

Shuttle Flight Operations Manual

Volume 4B: S-band

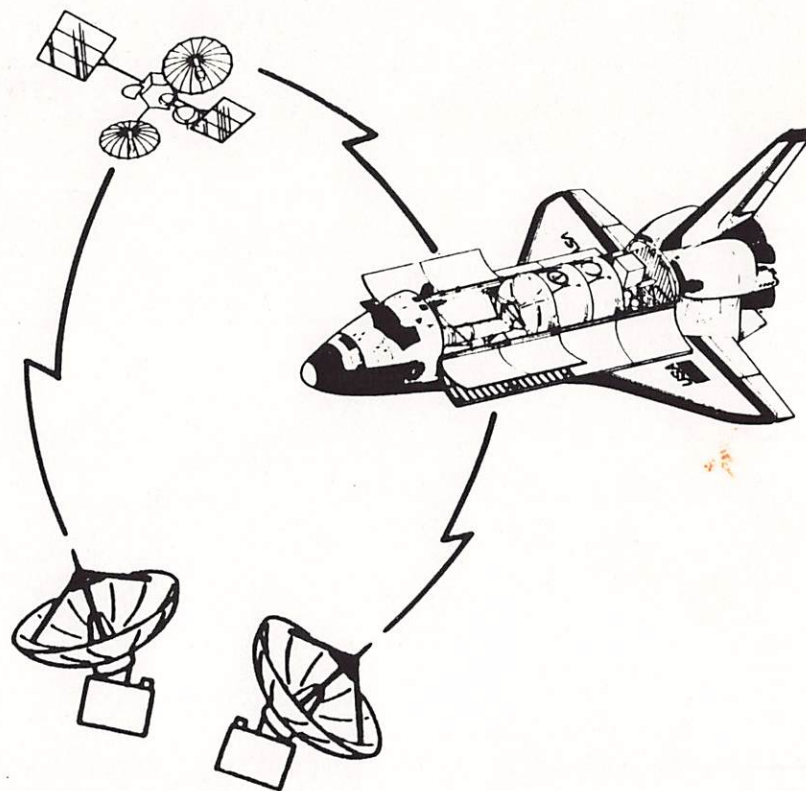
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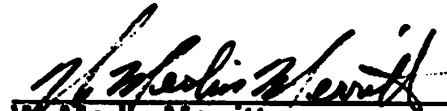
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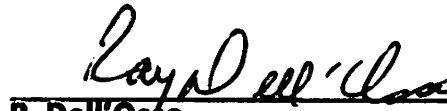
Shuttle Flight Operations Manual Volume 4B: S-band

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Approved by:



W. Merlin Merritt
Head, Communications and Instrumentation



R. Dell'Osso
Chief, Systems Training Branch

Mission Operations Directorate
Training Division
Systems Training Branch

Tony M. Patiño, Jr.

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Section 1: Introduction

The S-band systems consist of seven black boxes of communication and data processing equipment aboard the Space Shuttle Orbiter. The equipment generates two types of radio frequency (rf) links with the ground control stations. Both links utilize electromagnetic waves in the 2-3 GHz range.

The Orbiter also generates communication links on wavelengths near 13-15 GHz (K-band) and 200-300 MHz (UHF). These links are discussed in other documents.

The S-band systems are two of four systems comprising the communications subsystems group.

The principal elements of the S-band system are grouped into two types of S-band subsystems. The phase modulation (PM) subsystem is the primary link between the Orbiter and, for brevity, the ground. This link carries the downlink digital voice and Orbiter telemetry, which includes general purpose computer (GPC) downlists and systems data. It also carries uplink digital voice and uplink commands. The technique of phase modulation is shifting of the carrier frequency's phase in proportion to the magnitude of the parameters being transmitted.

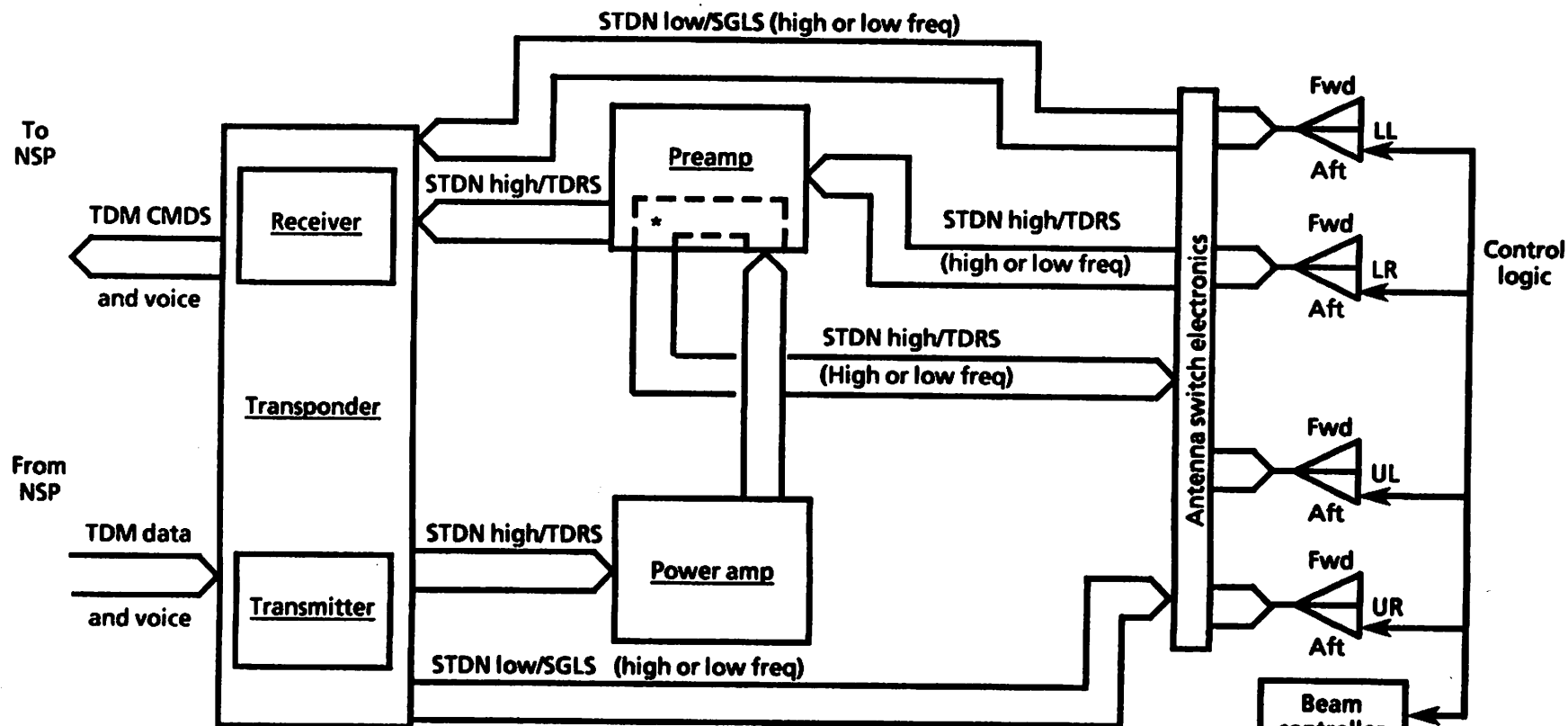
The other subsystem is frequency modulation (FM). This subsystem is used to transmit to the ground a variety of different types of data. These types include main engine data, TV, operational and payload recorder data, and data related to payloads. This subsystem transmits only to the ground. There is no uplink into this subsystem via rf. The technique used to transmit this data is called frequency modulation. This technique shifts the carrier frequency's value or frequency in proportion to the magnitude of the parameters being transmitted.

PM Subsystem

The PM subsystem can best be described as a multi-functional transmit/receive communication link. Figure 1-1 shows a block diagram representation of the PM subsystem. Incoming signals are passed from one of four "quad" antennas which support the PM subsystem to the S-band antenna switch to the preamplifier. The preamplifier will do one of two signal processings depending upon the control and moding of the PM system. In one mode the preamp will take the signal from the antenna and amplify it before passing it to the transponder. In the other mode, the preamp will take the signal from the antenna and pass it along to the transponder unamplified. The transponder will take this signal and retransmit a signal in phase to the one received from the preamplifier at a fixed ratio to the received signal. This is called coherent turnaround. This retransmitted signal is received on the ground where the two-way doppler shift is measured to obtain the relative velocity of the Orbiter with respect to the ground station.

The transponder also rf demodulates the incoming signal, which is a multiplexed combination of commands and digitized voice. In addition, there may be a 1.7 MHz sub-carrier ranging signal present. The ranging signal is immediately retransmitted back to the ground where the elapsed two-way propagation time is used to calculate the range of the Orbiter from the ground station. The rf demodulated command/voice signals are routed to the network signal processor (NSP).

The NSP demultiplexes the commands and/or voice. The commands are sent to the command buffer where they are accessed by the command multiplexer-demultiplexer (MDM). The voice signals are converted from digital to analog and sent to the audio distribution subsystem and thereby, to the crew.



*NOTE: The PA routes the STDN high/TDRS data to the Preamp which routes the data to the switch beam antennas.

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Figure 1-1.- S-band PM subsystem block diagram.

The outgoing signal path is the reverse of the incoming path except the signal detours through the power amplifier. The power amp is like the preamp in that the control and moding will cause the power amp to either process and amplify the signal or not. For outgoing data, the separate functions of the NSP and transponder are essentially reversed. The NSP will digitize voice and multiplex it with telemetry from the operational instrumentation (OI) system and send it to the transponder. The transponder phase modulates the carrier frequency with the data from the NSP before sending it on to the power amp. The NSP also has an additional function for the multiplexed data. It sends the data to the operations recorders (ops recorders) for recording and later playback through the FM system.

FM Subsystem

The FM subsystem is made up of the FM signal processor, the FM transmitter, the FM rf switch, the FM portion of the S-band antenna switch and the FM hemi antennas. The primary function of this communication subsystem is to provide another rf path to the ground to support other data type requirements. This link provides such things as live or taped video of crew or space activities, playback of data recorded when the Orbiter was out of view of a ground tracking station, or playback/realtime payload data during payload operations. Figure 1-2 shows a block diagram of how the boxes are connected. The FM signal processor (FMSP) receives data or signals from the following sources: the ops recorders, payload recorders, TV, main engine data (ME), or a variety of data/signals from the payload station distribution panel (PSDP) which can be either digital or analog. These signals are then routed to the FM transmitter to modulate the carrier for transmission to the ground station. Only one of the above mentioned inputs can be routed to the transmitter at a time. The transmitter output is routed through the rf

switch and then into the antenna electronics. The antenna electronics, which has its internal switches controlled by the GPC, then relays the transmitter signal to the selected antenna, the upper or lower.

The FM transmitter receives signals from the FMSP and passes them to the FM rf switch after imposing them onto an S-band carrier and amplifying the resulting signal. The FM transmitter interfaces with the ground command interface logic controller (GCILC) and MDM PL-1 and is singly redundant. The FM rf switch takes the output of the two FM transmitters (of which only one is active at a time), and passes it to the S-band FM section of the antenna electronics.

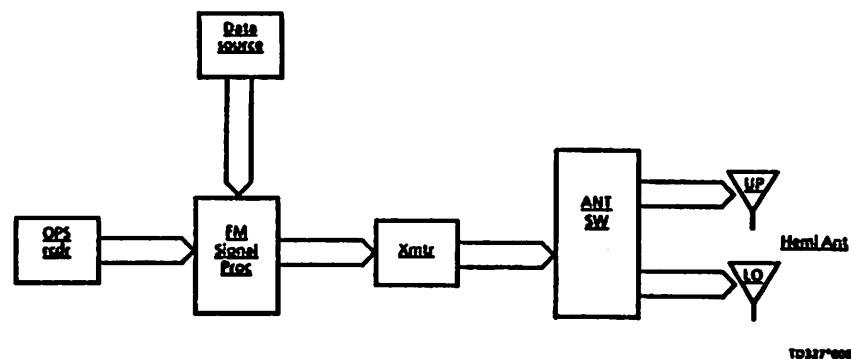


Figure 1-2.- S-band FM system functional block diagram.

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Section 2: System Interfaces

Ground Command Interface Logic Controller

The ground command interface logic controller (GCILC) is a vital and integral part of the communications subsystem. The main function of this device is to accept uplink commands via the PL MDMs 1 and 2, decode the commands, and output the appropriate control signals to switch, activate, etc., the corresponding communication line replacement unit (LRU). This is also the device by which switch control functions are implemented; i.e., a switch is positioned and its control signal goes into the GCILC and the GCILC outputs the appropriate signal or signals to the affected LRUs. The S-band PM and FM portions of the K-band Comm/Radar, PL Comm, and closed-circuit television (CCTV) are the subsystems which are controlled using the GCILC.

The GCILC consists of two PL MDM data buffer cards which detect and decode commands destined to the GCILC and route them to 16 decoder driver cards. The decoder driver cards have dual-redundant prom decoders which set discrete off or discrete on commands to the respective hybrid driver card. The hybrid driver cards provide the discretizes to the particular LRUs to perform the various switching functions.

Figure 2-1 shows a representation of the GCILC in block form. There are 16 decoder driver cards, 15 with 16 hybrid drivers and 1 with 10 hybrid drivers.

Figure 2-2 shows a schematic of the hybrid driver. The driver sense is used by the multiplexer to tell the present state of the output panel driver. This is used to set the

command driver to the state that the panel driver is in when the GCILC is configured from a panel to a command configuration. The series interlock input is used by the driver to inhibit the command driver output until all the series interlocked drivers associated with that command driver are turned on. The command power is an external line that will power the command driver. This power can be either a main bus or a control bus. The interlock output is used by other hybrid drivers to inhibit their output to simulate the mechanical interlock of a switch. Driver output and telemetry output are self explanatory. The switch power is like the command power input except it will be only control bus power.

Earlier there was mention of a command mode and a panel mode. A description of each mode follows to explain their function. There are five switches in the Orbiter that configure the S-band PM, FM, PL Comm, K-band, and CCTV for panel or command mode. The panel mode allows the panel switches to drive the outputs of the GCIL to switch, turn on, etc. the associated LRUs. In the command mode, the GCIL is configured to accept ground commands or SPEC1 entries to drive the outputs of the GCIL. In the command mode the panel switches can be moved but will have no effect on the system.

Systems Power Interfaces

The S-band system operates from the Orbiter primary power source. It uses the main dc power busses A, B, and C, with steady state limits of 24 to 32 volts. The S-band system does not interface directly with the essential dc power source.

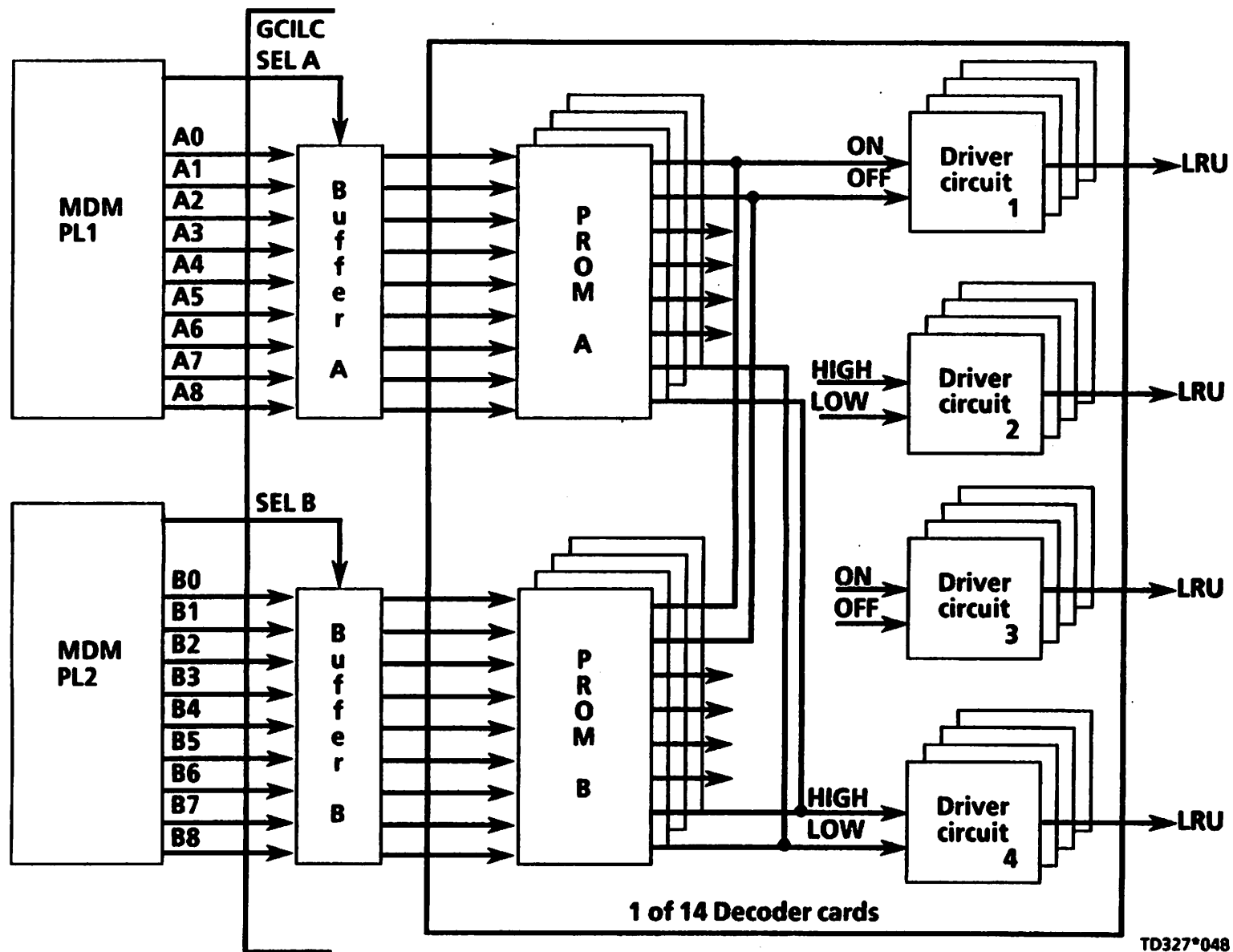
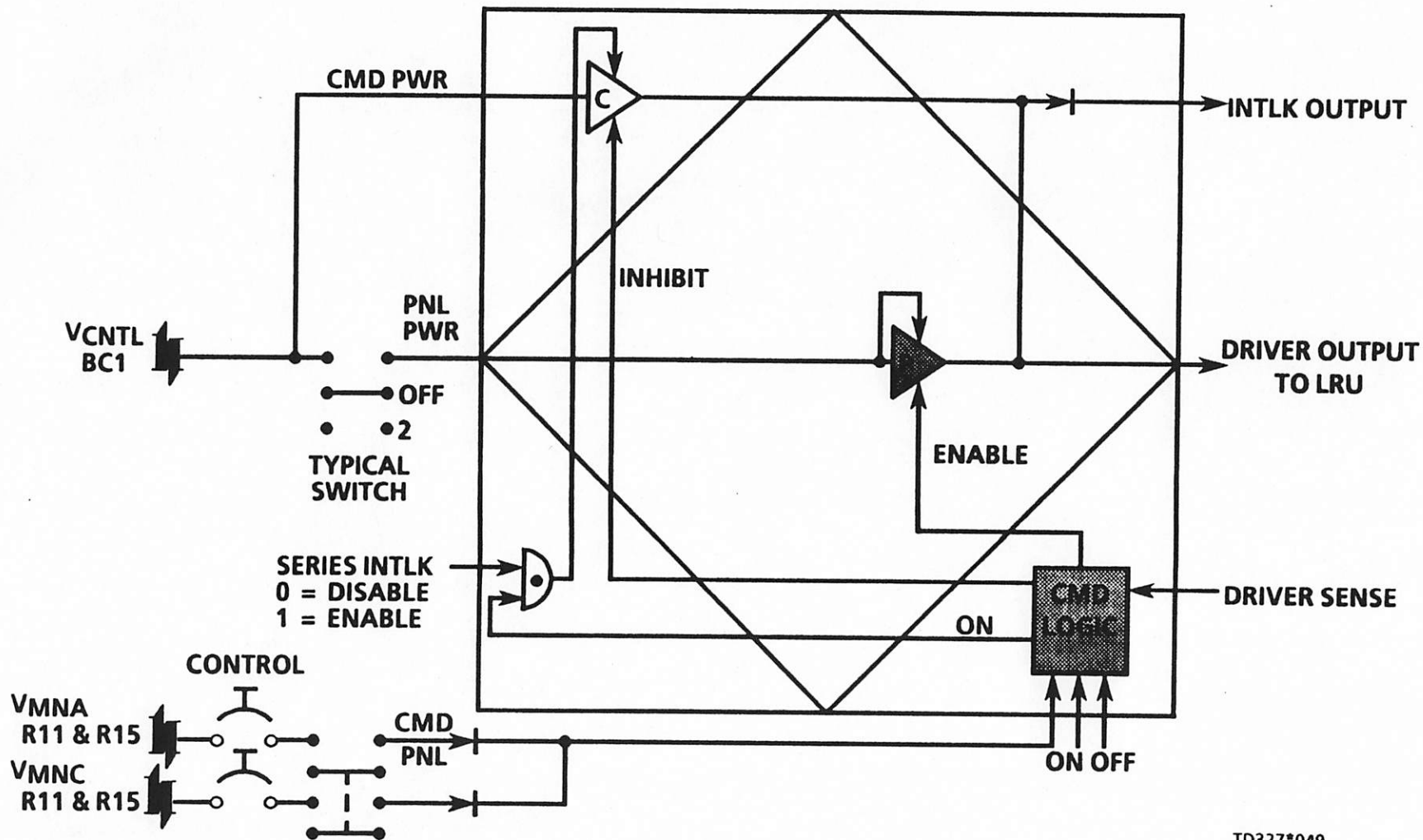


Figure 2-1.—Representation of the GCILC in block form.

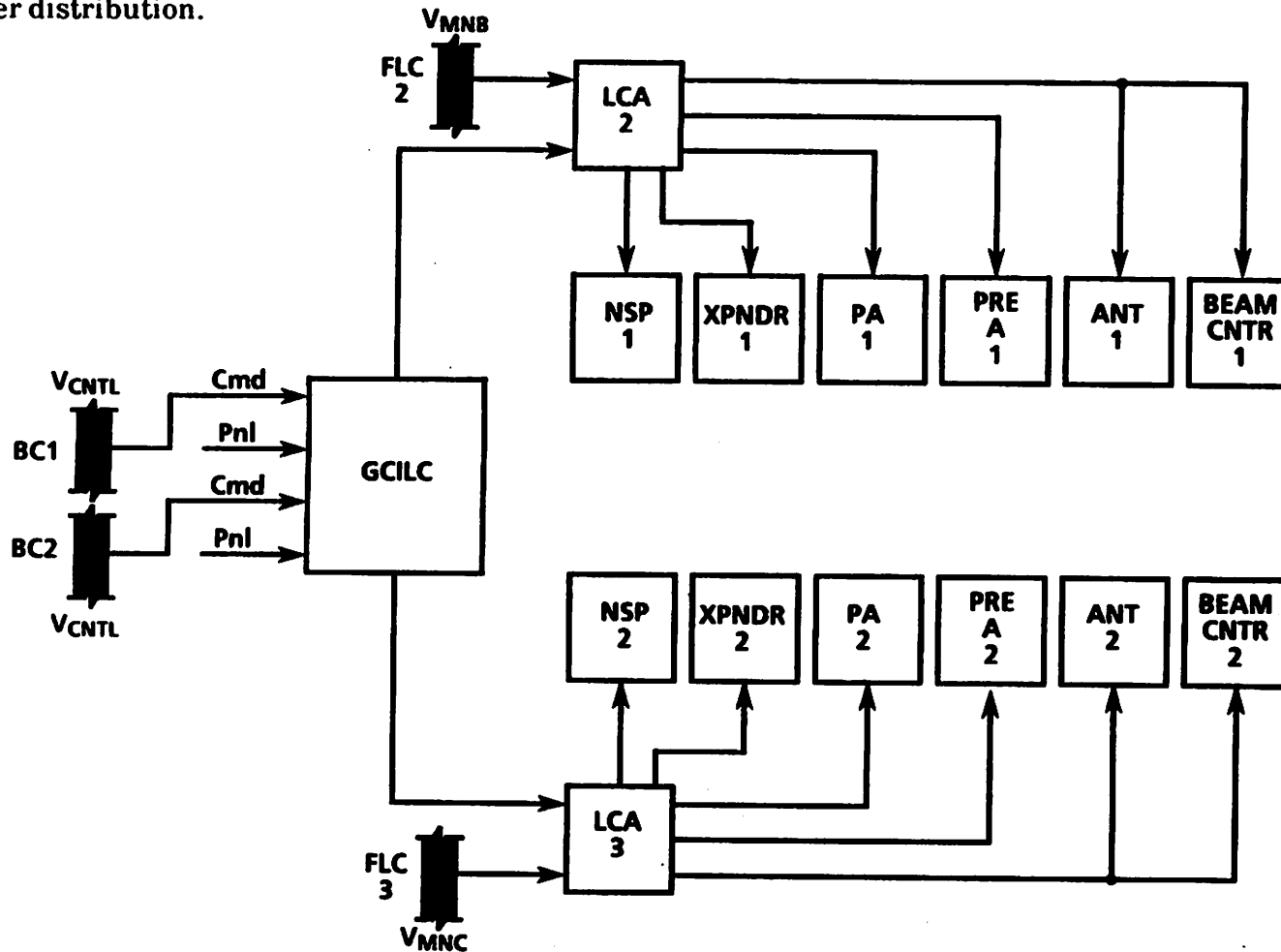


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Figure 2-2.- Diagram of the hybrid driver.

PM Subsystem Power Distribution

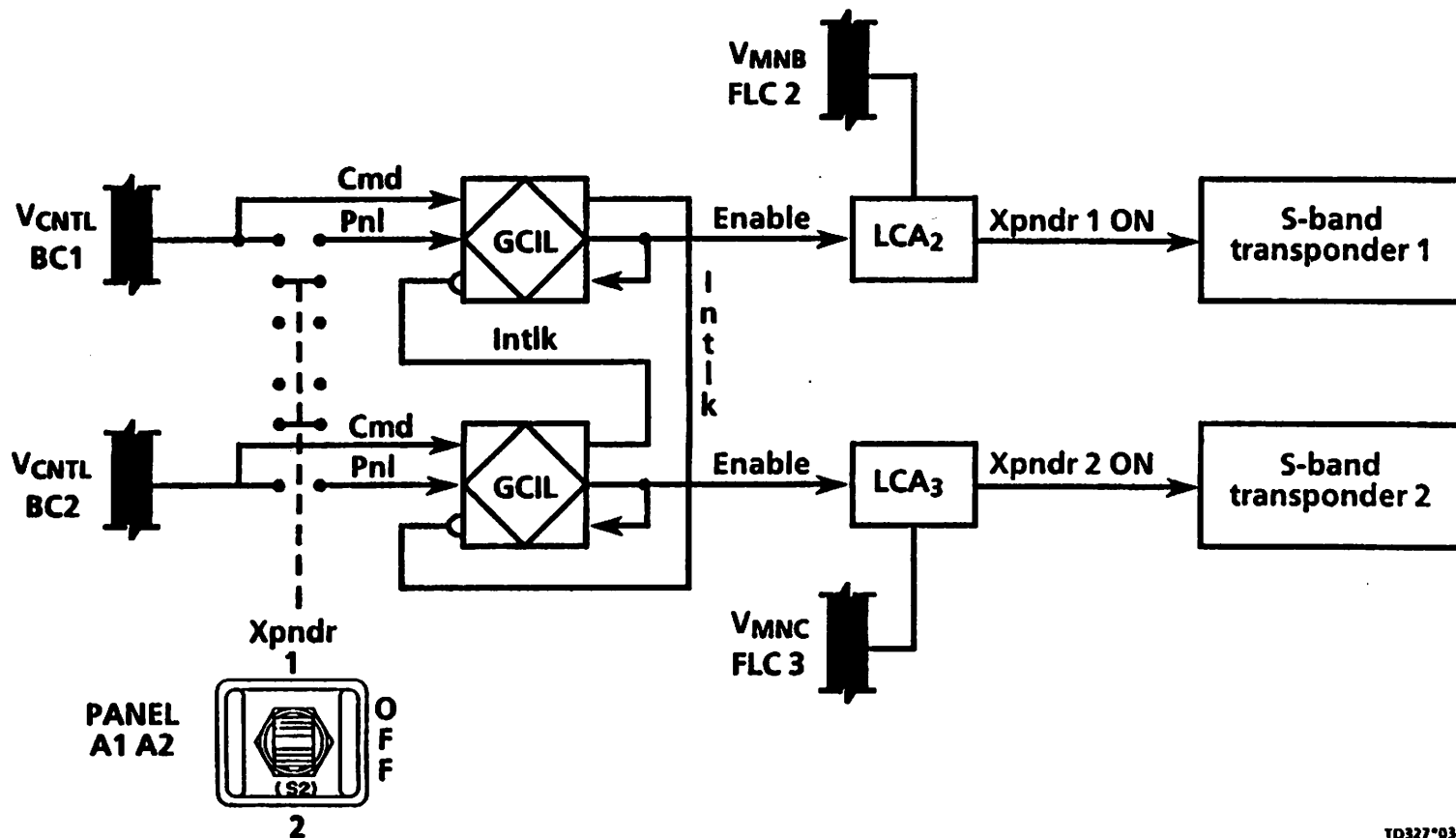
The PM subsystem is powered primarily by main dc busses B and C. Main bus A interfaces at a single point at the remote power control (RPC) following ground command interface logic (GCIL) #10/8, supplying power amplifier #2 standby power. Reference figure 2-3 for a drawing of the power distribution.



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Figure 2-3.- S-band subsystem power distribution.

S-Band Transponder Power. Transponder #1 is powered from main B, forward load controller #2. Control is from control bus BC1. Transponder #2 is powered from main C, forward load controller #3. Control is from control bus BC2. Reference figure 2-4 for a drawing of the power distribution.

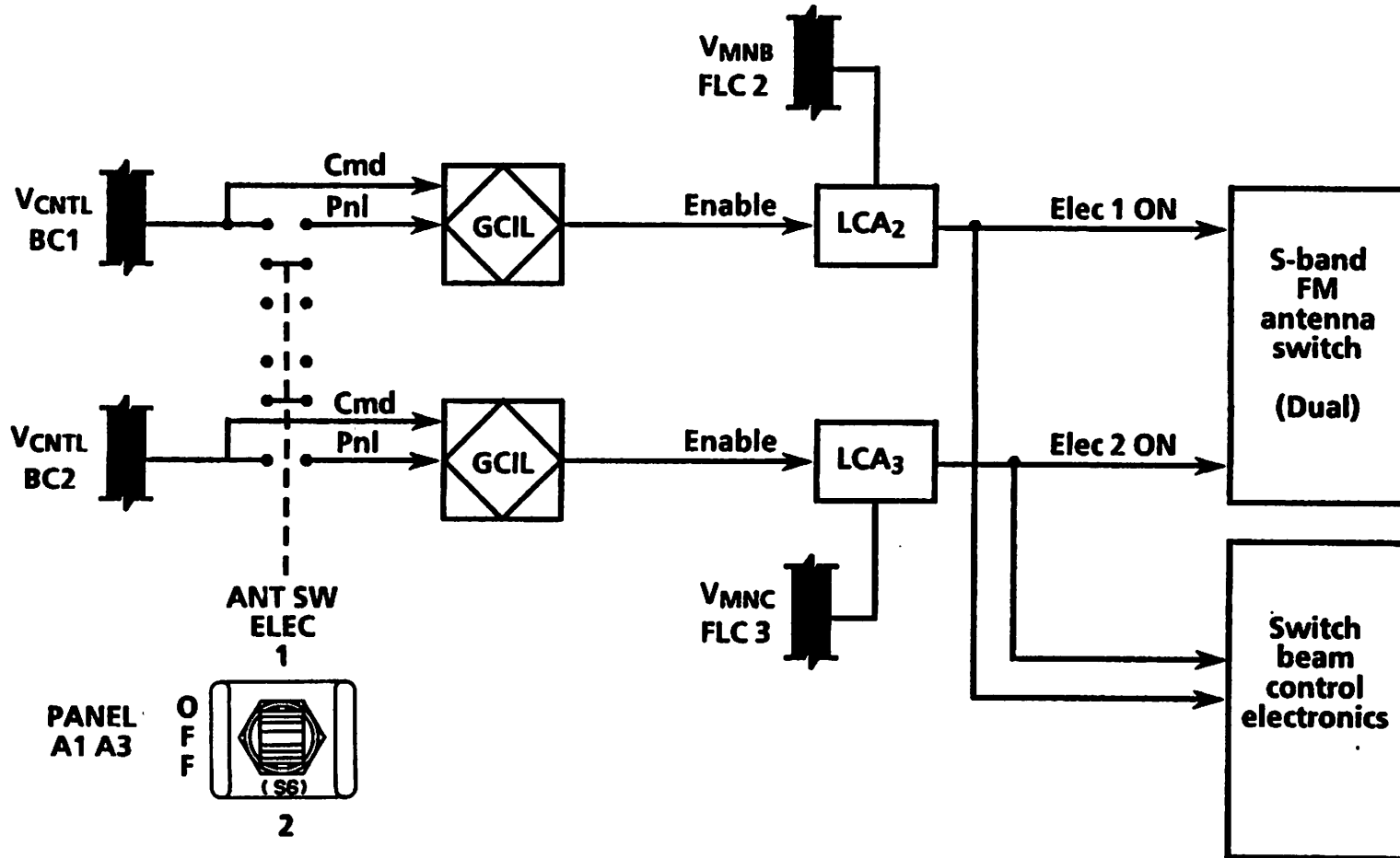


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Figure 2-4.- S-band transponder selection.

S-Band Antenna Switch Power (Quad Section). The S-band antenna switch is a dual unit in a single case. It is further divided into PM sections and FM sections. The FM section's power and control are discussed in the FM Subsystem Power Distribution subsection. The PM section's #1 unit is powered from main B, load control assembly

#2. It is controlled by GCIL with control bus BC1. The PM section's #2 unit is powered from main C, load control assembly #3. The #2 unit is controlled by control bus BC2 through GCIL. Reference figure 2-5 for a drawing of the power distribution.



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Figure 2-5.- S-band antenna switch selection and switch beam control electronics.

S-Band Power Amp Power. The S-band power amp is a dual unit in a single case. The unit #1 is powered from dc main bus B, forward power controller #2. Control signals come from control bus BC1. Operate control for #1 comes from main B, forward load controller #2. The unit #2 is

powered from dc main bus C, forward power controller #3. Unit 2 control power comes from control bus BC2. Operate control for #2 comes from main C, forward load controller #3. Reference figure 2-6 for a drawing of the power distribution.

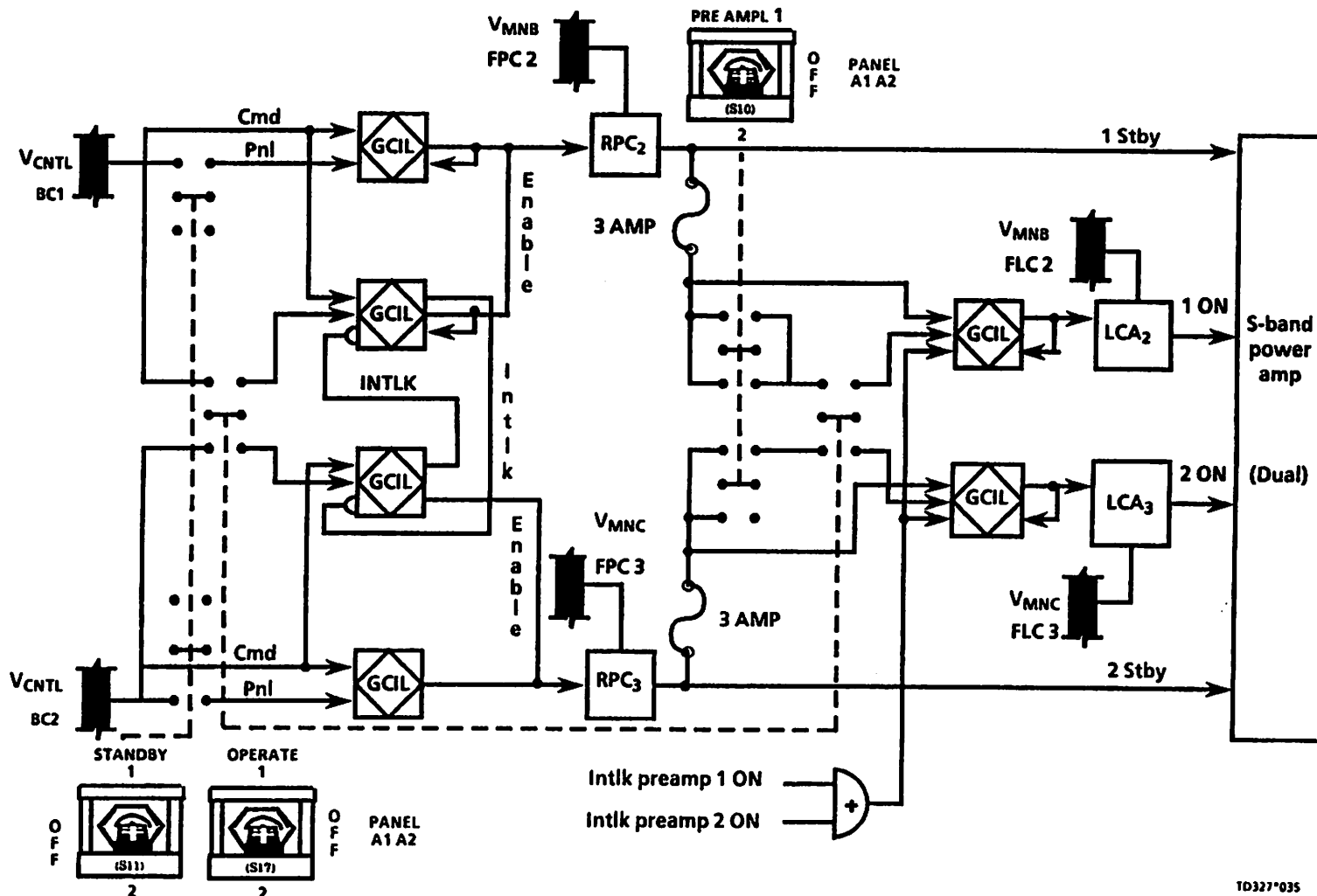


Figure 2-6.- S-band power amplifier selection.

S-Band Preamp Power. The preamp is also a dual unit in a single case. Unit #1 is powered from dc main B, forward load controller #2. Control is from control bus BC1 through GCIL. Unit #2 is powered from dc main C, forward load controller #3. Unit #2 control is from control bus BC2. Both of the above units have a pair of GCILs

assigned to them controlling heater circuits and power circuits. Unit #1 has GCIL controlling its heater and GCIL controlling its power. Unit #2 has GCIL controlling its heater and GCIL controlling its power. Reference figure 2-7 for a drawing of the power distribution.

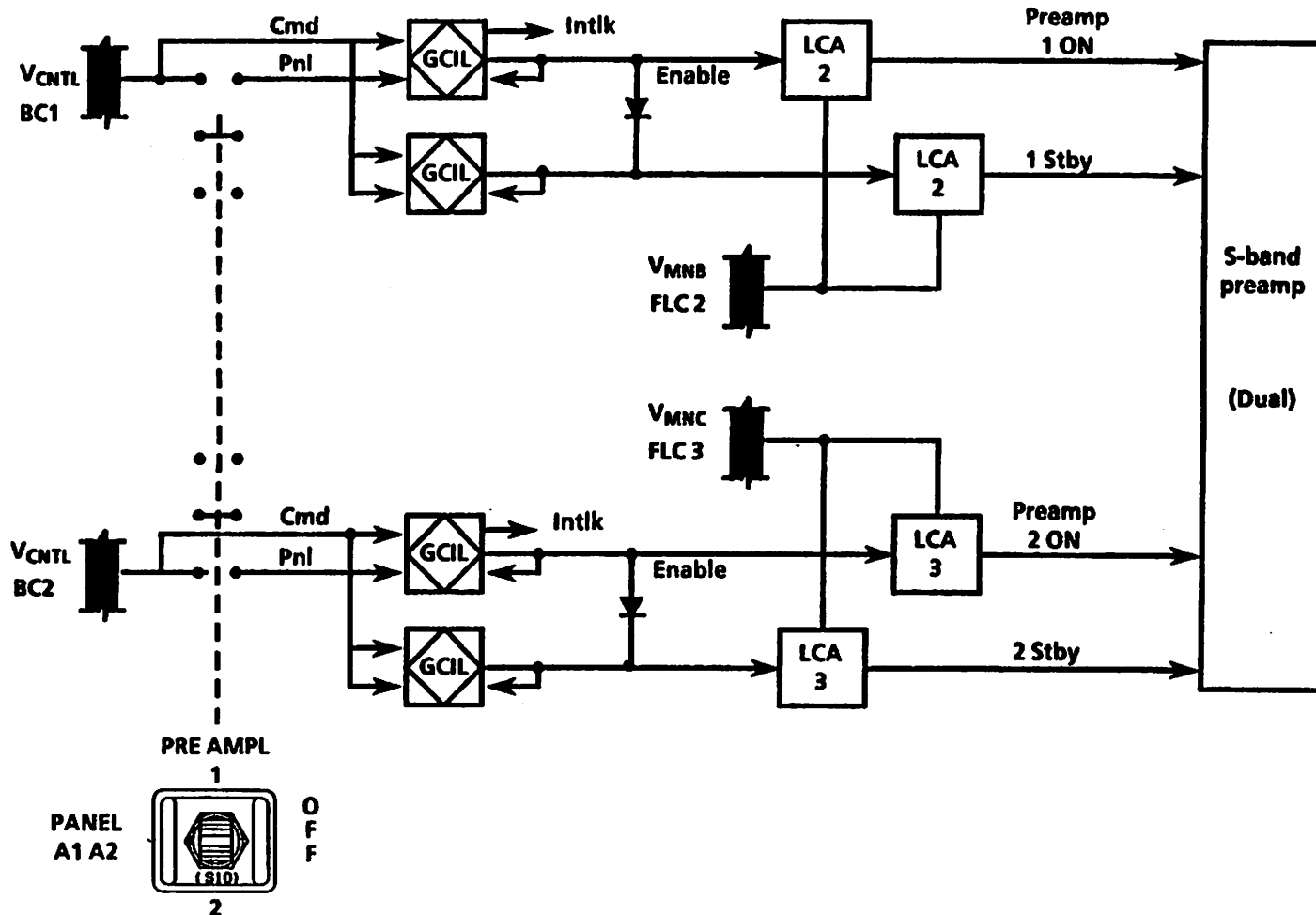


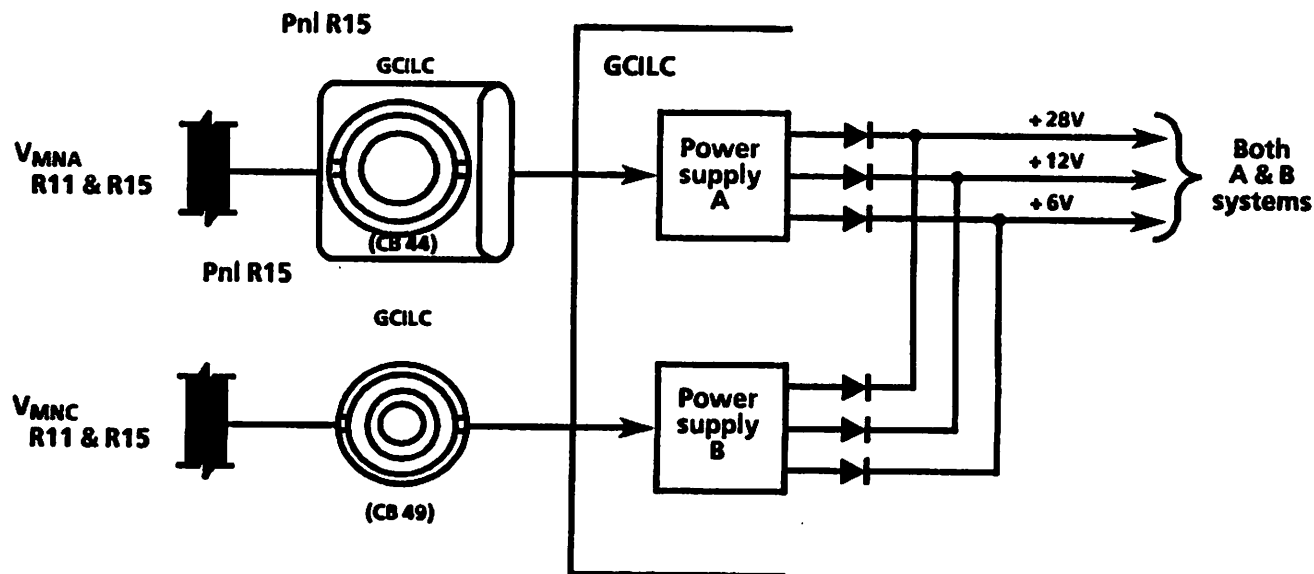
Figure 2-7.- S-band preamplifier selection.

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GCIL Power

The GCIL is another dual unit within one case. It has systems A and B powered by dc mains A and C. Redundancy is incorporated by driving power supply A19 within

the GCILC with main A, and driving power supply A20 with main C. Both supply A19 and A20 are connected through isolator circuitry to both systems A and B. Reference figure 2-8 for a drawing of the power distribution.



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Figure 2-8.- GCILC power.

FM Subsystem Power Distribution

The FM S-band subsystem is powered by dc mains B and C, forward load controllers 2 and 3. Reference figure 2-9 for a drawing of the power distribution.

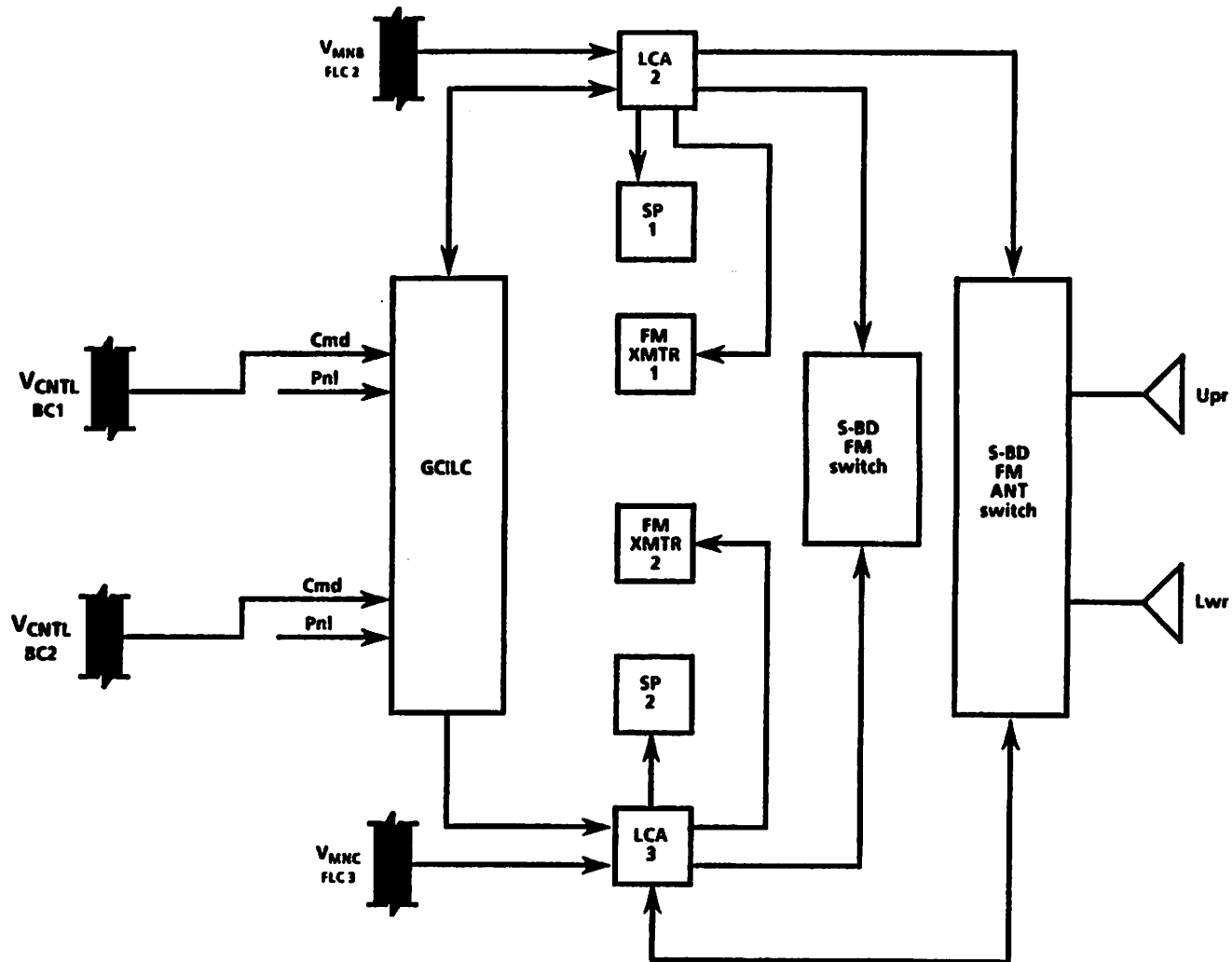


Figure 2-9.— S-band FM subsystem power distribution.

FM Signal Processor Power. The FMSP is a dual unit in a single case. Unit 1 receives power from dc main B, forward load controller #2. Control is exercised through GCIL driver from control bus BC1. Unit 2 receives

power from dc main C, forward load controller #3. Unit 2 control is exercised through GCIL driver from control bus BC2. Reference figure 2-10 for a drawing of the power distribution.

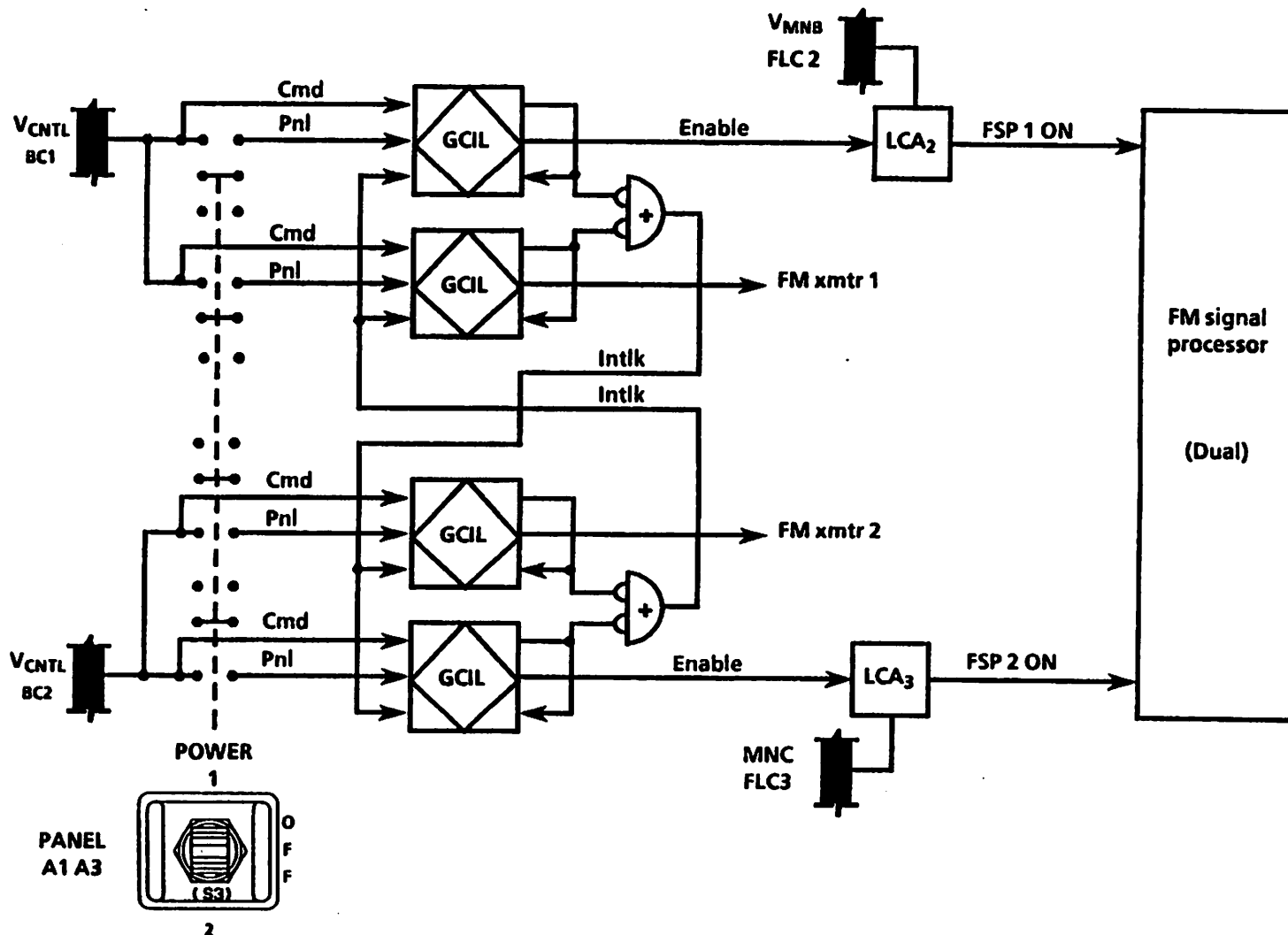
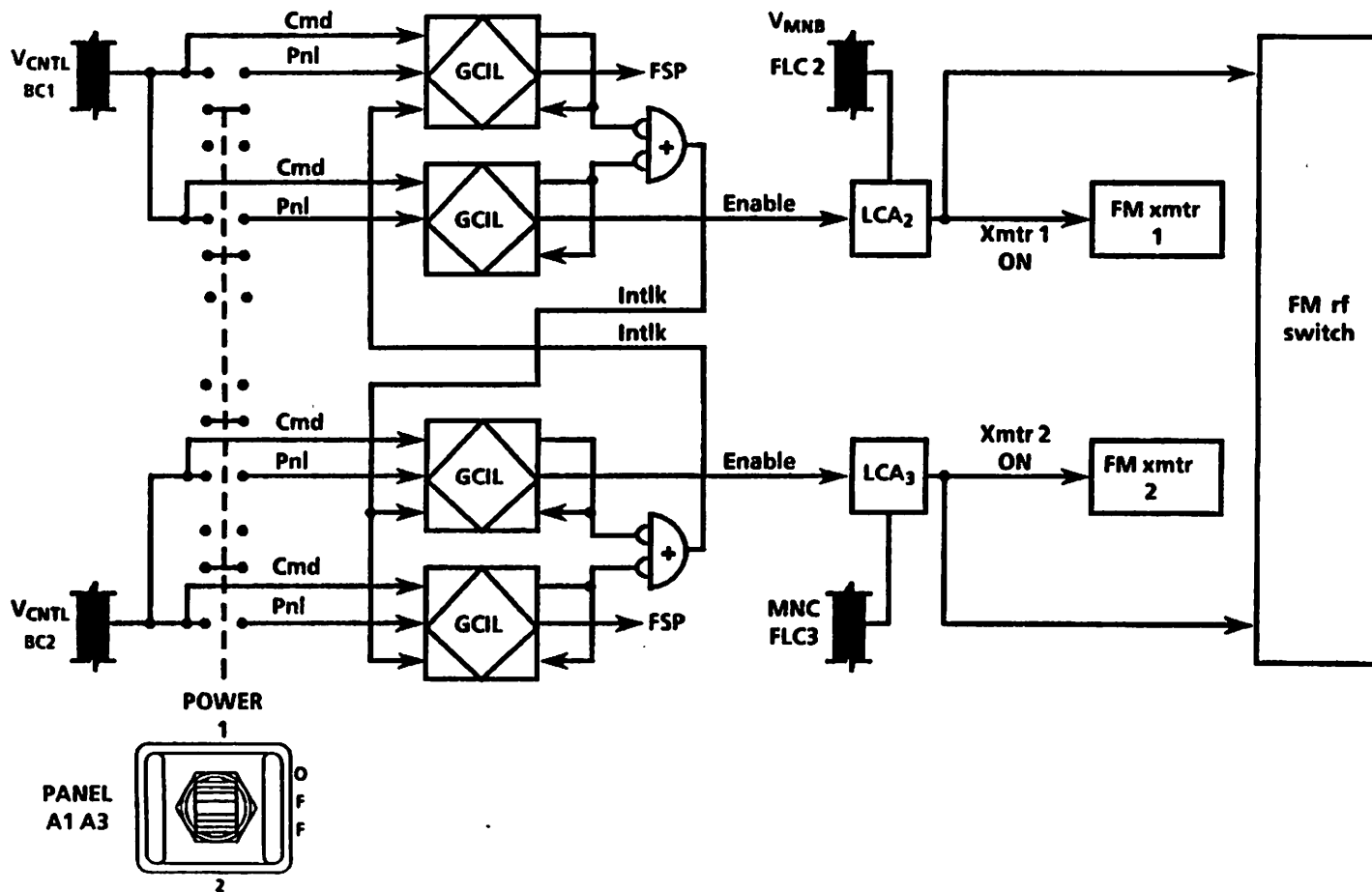


Figure 2-10.-- FM signal processor selection.

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FM Transmitter Power. The FM transmitter is two separate units in two separate cases. Unit #1 is powered from dc main B, forward load controller #2. Control comes through a logic circuit from GCIL driver and launch forward multiplexer #1 for "on" and "off" signals, respectively. GCIL driver receives control power from control bus BC1. Unit 2 is powered from dc main C,

forward load controller #3. Control also comes through a logic circuit from GCIL and launch forward multiplexer #1, for "on" and "off" signals, respectively. GCIL receives control power from control bus BC2. Reference figure 2-11 for a drawing of the power distribution.

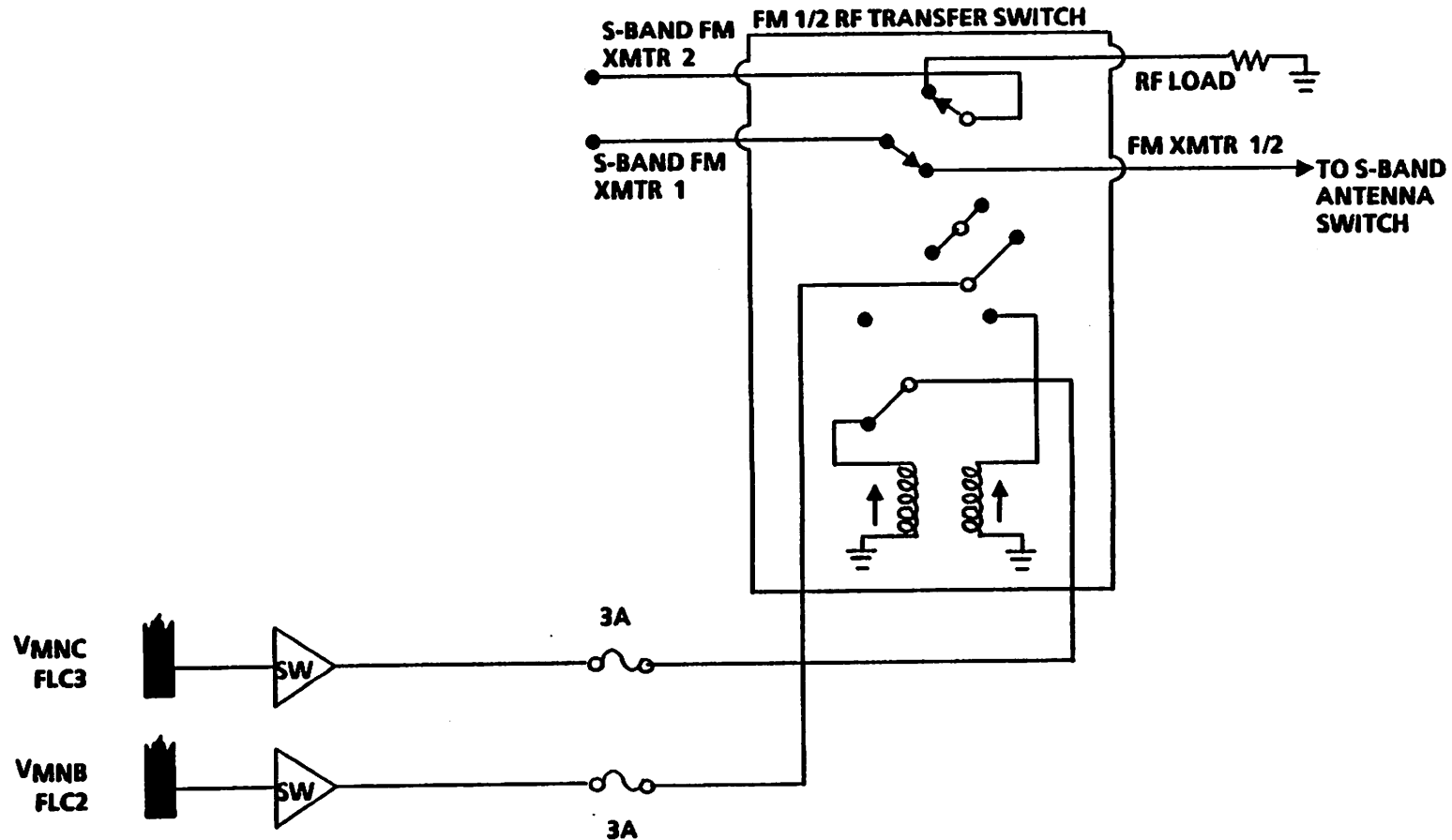


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Figure 2-11.—FM transmitter selection and FM rf switch power.

FM RF Switch Power. The FM rf switch takes power from both dc mains B and C. The solenoid which turns unit 1 on while turning unit 2 off takes power from main B through

FLC #2. The solenoid which reverses the above, takes power from main C through FLC #3. Reference figure 2-12 for a drawing of the power distribution.



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Figure 2-12.- S-band FM rf switch power.

S-Band Antenna Switch (Hemi Section). The S-band antenna switch is also a dual unit in a single case. It is further divided into PM sections and FM sections. The PM section's power and control was discussed earlier. The FM section's #1 unit is powered from main B, load control

assembly #2. It is controlled by GCIL with control bus BC1. The FM section's #2 unit is powered from main C, load control assembly #3. The #2 unit is controlled by control bus BC2 through GCIL. Reference figure 2-13 for a drawing of the power distribution.

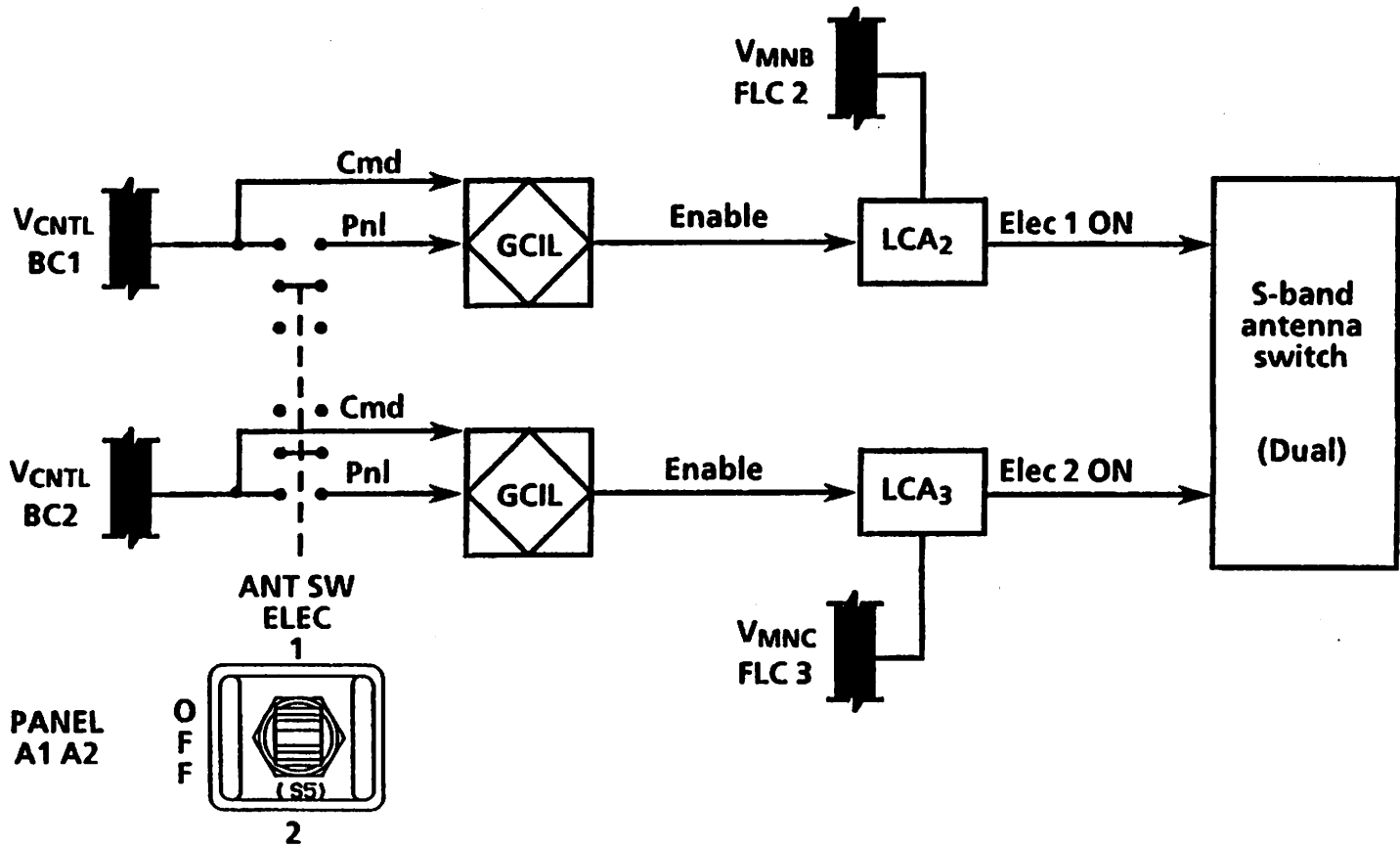


Figure 2-13.- S-band FM antenna switch selection.

GPC Interfaces

The last interface with the S-band system is with the general purpose computers (GPCs). Earlier, Section 1 mentioned that there were four "quad" antennas associated with the S-band PM subsystem and two "hemi" antennas with the S-band FM subsystem. The reason there are so many antennas is that for any Orbiter attitude, there needs to be an antenna that can communicate with either a ground tracking station or the tracking and data relay satellite (TDRS). Also, all antennas cannot radiate

all at once, so one has to be selected to transmit and receive. Therefore, one antenna is selected based upon Orbiter attitude and a line-of-sight vector to the tracking station. This is where the GPCs come into play.

The GPCs use the current Orbiter state vectors plus the predetermined tracking station locations, and compute a look angle that will determine which antenna to use. The GPC will then command, through the PL MDMs, the antenna electronics to switch to the designated antenna. Figure 2-14 shows a block diagram overview of the GPC and also the D and C interface for antenna selection.

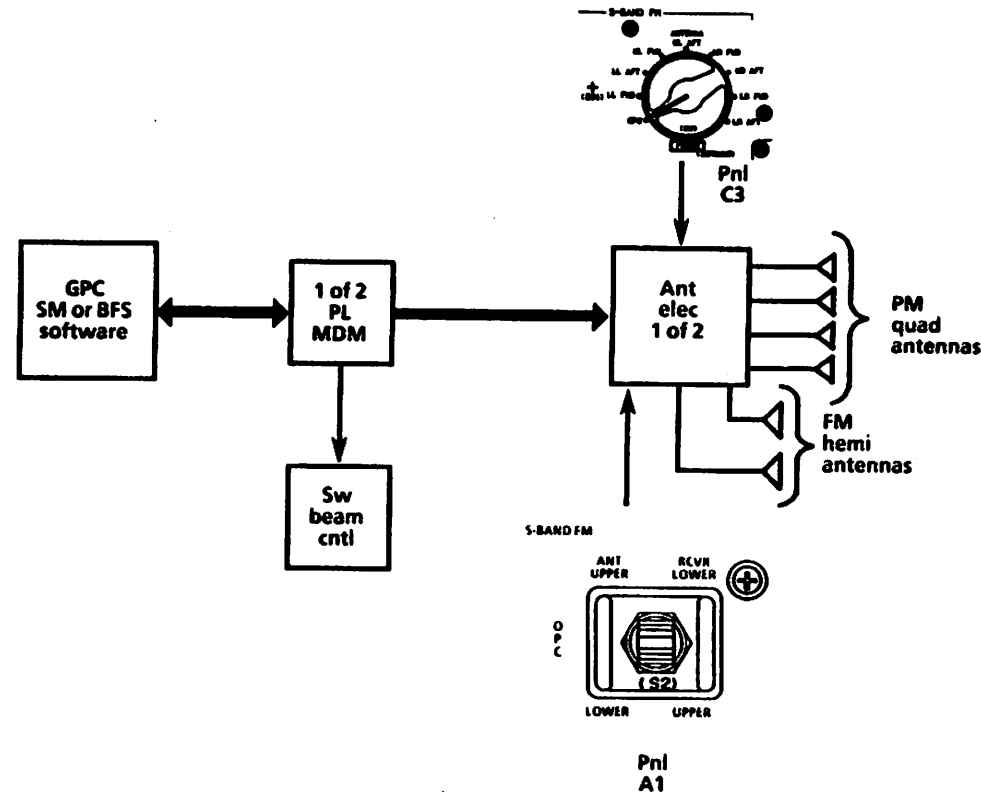


Figure 2-14.- Block diagram overview of the GPC.

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Section 3: Functional Description

PM System

S-Band PM Transponders

The transponder is a multimode S-band communications unit which operates in three primary modes: space ground link system (SGLS) direct, spaceflight tracking and data network (STDN) direct, and STDN HI power/tracking and data relay satellite (TDRS) and several secondary modes. The transponder supports full duplex communication in any of the primary modes, provides doppler turnaround during coherent operation, and provides tone ranging turnaround in two of the primary modes (STDN direct and STDN HI). Turnaround ranging is accomplished exclusively with tones on the 1.7 MHz subcarrier. The receive only mode supports uplink data reception and provides a coherent oscillator output for one-way doppler extraction.

A block diagram of the transponder is shown in figure 3-1. The transponder receiver searches for, acquires, tracks, and coherently demodulates either residual carrier PM signals (in the SGLS or STDN modes) or suppressed carrier phase shift keyed signals (in the TDRS mode). Acquisition of the spread spectrum code in the TDRS mode is accomplished prior to carrier acquisition. The receiver is configured as a Costas loop for carrier acquisition and tracking. Because of the low signal-to-noise ratio (SNR) operating threshold, the costas loop exhibits a potential false-locking problem when a suppressed carrier PSK data modulated signal is being acquired. The potential problem is operationally circumvented by allowing the carrier to be acquired prior to PSK modulation being

imposed. Symbol synchronization is performed in the network signal processor after carrier acquisition.

Functional Description

A functional transponder block diagram is shown in figure 3-1. The received signal, processed through the preamplifier LRU in the TDRS mode or through the transponder triplexer receive filter (high or low) in the SGLS or STDN direct link modes, is amplified by a low-noise S-band preamplifier prior to down conversion to approximately 240 MHz. A second coherent down conversion brings the signal to 31 MHz where, in the TDRS mode, despreading is accomplished by the spread spectrum processor which uses a noncoherent code search loop. The TDRS despread signal is routed to the Costas loop which is used to derive phase tracking information. In the SGLS and STDN modes of operation, the costas loop is also used to track the residual carrier.

Demodulation of NSP command data and ranging information is accomplished using an off-line wideband phase detector, so that the phase lock loop detector predetection bandwidths can be optimized for tracking performance. Both tone ranging and data outputs from the receivers are noncoherently automatic gain controlled (AGCed) to maintain modulation index and data voltage, respectively.

As shown in figure 3-2, all frequencies are derived from two switchable voltage-controlled crystal oscillator (VCCO) subassemblies and one reference crystal oscillator. The reference oscillator operates at 31 MHz and thus places the second intermediate frequency (IF) at 31 MHz. This is sufficiently high in frequency to provide good first IF image rejection and still allow the use of narrowband second IF filters. Channel selection is provided by

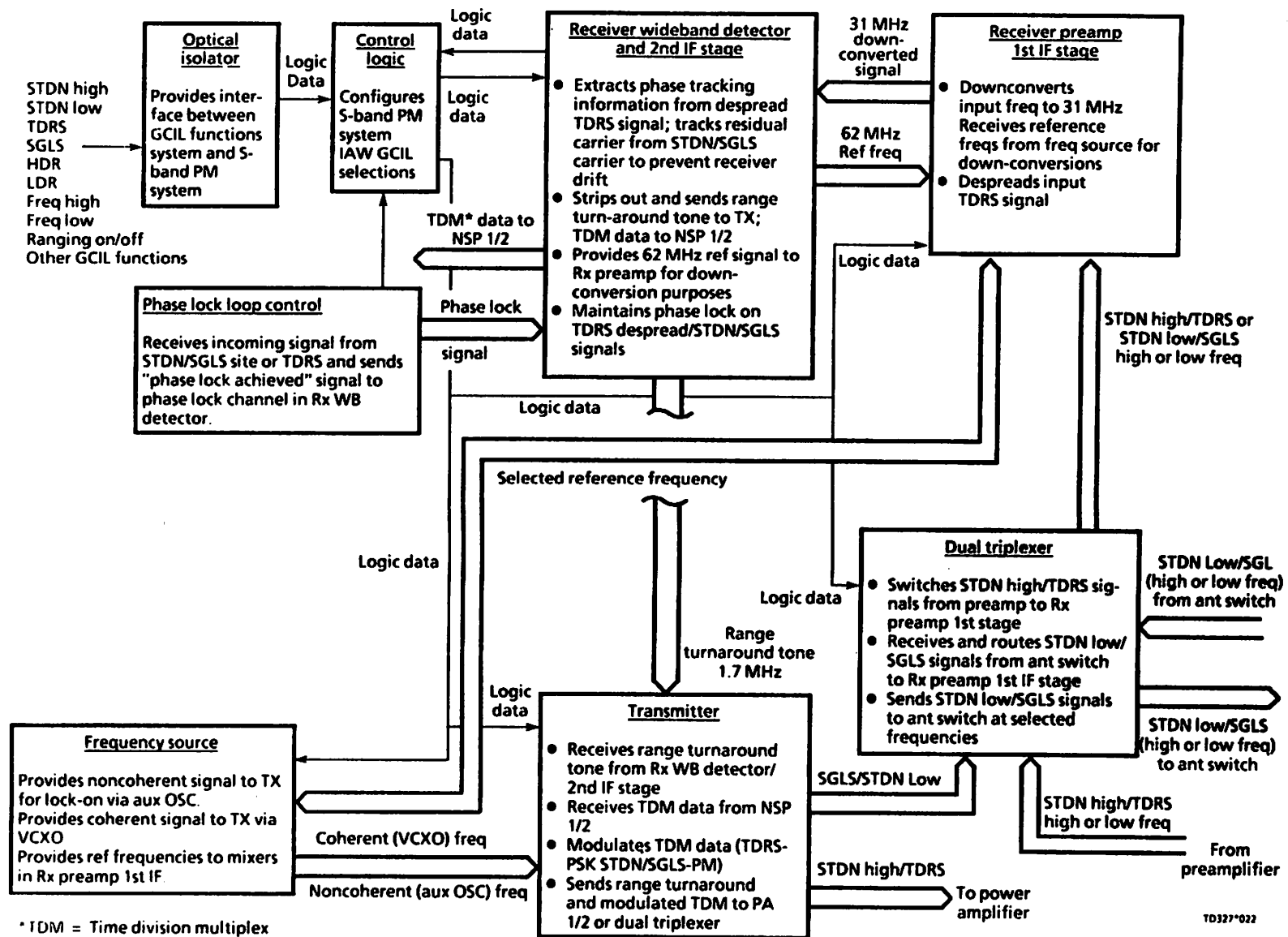
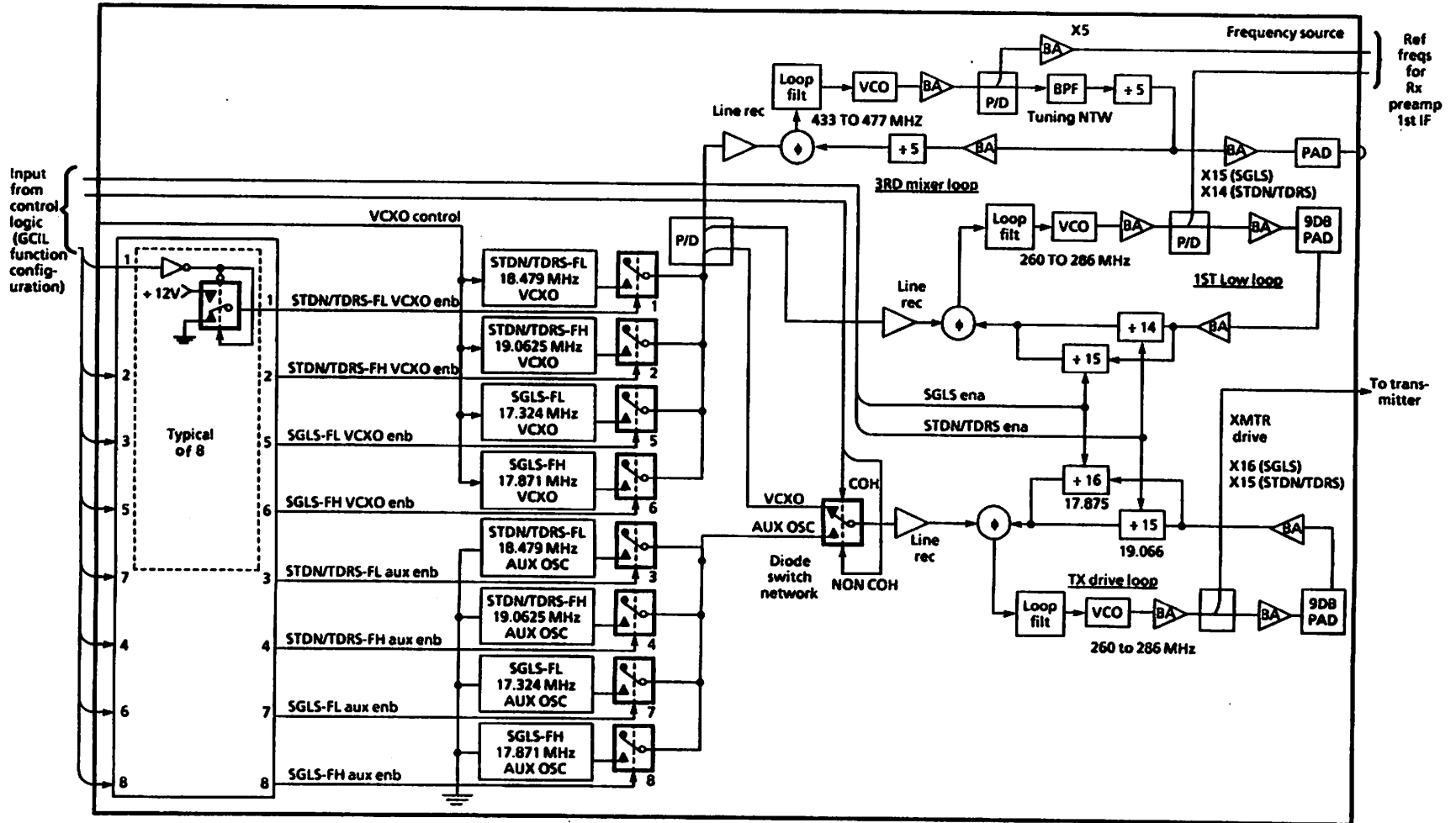


Figure 3-1.- S-band PM transponder descriptive block diagram.



Schematic Frequency Source

TD327*027

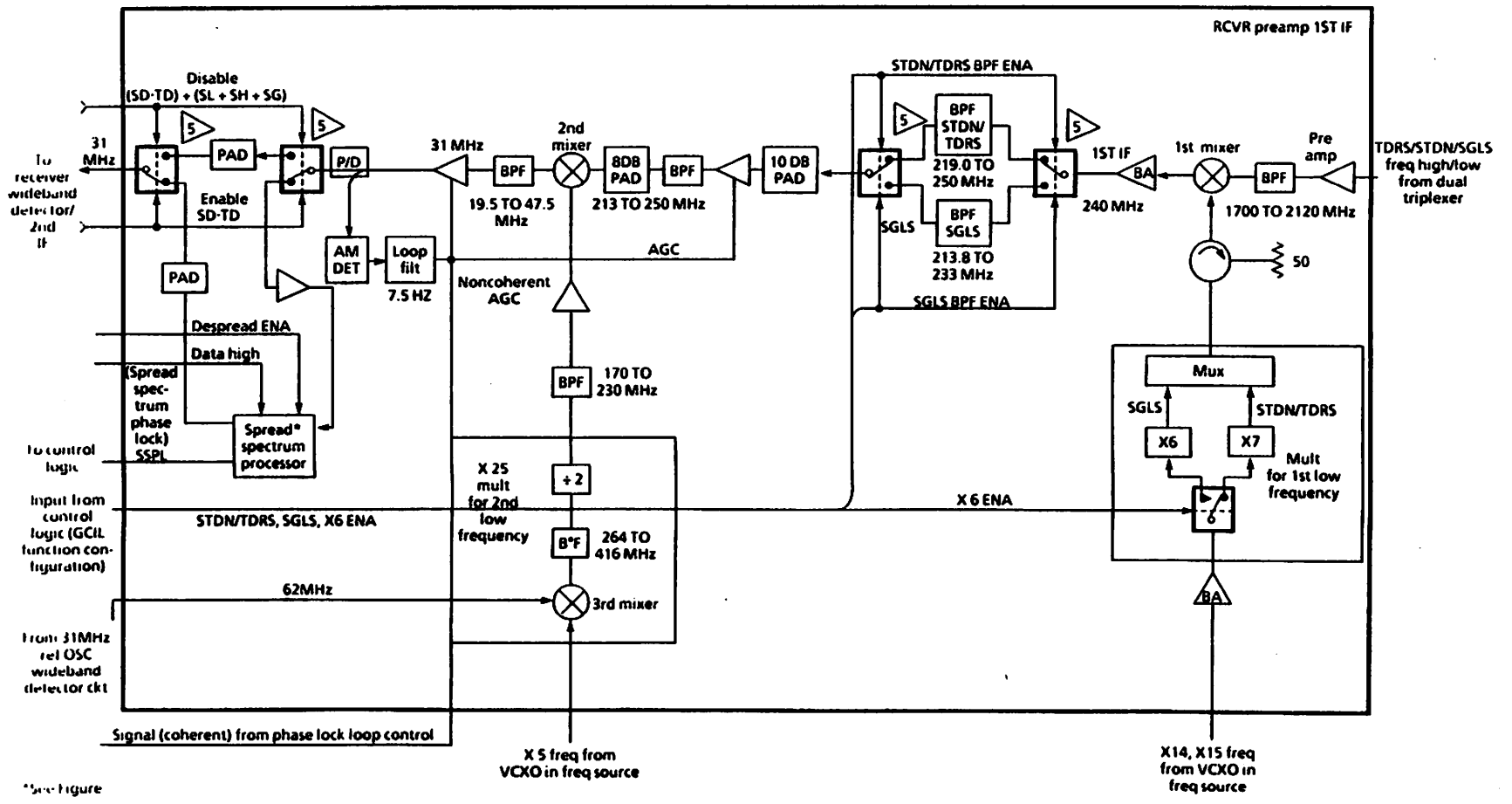
Figure 3-2. Schematic of frequency sources.

changing the voltage controlled transmit oscillator (VCXO) frequency. Each VCXO subassembly contains four VCXOs for two-channel operation in either SGLS or STDN/TDRS modes. Although only two noncoherent transmit frequencies are received, a four-channel VCXO (with grounded input) identical to the receiver VCXO is used rather than a different unit for logistics and cost reasons. A simple unique multiplier configuration is used employing phase-locked oscillators to accomplish the x25 (second local oscillator (LO)), x14 or x15 (first LO) and x15 or x16 (transmitted drive) multiplication. The multiplication factor can be changed by changing the divider feedback ratios. The technique provides the wide percentage bandwidth multiplication required for multimode operation while yielding very low spurious products. The final first local oscillator multiplication ratio (x6 or x7) is selected as a function of mode.

The third mixer in the second LO chain offsets the second LO frequency using a 62-MHz reference signal, so that the second IF is fixed and does not vary as a function of received frequency (see figure 3-3). Therefore, the spread spectrum processor and the Costas detector preselection filters can be operated at a very low SNR and at the same center frequency regardless of input channel selection. The drive frequencies to the third mixer are at twice the first IF and twice the reference oscillator frequency (see figure 3-4). This eliminates the potential problem of generating a high-level signal at the third mixer exactly equal to the first IF which could result in a self-lock condition. Additionally, by using an "offset" oscillator and thus placing the high gain second IF at a frequency noncoherently related to the S-band input signals, regeneration or self-lock problems are eliminated that can otherwise arise in systems where the second IF is at a submultiple of the S-band input frequency. Figure 3-5 depicts the schematic of the transponder transmitter.

Downlink STDN or SGLS linear modulation is accomplished at about 560 MHz and then multiplied by 4 to

S-band. The original TDRS mode biphas modulator was eliminated in favor of linear modulation at 560 MHz ($\pm 1/8$) and multiplication to S-band (x4) in order to avoid undesired sidebands which would have caused payload receiver interference. An S-band solid state power amplifier provides a low-level SGLS/STDN or high-level output (STDN/TDRS) depending on mode selection.



*See Figure

10127005

Figure 3-3.- Schematic receiver pre-amp/1st IF.

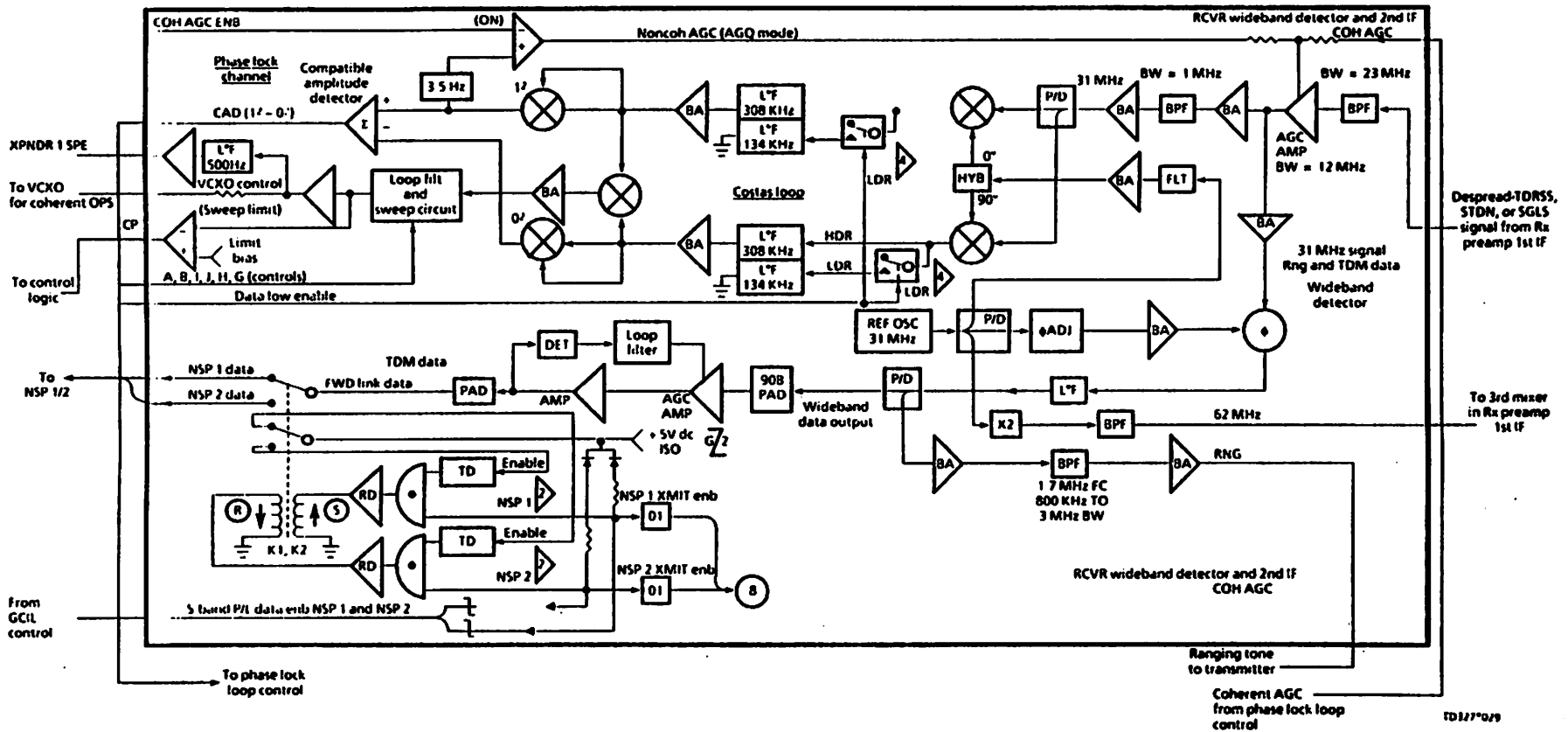
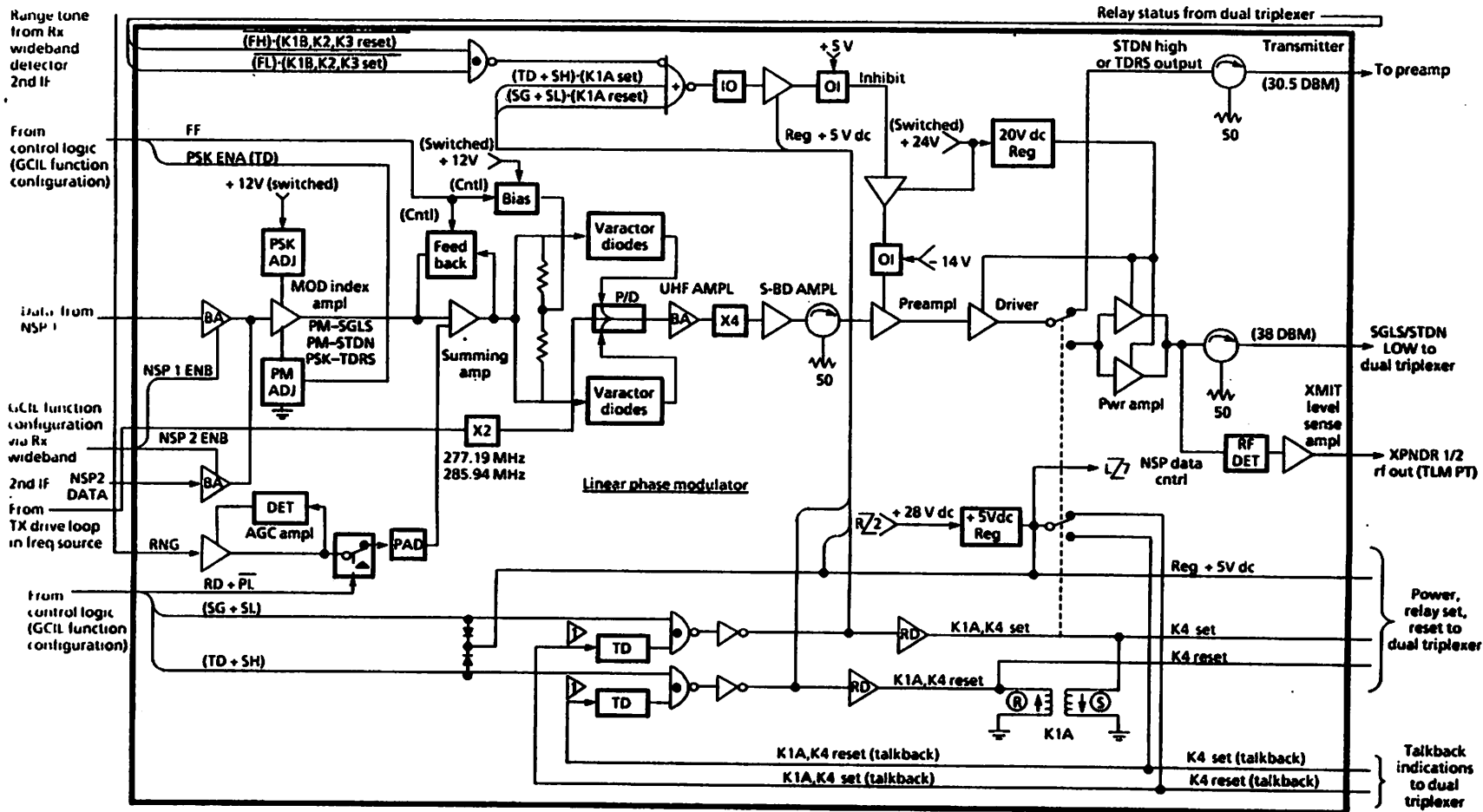


Figure 3-4.- Schematic of receiver wideband detector and 2nd IF.



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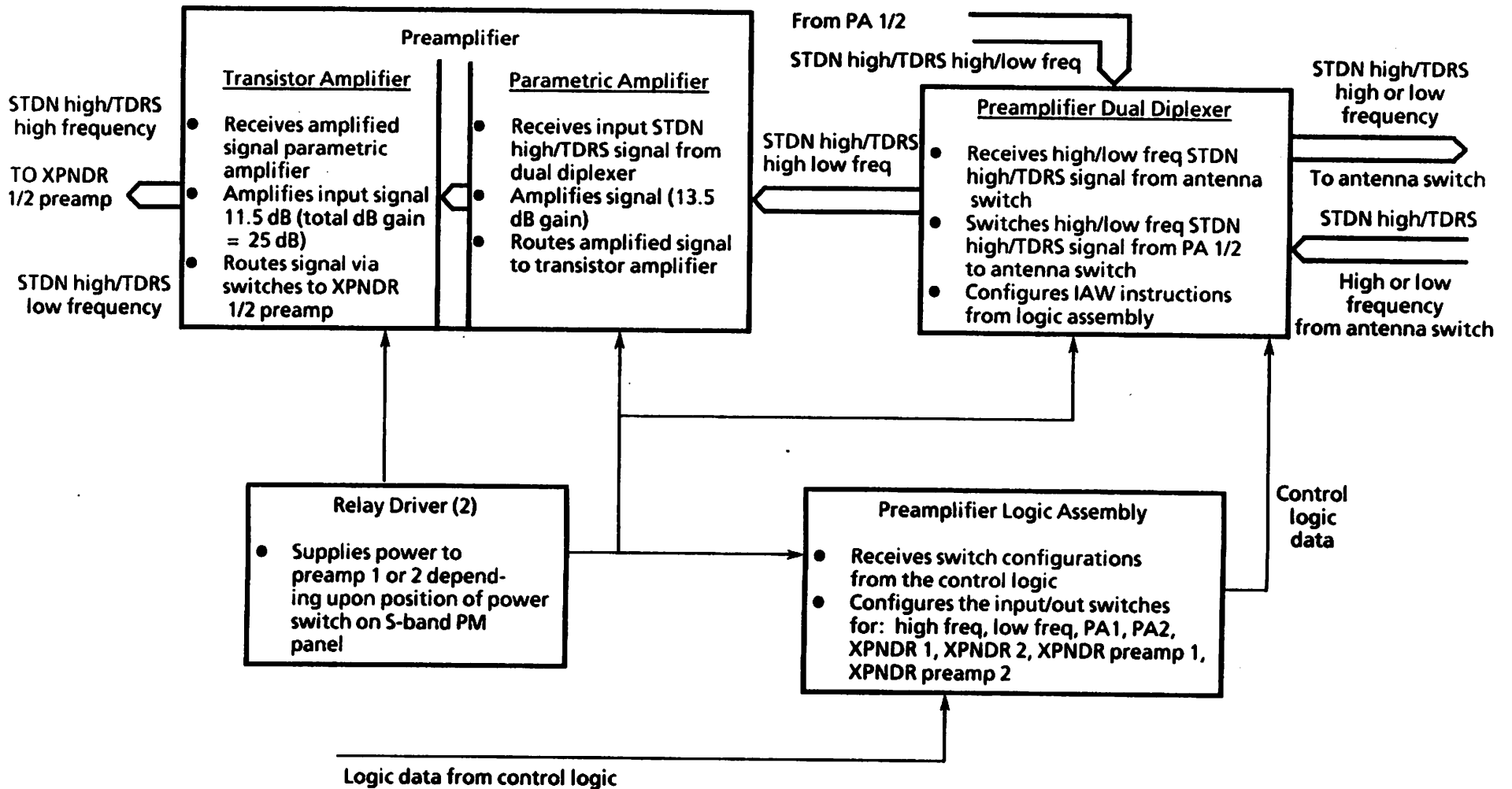
Figure 3-5.- Schematic of transmitter.

S-Band Preamplifier

The S-band preamplifier provides the following functions:

- **Provides rf interfaces for a satisfactory operation of the TDRS or STDN duplex rf link, S-band antenna switch, S-band power amplifiers, and transponder assembly.**
- **Accepts received S-band rf signals of 2106.406 MHz or 2041.947 MHz from the antenna switch.**
- **Amplifies the received S-band signal and transfers it to the transponder.**
- **Accepts transmitted S-band signals of 2287.5 MHz or 2217.5 MHz from power amplifier.**
- **Routes transmitted S-band signal to the antenna switch.**
- **Provides rf multiplexing for duplex operation.**

Figure 3-6 shows the block diagram of the preamplifier assembly, which consists of internally redundant, functionally independent parametric amplifier modules with switching regulator/dc-to-dc converters, rf diplexers, and the necessary rf switching and control logic to perform the required preamplifier functions. The key component in the preamplifier assembly is the parametric amplifier module.



TD327*010

Figure 3-6.- S-band PM preamplifier assembly descriptive block diagram.

A block diagram of the parametric amplifier module is shown in figure 3-7. A single-stage, low noise parametric amplifier with a gain of 13.5 dB is followed by a transistor amplifier with a gain of 11.5 dB. The combined gain of the two stages meets the overall preamp gain and noise figure requirements. The relatively low gain of the parametric amplifier stage produces gain stability and enables a bandwidth which covers both receive channels with band switching within the module.

The parametric amplifier (paramp) preamplifier stage of the preamp module consists of a balanced preamp which uses a pair of Schottky-barrier varactors, coupled to a low-loss, four-port circulator. A Gunn diode oscillator (GDO), operating at about 50 GHz, is used as a fundamental-frequency pump source. The relatively high pump frequency enables a noise figure within the required range while using a low parametric amplifier stage gain.

Two heater circuits maintain preamplifier module gain stability over the expected temperature range of 25 to 120 °F. The GDO is maintained at 175 °F \pm 1 °F over the entire baseplate temperature range to obtain a constant pump power level. A separate heater and temperature controller is used to stabilize the circulator ferrites at 95 °F \pm 25 °F to provide a constant source impedance to the parametric stage over the temperature range. A thermistor is mounted in the paramp to provide a bias voltage change with temperature to compensate for the varactor contractor potential temperature dependence.

The standby mode provides heater power to the redundant half of the paramp module to permit fast switchover without requiring a 10-minute warmup period.

The parametric amplifier module voltage regulators provide highly regulated, low ripple voltages for the GDO and for paramp bias. A test point output is provided which is a voltage proportional to varactor current for monitoring for proper operation of the parametric amplifier.

The required parametric amplifier module input voltages are provided by functionally independent switching regulator/dc-to-dc converters (see figure 3-8). The high and low channel rf diplexers allow duplex capability via a single antenna port. The required rf switching is accomplished by coaxial transfer switches, SW1, SW2, and SW3. The filter box in figure 3-7 conditions the power and input controls entering the preamplifier assembly.

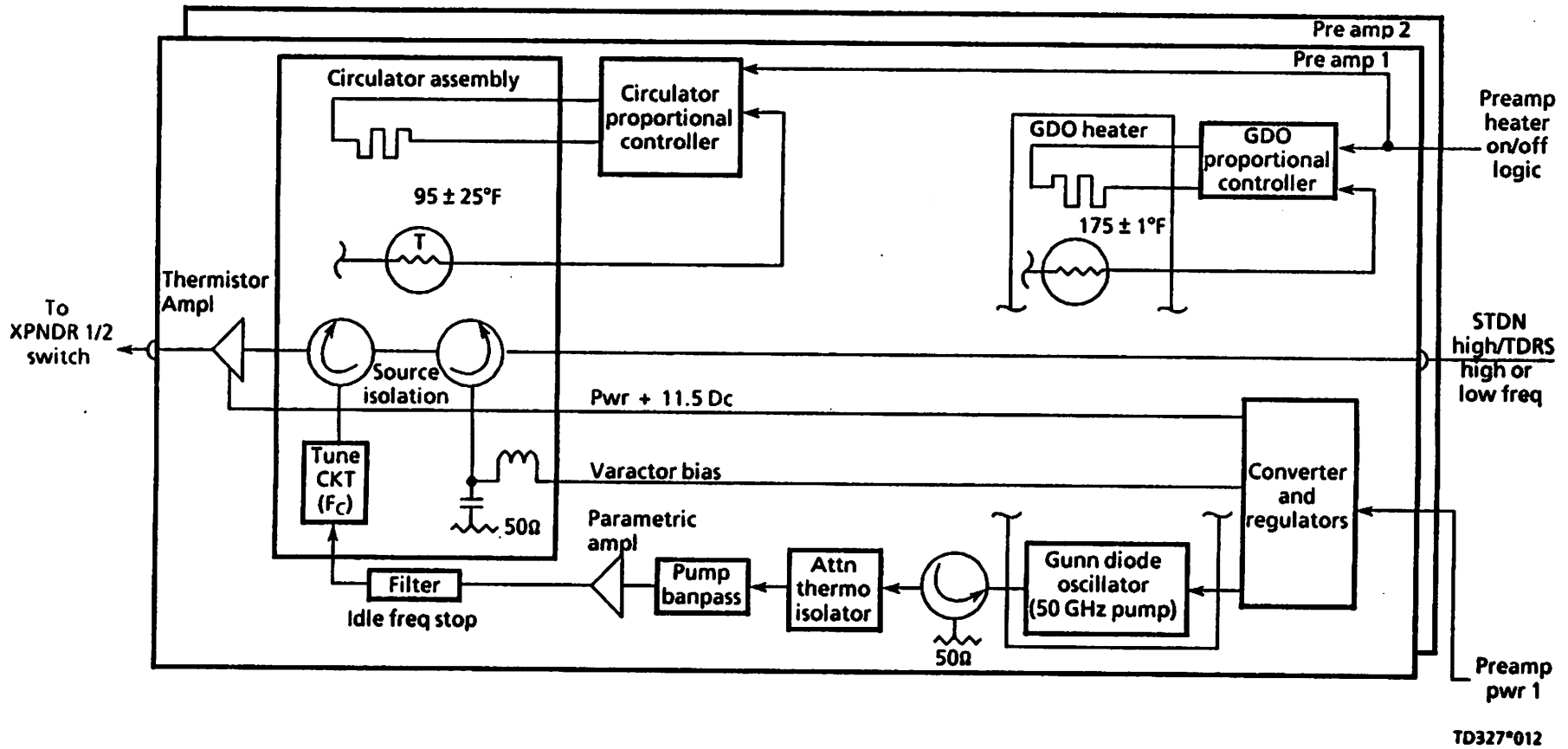
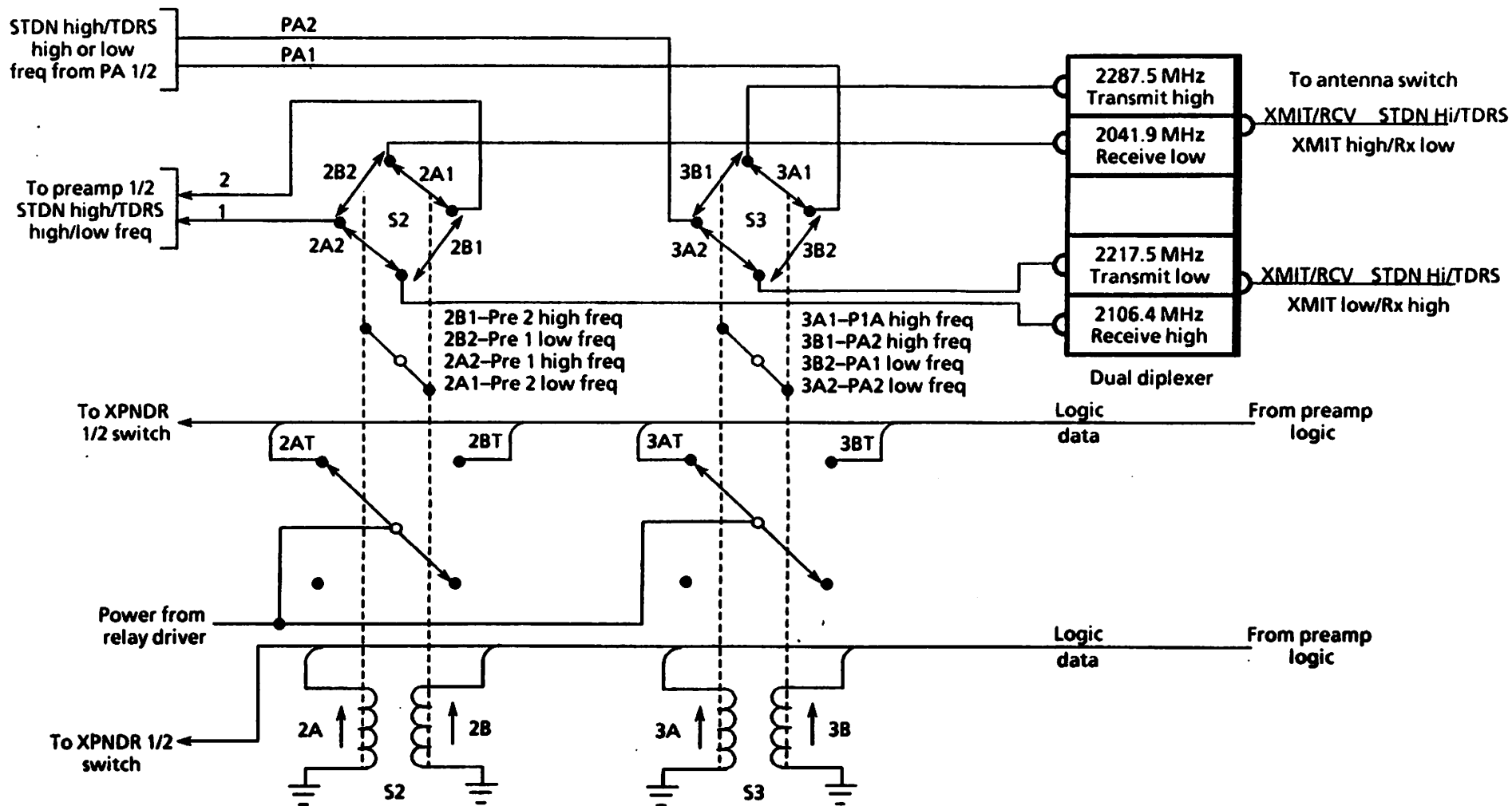


Figure 3-7.- Schematic of the preamplifier.

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TD327*013

Figure 3-8.- Schematic of the dual amplifier and preamplifier switch.

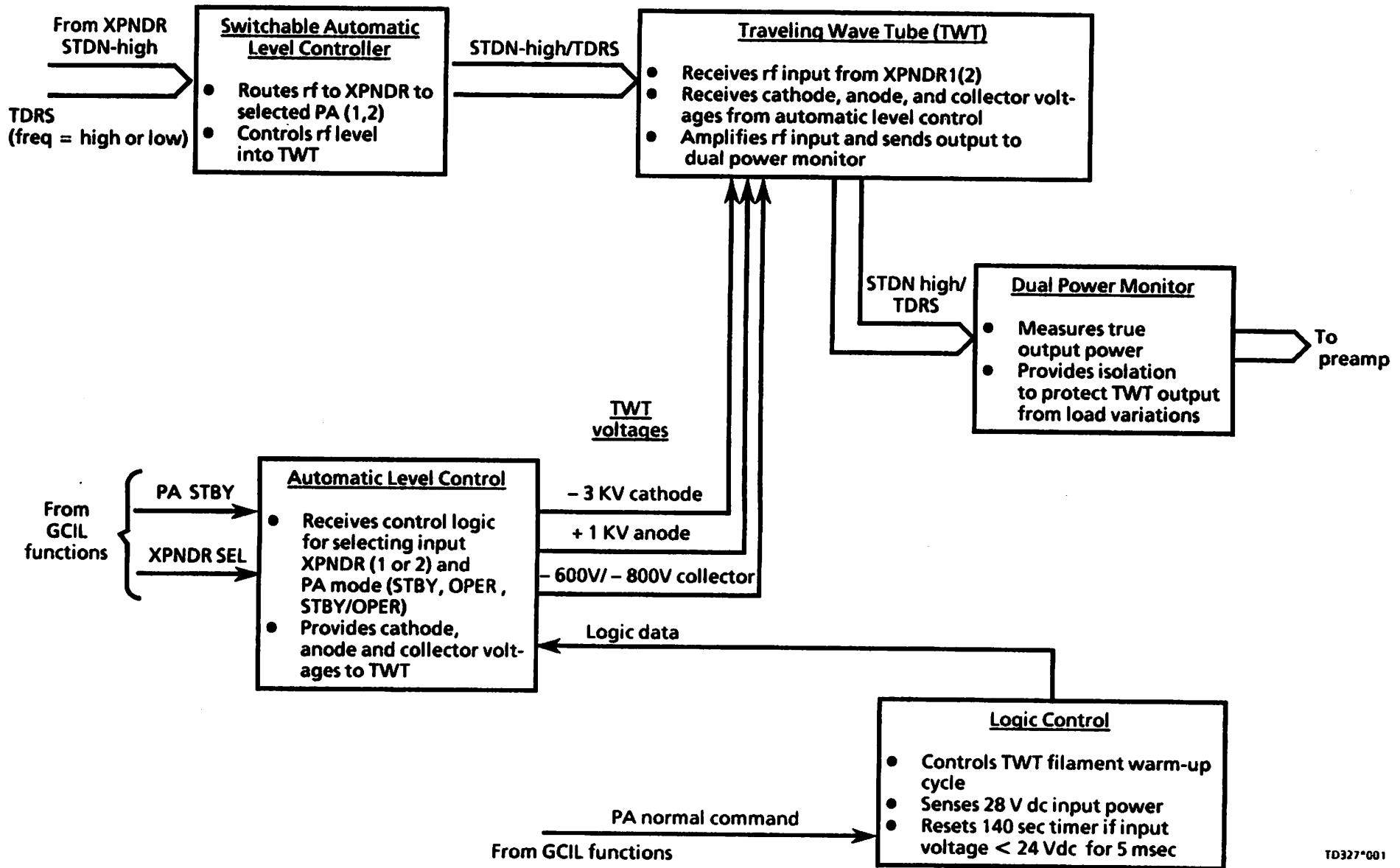
S-Band Power Amplifier

Figure 3-9 is the block diagram of the S-band power amplifier. The unit consists of the following subassemblies:

- 1 logic control
- 1 switch control assembly
- 2 traveling wave tubes (TWT)
- 2 power monitor/ isolators
- 1 switchable automatic level control.

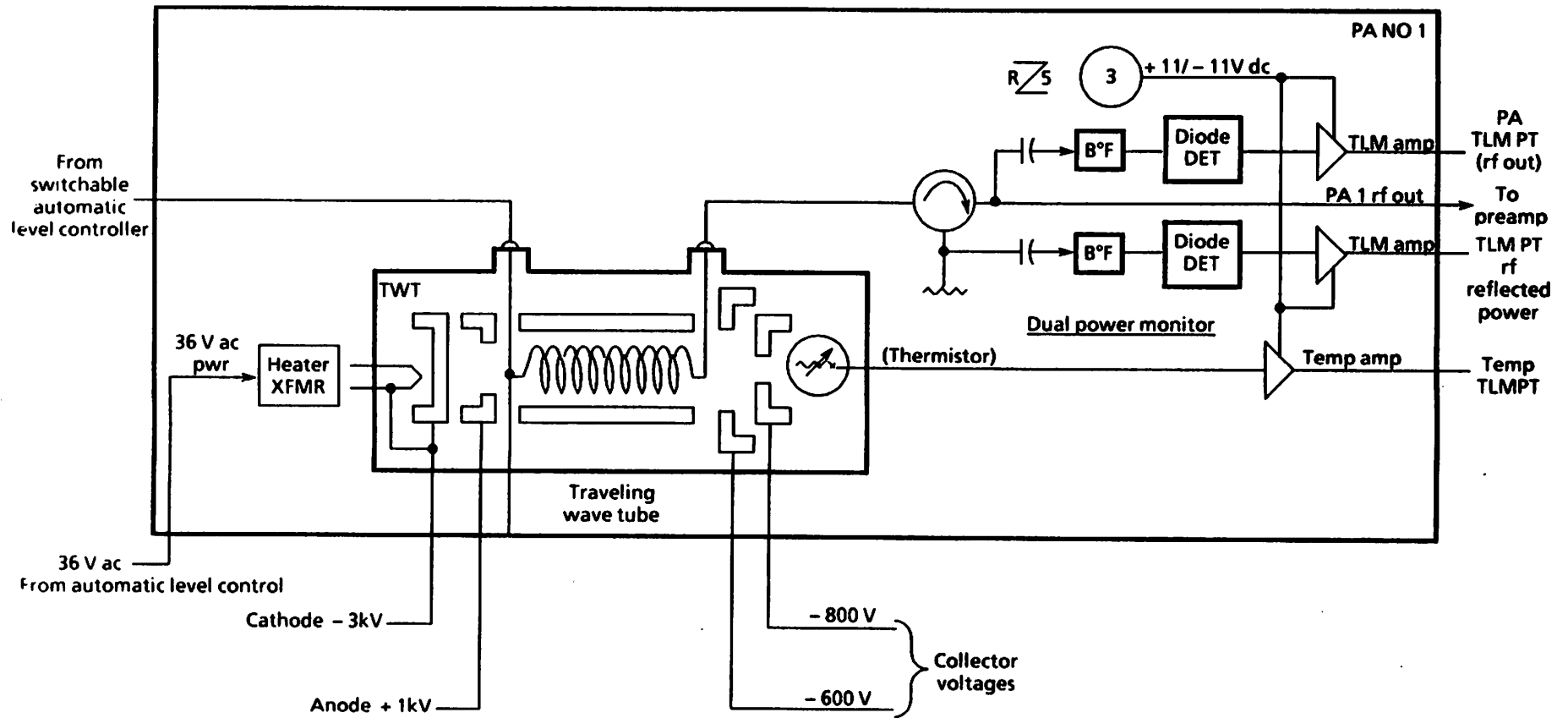
The TWT is a WJ-448-3 tube capable of operating at 175 watts rf output at approximately 43 percent efficiency. Reference figure 3-10. The dual power monitor (forward and reverse) and isolator are located at the output. The isolator load is mounted on the baseplate to dissipate the total TWT output in the presence of a high voltage standing wave ratio (VSWR) load. The isolator section is magnetically shielded from the TWT field.

Figure 3-11 depicts the automatic level control. The switchable automatic level control is self-contained. It contains the rf transfer switch for transferring either rf input to either TWT amplifier. The switch is logically controlled in the electronic power converter (EPC) so that the active TWT amplifier will always receive the active transponder input. The absorptive attenuator is controlled by the EPC which senses the signal from the power monitor. The rf input is then optimized for the TWT. The EPC will turn off the TWT if insufficient rf power is present.



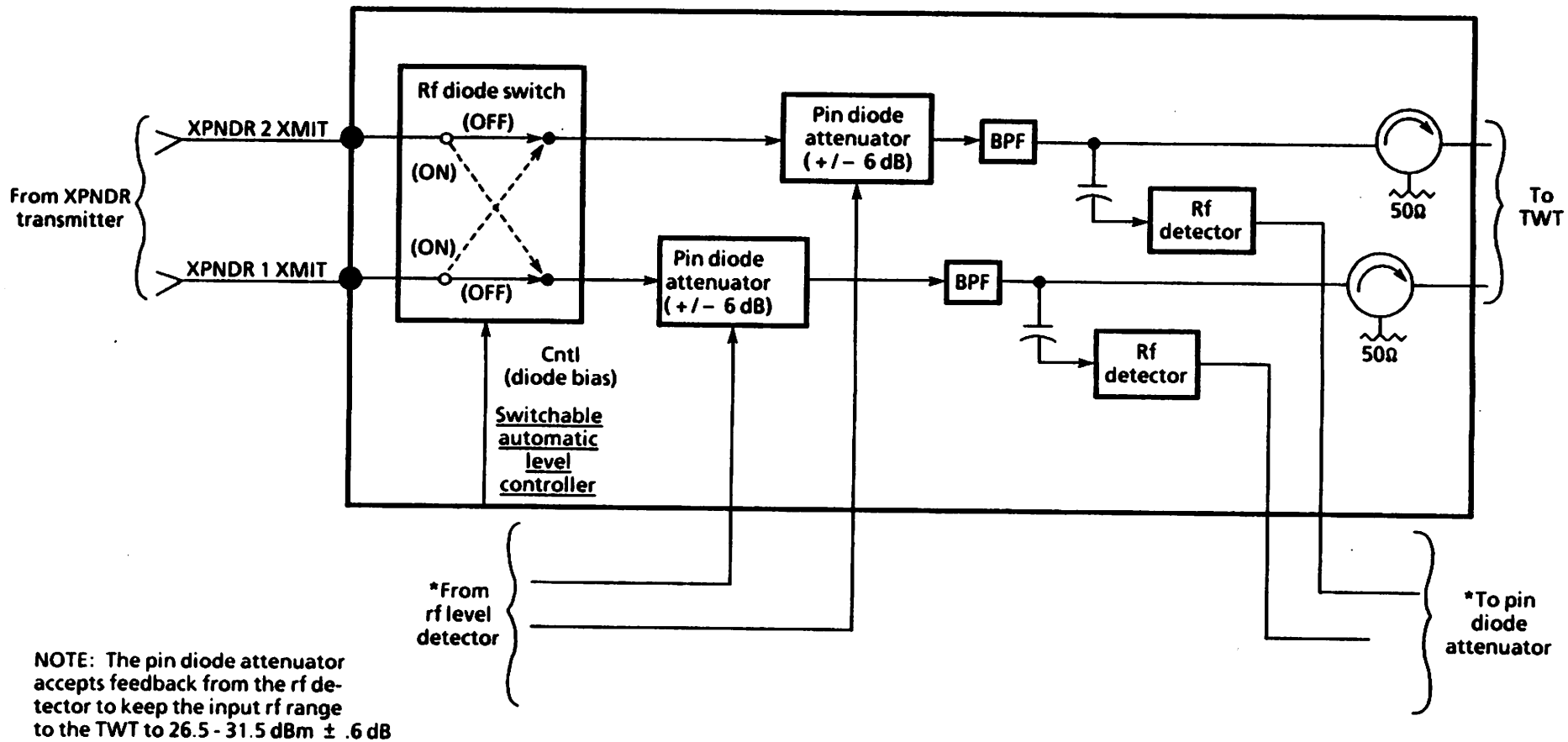
TD327*001

Figure3-9.- S-band power amplifier descriptive block diagram.



TD327*004

Figure 3-10.- Schematic of traveling wave tube and dual power monitor.



TD327*003

Figure 3-11.- Schematic of switchable automatic level controller.

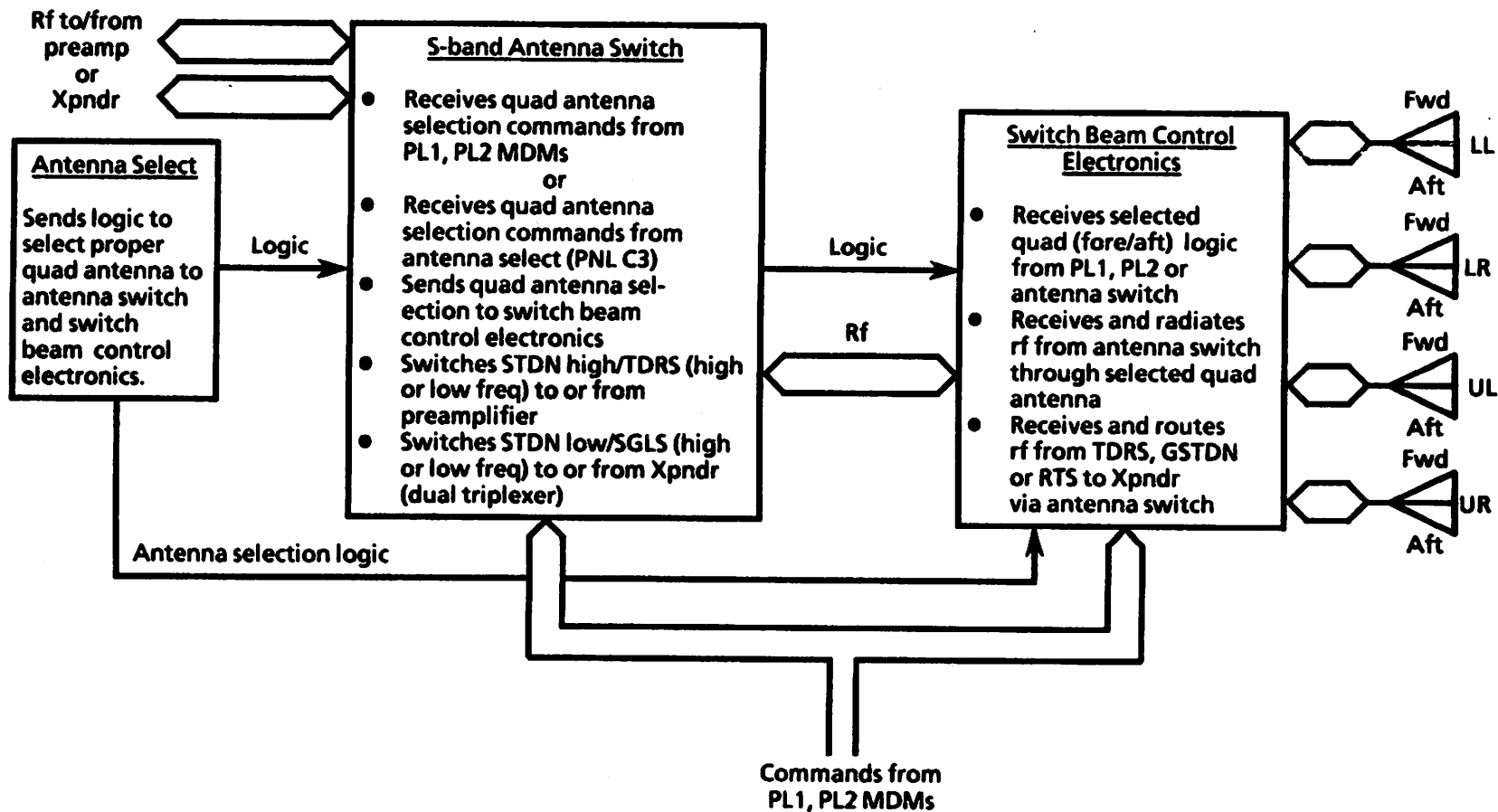
Antenna Switch Electronics

The antenna electronics consist of three subassemblies to control and route the S-band frequencies. There are three for the PM section and three for the FM section. There are two electronic LRUs for redundancy just as in the rest of the S-band system. Figure 3-12 gives a block diagram for the antenna electronics.

The first subassembly is a set of logic gates that determine which antenna has been selected, either from switch selection or from the GPC software. It will then output a control signal to the pulser subassembly to switch the contacts in the rf coax switch. The pulser is exactly that. It will pulse its output to change the coax switch. It does not hold its output to the last state chosen. A magnet in the coax switch holds the contacts in their selected states. Figure 3-13 shows the logic subassembly with its outputs defined in logic algebra for simplicity.

The pulser subassembly takes the output of the logic gates and converts it to a one-shot that drives a two stage cascaded transistor driver, which in turn completes a circuit ground for the relay coils in the coax switch itself. The pulser works on a 100 msec charge/discharge rate. This time delay will inhibit pulser output changes until the capacitor in figure 3-14 is discharged.

The last subassembly is the rf switches. Instead of a redundant set of switches like the completely redundant set of logic gates and pulsers, there is really only one set of switches which have redundant switching relays. This keeps the rf plumbing and couplers down to a minimum while maximizing reliability. Figure 3-13 shows how they are interconnected to the pulsers and the S-band rf from the transponders/power amps.



TD327*016

Figure 3-12.- S-band PM antenna switch descriptive block diagram.

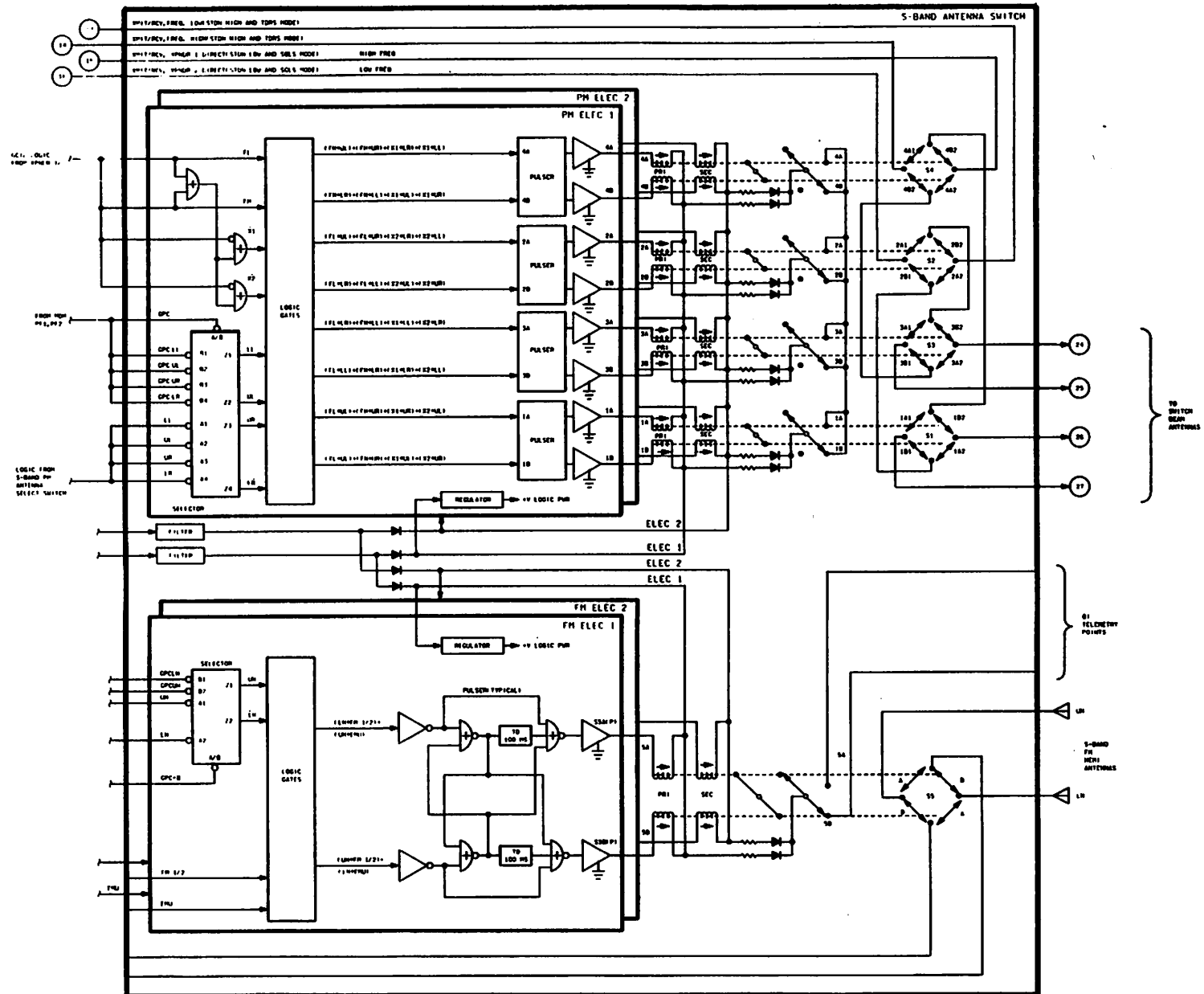
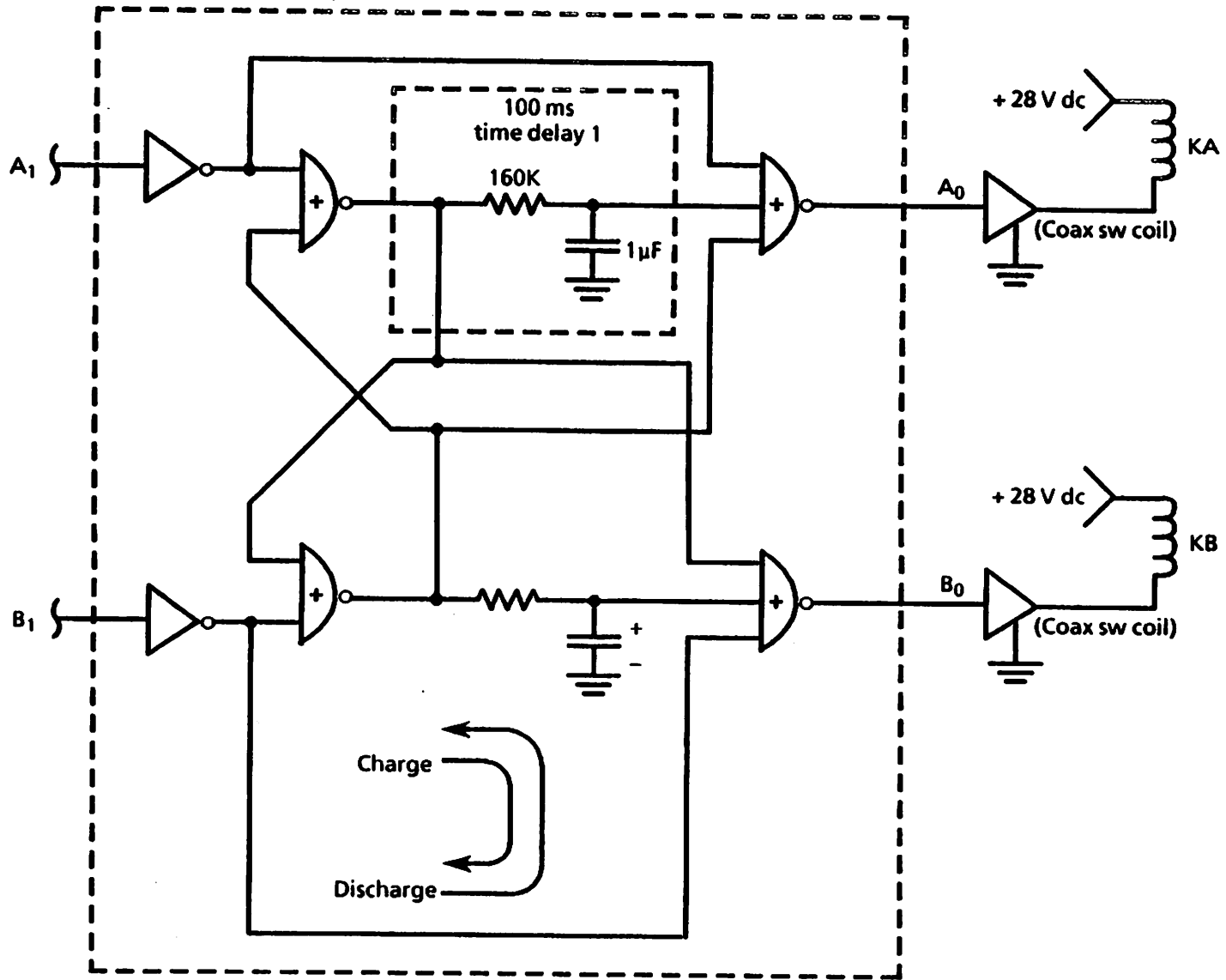


Figure 3-13.- Schematic of S-band antenna switch.



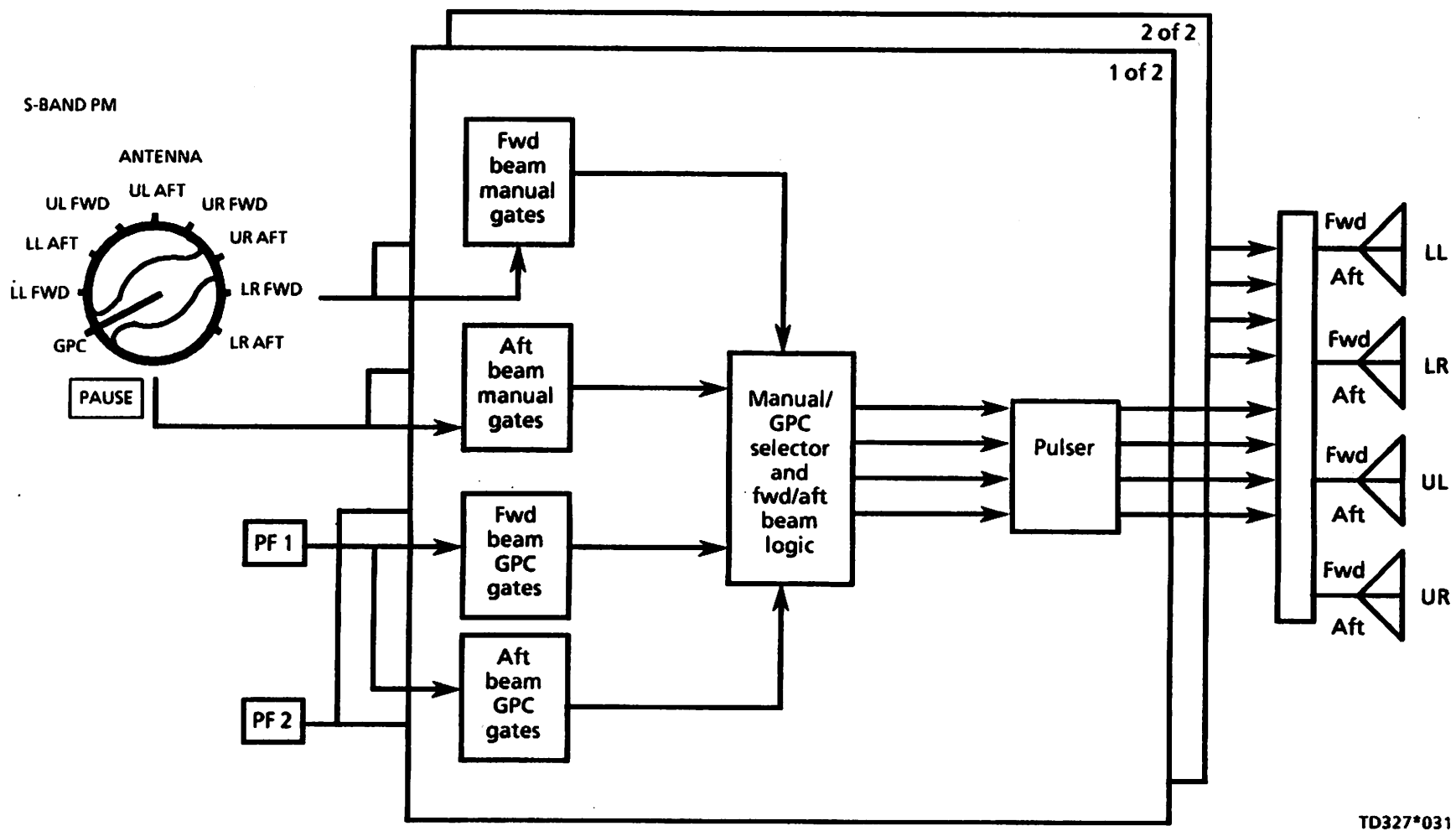
TD327*044

Figure 3-14.- Pulsar subassembly.

Switch Beam Controller

With the advent of TDRS, the quad antennas, used to communicate with the ground, needed to be modified to accomodate this new rf link. Since the antennas only boost the power output by about 3dB, and the distance between TDRS and the Orbiter is many multiples the distance between the ground tracking station and the Orbiter, there was needed a mechanism to concentrate a fixed power output into a narrower antenna beam pattern. Along with an antenna modification, an antenna beam controller LRU was added. Figure 3-15 shows the beam controller black box diagram. Notice how similar it is to the antenna electronics LRU. It has some logic gates and a dual set of pulsers. It has no coax switch in the LRU; the coax switch is located in the antenna cavity.

The whole function of this box is to accept inputs from either the GPC interface or the rotary switch on panel C3, and set the relays in the antenna coax switch that will allow the antenna to radiate in a specified direction. The directions nomenclature are called forward and aft. The physical directions are forward in the direction of the Orbiters nose and aft in the direction of the Orbiters tail section.



TD327*031

Figure 3-15.- Switch beam control electronics.

Quad Antennas

There are six antennas associated with the S-band system, four "steerable quads" for the S-band PM subsystem and two "hemi" antennas for the FM subsystem.

The PM antennas each consist of two cross-dipole antennas inserted into an antenna cavity. This cavity is then covered with a radome which in turn is covered by Orbiter TPS. Figure 3-16 shows the antenna assembly and its cross-sectional view in the cavity. The name "steerable" does not mean the antennas move physically, but by adjusting the phase on each dipole, the beam can be electronically steered in the direction desired. Figure 3-17 shows a schematic diagram showing the mechanism by which the rf coming in can be electronically steered. Also, a table is included to show which phase is needed on which dipole to create a forward or aft beam.

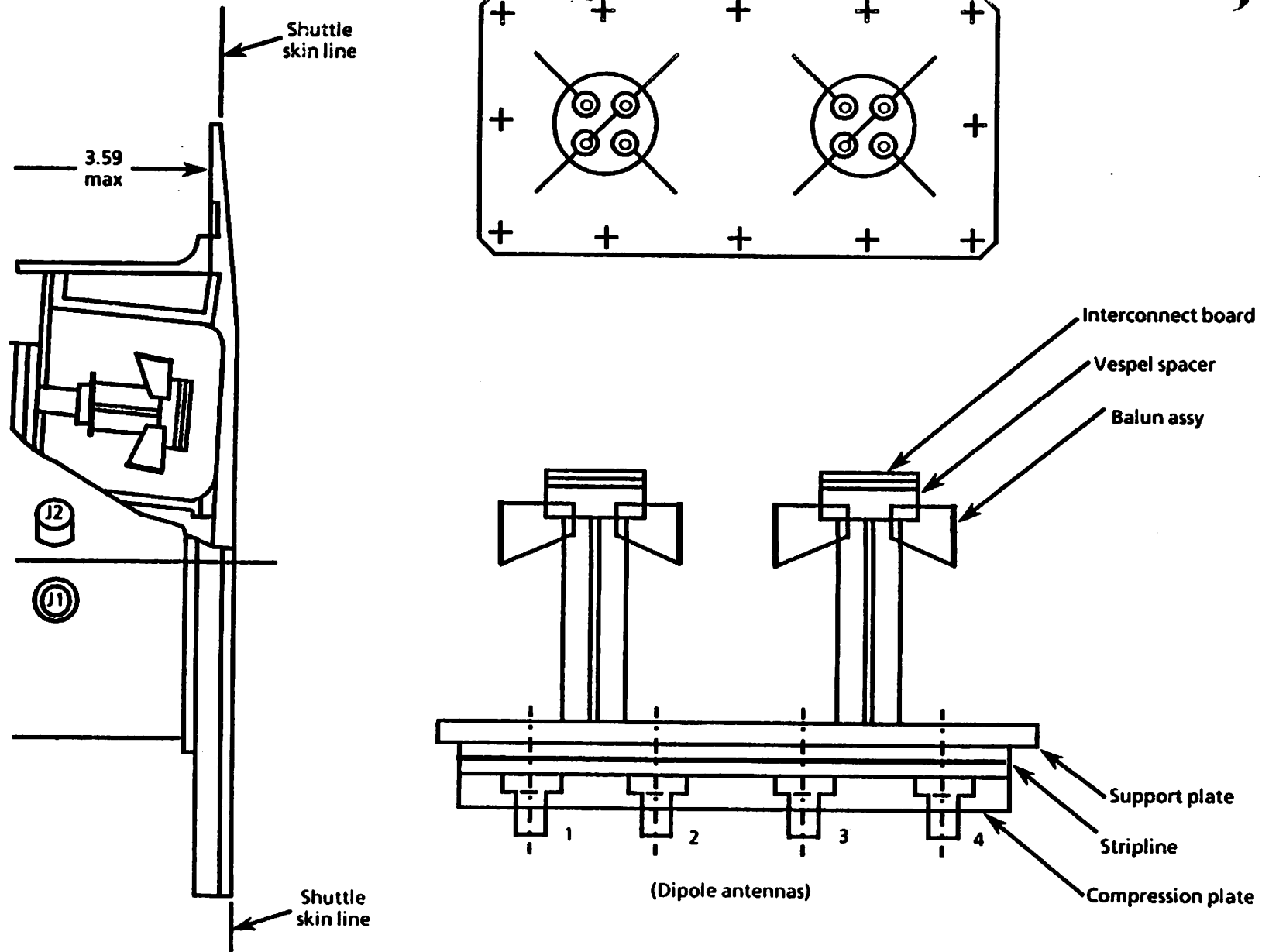
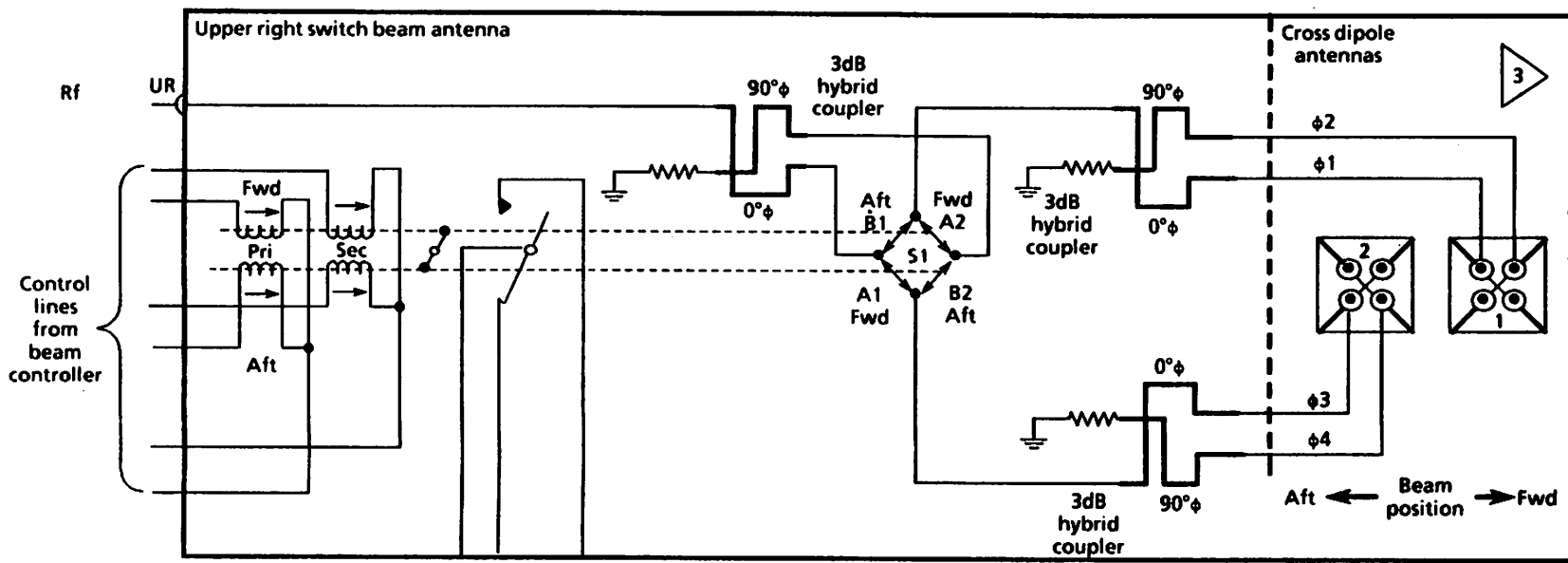


Figure 3-16.- Antenna assembly and its cross-sectional view in the cavity.

TD327*043



Dipole	Phase	Beam Position	
		Aft	Fwd
1	Q1	0°	90°
	Q2	90°	180°
2	Q3	90°	0°
	Q4	80°	90°

TD327*042

Figure 3-17.- Schematic diagram of a quad antenna steering mechanism.

FM Subsystem

The overall description of the FM subsystem was given in section 1. This section describes the functions of the individual major assemblies.

FM Signal Processor

The FM signal processor (FMSP) is essentially a multiple-mode, signal-conditioning/processing assembly. The unit has seven modes corresponding to the various heterogeneous data-gathering equipment; it interfaces to the two operational FM transmitters. It accomplishes baseband signal modulation, mixing, routing, conditioning, impedance matching, and operational mode switching. Figure 3-18 shows the position of the FMSP in the S-band system.

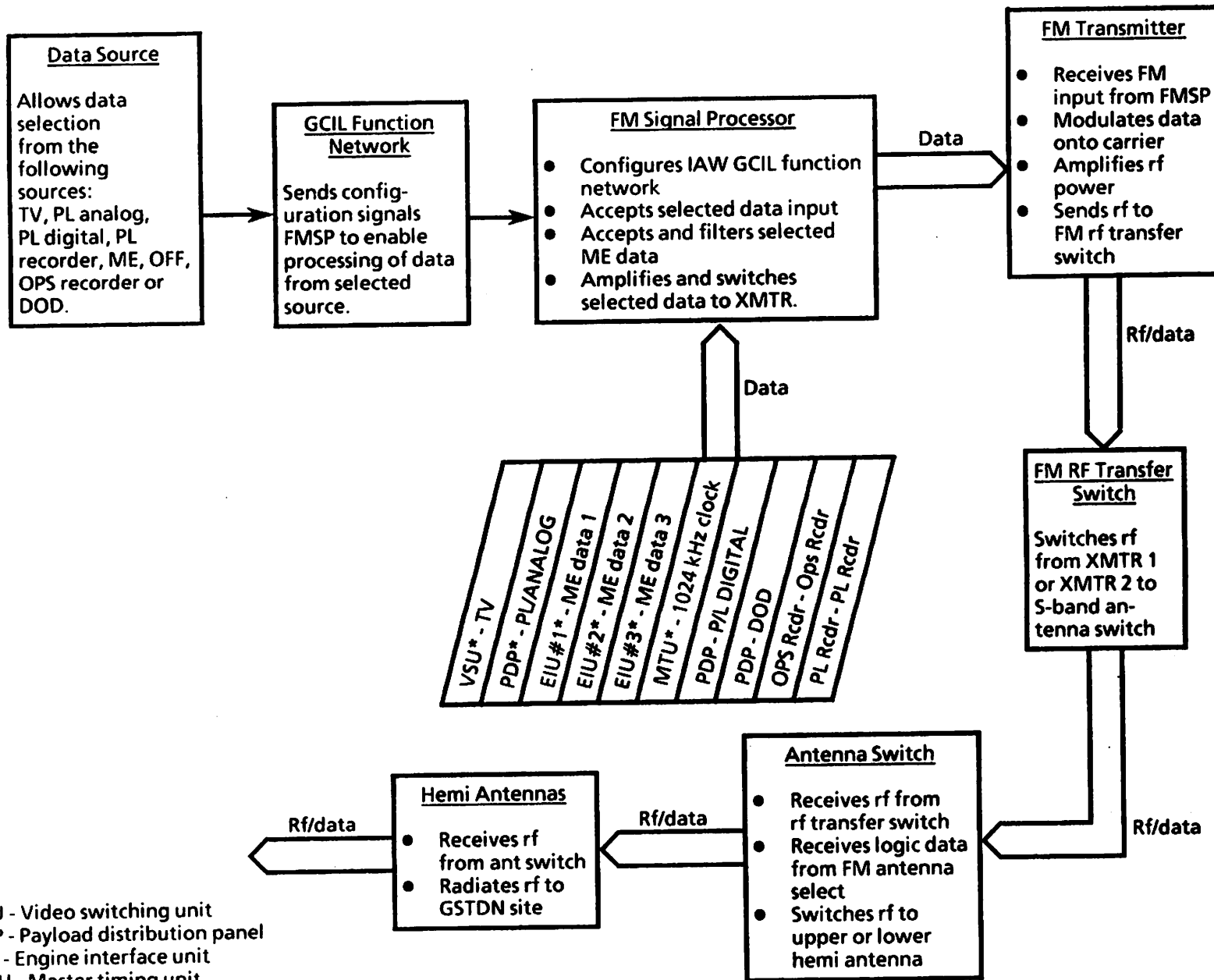
The functions required of the FMSP are as follows:

- Accept and condition biphas-L or NRZ-L digital signals for frequency modulation of the interfacing FM transmitter or provide an output for ground support equipment (GSE) checkout.
- Accept and condition video signals for frequency modulation of the interfacing FM transmitter, or provide an output for GSE checkout.
- Accept and condition biphas-L main engine data for phase-shift-keying the internal and subcarrier oscillators for frequency modulation of the FM transmitter, or provide an output for GSE checkout.
- Provide isolated output signals, consisting of one of the following operating modes, to the FM transmitter or the FM transmitter and GSE. A short or open circuit on the outputs FM XMTR # 1, GSE interface, or FM XMTR # 2, shall not prevent

normal output to be delivered by those ports not shorted or open circuited.

- Television
- Recorded PCM (ops recorder)
- Main engine data
- Wideband digital data (payload digital)
- Digital data encrypted (DOD)
- Wideband analog data (payload analog)
- Recorded PCM 25.5 kbps to 1024 kbps (payload recorder)

Refer to figure 3-19 for the above mentioned FMSP function descriptions.



* VSU - Video switching unit
PDP - Payload distribution panel
EIU - Engine interface unit
MTU - Master timing unit

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Figure 3-18.- S-band FM system descriptive block diagram.

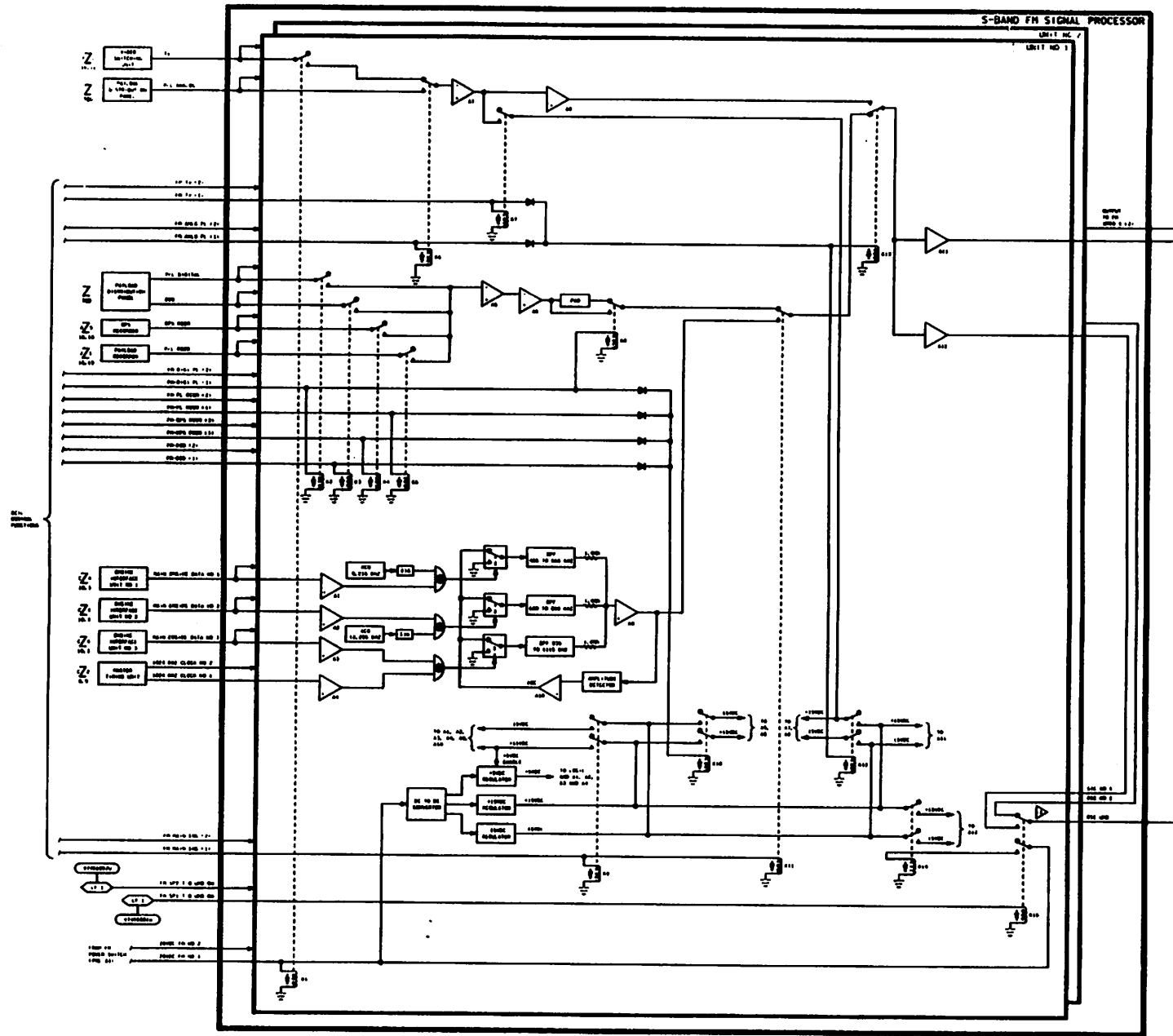


Figure 3-19.- S-Band FM signal processor.

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TV Mode. There are nine data paths into the unit in addition to power, clock, and mode-select inputs. The television input comes from the video switching unit. The presence of video data will alter the waveform to some extent. Since the TV system uses a color wheel, the color burst is not used in the normal manner, but is used as a frequency sync signal for all cameras. The TV path consists of an isolation amplifier, mode selection relays, application of an offset voltage, wideband amplifier, and power output amplifier. Selection of the TV mode is accomplished by activation of GCIL drivers 10/1 and 6/5 for FMSP #1, or GCIL drivers 10/6 and 14/5 for FMSP #2. The TV mode is designated mode 1.

Main Engine Data Mode. The FMSP has a three-channel main-engine data mode corresponding to receiving data from the three engine interface units (EIUs). The EIUs use Manchester II biphasic logic data at 60 kbps to the three main engine channels. Each channel is a resistive pad followed by a difference amplifier which drives a phase modulator. The phase modulation is done at 576 kHz, 768 kHz, and 1024 kHz, derived from the 1024 kHz clock input and two crystal oscillators. The phase difference corresponding to a "one" input versus a "zero" input is 180 degrees. The phase-modulated subcarriers are each then band-pass filtered to ± 75 -90 kHz @ dB down and summed. The output amplitude of the bandpass filters is regulated to a 5 percent variation with an automatic gain control (AGC) loop. The signal passes through mode-selection switching into a pair of wideband output driver amplifiers which interface with one of the operational FM transmitters and the GSE umbilical. FMSP 1 outputs to FM transmitter 1, and FMSP 2 outputs to FM transmitter 2. Both FMSPs output to the GSE umbilical.

Payload Analog Data Mode. The third mode of the FMSP is to accept analog data through an umbilical to an onboard payload in the payload bay. Acceptable signals lie in the 300 Hz to 4 MHz band with 1 volt ± 10 percent peak-to-peak, into a 75 ohm, balanced, differential input. Except for the input balun being replaced by a resistive pad, the payload analog circuit is nearly the same as the TV circuit within the FMSP.

Ops Recorder Mode. The fourth mode of the FMSP is to accept Ops recorder dumps consisting of digital biphasic-L signals at 25.5 kbps to 1024 kbps, with 3 to 9 volts peak-to-peak amplitude into a 71 ohm balanced differential input. The signal processing chain is two difference amplifiers in series followed by a resistive pad which feeds a parallel pair of wideband output driver amps (the same pair as is used in all modes).

Payload Recorder Mode. The fifth mode of the FMSP is to accept payload recorder dumps. The signal characteristics and processing are identical to the Ops recorder mode.

Payload Digital Data Mode. The sixth mode of the FMSP is to accept payload wideband digital data consisting of biphasic-L, NRZ-L, or Manchester II in the range 200 bps to 2 Mbps (5 Mbps for NRZ-L). Five volts amplitude ± 75 ohms is accepted. The processing is the same as the FMSP Ops recorder mode as mentioned above.

DOD. The seventh mode of the FMSP is to accept narrow-band, payload, encrypted data consisting of biphasic-L, Manchester II, or NRZ-L in the range 250 bps to 256 kbps, at 1.27 volts peak-to-peak ± 5 percent into a 75 ohms impedance. The processing is the same as the FMSP ops recorder mode.

FM Transmitter

The FM transmitter consists of four sections; the exciter and modulator, a multiplier, a power amplifier, and a power supply. Figure 3-20 shows the connections of these modules that make up a transmitter.

The transmitter accepts the output of the FM signal processor and applies the signal to a voltage controlled oscillator (VCO). This oscillator output is then mixed with a reference crystal oscillator (XCO). This composite output now has to be multiplied to bring it up to the S-band frequency of 2250 MHz. The multiplier/filter section does just that by taking the exciter output and multiplying times 3. After that, the signal is filtered to provide a clean carrier plus data to the rf power amplifier section.

The rf power amplifier section takes the multiplier output and amplifies the signal up to the required power level. The power output is specified to be 15 watts of rf power to the antenna switch. The power is monitored via telemetry presented to the ground through the instrumentation subsystem.

The last section is the power supply. It takes Orbiter 28 volts main power and divides and regulates the respective voltages that are required within the FM transmitter. The radio frequency interference (RFI) filter is used to attenuate any rf that may happen to be on the main bus due to rf leakage from any other black boxes. This prevents outside rf from disrupting the operation of the FM transmitter.

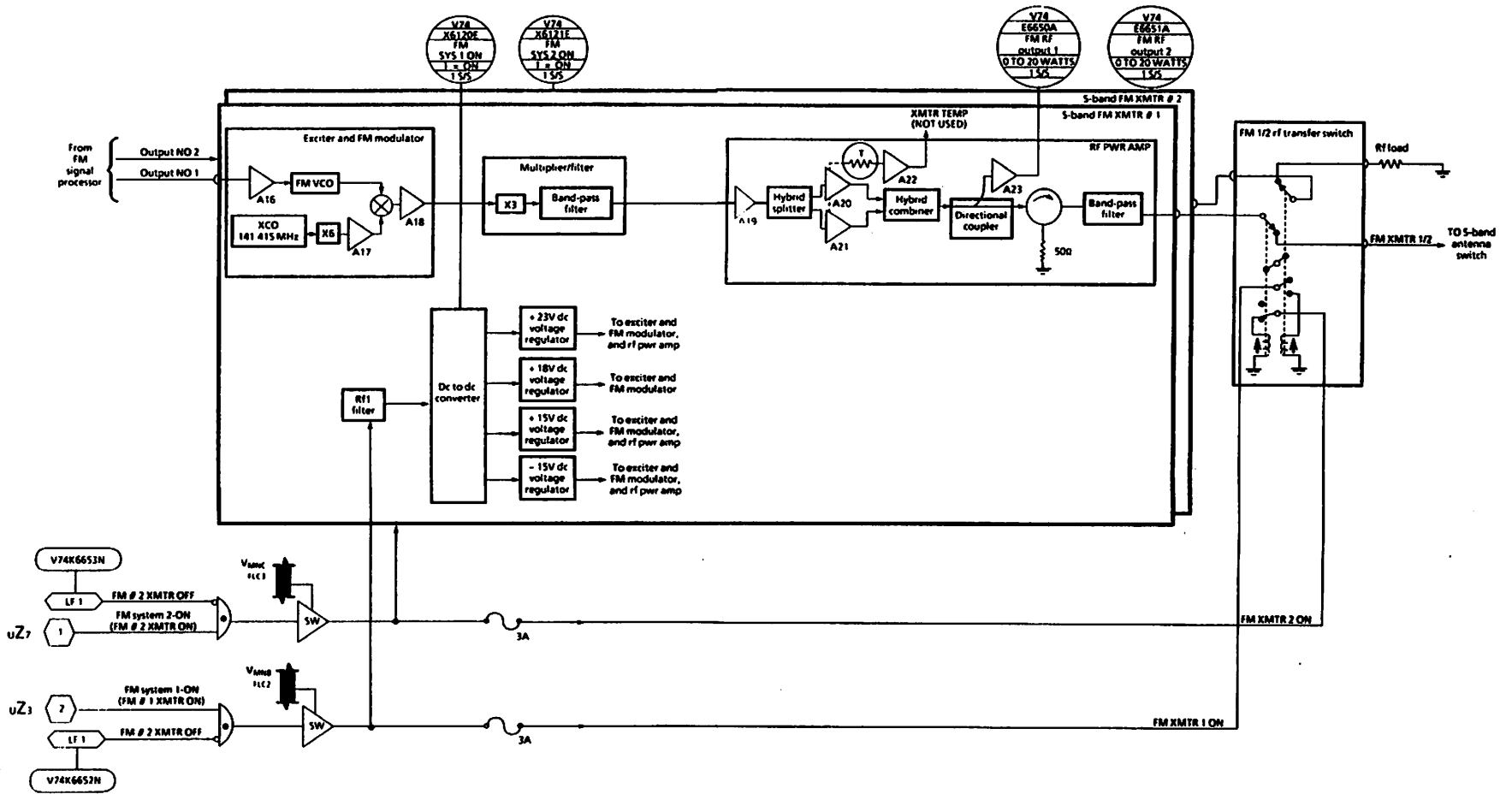


Figure 3-20.- Schematic of the interfaces to the FM transmitter.

FM Antenna Electronics

The antenna electronics for the FM subsystem perform that same type of function as the PM antenna electronics, i.e., control and route the FM rf from the transmitter to the FM hemi antennas. There are three subassemblies that constitute the FM antenna electronics; a set of logic gates, a pulser subassembly, and some rf switches. Refer to figure 3-21 for the following discussion.

The first subassembly is a set of logic gates that determine which antenna has been selected, from either switch selection or from GPC software. It will then output a control signal to the pulser subassembly to switch the contacts in the rf coax switch. The pulser is exactly what its name implies. It will pulse its output to change the state of the coax switch. It does not hold its output to the last state chosen. A magnet in the coax switch holds the contacts in their selected states.

The pulser subassembly takes the output of the logic gates and converts it to a one-shot that drives a two stage cascaded transistor driver. See figure 3-22. This, in turn, completes a circuit ground for the relay coils in the coax switch itself. The pulser works on a 100 msec charge/discharge rate. This time delay will inhibit pulser output changes until the capacitor is discharged.

The last subassembly is the rf switch. Again, like with the PM rf switches, there is one set of switches with redundant switching relays. This allows for maximum reliability with minimum rf plumbing. Figure 3-21 shows how the switch is connected to the pulsers and the S-band rf from the FM transmitters to the antennas.

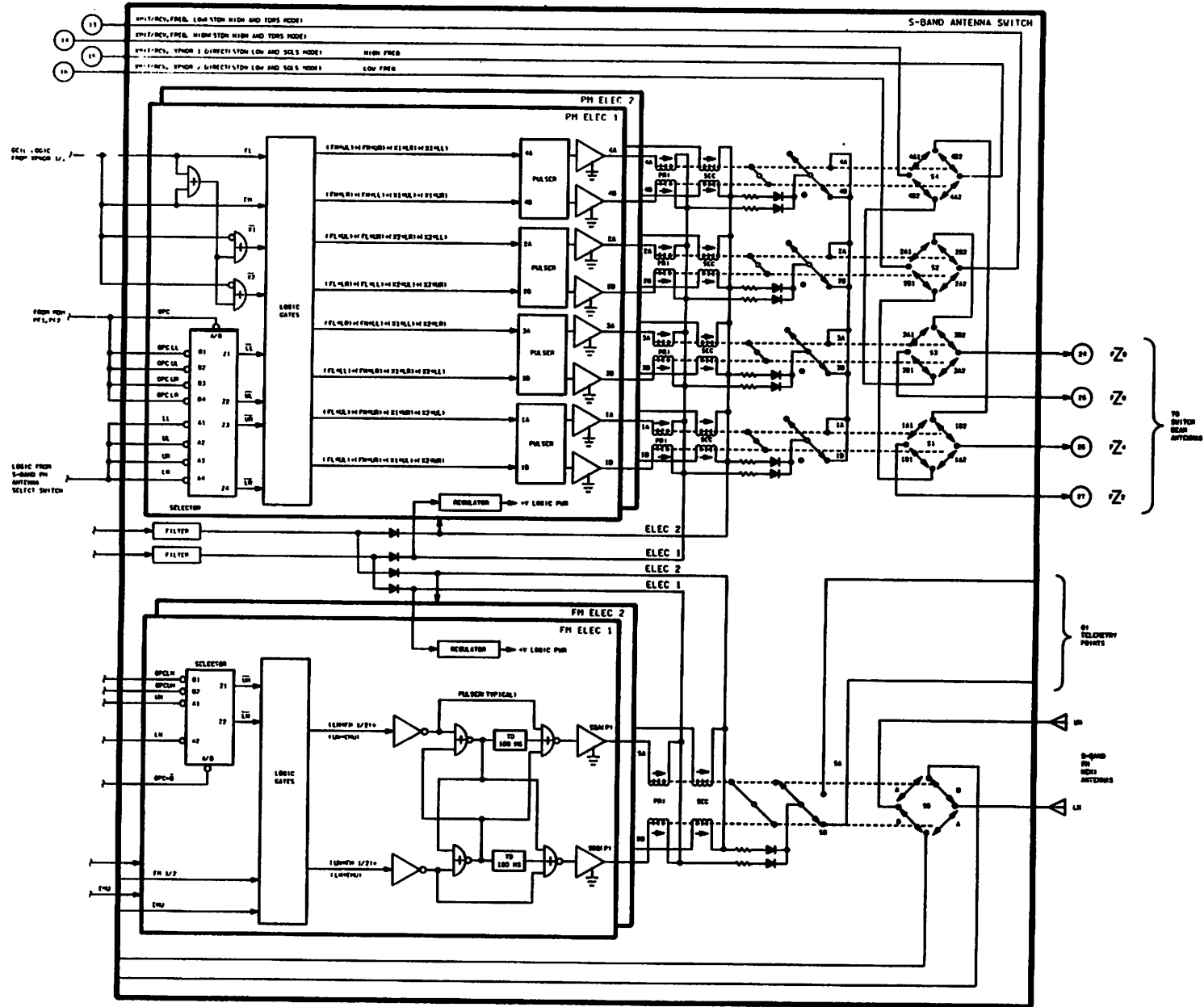
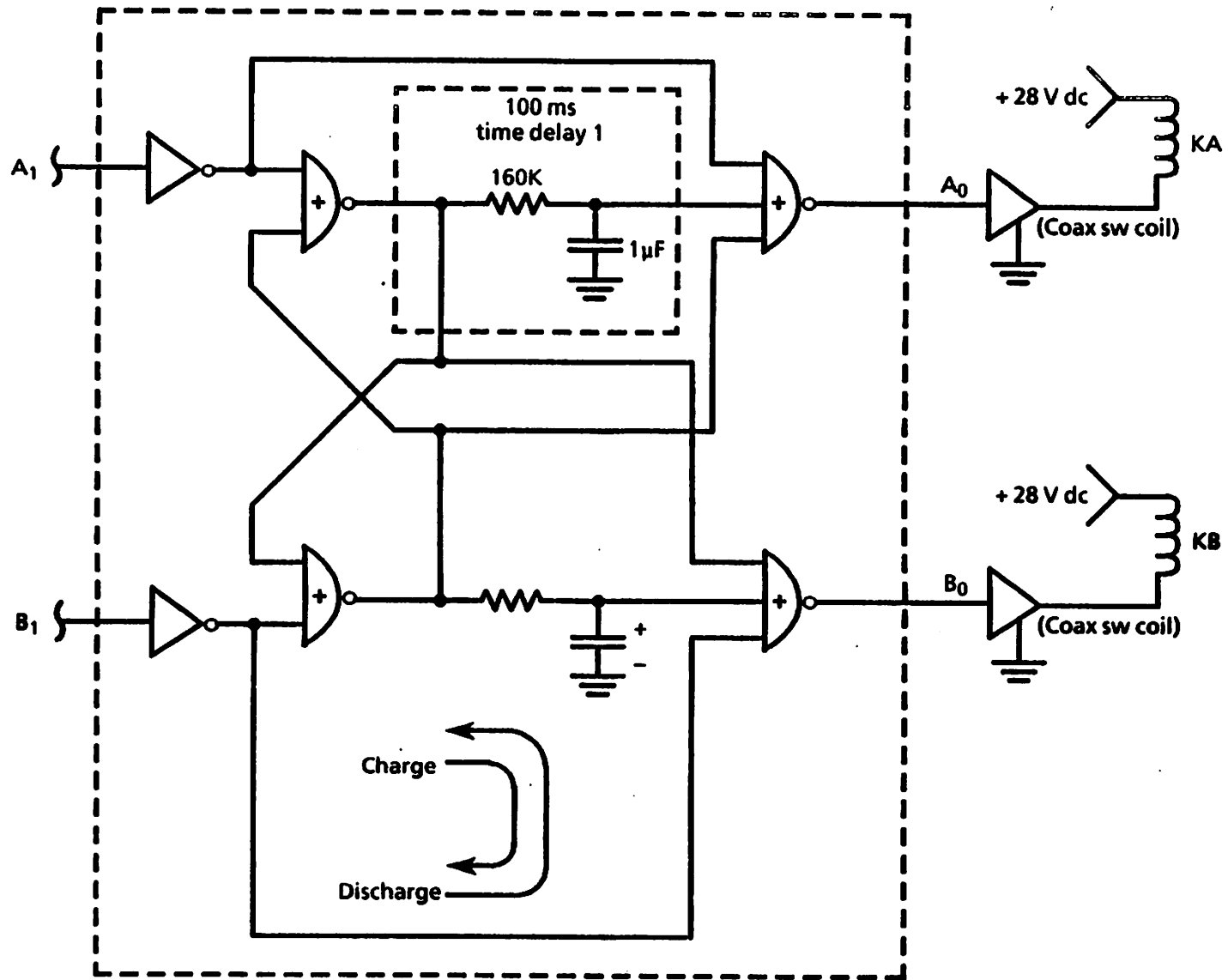


Figure 3-21.-Schematic of S-band antenna switch.

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Figure 3-22.- Diagram of a pulser subassembly.

FM Hemi Antennas

There are two antennas associated with the FM subsystem. These have been given the descriptive name of "hemi" antennas due to their radiation pattern. There is one located on the top of the Orbiter situated above the crew cabin along the Orbiter center line. The other antenna is located on the bottom below the crew cabin situated along the centerline of the Orbiter. Figure 3-23 shows the upper and lower antenna cavities and their orientation along the body axis.

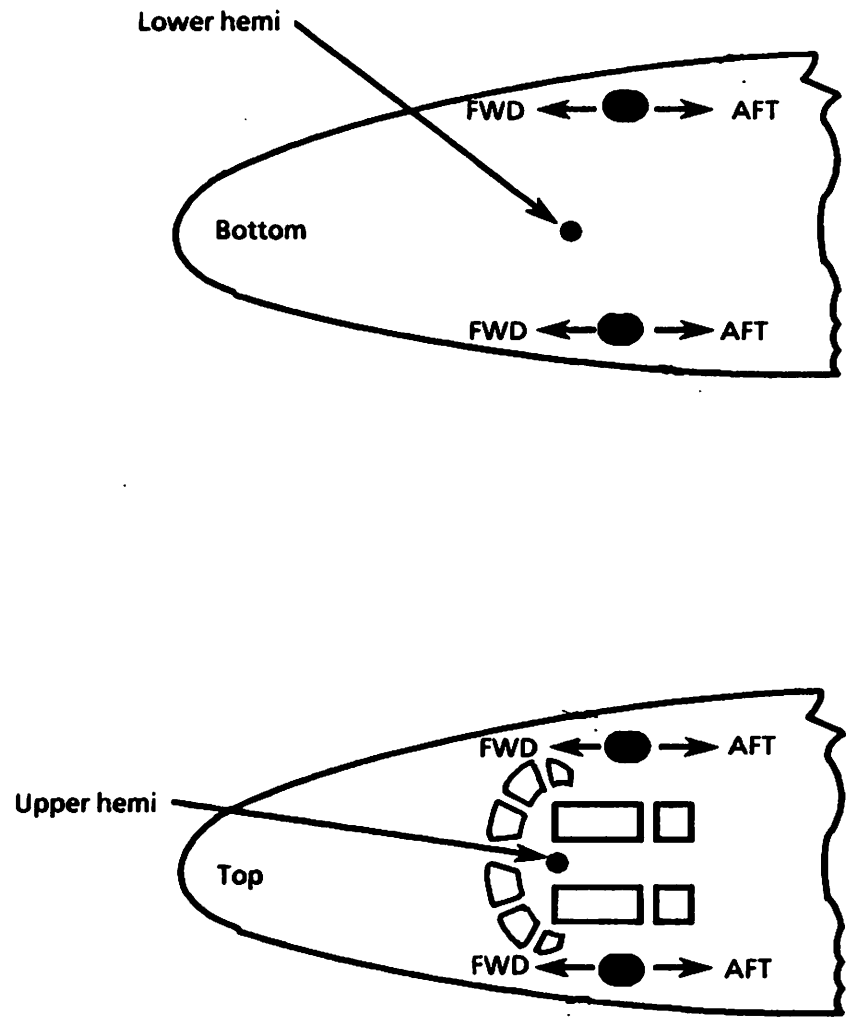


Figure 3-23.- S-band hemi antenna locations.

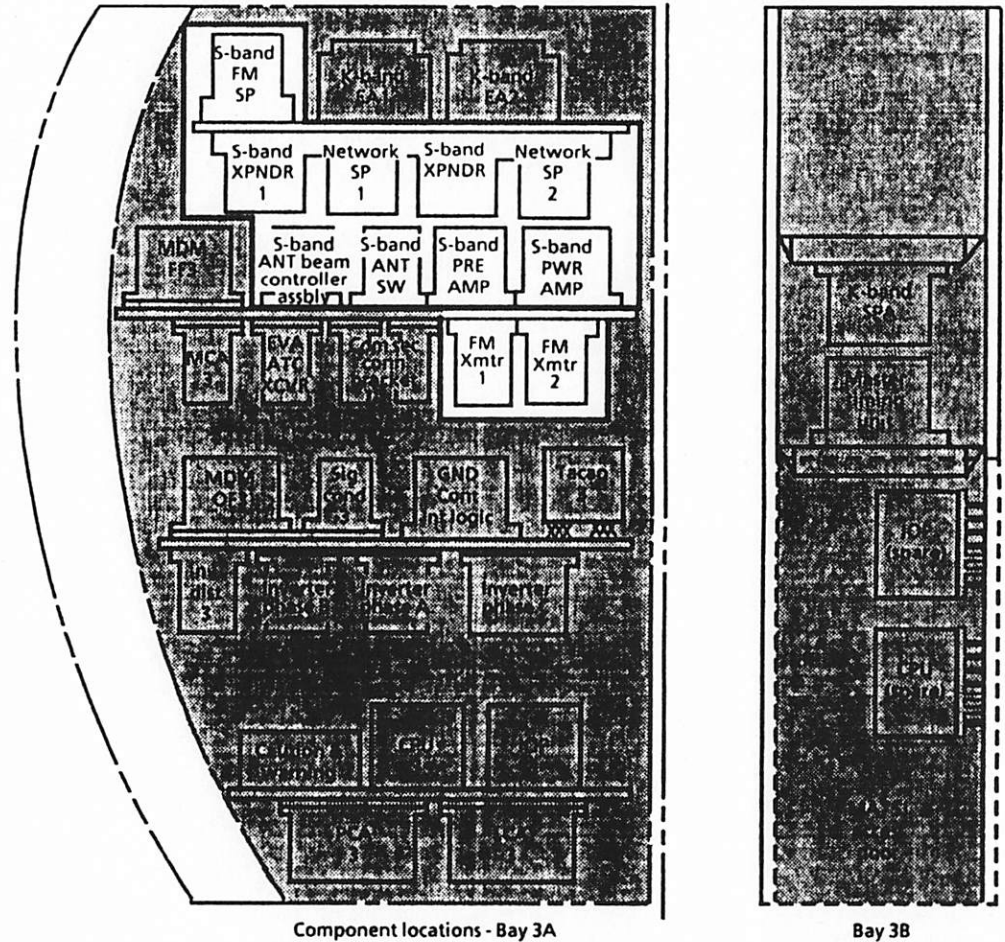
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Section 4: Equipment Locations

This section shows the avionics locations and antenna locations for the S-band PM and FM subsystems. Also, it shows the panel locations in the forward and aft crew station for PM and FM subsystems.

S-Band PM & FM Avionics Locations

Figure 4-1 shows the S-band PM and FM avionics locations.



TD327*046

Figure 4-1.- Avionics bay S-band PM and FM electronics equipment locations.

S-Band PM Panel Location

Refer to figures 4-2 and 4-3 for S-band PM panel locations.

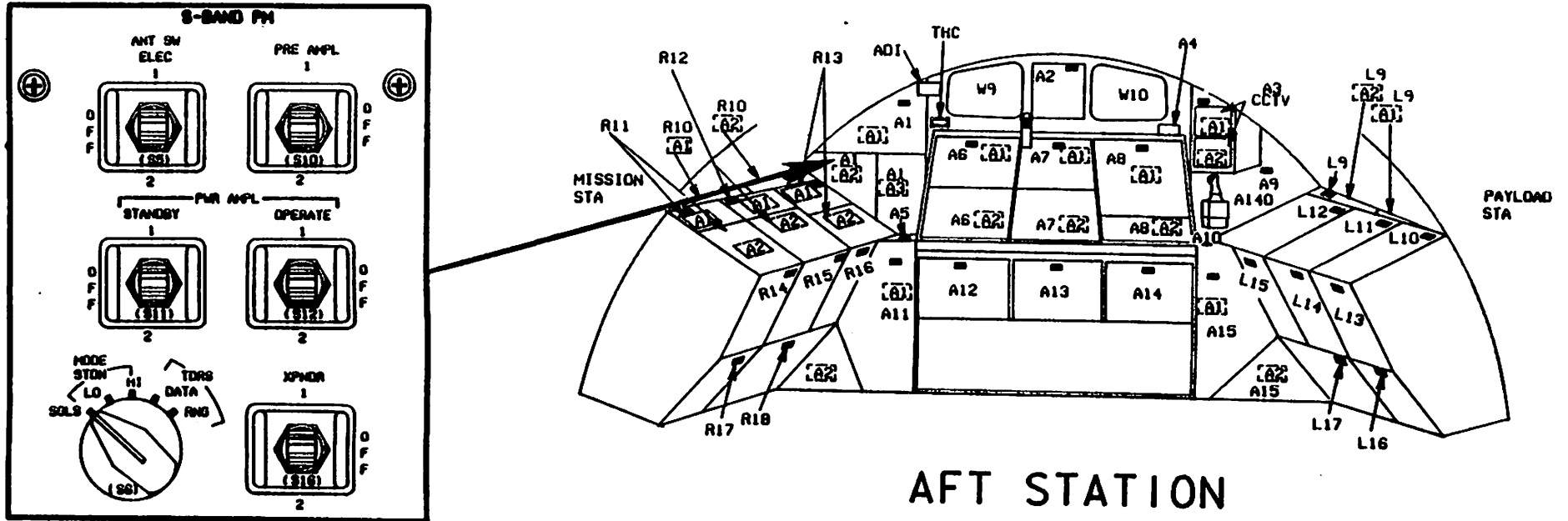


Figure 4-2.- Aft station.

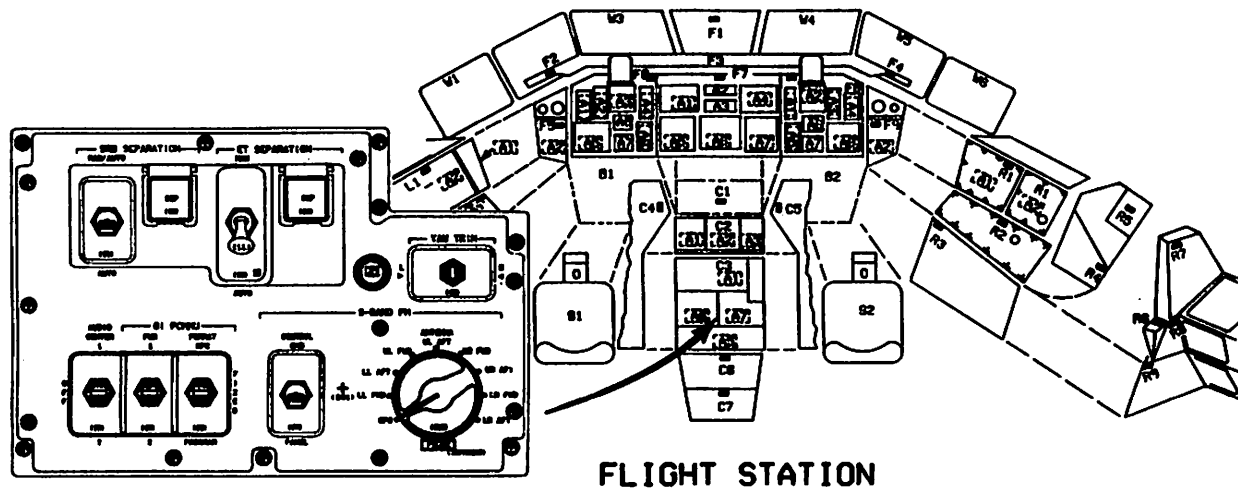


Figure 4-3.- S-band antenna switch and associated panels.

S-Band FM Panel Locations

See figure 4-4 for S-band FM panel locations.

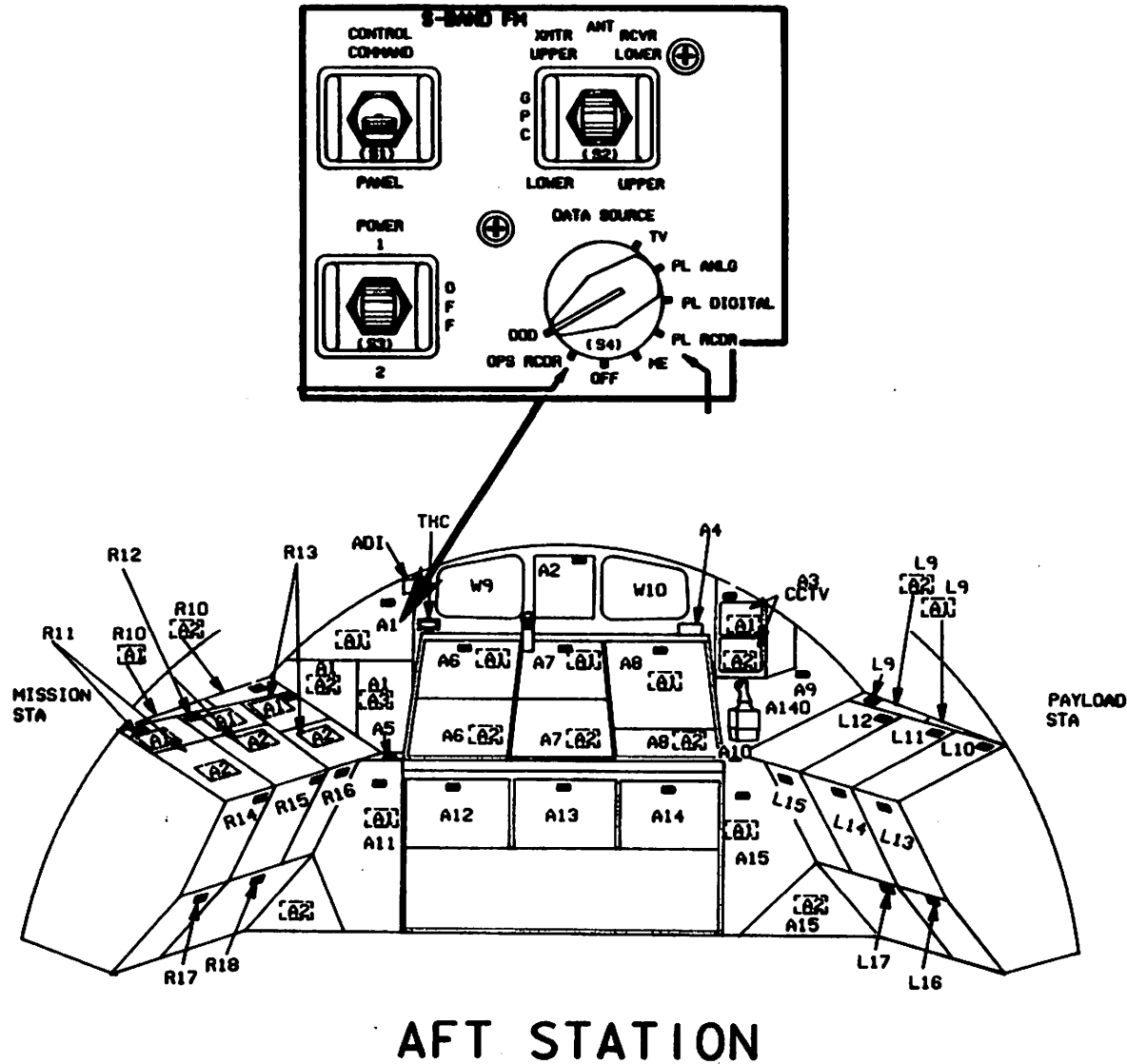


Figure 4-4.- S-band FM panel locations.

S-Band Ant External Locations

Refer to figure 4-5 for S-band antenna external locations.

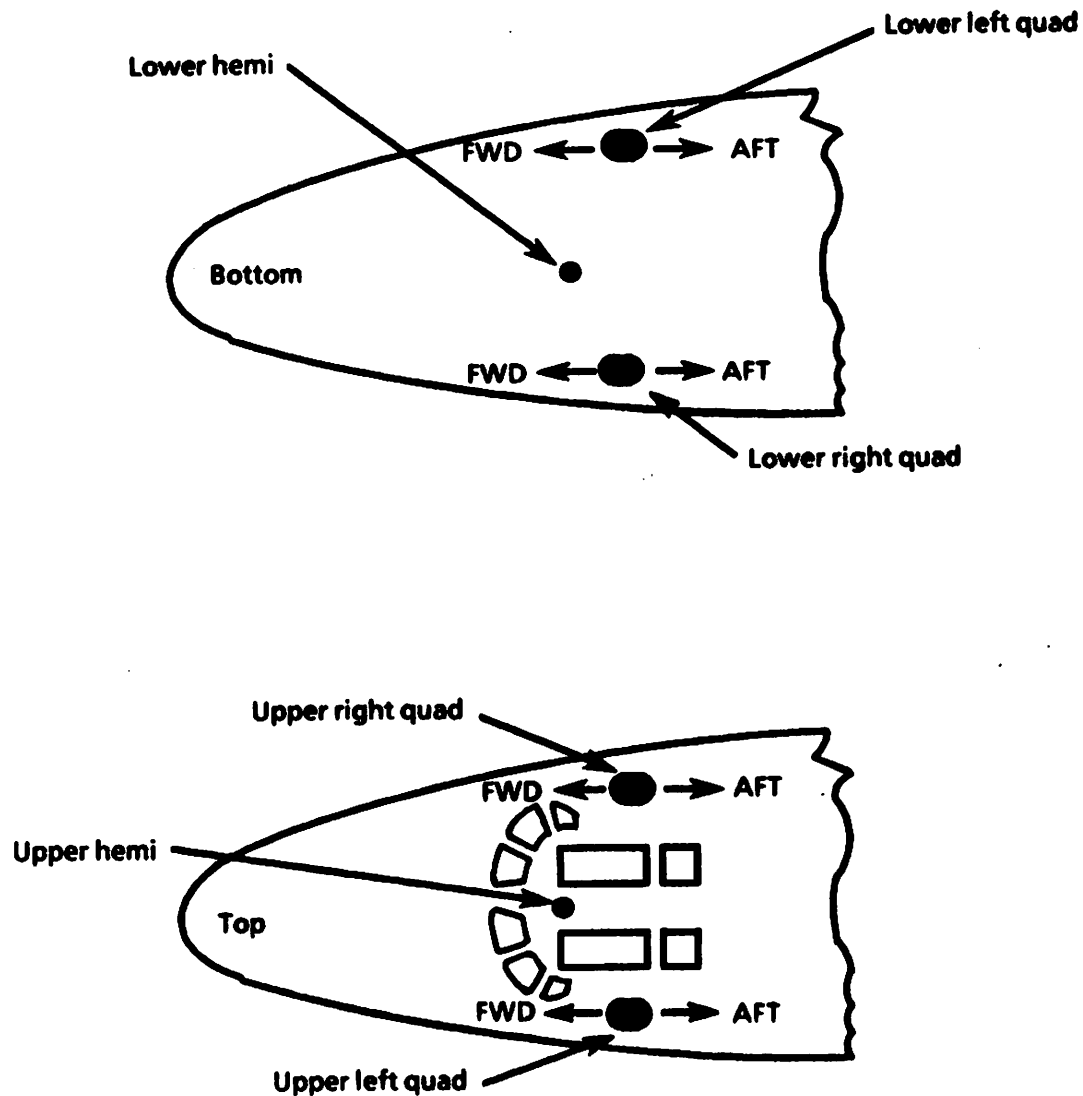


Figure 4-5.- S-band antenna locations.

Section 5: Displays and Controls

This section encompasses detailed descriptions of all displays and controls used by the flight crew to operate the S-band system. Illustrations of panels and associated switches, indicators, circuit breakers, etc., are included. Displays and controls are summarized in a tabular form with descriptions of their functions.

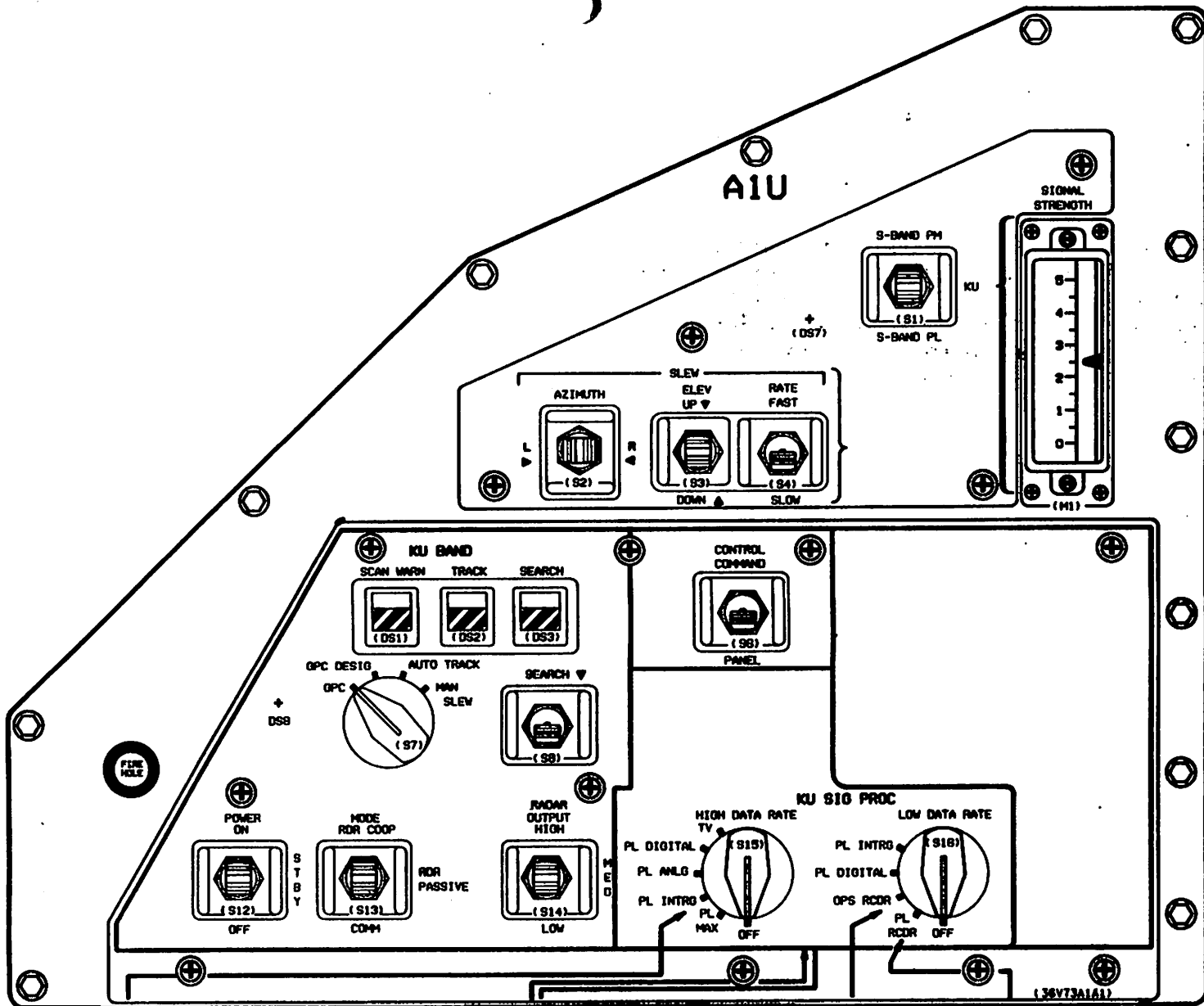


Figure 5-1a. - Panel A1 U.

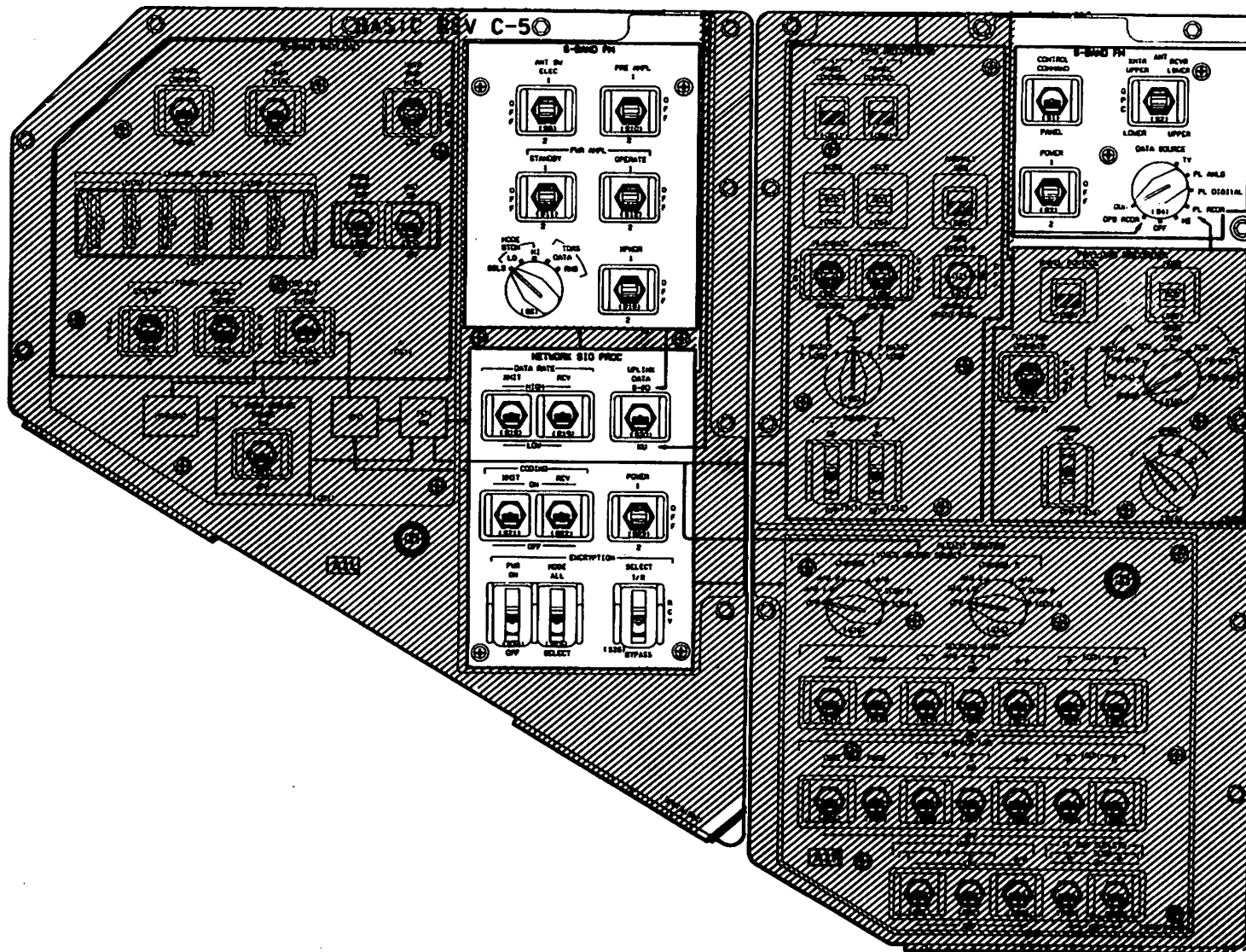


Figure 5-1b. – Panel A1 S-band PM and FM control.

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Panel A1U

Display & Control Title	Function	Associated D&C	Remarks
Signal strength IND	Provides an indication of S-band signal strength for the active S-band PM transponder uplink signal, the active payload (PL) S-band transponder, or the K-band transponder selected by the signal strength switch.	(A1) Signal strength SW (A1) Display/slew SW (A1) S-band PM antenna SW (F9) Dc amps/SIG STR IND	
Signal strength SW S-band PM S-band PL	Applies voltage representative of active S-band PM transponder receiver signal strength to the indicator. Same as the S-band PM position except for the S-band PL system.	(A1) Signal strength IND (A1) S-band PM SPNDR SW	

Panel A1L

Display & Control Title		Function	Associated D&C	Remarks
ANT SW	SW	Three-position switch that applies or removes power to one of the two antenna switch assembly antenna control electronics assemblies. In addition, it enables S-band PM and AM antenna switches.	(A1) S-band PM - antenna switch selector (SW) for ELEC 1, ELEC 2 or OFF position.	
	ELEC 1	Selects antenna controls electronics number 1.	(A1)	
	ELEC 2	Same as the 1 position except controls electronics number 2.	(A1)	
PRE AMP	SW	Three-position switch that applies or removes power to one of the two preamplifier assemblies.	(A1) S-band PM - preamplifier selector switch (SW) for PRE AMPL 1, PRE AMPL 2, or OFF position.	
	PRE AMPL 1	Selects preamplifier assembly number 1.	(A1)	
	PRE AMPL 2	Selects preamplifier assembly number 2.	(A1)	

Panel A1L

Display & Control Title	Function	Associated D&C	Remarks
PWR AMPL	The following two switches apply standby and operate power to the selected power amplifier.	(A1) S-band PM-(SW) power amplifier for selection of STANDBY 1, STANDBY 2, or OPERATE 1	NOTE: The above PRE AMPL switch must be in the 1 or 2 position for these switches to be active.
STANDBY 1 SW	Selects power amplifier 1 in the standby mode.	(A1)	NOTE: A 140-second delay is provided for warmup if the standby switch is in the OFF position.
STANDBY 2 SW	Same as 1 for power amplifier 2.	(A1)	
OPERATE 1 SW	Selects power amplifier 2 in the operate mode.	(A1)	
OPERATE 2 SW	Same as 1 for power amplifier 2.	(A1)	

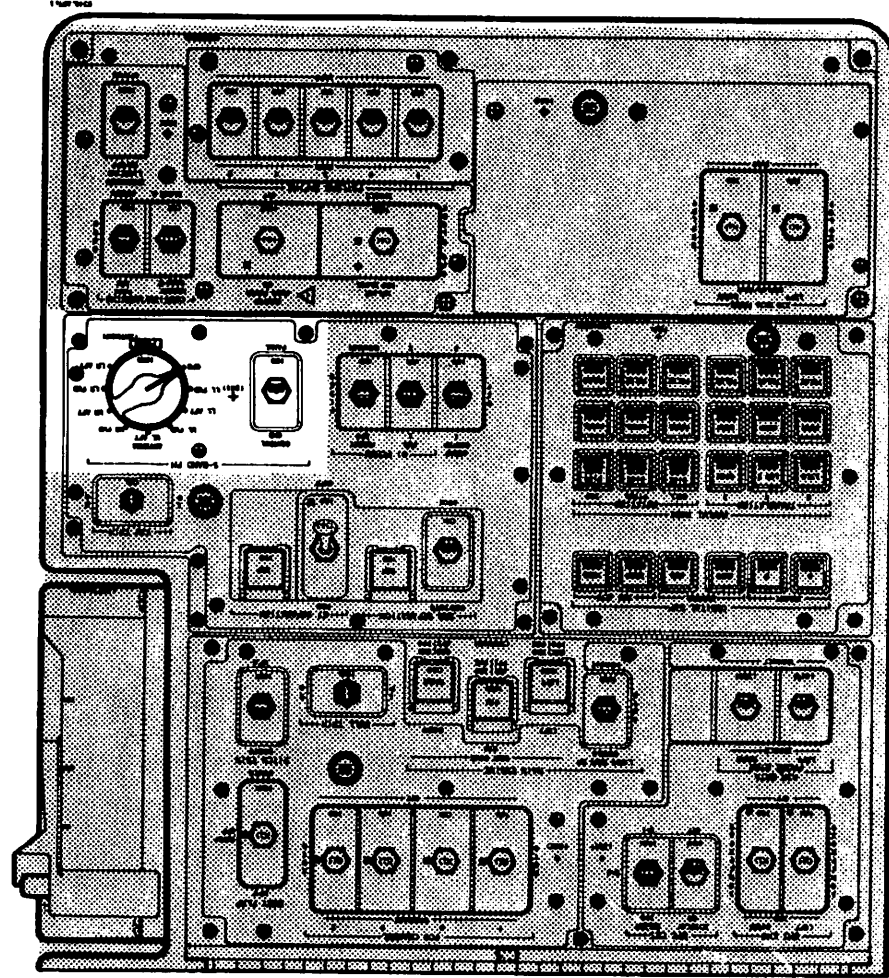
Panel A1L

Display & Control Title		Function	Associated D&C	Remarks
MODE	ROT	This rotary switch provides selection of power levels and interfaces for the STDN and TDRS modes of operation.	(A1) S-band PM - (ROT), rotary switch for the selection of STDN or TDRS mode.	NOTE: In the low-power modes data is routed directly to the transponder. In the high-power modes data is routed to the transponder through the preamp for uplink and the power amplifier for downlink.
	SGLS	Selects the SGLS operating mode. (SGLS mode bypasses PA's and preamps.)	(A1)	
	STDN LO	Selects the STDN low-power operating mode.	(A1)	
	STDN HI	Selects the STDN high-power operating mode.	(A1)	

Panel A1L

Display & Control Title	Function	Associated D&C	Remarks
<p style="text-align: center;">TDRS DATA ROT</p> <p>XPNDR SW</p>	<p>Selects the TDRS high-power operating mode.</p> <p>This switch selects S-band transponder for the modes selected above.</p> <p>1 Selects TRANSPONDER 1.</p> <p>2 Selects TRANSPONDER 2.</p>	<p>(A1)</p> <p>(A1) S-band PM - (SW), position switch that selects TRANSPONDER 1, TRANSPONDER 2, or OFF position.</p> <p>(A1)</p> <p>(A1)</p>	

Figure 5-2.- Panel C3.

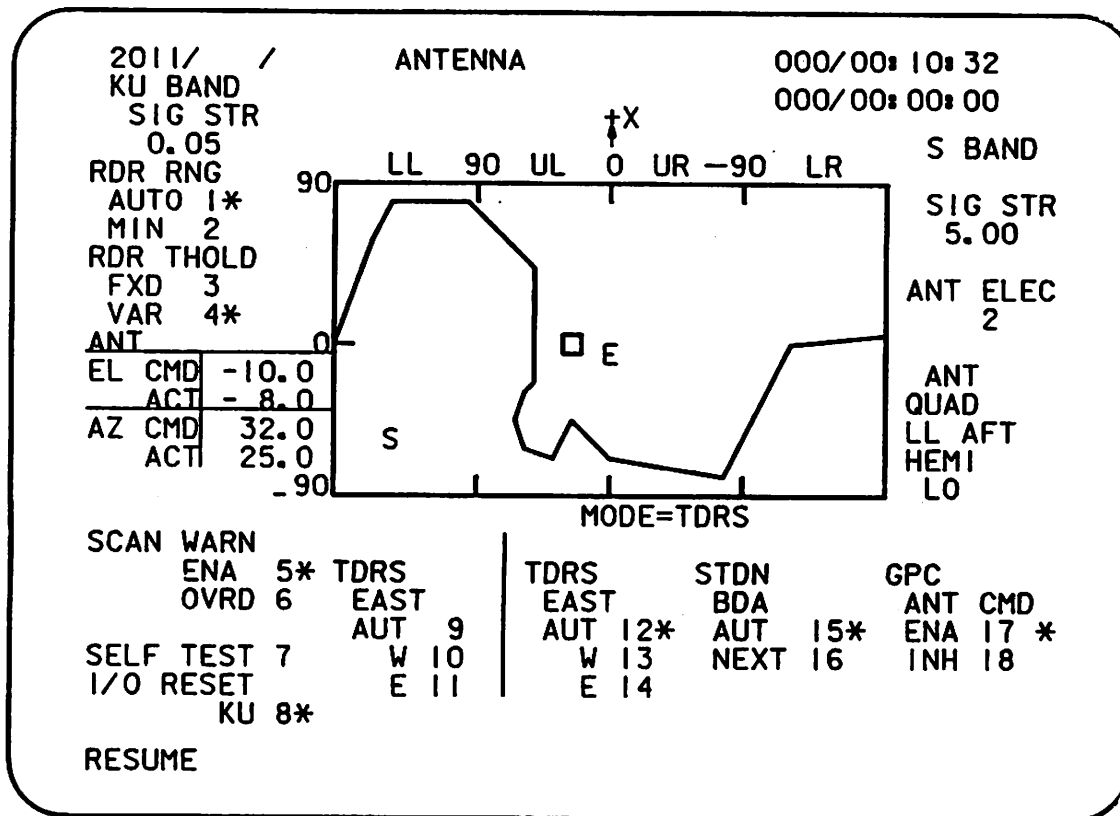


Panel C3

<p>S-band PM</p> <p>CONTROL</p> <p>CMD</p> <p>PANEL</p> <p>ANTENNA</p>	<p>sw</p> <p>rot</p>	<p>The switches on this panel subsection are associated with the S-band PM switches on panel A1.</p> <p>This two-position switch is a GCIL input which enables or disables the associated switches on panel A1.</p> <p>Provides the GCIL input which disables the panel A1 switches and enables the GCIL to respond to commands.</p> <p>Provides the GCIL input which enables the panel A1 switches.</p> <p>This rotary switch provides for manual or GPC control of PM system antenna selection.</p>
---	---	---

Panel R15

Display & Control Title	Function	Associated D&C	Remarks
cb MNA GCILC	Applies main bus power to the GCILC primary power supply and both MDM data buffers. Provides power to the control switches for onboard or ground command control selection.	(C3) S-band PM control SW (A1) S-band payload control SW (A1) S-band FM control SW (A1) K-band comm system control SW (AT) CCTV power	The GCILC provides the interface for controlling Shuttle comm system either by uplink commands or onboard switches. The MNC GCILC circuit breaker powers a redundant power supply.
cb MNC GCILC	Same as the MNA GCILC circuit breaker except the secondary power supply.	Same as GCILC MNA CB.	



3182. ART, 3

Figure 5-4. - Orbiter ANTENNA CRT display.

Table 5-1.- OPS 201 ANTENNA display, S-band section

Status display	Interactive item	Display location	Description/function
ORB PROJECTION		CTR	Pictorial flat projection of Orbiter, oriented as shown by " + x" axis indicator.
S		In Pictorial	Shows current location of S-band ground station(s) relative to Orbiter.
E,W		In Pictorial	Shows current location(s) of East, West TDRS relative to Orbiter.
SIG STR		UP RT	Shows relative strength of Orbiter received S-band PM rf signal, 0-5 scale.
ANTELEC		UP RT	Shows which of two S-band antenna control electronics elements is active.
ANT QUAD		RT CTR	Shows which of eight S-band PM (QUAD) antennas is selected. A down arrow (↓) denotes a miscompare between GPC command and actual antenna selected.
HEMI		RT CTR	Shows which of two S-band FM (Hemi) antennas is selected. A down arrow (↓) denotes a miscompare between GPC command and actual antenna selected.
MODE =	TDRS	LO CTR	Shows S-band PM system is in TDRS mode.
	STDN HI	LO CTR	Shows S-band PM system is in STDN high power mode.
	STDN LO	LO CTR	Shows S-band PM system is in STDN low power mode.
	SGLS	LO CTR	Shows S-band PM system is in SGLS mode.

COMM/RCDR, SPEC 76 (see sample, figure 5-5) gives status, mode, and configuration data on many communication and instrumentation systems LRUs. There are no interactive items for access/execution by the crew. COMM/RCDR data specific to the S-band PM system LRUs are briefly described in table 5-2.

2011 076	COMM/RCDR	000/00:08:36
S-BAND PM		000/00:00:00
XPND	2 KU-BAND	
MODE	S-HI PA TEMP	
SPD SPEC	OFF GMBL TEMP	+139
RANGING	OFF	
PREAMP	2 SPD SPEC	A + 35
FREQ	HI CCTV	B + 28
PWR AMPL		ON
OPER	2 CNTL UNIT	B
STBY	1 CAM OVER-TEMP	
TEMP 1	178 GCIL CONFIG	CMD
2	178	
NSP	RECORDERS	
FR SYNC 1	NO	OPS 1 OPS 2 PL
2	YES	STBY STBY STBY
FAIL SAFE	ENA	TRK 14 1
DATA XMIT	HI	DIR REV FWD FWD
RCV	HI	%TAPE 0 39 0
UL DATA	S	TAPE STOP STOP STOP
CODING XMIT	OFF	TEMP 50 50 0
RCV	OFF	BITE
RCDR INPUT	D/VO	FL↓
SPEC 76 PRO		(XX)

1437. ART, 4

Figure 5-5. - COMM/RCDR CRT display.

Table 5-2.- COMM/RCDR CRT display, S-band section

Text		Display location	Description/function
XPND	OFF	UP LFT	Both LRUs OFF
	BLANK	UP LFT	Both LRUs unpowered (OFF)
	1	UP LFT	XPNDR 1 ON
	2	UP LFT	XPNDR 2 ON
MODE	S-HI	UP LFT	STDN high power mode
	S-LO	UP LFT	STDN low power mode
	SGLS	UP LFT	SGLS mode
	TDRS	UP LFT	TDRS mode
SPD SPEC	ON		RF signal from TDRS to SSO is in spread spectrum mode.
	OFF		RF signal from TDRS to SSO is not in spread spectrum mode.
RANGING	ON		Tone ranging ON
	OFF		Tone ranging OFF
PREAMP	OFF		Both LRUs OFF
	1		Preamp 1 ON
	2		Preamp 2 ON
FREQ	HI		S-band PM system is in high frequency mode.
	LO		S-band PM system is in low frequency mode.
PSW AMPL OPER	OFF		Both power amplifiers OFF
	1		PA 1 ON
	2		PA 2 ON
STBY	OFF		Neither PA in standby
	1		PA 1 in standby
	2		PA 2 in standby

The following data refer to LRUs which are not part of the S-band PM system, but both NSP and GCIL have major data (NSP) and control (GCIL) interfaces with that system.

Table 5-2 (Continued)

Text	Display location	Description/function
NSP FR SYNC 1 YES 1 NO	LO LFT LO LFT	NSP 1 has (YES)/has not (NO) achieved frame synchronization of the UL/FL operational TDM data stream.
2 YES 2 NO	LO LFT LO LFT	NSP 2 has (YES)/has not (NO) achieved frame synchronization of the UL/FL operational TDM data stream.
FAIL SAFE ENA INH	LO LFT	Parameter for automatic fail-safe switchover from K-band FL to S-band FL is enabled/inhibited.
DATA XMIT LO HI	LO LFT LO LFT	S-band PM system is in low data rate mode for SSO transmit. S-band PM system is in high data rate mode for SSO transmit.
DATA RCV LO HI	LO LFT LO LFT	S-band PM system is in low data rate mode for SSO receive. S-band PM system is in high data rate mode for SSO receive.
UL DATA S KU	LO LFT LO LFT	UL/FL data source for NSP is S-band PM system. FL data source for NSP is K-band system.
CODING XMIT OFF ON	LO LFT LO LFT	SSO transmitted operational TDM data is not convolutionally encoded. SSO transmitted operational TDM data is convolutionally encoded.

Table 5-2 (Concluded)

Text	Display location	Description/function
CODING RCV OFF	LO LFT	SSO is not configured for processing of convolutionally encoded FL operational TDM data.
ON	LO LFT	SSO is configured for processing of convolutionally encoded FL operational TDM data.
RCDR INPUT DATA	LO LFT	OPS recorder is recording only operational telemetry data (no voice).
D/VO	LO LFT	OPS recorder is recording operational telemetry plus selected voice loop(s).
GCIL CONFIG PNL ↓	RT CTR	GCILC is in panel mode. S-band, K-band, and CCTV systems have reverted to panel control.
CMD	RT CTR	GCILC is in command mode. Each individual GCILC-controlled system can be controlled only by GCIL commands if that system control switch is in COMMAND position, or only by panel switches/selectors if control switch is in PANEL position. See section on GCIL for details.

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Section 6: Systems, Performance, Limitations, and Capabilities

Performance Characteristics

Signal Characteristics - PM

Interface characteristics for the control and telemetry type signals listed in figures 6-1 through 6-6 are found below by using the index numbers provided with each signal. All power interfaces are 28 V dc \pm 4 V dc.

T1

Data rate	Discrete signal
Waveform	Continuous dc level
Level	+5 V to -5 V dc
Termination	Differential analog

C1

Data rate	Discrete signal
Waveform	Continuous dc level
Level	(1) 24 to 32 V dc
	(0) 0 to 3 V dc
Source current	12 mA at 28 V dc
Termination	Single ended, return on pwr ground

R1

Frequency	STDN 2041.947 MHz 2106.406 MHz
	SGLS 1775.733 MHz 1831.787 MHz
Signal strength	Min. - 128 dBm Max. - 30 dBm
Doppler parameters	Max shift \pm 60 kHz Max rate 5 kHz/sec

R2

Frequency	STDN 2041.947 MHz or TDRS 2106.406 MHz
Signal strength	STDN Min - 110 dBm Max - 30 dBm TDRS Min - 107 dBm Max - 30 dBm
Doppler parameters	Max shift \pm 60 kHz Max rate STDN \pm 5 kHz/sec TDRS \pm 80 Hz/sec

T2

Data rate	Discrete signal
Waveform	Continuous dc level
Level	(1) 18 to 32 V dc (0) 0 to 3 V dc
Termination	Single ended, return on pwr ground

T3

Data rate	Discrete signal
Waveform	Continuous dc level
Level	0 to +5 V dc
Termination	Balanced differential analog

R6

Frequency	2287.5 MHz
	2217.5 MHz
Power	73 to 150 watts
Modulation	TDRS PSK
	STDN HI PM

C2

Data rate	Discrete signal
Waveform	Continuous dc
Level	(1) 18 to 32 V dc
	(0) 0 to 6 V dc
Source current	10 ma at 28 V dc
Termination	Single ended, return on pwr ground

R3

Frequency		
SGLS/STDN	noncoherent	2217.5 MHz \pm .001%
SGLS	coherent	256/205 of rcvd freq
STDN	coherent	240/221 of rcvd freq
SGLS/STDN	noncoherent	2287.5 MHz \pm .001%
SGLS	coherent	256/205 of rcvd freq
STDN	coherent	240/221 of rcvd freq
Rf power		2 watts min
Modulation index		1.1 w/o ranging
		1.0 w/ranging

R4

Frequency		
STDN HI/TDRS	noncoherent	2217.5 MHz \pm .001%
STDN HI/TDRS	coherent	240/221 of rcvd freq
STDN HI/TDRS	noncoherent	2287.5 MHz \pm .001%
STDN HI/TDRS	coherent	240/221 of rcvd freq
RF power		+30 dBm \pm 1.8 dB
Modulation		TDRS Phase shift keyed (PSK)
		STDN HI Phase modulation (PM)

R5

Frequency	2106.406 MHz
	2041.947 MHz
Power	-55 dBm to -130 dBm
	+3 dBm (max)
Modulation	TDRS PSK
	STDN HI PM

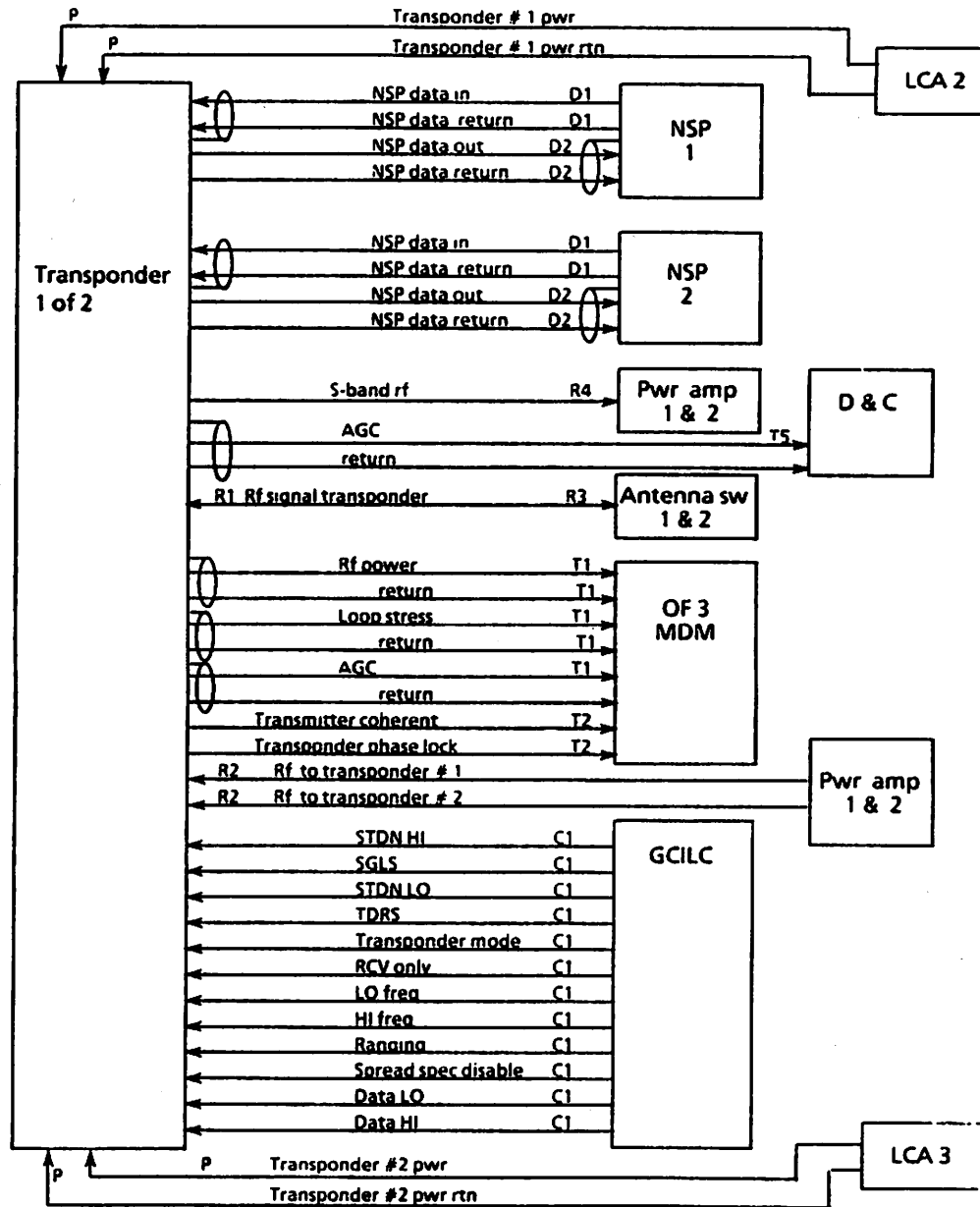


Figure 6-1.-Transponder interfaces.

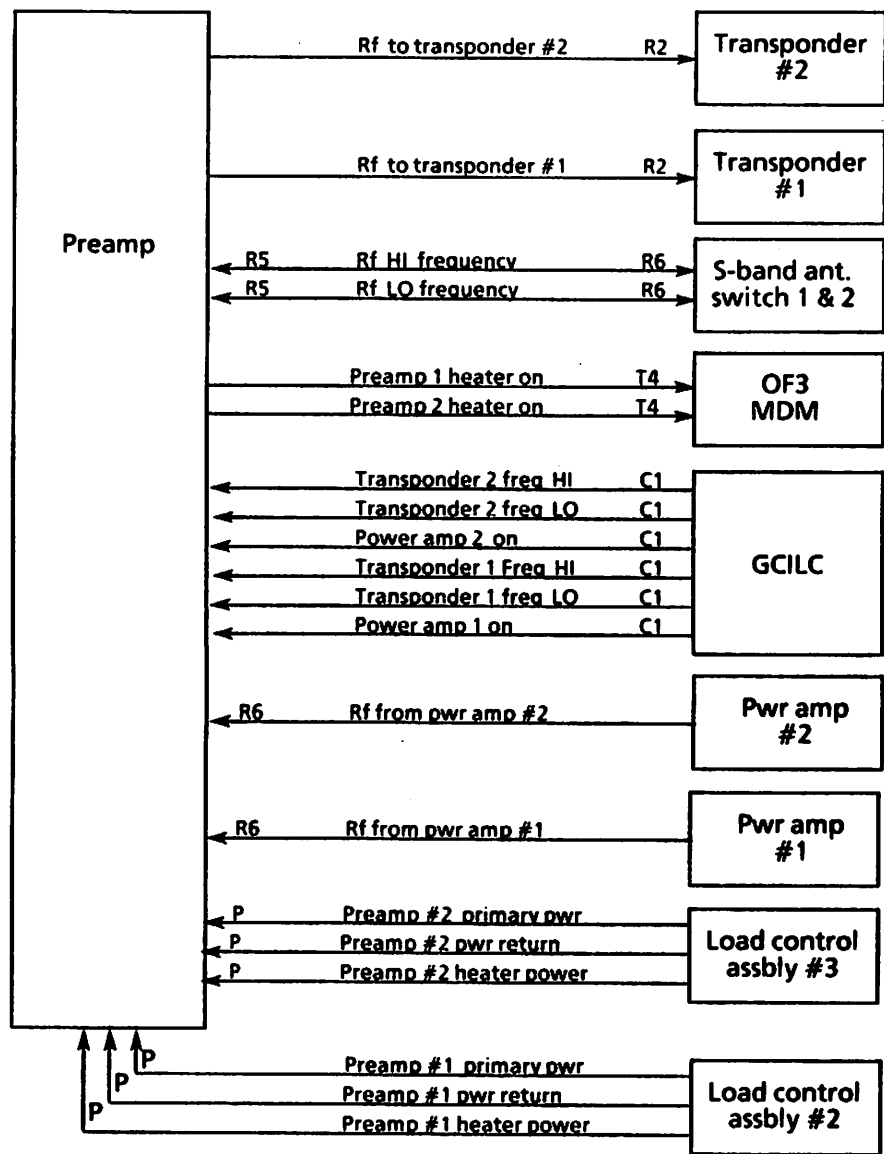


Figure 6-2.- Preamplifier interfaces.

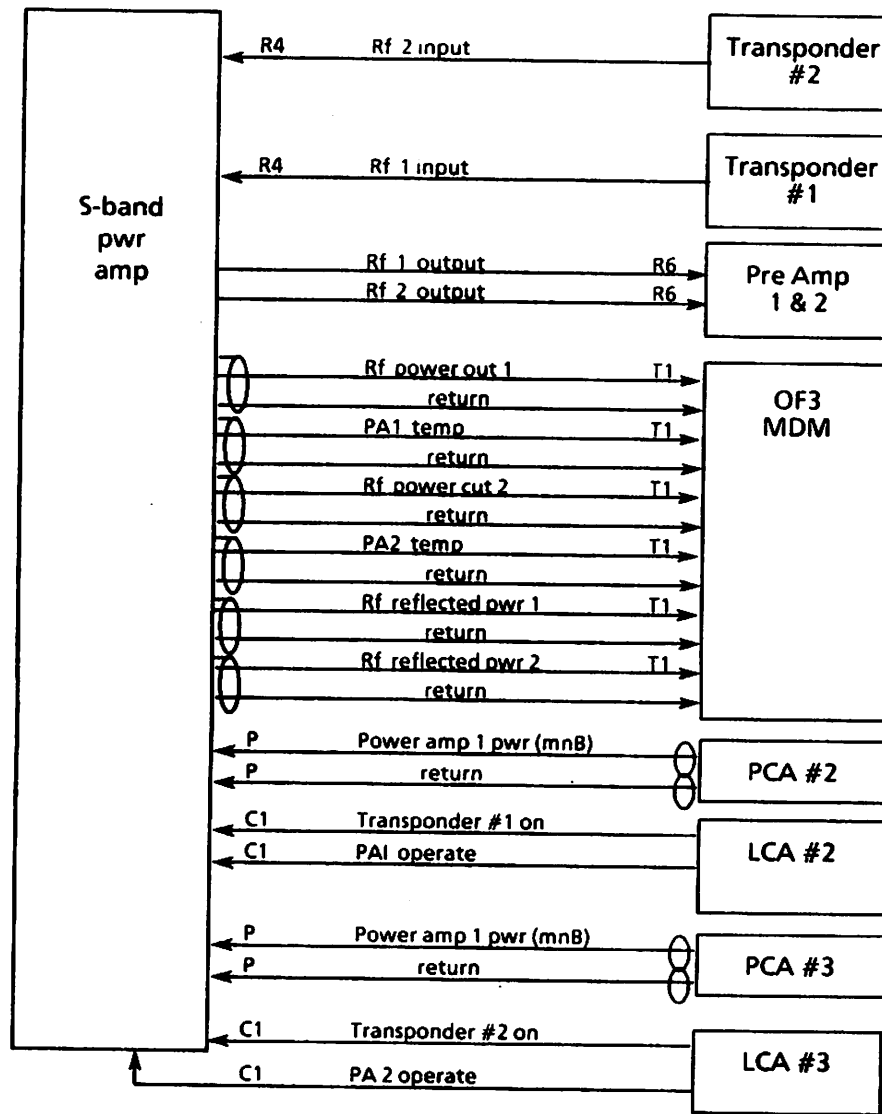


Figure 6-3.- Power amplifier interfaces.

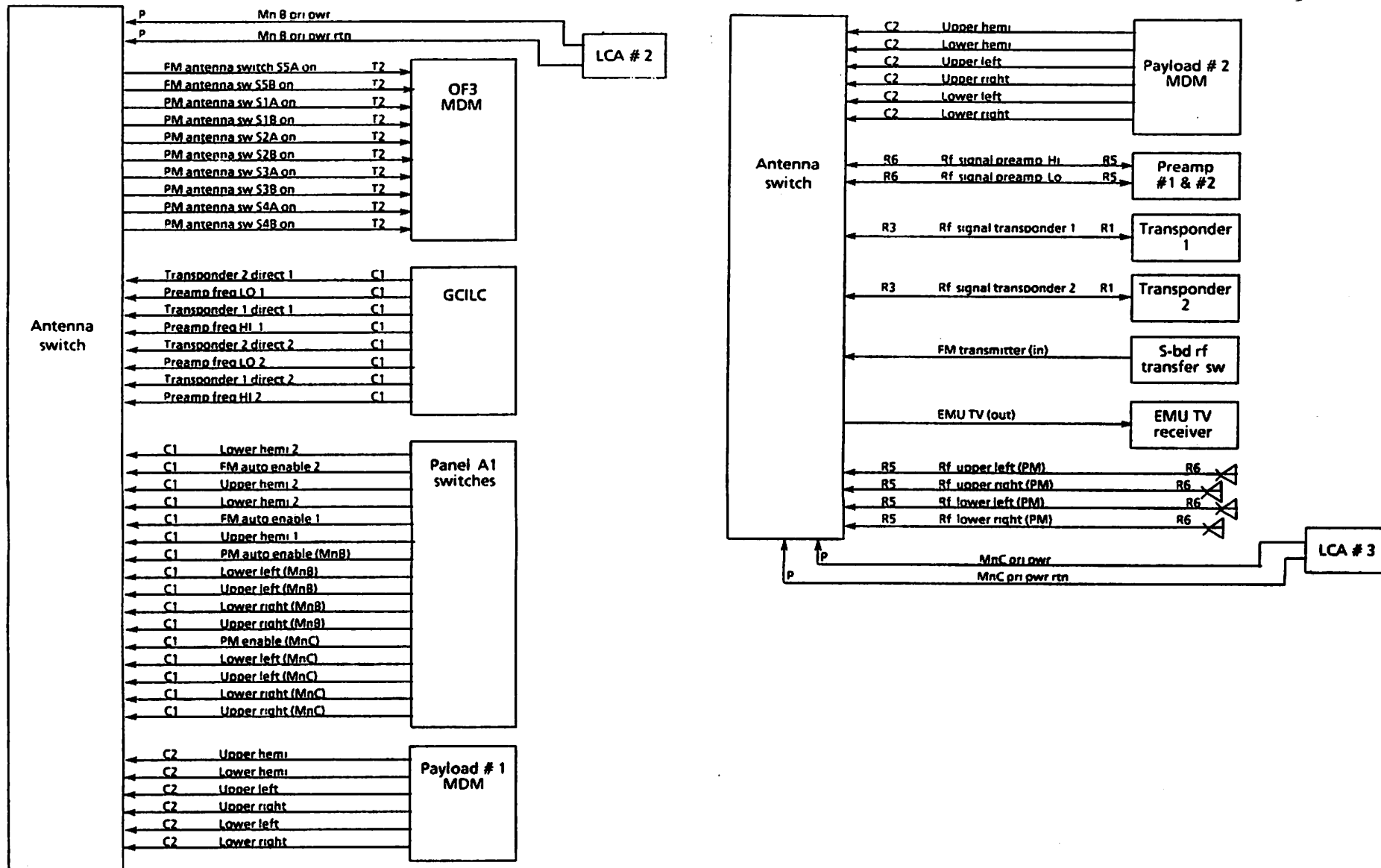


Figure 6-4.- Antenna switch interfaces.

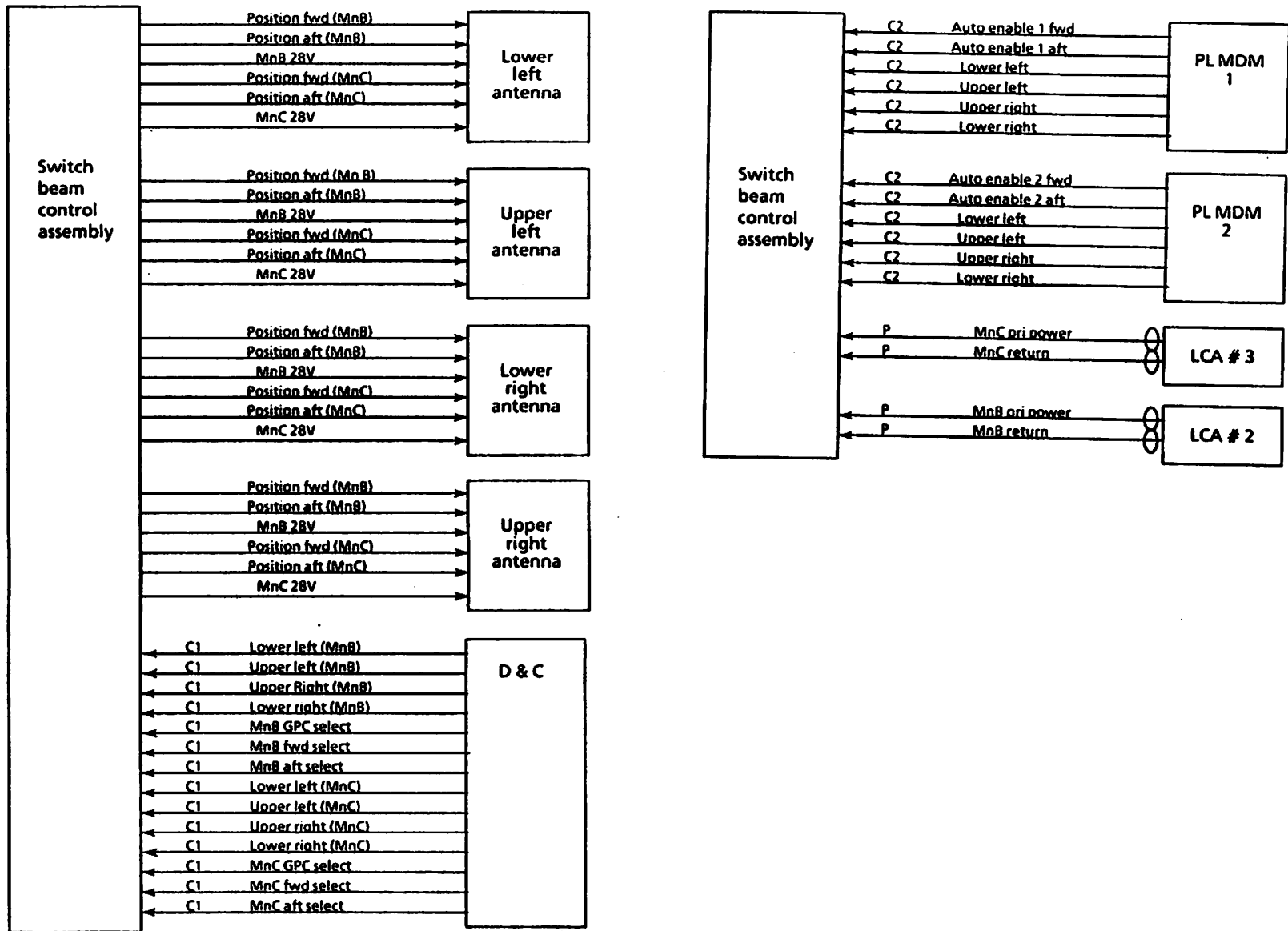


Figure 6-5.- Switch beam control interfaces.

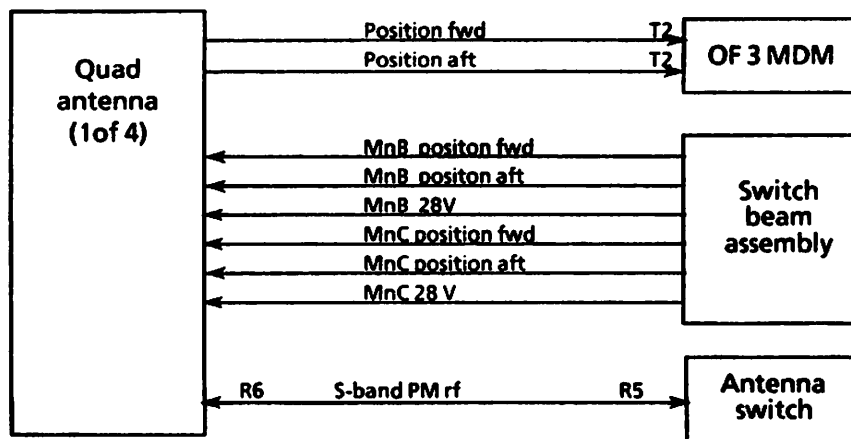


Figure 6-6.—PM quad interfaces.

Signal Characteristics - FM

Interface characteristics for the control and telemetry signals listed in figures 6-7 through figure 6-10 are found on pages 6-11 through 6-14 by using the index numbers provided with each signal.

C2

Data rate	Discrete signal
Waveform	Continuous dc level
Level	(1) 18 to 32 volts
	(0) 0 to 6 volts
Source current	10 MA (maximum) at 28 Vdc
Termination	Single ended, return on pwr ground

C1

Data rate	Discrete signal
Waveform	Continuous dc level
Level	(1) 24 to 32 volts
	(0) 0 to 3 volts
Source current	10 MA (maximum) at 28 Vdc
Termination	Single ended, return on pwr ground

T4

Data rate	Discrete signal
Waveform	Continuous dc level
Level	(1) 18 to 32 volts
	(0) 0 to 3 volts
Termination	Single ended, return on pwr ground

R7

Signal type
Power level

Frequency
Modulation

Rf S-band
15 watts maximum
10 watts minimum
2250.0 MHz
FM

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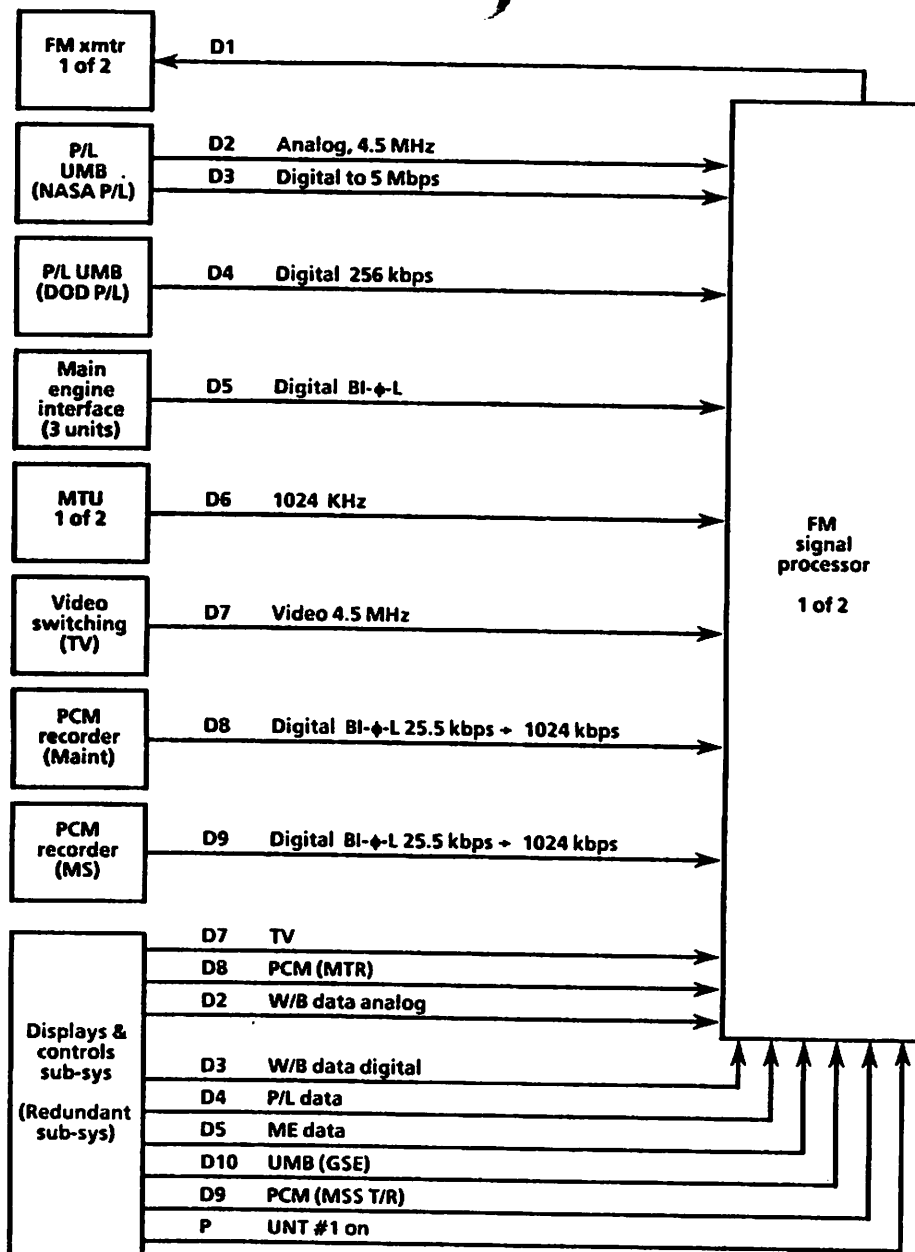
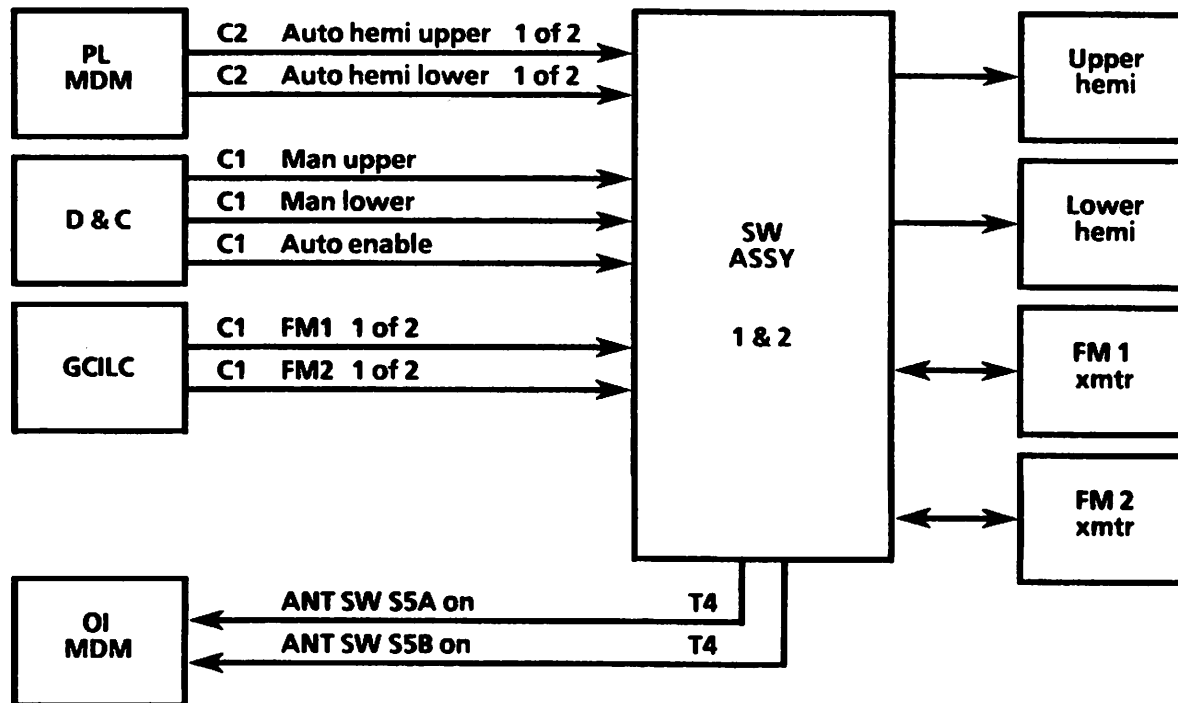


Figure 6-7.- Interfaces to FMSP.

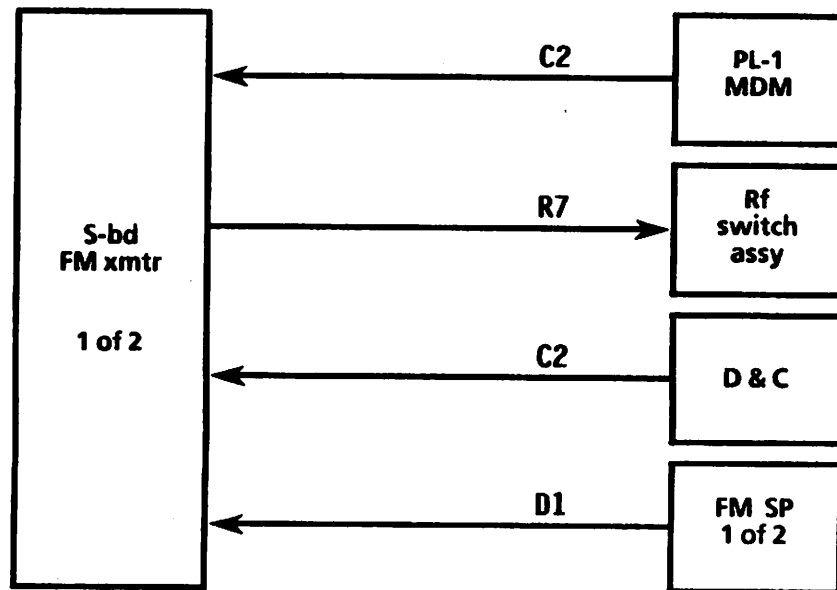
SFOM*001



Switch Assbly
S-BD FM

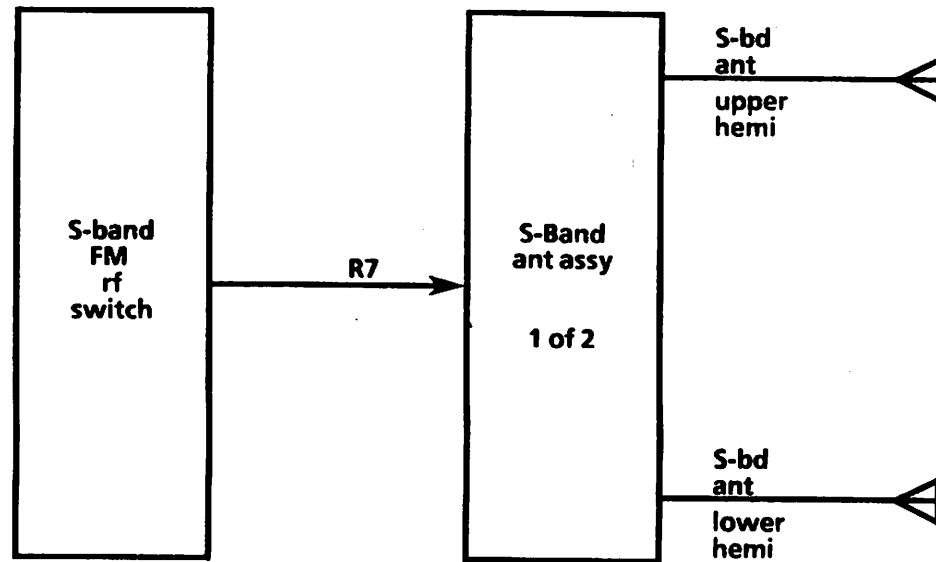
SFOM*002

Figure 6-8.- Interfaces to Switch Assembly.



SFOM*003

Figure 6-9.- S-band FM XMTR.



SFOM*004

Figure 6-10.- S-band FM antenna.

S-Band PM & FM R.F. Interface

Downlink Characteristics

Tables 6-1 through 6-4 give the characteristics of the Orbiter data and rf for the PM and the FM systems.

TABLE 6-1.- SSO-to-GSTDN S-band PM direct downlink interface characteristics

INFORMATION		TIME-DIVISION MULTIPLEXING	CARRIER MODULATION		CARRIER MODULATION	
CHANNEL	RATE or FREQUENCY		COHERENT CARRIER	AUX OSC CARRIER	COHERENT CARRIER	AUX OSC CARRIER
Voice 1 a	32/32 kbps b	Sync pattern: 76571440 g c Bit rate: 192/96 kbps b ± 0.01% Bit format: bi-phase-L	PM $\beta = 0.55$ ± 10% rad	PM $\beta = 0.55$ ± 10% rad	240/221	2287.5 ± 0.001% MHz
Voice 2 a	32/off kbps b					
Telemetry	128/64 kbps b					
Ranging turn-around	1.7 MHz d	NA	PM $\beta = 1.0$ + 20% - 10% rad	NA e	rcvd. freq.	2217.5 ± 0.001% MHz

SSO MIN EIRP f	ANTENNA POLARIZATION	GSTDN MIN G/T g		GSTDN REQUIRED P_{rec}/N_0 , dBHz 1			
		m	dB/K	Downlink Modulation	Carrier Acquisition h	Ranging and/or Doppler Tracking i	Data Acquisition m
0.1 dBW	RCP	9 12 26	22.0 21.2 31.2	Coherent carrier: Data (HDR/LDR) + Ranging channel	63.5	53.5 j	HDR: 70.7 LDR: 67.7
				Auxiliary oscillator carrier: Data (HDR/LDR)	61.2	51.2 k	HDR: 68.3 LDR: 65.3
				Coherent carrier: Unmodulated	59.8	49.8 l	NA

- a Delta-modulated
- b High data rate (HDR)/low data rate (LDR)
- c TDM frame sync uses telemetry sync pattern
- d Center frequency of the turnaround bandpass filter
- e Ranging turnaround channel is not transmitted in the auxiliary oscillator carrier mode
- f Based on 3 dB SSO antenna gain with about 94% coverage
- g Nominal G/T at 3° above land mask. Below 3°, G/T decreases as described in STDN Link Analysis Handbook, Volume 3: STDN S-Band Antenna Gains, EIRPs, and Antenna Noise Temperatures. Site-to-site variations are included in this document
- h 90% probable in 3 seconds
- i Carrier in-lock tracking with required Doppler measurement and ranging performance
- j Two-way Doppler and ranging (when used)
- k One-way Doppler
- l Two-way Doppler only
- m For 10^{-4} BER

TABLE 6-2.- SSO-to-TDRSS S-band return link interface characteristics

INFORMATION		TDM MULTIPLEXING AND ENCRYPTION c	CHANNEL ENCODING AND DECODING	CARRIER MODULATION
CHANNEL	RATE			
Voice 1 a	32/32 kbps b	Sync pattern: 76571440g d Bit rate: 192/96 kbps b	Code rate: 1/V = 1/3	PSK
Voice 2 a	32/off kbps b		Constraint length: K = 7 bits	$\beta = \pi/2$
Telemetry	128/64 kbps b		Generator sequence: 7566127g	rad $\pm 11^\circ$
			Symbol rate: 576/288 kbps b $\pm 0.01\%$	
			Symbol format: bi-phase-L	
			Decoding algorithm: 8-level soft-decision Viterbi (maximum likelihood)	

TABLE 6-3.- SSO-to-GSTDN SGLS S-band FM direct downlink interface characteristics

INFORMATION		SUBCARRIER FREQUENCY and MODULATION	CARRIER PEAK FREQUENCY DEVIATION
CHANNEL a	BIT RATE or BASEBAND WIDTH		
Main engine 1 b	60 kbps $\pm 0.01\%$	576 kHz $\pm 0.01\%$ PSK	635 kHz $\pm 15\%$
Main engine 2 b	60 kbps $\pm 0.01\%$	768 kHz $\pm 0.01\%$ PSK	635 kHz $\pm 15\%$
Main engine 3 b	60 kbps $\pm 0.01\%$	1024 kHz $\pm 0.01\%$ PSK	635 kHz $\pm 15\%$
Television	4.5 MHz	NA	4.5 MHz $\pm 15\%$
Payload - digital c	200 bps to 5 Mbps $\pm 0.01\%$	TBD	2 MHz $\pm 15\%$
Payload - analog	300 Hz to 4 MHz	NA	2 MHz $\pm 15\%$
Playback - OI b	60-1024 kbps $\pm 0.5\%$ d	NA	635 kHz $\pm 15\%$
Playback - PL b	25.5-1024 kbps $\pm 0.5\%$ d	NA	635 kHz $\pm 15\%$

- a One channel at a time, except all three main engine channels together
- b Bi-phase-L signal format
- c NRZ-L format, 200 bps - 5 Mbps. Bi-phase-L format, 200 bps - 2 Mbps
- d Channels recorded and playback bit rates will be established for each mission

TABLE 6-4.- SSO-to-SGLS S-band PM direct downlink interface characteristics

CARRIER FREQUENCY		SSO MIN EIRP	ANTENNA POLARIZATION	TDRSS REQUIRED (Pre)of		
COHERENT CARRIER	AUX OSC CARRIER			RETURN MODULATION	CHANNEL or FUNCTION	dBW
240/221	2287.5 $\pm 0.001\%$ MHz	16 dBW e	RCP	High rate data	192 kbps TDM 2-way Doppler	-177.7 TBD
x rcvd. freq.	or 2217.5 $\pm 0.001\%$ MHz			Low rate data	96 kbps TDM 2-way Doppler	-180.7 TBD
				Unmodulated	2-way Doppler	TBD g TBD h

INFORMATION		TIME-DIVISION MULTIPLEXING	CARRIER MODULATION		CARRIER FREQUENCY	
CHANNEL	RATE or FREQUENCY		COHERENT CARRIER	AUX OSC CARRIER	COHERENT CARRIER	AUX OSC CARRIER
Voice 1 a	32/32 kbps b	Sync pattern: 76571440g c	PM	PM	256/201	2287.5 $\pm 0.001\%$ MHz
Voice 2 a	32/off kbps b	Bit rate: 192/96 kbps b $\pm 0.01\%$	$\beta = 0.55$ $\pm 10\%$	$\beta = 0.55$ $\pm 10\%$	x rcvd. freq.	or 2217.5 $\pm 0.001\%$ MHz
Telemetry	128/64 kbps b	Bit format: bi-phase-L	rad	rad		

- a Delta-modulated
- b High data rate (HDR)/low data rate (LDR)
- c TDM frame sync uses telemetry sync pattern

- a Delta-modulated
- b High data rate/low data rate
- c Capable of unencrypted operation
- d TDM frame sync uses telemetry sync pattern
- e Based on 3 dB SSO antenna gain with about 94% of coverage
- f For no RFI, no polarization loss, and complying with TDRSS user constraints (4.4.2.2). May be reduced 2.5 dB if dual TDRSS return links are used (6.2.2). RFI requires increase of TBD dB
- g TDRSS configured for high rate data
- h TDRSS configured for low rate data

Uplink Characteristics

Tables 6-5 through 6-7 give the characteristics of the Orbiter data and rf for the PM system. There is no uplink into the FM system.

TABLE 6-5.- GSTDN-to-SSO S-band direct uplink interface characteristics

INFORMATION		PREMODULATION PROCESSING	CARRIER MODULATION		CARRIER FREQUENCY
CHANNEL	RATE or FREQUENCY		RANGING ON	RANGING OFF	
Voice 1 a	32/24 kbps b	Time-Division-Multiplexing Sync pattern: 76571440g Bit rate: 72/32 kbps b ± 0.001% Bit format: bi-phase-L	PM	PSK	2106.406300 MHz or 2041.947900 MHz
Voice 2 a	32/off kbps b		$\beta = 1.1$	$\beta = \pi/2$	
Command	6.4 kbps c		± 10%	± 10%	
Synchronization	1.6 kbps d		rad	rad	
Major tone e	500 kHz	Subcarrier Phase Modulation	PM	NA	
Minor tone f	100/20/4 kHz 800/160/40/10 Hz g	Subcrr freq: 1.7 Mhz h Major tone: $\beta = 0.6 \pm 10\%$ rad Minor tone: $\beta = 0.6 \pm 10\%$ rad	$\beta = 1.0$ ± 10% rad		

- a Delta-modulated
- b High data rate/low data rate
- c 2.4 kbps command channel is dummy filled to 2.5 kbps, BCH (127,50) encoded to 6.35 kbps, and dummy filled to 6.4 kbps before multiplexing with the other channels
- d 1.2 kbps sync pattern dummy filled to 1.6 kbps
- e Continuous during ranging
- f 7 minor tones one at a time only during major tone phase delay resolution
- g The 800, 160, 40, or 10 Hz minor tone is modulated onto the 4 kHz tone for transmission
- h Frequency stability 3 parts in 10^{11} short term
- i Based on 3 dB SSO antenna gain with about 94% of coverage
- j 90% probable in 6 seconds. Normal uplink acquisition with modulation off
- k Carrier in-lock tracking with mean time to lose lock at least 1 hour. Carrier and ranging channel are not turned around when carrier is not in lock
- l For 10^{-4} BER
- m In the absence of uplink ranging subcarrier, ranging channel noise is turned around
- n Ranging channel is not turned around

GSTDN MIN EIRP		ANTENNA POLARIZATION	SSO MIN G/T i	SSO REQUIRED P_{rec}/N_o , dBHz			
m	dBW			UPLINK MODULATION	CARRIER ACQUISITION j	CARRIER and RANGE CHANNEL TURNAROUND k	DATA ACQUISITION l
9 26	76 83.5	RCP	-34.6 dB/K	High rate data with ranging	NA	52.1	61.8
				Low rate data with ranging	NA	51.1	58.3
				High rate data w/o ranging	NA	49.1 m	58.5
				Low rate data w/o ranging	NA	48.1 m	55.0
				Unmodulated	45.0	44.0 n	NA

TABLE 6-6.- TDRSS-to-SSO S-band forward link interface characteristics

INFORMATION		TDM MULTIPLEXING and ENCRYPTION	CHANNEL ENCODING and DECODING	SPECTRUM SPREADING e
CHANNEL	RATE			
Voice 1 a	32/24 kbps b	Sync pattern: 76571440 _g Bit rate: 72/32 kbps b	Code rate: 1/V = 1/3	PN chip rate: 11.232 Mcps
Voice 2 a	32/off kbps b		Constraint length: K = 7 bits	PN sequence length: 1023 chips
Command	6.4 kbps c		Generator sequence: 7566127 _g	PN sequence format: NRZ-L
Synchroni- zation	1.6 kbps d		Symbol rate: 216/96 kbps b ± 0.001% Symbol format: bi-phase-L Decoding algorithm: 8-level soft-decision Viterbi (maximum likelihood)	

TABLE 6-7.- SGLS-to-SSO S-band direct uplink interface characteristics

INFORMATION		PREMODULATION PROCESSING	CARRIER MODULATION	CARRIER FREQUENCY
CHANNEL	RATE or FREQUENCY			
Voice 1 a	32/24 kbps b	Time-Division-Multiplexing	PSK	1831.787 MHz
Voice 2 a	32/off kbps b	Sync pattern: 76571440 _g	$\beta = 1.57$	or
Command	6.4 kbps c	Bit rate: 72/32 kbps b ± 0.001%	± 10%	1775.733 MHz
Synchroni- zation	1.6 kbps d	Bit format: bi-phase-L	rad	

- a Delta-modulated
- b High data rate/low data rate
- c 2.4 kbps command channel is dummy filled to 2.5 kbps, BCH(127,50) encoded to 6.35 kbps, and dummy filled to 6.4 kbps before multiplexing with the other channels
- d 1.2 kbps sync pattern dummy filled to 1.6 kbps

CARRIER MODULA- TION	CARRIER FREQUENCY	TDRSS MIN EIRP	ANTENNA POLARIZA- TION	SSO MIN G/T	SSO REQUIRED P_{rec}/N_0 , dBHz			
					FORWARD MODULA- TION	CARRIER ACQUI- TION i	CARRIER TURNA- ROUND 1	DATA ACQUI- TION m
PSK $\beta = \pi/2$ rad $\pm 3^\circ$	2106406300 Hz	46 DBW g	RCP	-29.0 dB/K h	High rate data	52.7	52.5	55.0 n
	or 2041947900 Hz				Low rate data	48.5	48.0	51.5
	f				Unmodu- lated	50.7 j 47.0 k	49.2 j 46.5k	NA NA

- a Delta-modulated
- b High data rate/low data rate
- c 2.4 kbps command channel is dummy filled to 2.5 kbps, BCH (127,50) encoded to 6.35 kbps, dummy filled to 6.4 kbps, and permuted for authentication before multiplexing with the other channels
- d 1.2 kbps sync pattern dummy filled to 1.6 kbps
- e Capable of unspread operation
- f Plus TDRS/ground Doppler shift
- g High power mode at 50% duty factor. Includes pointing loss and transponder loss
- h Based on 3 dB SSO antenna gain with about 94% of coverage
- i 90% probable in 12 seconds with forward carrier spread
- j SSO high data rate configuration
- k SSO low data rate configuration
- l Carrier in-lock tracking with mean time to lose lock at least 1 hour
- m For 10^{-4} BER
- n Not achieved

Data Interfaces

Uplink Data Interface

The following information lists the data characteristics for uplink into the PM system. Refer back to figure 6-1 through figure 6- to find their interfaces with the PM system.

Downlink Data Interface

The following information lists the data characteristics for downlink data through the PM and FM system. Also refer back to figure 6-1 through figure 6- to find their place in the system.

PM Downlink Output Characteristics

From Network Signal Processors 1 And 2

D1

A. Signal	Digital Data
B. Data rate	96/192 kbps
C. Data type	Manchester II Biphase L in accordance with MIL STD-442, serial digital data
D. Voltage amplitude line to line	2.5 to 9.0 V peak-to-peak
E. Signal termination	Differential, directed coupled
F. Load impedance	75 ± 5 ohms
G. Source impedance	75 ± 5 ohms
H. Rise or fall times	100 ns max
I. Input data jitter	0.5 percent of bit period, max
J. Offset voltage	1.6 ± 0.8 V

PM Uplink Output Characteristics

Inputs To Network Signal Processors 1 And 2

D2

A. Signal	Digital data
B. Data rate	72 kbps
C. Data type	Manchester II biphas-L
D. Polarity, line 1	Binary one (10)
with respect to line 2	Binary zero (01)
E. Voltage amplitude	100 mV RMS min; 260 mV RMS max
F. Source	Balanced differential, ac coupled
G. Source impedance	Less than 1.4 K ohms
H. Termination	Differential, direct coupled
I. Load impedance	75 \pm 5 ohms
J. Rise and fall times	390 ns or less
K. RMS jitter	0.5 percent of one bit period
L. Offset voltage	2 \pm 0.5 V either line to signal ground supplying 50 μ A max signal to ground

FM Downlink Output Characteristics

D3 From CCTV

A. Signal Characteristics

- | | |
|----------------------------------|--|
| 1. Signal | Composite TV video waveform per EIA RS 330 |
| 2. Frame rate | 29.97 per second |
| 3. Line/frame | 525 (interlaced) |
| 4. Aspect ratio | 4/3 |
| 5. Horizontal scanning frequency | 15734.264 Hz |
| 6. Vertical scanning frequency | Horizontal frequency/262.5 |
| 7. Bandwidth | Dc to 4.5 MHz at TBD dB |
| 8. Level | 1.0 V peak-to-peak \pm 10 percent with the synchronized tip of the black reference at 0 V (measured from synchronized tip to white reference level) plus video on signal line, minus video on signal return line |
| 9. Termination | Balanced differential, direct-coupled |
| 10. Source impedance | 75 \pm 5 ohms |

- | | |
|--------------------|-----------------|
| 11. Load impedance | 75 \pm 5 ohms |
|--------------------|-----------------|

- | | |
|---------------------------|--|
| B. Overvoltage protection | There shall be no damage or performance degradation after the application of up to 4V peak-to-peak of signal to the channel input. |
|---------------------------|--|

D4 From Payload (Analog)

- | | |
|---------------------|---|
| A. Signal | Analog |
| B. Bandwidth | Dc to 4.5 MHz |
| C. Data type | Analog or payload TV |
| D. Amplitude | 1.0 V peak-to-peak to line \pm 10 percent |
| E. Load impedance | 75 \pm 5 ohms |
| F. Source impedance | 75 \pm 5 ohms |
| G. Termination | Differential direct-coupled |
| H. RMS SNR | 45 dB peak-to-peak signal to RMS noise |
| I. Phase jitter | \pm 2 percent of pulse period for TV synchronizing pulses |

D5 From Payload Digital

- | | |
|-----------------------|--|
| A. Signal | Digital data |
| B. Data rate and type | 16 kbps to 1.024 Mbps NRZ-L or 16 kbps to 1.024 Mbps at biphas-L |

- C. Voltage amplitude line-to-line 1.8 V to 5.0 V peak-to-peak measured line-to-line
- D. Load impedance 75 ± 5 ohms
- E. Source impedance 75 ± 5 ohms
- F. Termination Differential direct-coupled
- G. RMS SNR 35 dB
- H. Rise or fall times 5 percent of a bit period
- I. Frequency jitter Plus or minus a frequency deviation of 0.01 percent RMS of the data rate at a rate of 0.01 percent RMS of the data rate.

D6 From Operations Recorder

- A. Signal Operational recorder playback digital data
- B. Data rate 25.5 kbps to 1.024 Mbps
- C. Data type Manchester II, biphase-L
- D. Voltage amplitude 2.5 to 9.0 V peak-to-peak
- E. Load impedance 75 ± 5 ohms
- F. Source impedance 75 ± 5 ohms
- G. Rise and fall times 10 percent of a bit period, max
- H. Termination Differential, direct coupled
- I. Phase jitter and asymmetry ± 2 percent max

D7 From Payload Recorder

- A. Signal Payload recorder playback digital data
- B. Data rate 25.5 kbps to 1.024 Mbps
- C. Data type Manchester II, biphase-L
- D. Voltage amplitude line-to-line 2.5 to 9.0 V peak-to-peak
- E. Load impedance 75 ± 5 ohms
- F. Source impedance 75 ± 5 ohms
- G. Rise and fall times 10 percent of a bit period, max
- H. Termination Differential, direct coupled
- I. Phase jitter and asymmetry ± 2 percent max

D8 From S-bd FM main engines (3)

- A. Signal Digital
- B. Data rate 60 kbps (one from each engine)
- C. Data type Manchester II, biphase-L
- D. Voltage amplitude 2.5 to 9.0 V peak-to-peak
- E. Load impedance 75 ± 5 ohms
- F. Source impedance 75 ± 5 ohms
- G. Rise and fall times 10 percent of a bit period, max

- H. Termination Differential, direct coupled
- I. Phase jitter and asymmetry ± 2 percent max

D9 From DOD Payload - Digital

- A. Signal Digital
- B. Data rate 250 bps to 256 kbps
- C. Data type Manchester II, biphas-L or NRZ-L
- D. Voltage amplitude 1.0 Vpp \pm 0.6 Vdc
True (1) 1.1 pp \pm 0.5 Vdc (NRZ)
False (0) minus 0.3 to plus 0.4 Vdc (NRZ)
- F. Source impedance 75 ohms \pm 10%
- G. Rise and fall times Less than 100 nano-sec
- H. Source coupling method Balanced differential
- I. Common mode Signals from dc to 2.0 MHz up to 1 volt peak line-to-ground

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Appendix A: Acronyms and Abbreviations

AGC	automatic gain control	KHz	kiloHertz
AMP	amplifier	LCA	load controller assembly
ANT	antenna	LL	lower left
BPF	band pass filter	LO	local oscillator
CCTV	closed-circuit television	LR	lower right
COMM	communications	LRU	line replacement unit
D&C	displays and control	MDM	multiplexer-demultiplexer
dB	decibel	ME	main engine
dBm	decibels referred to 1 milliwatt	MHz	megaHertz
DOD	Department of Defense	MTU	master timing unit
EIU	engine interface unit	NSP	network signal processor
ELEC	electronics	OI	operational instrumentation
EPC	electronic power converter	Ops	operations
FLC	forward load controller	osc	oscillator
FM	frequency modulation	PA	power amplifier
FMSP	FM signal processor	paramp	parametric amplifier
freq	frequency	PCA	power control assembly
GCIL	ground command interface logic	PDP	payload distribution panel
GCILC	ground command interface logic controller	PL	payload
GDO	Gunn diode oscillator	PM	phase modulation
GHz	gigaHertz	PSDP	payload station distribution panel
GPC	general purpose computer	PSK	phase shift keyed
GSE	ground support equipment	PWR	power
GSTDN	ground spaceflight tracking and data network	RCDR	recorder
IF	intermediate frequency	rcvd	received
ind	indicator	RCVR	receiver
		rf	radio frequency
		RFI	radio frequency interference

RPC	remote power control
SGLS	space ground link system
SNR	signal-to-noise ratio
SP	signal processor
SSO	Space Shuttle Orbiter
STBY	standby
STDN	spaceflight tracking and data network
sw	switch
TDM	time division multiplex
TDRS	tracking and data relay satellite
TPS	thermal protection system (tiles)
TWT	traveling wave tube
UHF	ultra-high frequency
UL	upper left
UR	upper right
V	volts
VCCO	voltage-controlled crystal oscillator
VCO	voltage-controlled oscillator
VCXO	voltage-controlled transmit oscillator
VSU	video switching unit
VSWR	voltage standing wave ratio
W/B	wideband
XCO	reference crystal oscillator
XFMR	transformer
XMTR	transmitter
XPNDR	transponder