformer T2001. The d-c

return path for the magnetron is taken from one side of T2004 through inductance L2003 to terminal No. 1 on TB2007. L2003 contributes further filtering to any residual high-frequency pulses that may be on the d-c return line. From terminal 1 on TB2007 the d-c return path is through two relays, K2001 and K2002. These are, respectively, the undercurrent and the overcurrent relays. Each relay has an adjustable shunt resistor so that the relay may be set to throw in or out at the desired current ratings. From these relays the d-c return path continues through a milliammeter, M2002, and out of the unit on terminal 2 of TB2001 to a remote meter and ground. The average power input to the transmitter is approximately 1400 watts. The peak power input is 1.4 megawatts and, with the magnetron efficiency of approximately 50 percent, the peak output power into the waveguide is approximately 700 kilowatts.

g. Control Circuits. - Also included in the transmitter cabinet are control circuits to raise and lower the primary voltage on the modulator plate transformer, switches to operate the transformer, switches to operate the transmitter in either the standby or the radiate condition and a switch to turn off all the a-c power in the transmitter cabinet. These a-c control circuits are fully described in the paragraph on the a-c distribution system.

3. HYDROGEN THYRATRON MODULATOR, UNIT 2300

a. Introduction. - The hydrogen thyatron modulator is used to pulse-modulate the 4J47 magnetron in the Transmitter, Unit 2000. The modulator and its associated keying circuit are aperiodic in operation so that pulse-time modulation may be employed for the transmission of nutator scan information to the Lark missile. The modulator receives its keying pulse from the target range unit and develops a pulse suitable for application through a pulse transformer to the magnetron. The input pulse to the modulator has a peak amplitude of approximately 30 volts positive, and a duration of one microsecond. The modulator output pulse is a nine-kilovolt pulse of one microsecond duration. It is coupled to the transmitter through a 50-ohm pulse cable. In the Lark system, the average pulse repetition frequency is 576 pulses per second. However, since the Lark SP-1M radar may be used in conjunction with other guided-missile equipment, the average pulse repetition frequency may be varied from 350 to 900 pulses per second with pulse-time modulation capabilities of as high as 50 percent of the time between pulses at the mean repetition frequency. The thyatron modulator unit must be capable of operating over

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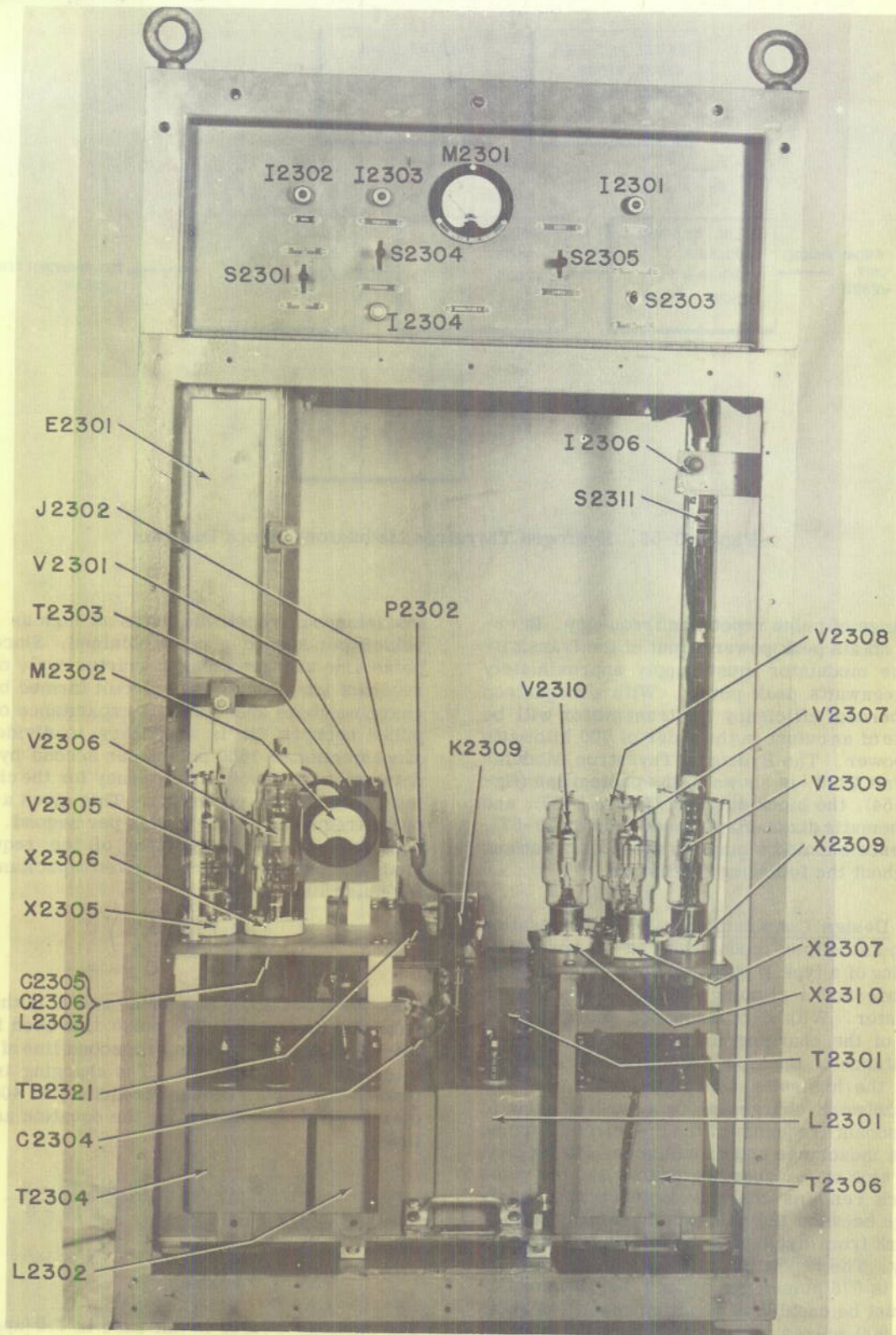


Figure 3-54. Hydrogen Thyatron Modulator With Top Panel Closed - Front View

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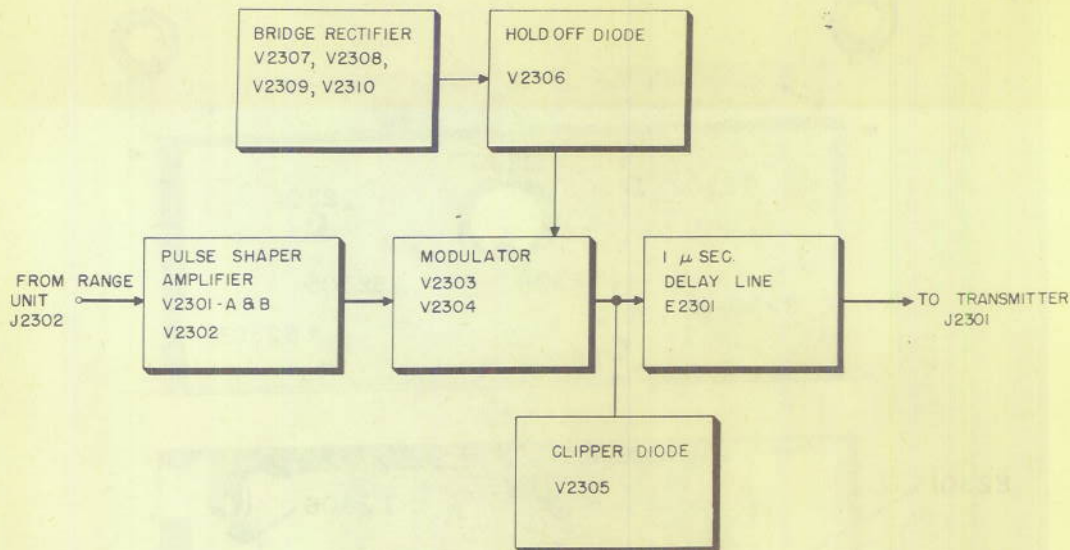


Figure 3-55. Hydrogen Thyatron Modulator - Block Diagram

this range of pulse repetition frequency. In order to obtain peak power output of the transmitter, the modulator must supply approximately 1.4 megawatts peak power. With a magnetron of 50 percent efficiency the transmitter will be capable of an output in the order of 700 kilowatts peak power. The Hydrogen Thyatron Modulator, Unit 2300, is shown in the photograph (figure 3-54), the block diagram (figure 3-55), and the schematic diagrams (figures 3-56 and 3-57). Reference should be made to these illustrations throughout the following discussion.

b. Design Considerations. - For operation with pulse-time modulation, d-c resonance charging of a type E pulse network using a hold-off diode and a clipping diode, is used in the modulator. With d-c resonance charging, the value of the charging inductance and the input capacitance of the type E pulse network determines the highest usable repetition rate. The pulse network charges along a quarter cycle of the resonant frequency of the L-C circuit formed by this inductance and capacitance. At the peak of the sine wave, charging ceases and the pulse network remains charged to twice the supply voltage because the hold-off diode prevents the network from discharging back through the power supply. The repetition rate for the Lark SP-1M radar is 576 pulses per second, but the modulator must be capable of handling repetition rates up to 900 pulses per second, with 50 percent pulse-time modulation. At an average repetition frequency of 900 pulses per second, peak

instantaneous repetition rates as high as 1600 pulses per second may be obtained. Since the pulse line charges along a quarter cycle of the resonant frequency of the circuit formed by the charging choke and the input capacitance of the pulse network, it is necessary to divide the aforementioned 1600 pulses per second by 4 to determine the resonant frequency for the charging choke and the pulse line. This gives a resonant frequency of 400 cycles per second. The equation for the calculation of the required charging inductance for any given capacitance of the pulse line is:

$$L = \left(\frac{1}{2\pi f_R} \right)^2 C \quad (1)$$

L is the inductance in henries and C is the capacitance in farads. The pulse line used in the SP-1M system is a one microsecond line of 0.02 microfarads capacitance. The charging inductance value for a resonant frequency of 400 cycles is given by substituting the equation as follows:

$$L = \frac{\left(\frac{1}{400 \times 6.28} \right)^2}{2 \times 10^{-8}} = \frac{15.8 \times 10^{-8}}{2 \times 10^{-8}} \quad (2)$$

or

$$L = 7.9 \text{ henries} \quad (3)$$

The inductance value in this case is 7.9 (approximately 8) henries. Figure 3-58 shows the wave shape of the charging cycle with an 8-henry choke

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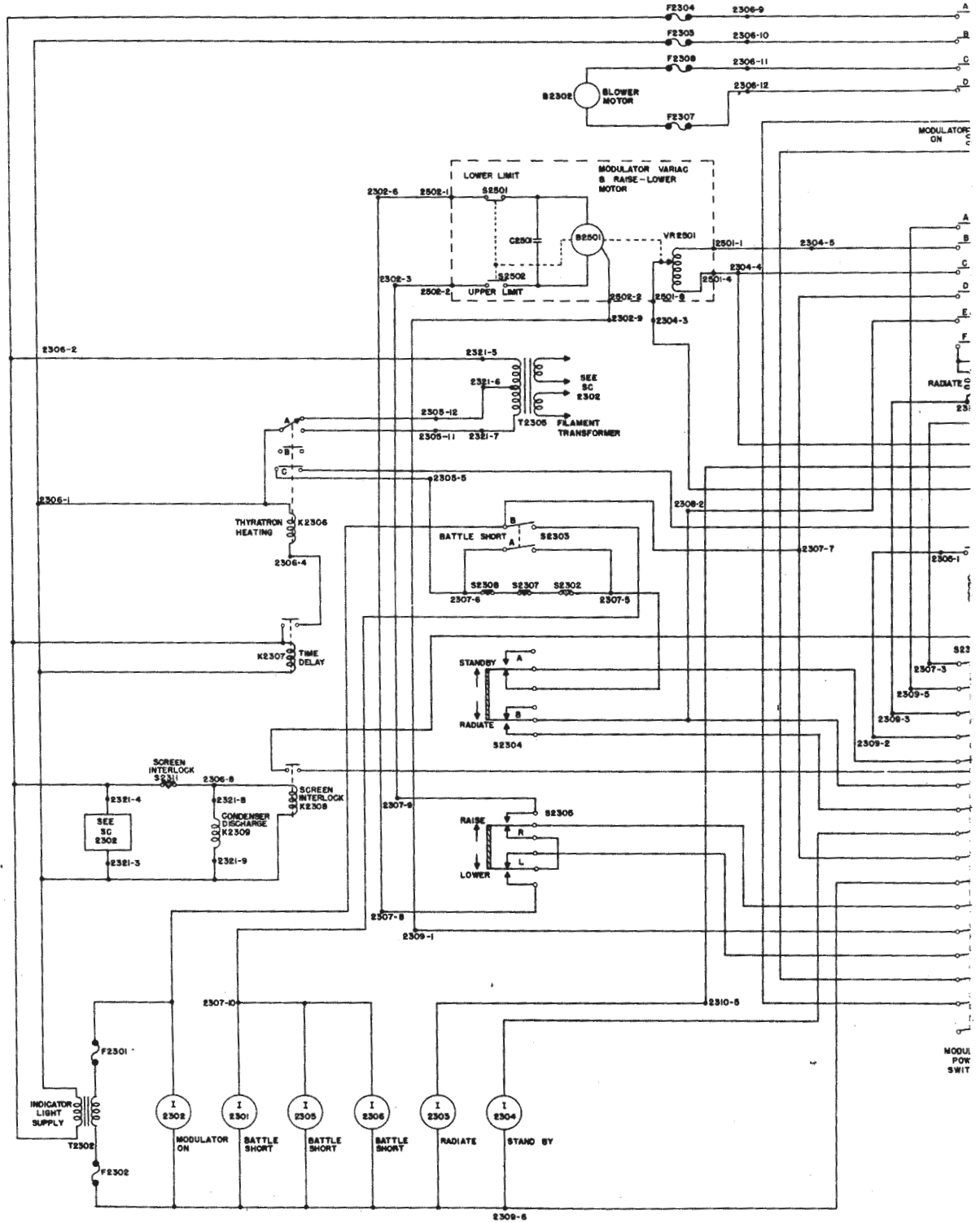
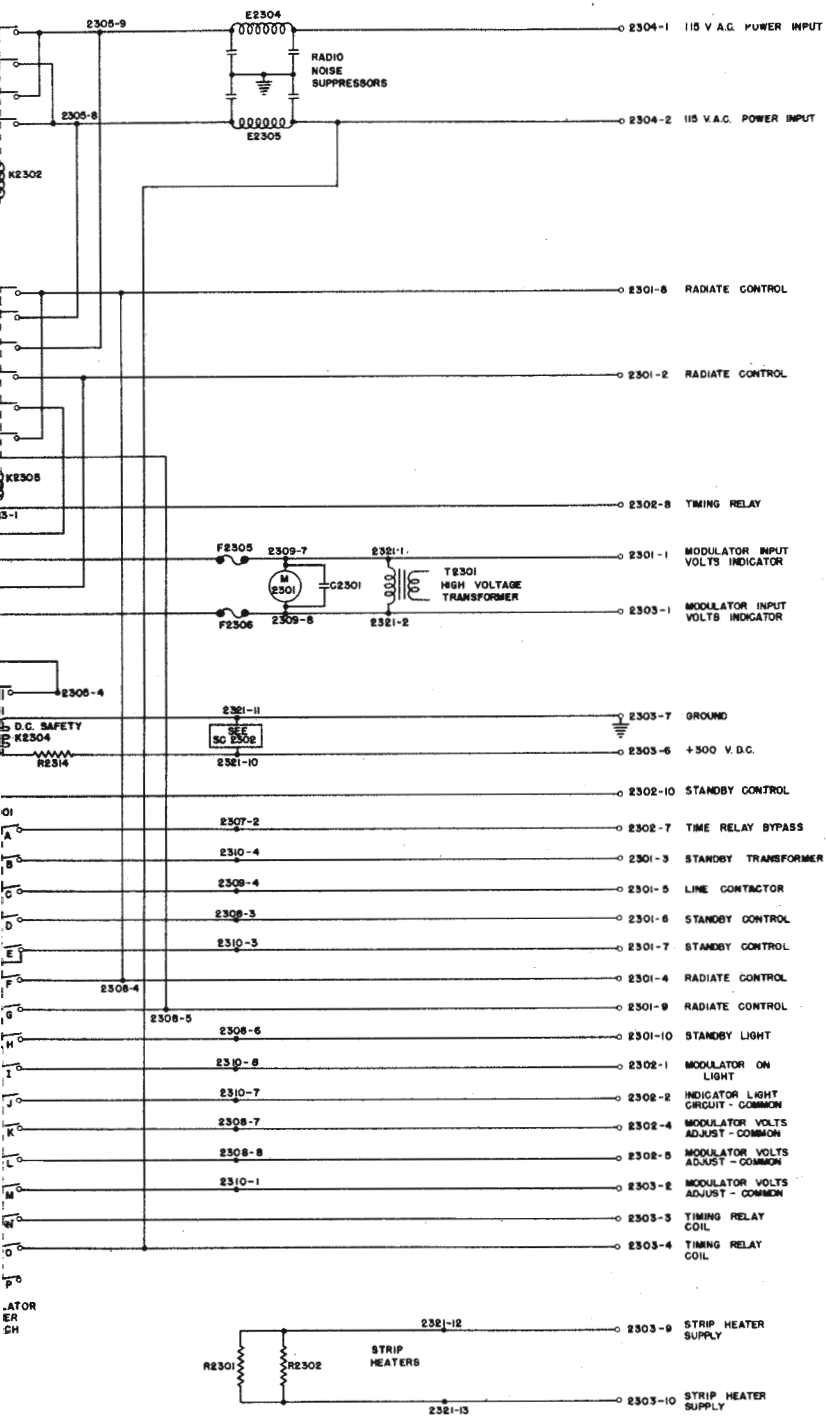


Figure 3-56. Hydrogen Thyratron Modulator - Schematic Diagram



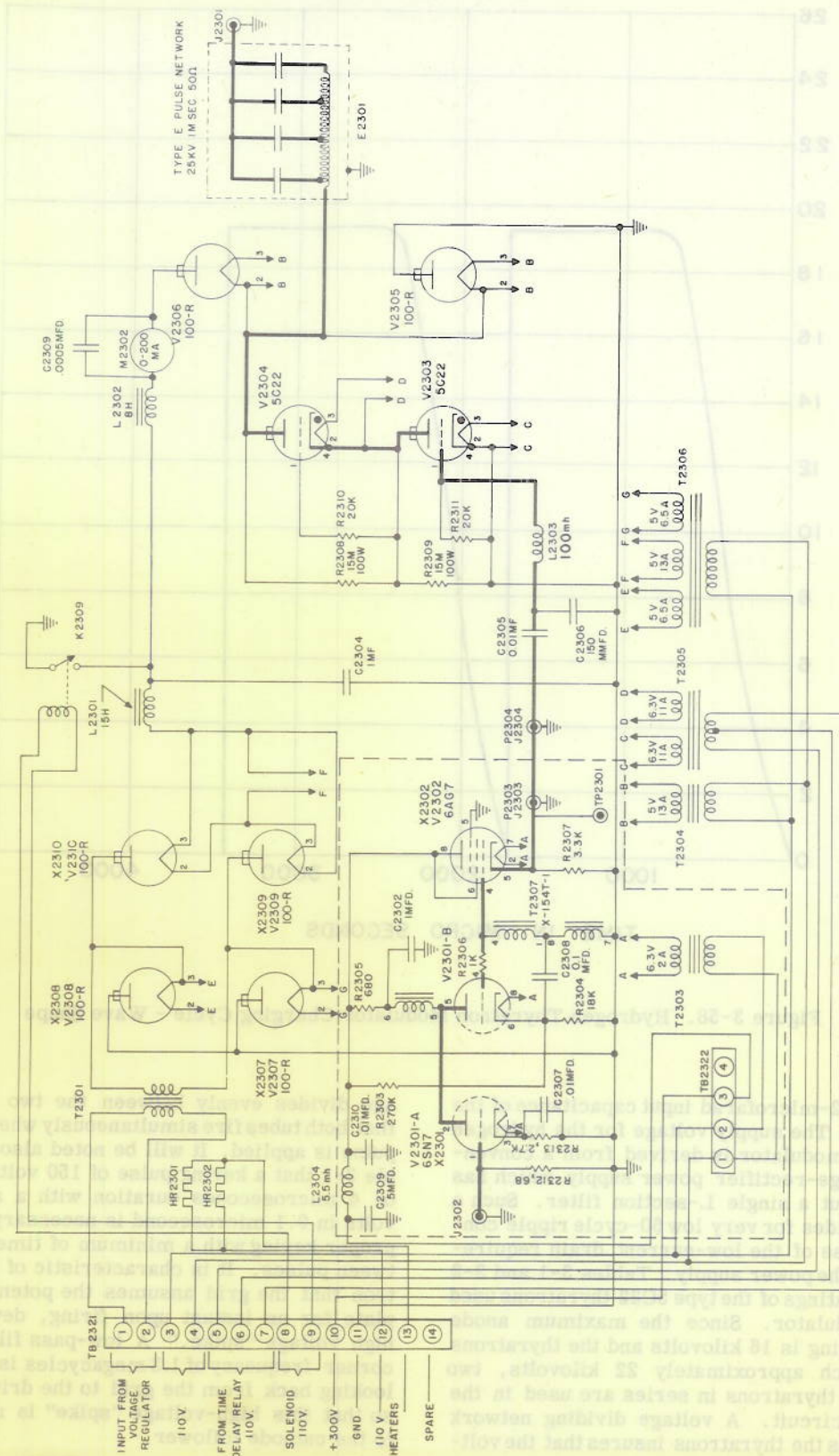


Figure 3-57. Hydrogen Thyatron Modulator - Operational Circuit - Schematic Diagram

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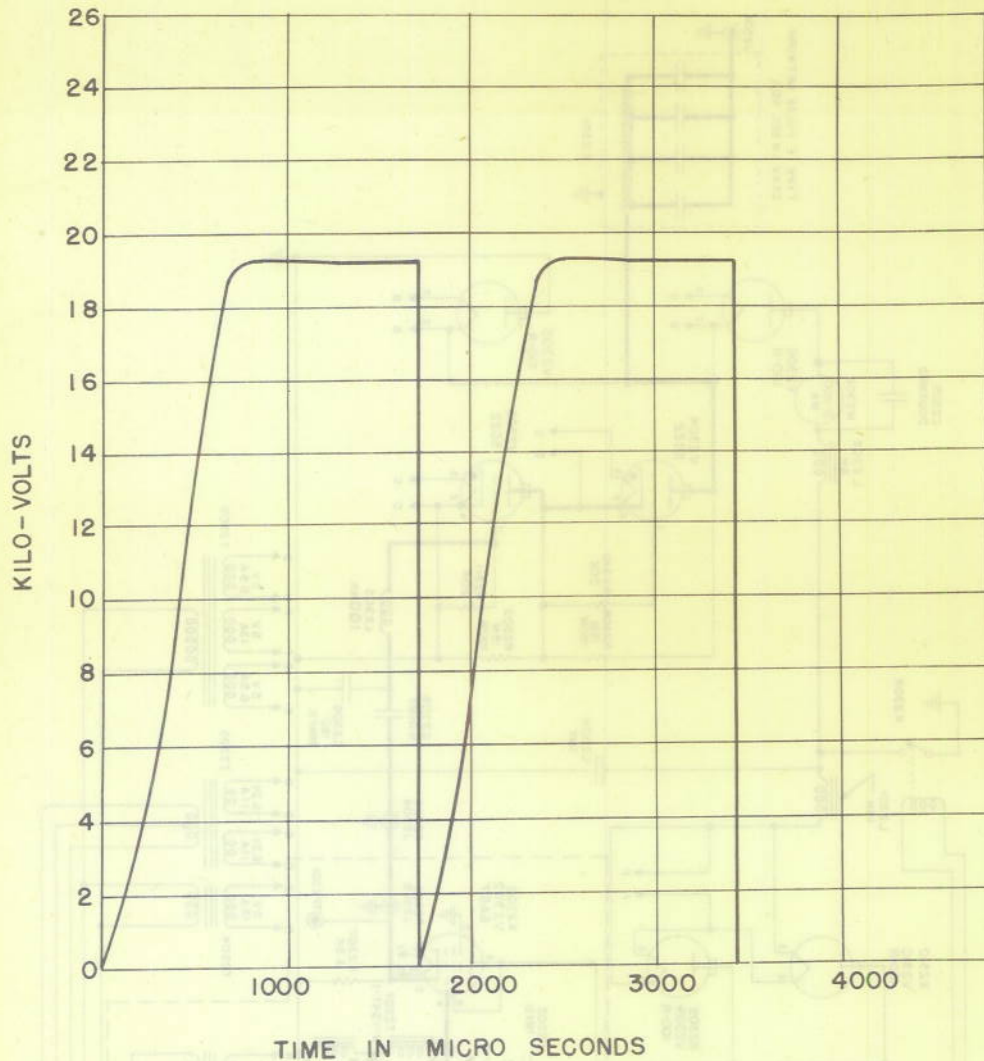


Figure 3-58. Hydrogen Thyatron Modulator Charging Cycle - Wave Shape

and the 0.02-microfarad input capacitance of the pulse line. The supply voltage for the hydrogen thyatron modulator is derived from a conventional bridge-rectifier power supply which has at its output a single L-section filter. Such a filter provides for very low 60-cycle ripple content because of the low-current drain requirements for the power supply. Tables 3-1 and 3-2 show the ratings of the type 5C22 thyatrons used in the modulator. Since the maximum anode voltage rating is 16 kilovolts and the thyatrons must switch approximately 22 kilovolts, two type 5C22 thyatrons in series are used in the switching circuit. A voltage dividing network used across the thyatrons insures that the volt-

age divides evenly between the two tubes and that both tubes fire simultaneously when a keying pulse is applied. It will be noted also from Table 3-1 that a keying pulse of 150 volts peak and of 4 microseconds duration with a rise to 80 volts in 0.1 microsecond is necessary to insure proper keying with a minimum of time jitter between pulses. It is characteristic of the thyatron that the grid assumes the potential of the plate for an instant upon firing, developing a high voltage "spike." A low-pass filter with a corner frequency of 1.3 megacycles is employed looking back from the grid to the driver stage, so that this high-voltage "spike" is not applied to the cathode follower.

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TABLE 3-1

TYPE 5C22 THYRATRON - ELECTRICAL RATINGS AND OPERATING CONDITIONS

Heater voltage	6.3 ± 7.5% volts
Heater current at 6.3 volts	9.6 to 11.6 amps.
Cathode heating time	300 sec. min.
Peak anode voltage	16.0 KV max.
Peak inverse anode voltage	16.0 KV max.
	5% of epy min.
	Note 2
Peak anode current	325 amps. max.
Average anode current	200 ma. max.
Pulse duration (measured at 1/2 amplitude)	6.0 μsec. max.
Pulse repetition frequency	Note 1
Duty cycle (Note 3)	0.001 max.
Grid drive (Note 4)	
a) peak grid voltage	150 volts min.
b) time of rise	1.0 μsec. max.
c) pulse duration measured at 50 volts min. amplitude.	4.0 μsec. min.
d) impedance of grid drive circuit.	500 ohms max.
Peak inverse grid voltage	200 volts max.
Ambient temperature	-50°C. to + 90°C.

Note 1 — The maximum pulse repetition frequency (prf in pulses per second) will depend on the peak forward anode voltage (epv in volts) according to the formula

$$(epv)^2 \times (prf) = 2.6 \times 10^{11} \text{ max.}$$

Note 2 — In pulse operation, the peak inverse voltage should not exceed 5 KV during the 25 microseconds immediately following the pulse.

Note 3 — The duty cycle is defined as the product of the pulse duration in seconds and the pulse repetition frequency in pulses per second.

Note 4 — Measurements are at the tube socket with the thyatron grid disconnected.

TABLE 3-2

TYPE 5C22 THYRATRON - MECHANICAL SPECIFICATIONS

Envelope	T20
Cap	Special
Base	RMA 4310 metal shell
Mounting Position	Any, properly clamped at base

Note 1 — Tube may be operated in any position but should be clamped by base only.

Note 2 — Return for cathode current should be to Pin No. 4 only.

Note 3 — No cooling stream of air should be directly applied to the tube envelope.

Note 4 — Tube should be kept away from strong fields which could ionize gas in the tube.

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c. Measured Performance Characteristics of the Physical System. - During bench tests on the modulator and keyer, the following facts were brought forth. With a positive keying pulse applied from the range unit at an amplitude of 30 volts positive and with a duration of 1 microsecond, the output of the keyer unit is a pulse of 16 microseconds duration with a peak amplitude of 200 volts rising to 80 volts in 0.1 microsecond and staying above a 50-volt level for the remainder of the 16 microseconds. With a d-c input voltage of 10 kilovolts, the pulse line charges to a peak voltage of 19 kilovolts and the input to the coaxial cable and magnetron pulse transformer is a peak voltage of 9.5 kilovolts. A typical set of operating voltages for the hydrogen thyratron modulator is as follows:

A-c voltage input	70 volts
Power supply d-c voltage output	10 kilovolts
Pulse-line storage voltage	19 kilovolts
Modulator peak output voltage	9.5 kilovolts

d. Signal Flow. (See figure 3-57.) - The keying pulse for the pulse shaping circuit is received from J301 in the target range unit and is applied via J2302, to the grid of V2301A in the modulator. The signal from the plate of V2301A is applied to the plate of V2301B, a blocking oscillator. The output signal is taken from the grid of V2301B, and is applied to the grid of V2302, a cathode-follower driver stage. The signal from the cathode of V2302 is the modulator keying pulse. It is applied via J2303, J2304, C2305, and L2303 to the grid of one of the hydrogen thyratrons, V2303, L2303 and C2306 form a low-pass filter for transmission back from the grid of V2303. Since V2302 presents a low source impedance, these elements have little effect on the forward transmission. When V2303 fires, the pulse from its plate is applied to the cathode of the second thyratron V2304, firing it. When these tubes are keyed, they short-circuit one end of the type E pulse line. This action starts a transient along the pulse line and places one half of the voltage to which the line was charged across the load. The transient is reflected and reversed in polarity at the thyratron end of the pulse line and returns to the load end discharging the line. The output of the pulse line is coupled to the transmitter through J2301 and a 50-ohm pulse cable. If magnetron cathode sparking occurs, the type E pulse network is loaded by a very low impedance. This condition may cause reflections from the load impedance when the pulse line is discharging. A voltage wave reflected from the capacitance end of the pulse line will travel down the line toward the thyratrons at a negative polarity and on the next charging cycle cause the pulse line to charge to an extremely high potential, per-

haps damaging the capacitors in the pulse line. A clipper diode V2305 is utilized to clip any negative reflections, thus eliminating any chance of an overvoltage condition.

e. Control Circuits. - The following is a brief description of the modulator control circuits. When the main switch on the console is in the ON position and S2301 on the front panel of the modulator is closed, the 110-volt power is applied to the modulator. The 300-volt power is applied at all times when the radar equipment is on, whether S2301 is closed or not. When S2301 is closed, the 110-volt power is applied to all modulator filament transformer primaries and to the three-minute time-delay employed to preheat the hydrogen thyratrons filaments at 7.5 volts. After three minutes, the time-delay relay reduces the secondary voltage to 6.3 volts and provides power through interlocks to K2309, a safety relay employed to short the output of the high voltage supply when the safety screen is removed. S2301 also applies voltage to the induction regulator raise-lower motor so that the voltage applied to the primary of the high-voltage transformer may be varied. The raise-lower switches either raise the output voltage of the voltage regulator or lower it, the limits being 70 to 140 volts. The three-minute time delay also prevents the application of voltage to the primary of the high-voltage transformer until the tubes are heated. When the equipment comes into the standby position, the radiate switches, if thrown, apply 120 volts to the induction regulator whose output feeds the high-voltage plate transformer. The battle short switches may be used to short out the door interlocks so that the doors may be opened and the equipment operated. However, these switches do not short out the safety screen interlock. The safety screen is interlocked only with the radiate circuits so that power will not be applied to the primary of the high-voltage transformer when the screen is removed. The safety screen must be in place at all times to operate the modulator.

4. MODULATOR INDUCTION REGULATOR, UNIT 2500 (See figures 3-59 and 3-60.)

Control of the voltage appearing on the pulse line is obtained by controlling the voltage applied to the low voltage terminals of the modulator high voltage transformer by means of the motor-driven induction voltage regulator, VR2501 of the Modulator Induction Regulator, Unit 2500. The voltmeter M2301 (figure 3-54) in the modulator reads zero to 150 volts and is connected across the 135 volt winding of the modulator transformer. The induction voltage regulator VR2501 (figure 3-59) is located on a platform next to the

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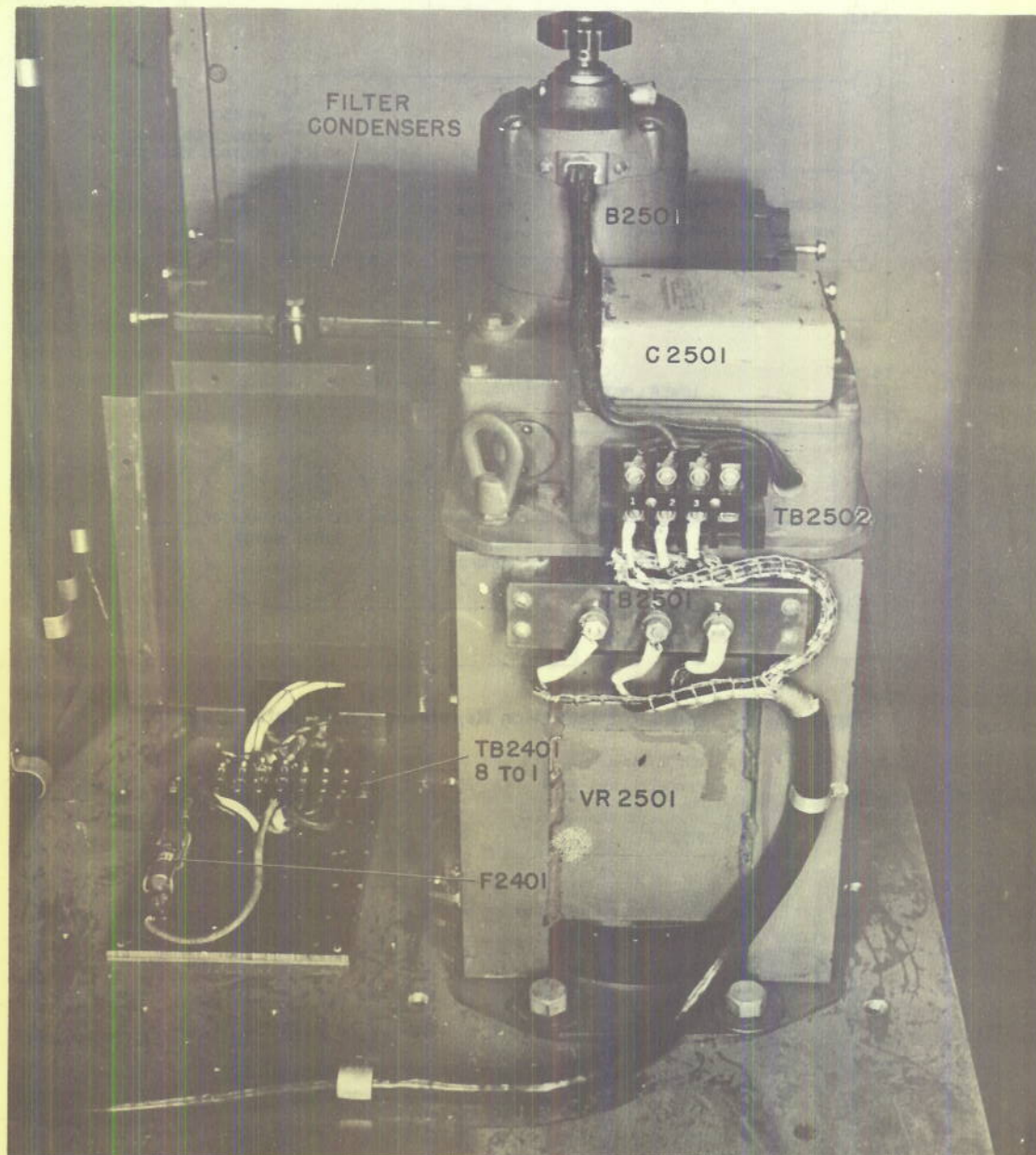


Figure 3-59. Modulator Induction Regulator - Top View

modulator and is rated at 60 cycles, single-phase, 0.568 kva, 115 volts, + 35 volts, at 16.2 amperes. The regulator consists of a movable rotor on which is wound the shunt winding connected across the 115-volt line, and a stator on which is wound a 35-volt series winding connected in series with a supply line to T2301. (See figure 3-60.) In a single-phase regulator of this type, a constant flux is produced in the shunt or primary winding which induces the

voltage in the series or secondary winding. The voltage induced in the series winding can be varied by changing the position of the rotor because this varies the primary flux linking the secondary winding. The secondary voltage may be reduced from a maximum in phase with the primary voltage to zero and then to a maximum in a direction to buck the primary voltage. Therefore, turning the rotor over a range of 180 degrees varies the output voltage continuously

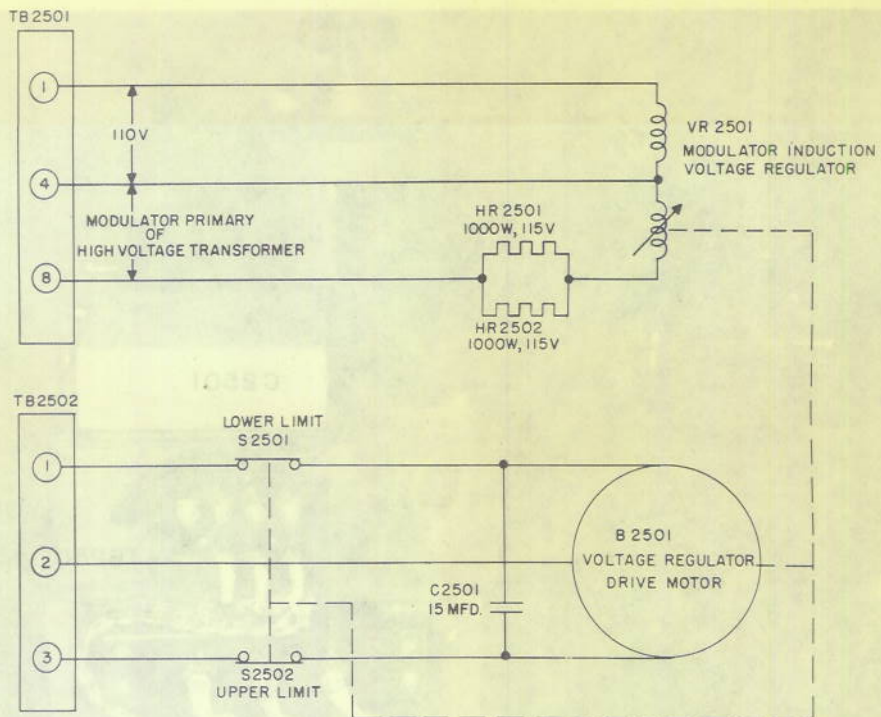


Figure 3-60. Modulator Induction Regulator - Schematic Diagram

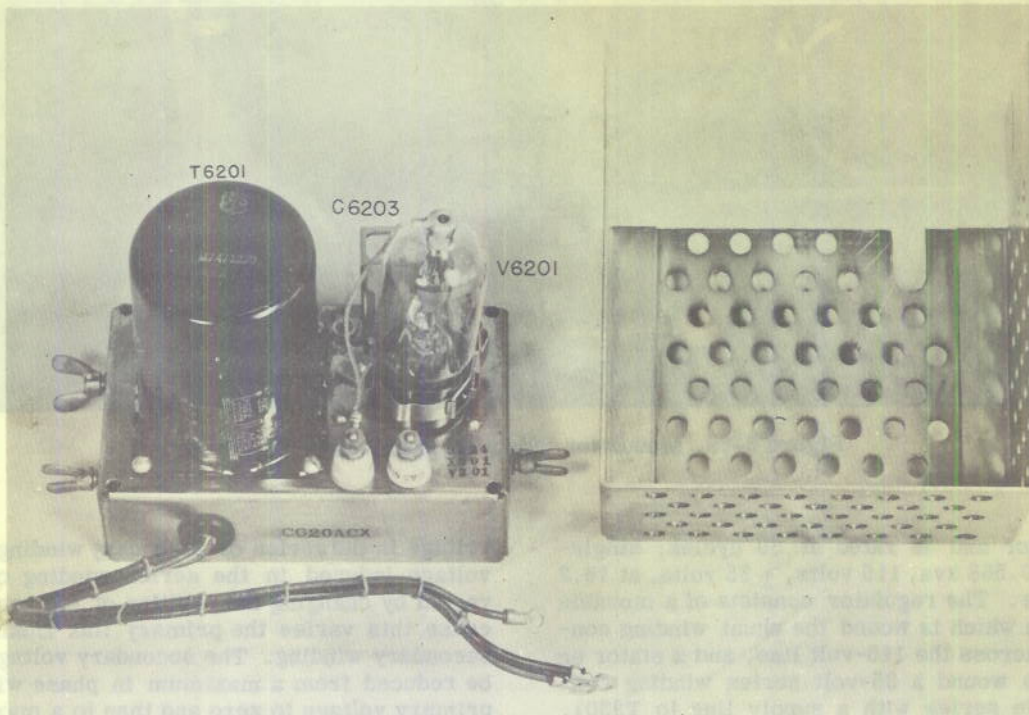


Figure 3-61. Keep-alive Power Supply - Top View

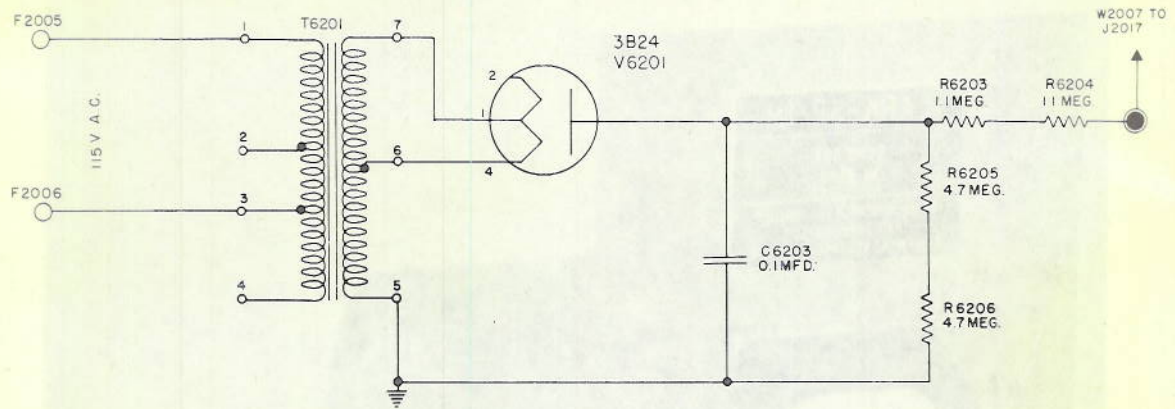


Figure 3-62. Keep-alive Power Supply - Schematic Diagram

over the range of values between the line voltage minus the series voltage and the line voltage plus the series voltage. Strip heaters HR2501 and HR2502 (figure 3-60) are placed in series with the rotor of the induction voltage regulator to act as current limiters protecting the magnetron and modulator from switching transients. The mechanism for rotation of the rotor of the voltage regulator VR2501 consists of a double worm and gear assembly driven by 1/40-hp, 120-volt 60-cycle, single-phase, 1000-rpm, capacitor-type motor B2501 (figure 3-60). The motor is remotely controlled by a lever-type switch, S2305, which is mounted on the modulator control panel (figure 3-54). This switch is of the momentary or spring-return type, returning to the neutral position after release so that the motor operates only during the time in which the switch is held in the RAISE or LOWER position. Approximately 40 seconds is required for the motor to operate the regulator from maximum LOWER to maximum RAISE position or vice versa. A knob is provided at the upper end of the motor shaft for manual operation. Limit switches S2501 and S2502 (figure 3-60) of the microswitch type are operated by cams on the motor shaft. These switches open the supply circuit to the motor to limit the travel of the regulator rotor in each direction. The regulator rotor and main worm are equipped with tapered roller bearings and the motor rotor with ball bearings. All these bearings are grease packed when assembled and should require very little attention.

5. THE KEEP-ALIVE POWER SUPPLY, UNIT 6200 (See figures 3-61 and 3-62.)

The Keep-alive Power Supply, Unit 6200, is mounted in the top compartment of the trans-

mitter. (See figure 3-43.) It consists of a half-wave rectifier capable of supplying a maximum current of 0.25 milliamperes at 925 volts to the keep-alive electrode of the duplexer tubes V2002 and V2004 in the transmitter. In this manner, a source of stray ions is provided within the gas discharge tube which, in consequence, fires more rapidly when the transmitter generates a pulse, thus protecting the receiver before the high-powered transmitter pulse builds up to any considerable voltage. The keep-alive power supply unit consists of a type 3B24 rectifier tube, V6201, to which plate and filament voltages are supplied through the tapped secondary winding of transformer T6201. The primary of this transformer is energized from the 115-volt 60-cycle supply line through transmitter ON-OFF switch S2001. The plate circuit of rectifier tube V6201 includes two filter resistors, R6205 and R6206, and filter capacitor C6203. The high-d-c voltage developed at the plate of the tube is applied to the keep-alive electrode of duplexer tubes V2002 and V2004 through three series-connected current limiting resistors, R6203, R6204 and R2025 (R2025 is in J2017 at the TR box).

6. THE ECHO BOX, TYPE COY-14AAW, UNIT 4700 (See figures 3-63 and 3-64.)

The Echo Box, Unit 4700, may be used to perform the following checks and measurements on the operation of the Lark SP-1M system.

- (1) Indication of proper tuneup.
- (2) Overall r-f performance check.
- (3) Indication of transmitter power output.
- (4) Measurement of transmitter frequency.
- (5) Analysis of transmitter frequency spectrum.
- (6) Measurement of local oscillator frequency.

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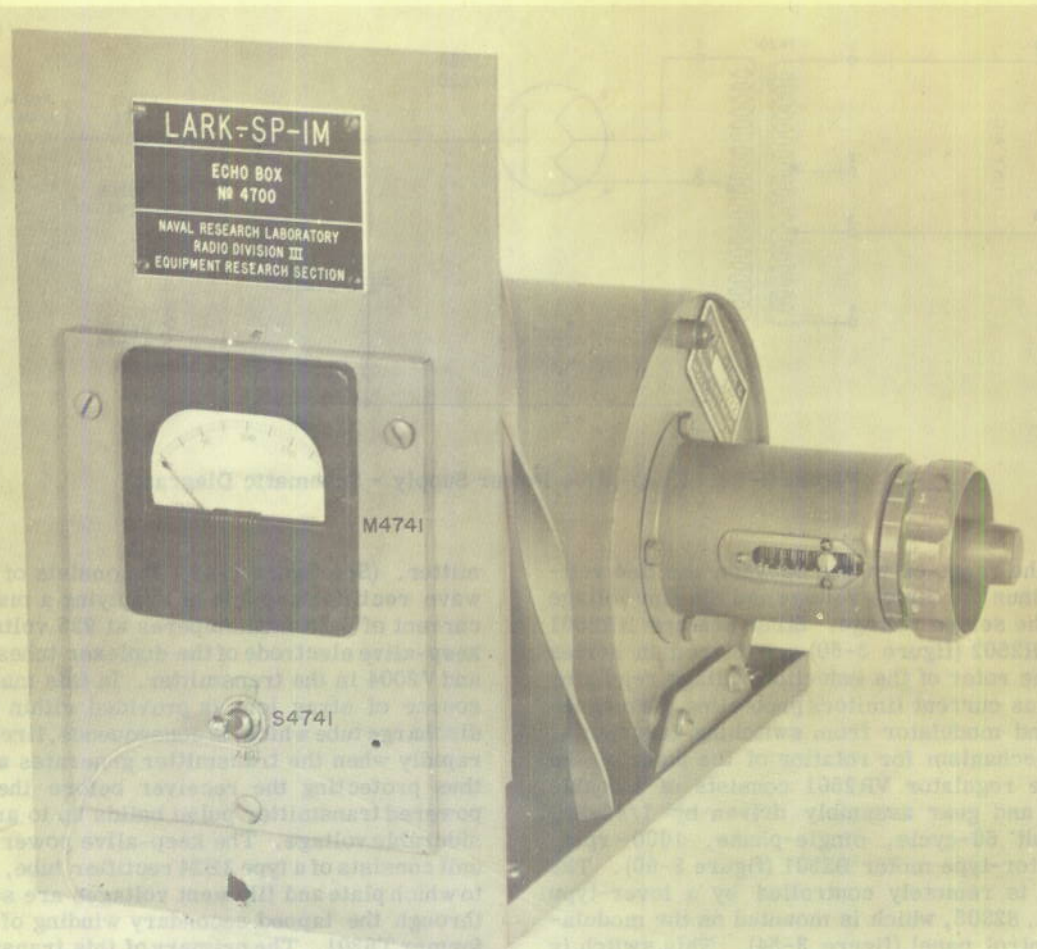


Figure 3-63. Echo Box - Front View

The echo box is a cylindrical resonant cavity, 6 inches in diameter and 5-1/2 inches in length. Inside the cylinder is a piston or plunger which moves to vary the length of the cavity. A scale with a marker in the position of the tuning knob is used with a calibration chart to determine the resonant frequency of the cavity. This echo box is similar to other S-band echo boxes. Radio-frequency energy is inductively coupled in and out of the cavity by coupling loops in the side of the box parallel to the ends. The energy absorbed by the echo box is indicated by a microammeter connected to the output coupling loop. The inside of the cavity is silver plated and highly polished to raise the "Q." A small amount of r-f absorbing material is placed in the small cavity behind the plunger to prevent this cavity from affecting the operation. Electrically the echo box cavity is equivalent to a sharply tuned L-C resonant circuit. However, it is not

correct to consider any particular part of the box as a capacitance or inductance in the equivalent circuits. The frequency to which the box is resonant depends upon the physical size of the resonant cavities. When the length of the cavity is decreased, the resonant frequency is raised; when the length of the cavity is increased, the resonant frequency is lowered. Figure 3-65 shows the equivalent echo box circuit. R-f energy from the radar antenna is picked up by the probe in the transmitter waveguide section and is fed into the echo box cavity through a cable and a coupling loop. During the radar pulse, the resonant cavity of the echo box accepts r-f energy, and oscillations build up for the duration of the pulse. After the pulse, the oscillations in the echo box gradually die out because some of the energy is dissipated in the resonant cavity, some is coupled out to the crystal rectifier and microammeter, and some is coupled

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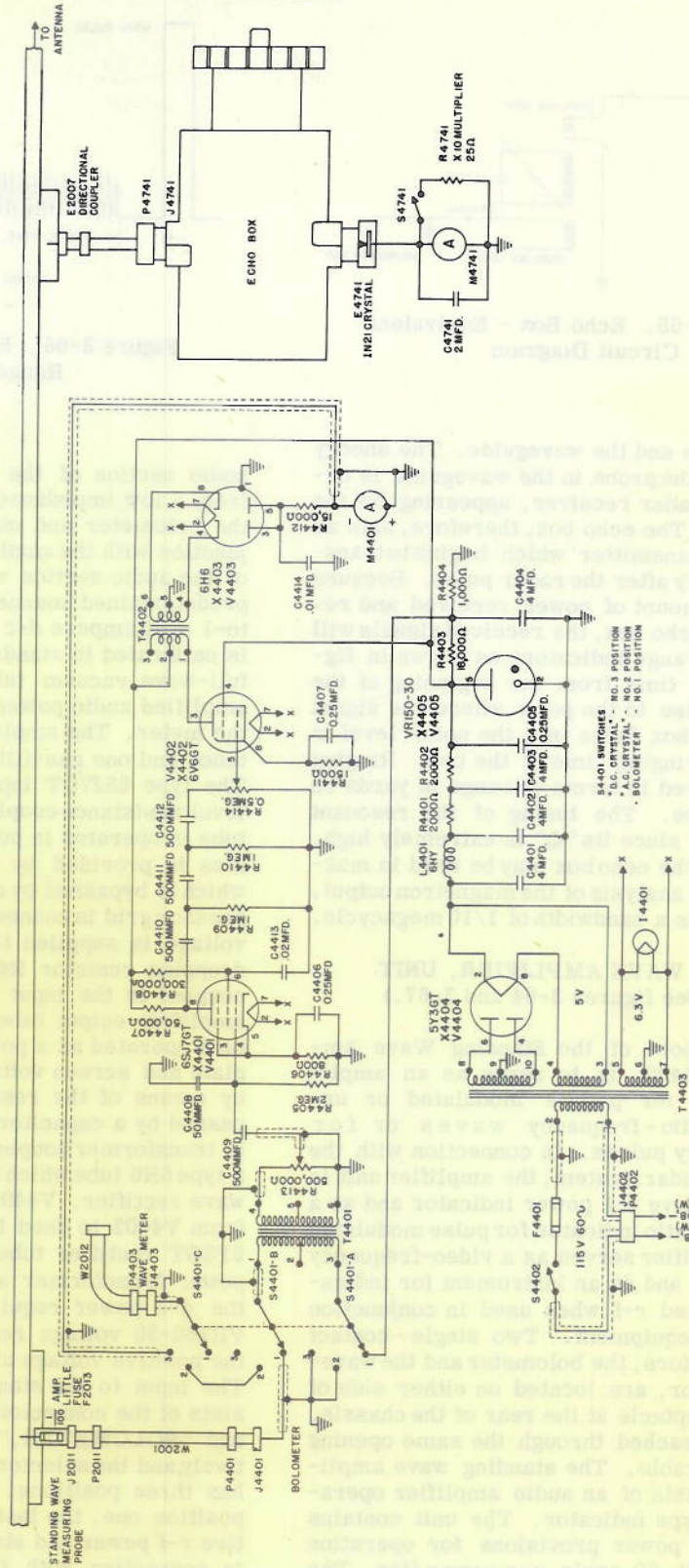


Figure 3-64. Echo Box and Standing Wave Amplifier - Schematic Diagram

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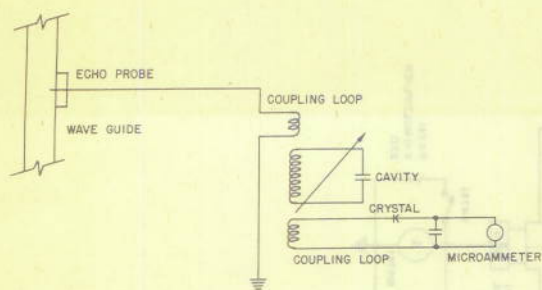


Figure 3-65. Echo Box - Equivalent Circuit Diagram

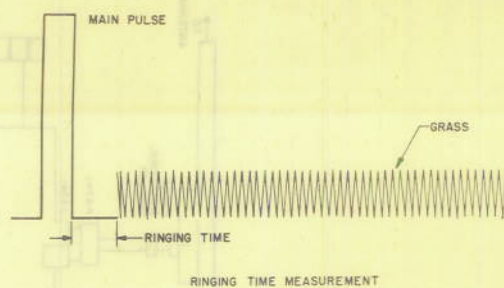


Figure 3-66. Echo Box Signals on Range Indicator

out to the probe and the waveguide. The energy radiated from the probe in the waveguide is detected in the radar receiver, appearing on the range scopes. The echo box, therefore, acts as a miniature transmitter which begins to transmit immediately after the radar pulse. Because of the large amount of power received and returned by the echo box, the received signals will appear on the range indicators as shown in figure 3-66. The time from the beginning of the transmitted pulse to the point where the signal from the echo box fades into the noise level is known as the ringing time of the box. Ringing time is measured in terms of range in yards on the range scope. The tuning of the resonant cavity is sharp since its "Q" is extremely high. Consequently, the echo box may be used in making a spectrum analysis of the magnetron output. The echo box has a bandwidth of 1/10 megacycle.

7. STANDING WAVE AMPLIFIER, UNIT 4400 (See figures 3-64 and 3-67.)

The purpose of the Standing Wave Amplifier, Unit 4400, is to serve as an amplitude indicator for pulse modulated or unmodulated radio-frequency waves or for video-frequency pulses. In connection with the Lark SP-1M radar system, the amplifier unit is used as a relative r-f power indicator and as a standing wave ratio indicator for pulse modulated r-f. The amplifier serves as a video-frequency pulse indicator and as an instrument for indicating unmodulated r-f when used in conjunction with external equipment. Two single-contact coaxial connectors, the bolometer and the wave-meter connector, are located on either side of the power receptacle at the rear of the chassis. They can be reached through the same opening as the power cable. The standing wave amplifier unit consists of an audio amplifier operating a meter type indicator. The unit contains the necessary power provisions for operation from a 115-volt, 60-cycle, a-c power line. The

audio section of the unit is designed to work from a low impedance source as represented by the bolometer and other circuits used in conjunction with the amplifier unit. The sensitivity of the audio section varies with frequency in a predetermined manner. The indicator is a 0-to-1 milliamperes d-c meter, the scale of which is calibrated in standing wave voltage ratios. A full-wave vacuum tube rectifier converts the amplified audio power into d-c for operation of the meter. The amplifier contains four vacuum tubes and one gas-filled voltage regulator tube. The type 6SJ7GT input tube, V4401, is a low-level resistance coupled voltage amplifier. The tube is operated in pentode connection. Cathode bias is provided by means of resistor R4406 which is bypassed by capacitor C4406. The suppressor grid is connected to the cathode. Screen voltage is supplied through the series voltage dropping resistor R4408. V4401 is resistance coupled to the input grid of V4402, the audio amplifier output tube. V4402 is a type 6V6GT tube operated as a power amplifier with reduced plate and screen voltages. It is cathode biased by means of the resistor R4411 which is bypassed by a capacitor C4407. The plate circuit is transformer coupled to the cathodes of V4403, a type 6H6 tube which serves as a low-level full-wave rectifier. V4403 rectifies the audio signal from V4402 to feed the d-c meter. V4404, a 5Y3GT rectifier tube, in conjunction with the power transformer and filter circuit, supplies the d-c power required by the unit. A type VR150-30 voltage regulator, V4405, maintains the positive voltage at approximately 150 volts. The input to the standing wave amplifier consists of the connectors marked "WAVEMETER" and "BOLOMETER," J4403 and J4401 respectively, and the selector switch S4401. This switch has three positions. When switch S4401 is in position one, the instrument serves as a relative r-f power and standing wave ratio indicator in connection with the radar system. These

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measurements are based upon use of the bolometer. The bolometer in this unit consists of a fine wire enclosed in a cartridge and mounted in a probe. The wire is made a part of the input circuit of the amplifier unit by connecting leads coming from the probe to the bolometer connection. With the switch in the bolometer position, (position one) the amplifier input section is connected to the bolometer connector. The amplifier unit provides a constant direct current through the bolometer wire via the primary of the input transformer T4401. The voltage for producing this current originates across the voltage divider branch resistor R4404. The biasing voltage, approximately 7.5 volts positive to ground with the bolometer disconnected, can be measured between the center contact of the bolometer connector and ground. By insert-

ing the probe in a slotted waveguide, the bolometer wire is exposed to the field within the guide. Radio-frequency currents set up in the bolometer wire will, by heating up the wire, change its d-c resistance. Since the r-f field within the waveguide or transmission line is pulse-modulated at an audio rate, the change in the d-c resistance of the bolometer wire will take place at the same audio rate. This pulsating resistance variation transforms the d-c current sent by the amplifier through the bolometer into a pulsating d-c current, the audio component of which passes via the input transformer T4401 into the amplifier section of the unit. Since the audio voltage introduced in the amplifier unit is a measure of field intensity in the waveguide, the bolometer amplifier combination provides a means of measuring the rel-

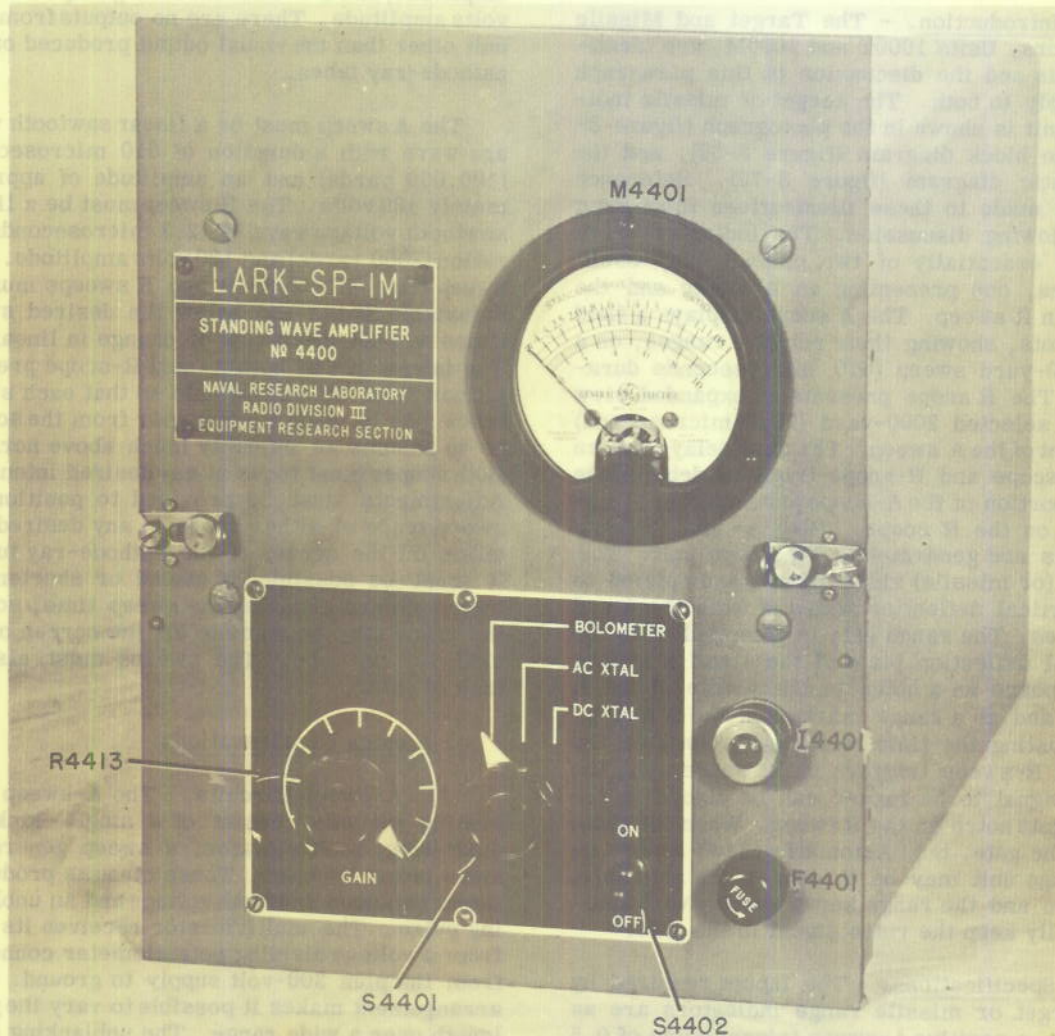


Figure 3-67. Standing Wave Amplifier - Front View

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ative r-f power output of the radar system. When the probe is moved within a waveguide slotted for this purpose, the combination will serve as a standing wave ratio indicator. Since the audio voltage introduced into the amplifier is proportional to the square of the field intensity in the waveguide, the indicator meter scale is calibrated according to the inverse square law. Switch position two on the standing wave indicator puts the amplifier into the a-c crystal position, where it can be used to indicate video

pulses. Switch position three connects the amplifier to the d-c crystal position. The only position that is used with the Lark SP-1M equipment is switch position one (the bolometer position). When used in this position, the unit will indicate the standing wave voltage ratio existing in the waveguide. Since there are no provisions in the equipment for adjusting this standing wave ratio, it can only be used as a check from time to time to determine whether the r-f plumbing system has become dirty or damaged.

Subsection 3-4. Indicators

1. TARGET AND MISSILE INDICATORS, UNITS 1000T AND 1000M

a. Introduction. - The Target and Missile Indicators, Units 1000T and 1000M, are identical units and the discussion in this paragraph will apply to both. The target or missile indicator unit is shown in the photograph (figure 3-68), the block diagram (figure 3-69), and the schematic diagram (figure 3-70). Reference will be made to these illustrations throughout the following discussion. The indicators each consist essentially of two cathode-ray oscilloscopes, one presenting an A sweep and the other an R sweep. The A scope displays a field of targets, showing their relative ranges, on a 100,000-yard sweep (610 microseconds duration). The R scope presents an expanded view of any selected 2000-yard (12.2-microsecond) segment of the A sweep. The time delay between the A-scope and R-scope triggers determines which portion of the A-scope presentation is displayed on the R scope. Both A- and R-scope triggers are generated in the range unit. The target (or missile) video signals are applied to the vertical deflection plates of both the A and R scopes. The range gate is also applied to the vertical deflection plate of the A and R scopes and appears as a notch in the middle of the R sweep and as a range marker on the A sweep. By adjusting the time relationship between the A- and R-sweep triggers in the range unit, the video signal to be ranged can be placed in the range gate notch on the R sweep. When the video is in the gate, the "Automatic-Slew" switch on the range unit may be thrown to the automatic position and the range servo system will automatically keep the video signal in the gate.

b. Specifications. - The inputs required by the target or missile range indicators are as follows: a positive A-sweep trigger pulse of 0.5 microsecond duration and 25 volts peak amplitude; a positive R-sweep trigger pulse of 0.5

microsecond duration and 25 volts peak amplitude; ungated video pulses of 75 volts maximum amplitude; and a 1-microsecond gate pulse of 20 volts amplitude. There are no outputs from this unit other than the visual output produced on the cathode-ray tubes.

The A sweep must be a linear sawtooth voltage wave with a duration of 610 microseconds (100,000 yards) and an amplitude of approximately 180 volts. The R sweep must be a linear sawtooth voltage wave of 12.2 microseconds duration (2000 yards) and 180 volts amplitude. The sweep time of both the A and R sweeps must be adjustable above and below the desired sweep times without distortion or change in linearity. The intensities of both A- and R-scope presentations must be controllable so that each sweep trace may be made to disappear from the screen or to assume an intensity much above normal. Both scopes must focus at any desired intensity. Adjustments must be provided to position the sweep trace of either scope to any desired position on the screen of the cathode-ray tubes. It must be possible to extend or shorten the sweep without changing the sweep time, so that the trace may be made to fit the screen of the cathode-ray tube. The sweeps must also be free of jitter.

c. Design Considerations.

1). A-Sweep Circuits. - The A-sweep generating circuits consist of a single-kick, or start-stop, multivibrator, a sweep generator, and a phase inverter. These circuits produce a linear balanced sawtooth voltage and an unblanking pulse. The multivibrator receives its bias from a voltage dividing potentiometer connected from the plus 300-volt supply to ground. This arrangement makes it possible to vary the pulse length over a wide range. The unblanking pulse is taken from a voltage divider in the plate circuit of the second half of the multivibrator. This

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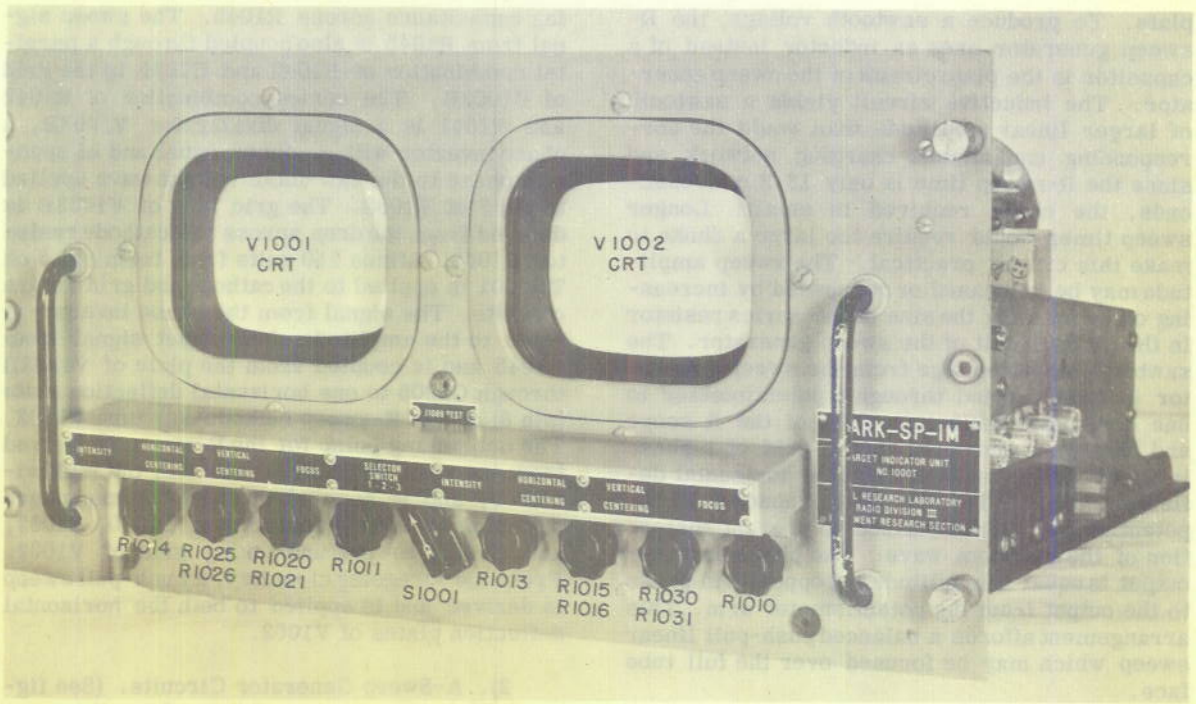


Figure 3-68. Target or Missile Indicator Unit - Front View

pulse is of the same length as the pulse coupled to the sweep generator. The 100,000-yard sawtooth voltage wave is generated with a capacitance charging network in the plate circuit of the sweep generator. The sawtooth output of the sweep generator is applied to one horizontal deflection plate of the cathode-ray tube and, through a voltage divider, to the grid of a phase inverter which supplies the other horizontal deflection plate. The sawtooth voltage output from the phase inverter is equal in amplitude and 180 degrees out of phase with the sawtooth output of

the sweep generator. This arrangement affords a balanced push-pull sweep voltage and makes it possible to focus the entire sweep trace.

2). R-Sweep Circuits. - The R-sweep generator is triggered by a single-kick multivibrator which is an exact duplicate of the multivibrator in the A-sweep circuit except for the time-constant determining the length of the output pulse. The pulse applied to the sweep generator grid is taken from one plate of the multivibrator and the unblanking pulse is taken from the other

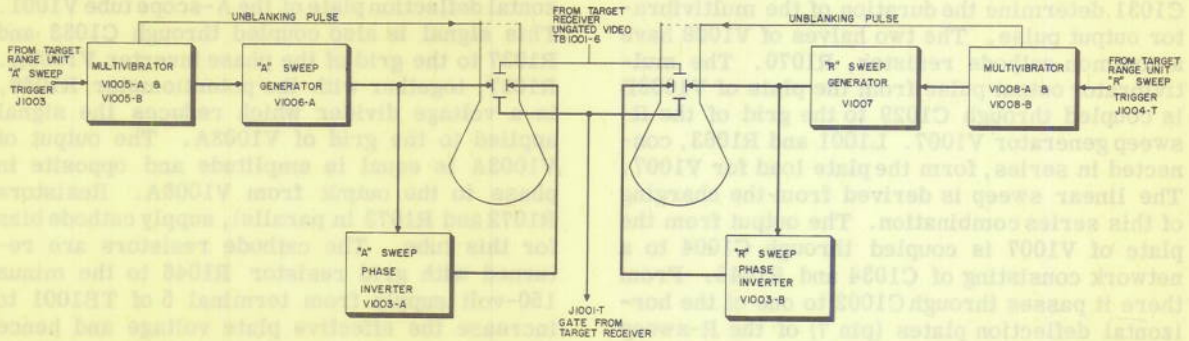


Figure 3-69. A and R Indicators - Block Diagram

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plate. To produce a sawtooth voltage, the R-sweep generator uses an inductor instead of a capacitor in the plate circuit of the sweep generator. The inductive circuit yields a sawtooth of larger linear amplitude than would the corresponding capacitance charging network and since the R-sweep time is only 12.2 microseconds, the choke required is small. Longer sweep times would require too large a choke to make this circuit practical. The sweep amplitude may be increased or decreased by increasing or decreasing the size of the series resistor in the plate circuit of the sweep generator. The sawtooth output voltage from the sweep generator is first applied through a potentiometer to one horizontal deflection plate of the R scope and through a network, to the grid of a phase inverter which supplies the other horizontal deflection plate. The parasitic capacity of the potentiometer is neutralized to prevent distortion of the sawtooth wave. The phase-inverter output is equal in amplitude and opposite in phase to the output from the potentiometer arm. This arrangement affords a balanced push-pull linear sweep which may be focused over the full tube face.

d. Performance Characteristics. - Bench tests show that the units were well within the performance specifications given in paragraph 1b of this subsection.

e. Circuit Description.

1). R-Sweep Generating Circuits. (See figure 3-70.) - The R-sweep generating circuits consist of V1008B, V1008A, V1007, V1003B, and V1002. The R-sweep trigger from the range unit is applied to the grid of V1008B through J1004 and C1032, and appears across R1071, the grid return resistor for V1008B, and CR1002, a 1N34 crystal diode. The latter component bypasses to ground any negative portion of the input trigger. V1008B and V1008A comprise a single-kick multivibrator. R1065, R1066, and C1031 determine the duration of the multivibrator output pulse. The two halves of V1008 have a common cathode resistor, R1070. The multivibrator output pulse from the plate of V1008B is coupled through C1029 to the grid of the R-sweep generator V1007. L1001 and R1063, connected in series, form the plate load for V1007. The linear sweep is derived from the charging of this series combination. The output from the plate of V1007 is coupled through C1004 to a network consisting of C1034 and R1045. From there it passes through C1002 to one of the horizontal deflection plates (pin 7) of the R-sweep cathode-ray tube V1002. R1045 is an amplitude control which determines the amplitude of the sweep on pin 7 of V1002. C1034 is a neutraliz-

ing capacitance across R1045. The sweep signal from R1045 is also coupled through a parallel combination of R1042 and C1035 to the grid of V1003B. The series combination of R1042 and R1041 is a signal divider for V1003B, a phase inverter with an output equal and of opposite phase to the saw-tooth voltage wave applied to pin 7 of V1002. The grid bias of V1003B is derived from the drop across the cathode resistor R1062. Minus 150 volts from terminal 5 on TB1001 is applied to the cathode and grid return circuits. The signal from the phase inverter is equal to the amplitude of the input signal from R1045 and is coupled from the plate of V1003B through C1005 to one horizontal deflection plate (pin 8) of the R-sweep cathode-ray tube V1002. The unblanking pulse for the R-sweep is derived from the plate of V1008A, one-half the multivibrator, and is coupled through the impedance matching network (consisting of C1030, R1067, and C1003) to the unblanking grid of V1002. From the foregoing circuitry, a push-pull sweep is derived and is applied to both the horizontal deflection plates of V1002.

2). A-Sweep Generator Circuits. (See figure 3-70.) - The A-sweep trigger from the range unit is applied to J1003 and is coupled through C1023 to the grid of V1005A. R1052 is the grid return resistor for V1005A. A 1N34 crystal, CR1001, eliminates any negative portion of the input trigger. V1005A and V1005B comprise a single-kick multivibrator whose pulse length is determined by C1024, R1057, and R1058. R1053 is the plate load resistor of V1005A and the series combination of V1055 and R1056 are the plate load resistors of V1005B. The two halves of V1005 have a common cathode resistor R1054. The signal from the plate of V1005A is coupled through C1025 to the grid of V1006A. R1059 is the grid return resistor of V1006A. V1006A is the A-sweep generator whose plate load is R1061 and C1028. The cathode of V1006A is connected to minus 150 volts. The sawtooth from the plate of V1006A is coupled through C1015 to one horizontal deflection plate of the A-scope tube V1001. This signal is also coupled through C1033 and R1037 to the grid of the phase inverter V1003A. R1037, together with the potentiometer R1046, is a voltage divider which reduces the signal applied to the grid of V1003A. The output of V1003A is equal in amplitude and opposite in phase to the output from V1006A. Resistors R1072 and R1073 in parallel, supply cathode bias for this tube. The cathode resistors are returned with grid resistor R1046 to the minus 150-volt supply from terminal 5 of TB1001 to increase the effective plate voltage and hence the output capability of the phase inverter. R1035 is the plate load resistor of V1003A. The signal is derived from the plate of V1003A and

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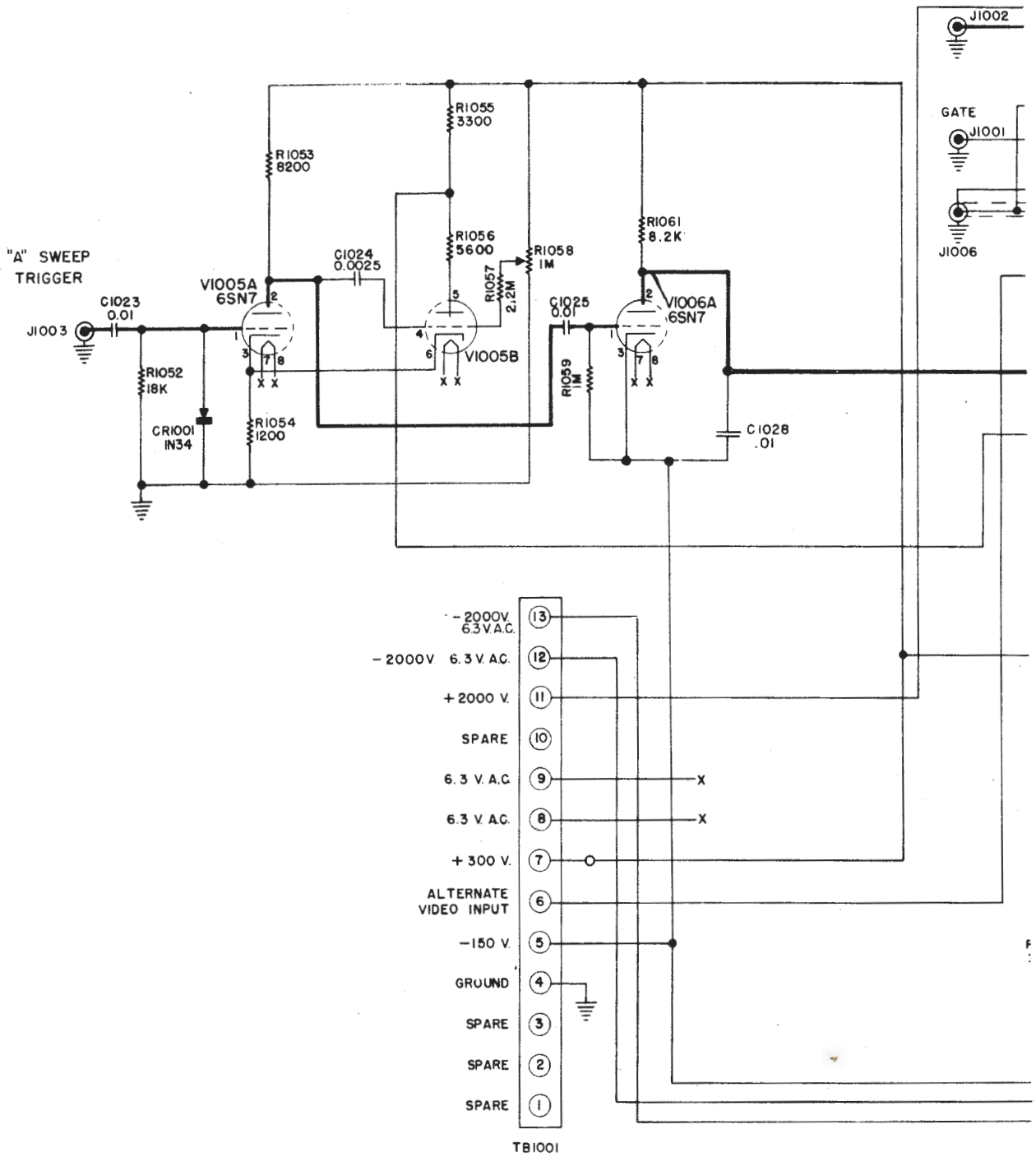
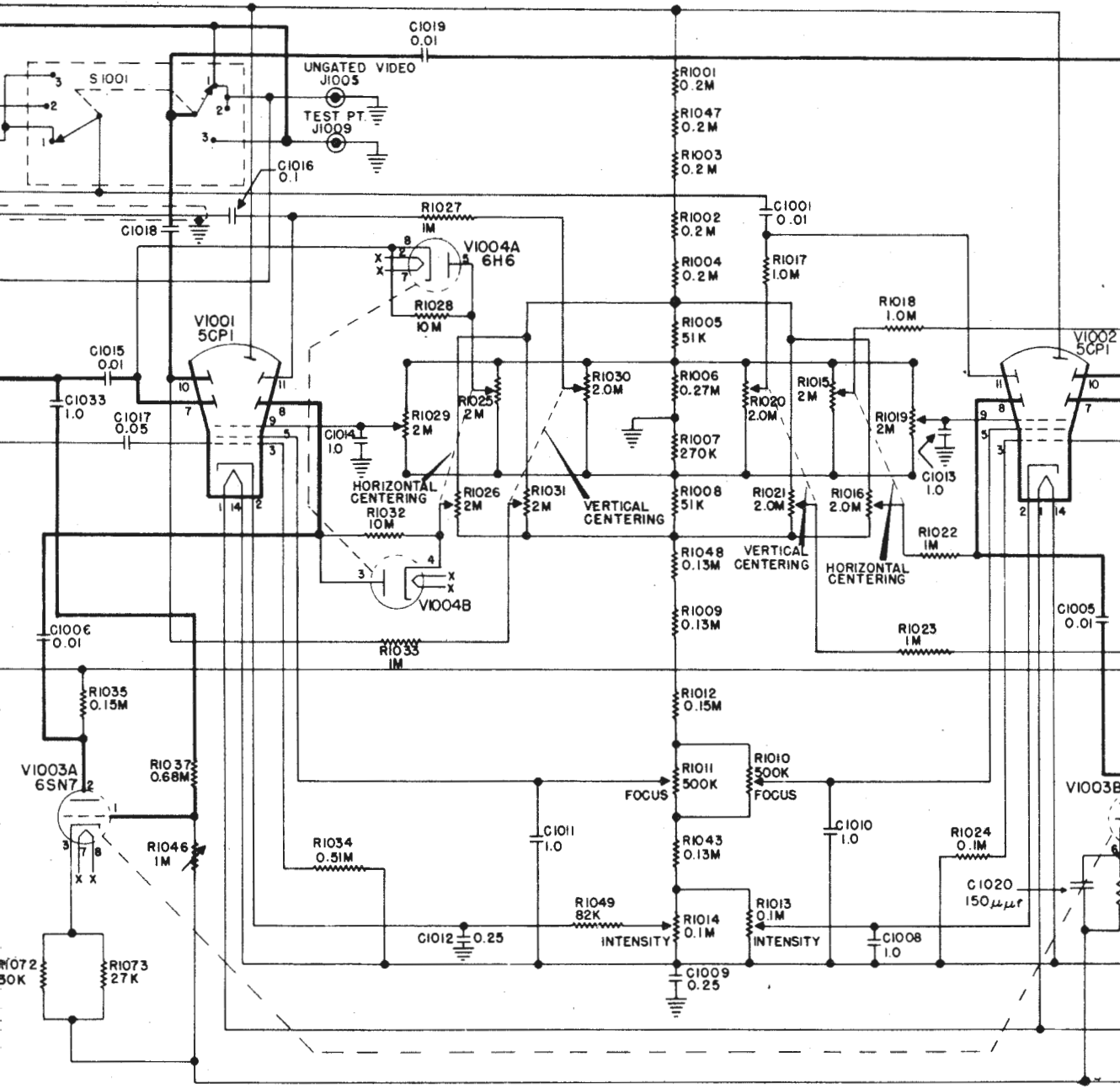
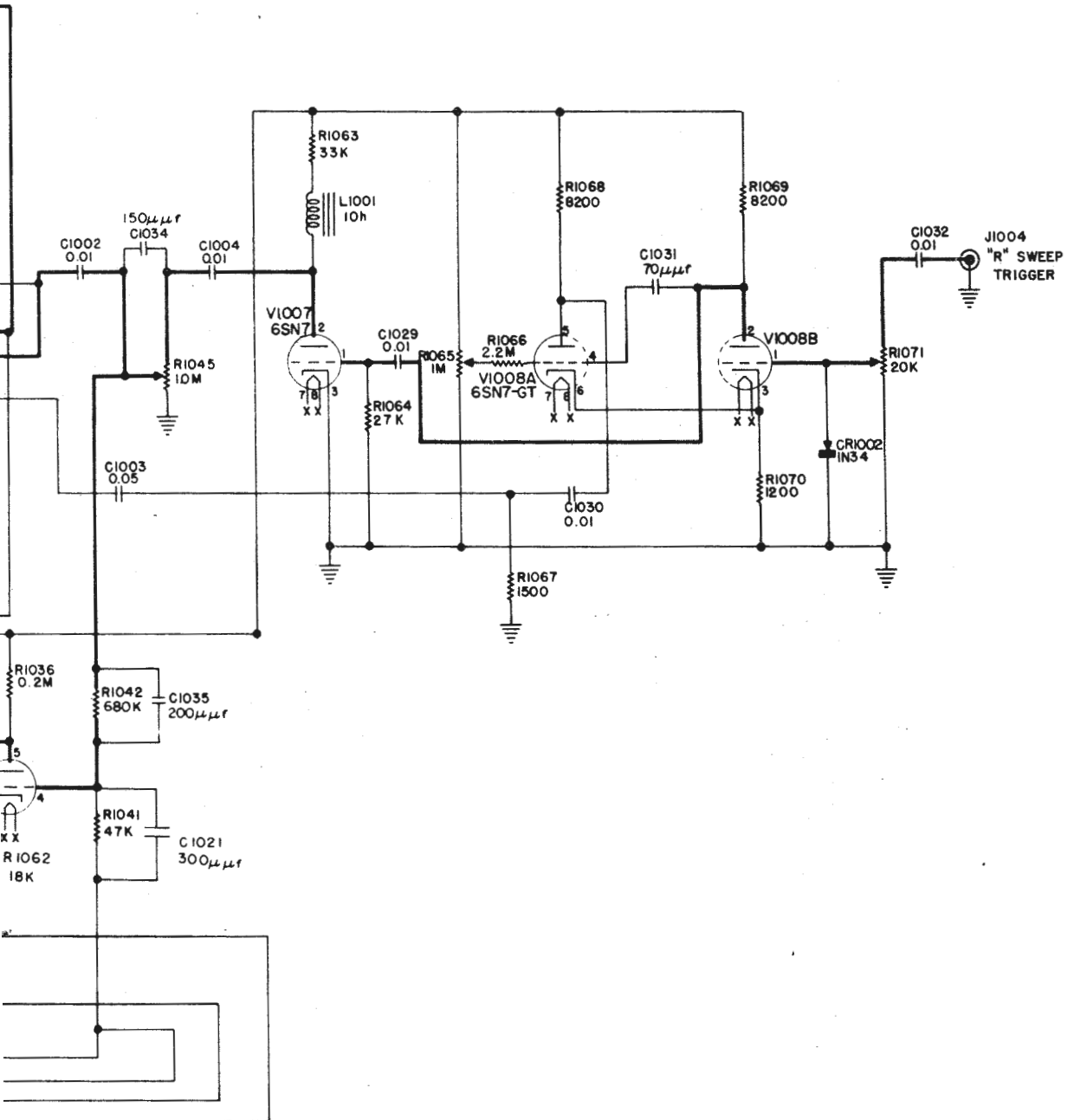


Figure 3-70. Target or Missile Indicator Unit - Schematic Diagram



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is coupled through capacitor C1006 to one horizontal deflection plate (pin 8) of the cathode-ray tube V1001. V1004B is a clamping diode which restores the d-c component of the sweep applied to pin 8 of V1001. R1032 is the load resistor of V1004B. Unblanking pulses are obtained from a tap on the plate load resistor of V1005B and are applied through C1017 to the unblanking grid of V1001. A d-c restorer diode V1004A restores the d-c component of the sweep applied to pin 7 of V1001. R1028 is the load resistor V1004A. Intensifier voltage, plus 2000 volts, is applied to V1001 and V1002 from terminal 11 of TB1001. This plus 2000 volts is also applied to the voltage divider consisting of the following series resistors: R1001, R1047, R1003, R1002, R1004, R1005, R1006 to ground. The minus 200 volts is applied to the series divider consisting of: R1013 and R1014 in parallel, R1043, R1010 and R1011 in parallel, R1012, R1009, R1048, R1008, R1007 to ground. C1009, a filter condenser, is also connected to the minus 2000 volts. Intensity potentiometers R1014 and R1013 apply negative voltage to the cathodes of V1001 and V1002 respectively. C1012 and C1008, also connected to the cathodes, are filter condensers. R1049 provides additional filtering for the cathode of V1001. R1011 and R1010 which are bypassed by C1011 and C1010 are focus potentiometers for V1001 and V1002 respectively. Vertical and horizontal centering for the two cathode ray tubes are controlled by ganged dual potentiometers. For V1002, R1020 and R1021 are the vertical centering, and R1015 and R1016 the horizontal centering potentiometers. For V1001, R1025 and R1026 are the horizontal centering, and R1030 and R1031 the vertical centering potentiometers. R1029 and R1019 are the auxiliary focus controls for V1001 and V1002 respectively.

The ungated video from the receiver is applied to J1005 through switch S1001 and capacitor C1018, to one vertical deflection plate (pin 10) of V1001. Ungated video is coupled through C1019 to one vertical deflection plate (pin 10) of V1002. The range gate is applied to J1001 and coupled through switch S1001, through C1001, to a vertical deflection plate (pin 11) of V1002. The gate is also coupled through C1016 to one vertical deflection plate (pin 11) of V1001.

2. PPI UNIT, UNIT 800

a. Introduction. - The PPI Unit, Unit 800, (plan position indicator unit) presents a polar display of targets in train and range with range presentations of 4, 20, 50, 100, and 200 miles. Both delayed and undelayed sweeps are available. The PPI unit also serves as the primary control location for the bearing and elevation

handwheels controlling the antenna mount. The PPI unit generates its own time base for various range sweeps presented on the plan position indicator scope. Range measurement in the PPI unit is independent (except for the trigger input) of that of the Target Range Unit, Unit 300, of the system. Discussion of the servo functions included in the PPI chassis will be found in the discussion of the train and elevation servo systems in this section, subsection 3-11, of the report. The local oscillator tuning, AFC on-off, and other minor control functions are also not discussed here and will be described in appropriate sections of the instruction book. The PPI unit is shown on the photograph (figure 3-71), the block diagram (figure 3-72), the gear train schematic (figure 3-73), and the schematic diagram (figure 3-74). Reference should be made to these illustrations throughout the following discussion.

As determined by the setting of the pattern switch, the PPI unit is triggered by either the A-sweep or the R-sweep trigger from the Target Range Unit, Unit 300. Video from the radar receiver is also supplied to the PPI unit. The trigger and video inputs are the only signals required for the operation of the indicator portions of the PPI unit.

b. Circuit Description. - The input circuit of the PPI unit consists of a time-base multivibrator which establishes timing control of the remainder of the indicator circuits in the unit. This multivibrator incorporates a triode V806A, and a pentode V805. (See figure 3-74.) Only the first three elements (cathode, control grid, and screen grid) of the pentode are utilized in the multivibrator itself. If these elements are considered to constitute the triode, as they do from a functional standpoint, the multivibrator circuit resembles a standard cross-connected multivibrator. Feedback is obtained directly from the triode plate to the pentode control grid through R802. A second feedback circuit is between the grid of the triode and the screen grid (effective plate) of the pentode, through any one of five capacitors. The capacitors are switched into the circuit by means of one section of the range switch S801. The capacity is selected in each range to provide the proper time constant in association with a series resistance, R801 and R809. Thus, as range is switched, the time base changes accordingly. The A-sweep trigger from the Range Unit, Unit 300T, is applied through J801 to the screen grid of the pentode, and through the range switch, capacitor C801, and one of the five time-constant-determining capacitors just mentioned to the control grid of the triode V806A. In the quiescent condition, V805 is cut off while V806A conducts heavily.

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The negative trigger upsets this condition by driving the triode V806A into cut-off which, in turn, causes V805 to carry appreciable plate and screen current. This state represents the dynamic condition which is maintained as long as V806A remains at cut-off. The R-C combination determines the duration of this condition. In the quiescent stage, the plate of the triode is at its lowest voltage while the plate of the pentode is at the supply voltage. In the dynamic stage, the plate of the triode rises to the supply voltage while the plate voltage of the pentode drops to a low value. Thus the triode delivers a square positive gate while the pentode delivers a square negative gate. This gate is the time base of the indicator portions of the PPI unit and it controls all other accompanying functions. A pentode is used as one of the vacuum tubes of the multivibrator because the negative gate is needed to drive several circuits. The plate of the pentode delivers an appreciable amount of power without loading or otherwise seriously interfering with the operation of the multivibrator. It constitutes a means of electron coupling

between the load and the multivibrator circuits. The high degree of circuit isolation thus obtained is particularly important in the shorter PPI ranges where parasitic capacities of the lead circuits tend to cause instability and otherwise unreliable operation of the multivibrator itself.

The PPI sweep generator is composed of V804A and its associated components. (See figure 3-74.) In the quiescent stage, the control grid voltage of V804A is zero or perhaps positive by a very small amount. Grid current through R866 maintains the near-zero voltage. The vacuum tube, therefore, represents a low impedance so that its plate voltage is also near-zero. The plate load resistance consists of R807, which is always in the circuit, and one of the resistors, R811 through R814, selected by means of the range switch. Note that in the minimum range of four miles only R807 is in the plate circuit.

The sweep generator tube is excited by the negative time-base pulse from the input multivibrator. This pulse cuts off the plate current

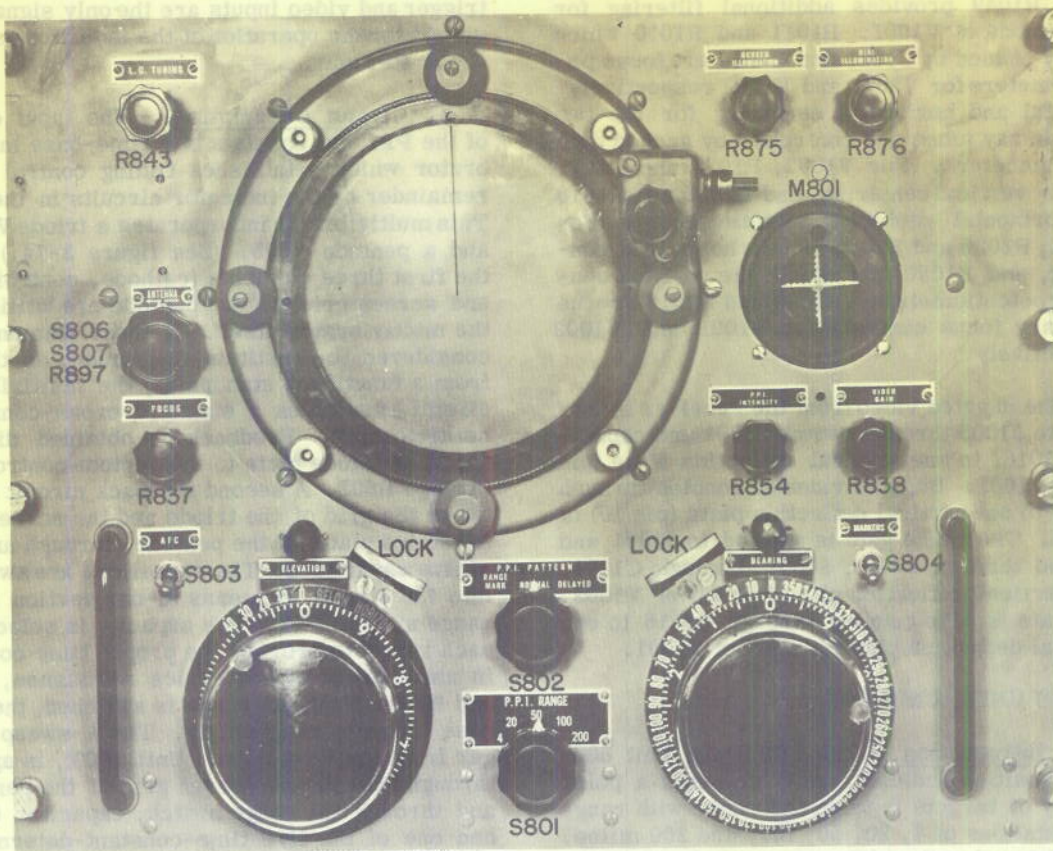


Figure 3-71. PPI Unit - Front View

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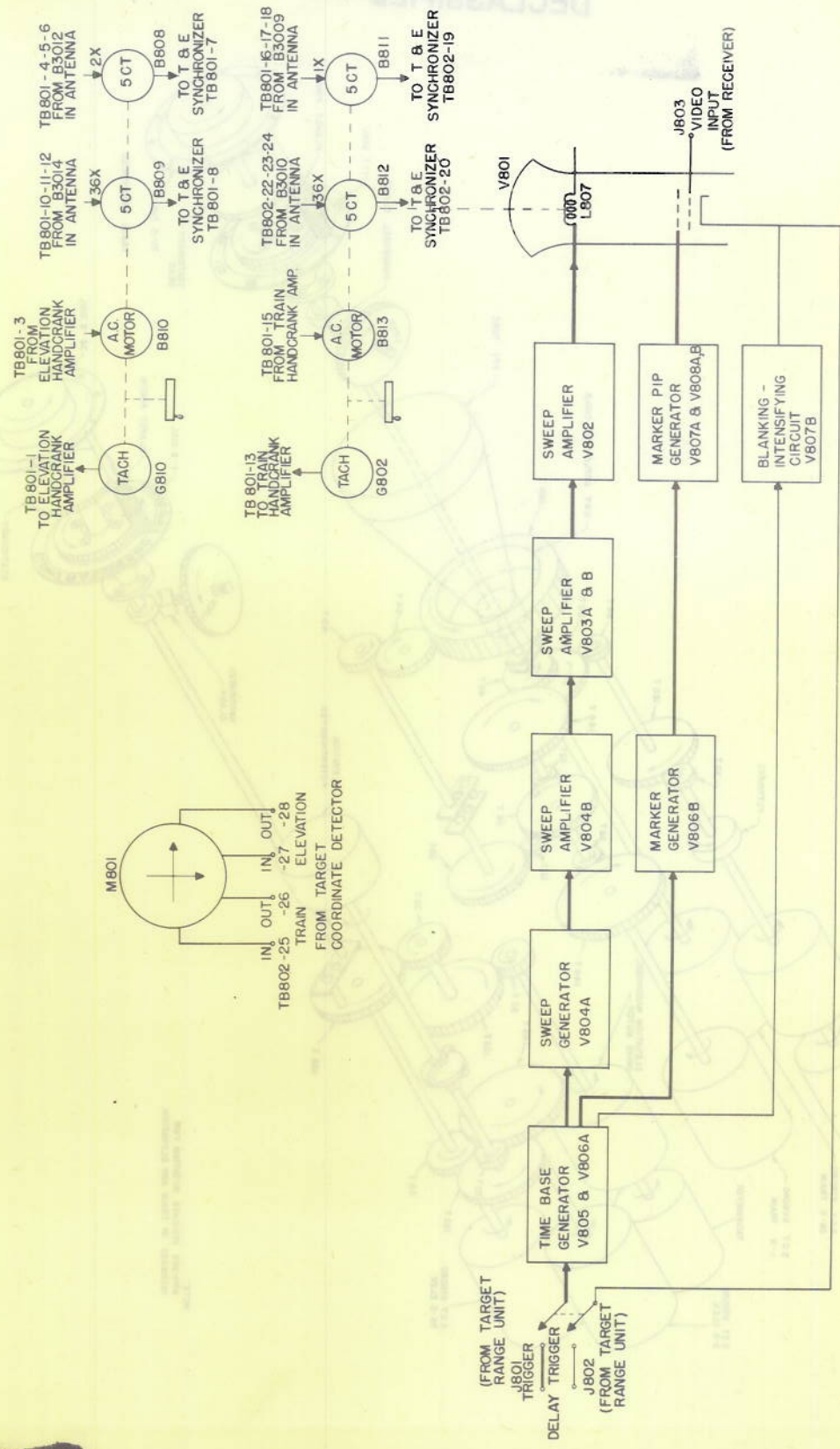


Figure 3-72. PPI Unit - Block Diagram

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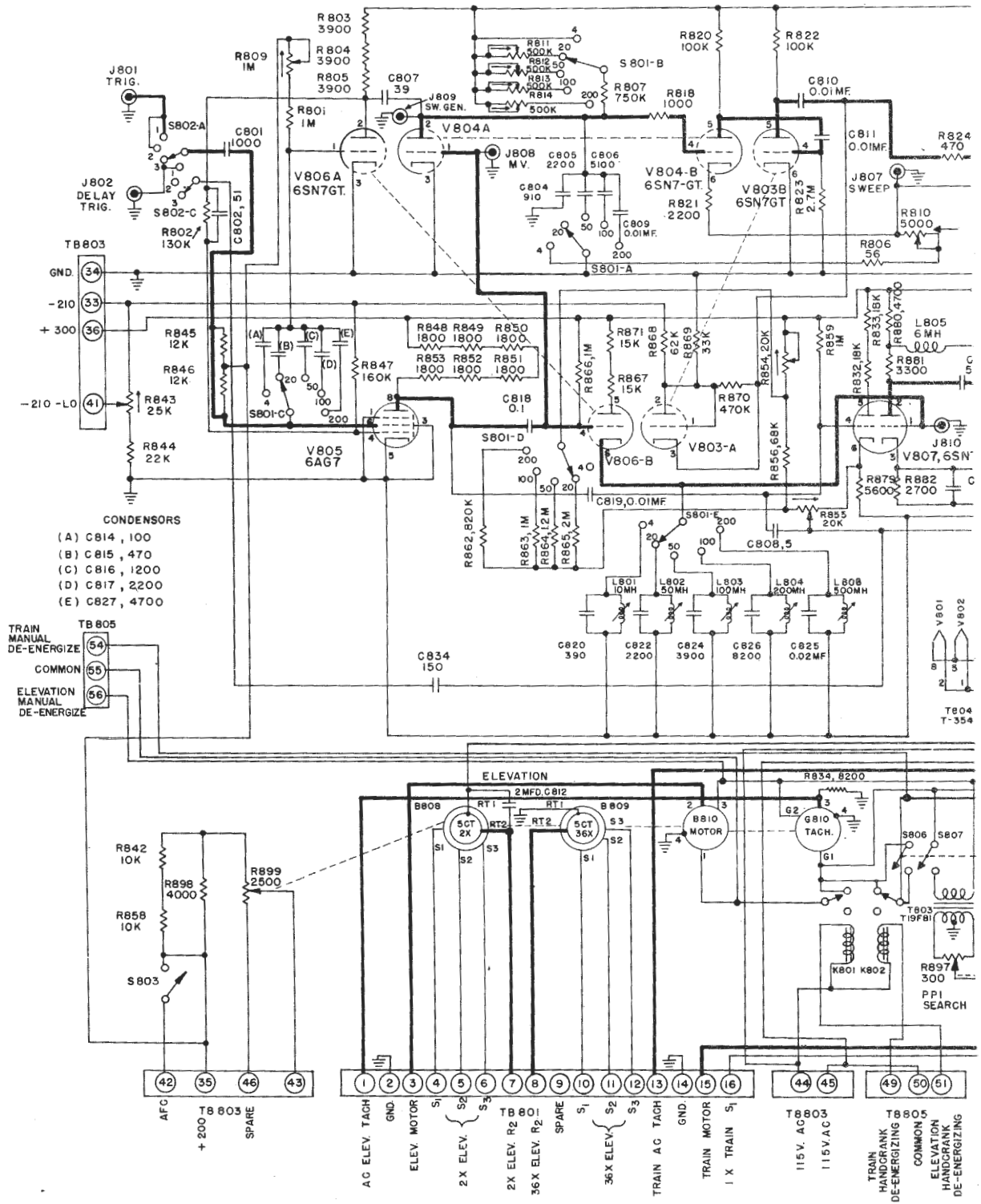
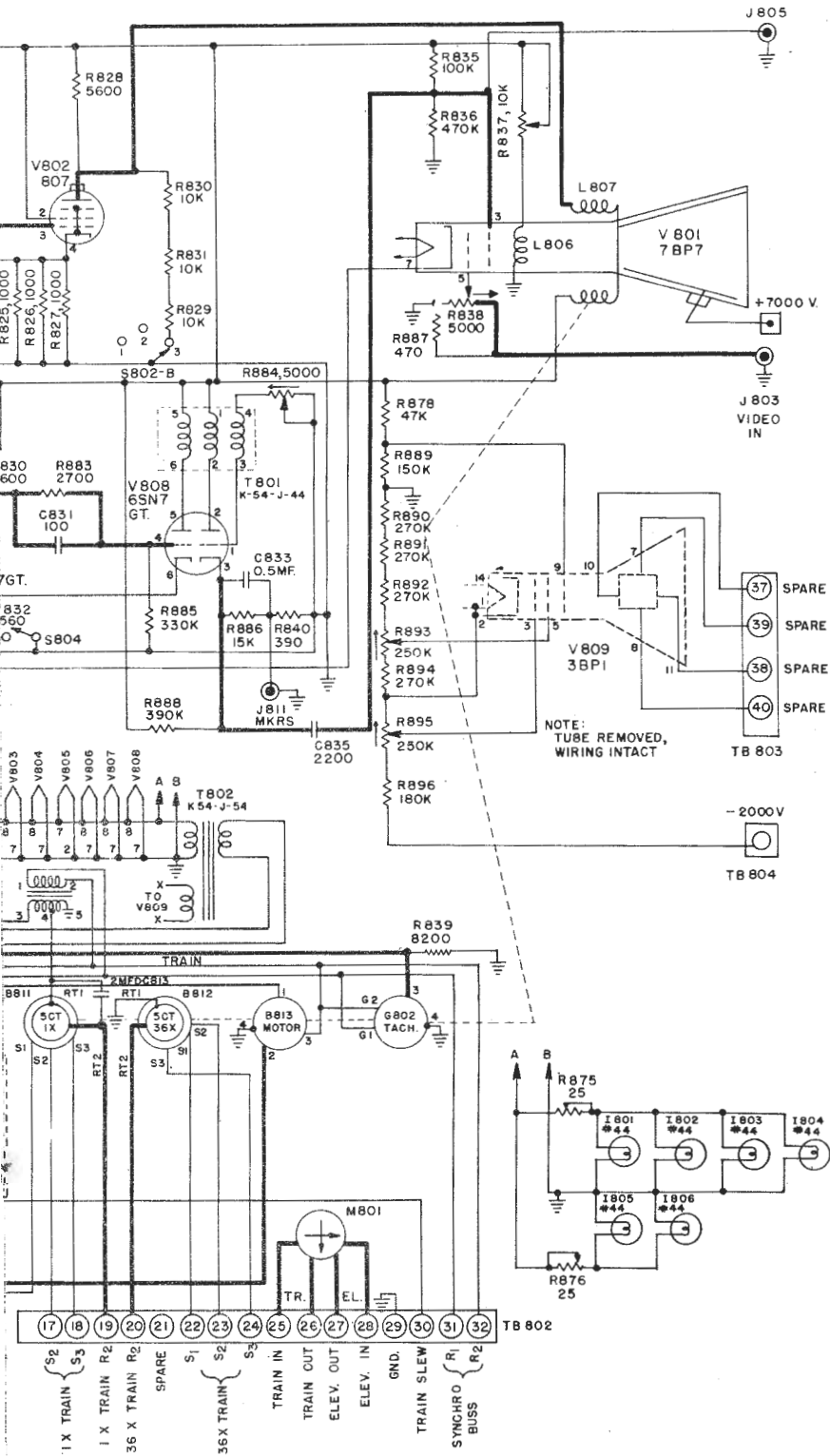


Figure 3-74. PPI Unit - Schematic Diagram



through V804A and holds it beyond cut-off for the duration of the pulse. When this happens, the plate voltage, as might be expected, rises. The rise, however, is exponential in form, because of the presence of the shunt capacity, as selected by the range switch S801-A, in the plate circuit. In the four-mile range, only C804 is present and the slope of the rising voltage is rather steep. At the same time the gate is short so that a substantially linear rise is obtained. At longer ranges, correspondingly larger capacitors (C805, C806, or C809) are shunted across C804 by means of S801A, resulting in correspondingly smaller slopes in voltage, for correspondingly longer periods of time. Thus the total voltage rise is maintained essentially equal in all ranges while the total rise is very nearly linear. Note that S801B selects separate adjustable resistors in each range above four miles so that the sweep sizes may be adjusted to be exactly equal. Since the current sweep amplifier which follows uses triode tubes feeding an inductive load, the high-frequency response is somewhat less than desired and some form of compensation is needed for the short range sweep (four miles). This equalization is accomplished by applying the positive time-base pulse, through a differentiating capacitor C807, to the plate of the sweep generator. This action produces a sharp pulse of positive voltage across the plate circuit at the beginning of the sweep, giving the sweep a very sharply defined and accurately located starting point. Without this extra "push," the sweep is delayed somewhat and does not start at zero range. Further compensation in the four-mile range is provided in the sweep amplifier itself. Compensation at the longer ranges is not necessary; in these ranges, C807 has a negligible effect.

The sweep amplifier consists of V804B and V803B; V803A serves as a clamper tube, while V802 is the output amplifier which feeds the deflection coil of V801 directly.

In the quiescent stage, V802 is cut off so that no current flows through the parallel resistors R825 through R827. The amplifier then represents a high-gain system. The (positive) sweep voltage is impressed on the grid of V804B, is amplified in V804B and V803B, and appears at the grid of V802 as a positive voltage. Because of the very high gain of the amplifier, V802 is driven into plate current conduction in an extremely short period of time. Plate current flows in R825 through R827 which then produces a degenerative voltage at the cathode of V804B. The degeneration reduces the overall gain of the three stages nearly to unity, and contributes to the linearity of the plate current of V802 and thus, in turn, improves the linearity

of the sweeps. The clamping tube V803A insures the return of the voltage at the grid of V802 to minus 70 volts at the termination of the sweep. In other words, the clamper establishes a minus 70-volt base for the excitation to V802. The clamper tube, V803A, and the degenerative feedback in this circuit are employed as a means for overcoming the variation in cut-off voltage between various type 807 tubes which might be used as replacements for the output amplifier V802. It is essential that the output tube return to cut-off between sweeps so that zero deflection is then obtained. Only in this way can the scope sweep trace be made to start at the center point on the PPI screen. The only assurance that cut-off will be obtained, regardless of tube replacement in normal variation over a period of time, is to make the voltage return to a point which exceeds the cut-off by a safe margin. The value of minus 70 volts fulfills this requirement. The difficulty with this arrangement is that time is consumed in driving the output tube into the conductive region. This time is made negligible, by providing an initial slope which is extremely steep. The degenerative feedback circuit is employed to obtain the necessary steep slope. While V802 is cut off, no feedback takes place and the gain of the preceding amplifier is very high. Since the slope of the driving voltage is very steep, plate current conduction occurs in such a short time that no practical loss of PPI range is obtained. As soon as plate current conduction starts, the feedback takes control, the gain drops, and the slope assumes a magnitude which will produce a linear sweep trace.

The switch S802B in the plate circuit of the output amplifier is a part of the pattern switch. Its purpose is to bleed a certain amount of current through a deflection coil when the pattern switch is in the delayed position. This puts a "pole" in the center of the PPI screen which serves as an unmistakable indication of the fact that the PPI presentation is delayed, that is, that the center is not zero miles as it normally is.

Range markers are generated in the PPI unit in synchronism with the other functions. The first step in this operation is the development of a sine wave. This is done in the circuit involving a group of tuned circuits together with V806B. (See figure 3-74.)

The control grid of V806B is connected directly to the control grid of V804A (sweep generator) so that it too is at zero in the quiescent stage. The plate is connected to the supply voltage through current limiting resistors R867 and R871. The cathode circuit includes any one of

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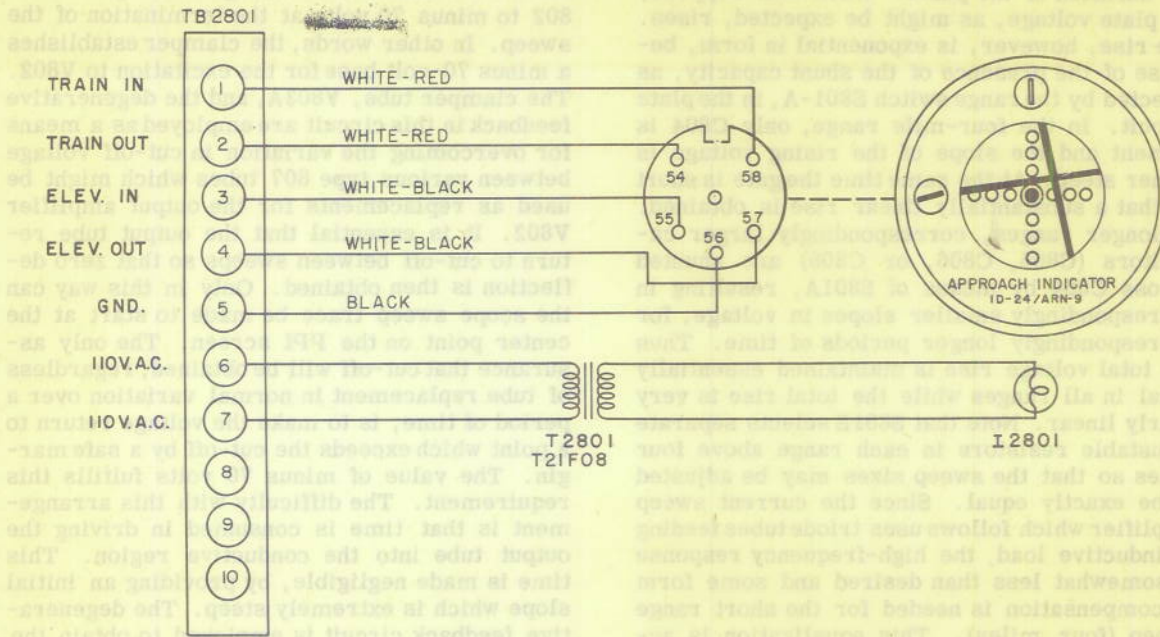


Figure 3-75. Missile Cross-pointer Meter - Schematic Diagram

five L-C circuits as determined by the setting of the range switch. Thus, in the absence of a time-base pulse, an appreciable amount of current flows through the included coils. As determined by the range switch S801, these coils are L801 through L804 and L808.

The coil current produces within the coil itself, a magnetic field in which energy is stored. When the negative time-base pulse is applied to the grid, plate current is cut off and the stored energy sets up damped oscillatory voltage across the L-C circuits. The frequency of oscillation is governed by the values of the inductance and capacitance of the circuit. When the time-base pulse is terminated, plate current flow is restored and the oscillation is suppressed.

The sinusoidal voltage is applied directly to the grid of V807A. This tube is operated so that the exciting voltage drives it from cut-off in one direction to plate current saturation in the other. This distorts the sine waves by steepening the slope and flattening the top. The succeeding stage is coupled back to the cathode of the first so that regenerative feedback is obtained. This steepens the slope even more. The plate circuit of V808B includes a blocking oscillator trans-

former T801. The steepened slope of the sine wave provides a synchronizing force on the blocking oscillator. The blocking oscillator is fired on every negative going pulse developed in V808B. It develops across R840 sharp pulses which are used as markers. The characteristics of the circuits involved are so chosen that a marker appears exactly 360 degrees after the start of the time base and, of course, each 360 degrees thereafter. (The "360 degrees" refers to the sine-wave frequency of the marker oscillator, V806B.)

The frequencies of the marker circuits are as follows:

Range	Marker Frequency	Marker Mileage
4 miles	81.95 kc	1
20 miles	16.39 kc	5
50 miles	8.195 kc	10
100 miles	4.097 kc	20
200 miles	1.639 kc	50

The PPI tube V801 is intensified in cathode, grid, and first anode circuits. Video signals are applied to the grid and markers, which are obtained from circuits described above, to the first anode. The cyclic intensifying of the PPI

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tube is done in the cathode circuit. A triode tube, V807B, is used to develop the intensifying voltage. The negative time-base pulse from the time-base multivibrator is applied to the control grid of V807B and drives it from zero to cut-off. The accompanying change in cathode voltage is used to intensify the cathode-ray tube. Potentiometers R855 and R854, make possible the adjustment of brightness over a convenient range. R855 is located on the chassis of the PPI unit. Its purpose is to select a mean value of intensifying voltage to suit whatever cathode ray tube is in use. R854, located at the control panel, is the operator's control. In order to keep the brightness constant with change in range (a change in range is accompanied by a change of percentage time intensified), fixed resistors R862 through R865 are shunted across R856 which is in series with the adjustment potentiometers by means of the range switch. The values of these resistors were selected to provide a presentation of equal brilliance in all ranges. When the pattern switch S802C is in the "range mark" position, the ranging notch is also applied to the cathode of the cathode-ray tube through C834. The notch is differentiated by C834 in the resistor network between cathode and ground. The trailing edge of the notch provides a positive pip which brightens the trace and provides a range mark which very nearly coincides the range indicated on the Target Range Unit, Unit 300. Actually, the marker follows the trailing edge of the notch so that it is an approximate indication of range only. This approximation is particularly noticeable when the shorter PPI ranges are employed.

The PPI unit of the original SP-1M system used a spot-scope presentation of train and elevation errors. The cathode-ray oscilloscope tube V809 used in this presentation has been removed from the PPI unit and its function is now performed by the cross-pointer meter M801. (See the note on figure 3-74: "TUBE REMOVED, WIRING INTACT.") The wiring associated with the spot-scope indicator V809 has been left intact in the PPI unit. The cross-pointer meter M801, located on the front panel of the PPI unit, gives a visual indication of the train and elevation errors of either the target or missile channel (depending upon which channel is controlling the radar antenna).

3. THE MISSILE CROSS-POINTER METER, UNIT 2800

The Missile Cross-pointer Meter, Unit 2800, is mounted on top of the control console. The unit serves as a monitor giving a visual indication of the train and elevation error signals of the channel, either target or missile, which is not controlling the radar antenna at the given time. The unit consists of a cross-pointer meter, an illuminating lamp (I2801), and a step-down transformer (T2801) which serves as a supply source for the illuminating lamp. The unit is shown schematically on figure 3-75.

4. REMOTE RANGE INDICATOR, UNIT 8500

For a discussion of the Remote Range Indicator, Unit 8500, refer to this section, subsection 3-6, on the data recording equipment.

Subsection 3-5. Mechanical Design of Antenna and Trailers

1. ANTENNA UNIT, UNIT 3000

a. General. - The Antenna Unit, Unit 3000, consists principally of the antenna mount, the nutator assembly, and the radar reflector. Figure 3-76 is a block diagram of the antenna unit. A schematic diagram of the antenna unit and synchro capacitor unit is provided in Figure 3-77. The unit as a whole is mounted on an elevator platform. Discussion of the electrical circuits of the unit will be found in this section, subsection 3-11, on the train and elevation servo drive systems.

b. Antenna Mount.

1). Introduction. - The Lark SP-1M antenna mount supports the radar reflector of the an-

tenna assembly and positions it in train and elevation. (See figures 3-78, 3-79, and 3-80.) The mount is the same as that used on the standard SP-1M radar installations except for the minor modifications described below.

2). Specifications. - The major performance specifications for the antenna mount are included as a part of the servo drive system specifications, and are discussed in this section, subsection 3-11. The following additional requirements should be met by the mount:

a). The mount shall attain a maximum velocity of at least 50 degrees per second in train and 25 degrees per second in elevation. The large train velocity is required for rapid slewing to acquire a target.

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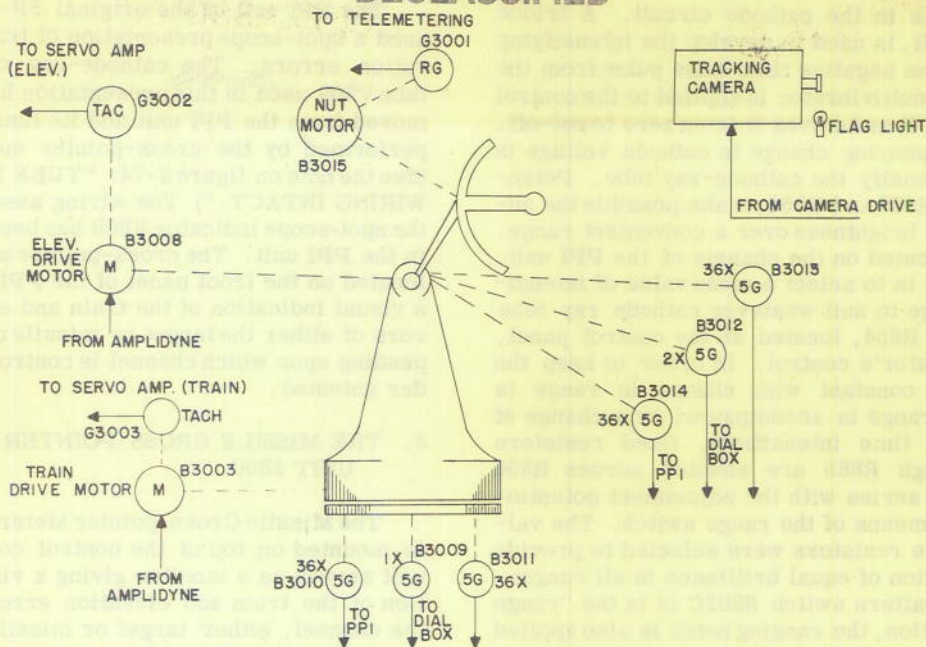


Figure 3-76. Antenna Unit - Block Diagram

b). The mount shall be able to accelerate at a rate of 80 degrees per second² about both axes.

c). The mount power drives shall be capable of continued operation at design velocities and accelerations without developing excessive play or other mechanical failure.

d). The static unbalance of the mount about the elevation axis shall not exceed 50 pound-feet.

e). The mount shall furnish a d-c tachometer voltage output for both axes.

f). No mechanical resonance shall occur at a frequency below 200 radians per second.

3). Design Considerations. - An analysis of a standard SP-1M antenna mount (serial 77) was made to verify its compliance with specifications a) through d). The results are given below.

a). The mount will attain a 50-degree-per-second velocity in train at 3935 rpm of the motor. This is 14 per cent above the motor's rated speed, but satisfactory operation is expected. At the same speed of the elevation drive motor, the mount will elevate at 22 degrees per

second. This is slightly below the specification requirement, but it was decided that the effort required to change the mount to meet specifications would be excessive.

b). On the basis of the measured inertias of the mount, motor, and gear trains, the mount will accelerate in train at 29 degrees per second² with rated motor current, or at 82 degrees per second² with 285 per cent rated motor current. The latter figure is approximately the maximum which the amplidyne generator will deliver. The accelerations about the elevation axis will be 19 degrees per second² and 56 degrees per second² for rated current and for 285 per cent rated current, respectively.

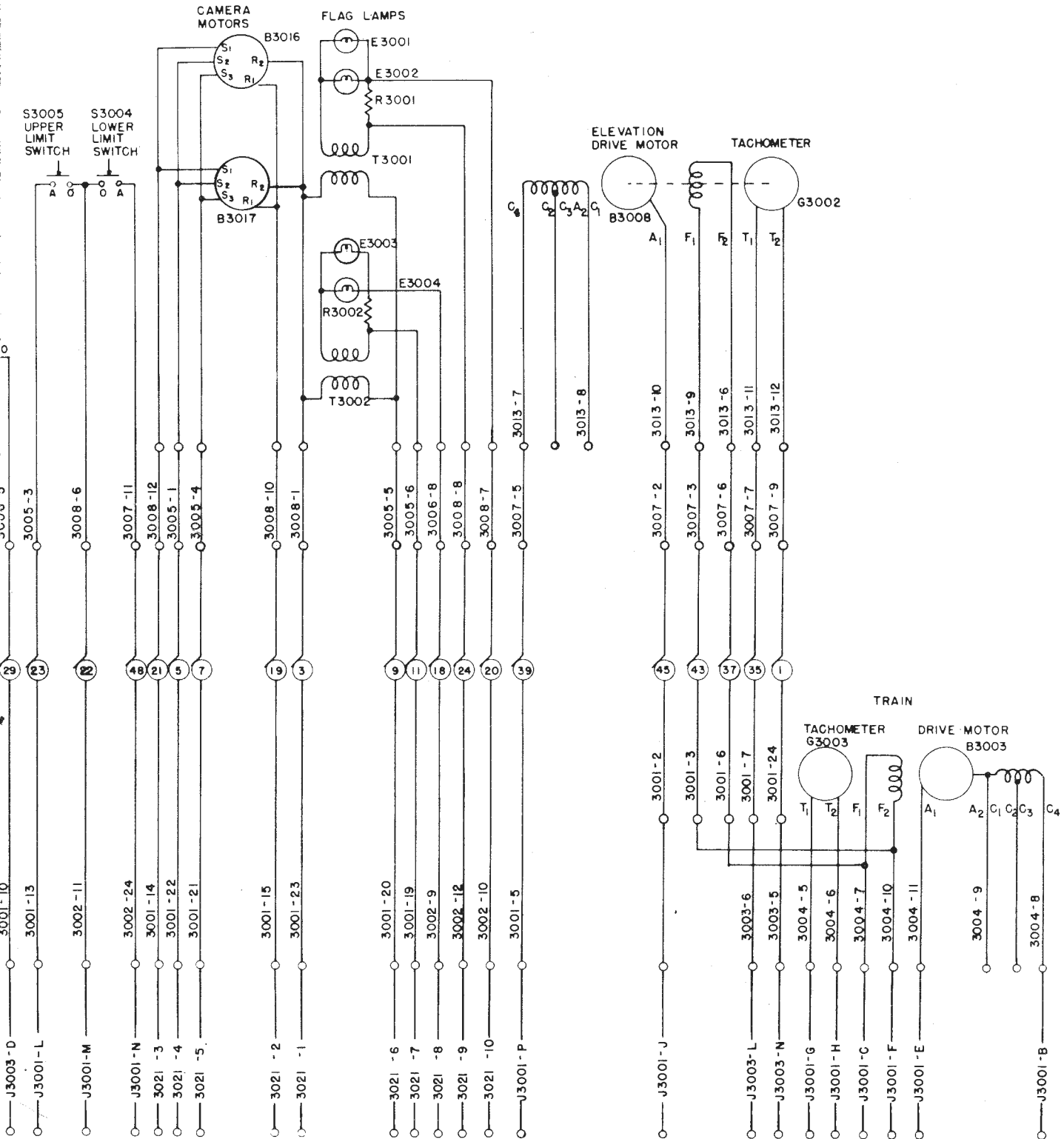
c). The power drives were considered sufficiently rugged to give continued service when driven by the motors in the mount.

d). The static unbalance of the mount about the elevation axis amounted to about 300 pound-feet.

e). No objectionable mechanical resonances were observed in the mount structure.

The mount was statically balanced about the elevation axis, using trial and error methods. (See figure 3-81.) Since the tracking cam-

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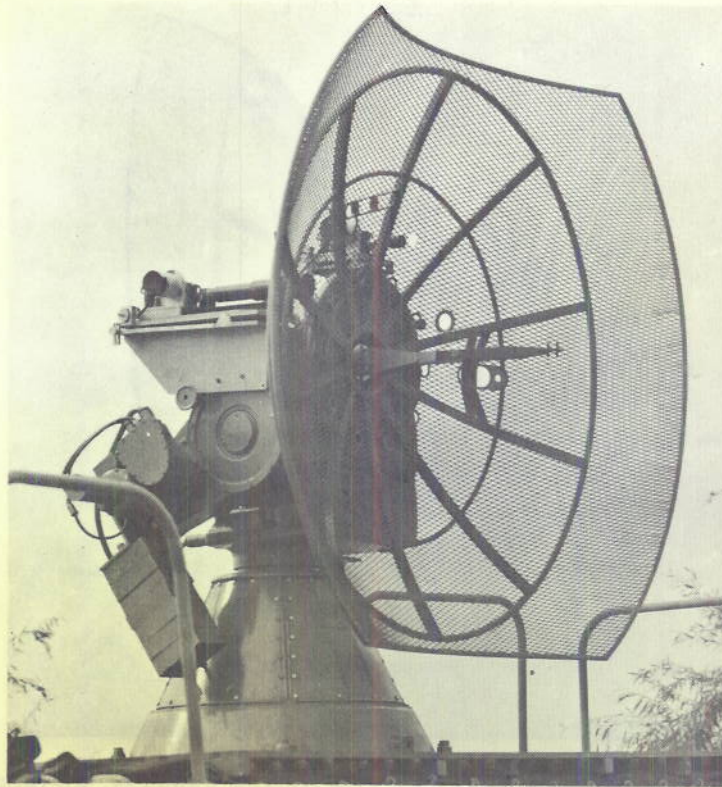


Figure 3-78. Antenna Unit - Front Oblique View Showing Camera

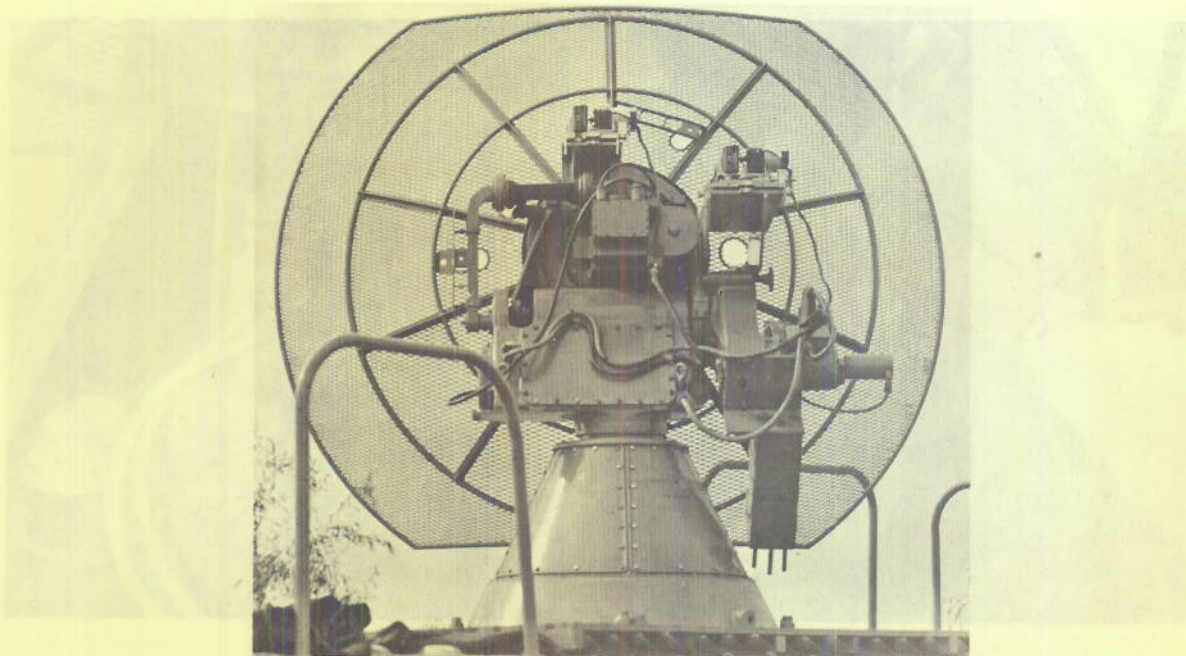


Figure 3-79. Antenna Unit - Rear View Including Cameras, Waveguide, and Pedestal



Figure 3-80. Antenna Unit - Left Side View Showing Cameras, Elevation Motors, Counterbalance, and Pedestal

Figure 3-80. Antenna Unit - Left Side View Showing Cameras, Elevation Motors, Counterbalance, and Pedestal

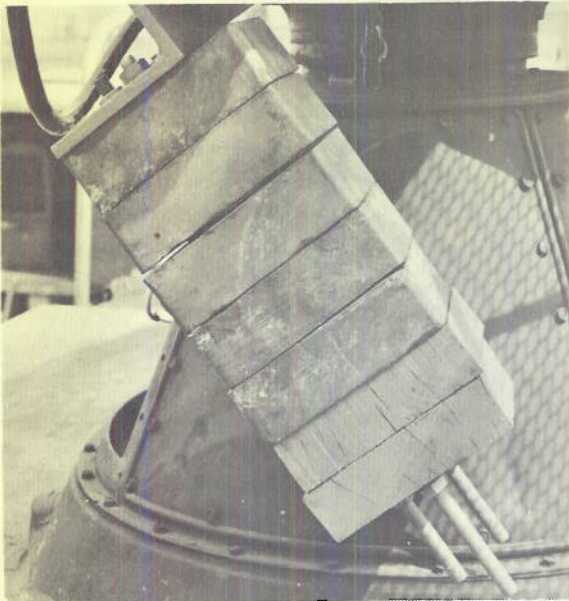


Figure 3-81. Details of Counterweight for Antenna



Figure 3-82. Antenna Train Motor and Tachometer in Pedestal

...and mounts introduce moments of the order of 100 pound-feet, torsionless counterweights are provided to balance these beams. Since the CR gear against direct-current generators are installed to furnish the required d-c tachometer voltage. In order to couple the generator to the motor shaft by means of gears, the gear train is designed to furnish the required gear ratio.

...limit stop in the mount, the antenna dipole must remain in a vertical position while moving in a circular path with respect to the parabolic reflector. One way of obtaining this relative motion is by an

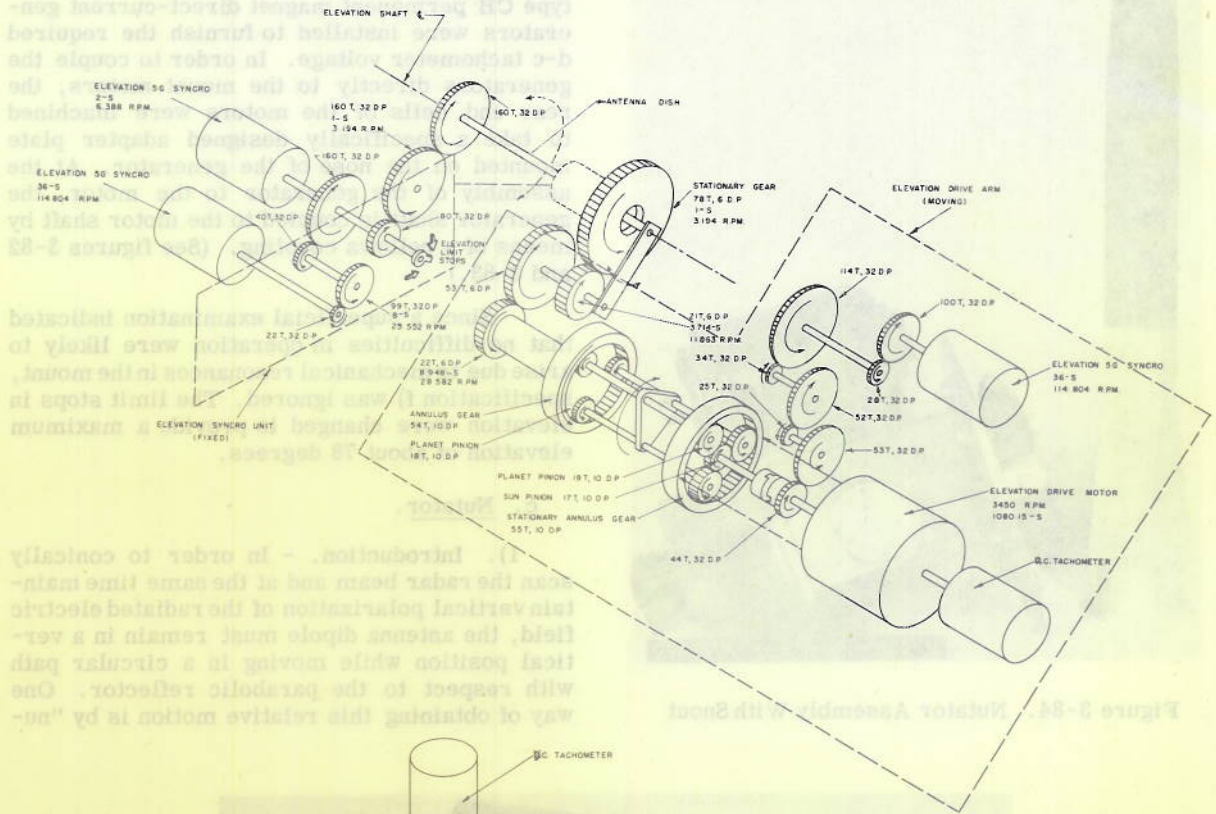
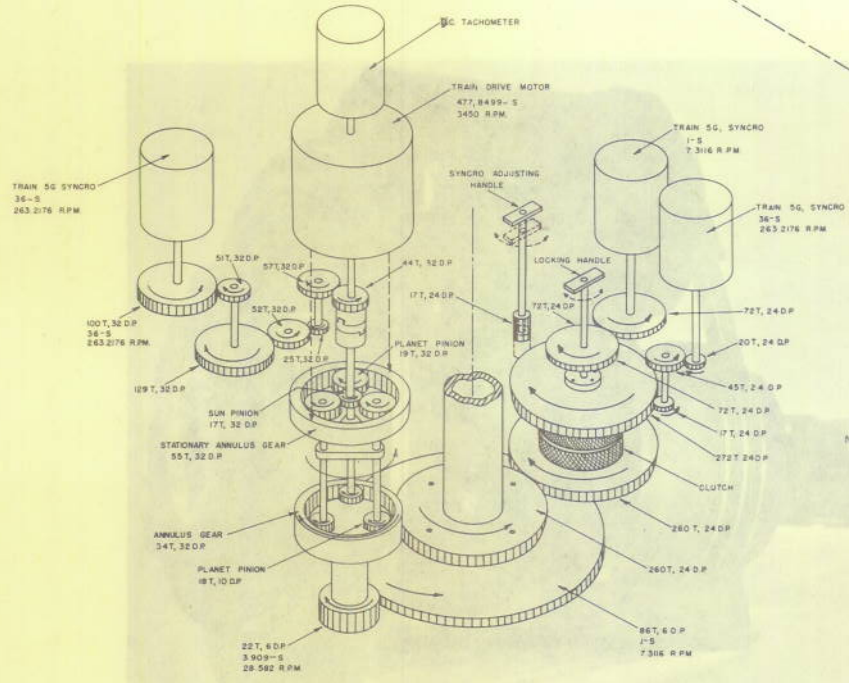


Figure 3-84. Antenna Assembly Gear Train



NOTE
ARROWS SHOW DIRECTION OF ROTATION FOR COUNTER CLOCKWISE ROTATION IN TRAIN AS VIEWED FROM THE TOP OF THE MOUNT AND FOR DEPRESSING THE ANTENNA IN ELEVATION

Figure 3-83. Antenna Gear Train and Synchros

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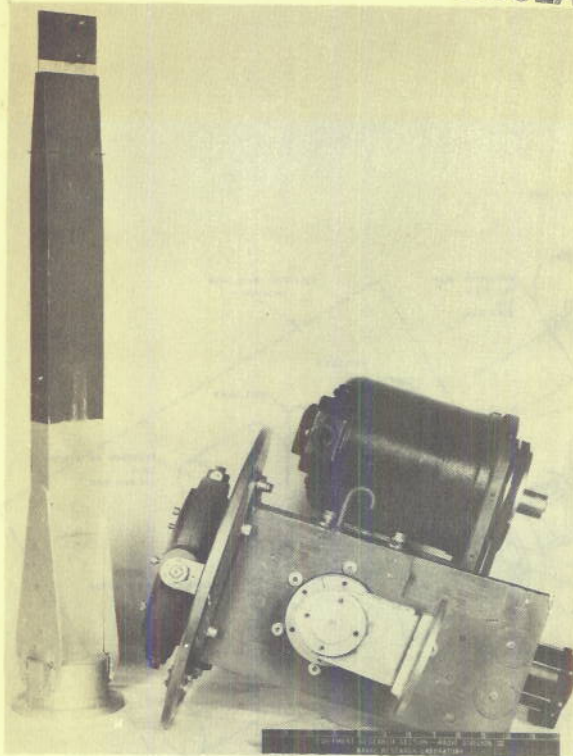


Figure 3-84. Nutator Assembly With Snout

eras and mounts introduce moments of the order of 100 pound-feet, removable counterweights are provided to balance these items. Elinco type CB permanent magnet direct-current generators were installed to furnish the required d-c tachometer voltage. In order to couple the generators directly to the mount motors, the rear end bells of the motors were machined to take a specifically designed adapter plate mounted on the nose of the generator. At the assembly of the generator to the motor, the generator shaft is coupled to the motor shaft by means of a bellows coupling. (See figures 3-82 and 3-83.)

Since a superficial examination indicated that no difficulties in operation were likely to arise due to mechanical resonances in the mount, specification f) was ignored. The limit stops in elevation were changed to provide a maximum elevation of about 78 degrees.

c. Nutator.

1). Introduction. - In order to conically scan the radar beam and at the same time maintain vertical polarization of the radiated electric field, the antenna dipole must remain in a vertical position while moving in a circular path with respect to the parabolic reflector. One way of obtaining this relative motion is by "nu-

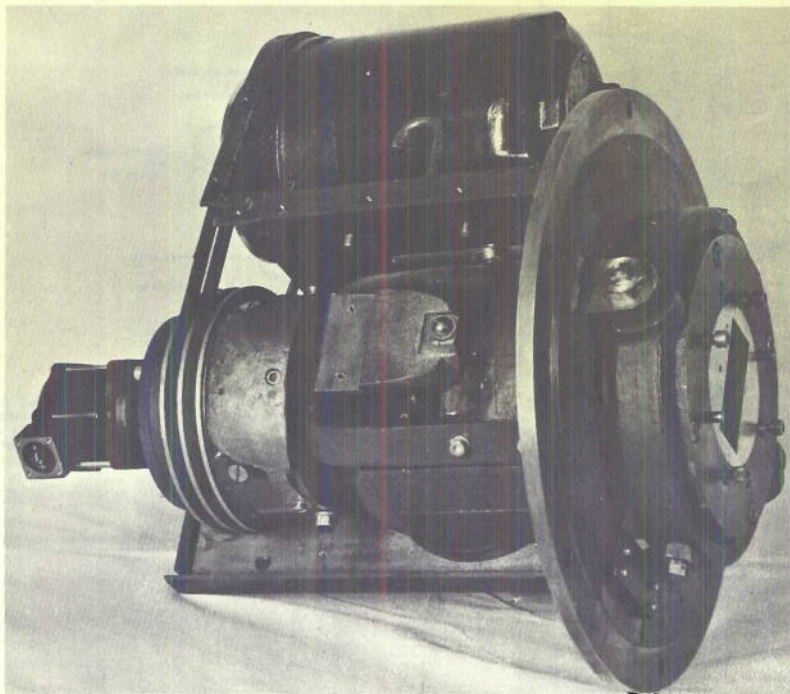


Figure 3-85. Nutator Assembly Without Snout

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tating" the waveguide feed. For this purpose the antenna unit includes a nutator assembly. (See figures 3-84 through 3-87.)

2). Specifications. - The nutator is required to meet the following specifications:

- a). Produce a two-way radiation pattern which will be three db down at crossover.
- b). The beam shall be vertically polarized.
- c). The mechanism must scan at a constant speed of 24 cycles per second, ± 0.1 cy-

cle, based on a 60-cycle power line frequency.

d). The mechanism must give trouble-free performance for a period in excess of 2000 hours of operation.

3). Design Considerations. - The scanner assembly (nutator) from the SCR-615B radar equipment was selected for modification as the best available S-band antenna assembly. Proper polarization was obtained by mounting the nutator assembly in a position rotated 90 degrees from its designed orientation. The scan frequency was raised to 24 cycles from the original

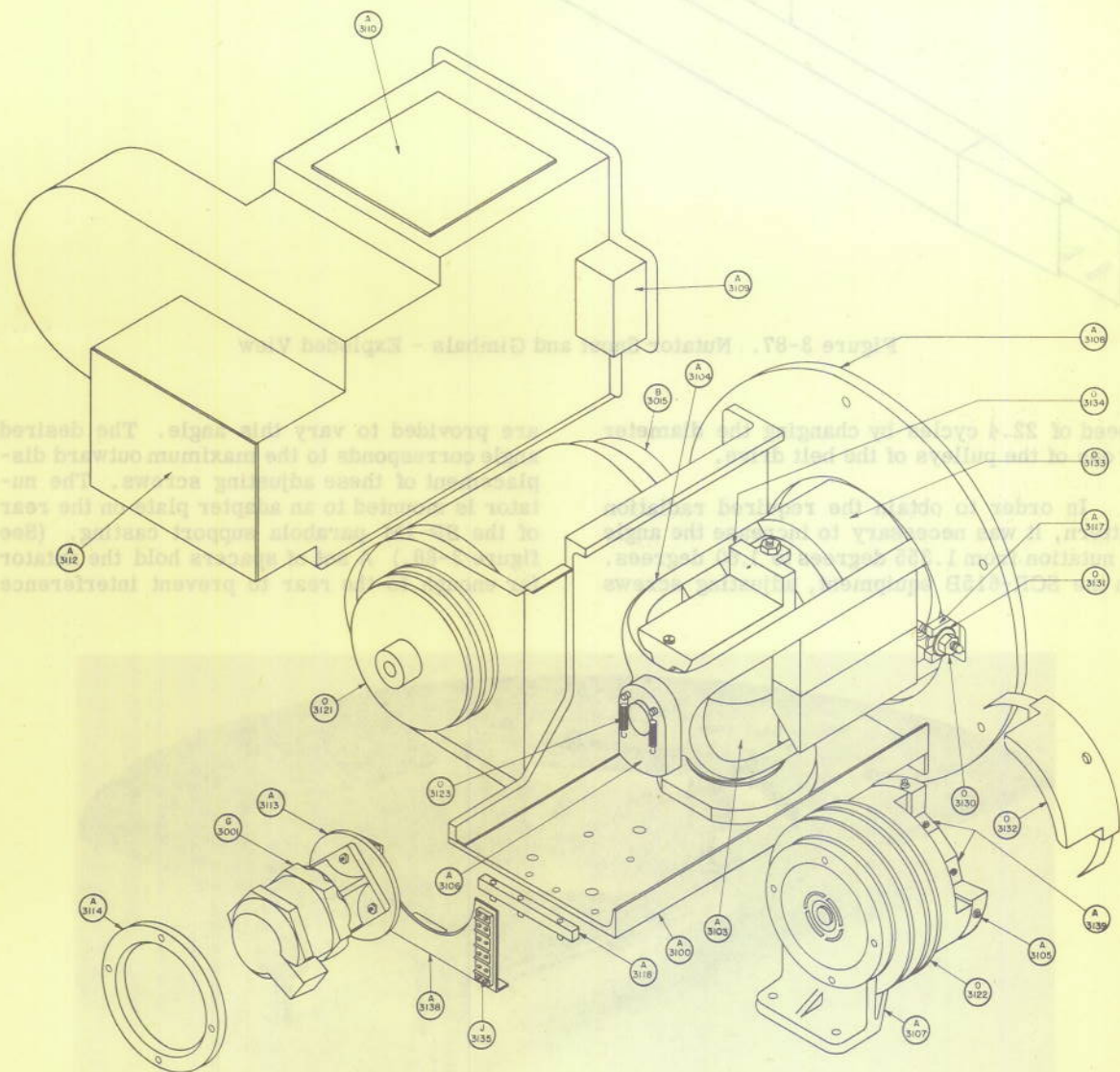


Figure 3-86. Nutator Disassembly for Belt Replacement

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cle, based on a 60-cycle power line frequency.
 (d) The mechanism must give trouble-free performance for a period in excess of 2000 hours of operation.

3) Design Considerations - The scanner assembly (nutator) from the SCR-615B radar equipment was selected for modification as the best available S-band antenna assembly. Proper polarization was obtained by mounting the nutator assembly in a position rotated 90 degrees from its design orientation. The scan frequency was raised to 24 cycles from the original

lating the waveguide lead. For this purpose the antenna will include a nutator assembly. (See figures 3-87 through 3-89.)
 (a) The nutator is a circular component which will be mounted on the scanner assembly. The beam position is determined by the nutator's rotation. (b) The beam position is determined by the nutator's rotation. (c) The mechanism must give trouble-free performance for a period in excess of 2000 hours of operation. (d) The mechanism must give trouble-free performance for a period in excess of 2000 hours of operation.

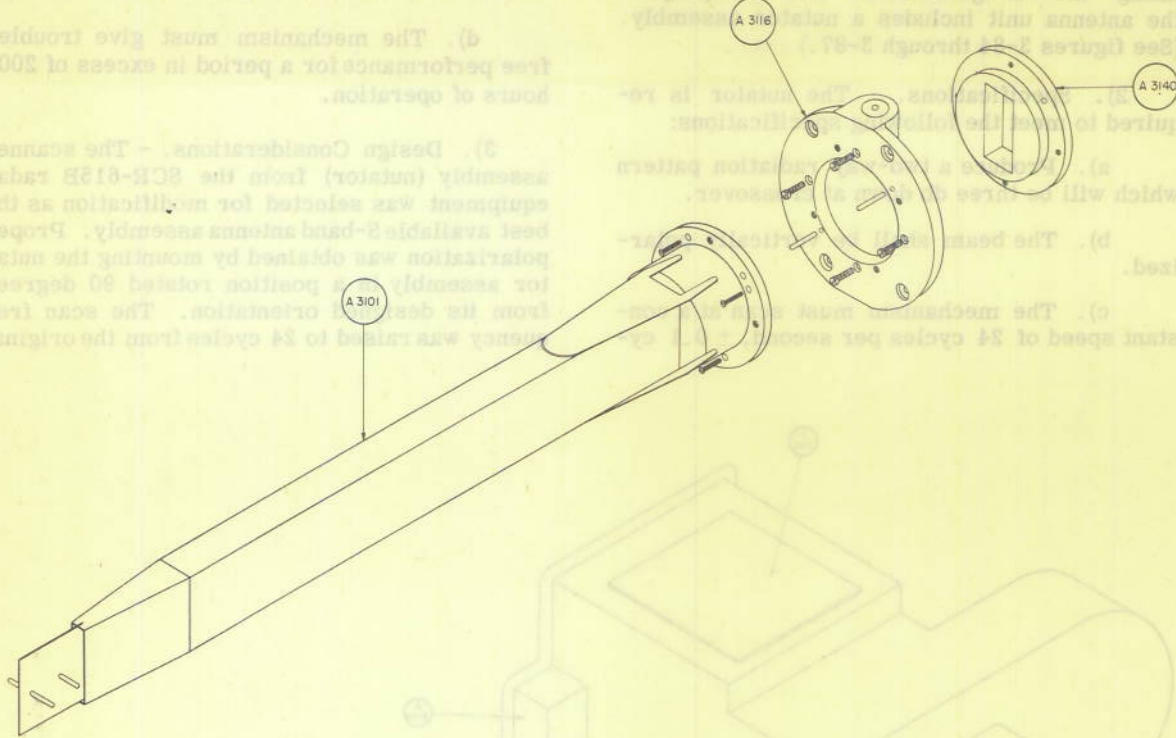


Figure 3-87. Nutator Snout and Gimbals - Exploded View

speed of 22.4 cycles by changing the diameter of one of the pulleys of the belt drive.

In order to obtain the required radiation pattern, it was necessary to increase the angle of nutation from 1.355 degrees to 1.60 degrees. On the SCR-615B equipment, adjusting screws

are provided to vary this angle. The desired angle corresponds to the maximum outward displacement of these adjusting screws. The nutator is mounted to an adapter plate on the rear of the SP-1M parabola support casting. (See figure 3-88.) A set of spacers hold the nutator far enough to the rear to prevent interference



Figure 3-88. Dural Mounting Plate for Nutator Motor (Back of Antenna)

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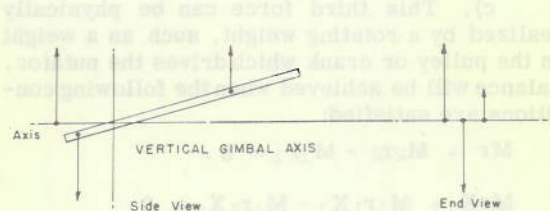
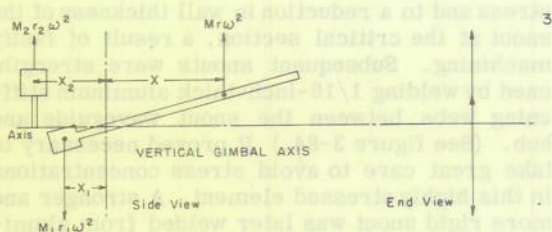
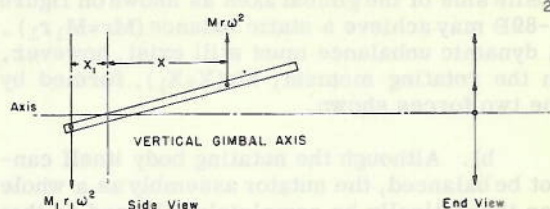
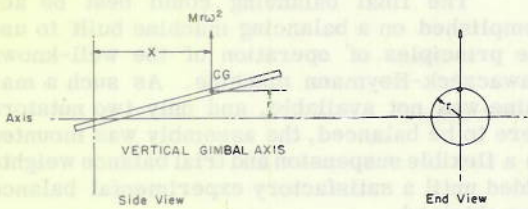


Figure 3-89. Nutator Balancing

between the nutator gimbals ring and the parabola support casting. With the nutator mounted in this position, it was necessary to make an adapter which increased the length of the waveguide snout in order to place the dipole at the focus of the parabola reflector. (See figure 3-87.)

The changes in nutating angle and in the length of the nutator snout result in a dynamic and static unbalance and in an increase of approximately 90 per cent in snout bending stress. The balancing of the nutator is described in the following subparagraph.

4). Nutator Balancing. - The balancing of a nutator is a problem slightly different from the usual balancing of a rotating body since it is characteristic of a nutating body that any point on the body moves in a circle of diameter proportional to the distance, X, of the point from the gimbals axes, and lying in a plane perpendicular to the axis. (See figure 3-89A.)

a). A nutating waveguide snout would, in general, have a rotating unbalance force of magnitude F, given by $F = \int_0^l P\omega^2 m dx$, where ω is the angular velocity of nutation, m is the mass of the snout per unit length, P is the radius of

the circle in which an element of snout moves, and l is the total length of the snout. x is measured from the gimbals axis along the nutation axis. In order to simplify the following expressions, m will be assumed constant. The analysis procedure is general, however.

Letting θ be the angle of nutation, the rotating force will be given by

$$F = \omega^2 m \sin \theta \int_0^l x dx = \frac{\omega^2 m \sin \theta l^2}{2}$$

or, letting the total mass of the snout be given by M, and noting that $M = ml$,

$$F = \frac{\omega^2 M l \sin \theta}{2}$$

It can be shown that this distributed force may be replaced by a concentrated force acting at $\frac{2l}{3}$. This is shown schematically on figure 3-89A, where

$$r = \frac{l \sin \theta}{2}, \text{ and } X = \frac{2l}{3}.$$

It can be seen from figure 3-89B that it is impossible to completely balance a nutating body itself. The addition of a weight M_1 on the op-

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posite side of the gimbal axes as shown on figure 3-89B may achieve a static balance ($Mr=M_1r_1$). A dynamic unbalance must still exist, however, in the rotating moment, $Mr(X+X_1)$, formed by the two forces shown.

b). Although the nutating body itself cannot be balanced, the nutator assembly as a whole can theoretically be completely balanced so that it will transmit no vibrations to the antenna mount. This balance is achieved by adding a third rotating force to the system as shown in figure 3-89C.

c). This third force can be physically realized by a rotating weight, such as a weight on the pulley or crank which drives the nutator. Balance will be achieved when the following conditions are satisfied:

$$Mr + M_2r_2 - M_1r_1 = 0,$$

$$MrX + M_1r_1X_1 - M_2r_2X_2 = 0.$$

In an actual nutator, X_1 should be short compared to X , in order to keep the size of the equipment within reasonable bounds. This means that r_1 will be very small and not possible to control. M_1 will therefore be very large. M_1 , M_2 , and r_2 are then the quantities which may be varied to balance the nutator. It must be remembered that the forces discussed here are all rotating vectors whose positions are shown as of one instant in these figures. The phases of M and M_1 (any mass on the nutating element) are fixed, but the centers of gravity of the two should both lie on the line passing through the intersection of the gimbal axes in order to avoid the situation shown in figure 3-89D.

d). Care must of course be taken to locate M_2 in such a position that the force $M_2r_2\omega^2$ will be in phase with $Mr\omega^2$.

The final balancing could best be accomplished on a balancing machine built to use the principles of operation of the well-known Lawaczeck-Heymann machine. As such a machine was not available, and only two nutators were to be balanced, the assembly was mounted on a flexible suspension and trial balance weights added until a satisfactory experimental balance was obtained.

5). Performance. - The snout of the first modified nutator broke off after about 50 hours of operation. This early fatigue failure was due to the above-mentioned increase in bending stress and to a reduction in wall thickness of the snout at the critical section, a result of faulty machining. Subsequent snouts were strengthened by welding 1/16-inch-thick aluminum stiffening webs between the snout waveguide and hub. (See figure 3-84.) It proved necessary to take great care to avoid stress concentrations in this highly stressed element. A stronger and more rigid snout was later welded from aluminum sheet. (See figure 3-90.)

A new sheet metal housing was constructed to provide weather protection for the nutator mechanism. The nutator snout protrudes through a flexible rubber boot which covers the opening between the spider and reflector.

6). Nutator Maintenance. - Troubles in maintaining the SP-1M nutator will occur when there is insufficient clearance between (a) the outer gimbal ring and the adapter plate, or (b) the eccentric frame counterweight and the internal waveguide. Both troubles are accompanied by a chattering noise, once the nutator is rotating at scan frequency.

The first interference can be observed if the nutator is viewed from the front of the dish

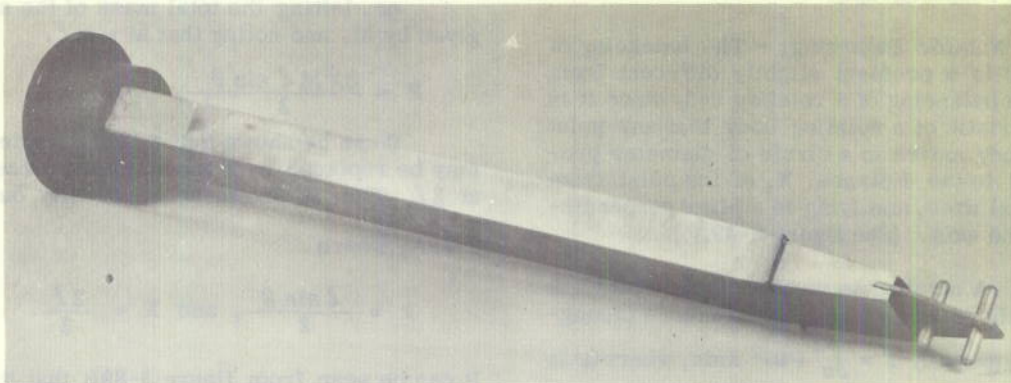


Figure 3-90. Nutator Snout With Tapered Walls

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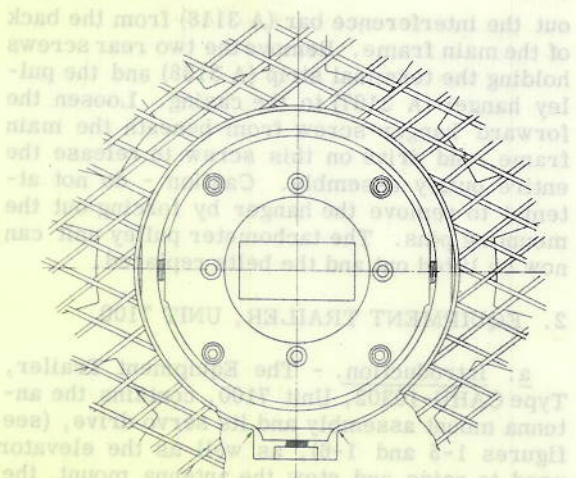


Figure 3-91. Nutator Interference Diagram

(figure 3-91). The difficulty is corrected by loosening the bolts holding the assembly to the adapter plate, and retightening them after the nutator has been raised to its correct position by use of a block and tackle.

Unless interference between the gimbal ring and plate is visible, unfasten the screws holding the internal waveguide (A 3103) to the main frame (A 3100) (see figures 3-86 and 3-92). If, at this point, the noise ceases, the gimbal ring has been improperly centered and is causing the counterweight (O 3133) to strike the waveguide. Remove the cover (A 3109) and recenter the nutator by adjusting nuts (O 3130) against angle (A 3117).

Continual use of the nutator may cause either the rotating (O 3132) or the small eccentric frame (O 3134) counterweight to shake loose.

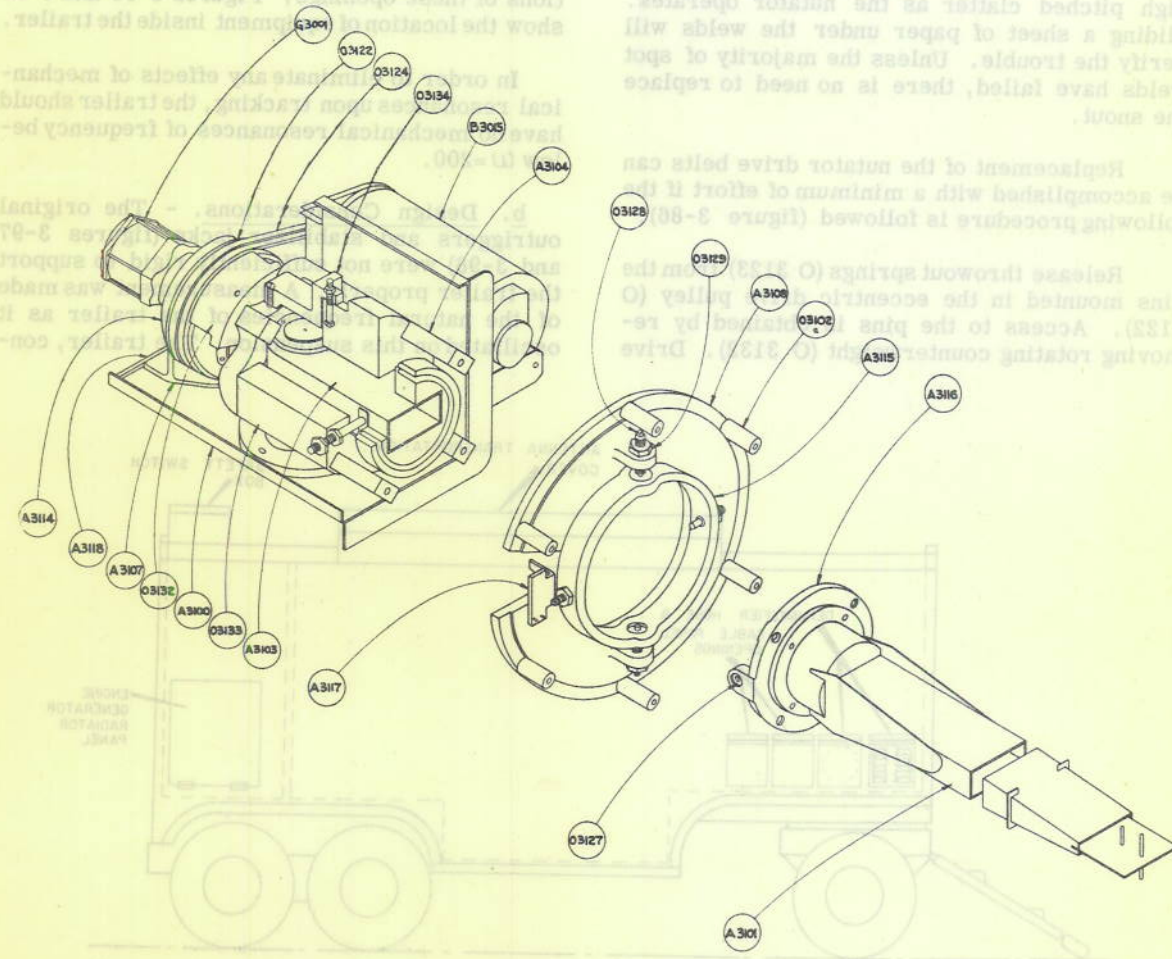


Figure 3-92. Nutator - Exploded View

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(See figure 3-86.) Take off the main cover (A 3109) and securely fasten the counterweight screws.

It is sometimes possible for the eccentric throwout (A 3106) to move in the opposite direction to that intended. When this occurs the mount will shake violently as soon as power is applied. At the same time the snout will nutate through a very small angle. To correct the trouble, remove the cover and rotating counterweight (O 3132) (figure 3-86) and turn the two limit screws (A 3139) until the eccentric throwout operates in a normal fashion.

Due to defects in their manufacture, certain of the cast snouts may fatigue and fail under continued usage. In such case, it is necessary to replace the defective snout.

Failure of the spot welds between the web and snout is not so serious. The symptom is a high pitched clatter as the nutator operates. Sliding a sheet of paper under the welds will verify the trouble. Unless the majority of spot welds have failed, there is no need to replace the snout.

Replacement of the nutator drive belts can be accomplished with a minimum of effort if the following procedure is followed (figure 3-86).

Release throwout springs (O 3123) from the pins mounted in the eccentric drive pulley (O 3122). Access to the pins is obtained by removing rotating counterweight (O 3132). Drive

out the interference bar (A 3118) from the back of the main frame. Remove the two rear screws holding the terminal strip (A 3138) and the pulley hanger (A 3107) to the casing. Loosen the forward hanger screw from beneath the main frame, and drive on this screw to release the entire pulley assembly. Caution - do not attempt to remove the hanger by forcing out the mounting pins. The tachometer pulley unit can now be lifted out and the belts replaced.

2. EQUIPMENT TRAILER, UNIT 7100

a. Introduction. - The Equipment Trailer, Type CAHU-10302, Unit 7100, contains the antenna mount assembly and its servo drive, (see figures 1-5 and 1-6), as well as the elevator used to raise and stow the antenna mount, the radar transmitter and modulator, the power control panel, and certain auxiliary equipment. The line sketches (figures 3-93 and 3-94) show the external openings of the trailer and the functions of these openings. Figures 3-95 and 3-96 show the location of equipment inside the trailer.

In order to eliminate any effects of mechanical resonances upon tracking, the trailer should have no mechanical resonances of frequency below $\omega = 200$.

b. Design Considerations. - The original outriggers and stabilizer jacks (figures 3-97 and 3-98) were not sufficiently rigid to support the trailer properly. A measurement was made of the natural frequencies of the trailer as it oscillated on this suspension. The trailer, con-

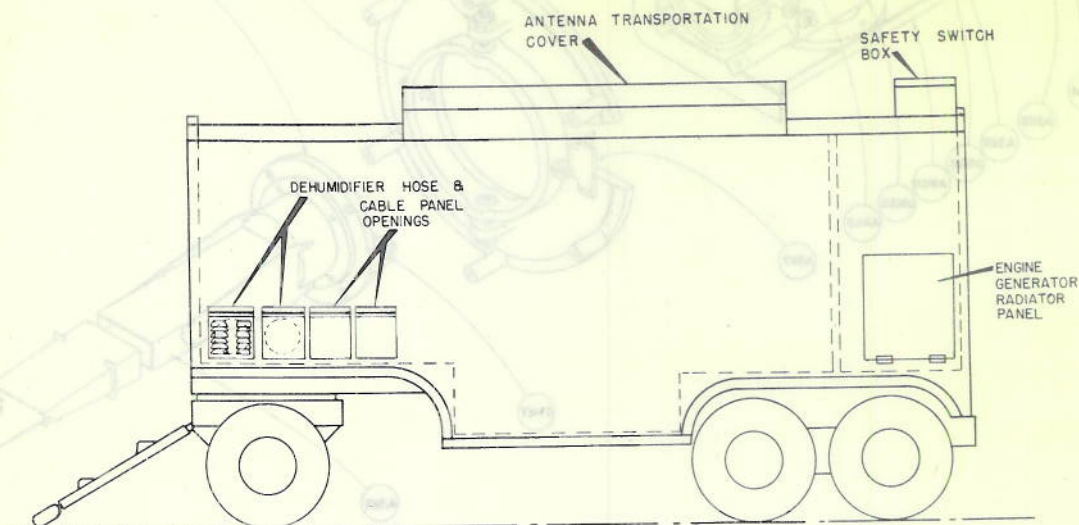


Figure 3-93. Equipment Trailer - Road Side Exterior View - Line Drawing

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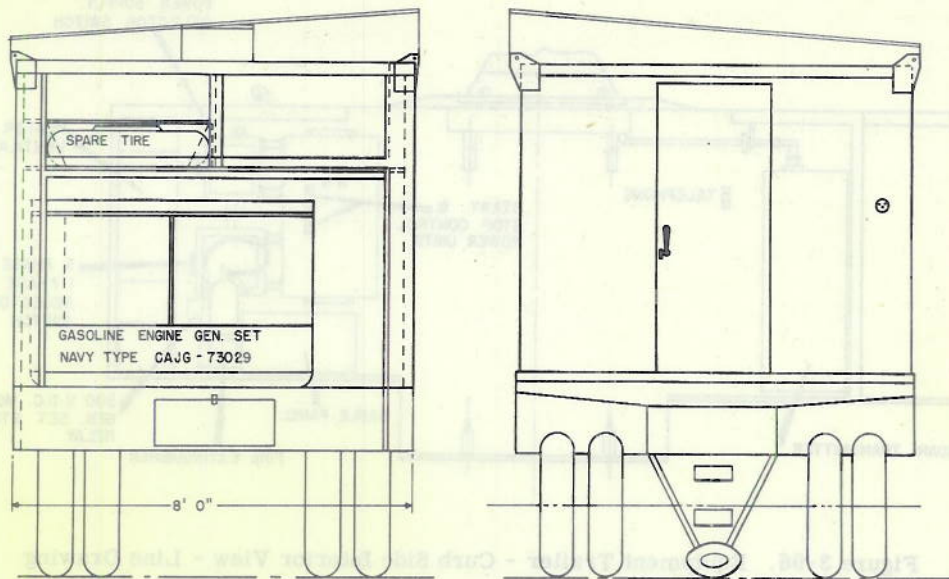


Figure 3-94. Equipment Trailer - Front and Rear Exterior Views - Line Drawing

sidered as a rigid body, oscillated at a frequency of 22 radians per second transversely, 16 radians per second longitudinally, and about 40 radians per second vertically. More rigid supports were constructed to hold the trailer frame. (See figure 1-5.)

Several of the shafts of the lower elevator sheaves failed under load on SP-1M equipment

serial 77. All sheave brackets were therefore modified, and larger shafts installed. (See figure 3-99.)

In the interests of safety, a step ladder was built for the use of personnel climbing to the trailer roof, and hand rails were constructed around the roof. (See figure 1-5.)

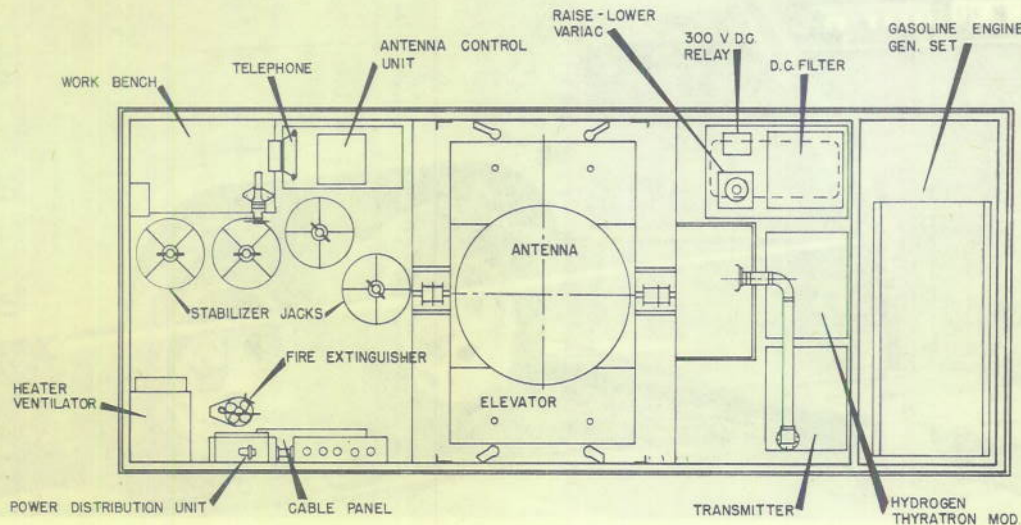


Figure 3-95. Equipment Trailer - Top Interior View - Line Drawing

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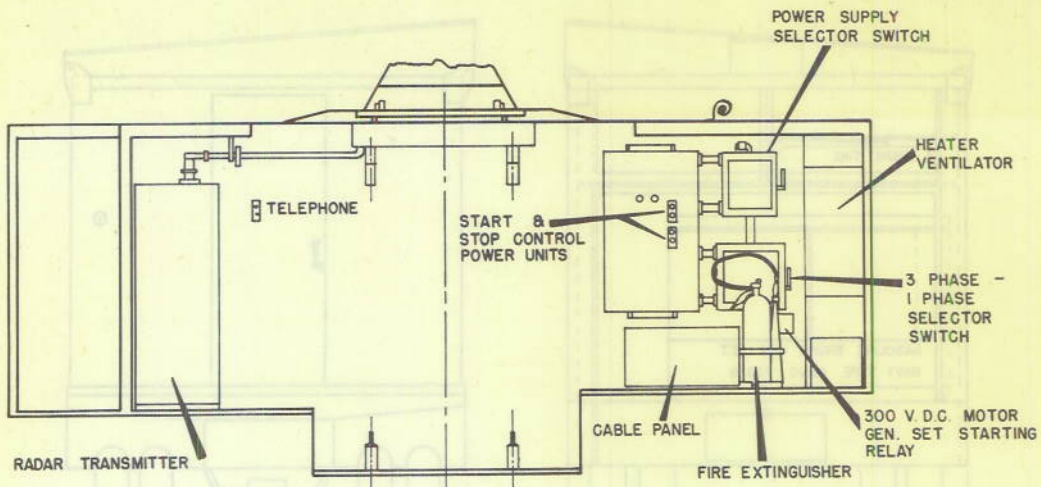


Figure 3-96. Equipment Trailer - Curb Side Interior View - Line Drawing



Figure 3-97. Outrigger and Jack for Equipment Trailer

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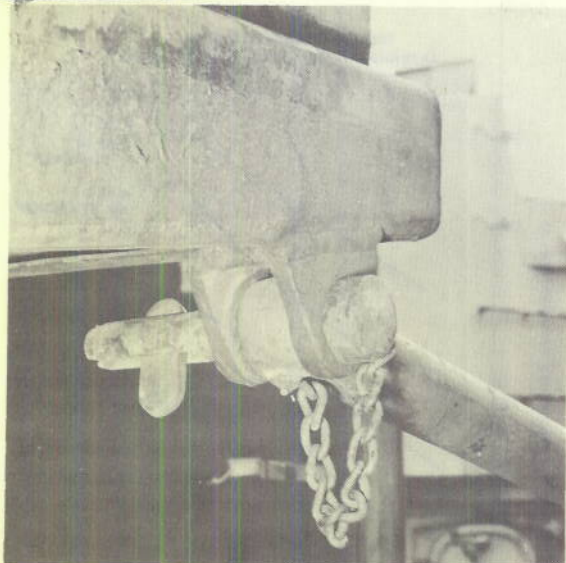


Figure 3-98. Clevis Pin - Detail

c. Performance Tests on Trailer Stiffening.
 - After stiffeners had been installed in the trailer, vibration studies were conducted to determine the frequencies and magnitudes of trailer mechanical resonances. The antenna mount itself was used as a mechanical oscillator in these tests: that is, the mount was oscillated sinusoidally at the desired frequencies, so that its torque reaction provided a test disturbance for the trailer. An NRL servo system test signal generator was used to control the amplitude and frequency of the mount motion. In order to obtain a frequency response test curve which can be strictly correlated with a calculated curve, the sinusoidal torque applied must be a known function of the frequency. Preferably this torque should have a constant amplitude. Since the equipment, however, contains no method for controlling the torque applied, an attempt at a constant torque run was made by keeping the amplitude of mount motion inversely proportional to the square of the frequency (dropping off at 40 db per decade). The amplitude was chosen to give a torque of 620 pound-feet at low frequencies. A truly constant-torque run was not obtained, since the mechanical system heavily loads the servo system near the frequencies of mechanical resonance.

The horizontal displacements of a point on the base of the mount and a point on the rub rail aft of the forward stiffener were measured with MB electrical seismographic pickoffs. The frequency response curves obtained in this manner indicated possible resonances at $\omega = 15, 30, 45, 60, 75$ radians per second. These values



Figure 3-99. Sheave in Antenna Elevator With Larger Shaft

for frequencies are approximate only. The values for amplitude are inconclusive because of (a) the loading effect mentioned above and (b) the nonlinearity of the system. In general, the amplitude of vibration at any given frequency was not linearly proportional to the amplitude of the exciting torque. Curves of vibration amplitude versus exciting velocity were run at two frequencies, $\omega = 20$ and $\omega = 30$ radians per second. These curves are shown on figures 3-100 and 3-101. Figures 3-225 and 3-226 show antenna response after stiffeners were installed.

3. OPERATIONS TRAILER, UNIT 7200

a. Introduction. - The Operations Trailer, Type CAHU-10302, Unit 7200, has a body similar to that of the equipment trailer. (See figures 1-25 and 1-26.) It contains the radar console, the telescope unit, communications equipment, and all data recording equipment except the tracking cameras. The line sketches (figures 3-102 through 3-104) show the location of the principal units in the trailer. Figure 3-105 shows the cable reels in the rear of the trailer body. Overall dimensions and location of external openings in the body are shown in figures 3-106 and 3-107.

b. Design Considerations. - Principal changes in the trailer structure are related to the instal-

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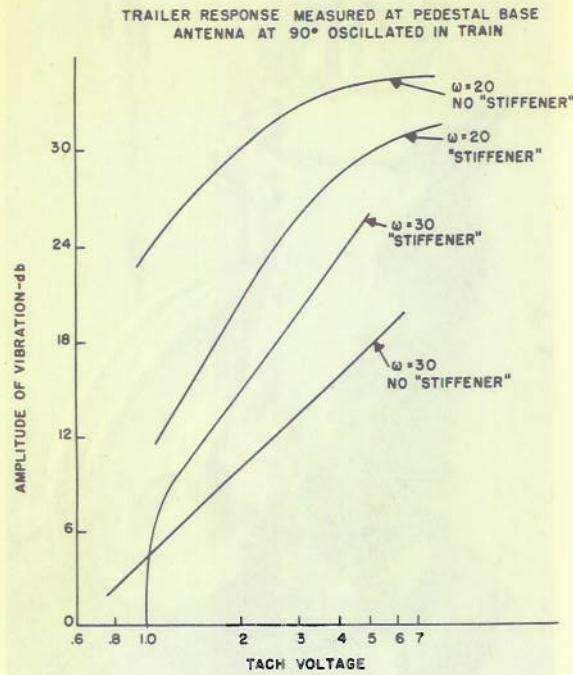


Figure 3-100. Vibration Amplitude Versus Exciting Velocity

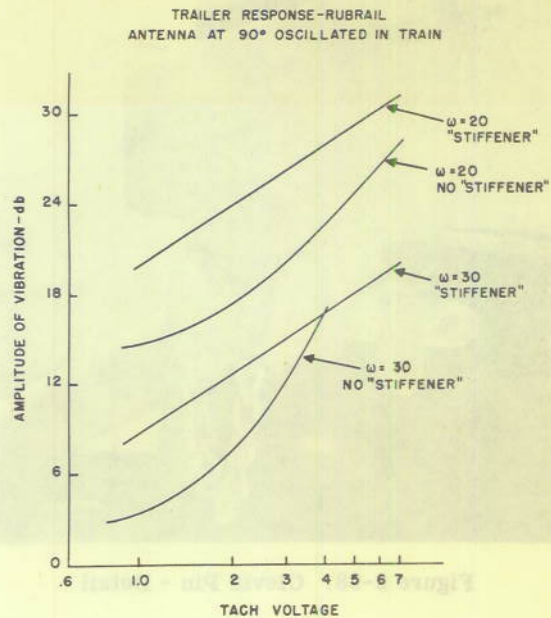


Figure 3-101. Vibration Amplitude Versus Exciting Velocity

lation of the telescope unit. The base of this unit was mounted on steel beams on the deck of the trailer. The telescope was extended through a circular hole cut in the roof, bringing the line of sight clear of the roof. A transparent plastic weather dome is used to cover the hole in the roof. A wooden cover was furnished for use when shipping the trailer.

A third rack, the "missile frame" was added to the radar console to accommodate additional units. The deck of the trailer was changed to give a single level for all three racks and the space immediately in front of them.

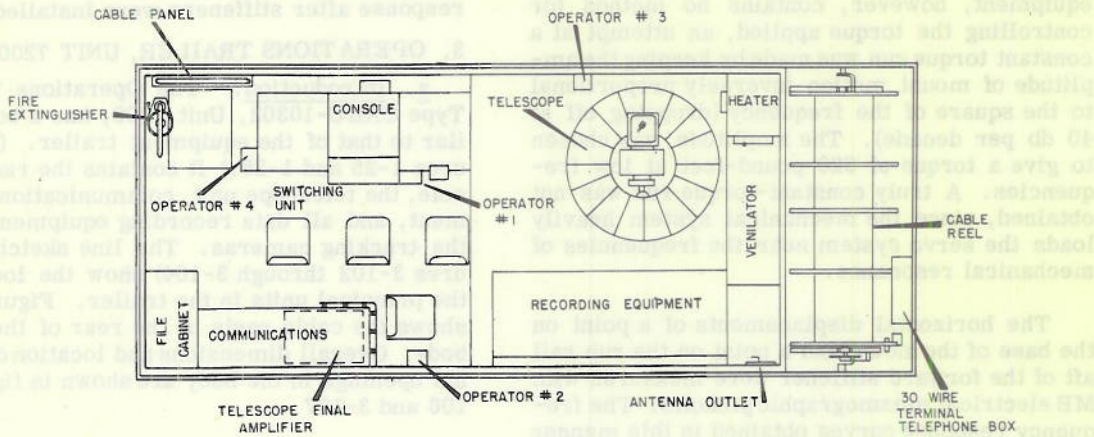


Figure 3-102. Operations Trailer - Top View - Line Drawing

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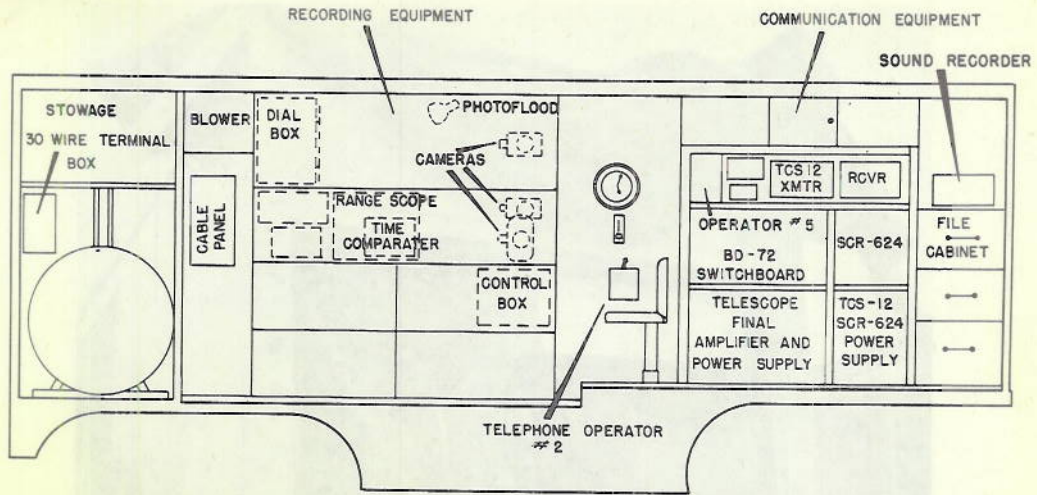


Figure 3-103. Operations Trailer - Road Side Interior View - Line Drawing

4. SPARE PARTS TRAILER, UNIT 7300

a. Introduction. - The Spare Parts Trailer, Type CAHU-10302, Unit 7300, has a body similar to those of the operations and equipment trailer (see figure 3-108). It is equipped with boxes and drawers containing the spare parts for all units of the Lark SP-1M radar equipment as well as test and recording equipment. Figure 3-109 shows the layout of these storage facilities. The location of spares for the various

units of the equipment is designated by the unit numbers.

Figures 3-110 and 3-111 show the interior of this trailer, looking aft and forward, respectively. Figure 1-59 shows the interior of the trailer looking aft (tailgate open). In this view, the operations trailer stabilizer jacks, the equipment trailer ladder and the spare motor-generator are shown stowed in their location for shipment.

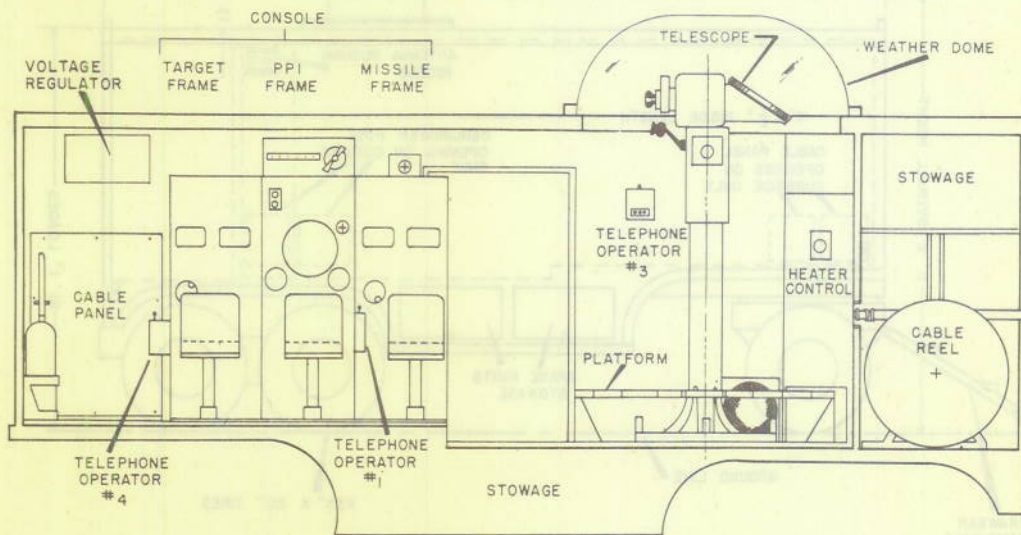


Figure 3-104. Operations Trailer - Curb Side Interior View - Line Drawing

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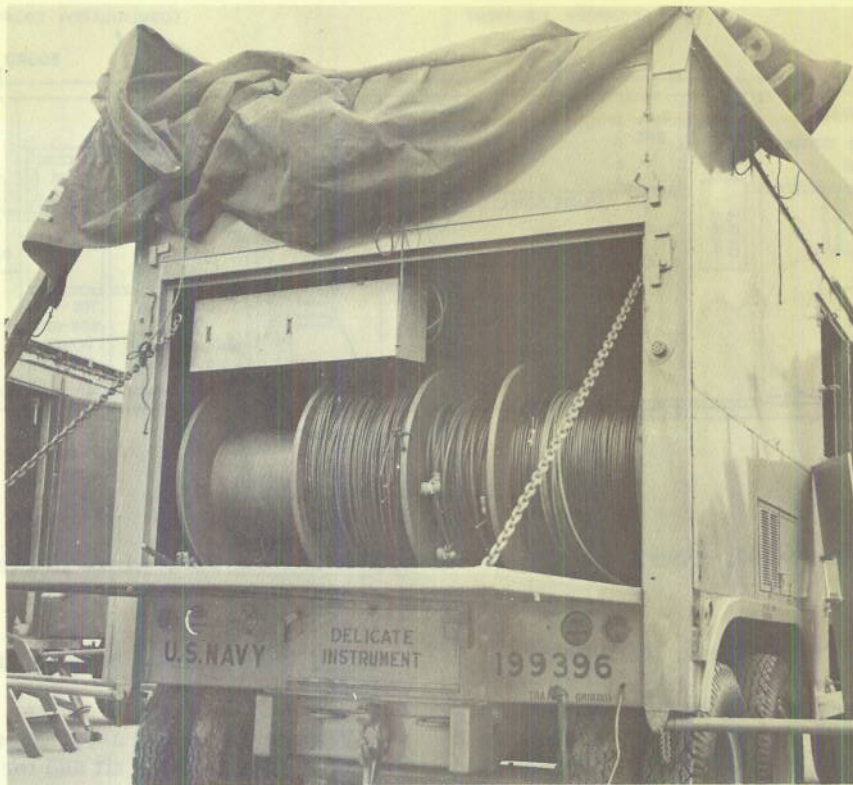


Figure 3-105. Cable Reels in the Rear of the Operations Trailer

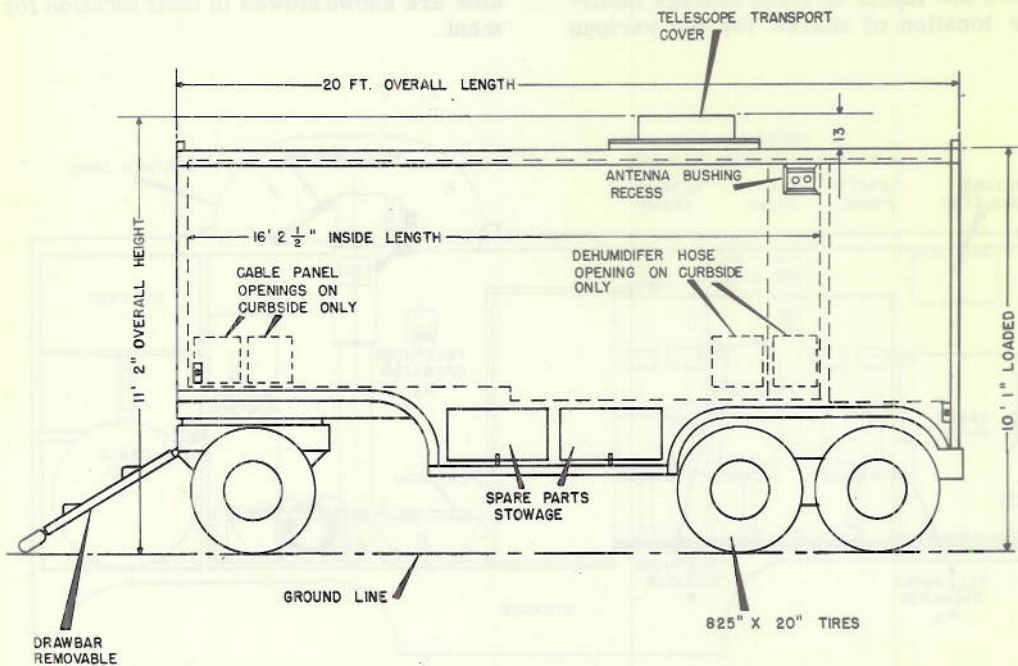


Figure 3-106. Operations Trailer - Road Side Exterior View - Outline Drawing

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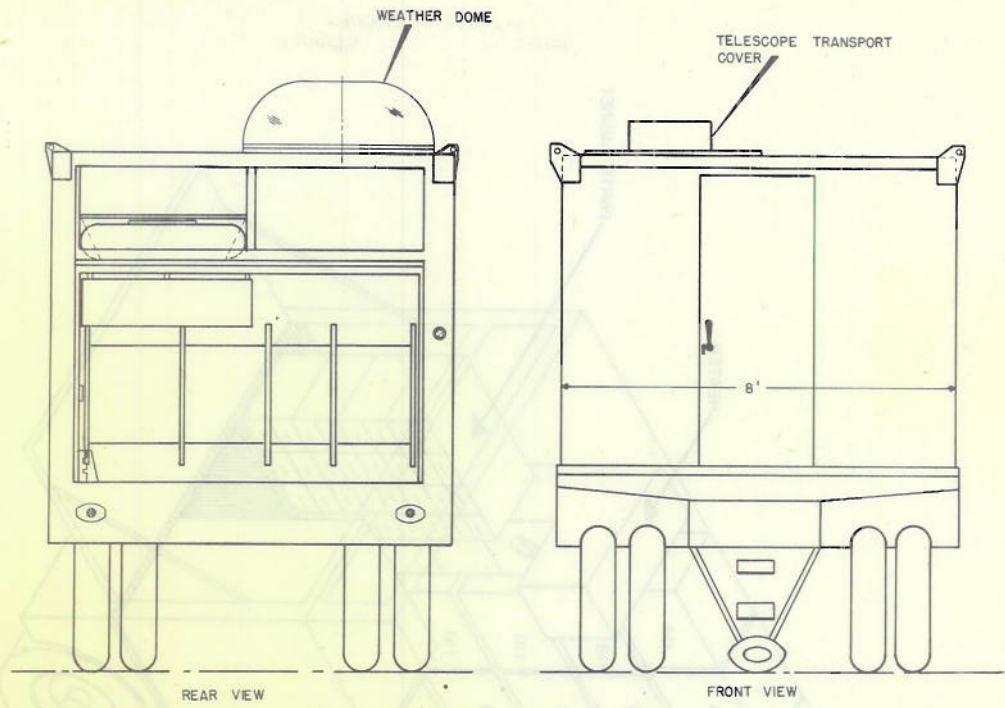


Figure 3-107. Operations Trailer - Front and Rear Exterior Views - Outline Drawing



Figure 3-108. Spare Parts Trailer

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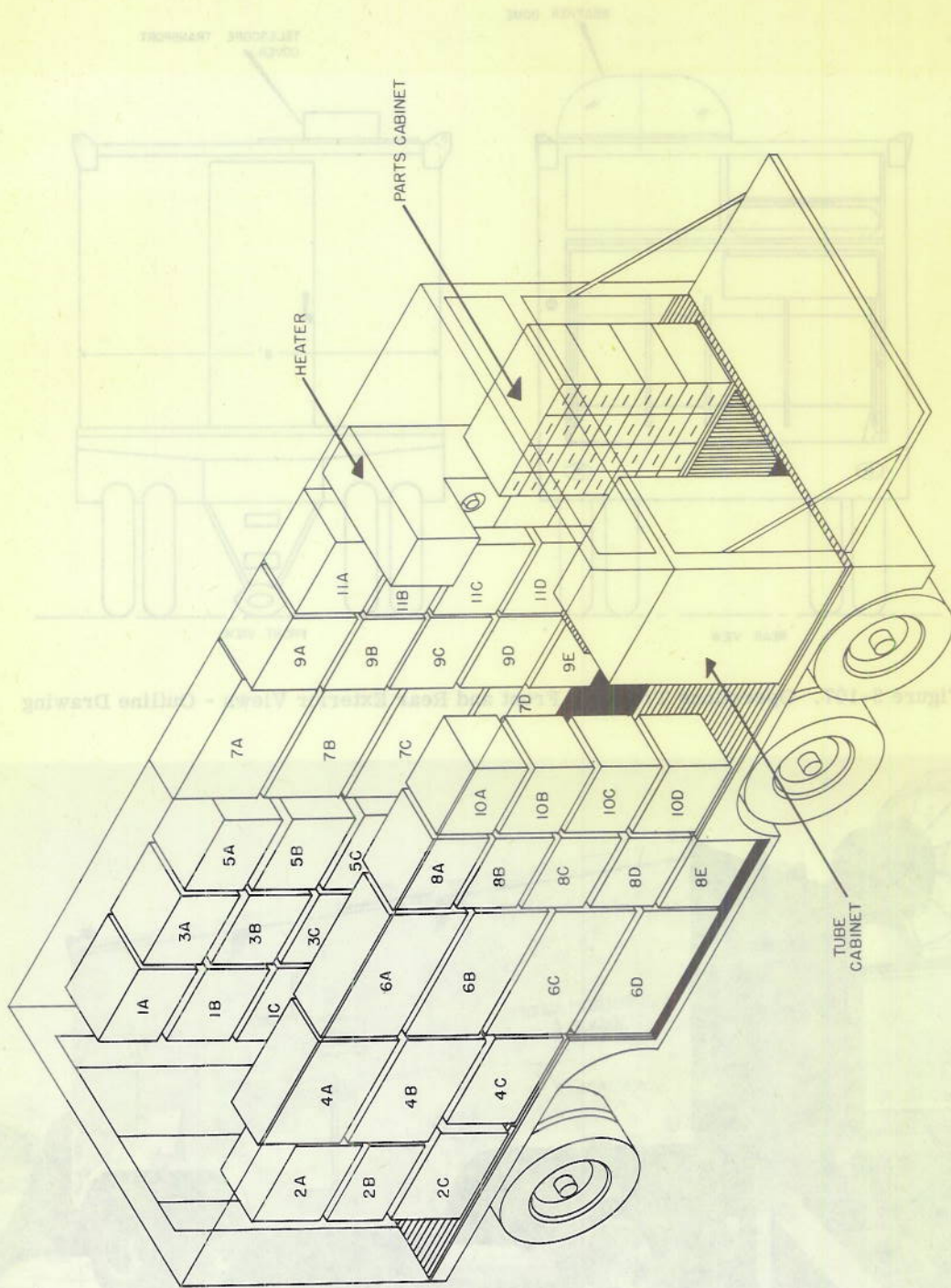


Figure 3-109. Spare Parts Trailer - Storage Facilities - Line Drawing

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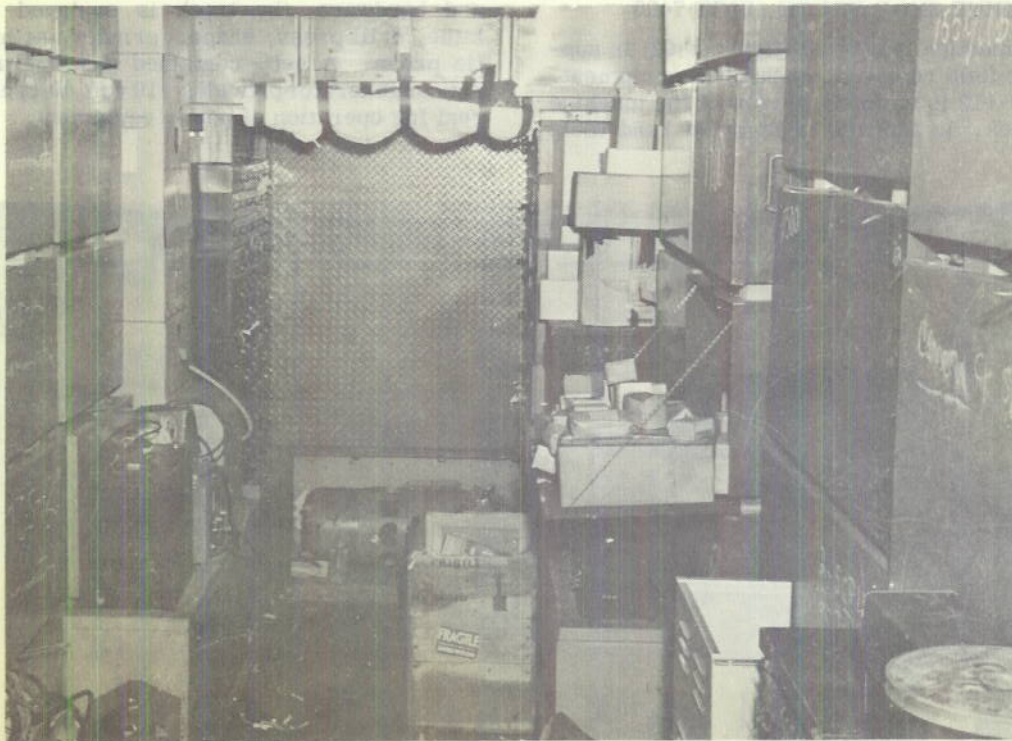


Figure 3-110. Spare Parts Trailer - Rear Interior View

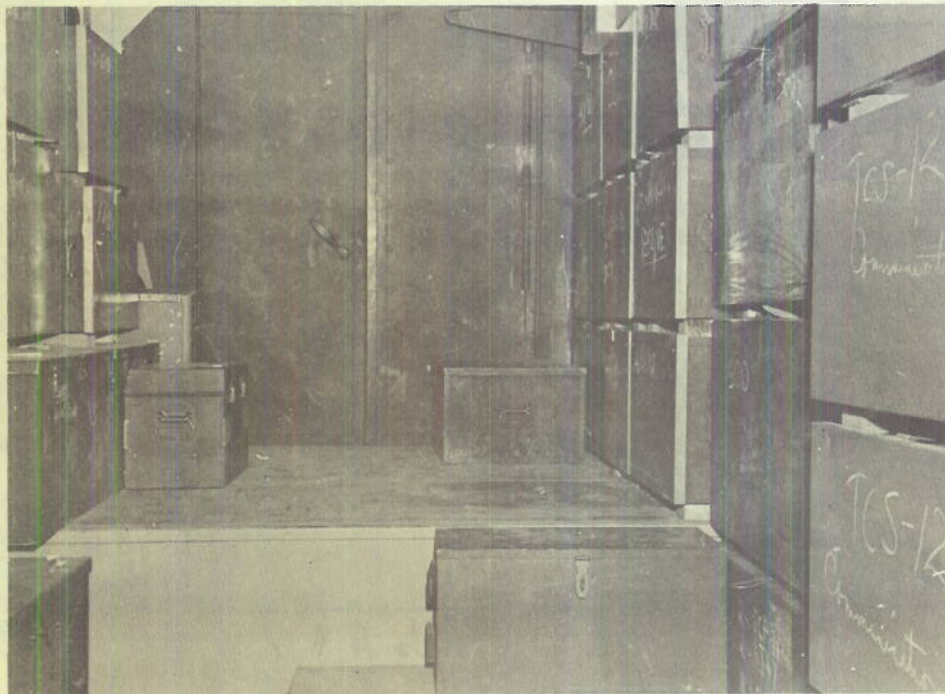


Figure 3-111. Spare Parts Trailer - Front Interior View

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5. MACHINE SHOP TRUCK, UNIT 7400

The machine shop truck (figure 1-62) is supplied for field repair of mechanical equipment. Figure 3-112 is an interior view of the machine shop truck. In addition to assorted hand tools

and hardware, the truck is equipped with a lathe, drill press, shaper, grinder and hydraulic press. A self-contained gasoline-motor-driven generator provides 110 volt 60 cycle current for operation of power equipment.



Figure 3-112. Machine Shop Truck - Interior View

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6. DEHUMIDIFIER UNITS, UNIT 5400

a. Introduction. (See figures 1-60 and 3-113 through 3-115) - The dehumidifiers, two of which are used with the Lark SP-1M equipment, are Navy Type CAJH-10306 units modified to use electric motors in place of the gasoline engines. For detailed instructions on service and repair of the compressor and associated parts, refer to the "Instruction Book for Navy Type CAJH-10306 Dehumidifying Equipment Mounted on Trailer, Navy Type CAKL-10311." All references in the instruction book to the gasoline engine and its associated parts should, of course, be disregarded.

The dehumidifier units are portable air conditioning units, designed to maintain predetermined conditions of temperature and humidity within the radar trailers. Each unit consists of a York 2-5/8 x 2-1/2 inch, two-cylinder Freon-12 compressor, V-belt driven from a five-

horsepower, 230-volt, three-phase electric motor. Transformers are provided to permit operation from a 115-volt, three-phase supply where 230-volt, three-phase, power is not available. The Freon-12 condenser is of air-cooled design. The evaporator consists of a finned coil. A double inlet Sirocco fan for circulating air is mounted near the top of the unit and is driven from the compressor flywheel. A high pressure Freon-12 cut-out is mounted on the control panel and wired so that if the condenser pressure becomes excessive, the cut-out trips and stops the electric motor. An Alco thermal expansion valve controls the flow of Freon-12 from the receiver to the evaporator coil.

The complete system is mounted and housed on a two-wheel trailer as shown in figure 3-113. Canvas ducts for return and supply air are furnished and may be used in one or two lengths as required. The entire unit is metal covered. Access is provided by doors in front and back.

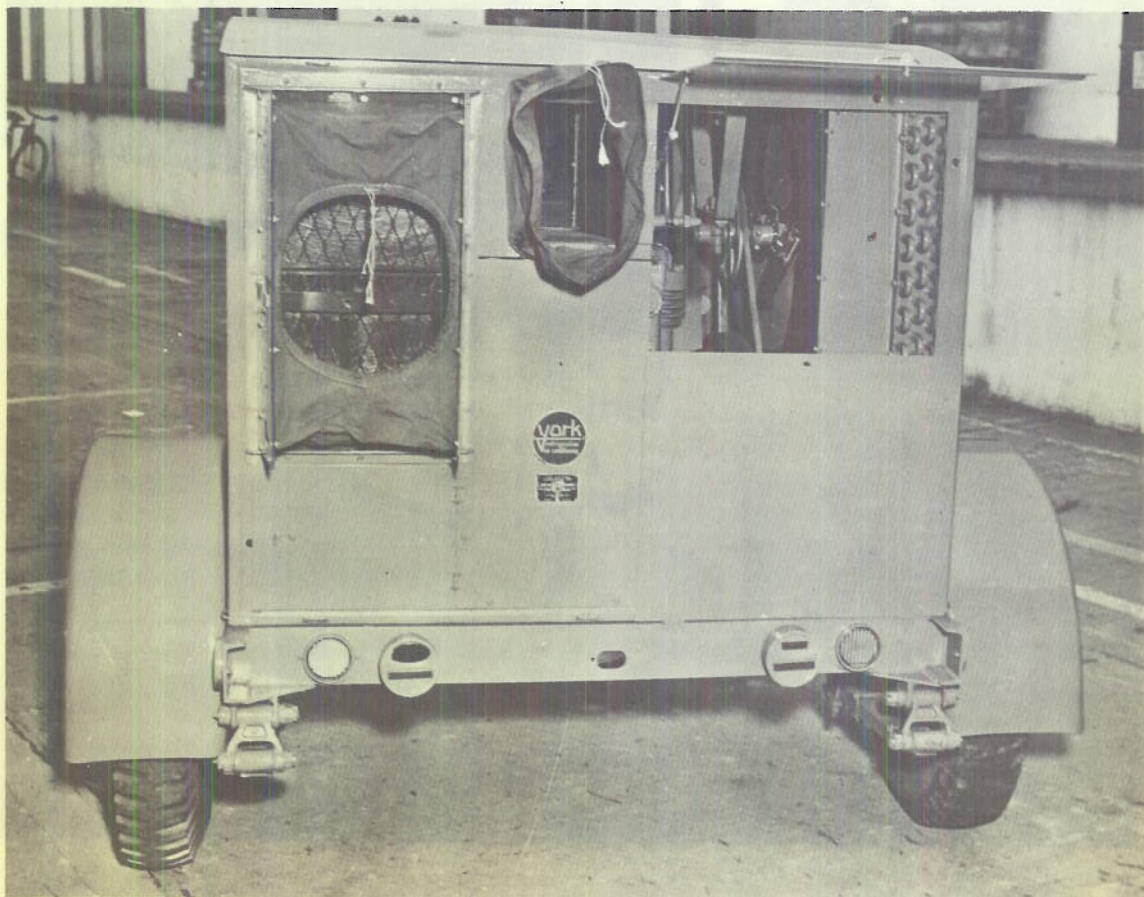


Figure 3-113. Dehumidifier - Rear View

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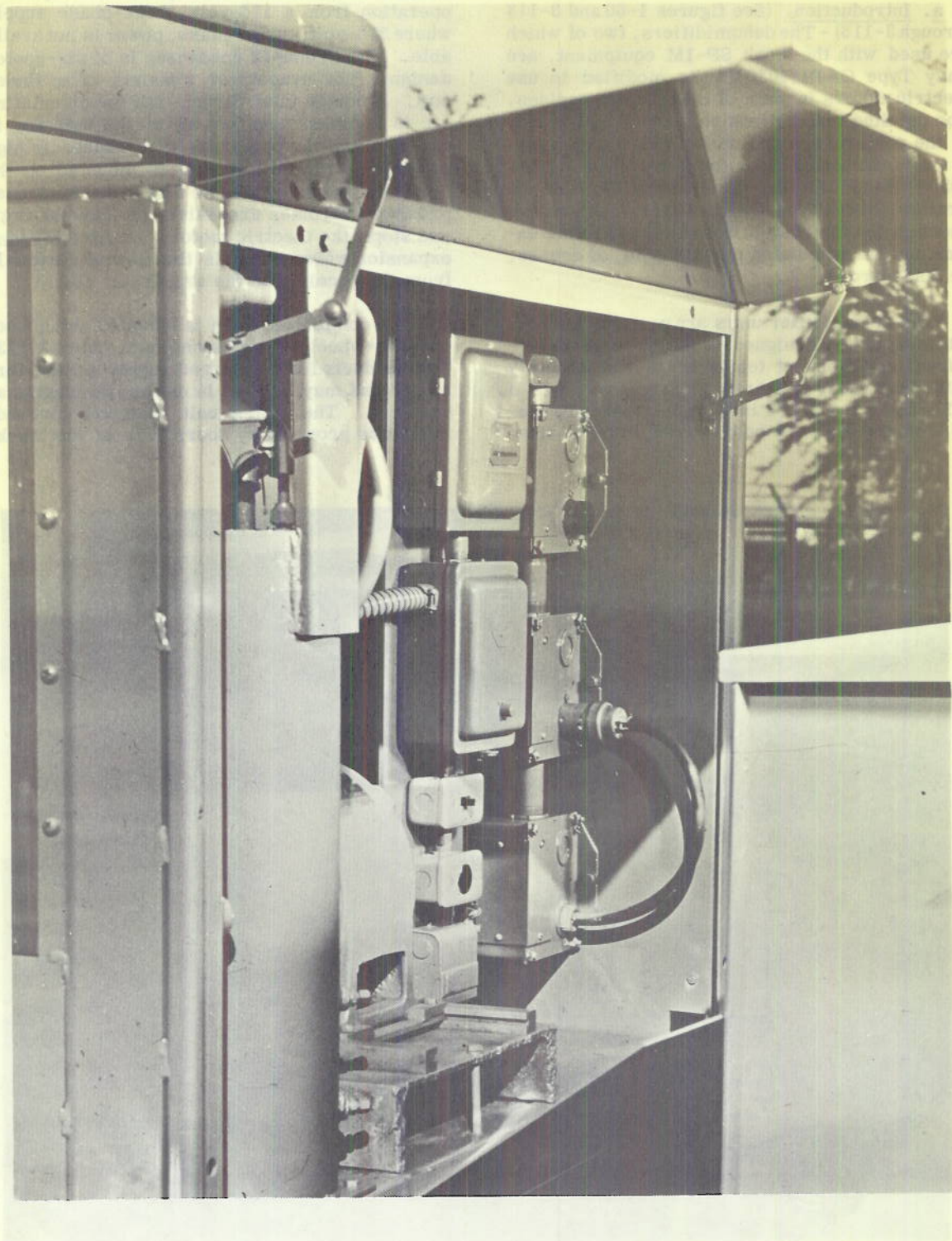


Figure 3-114. Dehumidifier - Front View With Panel Removed

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The thermostat located consists of two major parts: a bimetallic strip and a microswitch. The bimetallic strip causes the bimetallic contacts of the thermostat to open and close the dehumidifier to run. The thermostat is a microswitch and opens the microswitch contacts and opens the microswitch contacts.

The thermostat is a bimetallic strip and a microswitch. The bimetallic strip causes the bimetallic contacts of the thermostat to open and close the dehumidifier to run. The thermostat is a microswitch and opens the microswitch contacts and opens the microswitch contacts.

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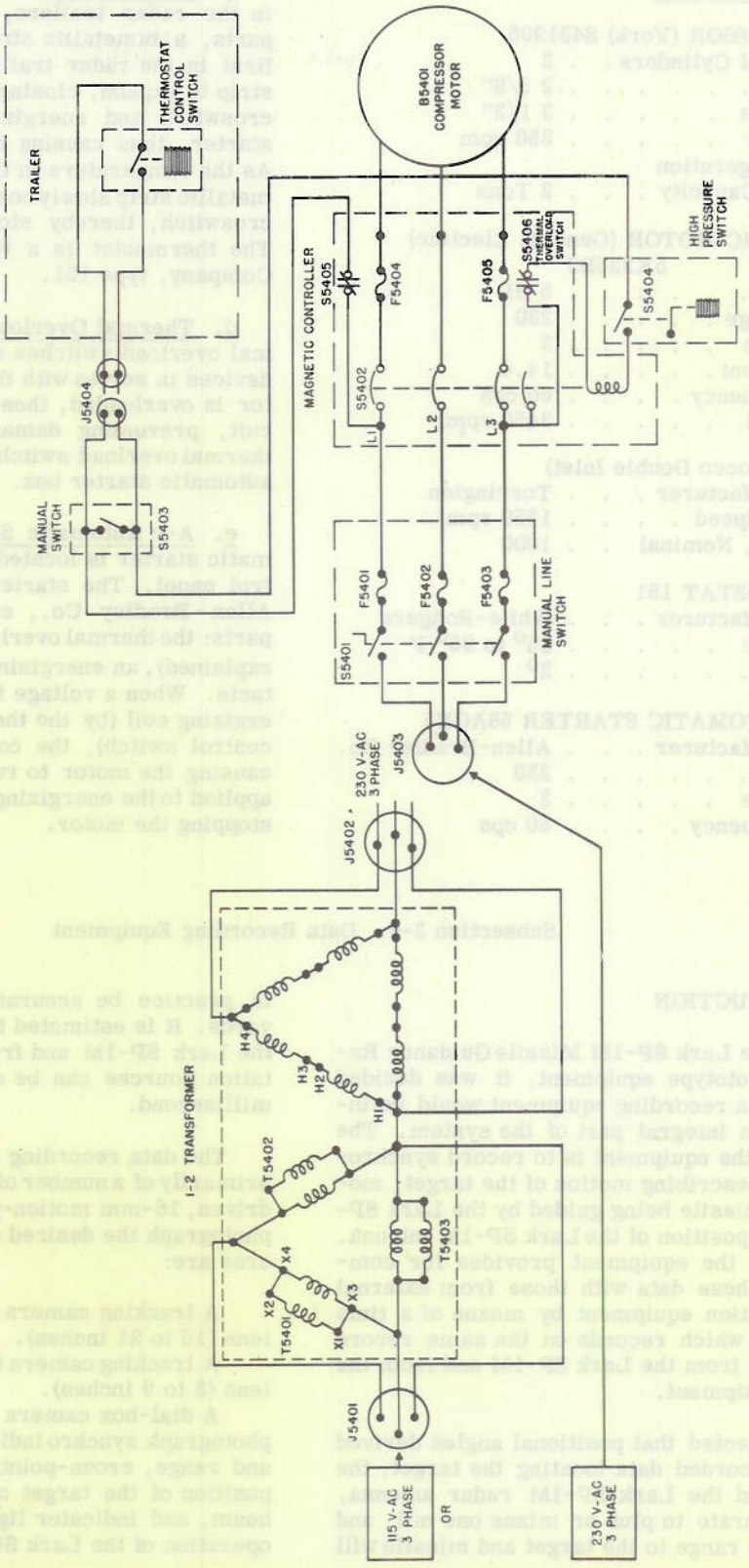


Figure 3-115. Dehumidifier - Schematic Diagram

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b. Specifications.

COMPRESSOR (York) S431906

No. of Cylinders . . . 2
 Bore 2 5/8"
 Stroke 2 1/2"
 Speed 850 rpm
 Refrigeration
 Capacity 2 Tons

ELECTRIC MOTOR (General Electric)
5K225D3

Size 5 HP
 Voltage 230
 Phase 3
 Current 14.4
 Frequency 60 cps
 Speed 3450 rpm

FAN (Sirocco Double Inlet)

Manufacturer . . . Torrington
 Fan Speed 1550 rpm
 CFM, Nominal . . . 1000

THERMOSTAT 151

Manufacturer . . . White-Rodgers
 Range 65° to 95° F
 Diff 2°

A-C AUTOMATIC STARTER 58AGN5

Manufacturer . . . Allen-Bradley Co.
 Volts. 230
 Phase 3
 Frequency 60 cps

c. Thermostat. - The thermostat, located in the radar trailers, consists of two major parts, a bimetallic strip, and a microswitch. Heat in the radar trailer causes the bimetallic strip to expand, closing the contacts of the microswitch and energizing the a-c automatic starter, thus causing the dehumidifier to run. As the temperature in the trailer drops, the bimetallic strip slowly contracts and opens the microswitch, thereby stopping the dehumidifier. The thermostat is a White-Rodgers Electric Company, type 151.

d. Thermal Overload Switches. - The thermal overload switches are bimetallic protective devices in series with the motor. When the motor is overloaded, these devices open the circuit, preventing damage to the motor. The thermal overload switches are located in the a-c automatic starter box.

e. A-c Automatic Starter. - The a-c automatic starter is located on the dehumidifier control panel. The starter, manufactured by the Allen-Bradley Co., consists of three major parts: the thermal overload switches (previously explained), an energizing coil, and the line contacts. When a voltage is impressed on the energizing coil (by the thermostat or the manual control switch), the coil closes the contacts, causing the motor to run. When no voltage is applied to the energizing coil, the contacts open, stopping the motor.

Subsection 3-6. Data Recording Equipment

1. INTRODUCTION

Since the Lark SP-1M Missile Guidance Radar is a prototype equipment, it was decided that the data recording equipment would be included as an integral part of the system. The purpose of the equipment is to record synchronized data describing motion of the target, motion of the missile being guided by the Lark SP-1M, and the position of the Lark SP-1M antenna. In addition, the equipment provides for comparison of these data with those from external instrumentation equipment by means of a time comparator which records on the same record time signals from the Lark SP-1M and from the external equipment.

It is expected that positional angles derived from the recorded data locating the target, the missile, and the Lark SP-1M radar antenna, will be accurate to plus or minus one mil, and that derived range to the target and missile will

in practice be accurate to plus or minus 35 yards. It is estimated that the time bases from the Lark SP-1M and from external instrumentation sources can be correlated to within one millisecond.

The data recording equipment is comprised primarily of a number of synchronized, synchro-driven, 16-mm motion-picture cameras used to photograph the desired quantities. These cameras are:

A tracking camera with a long focal-length lens (10 to 21 inches).

A tracking camera with a short focal-length lens (3 to 6 inches).

A dial-box camera with a one-inch lens to photograph synchro indications of beam position and range, cross-pointer meters indicating the position of the target and missile in the radar beam, and indicator lights showing the mode of operation of the Lark SP-1M.

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A remote-range-indicator camera with a one-inch lens.

A time-comparator camera with a one-inch lens.

All of these, except the time-comparator camera, are Bell and Howell "Auto Load" motion-picture cameras, modified so that they are directly driven by Navy Type 5F synchros at 10 frames per second. The time-comparator camera is a Bell and Howell type 70-DA camera, suitably modified to be used as a continuous strip camera. This camera is driven at a film speed equivalent to 10 or 15 frames per second (approximately 3 or 4.5 inches per second) by a Navy Type 5F synchro.

The use of Navy Type 5F synchro motors as drivers for the various cameras insures that all cameras run at the same speed and that all shutters open simultaneously. Although the time-comparator camera does not have a shutter, its film speed is controlled by the driving synchro, and is directly correlated with the speed of the other cameras. All cameras, except the one used to photograph the time comparator, have two small incandescent lamps ("flag lights") installed between the lens and the rotating shutter. These lights are turned on at the beginning of a run until the camera drivers come up to speed and are then extinguished. While the flag lights are on, the film in all cameras is simultaneously fogged, and a common starting point is thus established on all film records. For the time comparator, the flag lights are installed on the face of the time-comparator unit itself rather than in the camera.

a. Camera Equipment

1). Main Tracking Camera. - The main tracking camera, mounted on the radar antenna, uses a special lens system incorporating a calibrated reticule and having an overall effective focal length of from 10 to 21 inches. Because two lenses are used in the lens system, an image inversion will result on the film. Whether an overall focal length of 10 or 21 inches is used, depends on the desired field of view and magnification (a 10-inch lens has a field of view of about 1.6 by 2.2 degrees, and the 21-inch lens about 0.8 by 1.1 degrees).

2). Auxiliary Tracking Camera. - The auxiliary tracking camera is also mounted on the radar antenna. Its purpose is to record tracking deviations at the beginning of a run, and at any other portion of a run where tracking errors are larger than those which can be accommodated by the field of view of the main tracking camera. A standard lens with a focal length of three to

six inches is used (a three-inch lens has a field of view of about 5.4 by 7.3 degrees, a six-inch lens about 2.7 by 3.6 degrees).

3). Dial Box Camera. - The dial box camera uses a standard one-inch lens and is used to photograph the face of the Dial Box Unit, Unit 8100, which is made up of five-inch dials attached to the shafts of Navy Type 5F synchros, and other indicators, including bull's-eye lights, and meters. The dial box data indications are as follows:

a). Synchro positional data.

1. Radar bearing and elevation. 4 dials.
2. Radar range (missile) . . . 2 dials.
3. Radar range (target) . . . 2 dials.
4. Remote course generator range. 2 dials.

b). Indicator lights and meters.

1. Automatic radar elevation tracking light.
2. Automatic radar train tracking light.
3. Pulse-time modulation light.
4. Computer light.
5. Local light.
6. Telescope light.
7. Control cross-pointer meter (indicates relative position of object being tracked: i. e., the object which activates tracking circuits).
8. Monitor cross-pointer meter (indicates position of another object in the radar beam).

Dials are 2 and 36 speeds for elevation, 1 and 36 speeds for bearing, 1000 and 100,000 yards per revolution for radar range, and 2000 and 72,000 yards per revolution for range from the computer used as a remote course generator. Fine dials are scaled in degrees and tenths of a degree. All indicator lights are on when the indicated quantity is of a positive sense.

4). Remote-Range-Indicator Camera. - The remote-range-indicator camera uses a standard one-inch lens to photograph the face of a remote-range oscilloscope. The oscilloscope presents expanded portions of the two range gates in the Lark SP-1M (R-sweep presentations), and is included to account completely for target interference, beacon operation, and other pertinent information. Also included on the front of the unit are four indicator lights: control and automatic range lights for the missile video and the target video. Here, again, the lighted light indicates a positive action.

5). Time-Comparator Camera. - A synchro-driven, continuous-strip camera using a standard one-inch lens is used to photograph the face of the time comparator. The comparator unit contains two strobotron tubes actuated by pulses from the Lark SP-1M and from an external instrumentation source. Pulses from the Lark SP-1M are derived from a commutator unit attached to a 5F synchroparalleled with the camera drivers: one pulse per revolution of the synchro results; a total of ten per second. Pulses from the external instrumentation source are received by a radio receiver and converted to such form that they will actuate the other strobotron. The face of the comparator unit has two machined slits, one facing each strobotron. These slits are so oriented that they lie in a straight line across the direction of film travel. In addition, a flag light is mounted on the face of the comparator in line with the slits to record the starting time of the run on the continuous-strip comparator camera.

b. Camera Control Unit. - All cameras are controlled from the Camera Control Unit, Unit 8200, located inside the Operations Trailer. This unit contains a Navy Type 7G synchro generator turned by a single-phase synchronous motor properly geared to turn the synchro at 600 revolutions per minute, jacks to connect the 5F camera drivers to the 7G transmitter, a time delay relay to control the flag lights in the camera, a synchronous-motor timer to indicate camera running time, bull's-eye indicator lamps to monitor flag light operation, outlets to three flood lights used to illuminate the dial box, an excitation switch to energize the synchros, a switch to energize the synchronous motor, and a jack to allow for remote operation of the cameras.

2. DESCRIPTION OF UNITS.

a. General. - Figure 3-116 is included to give an overall functional picture of the data recording equipment. The data indicators are schematically represented, along with functional representations of the flow of data from various units throughout the Lark SP-1M to the indicators. The data recording cameras are represented schematically and are located so that the data to be recorded fall within the angular field of view shown. Attention is directed, also, to the sound recorder unit at the right edge of the figure. All voice communications are to be recorded, including messages to and from external sources, and messages exchanged within the Lark SP-1M via telephones.

b. Dial Box Unit, Unit 8100. (See figures 3-117, 3-118, and 3-119.) - Figure 3-119 shows

the dial box unit installed inside the Lark SP-1M trailer. The face of the dial box is composed of fourteen five-inch dials, two cross-pointer meters, six bull's-eye lights, a run number counter, and a card holder for a card giving other pertinent information concerning the test. The dials are made of sheet aluminum and are attached to the shafts of Navy Type 5F synchros located in a steel plate behind the dial box face. The face of the dial box and the dials are painted dull black to reduce light reflections during the photographing process. The dials were engraved after being painted so that the markings on the dials are sharply contrasted against the black background.

The synchros in the dial box are connected to various synchro generators in the Lark SP-1M to furnish concentrated indication of radar bearing, radar elevation, radar range (missile), radar range (target), and remote course generator (computer) range. Synchro dial speeds are 2 and 36 speeds for elevation, 1 and 36 speeds for bearing, 1000 and 100,000 yards per revolution for radar range, and 2000 and 72,000 yards per revolution for range from the computer used as a remote course generator. Fine dials indicating angular quantities are scaled in degrees and tenths of a degree. Counterclockwise rotation of all dials indicates increasing amplitude for the quantity indicated.

Six bull's-eye lamps are located in the central portion of the dial box face and are used to indicate the following operating conditions of the Lark SP-1M:

- 1). Automatic radar elevation tracking.
- 2). Automatic radar train tracking.
- 3). Pulse-time modulation.
- 4). Computer.
- 5). Local.
- 6). Telescope.

The lamps are illuminated when the operating condition specified is in operation.

Two cross-pointer meters are located in the center of the dial box face. The control meter on the left indicates the position of the object being tracked in the radar beam (i.e., the object which activates the angular tracking circuits) as indicated by the angular error measuring circuits in the radar. The monitor meter indicates the position of any other object in the radar beam as sensed by the radar.

Statistics of a particular run are indicated on a card in the cardholder in the central portion of the dial box face (date, test number, etc.) and by the run number counter in the upper right

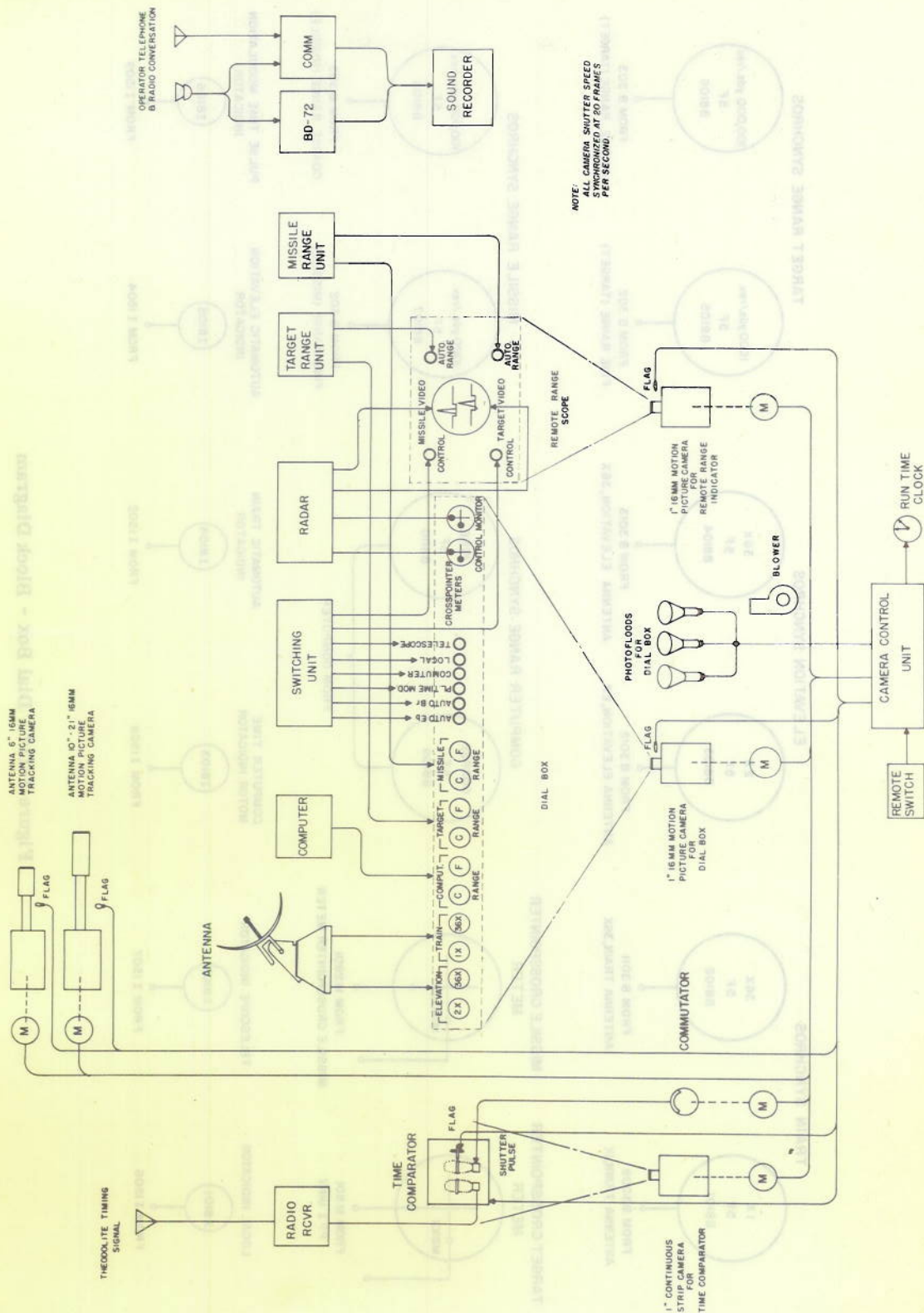


Figure 3-116. Data Recording Equipment - Block Diagram

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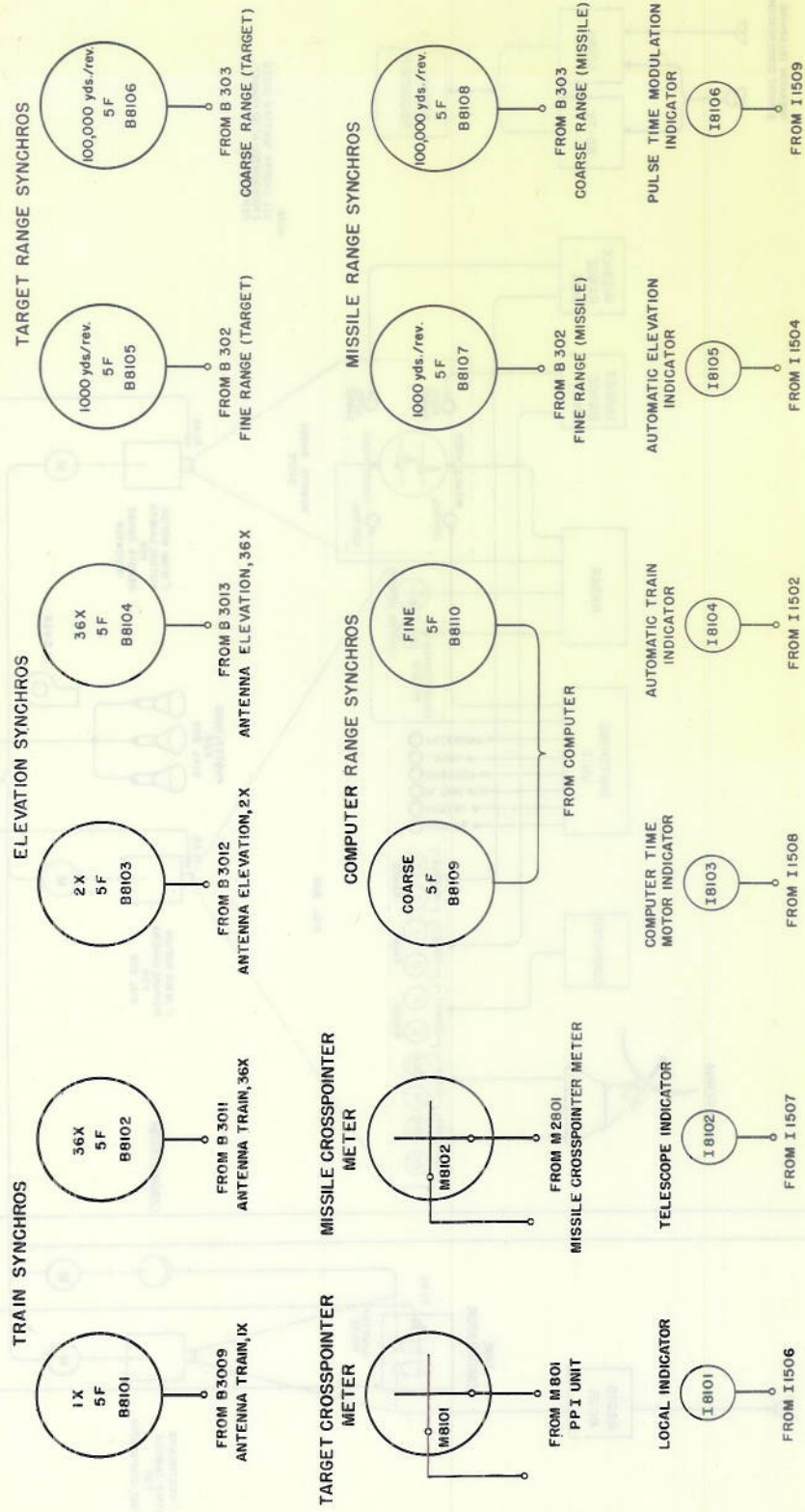


Figure 3-117. Dial Box - Block Diagram

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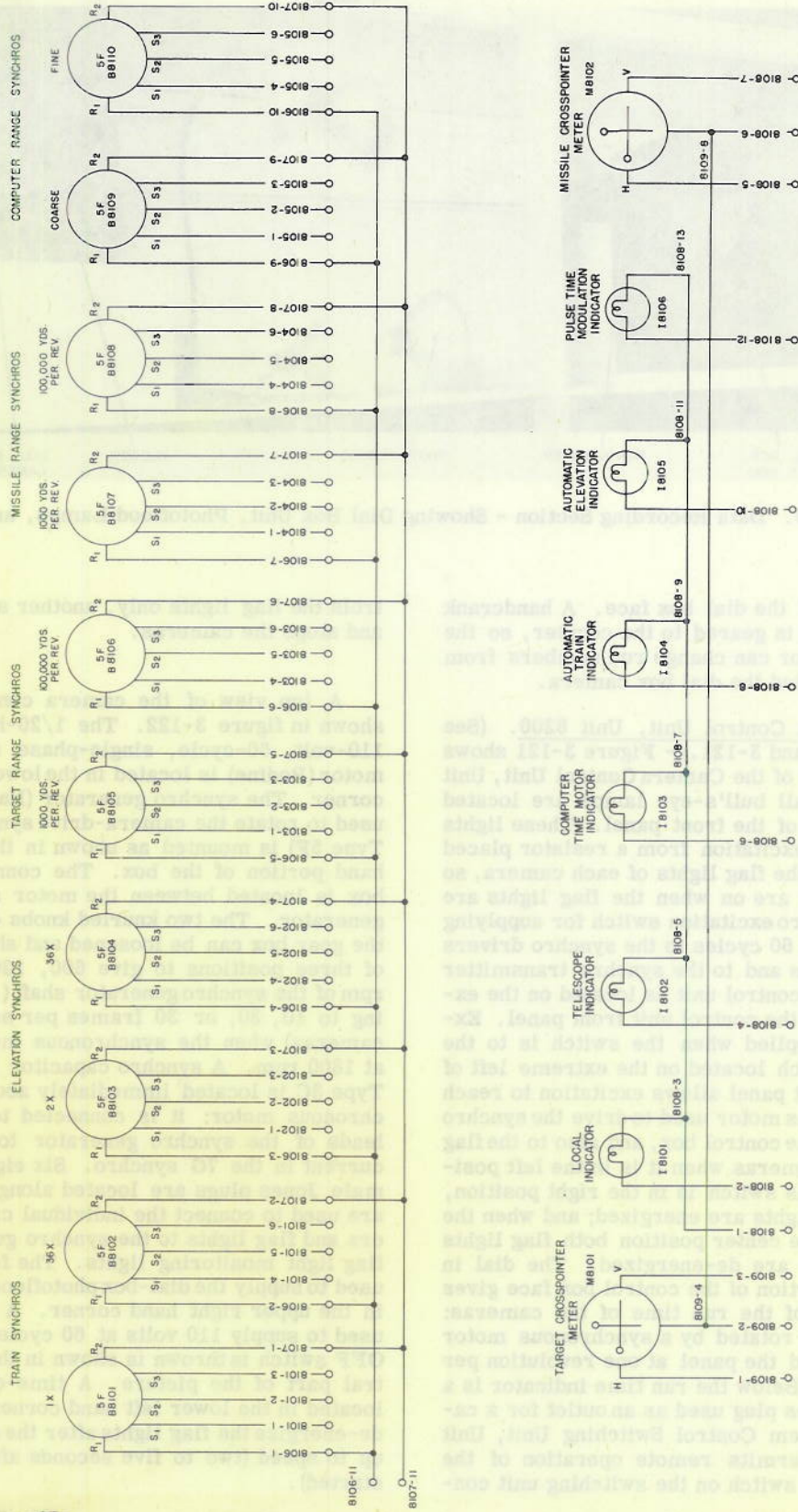


Figure 3-118. Dial Box Unit - Schematic Diagram

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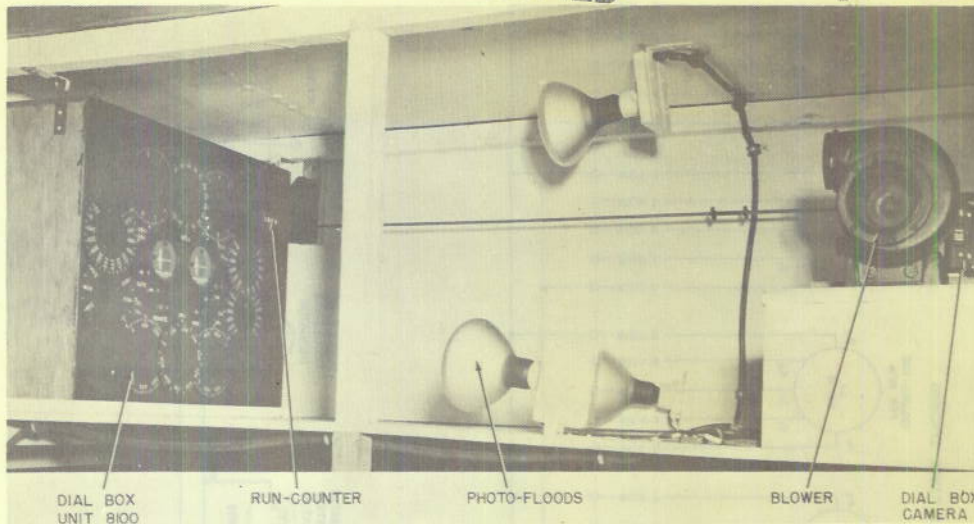


Figure 3-119. Data Recording Section - Showing Dial Box Unit, Photoflood Lamps, and Blower

hand corner of the dial box face. A handcrank on a long shaft is geared to the counter, so the camera operator can change run numbers from his station behind the dial box camera.

c. Camera Control Unit, Unit 8200. (See figures 3-120 and 3-121.) - Figure 3-121 shows the front panel of the Camera Control Unit, Unit 8200. Six small bull's-eye lamps are located across the top of the front panel. These lights receive their excitation from a resistor placed in series with the flag lights of each camera, so that the lamps are on when the flag lights are on. The synchro excitation switch for supplying 110 volts ac at 60 cycles to the synchro drivers on the cameras and to the synchro transmitter in the camera control unit is located on the extreme right of the control unit front panel. Excitation is supplied when the switch is to the left. The switch located on the extreme left of the control unit panel allows excitation to reach the synchronous motor used to drive the synchro generator in the control box, and also to the flag lights in the cameras when it is in the left position. When this switch is in the right position, only the flag lights are energized; and when the switch is in the center position both flag lights and the motor are de-energized. The dial in the central portion of the control box face gives an indication of the run time of the cameras: the pointer is rotated by a synchronous motor mounted behind the panel at one revolution per five minutes. Below the run time indicator is a four-wire Jones plug used as an outlet for a cable to the System Control Switching Unit, Unit 1500. This permits remote operation of the cameras: one switch on the switching unit con-

trols the flag lights only, another switch starts and stops the cameras.

A top view of the camera control unit is shown in figure 3-122. The 1/20-horsepower, 110-volt, 60-cycle, single-phase synchronous motor (Bodine) is located in the lower right hand corner. The synchro generator (Navy Type 7G) used to rotate the camera-drive synchros (Navy Type 5F) is mounted as shown in the upper left hand portion of the box. The connecting gear box is located between the motor and synchro generator. The two knurled knobs on the top of the gear box can be loosened and shifted to any of three positions to give 600, 1200, or 1800 rpm of the synchro generator shaft (corresponding to 10, 20, or 30 frames per second at the cameras) when the synchronous motor rotates at 1800 rpm. A synchro capacitor Mk 1 Mod 3 Type 3C is located immediately above the synchronous motor: it is connected to the stator leads of the synchro generator to reduce the current in the 7G synchro. Six eight-wire female Jones plugs are located along the top and are used to connect the individual camera drivers and flag lights to the synchro generator and flag light monitoring lights. The female outlet used to supply the dial-box photofloods is located in the upper right hand corner. A power relay used to supply 110 volts at 60 cycles when ON-OFF switch is thrown is shown in the lower central part of the picture. A time-delay relay, located in the lower left hand corner, is used to de-energize the flag lights after the cameras are up to speed (two to five seconds after they are started).

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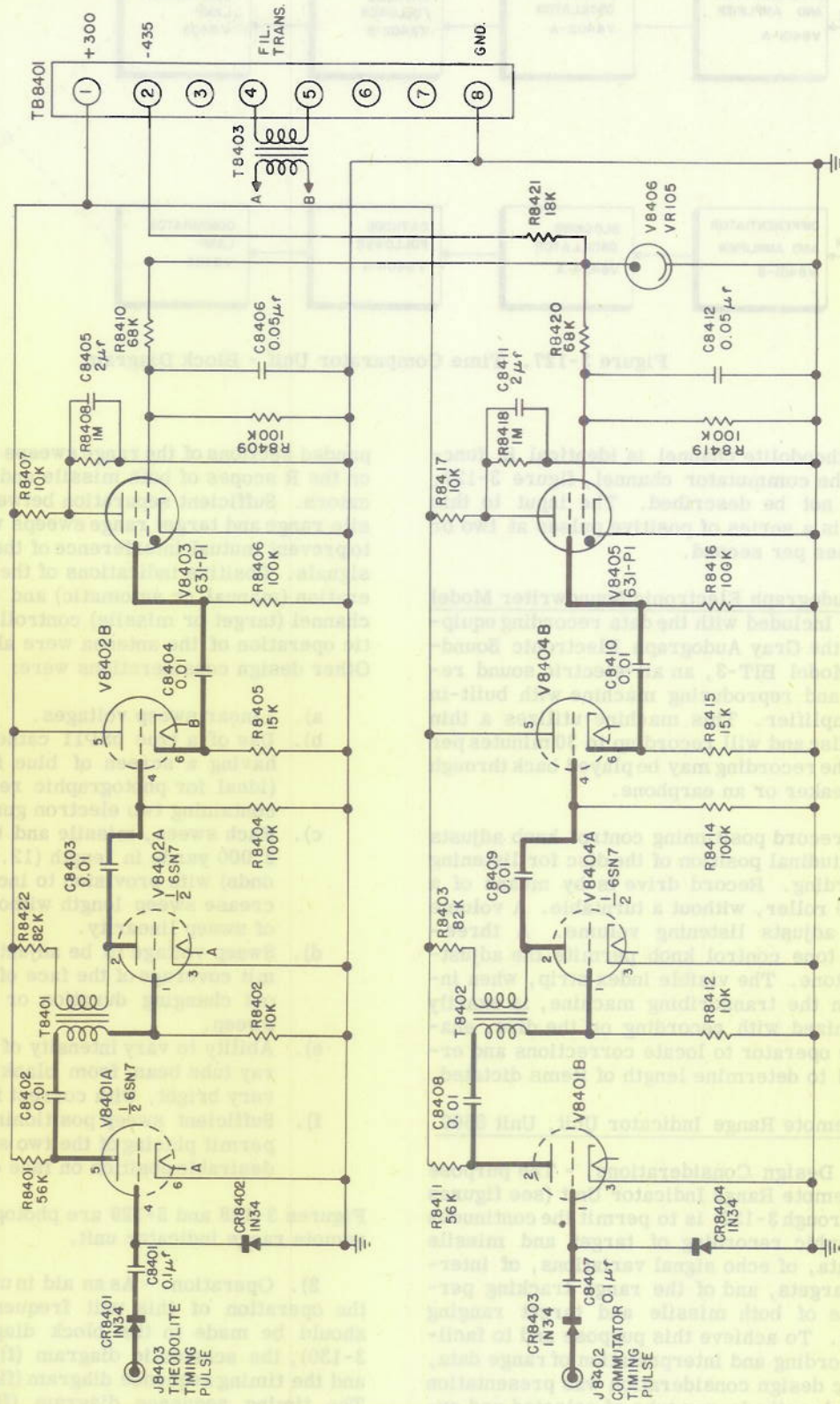


Figure 3-126. Time Comparator Unit - Schematic Diagram

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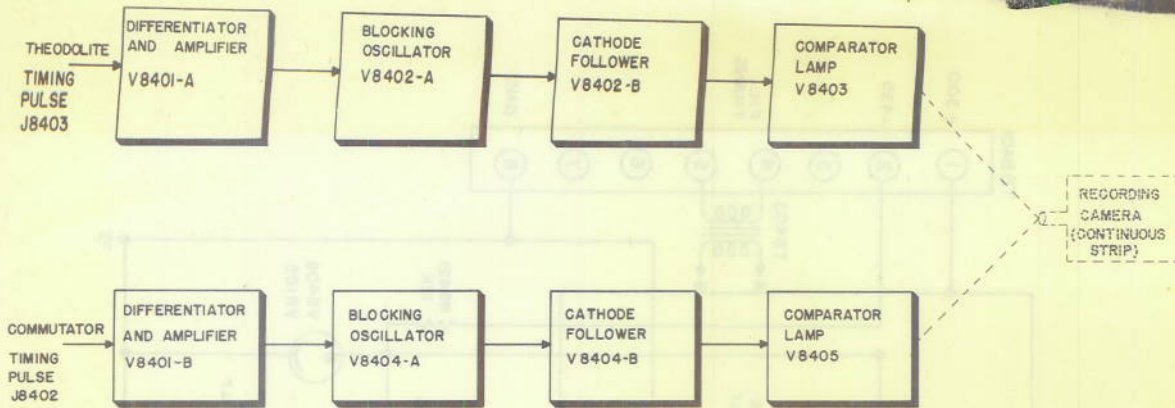


Figure 3-127. Time Comparator Unit - Block Diagram

The theodolite channel is identical in function to the commutator channel, figure 3-127, and will not be described. The input to this channel is a series of positive pulses at two or four pulses per second.

e. Audograph Electronic Soundwriter Model BIT-3. - Included with the data recording equipment is the Gray Audograph Electronic Soundwriter Model BIT-3, an all-electric sound recording and reproducing machine with built-in audio amplifier. This machine utilizes a thin plastic disc and will record up to 30 minutes per side. The recording may be played back through a loudspeaker or an earphone.

The record positioning control knob adjusts the longitudinal position of the disc for listening or recording. Record drive is by means of a pressure roller, without a turntable. A volume control adjusts listening volume. A three-position tone control knob permits the adjustment of tone. The visible index strip, when inserted in the transcribing machine, is exactly synchronized with recording on the disc, enabling the operator to locate corrections and errors and to determine length of items dictated.

f. Remote Range Indicator Unit, Unit 8500.

1). Design Considerations. - The purpose of the Remote Range Indicator Unit (see figures 3-128 through 3-132) is to permit the continuous photographic recording of target and missile range data, of echo signal variations, of interfering targets, and of the range tracking performance of both missile and target ranging systems. To achieve this purpose and to facilitate recording and interpretation of range data, the basic design consideration was presentation on a single cathode-ray tube of selected and ex-

panded sections of the range sweeps as displayed on the R scopes of both missile and target indicators. Sufficient separation between the missile range and target range sweeps was required to prevent mutual interference of the gated video signals. Positive indications of the mode of operation (manual or automatic) and of the video channel (target or missile) controlling automatic operation of the antenna were also desired. Other design considerations were:

- a). Linear sweep voltages.
- b). Use of a type 5SP11 cathode-ray tube having a screen of blue fluorescence (ideal for photographic recording) and containing two electron guns.
- c). Each sweep, missile and target, to be 2,000 yards in length (12.2 microseconds) with provision to increase or decrease sweep length without distortion of sweep linearity.
- d). Sweep voltage to be adjustable to permit coverage of the face of scope without changing duration or linearity of sweep.
- e). Ability to vary intensity of the cathode-ray tube beam from blank condition to very bright, with correct focus.
- f). Sufficient sweep positioning voltage to permit placing of the two sweeps in any desirable position on face of the scope.

Figures 3-128 and 3-129 are photographs of the remote range indicator unit.

2). Operation. - As an aid in understanding the operation of this unit frequent reference should be made to the block diagram (figure 3-130), the schematic diagram (figure 3-131), and the timing sequence diagram (figure 3-132). The timing sequence diagram (figure 3-132)

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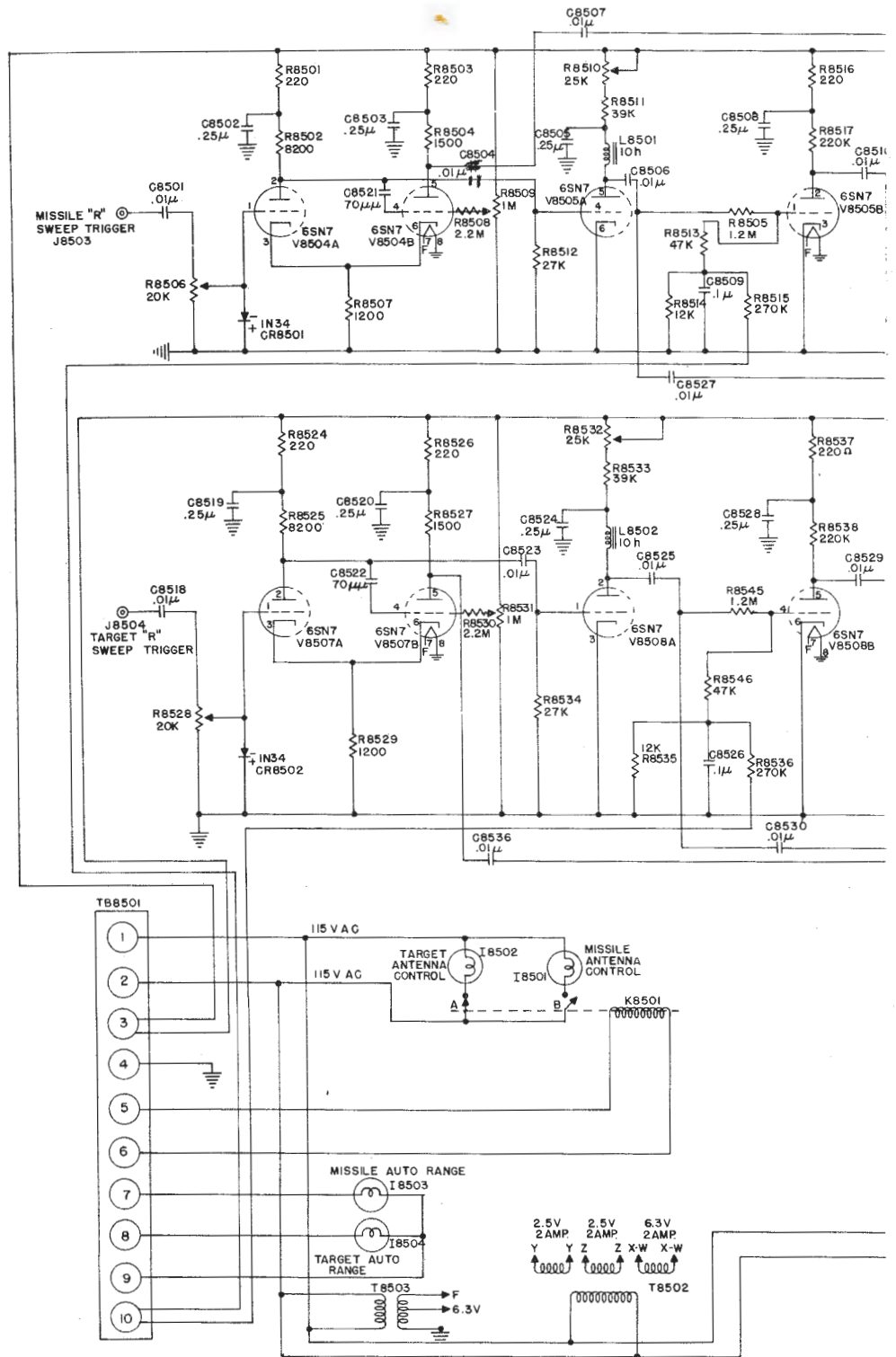
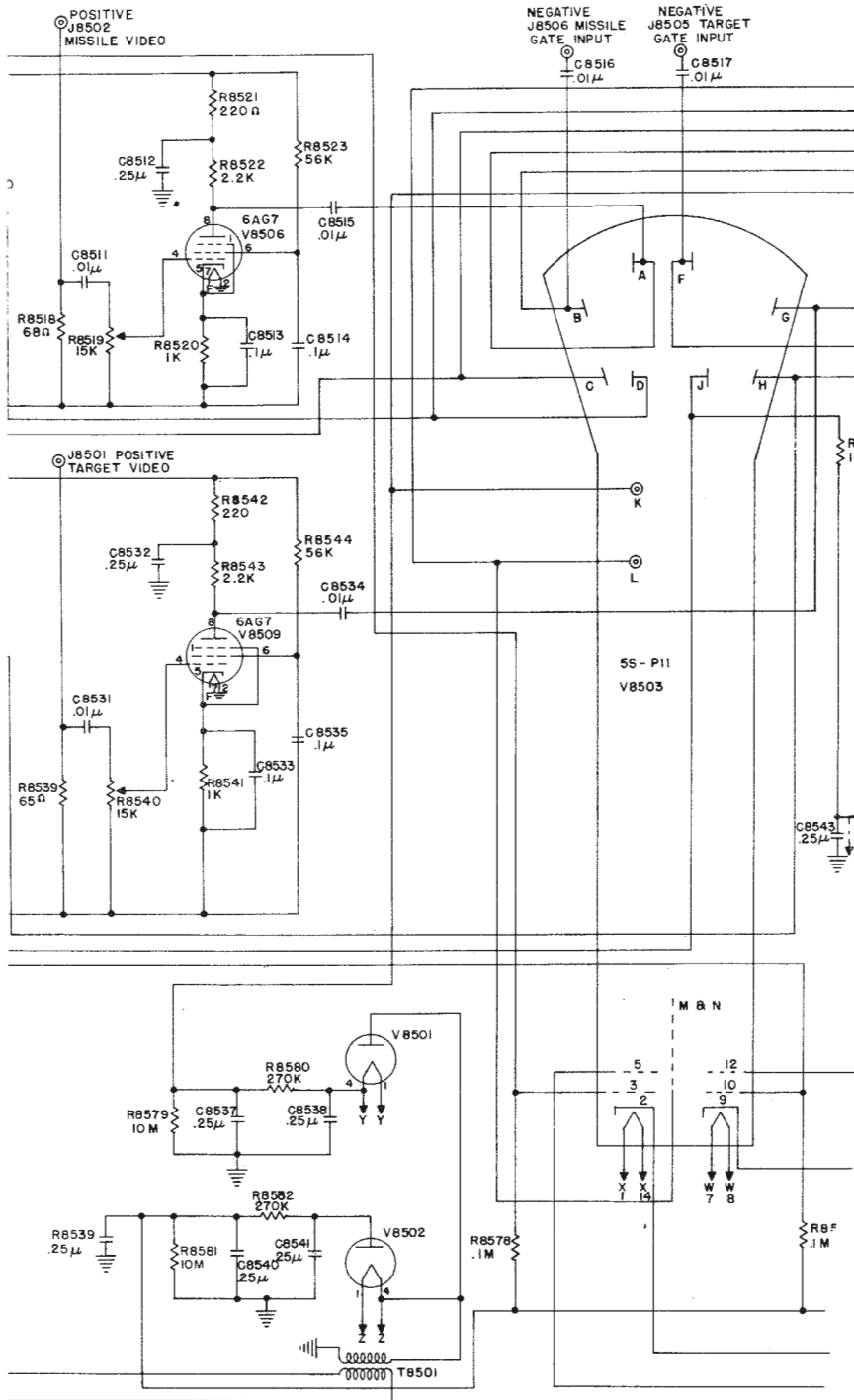
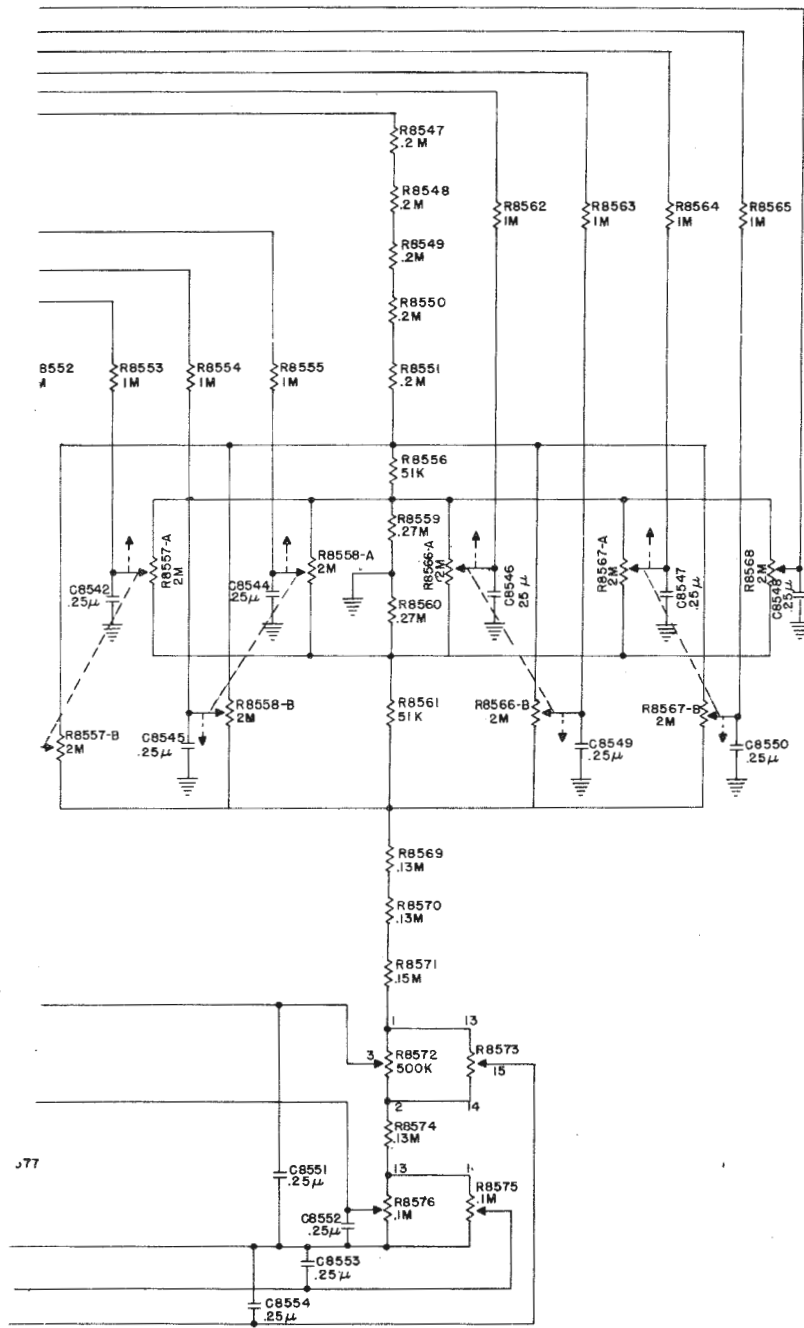


Figure 3-131. Remote Range Indicator Unit - Schematic



matic Diagram



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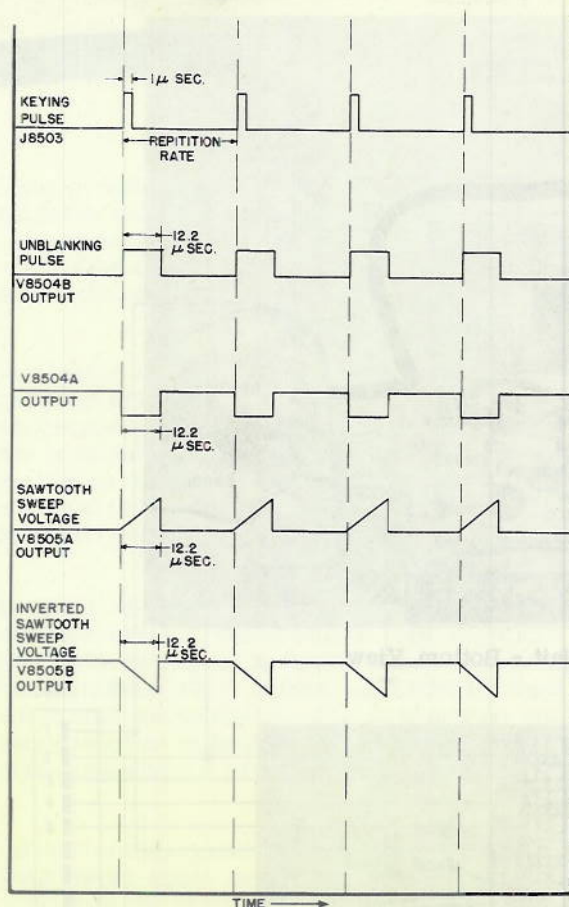


Figure 3-132. Remote Range Indicator Unit - Missile Channel Wave Forms

meter R8509 which controls the width of the pulses emitted by the single-kick multivibrator V8504A and B. This output is then fed through C8527 to one of the horizontal deflecting plates of one section of the double gun cathode-ray tube. The same signal is also fed to the grid of V8505B which inverts the signal and delivers it, 180 degrees out of phase, to the opposite horizontal deflecting plate through C8510. Figure 3-132, line 3, shows the sweep signals at the plates of V8505A and B. The potentiometer R8510 is the sweep amplitude adjustment.

The positive pulse (12.2 microseconds) from the plate of V8504B is fed through C8504 to the grid of one section of the cathode-ray tube as the unblanking voltage. Thus with each trigger pulse at jack J8503 there is initiated simultaneously, an unblanking and a sweep voltage of 12.2 microseconds duration.

At jack J8502 a positive missile video pulse is fed to the grid of V8506 a video amplifier stage, and its output which is negative is fed through C8515 to the lower vertical deflection plate of one section of the cathode-ray tube. The amplitude of the video pulse is adjustable by R8519.

At jack J8506 the negative missile gate signal is fed through C8516 directly to the upper vertical deflection plate.

The target channel contains the same circuits as the missile channel and operates in the same manner with the exception that its outputs are fed to the other section of the double-gun cathode-ray tube and that its inputs are initiated by target signals.

V8501 and V8502, connected in a voltage doubling circuit, form the d-c high voltage supply for the cathode-ray tube, V8503. The voltage divider for obtaining the intensity, focus, and vertical and horizontal deflection potentials is conventional with the exception that, since the cathode-ray tube contains two guns, two sets of controls are required.

Four front panel indicator lights I8501, I8502, I8503 and I8504 are placed near the face of the cathode-ray tube. Lights I8501 and I8502 indicate whether the missile or target channel is controlling automatic operation of the antenna. Lights I8503 and I8504 indicate whether system operation is manual or automatic.

3). Adjustment and Alignment of Equipment.

- Adjustment and alignment of the instrument is done with the radar in operating condition. In order to adjust the height of the presentation of the video signals on the cathode-ray tube it is necessary that targets be gated. A synchroscope is required for adjustment.

With the radar equipment energized there will be an R-sweep trigger generated whose amplitude may be adjusted by the potentiometer R8506. Apply the output (plate) voltage of V8504B to the synchroscope. Then adjust R8506 until there is positive action of the single-kick multivibrator V8504A and V8504B. R8508 is then adjusted to give a pulse 12.2 microseconds wide as shown on the synchroscope. Place the input of the synchroscope on the output of the sweep generator circuit V8505A. The sweep duration should be 12.2 microseconds; it may be necessary to make a slight adjustment of potentiometer R8508 until the sweep is exactly 12.2 microseconds long. While looking at the presentation on the cathode-ray tube V8503, adjust the amplitude potentiometer R8510 until the sweep covers the face of the tube.

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Subsection 3-7. Analysis and Interpretation of Recorded Data

1. INTRODUCTION

a. Data recording equipment is an integral part of the Lark SP-1M Radar and is used to make the system a complete guidance and evaluation unit, independent of other facilities. In order that definite conclusions be determined regarding a particular Lark flight, the data recorded in the Lark SP-1M during the flight must be subjected to a detailed analysis. Since the purpose of each flight will probably be somewhat different from that of other flights, it will be impractical to give a comprehensive discussion of all the different analysis procedures which may be required. However, most of the techniques of data analysis can be shown by considering a single flight. The succeeding paragraphs of this subsection, therefore, give a discussion of the flight of Lark XSAM-4, Serial 91. Although this flight was conducted primarily to evaluate the characteristics of noise in the Lark SP-1M system, many of the analysis techniques used here can be applied to other flights.

b. The Lark missile XSAM-4, Serial 91, was launched from the Convair short-length launcher at the Naval Ordnance Test Station, Inyokern, California, on 21 January 1949. The purpose of the flight was to determine the nature of the noise in the NRL mid-course guidance system operated in an "open-loop" condition. The Lark SP-1M was operated in conjunction with the AN/APW-4 mid-course guidance receiver and the transmitter portion of the AN/DPN-3 beacon, both of which were located in the missile. The guidance receiver was not used to control the missile in this flight. The Lark SP-1M, in automatic control, tracked the missile from the launcher, and pertinent data regarding the operation of the AN/APW-4 receiver were telemetered back to the ground station throughout the flight. Additional data were recorded photographically at the Lark SP-1M to determine its tracking performance on a beacon-equipped missile and to evaluate its capabilities as an independent system for determining missile position. Trajectory data as given by the Askania theodolite system at NOTS were used as the standard in estimating the accuracy of the NRL-determined flight path.

c. The quantities needed to determine missile position were recorded at the Lark SP-1M site by means of synchronized, synchro-driven, 16-mm, motion-picture cameras driven at ten frames per second from the Lark SP-1M power supply. The recorded data include:

1). The deviations of the radar line-of-sight from the missile as recorded by two tracking cameras located on the radar antenna mount. (One tracking camera was equipped with a 21-inch lens with a built-in reticule, the other with a standard 6-inch lens.)

2). Bearing and elevation of the radar line-of-sight, echo and beacon range to the missile, Lark SP-1M mode of operation, and crosspointer meter information regarding the position of the missile in the radar beam. (These quantities are presented on the face of the "dial box" located in the operations trailer and are recorded by the dial-box camera.)

3). Time markers indicating the times at which the NRL synchronized camera shutters were open and the times of the pulses which actuate the NOTS theodolites. (The marker pulses are presented as slits of light on the face of the time-comparator unit located in the operations trailer and are recorded by a continuous-strip camera.)

It had been planned to photograph the "echos" in both the echo and beacon range gates; however, technical difficulties before this particular flight prevented recording these quantities. (All other flights have these data included.)

2. TRACKING PERFORMANCE OF THE LARK SP-1M

a. The tracking deviations of the radar line-of-sight from the missile were recorded by two cameras located on the radar antenna mount. One tracking camera employed a 21-inch lens with built-in reticule to provide suitable magnification of the image in those regions where the tracking deviations were small. In order to record larger tracking deviations, an additional tracking camera with a standard 6-inch lens was used. Representative frames from the films exposed in the two tracking cameras during the flight are shown in photographs (a) through (e) in figure 3-136. Photographs (a), (c), and (e), taken by the camera with the 6-inch lens, show the missile on the launcher, at booster separation, and at the apex of the trajectory. A frame of film exposed in this camera represents a field of view of 2.71 by 3.64 degrees. The small dark object in the lower right hand corner of photograph (c) is the booster unit shortly after its separation from the missile proper. Pictures of the missile on the launcher and at booster separation, as taken by the camera with the 21-inch lens, are shown in (b) and (d). The dis-

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tance from the center of the crosshairs to the first index mark represents an angular measure of 0.10 degree. Pictures (c) and (d) were taken at the same point in the missile trajectory; however, the booster is not visible in (d) because of the restricted field of view associated with the 21-inch lens.

b. Prior to the flight, tracking runs were made on an SNB aircraft flying radial courses in order that the tracking cameras could be collimated with the Lark SP-1M line-of-sight. Collimation was effected by viewing the aircraft image through a standard critical focuser in each of the cameras as the Lark SP-1M tracked the aircraft, and by adjusting each of the cameras so that the mean tracking was very nearly coincident with the crosshairs in the 21-inch lens and the center of the frame in the 6-inch lens.

c. Tracking corrections, i.e., differences of the angular positions of the missile and the Lark SP-1M line-of-sight, were measured by projecting each individual frame of the tracking films on a suitably calibrated screen. The center of the crosshairs was used as the zero reference for the tracking film taken with the 21-inch lens. The corresponding point on the 6-inch film was established on the first frame, and this point was used as the zero reference for all succeeding frames. Each frame of both films was projected on a calibrated screen, and the lateral and vertical tracking corrections were measured to the nearest hundredth of a degree. The recorded tracking corrections were later added to the angular positions of the Lark SP-1M line-of-sight to obtain the angular positions of the missile with respect to the Lark SP-1M location.

d. Tracking errors of the Lark SP-1M during the flight are presented graphically in figure 3-137. Lateral and vertical deviations of the Lark SP-1M line-of-sight from the missile in mils (milliradians) have been plotted every half-second in order to provide an estimate of the tracking performance of the Lark SP-1M. Time in seconds measured from the booster ignition time and the range to the missile in yards are indicated on the abscissa. Discontinuities in the tracking error curves near the end of the flight were caused by inability to identify the missile on the tracking film. The means and the standard deviations of the lateral and vertical tracking errors were computed and are tabulated below:

Mean		Radial "h"	Standard Deviation		Radial "s"
Lat.	Vert.		Lat.	Vert.	
-1.6 mils (-0.09°)	0.5 mils (0.03°)	1.6 mils (0.09°)	1.4 mils (0.08°)	1.4 mils (0.08°)	1.4 mils (0.08°)

The values listed are expressed in mils, and equivalent values in degrees are shown in parentheses. Radial "h" combines the lateral and vertical means (defined as the square root of the sum of the squares of the lateral and vertical means). Radial "s" is given to combine lateral and vertical standard deviations and is equal to the square root of one-half the sums of the squares of the lateral and vertical standard deviations. In computing the means and the standard deviations the boost phase (zero to 5.5 seconds) has been excluded, because the tracking problem during this period was not considered to be representative. For the most part, the magnitude of the means can be attributed to the procedure used in collimating the tracking cameras with the radar line-of-sight. The standard deviations obtained here are comparable with those for tracking runs with the Lark SP-1M on a beacon-equipped SNB aircraft.

3. DETERMINATION OF MISSILE POSITION

a. A synchronized camera located in the Lark SP-1M operations trailer was used to photograph the face of a box containing dials which indicated values of the radar elevation angle (REbc and REbf), radar bearing angle (RBrc and RBrf), echo range (TRc and TRf), and beacon range (MRc and MRf). The c and f on the dial indications refer to the coarse and fine dials respectively. A picture of the face of the dial box is shown in (f) of figure 3-136. The six lights located in the central portion of the box indicate the mode of operation of the Lark SP-1M. The cross-pointer meters indicate information regarding the position of the missile in the radar beam, and the two dials (CRc and CRf) on the right side of the dial box were not used during this flight.

b. In order to correlate the Lark SP-1M data with those obtained by other instrumentation facilities, the exposure times of the NRL cameras and the time markers used to actuate the theodolites were recorded by a time-comparator camera located in the operations trailer. This camera is of the continuous-strip type and is used to photograph two strobos, each located behind a narrow slit in the face of the time-comparator unit. One strobos was fired by the radio time signals used to actuate the NOTS Askania theodolites, the other by a commutator which operated each time the shutters in the NRL synchronized cameras reached their maximum

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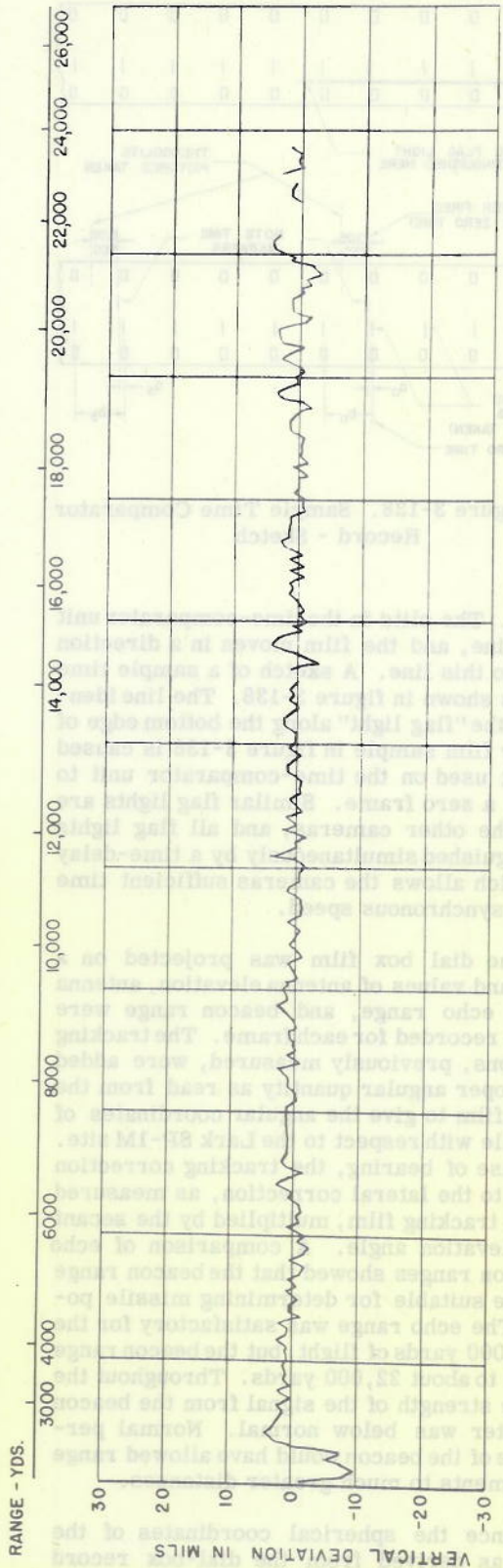
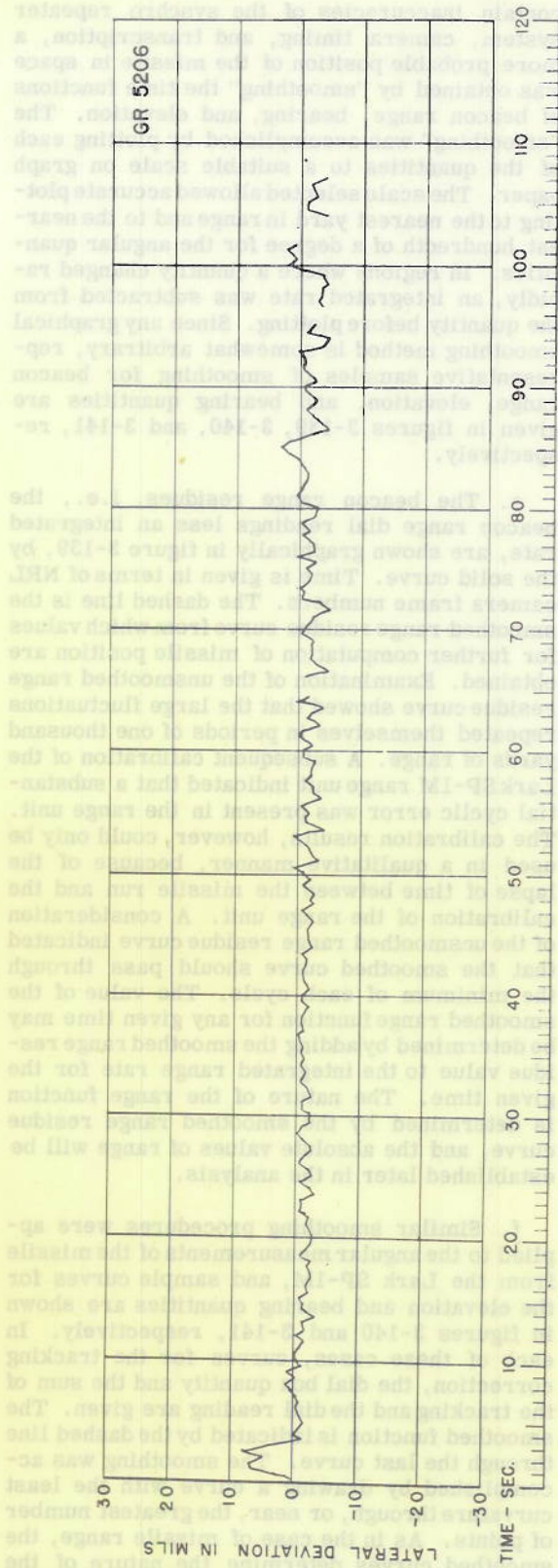


Figure 3-137. Lark SP-1M Automatic Tracking Errors - Beacon Operation, XSAM-4 Missile Serial 91, Receding Course

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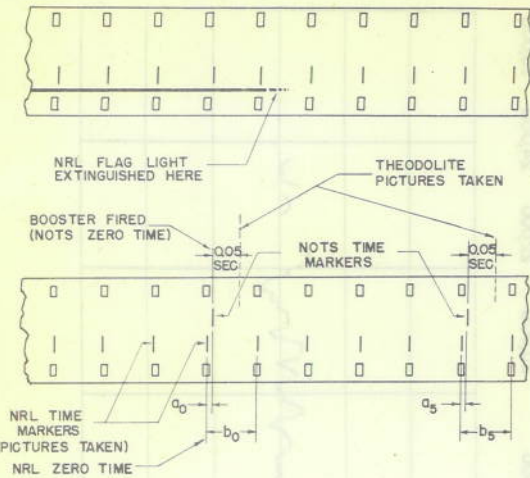


Figure 3-138. Sample Time Comparator Record - Sketch

openings. The slits in the time-comparator unit lie on a line, and the film moves in a direction normal to this line. A sketch of a sample time record is shown in figure 3-138. The line identified as the "flag light" along the bottom edge of the upper film sample in figure 3-138 is caused by a light used on the time-comparator unit to establish a zero frame. Similar flag lights are used in the other cameras, and all flag lights are extinguished simultaneously by a time-delay relay which allows the cameras sufficient time to attain synchronous speed.

c. The dial box film was projected on a screen, and values of antenna elevation, antenna bearing, echo range, and beacon range were read and recorded for each frame. The tracking corrections, previously measured, were added to the proper angular quantity as read from the dial-box film to give the angular coordinates of the missile with respect to the Lark SP-1M site. In the case of bearing, the tracking correction is equal to the lateral correction, as measured from the tracking film, multiplied by the secant of the elevation angle. A comparison of echo and beacon ranges showed that the beacon range was more suitable for determining missile position. The echo range was satisfactory for the first 13,000 yards of flight, but the beacon range was good to about 22,000 yards. Throughout the flight the strength of the signal from the beacon transmitter was below normal. Normal performance of the beacon would have allowed range measurements to much greater distances.

d. Since the spherical coordinates of the missile as derived from the dial-box record

contain inaccuracies of the synchro repeater system, camera timing, and transcription, a more probable position of the missile in space was obtained by "smoothing" the time functions of beacon range, bearing, and elevation. The "smoothing" was accomplished by plotting each of the quantities to a suitable scale on graph paper. The scale selected allowed accurate plotting to the nearest yard in range and to the nearest hundredth of a degree for the angular quantities. In regions where a quantity changed rapidly, an integrated rate was subtracted from the quantity before plotting. Since any graphical smoothing method is somewhat arbitrary, representative samples of smoothing for beacon range, elevation, and bearing quantities are given in figures 3-139, 3-140, and 3-141, respectively.

e. The beacon range residues, i.e., the beacon range dial readings less an integrated rate, are shown graphically in figure 3-139, by the solid curve. Time is given in terms of NRL camera frame numbers. The dashed line is the smoothed range residue curve from which values for further computation of missile position are obtained. Examination of the unsmoothed range residue curve showed that the large fluctuations repeated themselves in periods of one thousand yards of range. A subsequent calibration of the Lark SP-1M range unit indicated that a substantial cyclic error was present in the range unit. The calibration results, however, could only be used in a qualitative manner, because of the lapse of time between the missile run and the calibration of the range unit. A consideration of the unsmoothed range residue curve indicated that the smoothed curve should pass through the minimum of each cycle. The value of the smoothed range function for any given time may be determined by adding the smoothed range residue value to the integrated range rate for the given time. The nature of the range function is determined by the smoothed range residue curve, and the absolute values of range will be established later in the analysis.

f. Similar smoothing procedures were applied to the angular measurements of the missile from the Lark SP-1M, and sample curves for the elevation and bearing quantities are shown in figures 3-140 and 3-141, respectively. In each of these cases, curves for the tracking correction, the dial box quantity and the sum of the tracking and the dial reading are given. The smoothed function is indicated by the dashed line through the last curve. The smoothing was accomplished by drawing a curve with the least curvature through, or near, the greatest number of points. As in the case of missile range, the smoothed curves determine the nature of the

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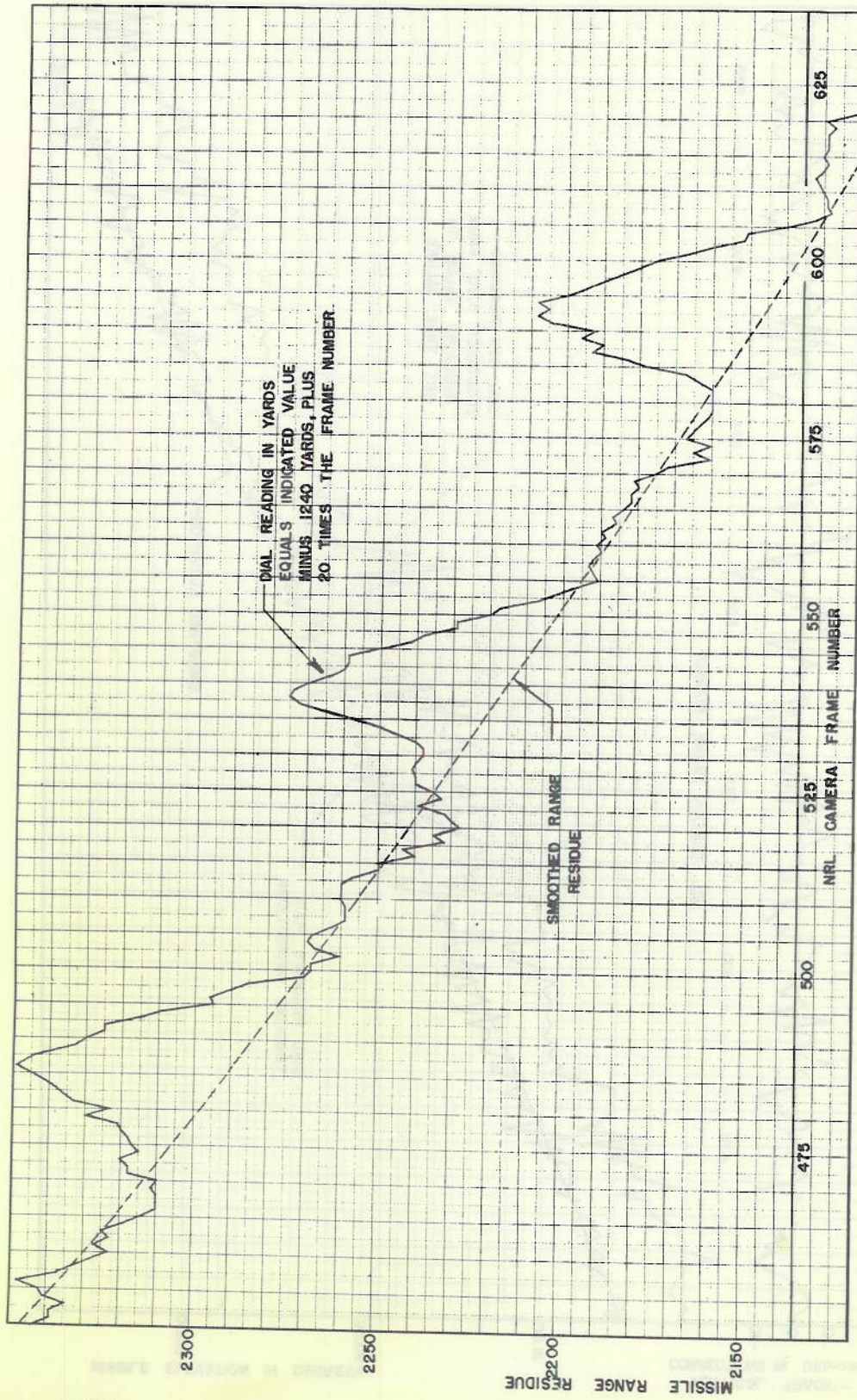


Figure 3-139. Missile Range Residues - Smoothed and Unsmoothed

Figure 3-139. Missile Range Residues - Smoothed and Unsmoothed

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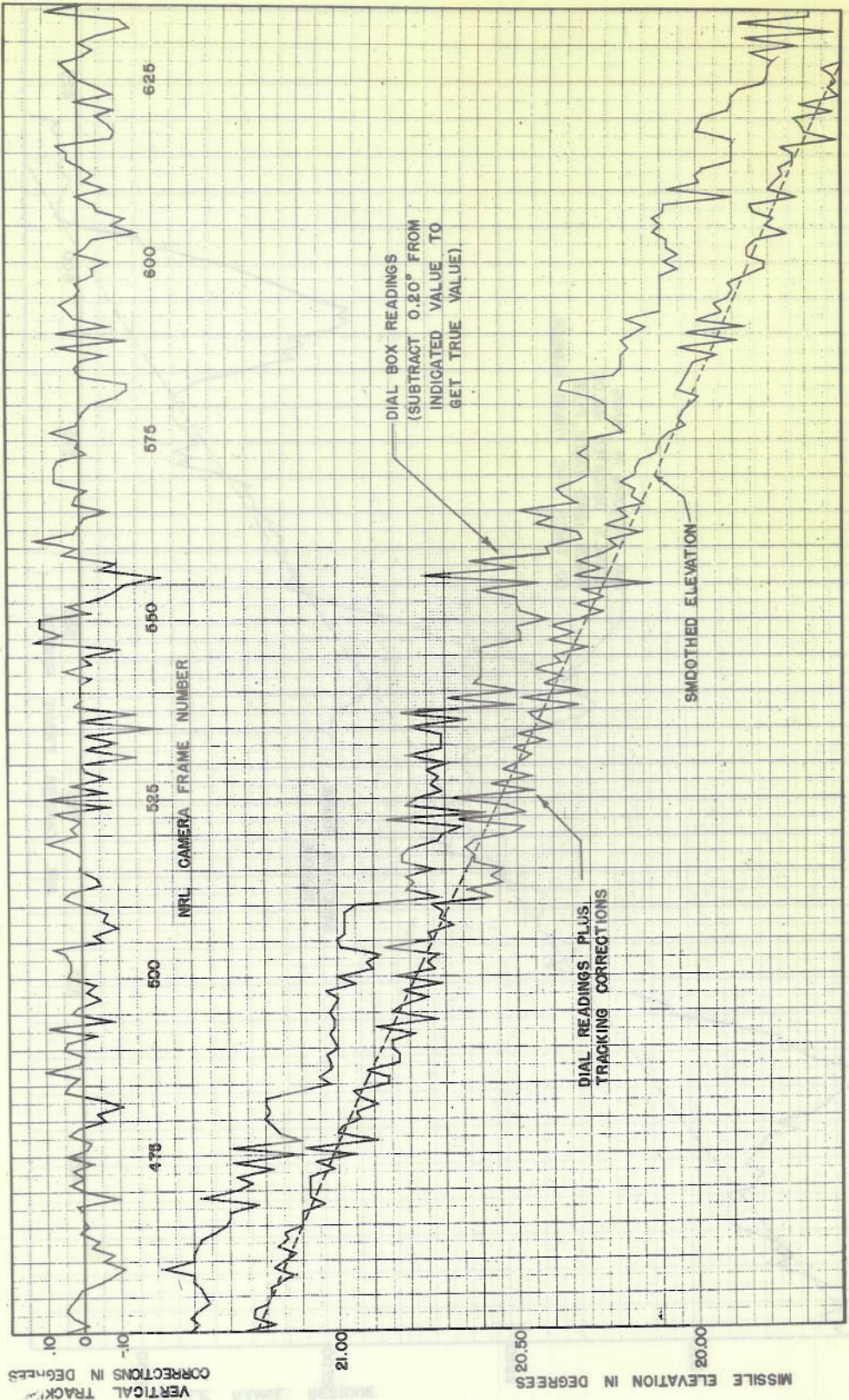


Figure 3-140. Missile Elevation Data - Smoothed and Unsmoothed

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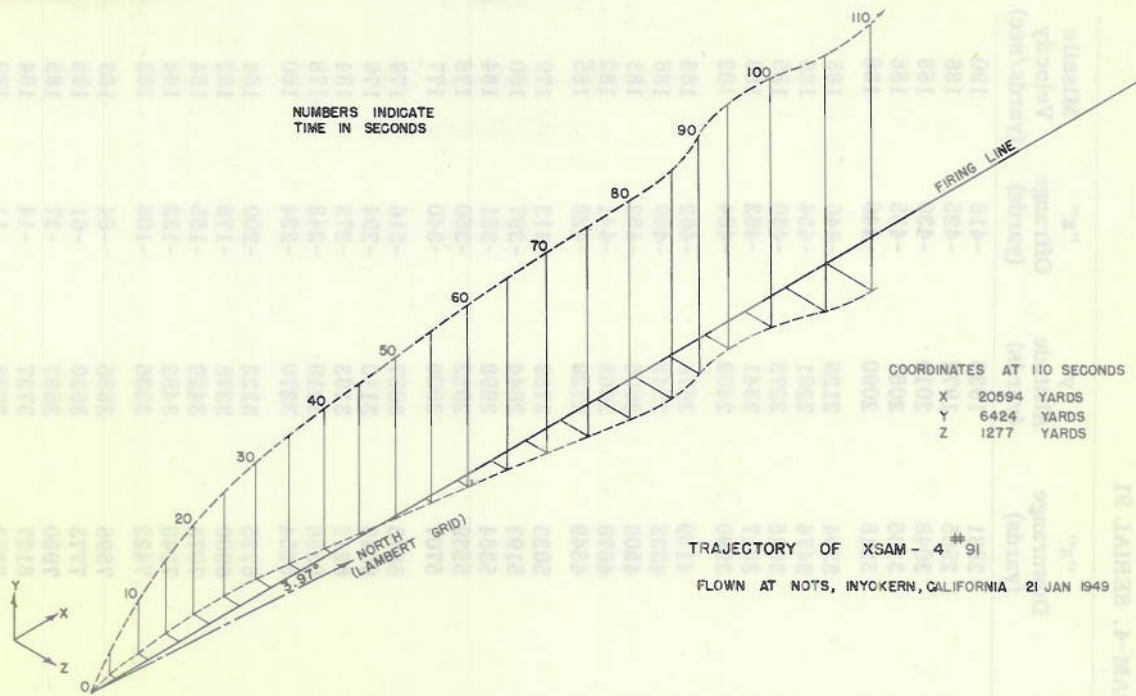


Figure 3-143. Missile Trajectory - XSAM-4, Serial 91 - Graphical Representation in Three Dimensions

inaccuracies in range as might be expected from variation in the position of the beacon signal in the range gate. Technical difficulties prevented recording these data on this flight, consequently, the nature of the beacon signal variation with the range gate is not known. The sharp oscillations toward the end of the flight data are due to roughness in the NOTS theodolite data; this can be verified by taking first differences of the NOTS calculated values.

1. The mean and standard deviation of the differences for each coordinate were calculated and are given below:

Coordinate	Mean	Standard Deviation
Down range	7.8 yards	7.2 yards
Offrange	-5.6	5.5
Altitude	8.3	5.8

Differences during the first ten seconds of the flight time were excluded because the initial acceleration of the missile introduced a considerable following error. This effect is displayed most prominently in the down-range difference curve. If normal distributions are assumed, the magnitude of the standard deviation indicates that 98 per cent of the points for any of the coordinates will lie within a region of plus or minus 22 yards of the mean.

4. FLIGHT SUMMARY

The Lark SP-1M, in automatic control, tracked the missile from the L-4 launcher to a position about 21,000 yards downrange, 1300 yards offrange, and 6400 yards altitude. The time of flight to this position was approximately 115 seconds. The strength of the signals received at the Lark SP-1M from the beacon was below normal during the entire flight. This probably accounts for the termination of the Lark SP-1M tracking at 115 seconds. No suitable tracking data were obtained from the Askania theodolites beyond about 105 seconds. Trajectory data were computed at half-second intervals for the first twenty seconds of the flight and at one-second intervals for the remainder of the instrumented flight and are given in table 3-3. A three-dimension graphical representation of the missile trajectory, based on the data of table 3-3, is shown in figure 3-143. This figure shows that the missile turned to the left and climbed as it left the launcher, turned right at about 25 seconds, and then oscillated about a line slightly east of the firing line until tracking ceased. The missile climbed continuously for about 110 seconds. Because of the termination of tracking information at about the apex of the trajectory, no estimate of the impact location could be made.

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TABLE 3-3
 TRAJECTORY DATA FOR MISSILE XSAM-4, SERIAL 91

NOTS Time (sec)	"x" Downrange (yards)	"y" Altitude (yards)	"z" Offrange (yards)	Missile Velocity (yards/sec)	NOTS Time (sec)	"x" Downrange (yards)	"y" Altitude (yards)	"z" Offrange (yards)	Missile Velocity (yards/sec)
0.05	7	4	7	0	17.55	2881	1930	-418	190
0.55	22	11	8	51	18.05	2965	1972	-425	186
1.05	52	28	7	96	18.55	3048	2010	-430	188
1.55	103	63	4	153	19.05	3135	2051	-435	188
2.05	181	109	-2	200	19.55	3218	2090	-440	186
2.55	265	179	-17	227	20.05	3304	2128	-446	185
3.05	349	257	-38	230	21.05	3474	2201	-454	186
3.55	433	329	-62	231	22.05	3645	2273	-460	185
4.05	520	403	-89	231	23.05	3817	2341	-462	186
4.55	606	473	-114	227	24.05	3990	2409	-464	182
5.05	692	543	-138	229	25.05	4159	2476	-462	185
5.55	778	617	-159	226	26.05	4332	2542	-459	186
6.05	862	687	-177	226	27.05	4506	2606	-452	183
6.55	951	758	-193	223	28.05	4678	2668	-441	182
7.05	1035	824	-207	222	29.05	4849	2729	-428	185
7.55	1128	890	-218	231	30.05	5023	2789	-413	179
8.05	1221	958	-232	232	31.05	5193	2844	-397	180
8.55	1316	1023	-245	227	32.05	5364	2898	-381	184
9.05	1410	1082	-257	224	33.05	5539	2952	-360	178
9.55	1504	1142	-269	221	34.05	5707	3006	-340	177
10.05	1595	1201	-280	211	35.05	5875	3057	-316	179
10.55	1679	1257	-291	207	36.05	6045	3110	-294	176
11.05	1769	1311	-303	207	37.05	6212	3163	-273	184
11.55	1856	1363	-313	203	38.05	6386	3216	-248	178
12.05	1942	1414	-325	201	39.05	6554	3270	-224	180
12.55	2027	1465	-338	204	40.05	6725	3322	-200	184
13.05	2116	1517	-350	205	41.05	6900	3376	-178	182
13.55	2203	1568	-358	197	42.05	7073	3429	-155	184
14.05	2287	1614	-366	196	43.05	7248	3482	-132	184
14.55	2373	1663	-374	199	44.05	7422	3536	-108	183
15.05	2460	1711	-382	197	45.05	7596	3586	-84	186
15.55	2545	1758	-390	193	46.05	7773	3638	-61	185
16.05	2629	1802	-397	191	47.05	7950	3687	-37	185
16.55	2714	1845	-405	188	48.05	8127	3737	-14	184
17.05	2796	1887	-412	188	49.05	8302	3788	11	189

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TABLE 3-3
TRAJECTORY DATA FOR MISSILE XSAM-4, SERIAL 91 (Continued)

NOTS Time (sec)	"x" Downrange (yards)	"y" Altitude (yards)	"z" Offrange (yards)	Missile Velocity (yards/sec)	NOTS Time (sec)	"x" Downrange (yards)	"y" Altitude (yards)	"z" Offrange (yards)	Missile Velocity (yards/sec)
50.05	8483	3836	38	185	85.05	15217	5407	1047	206
51.05	8661	3880	62	188	86.05	15417	5454	1035	205
52.05	8840	3931	89	186	87.05	15615	5496	1004	207
53.05	9018	3979	116	185	88.05	15813	5540	963	210
54.05	9196	4023	143	190	89.05	16009	5590	907	207
55.05	9378	4071	169	186	90.05	16200	5641	847	204
56.05	9557	4117	193	185	91.05	16391	5686	792	211
57.05	9734	4164	220	188	92.05	16592	5727	742	211
58.05	9914	4211	247	188	93.05	16796	5761	700	202
59.05	10094	4256	275	190	94.05	16994	5793	674	224
60.05	10276	4301	303	191	95.05	17216	5822	658	220
61.05	10460	4343	332	197	96.05	17433	5859	651	218
62.05	10649	4389	363	193	97.05	17649	5888	657	219
63.05	10834	4435	391	196	98.05	17865	5917	673	222
64.05	11022	4482	419	200	99.05	18083	5949	697	231
65.05	11214	4527	451	199	100.05	18308	5974	742	240
66.05	11406	4572	479	201	101.05	18535	6009	812	244
67.05	11599	4619	512	198	102.05	18764	6039	891	244
68.05	11789	4664	543	200	103.05	18995	6081	958	238
69.05	11982	4707	574	200	104.05	19221	6124	1018	237
70.05	12174	4752	606	203	105.05	19447	6171	1071	239
71.05	12369	4797	639	201	106.05	19675	6222	1121	238
72.05	12563	4841	670	202	107.05	19905	6269	1162	239
73.05	12758	4885	702	204	108.05	20134	6323	1202	242
74.05	12955	4927	737	207	109.05	20364	6387	1239	236
75.05	13155	4968	772	206	110.05	20594	6424	1277	246
76.05	13354	5012	805	209	111.05	20836	6447	1312	248
77.05	13556	5055	838	212	112.05	21081	6452	1351	247
78.05	13761	5100	866	210	113.05	21325	6457	1387	
79.05	13965	5143	895	214					
80.05	14173	5184	925	215					
81.05	14382	5227	949	220					
82.05	14594	5275	982	217					
83.05	14804	5321	1013	212					
84.05	15011	5361	1037	211					

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Subsection 3-8. Power Sources and Distribution System

1. GENERAL

The primary power required to operate the Lark SP-1M is 15-kva, 3-phase, 120-volt, 60-cycle alternating current; regulated to ± 0.25 cycles per second and ± 0.5 volts. This power may be supplied from either mobile or station sources.

a. Station Power. - The Lark SP-1M can be operated from 120-volt, 3-wire, 3-phase, 60 ± 0.25 cycle, alternating current directly; or by 120-volt, 4-wire, 3-phase, 60 ± 0.25 cycle, alternating current, or 220-volt, 3- or 4-wire, 3-phase, 60 ± 0.25 cycle, alternating current, by use of the transformer bank in the Mobile Power Unit, PE137A.

Because of excessive variations in line voltage of the station a-c power source supplied to the Lark SP-1M Serial 77, it was necessary to install an a-c voltage regulator. (See figures 3-144 through 3-148. Regulation was accomplished by rectifying a sample of the a-c voltage at the filament transformer primaries and comparing this d-c voltage with a fixed d-c voltage. The changing d-c difference voltage was fed to a balanced modulator. The a-c output of the modulator was amplified and used to control an a-c servo motor which drove a three-phase variac coupled in series with the station power input so that variac output would add to or subtract from the station power voltage as required. The regulator is designed to correct at a rate of 1 volt per second through a range of ± 10 volts.

b. Mobile A-c Power Supplies. - Two mobile a-c power supplies are integral parts of the Lark SP-1M. These are:

Power Unit PE137 and A-c Voltage Regulator, Unit 5300,
15-kw Gasoline Engine Alternator, Unit 5000.

These two units provide normal and "standby" power.

1). Power Unit PE137, Unit 5300. - Power Unit PE137 is a portable self-contained gasoline-electric power plant consisting of a four-cylinder gasoline engine driving an alternating-current generator mounted in a truck van. (See figures 3-149 and 3-150.) The output of the generator is a three-phase, four-wire, Y-connected 115-volt, 35-kva supply. The power unit van includes three transformers to convert the Y-connected three-phase system to a delta-connected system. (See figures 3-151 and 3-152.) Technical Man-

ual TM 11-921 describes the detailed operation of this power unit.

An a-c voltage regulator modification has been added to the PE137 unit, which maintains the primary voltage of the radar console filament transformers at 118 volts independent of the load. This regulator is shown in figure 3-153 and in figure 3-154. With switch S-5301 closed, a sample of the console filament transformer primary voltage is supplied as a reference voltage to the regulator unit. This voltage applies power to indicator lamp I5301, to the primary of T5304, a 2:1 stepdown transformer, and energizes relay K5301. Energizing the relay connects the 40-volt output from a preset variac VR5301, to the bridge rectifier which supplies d-c voltages to control the exciter field of the generator. When the radar equipment is turned off, relay K5301 is de-energized and the output voltage of the PE137 generator is used as a reference source.

2). 15-kw Gasoline Engine Alternator, Unit 5000. - The second a-c power source supplied with the equipment is a 15-kw (18.75 KVA, 80% pf), 60-cycle, 115-volt, three-phase power supply contained in the rear of the equipment trailer and wired directly into the power distribution panel. (See figures 3-155 and 3-156.) This power supply is sufficient to operate the radar equipment on a standby basis but cannot maintain the supply frequency within plus or minus 0.25 cycle under the varying loads placed on it during the flight of a missile.

2. A-C DISTRIBUTION UNITS

The following units are used in the Lark SP-1M to distribute the a-c power:

Power Distribution Panel, Unit 4900
D-c Motor Generator Relay Unit, Unit 6300
Power Control Unit, Unit 1400

a. Power Distribution Panel, Unit 4900. - The Power Distribution Panel, Unit 4900, located in the equipment trailer, provides the initial distribution point for all a-c power used in the Lark SP-1M. (See figures 3-157, 3-158, and 3-159.) A-c power from either Power Unit PE137 or the station power lines enters the equipment trailer and the power distribution panel (figure 3-157) through TB5109 marked "Engine Alternator No. 2." Power from the 15-kw Gasoline Engine Alternator, Unit 5000, in the equipment trailer is designated "Engine Alternator No. 1." As shown in figure 3-159,

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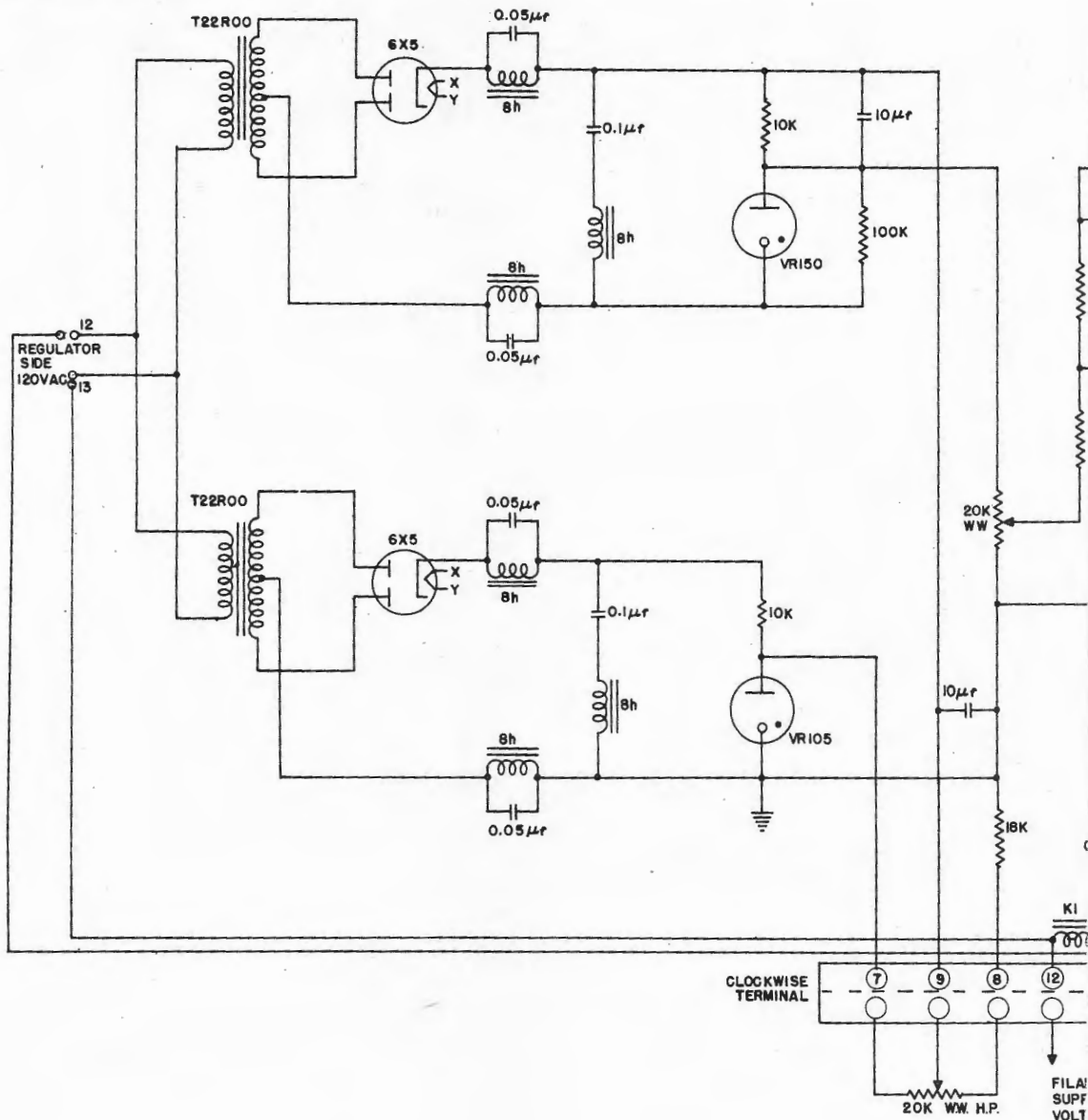
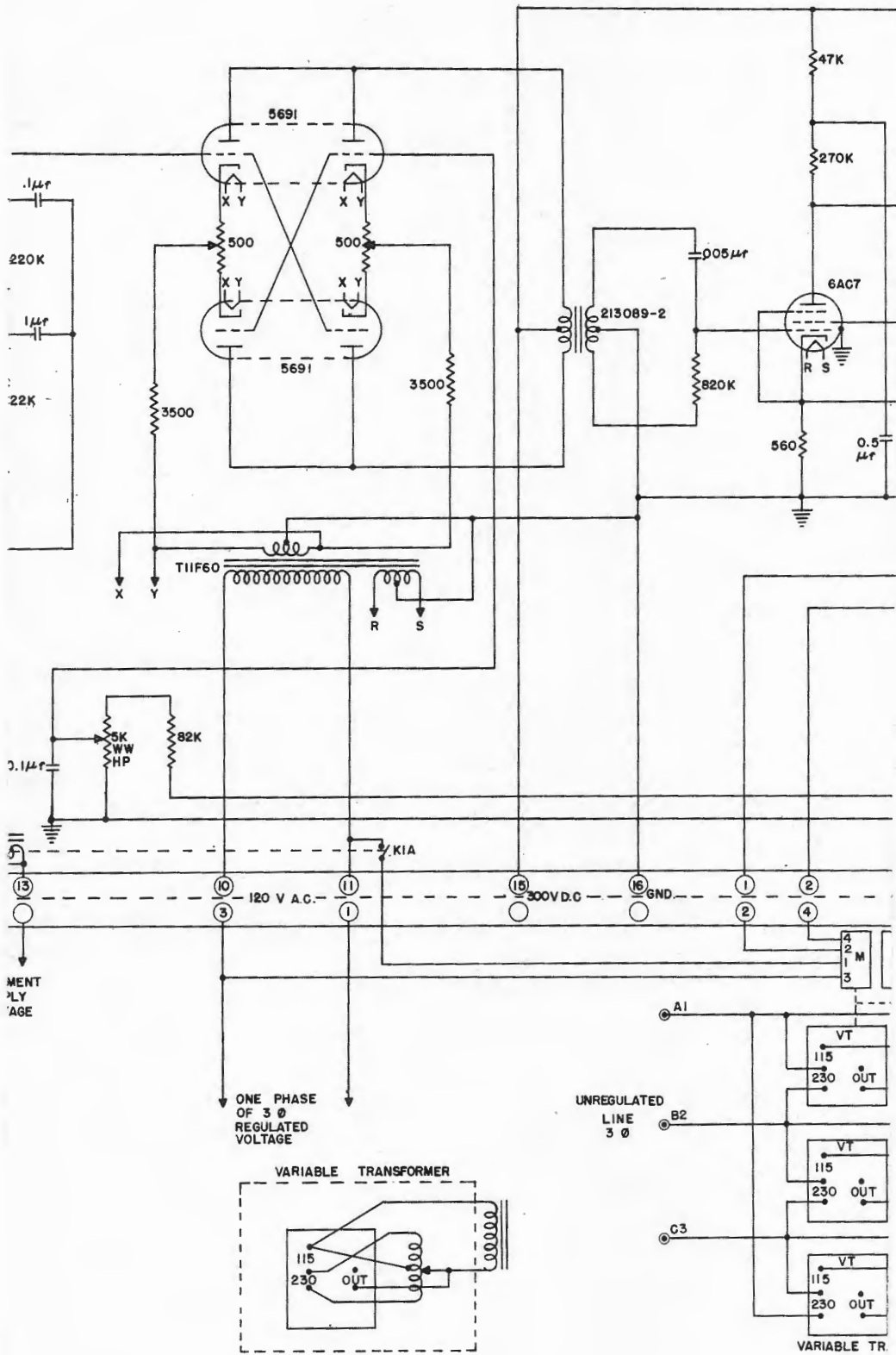
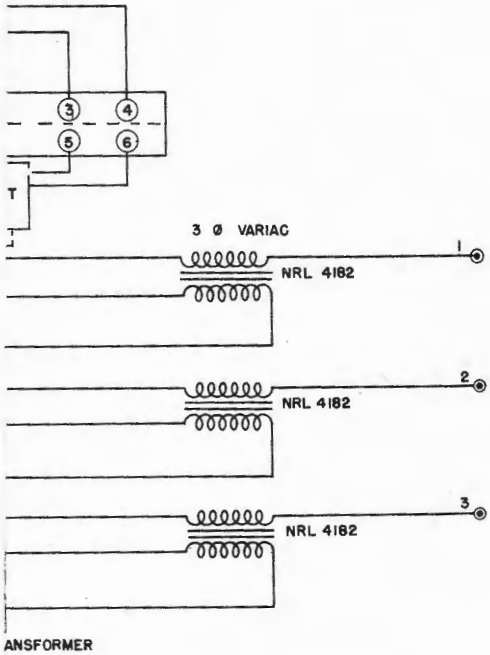
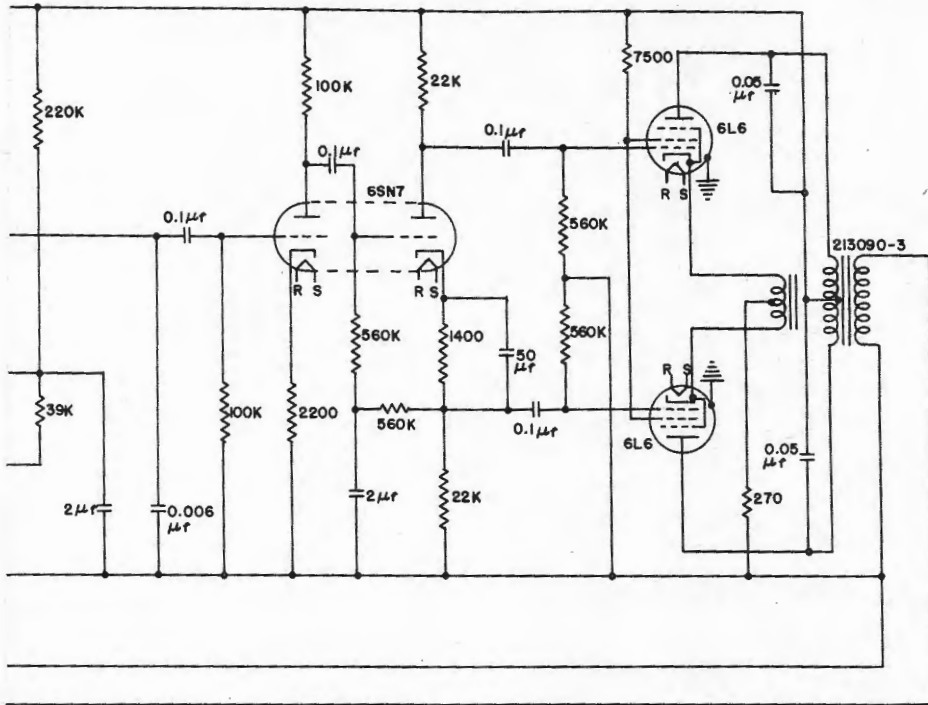


Figure 3-144. A-c Voltage Regulator - Schematic Diagram





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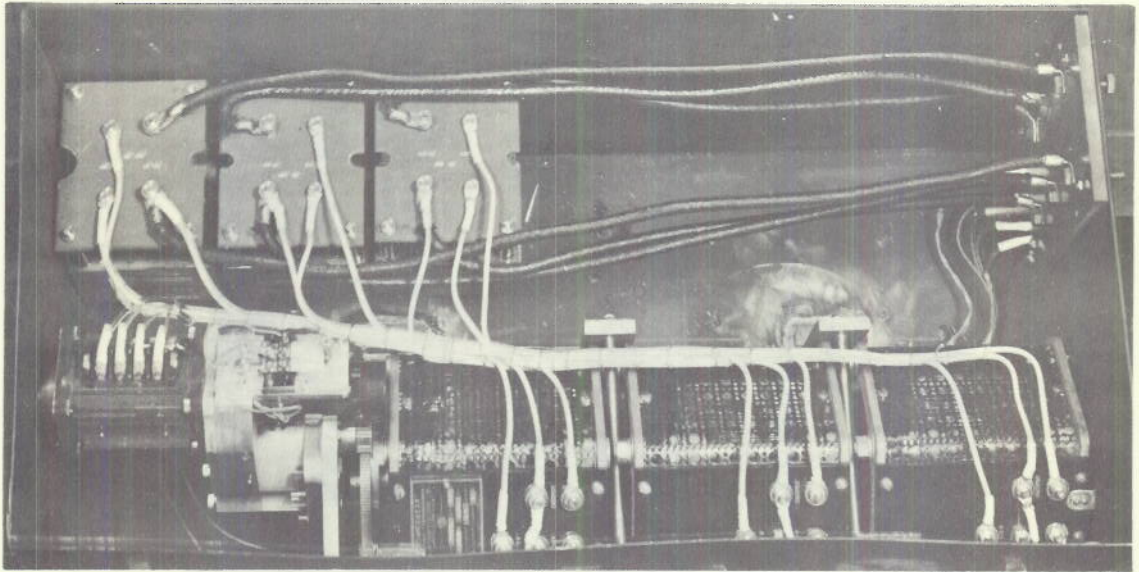


Figure 3-145. A-c Voltage Regulator Variac - Top View

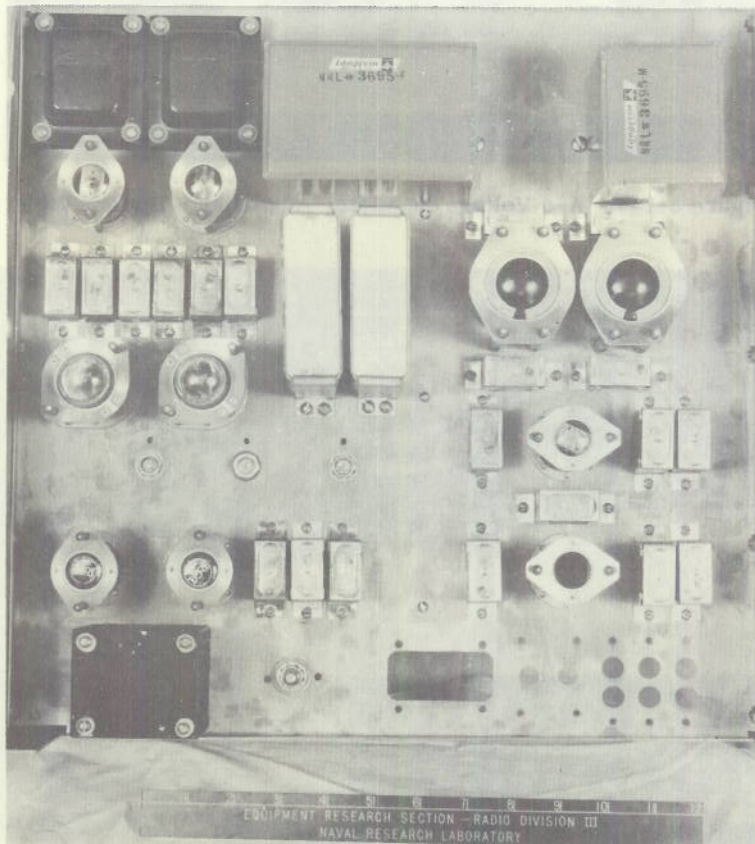


Figure 3-146. A-c Voltage Regulator Amplifier - Top View

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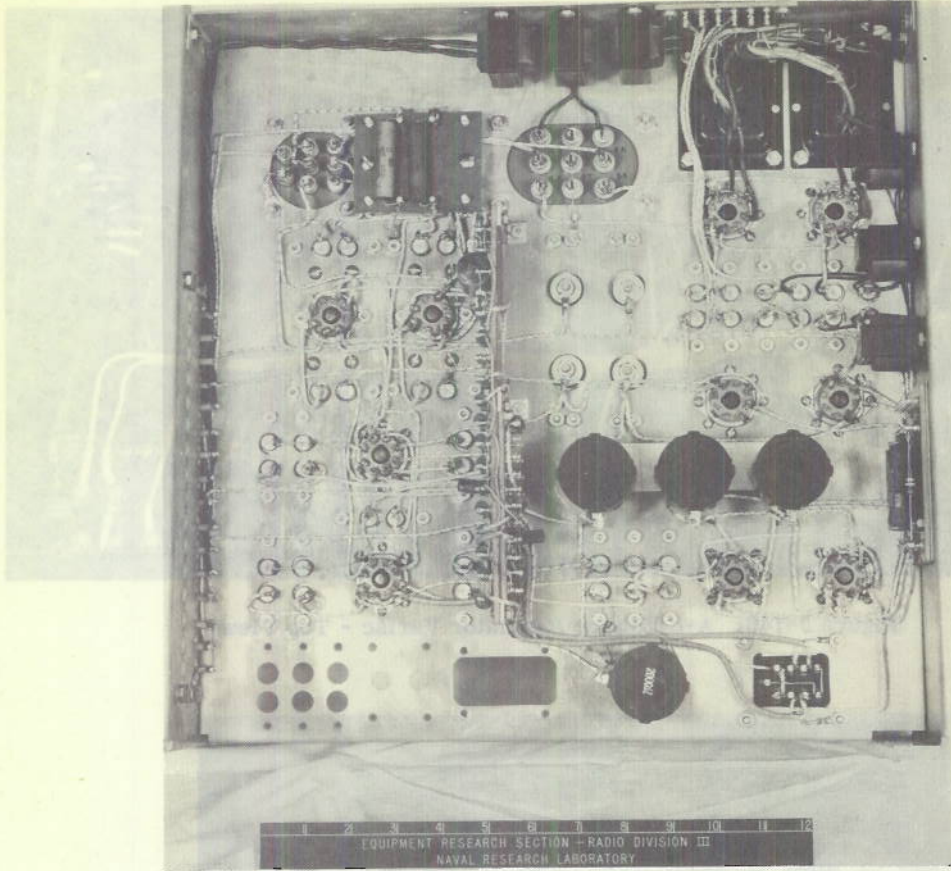


Figure 3-147. A-c Voltage Regulator Amplifier - Bottom View

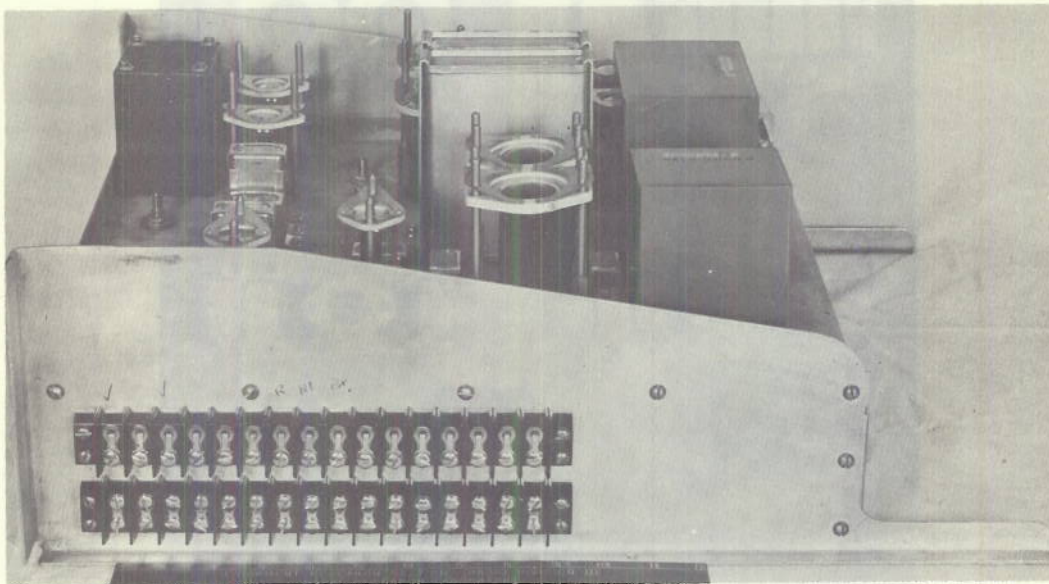


Figure 3-148. A-c Voltage Regulator Amplifier - Right Side View

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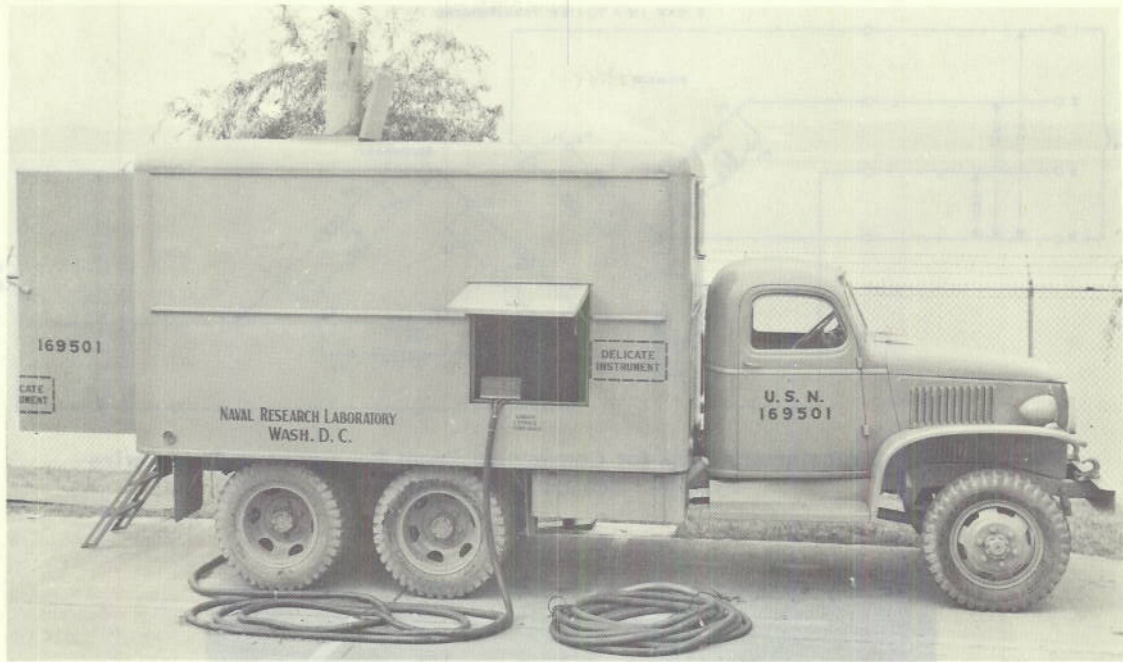


Figure 3-149. Power Unit PE137 - Left Side View

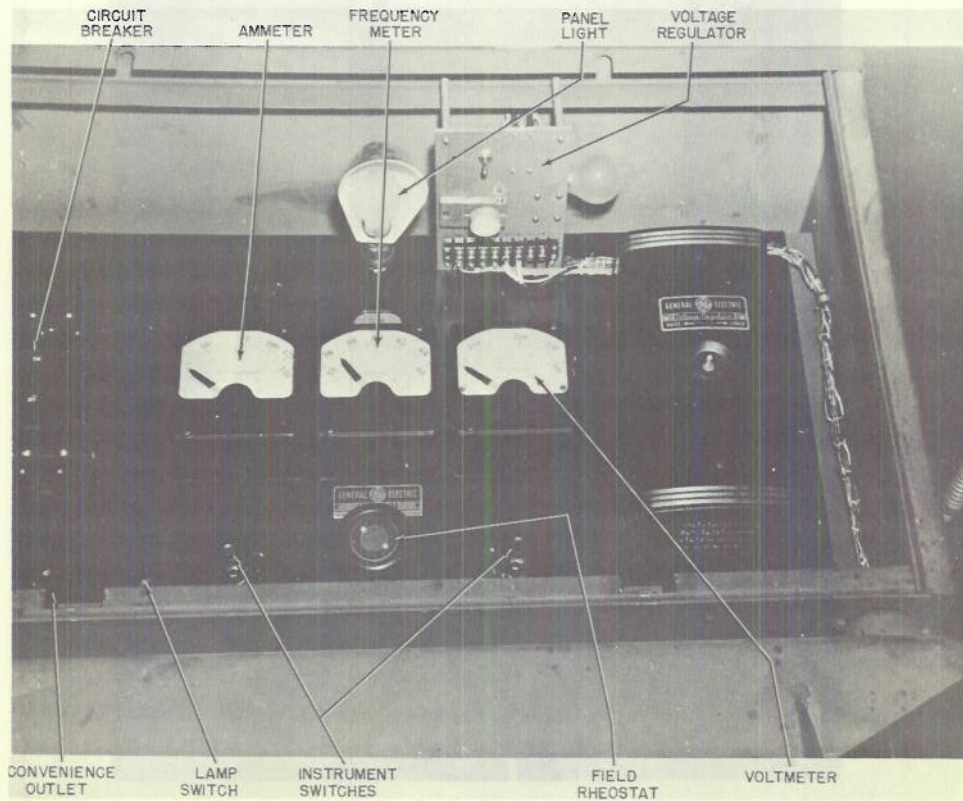


Figure 3-150. Power Unit PE137 - Control Panel

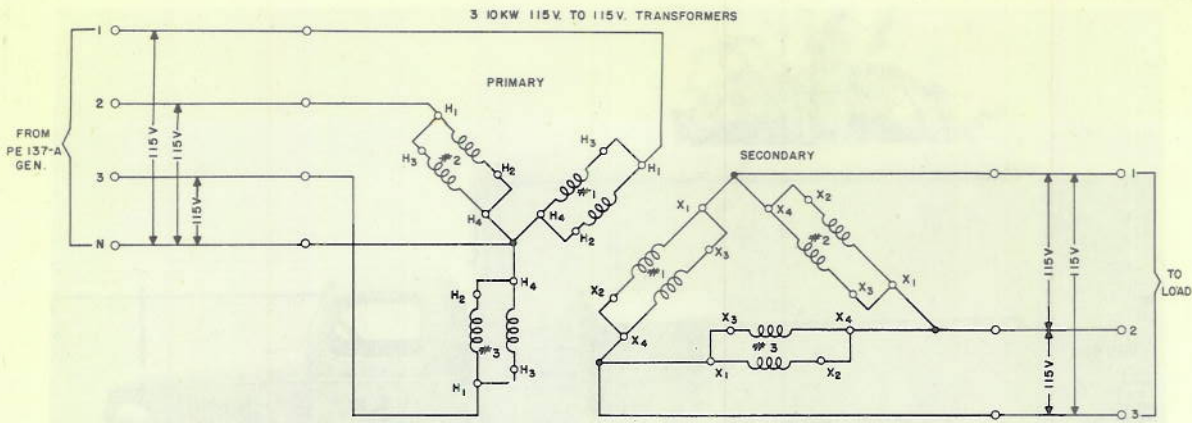


Figure 3-151. Transformer Bank for Conversion From Four-wire to Three-wire System - Schematic Diagram

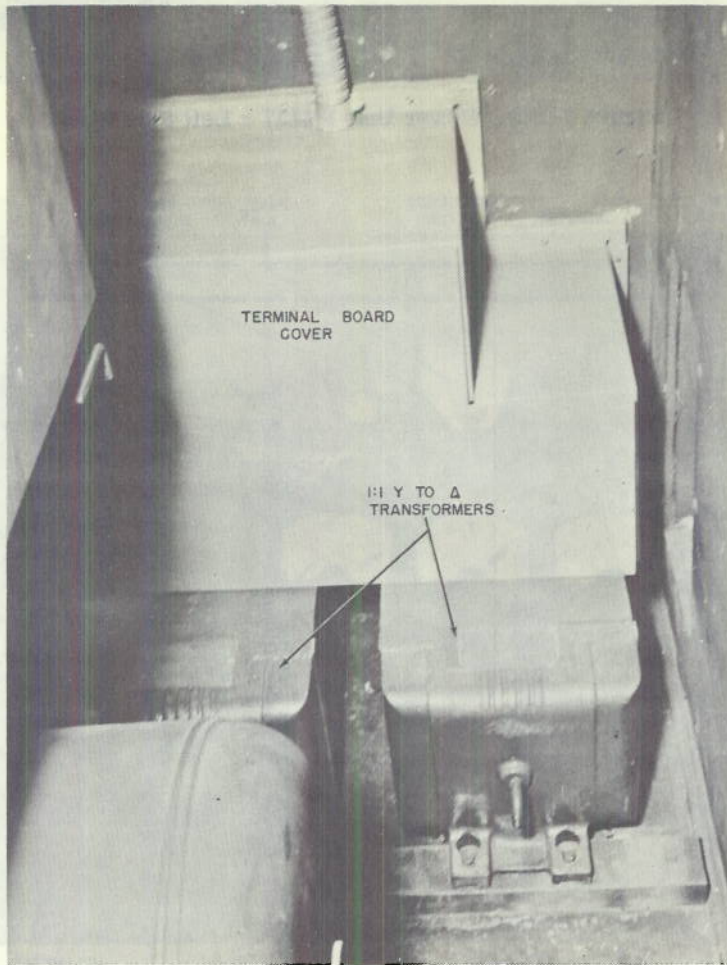


Figure 3-152. Transformers and Cover for Filters for PE137 Power Unit

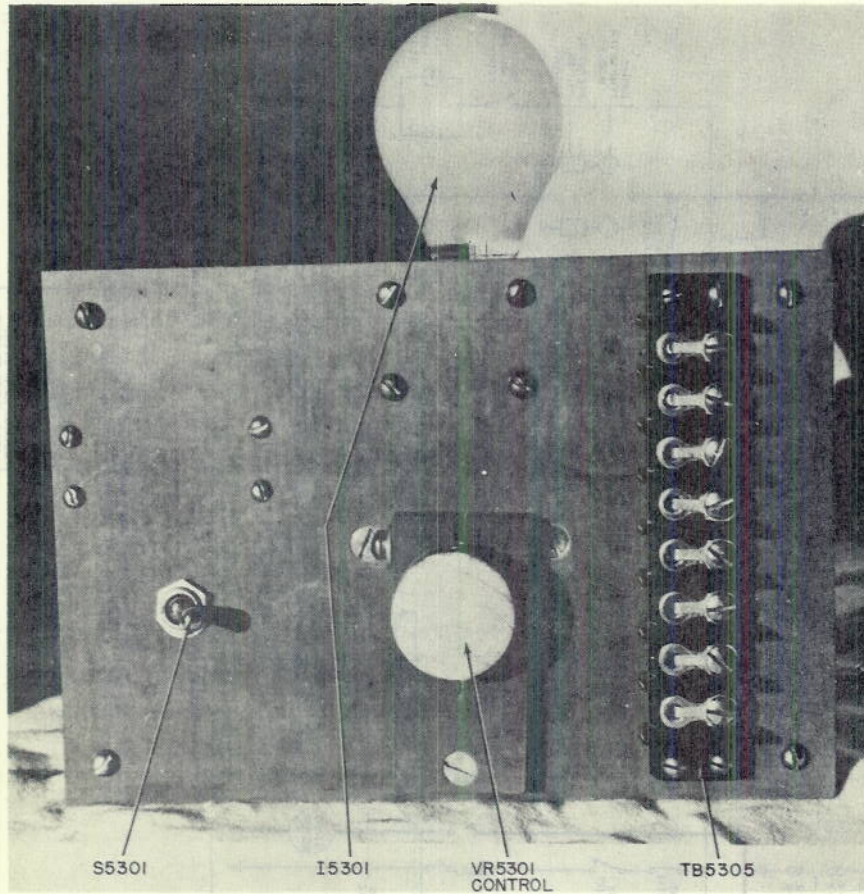


Figure 3-153. A-c Voltage Regulator for Power Unit PE137 - Front View

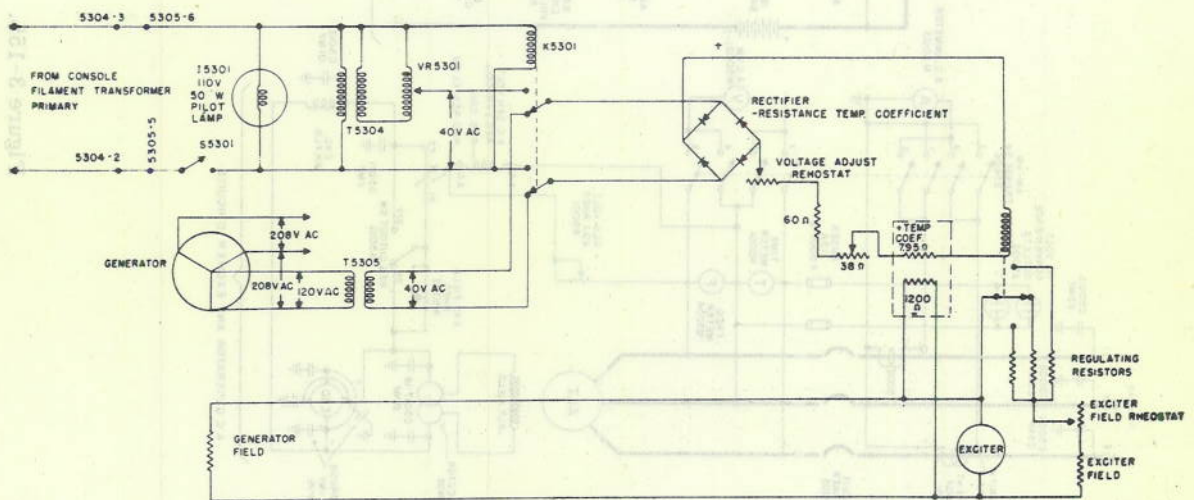


Figure 3-154. A-c Voltage Regulator - Schematic Diagram

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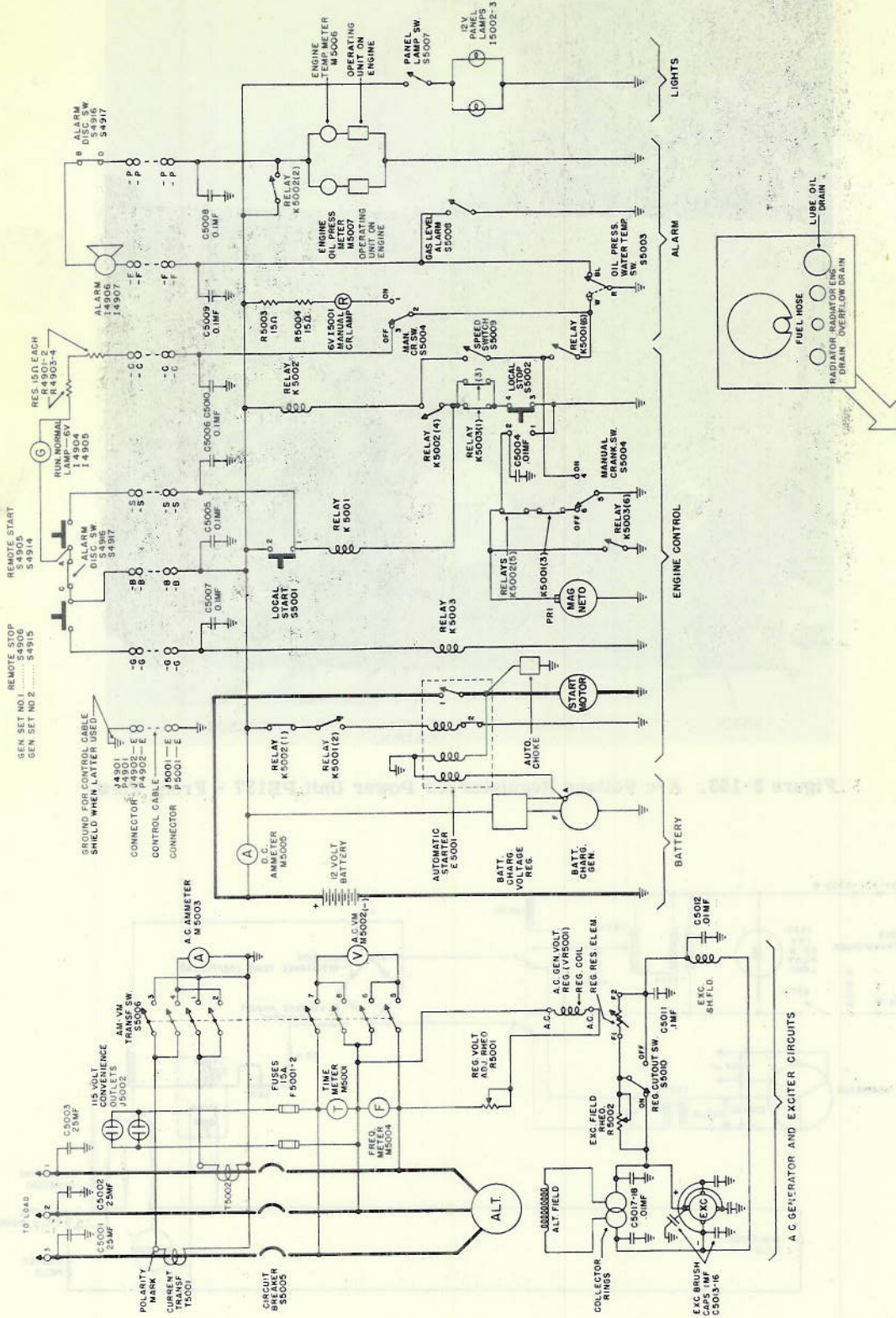


Figure 3-155. 15-Kw Gasoline Engine Alternator - Schematic Diagram

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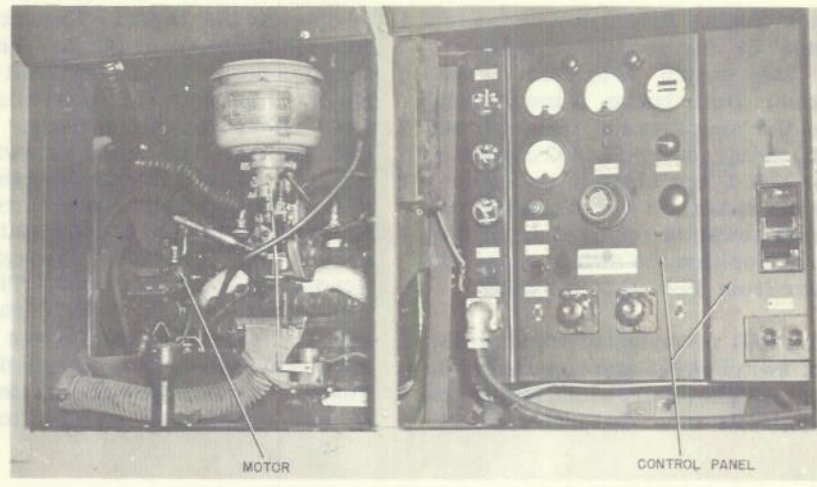


Figure 3-156. 15-Kw Gasoline Engine Alternator - Front View

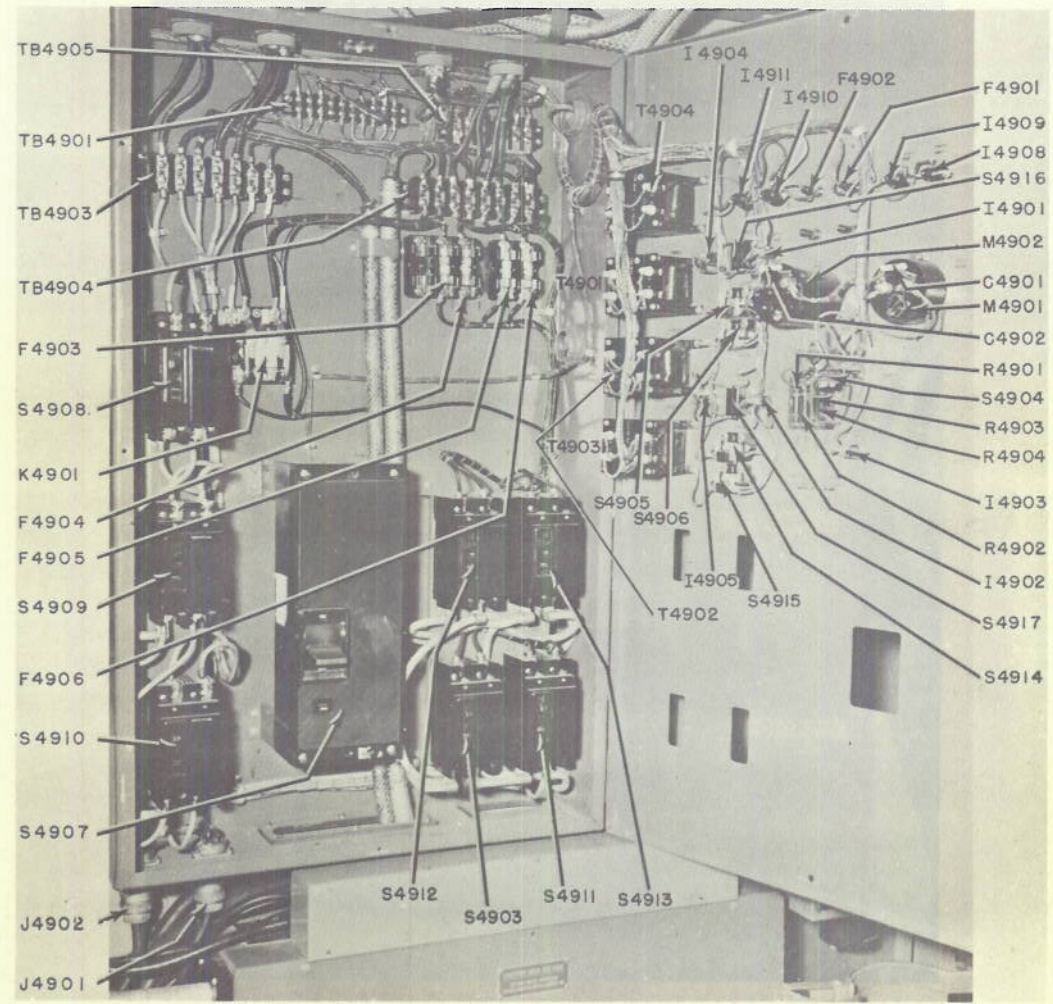


Figure 3-157. Power Distribution Panel With Door Open - Front View

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power from either Engine Alternator No. 1 or No. 2 is selected by the generator selector switch, S4902. This switch is located to the right of the Power Distribution Panel, Unit 4900, and above the single-phase-three-phase switch, S4901. In the up position S4902 connects Engine Generator No. 1, contained in the equipment trailer, to the radar. In the horizontal or neutral position all power is removed from the radar. In the down position the switch connects the external power from TB5109 to the radar.

Transformer T4901 is connected across terminals 1 and 2 of switch S4902 and supplies five volts to the indicator light I4901, which indicates when power is available from Generator No. 1

to operate the radar. Transformer T4902 is connected across terminals 7 and 8 of S4902 and supplies power to the five-volt indicator light, I4902, to indicate that power is being supplied from either the station power lines or Power Unit PE137. The output of switch S4902, terminals 4, 5, and 6, is connected to S4901, terminals 10 and 11, 12 and 9, respectively, and is also connected to the 445-volt D-c Motor Generator Unit, Unit 2400, through the D-c Motor Generator Relay Unit 6300. The single-phase-three-phase switch, S4901, should always be kept in the three-phase position since the equipment will not operate on single-phase power. Phase 1 is connected across terminals 6 and 8 of S4901 and supplies power to the 50-ampere

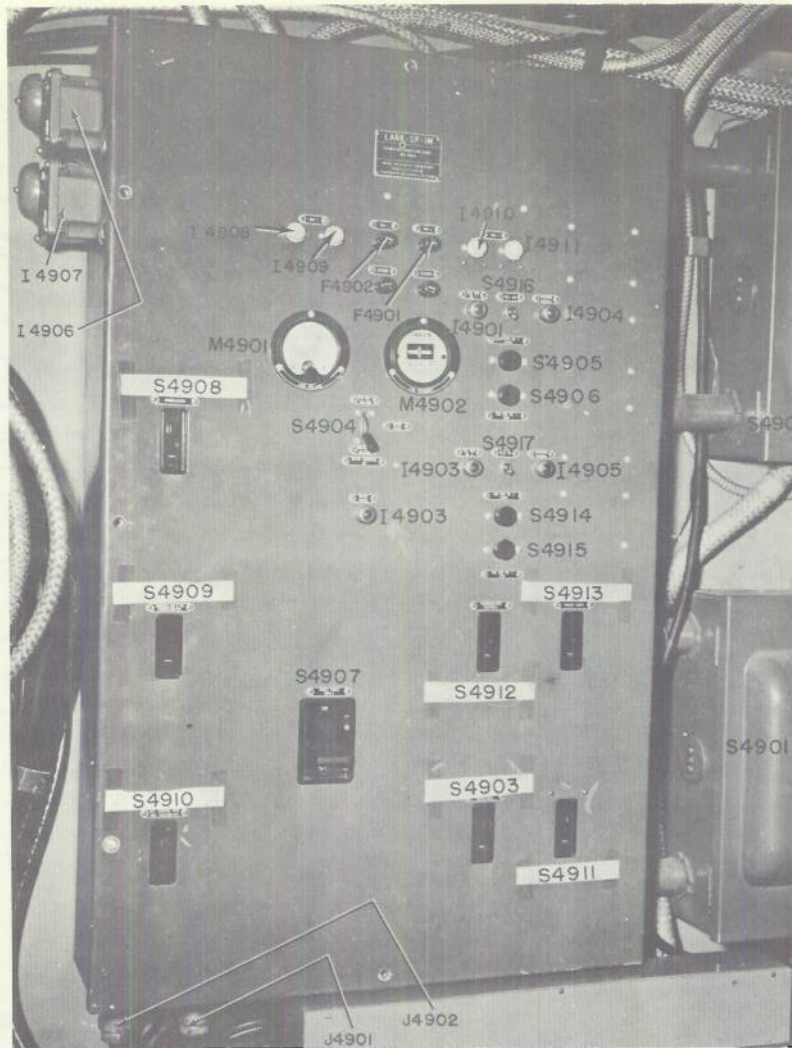


Figure 3-158. Power Distribution Panel With Door Closed - Front View

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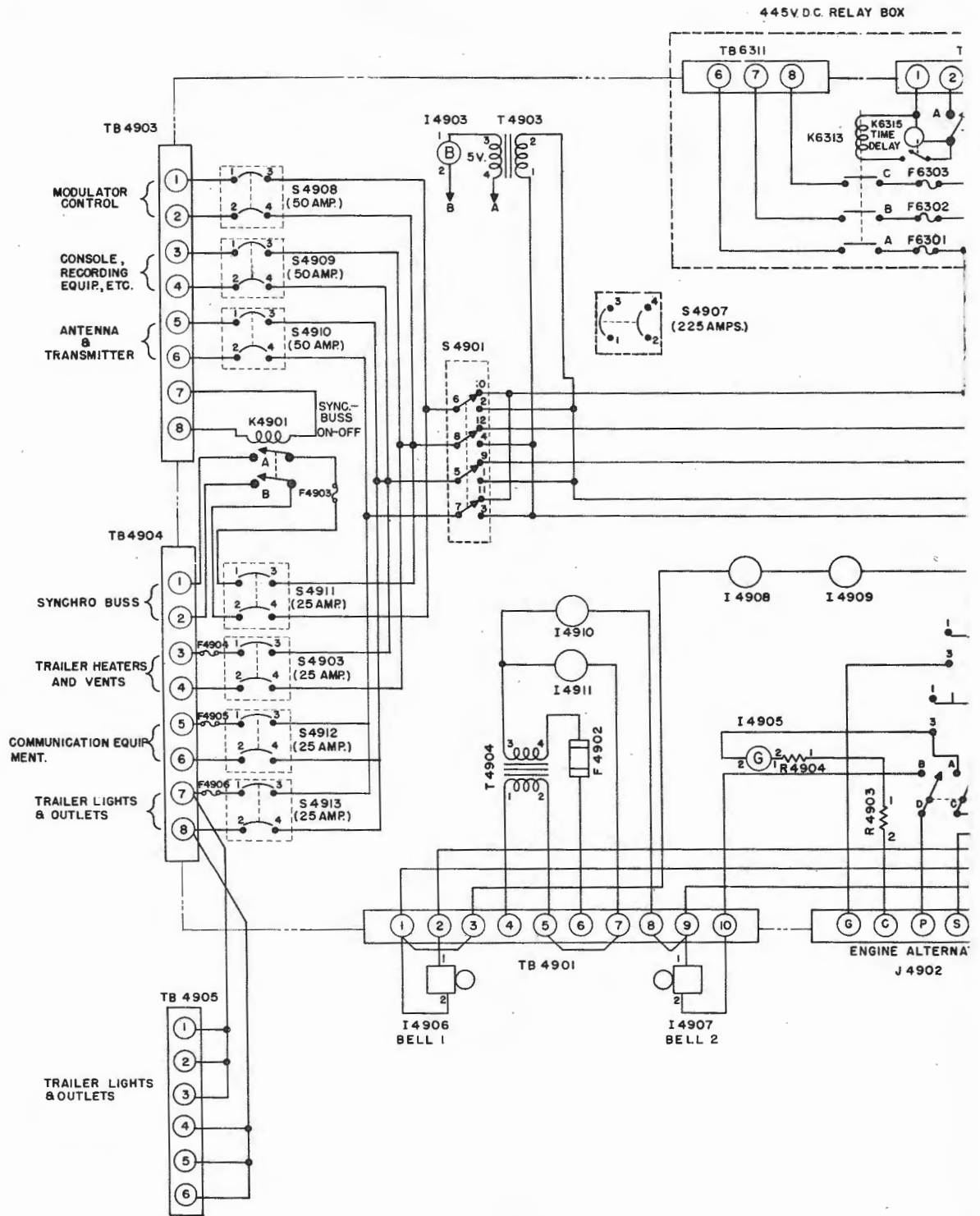
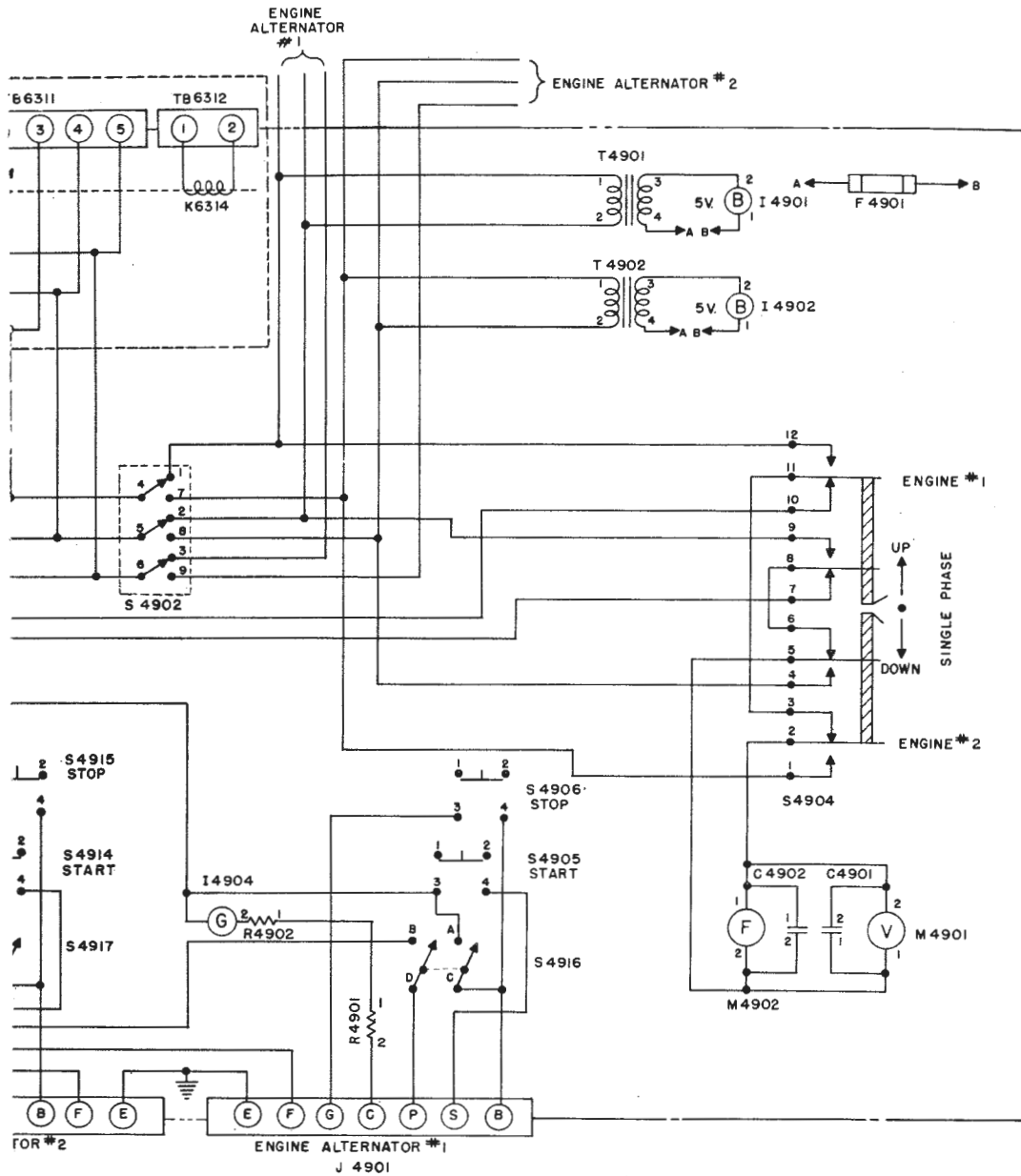


Figure 3-159. Power Distribution Panel - Schematic Diagram



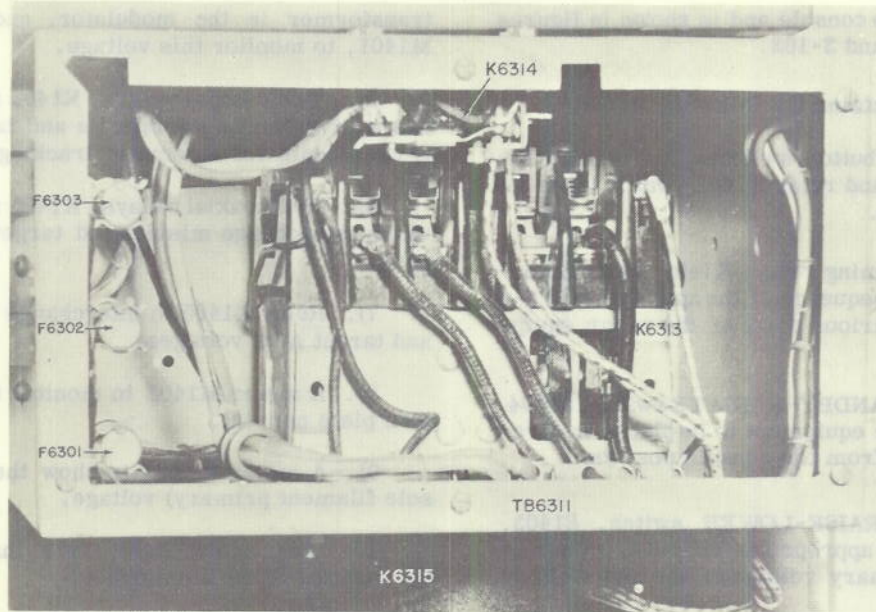


Figure 3-160. D-c Relay Box

circuit breaker S4908 and to switch S4911. Phase 2 is connected across terminals 5 and 8 of S4901 and supplies power to the 50-ampere circuit breaker S4909 and to switch S4903. Phase 3 is connected across terminals 5 and 7 of S4901 and supplies power to the 50-ampere circuit breaker S4910 and to switches S4912 and S4913.

Unit 6300, applies three-phase a-c power to the a-c motor, B2401, of the d-c motor generator. This unit is located in the equipment trailer between switch S4901 and the cable panel. (See the photograph figure 3-160 and the schematic diagram figure 3-159.)

b. D-c Motor Generator Relay Unit, Unit 6300. - The D-c Motor Generator Relay Unit,

c. Power Control Unit, Unit 1400. - The Power Control Unit, Unit 1400, provides control and distribution at the radar console of the a-c power used in the radar circuits. This unit

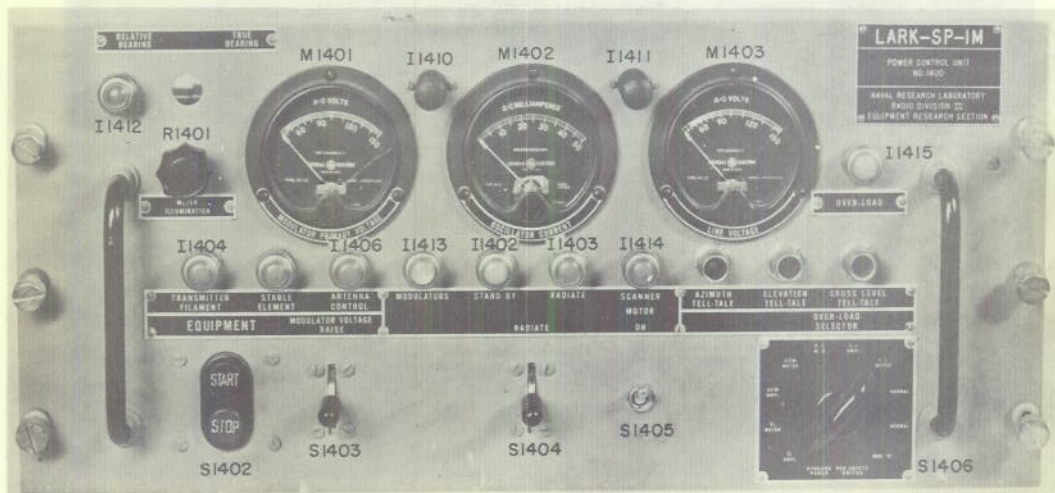


Figure 3-161. Power Control Unit - Front View

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is located in the console and is shown in figures 3-161, 3-162, and 3-163.

The unit contains the following items:

1). Push button switches for turning the equipment on, and relay K1402, which locks in the start button.

2). The timing relay, K1401 which determines the time sequence of the application of a-c power to the various parts of the radar equipment.

3). The STANDBY-RADIATE switch, S1404, which allows the equipment to be placed in a radiate condition from the console position.

4). The RAISE-LOWER switch, S1403, which, through appropriate circuits, raises or lowers the primary voltage of the high-voltage

transformer in the modulator, and a meter, M1401, to monitor this voltage.

5). Two coaxial relays, K1403 and K1404, which interchange the missile and target gated video signals for automatic tracking purposes.

6). Two coaxial relays, K1406 and K1407, which interchange missile and target gate triggers.

7). Relay K1405 to interchange the missile and target AGC voltages.

8). A meter M1402 to monitor the magnetron plate current.

9). A meter M1403 to show the line (console filament primary) voltage.

10). An overload light, I1415, that indicates overheating of the amplidyne.

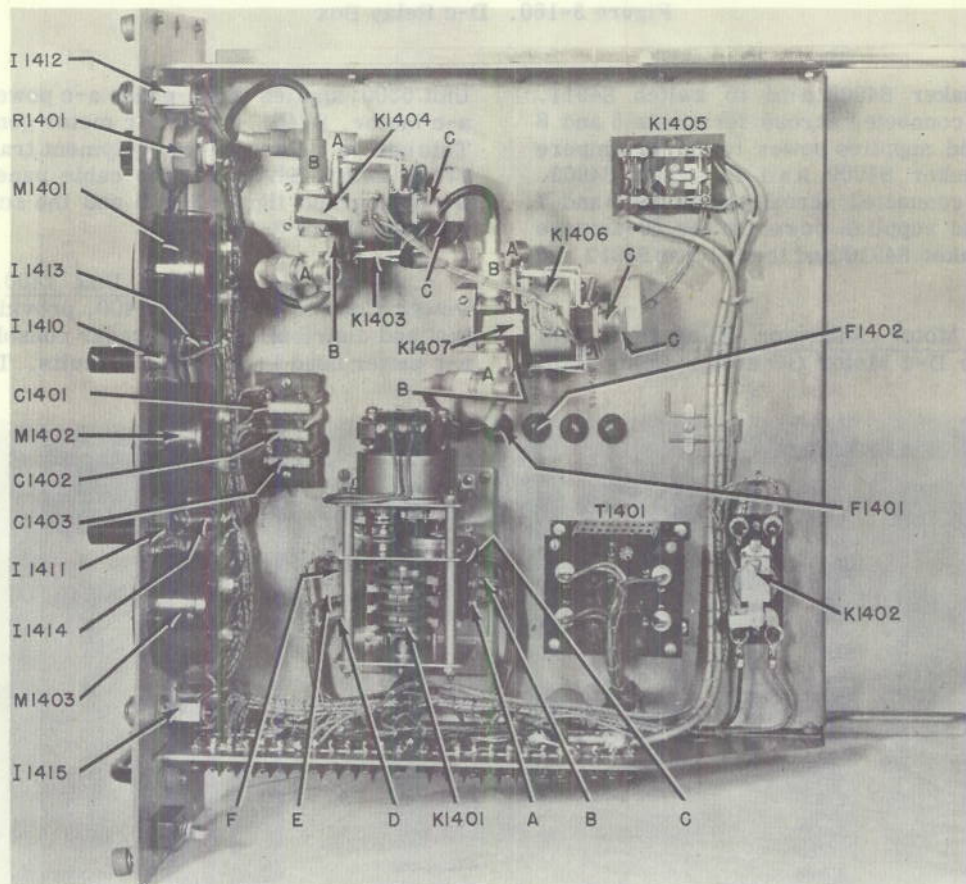


Figure 3-162. Power Control Unit - Top View

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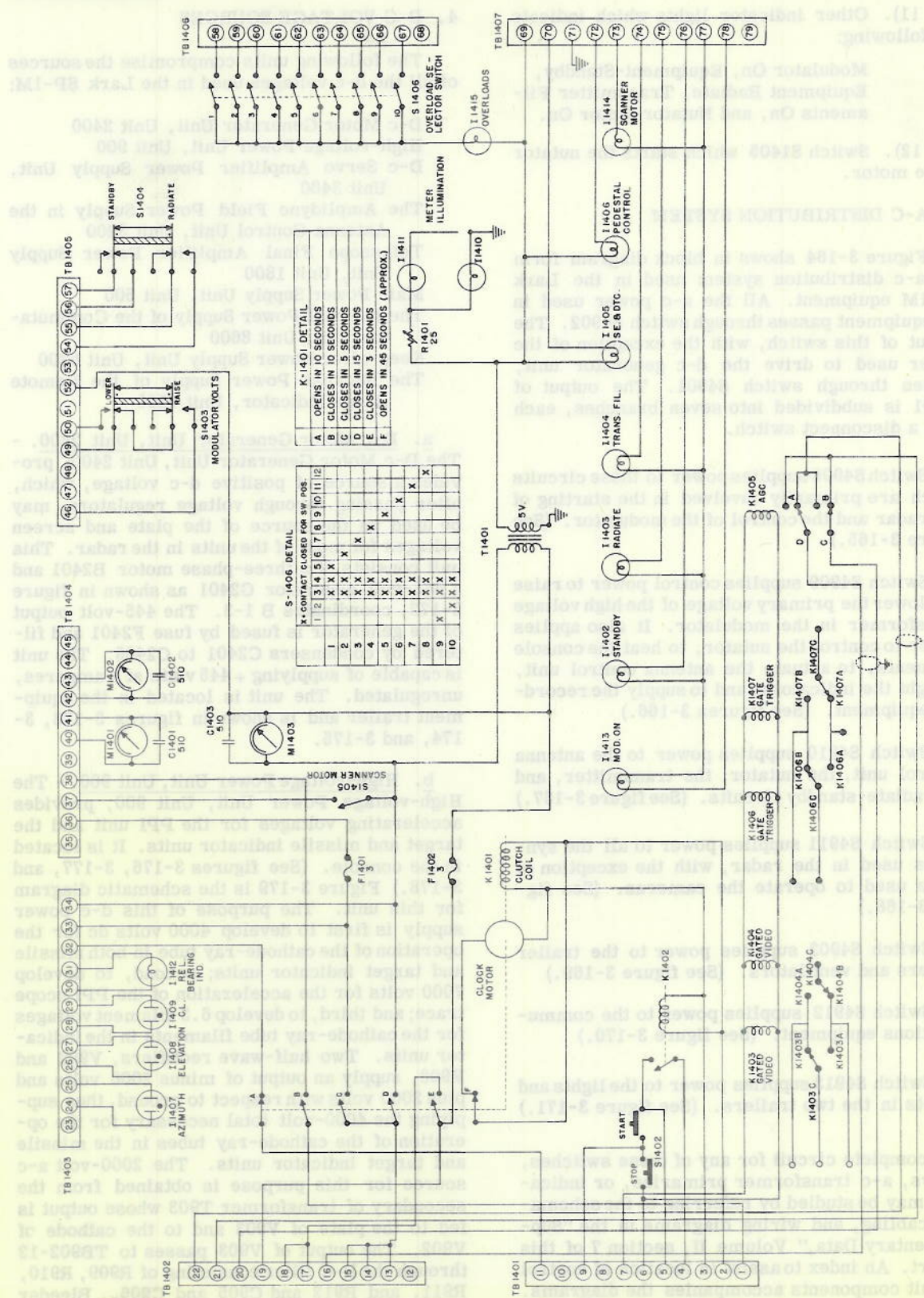


Figure 3-163. Power Control Unit - Schematic Diagram

3-170

11). Other indicator lights which indicate the following:

Modulator On, Equipment-Standby, Equipment Radiate, Transmitter Filaments On, and Nutator Motor On.

12). Switch S1405 which starts the nutator drive motor.

3. A-C DISTRIBUTION SYSTEM

Figure 3-164 shows in block diagram form the a-c distribution system used in the Lark SP-1M equipment. All the a-c power used in the equipment passes through switch S4902. The output of this switch, with the exception of the power used to drive the d-c generator unit, passes through switch S4901. The output of S4901 is subdivided into seven branches, each with a disconnect switch.

Switch S4908 supplies power to those circuits which are primarily involved in the starting of the radar and the control of the modulator. (See figure 3-165.)

Switch S4909 supplies control power to raise and lower the primary voltage of the high voltage transformer in the modulator. It also applies power to control the nutator, to heat the console filaments, to actuate the antenna control unit, to light the indicators, and to supply the recording equipment. (See figures 3-166.)

Switch S4910 supplies power to the antenna control unit, the nutator, the transmitter, and the radiate-standby circuits. (See figure 3-167.)

Switch S4911 supplies power to all the synchros used in the radar, with the exception of those used to operate the cameras. (See figure 3-168.)

Switch S4903 supplies power to the trailer heaters and ventilators. (See figure 3-169.)

Switch S4912 supplies power to the communications equipment. (See figure 3-170.)

Switch S4913 supplies power to the lights and outlets in the two trailers. (See figure 3-171.)

The complete circuit for any of these switches, relays, a-c transformer primaries, or indicators may be studied by referring to the schematic, cabling, and wiring diagrams in the "Supplementary Data," Volume II, section 7 of this report. An index to assist in location of control circuit components accompanies the diagrams.

4. D-C VOLTAGE SOURCES

The following units comprise the sources of all the d-c voltages used in the Lark SP-1M:

D-c Motor Generator Unit, Unit 2400
High-voltage Power Unit, Unit 900
D-c Servo Amplifier Power Supply Unit, Unit 3400

The Amplidyne Field Power Supply in the Antenna Control Unit, Unit 3200

Telescope Final Amplifier Power Supply Unit, Unit 1800

Main Power Supply Unit, Unit 500

The Internal Power Supply of the Commutator Unit, Unit 8600

Keep-alive Power Supply Unit, Unit 6200

The Internal Power Supply of the Remote Range Indicator, Unit 8500

a. D-c Motor Generator Unit, Unit 2400. - The D-c Motor Generator Unit, Unit 2400, provides a source of positive d-c voltage, which, after passing through voltage regulators, may be used as the source of the plate and screen voltages for most of the units in the radar. This unit consists of a three-phase motor B2401 and a 445-volt generator G2401 as shown in figure 3-172, coordinates B 1-3. The 445-volt output of the generator is fused by fuse F2401 and filtered by condensers C2401 to C2408. The unit is capable of supplying + 445 volts at 4 amperes, unregulated. The unit is located in the equipment trailer and is shown in figures 3-173, 3-174, and 3-175.

b. High-voltage Power Unit, Unit 900. - The High-voltage Power Unit, Unit 900, provides accelerating voltages for the PPI unit and the target and missile indicator units. It is located in the console. (See figures 3-176, 3-177, and 3-178.) Figure 3-179 is the schematic diagram for this unit. The purpose of this d-c power supply is first to develop 4000 volts dc for the operation of the cathode-ray tube in both missile and target indicator units; second, to develop 7000 volts for the acceleration of the PPI scope trace; and third, to develop 6.3 filament voltages for the cathode-ray tube filaments in the indicator units. Two half-wave rectifiers, V902 and V903, supply an output of minus 2000 volts and plus 2000 volts with respect to ground, thus supplying the 4000-volt total necessary for the operation of the cathode-ray tubes in the missile and target indicator units. The 2000-volt a-c source for this purpose is obtained from the secondary of transformer T903 whose output is fed to the plate of V903 and to the cathode of V902. The output of V903 passes to TB902-12 through the R-C filter consisting of R909, R910, R911, and R912 and C905 and C906. Bleeder

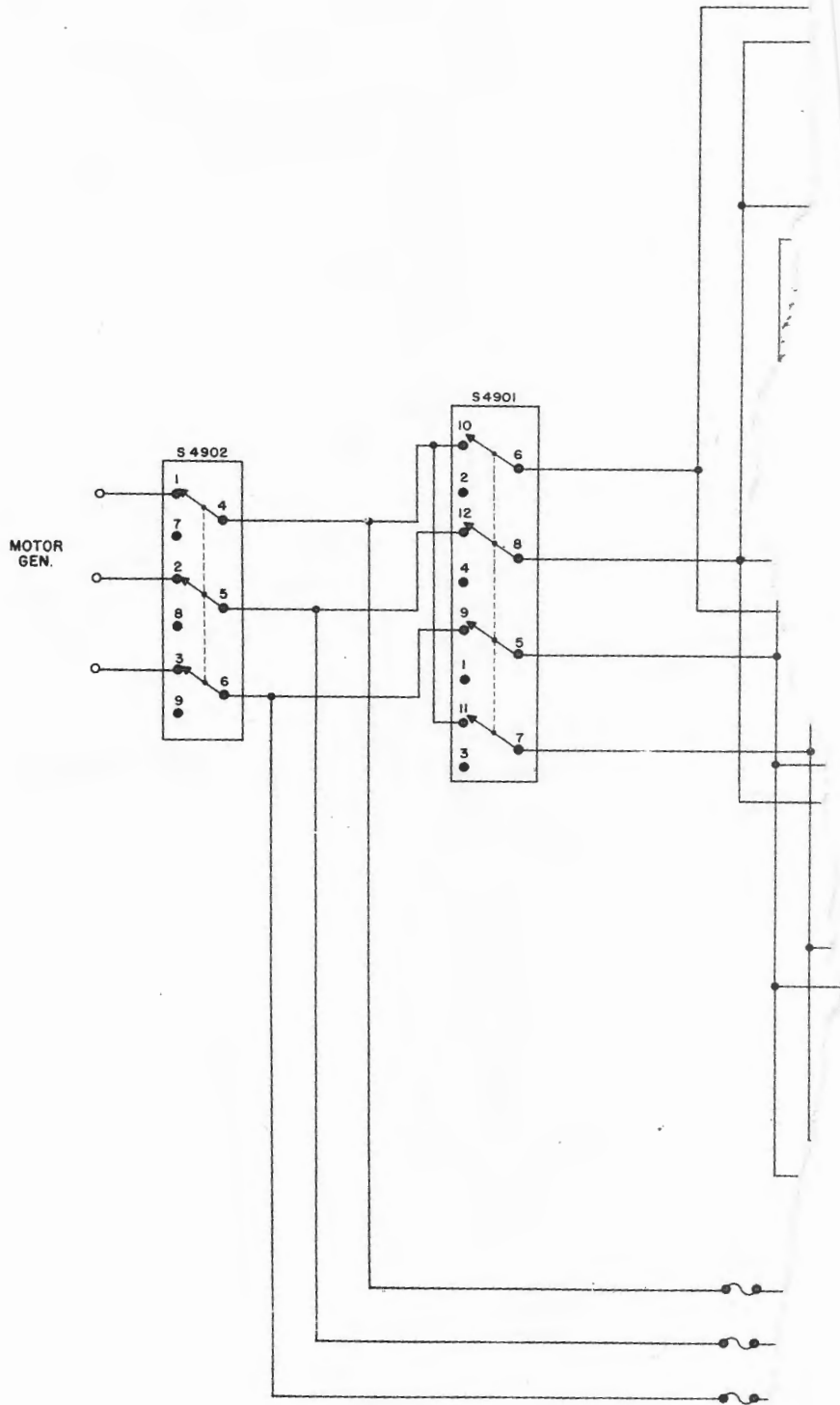
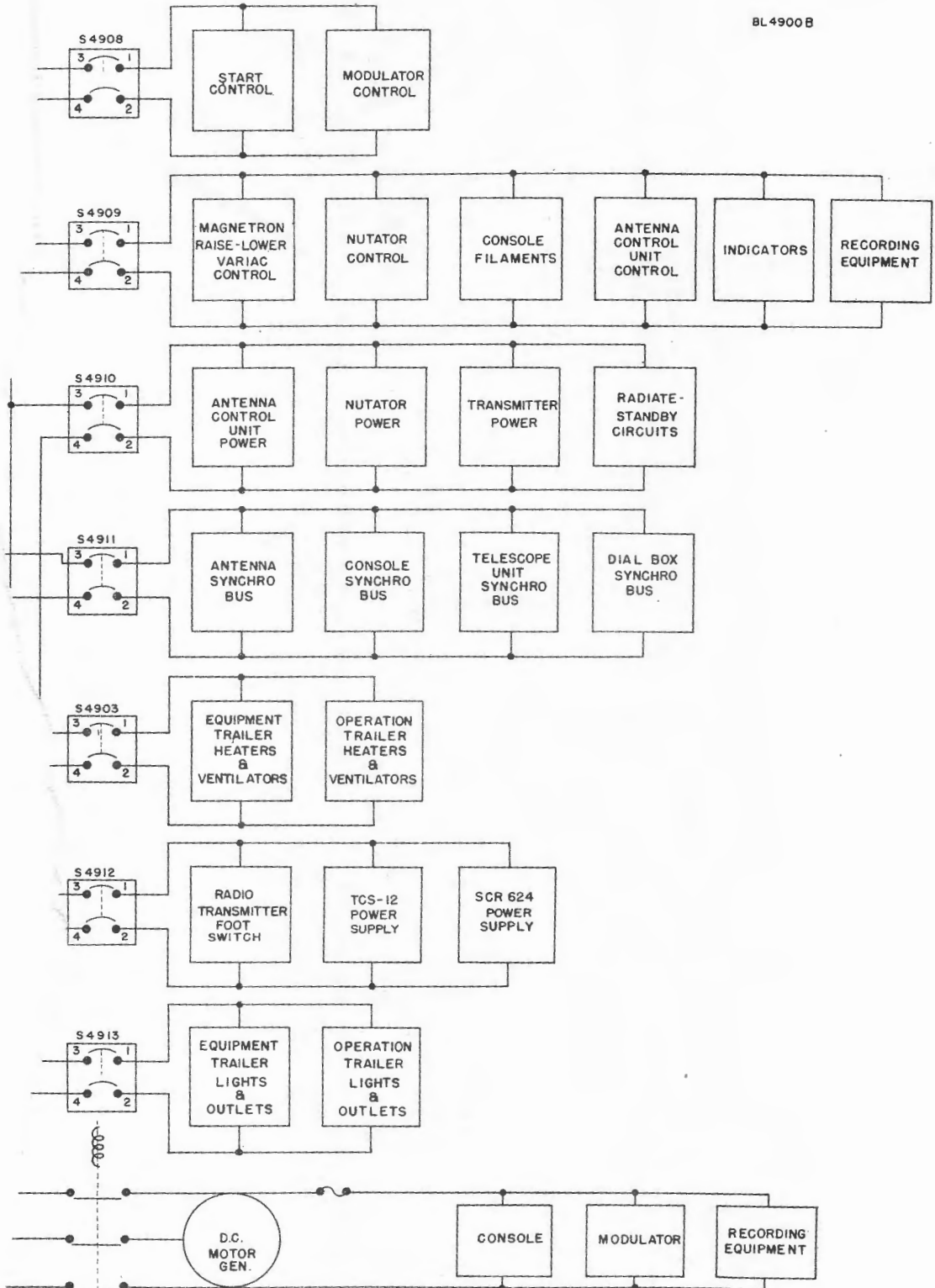


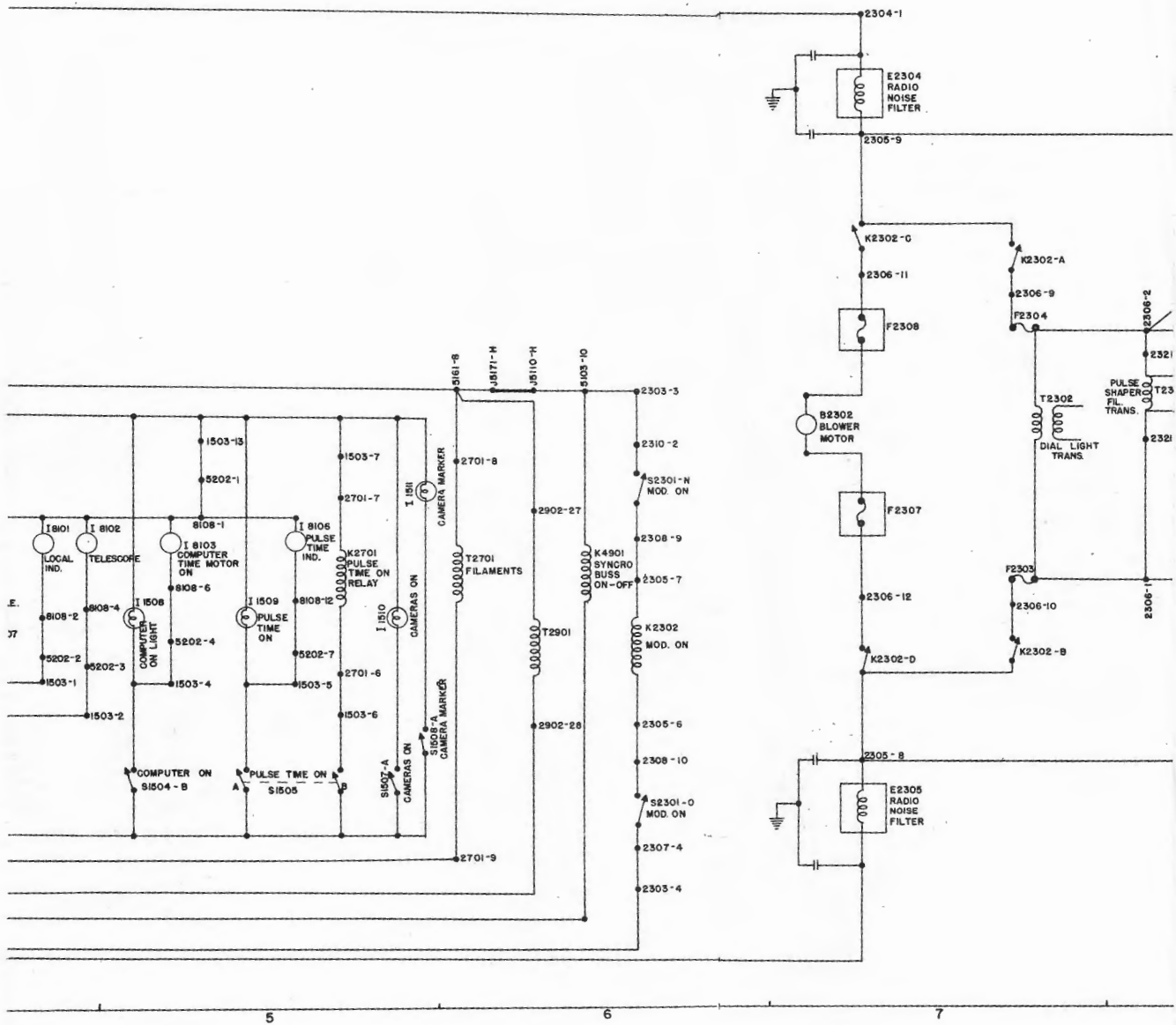
Figure 3-164. Power Distribution System -



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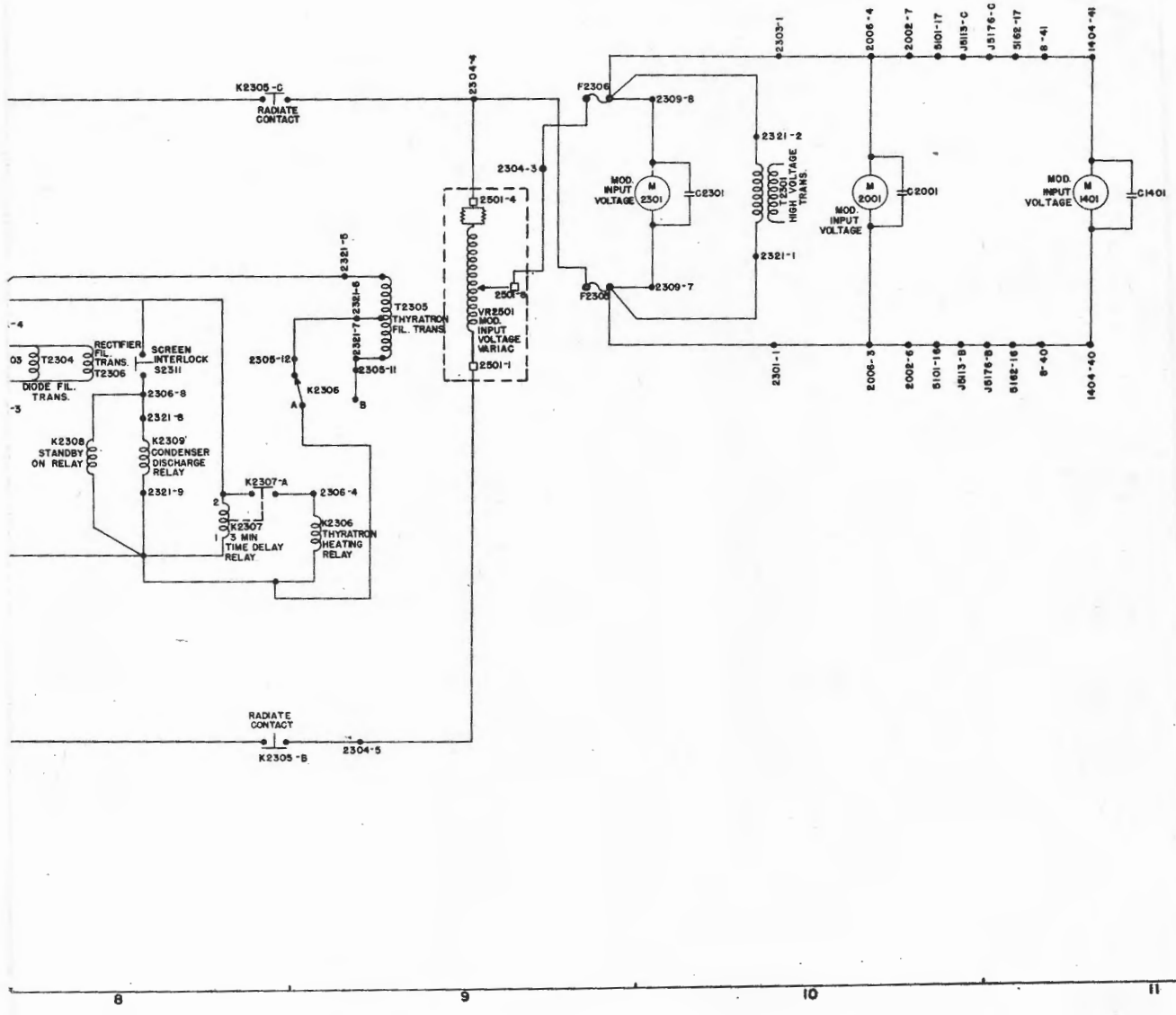
Block Diagram



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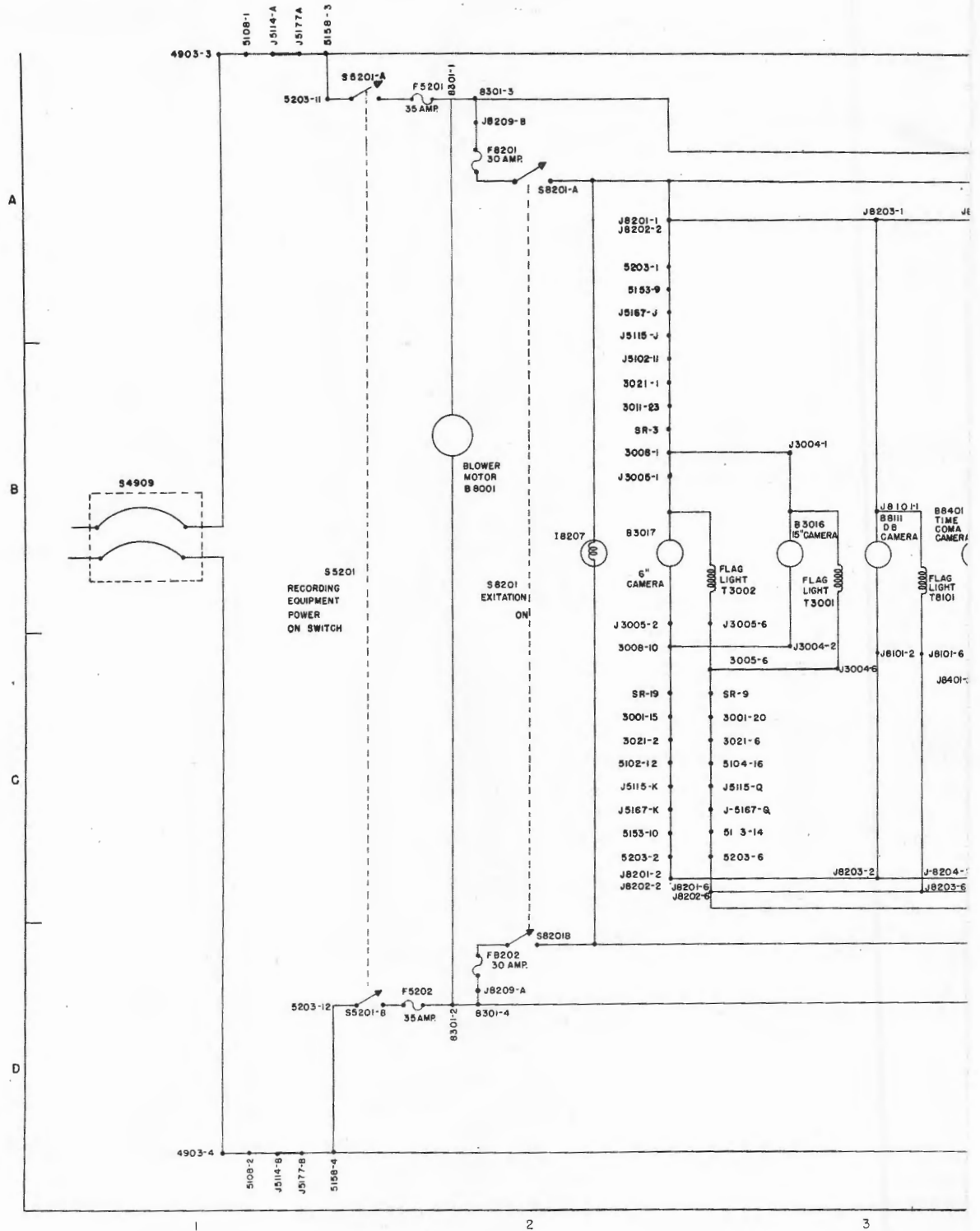
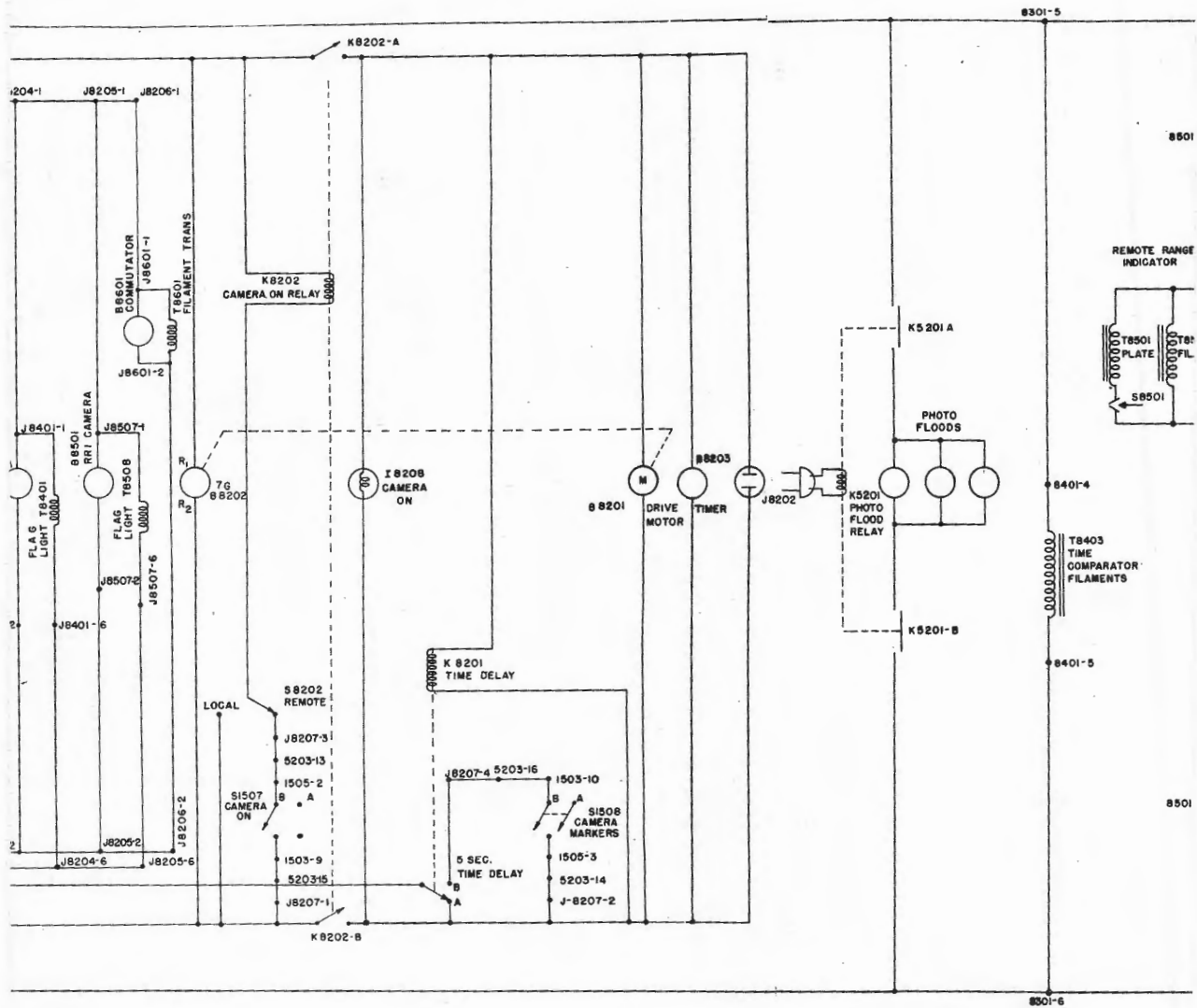
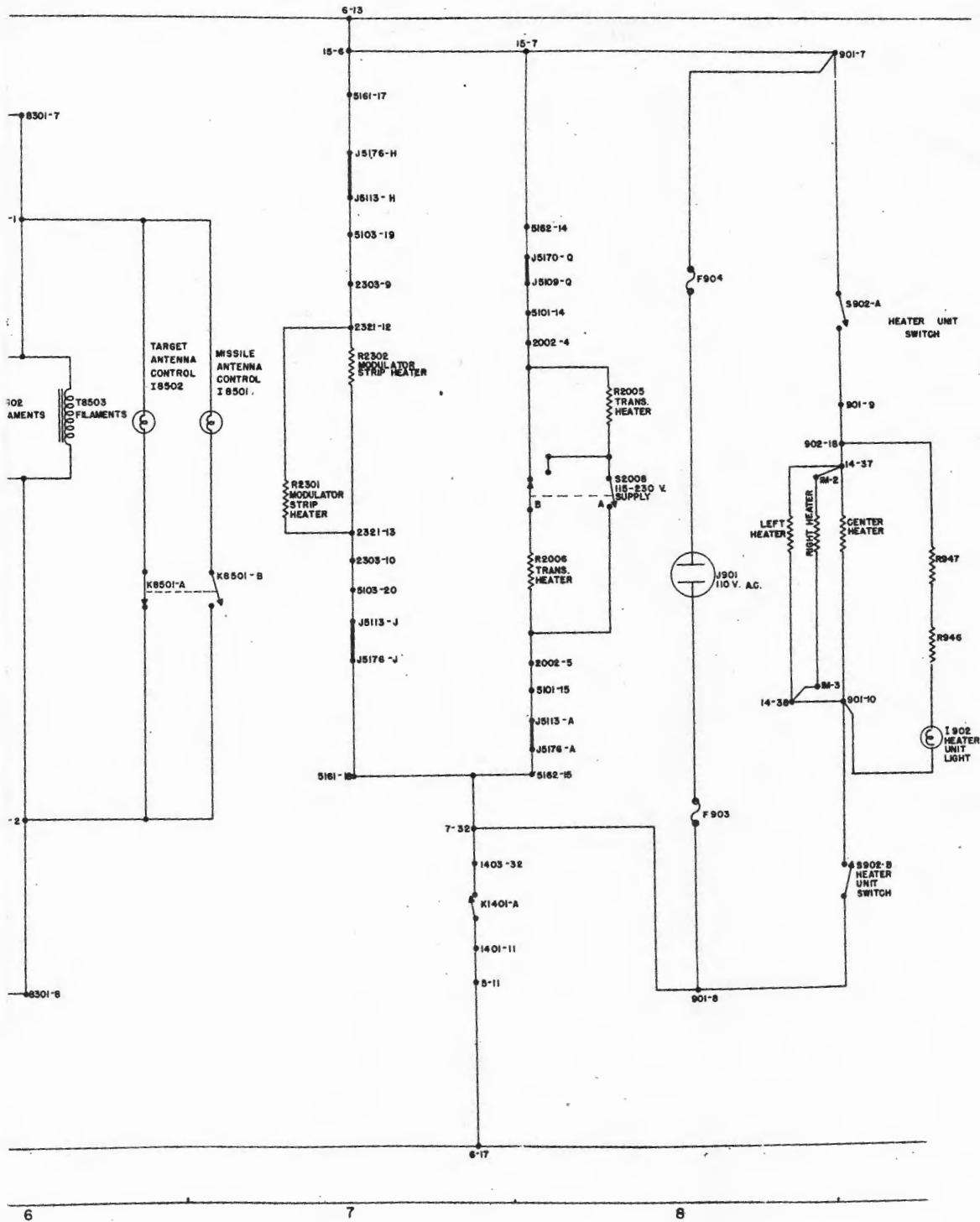


Figure 3-166. (Sheet 1 of 3 Sheets) A-c Distribution System - Switch S4909

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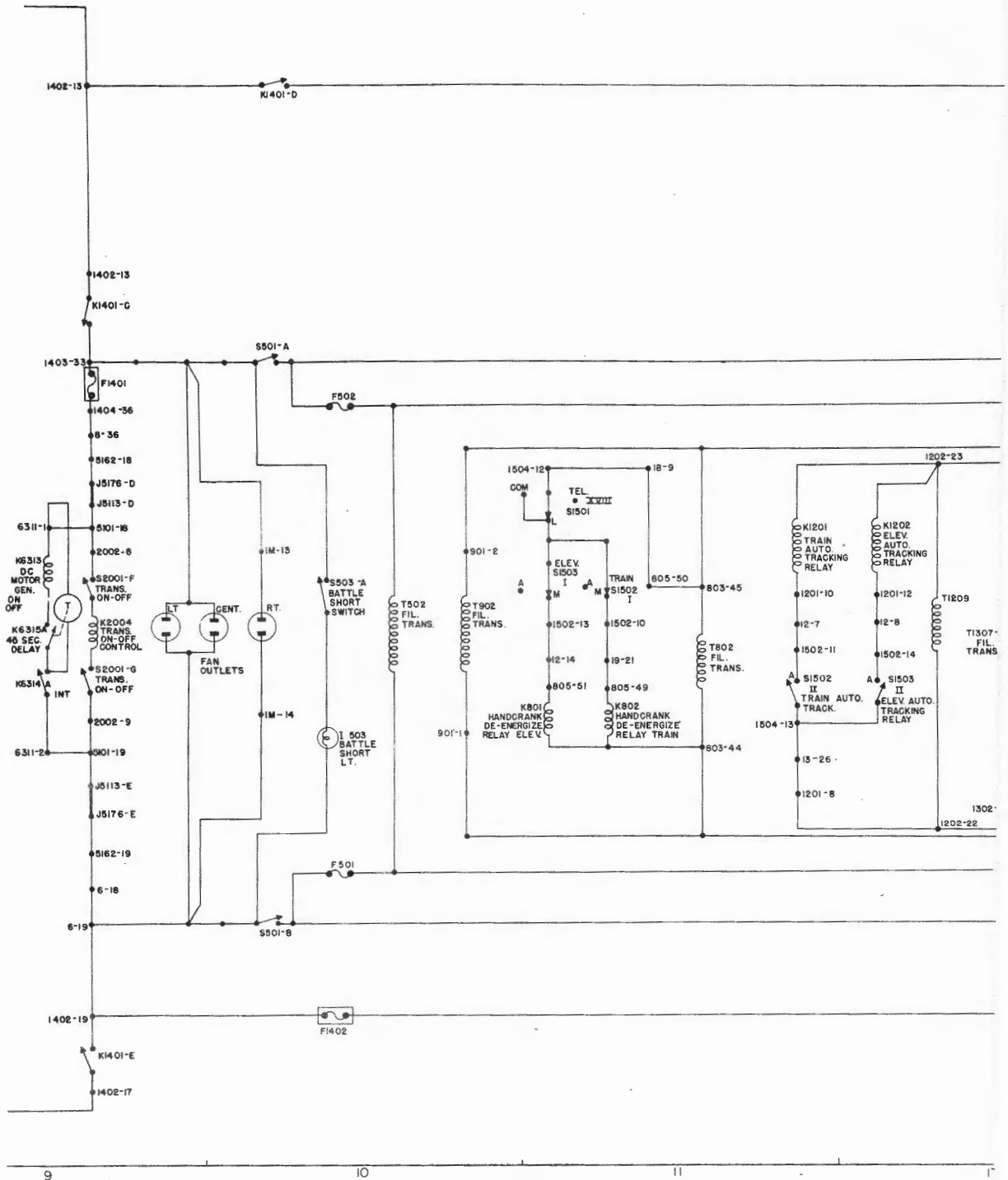
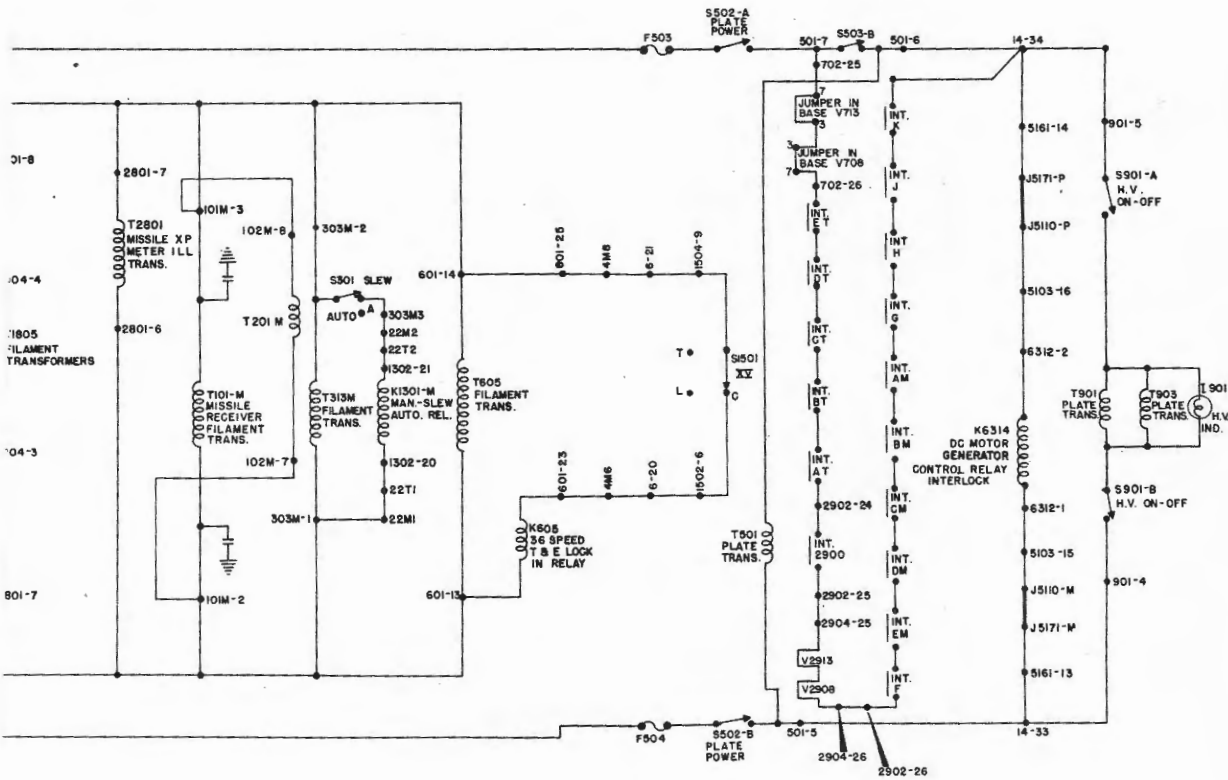


Figure 3-166. (Sheet 2 of 3 Sheets) A-c Distribution System - Switch S4909

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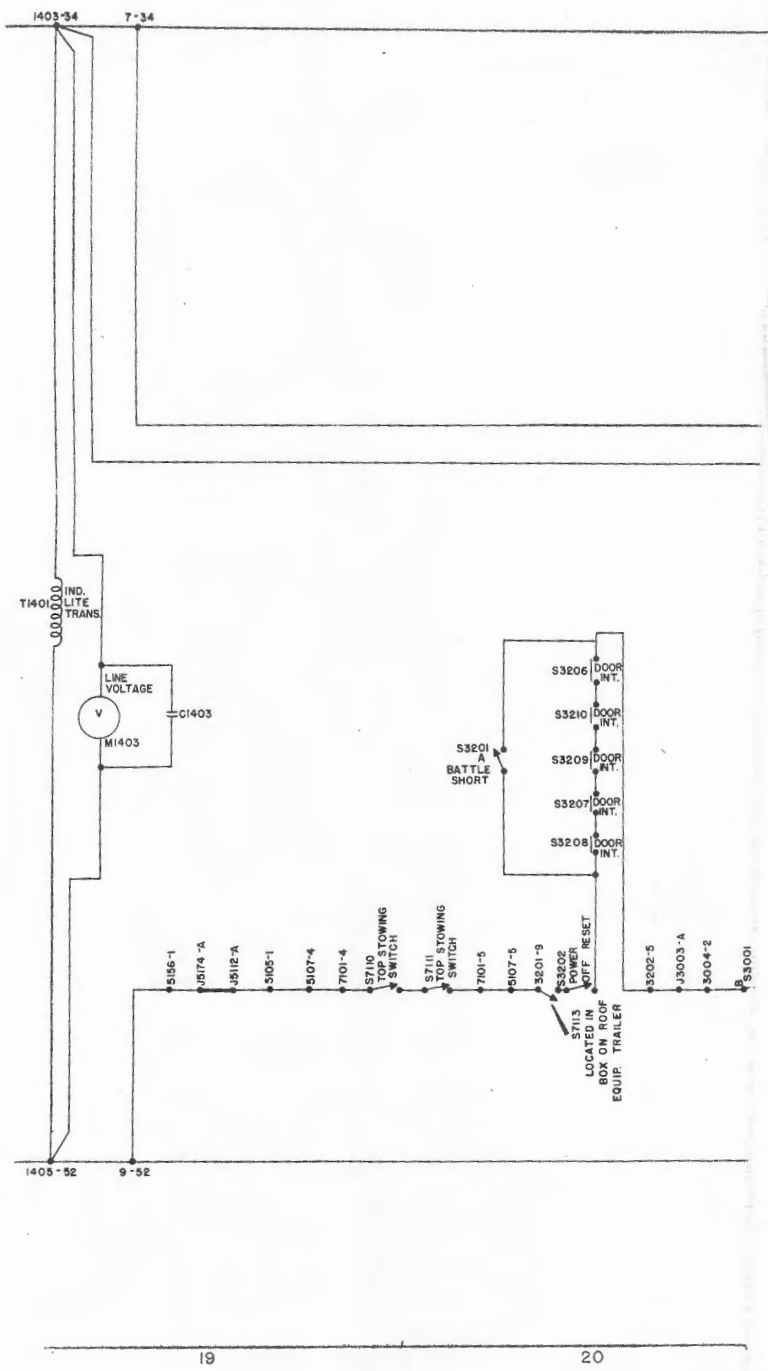
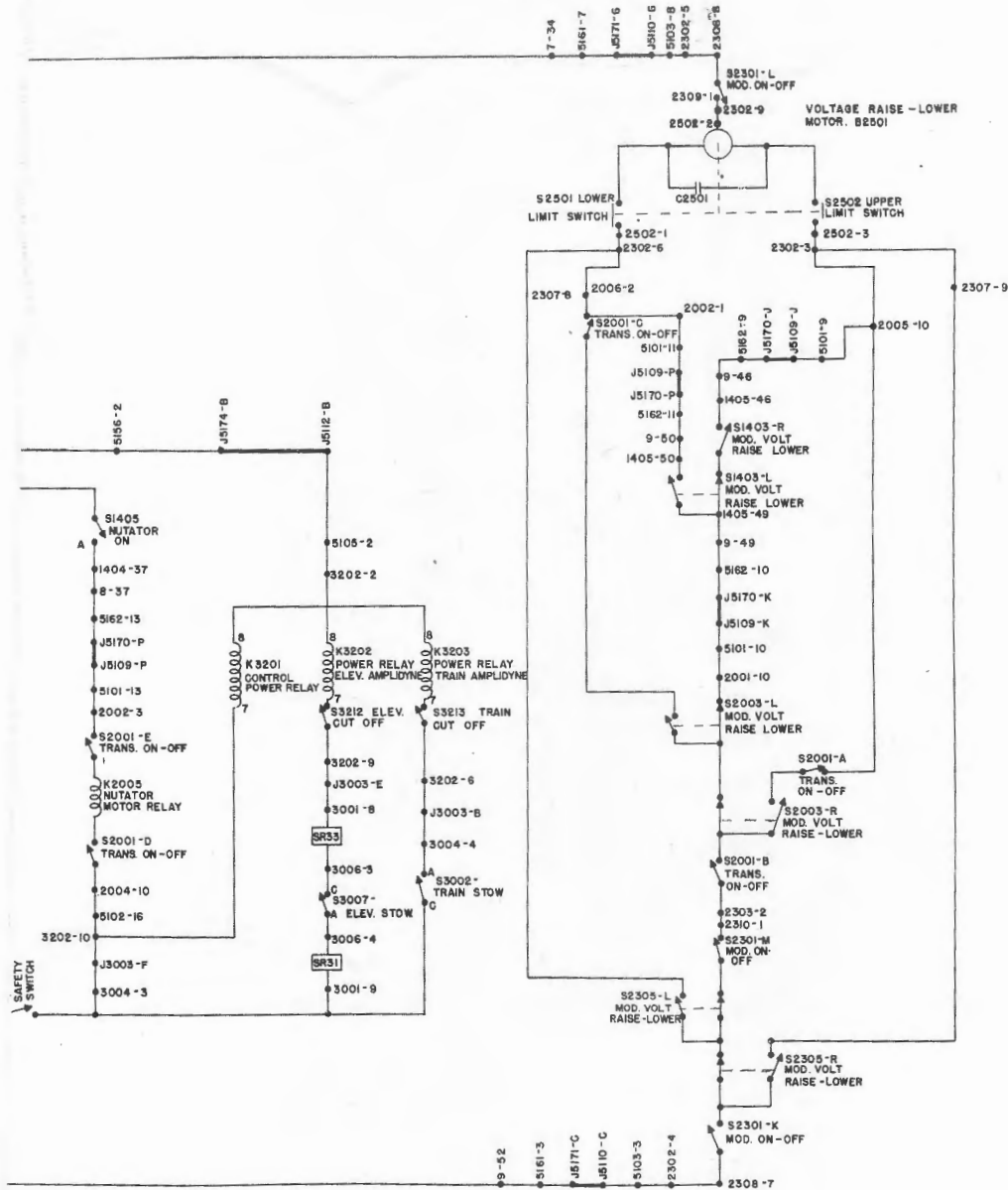


Figure 3-166. (Sheet 3 of 3 Sheets) A-c Dis

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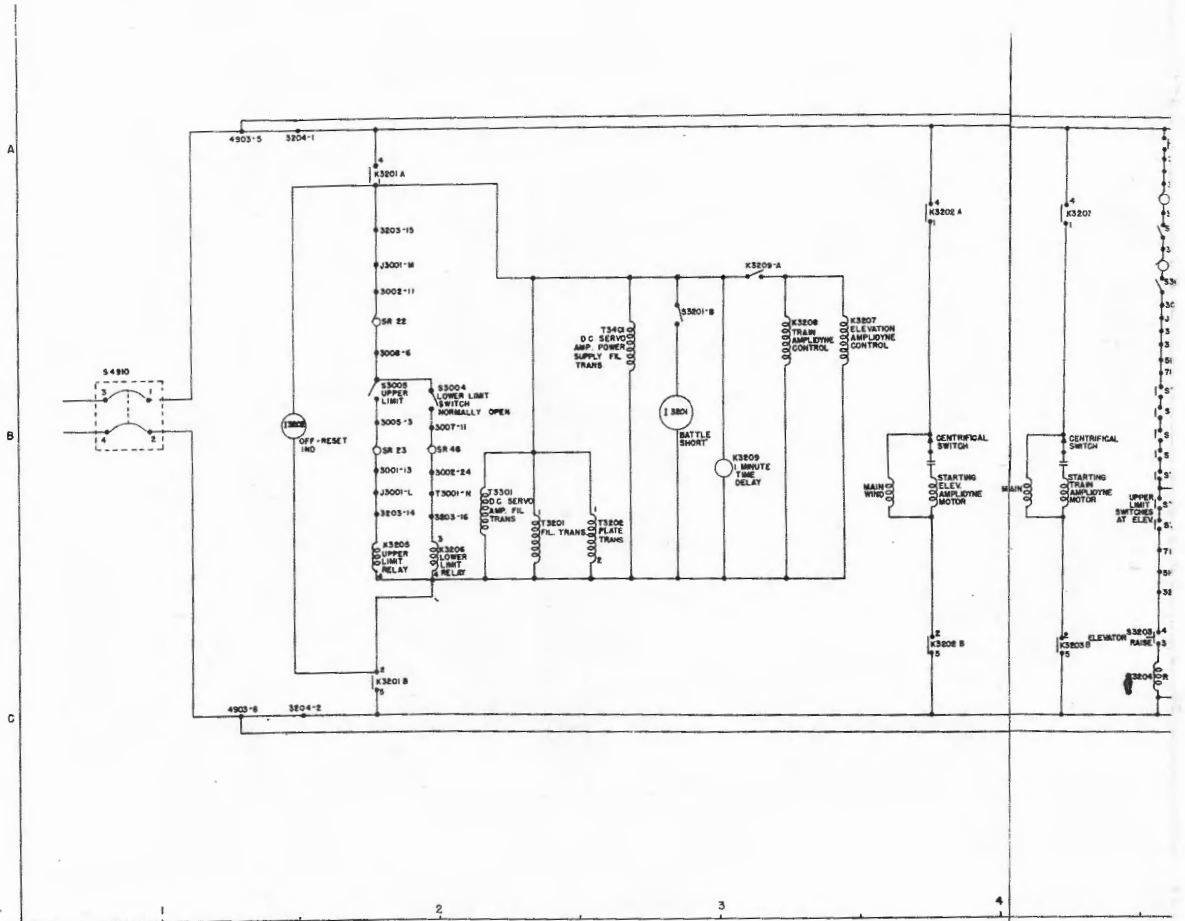
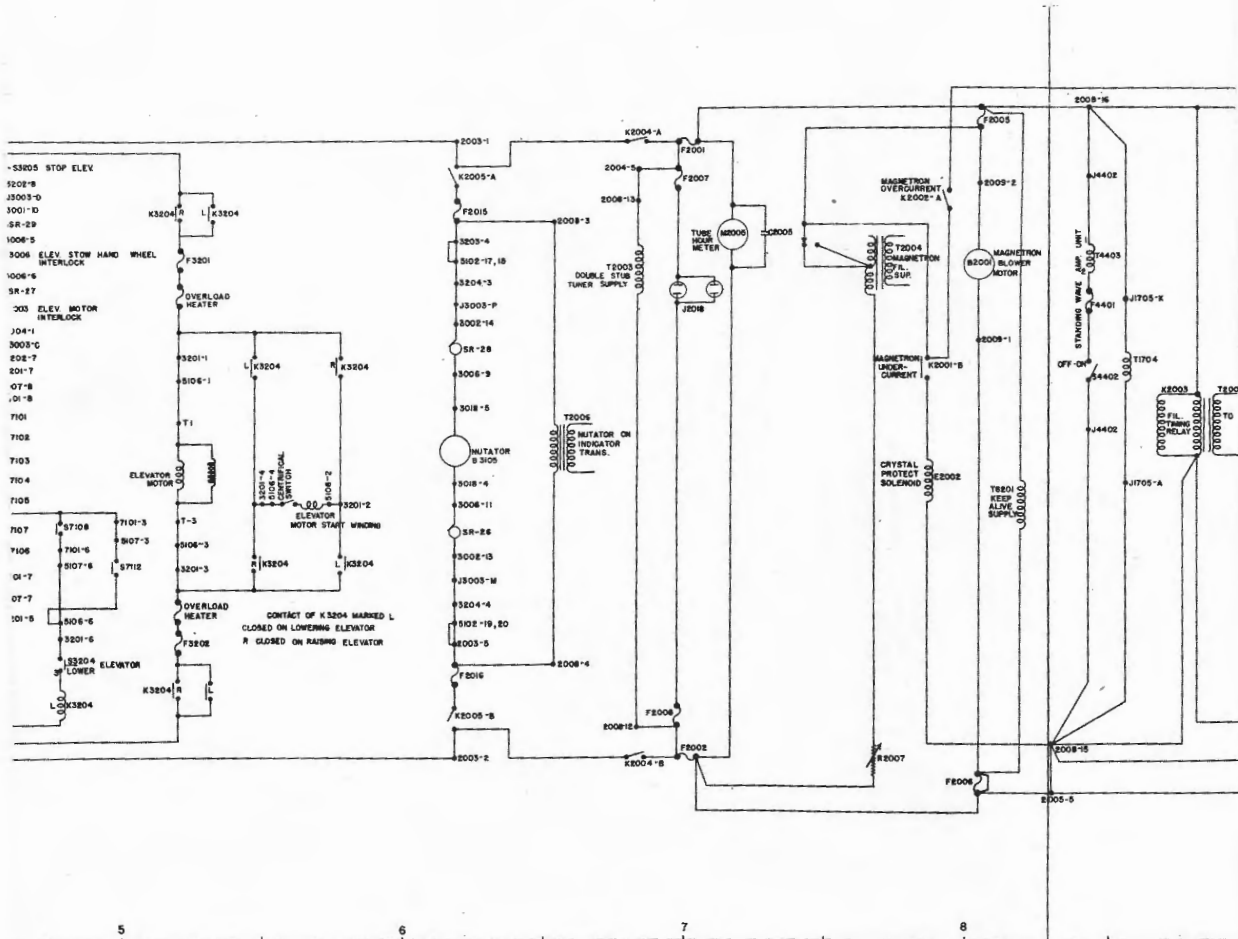
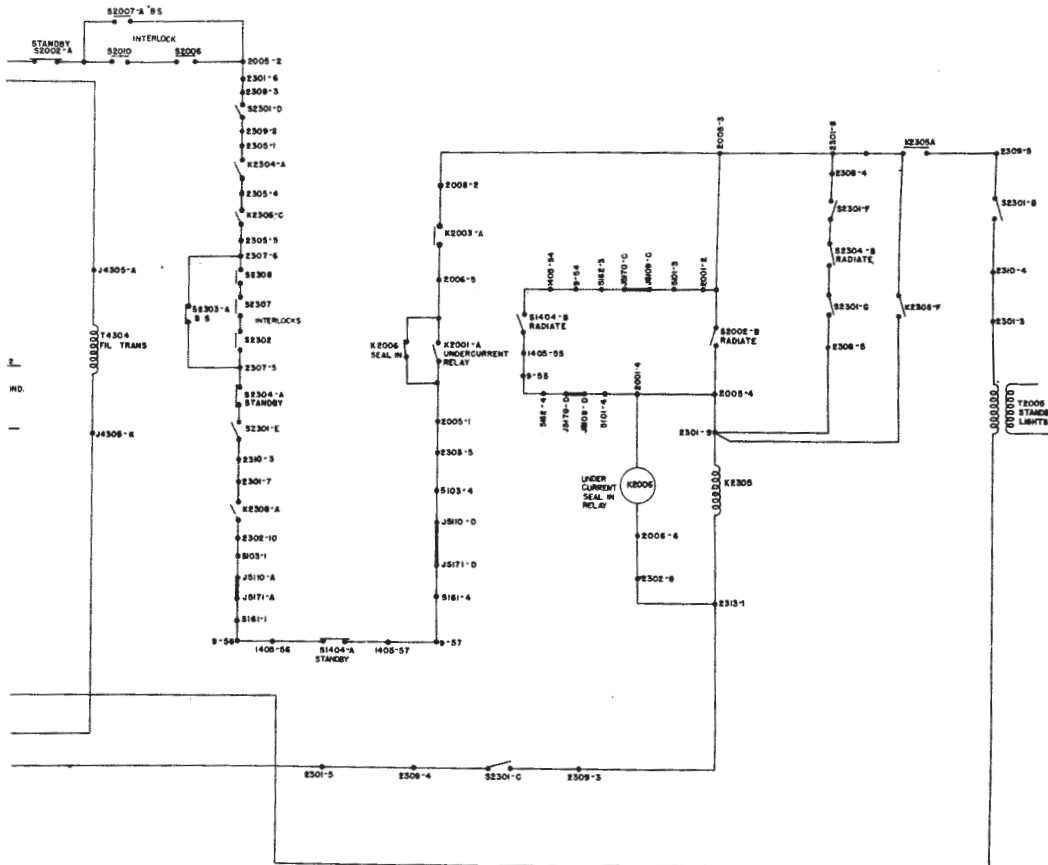


Figure 3-167. A-c Distribution System - Switch S4910

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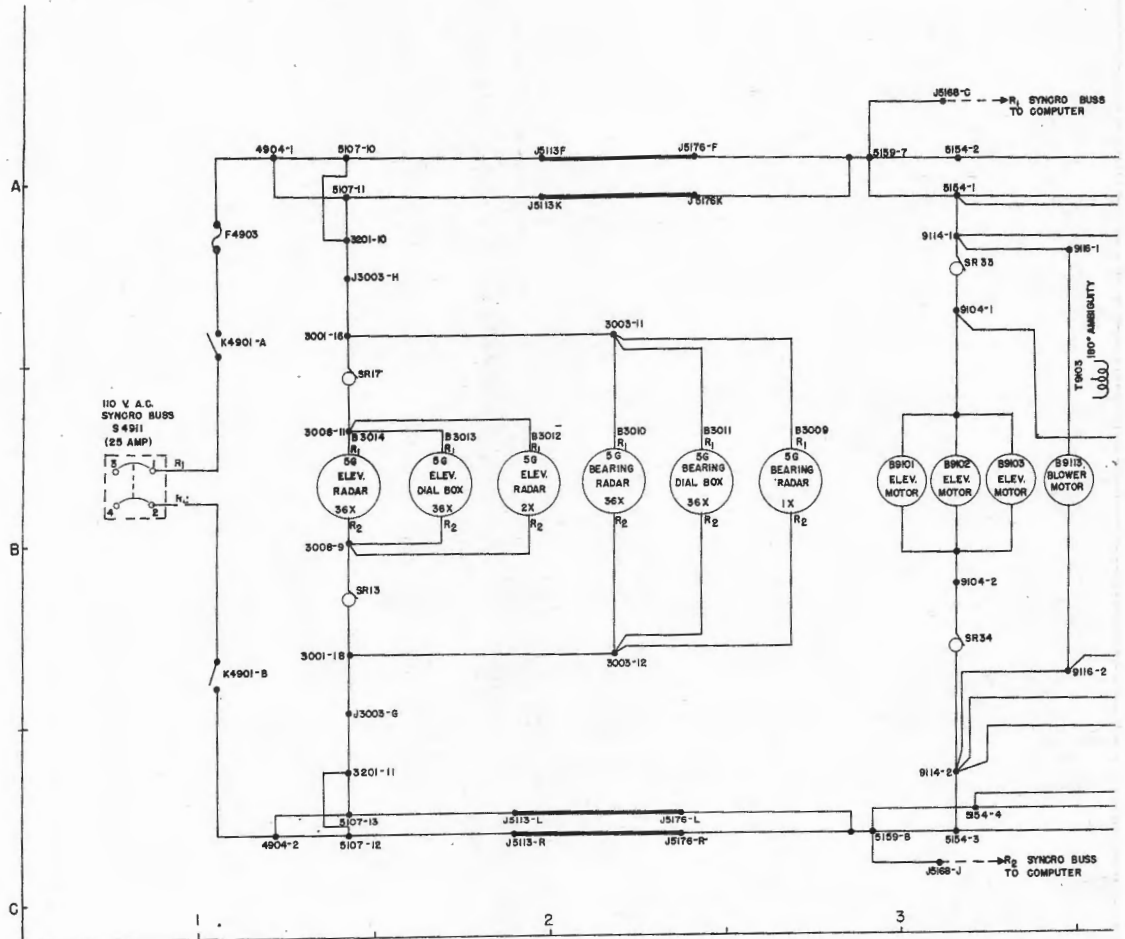
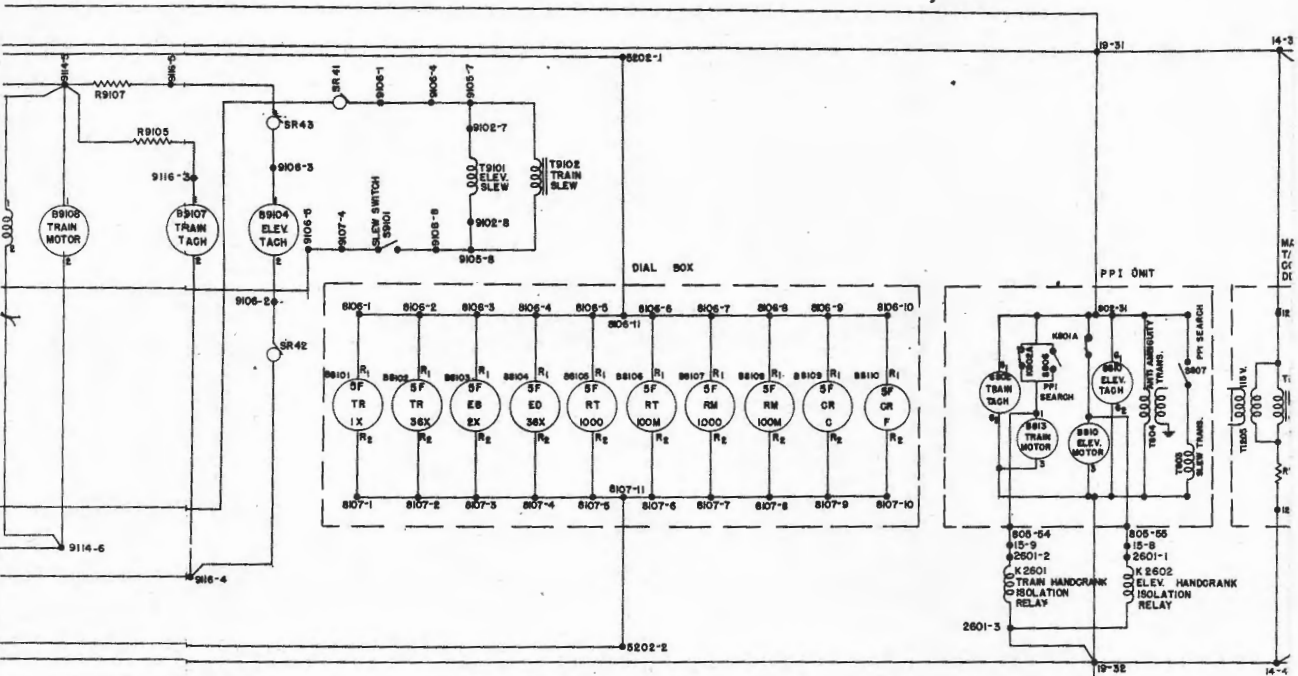


Figure 3-168. A-c Distribution System - Switch S4911

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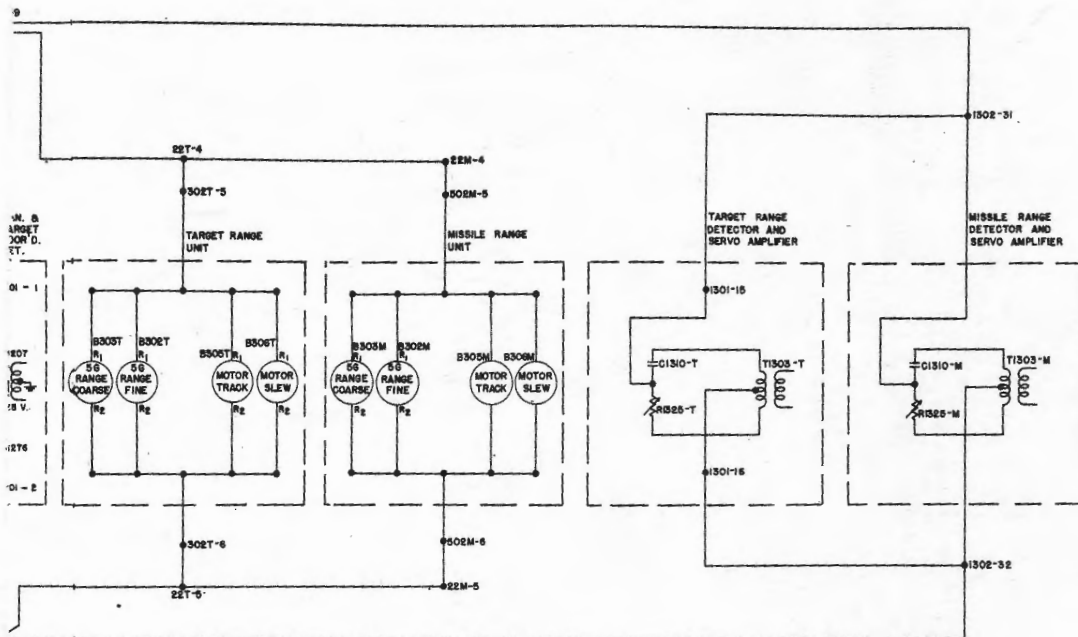


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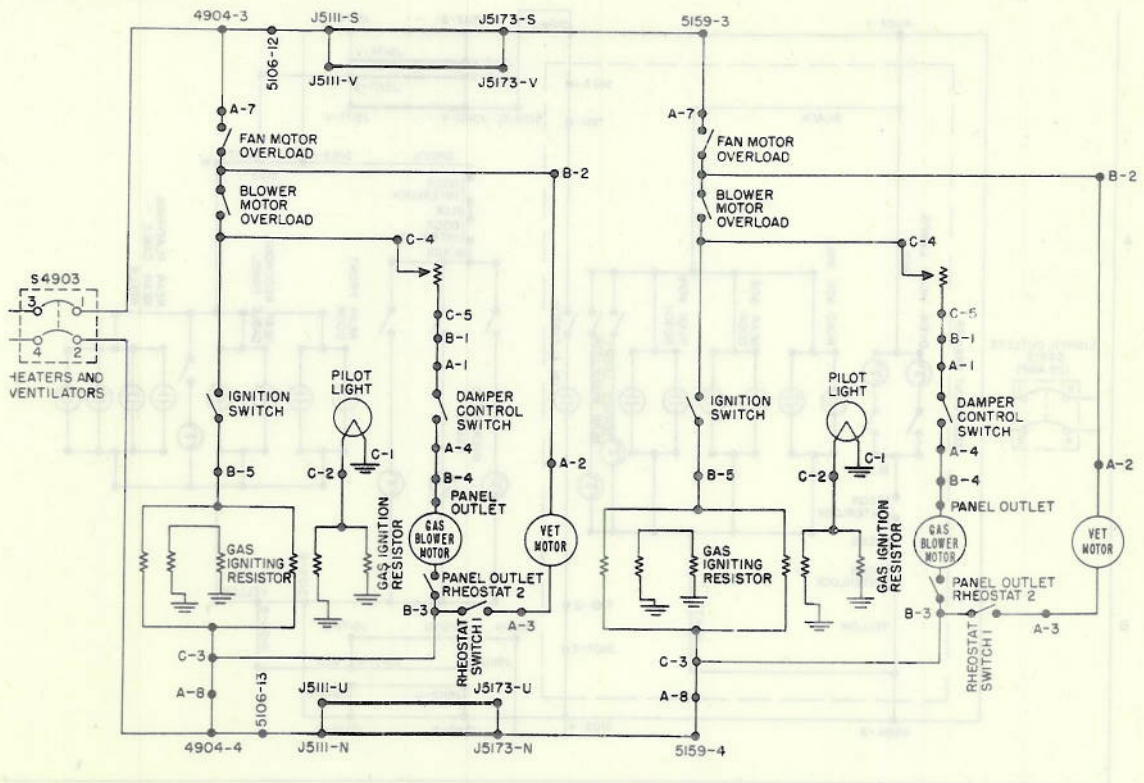


Figure 3-169. A-c Distribution System - Switch S4903

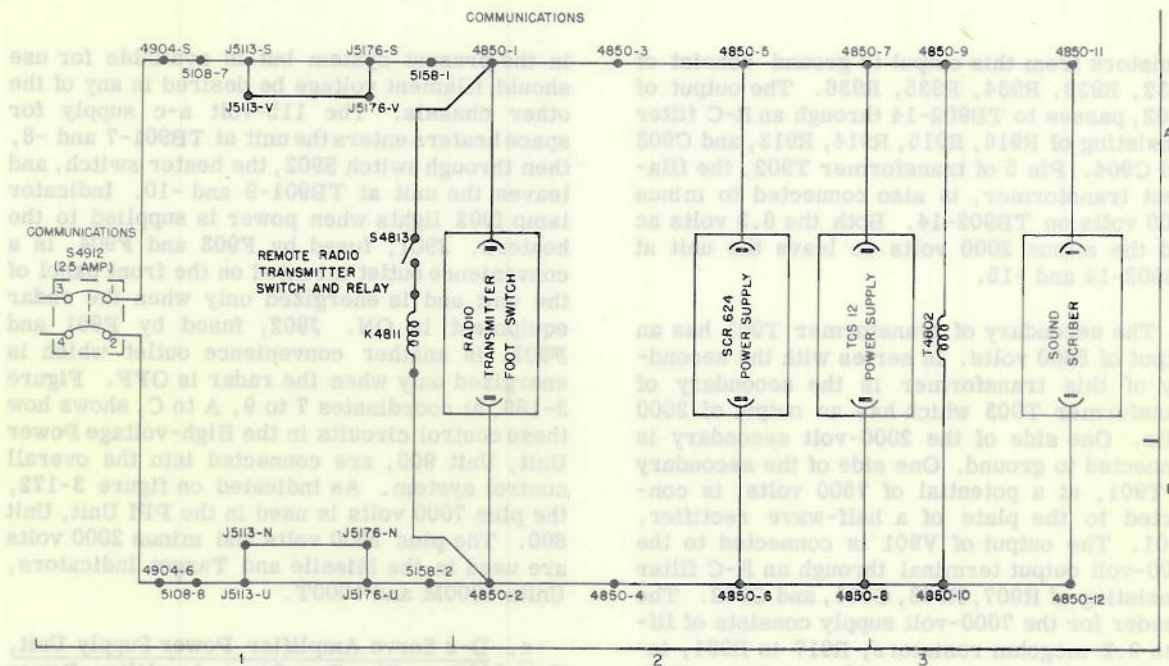


Figure 3-170. A-c Distribution System - Switch S4912

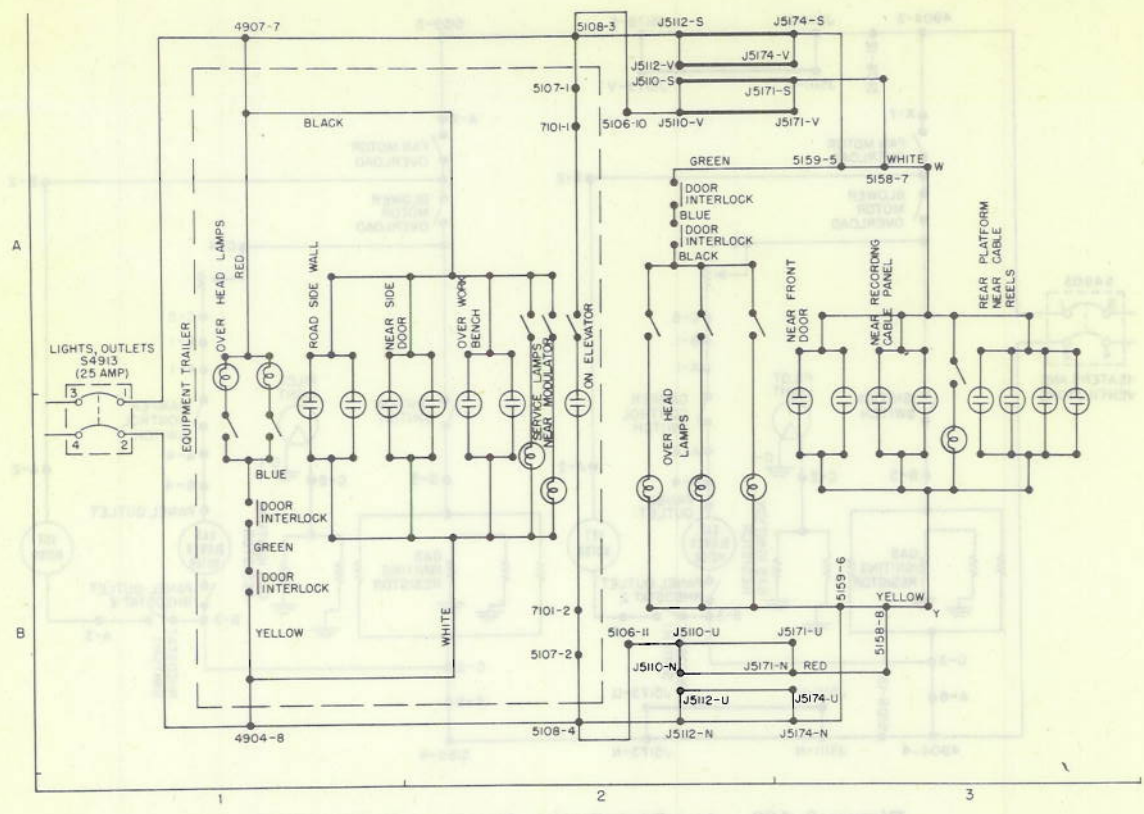


Figure 3-171. A-c Distribution System - Switch S4913

resistors from this output to ground consist of R932, R933, R934, R935, R936. The output of V902, passes to TB902-14 through an R-C filter consisting of R916, R915, R914, R913, and C903 and C904. Pin 5 of transformer T902, the filament transformer, is also connected to minus 2000 volts on TB902-14. Both the 6.3 volts ac and the minus 2000 volts dc leave the unit at TB902-14 and -15.

The secondary of transformer T901 has an output of 5500 volts. In series with the secondary of this transformer is the secondary of transformer T903 which has an output of 2000 volts. One side of the 2000-volt secondary is connected to ground. One side of the secondary of T901, at a potential of 7500 volts, is connected to the plate of a half-wave rectifier, V901. The output of V901 is connected to the 7000-volt output terminal through an R-C filter consisting of R907, R908, C901, and C902. The bleeder for the 7000-volt supply consists of fifteen 2.2 megohm resistors, R917 to R931, inclusive, in series totaling 33 megohms. Pins 3 and 4 of transformer T902 supply 6.3 volts ac for filaments. The filament output is not used

in the present system but is available for use should filament voltage be desired in any of the other chassis. The 115-volt a-c supply for space heaters enters the unit at TB901-7 and -8, then through switch S902, the heater switch, and leaves the unit at TB901-9 and -10. Indicator lamp I902 lights when power is supplied to the heaters. J901, fused by F903 and F904, is a convenience outlet mounted on the front panel of the unit and is energized only when the radar equipment is ON. J902, fused by F901 and F902, is another convenience outlet which is energized only when the radar is OFF. Figure 3-166, at coordinates 7 to 9, A to C, shows how these control circuits in the High-voltage Power Unit, Unit 900, are connected into the overall control system. As indicated on figure 3-172, the plus 7000 volts is used in the PPI Unit, Unit 800. The plus 2000 volts and minus 2000 volts are used in the Missile and Target Indicators, Units 1000M and 1000T.

c. D-c Servo Amplifier Power Supply Unit, Unit 3400. - The D-c Servo Amplifier Power Unit, Unit 3400, provides d-c power for the D-c Servo Amplifier Unit 3300. It is located above

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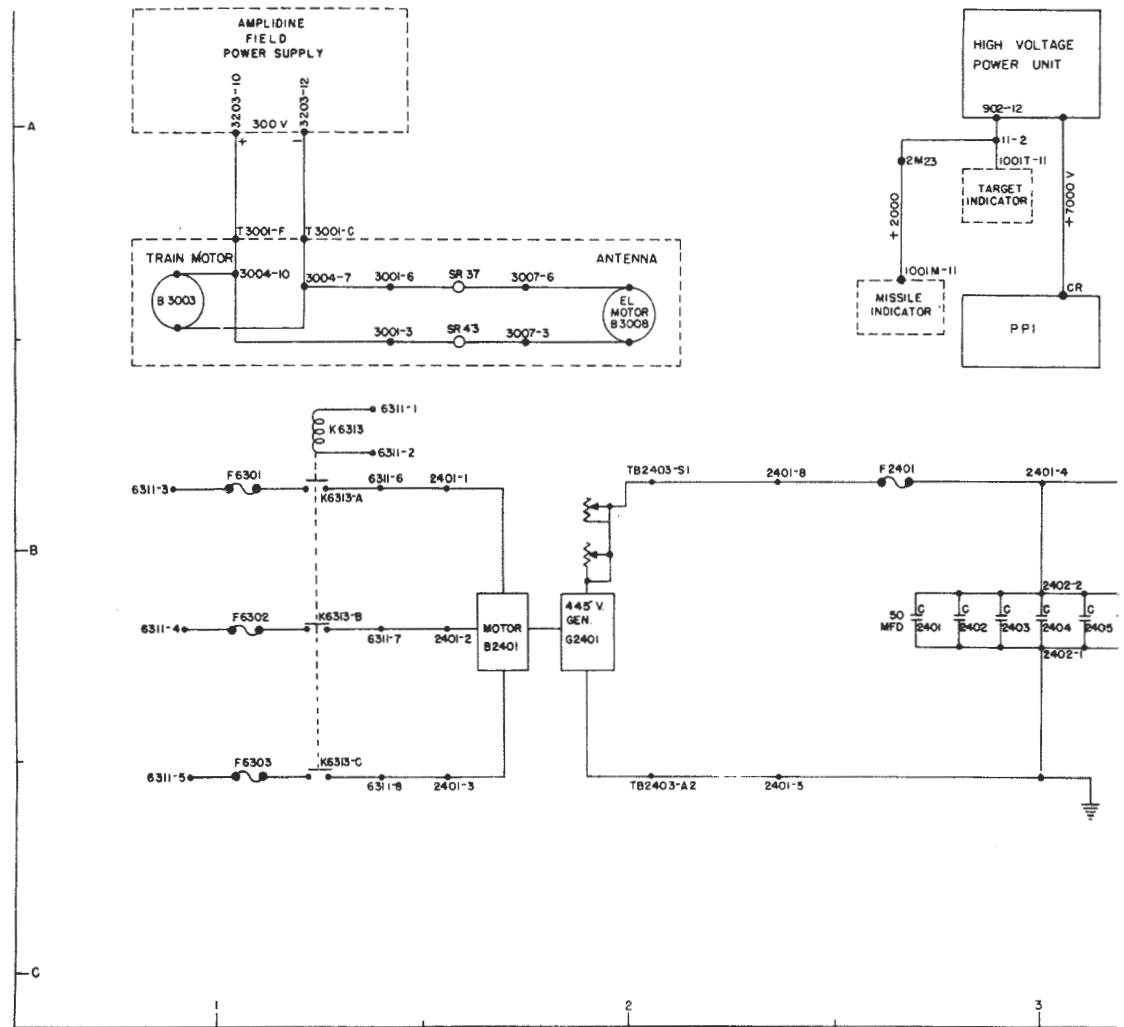
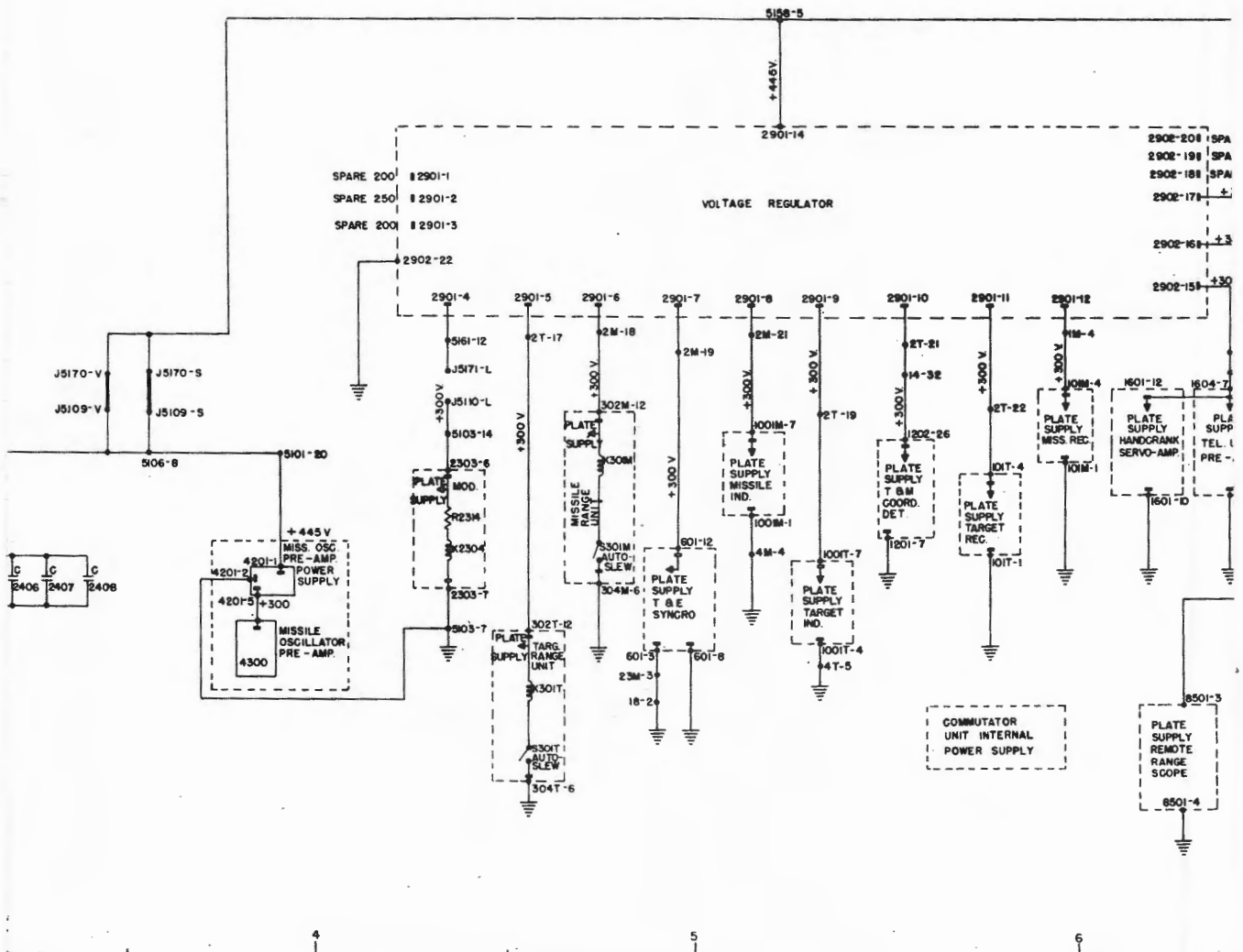
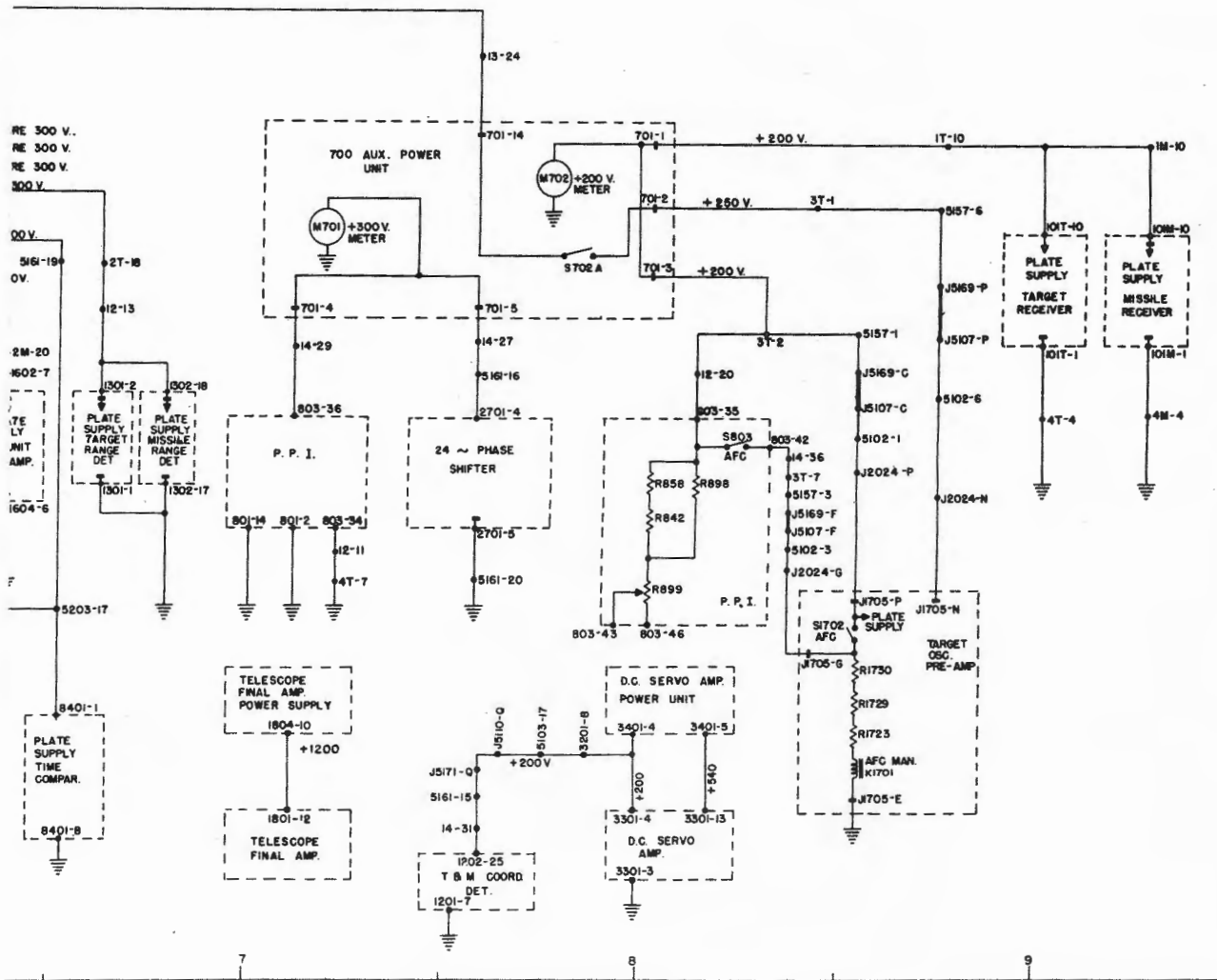


Figure 3-172. D-c Supplies - Positive

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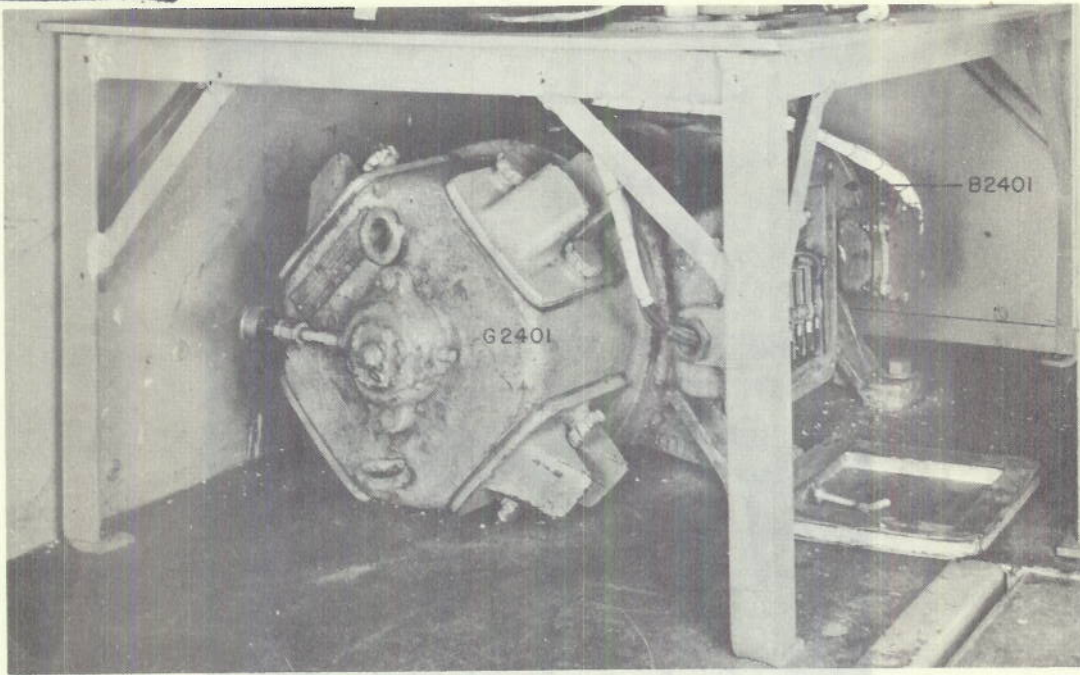


Figure 3-173. D-c Motor Generator - Top View

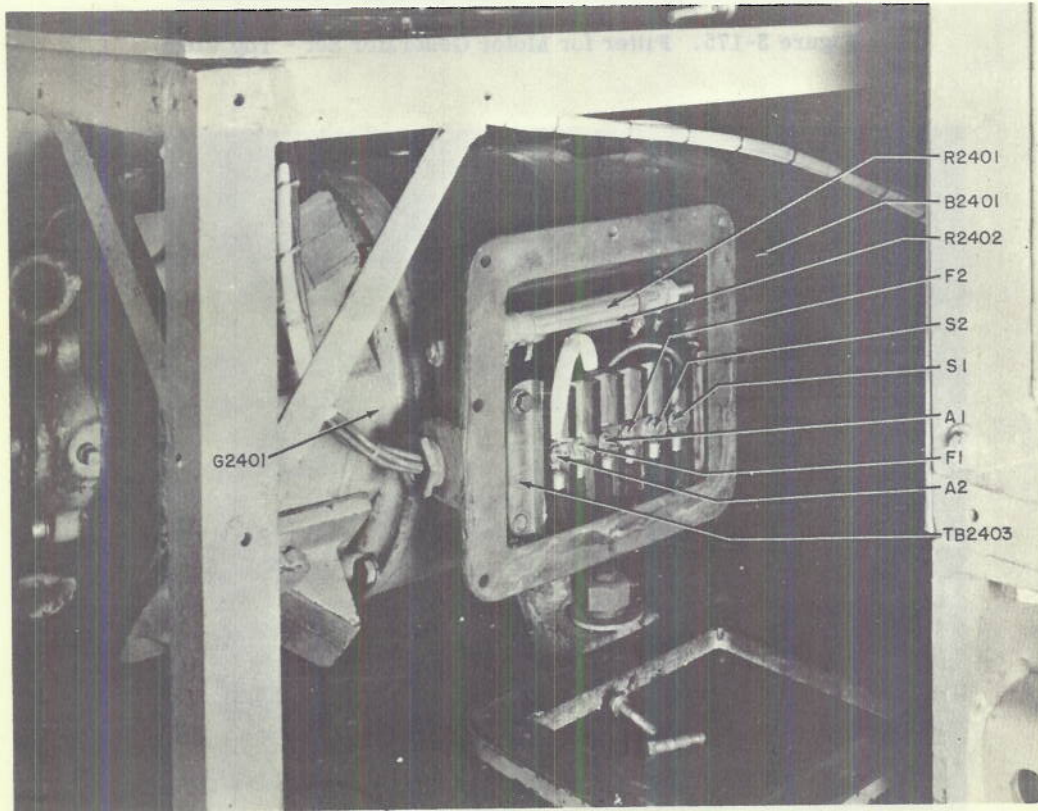


Figure 3-174. Terminal Box on Motor Generator Set - Front View

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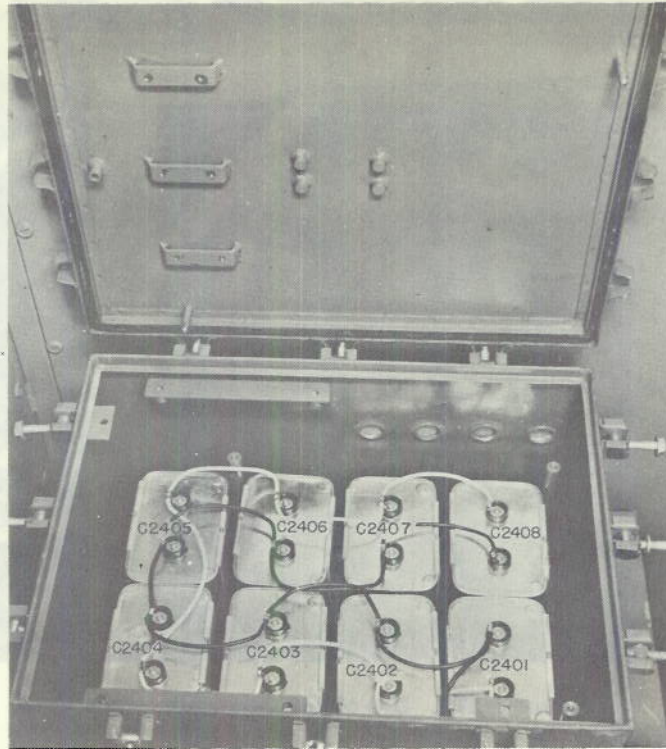


Figure 3-175. Filter for Motor Generator Set - Top View

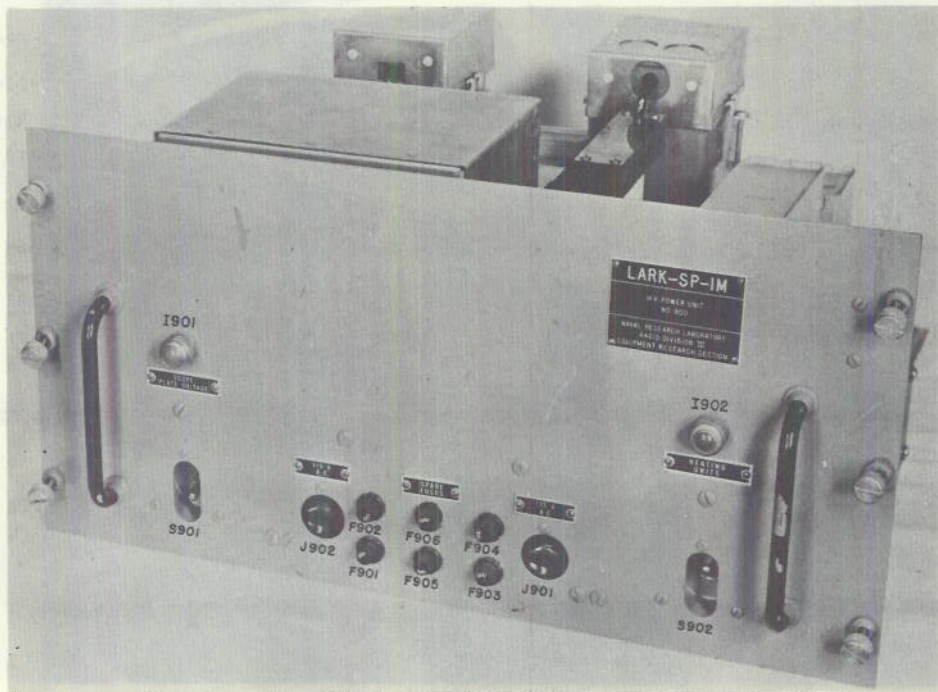


Figure 3-176. High-voltage Power Unit - Front View

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the Antenna Control Unit, Unit 3200, in the equipment trailer. (See figures 3-180 and 3-181.)

Figure 3-172 at coordinates 8C, shows the D-c Servo Amplifier Power Unit, Unit 3400. It has two positive output voltages, 540 volts and 200 volts. Figure 3-182 shows the circuits of the power supply. The a-c input for the unit is connected to the primary of transformer T3401. The transformer has six output windings supplying the following voltages: 1350 volts, 650 volts, 5 volts, and three outputs of 6.3 volts. The 1350-volt output winding is center tapped and feeds the full-wave rectifier tube V3401. The output of the rectifier is smoothed by a filter consisting of C3401A and C3401B, choke L3401, and C3204. Bleeder resistor R3403 is connected across the 540 volt output. The 540 volt output appears at TB3401-5 and is fed directly to TB3301-13 of the d-c servo amplifier unit. For 5 volts to appear across the filament

of V3401 it is necessary to have R3401A and R3401B as well as R3402A and R3402B in series with the filament supply to drop the voltage from 6.3 to 5 volts. The D-c Servo Amplifier Power Unit, Unit 3400, also has a plus 200-volt output used in the low-level amplifier stages of the error signal channel in the target and manual coordinate detector and in the high-level stages in the D-c Servo Amplifier, Unit 3300. The entire amplification system for the error signal channel is fed from the same power supply to prevent power supply variations from independently affecting the high- and low-level amplifier stages and to eliminate spurious operations resulting from unbalances. The plus 200-volt supply is electronically regulated and consists of a full-wave rectifier tube, V3402, whose output is filtered through the filter consisting of C3403, L3402, and C3404. V3404 is in series with this regulated voltage. A bleeder consisting of R3413, R3414, and R3415 is placed across this supply. R3414 has a variable center tap which is connected through R3412 to the grid of V3405. The grid of V3405 is operated at approximately 100 volts above ground. V3406, a 105-volt reg-

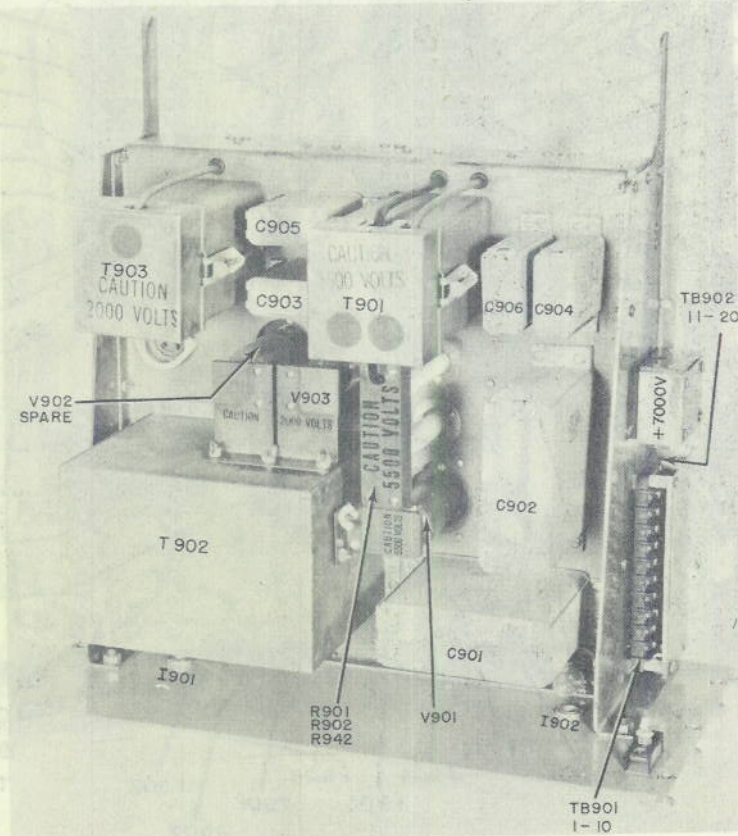


Figure 3-177. High-voltage Power Unit - Top View

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ulator tube in series with the cathode of V3405, brings the cathode up to plus 105 volts. The plate of the amplifier tube, V3405, is connected to the grid of V3404. Therefore, any variations in voltage which appear across the regulated output are fed through V3405, amplified, and applied to the grid of V3404 changing the series resistance of this tube changing the output of the voltage regulator. The regulated output voltage is applied to TB3401-4.

of the Target and Manual Coordinate Detector Unit, Unit 1200. Minus 150 volts is obtained from the half-wave rectifier tube, V3403. The cathode of the rectifier tube, V3403, is connected to one side of the 650-volt winding of the plate transformer of rectifier tube V3402. The output of V3402 is filtered by the R-C network consisting of R3404 and C3405 and is regulated to 150 volts by V3407, a 150-volt regulator tube.

Figure 3-183 also shows that the D-c Servo Amplifier Power Supply, Unit 3400, supplies minus 150 volts from TB3401-7 to TB1202-12

d. Amplidyne Field Power Supply in the Antenna Control Unit, Unit 3200. - The amplidyne field power supply provides an ungrounded d-c source of voltage for the field coils of the am-

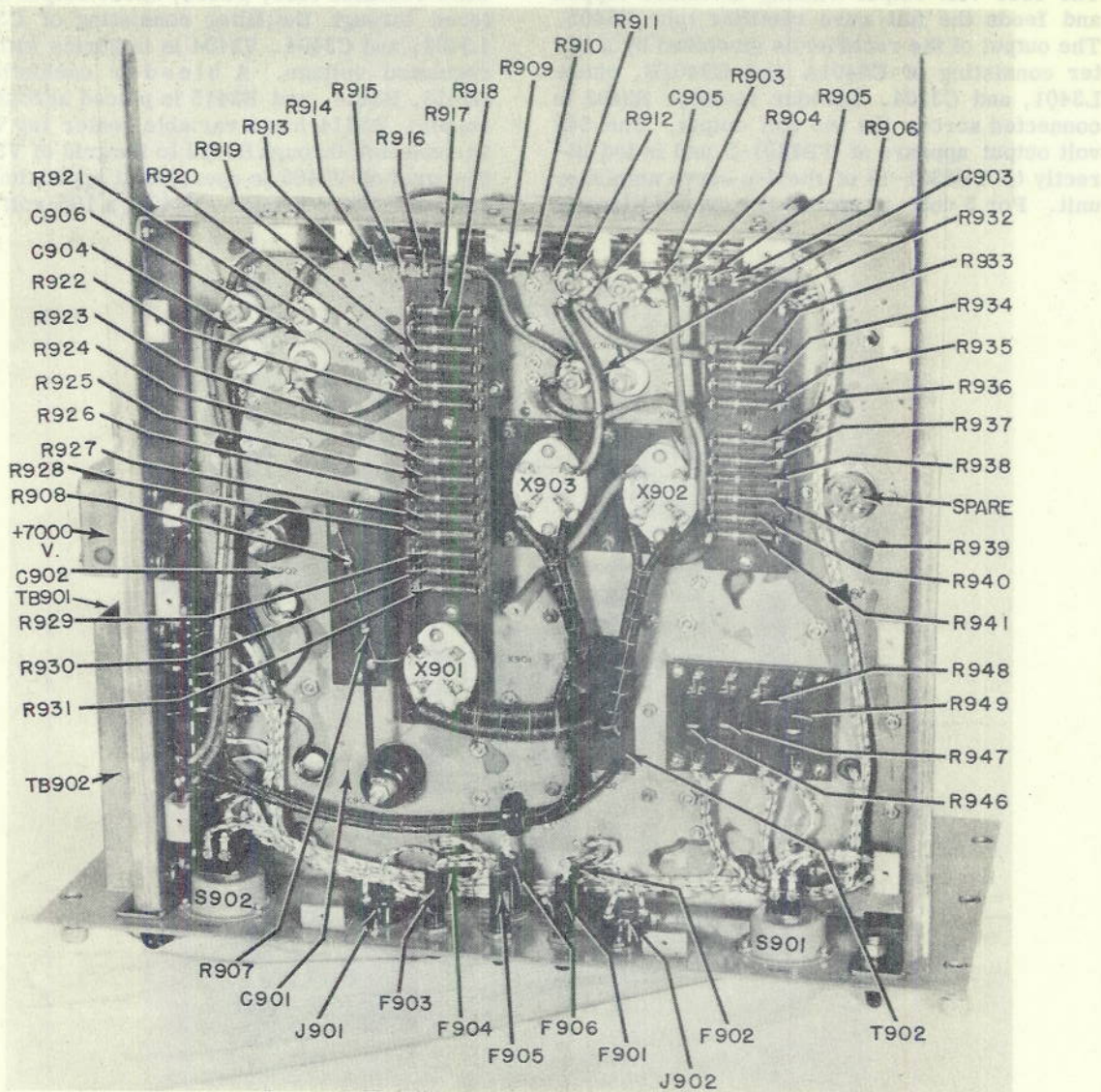


Figure 3-178. High-voltage Power Unit - Bottom View

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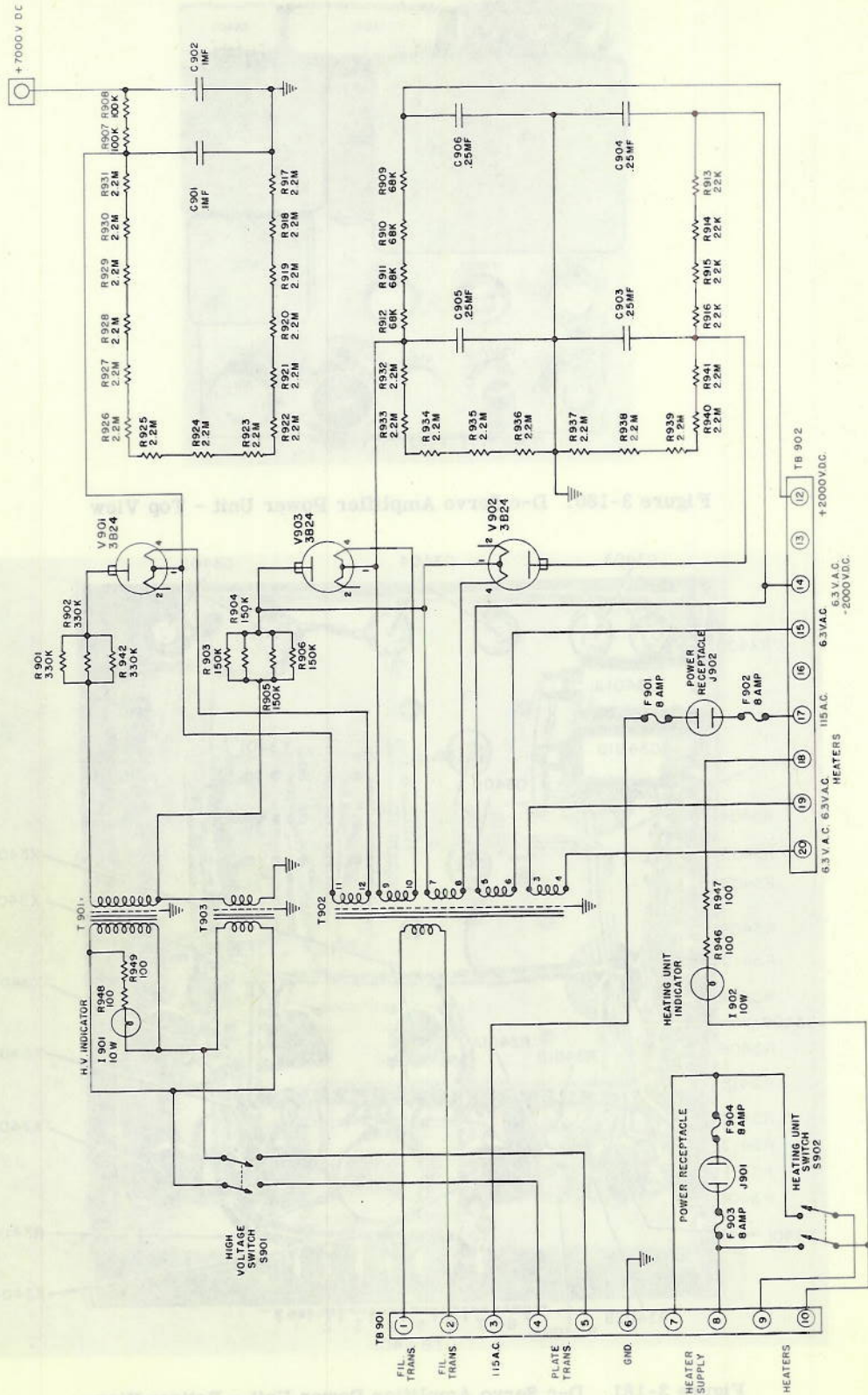


Figure 3-179. High-voltage Power Unit - Schematic Diagram

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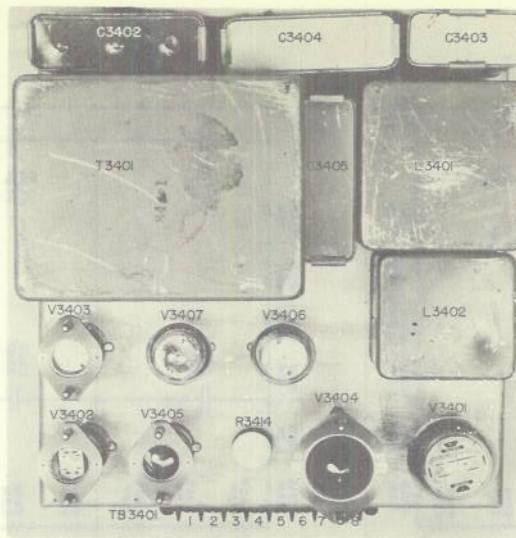


Figure 3-180. D-c Servo Amplifier Power Unit - Top View

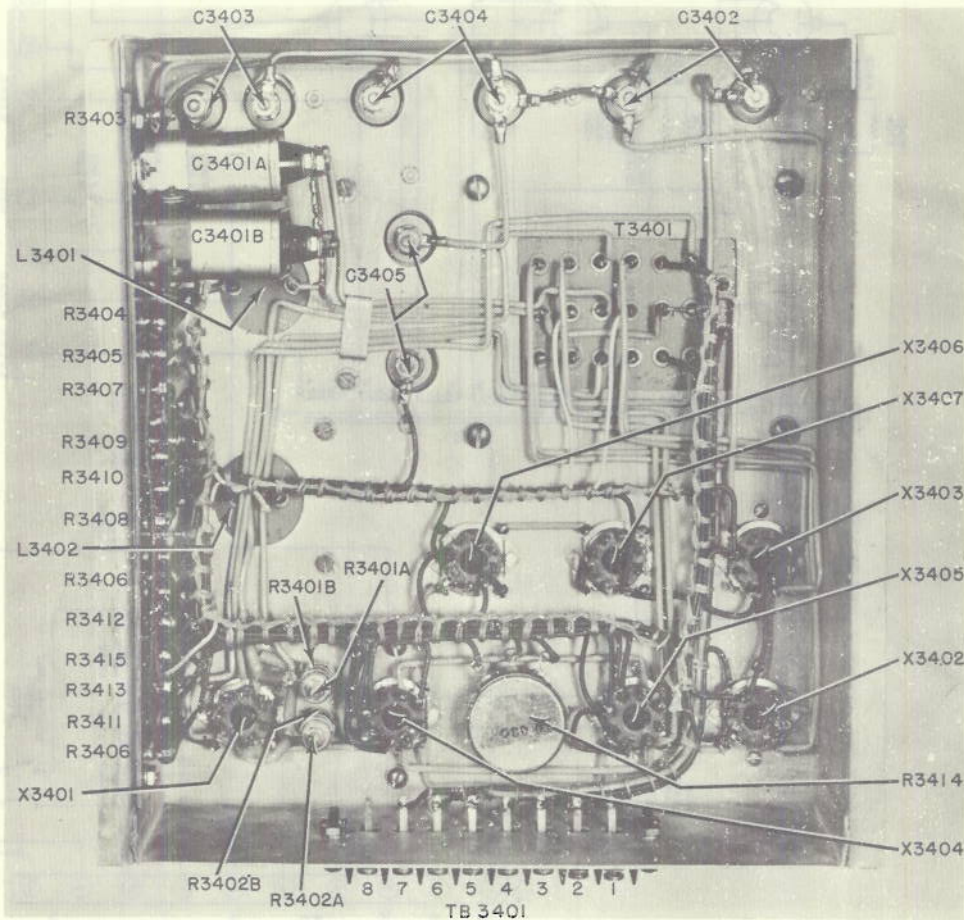


Figure 3-181. D-c Servo Amplifier Power Unit - Bottom View

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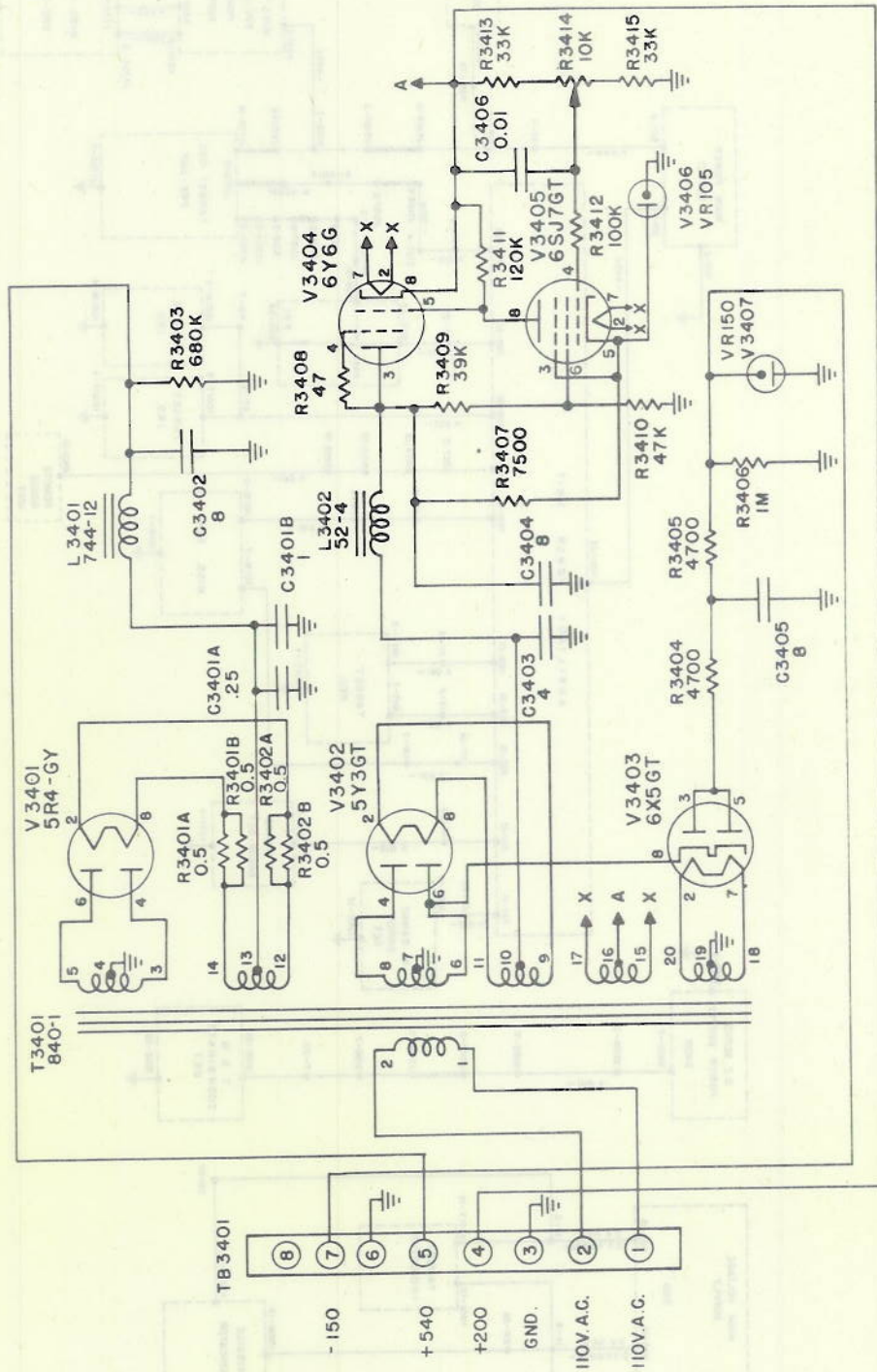


Figure 3-182. D-c Servo Amplifier Power Unit - Schematic Diagram

plidynes. It is located in the Antenna Control Unit, Unit 3200.

Figure 3-172, at coordinates I,A, shows in block diagram form the power supply which supplies 300 volts dc for the field of the amplidynes. Figure 3-248 shows the circuitry for this power supply. The power supply is located within the Antenna Control Unit, Unit 3200, and consists of V3201, a full-wave rectifier, T3201, its filament transformer, and T3202, its plate transformer. The output of the rectifier has a bleeder resistor consisting of R3201, R3202, and R3203 across its output. The output appears on TB3203-10 and -12 and is fed to the fields of the train drive motor, B3003, and the elevation drive motor, B3008, in the antenna.

e. Telescope Final Amplifier Power Supply, Unit 1800. - The Telescope Final Amplifier Power Supply, Unit 1800, provides the high-voltage supply to the Telescope Final Amplifier, also Unit 1800. It is located in the operations trailer. (See figures 3-184, 3-185, and 3-186.)

Figure 3-172, 7-B, shows that the Telescope Final Amplifier Power Supply, Unit 1800, has a plus 1200-volt output from TB1804-10 which is supplied to the telescope final amplifier at TB1801-12. Figure 3-186 shows the circuitry

for the power supply. A-c power is applied to the primary of T1805, the filament transformer, and to the plate transformer, T1804. These transformers feed the full-wave rectifier which consists of tubes V1809 and V1810. The output voltage is filtered by the inductances L1801 and L1802 and the capacitances C1815 and C1816. Resistors R1825 and R1827 form a bleeder.

f. Main Power Unit, Unit 500. - The Main Power Unit, Unit 500, supplies all the negative d-c voltages for the radar equipment. It is located in the console in the operations trailer. (See figures 3-187 through 3-191.)

The 115-volt a-c input power enters on TB501-13 and -14 and is connected to the main power switch, S501. The output of this switch supplies the plate power switch, S502, all the console filament circuits through TB501-11 and -12, and filament transformer T502. The plate transformer, T501, the high-voltage transformers, T901 and T903, and the d-c motor generator relay, K6300, are energized from the plate power switch, S502, through interlocks and a battle short switch, S503. (See figure 3-191 and figure 3-166 at coordinates 18, B and C.)

The secondary of filament transformer, T502, has four windings which supply the con-



Figure 3-184. Telescope Final Amplifier Power Supply - Front View

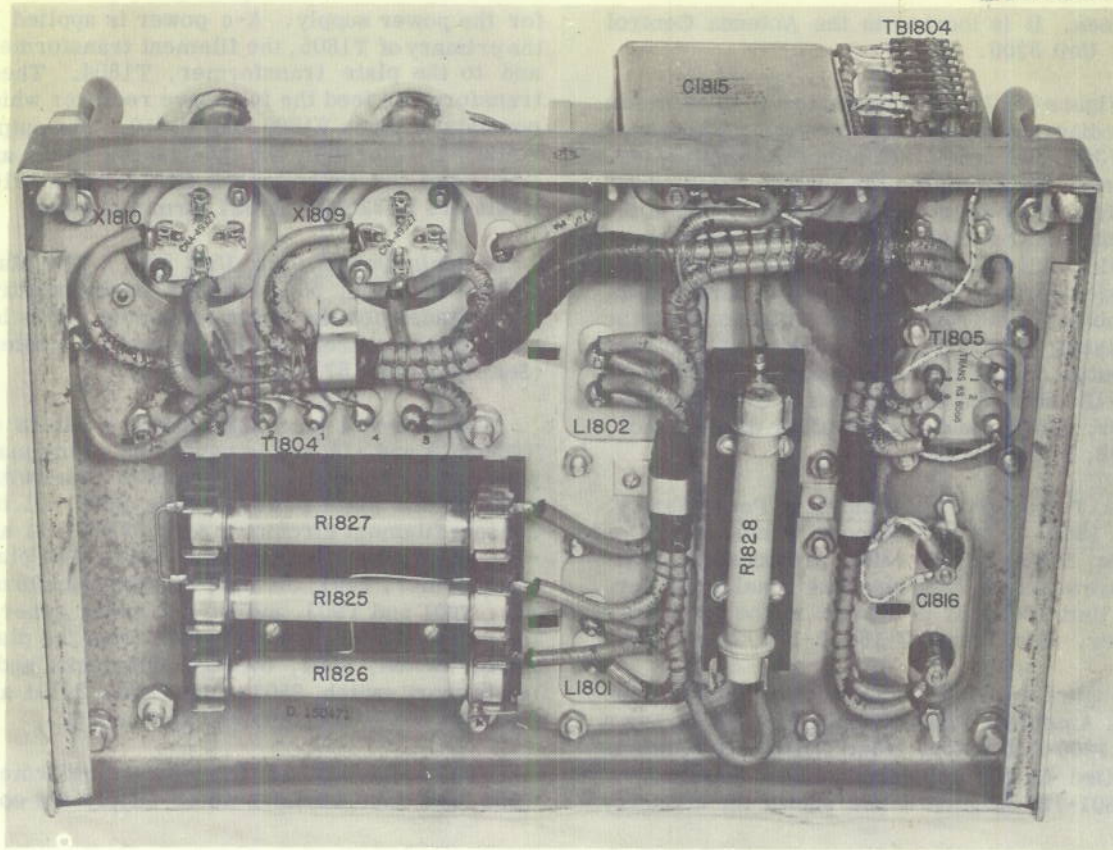


Figure 3-185. Telescope Final Amplifier Power Supply - Bottom View

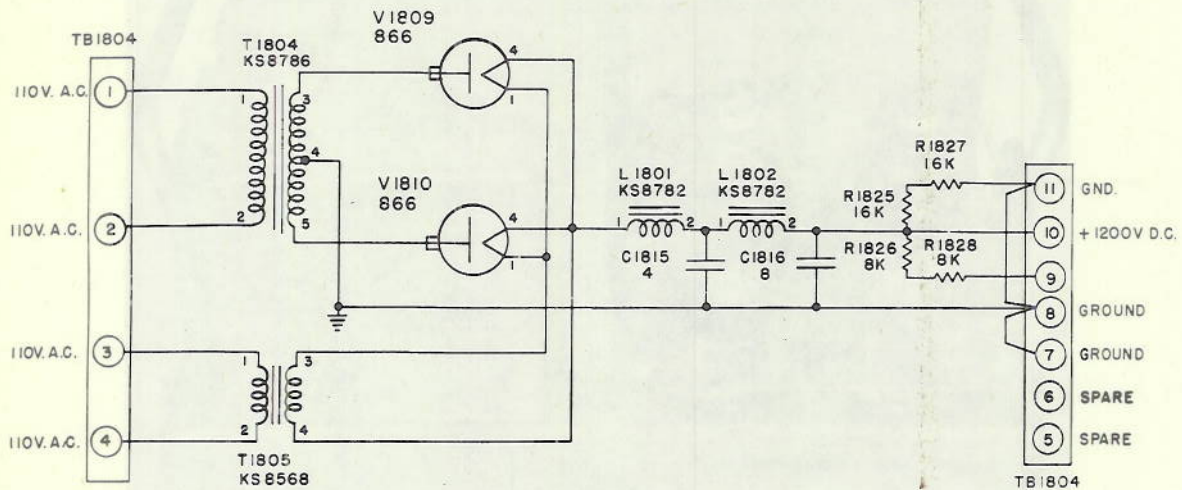


Figure 3-186. Telescope Final Amplifier Power Supply - Schematic Diagram

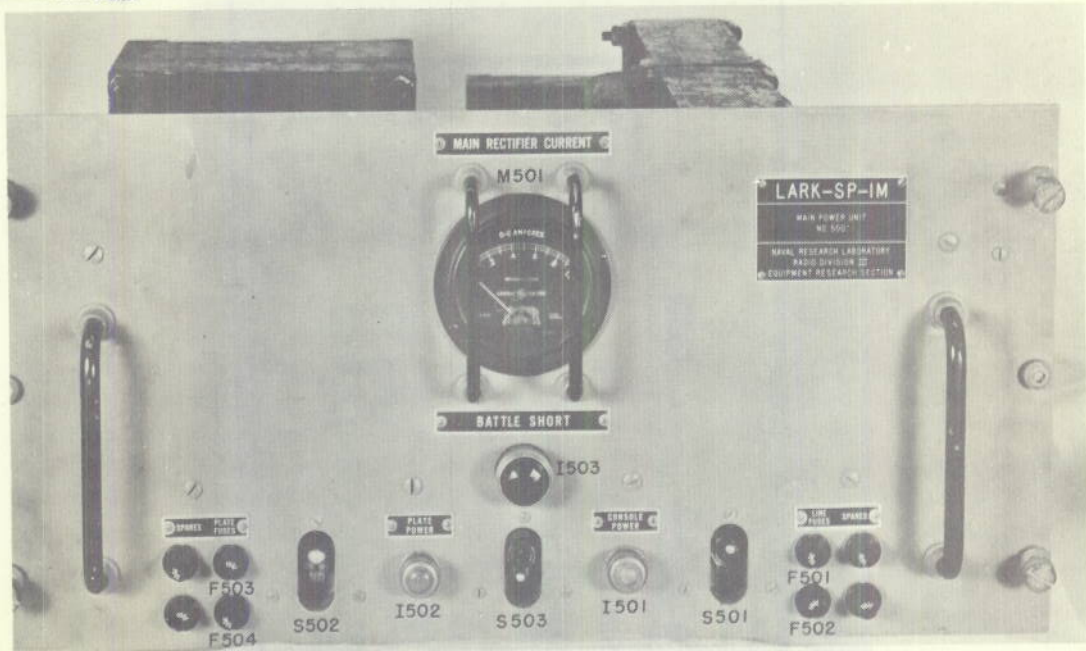


Figure 3-187. Main Power Unit - Front View

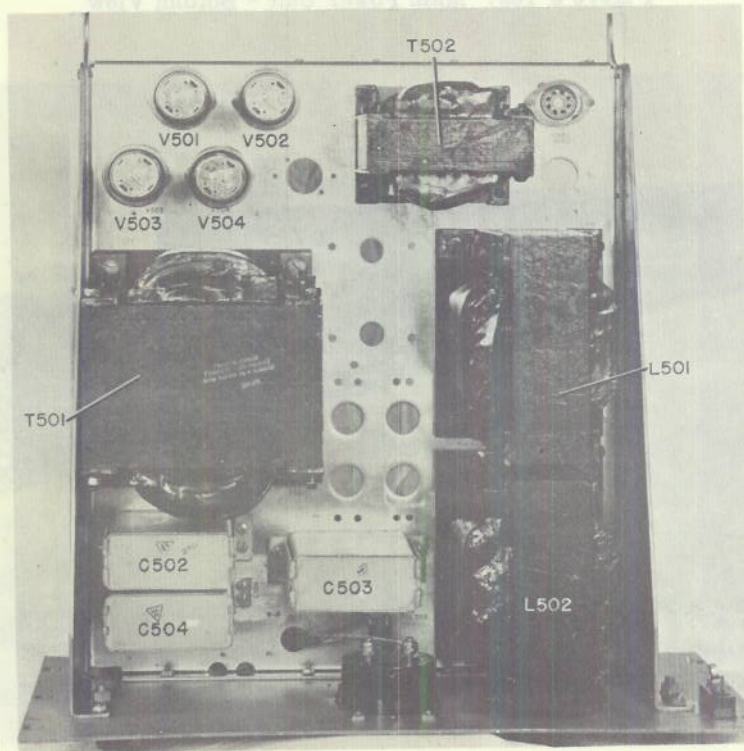


Figure 3-188. Main Power Unit - Top View

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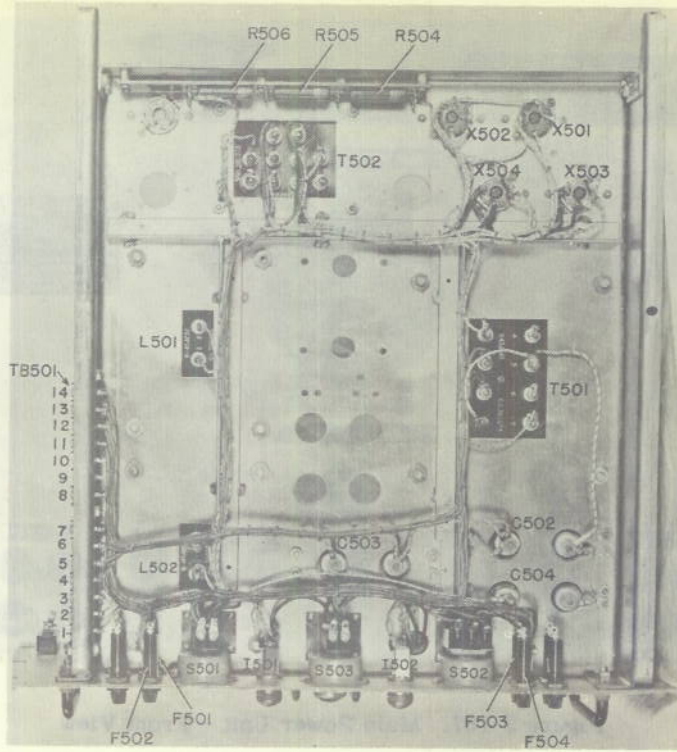


Figure 3-189. Main Power Unit - Bottom View

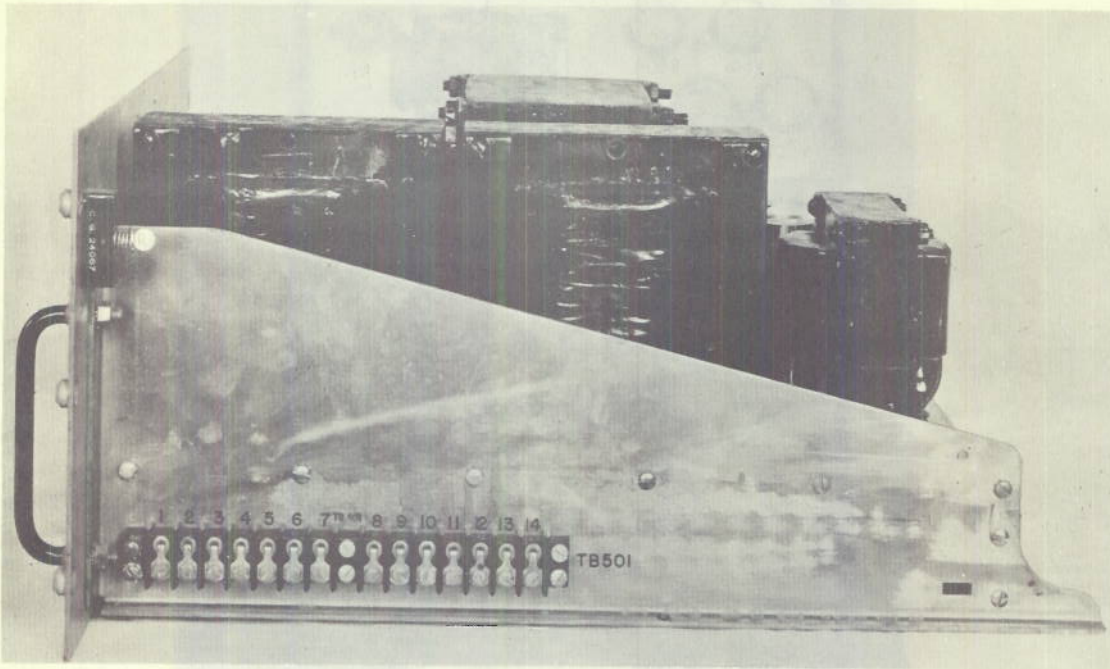


Figure 3-190. Main Power Unit - Right Side View

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sole power indicator, I501, the plate power indicator, I502, and the filament voltages for the rectifier tubes, V501, V502, V503 and V504.

The secondary of plate transformer, T501, has a grounded center tap so that 550 volts is impressed on the cathodes of four 5U4G's arranged as full-wave rectifiers which produce minus 450 volts dc. The filter for this rectifier consists of L501, L502, C501, C502, and C503. Rectifier current meter, M501, measures the minus 450-volt d-c current. The bleeder consists of R504, R505, R506.

This power supply has a capacity of one ampere at 450 volts.

g. Internal Power Supply of the Commutator Unit, Unit 8600. - Figure 3-172, at coordinates 6, C, shows the internal power supply of the Commutator Unit, Unit 8600. This power supply furnishes a commutated d-c pulse for the time comparator unit and is discussed in the description of the data recording equipment in this section, subsection 3-6.

h. Keep-alive Power Supply, Unit 6200. - The Keep-alive Power Supply, Unit 6200, provides power for a source of stray ions in the duplexer gas discharge tubes, V2002 and V2004. The keep-alive power supply is located in the top section of the Transmitter Unit, Unit 2000. The circuit description of the keep-alive power supply is given in this section, subsection 3-3.

It consists of a 925-volt half-wave rectifier unit capable of supplying a maximum current of 0.25 milliamps. The a-c power for this unit is applied to the primary of the transformer T6201 (figure 3-167 at coordinates B, 8). The secondary voltage of this transformer is applied to the half-wave rectifier tube, V6201.

i. Internal High-voltage Power Supply of the Remote Range Indicator Unit, Unit 8500. - The high voltages required for the cathode-ray tube used in the Remote Range Indicator Unit, Unit 8500, are generated within the unit and are described in the discussion of the remote range indicator unit, this section, subsection 3-6.

5. D-C VOLTAGE REGULATORS

There are three d-c voltage regulators used in the Lark SP-1M equipment:

Auxiliary Power Unit, Unit 700
D-c Voltage Regulator, Unit 2900
Missile Oscillator Preampifier Power Supply Unit 4200

a. Auxiliary Power Unit, Unit 700. - The Auxiliary Power Unit, Unit 700, provides a regulated supply for some of the negative voltages used in the equipment and a regulated supply for those positive voltages which do not require isolation from noise sources.

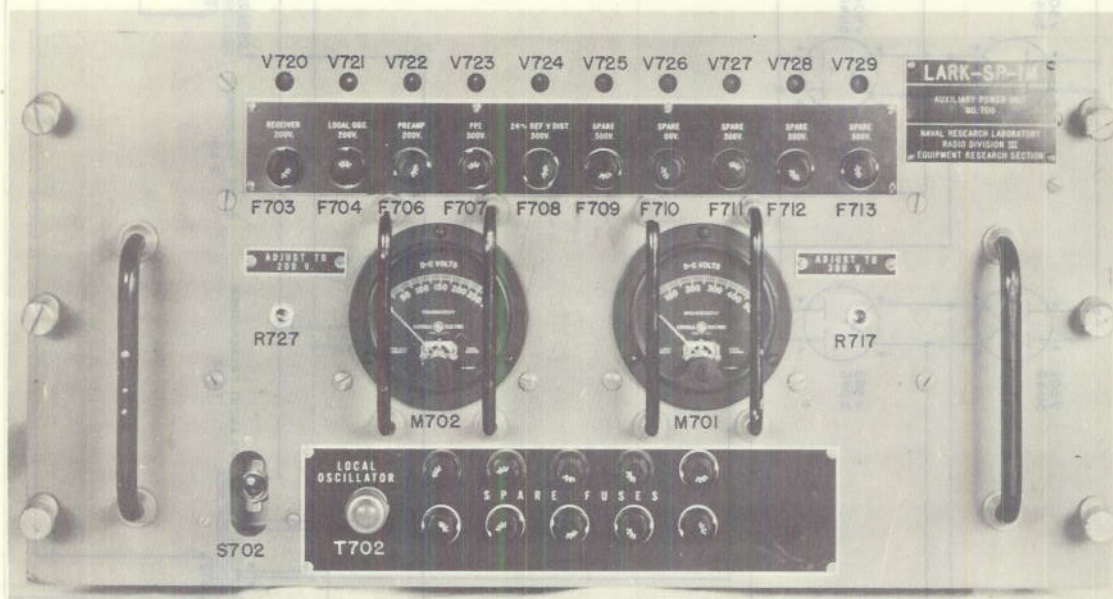


Figure 3-192. Auxiliary Power Unit - Front View

The unit is located in the console in the operations trailer. (See figures 3-192, through 3-195.)

The plus 445 volts from the d-c generator is supplied to the Auxiliary Power Unit, Unit 700, through TB701-14 (figure 3-172). The schematic for this voltage regulator is given in figure 3-196. Tubes V701 through V706, and tube V718 are regulator tubes and are in series with the 300-volt regulated output. The bleeder across the 300-volt regulated output consists of R718, R717, and R716. R717 is a variable resistor which is tapped off to the grid of the voltage amplifier tube, V707. The voltage on the grid is approximately plus 150 volts; therefore, the 150-volt regulator tube, V708, connected to the cathode of tube V707, is necessary to hold the cathode to plus 150 volts, approximately the potential of the grid. The regulated 300 volts is applied to the plate of V707 through resistor R712. Variations in the output voltage of the regulated voltage supply are impressed on the grid of V707 and appear, amplified, at the plate. Since the plate of V707 is connected to the con-

trol grids of the tubes in series with the plus 445 volt supply, V701 through V706 and V718, the plate potential of V707 controls the resistance of these tubes and thus controls the output of the regulator. The regulated plus 300-volt output appears at the following terminals: TB701-4 which is connected to TB803-36 of the PPI unit; TB701-5 connected to TB2701-4 of the reference voltage distribution unit; and TB701-6, -7, -8, -9, and -10 which are spare 300-volt regulated outputs. In addition to the plus 300-volt regulator, Unit 700 has a plus 200-volt regulator consisting of tubes V709, V710, and V711, in series with the regulated 200-volt output. The bleeder resistor across this 200-volt regulated output is R728, R727, and R726. The center tap of the variable resistor, R727, is connected to the grid of the voltage amplifier tube, V712. The voltage on this grid is approximately 100 volts. A type VR105 voltage regulator tube, V713, is used in series with the cathode of tube V712 to keep the cathode of tube V712 at plus 105 volts, approximately the potential at the grid of V712. The plate of V712 is connected to the control grids of the tubes V709, V710, and V711,

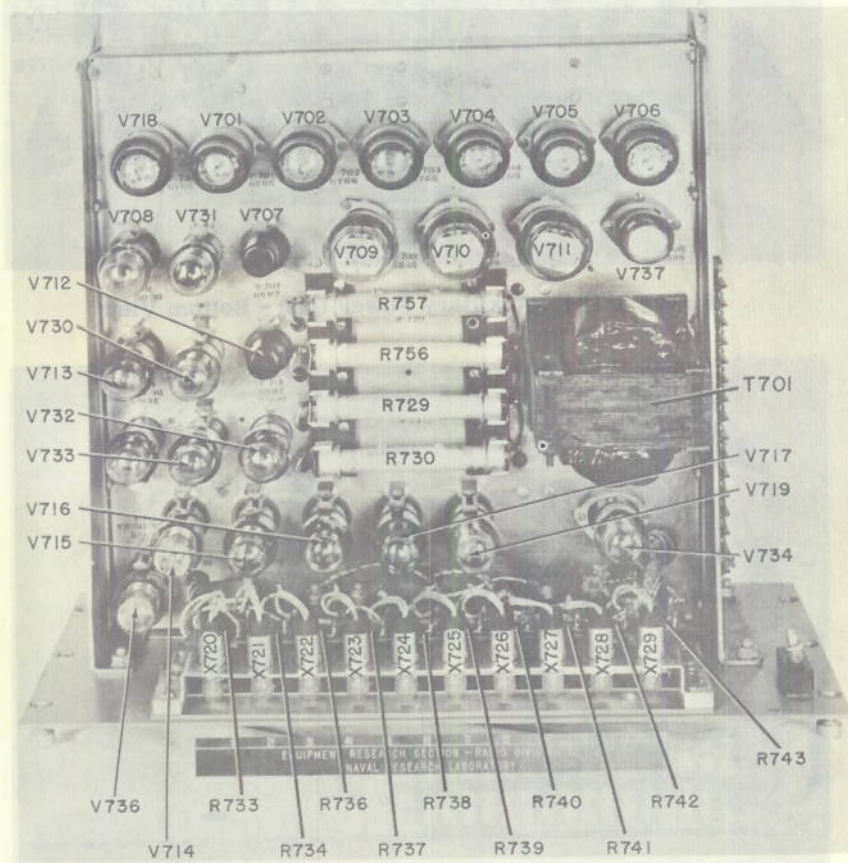


Figure 3-193. Auxiliary Power Unit - Top View

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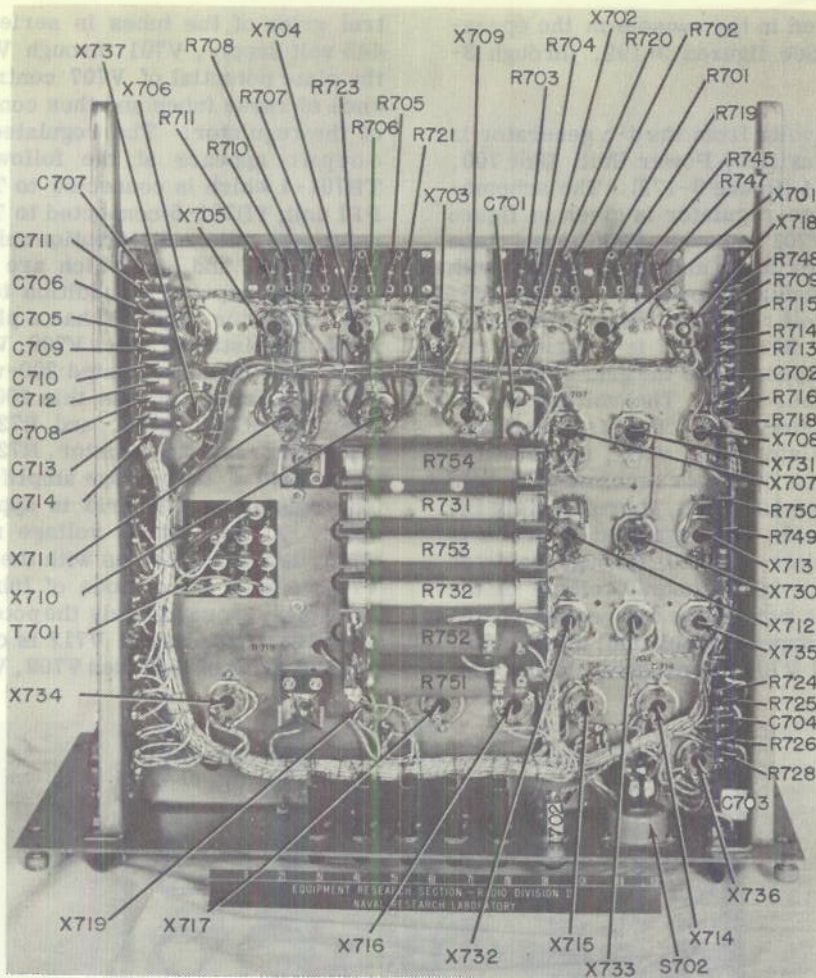


Figure 3-194. Auxiliary Power Unit - Bottom View

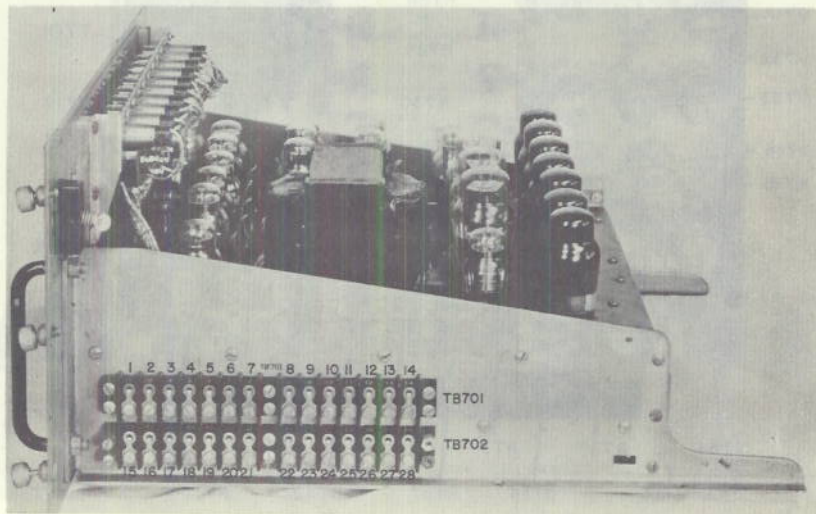


Figure 3-195. Auxiliary Power Unit - Right Side View

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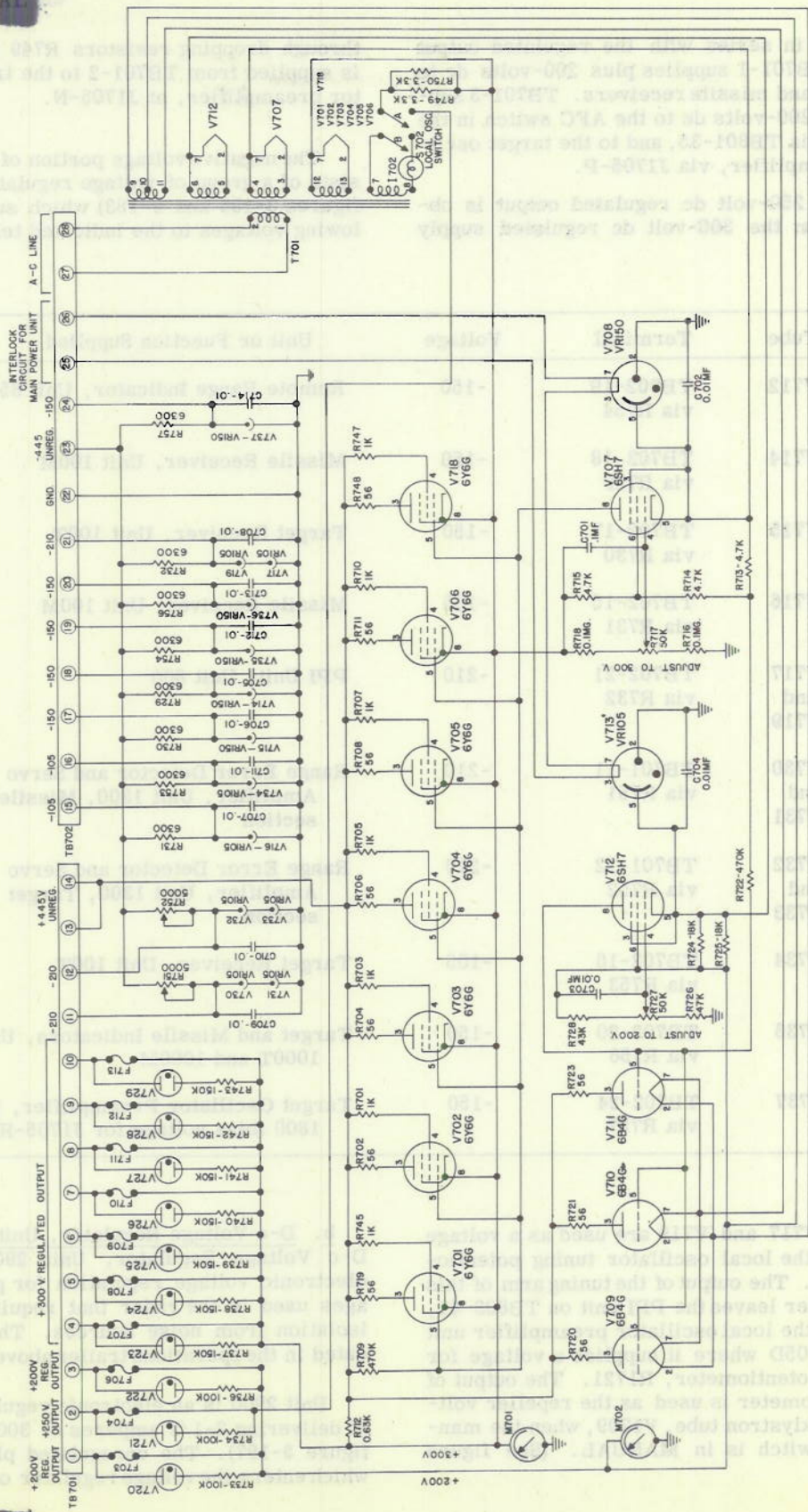


Figure 3-196. Auxiliary Power Unit - Schematic Diagram

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which are in series with the regulated output supply. TB701-1 supplies plus 200-volts dc to the target and missile receivers. TB701-3 supplies plus 200-volts dc to the AFC switch in the PPI unit, via TB801-35, and to the target oscillator preamplifier, via J1705-P.

A plus 250-volt dc regulated output is obtained from the 300-volt dc regulated supply

through dropping resistors R749 and R750 and is supplied from TB701-2 to the target oscillator preamplifier, at J1705-N.

The negative voltage portion of this unit consists of a group of voltage regulator tubes (see figures 3-196 and 3-183) which supply the following voltages to the indicated terminals:

Tube	Terminal	Voltage	Unit or Function Supplied
V712	TB702-19 via R754	-150	Remote Range Indicator, Unit 8500
V714	TB702-18 via R729	-150	Missile Receiver, Unit 100M
V715	TB702-17 via R730	-150	Target Receiver, Unit 100T
V716	TB702-15 via R731	-105	Missile Receiver, Unit 100M
V717 and V719	TB702-21 via R732	-210	PPI Unit, Unit 800
V730 and V731	TB701-11 via R751	-210	Range Error Detector and Servo Amplifier, Unit 1300, Missile section
V732 and V733	TB701-12 via R752	-210	Range Error Detector and Servo Amplifier, Unit 1300, Target section
V734	TB702-16 via R753	-105	Target Receiver, Unit 100T
V736	TB702-20 via R756	-150	Target and Missile Indicators, Units 1000T and 1000M
V737	TB702-24 via R757	-150	Target Oscillator Preamplifier, Unit 1800 (bias voltage for J1705-H)

Tubes V717 and V719 are used as a voltage supply for the local oscillator tuning potentiometer R843. The output of the tuning arm of this potentiometer leaves the PPI unit on TB803-41, and enters the local oscillator preamplifier unit on jack J1705D where it supplies a voltage for the tuning potentiometer, R1721. The output of this potentiometer is used as the repeller voltage for the klystron tube, V1709, when the manual AFC switch is in MANUAL. (See figure 3-183.)

b. D-c Voltage Regulator, Unit 2900. - The D-c Voltage Regulator, Unit 2900, provides electronic voltage regulation for positive voltages used in the radar that require maximum isolation from noise sources. The unit is located in the operations trailer above the console.

Unit 2900 is an electronic regulator capable of delivering 2-1/2 amperes at 300 volts. (See figure 3-197). The unregulated plus 445 volts which enters the voltage regulator on TB2901-13

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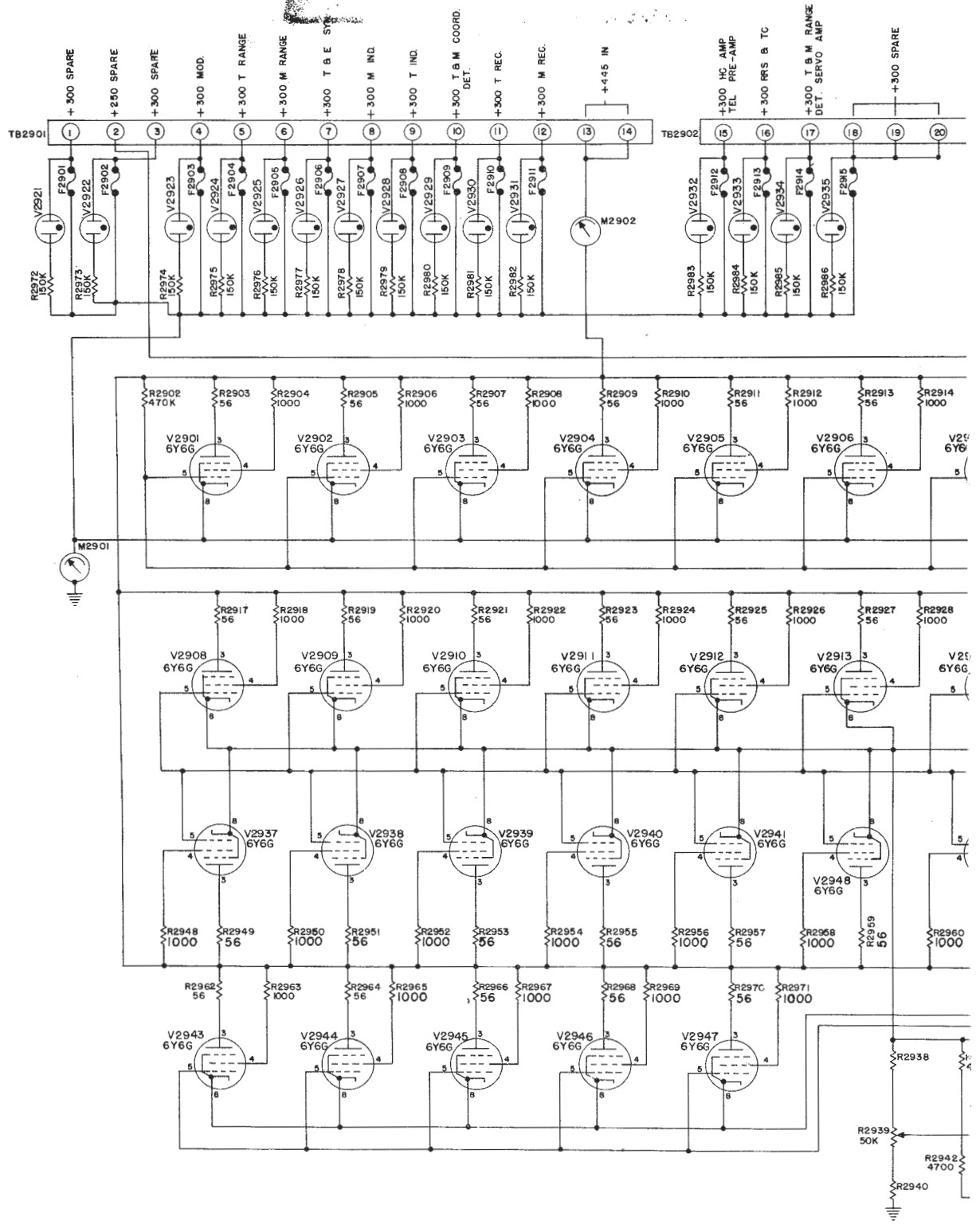
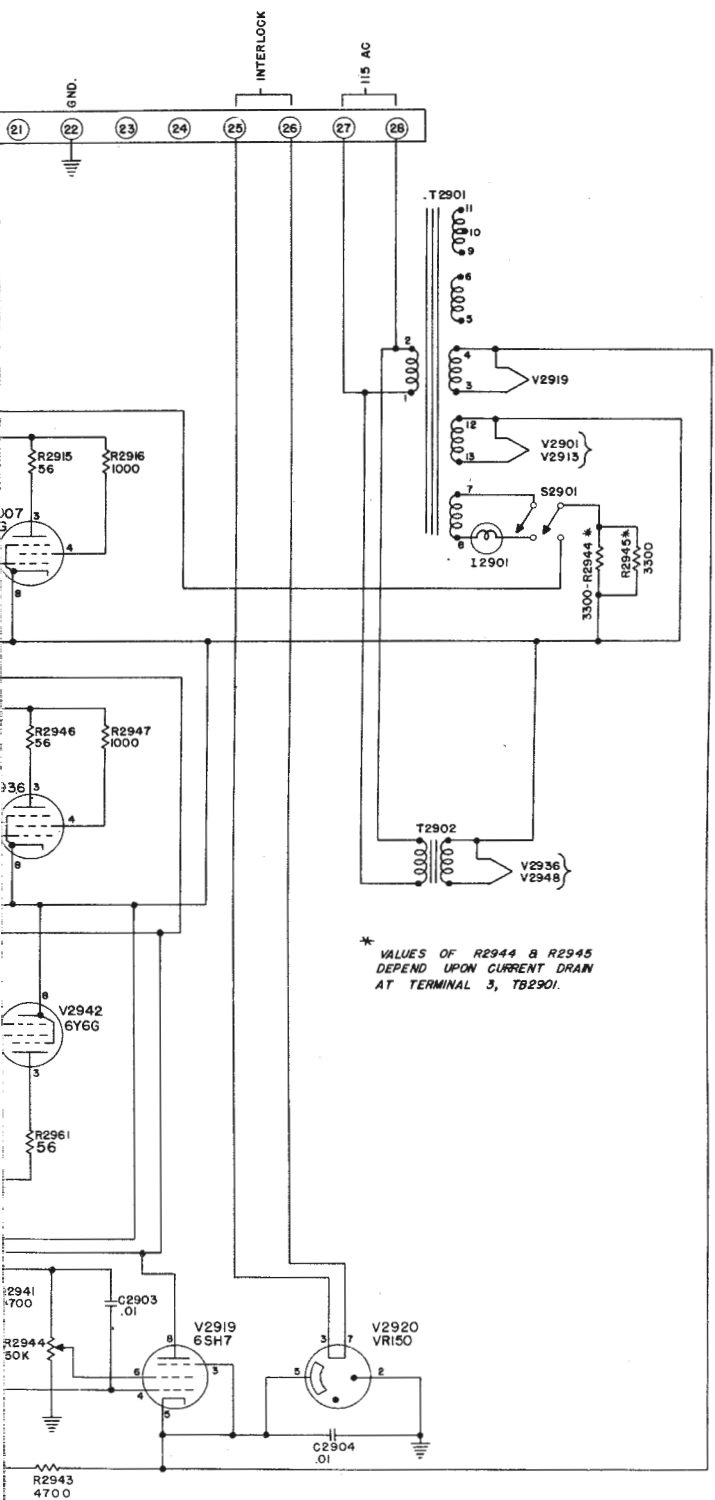


Figure 3-197. D-c Voltage Regulator Unit - Schematic Diagram



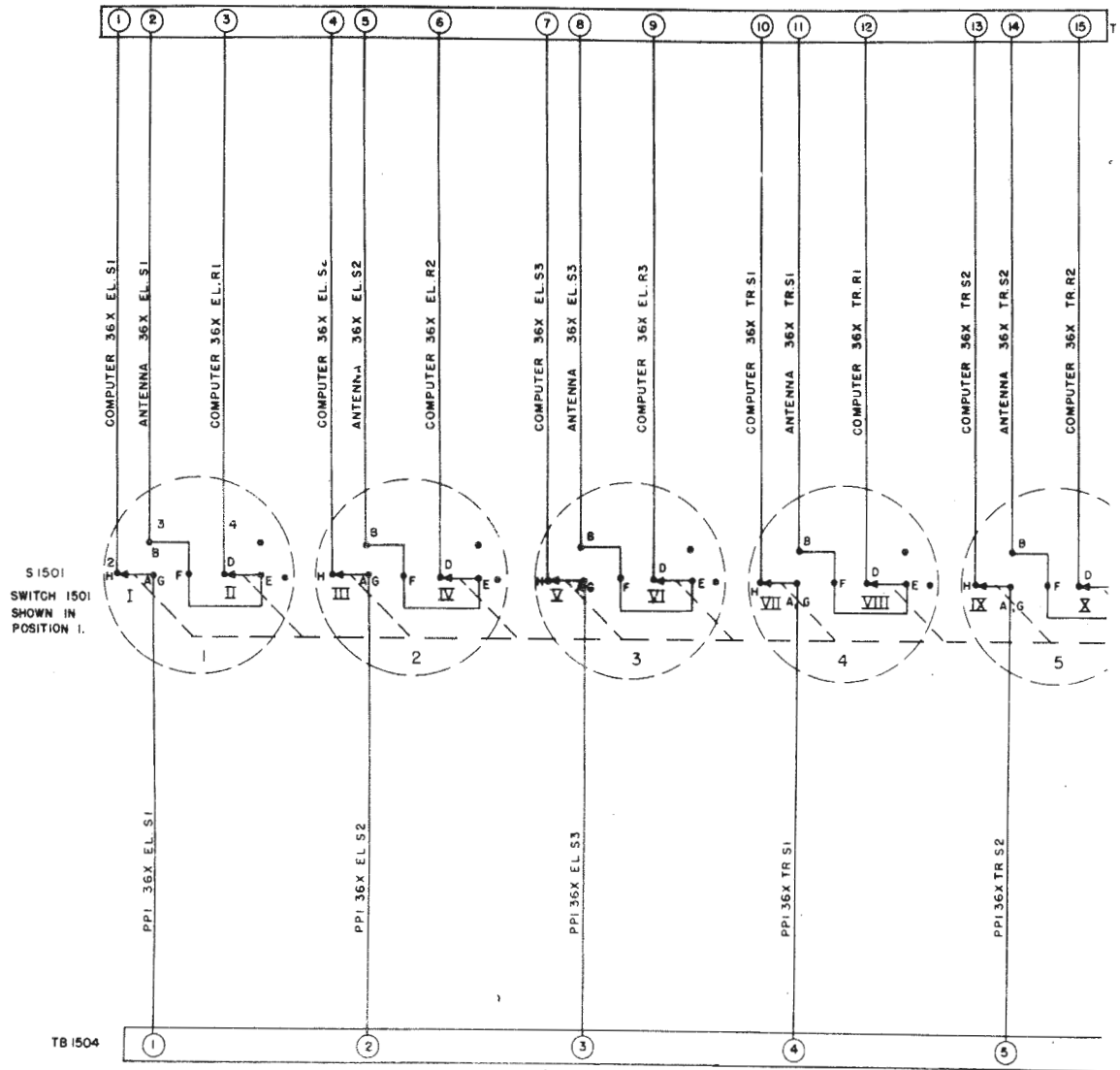
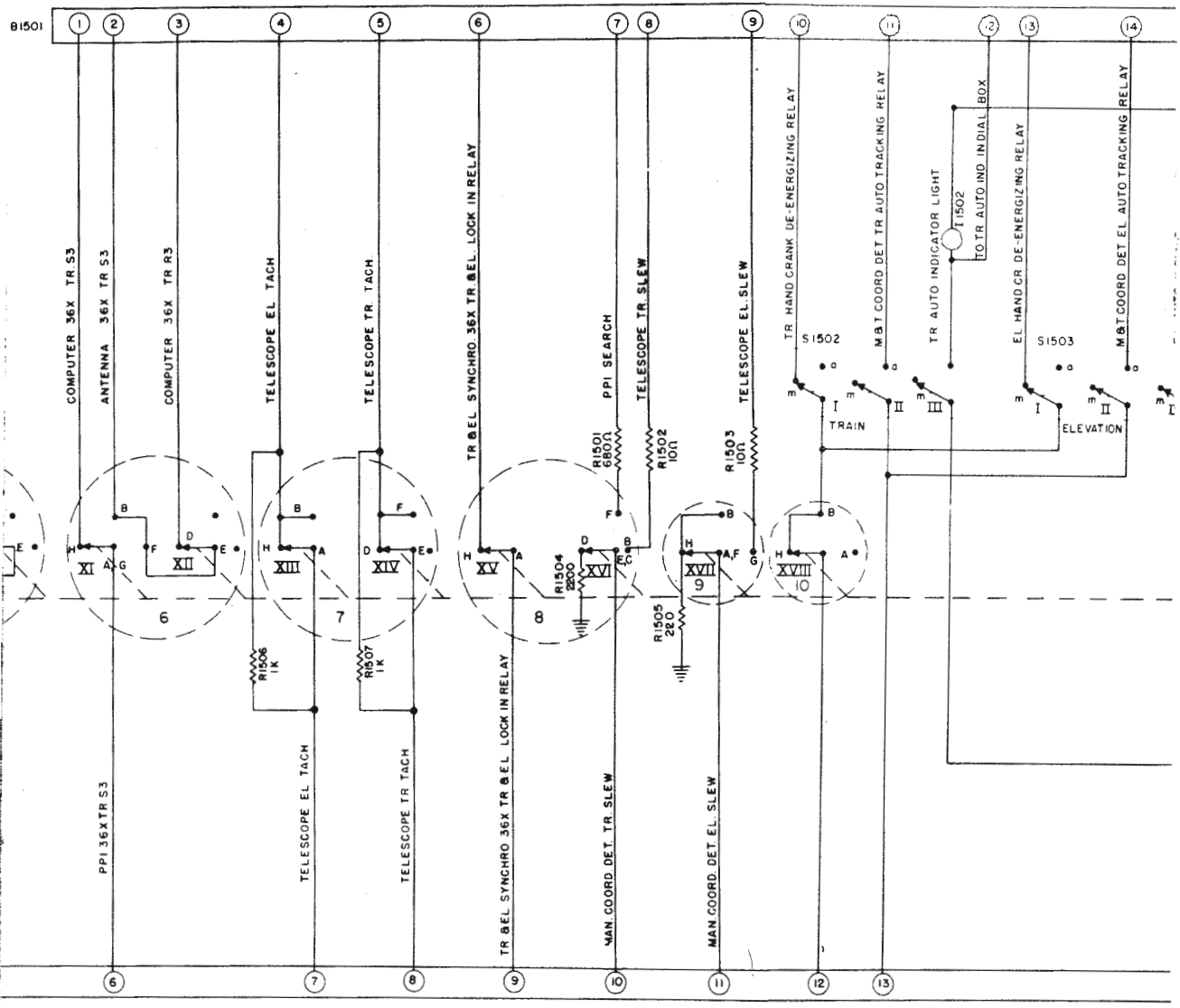
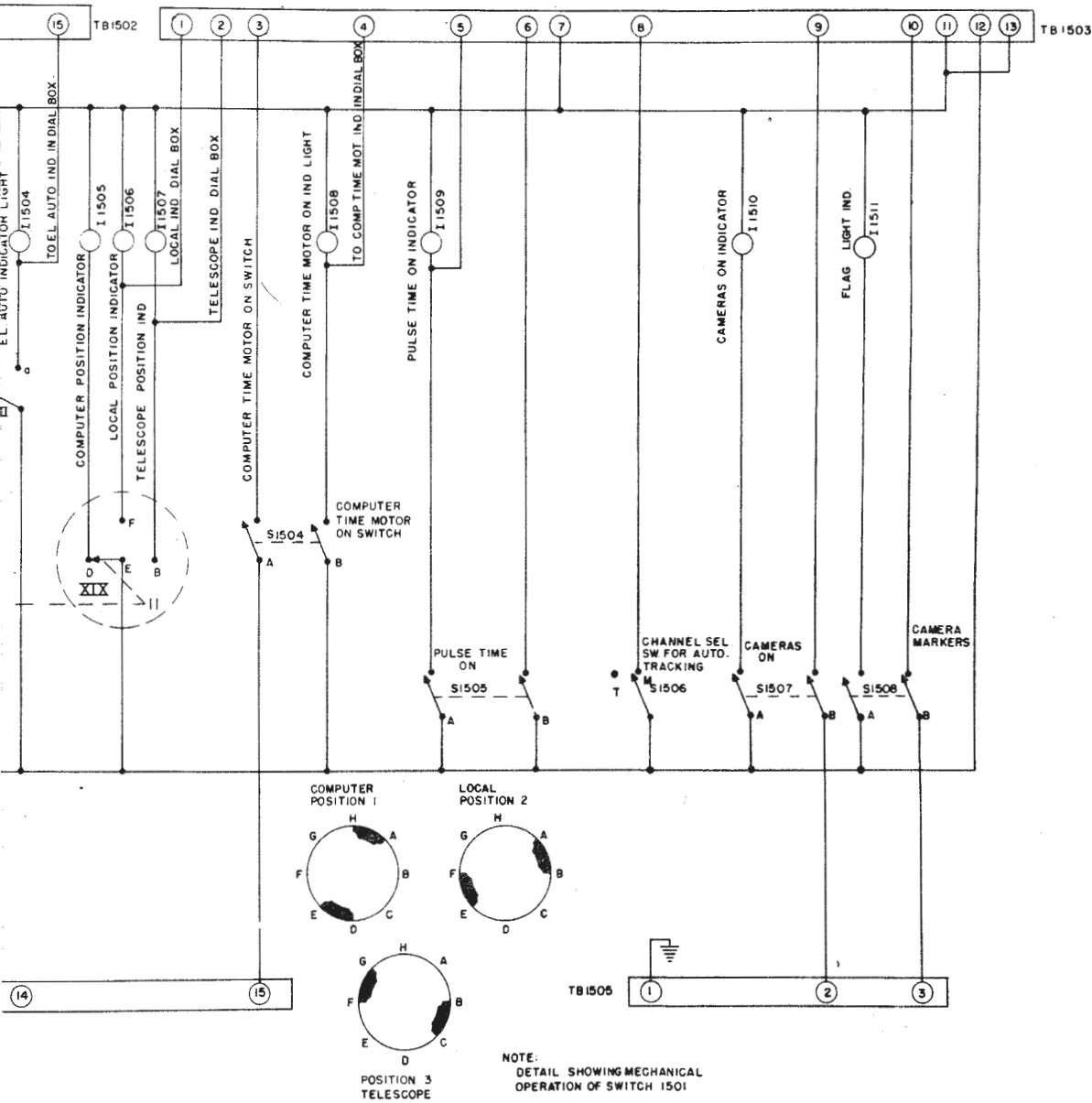


Figure 3-200. System Control Switching Unit - Schematic Diagram



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system control switching. It should be remembered that this is a functional block diagram so the actual control switching is somewhat more complicated because of the necessity of switching several functions in some cases rather than switching a single function.

2. SPECIFICATIONS

Reduction in the number of switches required for any mode, or change in mode, of operation reduces the probability of operator error under the stress of a missile flight or tactical use. Hence, the number of switches required for operation of the equipment should be kept to a minimum and, where possible, a single switch should control the mode of operation. However, the necessity for maximum flexibility of operation in a prototype equipment sometimes conflicts with the desire for simplicity and a compromise must be made. This conflict sometimes results in the use of two switches for changing the mode of operation where one could be made to suffice. The major modes of operation are: COMPUTER, LOCAL and TELESCOPE, hence, most functions which are connected for these modes of operation are taken care of by use of a single multiple-wafer, three-position switch.

3. PHYSICAL COMPONENTS

The System Control Switching Unit, Unit 1500, is built in a brass framework with removable sides. There is a three-position eleven-wafer switch, two three-pole double-throw switches, four double-pole single-throw switches, and one single-pole double-throw switch. There are, in addition, nine indicator lights which show switch position. The unit is shown in figures 3-201 through 3-203.

4. CIRCUIT DESCRIPTION

S1501 (figure 3-201) has three positions. They are: COMPUTER, LOCAL and TELESCOPE. The switch mechanism (figures 3-202 and 3-203) contains eleven wafers, eight of which have six contacts each as shown in figure 3-200. The remaining three wafers have only three contacts each. In many cases, these switch contacts actuate relays in other units and in a few cases the actuated relays actuate additional relays.

In discussing S1501 each position, COMPUTER, LOCAL, and TELESCOPE, will be considered in order. Where any of the additional nine mode-of-operation control switches are

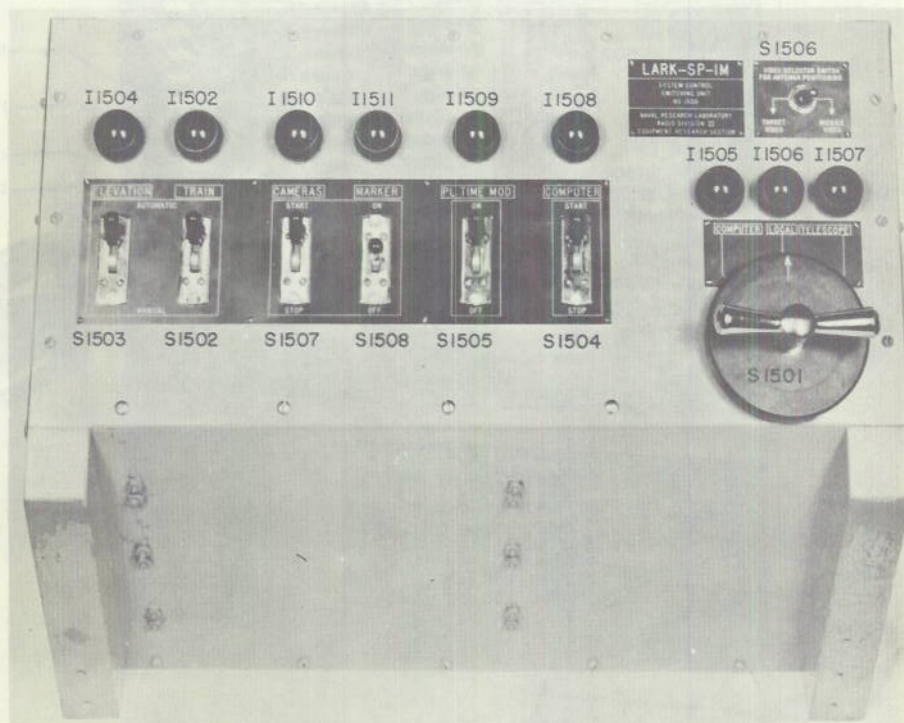


Figure 3-201. System Control Switching Unit - Front View

interrelated, they will be considered. Two switches which are part of the system control but are not on the switching unit are the antenna slew switch on the PPI, S807, and the Automatic Range Switch, S301 on each range unit.

Study of figure 3-200 will show that wafers 1 through 6 inclusive are identical except that the first three are concerned with antenna and PPI elevation functions and the next three are concerned with antenna and PPI train functions. It should be further observed that the first eight wafers have 3 contacts on each side. The sides

(sections) are given roman numbers I through XVI.

a. Computer Position, S1501. - Wafers 1, 2 and 3, sections I through VI inclusive are used to connect the 36X computer differential generator in series with the 36X handcrank synchro in the PPI and the 36X synchro in the antenna for the elevation functions. This is shown in figure 3-204.

In this mode of operation both the handcranks in the PPI and the antenna elevation and train

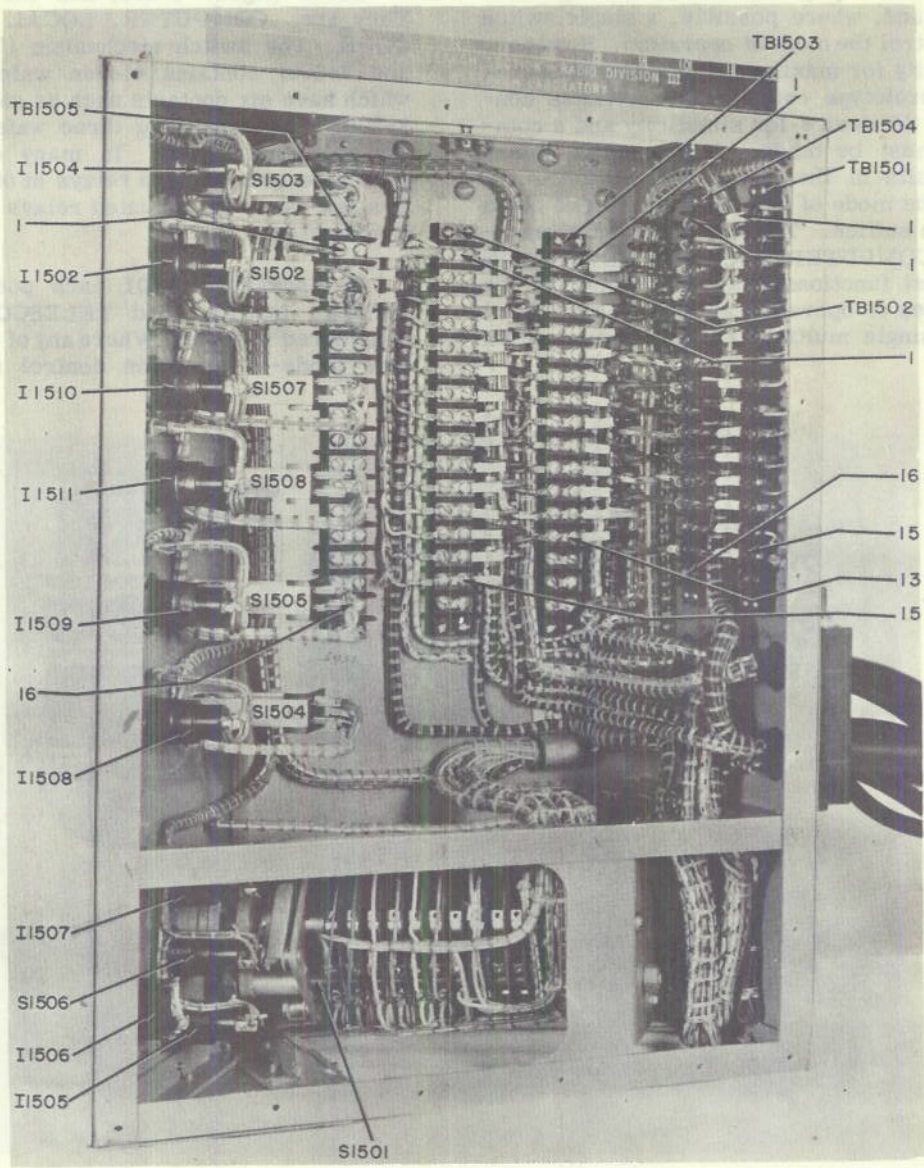


Figure 3-202. System Control Switching Unit - Top View

synchros are driven by the computer synchros provided the computer start switch (S1504), is in the "START" position. This switch as shown in figure 3-200 turns on the computer motor, the indicator light I1508 (figure 3-201), and the computer indicator light, I8103, in the dial box as shown in figure 3-118.

Wafer 7, sections XIII and XIV short circuit the output of the elevation and train handwheel tachometers in the telescope. This eliminates a control path between the telescope and the Antenna Control Unit, Unit 3200 (figures 3-204 and 3-205) so that movement of the telescope handwheels will not affect the system.

Wafer 8, section XV (figure 3-166) energizes the 36X train and elevation lock-in relay, K605, so that the system can only operate in 36X.

Section XVI of wafer 8 grounds the train slew input to the manual coordinate detector, through a 2200 ohm resistor. (See figures 3-204 and 3-200.) The input to the manual coordinate detector is thus terminated to reduce greatly the amount of noise in the output of the detector.

Wafer 9, section XVII, performs the same operation in elevation as section XVI performs in train. (See figures 3-200 and 3-205.)

Wafer 10, section XVIII, applies energy to the elevation handcrank de-energizing relay, K801, provided S1503 is in the manual position. (See figure 3-166.) In the same way it applies energy to the train handcrank de-energizing relay K802, if S1502 is in the manual position.

Wafer 11, section XIX, operates the Computer Indicator Light I1505 only. (See figure 3-201.)

b. Local Position, S1501. - When S1501 is in Local Position (figure 3-200), sections II, IV, VI, VIII, X and XII of wafers 1 through 6 inclusive are open. Sections I, III and V of wafers 1, 2 and 3 connect the antenna 36X elevation synchro generator and the PPI 36X elevation synchro control transformer in series. In the same way sections VII, IX and XI of wafers 4, 5 and 6 connect the antenna 36X train and the PPI 36X train in series. The computer synchro is removed from these circuits.

Wafer 7, sections XIII and XIV still short circuit the output of elevation and train telescope d-c tachometers, B9111 and B9112. (See figures 3-204 and 3-205.)

Wafer 8, section XV is now open. This formerly operated the 36X train and elevation lock-in relay.

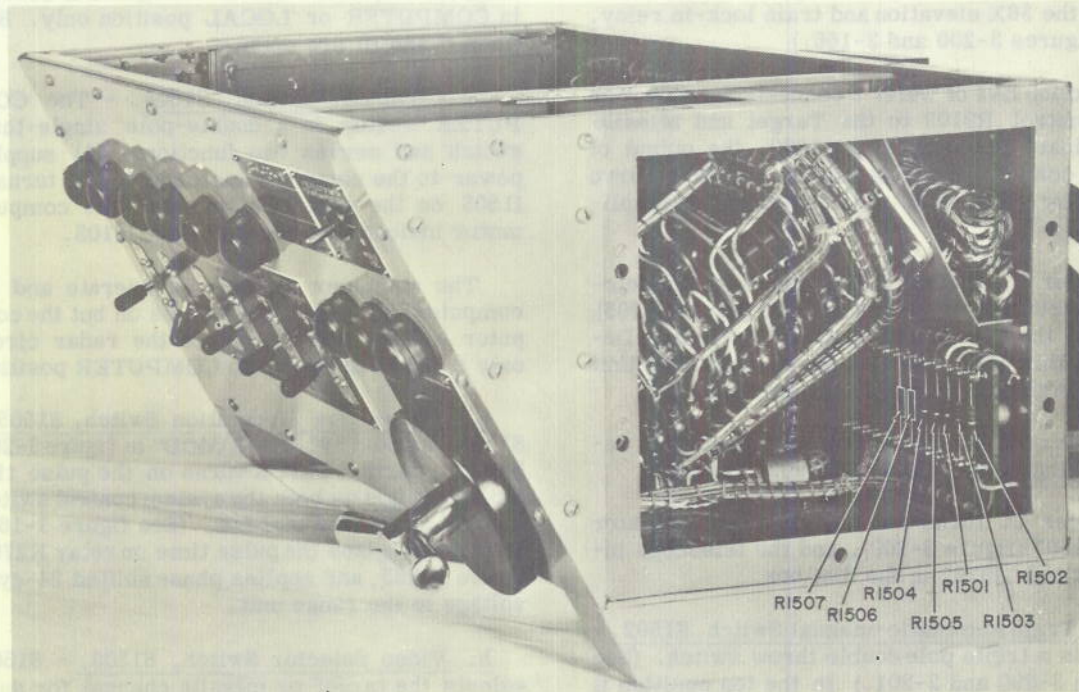


Figure 3-203. System Control Switching Unit - Right Side View

Wafer 9, section XVII still connects the input of the target and manual coordinate detector to ground through a resistor R1505. (See figure 3-205.)

Wafer 10, section XVIII still operates exactly as it did in the Computer Position of S1501.

Wafer 11, section XIX turns on the local position indicator light I1506 and the dial box local indicator light I8101.

c. Telescope Position, S1501. - When S1501 is in TELESCOPE position, sections II, IV, VI, VIII, X and XII of wafers 1 through 6 inclusive are open just as they are in local position (figure 3-200). Sections I, III, V, VII, IX and XI of wafers 1 through 6 inclusive are used to connect the 36X PPI synchro control transformer and the 36X antenna synchro generator in series just as in the local position (figure 3-200).

Wafer 7, sections XIII and XIV remove the short circuit from the output of B9111 (figure 3-205), the elevation handwheel tachometer of the telescope, and of B9112 (figure 3-204), the train handwheel tachometer of the telescope, and supplies the output voltages of these tachometers to the input of the D-c Servo Amplifier, Unit 3300, to drive the antenna if the handwheels are turned.

Wafer 8, section XV is open thus de-energizing the 36X elevation and train lock-in relay. (See figures 3-200 and 3-166.)

Section XVI of wafer 8 connects the elevation slew control R9103 to the Target and Missile Coordinate Detector, Unit 1200, the output of which controls the antenna via the D-c Servo Amplifier, Unit 3300, and the elevation amplidyne.

Wafer 9, section XVII, connects the telescope elevation slew control R9101 (figure 3-205), through the Target and Manual Coordinate Detector, Unit 1200, the D-c Servo Amplifier Unit 3300 and the amplidyne to the antenna.

Wafer 10 which controls the handcrank de-energizing relay, K801 and K802, is open.

Wafer 11 turns on the telescope indicator light I1507 (figure 3-200), and the telescope indicator light I8102 in the dial box.

d. Train Automatic-manual Switch, S1502. - S1502 is a triple pole double throw switch. (See figures 3-200 and 3-201.) In the top position it controls automatic train and in the bottom position, manual train.

In the AUTOMATIC position, section I (figure 3-200) opens the circuit to the train handcrank de-energizing relay, K802 (figure 3-74); section II closes the circuit to the train automatic tracking relay, K1201 (figure 3-220); section III closes the circuit to the train automatic indicator light I1502, (figure 3-200) and the train automatic indicator light I8104, (figure 3-118) in the dial box.

In the MANUAL position, section I closes the circuit to the train handcrank de-energizing relay K802 which will be energized if S1501 is in COMPUTER or LOCAL position only. Sections II and III are open.

e. Elevation Automatic-manual Switch, S1503. - S1503 is identical to S1502 except that it controls elevation functions. (See figures 3-200 and 3-201.)

In the AUTOMATIC position, section I (figure 3-200), opens the circuit to the elevation handcrank de-energizing relay K801; section II closes the circuit to the elevation automatic tracking relay K1202; section III closes the circuit to the elevation automatic indicator light I1504 and the elevation automatic indicator light I8105 in the dial box.

In the MANUAL position, section I closes the circuit to the elevation handcrank de-energizing relay, K801, which will be energized if S1501 is in COMPUTER or LOCAL position only. Sections II and III are open.

f. Computer Switch, S1504. - The COMPUTER switch is a double-pole single-throw switch and serves two functions: (1) supplies power to the computer motor and, (2) turns on I1508 on the switching unit and the computer motor indicator on the dial box, I8103.

The computer motor will operate and the computer indicator light will be on but the computer will be connected into the radar circuit only if S1501 is turned to COMPUTER position.

g. Pulse-time Modulation Switch, S1505. - S1505, marked "PL TIME MOD" in figure 3-201, has two parts. Part A turns on the pulse time indicator light on both the system control switching unit and on the dial box. (See figure 3-165.) Part B energizes the pulse time on relay K2701, figure 3-285, and applies phase shifted 24-cycle voltage to the range unit.

h. Video Selector Switch, S1506. - S1506 selects the target or missile channel for automatic tracking. (See figure 3-165.) The switch is open for target channel operation. When the

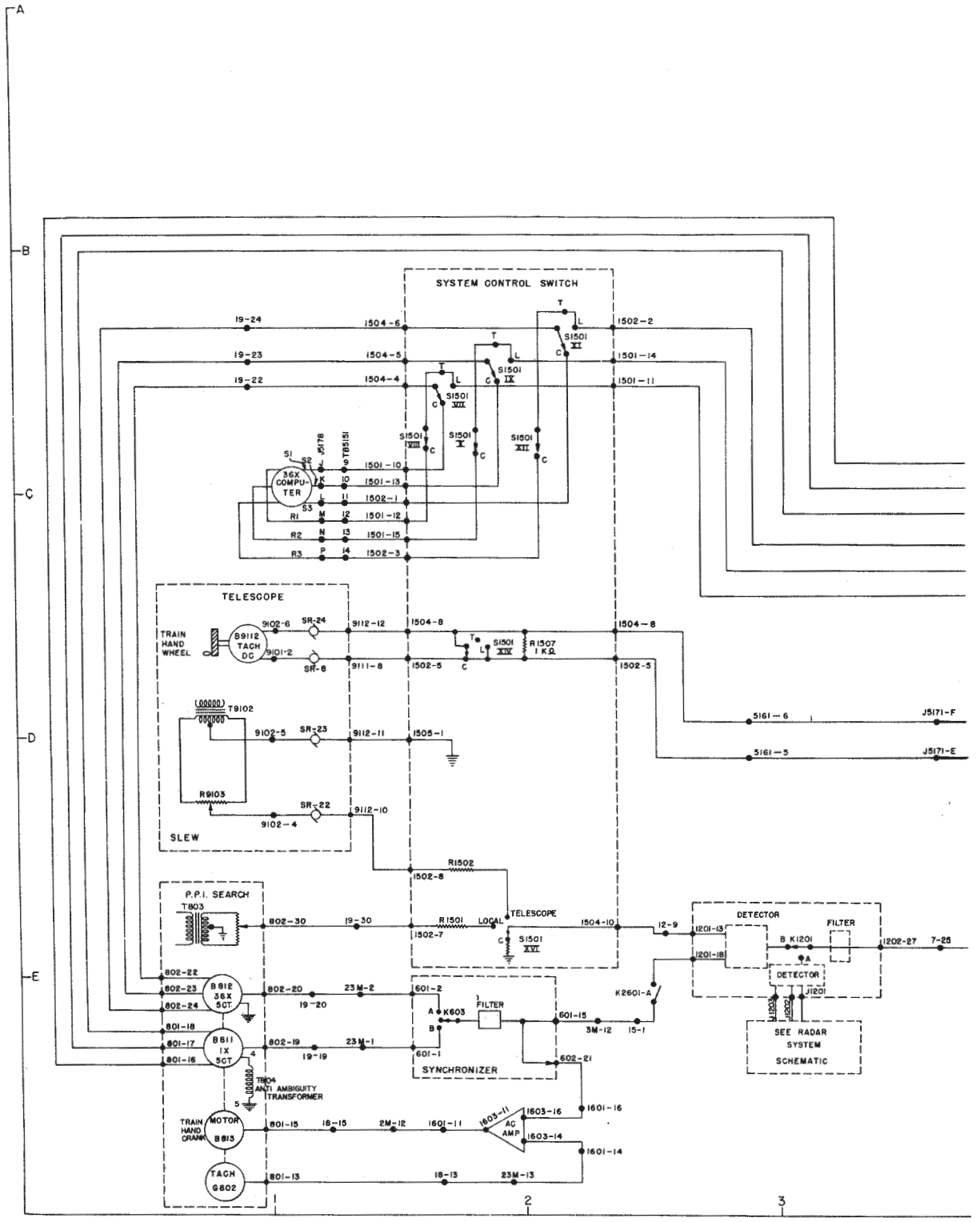
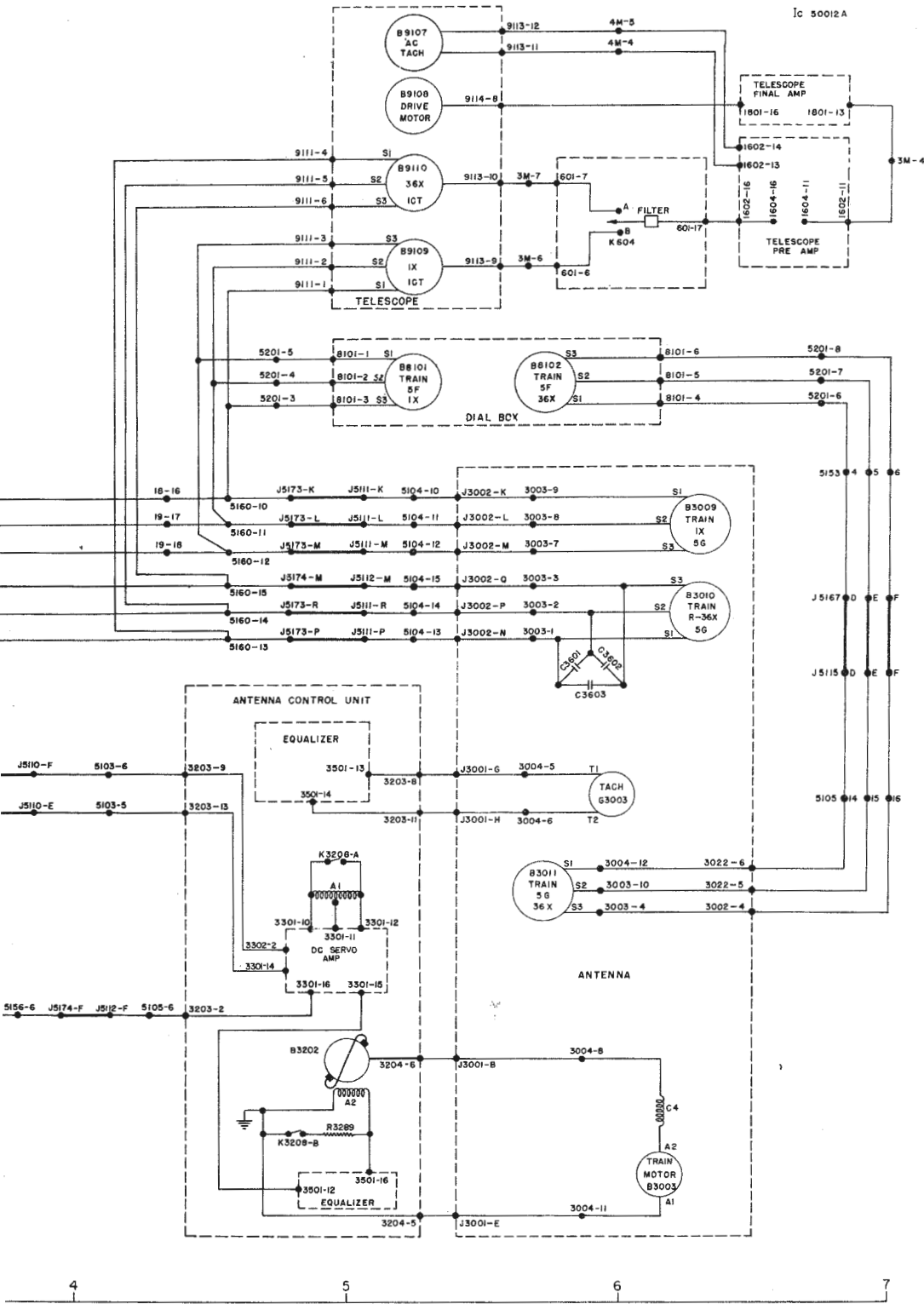


Figure 3-204. Train Antenna Positioning System



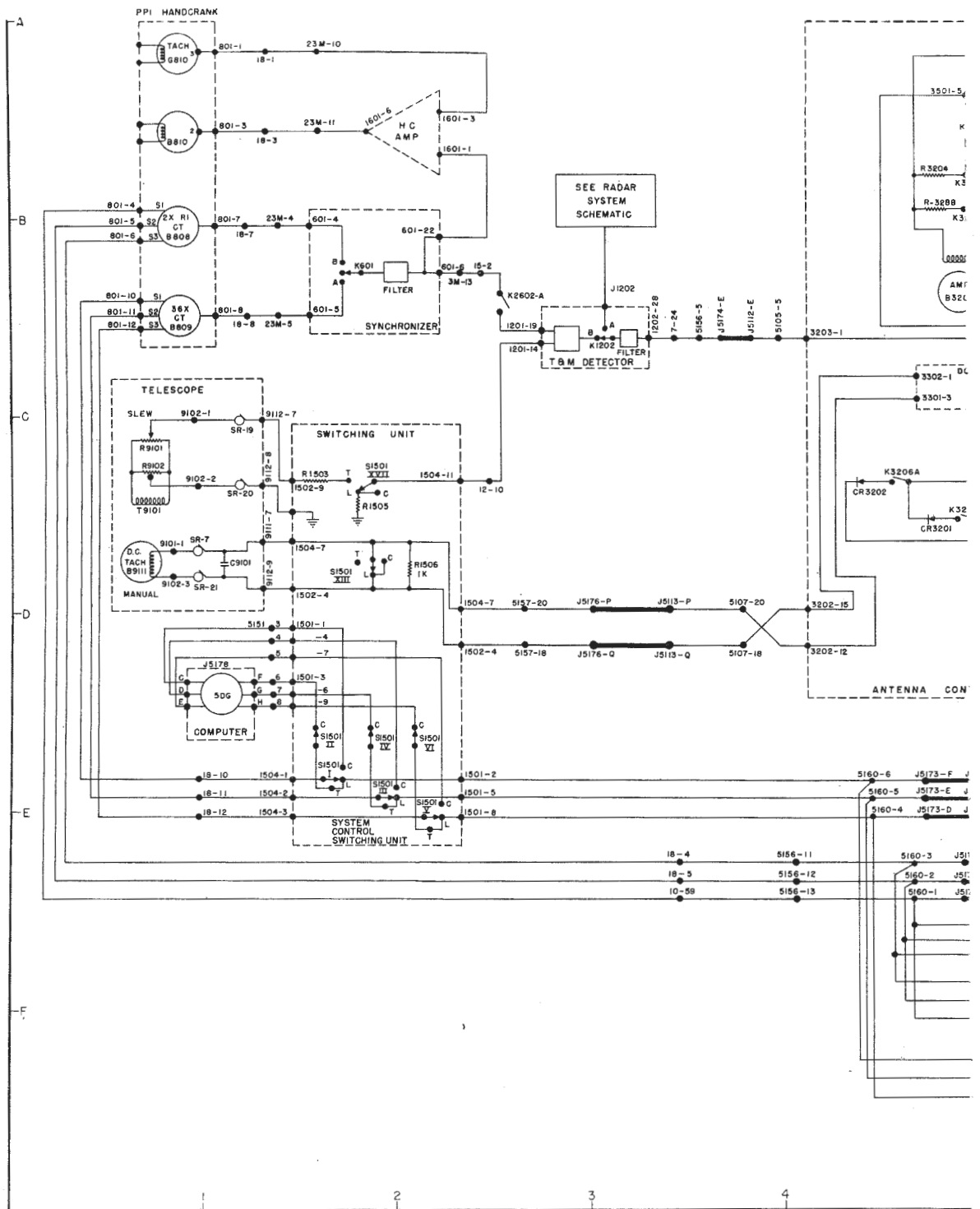


Figure 3-205. Elevation Antenna Positioning System

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switch is closed eight relays are activated. These are: antenna control indicator selector relay, K8501; gated video coax. relays, K1404, K1403; ACG relay, K1405; gate trigger relays, K1406 and K1407; servo gain relays, K606 and K1203.

K1403 and K1404, figure 3-163, are coaxial relays and switch the gated video to the target and manual coordinate detector from the missile receiver rather than from the target receiver.

K1405 (figure 3-163), switches the AGC from the target receiver to the missile receiver.

K1406 and K1407 (figure 3-163) are coaxial relays and switch the gate trigger from the target to the missile receiver.

K606 and K1203 are servo gain relays. (See figures 3-256 and 3-220.) When the switch S1506 is in the target position, the Synchronizer and Missile Coordinate Detector, Unit 600, has a maximum gain and the Target and Manual Coordinate Detector, Unit 1200, has a minimum

gain. Closing S1506 reverses the above condition.

K8501 operates two indicator lights on the Remote Range Indicator, Unit 8500. (See figure 3-131.) When the relay is unenergized the target antenna control light, I8502, is on. When the relay is energized the missile antenna control light, I8501, is on.

i. Camera Switch, S1507, and Marker Switch, S1508. - S1507 (figure 3-201), is used to turn on all cameras. Details of operation can be best seen on figure 3-166. Throwing the switch to "CAMERAS START" position energizes relay K8202 which applies the 115 volts ac to the drive motor. The "CAMERA ON" light I8208 is turned on; and voltage is applied to the flag or marker lights and to the time delay relay which controls the marker lights. At the end of 5 seconds all marker lights are turned off. When the time delay relay opens the marker light circuit it also closes another switch so that the marker switch S1508 can be used to put markers on the film at any time. In addition, relay K5201 turns on the photoflood lamps in the recording cabinet to illuminate the dials of the dial box.

Subsection 3-10. Simulated Target Programmer

1. INTRODUCTION

The function of the Simulated Target Programmer, is to provide repeatable target course inputs to the radar system for missile performance tests. During the operational tests of a missile the problem of supplying a suitable, perhaps expendable, physical target is obviated by using a simulated target obtained by supplying train, elevation, and range data for the radar system from a course generator. The specific target course may be preselected and repeated as desired. The relative performance exhibited by a succession of missiles may be determined on a scientifically sound basis.

Two completely different Simulated Target Programmers have actually been planned, and will be described in this report. The earlier plan is shown in the block diagrams (figures 3-206 and 3-207). The later plan is shown in the block diagram figure 3-209.

2. FIRST PLAN FOR SIMULATED TARGET PROGRAMMER

The equipment involved in the Simulated Target Programmer as shown in the block dia-

grams (figures 3-206 and 3-207) includes, (1) a Computer Mk. 1, Unit 3700, (2) a Tactical Course Generator, Unit 5900, and (3) a Programmer Servo System having an adjustable frequency bandwidth.

Either the Computer Mk. 1, Unit 3700, or the Tactical Course Generator, Unit 5900, may be used as generators of course data. An extremely wide range of a special class of target courses (i.e., straight-line courses) may be generated by the Computer Mk. 1. The Tactical Course Generator is a cam-actuated device in no way limited to a particular class of courses. Target courses may be selected and cams made for courses based on mathematical formulation or on any empirical specification. In use, the limits in course selection are set by the availability of suitable cams.

The Programmer Servo System serves to (1) smooth the course generator output to an adjustable degree, (2) provide suitable synchro data outputs for reinsertion in the Computer Mk. 1 (when used) and for dial box recording purposes, and (3) control the radar antenna position in train and elevation by controlling synchro differential generators placed in the radar

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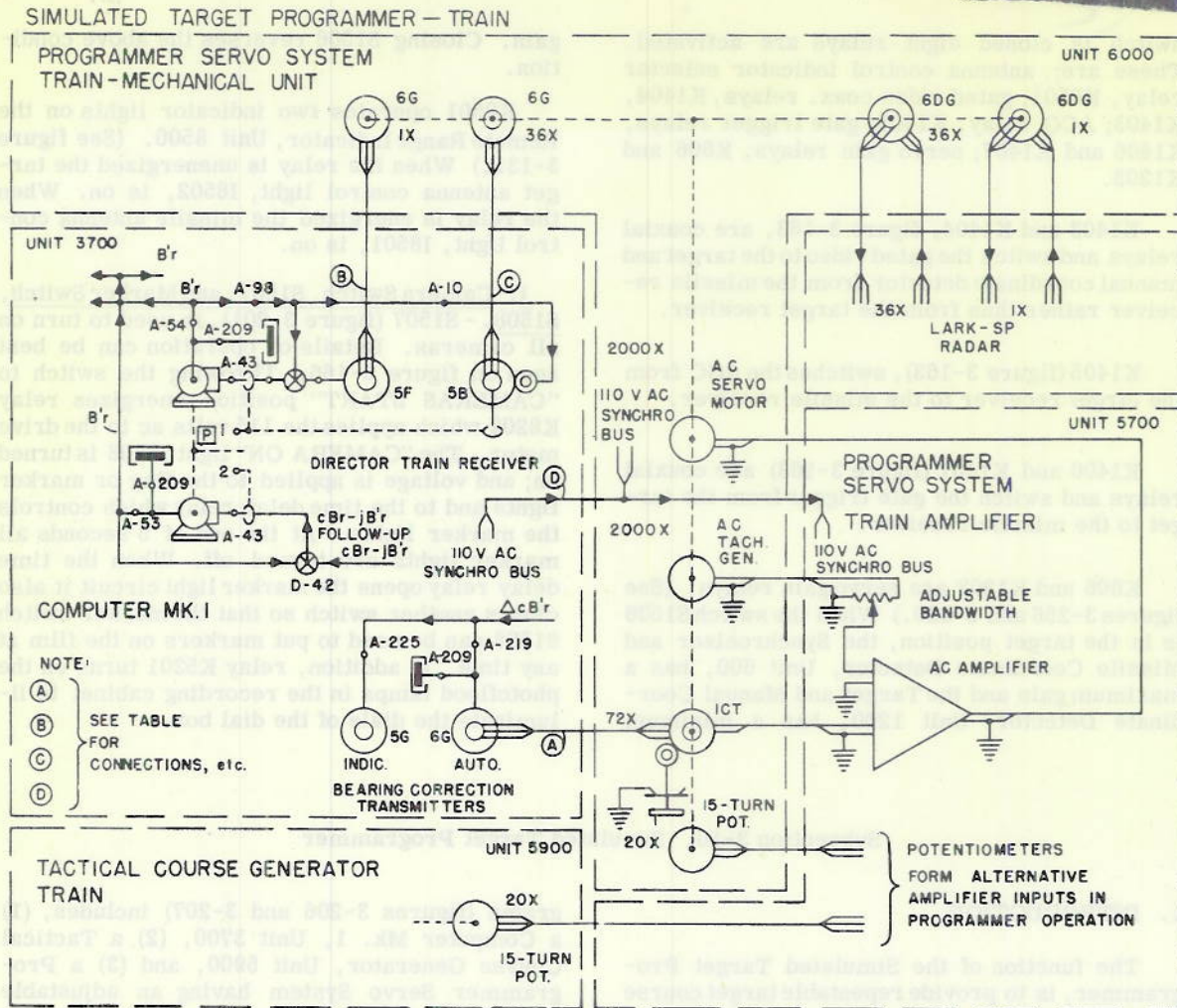


Figure 3-206. Simulated Target Programmer - Train Block Diagram

servo system antenna to handcrank synchro-data channels. The Programmer Servo System consists of two mechanical units (train unit 5500 and elevation unit 5600) and two servo amplifiers (train unit 5700 and elevation unit 5800).

a. Computer Mk. 1, Unit 3700, Details. - The Computer Mk. 1, Unit 3700, is a standard U. S. Navy anti-aircraft fire control computer used here for its course generation capabilities. The block diagram (figure 3-206) shows the portions of the computer involved in the connections made for use in the train coordinate of the Simulated Target Programmer. The portions of the computer are as shown on Schematic Diagram 210711 in the Instruction Book for Computer Mk. 1, Mod. 7, 13, O.D. 4174 (Restricted).

The Bearing Correction Transmitter output is smoothed by the servo system before being returned to the Director Train Receiver.

The block diagram (figure 3-207) shows similar information for the elevation coordinate. Table 3-4 provides synchro information regarding locations and connections in the Computer Mk. 1 as used in the Simulated Target Programmer.

In operating the Computer Mk. 1, the initial target angle, elevation angle, bearing angle, range, target speed, and rate of climb for the selected straight line course are set into the computer. These quantities are selected with due regard to the initial phase of the missile trajectory.

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TABLE 3-4

SYNCHRO INFORMATION FOR TARGET PROGRAMMER

KEY SECTION	FUNCTION	TYPE	DESIG.	SPEED	ROTATION	QTY.	CIRCUIT DESIG.	TERMINAL NO. & LOCATION
A D	BEARING CORRECTION TRANSMITTER (AUTO.)	6G	B	72	CCW	S1	14GSP71	62 BEHIND COVER
						S2	14GSP72	63 No. 4
						S3	14GSP73	64 No. 4
						R1	14GSP7	65
						R2	14GSSP7	66
G	ELEVATION CORRECTION TRANSMITTER (AUTO.)	6G	A	72	CW	S1	15GSP73	57 BEHIND COVER
						S2	15GSP72	58 No. 4
						S3	15GSP71	59
						R1	15GSP7	60
						R2	15GSSP7	61
B	RANGE CORRECTION TRANSMITTER	5G	E	1000 yds/rev	CCW	S1	32GS71	52 BEHIND COVER
						S2	32GS72	53 No. 4
						S3	32GS73	54
						R1	32GS7	55
						R2	32GSS7	56
C	DIRECTOR TRAIN RECEIVER	5F	AL	1	CCW	S1	4GS71	196 BEHIND COVER
						S2	4GS72	197 No. 7
						S3	4GS73	198
						R1	4GS7	200
						R2	4GSS7	201
E	DIRECTOR ELEVATION RECEIVER	5B	AK	36	CW	S1	4GS76	203
						S2	4GS75	204
						S3	4GS74	205
						S1	5GS73	110
						S2	5GS72	111
F	DIRECTOR ELEVATION RECEIVER	5F	AE	2	CW	S3	5GS71	112 BEHIND COVER
						R1	5GS7	113 No. 7
						R2	5GSS7	115
						S1	5GS74	117
						S2	5GS75	118
		5B	AD	36	CCW	S3	5GS76	119

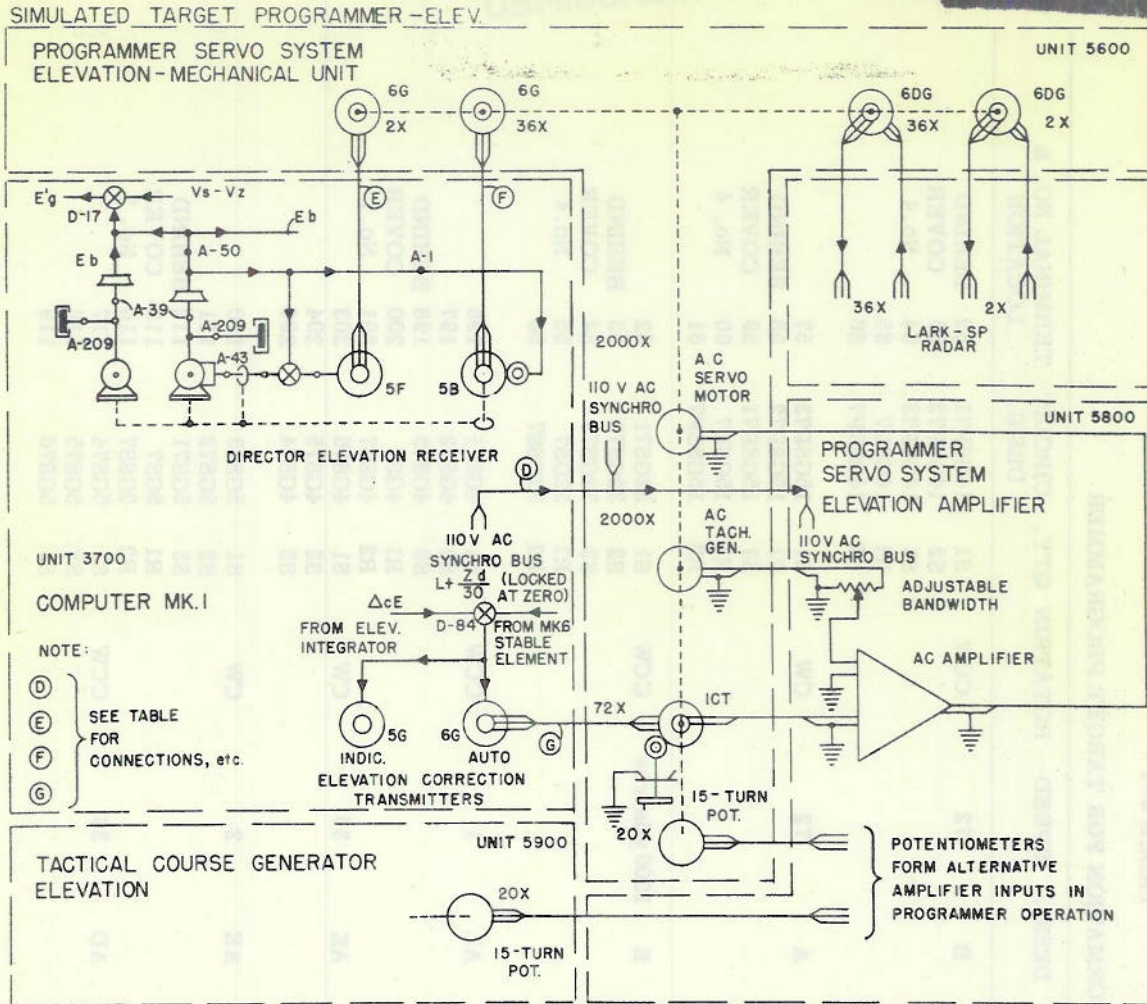


Figure 3-207. Simulated Target Programmer - Elevation Block Diagram

b. Tactical Course Generator, Unit 5900. - The Tactical Course Generator, Unit 5900, consists of a time motor which operates bearing and elevation potentiometers through cam-actuated follow-up mechanisms. Range data are not generated as such data enter into the radar system only at the dial box for recording purposes. Analysis of a dial box presentation would recover only the previously planned target range as a function of time.

c. Programmer Servo System, Details of Mechanical Portions, Unit 5500 and Unit 5600. - The servo system portions of the Simulated Target Programmer comprise electronic and mechanical units. The Train Unit, Unit 5500, and the Elevation Unit, Unit 5600, differ mechanically only in the speed of the fine-speed synchro

outputs. Each unit contains an a-c servo motor with a direct-coupled a-c tachometer generator. The motor is geared to a synchro control transformer and a 15-turn potentiometer that act as alternate input signal receivers for the servo system. The control transformer is bearing mounted with the stator position adjustable by means of a handcrank. In operation, the Computer Mk. 1 output and input relationship requirements are established and the handcrank adjustment made secure by means of a mechanical shaft-locking arrangement. The servo motor is also geared to drive two synchro generators and two synchro differential generators. The synchro generators supply position data back into the Computer Mk. 1 and data to the Dial Box, Unit 8100. The synchro differential generators provide the train and elevation posi-

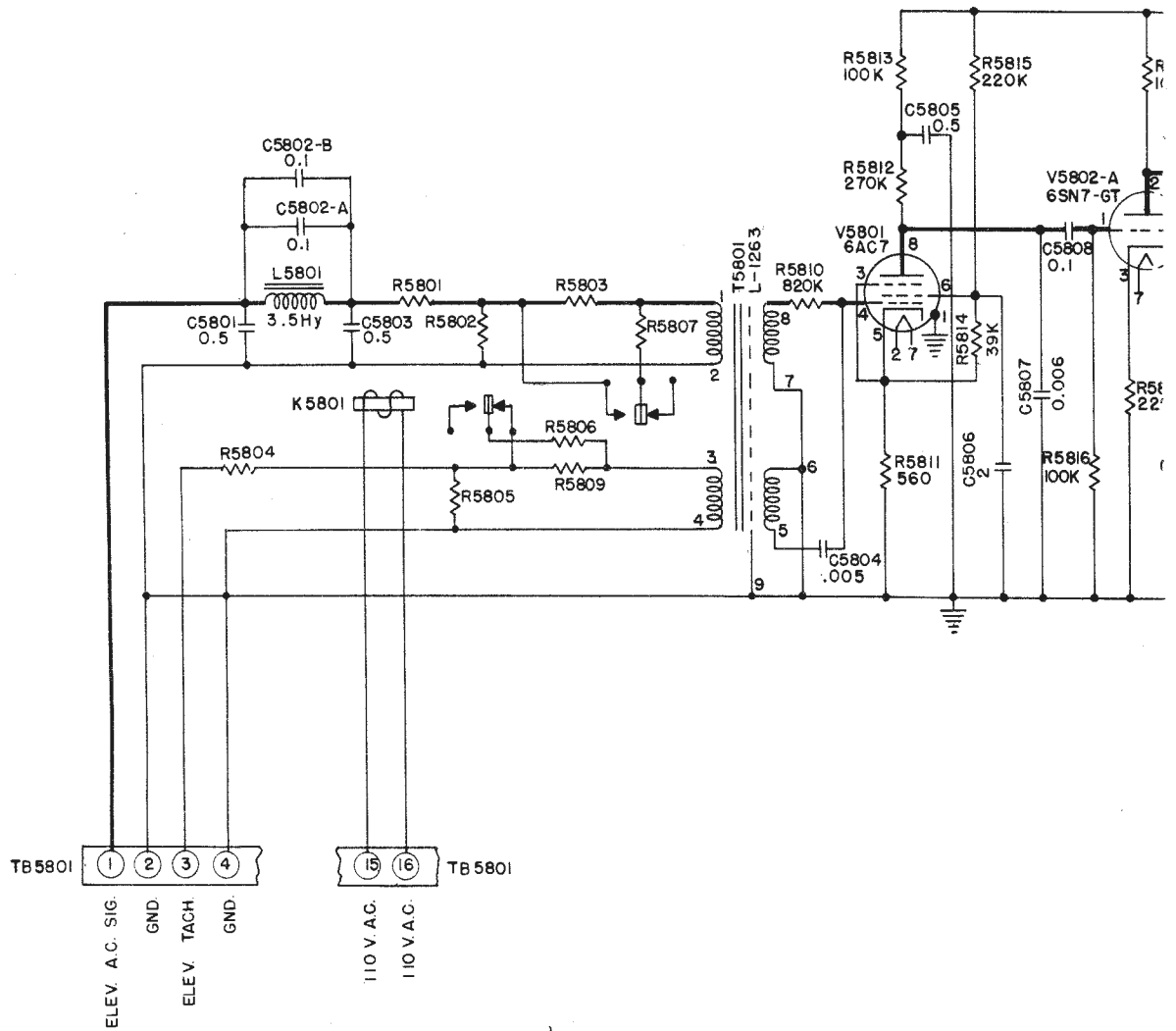
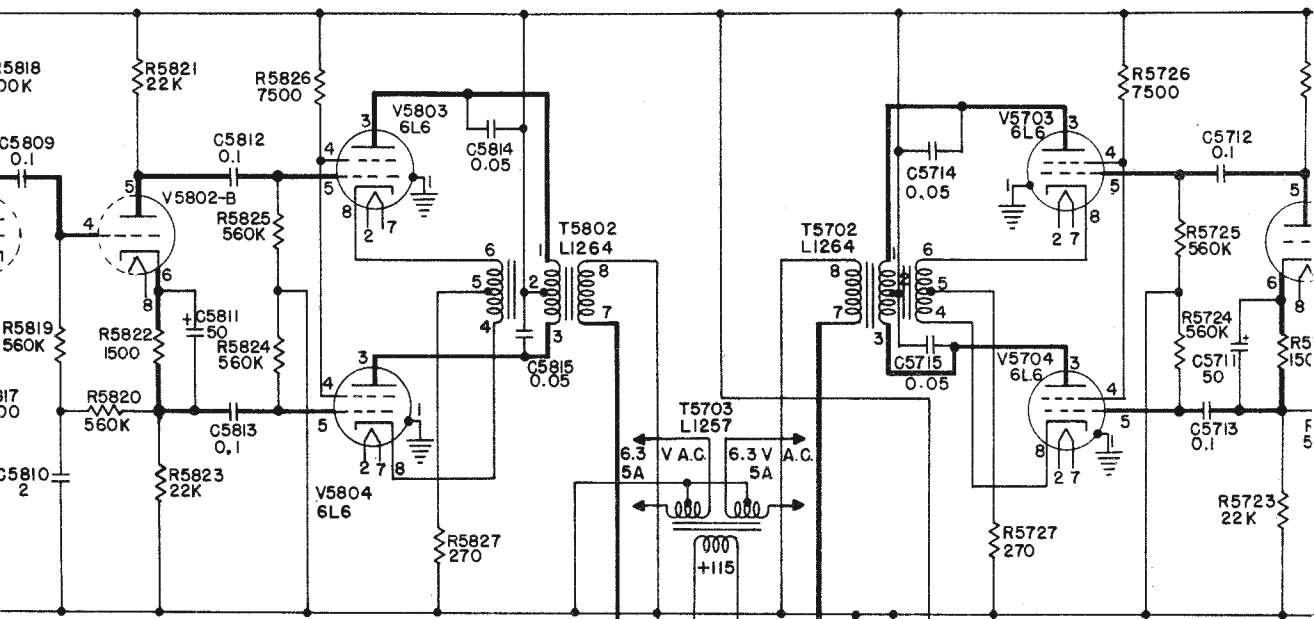


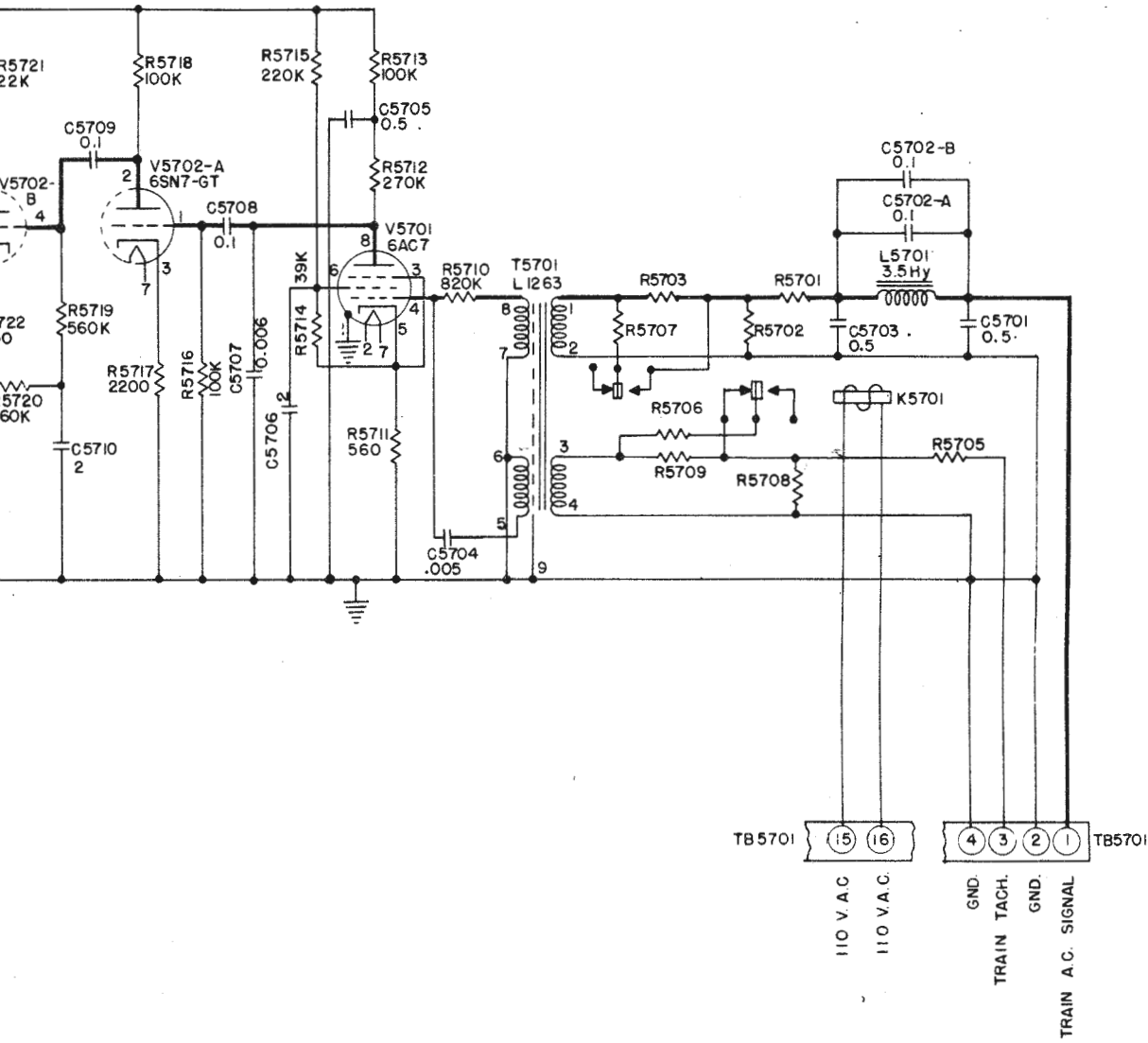
Figure 3-208. Train and Elevation Amplifier Unit for Simulated Target Programmer - Schematic Diagram



TB 5801 5 6 9 10 TB 5701

A.C. ELEV. MOTOR
 GND.
 115 V. A.C.
 115 V. A.C.

A.C. TR. MOTOR
 GND.
 GND.
 +300 V. D.C.



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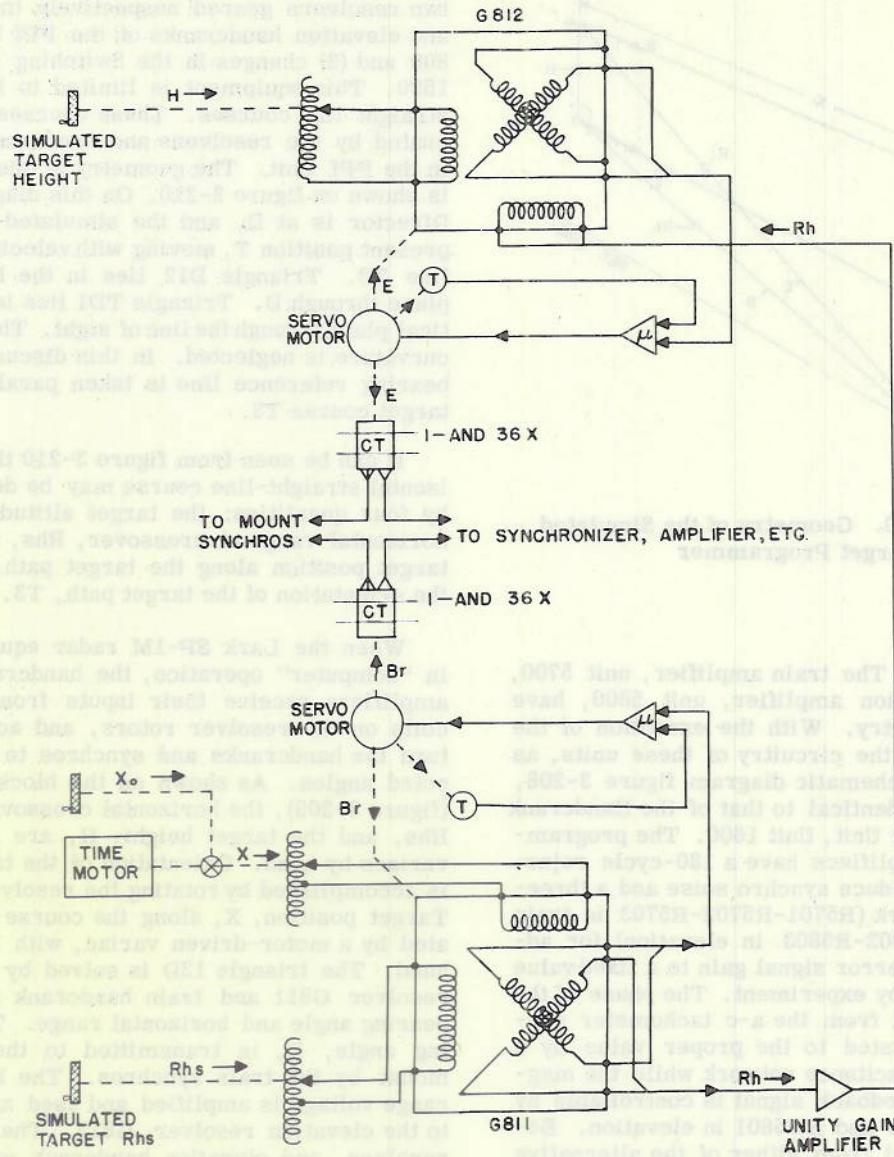


Figure 3-209. Simulated Target Programmer Train and Elevation Channels (Second Plan)

tion control of the radar beam. The synchro bus of the Computer Mk. 1 is cabled to the servo system for both synchro and servo motor and tachometer field supply.

A 180-degree maximum angular position variation during the target course is assumed in the gearing ratio specifications. Thus, the 20-speed, 15-turn potentiometer has a 45-degree beginning- and end-of-run margin provided the

mid-run angular position is made to correspond to the mid-potentiometer position. This setting is facilitated by the dials provided at the unit.

d. Programmer Servo System, Details of Electronic Portions, Unit 5700 and Unit 5800. - The electronic portions of the Simulated Target Programmer consist of two a-c servo amplifiers mounted on a single chassis located directly above the chassis of mechanical portions of the

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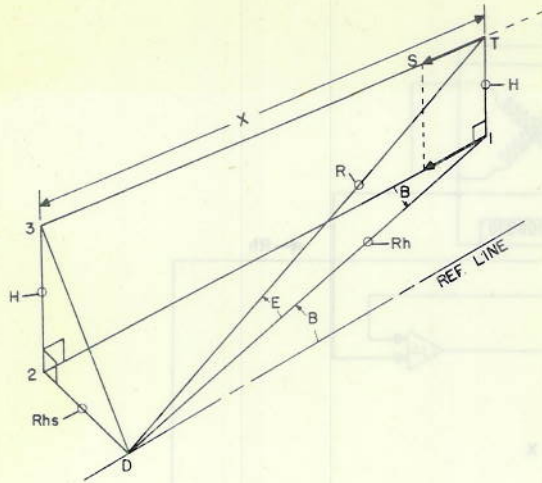


Figure 3-210. Geometry of the Simulated Target Programmer

servo system. The train amplifier, unit 5700, and the elevation amplifier, unit 5800, have identical circuitry. With the exception of the input circuits, the circuitry of these units, as shown on the schematic diagram figure 3-208, is essentially identical to that of the Handcrank Servo Amplifier Unit, Unit 1600. The programmer servo amplifiers have a 180-cycle rejection filter to reduce synchro noise and a three-resistor network (R5701-R5702-R5703 in train and R5801-R5802-R5803 in elevation) for adjustment of the error signal gain to a fixed value as determined by experiment. The phase of the feedback signal from the a-c tachometer generators is adjusted to the proper value by a resistance-capacitance network while the magnitude of the feedback signal is controllable by SW5701 in train and SW5801 in elevation. Because the signal from either of the alternative target course generators contains large noise components, an important function of the programmer servo system is smoothing or integrating the data. The degree of smoothing is made controllable by adjustment of the amount of feedback signal. The adjustment effectively controls the frequency bandwidth characteristics of the servo system.

3. SECOND PLAN FOR SIMULATED TARGET PROGRAMMER

a. General. - The second plan for a Simulated Target Programmer, as shown on the block diagram (figure 3-209), is actually under construction. The equipment involved includes

(1) a Programmer Control Unit, Unit 3800, (2) two resolvers geared respectively to the train and elevation handcranks of the PPI Unit, Unit 800 and (3) changes in the Switching Unit, Unit 1500. This equipment is limited to horizontal straight line courses. These courses are generated by the resolvers and handcrank servos in the PPI Unit. The geometry of the situation is shown on figure 3-210. On this diagram, the Director is at D, and the simulated target at present position T, moving with velocity S along line T3. Triangle D12 lies in the horizontal plane through D. Triangle TD1 lies in the vertical plane through the line of sight. The earth's curvature is neglected. In this discussion, the bearing reference line is taken parallel to the target course T3.

It can be seen from figure 3-210 that a horizontal straight-line course may be determined by four quantities: the target altitude, H, the horizontal range at crossover, Rhs, the initial target position along the target path, X_o, and the orientation of the target path, T3.

When the Lark SP-1M radar equipment is in "computer" operation, the handcrank servo amplifiers receive their inputs from the null coils on the resolver rotors, and accordingly turn the handcranks and synchros to the computed angles. As shown on the block diagram (figure 3-209), the horizontal crossover range, Rhs, and the target height, H, are set up on variacs by hand. Orientation of the target path is accomplished by rotating the resolver frame. Target position, X, along the course is generated by a motor-driven variac, with X_o set by hand. The triangle 12D is solved by the train resolver G811 and train handcrank servo for bearing angle and horizontal range. The bearing angle, B, is transmitted to the antenna mount by the train synchros. The horizontal range voltage is amplified and used as an input to the elevation resolver, G812. The elevation resolver, and elevation handcrank servo system, solve triangle DT1 for angle of elevation E. E is transmitted to the antenna mount by the elevation synchros.

b. Programmer Control Unit, Unit 3800, Details. - The Programmer Control Unit contains the two hand-controlled variacs and the motor driven variac used for setting the independent variables of a generated target course. Figure 3-211 is a schematic drawing of the unit. This unit contains one unity gain amplifier used to amplify the RL output of G811 to the level required to excite elevation resolver G812. Figures 3-212 through 2-215 are photographs of the unit. In addition, the Programmer Control Unit carries three spare unity gain amplifiers.

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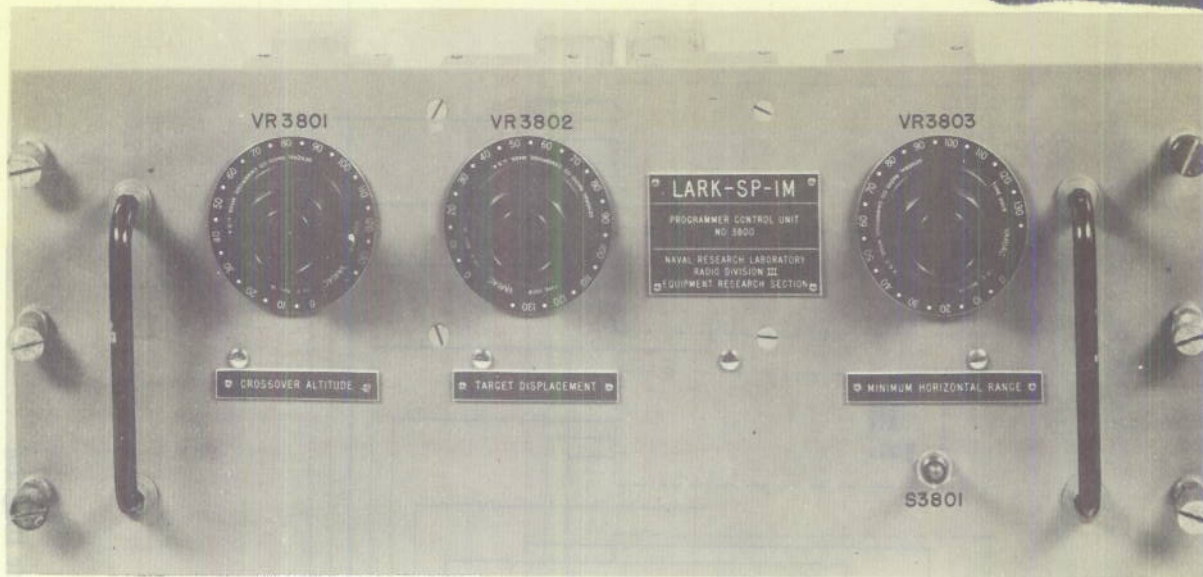


Figure 3-212. Programmer Control Unit - Front View

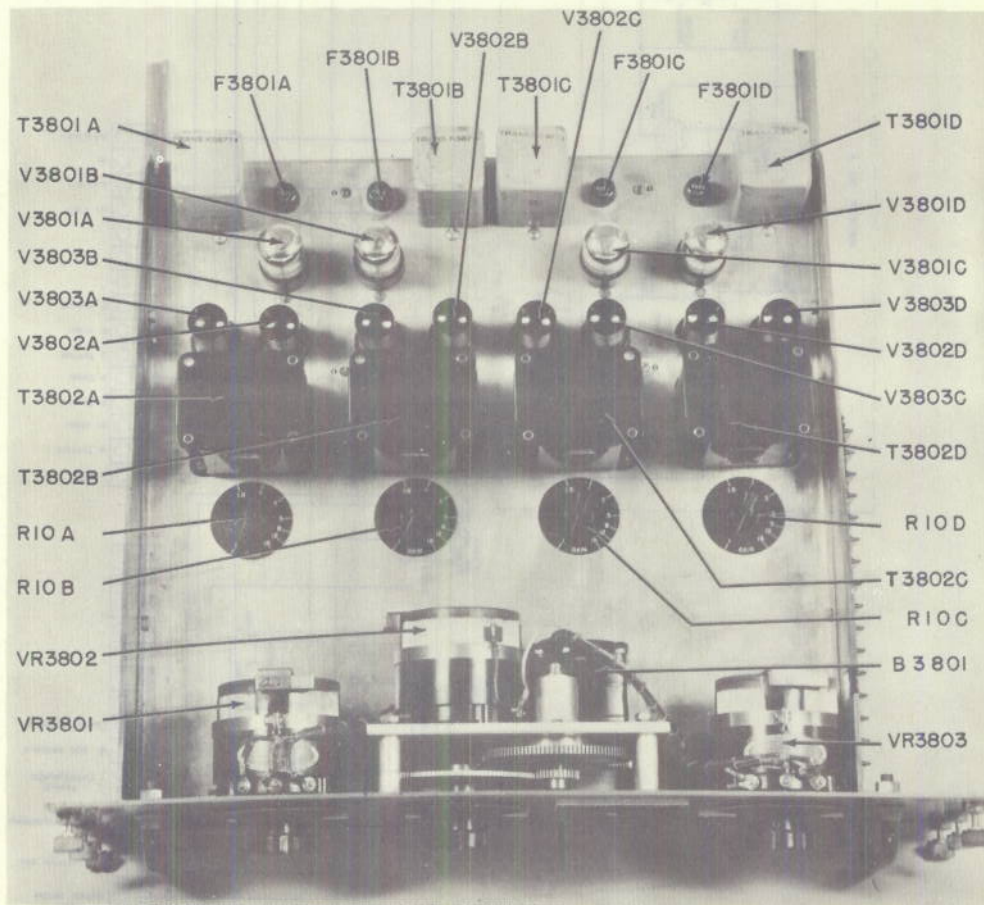


Figure 3-213. Programmer Control Unit - Top View

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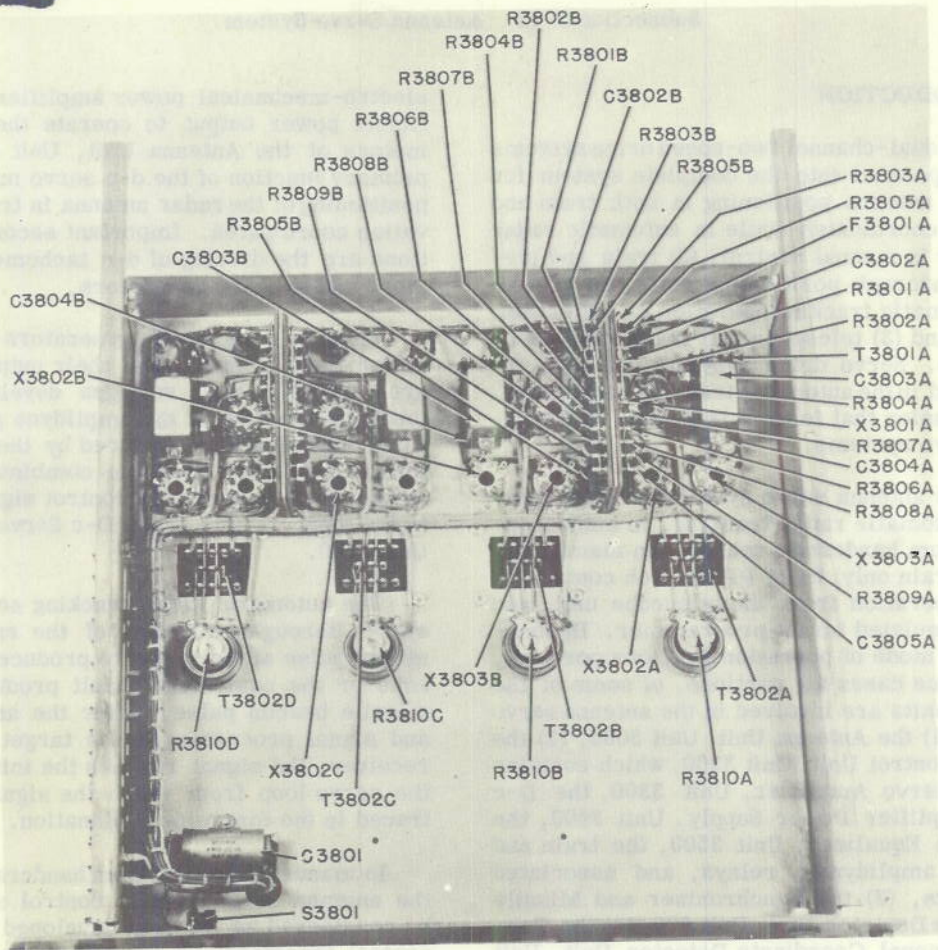


Figure 3-214. Programmer Control Unit - Bottom View

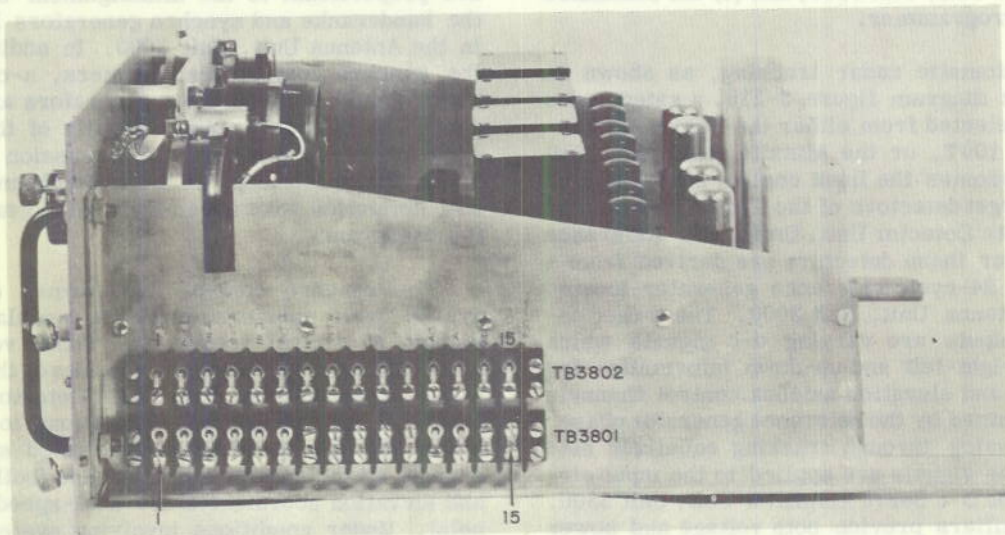


Figure 3-215. Programmer Control Unit - Right Side View

Subsection 3-11. Antenna Servo System

1. INTRODUCTION

Three dual-channel two-speed drive systems are incorporated into the complete system for (1) radar antenna positioning in both train and elevation coordinates while in automatic radar control or in manual control, (2) train and elevation handcrank positioning while the system is in automatic tracking operation or under slew control, and (3) telescope unit train and elevation drive. Servo drive systems are also incorporated in the automatic tracking range units. The discussion that follows is limited to the antenna servo systems.

a. The antenna servo systems may be operated in automatic radar tracking, in manual operation from handcrank control, in manual operation (train only) from PPI search control, in manual operation from the telescope unit, and from a simulated target programmer. Depending on the mode of operation, various portions, and in some cases all portions, of some of the following units are involved in the antenna servo system: (1) the Antenna Unit, Unit 3000, (2) the Antenna Control Unit, Unit 3200, which contains the D-c Servo Amplifier, Unit 3300, the D-c Servo Amplifier Power Supply, Unit 3400, the D-c Servo Equalizer, Unit 3500, the train and elevation amplidyne, relays, and associated components, (3) the Synchronizer and Missile Coordinate Detector Unit, Unit 600, (4) the Target and Manual Coordinate Detector Unit, Unit 1200, (5) the System Control Switching Unit, Unit 1500, (6) the PPI Unit, Unit 800, (7) the Telescope Unit, Unit 9100, and (8) the Simulated Target Programmer.

In automatic radar tracking, as shown on the block diagram figure 3-216, a gated video signal, selected from either the Target Receiver, Unit 100T, or the Missile Receiver, Unit 100M, becomes the input control signal applied to the target detectors of the Target and Manual Coordinate Detector Unit, Unit 1200. Reference signals for these detectors are derived from a 2-phase, 24-cycle reference generator located in the Antenna Unit, Unit 3000. The target detector outputs are varying d-c signals which provide right-left and up-down information for the train and elevation antenna control channels as determined by the reference generator phase. After passing through tracking equalizer networks, the signals are applied to the input circuits of the D-c Servo Amplifier Unit, Unit 3300. The amplifiers provide both voltage and power gain and excite the control fields of amplidyne generators. The amplidyne generators act as

electro-mechanical power amplifiers with sufficient power output to operate the d-c servo motors of the Antenna Unit, Unit 3200. The primary function of the d-c servo motors is the positioning of the radar antenna in train and elevation coordinates. Important secondary functions are the driving of d-c tachometer generators and synchro generators.

The d-c tachometer generators are driven at servo motor speed and their output voltages are combined with voltages developed in the feedback windings of the amplidyne generators. After modifications produced by the D-c Servo Equalizer, Unit 3500, the combined feedback voltage is mixed with the control signals applied to the input circuits of the D-c Servo Amplifier, Unit 3300.

The automatic radar tracking servo loop is closed through reflection of the radar transmitted pulse at the target to produce a received echo or the equivalent result produced by the missile beacon pulse. After the amplification and signal processing by the target or missile receiver, the signal reaches the initial point in the servo loop from which the signal flow was traced in the foregoing explanation.

In manual operation from handcrank control, the antenna servo system control signals may be considered as voltages developed by synchro control transformers located in the PPI Unit, Unit 800, and geared to the handcranks. The synchro control transformer voltage outputs are proportional to the misalignment between the handcranks and synchro generators located in the Antenna Unit, Unit 3000. In addition to the synchro control transformers, a-c servo motors and a-c tachometer generators are also geared to the handcranks. Details of this arrangement are given in the discussion of the handcrank servo loop. In the train channel, the PPI deflection yoke assembly is also geared to the handcranks.

The synchro control transformer outputs are 60-cycle carriers amplitude modulated by signals of control frequency. These voltages are used in the synchronizer circuits of the Synchronizer and Missile Coordinate Detector Unit, Unit 600. The synchronizer functions to select either the fine-speed or coarse-speed synchro channel as the control signal source (both train and elevation coordinates are dual-speed channels). Under conditions involving system following errors less than fine-speed errors of 90 degrees (corresponding to 2.5 degrees error at

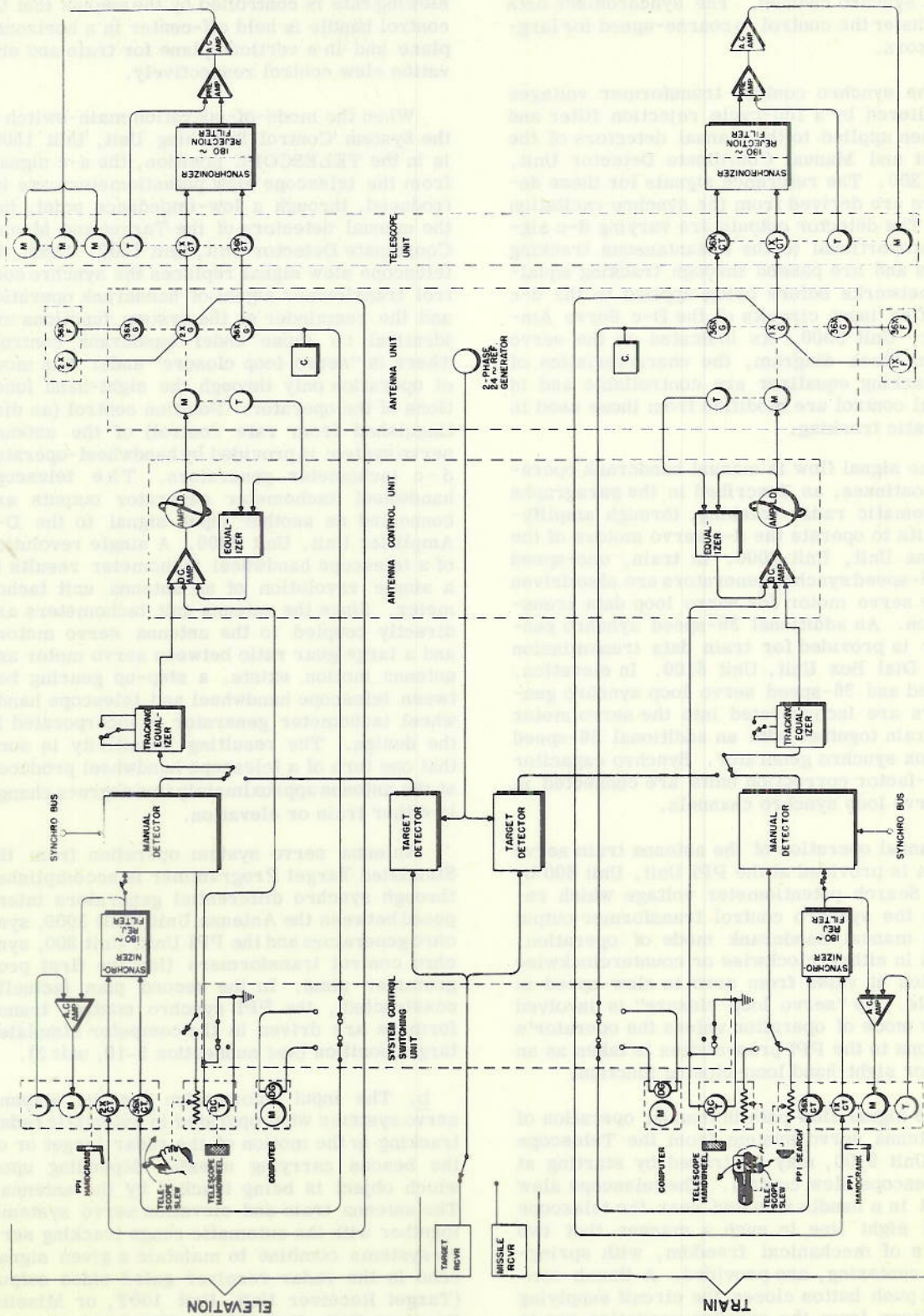


Figure 3-216. Train and Elevation Servo - Block Diagram

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one-speed) tracking is performed using the fine-speed synchro channel. The synchronizer acts to transfer the control to coarse-speed for larger errors.

The synchro control transformer voltages are filtered by a 180-cycle rejection filter and are then applied to the manual detectors of the Target and Manual Coordinate Detector Unit, Unit 1200. The reference signals for these detectors are derived from the synchro excitation bus. The detector outputs are varying d-c signals proportional to the instantaneous tracking errors and are passed through tracking equalizer networks before being applied to the d-c amplifier input circuits of the D-c Servo Amplifier, Unit 3300. As indicated on the servo system block diagram, the characteristics of the tracking equalizer are controllable and in manual control are modified from those used in automatic tracking.

The signal flow in manual handcrank operation continues, as described in the paragraphs on automatic radar tracking, through amplifying units to operate the d-c servo motors of the Antenna Unit, Unit 3000. In train, one-speed and 36-speed synchro generators are also driven by the servo motor for servo loop data transmission. An additional 36-speed synchro generator is provided for train data transmission to the Dial Box Unit, Unit 8100. In elevation, 2-speed and 36-speed servo loop synchro generators are incorporated into the servo motor gear train together with an additional 36-speed dial box synchro generator. Synchro capacitor power-factor correction units are connected in the servo loop synchro channels.

Manual operation of the antenna train servo system is provided at the PPI Unit, Unit 800 by a PPI Search potentiometer voltage which replaces the synchro control transformer output of the manual handcrank mode of operation. Search in either clockwise or counterclockwise direction at rates from zero to slew speed is possible. No "servo loop closure" is involved in this mode of operation unless the operator's reactions to the PPI presentation is taken as an operator sight-hand loop-closing function.

The signal flow path in manual operation of the antenna servo system from the Telescope Unit, Unit 9100, may be traced by starting at the telescope slew control. The telescope slew control is a handle mounted near the telescope optical sight line in such a manner that two degrees of mechanical freedom, with spring-loaded centering, are provided. A thumb-controlled push button closes the circuit supplying a-c voltage from the synchro excitation bus to

train and elevation slew potentiometers. The slewing rate is controlled by the amount that the control handle is held off-center in a horizontal plane and in a vertical plane for train and elevation slew control respectively.

When the mode-of-operation main-switch of the System Control Switching Unit, Unit 1500, is in the TELESCOPE position, the a-c signals from the telescope slew potentiometers are introduced, through a low-impedance point, into the manual detectors of the Target and Manual Coordinate Detector Unit, Unit 1200. Thus, the telescope slew signal replaces the synchro control transformer signal of handcrank operation and the remainder of the system functions are identical to those under handcrank control. There is "servo loop closure" under this mode of operation only through the sight-hand functions of the operator. Position control (as distinguished from rate control) of the antenna servo system is provided by handwheel-operated d-c tachometer generators. The telescope handwheel tachometer generator outputs are connected as another input signal to the D-c Amplifier Unit, Unit 3300. A single revolution of a telescope handwheel tachometer results in a single revolution of an antenna unit tachometer. Since the antenna unit tachometers are directly coupled to the antenna servo motors and a large gear ratio between servo motor and antenna motion exists, a step-up gearing between telescope handwheel and telescope handwheel tachometer generator is incorporated in the design. The resulting sensitivity is such that one turn of a telescope handwheel produces at the antenna approximately five degrees change in either train or elevation.

Antenna servo system operation from the Simulated Target Programmer is accomplished through synchro differential generators interposed between the Antenna Unit, Unit 3000, synchro generators and the PPI Unit, Unit 800, synchro control transformers (for the first programmer plan). In the second plan (actually constructed), the PPI synchro control transformers are driven to the computer simulated target position (see subsection 3-10, unit 3).

b. The input information for the antenna servo systems when operated in automatic radar tracking is the motion of the radar target or of the beacon carrying missile depending upon which object is being tracked by the antenna. The antenna train and elevation servo systems together with the automatic range tracking servo systems combine to maintain a given signal echo in the radar receiver gated video output (Target Receiver Unit, Unit 100T, or Missile Receiver Unit, Unit 100M). The gated receiver

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output is a succession of pulses, one for each transmitter pulse. Automatic gain control circuits operate to maintain the receiver output pulse amplitudes at a constant average value for the target on line-of-sight conditions. For the target off of radar centerline, the pulses become amplitude modulated at the radar-beam scan frequency. The number of degrees off target is directly related to the amount of modulation while up-down and right-left position information is derived from the phase of the modulation. The phase is established with relationship to the position of the beam by means of a two-phase reference generator at the antenna. Thus, the two information inputs to the antenna servo systems when in automatic radar tracking are the radar receiver gated video output pulse and the antenna reference generator voltages.

The input information for the antenna servo systems when in manual operation from handcrank control is the operator's hand motion as he observes the PPI presentation and also reacts to the A-scope and R-scope patterns and cross-pointer meter indication. It may be considered, however, that the synchro control transformer output voltages (these units act as electro-mechanical transducers from mechanical shaft motion to electrical modulation of a 60-cycle carrier voltage) are the servo system information inputs. The amplitude of the mod-

ulated 60-cycle voltage is a direct measure of the angular misalignment between the handcrank synchro control transformer position and the antenna unit synchro generator position while the phase of the modulated voltage provides the sense function. The above signals together with a synchro bus reference signal represent the two information inputs for the antenna servo systems when in manual operation from handcrank control.

In manual operation from the PPI Search control, the train synchro control transformer output is replaced with a voltage derived from the PPI Search potentiometer which is excited by a voltage derived from the synchro bus. This is an adjustable rate function without servo loop closure and the operator is the input information "source." The control serves as a convenient train slew control at the console as well as the labeled PPI Search function.

In manual operation of the antenna servo system from the Telescope Unit, the input information is operator reaction to visual observations of the target maneuvers as translated into voltages from the slew control or from the position control handwheels. Train and elevation slew control potentiometers, excited from the synchro bus, provide rate control voltages identical to those mentioned in the paragraph on

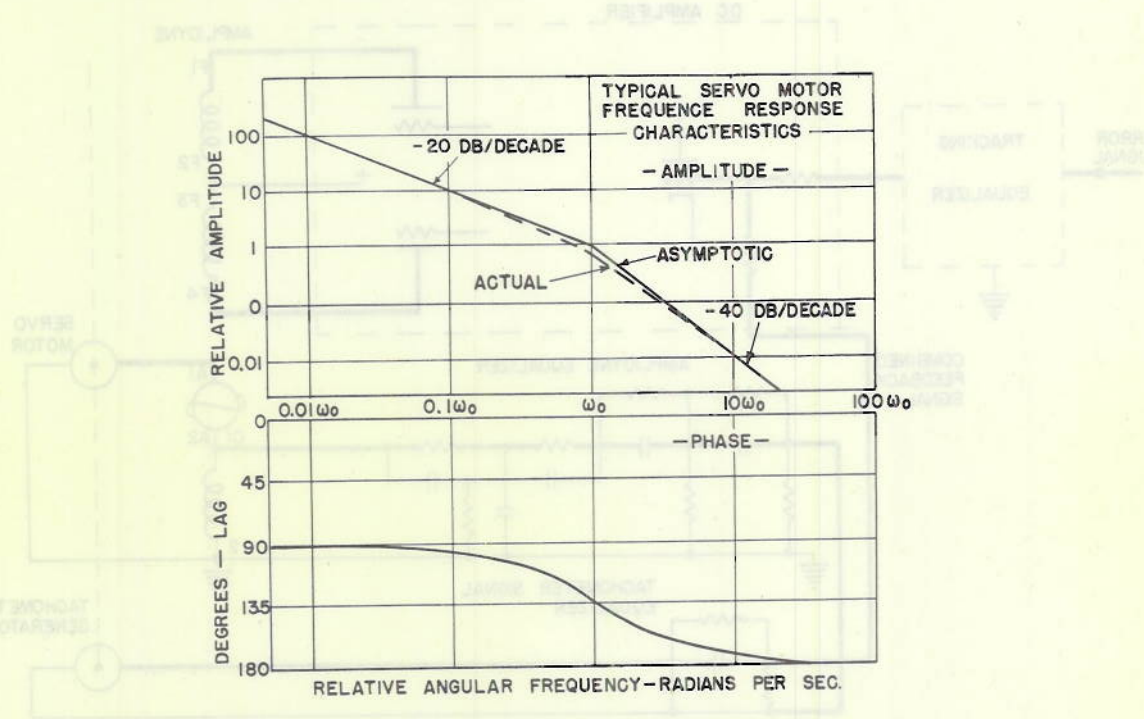


Figure 3-217. Approximation to Servo Motor Frequency Response Characteristic

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the PPI Search feature. The position control handwheel motion produces d-c voltages from tachometer generators that are introduced as input information.

In operation of the antenna servo system by the Simulated Target Programmer, the System Control Switching Unit is set at computer position.

All of the various information inputs described in the foregoing paragraphs are utilized for the primary purpose of positioning the radar antenna in train and elevation angle. The required output is primarily antenna position in train and elevation angle with the important secondary outputs of handcrank and telescope tracking of antenna position.

2. SYSTEM SPECIFICATIONS

The desired performance specifications for the antenna servo system, as initially outlined, are based upon requirements imposed by the intended operational use of the Lark SP-1M Radar and upon the limitations imposed by the performance characteristics of certain components of the SP-1M Radar. Elimination of the restrictions imposed by the SP-1M servo motors, gear

trains, and amplidyne generators were considered beyond the scope of the system modifications to be undertaken. The specifications for each servo system are discussed in the paragraphs on the units.

3. DESIGN CONSIDERATIONS

a. Antenna Automatic Radar Tracking Servo System. - The antenna automatic radar tracking servo loop forward- or μ -path gain characteristic contains, to the degree of exactness required for design purposes, a gain-set term of a mathematical form approximating the servo motor-amplidyne characteristic and a group of terms due to the tracking equalizer. A third term taking proper account of the unstable trailer pedestal mounting position effects should be included in the open loop expression. In the following treatment, these effects are shown as a deviation from the design characteristics. The feedback- or β -path characteristic is taken as equal to minus unity because a simple degenerative connection is effected by the radar pulse-echo process.

1). Servo Motor-amplidyne Transfer Characteristics. - The frequency transfer characteristic of the servo motor and tachometer combined

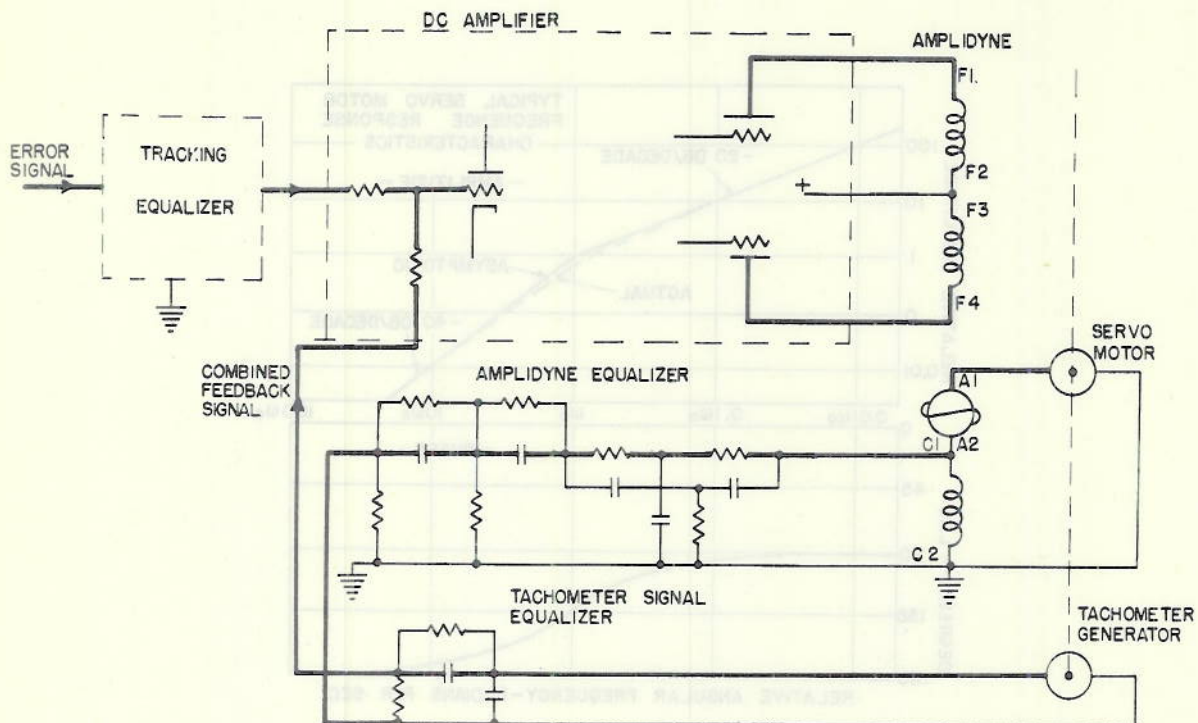


Figure 3-218. Antenna Automatic Radar Tracking Servo System - Power Drive Details

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is basically that of a perfect integrator to an angular frequency in the neighborhood of $\omega = 30$ followed initially by a region having a double-integrator characteristic as shown by figure 3-217. The slope of the amplitude characteristic in the low frequency region is minus 20 decibels per decade or a ten-to-one decrease in response amplitude for a ten-to-one increase in the frequency of the constant amplitude applied signal. The higher frequency region asymptotic characteristic has a slope of minus 40 decibels per decade. The frequency at which the asymptotic characteristic changes slope, known as a reference or "corner" frequency, is indicated in figure 3-217 as ω_0 . The actual characteristic deviates three db from the asymptotes at the corner frequency. The phase associated with a minus 20 db per decade slope is 90 degrees lag as shown. The minus 40 db per decade slope is associated with a 180-degree phase lag between response and applied signal. The mid-value of minus 135 degrees occurs at the corner frequency and the phase characteristic is seen to be symmetrical about this frequency.

(6) In the Lark SP-1M system, the antenna servo motors are d-c motors with control power supplied by amplidyne generators. In turn, the

control fields of the amplidyne generators are supplied from d-c servo amplifiers. The servo amplifiers provide suitable voltage gain and sufficient power to excite the amplidyne control fields. In addition to the error signal input, two feedback signals are coupled through a resistive mixing network to the amplifier input. The voltage developed at the amplidyne compensation field winding is modified by an equalizer network to form one of the feedback signals as shown in figure 3-218. The voltage from the antenna motor tachometer generator is modified by an equalizer and forms the other feedback signal. The combined effect of the circuits is to extend the initial minus 20 db per decade slope of the servo motor characteristic shown in figure 3-217 to a corner frequency somewhat greater than $\omega=100$. For the design of the remaining portions of the system, it is assumed that the characteristic shown in figure 3-217 is a sufficiently accurate representation of the amplifier-amplidyne-motor-tachometer combination with ω_0 much greater than $\omega=100$.

2). Antenna Automatic Radar Tracking Error Signal Characteristics. - The error signal actuating the antenna servo system under automatic radar tracking conditions is derived from

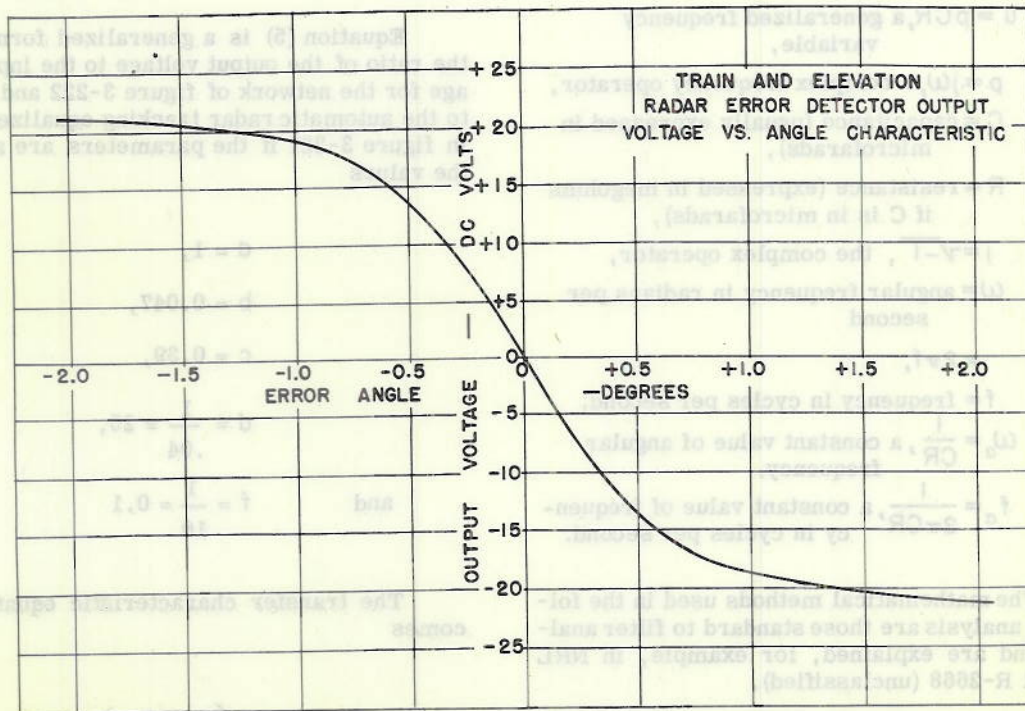


Figure 3-219. Error Angle to Voltage Conversion Characteristic as Determined Experimentally Using a Fixed Target

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the transmitted-pulse - reflected-echo process and involves the antenna system with the radar receiver and the tracking demodulators. The results of experimental tests of the completed equipment are shown in figure 3-219. The error voltage was measured using terminals 19 (elevation) and 18 (train) of TB1202. (See schematic figure 3-220.) The measurements were made by moving the antenna in 1/2-degree steps both above and below and to the right and left of the on-target position. The characteristic found was the same for elevation and train.

The maximum sensitivity, as measured at the points indicated, is found to be approximately 35 volts per degree error.

3). Tracking Equalizer. - As taken from the schematic, figure 3-220, the tracking equalizer while in automatic radar tracking is that shown in figure 3-221. The network consists of two low-pass resistance-capacitance filters in cascade with a series resistance in the shunt branch of the first section. For purposes of analysis, the circuit is given generalized parameters as shown in figure 3-222 in which

$$u = \rho CR = \frac{p}{\omega_a} = j \frac{\omega}{\omega_a} = \sqrt{-1} \frac{f}{f_a} \quad (1)$$

where $u = \rho CR$, a generalized frequency variable,

$\rho = j\omega$, a complex frequency operator,
 $C =$ capacitance (usually expressed in microfarads),

$R =$ resistance (expressed in megohms if C is in microfarads),

$j = \sqrt{-1}$, the complex operator,

$\omega =$ angular frequency in radians per second

$$= 2\pi f,$$

$f =$ frequency in cycles per second,

$\omega_a = \frac{1}{CR}$, a constant value of angular frequency,

$f_a = \frac{1}{2\pi CR}$, a constant value of frequency in cycles per second.

The mathematical methods used in the following analysis are those standard to filter analysis and are explained, for example, in NRL Report R-2668 (unclassified).

Using the concept of voltage division in accordance with impedance ratios, the transfer characteristic, Q , may be written as follows:

$$Q = \frac{\frac{d}{u}}{\frac{d}{u} + c} \cdot \frac{\frac{(\frac{d}{u} + c)(\frac{f}{u} + b)}{\frac{d}{u} + c + \frac{f}{u} + b}}{\frac{(\frac{d}{u} + c)(\frac{f}{u} + b)}{\frac{d}{u} + c + \frac{f}{u} + b} + a} \quad (2)$$

$$= \frac{\frac{d}{u} \frac{f+bu}{u}}{\frac{df}{u^2} + \frac{db}{u} + \frac{fc}{u} + cb + \frac{ad}{u} + ac + \frac{af}{u} + ab} \quad (3)$$

$$= \frac{d(f+bu)}{u^2(ab+ac+cb) + u(ad+af+db+cf) + df} \quad (4)$$

$$= \frac{(1 + u \frac{b}{f})}{u^2 \left(\frac{ab+ac+bc}{df} \right) + u \left(\frac{ad+af+bd+cf}{df} \right) + 1} \quad (5)$$

Equation (5) is a generalized formula for the ratio of the output voltage to the input voltage for the network of figure 3-222 and applies to the automatic radar tracking equalizer shown in figure 3-221 if the parameters are assigned the values

$$\begin{aligned} a &= 1, \\ b &= 0.047, \\ c &= 0.39, \\ d &= \frac{1}{.04} = 25, \\ \text{and } f &= \frac{1}{10} = 0.1 \end{aligned} \quad (6)$$

The transfer characteristic equation becomes

$$Q = \frac{\left(1 + \frac{u}{2.128} \right)}{0.182132u^2 + 10.5256u + 1} \quad (7)$$

C [REDACTED]

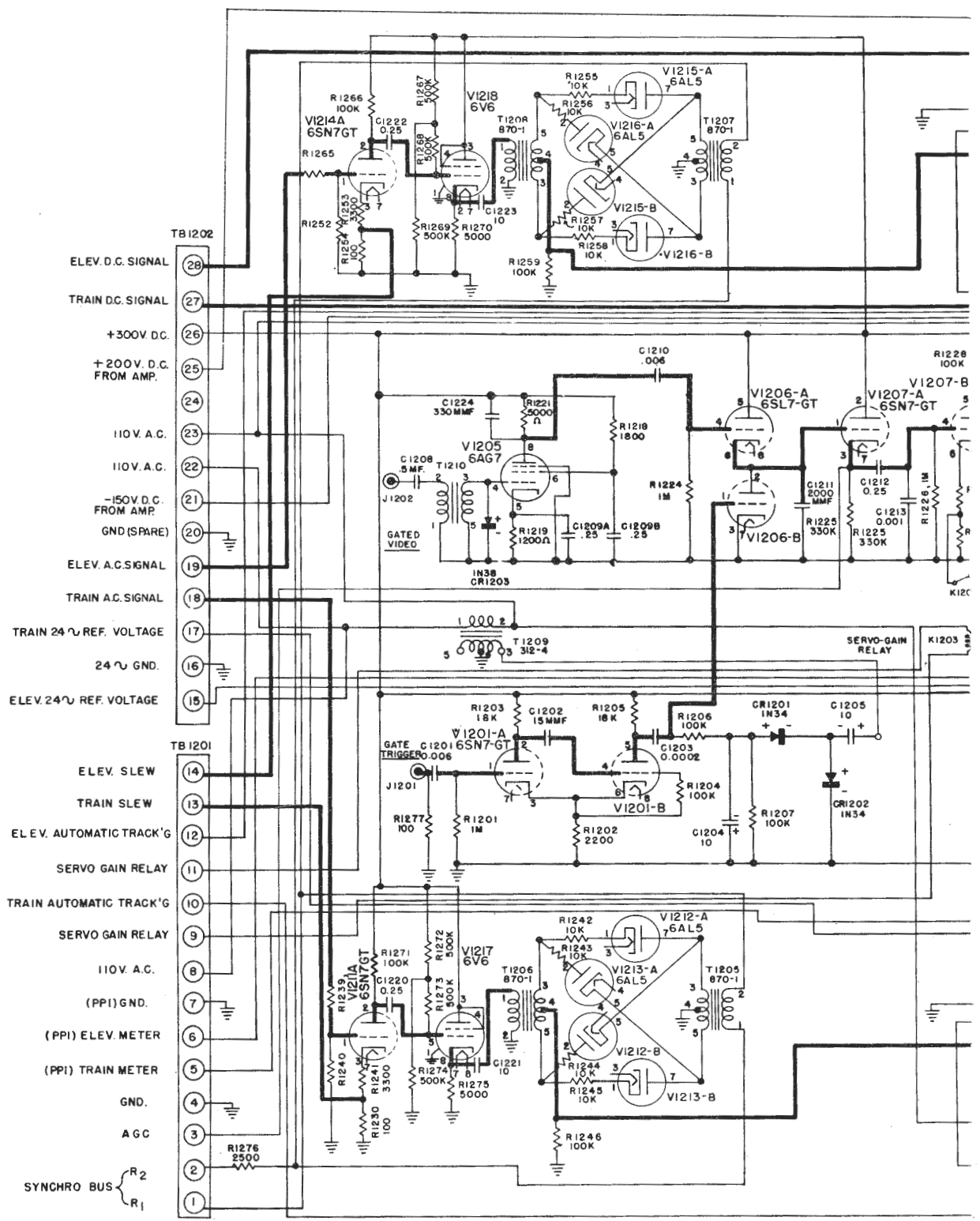
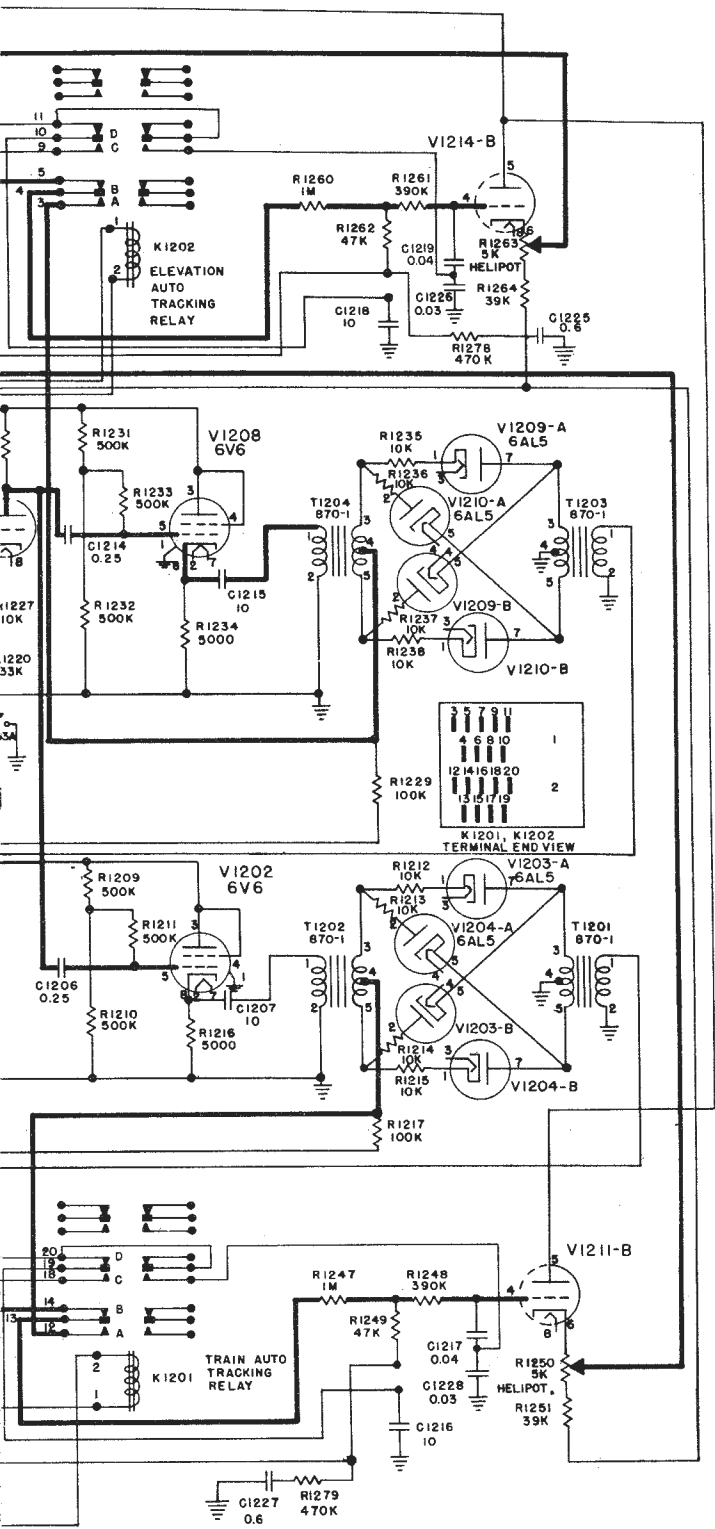


Figure 3-220. Target and Manual Coordinate Detector Unit, Unit 1200 - Schematic Diagram



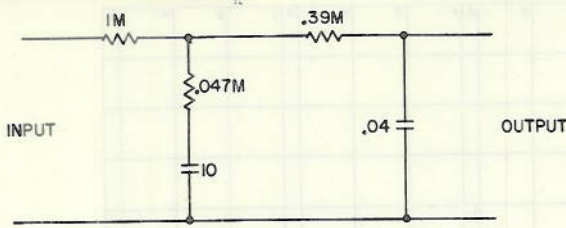


Figure 3-221. Antenna Automatic Radar Tracking Equalizer

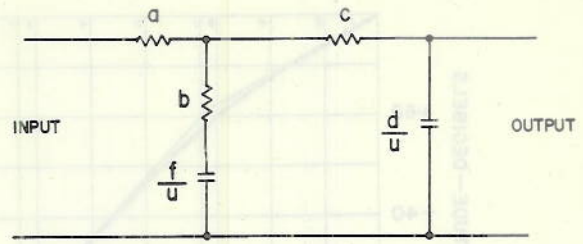


Figure 3-222. Tracking Equalizer Shown With Generalized Parameters Used in Mathematical Analysis

$$= \frac{\left(1 + \frac{p}{2.128}\right)}{\left(1 + \frac{p}{0.0951}\right)\left(1 + \frac{p}{57.6959}\right)} \quad (8)$$

Equation (8) may be written in the form

$$Q = \left(\frac{2.128 + p}{2.128}\right) \left(\frac{0.0951}{0.0951 + p}\right) \left(\frac{57.6959}{57.6959 + p}\right) \quad (9)$$

Setting $\omega_2 = 0.0951$,

$$\omega_3 = 2.128, \quad (10)$$

and $\omega_4 = 57.7$,

the equalizer characteristic has the basic form

$$Q = \left(\frac{\omega_2}{\omega_2 + p}\right) \left(\frac{\omega_3 + p}{\omega_3}\right) \left(\frac{\omega_4}{\omega_4 + p}\right) \quad (11)$$

where ω_2 , ω_3 , and ω_4 have the values given in (10).

The first and third terms of the expressions are "low-pass" terms identical to that obtained from a single-section resistance-capacitance network in which the "corner frequency" is given by ω_2 and by ω_4 , respectively, while the second term is a reciprocal low-pass term with the corner at ω_3 .

4). Open-loop Characteristic. - The complete expression for the open-loop characteristic is the combination of the servo amplifier-amplidyne-motor-equalizer term approximated by p/ω_1 where $\omega_1 = 100$ as explained in paragraph (1) above and the tracking equalizer terms of equation (11). The resulting expression is

$$\mu = \frac{100}{p} \cdot \frac{.0951}{.0951 + p} \cdot \frac{2.128 + p}{2.128} \cdot \frac{57.7}{57.7 + p} \quad (12)$$

or

$$\mu = \frac{\omega_1}{p} \left(\frac{\omega_2}{\omega_2 + p}\right) \left(\frac{\omega_3 + p}{\omega_3}\right) \left(\frac{\omega_4}{\omega_4 + p}\right) \quad (13)$$

where $\omega_1 = 100$,

$\omega_2 = 0.0951$,

$\omega_3 = 2.128$,

and $\omega_4 = 57.7$.

The methods explained in NRL Report R-2668 provide a relatively simple means for plotting the amplitude and phase versus frequency characteristics of the expression for μ as given by equation (13). These characteristics are shown in figure 3-223 and figure 3-224, respectively.

One of the major concerns in servo system design is that the system be stable or non-oscillatory under all input signals to which it may be subjected. The slope of the open-loop amplitude characteristic must be less than minus 40 db per decade in the region of gain cross-over (i.e. zero db gain) because a phase shift of minus 180 degrees is associated with an extended minus 40 db per decade slope. Figure 3-223 shows a slope of minus 24 db per decade at gain cross-over and phase of minus 118 degrees. The difference between the oscillation producing minus 180-degree phase shift and the actual phase at cross-over is termed "phase margin." Figure 3-224 shows a phase margin for the system of 62 degrees as determined at $\omega = 5.25$, the frequency of gain cross-over.

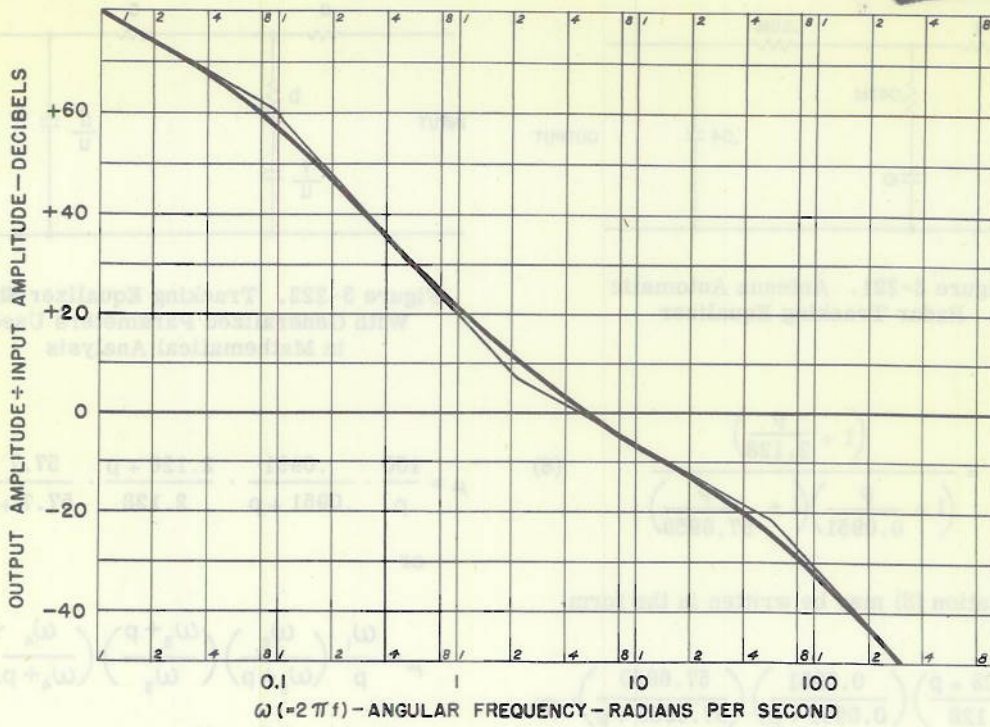


Figure 3-223. Antenna Automatic Radar Tracking - Open-loop Gain Characteristic

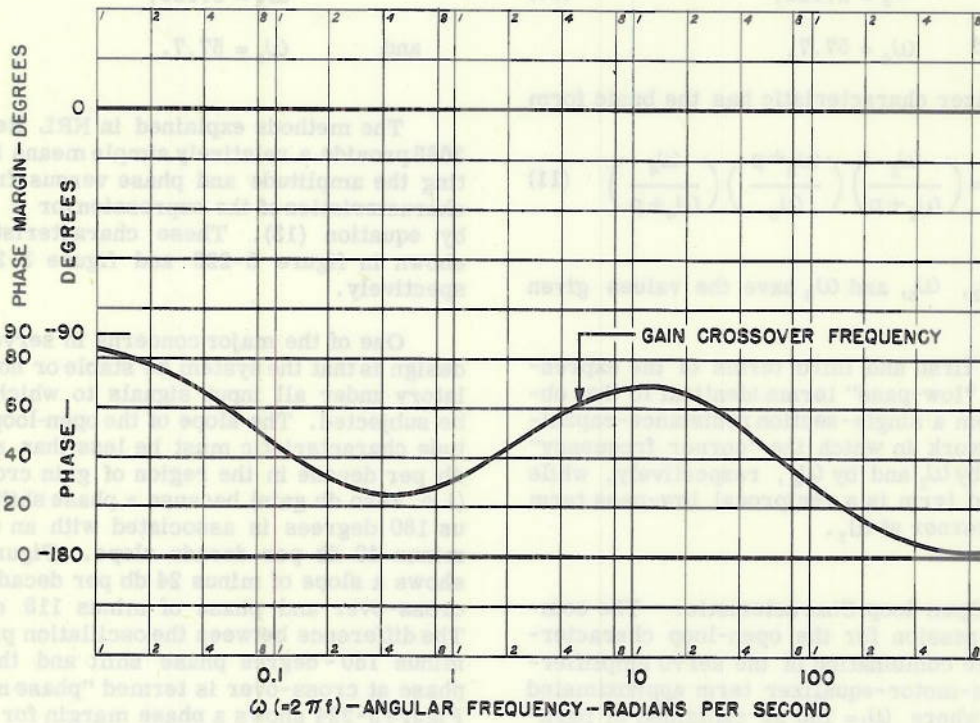


Figure 3-224. Antenna Automatic Radar Tracking - Open-loop Phase Characteristic

A servo system must be stable against voltage variations, friction variations, tube gain changes due to replacements, and other such factors. A measure of the freedom from such difficulties is the "gain margin" as measured at the frequency associated with minus 180-degree phase shift. Figure 3-192 shows a gain margin greater than 70 db as measured at $\omega = 1000$, for the phase cross-over frequency has not been reached even at this high frequency. However, because of cut-off frequencies not considered here, the gain margin in practice is much less.

5). Closed-loop Characteristic. - The closed-loop characteristic for antenna automatic radar tracking is obtained by setting the expression for μ given by equation (13) into the formula

$$G = \frac{\mu}{1 + \mu} \quad (14)$$

The result,

$$G = \frac{\frac{\omega_1}{p} \cdot \frac{\omega_2}{\omega_2 + p} \cdot \frac{\omega_3 + p}{\omega_3} \cdot \frac{\omega_4}{\omega_4 + p}}{1 + \frac{\omega_1}{p} \cdot \frac{\omega_2}{\omega_2 + p} \cdot \frac{\omega_3 + p}{\omega_3} \cdot \frac{\omega_4}{\omega_4 + p}}, \quad (15)$$

reduces to the form

$$G = \frac{\left(1 + \frac{p}{\omega_3}\right)}{p^3 \frac{1}{\omega_1 \omega_2 \omega_4} + p^2 \frac{\omega_2 + \omega_4}{\omega_1 \omega_2 \omega_4} + p \frac{\omega_1 + \omega_3}{\omega_1 \omega_3} + 1} \quad (16)$$

After substitution of the numerical values of ω_1 , ω_2 , ω_3 , and ω_4 into the denominator, the cubic

$$p^3 0.0018224 + p^2 0.105326 + p 0.479925 + 1 = 0 \quad (17)$$

when factored, shows one negative real root and a complex conjugate pair with negative real parts. Equation (16) becomes

$$G = \frac{\left(1 + \frac{p}{2.128}\right)}{\left(1 + \frac{p}{53.023}\right) \left(1 + \frac{p}{2.386 - j 2.158}\right) \left(1 + \frac{p}{2.386 + j 2.158}\right)} \quad (18)$$

Equation (18) is the antenna automatic radar tracking closed-loop frequency response characteristic equation from which both the gain and phase characteristics may be computed. These are shown in figure 3-225 and figure 3-226, respectively.

The variation of the closed-loop gain as a function of frequency shows a slow rise from zero db gain at zero frequency to a maximum of approximately plus 1.5 db near $\omega = 2.5$ and then a decrease to zero db at $\omega = 4.5$. The gain has dropped to minus 3 db at $\omega = 6.8$ and continues to drop at an initial slope of minus 20 db per decade. The minus 20 db per decade slope increases to a minus 40 db per decade slope with the corner located at $\omega = 53.02$ radians per second.

The closed-loop phase characteristic shown in figure 3-226 shows the near zero phase associated with the zero slope gain region below $\omega = 1$, a minus 90-degree phase in the neighborhood of $\omega = 10$ where the gain slope is approximately minus 20 db per decade, and a final phase asymptotic to minus 180 degrees in agreement with the final minus 40 db per decade slope of the gain characteristic.

6). Pedestal and Trailer Mounting Effects. - The variations in the frequency response characteristics of the antenna automatic tracking servo system were partially investigated by the introduction of a constant-amplitude variable-frequency signal into the d-c servo amplifier input. The effects of the non-rigid trailer top mounting of the antenna pedestal react on the servo motor as a variable loading. The voltage developed by the feedback tachometer generator was recorded as an indirect measure of the servo motor shaft excursions.

The results are plotted on figure 3-225 and appear as deviations from the design characteristic. Negligible degradation in performance due to the pedestal mounting position may be expected in the frequency region below approximately $\omega = 3$. A more complete discussion of the foregoing may be found in the subsection on the mechanical design of the antenna and trailers.

7). Antenna Automatic Radar Tracking Servo Error Expressions. - A conservative approximation to the tracking error to be expected with a servo system may be derived as follows. Consider the generalized representation of a servo system shown in figure 3-227 in which

θ_i = input (equivalent angle),

θ_o = output (equivalent angle),

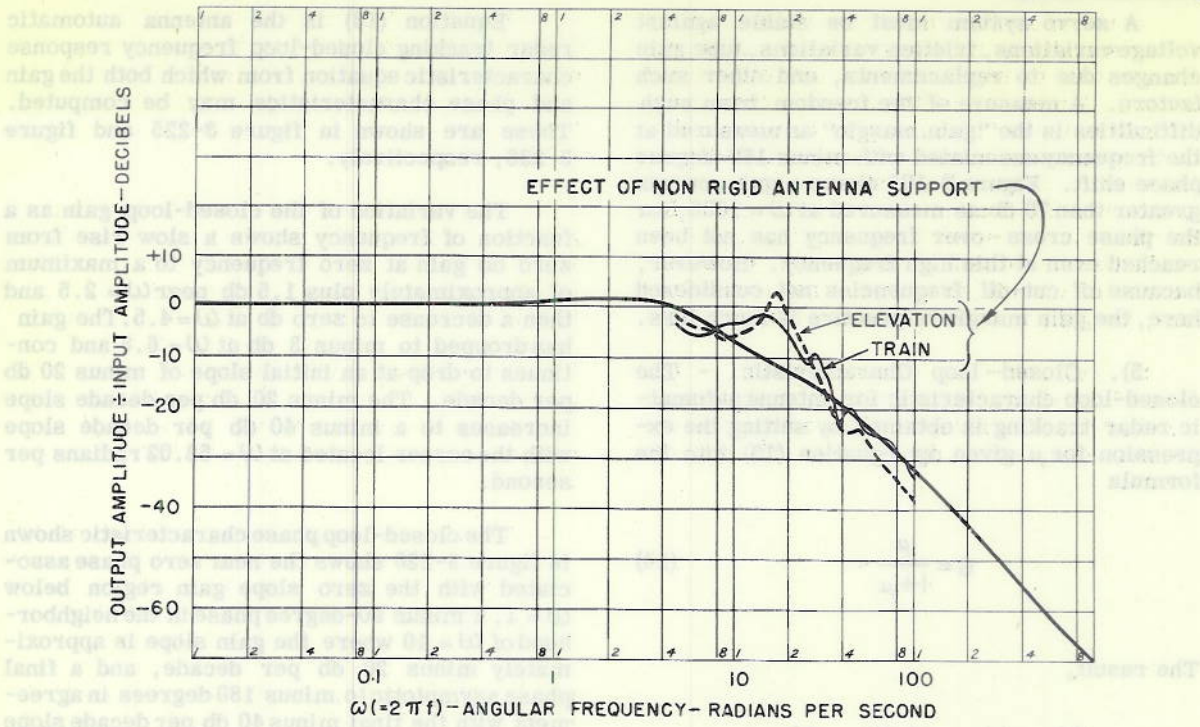


Figure 3-225. Antenna Automatic Radar Tracking - Closed-loop Gain Characteristic

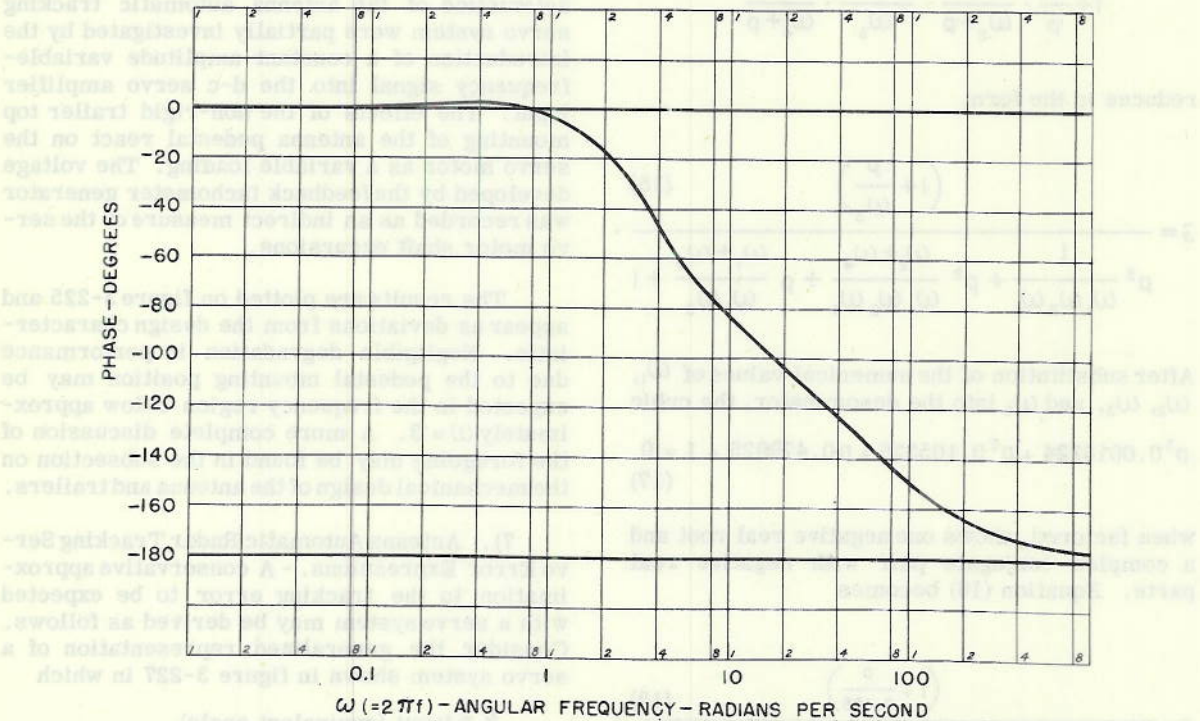


Figure 3-226. Antenna Automatic Radar Tracking - Closed-loop Phase Characteristic

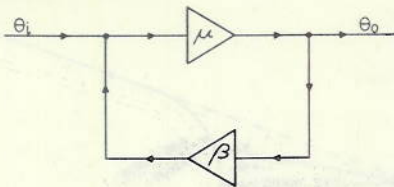


Figure 3-227. Servo System - Generalized Representation

μ = forward gain characteristic, and

β = feedback characteristic.

From the equation

$$\theta_o = \theta_i \mu + \mu \beta \theta_o, \quad (19)$$

the output is found equal to

$$\theta_o = \frac{\mu}{1 - \mu \beta} \theta_i. \quad (20)$$

In the servo systems under consideration, $\beta = -1$ and the output becomes

$$\theta_o = \frac{\mu}{1 + \mu} \theta_i. \quad (21)$$

The input-output error expression, ϵ , may be written as follows:

$$\begin{aligned} \epsilon &= \theta_i - \theta_o, \\ &= \left(1 - \frac{\mu}{1 + \mu}\right) \theta_i, \quad (22) \\ &= \left(\frac{1}{1 + \mu}\right) \theta_i. \end{aligned}$$

From figure 3-223 it is seen that for all frequencies below $\omega = 5.25$ the open-loop gain (i.e., the value of μ) is greater than unity and that for all tracking signal input frequencies $\mu \gg 1$. The error expression may be closely approximated by

$$\epsilon \doteq \frac{1}{\mu} \theta_i. \quad (23)$$

Again, considering the low-frequency region only, the μ characteristic may be approximated by the initial minus 20 db per decade slope the projection of which crosses the zero-db axis at $\omega = 100$ (i.e. $\omega = \omega_1$) and the second asymptotic segment having a minus 40 db per decade slope starting at $\omega = 0.0951$ (i.e. $\omega = \omega_2$) as shown in figure 3-228. The illustrated asymptotic gain characteristic represents the first two terms of equation (13). Thus,

$$\mu \doteq \frac{\omega_1}{p} \cdot \frac{\omega_2}{\omega_2 + p}. \quad (24)$$

Substitution into equation (23) gives

$$\begin{aligned} \epsilon &\doteq \frac{p}{\omega_1} \cdot \frac{\omega_2 + p}{\omega_2} \cdot \theta_i, \\ &= \frac{p \theta_i}{\omega_1} + \frac{p^2 \theta_i}{\omega_1 \omega_2}. \quad (25) \end{aligned}$$

The expression $p \theta_i$ has, in transient analysis, the significance of the first derivative of θ_i with respect to time. Similarly, $p^2 \theta_i$ is the second derivative of θ_i with respect to time. Equation (25) may be written in the equivalent form

$$\epsilon \doteq \frac{\dot{\theta}_i}{\omega_1} + \frac{\ddot{\theta}_i}{\omega_1 \omega_2}, \quad (26)$$

where ϵ = output minus input or error angle,

$\dot{\theta}_i$ = input angular velocity, and

$\ddot{\theta}_i$ = input angular acceleration.

For the particular characteristic under consideration the velocity constant is $\omega_1 = 100$ and the acceleration constant is $\omega_1 \omega_2 = 100 \times 0.0951 = 9.51$. Thus, for the antenna automatic radar tracking servo system, the error expression becomes

$$\epsilon \doteq \frac{\dot{\theta}_i}{100} + \frac{\ddot{\theta}_i}{9.5}. \quad (27)$$

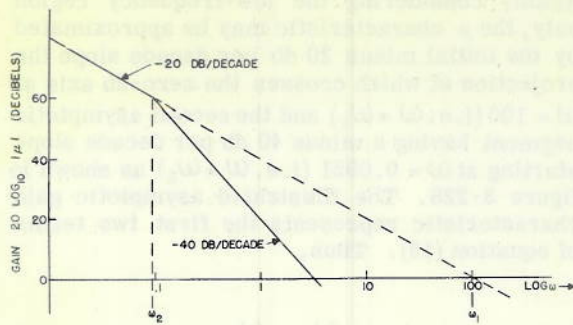


Figure 3-228. Approximation of μ - Characteristic for Error Expression Determination

Elsewhere in this report (e.g., the system specifications) the error expression

$$\epsilon = \frac{\dot{\theta}_i}{100} + \frac{\ddot{\theta}_i}{10} \quad (28)$$

has been indicated. The round figures of equation (28) are within the equalizer component tolerances, easier to use and remember, and represent only slightly greater tracking performance than the computed value given in equation (27).

The value of knowing the error expression lies in being able to predict tracking performance for specified target courses. The specified course may be analyzed and time plots of position, velocity, and acceleration made for the train, elevation, and range coordinates. It is usually desirable to start at a point in the course where transient effects will be small and then to follow through the whole course determining the error for each space coordinate separately. The error expressions for train and elevation are the same, equation (28), except that for train it must be remembered that the radar measures the error in the slant plane. Thus, equation (27) should include a multiplier term, secant E , for tracking involving any but the lowest elevation angles. The error expression for the range coordinate may be found in the subsection of the report treating the range system. A suitable combination of the three coordinate errors yields the spatial vector error.

A grasp of the significance and of the magnitude represented by the error expression may be gained by considering a specific target course. It should be emphasized that the following is merely one of an infinite number of possible

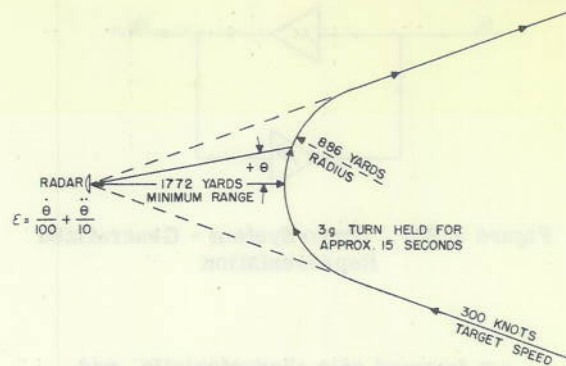


Figure 3-229. Typical Target Aircraft Course

target courses and is introduced here to indicate clearly the manner in which the error expression may be used to predict the performance of the servo system. In the introduction to the report, section I, it was stated that the initial Lark guidance specifications called for a missile capable of attacking an approaching enemy aircraft traveling at a speed of 300 knots and capable of executing 3g turns. Such a course is illustrated in figure 3-229 in which the aircraft target is at antenna altitude and holds the turn for something slightly less than 15 seconds. The minimum range specified is two times the target turning radius.

Figure 3-230 shows four plots of course components and error as a function of time as measured from the minimum range point. The top curve shows that the radar antenna trains through approximately 40 degrees with a maximum angular velocity, occurring at minimum range, equal to 16 degrees per second. The second curve shows the velocity as a function of time with maximum rates of change of 9.5 degrees per second per second occurring approximately 3.5 seconds each side of minimum range as shown on the third curve. Because the acceleration component for this particular course is great, and the error expression (equation 28) shows an acceleration constant smaller than the velocity constant by a factor of ten, the error curve assumes a shape very similar to the acceleration curve shape. For other courses the error curve may be more similar to the velocity curve.

The fourth curve, error as a function of time, shows a maximum one degree lag approximately three seconds before minimum range and a maximum lead of approximately 0.9 degrees about four seconds after the minimum range point. This error is well within radar

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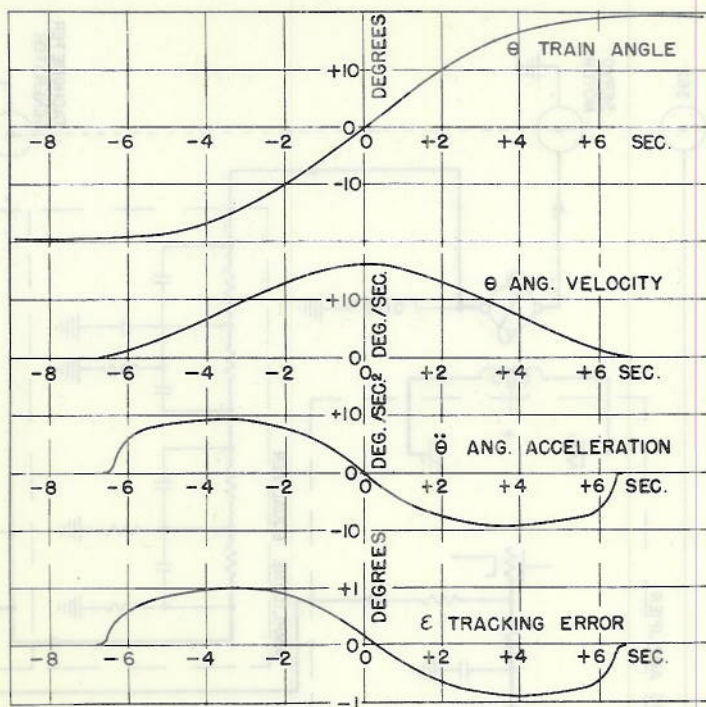


Figure 3-230. Position, Velocity, Acceleration and Tracking Error for Typical Target Aircraft Course

beamwidth limitations. It should not be necessary to point out that the course illustrated is not a typical course for missile-aircraft engagement but serves merely to illustrate the tracking capabilities of the radar, and a general method for determining tracking accuracy.

b. Antenna Handcrank Tracking Servo System. - The antenna handcrank tracking servo system is mathematically similar to the antenna automatic radar tracking servo system. The difference is due to a modification in the tracking equalizer constants that results when relays K1201 and K1202 (see the schematic figure 3-220) are unenergized for manual antenna operation from the PPI position. Position feedback is accomplished by synchro data transmission rather than by the radar pulse-echo process of automatic radar tracking but is the same 100 per cent negative feedback or simple degenerative connection.

Figure 3-231 shows in a simplified form the portions of the Lark SP-1M radar pertinent to the handcrank-antenna servo system.

The details of alternate a-c signals to the amplifier originating at the PPI Antenna Scanning potentiometer and at the telescope slew

control potentiometers are not shown on figure 3-231. These signals are mixed and introduced (via appropriate switching) into the servo system through V1211A (train) and V1214A (elevation) as seen on the schematic, figure 3-220.

1). Open-loop Characteristics. - The equalizer shown in figure 3-232 is traced from the circuit shown in the schematic, figure 3-220, and is the same configuration illustrated by figure 3-222 for which the transfer characteristic equation (5) applies. Here, the constants have the values

$$\begin{aligned}
 a &= 1, \\
 b &= 0.517, \\
 c &= 0.39, \\
 d &= \frac{1}{0.01714} = 5833,
 \end{aligned}
 \tag{29}$$

$$\text{and } f = \frac{1}{0.6} = 1.667.$$

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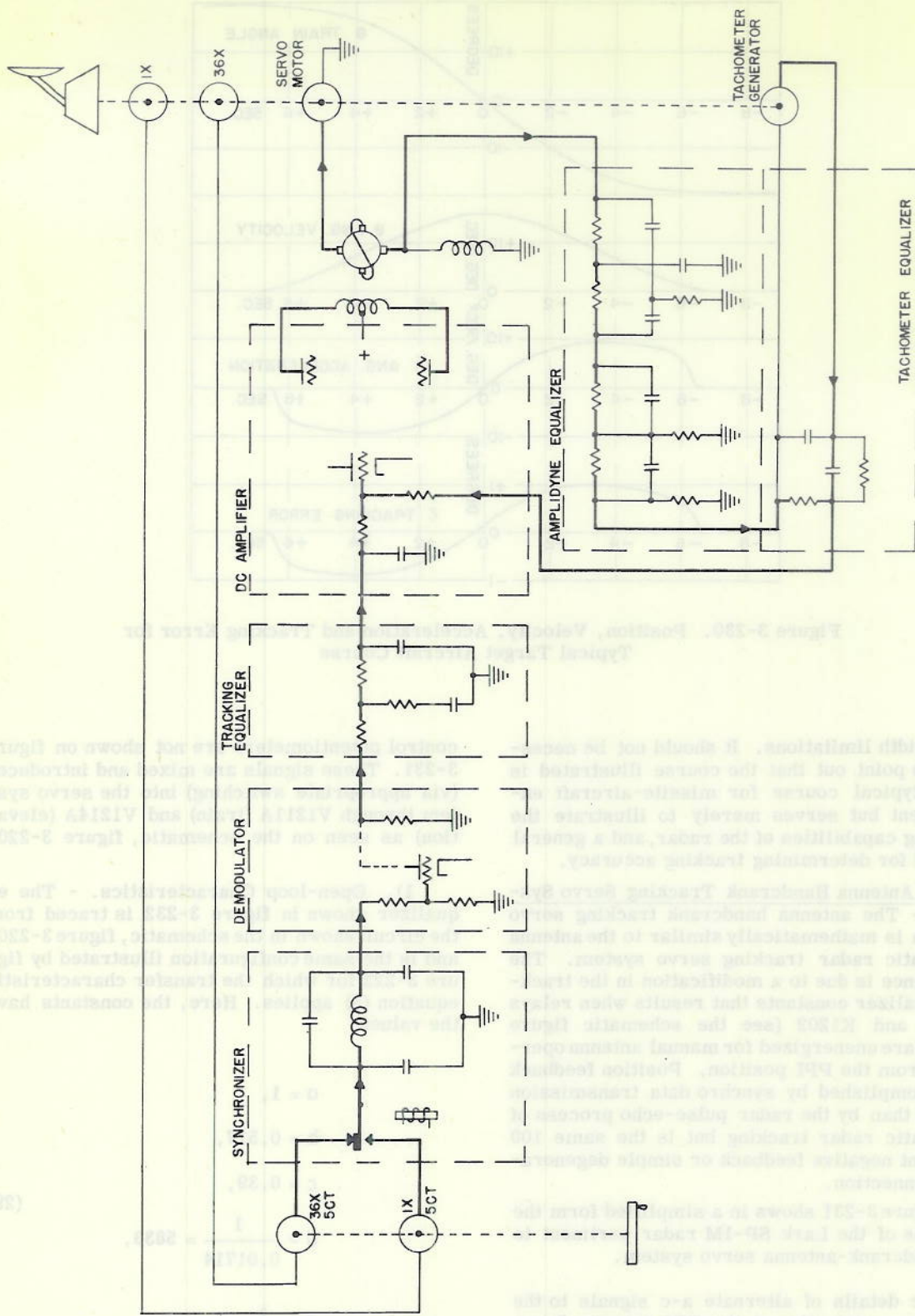


Figure 3-231. Antenna Handcrank Tracking Servo System

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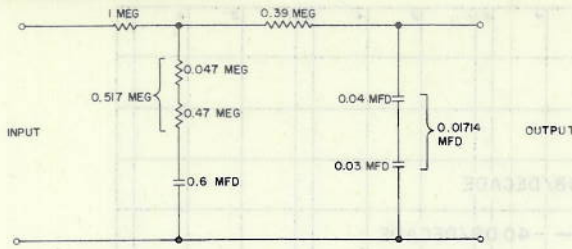


Figure 3-232. Antenna Handcrank Tracking Equalizer

The equalizer transfer characteristic equation becomes

$$\alpha = \frac{\left(1 + \frac{p}{3.2237}\right)}{\left(1 + \frac{p}{1.0854}\right)\left(1 + \frac{p}{80.8256}\right)} \quad (30)$$

The basic characteristic of the servo amplifier-amplidyne-motor-equalizer combination is that of a perfect integrator having the mathematical form of a constant divided by the complex operator p . However, as compared with the gain level employed in antenna automatic radar tracking, the specifications call for a reduced gain so that the equivalent of ω_1 of the automatic radar tracking servo becomes

$$\omega_8 = \frac{35}{p} \quad (31)$$

for the handcrank loop.

The procedure for experimentally adjusting the gain setting involves opening the servo loop at the d-c amplifier input and short circuiting the input to ground by switching S3301 (train or S3302 for elevation) from the zero position. If the antenna drifts, the d-c amplifier balance must be checked, for the foregoing action should lock the antenna at a fixed angular position. Assuming that the train channel gain setting is being adjusted, measure the voltage going to the d-c amplifier at TB1202-27 (to ground, TB1202-20). This will be zero for a position of the train handwheel corresponding to the antenna position. Next, misadjust the potentiometer R1250 to produce a moderate voltage unbalance, say three volts (between TB1202-27 and TB1202-20). Then, switch S3301 back to operate and meas-

ure seconds per revolution of the antenna. This has been found to result in 3.3 degrees per second per volt. Readjust R1250 to balance position and open the loop by switching S3301 from the operate position.

Displace the handwheel a small recorded amount and measure the voltage to the d-c amplifier and compute the volts per degree handcrank error.

The specifications call for 35 degrees per second antenna velocity for one degree error in antenna tracking of the handcrank. Using the equation

$$\epsilon = \frac{\dot{\theta}_1}{\omega_8} = \frac{\dot{\theta}_1}{35} \quad (32)$$

which holds when the antenna is rotating at a constant speed and, therefore, no acceleration is present, it is seen that one degree error must correspond to 35 degrees per second. Dividing,

$$\frac{35 \text{ degrees/second}}{3.3 \text{ degrees/second/volt}} = 10.6 \text{ volts} \quad (33)$$

at the d-c amplifier input must be obtained per degree error of handcrank. The resistor combination R1239-R1240 acts as a signal-divider and must be adjusted to produce the 10.6 volts per degree handcrank error. This should be done for small errors, say 0.1 degrees. Once selected, R1239-R1240 need not be replaced (unless damaged). Switch S3301 may now be returned to the operate position.

Maintenance checks of the system operation are facilitated by the known intermediate gain point. That is, one degree handcrank error should produce 10.6 volts at the d-c amplifier input and three volts at the d-c amplifier input should produce 10 degrees per second antenna velocity.

The system gain-setting term $35/p$, when combined with the equalizer equation gives the open-loop gain expression

$$\mu = \frac{\omega_8}{p} \left(\frac{\omega_5}{\omega_5 + p}\right) \left(\frac{\omega_6 + p}{\omega_6}\right) \left(\frac{\omega_7}{\omega_7 + p}\right) \quad (34)$$

where $\omega_8 = 35$,

$\omega_5 = 1.085$,

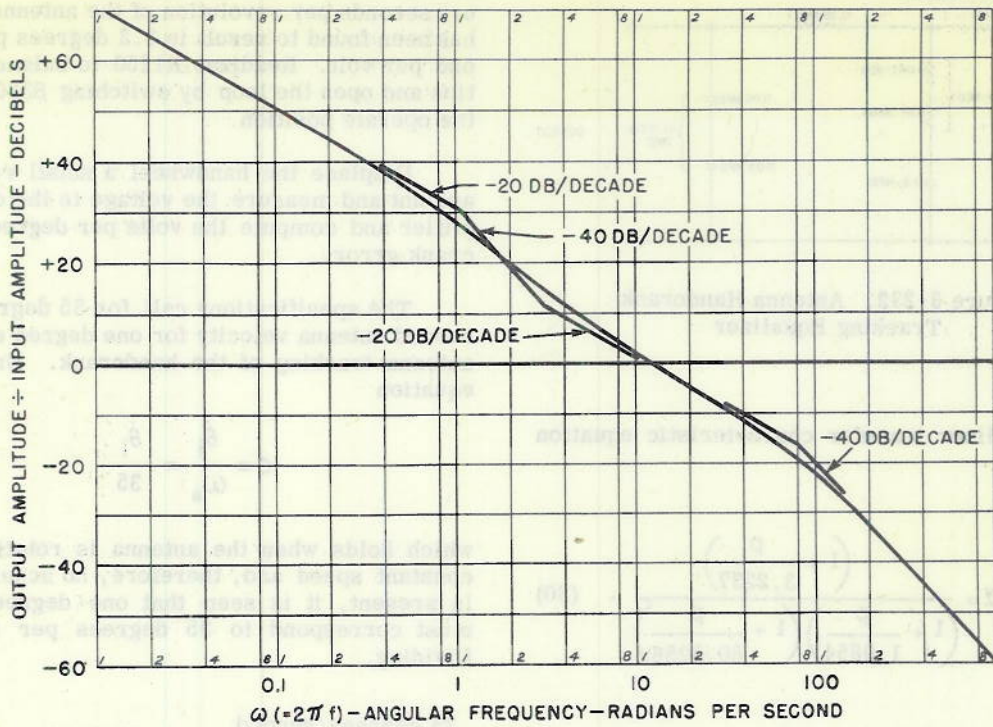


Figure 3-233. Antenna Handcrank Servo - Open-loop Gain Characteristic

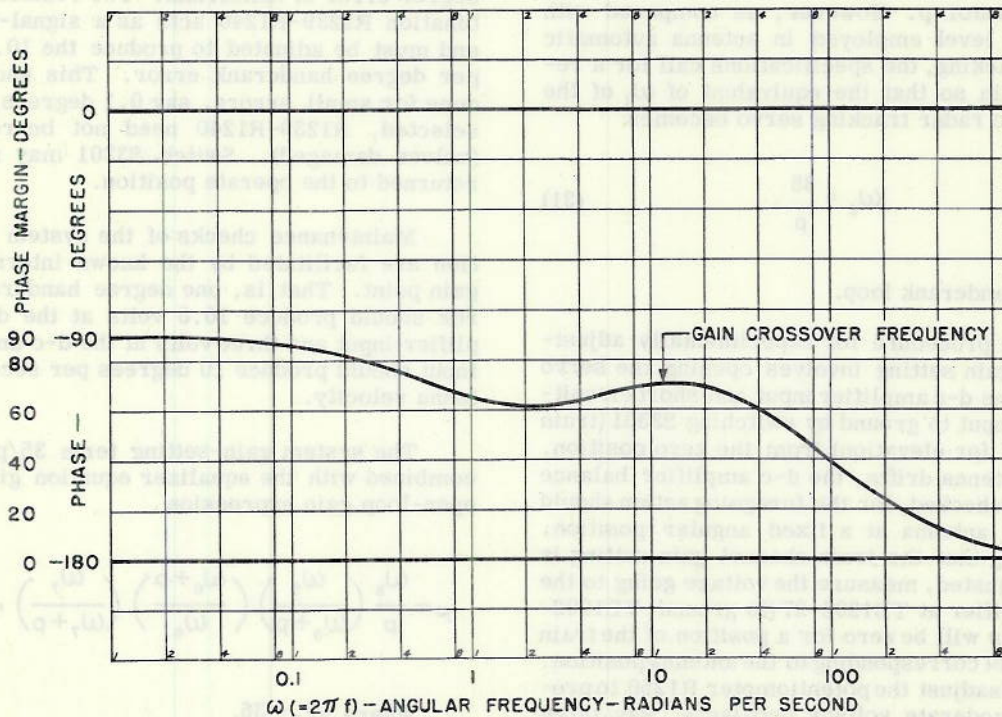


Figure 3-234. Antenna Handcrank Servo - Open-loop Phase Characteristic

$$\omega_6 = 3.224,$$

and $\omega_7 = 80.826.$

where $\omega_6 = 3.224,$

$$\omega_9 = 4.387,$$

$$\omega_{10} = 10.428,$$

and $\omega_{11} = 67.096.$

The open-loop gain characteristic is shown in figure 3-233 and is seen to have asymptotic segments of minus 20 db per decade, minus 40 db per decade, minus 20 db per decade, and a final minus 40 db per decade slope. Gain cross-over occurs near $\omega = 12$ with the actual characteristic slope approximately equal to minus 22.5 db per decade. The phase characteristic shown in figure 3-234 exhibits a phase margin of 70 degrees and shows an asymptotic approach to phase cross-over. As measured at $\omega = 1000$, the design gain margin is seen to be greater than 60 db. However, because of cut-off frequencies not considered here, the gain margin in practice is much less.

Equation (38) is the antenna handcrank tracking closed-loop frequency response characteristic equation having the gain and phase responses shown by figures 3-235 and 3-236, respectively. The maximum gain rise is seen to be approximately one db occurring near $\omega = 4$. The gain goes through zero db at $\omega = 9$ and has a minus 20 db per decade slope followed by a final minus 40 db per decade slope. The phase characteristic rises slowly from zero frequency to a maximum one degree lead near $\omega = 0.5$, drops to zero at $\omega = 1$ and increases to minus 180 degrees at a very uniform rate crossing minus 90 degrees at $\omega = 30$.

2). Closed-loop Characteristics. - The closed loop characteristic becomes

$$G = \frac{\mu}{1+\mu}, \tag{35}$$
$$= \frac{\left(1 + \frac{p}{\omega_6}\right)}{p^3 \frac{1}{\omega_5 \omega_7 \omega_8} + p^2 \frac{\omega_5 + \omega_7}{\omega_5 \omega_7 \omega_8} + p \frac{\omega_6 + \omega_8}{\omega_6 \omega_8} + 1}$$

3). Error Expression. - The open-loop gain characteristic may be approximated for low-frequency input signals by using the first two terms of equation (34) as follows:

$$\mu = \frac{\omega_8}{p} \left(\frac{\omega_5}{\omega_5 + p} \right) \tag{39}$$

After substitution of the values for $\omega_5, \omega_6, \omega_7,$ and ω_8 into the denominator, the cubic to be factored is

where $\omega_8 = 35,$

and $\omega_5 = 1.085.$

$$p^3 0.00032579 + p^2 0.0266859 + p 0.338745 + 1 = 0. \tag{36}$$

Following the procedure leading to equation (23),

$$\epsilon = \frac{1}{\mu} \theta_i,$$
$$= \frac{p}{\omega_8} \left(\frac{\omega_5 + p}{\omega_5} \right) \theta_i,$$
$$= \frac{\dot{\theta}_i}{\omega_8} + \frac{\ddot{\theta}_i}{\omega_8 \omega_5}, \tag{40}$$

Equation (35) then becomes

$$G = \frac{\left(1 + \frac{p}{3.224}\right)}{\left(1 + \frac{p}{4.387}\right) \left(1 + \frac{p}{10.428}\right) \left(1 + \frac{p}{67.096}\right)} \tag{37}$$

which has the form

$$G = \frac{\omega_6 + p}{\omega_6} \cdot \frac{\omega_9}{\omega_9 + p} \cdot \frac{\omega_{10}}{\omega_{10} + p} \cdot \frac{\omega_{11}}{\omega_{11} + p} \tag{38}$$

$$\epsilon = \frac{\dot{\theta}_i}{35} + \frac{\ddot{\theta}_i}{38}. \tag{41}$$

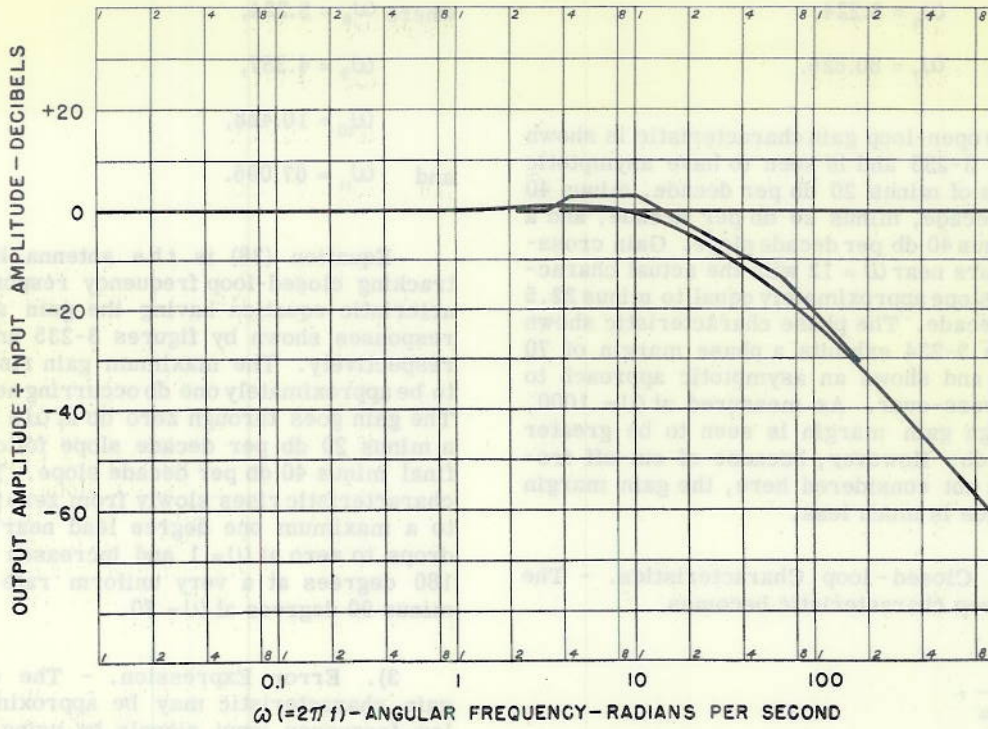


Figure 3-235. Antenna Handcrank Servo - Closed-loop Gain Characteristic

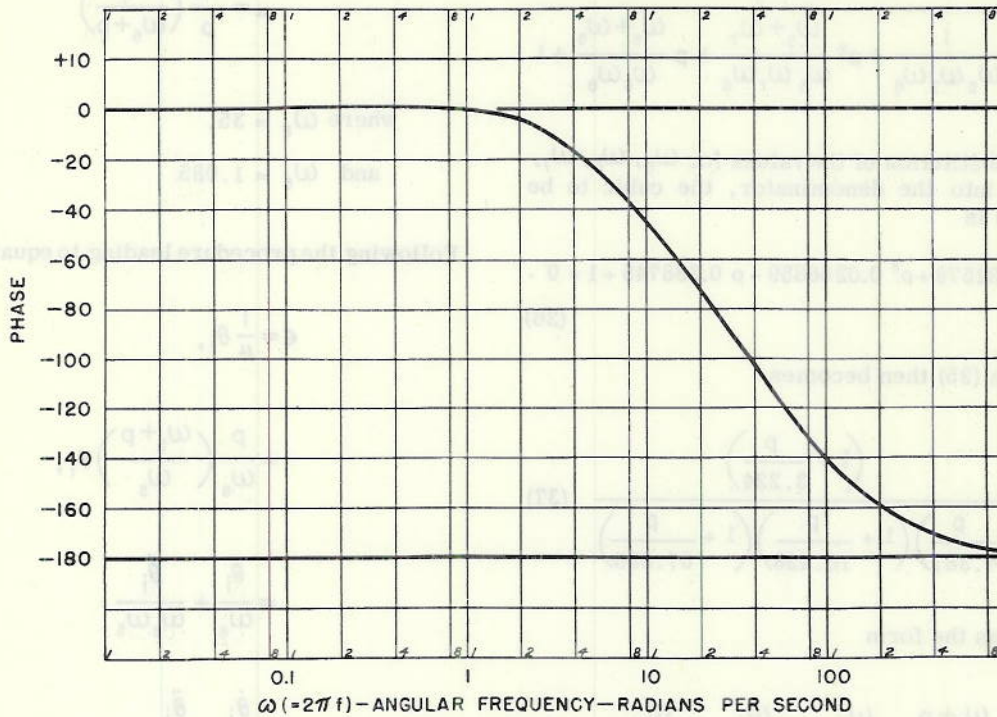


Figure 3-236. Antenna Handcrank Servo - Closed-loop Phase Characteristic

As compared with the error expression given in equation (28) for antenna automatic radar tracking, the error expression given by equation (41) for antenna tracking of the hand-crank shows that the velocity error component is greater by the factor 100/35 but the acceleration error component is smaller by the factor 38/10. Here, a wider bandpass is usable because the system noise components are a much smaller problem when synchro data are used for position closure as compared with the radar pulse-target echo position closure loop.

Under manual operation, the system performance has been purposely limited to those values of maximum velocity and acceleration which, if continuously applied, would not endanger the life expectancy of any parts of the

system, in particular, the servo motor. These limitations are not imposed under automatic operation because target conditions cannot produce excessive velocity and acceleration for long enough periods of time to cause damage.

As an illustration, if in automatic radar tracking a steady state error of one degree is developed by a cooperative target, the equivalent error voltage (from figure 3-219) of 19 volts would produce a train velocity of 63 degrees per second which is in excess of the 35-degree-per-second velocity under manual operation for a one degree steady state error.

The acceleration error is reduced under manual operation because the requirements of moving rapidly to a new position are greater

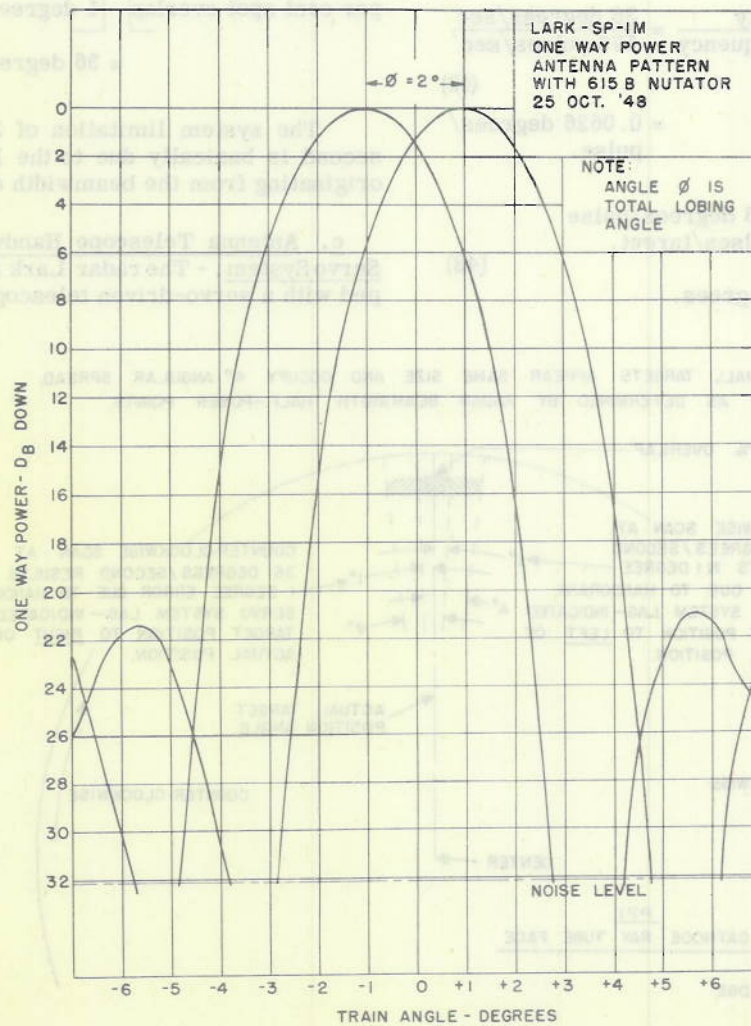


Figure 3-237. Antenna Power Pattern

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while in manual operation. The handwheels are geared down so that the operator can train 10 degrees per revolution and has a satisfactorily fine position-setting control. At the same time, rough handwheel operation is less likely to develop damagingly high servo motor speeds. Operators should try for smooth operation but, if tempted to operate otherwise, the system electronic limitations protect against damage.

The PPI search control and handcrank follow-up are designed so that a maximum train slew velocity of 36 degrees per second can be obtained. Assume that a reasonable number of echopulses per target for detection is five. The radar pulse repetition frequency is 576 pulses per second. The minimum target size that may be thus adequately illuminated is calculated as follows:

$$\frac{\text{Antenna slew velocity}}{\text{Pulse repetition frequency}} = \frac{36 \text{ degrees/sec}}{576 \text{ pulses/sec}} \quad (42)$$

$$= 0.0626 \text{ degrees/pulse.}$$

$$\text{Target Size} = 0.0626 \text{ degrees/pulse} \times 5 \text{ pulses/target,} \quad (43)$$

$$= 0.3 \text{ degrees.}$$

For five pulses per target illumination where the target is less than 0.3 degrees in size, a slew velocity of less than 36 degrees per second must be used. The target position as determined from the PPI presentation is a function of spot size and scan velocity. That is to say, clockwise scan may indicate a fixed target at one angular position whereas counterclockwise scan may give another angular position if the scan velocity is too great. The maximum scan velocity should result in approximately 50 per cent spot overlap. For all targets smaller than the beam width, the spot diameter is determined by the beam width (see figure 3-237) and using one-half power points, the spot size becomes four degrees (see figure 3-238). The computed scan velocity limitation becomes

$$\text{Maximum allowable scan velocity for 50 per cent spot overlap} = \frac{36 \text{ degrees/sec}}{1 \text{ degree error}} \times 1 \text{ degree error,} \quad (44)$$

$$= 36 \text{ degrees/sec.}$$

The system limitation of 36 degrees per second is basically due to the PPI limitations originating from the beamwidth dimensions.

c. Antenna Telescope Handwheel Tracking Servo System. - The radar Lark SP-1M is equipped with a servo-driven telescope position from

ALL SMALL TARGETS APPEAR SAME SIZE AND OCCUPY 4° ANGULAR SPREAD ON PPI AS DETERMINED BY RADAR BEAMWIDTH HALF-POWER POINTS.

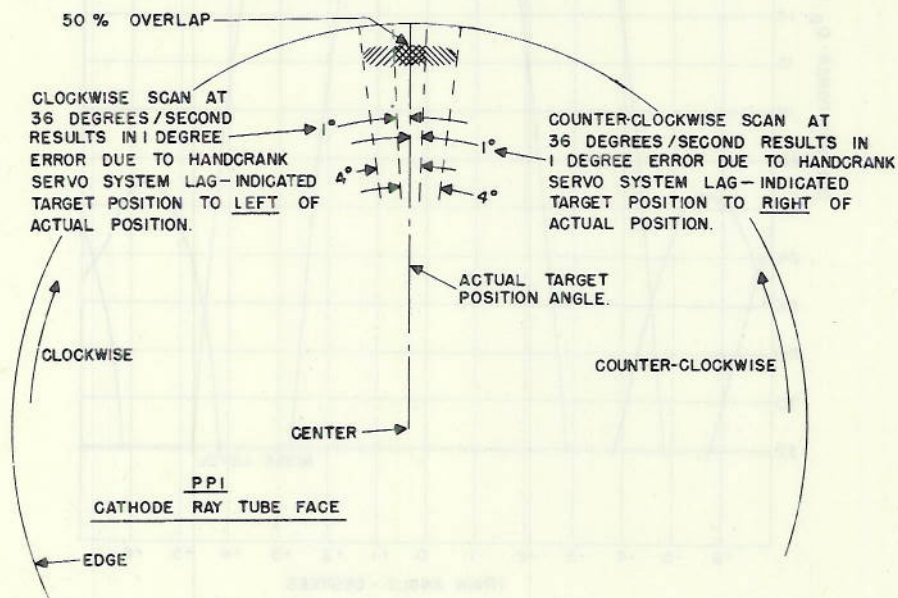


Figure 3-238. Error in PPI Presentation Due to Antenna Scan

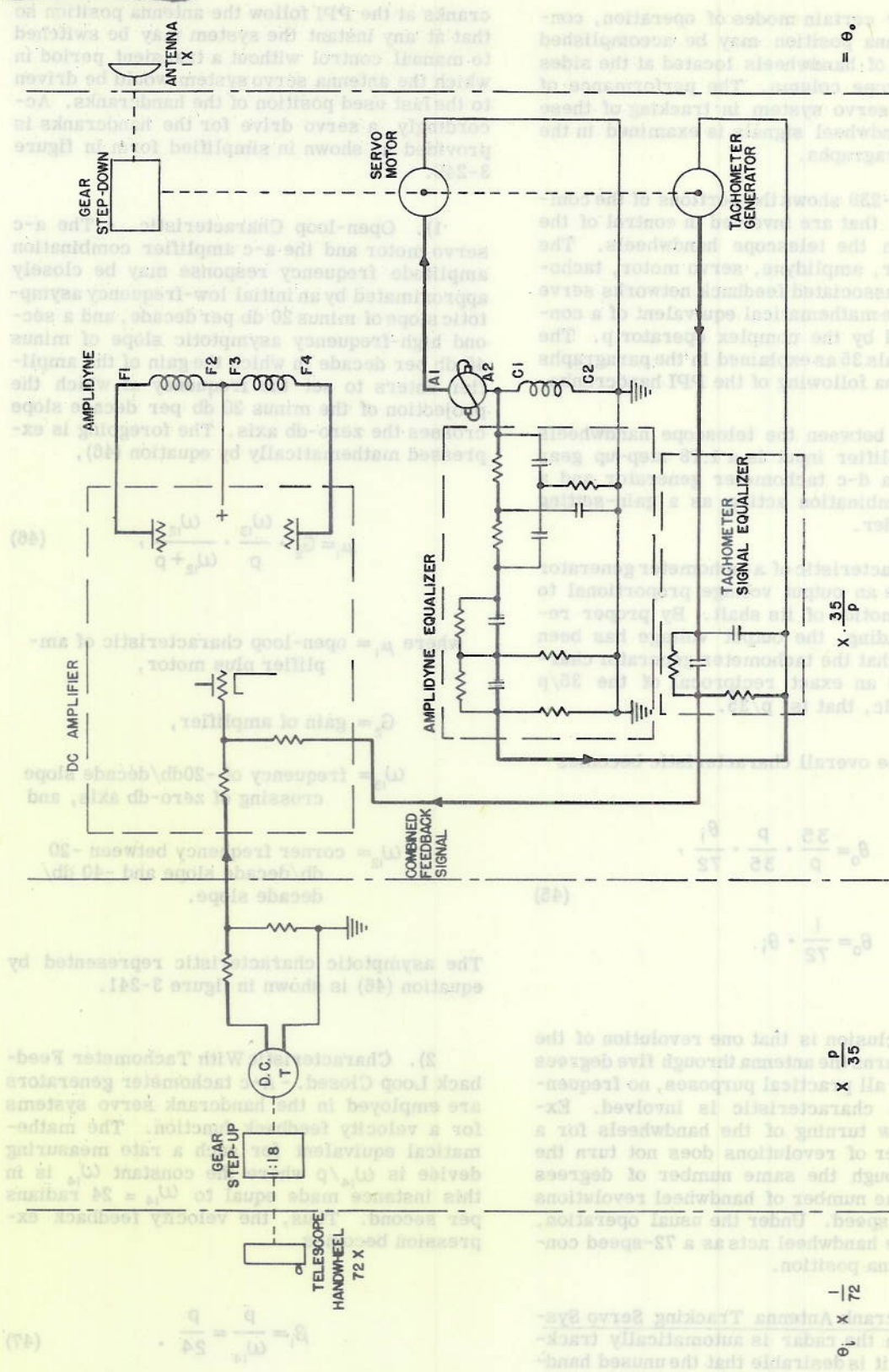


Figure 3-239. Antenna Telescope Handwheel Tracking Servo System.

which, under certain modes of operation, control of antenna position may be accomplished by operation of handwheels located at the sides of the telescope column. The performance of the antenna servo system in tracking of these telescope handwheel signals is examined in the following paragraphs.

Figure 3-239 shows the portions of the complete system that are involved in control of the antenna from the telescope handwheels. The d-c amplifier, amplidyne, servo motor, tachometer, and associated feedback networks serve to provide the mathematical equivalent of a constant divided by the complex operator p . The constant equals 35 as explained in the paragraphs on the antenna following of the PPI handcranks.

Located between the telescope handwheels and the amplifier input is a 1:18 step-up gear box driving a d-c tachometer generator and a resistor combination acting as a gain-setting voltage-divider.

The characteristic of a tachometer generator is to produce an output voltage proportional to the rate of motion of its shaft. By proper resistance loading, the output voltage has been adjusted so that the tachometer generator characteristic is an exact reciprocal of the $35/p$ characteristic, that is, $p/35$.

Thus, the overall characteristic becomes

$$\theta_o = \frac{35}{p} \cdot \frac{p}{35} \cdot \frac{\theta_i}{72}, \quad (45)$$

$$\theta_o = \frac{1}{72} \cdot \theta_i.$$

The conclusion is that one revolution of the handwheel turns the antenna through five degrees and that, for all practical purposes, no frequency response characteristic is involved. Extremely slow turning of the handwheels for a given number of revolutions does not turn the antenna through the same number of degrees that the same number of handwheel revolutions will at high speed. Under the usual operation, however, the handwheel acts as a 72-speed control of antenna position.

d. Handcrank Antenna Tracking Servo System. - When the radar is automatically tracking a target it is desirable that the unused hand-

cranks at the PPI follow the antenna position so that at any instant the system may be switched to manual control without a transient period in which the antenna servo system would be driven to the last used position of the handcranks. Accordingly, a servo drive for the handcranks is provided as shown in simplified form in figure 3-240.

1). Open-loop Characteristic. - The a-c servo motor and the a-c amplifier combination amplitude frequency response may be closely approximated by an initial low-frequency asymptotic slope of minus 20 db per decade, and a second high-frequency asymptotic slope of minus 40 db per decade in which the gain of the amplifier enters to set the frequency at which the projection of the minus 20 db per decade slope crosses the zero-db axis. The foregoing is expressed mathematically by equation (46),

$$\mu_1 = G_2 \cdot \frac{\omega_{13}}{p} \cdot \frac{\omega_{12}}{\omega_{12} + p}, \quad (46)$$

where μ_1 = open-loop characteristic of amplifier plus motor,

G_2 = gain of amplifier,

ω_{13} = frequency of -20db/decade slope crossing of zero-db axis, and

ω_{12} = corner frequency between -20 db/decade slope and -40 db/decade slope.

The asymptotic characteristic represented by equation (46) is shown in figure 3-241.

2). Characteristic With Tachometer Feedback Loop Closed. - A-c tachometer generators are employed in the handcrank servo systems for a velocity feedback function. The mathematical equivalent for such a rate measuring device is ω_{14}/p where the constant ω_{14} is in this instance made equal to $\omega_{14} = 24$ radians per second. Thus, the velocity feedback expression becomes

$$\beta_1 = \frac{p}{\omega_{14}} = \frac{p}{24}. \quad (47)$$

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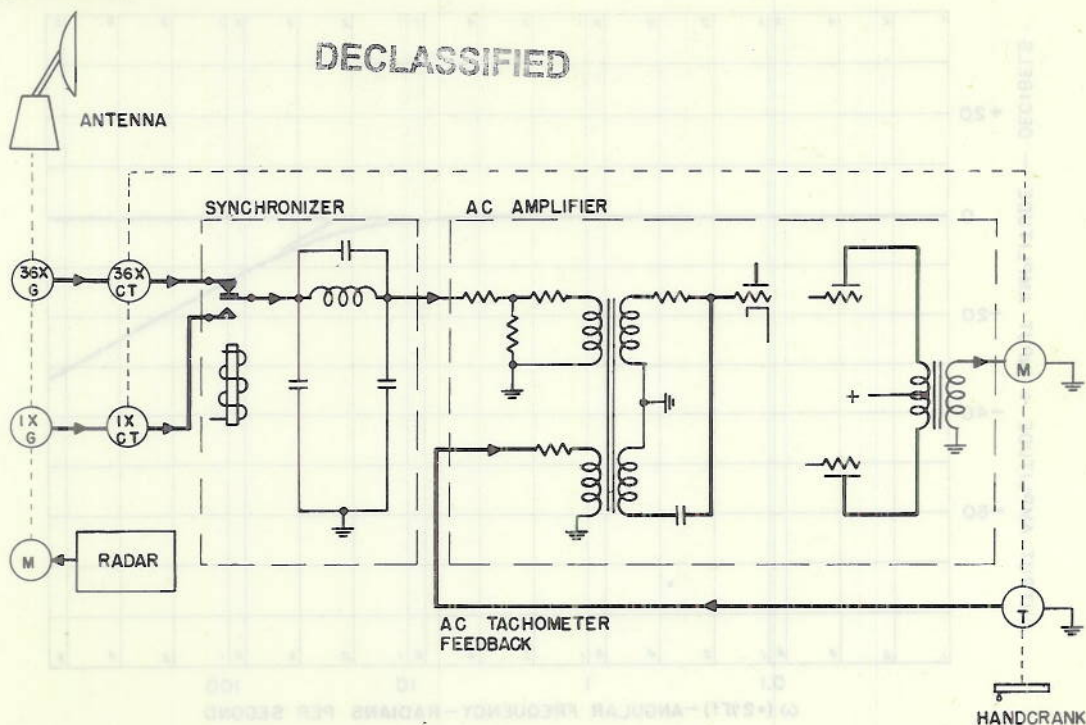


Figure 3-240. Handcrank Antenna Tracking Servo System

For tachometer feedback loop closed,

$$\mu = \frac{\mu_1}{1 + \mu_1 \beta_1}$$

$$\mu = \frac{K_2 \cdot \frac{\omega_{13}}{p} \cdot \frac{\omega_{12}}{\omega_{12} + p}}{1 + K_2 \cdot \frac{\omega_{13}}{p} \cdot \frac{\omega_{12}}{\omega_{12} + p} \cdot \frac{p}{\omega_{14}}} \quad (48)$$

In the expression for μ , the product $\mu_1 \beta_1 \gg 1$ for all frequencies of interest so that equation (48) may be approximated by

$$\mu \doteq \frac{\omega_{14}}{p} \quad (49)$$

meter feedback loop closed, equation (49) may be taken as the open-loop characteristic in the usual sense (i.e. open-loop meaning open-position-loop). Position feedback is represented mathematically by the quantity -1 as a simple degenerative connection only is involved here.

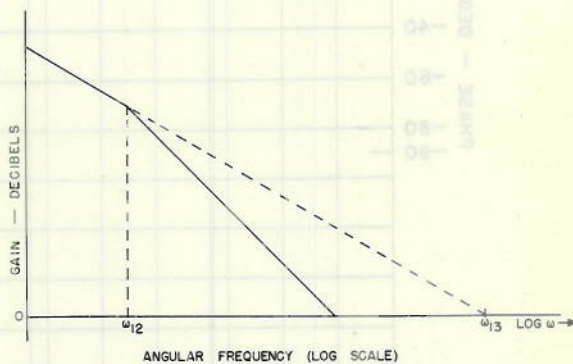


Figure 3-241. Handcrank Antenna Tracking Asymptotic Gain Characteristic With Tachometer Feedback and Position Feedback Loop Open

3). Characteristics With Position-loop Closed. - With the local or secondary tacho-

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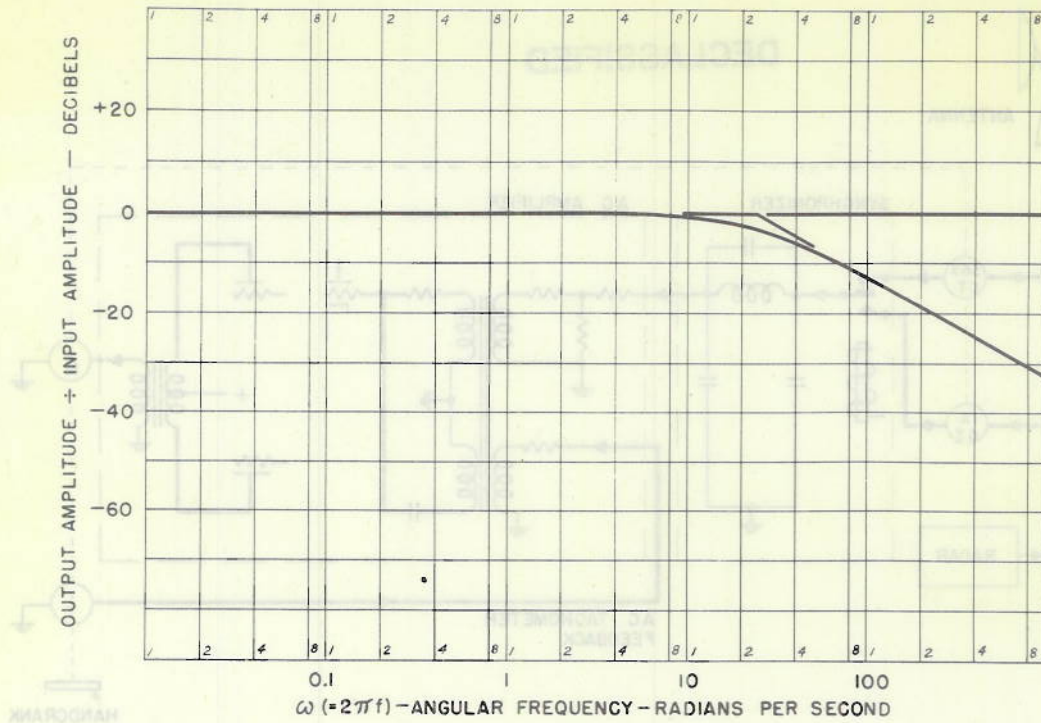


Figure 3-242. Handcrank Tracking Antenna - Closed-loop Gain Characteristics

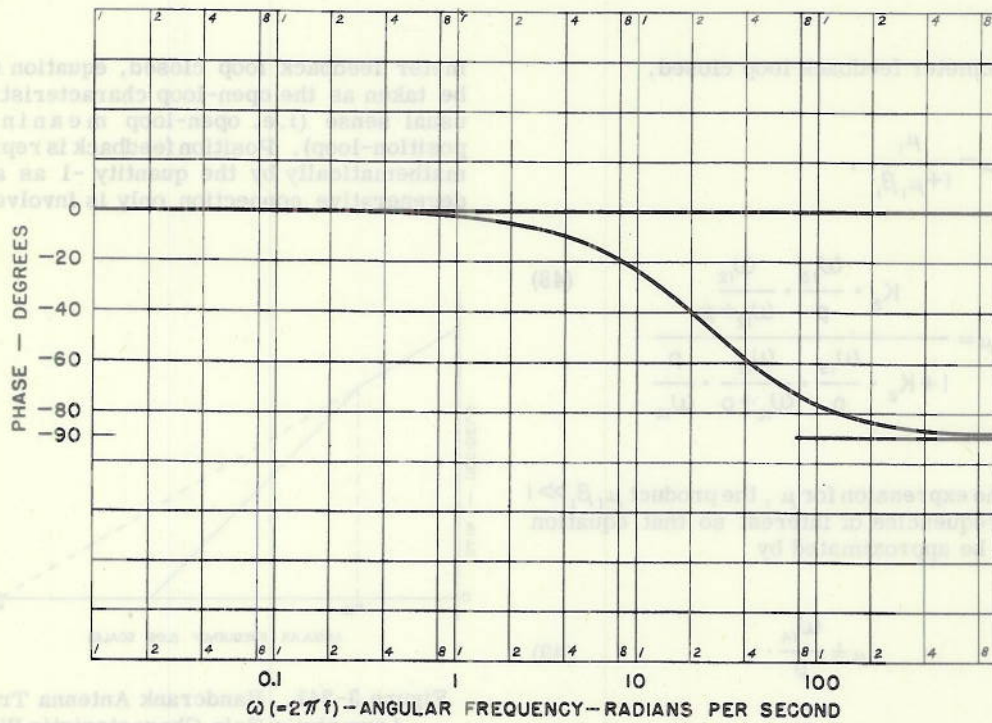


Figure 3-243. Handcrank Tracking Antenna - Closed-loop Phase Characteristics

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Thus, the closed-loop characteristic equation becomes

$$G = \frac{\mu_1}{1 + \mu_1}$$

$$= \frac{\frac{\omega_{14}}{p}}{1 + \frac{\omega_{14}}{p}}, \quad (50)$$

$$G = \frac{\omega_{14}}{\omega_{14} + p},$$

where $\omega_{14} = 24$.

The expression given in equation (50) is identically equivalent to that of a simple low-pass single-section resistance-capacitance filter in which the RC product is the reciprocal of 24. The characteristic is shown graphically by the gain and phase curves of figures 3-242 and 3-243, respectively.

4). Error Expression for Handcrank Antenna Servo System. - Following the procedure previously explained, the error expression for the handcrank antenna tracking servo systems is

$$\epsilon \doteq \frac{1}{\mu} \theta_i,$$

$$= \frac{p}{\omega_{14}} \cdot \theta_i, \quad (51)$$

$$= \frac{\dot{\theta}_i}{\omega_{14}},$$

$$= \frac{\dot{\theta}_i}{24}.$$

The error is seen to be primarily a velocity error and the velocity error constant equals 24.

e. Telescope Antenna Tracking Servo System. - An optical monitoring position is provided in the Lark SP-1M radar system which consists of a servo-driven telescope pedestal arranged so that the telescope line-of-sight an-

gular position follows the radar antenna angular position at all times. A simplified diagram showing the servo system details is given by figure 3-244.

The servo system may be represented in a generalized manner given in figure 3-245 and is seen to contain a local feedback loop consisting of a tachometer generator voltage proportional to the rate of change of output position. Around the above combination is the main feedback position-closure loop.

1). Open-loop Characteristics. - With both position and rate-of-change of position feedback loops open, the forward gain μ_1 , of the amplifier-motor combination may be represented mathematically by

$$\mu_1 = A_2 \cdot \frac{\omega_{15}}{p} \cdot \frac{\omega_{16}}{\omega_{16} + p}, \quad (52)$$

where the values of ω_{15} and ω_{16} are high. The characteristics of the tachometer may be indicated by

$$\beta_1 = \frac{p}{\omega_{17}}, \quad (53)$$

where the voltage fed back is adjusted to meet the system specifications of 10 degrees per second for 0.1 degree tracking error, i.e., $\omega_{17} = 100$. The expression for μ becomes

$$\mu = \frac{\mu_1}{1 + \mu_1 \beta_1},$$

$$= \frac{A_2 \cdot \frac{\omega_{15}}{p} \cdot \frac{\omega_{16}}{\omega_{16} + p}}{1 + A_2 \cdot \frac{\omega_{15}}{p} \cdot \frac{\omega_{16}}{\omega_{16} + p} \cdot \frac{p}{\omega_{17}}}, \quad (54)$$

For the signal frequencies of interest, $\mu_1 \beta_1 \gg 1$ and equation (54) reduces to

$$\mu \doteq \frac{\omega_{17}}{p}, \quad (55)$$

for the open-loop system gain.

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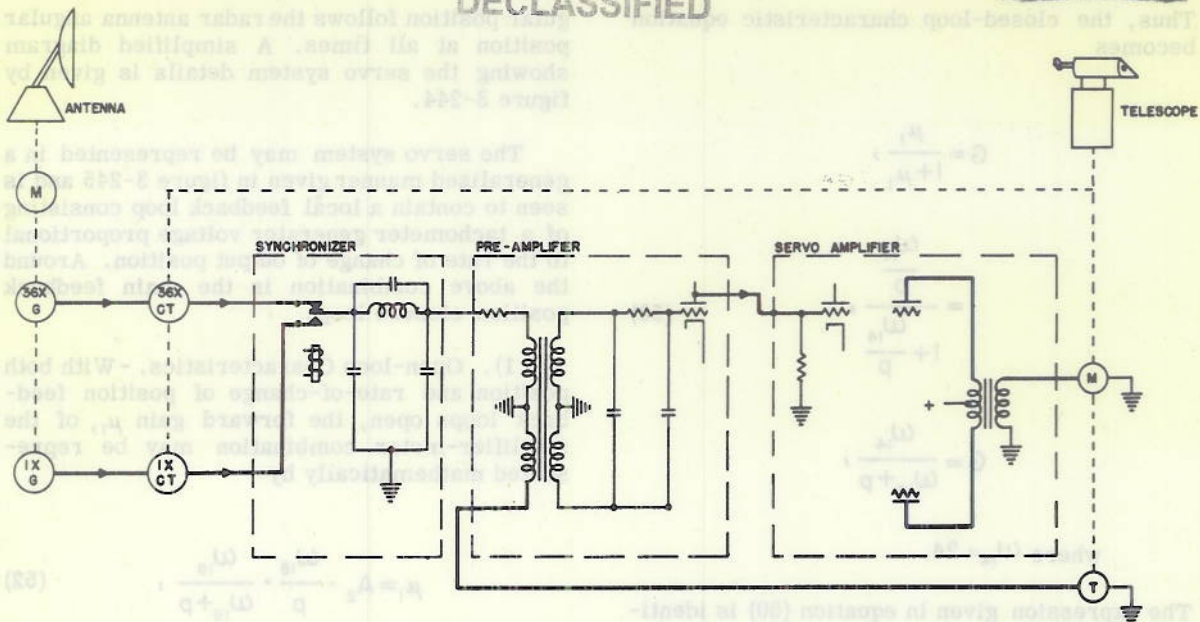


Figure 3-244. Telescope Antenna Tracking Servo System

2). Closed-loop Characteristics. - Using the methods previously detailed the closed-loop characteristics are found to be

$$G = \frac{\mu}{1 + \mu},$$

$$= \frac{\frac{\omega_{17}}{p}}{\omega_{17} + \frac{\omega_{17}}{p}},$$

$$= \frac{\omega_{17}}{\omega_{17} + p} \tag{56}$$

The expression of equation (56) is recognized as a simple low-pass transmission characteristic identical with that obtained for the handcrank tracking of the antenna except that the corner frequency is higher, i.e., $\omega_{17} = 100$ radians per second.

Figures 3-246 and 3-247 show the closed-loop gain and phase characteristics, respectively.

3). Error Expression. - The error expression is derived from the open-loop characteristic and is found to be

$$\epsilon \approx \frac{1}{\mu} \theta_i,$$

$$= \frac{p}{\omega_{17}} \theta_i, \tag{57}$$

$$\dot{\theta}_i = \frac{\dot{\theta}_i}{100}.$$

With only a velocity error and that error small (i.e., velocity error constant, $\omega_{17} = 100$, large), it may be expected that the observations through the telescope will give an accurate instantaneous measure of the tracking in progress and such is the case.

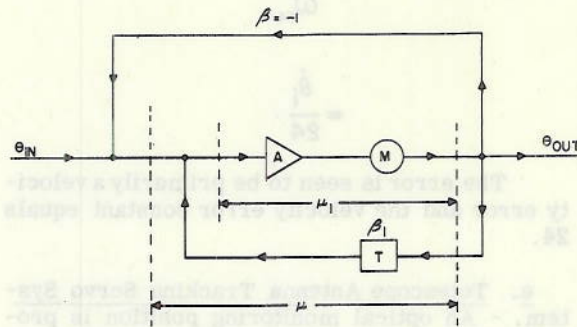


Figure 3-245. Telescope Antenna Tracking Servo System - Generalized Block Diagram

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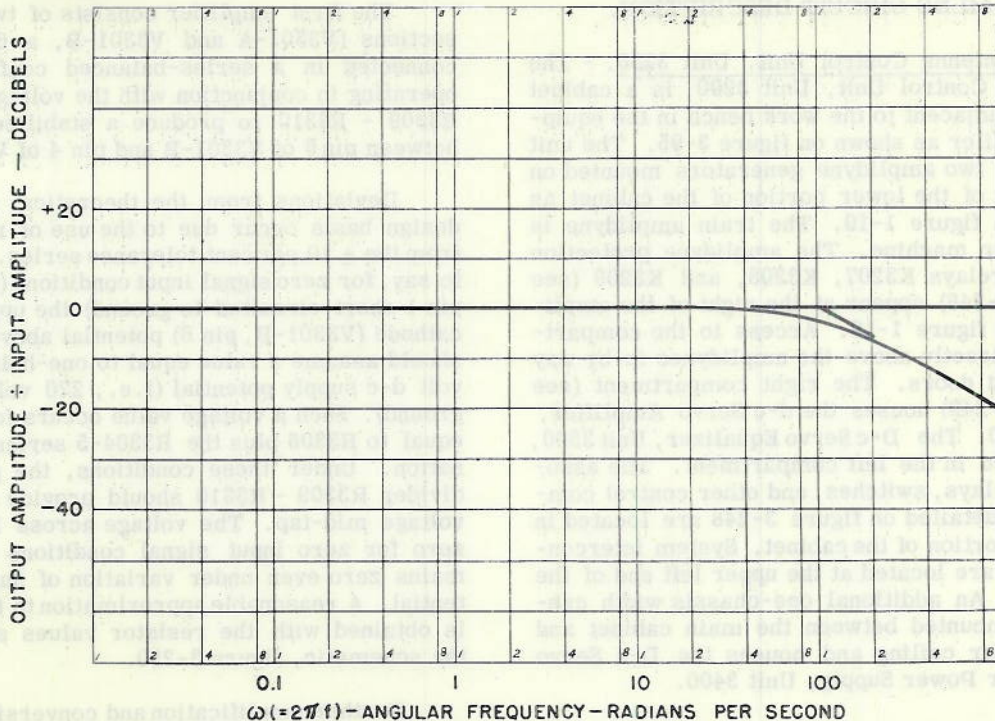


Figure 3-246. Telescope Antenna Tracking Servo - Closed-loop Gain Characteristics

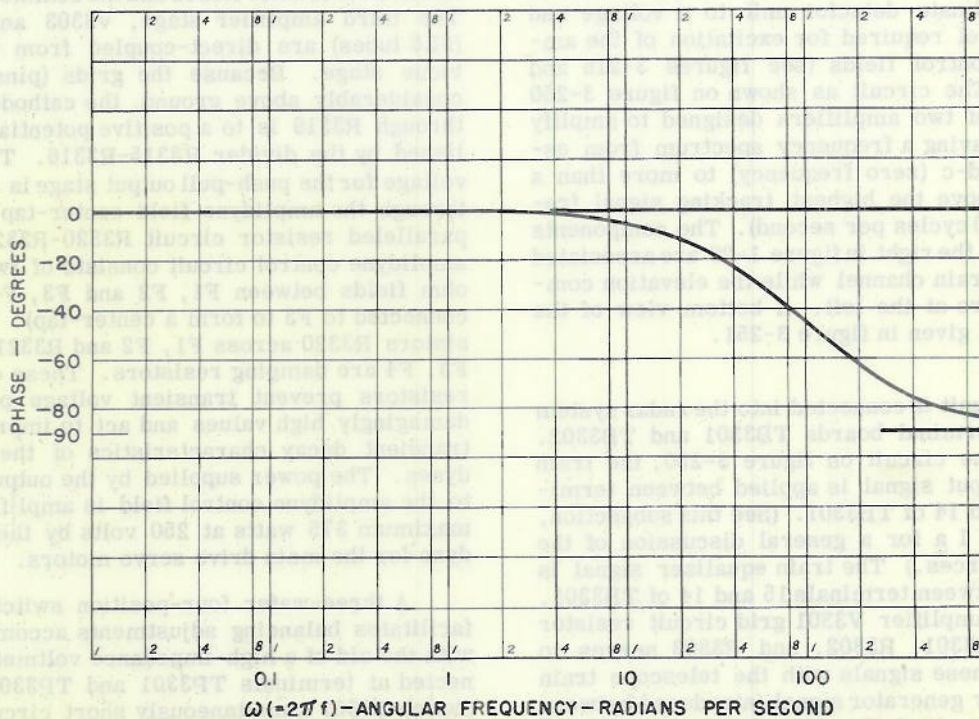


Figure 3-247. Telescope Antenna Tracking Servo - Closed-loop Phase Characteristics

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4. DETAILED CIRCUIT DESCRIPTION.

a. Antenna Control Unit, Unit 3200. - The Antenna Control Unit, Unit 3200, is a cabinet located adjacent to the work bench in the equipment trailer as shown on figure 3-95. The unit contains two amplidyne generators mounted on the back of the lower portion of the cabinet as shown in figure 1-19. The train amplidyne is the lower machine. The amplidyne protection circuit relays K3207, K3208, and K3209 (see figure 3-248) appear at the right of the amplidyne in figure 1-19. Access to the compartments directly above the amplidyne is by way of hinged doors. The right compartment (see figure 3-249) houses the d-c Servo Amplifier, Unit 3300. The D-c Servo Equalizer, Unit 3500, is located in the left compartment. The associated relays, switches, and other control components detailed on figure 3-248 are located in the top portion of the cabinet. System interconnections are located at the upper left end of the cabinet. An additional one-chassis width cabinet is mounted between the main cabinet and the trailer ceiling and houses the D-c Servo Amplifier Power Supply, Unit 3400.

1). D-c Servo Amplifier, Unit 3300. - The D-c Servo Amplifier, Unit 3300, is a dual-channel servo amplifier supplying amplification of the signal voltages from the target and manual coordinate detector unit to a voltage and power level required for excitation of the amplidyne control fields (see figures 3-216 and 3-248). The circuit as shown on figure 3-250 consists of two amplifiers designed to amplify signals having a frequency spectrum from essentially d-c (zero frequency) to more than a decade above the highest tracking signal frequency (30 cycles per second). The components located at the right in figure 1-20 are associated with the train channel while the elevation components are at the left. A bottom view of the chassis is given in figure 3-251.

The unit is connected into the radar system through terminal boards TB3301 and TB3302. Tracing the circuit on figure 3-250, the train channel input signal is applied between terminals 16 and 14 of TB3301. (See this subsection, paragraph 1 a for a general discussion of the signal sources.) The train equalizer signal is applied between terminals 15 and 14 of TB3301. The first amplifier V3301 grid circuit resistor network R3301, R3302, and R3303 serves to combine these signals with the telescope train tachometer generator signal introduced between the lower end of the grid return and ground (TB3302-2 and TB3301-14).

The first amplifier consists of two triode sections (V3301-A and V3301-B, a 6SL7-GT) connected in a series-balanced configuration operating in conjunction with the voltage divider R3309 - R3310 to produce a stabilized output between pin 6 of V3301-B and pin 4 of V3302-B.

Deviations from the theoretical optimum design basis occur due to the use of resistors from the ± 10 per cent tolerance series. That is to say, for zero signal input conditions (V3301-A pin 1 short circuited to ground) the upper tube cathode (V3301-B, pin 6) potential above ground should assume a value equal to one-half the 540 volt d-c supply potential (i.e., 270 volts above ground). Such a voltage value occurs for R3307 equal to R3306 plus the R3304-5 series combination. Under these conditions, the potential divider R3309 - R3310 should provide a supply voltage mid-tap. The voltage across R3308 is zero for zero input signal conditions and remains zero even under variation of supply potential. A reasonable approximation to the ideal is obtained with the resistor values shown in the schematic, figure 3-250.

Further amplification and conversion from single-ended to double-ended output is provided by the second amplifier V3302-A and -B (a 6SN7-GT dual triode). Linearization is provided by the degeneration due to the unbypassed cathode resistance R3312 and the common R3311. The third amplifier stage, V3303 and V3304 (6L6 tubes) are direct-coupled from the previous stage. Because the grids (pins 5) are considerably above ground, the cathode return through R3319 is to a positive potential established by the divider R3315-R3316. The plate voltage for the push-pull output stage is supplied through the amplidyne field center-tap and the paralleled resistor circuit R3320-R3321. The amplidyne control circuit consists of two 1220-ohm fields between F1, F2 and F3, F4 (F2 is connected to F3 to form a center-tap). The resistors R3320 across F1, F2 and R3321 across F3, F4 are damping resistors. These damping resistors prevent transient voltage peaks of damagingly high values and act to improve the transient decay characteristics of the amplidyne. The power supplied by the output stage to the amplidyne control field is amplified to a maximum 375 watts at 250 volts by the amplidyne for the main drive servo motors.

A three-wafer four-position switch S3301 facilitates balancing adjustments accomplished with the aid of a high-impedance voltmeter connected at terminals TP3301 and TP3302. The switch S3301 simultaneously short circuits the input to ground and connects the voltmeter into the circuit for the three balance adjustment po-

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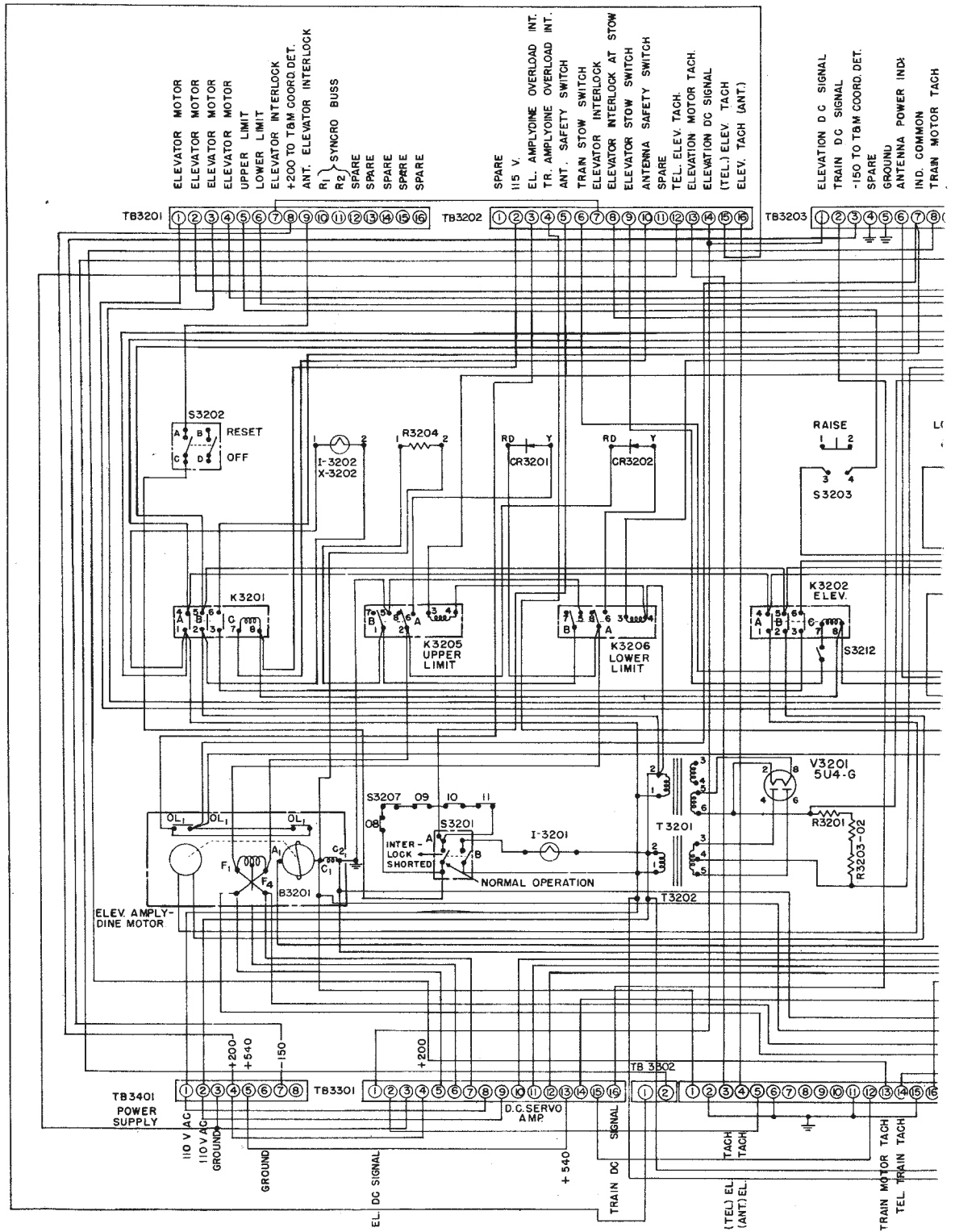
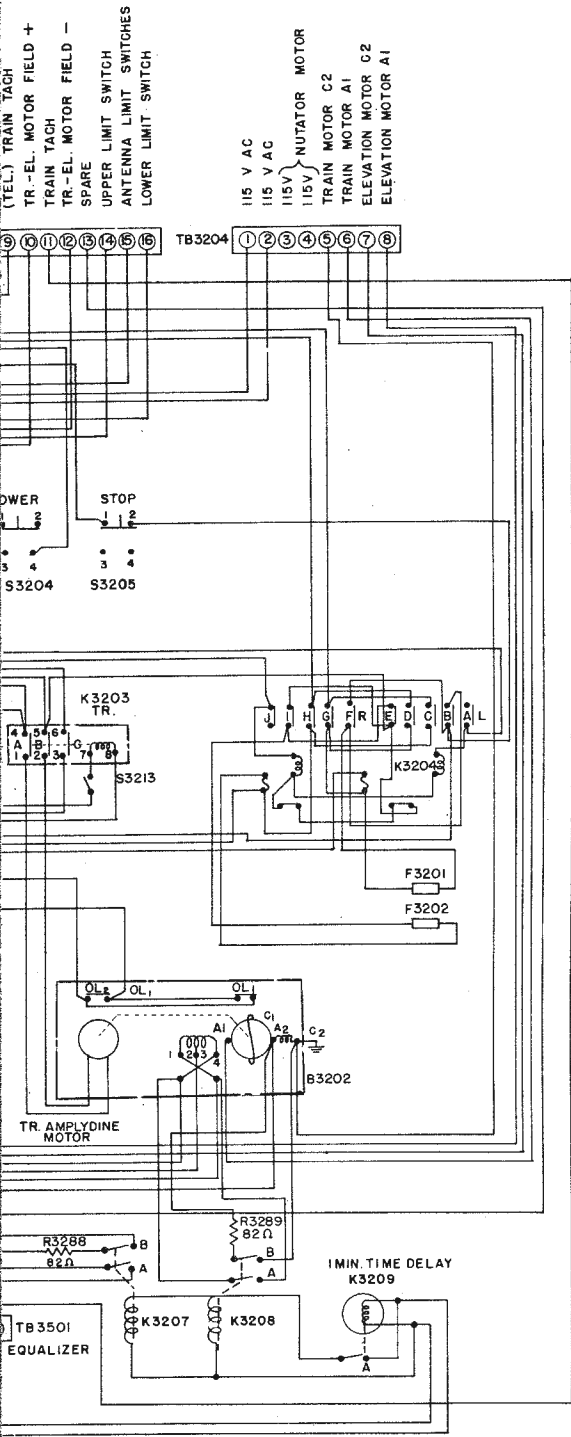


Figure 3-248. Antenna Control Unit - Schematic Diagram



sitions. The first amplifier stage is balanced with S3301 in position 1 by adjustment of R3305 to zero volts dc on the test voltmeter. Similarly, R3312 and R3319 are adjusted at positions 2 and 3 respectively. The procedure should be repeated until each stage is balanced and the residual voltage across the amplidyne field is less than 0.1 volts. Balance should be checked after the equipment has been in operation for one-half hour. If tubes are replaced or any other circuit conditions modified, balance checks should be made.

2). D-c Servo Equalizer, Unit 3500. -The D-c Servo Equalizer, Unit 3500, is a dual-channel resistance-capacitance equalizer providing amplidyne feedback signal and motor tachometer generator signal mixing and filtering for the train and elevation main servo drive system. The schematic, figure 3-252, shows circuit details. The block diagram, figure 3-216, shows the relationship with the system wherein the two blocks labeled "equalizer" are contained in Unit 3500. The antenna control unit schematic, figure 3-248, shows connections as made to the terminal board of the unit, TB3501. The appearance of the unit and the location of the components is given by the top and bottom view photographs (figures 3-253 and 3-254).

A signal derived from the amplidyne compensation field C1, C2 is connected through TB-3501-16 and -15. An undesirable 720-cycle component is reduced by the filtering action of the resistance-capacitance parallel-T network. A two-section shunted-high-pass network follows the parallel-T. The specific values used were determined from frequency response measurements made upon the complete equipment and were selected to provide as wide a frequency bandpass as could be obtained within amplidyne-servo motor limitations. An important part of the servo system frequency response control is derived from tachometer generator feedback. The tachometer generator is directly coupled to the servo motor shaft and produces approximately two volts per 100 rpm. The signal is introduced into unit 3500 at terminals TB3501-14 and -13. The brush ripples are reduced by C3501. The tachometer signals are proportional to the rate of change of antenna position. An additional "derivative" action is introduced by the frequency response of the shunted-high-pass section. The "corner" frequencies of this network were chosen to combine properly with the amplidyne signal for maximum system bandpass. The modified amplidyne feedback signal appearing across R3504 is added with the modified tachometer generator signal appearing across R3506 to provide the

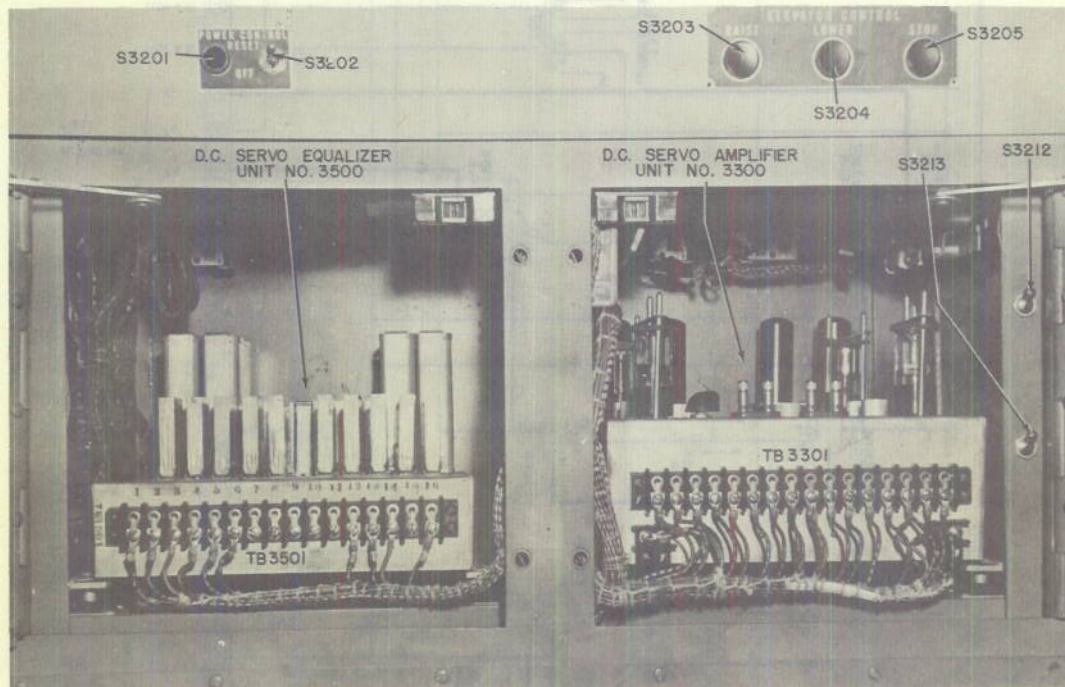


Figure 3-249. Antenna Control Unit - Showing Location of D-c Servo Equalizer Unit and D-c Servo and D-c Servo Amplifier Unit

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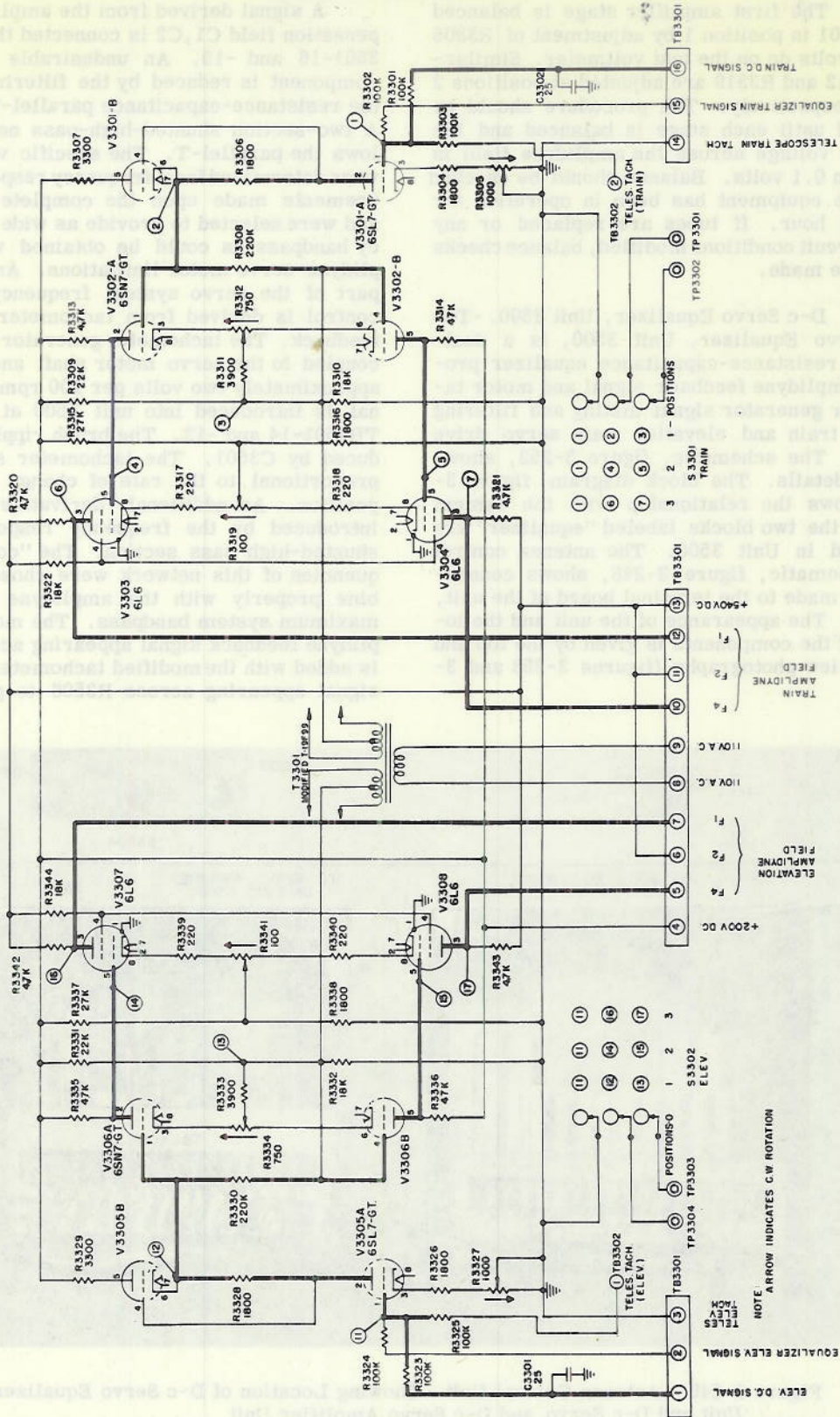


Figure 3-250. D-c Servo Amplifier Unit, Unit 3300 - Schematic Diagram

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train output signal of the unit, at TB3501-12 and -11.

A similar circuit with different constants is used for the elevation channel.

3). D-c Servo Amplifier Power Supply, Unit 3400. - The D-c Servo Amplifier Power Supply, Unit 3400, is discussed in detail in the paragraph on power sources. The unit provides + 540 volts and + 200 volts dc for the D-c Servo Amplifier, Unit 3300.

4). Amplidyne and Power Control Circuits. - The circuits associated with the am-

plidyne and power control in the antenna control unit are the same as those used in the original SP-1M Radar and are not detailed here. (See figure 3-248.)

b. Antenna Unit, Unit 3000. - The modification of the original SP-1M antenna unit, consisting principally in the addition of train and elevation tachometers (G3003 and G3002, respectively) to the train and elevation servo drive motors (B3003 and B3008, respectively) and in the addition of a new nutating mechanism adapted from the SCR-615B radar equipment, is described in subsection 3-5 of this section and will not be detailed here.

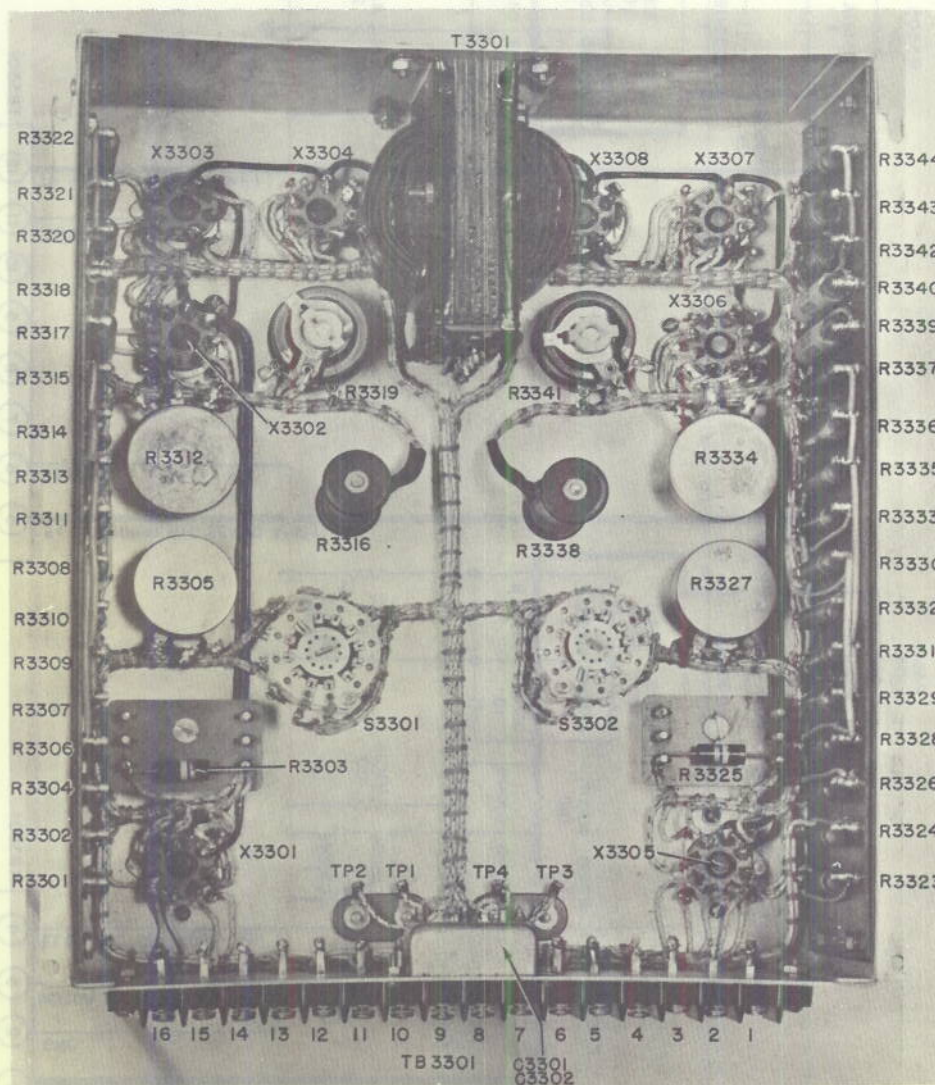


Figure 3-251. D-c Servo Amplifier - Bottom View

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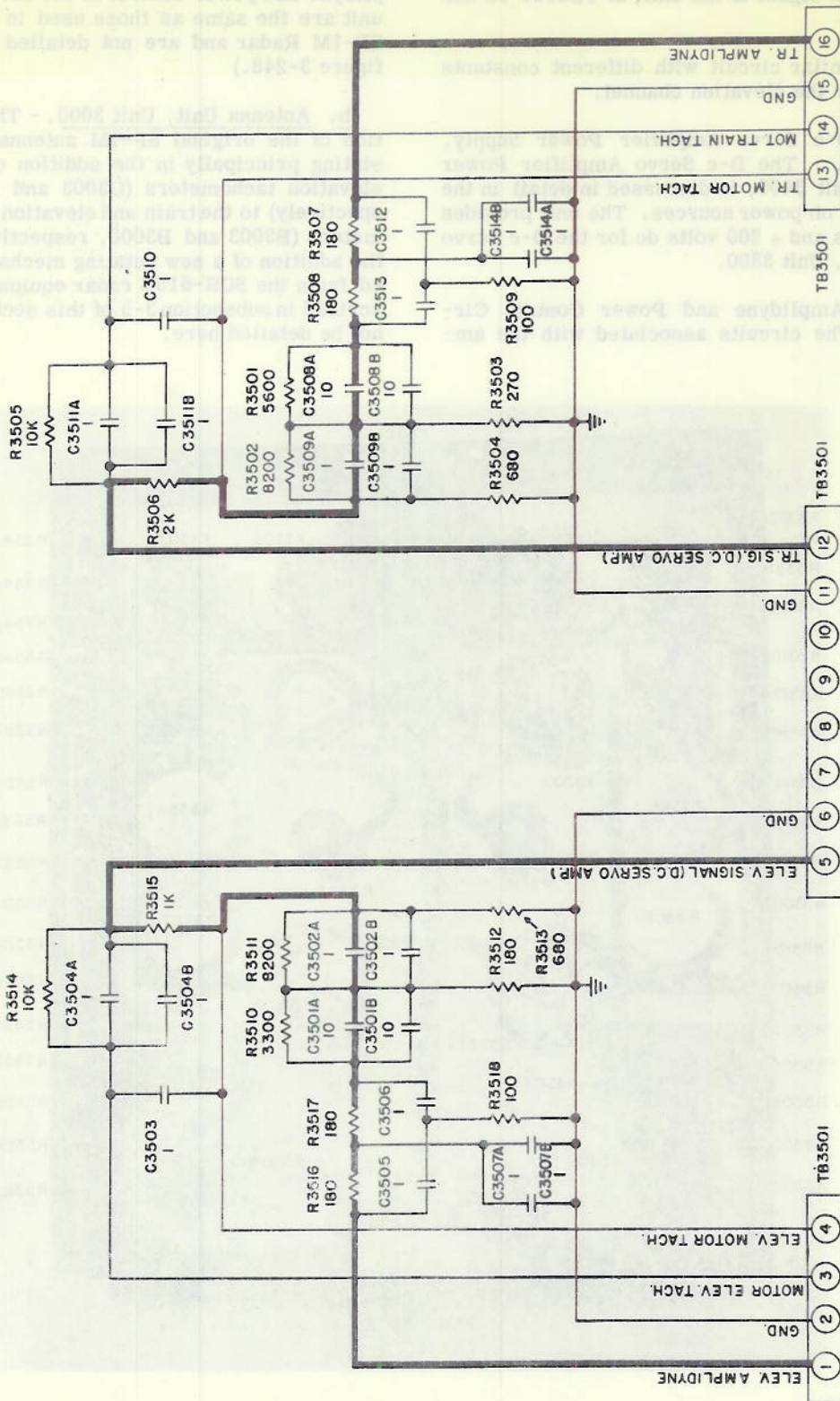


Figure 3-252. D-c Servo Equalizer - Schematic Diagram

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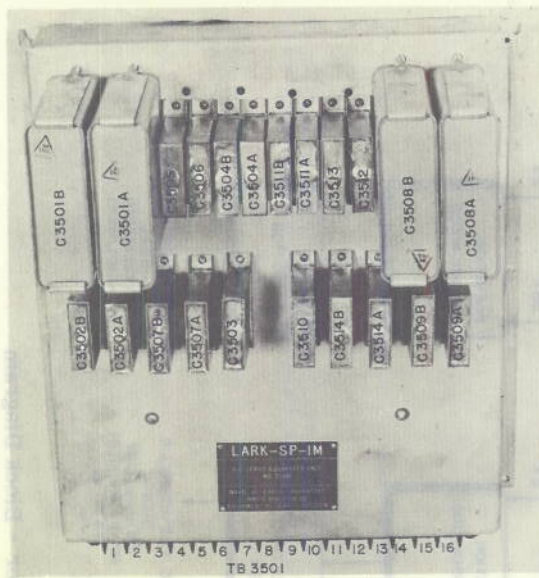


Figure 3-253. D-c Servo Equalizer - Top View

c. Synchro Capacitor Unit, Unit 3600. - The Synchro Capacitor Unit, Unit 3600, is a two-capacitor assembly mounted inside the equipment trailer on the underside of the antenna pedestal as shown in the photograph, figure 1-23. Each capacitor unit is a delta-connected assembly of three 10-mfd condensers used across the synchro data transmission lines for power factor correction purposes.

The interconnection diagram, figure 3-204, shows connections between S1-S2-S3 of B3010 and the condensers C3601, C3602, and C3603 for the train 36-speed channel. Figure 3-205 shows connections between S1-S2-S3 of B3014 and the condensers C3604, C3605, and C3606 as made below the slip rings SR-42, SR-44, and SR-46 for the elevation 36-speed channel.

The synchro capacitors are shown in the antenna unit block diagram, figure 3-216.

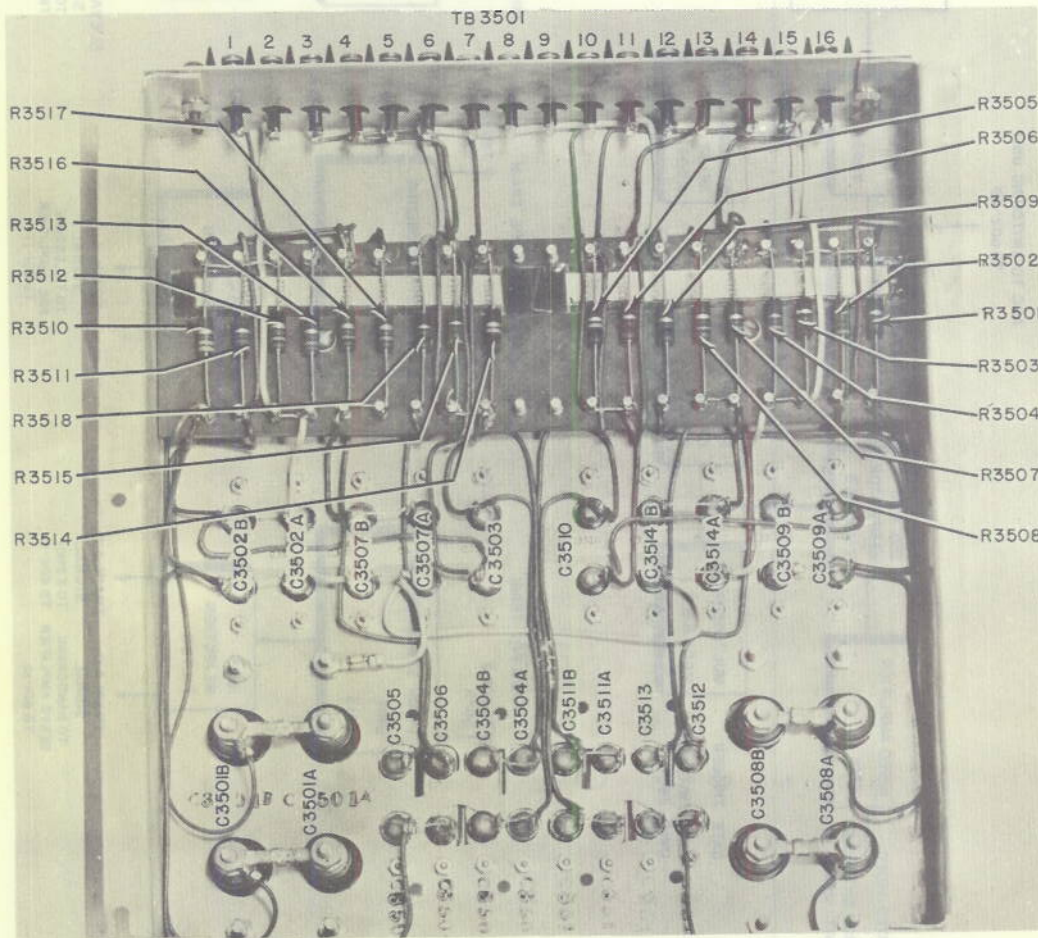


Figure 3-254. D-c Servo Equalizer - Bottom View

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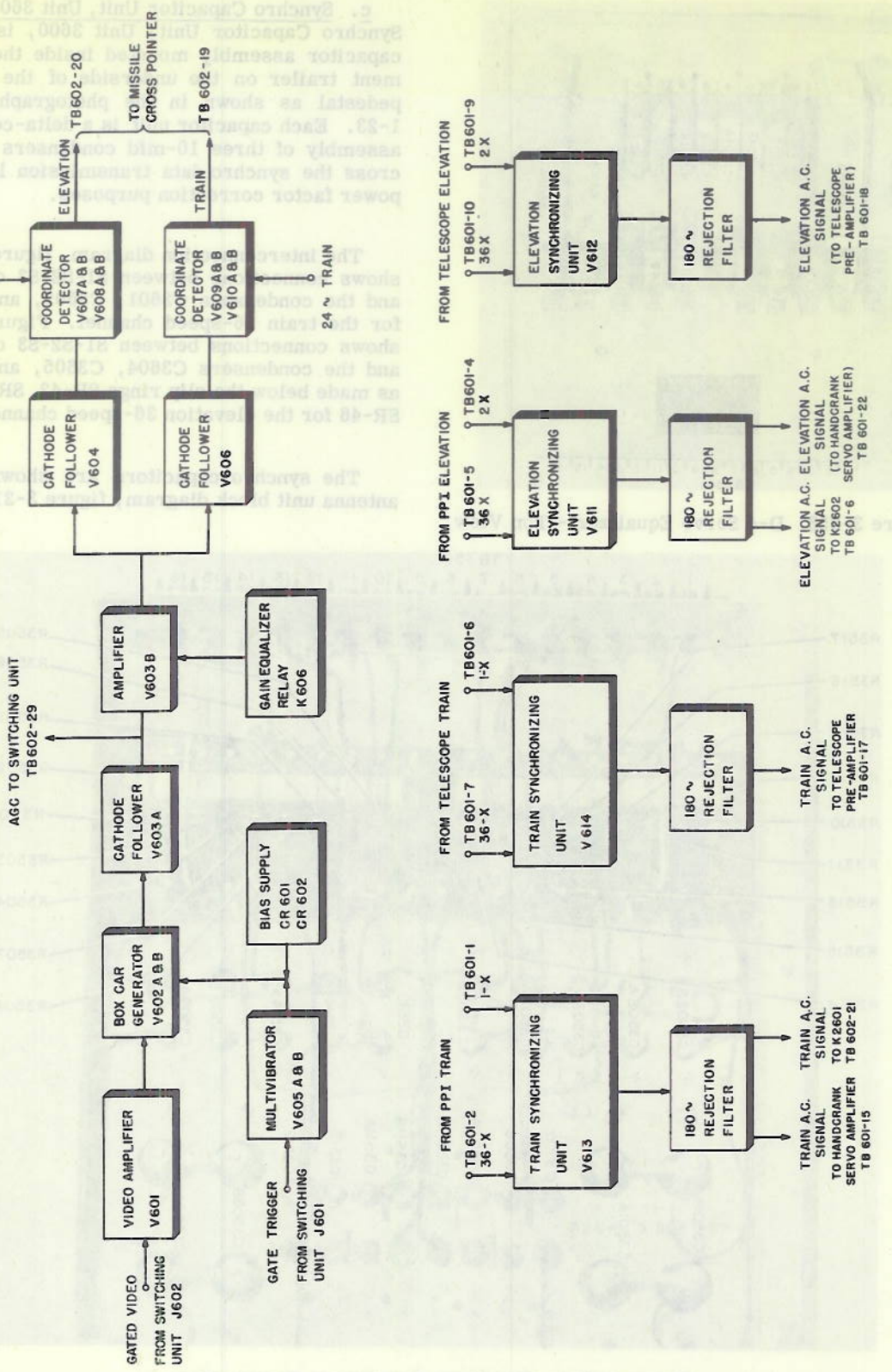


Figure 3-255. Synchronizer and Missile Coordinate Detector - Block Diagram

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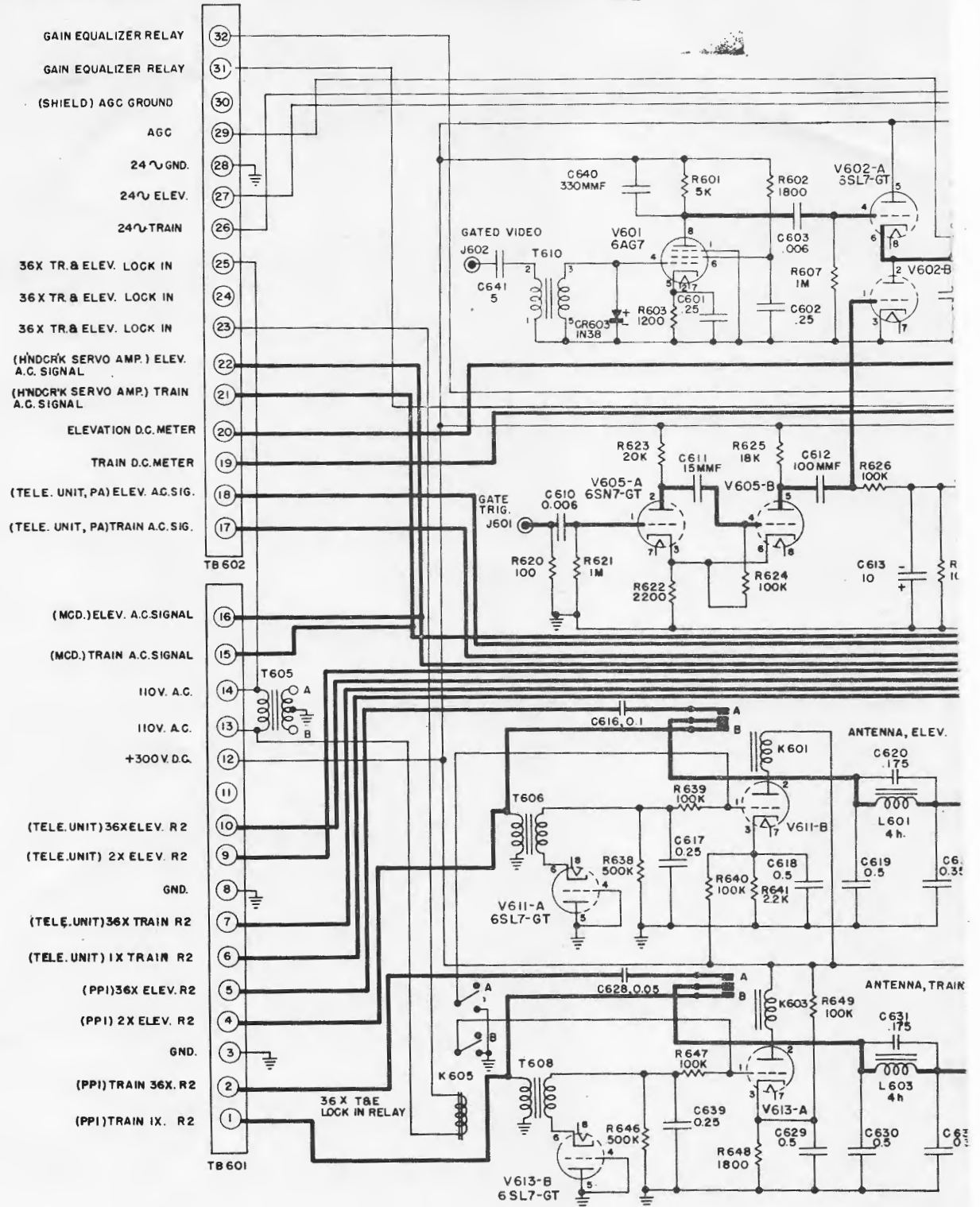
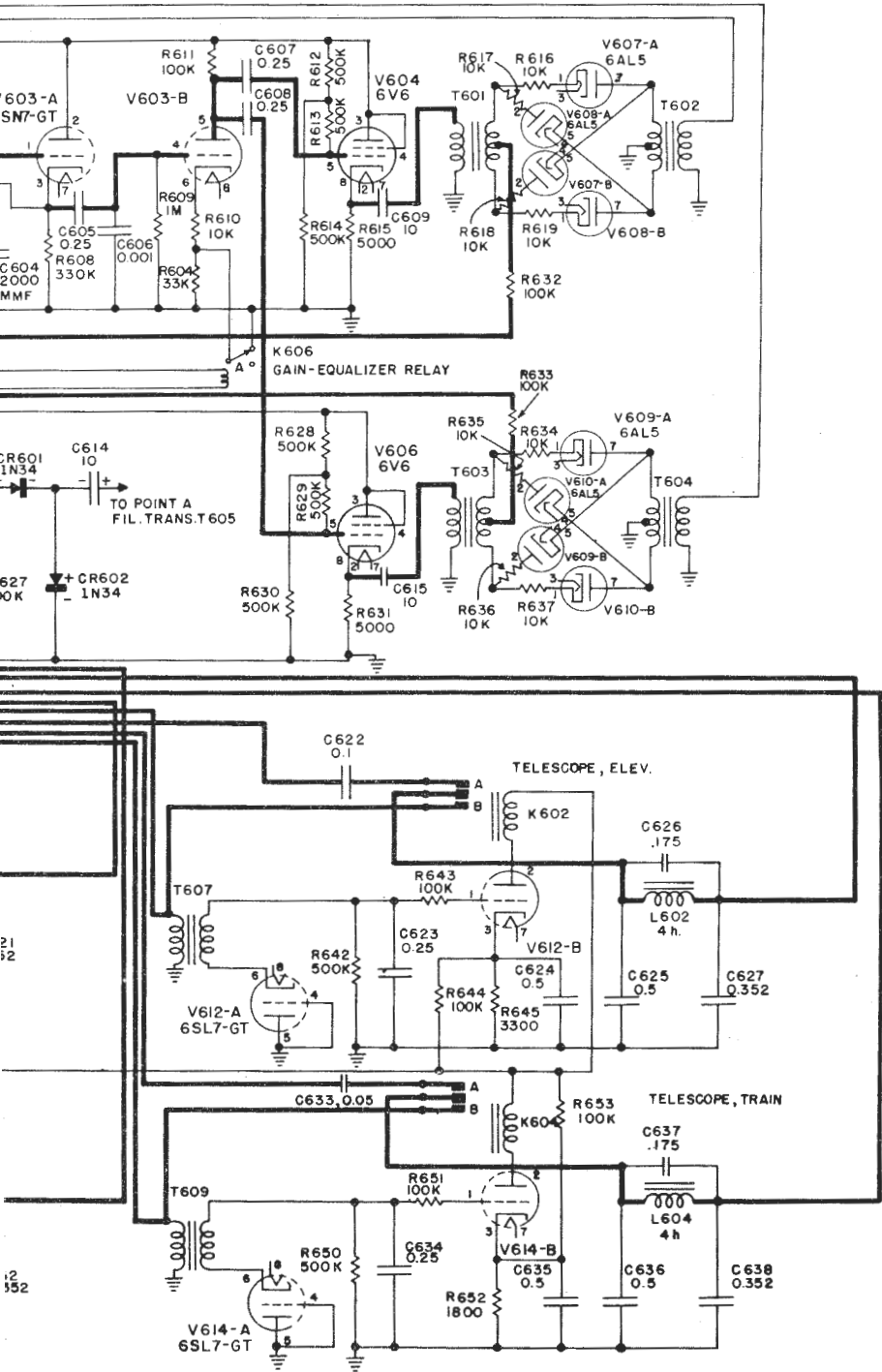


Figure 3-256. Synchronizer and Missile Coordinate Detector Unit - Schematic Diagram

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d. Synchronizer and Missile Coordinate Detector Unit, Unit 600. - The Synchronizer and Missile Coordinate Detector Unit, Unit 600, as the name indicates, performs two entirely different functions which, because of space problems, are located on one chassis. On block diagram figure 3-216, the four blocks labeled "synchronizer, 180 cycle rejection filter" are functions performed in unit 600. The interconnection diagram, figure 3-204, shows the train antenna synchronizer near coordinates 2, E and the train telescope synchronizer near coordinates 6, B. The interconnection diagram, figure 3-205, shows the elevation antenna synchronizer near coordinates 2, B and the elevation telescope synchronizer near coordinates 8, F. The interconnection diagram figure 3-41 shows the missile coordinate detector at the extreme lower right. Figure 3-255 is a block diagram of the synchronizer and missile coordinate detector. The schematic diagram, figure 3-256, shows the circuit details of unit 600. The top, bottom and the right side views are shown in figures 3-257, 3-258 and 3-259, respectively.

The basic function of the synchronizer circuit is that of switching from the fine-speed synchro data to the coarse-speed synchro data when the antenna or following unit has a large misalignment with the handcrank or other data transmitter.

The missile coordinate detector functions to derive up-down and right-left information from the missile (beacon) receiver gated video output for error meter and, when used, for antenna drive.

1). The coarse (one-speed) synchro generator signal giving a measure of antenna train position is coupled through a transformer T608 to a detector V613-B that develops a d-c voltage across the resistance-capacitance load (R646 - C639). The amplifier V613-A with the relay K603 as a plate load is designed to close the relay when the d-c voltage coupled to the grid (pin 1, V613-A) rises to a value equivalent to 2-1/2 degrees antenna-handcrank misalignment. Because the train fine-speed channel is geared

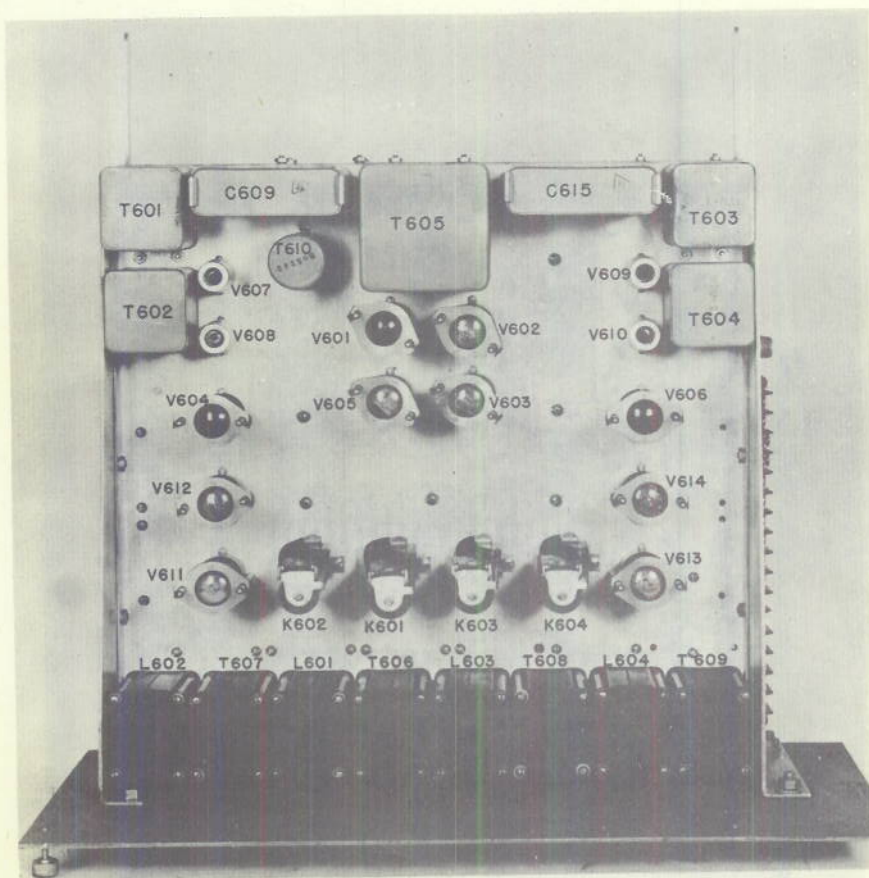


Figure 3-257. Synchronizer and Missile Coordinate Detector - Top View

to 36-speed the 2-1/2 degrees in the coarse channel is equivalent to 90 degrees error in the fine-speed channel. For the normal small error tracking condition the 36-speed error signal at TB601-2 coupled through C628 goes through the relay K603 contacts to a low-pass filter. The filter composed of C630, L603, C631, and C632 passes signals in the neighborhood of 60 cycles without sensible alteration. The frequency characteristic of the filter shows a small rise near 84 cycles and a large attenuation (30 to 40 db depending upon the particular choke and condensers used) at 180-cycles. At higher frequencies the attenuation gradually decreases to a lower value. In this manner, unwanted synchro noise components are eliminated from the servo system amplifier input cabled from TB602-21. The other three synchronizer-filter circuits are identical to the antenna train circuit.

2). Relay K605 acts to disable the antenna train and elevation synchronizers to cause only fine-speed operation when the main system operation switch S1501 is in COMPUTER position.

3). The missile coordinate detector portion of unit 600 operates with inputs from missile (beacon) receiver gated video and gate trigger to produce varying d-c outputs proportional to up-down and right-left antenna tracking errors. The varying d-c voltages are used for missile error meter excitation and for antenna positioning under missile video tracking conditions.

Tracing the circuit on the schematic, figure 3-256, the gated video from the missile receiver is connected at J602 and coupled through C641 and T610 to the grid of V601. The gated video at V601, pin 4, is a positive-polarity pulse occurring once per repetition-frequency cycle with only traces of negative-polarity voltage which is eliminated from the V601 input by the crystal rectifier CR603. V601 acts as a video amplifier with output coupled through C603 to the grid of V602A. The circuit composed of V602A, V602B and V603A with their associated components is a 100-per-cent pulse stretcher. (See figure 3-260.) This circuit is used to in-

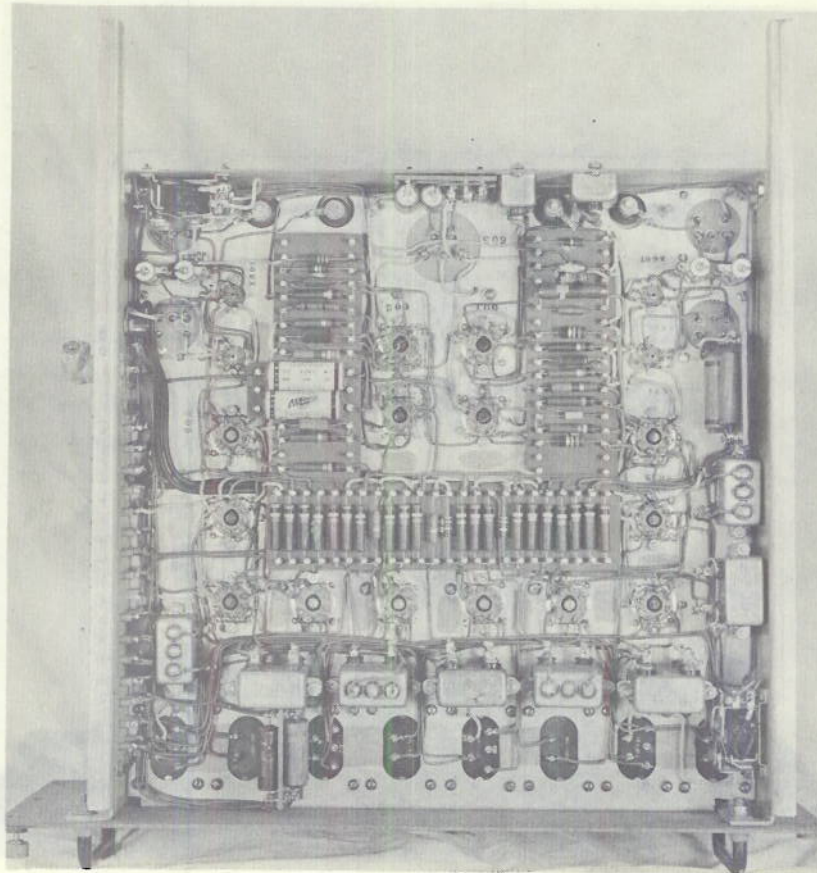


Figure 3-258. Synchronizer and Missile Coordinate Detector - Bottom View

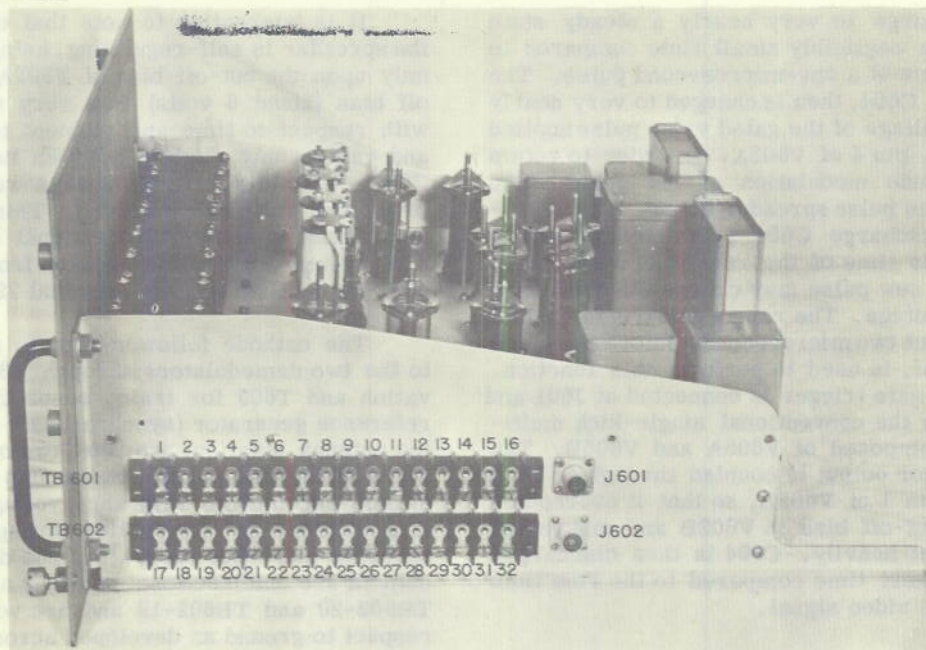


Figure 3-259. Synchronizer and Missile Coordinate Detector - Right Side View

crease the energy level of the gated video signal without increasing the noise level and operates in the following manner:

V602A is a cathode follower which charges condenser C604 when a positive signal is applied to the grid, pin 4 of V602A. V602B and V603A are operated at cut-off bias under quiescent

conditions so that the charge on C604 cannot leak off except through the very high leakage resistance of the insulators in the tubes, sockets, and wiring. Such a high leakage resistance can be neglected for the lengths of time involved in this case. The condenser and its charging resistor (i.e., the plate to cathode resistance of V602A) are so proportioned that the condens-

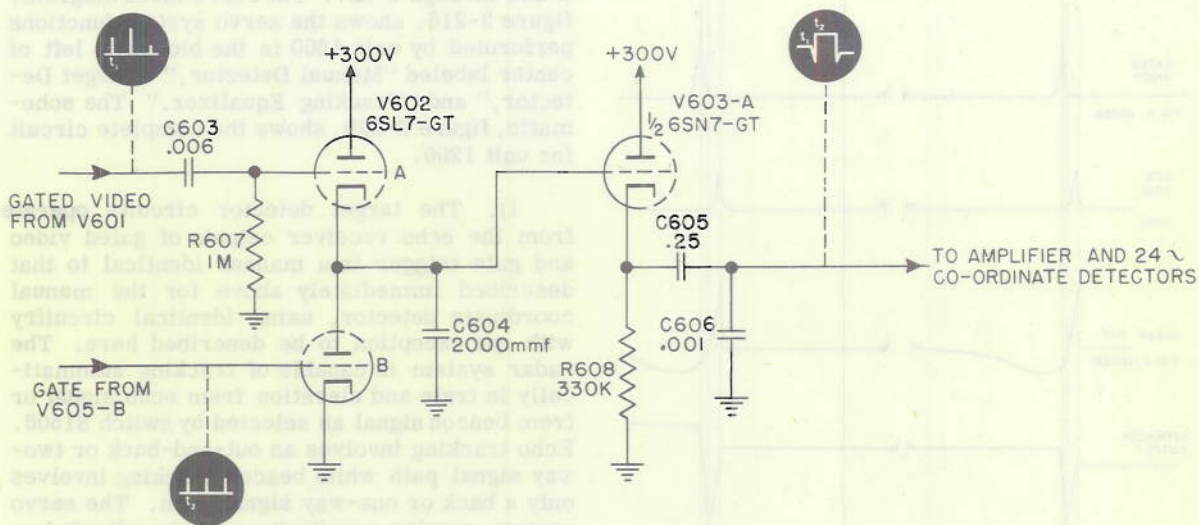


Figure 3-260. "Box Car Generator", or Pulse Stretcher, and Cathode Follower - Simplified Schematic Diagram

er will charge to very nearly a steady state voltage in a negligibly small time compared to the rise time of a one-microsecond pulse. The condenser, C604, then is charged to very nearly the peak voltage of the gated video pulse applied to the grid, pin 4 of V602A. In order to retain the amplitude modulation of the gated video pulses in the pulse spreader output, it is necessary to discharge C604 a few microseconds prior to the time of the receipt of a new pulse so that the new pulse may charge the condenser to a new voltage. The range-gate trigger, which occurs about two microseconds before the gated video signal, is used to perform this function. The range-gate trigger is connected at J601 and used to key the conventional single-kick multivibrator composed of V605A and V605B. The multivibrator output is coupled through C612 to the grid, pin 1 of V602B, so that it overcomes the fixed cut-off bias on V602B and makes the tube conduct heavily. C604 is thus discharged in a very short time compared to the rise time of the gated video signal.

V603A is a cathode follower used to take output from the spreader without loading C604. The output of V603A is taken from the cathode, pin 7, and coupled through C605 to the grid, pin 4 of V603B. C606 removes the negative spikes from the spread pulses so that the input to V603B has a sine-wave-modulated d-c voltage characteristic.

The wave forms for the pulse spreader are shown on 3-261.

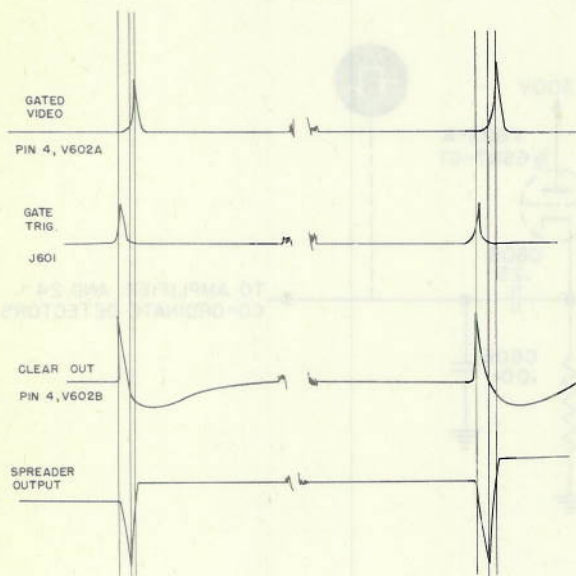


Figure 3-261. Pulse Spreader Wave Forms

It is interesting to note that the action of the spreader is self-regulating, being dependent only upon the cut-off bias of V602A. The cut-off bias (about 8 volts) is a very stable point with respect to time and ambient temperature and varies only slightly between tubes. Thus C604, when discharged, always returns to a level of 8 volts above ground. This feature is very useful in setting the no-signal level of the AGC system whose input is taken from the cathode, pin 7 of V603A, via terminal 29 of TB601.

The cathode follower outputs are coupled to the two demodulators through T601 for elevation and T603 for train, respectively. The reference generator (synchronously driven with the antenna nutation) provides two outputs having a 90-degree phase relationship. The two phases become the reference voltages for the demodulators and are applied through T602 for elevation and T604 for train. The demodulator outputs are unidirectional voltages appearing at TB602-20 and TB602-19 and are voltages with respect to ground as developed across R632 and R633.

e. Target and Manual Coordinate Detector Unit, Unit 1200. - The Target and Manual Coordinate Detector Unit, Unit 1200, contains two demodulators for automatic target echo antenna tracking, two demodulators for manual antenna control from the PPI synchro handcranks, and tracking equalizer networks that control the servo system frequency bandpass characteristics. Figure 3-262 is a block diagram of the Target and Manual Coordinate Detector Unit. Unit 1200 is shown in the photographs, figures 3-263 through 3-267. The servo block diagram, figure 3-216, shows the servo system functions performed by unit 1200 in the blocks to left of center labeled "Manual Detector," "Target Detector," and "Tracking Equalizer." The schematic, figure 3-220, shows the complete circuit for unit 1200.

1). The target detector circuits operate from the echo receiver outputs of gated video and gate trigger in a manner identical to that described immediately above for the manual coordinate detector, using identical circuitry with one exception to be described here. The radar system is capable of tracking automatically in train and elevation from echo signal or from beacon signal as selected by switch S1506. Echo tracking involves an out-and-back or two-way signal path while beacon tracking involves only a back or one-way signal path. The servo system angular sensitivity must be adjusted as a function of the type of video used and such adjustment is by relay K1203A which changes the coordinate detector input gain (by shorting out

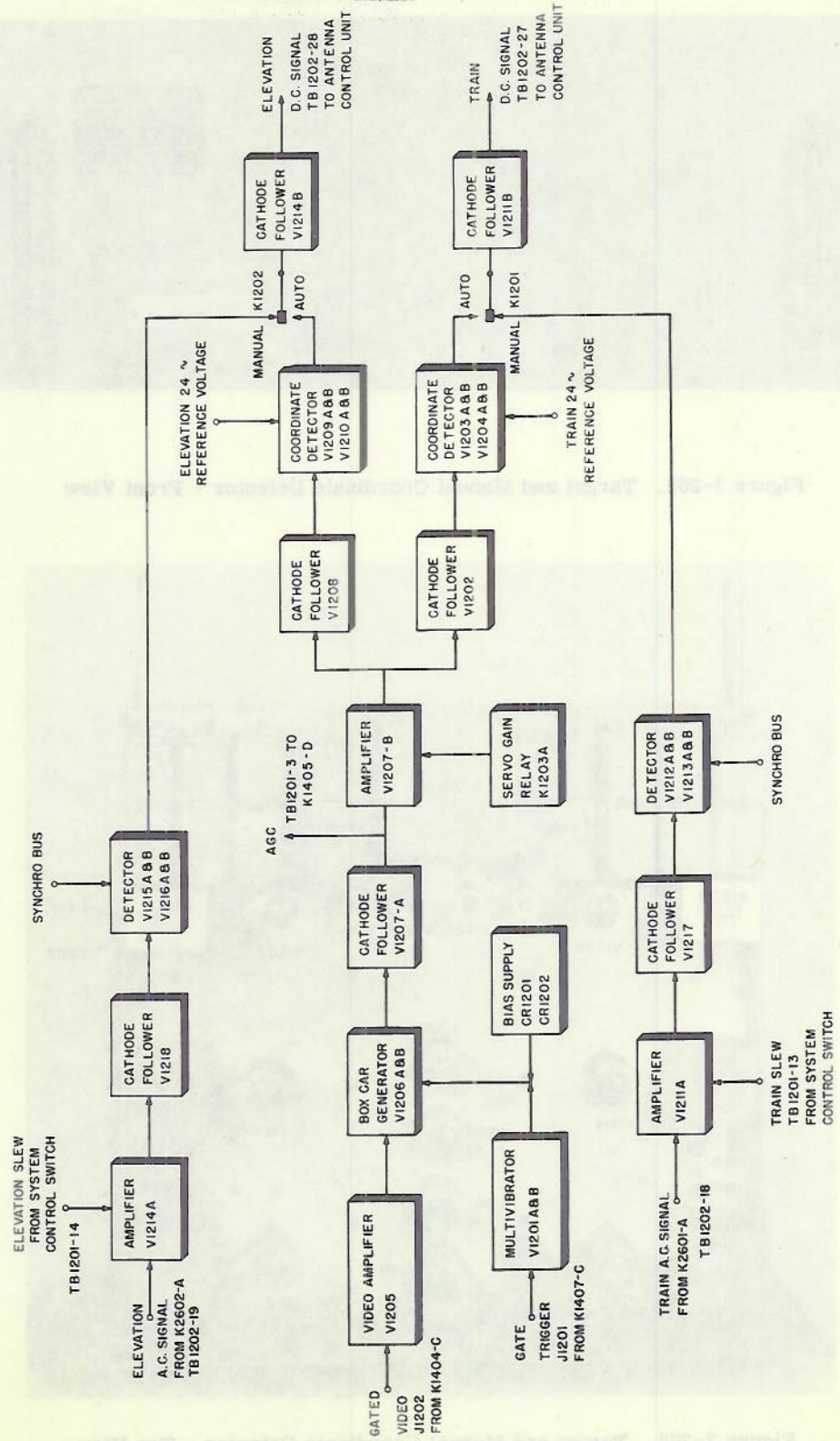


Figure 3-262. Target and Manual Coordinate Detector - Block Diagram

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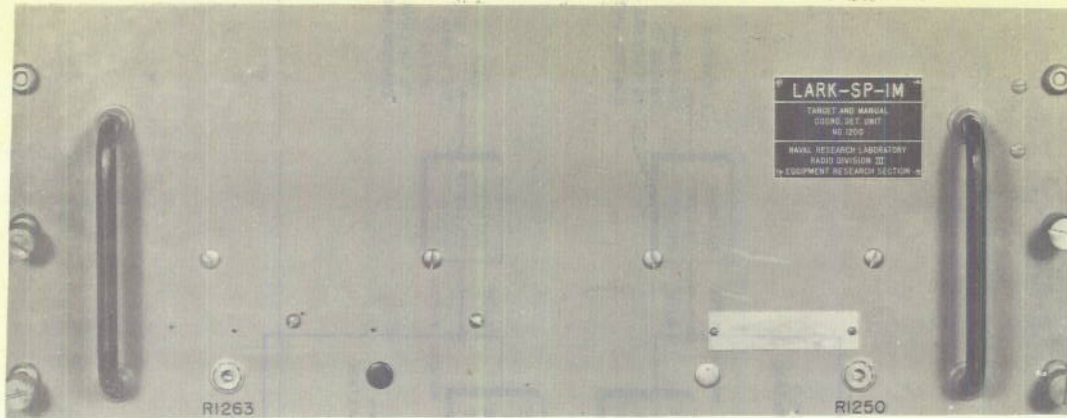


Figure 3-263. Target and Manual Coordinate Detector - Front View

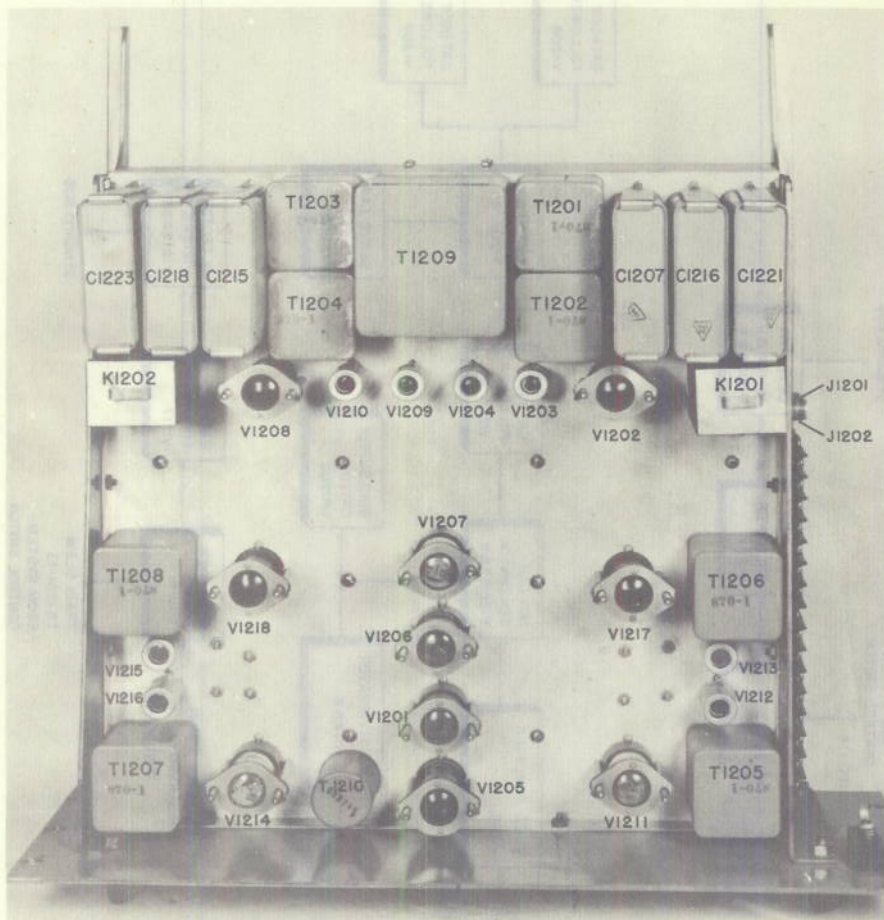


Figure 3-264. Target and Manual Coordinate Detector - Top View

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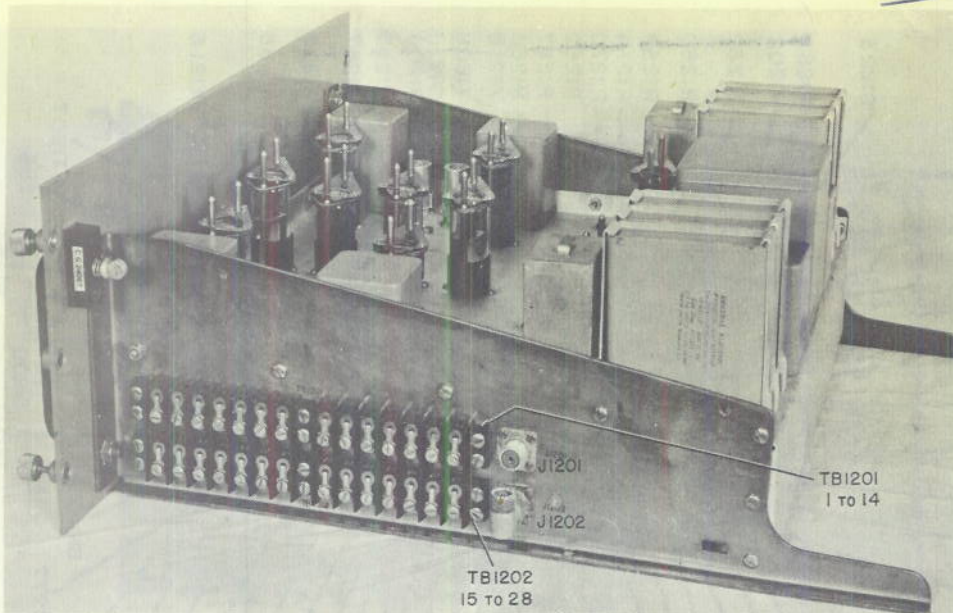


Figure 3-267. Target and Manual Coordinate Detector - Right Side View

R1220). The detector outputs appear across R1217 in train and R1229 in elevation and go to automatic tracking relays from which the signal flow is described in the following paragraph.

2). The manual detector circuits operate from synchro control transformer outputs and the synchro bus as a reference voltage. Misalignment between the antenna synchro genera-

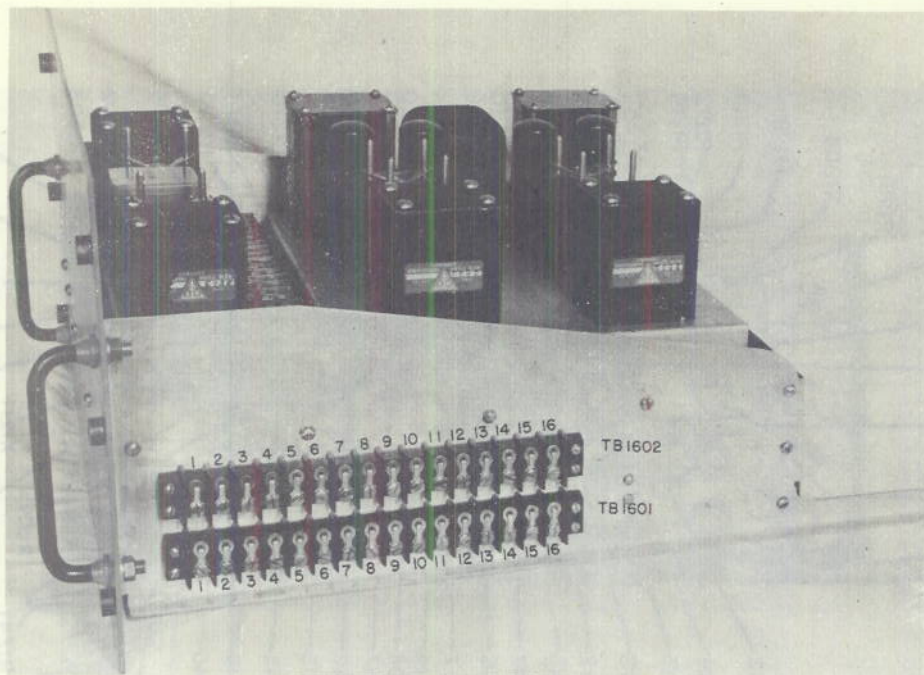


Figure 3-268. Handcrank Servo Amplifier and Telescope Servo Preamplifier - Right Side View

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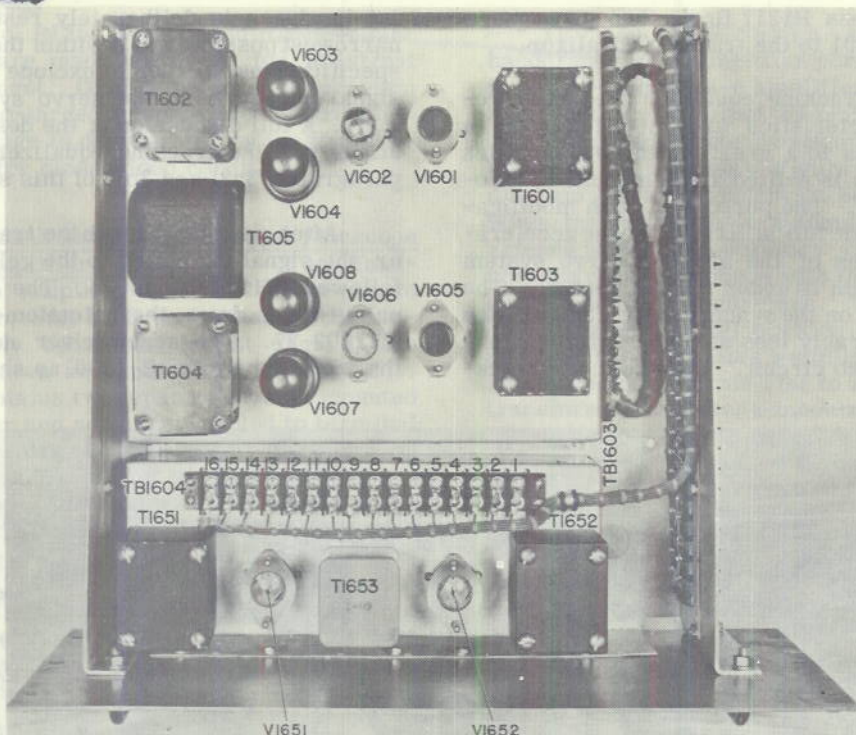


Figure 3-269. Handcrank Servo Amplifier and Telescope Servo Preamplifier - Top View

tors and the PPI synchro control transformers results in an amplitude-modulated suppressed-carrier signal with magnitude proportional to the angular misalignment and with phase giving the right-left or up-down sense. Tracing the circuit on figure 3-220, the train signal is connected from TB1202-18 (and ground) to the input grid of V1211A (pin 1) through R1239. Train slew signal from the PPI search control (or from the telescope train slew control when the system control switch S1501 is turned from LOCAL to TELESCOPE) is introduced at the cathode tap between R1230 and R1241. V1211A amplifies the signal (a nominal 60-cycle signal) and V1217 acts as an impedance step-down circuit with suitable power output for T1206 primary excitation. The demodulator circuit utilizing V1212 and V1213 has a 60-cycle synchro-bus reference signal applied through T1205. The unidirectional voltage output of the demodulator appears across R1246 and is a varying voltage either plus or minus with respect to ground depending upon the phase of the input. The signal flows through contacts B of relay K1201 to the tracking equalizer network when the system is in manual operation. When in automatic tracking operation the signal from the demodulator utilizing V1203 and V1204 as

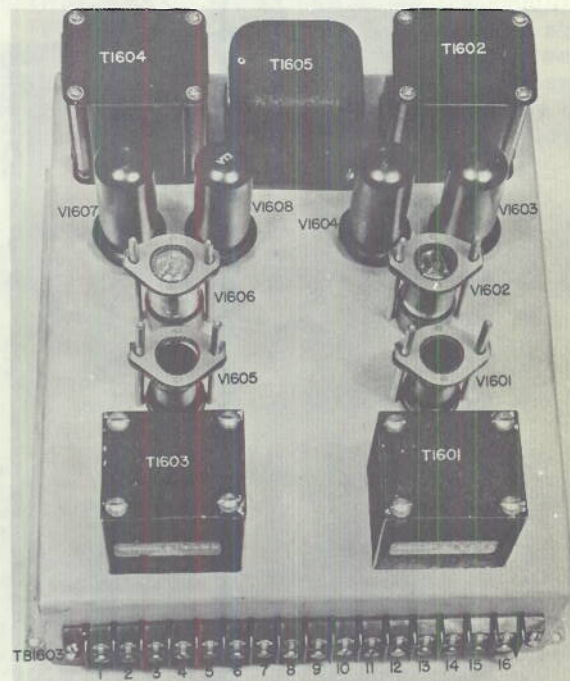


Figure 3-270. Handcrank Servo Amplifier - Top View

The first amplifier (V1601) is operated at reduced plate supply voltage (less than 300 volts by the drop through R1607) and has reduced gain due to the un-bypassed cathode resistor R1606. The condenser C1604 provides additional high-frequency noise component filtering. The signal is coupled through C1605 to the second amplifier, V1602-A and through C1606 to V1602B. The second half of V1602 is a phase inverter providing double-ended output at an impedance level suitable for driving the push-pull output stage. The normal operation is Class A throughout but reasonably low distortion occurs at higher signal level. The two resistors R1617 and R1618 are a selected pair as are the final stage grid resistors R1619 and R1620. Operation of the final stage is linearized by the introduction of a feedback voltage from the output transformer tertiary winding connected degeneratively in the cathode circuits of V1603-V1604. The cathode biasing resistor R1622 is un-bypassed for additional harmonic degeneration. The condensers C1611 and C1612 serve to supply the reactive component of the motor control field winding and thus correct the load power factor. The servo motor control field connection is to TB1603-11 and -10. A single center-tapped 6.3-volt, 5-ampere filament transformer supplies heater power to both channels. The elevation channel is identical in every respect to the train channel except for the error signal gain adjustment as set by the resistor combination R1623-24-25.

2). Telescope Servo Preamplifier. - The telescope preamplifier portion of Unit 1600 is a dual-channel amplifier operating from synchro error signals generated by antenna-telescope misalignment. A feedback signal developed by an a-c tachometer driven at telescope servo motor shaft speed is properly phased by a loading resistor located in the switching unit (R1507 in train and R1506 in elevation). Figure 3-277 is a block diagram of the Telescope Servo Preamplifier.

Tracing the train channel circuit on figure 3-232, the error signal is connected through TB1604-16 and -15 and resistor R1651 to one input winding of T1651. The feedback signal is connected through TB1604-14 and -13 and resistor R1652 to the other input winding of T1651. The two identical secondary windings of T1651 are connected through a phase shift network to the first amplifier. Condenser C1652 provides high frequency filtering. The values of R1653, C1651, and C1659 are chosen to produce the maximum motor torque by proper phasing between the synchro bus excited motor field winding and the amplifier excited control field winding. The dual triode V1651 is a resistance-capacitance coupled two-stage amplifier with degeneration in each stage due to unbypassed cathode resistors. The amplifiers provide linear frequency response over a bandwidth of a decade above and below the tracking frequency band which may be considered to extend for 30 cycles

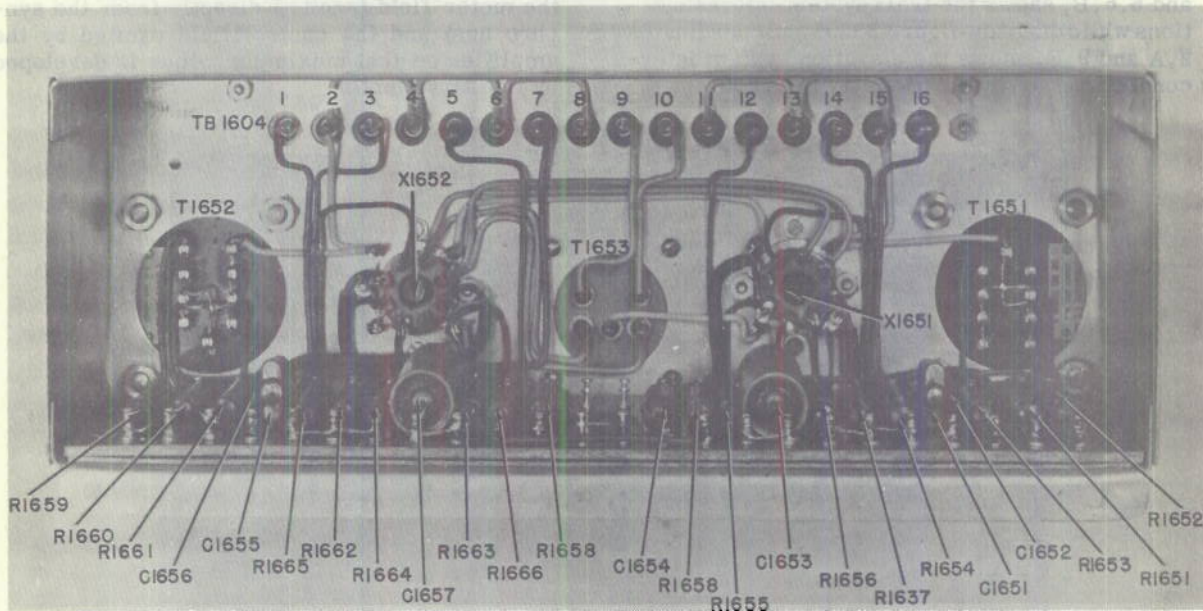


Figure 3-273. Telescope Servo Preamplifier - Bottom View

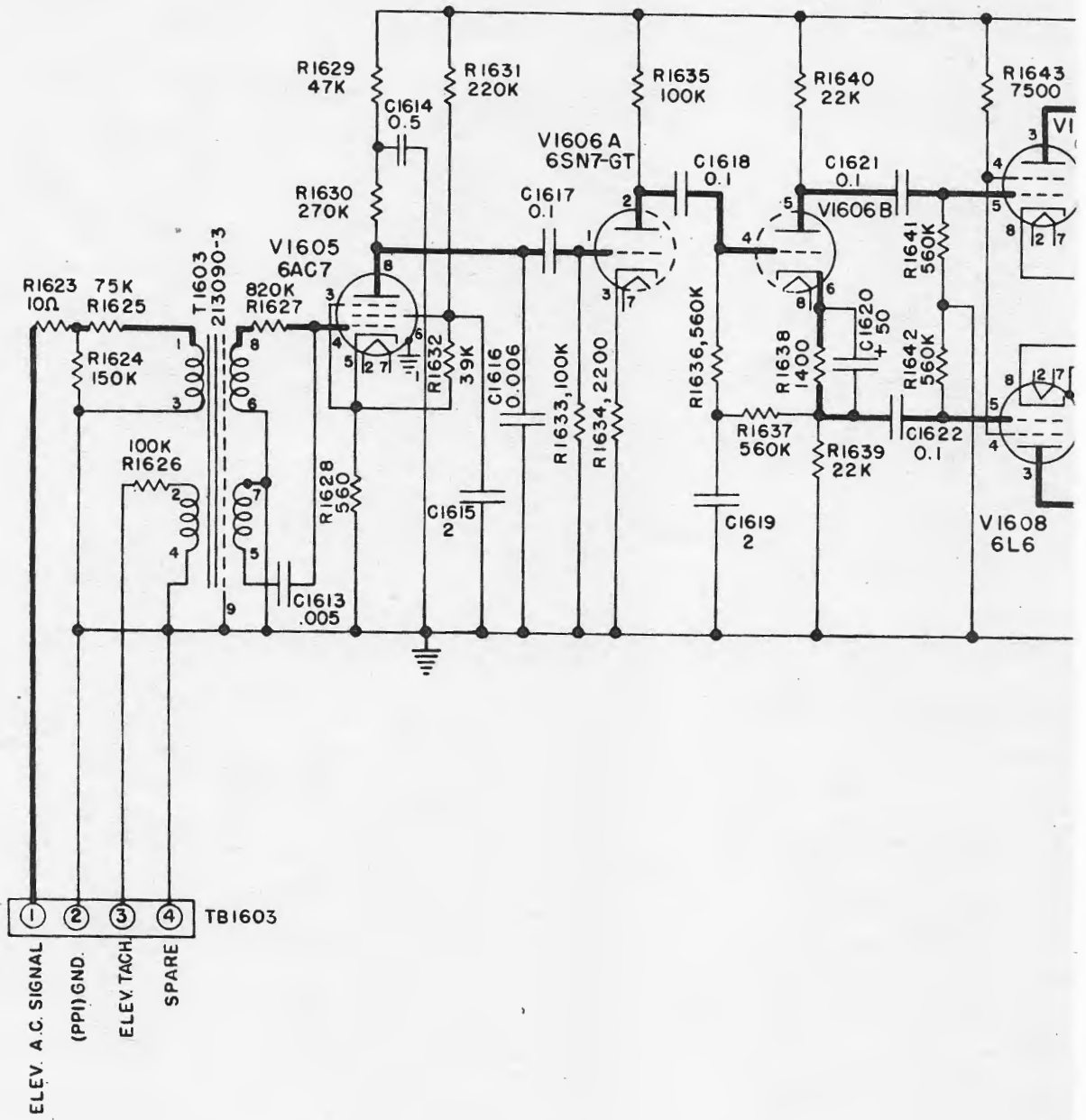
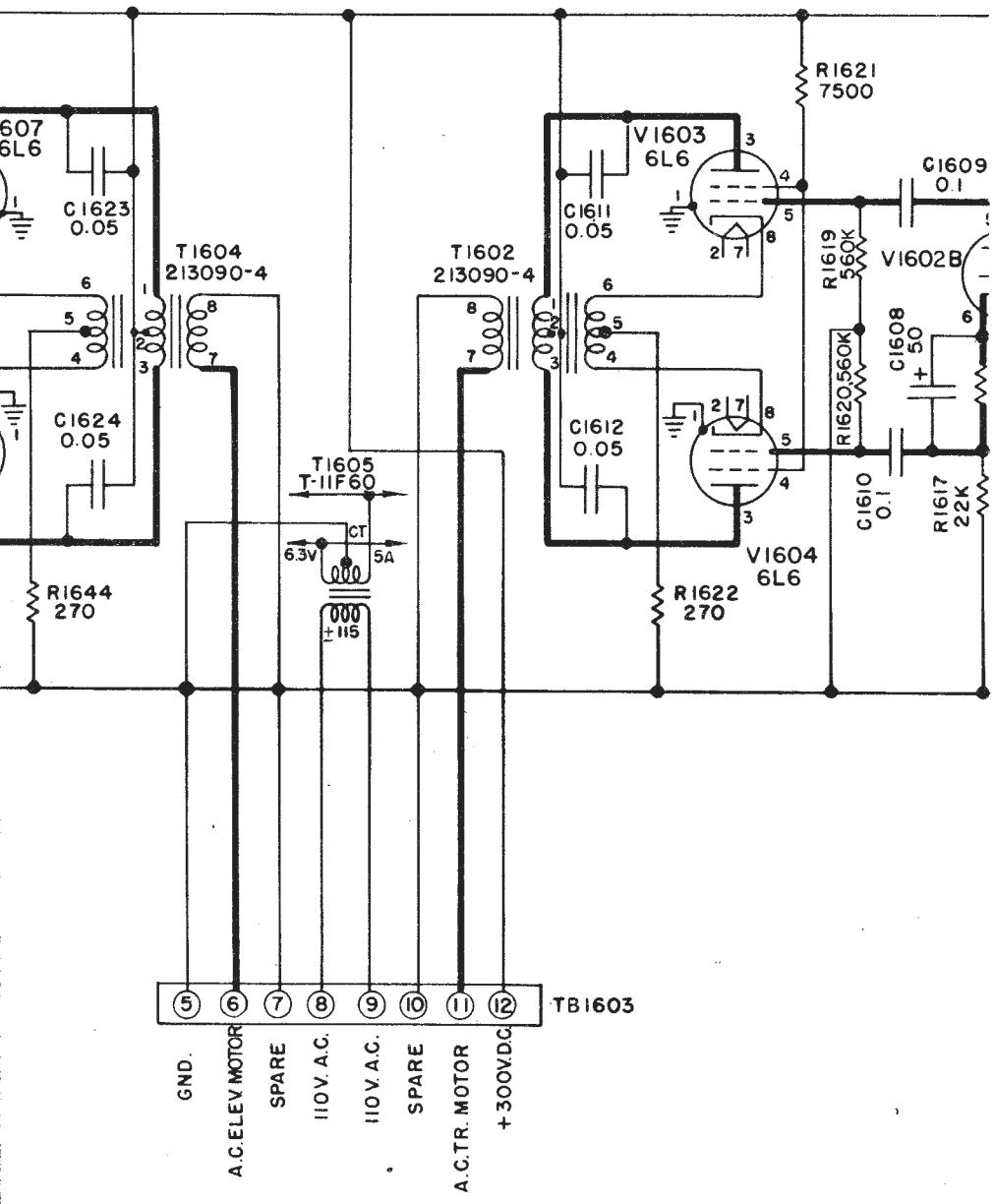
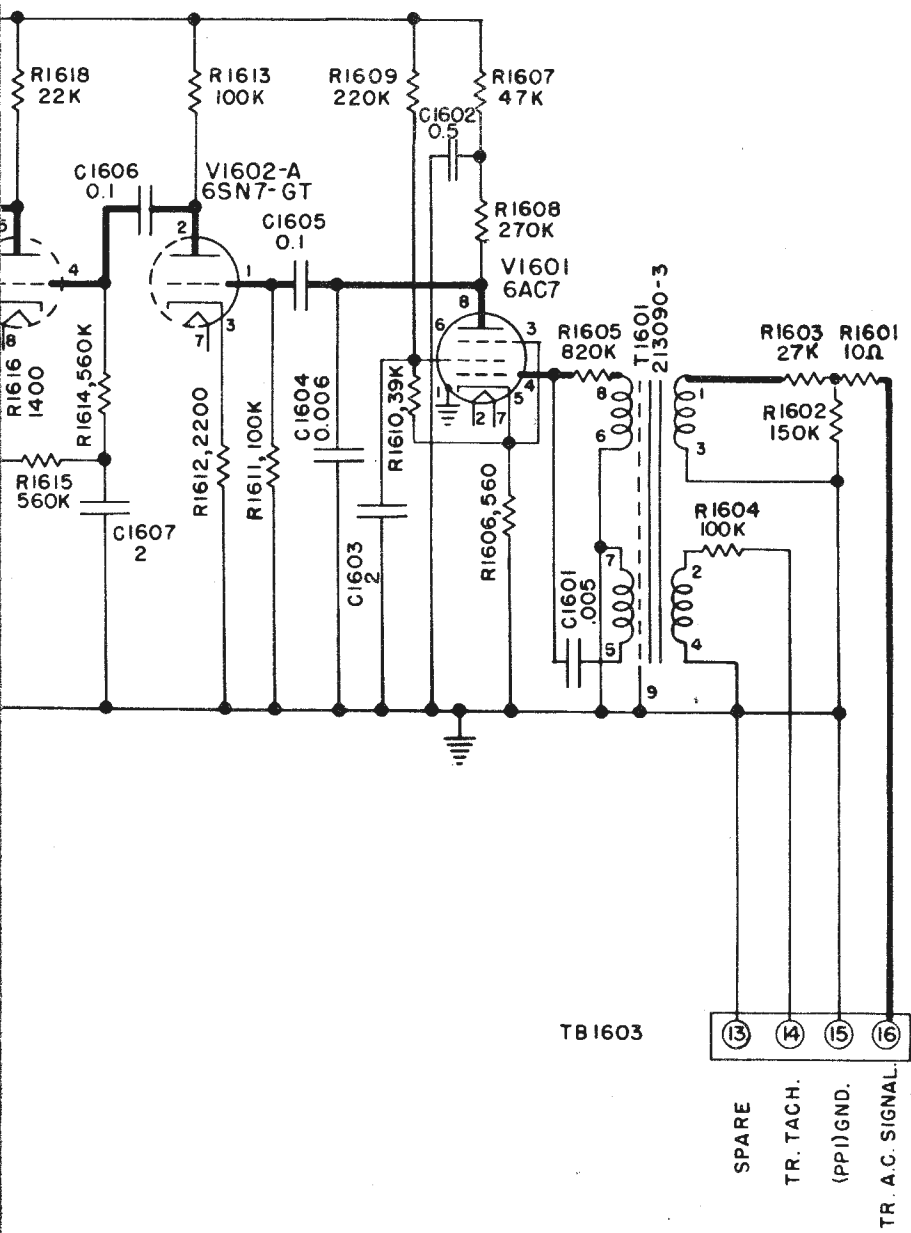


Figure 3-274. Handcrank Servo Amplifier - Schematic Diagram





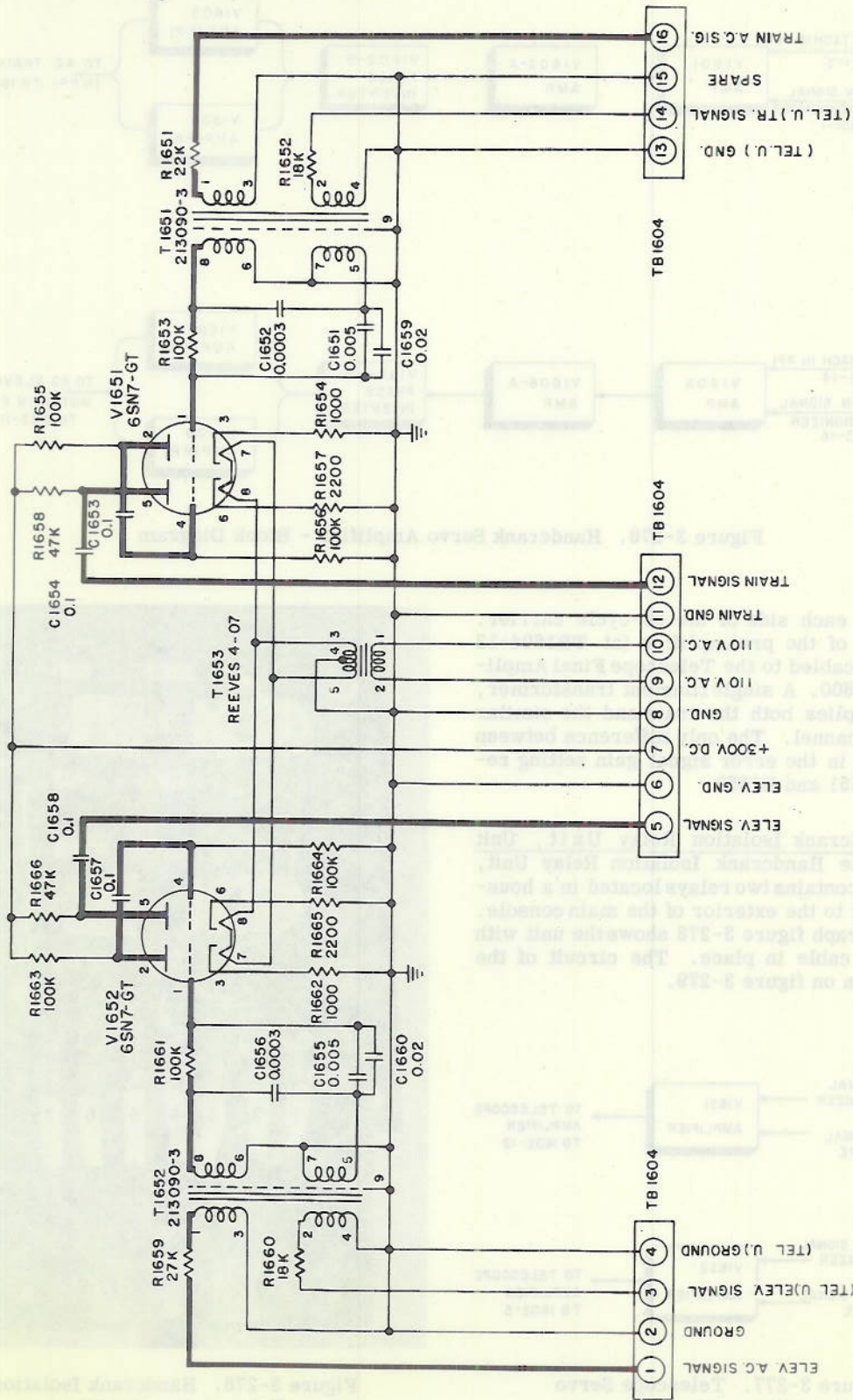


Figure 3-275. Telescope Servo Pre-amplifier - Schematic Diagram

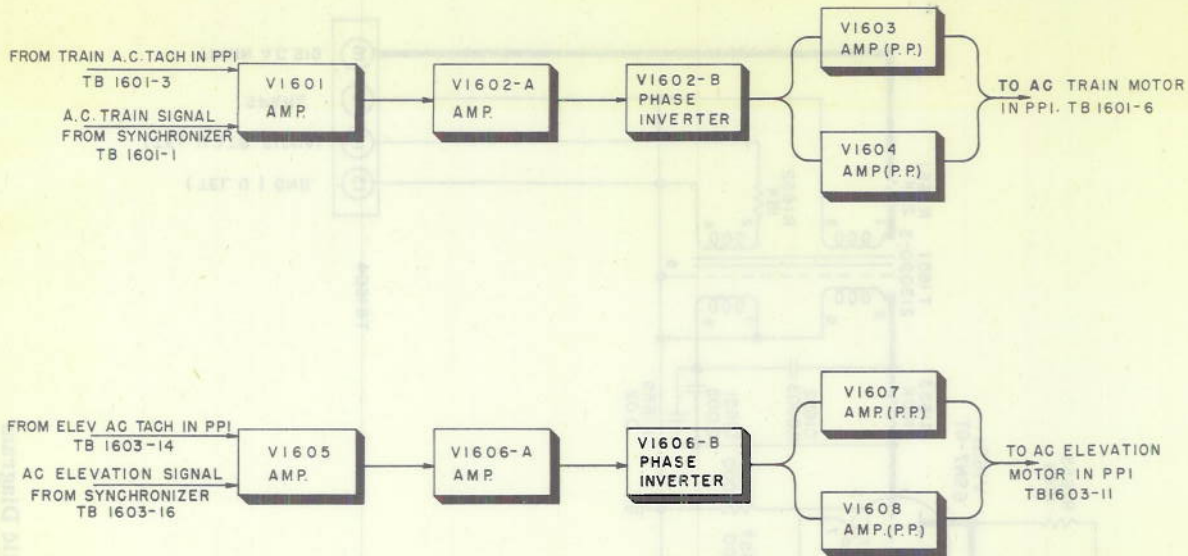


Figure 3-276. Handcrank Servo Amplifier - Block Diagram

per second each side of the 60-cycle carrier. The output of the preamplifier (at TB1604-12 and -11) is cabled to the Telescope Final Amplifier, Unit 1800. A single filament transformer, T1653, supplies both the train and the similar elevation channel. The only difference between channels is in the error signal gain setting resistors R1651 and R1659.

g. Handcrank Isolation Relay Unit, Unit 2600. - The Handcrank Isolation Relay Unit, Unit 2600, contains two relays located in a housing secured to the exterior of the main console. The photograph figure 3-278 shows the unit with connecting cable in place. The circuit of the unit is given on figure 3-279.

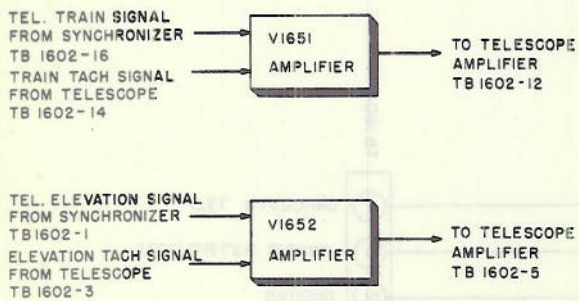


Figure 3-277. Telescope Servo Preamplifier - Block Diagram

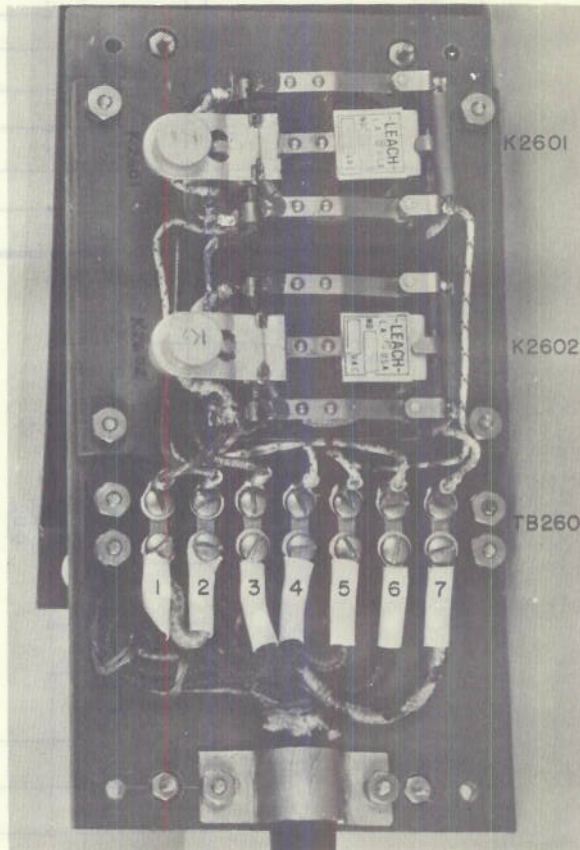


Figure 3-278. Handcrank Isolation Relay Unit - Top View

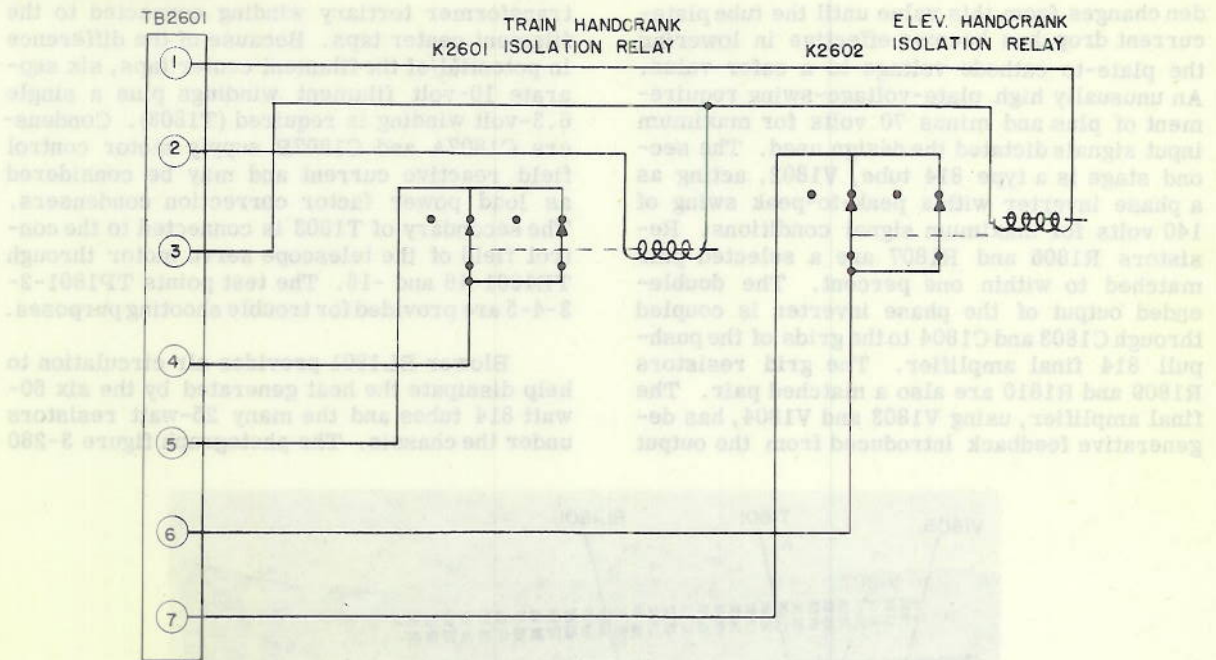


Figure 3-279. Handcrank Isolation Relay Unit - Schematic Diagram

Each of the two a-c relays operate as single-pole single-throw switches. As shown on figure 3-168, one relay coil is connected in parallel with each of the handcrank servo motor field excitation supplies. When the relays are unenergized, the contacts are closed and the handcrank synchro control transformer signal is connected to the target and manual coordinate detector unit. When the relays are energized, the detector unit is isolated from the handcrank output signal. The train relay K2601-A circuit is shown on figure 3-204 near coordinates 2.5,E. The elevation relay K2602-A circuit is shown on figure 3-205 near coordinates 2.6,C.

h. Telescope Final Amplifier, Unit 1800. - The Telescope Final Amplifier, Unit 1800, is mounted in a cabinet together with the Telescope Amplifier Power Unit, Unit 1800, located below the communications control panel on the opposite side from the main console in the operations trailer. The photograph, figure 3-280, shows the two units in place with the cabinet door removed. The amplifier chassis top view appears in figure 3-281, while the bottom chassis view is given by figure 3-282. The dual-channel amplifier is shown in two sections on figure 3-216 at the extreme right, labeled "A.C. AMP." Interconnection diagrams figure 3-204 and figure 3-205 also show unit 1800 at the extreme right. A block diagram of the

telescope final amplifier is shown in figure 3-283. The complete circuit of the amplifier is given in figure 3-284.

1). The Telescope Amplifier Power Unit is described in detail in the subsection on power sources. The supply provides 1200 volts dc at one-half ampere.

2). The Telescope Final Amplifier, Unit 1800, is a dual-channel amplifier supplying driving power for the control fields of the a-c servo motors of the telescope unit from input signals supplied by the Telescope Servo Pre-amplifier, Unit 1800. Tracing the train circuit on figure 3-238 from the input connections at TB1801-13 and -14, the first stage of amplification is provided by the paralleled triode sections of V1801 having a grid return through R1801, an unbypassed cathode resistor R1803, and a plate load resistor R1802. Particular note should be taken of the fact that the plate supply for the 6SN7-GT tube is the full 1200-volt supply. The unusually high supply voltage hazards are somewhat offset by the fact that all filaments have a two-minute pre-heat before application of the plate voltage. In addition, the succeeding stage grid potential is at approximately 210 volts positive as set by the resistance divider combination, R1805-R1804. The coupling condenser C1801 tends to prevent sud-

den changes from this value until the tube plate-current drop has become effective in lowering the plate-to-cathode voltage to a safer value. An unusually high plate-voltage-swing requirement of plus and minus 70 volts for maximum input signals dictated the design used. The second stage is a type 814 tube, V1802, acting as a phase inverter with a peak-to-peak swing of 140 volts for maximum signal conditions. Resistors R1806 and R1807 are a selected pair matched to within one percent. The double-ended output of the phase inverter is coupled through C1803 and C1804 to the grids of the push-pull 814 final amplifier. The grid resistors R1809 and R1810 are also a matched pair. The final amplifier, using V1803 and V1804, has degenerative feedback introduced from the output

transformer tertiary winding connected to the filament center taps. Because of the difference in potential of the filament center taps, six separate 10-volt filament windings plus a single 6.3-volt winding is required (T1803). Condensers C1807A and C1807B supply motor control field reactive current and may be considered as load power factor correction condensers. The secondary of T1803 is connected to the control field of the telescope servo motor through TB1801-16 and -15. The test points TP1801-2-3-4-5 are provided for trouble shooting purposes.

Blower BL1801 provides air circulation to help dissipate the heat generated by the six 50-watt 814 tubes and the many 25-watt resistors under the chassis. The photograph figure 3-280

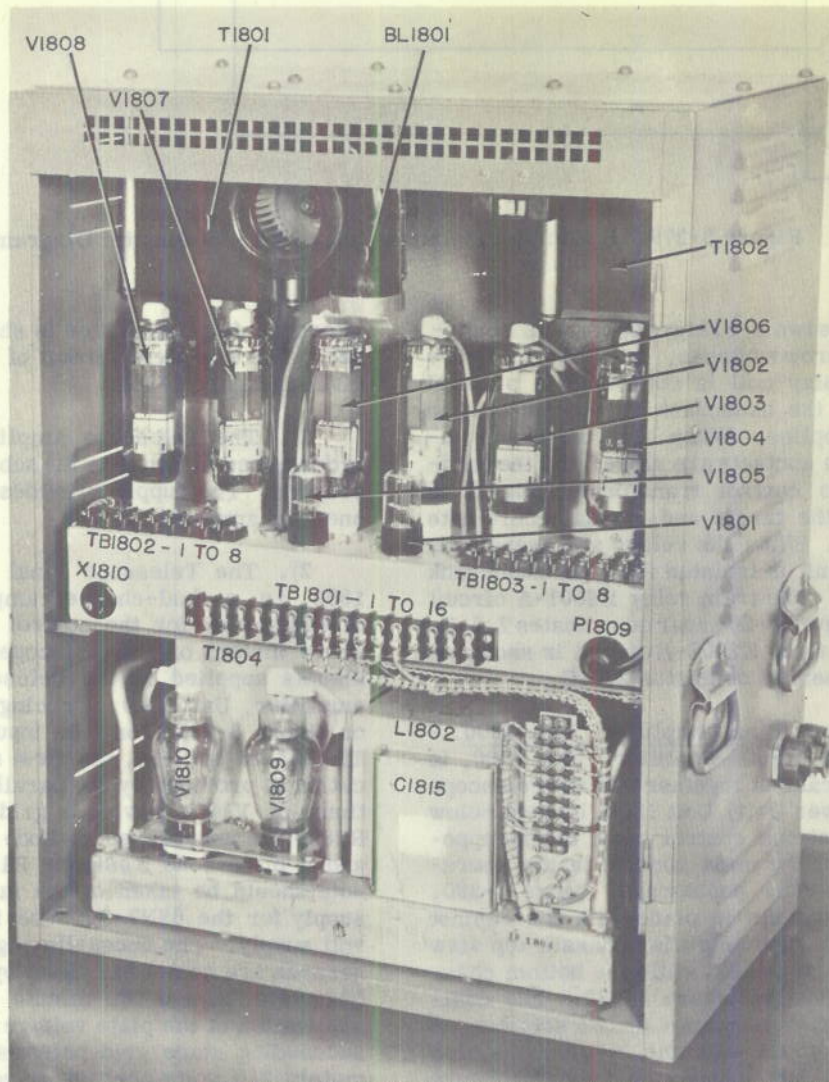


Figure 3-280. Telescope Final Amplifier and Power Supply in Cabinet - Front View

shows the two output transformers located in the back upper corners of the cabinet and the terminal boards TB1802 and TB1803 to which they are cabled. Primary connections for T1803 and T1802 are directly connected to the ceramic-insulated terminals of the dual condensers C1807A-B and C1814A-B. The important cabinet interlock appears at the cabinet top between BL1801 and T1802 in figure 3-280. As seen on figure 3-284, the interlock is in series with the 2-minute time delay relay K1801 contacts and the plate transformer of the power supply. Socket X1809 provides 120 volts ac for the blower while X1810 is a convenience outlet for test VTVM use.

Extreme caution should be exercised in all work near the amplifier and its potentially lethal 1200-volt, one-half ampere power supply.

i. Reference Voltage Distribution Unit, Unit 2700. - The Reference Voltage Distribution Unit, Unit 2700, consists of six cathode followers, two amplifiers, and a phase shifting network, the latter using a component resolver to accomplish the phase shift. (See figure 3-285.) The desired high input and low output impedances are

obtained by the use of the cathode followers. The input from the two-phase lobing generator appears at terminals 1 and 2 on terminal board TB2701. Voltage goes through dropping resistors R2701, R2703, R2702, and R2704 to prevent overloading the component resolver B2701. These resistors, in conjunction with the windings of B2701, act as a voltage divider to prevent overdriving the cathode followers V2704, V2705, V2706, and V2707. A sine-wave voltage, continuously variable in phase, appears at terminals S2 and S4 of B2701. From these terminals the voltage is fed through the three-section, 180-cycle filter composed of R2705, R2706, R2707, C2701, C2702, and C2703. Shifting of phase is accomplished by rotation of the rotor of B2701. The rotor shaft is brought out to the front panel of the unit where a dial calibrated in degrees from 0 to 360 is located. Once this dial is set to a zero reference point, the phase can be shifted in either direction by any amount as indicated by the calibrations on the phase-shift dial. The two output voltages which are phase shifted appear at J2701 and J2702. These two outputs go to the two range units described in this section, subsection 3-1. The amplitude of these outputs can be adjusted by potentiometer R2708 which is also a front

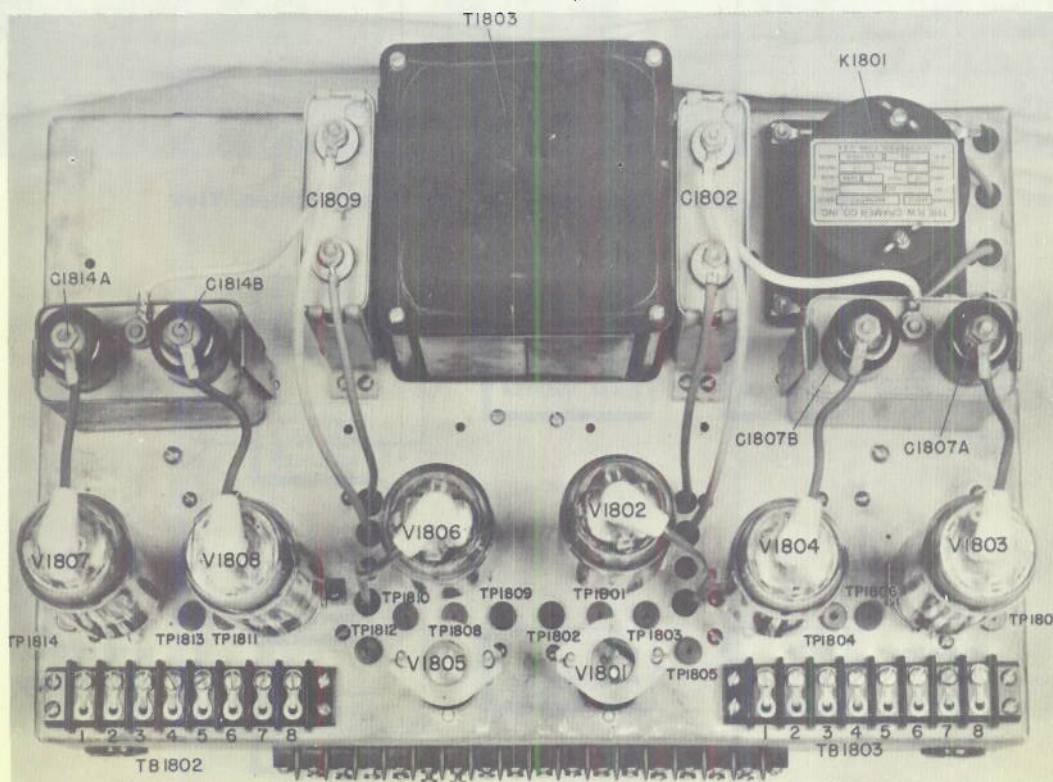


Figure 3-281. Telescope Final Amplifier - Top View

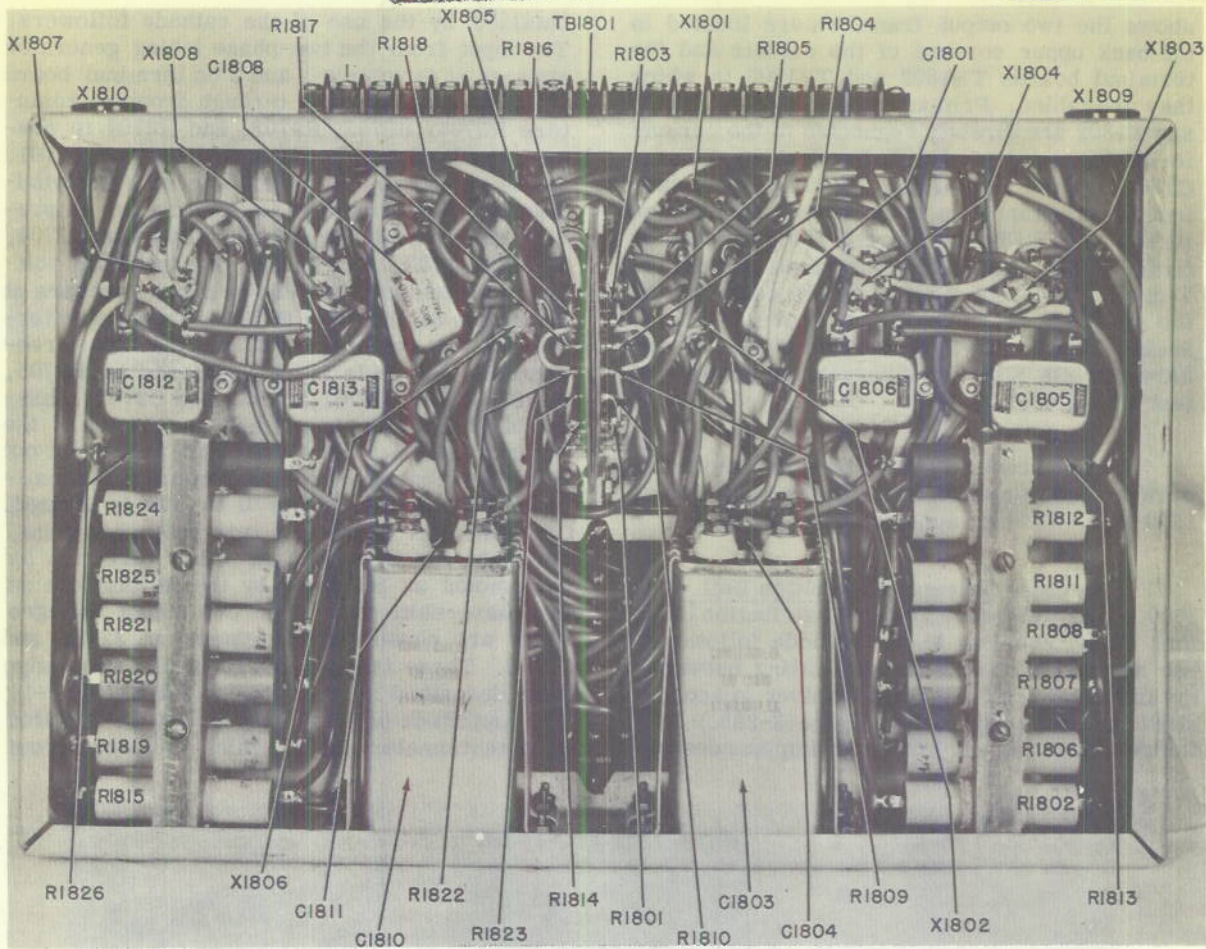


Figure 3-282. Telescope Final Amplifier - Bottom View

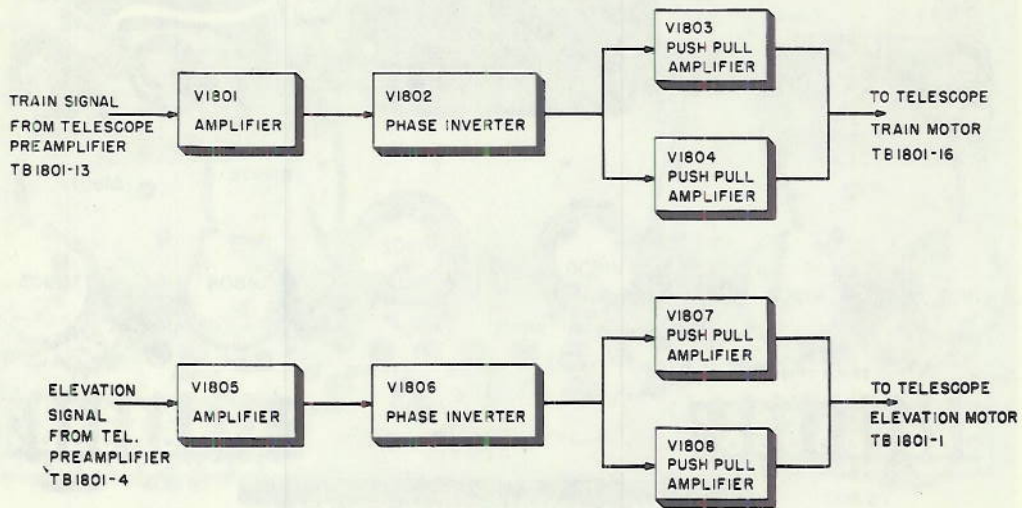
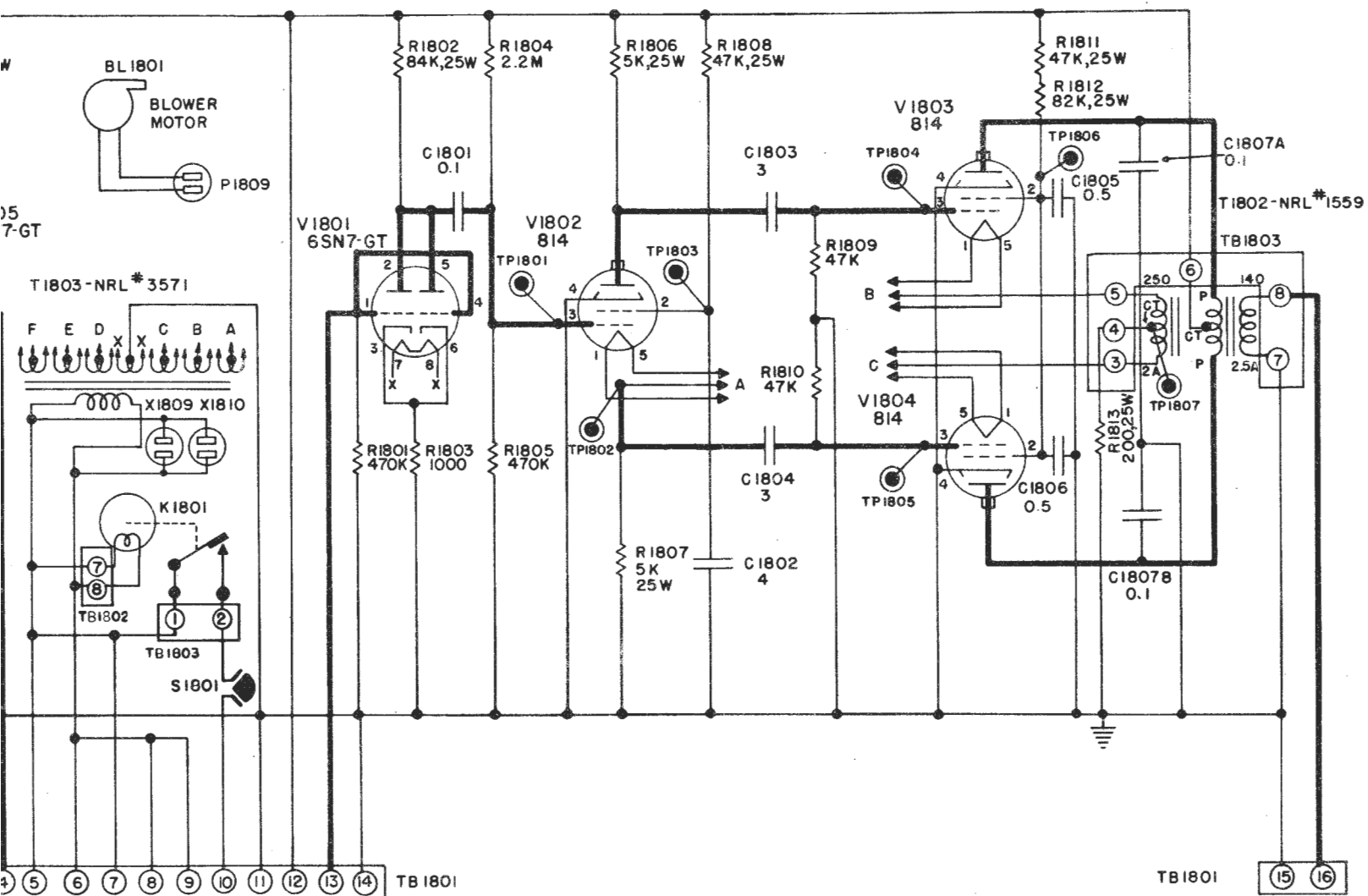


Figure 3-283. Telescope Final Amplifier - Block Diagram



4 5 6 7 8 9 10 11 12 13 14 TB 1801
 15 16 TB 1801

ELEV. SIGNAL
 110V A.C.
 110V A.C.
 FIL. TRANSF. { 110V A.C.
 TB 1804
 PLATE TRANSF. { 110V A.C.
 TB 1804
 110V A.C.
 GND.
 1200V.D.C.
 TRAIN SIGNAL
 TRAIN GND.
 (TEL. U) TRAIN GND.
 TEL. U TRAIN CONTROL SIG.

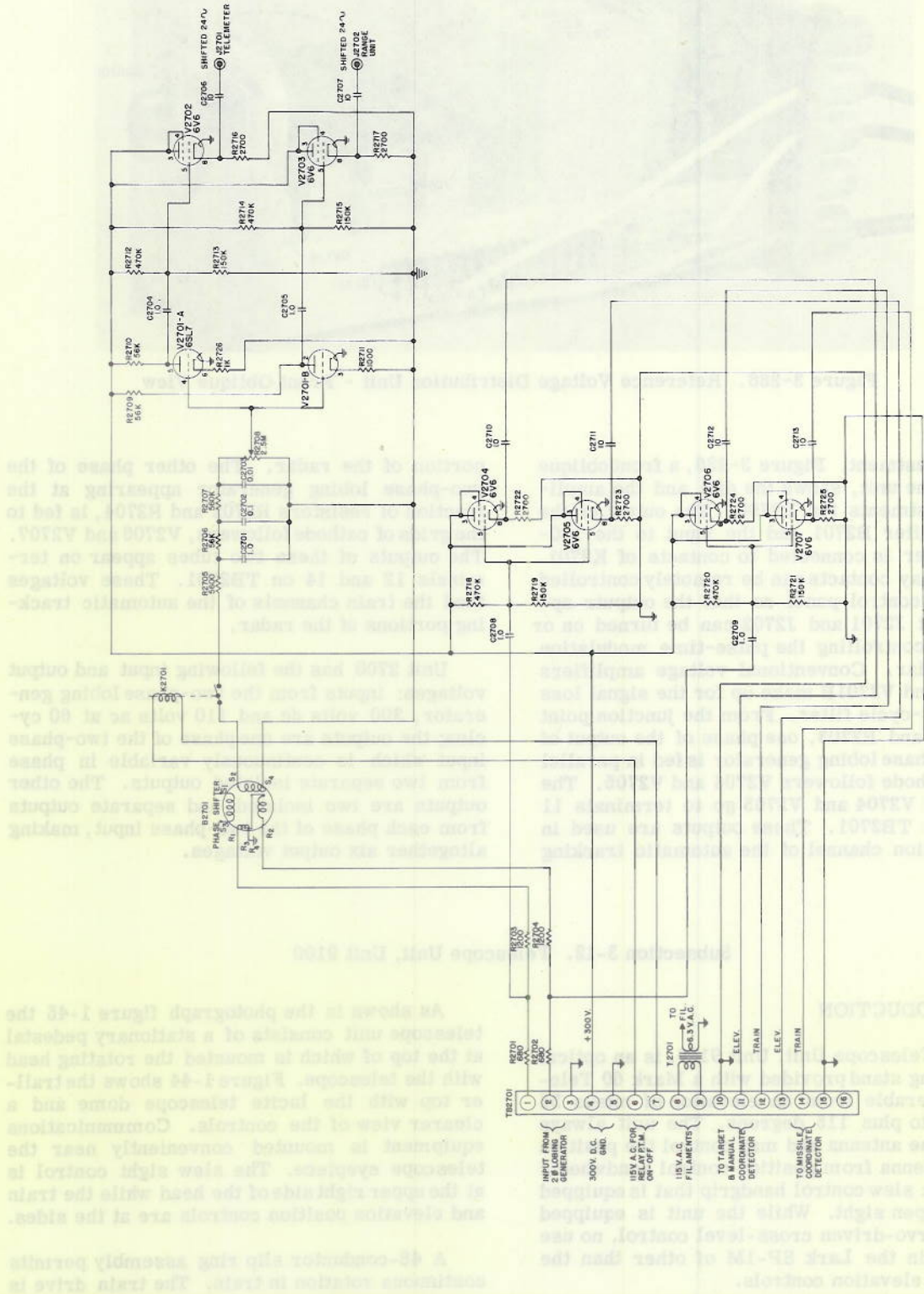


Figure 3-285. Reference Voltage Distribution Unit - Schematic Diagram

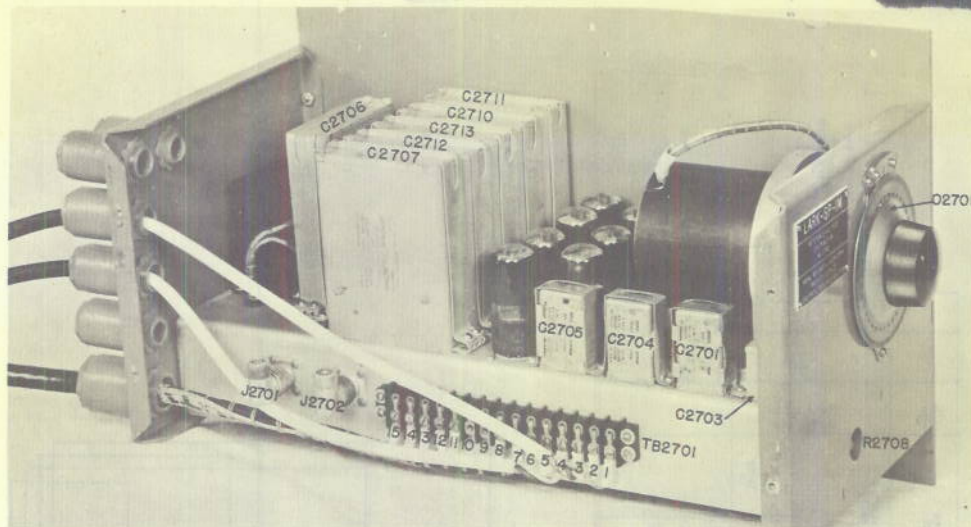


Figure 3-286. Reference Voltage Distribution Unit - Front Oblique View

panel adjustment. Figure 3-286, a front oblique view of the unit, shows the dial and the amplitude adjustments for R2708. The output of the phase shifter B2701 and the input to the 180-cycle filter is connected to contacts of K2701. These relay contacts can be remotely controlled from the control panel so that the outputs appearing at J2701 and J2702 can be turned on or off, thus controlling the pulse-time modulation of the radar. Conventional voltage amplifiers V2701A and V2701B make up for the signal loss in the 180-cycle filter. From the junction point of R2701 and R2703, one phase of the output of the two-phase lobing generator is fed in parallel to the cathode followers V2704 and V2705. The outputs of V2704 and V2705 go to terminals 11 and 13 on TB2701. These outputs are used in the elevation channel of the automatic tracking

portion of the radar. The other phase of the two-phase lobing generator appearing at the junction of resistors R2702 and R2704, is fed to the grids of cathode followers, V2706 and V2707. The outputs of these two tubes appear on terminals 12 and 14 on TB2701. These voltages feed the train channels of the automatic tracking portions of the radar.

Unit 2700 has the following input and output voltages: inputs from the two-phase lobing generator, 300 volts dc and 110 volts ac at 60 cycles; the outputs are one phase of the two-phase input which is continuously variable in phase from two separate isolated outputs. The other outputs are two isolated and separate outputs from each phase of the two-phase input, making altogether six output voltages.

Subsection 3-12. Telescope Unit, Unit 9100

1. INTRODUCTION

The Telescope Unit, Unit 9100, is an optical monitoring stand provided with a Mark 60 Telescope operable from an elevation of minus 25 degrees to plus 115 degrees. The unit always follows the antenna and may control the position of the antenna from position control handwheels or from a slew control handgrip that is equipped with an open sight. While the unit is equipped with a servo-driven cross-level control, no use is made in the Lark SP-1M of other than the train and elevation controls.

As shown in the photograph figure 1-45 the telescope unit consists of a stationary pedestal at the top of which is mounted the rotating head with the telescope. Figure 1-44 shows the trailer top with the lucite telescope dome and a clearer view of the controls. Communications equipment is mounted conveniently near the telescope eyepiece. The slew sight control is at the upper right side of the head while the train and elevation position controls are at the sides.

A 48-conductor slip ring assembly permits continuous rotation in train. The train drive is

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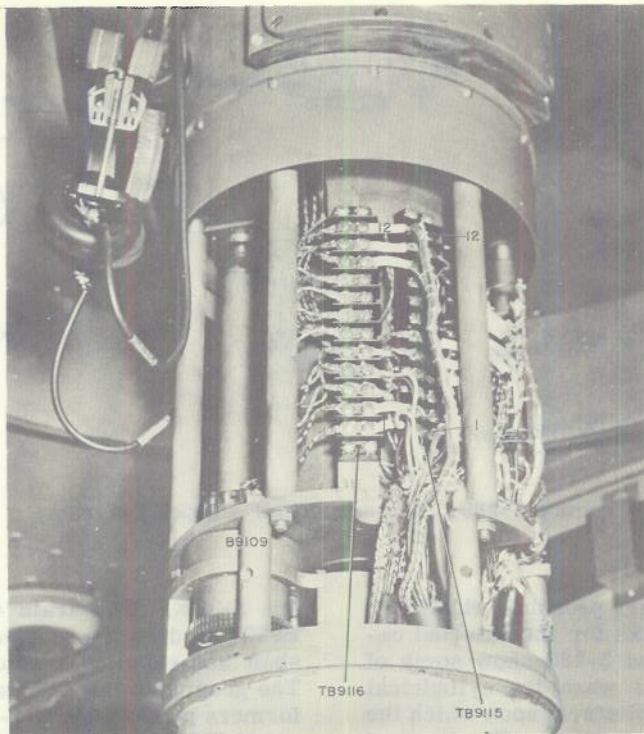


Figure 3-287. Telescope Column Showing Terminal Boards - Front View

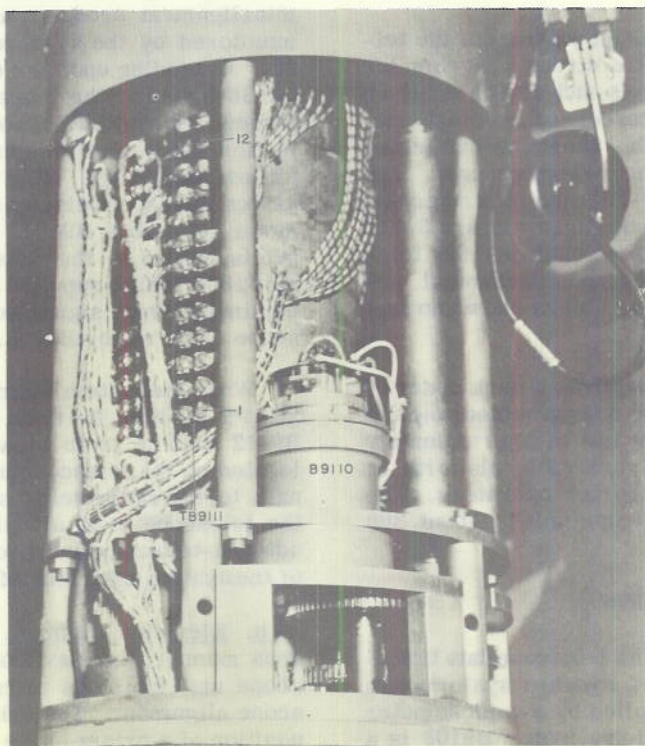


Figure 3-288. Telescope Column Showing Terminal Boards - Rear View

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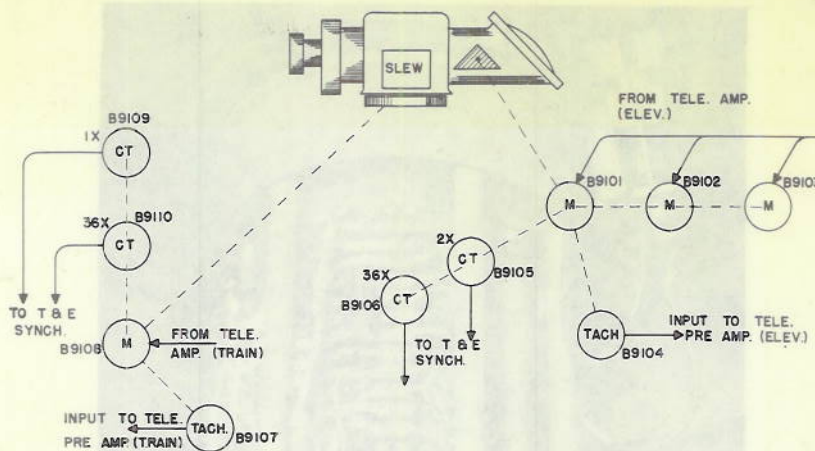


Figure 3-289. Telescope Unit - Block Diagram

contained in the stationary pedestal, which also houses all terminal blocks for the external cables. Figures 3-287 and 3-288 show some of the components exposed when the cylindrical shield is lowered. The platform upon which the observer stands does not rotate. The base of the fixed pedestal includes leveling screws and provision for incremental rotation of the pedestal in train.

Figure 3-289 is a block diagram of the telescope unit. A schematic circuit diagram for the telescope unit controls and drives is given in figure 3-290. The interconnection diagrams, figures 3-204 and 3-205, show system interconnections involving the telescope unit. The wiring diagram figure 3-291 shows further details. The functional block diagram figure 3-216 of the radar servo systems includes the telescope unit. The gearing and mechanical arrangement of the telescope unit is shown on figure 3-292.

The telescope unit requires a deck space of about 3 feet in radius for adequate clearance in operating. An overall height of approximately 6 feet is required. A removable platform is provided to adjust for shorter operators. The total weight of the telescope unit is about 300 pounds.

2. CIRCUIT DESCRIPTION

a. Train Channel. - The telescope data transmission is a dual-speed synchro system with velocity information supplied by a-c tachometer generators. The train drive motor B9108 is a two-phase a-c motor with the motor field excited directly from the synchro bus. (See figure

3-292.) The train tachometer generator B9107 is directly coupled to the servo motor shaft and supplies a velocity feedback signal. The gearing to the 1CT synchro control transformers places them at 1-speed (B9109) and 36-speed (B9110) for the servo motor at 324-speed.

The antenna synchro generators excite the telescope synchro control transformers and misalignment produces a voltage output that is monitored by the synchronizer circuits of unit 600. Depending upon the error magnitude either the 36-speed or the 1-speed signal is connected through relay K604, through the 180-cycle rejection filter, and then to the telescope preamplifier, unit 1600. The preamplifier also receives telescope velocity signal from the tachometer generator B9107. The preamplifier output is cabled to the telescope final amplifier, unit 1800, which supplies a 100-watt output (for maximum input signal conditions) to the telescope drive motor B9108.

When the system control switch is in TELESCOPE position, the train handwheel tachometer B9112 and the train slew potentiometer R9103 located on the telescope unit serve as input signals to the radar servo system. The drive for the telescope is at all times controlled by the antenna-telescope synchro alignment regardless of the system switching of the control functions.

b. Elevation Channel. - In an exactly analogous manner, the elevation channel of the telescope unit functions to maintain antenna-telescope alignment. The drive motors control the position of a prism in the optics of the Mark 60 Telescope so that the operator always looks into the telescope with his line-of-sight horizontal.

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ELEVATION

TRAIN

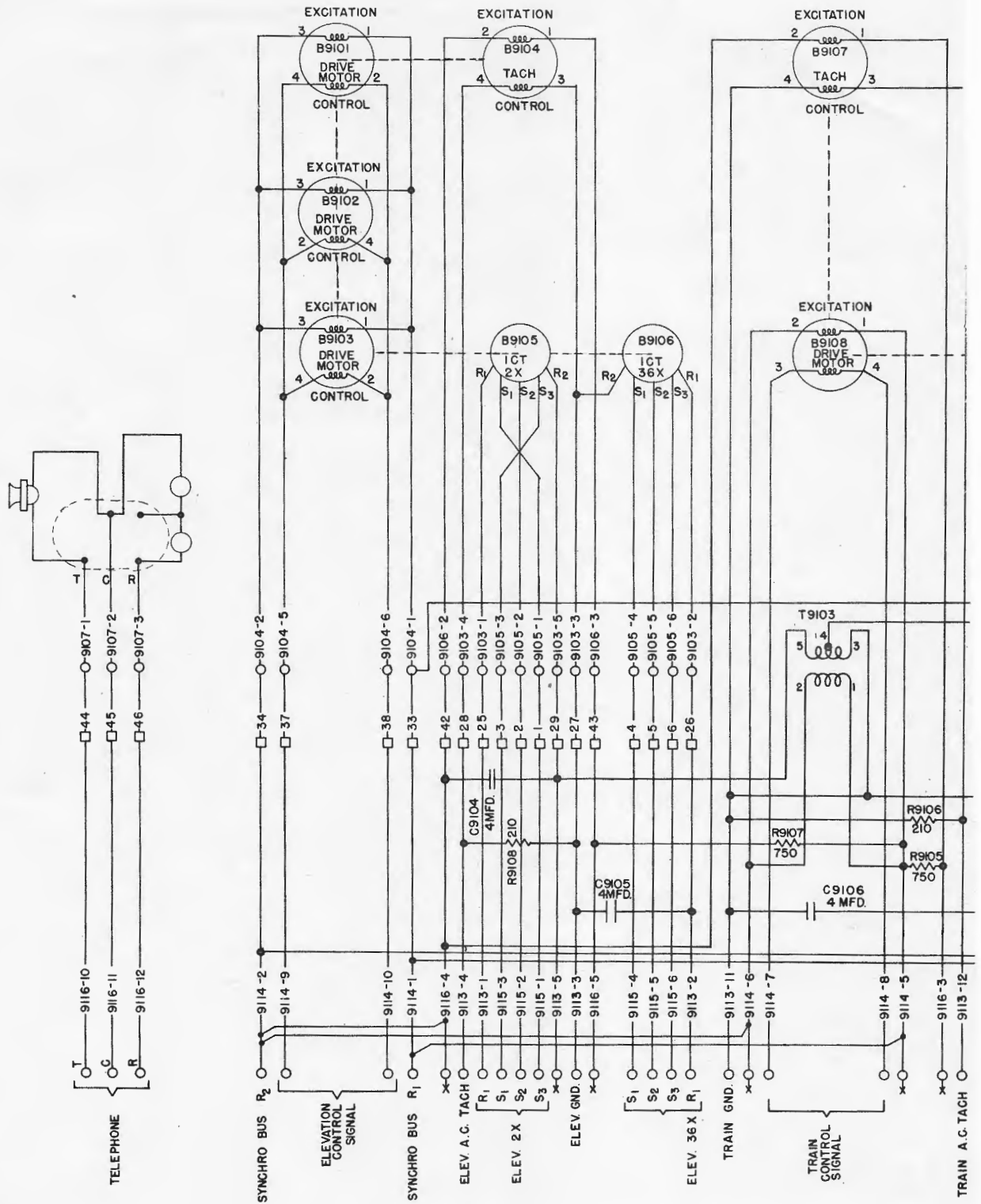
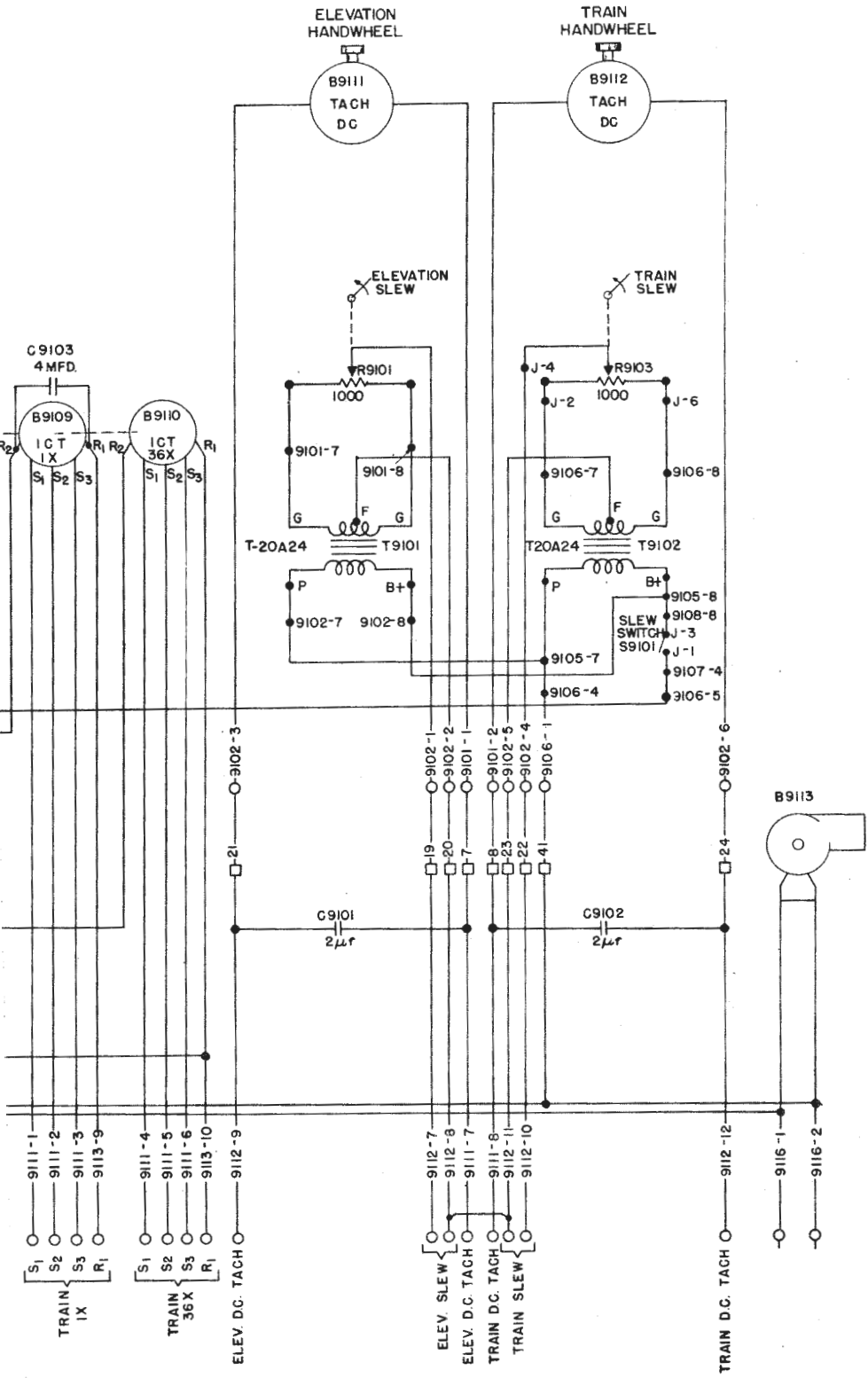


Figure 3-290. Telescope Unit - Schematic Diagram



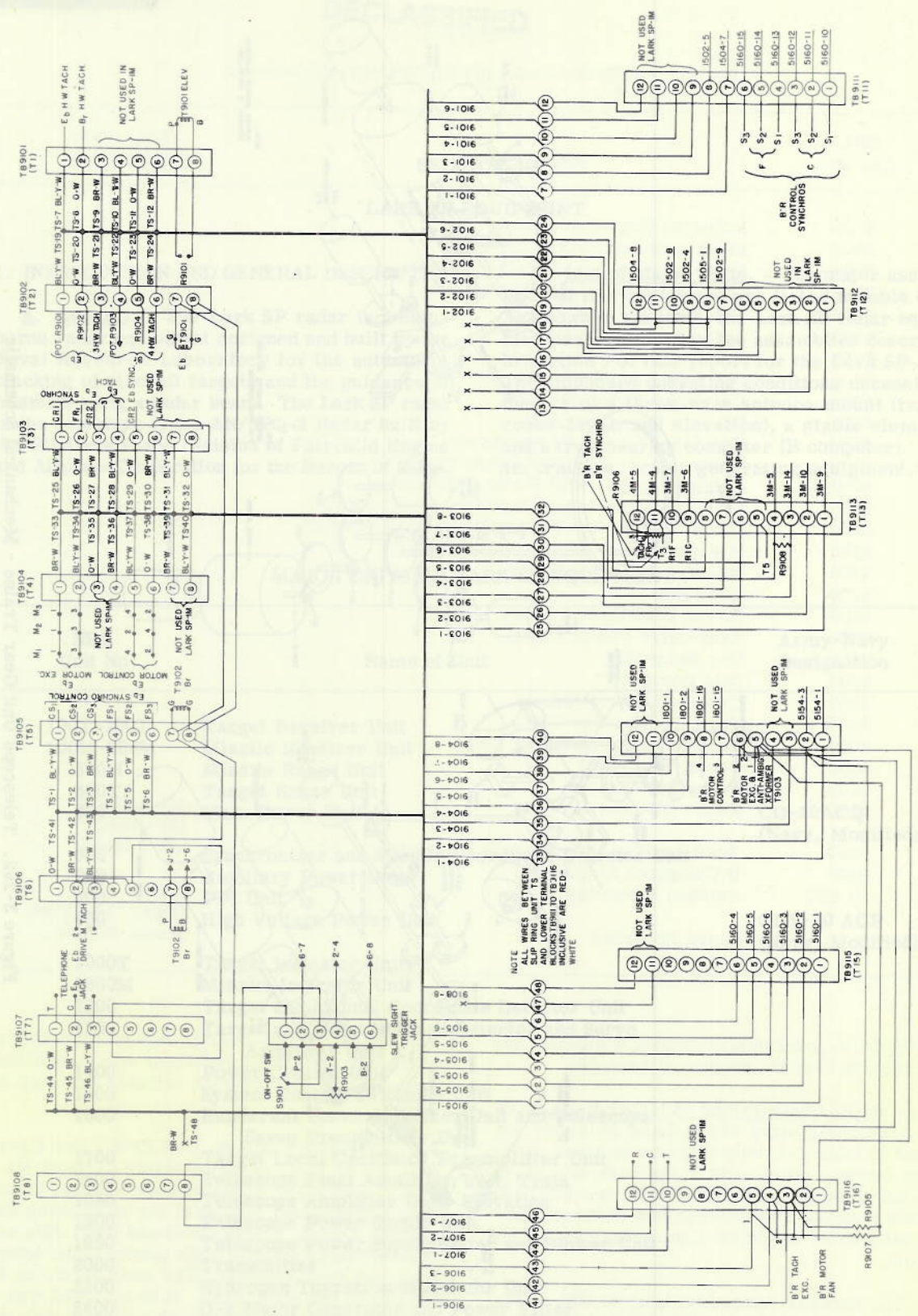


Figure 3-291. Telescope Unit - Wiring Diagram

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TABLE 4-1

MAJOR UNITS OF LARK SP EQUIPMENT (Continued)

NRL Unit No.	Name of Unit	Army-Navy Designation
2500	Induction Regulator Unit	
2600	Handcrank Isolation Relay Unit	
2700	Reference Voltage Distribution Unit	
2800	Missile Cross-pointer Meter Unit	
2900	D-c Voltage Regulator	
3200	Antenna Control Unit	
3300	D-c Servo Amplifier Unit	
3400	D-c Servo Amplifier Power Unit	
3500	D-c Servo Equalizer Unit	
3600	Synchro Capacitor Unit	
3800	Simulated Target Programmer	
3900	Telescope Cross-level Servo Amplifier	
4000	Antenna Cross-level Servo Amplifier	
4100	Antenna Cross-level Amplifier Power Supply	
4200	Missile Oscillator Preamplifier Power Supply	
4300	Missile Oscillator Preamplifier Unit	
4400	Standing Wave Amplifier	
4700	Echo Box	
4900	Power Distribution Panel	
6200	Keep-alive Power Supply	
6300	D-c Relay Box	
8100	Dial Box Unit	
8200	Camera Control Unit	
8400	Time Comparator Unit	
8500	Remote Range Indicator Unit	
8600	Commutator Unit	
9100	Telescope Unit	
9200	Stable Element	Mk 8 Mod 2 (Modified)
9300	True Bearing Computer (B Computer)	Mk 1 Mod 0
9400	B Computer Amplifier	
50,000	Antenna Assembly	CG-66 AHP (Navy, Modified)
	Sound Recorder	Model B-AVE

humidifiers, and communications equipment are not required for the shipboard Lark SP.

c. Brief Descriptions of Major Units. - Of the component units of the Lark SP radar, as listed in table 4-1, only those units which differ from corresponding units in the Lark SP-1M, or are not present in the Lark SP-1M, are described in this section. For descriptions of the remaining units refer to section I, paragraph 2b, of this report.

1). Antenna Assembly, Unit 50,000. - The Antenna Assembly, type CG-66AHP (modified),

Unit 50,000, is a three-axis mount supporting an eight-foot parabolic reflector and a modified Lark SP-1M nutator with suitable wave-guide feed.

2). Stable Element, Unit 9200. (See figure 4-1.) - The NRL-modified Stable Element Mk 8 Mod 2, Unit 9200, installed below-decks, measures cross-level and level for stabilizing the antenna mount. Cross-level and level data are transmitted by synchro units geared to the cross-level and level gimbals. The instrument can be trained in the deck plane. It is equipped with a deck tilt corrector. The deck tilt corrector re-

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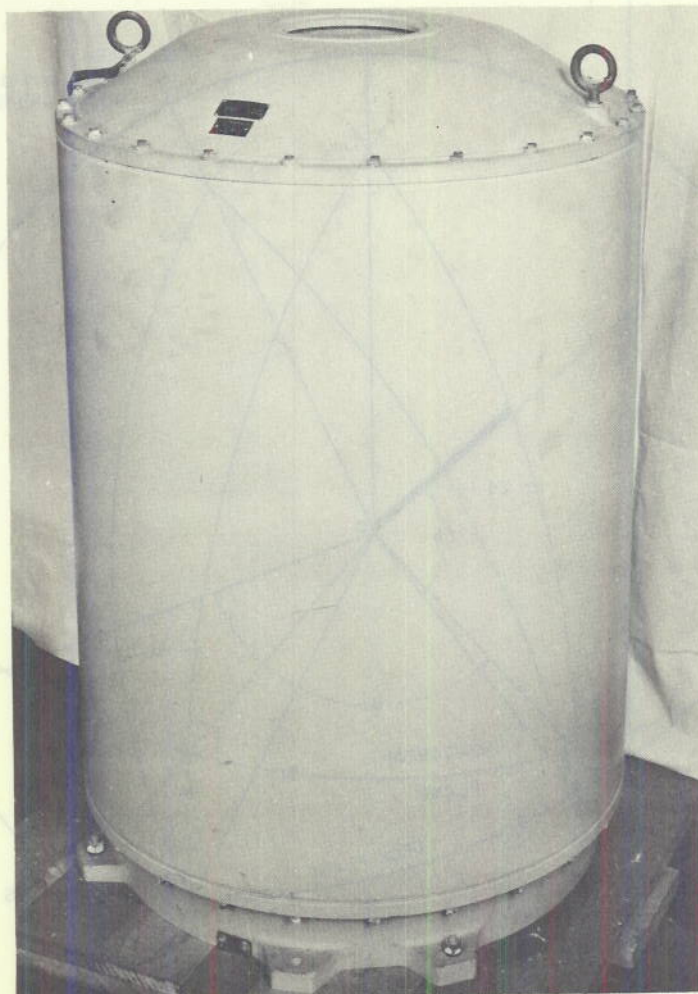


Figure 4-1. Stable Element, Unit 9200

ceives level, cross-level, and director train mechanically and computes relative target bearing (Br).

3). True Bearing Computer, Unit 9300. - The True Bearing Computer Mk 1 Mod 0 (B computer), Unit 9300, is a specially designed bulkhead-mounted electro-mechanical computer. It is used to compute true target bearing (B) from the information furnished from the antenna mount and stable element.

d. Power Requirements. - The power requirements for the Lark SP equipment are as follows:

Radar (components common to Lark SP and Lark SP-1M) and Antenna Assembly: 50 amps at 110 volts, 3-phase, 60 cycles.

Stable Element: 10 amperes, three-phase, at 115 volts, 60 cps. (70 amperes starting)

2.5 amperes, single-phase, at 115 volts, 60 cps.

True Bearing Computer (Including Amplifier Unit): 10 amperes, single-phase, at 115 volts, 60 cps.

2. SYSTEM INTEGRATION

a. General. - The Lark SP radar equipment is stabilized to facilitate tracking and to permit presentation of data in "true" coordinates. The major differences between the Lark SP system and the Lark SP-1M equipment result from the assemblies added for stabilization.

b. Geometry of System. - The geometry involved in the stabilization is shown on the diagram (figure 4-2), where own ship is taken as the origin. The angles of interest to the Lark SP problem are defined as follows:

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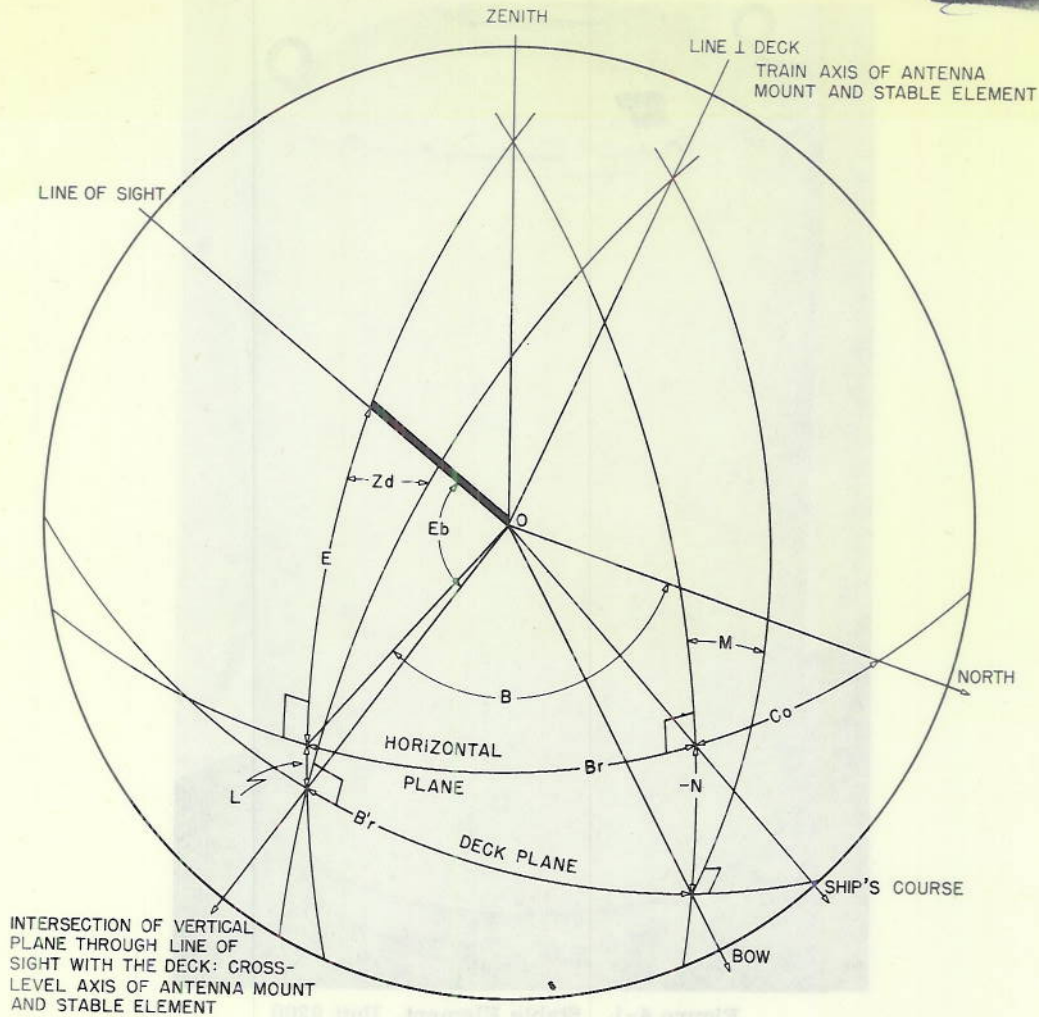


Figure 4-2. Stabilization Geometry

B = True Target Bearing: the angle between a north-south line and the vertical plane through the line of sight, measured in a horizontal plane clockwise from the north. It can be seen from figure 4-2 that

$$B = Br + Co.$$

Br = Relative Target Bearing: the angle between the vertical plane through the fore-and-aft axis of the own ship and the vertical plane through the line of sight, measured in a horizontal plane clockwise from the bow.

B'r = Director Train measured on the deck (stabilized): the angle between the fore-and-aft axis of own ship and the vertical plane through the line of sight, measured in the deck plane clockwise from the bow.

jB'r = Deck Tilt Correction (stabilized): the angle which must be added to director train to give relative target bearing, thus:

$$B'r + jB'r = Br.$$

jB'r does not appear on the diagram, figure 4-2, since it is the arithmetic difference between two angles not in the same plane.

Co = Own Ship Course: the angle between a north-south line and the vertical plane through the fore-and-aft axis of the ship, measured in the horizontal plane.

E = Target Elevation: the angle above the horizontal of the line of sight, measured in the vertical plane through the line of sight.

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E_b = Director Elevation (stabilized): the elevation of the director line of sight above the deck measured in the vertical plane through the line of sight.

L = Level Angle, measured about an axis in the horizontal plane: the angle between the horizontal plane and the deck plane, measured in the vertical plane through the line of sight. (Positive when the deck toward the target is below the horizontal plane.)

M = Roll Angle, measured about an axis in the deck: the angle, measured in the athwartship plane perpendicular to the deck, between its intersection with the horizontal plane and with the deck plane. (Positive when the starboard side of ship is up.)

N = Pitch Angle, measured about a horizontal axis: the angle, measured about the intersection of the horizontal plane with the athwartship plane perpendicular to the deck, between the vertical plane and a plane perpendicular to the deck through this axis. (Positive when the bow of the ship is up.)

Z_d = Cross Level Angle, measured about an axis in the deck: the angle, measured about the intersection of the plane of the deck with the

vertical plane through the line of sight, between the vertical plane and a plane perpendicular to the deck through this axis. (Positive if, when you face the target, the right hand side of the ship is up.)

The antenna mount, its train axis being set perpendicular to the deck plane, trains in the deck plane, measuring angle $B'r$. This quantity is transmitted to the stable element, which also trains in the deck plane, orienting its cross-level axis parallel to the intersection of the vertical plane through the line of sight with the deck. Since the stable element follow-ups maintain the gyroscope gimbal in a true horizontal plane, synchros geared to the two follow-up gimbals will measure the values of Z_d and L in the correct plane. Z_d is transmitted to the antenna mount cross-level servo which maintains the elevation axis of the antenna mount in a horizontal position. Since the elevation axis is horizontal, the antenna mount measures E_b in the vertical plane through the line of sight.

c. Main Train Loop. - The signal flow for the train system is shown in figure 4-3. The main tracking loop is here shown in heavy print. Three modes of operation are provided: hand-crank control, remote control from a telescope unit, and automatic radar tracking. The director

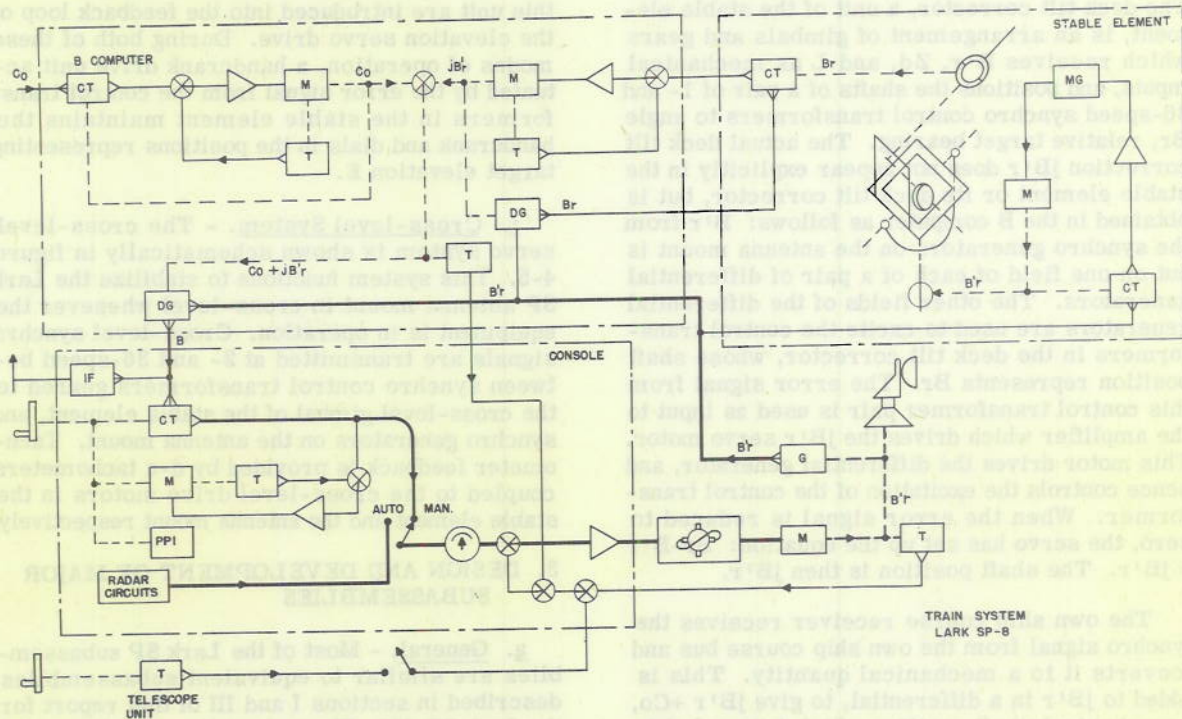


Figure 4-3. Train Servo Loop - Block Diagram

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train angle, $B'r$, is transmitted to the stable element and the true bearing computer at 1- and 36-speed by synchro generators geared to the antenna. Corrections are added to this quantity in one of the differential generators of the B computer, to give a synchro signal representing true bearing. This true bearing signal is transmitted to a pair of synchro control transformers geared to the bearing handcrank and dials of the main console. When handcrank control is to be used, the error signal from this control transformer is applied as the input to the train servo drive. Thus the handcranks may be used to train the director to any desired true bearing without reference on the part of the operator to changes in own ship's course, or effects of roll and pitch.

In automatic radar tracking, the radar error signal is used as the input to the train servo drive in place of the error signal from the control transformers in the main console. In order to indicate the true bearing of the antenna, and to keep the handcranks in synchronism, a handcrank servo drive is provided in the control console. This unit is identical to the handcrank drive of the Lark SP-1M. When operation is by control from a remote telescope unit, the output of the train tachometer on the telescope pedestal is introduced into the feedback loop of the train servo drive of the antenna mount.

d. Deck Tilt and Own Ship Course Correction. - The deck tilt corrector, a unit of the stable element, is an arrangement of gimbals and gears which receives $B'r$, Z_d , and L as mechanical inputs, and positions the shafts of a pair of 1- and 36-speed synchro control transformers to angle B_r , relative target bearing. The actual deck tilt correction $jB'r$ does not appear explicitly in the stable element or its deck tilt corrector, but is obtained in the B computer as follows: $B'r$ from the synchro generators on the antenna mount is put on one field of each of a pair of differential generators. The other fields of the differential generators are used to excite the control transformers in the deck tilt corrector, whose shaft position represents B_r . The error signal from this control transformer pair is used as input to the amplifier which drives the $jB'r$ servo motor. This motor drives the differential generator, and hence controls the excitation of the control transformer. When the error signal is reduced to zero, the servo has set up the equation: $B_r - B'r = jB'r$. The shaft position is then $jB'r$.

The own ship course receiver receives the synchro signal from the own ship course bus and converts it to a mechanical quantity. This is added to $jB'r$ in a differential, to give $jB'r + Co$, a mechanical shaft rotation which is coupled to the shaft of the true bearing differential gener-

ator. The $B'r$ synchro signal from the antenna mount is connected to one field of the true bearing differential generator. Since the rotor of this differential generator is connected to the $jB'r + Co$ shaft, the output is $B'r + jB'r + Co$, or true target bearing, B . Thus:

$$B = B'r + jB'r + Co$$

e. Elevation Loop. - The elevation servo loop is shown schematically in figure 4-4. The three modes of operation discussed for the train loop also apply to the elevation loop. Antenna elevation, E_b , is measured by synchro generators geared to the mount, and transmitted to synchro differential generators located in the PPI unit in the console. Level angle is measured by control transformers in the stable element, also connected to the differential generators in the PPI unit.

When the system is in handcrank control, the error signal from these control transformers serves as input to the elevation servo drive. The diagram indicates the general arrangement of this drive which is identical to that used with the Lark SP-1M as described in section III of this report.

Under automatic radar operation, the radar error signal is the input to the elevation servo drive. When the system is controlled from the telescope unit, elevation tachometer signals from this unit are introduced into the feedback loop of the elevation servo drive. During both of these modes of operation, a handcrank drive unit actuated by the error signal from the control transformers in the stable element maintains the handcrank and dials in the positions representing target elevation E .

f. Cross-level System. - The cross-level servo system is shown schematically in figure 4-5. This system functions to stabilize the Lark SP antenna mount in cross-level whenever the equipment is in operation. Cross-level synchro signals are transmitted at 2- and 36-speed between synchro control transformers geared to the cross-level gimbal of the stable element, and synchro generators on the antenna mount. Tachometer feedback is provided by d-c tachometers coupled to the cross-level drive motors in the stable element and the antenna mount respectively.

3. DESIGN AND DEVELOPMENT OF MAJOR SUBASSEMBLIES

a. General. - Most of the Lark SP subassemblies are similar to equivalent subassemblies described in sections I and III of this report for the Lark SP-1M. The major subassemblies which are significantly different from the Lark SP-1M

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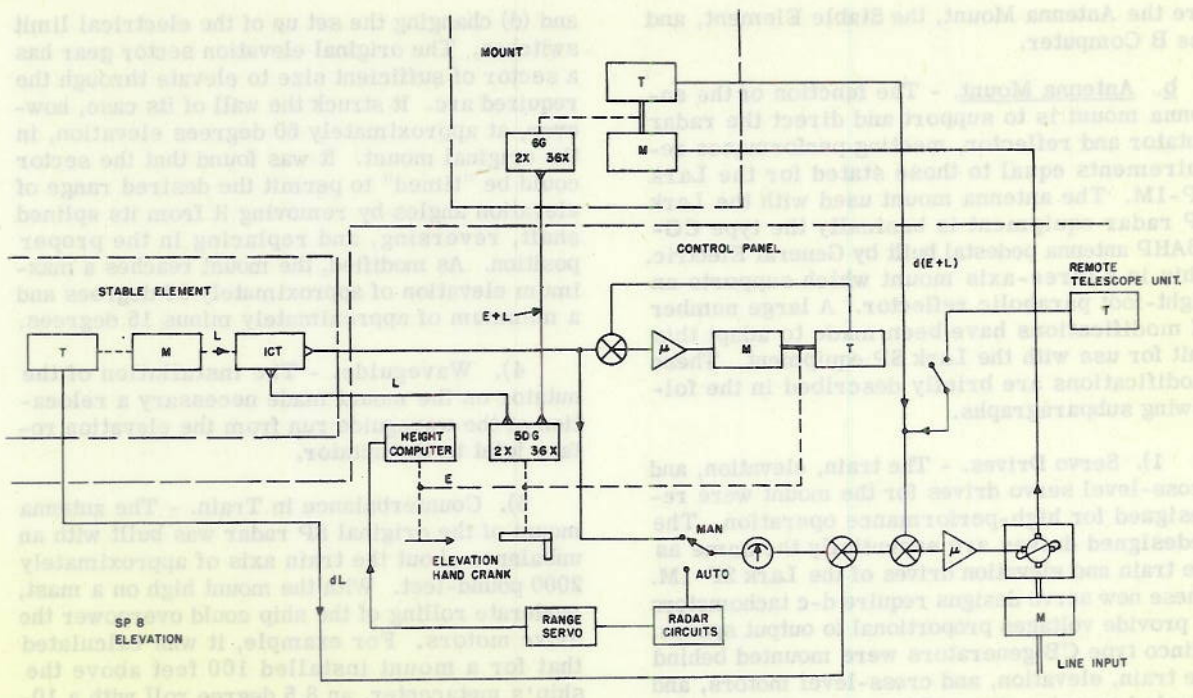


Figure 4-4. Elevation Servo Loop - Block Diagram

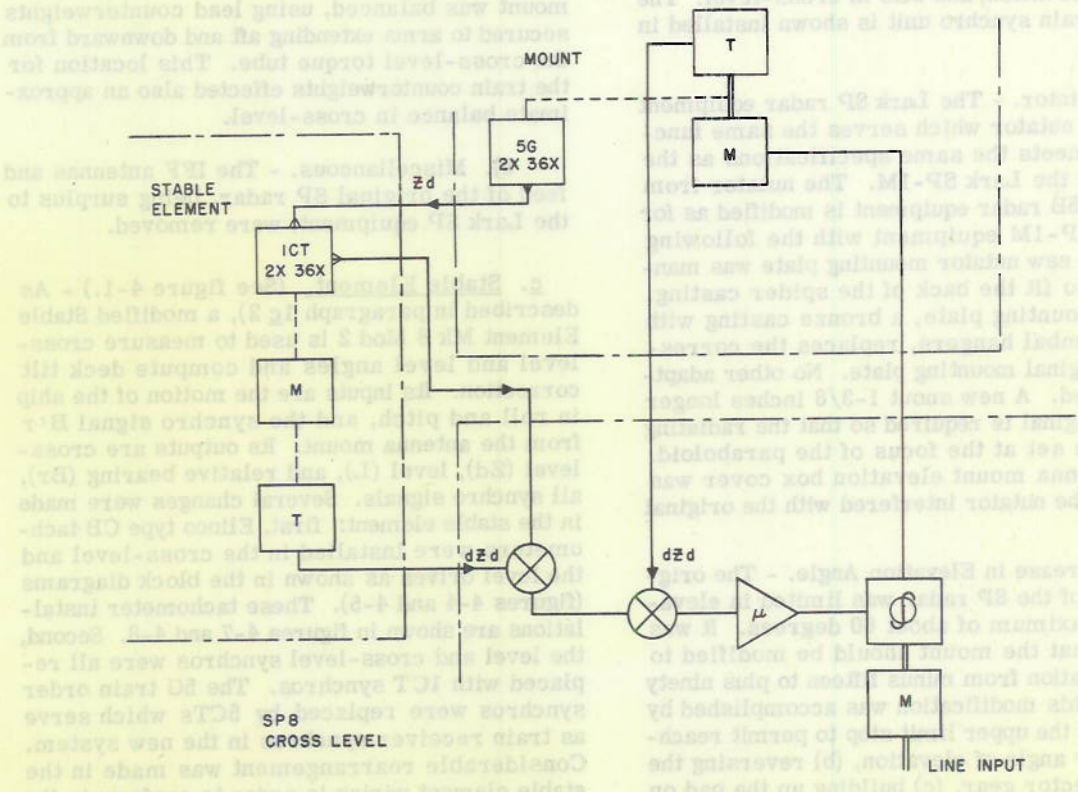


Figure 4-5. Cross-level Servo Loop - Block Diagram

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are the Antenna Mount, the Stable Element, and the B Computer.

b. Antenna Mount. - The function of the antenna mount is to support and direct the radar nutator and reflector, meeting performance requirements equal to those stated for the Lark SP-1M. The antenna mount used with the Lark SP radar equipment is basically the type CG-66AHP antenna pedestal built by General Electric. This is a three-axis mount which supports an eight-foot parabolic reflector. A large number of modifications have been made to adapt this unit for use with the Lark SP equipment. These modifications are briefly described in the following subparagraphs.

1). Servo Drives. - The train, elevation, and cross-level servo drives for the mount were redesigned for high-performance operation. The redesigned drives are essentially the same as the train and elevation drives of the Lark SP-1M. These new servo designs require d-c tachometers to provide voltages proportional to output speeds. Elinco type CB generators were mounted behind the train, elevation, and cross-level motors, and coupled to extensions of the respective motor shafts by bellows couplings. The 5CT synchros in the mount were replaced with 6G synchros in train and elevation, and 5Gs in cross-level. The modified train synchro unit is shown installed in figure 4-6.

2). Nutator. - The Lark SP radar equipment requires a nutator which serves the same functions and meets the same specifications as the nutator for the Lark SP-1M. The nutator from the SCR-615B radar equipment is modified as for the Lark SP-1M equipment with the following changes: a new nutator mounting plate was manufactured to fit the back of the spider casting. The new mounting plate, a bronze casting with integral gimbals, replaces the corresponding original mounting plate. No other adapters are used. A new snout 1-3/8 inches longer than the original is required so that the radiating dipoles are set at the focus of the paraboloid. A new antenna mount elevation box cover was cast since the nutator interfered with the original cover.

3). Increase in Elevation Angle. - The original mount of the SP radar was limited in elevation to a maximum of about 60 degrees. It was specified that the mount should be modified to permit elevation from minus fifteen to plus ninety degrees. This modification was accomplished by (a) changing the upper limit stop to permit reaching a higher angle of elevation, (b) reversing the elevation sector gear, (c) building up the pad on the spider which strikes the lower limit stop,

and (d) changing the set up of the electrical limit switches. The original elevation sector gear has a sector of sufficient size to elevate through the required arc. It struck the wall of its case, however, at approximately 60 degrees elevation, in the original mount. It was found that the sector could be "timed" to permit the desired range of elevation angles by removing it from its splined shaft, reversing, and replacing in the proper position. As modified, the mount reaches a maximum elevation of approximately 90 degrees and a minimum of approximately minus 15 degrees.

4). Waveguide. - The installation of the nutator on the mount made necessary a relocation of the waveguide run from the elevation rotary joint to the nutator.

5). Counterbalance in Train. - The antenna mount of the original SP radar was built with an unbalance about the train axis of approximately 2000 pound-feet. With the mount high on a mast, moderate rolling of the ship could overpower the drive motors. For example, it was calculated that for a mount installed 100 feet above the ship's metacenter, an 8.5 degree roll with a 10-second period is the maximum tolerable. The other modifications mentioned have little effect on this unbalance. For the Lark SP system the mount was balanced, using lead counterweights secured to arms extending aft and downward from the cross-level torque tube. This location for the train counterweights effected also an approximate balance in cross-level.

6). Miscellaneous. - The IFF antennas and feed of the original SP radar, being surplus to the Lark SP equipment, were removed.

c. Stable Element. (See figure 4-1.) - As described in paragraph 1c 2), a modified Stable Element Mk 8 Mod 2 is used to measure cross-level and level angles and compute deck tilt correction. Its inputs are the motion of the ship in roll and pitch, and the synchro signal B'r from the antenna mount. Its outputs are cross-level (Zd), level (L), and relative bearing (Br), all synchro signals. Several changes were made in the stable element: first, Elinco type CB tachometers were installed in the cross-level and the level drives as shown in the block diagrams (figures 4-4 and 4-5). These tachometer installations are shown in figures 4-7 and 4-8. Second, the level and cross-level synchros were all replaced with 1CT synchros. The 5G train order synchros were replaced by 5CTs which serve as train receiver synchros in the new system. Considerable rearrangement was made in the stable element wiring in order to conform to the changed method of operation.

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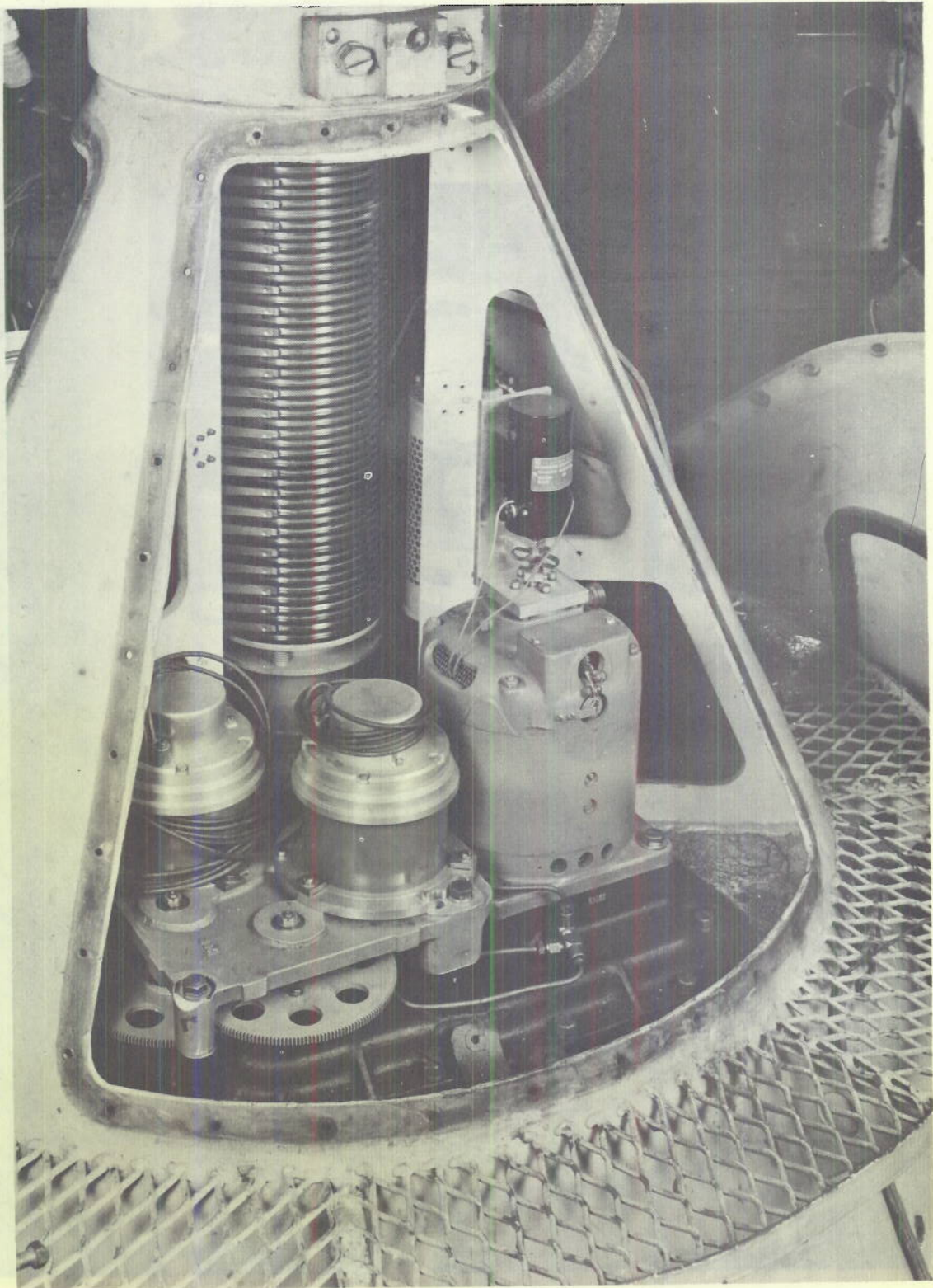


Figure 4-6. Train Synchro Unit Installation

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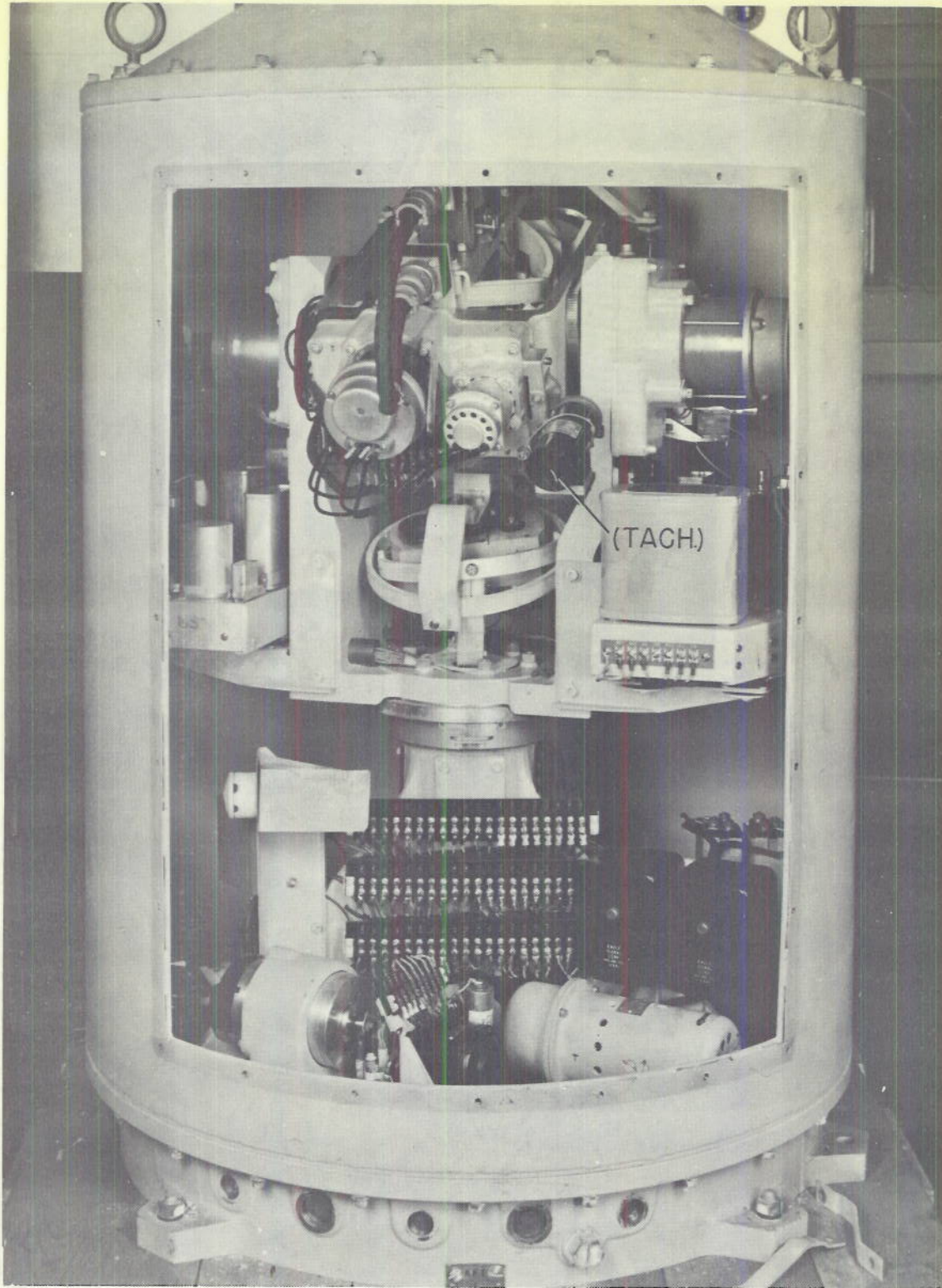


Figure 4-7. Stable Element-Level Tachometer Installation

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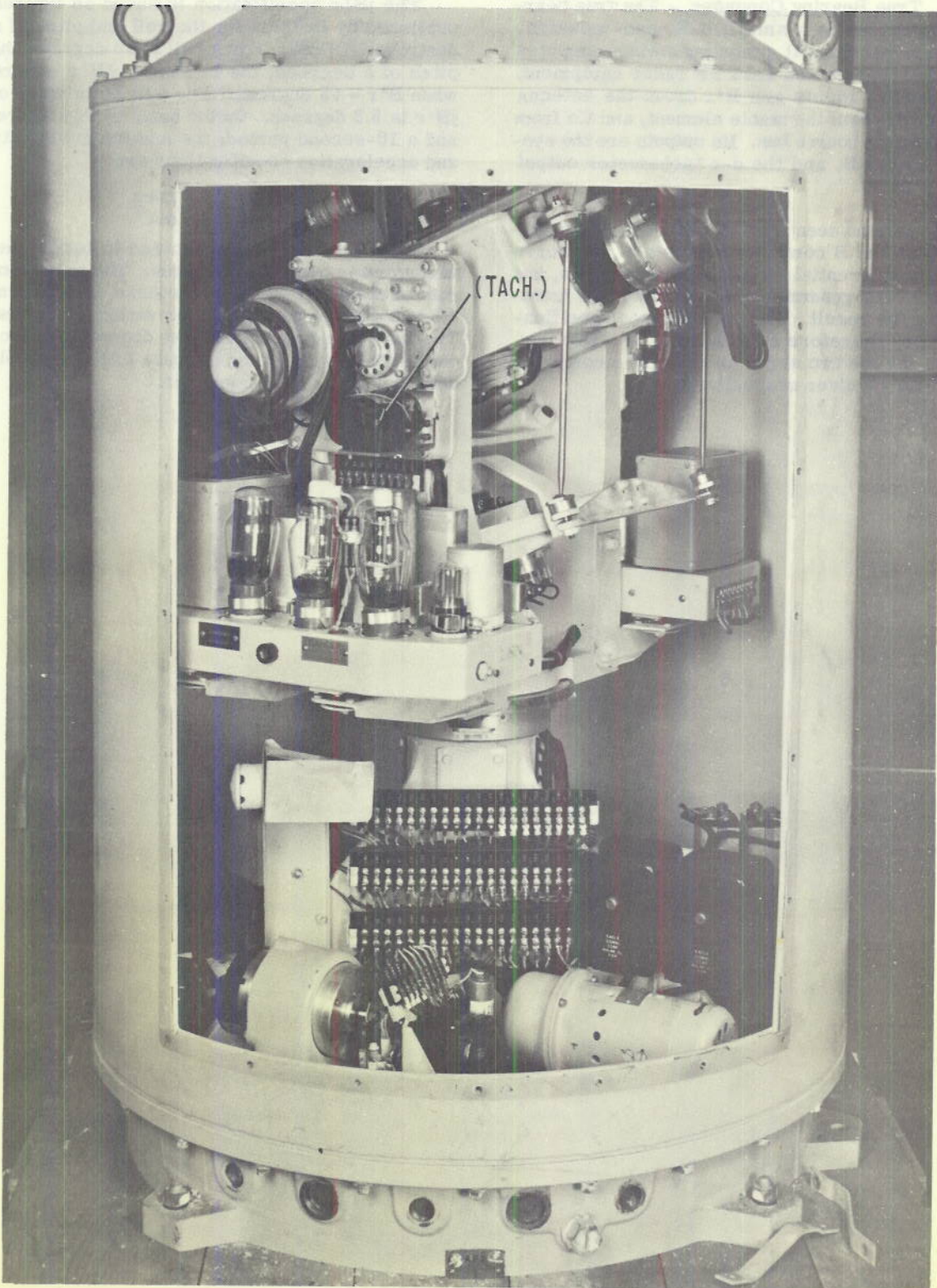


Figure 4-8. Stable Element-Cross-Level Tachometer Installation

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d. True Bearing Computer. - The true bearing computer is a small, bulkhead-mounted, electro-mechanical computer which computes true bearing for the Lark SP radar equipment. Its synchro inputs are B'r from the antenna mount, Br from the stable element, and Co from the own ship course bus. Its outputs are the synchro signal B, and the d-c tachometer output d(Co + jB'r).

As may be seen from the block diagram (figure 4-3), the B computer consists of two servo units, a differential for adding their outputs, and a differential generator and tachometer for transmitting the result. The performance specifications are therefore expressed as the requirements for the two servo units, a jB'r computer and a Co receiver respectively.

The jB'r specification is based on figures published by BuShips for the roll and pitch of a destroyer, DD692. For a roll of 30 degrees and pitch of 5 degrees, the maximum jB'r occurs when B'r = 45 degrees. The maximum value of jB'r is 5.3 degrees. On the basis of this figure, and a 10-second period, the maximum velocity and acceleration specifications are:

$$\begin{aligned}\theta'_{\max} &= 3.33^{\circ}/\text{sec}, \\ \theta''_{\max} &= 2.1^{\circ}/\text{sec}^2.\end{aligned}$$

The Co receiver is required to follow the variations in own ship's course. The maximum rate of change of own ship's course varies from 1.5 to 2 degrees per second for various warships. The unit was designed for three degrees per second so that gearing could be made interchangeable with that of the jB'r computer.

Figure 4-3. Block Diagram - Course Level Tachometer Installation

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SECTION V

SYSTEM INSTALLATION, ADJUSTMENT, AND OPERATION

Subsection 5-1. Installation and Take-down Procedures

1. SELECTION OF RADAR SITE

For beam-rider flight tests, the radar equipment should be placed as close as possible to the missile launcher to minimize the range at which control can commence; however, the minimum range is limited by the following conditions:

a. Since it may be necessary to track the missile optically during the launching period, the site must be far enough from the launcher so that the booster smoke will not obscure the missile for the first few seconds of flight. Launching photography shows that this problem is not serious if the radar is at least 150 yards behind the launcher and 150 yards upwind.

b. To keep the launcher beyond the transmitter pulse recovery area, the radar should be located at least 200 yards behind the launcher.

c. Because of the possibility of missile explosion on the launcher, the radar should not be located closer than 150 yards to the launcher to insure protection against fragments and corrosive fuel. At less than 500 yards, equipment and operators should be protected by barricades. Beyond 500 yards, protective cover will be unnecessary.

d. The tracking of the missile by the radar during the launching phase imposes the most stringent limits on the radar-to-launcher distance. The error angle in tracking must be kept below the angle at which 100 percent modulation of the beam occurs. This angle should be kept below 1.25 degrees. The error expression is:

$$\epsilon = \frac{\dot{\theta}}{100} + \frac{\ddot{\theta}}{10}$$

Studies of the variation of the elevation angle of the radar beam at various ranges show that the maximum error during launching versus the distance to the launcher is as follows:

Range (Yards)	Maximum Error (Degrees)
100.....	3.75
200.....	2.10
250.....	1.50
300.....	1.25

Therefore the tracking capabilities of the radar limit the minimum range from radar to launcher to 300 yards.

e. The beam-rider receiver crystal is not protected against signals of the strength emitted by the Lark SP-1M at short range. The minimum distance between the beam-rider receiver and radar must therefore be restricted. Since the beam-rider receiver is in the "receive" position while the missile is on the launcher, the minimum distance from radar to launcher must be 600 yards.

f. If the missile is tracked optically during the booster phase of the launching, the Lark SP-1M must be placed at a distance that will enable the telescope operator to keep the missile in the field of view of the optics during the period of high missile accelerations without relying upon a high order of manual tracking skill. If the equipment is located at a point where the missile would still be in the field of view of the telescope at booster separation even with no movement of the optics, a reasonable amount of optical tracking error can be tolerated while attempting capture. Assuming the launching angle of the Lark missile to be 30 degrees and the booster phase until separation to be approximately two seconds along a normal trajectory, the missile will reach an altitude of 385 feet at a horizontal range of 225 yards from the launcher: the telescope unit has an optical system subtending a field of view of 8 degrees or 385 feet at 925 yards. Since the desired field of view to be observed is located 225 yards ahead of the launcher, it will be necessary to position the optical system 700 yards to the rear of the launcher. This distance of 700 yards, therefore, dictates the minimum range between the Lark SP-1M and the launcher. (See figure 5-1.)

g. The line of sight from the radar to the launcher should be over level ground and, as far as practicable, be free from buildings, telephone poles, and all reflecting surfaces over an area 30 degrees in bearing on either side of the line of sight. This will minimize the tracking problem during the launching phase.

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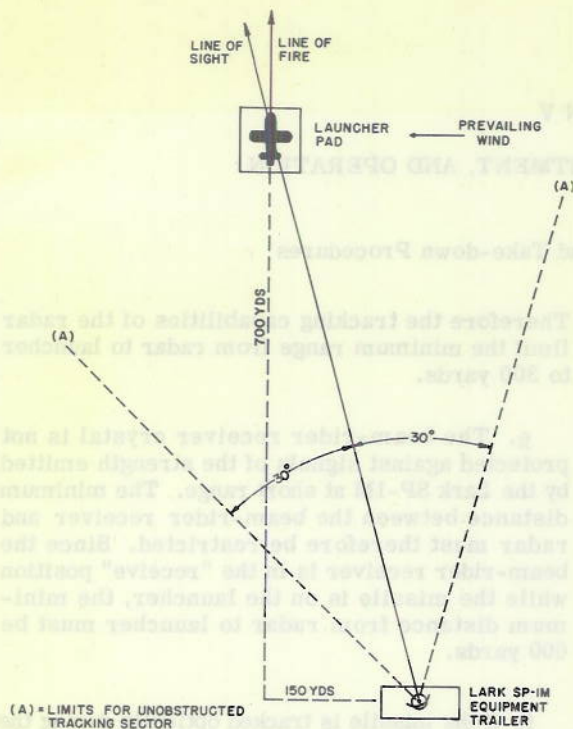


Figure 5-1. Location of Lark SP-1M at Field Site

h. The radar site should be at the same elevation as the launcher to permit tracking of the missile to low angles of elevation.

2. PREPARATION OF SITE

Figure 5-2 shows the exact field arrangement of all units of the Lark SP-1M. The operations and equipment trailers are supported by a 40- by 65-foot concrete platform capable of sustaining 1800 pounds per square foot. The remaining units are located on a hard black top surface. The operations and equipment trailers are situated to minimize the parallax between the optical handstand and the radar antenna in the sector used for missile tracking and guidance. The location of the other units is optional, but the position indicated should provide the greatest convenience and access.

The purpose of the concrete pad and the hard surface is to maintain the level of the operations and equipment trailers, to insure accurate positional data from the antenna, provide level positions for rotating machinery in all units that are not stabilized, provide a level altitude for all floors and bench spaces in non-stabilized units,

and present a surface that can be kept relatively free from the sand, dirt, and trash which normally accompany a field installation.

3. SETTING-UP PROCEDURE

After the trailers and vehicles have been placed, the following setting-up procedure will minimize time and effort:

a. Initial Preparation.

1). Set hand brakes on all trailers and vehicles.

2). Open all doors and tailgates of trailers. Uncover all ventilation openings, especially the door and louver on either side of the equipment trailer compartment containing the gasoline alternator.

3). Open the roof hatch on the power van and install the gasoline alternator muffler pipe.

b. Cabling Installation. - Remove all cables that are needed to interconnect the equipment and operations trailers from the cable reel. (See figure 5-3 for cable panel jacks and the corresponding interconnecting cables.) In order to protect the small pins in the cable connectors and clamping ring from dirt and breakage, unreel the cables only as fast as they can be connected. Do not permit the end of any cable to drag. Cable markers on the cable correspond to the cable number on the cable panel. Pass the cable behind the front wheel dolly, under the equipment trailer, and attach to the equipment trailer cable panel. Be sure the keys and slots on the connectors are aligned before they are attached to the cable panel; otherwise, either the pins will be bent, broken, shorted, or the receptacle in the cable panel will be pushed in. Care must be exercised in this operation as there will be no indication of breakage until power is applied.

Run the cables neatly between the trailers and take up the slack in a large loop running under the operations trailer. To prevent wear of all cables and crushing of coaxial cable, protect exposed cables with planking. Remove the three-conductor power cable (cable 28) from the power van and connect between the three terminals on the power unit and equipment trailer cable panels. The numbers of the cable terminals must correspond with the numbers on the cable panels to maintain correct phase rotation of the main power. Run out cables to the timing truck, telemetering equipment, and communications lines to remote stations. The cable panel for telephone lines is found in the reel compartment of the operations trailer.

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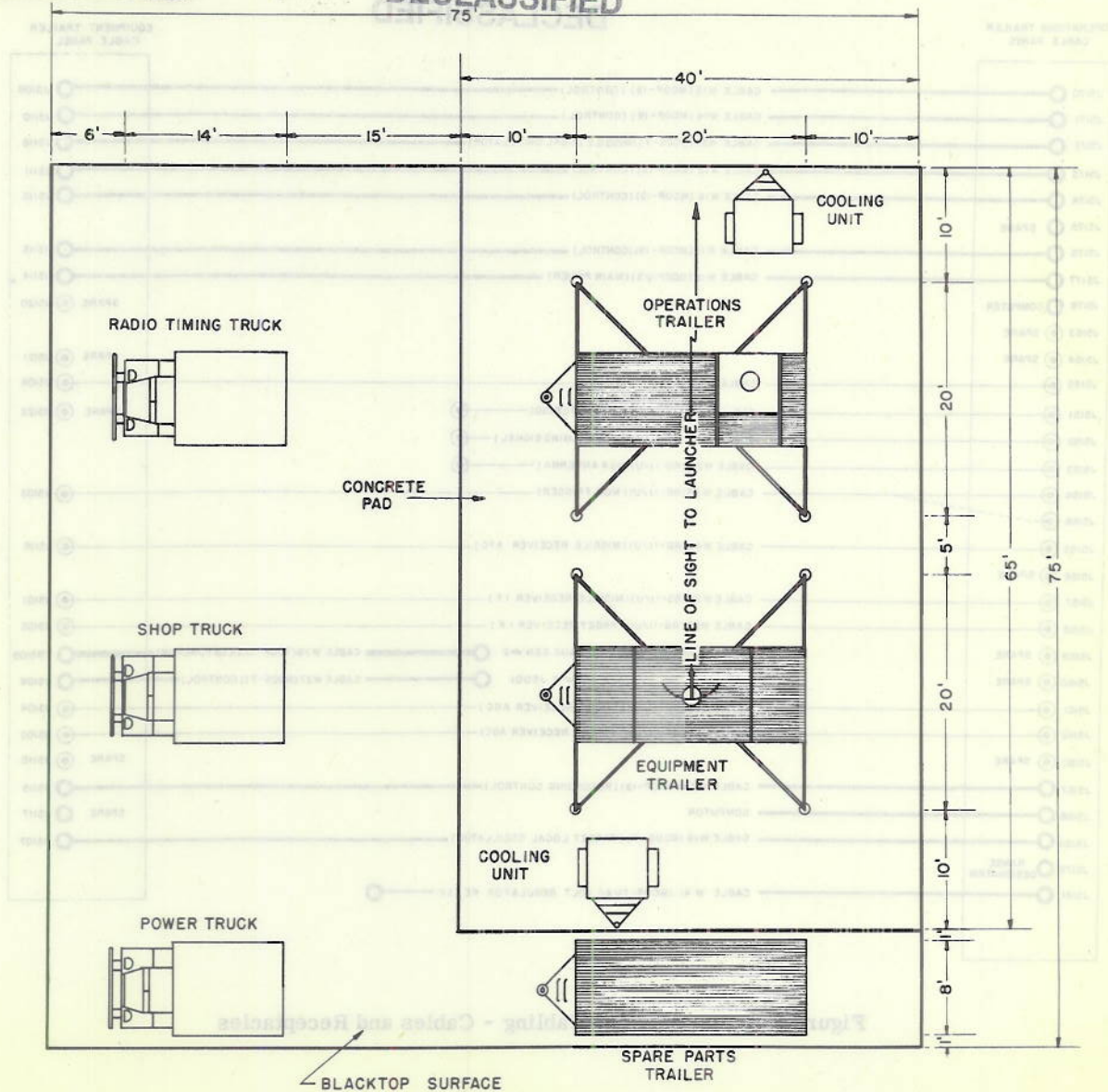


Figure 5-2. Arrangement of Lark SP-1M Units on Concrete Pad

c. **Grounding the Equipment.** - Ground the equipment, operations, and auxiliary trailers with the ground stakes. If ground is not too hard, drive the stake in with the eight-pound mason's hammer; in rocky ground or on a rock, drill a small hole with the rock drills, insert the ground stake, and tamp it tightly with chips, earth, etc. Bolt the lug end of each grounding cable fast to the grounding terminal on the trailer.

d. **Trailer Stabilization.** - Remove the stabilizers from the tunnel compartment in the opera-

tions trailer and from the roof of the spare parts trailer. One set of outriggers is to be used with the operations trailer and the other set with the equipment trailer. One set of stabilizer jacks is stowed in the equipment trailer and the other set in the spare parts trailer. Erect the stabilizers and stabilizer jacks on both trailers as shown in figure 5-4. The diagonal corners are interchangeable. Attach each stabilizer to the upper clevis first and then to the lower clevis for ease of handling. The stabilizer jacks should be placed under the stabilizer and brought up snugly by hand

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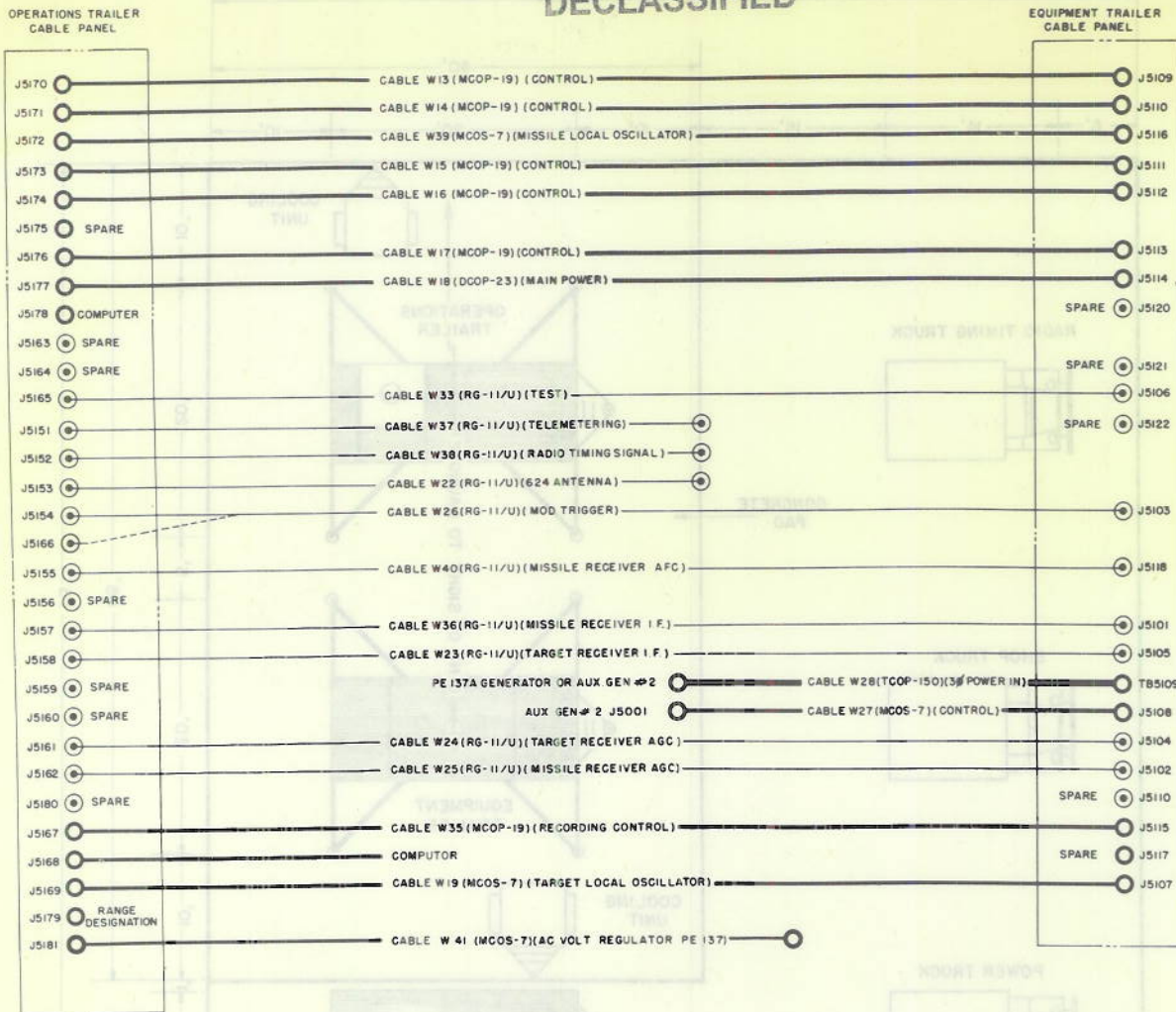


Figure 5-3. Intertrailer Cabling - Cables and Receptacles

to fit in the sockets on each stabilizer. The 10-inch carpenter's level found in the work bench of the equipment trailer is used on the deck of the trailer to check the level. Since each trailer weighs about twelve tons, leveling must be an orderly operation; otherwise the trailer may be badly twisted. With the jacks, raise each corner one revolution at a time, going from one corner to another until the trailer load is completely removed from the wheel suspension. Trim the elevation of each jack until the level indicates that the floors of the trailer are level lengthwise and crosswise. Remove the two rear stiffeners from the tunnel compartment of the equipment trailer. Place the rear stiffeners and timbers under the rear cross member of the equipment trailer as

shown in figure 5-5. Remove the two front jacks and shoes from the spare parts trailer and attach to the clevises behind the front dolly of the equipment trailer as shown in figure 5-6. Lower the rear stabilizer jacks one revolution at a time until the trailer load is evenly distributed between the rear stiffeners and the rear stabilizer jacks. Lower the front stabilizer jacks until the trailer returns to a level position, and then insert bars in the forward stiffeners and tighten until the load is distributed between the front stabilizer jacks and the front bench jack. Turn down all lock nuts on the stabilizer jacks on both trailers.

e. Installation of Power Sources. - The Lark SP-1M operates on 115-volt, 60-cycle, three-

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Figure 5-4. Stabilizer and Stabilizer Jack



Figure 5-5. Rear Stiffeners and Timbers Under Rear Crossmember of Equipment Trailer

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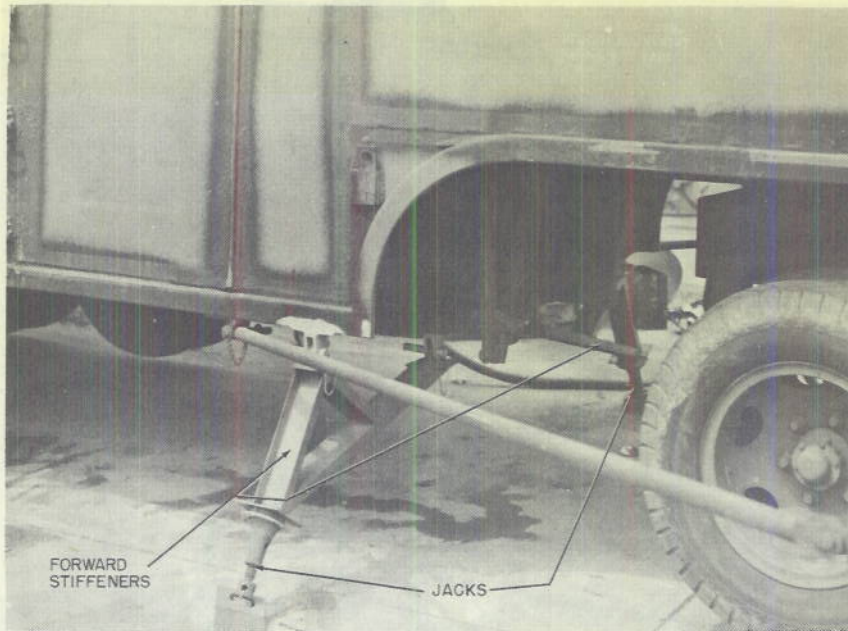


Figure 5-6. Forward Stiffeners Under Equipment Trailer

phase power and has a total power consumption of approximately 15 kilowatts. Power can be provided from three sources: the main generator, Power Unit PE137; the standby generator, Gasoline Engine A-c Generator Navy Type CAJG-73029; and line power. The power must be regulated to maintain the voltage to plus or minus one volt and the frequency to plus or minus one quarter of a cycle under full load conditions. Power from the main generator or from the line is connected externally. The standby power is introduced internally. Complete instructions for the preparation and operation of the two motor generator sets can be found in the following publications:

PE-137A 25 Kw Gasoline Engine A-c Generator: TM 11-921.
Navy Type CAJG-73029 15 Kw Gasoline Engine A-c Generator: SP-1M Instruction Book.

Switch the power selector switch, S4901, and the generator selector switch, S4902, to the ON position. Keep all circuit breakers on the Power Distribution Unit, Unit 4900, in the OFF position. Close the circuit breaker on Power Unit PE137 and allow the unit to warm up for 15 minutes. If it is necessary to use the standby generator, press the start button of generator No. 1 on the power distribution unit. When the green warning light indicates, power is available to the board.

f. Antenna Installation. - While the engine is warming up, the antenna is raised in the following manner:

- 1). Remove the aluminum ladder from the spare parts trailer and hang it on the eyes at the rear edge of the equipment trailer roof.
- 2). Remove the guard rails from the spare parts trailer and drop them in the sockets around the roof of the equipment trailer.
- 3). Unlash the roof tarpaulin, roll it back and lash it down.
- 4). Remove the wooden transportation cover over the antenna and stow on the ground out of the way.
- 5). Remove all four stowing nuts which hold down the elevator while in transit, and place all four in sockets provided on the elevator. The elevator is so interlocked that this must be done prior to any attempts to raise it.
- 6). Check clearance between pedestal and elevator. The distance should be one inch all around the base of the pedestal.
- 7). Before applying power to drive the elevator motor, switch the antenna pedestal safety switch to SAFE.

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8). Close the breaker on the power distribution unit marked ANTENNA CONT., switch S4910.

9). With all four nuts placed in the sockets, the roof opening clear, and the RESET control on the antenna control unit in the RESET position, press and hold the RAISE button on the antenna control unit. Watch the antenna carefully for possible interferences while rising.

10). The elevator will stop within a fraction of an inch of the maximum rise. Remove the stowing nuts from their sockets and spin each on a top-stowing lug which protrudes through the elevator platform. Work from corner to corner around the elevator taking up the gap evenly. Tighten each unit without resorting to an extension bar.

11). Remove the two roof sections from the spare parts trailer and secure them over the roof openings on either side of the elevator.

12). Unroll the tarpaulin at the base of the pedestal and lash down.

13). Remove the two sections of roof grating from the spare parts trailer and place around the base of the pedestal. When the two sections are in place, fasten the grating together with the hooks and eyes at each end.

14). Level the antenna assembly by the adjusting screws at the base of the pedestal, using the 10-inch carpenter's level as a reference on the right-angle slots of the level plate on the elevation synchro housing unit. Work the adjusting screws in opposite pairs until the bubble is centered with the level in either slot of the level plate. Then tighten the locking nuts and recheck. Slight readjustments may be necessary. Make these adjustments carefully as all positional information transmitted by the antenna is referenced to the horizontal plane established by the leveling procedure.

15). Remove the nutator snout from the spare parts trailer. Remove the protective covering on the front of the nutator and screw on the nutator snout with the wide dimension of the waveguide cross-section horizontal and the serial number up. Tighten the screws.

16). Stowed on the floor in front of the modulator unit is a yellow section of waveguide. Insert and secure this section in the space between the guide coming from the transmitter and the guide under the antenna pedestal.

17). Turn the train locking handwheel counterclockwise until it stops. Because of the new ele-

vation stowing angle of the antenna with the modified nutator from the SCR-615B, the elevation stowing interlock can no longer be used; however, check to see that the elevation locking handwheel is turned fully counterclockwise to clear the plunger from the mount.

g. Telescope Installation. - Remove the telescope unit transportation cover from the roof of the operations trailer and stow on the ground. Remove one observation dome and canvas hood from the dome box and install on the bolt circle around the telescope hatch. Handle the dome carefully to prevent scratching. Place the hood over the dome with the felt lining toward the dome. Install the slewing handle and slew sight on the telescope. Remove the three clamps on the telescope leveling ring and the transportation blocks from under the telescope.

The telescope pedestal is now resting on the leveling lugs and the leveling procedure can commence. Arbitrarily assign the numbers 1, 2, and 3 to the three adjusting screws on the telescope mounting ring. Rotate the head of the telescope until the axis of the spirit level on the head is perpendicular to the axis through the No. 1 and No. 2 adjusting screws. Work adjusting screw No. 3 until the bubble indicates level. Rotate the head of the telescope 90 degrees until the axis of the spirit level is parallel to the axis through the No. 1 and No. 2 adjusting screws. Work adjusting screws No. 1 and No. 2 in equal and opposite directions until the bubble indicates level. This procedure should be repeated to recheck the level. Tighten down the three adjusting screw clamps. Slight readjustments may be necessary to correct the level as a result of changes introduced during the clamping. Completion of this operation collimates the vertical axes of the antenna pedestal and the telescope unit.

h. Installation of Radio Equipment. - Remove the antenna mast for the SCR-624A radio equipment from the tunnel of the operations trailer and erect in accordance with instructions in the SCR-624A instruction book. Suspend the antenna for the TCS-12 radio equipment from the top of the mast to the insulator provided on the operations trailer. The mast should also be located to the rear and right of the concrete pad by about 100 feet to prevent the TCS-12 antenna wire from fouling the radar antenna. Locating the antenna to the rear prevents interference by the mast with optical viewing of the guidance sector of the firing range.

i. Dehumidifier Units. - If the climate requires the use of the dehumidifier units, park them as close as possible to the duct outlets in the sides of the operations and equipment trail-

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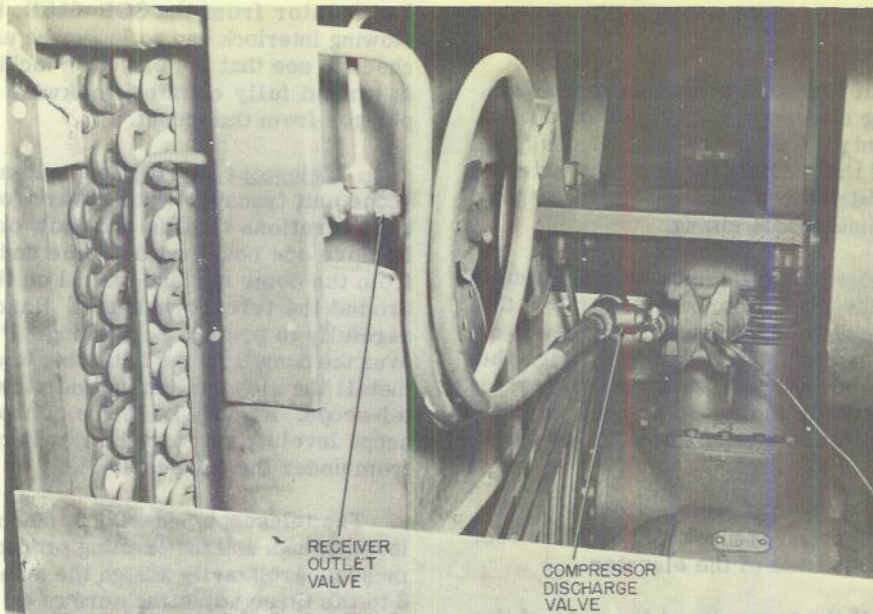


Figure 5-7. Dehumidifier Unit - Showing Receiver Outlet Valve and Compressor Discharge Valve

ers. Set the hand brakes on the dehumidifier trailers. Connect the ducts for air discharge and air return to the unit. The ducts are stowed in the box on the front of the dehumidifier trailer. Next open the front and rear top doors, remove the seal caps and open the receiver outlet valve and compressor discharge valve. (See figure 5-7.) Remove the supply line from the box on the trailer and connect it to the 115-volt three-phase or 230-volt three-phase supply.

j. Heaters. - Use of the heaters in the operations and equipment trailers will be determined by climatic conditions. Refer to the SP-1M instruction book for operating instructions.

k. Data Recording Equipment. - Most of the data recording equipment is located in a wooden-framework, plywood-covered structure located in the operations trailer, opposite the side entrance. (See figures 1-47 and 1-48.) There are three shelves to house the following equipment:

- 1). The dial box and its camera on the top shelf.
- 2). The remote range indicator, the time comparator, the commutator, the remote range indicator camera, and the time comparator camera on the second shelf.

- 3). The camera control unit on the bottom shelf.

All cameras and the camera control unit are located at the forward end of the shelves. The compartments containing cameras are light tight. The compartment which houses the dial box is painted white to insure adequate lighting from three photofloods (type R2) on the dial box face. Any additional space in the compartments is used to store film, spare parts for the data recording equipment, tools, etc.

- 4). Mount the two tracking cameras on the adjustable mounts attached to the framework which supports the radar antenna and paraboloid reflector. (See figure 5-8.) The main tracking camera mount is located to the right and above the antenna axis, behind the reflector, and the auxiliary tracking camera mount is above the antenna nutator behind the reflector.

4. TAKE-DOWN PROCEDURE

When it becomes necessary to relocate the ground station at other firing ranges, the following take-down procedure should be used:

- a. Antenna Take-down. - Stow the antenna assembly in the following manner:

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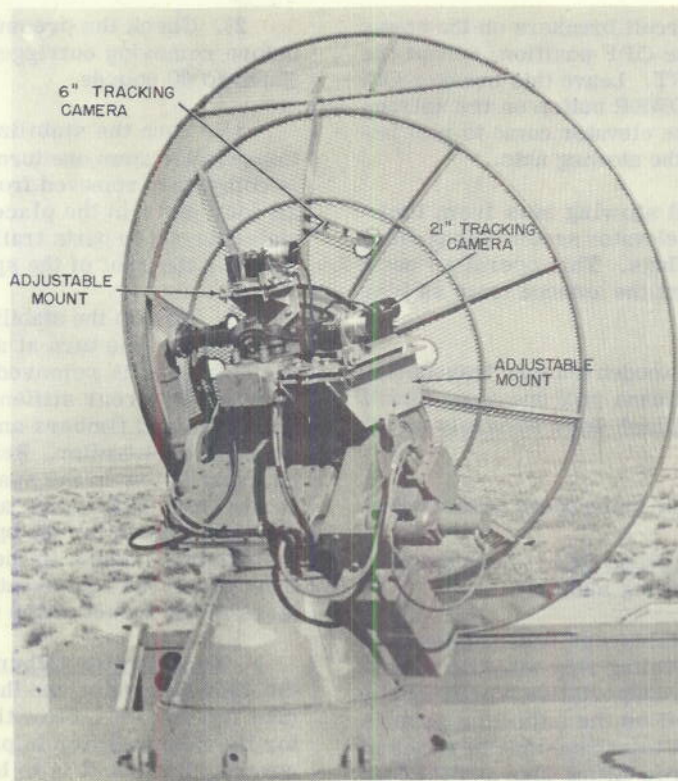


Figure 5-8. Tracking Cameras on Antenna

- 1). Turn the antenna to point along the fore-and-aft axis of the trailer. Remove the nutator snout, the tracking camera unit, and the antenna dish extensions and stow in the spare parts trailer. Select a convenient angle of elevation for removal of these parts, but keep the pedestal safety switch in the SAFE position while working on the antenna.
- 2). Remove the guard rails and roof grating from the equipment trailer and stow in the spare parts trailer.
- 3). Work the adjusting screws until the clearance between the pedestal and elevator is one inch all around.
- 4). Unlash the tarpaulin and roll it about the base of the pedestal, folding each side toward the center. Lash the roll to the base to prevent fouling while the elevator is lowered.
- 5). Put the pedestal safety switch in the RUN position and turn the train handwheel until the dish is over the curbside of the trailer and the axis of the trunnions is parallel to the fore-and-aft axis of the trailer. Move the elevation handwheel until the antenna dish runs into the upper elevation stops. Throw the pedestal switch to SAFE.
- 6). Turn the ON-OFF controls on the modulator and transmitter to OFF. Remove the waveguide section below the elevator and stow in front of the modulator.
- 7). Turn the train locking handwheel fully clockwise and turn the radar off at the console by operating the EQUIPMENT STOP button.
- 8). Unfasten the removable roof sections and stow in the spare parts trailer.
- 9). Unfasten the stowing nuts which hold the elevator in the elevated position. Do not remove nuts individually, because the weight of the elevator would then be supported on only a part of the structure. Work around the elevator, loosening each nut the same amount, approximately a half-turn at a time. The nuts will spin off easily when the load is carried on the elevator cables. Place all four nuts in the sockets on the elevator.
- 10). Clear the elevator well of all equipment, tools, and dirt. Inspect elevator cables and check to see they are started properly on drums.

11). Throw all circuit breakers on the power distribution unit to the OFF position; except the one marked ANT. CONT. Leave this breaker ON. Press and hold the LOWER button on the antenna control unit, and let the elevator come to rest before removing any of the stowing nuts.

12). Remove all stowing nuts from their sockets and fasten the elevator securely in position to the lower-stowing lugs. This operation must be completed to prevent the antenna from shifting during transit.

13). Replace the wooden antenna transportation cover over the antenna roof opening. Unroll the roof tarpaulin and lash down securely on all sides.

14). Stow the ladder in the spare parts trailer.

b. Stowing the Telescope Unit. - Stow the telescope unit in the following manner:

1). Remove the telescope base clamps and raise the telescope leveling ring with the adjusting screws until the transportation blocks can be put in place. Back off on the adjusting screws until the weight of the telescope unit is relieved from the adjusting screw lifting lugs and the load is fully supported by the transportation blocks. Insert bolts through the leveling ring and transportation blocks and fasten to the cross bracket. Tighten with a wrench.

2). Remove the slew sight from the telescope unit; remove and stow the telescope dome, and replace the telescope transportation cover on the telescope hatch. Block up the telescope rotating head to the transportation cover to prevent movement during transit.

c. Disconnecting the Cables. - At the power distribution unit, turn all circuit breakers to OFF, then stop the power supply.

1). Disconnect the interconnecting cables one at a time from the equipment and operations trailers and roll immediately on the cable reel. In the process of winding cables, inspect them for breaks or tears. Attach the end connector of one cable to that of the next with the rope supplied, tying the two with half-hitches. Do not drop the connectors; keep off ground, and free from dirt.

2). Disconnect the main power cable from the equipment trailer and the power unit and stow in power van.

d. Dismantling the Stabilization Equipment.

1). Lift all ground stakes and stow in trailers.

2). Check the pressure of the trailer tires before removing outriggers. Tires must be inflated to 60 pounds.

3). Turn the stabilizer jacks on the operations trailer down one turn at a time until the load is completely removed from the stabilizers. Bolt all four jacks in the place provided on the front end of the spare parts trailer, and stow the stabilizers on the roof of the spare parts trailer.

4). Turn up the stabilizer jacks on the equipment trailer one turn at a time, until the weight of the trailer is removed from the front bench jacks and the rear stiffeners. Remove the rear stiffeners and timbers and stow in the tunnel of the equipment trailer. Remove the forward stiffeners and stow in the spare parts trailer. Now remove the stabilizers and stabilizer jacks as described above for the operations trailer. Stow the stabilizer jacks in the place provided in the front end of the equipment trailer and the stabilizers in the tunnel of the operations trailer.

e. Securing the Dehumidifier Units. - Close the discharge valve and the receiver outlet valve. (See figure 5-7.) Stow the air duct and cables for the dehumidifier in parts boxes and secure covers. If the unit is to be shut down for an extended period of time, use the following procedure:

1). Remove the low-pressure gauge from the tool box and attach it to the connection provided in the suction line. (See figure 5-9.)

2). Close the receiver outlet valve at the top of the receiver.

3). Start the compressor and run it until all of the refrigerant is pumped out of the evaporator coil and the pressure on the gauge shows one to two pounds.

4). Turn off the power and, when the compressor stops rotating, close the valve in the compressor discharge line.

5). Remove the gauge and replace it in the tool box.

f. Securing the Radio Equipment. - Dismantle the antenna of the SCR-624A radio equipment in accordance with the instruction book for that equipment and stow in the operations trailer tunnel. Reel in the antenna for the TCS-12 equipment and stow in the spare parts trailer.

g. Securing the Power Supplies. - Remove the muffler from the exhaust manifold on the PE137 generator and secure in the power truck. Close the exhaust hatch, take up the ladder, and secure the doors and cable panel opening.

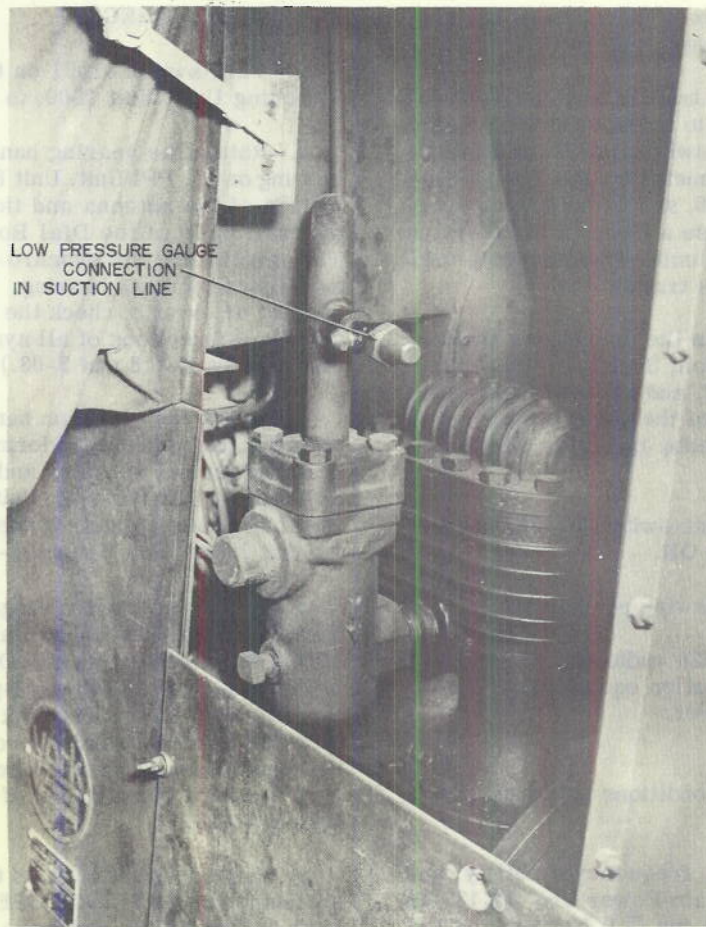


Figure 5-9. Dehumidifier Unit - Showing Gauge Connection in Section Line

h. Securing the Trailers.

1). Inspect the equipment, operations, and spare parts trailers and secure all loose gear. Tighten the fasteners on all panels of the equipment.

2). Close all doors and openings on the trailers. Seal if necessary.

3). Before the trailers or vehicles are moved, inspect running conditions as specified in SP-1M instruction book.

Subsection 5-2. Operation and Initial Adjustments

1. GENERAL

When the set-up procedure has been completed as described in this section, subsection 5-1, paragraph 3, the equipment can be operated. It will be assumed that the equipment is undamaged and is in such condition as to respond normally to the sequence of operations and adjustments described below. The following procedure should be observed to insure correct operation and obtain optimum performance with the minimum of effort.

2. STARTING EQUIPMENT

a. Switch the power selector switch, S4901, the generator selector switch, S4902, and all switches on the Power Distribution Unit, Unit 4900, to OFF. Throw the circuit breaker on the power control panel of the Main Power Unit PE137 to OFF.

b. Start the Main Power Unit PE137 by following starting instructions described in TM 11-921.

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Allow full warm-up time. Then throw the circuit breaker on the power panel to ON.

c. In the equipment trailer, switch the power selector switch, S4901, to **THREE PHASE**. Switch the generator selector switch, S4902, to **GENERATOR TWO**. The voltmeter on the Power Distribution Unit, Unit 4900, should indicate approximately 115 volts. Close all circuit breakers on the power distribution unit. Open console vent cover on the operations trailer.

d. At the console in the operations trailer, depress the start button, S1402, on the Power Control Unit, Unit 1400, and allow the equipment to warm up. The end of the warm-up period is indicated when the standby indicator, I1402, indicates.

e. Operate the radiate switch, S1404, to energize the transmitter to ON.

f. Energize the following equipment:

TCS-12 and SCR-624 radio equipment.
Heaters and ventilation equipment.
Recording equipment.
Trailer lighting.

g. Under full load conditions adjust all power supplies as follows:

1). Adjust speed, frequency stability, and voltage output of the Main Power Unit PE137 to deliver 120 volts at 60 cps (± 0.10 cycle) at the console. (See TM 11-921 and subsection 5-1, paragraph 3e, of this section for the regulation adjustments of frequency and voltage.)

2). Adjust output of the Auxiliary Power Unit, Unit 700, by means of potentiometer R727 to 200 volts.

3). Operate the radiate switch, S1404, to OFF. Leave the equipment in STANDBY.

4). Turn the system control selector switch, S1501, on the System Control Switching Unit, Unit 1500, to LOCAL and balance the D-c Servo Amplifier Unit, Unit 3300, in the Antenna Control Unit, Unit 3200. (Refer to section III, subsection 3-11, paragraph 4a1.)

5). Turn switch S1501 on the System Control Switching Unit, Unit 1500, to TELESCOPE. Balance the line of sight drift observed through the optics of the Telescope Unit, Unit 9100, by adjusting R1250 for bearing and R1263 for elevation at the front panel of the Target and Manual Coordinate Detector Unit, Unit 1200.

3. SYNCHRO CHECK

a. Turn switch S1501 on the System Control Switching Unit, Unit 1500, to LOCAL.

b. Rotate the bearing handwheel to increase bearing on the PPI Unit, Unit 800, and observe the motion of the antenna and the 1- and 36-speed synchro dials of the Dial Box Unit, Unit 8100. The antenna and the synchro dials should rotate to indicate increase bearing. If the motion is incorrect or erratic, check the electrical zero and synchro connections of all synchros in this loop. (See figures 3-118 and 3-83.)

c. Rotate the elevation handwheel to increase elevation and observe performance of the antenna in elevation and of the 2- and 36-speed synchro dials on the Dial Box Unit, Unit 8100. Check electrical zero and synchro connections if necessary for this loop. (See figures 3-118 and 3-83.)

d. Rotate the manual range handwheels of the Target and Missile Range Units, Units 300T and 300M, to increase range. Observe rotation of 1000-yard- and 100,000-yard-per-revolution dials for both units on the Dial Box Unit, Unit 8100. If these dials do not rotate in correspondence with the range counter direction, check the electrical zero synchro connections of these loops. (See figure 3-118.)

e. Turn switch S1501 on the system control switching unit to TELESCOPE. Actuate the slew sight switch, S9101, and move the antenna by displacing the slew sight. The telescope unit optical head should rotate in the same direction of bearing as the antenna. The optics of the telescope should elevate with the antenna. If movement of the telescope is not correct, check the voltage and polarity of the slew sight potentiometers, R9101 and R9103, at TB1201, terminals 13 and 14 of the Target and Manual Coordinate Detector Unit, Unit 1200.

f. Turn switch S1501 to LOCAL.

4. R-F ADJUSTMENTS

a. General. - With equipment in STANDBY, depress the radiate switch, S2002, to RADIATE at the Transmitter Unit, Unit 2000. Observe the magnetron current meter, M2002, on the control panel of the Transmitter Unit, Unit 2000; adjust the current by appropriate movement of the raiselower switch, S2003, until the magnetron current is 25 ma. The following steps require two operators, one at the console in the operations trailer and another at the Transmitter Unit, Unit 2000, in the equipment trailer. Establish communications between these two stations with a telephone

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set at the EE8 box on the bulkhead adjacent to the transmitter, and the other head set at range operator No. 1, range operator No. 2, PPI operator, or communications operator box in the vicinity of the console. Connect the two operators by depressing line switch No. 12 (equipment trailer) on the BD-72 telephone switchboard.

b. Reading Echo Box. - In the Transmitter Unit, Unit 2000, tune the Echo Box Unit, Unit 4700, for resonance. Rotate the vernier dial and observe meter M4741 for a peak deflection of 100 or better. From the chart on the back of the transmitter unit door determine the frequency from the reading of the vernier dial. Record for future reference.

c. Preliminary Adjustment of Scopes. - In the operations trailer adjust the centering, focus, and intensity of the A and R scopes of the Target Indicator Unit, Unit 1000T, and the Missile Indicator Unit, Unit 1000M, with the front panel controls to desired performance.

d. Head-end Tuning (Target Channel).

1). Turn the AGC-MAN gain switch, S101T, on the front panel of the Target Receiver Unit, Unit 100T, to MAN and rotate the MANUAL GAIN control, R228T, until a usable level of signal appears on the A scope of the Target Indicator Unit, Unit 1000T. This level must be reduced as the tuning improves, since the signal should be kept below saturation level in order to detect changes in tuning.

2). Replace crystal E2005 in the target TR box, V2002, if necessary. Set the FINE TUNE control, R843, on the front panel of the PPI Unit, Unit 800, and the FINE TUNE control, R1721, on the front panel of the Target Local Oscillator Preamplifier Unit, Unit 1700 (in the transmitter unit), to the center of the potentiometer travel. Turn the AFC-MAN switch, S1702, at the target local oscillator preamplifier unit and the AFC-MAN switch, S803, at the PPI unit to MAN. Tune the COARSE TUNING control on the target local oscillator preamplifier unit until a maximum signal height is observed on the A scope of the target indicator unit.

3). Tune the FINE TUNE control on the target local oscillator preamplifier unit and the PPI unit and observe the crystal current on meter M1701. Maximum crystal current should be coincident with a maximum signal observed on the A scope. If this does not occur and the crystal current response is erratic while scanning the FINE TUNE control for resonance, the klystron, V1709, is operating on an incorrect mode. Retune the COARSE TUNING control and repeat the opera-

tion in this paragraph until the proper relationship is obtained between crystal current and maximum signal. Adjust the local oscillation injection thumbscrew to obtain 0.5-ma crystal current.

e. TR and ATR Tuning (Target Channel). - Loosen the tuning slug locks on the lower TR box, V2002, and the ATR box, V2003, on the duplexer in the transmitter unit. Turn the tuning slugs on the TR box in corresponding increments for a maximum signal return on the A scope of the target indicator unit. Repeat for the ATR box tuning slugs. Tighten the tuning slug locks.

f. Head-end Tuning (Missile Channel).

1). Turn the AGC-MAN gain control switch, S101M, on the front panel of the Missile Receiver Unit, Unit 100M, to MAN and rotate the MANUAL GAIN control, R228M, until a usable level of signal appears on the A scope of the Missile Indicator Unit, Unit 1000M. This level must be reduced as the tuning improves since the signal should be kept below saturation level in order to detect changes in tuning. (The signal used in tuning the missile channel can be derived from the DPN-3 beacon or injected into the system from the signal generator TS 155/UP. See instruction manual for TS 155/UP.)

2). Replace crystal E2008 in the missile TR box, V2004, if necessary. Set the FINE TUNE control, R260M, on the front panel of the Missile Receiver Unit, Unit 100M, to the center of the potentiometer travel. Set the AFC-MAN switch, S100M, on the front panel of the Missile Receiver Unit, Unit 100M, to MAN. Tune the COARSE TUNING control on the missile local oscillator preamplifier unit until a maximum signal height is observed on the A scope of the missile indicator unit.

3). Tune the FINE TUNE control on the missile local oscillator preamplifier unit and the missile receiver unit and observe the crystal current on meter M101M on the front panel of the missile receiver unit. Maximum crystal current should be coincident with a maximum signal observed on the A scope. If this does not occur and the crystal current response is erratic while scanning the FINE TUNE control for resonance, the klystron, V4308, is operating on an incorrect mode. Retune the COARSE TUNING control and repeat the operation described above until the proper relationship is obtained between the crystal current and maximum signal.

g. TR Tuning (Missile Channel). - Loosen the tuning slug locks on the upper TR box, V2004, on the duplexer in the transmitter unit. Turn the tuning slugs on the TR box in corresponding in-

crements for a maximum signal return on the A scope of the missile indicator unit. Tighten the tuning slug locks.

h. Modulator Current Reading. - Open the front cabinet doors of the Modulator Unit, Unit 2300, and read the current of the high voltage power supply output on meter M2302. The current should read 80-100 ma. Any other reading indicates either that the magnetron, the hydrogen thyratron, or a clipping diode is malfunctioning or that the repetition rate is incorrect. (See paragraph 5 immediately below.)

5. RANGE UNIT ADJUSTMENTS

a. Target Range Unit, Unit 300T. - Adjustment of the Range Unit, Unit 300, is performed in four steps: adjustment of the repetition rate, adjustment of blocking oscillator V303, adjustment of the bridge circuits, and adjustment of blocking oscillator V319. These steps, as described in the following subparagraphs, should be performed in the order given.

1). Adjustment of Repetition Rate. - Pull the Target Range Unit, Unit 300T, out of the rack to the servicing position. Check the repetition rate with the frequency standard unit as follows: (See subsection 5-4 of this section for operation of the standard.)

a). Connect a Dumont 224-A oscilloscope, or its equivalent to the 576 cycle per second terminals on the frequency standard so as to make a circular trace on the oscilloscope.

b). Connect the "A" sweep trigger, available at J302 in the target range unit, to the "Z" axis terminal on the front of the oscilloscope. This trigger is used to intensity modulate the oscilloscope beam.

c). Rotate the repetition frequency adjusting potentiometer, R321, at the right front edge of the range unit chassis, to produce the lowest repetition frequency.

d). Turn the repetition frequency potentiometer up slowly in a direction to increase the repetition frequency. At the proper repetition frequency the brightened spot on the circular trace on the oscilloscope will be stopped rotating about the circular trace on the oscilloscope face.

CAUTION

It is necessary to increase the repetition frequency from the low side to arrive at the correct setting. It is possible to adjust the repetition frequency against the

frequency standard so that it is 2, 3, or 4 times as high as that desired if the potentiometer is not rotated from the lowest possible repetition frequency.

e). Set the magnetron current to 25 ma with the raise-lower control S1403.

2). Adjustment of Blocking Oscillator V303. - Adjust the frequency of the phase-locked blocking oscillator V303 by setting C375 for minimum time jitter of the signal as observed with a servoscope at pin 6 of V303. The servoscope should be synchronized with the A-sweep trigger and the sweep length should be approximately 100 microseconds. A photograph of the oscilloscope presentation appears in figure 3-19.

3). Adjustment of Bridge Circuit. - The bridge circuit feeding the 164-kc phase shifter is composed of T309, C380, C357, C356, R397, R398, and R399. It is essential that the amplitudes of the 164-kc signals feeding each plate be equal and that the phase shift between each successive plate be 90 degrees. The adjustments for this condition may be made directly only in an approximate manner since any impedance connected into the circuit for measurement purposes will upset the adjustment. A direct adjustment however is useful for getting the controls into an approximately correct setting so that further adjustments may proceed more quickly. This is done as follows:

a). Connect together, in parallel, the horizontal and vertical input terminals of the range unit bridge adjuster, described in subsection 5-4 of this section, and apply to the paralleled terminals the signal from any one of the test points T-1, T-2, T-3, or T-4.

b). Connect the output terminals of the range unit bridge adjuster respectively to the horizontal and vertical input terminals of a standard oscilloscope, such as DuMont 224A.

c). Observing the output of the bridge adjuster on the scope, set the phase potentiometer in the bridge adjuster to give an "in-phase" pattern on the oscilloscope and adjust the amplifier gain controls on the oscilloscope to give equal horizontal vertical amplitudes at a convenient level. After setting the gain controls, recheck the setting of the phase potentiometer since the phase shift in the oscilloscope amplifiers may vary with the setting of the gain controls. This procedure should set up the test equipment so that the horizontal and vertical channels have exactly the same gain and phase shift. Remove the connection between the input terminals of the bridge adjuster, but leave the oscilloscope connected.

The test equipment is now ready to make a preliminary adjustment of the range unit bridge.

d). Connect the input terminals of the bridge adjuster respectively to test points T-1 and T-4 and set the amplitude of the 164-kc signal at T-1 equal to that at T-4 by adjusting R397.

e). Set the phase difference between the signals at T-1 and T-4 at 180 degrees by adjusting C380. Since these adjustments interact, it may be necessary to repeat step d).

f). With input terminals of the bridge adjuster connected to T-1 and T-2, set the phase difference between the signals at T-1 and T-2 at 90 degrees by adjusting R399.

g). Similarly, set the phase difference between the signals at T-3 and T-4 at 90 degrees by adjusting R398.

h). Recheck all the steps given above since there is interaction between adjustments which is particularly bad if any of the controls were far away from the correct setting. The range unit is now preliminarily adjusted to give a smooth output of continuously variable phase.

i). Remove the range unit bridge adjuster and oscilloscope from the circuit.

j). Observe the output at J310 on a standard oscilloscope (set sweep to show about 20 cycles of the signal) while the range unit is being slewed at a relatively high speed. The variation in amplitude should be less than one percent if the bridge is properly adjusted. The adjustment will probably be nearly correct; that is, there will probably be about 10 percent amplitude modulation of the 164-kc output when the range unit is slewed. In this case, one or a combination of the controls, C380, R397, R398, and R399, have not been properly adjusted; the finding of the proper control is a cut and try process. Turn each control a slight amount while slewing the range unit and observe the nature of the output at J310. Turning any control too far will probably necessitate starting over from the beginning. Continue this process until the amplitude modulation has been brought within the limits given.

4). Adjustment Blocking Oscillator V319. - Set the frequency of the phase-locked blocking oscillator V319 as described in paragraph above for the adjustment of V303, using the R-sweep trigger to synchronize the oscilloscope and observing the waveshape present at pin 6 of V319. C364 is then adjusted for minimum time jitter.

b. Missile Range Unit, Unit 300M. - Adjust the missile range unit as described immediately above for the target range unit.

6. SWEEP CALIBRATION, TARGET RANGE INDICATOR UNIT, UNIT 1000T.

a. Throw the SLEW-AUTO switch, S301T, to SLEW, and slew the range gate from zero to 100,000 yards with the slew knob.

CAUTION

Do not drive the gear train into the stops at high speed.

Observe the motion of the range gate on the A scope of the target indicator unit. The range gate (a negative pip on the A scope sweep) should move across the sweep with no jump or delay. Jumps or delay occurring at long ranges can be eliminated by adjusting the potentiometer R369T. Short range corrections are made with R371T. These adjustments are made from the top of the range unit.

b. Turn the range handcrank until range counter reads 100,000 yards. Adjust the A SWEEP-TIME potentiometer, R1058T on the left side of the target indicator unit chassis until the range gate appears one quarter inch from the end of the A-scope sweep.

c. Adjust the A SWEEP-LENGTH potentiometer, R1046T, on the left side of the target indicator unit chassis until the A-scope sweep length is extended to 1/4 inch from each edge of the visible screen of the indicator.

d. Calibrate the R-scope sweep time by slewing the range unit until an echo appears on the R sweep in the target indicator unit. Turn the handcrank until the echo is moved to the extreme left edge of the R sweep. Read and record the range indicated on the range counter. Turn the range handcrank until the echo is at the extreme right edge of the R sweep. Read and record the range. Adjust the R SWEEP-TIME potentiometer, R1065T, located on the left side of the target indicator unit chassis, until the difference between these readings is 2000 yards.

e. Adjust the R-sweep length with the R SWEEP-LENGTH potentiometer, R1045T, until the R sweep extends to 1/4 inch from each edge of the visible width of the indicator screen.

7. SWEEP CALIBRATION MISSILE RANGE INDICATOR UNIT, UNIT 1000M

Calibrate the A and R sweeps of the Missile Indicator Unit, Unit 1000M, with the Missile Range

Unit, Unit 300M, as described for the target range unit in paragraph 6 immediately above. Whenever a potentiometer adjustment is required in the target indicator or range unit, make the same adjustment with the corresponding part in the missile indicator or range unit; i.e., the R SWEEP-LENGTH potentiometer R1045T becomes the R SWEEP-LENGTH potentiometer R1045M.

8. RECEIVER ADJUSTMENT

a. Target Receiver Unit, Unit 100T.

1). Pull out the Target Receiver Unit, Unit 100T, from the console until the rear of the chassis is accessible.

2). Turn the RADIATE switch, S1404, on the power control unit to STANDBY.

3). Turn the MAN-AGC switch, S101T, to AGC and adjust the GATING LEVEL potentiometer, R228T, at the left rear edge of the chassis until the grass is set to 1/4 inch on the A and R scopes.

4). Turn the RADIATE switch, S1404, to RADIATE.

5). Select a strong signal, other than the transmitter pulse, and operate the target range unit until the signal is centered in the notch of the R sweep on the target indicator unit. Adjust the AGC LEVEL potentiometer, R241T, until this signal is twice the height of the notch.

6). Return the target receiver unit to its place in the console and secure.

b. Missile Receiver Unit, Unit 100M. - Adjust the gating level of the Missile Receiver Unit, Unit 100M, by using the procedure described above for the target receiver unit. The test signal can be derived from the DPN-3 beacon or injected into the Lark SP-1M from the TS155/UP.

9. PPI UNIT ADJUSTMENT

Adjust the VIDEO GAIN control, R838, the INTENSITY control, R895, and the FOCUS control, R837, until a sharp trace of desired intensity and signal level is obtained on the screen of the PPI tube, V801. Turn the PPI PATTERN switch, S802, to the 4-mile position. Turn the target range unit handcrank to 8,000 yards (4 miles) and adjust the SWEEP-LENGTH 4-MILE potentiometer, R810, until the range strobe appears at the outer edge of the PPI tube. Repeat this process for the 20- and 50-mile sweeps by adjusting potentiometers R811 and R812, respectively, in conjunction with corresponding target range unit ranges of 40,000 and 100,000 yards.

10. REFERENCE VOLTAGE GENERATOR ADJUSTMENT

a. Operate the pedestal safety switch, S3001, and safety switch, S7113, located on the roof of the equipment trailer to RUN and the NUTATOR switch, S1405, on the power control unit to ON.

b. Select a fixed optical target and gate its signal on the R sweep of the target indicator unit. Throw the AUTO-SLEW switch, S301T, on the target range unit to AUTO. Turn the ANTENNA POSITIONING VIDEO SELECTOR switch, S1501, on the front panel of the System Control Switching Unit, Unit 1500, to TARGET. Throw the TRAIN and ELEVATION AUTO-MAN switches, S1502 and S1503, to AUTO. Remove the back cover of the reference voltage generator on the nutator at the antenna pedestal. Loosen the clamping screws on the reference voltage generator.

c. Two operators are required for the following procedure. The console operator oscillates the antenna with the BEARING BALANCE CONTROL, R1250, at the front panel of the Target and Manual Coordinate Detector Unit, Unit 1200. An observer on the roof of the equipment trailer views the selected optical target through the boresight telescope. The reference voltage generator is rotated until the target motion in the optics is parallel to the horizontal crosshair of the telescope. Readjust the BEARING BALANCE CONTROL, R1250, as described in paragraph 2c5) of this subsection.

d. Lock the clamping screw and replace the reference voltage generator cover plate.

e. Connect a coaxial cable between the TELEM. jack, J5151, at the operations trailer cable panel and the nutator phasing unit (strobolux and keyer) on the roof of the equipment trailer. (A brief description of the nutator phasing unit is given in subsection 5-4, paragraph 1, of this section.) Illuminate the dipoles at the end of the nutator wobbler snout with the strobolux. Rotate the phase dial of the 24-cycle Reference Voltage Distribution Unit, Unit 2700, until the wobbler is "stopped" at the top of its rotation. Loosen the locking screws on the phase dial and set the scale to zero. Tighten locking screws.

Record any setting of the phase dial resulting from operation with external equipment requiring a phase shift of the reference voltage.

f. If the reference voltage generator is replaced or rerotated for any reason, proceed as described above in this paragraph, step c. "Stop" the wobbler with the strobolux test unit by rotat-

ing the phase dial. Loosen the phase dial locking screw and rotate the scale to zero. Tighten the locking screw and rotate the dial to the setting recorded for external equipment (see step e of this paragraph).

11. DEHUMIDIFIER ADJUSTMENT

a. General. - The following subparagraphs give the general procedure for adjustment of each of the two Dehumidifier Units, Units 5400, used with the Lark SP-1M equipment. Except for the substitution of electric motor drives for the original gasoline engine drives, the units are the same as the corresponding units in the SP-1M. More detailed information may consequently be obtained from the handbooks on the original units.

b. Adjustment. - Make sure the manual line switch S5401 is in the OFF position. Plug the line into the proper receptacle. For 230-volt operation, the line plug is connected to receptacle J5403, and plug J5402 is not connected to any receptacle. For operation from the 115-volt supply, the line plug is connected to receptacle J5401, and plug J5402 is connected to receptacle J5403.

Plug the thermostat line into the receptacle J5404. Throw the manual control switch S5403 to the OFF position. Throw the manual line switch S5401 to the ON position. Check the rotation of the motor by throwing the manual line switch S5401 to the ON and OFF positions quickly. Rotation should be counterclockwise as seen from the pulley end of the motor. If the motor runs backward, interchange any two leads from the supply to the motor. To attain temperature control, set the thermostat at the desired temperature and throw the manual control switch to the ON position.

c. Lubrication. - After every 100 hours of operation or every 30 days, oil the fan shaft bearings and the electric motor bearings with SAE 30 motor oil.

d. Fan Belt Adjustment. - Adjust the fan belt tension by moving the compressor.

e. Compressor Belt Adjustment. - Adjust the compressor belt tension by moving the electric motor with the crank that will be found in the tool box.

12. ORIENTATION

a. Boresighting. - Switches must be set as follows:

- RADIATE switch, S1404, to RADIATE.
- NUTATOR switch, S1405, to ON.
- CONTROL SELECTOR switch, S1501, to LOCAL.
- VIDEO ANTENNA POSITIONING switch, S1506, to TARGET.
- ELEVATION and TRAIN AUTO - MAN switches, S1502 and S1503, to MAN.
- SLEW-AUTO switch, S301T to SLEW.

Boresighting is accomplished on an airborne target instructed to fly on incoming and outgoing radial runs with respect to the radar at medium altitudes, 2000 to 5000 feet. As the readings on the PPI elevation and bearing handcranks do not as yet correspond to the true position of the antenna, the PPI operator must be coached on target by telephone from an observer on the roof of the equipment trailer.

1). When the target echo is observed on the A scope of the target indicator unit, the target range operator slews the range unit until the echo is gated on the R scope and then throws the SLEW-AUTO switch to AUTO. When the echo is automatically tracked in range, the PPI operator throws the ELEVATION and TRAIN AUTO-MAN switches, S1502 and S1503, to AUTO.

2). The observer on the roof observes the target through the boresight telescope and corrects the vertical and horizontal adjusting screws until the target appears at the intersection of the vertical and horizontal crosshairs of the boresight telescope. Because of the mechanical play in the adjusting mechanism of the telescope, it is difficult to obtain an accurate setting of the crosshairs. Therefore, the boresight telescope must not be used for any quantitative measurements. It merely serves as an antenna observation point for qualitative information.

3). Remove the lens cap from the 21-inch tracking camera unit on the antenna, and insert a critical focuser in the camera. Set the lens focus to infinity, and set the aperture for maximum exposure. Throw the ENERGIZE switch, S8201, on the front panel of the Camera Control Unit, Unit 8200, to OFF. Rotate the camera drive coupling on the top, right front edge of the camera, until the film framer is completely uncovered by the camera shutter. Unlock the vertical and horizontal locking nuts on the camera mount. Adjust the elevation and bearing adjusting screws until the target is centered in the vertical and horizontal crosshairs of the 21-inch camera optics. Lock the elevation and horizontal locking nuts. This operation must be done carefully and the final setting of the camera optical axis should be determined by observations over several runs. (Since the field of view of the 21-inch lens is no

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more than approximately one degree, it may be necessary to make the initial setting of the camera line of sight coincide with that of the bore-sight telescope. This can be done by manually centering the optics of the boresight telescope on an optical target. Operate the adjusting screws of the 21-inch camera mount until this same target is seen at the crosshairs of the 21-inch camera optics. Accurate alignment of the 21-inch camera line of sight can proceed from this position as described above.) Remove the lens cap from the 6-inch tracking camera unit. Insert a critical focuser in the camera, rotate the shutter to clear the framer, and operate the adjusting screws on the mount to center the optical target in the field of view.

b. "True" Orientation.

1). Throw the ELEVATION and TRAIN AUTO-MAN switches, S1502 and S1503, to MAN. Rotate the elevation and bearing handwheels of the PPI Unit, Unit 800, until an optical target of accurately known true bearing and elevation with respect to the radar bearing and elevation axes appears at the intersection of the crosshairs of the 21-inch camera.

2). Lock the antenna pedestal bearing clamp, and turn the ANTENNA SAFETY switch to SAFE. Check the alignment of the crosshairs of the 21-inch camera and correct any shift of the line of sight by repositioning the antenna. Lock the handcrank locking nuts.

3). Turn the CONTROL SELECTOR switch, S1501, to TELESCOPE to energize the handcrank servos. Remove the handcranks from the shafts and reset the dials to read the true position of the target.

4). Turn the INTENSITY control on the front panel of the PPI unit to make the sweep on the PPI tube visible. Loosen and adjust the bearing handcrank micro-coupling to the deflection coils. Rotate the deflection coils until the sweep direction corresponds to the true bearing of the target with the top of the PPI screen as north.

c. Synchro Orientation - Dial Box Unit, Unit 8100.

1). Loosen the clamps on the 36X bearing synchro, B8102, on the Dial Box Unit, Unit 8100, and rotate the synchro case until its dial setting corresponds to the tens digit of the true bearing of the target. Tighten the synchro clamps. Loosen the clamps on the 1X bearing synchro, B1801, and set the dial approximately to the 100 digit of the target bearing. Tighten the clamps.

2). Loosen the clamps on the 36X elevation synchro, B8104, and rotate the synchro case until its dial corresponds to the tens digit of the true elevation angle of the target. Set the 2X elevation synchro, B8103, to the approximate target elevation angle.

3). Turn the control selector switch, S1501, to LOCAL. Unlock the antenna pedestal clamp, the handcrank locks, and throw the PEDESTAL SAFETY switch to RUN. After the time delay relay, K3209, has energized the antenna drive (1 minute), rotate the elevation and bearing handwheels until their dials indicate the elevation and bearing as zero.

4). Observe the 1X bearing synchro, B8101, and the 2X elevation synchro, B8103, and see that the dials correspond to zero.

d. Telescope Orientation.

1). Rotate the elevation and bearing handcranks on the PPI unit until a fixed optical target is observed on the crosshairs of the 21-inch camera. To reduce the effects of parallax, the position of this target should be near the center of the area in which the radar will be employed. Lock the elevation and bearing handcrank locking nuts.

2). Pull out the Synchronizer and Missile Coordinate Detector Unit, Unit 600, and remove the telescope bearing and elevation synchronizing tubes, V614 and V612. Remove the dust covers from the synchronizing relays, K604 and K602. Remove the pedestal and rotating head inspection covers from the Telescope Unit, Unit 9100.

3). Energize the telescope 1X bearing channel by holding relay K604 in the down position. Loosen the telescope unit 1X and 36X bearing synchros, B9109 and B9110. Rotate the 1X bearing synchro case until the target approaches the vertical crosshair of the telescope unit optics. Tighten the bearing 1X synchro clamps. Release relay K604 and block it in the up position to energize the telescope 36X bearing channel. Rotate the 36X bearing synchro to bring the vertical crosshair of the optics on target. Tighten the 36X bearing synchro clamps. Manually operate the relay K604 and eliminate any horizontal motion of the line of sight by rotating the bearing 1X synchro. Return V614 and replace the dust cover over relay K604.

4). Energize the telescope 2X elevation channel by holding relay K602 in the down position. Loosen the telescope unit 2X and 36X elevation synchros, B9105 and B9106. Rotate the 2X elevation synchro case until the target approaches

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the horizontal crosshair of the telescope unit optics. Tighten the elevation 2X synchro clamps. Release relay K602 and block it in the up position to energize the telescope 36X elevation channel. Rotate the 36X elevation synchro to bring the horizontal crosshair of the optics on target. Tighten the 36X elevation synchro clamps. Manually operate relay K602 and eliminate any vertical motion of the line of sight by rotating the elevation 2X synchro. Return V612 and replace the dust cover over relay K602.

e. Range Orientation (Target and Missile Channel).

1). Throw the SLEW-AUTO switches, S301T and S301M, to SLEW and turn the range cranks of the target and missile range units until the range counters read zero. Pull out the range units and loosen the setscrew of gear 0373 on the phase-shifter condensers, C381T and C381M. Rotate the phase-shifter shaft until the transmitter pulse is centered in the range gates of the target and missile R scopes of the target and missile indicator units. Tighten the setscrews and slide the range units back in the racks.

2). Rotate the antenna until a target of known (surveyed) radar range is observed on the A scope of the target indicator unit. Because of "leak through," this same target can be observed on the A scope of the missile indicator. Gate the signal on the R scopes.

3). Loosen the synchro clamps of the target and missile 1000-yard-per-revolution range synchros, B8105 and B8107, on the dial box unit and rotate the synchro cases until the dials correspond to the 1000-yard digit of the range. Tighten the synchro clamps. Loosen the synchro clamps of the target and missile 100,000-yard-per-revolution range synchros, B8106 and B8108, and rotate the synchro dials to read to the 100,000-yard digit of the target range. Tighten the synchro clamps. Rotate the range unit handcranks until the counters read zero. If necessary, reset the target and missile 100,000-yard-per-revolution synchros, B8106 and B8108, until the dials read zero.

13. RECORDING EQUIPMENT

a. Camera Equipment.

1). Open the top cover of the Camera Control Unit, Unit 8200, and move the gear shift lever of the camera drive motor (B8201) gear box to the desired camera speed. The speed selection available corresponds to 10, 20, or 30 frames per second.

2). Throw the ENERGIZE switch, S8201, to ON. Operate the CAMERA switch, S1507, on the system control switching unit to START. Check the operation of the photofloods and the flag lights. All flag lights will be operated properly if the indicator lights, I8201 to I8206, are all brightly illuminated. Low illumination of the indicator indicates that one of the flag lights in the camera is burned out. No illumination of the indicators indicates that both flag lights are out.

3). With the camera operating, observe the rotation of each camera motor drive coupling. The rotation of the drive motor is correct if the coupling rotates clockwise as viewed from the motor side of the camera assembly.

4). Operate the camera switch, S1507, to STOP. Loosen the clamps on all the synchro drive motors except the motor of the Time Comparator Camera Unit, Unit 8400, and rotate the synchro case until the angle of the shutter opening is bisected by the diagonal of the framer as observed through the rear opening of the camera. Tighten the clamps. Loosen the clamps on the Commutator Unit, Unit 8600, and rotate the synchro motor case until the brush is in the center of the commutator contact segment. Tighten the clamps.

5). Set the INTENSITY, FOCUS, HORIZONTAL, and VERTICAL controls on the remote range indicator unit so that the bright spot of the left edge of each sweep is hidden by the tube mask, the intensity is the highest permissible without excessive halation, and the distance between sweeps is sufficient to avoid overlapping of signal traces, with the range gates superposed.

6). Connect the remote timing source to TIMING jack, J5152, on the operations trailer cable panel to trigger the strobotron behind the right hand slit on the front panel of the Time Comparator Unit, Unit 8600.

7). Set the focusing barrels of the tracking cameras to infinity. Place a critical focuser in the dial box camera and the remote range indicator camera, and adjust the focus barrel of the lenses until a sharp image is obtained on the ground glass of the viewer. Remove the side cover of the time comparator camera, place a piece of onion-skin paper in the film gate, and adjust the focusing barrel of the lens until a sharp image is obtained. For 10 frames per second film speed set the camera apertures as follows: main tracking lens (60° shutter, Kodachrome),

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f 6.3 for bright, sunny day; auxiliary tracking lens (60° shutter, Kodachrome), f 8 for bright, sunny day; dial box lens (10° shutter, Super X), f 5.6; remote range lens (130° shutter, Super X), f 1.5; and continuous strip lens (Super XX), f 4.

b. Sound Recorder. - Place a record on the Audograph sound recorder, turn the volume control switch to ON, and place the recorder across the communications circuit by depressing line switch No. 3 on the telephone switchboard BD-72. Throw the control lever on the recorder to RECORD and test-modulate from each telephone and radio operator position. Throw the recorder control lever to LISTEN and check the modulation.

c. Final Preparation of Recording Equipment. - If the data recording equipment is to be employed, several important preparations must be completed on the day of expected operation of the Lark SP-1M prior to the launching time of the missile. The following preparations are arranged chronologically to insure accuracy of data and a minimum of effort:

1). Minus Four Hours. - Turn on radar and leave in RADIATE.

2). Minus Two Hours.

a). Recheck repetition rate as described in paragraph 5 of this subsection.

b). Check 24 cycle scan frequency. While it is seldom necessary to adjust the scan frequency to 24 cycles per second it is occasionally necessary to check the frequency. This is done in the following manner. A Dumont 224 oscilloscope is connected to the Frequency Standard so that the horizontal sweep is derived from the standard at 24 cycles per second. The vertical deflection plate or vertical amplifier of the oscilloscope is connected to the cable entering J303 in the target range unit by means of "tee" coaxial connector. This applies the signal from the standard to the "X" axis of the oscilloscope, and the signal from the 24 cycle reference generator at the nutator to the "Y" axis of the oscilloscope. If the nutator is scanning at exactly 24 cycles per second, the pattern on the oscilloscope will be either elliptical or circular depending upon the relative amplitudes of the signal from the frequency standard and the signal from the reference generator located at the nutator. Furthermore, the circular or elliptical pattern will remain stationary. By counting the rotational frequency of the pattern on the oscilloscope it is possible to estimate the actual frequency of the scan. If the frequency of the scan does not lie between 23.9 and 24.1 cycles, per second, it will be necessary to check the operation of the nutator

drive motor or nutator itself. If the line frequency is other than 60 cycles, plus or minus one quarter of a cycle, the scanning frequency will not lie between 23.9 and 24.1 cycles. In practice, it may be necessary to adjust or replace the nutator drive belts every 500 hours of operation.

c). Station operators at the target range unit, the PPI unit, the missile range unit, the communication operator's position, and on the roof of the equipment trailer. Connect the radio communications, the sound recorder, and all operators' headsets to the intercommunications system through the telephone switchboard BD-72.

d). Manually position the radar antenna until the missile launcher and a standard target both appear in the field of view of the 21-inch tracking camera. (The standard target should be a solid post with a black and white checkerboard pattern. The target must be located as close to the launcher as possible. The position of this target with respect to the Lark SP-1M and other survey points must be known to the nearest 0.01 degree, and one yard in range.) Gate the missile beacon signal on the R scope of the missile indicator unit with the missile range unit. The range indicated on the missile range unit counter, minus the known surveyed distance between the Lark SP-1M and the launcher, is the beacon range delay. Record this range delay for later corrections to missile range data.

e). Check the operation of all cameras and flag lights. Load the time comparator camera using a one hundred foot reel of Super XX film. Hold the CAMERA switch, S1507, in the START position. Run until the film footage indicator on the time comparator camera shows that twenty feet of film have been exposed. This is necessary because loading the time comparator camera in the light will fog the first portion of the film. Load the remaining cameras. 50 foot outdoor Kodachrome magazines are used in the tracking cameras and 50 foot Super X magazines in the dial box and remote range indicator cameras.

CAUTION

Make sure that the magazine is fully inserted into the camera and the camera door is closed. Failure to observe this caution will cause the film to jam and a subsequent loss of photographic data.

Remove lens caps. Make out a run card showing the date and test identification number, and insert the card in the holder on the front panel of the dial box unit. Turn the run number counter crank until the desired run identification number ap-

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pears on the counter at the dial box. Close and secure all panels on the data recording cabinet.

f). With the antenna still pointed at the launcher under manual control, hold the CAMERA switch, S1507, in the START position. Return the switch to STOP after 8 seconds. This photographic record establishes the antenna position with respect to the launcher and records any misalignment of the tracking cameras. Leave all cameras loaded.

3). Minus One Hour. - Turn the PTM switch, S1505, to ON. Complete all necessary checkouts with guidance equipment at missile.

4). Minus Fifteen Minutes. - Make final determination and setting of tracking camera exposures.

5). Minus Ten Minutes. - Turn on sound recorder and throw the control lever to RECORD. Record all pertinent information: date, test number, run number, operators' names and positions, weather, missile description, etc.

6). Minus Two Minutes. - Turn the CONTROL SELECTOR SWITCH, S1501, to TELESCOPE. The telescope operator centers the antenna on the launcher and reports to the PPI operator. The PPI operator turns the NUTATOR switch, S1405, to ON. The missile range operator gates the beacon signal from the missile, and turns the SLEW-AUTO switch, S301M, to AUTO. The PPI operator throws the ANTENNA POSITIONING VIDEO SELECTOR switch, S1506, to MISSILE, and the ELEVATION and TRAIN AUTO-MAN switches, S1503 and S1502, to AUTO. The target range operator sets the target range unit, in manual, to the surveyed range to the launcher, and awaits the appearance of the mis-

sile signal after launching before commencing automatic tracking.

7). Minus Five Seconds. - The PPI operator throws the CAMERA switch, S1507, to START.

8). Zero Time. - When the missile is fired, it is automatically tracked off the launcher. The telescope operator and the target range operator report the separation of the booster from the missile. Automatic tracking continues until a predetermined altitude is reached for initial beam rider control. From this point beam movements proceed according to the flight plan for the particular missile under test.

9). Post Flight Check. - Immediately upon completion of the test flight, check the cyclic error of the range unit by ranging against the output pulses of the sixteenth-harmonic frequency multiplier, described in subsection 5-4, paragraph 3, of this section. This unit makes it possible to get accurate 62.5-yard increments of range. The unit is connected into the range unit as shown in figure 5-22. The wave shapes which are presented on the test scope are shown in figure 5-23. The differentiated leading edge of the range gate is matched against the 62.5-yard pulse as shown and the range counter is read. A series of such readings should be taken in the range intervals 1000-3000, 11000-13000, 21000-23000, 31000-33000 yards, and so on. The readings should be spaced 62.5 ± 5 yards and the readings from interval to interval should repeat in the units column (i.e. last digit) to ± 2 yards for a correct adjustment of the bridge. This cyclic error check should be repeated after each missile flight and whenever the performance of the range unit indicates the presence of excessive cyclic error. Excessive cyclic error indicates the need for a readjustment of the bridge circuit.

Subsection 5-3. Communications Equipment

1. GENERAL (See figures 5-10, 5-11, and 5-12.)

The communications equipment necessary for coordinated operation of the Lark SP-1M radar, as an independent unit and in conjunction with other activities, is installed as an integral part of the system. Communications between and in the trailers is effected through battery operated telephones. A master switchboard BD-72, controls the distribution of calls. During aircraft flight tests, communication between aircraft and trailers is carried out over VHF or MHF radio equipment (SCR-624 or TCS-12 re-

spectively). (See figure 5-10.) Which of the radio equipments is used depends on the location of the trailers and the type of communications equipment used by the control tower at the test station. All communications are recorded on a sound recorder which is tied in to the telephone switchboard.

The communications equipment is interconnected as shown in the schematic diagram, figure 5-11. Complete information on installation, adjustment, and operation of the principal components listed above may be found in separate hand-

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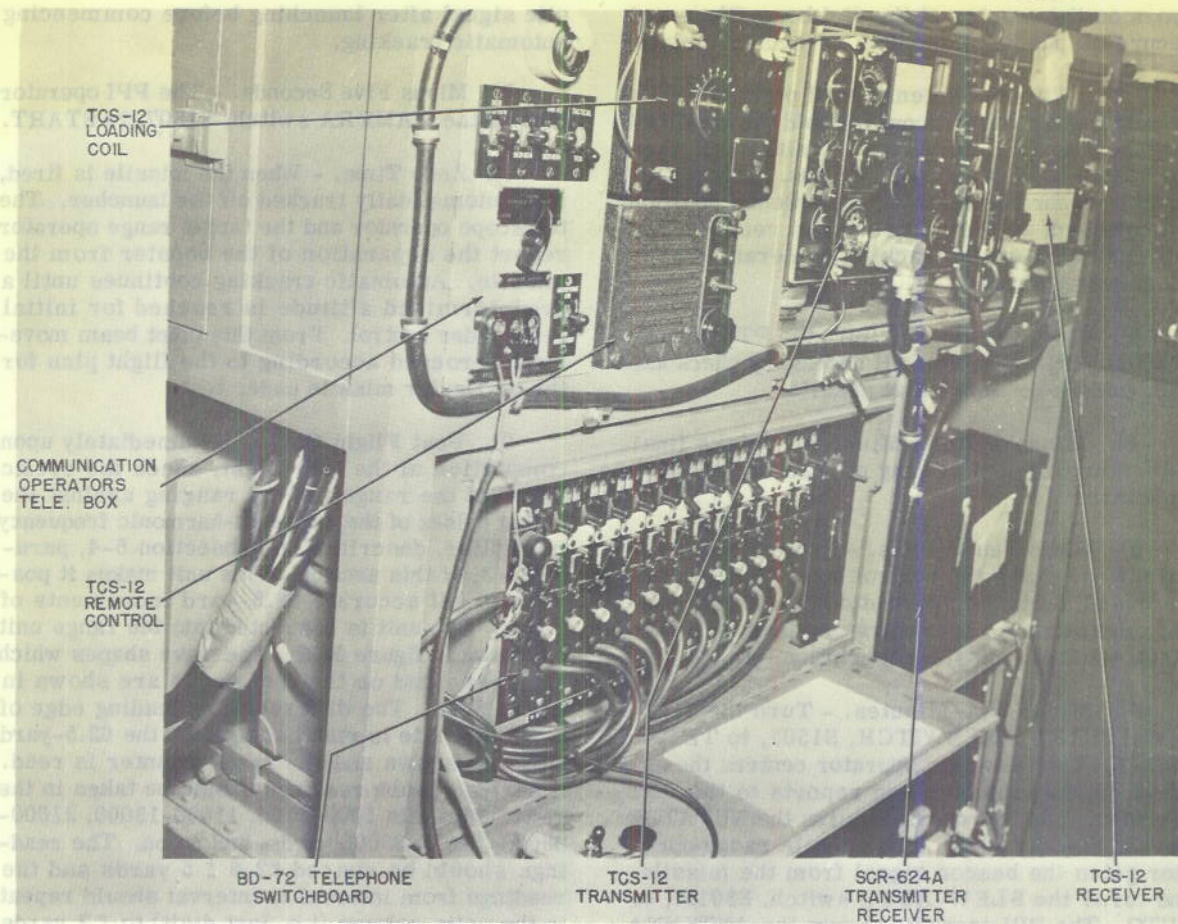


Figure 5-10. Communications Equipment - Front View of TCS-12, SCR-624, and BD-72

books. For quick reference, however, a brief description of the equipment has been included in the following subparagraph.

2. SCR-624 RADIO EQUIPMENT

Radio equipment SCR-624 is a complete radio ground station (consisting of a transmitter and a receiver) designed for communication work at ultra-high frequencies. The equipment may be operated on any one of four crystal-controlled channels within 100 to 156 megacycles.

The normal carrier power of this equipment is 6 to 8 watts at its operating frequency. The a-c power requirements are 100- to 130-volt or 200- to 260-volt, 40- to 60-cycle, single-phase power, supplied by an a-c power line or by an auxiliary power unit. The power source must be able to furnish 325 watts at 115 volts, or 320 watts at 230 volts. Additional SCR-624 informa-

tion may be obtained from the Handbook of Maintenance Instructions for Radio Sets SCR-624-A and SCR-624-B (AN OB-40SCR624-2).

3. TCS-12 RADIO EQUIPMENT

The TCS-12 radio equipment is a complete radio transmitting and receiving set designed for use in portable and mobile installations. The frequency range, 1500 to 12,000 kc, is covered in three bands: Band 1 - 1500 to 3000 kc, band 2 - 3000 to 6000 kc, and band 3 - 6000 to 12,000 kc. A three-position, two-section switch is used to select the desired band. The power output is 20 watts on voice and 40 watts on CW at all frequencies. Power units are available for operation from 12-, 24-, 32-, 115-, or 230-volt d-c power sources or from 115- or 230-volt, 60-cycle, a-c power sources. Operation from these power sources is accomplished by the use of three separate power units. (See figure 5-12.)

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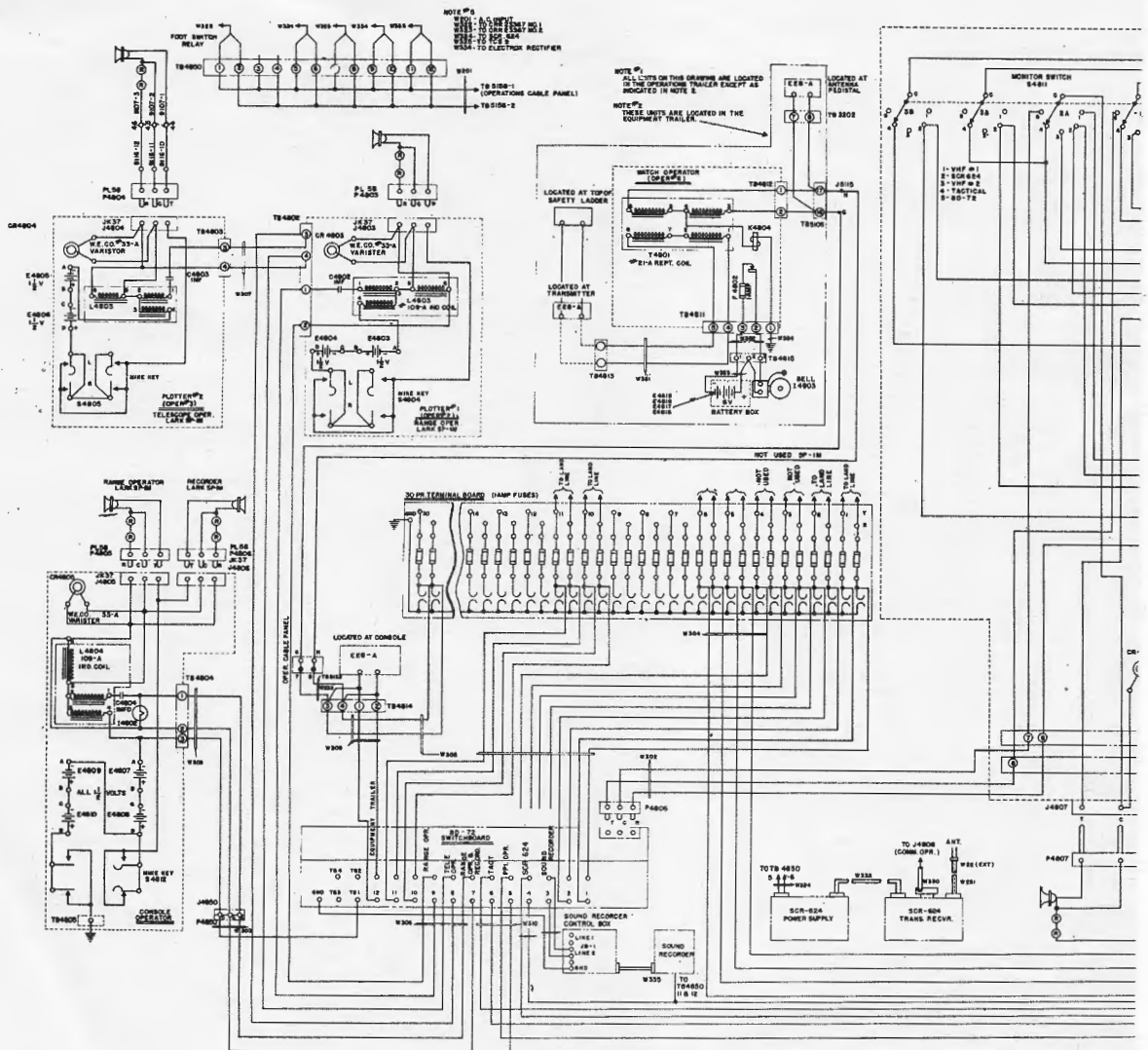
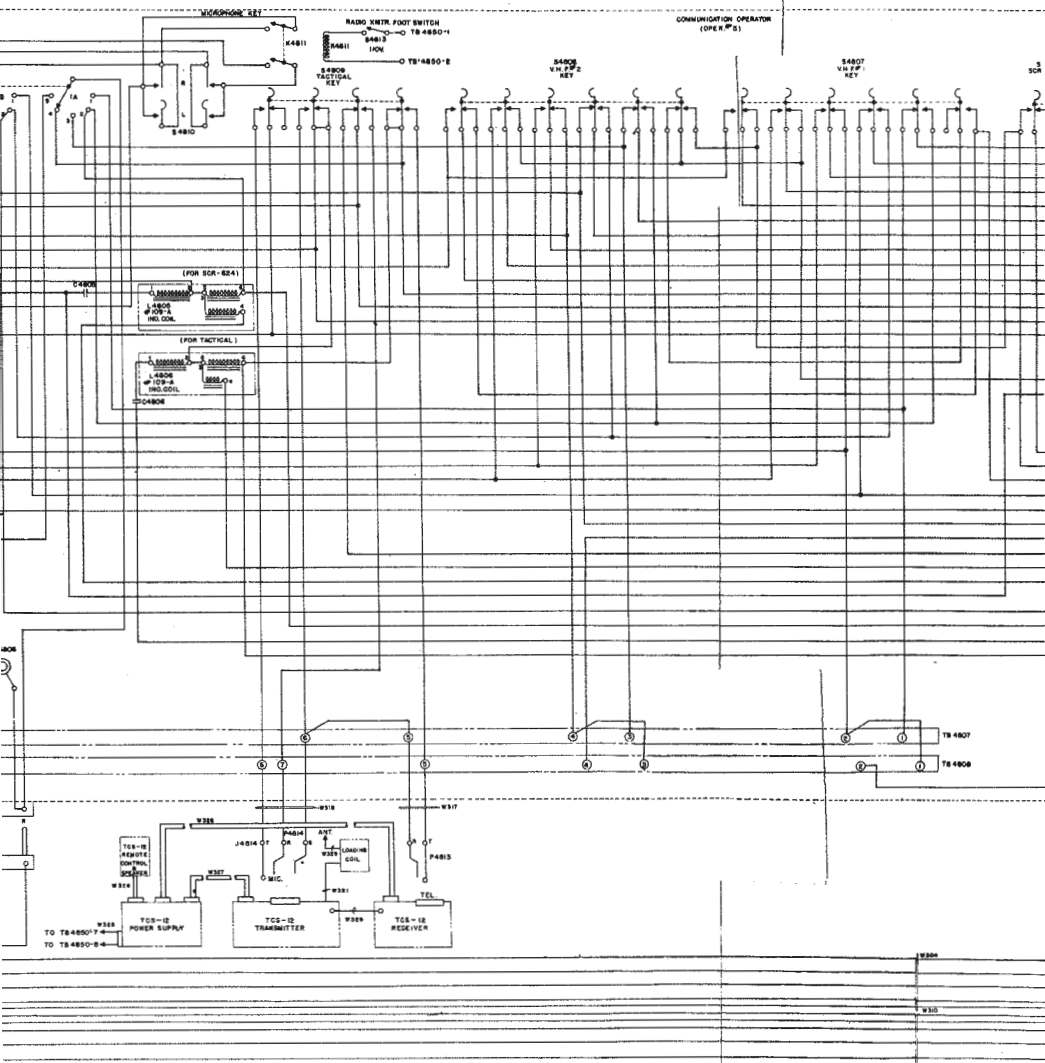
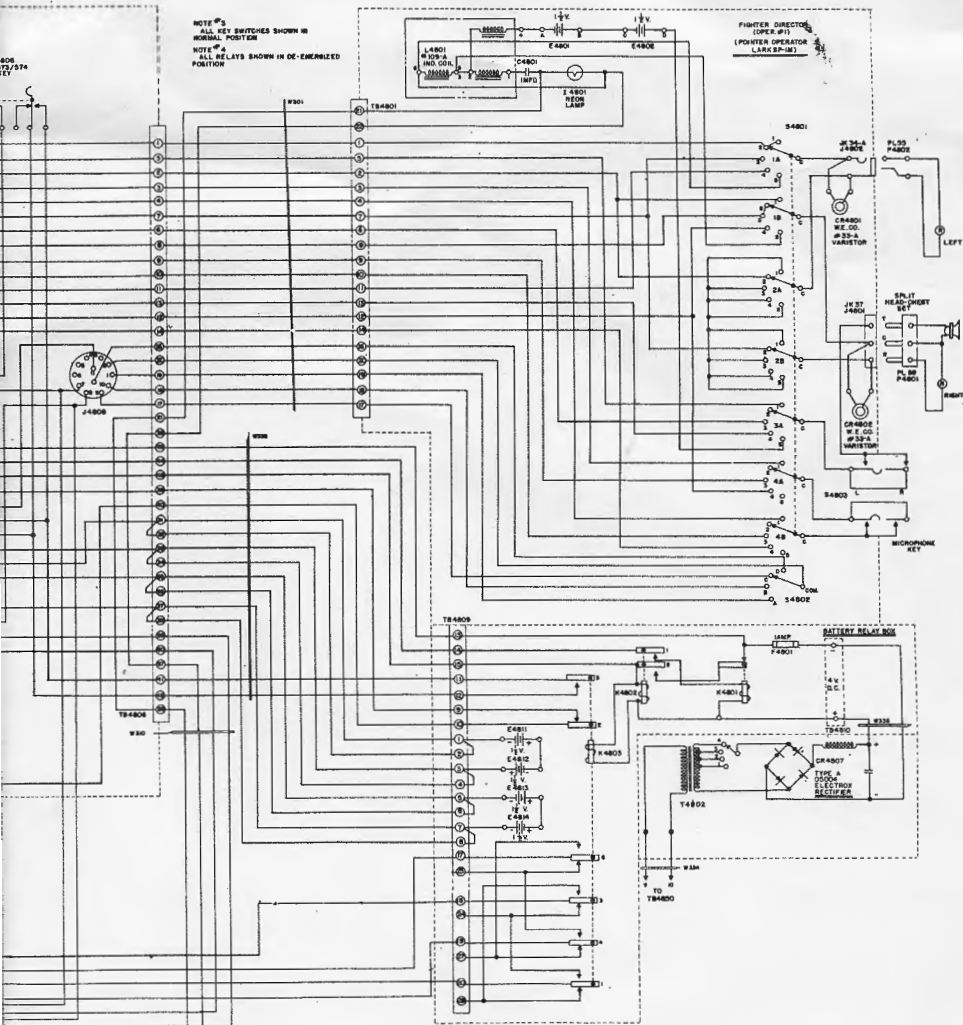


Figure 5-11. Communications Section - Schematic Diagram





NOTE #1
ALL KEY SWITCHES SHOWN IN
NORMAL POSITION

NOTE #2
ALL RELAYS SHOWN IN DE-ENERGIZED
POSITION

FIGHTER OBJECTIVE
(OPER. #1)
(POWER OPERATOR
LAMP #1-102)

BATTERY RELAY BOX

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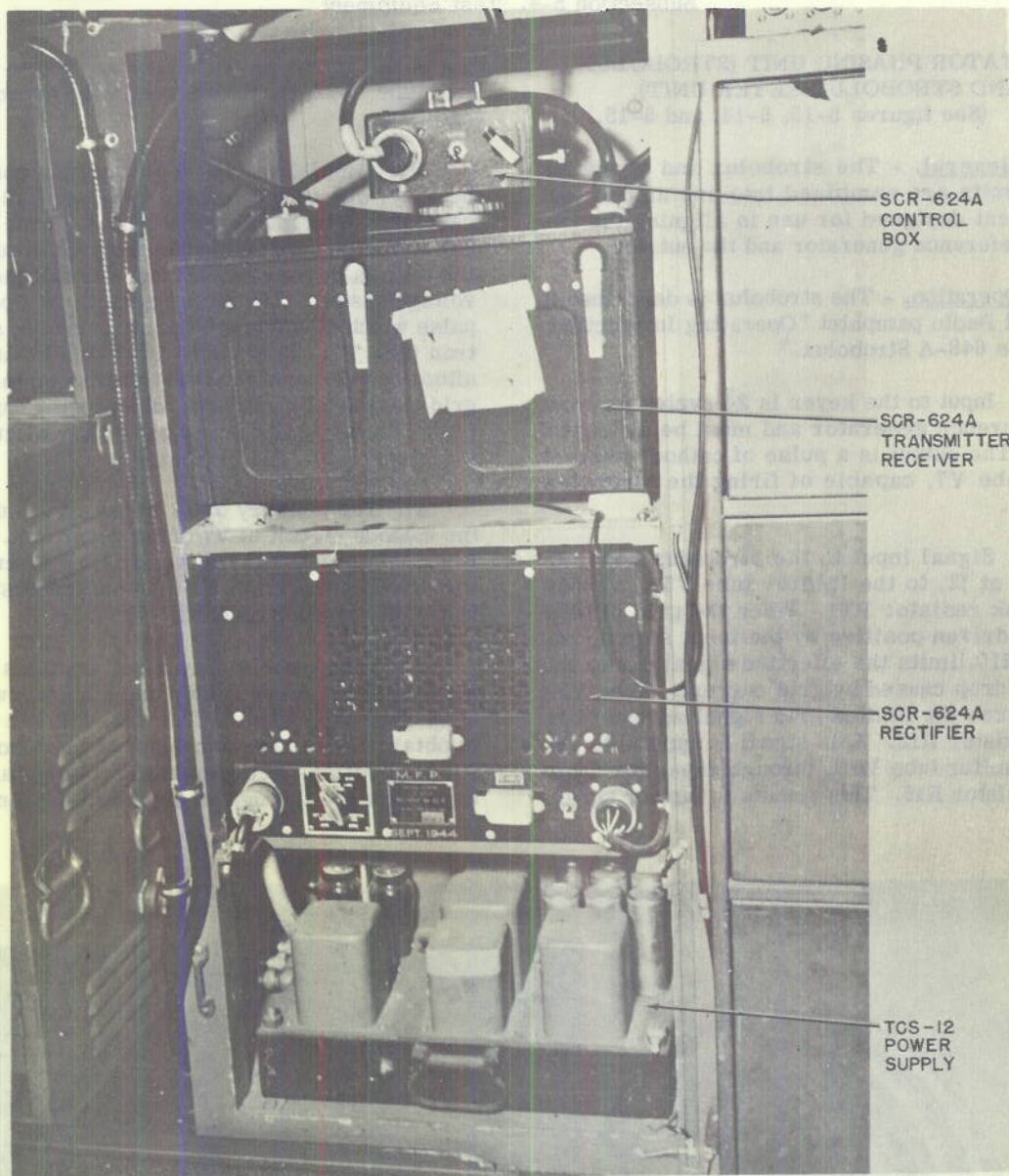


Figure 5-12. Communications Equipment - Front View of Power Supplies

The output voltages of the power units are filtered to reduce ripple and noise components. For wiring diagrams, schematics, and other information, refer to the instruction book for Navy Model TCS-12 Radio Telephone and Telegraph Transmitting and Receiving Equipment.

4. SWITCHBOARD BD-72

The switchboard used in the Lark SP-1M is

a type BD-72. (See figure 5-10.) This switchboard has accommodations for handling twelve calls; or, when all the jacks are interconnected, a single call may be carried over twelve lines making it possible for twelve people to participate in one conversation. The output of the radio receiver may be piped into the switchboard to enable personnel in other trailers to listen in on these calls. The function of the switchboard in the communication system is shown in figure 5-11.

Subsection 5-4. Test Equipment

1. NUTATOR PHASING UNIT (STROBOLUX AND STROBOLUX KEYER UNIT).

(See figures 5-13, 5-14, and 5-15.)

a. General. - The strobolux and strobolux keyer units are combined into one unit of test equipment designed for use in aligning the 24-cycle reference generator and the nutator.

b. Operation. - The strobolux is described in General Radio pamphlet "Operating Instructions for Type 648-A Strobolux."

1). Input to the keyer is 24 cycles as from the reference generator and must be at least 4 volts. The output is a pulse of cathode current from tube V7, capable of firing the strobolux tube V2.

2). Signal input to the strobolux keyer is applied at J2, to the limiter tube V5A, across grid leak resistor R11. When the grid of tube V5A is driven positive by the input signal, resistor R10 limits the effective signal due to the voltage drop caused by grid current. Tube V5A reproduces the limited grid signal across plate load resistor R12. This signal is applied to another limiter tube V5B, through capacitor C9 to grid resistor R15. This results in further squar-

ing of the signal which is then applied to amplifier tube V6, through differentiating network C10 and R18.

3). Amplifier tube V6 normally conducts heavily, due to a negative bias applied to the cathode. When the negative portion of the differentiated signal is applied to the grid of tube V6, the tube is driven to near cut-off and the plate voltage rises. This action results in a positive pulse which is applied to the outer grid of strobotron tube V7. This pulse is of sufficient magnitude to overcome the negative bias on the inner grid and the tube conducts, discharging capacitor C13. This results in a heavy flow of current while capacitor C13 discharges.

4). The primary of T2 of the strobolux is in the cathode circuit of V7 of the keyer unit. Thus, when V7 is pulsed, the heavy flow of current through the primary of T2 is of sufficient strength to key the strobotron unit.

5). The strobolux keyer unit contains a full-wave positive power supply and a half-wave negative regulated supply. The 115-volt a-c supply is obtained from the a-c input of the strobolux. All connections between the strobolux and the keyer unit are through an amphenol 8-prong con-

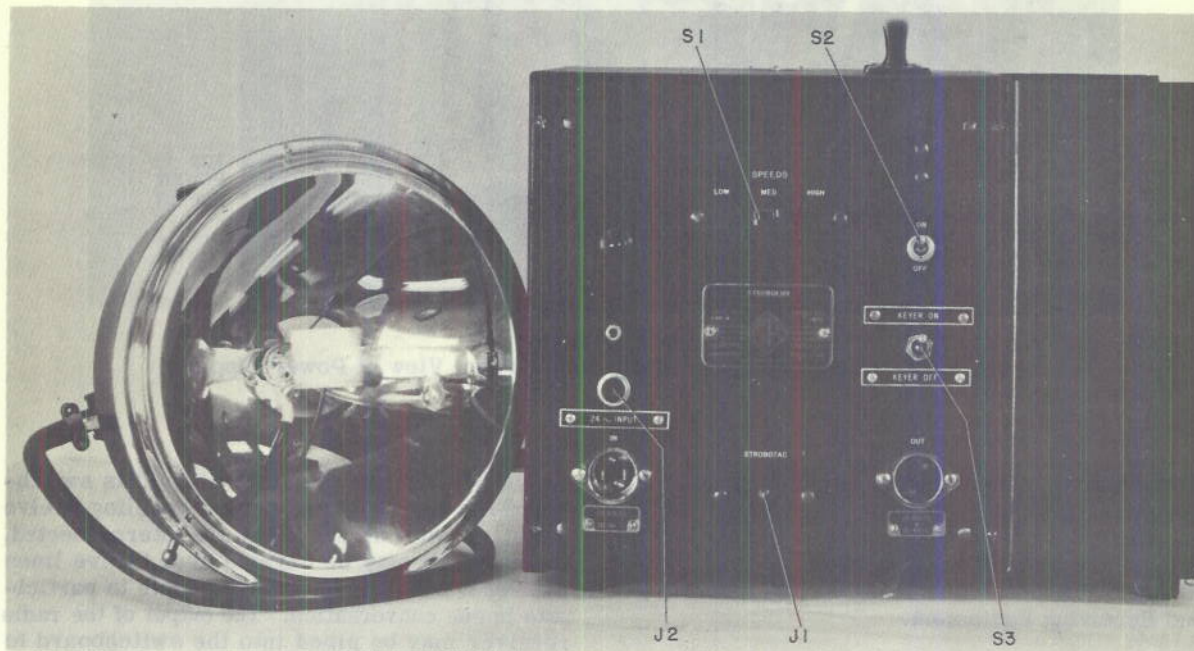


Figure 5-13. Nutator Phasing Unit - Front View

necter. Wave forms and voltages are shown on the figure 5-15.

2. RANGE UNIT BRIDGE ADJUSTER

Since the phase-splitting bridge circuits in the range unit are extremely sensitive to loading of any kind, measuring instruments must be isolated from these circuits when adjusting for properly phased signals. The range unit bridge

adjuster accomplishes this isolation through high-impedance, low-capacity-input cathode followers. The output of the cathode followers is fed to a cathode-ray oscilloscope for phase measurement.

The range unit bridge adjuster has its own self-contained power supply and operates from 115 volts ac. The unit is shown in the photograph figure 5-16 and in the schematic diagram, figure 5-17.

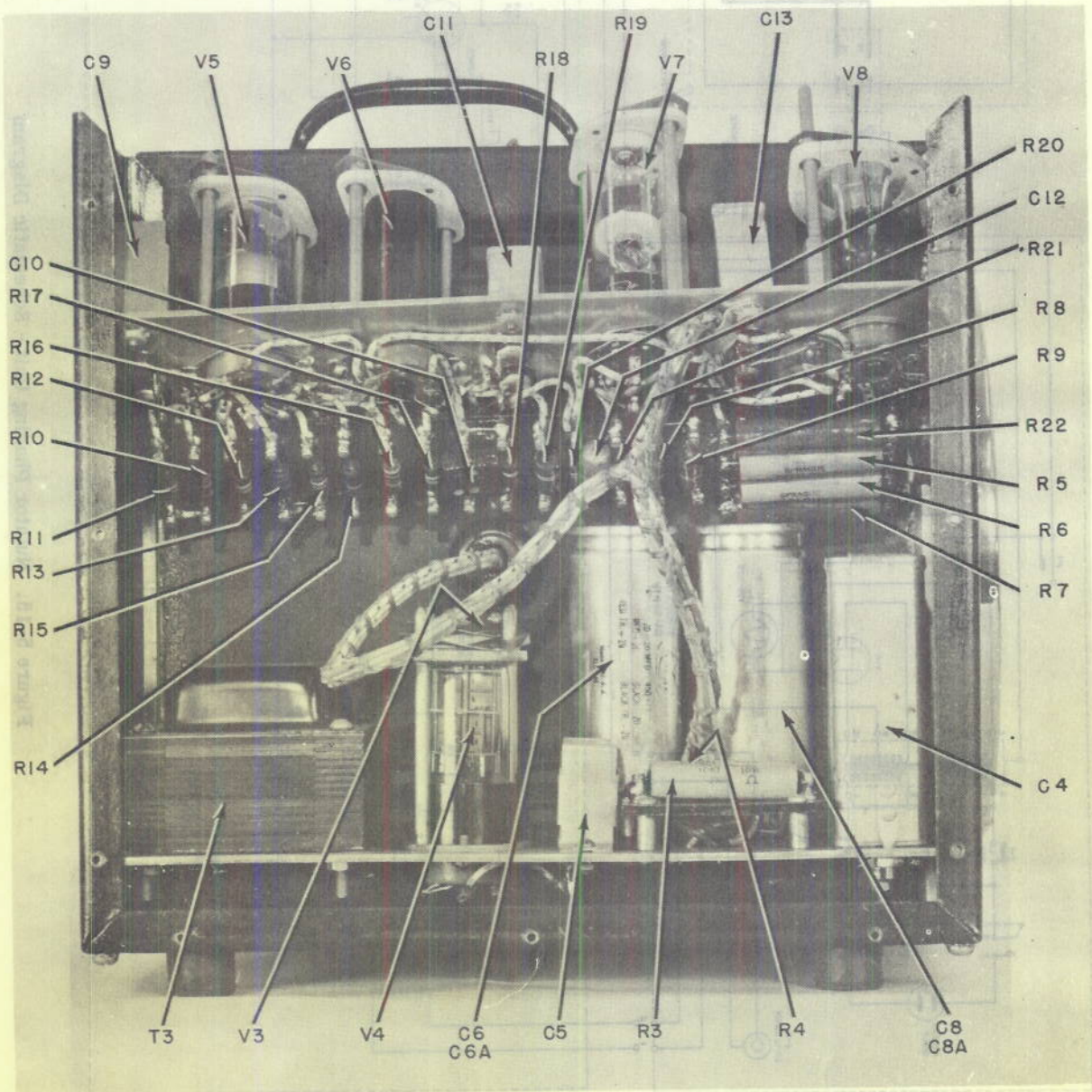


Figure 5-14. Nutator Phasing Unit Keyer Chassis - Upper Shelf Tilted

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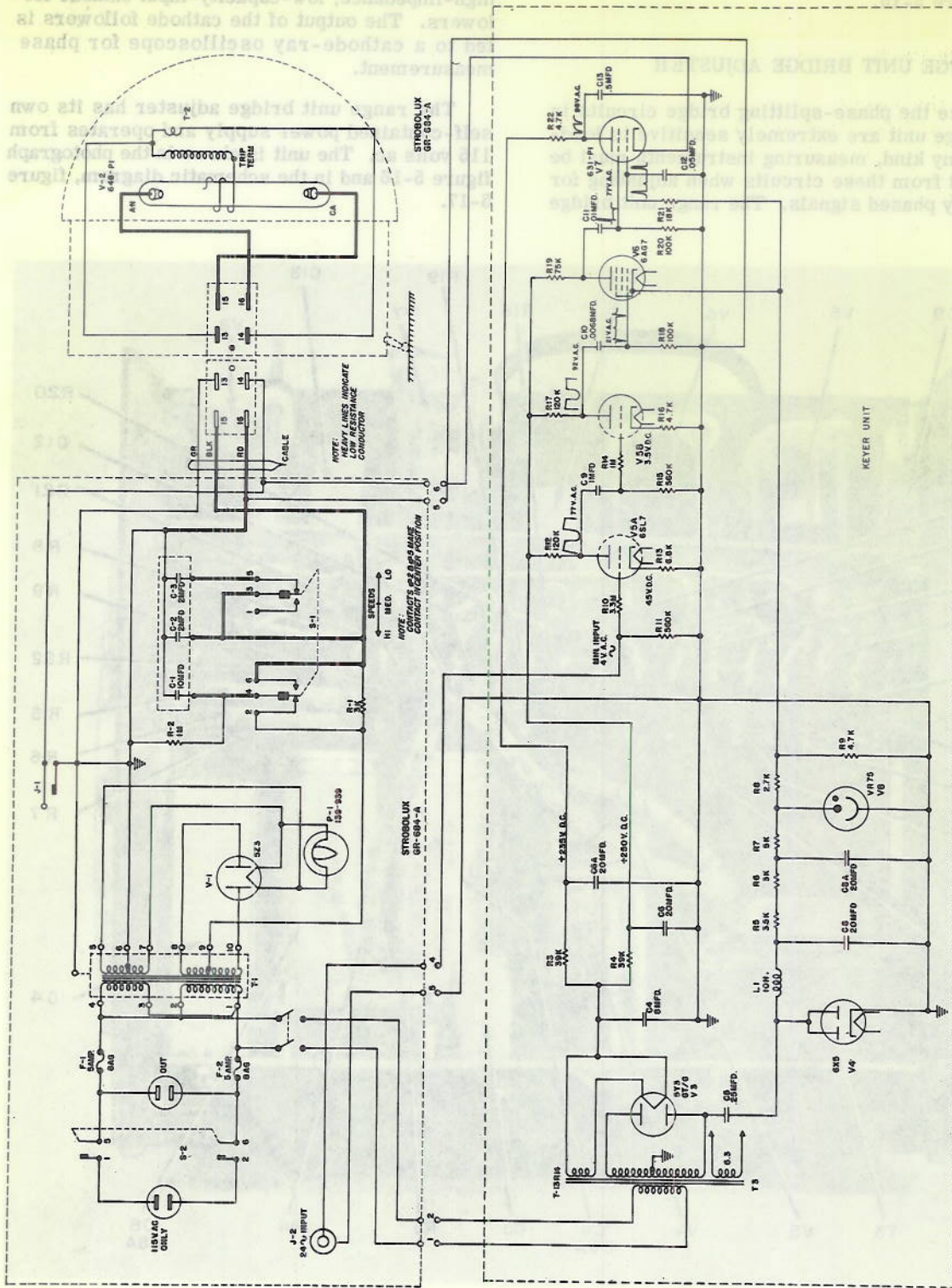


Figure 5-15. Nutator Phasing Unit - Schematic Diagram

Figure 5-14. Nutator Phasing Unit Keyer Controls - Upper Shell Titled

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Figure 5-16. Range Unit Bridge Adjuster - Front View

3. FREQUENCY STANDARD (See figures 5-18, 5-19 and 5-20.)

a. General. - The use of the Lark SP-1M in conjunction with the Lark Missile is predicated upon the operation of the Lark SP-1M at a repetition frequency of 576 cycles per second, plus or minus five percent, and upon the use of a scan frequency of 24 cycles per second, plus or minus one tenth of one cycle per second. These frequency tolerances are necessary because the control receiver (AN/APW-4) in the missile contains frequency selective circuits. The frequency standard is used to adjust the repetition frequency and the scan frequency so they remain within the proper tolerances.

b. Outputs. - The frequency standard receives no inputs from the Lark SP-1M except 115-volt a-c, 60-cycle, single-phase power at 75 watts. The unit is required to produce two simultaneous output signals at 576 and 24 cycles per second. Each output is two phase with 90 degrees phase difference, so that each frequency can be displayed upon an oscilloscope as a circular trace. The output frequency is maintained within 0.005 percent of the correct value over a wide temperature range.

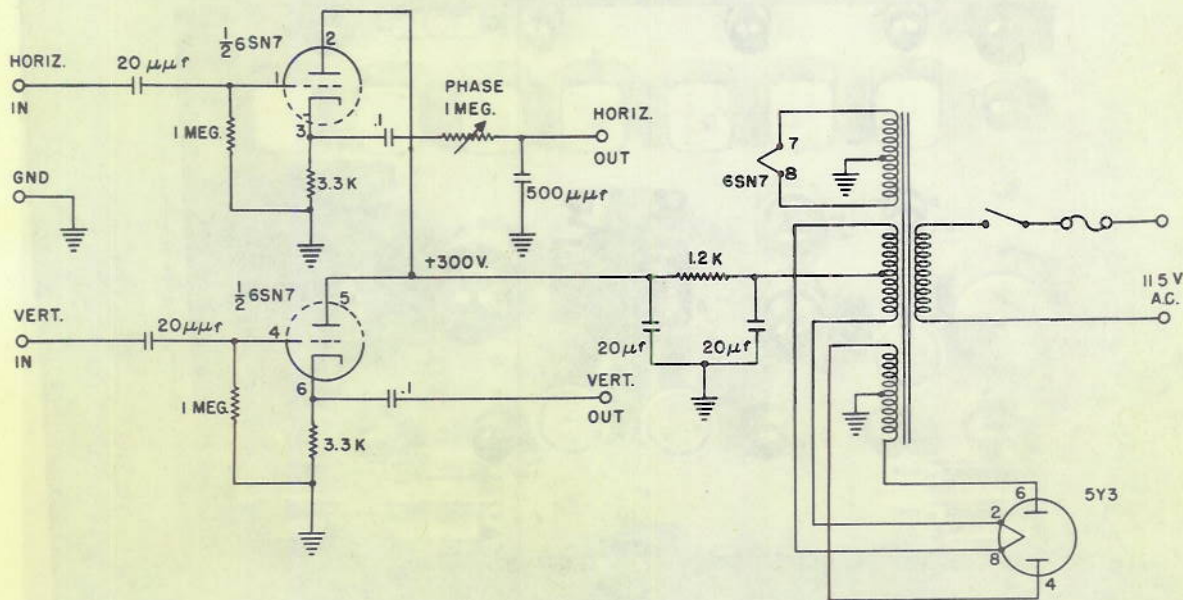


Figure 5-17. Range Unit Bridge Adjuster - Schematic Diagram

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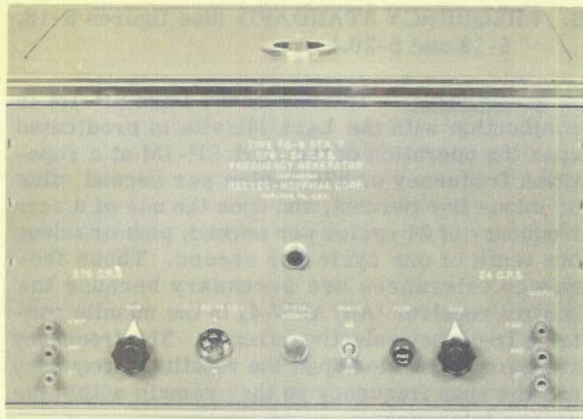


Figure 5-18. Frequency Standard - Front View

oscillator, composed of V102A and V102B. The oscillator operates at a frequency of 92.16 kc plus or minus 0.005 percent over a temperature range of 0 degrees to 50 degrees Centigrade. The output of the crystal oscillator is connected to an auxiliary circuit composed of V101A, V101B, and a relay, K101 whose contacts are connected to disable the output amplifiers in case of failure of the crystal oscillator. A relay contact on K101 is also connected to a front panel indicator, V110, which indicates that the crystal oscillator is operating. V103A is a cathode follower that is used to feed signal power from the oscillator to the divider circuits. V103B, V104A, V104B, and V105A are a chain of cascaded blocking oscillator dividers which produce a frequency division of 160. The output of V105A is at 576 cycles per second. This output is filtered by the selective amplifier composed of V107A and V107B. The signal is amplified by V108A and connected to the network consisting of C127 and R162, a 90 degree phase shifter. The two 90 degree signal components are amplified by V108B and connected through the cathode followers, V109A and V109B,

c. Signal Flow. - Figure 5-20 is a schematic drawing of the frequency standard. Figure 5-19 is a top view. The unit is controlled by a crystal

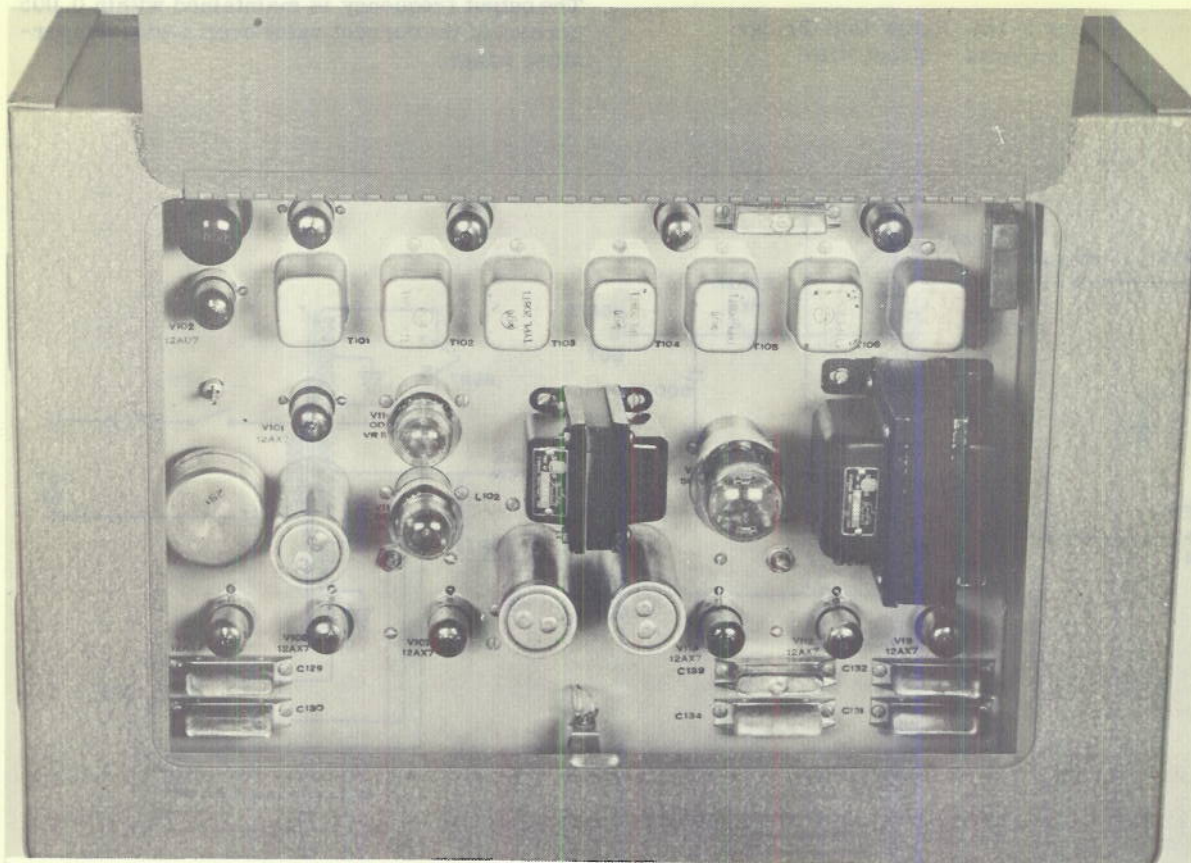
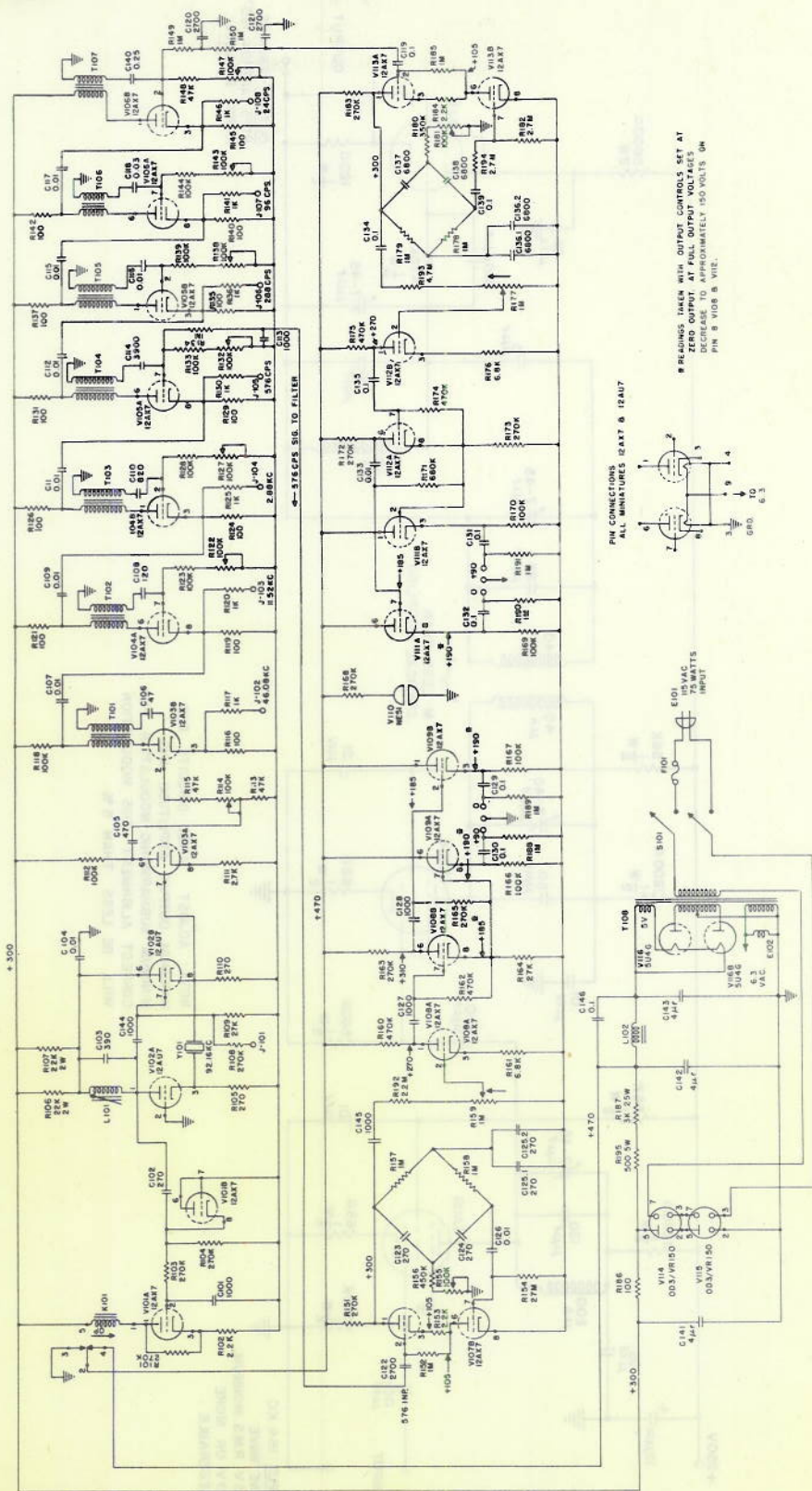


Figure 5-19. Frequency Standard - Top View

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9 READINGS TAKEN WITH OUTPUT CONTROLS SET AT 100V AC INPUT. READINGS WILL INCREASE AS INPUT VOLTAGE DECREASES TO APPROXIMATELY 100 VOLTS 0M PIN 8 V08 & V12.

PIN CONNECTIONS ALL MINIATURES 12AX7 & 12AU7

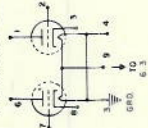


Figure 5-20. Frequency Standard - Schematic Diagram

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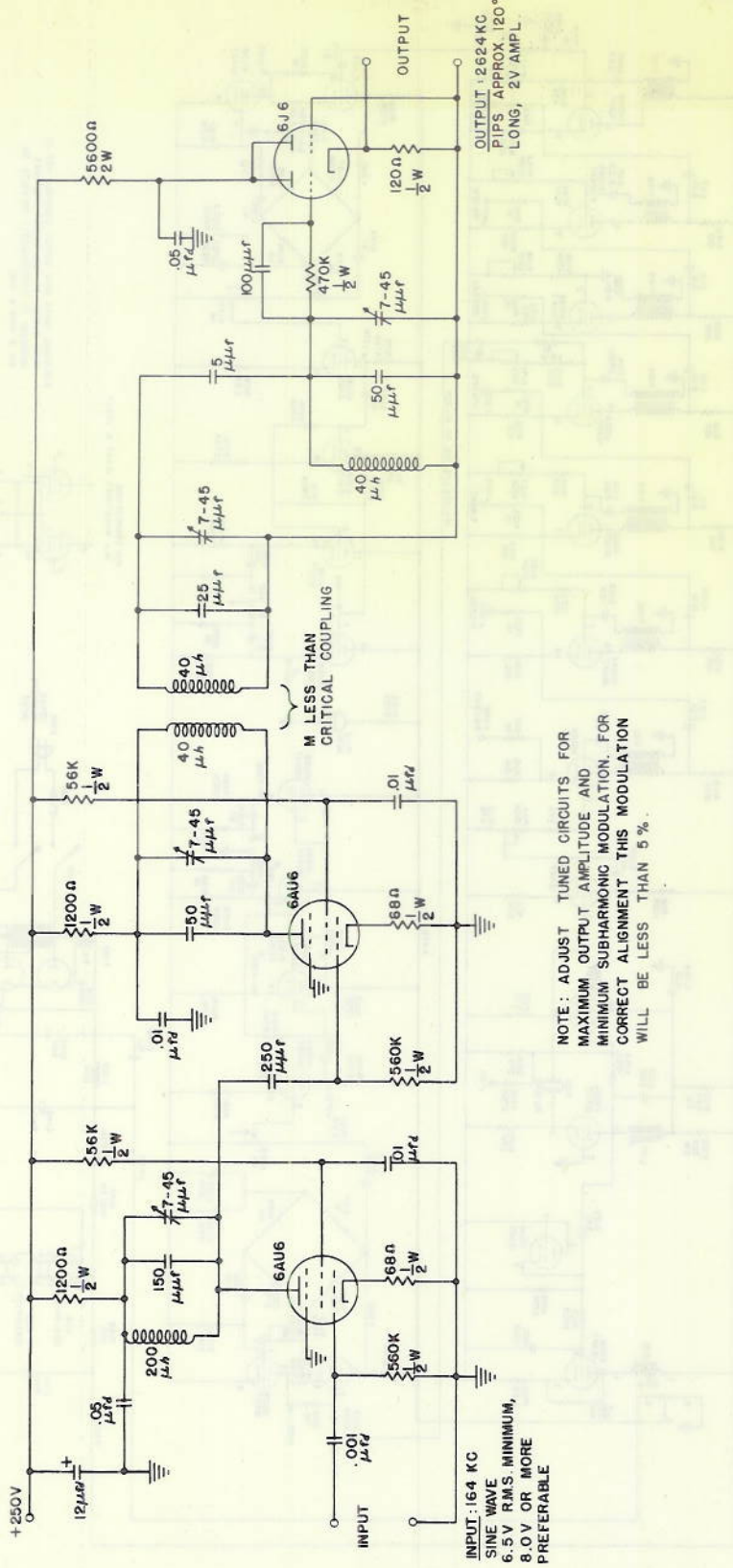


Figure 5-21. Sixteenth Harmonic Frequency Multiplier - Schematic Diagram

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to the output terminals. V105B, V106A and V106B are additional blocking oscillator dividers used to divide the 576 cycles per second signal to 24 cycles per second. The 24 cycle per second signal from V106B is filtered by the selective amplifier, V113A and V113B, is amplified in V112B and connected to the phase shifter, C135 and R174. The two 90 degree signal components are fed to the output terminals through the amplifier V112A, and the cathode followers, V111A and V111B. The unit is powered by a conventional, self-contained power supply.

d. Operation. - Figure 5-18 is a front view of the frequency standard. The 576 cycle per second output appears at the right hand side of the unit, the center terminal being ground, the upper terminal a 90 degree signal, and the lower terminal a zero degree signal. At the left of the terminal posts is the gain control for the 576 cycle per second signal. The 24 cycle per second signal output appears at the left hand side of the unit, the center post being ground, the upper post the 90 degree signal, and the lower post the zero degree signal. The gain control for the 24 cycle per signal is to the right of the terminal posts.

e. Maintenance.

1). Crystal Oscillator. - If the crystal oscillator fails as indicated by failure of the lamp marked "Crystal Activity" to glow, check the plate supply voltage to V102. Next check crystal voltage at J-101 by means of a VTVM. The reading should be approximately -2 volts dc. If no voltage is indicated, the tube V-102 should be replaced.

2). Dividers. - In the event of failure of one or more of the frequency dividers check each divider starting with the first. To test the 46.08 kc divider it is advisable to use an oscilloscope having a "Z" axis timing input. This input should be connected to J-101 with maximum gain of the "Z" axis amplifier as the 92.16 kc signal is of low amplitude because of the series resistor R-108. By observing the signal at J-102 using "Z" axis 92.16 kc blanking, setting the 2:1 division is accomplished. All subsequent dividers may be adjusted by utilizing only the Y axis amplifier connected to J-103 to J-108 inclusive and counting the pulses. The pulses from the driving divider will be negative and the pulse from the divider being adjusted will be positive. Both types of pulses will be displayed simultaneously and the division ratio may be determined by inspection.

3). Filters. - None of the filter circuit components are critical except the elements of the

Parallel "T" network which must be maintained within ± 1 percent. These components are R-178, R-179, R-180, R-181 and C-137, C-138 for the 24 cps filter and R-155, R-156, R-157, R-158 and C-123, C-124 for the 576 cps filter. If the filter cannot be restored to optimum output by readjustment of R-155 or R-181 for the respective filters then either the capacitors or resistors may have to be changed. Improper adjustment of the filter is usually indicated by a reduction in output.

4). Phase Shifter. - The 90° phase shifter is dependent upon the resistor and capacitor elements C-133, R-171 and C-127, R-162 maintaining their values. When properly adjusted the reactance of the capacitor should equal that of its associated resistor at the desired frequency. Occasionally a slight readjustment of either the capacitance or resistance might be in order. This may be done by setting up an oscilloscope so that the X and Y axis deflection sensitivity on the oscilloscope tube are the same for a given signal, then connect the Y axis terminals across the R value and the X axis terminals across the C value and adjust either R or C until a circle pattern is obtained.

4. SIXTEENTH HARMONIC FREQUENCY MULTIPLIER

The cyclic error of the Range Unit, Unit 300 should be periodically checked. In making this check, an accurate calibration standard is necessary. This requirement is met by the sixteenth harmonic frequency multiplier which generates calibration pulses, spaced 62.5 yards apart in radar range, from the 164-kc timing wave in

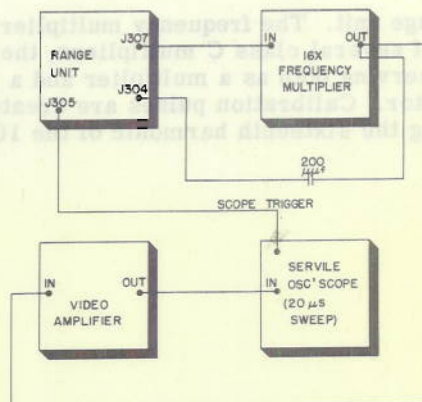
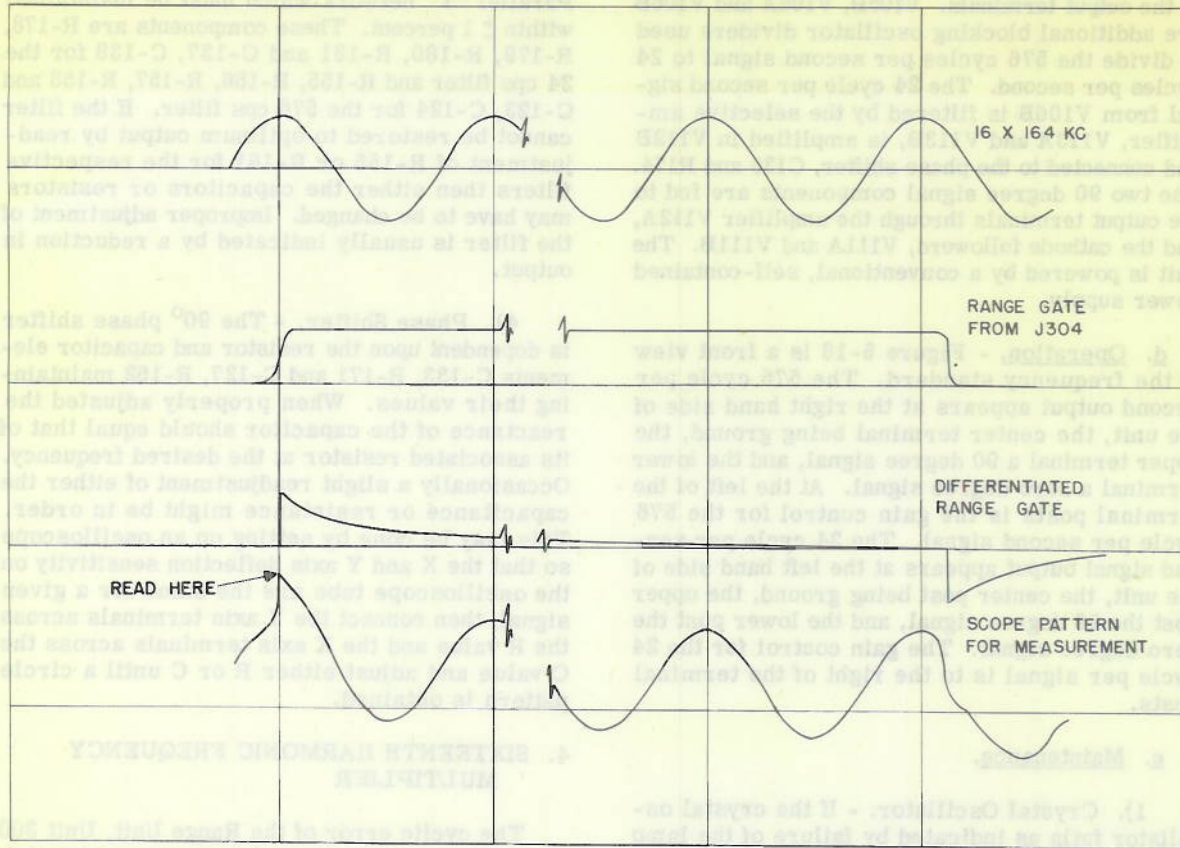


Figure 5-22. Sixteenth Harmonic Frequency Multiplier Connections to the Range Unit - Block Diagram



0 ("A" SWEEP TRIG)
 t →
 WAVE FORMS FOR
 CYCLIC ERROR MEASUREMENT

Figure 5-23. Wave Forms For Cyclic Error Measurement

the range unit. The frequency multiplier consists of several class C multipliers, the final stage serving both as a multiplier and a pulse generator. Calibration pulses are created by clipping the sixteenth harmonic of the 164-kc signal.

The unit requires both filament power and plus 300 volts dc from the radar for its operation. It is shown schematically in figure 5-21; connections to the range unit are shown in figure 5-22; and the wave forms observed during the test are shown in figure 5-23.

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