

USA006030
Basic
(supersedes TD122)

Space Flight Operations Contract

Ku-band Operations Workbook

KU OPS 21002

September 21, 2004

Contract NAS9-20000

Copyright © 2004 by United Space Alliance, LLC. These materials are sponsored by the National Aeronautics and Space Administration under Contract NAS9-20000. The U.S. Government retains a paid-up, nonexclusive, irrevocable worldwide license in such materials to reproduce, prepare derivative works, distribute copies to the public, and to perform publicly and display publicly, by or on behalf of the U.S. Government. All other rights are reserved by the copyright owner.



Ku-band Operations Workbook

KU OPS 21002

Prepared by

Original approval obtained

Robert C. Murray, II
Book Manager
USA/Communications/Payloads

Approved by

Original approval obtained

Jacqueline Prewitt
Manager
USA/Communications/Payloads

REVISION LOG

| Rev. letter | Change no. | Description | Date |
|------------------------|-----------------------|--|-------------|
| Basic | | USA number assigned to document; supersedes TD122; updates throughout document | 09/21/2004 |

LIST OF EFFECTIVE PAGES

The current status of all pages in this document is shown below:

| Page No. | Change No. |
|------------|------------|
| Foreword | Basic |
| Preface | Basic |
| i – v | Basic |
| 1-1 – 1-4 | Basic |
| 2-1 – 2-5 | Basic |
| 3-1 – 3-16 | Basic |
| 4-1 – 4-13 | Basic |
| 5-1 – 5-19 | Basic |
| 6-1 – 6-13 | Basic |
| 7-1 – 7-10 | Basic |
| 8-1 – 8-11 | Basic |
| 9-1 – 9-3 | Basic |
| A-1 – A-4 | Basic |
| B-1 – B-5 | Basic |
| C-1 – C-20 | Basic |
| D-1 – D-2 | Basic |

FOREWORD

The content of this document was provided by the Communications Group, Shuttle/Network Communications Department, Space Flight Training Division, Mission Operations Directorate (MOD), Lyndon B. Johnson Space Center (JSC), National Aeronautics and Space Administration (NASA). Integrated Documentation Services (IDS) provided technical documentation support. Any questions concerning this workbook or any recommendations should be directed to the workbook book manager, Robert Murray at DT37, (281) 244-7345.

This material is for training purposes only and should not be used as a source of operational data. All numerical data, displays, and checklist references are intended as examples. To determine any prerequisites before using this document, consult the applicable Certification Plan. For shuttle manuals, consult the Flight Operations Support Personnel Training Guide (Blue Book) or the Crew Training Catalog. For Space Station manuals, consult the appropriate Space Station Certification Training Guide or Training Administration Management System (TAMS). The applicable training package should be studied before attending any classroom session or lesson for which this is a prerequisite.

A Training Materials Evaluation is included at the end of this document. Inputs to this sheet will be used to evaluate the lesson material. You do not need to sign the sheet.

PREFACE

This workbook is designed to furnish the operational knowledge needed by a crewmember to successfully interface with the Ku-band system. The workbook does not contain the actual Flight Data File (FDF) procedures but explains how the crew interfaces with the Ku-band system to accomplish the procedures.

This workbook is divided into nine sections. Section 1 (Introduction) is a brief overview of the total communications system and the Ku-band system itself. Section 2 (Components) is a brief overview of the components that make up the Ku-band system. The remaining sections address Ku-band operations.

Begin each section by reading the objectives and the learning material. If you are already familiar with the subject matter, skip to the section questions. If the material is new to you, be sure to read all the text carefully before completing the questions. The purpose of the questions is to emphasize the information you should have learned from reading the associated section. Before progressing to another section, you should know and understand the correct answers to each of the questions. The answers are in Appendix B and explain the correct response.

CONTENTS

| Section | Page |
|---|------------|
| 1.0 INTRODUCTION | 1-1 |
| 2.0 COMPONENTS..... | 2-1 |
| 2.1 PERFORMANCE OBJECTIVES..... | 2-1 |
| 2.2 OVERVIEW | 2-1 |
| 2.3 DEPLOYED ASSEMBLY | 2-2 |
| 2.4 ELECTRONICS ASSEMBLY 1 | 2-3 |
| 2.5 ELECTRONICS ASSEMBLY 2 | 2-3 |
| 2.6 SIGNAL PROCESSOR ASSEMBLY..... | 2-4 |
| 2.7 SUMMARY..... | 2-4 |
| 2.8 QUESTIONS..... | 2-5 |
| 3.0 ANTENNA DEPLOYMENT | 3-1 |
| 3.1 PERFORMANCE OBJECTIVES..... | 3-1 |
| 3.2 INTRODUCTION | 3-1 |
| 3.3 KU-BAND ANTENNA HEATERS..... | 3-2 |
| 3.4 DEPLOYMENT | 3-5 |
| 3.5 POWER DISTRIBUTION..... | 3-9 |
| 3.6 SUMMARY..... | 3-10 |
| 3.7 QUESTIONS..... | 3-12 |
| 4.0 KU-BAND ACTIVATION | 4-1 |
| 4.1 PERFORMANCE OBJECTIVES..... | 4-1 |
| 4.2 INTRODUCTION | 4-1 |
| 4.3 ACTIVATION | 4-1 |
| 4.3.1 Initialization Sequence | 4-4 |
| 4.3.2 Self-Test | 4-6 |
| 4.4 SUMMARY..... | 4-7 |
| 4.5 QUESTIONS..... | 4-9 |
| 5.0 ANTENNA OPERATIONS..... | 5-1 |
| 5.1 PERFORMANCE OBJECTIVES..... | 5-1 |
| 5.2 OVERVIEW | 5-1 |
| 5.3 ANTENNA OPERATIONS | 5-2 |
| 5.4 GIMBAL ANGLE TRANSFORMATION..... | 5-5 |
| 5.4.1 Antenna LOS Position Displays | 5-6 |
| 5.5 OPERATIONAL MODES | 5-8 |
| 5.5.1 Antenna Steering | 5-9 |
| 5.5.2 Search..... | 5-14 |
| 5.5.3 Antenna Stabilization | 5-15 |
| 5.6 FLIGHT ANOMALIES | 5-16 |
| 5.7 SUMMARY..... | 5-17 |
| 5.8 QUESTIONS..... | 5-18 |

| Section | | Page |
|---|--|-------------|
| 6.0 COMMUNICATIONS OPERATIONS | | 6-1 |
| 6.1 PERFORMANCE OBJECTIVES..... | | 6-1 |
| 6.2 OVERVIEW | | 6-1 |
| 6.3 COMMUNICATIONS SYSTEM COMPONENT INTERFACES AND DATA FLOW | | 6-2 |
| 6.3.1 Forward Link | | 6-3 |
| 6.3.2 Return Link..... | | 6-4 |
| 6.4 COMMUNICATIONS SYSTEM CAPABILITIES..... | | 6-4 |
| 6.4.1 Modes of Operation | | 6-4 |
| 6.4.2 Ku-band/S-band PM Auto K to S; Auto S to K operation | | 6-10 |
| 6.5 SUMMARY..... | | 6-11 |
| 6.6 QUESTIONS..... | | 6-12 |
| 7.0 RADAR OPERATIONS | | 7-1 |
| 7.1 PERFORMANCE OBJECTIVES..... | | 7-1 |
| 7.2 OVERVIEW | | 7-1 |
| 7.3 RADAR SYSTEM..... | | 7-2 |
| 7.4 RADAR OPERATIONS..... | | 7-2 |
| 7.5 SUMMARY..... | | 7-9 |
| 7.6 QUESTIONS..... | | 7-10 |
| 8.0 STOW OPERATIONS | | 8-1 |
| 8.1 PERFORMANCE OBJECTIVES..... | | 8-1 |
| 8.2 INTRODUCTION | | 8-1 |
| 8.3 ANTENNA STOW | | 8-1 |
| 8.4 DIRECT STOW..... | | 8-6 |
| 8.5 CONTINGENCY STOW..... | | 8-8 |
| 8.6 SUMMARY..... | | 8-8 |
| 8.7 QUESTIONS..... | | 8-11 |
| 9.0 JETTISON | | 9-1 |
| 9.1 PERFORMANCE OBJECTIVES..... | | 9-1 |
| 9.2 INTRODUCTION | | 9-1 |
| 9.3 JETTISON..... | | 9-1 |
| 9.4 QUICK RESPONSE JETTISON | | 9-2 |
| 9.5 SUMMARY..... | | 9-2 |
| 9.6 QUESTIONS..... | | 9-3 |

APPENDIXES

| Appendix | | Page |
|-----------------|--|-------------|
| A | ACRONYMS AND ABBREVIATIONS..... | A-1 |
| B | ANSWERS | B-1 |
| C | CONTROLS AND DISPLAYS | C-1 |
| D | REFERENCES..... | D-1 |

TABLES

Table

| | | |
|-----|--|------|
| 3-1 | Ku-band antenna heater overtemp messages | 3-5 |
| 5-1 | Antenna steering mode capabilities..... | 5-9 |
| 5-2 | Scan/range definition..... | 5-15 |
| 5-3 | Stabilization modes | 5-16 |
| 6-1 | Ku-band forward link capabilities..... | 6-4 |
| 6-2 | Ku-band return link capabilities | 6-5 |

FIGURES

| Figure | | Page |
|--------|--|------|
| 1-1 | Space shuttle communication system | 1-1 |
| 1-2 | Ku-band RF links | 1-4 |
| 2-1 | Ku-band system overview | 2-1 |
| 2-2 | Block diagram of Ku-band communications system | 2-2 |
| 2-3 | Block diagram of Ku-band radar system | 2-2 |
| 2-4 | Ku-band deployed assembly | 2-3 |
| 3-1 | Deployed assembly positions - stowed/deployed | 3-1 |
| 3-2 | Antenna heater power | 3-2 |
| 3-3 | Ku-band antenna heaters | 3-3 |
| 3-4 | OI monitoring of DA heater temperatures | 3-4 |
| 3-5 | SM SPEC 76 COMM/RCDR display | 3-4 |
| 3-6 | KU PWR switch interfaces | 3-6 |
| 3-7 | Ku-band GCIL KU CNTL switch | 3-7 |
| 3-8 | Ku-band deploy/stow functional block diagram | 3-8 |
| 3-9 | Deploy/stow power | 3-10 |
| 3-10 | Panel A1U | 3-12 |
| 3-11 | Panel R13L | 3-13 |
| 3-12 | Panel R14 | 3-13 |
| 3-13 | Ku-band ant deploy | 3-14 |
| 4-1 | Ku-band power | 4-2 |
| 4-2 | Ku-band activation configuration | 4-3 |
| 4-3 | Gimbal angle movement | 4-4 |
| 4-4 | Interfaces for the initialization sequence | 4-5 |
| 4-5 | SM OPS 2011 ANTENNA display | 4-6 |
| 4-6 | Ku-band system and SM GPC interface | 4-6 |
| 4-7 | Ku-band comm mode interfaces | 4-8 |
| 4-8 | Panel A1U | 4-9 |
| 4-9 | Panel A2 | 4-10 |
| 4-10 | Panel R14 | 4-10 |
| 4-11 | Ku-band activation | 4-11 |
| 5-1 | Ku-band deployed assembly | 5-1 |
| 5-2 | Deployed assembly positions - stowed/deployed | 5-2 |
| 5-3 | Gimbal angle movement limits | 5-3 |
| 5-4 | Obscuration line from the ANTENNA display | 5-4 |
| 5-5 | Beta only masking of 20° | 5-4 |
| 5-6 | Beta + mask of 20° | 5-5 |
| 5-7 | Elevation/azimuth in relation to XYZ coordinates | 5-6 |
| 5-8 | Panel A2 elevation/azimuth digital display | 5-6 |
| 5-9 | Ku-band antenna azimuth and elevation | 5-8 |

| Figure | | Page |
|---------------|--|-------------|
| 5-10 | Ku-band interfaces for the GPC and GPC designate modes | 5-10 |
| 5-11 | Ku-band interfaces for the auto track mode | 5-11 |
| 5-12 | Ku-band interfaces for the manual slew mode | 5-12 |
| 5-13 | Ku-band interfaces for range tracking | 5-13 |
| 5-14 | Antenna search pattern | 5-14 |
| 6-1 | Ku-band communications system RF interface | 6-1 |
| 6-2 | Ku-band comm system forward link | 6-2 |
| 6-3 | Ku-band comm system return link | 6-3 |
| 6-4 | Ku-band forward link mode 1 configuration | 6-6 |
| 6-5 | Ku-band forward link mode 2 configuration | 6-7 |
| 6-6 | Ku-band return link mode 1 configuration | 6-8 |
| 6-7 | Ku-band return link mode 2 configuration | 6-9 |
| 6-8 | SM SPEC 76 COMMUNICATIONS display | 6-10 |
| 7-1 | Ku-band RF links | 7-1 |
| 7-2 | Block diagram of the Ku-band radar system | 7-2 |
| 7-3 | GNC GPC to SM GPC interface enable | 7-3 |
| 7-4 | Ku-band interfaces | 7-4 |
| 7-5 | Ku-band radar configuration | 7-5 |
| 7-6 | Rendezvous radar sensor enable | 7-6 |
| 7-7 | Radar mode interfaces for auto track acquisition | 7-7 |
| 7-8 | Comm mode interfaces | 7-8 |
| 8-1 | Ku-band stow interfaces | 8-2 |
| 8-2 | Positioning antenna for stow | 8-4 |
| 8-3 | Ku-band stow functional block diagram | 8-5 |
| 8-4 | Ku-band direct stow functional block diagram | 8-7 |
| 8-5 | Ku-band CCTV overlay | 8-8 |
| 8-6 | Ku-band ant stow | 8-9 |
| 9-1 | Jettison power | 9-2 |

1.0 INTRODUCTION

The goal of the workbook is to prepare the reader to perform onboard procedures associated with the space shuttle communication system. Figure 1-1 is a simplified diagram of the various communication subsystems and interfaces of the orbiter. Each block in the figure represents a training manual that is dedicated to that particular subsystem.

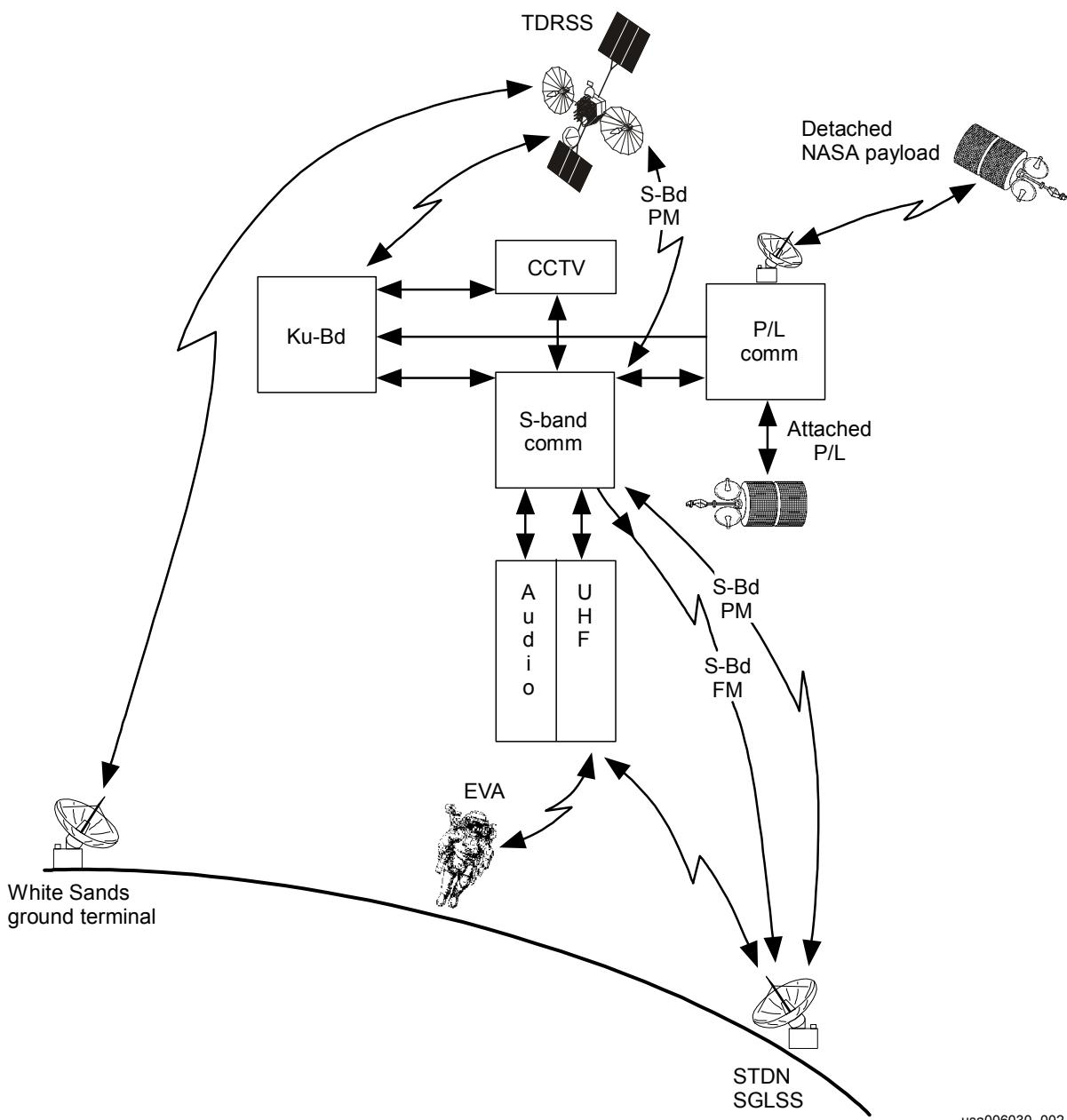


Figure 1-1. Space shuttle communication system

The space shuttle communication system is more than a link for the transfer of voice between two or among several sources. In addition to voice, the orbiter communication system also accommodates the transfer of telemetry, commands, and documents. The transfer of this information takes place through hardline and/or Radio Frequency (RF) links. Hardline refers to the transfer of information through wires connecting the communication devices; RF is the transfer of information via a radio signal.

The communication system of the orbiter consists of three main RF ground links and several subsystems. The RF links are Space Tracking and Data Network (STDN), Space Ground Link System (SGLS), and Tracking and Data Relay Satellite System (TDRSS). Figure 1-1 illustrates the transmit/receive systems. Both STDN and SGLS sites support communications via Ultrahigh Frequency (UHF), S-band Phase Modulation (S-Bd PM), and S-band Frequency Modulation (S-Bd FM). The STDN sites are owned by the National Aeronautics and Space Administration (NASA). SGLS sites are owned by the military. TDRSS supports only the Ku-band (Ku-Bd) and S-Bd PM communication systems. The S-Bd PM system is an Uplink and Downlink (UL/DL) source; telemetry and commands are sent and received through this system via TDRSS or STDN/SGLS sites. The S-Bd FM system is a downlink (only) RF link to a ground site. The S-Bd FM system allows downlink of selected information while using the S-Bd PM system for voice and data. The S-band COMM block represents the S-band PM, Network Signal Processor (NSP), instrumentation, recorders, and S-band FM systems and their interfaces. The operations of these systems are discussed in S-band Comm/In 21002.

The Ku-Bd system is another path through which the crew can achieve two-way communication. In contrast to S-Bd, the Ku-Bd system does not have STDN or SGLS site coverage. The Ku-Bd system has more channels (three) and a greater data capacity with which to downlink Closed-Circuit Television (CCTV), voice, Payload (P/L) telemetry, solid state recorder data, and orbiter telemetry. Ku-Bd is limited to on-orbit operations with the TDRSS. Due to its increased capacity, Ku-Bd is the preferred RF system while S-Bd is prime. This workbook covers operations and limitations of the system.

The UHF system also provides two-way communication with a ground site during the ascent and entry phases of flight. The Space to Space Communications System (SSCS) is prime for Extravehicular Activity (EVA) operations and rendezvous voice operations, specifically establishing voice contact with the International Space Station (ISS). This system has the capability to allow communication between the EVA astronaut and the orbiter or an Intravehicular Activity (IVA) astronaut. The audio system is the main source for the transfer of voice and caution and warning tones/alarms. The audio and UHF systems are both explained in the AUDIO/UHF 21002 Workbook.

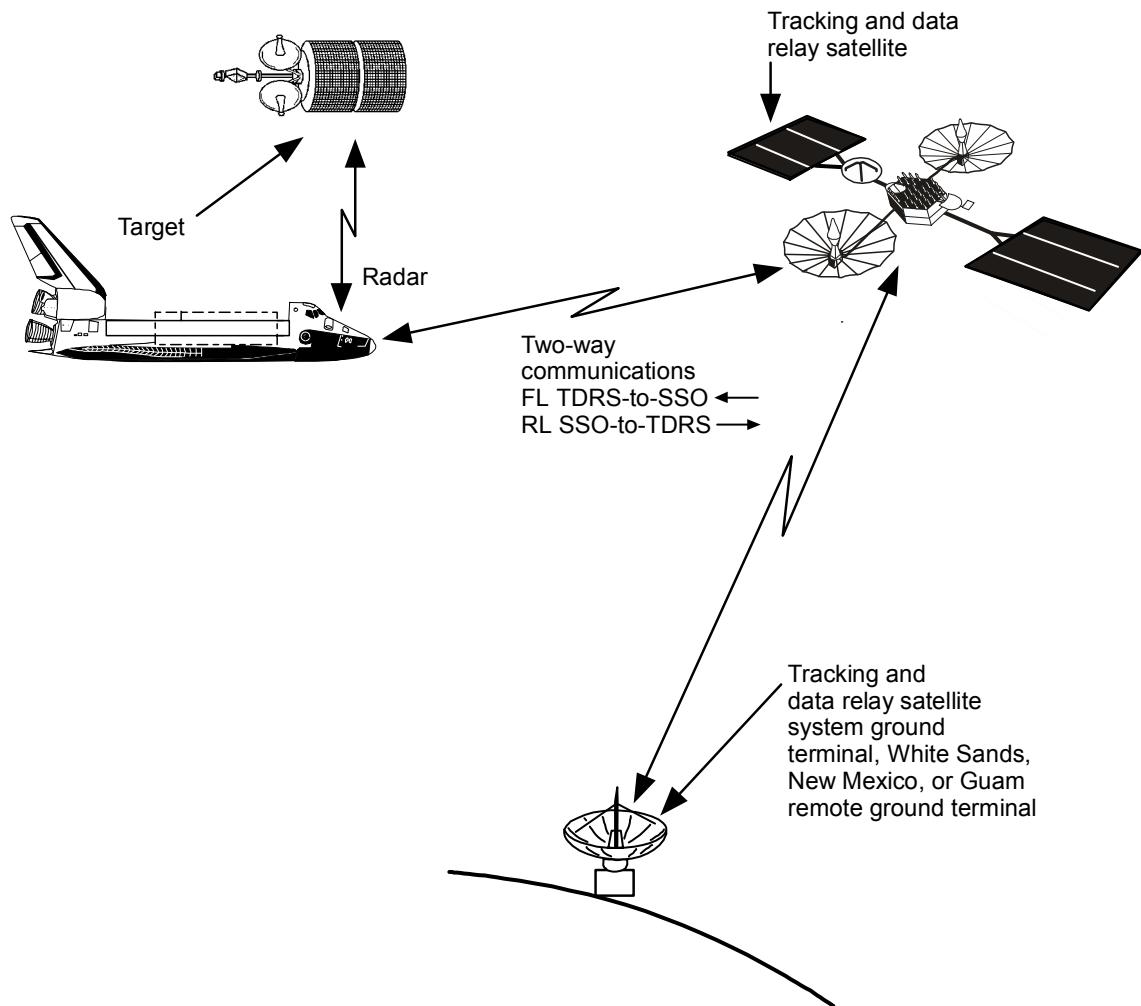
Communication to payloads is achieved through the S-band PM Payload (S-Bd P/L) System for a detached payload or through hardline for P/Ls that have not been deployed. The hardline link is used to verify the operation or the status of a payload before deployment. Further information on the P/L COMM system is found in the P/L COMM/OIU 21002 Workbook.

The CCTV system is used by the crew to support payload operations and EVA operations, to record crew activities, and to downlink television (recorded or live). More information is in the CCTV OPS 21108 Study Guide.

The purpose of this workbook is to discuss the operations of the Ku-band system. The Space Shuttle Orbiter (SSO) contains one Ku-band system that can be used on orbit either for two-way communications (Forward Link (FL) and Return Link (RL)) with the ground controllers or for radar detection and tracking of targets during rendezvous and proximity operations. The communications (comm) and radar modes are not available simultaneously. They share a wide-band, multifunction transmitter, a two-channel angle tracking receiver, and a parabolic reflector antenna that are part of the Deployed Assembly (DA) Line Replaceable Unit (LRU), which is stowed in the payload bay during launch and entry, and deployed on orbit. For communications, the orbiter Ku-band system has a two-way RF interface with a geosynchronous Tracking and Data Relay Satellite (TDRS). Each TDRS also has an RF interface with the tracking and data relay satellite system ground terminal at White Sands, New Mexico, or the Guam Remote Ground Terminal (Figure 1-2). The Ku-band system can automatically search for, detect, and track the TDRS and can automatically switch between the satellites as required by the space shuttle orbital position. In the radar mode, the Ku-band system can be used to detect and track another space vehicle or a payload to aid the orbiter in rendezvous and proximity operations.

During a rendezvous operation, the radar system is used as a sensor that provides target angle, range, and range-rate information for updating the rendezvous navigation data. The operation is similar to using the Crew Optical Alignment Sight (COAS) or the Star Tracker (ST), except that radar provides target range and range-rate data in addition to angle data. During proximity operations, the system is used as a real-time source of information, representing position and closing velocity of the orbiter with respect to the target.

This workbook provides details about crew actions required for nominal and contingency operations of the Ku-band system. The nominal operations include deployment of the DA, activation of the Ku-band system, on-orbit operations, and stowage of the DA. Possible contingency operations include forced stowage of the DA using the direct stow switch or jettison of the DA. This workbook begins with an overview of the components that make up the Ku-band system.



usa006030_001

Figure 1-2. Ku-band RF links

2.0 COMPONENTS

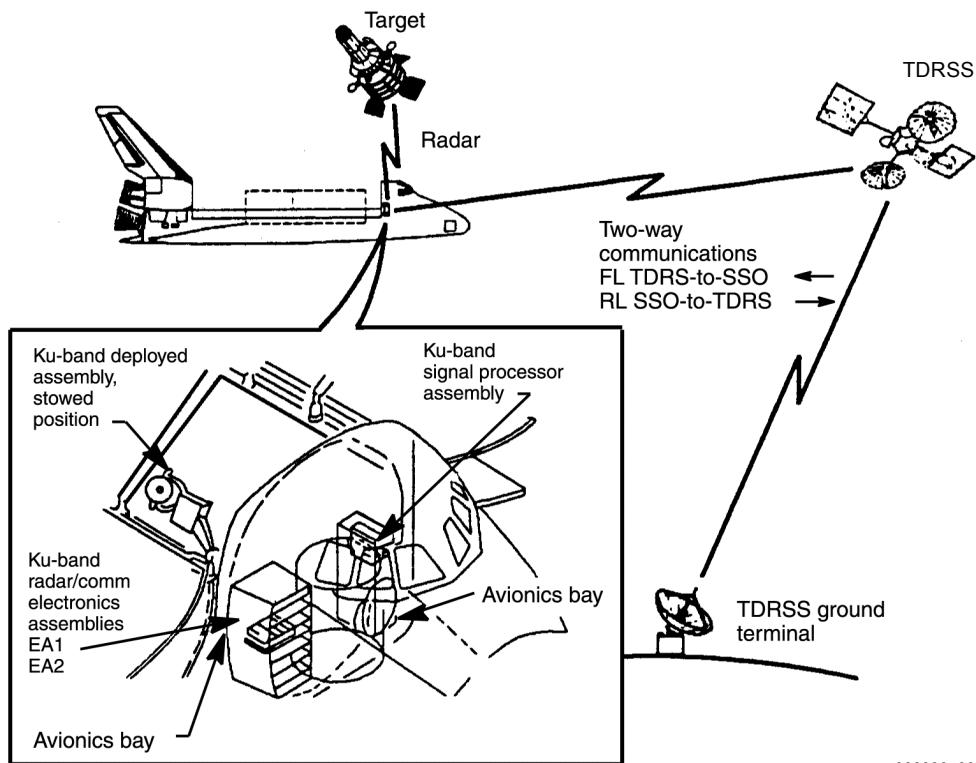
2.1 PERFORMANCE OBJECTIVES

The student should be prepared to accomplish the following tasks after studying this section of the workbook:

- a. Identify the main purpose of the Deployed Mechanical Assembly (DMA), the Deployed Electronics Assembly (DEA), Electronics Assembly 1 (EA1), EA2, and the Signal Processor Assembly (SPA)
- b. Identify the LRU associated with the comm mode and the LRU used in the radar mode

2.2 OVERVIEW

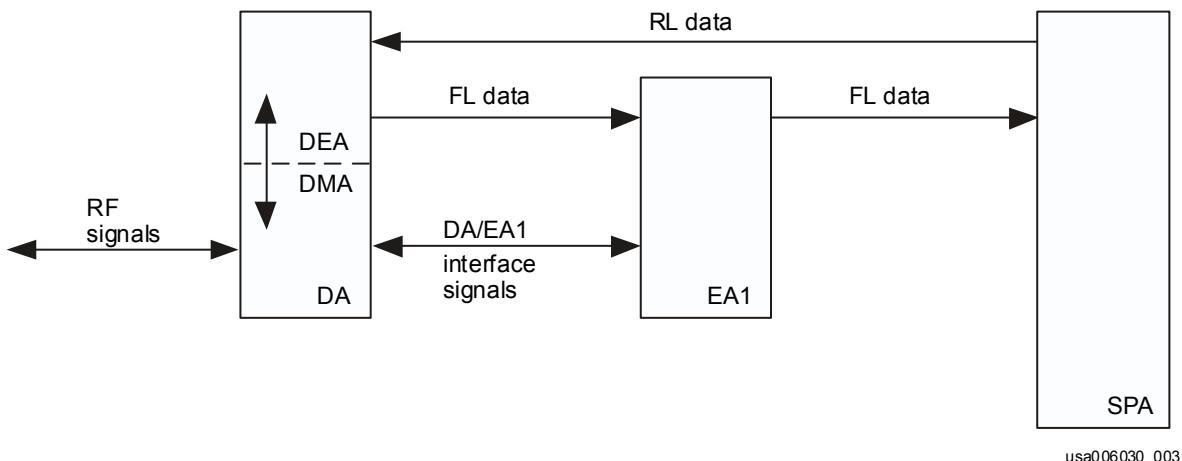
The Ku-band system consists of four electronics assemblies and a mechanical assembly, as illustrated in Figure 2-1. One of the electronics LRU and the mechanical assembly are mounted together to form the deployed assembly. The DA is pivot-mounted on the starboard payload bay sill longeron just behind the crew compartment. The three electronics LRU are mounted in forward avionics bays.



usa006030_006

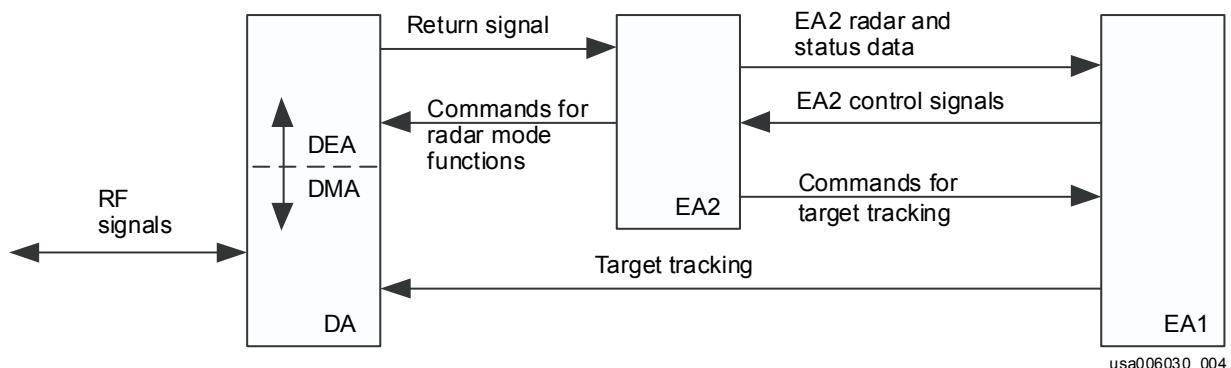
Figure 2-1. Ku-band system overview

The purpose of this section is to provide a brief description of the Ku-band system components. The major components are the DA, EA1, EA2, and the SPA. The comm mode utilizes the DA, EA1, and the SPA (Figure 2-2). The radar mode utilizes the DA, EA1, and EA2 (Figure 2-3).



usa006030_003

Figure 2-2. Block diagram of Ku-band communications system



usa006030_004

Figure 2-3. Block diagram of Ku-band radar system

2.3 DEPLOYED ASSEMBLY

The deployed assembly consists of the DMA and the DEA (Figure 2-4). The DMA includes the antenna dish, the alpha and beta gimbals and their associated gimbal drive motors, and the rate-sensing gyro assembly. The antenna provides the RF interface with the TDRS or a target when there is a line of sight between the antenna and the satellite or the target. The alpha and beta gimbals provide a two-axis gimbal system for the Ku-band antenna. The gimbal drive motors position the antenna dish. The rate gyro assembly provides angle-rate data for inertial stabilization of the antenna when the antenna is not angle tracking a TDRS or a radar target.

The DEA contains the Ku-band RF equipment such as the comm/radar select, RF attenuators for RF power output selection in radar mode, the transmitter, the receiver, and logic controls for RF signal routing for comm or radar operation. The RF power output for the radar mode can be high, medium, or low, but the comm mode has only high power output.

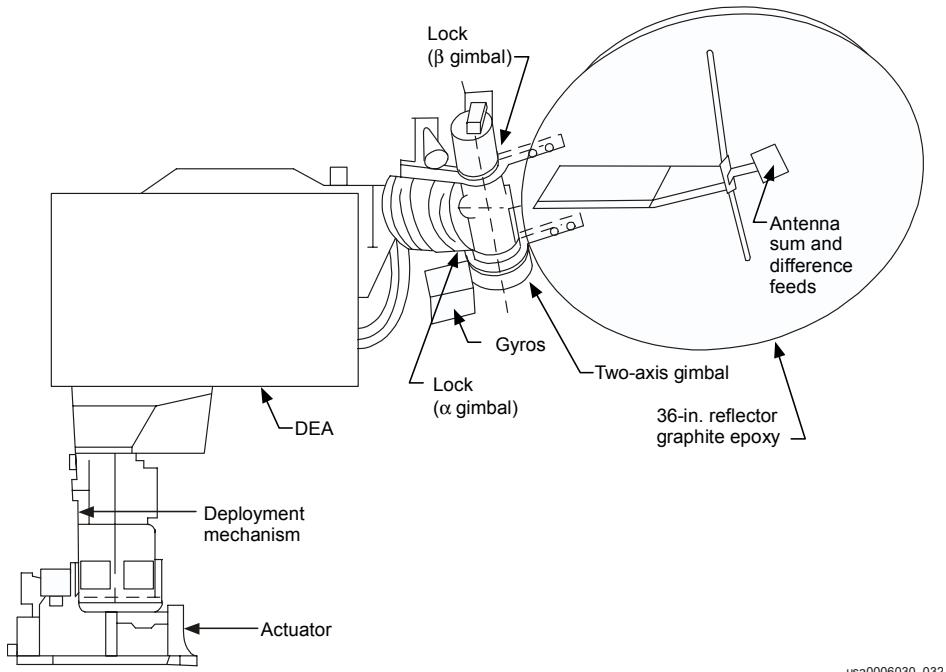


Figure 2-4. Ku-band deployed assembly

2.4 ELECTRONICS ASSEMBLY 1

EA1 is the radar/comm interface and control LRU. It contains the antenna control electronics and the comm data processor. The antenna control electronics provides inputs to the servo system for positioning the antenna gimbal motors. Position rate data are derived from designated angles commanded by the Systems Management (SM) General Purpose Computer (GPC), by the slew switches on Panel A1U, or by the automatic closed-loop tracking system internal to EA1. The azimuth and elevation data are transformed in the EA1 microprocessor to alpha and beta gimbal angles. The comm data processor demodulates the carrier from the forward link signal and sends the data to the SPA. EA1 also provides data to onboard displays, meters, and GPCs.

If EA1 fails, Ku-band forward link, return link, and stow capabilities are lost.

2.5 ELECTRONICS ASSEMBLY 2

EA2 is the radar signal processor and is used only when the Ku-band system is in the radar mode. It sends commands to the DEA for control of the radar mode functions, such as transmitter frequency, transmitter RF output power level, and transmitter and receiver gating logic and to EA1 for antenna radar lobing controls to allow target

tracking. EA2 receives and processes the radar return signal from the receiver in the DEA. The processing determines the range, the range rate, and the angle rate of the target.

If EA2 fails, the Ku-band radar mode capabilities are lost, but the Ku-band system can still be used in the comm mode.

2.6 SIGNAL PROCESSOR ASSEMBLY

The SPA, used only in the communications mode, is the communications signal processor. The SPA controls data routing and management. It also provides the Ku-band interface with the orbiter NSP, the payload system, and several data sources. Return link data are always present at the input to the Ku-band and S-band systems. Placing the Ku-band system in the communications mode will allow it to transmit RL data to the TDRS. FL operational data are processed by the NSP when the Ku-band system is in the communications mode and the NSP is in the Ku-band mode, as selected by the NSP UPLK DATA function of the system, configured by the switch on Panel A1L or commanded from the ground.

If the SPA fails, the Ku-band comm mode capabilities are lost, but the Ku-band system can still be used in the radar mode.

2.7 SUMMARY

The Ku-band system consists of the DMA, the DEA, EA1, EA2, and the SPA. The DMA includes the antenna dish and gimbals to provide an RF interface with the TDRS system. The DEA provides the RF equipment. Together, the DMA and the DEA make up the DA. EA1 provides the radar/comm interface and control. EA2 is the radar signal processor, and the SPA is the communications signal processor. The communications mode utilizes the DA, EA1, and the SPA. The radar mode utilizes the DA, EA1, and EA2.

2.8 QUESTIONS

For questions 1 to 5, match the assembly with its purpose.

1. _____ Deployed electronics assembly
2. _____ Deployed mechanical assembly
3. _____ Electronics assembly 1
4. _____ Electronics assembly 2
5. _____ Signal processor assembly
 - a. Communications signal processor
 - b. Ku-band RF equipment
 - c. Radar/comm interface and control LRU
 - d. Includes antenna dish and gimbals to provide the RF interface with the TDRS system
 - e. Radar signal processor
6. In the communications mode, the Ku-band system uses
 - a. EA1 and EA2 only
 - b. DA, EA2, and SPA
 - c. DA, EA1, and EA2
 - d. DA, EA1, and SPA
7. In the radar mode, the Ku-band system uses
 - a. EA1 and EA2 only
 - b. DA, EA2, and SPA
 - c. DA, EA1, and EA2
 - d. DA, EA1, and SPA

3.0 ANTENNA DEPLOYMENT

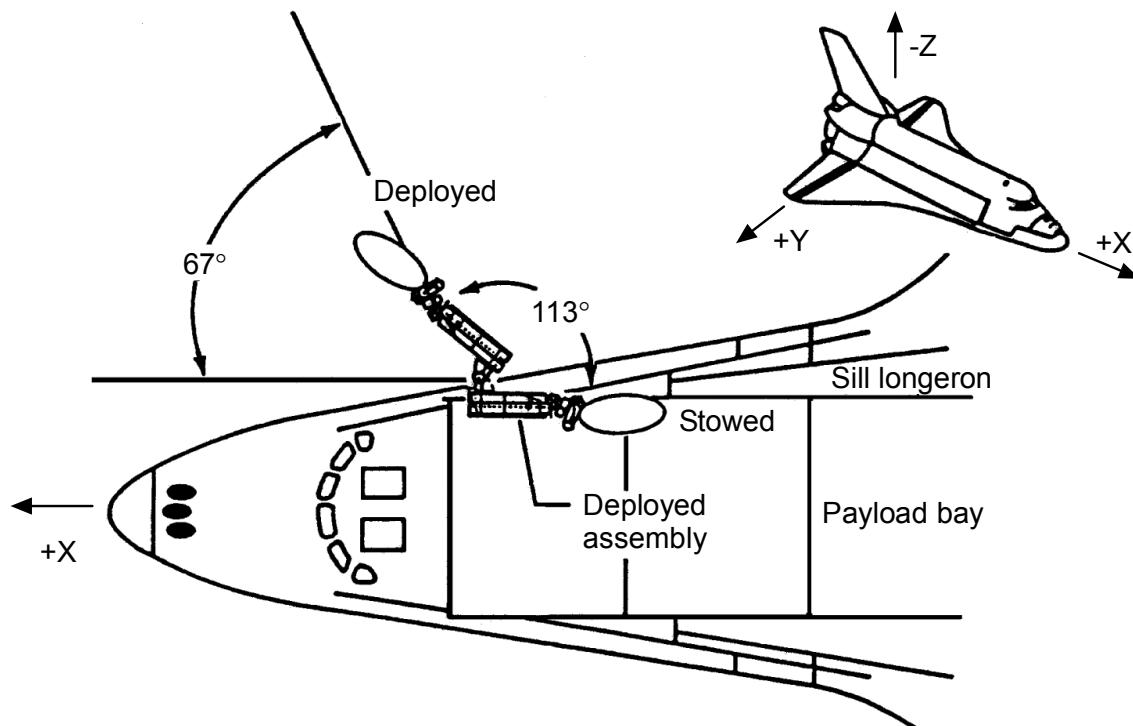
3.1 PERFORMANCE OBJECTIVES

The student should be prepared to accomplish the following tasks as a result of studying this section of the workbook:

- Identify the switches and the panels used in deploying the Ku-band antenna
- Describe the deploy operations
- Describe the power distribution for the deploy sequence
- Describe the flight rules relating to deploy operations

3.2 INTRODUCTION

During either the ascent or entry phase of flight, the Ku-band antenna is stowed parallel to the sill longeron just inside the starboard payload bay door and radiator assembly (Figure 3-1). The antenna gimbals are locked at specific angles to ensure clearance between the antenna dish and the closed payload bay door and radiator. The Ku-band deployed assembly with steerable dish antenna must be deployed after the orbiter is on orbit and the payload bay doors are opened so that the Ku-band system can be used. In the deployed position, the DA is positioned outboard along the starboard side of the crew compartment at an angle of 67° to the orbiter $+X$ -axis.

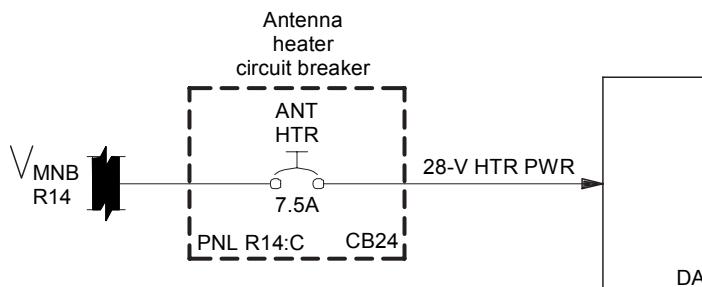
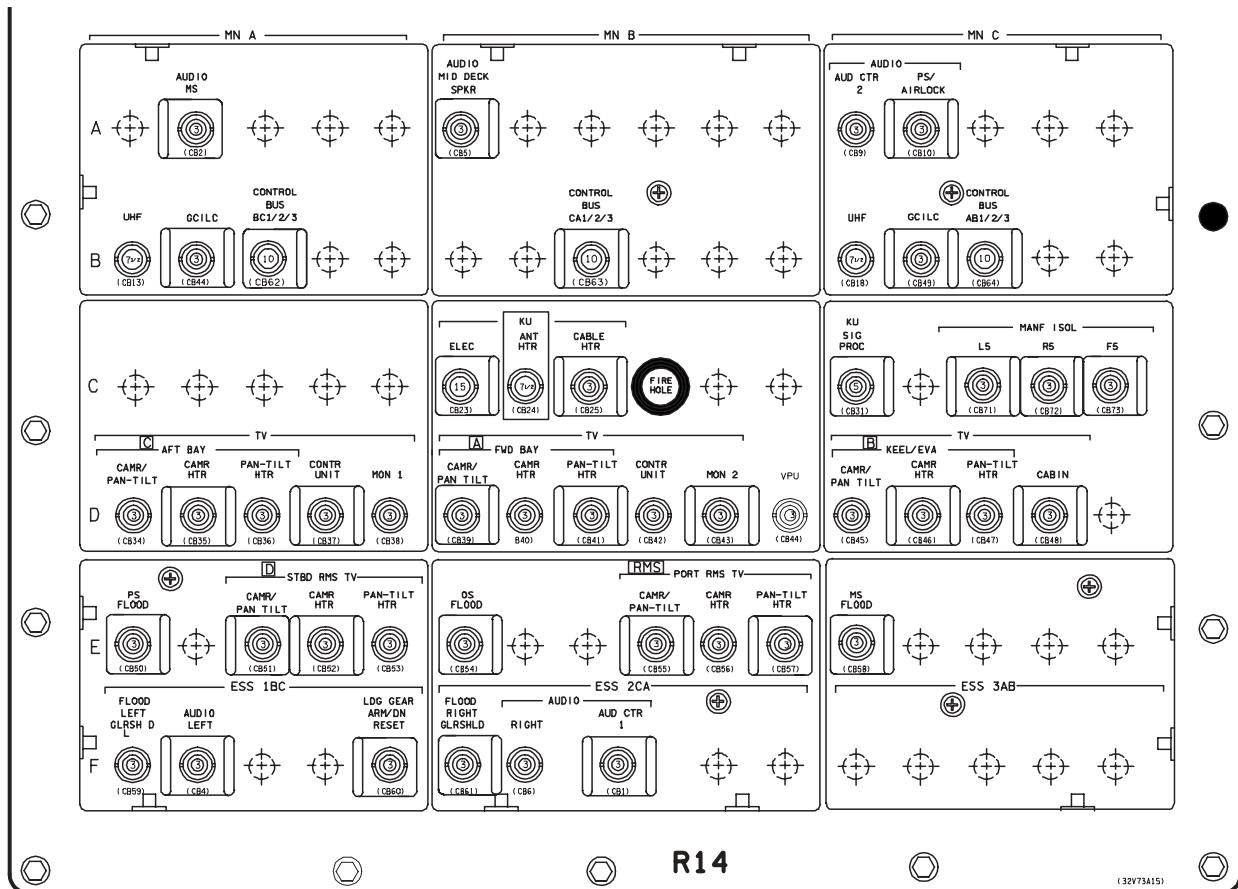


usa006030_033.cnv

Figure 3-1. Deployed assembly positions - stowed/deployed

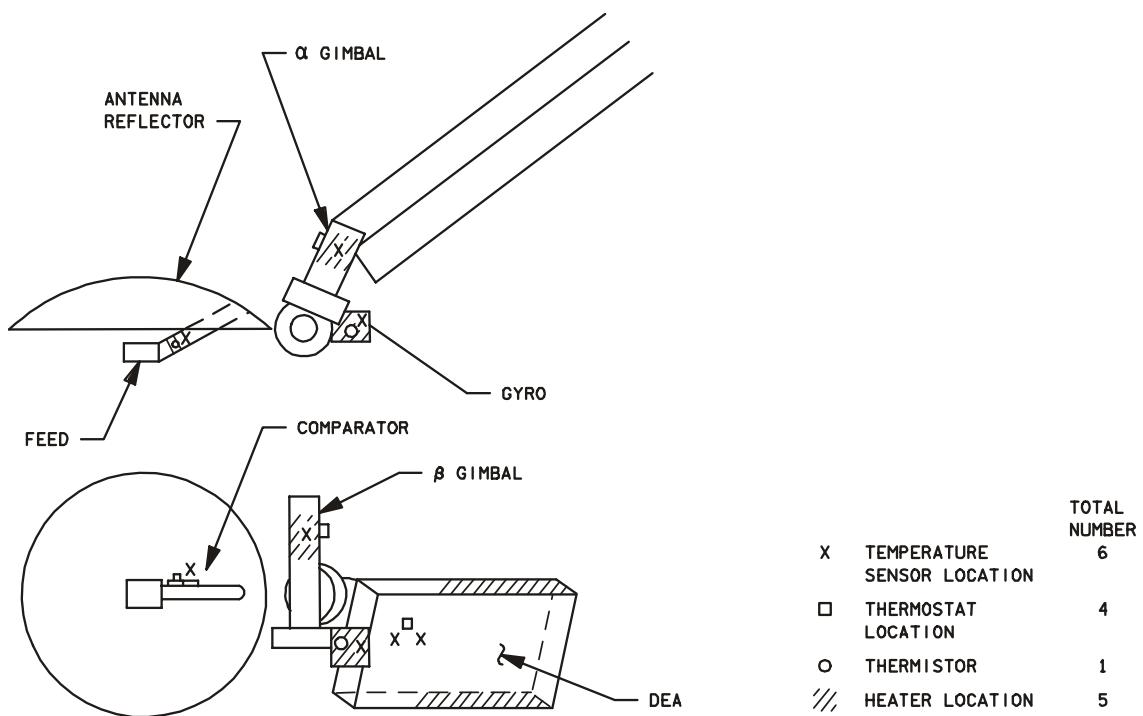
3.3 KU-BAND ANTENNA HEATERS

Preparation for the deployment of the antenna begins during post insertion activities. The Aft Station Config Cue Card, located in the Post Insertion Checklist, directs the crew to close the KU ANT HTR circuit breaker (cb) on Panel R14 (Figure 3-2). This action provides power to five thermostatically controlled heaters that maintain specified temperatures for the DEA, the gimbals, the gyro assembly, and the antenna feed horn (Figure 3-3). It also enables the associated temperature monitoring circuits at the same time. The Ku-band antenna heaters are required for normal Ku-band operations to prevent freezing of the gyros and to keep the equipment warm.



USA006030_034

Figure 3-2. Antenna heater power

00603016.ART₉ 1**Figure 3-3. Ku-band antenna heaters**

Sensors monitor the temperatures of the heaters in the Operational Instrumentation (OI) system (Figure 3-4). Normal antenna heater temperatures range from 5° to 150° F. The temperatures of the Ku-band Power Amplifier (PA), the alpha and beta gimbals, and the gyro assembly are shown on SM SPEC 76 Communications display (Figure 3-5). PA TEMP indicates the temperature in the DEA in the vicinity of the Traveling Wave Tube (TWT) PA. The same measurement is sent to Mission Control Center (MCC) as "transmitter" temperature. If the PA TEMP exceeds its limit, an up arrow will appear in the status column, an alert tone will be generated, and a message will appear. An up arrow, an alert tone, and a Cathode Ray Tube (CRT) message will also be generated if GMBL A TEMP, GMBL B TEMP, or GYRO TEMP exceeds its upper software limits. The messages and software limits are shown in Table 3-1.

Figure 3-13 illustrates the current KU-BD ANT DEPLOY procedures listed in the current Orbit Ops Checklist.

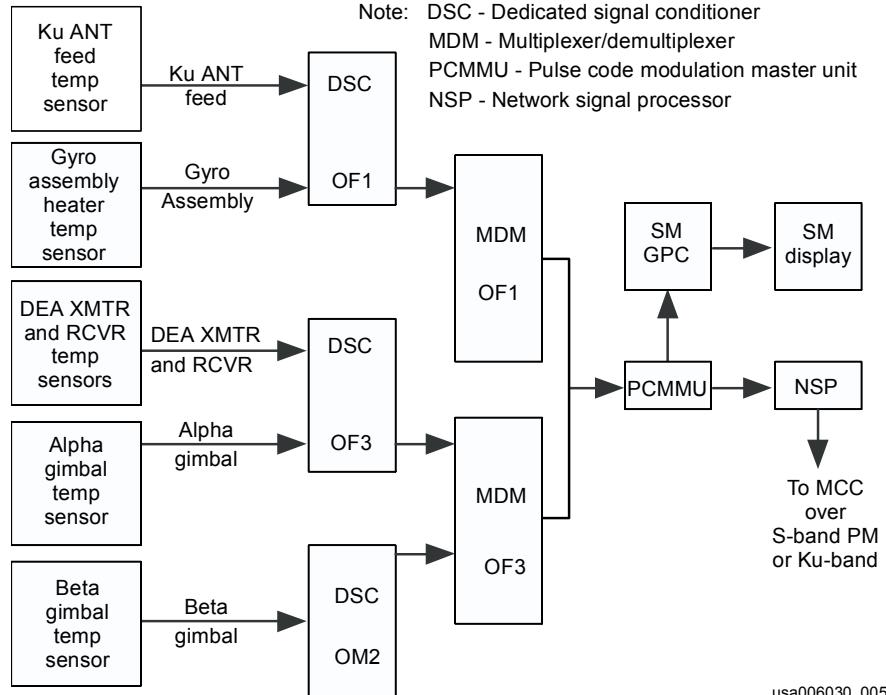


Figure 3-4. OI monitoring of DA heater temperatures

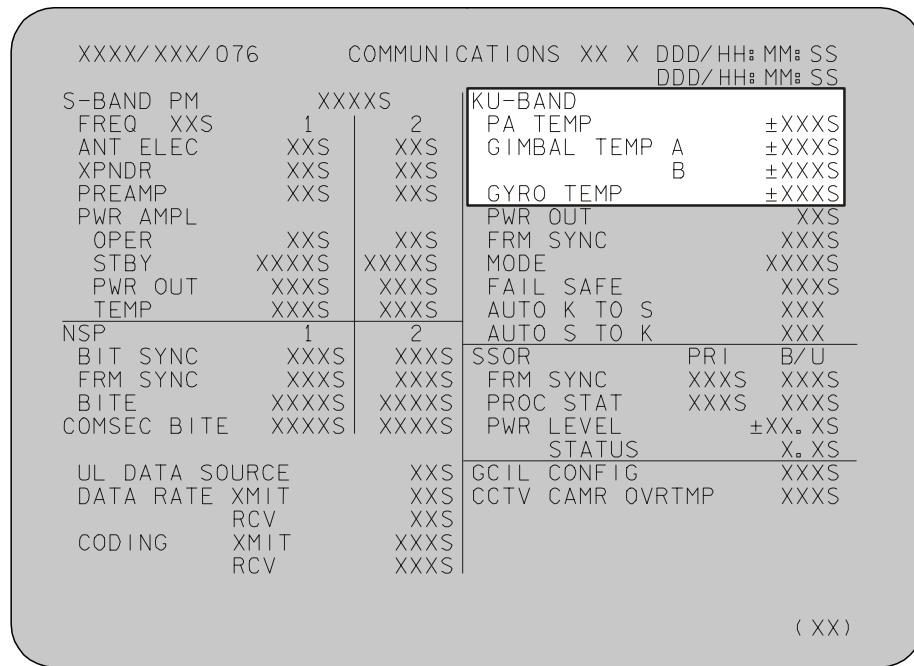


Figure 3-5. SM SPEC 76 COMM/RCDR display

Table 3-1. Ku-band antenna heater overtemp messages

| Measurement | SPEC 76 | |
|--------------------|--------------------------|--------------------|
| | Upper software limit, °F | Message |
| PA TEMP | 171 | S76 KU-XMTR TEMP |
| GMBL A TEMP | 150 | S76 KU-GMBL A TEMP |
| GMBL B TEMP | 166 | S76 KU-GMBL B TEMP |
| GYRO TEMP | 155 | S76 KU-GYRO TEMP |

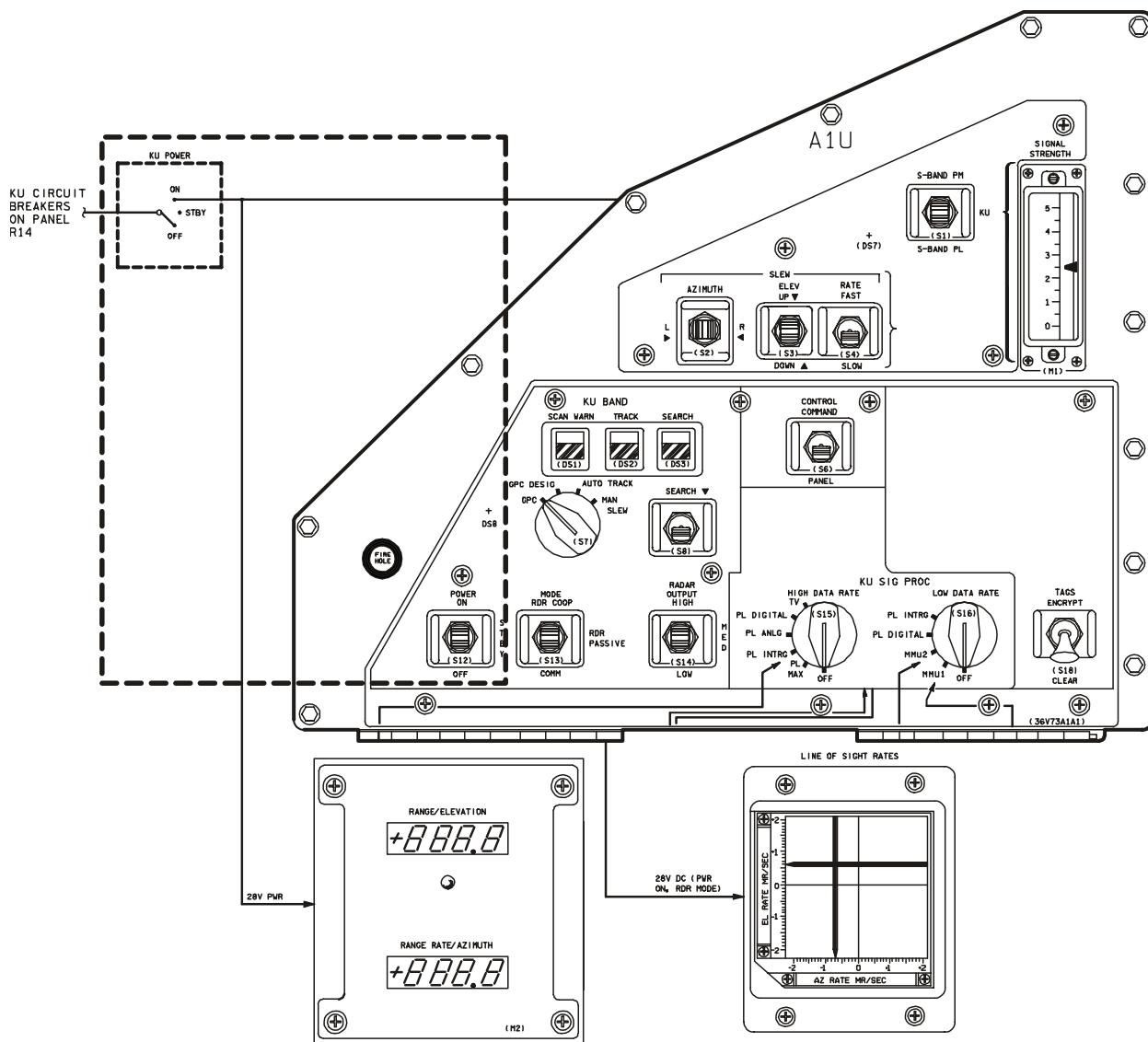
The CRT messages will lead the crew to COMM 2.2a in the Malfunction Procedures book. The procedure will lead the crew to open the KU ANT HTR cb. This action removes power from all of the antenna heaters.

Loss of temperature control of the gyro or the gimbals may cause problems with locking the antenna for stowing. Stowing the deployed assembly with an unlocked antenna could result in damage to the antenna or to the adjacent radiator panel during entry. Temperature control of the antenna feed, the transmitter, and the receiver is also required to prevent damage to these components. Flight rules state that if the temperature of any of the heaters cannot be maintained within the set limits or if the temperatures cannot be monitored, the Ku-band antenna should be deactivated and stowed. Flight-specific exceptions may exist for flights in which the Ku-band system is needed for high-priority operations. Any exceptions will be identified in the flight-related Flight Rule Annex.

3.4 DEPLOYMENT

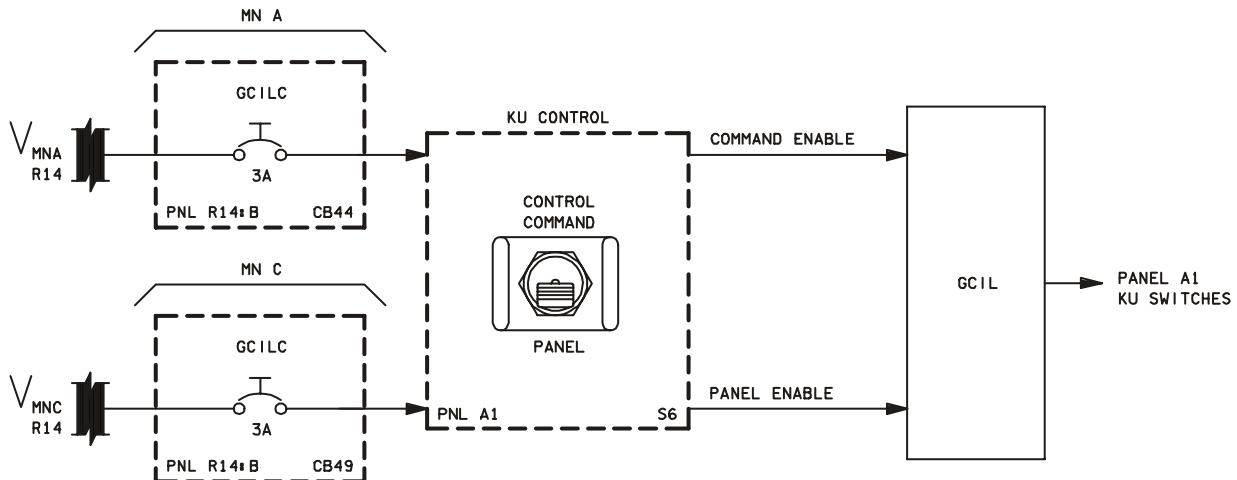
Deployment of the Ku-band antenna normally occurs after post insertion activities, but the exact time is flight dependent and can be found in the Flight Plan. The antenna deploy procedure is located in the Orbit Operations Checklist of the Flight Data File (FDF). The first step of the deploy procedure is to check that the KU PWR switch on Panel A1U is in the OFF position (Figure 3-6). The power is off during the deploy to prevent the Ku-band antenna from initializing prematurely. When the power is off, none of the Ku-band switches or meters are powered, except the KU CNTL switch and the SIG STRENGTH select switch. The KU CNTL switch is redundantly powered by MNA and MNC through cb's on Panel R14 (Figure 3-7). The SIG STRENGTH meter can still receive S-band PL or S-band PM signal strength if the SIG STRENGTH select switch is configured correctly.

Most of the Ku-band system is Ground Command Interface Logic (GCIL) controlled. The KU CNTL switch is located on Panel A1U. When the KU CNTL switch is in CMD, only ground commands affect the system configuration. When the KU CNTL switch is in PNL, only the panel switches affect the system configuration. Therefore, the next step of the deploy procedure is to put the KU CNTL switch in PNL so that changes to the GCIL-controlled switches on Panel A1U can be read.



USA006030_035

Figure 3-6. KU PWR switch interfaces

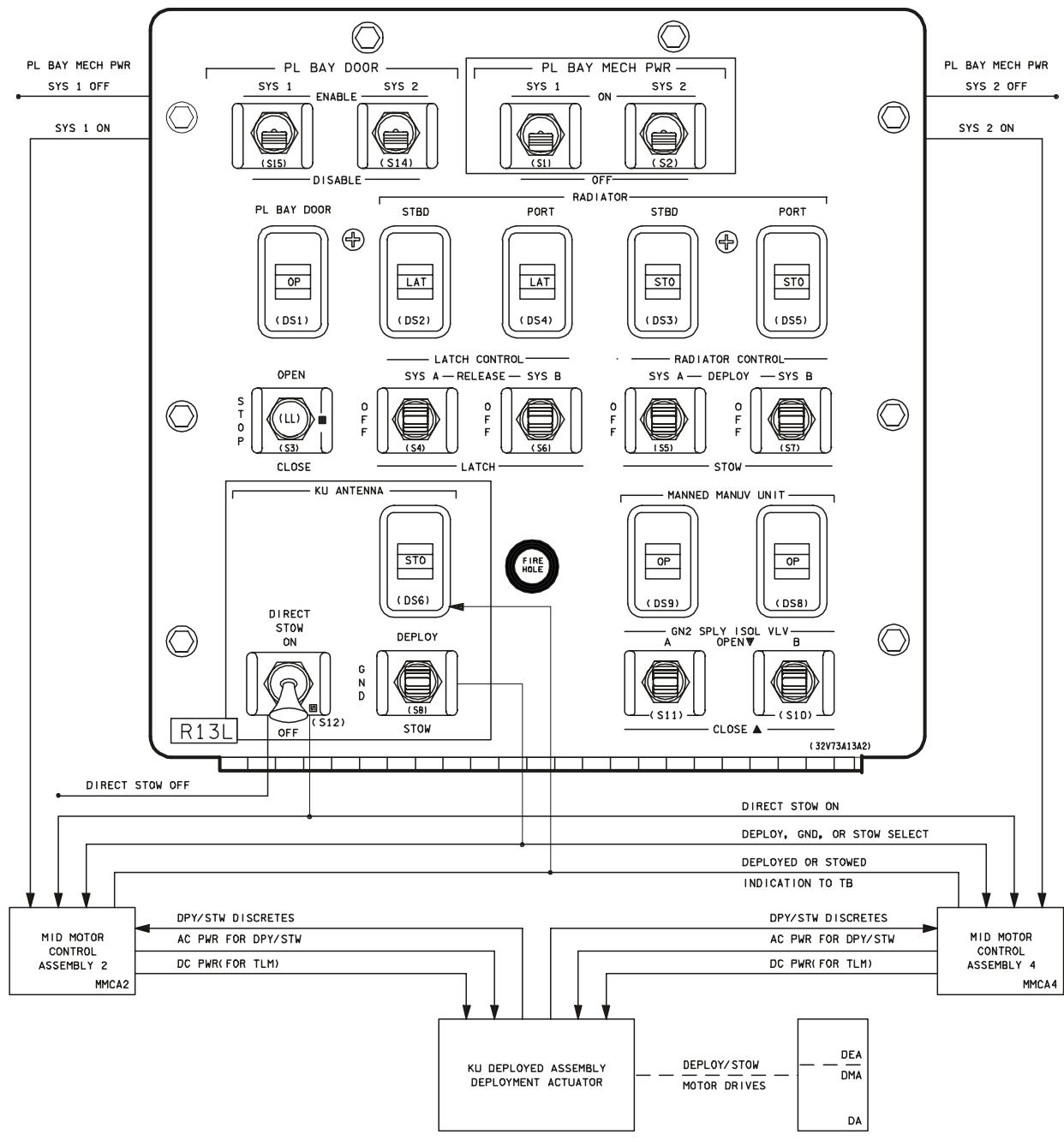


00603018.SCH 1

Figure 3-7. Ku-band GCIL KU CNTL switch

Some of the Ku-band switches, POWER/MODE, are not commandable by flight controllers. Therefore, the KU CNTL switch does not control them. The GCIL-controlled switches are the KU PWR, the KU antenna steering mode rotary, the KU SIG PROC LDR channel rotary, and the KU SIG PROC HDR channel rotary. Also, ground controllers can command the KU mode from RDR to COMM, but not from COMM to RDR.

Actual deployment utilizes controls on Panel R13L (Figure 3-8). The crew should first check that the KU ANT DIRECT STO switch is OFF. This is a precaution to prevent a phase-to-phase short when the KU ANT switch is taken to DPY. The short may cause the motor cb to pop. Next, the PL BAY MECH PWR SYS 1 and SYS 2 switches are taken to ON to energize relays in the Mid Motor Control Assemblies (MMCA2 and MMCA4). This action provides three-phase ac power to system 1 and system 2 motors. The KU ANT switch is taken to DPY. This action initiates the deploy sequence. The KU ANT talkback (tb) is set to barberpole (bp) and should stay bp until the DA is fully deployed. Two motors deploy the Ku-band antenna in about 23 seconds. If only a single motor is operating, the deploy will take about 46 seconds. The flight rule pertaining to this problem requires that the antenna be stowed as soon as possible if redundant Ku-band antenna stow capability is lost. If the Ku-band system is critical for mission success, then flight-specific flight rules may waive the redundant stow capability requirement. If single motor time occurs, the crew should consult with the MCC before activating the Ku-band system. The Instrumentation Communications Officer/Maintenance, Mechanical, Arm, Crew Systems (INCO/MMACS) Flight Controllers will want to troubleshoot the problem. When the DA is fully deployed and the KU ANT tb indicates DPY, the KU ANT switch is taken to GND to remove logic power from the MMCAs. After the deploy is complete, the PL BAY MECH PWR switches for system 1 and system 2 are taken to OFF to remove ac power.



00603019. PNL, 1

Figure 3-8. Ku-band deploy/stow functional block diagram

If the tb does not go to DPY in 46 seconds, the crew should perform specific malfunction procedures, as directed by MCC. Several different failures may prevent the DPY indication on the KU ANT tb, such as tb failure, KU ANT DPY/STO switch failure, limit switch mechanism failure, jammed mechanism, intermittent operations, or mechanical failure. A KU ANT DPY/STO switch failure may require the Ku-band Antenna Contingency Deploy/Stow In-Flight Maintenance (IFM). IFM procedures are located in the IFM Checklist of the FDF. If the limit switch mechanism fails in the STO position, the Ku-band Antenna Deploy/Stow microswitch failure procedure, MECH SSR-

7, will be required for stow operations. If the limit switch mechanism fails to transfer the deploy signal, the failure results in the loss of Ku-band comm and radar ops. A limit switch failure, a jammed mechanism failure, intermittent ops, or a mechanical failure may lead the crew to the Contingency Ku-Bd ANT Direct Stow procedure, MECH SSR-5. An antenna jettison may be required if a mechanical failure or a jammed mechanism occurs. The antenna jettison procedure is discussed in Section 9.0 of this workbook. There is a flight rule that requires the antenna to be stowed if attempts to fully deploy the Ku-band antenna are unsuccessful.

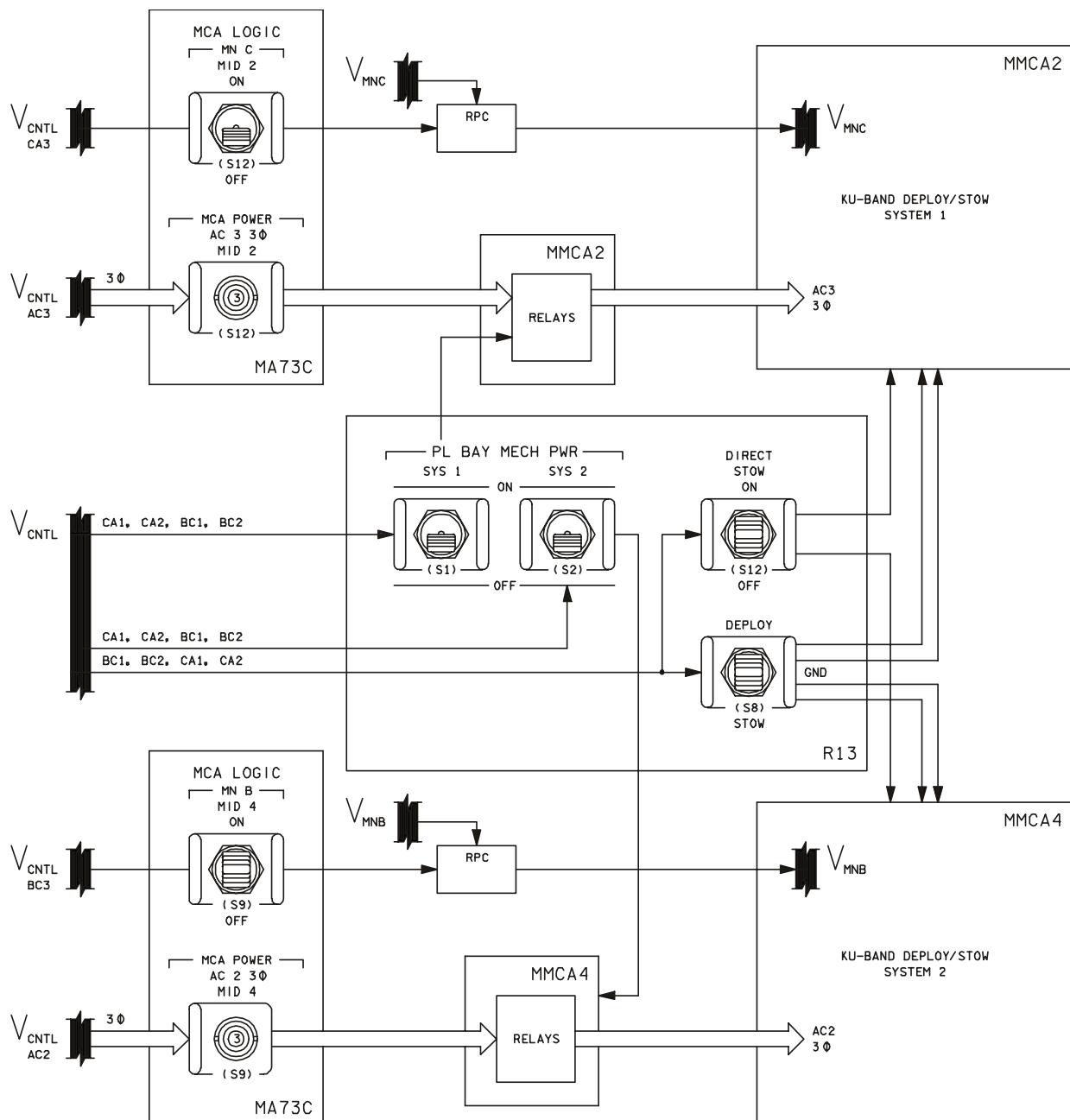
CAUTION

Care must be taken to ensure that the payload bay doors are fully open before deploying or stowing the DA to avoid damage to the door, the radiator, or the DA itself.

3.5 POWER DISTRIBUTION

Figure 3-9 illustrates the distribution of power used for deploying and stowing the Ku-band antenna. Power from redundant three-phase ac power buses (AC 3 and AC 2) is made available to system 1 and system 2 motors through cb's on Panel MA73C and relays in MMCA's (MMCA2 and MMCA4). The relays are energized through the ON contacts of the PL BAY MECH PWR SYS 1 and SYS 2 switches on Panel R13L.

Power from MNC and MNB dc buses is applied to the associated Motor Control Assemblies (MCAs) through Remote Power Controllers (RPCs). The RPCs are controlled by control bus voltages (CA3 and BC3) through MCA LOGIC switches on Panel MA73C (Figure 3-9). When all of the specified switches and cb's are closed, both ac and dc power are present in the associated MCAs. The appropriate positioning of the KU ANT switch applies a dc control voltage to the logic circuits in the MCAs, which enable two additional relays to provide ac power to the system 1 and system 2 motors and thereby initiate the deploy or the stow procedure.



00603020. SCH 1

Figure 3-9. Deploy/stow power

3.6 SUMMARY

On ascent, the Ku-band antenna is stowed in the payload bay. The Ku-band antenna is not usable until it is deployed from the payload bay. Using the Post Insertion Checklist and Panel R14, the crew can prepare for deployment by activating the DA heaters. The deploy operations are accomplished by using the Orbit Operations Checklist, Panel A1U, and Panel R13L. The deploy operations require ac power for the redundant

motors used to deploy and stow the DA. The logic for initiating the deploy or the stow procedures requires dc control bus power.

There are several flight rules that the crew must follow when working with the Ku-band system. Some of these rules pertain to controlling and monitoring the heaters, to the redundant motor stow capability, and to the ability to fully deploy the DA.

Figure 3-13 illustrates the current KU-BD ANT DEPLY procedure listed in the current Orbit Ops Checklist.

3.7 QUESTIONS

For questions 1 to 6, identify the switch(es), the cb(s), or the tb and the corresponding panel that will provide the function indicated (Figure 3-10, Figure 3-11, and Figure 3-12).

1. Provides power to the five heaters on the DA
2. Allows power to get to Ku switches and meters
3. Allows the configuration of the system to be controlled by the ground or the crew, depending on its position
4. Applies the dc control voltage needed to initiate deploy or stow of the Ku-band antenna
5. Indicates whether the antenna is deployed or stowed
6. Makes three-phase ac power available to the deploy/stow motors in MMCA2 and MMCA4

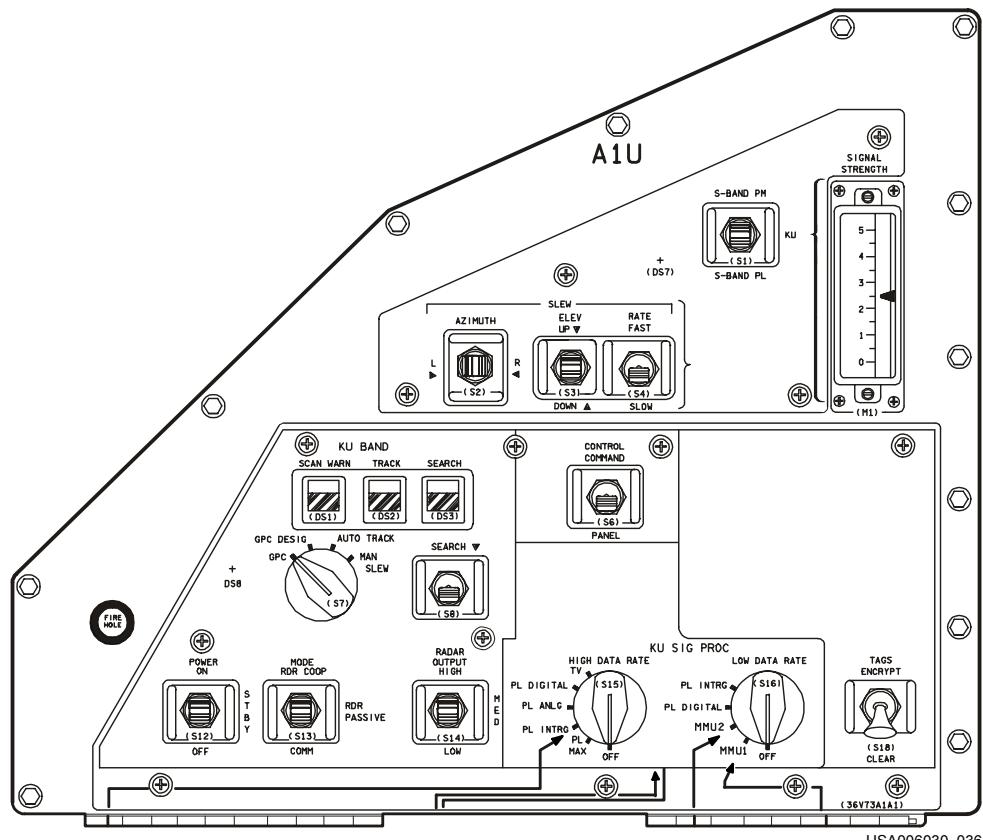
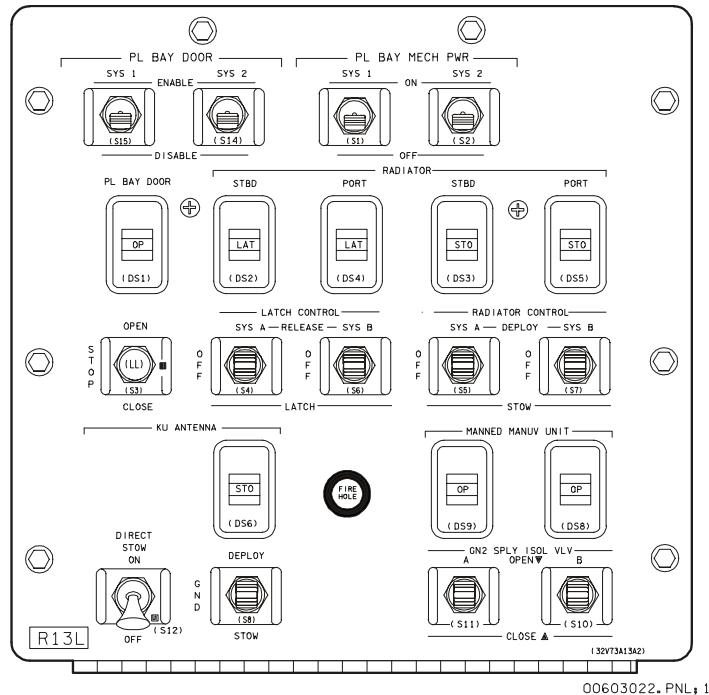
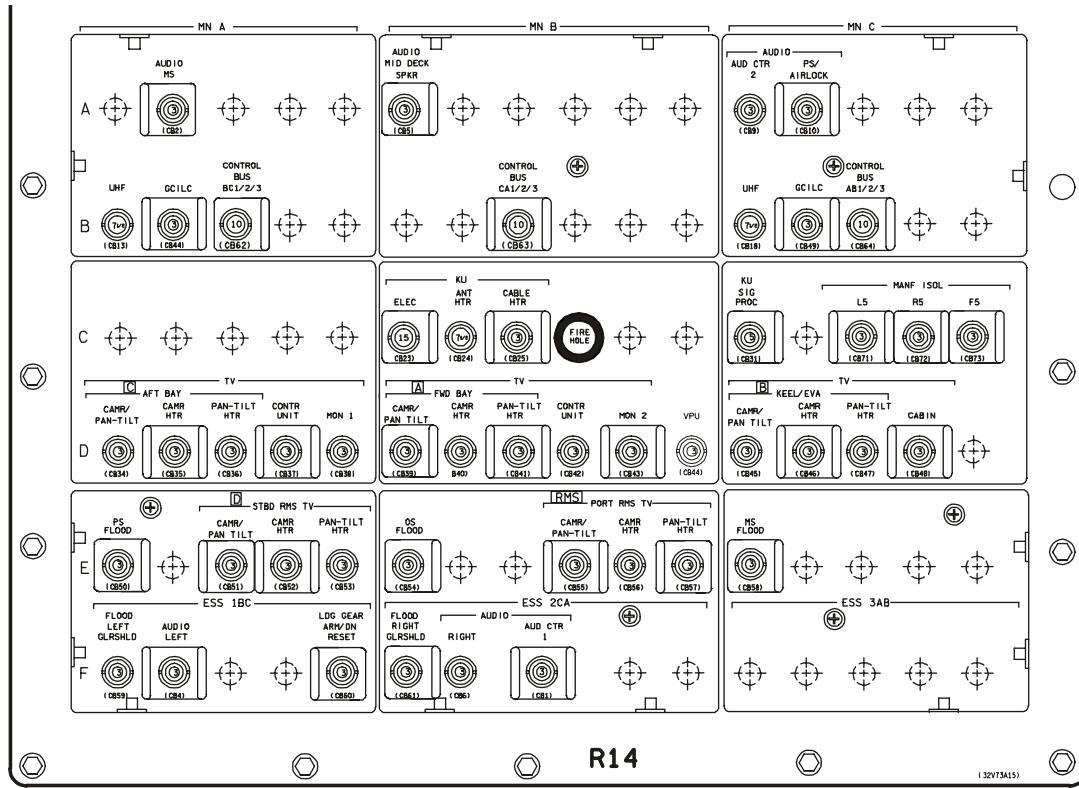


Figure 3-10. Panel A1U



00603022. PNL; 1

Figure 3-11. Panel R13L



USA006030_037

Figure 3-12. Panel R14

COMM/
INST

KU-BD ANT DEPLOY

A1U . KU PWR – OFF
 CNTL – PNL
R13L . ANT DIRECT STO – OFF

PL BAY MECH PWR SYS 1,2 (two) – ON
KU ANT – DPY

- * If tb not DPY after 46 sec, *
- * KU ANT – GND *
- * Perform MAL, MECH, 9.3a *

When KU ANT tb – DPY (~23 to 46 sec),
KU ANT – GND

PL BAY MECH PWR SYS 1,2 (two) – OFF

2-2 ORB OPS/ALL/GEN J

Figure 3-13. Ku-band ant deploy

7. True or false? The KU ANT HTR cb should be opened during post insertion activities in preparation for deployment of the Ku-band antenna.
8. True or false? The Ku-band antenna can be safely deployed only when the orbiter is on orbit and the payload bay doors are opened.
9. The procedure for the deployment of the Ku-band antenna is located in the:
 - a. Flight Plan
 - b. Orbit Operations Checklist
 - c. Post Insertion Checklist
 - d. All of the above
10. At the beginning of the deploy procedure, the crewmember should check that the KU PWR switch is off:
 - a. To prevent the Ku-band antenna from initializing prematurely
 - b. To prevent loss of signal through TDRS
 - c. To prevent commanding from the ground
 - d. All of the above
11. True or false? The KU CNTL switch must be in CMD for the switch movements to be acknowledged.
12. When the PL BAY MECH PWR SYS 1 and SYS 2 switches are taken to ON and the KU ANT DPY/STO switch is taken to DPY, the Ku-band antenna deploy sequence is initiated. The deploy sequence takes:
 - a. 23 seconds for dual-motor deploy
 - b. 23 seconds for single-motor deploy
 - c. 46 seconds for single-motor deploy
 - d. a and c
13. The KU ANT tb should indicate DPY when:
 - a. The KU ANT switch is taken to DPY
 - b. The antenna is fully deployed
 - c. The PL BAY MECH PWR SYS 1 and SYS 2 switches are taken to ON
 - d. All of the above

14. For the deploy and stow operations, power from redundant three-phase ac power buses (AC 3 and AC 2) is available to system 1 and system 2 motors through cb's on Panel MA73C and relays in MMCAs (MMCA2 and MMCA4). The relays are energized through the ON contacts of the:
- KU ANT switch on Panel R13L
 - KU PWR switch on Panel A1U
 - PL BAY MECH PWR SYS 1 and SYS 2 switches on Panel R13L
 - a and b
15. The _____ switch applies a dc control voltage to the system 1 and system 2 MCAs to initiate the deploy or stow procedure.
- KU ANT
 - KU CNTL
 - KU PWR
 - a and c
16. True or false? Flight rules state that the Ku-band antenna should be deactivated and stowed if the heater temperatures cannot be controlled or monitored.
17. True or false? There is a flight rule that states that nominally the Ku-band antenna should remain deployed as long as one deploy/stow motor is operating.
18. True or false? There is a flight rule that states that the antenna should be stowed if attempts to fully deploy the antenna are successful.

4.0 KU-BAND ACTIVATION

4.1 PERFORMANCE OBJECTIVES

The student should be prepared to accomplish the following tasks as a result of studying this section of the workbook:

- a. Identify the panels and switches used during the activation procedure
- b. Describe the initialization sequence
- c. Explain the purpose of the self-test

4.2 INTRODUCTION

The deployment of the DA is the first step in gaining the use of the Ku-band system. After the deploy procedure is complete, the antenna gimbal locking pins are still holding the antenna dish in the stowed position. To remove the locking pins and gain use of the Ku-band system, the activation procedure must be performed. This procedure enables the crew to activate the Ku-band system in the communications mode. The activation procedure is located in the Orbit Operations Checklist. Ku-band activation deploy and activation is called out in the Post Insertion Checklist.

4.3 ACTIVATION

The first step in the activation procedure has the crew configure the KU cb's on Panel R14 (Figure 4-1). These cb's provide power to the Ku-band system through MNB and MNC. The KU ELEC cb is closed to provide MNB power to some Ku-band electronic circuitry and main B control power to an RPC to allow MNC power to get to EA1. In addition, the KU ELEC cb provides GCIL CMD DRIVER power when the KU PWR switch is ON and the COMM mode is selected. It also provides power to the Ku-band portions of Panels A1U and A2, except to the KU SIG PROC HDR (High Data Rate) and Low Data Rate (LDR) rotary switches on Panel A1U. The crew checks that the KU ANT HTR cb is closed to provide power to the five heaters on the DA and that the KU CABLE HTR cb is open. The CABLE HTR cb is not closed because it is not used. The KU SIG PROC cb is closed to provide MNC power to the Ku-band SPA, and it will provide power to the KU SIG PROC HDR and LDR rotary switches on Panel A1U when the KU PWR switch is ON and the COMM mode is selected.

The next step is to check the configuration of the switches on Panel A1U in accordance with the activation procedure. This includes checking that the KU RADAR OUTPUT switch is in HI, and taking the KU MODE switch to RDR PASSIVE, the KU PWR switch to ON, and the KU CNTL switch to PNL (Figure 4-2). Cycling the Ku CNTL switch to PNL will enable the power to the Ku-band system. The Ku-band initialization sequence will then begin.

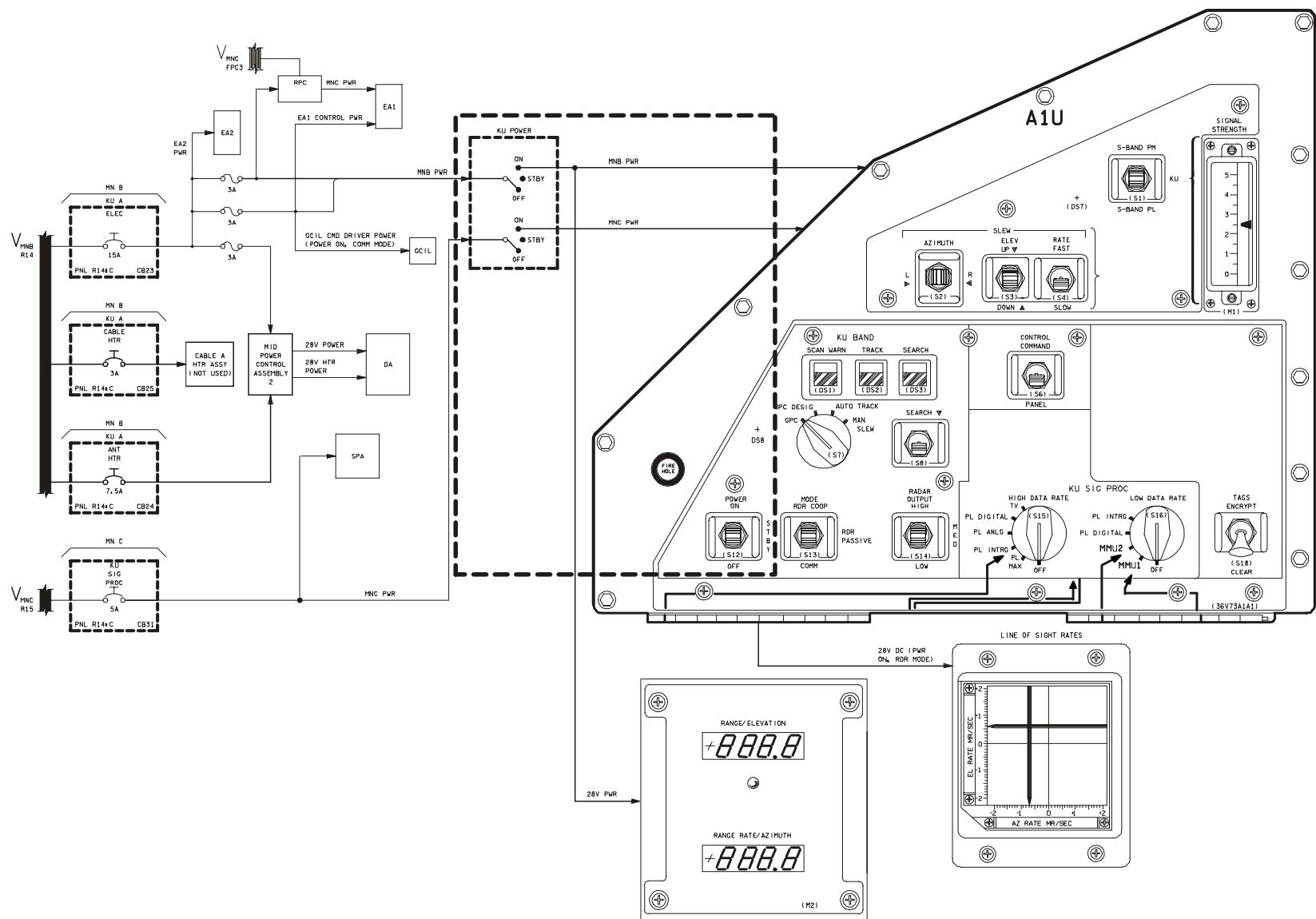


Figure 4-1. Ku-band power

USA006030_038

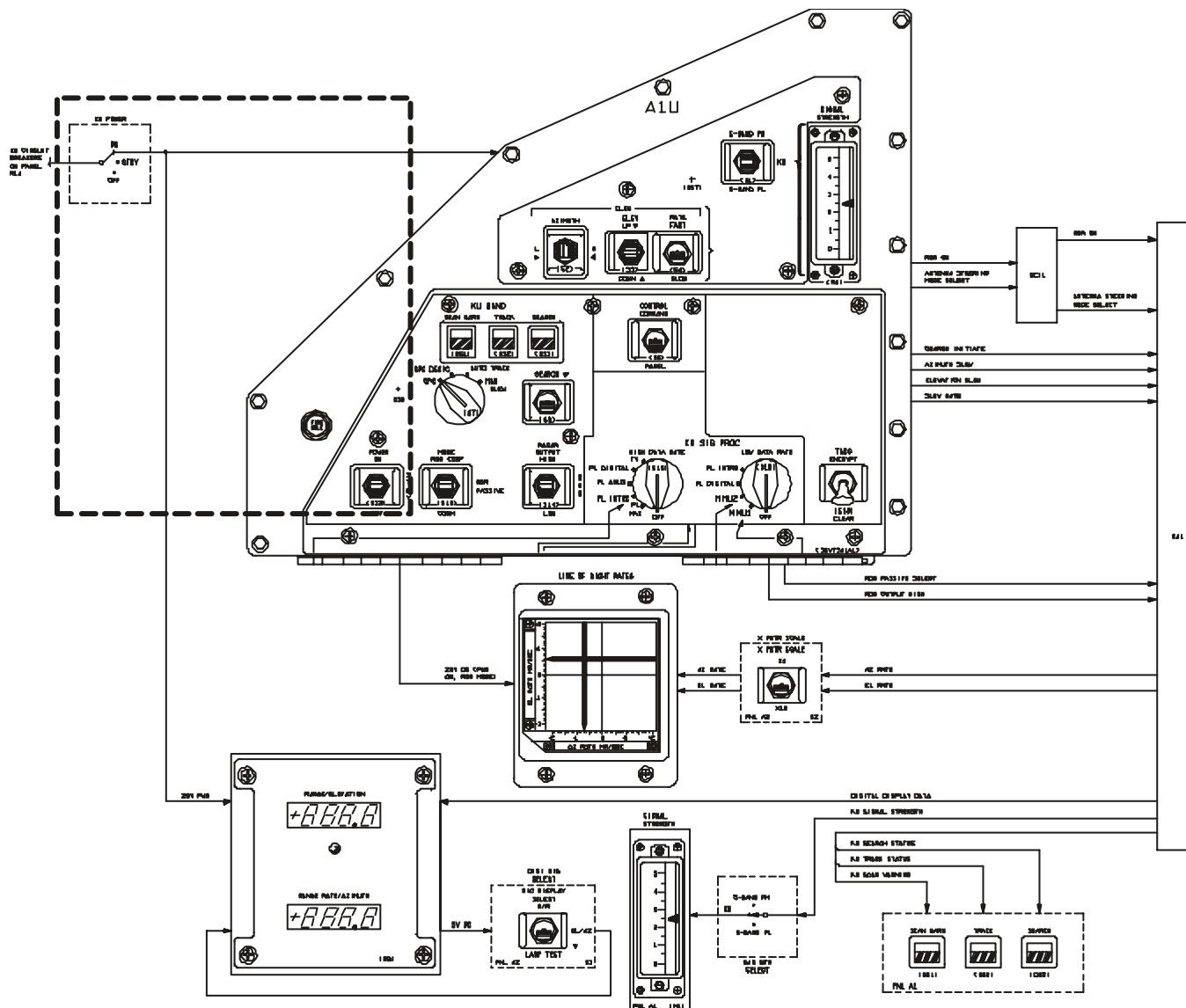


Figure 4-2. Ku-band activation configuration

4.3.1 Initialization Sequence

The initialization sequence begins with the spinup of the gyros and the initialization of the EA1 microprocessor. Next, the gimbal locking pins are removed. After removal of the gimbal locking pins, the antenna is free to move and is commanded to find the Master Index Pulse (MIP) angles. The movement is limited by the gimbal stops (Figure 4-3). The alpha (α) gimbal has a full 360° movement with a stop at the $+154^\circ/-206^\circ$ angle. The beta (β) gimbal is limited to 160° of movement: -85° forward to 75° aft from the 0° position.

The MIP angles are reference angles that are loaded into the microprocessor whenever the differential encoder disk on the gimbal motor shaft is at that position. The beta MIP angle is -23.25° and the alpha MIP angle is 116.5° (Figure 4-3). The antenna is commanded to the beta MIP angle first and then to the alpha MIP angle. Once the gimbals have reached the MIP angles, the gimbal angles are commanded to $0^\circ/0^\circ$. This action positions the antenna so that the radar beam is parallel to the orbiter minus Z-axis. The $0^\circ/0^\circ$ position should be reflected on the digital display on Panel A2 when the DIGI-DIS SEL switch is in EL/AZ (Figure 4-4). The MIP search and the $0^\circ/0^\circ$ antenna positioning are controlled by an automatic program in the EA1 microprocessor. The final antenna position is reached about 2 minutes after the Ku-band system is powered on.

The initialization sequence also includes the TWT warmup, which nominally takes 3.5 to 4 minutes. The initialization process is complete in approximately 4 minutes, but there is no indication that it is complete.

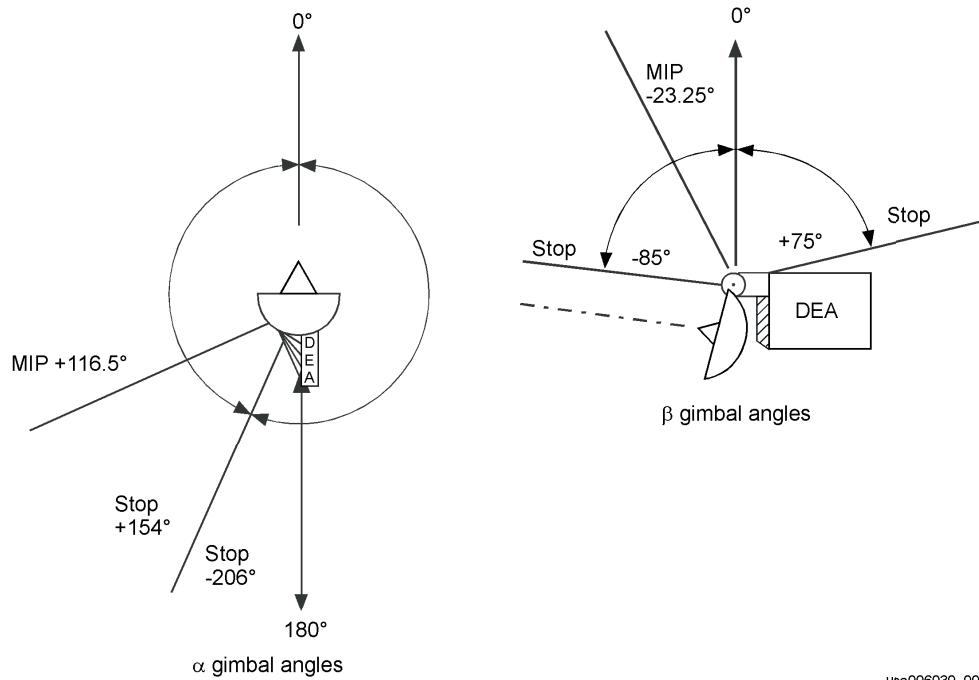
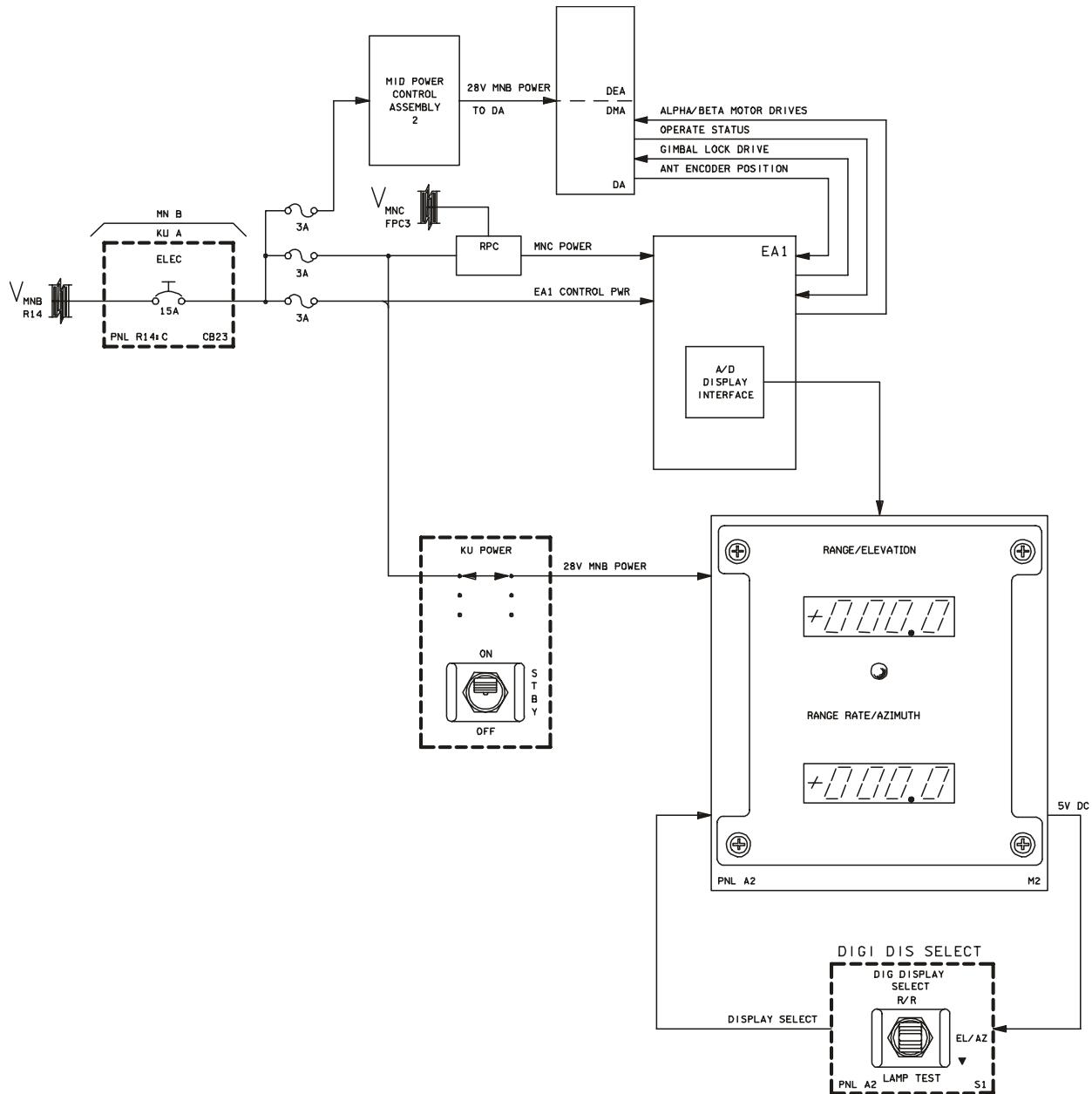


Figure 4-3. Gimbal angle movement

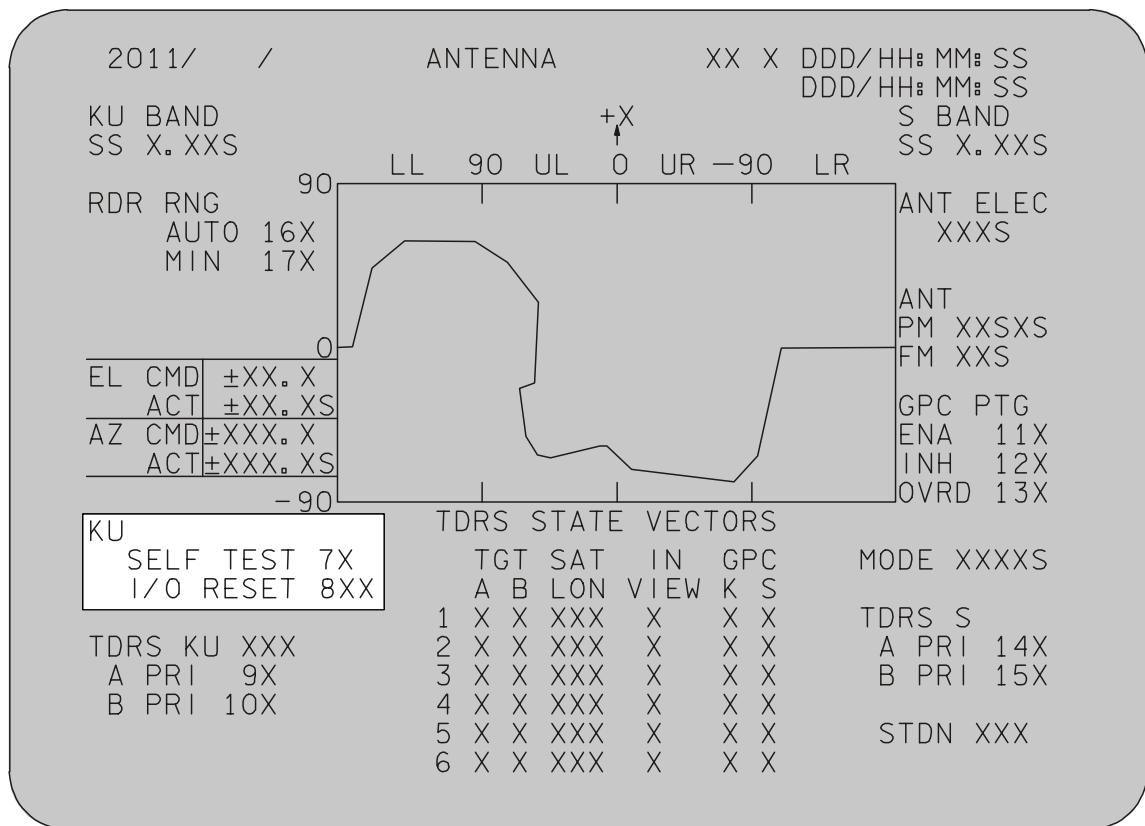
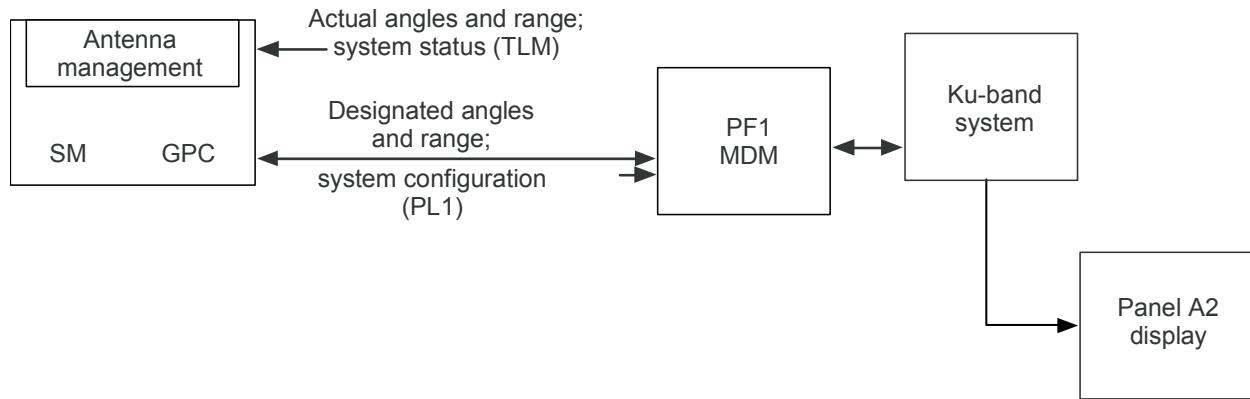
usa006030_007



00603026.SCH§ 1

Figure 4-4. Interfaces for the initialization sequence

While the initialization sequence is taking place, the crew performs an I/O RESET KU on the SM OPS 2011 ANTENNA display (Figure 4-5). The I/O RESET KU connects the interface between the Ku-band system and the SM GPC through MDM PF1 (Figure 4-6). The interface allows the SM GPC to perform its management of the Ku-band antenna. This includes antenna pointing and other status/control Input/Output (I/O) during both radar and comm ops.

00603011. CRT₂**Figure 4-5. SM OPS 2011 ANTENNA display**

usa006030_008

Figure 4-6. Ku-band system and SM GPC interface

4.3.2 Self-Test

Once the initialization sequence is complete, the crew can start the self-test from the SM OPS 2011 ANTENNA display (Figure 4-5). Any attempts to initiate the self-test before the initialization sequence is complete may cause the self-test to fail. The

purpose of the self-test is to perform a series of tests to demonstrate that the EA1, the EA2, and the DA units are operational. The self-test can be performed only in the radar mode. The KU MODE switch was placed in RDR PASSIVE earlier in the procedure for that reason. Also, the KU RADAR OUTPUT must be HI. Medium or low output power selected on the panel may cause the system to fail the self-test. The DIGI-DIS select switch is placed in the *R/R* position before initiating the self-test.

The self-test consists of nine individual tests. These tests check the EA1 software, power supplies, antenna control and pointing, transmitter operations, and radar mode operations. The crew has limited visibility into the system during self-test via the antenna display (signal strength and angle data) and the dedicated meters on Panel A1U (signal strength) and Panel A2 (range/range rate or angle data and line-of-sight rates). The ground controller has a more comprehensive view of the self-test (real time if during Acquisition of Signal (AOS) or via dumped data if during Loss of Signal (LOS)) but usually has to review the individual tests to determine the cause if self-test fails. Although MCC flight controllers can see the result of each test, the crew can see only the final result. When the self-test is complete, the KU SCAN WARN, TRACK, and SEARCH tb's on Panel A1U will be gray, and if all tests were passed, the R/EL digital display on Panel A2 will show +888.8 when the DIGI-DIS SEL switch is in R/RDOT. If any portion of the self-test fails, the display will show +333.3 and the crew should check with MCC on the action to take.

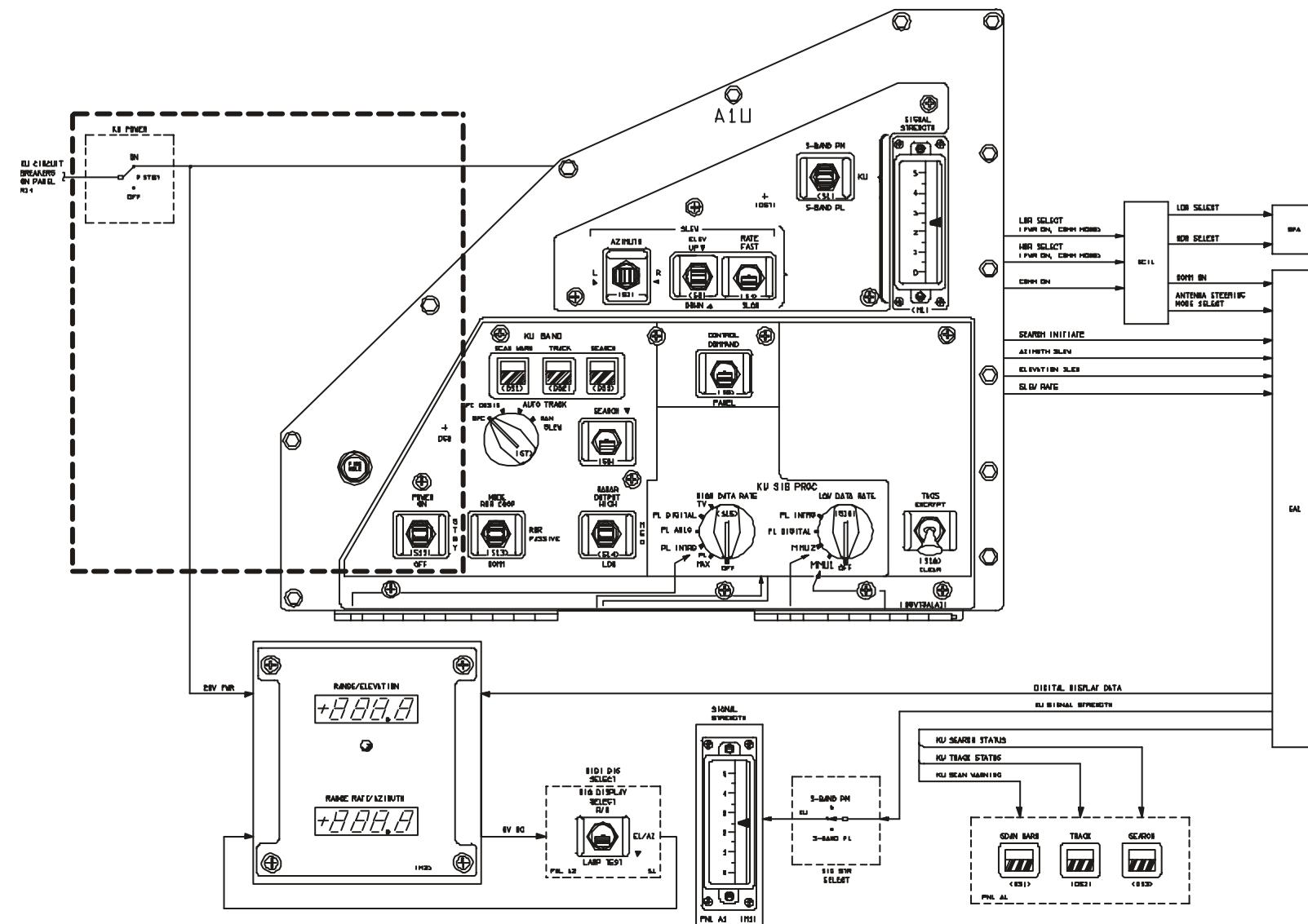
The radar self-test has failed on several flights. Usually, the failure indicated is a known condition, and the crew will be so advised once the self-test is complete.

After completion of the self-test (approximately 3 minutes 20 seconds), the Ku-band system is configured for communications operations (Figure 4-7).

4.4 SUMMARY

Once the antenna has been deployed, the Ku-band system must be activated. Antenna activation is accomplished by using the Orbit Operations Checklist, Panel R14, Panel A1U, Panel A2, and the SM OPS 2011 ANTENNA display. The activation procedure includes an initialization sequence and a self-test. The initialization sequence prepares the antenna for use. The self-test performs a series of tests to demonstrate that the system is operational or to indicate if any LRUs have failed.

Figure 4-11 illustrates the current KU-ACTIVATION procedure listed in the current Orbit Ops Checklist.



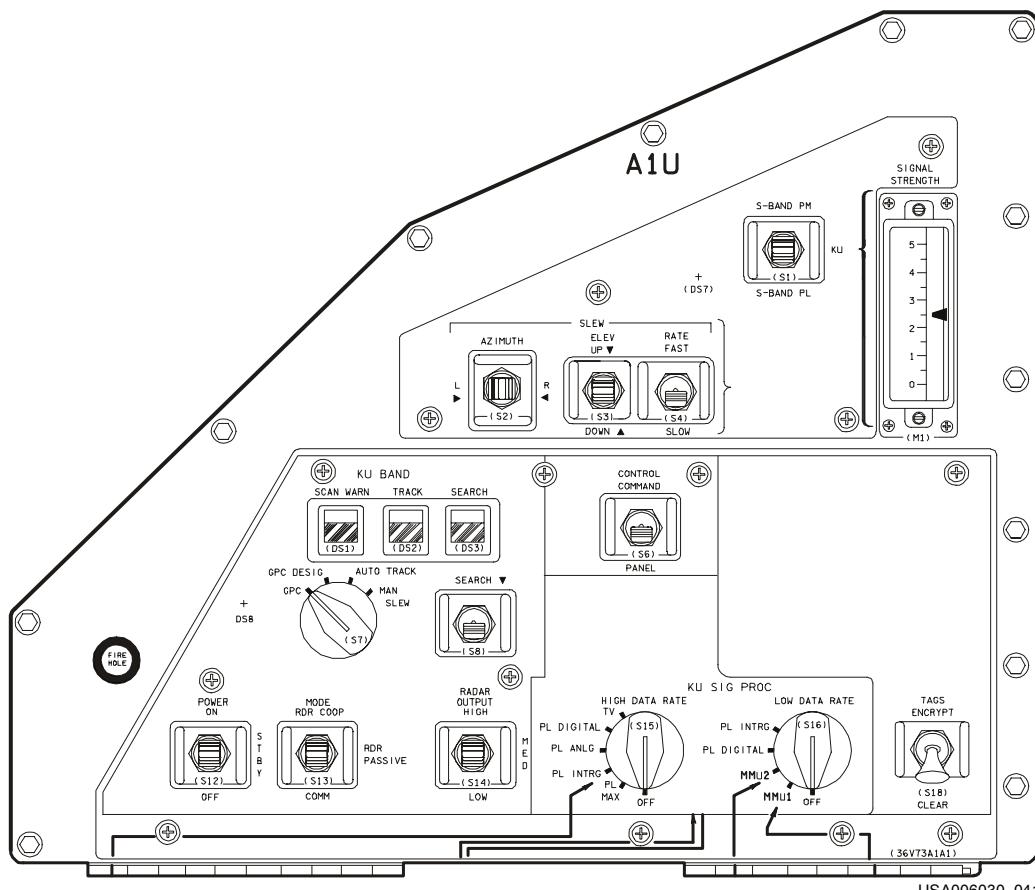
USA006030_040

Figure 4-7. Ku-band comm mode interfaces

4.5 QUESTIONS

For questions 1 to 6, identify the switch or the cb and the corresponding panel that will provide the function indicated (Figure 4-8, Figure 4-9, or Figure 4-10).

1. Provides power to the five heaters on the DA
2. Used to select the desired radar output power
3. Provides power to the Ku-band electronic circuitry
4. Provides power to the Ku-band SPA
5. Used to select the desired digital display
6. Allows power to get to Ku-band switches and meters and starts the antenna initialization
7. Used to select between communications and radar operations



USA006030_041

Figure 4-8. Panel A1U

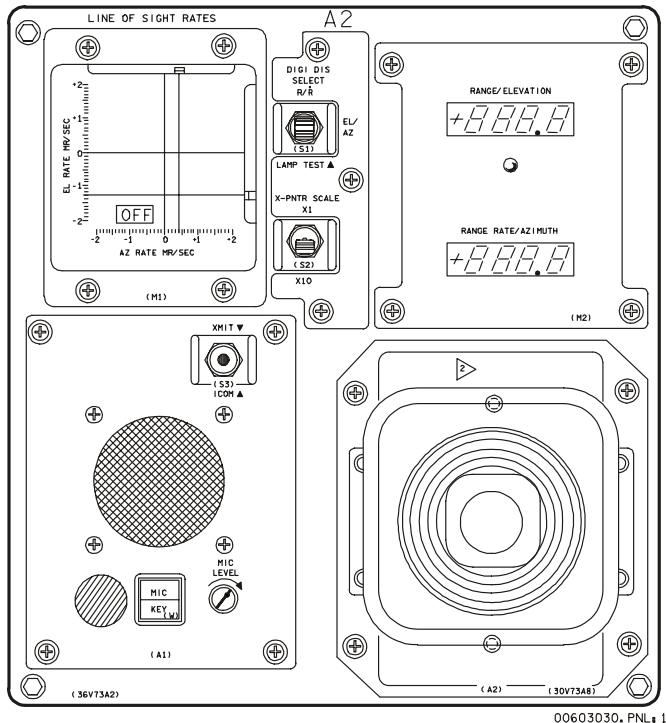


Figure 4-9. Panel A2

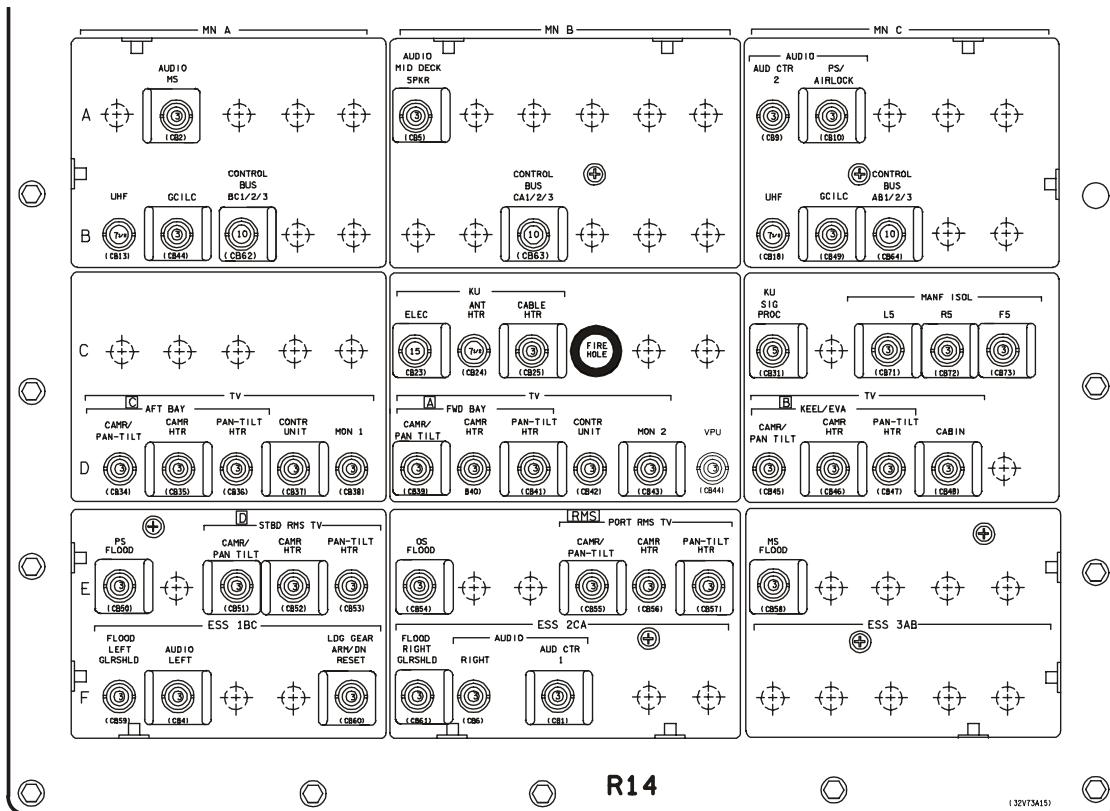


Figure 4-10. Panel R14

KU-BD ACTIVATION

R14:C cb MNB KU ELEC – cl
 ?ANT HTR – cl
 ?CABLE HTR – op
 MNC KU SIG PROC – cl

A1U ?SIG STRENGTH sel – KU
 ?SLEW RATE – SLOW
 ?KU SCAN WARN tb – bp
 ?TRACK tb – bp
 ?SEARCH tb – bp
 ?sel – MAN SLEW
 ?RADAR OUTPUT – HI
 ?SIG PROC HDR – TV
 ?LDR – OPS RCDR
 MODE – RDR PASSIVE
 PWR – ON
 ?CNTL – PNL

CRT **SM ANTENNA**
 I/O RESET KU – ITEM8 EXEC (*)

NOTE
System warmup takes ~4 min

A2 DIGI-DIS SEL – EL/AZ
 ?R/EL ind: +000.0
 ?R/AZM ind: +000.0

 DIGI-DIS SEL – R/R

CRT When warmup complete,
 SELF TEST – ITEM 7 EXEC (*)

A1U When SELF TEST complete (~3 min):
 ?KU SCAN WARN tb – gray
 ?TRACK tb – gray
 ?SEARCH tb – gray

A2 ?R/EL ind: +888.8
If R/EL ind: +333.3, ?MCC

Cont next page

2-3 ORB OPS/ALL/GEN J

Figure 4-11. Ku-band activation

| | | |

CRT SELF TEST – ITEM 7 EXEC (no *)

A1U KU MODE – COMM
SEL – GPC DESIG
CNTL – CMD

| | | |

2-4 ORB OPS/ALL/GEN J

Figure 4-11. Ku-band activation (concluded)

8. The Ku-band initialization sequence starts when the:
 - a. KU MODE switch is taken to RDR PASSIVE
 - b. KU ELEC cb is closed
 - c. KU PWR switch is taken to ON
 - d. None of the above
9. Which of the following choices is part of the initialization sequence?
 - a. Microprocessor initialization and gyro spinup
 - b. Gimbal locking pin removal
 - c. Antenna alignment
 - d. All of the above
10. The initialization sequence is complete in approximately _____ minutes. This gives the traveling wave tube time to warm up.
 - a. 4
 - b. 7
 - c. 2
 - d. 10
11. The purpose of the self-test is to perform a series of tests to demonstrate that the following assembly is operational:
 - a. EA1
 - b. EA2
 - c. DA
 - d. All of the above

5.0 ANTENNA OPERATIONS

5.1 PERFORMANCE OBJECTIVES

The student should be prepared to accomplish the following tasks after studying this section of the workbook:

- a. Identify the antenna maskings used with the Ku-band system
- b. Explain the different antenna steering modes

5.2 OVERVIEW

The Ku-band antenna consists of a 36-inch parabolic reflector with a five-element monopulse feed. The antenna is edge-mounted on dual-axis gimbals (Figure 5-1). The alpha gimbal is mounted on the DEA.

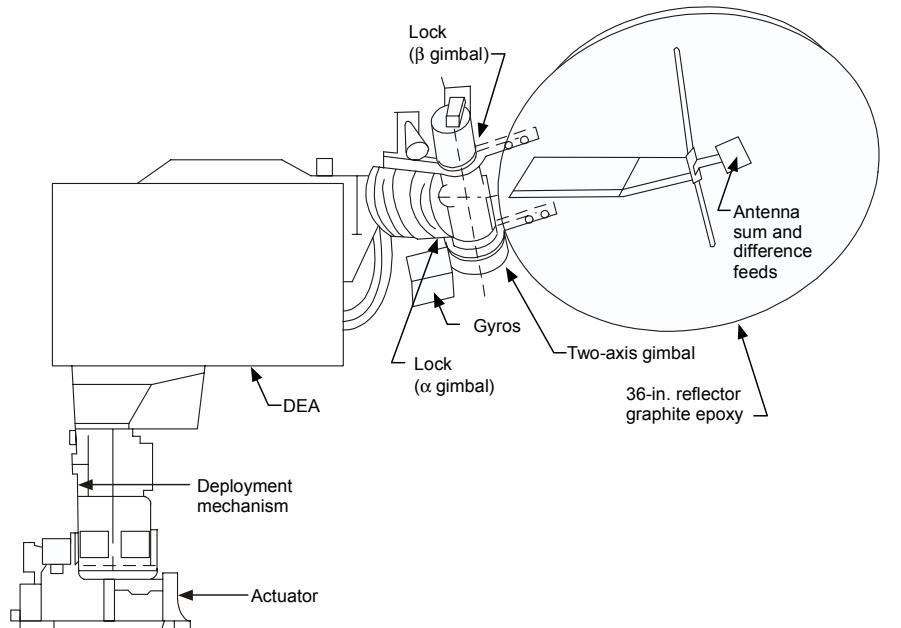
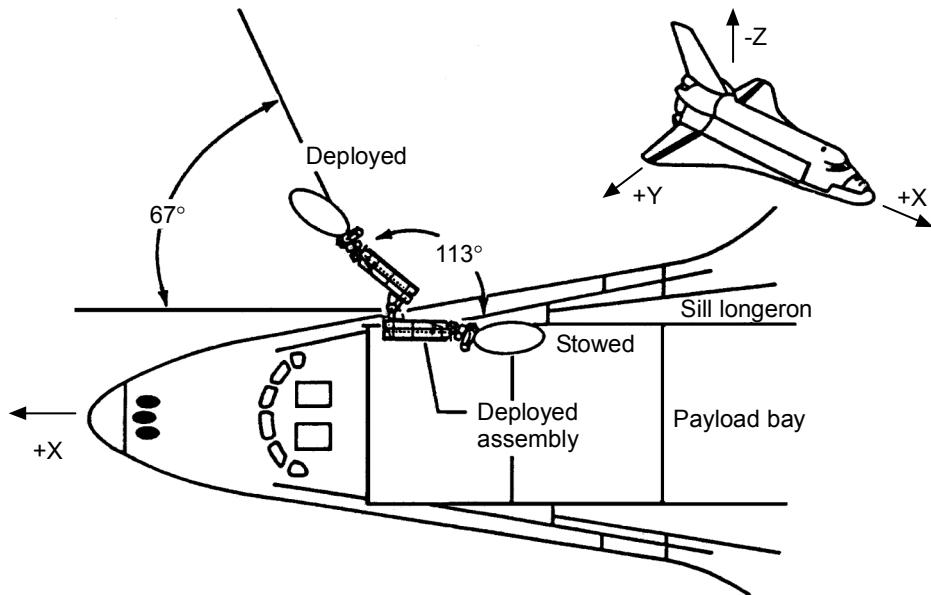


Figure 5-1. Ku-band deployed assembly

When the antenna is deployed, the alpha gimbal axis pole is positioned at an angle of 67° with the orbiter +X-axis on the starboard side (Figure 5-2). The DA pivots on a pedestal that is attached to the orbiter starboard sill longeron. When it is stowed, the DA lies inside the payload bay doors and radiators, along the sill longeron.



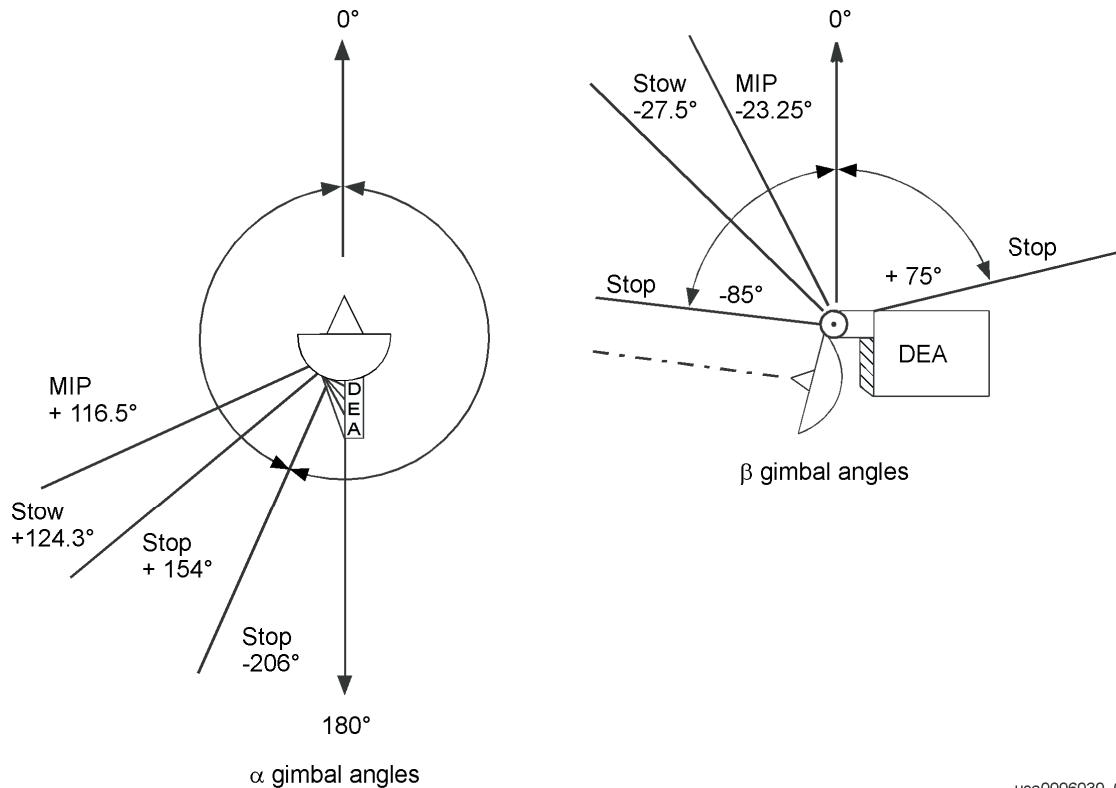
usa006030_033.cnv

Figure 5-2. Deployed assembly positions - stowed/deployed

Once the DA has been deployed and activated, antenna operations can begin. The antenna can be used for either communication operations or radar operations. The purpose of this section is to discuss antenna operations that are common for communications and radar modes. The sections that follow provide details of operations specific to each mode.

5.3 ANTENNA OPERATIONS

Figure 5-3 shows gimbal angle movement limits as seen through the poles of the alpha and beta gimbal axes. The alpha gimbal has a full 360° movement with a stop at the $+154^\circ/-206^\circ$ angle to prevent wraparound of the beta gimbal control cable. The beta gimbal is limited to 160° of movement. This limit leaves a 10° cone of inaccessibility toward the forward end of the orbiter along the alpha pole, and a 30° cone of inaccessibility along the pole line in the reverse direction. Because the Ku-band system is normally operated in the area above the payload bay (along the -Z-axis) during radar operations, the no coverage zones normally are not encountered.



usa0006030_010

Figure 5-3. Gimbal angle movement limits

In addition to the no coverage areas, there are obscuration zones; i.e., areas in which the antenna Line of Sight (LOS) with a TDRS or a target is obscured by parts of the orbiter body. Three maskings have been developed to protect the orbiter and areas around the orbiter: obscuration mask, beta only, and beta + mask. Originally, the obscuration mask was developed. The obscuration mask is shown on the SM OPS 2011 ANTENNA display (Figure 5-4). The obscuration mask is an approximate outline of the blockage caused by the orbiter body plus a 5° buffer. A scan warning system monitors the antenna beam position relative to the obscuration mask. If the antenna beam is pointed into the obscuration mask, the KU SCAN WARN tb on Panel A1U will go gray, and radiation from the Ku-band TWT Amplifier (TWTA) can be inhibited. The obscuration mask is still used for the radar mode, but the comm mode now uses the beta and beta + mask.

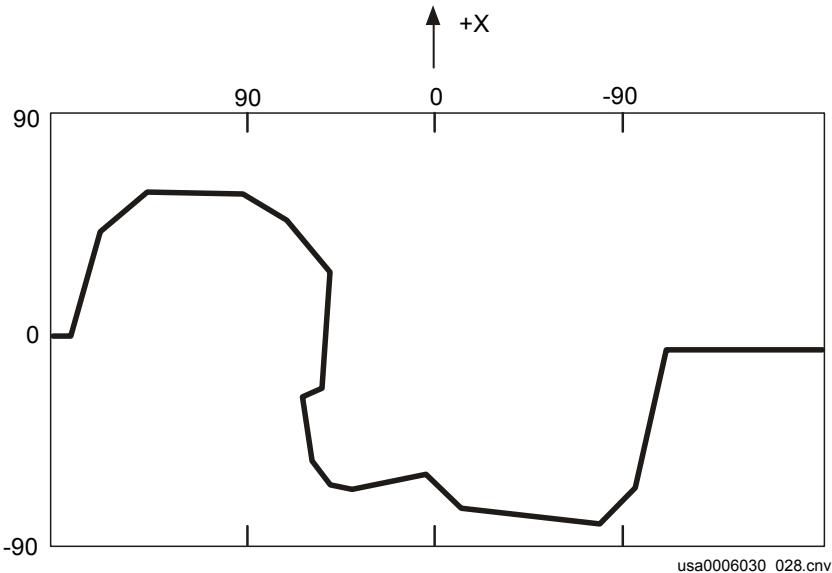


Figure 5-4. Obscuration line from the ANTENNA display

The beta only and beta + mask were developed to allow more control of when the Ku-band TWTA could radiate. The beta refers to the beta gimbal angle. The angle is set by the INCO and depends on the type of protection desired. A beta only masking of 20° is shown in Figure 5-5. In the beta only mode, the TWTA is inhibited only when the Ku-band antenna beam is pointing below the beta line. The shaded area in Figure 5-5 indicates where the TWTA is inhibited, if a beta only mask of 20° is active.

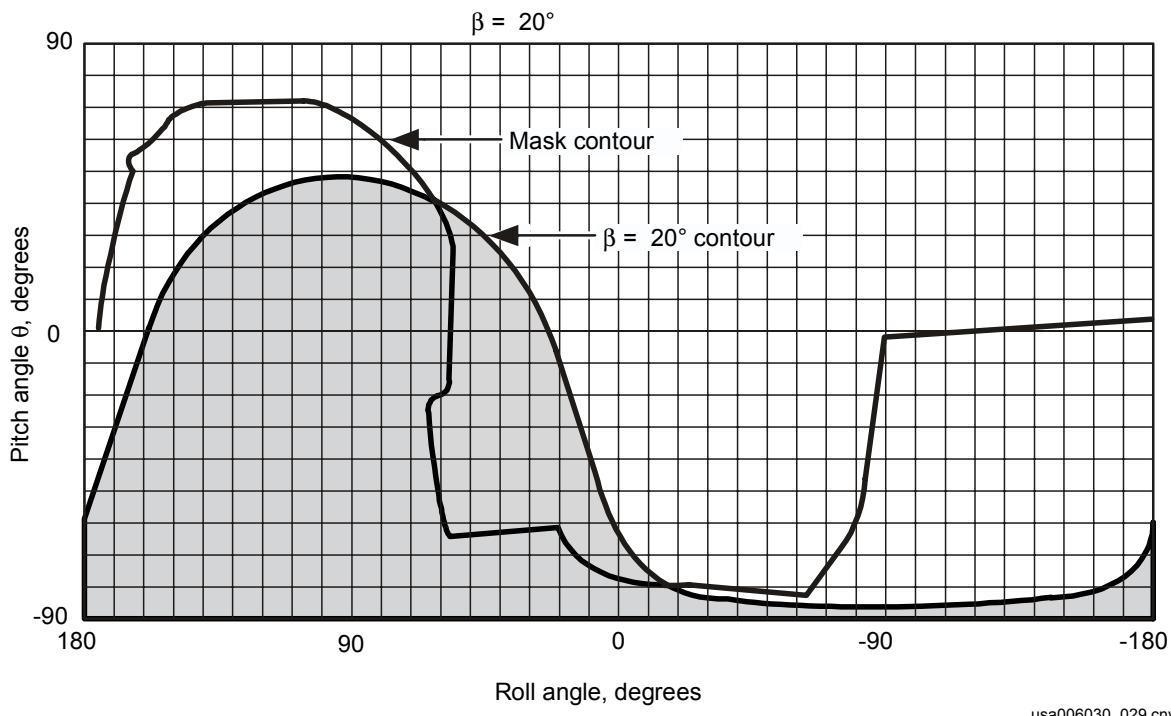
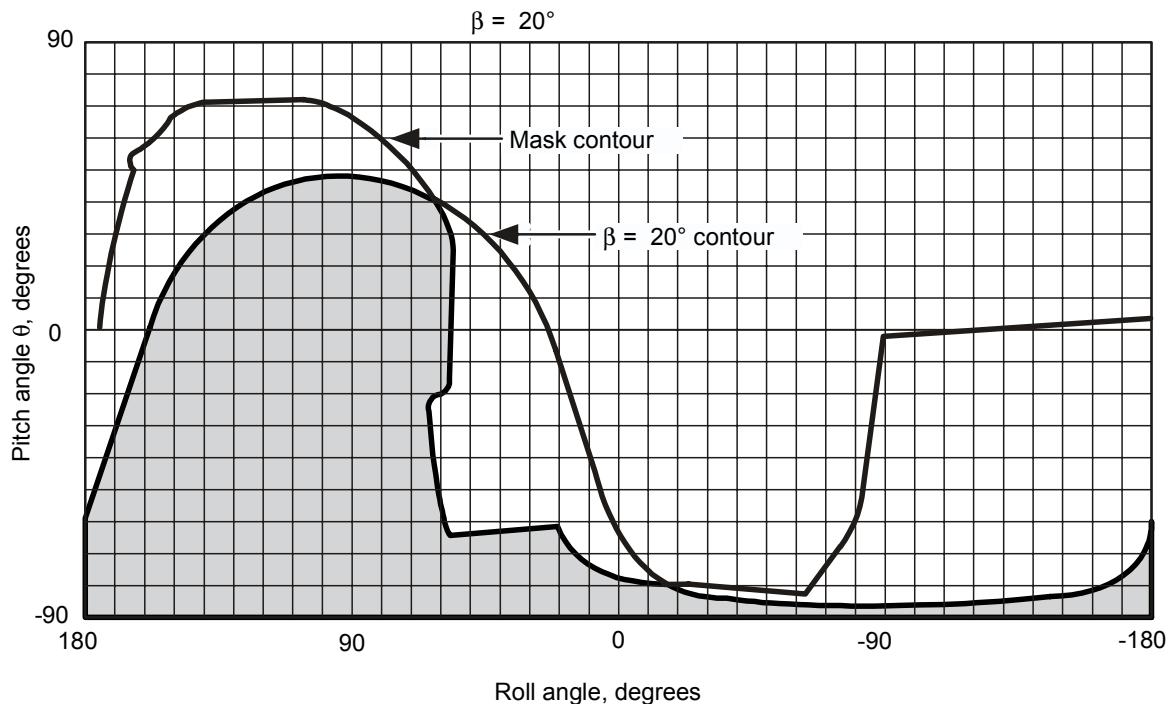


Figure 5-5. Beta only masking of 20°

A beta + mask of 20° is illustrated in Figure 5-6. In the beta + mask mode, the TWTA is inhibited only when the Ku-band antenna beam is pointing below the beta line and into the obscuration mask. The shaded area in Figure 5-6 indicates where the TWTA is inhibited, with a beta + mask at 20° active.



usa006030_030.cnv

Figure 5-6. Beta + mask of 20°

The beta only and beta + mask zones can be seen on the INCO Antenna Management display, but are unavailable to the crew. Appendix C, Figure C-10 shows the new SPEC 76 display.

5.4 GIMBAL ANGLE TRANSFORMATION

Antenna position information is read out on orbiter displays (ANTENNA display and Panel A2) as azimuth and elevation angles referenced to the orbiter -Z-axis. The azimuth/elevation information is derived from alpha/beta gimbal axis encoder transformations. Since the DA is offset 67° from the orbiter +X-axis in the deployed position, azimuth/elevation angles are not the same as alpha/beta angles, except for the $0^\circ/0^\circ$ angle. The azimuth/elevation angles must be derived from a trigonometric transformation of the alpha/beta gimbal angles. This coordinate conversion is done in the EA1 microprocessor.

5.4.1 Antenna LOS Position Displays

Figure 5-7 shows a representation of Ku-band antenna elevation and azimuth angles in relation to orbiter XYZ coordinates. The elevation/azimuth values depicted in Figure 5-7 are read in the orbiter on the ANTENNA display and on the Panel A2 elevation and azimuth digital display (Figure 5-8).

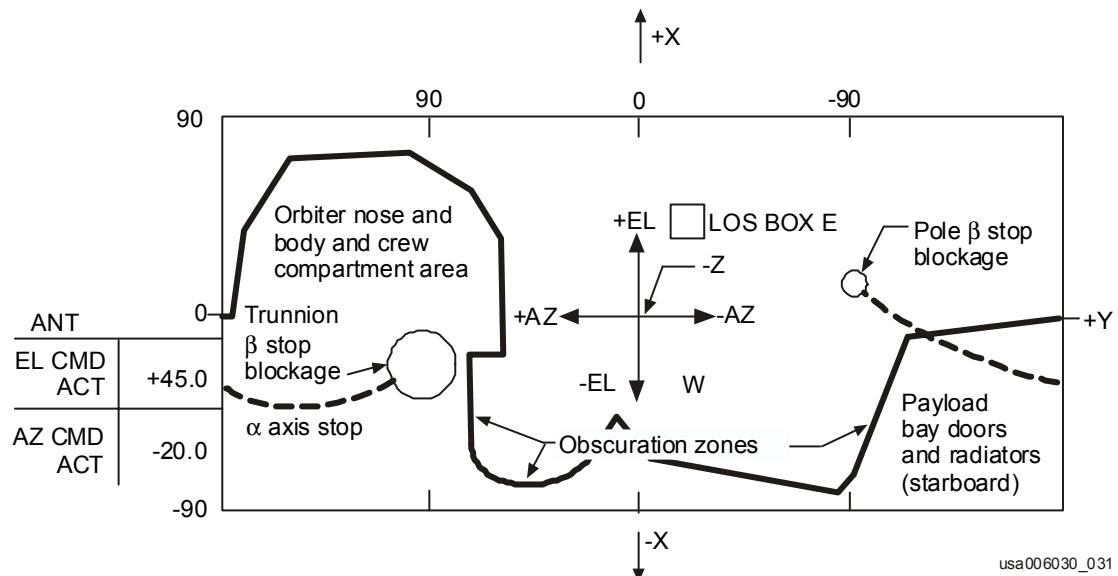


Figure 5-7. Elevation/azimuth in relation to XYZ coordinates

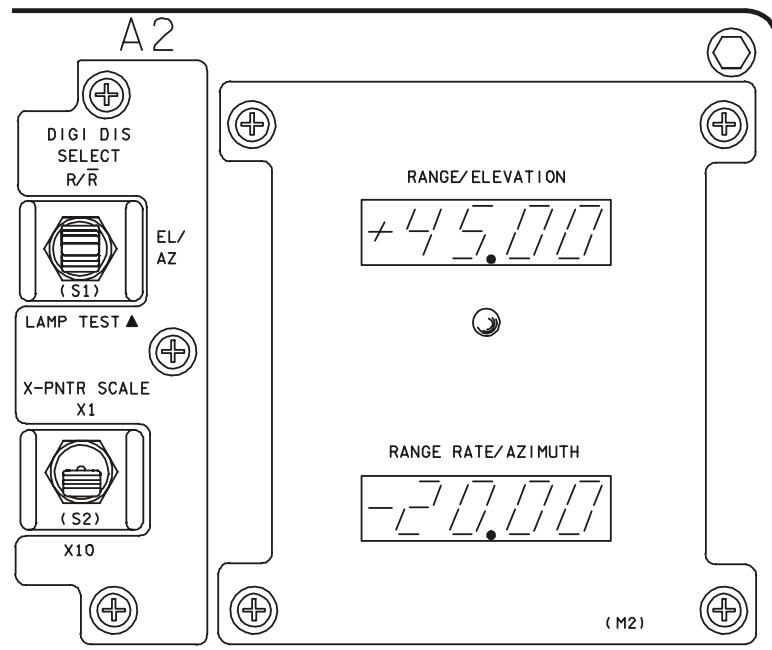


Figure 5-8. Panel A2 elevation/azimuth digital display

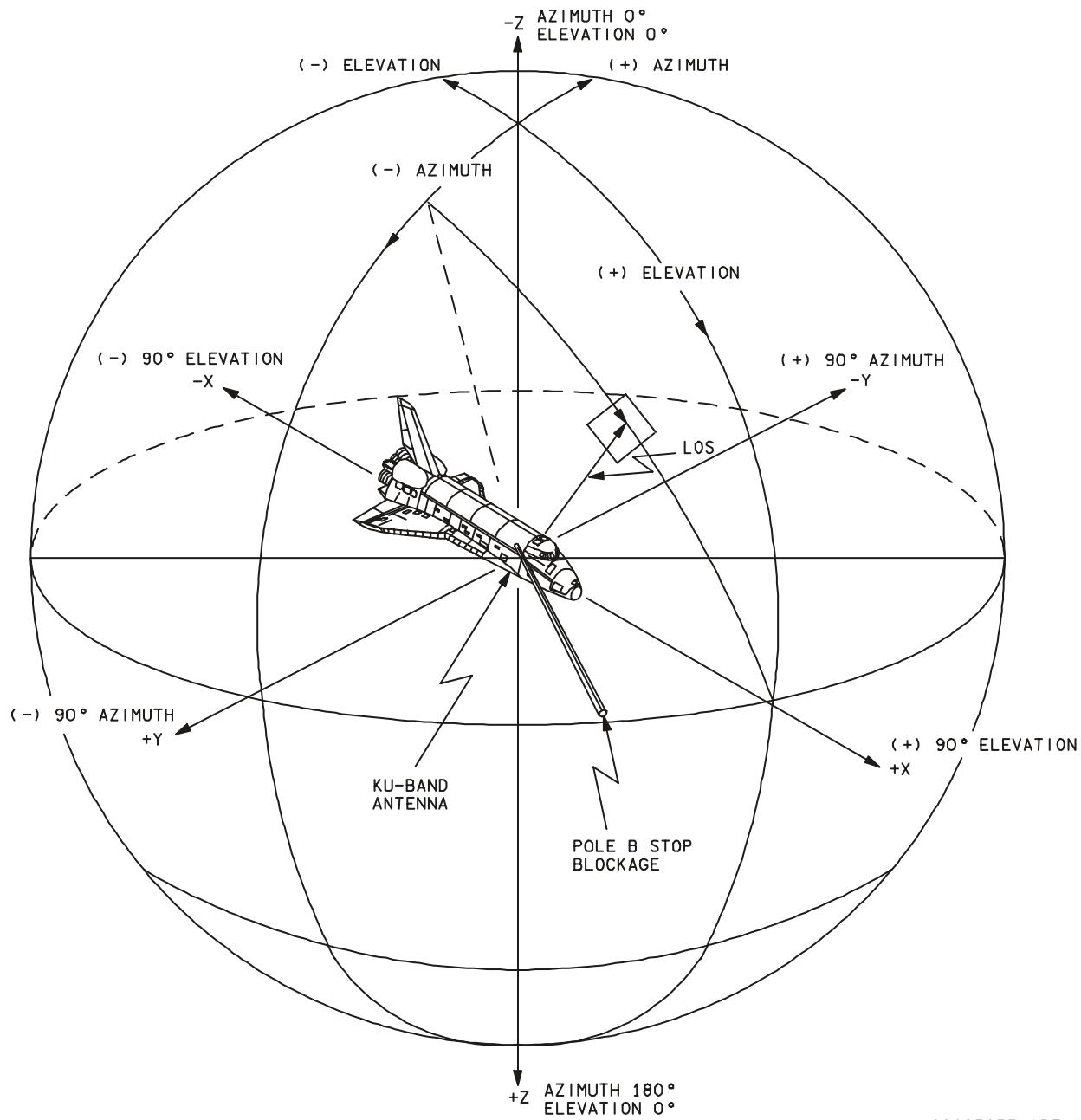
Panel A2 digital readouts display range/range rate or elevation/azimuth, depending on the position of the DIGI-DIS SEL switch. With the switch in the EL/AZ position, the digital display indicates Ku-band antenna elevation/azimuth pointing angle (LOS position).

The antenna display indicates antenna-pointing angle in two ways

- ANT EL ACT and ANT AZ ACT represent actual antenna pointing angles in elevation and azimuth.
- The “box” on the pictorial portion of the display represents the Ku-band antenna-pointing angle relative to the spacecraft coordinate system.

Note: ANT EL CMD and ANT AZ CMD represent GPC commanded antenna pointing angles.

Figure 5-7 to Figure 5-9 have been annotated to illustrate an actual LOS pointing angle of +45.0° elevation and -20.0° azimuths. The 0° elevation/0° azimuth antenna beam position is along a line parallel to the -Z-axis. Positive (up) elevation movements are along the +X-axis toward the orbiter nose. Positive (right) azimuth movements are away from the -Z-axis along the -Y-axis, toward the orbiter port side. Figure 5-7 also illustrates the alpha and beta stops as seen by the antenna.



00603033. ART, 1

Figure 5-9. Ku-band antenna azimuth and elevation

5.5 OPERATIONAL MODES

The Ku-band system has four antenna steering modes for locating and tracking a target or a TDRS. These include crew-controlled automatic and manual antenna steering with programmed spiral search routines for angular acquisition, plus range tracking. Range tracking is discussed in the subsection entitled "Tracking." In addition, there are two antenna stabilization modes. Table 5-1 illustrates the available combinations of antenna steering, tracking, search, and stabilization modes. These topics are also discussed in the following paragraphs.

5.5.1 Antenna Steering

The Ku-band system provides four antenna steering modes, each having a different combination of capabilities for acquiring and tracking a target or a TDRS. The four modes are GPC, GPC designate, auto track, and manual slew. All are mutually exclusive and crew selectable (Table 5-1).

Table 5-1. Antenna steering mode capabilities

| Steering mode | Computer steering | Manual steering | Angle tracking | Signal tracking* | Search | Stabilize |
|---------------|-------------------|-----------------|----------------|------------------|----------|-----------|
| GPC | X | | X | X | Computer | Inertial |
| Designate | X | | | X | | Both** |
| Auto | | X | X | X | Manual | Inertial |
| Manual | | X | | X | | Body |

*In COMM, track means signal present for GPC designate and manual slew and also angle track in GPC and auto track. In RADAR, track means range track for GPC designate and manual slew and also angle and angle-rate track in GPC and auto track.

**The antenna system may be either body or inertially stabilized as determined by a real-time command through the GPC.

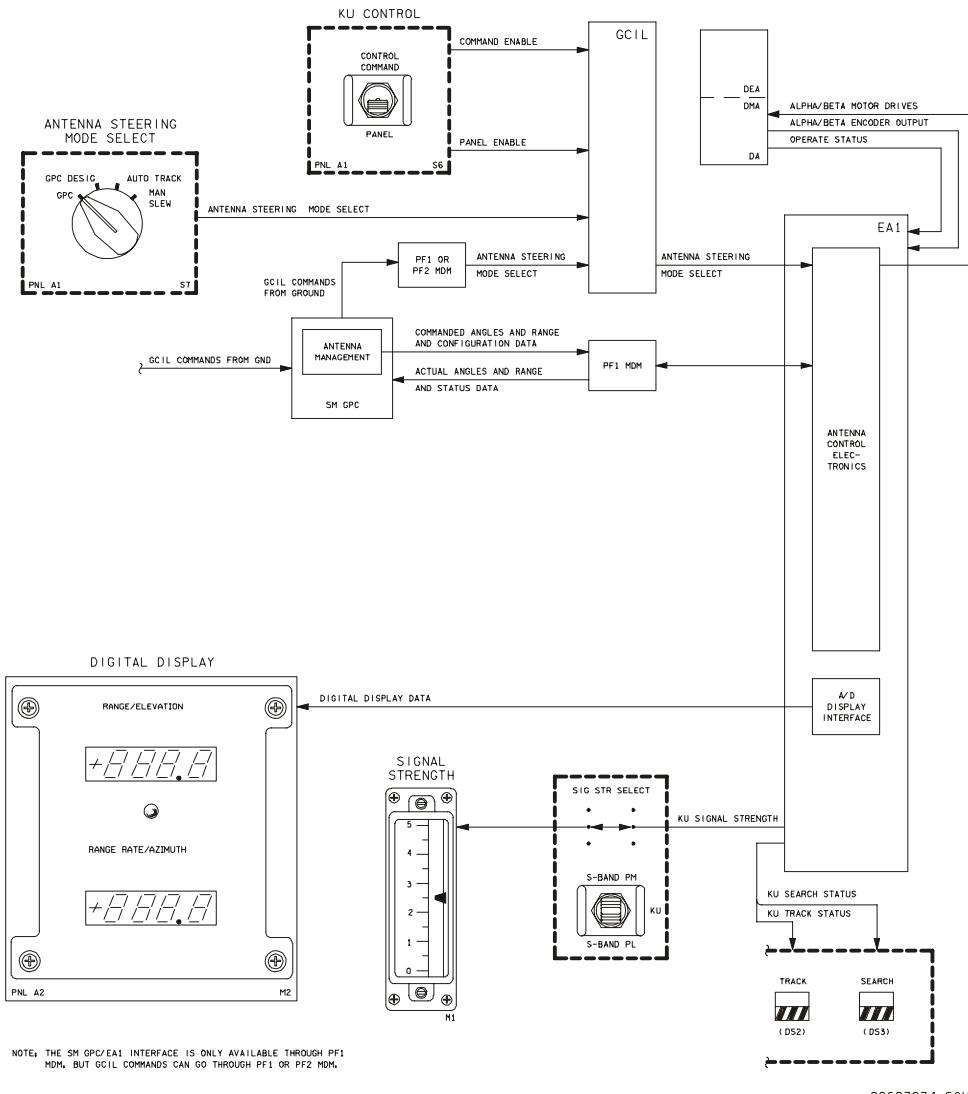
5.5.1.1 GPC

The GPC mode is fully automatic in all phases of target acquisition. The interfaces for the GPC mode are shown in Figure 5-10. When the GPC mode is selected, EA1 will point the antenna to the commanded angles received from the SM GPC. If a received signal is detected, the automatic closed-loop system internal to EA1 will angle track the target and provide data to the SM GPC and to panel displays (Tracking subsection). If the received signal is not detected, the antenna is automatically commanded to search around the commanded point (Search subsection). The antenna is inertially stabilized during the search operation (Antenna Stabilization subsection).

Once angle track is acquired, the antenna will continue to track the target until it loses lock; then, the antenna will stop and wait 20 seconds. If automatic lock is not achieved, the antenna will respond to new SM GPC-commanded angles and repeat the process detailed in the preceding paragraph.

5.5.1.2 GPC Designate

The GPC designate mode provides the same commanded angles as the GPC mode without angle search or angle track (Tracking subsection) capabilities. No closed-loop angle tracking is provided and detection of a received signal is not required. The commanded angles are updated every 2 seconds by the SM GPC. The antenna may be either inertially or body stabilized (Antenna Stabilization subsection). The interfaces for the GPC designate mode are the same as for the GPC mode and can also be seen in Figure 5-10.



00603034.SCH# 1

Figure 5-10. Ku-band interfaces for the GPC and GPC designate modes

5.5.1.3 Auto Track

In the auto track mode, the KU EA1 does not respond to the commanded angles from the SM GPC. The antenna must be pointed manually using the SLEW switches on Panel A1U. If a received signal is detected, the automatic closed-loop system angle tracks the target the same as it would in the GPC mode. If a received signal is not detected, a search must be manually initiated using the KU SEARCH switch on Panel A1U. The SLEW RATE switch must be in SLOW in order for the antenna to lock onto the received signal and track it while the antenna is being slewed by the crew. Once the received signal is detected, manual control is inhibited until lock with the received signal is lost. The crew can force the system to break lock by going to manual slew mode and slewing the antenna away from the target. If the lock is lost, the antenna must be pointed again using the manual controls. The interfaces for the auto track mode are shown in Figure 5-11.

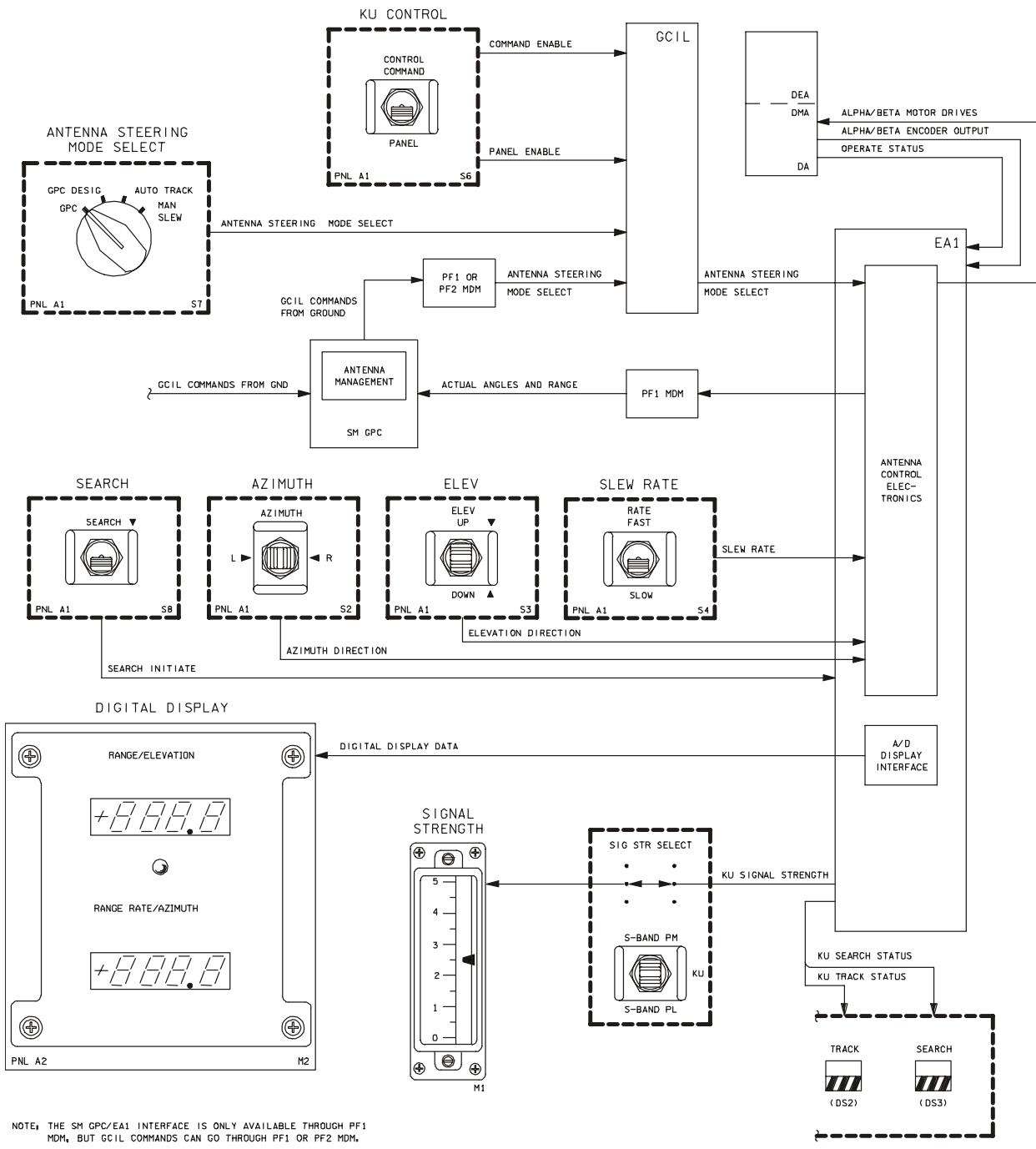


Figure 5-11. Ku-band interfaces for the auto track mode

The auto track mode would be required if an SM GPC failure or GPC to Ku-band interface failure should occur, requiring the antenna to be manually positioned to point at a desired target or TDRS and manually forced into the search mode. The auto track mode is used for the KU-BD Manual Acquisition procedure (ORB OPS C/L) in the comm mode and the RR Auto Track ACQ procedure (RNDZ OPS) in the radar mode.

5.5.1.4 Manual Slew

The manual slew mode provides manual control of antenna movement. Angle search or angle tracking is not available in this mode. The antenna is body stabilized at all times. The interfaces for the manual slew mode are shown in Figure 5-12.

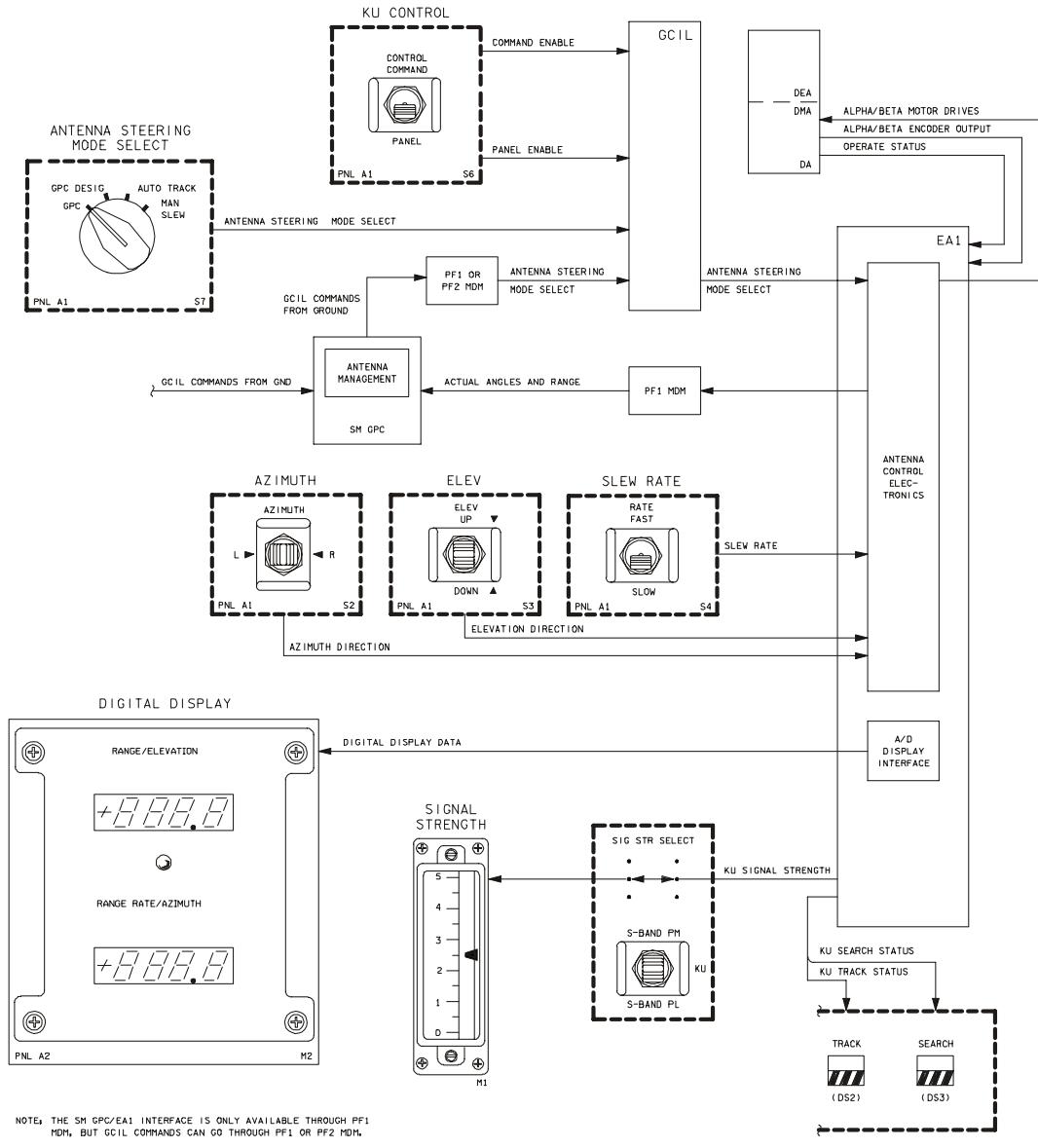


Figure 5-12. Ku-band interfaces for the manual slew mode

5.5.1.5 Tracking

The Ku-band system uses angle tracking to maintain the appropriate antenna pointing to keep the target within the antenna beam. The KU TRACK tb on Panel A1U is gray whenever a target is being tracked. The orbiter Ku-band system accomplishes angle tracking in two ways:

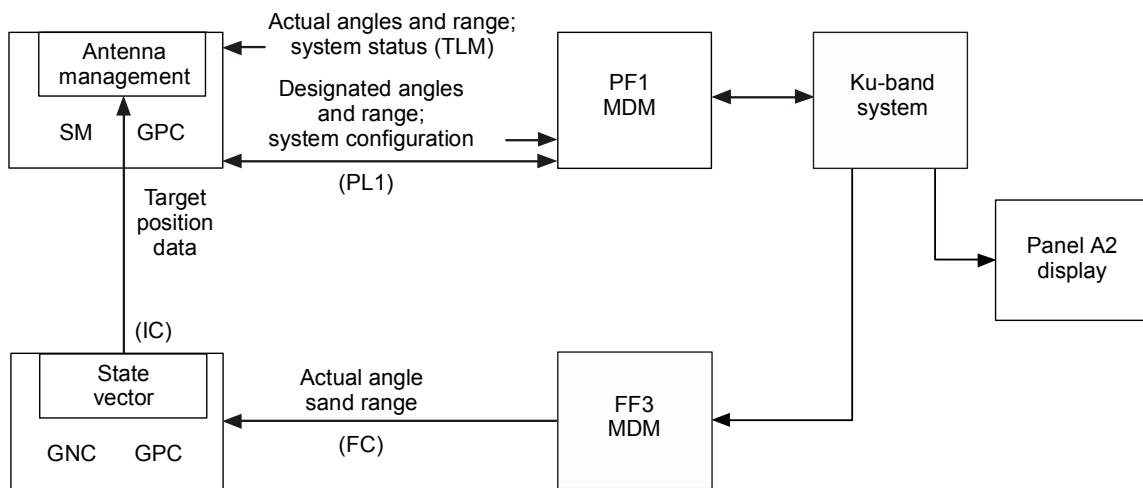
- Computer or manual commanding
- Automatic (auto) servosystem

During computer or manually commanded tracking, the antenna beam angle is positioned using sources external to the Ku-band system. Computer tracking provides commanded angle data, based on combined target and orbiter state vector information. Manual tracking applies manually initiated rates to the antenna control system from the SLEW switches on Panel A1U.

Automatic angle tracking is accomplished by applying error rates to the antenna control system from a receiving system that measures the target position relative to the antenna beam center. This configuration constitutes a closed-loop servosystem internal to the Ku-band system. It ignores external computer or manual commands when the loop is closed.

In addition to the angle tracking capability, the Ku-band system can track the target range. Range tracking is accomplished by electronically measuring the time between a transmitted radar pulse and a return pulse from the target. The range tracking capability is available only in the radar mode, but is available in all antenna steering modes.

Range tracking is automatic in all of the antenna steering modes, although computer-commanded ranges are applied to the Ku-band system until tracking is achieved. When in the radar mode, the Ku-band system can provide actual antenna angle, angle-rate, range, and range-rate data to the GNC GPC through a Multiplexer/Demultiplexer (MDM) interface, specifically FF3, for rendezvous and proximity operations (Figure 5-13).



usa006030_011

Figure 5-13. Ku-band interfaces for range tracking

5.5.2 Search

After the antenna has been positioned to the estimated target elevation and azimuth angles, there should be evidence of a target-received signal such as signal strength or automatic track. If there is no evidence of a received signal, EA1 will execute programmed routines automatically in GPC or manually in auto track, which cause the antenna to search for the target in a spiral pattern starting at the designated point (Figure 5-14). During the search, the antenna beam spirals out to a maximum of 30° from the designated angle in the radar mode and a maximum of 10° in the comm mode. The KU SEARCH tb on Panel A1U is gray whenever a search is in progress.

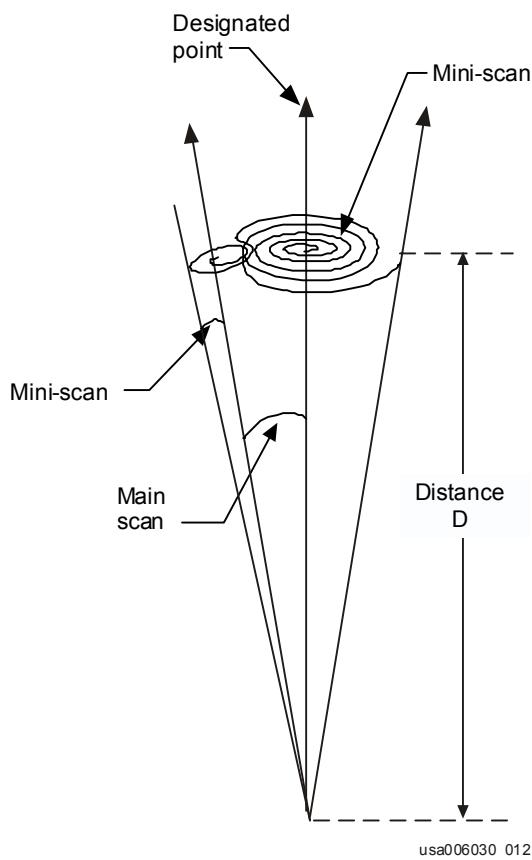


Figure 5-14. Antenna search pattern

A search is available only for the GPC and auto track antenna steering modes. In the GPC antenna steering mode and radar mode, the maximum angle of search from the designated point is inversely proportional to designated range (Table 5-2). The smallest search spirals outward to a maximum of 6.2° from the designated point for designated ranges from 145 to 300 nautical miles (n. mi.). If the antenna drive system detects but overshoots the target during a spiral search, a mini-scan program is automatically initiated near the point of detection. The mini-scan searches up to a maximum of 9° for the radar mode and a maximum of 4° for the comm mode. In the auto track antenna steering mode, only a manually initiated main scan is provided, 30° in the radar mode and 10° in the comm mode.

In addition to angle search, the Ku-band system provides a range search for the radar mode. The process includes electronically varying the timing within the range system until it coincides with the time interval between transmitted and received radar pulses. Once the intervals coincide, range track is established, and the range data output represents the range between the target and the orbiter. The crew can read the range and range-rate values as panel and CRT parameters.

Table 5-2. Scan/range definition

| Operational mode | Range designate, n. mi. | Mini-scan time, sec | Mini-scan, deg | Main scan, deg* | 1 scan time, sec |
|-------------------------|--------------------------------|----------------------------|-----------------------|------------------------|-------------------------|
| Radar auto | - | 10.1 | 9 | 30 | 60 |
| Radar GPC | 0 - 8 | 10.1 | 9 | 30 | 60 |
| Main scan | 8 - 9.2 | 10.1 | 9 | 27.7 | 60 |
| | 9.2 - 10.3 | 10.1 | 9 | 24.4 | 60 |
| | 10.3 - 11.8 | 10.1 | 9 | 21.7 | 60 |
| | 11.8 - 15 | 10.5 | 9 | 19.6 | 60 |
| | 15 - 25 | 13.8 | 9 | 16.5 | 60 |
| | 25 - 40 | 18.7 | 9 | 13.4 | 60 |
| | 40 - 65 | 24.1 | 9 | 11 | 60 |
| | 65 - 145 | 33.8 | 9 | 8 | 60 |
| | 145 - 300 | 43.6 | 9 | 6.2 | 60 |
| Mini-scan | >3.9 | 54 | 9 | 9.95 | 60 |
| Comm | - | 40.1 | 4 | 10 | 145 |

*The mini-scan programs controls the first 9° of any radar main scan.

5.5.3 Antenna Stabilization

The Ku-band system provides body and inertial antenna stabilization modes. When body stabilized, the antenna beam remains in a fixed relationship to the orbiter X-axis, Y-axis, and Z-axis when orbiter attitude changes are made. When inertially stabilized, the antenna beam remains aligned to a point in inertial space, regardless of the orbiter attitude changes. This applies only when the angle tracking system is not tracking a target. In the target angle-tracking mode, the system aligns the antenna beam to the target and antenna rate-sensing gyros compensate for any orbiter attitude changes.

As shown in Table 5-3, each antenna steering mode has a specific stabilization mode, except the GPC designate mode. The GPC designate mode provides either body or inertial stabilization mode as determined by a real-time GPC command (not available to the crew). Since the GPC designate mode provides range track only, inertial stabilization is in effect when tracking a target.

Table 5-3. Stabilization modes

| Steering mode | Body | Inertial |
|----------------------|-------------|-----------------|
| GPC | | X |
| GPC designate* | X | X |
| Auto | | X |
| Manual | X | |

*Stabilization mode dependent on GPC command.

5.6 FLIGHT ANOMALIES

The antenna operations have been affected by several anomalies on past flights. Some of these anomalies and their causes are discussed in the paragraphs that follow.

There have been several cases in which the antenna failed to point to the commanded azimuth and elevation angles. In one case, the antenna failed to point to the commanded angles for about one-half hour, during which the alpha gimbal temperature increased 30° F. After an antenna “whip around,” the commanded and actual angles agreed, and the alpha gimbal temperature returned to normal. Post flight analysis failed to identify the cause of the anomaly. In another case, it was decided that the Ku-band was not mandatory for the mission and therefore would be stowed. When the antenna was manually slewed to near the gimbal lock angles, an oscillation was observed and the system was put in standby until a procedure was developed to enhance the stow activity. The antenna was then successfully slewed to the lock angles, the gimbals were locked, and the DA was stowed. The most probable cause of the anomaly was that the top lock arm failed to fully retract and thus prevented the antenna from rotating.

Another problem occurred when one of three screws holding the beta motor brush-block assembly came out and shorted the motor windings at the negative stop (-85°). This short caused the failure of the beta motor drive output transistors in EA1 and resulted in uncontrolled oscillation of the alpha gimbal when its servo loop became unstable. Power to the system was cycled off, then on, and since the beta gimbal could not move, the microprocessor in EA1 set the beta master index pulse register to -23.25° as if it had found it. Actually, the beta gimbal was positioned at an angle of -85°. The azimuth and elevation angles were determined using an offline angle transformation program (including the delta beta angle of 61.75°), and the orbiter was maneuvered to point the Ku-band antenna line of sight to the TDRS and maintained in this attitude (TDRS track) while the TDRS was in view. During an EVA, the crew performed an IFM procedure to lock the gimbals. The antenna was deployed again (with the gimbals locked) and the TDRS track attitude was used to maintain communications for the remainder of the mission.

The TWTA was the cause of a flight anomaly because it failed to turn on when commanded. Cycling the KU PWR switch from ON to STBY to ON had no effect; however, cycling ON to OFF to ON resulted in normal operation. This return to normal operation indicated that the TWT protection circuit was latched (three faults detected in 3 seconds sets the latch) and high voltage was removed from the TWT. If the system is off for more than 3 seconds but less than 9 seconds, the latch will be reset and the 3.5-minute TWT warmup will be bypassed. This fault could have been caused by a transient when commanding the TWT off (observed in ground tests) or by the TWT arcing. This arcing phenomenon is generally associated with "new" TWTS and is caused by contaminants in the tube that are burned out by normal operation as the tube ages.

Another case of uncontrolled antenna motion occurred when a loose washer in the DEA Low-Voltage Power Supply (LVPS) caused a momentary short that latched the LVPS off. The DEA LVPS provides power to the gyro electronics and, if removed, will cause both alpha and beta gimbal servo loops to become unstable, resulting in erratic antenna motion. The LVPS latch can be removed by cycling system power if the short is no longer present.

During STS-37, the Ku-band system exhibited intermittent angle tracking problems in the communications mode while the system was in the GPC mode. After orbit 61, no further anomalies were seen in the communications mode and no anomalies occurred during the 7 hours of radar operations. Post-flight testing did not repeat the anomaly; however, metallic shavings were found on the front and the back of the antenna. The most probable cause for the angle tracking anomaly is that one of the metallic shavings interfered with the angle-error signal used in the automatic closed-loop tracking system. If this anomaly were to repeat in flight, the system could be switched to the GPC designate antenna steering mode, where closed-loop angle tracking is not required.

5.7 SUMMARY

Once the DA has been deployed and activated, antenna operations can begin. These operations include antenna movement that can be limited by gimbal stops and antenna coverage that can be limited by one of three maskings: obscuration mask, beta only, or beta + mask. The Ku-band system has four antenna steering modes that can be used in performing antenna operations. These modes are GPC, GPC designate, auto track, and manual slew. Each mode uses a different combination of steering, search, track, and stabilization capabilities. All of the antenna steering modes are functional in both the comm mode and the radar mode.

5.8 QUESTIONS

1. Which of the following maskings can be seen on the SM OPS 2011 ANTENNA display?
 - a. Obscuration mask
 - b. Beta only mask
 - c. Beta + mask
 - d. All of the above
2. The obscuration mask works in conjunction with the scan warning system. In the RADAR mode, if the Ku-band antenna points in the area below the obscuration mask, the radiation from the TWT will be _____ and the KU SCAN WARN tb on Panel A1U will go _____.
 - a. Enabled, gray
 - b. Enabled, barberpole
 - c. Inhibited, gray
 - d. Inhibited, barberpole
3. In the beta only mode, the radiation from the TWT will be inhibited if the Ku-band antenna points in the area
 - a. Of the obscuration mask
 - b. Below the beta line
 - c. Both a and b
 - d. Either a or b
4. In the beta + mask mode, the radiation from the TWT will be inhibited if the Ku-band antenna points in the area
 - a. Of the obscuration mask
 - b. Below the beta line
 - c. Both a and b
 - d. Either a or b

For questions 5 to 8, match each of the following antenna steering modes with its list of capabilities.

- | | |
|------------------------|--|
| 5. GPC _____ | a. Manual steering, no angle search, no angle track, and body stabilization. |
| 6. GPC designate _____ | b. Commanded angles provided by the SM GPC, automatic search, automatic track, and inertial stabilization. |
| 7. Auto track _____ | c. Manual steering, manual search, automatic track, and inertial stabilization. |
| 8. Manual slew _____ | d. Commanded angles provided by the SM GPC, no angle search, no angle track, and inertial or body stabilization. |

6.0 COMMUNICATIONS OPERATIONS

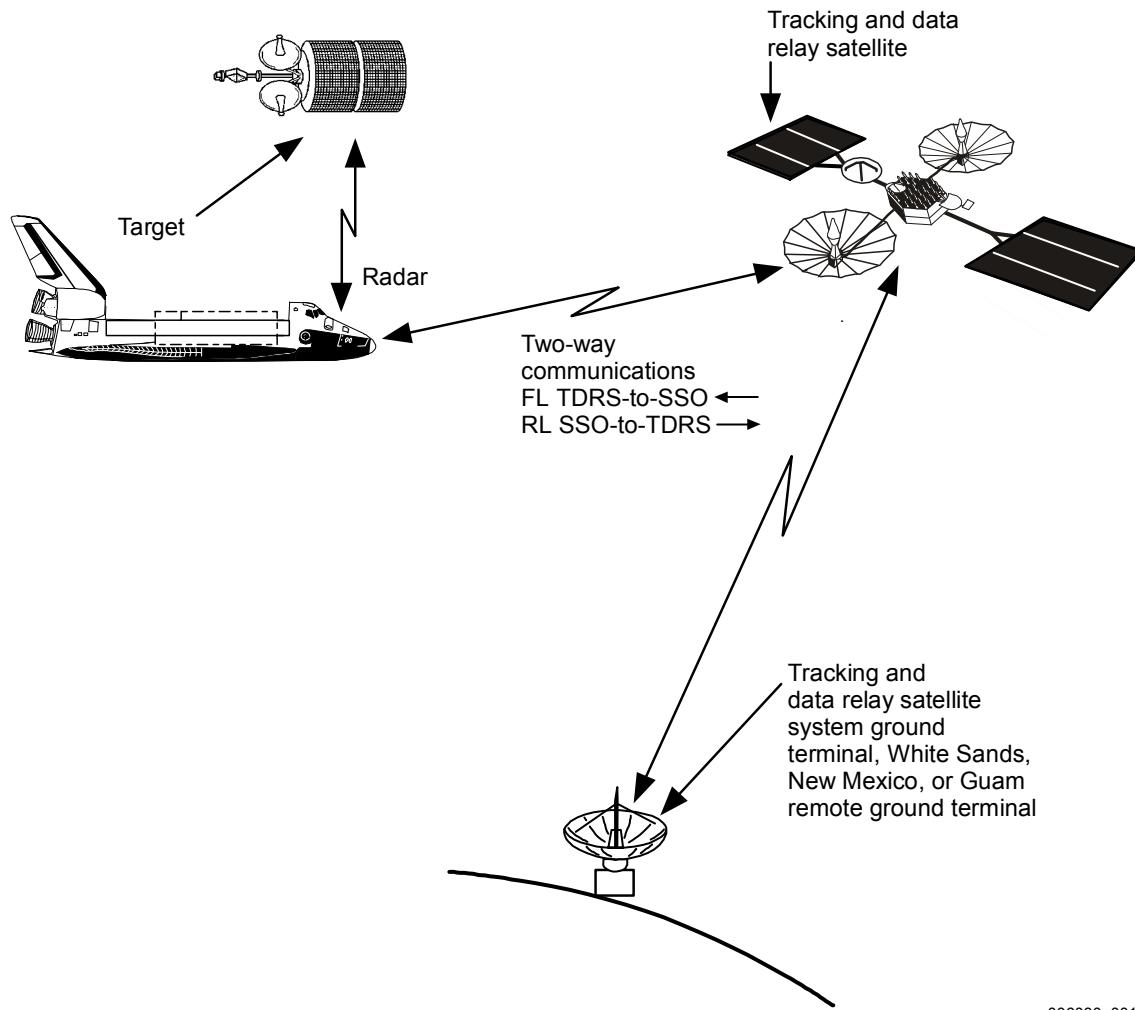
6.1 PERFORMANCE OBJECTIVES

The student should be prepared to accomplish the following tasks as a result of studying this section of the workbook:

- a. Identify the Ku-band LRUs used for the forward and return links
- b. Describe the different modes of operation for the Forward Link and the Return Link

6.2 OVERVIEW

The Ku-band communications system can be used to transfer information between the orbiter and a ground terminal by utilizing the TDRS system (Figure 6-1). Two-way communication is possible through an RF interface with each TDRS. The TDRS then has an RF interface with a ground terminal at White Sands, New Mexico, or the Guam Remote Ground Terminal.



usa006030_001

Figure 6-1. Ku-band communications system RF interface

The Ku-band system can search for, detect, and track the TDRS. Although only one TDRS can be accessed at a time, the Ku-band system can switch between the satellites as required by orbiter position and Ku-band antenna attitude. For Ku-band system operations in the comm mode, orbiter attitude may be constrained by experiment requirements or for other reasons, and the antenna normally will have to move to track the TDRS.

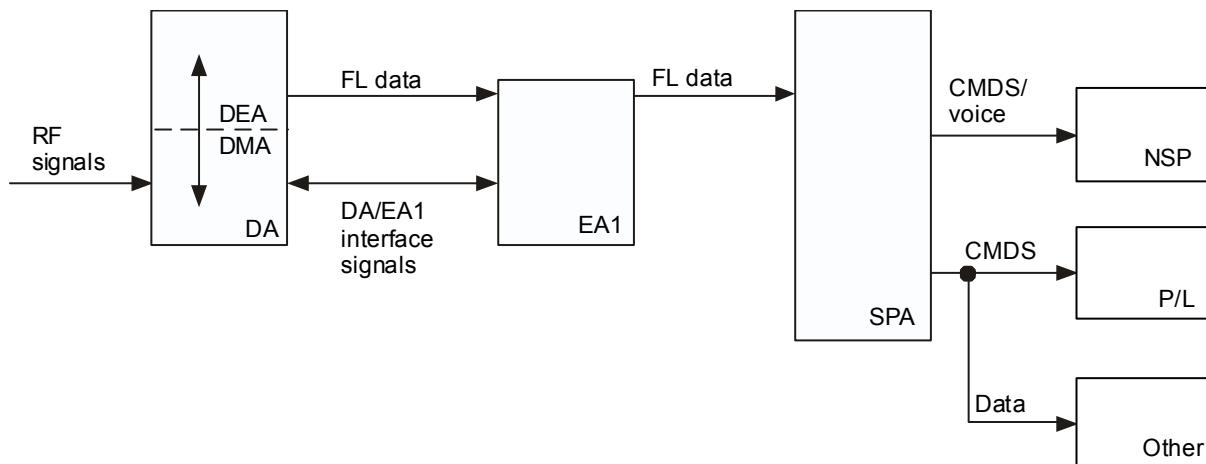
The FL from the TDRS to the orbiter can carry ground-generated commands and voice. The FL may also contain other information or payload commands. The RL from the orbiter to the TDRS transmits voice, telemetry data, and video information to the TDRS for relay to the ground terminal. Because the Ku-band carrier frequencies provide a much greater capacity for information to be transmitted than do the S-band PM and S-band FM systems, much higher data rates can be accommodated by the Ku-band system.

Although the Ku-band system has greater capabilities and more flexibility than even the S-band PM and S-band FM systems combined, it is a single-string system. The aforementioned S-band systems are largely redundant. Also, of course, use of the Ku-band system is limited to on-orbit operations; the S-band PM and S-band FM systems are usable during ascent and entry, as well as on orbit.

The Ku-band comm system component interfaces, data flow, and capabilities are discussed in the following paragraphs.

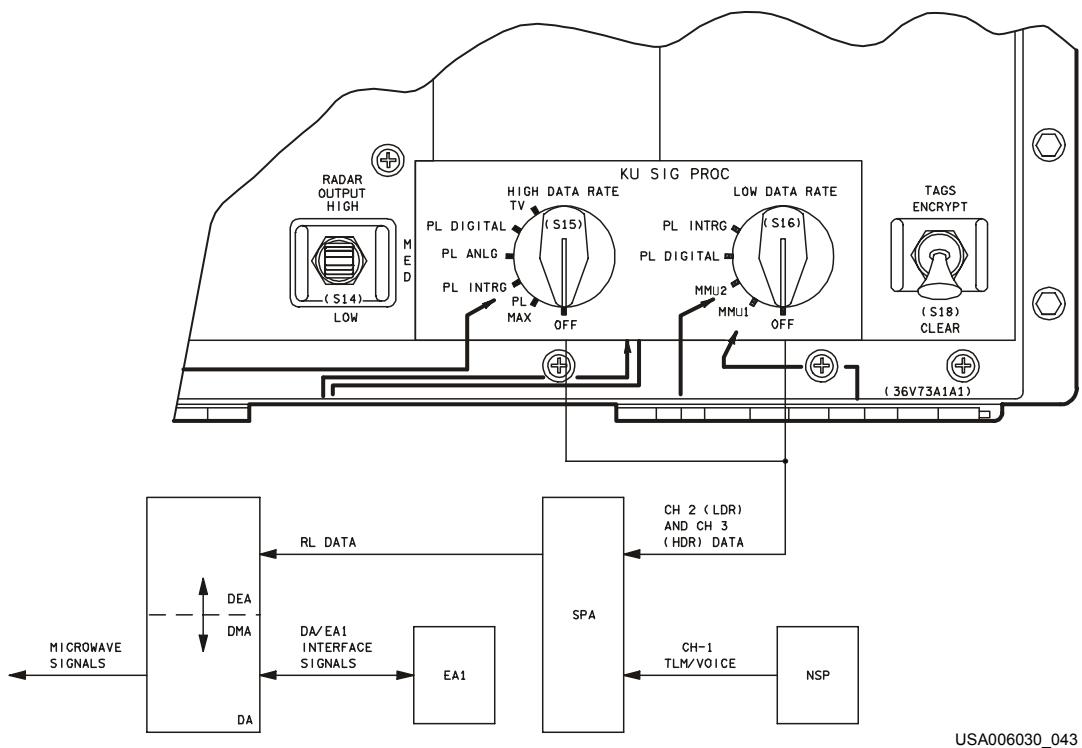
6.3 COMMUNICATIONS SYSTEM COMPONENT INTERFACES AND DATA FLOW

In the communications mode, EA1 and the Ku-band SPA are used together with the DA. The component interfaces for the comm mode can be seen in Figure 6-2 for the FL and Figure 6-3 for the RL.



usa006030_014

Figure 6-2. Ku-band comm system forward link



USA006030_043

Figure 6-3. Ku-band comm system return link

6.3.1 Forward Link

One function of the Ku-band system is to receive the FL signal from the TDRS and process it for use by other orbiter systems (Figure 6-2). The Ku-band antenna on the deployed assembly receives the FL. The forward link data are then output to EA1. In EA1, the FL data are demodulated and output to the SPA.

If the FL signal is 72 kbps (commands and voice only), it is passed through the SPA without any processing and sent to the NSP. If the signal is 216 kbps (commands/voice and Orbiter Communications Adapter (OCA) or P/L command data), 16 kbps are used by the SPA for bit and frame synchronization and the remaining 200 kbps are demultiplexed by the SPA to provide a 72-kbps signal to the NSP and a 128-kbps signal to other systems or the payload communications system. The FL data sent to the NSP from the SPA are demultiplexed into voice and orbiter commands and routed to the appropriate locations. The 128-kbps signal goes to other uplink systems and the payload comm system, but is only accepted by the system to which the data are addressed.

6.3.2 Return Link

The RL signal consists of three channels of data (Figure 6-3). The NSP combines the orbiter voice and telemetry and outputs the data to the SPA. This is the same voice and telemetry data processed by the S-band PM system. The SPA receives channel 1 from the NSP and channels 2 and 3 from the selected data sources. The rotary switches for channels 2 and 3 (KU SIG PROC LDR and HDR, respectively) are located on Panel A1U. The SPA then multiplexes the three channels of information and outputs the signal to the DEA. The signal is amplified by the TWTA. The signal is then radiated to the TDRS and relayed to the ground stations at Guam or White Sands, New Mexico.

6.4 COMMUNICATIONS SYSTEM CAPABILITIES

6.4.1 Modes of Operation

For communications use, there are two modes of operation for both the FL and the RL. The two modes provide flexibility for accommodation of different classes of payloads, both attached and detached. The operational modes are independent; i.e., each link may be in either mode, depending on the operational requirements. Operational modes are normally coordinated by ground personnel and managed by ground-based commands, with the Ku-band system in the command mode. With the system in the panel mode, the crew can use panel inputs to arrange the SPA inputs so as to effectively select RL mode 1 or 2, but there are no panel controls for crew control of the FL mode. The ground controller selects FL mode 1 or 2 and a corresponding command configures the SPA for the correct mode.

The communications system capabilities are summarized in Tables 6-1 and 6-2 for FL and RL, respectively. Because the modulation technique used for RL mode 1 is a form of Phase Modulation (PM), and that for RL mode 2 is Frequency Modulation (FM), the modes are sometimes referred to as PM mode (mode 1) and FM mode (mode 2).

Table 6-1. Ku-band forward link capabilities

| FL transmits | Data functions | Mode 1 216 kbps | Mode 2 72 kbps |
|------------------|---|--------------------|-------------------|
| Operational data | Voice - A/G 1 and A/G 2 and commands (CMDs) | X | X |
| Forward data | Payload CMDs or other uplink data (OCA) | X | |

Table 6-2. Ku-band return link capabilities

| Channel | RL transmits | Data functions | Mode 1 PM | Mode 2 FM |
|----------------|---------------------------------------|---|----------------------|----------------------|
| 1 | Operational data | Voice - A/G 1 and A/G 2 and telemetry (TLM) | X | X |
| 2 | Payload data or SSO ops playback data | Attached PL real-time DIG TLM (PL DIGITAL) or PL RCDR playback TLM (PL RCDR) or SSO ops RCDR playback TLM (Solid State/OPS/ RCDR) or detached PL "bent-pipe" TLM (PL INTRG) | X | X |
| 3 | Payload data or TV video | High-rate-data TLM (PL MAX) Attached PL analog TLM (PL ANLG) or attached PL digital TLM (PL DIGITAL) or TV video (TV) or detached PL "bent-pipe" TLM (PL INTRG) | X | X |

The data stream for both modes of the Ku-band forward link contains the same basic information as does the S-band PM forward link operational data stream in HDR mode. Mode 1 FL provides the additional capability to transmit to the orbiter a 128-kbps data stream (forward data) that may be used either for transmitting payload commands or for sending data to other orbiter systems, including OCA. FL mode 1 and mode 2 are Figure 6-4 and illustrated in Figure 6-5, respectively.

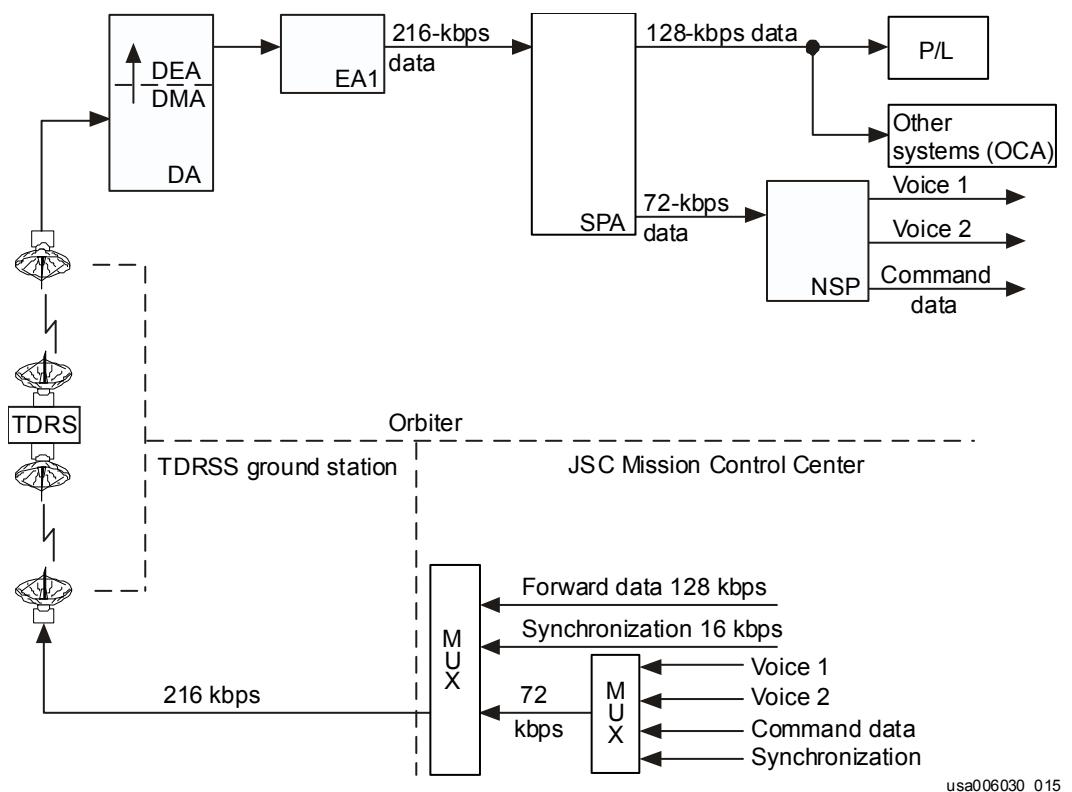
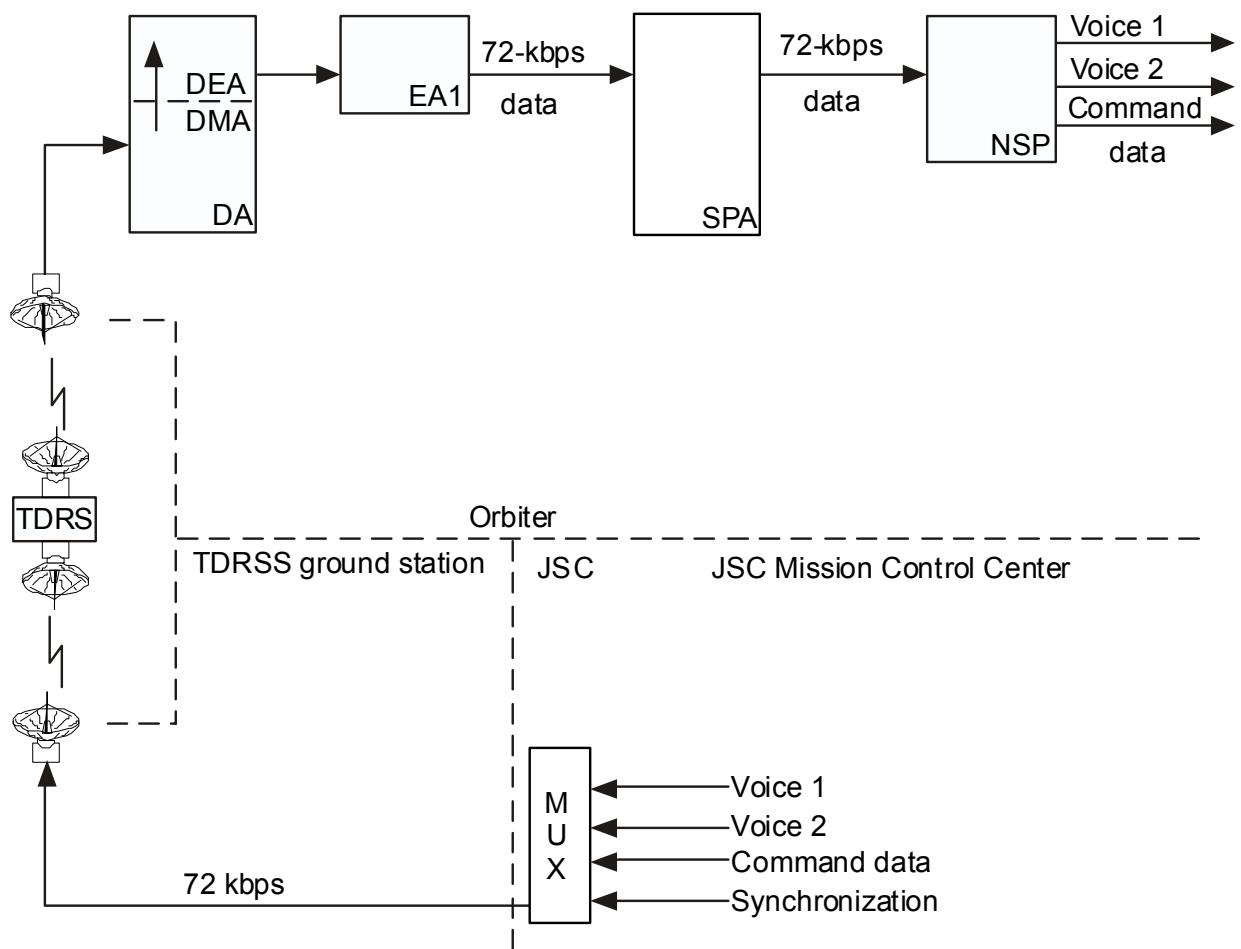


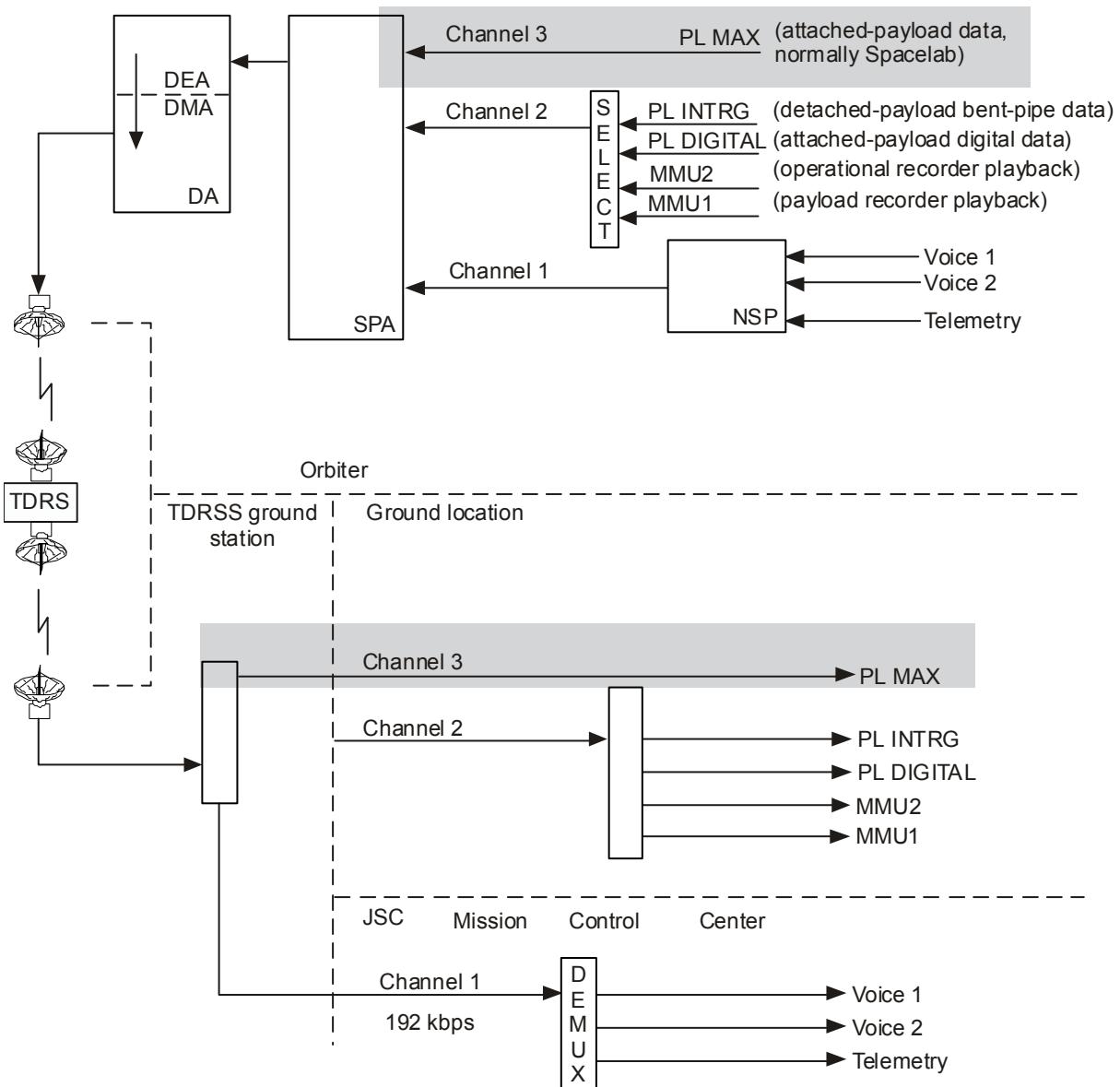
Figure 6-4. Ku-band forward link mode 1 configuration



usa006030_016

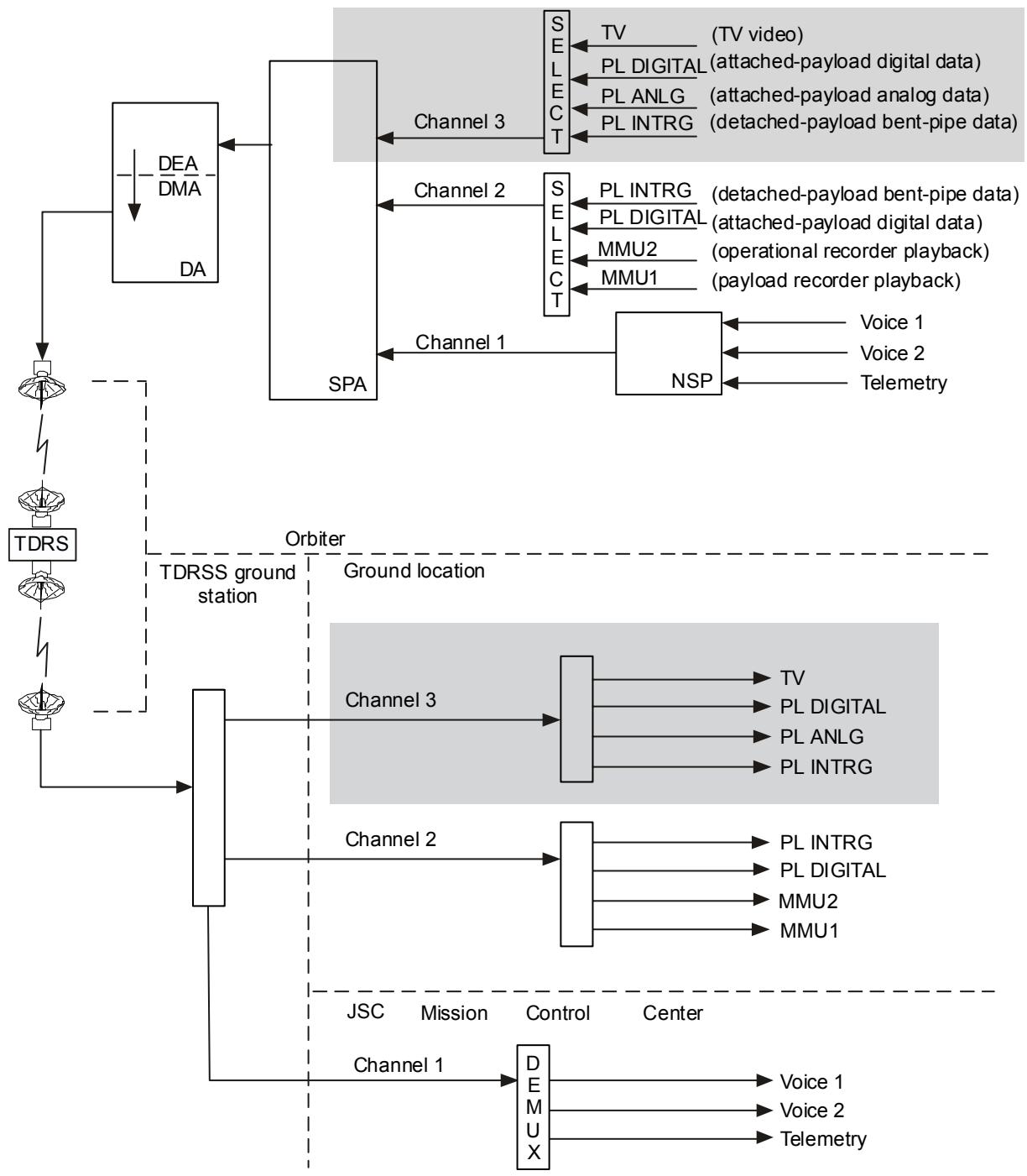
Figure 6-5. Ku-band forward link mode 2 configuration

Modes 1 and 2 of the Ku-band RL provide three simultaneous channels for RL data. For both modes, channel 1 handles operational data, which contain the same information as the return link S-band PM data in the high-data-rate mode. Channels 2 and 3 of the Ku-band RL offer telemetry functions roughly analogous to those of the S-band FM system, but of much greater total capacity. RL mode 1 and mode 2 are illustrated in Figure 6-6 and Figure 6-7, respectively.



usa006030_017

Figure 6-6. Ku-band return link mode 1 configuration

**Figure 6-7. Ku-band return link mode 2 configuration**

6.4.2 Ku-band/S-band PM Auto K to S; Auto S to K operation

When the Ku-band comm system is being used for the uplink source, the crew configures the NSP on Panel A1L as follows:

- NSP UPLK DATA - KU
- NSP DATA RATE XMIT/RCV - HI/HI
- NSP CODING XMIT/RCV - ON/OFF

The orbiter is provided with systems management (SM) software that maximizes Ku-band usage during orbit. INCO flight controllers have commands that will enable the SM GPC to automatically enable handover of the NSP Uplink Data Source to Ku-band when the Ku-band forward link is available and back to S-band when the Ku-band forward link is either lost or blocked. If the Ku-band forward link signal strength is greater than 1 and the Ku-band data present flag is good for 15 seconds, then the NSP UL Data Source changes to Ku. If the Ku-band data present flag is lost for 5 seconds, the NSP UL Data Source changes back to S-band. The Enable (ENA) or Inhibit (INH) indication for these operations, as well as the selected UL Data Source, can be seen on SM SPEC 76 COMMUNICATIONS display (Figure 6-8).

| XXXX/XXX/076 | | COMMUNICATIONS | | XX | X | DDD:HH:MM:SS |
|----------------|-------|----------------|-------|------------------|------|--------------|
| | | | | DDD:HH:MM:SS | | |
| S-BAND PM | | XXXXS | | KU-BAND | | |
| FREQ | XXS | 1 | 2 | PA TEMP | | ±XXXS |
| ANT ELEC | XXS | | XXS | GIMBAL TEMP A | | ±XXXS |
| XPNDR | XXS | | XXS | B | | ±XXXS |
| PREAMP | XXS | | XXS | GYRO TEMP | | ±XXXS |
| PWR AMPL | | | | PWR OUT | | XXS |
| OPER | XXS | | XXS | FRM SYNC | | XXXS |
| STBY | XXXXS | | XXXXS | MODE | | XXXXS |
| PWR OUT | XXS | | XXS | FAILSAFE | | XXXS |
| TEMP | XXS | | XXS | AUTO K TO S | | XXX |
| NSP | | 1 | 2 | AUTO S TO K | | XXX |
| BIT SYNC | XXS | | XXS | SSOR | PRI | B/U |
| FRM SYNC | XXS | | XXS | FRM SYNC | XXXS | XXXS |
| BITE | XXXXS | | XXXXS | PROC STAT | XXXS | XXXS |
| COMSEC BITE | XXXXS | | XXXXS | PWR LEVEL | | ±XX. XS |
| UL DATA SOURCE | | XXS | | STATUS | | X. XS |
| DATA RATE XMIT | | XXS | | GCIL CONFIG | | XXXS |
| RCV | | XXS | | CCTV CAMR OVRTMP | | XXXS |
| CODING | XMIT | XXS | | | | |
| | RCV | XXS | | | | |
| | | | | | | (XX) |

00603005.CRT 2

Figure 6-8. SM SPEC 76 COMMUNICATIONS display

6.5 SUMMARY

The Ku-band comm system provides two-way communication with a ground terminal by utilizing the TDRS system. The comm system utilizes the EA1, the SPA, and the DA to process the forward and return links. The FL carries ground-generated commands and voice data. The FL may also contain payload command data or other information. The RL consists of three channels of data. Channel 1 contains the voice and telemetry from the NSP. Channels 2 and 3 provide data from additional selected data sources. There are two modes of operation for both the FL and the RL.

6.6 QUESTIONS

1. Which of the following LRUs does the Ku-band comm system forward link go through?
 - a. DA, EA1, EA2, and SPA
 - b. DA, EA1, and SPA
 - c. DA, EA1, and EA2
 - d. DA and SPA
2. Which of the following LRUs does the Ku-band comm system return link go through?
 - a. SPA, EA2, EA1, and DA
 - b. SPA, EA1, and DA
 - c. EA2, EA1, and DA
 - d. SPA and DA
3. What data are provided by the mode 1 forward link?
 - a. Voice
 - b. Commands
 - c. Payload commands or OCA
 - d. All of the above
 - e. a and b only
4. What data are provided by the mode 2 forward link?
 - a. Voice
 - b. Commands
 - c. OCA or payload commands
 - d. All of the above
 - e. a and b only

5. For mode 1 return link, the data source for channel 3 can be
 - a. PL MAX
 - b. TV, PL ANLG, PL DIGITAL, or PL INTRG
 - c. Solid State/OPS RCDR
 - d. All of the above
6. For mode 2 return link, the data source for channel 3 can be
 - a. PL MAX
 - b. TV, PL ANLG, PL DIGITAL, or PL INTRG
 - c. Solid State/OPS RCDR
 - d. All of the above

7.0 RADAR OPERATIONS

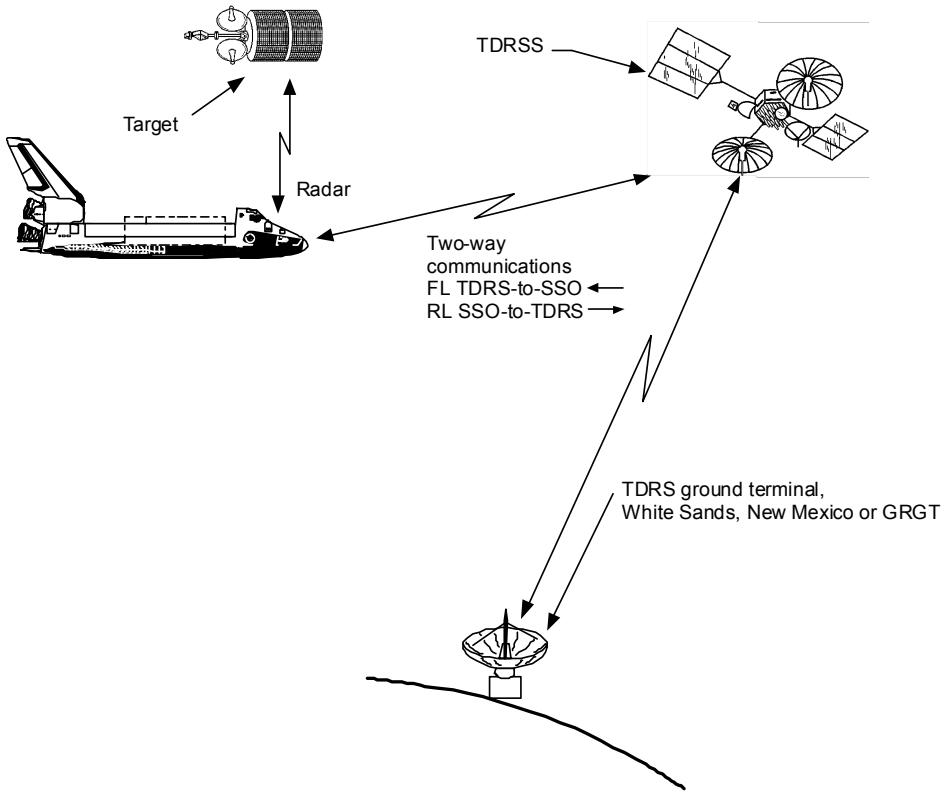
7.1 PERFORMANCE OBJECTIVES

The student should be prepared to accomplish the following tasks after studying this section of the workbook:

- Describe Ku-band radar system operations
- State the purpose of the Ku-band radar system during rendezvous operations

7.2 OVERVIEW

In addition to the communications operations discussed in the previous section, the Ku-band system can perform rendezvous radar operations (Figure 7-1). Two radar operation modes are available, passive ("skin" track) and cooperative (target has a transponder). The cooperative mode is not used currently. The purpose of the radar system in the passive mode is to search for, acquire, and track targets out to approximately 12 n. mi. and to provide target data, consisting of target angle, angle rate, range, and range rate to the crew via CRT and dedicated displays and to the ground via the S-band return link. The radar is similar to a basic radar system in that it transmits a pulsed continuous S-wave signal and derives target information from the echo signal.



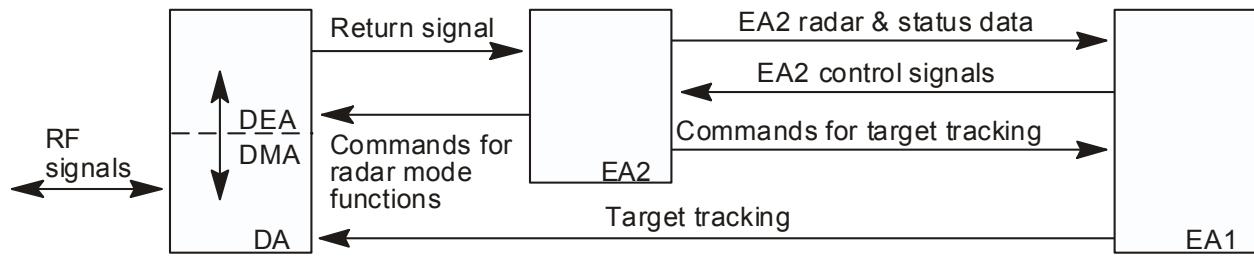
usa006030_019

Figure 7-1. Ku-band RF links

7.3 RADAR SYSTEM

The Ku-band system components used during radar operations are EA1, EA2, and the DA. EA2, the radar signal processor, sends commands to the DEA for control of the radar mode functions such as transmitter frequency, transmitter RF output power level, and transmitter and receiver gating logic. EA2 sends commands to EA1 for antenna radar lobing controls to allow target tracking. The return signal is output from the receiver in the DEA to EA2, where it is processed to determine the range, the range rate, and the angle rate of the target. A block diagram of the radar system is given in Figure 7-2.

The Ku-band system will be used in the radar mode during rendezvous/proximity operations, but may be used in the comm mode when radar is not required. During a rendezvous operation, the radar system is used as a sensor that provides target angle, range, and range-rate information for updating the rendezvous navigation data. During proximity operations, the system is used as a real-time source of information, representing position and closing velocity of the target with respect to the orbiter. This information can be seen on the digital display on Panel A2. Panel A2 also contains the LINE OF SIGHT RATES meter, which is used to maintain station keeping with a deployed payload. In addition, panel and CRT display indications register the angular movements of the antenna in inertial space when angle tracking is active.



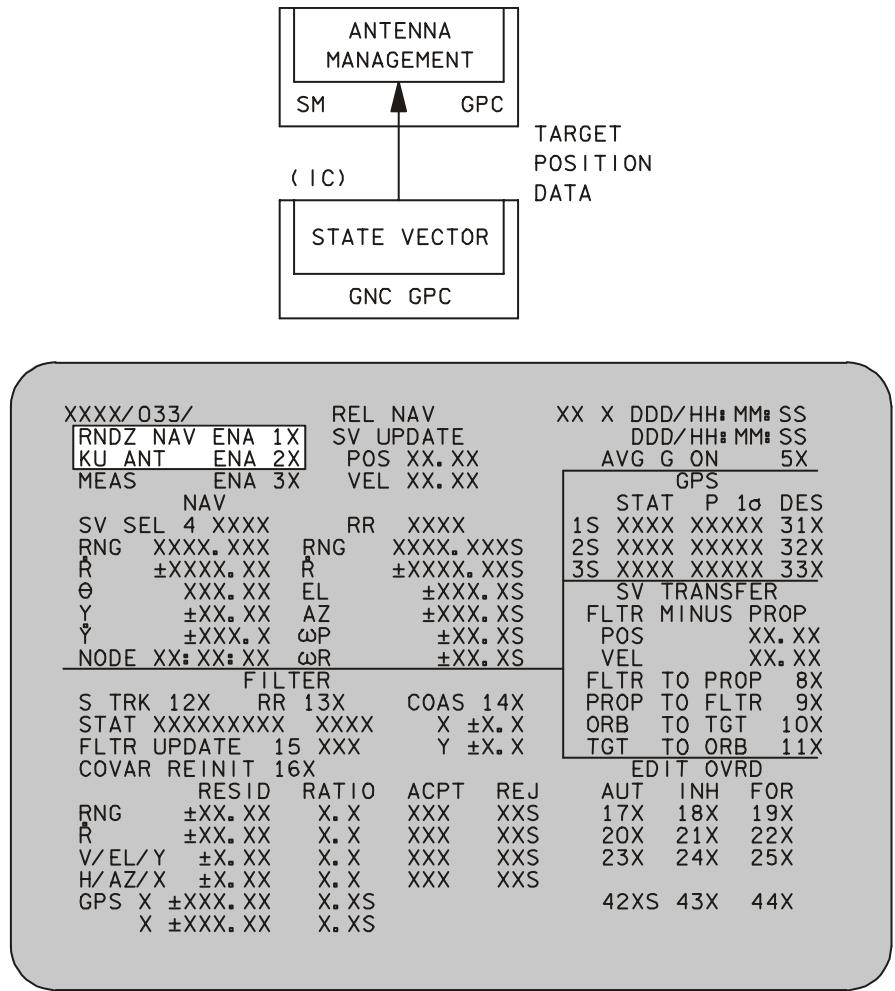
usa006030_020

Figure 7-2. Block diagram of the Ku-band radar system

7.4 RADAR OPERATIONS

The procedures for radar operations can be found in the Rendezvous Operations Checklist of the FDF. This section encompasses the Ku-band radar portions of the checklist. Additional information on rendezvous operations can be found in the Rendezvous/Proximity Operations Crew Training Handbook. To begin, the Ku-band system is prepared for operations in the radar mode by doing a self-test to check out the system. This is the same self-test performed in the Ku-band activation procedure.

The GNC GPC compares the target State Vector (SV) and the orbiter SV to determine target pointing vector information. For performing the comparison, the rendezvous navigation programs must be enabled by doing the RNDZ NAV ENA item 1 entry on GNC SPEC 33. The interface from the GNC GPC to the SM GPC must be enabled to allow the target pointing vector information to be used by the SM GPC to point the Ku-band antenna. The interface is enabled by doing the KU ANT ENA item 2 entry on GNC SPEC 33 (Figure 7-3).



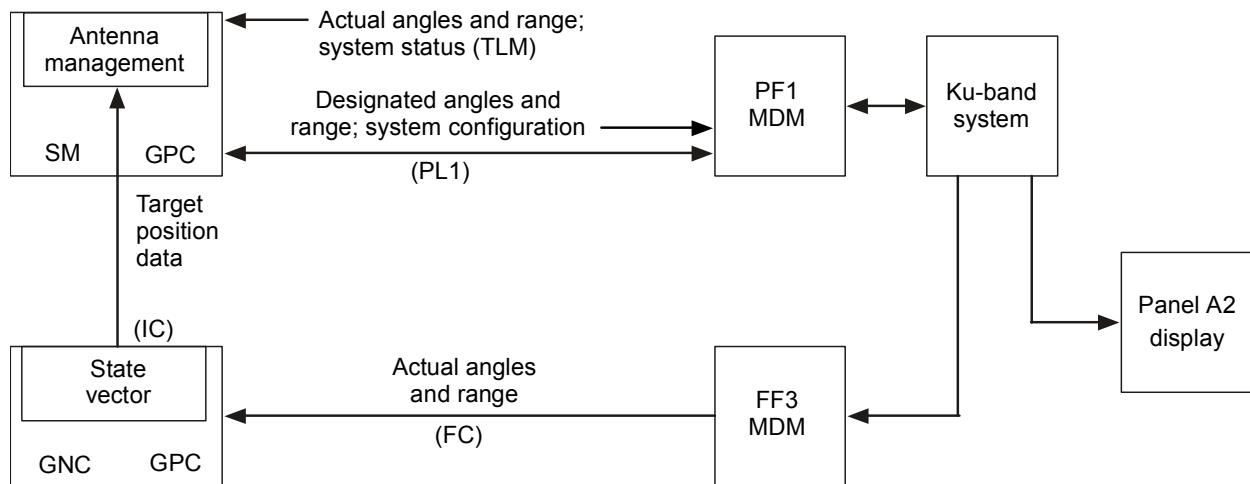
00603014.CRT, 3

Figure 7-3. GNC GPC to SM GPC interface enable

The Ku-band system interfaces with the GNC GPC through FF3 MDM (Figure 7-4). This interface is necessary for the Ku-band system to transfer radar information to the GNC GPC for processing by the rendezvous navigation programs. Performing a GNC I/O reset enables the interface.

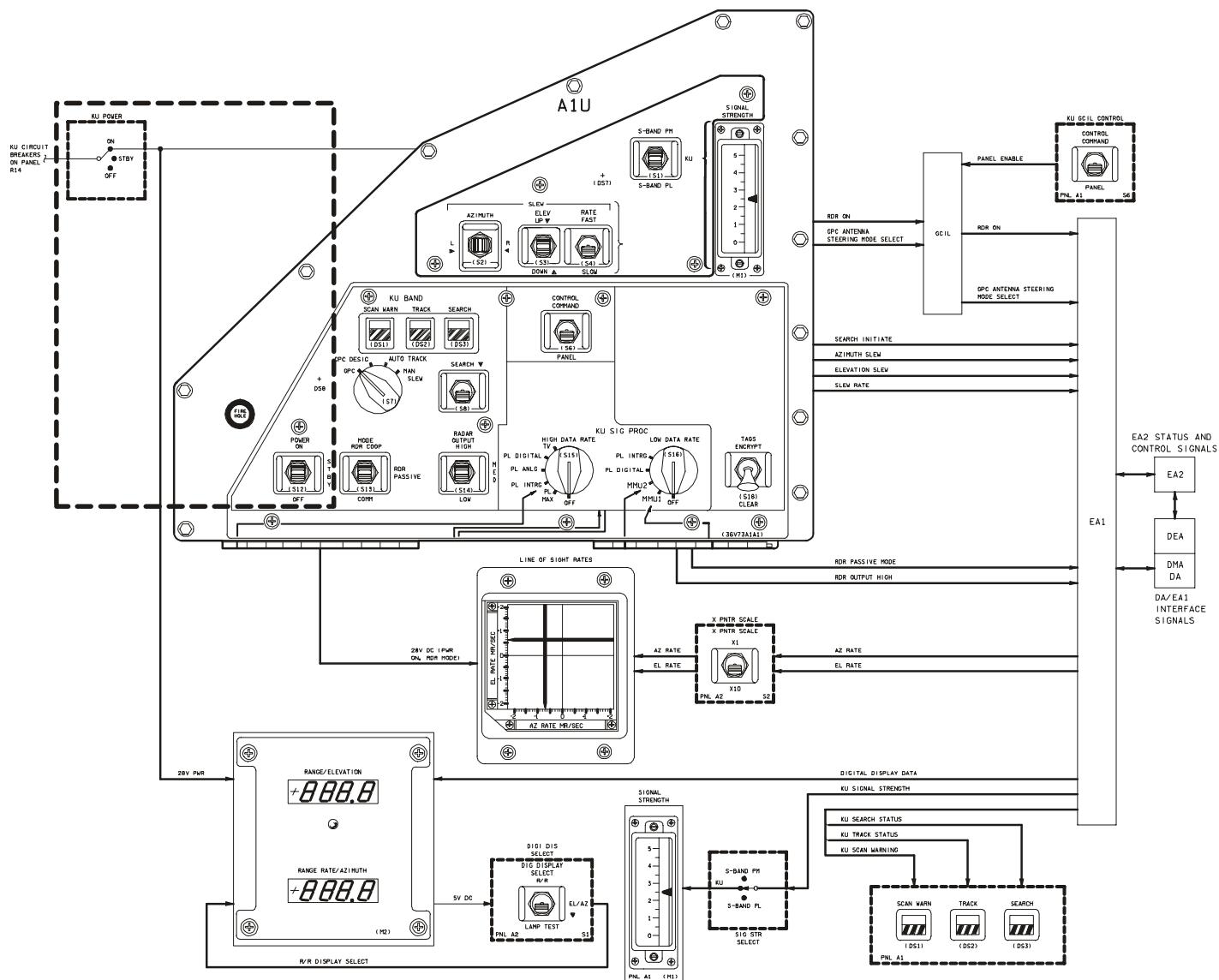
Next, Panels A1U and A2 must be configured for radar operations: KU MODE in RDR PASSIVE, GPC antenna steering mode, KU RADAR OUTPUT in HI, KU CNTL in PNL, and DIGI-DIS SEL on R/R (Figure 7-5). The radar operations are performed in the panel mode for crew control of the Ku-band system.

The SM GPC will now point the Ku-band antenna at the desired rendezvous target. The interface between the SM GPC and the Ku-band system was enabled during the Ku-band system activation. When the Ku-band radar signal lock-on occurs, the KU TRACK tb should go gray, the signal strength meter should indicate the presence of a signal, and the antenna position should be at or near 0° elevation, 0° azimuth.



usa006030_022

Figure 7-4. Ku-band interfaces



USA006030_044

Figure 7-5. Ku-band radar configuration

Once lock has occurred, the Rendezvous Radar (RR) sensor is enabled to provide sensor data. RR is enabled by doing an item 13 entry on SPEC 33 (Figure 7-6). Next, SPEC 33 is used to check the validity of the RR data. Once the RR data meet the criteria specified in the RNDZ OPS procedure, the data can be used to update the filter SV.

| | | |
|---------------------|----------------|---------------------|
| XXXX/033/ | REL NAV | XX X DDD:HH: MM: SS |
| RNDZ NAV ENA 1X | SV UPDATE | DDD:HH: MM: SS |
| KU ANT ENA 2X | POS XX. XX | Avg G ON 5X |
| MEAS ENA 3X | VEL XX. XX | |
| NAV | | |
| SV SEL 4 XXXX | RR XXXX | STAT P 1σ DES |
| RNG XXXX. XXX | RNG XXXX. XXXS | 1S XXXX XXXXX 31X |
| R ±XXXX. XX | R ±XXXX. XXS | 2S XXXX XXXXX 32X |
| θ XXX. XX | EL ±XXX. XS | 3S XXXX XXXXX 33X |
| Y ±XX. XX | AZ ±XXX. XS | |
| Y ±XXX. X | WP ±XX. XS | |
| NODE XX: XX: XX | WR ±XX. XS | |
| FILTER | | |
| S TRK 12X | COAS 14X | FLTR TO PROP 8X |
| RR 13X | X ±X. X | PROP TO FLTR 9X |
| STAT XXXXXXXXX XXXX | Y ±X. X | ORB TO TGT 10X |
| FLTR UPDATE 15 XXX | | TGT TO ORB 11X |
| COVAR REINIT 16X | | EDIT OVRD |
| RNG ±XX. XX | RESID X. X | AUT INH FOR |
| R ±XX. XX | RATIO XXX | 17X 18X 19X |
| V/EL/Y ±X. XX | XX. X | 20X 21X 22X |
| H/AZ/X ±X. XX | XXX XXXS | 23X 24X 25X |
| GPS X ±XXX. XX | X. XS | 42XS 43X 44X |
| X ±XXX. XX | X. XS | |

00603001.CRT, 3

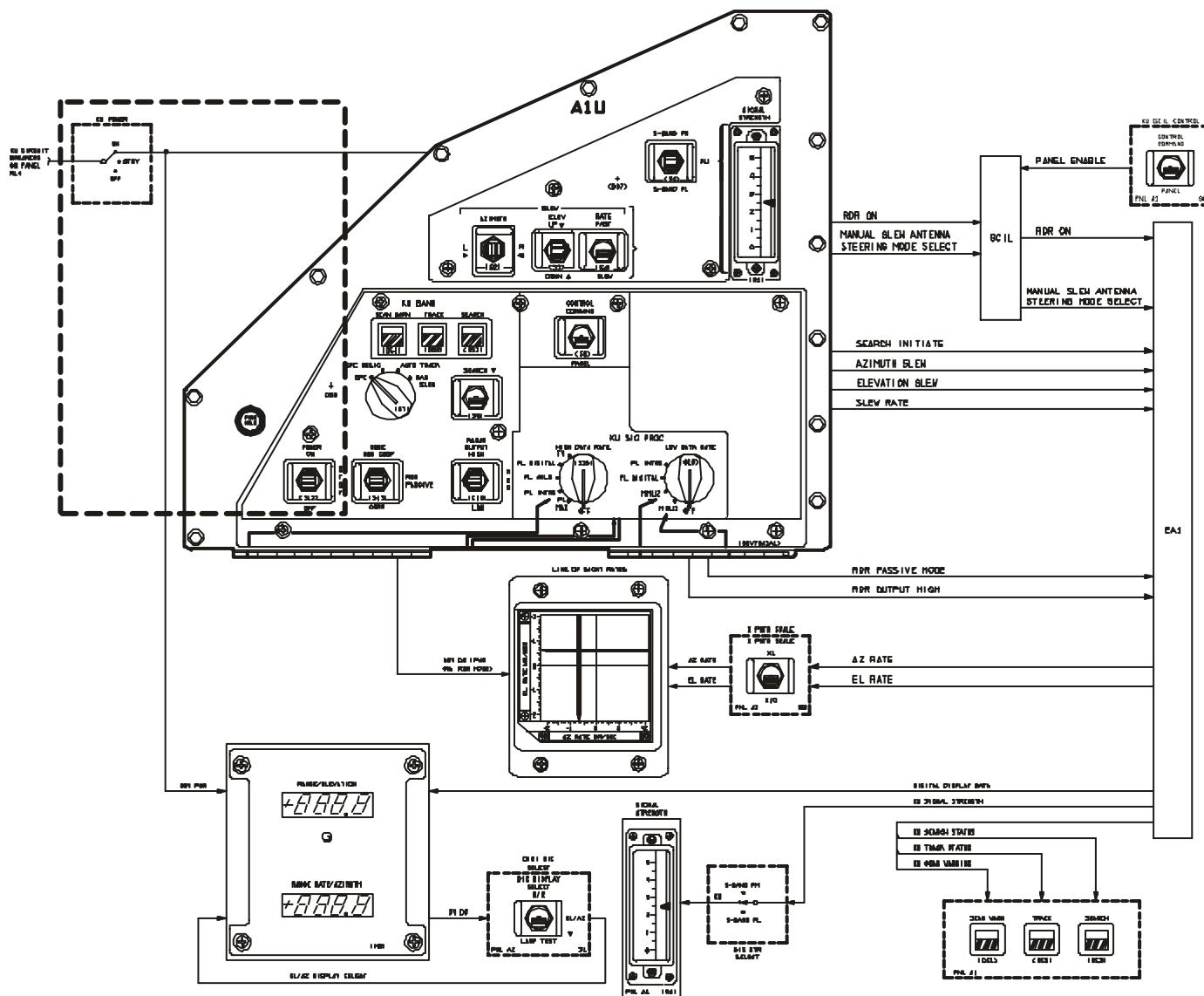
Figure 7-6. Rendezvous radar sensor enable

If no lock occurs by the time the range is 60,000 feet, the crew should perform the RR Auto Track ACQ procedure (Contingency Operations, RNDZ OPS). In the auto track mode, the slew switches should be moved as required until EL/AZ=0°/0° (Figure 7-7). If the KU TRACK tb is bp, then a manual search should be initiated to try to get lock-on. If no lock occurs within 1 minute, the Ku-band system is returned to the GPC antenna steering mode.

After the orbiter has moved close enough to the target, the crew will begin to use the RR range, range-rate, and angle-rate data to maintain a target position relative to the orbiter and to monitor distance and closure rates on the target. The range and range-rate data are displayed on the Panel A2 digital display. The KU RADAR OUTPUT switch is taken to LO power, per the FDF to prevent damage to the target from Ku-band RF output.

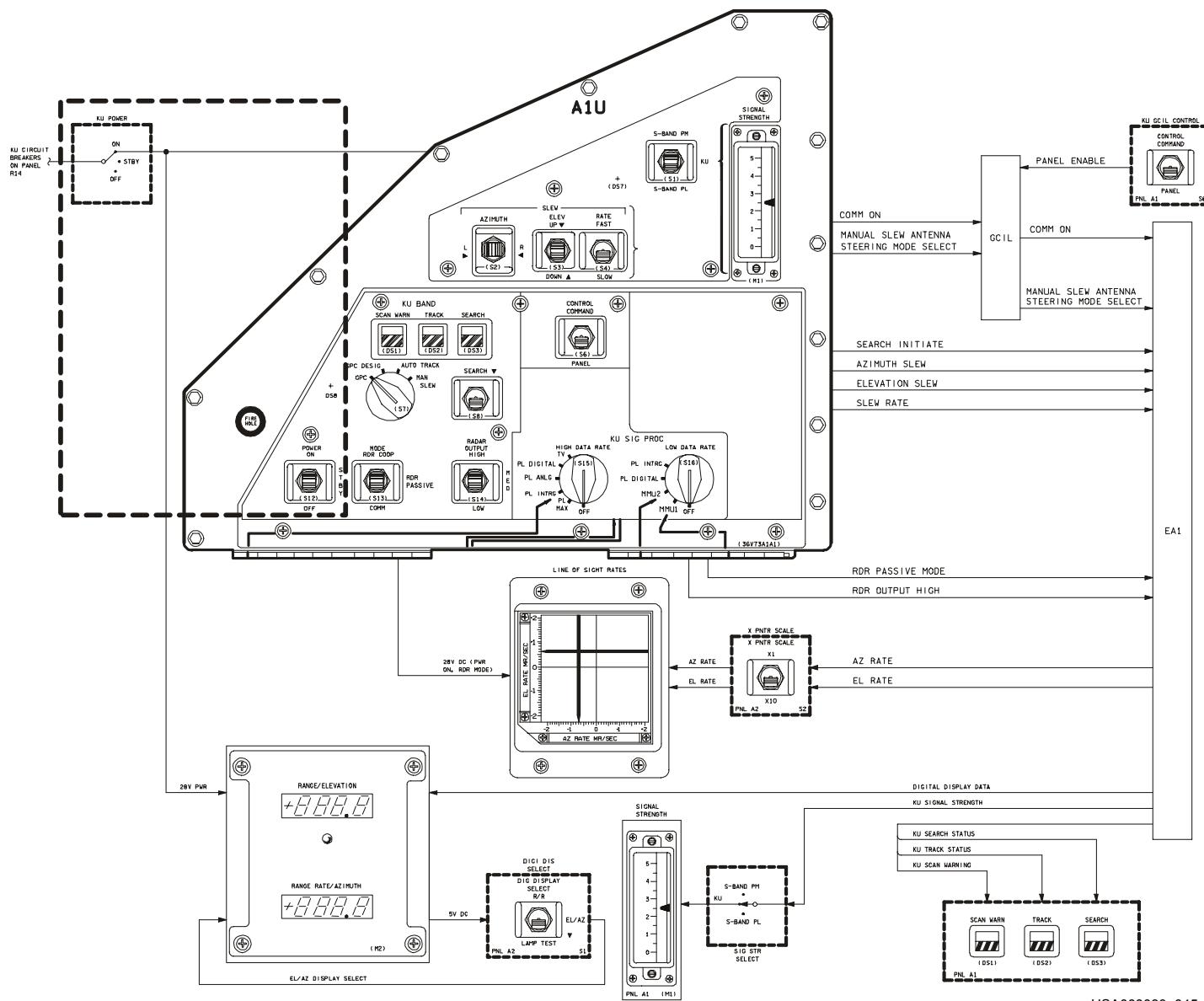
When RR breaks lock or RR range is 80 feet, the KU PWR switch is taken to STBY to inhibit RF output and to protect the rendezvous target. Although RF output is inhibited in the STBY mode, the TWTA will remain at operating temperature.

After the rendezvous with the target, the RNDZ NAV is disabled by doing an item 2 entry and an item 1 entry on SPEC 33. Also, the Ku-band system is reconfigured for comm operations: check that KU PWR is STBY, KU CNTL is CMD, KU MODE is COMM, antenna steering mode is in either GPC or GPC Des, and DIGI-DIS SEL is EL/AZ (Figure 7-8).



USA006030_045

Figure 7-7. Radar mode interfaces for auto track acquisition



USA006030_045a

Figure 7-8. Comm mode interfaces

7.5 SUMMARY

Two radar operation modes are available, but so far only the radar passive mode has been used. The purpose of the radar system in the passive mode is to search for, acquire, and track targets and to provide target data consisting of target angle, angle rate, range, and range rate to the crew via dedicated and CRT displays and to the ground controllers via the S-band return link. The radar system transmits a signal to a target and derives the target information from the echo signal. During rendezvous operations, the radar system is used as a sensor that provides target angle, angle-rate, range, and range-rate information for updating the rendezvous navigation data. During proximity operations, the system is used as a real-time source of information representing position and closing velocity of the target with respect to the orbiter.

7.6 QUESTIONS

1. The purpose of the radar system in the passive mode is to search for, acquire, and track targets and to provide target data. What target data are provided?
 - a. Target angle and angle rate
 - b. Range
 - c. Range rate
 - d. All of the above
2. True or false? In the radar passive mode, the radar system works by transmitting a signal and deriving target information from the echo signal.
3. During rendezvous operations, the Ku-band radar system is used as a sensor that provides _____ information for updating the rendezvous navigation data.
 - a. Target angle and angle rate
 - b. Range
 - c. Range rate
 - d. All of the above

8.0 STOW OPERATIONS

8.1 PERFORMANCE OBJECTIVES

The student should be prepared to accomplish the following tasks as a result of studying this section of the workbook:

- Explain the sequence of events that occur during the Ku-band stow procedures
- Explain the rationale for using the direct stow switch
- Describe the flight rules related to the stow operations

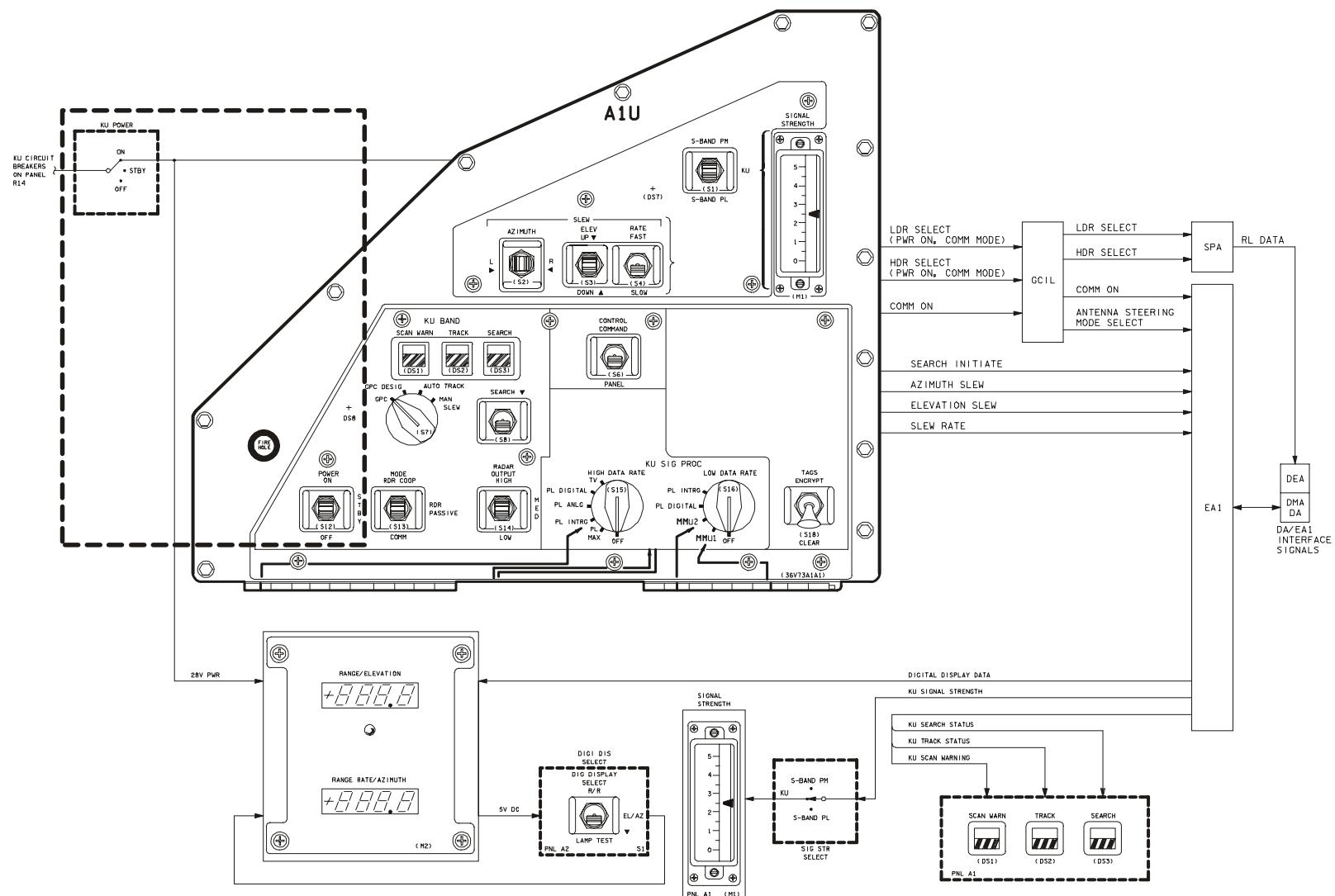
8.2 INTRODUCTION

The Ku-band antenna must be stowed in preparation for closing the payload bay doors for entry. The antenna is nominally returned to the stowed position during de-orbit preparation. The KU-BD ANT Stow procedure can be found in the Orbit Operations Checklist of the FDF.

8.3 ANTENNA STOW

The first step in the antenna stow procedure is to have the crew check switches on Panel R13L and configure switches on Panels A1U and A2: check that KU PWR is ON, MAN SLEW antenna steering mode, RDR PASSIVE mode, PNL control, and check that EL/AZ is selected on the DIGI-DIS SEL switch (Figure 8-1). The radar passive mode is used to minimize the effect of a power failure in stowing the antenna. The MAN SLEW selection is needed for cable positioning operations. The purpose of the cable positioning is to ensure that the cables through the rotary joint are free so they do not bind and cause erratic gimbal movement. The cable positioning procedure is no longer performed prior to stow operations.

The Digital Autopilot (DAP) will be configured to VERN or FREE DRIFT. This action is required by the flight rules to ensure proper gimbal locking during the antenna stow sequence. Damage to the gimbal locking mechanism may occur if orbiter movement is excessive.



USA006030_046

Figure 8-1. Ku-band stow interfaces

Next, the KU ANT switch is taken to STO. This step initiates a sequence of events that prepares the antenna for stowing. The events take about 50 seconds to complete. First, EA1 sends signals to the DEA to move the antenna to the stow angles, -29.0° ELEV/-125.0° AZM ($\pm 1^\circ$). The positioning performed by the crew was to get the antenna close to these angles so the antenna would not have to travel far to the stow position. After the antenna is positioned, the gimbal locking pins are driven in to secure the antenna in the proper stow position. The BOOM STOW ENABLE II signal is enabled when the pins are in place. EA1 initiates a wiggle test via the DEA to confirm that the gimbals are securely locked. If the pins are not locked when the wiggle test is performed, the antenna motion will be evident. When the wiggle test is completed successfully, EA1 enables a BOOM STOW ENABLE I signal which is indicated by a stow tb on Panel R13L (Figure 8-2).

Flight rules prohibit stowing the Ku-band DA without the gimbal locking pins in place, which secures the antenna in the correct stow position. Any antenna movement or change of angles is considered an indication that the gimbals are not locked. Several problems can cause incorrect angle readings; such as failure of the KU ANT DPY/STO switch, a gimbal lock failure, failure of the wiggle test or alpha/beta gimbal, or failure of the BOOM STOW ENABLE I or II signal. The KU ANT Deploy/Stow microswitch failure may require the Ku-band Antenna Contingency Deploy/Stow IFM. The gimbal lock failure may require the Ku-band Antenna Contingency Stow-Gimbal Lock IFM. Failure of the wiggle test or the alpha/beta gimbal may require an EVA and/or the Ku-band Antenna Contingency Stow-Gimbal Lock IFM. If either of the BOOM STOW ENABLE signals fails, an antenna jettison may be required. The antenna jettison procedure is discussed in Section 9.0.

If the angles are correct, the PL BAY MECH PWR SYS 1 and 2 switches (Panel R13L) are taken to ON (Figure 8-3). This action initiates the antenna stow only if BOOM STOW ENABLES I and II have been set. The KU ANT tb (Panel R13L) should go bp as soon as the antenna moves from the fully deployed position, and the tb should indicate STO in approximately 23 to 46 seconds. If the tb does not indicate STO in 46 seconds, the crew must perform malfunction procedures as directed by MCC.

Several different failures may prevent the STO indication on the KU ANT tb, including tb failure, limit switch mechanism failure, intermittent operations, mechanical failure or jammed mechanism, or any of the failures mentioned previously. If the limit switch mechanism fails in the deploy position, the Ku-band Antenna Deploy/Stow microswitch failure procedure, MECH SSR-7, will be required for subsequent deploy operations. If the KU ANT tb is bp and the DA is not stowed, the Ku-Bd ANT Deploy (ORB OPS) may be performed and the Contingency Ku-Bd ANT Direct Stow procedure, MECH SSR-5, may be performed. A STO tb will indicate that the problem was intermittent operations. If the tb is still bp, the problem is due to a mechanical failure or a jammed mechanism. An antenna jettison may be required if a mechanical failure or a jammed mechanism occurs.

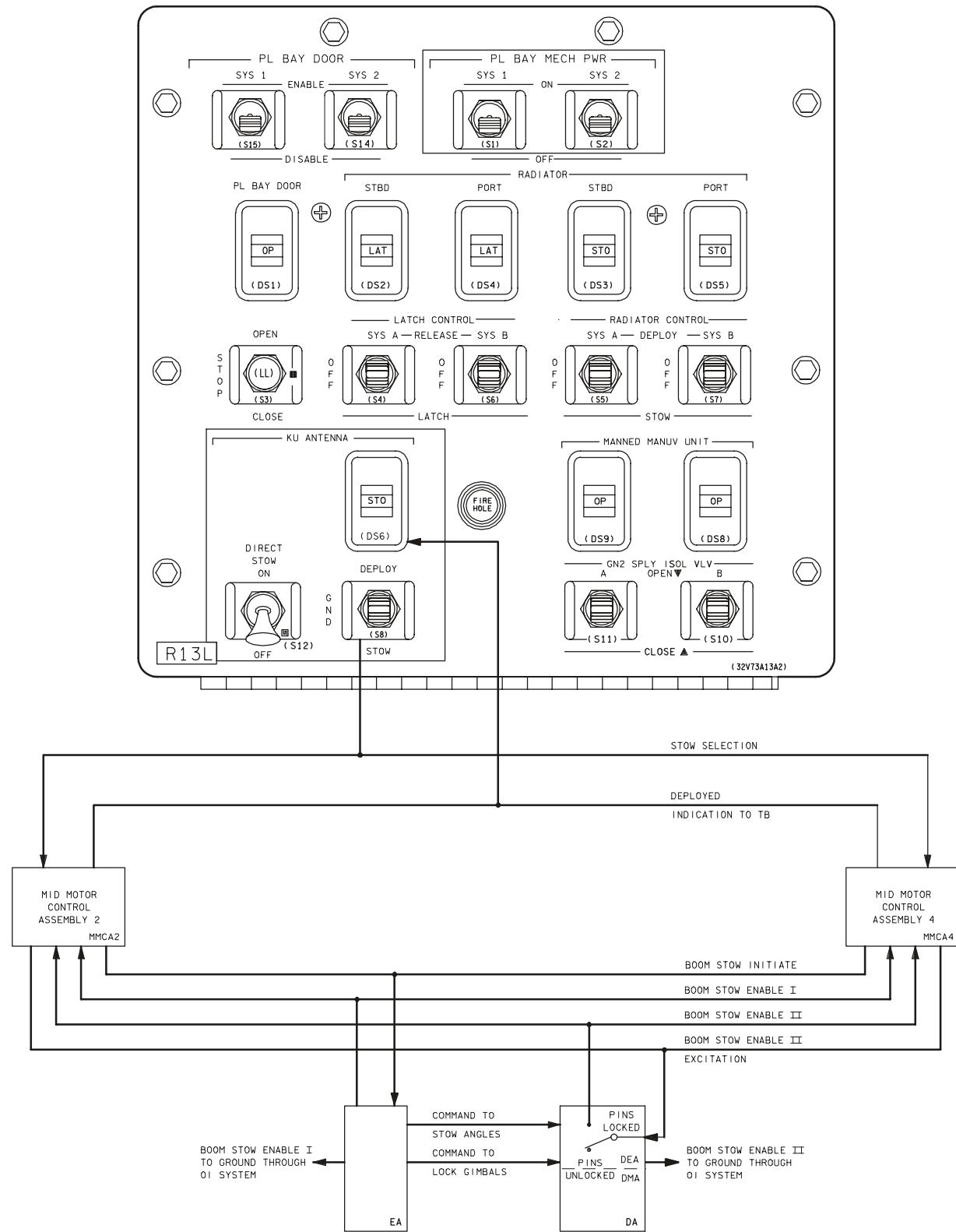
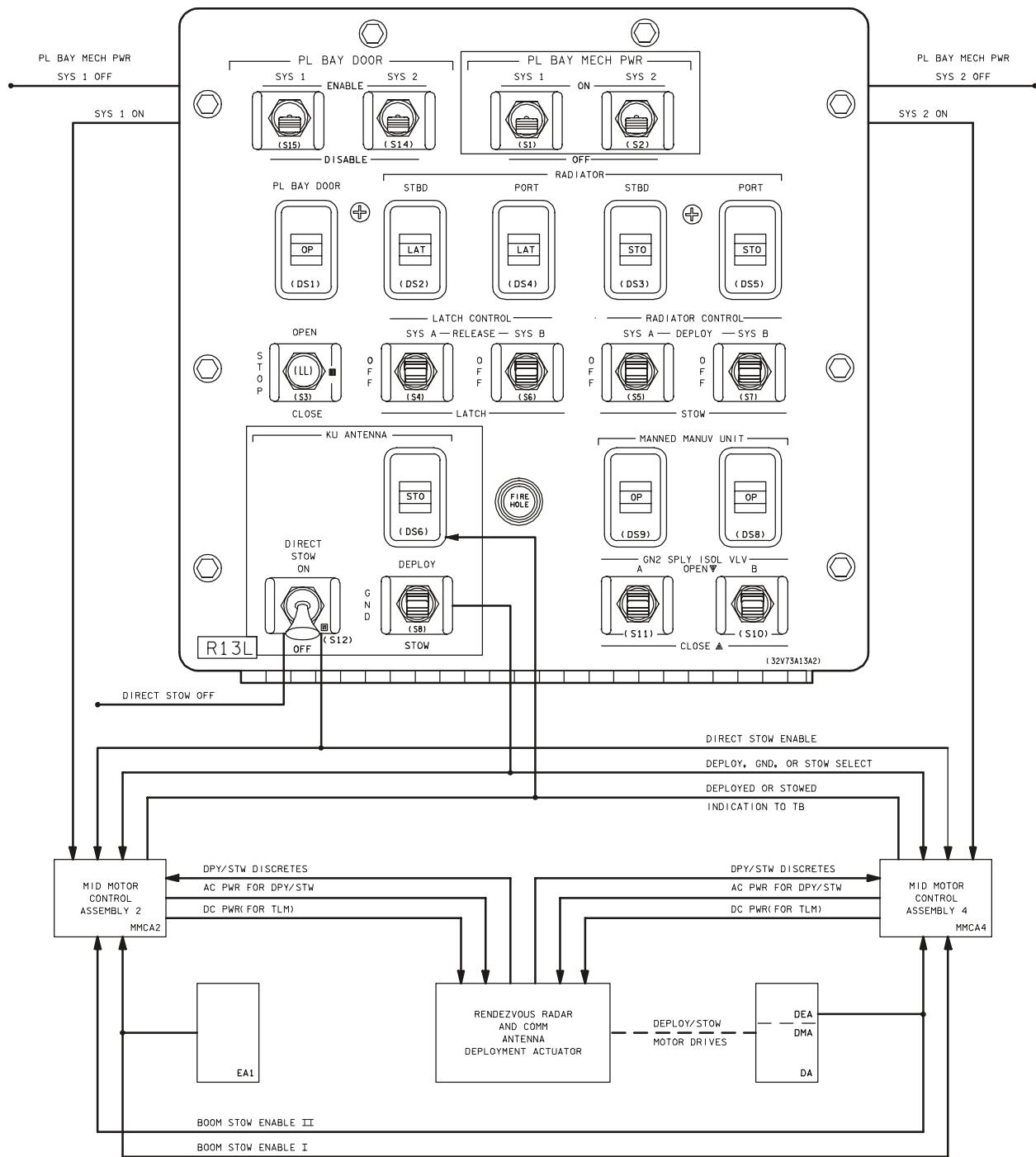


Figure 8-2. Positioning antenna for stow



00603050, SCH 1

Figure 8-3. Ku-band stow functional block diagram**CAUTION**

Before the Ku-band antenna is deployed, the KU PWR switch must be moved to OFF to prevent retracting the gimbal locking pins.

Once the antenna is stowed, the KU PWR switch is taken to OFF (Panel A1U), the MNB KU ELEC and MNC KU SIG PROC circuit breakers are opened (Panel R14C), and the KU ANT switch is taken to GND (Panel R13L). Finally, the PL BAY MECH PWR SYS 1 and 2 switches are taken to OFF.

In addition to the malfunctions mentioned previously, the Ku-band antenna stow will be prevented if the power to EA1 is lost. The power loss could be due to a shorted line of sight rates meter, digital display meter, or EA2, or to other failures causing the loss of RPC no. 53. RPC no. 53 controls MNC power to EA1. To stow the antenna, the Ku-band Antenna Contingency Stow - EA1 Alternate Power IFM must be executed.

8.4 DIRECT STOW

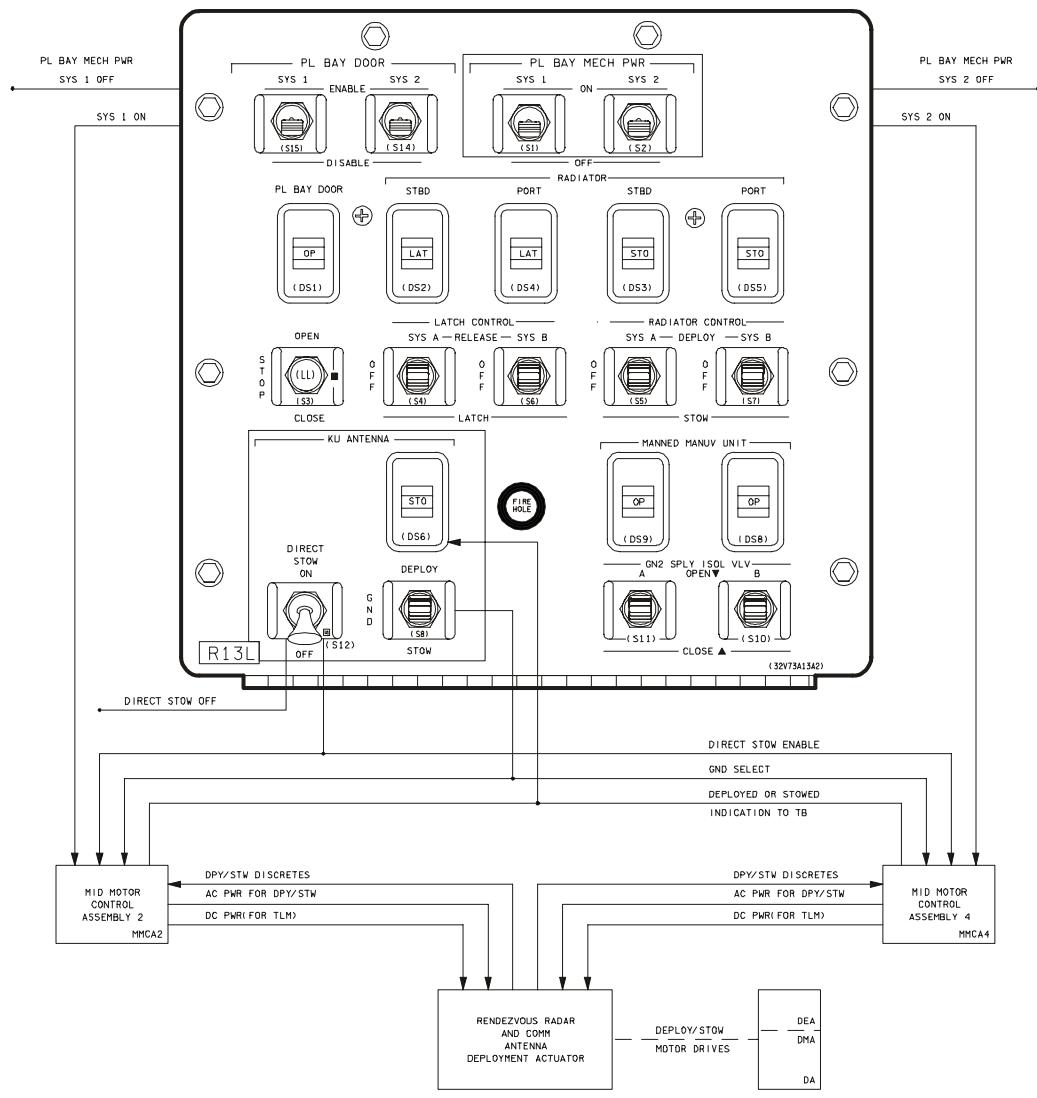
The Contingency Ku-Bd ANT Direct Stow procedure, MECH SSR-5 in the Malfunction Procedures book, is used when the antenna will not stow via the normal stow process. This procedure will not be used unless the antenna dish gimbals are verified to be in the nominal stow position with the antenna gimbal pins locked. If the antenna dish is not in a nominal stow position, it could damage the radiators and/or payload bay doors when the DA is stowed.

For the Direct Stow procedure, the CCTV system is configured to monitor the Ku-band antenna as it is stowed. Once the CCTV system is ready, switches on Panels R13L and A1U must be configured. This action includes taking KU PWR to OFF and KU ANT to Ground (GND). The power must be off to prevent the antenna from radiating during stow.

CAUTION

The KU ANT switch must be in the GND position prior to use of the KU ANT DIRECT STO switch to prevent a phase-to-phase short of the stow/deploy motors.

Once the KU ANT switch is in GND, the stow process can be initiated by taking the KU ANT DIRECT STO switch and PL BAY MECH PWR switches to ON. The DIRECT STO ON applies a signal to MID MCA2 and MID MCA4 that simulates proper BOOM STOW ENABLE I and II signals, allowing the Ku-band DA to be stowed in the absence of either or both BOOM STOW ENABLE signals. When the KU ANT tb shows STO (23 to 46 seconds), the KU ANT DIRECT STO switch and the PL BAY MECH PWR switches are taken to OFF (Figure 8-4).



00603042. SCH; 1

Figure 8-4. Ku-band direct stow functional block diagram

Finally, the CCTV system is used to verify that the Ku-band antenna is within the stow envelope. This verification is necessary to allow the payload bay doors to be closed without damage to them or the radiators. The correct stow position for the Ku-band antenna is shown on the Ku-band CCTV overlay (Figure 8-5). To enable proper use of the overlay, the CCTV monitor must be in the UNDERSCAN mode.

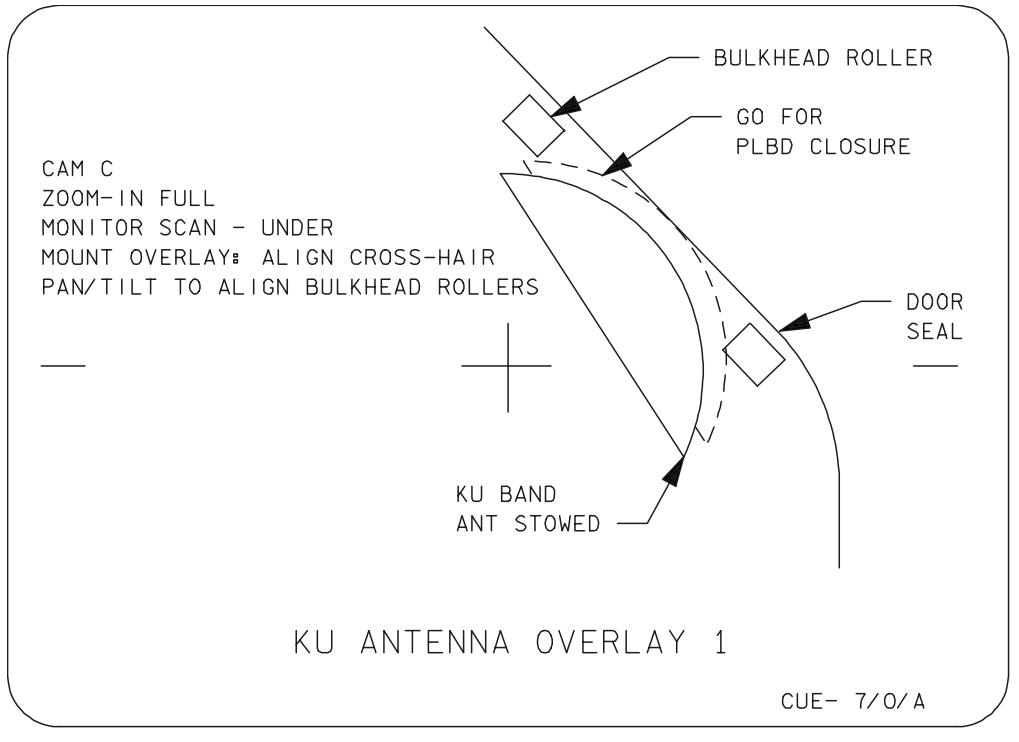


Figure 8-5. Ku-band CCTV overlay

Note: This figure is smaller than actual size.

8.5 CONTINGENCY STOW

The Ku-Bd ANT Stow procedure mentioned previously is used during nominal operations. Another stow procedure (called Stow Ku-Bd Antenna) is located in the Contingency De-Orbit Preparation Checklist of the FDF and is used only in case of an emergency de-orbit. The emergency stow procedure differs somewhat from the Ku-Bd ANT Stow procedure. Since it is designed for a worst-case scenario, activities that are not absolutely necessary are omitted.

8.6 SUMMARY

The Ku-band antenna must be stowed in preparation for closing the payload bay doors for entry. The Ku-Bd ANT Stow procedure includes the following events: positioning the antenna to the stow angles, driving in the gimbal locking pins, performing a wiggle test, and stowing the antenna. Flight rules prohibit the stowing of the Ku-band DA without the gimbal locking pins in place, securing the antenna in the correct stow position. If the antenna will not stow via normal stow activities, the Direct Stow procedure can be used as long as the antenna gimbals are verified to be in the nominal stow position with the antenna gimbal pins locked.

Figure 8-6 illustrates the current KU-BD ANT STOW procedure listed in the current Orbit Ops Checklist.

KU-BD ANT STOW

R13L . PL BAY MECH PWR SYS 1,2 (two) – OFF
A1U . KU CNTL – CMD
PWR – ON
 MODE – RDR PASSIVE
 CNTL – PNL
 sel – MAN SLEW
A2 . DIGI-DIS SEL – EL/AZ
A1U SLEW RATE – as reqd

 SLEW ELEV – as reqd:
A2 R/EL ind: -27.0 ($\pm 1^\circ$)

A1U SLEW AZM – as reqd:
A2 R/AZM ind: -123.0 ($\pm 1^\circ$)

LOCK GIMBALS

NOTE

KU ANT sw must remain in STOW until
STOW DEPLOYED ASSEMBLY complete

DAP: VERN(FREE)

R13L KU ANT – STOW

A2 . R/EL ind: -29.0 ($\pm 1^\circ$)
 . R/AZM ind: -125.0 ($\pm 1^\circ$)

00:00 StartEventTimer
A2 Monitor KU ANT gimbal angles for 50 sec
 (gimbal lock test), then:

 * If KU ANT gimbal movement occurs *
 * within 50 sec, and/or if gimbal *
 * angles incorrect after 50 sec, *
 * perform MAL, MECH, 9.3c *

DAP: as reqd

Cont next page

2-5 ORB OPS/ALL/GEN J

Figure 8-6. Ku-band ant stow

STOW DEPLOYED ASSEMBLY

R13L PL BAY MECH PWR SYS 1,2 (two) – ON
 ?KU ANT tb – STO (~23 to 46 sec)

* If tb not STO after 46 sec, *
* perform MAL, MECH, 9.3b *

A1U KU PWR –OFF (Expect ‘BCE BYP KU’ msg)
R14:C cb MNB KU ELEC – op
 MNC KU SIG PROC – op

R13L PL BAY MECH PWR SYS 1,2 (two) – OFF
 KU ANT – GND

OCA If not in D/O Prep,
 go to OCA S-BAND MODEM (MFX)
 ACTIVATION (PGSC)

2-6 ORB OPS/ALL/GEN J

Figure 8-6. Ku-band ant stow (concluded)

8.7 QUESTIONS

1. Taking the KU ANT switch to STO initiates a sequence of events that prepares the antenna for stowing. Which of the following lists gives the events in the correct order?
 - a. Move the antenna to the stow angles, drive in the gimbal locking pins, and perform a wiggle test.
 - b. Drive in the gimbal locking pins, move the antenna to the stow angles, and perform a wiggle test.
 - c. Move the antenna to the stow angles, stow the antenna, and drive in the gimbal locking pins.
 - d. Move the antenna to the stow angles, stow the antenna, and perform the wiggle test.
2. The _____ switch will be used only when the antenna will not stow via the normal stow process. By using this switch, the Ku-band DA can be driven to the stow position, even if either or both BOOM STOW ENABLE signals are missing.
 - a. KU ANT DPY/STO
 - b. KU ANT DIRECT STO
 - c. KU PWR
 - d. None of the above
3. True or false? Flight rules prohibit the stowing of the Ku-band DA without the gimbal locking pins in place, securing the antenna in the correct stow position.

9.0 JETTISON

9.1 PERFORMANCE OBJECTIVES

The student should be prepared to accomplish the following tasks after studying this section of the workbook:

- Explain when the jettison procedure is used
- Describe the sequence of events that occurs during the jettison procedure

9.2 INTRODUCTION

In the deployed position, the DA interferes with closing the payload bay doors. The Ku-band antenna must be stowed within a specific stow envelope with the gimbals locked for the payload bay doors to be properly closed. If for any reason the DA cannot be stowed, it must be jettisoned before the orbiter can enter the atmosphere. The Ku-Bd ANT Jettison procedure is located in the Orbit Operations Checklist of the FDF.

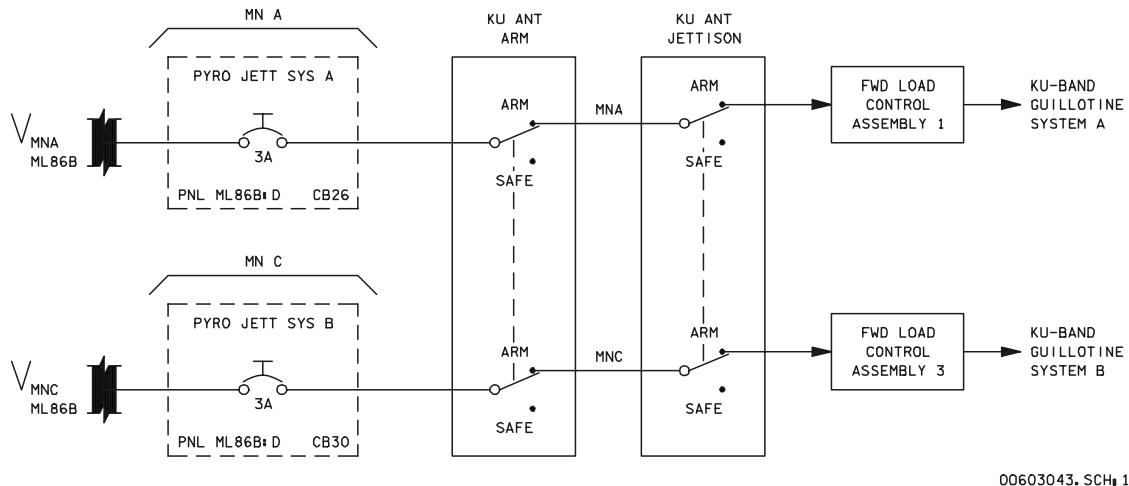
9.3 JETTISON

In the first part of the procedure, the CRT and Panel A6U are used to maneuver the orbiter for the jettison operations. Next, the Ku-band system is configured for the jettison. The KU PWR switch is taken to OFF, the Ku-band cb's on Panel R14 are opened, the PYRO KU ANT ARM and JETT switches (Panel A14) are checked to make sure they are in SAFE, and the MCA LOGIC MNC MID 2 and MNB MID 4 switches on Panel MA73C are taken to OFF. The reason the power switches are taken to OFF and the cb's are opened is to prevent a spike when the antenna cable is cut.

Next, the MNA PYRO JETT SYS A KU ANT and the MNC PYRO JETT SYS B KU ANT cb's are closed; this action applies redundant power to the PYRO KU ANT ARM and JETT switches on Panel A14 (Figure 9-1). The CCTV system is configured to monitor the jettison.

The actual jettison operation begins when the PYRO KU ANT ARM switch is taken to ARM. This allows power to get to the JETT switch and removes control power that allowed the DA heaters to be monitored. After waiting 1 second, the PYRO KU ANT JETT switch is taken to JETT (Figure 9-1). This action initiates the jettison. The pyrotechnics cause a guillotine to cut the antenna cable and cause bolts holding the DA to be fractured. The orbiter then maneuvers away from the DA.

When the DA is no longer visible, the crew completes the cleanup portion of the procedures. This includes taking the ARM and JETT switches back to SAFE, opening the PYRO JETT SYS A and B KU ANT cb's, and taking the MCA LOGIC MNC MID 2 and MNB MID 4 switches back to ON.

**Figure 9-1. Jettison power**

9.4 QUICK RESPONSE JETTISON

The jettison procedure mentioned previously is used when all possible attempts to stow the Ku-band DA have failed. Another jettison procedure (called Quick Response Jettison) is located in the Contingency De-Orbit Preparation Checklist of the FDF and is used only in the case of an emergency de-orbit. The Quick Response Jettison procedure differs somewhat from the aforementioned jettison procedure. Since designed for a worst-case scenario, activities that are not absolutely necessary are omitted.

9.5 SUMMARY

In the deployed position, the DA interferes with closing the payload bay doors. If for any reason the DA cannot be stowed, it must be jettisoned. The Ku-Bd ANT Jettison procedure includes configuring the Ku-band system, taking the PYRO KU ANT ARM switch to ARM, taking the PYRO KU ANT JETT switch to JETT, and maneuvering the orbiter away from the released DA. When the ARM and JETT selections have been made, the jettison is initiated.

9.6 QUESTIONS

1. The _____ procedure is used when the DA cannot be stowed.
 - a. Contingency Ku-Bd Ant Direct Stow
 - b. Ku-Bd Cable Positioning
 - c. Ku-Bd ANT Jettison
 - d. Ku-Bd Manual Acquisition
2. When the PYRO KU ANT ARM switch is taken to ARM and the PYRO KU ANT JETT switch is taken to JETT, the jettison is initiated. The pyrotechnics cause a guillotine to cut the antenna cable and cause _____.
 - a. The DA to blow away from the orbiter
 - b. The DA to stow
 - c. The DA to deploy
 - d. The bolts holding the DA to be fractured

APPENDIX A
ACRONYMS AND ABBREVIATIONS

| | |
|----------|-------------------------------|
| α | alpha |
| A/G | Air-to-Ground |
| AC | Alternating current |
| ACQ | Acquisition |
| ANT | Antenna |
| AOS | Acquisition of Signal |
| AUTO | Automatic |
| AZ | Azimuth |
| AZM | Azimuth |
| β | beta |
| bp | barberpole |
| cb | circuit breaker |
| CCTV | Closed Circuit Television |
| CMD | Command |
| CNTL | Control |
| COAS | Crew Optical Alignment Sight |
| comm | Communication(s) |
| COMSEC | Communications Security |
| Config | Configuration |
| CRT | Cathode Ray Tube |
| DA | Deployed Assembly |
| DAP | Digital Autopilot |
| DC | Direct current |
| DEA | Deployed Electronics Assembly |
| DIG | Digital |
| DIGI | Digital |
| DIS | Display |
| DL | Downlink |
| DMA | Deployed Mechanical Assembly |
| DPY | Deploy |
| DSC | Dedicated Signal Conditioner |
| EA | Electronics Assembly |
| EA1 | Electronics Assembly 1 |
| EA2 | Electronics Assembly 2 |
| EL | Elevation |
| ELEC | Electronic |
| ELEV | Elevation |
| ENA | Enable |
| EVA | Extravehicular Activity |

| | |
|---------|--|
| F | Fahrenheit |
| FDF | Flight Data File |
| FF | Flight Forward |
| FL | Forward Link |
| FM | Frequency Modulation |
| GCIL | Ground Command Interface Logic |
| GCILC | Ground Command Interface Logic Controller |
| GNC | Guidance, Navigation, and Control |
| GND | Ground |
| GPC | General Purpose Computer |
| HDR | High Data Rate |
| HTR | Heater |
| I/O | Input/Output |
| IFM | In-Flight Maintenance |
| INCO | Integrated Communications Officer |
| INH | Inhibit |
| INST | Instrumentation |
| ISS | International Space Station |
| IVA | Intravehicular Activity |
| JETT | Jettison |
| JSC | Lyndon B. Johnson Space Center |
| KU | Ku-band |
| KU-BD | Ku-band |
| Ku-Bd | Ku-band |
| LDR | Low Data Rate |
| LOS | Line of Sight |
| | Loss of Signal |
| LRU | Line Replaceable Unit |
| LVPS | Low-Voltage Power Supply |
| MAN | Manual |
| MCA | Motor Control Assembly |
| MCC | Mission Control Center |
| MDM | Multiplexer/Demultiplexer |
| MECH | Mechanical |
| Microsw | Microswitch |
| MIP | Master Index Pulse |
| MMACS | Maintenance, Mechanical, Arm, and Crew Systems |
| MMC | Mid Motor Controller |
| MMCA | Mid Motor Control Assembly |
| MNA | Main (bus) A |

| | |
|-----------|---|
| MNB | Main (bus) B |
| MNC | Main (bus) C |
| MOD | Mission Operations Directorate |
| MSTR | Master |
| n. mi. | Nautical mile |
| NASA | National Aeronautics and Space Administration |
| NAV | Navigation |
| NRZ | Non-Return-to-Zero |
| NRZ-L | Non-Return-to-Zero Level |
| NSP | Network Signal Processor |
| OI | Operational Instrumentation |
| OCA | Orbiter Communications Adapter |
| OPS | Operations |
| OVRD | Override |
| OVRTMP | Overtemperature |
| P/L | Payload |
| PA | Power Amplifier |
| PCMMU | Pulse Code Modulation Master Unit |
| PF | Payload Forward |
| PL | Payload |
| PM | Phase Modulation |
| PNL | Panel |
| Prep | Preparation |
| PROC | Processor |
| PWR | Power |
| PYRO | Pyrotechnics |
| R | Range |
| \dot{R} | Range Rate |
| RCDR | Recorder |
| RDR | Radar |
| RF | Radio Frequency |
| RL | Return Link |
| RNDZ | Rendezvous |
| RPC | Remote Power Controller |
| RR | Rendezvous Radar |
| S-Bd | S-band |
| S/L | Spacelab |
| SEL | Select |
| SGLS | Space Ground Link System |
| SGLSS | SGLS Site |
| SIG | Signal |
| SM | Systems Management |

| | |
|-------|--|
| SPA | Signal Processor Assembly |
| SSO | Space Shuttle Orbiter |
| SSR | Single System Recovery |
| ST | Star Tracker |
| STBY | Standby |
| STDN | Space Tracking and Data Network |
| STO | Stow |
| STV | Secure Television |
| SV | State Vector |
| SYS | System |
| TB/tb | Talkback |
| TDRS | Tracking and Data Relay Satellite |
| TDRSS | Tracking and Data Relay Satellite System |
| TEMP | Temperature |
| TLM | Telemetry |
| TWT | Traveling Wave Tube |
| TWTA | Traveling Wave Tube Amplifier |
| UHF | Ultrahigh Frequency |
| UL | Uplink |
| VAR | Variable |

APPENDIX B ANSWERS

Answers to Section 2

1. (b) The DEA contains the Ku-band RF equipment.
2. (d) The DMA includes the antenna dish and gimbals to provide the RF interface with the TDRS system.
3. (c) EA1 is the radar/comm interface and control LRU.
4. (e) EA2 is the radar signal processor.
5. (a) The SPA is the communications signal processor.
6. (d) In the communications mode, the Ku-band system uses the DA, EA1, and SPA.
7. (c) In the radar mode, the Ku-band system uses the DA, EA1, and EA2.

Answers to Section 3

1. The KU ANT HTR cb on Panel R14 provides power to the five heaters on the DA.
2. The KU PWR switch on Panel A1U allows power to get to KU switches and meters.
3. The KU CNTL switch on Panel A1U allows the configuration of the system to be controlled by the ground or the crew, depending on its position.
4. The KU ANT switch on Panel R13L applies the dc control voltage needed to initiate deploy or stow of the Ku-band antenna.
5. The KU ANT tb on Panel R13L indicates whether the antenna is deployed or stowed.
6. The PL BAY MECH PWR SYS 1 and SYS 2 switches on Panel R13L allow three-phase ac power to get to the deploy/stow motors in MMCA2 and MMCA4.
7. False. The KU ANT HTR cb should be closed during post insertion activities in preparation for deployment of the Ku-band antenna.
8. True. The Ku-band antenna can be safely deployed only when the orbiter is on orbit and the payload bay doors are opened.
9. The procedure for the deployment of the Ku-band antenna is located in the Orbit Operations Checklist.

10. At the beginning of the deploy procedure, the crewmember should check that the KU PWR switch is off to prevent the Ku-band antenna from initializing prematurely.
11. False. The KU CNTL switch must be in PNL for the switch movements to be acknowledged.
12. d. When the PL BAY MECH PWR SYS 1 and SYS 2 switches are taken to ON and the KU ANT DPY/STO switch is taken to DPY, the Ku-band antenna deploy sequence is initiated. The deploy sequence takes 23 seconds for dual-motor deploy and 46 seconds for single-motor deploy.
13. b. The KU ANT talkback should indicate DPY when the antenna is fully deployed.
14. c. For the deploy and stow operations, power from redundant three-phase ac power buses (AC 3 and AC 2) is applied to system 1 and system 2 motors through cb's on Panel MA73C and relays in mid motor control assemblies (MMCA2 and MMCA4). The relays are energized through the ON contacts of the PL BAY MECH PWR SYS 1 and SYS 2 switches on Panel R13L.
15. a. The KU ANT switch applies a dc control voltage to the system 1 and system 2 MCAs to initiate the deploy or stow procedure.
16. True. Flight rules state that the Ku-band antenna should be deactivated and stowed if the heater temperatures cannot be controlled or monitored.
17. False. There is a flight rule that states that nominally the Ku-band antenna should be stowed as soon as possible if only one deploy/stow motor is operating.
18. False. There is a flight rule that states that the antenna should be stowed if attempts to fully deploy the antenna are unsuccessful.

Answers to Section 4

1. The KU ANT HTR cb on Panel R14 provides power to the five heaters on the DA.
2. The KU RADAR OUTPUT switch on Panel A1U is used to select the desired output power.
3. The KU ELEC cb on Panel R14 provides power to the Ku-band electronic circuitry.
4. The KU SIG PROC cb on Panel R14 provides power to the Ku-band SPA.
5. The DIGI-DIS SEL switch on Panel A2 is used to select the desired digital display.
6. The KU PWR switch on Panel A1U allows power to get to Ku-band switches and meters and starts the antenna initialization.

7. The KU MODE switch on Panel A1U is used to select between communications and radar operations.
8. c. The Ku-band initialization sequence starts when the KU PWR switch is taken to ON.
9. d. Microprocessor initialization and gyro spinup, gimbal locking pin removal, and antenna alignment are all part of the initialization sequence.
10. a. The initialization sequence is complete in approximately 4 minutes, which gives the traveling wave tube time to warm up.
11. d. The purpose of the self-test is to perform a series of tests to demonstrate that the EA1, EA2, and DA assemblies are operational.

Answers to Section 5

1. a. The obscuration mask can be seen on SM OPS 2011 ANTENNA display.
2. c. The obscuration mask works in conjunction with the scan warning system. If the Ku-band antenna points in the area below the obscuration mask, the radiation from the TWT will be inhibited and the KU SCAN WARN talkback on Panel A1U will go gray.
3. b. In the beta only mode, the radiation from the TWT will be inhibited if the Ku-band antenna points in the area below the beta line.
4. c. In the beta + mask mode, the radiation from the TWT will be inhibited if the Ku-band antenna points both in the area of the obscuration mask and below the beta line.
5. b. When the GPC mode is selected, the capabilities include commanded angles provided by the SM GPC, automatic search, automatic track, and inertial stabilization.
6. d. When the GPC designate mode is selected, the capabilities are commanded angles provided by the SM GPC, no angle search, no angle track, and inertial or body stabilization.
7. c. Manual steering, manual search, automatic track, and inertial stabilization are part of the auto steering mode.
8. a. Manual steering, no angle search, no angle track, and body stabilization are part of the manual slew mode.

Answers to Section 6

1. b. The Ku-band comm system forward link goes through the DA, EA1, and SPA.
2. d. The Ku-band comm system return link goes through the SPA and DA.
3. d. The data provided by the mode 1 forward link are voice, commands, and payload commands.
4. e. The data provided by the mode 2 forward link are voice and commands.
5. a. For mode 1 return link, the data source for channel 3 can only be PL MAX.
6. b. For mode 2 return link, the data source for channel 3 can be TV, PL ANLG, PL DIGITAL, or PL INTRG.

Answers to Section 7

1. d. The purpose of the radar system in the passive mode is to search for, acquire, and track targets and to provide target data. The target data provided are target angle and angle rate, range, and range rate.
2. True. In the radar passive mode, the radar system works by transmitting a signal and deriving target information from the echo signal.
3. d. During rendezvous operations, the Ku-band radar system is used as a sensor that provides target angle and angle rate, range, and range rate information for updating the rendezvous navigation data.

Answers to Section 8

1. a. Taking the KU ANT switch to STO initiates a sequence of events that prepare the antenna for stowing. The proper sequence of events is moving the antenna to the stow angles, driving in the gimbal locking pins, and performing a wiggle test.
2. b. The KU ANT DIRECT STO switch will be used only when the antenna will not stow via the normal stow process.
3. True. Flight rules prohibit the stowing of the Ku-band DA without the gimbal locking pins in place, securing the antenna in the correct stow position.

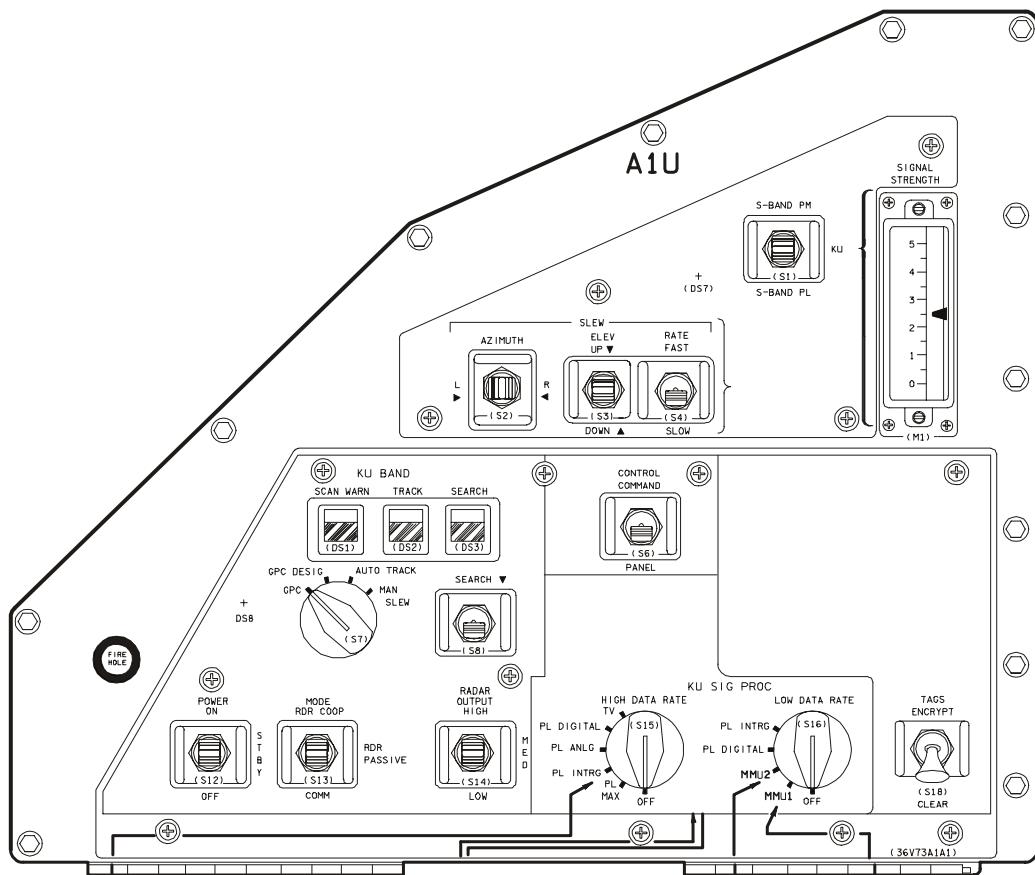
Answers to Section 9

1. c. The Ku-Bd ANT Jettison procedure is used when the DA cannot be stowed.
2. d. When the PYRO KU ANT ARM switch is taken to ARM and the PYRO KU ANT JETT switch is taken to JETT, the jettison is initiated. The pyrotechnics cause a guillotine to cut the antenna cable and cause bolts holding the DA to be fractured.

APPENDIX C

CONTROLS AND DISPLAYS

This section includes detailed descriptions of all controls and displays used by the flight crew to operate the Ku-band system. Illustrations of panels, displays and associated switches, indicators, circuit breakers, etc., are included. Controls and displays are tabulated with descriptions of their functions.



USA006030_047

Figure C-1. Panel A1U

Panel A1U Controls and Displays

Refer to Figure C-1 for Panel A1U illustration.

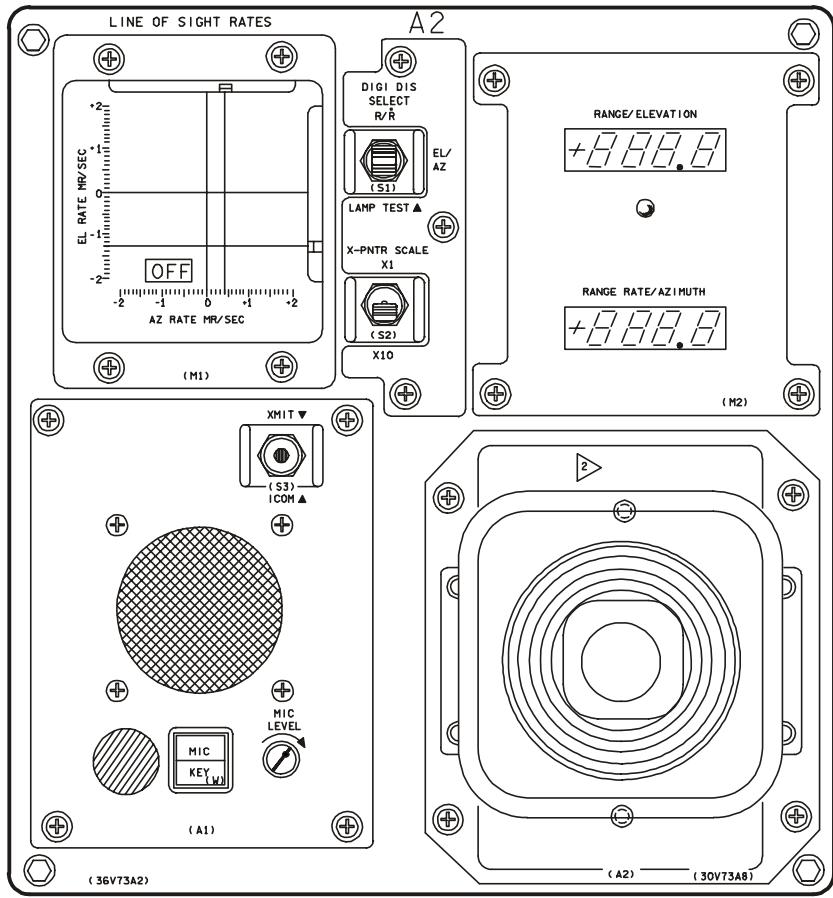
| Nomenclature | Description |
|--------------------------|---|
| S-band PM, KU, S-band PL | sel Selects receiver signal strength source for the adjacent meter indicator. |
| S-band PM | Not used for Ku-band operation. |
| KU | Selects Ku-band receiver signal strength. |
| S-band PL | Not used for Ku-band operation. |

| Nomenclature | | Description |
|-----------------|-----|--|
| SIGNAL STRENGTH | ind | Represents the magnitude of received signal strength. The analog voltage for this indication originates in the receiver automatic gain control circuitry. Note: The signal strength data are displayed on SM OPS 201 ANTENNA display. |
| SLEW | | Provide manual steering for the Ku-band antenna in auto track and manual slew modes only. Note: The antenna angular position may be read on Panel A2 digital readouts. |
| AZIMUTH | sw | Momentary switch that provides control of azimuth movement. L Provides a signal that results in the Ku-band antenna rotating to the left (+Y-axis). ctr Removes signals from the Ku-band antenna slew azimuth circuit. R Provides a signal that results in the Ku-band antenna rotating to the right (-Y-axis). |
| ELEV | sw | Momentary switch that provides control of elevation movement. UP Provides a signal that results in the Ku-band antenna rotating upward (+X-axis). ctr Removes signals from the Ku-band antenna slew elevation circuit. DOWN Provides a signal that results in the Ku-band antenna rotating downward (-X-axis). |
| RATE | sw | Provides steering rate control of the antenna movement in azimuth and elevation. FAST Provides a 20-deg/sec antenna movement rate. SLOW Provides a 0.4-deg/sec antenna movement rate. |
| KU-BAND | tb | Talkbacks that provide system status. In addition, they are used to indicate the successful completion of the radar self-test. |
| SCAN WARN | tb | Provides an indication of the status of the scan warning system. gray Indicates that the antenna is pointing in the obscuration mask. barberpole Indicates that the antenna beam is not pointing in the obscuration mask. |

| Nomenclature | | Description |
|---------------|-----|---|
| TRACK | tb | Provides an indication of the status of the tracking system. |
| gray | | Indicates that the tracking system is tracking a target in angles and/or range. |
| barberpole | | Indicates that the tracking system is not tracking a target. |
| SEARCH | tb | Provides an indication of the status of the spiral search system. |
| gray | | Indicates that a spiral search is in progress. |
| barberpole | | Indicates that a search is not in progress. |
| CONTROL | sw | A two-position switch used to determine whether parts of the Ku-band system are under panel (crew) or ground (command) control. |
| COMMAND | | The functions of power, steering mode, high-data-rate, and low-data-rate switches are controlled by ground commands. Ground controllers can command to the communications mode, but not to the radar mode. |
| PANEL | | Enables the Panel A1U switches. |
| STEERING MODE | rot | Provides manual selection of the four antenna steering modes. |
| GPC | | Ku-band antenna steering is controlled by the GPC until target tracking is accomplished. Tracking continues in both angles and range. Note: If track is not accomplished when the antenna reaches the GPC designated position, a spiral search will be automatically initiated by GPC command. |
| GPC DESIG | | Ku-band antenna steering is controlled by the GPC. Range tracking is initiated automatically when the target is detected. Angle tracking is not available. Antenna steering is dependent on a GPC update at 2-second intervals. |
| AUTO TRACK | | Ku-band antenna steering is crew-initiated by using the manual slew switches on this panel. If a target is detected, the system will auto track in angles and range. When tracking is initiated, further manual control is inhibited. |

| Nomenclature | Description |
|--------------|--|
| MAN SLEW | Ku-band antenna steering is controlled solely from the manual slew switches on this panel. Only range tracking is available; no auto angle tracking and no searching. |
| SEARCH | sw In the momentary position, this switch initiates a search sequence around the designated antenna angle. It is used in the auto-track steering mode only. |
| POWER | sw Provides power status signals to the Ku-band system. |
| ON | This position fully activates the Ku-band system after the DA is deployed. It provides signal power to the manual slew switches, the antenna steering mode switch, the radar/comm mode switch, the search switch, and the Panel A2 digital readouts. Approximately 2 minutes after positioning this switch to ON, antenna steering control may be exercised, but the radar transmitter is not enabled for another 2 minutes. |
| STBY | This position initiates the timeouts, but transmitter power is inhibited; ac power is removed from the gimbal motors. |
| OFF | Ku-band power removed. |
| MODE | sw Provides status signals to the Ku-band electronics. |
| RDR COOP | Configures the Ku-band system for a beacon-type target. Also applies power to the RADAR OUTPUT switch and the Line-of-Sight (LOS) meter on Panel A2. |
| RDR PASSIVE | Configures the Ku-band system for a skin-track target. Also applies power to the RADAR OUTPUT switch and the LOS meter on Panel A2. |
| COMM | Configures the Ku-band system to be used for communications rather than radar. Also applies signal power to the HIGH DATA RATE and LOW DATA RATE rotary switches. |
| RADAR OUTPUT | sw Provides manual control of the maximum power output of the radar transmitter. |
| HIGH | Selects a maximum power output of about 50 watts. |

| Nomenclature | Description |
|----------------|---|
| MED | Selects a maximum power output of 12 decibels below 50 watts. |
| LOW | Selects a maximum power output of 24 decibels below 50 watts. |
| KU SIG PROC | rot Rotaries provide control for selection of data sources to be applied to the Ku-band signal processor. Used in the comm mode only. |
| HIGH DATA RATE | rot Provides selection of data source for Ku-band SPA channel 3. |
| OFF | No data selection - no data in channel 3. |
| PL MAX | Selects Non-Return-to-Zero (NRZ) payload data for mode 1, channel 3. |
| PL INTRG | Selects "bent-pipe" data from payload interrogator, mode 2, channel 3. |
| PL ANLG | Selects analog payload data for mode 2, channel 3. |
| PL DIGITAL | Selects Non-Return-to-Zero Level (NRZ-L) payload data for mode 2, channel 3. |
| TV | Selects data from the video switching unit for mode 2, channel 3. |
| LOW DATA RATE | rot Provides selection of data source for Ku-band SPA channel 2. |
| OFF | No data selection for channel 2. |
| PL RCDR | Selects payload recorder data for mode 1, channel 2, or mode 2, channel 2. |
| MMU 1 | Selects solid state recorder data for mode 1, channel 2, or mode 2, channel 2. |
| PL DIGITAL | Selects PL digital data for mode 1, channel 2, or mode 2, channel 2. |
| PL INTRG | Selects "bent-pipe" data from payload interrogator for mode 1, channel 2, or mode 2, channel 2. |



00603030.PNL 1

Figure C-2. Panel A2

Panel A2 Controls and Displays

Refer to Figure C-2 for Panel A2 illustration.

| Nomenclature | Description |
|---------------------|--|
| LINE OF SIGHT RATES | <p>ind Provides cross point meter scales that register azimuth and elevation movements of the Ku-band antenna in inertial space during angle tracking operation.</p> <p>There are two scales for each meter movement. The X-PNTR SCALE switch selects the meter scales.</p> <p>Note: This indicator is used during proximity operations to register orbiter pitch and roll movement if the radar system is closed-loop tracking the target, and the antenna azimuth and elevation are held constant.</p> |

| Nomenclature | | Description |
|--------------------|------|---|
| OFF | flag | Indicates that meter power is off or that >6-percent error signals are present in the meter. |
| X-PNTR SCALE | sw | Provides meter scale selection for the LINE OF SIGHT RATES indicator. |
| X1 | | Provides selection of a zero to ± 2 -mrad/sec scale. |
| X10 | | Provides selection of a zero to ± 20 -mrad/sec scale. |
| DIGI-DIS SELECT | sw | Determines the source of data displayed on the adjacent digital readout. |
| R/R | | Provides selection of RANGE (R) and RANGE RATE (R) data source. |
| EL/AZ | | Provides selection of ELEVATION (EL) and AZIMUTH (AZ) data source. |
| LAMP TEST | | Provides a test signal for the segments of both digital readouts, including decimal points. |
| RANGE/ELEVATION | ind | Provides range or elevation data as selected by the DIGI-DIS SELECT switch. Note: Range readouts are from 0 to 2621 thousands of feet (kfeet) with a floating decimal point. The smallest increment is 10 feet. Elevation readouts are from zero to $\pm 102.3^\circ$ in 0.1° increments. |
| RANGE RATE/AZIMUTH | ind | Provides range rate or azimuth data as selected by the DIGI-DIS SELECT switch. Note: RANGE RATE readouts are from 0 to 1638 ft/sec with a floating decimal point. The smallest increment is 0.1 ft/sec. Azimuth readouts are from zero to $\pm 204.7^\circ$ in 0.1° increments. |
| FAULT | ind | The red lamp between the digital readouts indicates invalid data received by the digital display, a digital lamp segment failure, or an internal self-test failure. (Not radar self-test.) |

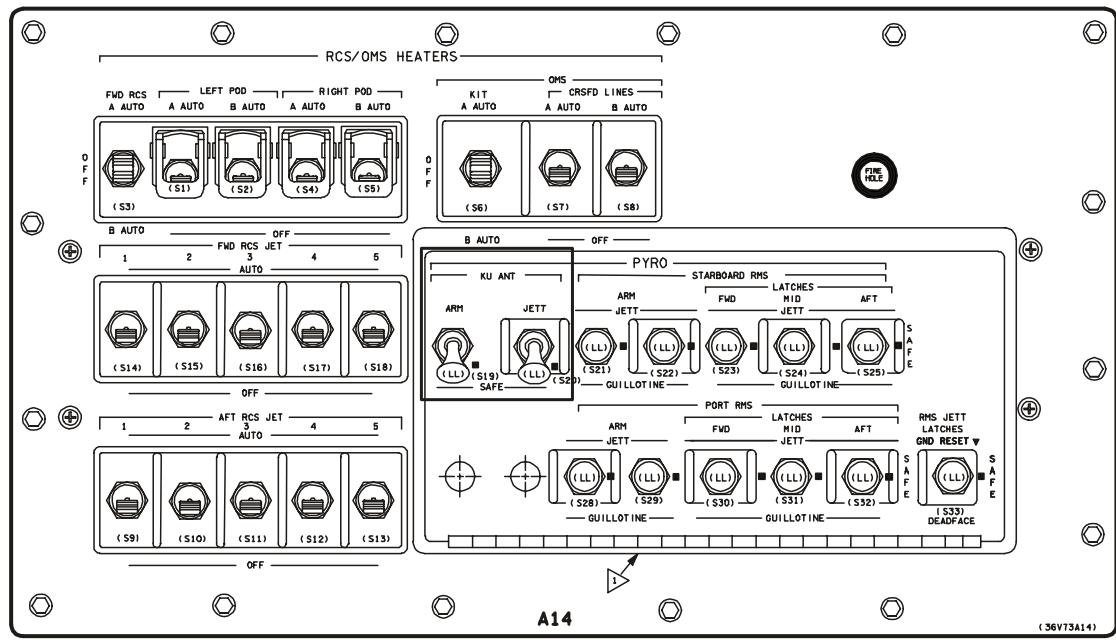
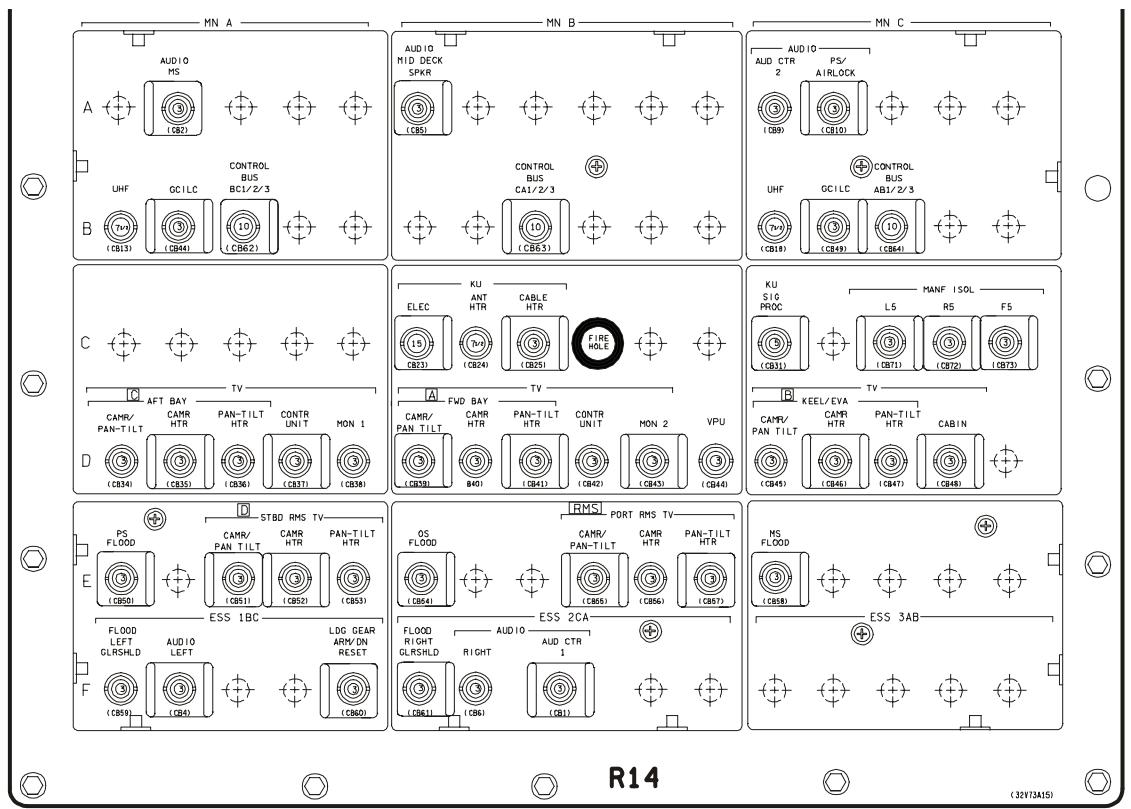


Figure C-3. Panel A14

Panel A14 Controls

Refer to Figure C-3 for Panel A14 illustration.

| Nomenclature | Description |
|--------------|--|
| PYRO KU ANT | Two switches that provide control for jettisoning the DA. |
| ARM/SAFE | sw A lever lock switch that provides an arming signal to the jettison switch and a disable signal in the SAFE position. |
| JETT/SAFE | sw A lever lock switch that provides a firing signal to the Ku-band antenna jettison pyrotechnics when the ARM/SAFE switch is in the ARM position. The signal is disabled in the SAFE position. CAUTION Before performing the jettison operation, the KU ELEC, ANT HTR, and SIG PROC circuit breakers on Panel R14 must be opened. |

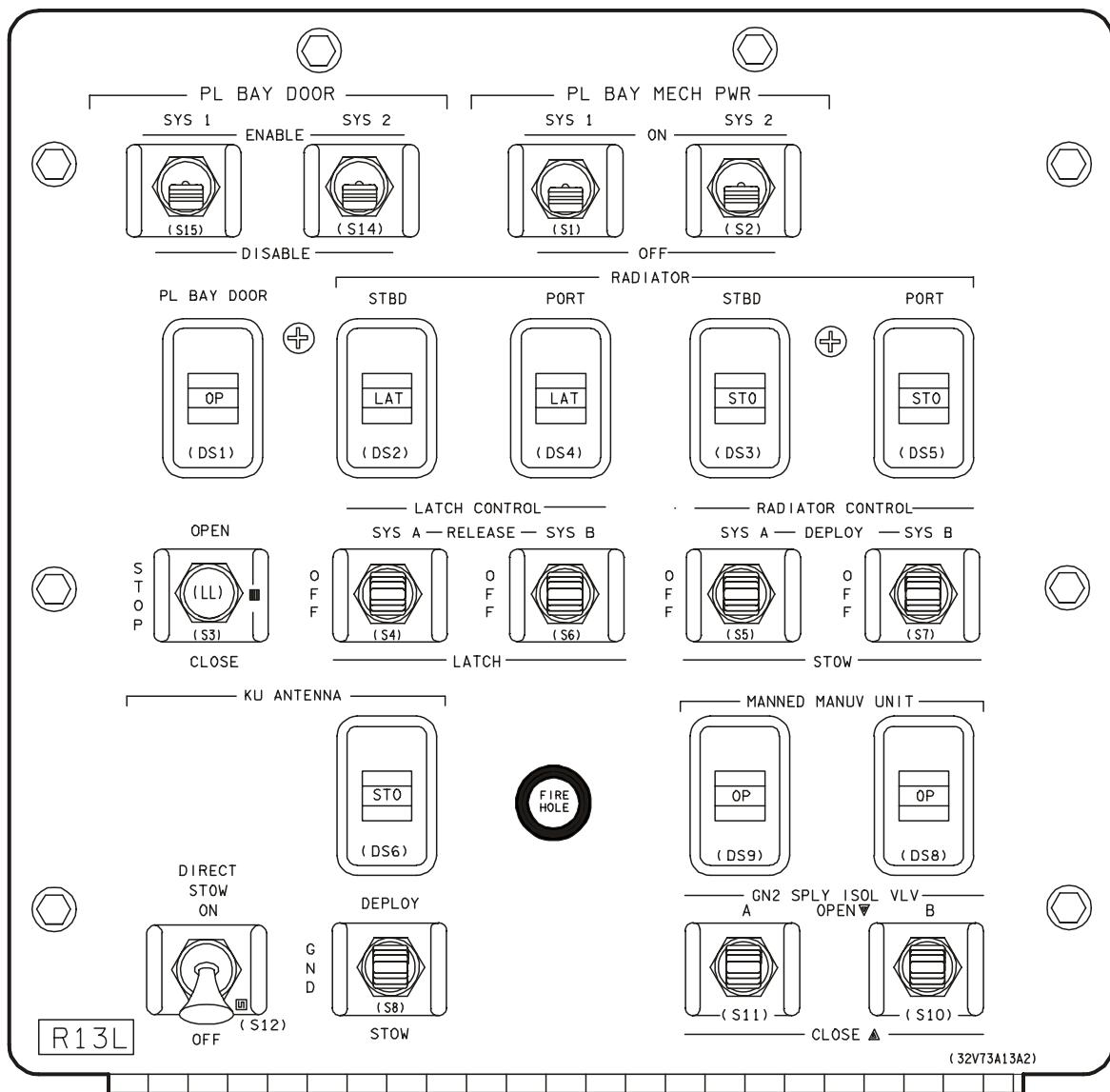


USA006030_048

Figure C-4. Panel R14**Panel R14 Controls**

Figure C-4 shows Panel R14 controls.

| Nomenclature | Description |
|--------------|---|
| KU | A set of circuit breakers for protecting the Ku-band electrical and electronics circuitry. |
| ELEC | cb Protects Ku-band electronic circuitry and provides power to the controls and indicators on Panels A1 and A2. |
| ANT HTR | cb Protects and controls the power for the Ku-band antenna heater circuits. |
| CABLE HTR | cb Not used. |
| KU SIG PROC | cb Protects and controls power to the Ku-band signal processor and switches on Panel A1. Note: The Ku-band signal processor is used for communications only. |



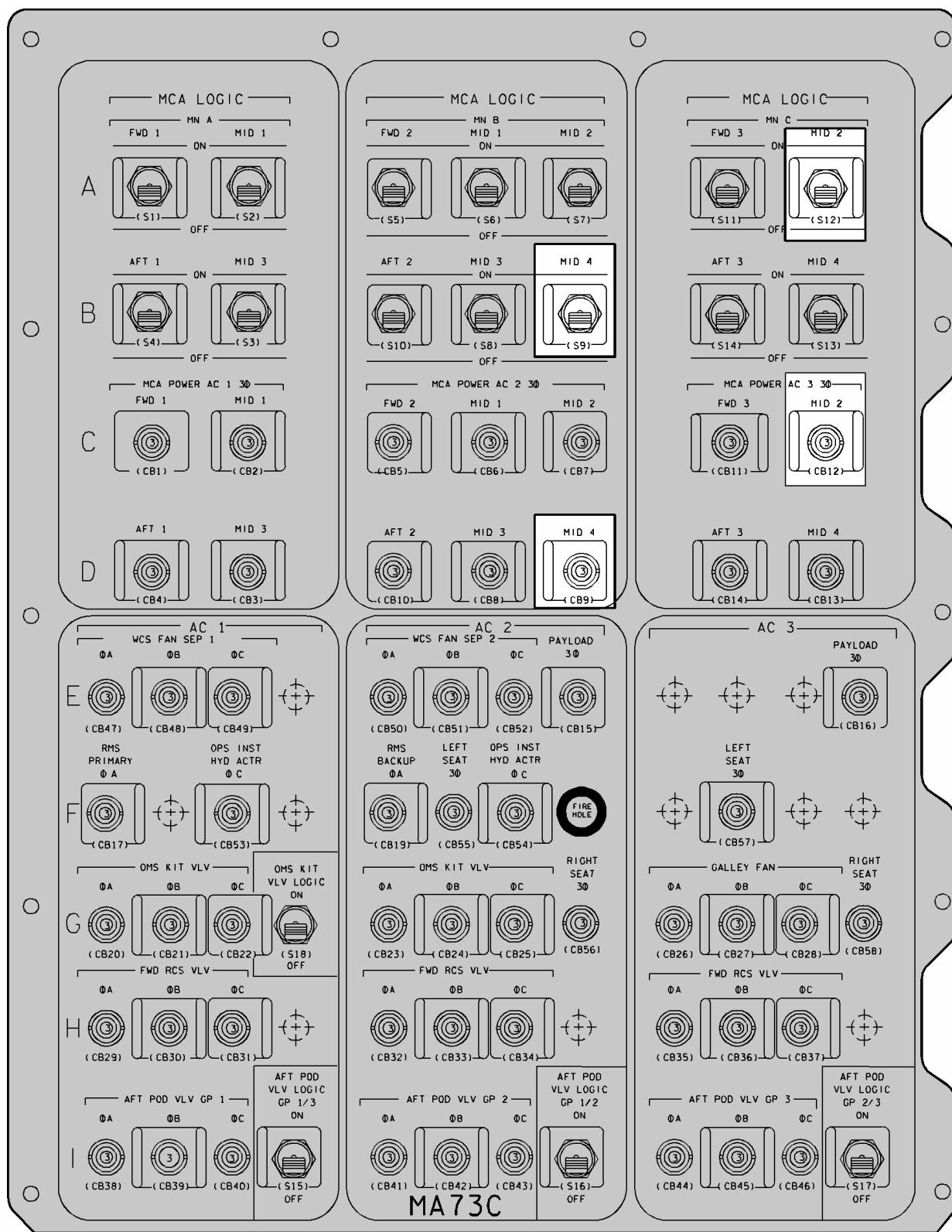
00603022. PNL 1

Figure C-5. Panel R13L**Panel R13L Controls and Displays**

Refer to Figure C-5 for Panel R13L illustration.

| Nomenclature | Description |
|--------------------------|---|
| PL BAY MECH PWR SYS 1(2) | sw Two switches that provide power control for redundant motors in motor control assemblies (MCAs). |
| ON | Allows three-phase power to the system 1(2) DEPLOY/STOW MCA. |

| | | |
|-------------|----|---|
| OFF | | Removes three-phase ac power from the system 1(2) DEPLOY/STOW MCA. |
| KU ANT | tb | Indicates the DEPLOY/STOW status of the DA. |
| STO | | Indicates that the DA is in the stowed position. |
| bp | | Indicates that the DA is between the deployed and the stowed positions. |
| DPY | | Indicates that the DA is in the deployed position. |
| DIRECT STOW | sw | A two-position lever lock switch that is used to “force stow” the DA when a normal stow cannot be accomplished. |
| ON | | Forces ac power to the MCA to drive the DA to the stowed position. The DEPLOY/STOW switch (below) must be in the GND position when the DIRECT STOW switch is used. |
| OFF | | The inactive position of this switch. |
| DEPLOY/STOW | sw | Provides control for deployment and stowage of the DA. |
| DEPLOY | | Initiates the deploy sequence of the DA by applying control signals to the redundant MCAs. |
| GND | | Active only when ground control through an umbilical is required. At all other times, this position is OFF. |
| STOW | | Initiates the stow sequence. |



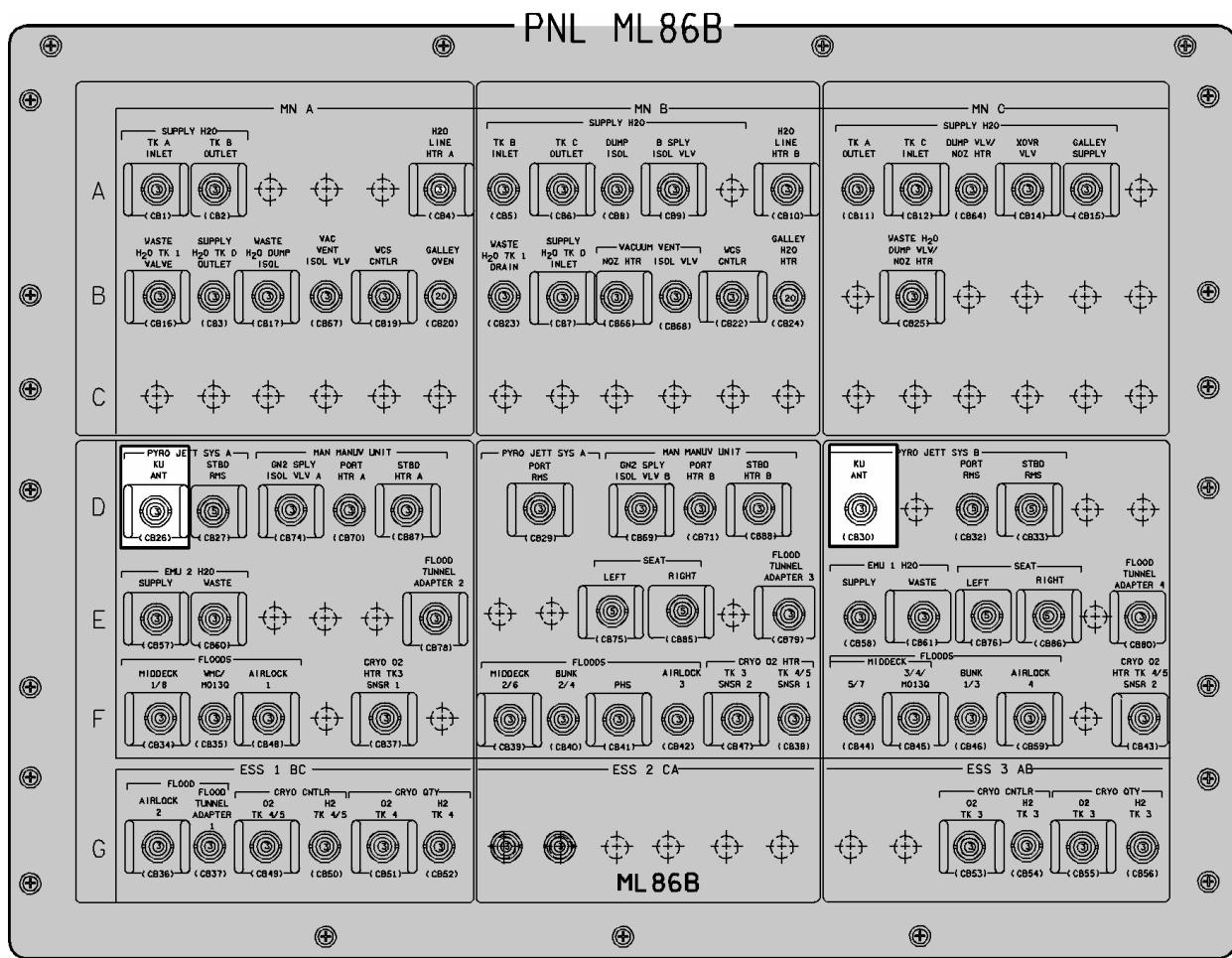
00603009. PNL 1

Figure C-6. Panel MA73C

Panel MA73C Controls

Refer to Figure C-6 for Panel MA73C illustration.

| Nomenclature | Description | |
|-------------------|-------------|---|
| MCA LOGIC MN B | | Switches that provide main B dc power to six MCAs. |
| MID 4 | sw | Controls power to the DEPLOY/STOW SYSTEM 1 MCA. |
| MCA POWER AC 2 3φ | | Circuit breakers that protect ac power to six MCAs. |
| MID 4 | cb | Provides control and protection for ac power applied to SYSTEM 1 MCA. |
| MCA LOGIC MNC | | Same as MN B except for MN C. |
| MID 2 | sw | Controls power to the DEPLOY/STOW SYSTEM 2 MCA. |
| MCA POWER AC 3 3φ | | Same as AC 2 except for AC 3. |
| MID 2 | cb | Provides control and protection for ac power applied to the SYSTEM 2 MCA. |



00603010, PNL 1

Figure C-7. Panel ML86B**Panel ML86B Controls**

Refer to Figure C-7 for Panel ML86B illustration.

| Nomenclature | Description |
|-------------------------------|---|
| PYRO JETT SYS A (B) KU ANT cb | <p>These circuit breakers provide protection for power applied to the A(B) Ku-band jettison system.</p> <p>Note: The A and B systems are redundant.</p> |

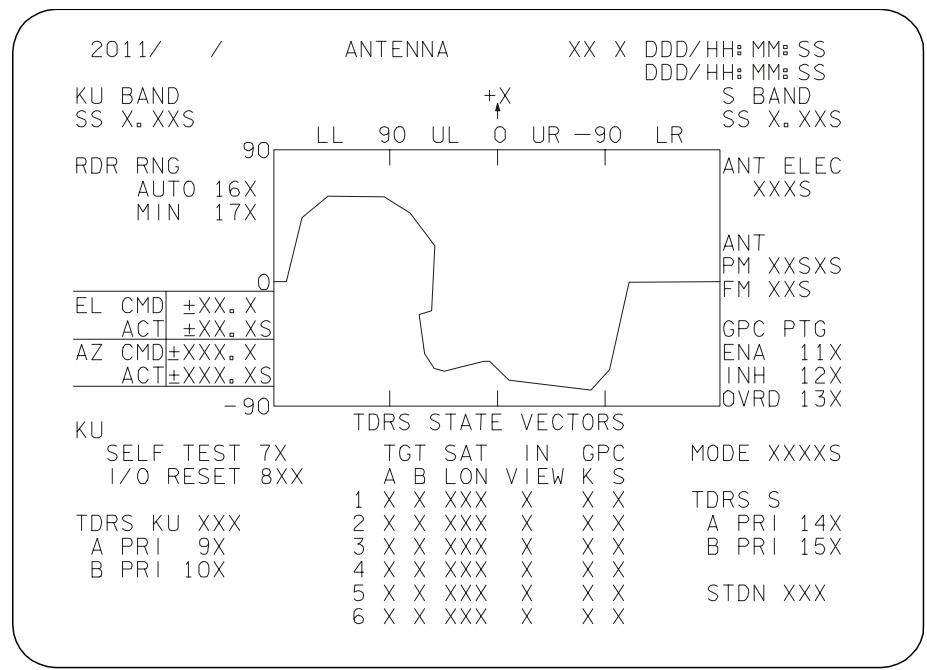


Figure C-8. SM OPS 2011 ANTENNA display

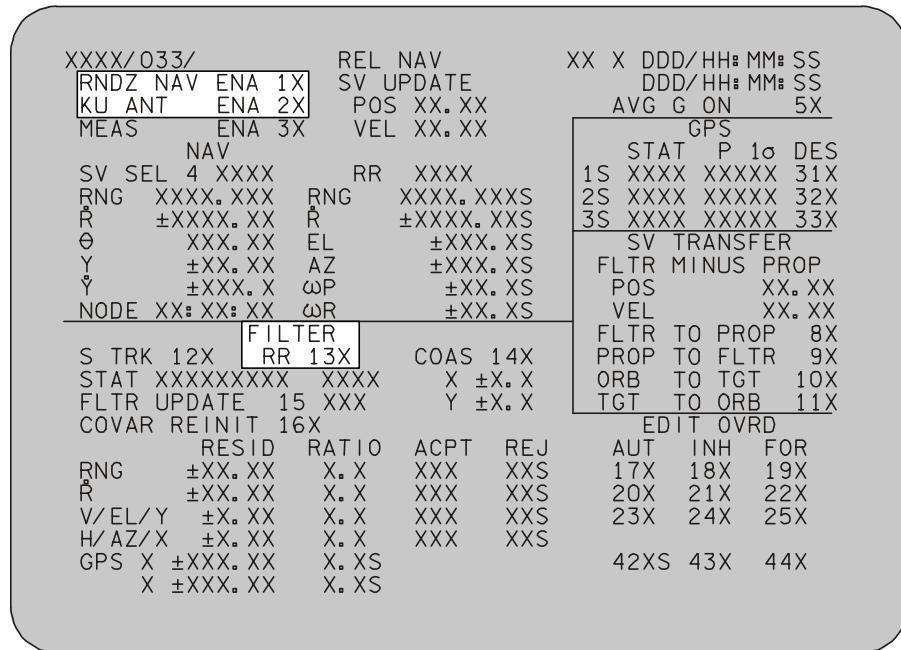
SM Antenna (SM OPS 2011) Display

The SM ANTENNA display provides control and observation of Ku-band antenna and receiver operation. Refer to Figure C-8 for this display.

| Nomenclature | Description |
|--------------|---|
| KU BAND | All parameters on the left side of the display pertain to Ku-band operation. |
| SIG STR | Displays a representation of Ku-band received signal strength. |
| RDR RNG | Allows GPC control of the type of range search initiated prior to target track. |
| AUTO 16 | "ITEM 16 EXEC" selects a range search controlled by the GPC-designated target range. The display is initialized with item 1 active. |
| MIN 17 | "ITEM 17 EXEC" selects a range search out to 2400 feet, and antenna angles of 0°/0° when the Ku-band antenna steering mode is GPC. |
| ANT | Displays designated and actual antenna azimuth and elevation angles in tenths of degrees. |
| EL CMD | Antenna elevation commanded from the SM GPC in the GPC or the GPC designate mode. |

| Nomenclature | Description |
|----------------|---|
| ACT | Actual Ku-band antenna elevation derived from gimbal positions. The parameter is valid only when the I/O RESET KU 8 is active. |
| AZ CMD | Antenna azimuth commanded from the SM GPC. |
| ACT | Actual Ku-band antenna azimuth. (Same as EL ACT.) |
| SELF TEST 7 | "ITEM 7 EXEC" provides start and terminate control for the radar self-test function. An "*" is displayed when the self-test is active. When the test is complete, item 7 must again be executed to deactivate the self-test function before normal radar operation can be restored. To run the test again, item 7 must be reinitialized. |
| I/O RESET KU 8 | "ITEM 8 EXEC" enables the interface between the SM GPC and the Ku-band system. The two status locations (XX) are used to identify the status of the interface. The first status field indicates whether the interface is enabled ("*"). The second status field indicates whether the SM GPC to Ku-band system interface is active. An "M" indicates the SM GPC to Ku-band system is inactive. If the Ku-band system is powered down, the "M" is present and the SM GPC bypasses the interface. |
| MODE | If the text (XXXX) below indicates "TDRS," the S-Bd antenna (ANT) commanded (CMD) will be towards the appropriate assigned TDRS. If the text indicates "STDN," the antenna-commanded angles would be commensurate with the location of the SM GPC-designated EAST TDRS. If the text (XXXX XXX) indicates "EAST TGT" or "WEST TGT," the antenna-commanded angles are commensurate with the GNC GPC-designated target location. TGT is present when ITEM 2 on GNC SPEC 33 is active. |

| Nomenclature | Description |
|--------------|---|
| A PRI 9 X | If AUT 9* has been executed, the selection of TDRS "EAST" or "WEST" is determined by the SM GPC antenna management program. The display is initialized with AUT 9* active. |
| B PRI 10 X | If W 10* has been executed, the SM GPC antenna management program TDRS selection is overridden and the antenna-commanded angles are forced to be commensurate with the location of the WEST TDRS. |



00603001.CRT 3

Figure C-9. GNC SPEC 33 relative navigation display**REL NAV (GNC SPEC 33, Available in OPS 2) Display**

The GNC REL NAV display provides parameters relative to target position and parameters plus control for updating the target state vector using the Ku-band radar as a sensor. Refer to Figure C-9 for this display.

| Nomenclature | Description |
|----------------|---|
| RNDZ NAV ENA 1 | "ITEM 1 EXEC" provides the control for enabling and disabling rendezvous navigation software in the GNC GPC. |
| KU ANT ENA 2 | "ITEM 2 EXEC" enables and disables the transfer of target position data between the GNC and SM computer antenna management program. Item 1 must be active for this entry to be legal. |
| FILTER | The parameters under this heading provide monitor and FLTR control for updating the FLTR (item 4) program through a Kalman filter system. |
| RR13 | "ITEM 13 EXEC" selects the Ku-band radar system as the sensor. |

| XXXX/XXX/076 | | COMMUNICATIONS | | XX X | DDD/HH:MM:SS |
|----------------|-------|------------------|------|--------------|--------------|
| | | | | DDD/HH:MM:SS | |
| S-BAND PM | XXXXS | KU-BAND | | | |
| FREQ XXS | 1 | PA TEMP | | ±XXXXS | |
| ANT ELEC | XXS | GIMBAL TEMP A | | ±XXXXS | |
| XPNDR | XXS | B | | ±XXXXS | |
| PREAMP | XXS | GYRO TEMP | | ±XXXXS | |
| PWR AMPL | | PWR OUT | | XXS | |
| OPER | XXS | FRM SYNC | | XXXS | |
| STBY | XXXXS | MODE | | XXXXS | |
| PWR OUT | XXXS | FAIL SAFE | | XXXS | |
| TEMP | XXXS | AUTO K TO S | | XXX | |
| NSP | 1 | AUTO S TO K | | XXX | |
| BIT SYNC | XXXS | SSOR | PRI | B/U | |
| FRM SYNC | XXXS | FRM SYNC | XXXS | XXXS | |
| BITE | XXXXS | PROC STAT | XXXS | XXXS | |
| COMSEC BITE | XXXXS | PWR LEVEL | | ±XX. XS | |
| UL DATA SOURCE | | STATUS | | X. XS | |
| DATA RATE XMIT | XXS | GCIL CONFIG | | XXXS | |
| RCV | XXS | CCTV CAMR OVRTMP | | XXXS | |
| CODING | XMIT | | | | |
| | RCV | | | | |

(XX)

00603012.CRT 2

Figure C-10. SM SPEC 76 communication/SSOR display**COMM/RCDR Display**

This display is used to monitor Ku-band antenna temperatures. Refer to Figure C-10 for this display.

| Nomenclature | Description |
|---------------------|---|
| KU-BAND | The first seven items under this heading pertain to Ku-band operations. |
| PA TEMP - GYRO TEMP | These parameters display deployed assembly temperatures. An up arrow (=) indicates that the upper temperature limit has been exceeded. |
| PA TEMP | This parameter displays the transmitter power amplifier temperature. An SM alert occurs if the temperature is higher than 171° F. |
| GMBL TEMP | This parameter displays the antenna α and β gimbal temperatures. An SM alert occurs if the temperature is higher than 150° F for the α gimbal or 166° F for the β gimbal. On the display, A represents the α gimbal and B represents the β gimbal. |
| GYRO TEMP | This parameter displays the antenna gyro temperature. An SM alert occurs if the temperature is higher than 155° F. |

| Nomenclature | Description |
|--------------|--|
| | <p>Note: These parameters are part of the operational instrumentation system, but are not active until the ANT HTR circuit breaker on Panel R14 is closed.</p> |
| PWR OUT | This parameter displays the output power of the TWTA in watts. |
| FR SYNC | This parameter displays YES if frame sync is achieved on the forward link. Otherwise, NO is displayed. Frame sync will only occur if in forward link mode 1. |
| MODE | This parameter displays the mode of operation: COMM or RDR. |
| AUTO K TO S | When Enabled “ENA” by ground command, forces KU FL to S-Bd if no KU FL for 5 seconds. |
| AUTO S TO K | When Enabled “ENA” by ground command, forces S-Bd to KU if KU FL good for 15 seconds. |

APPENDIX D REFERENCES

INCO Systems Brief

- Section 18: Ku-band Radar/Communications System
- Section 19: Software Description for the Ku-band Integrated Radar and Communications Equipment Electronic Assembly 1

Space Shuttle Systems Handbook

- Section 15 Drawing 15.7: Ku-band Antenna Deploy/Stow/Jettison
- Section 16 Drawing 16.1: Comm Overview Ku-band
- Drawing 16.5: Ku-band System

Flight Data File

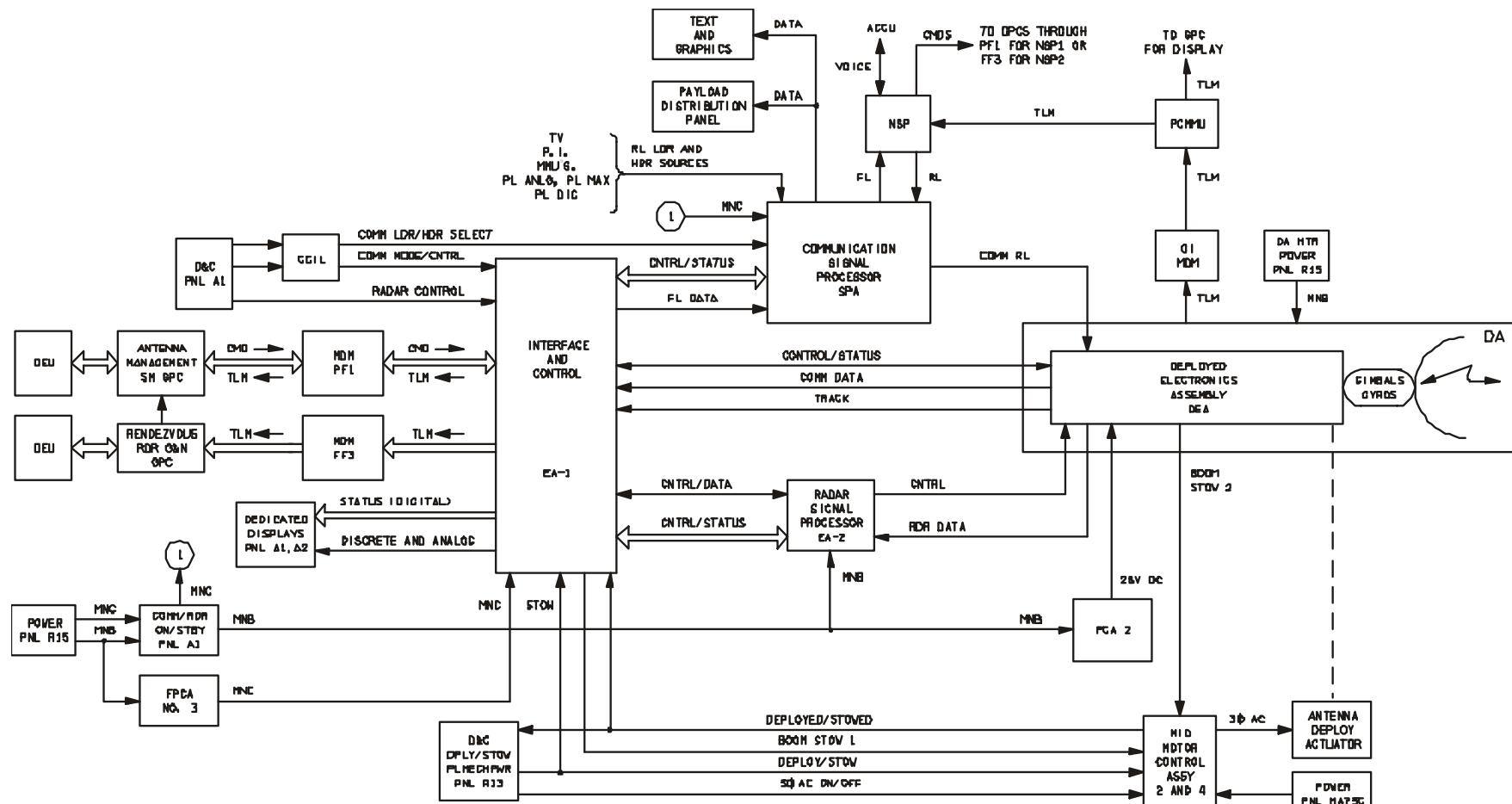
- Contingency De-Orbit Preparation Checklist
- De-Orbit Preparation Checklist
- Flight Plan
- In-Flight Maintenance Checklist
- Malfunction Procedures
- Orbit Operations Checklist
- Post Insertion Checklist
- Rendezvous Operations Checklist
- Space Shuttle Operational Flight Rules

Workbooks

- Shuttle Flight Operations Manual, Volume 4C: Ku-band Comm Radar Systems
- Rendezvous/Proximity Operations Crew Training Handbook

Subject Matter Experts

- Robin Enochs, DT37/Shuttle Comm/NSS Training Section
- Robert Murray, DT37/Shuttle Comm/NSS Training Section
- Marty O'Hare, Ku Bd System Manager, Boeing



DD060304T, PNL 1
usa006040_049

Figure D-1. Ku-band overview diagram

Training Materials Evaluation

Please answer the following questions regarding the lesson that you have just completed. Your feedback allows us to produce more effective training materials. *When completed, mail to: Communication/Payloads, DT37.*

TITLE/LESSON CODE: Ku-band Operations Workbook/KU OPS 21002

SIZE OF AUDIENCE/CLASS:

1. How well did this lesson meet its purpose?

For each statement below, mark one box on the scale:

- a. The lesson objectives are clearly stated.
 - b. The lesson objectives are clearly defined.
 - c. The lesson effectively teaches skills and information.
 - d. The lesson meets its purpose and objectives.

2. How satisfying is the content of this lesson?

For each statement below, mark one box on the scale:

- a. The information is structured in a logical flow.
 - b. The content is clear.
 - c. The content is complete.
 - d. The level of detail is correct for this information.
 - e. The amount of information is effective.
 - f. The graphics contribute to my understanding.

3. How appealing was the presentation of this lesson?

For each statement below, mark one box on the scale:

- a. The overall presentation is appealing.
 - b. The visuals chosen are appropriate for the lesson.
 - c. The visuals make the information more interesting.
 - d. The graphics are legibly reproduced.
 - e. The audio/visual or print quality is good.

4. How valuable is this information?

For each statement below, mark one box on the scale:

- a. *The lesson teaches skills and information I need.*
 - b. *The lesson meets my expectations.*
 - c. *This information is useful for later reference.*
 - d. *I would recommend this lesson to others.*

**PLEASE WRITE YOUR COMMENTS/QUESTIONS ON THE BACK OF THIS FORM.
EXPLAIN ANY NEGATIVE ANSWERS IN SPECIFIC TERMS
THANK YOU IN ADVANCE FOR YOUR ASSISTANCE!**