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COLLINS

engineering report

Design Analysis - Unified S-Band System for Apollo Network

Volume 2, Parts III, IV, and V

Contract NAS5-9035

Dallas Division | Collins Radio Company, Dallas, Texas

Printed in U. S. A.

part III

station layouts

3.1 OPERATIONS ROOM EQUIPMENT ARRANGEMENT.

At the time of submission of this design analysis, neither final building plans nor operations room dimensions were available for any of the 30-foot Unified S-Band sites. Information obtained from the Field Facilities Branch at GSFC indicates that, in general, the operations room will be approximately 35 feet by 50 feet. The window for antenna viewing will normally be in the 35-foot side of the operations room. Preliminary plan views of the Carnarvon operation building show a somewhat different arrangement of the antenna operations room at that station, which will require some modification to standard plan. From information now available it may be assumed that, while similar, the layout for each station will require an individual operations room plan.

A tentative basic arrangement of a typical station is included as figure 3-1. Attached as figures 3-2, 3-3, and 3-4 are the artists concepts of the appearance of the station in general, a detail view of the servo console-RF control area, and a view of the data and timing equipment arrangement.

3.2 RACKS.

The data and timing system equipment will be mounted in a modified Collins Rack Series C-8000. The remainder of the operations room equipment will be mounted in standard Emcor II racks. Listed below are the dimensions of the type racks to be used.

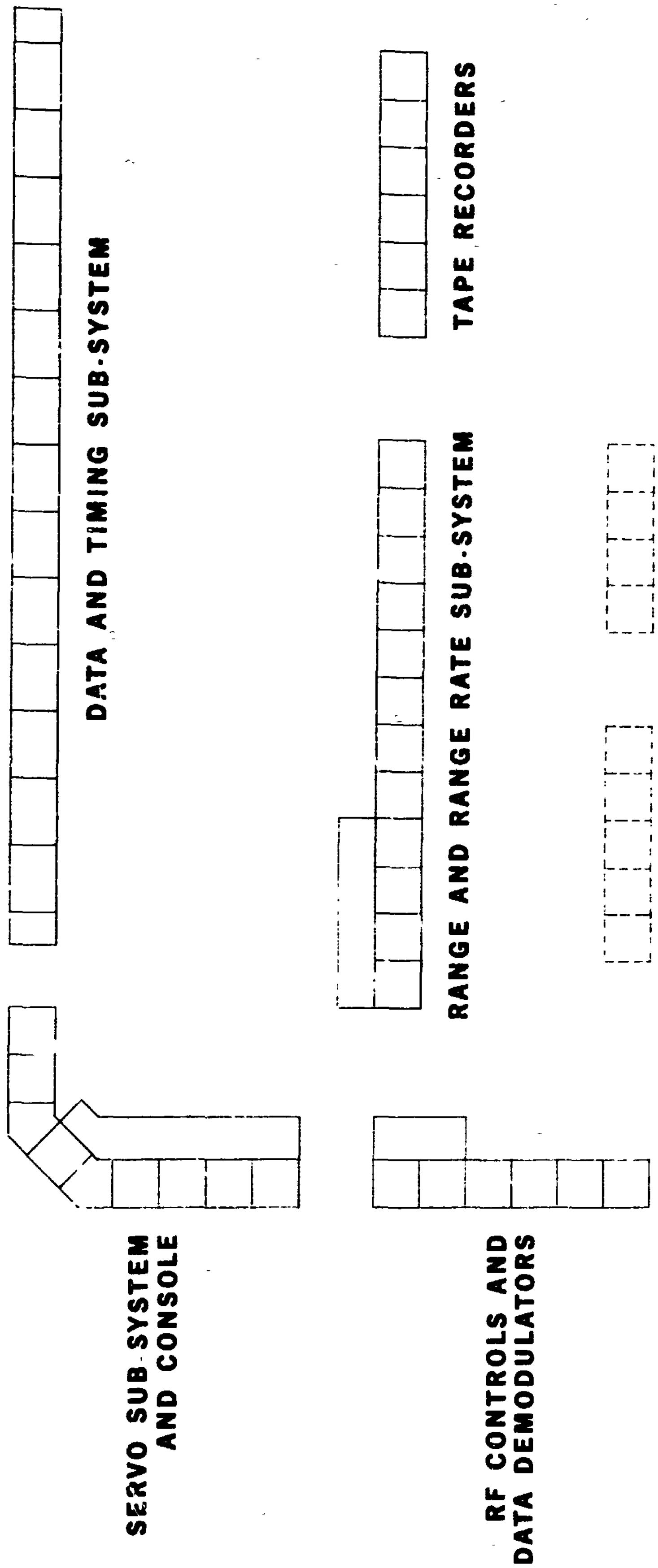


Figure 3-1. Basic Arrangement of Station (Tentative)

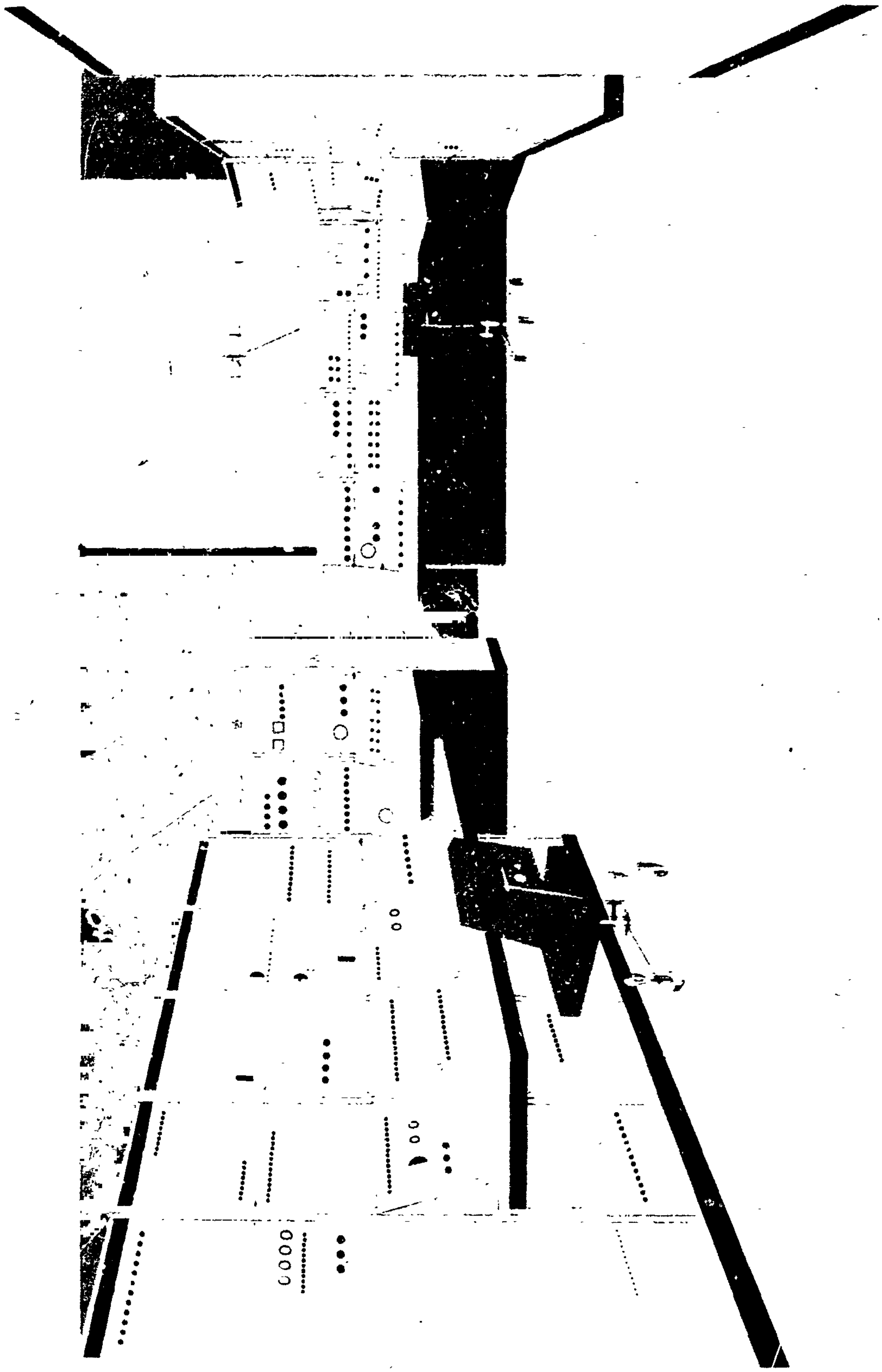


Figure 3-2. Artist's Concept of Station Appearance

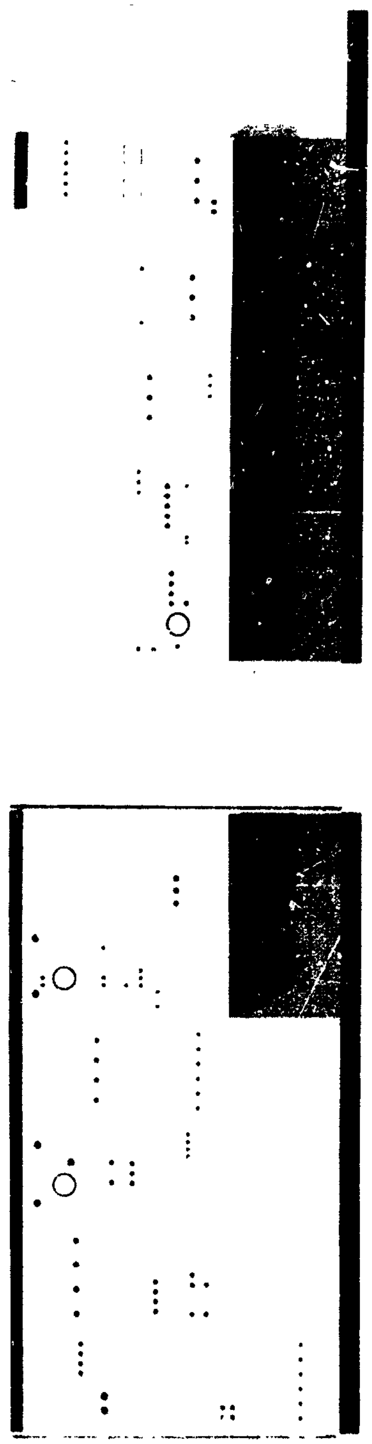


Figure 3-3. View of Servo Console-RF Control Area, Artist's Concept

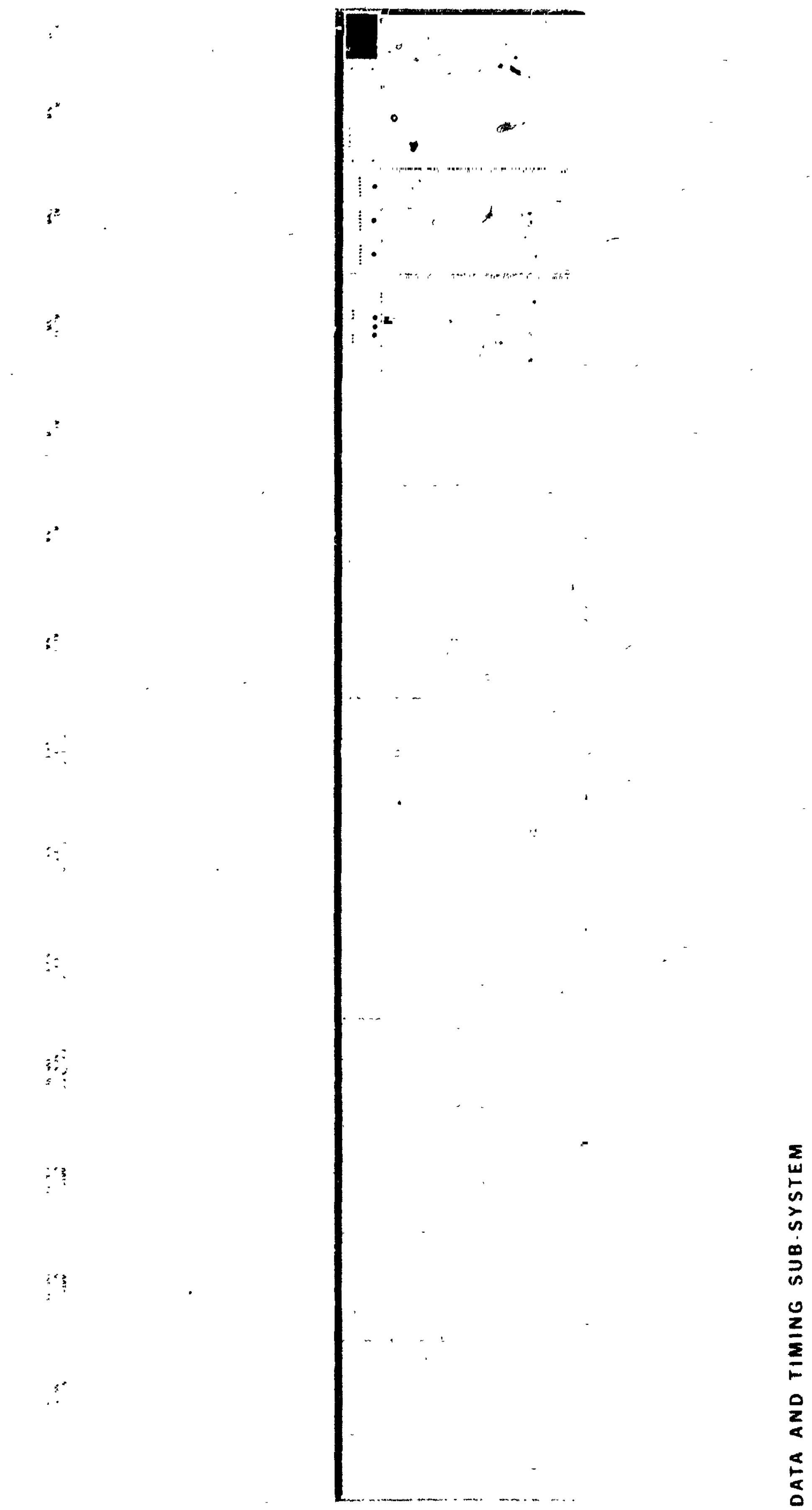


Figure 3-4. Data and Timing Equipment Arrangement, Artist's Concept

	Height (in.)	Width (in.)	Depth (in.)
Timing and Data	69	26	25-1/2
Console Area	50-5/8	21-1/16	25-1/2
All other station racks	76-7/8	21-1/16	25-1/2

All racks will be painted Federal Standard 595 - Number 26440.

3.3 CABLING.

All cabling in the operations room will be installed under the computer type floor. Entry to the individual racks will be from the bottom through ports cut in the floor sections. The area around cable entries will be sealed in order to properly control cool air flow. No overhead or over-the-end cable entries will be made. Outside cabling will be suitable for its environment and will be properly secured to cable trays, cable supports, etc..

3.4 EQUIPMENT COOLING.

The Field Facilities Branch of GSFC plans to provide a cooled air supply under the computer type floor. The temperature for this air supply is assumed to be about 58° F, under about 0.1-psi pressure. Under-the-floor cooling air will be used for operations room equipment cooling insofar as possible. In certain racks, blowers will be required to assist the under-the-floor air system. In certain designated critical areas, emergency blowers will be installed to assist in cooling in case of failure of the central cool air system.

3.5 ELECTROMECHANICAL BUILDING AND HEAT EXCHANGER AREA.

A small diamond-shaped building will be provided at the base of the antenna to house such items as the PA and its power supply. The size of this building will be approximately 9 feet square. A diagram showing the tentative arrangement of this building is included as figure 3-5. A heat exchanger unit for temperature control of the liquid coolant from the Klystron tube cooling manifold will be located about 100 feet from the antenna base. The heat exchanger will require no shelter. The exact size of the unit is not determined at this time, but it is expected that the unit, including work space, will require a concrete pad space approximately 12 feet by 15 feet.

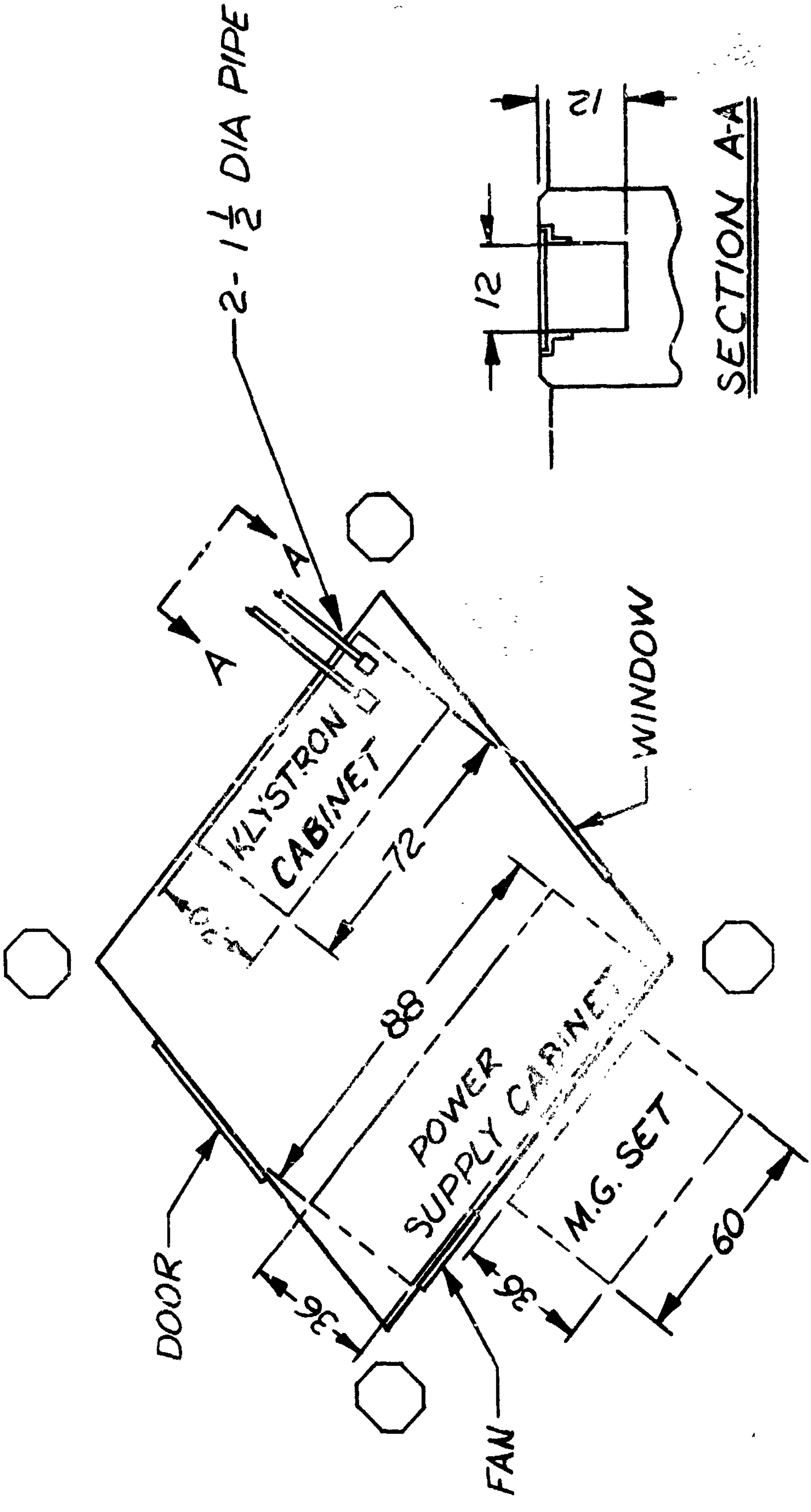


Figure 3-5. Plan of Equipment House for 30-Foot Antenna
(Not to Scale)

A covered cable trough approximately 12 inches square will be routed at ground level between the pad and the antenna base. This trough will provide protection for coolant lines, power wiring, and control cables.

3.6 POWER AMPLIFIER MOTOR GENERATOR.

A small shelter must be provided for the motor generator for the power amplifier. This generator has a very high operational noise level and cannot be placed in a confined area where personnel must work. The shelter for this unit may be attached to the electromechanical building, or it can be at the heat exchanger pad.

3.7 POWER REQUIREMENTS AND HEAT DISSIPATION.

Attached as figure 3-6 is a chart of estimated power requirements and heat dissipation for a 30-foot station. Power requirements and heat dissipation for partial systems is included in the attached Installation Design Criteria.

3.8 PARTIAL SYSTEM.

The Installation Design Criteria for the JPL 85-foot antenna partial system, the GSFC 85-foot antenna partial system, and the Apollo Ships partial system are presented in the following paragraphs.

3.8.1 INSTALLATION DESIGN CRITERIA FOR JPL 85-FOOT ANTENNA PARTIAL SYSTEM.

3.8.1.1 INTRODUCTION. The following installation design criteria is outlined in Items 3(a-5) and 3(b-5) of contract NAS5-9035, dated 14 July 1964. Subject criteria contains the information required to enable a contractor normally in the business of on-site installation to install and integrate subject items of equipment into an existing system. Equipment provided is generally made up of separate units and, therefore, calbing is not provided; however, the type of cable connectors n the equipment is specified to enable the installation contractor to provide proper material for the installation. Racks are not provided for separate units except in the case of the signal data demodulator, where each unit makes up a complete rack of equipment.

3.8.1.2 EQUIPMENT TO BE INSTALLED.

3.8.1.2.1 SINGLE SYSTEM. The following items will be provided by Collins for a JPL Partial Single System.

POWER REQUIREMENTS AND HEAT DIS

EQUIPMENT	POWER V	POWER Ø	POWER CPS	KW
TRACKING DATA PROCESSOR	110	1	60	2.64
ANT. POSITION PROGRAMMER	110	1	60	3.74
ENCODER	110	1	60	0.55
TIMING SYSTEM	110	1	60	4.18
DATA DEMODULATOR NO. 1	110	1	60	0.22
DATA DEMODULATOR NO. 2	110	1	60	0.22
SERVO AMPLIFIER	110	1	60	2.75
SERVO CONSOLE RACK NO. 1				
SERVO CONSOLE RACK NO. 2				
RF RACK NO. 1	110	1	60	0.55
RF RACK NO. 2	110	1	60	0.55
RF RACK NO. 3	110	1	60	0.55
RF RACK NO. 4	110	1	60	0.55
RF & COLLIMATION CONTROL	110	1	60	0.55
DATA CONSOLE NO. 1	110	1	60	0.55
DATA CONSOLE NO. 2	110	1	60	0.55
OPTICAL RECORDING RACK	110	1	60	0.55
OPTICAL MONITOR RACK	110	1	60	0.66
COLLIMATION SYSTEM	110	1	60	3.3
ANTENNA BASE				
X DRIVE	440	3	60	13.2
Y DRIVE	440	3	60	13.2
CONVENIENCE OUTLETS (X)	110	1	60	1.7
CONVENIENCE OUTLETS (Y)	110	1	60	1.7
WARNING SYS (LIGHTS & HORN)	110	1	60	3.3
WHEEL HOUSE	208	3	60	6.6
HEAT EXCHANGER NO. 1	440	3	60	14.0KVA
RF POWER AMP NO. 1	208	3	60	8.0KVA
MOTOR GENERATOR NO. 1 (100 HP)	440	3	60	75.0KVA
ANTENNA LIGHTS	110	1	60	1.7

NOTES:
1. THREE 10 AMP CIRCUITS ON EACH 208 3Ø LINE TO NEUTRAL IS ACCEPTABLE
2. THREE 15 AMP CIRCUITS ON EACH 208 3Ø LINE TO NEUTRAL IS ACCEPTABLE
3. MAXIMUM STARTING CURRENT 60 AMPS/PHASE
4. MAXIMUM STARTING CURRENT 115 AMP/PHASE; THIS POWER REQUIREMENT IS FOR 20 KW OPE

HEAT TO BE DISSIPATED (WATTS)	CIRCUIT REQUIREMENTS	NOTES
2640	ONE 30 AMP CIRCUIT	1
3740	ONE 50 AMP CIRCUIT	2
550	P/O 2A	
4180	ONE 50 AMP CIRCUIT	2
220	ONE 15 AMP CIRCUIT	
220	P/O 4A	
500	ONE 25 AMP CIRCUIT	
500	FOR ENTIRE SERVO	
500	SYSTEM	
550	ONE 15 AMP CIRCUIT	
550	P/O 7A	
550	ONE 15 AMP CIRCUIT	
550	P/O 7C	
550	ONE 15 AMP CIRCUIT	
550	ONE 15 AMP CIRCUIT	
550	P/O 9A	
550	ONE 15 AMP CIRCUIT	
660	P/O 10	
2000	TWO 15 AMP CIRCUITS AT TOWER	
	10 AMP/PHASE	3
	10 AMP/PHASE	3
	ONE 15 AMP CIRCUIT	
	ONE 15 AMP CIRCUIT	
	ONE 30 AMP CIRCUIT	
	20 AMP/PHASE TO NEUTRAL	
	10 AMP/PHASE	
	15 AMP/PHASE	
	57 AMP/PHASE	4
	ONE 15 AMP CIRCUIT	

RATION OF THE POWER AMPLIFIER

Figure 3-6. Power Requirements and Heat Dissip..tion Chart

2

(1) One each - Updata Subcarrier Oscillator

(2) One each - Signal Data Demodulator

(3) One each - Verification Receiver.

3.8.1.2.2 DUAL SYSTEM. The following items of equipment will be added to equipment listed in paragraph 3.9.1.2.1 to make up a JPL Partial Dual System.

(1) One each - Updata Subcarrier Oscillator

(2) One each - Signal Data Demodulator

(3) One each - Verification Receiver.

3.8.1.3 EQUIPMENT DESCRIPTION.

3.8.1.3.1 UPDATA SUBCARRIER OSCILLATOR. All components of this unit are mounted on a 19- by 3-1/2-inch standard rack panel. The unit requires 110-volt, single-phase, 60-cycle power. The heat dissipation will not exceed 80 watts, and no cooling other than normal rack ventilation is required. The unit is made up of two subcarrier oscillators; one for voice, and one for updata functions. Mode switching for the unit is provided on the panel so that either or both of the oscillator outputs are available at the output to the modulator at the proper voltage level.

The inputs to both the voice and tone oscillator will be on 600-ohm lines balanced to ground, and the output following the combiner is at 1000 ohms. The inputs are to a 5-pin Amphenol terminal No. 126-216; pins D and E are signals and pin H is shield. The mating connector on the incoming cable is an Amphenol No. 126-223. The output is a standard BNC connector.

A system block diagram of this unit is included as figure 3-7. Additional information regarding the updata subcarrier oscillator is contained in Collins Specification 126-0447-010. A dual system is made up by the addition of a second unit.

3.8.1.3.2 SIGNAL DATA DEMODULATOR. The signal data demodulator equipment will be packaged in a standard Emcor II rack 76-7/8 inches high, 22 inches wide, and 25-1/2 inches deep. The components will be mounted on standard 19-inch panels. The entire rack may require rfi shielding. Rfi shielding requirements are not fully determined at this time. The rack will be cooled with a 300-cfm McLean Blower Model M2EB424. The blower will be mounted in the lower front of the rack, and the air will

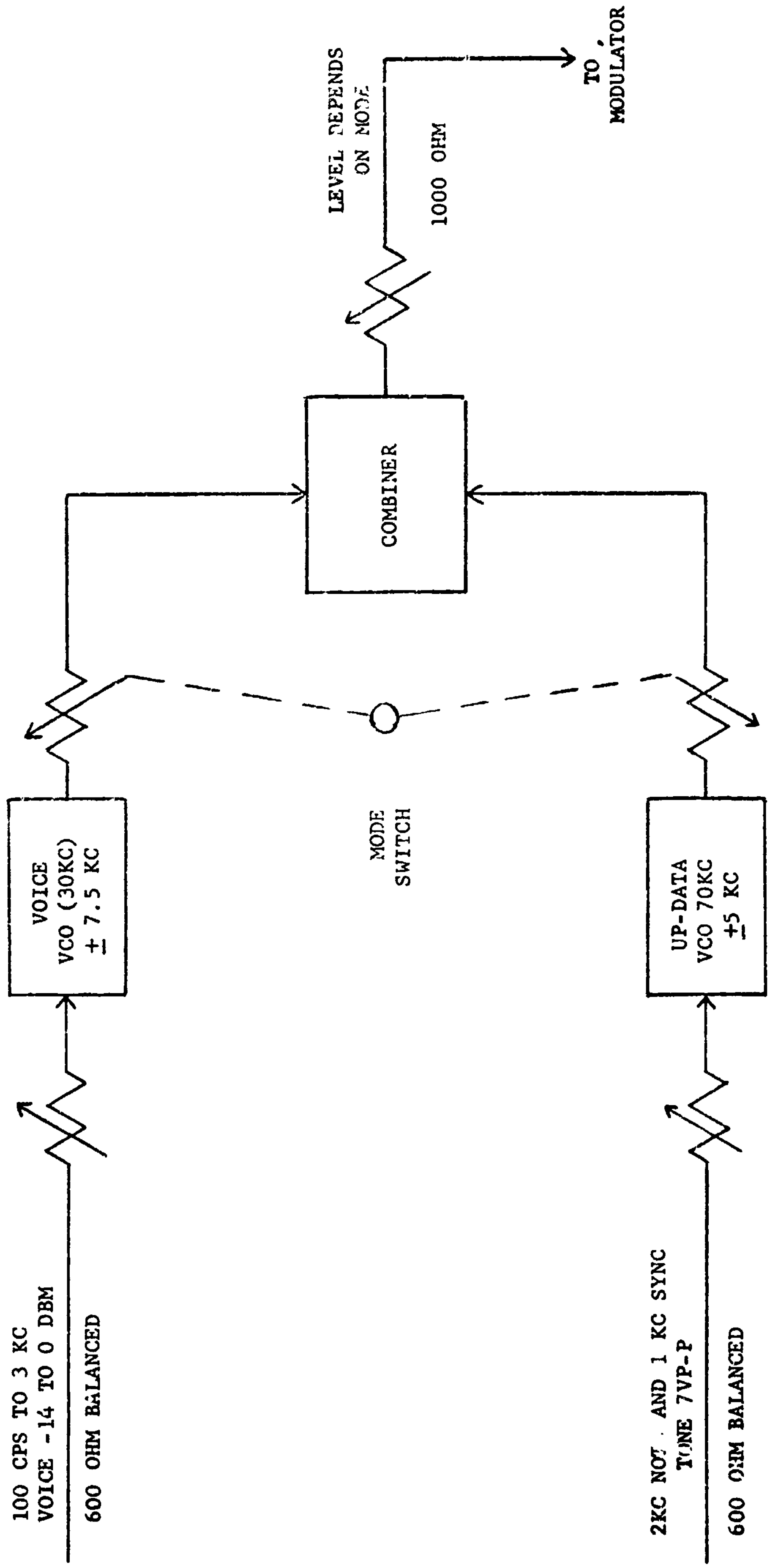


Figure 3-7. Up-Data Subcarrier Oscillator

be exhausted from the rack by way of a filter mounted near the top of the rear door.

The electrical requirement for this rack is one 15-amp circuit providing 110-volt, single-phase, 60-cycle power. The heat dissipation of the entire rack of equipment is 220 watts.

All inputs to this equipment at 10 mc or over will be on TNC connectors. Incoming coaxial cables will be 50 ohms. Outputs from the unit will be on coaxial type BNC connectors, and outgoing coaxial cable will be 93 ohms. General information regarding input and output functions is indicated on the block diagram of this unit, which is included as figure 3-8. Additional information regarding the signal data demodulator is contained in Collins Specification 126-0429-000. A dual system is made up by the addition of the second complete unit.

3.8.1.3.3 VERIFICATION RECEIVER SYSTEM. The verification receiver system consists of a modified multirange telemetry receiver (Vitro Electronics type number R-1037A) and a subcarrier demodulator panel. Each of the above referenced units is mounted on 19-inch by 5-1/4-inch standard rack panel. The total rack space required per system is 10-1/2 inches. Total weight of the two units is approximately 40 pounds.

The units will dissipate a heat load of approximately 80 watts. The units operate on 110-volt, single-phase, 60-cycle electrical power. A satandard 15-amp circuit is more than adequate for the operational load. No special cooling is required for this equipment, and it performs in a satisfactory manner in a rack with normal ventilation.

A single coaxial cable type input at 50 ohms to an N-type connector is provided on the receiver. Cable between the receiver and the demodulator is provided with the unit. The outputs from the demodulator are four BNC type connectors.

Additional information on the verification receiver system is contained in Collins Specification 126-0431-001. A dual system is made up by the addition of a second unit.

3.8.2 INSTALLATION DESIGN CRITERIA FOR GSFC 85-FOOT ANTENNA PARTIAL SYSTEMS.

3.8.2.1 INTRODUCTION. The following installation design criteria is submitted in compliance with the requirements outlined in Items 4(a-5) and 4(b-5) of contract NAS5-9035, dated 14 July 1964. Subject criteria contains information available at this time regarding size, wieght, power requirements, heat dissipation, location, etc..

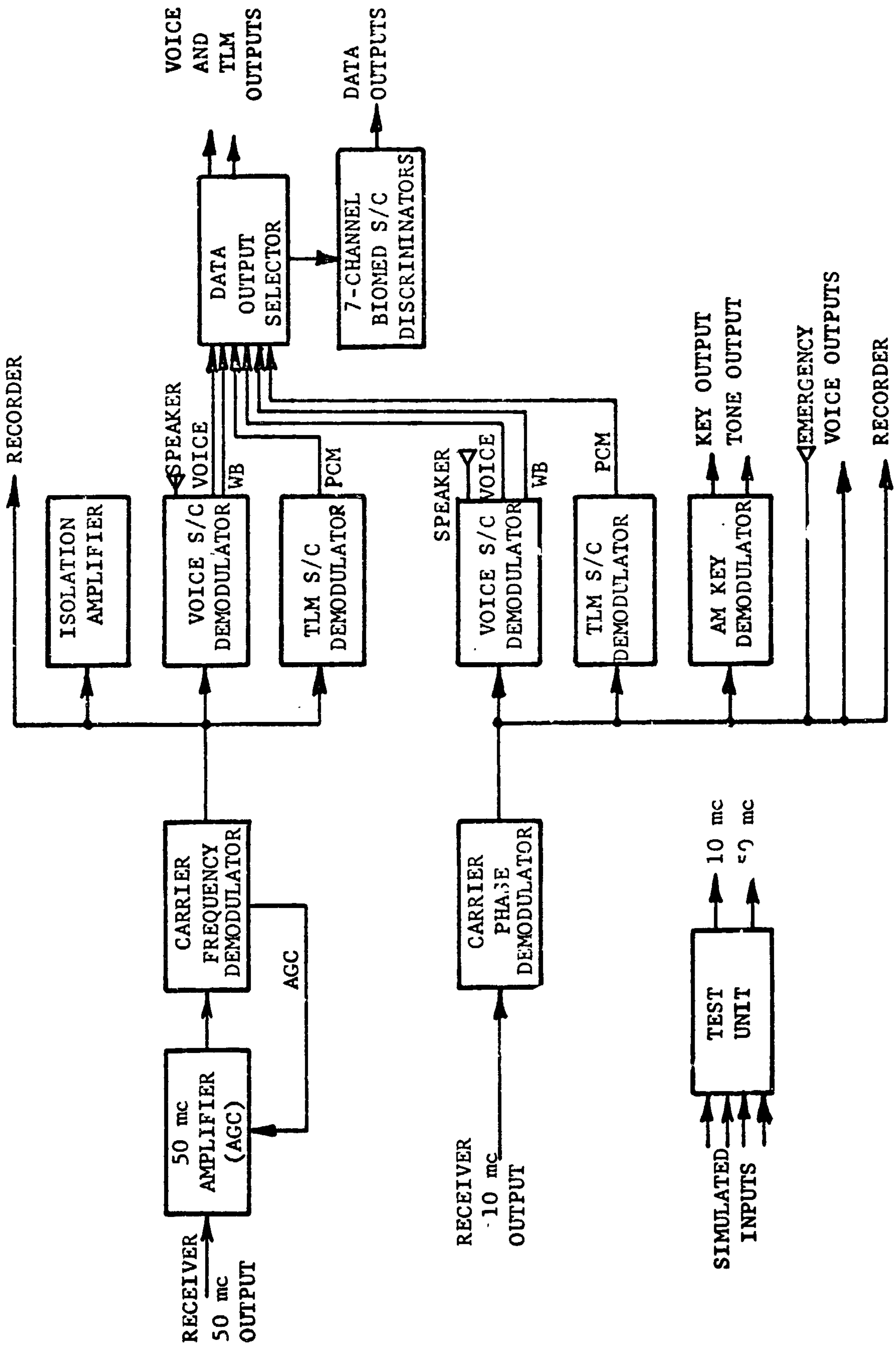


Figure 3-8. Signal Data Demodulator Subsystem, Block Diagram

The information is provided in sufficient detail to enable a contractor normally in the business of on-site installation to install and integrate subject items of equipment into an existing system. The arrangement and placement information regarding certain antenna mounted components of the PA system is provided as an example only since the size and configuration of the wheel house and building at the base of the antenna can only be assumed.

3.8.2.2 EQUIPMENT TO BE INSTALLED.

3.8.2.2.1 SINGLE SYSTEM. The following components and/or subsystems will be provided for a GSFC 85-foot Antenna Partial System [Item 4(a-5) Single System] .

(1) One each - Updata Subcarrier Oscillator
(2) One each - Signal Data Demodulator
(3) One each - Verification Receiver System
(4) One each - Power Amplifier System
(5) One each - Tracking Data Processor
(6) One each - Timing System
(7) One each - Parametric Amplifiers
(8) One each - Paramp.

3.8.2.2.2 DUAL SYSTEM. The following components and/or subsystems, when added to items listed in paragraph 3.8.2.2.1 above will complete a dual system [Item 4(b-5) Dual System] .

(1) One each - Updata Subcarrier Oscillator
(2) One each - Signal Data Demodulator
(3) One each - Verification Receiver System
(4) One each - Power Amplifier System
(5) One each - Tracking Data Processor.

3.8.2.3 EQUIPMENT DESCRIPTION - GSFC PARTIAL SINGLE SYSTEM.

3.8.2.3.1 THE UPDATA SUBCARRIER OSCILLATOR. All components of this unit are mounted on 19 by 3-1/2-inch standard rack panel. The unit requires 110-volt, single-phase, 60-cycle power. The heat dissipation will not exceed 80 watts, and no cooling other than normal rack ventilation is required. The unit is made up of two subcarrier oscillators; one for voice, and one for updata functions. Mode switching for the unit is provided on the panel so that either or both of the oscillator outputs are available at the output to the modulator at proper voltage level.

The inputs to both the voice and tone oscillator will be on 600-ohm lines balanced to ground, and the output following the combiner is at 1000 ohms. The inputs are to a 5-pin Ampheno 1 terminal No. 126-216; pins D and E are signals and pin H is shield. The mating connector on the incoming cable is an Amphenol No. 126-233. The output is a standard BNC connector. A system block diagram of this unit is included as figure 3-9. Additional information regarding Updata Subcarrier Oscillator is contained in Collins Specification 126-0447-010.

3.8.2.3.2 SIGNAL DATA DEMODULATOR. The signal data demodulator equipment will be packaged in a standard Emcor II rack 76-7/8 inches high, 22 inches wide, and 25-1/2 inches deep. The components will be mounted on standard 19-inch panels. The entire rack may require rfi shielding. Rfi shielding requirements are not fully determined at this time. The rack will be cooled with a 300-cfm McLean Blower Model M2EB424. The blower will be mounted in the lower front of the rack, and the air will be exhausted from the rack by way of a filter mounted near the top of the rear door.

The electrical requirements for this rack is one 15-amp circuit providing 110-volt, single-phase, 60-cycle power. The heat dissipation of the entire rack of equipment is 220 watts.

All inputs to this equipment at 10 mc or over will be on TNC connectors. Incoming coaxial cables will be 50 ohms. Outputs from the unit will be on coaxial-type BNC connectors, and outgoing coaxial cable will be 93 ohms. General information regarding input and output functions is indicated on the block diagram of this unit, which is included as figure 3-10. Additional information regarding the signal data demodulator is contained in Collins Specification 126-0429 (appendix a).

3.8.2.3.3 VERIFICATION RECEIVER SYSTEM. The verification receiver system consists of a modified multirange telemetry receiver (Vitro Electronics type number R-1037A) and a subcarrier demodulator panel. Each of the above referenced units is mounted on 19-inch by 5-1/4-inch standard rack panels. The total rack space required per system is 10-1/2 inches. Total weight of the two units is approximately 40 pounds.

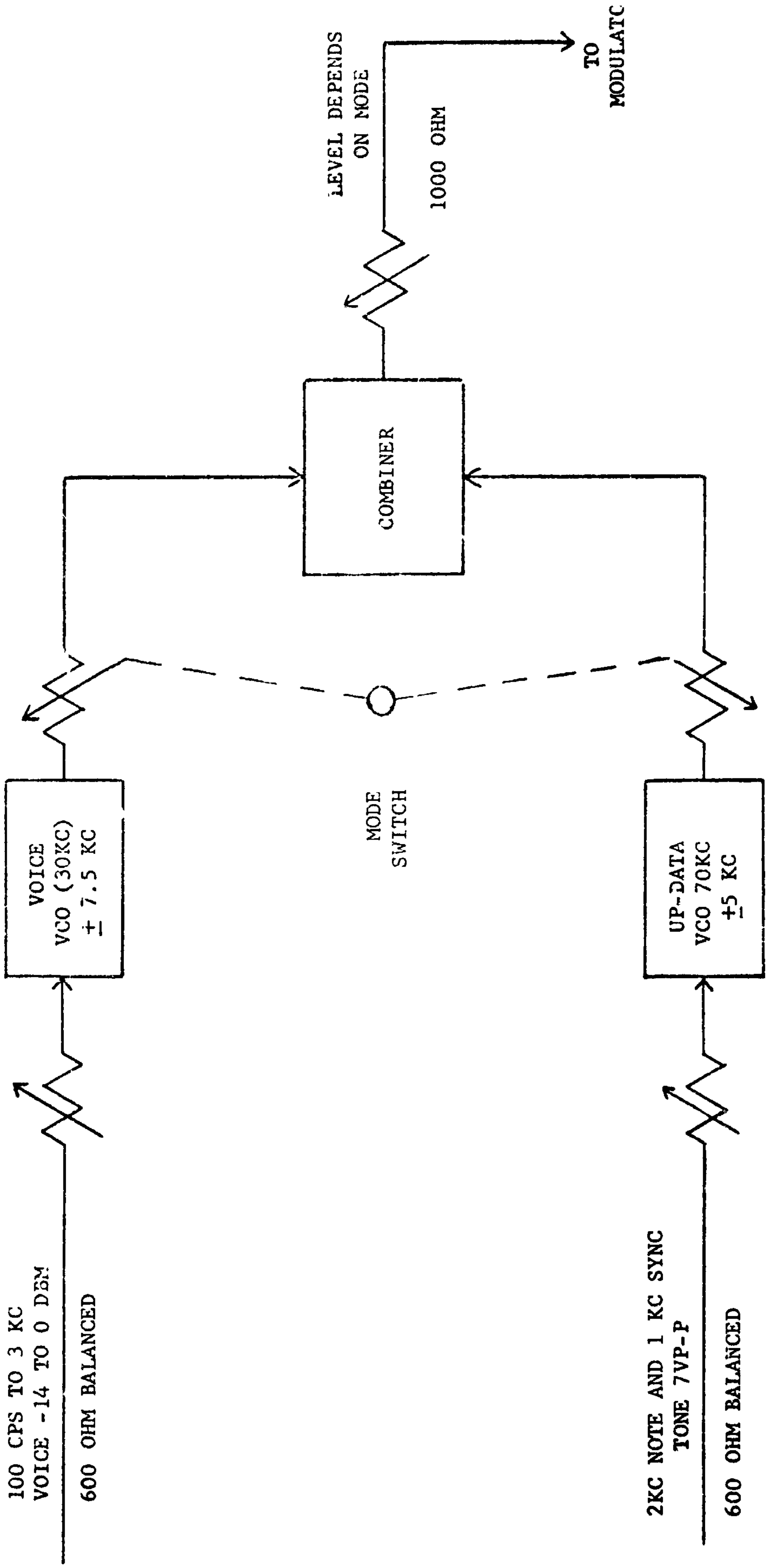


Figure 3-9. Up-Data Subcarrier Oscillator

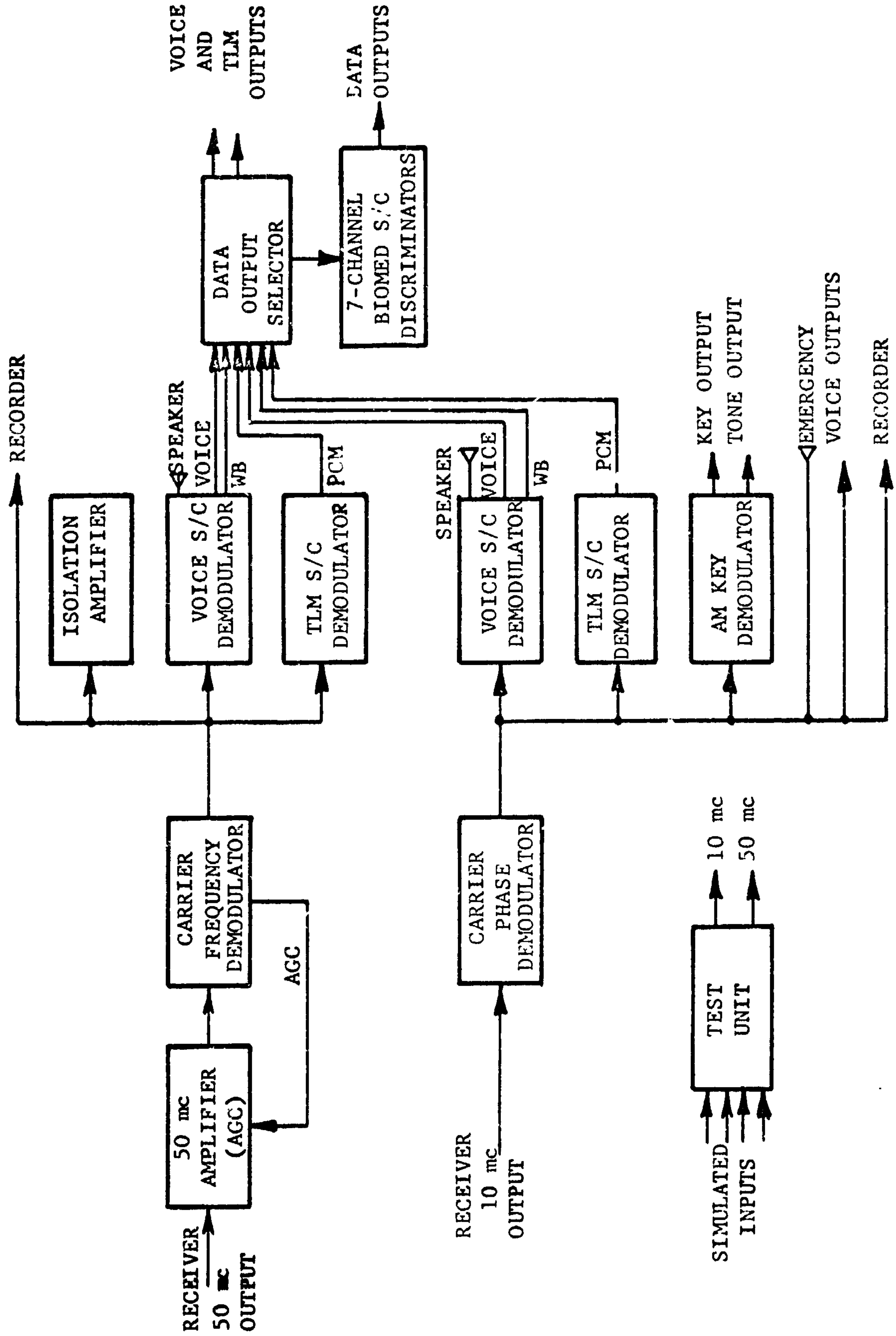


Figure 3-10. Signal Data Demodulator Subsystem Block Diagram

The units will dissipate a heat load of approximately 80 watts. The units require 110-volt, single-phase, 60-cycle electrical power. A standard 15-amp circuit is more than adequate for the operational load. No special cooling is required for this equipment, and it performs in a satisfactory manner in a rack with normal ventilation.

A single coaxial cable type input at 50 ohms to an N-type connector is provided on the receiver. Cable between the receiver and the demodulator is provided with the unit. The outputs from the demodulator are four BNC type connectors.

Additional information on the verification receiver system is contained in Collins Specification 126-0431-001. A dual system is made up of two complete units.

3.8.2.3.4 S-BAND POWER AMPLIFIER.

3.8.2.3.4.1 GENERAL. The power amplifier presents the most complicated installation problem of the partial system. Certain details regarding the placement of equipment are assumed or are recommended locations only in view of the fact that details of antenna, electromechanical building, etc., is not yet available.

Contract NAS5-9035 requires delivery of the equipment for a single and dual system concurrently. In view of the concurrent delivery, this criteria is based on the simultaneous installation of equipment necessary to complete a dual system. Installation of a single system would require only a reduction in the scope of the task outlined herein.

3.8.2.3.4.2 EQUIPMENT LAYOUT AND LOCATION.

(1) Power Amplifier Cabinets and Equipment. The power amplifier cabinets are located on one side of the electronics room (sometimes called the wheel house), which is within the Y-wheel structure of the antenna and just below the ring or box girder. In addition, this room will contain approximately four racks of equipment on standard 19-inch panels. These racks may either be standard units mounted in the electronics room or may be special units built in by the antenna manufacturer. Figure 3-11 is a plan view of this possible arrangement. Figure 3-12 is a simplified isometric drawing of the same area.

(2) High Power Combiner. The high power combiner is also to be located in the electronics room or in the immediate vicinity.

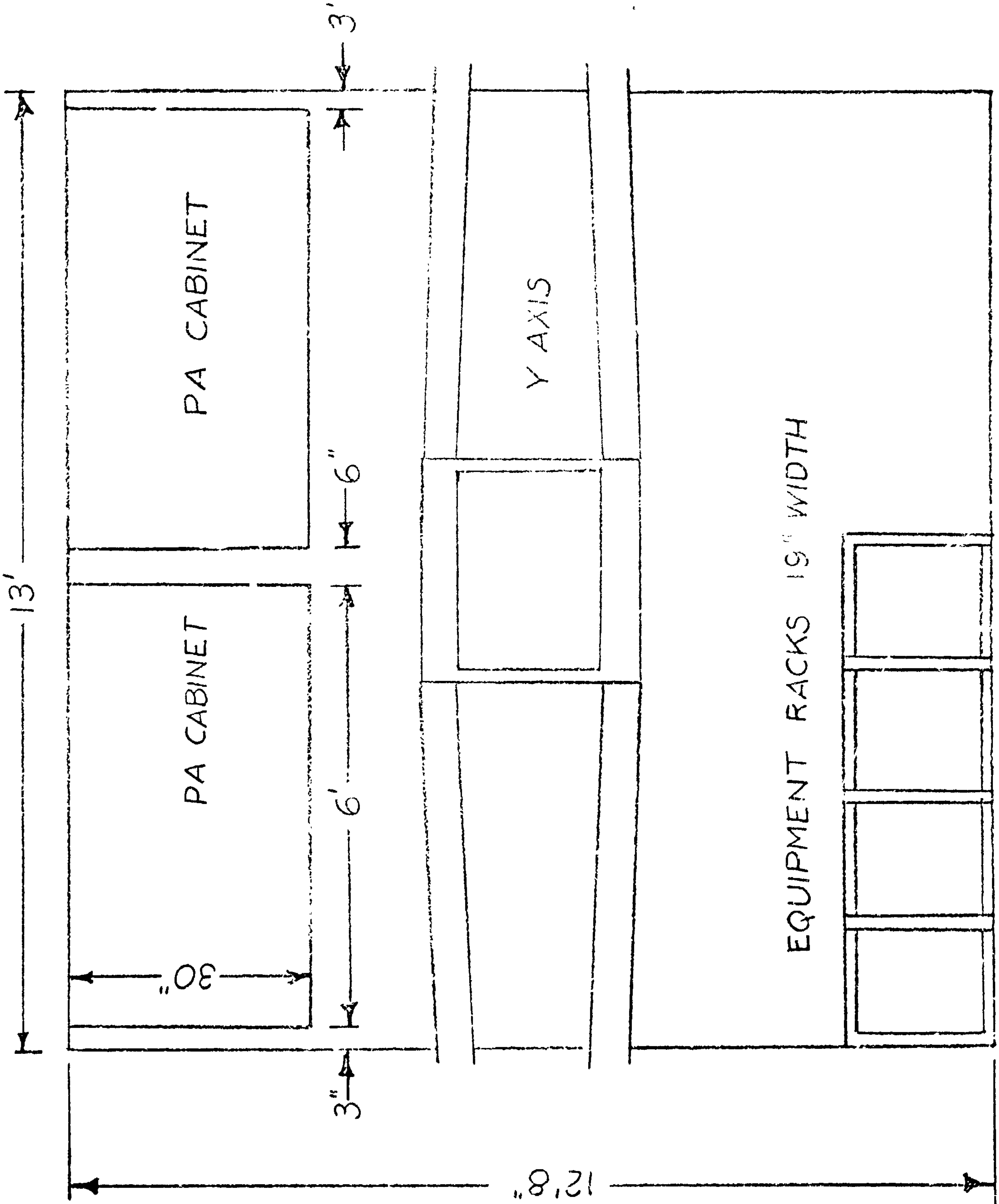


Figure 3-11. Electronic Room 85' Antenna
(Not to Scale)

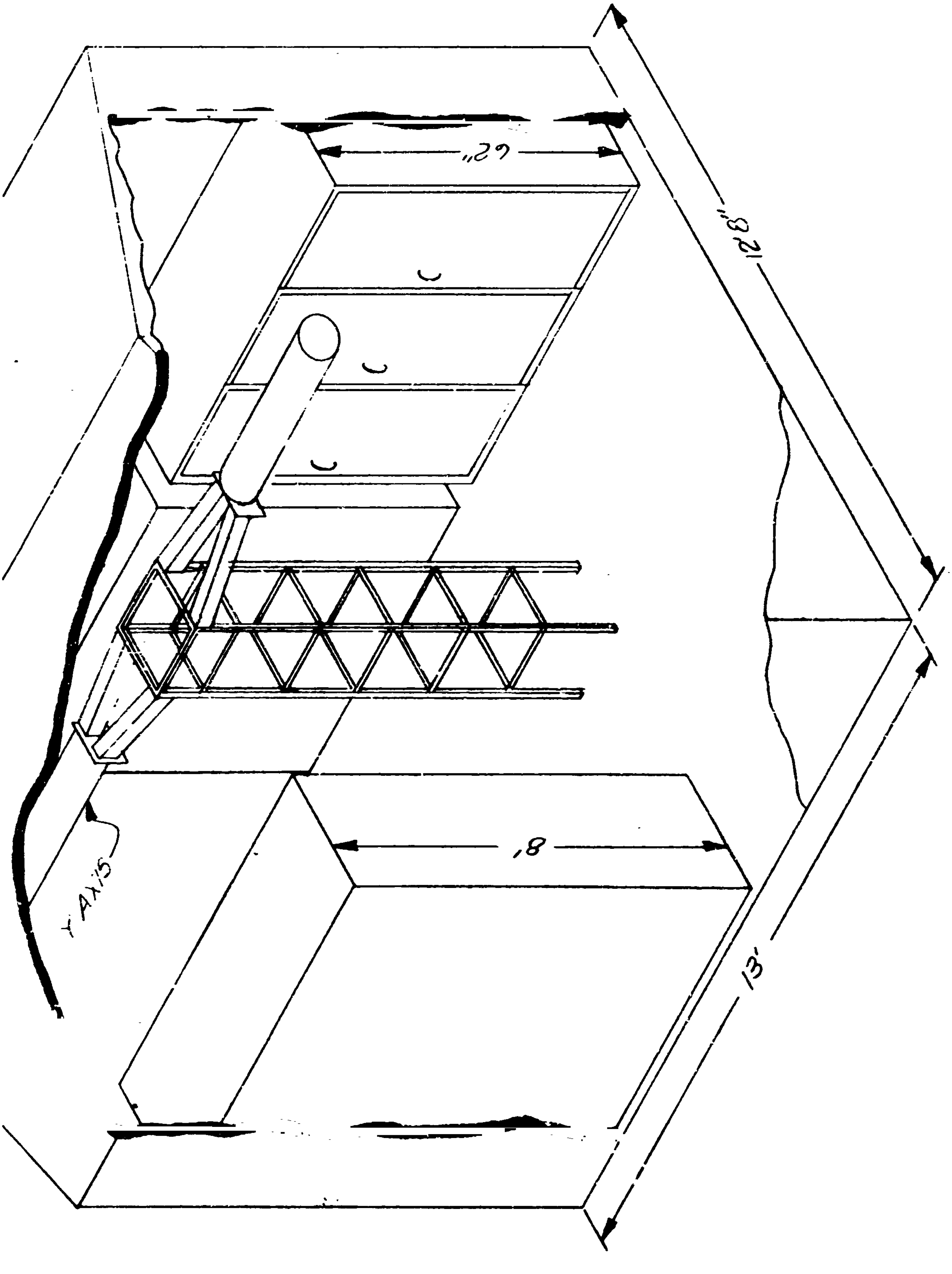


Figure 3-12. Electronic Room 85' Antenna, Dual System

(3) The Power Supply Cabinets. The power supply cabinets will be located in the electromechanical building at the base of the antenna. Arrangement of this equipment will be contingent on the size and layout of this building.

(4) The Motor Generator Units. The motor generator unit produces a high noise level and cannot be placed in the electromechanical building in view of discomfort to operating personnel. The units may be located in a small shelter adjacent to the electromechanical building or if preferred in a similar shelter near the heat exchanger pad.

(5) The Heat Exchanger. The heat exchanger pad should be located not less than 100 feet from the antenna base. Exact location of the heat exchanger pad will be contingent on the general station layout and the terrain immediately adjacent to the antenna. The size of the pad is 12 feet by 15 feet. Location of holddown studs will be available later.

(6) Remote Controls. Remote controls for the power amplifier will be located in the operations room. Exact location and arrangement will require coordination with the contractor-provided racks and console for the operations room.

3.8.2.3.4.3 CABLING. A simplified cabling outline has been included as figure 3-13. This outline shows the various multiconductor and coax cables needed for interconnection of the equipment.

Each power amplifier cabinet will have three multiconductor cables, one high-voltage cable, two caox cables, and one waveguide connected to it. The multiconductor cables are for power and the coax cables are for the input from the PA driver and the output to the verification receiver. The waveguide from the two PA's will be connected to the combiner and from there to the feed.

Cables for each power supply cabinet consist of the 208-volt input cable, control cable from the remote console, interlock wiring, control cable to the heat exchanger, 400-volt cable from the motor generator, and the four cables to the power amplifier. In addition, there will be an inlet and outlet pipe for the coolant from the heat exchager. The cabling and coolant lines are not provided with the unit. Connector inform-

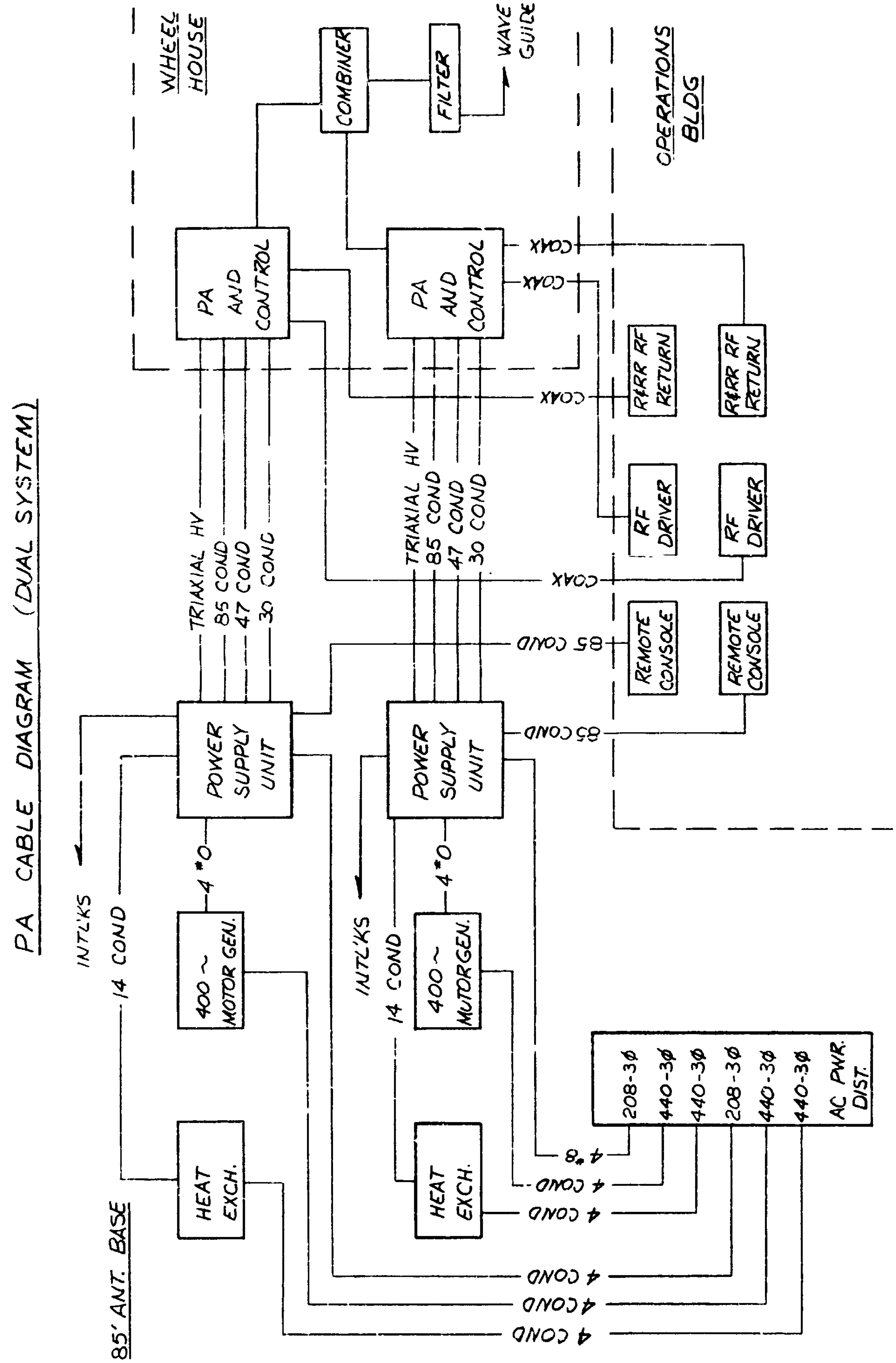


Figure 3-13. PA Cable Diagram (Dual System)

ation is not finalized at this time, but mating connectors will be provided with the equipment.

3.8.2.3.4.4 POWER CONSUMPTION AND VOLTAGE INPUT. Each power amplifier will be capable of an output power of 20 kw cw. The allowable power consumpiton for each complete amplifier assembly, including the heat exchanger, is 62 kva at 10-kw radiated power and 97 kva at 20-kw radiated power.

The voltage inputs to the separate units are as follows:

(1) Motor Generator, 440 volts, 3-phase

(2) Heat Exchanger, 440 volts, 3-phase

(3) Power Supply Cabinet, 208 volts, 3-phase.

3.8.2.3.4.5 HEAT DISSIPATION. The heat dissipation for the various components of the power amplifier assembly is as follows:

(1) Power Supply Cabinet - 3165 watts

(2) Motor Generator - 6 kw

(3) Power Amplifier Cabinet. The amount of heat dissipated by the power amplifier cabinet to the room will depend upon the difference between the room temperature and the inside cabinet temperature. Sources of heat input to the cabinet are:

(a) Approximately 200 watts from the klystron heater

(b) Heat given off from the coolant manifold that will be at an average temperature of approximately 65° C (149° F).

(4) Heat Exchanger. This unit is installed outside and dissipates heat to the atmosphere.

(5) Combiner. Heat dissipation values are undetermined at this time for the combiner.

3.8.2.3.4.6 WEIGHT. The weights of the units as given below are approximate. It is assumed, however, the actual values will not be greater than those given.

(1) Power Amplifier Cabinet, 1300 pounds

(2) Power Supply Cabinet, 4300 pounds

(3) Heat Exchanger, 4000 pounds

(4) Motor Generator, undetermined.

3.8.2.3.4.7 SIZE. The dimensions of the units are as follows:

(1) Power Amplifier Cabinet, 72 inches in length, 30 inches in width, and 62 inches in height

(2) Equipment racks, four standard 19-inch rack widths and approximately 8 feet high

(3) Power Supply Cabinet, 88 inches in length, 36 inches in width, and 72 inches in height

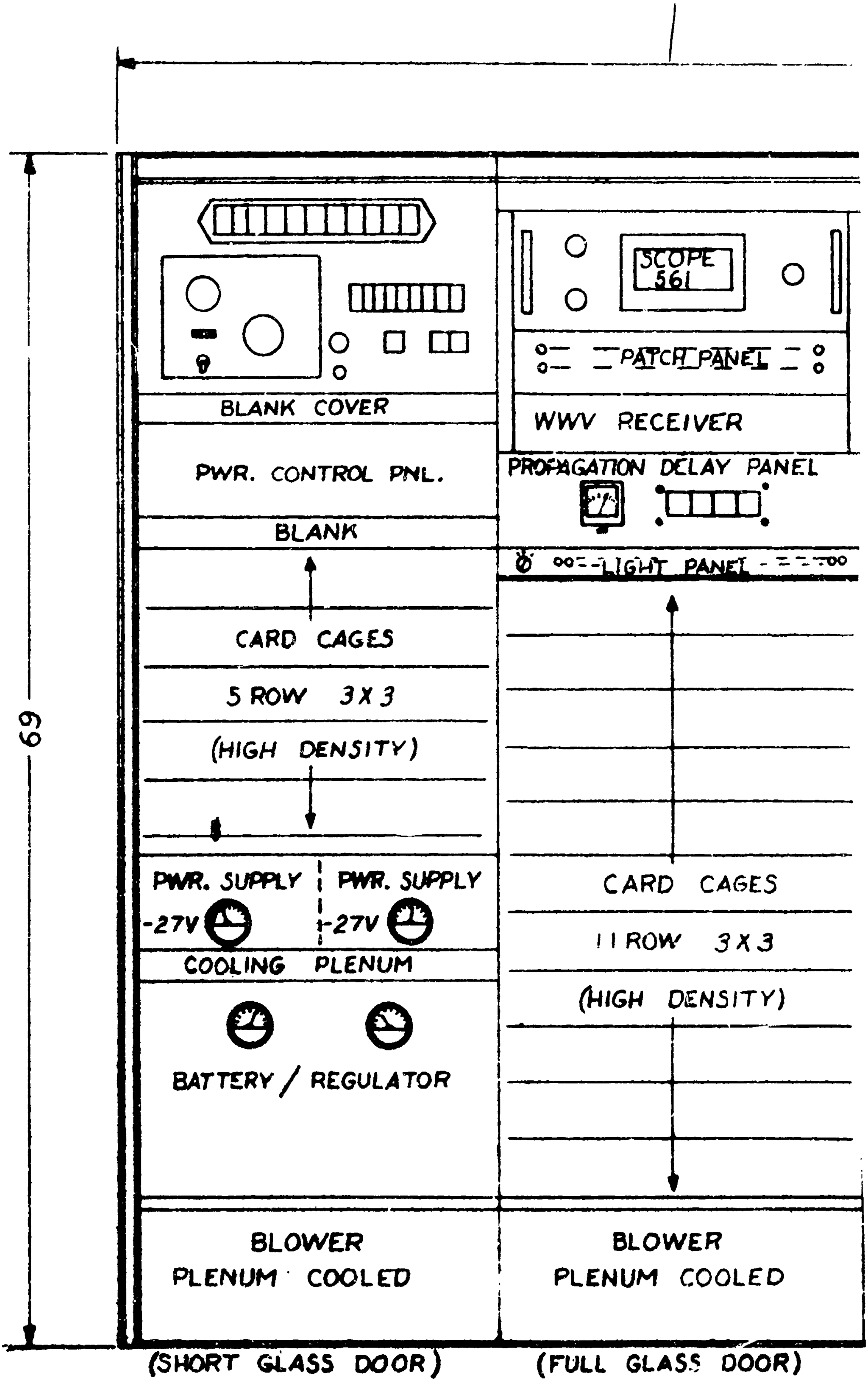
(4) Heat Exchanger, approximately 12 feet in length, 7 feet in width, and 6 feet in height

(5) Motor Generator, dimensions are not available at this time.

(6) Combiner, dimensions are not available.

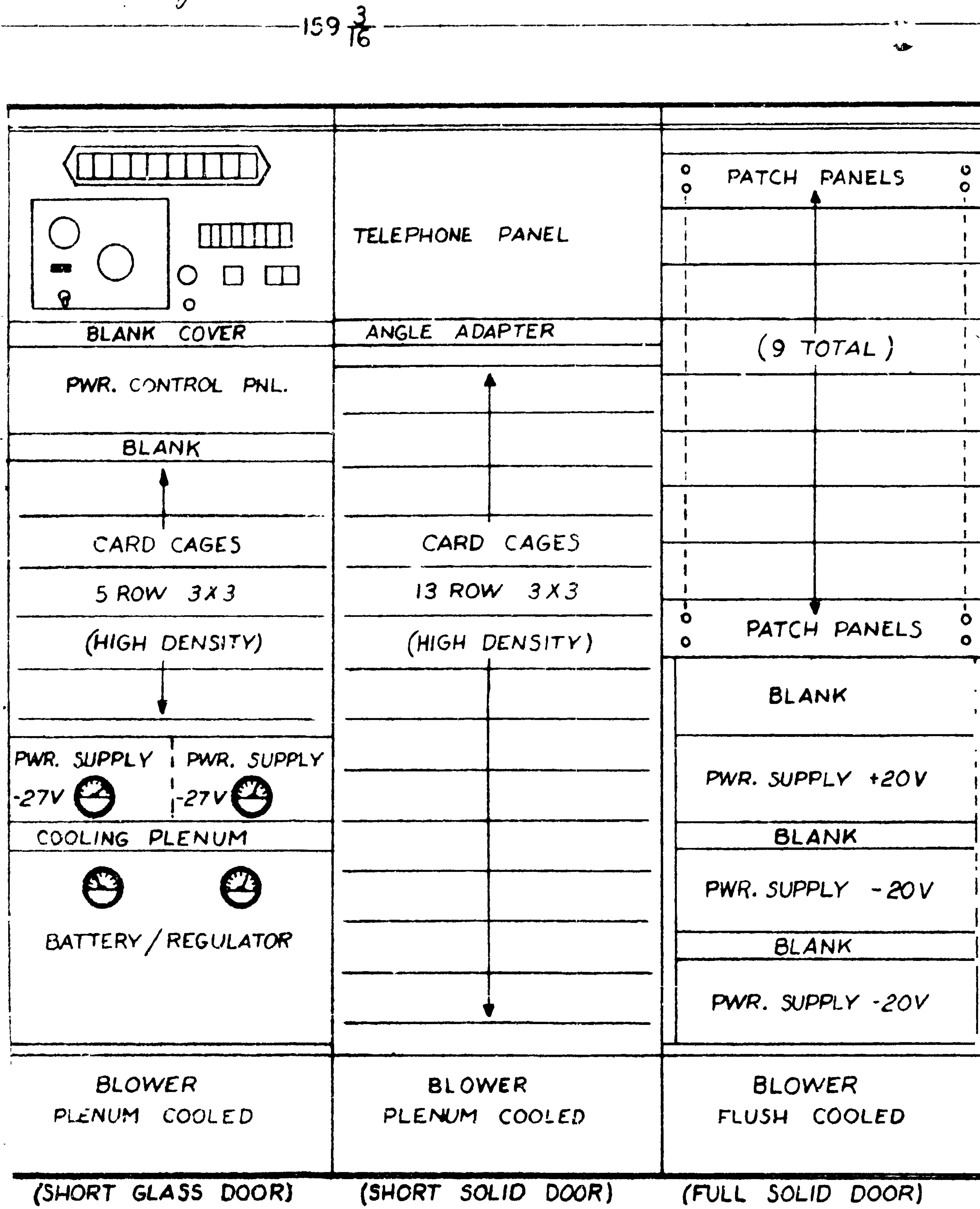
3.8.2.3.5 TRACKING DATA PROCESSOR. The tracking data processor for a single system is made up of three complete and one partial rack of equipment. The dimensions of the racks are as shown in figure 3-14. In order to provide a dual system, additional equipment i- added to the partial system. The power requirements and heat dissipation differences between a single and dual system are insignificant and are, therefore, given here for a dual system only. The entire tracking data processor requires 2.64 kilowatts of power, and therefore will operate from one 30-amp circuit at 110-volt, single-phase, 60-cycle power. Heat dissipation is 2640 watts. Blowers are located in the lower rear of each rack, and cooling air is forced up through the rack and exhausted by leakage out the front and top of the rack. All cable entries to the units is from the bottom; however, a cableway is provided along the upper part of the unit to accommodate rack-to-rack cable if desired. The volume of cable and connector information for the unit is too great to be included in this design criteria. Complete information regarding cables and connectors is contained in Collins Radio Company Specification on the tracking data processor. The Specification number is 568-9835-00.

3.8.2.3.6 TIMING SYSTEM. A single timing system is provided for the GSFC partial system. The dimensions of the racks making up this system are as shown in figure 3-15. The power requirement for the timing system is 4.18 kilowatts. One 50-amp

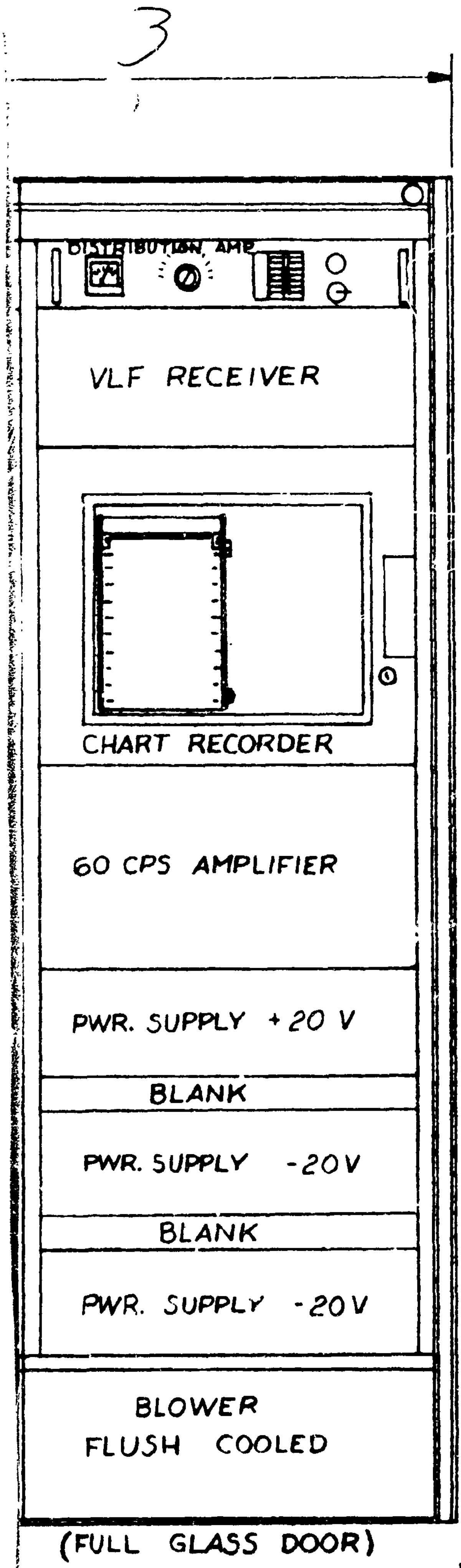

69
SCOPE 561
PATCH PANEL
BLANK COVER
WWV RECEIVER
PWR. CONTROL PNL.
PROPAGATION DELAY PANEL
BLANK
LIGHT PANEL
CARD CAGES
5 ROW 3 X 3
(HIGH DENSITY)
PWR. SUPPLY
-27V
PWR. SUPPLY
-27V
COOLING PLENUM
BATTERY / REGULATOR
CARD CAGES
11 ROW 3 X 3
(HIGH DENSITY)
BLOWER
PLENUM COOLED
BLOWER
PLENUM COOLED
(SHORT GLASS DOOR)
(FULL GLASS DOOR)

III-25(1)

2


159 3/16
TELEPHONE PANEL
PATCH PANELS
BLANK COVER
ANGLE ADAPTER
(9 TOTAL)
PWR. CONTROL PNL.
BLANK
CARD CAGES
5 ROW 3X3
(HIGH DENSITY)
CARD CAGES
13 ROW 3X3
(HIGH DENSITY)
PATCH PANELS
BLANK
PWR. SUPPLY -27V
PWR. SUPPLY -27V
PWR. SUPPLY +20V
COOLING PLENUM
BLANK
PWR. SUPPLY -20V
BATTERY / REGULATOR
BLANK
PWR. SUPPLY -20V
BLOWER
PLENUM COOLED
BLOWER
PLENUM COOLED
BLOWER
FLUSH COOLED
(SHORT GLASS DOOR)
(SHORT SOLID DOOR)
(FULL SOLID DOOR)

Figu



·e 3-14. Prototype Timing System

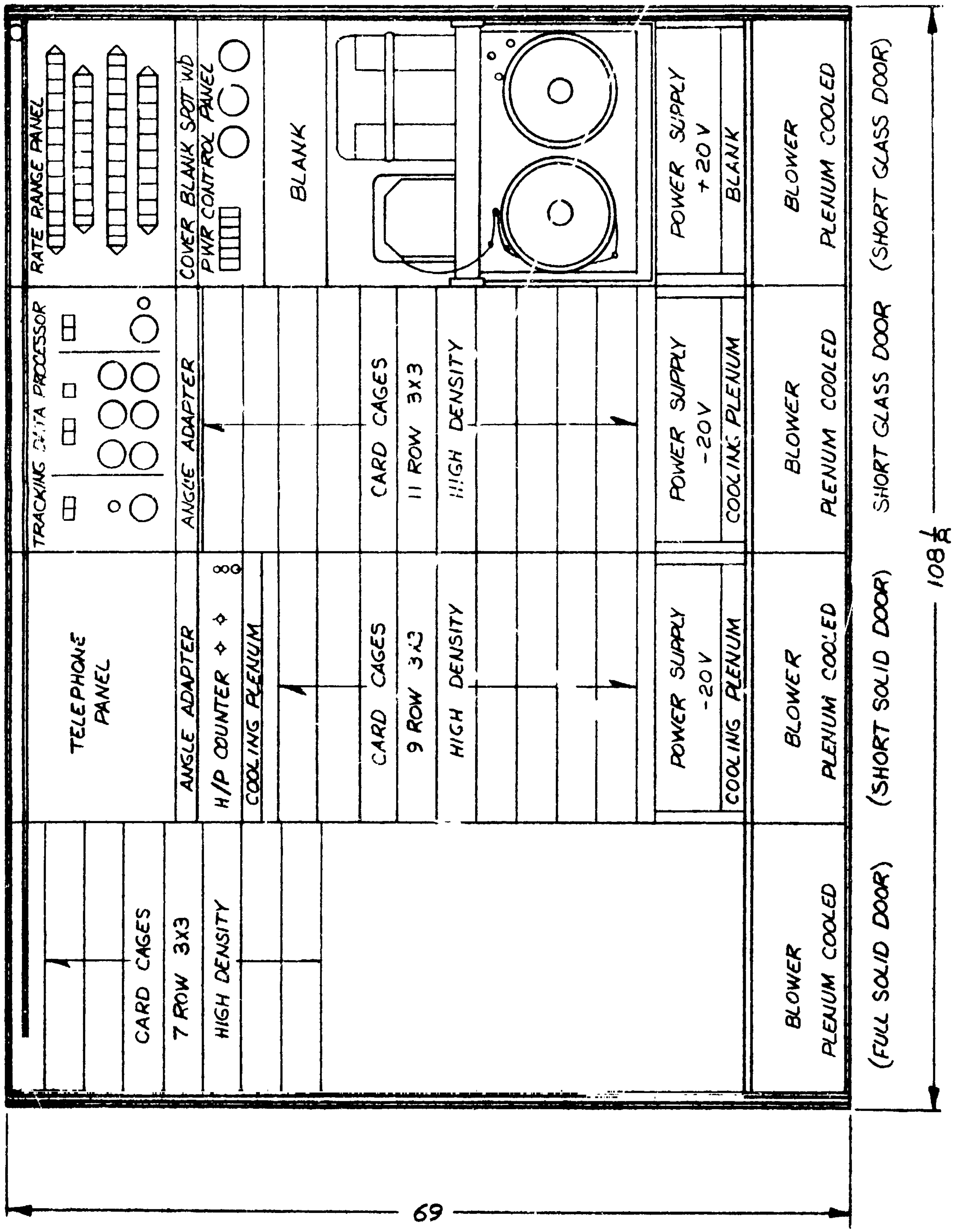


Figure 3-15. Tracking Data Processor (Dual) (Prototype)

circuit at 110-volt, single-phase, 60-cycle power is required. The heat dissipation for the entire unit is 4180 watts. Blowers are mounted in the lower rear of each rack, and cooling air is forced up through the racks and exhausted by leakage out the front and top of the rack. All cable entry to the racks is from bottom; however, a cableway is provided along the upper part of the unit to accommodate rack-to-rack cable if desired. The volume of cable and connector information for this unit is too great to be included in this design criteria. Complete information regarding cables and connectors is contained in Collins Radio Company Specification on the TE-411 Apollo Timing System. The specification number is 568-9836-00.

3.8.2.3.7 PARAMETRIC AMPLIFIER. Two each parametric amplifiers are provided for the GSFC partial system. The main units are basically the same in appearance and function; however, the unit for use with the main system will provide five outputs while the unit for the acquisition system will provide only one output. Both units will be mounted in the electronics room located just behind the ring girder of the antenna. A remote control unit for the antenna-mounted parametric amplifier is mounted in the operations building.

The case size of the antenna-mounted component is approximately 15-7/16 inches by 10-1/8 inches by 9-1/2 inches. The unit will weigh about 50 pounds. Four mounting tabs with 9/32 holes are provided for mounting the unit. The case will be pressurized and heat will be dissipated by convection and conduction. The antenna-mounted unit will require 110-volt, single-phase, 60-cycle power.

The remote control unit will be rack-mounted on a standard rack panel 19 inches by 8-3/4 inches. The rack-mounted unit will require less than 100 watts of 110-watt, single-phase, 60-cycle power. Heat dissipation from the rack will not exceed 100 watts.

Rf inputs and outputs to the antenna-mounted parametric amplifier unit will be on type N coaxial connectors. Control and power function will be, on MS connectors. Final information required to fabricate cables is not available as of this date. It is expected that subject information will be available by 15 November 1964.

Details regarding the main channel paramp is contained in Collins Specification 126-0424-001 and for the acquisition paramp in specification 126-0425-001.

3.8.2.4 SUMMARY. Certain manuals, cable sheets, cabinet dimensions, and various other detailed instructions will be provided to supplement this document.

Attached as figure 3-16 is a block diagram showing, in outline form, the relationship of the equipment provided under Item 4 of NAS5-9035 with other equipment assumed to be a part of the GSFC 85-foot Apollo System.

3.8.3 INSTALLATION DESIGN CRITERIA FOR EQUIPMENT FOR INSTRUMENTATION APOLLO SHIPS.

3.8.3.1 INTRODUCTION. The following Installation Design Criteria is prepared in accordance with the requirements of Items 5 (a-5) and 5(b-5) of Contract NAS5-9035, dated 14 July 1964. Subject criteria contains the information required to enable a contractor normally in the business of installation of electronic equipment on shipboard to install and integrate subject item of equipment into an existing system. Equipment provided is generally made up of separate units; therefore, cabling is not provided. The type of cable connectors on the equipment is specified, insofar as is possible at this time, to enable the installation contractor to provide proper material for the installation. Racks are not provided for separate units except in the case of the signal data demodulator where each unit makes up a complete rack of equipment. Items such as instruction manuals, cable diagrams, etc. will be provided to assist the contractor in preparing for installation and in actual installation.

3.8.3.2 EQUIPMENT TO BE INSTALLED.

3.8.3.2.1 SINGLE SYSTEM. The following items will be provided by Collins for a single system equipment for instrumentation Apollo ships single system.

one each - Updata subcarrier Oscillator

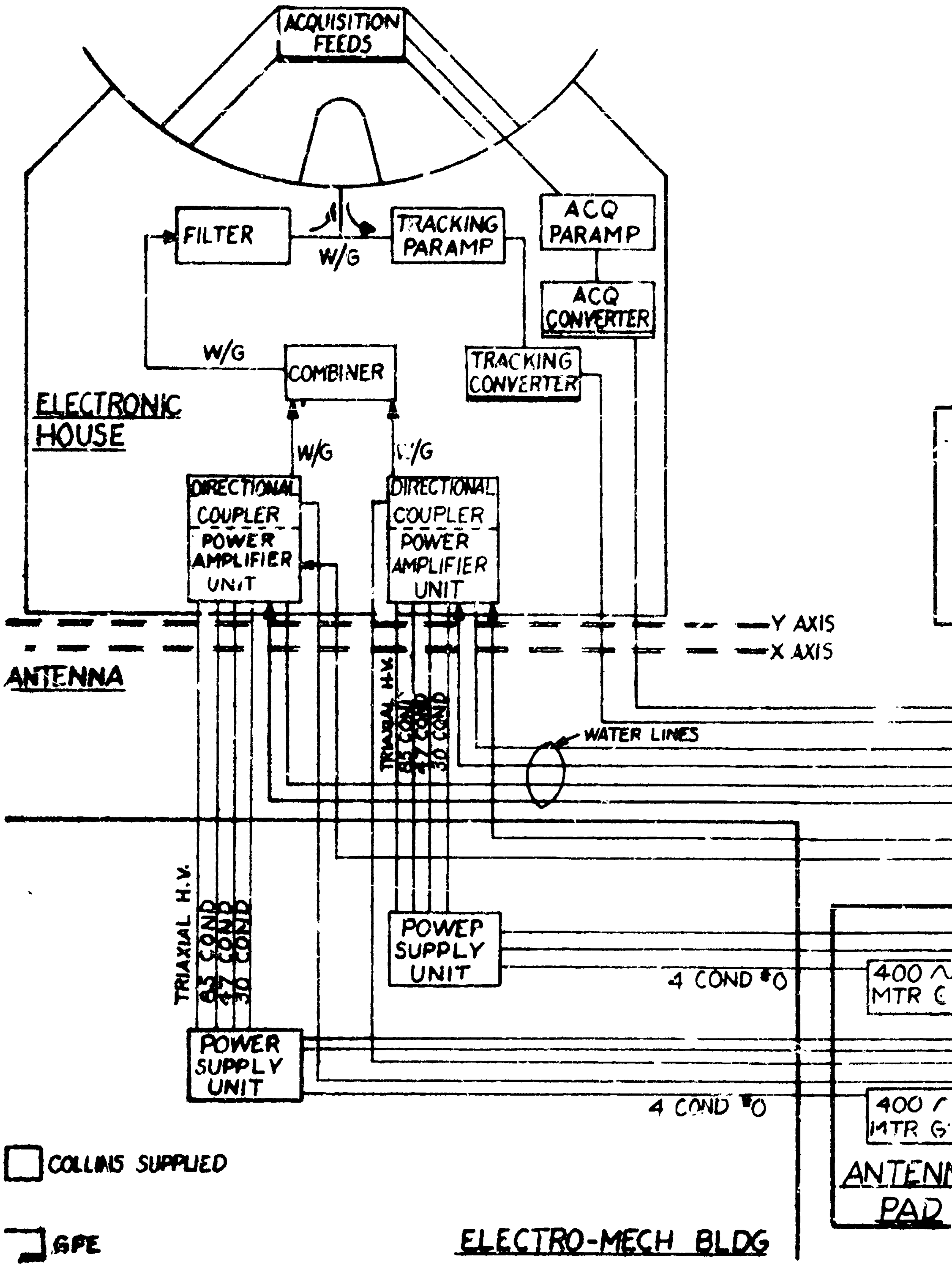
one each - Signal Data Demodulator

one each - Verification Receiver

one each - Power Amplifier Unit

one each - Acquisition Antenna and Feed

two each - Parametric Amplifier


ACQUISITION FEEDS
FILTER
W/G
TRACKING PARAMP
ACQ PARAMP
ACQ CONVERTER
W/G
COMBINER
TRACKING CONVERTER
ELECTRONIC HOUSE
W/G
W/G
DIRECTIONAL COUPLER
POWER AMPLIFIER UNIT
DIRECTIONAL COUPLER
POWER AMPLIFIER UNIT
Y AXIS
X AXIS
ANTENNA
TRIAXIAL H.V.
85 COND
47 COND
30 COND
WATER LINES
TRIAXIAL H.V.
85 COND
47 COND
30 COND
POWER SUPPLY UNIT
4 COND #0
400 ~ MTR G
POWER SUPPLY UNIT
4 COND #0
400 ~ MTR G
ANTENN PAD
COLLINS SUPPLIED
GFE
ELECTRO-MECH BLDG

III-29 ①

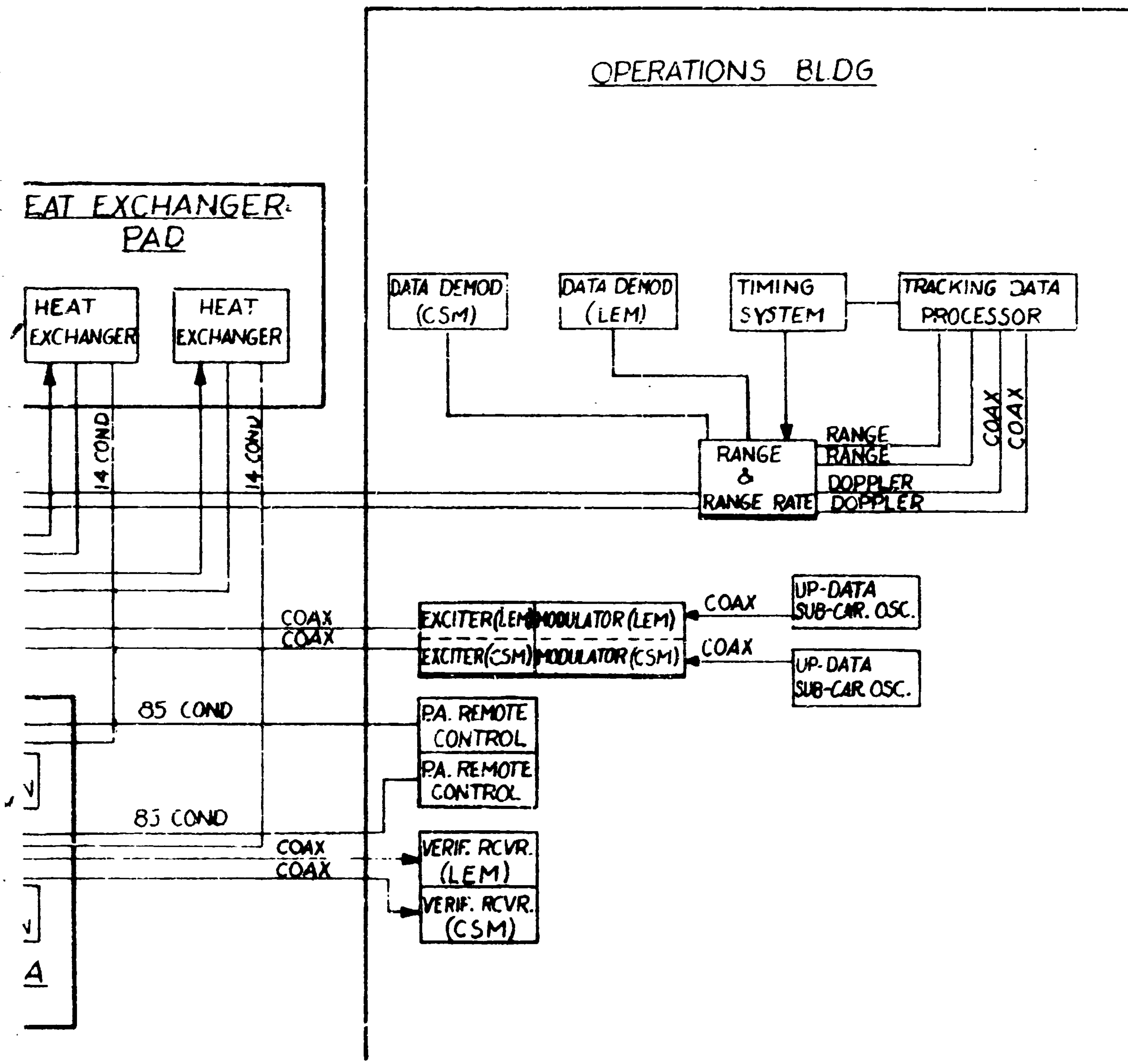


Figure 3-16. Cable Block Diagram
GSFC 85' Dual System

3.8.3.2.2 DUAL SYSTEM. The following items of equipment will be added to equipment listed in section 1 to make up the equipment for instrumentation for Apollo ships dual system.

one each - Updata Subcarrier Oscillator

one each - Signal Data Demodulator

one each - Verification Receiver

3.8.3.3 EQUIPMENT DESCRIPTION.

3.8.3.3.1 THE UPDATA SUBCARRIER OSCILLATOR. All components of this unit are mounted on 19 x 3-1/2 inch standard rack panel. The unit requires 110-volt, single-phase, 60-cycle power. The heat dissipation will not exceed eighty (80) watts and no cooling other than normal rack ventilation is required. The unit is made up of two (2) subcarrier oscillators, one for voice and one for updata functions. Mode switching for the unit is provided on the panel so that either or both of the oscillator outputs are available at the output to the modulator at proper voltage level.

The inputs to both the voice and tone oscillator will be on 600 ohm lines balanced to ground and the output following the combiner is at 1000 ohm. The inputs are to a 5-pin Amphenol terminal #126-216; pins D and E are signals and pin H is shield. The mating connector on the incoming cable is an Amphenol #126-223. The output is a standard BNC connector.

A system block diagram of this unit is included as figure 3-9. Additional information regarding Updata Subcarrier Oscillator is contained in Collins Specification 126-0447-010. A dual system is made up by the addition of a second unit.

3.8.3.3.2 SIGNAL DATA DEMODULATOR. The Signal Data Demodulator equipment will be packaged in a standard Emcor rack 76-7/8 inches high, 22 inches wide, and 25-1/2 inches deep. The components will be mounted on standard 19 inch panels. The entire rack may require RFI shielding. RFI shielding requirements are not fully determined at this time. The rack will be cooled with a 300 CFM McLean Blower Model M2EB424. The blower will be mounted in the lower front of the rack and the air will be exhausted from the rack by way of a filter mounted near the top of the rear door.

The electrical requirements for this rack is one 15 amp circuit providing 110-volt, single-phase, 60-cycle power. The heat dissipation of the entire rack of equipment is 220 watts.

All inputs to this equipment at 10 MC or over will be on TNC connectors. Incoming coaxial cables will be 50 ohm. Outputs from the unit will be on coaxial type BNC connectors and outgoing coaxial cable will be 93 ohms. The total number of input and output cables from the unit is not specified herein as these requirements will be to a great extent contingent on other equipment in the station and assigned mission; general information regarding input and output functions is indicated on the block diagram of this unit which is included as figure 3-10. Additional information regarding the Signal Daa Data Demodulator is contained in Collins Specification 126-0429-000. A dual system is made up by the addition of the second complete unit.

3.8.3.3.3 VERIFICATION RECEIVER SYSTEM. The verification receiver system consists of a modified multirange telemetry receiver (Vitro Electronics type number R-1037A) and a subcarrier demodulator panel. Each of the above referenced units is mounted on a 19-inch by 5-1/4-inch standard rack panel. The total rack space required per system is 10-1/2 inches. Total weight of the two units is approximately 40 pounds.

The units will dissipate a heat load of approximately 80 watts. The units operate on 110-volt, single-phase, 60-cycle electrical power. A standard 15-amp circuit is more than adequate for the operation load. No special cooling is required for this equipment, and it performs in a satisfactory manner in a rack with normal ventilation.

A single coaxial cable type input at 50 ohms to an N-type connector is provided on the receiver. Cable between the receiver and the demodulator is provided with the unit. The outputs from the demodulator are four BNC type connectors.

Additional information on the verification receiver system is contained in Collins Specification 126-0431-001. A dual system is made up by the addition of a second unit.

3.8.3.3.4 S-BAND POWER AMPLIFIER.

3.8.3.3.4.1 GENERAL. The power amplifier presents the most complicated installation problem of the partial system. Certain details regarding the placement of equipment are assumed or are recommended locations only in view of the fact that details of the ship arrangement, etc., are not available to this contractor.

3.8.3.3.4.2 EQUIPMENT LAYOUT AND LOCATION.

(1) Power Supply and Power Amplifier.

The power amplifier power supply and power amplifier should be located in proximity to the operations room, but should be in a separate room because of power requirements, high voltages, and other hazards.

(2) RF Transmission to the Feed.

This contractor is required only to provide the rf output port from the power amplifier. Design of the waveguide system, coaxial or rotator joints, etc., are to be provided by the installation contractor. Waveguide type WR430 is used on rf transmission on other Apollo power amplifier systems.

(3) The Motor Generator Unit.

The motor generator unit produces a high noise level and cannot be placed in the same room as the power supply or power amplifier in view of discomfort to operating personnel. The unit can be placed in a relatively small area providing proper cooling facilities are available. Nominal soundproofing may be required.

(4) Heat Exchanger.

No heat exchanger is required for this system since it is directed that the central ship's liquid coolant system will be used.

(5) Remote Controls.

The remote controls for the power amplifier will be located in the operations room. Exact location and arrangement will require coordination with the contractor providing rack and console for the operations room.

3.8.3.3.4.3 CABLING. A simplified tentative cable diagram has been included as figure 3-17. This outline indicates the various multiconductors and coax cables needed for interconnection of the equipment.

Each power amplifier cabinet will have three multiconductor cables, one high voltage cable, two coax cables, and one waveguide connected to it. The multiconductor cables are for power and the coax cables are for the input from the PA driver and the output to the verification receiver. The waveguide from the two PA's will be connected to the combiner and from there to the feed.

Cables for each power supply cabinet consists of the 208-volt input cable, control cable from the remote console, interlock wiring, control cable to the heat exchanger, 400-volt cable from the motor generator, and the four cables to the power amplifier. In addition, there will be an inlet and outlet pipe for the coolant from the heat exchanger. The cabling and coolant lines are not provided with the unit. Connector information is not finalized at this time, but mating connectors will be provided with the equipment.

3.8.3.3.4.4 POWER CONSUMPTION AND VOLTAGE INPUT. The power amplifier will be capable of an output power of 20 kw cw. The allowable power consumption for each complete amplifier assembly, without heat exchanger, is 48 kva at 10-kw radiated power and 61 kva at 20-kw radiated power.

The voltage inputs to the various components of the power amplifier assembly are as follows:

(1) Motor Generator, 440 volts, 3-phase

(2) Power Supply Cabinet, 208 volts, 3-phase.

3.8.3.3.4.5 HEAT DISSIPATION. The heat dissipation for the various components of the the power amplifier assembly is as follows:

(1) Power Supply Cabinet, 3165W

(2) Motor Generator, 6 kw

(3) Power Amplifier Cabinet. - The amount of heat dissipated by the power amplifier cabinet to the room will depend upon the difference between the

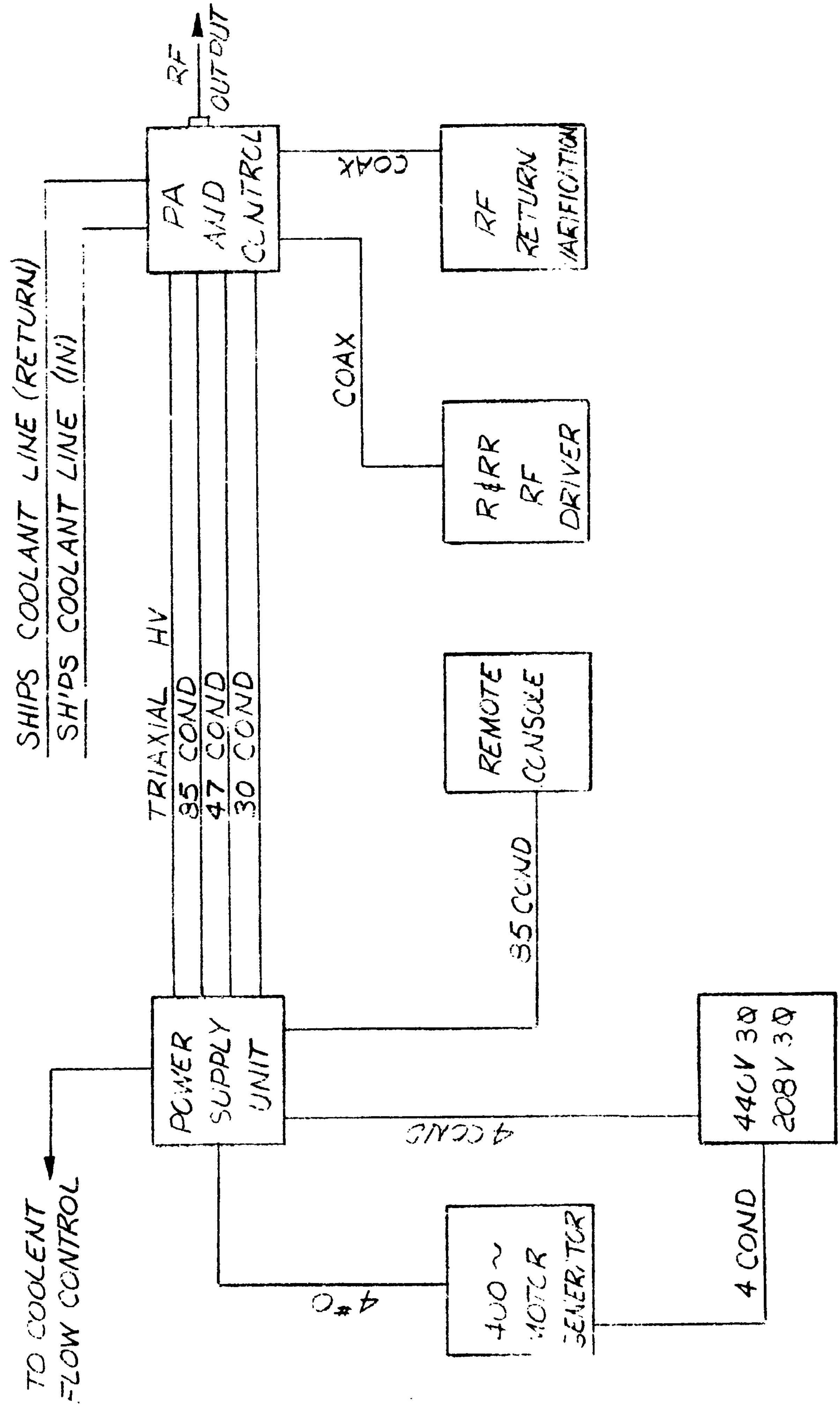


Figure 3-17. Tentative Cable Diagram, Apoilo Ships PA System

room temperature and the inside cabinet temperature. Sources of heat input to the cabinet are:

(a) Approximately 200 watts from the klystron heater

(b) Heat given off from the coolant manifold, which will be at an average temperature of approximately 65° C (149°F).

3.8.3.3.4.6 WEIGHT. The weights of the units as given below are approximate. It is assumed, however, that the actual values will not be greater than those given.

(1) Power Amplifier Cabinet, 1200 pounds

(2) Power Supply Cabinet, 4300 pounds

(3) Motor Generator, undetermined.

3.8.3.3.5 ACQUISITION ANTENNA AND FEED. The acquisition antenna and feed system design is not complete because of the recent addition of the polarization switching requirement. It is not possible in this installation design criteria to provide complete details as to mechanics of mounting the antenna on the prime reflector. The following general information and guidance regarding the size, weight, mounting provision, cabling, and remote control of the acquisition system is provided.

(1) The Antenna and Radome.

The basic antenna is a 36-inch parabolic reflector with feeds enclosed in a radome. Mounting attachments are provided for the sides of the reflector. A preliminary sketch of the acquisition antenna is included in figure 3-18. The weight of the entire assembly is estimated to be 90 pounds.

(2) Mounting Provisions and Location.

The acquisition antenna may be mounted on the periphery of the prime antenna or near the apex of the quadripod assembly (back-to-back with subreflector of the prime system). The selection of the position for m mounting the acquisition antenna will be contingent on mechanical criteria, plus blockage of the prime antenna. Electronically, operation of the antenna will be satisfactory in either location.

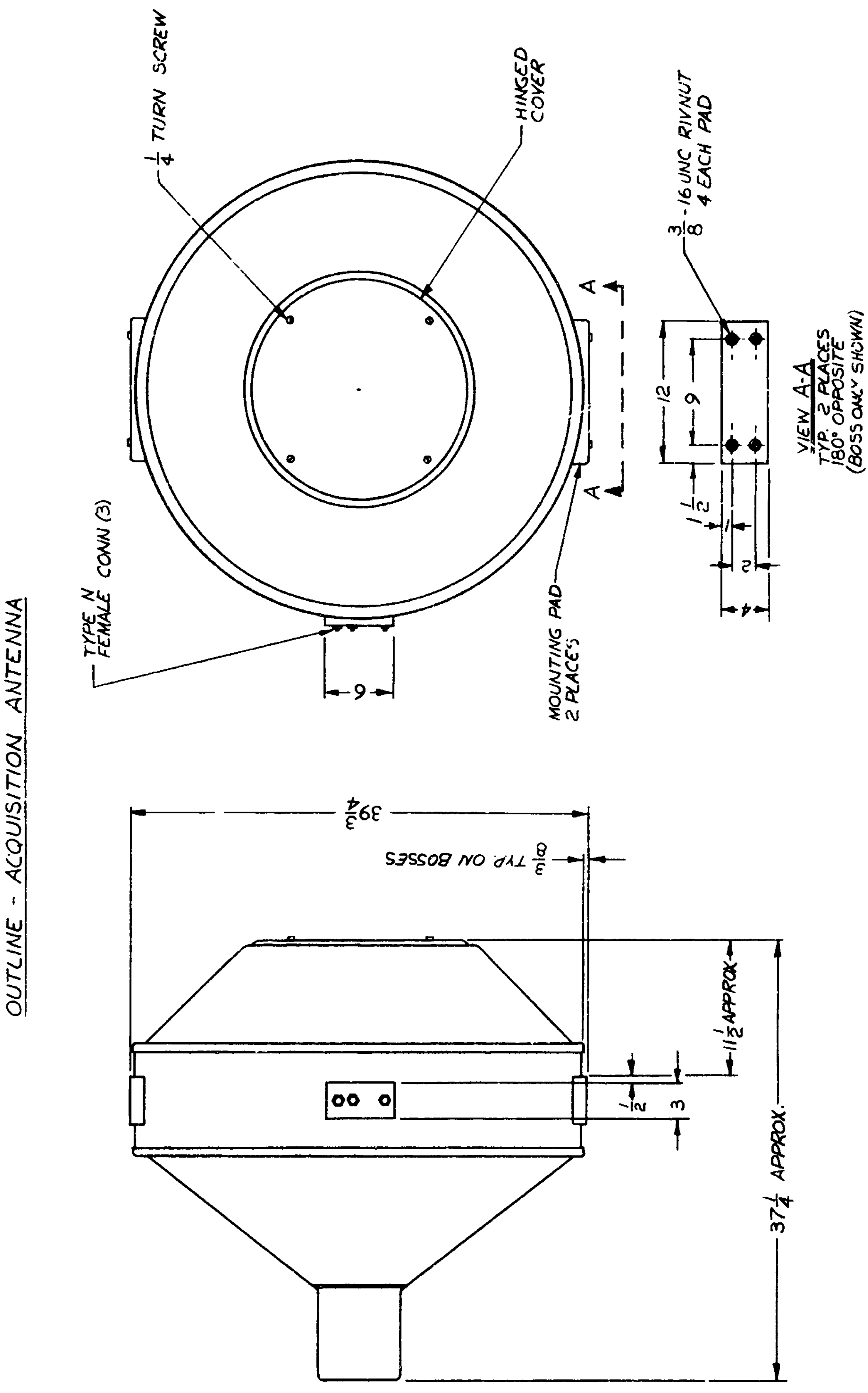


Figure 3-18. Outline, Acquisition Antenna

(3) Cabling.

Three rf outputs to N-type connectors are provided on the side of the antenna. These outputs include X error, Y error, and sum. The sum channel is fed directly to the paramp and the X and Y channels to the converter. An AN-type connector will receive the control function for the polarization switch. Polarization position indicator functions will be provided on this same connector.

(4) Remote Polarization Control.

A remote polarization control will be located in the operations room. The control will be on a standard 3-1/2-inch rack panel. Cabling data for the cable between the polarization remote control and the antenna will be available later.

3.8.3.3.6 PARAMETRIC AMPLIFIER. Two each parametric amplifiers are provided for the Apollo Ships system. The main units are basically the same in appearance and function; however, the unit for use with the main system will provide five outputs while the unit for the acquisition system will provide only one output. Information regarding the ship's antenna is not available to this contractor; therefore, actual position of the parametric amplifiers on the ship's antenna cannot be specified. It is suggested that the paramps be placed on the antenna as closely as possible to the feed system. Details as to mounting must be worked out by the installation contractor. The remote control unit for the antenna-mounted parametric amplifier is mounted in the operations room.

The case size of the antenna-mounted component is approximately 15-7/16 inches by 10-1/8 inches by 9-1/2 inches. The unit will weight about 50 pounds. Four mounting tabs with 9/32 holes are provided for mounting the unit. The case will be pressurized, and heat will not dissipate from the unit by a flow of air through the unit. The antenna-mounted unit will require 110-volt, single-phase, 60-cycle power.

part IV

system performance

4.1 EFFECTS DUE TO THERMAL NOISE.

4.1.1 EQUIVALENT ANTENNA NOISE TEMPERATURE.

The antenna noise temperature is basically determined by the temperature of its "observable" environment. The noise sources of the environment include land, sea, atmosphere, radio stars, galaxies, and common impulsive noises. Common impulsive noises are generally man-made, and the site is generally selected to minimize such noise sources. At low frequencies the major noise source is cosmic radio noise from the sky and gives use to the concept of sky temperature, T_{sky}, which is an equivalent black-body temperature of the sky. T_{sky} is equal to the temperature of the black-body occupying the same region of the sky and giving the same noise intensity as that actually measured by the antenna.

The calculation of the effective noise temperature of an antenna must take into account the antenna pattern and the multitude of noise sources at different temperatures. The tools for making such a calculation are the principle of reciprocity and ray theory.[1] Reciprocity permits the assumption that the noise received by an antenna from each direction over a small solid angle is proportional to the product of the absorbed power in that direction, if the antenna were transmitting, and the ambient temperature of the absorbing medium for the given solid angle. Ray theory allows the 3-dimensional pattern of the antenna to be divided into small solid angles or rays. For example,

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[1] R.C. Hansen, "Low Noise Antennas," The Microwave Journal, Vol. 2, No. 6 June 1959, pp 19-24

a narrow beam antenna may be pointed at about 10° above the horizon. Part of the antenna pattern rays will strike the ground and be absorbed, representing noise at the ground temperature. The energy of each ray that strikes the ground and is not absorbed will be reflected (according to ray theory for reflection) and will be partly absorbed in the atmosphere through which the ray travels. The remainder of the energy will be absorbed in galactic space. Thus, for a ray that strikes the ground, there are three different sources of noise; ground, air, and space, with with a different ambient temperature. The ray temperature is found by adding the different contributions weighted according to ambient temperatures and the amount of power absorbed. With a highly directive antenna, most of the rays will not strike the ground but will pass through the atmosphere and be absorbed in galactic space. Thus, the majority of the rays will have two noise sources; air and galactic space, each of which has a much lower temperature than the ground. The noise temperature of the antenna is determined by adding all of the ray temperatures.

This process of determining the noise temperature of an antenna may be formulated more concisely by using standard mathematical symbols. Assume that the antenna is transmitting and divide its patterns into a number of rays. Let each ray occupy the small solid angle $\Delta \Omega$ (all space is a solid angle of 4π steradians). Then the i^{th} ray will have a fraction of the total radiated power given by $G_i \Delta \Omega / 4 \pi$ where G_i is the gain of the i^{th} ray determined by the antenna patterns and is a function of Ω. This ray may be incident upon several objects, each with a different ambient temperature and absorbing factors. Let α_{ij} be the fraction of the i^{th} ray that is absorbed by the j^{th} body. In general, α_{ij} is a function of the angle Ω, because the absorption of energy by a body is generally a function of the incident angle. Adding up the contributions from all of the rays, it can be shown[1] that the effective noise temperature T_A' for the antenna is

$$T_A' = \Sigma_i G_i \frac{\Delta \Omega}{4 \pi} \Sigma_j T_j \alpha_{ij}$$

where α_{ij} is the absorption ratio and T_j is the temperature of the $_{jth}$ body. $\frac{G_i \Delta \Omega}{4 \pi}$ represents the fraction of the total radiated power in the direction of interest.

1 Ibid, p. IV-1

In practice, the antenna noise temperature is calculated by dividing the antenna pattern into several sections; the main lobe, sidelobes, and backlobes, and an average gain and ambient temperature is assumed for each of these sections. The resulting section temperatures are added to determine the antenna effecitve noise temperatures. For example, the backlobe structure noise contributions for a directive antenna pointing towards the cold spot in the sky is assumed to be a hemisphere pattern of an isotropic antenna the gain of which is the average gain of the back lobes with respect to the main beam.

4.1.1.1 ANTENNA AT ZENITH. Using this procedure it is first necessary to calculate the percentage of power in the main beam, sidelobes, backlobes, etc. Hansen[1] gives the following for a circular aperture:

Taper	Percent Power in Main Beam	Percent Power Between 1/2 Power Points	Percent Power in Sidelobes
Uniform	83	47	17
$(1 - \rho^2)$	98	61	02

It is evident that for the $(1 - \rho^2)$ illumination taper, the power density at the edge of the dish is zero. This is a good assumption considering the low percentage of power in the sidelobes. In practice, illumination tapers on the order of 10 db are used. A good approximation for this illumination taper would be interpolated values of 91 percent in the main beam, 54 percent power between half-power points and 9 percent power in the sidelobes. However, these figures do not account for spillover past the subreflector or the parabolic reflector. Graphical integrations have been performed using the 30-foot Cassegrain geometry and the following results were obtained:

(1) Spillover past the parabolic reflector, 7.5 percent

(2) Spillover past the hyperbola, 12.5 percent

(3) Power in the idealized antenna pattern, 80 percent.

These factors may be combined with the ones given above to give the following:

Power in the main beam = (0.91) (0.80) (100%) = 72.8%

1 Ibid, p. IV-1

Power in the sidelobes, $\theta < \pm 90°$ = $[0.125 + (.085)(0.8)]$ $[100\%]$ = 19.3%

Power in the backlobes, $\theta > \pm 90°$ = $[0.075 + (0.005)(0.8)]$ $[100\%]$ = 7.9%

Power between half-power points = (0.54)(0.8) = 43.2%

This assumes that the sidelobe distribution of the idealized pattern is such that 0.5 percent power is in the backlobes and the rest (8.5 percent) is in the remaining sidelobes. Theta (θ) is measured from the boresight axis.

Using Hansen's method, the noise temperature is calculated for the antenna pointed at local zenith, ignoring solar contributions. The atmospheric absorption ratios are those given by Hansen, and they represent values for average angles of incidence.

Main Beam and Upper Lobes, G = 0.728 + 0.193 = 0.921

Back Lobes, G + 0.079

Source	Absorption Ratio (α)	Ambient Temp	Contribution to T_A'
Atmosphere	(0.021)	290°K	(0.921)(.021)(290) = 5.6°K
Galactic	(1.0)	8°K	(0.921)(0.979)(8) = 7.2°K
Ground	(1.0)	290°K	(0.079)(1.0)(209) = 22.9°K
Antenna and Subreflector[2]			= 1.5°K
		Total T_A'	= 37.2°K

Lossy transmission lines between the antenna and the receiver attenuate the noise power from the antenna while at the same time creating new noise due to thermal losses. Thus, if the output noise temperature at the antenna input terminals is T_A', the noise temperature at the output of the feed is

$T_A = T_A' e^{-2\alpha} + T_o(1 - e^{-2\alpha})$ where α is the circuit losses in nepers and T_o is the ambient temperature of the waveguide. According to Rantec, the power loss in

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2 Advanced Antenna Study Program Prepared for JPL by Blaw Knox Co., et al, 8 May 1961, pp A-51 - A-61.

the circuit and the horn is 0.5 db (or 0.0577 nepers). The antenna temperature for a pointing angle of 0° from zenith and quiet sky is ıen

$$T_A = (37.2)(.891) + 290\ (1 - .891)$$

$$= 33.1 + 31.6$$

$$= 64.7°K$$

4.1.1.2 ANTENNA AT HORIZON. A similar calculation is presented for the antenna pointed at the horizon. For this case it is assumed that 50 percent of the power radiated strikes the ground.

Source	α	T_o	Contribution to T_A'	
Atmosphere	(0.15)	290°K	(0.5)(0.15)(290)	= 21.8°K
Galactic	(1.0)	8°K	(0.5)(1.85)(8)	= 3.4°K
Ground	(1.0)	290°K	(0.5)(1.0)(290)	= 145°K
Antenna and Subreflector				= 1.5°K
		Total T_A'		171.7°K

Again, the effect of circuit losses is calculated to give the final antenna noise temperature for the antenna pointed at the horizon.

$$T_A = (171.7)(.891) + 290\ (1 - .891)$$

$$= 153 + 31.6$$

$$T_A = 184.6°K$$

4.1.1.3 ANTENNA POINTED AT MOON. For the case of the antenna pointed at the moon, it is assumed that the moon is near zenith and quiet sky conditions exist. Then the first set of calculations is valid if the noise power contribution of the moon is considered. The moon subtends an angle of 0.5° at earth. Since the half-power beam-width of the 30-foot antenna is approximately 1.9°, then the moon intercepts an average of about 25 percent of the power between the half-power points. The contribution to T_A' by the moon is

$$T_m = (0.43)(.25)(\alpha)(T_o)$$

An average figure for T_o is 200°K[3] while α is assumed to be 1.0.

Now T_m = (0.43)(.25)(1.0)(200)

= 21.5°K

Source	α	T_o	Contribution to T_A'
Atmosphere	(0.021)	290°K	5.6°K
Galactic	(1.0)	8°K	(0.91 - .108)(1)(8) = 6.3°K
Ground	(1.0)	290°K	22.9°K
Moon	(1.0)	200°K	21.5°K
Antenna and Subreflector			1.5
		Total T_A'	= 57.8°K

Now T_A is calculated as before:

$$T_A = (57.8)(.891) + (290)(1 - .891)$$

$$= 51.5 + 31.6$$

$$= \underline{\underline{83.1°K}}$$

4.1.1.4 SUMMARY.

Condition - Quiet Sky and	Antenna Noise Temperature
Antenna pointed at zenith	64.7°K
Antenna pointed at horizon	184.6°K
Antenna pointed at the moon near zenith	83.1°K

4.1.2 SUM CHANNEL PERFORMANCE.

The tracking receiver to be used in the Unified S-Band system is furnished to Collins Radio Company by the Government. Few details of the operation of the receiver

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3 A.R. Giddis, "Influence of External Noise on Antenna Temperature" Microwaves, Vol. 3, No. 6, June 1964, pp 16-21

are available to Collins at this time other than those which apply to a similar receiver now in use by JPL at the Goldstone tracking facility. In following paragraphs, various relationships will be developed as they pertain to the operational aspects of the Unified S-Band; however, it m t be recognized that these relationships are based on the present JPL receiver a the information available to Collins.

4.1.2.1 PHASE LOCK LOOP BANDWIDTH. The sum channel loop has in the present equipment three threshold noise bandwidths; 12, 48, and 152 cps. Since this receiver utilizes limiting, the loop bandwidth is not a constant for all ranges of input signal but increases with increasing signal level (as a function of the limiter suppression factor). At strong signals the loop noise bandwidths become 121, 252, and 478 cps, respectively.

Input signal power required for maintenance of receiver lock is a function of the system noise temperature. Using the parametric amplifier and with the antenna pointed at a quiet sky, the effective system noise temperature is 192.2°K. Tabulated below are values for threshold under various operating conditions and bandwidths.

ANTENNA POINTING	ANTENNA TEMP	SYSTEM** TEMP	12 CPS BW	THRESHOLD* 48 CPS BW	152 CPS BW
Quiet Sky	64.7°K	192.2°K	-165 dbm	-159 dbm	-154 dbm
Horizon	184.6°K	312.1°K	-163 dbm	-157 dbm	-152 dbm
Moon	83.1°K	210.3°K	-164.5 dbm	-158.6 dbm	-153.5 dbm

* At the rf carrier design threshold, the signal-to-noise ratio in the threshold closed-loop bandwidth ($2B_{LO}$) is unity (S/N = 1) and the phase error in the loop due to noise is 1.0 radian rms.

** The parametric amplifier has a 1.6- noise figure referred to 290°K. The effective internal noise temperature of the paramp is then:

$$T = (F-1)\, T_o \quad \text{or} \quad T = (1.44-1)\, 290°K$$

$$T = 127.5°K$$

In order to determine maximum tracking range for various bandwidths the following assumptions concerning the spacecraft equipment have been made:

<u>Spacecraft Power Amplifier output,</u> P_s = <u>10 watts</u> or +40 dbm

<u>Spacecraft antenna gain,</u> G_t = 1 or 0 db.

The range equations may be computed:

$$\frac{P_r}{P_t} = G_r \; G_t \; \left(\frac{\lambda}{4\pi r}\right)^2 \tag{1}$$

$$\lambda = \frac{0.3 \text{ kw}}{f_{mc}} \quad \text{where r in (1) is in km} \tag{2}$$

then,

$$\frac{P_r}{G_r} = (P_t G_t) \; \left(\frac{0.3}{f_{mc} \; r_{km} \; 4\pi}\right)^2 \tag{3}$$

Space loss in db notation is:

$$\hat{L}_{FS} = 20 \log r_{km} + 20 \log f_{mc} + 32.4 \text{ db} \tag{4}$$

$\hat{P}_t$ = +40 dbm

$\hat{G}_t$ = 0 db

$\hat{G}_r$ = 44 db

$\hat{P}_r$ = Received power (receiver input) = KT_eB at threshold.

The general down-link equation is then:

$$P_r = P_t + G_r + L_{FS} \text{ in dbm} \tag{5}$$

$$P_r = +40 + 44 - (20 \log r_{km} + 20 \log 2.285 + 32.4) \text{ dbm} \tag{6}$$

$$P_r = +84 - 67.2 - 32.4 - 20 \log r_{km} \text{ dbm} \tag{7}$$

$$P_r = -15.6 - 20 \log r_{km} \text{ dbm a} \tag{8}$$

and at threshold:

$$KT_eB = -15.6 - 20 \log r_{km} \text{ dbm} \tag{9}$$

Figure 4-1 is a plot of received carrier power levels at ranges up to and beyond lunar distances. Each line of the plot is representative of the carrier power available with the modulations indicated by the various modes. Since the phase lock receiver tracks carrier component only, modulation indices affect total tracking distance attainable before reaching threshold. Three vertical lines in figure 4-1 represent threshold at the loop bandwidths of the receiver. In all modulation modes indicated, it is noted that tracking can be maintained to the lunar surface with a 15-db margin at the widest loop bandwidth. With no reduction in carrier power due to modulation and with narrowest loop bandwidth (12 cps), a signal-to-noise (S/N) ratio of 37.5 db can be attained at lunar distances.

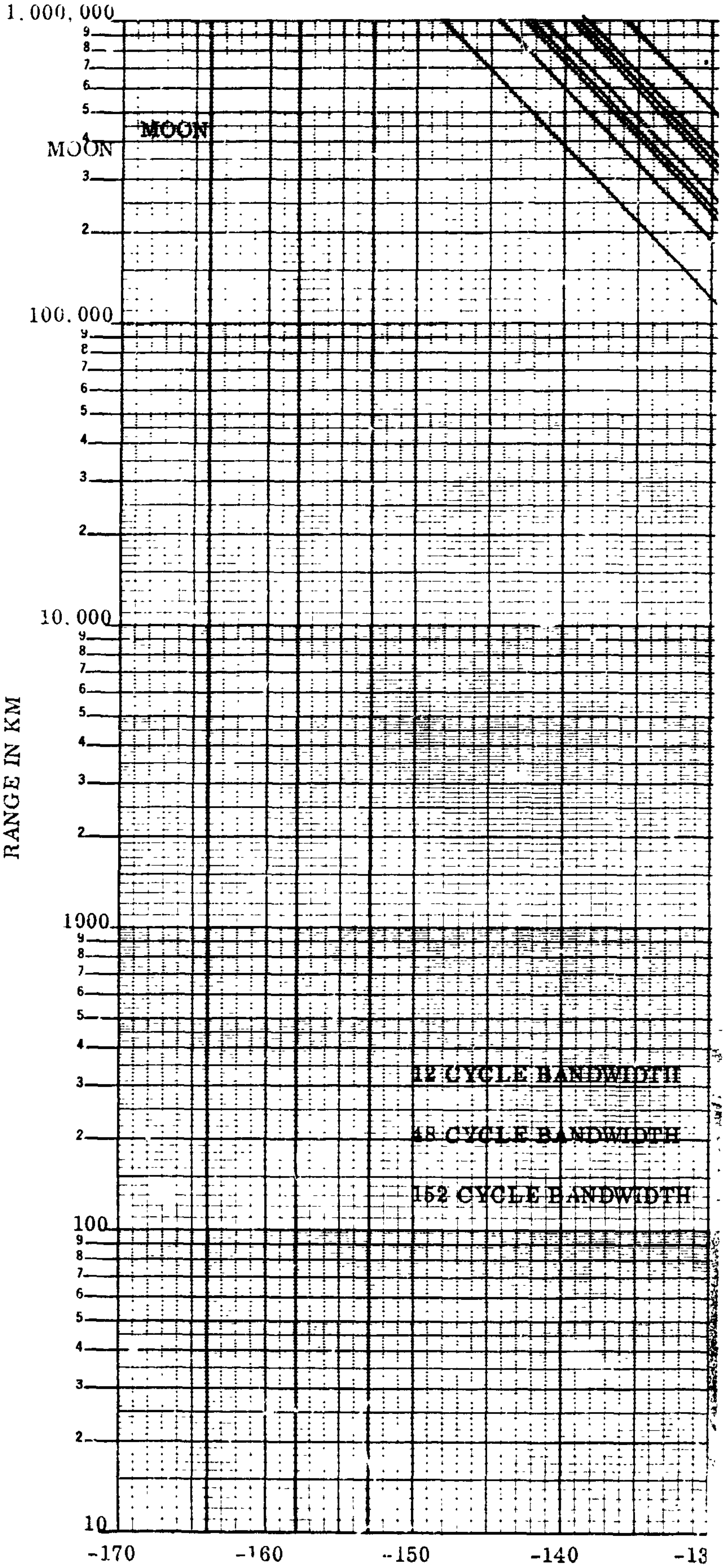
In the earth orbit stage, typical power levels received will be -70 dbm for a S/N ratio of 95 db. Earth orbit is assumed to be at an altitude of 150 nautical miles (278 km). At this altitude the slant range at an antenna angle of $\theta = 90°$ (horizon) will be 1904 km. The assumed relation between slant range and θ is:

$$r_1 = -6370 \sin \theta + 1904 \,(11-2 \sin^2 \theta - 1)^{1/2} \text{ km} \tag{10}$$

Slant range r_1 (for 150 NM orbit) is shown in figure 4-2 plotted as a function of θ.

The mean distance from earth to lunar surface is approximately 378,000 km for an antenna angle θ of 0° (zenith).

4.1.2.2 RECEIVER DATA OUTPUTS. The previous paragraph treated received signal power as a function of range for phase loop tracking purposes only. A communication threshold for various modulation modes can be determined for maximum ranges. This data is presented in figure 4-3, which is a plot of total signal-to-noise power density required at mode threshold, P_r/Φ_n, for the various modulation modes. Again, it is emphasized that the spacecraft antenna gain is assumed to be 0 db. It is evident that considerable improvement will be noted with an antenna gain of 20 db or more. However, based on the gain assumptions made for this analysis, margins of up to 40 db over the required P_r/Φ_n are indicated for earth orbit operations.


RANGE IN KM
1,000,000
100,000
10,000
1000
100
10
MOON
MOON
12 CYCLE BANDWIDTH
48 CYCLE BANDWIDTH
152 CYCLE BANDWIDTH
-170
-160
-150
-140
-13

2

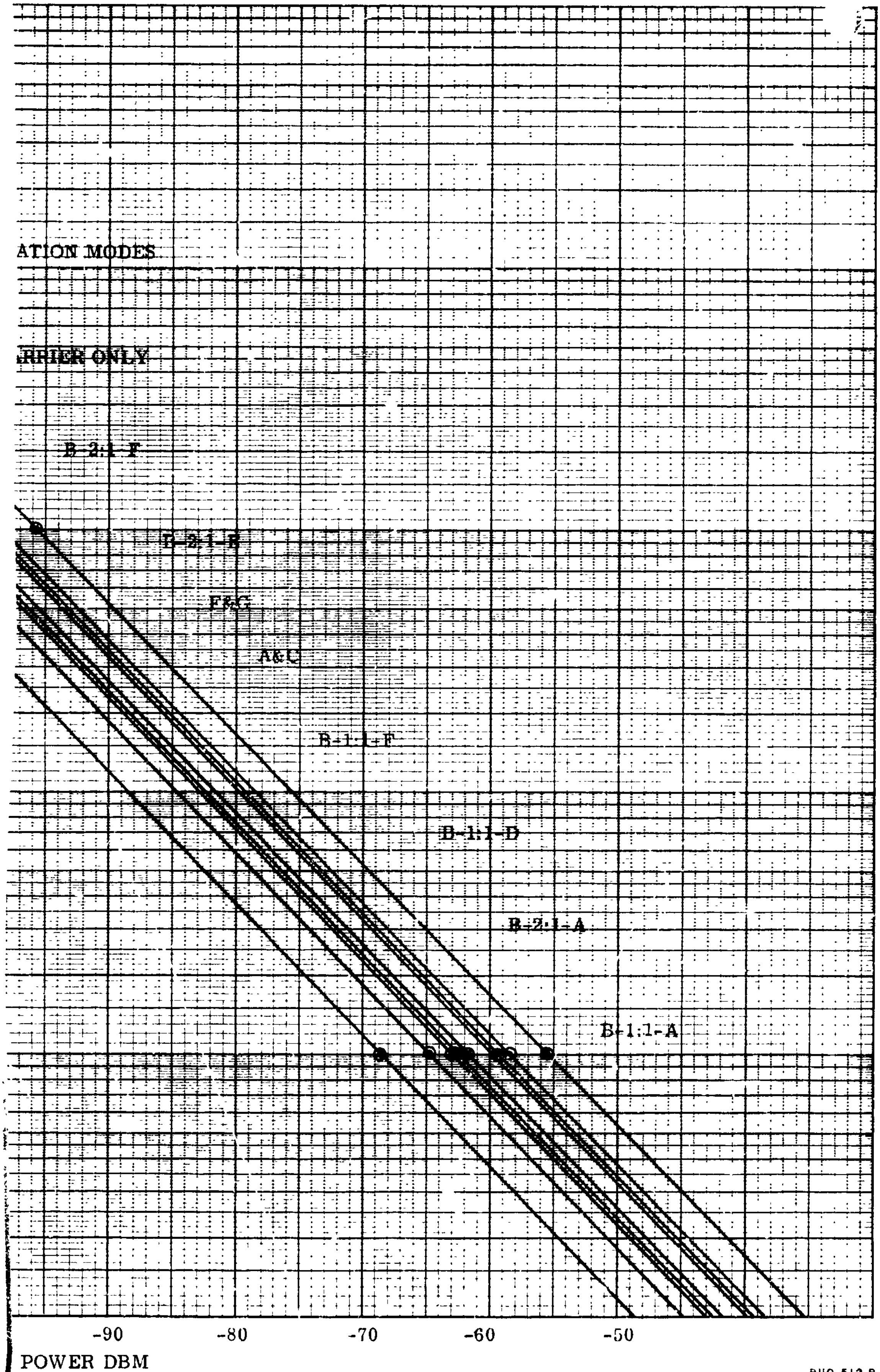


Figure 4-1. Received Carrier Power Levels at Ranges Up to and Beyond Linear Distances

2

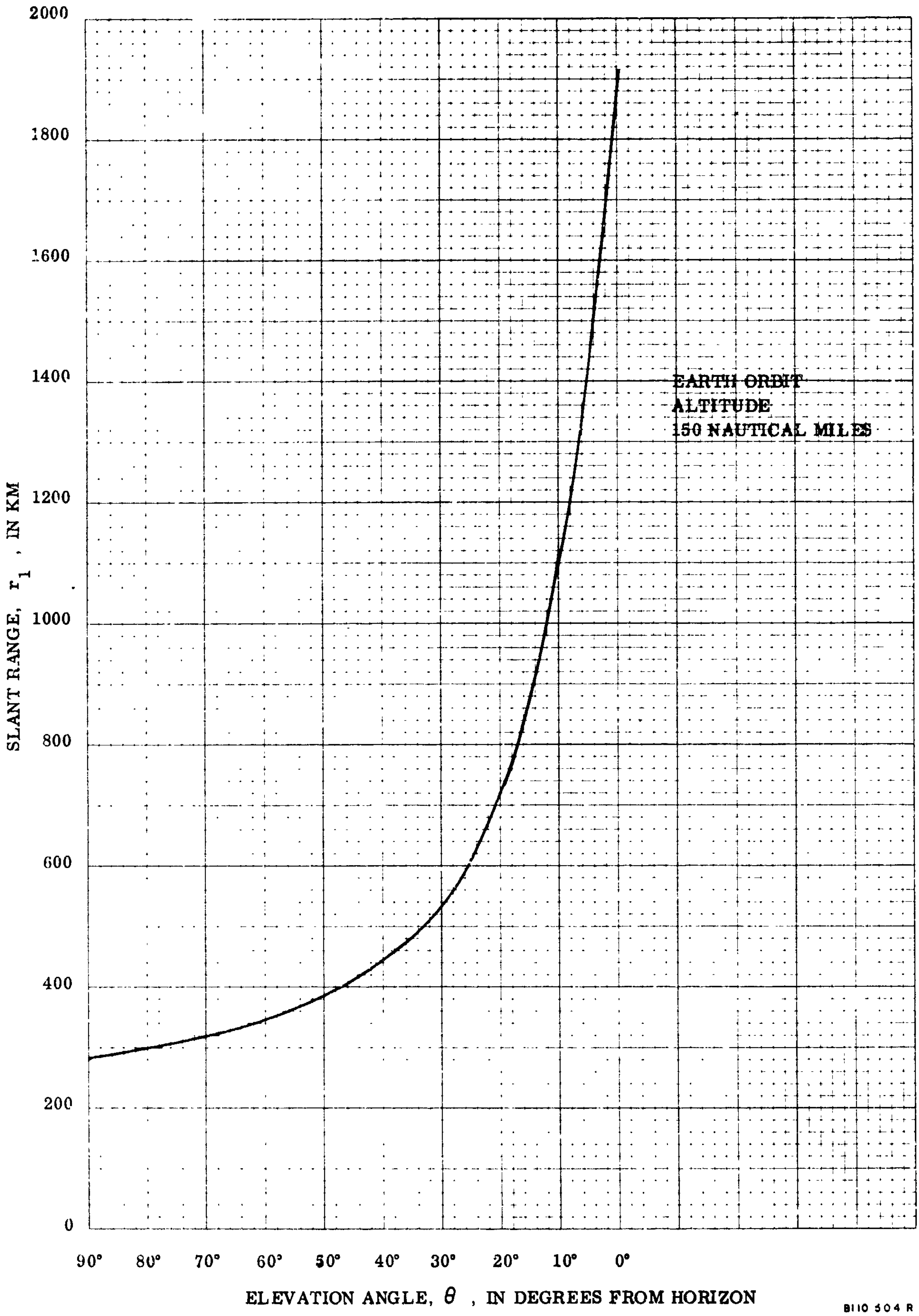


Figure 4-2. Slant Range r_1 for 150-Nautical-Mile Orbit as a Function of θ

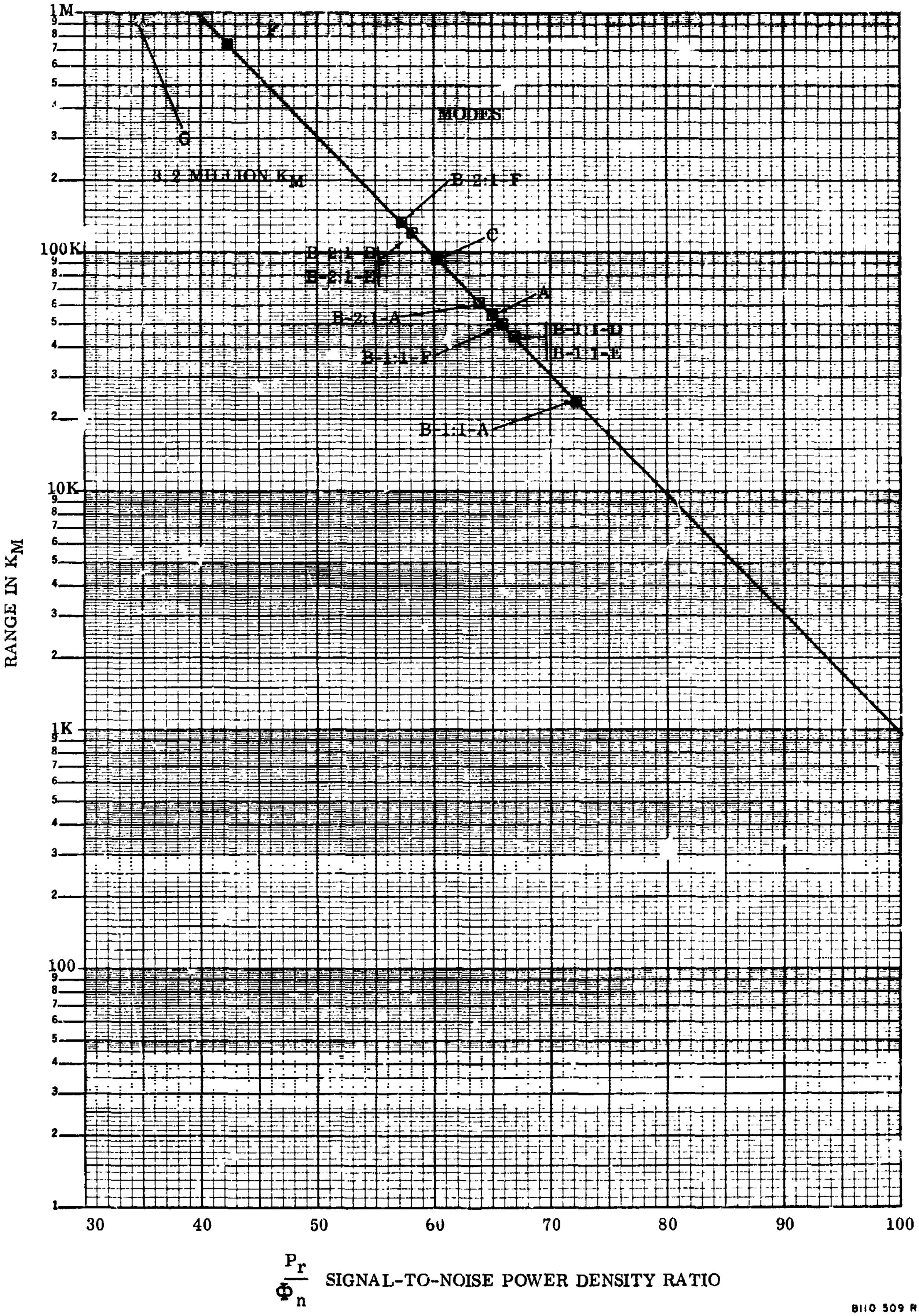


Figure 4-3. Total Signal-to-Noise Power Density Required at Mode Threshold

4.1.2.3 RECEIVER OPERATION FOR LUNAR ORBIT. The 30-foot Cassegrain antenna has a beamwidth of approximately 1.1°. A lunar orbit of 150-mile altitude subtends an angle at earth of 32 minutes of arc. Therefore, if the 30-foot antenna rf boresight is placed at the center of the moon, the energy received from the orbiting spacecraft will be down approximately 0.7 db from the beam maximum.

No attempt has been made in this report to analyse the effects of spacecraft blockage of the antenna pattern or the pattern nulls; however, assuming that an antenna of at least 20 db of directed gain is used at the spacecraft, the 30-foot antenna stations could be used for communication at lunar orbit distances.

The gain margins in the up-data link (developed in paragraph 4.3) indicate that both acm and LEM can be simultaneously communicated with by a 30-foot antenna dual station.

4.1.3 DIFFERENCE CHANNEL PERFORMANCE.

4.1.3.1 THERMAL NOISE TRACKING ERRORS. The rms angle error caused by the receiver thermal noise is derived in the following paragraphs. Figure 4-4 is a simplified block diagram of either X- or Y-axis of the tracking system. P_S is the received signal power level and N is the equivalent thermal noise due to the effective system noise temperature.

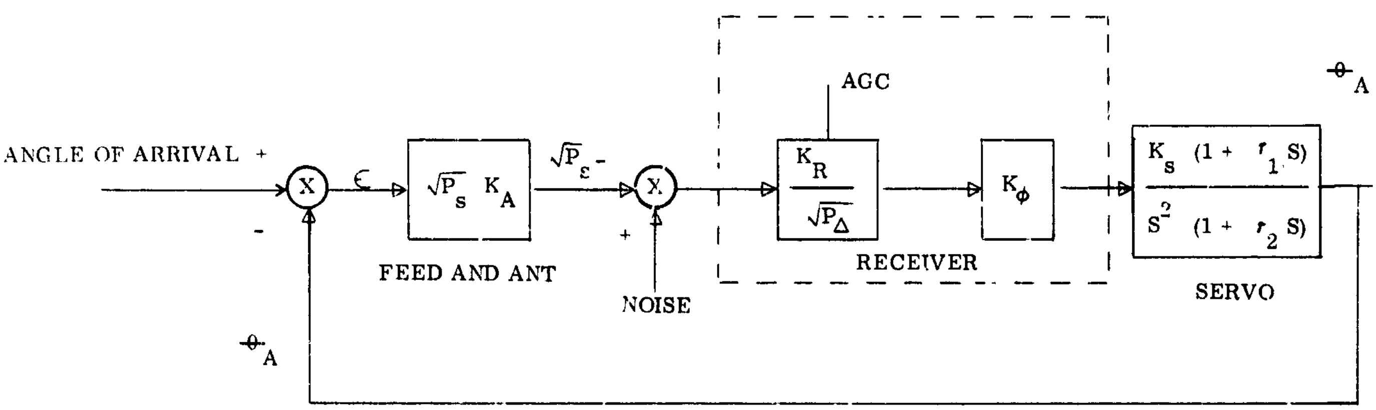


Figure 4-4. Simplified Block Diagram of System

K_a is the error slope of the antenna and feed system normalized to the sum channel signal.

The transfer function to the noise in the difference channel is shown in figure 4-5.

The acceleration error coefficient K_α of the system is equal to $K_R K_\phi K_S K_A$ and the closed loop transfer function is derived as follows:

$$G(S) = \frac{\dfrac{K_R K_\phi K_S (1 + \tau_1 S)}{\sqrt{P_S}\; S^2 (1 + \tau_2 S)}}{1 + \dfrac{K_R K_\Phi K_S K_A (1 + \tau_1 S)}{S^2 (1 + \tau_2 S)}} \tag{1}$$

$$G(S) = \frac{K\alpha}{K_A \sqrt{P_S}} \quad \frac{1 + \tau_1 S}{\tau_2 S^3 + S^2 + K_\alpha + K_\alpha \tau_1 S} \tag{2}$$

$$G(S) = \frac{1}{K_A \sqrt{P_S}} \quad \frac{1 + \tau_1 S}{1 + \tau_1 S + 1/K_\alpha S^2 + \tau_2/K_\alpha S^3} \tag{3}$$

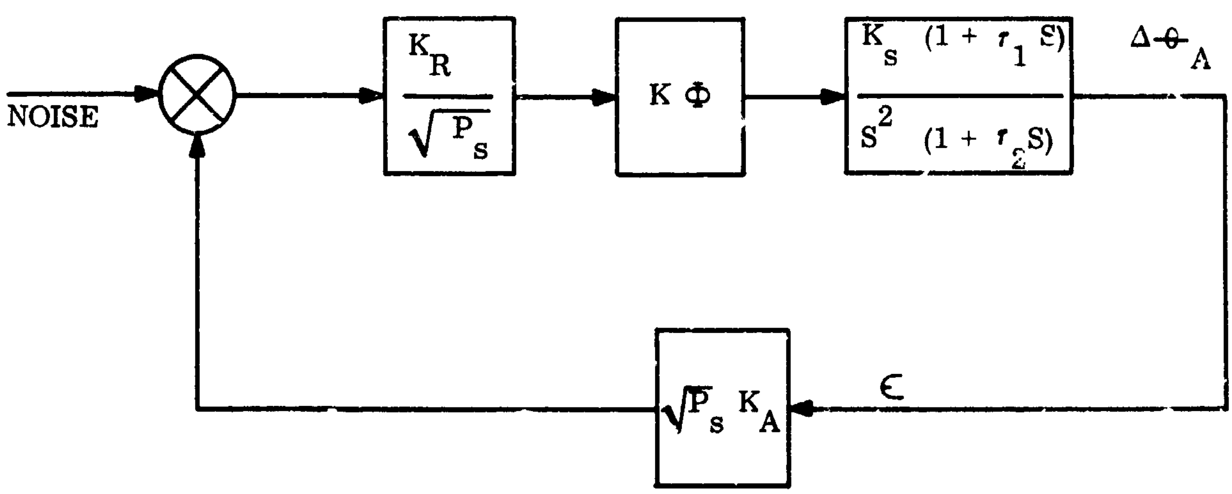
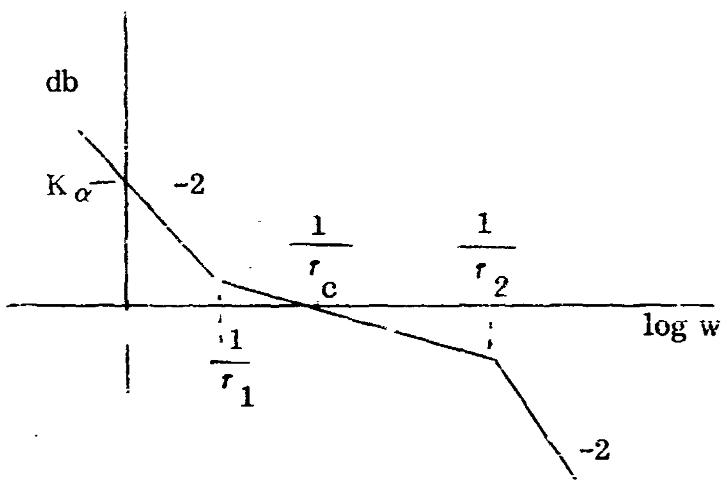


Figure 4-5. Noise Input to Angle Output

Figure 4-6 illustrates the relations between the parameters of the preceding equations,



$$T_c = \sqrt{\tau_1 \tau_2}$$

$$n^2 = \frac{1}{\tau_2}$$

$$K_\alpha = \frac{1}{\tau_1 \; c} = \frac{1}{n\tau_c^2}$$

Figure 4-6. Bodie Plot of Servo Open Loop

Since $K_\alpha = \dfrac{1}{n \, \tau_c^2}$ (3)

may be simplified to:

$$G\,(s) = \frac{1}{K_A \sqrt{P_S}} \left[\frac{1 + n\,\tau_c S}{1 + n\,\tau_c S + n\,\tau_c^2 S^2 + \tau_c^3 S^3} \right] \tag{4}$$

$$G(S) = \frac{1}{K_A \sqrt{P_S}} \left[\frac{1 + n\tau_c S}{(1 + \tau_c S)\,(1 + (n + 1)\;\tau_c S \quad \tau_c^2 S^2} \right] \tag{5}$$

Figure 4-7 is a Bodie plot of the closed loop transfer function.

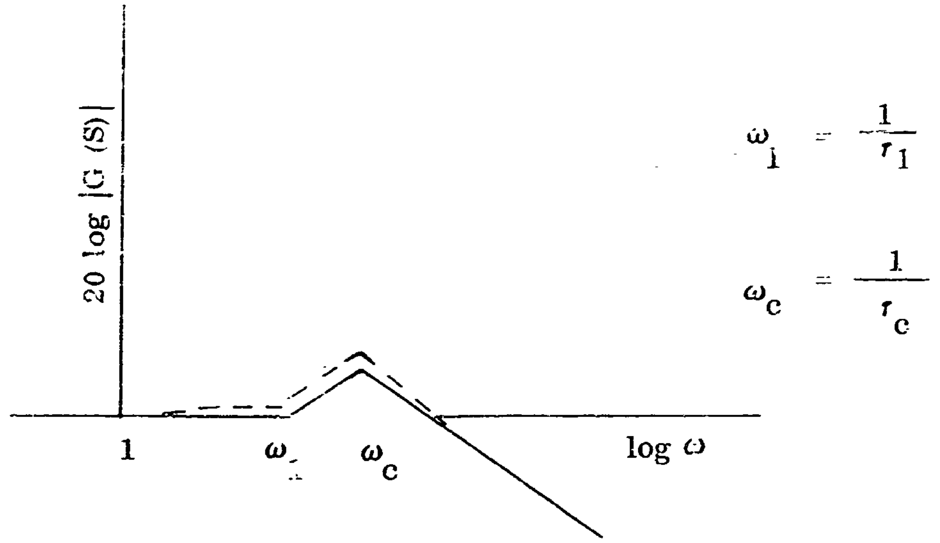


Figure 4-7. Bodie Plct of Servo System Closed Loop

The mean squared tracking error, $\overline{\Delta \Theta_A^2}$, may be computed from G (S) and the system thermal noise power spectrum, Φ_n, as follows.

$$\overline{\Delta \Theta_A^2} = \frac{1}{2\pi j} \int_{-j\infty}^{j\infty} \Phi_n \left| G(S) \right|^2 ds \tag{6}$$

where: $\Delta \Theta_A^2$ is the mean square noise in degrees Φ_n is power spectral density of the system thermal noise in watts per cps

$$\left| G(S) \right|^2 = G(S)\, G(-S) = \frac{C(S)\, C(-S)}{d(S)\, d(-S)} \left(\frac{1}{K_A \sqrt{P_S}} \right)^2$$

Simplifying equation (6):

$$\overline{\Delta \Theta_A^2} = \frac{\Phi_n}{(K_A \sqrt{P_S})^2} \quad \frac{1}{2\pi j} \left[\int_{-j\infty}^{j\infty} \frac{C(S)\, C(-S)}{d(S)\, d(-S)}\, ds \right] \tag{7}$$

We may define:

$$2\beta = \frac{1}{2\pi j_\alpha} \int_{-j\infty}^{j\infty} \frac{C(S)\, C(-S)}{d(S)\, d(-S)}\, ds \tag{7a}$$

Where: β is the equivalent noise bandwidth:

$$\overline{\Delta \Theta_A^2} = \frac{2\beta\, \Phi_n}{\left(K_A \sqrt{P_S}\right)^2} \tag{8}$$

Using equation (5) in (7a) gives:

$$\beta = \frac{n}{4\, \tau_c\, (n - 1)} \quad \text{CPS}$$

For $n = \sqrt{6}$ and $\frac{1}{\tau_c} = \omega_c$, which is in radians per second,

$$\beta = 0.422\, \omega_c \text{ (cps)} \tag{10}$$

where: ω_c is in radians/sec and is the servo open loop unit gain crossover frequency.
β is in cps.

Substituting the value of β and P_s in milliwatts into equation (8) and solving for the rms noise

$$\sqrt{\overline{\Delta \Theta_A^2}} = \frac{29.1}{K_a} \sqrt{\frac{\Phi_n\, \omega_c}{P_s}} \tag{11}$$

The 2-sided noise spectral density is derived as follows:

$$2\, \Phi_n = K\, T_A + K\, T_{300} F \tag{12}$$

where:

K is Boltzmann's Constant $= 1.38 \times 10^{-23}$ watts per cps per degree Kelvin.

T_A is the temperature of the antenna and assumed to be 60°K.

T_{300} is the temperature at the input of the receiver

F is the noise figure of the receiver difference channel and is 10 db

$$\Phi_n = 2.07 \times 10^{-20} \text{ (watts per cps)} \tag{13}$$

K_A is the normalized antenna error slope and is 1.39 deg^{-1} for the 30-foot antenna and feed and approximately 0.13 deg^{-1} for the 3-foot acquisition antenna at 2300 mc.

Substituting these values into equation (9) results in

$$\left(\overline{\Delta\Theta_A^2}\right)^{1/2} = 2.9 \times 10^{-9} \sqrt{\omega_c / P_S} \tag{14}$$

Figure 4-8 is a plot of the error normalized for ω_c of one radian per second versus the sum channel signal carrier component for the autotrack mode. Figure 4-9 is a plot of autotrack errors due to thermal noise versus sum channel power for the servo bandwidths. Also shown is a loci of bandwidth to limit the antenna axis peak acceleration to $5°/\sec^2$ due to receiver noise. Since the servo is intentionally limited at $5°/\sec^2$ acceleration; the linear system model does not apply for random tracking errors causing acceleration in excess of $5°/\sec^2$. A line is drawn at the -120 dbm signal level, which represents approximately a 20,000-nautical mile range for the S-band target.

4.1.3.2 RANGE LIMITATION DUE TO THERMAL TRACKING ERRORS. Expected receiver sum channel power is plotted in figure 4-1. Note that the range corresponding to a -120 dbm signal is about 38,000 kilometers or approximately 20,000 nautical miles. The expected received power is inversely proportional to the range squared and the tracking error is inversely proportional to the sum channel power; consequently the thermal amplitude error is directly proportional to range. This is plotted in figure 4-10, which shows the maximum 3-sigma errors due to thermal noise as the range is varied.

4.1.3.3 SUMMARY OF THERMAL NOISE TRACKING ERRORS. Figure 4-10 summarizes the 3-sigma errors due to thermal noise in the servo bandwidths proposed for satellite range in nautical miles. To get the expected errors in the acquisition mode, multiply the values on the graph by a factor of 10.

4.1.3.4 IMPROVEMENT IN PERFORMANCE UTILIZING COOLED RF AMPLIFIER. Some interest has been indicated in the use of a cooled paramp or a maser as a low-noise amplifier for use in the Unified S-Band. A comparison is made between the system temperature of the present equipment (paragraph 4.1.3.1) and the temperature that could be achieved with a cooled device.

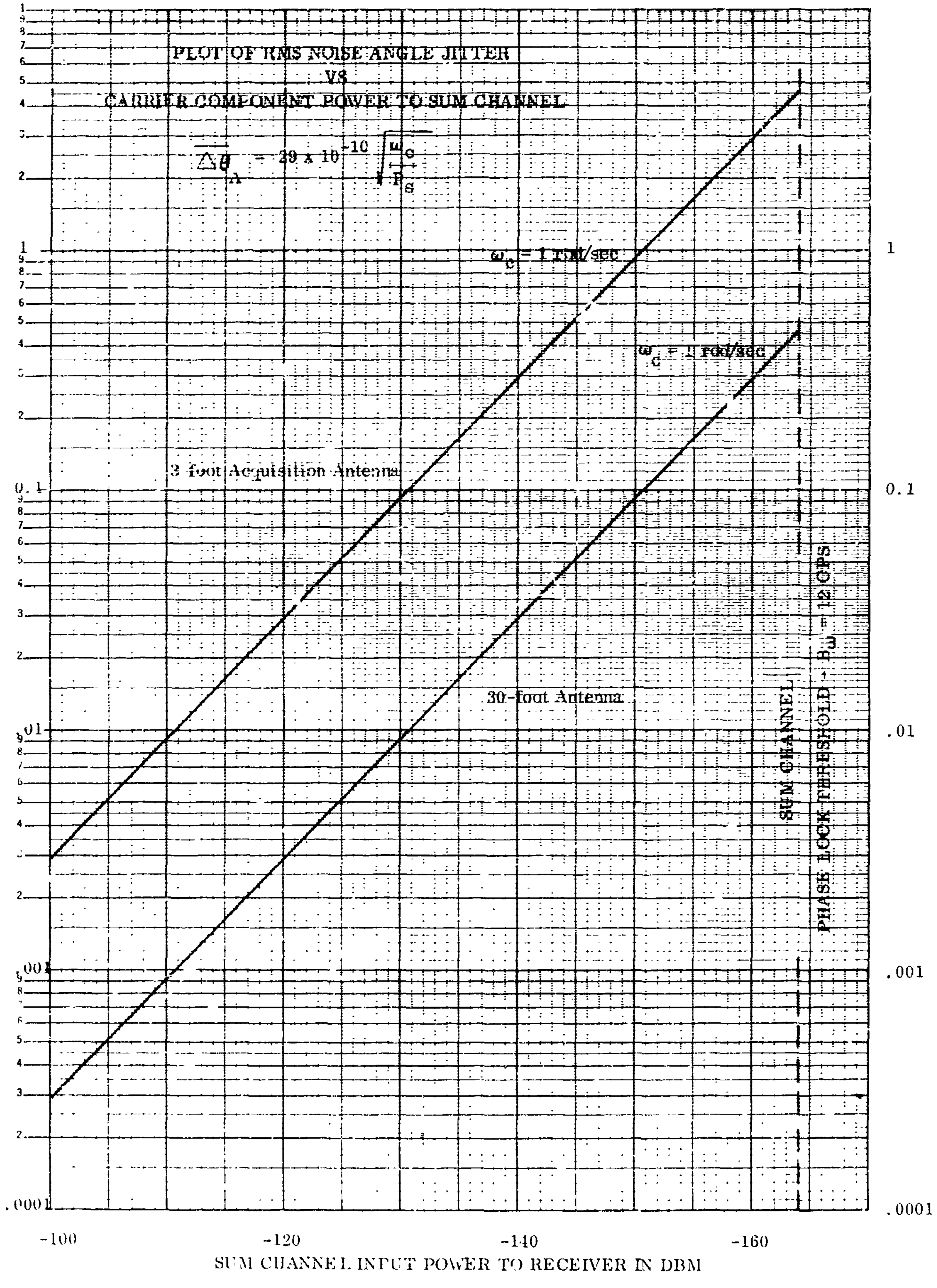


Figure 4-8. Error Normalized for ω_c of One Radian Per Second Vs. Sum Channel Signal Carrier Component for Autotrack Mode

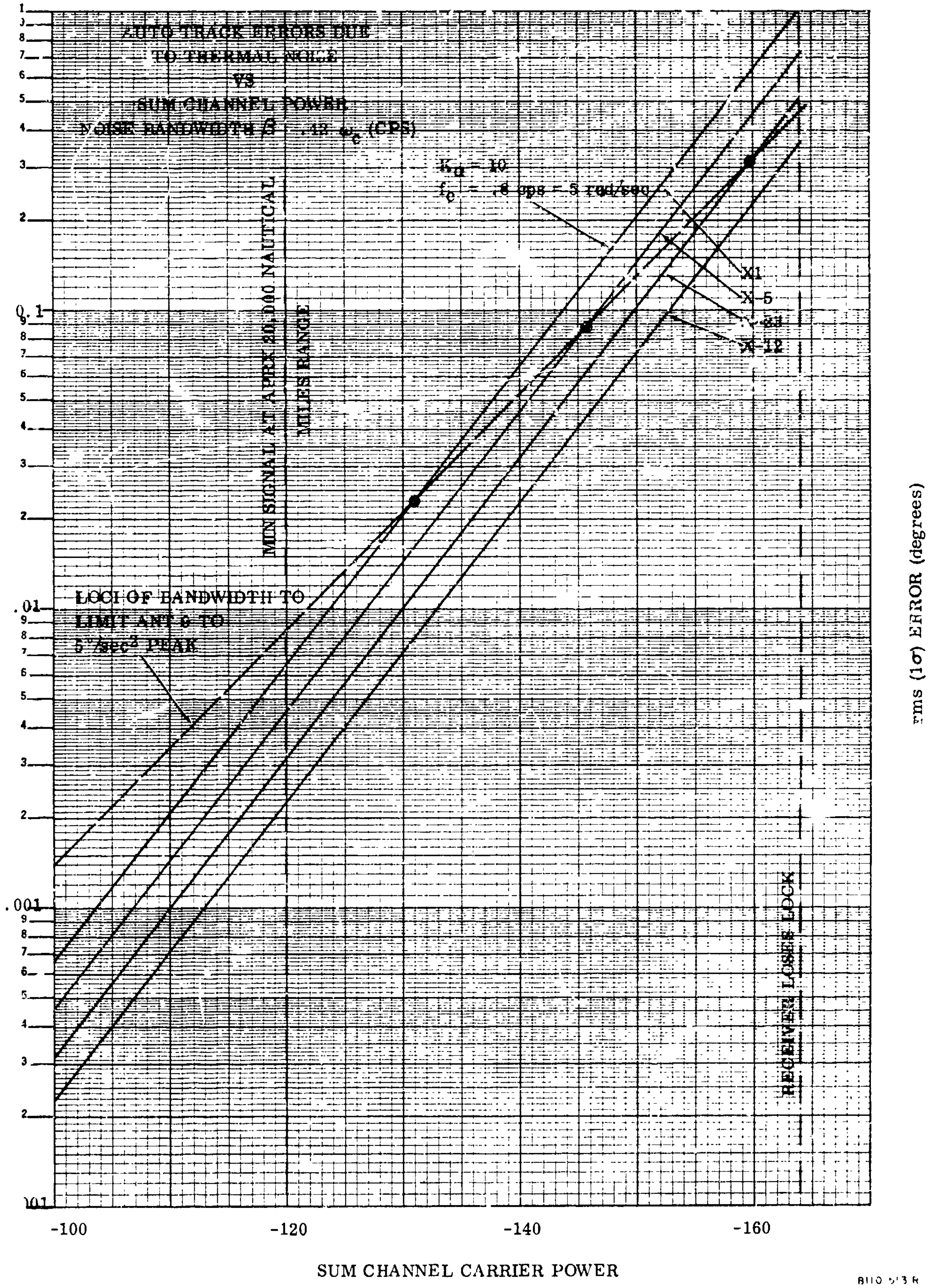


Figure 4-9. Autotrack Errors Due to Thermal Noise Vs. Sum Channel Power for Servo Bandwidths

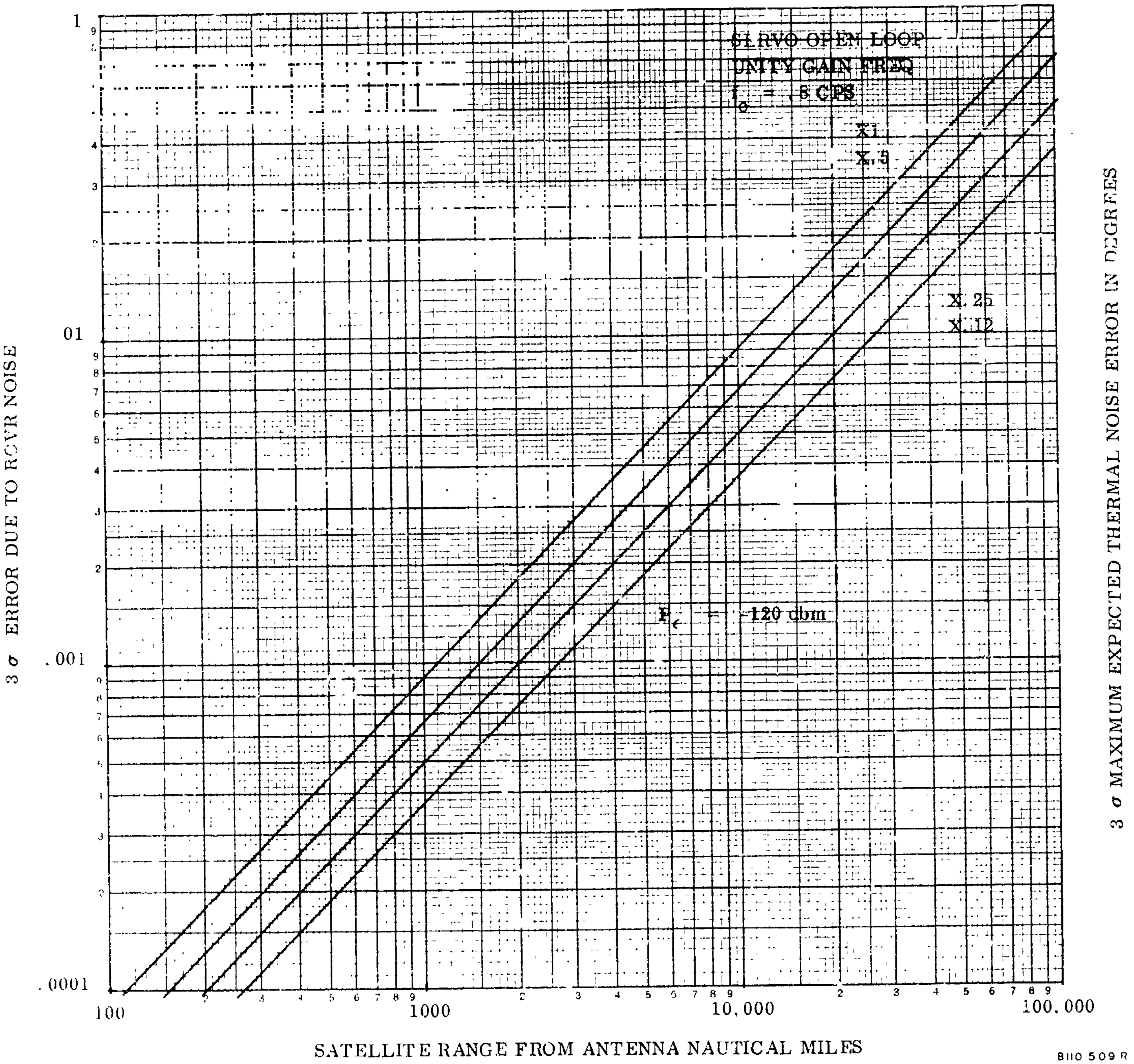


Figure 4-10. Maximum 3-Sigma Errors Due to Thermal Noise as Range is Varied

Assuming the use of a cooled paramp or a maser with a 20°K noise temperature, the following comparisons are made with the Unified S-Band paramp, which has a 127.5°K noise temperature.

			THRESHOLD		
ANTENNA POINTING	ANTENNA TEMP	SYSTEM TEMP	12 CPS BW (dbm)	48 CPS BW (dbm)	152 CPS BW (dbm)
Quiet Sky	64.7°K	84.7°K	-168.6	-162.6	-156.6
Horizon	184.6°K	204.6°K	-164.8	-158.8	-153.8
Moon	83.1°K	103.1°K	-167.6	-161.7	-156.6

It is seen that 3.6-db and 1.8-db improvement are obtained for the antenna pointed at quiet sky and horizon, respectively.

4.2 COMPOSITE MAIN TRACKING SYSTEM ERRORS, GODDARD SPACE FLIGHT CENTER.

Servo Specification GSFC-TDS-SRV-30, paragraph 3.3.3.10, states that " . . . the overall tracking error shall be no greater than 1.5 minutes (0.025°) of arc at a tracking frequency of 2300 mc. The tracking error is defined as the 3-sigma error for a Gaussian distribution of random variaties present in the system under the highest signal-to-noise ratio and maximum receiver sensitivity conditions. The systematic errors such as mechanical misalignment, electrical bias, receiver phase shift, and fixed translation errors shall not exceed 40 seconds of arc under the above conditions. The antenna shall be capable of tracking within the above random error tolerances in winds to 20 mph at 4° per second. In 20-mph to 3-mph winds, the tolerances can be doubled and in 30-mph to 45-mph winds, the tolerance can be increased fourfold . . ."

The tracking error specified above does not include tracking receiver thermal noise errors since it is specified for arbitrarily large signals.

In the sections that follow, the individual error contributions are summarized and a composite error prediction is given.

The system error on a per axis basis is defined here as the difference between the true direction of arrival of the respective axis component rf signal and the axis angle as measured by the system axis position encoder while in the autotrack mode. The total axis component error is separated into systematic (predictable and repeatable) errors and the 3-sigma value of the composite random (nonpredictable) error. The random errors are assumed to be statistically independent, to have Gaussian distributions, and to have zero mean values; therefore, the rms or 1 σ value of the composite is equal to the square root of the sum of the variances of the individual contributors. The main contributors to the tracking error are as follows:

(1) Rf boresight shift relative to axis angle encoders — caused by random and systematic dish deflections, feed deflections, feed boresight shift thermal and receiver noise, etc. If these processed boresight shifts are within the servo bandpass and are reduced by the servo, then an error is generated. Random errors may be due to thermal noise or to wind torques, whereas systematic errors may be due to antenna attitudes, gravity loads, etc.

(2) Axis angle measuring is subject to its own dynamic errors, quantitizing errors, shaft coupling deflection, and numerous others that contribute both random and systematic errors.

The overall system axis tracking error is defined as the difference between the true direction to the rf target and the axis angle as measured by the system axis position encoders. This error would include axis errors previously described plus errors due to rf transmission from the target to the antenna. Errors due to refraction and reflections are present but are not tabulated in this report.

4.2.1 ANTENNA AND FEED SYSTEM ERRORS.

The antenna structure rf boresight axis component referred to axis readout shaft and corrected for deflection from axis readout attachment to the ground survey monument are given in table 4-1. The errors are calculated and tabulated in Part II, section 1, of this report. A 20-mph wind and a structure acceleration of $5°/\text{sec}^2$ are the environmental conditions.

TABLE 4-1. SUMMARY OF ANTENNA STRUCTURE ERRORS

UNITS	RANDOM 3-sigma values		SYSTEMATIC peak values	
	X	Y	X	Y
Seconds	34	36	40	39
Degrees	.094	.01	.011	.011

4.2.2 SERVO DRIVE ERRORS.

Figure 4-11 is a summary of the maximum expected 3-sigma values of servo tracking errors as derived in Part II, section 12, of this report. All of the servo errors are classified as random errors. Note that this graph is for a 20-mph mean value of wind with Gaussian distributed 3-sigma gusts to 35 mph. Also tracking dynamics, gear noises, etc., are included; but rf thermal noise, antenna rf boresight, and readout errors are not shown. The errors are those generated when the servo tries to reduce the difference between the rf angle of arrival and the processed rf boresight to a minimum value.

The total rms error is the 1-sigma value calculated by taking the square root of the sum of the variances of the individual errors. The total error is composed of wind torque induced errors, dynamic errors due to acceleration maximums, and errors due to gear position noise. The 3-sigma value of the gear noise is assumed to be 0.006° and to be constant. The servo budget is given in table 4-2 for an earth satellite in a 130-mile high circular orbit.

Since it is assumed that the servo bandwidth will be decreased as the signal level decreases, a budget for each bandwidth is given.

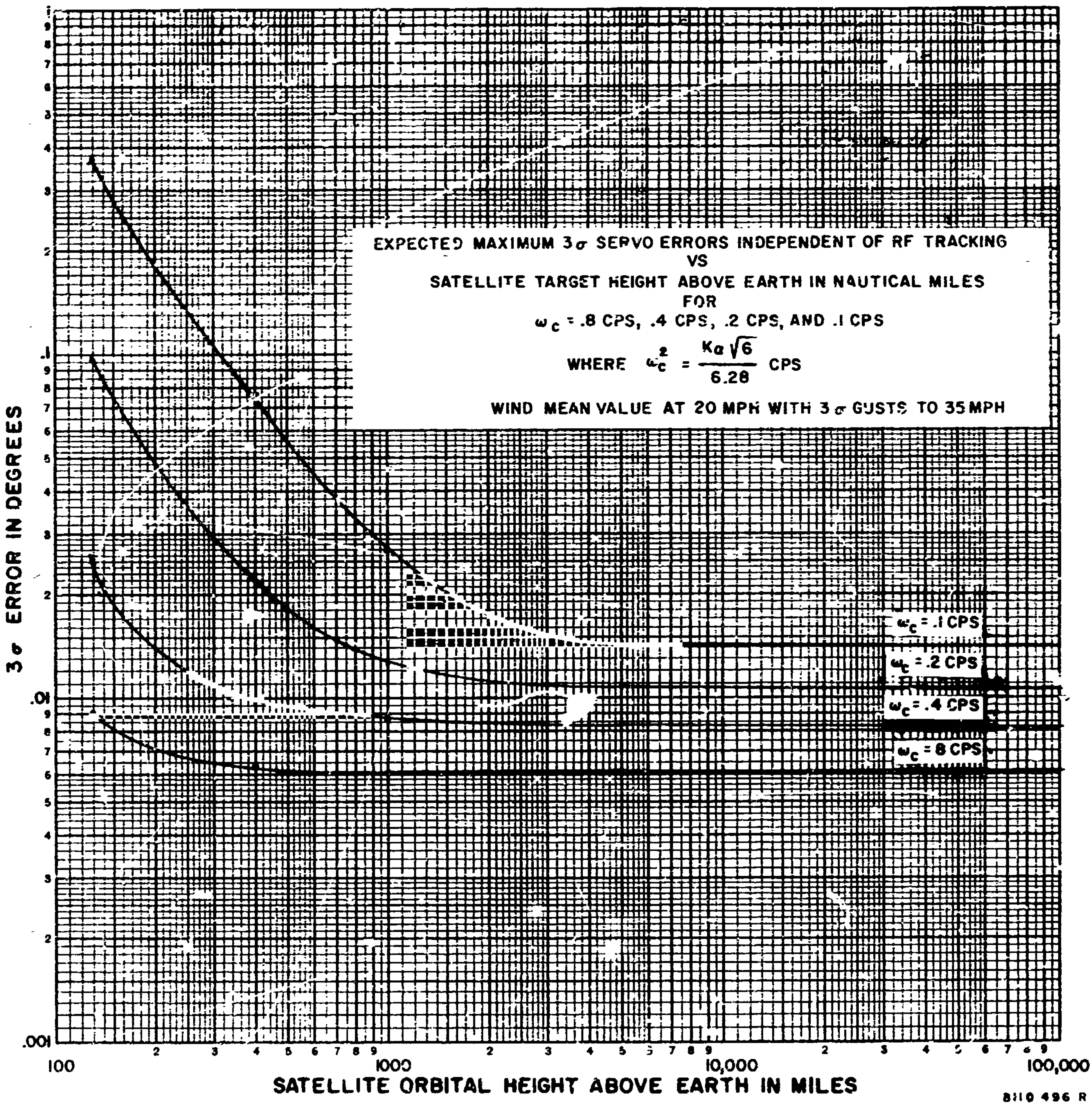


Figure 4-11. Summary of the Maximum Expected 3-Sigma Values of Servo Tracking Errors

TABLE 4-2. SERVO ERROR BUDGET

SOURCE	RANDOM 3-SIGMA ERRORS				SYSTEMATIC
	SERVO BANDWIDTH				
	X1	X.5	X.25	X.12	
20-MPH Wind	.002°	.006°	.009	.013	None
Dynamic Errors due to Acceleration Maximums. For 130-Mile Satellite	.006°	.024	.96°	.38°	None
	$K_a = \frac{10}{sec^2}$	$K_a = 2.5$	$K_a = 0.6$	$K_a = 0.16$	None
Errors due to Gear Position Noise and	0.006°	0.006°	0.006°	0.006°	None
Servo Drift	Nil	Nil	Nil	Nil	None
TOTAL 3-sigma	.009	.025	.097	0.38	None

4.2.3 COMPOSITE SYSTEM TRACKING ERROR.

Table 4-3 summarizes the expected errors derived from the subsystem error analysis. Figure 4-12 is a plot showing expected random tracking error versus satellite range minus the effects caused by polarization errors of the feed and minus rf transmission path errors.

It is seen that additional servo bandwidth restriction may reduce the tracking errors at long ranges by reducing the effects of thermal noise; the overall effect is currently being studied.

4.2.4 INCREASED ACCURACY — ANTENNA SUBSYSTEM.

A meeting was held with Blaw-Knox to discuss the cost of increasing the accuracy of the antenna subsystem by factors of up to 5 times that to which the system is presently being designed.

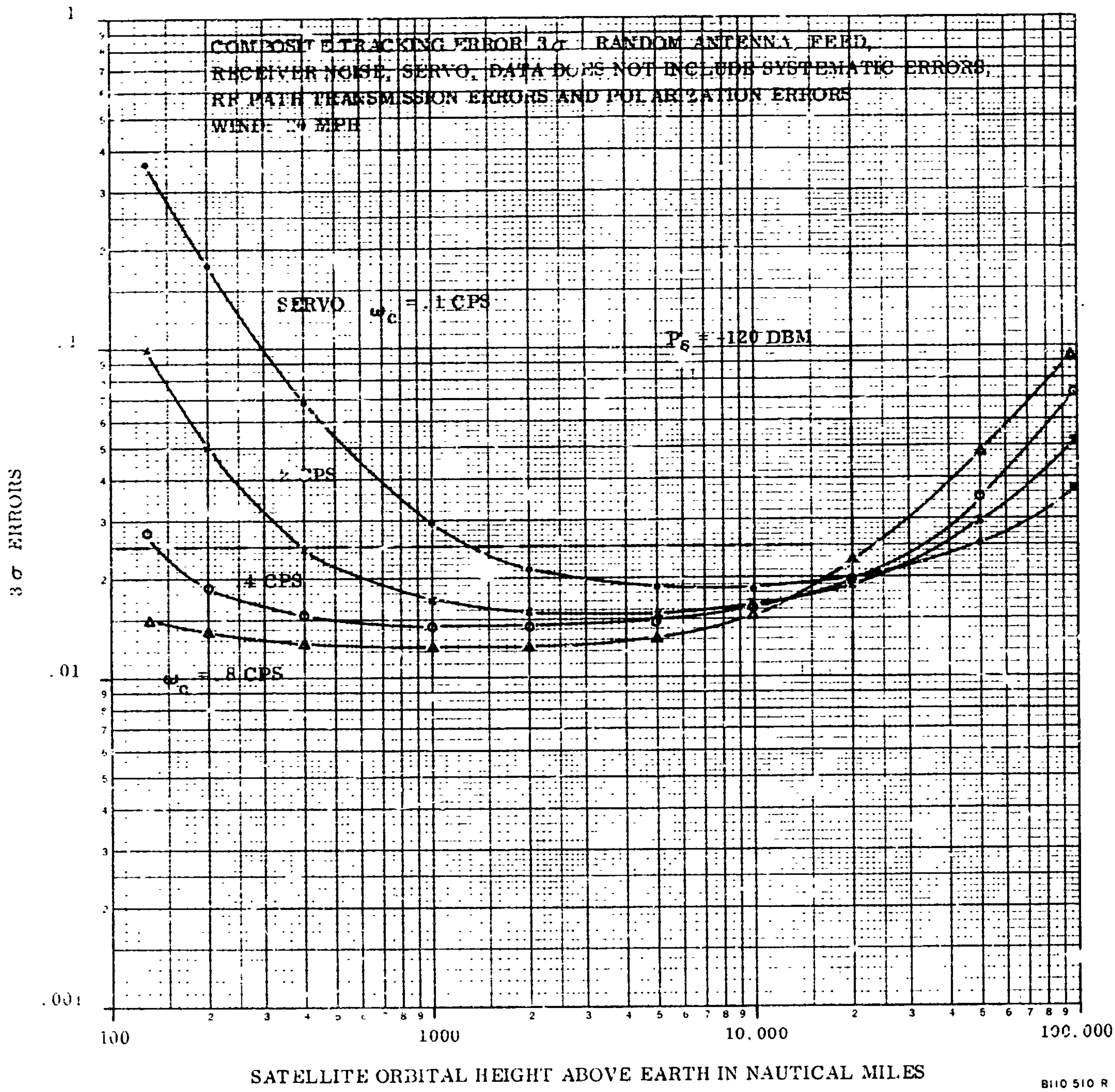


Figure 4-12. Expected Random Tracking Error Vs. Satellite Range

TABLE 4-3. SUMMARY OF TRACKING ERRORS

		SYSTEMATIC
Servo — see figure 4-11	0.009 at max bandwidth	—
Antenna Structure (see paragraph 4.2.1)	0.01 per axis	0.011
Receiver Thermal Noise (P_S = -110 dbm) (see figure 4-12)	0.002	—
Axis Position Encoder	0.0042	—
Feed-Exclusive of Polarization Errors	0.005	—
	3-sigma = 0.015	0.011
Feed Polarization Error (1% of beamwidth Design Objective -3% max.)	0.01	
	3-sigma = 0.018	

As a result of the above meeting, it is felt that a study program would have to be undertaken to determine the best method of approach for satisfying both economies and the desired accuracies. Several methods were mentioned for improving the accuracy, among them were:

(1) Possible use of a radome

(2) Testing and selection of axis bearings and other critical components

(3) Removal of all systematic errors by use of a computer and programmer technique

(4) Use of materials with higher modules of elasticity

(5) Possible use of cast aluminum reflector support structure with controlled environment.

In the tracking error analysis for the 30-foot antenna autotrack mode, two error contributors are dominant: (1) the error due to polarization shift and (2) the rf thermal noise contribution for satellite heights above 20,000 miles.

Although allowed a polarization error of 3 percent of beamwidth, Collins has set a goal and budget of 1 percent or approximately 0.01°. The effort necessary to insure a 0.5 percent polarization error maximum is an unknown quantity since many system parameters can affect this total error. For example, the dish elipticity, feed characteristics, quadrapod rf shadows, etc., can all contribute. Analysis and improvement beyond 1 percent of beamwidth will require additional system testing and hand pruning of the overall system on a test range. If decreased polarization error is required, Collins recommends that a study contract be awarded.

The rf thermal noise increases as the satellite range increases but decreases as the square root of the servo bandwidth decreases.

$$\Delta\theta_A = \frac{K_1 \sqrt{f_c}}{K_a \sqrt{P_S}} = \frac{K_2\, r \sqrt{f_c}}{K_a}$$

where:

r is the satellite range

f_c is the servo open loop unit gain crossover frequency

K_a is the antenna gain slope characteristic

K_2 is a constant

For conditions in which the target dynamics or ambient winds demand a high dynamic response of the servo system but the received signal-to-noise ratio from the target is too low for high accuracy tracking, an alternate aided track mode called autoprogram is planned. In this mode the inputs from the programmer are essentially high-passed to supply the high dynamic response. The receiver outputs and low-passed to filter the rf thermal noise and are then used to correct the positions as commanded by the taped data.

The exact performance of this mode is presently being studied on the Collins analog computer program and is not available at this time. It is hoped that this mode of operation will extend the range of operation while maintaining accurate tracking.

In our opinion the plot shown in figure 4-13 is representative of what could be expected by utilizing the present concepts but making design and component changes to improve the overall subsystem.

Curve number 2 is an approximation using new design concepts and fabrication processes. To arrive accurately at curves such as those plotted above would require extensive researching and analysis of the state-of-the-art for all materials and components.

4.3 ACQUISITION SYSTEM ERRORS.

GSFC servo specification GSFC-TDS-SRV-30, paragraph 3.3.3.9, states that ". . . The overall tracking error (wind velocity below 20 mph) shall be no greater than 12.0 minutes of arc at a tracking frequency of 2300 mc. The tracking error is defined as the 3-sigma error for a Gaussian distribution of random variants present in the system under the highest signal-to-noise ratio and maximum receiver sensitivity conditions." The specification thus states that the random 3-sigma value is ±0.2°. Table 4-4 lists the expected random and systematic errors associated with the acquisition system.

TABLE 4-4. EXPECTED RANDOM AND SYSTEMATIC ERRORS

SOURCE	3-SIGMA RANDOM	SYSTEMATIC
Servo Errors 20 mph + 3-sigma gusts to 35 mph	0.009°	—
Antenna Structure At Attachment Point Relative to Axis	.01°	0.017°
3-foot Dish and Feed		
Wind and Acceleration (Budget)	0.01°	
Crosstalk (Max.)	0.02	
Alignment		0.084°
Axis Encoders	0.0042	
	3-sigma = 0.027	0.101°
Feed Polarization Error (1% at Beamwidth)	0.1	
Total	3-sigma = 0.104	

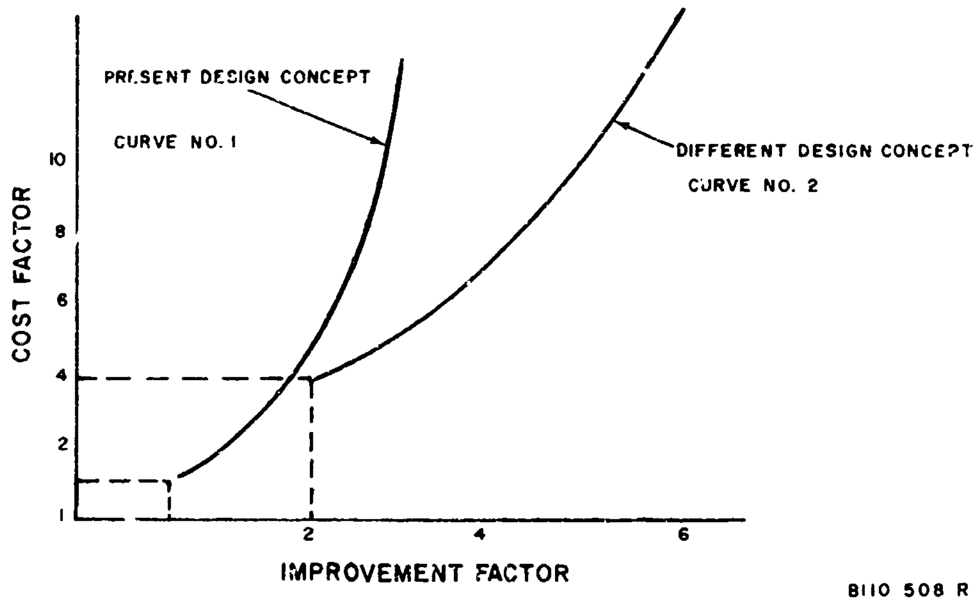


Figure 4-13. Expected Results from Using Present Concepts Plus Design and Component Improvements

At a signal strength of -120 dbm in the sum channel, the 3-sigma error is approximately ±0.208°. Figure 4-14 is a plot of expected receiver thermal noise errors versus satellite range. Figure 4-15 is a plot of expected errors versus satellite height. Note that beyond 10,000 miles a plot is made for a noise bandwidth of 0.014 cps, showing that extended range tracking is possible if an aided track mode such as autoprogrammer is used. The autoprogrammer is planned for the 30-foot system, but is not planned for acquisition.

4.4 TRANSMIT PERFORMANCE.

4.4.1 GENERAL.

The transmit or up-data link is composed, for purposes of this analysis, of the power amplifier (PA), rf transmission line, rf networks and feed, 30-foot antenna, space path, and spacecraft receiving system. The detailed parameters of the spacecraft receiving system are not known to Collins Radio Company; however, two basic assumptions are made concerning the receiving system. The receiving antenna is assumed to have unity gain, and the effective receiver threshold is assumed to be -140 dbm.

4.4.2 TRANSMITTED SIGNAL CHARACTERISTICS.

The radiated signal is basically a composite of three signals modulated on the S-Band carrier. These signals are combined as shown in figure 4-16. However, the full details of the individual signal parameters are not known at this time.

It is assumed that the sideband power will be such that the carrier and all subcarriers will reach their respective thresholds simultaneously.

4.4.3 UP-DATA LINK RANGE CONSIDERATIONS.

Certain parameters should be determined prior to calculating system range. The input to the power amplifier is specified at 0.5 watt. The PA itself will have a minimum gain of 47 db. The transmission line losses (waveguide, rotary joints, etc.) will not exceed 0.5 db. The feed and rf network subcontractor has defined the 2100-mc parameters of the feed and antenna as shown in the following listing.

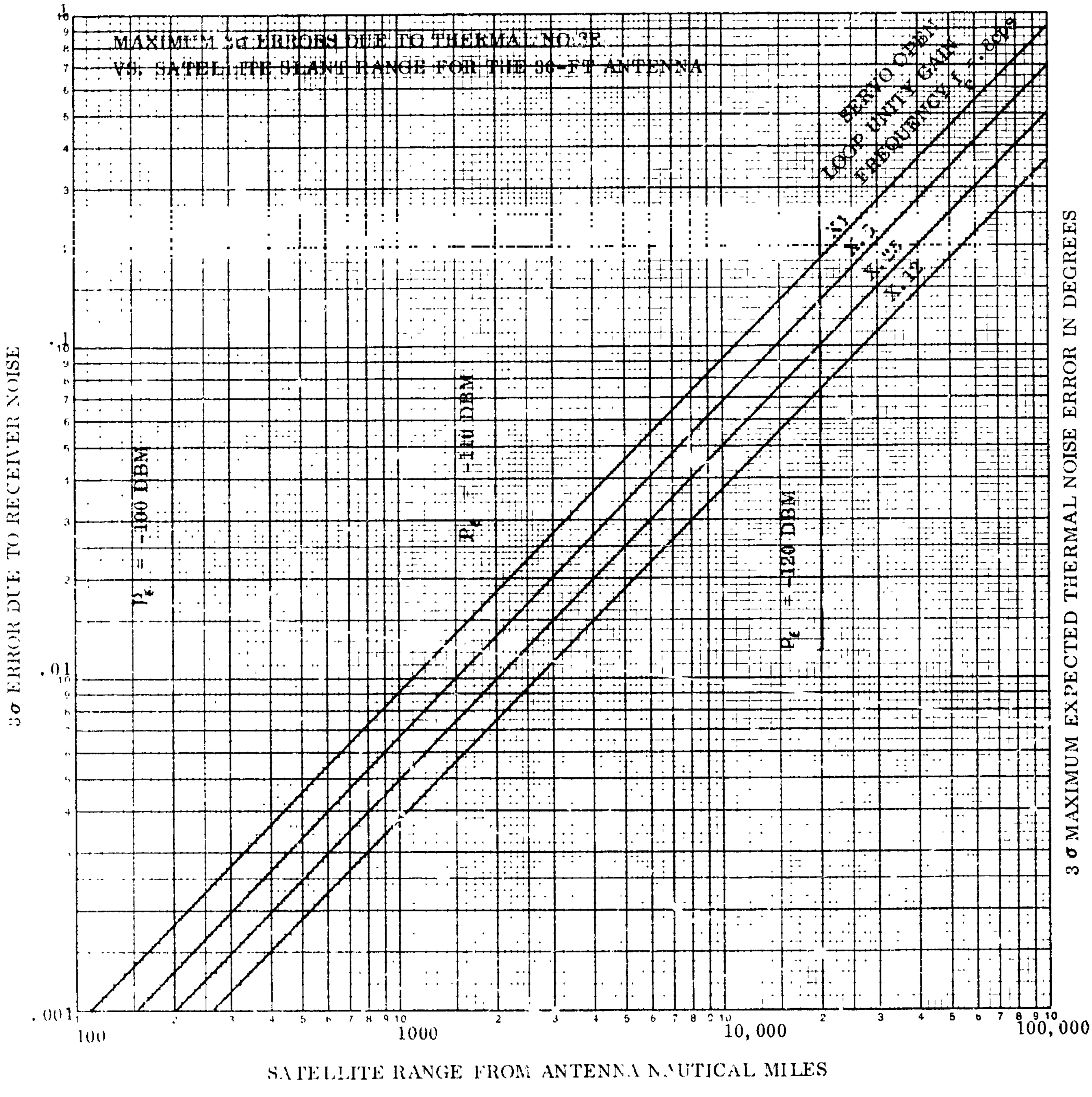


Figure 4-14. Expected Receiver Thermal Noise Errors Vs. Satellite Range

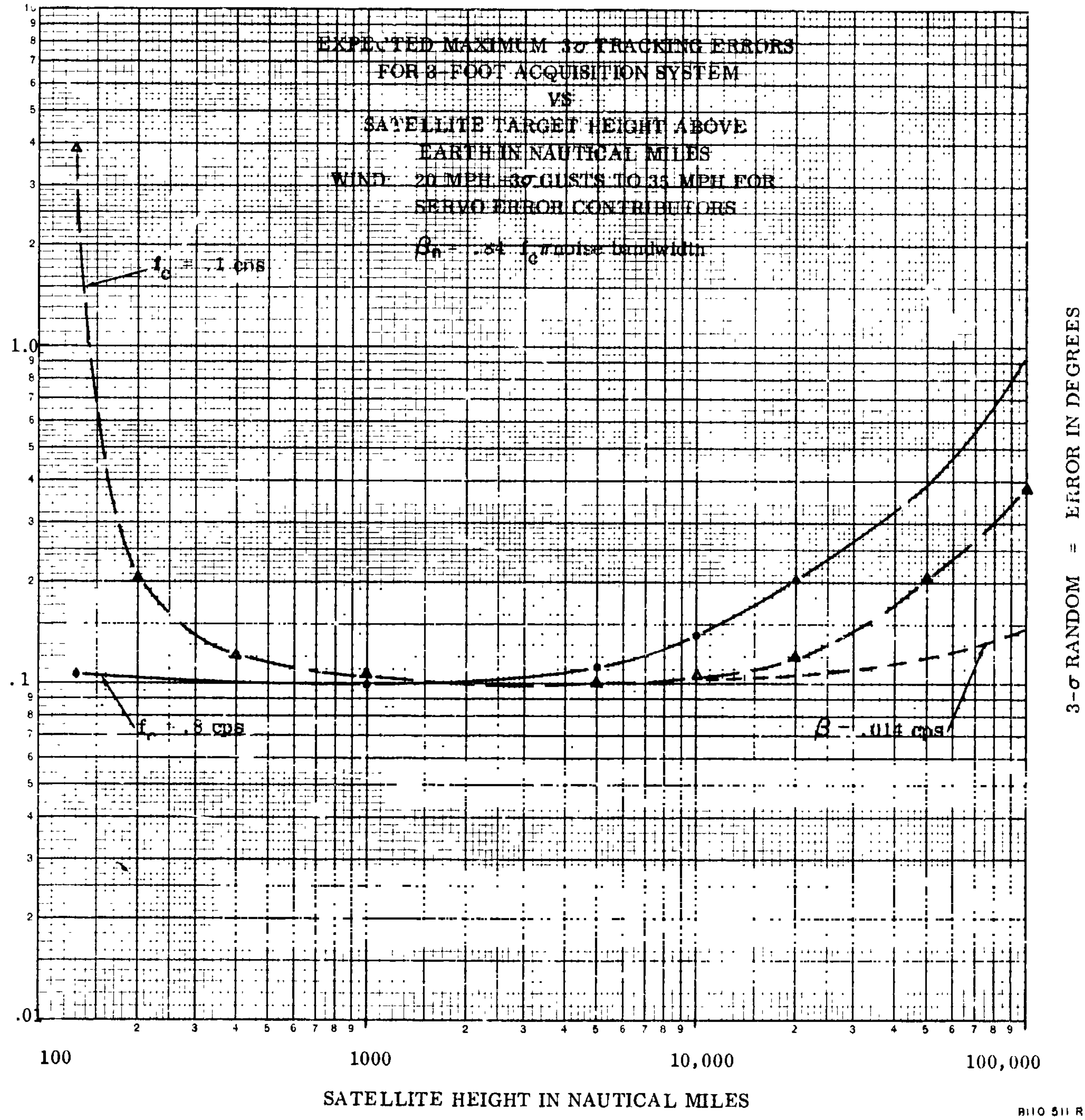


Figure 4-15. Expected Errors Vs. Satellite Height

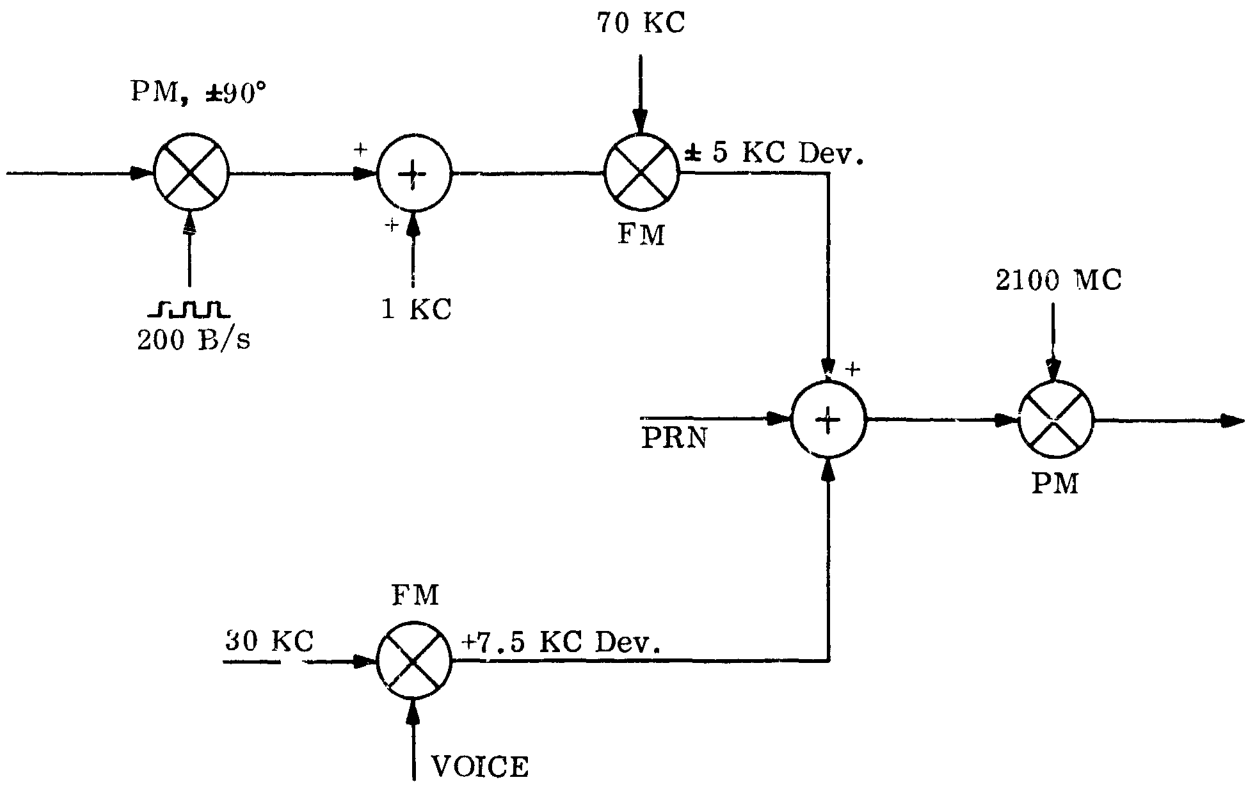


Figure 4-16. Up-Data Link Modulation Scheme

I^2R loss (feed and rf network)	-0.5 db
Aperture efficiency loss	-0.4 db
Aperture blockage	-0.3 db
Parabola/hyperbola surface tolerance losses	-0.1 db
Spillover loss	-1.0 db
Phase error loss	-0.3 db
Polarization error loss	-0.1 db
Antenna directivity	+46.0 db
Antenna gain	+43.2 db

The spacecraft receiver threshold is assumed to be -140 dbm. Again using

$$P_r/P_t \quad G_r G_t \left(\frac{\lambda}{4\pi r}\right)^2$$

$$\lambda \quad \frac{0.3\ \text{km}}{f_{mc}}, \quad r \text{ in km}$$

Or

$$\frac{P_r}{G_r} = \underbrace{(P_t G_t)}_{\text{ERP}} \quad \underbrace{\left(\frac{0.3}{f_{mc}\, r_{km}\, 4\pi}\right)^2}_{\text{SPACE LOSS}}$$

In decibel notation, space loss is

$$\hat{L}_{FS} = 20 \log r_{km} + 20 \log f_{mc} + 32.4 \text{ db}$$

$\hat{P}_t = \hat{P}_{in} + 47$ db where $\hat{P}_{in}$ is power in dbm applied to the power amplifier input

$\hat{G}_t = +43.2$ db

$\hat{G}_r = 1$ or 0 db (assumed)

$\hat{P}_r = 140$ db + $\hat{P}_m$, where $\hat{P}_m$ is the excess power or gain margin in db.

The general up-data equation may now be written as

$$\hat{P}_m - 140 \text{ dbm} = P_{in} + 47 \text{ db} + 43.2 \text{ db} - 32.4 \text{ db} - 20 \log f_{mc} \cdot$$
$$- 20 \log r_{km}$$

if $f_{mc} = 2100$,

$$\hat{P}_m = \hat{P}_{in} + 131 \text{ dbm} - 20 \log r_{km}$$

4.4.3.1 EARTH ORBIT. If a circular orbit of 150-nautical-mile altitude is assumed, the range r_1 at 0° antenna elevation angle will be 1904 km. This range will vary inversely with the antenna elevation angle, θ, as follows

$$r_1 = -6730 \sin \theta + 904 \sqrt{11.2 \sin^2 \theta - 1} \quad \text{km}$$

The slant range is plotted in figure 4-17 as a function of θ. The gain margin varies with θ by the following expression:

$$P_m = 158 \text{ dbm} - 20 \log (6370 \sin \theta + 1904 \sqrt{11.2 \sin^2 \theta + 1})$$

This relationship is also shown in figure 4-17.

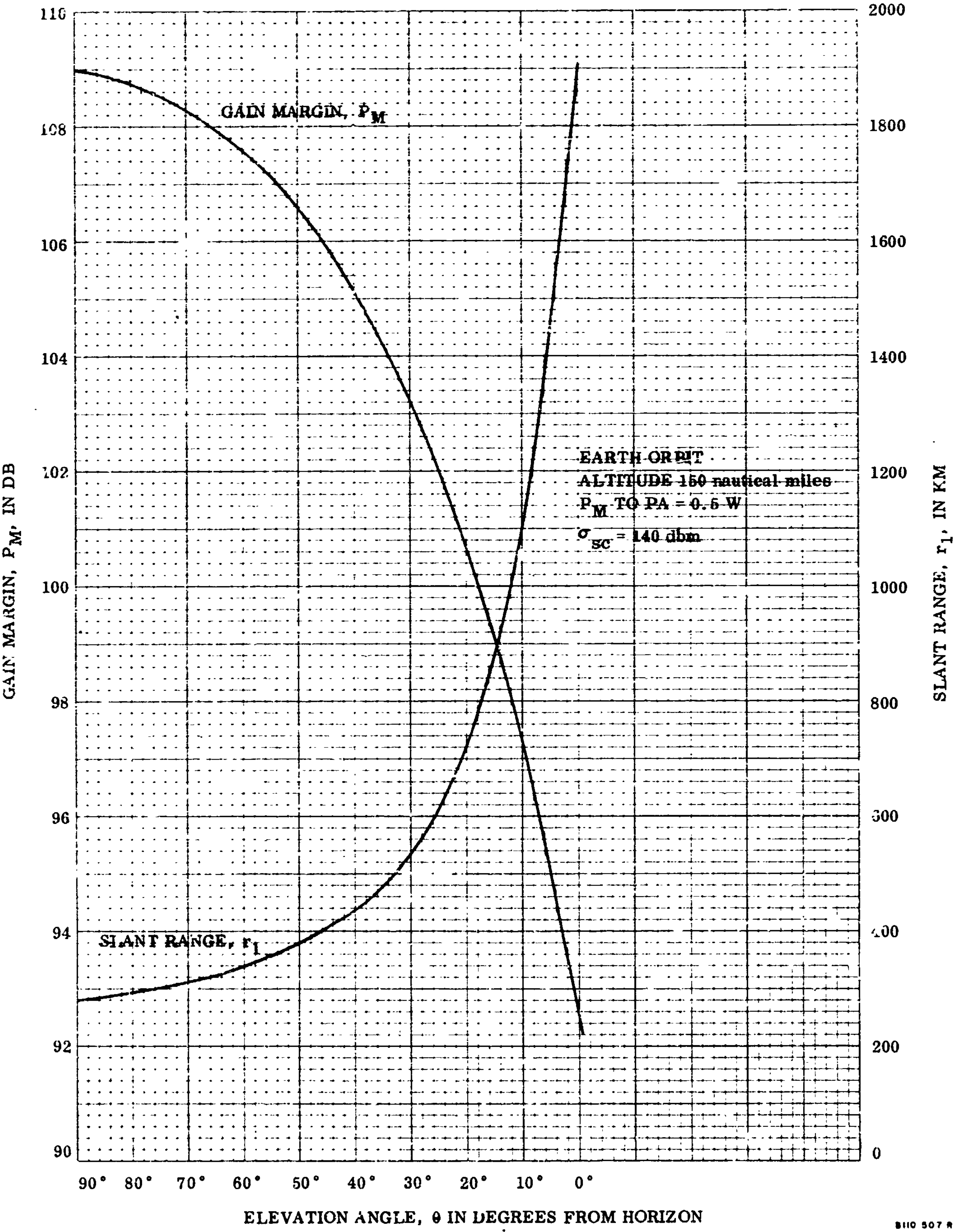


Figure 4-17. Slant Range as a Function of θ

It may be seen that the up-data system, in earth orbit, contains considerable gain margin. The effects on this margin by reducing the input to the power amplifier are shown in figure 4-18.

4.3.3.2 LUNAR ORBIT. The mean distance from the earth's surface to the moon (for 90° antenna elevation angle) is approximately 378,000 km. The gain margin equation now becomes

$$P_m = P_{in} + 19.4 \text{ dbm.}$$

This relationship indicates a 46.4-db power margin if P_{in} = 0.5 watt = +27 dbm. The effects of changes in input power upon gain margin are shown in figure 4-19.

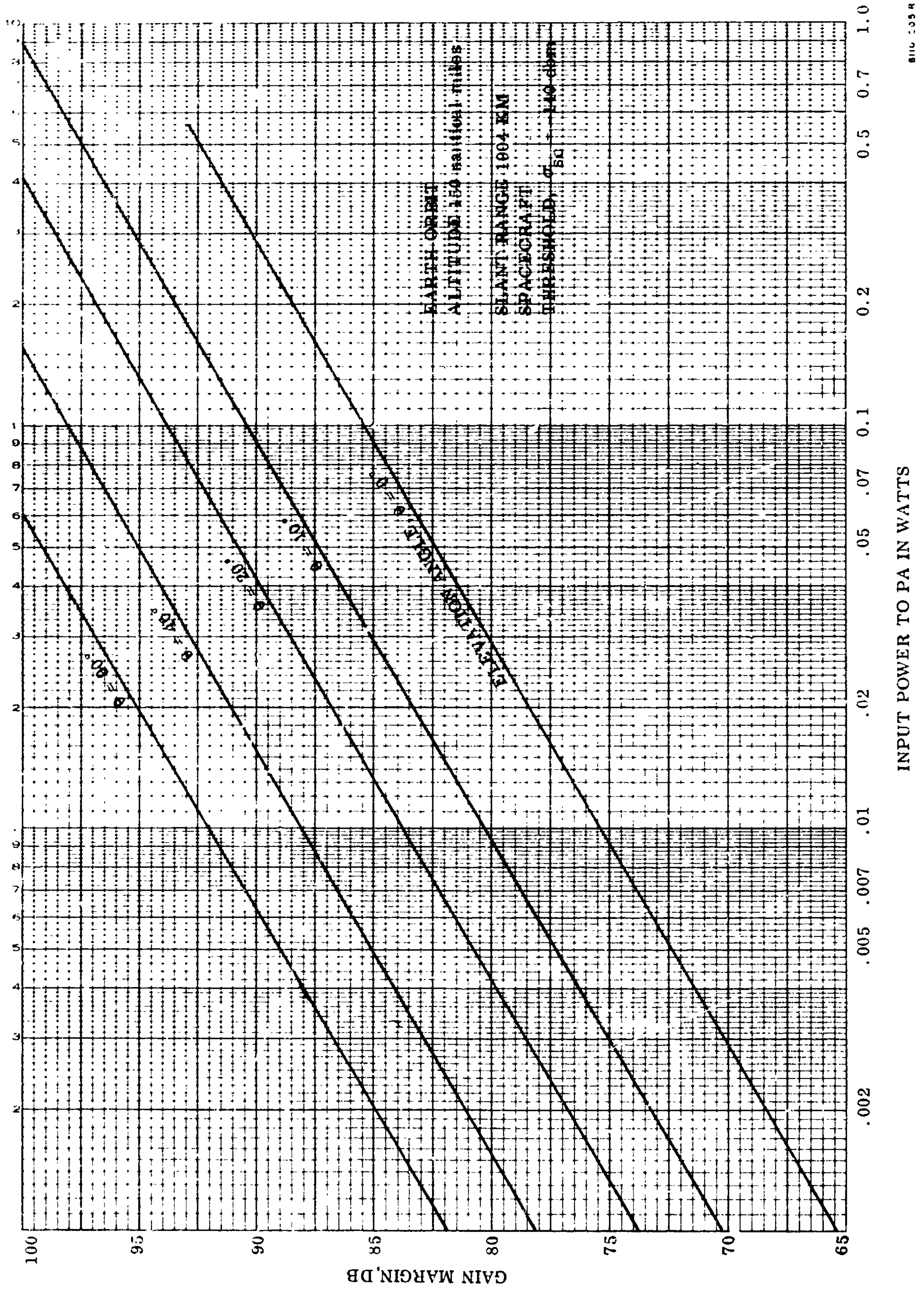


Figure 4-18. Effects on Gain Margin by Reducing Input to PA

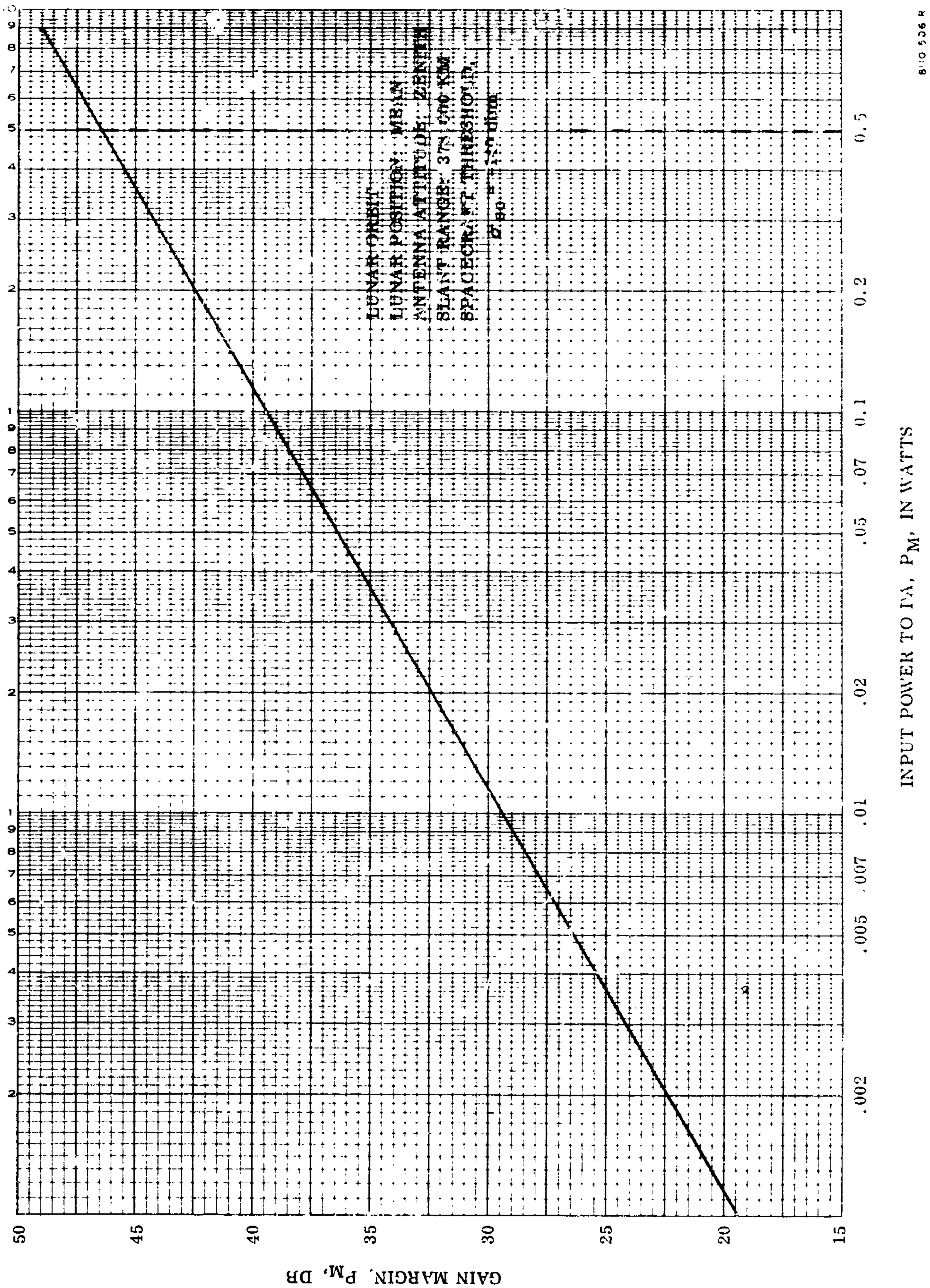


Figure 4-19. Effects of Changes in Input Power On Gain Margin

part V

appendices

appendix a

specification #126-0429 signal data demodulator

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVED
A	T 33732 Spec revised to meet engineering requirements.	28 Jul 1964	PEV
B	T 33759 Deleted 4 step attenuators on inputs of Adder of Figure 4, reworded para 11.1.1 , changed para. 12.4.1. from "Predetermined output levels" to "Carrier Modulation Level Indication", changed fig. 1 to show outputs instead of module blocks for recorder and displays, reworded para's 3.2.1.4, 3.3.2., 4 4.2.3., 4.4.3., 5.5.2.6., 5.5.6., 6.4.7., 7 3.2.4., 13 3, and 13 6 and added ** note to table II	30 Jul 1964	PEV
C	T34258 Reworded para 3 2.1 2, 3.2.1 4, 5.4.4.1, 12.2.3.2 12.3.2.3, 12,3.3.3 and 12.4, added "," between is and part in 5th para of page 11, added - tolerance and) to column headings of para 6.1.2, added ± 1 db tolerance to para 7.1.2, added para 12.2.2.3 and 12.2.3.2 and changed requirements of para 12 2.2 4 from 10^5 to 10^3.	4 Sept 1964	PEV

DESCRIPTION: Subsystem Specification for Unified S-Band Signal Data Demodulator

*DASH NUMBER: -001

*NOTICE: WHEN REFERRING TO PART NUMBER, SPECIFY DRAWING NUMBER FOLLOWED BY THE APPLICABLE DASH NUMBER.

The class designation and the symbols CAL, TA, CR, RA, NSR, and SSA which may appear on this drawing are for internal use only by the Collins Radio Company and are not related to the engineering data contained herein.

VENDOR	CODE IDENT NO.	VENDOR P/N

CLASS 3 | CAL CHANGE | CONTROL DRAWING | ENGRG PN None

NAME	DATE
PREP BY	A17
CHK BY B. Glamlusaale	17 Jul 1964
CHK x x x x x x x x x x	
PROJ ENGR D. Storey	4/17/64
DWG DATE July 1964	

COLLINS RADIO COMPANY
CEDAR RAPIDS, IOWA

SUBSYSTEM SPECIFICATION
UNIFIED S-BAND SIGNAL DATA DEMODULATOR

CODE IDENT NO 13499 | SIZE A | DRAWING NUMBER 126-0429*

SCALE NONE | WT NA | SHEET 1 of 42

REV C

TABLE OF CONTENTS
SUBSYSTEM SPECIFICATION
UNIFIED S-BAND SIGNAL DATA DEMODULATOR

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1. SCOPE:

The function of this system is to demodulate, with the most efficient demodulation techniques, the transmission modes of the Unified S-Band communication downlink as described in this specification. After demodulation, the system will filter, amplify, and distribute the data to its proper data reception points in the overall Unified S-Band System.

2. APPLICABLE DOCUMENTS

(a) MIL-E-4158C USAF (reference), Electronic Equipment Ground: General Requirements For

(b) MIL-F-14072, Finishes for Ground Signal Equipment

(c) NPC200-3, NASA Quality Publication

(d) GSFC-TDS-PCES-1, Packing and Crating Equipment for Export Shipment

(e) GSFC-TDS-RFS-208, Revision 1, Environmental Conditions

(f) MIL-C-45662A, Calibration Standards

(g) MIL-I-26600, Interference Control Requirements, Aeronautical Equipment

(h) Enclosure I to Exhibit F of GSFC REP Control Number 10001 dated 18 November 1963 (Applicable to Shipboard equipment only.)

3. GENERAL REQUIREMENTS

3.1 OPERATIONAL CRITERIA

The system described by this specification must be capable of demodulating the data transmission modes defined in Table I and described in paragraph 3.2. Selection circuitry will enable an operator to properly connect the demodulation system components for reception of any of the data transmission modes. All of the selection circuit functions are to be controlled from the front panel and not by changing cables or plug-in modules. In addition, remote selection of circuit functions will be provided, where specifically indicated in this specification.

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TABLE I

APOLLO MODULATION PARAMETERS
AND CARRIER DEMODULATOR PERFORMANCE

I	II	III	IV	V	VI	VII
		MODULATION INDICES		P_T/N_0 (db) (h)		S/N (db) IN (g)
MODE	CHANNEL	CARRIER	SUB-CARRIER		BANDWIDTH(KC)	COLUMN VI BANDWIDTH
A	Telemetry	1.25 (a)	1.57 (a)	65.0	150(f)	8.5
	Voice(e)	0.91 (a)	2.50 (b)	65.0	50(c)	9.4
	Carrier	-	-	65.0	0.2(c)	36.3
B-1:1-A	PRN Ranging	1.12 (a)			-	-
	Telemetry	1.25 (a)	1.57 (a)	72.2	150(f)	8.5
	Voice (e)	0.91 (a)	2.50 (b)	72.2	50(c)	9.5
	Carrier	-	-	72.2	0.2(c)	36.3
B-1:1-D	PRN Ranging	0.60 (a)			-	-
B-1:1-E	Telemetry	1.25 (a)	1.57 (a)	66.7	150(f)	8.5
	Voice (e)	0.91 (a)	2.50 (b)	66.7	50(c)	9.5
	Carrier	-	-	66.7	0.2(c)	36.3
B-1:1-F	PRN Ranging	0.45 (a)			-	-
	Telemetry	1.25 (a)	1.57 (a)	65.9	150(f)	8.5
	Voice (e)	0.91 (a)	2.50 (b)	65.9	50(c)	9.5
	Carrier	-	-	65.9	0.2(c)	36.3
B-2:1-A	PRN Ranging	1.12 (a)			-	-
	Voice	0.91 (a)	2.50 (b)	63.8	50(c)	4.7
	Carrier	-	-	63.8	0.2(c)	31.7
B-2:1-D	PRN Ranging	0.60 (a)			-	-
B-2:1-E	Voice (e)	0.91 (a)	2.50 (b)	58.1	50(c)	4.7
	Carrier	-	-	58.1	0.2(c)	31.5
B-2:1-F	PRN Ranging	0.45 (a)			-	-
	Voice (e)	0.91 (a)	2.50 (b)	57.3	50(c)	4.7
	Carrier	-	-	57.3	0.2(c)	31.5

TABLE I (con't)

I MODE	II CHANNEL	III MODULATION INDICES CARRIER	IV SUB-CARRIER	V $\frac{P_T}{\Phi_N}$ (db) (h)	VI BANDWIDTH(KC)	VII S/N (db) IN (g) COLUMN VI BANDWIDTH
C	Telemetry	1.25 (a)	1.57 (a)	60.2	6(f)	17.7
	Voice (e)	0.91 (a)	2.50 (b)	60.2	50(c)	4.7
	Carrier	-	-	60.2	0.2(c)	31.5
D-1	Telemetry	0.341 (b)	1.57 (a)	74.8	150(f)	10.7
	Voice (e)	0.320 (b)	2.50 (b)	74.8	50(c)	14.9
	#1	6.900 (b)	2.50 (b)	74.8	3(c)	53.8
	#2	4.550 (b)	2.50 (b)	74.8	4.55(c)	48.4
	#3	3.333 (b)	2.50 (b)	74.8	6.2(c)	44.3
	#4	2.500 (b)	2.50 (b)	74.8	8.3(c)	40.5
	#5	1.908 (b)	2.50 (b)	74.8	10.9(c)	37.0
	#6	1.428 (b)	2.50 (b)	74.8	4.5(c)	33.2
	#7	1.052 (b)	2.50 (b)	74.8	19.7(c)	29.3
	#8	0.800 (b)	2.50 (b)	74.8	25.9(c)	25.7
	#9	0.605 (b)	2.50 (b)	74.8	34.2(c)	22.1
D-2	Telemetry	0.341 (b)	1.57 (a)	-	150(f)	-
	Voice (e)	0.320 (b)	2.50 (b)	-	50(c)	-
E	Television	2.50 (b)	Not Appl.	75.7	400(d)	-
	Telemetry	0.341 (b)	1.57 (a)	75.7	150(f)	11.6
	Voice (e)	0.320 (b)	2.50 (b)	75.7	50(c)	16.0
F	Voice	1.25 (a)	Not Appl.	42.1	2.3(d)	5.0
	Carrier	-	-	42.1	0.2(c)	9.0
G	Key	1.25 (a)	100% (AM)	34.2	1.0(f)	1.3
	Carrier	-	-	34.2	0.2(c)	8.0

NOTES:

(a) Peak phase deviation (carrier phase modulated)
(b) Modulation index (carrier frequency modulated)
(c) Two-sided Loop noise Bandwidth
(d) Baseband one-sided noise bandwidth
(e) S... B... -M... S... subcarriers will be linearly summed ... and transmitted ... this subcarrier
Modulation indexes are shown in Table II
(f) Two-sided reference noise bandwidth at input of carrier demodulator
(g) This column gives the required S/N ... indicated bandwidth at the specified ... of P_T/Φ_N
(h) Total input signal power-to-noise spectral density at input to carrier demodulator

C

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON

FRACTIONS	DECIMALS	ANGLES
± NA	± NA	± NA

CODE IDENT NO 13499 | SIZE A | DRAWING NUMBER 126-0429

SCALE NONE | WT NA | SHEET 5

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This demodulation system must be compatible with existing receivers and must be capable of demodulating rf spectrums centered at 50 MC and 10 MC. The 50 MC data take off point is not controlled by AGC, and a 50 MC amplifier with appropriate AGC action is required as part of the demodulation system. The use of AGC circuitry in the carrier phase demodulator channel may also be required as defined in paragraph 5.4.8.

The receiver carrier frequency may be either phase modulated or frequency modulated. Therefore, this system will consist of two subsystems which contain the filters, subcarrier demodulators and distribution amplifiers required to transform the received data into suitable form for recording, futher processing, and audio or visual monitoring. In addition, narrow band phase demodulation is required for carrier demodulation of the emergency voice channel.

A conceptual block diagram is shown in Figure 1.

The isolation amplifier (paragraph 10) and subcarrier demodulators (paragraph 11) are required to be physically separable from the demodulator. These units must, therefore, have power supplies separate from those of the rest of the system.

The signal data demodulator system shall operate with Apollo Range and Range Rate (R & RR) receiver as shown in Figure 2 and as specified in paragraph 3.2.1. The demodulator performance when operating with the R & RR receiver shall be as specified herein. In addition, the demodulator system shall operate, with negligible reduction of performance, with an interim tracking receiver as specified in paragraph 3.2.2. In cases where conflicts of design occur between these two receivers, the R & RR receiver interface parameters shall take precedence.

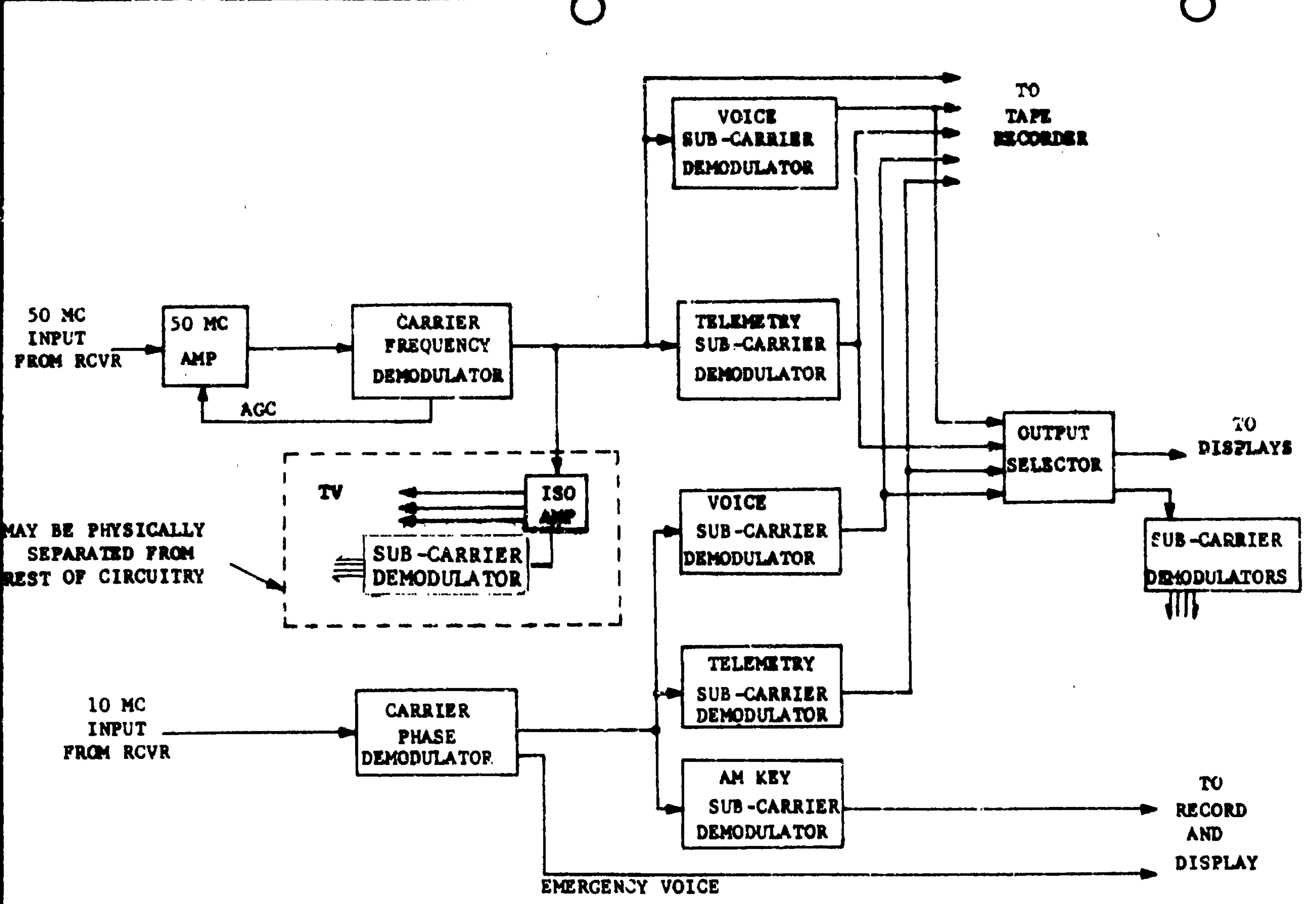

FIGURE 1: FUNCTIONAL BLOCK DIAGRAM FOR SIGNAL DATA DEMODULATOR SYSTEM (SPARE OUTPUTS NOT SHOWN)

REV C

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS ± NA DECIMALS ± NA ANGLES ± NA	CODE IDENT NO 13499	SIZE A	DRAWING NUMBER 126-0429
	SCALE NONE	WT NA	SHEET 7

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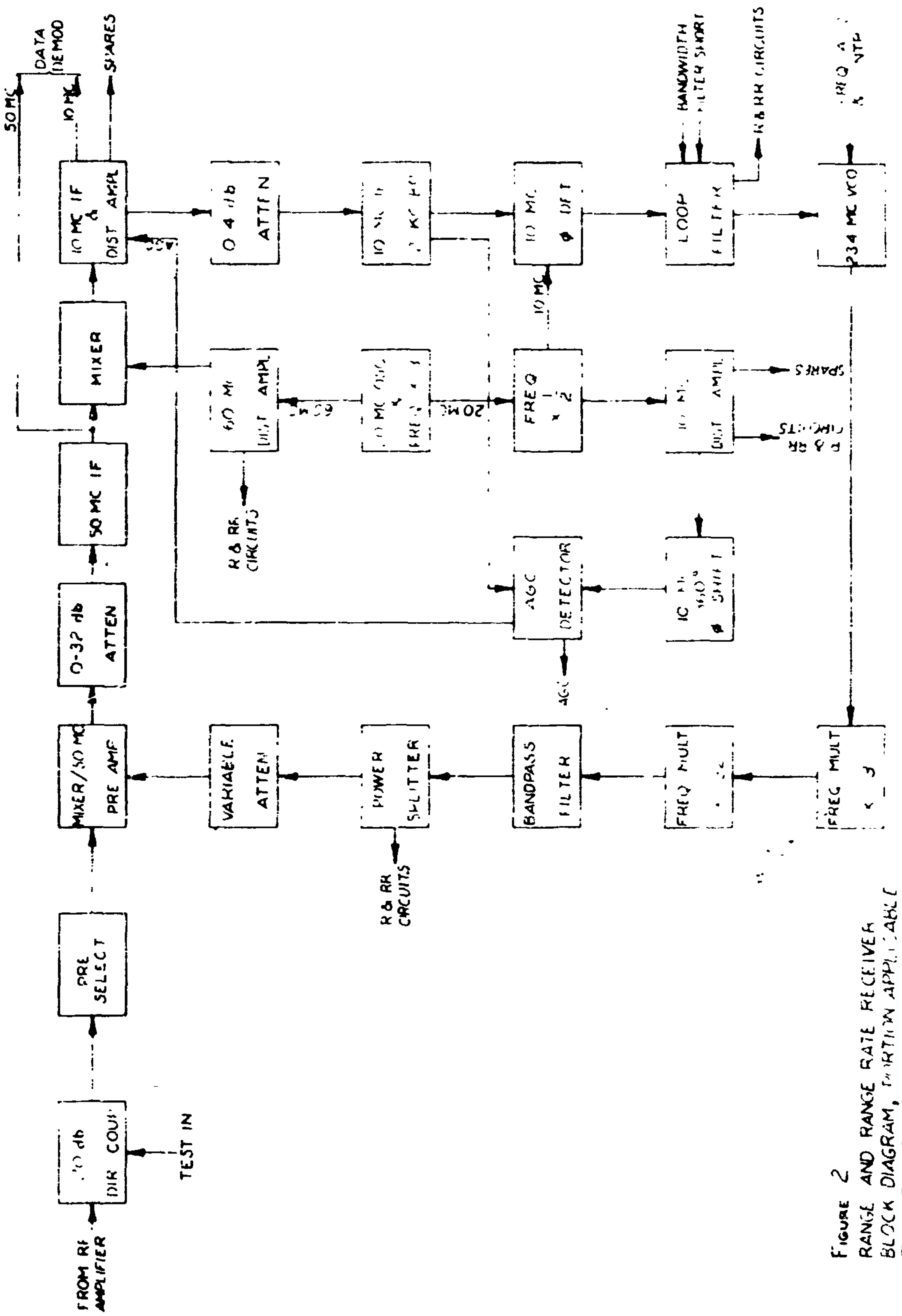

Figure 2
RANGE AND RANGE RATE RECEIVER
BLOCK DIAGRAM, PORTION APPLICABLE
TO DATA DEMODULATOR SIGNAL

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS ± NA DECIMALS ± NA ANGLES ± NA	CODE IDENT NO. 13499	SIZE A	DRAWING NUMBER 126-0429
	SCALE NONE	WT NA	SHEET 8

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3.2 RECEIVER-DEMODULATOR INTERFACE

3.2.1 RANGE AND RANGE RATE RECEIVER OUTPUT CHARACTERISTICS

3.2.1.1 50 MC OUTPUT SIGNAL LEVEL

Maximum: +15 dbm. Minimum: Below thermal noise.

The noise power density at the input to the demodulator system will be -109 dbm per cycle per second.

3.2.1.2 10 MC OUTPUT

The level of the carrier component of the signal, to be accepted by the demodulator without manual adjustment, will be within the range of -65 to -75 dbm. This component will be controlled within ±1 db for any given R & RR receiver. Level of other signal components will be determined by the modulation.

3.2.1.3 OUTPUT IMPEDANCE

50 ohms, VSWR 1.5:1 maximum.

3.2.1.4 DATA DEMODULATOR TAKEOFF POINTS

The 50 MC signal is derived in the receiver prior to any AGC action. The point is within a phase-lock loop but the loop will not necessarily be locked during fm operation. Maximum frequency uncertainty of the carrier due to all causes will be ±150 kc. The carrier frequency demodulator will operate with the maximum Doppler rates of the Apollo Spacecraft and the maximum search rates of the R & RR receiver and the spacecraft receiver.

The 10 MC signal is derived from the R & RR receiver at a point within both the carrier tracking and AGC loops. Frequency uncertainty of the carrier will be ±4 cps.

3.2.1.5 OUTPUT (IF) BANDWIDTHS AT -3 DB POINTS:

50 MC output...10 mc minimum

10 MC output...3.3 mc minimum

3.2.2 INTERIM TRACKING RECEIVER CHARACTERISTICS:

3.2.2.1 50 MC OUTPUT LEVELS:

When the tracking receiver is locked, the carrier component of the signal will be controlled to a fixed level of -10 dbm +3 db by the receiver, and the level of the signal components other than the carrier will vary with the modulation. When the tracking receiver is unlocked, the -10 dbm ±3 db level applies to the total signal power.

3.2.2.2 10 MC OUTPUT LEVELS:

Fixed level of 0 dbm ± 3 db with conditions identical to those of the 50 MC output.

3.2.2.3 OUTPUT IMPEDANCE:

50 ohms, VSWR 1.5:1 maximum

3.2.2.4 OUTPUT BANDWIDTHS AT -3 DB POINTS:

50 MC output...10 mc minimum

10 MC output...5 mc minimum

3.3 SIGNAL PARAMETERS (TABLE I)

3.3.1 APOLLO MODULATION PARAMETERS

I & II Modes and Channels

There are a total of sixteen possible received modes. Four of these modes have PRN ranging onl. for modulation and are therefore not listed in this specification. In all modes except E,F, & G, telemetry, where indicated, has been phase-modulated onto a 1.024-mc subcarrier and voice , where indicated, after linearly combining with biomedical fm subcarriers, has been frequency modulated onto a 1.25 mc subcarrier. When television, PRN ranging

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operational (analog) subcarriers and the above voice and telemetry signals are shown in combination for a given mode, they have been linearly summed and phase- or frequency-modulated onto the RF carrier, which enters the demodulator system at IF frequencies of 10 or 50 mc.

Modes D and E are FM. All others are PM.

Modes A and C are for voice and telemetry without ranging. Mode A is for the high bit rate telemetry (51.2 kb/sec) while Mode C is for the low bit rate telemetry (1.6 kb/sec).

All modes prefixed with a B include ranging. All modes noted B-1 include ranging, voice, and telemetry, and all modes noted B-2 include ranging and voice. The second designation for each of the B modes identifies the up-link mode that is being transmitted at the same time as the indicated down-link mode. For example, in mode B-1:1-A, mode B-1 is being transmitted to earth while an up-link mode (earth to spacecraft) denoted by A, is being transmitted. This A has nothing to do with the down-link Mode A.

The double notation is used to indicate how much the up-link carrier is phase deviated by the ranging signal. The spacecraft transponder performs a one-to-one turn around function on the ranging signal and up-link voice and telemetry. That is, part of the modulation of the down-link carrier will be determined by the up-link mode. Modes B-1:1-D and B-1:1-E are identical for the down-link. That is, in up-link modes D and E, the carrier is phase deviated the same amount by the ranging signal. The same is true of modes B-2:1-D and B-2:1-E.

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In Mode F, the voice signal is phase modulated directly on the carrier (no subcarrier). This mode is the emergency voice mode.

In Mode G, a 10 MC carrier is phase modulated by a 512 KC subcarrier. The subcarrier is turned off and on (100% AM), for transmission of Morse Code signals. This is called the "AM Key" mode.

Listed in Table II are the specifications for the seven bio-medical subchannels. These are fm/fm subcarriers which are linearly summed with voice and frequency modulated on the 1.25-MC subcarrier. They may or may not be transmitted in any of the listed Modes A through E. Additional information for these subcarriers is given in Table III, Section 12.

III. Carrier Modulation--

The third column indicates the modulation index of the carrier by the signal in Column II. It is given as peak phase deviation in the case of the PM modes and as the modulation index (ratio of peak frequency deviation to maximum modulation frequency, $\Delta f/f_m$) for the fm modes.

IV. Subcarrier Modulation--

The fourth column indicates the peak phase deviation of the subcarrier for telemetry and the fm modulation index of the voice subcarrier and of the nine (9) stored data subcarriers.

3.3.2 CARRIER DEMODULATION PERFORMANCE

V. Total Signal Power to-Noise Spectral Density--

This column lists a test value for total signal power-to-noise spectral density (Noise Spectral density in watts/cps) preceding the carrier demodulators for each mode. It is the minimum value of P_T/Φ_N required (for satisfactory performance in each

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS ± NA DECIMALS ± NA ANGLES ± NA	CODE IDENT NO 13499	SIZE A	DRAWING NUMBER 126-0429
	SCALE NONE	WT NA	SHEET 12

TABLE II

MODULATION PARAMETERS FOR BIO-MEDICAL SUB-CARRIERS

CHANNEL	FREQUENCY (KC)	1.25 MC SUB-CARRIER FM MOD. INDEX	BIO-MED SUB-CARRIER MOD. INDEX	LOOP NOISE BANDWIDTH (cps)*,	REQ'D (S/N)db IN COLUMN E BANDWIDTH
1	4	0.081	100	2[illegible]0	4.3
2	5.4	0.088	13[illegible]	280	4.5
3	6.8	0.093	170	29[illegible]	4.8
4	8.2	0.0964	205	370	4.1
5	9.[illegible]	0.0955	192	370	4.1
6	11.0	0.094	175	290	4.9
7	12.4	0.149	8.3	980	4.7

* Recommended values by CRC

** [illegible] values a[illegible] [illegible] phase lock loop discriminators are [illegible].

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON
FRACTIONS ± NA DECIMALS ± NA ANGLES ± NA

CODE IDENT NO	SIZE	DRAWING NUMBER
13499	A	126-0429
SCALE NONE	WT NA	SHEET 13

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mode where satisfactory performance is defined as having the carrier loops in lock and at least the specified required output signal to noise ratios present in the indicated loop noise bandwidths at the output of the carrier demodulators.

VI. Bandwidths--

Bandwidths in which S/N is to be measured at output of carrier demodulators.

VII. Signal to Noise Ratio

This column gives the signal to noise ratio (in the output noise bandwidth of column VI) for the specified modulation mode and the input (P_T/Φ_N) of column V.

3.4 **BANDWIDTH DEFINITIONS**

3.4.1 **LOOP NOISE BANDWIDTH**

Loop noise bandwidth is defined as the two-sided noise servo bandwidth which is equivalent to the rf noise bandwidth.

3.4.2 **LOOP BANDWIDTH**

Loop bandwidth is defined as the one-sided noise servo bandwidth which is equivalent to one-half the rf noise bandwidth.

3.5 **INDEX OF TABULATED SPECIFICATION**

Section 4	Carrier Frequency Demodulator
Section 5	Carrier Phase Demodulator
Section 6	Telemetry Subcarrier Demodulator
Section 7	Voice Subcarrier Demodulator
Section 8	AM Key Subcarrier Demodulator
Section 9	Data Output Selector
Section 10	Isolation Amplifier

Section 11 Sub-Carrier Demodulators

Section 12 Test Unit

Section 13 Operation and Mechanical

4.0 TABULATED SPECIFICATIONS FOR CARRIER FREQUENCY DEMODULATOR

4.1 FUNCTION

The carrier frequency demodulator shall accept and demodulate the 50 MC signals from the R & RR and tracking (interim) receivers. It shall consist of a 50 MC amplifier, a 50 MC frequency demodulator, and six output amplifiers.

4.2 50-MC AMPLIFIER

4.2.1 INPUT CHARACTERISTICS

Compatible with R & RR receiver output, as specified in paragraph 3.2:

4.2.1.1 CENTER FREQUENCY

50 MC $\pm$0.15 MC

4.2.1.2 IF BANDWIDTH

10 MC minimum at -3 db points.
40 MC Maximum at the -60 db point.

4.2.1.3 IMPEDANCE

50 ohms, VSWR 1.5:1 maximum

4.2.1.4 LEVEL

Shall provide AGC operation as given in paragraph 4.2.2.3 over input range as given in paragraph 3.2.

4.2.2 GAIN CONTROL

The FM Demodulator, in conjunction with the 50 MC amplifier, shall provide coherent or non-coherent AGC operation or manual gain control.

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4.2.2.1 GAIN MODE SELECTION

A switch will be provided to allow the operator to select AGC or manual gain control. When in the AGC position and the FM demodulator loop is locked, coherent AGC will be provided. When in the AGC position and the FM demodulator loop is unlocked, the non-coherent AGC will be provided. The transfer between the types of AGC will be automatic, with manual override.

4.2.2.2 AGC SPEEDS

Three seconds, 300 MS, 30 MS, or 3 MS, selectable by a front panel switch. The response is defined as the time interval (±10%) for the AGC bus voltage to reach 90% of the steady state value for a step change of 10 db in input signal that does not overload the equipment. The AGC detector will have equal charge and discharge times.

4.2.2.3 AGC CONTROL

Less than 3 db output variation for a CW input signal over the specified input range.

4.2.2.4 GAIN MARGIN

20 db gain in excess of that required to satisfy AGC and output requirements.

4.2.3 50 MC AMPLIFIER OUTPUT CHARACTERISTICS

4.2.3.1 NUMBER OF OUTPUTS

Two (identical). One for 50 MC demodulator, one spare.

4.2.3.2 LEVEL

Compatible with input level required for carrier FM demodulator.

4.2.3.3 IMPEDANCE

50 ohms, VSWR 1.5:1 maximum

4.2.3.4 ISOLATION BETWEEN OUTPUTS

40 db minimum

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4.3 CARRIER FM DEMODULATOR

4.3.1 TYPE OF DEMODULATOR

Modulation tracking phase-lock loop

4.3.2 LOOP NOISE BANDWIDTH AT THRESHOLD

4MC or 11MC ±10%, selectable from control panel without unlocking the loop.

4.3.3 LOCK INDICATOR

Front panel and remote indication of signal-lock or loss-of-lock operation will be provided.

4.3.4 LOOP DISABLE

It shall be possible, by means of a momentary front panel switch, to open the phase lock loop. In the open loop condition, the signal channel and manual tuning functions shall remain operational and the VCO frequency shall be 50 MC ±150 kc.

4.4 FM DEMODULATOR OUTPUT CHARACTERISTICS

4.4.1 NUMBER OF OUTPUTS

Six wide-band and one loop lock indication.

4.4.2 WIDEBAND OUTPUTS (IDENTICAL CHARACTERISTICS):

Telemetry Subcarrier Demodulator

Voice Subcarrier Demodulator

Isolation Amplifier

Recorder

Two Spares

4.4.2.1 IMPEDANCE

95 ohms, VSWR 2:1 maximum.

4.4.2.2 LEVEL

1 volt ± 5% rms, for a 0-dbm 50-MC input signal level and Mode D-2 modulation into the 50-MC amplifier.

4.4.2.3 FREQUENCY RESPONSE OF CARRIER DEMODULATOR AND WIDEBAND AMPLIFIERS

Flat within ± 2 db between 10 cps and 3 MC. (for 11 MC bandwidth).

4.4.2.4 ISOLATION BETWEEN OUTPUTS

40 db minimum.

4.4.2.5 DISTORTION

4.4.2.5.1 INTERMODULATION DISTORTION:

(a) With full Mode E modulation, the peak-to-peak amplitude, on the base-band, of the difference frequency (226 KC) of the telemetry and voice subcarriers shall be at least 60 db below the peak-to-peak TV picture signal.

(b) With an unmodulated telemetry subcarrier and a voice subcarrier modulated by a sine wave at the TV line frequency (3200 cps) and an index of 2.50, the peak to peak interference on the baseband at the line frequency shall be at least 40 db below the peak-to-peak TV picture signal with a design goal of at least 45 db.

(c) With unmodulated voice subcarrier and a telemetry subcarrier modulated by a sine-wave at the TV line frequency (3200 cps) and an index of 2.50, the peak-to-peak interference on the baseband at the line frequency shall be at least 40 db below the peak-to-peak TV picture signal with a design goal of at least 45 db.

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4.4.2.5.2 HARMONIC DISTORTION

Total harmonic distortion with one unmodulated subcarrier... less than 2%.

4.4.3 LOOP LOCK INDICATION

6.3 + 0, -10% volts for load of .5 amp when loop is in locked condition.

5.0 TABULATED SPECIFICATION FOR CARRIER PHASE DEMODULATOR

5.1 FUNCTION

The carrier phase demodulator shall accept and demodulate the 10 MC signals from the R & RR and tracking receivers. It shall have two modes of operation: Wideband and Emergency Voice.

5.2 INPUT CHARACTERISTICS

5.2.1 FREQUENCY

10 MC ± 4 cps.

5.2.2 IMPEDANCE

50 ohms, VSWR 2:1 maximum.

5.2.3 LEVEL

See receiver output information, paragraph 3.2.1 and loop sensitivity, paragraph 5.4.7.

5.3 SIGNAL CHANNEL CHARACTERISTICS

5.3.1 IF BANDWIDTH

3 MC minimum at the -3 db points.

14 MC maximum at the -60 db points.

5.4 CARRIER TRACKING LOOP CHARACTERISTICS

5.4.1 LOOP BANDWIDTH AT THRESHOLD

30 cps or 100 cps, ± 10% selectable from control panel without unlocking the loop.

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5.4.2 AUTOMATIC SIGNAL ACQUISITION

5.4.2.1 ACQUISITION TIME

Under the initial condition of a white guassian noise input signal at the levels specified in paragraph 5.4.7, the loop shall automatically acquire lock within 100 milliseconds after application of a jitter-free, steady-state, phase-coherent signal at a level of -70 dbm and at a frequency of 10 MC ± 4 cps.

5.4.2.2 ACQUISITION RANGE

± 4 cps, plus any loop VCO drift, centered at 10 MC.

5.4.3 MANUAL TUNING AND AUTOMATIC TRACKING RANGE

± 10 cps total.

5.4.4 OSCILLATOR STABILITY

[illegible] [illegible]

With noise free, steady-state, phase coherent, -70 dbm input signal and with a 3 db syutem noise figure (Reference), the demodulated output residual signal due to hum, noise and oscillator phase instabilities shall be -35 db with respect to the maximum (loop disabled) output for each tracking bandwidth and both wideband and emergency voice modes.

5.4.4.2 DRIFT (LONG-TERM)

Shall be limited to a value such that the loop will meet the acquisition characteristics specified in paragraph 5.4.2.1 without retuning, for a period of 400 hours continuous operation.

5.4.5 DEMODULATOR RESPONSE

Demodulator response to all internally-generated signals shall be at least 60 db below the specified outputs. In addition, the loop shall not lock to or give indication of the presence of such signals.

5.4.6 STATIC PHASE ERROR FOR INPUT CARRIER OFFSET OF 4 CPS

5° maximum.

5.4.7 OUTPUT PHASE NOISE

Under the condition of a jitter-free, steady-state, phase-coherent input signal at a level of -70 dbm, plus white gaussian noise with the power densities shown below, the output phase noise deviation shall not exceed 0.35 radians rms.

Loop Bandwidth	Noise Density
30 cps	-96 dbm/cps
100 cps	-101 dbm/cps

5.4.8 AGC CHARACTERISTICS

AGC, if required, will have the following characteristics:

5.4.8.1 GAIN MODES

Two (manual and AGC) selectable by front panel switch.

5.4.8.2 GAIN MODE SELECTION

Coherent AGC voltage will maintain control when the phase lock loop is in the "locked" condition. Manual override of mode selection and manual control of level will be provided.

5.4.8.3 AGC SPEEDS

3 seconds, 300 ms, 30 ms, or 3 ms, selectable by a front panel switch. The response is defined as the time interval (±10%) for the AGC bus voltage to reach 90% of the steady-state value for a step change of 10 db in input signal that does not overload the equipment. The AGC detector will have equal charge and discharge times.

5.4.8.4 AGC CONTROL

Less than 1 db output variation over specified input range of -70 dbm ± 5 db or (with attenuators; if necessary) 0 dbm ± 3 db.

5.4.8.5 GAIN MARGIN

20 db in excess of that required to satisfy AGC and loop input requirements.

5.4.9 FRONT PANEL

Front panel and remote indication of signal-lock or loss-of-lock operation will be provided.

5.4.10 LOOP DISABLE

It shall be possible, by means of a momentary front panel switch, to open the phase lock loop. In the open loop condition, the signal channel and manual tuning functions shall remain operational and the VCO frequency shall be such that the loop, after enabling, will meet paragraph 5.4.2.1.

5.5 FM DEMODULATOR OUTPUT CHARACTERISTICS

5.5.1 NUMBER OF OUTPUTS

Five wide-band, two emergency voice distribution, two emergency voice recorder, one speaker and one loop lock indication.

5.5.2 WIDE-BAND OUTPUTS (IDENTICAL CHARACTERISTICS)

Telemetry Subcarrier Demodulator

Voice Subcarrier Demodulator

AM Key Demodulator

Two Spares

5.5.2.1 IMPEDANCE

95 ohms, VSWR 2:1 maximum.

5.5.2.2 LEVEL

Each output shall be individually screwdriver adjustable, from 0 to 2 volts rms for ± 1 radian of phase deviation with a single subcarrier.

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5.5.2.3 FREQUENCY RESPONSE

Flat ± 2 db from 1 KC to 1.5 MC, with input as specified in paragraph 5.2 and 5.3.

5.5.2.4 PHASE RESPONSE

Linear ± 10° from 1 KC to 1.5 MC.

5.5.2.5 ISOLATION BETWEEN OUTPUTS

40 db minimum.

5.5.2.6 DISTORTION

Total harmonic distortion with one unmodulated tone at frequency of 100 kcps and peak phase deviation of 1.0 radian ... 2 % maximum.

5.5.3 EMERGENCY VOICE DISTRIBUTION OUTPUTS (TWO)

5.5.3.1 LEVEL

5 volts +10% rms for 1 KC modulation at ± 1.25 radians

5.5.3.2 IMPEDANCE

600 ±10% ohms, balanced to ground.

5.5.3.3 FREQUENCY RESPONSE

200 & 2500 cps at -3 db ± 1 db points relative to the level at 1 KC.

5.5.3.4 PHASE RESPONSE

Linear ±10% for a deviation of ± 1.25 radians.

5.5.3.5 TOTAL HARMONIC DISTORTION, MODE F

5% maximum.

5.5.4 EMERGENCY VOICE RECORDER OUTPUTS (TWO)

5.5.4.1 LEVEL

1 volt rms ± 10% under modulation conditions of 5.5.3.1.

5.5.4.2 IMPEDANCE

95 ohms, VSWR 2:1 maximum

5.5.4.3 TOTAL HARMONIC DISTORTION

5% maximum under modulation conditions of 5.5.3.1.

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5.5.4.4 **PHASE RESPONSE**

Linear ± 10% for a deviation of ± 1.25 radians.

5.5.5 EMERGENCY VOICE PANEL SPEAKER AND VOLUME CONTROL

5.5.5.1 DRIVING POWER

3 watts minimum, under modulation conditions of 5.5.3.1.

5.5.5.2 VOLUME CONTROL RANGE

0 to 3 watts for 1 KC modulation at ± 0.625 radians.

5.5.6 **LOOP LOCK INDICATION**

6.3 + 0, -10% volts for load of .5 amp, when loop is in locked condition.

6.0 TABULATED SPECIFICATIONS FOR TELEMETRY SUBCARRIER DEMODULATOR (2 REQUIRED)

6.1 GENERAL PERFORMANCE SPECIFICATIONS

6.1.1 FUNCTION

Demodulates bi-phase modulated subcarrier and provides an unconditioned serial output.

6.1.2 SIGNAL CHANNEL IF BANDWIDTHS

Three bandwidths, selectable by front-panel switch:

1 db BW (Minimum)	3 db BW (±10%)	Noise BW (±10%)
6 KC	6.45 KC	7.25 KC
150 KC	161 KC	180 KC
600 KC	645 KC	725 KC

Passband ripple shall be less than 0.11 db.

6.1.3 SPURIOUS RESPONSE

Demodulator response to all internally-generated signals shall be at least 60 db below the specified outputs.

6.1.4 PHASE DEMODULATOR LINEARITY

± 10% for a deviation of ± 1 radian.

6.1.5 PHASE JITTER OF THE DERIVED REFERENCE SIGNAL AT AN INPUT S/N OF 8.5 db

5° rms maximum at any IF bandwidth and all PCM bit rates specified in paragraphs 6.3.3 and 6.3.4.

6.2 INPUT CHARACTERISTICS

6.2.1 SUBCARRIER FREQUENCY

1.024 MC ±50 cps

6.2.2 LEVEL

Will operate as specified, without manual adjustment, for a telemetry subcarrier component of the carrier demodulator output (composite signal) varying between 0.1 and 1.0 volt rms.

6.2.3 IMPEDANCE

95 ohms, VSWR 2:1 maximum.

6.3 PCM SIGNAL CHARACTERISTICS

6.3.1 MODULATION

PSK ± 90° ± 2°(resolution of "one" a 'zero" ambiguity not required).

6.3.2 CODING

NRZ, RZ and Split-phase (within bandwidth constraints).

6.3.3 BIT RATE

100/sec to 200,000/sec.

6.3.4 MAXIMUM NUMBER OF SEQUENTIAL ALL-ONES OR ALL-ZEROS

Ten.

6.4 OUTPUT SPECIFICATIONS

6.4.1 NUMBER OF OUTPUTS ... 2 (Identical)

6.4.2 OUTPUT LEVEL

5 volts peak-to-peak minimum for any mode.

6.4.3 OUTPUT IMPEDANCE

95 ohms, VSWR 1.5:1 maximum.

6.4.4 FREQUENCY RESPONSE (INCLUDING VIDEO AMPLIFIER)

DC to 300 KC, 75 KC or 3 KC at -3 ± 1 db points, depending on position of the bandwidth switch.

6.4.5 PHASE RESPONSE OF VIDEO AMPLIFIER

Shall be linear ± 10° from DC to 80% of the -3 db bandwidths specified in para. 6.4.4.

6.4.6 ISOLATION BETWEEN OUTPUTS . . . 40 db minimum.

6.4.7 PHASE LOCK LOOP

If a phase lock loop is used in the Telemetry Subcarrier Demodulator, automatic loop acquisition and front panel and remote loop-lock indications shall be provided. Four loop bandwidths, approximately one decade apart, shall be provided and selectable from the front panel.

7.0 TABULATED SPECIFICATIONS FOR VOICE SUBCARRIER DEMODULATOR (TWO REQUIRED)

7.1 GENERAL PERFORMANCE SPECIFICATIONS

7.1.1 TYPE OF DEMODULATOR

Modulation tracking phase lock loop.

7.1.2 SIGNAL CHANNEL IF BANDWIDTH

75 KC at the -3 ± 1 db points.

7.1.3 LOOP NOISE BANDWIDTH

50 KC.

7.1.4 FRONT PANEL

Front panel and remote indication of signal-lock or loss-of-lock operation will be provided.

7.1.5 MODULATION SIGNAL INPUT

With a full Mode E modulation signal input to the carrier FM demodulator, . voice subcarrier modulated with a 3.66 KC signal only (index: 2.5) and an input P_T/Φ_N of 75.7 db, the S/N at the voice subcarrier wideband output, in a onesided noise bandwidth of 10 KC, shall be 7.0 db or better.

7.2 INPUT SPECIFICATIONS

7.2.1 SUBCARRIER FREQUENCY

1.250 MC ± 65 cps.

7.2.2 LEVEL

Will operate as specified, without manual adjustments, for a voice subcarrier component of the carrier demodulator output (composite signal) varying between 0.1 and 1.0 volt rms.

7.3 OUTPUT SPECIFICATIONS

7.3.1 NUMBER OF OUTPUTS

Three wideband (identical characteriscics, for tape recorder, output selector and spare), one loop lock indication, two audio and one loudspeaker.

7.3.2 LEVELS

7.3.2.1 WIDEBAND OUTPUT

Each output shall be individually adjustable, 0-2 volts rms minimum for all modes containing voice subcarrier.

7.3.2.2 LOOP LOCK INDICATION SIGNAL

6.3 volts +0, -10% for load of .5 amp when loop is in locked condition.

7.3.2.3 AUDIO OUTPUT

5 volts rms minimum, for modulation index of 2.5 with a 1 KC tone.

7.3.2.4 LOUDSPEAKER DRIVER AMPLIFIER

Volume control, 0 to 3 watts rms minimum for a modulation index of 1.25 with a 1 KC tone. Less than 5% total harmonic distortion.

7.3.3 BANDWIDTH

7.3.3.1 WIDEBAND OUTPUT

50 cps to 20 KC at -1 db points.

7.3.3.2 LOUDSPEAKER DRIVER AMPLIFIER

150 cps to 3.4 KC at -3 db points, -20 db at 4 KC.

7.3.3.3 AUDIO OUTPUT

50 cps to 3.4 KC at -3 db points, -20 db at 4 KC.

7.3.4 IMPEDANCES

7.3.4.1 WIDEBAND OUTPUT

95 ohms VSWR 1.5:1 maximum.

7.3.4.2 AUDIO OUTPUT

600 ohms ± 10% balanced to ground.

7.3.5 ISOLATION BETWEEN OUTPUTS

40 db minimum.

8.0 TABULATED SPECIFICATIONS FOR AM KEY SUBCARRIER DEMODULATOR

8.1 GENERAL PERFORMANCE SPECIFICATIONS

8.1.1 TYPE OF DEMODULATOR

Oscillator/mixer, to transpose 512-KC keyed signal to 1 KC, followed by a bandpass filter and diode detector. Shall provide audio tone and keyed DC outputs. A conceptual block diagram is given in Figure 3.

8.1.2 BANDPASS FILTER BANDWIDTHS

8.1.2.1 512 KC PREDETECTION FILTER

1 KC minimum at -3 db points, 1.5 KC maximum.

8.1.2.2 1 KC POST-DETECTION FILTER

100 cps at -3 db points minimum, 150 cps maximum.

8.1.3 OSCILLATOR STABILITY

Better than 1 part in 10^5 per day.

8.2 INPUT SPECIFICATIONS

8.2.1 INPUT FREQUENCY

512 KC ± 25 cps.

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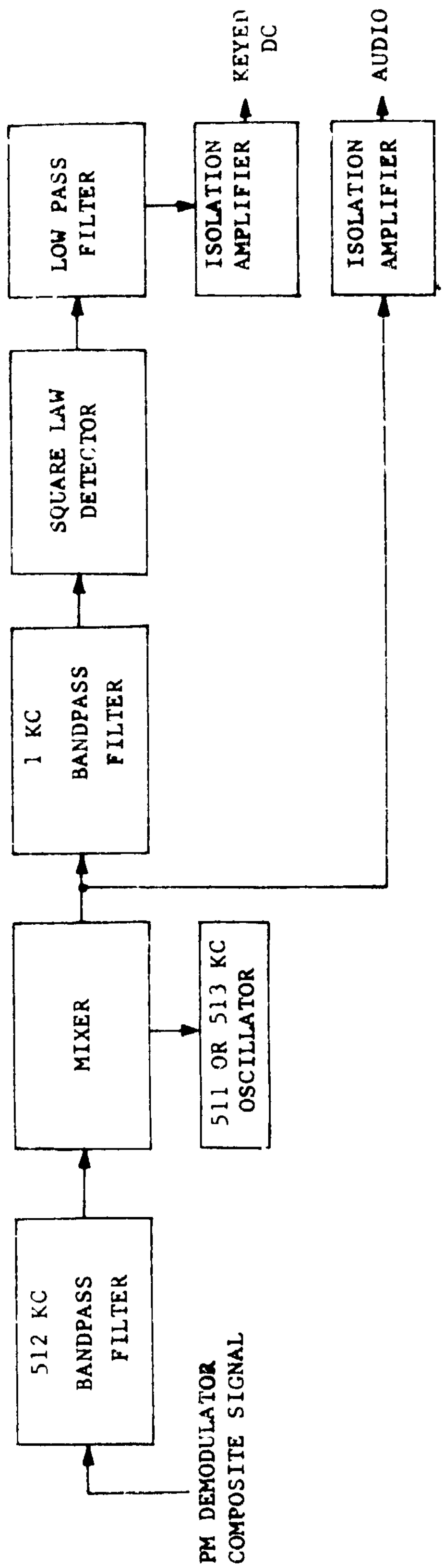

FIGURE 3. CONCEPTUAL BLOCK DIAGRAM AM KEY DEMODULATOR

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS ± NA DECIMALS ± NA ANGLES ± NA	CODE IDENT NO 13499	SIZE A	DRAWING NUMBER 126-0429
	SCALE NONE	WT NA	SHEET 29

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8.2.2 INPUT MODULATION

100% AM.

8.2.3 INPUT LEVEL

1 volt rms ± 3 db.

8.2.4 INPUT IMPEDANCE

95 ohm, VSWR 2:1 maximum.

8.3 OUTPUT SPECIFICATIONS

8.3.1 NUMBER OF OUTPUTS

Two d.c. (keyed) and two audio.

8.3.2 LEVELS

8.3.2.1 DC (KEYED)

0 ± .5 volt for absence of subcarrier; 0 to -7 volts, ± 10% screwdriver adjustable, for 1 V rms input at 512 KC.

8.3.2.2 AUDIO 1 volt rms ± 10% for 1 V rms input at 512 KC.

8.3.3 IMPEDANCE

8.3.3.1 DC (KEYED)

-100 ma minimum at -6 volts.

8.3.3.2 AUDIO

600 ohms ± 10% balanced to ground.

8.3.4 ISOLATION BETWEEN OUTPUTS

40 db minimum.

9.0 TABULATED SPECIFICATIONS FOR DATA OUTPUT SELECTOR

9.1 GENERAL PERFORMANCE SPECIFICATIONS

9.1.1 SELECTOR FUNCTION

The data outputs from the subcarrier demodulators shall be selectable by a single front panel switch or by remote contact closure. The selected "voice" output shall provide signals to the biomedical demodulators and external loads. The selector shall switch the following output signals:

(a) Telemetry demodulator

(b) Voice subcarrier demodulator (wideband)

(c) Voice subcarrier demodulator (voice)

9.1.2 SELECTOR GAIN

The selector shall hav unity gain ± 1 db from input to output on all channels.

9.1.3 VOICE SELECTOR CIRCUIT BANDWIDTH

At least 50 cps to 3.4 KC at -1 db points.

9.1.4 TELEMETRY SELECTION CIRCUIT

9.1.4.1 BANDWIDTH

DC to 500 KC minimum at -1 db point.

9.1.4.2 90% RISETIME

1.2 μs maximum.

9.2 INPUT AND OUTPUT SPECIFICATIONS

9.2.1 LEVEL

10 volts peak-to-peak maximum.

9.2.2 IMPEDANCE

95 ohms, VSWR 1.5:1 maximum.

9.2.3 OUTPUT NOISE

Output noise, when fed from a source equivalent to the voice demodulator, is at least 50 db below 1 volt rms.

10.0 TABULATED SPECIFICATIONS FOR ISOLATION AMPLIFIER

10.1 GENERAL PERFORMANCE SPECIFICATIONS

10.1.1 GAIN

Unity gain ± 1 db.

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10.1.2 TOTAL HARMONIC DISTORTION ADDED TO THE AMPLIFIED SIGNAL

1% maximum for 2 volts rms output level.

10.1.3 PHASE LINEARITY

±10° maximum variation between 10 cps and 500 KC.

10.1.4 LOCATION

Up to 200 feet from carrier frequency demodulator.

10.2 INPUT SPECIFICATIONS

10.2.1 LEVEL

0.1 to 2.0 volts rms, capable of input of 10 volts peak without damage.

10.2.2 IMPEDANCE

95 ohms, VSWR 2:1 maximum.

10.3 OUTPUT SPECIFICATIONS

10.3.1 NUMBER OF OUTPUTS: FOUR (IDENTICAL CHARACTERISTICS)

Subcarrier Demodulator

Television

Recorder

Spare

10.3.2 IMPEDANCE

95 ohm, VSWR 2:1 maximum.

10.3.3 ISOLATION BETWEEN OUTPUTS

40 db minimum.

11.0 TABULATED SPECIFICATIONS FOR SUBCARRIER DEMODULATOR UNIT

11.1 GENERAL PERFORMANCE SPECIFICATIONS

11.1.1 TYPE OF DEMODULATOR

Sixteen channel frequency demodulator with inputs connected in two groups...one 7 channel and one 9 channels.

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11.1.2 CHANNEL PARAMETERS

See Table II (section 3.2.1) and Table III.

11.1.3 STATIC LINEARITY

0.1% maximum over specified ranges.

11.1.4 DYNAMIC LINEARITY

1% maximum over specified ranges.

11.2 INPUT SPECIFICATION

11.2.1 NUMBER OF INPUTS: Two.

11.2.2 INPUT FREQUENCY GROUPS

3.8 KC to 12.7 KC (Group 1)

13 KC to 183 KC (Group 2)

11.2.3 COMPOSITE INPUT LEVEL

1 to 2 volts, rms each group.

11.2.4 CHANNEL INPUT LEVEL

0.02 to 0.5 volt rms.

11.2.5 GROUP INPUT IMPEDANCE

95 ohms, VSWR 2:1 maximum.

11.2.6 SIGNAL SOURCES AND QUANTITIES

PM/FM selector switch output . . . 7 (biomedical).

Frequency carrier demodulator output through the isolation amplifier...

9 (stored data).

11.3 OUTPUT SPECIFICATIONS

11.3.1 NUMBER OF OUTPUTS

Two from each channel; one for display and one for recorder.

11.3.2 LEVEL

3 v p-p for full deviation with load of 1000 ohms.

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11.3.3 SOURCE IMPEDANCE

Less than 1000 ohms.

11.3.4 ISOLATION BETWEEN OUTPUTS

40 db minimum.

12.0 TEST UNIT

12.1 FUNCTION

The test unit shall provide signals at the carrier and subcarrier frequencies of the demodulator input channels. A conceptual block diagram is given in Figure 4.

12.1.1 INPUT AND OUTPUT CONNECTIONS

Input and Output connections of sub-units will be brought to a Test Unit Patch Panel.

12.1.2 CARRIER SIGNAL CHANNELS

It will be possible to add known amounts of noise to the carrier signal channels.

12.1.3 EXTERNAL INPUTS

PCM, Voice, Video, Keyed AM, Clipped Speach signals and audio test signals shall be accepted by the Test Unit from external sources and used to modulate the subcarriers and/or the carriers.

12.1.4 IMPEDANCES

12.1.4.1 ALL VIDEO AND SUBCARRIER SIGNALS

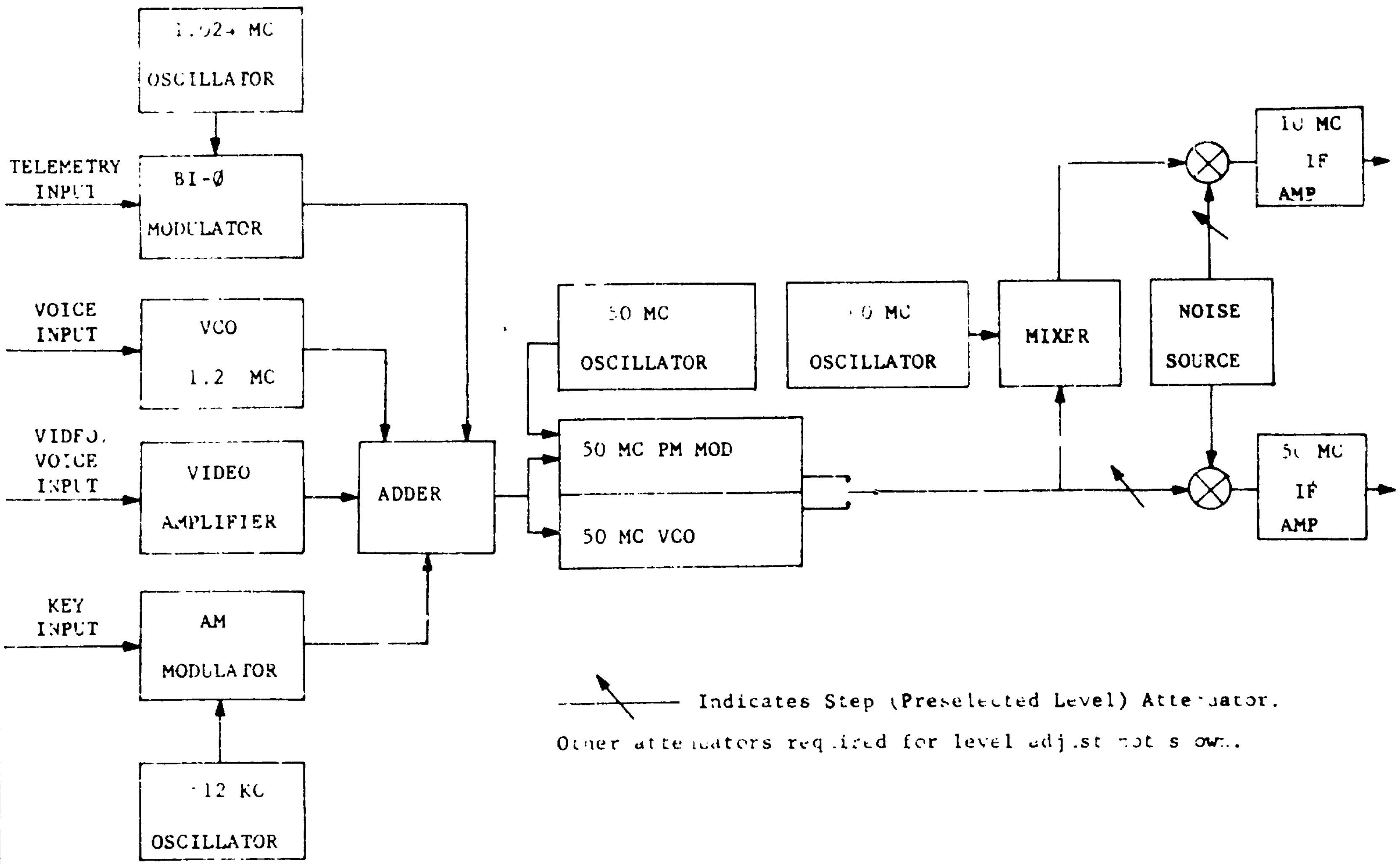
95 ohms, VSWR 2:1 maximum.

12.1.4.2 ALL 50-MC AND 10-MC SIGNALS

50 ohms, VSWR 1.5:1 maximum.

12.1.4.3 ALL OTHER INPUT SIGNALS

Same as the corresponding output of the demodulator system.



Indicates Step (Preselected Level) Attenuator.

Other attenuators required for level adjust not shown.

FIGURE 4. CONCEPTUAL BLOCK DIAGRAM, DEMODULATOR TEST UNIT

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UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS ± NA DECIMALS ± NA ANGLES ± NA	CODE IDENT NO. 13499	SIZE A	DRAWING NUMBER 126-0429
	SCALE NONE	WT NA	SHEET 35

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12.2 IF OUTPUT SIGNALS

12.2.1 GENERAL

Specified phase modulated signals will be simultaneously available at the 50-MC and the 10-MC outputs. Although only the 10-MC phase-modulated signal is required for demodulation, the 50-MC, phase-modulated signal will be present on the output from an R & RR receiver and is required in the test unit for realistic simulation of operating condiitons. In like manner, when a specified 50-MC frequency-modulated signal is present, a corresponding 10-MC, frequency-modulated signal will also be available.

12.2.2 50-MC, FREQUENCY MODULATED SIGNAL

12.2.2.1 MODULATION INDICES

The following peak indices will be provided for 2.5 volts p-p input of the respective signals:

12.2.2.1.1 TELEVISION

2.5 radians ± 5%.

12.2.2.1.2 TELEMETRY SUBCARRIER

0.34 radians ± 5%.

12.2.2.1.3 VOICE SUBCARRIER

0.32 radians ± 5%.

12.2.2.2 TOTAL RMS SIGNAL POWER OUTPUT LEVEL

-78 dbm to +18 dbm, variable by front panel control, in 1-db steps.

12.2.2.3 TOTAL RMS NOISE POWER OUTPUT LEVEL

-39 ± 2 dbm. An rms noise level of -20 dbm, +3, -0 db shall be available at the patch panel, prior to attenuation and mixing with the signal.

12.2.2.4 CARRIER FREQUENCY STABILITY

Better than 1 part in 10^3 per day.

12.2.2.5 CARRIER FREQUENCY TUNING RANGE

Greater than ±100 KC, centered to 50 MC.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS ± NA DECIMALS ± NA ANGLES ± NA	CODE IDENT NO. 13499	SIZE A	DRAWING NUMBER 126-0429	
	SCALE NONE	WT NA		SHEET 36

12.2.3 10-MC, PHASE MODULATED SIGNAL

12.2.3.1 MODULATION INDICES

The following peak indices will be provided for 2.5 volts p-p input of the respective signals.

12.2.3.1.1 TELEMETRY SUBCARRIER

1.25 radians ± 5%.

12.2.3.1.2 VOICE SUBCARRIER

0.91 radians ± 5%.

12.2.3.1.3 AM KEY SUBCARRIER

1.25 radians ± 5%.

12.2.3.1.4 CLIPPED VOICE

1.25 radians ± 5%.

12.2.3.2 TOTAL RMS SIGNAL POWER OUTPUT LEVEL

Continuously variable from -75 dbm to -65 dbm by front panel control.

12.2.3.3 TOTAL RMS NOISE POWER OUTPUT LEVEL

Maximum: -20 dbm, +3, -0 db. Zero to 100 db of attenuation, in 10-db steps, shall be provided by front panel control, at a point prior to addition with the signal. Attenuation accuracy for the 60-db position (noise level approximately -80 dbm) shall be ±3 db or better.

12.2.3.4 CARRIER FREQUENCY STABILITY

Better than 1 part in 10^6 per day.

12.2.3.5 CARRIER FREQUENCY TUNING RANGE

Greater than ± 50 cps, centered at 10 MC.

12.3 SUBCARRIER OUTPUT SIGNALS

12.3.1 1.024-MC TELEMETRY SUBCARRIER

12.3.1.1 MODULATION TYPE

Phase-shift keying

12.3.1.2 MODULATION INDEX

$\pm \frac{\pi}{2}$ radians ± 5% tolerance

12.3.1.3 PCM BIT RATE

100 to 200,000 bits per second

12.3.1.4 OUTPUT LEVEL

As required by test unit carrier modulators, adjustable ± 10 db.

12.3.1.5 FREQUENCY STABILITY

1 part in 10^5 per day.

12.3.1.6 FREQUENCY TUNING RANGE

Greater than ± 50 cps, centered at 1.024 MC.

12.3.2 1.25 MC VOICE SUBCARRIER

12.3.2.1 OSCILLATOR TYPE

VCO (frequency modulation).

12.3.2.2 MODULATION INDICES

12.3.2.2.1 VOICE

2.50 radians ± 5%.

12.3.2.2.2 BIOMEDICAL SIGNALS

See Tables II (Section 3.2.1) and III.

12.3.2.3 OUTPUT LEVEL

As required by test unit carrier demodulators, adjustable ± 10 db.

12.3.2.4 FREQUENCY STABILITY

Better than 1 part in 10^3 per day.

12.3.2.5 FREQUENCY TUNING RANGE

Greater than ± 65 cps, centered at 1.25 MC.

12.3.3 512-KC AM KEY SUBCARRIER

12.3.3.1 OUTPUT SIGNAL CHARACTERISTICS

Carrier key (100% AM modulation).

12.3.3.2 INPUT SIGNAL CHARACTERISTIC

Morse Code or DC to 25 cps square wave.

12.3.3.3 OUTPUT LEVEL

As required by test unit carrier phase modulators, adjustable ± 10 db.

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TABLE III

SIGNAL CHARACTERISTICS OF OPERATIONS DATA

Data Description	Detected Signal BW Requirements
Real Time	
Biomedical Data, 7 channels:	
(1) SCO freq. 4 KC ±200 cps	2 cps
(2) SCO freq. 5.4 KC ±270 cps	2 cps
(3) SCO freq. 6.8 KC ±340 cps	2 cps
(4) SCO freq. 8.2 KC ±410 cps	2 cps
(5) SCO freq. 9.6 KC ±384 cps	2 cps
(6) SCO freq. 11 KC ±330 cps	2 cps
(7) SCO freq. 12.4 KC ±248 cps	30 cps
Stored Data:	
9 Analog Channels:	
(1) SCO freq. 14.5 KC ±7.5%	435 cps
(2) SCO freq. 22 KC ±7.5%	660 cps
(3) SCO freq. 30 KC ±7.5%	900 cps
(4) SCO freq. 40 KC ±7.5%	1.2 KC
(5) SCO freq. 52.5 KC ±7.5%	1.575 KC
(6) SCO freq. 70 KC ±7.5%	2. 10 KC
(7) SCO freq. 95 KC ±7.5%	2. 85 KC
(8) SCO freq. 125 KC ±7.5%	3. 75 KC
(9) SCO freq. 165 KC ±7.5%	4. 95 KC

12.3.3.4 FREQUENCY STABILITY

Better than 1 part in 10^5 per day.

12.3.3.5 FREQUENCY TUNING RANGE

At least ± 30 cps, centered at 512 KC.

12.4 LEVEL CONTROL

12.4.1 CARRIER MODULATION LEVEL INDICATION

A panel-mounted meter shall be provided to measure the outputs of the subcarrier and Video/Voice units individually and after summing.

12.4.2 STEP ATTENUATORS

Step attenuators will provide known changes in the 50 MC signal level relative to noise and in the 10 MC noise level relative to signal, to simulate R & RR receiver action when the received signal changes.

13.0 OPERATION AND MECHANICAL CHARACTERISTICS

13.1 SIZE

The demodulator shall be designed to fit into a standard Emcor equipment cabinet (19 inch panel width). The exact size and configuration of the cabinet shall be established through design conferences with Collins Radio.

13.2 WEIGHT

To be determined.

13.3 TYPE OF CONSTRUCTION

The unit shall utilize solid-state techniques throughout. A design objective is to provide a minimum continuous operational life of 10,000 hours without failure. The unit shall be capable of continuous unattended operation.

The unit shall use modular sub-units to facilitate maintance. Individual sub-units shall be connected by connectors and mounting hardware so that any single sub-unit may be removed and replaced without requiring temporary removal of other sub-units.

Rack slides shall be used for the major assemblies. The construction and connectors for the modules shall be compatible with the above requirements and the leakage requirements necessary to meet the specified interchannel isolation and specified RFI level. Cable lengths shall be compatible with the installation. Cable clamps shall be used to minimize cable friction wear. Electrical connectors to the receiver rack shall be A/N Cannon type connectors. R-F (10 MC or greater) connectors shall be 50 ohm TNC type connectors. Other single-ended connectors shall be type BNC.

13.4 FINISH

The finish of the front panel shall be Federal Standard 595 grey #26440 per TT-E-529.

13.5 ENVIRONMENTAL CONDITIONS

As required by Rev. 1 of GSFC-TDS-RFS-208 and (for shipboard units) Enclosure 1 to Exhibit F for NASA RFP 10001 dated November 18, 1963.

13.6 SERVICE CONDITIONS

The equipment shall be capable of withstanding shock and vibration normally encountered in shipment. The equipment shall operate satisfacorily under conditions of vibration actually encountered in use in a fixed installation. Applicable documents are MIL- -4158C (design guide) and MIL-F-14072. MIL-E-16400 (Navy) is applicable to those units which are to be shipboard mounted (as defined in Enclosure I to Exhibit F of NASA RFP 10001, dated 18 November 1963).

13.7 WORKMANSHIP

The workmanship shall be of high quality using the best engineering practices for units of this size: Components shall be of military specifications quality or equivalent. All variable components such as pots, variable inductors, and capacitors shall have locking or torque-control facilities. Applicable Document is NASA Quality Publications NPC200-3 dated April 1962 plus addendum to NPC200-3 dated 27 September 1963.

14.0 DESIGN APPROVAL

Design approval shall be required for the complete specifications, block diagram, schematics, nameplates, mechanical layout and wiring assembly.

14.1 ACCEPTANCE TESTS

Acceptance tests will be run in accordance with a test procedure which has been reviewed and approved by Collins Radio Company. The procedure shall demonstrate compliance with the requirements of this specification. Collins and NASA personnel may witness this test. All test results are subject to their review and approval.

appendix b

specification #126-0427
high power combiner

REVISIONS

SYM	DESCRIPTION	DATE	APPROVED

DESCRIPTION: High Power Combiner Operating at S-Band

*DASH NUMBER: -001

*NOTICE: WHEN REFERRING TO PART NUMBER, SPECIFY DRAWING NUMBER FOLLOWED BY THE APPLICABLE DASH NUMBER.

The class designation and the symbols CAL, TA, CR, RA, NSR, and SSA which may appear on this drawing are for internal use only by the Collins Radio Company and are not related to the engineering data contained herein.

VENDOR	CODE IDENT. NO.		VENDOR P/N

CLASS	CAL CHANGE		ENGRG PN

NAME		DATE
PREP. BY	H.K. Solmer	7/16/64
CHK BY		
PROJ CHK		
PROJ ENGR		
DWG DATE		

COLLINS RADIO COMPANY
CEDAR RAPIDS, IOWA

HIGH POWER COMBINER
OPERATING AT S-BAND

CODE IDENT NO.	SIZE	
13499	A	126-0427*
SCALE NONE	WT	SHEET 1 of 8

1. SCOPE:

This specification covers the general and specific requirements for a high power combiner operating at S-band. The combiner is to be used to linearly combine two S-Band signals into a single output for transmission to an antenna feed. The combiner is to be mounted on the movable portion of a steerable tracking antenna. The specification includes the combiner, RF load, adapters and waveguide required to connect the output of two antenna mounted power amplifiers to the combiner.

2. APPLICABLE DOCUMENTS:

The equipment supplied under this specification shall be in accordance with the documents of 2.1 and 2.2 below.

2.1 SPECIFICATIONS:

(a) GSFC-TDS-RFS-208, Environmental Conditions.

(b) MIL-I-26600, Interference Control Requirements.

(c) MIL-E-4158C, Electronic Equipment Ground, General Requirements (refer.)

(d) MIL-F-14072, Finishes for Ground Signal Equipments.

(e) Collins Radio Company Specification 126-0426-001, S-Band Power Amplifier

2.2 PUBLICATIONS:

(a) NPC-200-3, NASA Quality Publication

2.3 PRECEDENCE OF SPECIFICATIONS:

In the event of conflict between the requirements of this specification and those listed above, the requirements of this specification shall take precedence.

3. ELECTRICAL REQUIREMENTS:

3.1 TYPE

The S-Band high power combiner shall be a waveguide hybrid or magic "T" type.

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3.2 INPUT:

3.2.1 INPUT SIGNAL:

The combiner shall receive two signals in the frequency range of 2090 to 2120 mc separated by approximately 5 mc and at a power level of up to 20 kw cw each. The input signals to the combiner will be supplied by power amplifiers described in Collins Radio Company Specification 126-0426-001, S-Band Power Amplifier.

3.2.2 INPUT MATCH:

The combiner input VSWR (both ports) shall not exceed 1.25:1 over the frequency range of 2090 to 2120 mc for operation under any environmental conditions and power levels specified herein.

3.3 OUTPUT:

3.3.1 OUTPUT SIGNAL:

The combiner shall provide an output signal consisting of up to 16 kw cw tones when supplied with input signals of up to 20 kw cw each. This combined output signal is intended to be furnished to a transmit antenna feed.

In addition, a second output shall direct wasted RF power to an RF load.

3.3.2 OUTPUT MATCH:

The combiner output shall deliver not less than 9 kw cw per tone when operating into a load of VSWR between 1.0 and 1.5 at any frequency within the frequency band specified herein.

3.3.3 OUTPUT WAVEGUIDE:

Care shall be taken in the finish, cleanliness, and joining of the waveguide components. The complete waveguide system is intended to be pressurized through to the antenna feed with dry nitrogen. The combiner shall be capable of positive pressurization to 0.5 psig. The output waveguide and

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components shall be WR-430.

3.3.4 OUTPUT COUPLER:

Directional couplers shall be provided at each output in order to monitor both combined output power and power to the RF load. Metering shall be provided on a remote panel to indicate combined output power and power to the RF load. Two incident power output and one reflected power output ports are required for monitoring.

3.3.5 ISOLATION:

At least 20 db of isolation shall be provided between inputs of the combiner. Variations in the RF load shall not cause degradation of the output signal.

3.3.6 LINEARITY:

The third order intermodulation product of two tones each producing 10 kw output and separated in frequency of 5 mc shall not exceed a level of 30 db below the level of either tone when the combiner is delivering power to a mismatched load producing any phase angle and a VSWR of 1.5 at the amplifier output. The requirements of this paragraph apply to any operating frequency in the frequency band specified herein.

3.3.7 RADIATION:

RF leakage from the combiner when operating under rated conditions shall not exceed that specified in MIL-I-26600 except that the level permitted shall be 50 db higher than that required by MIL-I-26600. The requirements of this paragraph apply when the combiner is operating at any frequency in the frequency band specified herein.

3.4 RF LOAD:

A radio-frequency dummy load shall be furnished capable of absorbing 5 kw of average power. The VSWR of this load shall not exceed 1.25 over the band 2090-2120 mc. The dummy load shall be equipped with flow meters and thermometers to determine the amplifier power output. The load shall be compatible

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with the heat exchanger coolant flow and pressure. The load shall be capable of pressurization to 0.5 psi and be completely RF shielded. Sufficient air and/or liquid coolant shall be supplied to allow the RF load to operate within ratings over the complete environmental range as specified. Suitable coolant flow valves, temperature controls, and pressure switches shall be provided to prevent any malfunctioning of, or damage to, the RF load, due to improper cooling. Adequate post-operative cooling shall be provided if required.

3.5 REMOTE CONTROL PANEL:

A remote control panel shall be provided which will contain as a minimum the following controls and indicators:

(a) Combined output power.

(b) Power RF load

(c) Coolant flow in RF load

(d) Safety interlock alarms

4. ENVIRONMENTAL:

4.1 ANTENNA MOUNTED EQUIPMENT:

4.1.1 TEMPERATURE:

4.1.1.1 OPERATION WITHOUT DEGRADATION:

The RF combiner system shall operate without degradation in performance in an ambient temperature range from +120 degrees F to 0 degrees F.

4.1.1.2 SURVIVAL:

The RF combiner system shall survive and operate, with degraded performance allowed, in an ambient temperature range from 120 degrees F to 130 degrees F and from -25 degrees F to 0 degrees F.

4.1.1.3 SOLAR RADIATION:

All temperatures measured in the shade.

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4.1.2 RELATIVE HUMIDITY:

0 to 100%.

4.1.3 ALTITUDE:

0 to 15,000 feet above mean sea level.

4.1.4 SHOCK AND VIBRATION:

The RF combiner shall operate within specifications under the shock and vibration conditions normally associated with equipment mounted on the movable portion of a steerable/tracking antenna Specifically, the antenna mounted portions of the combiner system shall be subjected to accelerations of 20 $^{o}/sec^{2}$ (at the X axis) under conditions of emergency stops. It is anticipated that the power amplifier section that is antenna mounted will be located approximately 40 feet from the X axis. Antenna structure resonance may reach 2.5 cps. In order to preclude introduction of sympathetic vibrations in the power amplifier at antenna structure resonance, the natural resonance of the power amplifier (antenna mounted sectiors) shall be above 3.0 cps.

4.2 INDOOR OPERATING EQUIPMENT:

4.2.1 TEMPERATURE:

Operate to specifications from +120 degrees F to +32 degrees F.

4.2.2 HUMIDITY:

Operate to specifications from 20% to 80% relative humidity.

4.2.4 DEGRADED PERFORMANCE:

Survive and operate but with degraded performance from 0% to 95% relative humidity.

4.2.5 ALTITUDE:

Operate to specifications from sea level to 15,000 above mean sea level.

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4.3 SHIPPING AND CRATED OUTSIDE STORAGE:

(a) Temperature: +100 degrees to -65 degrees F.

(b) Relative Humidity: 0 to 100%.

(c) Altitude: 0 to 35,000 feet above mean sea level.

(d) Shock and Vibration: Transportation by common carriers over unusually rough terrain.

(e) Salt Water: Equipment shall withstand a 50-hour salt spray test, and exhibit no corrosion when located within one mile of salt water.

(f) Desert Environment: Component parts shall not be damaged by sand or dust storms.

5. RELIABILITY:

The combiner system shall be designed for maximum reliability and lifetime under adverse environmental conditions.

6. MECHANICAL:

6.1 WEIGHT:

Total weight of the antenna mounted equipment shall be minimum consistent with good mechanical and electrical design and ability to perform to these specifications.

6.2 DIMENSIONS:

The volume of the antenna mounted equipment of the combiner shall be minimum consistent with good mechanical practice and compliance with performance specifications.

6.3 FINISH:

All exterior surfaces of cabinets, racks, panels shall be painted in accordance with MIL-F-14072.

6.4 CONNECTORS

Connectors where required shall be type N for RF and MS for power and control.

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6.5 MECHANICAL ATTACHMENTS:

Attachments means shall be provided to facilitate lifting where required.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS DECIMALS ANGLES ± ± ±	CODE IDENT NO. 13499	SIZE A	DRAWING NUMBER 126-0427
	SCALE NONE	WT	SHEET 8

appendix C

reliability analysis report

(1) Antenna Position Programmer

(2) Tracking Data Processor, Single

(3) Tracking Data Processor, Dual

(4) Timing System

COLLINS

COLLINS RADIO COMPANY

INFORMATION SCIENCE CENTER

NEWPORT BEACH, CALIFORNIA

PRELIMINARY RELIABILITY ANALYSIS REPORT

APOLLO UNIFIED S-BAND DATA HANDLING SYSTEM

(CONTRACT NAS 5-9035)

Date: 30 September 1964

Prepared By. J R Donan
J. R. Donan

W. G. Gaude
W. G. Gaude
Reliability & Q. C.
Research & Dev. Division

REVISIONS

SYM	REV.NO.	DATE	APPVD.	SYM.	REV.NO.	DATE	APPVD.	SYM	REV NO.	DATE	APPVD
				[redacted]	[redacted]	[redacted]	[redacted]				

TABLE OF CONTENTS

1. SCOPE

This report has been prepared in compliance with Item 3.3 of Collins Dallas Division Technical Requirements List 126-0437. The report contains detailed reliability and failure rate analyses for each major subsystem, including appropriate failure model diagrams for various configurations of the Time Standard subsystem.

2. APPLICABLE DOCUMENTS

The following documents have been used as reference material in the prepara tion of this report.

Collins Radio Co. Documents

126-0437 Technical Requirements List for Apollo Unified S-Band Network.

RDP-224 Guide Lines for Reliability Prediction of Electronic Equipment.

Other Publications

"Reliability Theory and Practice" textbook by Igor Bazovsky, Prentice-Hall, Inc., 196[illegible].

3. EQUIPMENT COVERED BY REPORT

The following major subsystems are included in this report:

a. TE 409 Antenna Position Programmer

b. TE 410 TDP with Dual Doppler

c. TE 410A TDP with Single Doppler

d. TE 411 Time Standard

Since details of the design are not yet available, the following equipments are not covered by this report and will be included in a later reliability analysis.

a. TE 412 Doppler Counter, Single Capability

b. TE 412A Doppler Counter, Dual Capability

4. BASIC ASSUMPTIONS AND SOURCES OF DATA

The following considerations have been used as a basis for performing the analyses of this report:

a. Except for emergency mode operating conditions, the average inlet air temperature has been assumed to be 85°F (30°C). This is the average temperature that is now being experienced at Collins Electronic Switching System Computer Terminals. Forced air cooling from central blowers is expected to be used throughout this system.

b. The reliability of the cooling system itself has not been evaluated. This area will be included in the next analysis report.

c. The failure rates for the C-8000 circuit cards have been obtained primarily from operating experience at the Cedar Rapids Computer Terminal. These cards have undergone a total of 150 million circuit card operating hours. They have experienced an overall average failure rate of .064% per 1000 hours per card over all card types for the last 108 million hours of operation.

   For all high usage card types, separate observed failure rate values are available and these are reflected in the summary tables for each subsystem analysis in the sections below. In the case of some low usage card types, the quantity of operating card hours was insufficient for a statistically valid failure rate computation; a predicted value based on the known parts population and on an observed part failure rate for the high usage cards has been given in these cases. Thus, the "card" level failure rate listings refer to observed card data, and the "part" level listings signify an average part failure rate extropolation to the card or unit function. In some cases, a "unit" level estimate is given which indicates an observed or predicted value on an equipment basis.

d. The failure rate values used and the resulting subsystem MTBF values obtained are expected to be realized by the subject equipments after continuous operation for 6 months. Since part infant failures occur rather slowly in an equipment which has utilized large stress derating factors, significant burn-in takes place during the first 6 months of operation. The MTBF improvement is expected to be in the order of 2.5 to 1 for the 6-month maturity point compared to the 1-month point.

e. The failure rate and reliability calculations are based on constant failure rates and on a parts population analysis. No attempt was made to obtain MTBF improvement by selecting specific signal paths, thus the analysis given assumes worst-case system complexity conditions. As is customary, exponential probability distributions have been assumed for all parts, circuit cards and units.

f. The APP and TDP subsystems are cases of pure series reliability, and a direct arithmetic summation of all failure rate contributions results. Also, the subsystem MTBF for each of these is the reciprocal of the failure rate due to exponential distributions throughout.

g. The Time Standard subsystems have several intentionally redundant paths. Exponential distributions prevail for the case of redundancy with periodic inspection However, the redundant networks are no longer exponential for redundancy without repair, and the MTBF and failure rate values are not related by the simple reciprocal.

h. The quantities used for parts and circuit cards are preliminary and are thus subject to some change as the detailed design becomes firm. These changes are expected to be relatively minor however.

i. The failure rate values for all purchased equipment are rough approximations. These will be upgraded as supplier estimates are received and as detailed stress analyses are submitted subsequent to contract awards.

5. ANTENNA POSITION PROGRAMMER

The APP subsystem is comprised entirely of equipment that is functionally in an "on-line" status. The reliability analysis is that of a pure series model for all parts, cards and purchased equipment. The failure rates assigned to the purchased equipments are only approximations since suppliers have not been selected at this time.

TABLE 5-1 Failure Rate Analysis. 9/30/64

Subsystem: Antenna Position Programmer, TE 409.

Inlet Temperature: 85^{o}F

Quantity	Item Description	Level of Prediction	Item Failure Rate %/1000 HR.	Subtotal Failure Rate %/1000 HR.
201	KA-Series	card	.041	8.241
522	KB-Series	card	.073	38.106
44	KV-42	part	.099	4.356
71	KZ-48	card	.17	12.07
3	KY-18	part	.072	.216
7	CB-Series	part	.018	.126
11	OS-28	part	.11	.121
1	RF-12	card	.07	.07
10	RI-11	part	.084	.840
84	RS-Series	card	.11	9.24
146	TR-57	card	.038	5.548
1100	CARD SUBTOTAL		.072% (Av.)	78.93%
1	Tape Reader	unit	* 5.0	* 5.0
1	Tape Handler	unit	* 5.0	* 5.0
1	D/A Converter	part	*28.0	* 28.0
3	20V. Power Supply	part	* 2.0	* 6.0
4	Angle Display	card	* 3.0	* 12.0
1	Time Display	card	* 3.0	* 3.0
11	PURCHASED EQUIP. SUBTOTAL			* 59.0%
81	MISCELLANEOUS PARTS SUBTOTAL		.03	2.43%

SUB-SYSTEM TOTAL FAILURE RATE . . . . 140.36 %/1000 Hr.

SUB-SYSTEM MTBF . . . . ** . 712 Hr.

* Indicates preliminary estimate, subject to revision after supplier selection has been made.

** $MTBF = \dfrac{10^5}{F.R.\%/1000\ Hr.}$

6. TRACKING DATA PROCESSOR, SINGLE DOPPLER

The introductory remarks of Section 5 above also apply to the TDP subsystem. The TDP has low and high speed outputs which represent a form of redundancy. The reliability analysis is made for all outputs functioning however, and thus neglects this fact of redundant signals.

TABLE 6-1 Failure Rate Analysis. 9/30/64

Subsystem: TE 410A, TDP With Single Doppler

Inlet Temperature: 85°F

Quantity	Item Description	Level of Prediction	Item Failure Rate %/1000 HR.	Subtotal Failure Rate %/1000 HR.
288	KA Series	card	.041	11.808
189	KB Series	card	.073	13.797
32	KV - 42	part	.099	3.168
4	KY - 18	part	.072	.288
5	KZ - 48	card	.17	.85
4	CB Series	part	.018	.072
55	GP - 21	card	.074	4.070
3	OA - 31	part	.061	.183
4	OS - 28	part	.11	.44
5	PD - 12	part	.021	.105
22	RI - 11	part	.084	1.848
313	RS Series	card	.11	34.43
176	TR - 57	card	.038	6.688
1100	CARD SUBTOTAL		.071% (Av.)	77.75 %
3	Power Supply	part	* 2.0	* 6.0
1	Tape Punch	unit	* 5.0	* 5.0
1	Tape Reader	unit	* 5.0	* 5.0
1	Interval Counter	part	*12.0	* 12.0
1	Tape Handler	unit	* 5.0	* 5.0
1	TTY Power Supply	part	* .3	.3
1	Filter	unit	* .2	* .2
1	10-Digit Display	card	* 5.0	* 5.0
1	12-Digit Display	card	* 6.0	* 6.0
2	Display P.S.	part	* .5	* 1.0
13	PURCHASED EQUIP. SUBTOTAL			45.5 %
31	Miscellaneous Parts		.04	1.2
240	Toggle Switches		.02	4.8
271	MISCELLANEOUS PARTS SUBTOTAL			6.0 %

SUBSYSTEM TOTAL FAILURE RATE 129.25%

SUBSYSTEM MTBF ....**. 774 Hr.

* and ** See notes on previous pages.

7. TRACKING DATA PROCESSOR, DUAL DOPPLER

The only difference between the single and dual doppler TDP subsystems is an increase in circuit card and purchased equipment quantities for the dual version. The reliability analysis is similar to that for the single doppler case.

ABLE 7-1 Failure Rate Analysis 9/30/64

Subsystem: TE 410, TDP With Dual Doppler

Inlet Temperature: 85°F

Quantity	Item Description	Level of Prediction	Item Failure Rate %/1000 HR.	Subtotal Failure Rate %/1000 HR.
288	KA Series	card	.041	10.988
378	KB Series	card	.073	27.594
40	KV - 42	part	.099	3.960
4	KY - 18	part	.072	.288
5	KZ - 48	card	.17	.85
4	CB Series	part	.018	.072
51	GP - 21	card	.074	3.774
3	OA - 31	part	.061	.183
4	OS - 28	part	.11	.44
5	PD - 12	part	.021	.105
17	RF - 12	card	.07	1.19
22	RI - 11	part	.084	1.848
364	RS - Series	card	.11	40.04
185	TR - 57	card	.038	7.030
1350	CARD SUBTOTAL		.073% (Av.)	98.36 %
3	Power Supply	part	* 2.0	* 6.0
1	Tape Punch	unit	* 5.0	* 5.0
1	Tape Reader	unit	* 5.0	* 5.0
1	Interval Counter	part	*12.0	* 12.0
1	Tape Handler	unit	* 5.0	* 5.0
1	TTY Power Supply	part	* .3	* .3
1	Filter	unit	* .2	* .2
2	10-Digit Display	card	* 5.0	* 10.0
2	12-Digit Display	card	* 6.0	* 12.0
4	Display P.S.	part	* .5	* 2.0
17	PURCHASED EQUIP. SUBTOTAL			57.5 %
31	Miscellaneous Parts		.04	1.2
240	Toggle Switches		.02	4.8
271	MISCELLANEOUS PARTS SUBTOTAL			6.0

SUBSYSTEM TOTAL FAILURE RATE .... 161.86 %

SUBSYSTEM MTBF ....**. 618 Hr.

8. TIME STANDARD SUBSYSTEM

The reliability analysis of this subsystem is rather complex since several branches of the equipment have intentionally been made redundant. Specifically, the basic time standard generation sections have need for extremely high dependability and thus utilize equipment redundancy as well as an emergency power source. In addition, all power supplies for this subsystem are individually redundant. Fortunately, in both these redundant cases the switchover between the two paths is performed instantaneously in the event of failure of one path, and no correction is required for switchover time loss.

The reliability model diagrams given below are not the same as system block diagrams, but rather represent the failure dependancies of the system. Thus, for the system to perform it's proper function, all elements that are in series must operate. If two or more items are in parallel, the system will continue to perform it's required function if one of the parallel elements is functioning. However, failure of all elements in a parallel path will result in system failure. There are two approaches to a redundant system both of which are presented here.

Redundancy Without Periodic Inspection

The first approach assumes system operation without repair until system failure has occurred. An improvement of system reliability is provided by the redundant elements, but the relationship between failure rate and MTBF is not a reciprocal function, as is the case for series components. The instantaneous failure rate of a parallel system is a variable function of the operating time although the MTBF is still a constant value. (1)

Redundancy With Periodic Inspection

The second approach assumes that the system is inspected periodically and any failed parts are repaired at the time of inspection. This inspection returns the system to a state of full redundancy each time the inspection is performed. Therefore, over long periods of time, the redundant system has an average constant failure rate and the MTBF is equal to the reciprocal of the failure rate. (2)

(1) Igor Bazovsky, "Reliability Theory and Practice" Prentice Hall, Inc. 1961, pp 99-100.
(2) Ibid. pp 200-201.

The difference between the two approaches is most dramatically evident in the analysis of the redundant paths indicated in Fig. 1 as XY. The MTBF of this redundant path without periodic inspection is 5706 hours. However, if inspection and repair is performed every 100 hours, the MTBF becomes 343,400 hours - thus an improvement factor of 58.

The MTBF value for the entire Time Standard Subsystem is also increased by use of periodic inspection. However, the difference is not very great since the major contributors to system failure rate are the non-redundant areas.

8.1 TIME STANDARD SUBSYSTEM, NORMAL OPERATING CONDITIONS WITHOUT PERIODIC INSPECTION — RELIABILITY CALCULATIONS

$$m = \int_0^{\infty} R(t)\, dt$$

$$R(t) = \prod_{i=0}^{n} r_i(t)$$

FROM FIG. 1

$$R(t) = e^{-(\lambda_1+\lambda_2+\lambda_3+\lambda_4+\lambda_5+\lambda_6+\lambda_7+\lambda_8+\lambda_9+\lambda_{10})t}(2-e^{-\lambda_1 t}) \cdot$$

$$\cdot (2-e^{-\lambda_6 t})(2-e^{-\lambda_{10} t})$$

LET $\lambda_S = \lambda_1+\lambda_2+\lambda_3+\lambda_4+\lambda_5+\lambda_6+\lambda_7+\lambda_8+\lambda_9+\lambda_{10}$

$$\therefore\ m = \int_0^{\infty} e^{-\lambda_S t}(2-e^{-\lambda_1 t})(2-e^{-\lambda_6 t})(2-e^{-\lambda_{10} t})\, dt$$

$$m = \frac{8}{\lambda_S} + \frac{2}{\lambda_S+\lambda_1+\lambda_6} - \frac{4}{\lambda_S+\lambda_1} - \frac{4}{\lambda_S+\lambda_6} - \frac{4}{\lambda_S+\lambda_8} - \frac{1}{\lambda_S+\lambda_1+\lambda_6+\lambda_8}$$

$$+ \frac{2}{\lambda_S+\lambda_1+\lambda_8} + \frac{2}{\lambda_S+\lambda_6+\lambda_8}$$

$$m_{XZ} = 920 \text{ HR}$$

TIME STANDARD SUBSYSTEM MTBF (WITHOUT INSPECTION) = **920 HR**

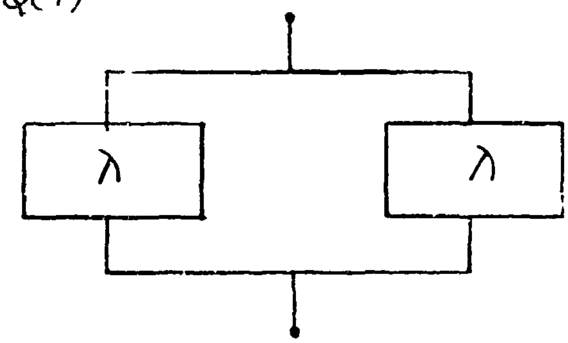
TIME STANDARD SUBSYSTEM, NORMAL OPERATING CONDITIONS

WITH PERIODIC INSPECTION AND REPAIR OF FAILED REDUNDANT PATHS - RELIABILITY CALCULATIONS

THE AVERAGE FAILURE RATE OF A REDUNDANT SYSTEM WITH TWO EQUAL PATHS WITH PERIODIC INSPECTION EVERY T HOURS IS:

$$\lambda_{AVG} = \frac{1}{m_T}$$

$$m_T = \frac{\int_0^T R(t)\,dt}{Q(T)} \qquad Q(t) = 1 - R(t)$$



$$R(t) = 1 - (1 - e^{-\lambda t})^2$$
$$Q(t) = (1 - e^{-\lambda t})^2$$

$$m_T = \frac{\int_0^T R(t)\,dt}{Q(T)}$$

$$m_T = \frac{\int_0^T \left[1 - (1 - e^{-\lambda t})^2\right] dt}{(1 - e^{-\lambda T})^2}$$

$$m_T = \frac{\frac{3}{2\lambda} - e^{-\lambda T}\left(\frac{2}{\lambda} - \frac{e^{-\lambda T}}{2\lambda}\right)}{1 - e^{-\lambda T}(2 - e^{-\lambda T})}$$

THE REDUNDANT PAIR IS EQUIVALENT TO A SINGLE ITEM WITH A FAILURE RATE EQUAL TO $\frac{1}{m_T}$ IF INSPECTION IS PERFORMED EVERY T HOURS AND ANY FAILED PARTS ARE REPAIRED

?.1 TIME STANDARD SUBSYSTEM, NORMAL OPERATING CONDITIONS WITH PERIODIC INSPECTION AND REPAIR OF FAILED REDUNDANT PATHS - RELIABILITY CALCULATIONS

THE EXPRESSION FOR m_T CAN BE APPROXIMATED BY:

$$m_T = \frac{\frac{3}{2\lambda} - (1-\lambda T)\left(\frac{2}{\lambda} - \frac{1-\lambda T}{2\lambda}\right)}{1-(1-\lambda T)(1+\lambda T)}$$

FROM FIG. 1, ASSUMING $T = 100$ HOURS

$\lambda_1 = 1.9\%/1000$ HR $\qquad \lambda_{1\,AVG} = .0036\%/1000$ HR

FOR THE REDUNDANT PATH $XY_A = XY_B$

$\lambda_{1\,AVG} = .0036\%/1000$ HR

$\lambda_2 = .944\%/1000$ HR

$\lambda_3 = 3.09\%/1000$ HR

$\lambda_4 = 8.48\%/1000$ HR

$\lambda_5 = 4.70\%/1000$ HR

$\lambda_{XY} = 17.218\%/1000$ HR

$\therefore \lambda_{XY\,AVG} = .291\%/1000$ HR

$\lambda_{6\,AVG} = .008\%/1000$ HR

$\lambda_7 = 7.09\%/1000$ HR

$\lambda_8 = 82.62\%/1000$ HR

$\lambda_9 = 3.11\%/1000$ HR

$\lambda_{10\,AVG} = .004\%/1000$ HR

$\lambda_{XZ} = 93.123\%/1000$ HR

TIME STANDARD SUBSYSTEM MTBF (WITH INSPECTION AND NECESSARY REPAIRS PERFORMED EVERY 100 HR) = 1074 HR

TABLE 8-1 Failure Rate Analysis 9/30/64

Subsystem: TE 411 Time Standard, On Line Equipment

Inlet Temperature: $85^{o}F$

Quantity	Item Description	Level of Prediction	Item Failure Rate %/1000 Hr.	Group Failure Rate Symbol	Group Failure R[illegible] %/1000 [illegible]
	-24V. Power Supply				
96	Misc. Parts	part	.020 (Av.)	λ 1	1.9
	Regulator				
200	Misc. Parts	part	.0047(Av.)	λ 2	.94
	Frequency Divider				
52	C-8000 Cards	card		λ 3	3.09
	Digital Clock & Display				
62	C-8000 Cards	card			3.48
62	Misc. New Cards	part	.081 (Av.)		5 [illegible]
124	SUBTOTAL			λ 4	8.48 %
	Time Code Generator				
66	C-8000 Cards	card		λ 5	4.70
	± 20V. Power				
192	Misc. Parts	part	.020 (Av.)	λ 6	4.0
	BCD - Binary Converter				
165	C-8000 Cards	card		λ 7	7.09
	Distribution Chassis				
689	C-8000 Cards	card			77.38
14	Misc. New Cards	part			.36
126	Misc. Parts	part	.039 (Av.)		4.88
	SUBTOTAL			λ 8	82.62 %
	Count Down Clock				
106	C-8000 Cards	card		λ 9	3.11
	-20V. Power Supply				
96	Misc. Parts	part		λ 10	2.0 %

	With Periodic Inspection	Without Periodi[illegible] Inspection
SUBSYSTEM TOTAL FAILURE RATE	* 93.1 %	**
SUBSYSTEM MTBF	***1074 Hr.	920 Hr.

* - Due to redundant paths, failure rate summation is not arithmetic sum, see reliability model analysis.

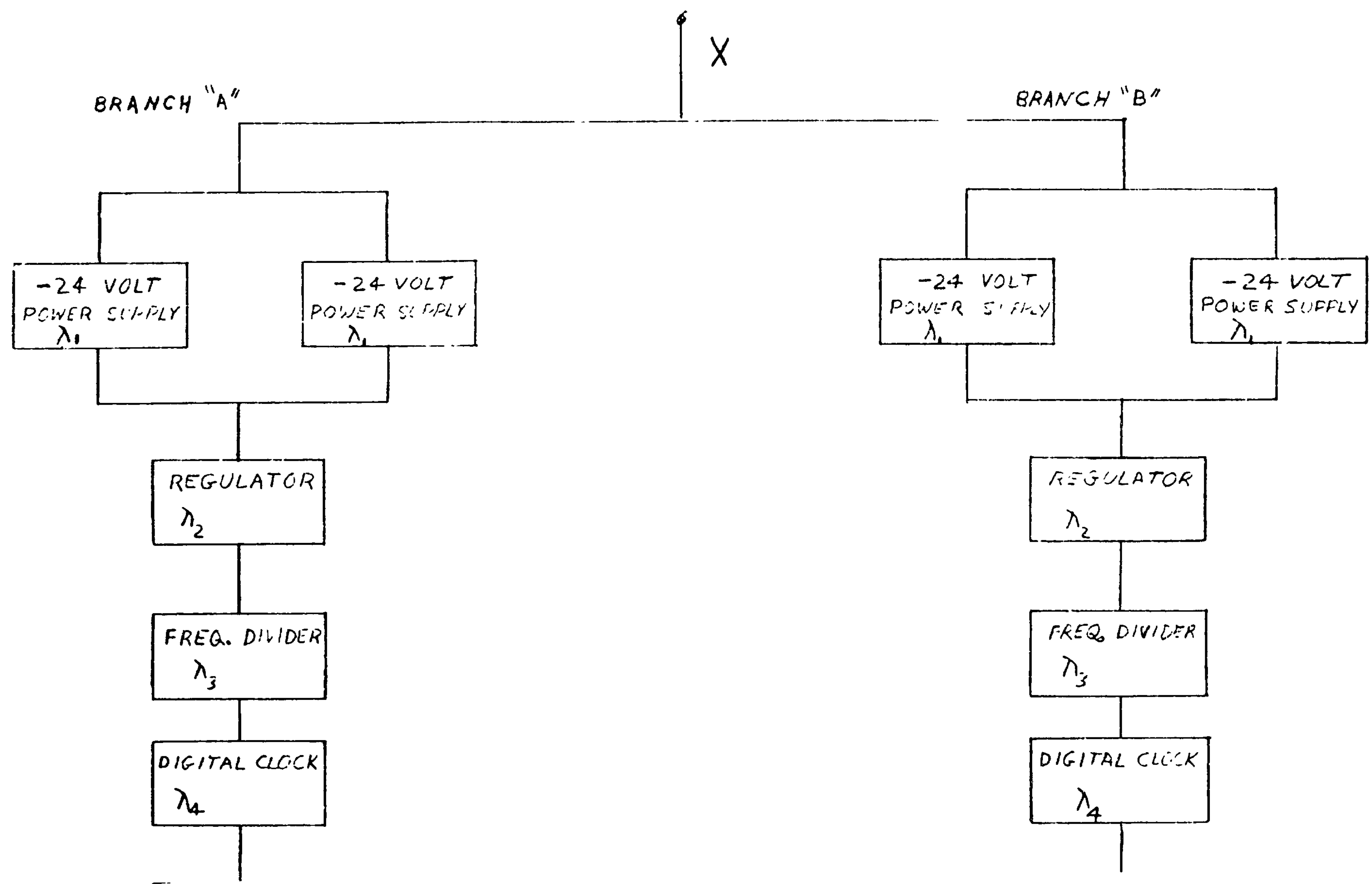
** - Subsystem failure rate without repair is not easily computed.

*** - For case with periodic inspection,

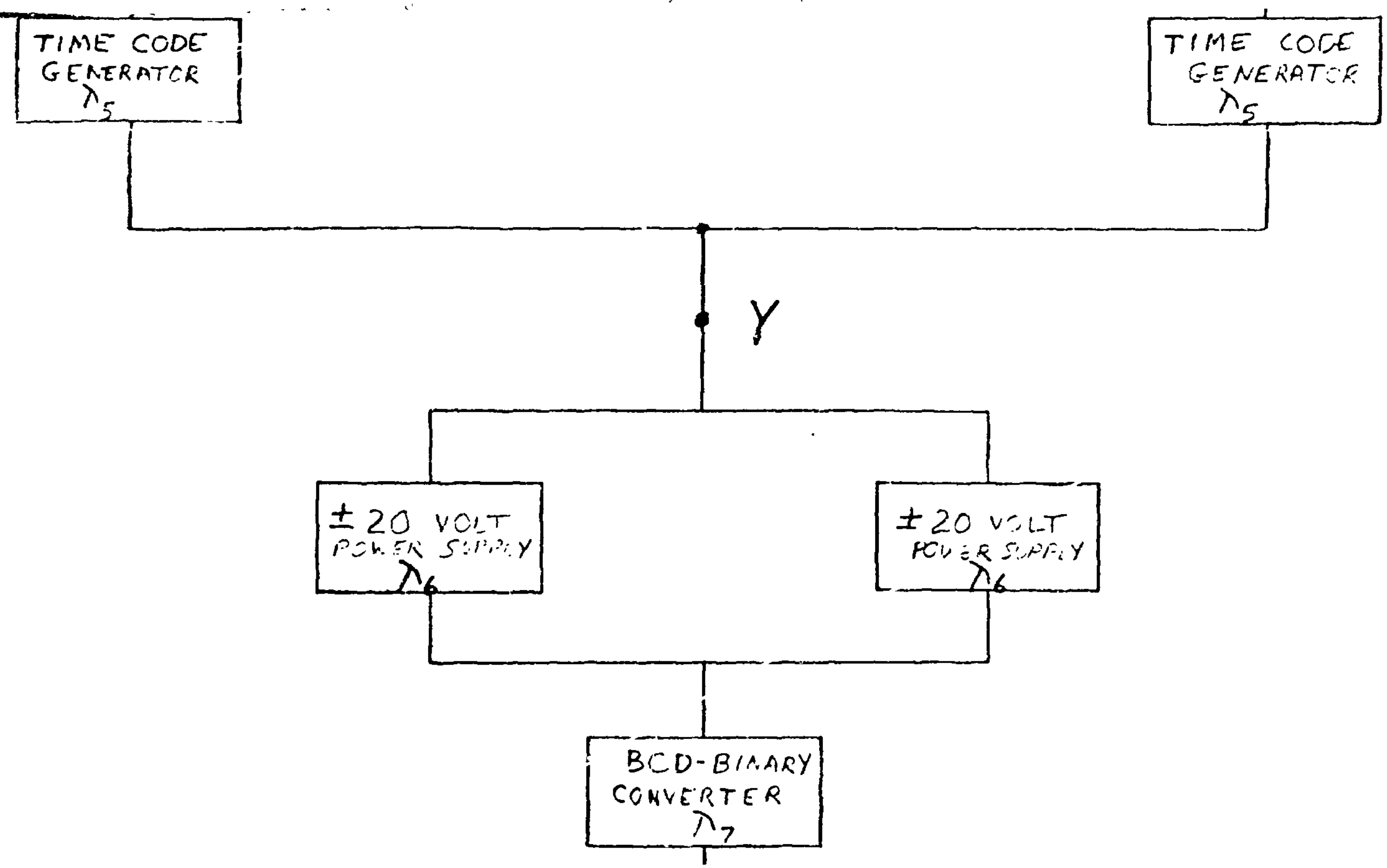
$$\mathrm{MTBF} = \frac{10^5}{\text{[illegible]}}$$

RELIABILITY MODEL

TE 411 TIME STANDARD SUBSYSTEM, NORMAL OPERATING CONDITIONS



17 ①



TIME CODE GENERATOR λ_5
TIME CODE GENERATOR λ_5
Y
±20 VOLT POWER SUPPLY λ_6
±20 VOLT POWER SUPPLY λ_6
BCD-BINARY CONVERTER λ_7

2

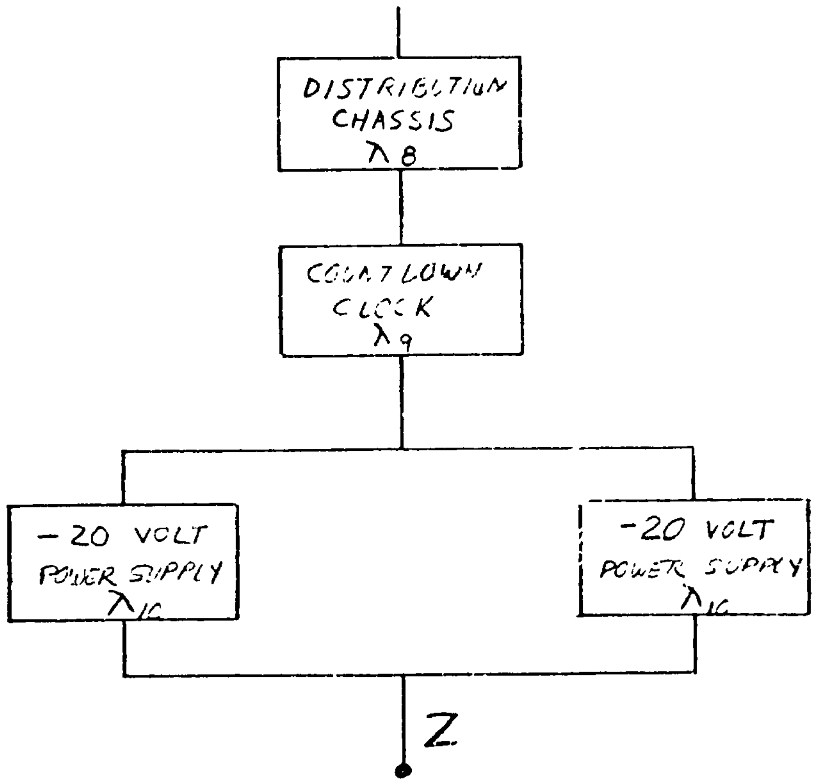

DISTRIBUTION
CHASSIS
λ8
COUNTDOWN
CLOCK
λ9
-20 VOLT
POWER SUPPLY
λ10
-20 VOLT
POWER SUPPLY
λ10
Z

FIGURE 8-1

TE 411 TIME STANDARD SUBSYSTEM, REDUNDANT PATH ANALYSIS, PATH XY

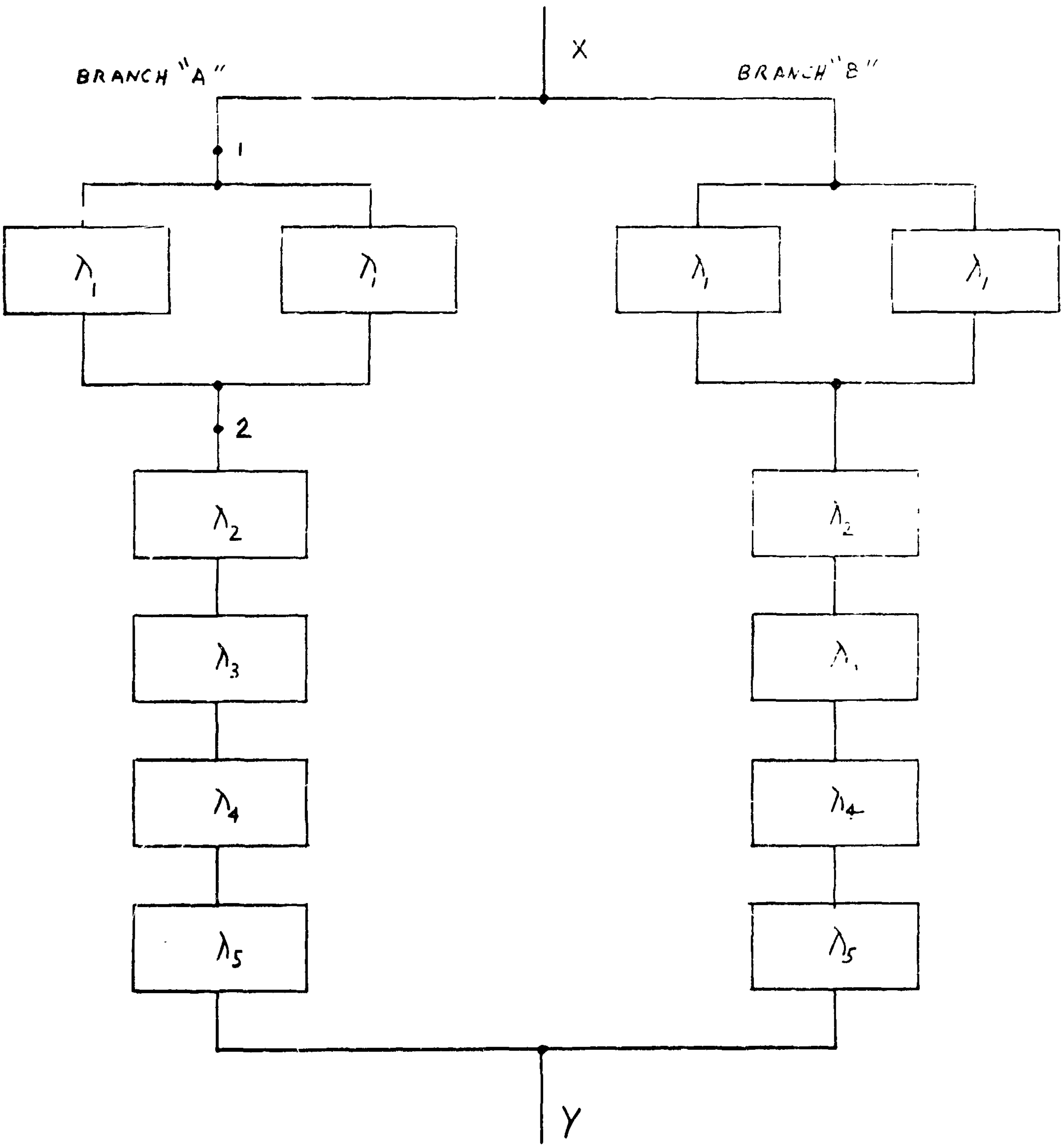


FIGURE 8-2

8.2 TE411 TIME STANDARD SUBSYSTEM REDUNDANT PATH ANALYSIS, PATH XY - RELIABILITY CALCULATIONS

MTBF CALCULATIONS, WITHOUT PERIODIC INSPECTION.

$$m = \int_0^\infty e^{-(\lambda_1+\lambda_2+\lambda_3+\lambda_4+\lambda_5)t}\left(2 - e^{-\lambda_1 t}\right) dt$$

$$m = \frac{2 \quad 1}{\lambda_1+\lambda_2+\lambda_3+\lambda_4+\lambda_5} - \frac{1}{2\lambda_1+\lambda_2+\lambda_3+\lambda_4+\lambda_5}$$

$$\underline{\underline{m = 5706 \text{ HR.}}}$$

MTBF CALCULATIONS, WITH INSPECTION AND REPAIR OF FAILED REDUNDANT PARTS PERFORMED EVERY 100 HOURS.

$$m_T = \frac{\frac{3}{2\lambda} - (1-\lambda T)\left(\frac{2}{\lambda} - \frac{1-\lambda T}{2\lambda}\right)}{1-(1-\lambda T)(1+\lambda T)}$$

FOR PATH 1-2, $\lambda = .019 \times 10^{-3}$ $T = 100$

$$\therefore m_{T_{1-2}} = 27.78 \times 10^6$$

$$\lambda_{AVG\ 1-2} = .0036\ \%/1000\ HR$$

FOR THE TOTAL PATH XY, $\lambda = \lambda_{AVG\ 1-2} + \lambda_2 + \lambda_3 + \lambda_4 + \lambda_5$

$\lambda = .1722 \times 10^{-3}$ $T = 100$

$\lambda_{AVG} = .291\ \%/1000\ HR.$

$$\therefore \underline{\underline{m_T = 343{,}400 \text{ HR.}}}$$

8.3 Time Standard Emergency Mode Analysis

The emergency mode of operation is the condition which would exist in the event of main power shut-down. The equipments which would continue to operate are the Frequency Divider, the Digital Clock. These are powered by the stand-by Emergency Power and the Regulators.

The Regulator and Digital Clock failure rates have been established in previous sections of this report. We have not been able to determine an assignable failure rate for the battery at the present time. However, the operating life for one full load cycle has been established as 5 hours. The calculations for the emergency mode of operation have been made to determine the probability of successful completion of such a 5-hour period of operation. As in the normal mode of operation, the principle of redundancy has been utilized to increase the probability of successful completion of the 5-hour period.

Certain aspects of the batteries' reliability have not yet been adequately studied. The main problem anticipated would be the possible degradation of battery operating life due to improper maintenance.

One of the necessary reliability requirements would thus be inclusion of the battery in the normal periodic maintenance. Provision of a means for determining the vitality of the battery would be required so that replacement could be affected at such time as the battery capability falls below the required minimum.

TABLE 8-2 Failure Rate Analysis

Subsystem: TE 411 Time Standard, Emergency Mode

Item Description	Item Failure Rate at 30°C (Blowers On) %/1000 Hr.	* Item Failure Rate at 50°C (Blowers Off) %/1000 Hr.
Emergency Power Source **		
Regulator	.944	6.32
Frequency Divider	3.09	20.70
Digital Clock	8.48	56.82
Total Path Failure Rate -	12.51 %	83.84 %
Single Path Reliability		.99581
Redundant Path Reliability		.9999824

* Failure rate at 50°C is 6.7 times the failure rate at 30°C as indicated on the following page.

** The batteries which supply the emergency power are assumed to have no assignable failure rate. See the text for further discussion.

TABLE 8-3 Failure Rate of Parts at Increased Temperature, Blowers OFF.

Subsystem: Time Standard, Emergency Mode

Part Type	% Failure Rate Contribution at 30°C Inlet Temperature	Failure Rate Increase Factor	Weighted Failure Rate %/1000 Hr.
Semiconductor	76	8	608
Resistor	4	2.7	10.8
Capacitor	8	2.0	16.0
Misc.	12	2.75	33.0
TOTAL	100 %		667.8 %

$$\text{Overall Factor} = \frac{\text{Failure Rate at } 50^{\circ}\text{C Inlet Temp.}}{\text{Failure Rate at } 30^{\circ}\text{C Inlet Temp.}} = 6.7$$

RELIABILITY MODEL

TE411 TIME STANDARD SUBSYSTEM, EMERGENCY MODE

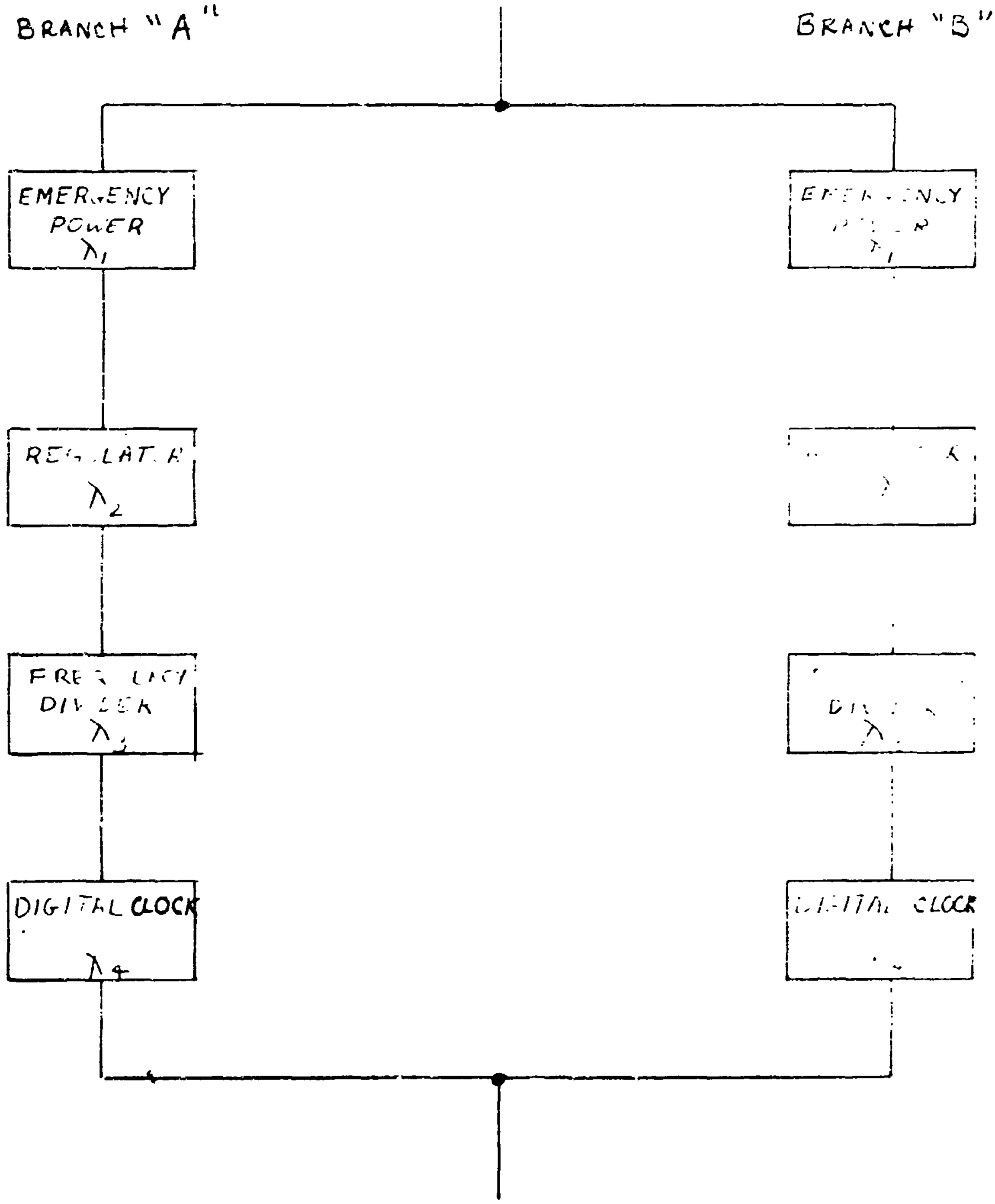


FIGURE 8-3.

TE411 TIME STANDARD SUBSYSTEM, EMERGENCY MODE (INLET TEMP.-F ?)-
RELIABILITY CALCULATIONS

<u>SINGLE PATH, BRANCH "A" OR "B"</u>

$$P\{5 \text{ HOUR SURVIVAL}\} = e^{-\lambda t}$$

$$= e^{-83.84 \times 10^{-5} \times 5}$$

$$P\{5 \text{ HOUR SURVIVAL}\} = \underline{\underline{.99581}}$$

<u>REDUNDANT PATHS (SEE FIG. E-3)</u>

$$P\{5 \text{ HOUR SURVIVAL}\} = 1 - (1 - e^{-\lambda t})^2$$

$$= 1 - (1 - e^{-83.84 \times 10^{-5} \times 5})^2$$

$$P\{5 \text{ HOUR SURVIVAL}\} = \underline{\underline{.9999824}}$$

TABLE 8-4 Failure Rate Analysis

Subsystem: Time Standard, Off-Line Equipment

Quantity	Item Description	Item Failure Rate %/1000 Hr.	Subtotal
	* Propagation Delay Generator Group		
5	KA Series	.041	.205
4	KB Series	.073	.29
4	CB - 15	.015	.06
4	OS - 28	.11	.44
2	New Designs	.075 (Av.)	.15
19	SUBTOTAL		1.15 %
1	60 cps Power Amplifier		**
1	WWV Receiver		**
1	Oscilloscope		**
1	VLF Receiver		**
1	Chart Recorder		**

* - Includes Delay Generator, Time Comparison Circuit, and Oscilloscope Trigger Circuit.

** - Failure rate data not yet available.

9. CONCLUSIONS

The foregoing report has given a detailed reliability analysis of the four major subsystems and has resulted in current predictions of MTBF for each. It is felt that, considering the highly complex nature of these equipments, the MTBF values are very favorable and represent a high degree of reliability. The following chart is presented as an overall summary and includes a listing of piece part usage together with a computed average part failure rate for all electronic circuits developed by Collins Radio Company. The corresponding evaluation of non-Collins equipment must be deferred until a later date. It is seen that the resulting values of part failure rate are approximately .003% per 1000 hours for all four subsystems. This value represents about the practical limit that is attainable with standard parts.

Subsystem	MTBF	* Total Parts Usage	** Resulting Average Part Failure Rate
TE 409 APP	712 Hr.	27,581	.0029%
TE 410 TDP	618 Hr.	34,021	.0031%
TE 410A TDP	774 Hr.	27,771	.0030%
TE 411 Time Std.	*** 1074 Hr.	37,936	***.0024%

* Includes Collins developed circuits only.

** In % per 1000 hr.

*** With periodic inspection of redundant paths.

appendix d

reliability analysis report encoding system

DATEX

RELIABILITY ANALYSIS

COLLINS RADIO

X-Y ANTENNA POSITION ENCODING SYSTEM

Subcontract 263230-T
DATEX SOR 16,556

1. AZIMUTH TRANSMITTER
2. AZIMUTH RECEIVER
3. ELEVATION TRANSMITTER
4. ELEVATION RECEIVER
5. INTERCABLING
6. LOGIC POWER SUPPLY
7. 400 CYCLE POWER SUPPLY

The Precision Angle Encoding System is a series system for reliability analysis, indicating that the failure of any component outlined in the diagram of reliability shown above makes the encoding system inoperative.

DAB:ht

DATEX

RELIABILITY - TABLE I

SUB-ASSEMBLY	MEAN TIME BETWEEN FAILURES IN HOURS m_i	RELIABILITY $R_i = e^{-\frac{t}{m_i}}$
AZIMUTH TRANSMITTER	150,000	.9433
AZIMUTH RECEIVER	25,000	.7033
ELEVATION TRANSMITTER	150,000	.9433
ELEVATION RECEIVER	25,000	.7033
INTERCABLING	100,000	.9158
LOGIC POWER SUPPLY	80,000	.8958
400 CYCLE POWER SUPPLY	100,000	.9158

CALCULATED VALUES

m_{s1} = 7947 hours

R_{s1} = 0.3306 (Based on annual inspection & preventive maintenance).

t = 3800 hours

DAB:ht

DATEX

RELIABILITY - TABLE II

SUB-ASSEMBLY	MEAN TIME BETWEEN FAILURES IN HOURS m_i	RELIABILITY $R_i = e^{-\frac{t}{m_i}}$
AZIMUTH TRANSMITTER	150,000	.9711
AZIMUTH RECEIVER	25,000	.8386
ELEVATION TRANSMITTER	150,000	.9711
ELEVATION RECEIVER	25,000	.8386
INTERCABLING	100,000	.9570
LOGIC POWER SUPPLY	80,000	.9465
400 CYCLE POWER SUPPLY	100,000	.9570

CALCULATED VALUES

m_{s_2} = 7947 hours

R_{s_2} = 0.5749 (Based on semi-annual inspection and preventive maintenance).

t = 4400 hours

DAB:ht

The Receiver Units have included within them the digital storage and output buffer circuits.

The 400 cycle power supply is an all solid state design with all components very conservatively rated.

DAB:ht

DEFINITIONS AND FORMULAE

$R_i = e^{\frac{-t}{m_i}}$

R_i = 1.000 indicates absolute reliability (No probability of failure for any length of mission time).

$R_s = R_1 \times R_2 \times R_3 - - - R_7$

(For series reliability systems)

$m_s = t \times \dfrac{LOG_{10}e}{LOG_{10}\left(\frac{1}{R_s}\right)}$ also, $m_s = \dfrac{}{\frac{1}{m_1} + \frac{1}{m_2} + \frac{1}{m_3} - - - -}$

e = 2.71828

$LOG_{10}e$ = 0.434294

R_i = Reliability of individual sub-assemblies (R_1 R_2 R_3 etc.) The probability that sub-assemblies will not fail during the mission time "t".

t = Mission time (the time interval in hours the equipment will work continuously before it is shut down for inspection, preventive maintenance and replacement, lubricating, cleaning, etc.)."t" should not exceed 8800 hours which is equivalent to a continuous service of 24 hours a day for one year.

m_i = Mean time between failures of individual sub-assemblies in hours after the initial "burn in" period based on tables, field experience and data. m_i includes the benefits of derating component rated characteristics for design reliability, i.e., a bulb rated at 28V and 3000 hours will have 60,000 hours life on 23 volts.

m_s = System mean time between failures.

REFERENCE: Reliability Theory and Practice
Igor Bazovsky
Prentice Hall, 1961

DAB:ht

appendix e

specification #511-4524 error code generator

COLLINS

specification - FUNCTIONAL

ERROR DETECTION CODE GENERATOR
OF THE
TRACKING DATA PROCESSOR
USED IN THE
APOLLO S-BAND NETWORK

PREPARED BY ____________ 9/17/64 DATE
L. A. Powell

APPROVED BY ____________ 9/17/64 DATE
F. E. Macy

APPROVED BY ____________ 9/17/64 DATE
O. P. Olson

APPROVED BY ____________ DATE

APPLICABLE INDEXING WORDS Error Detection Code Generator

REVISION SYMBOL	DESCRIPTION OF CHANGE	REVISION CONTROL NO.	APPROVED	RELEASE DATE
Orig.	None	W13473	O.P. Olson	9/17/64
A	Section 3.6.4 & 3.6.5, Figure 2 & 3	W13474	O. P. Olson	9/18/64
B	Section 2 & 3.3, Figure 1	W13655	O. P. Olson	10/9/64
C	Section 3.1.2, 3.3, 3.5, 3.6, Figure 2 & 3	W13724	O. P. Olson	10/19/64

FORM

1. SCOPE

This specification covers the functional requirements of the Error Detection Code Generator (EDCG) used in the Tracking Data Processor (TDP).

2. REFERENCE DOCUMENTS

NASA GSFC-TDS-TDP-1-REV 1 - Performance Specification for Tracking Data Processor.
126-0438-00 Collins Radio Company Specification, Tracking Data Processor.

3. REQUIREMENTS

3.1 FUNCTION - The Error Detection Code Generator, shown in Figure 1, shall perform the following functions:

1. Accepts data from RII of the TDP and provides the data to the polynomial code generator.

2. Originates check bits in groups of 33 bits or 22 bits by polynomial division applied to the data bits and converts the code word to non-zero modulus by the addition of special words.

3. Adds the check bits to the end of the corresponding data to form a code word and sends the composite to the modem and the magnetic tape recorder.

4. Accepts and provides control and timing signals to facilitate the transfer of data and timing to/from the TDP.

5. NOTE: This specification does not apply to the following functions which may be associated with the EDCG or the TDP.

   (a) Any integral test facility to check the operation of the EDCG.

   (b) The complete interface requirements of the TDP to the magnetic tape recorder.

   (c) The complete interface requirements of the TDP to the modem.

   (d) The interface requirements of the magnetic tape recorder to the modem.

3.2 MODE OF OPERATION - The EDCG shall be capable of four operating modes. The modes are determined by the following switches associated with the TDP.

A. Code Selection

   (1) A setting of 33 shall cause the polynomial code generator to provide 33 check bits.

   (2) A setting of 22 shall cause the polynomial code generator to provide 22 check bits.

B. Modem Rate Selection

(1) A setting of 2400 bits per second shall define the frame length to be 240 bits.

(2) Settings of 2000, 1200 or 600 bits per second shall define the frame length to be 200 bits.

The four operational modes of the EDCG shall be designated with the number of check bits followed by the frame length as follows:

22/200
22/240
33/200
33/240

3.3 HIGH SPEED DATA FORMAT - The bit positions within the frame are generalized in Table I. The order of sequencing the check bits shall be the most significant bit (33 or 22) first. The "spare" bits are a result of various code and frame selections and shall be treated the same as the "data" bits in their application to the polynomial code generator. The "sync" bits shall always be a binary zero.

	CODE SELECTION/FRAME SELECTION			
Function	22/200	22/240	33/200	33/240
Data	1-165	1-165	1-165	1-165
Spare	166-176	166-216	-	166-205
Check	177-198	217-238	166-198	206-238
Sync	199,200	239,240	199,200	239,240

HIGH SPEED DATA FORMAT BIT POSITIONS

TABLE I

3.4 TIMING - The EDCG receives its timing from the Timing System via the TDP. The GFE modem associated with the EDCG shall be externally timed, i.e., accept timing from the EDCG.

3.5 DESCRIPTION OF THE POLYNOMIAL CODES - The polynomial codes generated by the EDCG are of the type known as Bose-Chaudhuri codes. The following functions are the generator polynomial P(X) and the non-zero modulus M(X):

(1) 33 Bit Code

$$P(X) = X^{33} + X^{31} + X^{30} + X^{28} + X^{26} + X^{24} + X^{23} + X^{22} + X^{21} + X^{16} + X^{15} + X^{12} + X^{11} + X^{8} + X^{7} + X^{3} + X^{1} + 1$$

$$M(X) = X^{-5} + X^{-33}$$

(2) 22 Bit Code

$$P(X) = X^{22} + X^{20} + X^{14} + X^{13} + X^{12} + X^{11} + X^{8} + X^{7} + X^{5} + X^{3} + X^{1} + 1$$

$$M(X) = X^{-5} + X^{-22}$$

3.6 IMPLEMENTATION OF THE POLYNOMIAL CODES - The hardware to implement the polynomial generator functions consists of a shift register with provisions for the addition of special words and the proper number of modulo two adders. The number of shift register positions is equal to the order of the polynomial. The modulo two adders are placed between the elements of the register according to the polynomial generator function. The generators are implemented according to the diagram shown in Figures 2 and 3.

The operation of the code generator is as follows:

(1) Upon receipt of a start signal from the TDP, gate G1 is disabled and gate G2 is enabled.

(2) The data is clocked into the shift register and to the modem.

(3) Upon receipt of the proper number of data bits from the TDP (based upon the mode), gate G2 is disabled.

(4) A special word for converting the code word to a non-zero modulus is then added to the contents of the shift register. The 33-bit special word corresponds to the polynomial:

$$X^{31} + X^{30} + X^{27} + X^{25} + X^{23} + X^{22} + X^{20} + X^{18} + X^{17} + X^{16} + X^{15}$$
$$+ X^{14} + X^{12} + X^{10} + X^{5} + X^{4} + X^{2} + X$$

The 22-bit special word corresponds to the polynomial:

$$X^{21} + X^{19} + X^{16} + X^{15} + X^{11} + X^{10} + X^{9} + X^{8} + X^{7} + X^{5}$$

The addition of these special words is accomplished by complementing the contents of the shift register positions as shown in Figures 2 and 3. The addition is performed such that the check bits shall be enabled to the modem at the first modem bit time following the final spare bit (or data bit, depending on the format in Table I).

(5) After the special word has been added, gate G1 is enabled and the contents of the generator is then shifted to the modem. As the check bits are shifted out, zeros are shifted into the generator leaving it in a reset condition, i.e. all zeros.

(6) The generator remains in the reset condition waiting for the next start signal from the TDP.

3.7 INTERFACE SIGNALS WITH THE TDP - The following types of signals are required to interface the EDCG with the TDP:

(1) From the TDP to the EDCG

(a) Data - This signal contains the serial data information assembled by the TDP.

(b) Start Signal - This signal indicates the data is ready to be transferred from the TDP.

(c) Modem Timing - This signal consists of 600, 1000, 1200 or 2400 pps, dependent upon the selected modem rate.

(d) Code Selection - This signal indicates the number of check bits shall be 22 or 33.

(e) Modem Rate - This signal indicates the length of the frame shall be 200 or 240 bits.

(2) From the EDCG to the TDP

(a) Ready - This signal indicates the EDCG is in the operate mode and is ready to accept data from the TDP. (NOTE: this signal is not an indication of the operating condition of the modem or the communication link.)

(b) Shift Pulse - This signal indicates that the EDCG requires a bit of data from the TDP.

3.8 INTERFACE SIGNALS TO THE MODEM

(1) Encoded Message - This signal consists of the data bits, the check bits, and the synchronization bits to be transmitted.

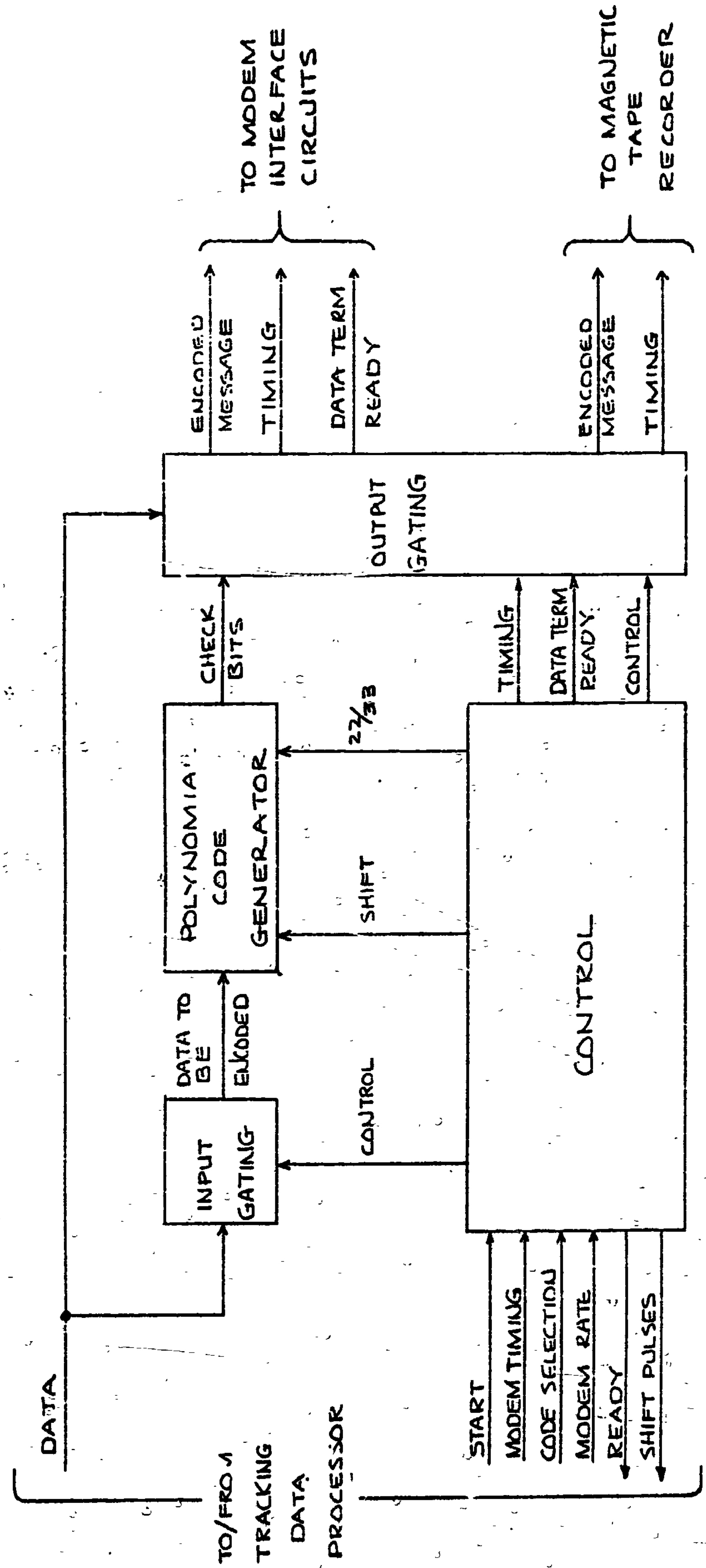
(2) Timing - This signal provides the transmit timing rate to the modem.

(3) Data Terminal Ready - This signal indicates the EDCG and TDP are ready to operate with the modem.

3.9 INTERFACE SIGNALS TO THE MAGNETIC TAPE RECORDER

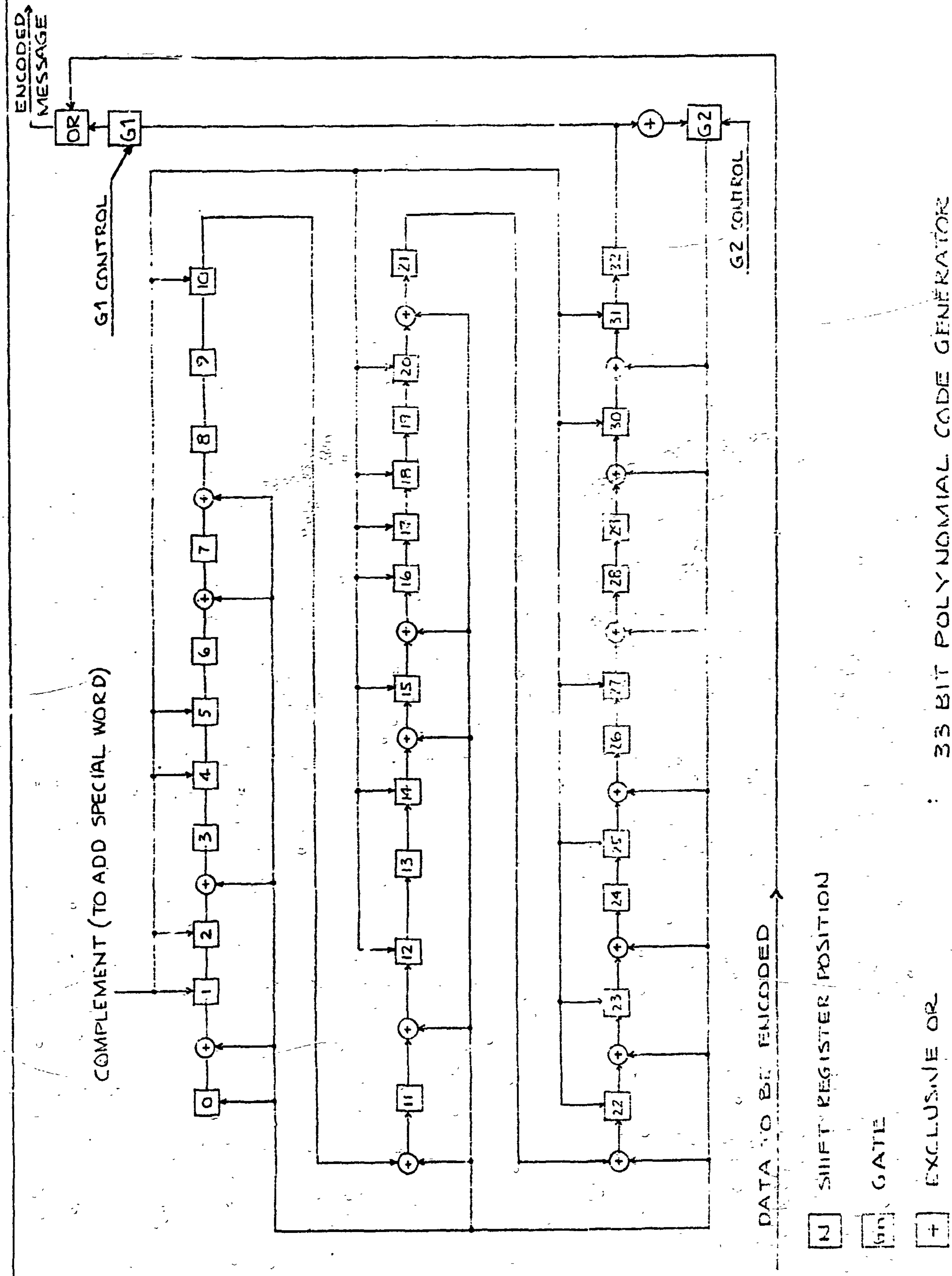
(1) Encoded Message - This signal consists of the data bits, the check bits, and the synchronization bits as sent to the modem.

(2) Timing - This signal consists of the modem transmit timing signal.



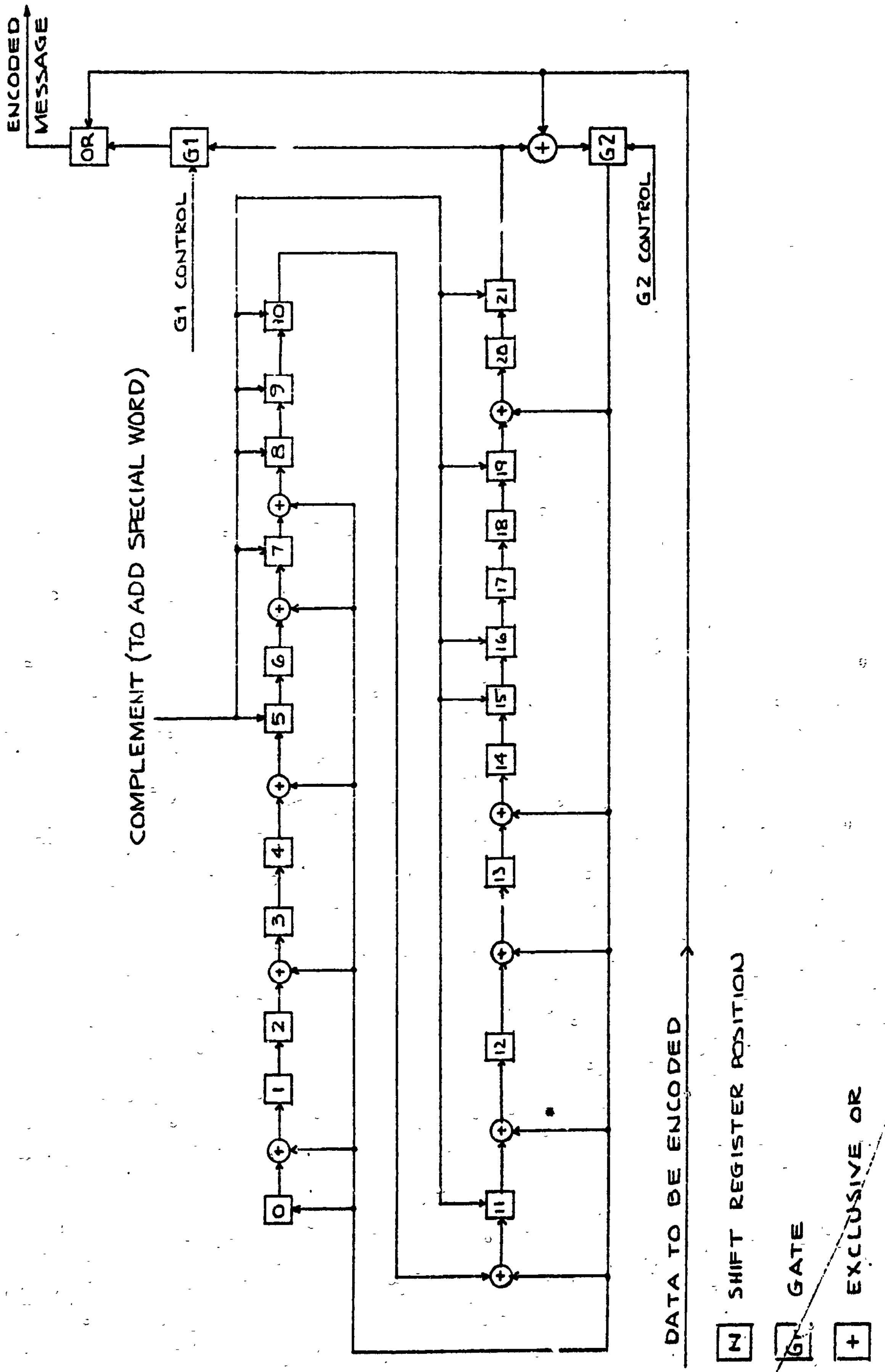
ERROR DETECTION CODE GENERATOR

FIGURE 4.



33 BIT POLYNOMIAL CODE GENERATOR

FIGURE 2.



22 BIT POLYNOMIAL CODE GENERATOR

FIGURE 3.

appendix f

message encoder unit specification #270-2175

REVISIONS

SYM	DESCRIPTION	DATE	APPROVED

FOR USE ONLY ON NASA APOLLO PROJECT.

Description:

1. This specification covers the requirements for the Message Encoder Unit (MEU) to be used with the Tracking Data Processor (TDP) in the Unified S-Band System of Apollo Network. The unit accepts serial data from the TDP and provides the required format to the High Speed Communication Equipment (HSCE) and the Magnetic Tape Recorder (MTR). The unit shall also accept reproduced data from the MTR for transmission by the HSCE.

PART NUMBER CONSISTS OF DRAWING NUMBER PLUS -010.

VENDOR	CODE IDENT. NO.		VENDOR P/N
OPI ... FOR ...			

CLASS 3 | CAL CHANGE | Source CONTROL DRAWING | ENGRG PN None

NAME	DATE
PREP BY [signature]	1 Oct 1964
CHK BY G. R. Silverman	2 Oct 1964
PROJ CHK	
PROJ ENGR L. G. Bassil	10/1/64
DWG DATE	

COLLINS RADIO COMPANY
CEDAR RAPIDS, IOWA

MESSAGE ENCODER UNIT

CODE IDENT NO. 13499 | SIZE A | DRAWING NUMBER 270-2175

SCALE NONE | WT | SHEET 1 of 13

2. APPLICABLE DOCUMENTS

The following documents, of the issue in effect on date of invitation for bids, form a part of this specification to the extent specified herein. Where the requirements of this specification and the latest issue of the listed documents conflict this specification shall govern.

Military Specifications

MIL-E-4158	Electronic Equipment, Ground, General Requirements for
MIL-I-26600	Interference Control Requirements, Aeronautical Equipment

Federal Specifications

TT-E-529	Enamel, Alykd, Semi-Gloss

C. R. C. Specifications

QAP-100	Quality Assurance Requirements for Vendors
580-0106-00	Finish, Paint, Process
511-4524	Error Detection Code Generator of the Tracking Data Processor used in the Apollo S-Band Network
TRL-126-0437	Test Procedure

EIA Standard

RS-232-A	Interface Between Data Processing Terminal Equipment and Data Communication Equipment

3. REQUIREMENTS

3.1 Design.- The Message Encoder Units shall contain the following basic elements:

Error Detection Code Generator (EDCS)

High Speed Communication Equipment (HSCE) Interface

Magnetic Tape Recorder (MTR) Interface

REV

3.1.1 Error Detection Code Generator Functions. - The Error Detection Code Generator shall perform the following functions (Complete functional requirements for the EDCG are given in specification 511-4524):

a. Accept data from the Tracking Data Processor and provide the data to a polynomial code generator.

b. Originate check bits in groups of 33 bits or 22 bits by polynomial division applied to the data bits.

c. Add check bits to the end of the corresponding data to form a code word and send the composite to the modem and the magnetic tape recorder.

d. Accept and provide control and timing signals to facilitate the transfer of data and timing to and from the Tracking Data Processor.

3.1.2. HSCE Interface Functions. -

The MEU shall have the capability of interfacing with the HSCE in accordance with EIA Standard RS-232-A (where applicable). The MEU operates with the HSCE in the Transmit-only mode. The HSCE shall be synchronized to the Apollo Time Standard by accepting its transmit timing signals from the MEU. (The MEU receives the selected transmit timing from the Time Standard via the TDP.)

3.1.3 MTR Interface Functions. -

The MEU shall have the capability of interfacing with an Ampex FR-600 Recorder/Reproducer System for the storage and playback of the high speed data.

REV

3.1.3.1 FR-600 characteristics. - The FR-600 (GFE) shall have the following characteristics during the recording and reproducing of the high speed data:

a. Tape speed. - 7-1/2 ips minimum

b. Servo system. - The FR-600 shall be provided with a servo system capable of accepting 60 cps from the timing system.

c. Record/reproduce system. -

(i) Encoded message. -

1 track
Frequency modulation (high level) system

(ii) Timing. -

1 track
Frequency modulation (high level) system

3.1.4 Operate/test modes. - Controls associated with the TDP shall determine the operating and test modes of the MEU. The MEU shall be capable of functioning in the following modes:

(1) On-line. - In this operating mode the MEU accepts the data from the TDP, provides the data bits, check bits and synchronization bits to the HSCE and the MTR. No action shall be taken on the reproduced signals from the MTR in this mode.

(2) Playback. - In this operating mode the MEU shall accept reproduced signals from the MTR and provide the required buffering, processing and adapting for transmission of the data by the HSCE. The EDCG is not required to provide check bits in this mode.

(3) MEU test. - The MEU shall be tested independently of the TDP and HSCE in this mode. The amount of self-checking circuitry shall be kept to a minimum.

(4) Integrated test. - The MEU shall be tested with the TDP and HSCE in this mode.

3.2 MEU general characteristics. -

3.2.1 Test functions. - The following functions are required to test the MEU:

a. Test-Code/Frame select. - The four modes used by the EDCG described in specification 511-4524 shall be selected by the following settings of this switch in either test mode.

22/200, 22/240, 33/200, 33/240

REV

3.2.1 Test functions (continued). -

b. Test-Pattern select. - This switch shall select three types of test patterns to be used in testing the MEU in the "MEU Test" or the "Integrated Test" modes.

c. Test-Clock select. - This switch shall select two types of test clocks to be used in the "MEU Test" mode.

(1) Continuous. - Provides continuous clock pulses to simulate the timing from the TDP.

(2) Manual. - Enables a single clock pulse to be applied to the required MEU circuitry being tested.

d. Manual clock. - Closure of this switch (when the Test Clock Select switch is in the "Manual" position) provides a single test clock pulse.

e. Clear. - This switch shall initialize the required circuits in any test mode

f. Non-compare indicator. - A single incandescent indicator shall light when the following conditions are all met:

(1) The MEU is in either test mode;

(2) A non-comparison exists between the generated check bit patterns and the stored correct pattern.

(3) The required number of bits have been provided the EDCG, that is, the correct pattern should normally have been generated.

3.2.2 Operating duty cycle. - Continuous.

3.2.3 Power dissipation. - watts.

3.2.4 Electrical overload protection. - Fuse with indicator mounted on rear of unit.

3.2.5 Radic frequency interference. - The MEU shall be designed with "Interference Control" using MIL-I-26600, Interference Control Requirements as a guide.

3.2.6 Power source. -

a. Voltage. - 105 to 125 V AC.

b. Frequency. - Single phase, 60 cps ± 5%.

c. Current load. -

3.3 Interface signals with the TDP. - The following types of signals are required to interface the MEU with the TDP:

3.3.1 From the TDP to the MEU. -

a. Data. - This signal contains the serial data information assembled by the TDP.

b. Start Signal. - This signal indicates the data is ready to be transferred from the TDP.

c. Modem Timing. - This signal consists of 600, 1200, 2000 or 2400 pps, dependent upon the selected modem rate.

d. Code Selection. - This signal indicates the number of check bits shall be 22 or 33.

e. Modem Rate. - This signal is used to indicate 200 or 240 bit frames.

3.3.2 From the MEU to the TDP. -

a. Ready. - This signal indicates the MEU is in the operate mode and is ready to accept data from the TDP. (NOTE: This signal is not an indication of the operating condition of the modem or the communication link.)

b. Shift Pulse. - This signal indicates that the MEU requires one bit of data from the TDP.

REV

3.3 Electrical Signal Characteristics: - The electrical signal characteristics used in the MEU Interface with the TDP shall be as follows:

Signal Logic	Zero	One
D.C. Voltage Level (nominal)	-3.2v	-0.8v
D.C. Signal Current (current flow into the input terminals is positive)	0.0 ma	2.87 ma

3.4 Interface with the HSCE. - The following signals are designated and utilized in accordance with EIA RS-232-A within the Apollo S-Band system requirements for transmission of the high speed data.

3.4.1 From the MEU to the HSCE. -

3.4.1.1 Transmitted Data (Circuit BA). -

a. Signals on this circuit are the serial bit stream (data bits, the check bits and the synchronization bit) to be transmitted.

b. The MEU shall hold this circuit in the marking condition during any time interval when no signals are to be transmitted.

c. The marking or spacing condition shall be held for the total duration of each signal element.

d. The HSCE shall transmit all data while the ON condition is maintained on the Request To Send (Circuit CA), Clear To Send (Circuit CB) and Data Set Ready (Circuit CC).

3.4.1.2 Request to Send (Circuit CA). -

a. Signals on this circuit condition the HSCE to transmit during the ON condition.

b. The ON condition shall be maintained at all times since the MEU operates with the HSCE in the Transmit-only mode.

3.4.1.3 Data Terminal Ready (Circuit CD). -

a. Signals on this circuit are used to control switching of the HSCE to the communication channel.

b. The ON condition causes the HSCE to be connected to communications channel.

c. The OFF condition removes the HSCE from the communications channel. (This condition shall be used when the MEU is being tested independently of the HSCE.).

3.4.1.4 Transmitter Signal Element Timing (Circuit DA). -

a. Signals on this circuit provide the HSCE with signal element timing information.

b. The waveform shall be a square wave with a duty cycle of 50% ± 1/2%. A transition from ON to OFF shall nominally indicate the center of each signal element on the Transmitted Data circuit.

c. This signal shall be synchronized to the Apollo Timing Standard at 600, 1200, 2000 or 2400 pps.

d. This signal shall have an accuracy of 0.01%.

3.4.2 From the HSCE to the MEU. -

3.4.2.1 Clear To Send (Circuit CB). -

a. Signals on this circuit are generated by the HSCE to indicate that it is prepared to transmit data.

b. The ON condition is a response to the ON condition on the Request to Send line (Circuit CA), delayed as may be appropriate for establishing a communication channel to a remote data processing terminal.

c. When the Request To Send signal is turned OFF, the Clear To Send signal shall also be turned OFF.

d. In Transmit-Only service, if the HSCE is arranged to be in transmit condition at all times, then the Clear To Send signal shall be in the ON condition at all times.

3.4.2.2 Data Set Ready (Circuit CC). -

a. Signals on this circuit are generated by the HSCE to indicate it is ready to operate.

b. The OFF condition shall be used to indicate:

(1) Any condition which disables any normal function associated with the class of service being furnished.

(2) The communication channel is switched to an alternate means of communication.

(3) The HSCE is not connected to a communication channel.

c. The ON condition shall appear at all other times; however, the ON shall not be interpreted either as an indication that a communication channel has been established to a remote station or the status of any remote station or equipment.

3.4.3 Ground. -

3.4.3.1 Protective Ground - (Circuit AA). - This conductor shall be electrically bonded to the machine or equipment frame. It may be further connected to external grounds as required by applicable regulations.

3.4.3.2 Signal Ground - (Circuit AB). - This conductor establishes the common ground reference potential for all interchange circuits except the Protective Ground. It may be connected to the frame or to the Protective Ground as required by applicable regulations or to minimize the introduction of noise into electronic circuitry.

3.4.4 Electrical Signal Characteristics. - The electrical signal characteristics for the signals used in the MEU interface with the HSCE shall be in accordance with EIA RS-232-A.

The following definitions shall apply:

Transmitted Data Binary State	One	Zero
Transmitted Data Signal Condition	Mark	Space
Control Circuit Functions	OFF	ON
D.C. Voltage Level (nominal)	-6v	+6v

3.5 Interface with the Magnetic Tape Recorder. -

3.5.1 From the TDP to the MTR. -

3.5.1.1 Transmitted Data. -

a. Signals on this circuit is the high speed data being transmitted which is sent to the FR-600 for recording on magnetic tape.

b. The waveform characteristics for this signal shall be the same as the Transmitted Data sent to the HSCE.

3.5.1.2 Transmitter Signal Element Timing. -

a. Signals on this circuit is signal element timing information which is sent to the FR-600 for recording on magnetic tape.

b. The waveform characteristics for this signal shall be the same as the Transmitter Signal Element Timing sent to the HSCE.

3.5.2 From the MTR to the TDP. - The following signals may be present whenever the FR-600 is in operation (either in the "Record" or "Reproduce" modes). The signals are not to be acted upon unless the MEU is in the "Playback" mode.

REV

3.5.2.1 Reproduced Data. - Signal on this circuit are the reproduced information from the recorded Transmitted Data input.

3.5.2.2 Reproduced Timing. - Signals on this circuit are reproduced information from the Transmitter Signal Element Timing input.

3.5.3 Electrical Signal Characteristics. - The electrical signal characteristics for the signals used in the MEU interface with the MTR shall be as follows:

a. From the MEU to the MTR. -

Transmitted Data Binary State	One	Zero
Transmitted Data Signal Condition	Mark	Space
Transmitter Signal Element Timing	OFF	ON
D.C. Voltage Level (nominal)	-6v	+6v

b. From the MTR to the MEU. - Suitable interface circuitry shall be provided in the MEU to accept the reproduced signal from the FR-600 which differs from the recorded signal as follows:

Output Impedance		1000 ohms
Output Level	1.0v rms	(10,000 ohms or greater output load.)

3.6 Mechanical. -

3.6.1 Racks. - The MEU shall be capable of being housed in Collins Radio Company standard computer type racks with 24" RETMA standard panel width, 26" deep and not to exceed 9-9/16" high.

3.6.2 Finish. - Front panel shall be black finished in accordance with Collins Radio Company;s process specification 580-0106-00, or equivalent approved by Collins Radio Company.

3.6.3 Identification. - The equipment nomenclature shall appear on the front panel on a nameplate, engraved or silkscreened. The manufacturer's identification and identification number, Collins Radio Company's specification control part number and other pertinent data shall be located at the rear of unit.

3.6.4 Connectors. -

3.6.4.1 Signal. - The connector(s)(and mating plugs) shall be provided on the rear of the unit.

a. Interface with the TDP - connector type is to be selected by Collins Radio Company.

b. Interface with the HSCE - A 25-pin male connector shall be used with pin arrangements as specified in EIA RS-232-A where applicable.

REV

c. Interface with the MTR - All signal inputs and outputs of the MEU and the FR-600 shall be made through BNC connectors.

3.6.5 Power. - A three prong twist plug shall be provided on the rear of the unit.

3.6.6 Cables. - The contractor shall not provide any interchange cables. The following design information is applicable:

3.6.6.1 Interface with the HSCE. - This cable shall be less than 50 feet in length and shall be terminated with a male connector at the HSCE.

3.6.6.2 Interface with the MTR. - The interchange cables shall be coaxial cable type RG 58 C/U.

3.6.7 Cooling. - The MEU shall be capable of being forced air cooled by blowers provided in the Collins rack.

3.6.8 Construction. - The MEU shall be of modular type construction so that the electronics circuitry can be readily replaced in the event of circuit failure.

3.7 Environmental. -

3.7.1 Shipping and crated outside storage (non-operating). -

3.7.1.1 Temperature. - -55^{o} to $72^{o}C$.

3.7.1.2 Humidity. - 0% to 100% relative humidity.

3.7.1.3 Shock and Vibration. - Withstand transportation and handling by common carriers over unusually rough terrain.

3.7.1.4 Desert Environment. - No damage to component parts from sand or dust storms.

3.7.2 Equipment operating with shelter and temperature and humidity control. -

3.7.2.1 Temperature. - Operate to specifications from 0^{o} to $50^{o}C$.

3.7.2.2 Humidity. - Operate to specifications from 20% to 80% relative humidity.

3.7.2.3 Survive and operate but with degraded performance from 0% to 95% relative humidity.

3.7.2.4 Shock and vibration. -

3.7.2.5 Withstand normal shock and vibration encountered in a fixed installation.

3.7.2.6 Ocean environment. - No corrosion when located within one mile of salt water.

3.7.2.7 Desert environment. - No damage to component parts from sand or dust storms.

3.8 Reliability assurance.-

3.8.1 Mean-time-between-failure estimate.- An estimate shall be prepared of equipment MTBF based on previously obtained operating life test data for equipments of the same or similar design. The test conditions used during such tests shall be specified, particularly external parameters such as ambient temperature, cooling method, electrical load and general environmental conditions. If life test data are not available, the supplier shall submit instead an MTBF prediction based on parts population and electrical/thermal stress analysis.

3.8.2 Stress derating schedule.- An abbreviated list shall be submitted which describes the average or maximum electrical/thermal stress existing for the various families of electrical parts used in this equipment. The list shall cover, as a minimum, all high usage electrical part types such as transistors, electron tubes, diodes, resistors, capacitors, and transformers where applicable. Submission of an existing design guidance chart which specifies maximum allowable stress ratios referred to part manufacturer's rating will normally satisfy the requirements of this paragraph.

3.8.3 Detailed parts stress analysis.- A detailed stress analysis shall be submitted which related the electrical and thermal stress for each electrical part used in the equipment to the rated value for that part. The analysis shall be based on a specified average inlet air temperature and on the use of the cooling method normally required for the equipment. Values used for electrical stress may either be measured or computed values. Values for part ambient temperature and average temperature rise for the equipment enclosure shall not be obtained by thermal measurements; a minimum of ten measured hot-spot temperature values shall be used for defining the equipment thermal profile. The analysis shall cover each different stage or circuit function within the equipment and shall provide a stress rating for each electrical part in that stage. Stages or other circuit groupings that are used more than once need not be repeated in the analysis report.

Collins Information Science Center shall provide assistance to the Supplier, if desired, in determining a suitable format for preparation of the stress analysis report. It may be desirable for the supplier to combine this stress analysis with a detailed MTBF computation that may also be required (Ref. paragraph 3.8.1 above).

3.9 Maintainability assurance.-

3.9.1 Mean-time-to-repair estimate.- An estimate shall be submitted of the equipment mean-time-to-repair (MTTR) based on the supplier's repair experience with equipments of the same or similar design.

REV

3.9.2 Preventative maintenance.- The supplier shall describe the nature and extent of periodic preventative maintenance that is required during the useful life of the equipment in order to obtain maximum operational reliability. This description may be abbreviated in form and need not contain lengthy maintenance schedules or procedures.

3.9.3 Detailed maintenance procedures.- The supplier shall provide schedules and procedures for performing preventative and emergency maintenance on the equipment. This information may be part of an existing instruction manual and need not be supplied separately.

4. QUALITY ASSURANCE PROVISIONS

4.1 In general, the supplier shall be responsible for the overall quality of all equipments supplied under this specification . The supplier shall maintain a quality control system which conforms with Part I of Collins Quality Assurance Procedure QAP-100.

4.2 In addition to the general requirements stated above, the supplier shall comply with those special Quality Requirements from Part II of QAP-100 that may be specified in the Purchase Order.

4.3 Test procedures will be submitted to Collins Radio Company for approval in accordance with Collins Radio Company TRL-126-0437. This test procedure must demonstrate that the equipment complies with the specification.

4.4 A pre-delivery acceptance test shall be performed at the contractor's plant and shall be witnessed by one or more Collins representatives. NASA representatives may also witness this test. This test shall be conducted by the contractor and the tests performed shall be the test outlined in the above acceptance test procedures.

5. PREPARATION FOR DELIVERY

5.1 The equipment shall be delivered as specified on the purchase order, subcontract, or letter.

5.2 The equipment shall be suitably packaged for shipment to the point specified.

6. NOTES

6.1 The class designation and the symbols CAL, TA, CR, RA, SSA and NSR, which may appear on this drawing, are for internal use only by Collins Radio Company and are not related to the engineering data contained herein.

6.2 Only the items listed on this drawing and identified by vendor's names, addresses, and part numbers have been tested and approved for specific applications in equipment designed by the Collins Radio Company. Substitute items shall not be used without prior testing and approval by the Collins Radio Company or the cognizant design activity if other than Collins Radio Company.