NASA CR
160929

Axiomatix

(NASA-CR-160929) SHUTTLE/PAYLOAD COMMUNICATIONS AND DATA SYSTEMS INTERFACE ANALYSIS Final Report (Axiomatix, Los Angeles, Calif.) 280 p HC A13/MF A01 CSCL 22B G3/16

N81-20157
THRU
N81-20163
Unclas
41775

SHUTTLE/PAYLOAD COMMUNICATIONS AND DATA SYSTEMS INTERFACE ANALYSIS

FINAL REPORT

Contract No. NAS 9-15604C

Technical Monitor: William E. Teasdale

Prepared for

NASA Lyndon B. Johnson Space Center
Houston, Texas 77058

Prepared by

Gaylord K. Huth

Contributions by

J.C. Springett
S. Udalov

Axiomatix

9841 Airport Blvd., Suite 912
Los Angeles, California 90045

Axiomatix Report No. R8012-4
December 31, 1980

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

N81-20158

1.0 EXECUTIVE SUMMARY

1.1 Purpose of Effort and Degree of Performance

The overall objective of the work has been to identify potential interface compatibility problems associated with interfacing OFT payload elements with Orbiter communications and data-handling elements that would result from payload or Orbiter failure to meet interface requirements contained in the Orbiter/cargo standard interface specification (NASA JSC ICD 2-19001). The potential interface compatibility problems can be associated with either attached payloads in the payload bay or detached payloads communicating with the Orbiter via an RF link.

Evaluation of the attached payload/Orbiter interfaces was made by investigating interface problem areas experienced between the IUS and the Orbiter since similar problems could be expected for other payloads. Some of the principal accomplishments made by Axiomatix during this evaluation are listed below:

(1) Identification of the four basic cases of attached payload interface problems, i.e.:

(a) Orbiter subsystems are in the design development stage; therefore, interface requirements have changed as the Orbiter subsystem design matured

(b) ICD 2-19001 reflects current subsystem design specifications but some externally derived requirements such as TDRSS user requirements are not reflected in Orbiter subsystem specifications; hence, they are not in the ICD

(c) Not all Orbiter subsystem capabilities are presented in the payload/Orbiter ICD's

(d) In some cases, payload/Orbiter ICD revision notices (PIRN's) have been made but these changes have not appeared in the Orbiter subsystem specification.

(2) Identification of areas of interface design difficulties:

(a) Each Orbiter signal-processing/data-handling unit has different payload interface requirements

(b) Digital interfaces with Orbiter subsystems have conflicting requirements when cable effects are taken into account.

(3) Recommendation of approach to resolve payload/Orbiter interface problems

(a) Identify payload user constraints

(b) Assess performance degradation for varying user constraints

(c) Develop payload/Orbiter interface design handbook.

When Axiomatix undertook to evaluate the detached payload interfaces with the Orbiter, it was found that these interfaces were not adequately defined in ICD 2-19001. Therefore, Axiomatix undertook the task of updating the ICD to include the interfaces as defined by the requirements and capabilities of the Orbiter subsystems--Payload Interrogator (PI), Payload Signal Processor (PSP), and the Communication Interface Unit (CIU). The principal accomplishments made by Axiomatix to provide clearly defined detached payload interfaces in the ICD are listed below:

(1) Provide a preliminary definition of the detached payload interfaces for review by Rockwell and NASA/JSC (Appendix II)

(2) Review the rough draft version of Rockwell Interface Revision Notice (IRN SD-152A) developed from the Axiomatix preliminary interface definition (Appendix III)

(3) Provide an updated detached payload interface definition to reflect changes in the PI, PSP and CIU as a result of PIRN's on these Orbiter subsystems (Appendix IV)

(4) Provide formulations of the minimum payload EIRP requirements for the PI/PSP combination (Appendix V)

(5) Provide restrictions on modulation forms for nonstandard detached payloads (Appendix VI), that is, payloads which use the bent-pipe capability of the Orbiter Ku-band Signal Processor (KuSP)

(6) Revise with Rockwell and NASA/JSC the IRN SD-152A to include the correct interface information due to changes resulting from the Critical Design Reviews (CDR's) for the PI, PSP and CIU (Appendix VII)

(7) Update IRN SD-152C to reflect the most recent Orbiter specifications and capabilities in terms of required flux density for payloads to communicate with the Orbiter (Section 5.0).

1.2 General Approach to the Activity

While performing the activities required by this contract, Axiomatix has worked closely with the cognizant NASA personnel, the Orbiter prime contractor (Boeing Aerospace Company), and the IUS, CIU and Orbiter payload communications equipment (PI and PSP) subcontractor (TRW Defense and Space Group). A vital part of this activity has involved Axiomatix attendance and participation in reviews with NASA, Rockwell and Boeing as shown in Figure 1.1. The tasks and reviews shown in this figure follow the principal accomplishments listed in the previous section.

The work performed under this contract was strongly interrelated to parallel efforts. The Axiomatix support for PDR's of the PI and PSP was provided through Contract NAS 9-15792, while the support for the CDR's was provided through Contract NAS 9-16067, Exhibit A. Axiomatix support for the IUS and CIU reviews and design critiques was provided through Contracts NAS 9-15409C and 9-16067, Exhibit A. This Axiomatix support to the hardware design development yielded an invaluable background to the details of the hardware design for evaluating potential interface problems. The overall payload/Orbiter/TDRSS (GSTDN) system support for Axiomatix was provided through Contracts NAS 9-15240 and 9-16067, Exhibit B. This Axiomatix support to the overall system ties together the various payload-related equipment as well as yielding an extensive insight into how the payload/Orbiter interface issues relate to the total system. Hence, Axiomatix is in a unique position to recommend resolution to payload/Orbiter interface problems for either a design change or an operational workaround.

1.3 Contents of the Final Report

There are three sections and seven appendices which address various aspects and details of the payload/Orbiter interface issues.

Section 3.0 contains the payload/Orbiter functional command signal flow and telemetry signal flow. Included in the section on command signal flow are functional descriptions of the various Orbiter communication/avionic equipment involved in processing a command to a payload either from the ground through the Orbiter or by the payload specialist on the Orbiter. Similarly, in the section on telemetry signal flow, functional descriptions of the various Orbiter communication/avionic equipment involved in processing telemetry data by the Orbiter and transmitting the processed data to the ground are presented.

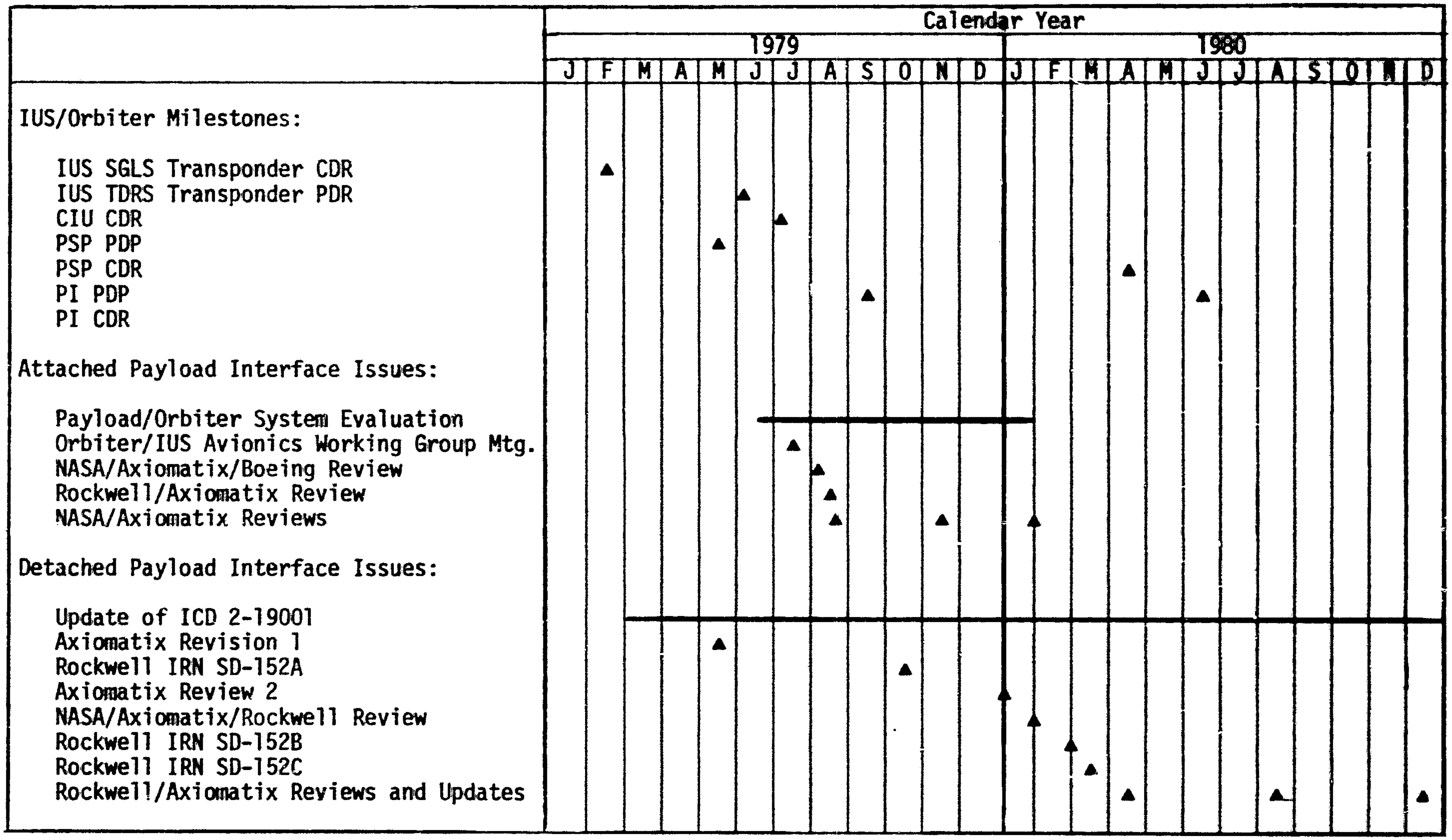


Figure 1.1. Schedule of Activity for Payload/Orbiter Interface Issues

Section 4.0 contains the results of the attached payload/Orbiter signal-processing and data-handling system evaluation. The causes of the majority of attached payload/Orbiter interface problems are delineated. Appendix I is the viewgraphs used to present the results of the attached payload/Orbiter system evaluation to NASA JSC on August 27, 1979. The remaining portion of Section 4.0 presents the Axiomatix recommendations to resolve future payload/Orbiter interface problems and provide more detailed design information to the payload designer attempting to interface with the Orbiter.

Finally, Section 5.0 presents the development of an update to ICD 2-19001 for detached payloads. Appendices II through VII are the documents developed by Axiomatix and Rockwell to arrive at the ICD 2-19001 update. The last part of Section 5.0 presents the changes necessary to the most recent IRN SD-152C (Appendix VII) as a result of the PI and PSP CDR's that have occurred since IRN SD-152C was issued on March 7, 1980. Also, a refined set of required flux density values for a detached payload to communicate with the Orbiter is presented in Section 5.0. This refined set of required flux density values incorporates the latest Orbiter capabilities and design specification changes.

N81-20159

2.0 INTRODUCTION

2.1 Statement of Work

2.1.1 Objectives

The objectives of this contract were to identify and resolve potential problems associated with interfacing payload elements with Orbiter communications and data-handling elements such as the Ku-band signal processor (KuSP), payload signal processor (PSP), payload interrogator (PI), payload data interleaver (PDI) and payload recorder (PR), and to assure the proper integration of payload and Orbiter communications elements such that acceptable end-to-end system performance will be achieved.

2.1.2 Stipulated Tasks

The contract statement of work calls out the following tasks.

"Task #1 - OFT Payload Interface Compatibility Analyses - The contractor shall, through analysis and/or simulation, identify potential interface compatibility problems (associated with interfacing OFT payload elements such as IUS, CIU, TDRS and PAM with Orbiter communications and data handling elements, i.e., the Ku-band signal processor, payload signal processor, payload interrogator, payload data interleaver, and payload recorders) that would result from payload or Orbiter failure to meet interface requirements contained in the Orbiter/cargo standard interface specification (NASA JSC ICD 2-19001). The contractor shall review Orbiter hardware documentation (procurement specifications, test documentation, etc.) pertaining to the above listed Orbiter elements, and existing payload interface hardware system design documentation as provided by NASA, for compatibility with the standard interface specification and payload ICR's."

"The contractor shall perform analyses of specific interface issues involving IUS, CIU, TDRS and PAM resulting from technical interface discussions with the candidate payloads during the performance period of this contract. The results of these analyses will be used by JSC as a data base to support negotiation of interface agreements and ICD's with the subject payloads."

"Task #2 - Problem Area Analyses and Resolution - The contractor shall determine and assess viable alternatives to payload system design, operational requirements, and/or interface configurations which will allow resolution or workaround of problems identified under task #1. Problems identified that are due to Orbiter failure to meet interface specifications shall be assessed and viable solutions shall be proposed."

2.1.3 General Approach

Potential interface compatibility problems can be associated with either attached payloads in the payload bay or detached payloads communicating with the Orbiter via an RF link. The effort under this contract was divided between an evaluation of the attached payload/Orbiter interfaces and of the detached payload/Orbiter interfaces. Evaluations of these interfaces were made by investigating interface problem areas experienced between the IUS and the Orbiter. To this end, Axiomatix worked closely with the cognizant NASA personnel, the Orbiter prime contractor (Rockwell International), the IUS prime contractor (Boeing Aerospace Co.) and the IUS, CIU and Orbiter payload communication equipment subcontra (TRW Defense and Space Group).

Figure 2.1 presents the subtasks which Axiomatix undertook to accomplish evaluations of the payload/Orbiter interfaces. In addition, Figure 2.1 shows the interrelation between the interface evaluations and the IUS and Orbiter payload communication hardware development. Since both the IUS and the Orbiter payload communication hardware are in the development stage, new potential interface issues occur as the systems mature. The preliminary and critical design reviews (PDR's and CDR's) provide very important forums to identify potential interface problem areas. Therefore, interface evaluations in many cases must be updated following the design reviews.

To perform the evaluation of the attached payload/Orbiter interfaces, Axiomatix reviewed ICD 2-19001 and the IUS/Orbiter-unique ICD. Also, as background for the ICD requirements, Axiomatix reviewed the Orbiter subsystem specifications. In order to discover details of the IUS/Orbiter interface problems, Axiomatix attended the IUS/Orbiter working group meetings and specially called meetings with Boeing and Rockwell. Both past and current IUS/Orbiter interface problems were reviewed to establish if similar problems might be encountered by future payloads attempting to interface with Orbiter subsystems. Results of the evaluation were reviewed with NASA over the past year.

The detached payload interfaces were not adequately defined in ICD 2-19001 so Axiomatix was tasked by NASA to rewrite Section 8.3 of ICD 2-19001 to properly define these interfaces. The first Axiomatix revision to this ICD was denoted Revision 1 and dated May 3, 1979.

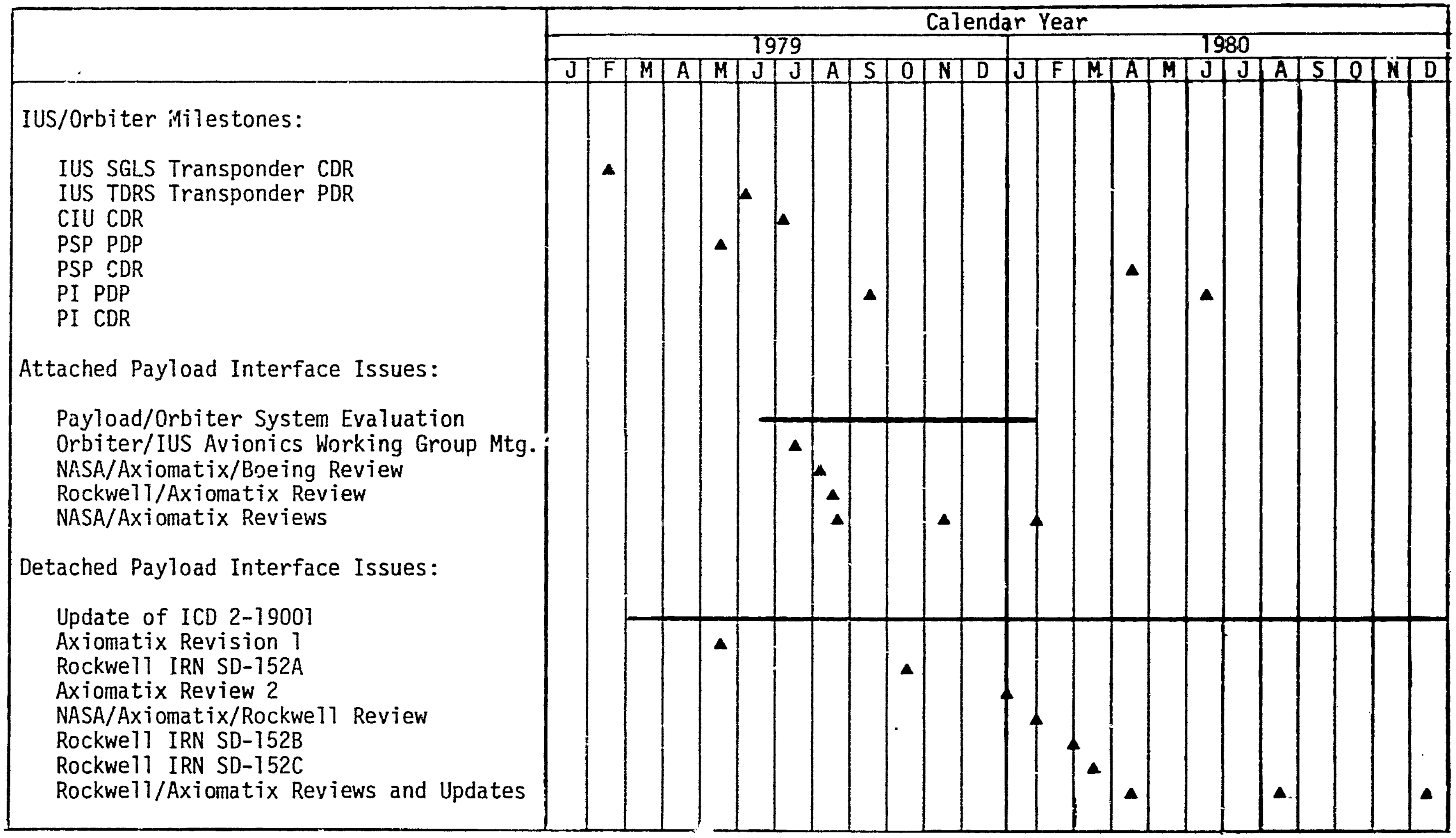


Figure 2.1. Schedule of Subtasks for Payload/Orbiter Interface Evaluations

Rockwell issued its rough draft version of Section 8.3 (IRN SD-152A) on October 3, 1979. Axiomatix reviewed IRD SD-152A and updated its own version of Section 8.3 and also issued Revision 2 on January 2, 1980. Following release of Revision 2, NASA, Axiomatix and Rockwell personnel met January 21-23, 1980 to update and correct IRN SD-152A. The result of the NASA/Axiomatix/Rockwell review was the Rockwell IRN SD-152B, issued February 28, 1980. there were some small changes made after the initial review of IRN SD-152B and the marked-up IRN was reissued on March 7, 1980 as IRN SD-152C. Since IRN SD-152C was issued, Axiomatix and Rockwell have had additional reviews to revise and update portions of IRN SD-152C. The results of these reviews and the Axiomatix recommendations for changes to IRN SD-152C and ICD 2-19001 are presented in Section 5.0 of this report.

2.1.4 Continuity with Previous Work

The previous stages of this contract (i.e., NAS 9-15604A and NAS 9-15604B) have provided aids to the payload communication system design. Contract NAS 9-15604A produced a report, "Guidelines for Choosing and Evaluating Payload Frequencies," Under Contract NAS 9-15604B, a handbook, "Users' Handbook for Payload-Shuttle Data Communication," was provided. Therefore, the present stage of the contract for resolving potential interface problems for attached and detached payloads was a logical follow-on effort.

2.1.5 Relationship to Parallel Work

The work performed under this contract was strongly interrelated to parallel efforts. Axiomatix support for PDR's of the PSP and PI was provided through Contract NAS 9-15792 while support for the CDR's was provided thorugh Contract NAS 9-16067, Exhibit A. Axiomatix support for the IUS and CIU reviews and design critiques was provided through Contracts NAS 9-15409C and NAS 9-16067, Exhibit A. This Axiomatix support to the hardware design development yielded an invaluable background to the details of the hardware design for evaluating potential interface problems. The overall payload/Orbiter/TDRSS (GSTD) system support for Axiomatix was provided through Contracts NAS 9-15240 and NAS 9-16067, Exhibit B. This Axiomatix support to the overall system ties together the various payload-related equipment as well as yielding an extensive insight into how the payload/ Orbiter interface issues relate to the total system. Hence, Axiomatix is in a unique position to recommend resolution to payload/Orbiter interface problems for either a design change or an operational workaround.

2.2 Organization of the Final Report

There are three sections and seven appendices which address various aspects and details of the payload/Orbiter interface issues.

Section 3.0 contains the payload/Orbiter functional command signal flow and telemetry signal flow. Included in the section on command signal flow are functional descriptions of the various Orbiter communication/avionic equipment that are involved in processing a command to a payload either from the ground through the Orbiter or by the payload specialist on the Orbiter. Similarly, in the section on telemetry signal flow, functional descriptions of the various Orbiter communication/avionic equipment that are involved in processing telemetry data by the Orbiter and transmitting the processed data to the ground are presented.

Section 4.0 contains the results of the attached payload/Orbiter signal-processing and data-handling system evaluation. The causes for the majority of the attached payload/Orbiter interface problems are delineated. Appendix I contains viewgraphs used to present results of the attached payload/Orbiter system evaluation to NASA JSC on August 27, 1979. The remaining portion of Section 4.0 presents Axiomatix recommendations to resolve future payload/Orbiter interface problems and provide more detailed design information to the payload designer attempting to interface with the Orbiter.

Finally, Section 5.0 presents the development of an update to ICD 2-19001 for detached payloads. Appendices II through VII are documents developed by Axiomatix and Rockwell to arrive at the ICD 2-19001 update. The last part of Section 5.0 presents the changes necessary to the most recent IRN SD-152C (Appendix VII) as a result of the PI and PSP CDR's that have occurred since IRN SD-152C was issued on March 7, 1980. Also, a refined set of required flux density values for a detached payload to communicate with the Orbiter is presented in Section 5.0. This refined set of required flux density values incorporates the latest Orbiter capabilities and design specification changes.

2.3 Recommendations for Future Effort

As a result of the attached payload/Orbiter signal-processing and data-handling system evaluation, Axiomatix recommends that an overall system study be performed which will provide the payload communication system designer with:

(1) Payload user constraints derived from Orbiter subsystem design requirements and capabilities and from TDRSS user constraints

(2) Performance degradation based on varying user constraint compliance

(3) "Designer's Handbook" which will show in detail methods of designing interface circuitry to meet all Orbiter and TDRSS user constraints.

3.0 PAYLOAD SIGNAL-PROCESSING/DATA-HANDLING EQUIPMENT

The Orbiter payload signal-processing/data-handling equipment has two primary functions: first, to process command data to the payloads and, second, to process telemetry data from the payloads. These functions can be performed in one of two modes: (1) the attached mode (a hard-line umbilical) and (2) the detached mode (L-band or S-band RF link).

3.1 Orbiter/Payload Functional Command Signal Flow

Figure 3.1 presents the command signal flow from the Orbiter to the payload in a functional form. For NASA missions, the payload signal processor (PSP) sends commands directly to the payload in the attached mode and through the payload interrogator (PI) in the detached mode. The NASA commands come to the PSP from the general-purpose computer (GPC) through a multiplexer/demultipler (MDM). For DOD missions, the communication interface unit (CIU) sends commands directly to the payload in the attached mode and through the PI in the detached mode. The DOD commands come to the CIU from the GPC through the MDM or directly from the Ku-band signal processor (KuSP). The commands from the KuSP and the network signal processor (NSP) which are passed through the GPC are generated on the ground and transmitted to the Orbiter using direct S-band network communication link or the S-band or Ku-band communication links through the tracking and data relay satellite system (TDRSS) A brief summary of the functions of each of the units involved in the command signal flow is presented in the next sections to delineate the interfaces where compatibility is required and potential interface problems can occur.

3.1.1 Payload Transponder

The payload transponder shown in Figure 3.1 actually includes the transponder to provide the RF link in the detached mode and a signal processor to process the commands directly in the attached mode and through the transponder in the detached mode.

NASA and DOD payload transponders are generically quite similar in terms of their functions and architectures. NASA transponders are standardized, with three mission-oriented types available: deep space transponders [for use with the Deep Space Network (DSN)], near-Earth

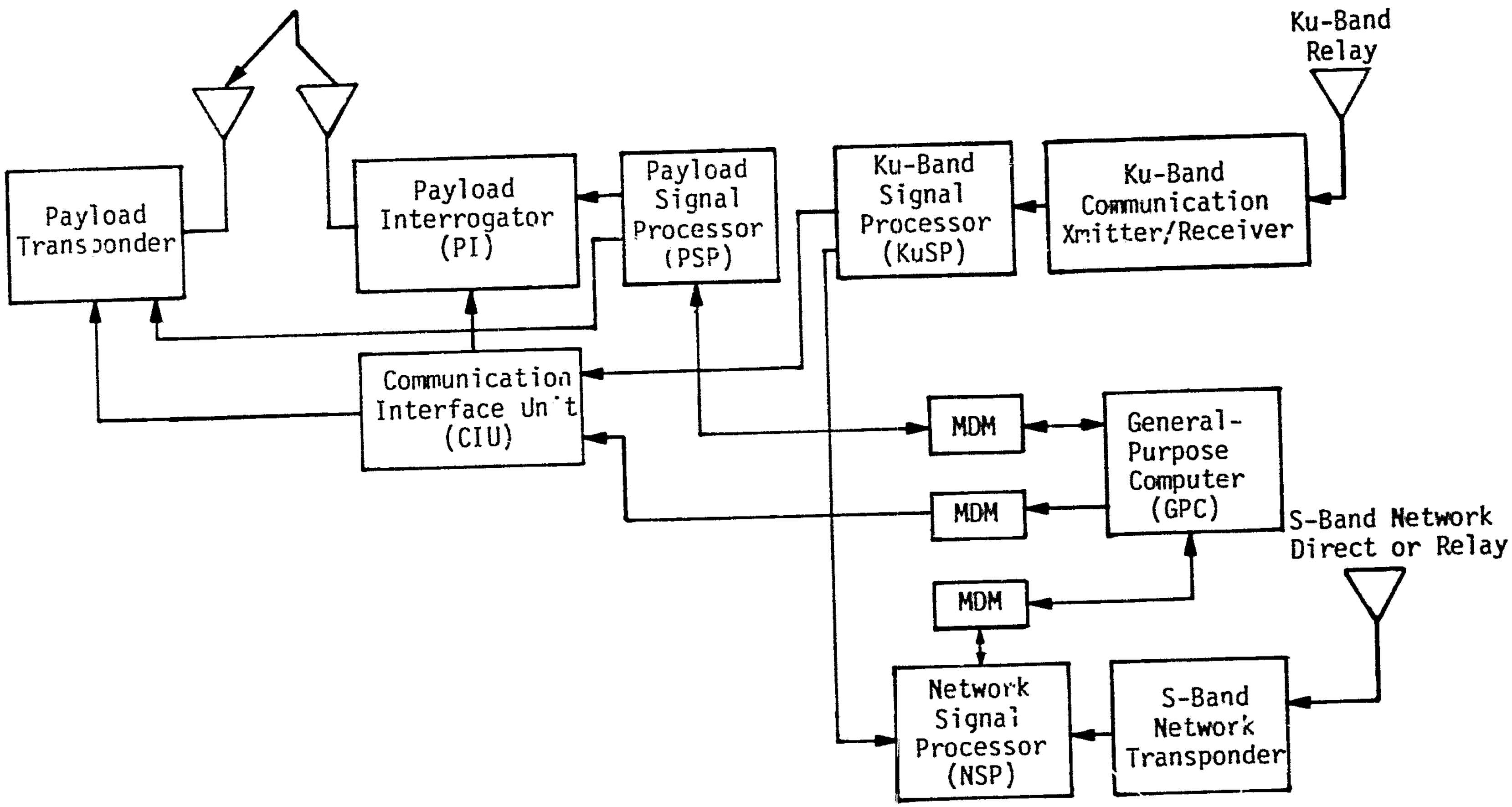


Figure 3.1. Orbiter/Payload Functional Command Signal Flow

transponders [for use with the space tracking and data network ground stations (GSTDN)], and TDRSS transponders (for use with TDRSS or GSTDN). DOD transponders interface with the USAF Satellite Control Facility (SCF).

Conspicuous differences between NASA and DOD transponders are the forward link frequency bands and transponding ratios. The NASA receive frequency range is S-band (2025 - 2120 MHz), while the DOD receive frequency range is L-band (1760 - 1840 MHz). The transmitter frequency is related to the receiver frequency by a ratio of integers, called the coherency (or turn-around) ratio. Both the NASA and DOD transmitter frequency ranges are S-band (2200 - 2300 MHz). The corresponding coherency ratios are, for NASA, 240/221, and for DOD, 256/205.

Figure 3.2 is a block diagram of the typical payload transponder. The forward link RF input is preselected, filtered for the frequency band utilized [S-band for NASA and L-band for Inertial Upper Stage (IUS) and DOD], and the input is then mixed down to the first IF. Further mixing translates the first IF signal to the second IF, where the output from the second IF amplifier is distributed to four phase detector/demodulator functions.

The carrier-tracking loop functions to acquire and track the residual carrier component of the input signal. A second-order tracking loop is employed. Frequency and phase coherence are supplied from the VCO to the synthesizer/exciter, where the coherent reference frequencies are derived for the demodulation functions.

AGC is obtained through in-phase demodulation of the residual carrier. The AGC voltage is filtered and applied to the first IF amplifier to control the gain of the receiver. The AGC voltage is also filtered and compared with a threshold to determine whether the carrier-tracking loop is in or out of lock.

The command demodulator coherently recovers the command phase modulation from the carrier. Spectral conditioning (in most cases, limited to lowpass filtering) is usually provided in the output to the signal processor command detector. Typical transponder receiver operating and performance parameters for commands are indicated in Table 3.1.

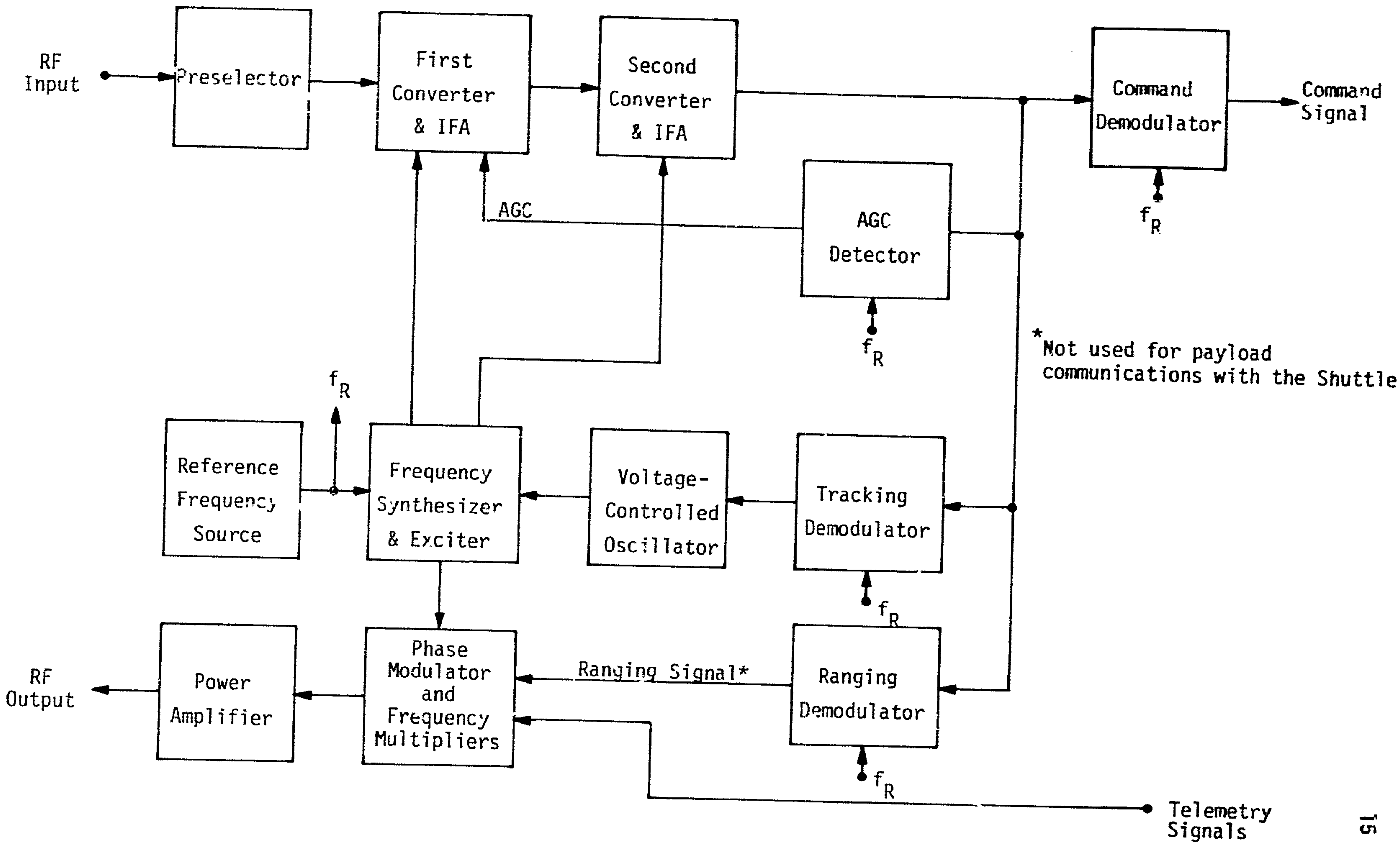


Figure 3.2. Typical Payload Transponder Diagram

Table 3.1. Typical Payload Transponder Receiver Characteristics

Item	Parameter and Range
Receive Frequency Range:	
L-Band Frequency (DOD)	1760 - 1840 MHz
S-Band Frequency (NASA)	2025 - 2120 MHz
Tracking Loop Bandwidth	18, 60, 200 or 2000 Hz
Tracking Loop Order	Second
AGC Dynamic Range	100 db
Command Channel Frequency Response	1 - 130 kHz
Noise Figure	5 - 8 dB

3.1.2 Payload Interrogator (PI)

Basically, the PI is a transceiver consisting of a receiver and a transmitter which are frequency excited or referenced to a universal frequency synthesizer that allows the PI to operate on any of 861 channel pairs. The transmitter operates on two distinct bands--1763 - 1840 MHz (L-band) and 2025 - 2120 MHz (S-band) and the receiver covers the band 2200 - 2300 MHz (S-band). Table 3.2 lists the principal operating characteristics of the transmitter.

Figure 3.3 shows a functional block diagram for the PI. A single RF port connects the PI to the payload antenna cable as the payload antenna serves to simultaneously receive and transmit signals. This port connects into the receiver input and transmitter output through an assembly known as the triplexer. The triplexer consists of six cavity-based bandpass filters which divide the receiver band and both transmit bands approximately in half. The two band assignments, designated "high" and "low," are used to provide payload communication with minimum interference to network communications. When the PI is transmitting to a DOD payload in the frequency band of 1763.7 - 1799.7 MHz and receiving in the frequency band of 2202.4 - 2247.5 MHz, the S-band network transponder transmits at 2287.5 MHz and receives DOD operational signals at 1831.787 MHz. Alternately, when

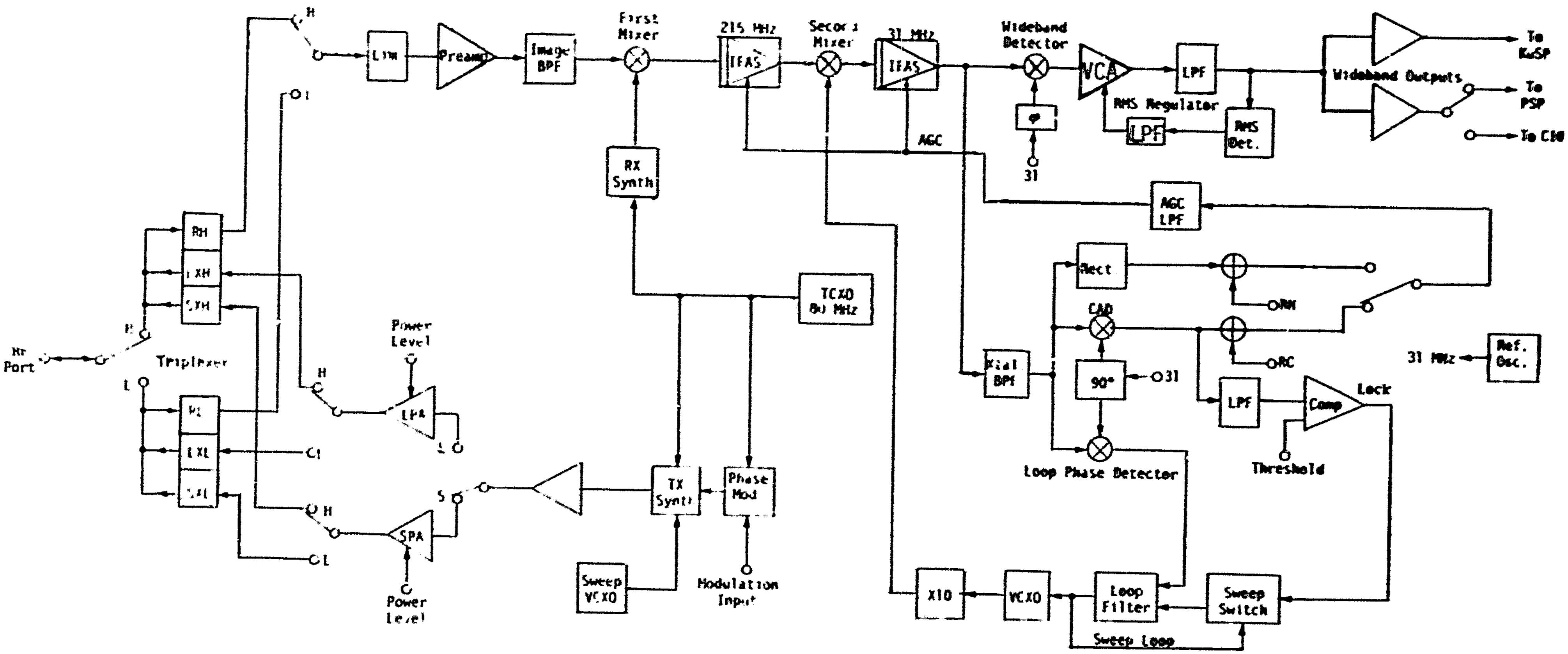


Figure 3.3. Payload Interrogator Functional Diagram

Table 3.2 Principal PI Transmitter Characteristics

Parameter	Value	Units
L-Band Frequency Range	1763 - 1840	MHZ
S-Band Frequency Range	2025 - 2120	MHz
Carrier Frequency Tolerance	±0.001	%
Carrier Phase Noise	10 max	degrees-RMS
Output Spurs	< -65	dBc
Phase Modulator	0.2 to 2.5	radians
Frequency Sweep Ranges	75 ± 5 55 ± 5 33 ± 3	kHz kHz kHz
Frequency Sweep Rates	10 ± 3 250 ± 75	kHz/sec Hz/sec
Power Level: High Medium Low	37 to 42 27 to 32 4 to 9	dBm dBm dBm

the PI is transmitting to a DOD payload in the 1803.7 - 1839.79 MHz band and receiving in the 2252.4 - 2297.5 MHz band, the the S-band network transponder transmits at 2217.5 MHz and receives DOD operational signals at 1775.773 MHz. Similarly, when the PI is transmitting to a NASA payload in the 2025.8 to 2072.56 MHz band and receiving in the 2200 - 2250.75 MHz band, the network transponder then transmits at 2287.5 MHz and receives NASA operational signals at 2106.406 MHz. Alternately, when the PI is transmitting to a NASA payload in the 2072.68 - 2119.79 MHz band and receiving in the 2250.875 to 2300.875 MHz band, the network transponder transmits at 2217.5 MHz and receives NASA operational signals at 2041.947 MHz.

Frequency synthesis for both the receiver and the transmitter is based upon a master 80 MHz temperature-controlled crystal oscillator (TCXO). Transmitter carrier phase modulation takes place at a fixed frequency which is subsequently translated to the proper output frequency within the transmitter synthesizer (TX). In order to frequency sweep the transmitter carrier, a VCXO sweep circuit is used, with its output also being input to the transmitter synthesizer. Thus, the output of the transmitter synthesizer is a discrete carrier, phase-modulated and frequency-swept signal with a nominal (no sweep) carrier frequency corresponding to the designated channel.

The transmitter synthesizer output is amplified to a level necessary to drive either of the output power amplifiers. Separate power amplifiers are used for L-band and S-band channels (respectively, LPA and SPA). Only one amplifier may be on or active at a given time. Either amplifier is capable of providing three selectable output power levels, as listed in Table 3.2. Power amplifier output is switched into the appropriate triplexer subband.

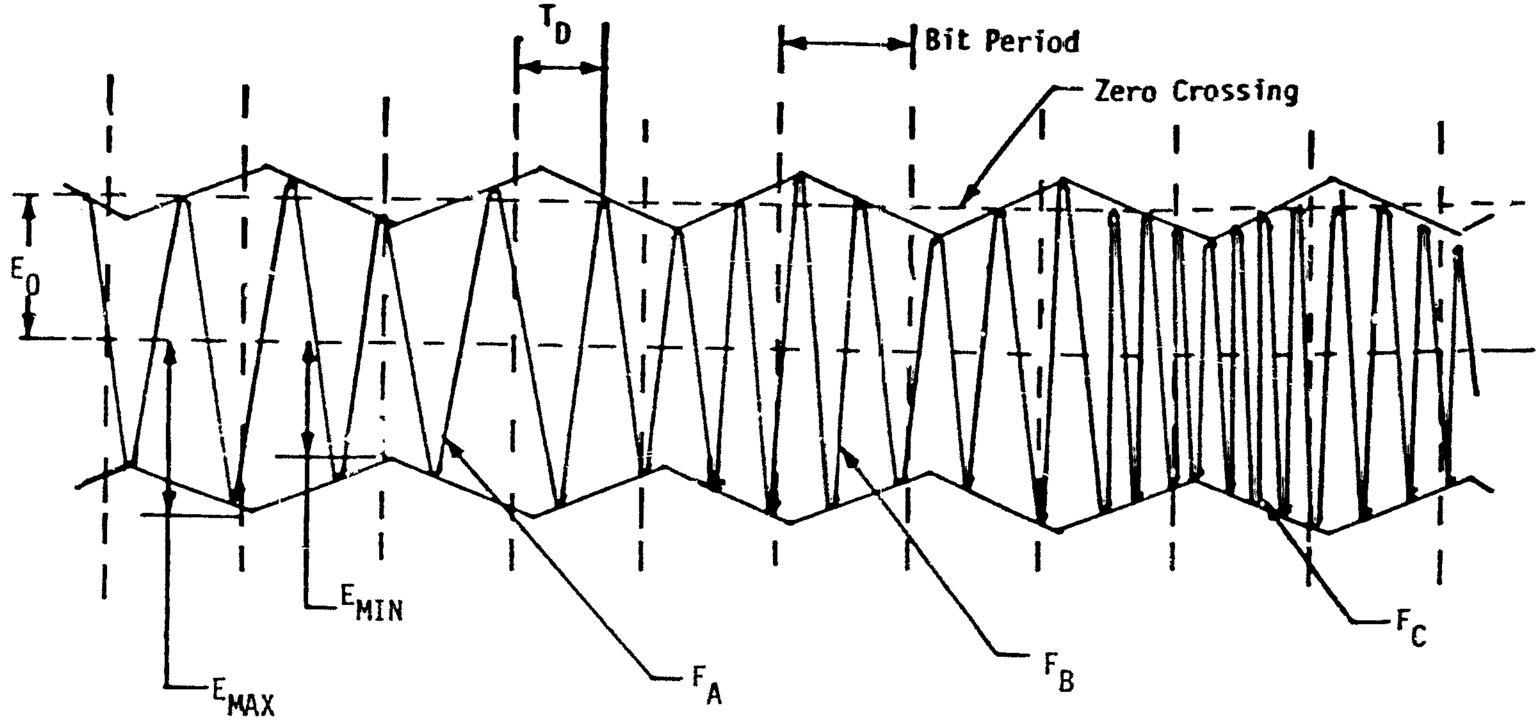
3.1.3 Communication Interface Unit (CIU)

The current function of the CIU is to provide command and telemetry data conditioning between the Orbiter and the IUS transponder. The CIU consists physically of four boxes and two control panels mounted in an Orbiter standard console. The CIU accepts command data from one of five sources, as follows:

(1) S-band MDM
(2) KuSP
(3) GN&C MDM
(4) Crew-generated data from control panel
(5) T-0 umbilical.

Input data is validated, formatted, modulated on an SGLS baseband carrier (see Figure 3.4) at 1 k baud, and forwarded to one of six destinations. In the attached mode, the CIU forwards the conditional command data directly over hard line to one of two redundant IUS transponders on one or two IUS's in the Orbiter payload bay. In the detached mode, the CIU forwards the conditioned command data to one of two redundant PI's for RF transmission to the IUS transponder.

Ground-generated commands may be received from either the KuSP or the NSP (through the GPC/MDM interface). Received as a continuous binary data stream at 128 kbps from the KuSP and 1 Mbps bursts from the GPC/MDM, they must be detected and buffered. The binary outputs of the buffers are either 4 kbps or 2 kbps which, when converted to the ternary format, become symbol rates of 2 ksps and 1 ksps, respectively. The input to the binary-to-ternary converter consists of serial data plus clock (two lines) and the output consists of the "S," "0," and "1" symbols plus clock (four lines).



T_D = Delay Time = 600 microseconds

$$\text{Percent Modulation} = \frac{E_{MAX} - E_{MIN}}{E_{MAX} + E_{MIN}} \times 100 = 50\% \pm 10\%$$

F_A = 65 kHz nominal = "S"

F_B = 76 kHz nominal = "0"

F_C = 95 kHz nominal = "1"

Figure 3.4. Command Tone Modulation Envelope

Crew-generated commands are input through the command generator and verification unit which outputs them in the proper ternary format. A priority selection switch determines whether ground or Orbiter-originated commands will be transmitted to the payload. The FSK/AM generator encodes the ternary commands into the proper signal for transmission to the payload. Three subcarrier tones of 65, 76 and 95 kHz (corresponding, respectively, to the "S," "0," and "1" symbols) are employed in a time-serial manner. The command rate clock, at one-half the symbol rate and in the form of a triangular wave, is amplitude modulated onto the composite tone stream, as shown in Figure 3.4. Attached payloads may receive either the ternary baseband or tone command signals from the CIU.

Figure 3.5 shows a simplified block diagram of the CIU. Microprocessor technology is fundamental to the CIU operation. The microprocessor performs frame synchronization, VCC extraction (required for DOD commands) and command authentication, and determines command rejection. The microprocessor also accepts GN&C data and provides the command generator function to send GN&C or crew-generated command data to the FM/AM modulator. The required binary-to-ternary conversion on the command data is also performed by the microprocessor. Additional functions performed by the microprocessor are CIU mode control and status display.

3.1.4 Payload Signal Processor (PSP)

Commands are handled by the PSP in such a manner as to (1) accept command messages in "burst" form and buffer store, (2) perform a validation check, (3) rate convert to the appropriate bit rate and prefix with an idle pattern, and (4) biphase modulate the serial command word onto a subcarrier. Data rates and signal characteristics for the command signal generation portion of the processor are tabulated in Table 3.3.

A PSP command functional block diagram is presented in Figure 3.6. As shown in this figure, PSP control/mode information and command data are transferred to the PSP from the general-purpose computer (GPC) via the MDM interface. For this purpose, a serial bilateral data bus operating at a rate of 1 Mbps is employed. Also, over this same serial bus, the PSP is able to transmit a status message to the GPC for the purpose of configuration and command data validation. Input/output in the proper mode is established to the PSP from the MDM using discrete (one-bit message) lines.

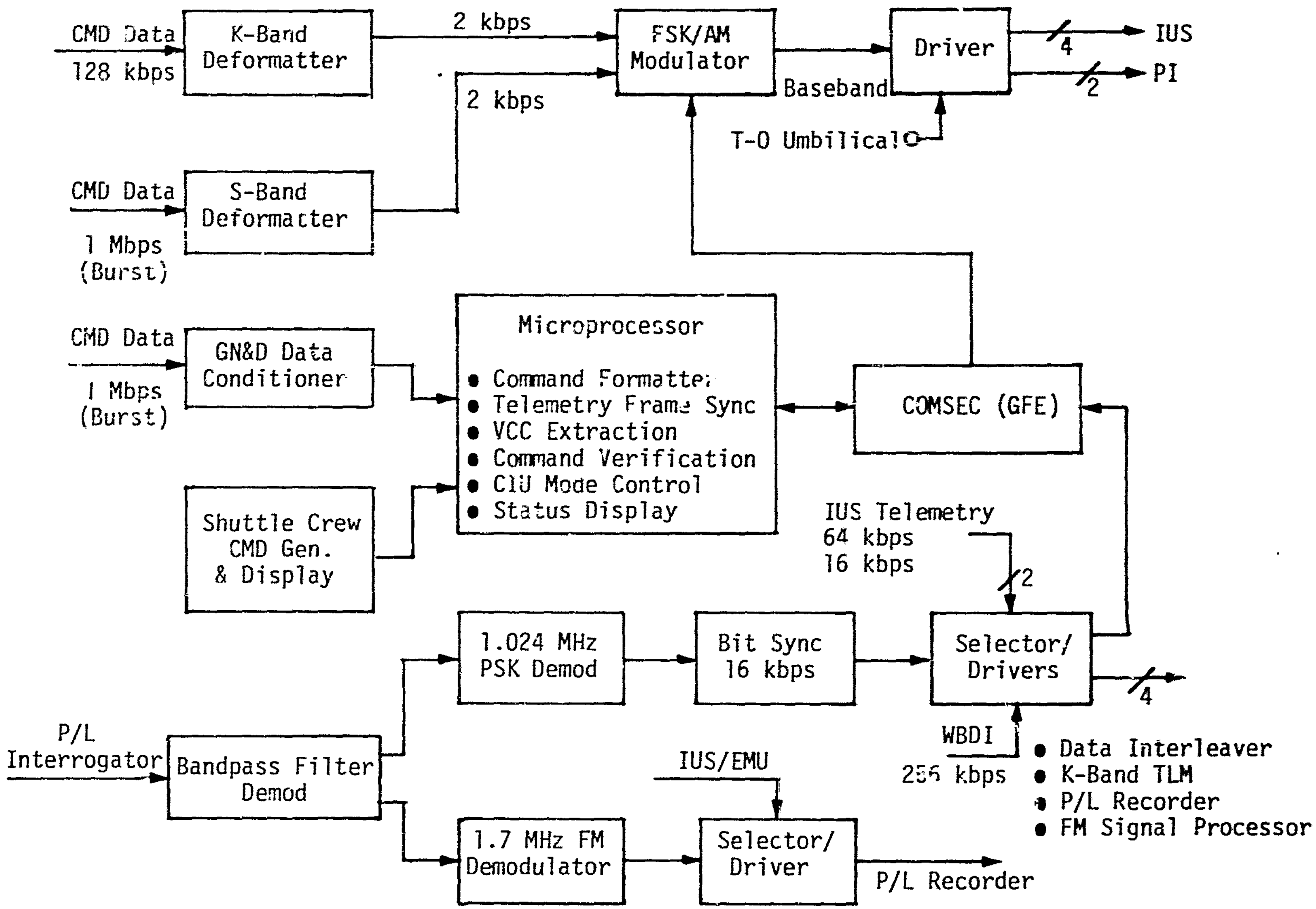
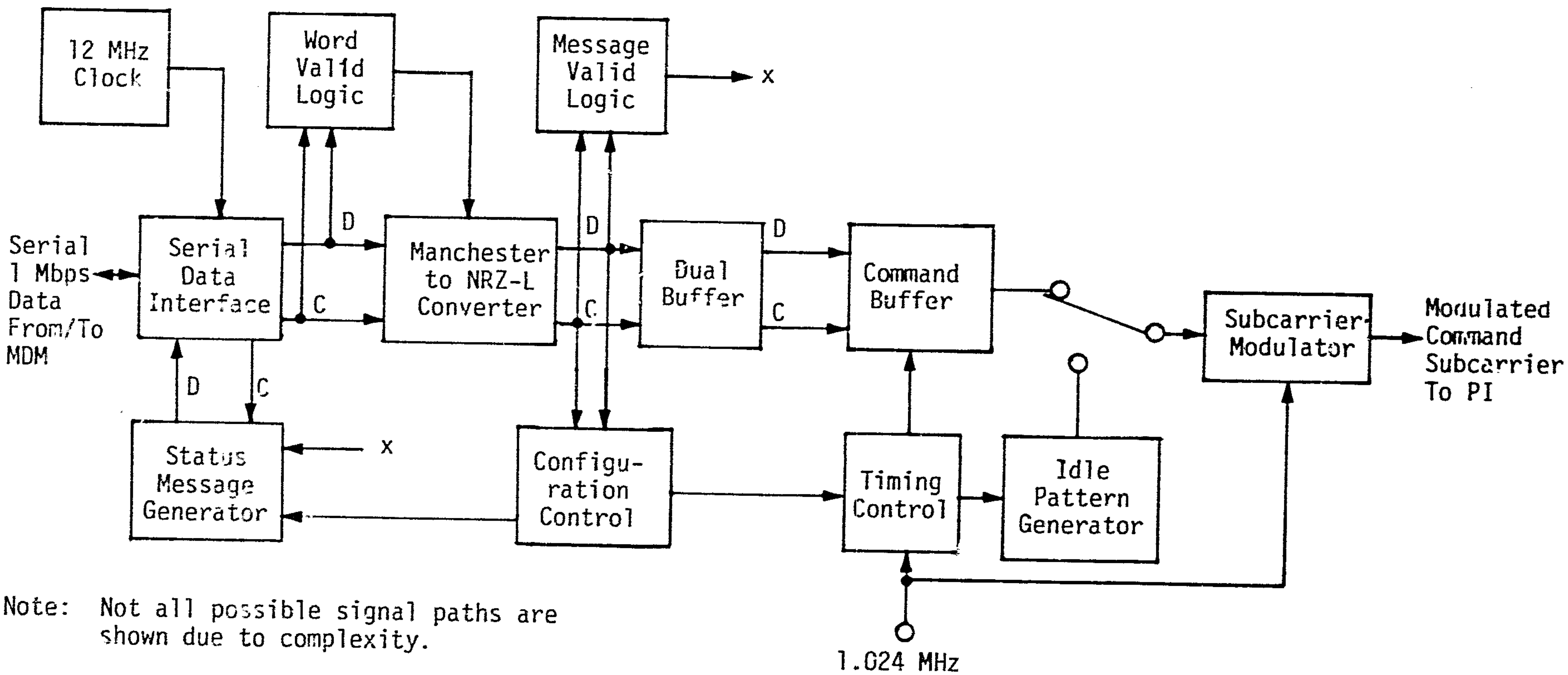


Figure 3.5. Communication Interface Unit Functional Block Diagram



Note: Not all possible signal paths are shown due to complexity.

Figure 3.6. PSP Command Functional Block Diagram

Table 3.3. PSP Command Signal Characteristics

Parameter	Value	Units
Subcarrier Waveform	Sinusoidal	-
Subcarrier Modulation	PSK, ±90	Degrees
Subcarrier Frequency	16	kHz
Idle Pattern	Alternating "ones" & "zeros"	
Bit Rates	$2000 \div 2^N$, $N = 0,1,2,\ldots,8$	bps

Within the PSP, a 1 MHz serial data interface is provided which performs data word detection and synchronization. All timing is generated from a master 12 MHz clock. The word validation logic examines the serial interface output to (1) check the integrity of the Manchester data waveform, (2) check parity, and (3) look for end-of-data identification. Failure to pass any of these tests results in inhibiting the Manchester-to-NRZ conversion operation.

All word-valid Manchester data is converted to serial NRZ-L data, after which it is clocked into the dual buffer. The dual buffer consists of two storage memories: one which receives current data at the 1 Mbps rate while the other is clocked out at a rate proportional to the 1.024 MHz clock. Thus, new command messages from the GPC/MDM may be received and stored at the 1 Mbps rate while, at the same time, command data may be transferred to the command subcarrier modulator at the selected payload command bit rate.

The message-valid logic examines all messages received from the GPC/MDM for illegal codes. Any illegal form detected is sufficient to inhibit further processing operations. A failure-to-pass message validation is transmitted through the status message generator back to the GPC, and a message repeat is requested.

The portion of the GPC message which corresponds to the PSP configuration information is processed by the configuration control which, in turn, is responsible for setting the PSP mode/operating parameters.

Configuration status is transmitted back to the GPC via the status message generator. Command message verification is also made using status message reportback to the GPC.

Valid command bits to be transmitted to the payload are clocked from the command buffer at the proper bit rate. Each command is prefixed with a command idle pattern of alternating "ones" and "zeros." (In fact, the command idle pattern can be transmitted any time when requested and in lieu of actual command bits.) Command bits or idle pattern bits biphase modulate a 16 kHz sinusoidal subcarrier which is output to the PI.

3.1.5 Orbiter Network Communication Equipment

Command data reaches the Orbiter from the ground by use of the network communication equipment. For commands, there are two sets of equipment: (1) the S-band transponder and network signal processor (NSP), and (2) the Ku-band receiver and Ku-band signal processor (KuSP).

3.1.5.1 S-band transponder and network signal processor (NSP)

The transponder is a multimode S-band communications unit which operates in three primary modes (DOD direct, GSTDN direct, and GSTDN Hi-Power/TDRS relay) and several secondary modes. The transponder supports full-duplex communication in any of the primary modes, provides Doppler turn-around during coherent operation, and provides tone ranging turn-around. Turn-around ranging is accomplished exclusively with tones on the 1.7 MHz subcarrier.

A block diagram of the network transponder is shown in Figure 3.7. The transponder receiver searches for, acquires, tracks and coherently demodulates either residual carrier PM signals in the DOD or GSTDN modes or suppressed carrier PSK signals in the TDRSS mode. Acquisition of the spread spectrum code in the TDRSS mode is accomplished prior to carrier acquisition. The receiver is configured as a Costas loop for carrier acquisition and tracking. Symbol synchronization is performed in the NSP after carrier acquisition.

In normal operation, the transmit frequency is coherently related to the received frequency by either the DOD 256/205 or the NASA 240/221 transponding (turn-around) ratio. On the power-limited TDRSS relay links, convolutional encoding is required, resulting in a symbol rate three times

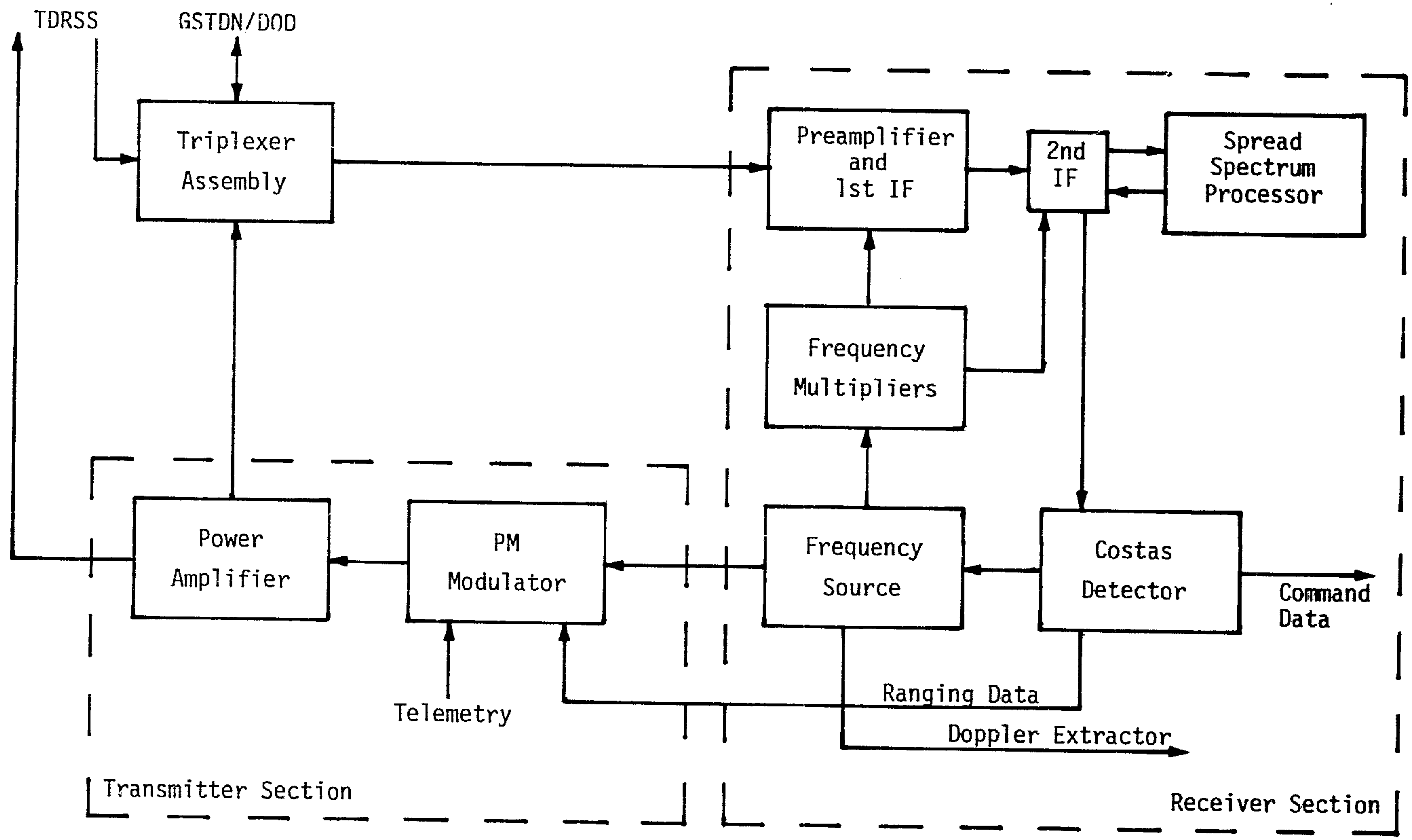


Figure 3.7. Network Transponder Functional Block Diagram

the information rate. The composite link data rates are shown in Table 3.4. The spectrum of the forward TDRS link is further spread to reduce the power spectral density impinging on the earth's surface by combining the coded data symbols with an 11.232 Mchips/s pseudonoise (PN) sequence of length 1023. The performance parameters for the transponder are presented in Table 3.5.

Table 3.4. Data Rates for Network PM Links

Link	Rate	Channels Available	Composite Link Rate	
			Direct (Bit Rate)	Relay (Rate 1/3 coded) (Symbol Rate)
Forward	High	Two 32 kbps voice One 8 kbps command	72 kbps	216 ksps
(Ground to Orbiter)	Low	One 24 kbps voice One 8 kbps command	32 kbps	96 ksps

This NSP performs the digital processing functions for the PM links. A block diagram is shown in Figure 3.8. All receiver input data first passes through the symbol synchronizer. Convolutionally encoded TDRSS-relayed data passes to the Viterbi decoder, and encrypted DOD data are output to an external COMSEC device, the output of which then goes to the frame synchronizer decoder. Unencrypted input data go directly to the frame synchronization decoder, the output of which drives the demultiplexer (demux). Voice data from the demux are rate-buffered to either 24 k bits/s or 32 k bits/s to the delta demodulators or the payload station when receiving digital voice data in the DOD mode. Command data are buffered to a BCH (Bose-Chaudhuri-Hocquenghem) error detection/correction decoder at a net 6.4 k bit/s rate. The performance parameters for the network signal processor are in Table 3.6.

Table 3.5. S-Band Transponder Performance Specifications

RECEIVER (AMBIENT TEMPERATURE)		
Noise Figure	8	dB Max
Doppler Accommodated	±55	kHz
Doppler Rate Accommodated	± 5	kHz/s Max
Tone-Ranging Response (±1 db)	1.5 to 1.9	MHZ
Tone-Ranging Delay	1.1	μs Max
Tone-Ranging Delay Variation	78.0	ns Max
Dynamic Range	-30 to -122	dBm Min

ACQUISITION PROBABILITY >0.9 IN 6 SECONDS

		MINIMUM SIGNAL LEVEL INTO TRANSPONDER	
MODE	MODULATION	32 kbps	72 kbps
STDN/SGLS	Bi-ϕ-L, PSK (No Ranging)	-117.0 dBm	-116.0 dBm
STDN Hi Power	Bi-ϕ-L, PSK* (No Tone Ranging)	-102.0 dBm	-101.0 dBm
TDRS*	Bi-ϕ-L, PSK	-103.0 dBm	- 98.8 dBm
TDRS*	Carrier Only	-104.5 dBm	-100.3 dBm

The tone ranging uplink signal shall be turned off during acquisition. Center frequency ± 50 kHz.

*Input noise power spectral density of -151 dBm/Hz, acquisition probability > 0.9 in 12s for TDRS LO & HI data.

PN ACQUISITION TIMES

P_r/N_0 (dB-Hz)	Average Acquisition Time (Seconds) 96 ksps	Average Acquisition Time (Seconds) 216 ksps	Average Time To Unlock (Seconds)
49.5	≤ 60	≤ N/A	≥3600
51	≤ 20		≥3600
53		≤ 30	≥3600
54	≤ 10.0	≤ 10.0	≥3600

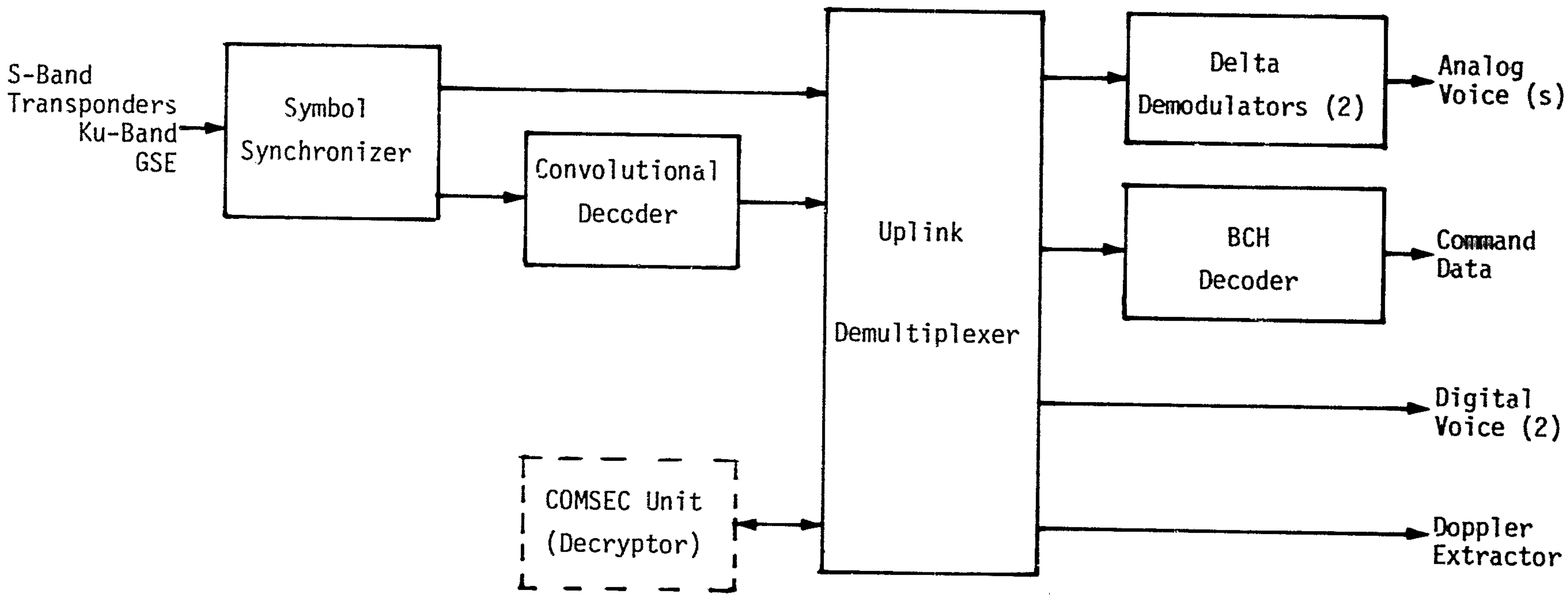


Figure 3.8. Forward Link Network Signal Processor Block Diagram

Table 3.6 Network Signal Processor Performance

NSP Bit Synchronizer	
Acquisition and Tracking Threshold SNR	-5 dB
Hard Decision Uncoded Data Detection (-5 dB $\leq$ SNR $\leq$ 10.6 dB)	< 0.6 dB from theory
Acquisition Time:	
Uncoded, SNR > 0 dB	1 s max
Coded, SNR > -3 dB	2 s max
NSP Viterbi Decoder	
For BER 10^{-1} to 10^{-6}	< 1 dB from theory
NSP BCH Command Decoder	
Probability of Undetected Error	10^{-18} max

3.1.5.2 Ku-band receiver and Ku-band signal processor (KuSP)

An overall block diagram of the Ku-band forward link data subsystem is shown in Figure 3.9. The characteristics of the received RF signal are given in Table 3.7. The forward link RF carrier transmitted by the TDRS is normally biphase-modulated with a modulo-two sum of data and PN code where the data and PN clocks are asynchronous. The data format is biphase-L (Manchester) and the PN code is NRZ-L. The PN code is a 1023 symbol Gold Code.

The system actually has two data modes, as shown in Table 3.8. In mode 1, the data rate is 216 k bit/s as described above, and the data stream is a time-multiplexed composite of 72 k bits/s of "operational data," 128 k bits/s of DOD command data to the CIU, and 16 k bits/s of overhead used for frame synchronization and data demultiplexing. After demultiplexing, the 72 k bits/s data are output in biphase-L format to network signal processors 1 and 2 (NSP 1 and 2). The 128 k bits/s data are output in NRZ-L format, with clock to the payload and text-and-graphics. In data mode 2, the received signal is demodulated and output directly to NSP 1 and NSP 2 without bit synchronization or bit detection. In this mode, the possible data rates are 32, 72, 96 or 216 k bits/s and the data format is always biphase-L.

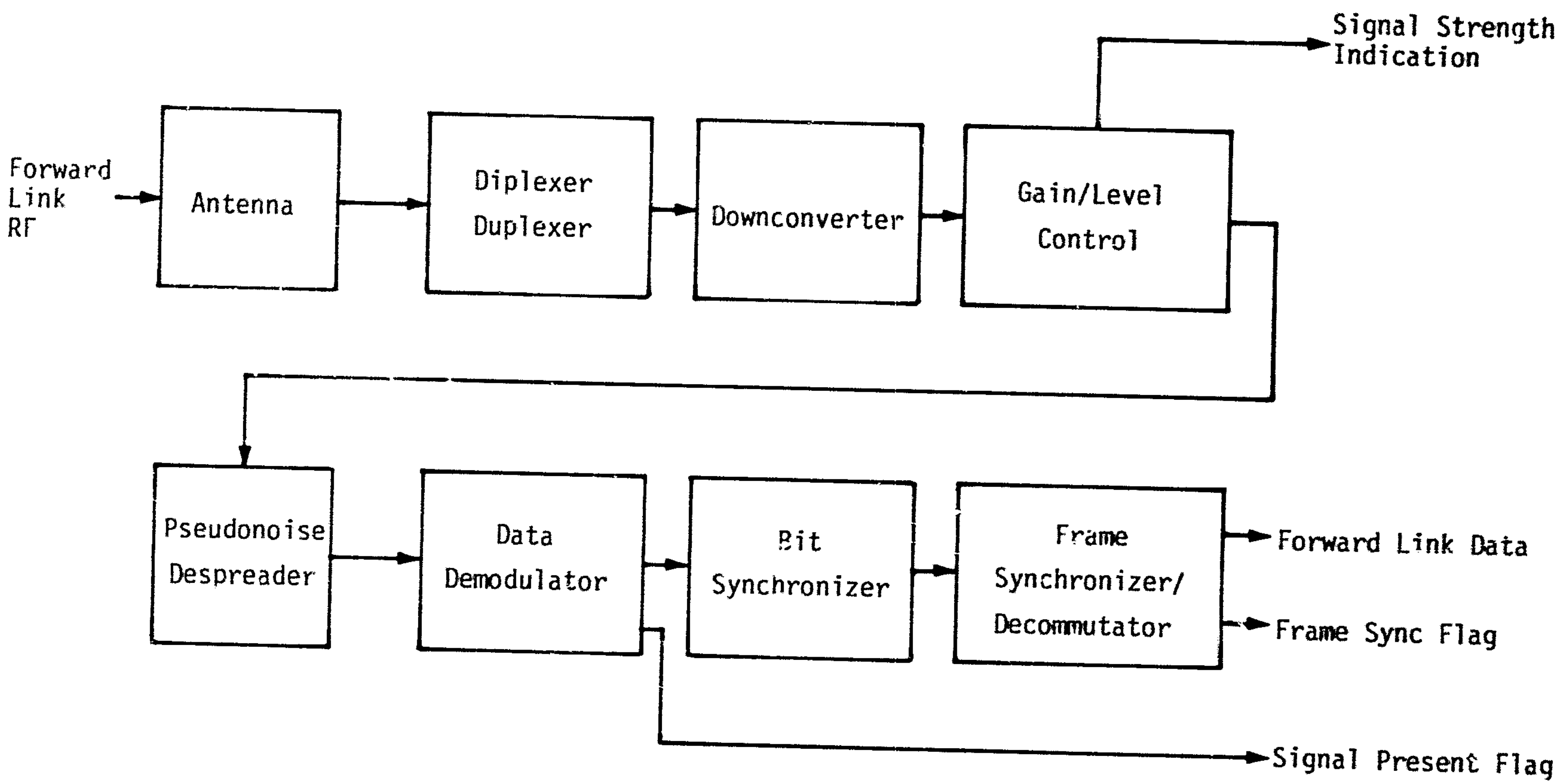


Figure 3.9. Ku-Band Forward Link Function

Table 3.7. Ku-Band Forward Link RF Signal Characteristics

Carrier frequency	13.775 GHz ± 10 kHz
Received wave polarization	Right-hand circular
Received wave axial ratio	1 dB max
Dynamic range of incident	-113.5 dBW/m^2 max
Flux density	-126.9 dBW/m^2 min
PN code length	1023 symbols
PN code rate	3.028031 Mchips/s ± 1 chip/s
PN code format	NRZ-L
Mode 1 data rate	216 kbps ± 22 bps
Mode 2 data rate	32 or 72 or 96 or 216 kbps
Data format (all modes)	Biphase-L (Manchester)
Modulation (when present)	Biphase

Table 3.8. Ku-Band Signal Processor Forward Link Data Characteristics

KuSP Interface	Type	Rate or Bandwidth
Mode 1		
Command/Text & Graphics--NSP (1,2) and Text & Graphics	Digital	72 kbps Command 128 kbps Text & Graphics 16 kbps Frame Sync (Manchester)
Command/DOD Payload Command Data--NSP(1,2)/CIU	Digital	72 kbps Command 128 kbps DOD Payload 16 kbps Frame Sync (Manchester)
Mode 2		
Operations Data--NSP(1,2)	Digital	32,72,96,216 kbps (Manchester)

Figure 3.10 illustrates the functional processing of the KuSP for data to be transmitted to the payload (i.e., the forward link). When the forward link contains the normal S-band 216 kbps operational data of the 72 kbps command data plus digital voice data, the data mode select is set to transfer the data directly to NSP 1 and 2 without any processing in the KuSP. Note that, in this data select position, the possible data rates are 32, 72, 96 and 216 kbps. When the 216 kbps forward link data contains either text and graphics data or DOD command data, then data mode select is set to transfer the 72 kbps command data to NSP 1 and 2. The 128 kbps DOD command data is actually 2 kbps which has been coded to use the available 128 kbps data rate without having to modify the KuSP bit synchronizer or frame synchronizer.

3.2 Payload/Orbiter Functional Telemetry Signal Flow

The payload/Orbiter functional telemetry signal flow is presented in Figure 3.11. In the attached mode, the payload transponder signal processor sends telemetry directly to the payload recorder (PR), payload data interleaver (PDI), S-band FM signal processor (FMSP), or KuSP. In the detached mode, telemetry is transmitted by the payload transponder to the PI. For NASA missions with standard data formats, the telemetry data passes from the PI to the PSP, which sends it to the PDI for data handling. For DOD missions with standard data formats, the telemetry data passes from the PI to the CIU, which distributes the processed data to the PR, PDI, FMSP or KuSP for data handling. When nonstandard telemetry data formats are used in the detached mode, the PI strips off the RF carrier and sends the unprocessed data to the KuSP for transmission to the ground. This mode is called the "bent-pipe" mode since the Orbiter performs no processing of the telemetry data other than carrier translation.

A brief summary of the functions of each of the units involved in the telemetry signal flow is presented in the next sections to delineate the interfaces where compatibility is required and potential interface problems can occur.

3.2.1 Payload Transponder

The payload transponder shown in Figure 3.11 actually includes the transponder to provide the RF link in the detached mode and a signal processor to process the telemetry data and interface with Orbiter data-handling equipment in the attacned mode. The block diagram of a typical

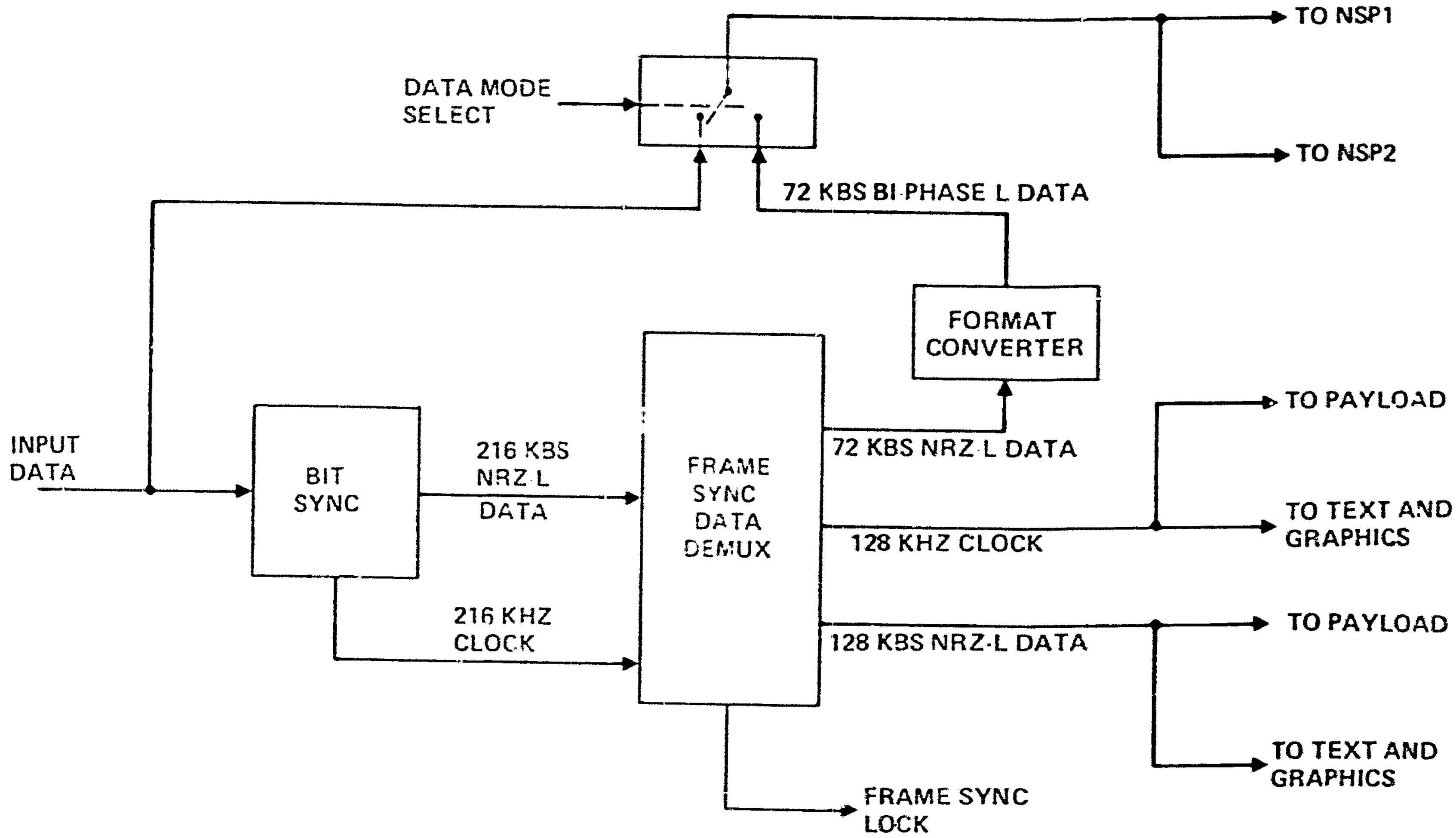


Figure 3.10. Ku-Band Signal Processor Forward Link Functional Block Diagram

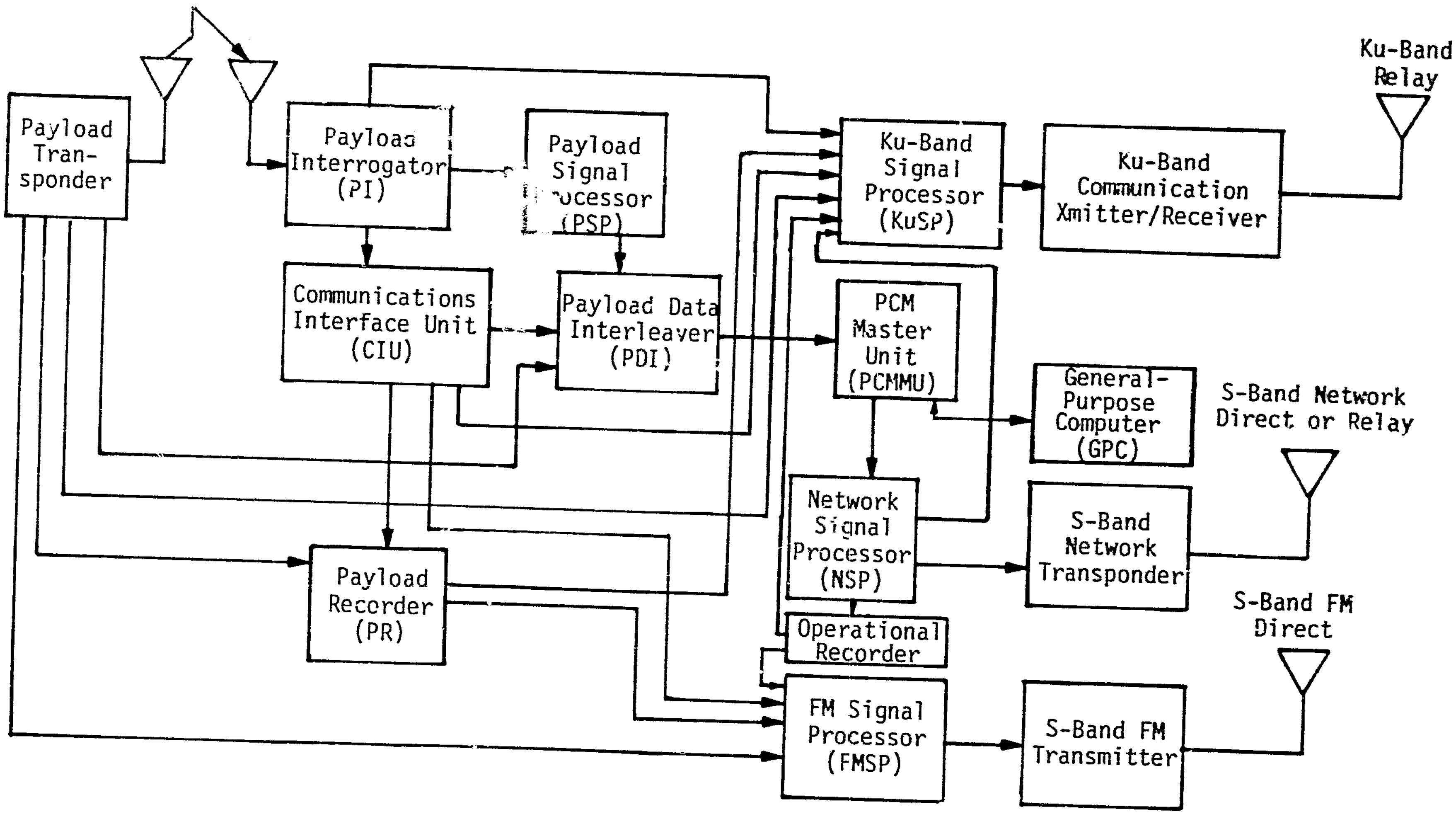


Figure 3.11. Payload/Orbiter Functional Telemetry Signal Flow

payload transponder was shown in Figure 3.2. As mentioned in subsection 3.1.1, the transmitter frequency is related to the receiver frequency by a ratio of integers, called the coherency (or turn-around) ratio. Both the NASA and DOD transmitter frequency ranges are S-band (2200 - 2300 MHz). The corresponding coherency ratios are, for NASA, 240/221, and for DOD, 256/205. Most transponders also have a turn-around ranging capability; there is, however, no plan to make use of such ranging capability with the payload/Orbiter link.

The synthesizer/exciter provides all reference frequencies to the transponder. A reference oscillator supplies standard frequencies to the receiver synthesizer, and coherence is provided by the receiver VCO. Synthesized frequencies are distributed to the receiver mixers and phase detectors and to the transmitter phase modulator through a frequency multiplier.

The phase modulator provides the means of modulating the return link carrier with telemetry and ranging signals. Its output drives the transmitter frequency multiplier, producing the required modulated carrier signal in the S-band frequency range.

Finally, the power amplifier raises the modulated S-band transmitter signal to the level required by the return link. For near-Earth spacecraft, the power levels may range from a few hundred milliwatts to several watts, while deep-space vehicles employ power levels on the order of 100 W.

Typical transponder transmitter operating and performance parameters are indicated in Table 3.9.

Table 3.9. Typical Payload Transponder Transmitter Characteristics

Item	Parameter and Range
Transmitter Frequency Range	2200 - 2300 MHz
Ranging Channel Frequency Response	1 kHz to 1.2 MHz
Transmitter Phase Deviation	Up to 2.5 radians
Transmitter Output Power	200 mW to 5W*

*Up to 200 watts with external power amplifiers.

3.2.2 Payload Interrogator (PI)

The functional block diagram of the PI was presented in Figure 3.3. As mentioned in subsection 3.1.2, the PI is basically a transceiver which is frequency excited or referenced to a universal frequency synthesizer that allows the PI to operate on any of 861 channel pairs. The PI receiver covers the 2200 - 2300 MHz band (S-band). Table 3.10 lists the principal operating characteristics of the PI receiver.

As shown in Figure 3.3, a single RF port connects the PI to the payload antenna cable as the Orbiter payload antenna serves to simultaneously receive and transmit signals. This port connects into the receiver input through an assembly known as the triplexer. The triplexer consists of six cavity-based bandpass filters which divide the receiver band and both transmit bands approximately in half to provide payload communication with minimum interference to network communications, as discussed in subsection 3.1.2.

Immediately following the triplexer receive switch and located at the input to the preamplifier is a power overload limiter. This limiter functions to protect the FET preamplifier itself from any damage for applied power levels as large as +36 dBm. The preamplifier output is input through an image frequency-rejecting BPF to the first mixer.

The function of the first mixer is to downtranslate the received signal to a fixed intermediate frequency (IF) of 215 MHz. Since the input signal carrier frequency may correspond to any one of the designated channels on the 2200 - 2300 MHz range, the mixer reference supplied by the receiver synthesizer (RX) must also cover a 100-MHz range (1985-2085 MHz). Following this mixer is a wideband IF amplifier assembly (IFAS) consisting of several stages of gain-controllable (AGC) amplification and bandpass filters.

A second mixer further downconverts the 215 MHz first IF signal to the 31 MHz second IF. The reference for this second mixer is derived from the tracking loop VCXO, so the second mixer represents the input to a quasilong loop phase-locked-loop (PLL) architecture. The second mixer is followed by an IFAS. At the output of the IFAS, the signal is effectively split into two principal channels.

Table 3.10. Principal PI Receiver Characteristics

Parameter	Value	Units
Input Frequency Range	2200 - 2300	MHz
Input Signal Level Operating Range	-124 to +36	dBm
AGC Range	-127 to -27	dBm
Noise Figure	7.0 max	dB
Thresholds: Acquisition	-120.0	dBm
Tracking	-124.0	dBm
Acquisition Sweep Range:		
Minimum	±112	kHz
Maximum	±132	kHz
Nominal Acquisition Sweep Range	330	kHz/sec
Frequency Rate Tracking	17	kHz/sec
False Lock Immunity	Sidebands <-26	dBc
Tracking Bandwidth	3200	Hz
Maximum Phase Noise	15	Degrees-RMS
Throughput Bandwidth:		
Minimum	4.3	MHz
Maximum	5.5	MHz
Output Signal Regulation	2.0 ± 0.4	VRMS
Throughput SNR Losses	2.1 max	dB

The wideband channel provides for modulation recovery and output to the appropriate processing units. A wideband phase demodulator referenced to a 31 MHz oscillator (which becomes phase coherent with respect to the signal carrier component by virtue of the carrier-tracking loop discussed subsequently) translates all of the signal first-order sidebands to the lowpass or baseband frequency region. The baseband waveform (which generally consists of signal-plus-noise) is then regulated to a fixed RMS value prior to being output.

A second 31 MHz channel is narrowband (approximately 30 kHz IF bandwidth) by virtue of the placement of a crystal BPF prior to two quadrature reference-driven demodulators. One of these demodulators, known as the loop phase detector, produces a carrier frequency/phase error voltage which is subsequently filtered and applied to the voltage control input of the PLL VCXO. The VCXO output is frequency multiplied by a factor of 10, whence it becomes the reference to the second mixer, thus completing the PLL circuit. For the conditions of proper PLL tracking, the frequency and phase of the received signal discrete carrier component at the input to the loop phase detector is in frequency-synchronous phase-quadrature with the 31 MHz derived reference.

Prior to achieving a condition of phase lock, the frequency difference between the received signal and the receiver references may be very large (> ±100 kHz). Thus, as an aid to attaining lock, the VCXO frequency is swept over the uncertainty range by means of the sweep loop. Once a state of lock is established, the sweep loop is disabled by the lock detector circuit.

The second demodulator of the narrowband quadrature pair is known as the coherent amplitude detector (CAD). If, when the PLL is locked, the input and reference to the loop phase detector have a 90° phase difference, the input and reference to the CAD then have a 0° phase relationship. As a result, the CAD output is a direct (zero frequency) voltage with amplitude proportional to the level of the received carrier. Such a voltage has two distinct uses: (1) as a means of indicating phase lock, and (2) the basis for receiver automatic gain control (AGC).

To implement a lock detector, the CAD output is input to a two-pole small bandwidth LPF which is followed by a comparator referenced to a fixed threshold. When the PLL is out of lock, any direct signal component and noise voltage appearing at the LPF output are essentially smaller than the threshold so that the comparator output will indicate a "false" or out-of-lock status. Conversely, if the PLL is locked, the direct voltage appearing at the LPF output is sufficiently greater than the threshold so that the comparator output becomes "true," indicating a state of in-lock.

An AGC voltage is formed by simply offsetting the CAD output (i.e., adding a reference voltage, RC), lowpass filtering, and feeding the result back to the voltage-controllable gain amplifiers within the first and second IFAS's. Since AGC is also needed for receiver acquisition conditions when the PLL is out of lock and no direct voltage is produced at the CAD output, a noncoherent AGC voltage is derived and used in this state. The implementation involves rectifying the 31 MHz output of the crystal BPF to obtain the AGC measure, adding a reference voltage RN, and switching the result into the AGC LPF (in lieu of the CAD output). Switching between noncoherent and coherent AGC is dependent upon which of the respective voltages is the largest.

3.2.3 Communication Interface Unit (CIU)

The current function of the CIU is to provide command and telemetry data conditioning between the Orbiter and the IUS transponder. The CIU receives IUS telemetry over hard line (attached) and from the PI (detached). In the attached or hard-line mode, the CIU receives data from one of two IUS's and provides selected telemetry data (NRZ-L) to the COMSEC and the PDI. The CIU provides the same telemetry data after NRZ-L to biphase-L conversion for selection to the Payload Recorder (PR), FMSP or KuSP. The CIU also receives NRZ-L data from the Wideband Data Interleaver (WBDI) on the IUS and performs NRZ-L to biphase-L conversion. The WBDI data is selected to be supplied to the PI, FMSP or KuSP. The IUS EMU analog environmental data is received by the CIU for selection to the PR. In the detached or RF modes, the CIU receives telemetry data from one of the two PI's as a PSK subcarrier (1.024 MHz) frequency multiplexed with FM/FM environmental data on a 1.7 MHz subcarrier. The CIU performs PSK demodulation and bit synchronization to generate NRZ-L telemetry data and clock to be supplied to the PDI. The same telemetry data is NRZ-L to biphase-L converted for selection to the PR, FMSP or KuSP. The CIU performs FM demodulation on the 1.7 MHz subcarrier to generate three-channel FM (16, 24 and 32 kHz). The CIU provides the three-channel FM plus a 100 kHz reference for selection to the PR.

Figure 3.5 shows a simplified block diagram of the CIU. The microprocessor at the heart of the CIU performs the bit synchronization function on the telemetry data for processing by a COMSEC and receives telemetry data (NRZ-L) and clock from the COMSEC.

3.2.4 Payload Signal Processor (PSP)

The PSP consists of two basic processors--one to handle telemetry data and the second to process and encode command messages. Telemetry input is in the form of data biphase modulated onto a subcarrier which is serially processed in such a manner as to (1) PSK demodulate the data from the subcarrier, (2) bit synchronize and matched-filter detect the data, and (3) frame synchronize the data. Table 3.11 lists the principal PSP telemetry signal-processing capabilities.

A telemetry functional block diagram of the PSP appears as Figure 3.12. Telemetry signal input may be derived from either the PI, which represents the operational input, or ground support equipment (GSE) for preflight test purposes. As the input signal is a biphase-modulated suppressed subcarrier waveform, the PSK demodulator functions to regenerate a coherent subcarrier reference which is used to phase demodulate the data from the subcarrier. Thus, the output from the PSK demodulator is composed of the telemetry bits. Subcarrier regeneration and tracking is accomplished by means of a polarity-type Costas loop.

The bit synchronizer is a digital data transition tracking loop (DTTL) of proven design and performance. Data detection itself is performed by integrating across an entire bit (in-phase integration or averaging) and taking the resulting polarity as representative of the bit value (+1 or -1). Bit clock synchronization is accomplished by means of integrating between bits (mid-phase integration or averaging) and using the resulting measure as an error signal which subsequently corrects the local bit timing clock source phase to maintain proper alignment with the received bits.

At the output of the bit synchronizer, a received serial telemetry data bit stream exists and is identical to that generated by the payload, with the exception of occasional bit errors. This data stream consists of random (insofar as processing is concerned) telemetry information plus regularly inserted frame synchronization words. It is these frame synchronization words that the frame synchronization processor searches for and locks onto so that the telemetry stream output by the PSP is frame synchronized.

Table 3.11 PSP Telemetry Signal-Processing Capabilities

Parameter	Value	Units
Subcarrier Waveform	Sinusoidal	-
Subcarrier Modulation	PSK, ±90	Degrees
Subcarrier Frequency	1.024	MHz
Bit Rates	$16 \div 2^N$, N = 0,1,2,3,4,	kbps
Bit Format	NRZ-L,M, or S, or Manchester-L,M, or S	-
Word Length	8	Bits
Minor Frame Length	8 to 1024	Words
Master Frame Length	1 to 256	Minor Frames
Transition Density	$\geq$ 64 transitions in 512 bits $\leq$ 64 consecutive bits w/o transition	

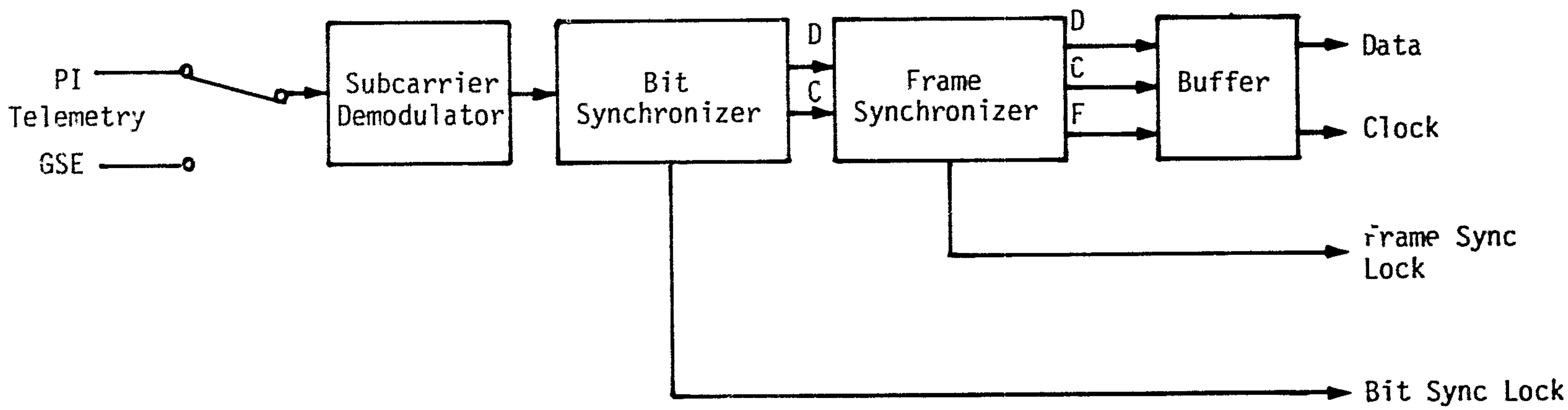


Figure 3.12. PSP Telemetry Functional Block Diagram

3.2.5 Payload Experiment Recorder (PR)

The data-recording system uses wideband digital and analog magnetic tape recorders to record and reproduce digital and analog signals. The magnetic tape recorder data storage system consists of two components. The first component comprises the multitrack coaxial reel-to-reel tape transport and its associated electronics. The tape transport features negator spring tension and contains a minimum of 2400 usable feet of 0.5-inch by 1-mil magnetized tape. The transport can store a minimum of 3.4×10^9 bits of digital data. The second component contains additional data conditioning circuitry and all other control logic and associated electronics.

Payload experiment data recording is provided via the payload station panel. Predetermined patch panel wiring permits digital data recording in either parallel (up to 14 tracks) or a combination of parallel-serial. Data rates from 25.5 kbps (lowest rate for a tape speed of 6 inches per second (ips)) to 1024 kbps (highest rate for a tape speed of 120 ips) can be selected from four tape speeds provide by premission wiring of recorder program plugs.

Analog data can be recorded on up to 14 tracks in parallel with frequencies from 1.9 kHz (lowest frequency for 6 ips tape speed) to 1.6 MHz (highest frequency for 120 ips tape speed) by premission program wiring. The basic recorder has the record/playback capabilities presented in Table 3.12 below.

Table 3.12. Payload Recorder Record/Playback Capabilities

Data Range (kbps)	Frequency Range (kHz)	Selectable Tape Speed (ips)	Time Per Track (min)
64- 128	1.9 - 250	15	32
128- 256	3.8 - 500	30	16
256- 512	7.5 -1000	60	8
512-1024	1.5 -1600	120	4

3.2.6 Multiplexer/Demultiplexer

The primary interface unit between the GPC and other subsystems is an MDM, shown in Figure 3.13. The MDM's act as a GPC-to-Orbiter format conversion unit. They accept serial digital information from the GPC's and convert or format this information into analog, discrete or serial digital form for transfer to Space Shuttle subsystems. The MDM's can also receive analog, discrete or serial digital information from the Space Shuttle subsystems and convert and format these data into serial digital words for transfer to the GPC. In addition, MDM's are used by the instrumentation subsystems, but only in a receive mode. Each MDM is controlled through either the primary port connected to the primary serial data bus or through the secondary port connected to the backup serial bus if failure is encountered with the primary system. The input and output of the MDM are via a multiplexer interface adapter (MIA).

The characteristics of the serial digital data input/output channels between the Orbiter subsystem (e.g., NSP, PSP, CIU) I/O buffer and the MDM are shown in Figure 3.14. The Word and Message Discretes are in the "0" states when the voltage level is between -0.6 V to +0.6 V and in the "1" states when the voltage level is between +2.1 V to +5.9 V. These discretes have differential signal termination with an impedance of 71 $\pm$7 ohms and a rise and fall time between 10 and 90 percent of 100 - 1000 ns, as shown in Figure 3.15.

When the Word Discrete is switched to a logical "1" state, the Orbiter subsystem is enabled to transmit individual words to the MDM. Figures 3.16 through 3.18 present the format for individual words to the MDM. Figure 3.16 illustrates the overall data format and shows the various parts of the MDM word. Figure 3.17 presents the specifications for the data coding. Note that the burst data rate to the MDM is 1 Mbps. The first three bits of each MDM words are used for word synchronization and are different from the normal Manchester-coded bits. Figure 3.18 presents the specifications for the nonvalid Manchester code used for word synchronization.

When the Message Discrete is switched to a logical "1" state, the Orbiter subsystem is initiated to transfer multiple words under the control of the Word Discrete beginning with the first word. Figure 3.19 presents the specifications for the Message Discrete and the relationship

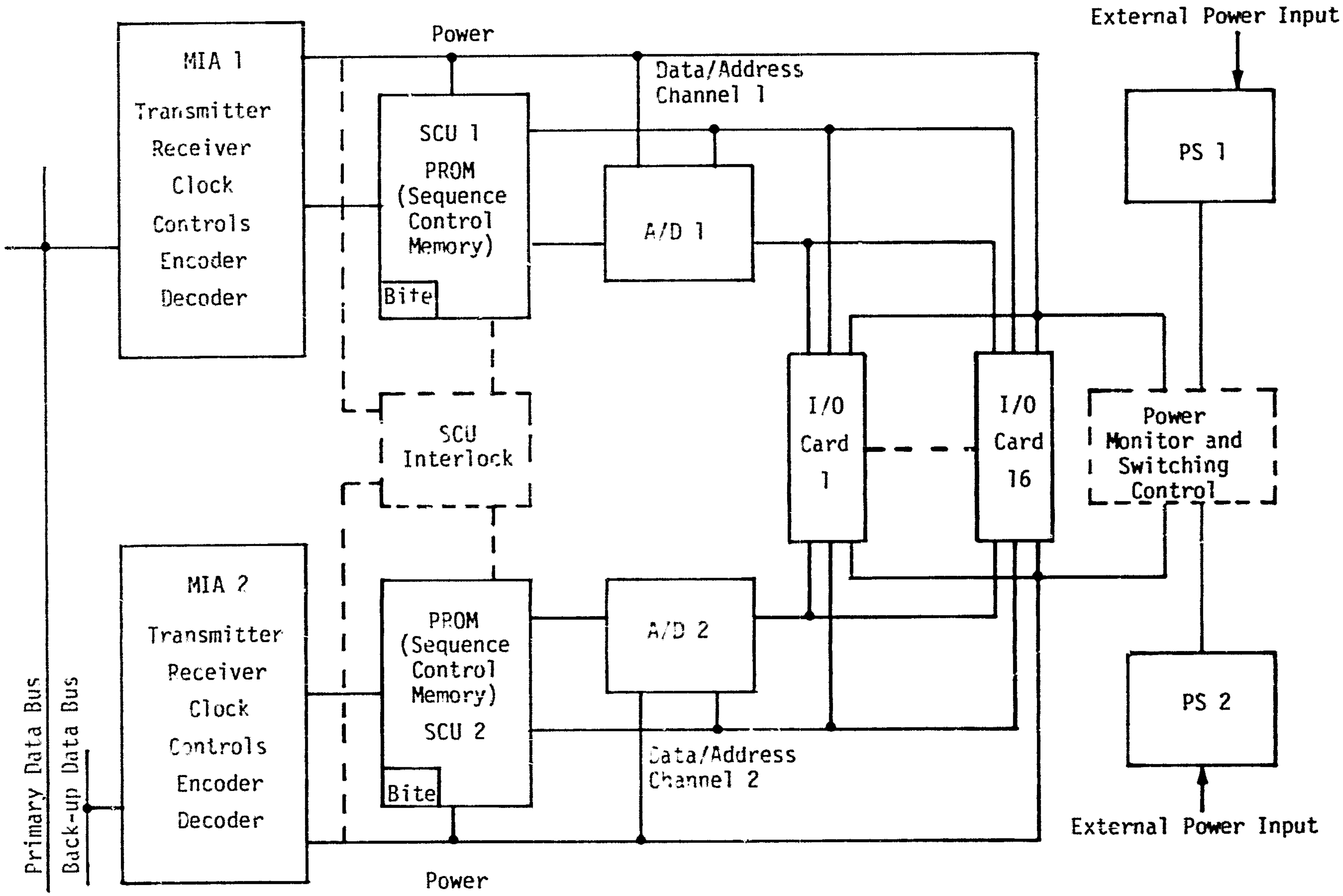


Figure 3.13. MDM System Block Diagram

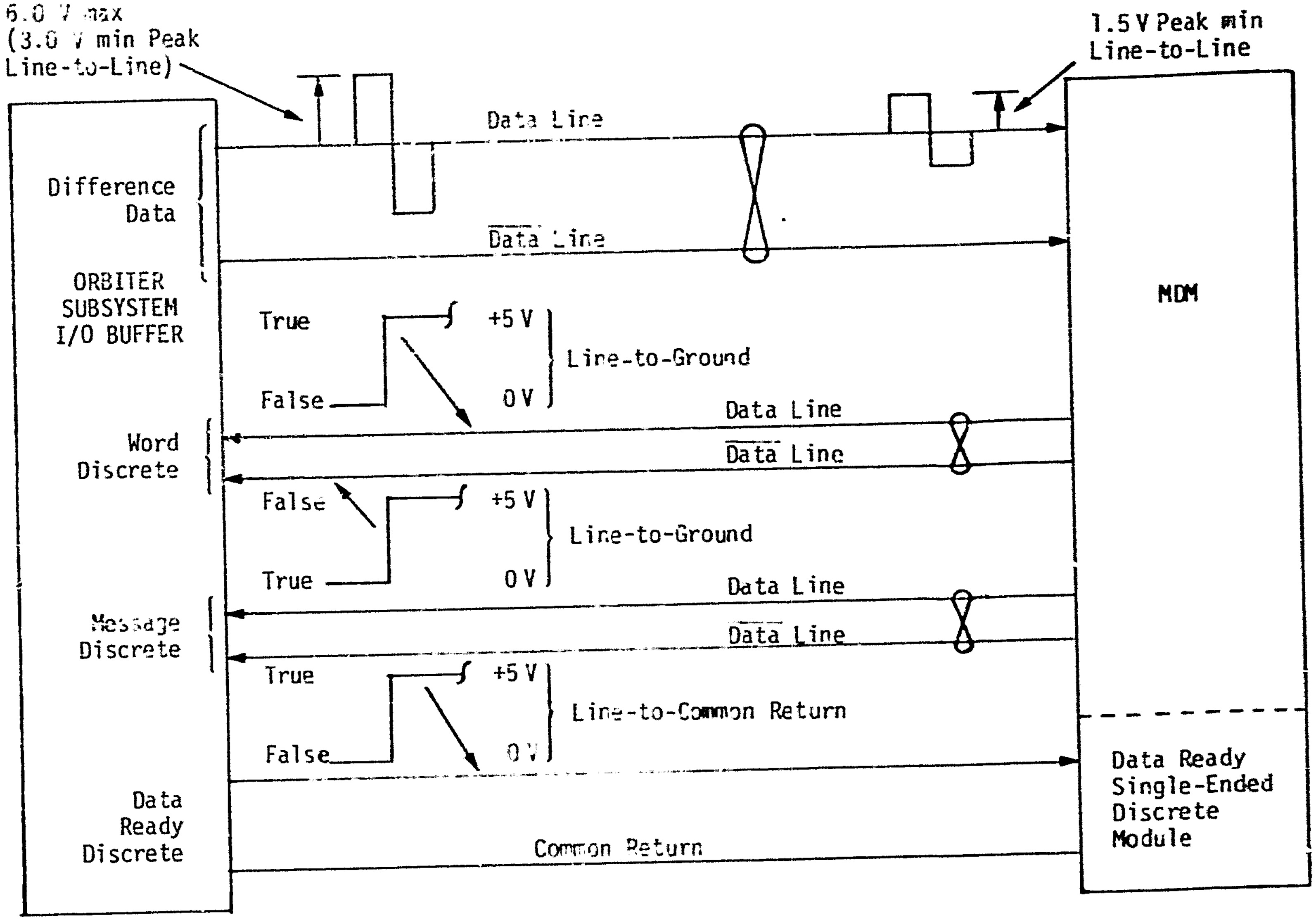
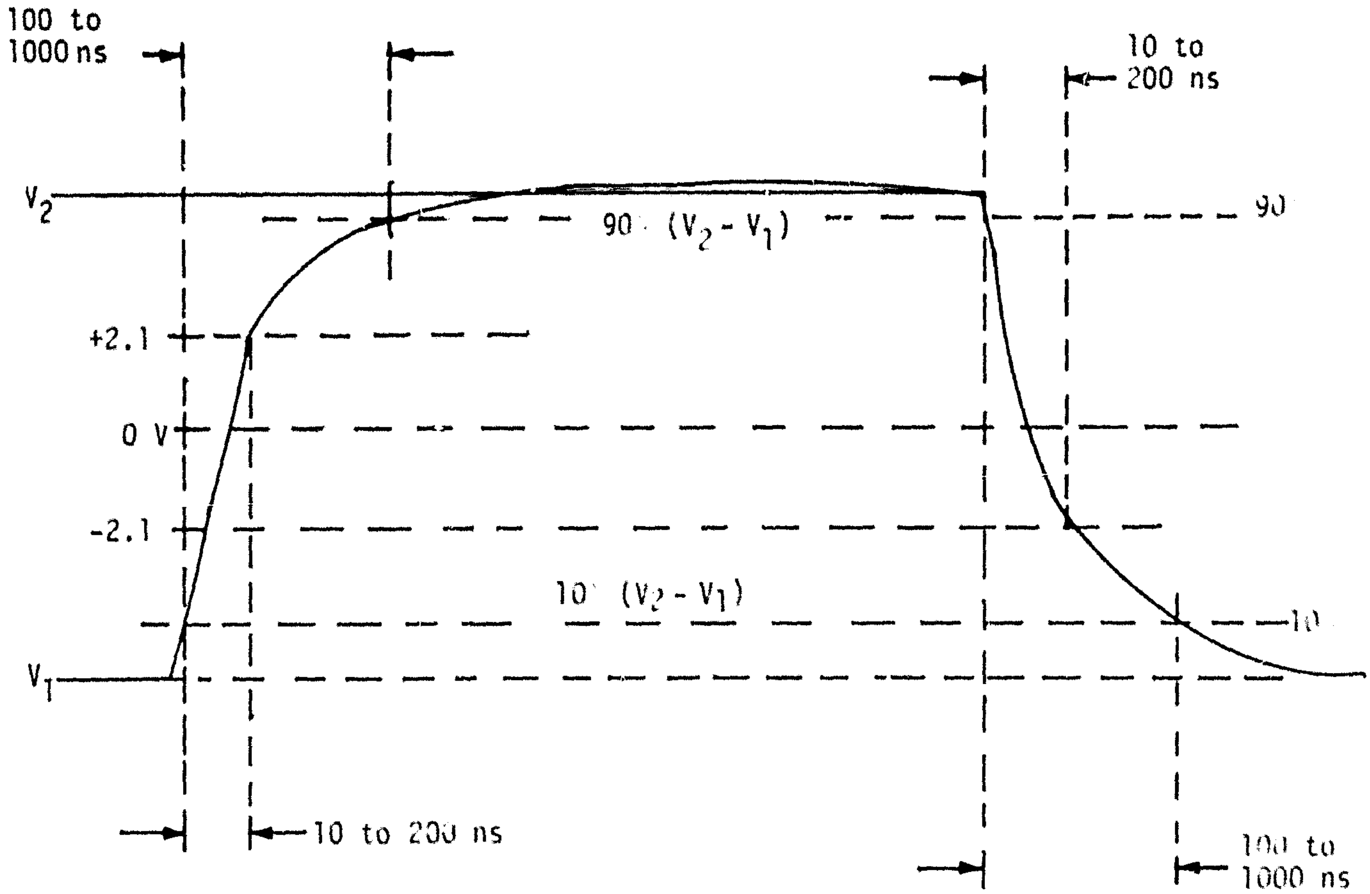


Figure 3.14. Serial Digital Input/Output Channel Interface



-5.9 volts $\leq V_1 \leq$ -2.1 volts

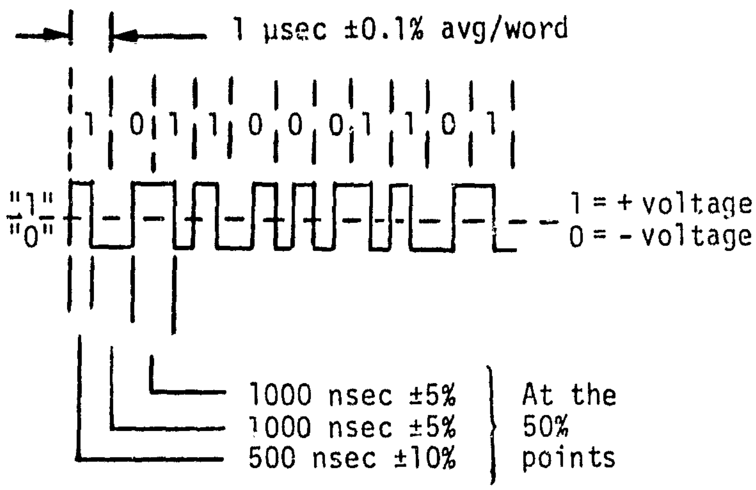
+2.1 volts $\leq V_2 \leq$ +5.9 volts

NOTE: Waveform represents line-to-line voltage excursion.

Figure 3.15. Rise and Fall Times

3	16		1
SYNC	SIGN OR MSB	DATA	PARITY

Figure 3.16. Serial Word Format



NOTE: Biphase Level (Manchester II)

"1" represented by 10
"0" represented by 01
for Data

"1" represented by 01
"0" represented by 10
for $\overline{\text{Data}}$

Figure 3.17. Data Code

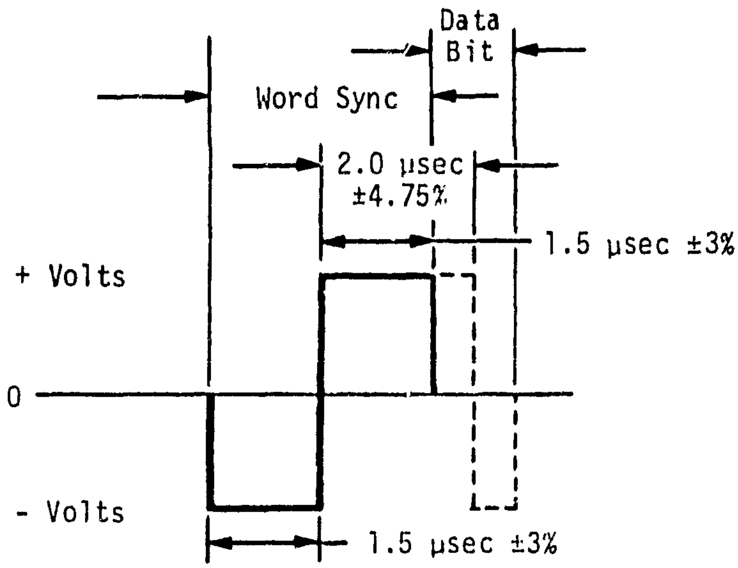


Figure 3.18. Data Word Synchronization, Nonvalid Manchester Code

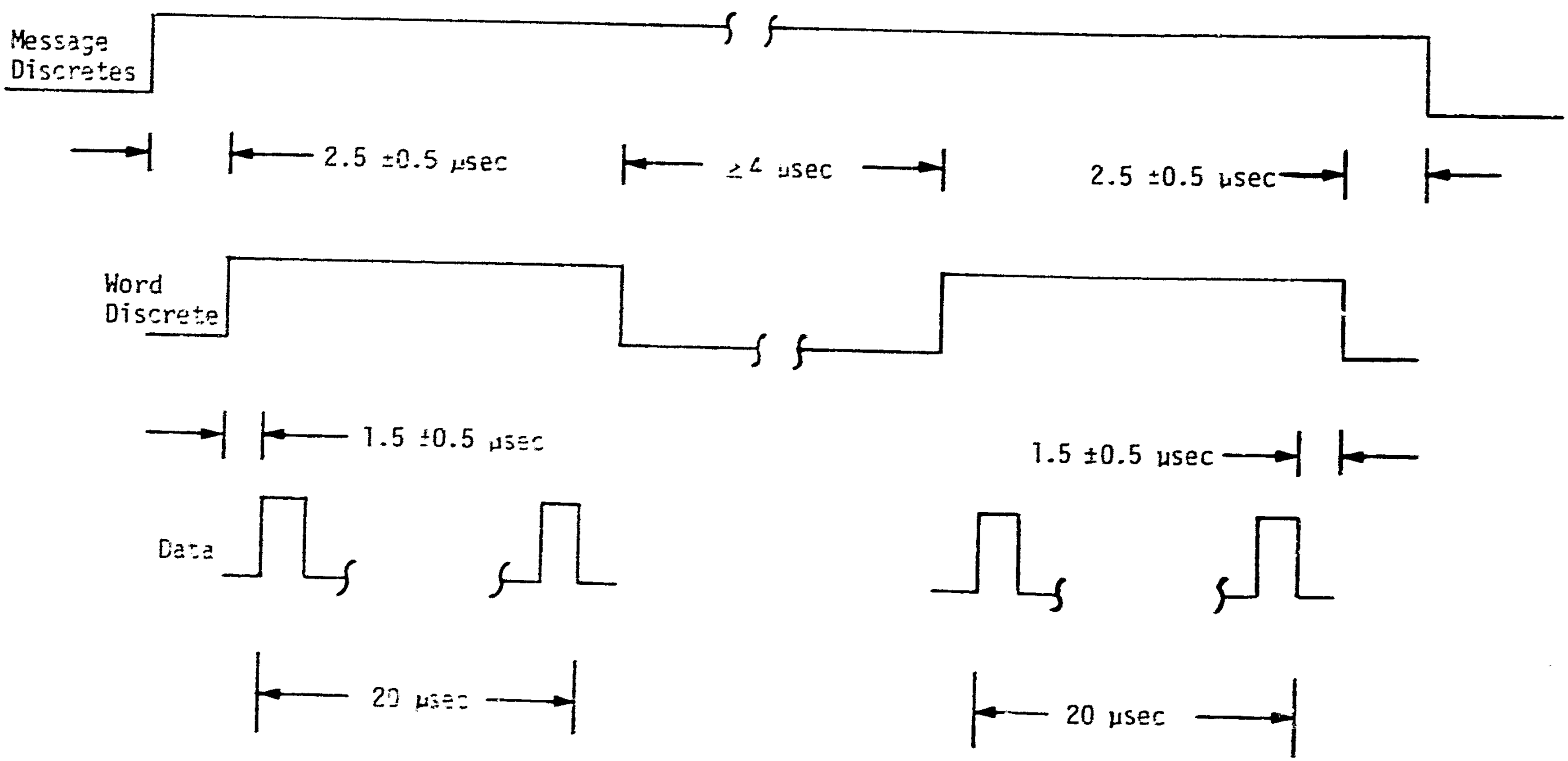


Figure 3.19. Serial Channel Data Transfer

between the Message Discrete and Word Discretes in the transfer of multiple MDM words.

Single-Ended Discretes are also shown in Figure 3.14. These discretes have the same logical state specifications as Word and Message Discretes; however, Single-Ended Discretes have rise and fall times of 20 μs (max). The power-off impedance and load impedance must be 10 kohms (max) with a line drive capacitance of 35 pf/ft (min). The corresponding intput current is 2.5 mA in the "0" state and 1.25 mA in the "1" state.

The characteristics of the analog interfaces with the MDM are a voltage range of 0 - 5 V (peak), a source impedance of 100 ohms (max), a load impedance of 500 kohms (min), a load "OFF" impedance of 100 kohms (min) and a line drive of 35 pf/ft (min). There can be only one analog interface per return.

3.2.7 PCM Master Unit

The block diagram of the PCMMU is presented in Figure 3.20. Operational instrumentation (OI) sensor data (designated as downlink data) are acquired by the PCMMU in conjunction with MDM's. The MDM's under control of the PCMMU's accept, encode and store the data in a random-access memory (RAM) located within the PCMMU. The stored data are "refreshed" (updated) periodically under the control of a preprogrammed read-only memory. This module is known as a "fetch PROM."

GPC sensor and derived data (designated as downlist data) are acquired by GPC's and sent by a data bus to the PCMMU's. The PCMMU provides a unique double-buffer memory for each computer input, which allows data reception asynchronously while synchronously outputting previously received data. This guarantees the homogeneity of the data (i.e., output data are not overlaid by incoming data). Payload data are processed through the PCMMU in the same manner as the OI sensor data except that the PCMMU interfaces with the PDI.

The OI PCMMU, after accepting data from the MDM, computers and PDI, formats the data into a serial digital output stream for telemetry, recording and GSE. Format control is provided by the output formatter, which is programmable and can be modified by a set of instructions from the computers.

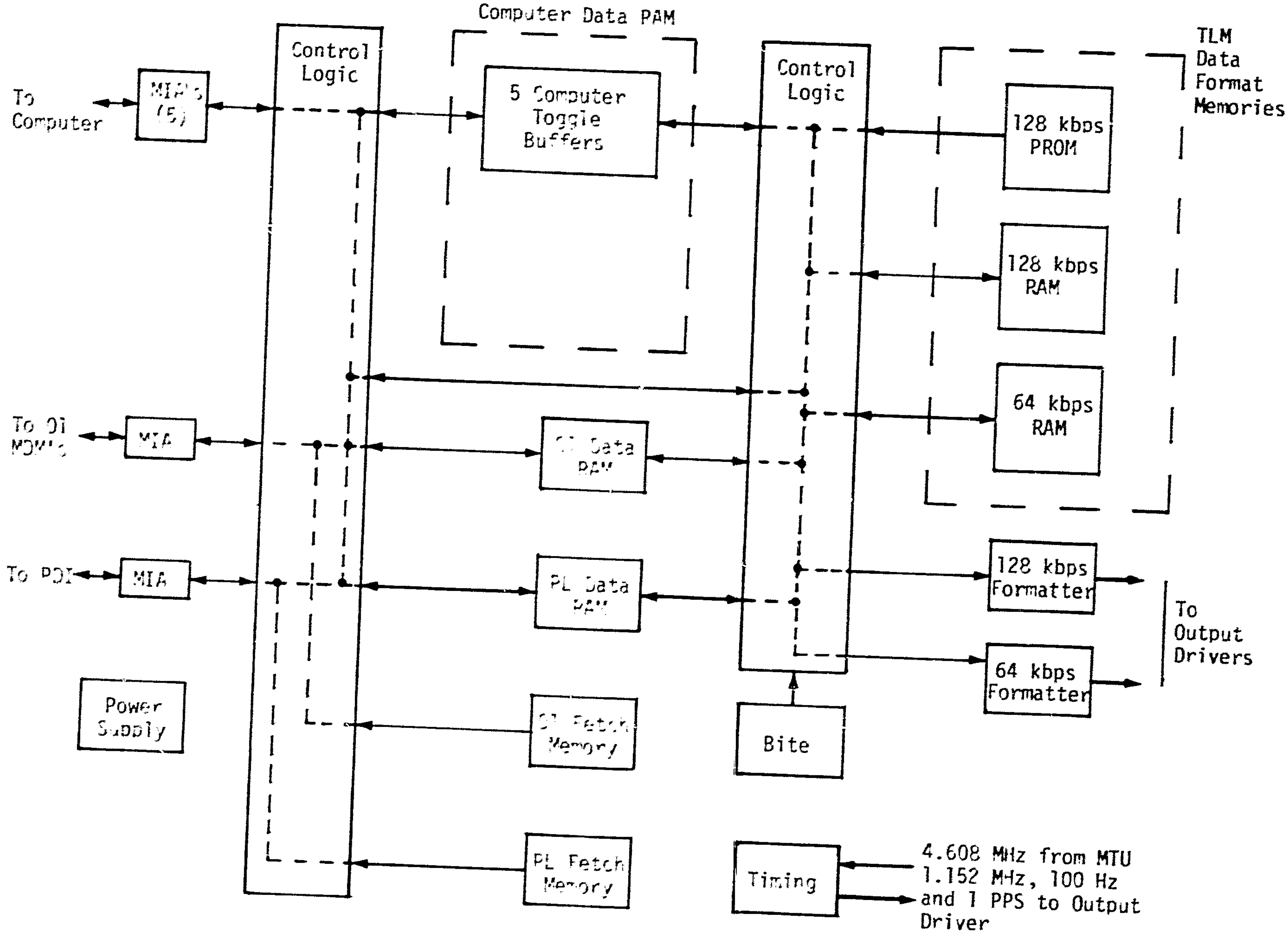


Figure 3.20. PCMMU Block Diagram

The PCMMU has a maximum output capability of 128 kbps for purposes of telemetry and on-board recording. The PCMMU, on command from the crew, can send 64 kbps of information. This mode is primarily used in conjunction with the low bit rate of the transmission system (S-band or Ku-band) and the TDRSS.

Formats have been developed for the ascent, on-orbit and entry phases and ground checkout. As noted in Figure 3.20, one of the format memories is a 128 kbps PROM having a fixed format and cannot be modified by the GPC. This format is used during power-up of the Orbiter and during the ascent phase. A fixed format is necessary because loss of power to the PCMMU would result in loss of information from 64/128 kbps RAM's (volatile memory).

3.2.8 Payload Data Interleaver

The programmable PCMMU can be modified from one flight to the next. Since the Shuttle provides transportation for many types of payloads, a programmable PDI was designed to interface with the PCMMU. The PDI (Figure 3.21) can accept data simultaneously from five different attached payloads, including the IUS/CIU and an input from the PSP, then select and individually decommutate the data for storage in a buffer memory. This memory is accessible to the PCMMU and the data are included with the Orbiter PCM stream. The PDI is programmed onboard from the mass memory through the GPC, which is used to select specific data from each payload PCM signal and transfer them to buffer memory locations. An input switch matrix selects four of the inputs for the bit synchronizers. The "chain" functions of bit synchronization, decommutation and word selection are provided for up to four simultaneous PCM streams in two possible modes, as listed below.

Mode 1. In this mode, a chain bit synchronizes, master-frame synchronizes, minor-frame synchronizes and word synchronizes to the incoming data stream. The word selector blocks data into proper words for storage in the data RAM and/or toggle buffer. PCM code type, bit rate, PCM format, synchronization codes and word selection are programmable under control of the decommutator format memories. Two word selection capabilities for this mode of operation are as follows: Type I--The first type selects all, or a subset of, the words in a payload PCM format minor

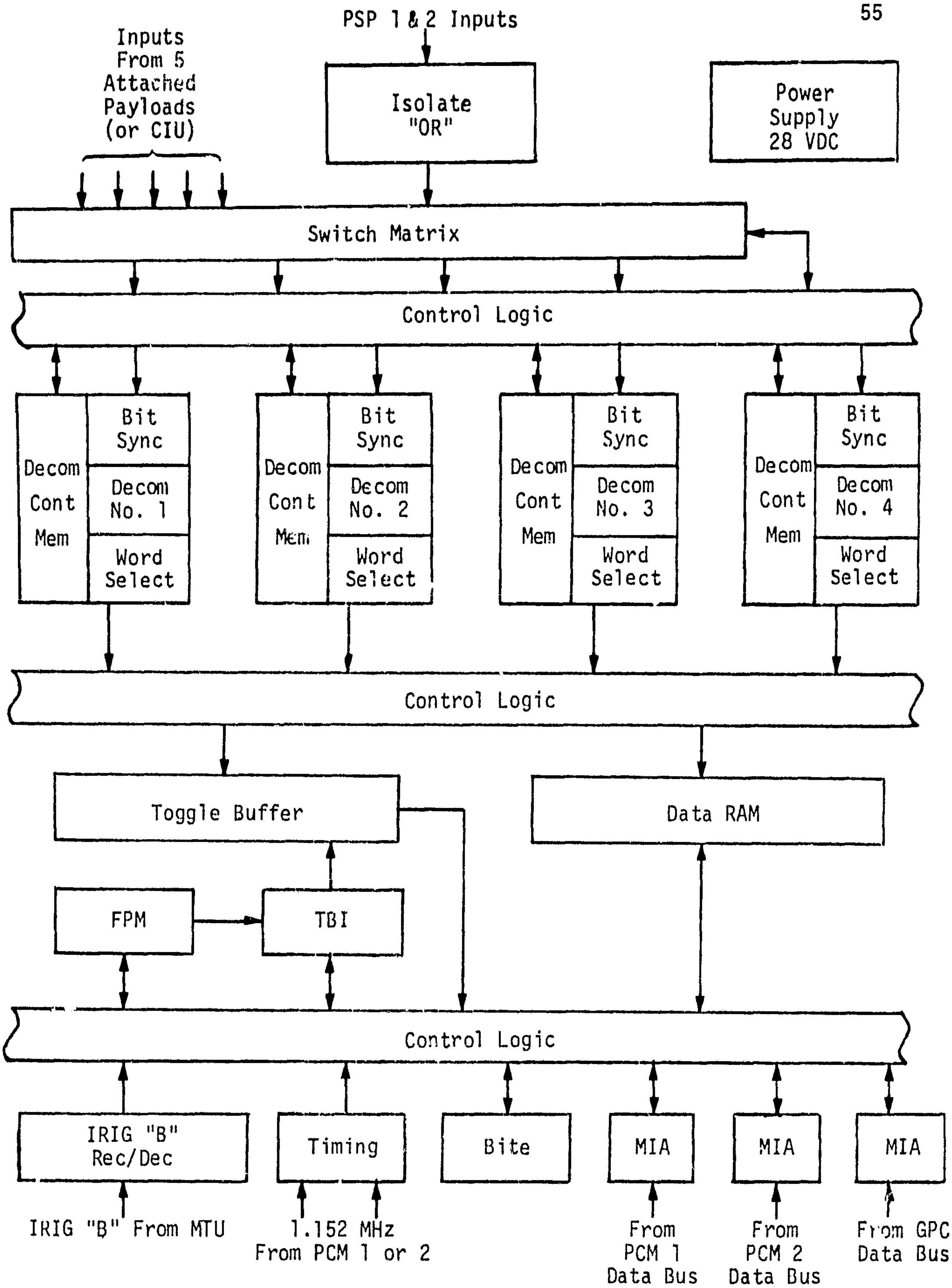


Figure 3.21. PDI Block Diagram

frame (or master frame for formats without minor frames) for storage in the toggle buffer. Type II--The second type of word selection is by parameter. The specification of a parameter consists of its word location within a minor frame, the first minor frame in which it appears, and its sample rate. The specification is provided as part of the decommutator control memory format load.

Mode 2. In this mode, a chain bit synchronizes to the incoming data, clocks it into eight-bit words, blocks the eight-bit words into frames, supplies synchronization pattern at the start of each frame and includes the status register as the last three 16-bit words of each frame. A homogeneous data set for this mode of operation is defined as all information within this PDI-created frame. Code type, bit rate, frame length and synchronization pattern are programmable under control of the decommutator format memories. The frames are supplied to the toggle buffer for storage as homogeneous data sets. No data is supplied to the data RAM in this mode of operation.

A status register containing the status and time for a given chain operation is provided by the word selector to the Toggle Buffer (TB) control logic. This logic regulates access to and from the half buffers by the word selectors and data busses. All requests for TB data by the data ports are processed through the Fetch Pointer Memory (FPM) and the Toggle Buffer Identifier (TBI). The TB control logic also partitions data from the word selector into homogeneous data sets for access by the data bus ports.

The FPM is used to identify which TB is to be accessed by a data bus port. It also allows access to any location in the data RAM by any of the PDI data bus ports at any time. FPM control logic routes all requests for TB data to the location in the FPM identified by the data bus command word. It further provides for loading and reading of formats to and from the FPM at any time by the data bus ports.

A data RAM for storage of data from the word selector by parameter is provided. The data RAM control logic steers data provided by the word selector into addresses in the data RAM specified by the decommutator control memory.

There are three data bus ports for interface with the Orbiter GPC that have read and write access into the switch matrix, decommutator control memory, FPM, PDI and data RAM.

An IRIG "B" receiver/decoder accepts an IRIG "B" code from an external source, decodes time and supplies it to the four status registers.

3.2.9 Orbiter Network Communication Equipment

Telemetry data is transmitted to the ground by using the network communication equipment. The Orbiter network communication equipment used for telemetry are (1) S-band PM transponder and NSP, (2) S-band FM transmitter and FM signal processor (FMSP), and (3) Ku-band transmitter and KuSP.

3.2.9.1 S-band PM transponder and network signal processor (NSP)

The S-band PM network transponder is a multimode S-band communication unit, as described in subsection 3.1.5.1. The functional block diagram of the network transponder is shown in Figure 3.7. In normal operation, the transmit frequency is 2217.5 MHz or 2287.5 MHz. The composite link data rates are shown in Table 3.13. The power amplifier assembly supplies high-power amplification of the network transponder output for TDRS/GSTDN (high power) modes, providing a minimum of 100 W RF output power.

Table 3.13. Data Rates for Network PM Links

Link	Rate	Channels Available	Composite Link Rate: Direct (Bit Rate)	Composite Link Rate: Relay (Rate 1/3 Coded) (Symbol Rate)
Return (Orbiter to Ground)	High	Two 32 kbps voice One 128 kbps telemetry	192 kbps	576 ksps
	Low	One 32 kbps voice One 64 kbps telemetry	96 kbps	288 ksps

The NSP performs the digital-processing funtions for the PM links. A block diagram of the NSP is shown in Figure 3.22. On-board analog voice signals are delta modulated using a modified ABATE algorithm and multiplexed with telemetry data. Data to be TDRSS relayed are convolutionally encoded (rate 1/3, constraint length 7). All digital output data are converted from NRZ-L to biphase-L prior to being transferred to the S-band transponder, Ku-band system or GSE umbilical.

3.2.9.2 S-band FM transmitter and FM signal processor (FMSP)

The FMSP and FM transmitter provide a capability for transmission of data not amenable for incorporation into the limited-rate PCM telemetry data stream. The data to be transmitted via FM include television, digital data from the main engines during launch, wideband payload data, or digital data from the PI or attached payload interface (API). The characteristics of the data and the performance specifications for the FMSP and FM transmitter are presented in Table 3.14.

Conditioning and multiplexing for FM transmission occur in the FMSP, as shown in Figure 3.23. Video and wideband digital and analog signals are routed to the FM transmitter with only matching and filtering, but narrowband digital engine data are placed on subcarriers at 576, 768, and 1024 kHz.

The FM transmitter operates at 2250 MHz with an output power of 10 W. Both baseband and RF filtering are provided to reduce out-of-channel interference to the PM and payload receivers. The nominal RF bandwidth is 10 MHz.

To further identify the interface between the payload system (i.e., the API and PR) and the FMSP, Table 3.15 presents the requirements of the input signals to the FMSP. As additional information concerning the data processing, Table 3.15 also presents the characteristics of the data signals output to the FM transmitter. Corresponding to each type of input signal, the signal source (i.e, API or PR) is identified. The signal type is either digital or analog, with the digital data further specified by the type of data coding. Note that, for the NASA wideband payload data, the data coding can be either Manchester II (biphase-L) or NRZ-L, but the Manchester-coded data is limited to data rates less than 2 Mbps rather than 5 Mbps for NRZ-L coded data. The signal level voltages all

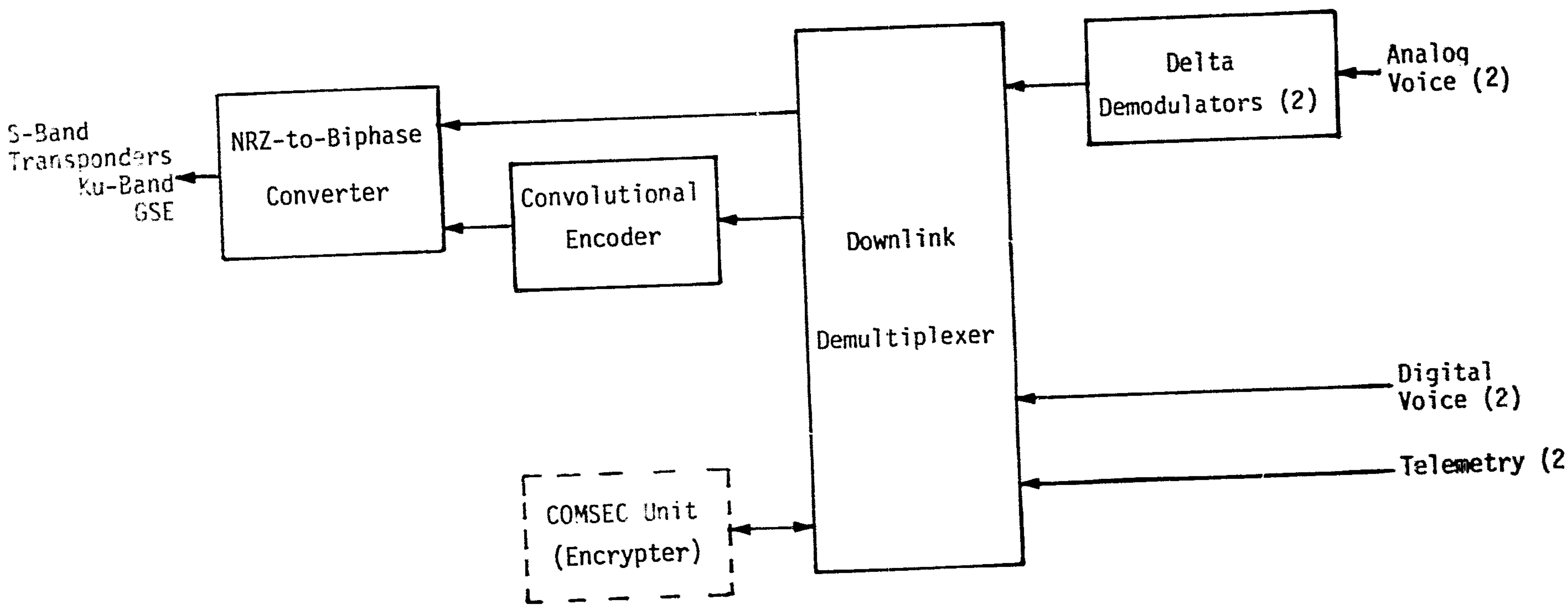


Figure 3.22. Return Link Network Signal Processor Functional Block Diagram

Table 3.14. S-Band FM Performance Specifications

FM Signal Processor	
TV Channel Input	EIA TV Standard RS 170
TV Channel Gain	19 dB ±0.8 dB to -0.25 dB
TV Channel Dynamic Range	51 dB ±0.25 dB
Frequency Response ±0.25 dB and Phase Ripple ±1.0°	DC to 4.5 MHz
CCIR K Factor	<2%
Main Engine	
Data in 3 Channels	60 kbps BPL
Subcarrier Frequencies	576 kHz, 768 kHz, 1024 kHz
Subcarrier Modulation	±180° at ±15°
Analog Data Bandwidth	300 Hz to 4 MHz
Wideband Digital Data Rate	200 bps to 5 Mbps NRZ, or 200 bps to 2 Mbps Manchester Coded
Recorded Data - 2 Channels Data Rate	25.5 kbps to 1024 kbps
Narrowband DOD Digital Data Rate	250 bps to 256 kbps
Input Common Mode Voltage (DC to 2 MHz)	1V max
FM Transmitter	
Frequency	2250.0 MHz ±0.003
Output Power (into 1.5:1 load)	10W min, 15W max
Deviation Sensitivity (for deviation up to ±4.5 MHz peak)	1 MHz/V peak ±10
Frequency Response ±1 dB	DC to 5.0 MHz
Incidental AM	5% max over input range
Incidental PM	<5 kHz RMS over modulation BW
Intermodulation Distortion (2-tone equal amplitude)	≤40 dB with frequency deviation ±1 MHz

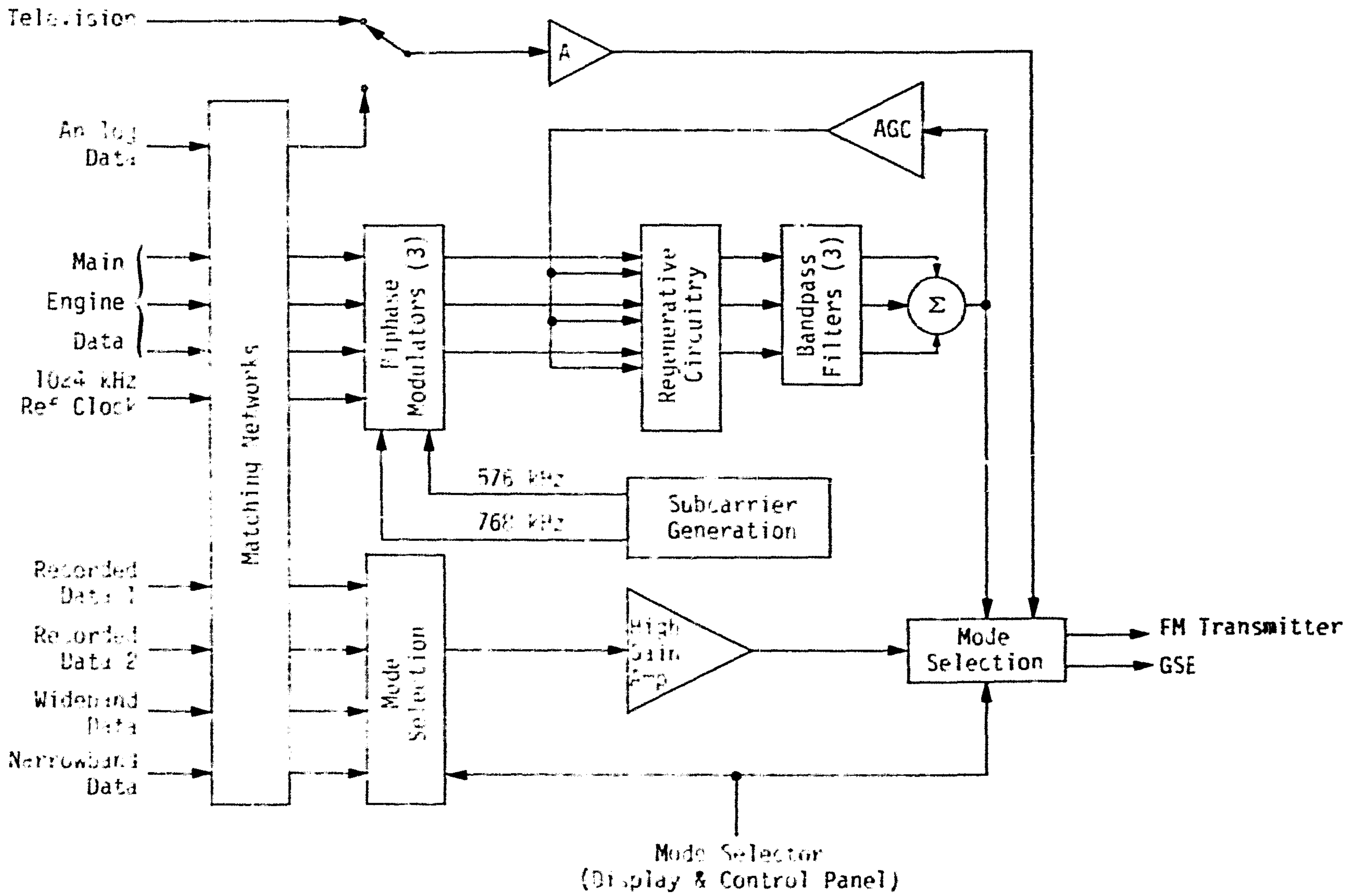


Figure 3.23. FM Signal Processor Functional Block Diagram

Table 3.15. Input and Output Signal Characteristics of FMSP for Payload Data

Signal	Signal Type	Data Coding	Data Rate	Signal Level	Rise/Fall Time	Coupling	Impedance
INPUT SIGNALS							
Recorded Data (PP)	Digital	Manchester II	22.5 kbps (min) 1024 kbps (max)	3-9V p/p line/line	<100 nsec ±2% asymmetry <0.1% bit jitter	Balanced Differential	71 ohms ±10%
Wideband Payload (API)	Digital	Manchester II NRZ-L	200 bps-2 Mbps 200 bps-5 Mbps	5V ±0.5 V p/p line/line	<50 nsec	Balanced Differential	75 ohms ±10%
Wideband Payload (API)	Analog	---	300 Hz-4 MHz	1V ±10% p/p line/line	---	Balanced Differential	75 ohms ±10%
DOD Payload (API or CIU)	Digital	Manchester II or NRZ-L	250 bps-250 kbps	1V ±0.6 V p/p line/line	<100 nsec	Balanced Differential	75 ohms ±10%
OUTPUT SIGNALS							
Recorded Data	Digital	Manchester II	22.5 kbps (min) 1024 kbps (max)	1.27V ±5% p/p	10% of bit duration; ±0.25 bit jitter	Single Ended	71 ohms ±10%
Wideband Payload	Digital	Manchester II NRZ-L	200 bps-2 Mbps 200 bps-5 Mbps	4V ±5% p/p	<10%	Single Ended	75 ohms ±10%
Wideband Payload	Analog	---	300 Hz-4 MHz	4V ±15% p/p	---	Single Ended	75 ohms ±10%
DOD Payload	Digital	Manchester II or NRZ-L	250 bps-250 kbps	1.27 V ±5%	<100 nsec	Single Ended	75 ohms ±10%

all peak-to-peak (p/p) and line-to-line for differential coupling and line-to-common for single-ended coupling. The impedance for all the signals is 75 ohms ± 10%, except the recorded data from the PR which is 71 ohms ± 10%.

The rise and fall times for the digital data are also presented in Table 3.15. It is desirable to keep the rise and fall times less than 10% but, in some cases, absolute times are specified which determine the type of output drivers required at the PR, API and payload. Note that there is an additional specification of ±2% data asymmetry and ±0.1% bit jitter on the PR output signal to reduce the degradation associated with these types of signal distortion. The output of the FMSP for the PR signal has a specification of ±0.25% bit jitter which is expected due to the multiplication of the jitter through the FMSP buffering. Actually, each of the input signals to the FMSP should have these specifications but, typically, these are not difficult specifications to meet except from tape recorders.

3.2.9.3 Ku-band transmitter and Ku-band signal processor (KuSP)

The characteristics of the data that must be processed by the KuSP on the return link are quite varied, as shown in Table 3.16. The return link is transmitted in one of two modes which are identified by the type of carrier modulation utilized. Mode 1 implements unbalanced quadriphase-shift-keying (UQPSK) while Mode 2 implements FM. In both modes of operation, two of the channels (1 and 2) UQPSK modulate a subcarrier. Mode 1 utilizes this modulated subcarrier along with the third channel to UQPSK the carrier, as shown in Figure 3.24. Mode 2 linearly sums the modulated subcarrier with the third channel and frequency modulates the carrier with the resultant summed signal, as shown in Figure 3.25.

Channel 1 always (Modes 1 and 2) carries the operations data of 192 kbps, consisting of 128 kbps telemetry data and two 32 kbps delta-modulated voice channels. Similarly, the data on Channel 2 does not change from Mode 1 to Mode 2. Channel 2 carries the output from the PR, the operational recorder (OR) and the PSP as well as low rate data for the API and narrowband bent-pipe data from the PI. The range of data rates handled by the KuSP Channel 2 is shown in Table 3.16 to be 16 - 1024 kbps Manchester-coded data, 16 - 2000 kbps NRZ-coded data or DC-2 MHz analog bent-pipe data.

Table 3.16. Ku-Band Signal Processor Return Link Data Characteristics

KuSP Interface	Data Type	Rate or Bandwidth
RETURN LINK		
CHANNEL 1 (MODE 1/MODE 2)		
Operations Data--NSP(1,2)	Digital	192 kbps (Manchester)
CHANNEL 2 (MODE 1/MODE 2)		
Payload Recorder (PR)	Digital	25.5 - 1024 kbps (Manchester)
Operations Recorder (OR)	Digital	25.5 - 1024 kbps (Manchester)
Payload low data rate--PSP (1,2) or Attached Payload Interface (API)	Digital	16 - 2000 kbps (NRZ) 16 - 1024 kbps (Manchester)
PI(1,2) low data rate	Digital/Analog	16 - 2000 kbps (NRZ) 16 - 1024 kbps (Manchester) 0 - 2 MHz
CHANNEL 3 (MODE 1)		
Attached Payload Interface (API)	Digital	2 - 50 Mbps (NRZ)
CHANNEL 3 (MODE 2)		
PI(1,2) high data rate	Digital/Analog	16 - 4000 kbps (NRZ) 0 - 4.5 MHz
Attached Payload Interface (API)	Digital/Analog	16 - 4000 kbps (NRZ) 0 - 4.5 MHz
Video Interface Unit	Analog	0 - 4.5 MHz

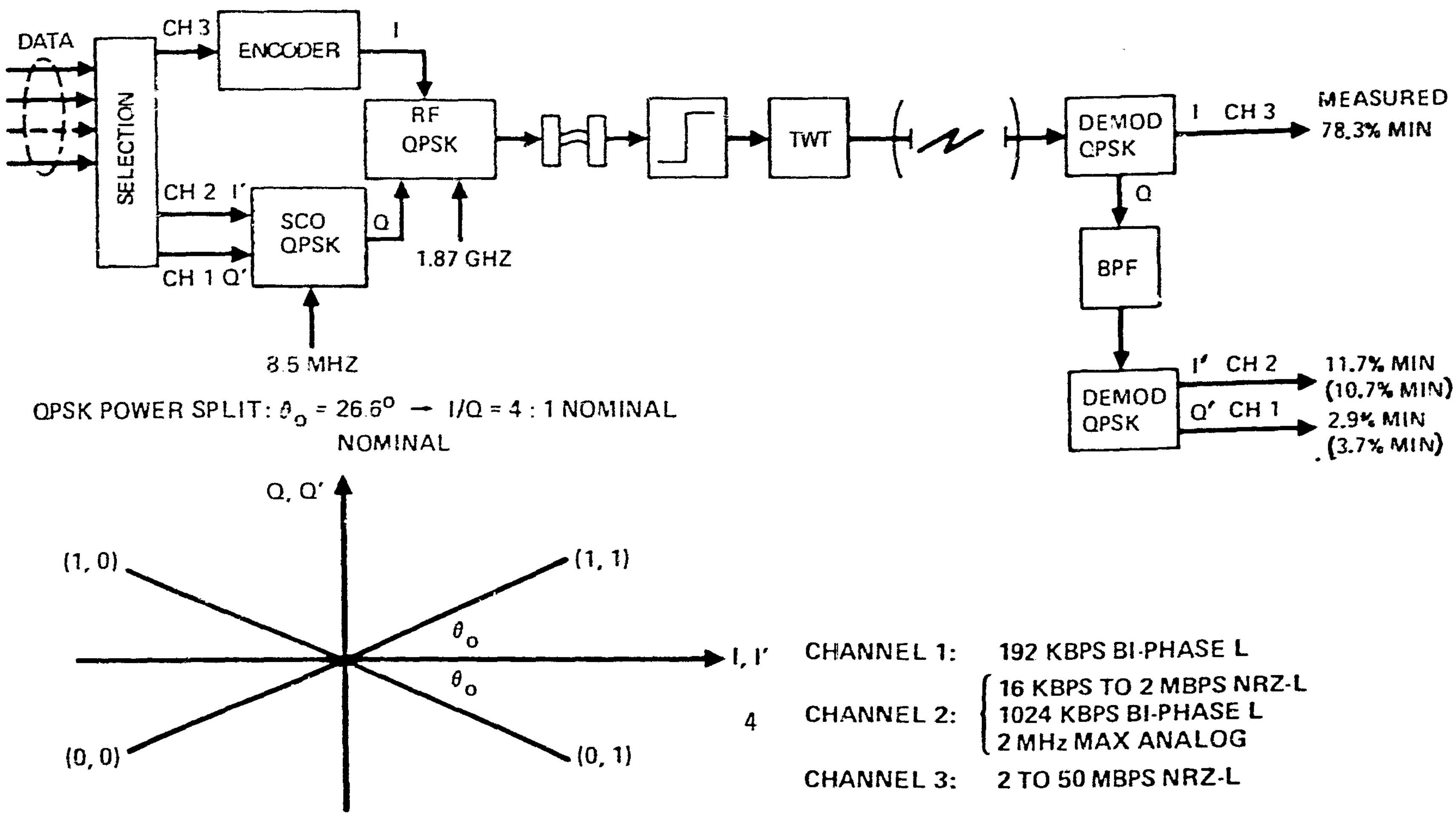


Figure 3.24. Ku-Band Mode 1 Three-Channel Modulation

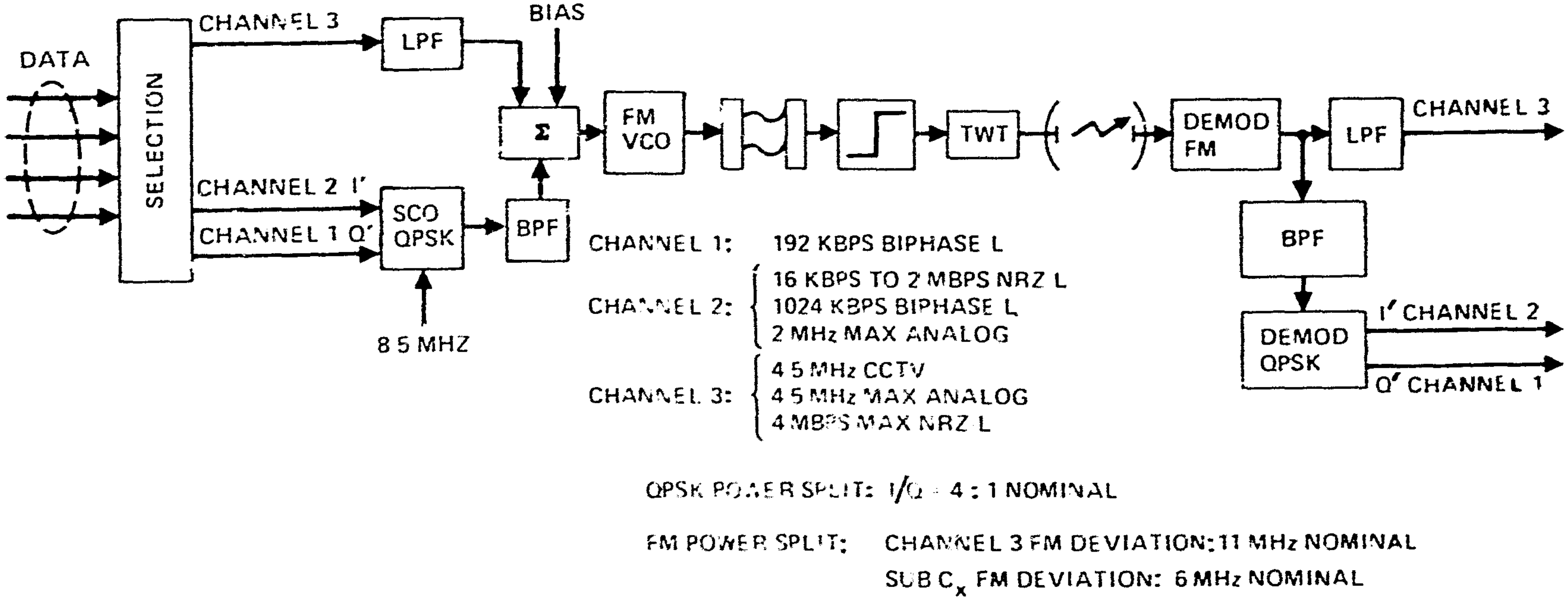


Figure 3.25. Ku-Band Mode 2 Three-Channel Modulation

The data carried on Channel 3 in Mode 1 is digital data of 2 - 50 Mbps (NRZ) which is rate 1/2-constraint length 7, convolutionally encoded by the KuSP to maintain adequate performance margin at a bit error probability of 10^{-6}. Because the output data rate of the convolutional encoder is twice the input, the input data clock must be doubled by the KuSP. The input clock is regenerated and synchronized with the input data to compensate for phase offsets and avoid sampling the data stream near transitions. A voltage-controlled oscillator (VCO) at twice the clock frequency is divided by two and compared in a phase/frequency detector. The detector output locks the VCO to twice the clock frequency over the entire frequency range of 2 - 5 MHz. Using the phase/frequency detector makes it possible to cover the 25:1 frequency range without selecting bands. To correct for asymmetry in both the clock (specified at 20% maximum) and data (specified at 25% maximum) at the KuSP input, a very symmetric clock is regenerated and used to clock the convolutional encoder. The data bits are sampled using a pulse generated every other clock pulse. The KuSP clock regeneration circuit maintains the sample pulse in the middle of the data bit. The KuSP reduces the encoder output data asymmetry to less than 10% for all input rates and for the input clock and data asymmetry up to their maximum specified values.

In Mode 2, the UQPSK-modulated 8.5 MHz subcarrier is filtered, as shown in Figure 3.25, by a bandpass filter with -3 dB points at 4.75 and 12.8 MHz. This BPF has extremely sharp low frequency skirts (-40 dB point $\geq$ 4.0 MHz) to minimize spectral spillover of the modulated subcarrier into the Channel 3 frequency band (DC-4.5 MHz). The Channel 3 input is passed through a lowpass filter with specified amplitude response of -3 dB at 5.5 MHz and -20 dB at 8.1 MHz. Differential delay is no more than 20 ns due to equalization. Although the combination of these two filters will provide excellent performance of the linear Channel 3, their selection is suboptimum for Channel 2 performance since the bandpass necessarily has a high bandwidth-to-center-frequency ratio and the lowpass filter provides only nominal skirt rejection. Note that the degradation to Channel 2 due to spectral spillover from Channel 3 depends on the type of data on Channels 2 and 3. The worst degradation occurs when Channel 2 is 2 Mbps NRZ digital data and Channel 3 has a flat spectrum greater than 8 MHz.

Table 3.16 presents the type of data present in Channel 3 for Mode 2. The data with the greatest spectral bandwidth and, hence, the most potential degradation to Channel 2 is the 4.0 Mbps NRZ digital data, but it is unlikely that Mode 2 would be used to transmit this data. More likely, Mode 1 would be used to transmit digital data at this high rate. The analog data from the PI can range from DC to 4.5 MHz but, since the PI contains a lowpass filter with effective noise bandwidth equal to 5 MHz, it can be expected that this signal will cause little degradation to Channel 2. The video interface unit (VIU) outputs a television signal with spectral bandwidth of approximately 4.5 MHz. Here again, there will be little spectral spillover into Channel 2 and there should be little degradation. The data from the API can be either digital data from 16 to 4000 kbps or analog data with spectral bandwidth from DC to 4.5 MHz. Again, high-rate digital data will probably be transmitted in Mode 1 rather than Mode 2. However, there is no filtering specified for the API; therefore, the greatest potential degradation to Channel 2 from Channel 3 occurs when Channel 2 contains 2 Mbps NRZ digital data and the output of the API has a larger spectral bandwidth than 4.5 MHz, resulting in significant spectral spillover. This worst-case degradation to Channel 2 is 3.3 dB. While the circuit margin on Channel 2 is large enough to allow this much degradation, use of the three channels for a given mission should be examined to guarantee that the correct mode is selected and that the data to be transmitted will achieve the required performance on each of the channels.

The return link output of the KuSP modulators is upconverted by the exciter of the Ku-band transmitter to 15.0034 GHz. The upconverter output is amplified to 10 mW by a four-stage GaAs FET limiting amplifier. The low AM-to-PM conversion of the limiting amplifier permits a significant relaxation of the TWT AM-to-PM conversion specification. The TWT in the transmitter amplifies the exciter output to 50 W minimum and sends it to the antenna through the diplexer/duplexer. The total return link EIRP is about 53 dBW.

4.0 ATTACHED PAYLOAD/ORBITER SIGNAL-PROCESSING AND DATA-HANDLING SYSTEM EVALUATION

Evaluation of the payload/Orbiter signal-processing and data-handling system by Axiomatix was requested in June 1979 because several interface problem areas were being experienced between the Orbiter and the IUS signal processors, and similar problems could be expected for other payloads. The Orbiter subsystems involved in the interface problems were: (1) the PDI because of conflicting requirements for rise/fall times and DATA/$\overline{DATA}$ skew, (2) the KuSP because of stringent rise/fall time requirements and (3) the PR because of data asymmetry and bit jitter requirements.

To perform the evaluation, Axiomatix reviewed the payload/Orbiter interface control document (ICD) 2-19001 and the IUS/Orbiter-unique ICD. Also, as background for the ICD requirements, Axiomatix reviewed the Orbiter subsystem specifications. In order to discover details of the interface problems, Axiomatix attended IUS/Orbiter working group meetings and specially called meetings with Boeing (the IUS system integrator). Both past and current IUS/Orbiter interface problems were reviewed to establish if similar problems might be encountered by future payloads attempting to interface with Orbiter subsystems.

4.1 Attached Payload/Orbiter Interface Problem Causes

As a result of reviewing the IUS/Orbiter interface problems with NASA, Rockwell and Boeing personnel, Axiomatix found that the interface problems occurred due to four basic causes. First, the Orbiter subsystems are in the design development stage and, therefore, interface requirements have changed as the Orbiter subsystem design matured. Second, ICD 2-19001 reflects current subsystem design specifications, but some externally derived requirements such as TDRSS user requirements are not all reflected in subsystem specifications; hence, they are not in the ICD. Third, not all Orbiter subsystem capability is presented in the payload/Orbiter ICD's. Also, ICD 2-19001 contains insufficient Orbiter subsystem detailed design data for the payload equipment designers to design the interface circuits. Finally, in some cases, payload/Orbiter ICD revision notices (PIRN's) have been made, but these changes have not appeared in the Orbiter subsystem specifications. There are several reasons why the Orbiter subsystem specifications do not get updated when the ICD's are changed. The most common reason is that there is little documentation to support differences between Orbiter subsystem specifications and payload/Orbiter ICD's. Typically, changes to the ICD interface requirements are generated by negotiation between the payload system designer and his Orbiter counterpart during meetings such as the IUS/Orbiter Working Group. PIRN's are generated and, after review, the ICD is updated; however, the next step of changing the Orbiter subsystem specification is not taken because, while the subsystem performance capability may be adequate, there is a vendor cost impact to change the specification. Not changing the Orbiter subsystem specification might be acceptable to a particular payload system designer but later, when another payload system designer encounters an interface design problem and discovers that the ICD and Orbiter subsystem specification do not agree, the negotiation must be repeated. Without adequate documentation regarding the reason for the difference between the ICD and the Orbiter subsytem specifications, much of the work involved in the first negotiation must be repeated.

After reviewing the past and current interface problem areas between the IUS and the Orbiter subsystems, it was found that the primary interface problem areas occurred in the attached telemetry processing. The Orbiter subsystems, as described in Section 3.0, have been designed for maximum flexibility and, while the Orbiter subsystem interfaces are consistent with each other, there is no standard interface. In fact, each Orbiter subsystem has different attached payload telemetry interface requirements. In some cases, such as the PDI, the interface requirements are self-conflicting so that all requirements cannot be met. To review in detail the interface requirements and potential problem areas, consider the SGLS and STDN/TDRS functional telemetry signal flows presented in Figures 4.1 and 4.2, respectively. In the attached mode, IUS telemetry comes from three sources: (1) the Signal Interface Unit (SIU), (2) the Environmental Measurement Unit (EMU) and, (3) the Wideband Data Interleaver (WBDI).

The FM vibration data consists of three sensors mounted on the spacecraft interface ring. Their analog output is signal conditioned to modulate three standard subcarriers in the EMU. The three subcarriers

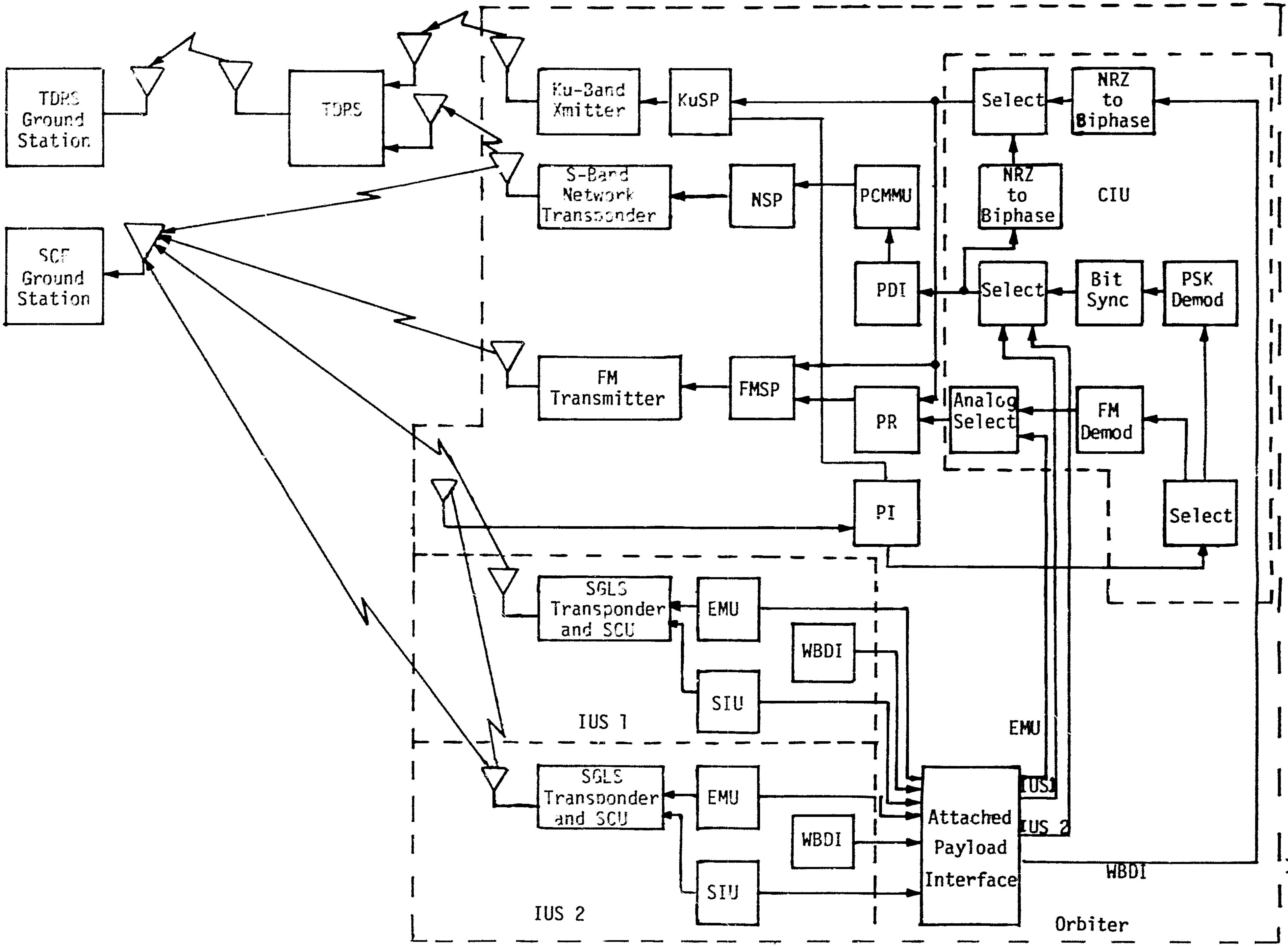


Figure 4.1. Functional SGLS Telemetry Signal Flow

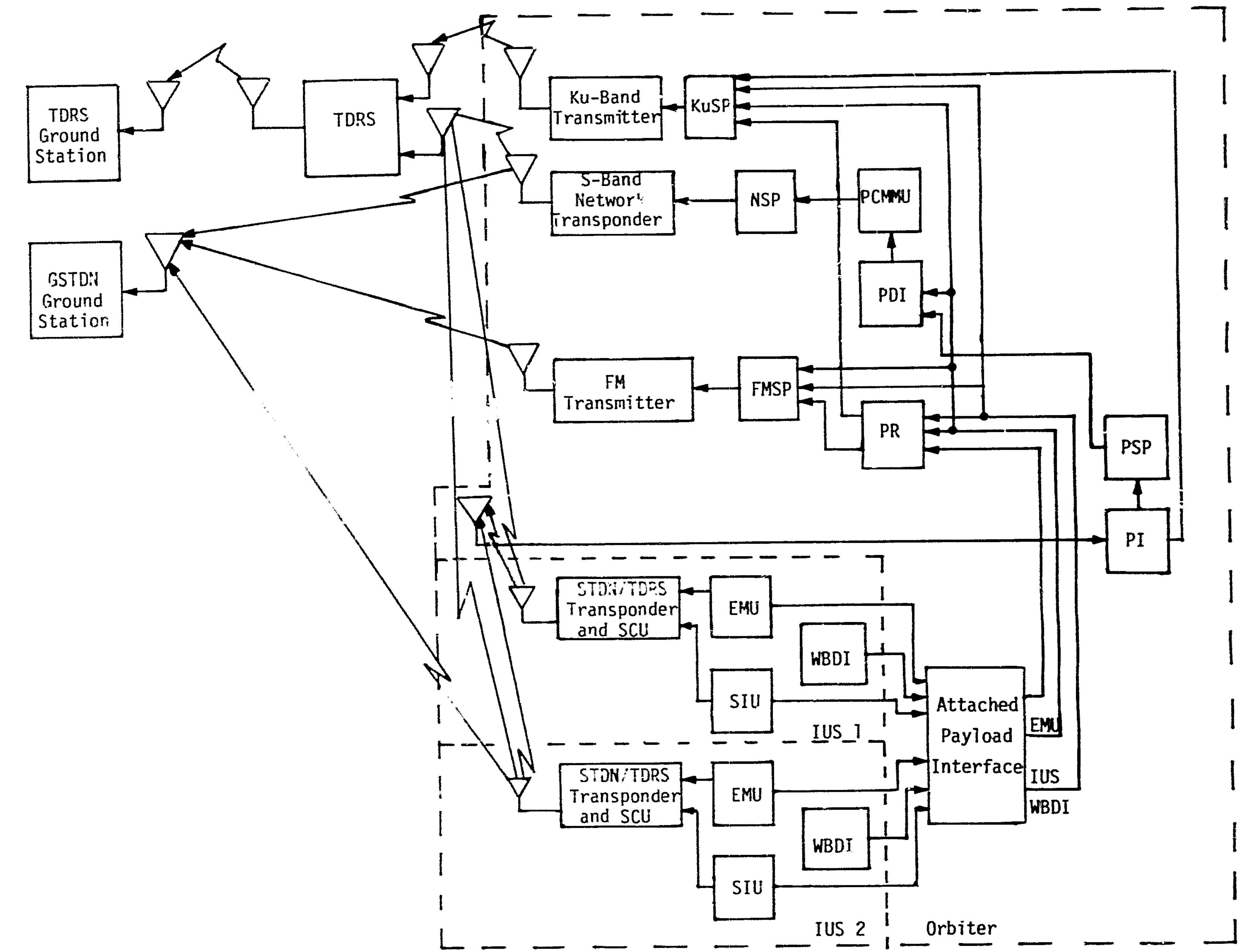


Figure 4.2. Functional STDN/TDRS Telemetry Signal Flow

are summed together and cabled directly to the attached payload interface and the transponder 1.7 MHz input port.

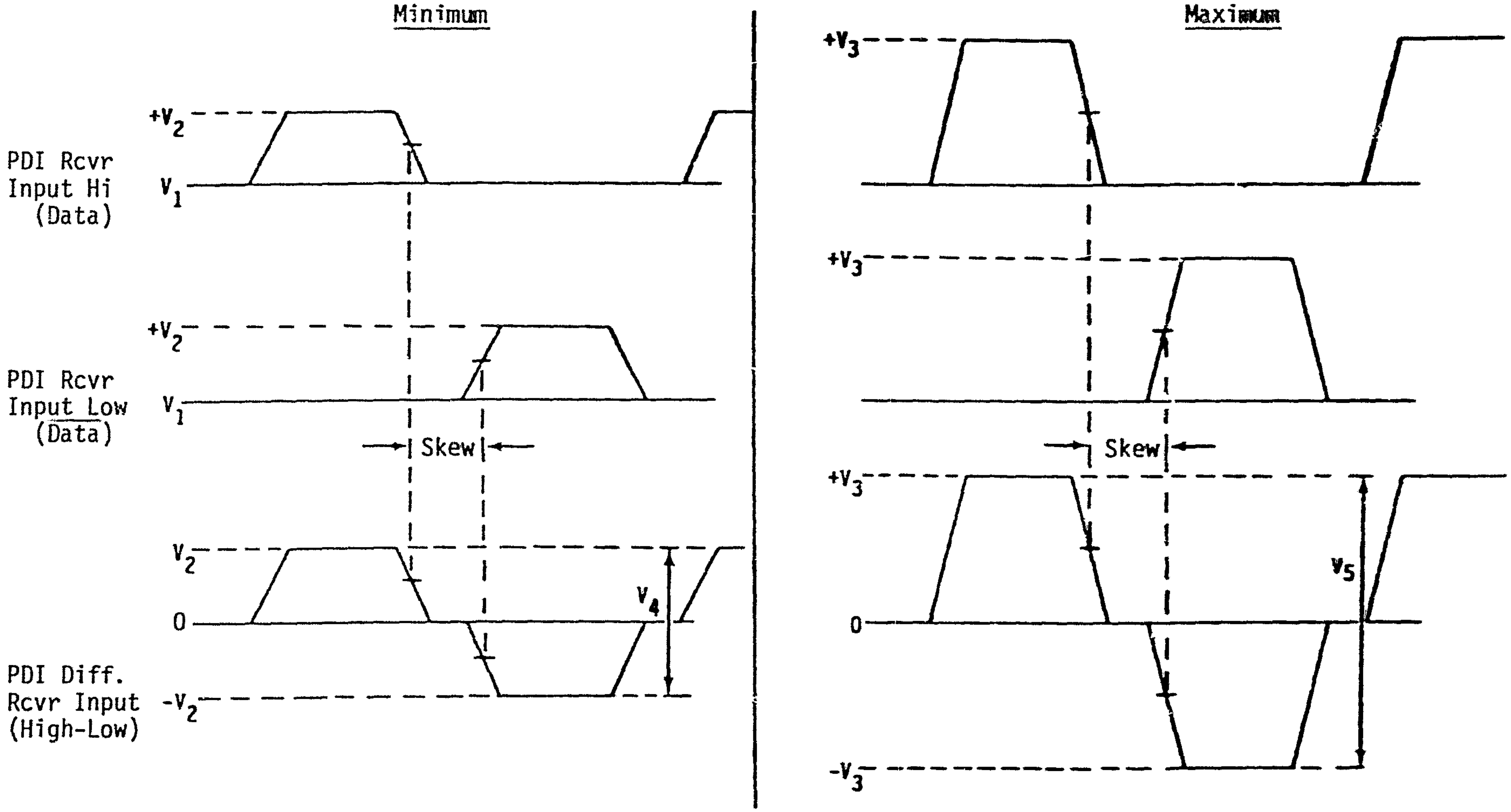
The WBDI interleaves up to six separate channels of asynchronous NRZ-L telemetry data. The WBDI output is serial NRZ-L data at a rate of 256 kbps.

As shown in Figure 4.1, the output of the attached payload interface is (1) EMU data from one of two IUS's sent to the CIU for selection to the Payload Recorder (PR), (2) WBDI data from one of two IUS's sent to the CIU for NRZ-L to biphase-L conversion and selection to the KuSP, FMSP and PR and, (3) SIU data from both IUS's (labeled IUS 1 and IUS 2 data in Figure 4.1) sent to the CIU for selection to the PDI or after NRZ-L to biphase-L conversion to the KuSP, FMSP and PR.

For the attached STDN/TDRS telemetry signal flow shown in Figure 4.2, note that the CIU is not used; therefore, the EMU, SIU and WBDI must interface directly with Orbiter subsystems. This means that the EMU must be designed to interface with the CIU or PR, that the SIU must be designed to interface with the CIU, PR, FMSP, PDI or KuSP, and that the WBDI must be designed to interface with the CIU, PR, FMSP or KuSP. Each of the Orbiter avionic subsystems have different interface requirements. While the SIU, WBDI and most of the CIU output signals are digital, the Orbiter avionic subsystem specifications tend to be more analog oriented than standard digital. In fact, the digital interfaces have conflicting requirements such as rise/fall times as defined in Figure 3.11, data skew as defined in Figures 4.3 and 4.4, data/clock skew as defined in Figure 4.5, bit jitter and bit asymmetry as defined in Figure 4.6, and signal amplitude specifications. Tables 4.1 to 4.5 present a comparison of digital signal interface parameters for each IUS/Orbiter avionic subsystem interface.

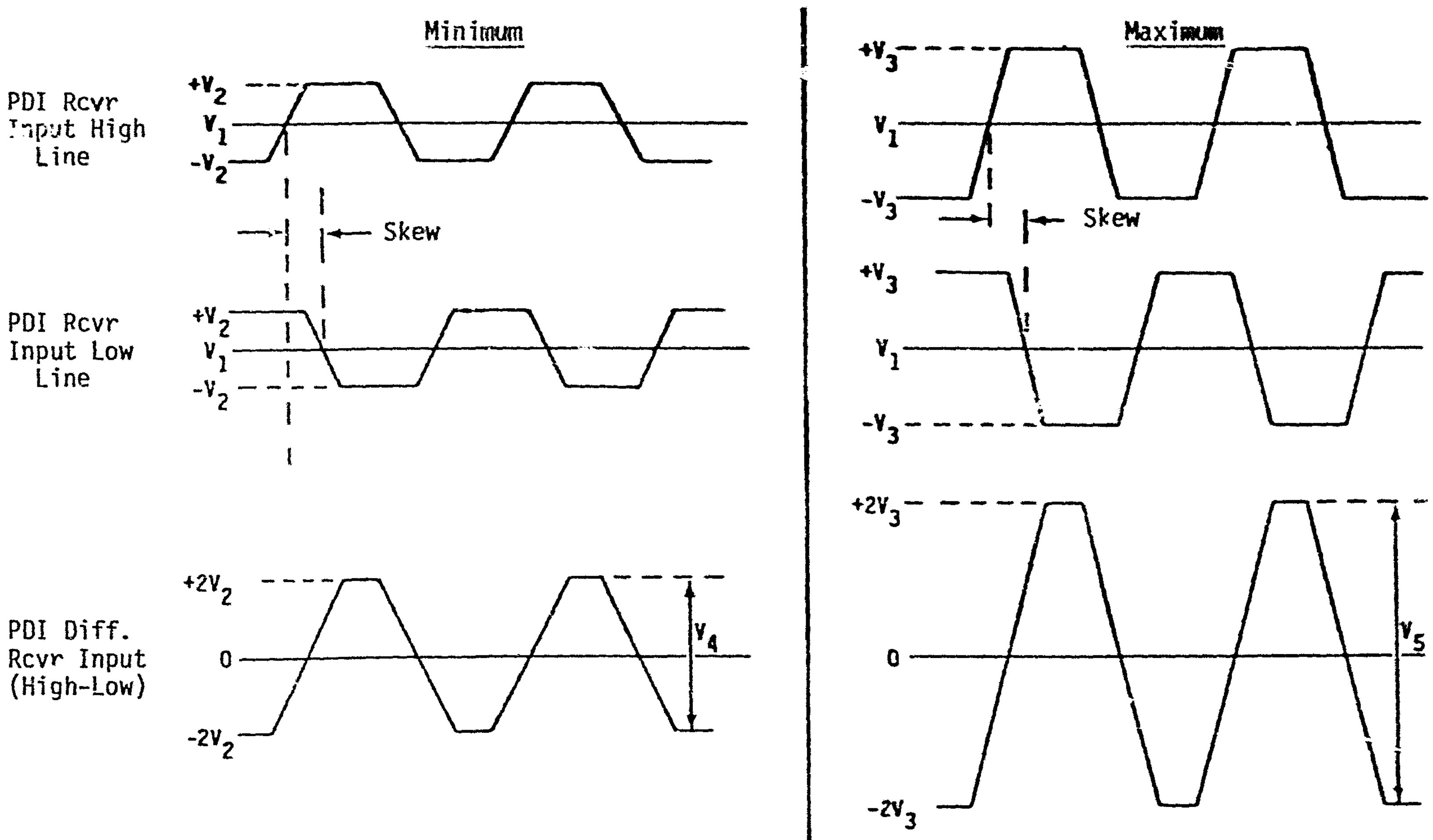
In Table 4.1, note that KuSP signal-level parameter is 2.3 to 5.0 V p-p, line-to-line, while a standard digital interface is 3 - 9 V p-p, line-to-line. Hence, special interface circuits are required by the CIU, SIU and WBDI for the KuSP interface, which has a significant cost impact.

In Table 4.2, the rise/fall times required are conflicting between various subsystems. Therefore, a separate interface circuit must be designed for each subsystem.



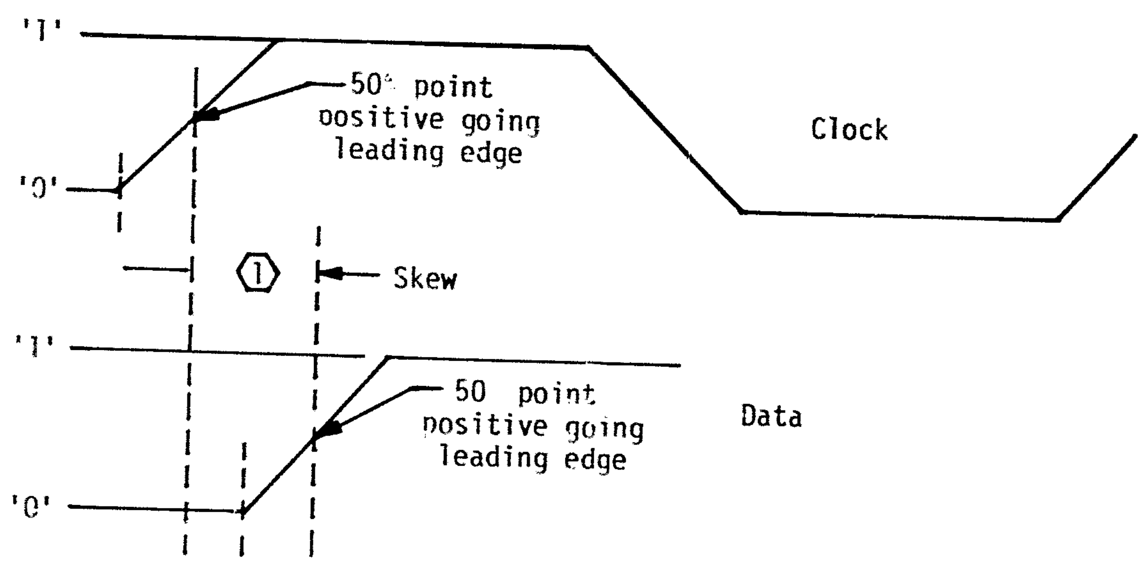
V_1 = Signal Ground
V_2 = 1.25 V line to signal ground
V_3 = 4.5 V line to signal ground
V_4 = 2.5 V p-p, line-to-line differential balanced
V_5 = 9.0 V p-p, line-to-line differential balanced
Skew = Maximum skew between 50% amplitude points of data/$\overline{data}$ signals = ±200 ns

Figure 4.3. Data/$\overline{Data}$--Differential Transmission



V_1 = Signal Ground
V_2 = 0.625 V
V_3 = 2.25 V
V_4 = 2.5 V p-p, differential line-to-line balanced
V_5 = 9.0 V p-p, differential line-to-line balanced
Skew = Maximum skew between high line signal V_1 crossover and low line signal V_1 crossover = ±200 ns

Figure 4.4. Skew with Bipolar Lines--Differential Transmission



(1) Maximum of 10 µs or ±5.0% of the clock period

Figure 4.5. Data/Clock

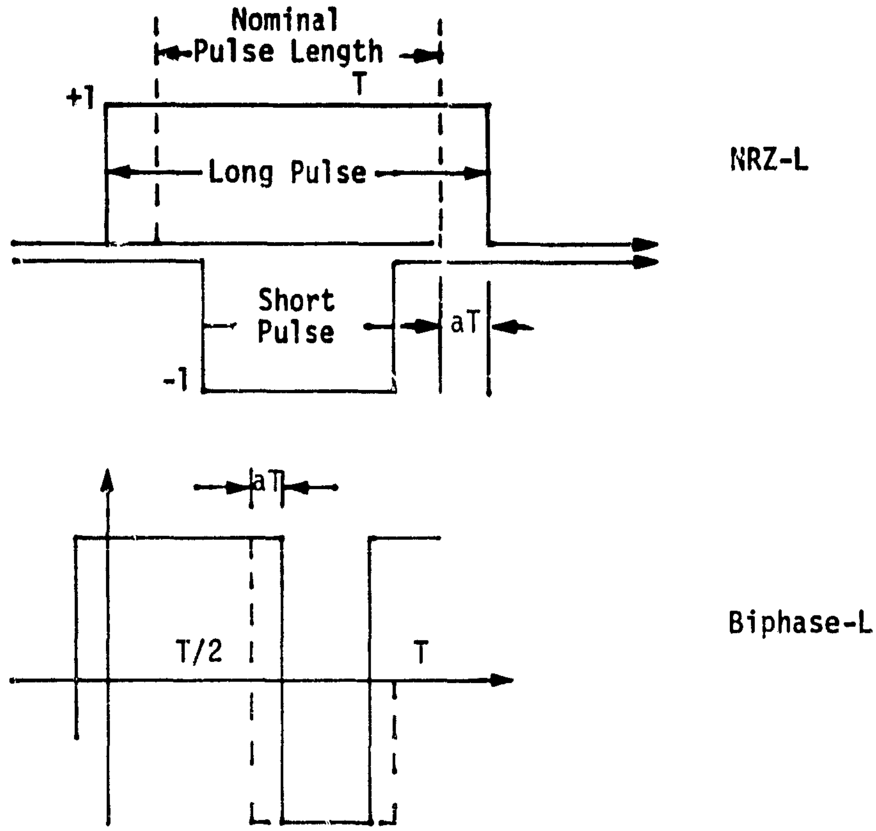


Figure 4.6. Data Asymmetry

Table 4.1. IUS/Orbiter Digital Interface Parameters

Parameter	Payload Recorder	Payload Data Interleaver	FM Signal Processor	Ku-Band Signal Processor
Signal Level	3.7-9 V p-p, line-to-line	2-12 V p-p, line-to-line (2.5-9.[illegible] V open PIRN)	5.0 ± 0.5 V p-p, line-to-line (Wideband) 1.0 ± 0.5 V p-p, line-to-line (DOD)	2.3-5.0 V p-p, line-to-line
RMS SNR	-	-	45 dB RMS to RMS noise DC to 2 MHz	35 dB minimum
Data Rates	25.5 kbps to 1.024 Mbps	10 bps to 64 kbps	200 bps - 5 Mbps, NRZ-L 200 bps - 2 Mbps, Biphase-L 250 bps - 256 kbps (DOD)	16 kbps - 2 Mbps NRZ-L,M,S 16 kbps to 1.024 Mbps Biphase-L,M,S 2-50 Mbps NRZ-L,M,S 16 kbps-4 Mbps, NRZ-L,M,S
Signal Code	Biphase-L	NRZ-L,M,S Biphase-L,M,S	NRZ-L Biphase-L	NRZ-L,M,S Biphase-L,M,S

Table 4.2. IUS/Orbiter Digital Interface Parameters

Parameter	Payload Recorder	Payload Data Interleaver	FM Signal Processor	Ku-Band Signal Processor
Rise and Fall Times	10% of bit duration	Maximum: 5 μs or 10% of bit duration, whichever is less Minimum: 100 ns	Maximum: 50 ns (Wideband) 100 ns (DOD)	5% or 50 ns, whichever is less (KuSP specification) ICD: 40 ns to 1 Mbps 20 ns 1-2 Mbps 5 ns 2-4 Mbps 10% of bit duration 2-50 Mbps
DATA/$\overline{\text{DATA}}$ Skew	-	±200 ns	-	-
Data Asymmetry	Included in bit jitter specification	-	- (±3% TDRSS user constraint; JSC recommends ±10%)	-
Waveform Distortion	-	Overshoot/undershoot less than 20% of signal level	-	-

Table 4.3. IUS/Orbiter Digital Interface Parameters

Parameter	Payload Recorder	Payload Data Interleaver	FM Signal Processor	Ku-Band Signal Processor
Frequency Jitter	-	-	-	±0.01% RMS of data rate at 0.01% RMS of the data rate
Bit Jitter	<2% of bit duration (p-p) (Includes data asymmetry)	-	-	- ($\leq$0.1% TDRSS user constraint)
Bit Rate Accuracy	-	±2%	-	-
Bit Rate Stability	-	1 part in 10^5 (60 s average)	-	0.01% (long term)
Clock/Data Skew	-	5% of clock period or 10 μs, whichever is less	-	-

Table 4.4. IUS/Orbiter Digital Interface Parameters

Parameter	Payload Recorder	Payload Data Interleaver	FM Signal Processor	Ku-Band Signal Processor
Clock Duty Cycle	-	50.0 ± 5%	-	-
Load Impedance	75 ± 10% ohms	Min: 74 ohms Max: 91 ohms	75 ± 10% ohms	75 ± 5 ohms 50 ± 10% ohms (2 - 50 Mbps)
Cable Impedance @ 1 MHz	75 ± 5 ohms,	75 ± 5 ohms, TSP 2900 pf capacitance*	75 ± 5 ohms, TSP	75 ± 5 ohms, TSP 50 ohms (RF 142BU (2 - 50 Mbps)
Source Impedance	TTL-compatible (TI 5514 IR equivalent)	-	75 ± 10% ohms	-
Noise Immunity	-	150 Mv p-p** DC to 100 kHz	-	-
Common Mode Voltage (Line-to-Signal Ground)	±15 V	±3 V	-	±10 V

*18-23 pf per foot of cable

**100 Mv p-p maximum EMI, 50 Mv p-p from payload

Table 4.5. Attached Payload/Orbiter Analog Interface Parameters

Parameter	Payload Recorder	FM Signal Processor	Ku-Band Signal Processor
Signal Level	1 V RMS ± 6 dB	1 V ± 10% peak-to-peak line-to-line	2 V RMS peak-to-peak line-to-line 7 V maximum
Bandwidth	1.9 kHz - 1.6 MHz	300 Hz - 4 MHz	DC to 4.5 MHz
Signal/Noise			45 dB RMS to RMS noise (minimum)
Coupling Type	Differential	Balanced differential	Balanced differential Direct coupled
Load Impedance	75 ± 5% Ohms	75 ± 10% Ohms	75 ± 5 Ohms
Cable Impedance	75 ± 5 Ohms, TSP	75 ± 5 Ohms, TSP	75 ± 5 Ohms, TSP
Source Impedance	Capable of driving 150 feet of cable	75 ± 10% Ohms	75 ± 5 Ohms
Common Mode Rejection	±15 V	±1 V DC to 2 MHz	±15 V DC to 10 kHz

In Table 4.3, the PR specification of less than 2% of the bit duration includes data asymmetry, which makes this a difficult specification for the CIU, SIU and WBDI to meet. Therefore, the interface design needs to be analyzed further to determine if this specification can be met.

Finally, the CIU and SIU interface with the PDI is a special problem area which is currently being worked by Boeing and the IUS/Orbiter Working Group. The minimum rise and fall time specifications shown in Table 4.2 require waveform filtering to slow down the maximum rise and fall time of the interface device. However, waveform filtering causes data skew.

Boeing's worst-case analysis shows that the original PDI specification of 100 ns minimum cannot be met simultaneously with the ±200 ns DATA/$\overline{\text{DATA}}$ skew specification. Preliminary Interface Revision Notice (PIRN) BAC026A resulting from the Orbiter/IUS Avionics Working Group Meeting of July 21-31, 1979 changes the PDI minimum rise and fall time specification to 32 ns. If PRIN BAC026A changes the PDI specification, Boeing feels that it is possible to meet both the specifications for rise and fall times and DATA/$\overline{\text{DATA}}$ skew.

The analog interface parameters for the attached IUS and the Orbiter subsystems are given in Table 4.5. There are three areas of discrepancy: (1) the 2V RMS p-p signal level requirement by the KuSP, (2) the signal/noise requirement for the KuSP, and (3) the small common mode rejection provided by the FMSP. The first and third discrepancies are the most serious because a special interface circuit must be designed to meet the requirement. The signal/noise requirement is established to guarantee performance through KuSP FM processing. In fact, similar signal/noise requirements should be established for the PR and FMSP.

4.2 Attached Payload/Orbiter Interface Problem Resolution and Recommendations

The most desirable problem resolution to interfacing with the Orbiter subsystems from the payload point of view would be for NASA/Rockwell to adopt standard digital and analog interfaces; however, the Orbiter subsystems are nearing completion of the development cycle. In fact, most Orbiter subsystems are in production. Therefore, standardizing the Orbiter subsystem interfaces would require the greatest immediate cost to the Space Shuttle program.

The next most desirable interface problem resolution from the payload point of view would be to design an attached payload interface unit that provides a standard interface with the payloads but also provides the required interface with each of the Orbiter subsystems. For the DOD missions, the CIU accomplishes the tasks required for the attached payload interface unit. Therefore, a simplified CIU with its standard payload interface could be used with NASA and commercial payloads. This approach would be less costly than redesigning the subsystems but would still require development of additional hardware, and space would have to be found in which to locate the new unit.

Another approach to resolving Orbiter subsystem interface problems with future payloads is to design interface circuits that could be incorporated into each payload design. With this approach, standard interface circuits would be available to provide the interface between the payload and a particular Orbiter subsystem. Thus, a payload would have only to incorporate the interface circuits corresponding to the Orbiter subsystems required for the mission. Once these standard interface units were designed, they could be available from vendors similar to the availability of the MIA's for interfacing with the MDM. The undesirable aspect of this approach is the lack of flexibility for the payload designer. That is, standard interface circuits might not exist in a form that could be packaged in the payload in an economical way. Also, as technological advances are made, a payload designer might want to incorporate these advances into the interface design in order to implement the best system in terms of cost, power, weight and complexity.

Axiomatix recommends that a detailed overall system study be performed to investigate the methods of designing interface circuitry to meet all Orbiter and TDRSS constraints. The output of this study should be a "Designers Handbook" that identifies the interface requirements of each Orbiter subsystem and shows in detail how to design the payload interface circuitry. This "Designers Handbook" could made an appendix to JSC-14241, which delineates the capabilities of the Orbiter subsystems. Axiomatix has provided two payload design guidance handbooks for SPIDPO in the past: the first was "Frequency Selection Guidelines" for payloads (under Contract NAS 9-15604A) so that a payload designer could optimize his choice of RF transmitter and receiver frequencies when operating with the Orbiter in the detached mode; the second was a "Communication Link Design Handbook" (under Contract NAS 9-15604B) to provide the payload communication performance through the Orbiter when the payload is in the detached mode.

The first task of a detailed overall payload/Orbiter interface system study should be to identify all payload user constraints. Some of these user constraints are derived from Orbiter subsystem requirements; however, other user constraints are derived from TDRSS requirements. These requirements should be reflected in the payload user constraints because, in the modes where the Orbiter only passes the payload data through the Ku-band communication system over the TDRSS, the payload communication parameters determine whether or not the TDRSS requirements are met, not the Orbiter subsystems.

The second task of the system study should be to assess the performance degradation for varying user constraint compliance. This information would allow the payload communication system designer to trade off performance degradation as a function of cost, weight, power and complexity of the payload communication system and interface circuitry. Axiomatix is currently analyzing the performance degradation for varying compliance of the Orbiter subsystems to TDRSS constraints under Contract NAS 9-15240.

5.0 DETACHED PAYLOAD INTERFACE CONTROL DOCUMENT REVISIONS

Early in 1979, Axiomatix undertook a rewrite of the then-existing Section 8.3, "Detached Payloads," of ICD 2-19001. A first revision (referred to in this report as Revision 1) was dated May 3, 1979 and transmitted to NASA/JSC and Rockwell for further action. This revision is included as Appendix II.

In October 1979, Rockwell issued its rough draft version of the subject Section 8.3 [Interface Revision Notice (IRN) SD-152A, dated October 3, 1979, included as Appendix III]. Rockwell's IRN was almost identically patterned after Axiomatix's Revision 1 as to paragraph numbering and wording. The largest superficial difference was that Rockwell chose to delete all performance numbers from the text of the paragraphs and place the numbers in table form in a format similar to that used for attached payloads.

Axiomatix was requested by JSC in late October to review the Rockwell IRN SD-152A draft. However, as the PI PDR was to be held in early November, Axiomatix waited to ascertain the changes made by TRW to the PI's performance before attempting the RI IRN assessment. The PDR disclosed some broad and significant changes to the PI operation which had substantial impact on the PI's interface with payloads. In addition, since the writing of Revision 1, many changes had been made in other payload supporting subsystems, notably, the PSP and CIU. As a result, Axiomatix felt the need to revise its own document before attempting to assess Rockwell's IRN SD-152A. This was accomplished during December 1979 and appears as Revision 2, dated January 2, 1980, and is included as Appendix IV.

The most significant and extensive Revision 2 changes appear in the paragraphs dealing with the PI (8.3.1.1 and divisions), SGLS Telemetry Signals (8.3.3.2 and divisions), and Nonstandard Payload Requirements (8.34 and divisions). Generally, however, upgrades have been made throughout the document, especially in terms of performance values.

Many of the intrinsic modifications TRW made to the PI which resulted in performance and interface changes have been reviewed in the final report to Contract NAS 9-15794, "Shuttle Orbiter S-Band Payload Communications Equipment Design Evaluation." Principally, these changes affected PI receiver carrier acquisition, carrier tracking, false lock, data signal output characteristics, and PI transmitter sweep. With respect to the PI/PSP combination, it has become possible to make high confidence calculations as to minimum payload EIRP requirements. Appendix V outlines the formulations.

The current design of the CIU has involved a significant reduction of the earlier proposed telemetry processing capabilities. Only one PSK data rate (16 kbps) remains on the 1.24 MHz subcarrier. The 1.7 MHz subcarrier is for FM/FM type signals only, utilizing but three simultaneous minor subcarriers.

Finally, the PI changes have led to some essential revisions of the nonstandard payloads modification restrictions. An outline of the philosophical changes is presented in Appendix VI.

Following Axiomatix's activity to produce Revision 2, the Rockwell IRN SD-152A was reviewed. As was stated previously, Rockwell adopted Axiomatix's Revision 1 but lifted the performance numbers out of the paragraphs proper and placed them in tables. They did not, however, follow this philosophy 100%; it was not done with respect to the Specific Non-Standard Modulation Restrictions (8.3.4.2.2).

When Axiomatix prepared Revision 1, each paragraph was written so that it was essentially self-contained as to the subject specification including all necessary numbers and qualifications. Tables were used to summarize the most important parameters/characteristics, but not all of the adjunct specifications found in the subparagraphs. There are, in fact, certain requirements which are difficult to express solely in table form without confusion resulting.

The RI approach in IRN SD-152A requires the reader to assimilate the paragraph to obtain the sense of the specification, then refer to one or more tables to gain the letter (i.e., numbers) of the specification. This requires both time and cross-page correlation which can lead to errors. Additionally, it often relegates the need or sense of the paragraph to mediocrity. As an example, consider paragraph 8.3.1.1.2.8.1 which, in Revision 1, stated:

> "For the purpose of acquisition, the receiver is swept ±85 kHz from the nominal receive frequency at a maximum rate of 10 kHz/sec."

Rockwell changed this to read:

> "For the purpose of acquisition, the receiver is swept from the nominal receive frequency..."

and there is no reference in the paragraph to the table containing the numbers of conditions. The "85 kHz" number appears in Table 8.3.1.1.2-1 (19 pages removed) as "±80 kHz," and the "10 kHz/sec" number appears nowhere.

A second general problem Axiomatix found with IRN SD-152A is that, with respect to Revision 1, many numbers were changed without apparent justification. Some numbers were upgraded correctly to reflect design or performance changes. Others, however, were changed to values that do not appear in any official RI or TRW document. Some numbers specified by Axiomatix as "TBS" were inserted but are in error in IRN SD-152A. As a result, it was essential that every number appearing in Rockwell's document be carefully reviewed against current source documents.

In Axiomatix's version, reference of receiver noise figure, transmitter output power, etc., was made to the PI RF input/output common port. (Revision 2 has made this quite explicit.) Rockwell, on the other hand, has referenced certain quantities to the RF input/output common port (e.g., noise figure) and others to the Orbiter antenna interface (e.g., the receiver carrier threshold levels, although IRN SD-152A does not specifically state that this has been done). Not stated is the attenuation factor between the antenna interface and the PI common port. As a result, the specifications cannot be used together to calculate, say, threshold carrier-to-noise spectral density power ratios. It is essential that one reference point be established and used throughout the ICD.

On January 21-23, 1980, Axiomatix, Rockwell and NASA personnel met at Rockwell to update and correct IRN SD-152A. It was decided that ICD 2-19001 had been written with very little narrative and that most of the critical interface information was contained in tables. While IRN SD-152A had indeed put much of the information into tables, much of the narrative was left which did not add anything to the overall section on detached payloads. Therefore, during the meeting, the narrative was reduced to an introduction, a delineation of interfaces for standard and nonstandard payloads, telemetry modulation criteria for nonstandard payloads, bent-pipe modes for detached payloads, and Ku-band rendezvous radar interfaces. Each of these sections of the narrative is very brief and is used primarily to direct the payload system designer to the proper tables containing the detailed requirements and capabilities. The narrative section on the telemetry modulation criteria for nonstandard payloads is more detailed because delineating the allowed characteristics of the nonstandard modulation is general in nature and more easily expressed as equations than entries in a table.

Also, at the January 20-23, 1980 meeting, all the critical interface data in the tables were updated to account for modifications made to the PI and PSP as a result of their PDR's for changes to the SGLS telemetry signals and for the current CIU design. These updates to the interface tables agreed with Axiomatix's Revision 2. In terms of referencing the PI receiver noise figure, PI transmitter output power, etc. to the PI RF input/output common port as in the Axiomatix documents, it was agreed during the meeting that the payload communication interface requirements with the Orbiter are Orbiter EIRP for commands and required incident flux density at the Orbiter for telemetry. Therefore, all Orbiter communication parameters were written in terms of Orbiter EIRP and incident flux density at the Orbiter. In this way, antenna gains, transmission losses, transmitter power, receiver noise figure, etc., do not have to be spelled out in the ICD. Rockwell incorporated all these changes into the IRN and issued IRN SD-152B on February 28, 1980. There were some small changes made after the initial review of IRN SD-152B and the marked-up IRN was reissued on March 7, 1980 as IRN SD-152C, which is included as Appendix VII.

Two changes to the PI parameters listed in IRN SD-152C have occurred as a result of the PI CDR held June 24-26, 1980. The first one is to carrier frequency stability listed in Table 8.3.1.1-1 of IRN SD-152C (Appendix VII). The carrier frequency stability specification was changed at the PI CDR to 0.001 rather than 0.0012 shown in IRN SD-152C. The second change is to the PI receiver output frequency response listed in Table 8.3.1.2-1 of IRN SD-152C. The output frequency response has an upper 3 dB cutoff of 4.3 MHz (minimum) to 5.5 MHz (maximum) rather than the 4.5 MHz shown in IRN SD-152C.

A final areas where IRN SD-152C needs correction is to the flux density required at the Orbiter. The flux density number listed in Table 8.3.1.2-1 of IRN SD-152C is incorrect by approximately 10^6. RI made a correction to these flux density numbers on April 7, 1980. The RI updated flux density requirements are given in Table 5.1; however, the antenna gain used to compute the flux density requirements appeared to NASA and Axiomatix to be too large. Therefore, the calculation for flux density is reviewed here and the recommended changes are made.

The incident flux density D_f is given by

$$D_f = \frac{P_{rec}}{A_e} \tag{1}$$

where P_{rec} is the received power (in watts) and A_e is the effective antenna aperture (in square meters). The value of A_e can be computed from

$$A_e = \frac{\lambda^2 G_r}{4\pi} \tag{2}$$

where λ^2 is the transmitted wavelength (in meters) and G_r is the receiving antenna gain on the Orbiter. The value of λ (in meters) with the transmitted frequency f_t given in megahertz is

$$\lambda = \frac{300}{f_t} \tag{3}$$

For 2200 MHz, $\lambda = 0.1364$ meters. The minimum specified G_r is 2.5 dB and the maximum specified G_r is 6.0 dB, or

$$\begin{aligned} G_r(\text{ratio}) &= 1.778 \text{ (minimum} \\ G_r(\text{ratio}) &= 3.981 \text{ (maximum)} \end{aligned} \tag{4}$$

The minimum specified G_r should be used to calculate the minimum values of the flux density requirements, but the maximum G_r should be used for the maximum in-lock tracking and maximum without damage.

Table 5.1. Updated Flux Density Requirements at the Orbiter Interface

Flux Density Requirement	Flux Density	Units	Comments
Acquisition	1.71×10^{-12}	watts/square meter	80° Antenna cone at 2200 MHz
Tracking			
Threshold	6.81×10^{-13}	watts/square meter	
In-Lock: (min)	4.29×10^{-12}	watts/square meter	
(max)	1.71×10^{-2}(1)	watts/square meter	
Maximum Level Without Damage	4.30×10^{3}	watts/square meter	

Note (1): Not specified to lock or track above this level

From (2), (3) and (4),

$$A_e = \frac{(0.1364)^2(1.778)}{4\pi} = 2.632 \times 10^{-3} \text{ (minimum)}$$

$$= \frac{(0.1364)^2(3.981)}{4\pi} = 5.894 \times 10^{-3} \text{ (maximum)} \qquad (5)$$

To relate the required flux density to the PI specifications, Table 5.2 presents the PI specifications for each performance parameter. The in-lock tracking parameter is the received power required for the PI to remain in lock for one hour on the average. The maximum in-lock tracking parameters is due to saturation of the IF amplifiers in the PI. The receive circuit loss is due to cables and connectors between the antenna and the PI. By adding the receive circuit loss to the PI specification, the required received power P_{rec} at the antenna can be determined. Using P_{rec} from Table 5.2, (1) and (5), the required flux density for each performance parameter can be calculated as shown in Table 5.3. The values in Table 5.3 are those recommended by Axiomatix for inclusion in ICD 2-19001 and should be used to modify IRN SD-152C.

C-2

Table 5.2. Required Received Power to Meet PI Specifications

Performance	PI Requirement in dBW (dBm) (1)	Receive Circuit Loss in dB (2)	Required Received Power	
			P_{rec} in dBW	P_{rec} in Watts
Acquisition	-150(-120)	9.8	-140.2	9.55×10^{-15}
Tracking				
Threshold	-154(-124)	9.8	-144.2	3.80×10^{-15}
In-Lock: (min)	-146(-116)	9.8	-136.2	2.40×10^{-14}
(max)	-27 (+3)	6.0	- 21.0	7.98×10^{-3}
Maximum without Damage	+6 (+36)	6.0	12.0	15.8

Notes: (1) PI requirement as of the PI CDR, June 24-26, 1980

(2) Receive circuit losses are Rockwell estimates as of December 1980.

Table 5.3. Recommended Flux Density Requirements at the Orbiter Interface

Flux Density Requirement	Flux Density	Units	Comments
Acquisition	3.63×10^{-12}	watts/square meter	80° antenna cone at 2200 MHz (2)
Tracking			
Threshold	1.44×10^{-12}	watts/square meter	
In-Lock: (min)	9.12×10^{-12}	watts/square meter	
(max)	1.35 (1,3)	watts/square meter	
Maximum Level without Damage	2.68×10^{3} (3)	watts/square meter	

Notes: (1) Not specified to lock or track above this level
(2) The maximum specified receiving antenna gain is used to calculate the flux density requirements
(3) The minimum specified circuit loss is used to calculate the flux density requirements

LIST OF APPENDICES

N81-20160

D3

APPENDIX I

PAYLOAD/ORBITER SIGNAL PROCESSING AND DATA HANDLING SYSTEM EVALUATION PRESENTATION

JULY 26, 1979

Axiomatix

PAYLOAD/ORBITER SIGNAL PROCESSING AND DATA HANDLING SYSTEM EVALUATION

GAYLORD K. HUTH

AXIOMATIX

PAYLOAD SIGNAL PROCESSING/DATA HANDLING EVALUATION PROBLEM STATEMENT

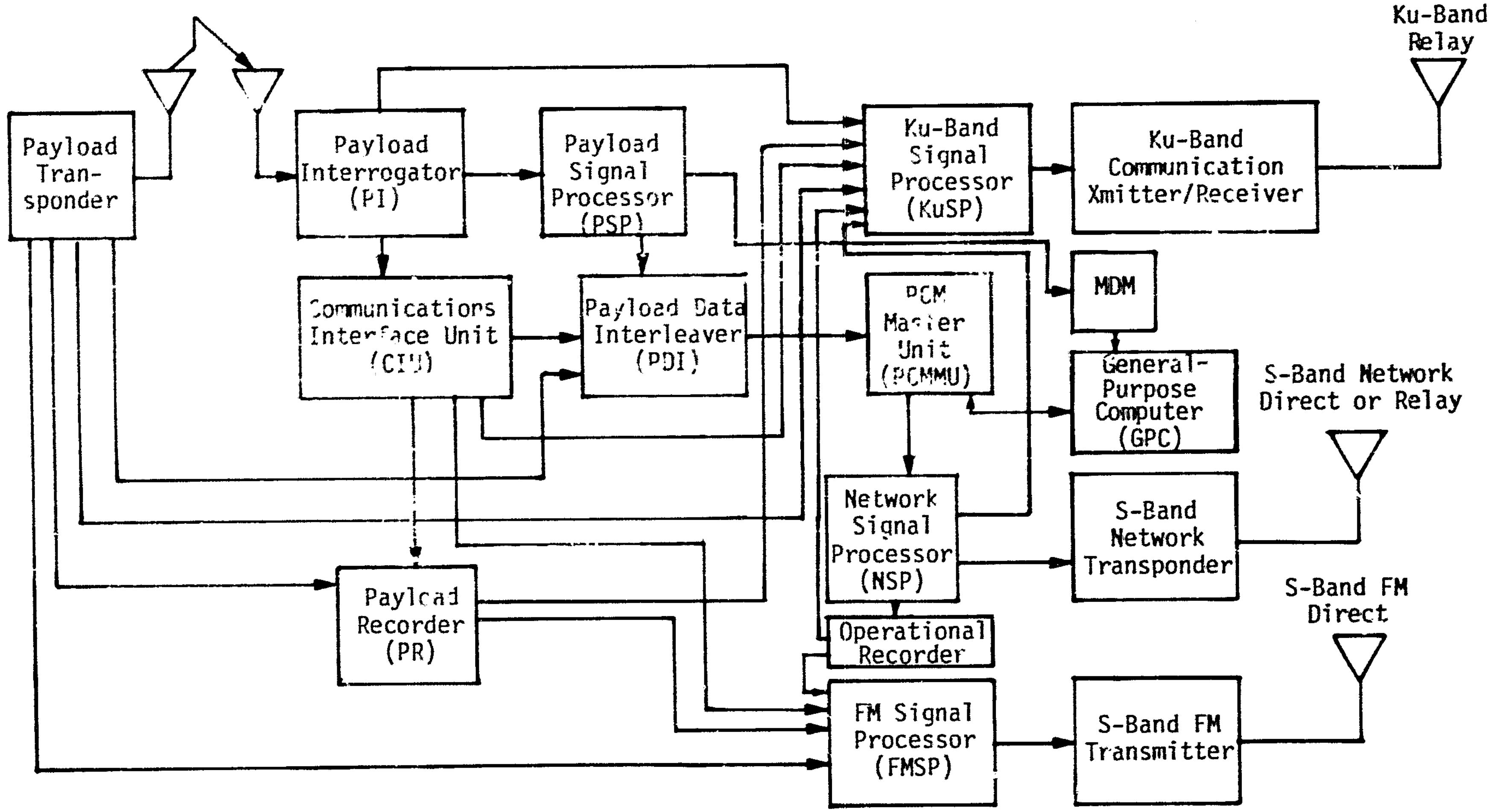
- IUS CURRENTLY CANNOT INTERFACE WITH ORBITER COMMUNICATIONS AND DATA SUBSYSTEMS
  - PAYLOAD DATA INTERLEAVER (RISE/FALL TIME - DATA/$\overline{\text{DATA}}$ SKEW REQUIREMENTS)*
  - KU-BAND SIGNAL PROCESSOR (RISE/FALL TIME REQUIREMENTS)
  - PAYLOAD RECORDER (DATA ASYMMETRY AND BIT JITTER REQUIREMENTS)

- OTHER PAYLOADS WILL EXPERIENCE SIMILAR INTERFACE PROBLEMS

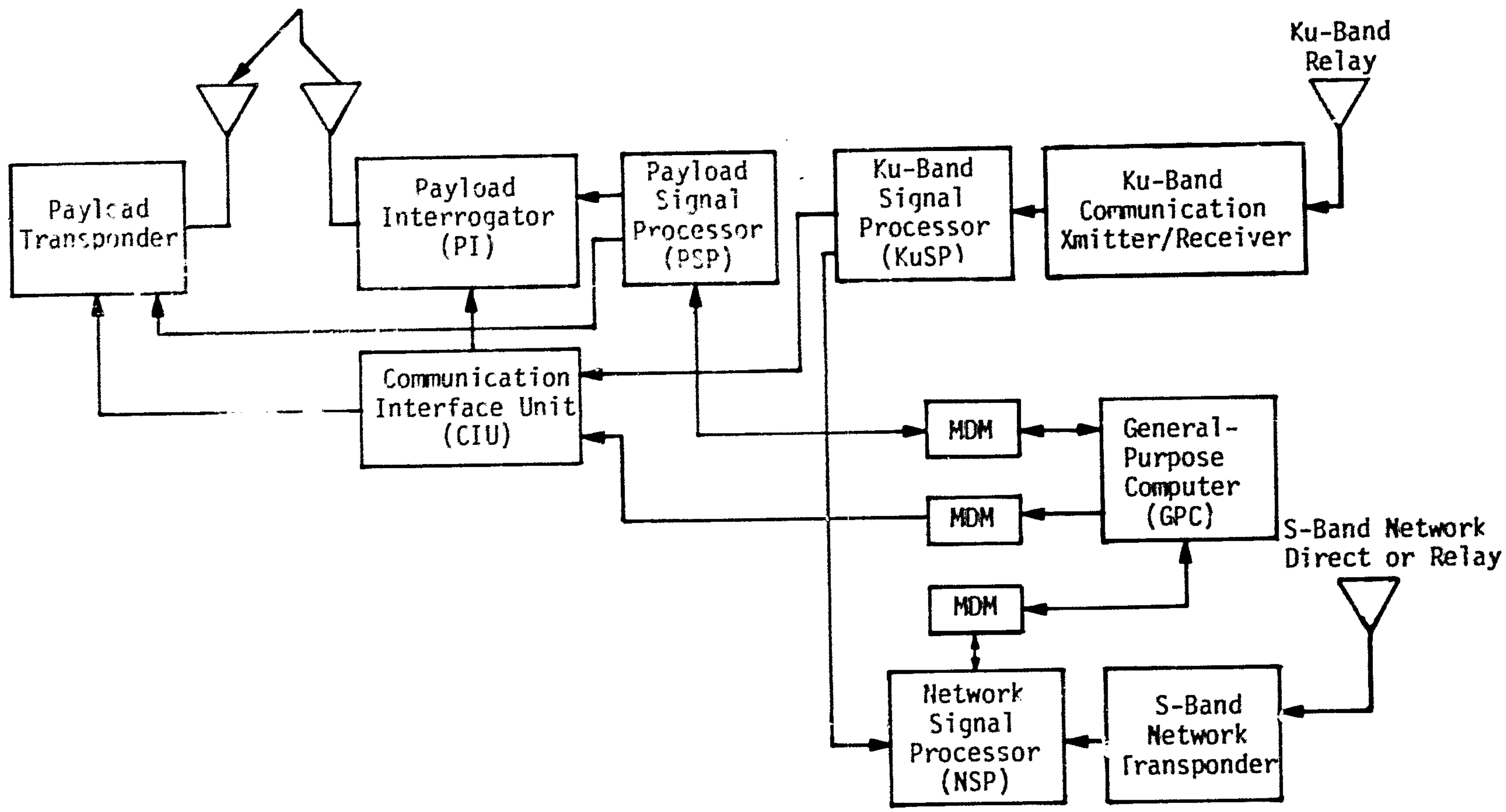
---

*ORBITER HAS VERY STRINGENT REQUIREMENTS FOR EMI

PAYLOAD/ORBITER FUNCTIONAL TELEMETRY SIGNAL FLOW



PAYLOAD/ORBITER FUNCTIONAL COMMAND SIGNAL FLOW



PAYLOAD SIGNAL PROCESSING/DATA HANDLING
EVALUATION OBJECTIVES

Axiomatix

- TASKED BY PROGRAM OFFICE/AVIONIC SYSTEM DIVISION (EH2) TO PERFORM SHORT EVALUATION STUDY (SIX WEEKS)
  - REVIEW PAYLOAD/ORBITER CORE ICD AND IUS/ORBITER-UNIQUE ICD
  - REVIEW ORBITER SUBSYSTEM SPECIFICATIONS
  - REVIEW PROBLEM AREAS ADDRESSED BY IUS/ORBITER WORKING GROUP MEETING ON JULY 12-13, 1979
  - REVIEW PAST AND CURRENT IUS/ORBITER INTERFACE PROBLEMS WITH BOEING
- RECOMMENDATIONS TO RESOLVE PAYLOAD/ORBITER INTERFACE PROBLEM AREAS
  - NASA/ROCKWELL CONSIDER ADOPTING STANDARD DIGITAL AND ANALOG INTERFACES
  - NASA ISSUE PAYLOAD DESIGN GUIDANCE HANDBOOK

PAYLOAD/ORBITER INTERFACE PROBLEM CAUSES

Axiomatix

- INTERFACE REQUIREMENTS HAVE CHANGED AS ORBITER SUBSYSTEM DESIGN MATURED
- CORE ICD REFLECTS CURRENT SUBSYSTEM DESIGN SPECIFICATIONS, BUT:
  - SOME EXTERNALLY DERIVED REQUIREMENTS (E.G., TDRSS USER REQUIREMENTS) ARE NOT REFLECTED IN SUBSYSTEM SPECIFICATIONS AND, HENCE, ARE NOT IN THE ICD
  - INSUFFICIENT ORBITER SUBSYSTEM DETAILED DESIGN DATA HAS BEEN AVAILABLE FOR FOR PAYLOADS TO DESIGN INTERFACE CIRCUITS
- PAYLOAD/ORBITER ICD CHANGE REQUESTS (PIRN'S) HAVE BEEN MADE, BUT THESE CHANGES HAVE NOT APPEARED IN SUBSYSTEM SPECIFICATIONS
  - IN SOME CASES, ROCKWELL HAS CONCLUDED THAT THE ORBITER SUBSYSTEM PERFORMANCE IS ADEQUATE AND HAS ELECTED NOT TO CHANGE THE SUBSYSTEM SPECIFICATIONS
  - THERE IS LITTLE DOCUMENTATION TO SUPPORT DIFFERENCES BETWEEN ORBITER SUBSYSTEM SPECIFICATIONS AND PAYLOAD/ORBITER ICD'S
- NOT ALL ORBITER CAPABILITY IS PRESENTED IN PAYLOAD/ORBITER ICD'S

- ATTACHED PAYLOAD SIGNAL PROCESSING/DATA HANDLING CHARACTERISTICS
  - DESIGNED FOR FLEXIBILITY
  - ORBITER SUBSYSTEM INTERFACES CONSISTENT WITH EACH OTHER

    --SOME INTERFACE SPECIFICATION DIFFERENCES (E.G., PSP/PDI)
  - EACH SIGNAL PROCESSING/DATA HANDLING UNIT HAS DIFFERENT PAYLOAD INTERFACE REQUIREMENTS
  - INTERFACE SPECIFICATIONS TEND TO BE MORE ANALOG-ORIENTED THAT STANDARD DIGITAL

- ATTACHED PAYLOAD SIGNAL PROCESSING/DATA HANDLING PROBLEM AREAS
  - DIGITAL INTERFACES HAVE CONFLICTING REQUIREMENTS SUCH AS RISE/FALL TIME, DATA/$\overline{DATA}$ SKEW, DATA/CLOCK SKEW, BIT JITTER, BIT ASYMMETRY, AND SIGNAL AMPLITUDE SPECIFICATIONS

    --IUS/ORBITER WORKING GROUP IS MAKING CHANGE REQUESTS ON AN INDIVIDUAL PARAMETER-BY-PARAMETER BASIS

    --STANDARD DIGITAL INTERFACE NEEDS TO BE DEFINED
  - ANALOG INTERFACES HAVE NO AMPLITUDE REGULATION IN ORBITER SUBSYSTEMS

    --PROPOSED ORBITER SUBSYSTEM REGULATION DETERMINED TO HAVE SIGNIFICANT COST IMPACT

PAYLOAD SIGNAL PROCESSING/DATA HANDLING EVALUATION SUMMARY (CONT'D)

- DETACHED PAYLOAD SIGNAL PROCESSING/DATA HANDLING CHARACTERISTICS
  - MOST STANDARD DATA RATES FOR NASA AND DOD INCLUDED IN DESIGN

    --PRELIMINARY ICD'S PREPARED FOR DETACHED NASA NEAR-EARTH, NASA DEEP-SPACE, AND DOD PAYLOADS (NAS 9-15604C--AXIOMATIX)
  - KU-BAND BENT-PIPE FOR MOST NONSTANDARD PAYLOAD TRANSMISSIONS

    --BENT-PIPE USER CONSTRAINTS ESTABLISHED (NAS 9-15240 [EH2]--AXIOMATIX)
- DETACHED PAYLOAD SIGNAL PROCESSING/DATA HANDLING PROBLEM AREAS
  - COHERENT TURN-AROUND COMMUNICATIONS WITH PAYLOADS NEEDS SYSTEM SPECIFICATIONS AS OPPOSED TO SUBSYSTEM SPECIFICATIONS ON SPURIOUS OUTPUTS, PHASE NOISE (INCLUDING TURN-AROUND PHASE NOISE), AND SIGNAL DROP-OUT TIMES

    --PRELIMINARY SYSTEM SPECIFICATIONS PREPARED (NAS 9-15240 [EH2]--AXIOMATIX)
  - NONCOHERENT MODES (INDEPENDENT TRANSMITTER/RECEIVER OPERATION) NEED TO ACCOMMODATE RELAXED AUXILIARY OSCILLATOR STABILITY SPECIFICATION

    --CHANGES TO PI TRANSMITTER AND RECEIVER SWEEP RANGES AND RATES HAVE BEEN INVESTIGATED. INITIALLY, IT APPEARED TO BE ONLY A PAPER CHANGE BUT, RECENTLY, IT APPEARS TO BE A HARDWARE PROBLEM.

PAYLOAD SIGNAL PROCESSING/DATA HANDLING RECOMMENDATIONS

- OVERALL SYSTEM STUDY
  - PAYLOAD DESIGN GUIDANCE HANDBOOK

    --AXIOMATIX PREPARED FREQUENCY SELECTION GUIDELINES FOR SPIDPO (NAS 9-15604A)

    --AXIOMATIX PREPARED LINK DESIGN HANDBOOK FOR SPIDRO (NAS 9-15604B)
  - IDENTIFY PAYLOAD USER CONSTRAINTS

    --DERIVED FROM ORBITER SUBSYSTEM REQUIREMENTS

    --DERIVED FROM TDRSS REQUIREMENTS
  - ASSESS PERFORMANCE DEGRADATION FOR VARYING USER CONSTRAINT COMPLIANCE

    --AXIOMATIX IS ANALYZING PERFORMANCE DEGRADATION FOR VARYING COMPLIANCE OF THE ORBITER TO TDRSS USER CONSTRAINTS (NAS 9-15240)

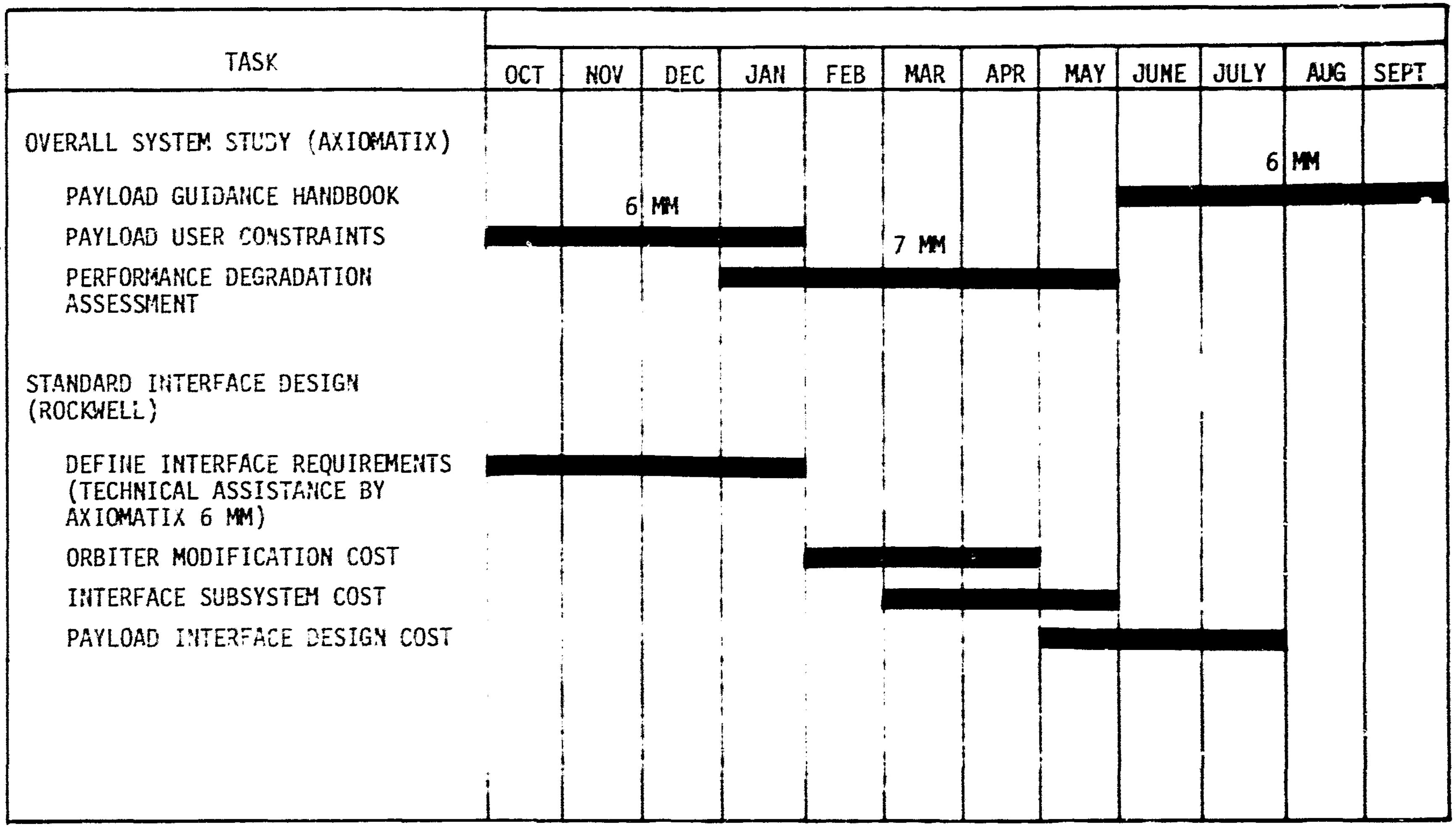
PAYLOAD INTERFACE ISSUES NOT ADDRESSED IN EVALUATION

- SOFTWARE CONSTRAINTS
- MDM INTERFACES
- DATA BUS INTERFACES
- CABLING CONSTRAINTS
- PRIMARY POWER INTERFACES

PAYLOAD SIGNAL PROCESSING/DATA HANDLING RECOMMENDATIONS (CONT'D)

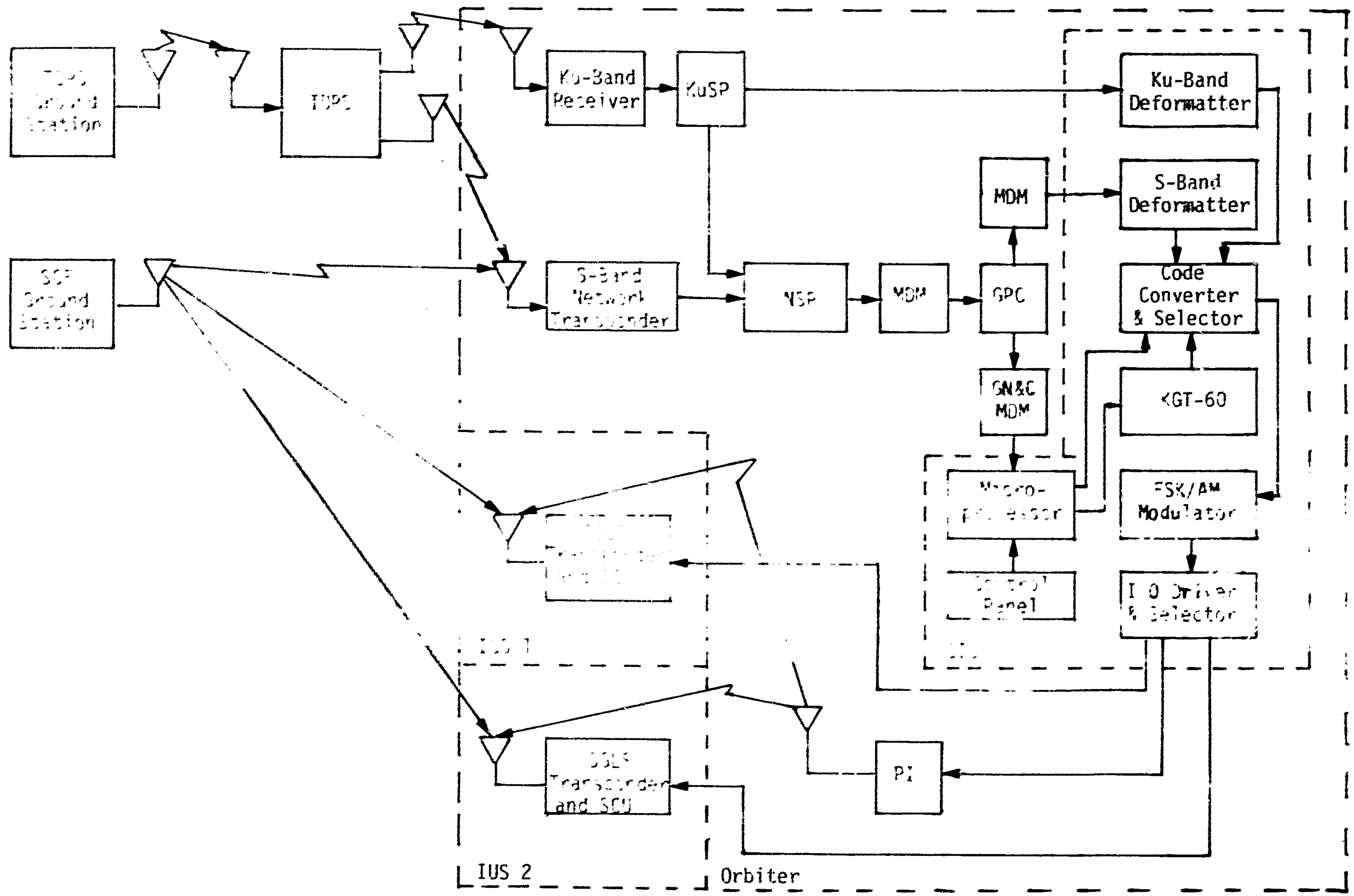
Axiomatix

- AXIOMATIX RECOMMENDS THAT NASA/ROCKWELL CONSIDER ADOPTING STANDARD DIGITAL AND ANALOG INTERFACES
  - DEFINE INTERFACES COMPATIBLE WITH NASA/DOD/INDUSTRY-ACCEPTED DESIGN STANDARDS
  - INVESTIGATE COSTS OF MODIFYING ORBITER SUBSYSTEM INTERFACES
  - INVESTIGATE COST OF DESIGNING ATTACHED PAYLOAD INTERFACE UNIT FOR NASA AND COMMERCIAL PAYLOADS (E.G., CIU FOR DOD MISSIONS)
  - INVESTIGATE COST OF DESIGNING INTERFACE CIRCUITS THAT CAN BE INCORPORATED INTO EACH PAYLOAD DESIGN

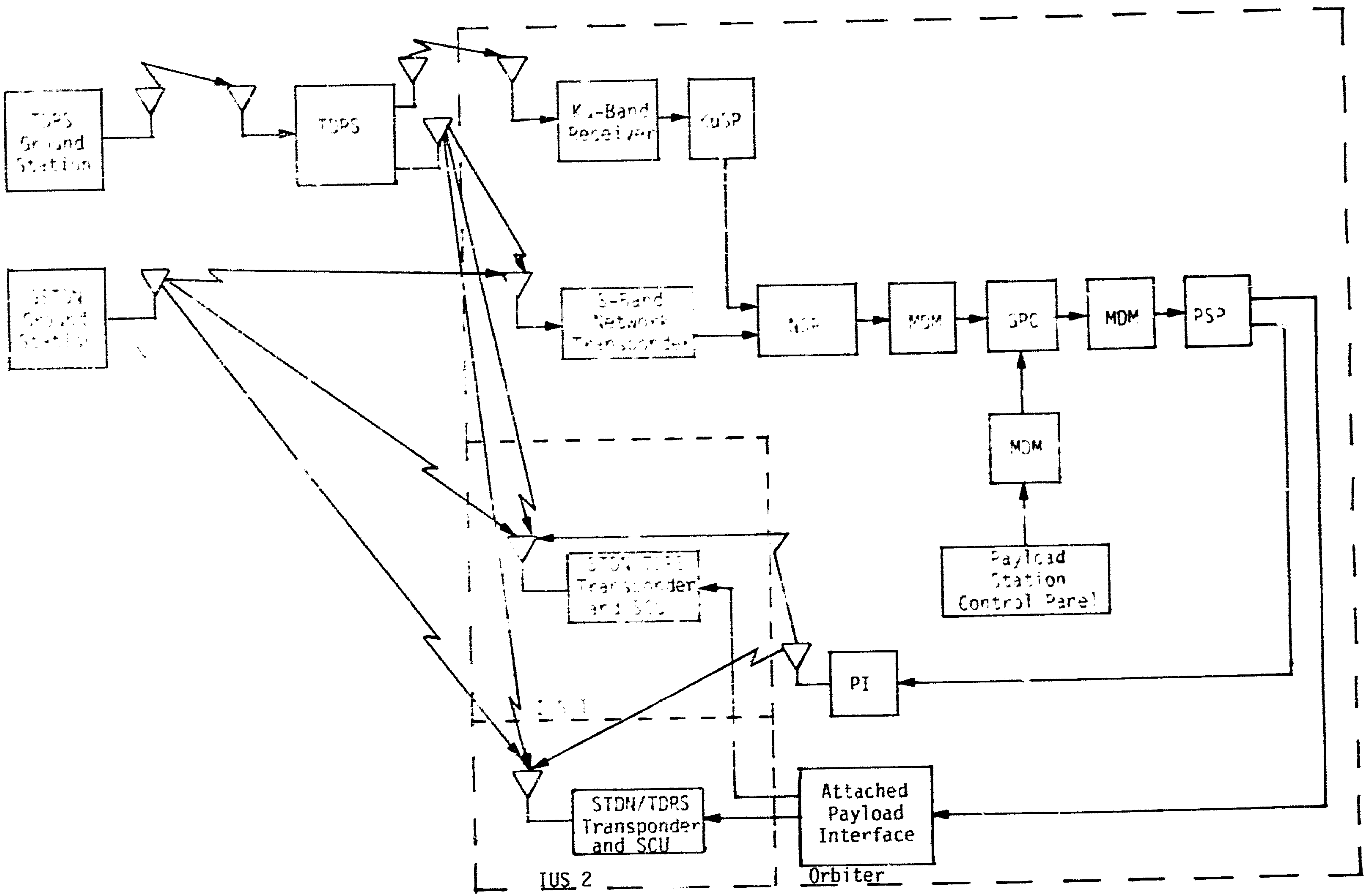

TASK
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEPT
OVERALL SYSTEM STUDY (AXIOMATIX)
PAYLOAD GUIDANCE HANDBOOK
PAYLOAD USER CONSTRAINTS
PERFORMANCE DEGRADATION ASSESSMENT
STANDARD INTERFACE DESIGN (ROCKWELL)
DEFINE INTERFACE REQUIREMENTS (TECHNICAL ASSISTANCE BY AXIOMATIX 6 MM)
ORBITER MODIFICATION COST
INTERFACE SUBSYSTEM COST
PAYLOAD INTERFACE DESIGN COST
6 MM
6 MM
7 MM

BACK-UP CHARTS

FUNCTIONAL SGLS COMMAND SIGNAL FLOW

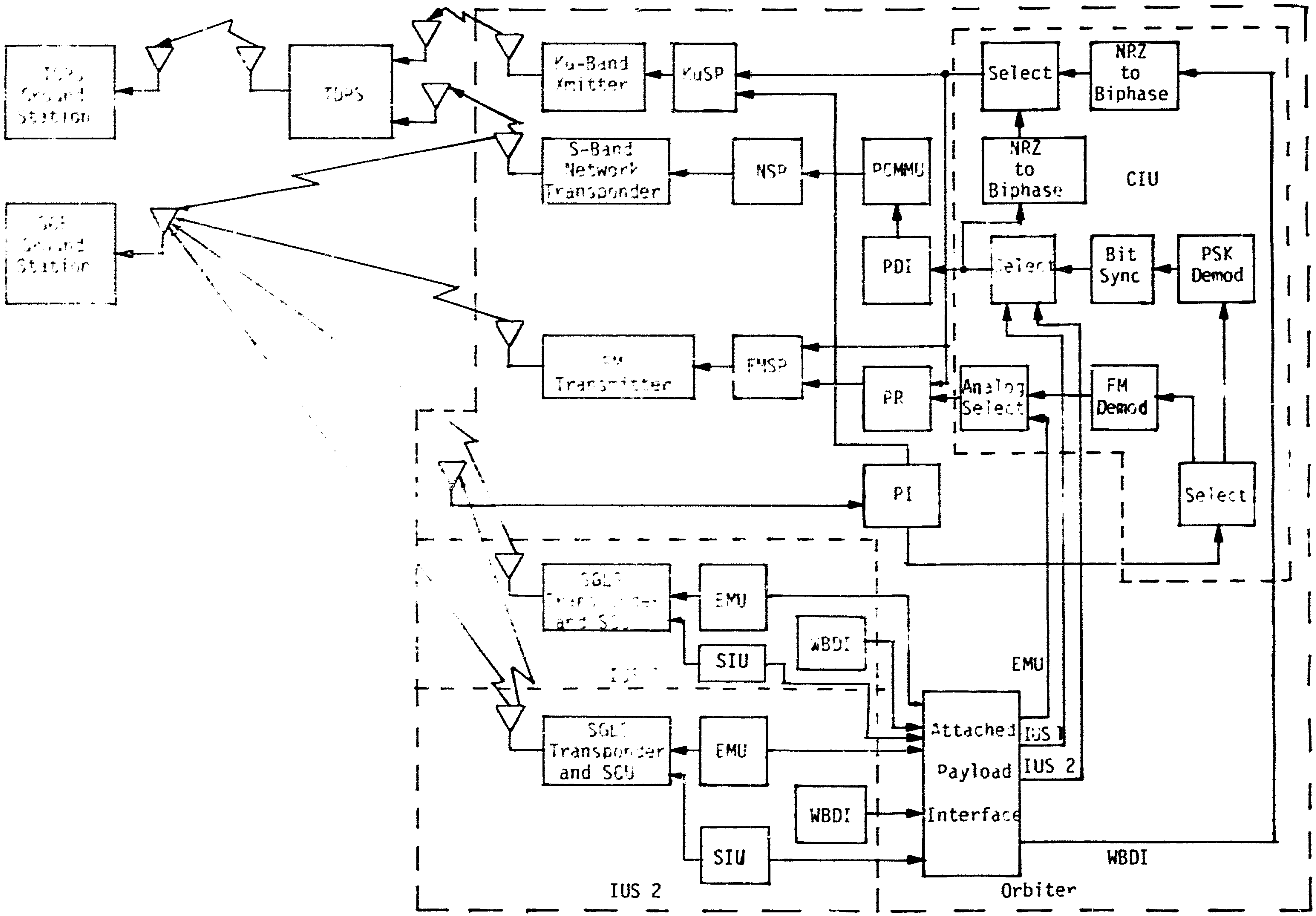


FUNCTIONAL STDN/TDRS IUS COMMAND SIGNAL FLOW

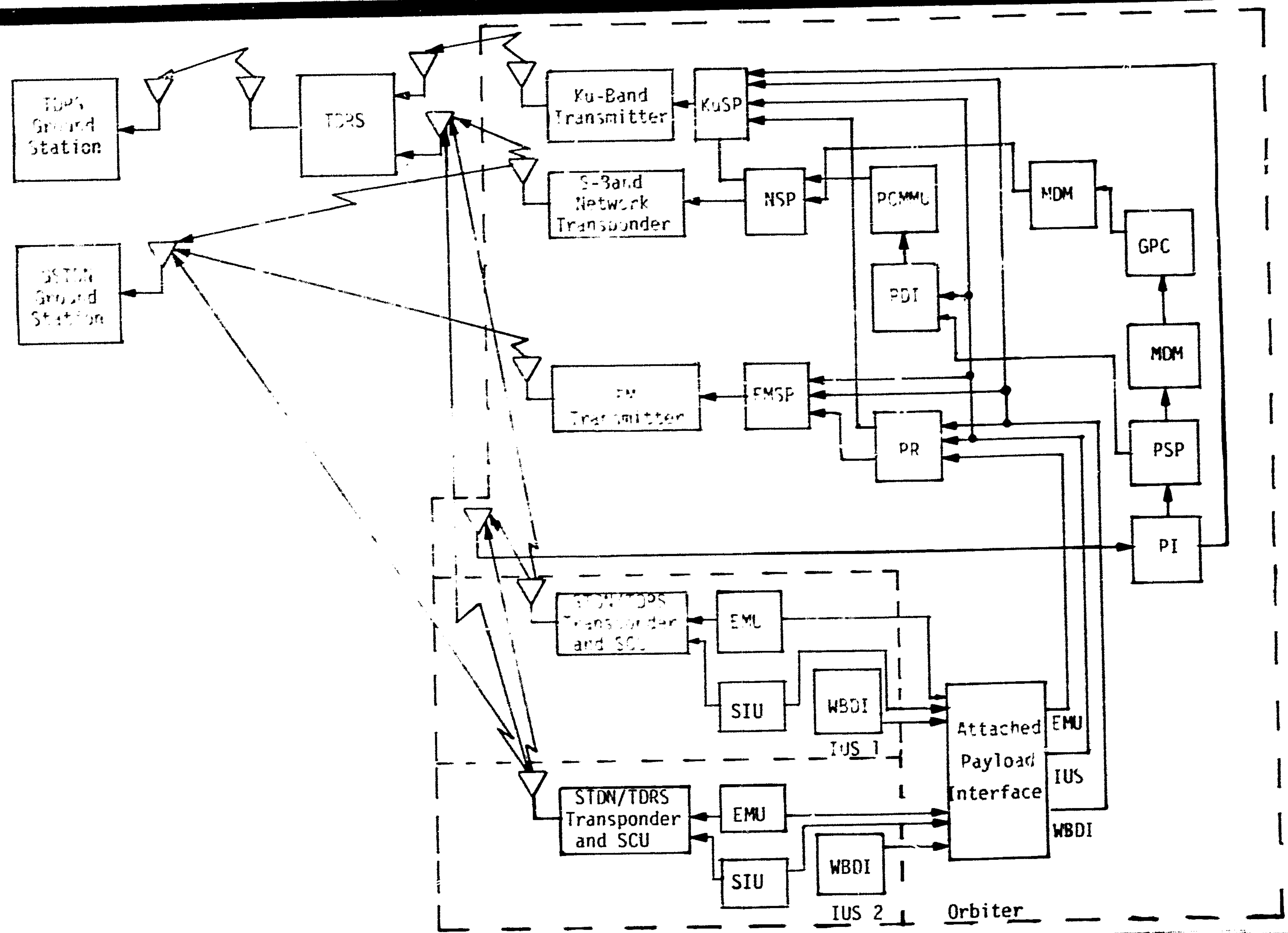


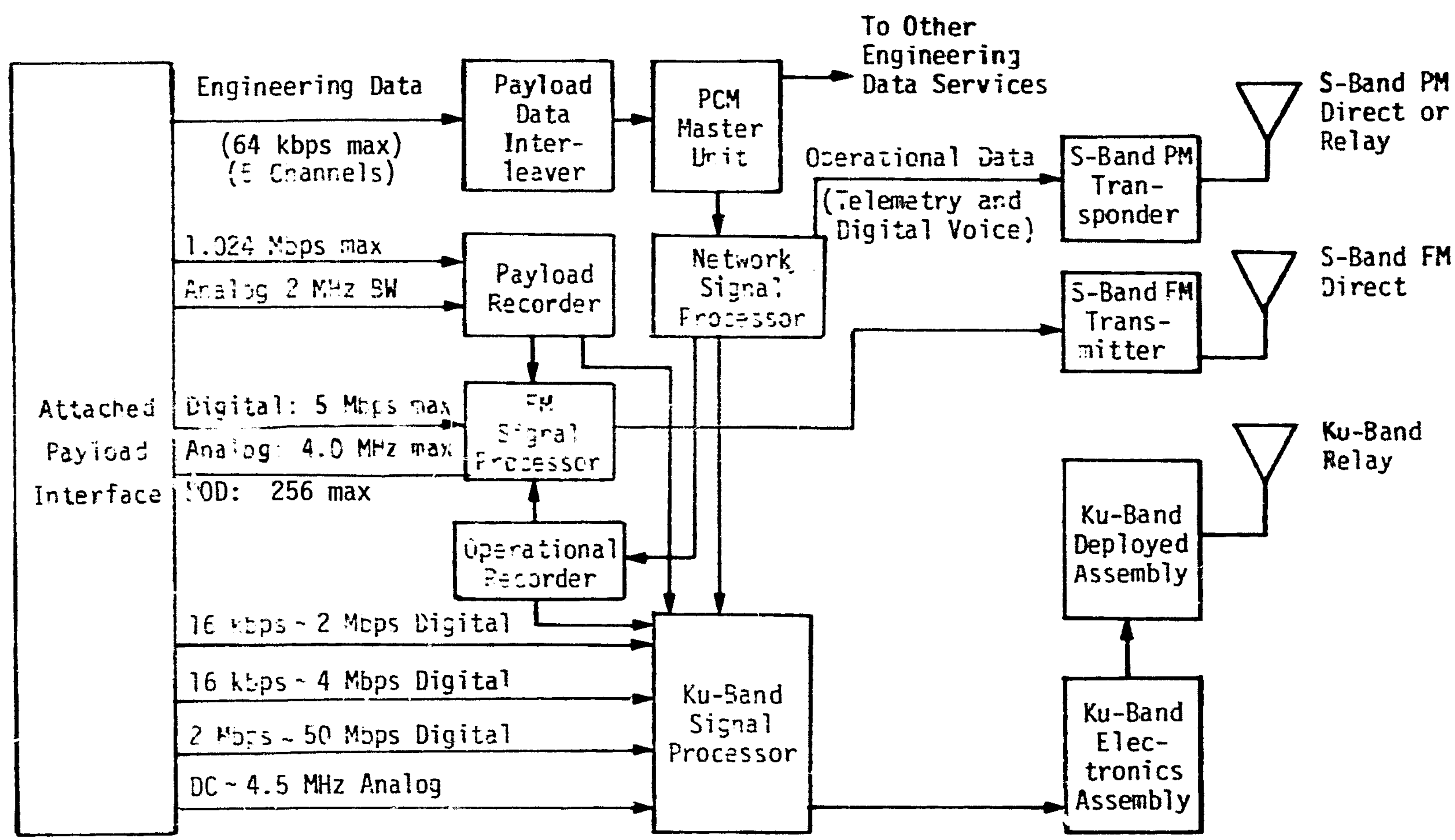
FUNCTIONAL SGLS TELEMETRY SIGNAL FLOW

Axiomatix

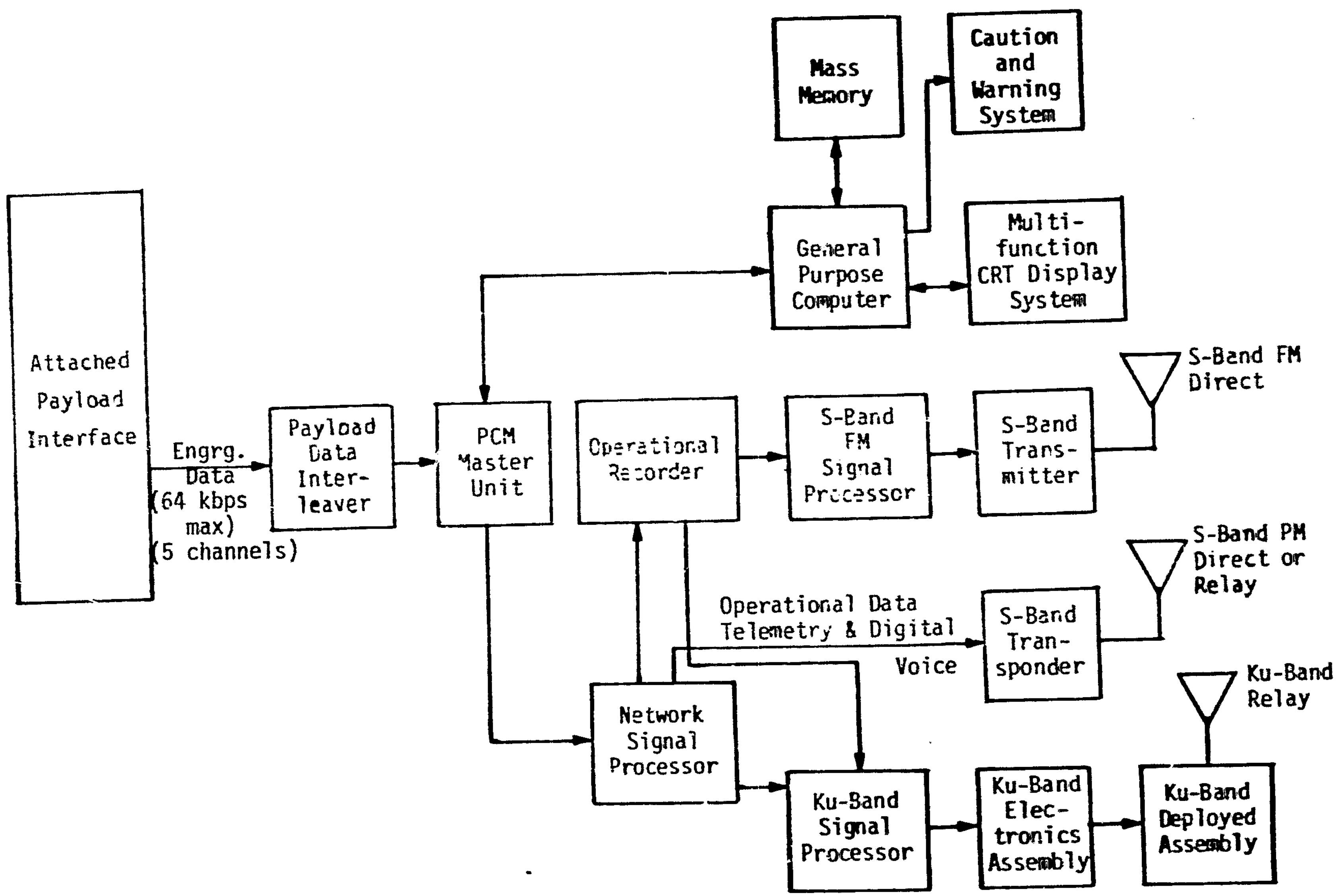


FUNCTIONAL STDN/TDRS TELEMETRY SIGNAL FLOW

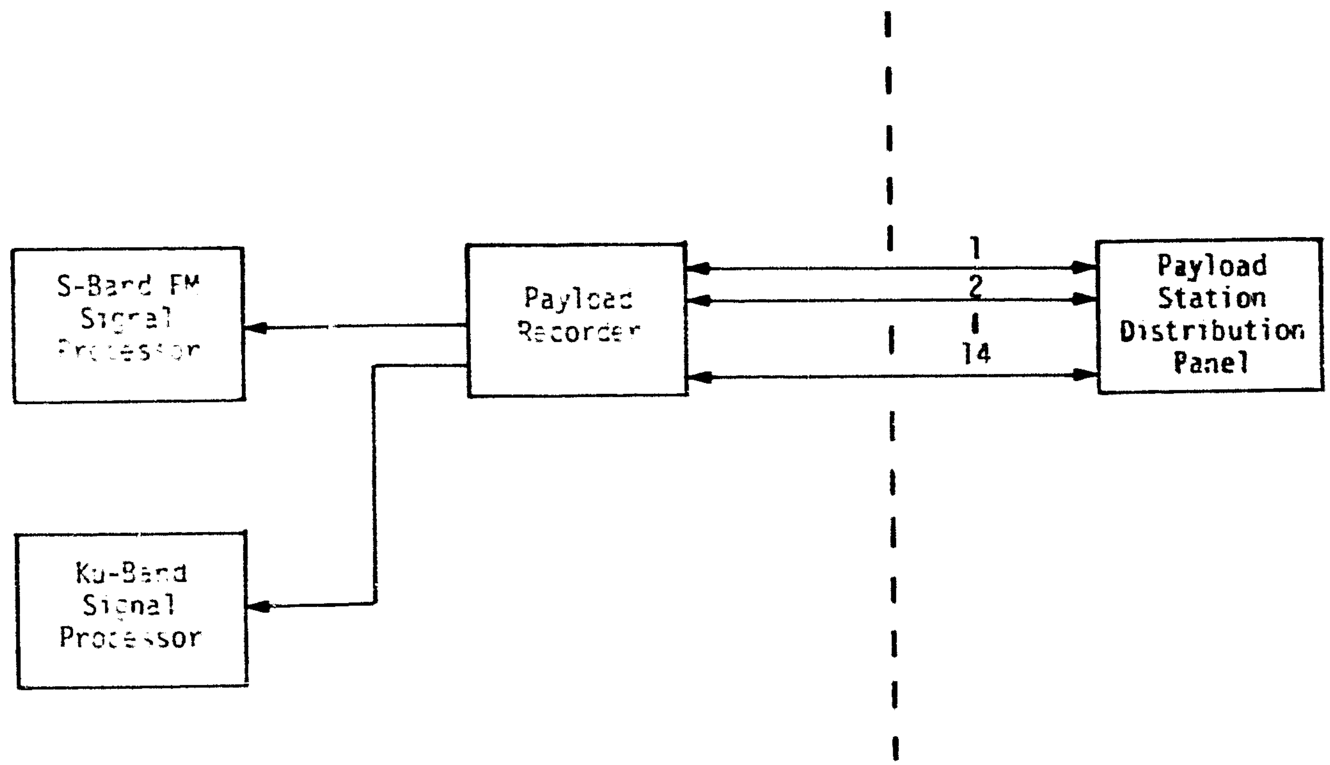



Attached Payload Interface
Engineering Data
(64 kbps max)
(5 Channels)
Payload Data Inter-leaver
PCM Master Unit
To Other Engineering Data Services
1.024 Mbps max
Analog 2 MHz BW
Payload Recorder
Network Signal Processor
Operational Data
(Telemetry and Digital Voice)
S-Band PM Tran-sponder
S-Band PM Direct or Relay
S-Band FM Trans-mitter
S-Band FM Direct
Digital: 5 Mbps max
Analog: 4.0 MHz max
SOD: 256 max
FM Signal Processor
Operational Recorder
16 kbps ~ 2 Mbps Digital
16 kbps ~ 4 Mbps Digital
2 Mbps ~ 50 Mbps Digital
DC ~ 4.5 MHz Analog
Ku-Band Signal Processor
Ku-Band Elec-tronics Assembly
Ku-Band Deployed Assembly
Ku-Band Relay

ATTACHED PAYLOAD ENGINEERING DATA INTERFACE



ATTACHED PAYLOAD DATA RECORDING INTERFACE



ATTACHED PAYLOAD/ORBITER DIGITAL INTERFACE PARAMETERS

Axiomatix

PARAMETER	PAYLOAD RECORDER	PAYLOAD DATA INTERLEAVER	FM SIGNAL PROCESSOR	KU-BAND SIGNAL PROCESSOR	AXIOMATIX PROPOSED STANDARD INTERFACE
SIGNAL LEVEL	3.7 - 9V P-P, LINE-TO-LINE	2-12V P-P, LINE-TO-LINE (2.5 - 9.0V OPEN PIRN)	5 0 ± 0.5V P-P, LINE-TO-LINE (WIDEBAND) 1.0 ± 0.5V P-P, LINE-TO-LINE (DOD)	2.3 - 5.0V P-P LINE-TO-LINE	3-9V P-P LINE-TO-LINE (FMSP AND KUSP HARDWARE IMPACT)
RMS SNR	-	-	45 DB P-P TO RMS NOISE DC TO 2 MHZ	35 DB MINIMUM	NO REQUIREMENT
DATA RATES	25.5 KBPS TO 1.024 MBPS	10 BPS TO 64 KBPS	200 BPS - 5 MBPS, NRZ-L 200 BPS - 2 MBPS, BIPHASE-L 250 BPS - 256 KBPS (DOD)	16 KBPS - 2 MBPS NRZ-L,M,S 16 KBPS TO 1.024 MBPS BIPHASE-L,M,S 2-50 MBPS NRZ-L,M,S 16 KBPS-4 MBPS, NRZ-L,M,S	CURRENT DATA RATES
SIGNAL CODE	BIPHASE-L	NRZ-L,M,S BIPHASE-L,M,S	NRZ-L BIPHASE-L	NRZ-L,M,S BIPHASE-L,M,S	NRZ-L,M,S BIPHASE-L,M,S (PR HARDWARE IMPACT)

ATTACHED PAYLOAD/ORBITER DIGITAL INTERFACE PARAMTERS

(PAGE 2 OF 4)

PARAMETER	PAYLOAD RECORDER	PAYLOAD DATA INTERLEAVER	FM SIGNAL PROCESSOR	KU-BAND SIGNAL PROCESSOR	AXIOMATIX PROPOSED STANDARD INTERFACE
RISE AND FALL TIMES	10% OF BIT DURATION	MAXIMUM: 5 μS OR 10% OF BIT DURATION WHICHEVER IS LESS MINIMUM: 100 NS	MAXIMUM: 50 NS (WIDEBAND) 100 NS (DOD)	5% OR 50 NS WHICHEVER IS LESS (KUSP SPEC) ICD: 40 NS UP TO 1 MBPS 20 NS 1-2 MBPS 5 NS 2-4 MBPS 10% OF BIT DURATION 2-50 MBPS	MAXIMUM: 10% OF BIT DURATION NO MINIMUM (TDRSS USER CONSTRAINT ≤5% MAXIMUM 800 PSEC MINIMUM)
DATA/$\overline{\text{DATA}}$ SKEW	-	±200 NS	-		NO REQUIREMENT (PDI HARDWARE IMPACT)
DATA ASYMMETRY	INCLUDED IN BIT JITTER SPECIFICATION	-	-	(±3% TDRSS USER CONSTRAINT; JSC RECOMMENDS ±10%)	±10%
WAVEFORM DISTORTION	-	OVERSHOOT/UNDER-SHOOT LESS THAN 20% OF SIGNAL LEVEL	-	-	NO REQUIREMENT (USER SIGNAL LEVEL SPECIFICATION) (PDI EMI IMPACT)

ATTACHED PAYLOAD/ORBITER DIGITAL INTERFACE PARAMETERS

(PAGE 3 OF 4)

PARAMETER	PAYLOAD RECORDER	PAYLOAD DATA INTERLEAVER	FM SIGNAL PROCESSOR	KU-BAND SIGNAL PROCESSOR	AXIOMATIX PROPOSED STANDARD INTERFACE
FREQUENCY JITTER	-	-	-	±0.01% RMS OF DATA RATE AT 0.01% RMS OF THE DATA RATE	NOT A NORMAL DIGITAL INTERFACE REQUIREMENT (TDRSS USER CONSTRAINT)
BIT JITTER	<2% OF BIT DURATION (P-P) (INCLUDES DATA ASYMMETRY)	-	-	- (≤0.1% TDRSS USER CONSTRAINT)	0.1% OF BIT DURATION
BIT RATE ACCURACY	-	±2%	-	-	±2%
BIT RATE STABILITY	-	1 PART IN 10^5 (60 SECONDS AVERAGE)	-	0.01% (LONG TERM)	0.01% (60-SEC AVERAGE)
CLOCK/DATA SKEW	-	±5% OF CLOCK PERIOD OR 10 μS WHICHEVER IS LESS	-	-	NO REQUIREMENT (PDI HARDWARE IMPACT)

PARAMETER	PAYLOAD RECORDER	PAYLOAD DATA INTERLEAVER	FM SIGNAL PROCESSOR	KU-BAND SIGNAL PROCESSOR	RECOMMENDED STANDARD INTERFACE
CLOCK DUTY CYCLE	-	50.0 ± 5%	-	-	50.0 ± 5%
LOAD IMPEDANCE	75 ± 10% OHMS	MIN: 74 OHMS MAX: 91 OHMS	75 ± 10% OHMS	75 ± 5 OHMS 50 ± 10% OHMS (2 - 50 MBPS)	MIN: 74 OHMS MAX: 91 OHMS
CABLE IMPEDANCE @ 1 MHZ	75 ± 5 OHMS, TSP	75 ± 5 OHMS, TSP 2900 pf CAPACITANCE	75 ± 5 OHMS, TSP	75 ± 5 OHMS, TSP 50 OHMS, RG 142BU (2 - 50 MBPS)	75 ± 5 OHMS, TSP 2900 pf CAPACITANCE MAXIMUM*
SOURCE IMPEDANCE	TTL COMPATIBLE (TI 5514 OR EQUIVALENT)	-	75 ± 10% OHMS	-	TTL COMPATIBLE
NOISE IMMUNITY	-	150 MV P-P** DC TO 100 KHZ	-	-	NO REQUIREMENT
COMMON MODE VOLTAGE (LINE-TO-SIGNAL GROUND)	±15V	±3V	-	-	±15V (PDI AND FMSP HARDWARE IMPACT)

*18-23 pf PER FOOT OF CABLE

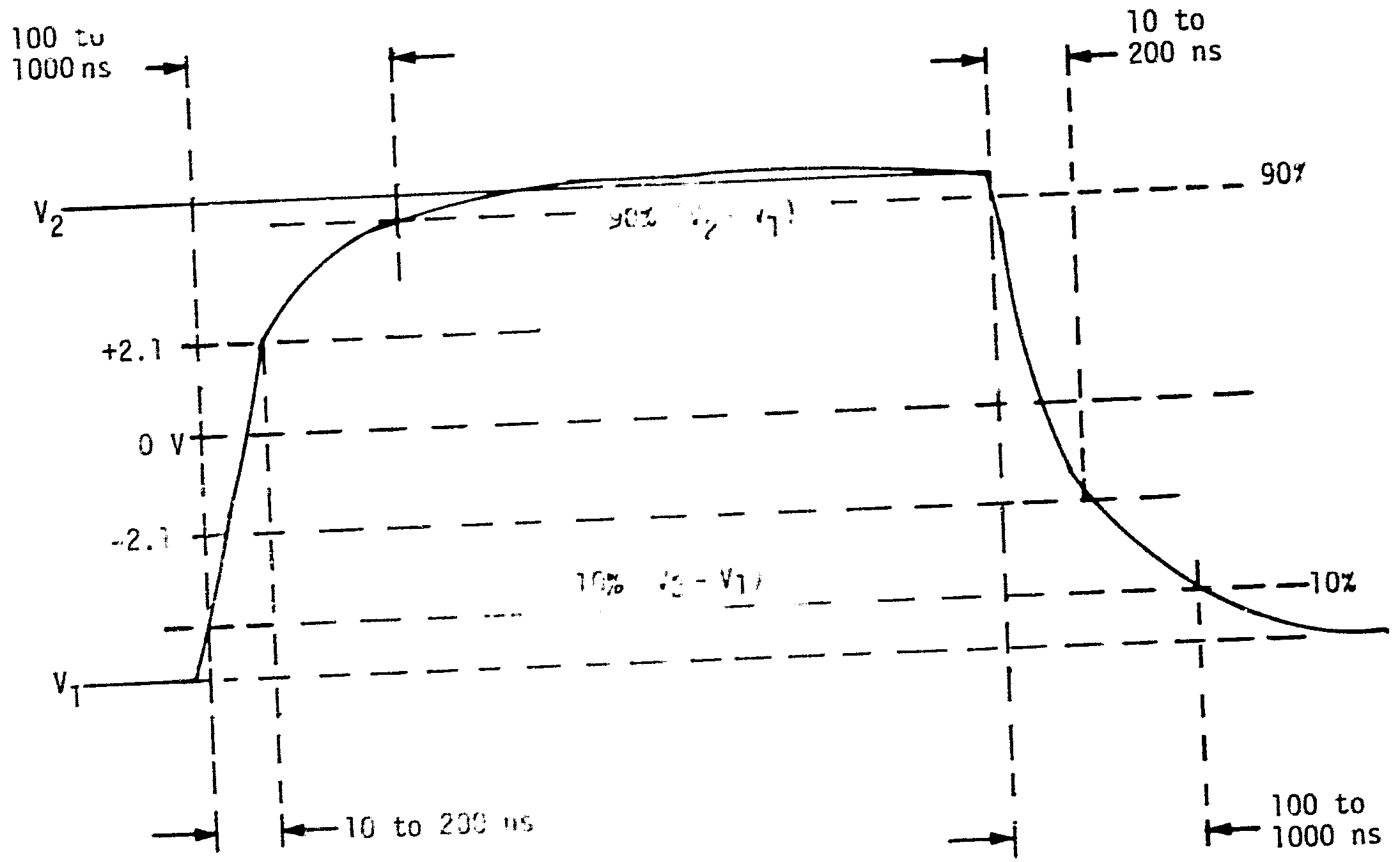
**100 MV P-P MAX EMI, 50 MV P-P FROM PAYLOAD

ATTACHED PAYLOAD/ORBITER ANALOG INTERFACE PARAMETERS

Axiomatix

PARAMETER	PAYLOAD RECORDER	FM SIGNAL PROCESSOR	KU-BAND SIGNAL PROCESSOR	AXIOMATIX PROPOSED STANDARD INTERFACE
SIGNAL LEVEL	1V RMS ± 6 DB	1V ± 10% P-P LINE-TO-LINE	2V RMS P-P LINE-TO-LINE 7V MAXIMUM	AMPLITUDE REGULATION AT ORBITER SUBSYSTEMS 1V RMS P-P, LINE-TO-LINE 3V MAX (HARDWARE IMPACT)
BANDWIDTH	1.9 KHZ - 1.6 MHZ	300 HZ - 4 MHZ	DC TO 4.5 MHZ	
SIGNAL/NOISE	-	-	45 DB P-P TO RMS NOISE (MINIMUM)	NO REQUIREMENT
COUPLING TYPE	DIFFERENTIAL	BALANCED DIFFERENTIAL	BALANCED DIFFERENTIAL DIRECT COUPLED	BALANCED DIFFERENTIAL
LOAD IMPEDANCE	75 ± 5% OHMS	75 ± 10% OHMS	75 ± 5 OHMS	75 ± 10% OHMS
CABLE IMPEDANCE	75 ± 5 OHMS, TSP	75 ± 5 OHMS, TPS	75 ± 5 OHMS, TSP	75 ± 5 OHMS, TSP
SOURCE IMPEDANCE	CAPABLE OF DRIVING 150 FT OF CABLE	75 ± 10% OHMS	75 ± 5 OHMS	75 ± 10% OHMS
COMMON MODE REJECTION	±15V	±1V DC TO 2 MHZ	±15V DC TO 10 KHZ	±15V (FMSP HARDWARE IMPACT)

RISE AND FALL TIME

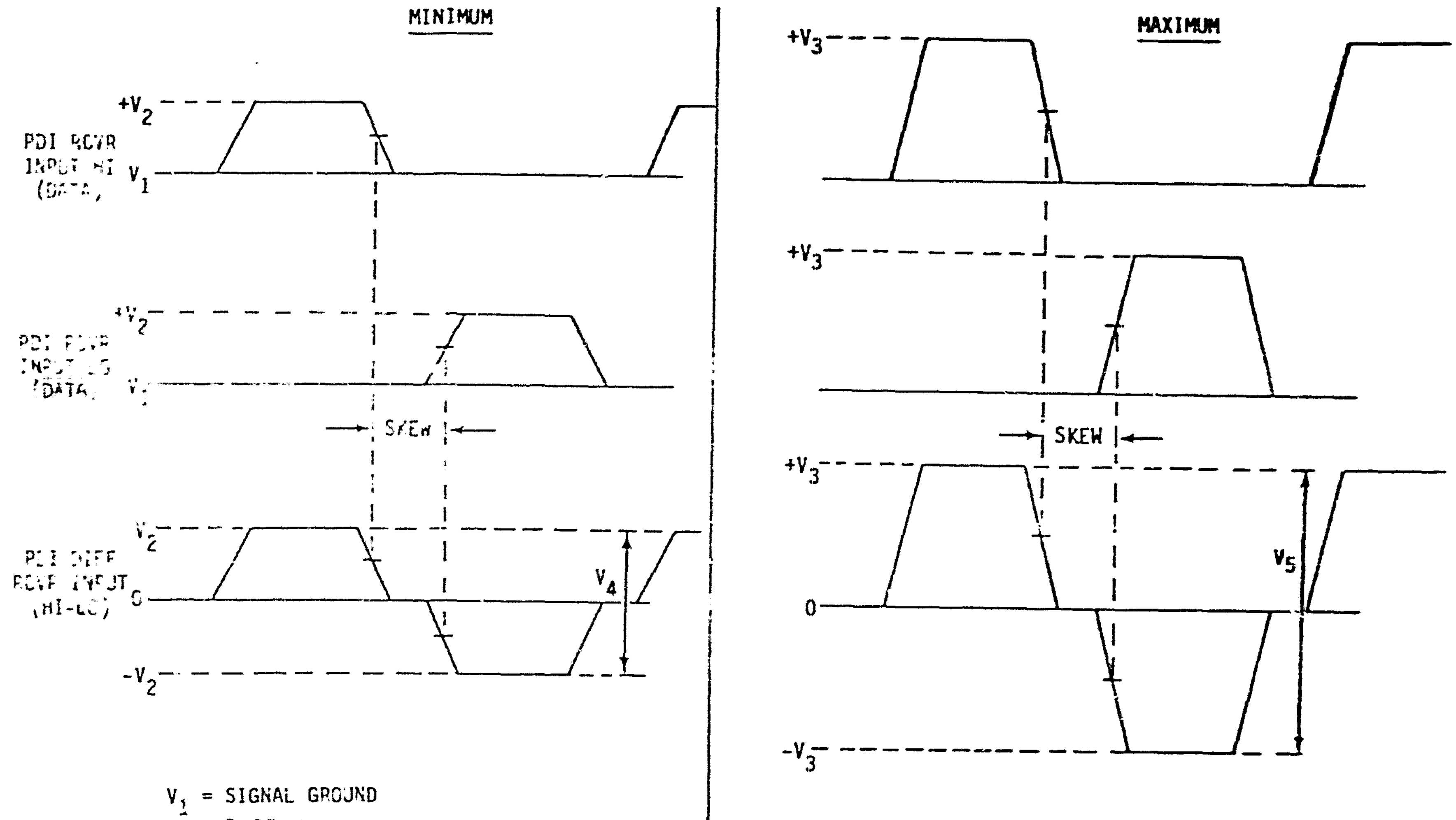


-5.9 volts ≤ V_1 ≤ [illegible] volts

+2.1 volts ≤ V_2 ≤ [illegible] volts

NOTE: Waveform represents line-to-line voltage excursion.

DATA/$\overline{\text{DATA}}$--DIFFERENTIAL TRANSMISSION



V_1 = SIGNAL GROUND

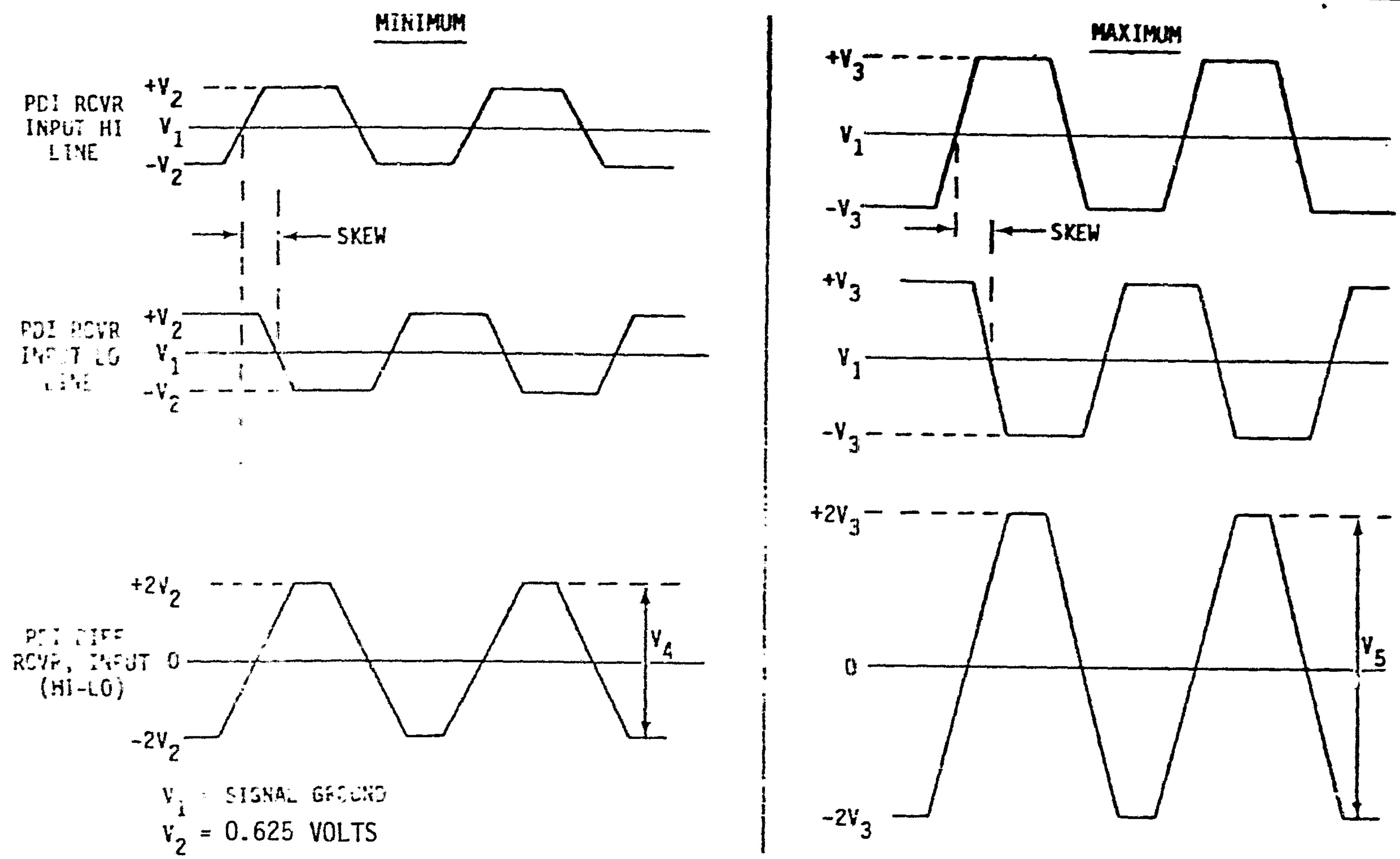
V_2 = 1.25 VOLTS LINE TO SIG GND

V_3 = 4.5 VOLTS LINE TO SIG GND

V_4 = 2.5 VOLTS P-P LINE-TO-LINE DIFFERENTIAL BALANCED

V_5 = 9.0 VOLTS P-P LINE TO LINE DIFFERENTIAL BALANCED

SKEW MAXIMUM SKEW BETWEEN 50% AMPLITUDE POINTS OF DATA/$\overline{\text{DATA}}$ SIGNALS = ± 200 NANOSECONDS



V_1 = SIGNAL GROUND

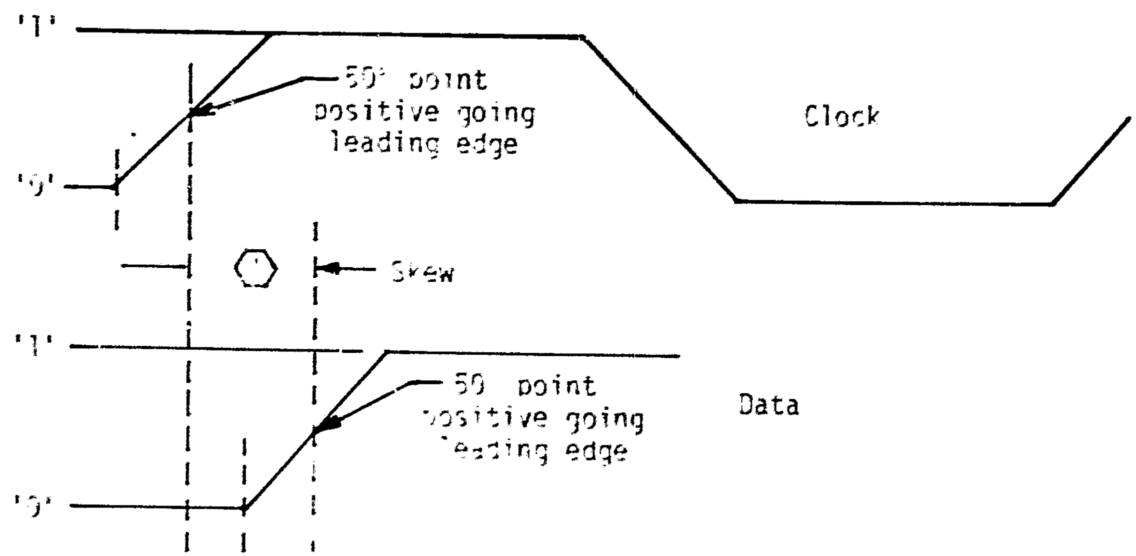
V_2 = 0.625 VOLTS

V_3 = 2.25 VOLTS

V_4 = 2.5 VOLTS P-P DIFFERENTIAL LINE-TO-LINE BALANCED

V_5 = 9.0 VOLTS P-P DIFFERENTIAL LINE-TO-LINE BALANCED

SKEW = MAXIMUM SKEW BETWEEN HI LINE SIGNAL V_1 CROSSOVER AND LO LINE SIGNAL V_1 CROSSOVER = $\pm$ 200 NANOSECONDS



1 Maximum of 10 ns or ±5.0 of the clock period

PAYLOAD/PAYLOAD DATA INTERLEAVER INTERFACE PROBLEM

5

Axiomatix

- MINIMUM RISE AND FALL TIME SPECIFICATIONS REQUIRE WAVEFORM FILTERING TO SLOW DOWN MAXIMUM RISE AND FALL TIME OF INTERFACE DEVICE

- WAVEFORM FILTERING CAUSES DATA/$\overline{\text{DATA}}$ SKEW

- MINIMUM 100 NS RISE AND FALL TIME CANNOT BE MET SIMULTANEOUSLY WITH ±200 NS DATA/$\overline{\text{DATA}}$ SKEW (BOEING WORST-CASE ANALYSIS)

- PIRN (BAC 026A) FROM ORBITER/IUS AVIONICS WORKING GROUP MEETING OF JULY 12-13, 1979 CHANGES PDI MINIMUM RISE AND FALL TIME SPECIFICATION TO 30 NS

- IF PIRN (BAC 026A) CHANGES PDI SPECIFICATION, THEN BOEING FEELS THAT IT IS POSSIBLE TO MEET BOTH THE SPECIFICATIONS FOR RISE AND FALL TIME AND DATA/$\overline{\text{DATA}}$ SKEW

- MORE ANALYSIS MUST BE PERFORMED BEFORE IT IS DETERMINED IF THE RISE AND FALL TIME AND DATA/$\overline{\text{DATA}}$ SKEW REQUIREMENTS OF THE PDI CAN BE MET

APPENDIX II

AXIOMATIX RECOMMENDATIONS FOR REVISION OF SECTION 8.3

OF ICD 2-19001 FOR DETACHED PAYLOADS

REVISION #1

MAY 3, 1979

DRAFT REVISION #1
5/3/79

REWRITE AND REVISION FOR SECTION 8.3 OF ICD NO. 2-19001

8.3 Detached Payloads. Paragraphs applicable to STDN, DSN, SGLS, and nonstandard payloads are indicated in the following breakdown:

STDN Payloads--Paragraphs 8.3.1 and 8.3.2, subparagraphs 8.3.2.1, 8.3.2.2 and 8.3.2.3.

DSN Payloads--Paragraphs 8.3.1 and 8.3.2, subparagraphs 8.3.2.1, 8.3.2.2 and 8.3.2.4.

SGLS Payloads--Paragraphs 8.3.1 and 8.3.3.

Nonstandard Payloads--Paragraphs 8.3.1 and 8.3.4.

8.3.1 S-Band Payload Interrogator (PI) Interface. The PI provides two-way RF communication between the Orbiter and detached payloads within a range of 10 nmi. In the following paragraphs, "characteristics" are those of the Orbiter avionics that the payload must be cognizant of, and "requirements" are specifications placed upon the payload communication equipment.

8.3.1.1 PI Performance Characteristics

8.3.1.1.1 Transmitter Characteristics. The principal transmitter characteristics are listed in Table 8.3.1.1.1-1.

8.3.1.1.1.1 Output Frequency Range. Two output frequency bands are provided, L-band and S-band, as summarized in Table 8.3.1.1.1.1-1.

8.3.1.1.1.1.1 STDN Channel Assignments. The transmit/receive frequency pair assignments for STDN-compatible detached payloads are listed in Table 8.3.1.1.1.1-2.

8.3.1.1.1.1.2 DSN Channel Assignments. The transmit/receive frequency pair assignments for DSN-compatible detached payloads are listed in Table 8.3.1.1.1.1-3.

8.3.1.1.1.1.3 SGLS Channel Assignments. The transmit/receive frequency pair assignments for SGLS-compatible detached payloads are listed in Table 8.3.1.1.1.1-4

8.3.1.1.1.2 Transmitter Triplexer Section. A triplexer is used between the payload antenna and the PI transmitter/receiver output/input terminals. This triplexer functions to divide the PI transmit and receive bands into low and high subbands for both the NASA and DOD modes of operation. The purpose of the low/high band selectivity is to prevent mutual interference between the PI and S-band network transponder during times of simultaneous operation.

TABLE 8.3.1.1.1-1 PRINCIPAL PI TRANSMITTER CHARACTERISTICS

Parameter	Value	Units	Subparagraph
L-Band Frequency Range	1763 - 1840	MHz	8.3.1.1.1.1
S-Band Frequency Range	2025 - 2120	MHz	8.3.1.1.1.1
Triplexer Subbands	See Subparagraph		8.3.1.1.1.2
Carrier Frequency Tolerance	±0.001	%	8.3.1.1.1.3
Carrier Phase Noise	10 max	degrees-RMS	8.3.1.1.1.4
Output Spurs	< - 65	dBc	8.3.1.1.1.5
Phase Modulator	0.2 to 2.5	radians	8.3.1.1.1.6
Frequency Sweep Range	±75 max	kHz	8.3.1.1.1.7
Frequency Sweep Rates	10	kHz/sec	8.3.1.1.1.8
	(TBS)	Hz/sec	8.3.1.1.1.8
Power Level--High	37	dBm	8.3.1.1.1.9
Medium	27	dBm	8.3.1.1.1.9
Low	4	dBm	8.3.1.1.1.9

TABLE 8.3.1.1.1.1-1 PAYLOAD INTERROGATOR OPERATING CHANNELS

	Frequency Range (MHz)	No. of Channels	Channel Spacing (kHz)
STDN S-Band Transmit and Receive			
S-Band Transmit	2025.833-2118.7	808	115.104
S-Band Receive	2200-2300.875	808	125.000
DSN S-Band Transmit and Receive			
S-Band Transmit	2110.243-2119.792	29*	341.049
S-Band Receive	2290.185-2299.814	27**	370.370
SGLS L-Band Transmit, S-Band Receive			
L-Band Transmit	1763.721-1839.795	20	4003.906
S-Band Receive	2202.5-2297.5	20	5000.000

*The top six channels are transmit only.

**The bottom four channels are receive only.

TABLE 8.3.1.1.1.1-2 STDN CHANNEL AND FREQUENCY ASSIGNMENTS

Refer to Appendix C for specific channel and frequency assignments.

Method of calculating frequencies is as follows:

Channel No. n = 1 to 808

Receive Frequency = 2200.000 + (n-1) x 0.125 MHz

Transmit Frequency = 2025.8334 + (n-1) x 0.115104 MHz

Transmit Frequency = 221/240 x Receive Frequency

TABLE 8.3.1.1.1.1-3 DSN CHANNEL & FREQUENCY ASSIGNMENTS

CHANNEL		TRANSMIT MHZ		RECEIVE MHZ	
		SPECIFIED	SYNTHESIZER	SPECIFIED	SYNTHESIZER
850				2290.185185	2290.185790
851				2290.555556	2290.555560
852				2290.925926	2290.925930
853				2291.296296	2291.296300
854	(56)	2110.243056	2110.243059	2291.666667	2291.666670
855		2110.584105	2110.584108	2292.037037	2292.037040
856		2110.925154	2110.925157	2292.407407	2292.407410
857		2111.266204	2111.266206	2292.777778	2292.777780
858		2111.607253	2111.607255	2293.148148	2293.148150
859		2111.948303	2111.948304	2293.518519	2293.518520
860		2112.289352	2112.289353	2293.888889	2293.888890
861		2112.630401	2112.630402	2294.259259	2294.259260
862		2112.971451	2112.971451	2294.629630	2294.629630
863	(14b)	2113.312500	2113.312500	2295.000000	2295.000000
864		2113.653549	2113.653549	2295.370370	2295.370370
865		2113.994599	2113.994598	2295.740741	2295.740740
866		2114.335648	2114.335647	2296.111111	2296.111110
867		2114.676697	2114.676696	2296.481981	2296.481480
868		2115.017747	2115.017745	2296.857852	2296.851850
869		2115.358796	2115.358794	2297.222222	2297.222220
870		2115.699846	2115.699843	2297.592593	2297.592590
871		2116.040895	2116.040892	2297.962965	2297.962960
872	(236)	2116.381944	2116.381941	2298.333333	2298.333330
873		2116.722994	2116.722990	2298.703704	2298.703700
874		2117.064043	2117.064039	2299.074074	2299.074070
875		2117.405092	2117.405088	2299.444444	2299.444440
876		2117.746142	2117.746137	2299.814315	2299.814810
877		2118.087191	2118.087186		
878		2118.428241	2118.428235		
879		2118.769290	2118.769284		
880		2119.110339	2119.110333		
881		2119.451389	2119.451332		
882		2119.792438	2119.792431		

unassigned channels: 883-899

TABLE 8.3.1.1.1.1-4 SGLS CHANNEL & FREQUENCY ASSIGNMENTS

CHANNEL	TRANSMIT ORBITER TO DOD PAYLOADS (MHz)	RECEIVE DCD PAYLOADS TO ORBITER (MHz)
900	1763.721	2202.500
901	1767.725	2207.500
902	1771.729	2212.500
903	1775.733	2217.500
904	1779.736	2222.500
905	1783.740	2227.500
906	1787.744	2232.500
907	1791.748	2237.500
908	1795.752	2242.500
909	1799.756	2247.500
910	1803.760	2252.500
911	1607.764	2257.500
912	1811.768	2262.500
913	1815.772	2267.500
914	1819.775	2272.500
915	1823.779	2277.500
916	1827.783	2282.500
917	1831.787	2287.500
918	1835.791	2292.500
919	1839.795	2297.500

Unassigned channels: 920-999

8.3.1.1.1.2.1 S-Band Subbands. The lowband is approximately 2025-2075 MHz and the highband is approximately 2074-2120 MHz.

8.3.1.1.1.2.2 L-Band Subbands. The lowband is approximately 1763-1803 MHz and the highband is approximately 1803-1840 MHz.

8.3.1.1.1.3 Carrier Frequency Tolerance. The maximum carrier frequency uncertainty is ±0.001% of the nominal carrier frequency (transmitter sweep disabled).

8.3.1.1.1.4 Carrier Phase Noise. The transmitter phase noise will produce no more than a 4° RMS tracking phase error in a 300 Hz two-sided tracking bandwidth and a 10° RMS tracking error in a 16 Hz two-sided tracking bandwidth.

8.3.1.1.1.5 Carrier Spurs. Any spurs appearing at the transmitter output will be at least 65 dB below the unmodulated carrier power level.

8.3.1.1.1.6 Carrier Phase Modulator. The phase modulator will accept analog or digital modulating signals. The modulator deviation characteristic is linear within ±4% over a deviation range of 0.2-2.5 rad. Frequency response is flat within ±0.5 dB from 1-200 kHz.

8.3.1.1.1.7 Carrier Frequency Sweep. The transmitter output frequency may be swept over three ranges: 75 ±5 kHz, 55 ±5 kHz, 33 ±3 kHz. The fast sweep rate for the 75 and 55 kHz ranges is 10 ±3 kHz/sec and, for the 33 kHz range, is (TBS) ± (TBS) Hz/sec. Frequency sweep is linear up and down in frequency, beginning at the nominal channel frequency. When the sweep is disabled, it remains in effect at the specified rate until the nominal carrier frequency is reached.

8.3.1.1.1.8 Selectable Transmitter Power Levels. Three selectable transmitter output power levels for either the L-band or S-band frequency ranges are available:

High	+37 dBm to +42 dBm
Medium	+27 dBm to +32 dBm
Low	+4 dBm to +9 dBm

8.3.1.1.2 Receiver Characteristics. The principal receiver characteristics are listed in Table 8.3.1.1.2-1.

8.3.1.1.2.1 Input Frequency Range. The receiver input frequency range is S-band, 2200-2300 MHz.

8.3.1.1.2.1.1 STDN Channel Assignments. See Paragraph 8.3.1.1.1.1.1.

8.3.1.1.2.1.2 DSN Channel Assignments. See Paragraph 8.3.1.1.1.1.2.

8.3.1.1.2.1.3 SGLS Channel Assignments. See Paragraph 8.3.1.1.1.1.3.

8.3.1.1.2.2 Receiver Triplexer Section. See Paragraph 8.3.1.1.1.2.

8.3.1.1.2.2.1 Receive Subbands. The lowband is approximately 2195-2257 MHz and the higband is approximately 2248-2306 MHz.

TABLE 3.3.1.1.2-1 PRINCIPAL PI RECEIVER CHARACTERISTICS

Parameter	Value	Units	Subparagraph
Input Frequency Range	2200 - 2300	MHz	8.3.1.1.2.1
Triplexer Subbands	See Subparagraph		8.3.1.1.2.2
Input Signal Level Range	-124 to +25	dBm	8.3.1.1.2.3
AGC Range	-124 to -20	dBm	8.3.1.1.2.4
Out-of-Band Interference	See Subparagraph		8.3.1.1.2.5
Noise Figure	7.0	dB	8.3.1.1.2.6
Thresholds: Acquisition	-122.5	dBm	8.3.1.1.2.7
Tracking	-124.0	dBm	8.3.1.1.2.7
Acquisition Sweep Range	±85	kHz	8.3.1.1.2.8.1
Acquisition Sweep Rate	10	kHz/sec	8.3.1.1.2.8.1
Frequency Rate Tracking	44	kHz/sec	8.3.1.1.2.8.2
Frequency Tracking Range	±100	kHz	8.3.1.1.2.8.3
Lock Detector Performance	See Subparagraph		8.3.1.1.2.9
False Lock Immunity	See Subparagraph		8.3.1.1.2.10
Tracking Bandwidth	(TBS)	Hz	8.3.1.1.2.11
Maximum Phase Noise	15	Degrees-RMS	8.3.1.1.2.12
Maximum SPE	15	Degrees	8.3.1.1.2.13
Throughput Bandwidth	4.5	MHz	8.3.1.1.2.14
Output Signal Regulation	See Subparagraph		8.3.1.1.2.15
Throughput SNR Losses	(TBS)	dB	8.3.1.1.2.16

8.3.1.1.2.3 Input Signal Level Range. The receiver is operable over a range of -124 to +25 dBm.

8.3.1.1.2.4 AGC Dynamic Range. The AGC maintains the receiver transfer function in a linear state over an input signal level range of -124 to -20 dBm.

8.3.1.1.2.4.1 Receiver Gain Saturation. Above -20 dBm, the receiver IF amplifier circuits begin to amplitude saturate. Although this should not adversely affect the demodulation of constant envelope signals, it may cause receiver false-lock under certain conditions. Overall receiver performance is not guaranteed above -20 dBm.

8.3.1.1.2.4.2 Receiver Protective Limiting. At input signal levels of +10 dBm and higher, a preamplifier protective diode breakdown limiter becomes operative. Purposeful receiver operation above +10 dBm is not recommended.

8.3.1.1.2.5 Out-of-Band Interference. The receiver will operate with no more than a 1.0 dB SNR performance degradation due to out-of-band interference for the conditions listed in Table 8.3.1.1.2.5-1.

8.3.1.1.2.6 Noise Figure. The receiver noise figure, as referenced to the RF common input/output port, is 7.0 dB maximum.

8.3.1.1.2.7 Carrier Acquisition and Tracking Thresholds. The minimum received discrete carrier signal level for guaranteed acquisition is -122.5 dBm. The minimum received discrete carrier signal level for guaranteed tracking and demodulation performance is -124.0 dBm.

8.3.1.1.2.8 Carrier Dynamic Acquisition and Tracking

8.3.1.1.2.8.1 Receiver Frequency Sweep. For the purpose of acquisition, the receiver is swept ±85 kHz from the nominal receive frequency at a maximum rate of 10 kHz/sec. (This sweep is unrelated to the transmitter sweep.)

8.3.1.1.2.8.2 Frequency Rate Tracking. The maximum in-lock frequency rate that may be tracked is 44 kHz/sec.

8.3.1.1.2.8.3 Frequency Tracking Range. The receiver maximum frequency offset tracking capability is ±100 kHz from the nominal carrier frequency.

8.3.1.1.2.9 Lock Detector Statistical Performance. Lock detector probability of false alarm (indicating that the receiver is in lock when it is not) is (TBS) for a carrier level of -122.5 dBm and standard payload modulation conditions. Lock detector probability of indicating that the receiver is out of lock when it is not is (TBS) for a carrier level of -124.0 dBm. The lock detector must indicate an out-of-lock state for more than (TBS) ms before the receiver automatically enters the sweep acquisition mode.

8.3.1.1.2.10 False Lock Immunity. The receiver will not false lock to carrier sideband components for any NASA (STDN and DSN) or SGLS standard modulation conditions for received signal levels less than -20 dBm. (See Paragraph 8.3.4.2.2 for nonstandard modulation conditions.)

TABLE 8.3.1.1.2.5-1 OUT-OF-BAND INTERFERENCE CONDITIONS

Interference Signal Level	Applicable Frequency Range
-65 dBm	Low Band: 2165 MHz to (f_R - 10) MHz and (f_R + 10) MHz to 2285 MHz
-65 dBm	High Band: 2220 MHz to (f_R - 10) MHz and (f_R + 10) MHz to 2340 MHz
-25 dBm	Low Band: 200 MHz to 2165 MHz and 2285 MHz to 16 GHz
-25 dBm	High Band: 200 MHz to 2220 MHz and 2340 MHz to 16 GHz

8.3.1.1.2.11 Phase Locked Loop (PLL) Bandwidths

8.3.1.1.2.11.1 Tracking Bandwidth. The in-lock PLL tracking noise bandwidth, when the receiver is operating within the linear coherent AGC range, is (TBS) Hz (two-sided) and the damping factor is (TBS).

8.3.1.1.2.11.2 Acquisition Bandwidth. The out-of-lock PLL noise bandwidth, when the receiver is operating within the noncoherent AGC control range, is (TBS) Hz (two-sided) maximum, with a damping factor of (TBS)

8.3.1.1.2.12 PLL Phase Noise Components. Components and maximum values which comprise the PLL phase noise are listed in Table 8.3.1.1.2.12-1.

8.3.1.1.2.13 PLL Static Phase Error. PLL static error components and maximum values are listed in Table 8.3.1.1.2.13-1.

8.3.1.1.2.14 Wideband Demodulator. A wideband sinusoid phase-characteristic demodulator provides recovery of all carrier phase modulations. The throughput lowpass 3 dB bandwidth of the receiver, demodulator and output circuits is 4.5 MHz.

8.3.1.1.2.15 Wideband Output Signal Regulation. The wideband demodulated signal output level to the PSP, CIU and bent-pipe ports is controlled by an RMS type of regulating loop. PSP and CIU signal waveforms plus noise are regulated to 2.0 ±0.4 V RMS and the output amplifier clips or limits all peak values (plus or minus) to approximately 4.0 V maximum. The KuSP or bent-pipe waveform plus noise is regulated to 2.0 ±0.4 V RMS and the output amplifier clips or limits all peak values (plus or minus) to approximately 3.5 V maximum.

8.3.1.1.2.16 Demodulation SNR Loss Components. Table 8.3.1.1.2.16-1 lists the receiver (including the PSP) SNR loss components and maximum values.

8.3.1.2 Antenna Characteristics. The PI/payload link utilizes a single hemispherical antenna for both transmitting and receiving.

8.3.1.2.1 Antenna Location. The antenna is located at the top of the payload bay forward bulkhead, as shown in Figure 8.3.1.2.1-1.

8.3.1.2.2 Antenna Type. The antenna is a single-element cross-dipole which operates on the frequency range of 1740-1850 MHz with a VSWR < 1.5:1, and on the 2000-2300 MHz frequency range with a VSWR < 2.0:1.

8.3.1.2.3 Gain. The maximum on-axis gain is between 2.5 and 3.0 dB.

8.3.1.2.4 Beamwidth. The 3 dB beamwidth is bounded by a 100° cone aligned with the +Z axis of the Orbiter.

8.3.1.2.5 Polarization. Antenna polarization is selectable as either right-hand circular (RHCP) or left-hand circular (LHCP).

8.3.2 NASA Standard Payload/PI/PSP Communication Characteristics and Requirements

8.3.2.1 Command Signals. A single form of command signal is allowed, with summary characteristics listed in Table 8.3.2.1-1.

TABLE 8.3.1.1.2.12-1 PI TRACKING LOOP PHASE NOISE COMPONENTS

Component Source	Maximum Phase Noise Contribution
Additive Noise	$< 10^\circ$ RMS
Oscillator Instability	$< 5^\circ$ RMS
Modulation Tracking	$< 10^\circ$ RMS

TABLE 8.3.1.1.2.13-1 PI TRACKING LOOP STATIC PHASE ERROR COMPONENTS

Component Source	Component Maximum Value
Frequency Offset (Detuning and doppler)	3°
Frequency Dynamics	12°
No Modulation Slewing (Nonstandard direct carrier modulations only, see subparagraph 8.3.4.2.2.4.2)	18°

TABLE 8.3.1.1.2.16-1 PI/PSP SNR LOSS COMPONENTS

Component	Loss (dB)
PI Noise Figure Tolerance	-0.5
PI Interference Degradation	-1.0
PI Phase Noise Loss	-0.1
PI Demodulation Phase Offset Loss	-0.2
PI Filtering Loss	-0.2
PI Nonlinear Loss	(TBS)
PSP Subcarrier Demodulator Loss	-0.6
PSP Bit Synchronizer Loss	-0.9

(TBS)

FIGURE ? 3.1 ?.?-1 PAYLOAD ANTENNA LOCATION

TABLE 8.3.2.1-1 NASA STANDARD COMMAND SIGNAL CHARACTERISTICS

Parameter	Value	Units	Subparagraph
Waveform	Sinusoidal	-	8.3.2.1.1
Modulation	PSK, ±90	Degrees	8.3.2.1.1
Subcarrier Frequency	16	kHz	8.3.2.1.2
Carrier Modulation Index	1.0 ± 0.1	Radians	8.3.2.1.3
Bit Rates	2000 : 2^N , N=0,1,2,...,8	bps	8.3.2.1.4.1

8.3.2.1.1 Modulation Waveform. The command waveform is a sinewave subcarrier PSK modulated (±90°) by the command bits.

8.3.2.1.2 Subcarrier Frequency. The nominal command subcarrier frequency is 16 kHz.

8.3.2.1.2.1 Subcarrier Harmonic Distortion. The maximum harmonic components do not exceed 1% of the fundamental frequency amplitude.

8.3.2.1.2.2 Subcarrier Frequency Stability. The 60-sec averaged subcarrier frequency will be within $\pm 1 \times 10^{-5}$ of the nominal subcarrier frequency.

8.4.3.1.3 Carrier Modulation Index. Carrier modulation index for the command waveform is 1.0 ± 0.1 radian peak.

8.3.2.1.4 Data Modulation

8.3.2.1.4.1 Data Rates. The command data rates may be any one of the following:

2000 bps, 1000 bps, 500 bps, 250 bps, 125 bps, 62.5 bps, 31.25 bps, 15.625 bps or 7.8125 bps.

8.3.2.1.4.2 Data Bit Format. The bit format may be NRZ-L, NRZ-M or NRZ-S. Transition of the data waveform will coincide with a zero crossing of the subcarrier.

8.3.2.1.4.3 Data Asymmetry. The data bit asymmetry will not exceed 2% of the nominal data bit period.

8.3.2.1.4.4 Data Bit Jitter. The data bit peak phase jitter will not exceed 3% of the data bit period.

8.3.2.1.4.5 Command Bit Preamble. Whenever actual command bits are not being modulated onto the subcarrier, a prefix consisting of alternating "one" and "zero" bits is employed. The prefix always begins with a "one" bit ends with a "(TBS)" bit just prior to the first command message bit.

8.3.2.2 Telemetry Signals. A single form of telemetry signal is allowed, with summary requirements listed in Table 8.3.2.2-1.

8.3.2.2.1 Modulation Waveform. The telemetry waveform shall be a sinewave subcarrier PSK modulated (±90°) by the telemetry bits.

8.3.2.2.2 Subcarrier Frequency. The nominal telemetry subcarrier frequency shall be 1.024 MHz.

8.3.2.2.2.1 Subcarrier Harmonic Distortion. The maximum harmonic components shall not exceed (TBS)% of the fundamental frequency amplitude.

8.3.2.2.2.2 Subcarrier Frequency Stability. The long-term subcarrier frequency stability (uncertainty) shall be within ±0.01% of the nominal subcarrier frequency.

8.3.2.2.3 Payload Transmitter Modulation Index. The payload carrier modulation index shall be 1.0 ±0.1 radian peak.

TABLE 8.3.2.2-1 NASA STANDARD TELEMETRY SIGNAL REQUIREMENTS

Parameter	Value	Units	Subparagraph
Waveform	Sinusoidal	-	8.3.2.2.1
Modulation	PSK, ±90	Degrees	8.3.2.2.1
Subcarrier Frequency	1.024	MHz	8.3.2.2.2
P/L Modulation Index	1.0 ± 0.1	Radians	8.3.2.2.3
Bit Rate	16×2^N, N = 0,1,2,3,4	kbps	8.3.2.2.4.1
Bit Format	NRZ-L,M, or S, or Manchester-L, M, or S	-	8.3.2.2.4.2
Word Length	8	Bits	8.3.2.2.5.1
Minor Frame Length	8 to 1024	Words	8.3.2.2.5.2
Master Frame Length	1 to 256	Minor Frames	8.3.2.2.5.4
Transition Density	≥ 64 transitions in 512 bits		8.3.2.2.5.6
	≤ 64 consecutive bits w/o transition		8.3.2.2.5.6

8.3.2.2.4 Data Modulation

8.3.2.2.4.1 Data Rates. The telemetry data rates shall be any one of the following:

16 kbps, 8 kbps, 4 kbps, 2 kbps or 1 kbps.

8.3.2.2.4.2 Data Bit Format. The bit format shall be NRZ or Manchester L, M or S. The bits and subcarrier may be asynchronous or, if synchronous, no specific transition versus subcarrier phase relationship is required.

8.3.2.2.4.3 Data Asymmetry. (TBS)

8.3.2.2.4.4 Bit Rate Stability. The bit rate stability shall be better than 0.1% of the nominal bit rate.

8.3.2.2.5 Data Structure Formats

8.3.2.2.5.1 Word Length. The basic data word length shall be eight bits. (Longer words may be realized as multiples of eight bits).

8.3.2.2.5.2 Minor Frame Length. A minor frame shall be a minimum of eight words up to a maximum of 1024 words.

8.3.2.2.5.3 Minor Frame Synchronization Words. Minor frame synchronization words shall consist of 8, 16, 24 or 32 bit groups.

8.3.2.2.5.4 Master Frame Length. A master frame shall be comprised of between one and 256 minor frames.

8.3.2.2.5.5 Master Frame Synchronization Word. The master frame synchronization word shall consist of an eight-bit unique pattern or an eight-bit minor frame count.

8.3.2.2.5.6 Transition Density. The minimum data transition density requirement shall be for 64 or more transitions in any 512-bit block and for no segment greater than 64 bits without a transition.

8.3.2.2.6 Payload Minimum EIRP. Table 8.3.2.2.6-1 lists the payload minimum EIRP required to achieve a 1×10^{-4} bit error for the bit rates listed under 8.3.2.2.4.1 at the output of the PSP for the conditions of 10 nmi range, worst-case tolerances, and a 0 dB performance margin.

8.3.2.3 STDN Near-Earth (NE) Transponder Turnaround Requirements. The following paragraphs also apply to TDRS user transponders operating in the STDN mode.

8.3.2.3.1 Forward Link Sweep Acquisition. The NE transponder forward link from the Orbiter to the payload will be frequency swept in the PI transmitter (for acquisition purposes) in accord with 8.3.1.1.1.7 utilizing the fast sweep rate of 10 kHz/sec over the ±75 kHz range.

TABLE 8.3.2.2.6-1 NASA PAYLOAD MINIMUM EIRP REQUIREMENTS

Bit Rate	EIRP
16 kbps	23.8 dBm
8 kbps	20.8 dBm
4 kbps	17.8 dBm
2 kbps	14.8 dBm
1 kbps	14.3 dBm*

*Set by carrier minimum acquisition level requirement.

8.3.2.3.1.1 Transponder Minimum PLL Acquisition Bandwidth. In order to achieve a 0.9 probability of carrier acquisition when the PI sweep crosses the transponder nominal receive frequency, the transponder two-sided loop noise bandwidth shall not be less than 200 Hz.

8.3.2.3.1.2 Sweep Tracking Requirement. The PI transmitter sweep may go through a number of complete sweep cycles before being disabled. The transponder receiver must therefore be capable of tracking the entire PI transmitter sweep range (±75 kHz) for the condition of PI transmitter maximum nominal frequency offset (±0.001%).

8.3.2.3.2 Return Link Sweep Acquisition. The PI receiver may be required to acquire the payload transmitter signal when the transponder is in its one-way mode (transmitter carrier frequency derived from the transponder auxiliary oscillator) or in the two-way mode with the forward link sweep transponded to the return link carrier.

8.3.2.3.2.1 Auxiliary Oscillator Stability. The long-term stability of the transponder transmitter's nominal carrier frequency as derived from the auxiliary oscillator shall be no worse than ±0.001%.

8.3.2.3.2.2 Auxiliary Oscillator-to-VCO Switchover. There are no PI-imposed requirements on the auxiliary oscillator-to-VCO switchover (when the forward link becomes acquired) in terms of the resulting frequency step.

8.3.2.3.2.3 PI Receiver Lock Loss Due to Auxiliary Oscillator-to-VCO Switchover. It is expected that, when the transponder switches its transmitter frequency source from auxiliary oscillator to the VCO, PI receiver lock (if it had been attained in the one-way mode) will be lost.

8.3.2.3.2.4 Transponder Turnaround Ratio. The transponder transmit/receive frequency turnaround ratio shall be 240/221.

8.3.2.3.2.5 Return Link Carrier Sideband Level Due to Forward Link Modulation Feedthrough. The maximum feedthrough modulation sidebands of the return link carrier by the forward link command modulation (16 kHz subcarrier) shall not exceed a return link sideband level greater than -35 dBc.

8.3.2.4 DSN Deep-Space (DS) Transponder Turnaround Requirements

8.3.2.4.1 Forward Link Sweep Acquisition. The NE transponder forward link from the Orbiter to the payload will be frequency swept in the PI transmitter (for acquisition purposes) in accord with 8.3.1.1.1.7 utilizing the slow sweep rate of (TBS) Hz/sec over the ±33 kHz range.

8.3.2.4.1.1 Transponder Minimum PLL Acquisition Bandwidth. In order to achieve a 0.99 probability of carrier acquisition when the sweep crosses the transponder nominal receive frequency, the transponder two-sided loop noise bandwidth shall not be less than (TBS) Hz. (It has been assumed that, when the DS transponder is operating with the Orbiter, the minimum receive signal level will be (TBS) dB above the PLL absolute threshold for which the nominal 18 Hz two-sided loop noise bandwidth occurs.)

8.3.2.4.1.2 Maximum Swept Acquisition Time. The time required to sweep the entire ±33 kHz frequency uncertainty range using the slow sweep rate will be (TBS) sec.

8.3.2.4.1.3 Sweep Tracking Requirement. In the slow sweep rate mode, the PI transmitter sweep will nominally go through one complete sweep cycle and then become disabled. The transponder receiver must therefore be capable of tracking the entire PI transmitter sweep range (±33 kHz) for the condition of PI transmitter maximum nominal frequency offset of ±0.001%.

8.3.2.4.2 Return Link Sweep Acquisition. The PI receiver may be required to acquire the payload transmitter signal when the transponder is in its one-way mode (transmitter carrier frequency derived from the transponder auxiliary oscillator) or in the two-way mode with the forward link sweep transponded to the return link carrier.

8.3.2.4.2.1 Auxiliary Oscillator Stability. The long-term stability of the transponder transmitter's nominal carrier frequency as derived from the auxiliary oscillator shall be no worse than ±0.001%.

8.3.2.4.2.2 Auxiliary Oscillator-to-VCO Switchover. There are no PI-imposed requirements on the auxiliary oscillator-to-VCO switchover (when the forward link becomes acquired) in terms of the resulting frequency step.

8.3.2.4.2.3 PI Receiver Lock Loss Due to Auxiliary Oscillator-to-VCO Switchover. It is expected that, when the transponder switches its transmitter frequency source from auxiliary oscillator to the VCO, PI receiver lock (if it had been attained in the one-way mode) will be lost.

8.3.2.4.2.4 Transponder Turnaround Ratio. The transponder transmit/receive frequency turnaround ratio shall be 240/221.

8.3.2.4.2.5 Return Link Carrier Sideband Level Due to Forward Link Modulation Feedthrough. The maximum feedthrough modulation sidebands of the return link carrier by the forward link command modulation (16 kHz subcarrier) shall not exceed a return link sideband level greater than -35 dBc.

8.3.3 DOD/SGLS Standard Payload/PI/CIU Communication Characteristics and Requirements

8.3.3.1 Command Signals. A single form of command signal is allowed, with summary characteristics listed in Table 8.3.3.1-1.

8.3.3.1.1 Modulation Waveform. The command signal is a ternary FSK/AM waveform with form as shown in Figure 8.3.3.1.1-1. Three command symbols are employed and the composite FSK waveform is 50% amplitude modulated by a triangular function of frequency equal to one-half the command symbol rate.

TABLE 8.3.3.1 1 SGLS STANDARD COMMAND SIGNAL CHARACTERISTICS

Parameter	Value	Units	Subparagraph
Waveform	Sinusoidal with AM	-	8.3.3.1.1
Modulation	Ternary FSK	-	8.3.3.1.1
			8.3.3.1.2
Symbol Frequencies	"S" = 65	kHz	
	"0" = 76	kHz	
	"1" = 95	kHz	
Carrier Modulation Indices	0.3 ± 10%	radians	8.3.3.1.3
	1.0 ± 10%	radians	
Symbol Rates	1000	sps	8.3.3.1.4.1
	2000	sps	

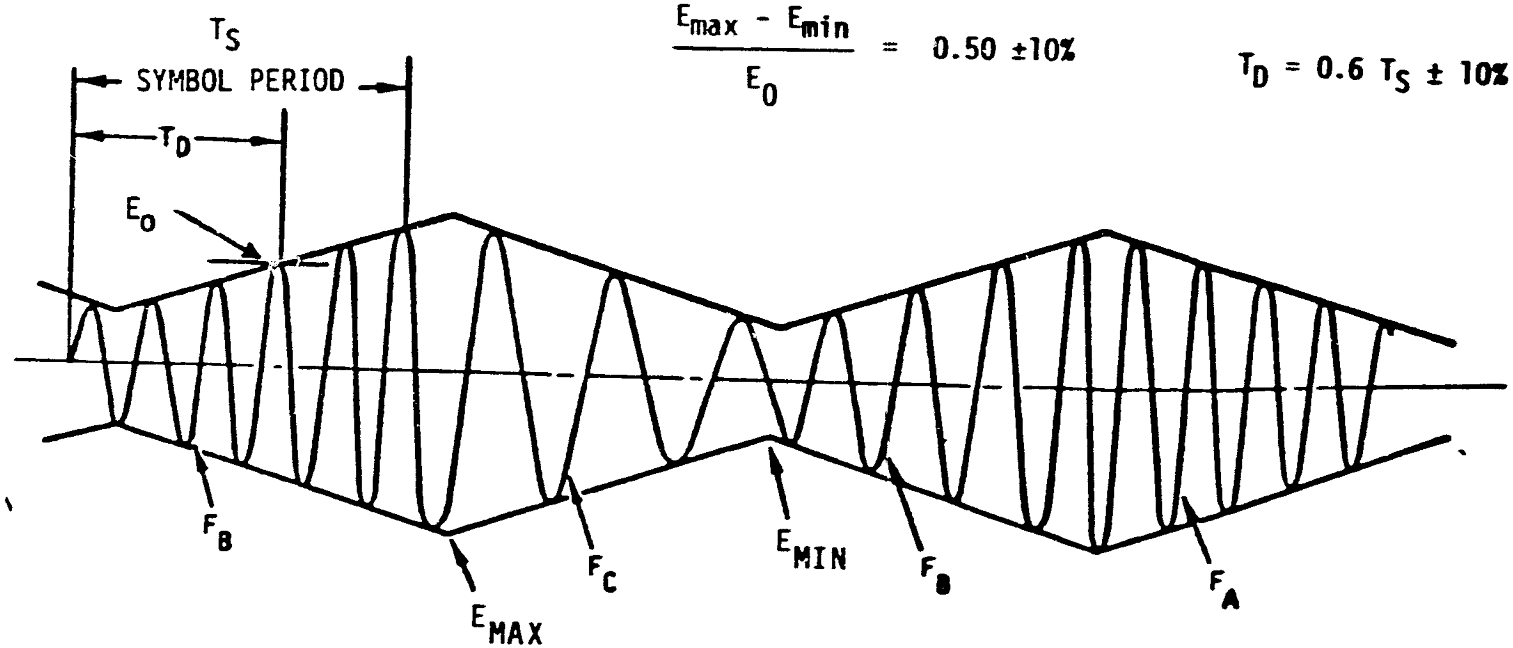


FIGURE 8.3.3.1.1-1 SGLS FSK/AM COMMAND WAVEFORM

8.3.3.1.2 Command Tone Frequencies. The command symbol tone frequencies are as follows:

Logic "S" - 65 kHz

Logic "0" - 76 kHz

Logic "1" - 95 kHz

8.3.3.1.2.1 Tone Frequency Accuracy. The maximum nominal tone frequency error will not exceed ±(TBS) %

8.3.3.1.3 Carrier Modulation Indices. Two carrier modulation indices are employed: 1.0 ±10% radians or 0.3 ±10% radians peak.

8.3.3.1.4 Data Modulation

8.3.3.1.4.1 Data Symbol Rates. The ternary symbols are transmitted at the rate of 1000 symbols/sec or 2000 symbols/sec.

8.3.3.1.4.2 Triangular AM Clock. A triangular waveform clock at one-half the symbol rate and with its positive zero crossing delayed by 0.6 T_S ±10% from the symbol epoch amplitude modulates the composite symbol stream with a 50% intensity.

8.3.3.1.4.3 Data Format (TBS)

8.3.3.1.4.4 Command Bit Preamble (TBS)

8.3.3.2 Telemetry Signals. Both PSK and FM subcarriers are allowed; summary requirements are listed in Table 8.3.3.2-1.

8.3.3.2.1 Modulation Waveforms

8.3.3.2.1.1 PSK Subcarriers. Digital telemetry waveforms shall be sinewave subcarriers PSK modulated (±90°) by the telemetry bits.

8.3.3.2.1.2 FM Subcarriers. The analog telemetry waveform shall be a sinewave subcarrier frequency modulated by the analog telemetry signal to a maximum deviation of ±(TBS) Hz-peak.

8.3.3.2.2 Subcarrier Frequencies. The nominal PSK subcarrier frequencies shall be 1.024 MHz and 1.7 MHz. The nominal FM subcarrier frequency shall be 1.7 MHz.

8.3.3.2.2.1 Subcarrier Harmonic Components. The maximum harmonic components of any subcarrier shall not exceed (TBS) % of the fundamental frequency amplitude.

8.3.3.2.2.2 PSK Subcarrier Frequency Stability. The long-term subcarrier frequency uncertainty shall be within ±0.01% of the nominal subcarrier frequency.

8.3.3.2.2.3 FM Subcarrier Frequency Accuracy. When the FM subcarrier is unmodulated, the maximum frequency offset from the nominal frequency shall not exceed (TBS) %.

TABLE 8.3.3.2-1 SGLS STANDARD TELEMETRY SIGNAL REQUIREMENTS

Parameter	Value	Units	Subparagraph
Waveforms	Sinusoidal	-	8.3.3.2.1
Modulations	PSK, ±90	Degrees	8.3.3.2.1.1
	FM, ±(TBS)	Hz-peak	8.3.3.2.1.2
Subcarrier Frquencies	PSK - 1.024	MHz	8.3.3.2.2
	PSK - 1.7	MHz	
	FM - 1.7	MHz	
P/L Modulation Indices	1.0 ± 10%	Radians	8.3.3.2.3
	0.3 ± 10%	Radians	
Digital Bit Rates	$256 \div 2^N$	kbps	8.3.3.2.4.1
	[N=0,1,2,...,10],		
	and 10	kbps	
Bit Format	NRZ-L or	-	8.3.3.2.4.2
	Manchester-L		
FM Frequency Response	100 - 200k	Hz	8.3.3.2.4.5
Data Word Length	(TBS)	Bits	8.3.3.2.5.1
Minor Frame Length	(TBS)	Words	8.3.3.2.5.2
Master Frame Length	(TBS)	Minor Frames	8.3.3.2.5.4
Transition Density	(TBS)		8.3.3.2.5.6

8.3.3.2.3 Payload Transmitter Modulation Indices. Each subcarrier shall employ one of two modulation indices: 1.0 ±10% rad peak or 0.3 ±10% rad peak. A maximum of two subcarriers may simultaneously modulate the carrier.

8.3.3.2.4 Subcarrier Modulations

8.3.3.2.4.1 Digital Data Rates. The telemetry digital data rates shall be any one of the following in accord with the specified subcarrier frequency:

1.024 MHz and 1.7 MHz Subcarriers		1.7 MHz Subcarrier Only
250 bps	8 kbps	128 kbps
500 bps	10 kbps	256 kbps
1 kbps	16 kbps	
2 kbps	32 kbps	
4 kbps	64 kbps	

8.3.3.2.4.2 Data Bit Format. The bit format shall be NRZ-L or Manchester-L.

8.3.3.2.4.3 Data Asymmetry. (TBS)

8.3.3.2.4.4 Bit Rate Stability. The bit rate stability shall be better than 0.1% of the nominal bit rate.

8.3.3.2.4.5 FM Signal Frequency Response. The baseband signal that frequency modulates the subcarrier shall have a highpass rolloff of (TBS) dB/octave beginning at 100 Hz and a lowpass rolloff of (TBS) dB/octave beginning at 200 kHz.

8.3.3.2.4.6 FM/FM Signal Structure. When the FM subcarrier is frequency modulated by a composite set of frequency modulated sub-subcarriers, the signal structure shall comply with the following requirements: (TBS).

8.3.3.2.5 Data Structure Formats

8.3.3.2.5.1 Word Length. The basic data word length shall be (TBS) bits.

8.3.3.2.5.2 Minor Frame Length. (TBS)

8.3.3.2.5.3 Minor Frame Synchronization Words. (TBS)

8.3.3.2.5.4 Master Frame Length. (TBS)

8.3.3.2.5.5 Master Frame Synchronization Word. (TBS)

8.3.3.2.5.6 Transition Density. (TBS)

8.3.3.2.6 Payload Minimum EIRP. Table 8.3.3.2.6-1 lists the payload minimum EIRP required to achieve a 1×10^{-4} bit error rate for the bit rates listed under 8.3.3.2.4.1 at the output of the CIU for the conditions of 10 nmi range, 1.0 rad modulation index, worst-case tolerances, and a 0 dB performance margin.

TABLE 8.3.3.2.6-1 SGLS PAYLOAD MINIMUM EIRP REQUIREMENTS

Bit Rate	EIRP
256 kbps	35.9 dBm
128 kbps	32.9 dBm
64 kbps	29.9 dBm
32 kbps	26.9 dBm
16 kbps	23.8 dBm
10 kbps	21.8 dBm
8 kbps	20.8 dBm
4 kbps	17.8 dBm
2 kbps	14.8 dBm
1 kbps	14.3 dBm*
500 bps	14.3 dBm*
250 bps	14.3 dBm*

*Set by carrier minimum acquisition level requirement.

8.3.3.3 DOD/SGLS Transponder Turnaround Requirements

8.3.3.3.1 Forward Link Sweep Acquisition. Some SGLS transponder receivers have a self-contained automatic sweep acquisition capability. The PI transmitter sweep capability is therefore not required for such transponders and will be disabled. For those SGLS transponders not having a self-contained automatic sweep acquisition capability, the PI transmitter will be frequency swept in accord with 8.3.1.1.1.7, utilizing the fast sweep rate of 10 kHz/sec over the ±55 kHz range.

8.3.3.3.1.1 Transponder Minimum PLL Acquisition Bandwidth. In order to achieve a 0.9 probability of carrier acquisition when the PI sweep crosses the transponder nominal receive frequency, the transponder two-sided loop noise bandwidth shall not be less than 200 Hz.

8.3.3.3.1.2 Sweep Tracking Requirement. The PI transmitter sweep may go through a number of complete sweep cycles before being disabled. The transponder receiver must therefore be capable of tracking the entire PI transmitter sweep range (±55 kHz) for the condition of PI transmitter maximum nominal frequency offset (±0.001%).

8.3.3.3.2 Return Link Frequency Stability and Acquisition Requirements

8.3.3.3.2.1 Auxiliary Oscillator Stability. The long-term stability of the transponder transmitter's nominal carrier frequency as derived from the auxiliary oscillator shall be no worse than ±0.001%.

8.3.3.3.2.2 Auxiliary Oscillator-to-VCO Switchover. There are no specific requirements as the resulting frequency step is expected to be within the PI receiver acquisition range.

8.3.3.3.2.3 PI Receiver Lock Loss Due to Auxiliary Oscillator-to-VCO Switchover. It is expected that, when the transponder switches its transmitter frequency source from auxiliary oscillator to the VCO, PI receiver lock (if it had been attained in the one-way mode) will be lost.

8.3.3.3.2.4 Transponder Turnaround Ratio. The transponder transmit/receive frequency turnaround ratio shall be 256/205.

8.3.3.3.2.5 Return Link Carrier Sideband Level Due to Forward Link Modulation Feedthrough. The maximum feedthrough modulation sidebands of the return link carrier by the forward link command modulation (65 kHz, 76 kHz, 95 kHz tones and the one-half symbol rate clock and its harmonics) shall not exceed a return link sideband level greater than -35 dBc.

8.3.4 Nonstandard Payload/PI/Bent-Pipe Communication Requirements. Nonstandard communications are those which do not conform to the NASA/PSP or DOD/CIU command and telemetry capabilities. Nonstandard communication signals must, however, comply with the PI capabilities and requirements.

8.3.4.1 Command Signals. An input port to the PI transmitter phase modulator exists aboard the Orbiter at the Payload Station (PS). This port allows nonstandard command signals to be transmitted from the PS; however, no ground through Orbiter-to-payload nonstandard command capability exists. Therefore, if such command transfer capability is required, use must be made of either the PSP or CIU standard command signalling capability. PS command signals must comply with the PI transmitter requirements of 8.3.1.1.1.

8.3.4.2 Telemetry Signals. Nonstandard telemetry signals are defined as those which cannot be handled by either the PSP or CIU. Such signals are acquired and demodulated by the PI, and the resulting baseband signal is transferred to the ground via the Ku-band bent-pipe link for processing. Nonstandard telemetry cannot be detected, sorted and displayed aboard the Orbiter. In order that nonstandard telemetry signals be compatible with the PI performance criteria, various conditions and restrictions are imposed as per the following subparagraphs.

8.3.4.2.1 General Payload Transmitter Modulation Criteria

8.3.4.2.1.1 Allowable Modulations. Phase modulation (PM) of the carrier is the only allowable type of modulation. Frequency modulation (FM) and amplitude modulation (AM) of the carrier are not permitted. Quadriphase and spread spectrum modulations are also not allowed.

8.3.4.2.1.2 Maximum Carrier Suppression. The maximum allowable carrier suppression due to the composite of all phase-modulating sources shall not exceed 10 dB.

8.3.4.2.1.3 Subcarrier Modulation. When subcarriers are employed, they may be either phase or frequency modulated. Amplitude modulated subcarriers are not permitted. Restrictions on the use of subcarriers are given under 8.3.4.2.2.2 and 8.3.4.2.2.3.

8.3.4.2.1.4 Direct Carrier Modulation by Baseband Signals. Direct carrier modulation by analog type baseband signals is not allowed. Direct carrier modulation by digital type baseband signals is allowed, subject to the restrictions given under 8.3.4.2.2.4.

8.3.4.2.2 Specific Nonstandard Modulation Restrictions

8.3.4.2.2.1 Discrete Frequency Component Sideband Levels. Carrier phase modulation by periodic signals (sinusoids, square-waves, etc.) having fundamental frequencies less than 200 kHz is not permitted. No incidental and/or spurious discrete frequency component sideband levels shall be greater than -32 dBc on a frequency range of $\pm$200 kHz about the carrier frequency.

8.3.4.2.2.2 Frequency Modulated Subcarriers

8.3.4.2.2.2.1 Analog Modulations. No analog signal frequency modulated subcarrier, on a frequency range of $\pm$200 kHz about the carrier frequency shall be allowed to phase modulate the carrier if the inequality

$$f_m \Delta f > 8 \times 10^3$$

is violated, where f_m is the bandwidth or maximum frequency of the baseband analog signal in Hz and Δf is the peak frequency deviation of the subcarrier in Hz. Provided that the above inequality is satisfied, the maximum allowable carrier phase modulation index, β, by the frequency modulated sinusoidal subcarrier shall be the lesser of 1.85 rad (106°) or the β which satisfies the relationship:

$$J_1(\beta)/J_0(\beta) = 5.43 \times 10^{-7} f_m \Delta f,$$

or the β which results in a lock detector false alarm probability greater than 1×10^{-4} when the lock detector bandwidth is centered on the FM subcarrier (i.e., on either relative subcarrier frequency sideband of the carrier). The value of β may be determined with the aid of Fig. 8.3.4.2.1-1.

8.3.4.2.2.2.2 Digital Modulations. No frequency-shift-keyed (FSK) subcarrier, on a frequency range of ±200 kHz about the carrier frequency, shall be allowed to phase modulate the carrier if the inequality

$$R_b > 2.5\times10^{2}$$

is violated, where R_b is the data bit rate (bps). Provided that the above inequality is satisfied, the maximum allowable carrier phase modulation index, β, by the FSK modulated sinusoidal subcarrier shall be the lesser of 1.85 rad (106°) or the β which satisfies the relationship

$$J_1(\beta)/J_0(\beta) \geq 6.9\times10^{-8}(R_b)^2$$

or the β which results in a lock detector false alarm probability greater than 1×10^{-4} when the lock detector bandwidth is centered on the FM subcarrier. The value of β may be determined with the aid of Fig. 8.3.4.2.1-1.

8.3.4.2.2.3 Phase Modulated Subcarriers

8.3.4.2.2.3.1 Analog Modulations. Phase modulation of subcarriers by analog baseband signals is not recommended due to inefficiency. As a result, no such modulations are expected and no guidelines have been developed.

8.3.4.2.2.3.2 Digital Modulations. No phase-shift-keyed (PSK) subcarrier, on a frequency range of ±200 kHz about the carrier frequency, shall be allowed to phase modulate the carrier if the inequality

$$R_b > 2.5\times10^{2}$$

is violated, where R_b is the data bit rate (bps). Provided that the inequality above is satisfied, the maximum allowable carrier phase modulation index, β, by the PSK modulated sinusoidal subcarrier shall be the lesser of 1.85 rad (106°) or the β which satisfies the relationship

$$J_1(\beta)/J_0(\beta) \geq 6.9\times10^{-8}(R_b)^2 ,$$

or the β which results in a lock detector false alarm probability greater than 1×10^{-4} when the lock detector bandwidth is centered on the FM subcarrier. The value of β may be determined with the aid of Fig. 8.3.4.2.1-1.

8.3.4.2.2.4 Direct Carrier Modulations

8.3.4.2.2.4.1 Analog Modulations. Direct phase modulation of the carrier by an analog baseband signal is not recommended due to inefficiency. As no such modulations are expected, no guidelines have been developed.

8.3.4.2.2.4.2 Digital Modulations. The criterion for the minimum allowable bit rate is based upon a carrier tracking loop RMS phase noise component due to modulation sidebands tracking of 10° or less. The allowable NRZ bit rate must therefore satisfy the following inequality:

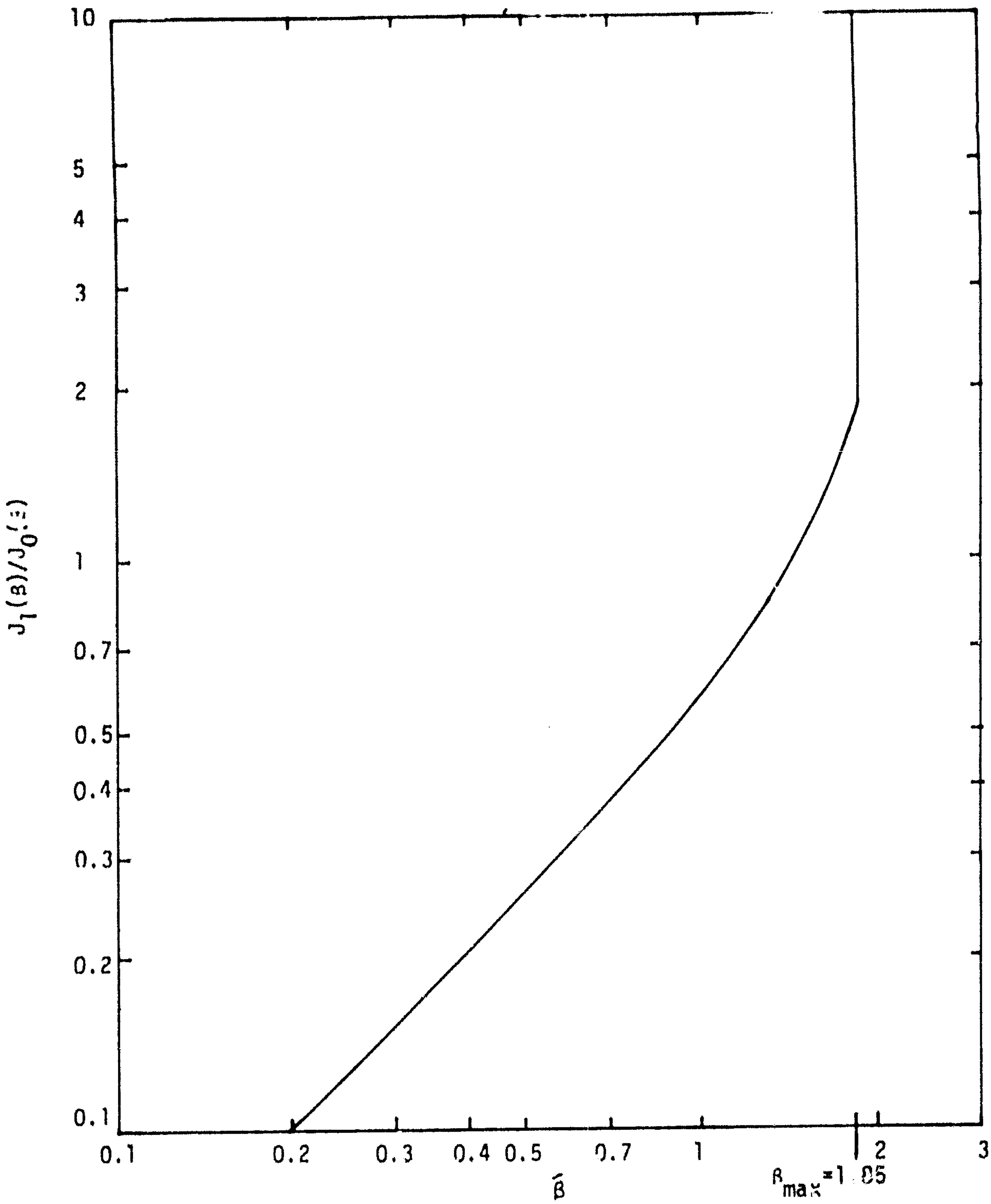


Figure 8.3.4.2.1-1 Curve Used for Determination of Modulation Index

$$R_b > 4.8 \times 10^4 \tan^2(\beta)$$

where the numerical coefficient is based upon the PI carrier tracking loop maximum in-lock noise bandwidth and β is the carrier phase deviation ($\beta \leq 71.5°$). In order to keep carrier loop phase slewing to less than 18° during a string of transitionless data bits, the maximum number of such bits shall be:

$$\text{Maximum No. of Bits Without Transition} = 1.65 \times 10^{-4} R_b$$

This transitionless period must be followed by a reasonable number of transitions in such a pattern that the slewing error is negated within a period of bits equal to five times the transitionless period. To avoid the problem of bit slewing, Manchestering of the bits is recommended. Given Manchestered bits, the minimum bit rate allowed is the larger bit rate calculated from:

$$R_b \geq 640 \tan^2(\beta)$$

$$R_b \geq 2.7 \times 10^3 \sqrt{\tan(\beta)} \ .$$

Maximum modulation index β for all digital modulations shall not exceed 71.5° or 1.25 rad.

8.3.4.2.3 Bent-Pipe Feedthrough Characteristics

8.3.4.2.3.1 PI/KuSP Configuration. Figure 8.3.4.2.3.1-1 shows the general PI/KuSP configuration for the bent-pipe. Telemetry signals may be input to either the narrowband or wideband channels as defined in the following subparagraphs.

8.3.4.2.3.2 Narrowband Channel. The anticipated use of the narrowband channel is by PSK or FM subcarriers which have nonstandard frequencies and/or nonstandard data rates or analog modulations. Characteristics are (TBS).

8.3.4.2.3.3 Wideband Channel. Wideband signals are defined as those which have maximum frequency components on the order of 4.5 MHz. Such signals are allowed to directly frequency modulate the Ku-band FM transmitter. The amount of deviation achieved depends upon the nature of the modulating waveform, its RMS and peak values being established by the PI wideband output noncoherent regulator (see subparagraph 8.3.1.1.2.15).

8.3.4.3 Nonstandard Transponder Turnaround Requirements. Nonstandard transponders are defined as those which are not explicitly STDN/NE (subparagraph 8.3.2.4) or SGLS (subparagraph 8.3.3.3) types. Nonstandard transponders must, however, conform to the PI frequency channel assignments and other PI acquisition and tracking requirements.

8.3.4.3.1 Frequency Channel Assignments and Turnaround Ratios. A nonstandard transponder must have a turnaround ratio of 240/221 and adhere to the channel assignments of Tables 8.3.1.1.1.1-2 and 8.3.1.1.1.1-3, or a turnaround ratio of 256/205 and adhere to the channel assignments of Table 8.3.1.1.1.1-4.

8.3.4.3.2 Forward Link Acquisition. A nonstandard transponder that does not possess an inherent receiver acquisition capability must make use of the PI transmitter sweep capability outlined under 8.3.1.1.1.7. Either

(TBS)

FIGURE 8.3.4.2.3.1-1 PI/KuSP BENT-PIPE INTERFACE CONFIGURATION of the two sweep rates may be employed and the transponder two-sided loop noise bandwidth shall not be less than the following limits:

Sweep Rate	PLL Noise Bandwidth
10 kHz/sec	>200 Hz
(TBS) Hz/sec	>(TBS) Hz

8.3.4.3.3 Forward Link Sweep Tracking. The nonstandard transponder must be capable of tracking the entire PI transmitter sweep range as defined under 8.3.1.1.1 7 for the condition of PI transmitter maximum nominal frequency offset of ±0.001%.

8.3.4.3.4 Return Link Sweep Acquisition. The PI receiver may be required to acquire the payload transmitter signal when the transponder is in its one-way mode (transmitter carrier frequency derived from the transponder auxiliary oscillator) or in the two-way mode with the forward link sweep transponded to the return link carrier.

8.3.2.3.5 Auxiliary Oscillator Stability. The long-term stability of the transponder transmitter's nominal carrier frequency as derived from the auxiliary oscillator shall be no worse than +0.001%.

8.3.2.3.5.1 Phase Noise. The transponder transmitter phase noise when the carrier is derived from the auxiliary oscillator shall not produce more than a 3° RMS tracking phase error in a 1000 Hz two-sided tracking bandwidth.

8.3.2.3.6 Return Link Incidental Modulations

8.3.2.3.6.1 Spurs. Any discrete frequency spurs within ±200 kHz of the return link carrier frequency shall be less than -32 dBc.

8.3.2.3.6.2 Forward Link Modulation Feedthrough. The maximum feedthrough modulation sidebands of the return link carrier by any frequency component of the forward link command modulation shall not exceed a return link sideband level greater than -35 dBc.

8.3.5. Ku-Band Rendezvous Radar Interfaces. The Ku-band and rendezvous radar will skin track a target in the passive mode or track a transponder-equipped target in the active mode.

8.3.5.1 Passive Mode Characteristics. The rendezvous radar shall have the interface characteristics defined in Table 8.3.5.1-1 when operative in the passive mode.

8.3.5.2 Active Mode Characteristics. The rendezvous radar shall have the interface characteristics defined in Table 8.3.5.2-1 when operating in the active mode.

8.3.5.3 Transponder Characteristics. The payload shall be specified with a transponder that is compatible with the Ku-band rendezvous radar. The transponder characteristics are TBD.

TABLE 8.3.5.1-1 RADAR PASSIVE MODE

ELECTRICAL INTERFACE CHARACTERISTICS

Parameter	Dimension	Value	Notes
1. Target Type			
Size	Square Meter	1.0 Minimum	Radar system sized to detect in 1 m² scintillating target at 12 minimum angular search field of 30 deg by 30 deg with 99% probability.
Scintillation Characteristics		Swirling Case I target	Target is stabilized in 3 axes to an angular rate of TBD deg/sec.
2. Radar Operating Frequency	GHz	Nominal Minimum at 13.75	4 Step Fudge Diversity - 52MHz per step during detection and tracking.
3. Antenna Characteristics			
Gain	dB	38.5	At 13.775 GHz
Sidelobe	dB relative to mainbeam	20 minimum	
Type		5 "Horn" monopulse, automatic tracking, front-fed parabola.	Two-gimbal antenna mount
4. Transmitter Power	Watts	50 peak, 10 average	Peak and average power are function of range and selectable duty cycle. Peak power variable over 45 dB range - Duty cycle variable 0.001 to 0.3

TABLE 8.3.5.1-1 RADAR PASSIVE MODE ELECTRICAL

INTERFACE CHARACTERISTICS (Continued)

Parameter	Dimension	Value	Notes
PRF	pulses/ sec	TBD Detection	
5. Receiver			
Noise Figure	dB	5	
Input Power Limits	watts average	50	At input port to low-noise amplifier
Dynamic range	dB	115	

TABLE 8.3.5.2-1 RADAR ACTIVE MODE ELECTRICAL

INTERFACE CHARACTERISTICS

Parameter	Dimension	Value	Notes
1. Target Type			
Transponder Pulse Beacon			Target carries coherent pulse transponder which retransmits amplified replica of received pulse. Beacon carrying target is stabilized in 3 axes to TBD deg/sec each axis.
Operating Range	ft.	1.824×10^6 Detection 100 minimum	
2. Beacon Characteristics			
Minimum Detectable Signal	dBm	TBD	Function of target antenna and receiver sensitivity
EIRP	dBW	TBD	
Coherence		TBD	
Delay	μsec	TBD	
3. Radar Characteristics			
Transmit Freq.	GHz	13.8 nominal	
Receive Freq.	GHz	13.8	Same as radar transmit freq. ±TBD Hz.
Antenna Gain	dB	38.5	Transmit and

TABLE 8.3.5.2-1 RADAR ACTIVE MODE ELECTRICAL

INTERFACE CHARACTERISTICS (Continued)

Parameter	Dimension	Value	Notes
			receive
Antenna side-lobe level	dB relative to main beam	20 minimun	
Antenna Type		5 "Horn" monopulse, automatic angle track, front-fed parabola	Two-gimbal antenna mount.
PRF's	pulses per sec.	224 search and track 7177 Track	For range greater than 10 nm. Range less than 10 nm.
Pulse widths	µsec.	Dual 4.15 and 0.122 4.15 0.122	Used in search ranger. Used for track when range >10 min. Used for track when range < 10 min.
Transmit Power	Watts	60	Peak-duty cycle in search or track and target range determines average power. Peak power controllable over 45 dB range.
Receiver noise Figure	dB	5	
Input Power Limit	Watts (average)	50 - damage level 2.5X10³ 1 dB gain compression	At input port to low-noise amp. Low-noise amp. to low-noise amp.
Dynamic Range	dB	115	

uma 35

APPENDIX III

PRELIMINARY INTERFACE REVISION NOTICE SD-152A

UPDATE OF SECTION 8.3 OF ICD 2-19001

FOR DETACHED PAYLOADS

OCTOBER 3, 1979

INTERFACE REVISION NOTICE

AFFECTED ICD		IRN		
1 NO ICD 2-19001	REV F	2 TRACKING IDENTIFIER	3 NO	4 SHEET 1 OF 45
7 PROGRAM CODE		A SD-152A		5. PANEL AFFECTED Avionics
8 TITLE SHUTTLE ORBITER/CARGO STANDARD INTERFACES		B		6 INITIATED BY Rockwell International
		C PCIN		

10 THIS IRN EFFECTIVITY

Orbiter Vehicles 102, 099, 103 & Subs.

8 PAYLOAD SPECIFIC ICDs

11 REASON FOR CHANGE

Update communications interfaces with detached payloads to current Orbiter design.

CHANGE ICD EFFECTIVITY	12 TO	13 FROM

14 IRN NO	15 NEW IRN EFFECTIVITY	16 PREVIOUS IRN EFFECTIVITY

17 DESCRIPTION OF CHANGE

1. DELETE: Section 8.3, DETACHED PAYLOADS, and replace with revised section, attached.
2. REVISE: Table of Contents, List of Tables and List of Figures to agree with this change.

NOTE: This PIRN includes data from IRN 060 (SD-036), IRN 080 (SD-113), PIRN JSC-015, and PIRN SD-145.

ROUGH DRAFT

ROUGH DRAFT

18 PREPARED BY	19 TECH CONCURRENCE	20. ORG.	21. DATE
W. K. McCarty WKM		Payload/Cargo Integration & Advanced Engineering	3 October 1979

22 CONCUR SIGNATURE AND ORGN	REV	DATE	SIGNATURE AND ORGN	REV	DATE	SIGNATURE AND ORGN	REV	DATE

23		JSC APPROVAL	DATE

8.3 Detached Payloads. The Payload Interrogator (PI) provides two-way RF communication between the Orbiter and detached payloads within a range of up to 10NM. This capability shall include acceptance and processing of tone commands for transmission on either the NASA or DOD payload frequencies. The PI shall not operate during ascent but shall be required to survive the environmnet during ascent without ~~dyr~~adation to subsequent performance. Paragraphs applicable to STDN, DSN, SGLS, and nonstandard payloads are indicated in the following breakdown:

NASA/STDN Payloads--Paragraphs 8.3.1 and 8.3.2.

NASA/DSN Payloads--Paragraphs 8.3.1 and 8.3.2.

DOD/SGLS Payloads--Paragraphs 8.3.1 and 8.3.3.

Nonstandard Payloads--Paragraphs 8.3.1, 8.3.4, and 8.3.5.

ROUGH DRAFT

The Ku-band rendezvous radar will skin-track a target in the passive mode or track a transponder-equipped target in the active mode. Paragraphs applicable to the Ku-band radar are 8.3.6.1, 8.3.6.2, and 8.3.6.3.

In the following paragraphs, "characteristics" are those of the Orbiter avionics that the payload must be cognizant of, and "requirements" are specifications placed upon the payload communications equipment.

8.3.1 S-Band PI Interface

8.3.1.1 PI Performance Characteristics.

8.3.1.1.1 Transmitter Characteristics. The principal transmitter characteristics are listed in Table 8.3.1.1.1-1.

8.3.1.1.1.1 Output Frequency Range. Two output frequency bands are provided: L-band (DOD) and S-band (NASA).

8.3.1.1.1.1.1 NASA/STDN Channel Assignments. The transmit/receive frequency pair assignments for STDN-compatible detached payloads are listed in Table 8.3.1.1.1.1.1-1.

8.3.1.1.1.1.2 NASA/DSN Channel Assignments. The transmit/receive frequency pair assignments for DSN-compatible detached payloads are listed in Table 8.3.1.1.1.1.2-1.

8.3.1.1.1.1.3 DOD/SGLS Channel Assignments. The transmit/receive frequency pair assignments for SGLS-compatible detached payloads are listed in Table 8.3.1.1.1.1.3-1.

8.3.1.1.1.2 Transmitter Triplexer Section. A triplexer is used in the PI transmitter/receiver. The triplexer functions to divide the PI transmit and receive bands into low and high subbands for both the NASA and DOD modes of operation. The purpose of the low/high band selectivity is to prevent mutual interference between the PI and S-band network subsystem during times of simultaneous operation.

8.3.1.1.1.3 Carrier Frequency Tolerance. The maximum carrier frequency uncertainty is a percentage of the nominal carrier frequency (transmitter sweep disabled). ? ±.001%

4° RMS - 30 Hz
1.8° RMS - 16 Hz
two sided tracking BW

8.3.1.1.1.4 Carrier Phase Noise. The transmitter will produce no more than the listed phase noise? in a steady-state error for an ~~18~~ 16 Hz two-sided tracking bandwidth loop.

8.3.1.1.1.5 Carrier Spurs. Carrier spurs are any spurs appearing at the transmitter output below the unmodulated carrier power level.

8.3.1.1.1.6 Carrier Phase Modulator. The phase modulator will accept analog or digital modulating signals. The modulator deviation characteristic is linear within the limits, over the range listed in Table 8.3.1.1.1-1. Frequency response is flat within the limits over the range listed in Table 8.3.1.1.1-1.

8.3.1.1.1.7 Carrier Frequency Sweep. Frequency sweep is linear up and down in frequency, beginning at the nominal channel frequency. When the sweep is disabled, it remains in effect at the specified rate until the nominal carrier frequency is reached.

8.3.1.1.1.8 Selectable Transmitter Power Levels. Three selectable transmitter output power levels for either the L-band or S-band frequency ranges are available at the orbiter antenna interface.

8.3.1.1.2 Receiver Characteristics. The principal receiver characteristics are listed in Table 8.3.1.1.2-1. The values in this paragraph are referenced to the Orbiter interface.

8.3.1.1.2.1 Input Frequency Range. See Table 8.3.1.1.2-1.

NASA/STDN Channel Assignments. See Table 8.3.1.1.1.1.1-1.

NASA/DSN Channel Assignments. See Table 8.3.1.1.1.1.2-1.

DOD/SGLS Channel Assignments. See Table 8.3.1.1.1.1.3-1.

8.3.1.1.2.2 Receiver Triplexer Section. See Paragraph 8.3.1.1.1.2.

ORIGINAL PAGE IS
OF POOR QUALITY

8.3.1.1.2.3 Input Signal Level Range. See Table 8.3.1.1.2-1.

8.3.1.1.2.4 AGC Dynamic Range. The AGC maintains the receiver transfer function in a linear state over an input signal level range.

8.3.1.1.2.4.1 Receiver Gain Saturation. Above the listed saturation level the receiver IF amplifier circuits begin to amplitude saturate. Although this should not adversely affect the demodulation of constant envelope signals, it may cause receiver false-lock under certain conditions. Overall receiver performance is not guaranteed above the listed saturation level.

8.3.1.1.2.4.2 Receiver Protective Limiting. At the listed input signal level and higher, a preamplifier protective diode breakdown limiter becomes operative. Purposeful receiver operation above this limit is not recommended.

8.3.1.1.2.5 Out-of-Band Interference. The receiver will operate with no more than the listed performance degradation due to out-of-band interference for the conditions listed in Table 8.3.1.1.2.5-1.

8.3.1.1.2.6 Noise Figure. The receiver noise figure is referenced to the RF PI common input/output port.

8.3.1.1.2.7 Carrier Acquisition and Tracking Thresholds. The acquisition threshold is the minimum received discrete carrier signal level for guaranteed acquisition. The tracking threshold is the minimum received discrete carrier signal level for guaranteed tracking and demodulation performance.

8.3.1.1.2.8 Carrier Dynamic Acquisition and Tracking.

8.3.1.1.2.8.1 Receiver Frequency Sweep. For the purpose of acquisition, the receiver is swept from the nominal receive frequency. Phase lock will be achieved within the time listed. (This sweep is unrelated to the transmitter sweep.)

8.3.1.1.2.8.2 Frequency Rate Tracking. The maximum in-lock frequency rate that may be tracked is listed in Table 8.3.1.1.2-1.

8.3.1.1.2.8.3 Frequency Tracking Range. The receiver maximum frequency offset tracking capability from the nominal carrier frequency is listed in Table 8.3.1.1.2-1.

8.3.1.1.2.9 Operating Performance. The PI reciever operation performance characteristics are listed in Table 8.3.1.1.2-1.

8.3.1.1.2.10 False Lock Immunity. The receiver will not false lock to carrier sideband components within the listed limits for any NASA (STDN and DSN) or SGLS standard modulation conditions for received signal levels as listed below the RF carrier power. (See Paragraph 8.3.4.2.2 for nonstandard modulation conditions.)

8.3.1.1.2.11 Phase Locked Loop (PLL) Bandwidths.

8.3.1.1.2.11.1 Tracking Bandwidth. The in-lock PLL tracking noise bandwidth, when the receiver is operating within the linear coherent AGC range is listed in Table 8.3.1.1.2-1.

8.3.1.1.2.11.2 Acquisition Bandwidth. The out-of-lock PLL noise bandwidth, when the receiver is operating within the noncoherent AGC control range, is listed in Table 8.3.1.1.2-1.

8.3.1.1.2.12 Wideband Demodulator. A wideband sinusoid phase-characteristic demodulator provides recovery of all carrier phase modulations. The throughput lowpass 3 dB bandwidth of the receiver, demodulator and output circuits is listed in Table 8.3.1.1.2-1.

8.3.1.1.2.13 Wideband Output Signal Regulation. The wideband demodulated signal output level to the CIU and bent-pipe ports is controlled by an RMS type of regulating loop. The output signal waveforms plus noise are regulated and all peak values (plus or minus) are clipped or limited by the output amplifier to the levels listed in Table 8.3.1.1.2-1.

8.3.1.2 Antenna Characteristics. The PI/payload link utilizes a single beam antenna for both transmitting and receiving. The principal antenna characteristics shall be as listed in Table 8.3.1.2-1.

8.3.1.2.1 Antenna Location. The antenna is located at the top of the cargo bay forward bulkhead, as shown in Figure 8.3.1.2.1-1.

8.3.2 NASA Standard Payload/PI/PSP Communication Characteristics and Requirements.

8.3.2.1 Command Signals. A single form of command signal is allowed, with summary characteristics listed in Table 8.3.2.1-1.

8.3.2.1.1 Modulation Waveform. The command waveform is a sinewave subcarrier PSK modulated by the command bits.

8.3.2.1.2 Subcarrier Frequency. See Table 8.3.2.1-1.

8.3.2.1.2.1 Subcarrier Harmonic Distortion. The maximum harmonic components as a percentage of the fundamental frequency amplitude are listed in Table 8.3.2.1-1.

8.3.2.1.2.2 Subcarrier Frequency Stability. The 60-sec averaged subcarrier frequency shall be within the listed percentage of the nominal subcarrier frequency.

8.3.2.1.3 Carrier Modulation Index. See Table 8.3.2.1-1.

8.3.2.1.4 Data Modulation.

8.3.2.1.4.1 Data Rates. The command data rate may be any one of the rates listed in Table 8.3.2.1-1.

8.3.2.1.4.2 Data Bit Format. The bit format may be NRZ-L, NRZ-M or NRZ-S. Transition of the data waveform will coincide with a zero crossing of the subcarrier.

8.3.2.1.4.3 Data Asymmetry. The data bit asymmetry is a percentage of the nominal data bit period.

8.3.2.1.4.4 Data Bit Jitter. The data bit peak phase jitter is a percentage of the data bit period.

8.3.2.1.4.5 Command Bit Preamble. Whenever actual command bits are not being modulated onto the subcarrier, a prefix consisting of alternating "one" and "zero" bits is employed. The prefix always begins with a "one" bit and will stop in the bit period before the first command message bit.

8.3.2.2 Telemetry Signals. A single form of telemetry signal is allowed, with summary requirements listed in Table 8.3.2.2-1.

8.3.2.2.1 Modulation Waveform. The telemetry waveform shall be a sinewave subcarrier modulated by the telemetry bits.

8.3.2.2.2 Subcarrier Frequency. See Table 8.3.2.2-1.

8.3.2.2.2.1 Subcarrier Harmonic Distortion. The maximum harmonic components as a percentage of the fundamental frequency amplitude are listed in Table 8.3.2.2-1.

8.3.2.2.2.2 Subcarrier Frequency Stability. The long-term subcarrier frequency stability (uncertainty) shall be within the listed tolerance of the nominal subcarrier frequency over one hour.

8.3.2.2.3 Payload Transmitter Modulation Index. See Table 8.3.2.2-1.

8.3.2.2.4 Data Modulation.

8.3.2.2.4.1 Data Rates. The telemetry data rates shall be as listed in Table 8.3.2.2-1.

8.3.2.2.4.2 Data Bit Format. The bit format shall be NRZ or Manchester L, M or S. The bits and subcarrier may be asynchronous or, if synchronous, no specific transition versus subcarrier phase relationship is required.

8.3.2.2.4.3 Data Asymmetry. The data asymetry is a percentage of a nominal bit period listed in Table 8.3.2.2-1.

8.3.2.2.4.4 Bit Rate Stability. The bit rate stability as a percentage of the nominal bit rate is listed in Table 8.3.2.2-1.

8.3.2.2.5 Data Structure Formats. Data structure formats shall be as specified in Table 8.3.2.2-1. The basic word length shall be eight bits, as specified therein, or shall be a multiple thereof. The master frame synchronization word shall consist of an eight-bit unique pattern located in first or last word or words of master frame-Format Type 1.

8.3.2.2.6 Payload Minimum Effective Isotropic Radiated Power (EIRP).Table 8.3.2.2.6-1 lists the payload minimum EIRP required to achieve the listed conditions.

8.3.2.3 NASA/STDN Near-Earth (NE) Transponder Turnaround Requirements. The following paragraphs also apply to TDRS user transponders operating in the STDN mode. The requirements are summarized in Table 8.3.2.3-1.

8.3.2.3.1 Forward Link Sweep acquisition. The NE transponder forward link from the Orbiter to the payload will be frequency swept in the PI transmitter (for acquisition purposes) in accord with Paragraph 8.3.1.1.1.7 utilizing the fast sweep rate listed, over the range listed in Table 8.3.2.3-1.

8.3.2.3.1.1 Transponder Minimum PLL Acquisition Bandwidth. In order to achieve a 0.9 probability of carrier acquisition when the PI sweep crosses the transponder (NE) nominal receive frequency, the transponder (NE) two-sided loop noise bandwidth shall be as listed in Table 8.3.2.3-1.

8.3.2.3.1.2 Sweep Tracking Requirement. The PI transmitter sweep may go through a number of complete sweep cycles before being disabled. The transponder receiver must therefore be capable of tracking the entire PI transmitter sweep range (±75 kHz) for the condition of PI transmitter maximum nominal frequency offset within the tolerance listed in Table 8.3.2.3-1.

8.3.2.3.2 Return Link Sweep Acquisition. The PI receiver may be required to acquire the payload transmitter signal when the transponder is in its one-way mode (transmitter carrier frequency derived from the transponder auxiliary oscillator) or in the two-way mode with the forward link sweep transponded to the return link carrier.

8.3.2.3.2.1 Auxiliary Oscillator Stability. The long-term stability of the transponder transmitter's nominal carrier frequency as derived from the auxiliary oscillator shall be no worse than the percentage listed in Table 8.3.2.3-1.

8.3.2.3.2.2 Auxiliary Oscillator-to-VCO Switchover. There are no PI-imposed requirements on the auxiliary oscillator-to-VCO switchover (when the forward link becomes acquired) in terms of the resulting frequency step. The PI will start resweep after transient within the time limits listed in Table 8.3.2.3-1.

8.3.2.3.2.3 PI Receiver Lock Loss Due to Auxiliary Oscillator-to-VCO Switchover. It is expected that, when the transponder switches its transmitter frequency source from auxiliary oscillator to the VCO, PI receiver lock (if it had been attained in the one-way mode) will be lost.

8.3.2.3.2.4 Transponder Turnaround Ratio. The transponder transmit/receive frequency turnaround ratio shall be as listed in Table 8.3.2.3-1.

8.3.2.3.2.5 Return Link Carrier Sideband Level Due to Forward Link Modulation Feedthrough. The maximum feedthrough modulation sidebands of the return link carrier by the forward link command modulation (16 kHz subcarrier) shall not exceed a return link sideband level greater than the level listed in Table 8.3.2.3-1.

8.3.2.4 NASA/DSN Deep-Space (DS) Transponder Turnaround Requirements. The requirements are summarized in Table 8.3.2.4-1.

8.3.2.4.1 Forward Link Sweep Acquisition. The NE transponder forward link from the Orbiter to the payload will be frequency swept in the PI transmitter (for acquisition purposes) in accord with Paragraph 8.3.1.1.1.7 utilizing the slow sweep rate listed, over the range listd in Table 8.3.2.4-1.

8.3.2.4.1.1 Transponder Minimum PLL Acquisition Bandwidth. In order to achieve a 0.99 probability of carrier acquisition when the sweep crosses the transponder nominal receive frequency, the transponder two-sided loop noise bandwidth shall not be less than the bandwidth listed in Table 8.3.2.4-1. (It has been assumed that, when the DS transponder is operating with the Orbiter, the minimum receive signal level will be TBD dB above the PLL absolute threshold for which the nominal 18 Hz two-sided loop noise bandwidth occurs.)

8.3.2.4.1.2 Maximum Swept Acquisition Time. The time required to sweep the entire ±33 KHz frequency uncertainty range using the slow sweep rate will be less than the time listed in Table 8.3.2.4-1.

8.3.2.4.1.3 Sweep Tracking Requirement. In the slow sweep rate mode, the PI transmitter sweep will nominally go through one complete sweep cycle and then become disabled. The transponder receiver must therefore be capable of tracking the entire PI transmitter sweep range (±33 kHz) for the condition of PI transmitter maximum nominal frequency offset of the percentage listed in Table 8.3.2.4-1.

8.3.2.4.2 Return Link Sweep Acquisition. The PI receiver may be required to acquire the payload transmitter signal when the transponder is in its one-way mode (transmitter carrier frequency derived from the transponder auxiliary oscillator) or in the two-way mode with the forward link sweep transponded to the return link carrier.

8.3.2.4.2.1 Auxiliary Oscillator Stability. The long-term stability of the transponder transmitter's nominal carrier frequency as derived from the auxiliary oscillator shall be no worse than the percentage listed in Table 8.3.2.4-1.

8.3.2.4.2.2 Auxiliary Oscillator-to-VCO Switchover. There are no PI-imposed requirements on the auxiliary oscillator-to-VCO switchover (when the forward link becomes acquired) in terms of the resulting frequency step. The PI will start resweep after transient within the time listed in Table 8.3.2.4-1.

8.3.2.4.2.3 PI Receiver Lock Loss Due to Auxiliary Oscillator-to-VCO Switchover. It is expected that, when the transponder switches its transmitter frequency source from auxiliary oscillator to the VCO, PI receiver lock (if it had been attained in the one-way mode) will be lost.

8.3.2.4.2.4 Transponder Turnaround Ratio. The transponder transmit/receive frequency turnaround ratio shall be as listed in Table 8.3.2.4-1.

8.3.2.4.2.5 Return Link Carrier Sideband Level Due to Forward Link Modulation Feedthrough. The maximum feedthrough modulation sidebands of the return link carrier by the forward link command modulation (16 kHz subcarrier) shall not exceed a return link sideband level greater than the level listed in Table 8.3.2.4-1.

8.3.3 DOD/SGLS Standard Payload/CIU Communication Characteristics and Requirements.

8.3.3.1 Command Signals. A single form of command signal is allowed, with summary characteristics listed in Table 8.3.3.1-1.

8.3.3.1.1 Modulation Waveform. The command signal is a ternary FSK/AM waveform with form as shown in Figure 8.3.3.1.1-1. Three command symbols are employed and the composite FSK waveform is 50% amplitude modulated by a triangular function of frequency equal to one-half the command symbol rate.

8.3.3.1.2 Command Tone Frequencies. The command symbol tone frequencies shall be as listed in Table 8.3.3.1-1.

8.3.3.1.2.1 Tone Frequency Accuracy. The maximum nominal tone frequency error will not exceed the tolerance listed in Table 8.3.3.1-1.

8.3.3.1.3 Carrier Modulation Indices. Two carrier modulation indices are employed as listed in Table 8.3.3.1-1.

8.3.3.1.4 Data Modulation.

8.3.3.1.4.1 Data Symbol Rates. The ternary symbols shall be transmitted at the rates listed in Table 8.3.3.1-1.

8.3.3.1.4.2 Triangular AM Clock. A triangular waveform clock at one-half the symbol rate and with its positive zero crossing delayed by 0.6 T ± 10% from the symbol epoch amplitude modulates the composite symbol stream with a 50% intensity.

8.3.3.1.4.3 Data Format. TBD

8.3.3.1.4.4 Command Bit Preamble. TBD

8.3.3.2 DOD/SGLS Telemetry Signals. Both PSK and FM subcarriers are allowed; summary requirements are listed in Table 8.3.3.2-1.

8.3.3.2.1 Modulation Waveforms.

8.3.3.2.1.1 PSK Subcarriers. Digital telemetry waveforms shall be sinewave subcarriers PSK modulated (±90°) by the telemetry bits.

8.3.3.2.1.2 FM Subcarriers. The analog telemetry waveform shall be a sinewave subcarrier frequency modulated by the analog telemetry signal to a maximum peak deviation as listed in Table 8.3.3.2-1.

8.3.3.2.2 Subcarrier Frequencies. The nominal PSK and FM subcarrier frequencies shall be as listed in Table 8.3.3.2-1.

8.3.3.2.2.1 Subcarrier Harmonic Components. The maximum harmonic components of any subcarrier as a percentage of the fundamental frequency amplitude are listed in Table 8.3.3.2-1.

8.3.3.2.2.2 PSK Subcarrier Frequency Stability. The long-term subcarrier frequency uncertainty as a percentage of the nominal subcarrier frequency is listed Table 8.3.3.2-1.

8.3.3.2.2.3 FM Subcarrier Frequency Accuracy. When the FM subcarrier is unmodulated, the maximum frequency offset from the nominal frequency shall not exceed the value listed in Table 8.3.3.2-1.

8.3.3.2.3 Payload Transmitter Modulation Indices. Each subcarrier shall employ one of the two modulation indices listed in Table 8.3.3.2-1. A maximum of two subcarriers may simultaneously modulate the carrier.

8.3.3.2.4 Subcarrier Modulations.

8.3.3.2.4.1 Digital Data Rates. The telemetry digital data rates shall be any one of the rates listed in Table 8.3.3.2-1 in accord with the specified subcarrier frequency.

8.3.3.2.4.2 Data Bit Format. The bit format shall be as listed in Table 8.3.3.2-1.

8.3.3.2.4.3 Data Asymmetry. The data asymmetry shall be as listed in Table 8.3.3.2-1.

8.3.3.2.4.4 Bit Rate Stability. The bit rate stability as a percentage of the nominal bit rate is listed in Table 8.3.3.2-1.

8.3.3.2.4.5 FM Signal Frequency Response. The baseband signal that frequency modulates the subcarrier shall have a highpass rolloff of 12 dB/octave above and below the frequency range listed in Table 8.3.3.2-1.

8.3.3.2.4.6 FM/FM Signal Structure. When the FM subcarrier is frequency modulated by a composite set of frequency modulated sub-subcarriers, the signal structure shall comply with the following requirements: TBD.

8.3.3.2.5 Data Structure Formats. Data structure formats shall be as specified in Table 8.3.3.2-1. Minor frame synchronization words shall be TBD. For Type II, the master frame synchronization word shall be 8 bits of any pattern, located in the first or last minor frame in any word column, other than the minor frame sync column. Transition density shall be TBD.

8.3.3.2.6 Payload Minimum EIRP. Table 8.3.3.2.6-1 lists the payload minimum EIRP required to achieve the tested conditions.

8.3.3.3 DOD/SGLS Transponder Turnaround Requirements. The requirements are listed in Table 8.3.3.3-1.

8.3.3.3.1 Forward Link Sweep Acquisition. Some SGLS transponder receivers have a self-contained automatic sweep acquisition capability. The PI transmitter sweep capability is therefore not required for such transponders and will be disabled. For those SGLS transponders not having a self-contained automatic sweep acquisition capability, the PI transmitter will be frequency swept in accord with Paragraph 8.3.1.1.1.7, utilizing the fast sweep rate listed, over the range listed in Table 8.3.3.3-1.

8.3.3.3.1.1 Transponder Minimum PLL Acquisition Bandwidth. In order to achieve a 0.9 probability of carrier acquisition when the PI sweep crosses the transponder nominal receive frequency, the transponder two-sided loop noise bandwidth shall not be less than that listed in Table 8.3.3.3-1.

8.3.3.3.1.2 Sweep Tracking Requirement. The PI transmitter sweep may go through a number of complete sweep cycles before being disabled. The transponder receiver must therefore be capable of tracking the entire PI transmitter sweep range (±55 kHz) for the condition of PI transmitter maximum nominal frequency offset listed in Table 8.3.3.3-1.

8.3.3.3.2 Return Link Frequency Stability and Acquisition Requirements.

8.3.3.3.2.1 Auxiliary Oscillator Stability. The long-term stability of the transponder transmitter's nominal carrier frequency as derived from the auxiliary oscillator shall be no worse than listed in Table 8.3.3.3-1.

8.3.3.3.2.2 Auxiliary Oscillator-to-VCO Switchover. There are no specific requirements as the resulting frequency step is expected to be within the PI receiver acquisition range.

8.3.3.3.2.3 PI Receiver Lock Loss Due to Auxiliary Oscillator-to-VCO Switchover. It is expected that, when the transponder switches its transmitter frequency source from auxiliary oscillator to the VCO, PI receiver lock (if it has been attained in the one-way mode) will be lost.

8.3.3.3.2.4 Transponder Turnaround Ratio. The transponder transmit/receive frequency turnaround ratio shall be as listed in Table 8.3.3.3-1.

8.3.3.3.2.5 Return Link Carrier Sideband Level Due to Forward Link Modulation Feedthrough. The maximum feedthrough modulation sidebands of the return link carrier by the forward link command modulation (65 kHz, 76 kHz, 95 kHz tones and the one-half symbol rate clock and its harmonics) shall not exceed a return link sideband level greater than the level listed in Table 8.3.3.3-1.

8.3.4 Nonstandard Payload/PI/Bent-Pipe Communication Requirements. Nonstandard communications are those which do not conform to the NASA/PSP or DOD/CIU command and telemetry capabilities. Nonstandard communication signals must, however, comply with the PI capabilities and requirements.

8.3.4.1 Command Signals. An input port to the PI transmitter exists aboard the Orbiter at the Payload Station (PS). This port allows nonstandard command signals to be transmitted from the PS; however, no ground through Orbiter-to-payload nonstandard command capability exists. Therefore, if such command transfer capability is require, use must be made of either the PSP or CIU standard command signalling capability. PS command signals must comply with the PI transmitter requirements of 8.3.1.1.1.

8.3.4.2 Telemetry Signals. See Paragraph 8.3.5.

8.3.4.2.1 General Payload Transmitter Modulation Criteria.

8.3.4.2.1.1 Allowable Modulations. Phase modulation (PM) of the carrier is the only allowable type of modulation. Frequency modulation (FM) and amplitude modulation (AM) of the carrier are not permitted. Quadriphase and spread spectrum modulations are also not allowed.

8.3.4.2.1.2 Maximum Carrier Suppression. The maximum allowable carrier suppression due to the composite of all phase-modulating sources shall not exceed 10 dB.

8.3.4.2.1.3 Subcarrier Modulation. When subcarriers are employed, they may be either phase or frequency modulated. Amplitude modulated subcarriers are not permitted. Restrictions on the use of subcarriers are given under 8.3.4.2.2.2 and 8.3.4.2.2.3.

8.3.4.2.1.4 Direct Carrier Modulation by Baseband Signals. Direct carrier modulation by analog type baseband signals is not allowed. Direct carrier modulation by digital type baseband signals is allowed, subject to the restrictions given under 8.3.4.2.2.4.

8.3.4.2.2 Specific Nonstandard Modulation Restrictions.

8.3.4.2.2.1 Discrete Frequency Component Sideband Levels. Carrier phase modulation by periodic signals (sinusoids, square-waves, etc.) having fundamental frequencies less than 200 kHz is not permitted. No incidental and/or spurious discrete frequency component sideband levels shall be greater than -32 dBc on a frequency range of ±200 kHz about the carrier frequency.

8.3.4.2.2.2 Frequency Modulated Subcarriers.

8.3.4.2.2.2.1 Analog Modulations. No analog signal frequency modulated subcarrier, on a frequency range of ±200 kHz about the carrier frequency shall be allowed to phase modulate the carrier if the inequality

$$f_M \Delta f > 8 \times 10^3$$

is violated, where f_M is the bandwidth or maximum frequency of the baseband analog signal in Hz and Δf is the peak frequency deviation of the subcarrier in Hz. Provided that the above inequality is satisfied, the maximum allowable carrier phase modulation index, β, by the frequency modulated sinusiodal subcarrier shall be the lesser of 1.85 rad (106°) or the β which satisfies the relationship:

$$J_1(\beta)/J_0(\beta) = 5.43 \times 10^{-7} f_M \Delta f,$$

or the β which results in a lock detector false alarm probability greater than 1 x 10^{-4} when the lock detector bandwidth is centered on the FM subcarrier (i.e., on either relative subcarrier frequency sideband of the carrier). The value of β may be determined with the aid of Fig. 8.3.4.2.1-1.

8.3.4.2.2.2.2 Digital Modulations. No frequency-shift-keyed (FSK) subcarrier, on a frequency range of ±200 kHz about the carrier frequency, shall be allowed to phase modulate the carrier if the inequality

$$R_b > 2.5 \times 10^2$$

is violated, where R_b is the data bit rate (bps). Provided that the above inequality is satisfied, the maximum allowable carrier phase modulation index, β, by the FSK modulated sinusoidal subcarrier shall be the lesser of 1.85 rad (106°) or the β which satisfies the relationship

$$J_1(\beta)/J_0(\beta) \geq 6.9 \times 10^{-8} (R_b)^2$$

or the β which results in a lock detector false alarm probability greater than 1 x 10^{-4} when the lock detecor bandwidth is centered on the FM subcarrier. The value of β may be determined with the aid of Fig. 8.3.4.2.1-1.

8.3.4.2.2.3 Phase Modulated Subcarriers.

8.3.4.2.2.3.1 Analog Modulations. Phase modulation of subcarriers by analog baseband signals is not recommended due to inefficiency. As a result, no such modulations are expected and no guidelines have been developed.

8.3.4.2.2.3.2 Digital Modulations. No phase-shift-keyed (PSK) subcarrier, on a frequency range of ±200 kHz about the carrier frequency, shall be allowed to phase nodulate the carrier if the inequality

$$R_b > 2.5 \times 10^2$$

is violated, where R_b is the data bit rate (bps). Provided that the inequality above is satisfied, the maximum allowable carrier phase modulation index, β, by the PSK modulated sinusoidal subcarrier shall be the lesser of 1.85 rad (106°) or the β which satisfies the relationship

$$J_1(\beta)/J_0(\beta) \leq 6.9 \times 10^{-8} (R_b)^2 ,$$

or the β which results in a lock detector false alarm probability greater than 1 x 10^{-4} when the lock detector bandwidth is centered on the FM subcarrier. The value of β may be determined with the aid of Fig. 8.3.4.2.1-1.

8.3.4.2.2.4 Direct Carrier Modulations.

8.3.4.2.2.4.1 Analog Modulations. Direct phase modulation of the carrier by an analog baseband signal is not recommended due to inefficiency. As no such modulations are expected, no guidelines have been developed.

8.3.4.2.2.4.2 Digital Modulations. The criterion for the minimum allowable bit rate is based upon a carrier tracking loop RMS phase noise component due to modulation sidebands tracking of 10° or less. The allowable NRZ bit rate must therefore satisfy the following inequality:

$$R_b > 4.8 \times 10^4 \tan^2 (\beta).$$

where the numerical coefficient is based upon the PI carrier tracking loop maximum in-lock noise bandwidth and β is the carrier phase deviation ($\beta \leq 71.5°$). In order to keep carrier loop phase slewing to less than 18° during a string of transitionless data bits, the maximum number of such bits shall be:

$$\text{Maximum No. of Bits Without Transition} = 1.65 \times 10^{-4} R_b$$

This transitionless period must be followed by a reasonable number of transitions in such a pattern that the slewing error is negated within a period of bits equal to five times the transitionless period. To avoid the problem of bit slewing, Manchestering of the bits is recommended. Given Manchestered bits, the minimum bit rate allowed is the larger bit rate calculated from:

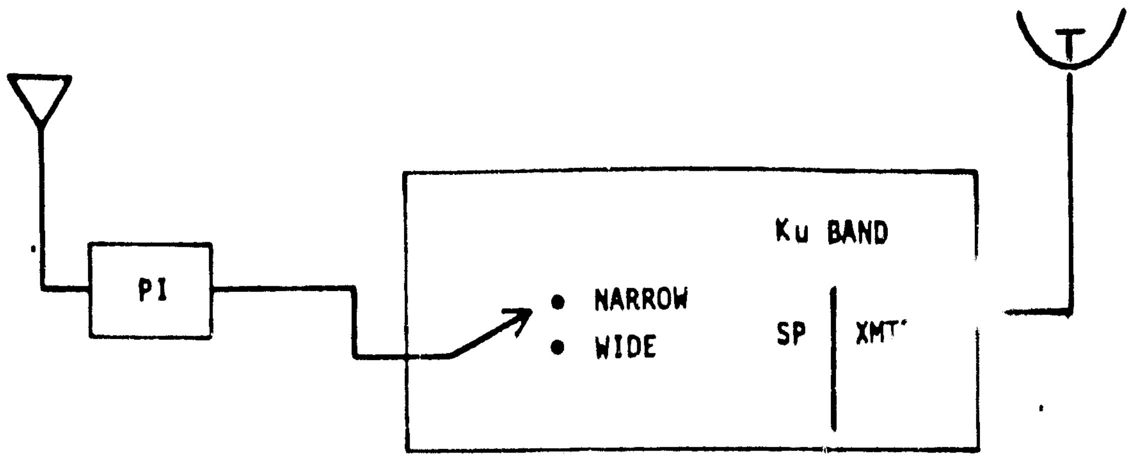
$$R_b \geq 640 \tan^2 (\beta)$$

$$R_b \geq 2.7 \times 10^3 \sqrt{\tan (\beta)} \ .$$

Maximum modulation index β for all digital modulations shall not exceed 71.5° or 1.25 rad.

8.3.4.2.3 Bent-Pipe Feedthrough Characterisitics. The payload transmitter may output "not-standard" signal/modulation forms which can only be processed by the PI. As such, it is the function of the PI receiver to acquire and track the carrier component of the payload signal, demodulate the carrier and transfer the resultant baseband signal to the KuSP for relaying to ground stations.

8.3.4.2.3.1 PI/Ku Band Configuration. The figure below shows the general PI/Ku Band configuration for the bent-pipe. Telemetry signals may be input to either the narrowband or wideband channels as defined in the following subparagraphs.



8.3.4.2.3.2 Narrowband Channel. The anticipated use of the narrowband channel is by PSK or FM subcarriers which have nonstandard frequencies and/or nonstandard data rates or analog modulations. Characteristics are listed in Table 8.3.4.2.3.2-1.

8.3.4.2.3.3 Wideband Channel. Wideband signals are defined as those which have maximum frequency components on the order of 4.5 MHz. Such signals are allowed to directly frequency modulate the Ku-band FM transmitter. The amount of deviation achieved depends upon the nature of the modulating waveform, its RMS and peak values being established by the PI wideband output noncoherent regulator (see subparagraph 8.3.1.1.2.13).

8.3.4.3 Nonstandard Transponder Turnaround Requirements. Nonstandard transponders are defined as those which are not explicitly STDN/NE (subparagraph 8.3.2.4) or SGLS (Subparagraph 8.3.3.3) types. Nonstandard transponders must, however, conform to the PI frequency channel assignments and other PI acquisition and tracking requirements.

8.3.4.3.1 Frequency Channel Assignments and Turnaround Ratios. A nonstandard transponder must adhere to either the NASA channel assignments of Tables 8.3.1.1.1.1.1-1 and 8.3.1.1.1.1.2-1 or the DOD channel assignments of Table 8.3.1.1.1.1.3-1. The corresponding transmit/receive turnaround ratio shall be as listed in Table 8.3.4.3-1.

8.3.4.3.2 Forward Link Acquisition. A nonstandard transponder that does not possess an inherent receiver acquisition capability must make use of the PI transmitter sweep capability outlined under 8.3.1.1.1.7. Either of the two sweep rates may be employed and the transponder two-sided loop noise bandwidth shall not be less than the limits listed in Table 8.3.4.3-1.

8.3.4.3.3 Forward Link Sweep Tracking. The nonstandard transponder must be capable of tracking the entire PI transmitter sweep range as defined under 8.3.1.1.1.7 for the condition of PI transmitter maximum nominal frequency offset listed in Table 8.3.4.3-1.

8.3.4.3.4 Return Link Sweep Acquisition. The PI receiver may be required to acquire the payload transmitter signal when the transponder is in its one-way mode (transmitter carrier frequency derived from the transponder auxiliary oscillator) or in the two-way mode with the forward link sweep transponded to the return link carrier.

8.3.4.3.5 Auxiliary Oscillator Stability. The long-term stability of the transponder transmitter's nominal carrier frequency as derived from the auxiliary oscillator shall be no worse than listed in Table 8.3.4.3-1.

8.3.4.3.5.1 Phase Noise. The transponder transmitter phase noise when the carrier is derived from the auxiliary oscillator shall not produce more phase error than listed in Table 8.3.4.3-1.

8.3.4.3.6 Return Link Incidental Modulations.

8.3.4.3.6.1 Spurs. Any discrete frequency spurs shall be below the unmodulated carrier power level by at least the amount listed in Table 8.3.4.3-1.

8.3.4.3.6.2 Forward Link Modulation Feedthrough. The maximum feedthrough modulation sidebands of the return link carrier by any frequency component of the forward link command modulation shall not exceed a return link sideband level greater than the level listed in Table 8.3.4.3-1.

8.3.5 PI/PS Ports for Non-Standard Payload Signal Processing. Payloads with command and/or telemetry formats that are incompatible with the standard formats described in Paragraph 8.3.2 may provide their own signal processing equipment for installation in the PS area of the Aft Flight Deck and interface it with the PI.

8.3.5.1 PI/PS Forward Link Data Input Characteristics. The PS input port interface characteristics for signals to be modulated on the PI forward RF link to a payload shall be as defined in Table 8.3.5.1-1.

8.3.5.2 PI/PS Return Link Data Output Characteristics. The PS output port interface characteristics for demodulated payload return RF link signals from the PI shall be as defined in Table 8.3.5.2-1.

8.3.5.3 PI/PS Control Discrete. A control discrete shall be provided to the PI to enable the PS input and output ports and disable the PSP input and output ports to/from the PI. The characteristics of the control discrete shall be as follows:

True State (PS ports to/from PI enabled)	18 to 32 VDC
False State (PSP ports to/from PI enabled)	0 to 3 VDC
Termination	Single ended return to pwr grnd
True State Current	10 milliamps maximum
Power Off Impedance	10 K ohms minimum
Load Impedance	3.2 K ohms minimum

8.3.5.4 PI/PS Selection Lines. Cargo element signal processors installed in the PS must know which PI has been selected for use so that command data and the PS control discrete can be sent to the correct interrogator. One of two lines from the forward load control assemblies (LCA) #2 and #3 shall contain a 28 VDC signal indicating which of the two interrogators has been powered on. These lines are available at the PSDP and shall be used to provide limited control power, as required, for the PSP. The characteristics of these two lines shall be as follows:

Logic '1' State (PI on)	24 to 32 VDC
Logic '0' State (PI off)	0 plus 2.5, minus 0 VDC
Maximum Current	125 milliamps
Termination	Single ended return to Power ground

8.3.5.5 PI/PS Overload Protection. Protection shall be provided in the payload user unit such that overloads will not fault the fusing in the LCA's.

8.3.5.6 PI/PS Power Return. If a power return line is required in the payload user unit, power return for Bus A, B or C may be used.

8.3.6 Ku-Band Rendezvous Radar Interfaces.

8.3.6.1 Passive Mode Characteristics. The rendezvous radar shall have the interface characteristics defined in Table 8.3.6.1-1 when operative in the passive mode.

8.3.6.2 Active Mode Characteristics. The rendezvous radar shall have the interface characteristics defined in Table 8.3.6.2-1 when operating in the active mode.

8.3.6.3 Transponder Characteristics. The payload shall be specified with a transponder that is compatible with the Ku-band rendezvous radar. The transponder characteristics are TBD.

TABLE 8.3.1.1.1-1 PRINCIPAL PI TRANSMITTER CHARACTERISTICS
NASA/DOD

PARAMETER	VALUE	UNITS	SUBPARAGRAPH
DOD/L-Band Frequency range			8.3.1.1.1.1
Lowband (Approx)	1763 - 1803	MHz	
Highband (Approx)	1803 - 1840	MHz	
NASA/S-Band Frequency Range			8.3.1.1.1.1
Lowband (Approx)	2025 - 2075	MHz	
Highband (Approx)	2074 - 2120	MHz	
Triplexer Subbands	See Subparagraph		8.3.1.1.1.2
Carrier Frequency Tolerance	±0.001	%	8.3.1.1.1.3
Carrier Phase Noise	≤10	Degrees RMS	8.3.1.1.1.4
Carrier Spurs	≤ - 65	dBc	8.3.1.1.1.5
Carrier Phase Modulator			8.3.1.1.1.6
Linearity	±8	%	
Deviation Range	0.2-2.5	Radians	
Frequency Response	1-500	kHz	
Response Flatness	±0.5	dB	
Carrier Sweep Range			8.3.1.1.1.7
NASA/STDN	75±5	kHz	
DOD/SGLS	55±5	kHz	
NASA/DSN	33±3	kHz	
Carrier Sweep Rates			8.3.1.1.1.7
75 KHz Range	10±3	KHz/sec	
55 KHz Range	10±3	KHz/sec	
33 KHz Range	250±75	Hz/sec	
Power Level--High	+29 min	dBm	8.3.1.1.1.8
Medium	+19 min	dBm	
Low	-4 min	dBm	

TABLE 8.3.1.1.1.1.1-1 NASA/STDN CHANNEL AND FREQUENCY ASSIGNMENTS

Refer to Appendix C for specific channel and frequency assignments. Method of calculating frequencies is as follows:

Channel No. n = 1 to 808

Receive Frequency = 2200.000 + (n-1) x 0.125 MHz

Transmit Frequency = 2025.8334 + (n-1) x 0.115104 MHz

Transmit Frequency = 221/240 x Receive Frequency

TABLE 8.3.1.1.1.1.2-1 NASA/DSN CHANNEL & FREQUENCY ASSIGNMENTS

Channel		Transmit MHz	Receive MHz
850			2290.185185
851			2290.555556
852			2290.925926
853			2291.296296
854	(56)	2110.243056	2291.666667
855		2110.584105	2292.037037
856		2110.925154	2292.407407
857		2111.266204	2292.777778
858		2111.607253	2293.148148
859		2111.948303	2293.518519
860		2112.289352	2293.888889
861		2112.630401	2294.259259
862		2112.971451	2294.629630
863	(14b)	2113.312500	2295.000000
864		2113.653549	2295.370370
865		2113.994599	2295.740741
866		2114.335648	2296.111111
867		2114.676697	2296.481481
868		2115.017747	2296.851852
869		2115.358796	2297.222222
870		2115.699846	2297.592593
871		2116.040895	2297.962963
872	(236)	2116.381944	2298.333333
873		2116.722994	2298.703704
874		2117.064043	2299.074074
875		2117.405092	2299.444444
876		2117.746142	2299.814815
877		2118.087191	
878		2118.428241	
879		2118.769290	
880		2119.110339	
881		2119.451389	
882		2119.792438	

Unassigned channels: 883-899

TABLE 8.3.1.1.1.1.3-1 DOD/SGLS CHANNEL & FREQUENCY ASSIGNMENTS

CHANNEL	TRANSMIT ORBITER TO DOD PAYLOADS (MHz)	RECEIVE DOD PAYLOADS TO ORBITER (MHz)
900	1763.721	2202.500
901	1767.725	2207.500
902	1771.729	2212.500
903	1775.733	2217.500
904	1779.736	2222.500
905	1783.740	2227.500
906	1787.744	2232.500
907	1791.748	2237.500
908	1795.752	2242.500
909	1799.756	2247.500
910	1803.760	2252.500
911	1807.764	2257.500
912	1811.768	2262.500
913	1815.772	2267.500
914	1819.775	2272.500
915	1823.779	2277.500
916	1827.783	2282.500
917	1831.787	2287.500
918	1835.791	2292.500
919	1839.795	2297.500

Unassigned Channels: 920-999

TABLE 8.3.1.1.2-1 PRINCIPAL PI RECEIVER CHARACTERISTICS NASA/DOD

PARAMETER	VALUE	UNITS	SUBPARAGRAPH
DOD/L-Band Frequency Range			8.3.1.1.2-1
Lowband (Approx)	2202 - 2252	MHz	
Highband (Approx)	2252 - 2297	MHz	
NASA/S-Band Frequency Range			8.3.1.1.2-1
Lowband (Approx)	2200 - 2252	MHz	
Highband (Approx)	2252 - 2300	MHz	
Triplexer Subbands	See Subparagraph		8.3.1.1.2.2
Input Signal Level Range	-110 to +20	dBm	8.3.1.1.2.3
AGC Range	-110 to -20	dBm	8.3.1.1.2.4
Gain Saturation	>-20	dBm	8.3.1.1.2.4.1
Protective Limiting	≥+10	dBm	8.3.1.1.2.4.2
Out-of-Band Interference	≤1.0	dBm SNR	8.3.1.1.2.5
Noise Figure	7.0 max.	dB	8.3.1.1.2.6
Carrier Thresholds:			
Acquisition	-110	dBm	8.3.1.1.2.7
Tracking	-114	dBm	8.3.1.1.2.7
Carrier Acquisition Sweep Range	±80	kHz	8.3.1.1.2.8.1
Carrier Phase Lock Time	≤5	Sec	8.3.1.1.2.8.1
Carrier Rate Tracking	44	kHz/sec	8.3.1.1.2.8.2
Carrier Tracking Range	±80	kHz	8.3.1.1.2.8.3
Operating Performance			8.3.1.1.2.9
Bit Error Rate	1x10-6	bits	
Range	-100.7 to +10	dBm	
Subcarrier Frequency	16	Kbps	
Modulation Index	1.1±10% or 1.7±10%		
False Lock Immunity			8.3.1.1.2.10
Sideband Components	±100	KHz	
Signal Levels	<26	dBm	
PLL Tracking Bandwidth (two-sided)	18	Hz	8.3.1.1.2.11.1

TABLE 8.3.1.1.2-1 PRINCIPAL PI RECEIVER CHARACTERISTICS NASA/DOC (Concluded)

PARAMETER	VALUE	UNITS	SUBPARAGRAPH
Damping Factor	0.707		
PLL Acquisition Bandwidth (two-sided)	100 Max	Hz	8.3.1.1.2.11.2
Damping Factor	0.707		
PLL Demodulator Bandwidth	4.5	MHz	8.3.1.1.2.12
Output Signal Regulation			8.3.1.1.2.13
To CIU	2.0±0.4	VRMS	
To Ku-Band or Bent Pipe	2.0±0.4	VRMS	
Output Signal Peak Limiter			8.3.1.1.2.13
To CIU	6.0 (Approx)	VRMS	
To Ku-Band or Bent Pipe (Approx)	8.0 (Approx)	VRMS	

TABLE 8.3.1.1.2.5-1 OUT-OF-BAND INTERFERENCE CONDITIONS PI RECEIVER

Interference Signal Level	Applicable Frequency Range
-65 dBm	Low Band: 2165 MHz to (f - 15) MHz and (f + 15) MHz to 2285 MHz
-65 dBm	High Band: 2220 MHz to (f - 15) MHz and (f + 15) MHz to 2340 MHz
-25 dBm	Low Band: 200 MHz to 2165 MHz and 2285 MHz to 16 GHz
-25 dBm	High Band: 200 MHz to 2220 MHz and 2340 MHz to 16 GHz

TABLE 8.3.1.2-1 PI/PAYLOAD LINK ANTENNA CHARACTERISTICS

PARAMETER	VALUE	UNITS	SUBPARAGRAPH
Location	See Figure 8.3.1.2.1-1		8.3.1.2
Type	Single-element cross-dipole.		8.3.1.2
Frequency Ranges	1740-1850 2000-2300	MHZ	8.3.1.2
Beam width	The 3 dB beamwidth is bounded by an 80° cone aligned with the +Z axis		8.3.1.2
Polarization (Selectable by a switch in the Orbiter)	RHCP or LHCP		8.3.1.2

TABLE 8.3.2.1-1 NASA STANDARD COMMAND SIGNAL CHARACTERISTICS

PARAMETER	VALUE	UNITS	SUBPARAGRAPH
Waveform	Sinusoidal	-	8.3.2.1.1
Modulation (Binary)	PSK, ±90	Degrees	8.3.2.1.1
Subcarrier Frequency	16	KHz	8.3.2.1.2
Subcarrier Harmonic Distortion	≤1	%	8.3.2.1.2.1
Subcarrier Frequency Stability (60-Second Avg)	±0.001	%	8.3.2.1.2.2
Carrier Modulation Index	1.0 ± 0.1	Radians	8.3.2.1.3
Data Rates	2000,1000,500 250,125, 125/2,125/4, 125/8 or 125/16	bps	8.3.2.1.4.1
Data Bit Format	NRZ-L, M or S	-	8.3.2.1.4.2
Data Asymmetry	≤2	%	8.3.2.1.4.3
Data Bit Jitter	≤3	%	8.3.2.1.4.4
Command Bit Preamble	See Subparagraph		8.3.2.1.4.5

TABLE 8.3.2.2-1 NASA STANDARD TELEMETRY SIGNAL REQUIREMENTS

PARAMETER	VALUE	UNITS	SUBPARAGRAPH
Waveform	Sinusoidal	-	8.3.2.2.1
Modulation	PSK, ±90	Degrees	8.3.2.2.1
Subcarrier Frequency	1.024 ±0.01%	MHz	8.3.2.2.2
Subcarrier Harmonic Distortion	≤1	%	8.3.2.2.2.1
Subcarrier Frequency Stability	$\pm 1 \times 10^{-5}$	MHz	8.3.2.2.2.2
P/L Modulation Index	1.0 ± 0.1	Radians	8.3.2.2.2.3
Bit Rate	16,8,4,2,1	kbps	8.3.2.2.4.1
Bit Format	NRZ-L,M or S, or Manchester-L, M, or S	-	8.3.2.2.4.2
Data Asymmetry	±2	%	8.3.2.2.4.3
Bit Rate Stability	< ±0.01	%	8.3.2.2.4.4
Basic Word Length	8	Bits	8.3.2.2.5.1
Minor Frame Length	8 to 1024	Words	8.3.2.2.5.2
Minor Frame Sync Words	8,16,24 or 32	Bit Groups	8.3.2.2.5.3
Master Frame Length	1 to 256	Minor Frames	8.3.2.2.5.4
Master Frame Sync Word	See Subparagraph		8.3.2.2.5.5
Transition Density	≥64 transitions in 512 bits		8.3.2.2.5.6
	≤64 consecutive bits w/o transition		8.3.2.2.5.6

TABLE 8.3.2.3-1 NASA/STDN NEAR EARTH (NE) TRANSPONDER TURNAROUND REQUIREMENTS

PARAMETER	VALUE	UNITS	SUBPARAGRAPH
Forward Link Sweep Acquisition			
Fast Sweep Rate	10	KHz/Sec	8.3.2.3.1
Frequency Range	±75	KHz	8.3.2.3.1
PLL Bandwidth	≥200	Hz	8.3.2.3.1.1
Sweep Tracking	±0.001 Max.	%	8.3.2.3.1.2
Return Link Sweep Acquisition			
Frequency Stability	±0.001	%	8.3.2.3.2.1
Post-Transient Resweep start	50 to 90	Millisecond	8.3.2.3.2.2
Switchover Lock Loss	See Subparagraph		8.3.2.3.2.3
Transponder Turnaround Ratio	240/221	-	8.3.2.3.2.4
Sideband Level	<-35 Max	dBc	8.3.2.3.2.5

TABLE 8.3.2.4-1 NASA/DSN TRANSPONDER TURNAROUND REQUIREMENTS

PARAMETER	VALUE	UNITS	SUBPARAGRAPH
Forward Link Sweep Acquisition			
Slow Sweep Rate	250	Hz/Sec	8.3.2.4.1
Frequency Range	±33	KHz	8.3.2.4.1
PLL Bandwidth	TBD	Hz	8.3.2.4.1.1
Acquistion Time	<10	Minutes	8.3.2.4.1.2
Sweep Tracking	±0.001 Max.	%	8.3.2.4.1.2
Return Link Sweep Acquisition			
Frequency Stability	±0.001	%	8.3.2.4.2.1
Post-Transient Resweep start	50 to 90	Millisecond	8.3.2.4.2.2
Switchover Lock Loss	See Subparagraph		8.3.2.4.2.3
Transponder Turnaround Ratio	240/221	-	8.3.2.4.2.4
Sideband Level	<-35 Max.	dBc	8.3.2.4.2.5

TABLE 8.3.2.2.6-1 NASA PAYLOAD MINIMUM EIRP REQUIREMENTS (1)

Bit Rate	EIRP
16 kbps	24.8 dBm
8 kbps	21.8 dBm
4 kbps	18.8 dBm
2 kbps	15.8 dBm
1 kbps	15.3 dBm*

*Set by carrier minimum acquisition level requirement.

(1) Required to achieve a 1 x 10⁻⁶ bit error for the bit rates listed under Paragraph 8.3.2.2.4.1 at the output of the PSP for the conditions of 10 NM range, worst-case tolerances, and a ~~— dB~~ 0 dB performance margin.

TABLE 8.3.3.1-1 DOD/SGLS STANDARD COMMAND SIGNAL CHARACTERISTICS

PARAMETER	VALUE	UNITS	SUBPARAGRAPH
Waveform	Sinusoidal with AM		8.3.3.1.1
Modulation	Ternary Fsk		8.3.3.1.1
Command Tone Frequencies	"S" = 65 "0" = 76 "1" = 95	kHz kHz kHz	8.3.3.1.2
Tone Frequency Accuracy	± 0.01	%	8.3.3.1.2.1
Carrier Modulation Indices	0.3 ± 10% or 1.0 ± 10%	radians radians	8.3.3.1.3
Symbol Rates	1000 or 2000	sps sps	8.3.3.1.4.1
Triangular AM Clock	See Subparagraph		8.3.3.1.4.2
Data Format	TBD		8.3.3.1.4.3
Command Bit Preamble	TBD		8.3.3.1.4.4

TABLE 8.3.3.2-1 DOD/SGLS STANDARD TELEMETRY SIGNAL REQUIREMENTS

PARAMETER	VALUE	UNITS	SUBPARAGRAPH
PSK Subcarriers			8.3.3.2.1.1
Waveform	Sinusoidal		
Modulation	PSK, ±90	Degrees	
FM Subcarriers			8.3.3.2.1.2
Waveform	Sinusoidal		
Modulation	FM, ±200	KHz, Peak	
Subcarrier Frequencies	PSK - 1.024 PSK - 1.7 FM - 1.7	MHz MHz MHz	8.3.3.2.2
Subcarrier Harmonic Components	≤ 0.1	%	8.3.3.2.2.1
PSK Subcarrier Frequency Stability	≤ 0.01	%	8.3.3.2.2.2
FM Subcarrier Frequency Accuracy	≤ 0.005	%	8.3.3.2.2.3
R/L Modulation Indices	1.0±10% or 1.7±10%	Radians, Peak Radians, Peak	8.3.3.2.3 8.3.3.2.3
Digital Bit Rates			8.3.3.2.4.1
1.024 MHz and 1.7 MHz Subcarriers	0.25, 0.5 1,2,4,8,10, 16,32,64, 128 and 256	Kbps	
1.7 MHz Subcarrier	128,256	Kbps	
Data Bit Format	NRZ-L or Manchester-L	-	8.3.3.2.4.2
Data Asymmetry	≤ ± 2	%	8.3.3.2.4.3
Bit Rate Stability	≤ 0.01	%	8.3.3.2.4.4
FM Frequency Response	100 to 200	Hz KHz	8.3.3.2.4.5

TABLE 8.3.3.2-1 DOD/SGLS STANDARD TELEMETRY SIGNAL REQUIREMENTS (Concluded)

PARAMETER	VALUE	UNITS	SUBPARAGRAPH
FM Word Length	8	Bits	8.3.3.2.5.1
FM Minor Frame Length	8 to 1024	Words	8.3.3.2.5.2
FM Minor Frame Sync Words	TBD		8.3.3.2.5.3
FM Master Frame Length	2 to 255	Words	8.3.3.2.5.4
FM Master Frame Sync Word	See Subparagraph		8.3.3.2.5.5
Transition Density	TBD		8.3.3.2.5.6

TABLE 8.3.3.2.6-1 DOD/SGLS PAYLOAD MINIMUM EIRP REQUIREMENTS (1)

Bit Rate	EIRP
256 kbps	36.9 dBm
128 kbps	33.9 dBm
64 kbps	30.9 dBm
32 kbps	27.9 dBm
16 kbps	24.8 dBm
10 kbps	22.8 dBm
8 kbps	21.8 dBm
4 kbps	18.8 dBm
2 kbps	15.8 dBm
1 kbps	15.3 dBm*
500 bps	15.3 dBm*
250 bps	15.3 dBm*

1.14 difference w/[illegible]

*Set by carrier minimum acquisition level requirement.

(1) Required to achieve a 1 x 10-[illegible] bit error rate for the bit rates listed under Paragraph 8.3.3.2.4.1 at the output of the CIU for the conditions of 10 NM range, 1-0 rad modulation index, worst-case tolerances, and a 0 dB performance margin.

TABLE 8.3.3.3-1 DOD/SGLS TRANSPONDER TURNAROUND REQUIREMENTS

PARAMETER	VALUE	UNITS	SUBPARAGRAPH
orward Link Sweep Acquisition			
Fast Sweep Rate	10	KHz/Sec	8.3.3.3.1
Frequency Range	±55	KHz	8.3.3.3.1
PLL Bandwidth	200	Hz	8.3.3.3.1.1
Sweep Tracking	±0.001 Max.	%	8.3.3.3.1.2
eturn Link Sweep Acquisition			
Frequency Stability	±0.001	%	8.3.3.3.2.1
Switchover Lock Loss	See Subparagraph		8.3.3.3.2.3
Transponder Turnaround Ratio	256/205	-	8.3.3.3.2.4
Sideband Level	< -35	dBc	8.3.3.3.2.5

TABLE 3.3.4.2.3.2-1 NARROW BAND "BENT PIPE" CHANNEL CHARACTERISTICS

a) PM 2.5 ≥ β ≥ 0.2 radians with a maximum residual carrier of -100.7 dBm for tracking.

b) The inband data spectral components within ±100 KHZ of the receive carrier frequency shall be 26 dB or more below the R.F. carrier power.

c) The intelligence contained in the received signal shall be ≤4.5 MHz at the 3 dB points (PI post detection BW.)

TABLE 8.3.4.3-1 NONSTANDARD TRANSPONDER TURNAROUND REQUIREMENTS

PARAMETER	VALUE	UNITS	SUBPARAGRAPH
Turnaround Ratio			8.3.4.3.1
NASA Type	240/221		
DOD Type	256/205		
PLL Bandwidth			8.3.4.3.2
Fast Sweep Rate (10 KHZ/Sec)	>200	Hz	
Slow Sweep Rate (250 HZ/Sec)	>18	Hz	
Sweep Tracking Offset	±0.001 Max.	%	8.3.4.3.3
Auxiliary Oscillator Stability	±0.001	%	8.3.4.3.5
Tracking Phase Error (1000 HZ 2-sided tracking bandwidth)	3	Degrees,rms	8.3.4.3.5.1
Spurs (within ±200 KHZ of return link carrier frequency)	at least 65	dbc	8.3.4.3.6.1
Sideband Level	-35	dBc	8.3.4.3.6.2

TABLE 8.3.5.1-1 PI/PS DATA INPUT ELECTRICAL INTERFACE CHARACTERISTICS

PARAMETER	UNITS	VALUE	NOTES
Carrier Modulation		PM	
Modulator Type		Linear	
Modulator Input Bandwidth	KHz	1 to 200	3 dB, one-sided
Signal Level		(1)	
Load Impedance	ohms	75 ± 5	
Load Termination		Differential, balanced direct coupled	

(1) 1.0 to 8.0 ± 10% peak-to-peak line-to-line ($0.2 \le \beta \le 2.5$). The phase deviation shall be directly proportional to the amplitude of the input signal. The linearity of the phase modulator shall be maintained to within 10% from 0.2 radians to 2.5 radians when measured from best straight line. (1.0 ± 0.1 volts, P-P, L-L, is equivalent to 2.5 radians)

TABLE 8.3.5.2-1 PI/PS DATA OUTPUT ELECTRICAL INTERFACE CHARACTERISTICS

PARAMETER	UNITS	VALUE	NOTES
Carrier Modulation		PM	
Interrogator I/F Bandwidth, Min.	MHz	10	Double-sided Passband, 3 dB
Postdetection Bandwidth, Min.	[illegible]	.001 to 4.5	one sided, 3 dB
Equiv. Source Modulation	Radians	0.3 to 1.3	(1)
Output Signal Level	volts	(2)	
Load Impendance	ohms	75 ±5	
Load Termination		Differential, balanced direct coupled	

(1) Modulation indices of up to 2.5 radians will be detected provided sufficient residual carrier is present.

(2) 2.0 ± 0.4 volts rms not to exceed 8 V peak-to-peak, line-to-line detected SC.

TABLE 8.3.6.1-1 RADAR PASSIVE MODE

ELECTRICAL INTERFACE CHARACTERISTICS

Parameter	Dimension	Value	Notes
1. Target Type			
Size	Square Meter	1.0 Minimum	(1)
Scintillation Characteristics		Swirling Case I target	Target is stabilized in 3 axes to an angular rate of TBD deg/sec.
2. Radar Operating Frequency	GHz	Nominal Minimum at 13.779	(2)
3. Antenna Characteristics			
Gain	db	38.5	At 13.775 GHz
Sidelobe	db relative to mainbeam	20 minimum	
Type		5 "Horn" monopulse, automatic tracking, front fed parabola.	Two-gimbal antenna mount
4. Transmitter Power	Watts	50 peak, minimum TWT output for high power mode	(3)
PRF	pulses/sec	nominal 7000 and 3000	PRF varies with range
5. Receiver			
Noise Figure	db	5	

TABLE 8.3.6.1-1 RADAR PASSIVE MODE

ELECTRICAL INTERFACE CHARACTERISTICS
(Concluded)

Parameter	Dimension	Value	Notes
Input Power Limits	milli-watts peak & CW	50	At input port to low-noise amplifier
Dynamic range	db	115	

(1) Radar system is designed to detect a 1 m² scintillating target at 12 NM with a probability of detection of 0,99. Angular searchfield varies with range from a 20 degree half angle cone at 12 NM to a maximum of a 30 degree half angle cone at 8 NM or less.

(2) 5 frequency, 4 step frequency diversity - 52 MHz per step during search, acquisition and tracking.

(3) Peak and average power vary with range and duty cycle. Duty cycle varies with range from approximately 0.001 to 0.3. Peak power selectable - medium and low power selections provide nominal reductions of 12 or 24 dB respectively. Automatic switch to TWT bypass (approx. 40 dB reduction in transmitted power) at short ranges.

TABLE 8.3.6.2-1 RADAR ACTIVE MODE ELECTRICAL

INTERFACE CHARACTERISTICS

Parameter	Dimension	Value	Notes
1. Target Type			
Transponder Pulse Beacon			Target carries coherent pulse transponder which retransmits amplified replica of received pulse. Beacon carrying target is stabilized in 3 axes to TBD deg/sec each axis.
Operating Range	Ft.	1.824×10^6 Detection 100 minimum	
2. Beacon Characteristics			
Minimum Detectable Signal	dbm	TBD	Function of target antenna and receiver sensitivity
EIRP	dbw	TBD	
Coherence		TBD	
Delay	μsec	10±0.1	
3. Radar Characteristics			
Transmit Freq.	GHz	13.883	
Receive Freq.	GHz	13.883	Same as radar transmit freq. ±5 MHz
Antenna Gain	db	38.5	Transmit and receive
Antenna side-lobe level	db relative to main beam	20 minimum	

TABLE 8.3.6.2-1 RADAR ACTIVE MODE ELECTRICAL

INTERFACE CHARACTERISTICS (Continued)

Parameter	Dimension	Value	Notes
Antenna Type		5 "Horn" monopulse, automatic angle track, front-fed parabola	Two-gimbal antenna mount.
PRF's	pulses per sec.	228 search and track 6970 Track 7171	For range greater than 9.5 NM Range less than 9.5 NM
Pulse widths	usec.	Dual 4.15 and 0.122 4.15 0.122	Used in search ranger. Used for search and track when range >9.5 NM Used for track when range < 9.5 NM
Transmit Power	Watts	50 peak, minimum TWT output for high power mode.	Peak power level selectable. medium and low power selections provide nominal reductions of 12 and 24 dB respectively.
Receiver noise Figure	db	5	
Input Power Limit	Milli-watts peak & CS	50 - damage level	At input port to low-noise amp.
Dynamic Range	db	115	

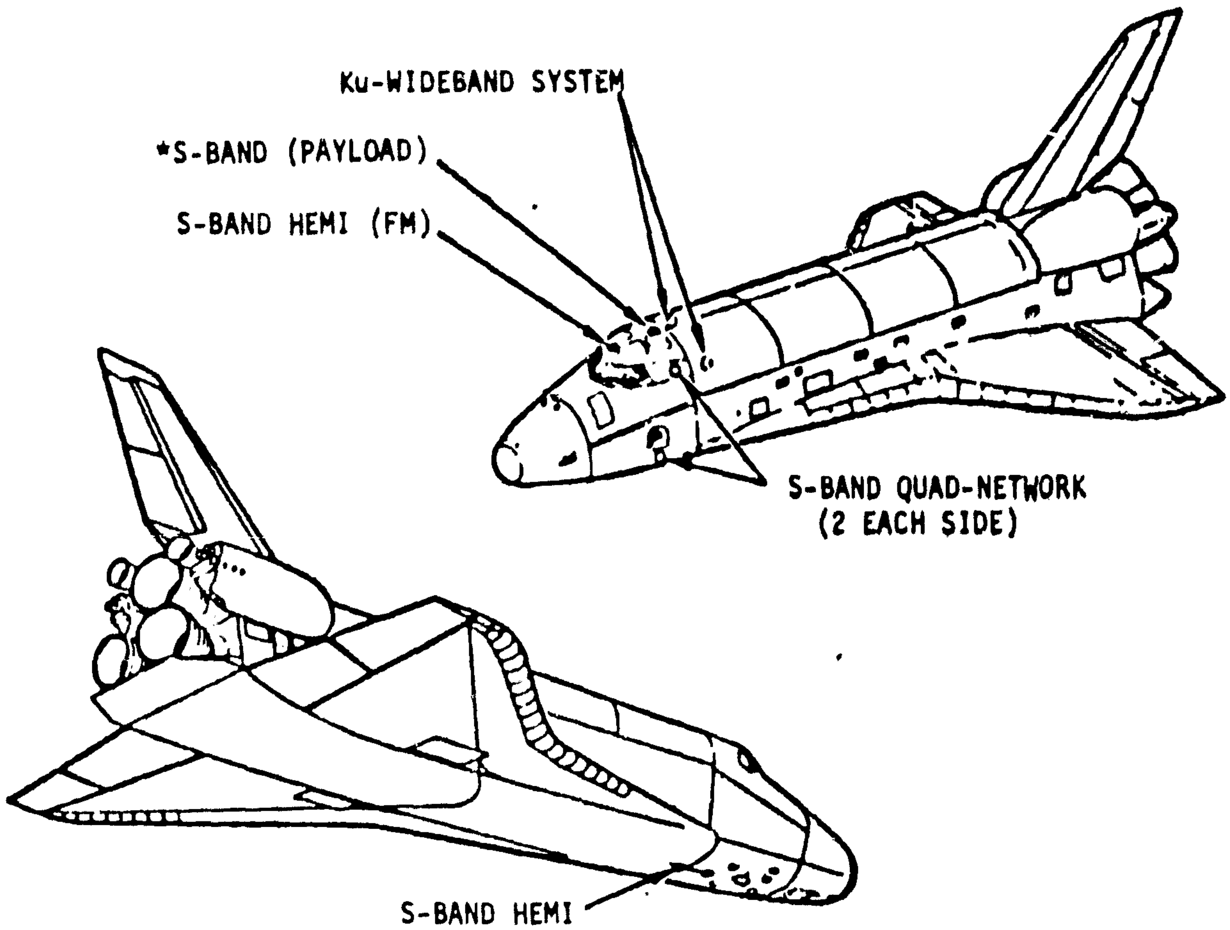
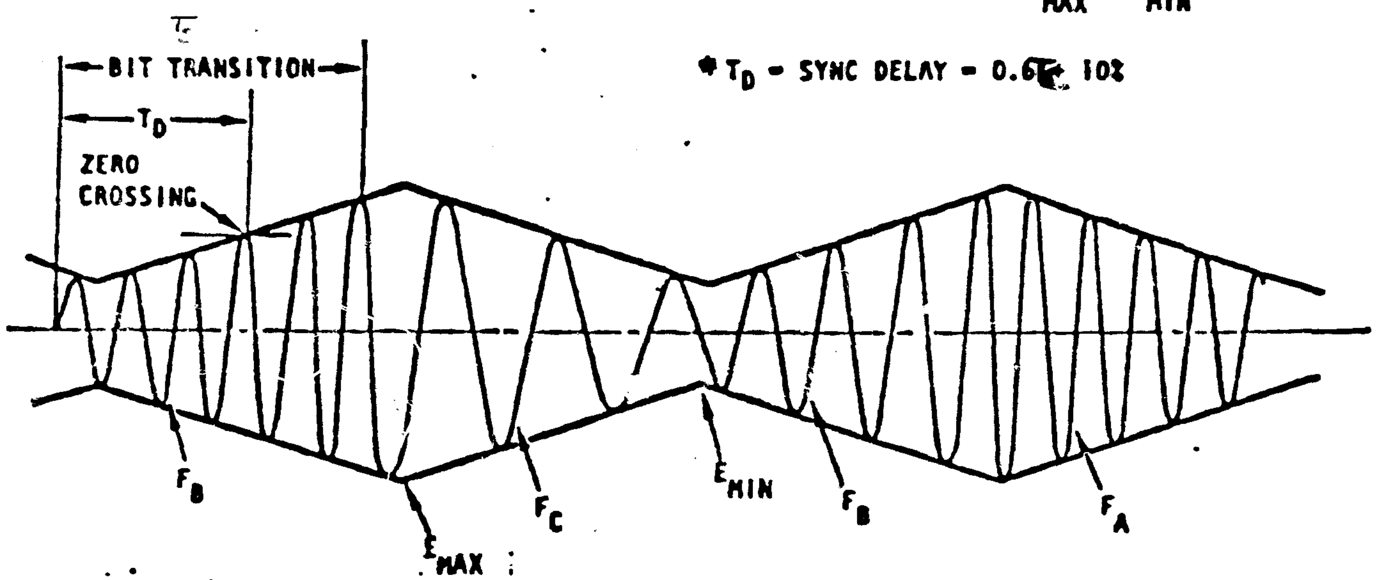


Figure 8.3.1.2.1-1 Antenna Location

MODULATION FACTOR: $(M) = \frac{E_{MAX} - E_{MIN}}{E_{MAX} + E_{MIN}} = 0.50 \pm 10\%$

* T_D = SYNC DELAY = $0.6\tau \pm 10\%$



WHERE: F_A = "1" = 95 KHz
F_B = "0" = 76 KHz
F_C = "S" = 65 KHz

NOTES:
1. A TRIANGULAR MODULATION ENVELOPE OF 500 KHz (FOR 1 KILOBAUD COMMANDS) OR 1000 Hz (FOR 2 KILOBAUD COMMANDS)
2. *ZERO CROSSING OF TRIANGULAR SYNC IS DELAYED FROM ZERO CROSSING OF BIT TRANSITION BY $0.6\tau \pm 10\%$ OF BIT PERIOD.

FIGURE 8.3.3.1.1-1 SGLS FSK/AM COMMAND WAVEFORM

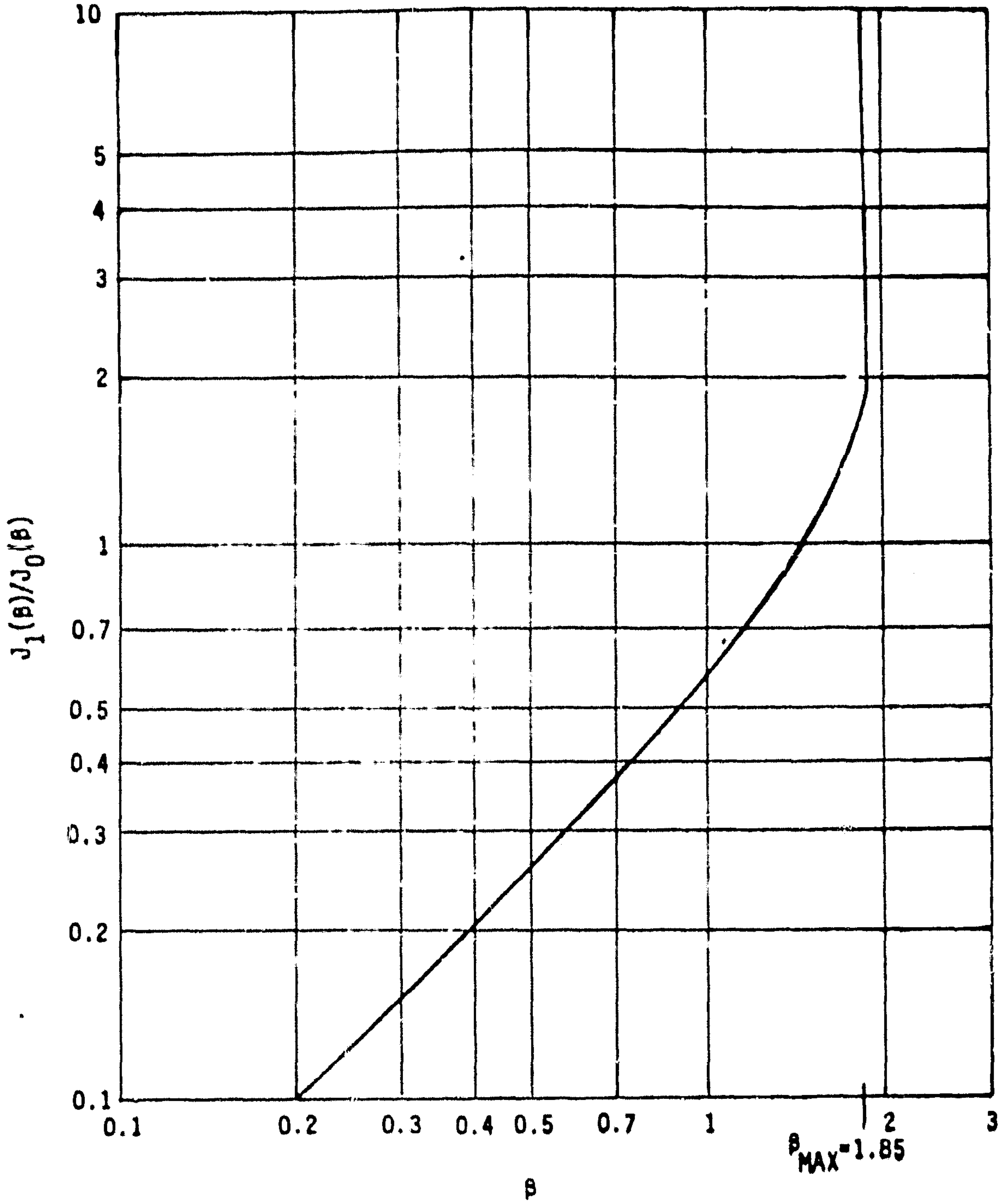


Figure 8.3.4.2.1-1 Curve Used for Determination of Modulation Index

APPENDIX IV

AXIOMATIX RECOMMENDATIONS FOR REVISION OF SECTION 8.3 OF ICD 2-19001 FOR DETACHED PAYLOADS

REVISION #2

JANUARY 2, 1980

DRAFT REVISION #2

1/2/80

REWRITE AND REVISION FOR SECTION 8.3 OF ICD NO. 2-19001

8.3 Detached Payloads. Paragraphs applicable to NASA/STDN, NASA/DSN, DOD/SGLS, and nonstandard payloads are indicated in the following breakdown:

NASA/STDN Payloads--Paragraphs 8.3.1 and 8.3.2, subparagraphs 8.3.2.1, 8.3.2.2 and 8.3.2.3.

NASA/DSN Payloads--Paragraphs 8.3.1 and 8.3.2, subparagraphs 8.3.2.1, 8.3.2.2 and 8.3.2.4.

DOD/SGLS Payloads--Paragraphs 8.3.1 and 8.3.3.

Nonstandard Payloads--Paragraph 8.3.1 and 8.3.4.

Note: Sometimes the acronym NASA appears by itself; it is to be understood that either STDN or DSN payloads are implied. STDN or DSN by themselves denote NASA payloads. DOD and SGLS by themselves refer to the same class of payloads.

8.3.1 S-Band Payload Interrogator (PI) Interface. The PI provides two-way RF communication between the Orbiter and detached payloads within a range of 10 nmi. In the following paragraphs, "characteristics" are capabilities of the Orbiter avionics that the payload must be cognizant of, and "requirements" are specifications placed upon the payload communication equipment.

8.3.1.1 PI Performance Characteristics

8.3.1.1.1 Transmitter Characteristics. The principal transmitter characteristics are listed in Table 8.3.1.1.1-1.

8.3.1.1.1.1 Output Frequency Range. Two output frequency bands are provided, L-band (DOD) and S-band (NASA), as summarized in Table 8.3.1.1.1.1-1.

8.3.1.1.1.2 DSN Channel Assignments. The transmit/receive frequency pair assignments for DSN-compatible detached payloads are listed in Table 8.3.1.1.1.1-3.

8.3.1.1.1.1.3 SGLS Channel Assignments. The transmit/receive frequency pair assignments for SGLS-compatible detached payloads are listed in Table 8.3.1.1.1.1-4.

8.3.1.1.1.2 Transmitter Triplexer Section. A triplexer is used between the payload antenna and the PI transmitter/receiver output/input terminals. This triplexer functions to divide the PI transmit and receive bands into low and high subbands for both the NASA and DOD modes of operation. The purpose of the low/high band selectivity is to prevent mutual interference between the PI and S-band network transponder during times of simultaneous operation.

TABLE 8.3.1.1.1-1 PRINCIPAL PI TRANSMITTER CHARACTERISTICS

Parameter	Value	Units	Subparagraph
L-Band Frequency Range	1763 - 1840	MHz	8.3.1.1.1.1
S-Band Frequency Range	2025 - 2120	MHz	8.3.1.1.1.1
Triplexer Subbands	See Subparagraph		8.3.1.1.1.2
Carrier Frequency Tolerance	±0.0012	%	8.3.1.1.1.3
Carrier Phase Noise	10 max	degrees-RMS	8.3.1.1.1.4
Output Spurs	> 67	dBc	8.3.1.1.1.5
Phase Modulator	0.2 to 2.5	radians	8.3.1.1.1.6
Frequency Sweep Ranges	±75 ±55 ±33	kHz kHz kHz	8.3.1.1.1.7
Frequency Sweep Rates	10	kHz/sec	8.3.1.1.1.8
	250	Hz/sec	8.3.1.1.1.8
Power Level--High	39	dBm	8.3.1.1.1.9
Medium	30	dBm	8.3.1.1.1.9
Low	7	dBm	8.3.1.1.1.9

TABLE 8.3.1.1.1.3-1 PAYLOAD INTERROGATOR OPERATING CHANNELS

	Frequency Range (MHz)	No. of Channels	Channel Spacing (kHz)
STDN S-Band Transmit and Receive			
S-Band Transmit	2025.833-2118.7	808	115.104
S-Band Receive	2200-2300.875	808	125.000
DSN S-Band Transmit and Receive			
S-Band Transmit	2110.243-2119.792	29*	341.049
S-Band Receive	2290.185-2299.814	27**	370.370
SGLS L-Band Transmit, S-Band Receive			
L-Band Transmit	1763.721-1839.795	20	4003.906
S-Band Receive	2202.5-2297.5	20	5000.000

*The top six channels are transmit only.

**The bottom four channels are receive only.

TABLE 8.3.1.1.1.1-2 STDN CHANNEL AND FREQUENCY ASSIGNMENTS

Refer to Appendix C for specific channel and frequency assignments. Method of calculating frequencies is as follows:

Channel No. n = 1 to 808

Receive Frequency = 2200.000 + (n-1) x 0.125 MHz

Transmit Frequency = 2025.8334 + (n-1) x 0.115104 MHz

Transmit Frequency = 221/240 x Receive Frequency

Table 8.3.1.1.1.1-3 DSN Channel & Frequency Assignments

Channel	Transmit MHz Specified	Receive MHz Specified
850		2290.185185
851		2290.555556
852		2290.925926
853		2291.296296
854 (56)	2110.243056	2291.666667
855	2110.584105	2292.037037
856	2110.925154	2292.407407
857	2111.266204	2292.777778
858	2111.607253	2293.148148
859	2111.948303	2293.518519
860	2112.289352	2293.888889
861	2112.630401	2294.259259
862	2112.971451	2294.629630
863 (14b)	2113.312500	2295.000000
864	2113.653549	2295.370370
865	2113.994599	2295.740741
866	2114.335648	2296.111111
867	2114.676697	2296.481981
868	2115.017747	2296.857852
869	2115.358796	2297.222222
870	2215.699846	2297.592593
871	2116.040895	2297.962965
872 (23b)	2116.381944	2298.333333
873	2116.722994	2298.703704
874	2117.064043	2299.074074
875	2117.405092	2299.444444
876	2117.746142	2299.814315
877	2118.087191	
878	2118.428241	
879	2118.769290	
880	2119.110339	
881	2119.451389	
882	2119.792438	

Unassigned channels: 883-899.

TABLE 8.3.1.1.1.1-4 SGLS CHANNEL & FREQUENCY ASSIGNMENTS

CHANNEL	TRANSMIT ORBITER TO DOD PAYLOADS (MHz)	RECEIVE DOD PAYLOADS TO ORBITER (MHz)
900	1763.721	2202.500
901	1767.725	2207.500
902	1771.729	2212.500
903	1775.733	2217.500
904	1779.736	2222.500
905	1783.740	2227.500
906	1787.744	2232.500
907	1791.748	2237.500
908	1795.752	2242.500
909	1799.756	2247.500
910	1803.760	2252.500
911	1607.764	2257.500
912	1811.768	2262.500
913	1815.772	2267.500
914	1819.775	2272.500
915	1823.779	2277.500
916	1827.783	2282.500
917	1831.787	2287.500
918	1835.791	2292.500
919	1839.795	2297.500

Unassigned Channels: 920-999

8.3.1.1.1.2.1 S-Band Subbands. The lowband is approximately 2025-2075 MHz and the highband is approximately 2074-2120 MHz.

8.3.1.1.1.2.2 L-Band Subbands. The lowband is approximately 1763-1803 MHz and the highband is approximately 1803-1840 MHz.

8.3.1.1.1.3 Carrier Frequency Tolerance. The maximum carrier frequency uncertainty is ±0.0012% of the nominal carrier frequency (transmitter sweep disabled).

8.3.1.1.1.4 Carrier Phase Noise. The transmitter phase noise will produce under nonvibration conditions no more than a 4° RMS tracking phase error in a 300 Hz two-sided tracking bandwidth and a 10° RMS tracking error in a 100 Hz two-sided tracking bandwidth. (Tracking loop damping factor = 0.707.)

8.3.1.1.1.5 Carrier Spurs. Any spurs appearing at the transmitter output 200 kHz away from the carrier frequency will be at least 69 dB below the unmodulated carrier power level. Within 200 kHz about the carrier, the spurs will be > 46 below the carrier level.

8.3.1.1.1.6 Carrier Phase Modulator. The phase modulator will accept analog or digital modulating signals. The modulator deviation characteristic is linear with ±5% over a deviation range of 0.2-2.5 rad. Frequency response is flat within ±0.5 dB from 1-200 kHz.

8.3.1.1.1.7 Carrier Frequency Sweep. The transmitter output frequency may be swept over three ranges: 75 ±5 kHz, 55 ±5 kHz, 33 ±3 kHz. The fast sweep rate for the 75 and 55 kHz ranges is 10 ±3 kHz/s and, for the 33 kHz range, is 250 ±75 Hz/s. Frequency sweep begins at the nominal channel frequency, sweeps up to the maximum frequency, reverses and sweeps down (through the nominal channel frequency) to the minimum frequency, reverses and sweeps up to the nominal channel frequency and stops.

8.3.1.1.1.8 Selectable Transmitter Power Levels. Three selectable transmitter output power levels for either the L-band or S-band frequency ranges are available at the input/output common port.

High	39 dBm ±2 dB
Medium	30 dBm ±3 dB
Low	7 dBm ±3 dB .

8.3.1.1.2 Receiver Characteristics. The principal receiver characteristics are listed in Table 8.3.1.1.2-1.

8.3.1.1.2.1 Input Frequency Range. The receiver input frequency range is S-band, 2200-2300 MHz.

8.3.1.1.2.1.1 STDN Channel Assignments. See Paragraph 8.3.1.1.1.1.1.

8.3.1.1.2.1.2 DSN Channel Assignments. See Paragraph 8.3.1.1.1.1.2.

8.3.1.1.2.1.3 SGLS Channel Assignments. See Paragraph 8.3.1.1.1.1.3.

8.3.1.1.2.2 Receiver Triplexer Section. See Paragraph 8.3.1.1.1.2.

8.3.1.1.2.2.1 Receive Subbands. The lowband is approximately 2195-2257 MHz and the highband is approximately 2248-2306 MHz.

TABLE 8.3.1.1.2-1 PRINCIPAL PI RECEIVER CHARACTERISTICS

Parameter	Value	Units	Subparagraph
Input Frequency Range	2200 - 2300	MHz	8.3.1.1.2.1
Triplexer Subbands	See Subparagraph		8.3.1.1.2.2
Input Signal Level Operating Range	-124 to +10	dBm	8.3.1.1.2.3
AGC Range	-124 to -20	dBm	8.3.1.1.2.4
Out-of-Band Interference	See Subparagraph		8.3.1.1.2.5
Noise Figure	7.0 max	dB	8.3.1.1.2.6
Carrier Thresholds: Acquisition	-122.5	dBm	8.3.1.1.2.7
Tracking	-124.0	dBm	8.3.1.1.2.7
Acquisition Sweep Range	±125	kHz	8.3.1.1.2.8.1
Acquisition Sweep Rate	330	kHz/sec	8.3.1.1.2.8.1
Frequency Rate Tracking	17	kHz/sec	8.3.1.1.2.8.2
Input Freq. Offset Range	±87	kHz	8.3.1.1.2.8.3
Lock Detector Performance	See Subparagraph		8.3.1.1.2.9
False Lock Immunity	See Subparagraph		8.3.1.1.2.10
Tracking Bandwidth	2320	Hz	8.3.1.1.2.11
Maximum Phase Noise	15	Degrees-RMS	8.3.1.1.2.12
Maximum SPE	10	Degrees	8.3.1.1.2.13
Throughput Bandwidth	< 5.5	MHz	8.3.1.1.2.14
Output Signal Regulation	See Subparagraph		8.3.1.1.2.15
Throughput SNR Losses	2.1 max	dB	8.3.1.1.2.16

8.3.1.1.2.3 Input Signal Level Range. The receiver is operable over a range of -124 to +10 dBm.

8.3.1.1.2.4 AGC Dynamic Range. The AGC maintains the receiver transfer function in a linear state over an input signal level range of -124 to -20 dBm.

8.3.1.1.2.4.1 Receiver Gain Saturation. Above -20 dBm, the receiver IF amplifier circuits begin to amplitude saturate. This should not adversely affect the demodulation of constant envelope signals. Overall receiver performance is not guaranteed about +10 dBm in terms of false lock immunity and output signal waveform integrity.

8.3.1.1.2.4.2 Receiver Protective Limiting. At input signal levels of zero dBm and higher, a preamplifier protective diode breakdown limiter becomes operative. Purposeful receiver operation above +10 dBm is not recommended.

8.3.1.1.2.5 Out-of-Band Interference. The receiver will operate with no more than a 1.0 dB SNR performance degradation due to out-of-band interference for the conditions listed in Table 8.3.1.1.2.5-1.

8.3.1.1.2.6 Noise Figure. The receiver noise figure, as referenced to the RF common input/output port, is 7.0 dB maximum.

8.3.1.1.2.7 Carrier Acquisition and Tracking Thresholds. The minimum received discrete carrier signal level for guaranteed acquisition is -122.5 dBm. The minimum received discrete carrier signal level for guaranteed tracking and demodulation performance is -124.0 dBm. Levels are referenced to the RF input/output common port.

8.3.1.1.2.8 Carrier Dynamic Acquisition and Tracking

8.3.1.1.2.8.1 Receiver Frequency Sweep. For the purpose of acquisition, the receiver is nominally swept ±125 kHz (±111 kHz minimum, ±132 kHz maximum) from the nominal receive frequency at a nominal rate of 330 kHz/s. (This sweep is unrelated to the transmitter sweep.)

8.3.1.1.2.8.2 Frequency Rate Tracking. The maximum in-lock frequency rate that may be tracked is 17 kHz/s.

8.3.1.1.2.8.3 Input Frequency Offset Range. The receiver maximum input frequency offset is ±87 kHz from the nominal carrier frequency.

8.3.1.1.2.9 Lock Detector Statistical Performance. Lock detector probability of false alarm (indicating that the receiver is in lock when it is note) is (TBS) for a carrier level of -122.5 dBm and standard payload modulation conditions. Lock detector probability of indicating that the receiver is out of lock when it is not is (TBS) for a carrier level of -124.0 dBm. The lock detector must indicate an out-of-lock state for more than 50 ms before the receiver automatically enters the sweep acquisition mode.

8.3.1.1.2.10 False Lock Immunity. The receiver will not false lock to carrier sideband components for any NASA or DOD standard modulation conditions for received signal levels less than +10 dBm. (See Paragraph. 8.3.4.2.2 for nonstandard modulation conditions.)

TABLE 8.3.1.1.2.5-1 OUT-OF-BAND INTERFERENCE CONDITIONS

Interference Signal Level	Applicable Frequency Range
-65 dBm	Low Band: 2165 MHz to (f_R - 15) MHz and (f_R + 15) MHz to 2285 MHz
-65 dBm	High Band: 2220 MHz to (f_R - 15) MHz and (f_R + 15) MHz to 2340 MHz
-25 dBm	Low Band: 200 MHz to 2165 MHz and 2285 MHz to 16 GHz
-25 dBm	High Band: 200 MHz to 2220 MHz and 2340 MHz to 16 GHz

8.3.1.1.2.11 Phase Locked Loop (PLL) Bandwidths

8.3.1.1.2.11.1 Threshold Tracking Bandwidth. The threshold in-lock PLL tracking noise bandwidth, when the receiver is operating within the linear coherent AGC range, is nominally 2320 Hz (two-sided) and the damping factor is 0.82.

8.3.1.1.2.11.1 Threshold Acquisition Bandwidth. The threshold out-of-lock PLL noise bandwidth, when the receiver is operating within the noncoherent AGC control range, is 3950 Hz (two-sided) maximum.

8.3.1.1.2.11.3 Strong Signal Acquisition Natural Frequency. The strong signal out-of-lock PLL natural frequency, when the receiver is operating within the noncoherent AGC control range, is approximately 6120 rad/s.

8.3.1.1.2.12 PLL Phase Noise Components. Components and maximum values which comprise the PLL phase noise are listed in Table 8.3.1.1.2.12-1.

8.3.1.1.2.14 Wideband Demodulator. A wideband sinusoid phase-characteristic demodulator provides recovery of all carrier phase modulations. The throughput lowpass 3 dB bandwidth of the receiver, demodulator and output circuits is between 4.0 and 5.5 MHz.

8.3.1.1.2.15 Wideband Output Signal Regulation. The wideband demodulated signal output level to the PSP, CIU (Payload Station) and bent-pipe ports is controlled by an RMS type of regulating loop. PSP and CIU signal waveforms plus noise are regulated to 2.0 ±0.6 V RMS and the output amplifier clips or limits all peak values (plus or minus) to approximately 4.0 V maximum. The KuSP or bent-pipe waveform plus noise is regulated to 2.0 ±0.6 V RMS and the output amplifier clips or limits all peak values (plus or minus) to approximately 3.5 V maximum.

8.3.1.1.2.16 Demodulation SNR Loss Components. Table 8.3.1.1.2.16-1 lists the receiver (including the PSP) SNR maximum loss components for standard modulations.

8.3.1.2 Antenna Characteristics. The PI/payload link utilizes a single hemispherical antenna for both transmitting and receiving.

8.3.1.2.1 Antenna Location. The antenna is located at the top of the payload bay forward bulkhead, as shown in Figure 8.3.1.2.1-1.

8.3.1.2.2 Antenna Type. The antenna is a single-element cross-dipole-fed cavity which operates on the frequency range of 1740-1850 MHz with a VSWR < 1.5:1, and on the 200-2300 MHz frequency range with a VSWR < 2.0:1.

8.3.1.2.3 Gain. The maximum on-axis gain is between 2.5 and 3.0 dB.

8.3.1.2.4 Beamwidth. The 3 dB beam width is bounded by a 160° cone aligned with the +Z axis of the Orbiter.

8.3.1.2.5 Polarization. Antenna polarization is selectable as either right-hand circular (RHCP) or left-hand circular (LHCP).

8.3.1.2.6 Antenna Cable and Connectors Insertion Loss. The cable that connects the antenna to the PI RF port has a signal insertion loss to either transmit or receive signals of -9.8 dB maximum.

8.3.2 NASA Standard Payload/PI/PSP Communication Characteristics & Requirements

8.3.2.1 Command Signals. A single form of command signal is allowed, with summary characteristics listed in Table 8.3.2.1-1.

TABLE 8.3.1.1.2.12-1 PI TRACKING LOOP PHASE NOISE COMPONENTS

Component Source	Maximum Phase Noise Contribution
Additive Noise	$< 10^{\circ}$ RMS
Oscillator Instability	$< 5^{\circ}$ RMS
Modulation Tracking	$< 10^{\circ}$ RMS

TABLE 8.3.1.1.2.13-1 PI TRACKING LOOP STATIC PHASE ERROR COMPONENTS

Component Source	Component Maximum Value
Voltage Offsets within Loop	8°
Frequency Dynamics	2°
No Modulation Slewing (Nonstandard direct carrier modulations only, see subparagraph 8.3.4.2.2.4.2)	18°

TABLE 8.3.1.1.2.16-1 PI/PSP SNR MAXIMUM LOSS COMPONENTS FOR STANDARD MODULATIONS

Component	Loss (dB)
PI Interference Degradation	-1.0
PI Phase Noise Loss	-0.2
PI Demodulation Phase Offset Loss	-0.5
PI Filtering Loss	-0.2
PI Nonlinear Loss	-0.2
PSP Subcarrier Demodulator and Bit Synchronizer Loss	-0.8

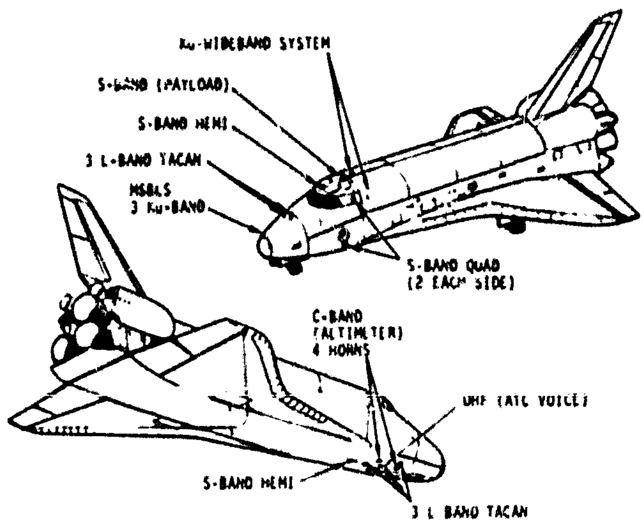


FIGURE 8.3.1.2.1-1 PAYLOAD ANTENNA LOCATION

TABLE 8.3.2.1-1 NASA STANDARD COMMAND SIGNAL CHARACTERISTICS

Parameter	Value	Units	Subparagraph
Waveform	Sinusoidal	-	8.3.2.1.1
Modulation	PSK, ±90	Degrees	8.3.2.1.1
Subcarrier Frequency	16	kHz	8.3.2.1.2
Carrier Modulation Index	1.0 ± 0.1	Radians	8.3.2.1.3
Bit Rates	$2000 \div 2^N$, N=0,1,2,...,8	bps	8.3.2.1.4.1

8.3.2.1.1 Modulation Waveform. The command waveform is a sine wave subcarrier biphase PSK modulated (±90°) by the command bits.

8.3.2.1.2 Subcarrier Frequency. The nominal command subcarrier frequency is 16 kHz.

8.3.2.1.2.1 Subcarrier Harmonic Distortion. The maximum harmonic components do not exceed 1% of the fundamental frequency amplitude.

8.3.2.1.2.2 Subcarrier Frequency Stability. The 60-sec averaged subcarrier frequency will be within $\pm 1 \times 10^{-5}$ of the nominal subcarrier frequency.

8.4.3.1.3 Carrier Modulation Index. Carrier modulation index for the command waveform is 1.0 ± 0.1 radian peak.

8.3.2.1.4 Data Modulation

8.3.2.1.4.1 Data Rate. The command data rates may be any one of the following:

2000 bps, 1000 bps, 500 bps, 250 bps, 125 bps, 62.5 bps, 31.25 bps, 15.625 bps or 7.8125 bps.

8.3.2.1.4.2 Data Bit Format. The bit format may be NRZ-L, NRZ-M or NRZ-S. Transition of the data waveform will coincide with a zero crossing of the subcarrier.

8.3.2.1.4.3 Data Asymmetry. The data bit asymmetry will not exceed 2% of the nominal data bit period.

8.3.2.1.4.4 Data Bit Jitter. The data bit peak phase jitter will not exceed 3% of the data bit period.

8.3.2.1.4.5 Command Bit Preamble. Whenever actual command bits are not being modulated onto the subcarrier, a prefix consisting of alternating "one" and "zero" bits is employed. The prefix always begins with a "one" bit ends with a "zero" bit just prior to the first command message bit.

8.3.2.2 Telemetry Signals. A single form of telemetry signal is allowed, with summary requirements listed in Table 8.3.2.2-1.

8.3.2.2.1 Modulation Waveform. The telemetry waveform shall be a sine-wave subcarrier PSK modulated (±90°) by the telemetry bits.

8.3.2.2.2 Subcarrier Frequency. The nominal telemetry subcarrier frequency shall be 1.024 MHz.

8.3.2.2.2.1 Subcarrier Harmonic Distortion. The maximum harmonic components shall not exceed 1% of the fundamental frequency amplitude.

8.3.2.2.2.2 Subcarrier Frequency Stability. The long-term subcarrier frequency stability (uncertainty) shall be within ±0.01% of the nominal subcarrier frequency.

8.3.2.2.3 Payload Transmitter Modulation Index. The payload carrier modulation index shall be 1.0 ±0.1 radian peak.

TABLE 8.3.2.2-1 NASA STANDARD TELEMETRY SIGNAL REQUIREMENTS

Parameter	Value	Units	Subparagraph
Waveform	Sinusoidal	-	8.3.2.2.1
Modulation	PSK, ±90	Degrees	8.3.2.2.1
Subcarrier Frequency	1.024	MHz	8.3.2.2.2
P/L Modulation Index	1.0 ± 0.1	Radians	8.3.2.2.3
Bit Rate	$16 \div 2^N$, N = 0,1,2,3,4	kbps	8.3.2.2.4.1
Bit Format	NRZ-L,M, or S, or Manchester-L, M, or S	-	8.3.2.2.4.2
Word Length	8	Bits	8.3.2.2.5.1
Minor Frame Length	8 to 1024	Words	8.3.2.2.5.2
Master Frame Length	1 to 256	Minor Frames	8.3.2.2.5.4
Transition Density	≥ 64 transitions in 512 bits		8.3.2.2.5.6
	≤ 64 consecutive bits w/o transition		8.3.2.2.5.6

8.3.2.2.4 Data Modulation

8.3.2.2.4.1 Data Rates. The telemetry data rates shall be any one of the following:

16 kbps, 8 kbps, 4 kbps, 2 kbps or 1 kbps.

8.3.2.2.4.2 Data Bit Format. The bit format shall be NRZ or Manchester L, M or S. The bits and subcarrier may be asynchronous or, if synchronous, no specific transition versus subcarrier phase relationship is required.

8.3.2.2.4.3 Data Asymmetry. The asymmetry in period between adjacent opposite polarity bits shall not exceed ±2% of the nominal bit period.

8.3.2.2.4.4 Bit Rate Stability. The bit rate stability shall be better than 0.1% of the nominal bit rate.

8.3.2.2.5 Data Structure Formats

8.3.2.2.5.1 Word Length. The basic data word length shall be eight bits. (Longer words may be realized as multiples of eight bits).

8.3.2.2.5.2 Minor Frame Length. A minor frame shall be a minimum of eight words up to a maximum of 1024 words.

8.3.2.2.5.3 Minor Frame Synchronization Words. Minor frame synchronization words shall consist of 8, 16, 24 or 32 bit groups.

8.3.2.2.5.4 Master Frame Length. A master frame shall be comprised of between one and 256 minor frames.

8.3.2.2.5.5 Master Frame Synchronization Word. The master frame synchronization word shall consist of an eight-bit unique pattern or an eight-bit minor frame count.

8.3.2.2.5.6 Transition Density. The minimum data transition density requirement shall be for 64 or more transitions in any 512-bit block and for no segment greater than 64 bits without a transition.

8.3.2.2.6 Payload Minimum EIRP. Table 8.3.2.2.6-1 lists the payload minimum EIRP required to achieve a 1×10^{-5} bit error for the bit rates listed under 8.3.2.2.4.1 at the output of the PSP for the conditions of 10 nmi range, worst-case tolerances, and a 0 dB performance margin.

8.3.2.3 STDN Near-Earth (NE) Transponder Turnaround Requirements. The following paragraphs also apply to TDRS user transponders operating in the STDN mode.

8.3.2.3.1 Forward Link Sweep Acquisition. The NE transponder forward link from the Orbiter to the payload will be frequency swept in the PI transmitter (for acquisition purposes) in accord with 8.3.1.1.1.7 utilizing the fast sweep rate of 10 kHz/sec over the ±75 kHz range.

TABLE 8.3.2.2.6-1 NASA PAYLOAD MINIMUM EIRP REQUIREMENTS

Bit Rate	EIRP
16 kbps	28.2 dBm
8 kbps	25.1 dBm
4 kbps	22.1 dBm
2 kbps	19.1 dBm
1 kbps	16.2 dBm*

*Set by carrier minimum acquisition level requirement.

8.3.2.3.1.1 Transponder Minimum PLL Acquisition Bandwidth. In order to achieve a virtual unity probability of carrier acquisition when the PI sweep crosses the transponder nominal receive frequency, the transponder two-sided loop noise bandwidth shall not be less than 500 Hz.

8.3.2.3.1.2 Sweep Tracking Requirement. The PI transmitter sweep goes though one complete sweep cycle before being disabled. The transponder receiver must therefore by capable of tracking the entire PI transmitter sweep range (±80 kHz worst case) for the condition of PI transmitter maximum nominal frequency offset (±0.0012%).

8.3.2.3.2 Return Link Acquisition. The PI receiver is required to acquire the payload transmitter signal when the transponder is in its one-way mode (transmitter carrier frequency derived from the transponder auxiliary oscillator) or in the two-way mode with the forward link sweep transponded to the return link carrier.

8.3.2.3.2.1 Auxiliary Oscillator Stability. The long-term stability of the transponder transmitter's nominal carrier frequency as derived from the auxiliary oscillator shall be no worse than ±0.001%.

8.3.2.3.2.2 Auxiliary Oscillator-to-VCO Switchover. There are no PI-imposed requirements on the auxiliary oscillator-to-VCO switchover (when the forward link becomes acquired) in terms of the resulting frequency step.

8.3.2.3.2.3 PI Receiver Lock Loss due to Auxiliary Oscillator-to-VCO Switchover. It is expected that, when the transponder switches its transmitted frequency source form auxiliary oscillator to the VCO, PI receiver lock (if it had been attained in the one-way mode) may be temporarily lost. PI receiver reacquisition by frequency sweeping will automatically ensue.

8.3.2.3.2.4 Transponder Turnaround Ratio. The transponder transmit/receive frequency turnaround ratio shall be 240/221.

8.3.2.3.2.5 Return Link Carrier Sideband Level due to Forward Link Modulation Feedthrough. The maximum feedthrough modulation sidebands of the return link carrier by the forward link command modulation (16 kHz subcarrier) shall not exceed a return link sideband level greater than -26 dBc.

8.3.2.4 DSN Deep-Space (DS) Transponder Turnaround Requirements

8.3.2.4.1 Forward Link Sweep Acquisition. The NE transponder forward link from the Orbiter to the payload will be frequency swept in the PI transmitter (for acquisition purposes) in accord with 8.3.1.1.1.7, utilizing the slow sweep rate of 250 Hz/s over the ±33 kHz range.

8.3.2.4.1.1 Transponder Minimum PLL Acquisition Bandwidth. In order to achieve a virtual unity probability of carrier acquisition when the sweep crosses the transponder nominal receive frequency, the transponder two-sided loop noise bandwidth shall not be less than 150 Hz, with a damping factor no larger than 3.0. (It has been assumed that, when the DS transponder is operating with the Orbiter, the minimum receive signal level will be strong to the extent that the transponder receiver's limiter suppression factor will be essentially unity.)

8.3.2.4.1.2 Swept Acquisition Time. The nominal time required to sweep the entire ±33 kHz frequency uncertainty range using the slow sweep rate profile will be 8.8 minutes from the time the sweep is initiated until the time the sweep is disabled.

8.3.2.4.1.3 Sweep Tracking Requirement. In the slow sweep rate mode, the PI transmitter sweep will nominally go through one complete sweep cycle and then become disabled. The transponder receiver must the efore be capable of tracking the entire PI transmitter sweep range (±36 kHz worst case) for the condition of PI transmitter maximum nominal frequency offset of ±0.0012%.

8.3.2.4.2 Return Link Sweep Acquisition. The PI receiver is required to acquire the payload transmitter signal when the transponder is in its one-way mode (transmitter carrier frequency derived from the transponder auxiliary oscillator) or in the two-way mode with the forward link sweep transponded to the return link carrier.

8.3.2.4.2.1 Auxiliary Oscillator Stability. The long-term stability of the transponder transmitter's nominal carrier frequency as derived from the auxiliary oscillator shall be no worse than ±0.001%.

8.3.2.4.2.2 Auxiliary Oscillator-to-VCO Switchover. There are no PI-imposed requirements on the auxiliary oscillator-to-VCO switchover (when the forward link becomes acquired) in terms of the resulting frequency step.

8.3.2.4.2.3 PI Receiver Lock Loss due to Auxiliary Oscillator-to-VCO Switchover. It is expected that, when the transponder switches its transmitter frequency source from auxiliary oscillator to the VCO, PI receiver lock (if it had been attached in the one-way mode) may be temporarily lost. PI receiver reacquisition by frequency sweeping will automatically ensue.

8.3.2.4.2.4 Transponder Turnaround Ratio. The transponder transmit/receive frequency turnaround ratio shall be 240/221.

8.3.2.4.2.5 Return Link Carrier Sideband Level Due to Forward Link Modulation Feedthrough. The maximum feedthrough modulation sidebands of the return link carrier by th forward link command modulation (16 kHz subcarrier) shall not exceed a return link sideband level greater than -26 dBc.

8.3.3 DOD/SGLS Standard Payload/PI/CIU Communication Characteristics and Requirements

8.3.3.1 Command Signals. A single form of command signal is allowed, with summary characteristics listed in Table 8.3.3.1-1.

8.3.3.1.1 Modulation Waveform. The command signal is a ternary FSK/AM waveform with form as shown in Figure 8.3.3.1.1-1. Three command symbols are employed and the composite FSK waveform is 50% amplitude modulated by a triangular function of frequency equal to one-half the command symbol rate.

TABLE 8.3.3.1-1 SGLS STANDARD COMMAND SIGNAL CHARACTERISTICS

Parameter	Value	Units	Subparagraph
Waveform	Sinusoidal with AM	-	8.3.3.1.1
Modulation	Ternary FSK	-	8.3.3.1.1
Symbol Frequencies	"S" = 65	kHz	8.3.3.1.2
	"0" = 76	kHz	
	"1" = 95	kHz	
Carrier Modulation Indices	0.3 ± 20%	radians	8.3.3.1.3
	1.0 ± 10%	radians	
Symbol Rates	1000	sps	8.3.3.1.4.1

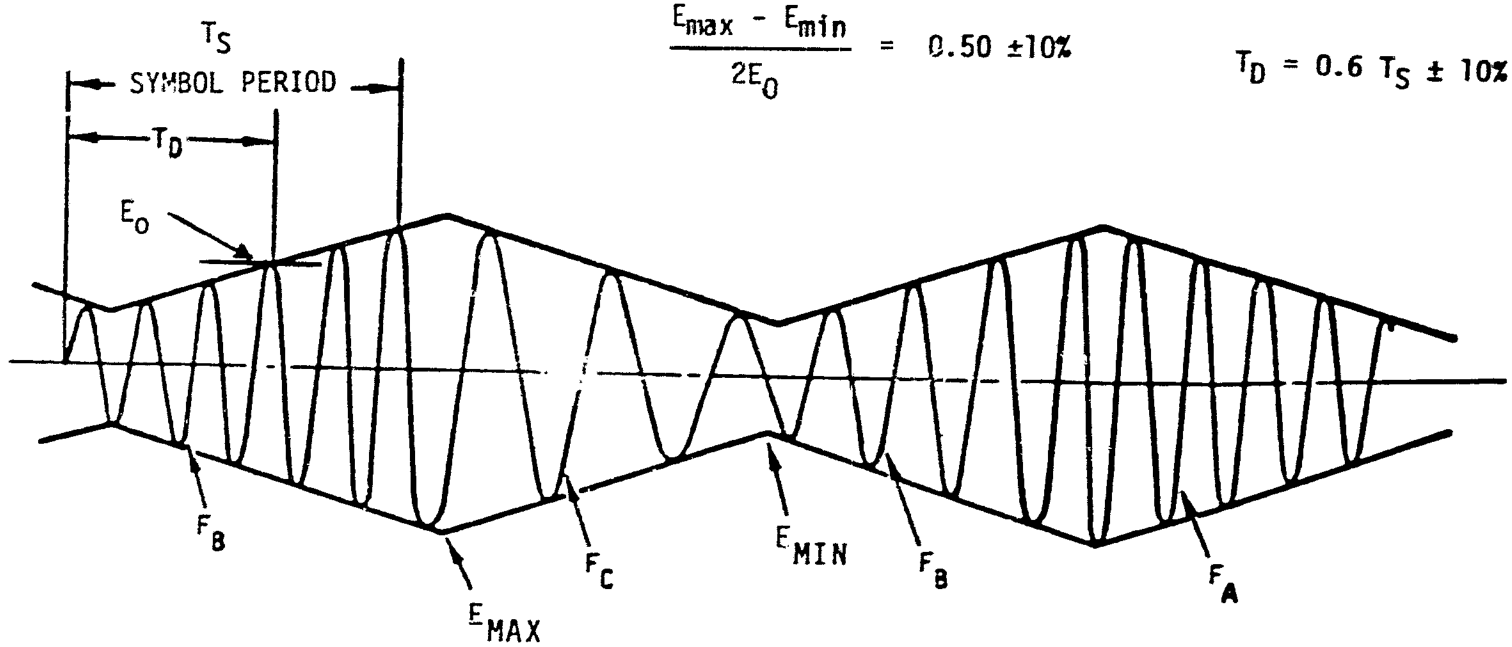


FIGURE 8.3.3.1.1-1 SGLS FSK/AM COMMAND WAVEFORM

8.3.3.1.2 Command Tone Frequencies. The command symbol tone frequencies are as follows:

Logic "S" - 65 kHz

Logic "0" - 76 kHz

Logic "1" - 95 kHz

8.3.3.1.2.1 Tone Frequency Accuracy. The maximum nominal tone frequency error will not exceed ±0.01%.

8.3.3.1.3 Carrier Modulation Indices. Two carrier modulation indices are employed: 1.0 ±10% radians or 0.3 ±20% radians peak.

8.3.3.1.4 Data Modulation

8.3.3.1.4.1 Data Symbol Rate. The ternary symbols are transmitted at the rate of 1000 ±0.01% symbols/second.

8.3.3.1.4.2 Triangular AM Clock. A triangular waveform clock at one-half the symbol rate and with its positive zero crossing delayed by 0.6 T_s ±10% from the symbol epoch amplitude modulates the composite symbol stream with a 50% intensity.

8.3.3.1.4.3 Data Format (TBS)

8.3.3.1.4.4 Command Bit Preamble (TBS)

8.3.3.2 Telemetry Signals. One PSK and one FM subcarrier are allowed; summary requirements are listed in Table 8.3.3.2-1.

8.3.3.2.1 PSK Subcarrier. The PSK subcarrier shall be sinusoidal biphase modulated (±90°) by the telemetry data waveform with at least a 30 dB subcarrier suppression.

8.3.3.2.1.1 Subcarrier Frequency. The nominal PSK subcarrier frequency shall be 1.024 MHz.

8.3.3.2.1.2 Subcarrier Frequency Accuracy. The long-term subcarrier frequency uncertainty shall be <±0.001% of the nominal subcarrier frequency.

8.3.3.2.1.3 Subcarrier Harmonic Components. The maximum harmonic components of any subcarrier shall not exceed (TBS)% of the fundamental frequency amplitude.

8.3.3.2.2 PSK Data Waveform. The PSK data waveform shall be Manchester-L.

8.3.3.2.2.1 PSK Data Rate. The PSK data rate shall be 16 kbps.

8.3.3.2.2.2 Data Rate Stability. The data rate stability shall be better than 0.001% of the nominal data rate.

8.3.3.2.3 FM Subcarrier and Modulation. An FM/FM structure shall be employed with sinusoidal subcarriers.

8.3.3.2.3.1 Master Subcarrier Frequency. The master subcarrier nominal frequency shall be 1.7 MHz.

Table 8.3.3.2-1 SGLS Standard Telemetry Signal Requirements

Parameter	Value	Units	Subparagraphs
Subcarrier Waveforms	Sinusoidal	-	8.3.3.2.1 & 8.3.3.2.3
PSK Subcarrier Frequency	1.024	MHz	8.3.3.2.1.1
PSK Data Waveform	Manchester-L	-	8.3.3.2.2
PSK Data Rate	16	kbps	8.3.3.2.2.1
FM Subcarrier Frequency	1.7	MHz	8.3.3.2.3.1
FM Structure	FM/FM	-	8.3.3.2.3
Analog Telemetry Subcarrier Frequencies	16 24 32	kHz kHz kHz	8.3.3.2.3.3
FM/FM Deviations	See Subparagraphs		8.3.3.2.3.5 & 8.3.3.2.3.6
Analog Telemetry	See Subparagraphs		8.3.3.2.3.7
P/L Modulation Indices	0.3 to 2.0	Radians	8.3.3.2.4
PSK Data Word Length	(TBS)	Bits	8.3.3.2.5.1
PSK Minor Frame Length	(TBS)	Words	8.3.3.2.5.2
PSK Master Frame Length	(TBS)	Minor Frames	8.3.3.2.5.4
PSK Transition Density	(TBS)	-	8.3.3.2.5.6

8.3.3.2.3.2 Master Subcarrier Frequency Accuracy. The long-term unmodulated subcarrier frequency uncertainty shall be <±0.1% of the nominal subcarrier frequency.

8.3.3.2.3.3 Minor Subcarrier Frequencies. The minor subcarrier's nominal frequencies shall be 16, 24 and 32 kHz.

8.3.3.2.3.4 Minor Subcarrier Frequency Accuracy. The long-term unmodulated minor subcarrier frequencies uncertainties shall be <±(TBS)% of the nominal minor subcarrier frequencies.

8.3.3.2.3.5 Master Subcarrier Modulation by the Minor Subcarriers. The master subcarrier shall be frequency modulated by the minor subcarriers with individual minor subcarrier peak deviations of the master subcarrier of (TBS) kHz.

8.3.3.2.3.6 Minor Subcarrier Modulation. Each minor subcarrier shall be frequency modulated by analog telemetry waveforms with a minor subcarrier peak deviation of (TBS) kHz.

8.3.3.2.3.7 Analog Telemetry Waveform Frequency Response. Any analog telemetry waveform shall have frequency content from 0 Hz to a -3 dB frequency of (TBS) kHz with a lowpass rolloff of 12 dB/octave.

8.3.3.2.4 Payload Transmitter Modulation Indices. The composite PSK and FM subcarriers shall phase modulate the carrier with peak modulation index between 0.3 and 2.0 radians set at the factory with an accuracy of ±15%.

8.3.3.2.5 Data Structure Formats

8.3.3.2.5.1 Word Length. The basic data word length shall be (TBS) bits.

8.3.3.2.5.2 Minor Frame Length. (TBS)

8.3.3.2.5.3 Minor Frame Synchronization Words. (TBS)

8.3.3.2.5.4 Master Frame Length. (TBS)

8.3.3.2.5.5 Master Frame Synchronization Word. (TBS)

8.3.3.2.5.6 Transition Density. (TBS)

8.3.3.2.6 Payload Minimum EIRP for PSK Data. The minimum EIRP required to achieve a $1x10^{-5}$ bit error rate for the 16 kbps data rate at the output of the CIU for the conditions of 10 nmi range, 1.0 radian modulation index, worst-case tolerances, and 0 dB performance margin is 28.2 dBm.

8.3.3.3 DOD/SGLS Transponder Turnaround Requirements

8.3.3.3.1 Forward Link Sweep Acquisition. Some SGLS transponder receivers have a self-contained automatic sweep acquisition capability. The PI transmitter sweep capability is therefore not required for such transponders and will be disabled. For those SGLS transponders not having a self-contained automatic sweep acquisition capability, the PI transmitter will be frequency swept in accord with 8.3.1.1.1.7, utilizing the fast sweep rate of 10 kHz/s over the ±55 kHz range.

8.3.3.3.1.1 Transponder Minimum PLL Acquisition Bandwidth. In order to achive a virtual unity probability of carrier acquisition when the PI sweep crosses the transponder nominal receive frequency, the transponder two-sided loop noise bandwidth shall not be less than 500 Hz.

8.3.3.3.1.2 Sweep Tracking Requirement. The PI transmitter sweep goes through one complete sweep cycle before being disabled. The transponder receiver must therefore be capable of tracking the entire PI transmitter sweep range (±60 kHz worst case) for the condition of PI transmitter maximum nominal frequency offset (±0.0012%).

8.3.3.3.2 Return Link Frequency Stability and Acquisition Requirements

8.3.3.3.2.1 Auxiliary Oscillator Stability. The long-term stability of the transponder transmitter's nominal carrier frequency as derived from the auxiliary oscillator shall be no worse than ±0.001%.

8.3.3.3.2.2 PI Receiver Lock Loss due to Auxiliary Oscillator-to-VCO Switchover. It is expected that, when the transponder switches its transmitter frequency source from auxiliary oscillator to the VCO, PI receiver lock (if it had been attained in the one-way mode) may be temporarily lost. PI receiver reacquisition by frequency sweeping will automatically ensue.

8.3.3.3.2.3 Transponder Turnaround Ratio. The transponder transmit/receive frequency turnaround ratio shalll be 256/205.

8.3.3.3.2.4 Return Link Carrier Sideband Level due to Forward Link Modulation Feedthrough. The maximum feedthrough modulation sidebands of the return link carrier by the forward link command modulation (65 kHz, 76 kHz, 95 kHz tones and the one-half symbol rate clock and its harmonics) shall not exceed a return link sideband level greater than -26 dBc.

8.3.4 Nonstandard Payload/PI/Bent-Pipe Communication Requirements. Nonstandard communications are those which do not conform to the NASA/PSP or DOD/CIU command and telemetry capabilities. Nonstandard communication signals must, however, comply with the PI capabilities and requirements.

8.3.4.1 Command Signals. An input port to the PI transmitter phase modulator exists aboard the Orbiter at the Payload Station (PS). This port allows nonstandard command signals to be transmitted from the PS by means of payload/user-supplied equipment. No ground-to-payload/user-supplied equipment command capability exists. Therefore, is such command transfer capability is required, use must be made of either the PSP or CIU standard command signalling capability. PS command signals must comply with the PI transmitter requirements of 8.3.1.1.1.

8.3.4.2 Telemetry Signals. Nonstandard telemetry signals are defined as those which cannot be handled by either the PSP or CIU. Such signals are acquired and demodulated by the PI, and the resulting baseband signal is (1) transferred to the ground via the Ku-band bent-pipe link for processing, or (2) made available at the Payload Station output port where it may be processed by payload/user-supplied equipment. In order that nonstandard telemetry signals be compatible with the PI performance criteria, various conditions and restrictions are imposed as per the following subparagraphs.

8.3.4.2.1 General Payload Transmitter Modulation Criteria

8.3.4.2.1.1 Allowable Modulations. Phase modulation (PM) of the carrier is the only allowable type of modulation. Frequency modulation (FM) and amplitude modulation (AM) of the carrier are not permitted. Quadriphase and spread spectrum modulations are also not allowed.

8.3.4.2.1.2 Maximum Carrier Suppression. The maximum allowable carrier suppression due to the composite of all phase-modulating sources shall not exceed 10 dB.

8.3.4.2.1.3 Subcarrier Modulation. When subcarriers are employed, they may be either phase or frequency modulated. Amplitude modulated subcarriers are not permitted. Restrictions on the use of subcarriers are given under 8.3.4.2.2.2 and 8.3.4.2.2.3.

8.3.4.2.1.4 Direct Carrier Modulation by Baseband Signals. Direct carrier modulation by analog type baseband signals is not allowed. Direct carrier modulation by digital type baseband signals is allowed, subject to the restrictions given under 8.3.4.2.2.4.

8.3.4.2.2 Specific Nonstandard Modulation Restrictions

8.3.4.2.2.1 Discrete Frequency Component Sideband Levels. Carrier phase modulation by periodic signals (sinusoids, square-waves, etc.) having fundamental frequencies less than 250 kHz is not permitted. No incidental and/or spurious discrete frequency component sideband levels shall be greater than -26 dBc on a frequency range of ±250 kHz about the carrier frequency.

8.3.4.2.2.2 Frequency Modulated Subcarriers

8.3.4.2.2.2.1 Analog Modulations. No analog signal frequency modulated subcarrier, on a frequency range of ±250 kHz about the carrier frequency shall be allowed to phase modulate the carrier if the inequality

$$f_m \Delta f > 4.6 \times 10^5$$

is violated, where f_m is the bandwidth or maximum frequency of the baseband analog signal in Hz and Δf is the peak frequency deviation of the subcarrier in Hz. Provided that the above inequality is satisfied, the maximum allowable carrier phase modulation index, β, by the frequency modulated sinusoidal subcarrier shall be the lesser of 1.85 rad (106°) or the β which satisfies the relationship:

$$J_1(\beta)/J_0(\beta) = 2 \times 10^{-7} \; f_m \Delta f,$$

or the β which results in a lock detector false alarm probability greater than 1×10^{-4} when the lock detector bandwidth is centered on the FM subcarrier (i.e., on either relative subcarrier frequency sideband of the carrier). The value of β may be determined with the aid of Fig. 8.3.4.2.1-1.

8.3.4.2.2.2.2 Digital Modulations. No frequency-shift-keyed (FSK) subcarrier, on a frequency range of ±250 kHz about the carrier frequency, shall be allowed to phase modulate the carrier if the inequality

$$R_b > 2 \times 10^3$$

is violated, where R_b is the data bit rate (bps). Provided that the above inequality is satisfied, the maximum allowable carrier phase modulation index, β, by the FSK modulated sinusoidal subcarrier shall be the lesser of 1.85 rad (106°) or the β which satisfies the relationship

$$J_1(\beta)/J_0(\beta) \geq 1.25 \times 10^{-9}(R_b)^2$$

or the β which results in a lock detector false alarm probability greater than 1×10^{-4} when the lock detector bandwidth is centered on the FM subcarrier. The value of β may be determined with the aid of Fig. 8.3.4.2.1-1.

8.3.4.2.2.3 Phase Modulated Subcarriers

8.3.4.2.2.3.1 Analog Modulations. Phase modulation of subcarriers by analog baseband signals is not recommended due to inefficiency. As a result, no such modulations are expected and no guidelines have been developed.

8.3.4.2.2.3.2 Digital Modulations. No phase-shift-keyed (PSK) subcarrier, on a frequency range of ±250 kHz about the carrier frequency, shall be allowed to phase modulate the carrier if the inequality

$$R_b > 2 \times 10^3$$

is violated, where R_b is the data bit rate (bps). Provided that the inequality above is satisfied, the maximum allowable carrier phase modulation index, β, by the PSK modulated sinusoidal subcarrier shall be the lesser of 1.85 rad (106°) or the β which satisfies the relationship

$$J_1(\beta)/J_0(\beta) \leq 1.25 \times 10^{-9}(R_b)^2,$$

or the β which results in a lock detector false alarm probability greater than 1×10^{-4} when the lock detector bandwidth is centered on the FM subcarrier. The value of β may be determined with the aid of Fig. 8.3.4.2.1-1.

8.3.4.2.2.4 Direct Carrier Modulations

8.3.4.2.2.4.1 Analog Modulations. Direct phase modulation of the carrier by an analog baseband signal is not recommended due to inefficiency. As no such modulations are expected, no guidelines have been developed.

8.3.4.2.2.4.2 Digital Modulations. The criterion for the minimum allowable bit rate is based upon a carrier tracking loop RMS phase noise component due to modulation sidebands tracking of 10° or less. The allowable NRZ bit rate must therefore satisfy the following inequality:

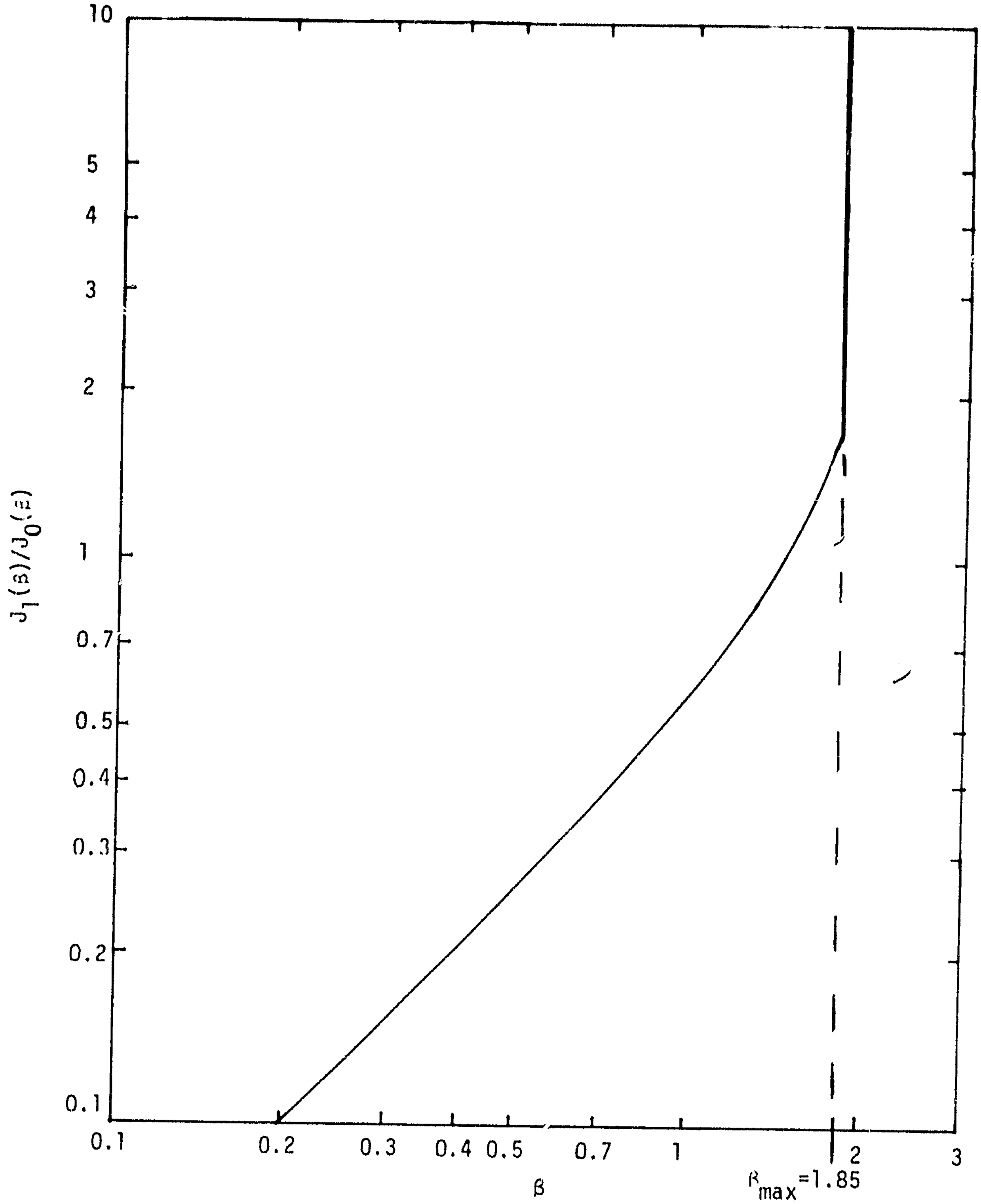


Figure 8.3.4.2.1-1 Curve Used for Determination of Modulation Index

$$R_b > 9.2 \times 10^4 \tan^2 (\beta)$$

where the numerical coefficient is based upon the PI carrier tracking loop maximum in-lock noise bandwidth and β is the carrier phase deviation ($\beta \leq$ 71.5°). In order to keep carrier loop phase slewing to less than 18° during a string of transitionless data bits, the maximum number of such bits shall be:

$$\text{Maximum No. of Bits Without Transition} = 1.0 \times 10^{-4} R_b$$

This transitionless period must be followed by a reasonable number of transitions in such a pattern that the slewing error is negated within a period of bits equal to five times the transitionless period. To avoid the problem of bit slewing, Manchestering of the bits is recommended. Given Manchestered bits, the minimum bit rate allowed is the larger bit rate calculated from:

$$R_b \geq 1.23 \times 10^3 \tan^2 (\beta)$$

$$R_b \geq 2.83 \times 10^4 \sqrt{\tan (\beta)} .$$

Maximum modulation index β for all digital modulations shall not exceed 71.5° or 1.25 rad.

8.3.4.2.3 Bent-Pipe Feedthrough Characteristics

8.3.4.2.3.1 PI/KuSP Configuration. Figure 8.3.4.2.3.1-1 shows the general PI/KuSP configuration for the bent-pipe. Telemetry signals may be input to either the narrowband or wideband channels as defined in the following subparagraphs.

8.3.4.2.3.2 Narrowband Channel. The anticipated use of the narrowband channel is by PSK or FM subcarriers which have nonstandard frequencies and/or nonstandard data rates or analog modulations. The signal output from the PI is passed through a hard limiter, following which it is treated as "digital data" by the KuSP subcarrier modulator.

8.3.4.2.3.3 Wideband Channel. Wideband signals are defined as those which have maximum frequency components on the order of 4.5 MHz. Such signals are allowed to directly frequency modulate the Ku-band FM transmitter. The amount of deviation achieved depends upon the nature of the modulating waveform, its RMS and peak values being established by the PI wideband output noncoherent regulator (see subparagraph 8.3.1.1.2.15).

8.3.4.3 Nonstandard Transponder Turnaround Requirements. Nonstandard transponders are defined as those which are not explicitly STDN/NE (subparagraph 8.3.2.4) or SGLS (subparagraph 8.3.3.3) types. Nonstandard transponders must, however, conform to the PI frequency channel assignments and other PI acquisition and tracking requirements.

8.3.4.3.1 Frequency Channel Assignments and Turnaround Ratios. A nonstandard transponder must have a turnaround ratio of 240/221 and adhere to the channel assignments of Tables 8.3.1.1.1.1-2 and 8.3.1.1.1.1-3, or a turnaround ratio of 256/205 and adhere to the channel assignments of Table 8.3.1.1.1.1-4.

8.3.4.3.2 Forward Link Acquisition. A nonstandard transponder that does not possess an inherent receiver acquisition capability must make use of the PI transmitter sweep capability outlined under 8.3.1.1.1.7. Either

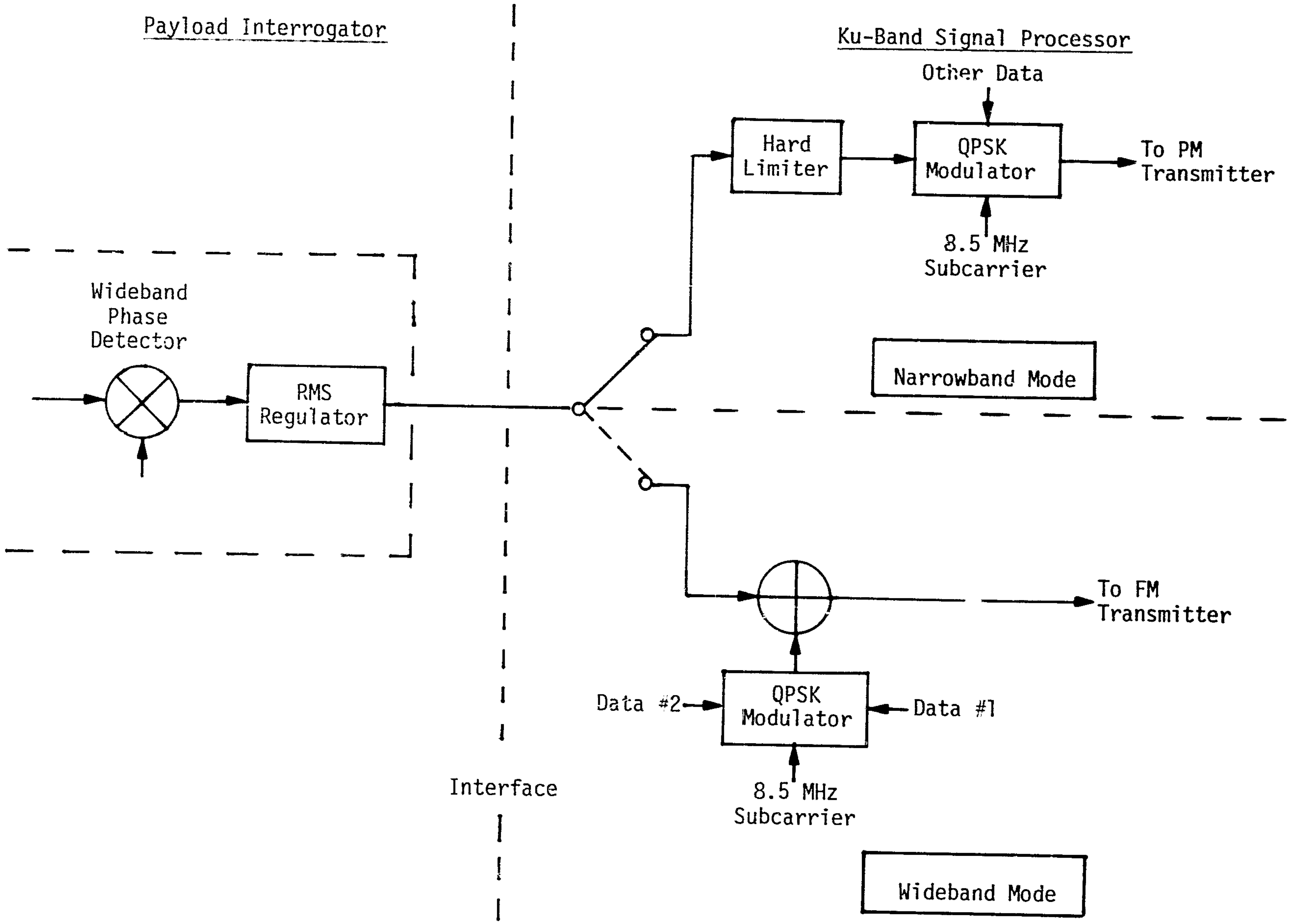


Figure 8.3.4.2.3.1-1 PI/KuSP Bent-Pipe Interface Configuration

of the two sweep rates may be employed and the transponder two-sided loop noise bandwidth shall not be less than the following limits:

Sweep Rate	PLL Noise Bandwidth
10 kHz/sec	>500 Hz
250 Hz/sec	>150 Hz

8.3.4.3.3 Forward Link Sweep Tracking. The nonstandard transponder must be capable of tracking the entire PI transmitter worst-case sweep range as defined under 8.3.1.1.1.7 for the condition of PI transmitter maximum nominal frequency offset of ±0.0012%.

8.3.4.3.4 Return Link Sweep Acquisition. The PI receiver is required to acquire the payload transmitter signal when the transponder is in its one-way mode (transmitter carrier frequency derived from the transponder auxiliary oscillator) or in the two-way mode with the forward link sweep transponded to the return link carrier.

8.3.2.3.5 Auxiliary Oscillator Stability. The long-term stability of the transponder transmitter's nominal carrier frequency as derived from the auxiliary oscillator shall be no worse than ±0.001%.

8.3.2.3.5.1 Phase Noise. The transponder transmitter phase noise when the carrier is derived from the auxiliary oscillator shall not produce more than a 3° RMS tracking phase error in a 1000 Hz two-sided tracking bandwidth.

8.3.2.3.6 Return Link Incidental Modulations

8.3.2.3.6.1 Spurs. Any discrete frequency spurs within ±250 kHz of the return link carrier frequency shall be less than -26 dBc.

8.3.2.3.6.2 Forward Link Modulation Feedthrough. The maximum feedthrough modulation sidebands of the return link carrier by any frequency component of the forward link command modulation shall not exceed a return link sideband level greater than -26 dBc.

8.3.5. Ku-Band Rendezvous Radar Interfaces. The Ku-band and rendezvous radar will skin track a target in the passive mode or track a transponder-equipped target in the active mode.

8.3.5.1 Passive Mode Characteristics. The rendezvous radar shall have the interface characteristics defined in Table 8.3.5.1-1 when operative in the passive mode.

8.3.5.2 Active Mode Characteristics. The rendezvous radar shall have the interface characteristics defined in Table 8.3.5.2-1 when operating in the active mode.

8.3.5.3 Transponder Characteristics. The payload shall be specified with a transponder that is compatible with the Ku-band rendezvous radar. The transponder characteristics are TBD.

TABLE 8.3.5.1-1 RADAR PASSIVE MODE

ELECTRICAL INTERFACE CHARACTERISTICS

Parameter	Dimension	Value	Notes
1. Target Type			
Size	Square Meter	1.0 Minimum	Radar system sized to detect in 1 m² scintillating target at 12 minimum angular search field of 30 deg by 30 deg with 99% probability.
Scintillation Characteristics		Swirling Case I target	Target is stabilized in 3 axes to an angular rate of TBD deg/sec.
2. Radar Operating Frequency	GHz	Nominal Minimum at 13.75	4 Step Fudge Diversity - 52MHz per step during detection and tracking.
3. Antenna Characteristics			
Gain	dB	38.5	At 13.775 GHz
Sidelobe	dB relative to mainbeam	20 minimum	
Type		5 "Horn" monopulse, automatic tracking, front-fed parabola.	Two-gimbal antenna mount
4. Transmitter Power	Watts	50 peak, 10 average	Peak and average power are function of range and selectable duty cycle. Peak power variable over 45 dB range - Duty cycle variable 0.001 to 0.3

TABLE 8.3.5.1-1 RADAR PASSIVE MODE ELECTRICAL

INTERFACE CHARACTERISTICS (Continued)

Parameter	Dimension	Value	Notes
PRF	pulses/ sec	TBD Detection	
5. Receiver			
Noise Figure	dB	5	
Input Power Limits	watts average	50	At input port to low-noise amplifier
Dynamic range	dB	115	

TABLE 8.3.5.2-1 RADAR ACTIVE MODE ELECTRICAL

INTERFACE CHARACTERISTICS

Parameter	Dimension	Value	Notes
1. Target Type			
Transponder Pulse Beacon			Target carries coherent pulse transponder which retransmits amplified replica of received pulse. Beacon carrying target is stabilized in 3 axes to TBD deg/sec each axis.
Operating Range	ft.	1.824×10^6 Detection 100 minimum	
2. Beacon Characteristics			
Minimum Detectable Signal	dBm	TBD	Function of target antenna and receiver sensitivity
EIRP	dBW	TBD	
Coherence		TBD	
Delay	μsec	TBD	
3. Radar Characteristics			
Transmit Freq.	GHz	13.8 nominal	
Receive Freq.	GHz	13.8	Same as radar transmit freq. ±TBD Hz.
Antenna Gain	dB	38.5	Transmit and

TABLE 8.3.5.2-1 RADAR ACTIVE MODE ELECTRICAL

INTERFACE CHARACTERISTICS (Continued)

Parameter	Dimension	Value	Notes
			receive
Antenna side-lobe level	dB relative to main beam	20 minimun	
Antenna Type		5 "Horn" monopulse, automatic angle track, front-fed parabola	Two-gimbal antenna mount.
PRF's	pulses per sec.	224 search and track 7177 Track	For range greater than 10 nm. Range less than 10 nm.
Pulse widths	µsec.	Dual 4.15 and 0.122 4.15 0.122	Used in search ranger. Used for track when range >10 min. Used for track when range < 10 min.
Transmit Power	Watts	60	Peak-duty cycle in search or track and target range determines average power. Peak power controllable over 45 dB range.
Receiver noise Figure	dB	5	
Input Power Limit	Watts (average)	50 - damage level $2.5X10^3$ 1 dB gain compression	At input port to low-noise amp. Low-noise amp. to low-noise amp.
Dynamic Range	dB	115	

APPENDIX V

PAYLOAD MINIMUM EIRP FORMULATIONS

APPENDIX V

PAYLOAD MINIMUM EIRP FORMULATIONS

The following is in reference to Section 8.3 and especially the entries for Tables 8.3.2.2.6-1 and 8.3.3.2.6-1 of ICD No. 2-19001. All formulas are given in logathithmic form.

EIRP Definition

The EIRP is the effective isotropic radiated power of the payload and consists of the three components:

$$EIRP = P_T + G_T + L_{TX}$$

where P_T is the transmitter total RF output power, G_T is the transmitting antenna gain, and L_{TX} is all transmitter circuit losses.

EIRP Relationship to Link and Receive Parameters

$$EIRP = P_R - G_R - L_{RT} - L_S$$

where

P_R = received power at the RF port of the PI

G_R = receive antenna gain

L_{RT} = total receive circuit losses

L_S = payload-to-Orbiter space loss

Carrier and Data Components of P_R

$$\text{Carrier Power} = P_{RC} = P_R + J_0^2(\theta)$$

$$\text{Data Power} = P_{RD} = P_R + 2J_1^2(\theta)$$

where θ is the transmitter phase modulation index. For standard payload modulations, $\theta = 1 \pm 0.1$ radian. The following table tabulates the Bessel function values.

	$\theta = 0.9$	$\theta = 1.0$	$\theta = 1.1$
$J_0^2(\theta)$	-1.9 dB	-2.3 dB	-2.9 dB
$2J_1^2(\theta)$	-4.8 dB	-4.1 dB	-3.5 dB

Parameter Values

G_R = -0.5 dB (gain at -3 dB cone edge)

L_{RT} = -10.3 dB (includes antenna to PI cable loss and polarization loss)

L_S = -125.0 dB (10 nmi @ 2300 MHz)

N_0 = -167 dB/Hz (7 dB NF)

E_B/N_0 = 9.6 dB ($P_e = 10^{-5}$)

$L_{PI/PSP}$ = -2.9 dB (total PI and PSP losses affecting data reception).

EIRP Based Upon Minimum Carrier Power Requirement

The minimum P_{RC} needed to satisfy the PI carrier acquisition requirement is

$$P_{RC}(\text{min}) = -122.5 \text{ dBm}$$

For the most unfavorable carrier power modulation index condition ($\theta = 1.1$):

$$EIRP_{min} = P_{RC} - J_0^2(1.1) = G_R - L_{RT} - L_S$$

$$= -122.5 - (-2.9) - \underbrace{(-0.5) - (-10.3) - (-125)}_{-(-135.8)}$$

$$\boxed{EIRP_{min} = 16.2 \text{ dBm}}$$

The EIRP may not be below this value regardless of the data power requirements.

EIRP Based Upon Data Power Requirement

The most unfavorable data power modulation index conditions is $\theta = 0.9$. The EIRP requirement is:

$$\text{EIRP} = E_b/N_0 + R_b - L_{PI/PSP} + N_0 - 2J_1^2(0.9) - G_R - L_{RT} - L_S$$

$$= 9.6 + R_b - (-2.9) - 167 - (-4.8) - (-135.8)$$

$$= R_b - 13.9$$

The table following tabulates the EIRP for the PSP data rates.

R_b - kbps	R_b - dB - kbps	EIRP (dBm)
1	30.0	16.1
2	33.0	19.1
4	36.0	22.1
8	39.0	25.1
16	42.1	28.2

Note that the EIRP for the 1 kbps rate is lower (by 0.1 dB) than the minimum required to meet the carrier acquisition requirement. Thus, the EIRP for 1 kbps must be specified at 16.2 dBm because of the possibility that θ could be 1.1 and not 0.9.

APPENDIX VI

AN UPDATE OF NONSTANDARD PAYLOAD MODULATION RESTRICTIONS

APPENDIX VI

AN UPDATE OF NONSTANDARD PAYLOAD MODULATION RESTRICTIONS

A rationale for nonstandard payload modulation restrictions was developed and published in Section 5.2, pages 98-119, of the final report to Contract No. NAS 9-15240D, "Shuttle Payload S-Band Communications Study," March 9, 1979 (Axiomatix Report No. R7903-1). The following outline discussion is an upgrade to these restrictions as a result of a change of philosophy by TRW toward PI receiver false lock avoidance. This changed philosophy by TRW concerns sweeping the receiver VCO sufficiently fast that sideband lock is precluded (rather than relying on the lock detector to discriminate between true lock and false lock signal conditions).

Brief Review of Swept Acquisition No-Lock Criteria

If the natural frequency, ω_n, of the PLL is such that:

$$\omega_n < \sqrt{\omega_{S\omega}}, \tag{1}$$

where $\omega_{S\omega}$ is the sweep rate, then lock will not occur on discrete frequency components.

Now the natural frequency, ω_n, is proportional to the amplitude of the discrete frequency as seen by the PLL. The amplitude of any carrier sideband as seen by the PLL during acquisition is a function of the receiver noncoherent AGC and the modulation index of the signal giving rise to the discrete carrier sideband. For phase modulation, the latter condition is proportional to $J_1(\beta)/J_0(\beta)$.

If ω_{nm} is the maximum value that the PLL natural frequency can attain for the carrier (the maximum value occurring for strong signal conditions of the receiver input), and $\omega_{S\omega}$ is specified or fixed, then a necessary condition for no-lock onto discrete frequency sidebands is:

$$\frac{J_1(\beta)}{J_0(\beta)} < \frac{\omega_{S\omega}}{\omega_{nm}^2} \tag{2}$$

Current TRW Parameter Values

The minimum receiver internal sweep rate is 330 kHz/s - 10% = 297 kHz/s.

The maximum PI transmitter sweep rate turned around by the payload transponder is 13 kHz/s x (240/221) = 14 kHz/s.

Since the receiver and transmitter sweeps are uncorrelated, the net effective minimum sweep rate is the difference;

$$f_s = 297 \text{ kHz/s} - 14 \text{ kHz/s} = 283 \text{ kHz/s}$$

TRW calculates the largest acquisition value of ω_n at threshold to be 2923 rad/s. Based upon a 300-kHz IF filter prior to the PLL and noncoherent AGC detector, the gain increase of the PLL from threshold to strong signal condtiions is determined to be a factor of 4.38. Thus,

$$\omega_{nm} = \sqrt{4.38} \times 2923 = 6120 \text{ rad/s.}$$

Taking the above values of f_s and ω_{nm},

$$\frac{J_1(\beta)}{J_0(\beta)} = \frac{2\pi \times 283 \times 10^3}{(6120)^2} = 0.047 = -26.5 \text{ dBc.}$$

This calculated value corresponds almost exactly with TRW's experimentally determined figure of -26 dBc.

Rev. 2 Restriction Changes

The -26 dBc discrete sideband level has been used throughout Section 8.3.4.2.1 where discrete frequency sideband levels are referred to.

A review was made of the wideband spectral sidebands criteria due to FM or PSK subcarrier modulation. It was determined that the general restrictions were over constraining by a factor of 2 because the wrong relationship was substituted in the original analysis for ω_n and $\omega_{s\omega}$.

Another update made is that the applicable frequency range about the carrier for the modulation restrictions has been increased from ±200 kHz to ±250 kHz due to TRW PI receiver changes with respect to IF bandwidth and acquisition sweep range.

APPENDIX VII

PRELIMINARY INTERFACE REVISION NOTICE SD-152C

UPDATE OF SECTION 8.3 OF ICD 2-19001

FOR DETACHED PAYLOADS

MARCH 7, 1980

INTERFACE REVISION NOTICE

AFFECTED ICD		IRN		
1 NO ICD 2-19001	REV F	2 TRACKING IDENTIFIER	3 NO	4 SHEET 1 OF 18
PROGRAM CODE		A SD-152C		5. PANEL AFFECTED Avionics
9 TITLE SHUTTLE ORBITER/CARGO STANDARD INTERFACES		B		6. INITIATED BY Rockwell International
		C PCIN		

10. THIS IRN EFFECTIVITY

Orbiter Vehicles 102, 099, 103 & Subs.

8 PAYLOAD SPECIFIC ICDs

11 REASON FOR CHANGE

Update the Detached Payloads interface description to reflect payload interrogator interface characteristics/requirements.

CHANGE ICD EFFECTIVITY	12. TO	13. FROM

14 IRN NO	15 NEW IRN EFFECTIVITY	16 PREVIOUS IRN EFFECTIVITY

17 DESCRIPTION OF CHANGE

REPLACE: existing Section 8.3 in its entirety with the attached revised section.

18 PREPARED BY	19 TECH CONCURRENCE	20 ORG.	21. DATE
D. Hampstead	F. Torres [signature]	Payload/Cargo Integration & Advanced Engineering	~~28 February 80~~ 7 MARCH 80

22 SIGNATURE AND ORGN	REV	DATE	SIGNATURE AND ORGN	REV	DATE	SIGNATURE AND ORGN	REV	DATE
[signature]		3/7/80	[signature] RI		3/15/80			
[signature]		3/12/80						
[signature]		3/12/80						
[signature] RI		3/13/80						

23			JSC APPROVAL	DATE		

8.3 DETACHED PAYLOADS

The Payload Interrogator shall provide full duplex RF communication between the Orbiter and detached payloads. This capability shall include transmission of commands to, and the reception of telemetry data from, such payloads. Both NASA (STDN and DSN) and DOD (SGLS) transmit/receive frequency pairs shall be available. See Appendix C for specific selectable channels.

In addition to two-way RF communication, Ku-band rendezvous radar shall also be available. The radar shall skin-track targets in the passive mode or actively track transponder equipped payloads.

In the following paragraphs, "characteristics" refers to those Orbiter avionics characteristics of which the payload must be cognizant, and "requirements" refers to specifications placed upon payload communication equipment.

8.3.1 Payload Interrogator (PI) RF Interfaces.

8.3.1.1 Transmitter Characteristics. The principal transmitter characteristics shall be as listed in Table 8.3.1.1-1.

8.3.1.2 Receiver Characteristics. The principal receiver characteristics shall be as listed in Table 8.3.1.2-1.

8.3.1.3 Antenna Characteristics. The PI/Payload link shall utilize a single beam antenna for both transmission and reception. The antenna shall have a beam width bounded by an 80° cone aligned with the +Z axis. Polarization, either RHCP or LHCP, shall be switch selectable ~~using a switch~~ in the Orbiter.

8.3.2 PI Data Interfaces. Data interfaces provided for detached payload use are classed as standard or non-standard. Standard interfaces are prewired interfaces provided by the baseline Orbiter employing pre-established data handling methods. Non-standard interfaces are those requiring payload-provided unique wiring and processing equipment to be installed at the AFD. Input/output data interfaces shall be available at the PSDP for access to and from the PI. Figure 8.3.2-1 presents a block diagram of the signal routing for both standard and non-standard operation.

8.3.2.1 Standard Payloads.

8.3.2.1.1 Commands. Command data shall be accepted by the Payload Signal Processor from the GPC. This data shall be modulated onto a 16 KHz subcarrier and handed off to the PI for RF transmission to detached payloads. Refer to Para. 8.2.5 and Table 8.2.5.1-1 for command structure and subcarrier performance characteristics.

8.3.2.1.2 Telemetry. Telemetry data in standard operation shall be modulated onto a 1.024 MHz subcarrier by the payload. The PI receiver shall strip the RF carrier and hand off the subcarrier signal to the PSP. A single form of telemetry signal shall be allowed with summary requirements as listed in Table 8.3.2.1.2-1.

8.3.2.2 Non-Standard Payloads.

(ref. 8.3.2.2.3)

8.3.2.2.1 Commands. A payload selectable input port to the PI transmitter shall exist at the payload station distribution panel (PSDP). This port shall allow non-standard command signals to directly modulate the PI transmitter. Such signals shall comply with the requirements shown in Table 8.3.2.2.1-1.

8.3.2.2.2 Telemetry. An output port from the PI receiver shall exist at the PSDP. The interface characteristics for demodulated RF signals from the PI shall be as defined in Table 8.3.2.2.2-1.

8.3.2.2.2.1 Telemetry Modulation Criteria. Phase modulation (PM) of the payload transmitter carrier shall be the only allowable type. (Quadriphase modulation shall not be not allowed). When employed, subcarriers shall be either phase or frequency modulated. Further restrictions on the use of subcarriers will follow. Direct carrier modulation by analog signals shall not be allowed: however, direct modulation by digital signals shall be allowed subject to restrictions to follow. Carrier modulation by periodic signals having fundamental frequencies less than 250 KHz shall not be permitted. No incidental and/or spurious discrete frequency component sideband levels shall be greater than 29 db below the unmodulated carrier within a frequency range of 250 KHz about the carrier.

8.3.2.2.2.1.1 Frequency Modulated Subcarriers.

a. Analog Modulations. The subcarrier frequency shall be greater than 250 KHz and the analog modulation shall satisfy the inequality:

$$f_m \Delta f > 4.6 \times 10^5$$

where f_m is the bandwidth or maximum frequency of the baseband analog signal in Hz and Δf is the peak frequency deviation of the subcarrier in Hz. Provided the above inequality is satisfied, the maximum allowable carrier phase modulation index, β, by the frequency modulated sinusiodal subcarrier shall be the lessor of 1.85 radians (106°) or the β which satisfies the relationship:

$$J_1(\beta)/J_0(\beta) = 2.0 \times 10^{-7} f_m \Delta f$$

b. Digital Modulations. The subcarrier frequency shall be greater than 250 KHz and the data bit rate (F_B) of the frequency shift keyed (FSK) modulation shall be greater than 2KBPS. Provided R_E is greater than 2KBPS, the maximum allowable carrier phase modulation index, β, by the FSK modulated sinusoidal subcarrier shall be the lessor of 1.85 radians (106°) or the β which satisfies the relationship:

$$J_1(\beta)/J_0(\beta) \geq 1.25 \times 10^{-9} (R_b)^2$$

8.3.2.2.2.1.2 Phase Modulated Subcarriers.

a. Analog Modulations. Phase modulation of subcarriers by analog baseband signals shall not be allowed.

b. Digital Modulations. The subcarrier frequency shall be greater than 250 KHz and R_b of the phase shift keyed (PSK) modulation shall be greater than 2KBPS. Provided R_E is greater than 2 KBPS the maximum allowable carrier phase modulation index, β, by the PSK modulated sinusoidal subcarrier, shall be the lessor of 1.85 radians (106°) or the β which satisfies the relationship:

$$J_1(\beta)/J_0(\beta) \leq 1.25 \times 10^{-9} (R_b)^2$$

8.3.2.2.2.1.3 Direct Carrier Modulation.

a. Analog Modulations. Direct phase modulation of the carrier by an analog baseband signal shall not be allowed.

b. Digital Modulations. The allowable NRZ bit rate must satisfy the following inequality:

$$R_b > 9.2 \times 10^4 \tan^2\beta$$

The maximum number of such bits without transition shall be less than $1.0 \times 10^{-4} R_E$. The minimum Bi-φ-L bit rate allowed shall be the larger bit rate calculated from:

$$R_b = 1.23 \times 10^3 \tan^2\beta \quad \text{, or}$$

$$R_b = 2.83 \times 10^4 \sqrt{\tan\beta}$$

The modulation index β for all digital modulations shall not exceed 71.5° or 1.25 radians.

8.3.2.2.3 PI/PS Control Discrete. A control discrete shall be provided [via the PSDP] to the PI to enable the PS input and output ports and disable the PSP input and output ports to/from the PI. The characteristics of the control discrete shall be as follows:

True State (PS ports to/from PI enabled)	18 to 32 VDC
False State (PSP ports to/from	0 to 3 VDC

PI enabled)	
Termination	Single ended return to pwr grnd
True State Current	10 milliamps maximum
Power Off Impedance	10 K ohms minimum
Load Impedance	3.2 K ohms minimum

Cargo element signal processors installed in the PS shall utilize an indication of which PI has been selected for use to direct command data and the PS control discrete to the correct interrogator. One of two circuits from the forward load control assemblies (LCA #2 and #3) shall contain a 28 VDC signal indicating which of the two interrogators has been powered on. Interfaces with these circuits at the PSDP shall be used to provide limited control power, as required, for the PI. The characteristics of the two circuits shall be as follows:

Logic '1' State (PI on)	24 to 32 VDC
Logic '0' State (PI off)	0 plus 2.5, minus 0 VDC
Maximum Current	125 milliamps
Termination	Single ended return to power ground

Circuit protection shall be provided in the cargo element user unit such that overloads shall not fault the fusing in the LCA's.

If a power return line is required in the Cargo element user unit, power return for Bus A, B or C shall be used.

8.3.3 Bent Pipe Modes for Detached Payloads. The Orbiter Payload Interrogator shall provide a 'bent-pipe' mode for detached payloads to permit the remodulation of received S-Band signals onto the Ku-band return link carrier. The Ku-band signal processor shall accept the demodulated signal from the payload interrogator and, as a function of its frequency content, route the signal, in response to external commands, to either the narrowband channel (Channel 2, mode 1 or mode 2) or the wideband channel (Channel 3, mode 2). Received data modulated on a single subcarrier and having its highest frequency component less than 2 MHz, shall be routed to the narrowband channel. Data modulated on more than one subcarrier and/or having frequency components between 2 MHz and 4.5 MHz, shall be routed to the wideband channel.

8.3.4 Ku-Band Rendezvous Radar Interfaces.

8.3.4.1 Passive Mode Characteristics. The rendezvous radar shall have the interface characteristics defined in Table 8.3.4.1-1 when operating in the passive mode.

8.3.4.2 Active Mode Characteristics. The rendezvous radar shall have the interface characteristics defined in Table 8.3.4.2-1 when operating in the active mode.

8.3.4.3 Transponder ~~Characteristics~~ REQUIREMENTS The payload shall be specified with a transponder that is compatible with the Ku-band rendezvous radar. The transponder characteristics are TBD.

TABLE 8.3.1.1-1 PRINCIPAL PI TRANSMITTER CHARACTERISTICS*

PARAMETER	VALUE	UNITS	NOTES
DOD/L-Band Frequency range (SGLS)	1763.721 to 1839.795	MHz	See Appendix C for individual channel freq. selections
NASA/S-Band Frequency Range:			
STDN	2025.833400 to 2117.916600	MHz	
DSN	2110.243056 to 2119.792438	MHz	
Carrier Frequency ~~Tolerance~~ Stability	±0.0012	%	
Carrier Phase Noise	≤10	Degrees RMS	(1)
Carrier Spurs	≤ − ~~65~~ 55**	dBc	
Carrier Sweep Range			
NASA (Wide)	±75±5	KHz	
DOD (Wide)	±55±5	kHz	
NASA/DOD (Narrow)	±33±3	kHz	
Carrier Sweep Rates			
75 KHz Range (Nominal)	10±3	KHz/sec	
55 KHz Range (Nominal)	10±3	KHz/sec	
33 KHz Range (Nominal)	250±75	Hz/sec	
EIRP--High	+29 min	dBm	Three selectable levels at antenna interface.
Medium	+19 min	dBm	
Low	−4 min	dBm	

* at Orbiter interface.
** 0.2 MHz to 16 GHz from carrier

(1) Steady state error for an ~~10 Hz two sided~~ 100 Hz (Nominal) tracking ~~bandwidth~~ loop bandwidth.

Table [illegible]

Flux Density at Orb. I/F			80° antenna cone at 2200 MHz
Acquisition	1.71×10^{-12}	Wts/Sq. Mtr	
Threshold	$6.81 \times 10^{[illegible]}$	Wts/Sq. Mtr	
Tracking: In Lock (MIN)	4.24×10^{-12}	Wts/Sq. Mtr	
In Lock (MAX)	$1.71 \times 10^{[illegible]}$ (1)	Wts/Sq. Mtr	
MAX. LEVEL W/O DAMAGE	$4.30 \times 10^{[illegible]}$	WTS/SQ. MTR	

(1) WILL NOT LOCK OR TRACK ABOVE THIS LEVEL

TABLE 8.3.1.2-1 PRINCIPAL PI RECEIVER CHARACTERISTICS*

PARAMETER	VALUE	UNITS	NOTES
DOD/L-Band Frequency Range (SGLS)	2202.500 to 2297.500	MHz	See Appendix C for individual channel freq selections
NASA/S-Band Frequency Range: STDN	2200.000 to 2300.000	MHz	
DSN	2290.185185 to 2299.814815	MHz	
Noise Figure (Max)	7.0 max.	dB	***
Carrier Acquisition Sweep Range (Min)	80	KHz	
Carrier Phase Lock Time	≤5	Sec	
Carrier Sweep Range Minimum	±112	KHz	
Maximum	±132	KHz	
Modulation Index	1.0±10%		
False Lock Immunity Sideband Components Signal Levels	**		
Output Frequency Response	.001 to 4.5	MHz	-3db Point
Flux Density at Orb. I/F Acquisition	4.30x10-6	Wts/Sq. Mtr	80° antenna cone at 2200 MHz
Tracking: Threshold	1.71x10-6	Wts/Sq. Mtr	
In Lock	1.08x10-5	Wts/Sq. Mtr	
Maximum	6.28x10-3	Wts/Sq. Mtr	
G/T (Gain/Temp)	-38.9	dB/degree K	
Input Phase Noise (Max)	±5	degrees	
Freq. Shift Rate	<17	KHz/Sec	
Freq. Shift	<87	KHz	
Carrier Suppression	<10	dB	
Modulation Types Carrier	PM		
Subcarriers	PM(FSK) or FM(FSK)		
Bent Pipe Limiting Ratio	2.9 to 4.4	V-P/V-RMS	

* At Orbiter interface

** To preclude false lock no periodic modulation components greater than -29 dbc shall be allowed within 250 KHz of the carrier frequency.

*** Referenced to the RF PI input/output port.

TABLE 8.3.2.1.2-1 STANDARD TELEMETRY SIGNAL REQUIREMENTS

PARAMETER	VALUE	UNITS	NOTES
Waveform	Sinusoidal	-	
Modulation	PSK, ±90	Degrees	(1)
Subcarrier Frequency	1.024 ±0.01%	MHz	
Subcarrier Harmonic Distortion (Max)	≤1.0	%	
Subcarrier Frequency Stability over 1 hour	<0.01	%	
P/L Modulation Index	1.0 ± 0.1	Radians	
Bit Rate	16,8,4,2,1	kbps	
Bit Format	NRZ-I,M or S, or Biφ-L, M, or S	-	
Data Asymmetry	≤ 2	%	
Bit Rate Stability	>0.01	%	
Data Formatting Reqts.	See Paragraph 8.2.1.1		
Transition Density	≥64 transitions in 512 bits		
	≥64 consecutive bits w/o transition		

(1) The data bits and subcarrier phase may be asynchronous or, if synchronous, no specific relationship is required.

TABLE 8.3.2.2.1-1 PSDP TO PI DATA INPUT ELECTRICAL INTERFACE REQUIREMENTS

PARAMETER	UNITS	VALUE	NOTES
Carrier Modulation		PM/FSK	
Modulator Type		Linear	
Modulator Input Bandwidth	KHz	1 to 200	3db, One-Sided
Signal Level	Volts	(1)	
Load Impedance	ohms	75 ± 5	
Load Termination		Differential, balanced direct coupled	

(1) 1.0 to 8.0 ± 10% peak-to-peak line-to-line ($0.2 \leq \beta \leq 2.5$). The phase deviation shall be directly proportional to the amplitude of the input signal. The linearity of the phase modulator shall be maintained to within 10% from 0.2 radians to 2.5 radians when measured from best straight line. (1.0 ± 0.1 volts P-P, L-L, is equivalent to 0.3 radians; 8.0 ± 0.8 volts, P-P, L-L, is equivalent to 2.4 radians.)

TABLE 8.3.2.2.2-1 PI TO PSDP DATA OUTPUT ELECTRICAL INTERFACE CHARACTERISTICS

PARAMETER	UNITS	VALUE	NOTES
Output Frequency Response ~~Bandwidth,~~	MHz	.001 to 4.5	one sided, 3 dB
Output Signal Level	VRMS	2.0±0.4	Not to exceed 8 volts P-P, I-L.
Load Impendance	ohms	75±5	
Load Termination		Differential, balanced direct coupled	

TABLE 8.3.4.1-1 RADAR PASSIVE MODE

ELECTRICAL INTERFACE CHARACTERISTICS

Parameter	Dimension	Value	Notes
1. Target Type			
Size	$Meter^2$	1.0 Minimum	(1)
Scintillation Characteristics		Swirling Case I target	Target stabilized in 3 axes to an angular rate of TBD deg/sec.
2. Radar			
Operating Frequency	GHz	Nominal Minimum at 13.779	(2)
3. Antenna Characteristics			
Sidelobe	db relative to mainbeam	20 minimum	
4. Transmitter Power			
EIRP	dbw	52 peak	At 13.779GHz (3)
PRF	pulses/sec	nominal 7000 and 3000	PRF varies with range
5. Receiver			
Noise Figure	db	5	

(1) Radar system is designed to detect a 1 m^2 scintillating target at 12 NM with a probability of detection of 0,99. Angular searchfield varies with range from a 20 degree half angle cone at 12 NM to a maximum of a 30 degree half angle cone at 8 NM or less.

(2) 5 frequency, 4 step frequency diversity - 52 MHz per step during search, acquisition and tracking.

(3) Peak and average power vary with range and duty cycle. Duty cycle varies with range from approximately 0.001 to 0.3. Peak power selectable - medium and low power selections provide nominal reductions of 12 or 24 dB respectively. Automatic switch to TWT bypass (approx. 40 dB reduction in transmitted power) at short ranges.

TABLE 8.3.4.2-1 RADAR ACTIVE MODE ELECTRICAL INTERFACE CHARACTERISTICS

Parameter	Dimension	Value	Notes
1. Target Type			
Transponder Pulse Beacon			Target carries coherent pulse transponder which retransmits amplified replica of received pulse. Beacon carrying target is stabilized in 3 axes to TBD deg/sec each axis.
Operating Range	Ft.	1.824×10^6 Detection 100 minimum	
2. Beacon Characteristics			
Minimum Detectable Signal	dbm	TBD	Function of target antenna and receiver sensitivity
EIRP	dbw	TBD	
Coherence		TBD	
Delay	μsec	10±0.1	
3. Radar Characteristics			
Transmit Freq.	GHz	13.883	
Receive Freq.	GHz	13.883	Same as radar transmit freq. ±5 MHz
Antenna side-lobe level	db relative to main beam	20 minimun	
Transmit Power EIRP	dB	52 peak	
PRF's	pulses per sec.	228 search and track	For range greater than 9.5 NM
		6970 Track	Range < 9.5 NM

TABLE 8.3.4.2-1 RADAR ACTIVE MODE ELECTRICAL

INTERFACE CHARACTERISTICS (Continued)

Parameter	Dimension	Value	Notes
Pulse widths	usec.	Dual 4.15 and 0.122	Used in search range.
		4.15	Used for search and track when range >9.5 NM
		0.122	Used for track when range < 9.5 NM
Receiver noise Figure	db	5	

TABLE C.2-1 NASA/DSN CHANNEL & FREQUENCY ASSIGNMENTS

Channel	Transmit MHz	Receive MHz
850		2290.185185
851		2290.555556
852		2290.9259[illegible]
853		2291.2962[illegible]6
854	2110.243056	2291.666667
855	2110.584105	2292.037037
856	2110.925154	2292.407407
857	2111.266204	2292.777778
858	2111.607253	2293.148148
859	2111.948303	2293.518519
860	2112.289352	2293.888889
861	2112.630401	2294.259259
862	2112.971451	2294.629630
863	2113.312500	2295.000000
864	2113.653549	2295.370370
865	2113.994599	2295.740741
866	2114.335648	2296.111111
867	2114.676697	2296.481481
868	2115.017747	2296.851852
869	2115.358796	2297.222222
870	2115.699846	2297.592593
871	2116.040895	2297.962963
872	2116.381944	2298.333333
873	2116.722994	2298.703704
874	2117.064043	2299.074074
875	2117.405092	2299.444444
876	2117.746142	2299.814815
877	2118.087191	
878	2118.428241	
879	2118.769290	
880	2119.110339	
881	2119.451389	
882	2119.792438	

Unassigned Channels: 883-899
Transmit/Receive Ratio: 221/240

TABLE C.2-2 DOD/SGIS CHANNEL & FREQUENCY ASSIGNMENTS

CHANNEL	TRANSMIT ORBITER TO DOD PAYLOADS (MHz)	RECEIVE DOD PAYLOADS TO ORBITER (MHz)
900	1763.721	2202.500
901	1767.725	2207.500
902	1771.729	2212.500
903	1775.733	2217.500
904	1779.736	2222.500
905	1783.740	2227.500
906	1787.744	2232.500
907	1791.748	2237.500
908	1795.752	2242.500
909	1799.756	2247.500
910	1803.760	2252.500
911	1807.764	2257.500
912	1811.768	2262.500
913	1815.772	2267.500
914	1819.775	2272.500
915	1823.779	2277.500
916	1827.783	2282.500
917	1831.787	2287.500
918	1835.791	2292.500
919	1839.795	2297.500

- Unassigned Channels: 920-999
  Transmit/Receive Ratio: 205/256

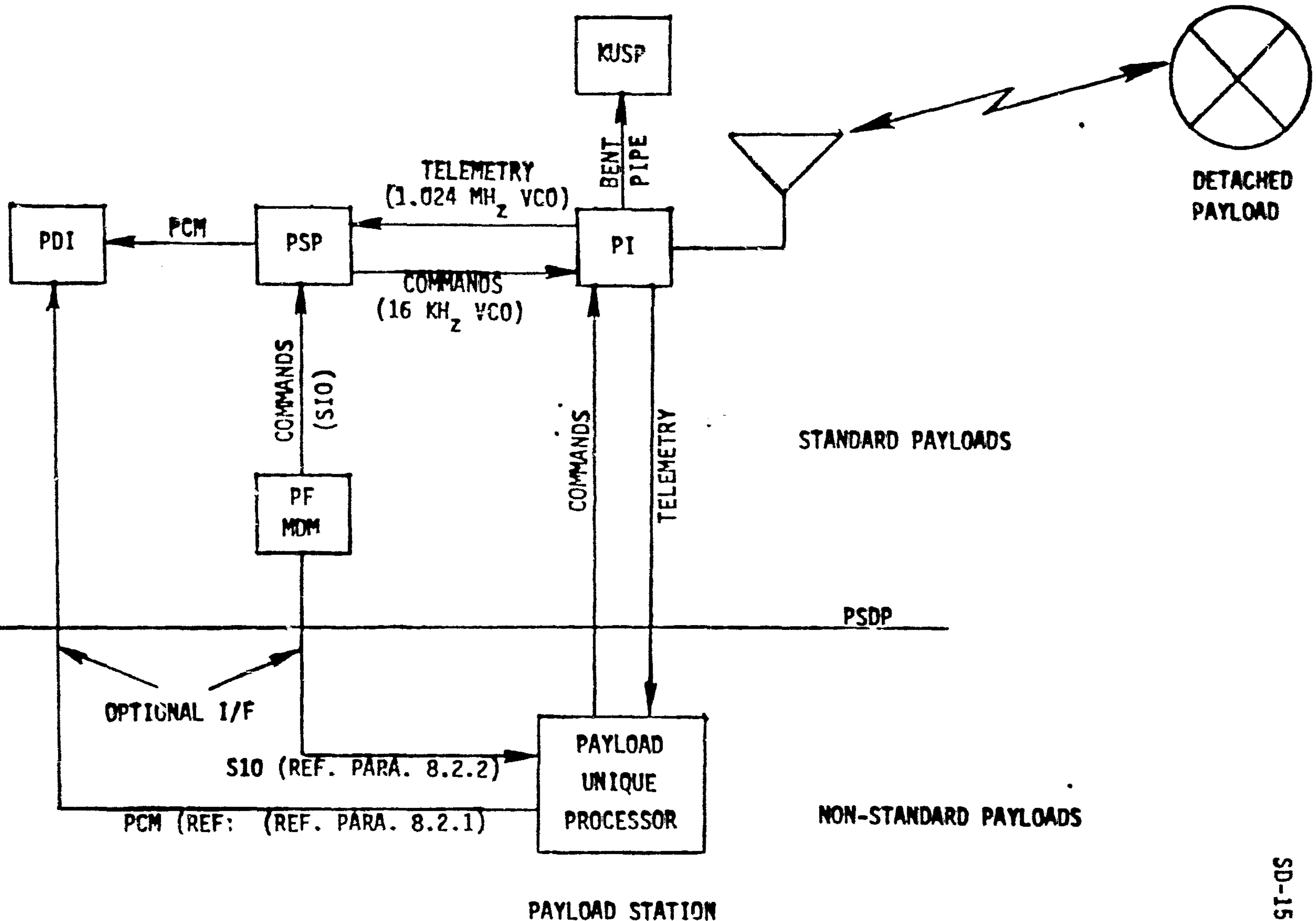


FIGURE 8.3.2-1 DETACHED PAYLOAD COMMUNICATION FLOW