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Interface Control Document for X-Band Phased Array Antenna (XPAA)/ Earth Observer-1 (EO-1) Spacecraft

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

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TBD List

Issue	Section Number	Resolution Date	Comment

Abstract

The Interface Control Document (ICD) for the New Millennium Project (NMP) X-Band Phased Array Antenna (XPAA) provides a definition of all functional, physical, and electrical characteristics of the XPAA that impact the Earth Orbiter-1 (EO-1) spacecraft on which it will be installed. The interface definition in the ICD is designed to ensure that equipment and software delivered by The Boeing Company will operate properly when installed on the EO-1 spacecraft, will meet the requirements for which it was designed, and will not adversely affect any aspect of the EO-1 spacecraft operations.

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Abbreviations and Acronyms

Section 1. Introduction

This interface control document (ICD) contains data and drawings required to define the interface characteristics of the X-Band Phased Array Antenna (XPAA) System (referred to herein as the "antenna" or "XPAA") that will be mechanically, functionally, and electrically integrated with the Earth Orbiter-1 (EO-1) spacecraft.

1.1 Scope and Purpose

The ICD will contain all software, hardware (mechanical), thermal, electrical power, radio frequency (RF) signal, logic or control signal, telemetry signal, data signal, and operational interfaces of the XPAA with the EO-1 spacecraft. Included are the essential services node (ESN) and the remote services node (RSN) components.

1.2 Antenna Subsystem Overview

The XPAA comprises 64 active radiating elements, each with an independent phase controller and power amplifier allowing electronic steering of the antenna beam. Element phases are calculated to point the beam at the commanded elevation and azimuth by an RSN provided by Litton Amecom. Telemetry and commands are transmitted to the antenna over a dual MIL-STD-1773 fiber optic data bus. An 8.225-GHz RF excitation is supplied by the Wideband Advanced Recorder/Processor (WARP) via a coaxial cable and consists of a quadriphase shift key (QPSK)-modulated signal at a data rate of 105 Mbps.

One advantage of an electronically steered antenna for small satellite applications, where platform stability is important, is that no reaction torque compensation is needed during a communications pass, thus allowing the simultaneous acquisition of precision optical data. The phased array is also smaller than a comparable mechanically steered gimbaled system while maintaining high data rate communications capabilities.

1.3 Applicable Documents

a. NASA Document 737-EO1-RSD-XPAA, "Performance Specification and Design Requirements for the New Millennium Program Earth Orbiter-1, X-Band Phased Array Antenna," released April 1, 1997

b. NASA Document 737-EO1-SOW-XPAA, "Statement of Work for the New Millennium Program Earth Orbiter-1, X-Band Phased Array Antenna," released April 4, 1997

c. SAI-SPEC-158, "EO-1 Verification Plan and Environmental Specification," dated July 31, 1997

d. MIL-STD-461C, Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference (Notice 1)

e. MIL-STD-462, Measurement of Electromagnetic Interference Characteristics

f. MIL-STD-1773B, Fiber Optics Mechanization of an Aircraft Internal Time-Division Command/Response Multiplex Data Bus

g. NASA document ICD-735-2827, "Essential Services Node Hardware Specification (revision 2.0)"

h. Litton Drawing No. 184622, "Chassis Assembly, LWH-14-.050"

~~i. Litton Document ICD TBD, "X-Band Exciter to Memory Interface Control Document~~

i. Litton document ICD-TBD, "X-Band Phased Array Antenna Remote Service Node Software Specification

j. Litton Amecon Document AM149-0020(155), System Level Electrical Requirements NMP EO-1 Flight

k. Litton Amecon Document AM149-0050(155) "Data Systems 1773 ICD-EO-1"

l. Boeing Document XPAA-093, "X-Band Phased Array Antenna (XPAA) Remote Services Node (RSN) Software Specification"

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Section 2. System Interface Diagram

2.1 General

An interconnect diagram is provided to show the system level interconnects for RF excitation, fiber optic control and telemetry signals, and direct current (dc) power. A service connector for software loading and a test connector for testing during integration are also shown. Electrical and signal characteristics as well as cabling are further defined in Section 5.

Figure 2-1 shows the system interface connections between the antenna and the WARP, the fiber optic star coupler, and the 28 V power supply.

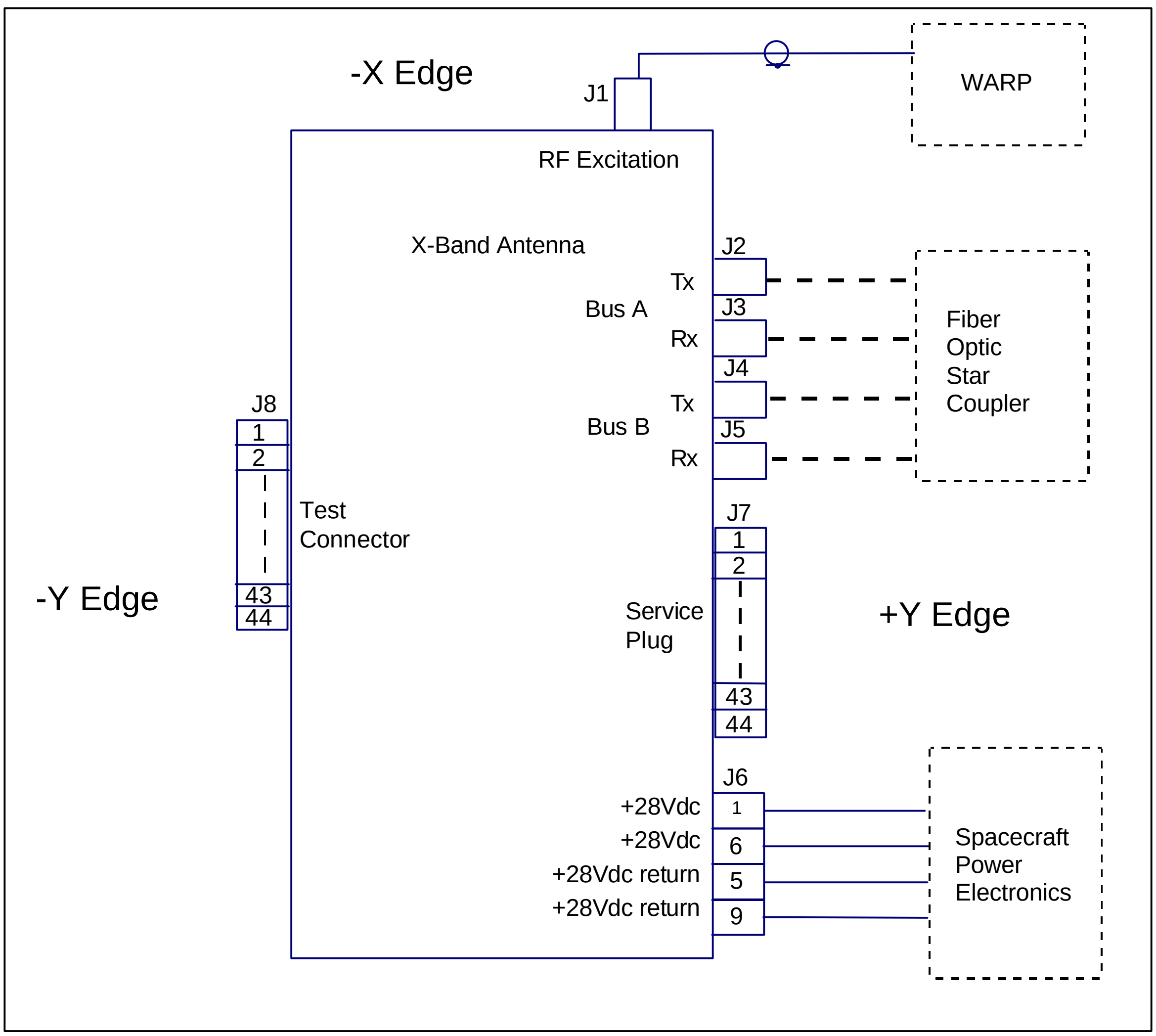

Figure 2-1. System Interface Diagram

Section 3. Mechanical Interface

3.1 General

The antenna enclosure is a two-level structure. The 64 radiating elements and the high-wattage dc-to-dc converters for the antenna 5 V power are located on the upper level, and an RSN controller board is located on the lower level. **Six dc-to dc converters, including the high wattage units for the antenna 5V power, are located on the RSN board or heat sink.** The lower level of the enclosure is geometrically identical to one slot of the Litton chassis (Litton Drawing No. 184622), permitting the generic RSN board to be accommodated without any mechanical change to the basic RSN.

3.2 Antenna Envelope

Figure 8-1 shows the physical envelope of the antenna. The RF excitation input is located on the -X direction face of the antenna. The service connector and the fiber optic connectors are located on the positive Y direction face. The test connector is located on the negative Y direction face. **The test connector is located on the negative Y direction face. The antenna coordinate system (relating x, y, and z direction to steering angle phi and theta) is described in AM149-0017(285), "A-Band Phased Array Antenna Remote Services Node Software**

3.3 Antenna Footprint and Fastener Requirements

Figure ~~8-2~~ **7-6** shows the mechanical footprint of the antenna. The antenna is secured to the mounting plate by eight NES 1578 ¼-28 threaded fasteners.

3.4 Antenna Mounting Requirements

A gasket of Chomerics Cho-Therm 1671 will be placed between the antenna flange and the mounting plate~~, and the ¼-28 fasteners torqued to 91 in-lb~~. **An EMI shielding gasket, Spira Shield SS-04, will be placed in the groove provided in the antenna mounting flange. The 1/4-28 fasteners are torqued to 91 ins-lbs. Figures 4-1 and 5-3 illustrate the details of the mounting configuration.**

3.5 Antenna Mass and Center of Mass

The antenna ~~shall~~ weigh**s** ~~not more than~~ 5.5**6** kg. ~~The center of mass shall be determined to an accuracy of ±2.5 mm in three dimensions.~~

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Section 4. Thermal Interface

4.1 General

The antenna shall be thermally coupled to the spacecraft interface plate. The nadir facing metal surface of the antenna shall be painted white. The nadir radiating surface shall consist of white Tefzel (DuPont 500 CLZ WTHP). The spacecraft shall supply the multilayer insulation (MLI) and heaters necessary to maintain the interface plate temperature within the limits described in Table 4-1. Figure 4-1 shows the various elements contributing to the thermal design.

Table 4-1. XPAA Temperature Limits

Limits	Operating (°C)	Non-Operating (°C)
Minimum temperature	0	-10
Maximum temperature	40	50

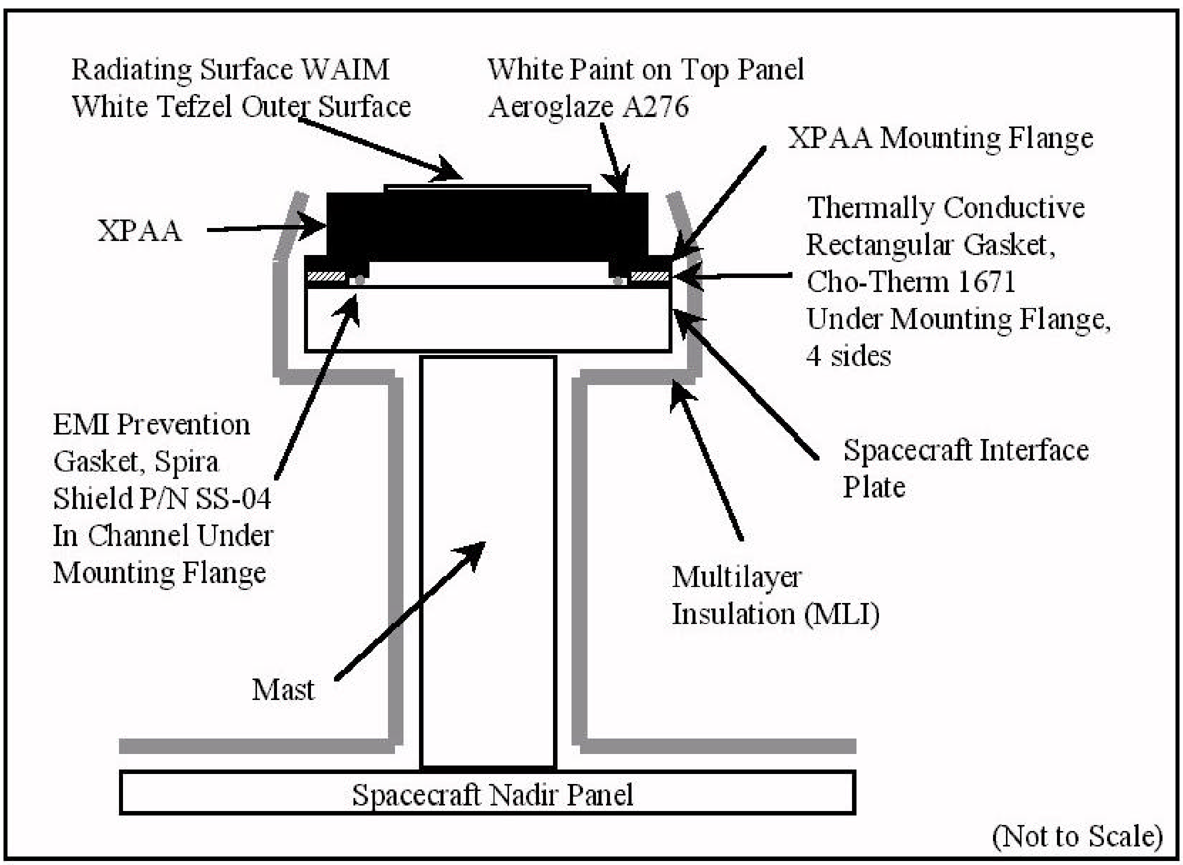

Figure 4-1 XPAA Thermal Interfaces

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Section 5. Electrical Interface

5.1 General

The antenna comprises a 64-element array and an RSN board. With the exception of the antenna modules, all electrical and electronic components are mounted on the RSN board.

5.2 Electrical Block Diagrams

Figure 5-1 shows the RSN electrical block diagram and external interfaces.

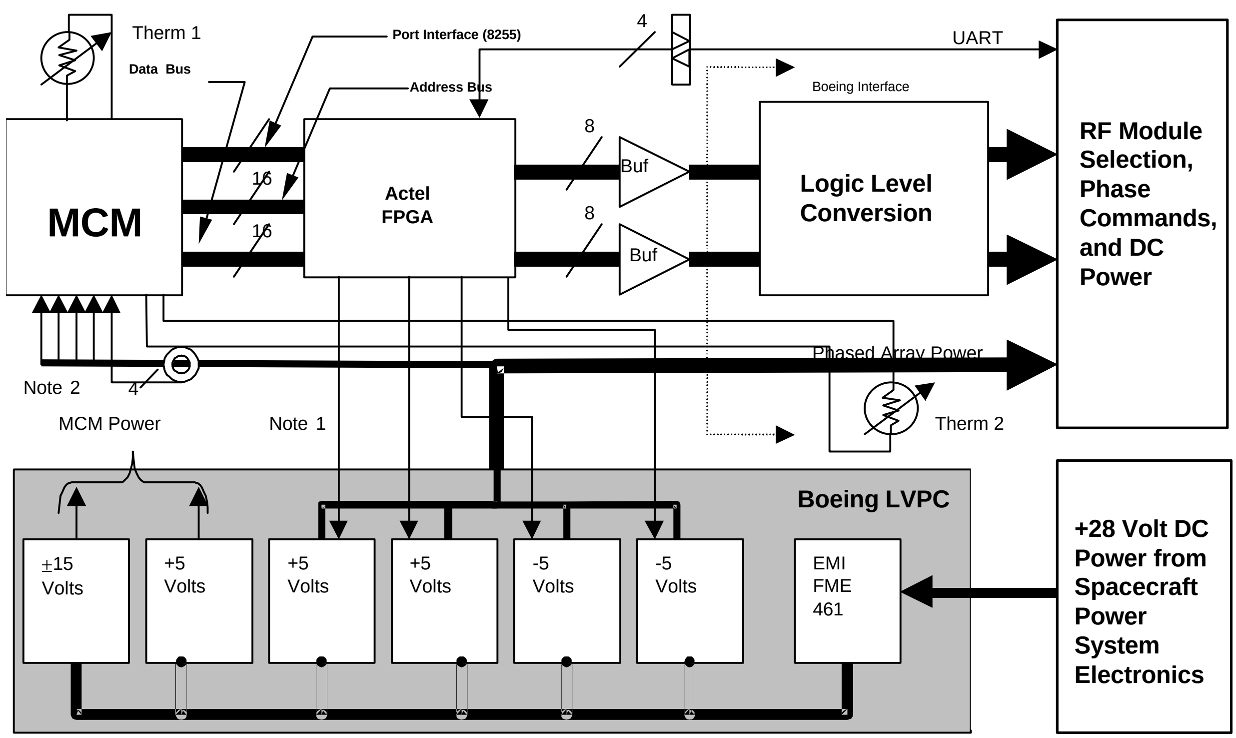

Figure 5-1. RSN Electrical Block Diagram

Support electronic components, a field programmable gate array (FPGA), level translation [transitor-transistor logic (TTL) to -5 to 0 V] integrated circuits, and six dc-to-dc power converters are located on the RSN board. Four low power converters and an RF interference (RFI) filter are located on the "A" side of the RSN board, and two 30-W converters are located

Figure 5-2 shows the RF module array diagram. The array is divided into two sections, which are fed by separate, low voltage power supplies for improved reliability.

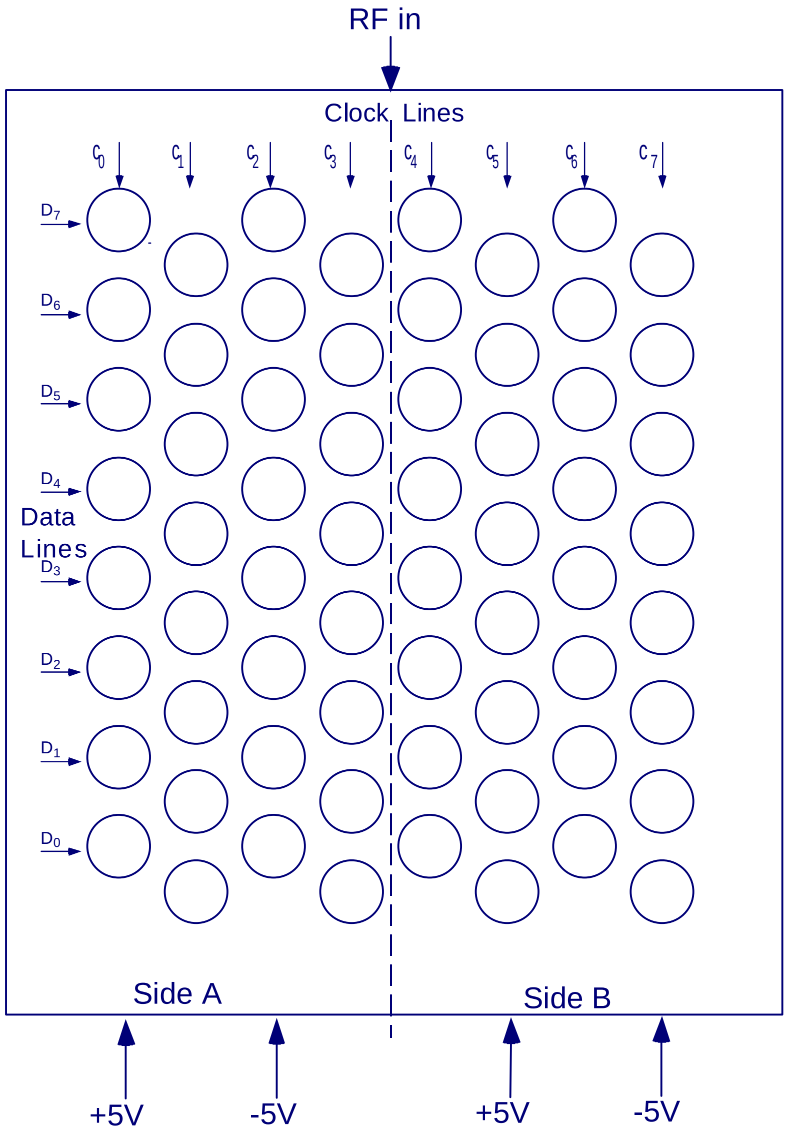

Figure 5-2. RF Module Array Diagram

5.3 RF Interface

Figure 5-3 shows the system RF allocations. The excitation is described in the Litton Exciter Specification, document number **5503158.** ~~TBD~~. The input interface connector is a female SMA connector mounted ~~at the center of~~ **on** the **–X edge of the enclosure close to the corner with the** +Y **edge.** ~~face of the enclosure.~~ The connector should be tightened to ~~6~~ **8** in**s**-lbs.

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5.4 Maximum RF Power Into the Antenna

RF excitation power applied to the RF input connector (J1) must not exceed ~~500~~ **100** mW or ~~27~~ **20**dBm.

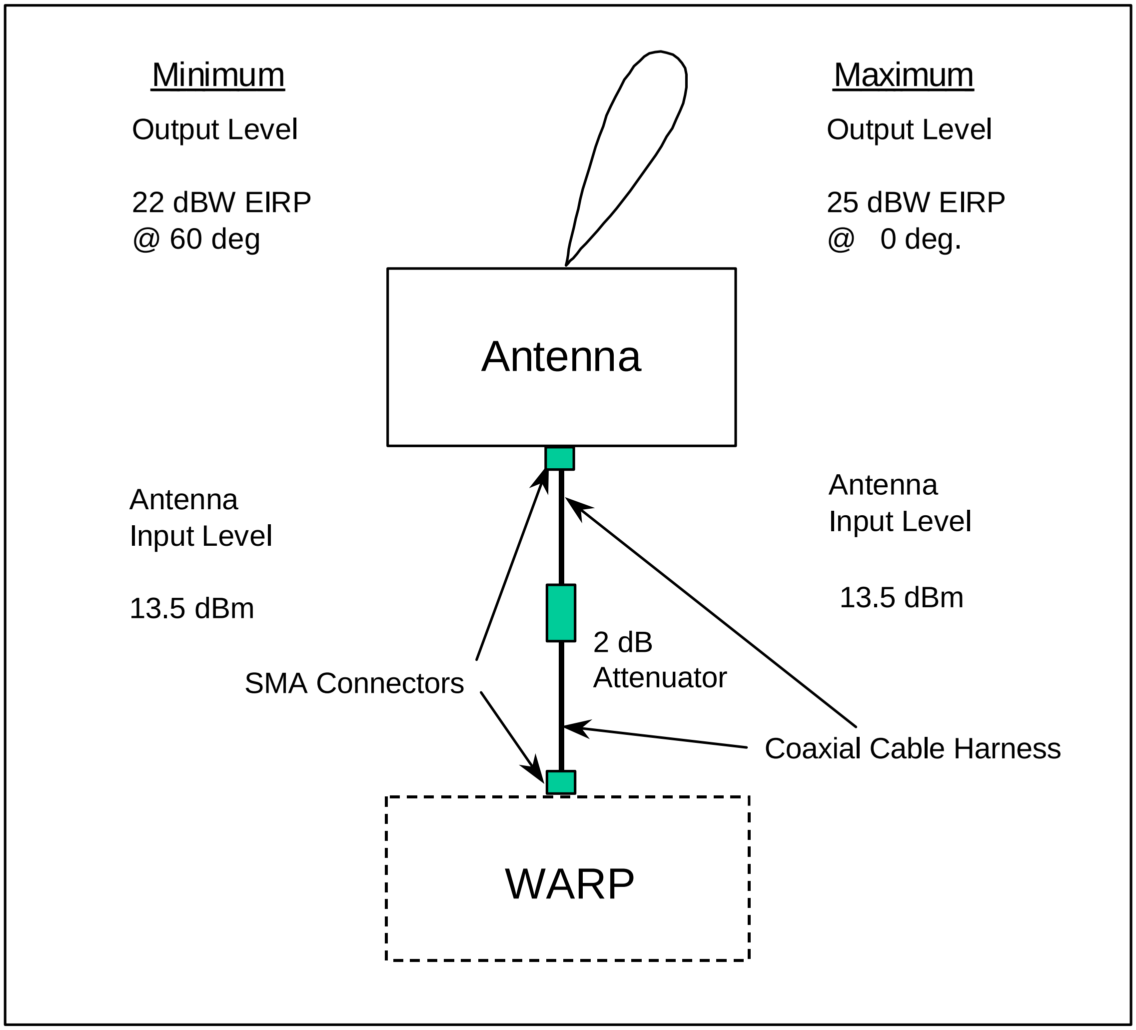

Figure 5-3. RF Allocations

5.5 DC Power Requirements

The nominal dc power requirement is 44 W with a worst case **(mounting plate temperature = 0 degrees c, prime power voltage = 35 v)** of ~~60~~ **56** W while transmitting. The antenna will operate over an input voltage range of 21 to 35 V with source impedance, transients, and ripple in accordance with the statement of work (SOW).

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The interface connector is J6, type 311P 409-1P, and the pin assignment is discussed in Section 5.9. When not transmitting, the ESN and 1773nterface draw approximately ~~3~~ **5** W.

5.6 Communications Interface

Command, pointing, and telemetry information is transmitted over a dual 1773 bus. The protocols are described in Litton Amecon Document AM149-0050(155). The output optical power for the 1773 transceivers is -11 dBm (minimum) and -6 dBm (maximum). There is an insertion loss of 0.15 dBm (maximum) associated with the fiber optic coupler that needs to be subtracted from the output power.

5.7 Cabling Interface

The antenna cabling interface is described in the cable harness ICD, Swales Document No. TBD.

5.8 EMI/RFI

The antenna will satisfy conducted and radiated emission and conducted and radiated susceptibility requirements as specified in ~~NASA document 737-EO1-SOW-XPAA~~. **AM-149-0020(155).**

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5.9 List of Connectors

The antenna external interfaces are implemented with the connectors listed in Table 5-1. Connector pin-outs are listed in Tables 5-2 through 5-4.

Table 5-1. Antenna Connectors

Connector Number	Connector Type	Pins Used	Description
J1	SMA	-	RF excitation input
J2	FC	Fiber	1773 Bus A input
J3	FC	Fiber	1773 Bus A output
J4	FC	Fiber	1773 Bus B input
J5	FC	Fiber	1773 Bus B output
J6	311-P409-1PB-15 9-pin D-type male	1,5,6,9	28 V input power

J7	311-P407-3S-B-15 44-pin D-type female	~~TBD~~ **1,2,9,10,11, 12,13,14,15, 16,17,18,19, 20,21,22,23, 24,25,26,27, 28,29,30,31, 32,39,40,41, 42,43,44**	Service connector
J8	311-P407-3S-B-15 44-pin D-type female	All	Test connector

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Table 5-2. Connector J6 Pin-Outs

Pin Number	Signal	Description
1	28 V in A	Switched +28 V power from spacecraft
5	28 V Return A	28 V power return
6	28 V in B	Switched +28 V power from spacecraft
9	28 V Return B	28 V power return

Table 5-3. Connector J7 Pin-Outs

TBD

Tablee 5-4. Connector J8 Pinouts (1 of 2)

Pin Number	Function	Description
1	CLK_0	Clock line 0
2	CLK_1	Clock line 1
3	CLK_2	Clock line 2
4	CLK_3	Clock line 3
5	CLK_4	Clock line 4
6	CLK_5	Clock line 5
7	CLK_6	Clock line 6
8	CLK_7	Clock line 7
9	PH_0	Phase line 0
10	PH_1	Phase line 1
11	PH_2	Phase line 2
12	PH_3	Phase line 3
13	PH_4	Phase line 4
14	PH_5	Phase line 5
15	PH_6	Phase line 6
16	PH_7	Phase line 7

17	+5V_EN_1	+5 V power supply 1 enable
18	+5V_EN_2	+5 V power supply 2 enable
19	-5V_EN_1	-5 V power supply 1 enable
20	-5V_EN_2	-5 V power supply 2 enable
21	+5V_ANT_1	Side 1 +5 V power input
22	+5V_ANT_1	Side 1 +5 V power input
23	+5V_ANT_1	Side 1 +5 V power input
24	+5V_ANT_2	Side 2 +5 V power input
25	+5V_ANT_2	Side 2 +5 V power input
26	+5V_ANT_2	Side 2 +5 V power input
27	-5V_ANT_1	Side 1 -5 V power input
28	-5V_ANT_1	Side 1 -5 V power input
29	-5V_ANT_2	Side 2 -5 V power input
30	-5V_ANT_2	Side 2 -5 V power input
31	28V_IN_F	28 V power monitor - IN
32	28V_RTN_F	28 V power monitor - RTN
33	GND	System ground
34	GND	System ground
35	GND	System ground
36	GND	System ground
37	GND	System ground
38	GND	System ground
39	GND	System ground
40	GND	System ground

Table 5-4. Connector J8 Pinouts (2 of 2)

Pin Number	Function	Description
41	GND	System ground
42	GND	System ground
43	GND	System ground
44	GND	System ground

Table 5.9.2-1 Connector J6 Pin-Outs

Pin Number	Function	Description
1	EPROM1	
2	GND	
3	SPARE	
4	SPARE	
5	SPARE	
6	SPARE	
7	SPARE	
8	SPARE	
9	BPC0	
10	BPC1	
11	BPC2	
12	GND	
13	BTXD1+	
14	BTXD0+	
15	BTXD0-	
16	EEPROM2	
17	WDT1	
18	GND	
19	MODE	
20	PRA	
21	PRB	
22	SD1	
23	DCLK	
24	GND	
25	BPC3	
26	BPC4	
27	GND	
28	BTXD1-	
29	BRXD0+	
30	BRXD0-	
31	WDT2	
32	GND	
33	SPARE	
34	SPARE	
35	SPARE	
36	SPARE	
37	SPARE	
38	SPARE	
39	BCP5	
40	BCP6	
41	BCP7	
42	GND	
43	BRXD1+	
44	BRXD1-	

Section 6. Software Interface

The software requirements are described in Boeing **Software Specification** Document ~~XPAA-093.~~ **AM149-0117(285), "X_Band Phased Array Antenna Remote Services Node Software Specification."**

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Section 7. Validation Interface

7.1 List of Validation Functions

On-orbit validation functions are described in the SOW. Housekeeping parameters recorded are voltages and currents supplied by each dc-to-dc converter, and the temperatures of the array baseplate and the ESN lid. Computation of the correct phases for a given θ and ϕ is verified by recording the 64 4-bit phase values transmitted to the 8 x 8 array together with the values of θ and ϕ received from the attitude control system.

7.2 Implementation of Validation Functions

7.2.1 Array Voltages

The +5 V and -5 V voltages supplied to each antenna array side are obtained by measuring the voltage at the array side of the resistor in series with dc-to-dc converter as shown in Figure 7-1.

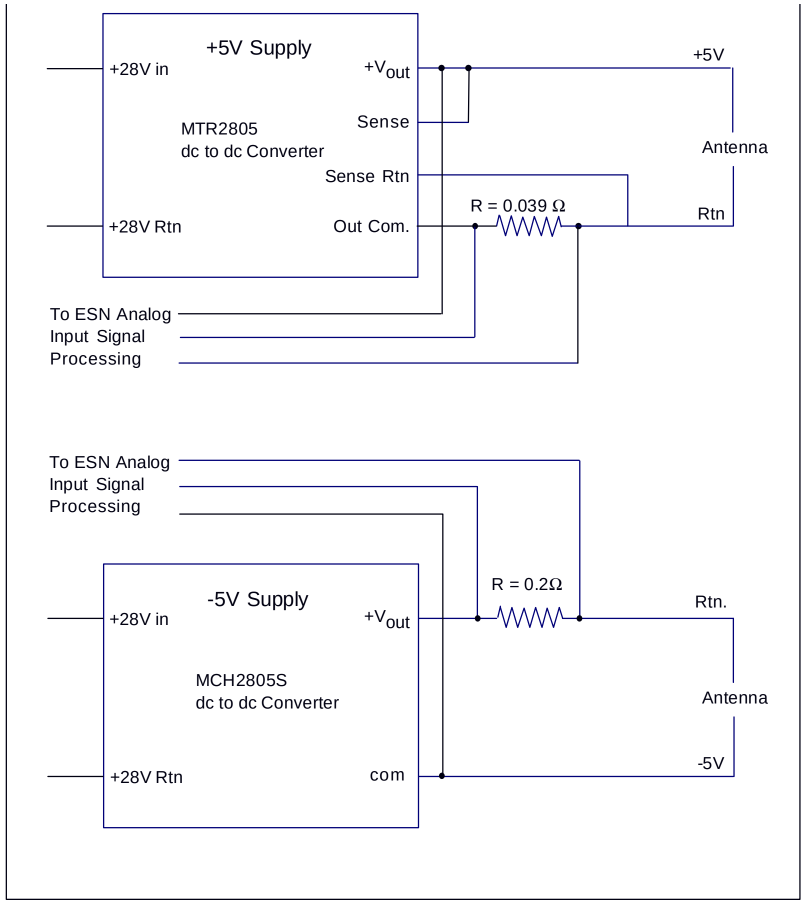

Figure 7-1. Antenna Power Supply Voltage Current Measurement Network

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7.2.2 Array Currents

The +5 V and -5 V currents supplied to each side antenna array are obtained as shown in Figure 7-1 by measuring the voltage drop across a resistor in series with the dc-to-dc converter and the antenna. The series resistors are chosen to provide a 2-percent precision. ~~current measurement assuming 0 V to +10 V and +10 V to -10V analog voltage ranges for the +5 V and -5 V lines, respectively, and 12-bit A-to-D conversion.~~

7.2.3 Temperature Measurements

The temperatures of the center of the array pressure plate**, the RSN heat sink,** and the ESN lid will be measured using thermistors as shown in Figure 7-2.

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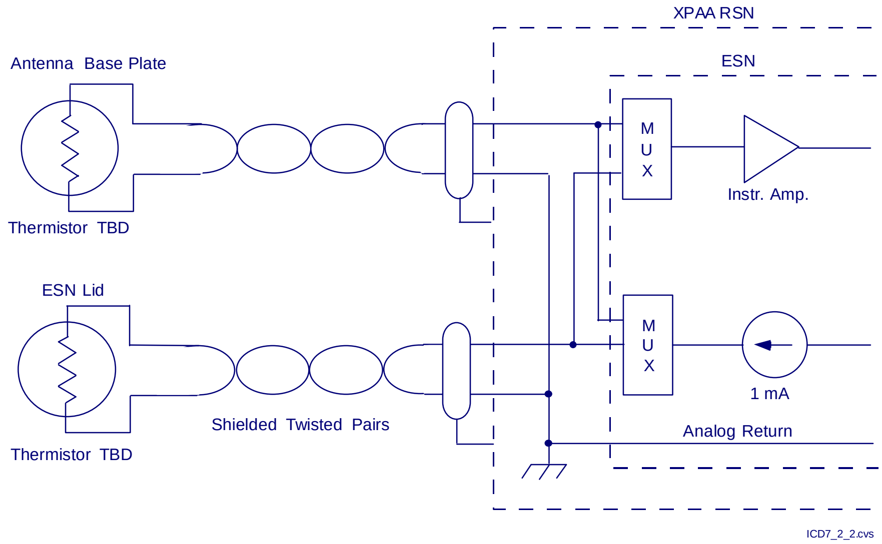

Figure 7-2. Temperature Measurement Interface

7.2.4 Phase Bit Verification

The contents of the memory array containing the 64 4-bit phase values (256 bits) will be retrieved and telemetered together with the commanded pointing angles. Further information as to formats is given in Boeing Document XPAA-093.

7.3 Ranges of Validation Functions

The expected values and acceptable ranges of the measured parameters are given in Table 7-1. Possible failure modes that will be detected are also given.

Table 7-1. Measured Parameter Values and Ranges

Parameter	Expected Value	Acceptable Range	Failure Mode Identified
+5 V antenna side A	5.0 V	+/- 0.1 V	Power supply/catastrophic hardware failure
+5 V antenna side B	5.0 V	+/- 0.1 V	Power supply/catastrophic hardware failure
-5 V antenna side A	-5.0 V	+/- 0.1 V	Power supply/catastrophic module failure
-5 V antenna side B	-5.0 V	+/- 0.1 V	Power supply/catastrophic module failure
Positive current side A	~~3.0~~ **2.6** to 3.9 A*	+/- ~~0.3~~ 0.**2** A **of expected**[+]	Module failure

Positive current side B	~~3.0~~ **2.6** to 3.9 A*	+/- ~~0.3~~ 0.**2** A **of expected**+	Module failure
Negative current side A	~~-90~~ **-100** ~~to -130~~ mA*	+/- ~~10~~ **2** mA+	Module failure, single-event latch-up
Negative current side B	~~-90~~ **-100** ~~to -130~~ mA*	+/- ~~10~~ **2** mA+	Module failure, single-event latch-up
~~Pressure~~ **Base** plate temperature	~~10~~ **3**^{o}C above cold plate*	+2^{o}C > expected T	Module failure
RSN HEAT SINK TEMP	**8 deg Above Cold Plate**	**+2 deg c > expected T**	**N/A**
ESN lid temperature	~~TBD~~ **5 deg c above RSN base**	~~TBD~~ **+2 deg c > expected T**	~~TBD~~ **N/A**
Phase bit array	Precalculated values	No variation	RSN failure, software error

NOTES: * = nominal values; final values determined after integration and testing
\+ = will depend on array temperature

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7.4 Telemetry Frequency

Housekeeping parameters are measured continuously, including during antenna non-operating periods. Housekeeping data and phase values are telemetered to the spacecraft command and data handling (C&DH) system every 8 seconds and telemetered to ground upon command.

7.5 RF Ground Test

7.5.1 Purpose

Functional testing of the antenna in the laboratory and in the thermal vacuum environment is required to verify general antenna performance. A test hood, which can be fitted over the antenna, has been designed and built. The hood comprises a stainless steel box lined with microwave absorbing material, and a probe to couple out a small fraction of the radiated energy. The hood will provide a measure of the total power radiated by the antenna, but no pointing information.

7.5.2 Mechanical Design

A drawing of the hood, Figure 8-3, shows the aluminum enclosure, lid, and probe. The inside of the enclosure and the inner surface of the lid are lined with Eccosorb SF microwave-absorbing material previously outgassed by heating in an oven for 16 hours at 177 ^{o}C. A low outgassing adhesive, GE RTV 566, is used to attach the Eccosorb to the aluminum surface.

The hood is secured to the antenna by the two antenna mounting bolts in the center of the X edges. These bolts must first be removed, the hood mounted over the antenna, and the bolts replaced. The bolts should be torqued to 91 in-lb. The RF cable must also be removed before mounting and replaced after mounting the hood.

NOTE: The mechanical configuration of the test hood requires that any MLI blankets around the sides of the antenna or on its mounting flange be removed prior to the hood's installation.

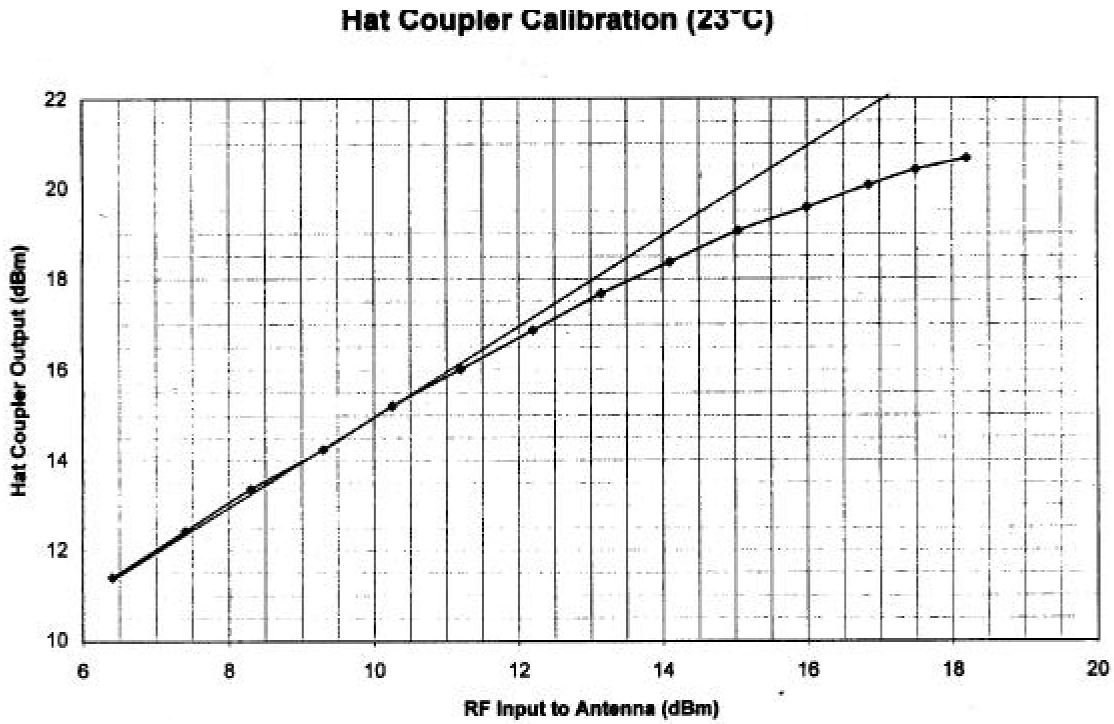

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Figure 7-3 HAT Coupler Calibration

7.5.3 Electrical Design

The probe in the center of the lid of the hood couples a small fraction of the radiated power. The connector is a UG-58A N-series female panel mount connector. The coupling coefficient ~~is of the order of -20 dB. The value of the coefficient will be revised after final testing of the antenna at Boeing.~~ **when the antenna is set to point at boresight is approximately 38 dB below the EIRP at boresight. The curve in Figure 7-3 relates the output of the coupler to the RF input array, as measured by Boeing during acceptance tests.**

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Figure 8-1. Antenna Mechanical Drawing

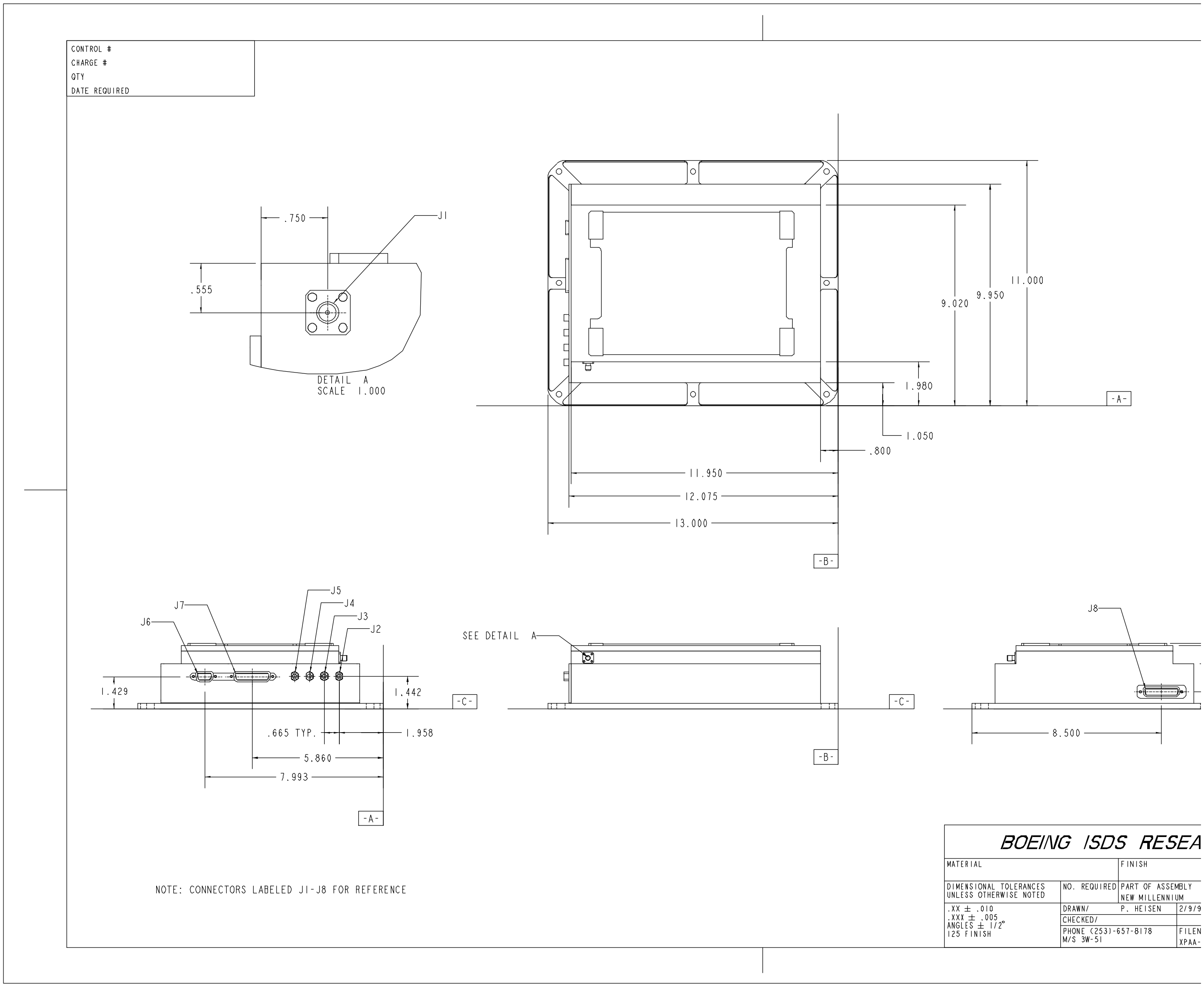


Figure 8-2. Antenna Footprint

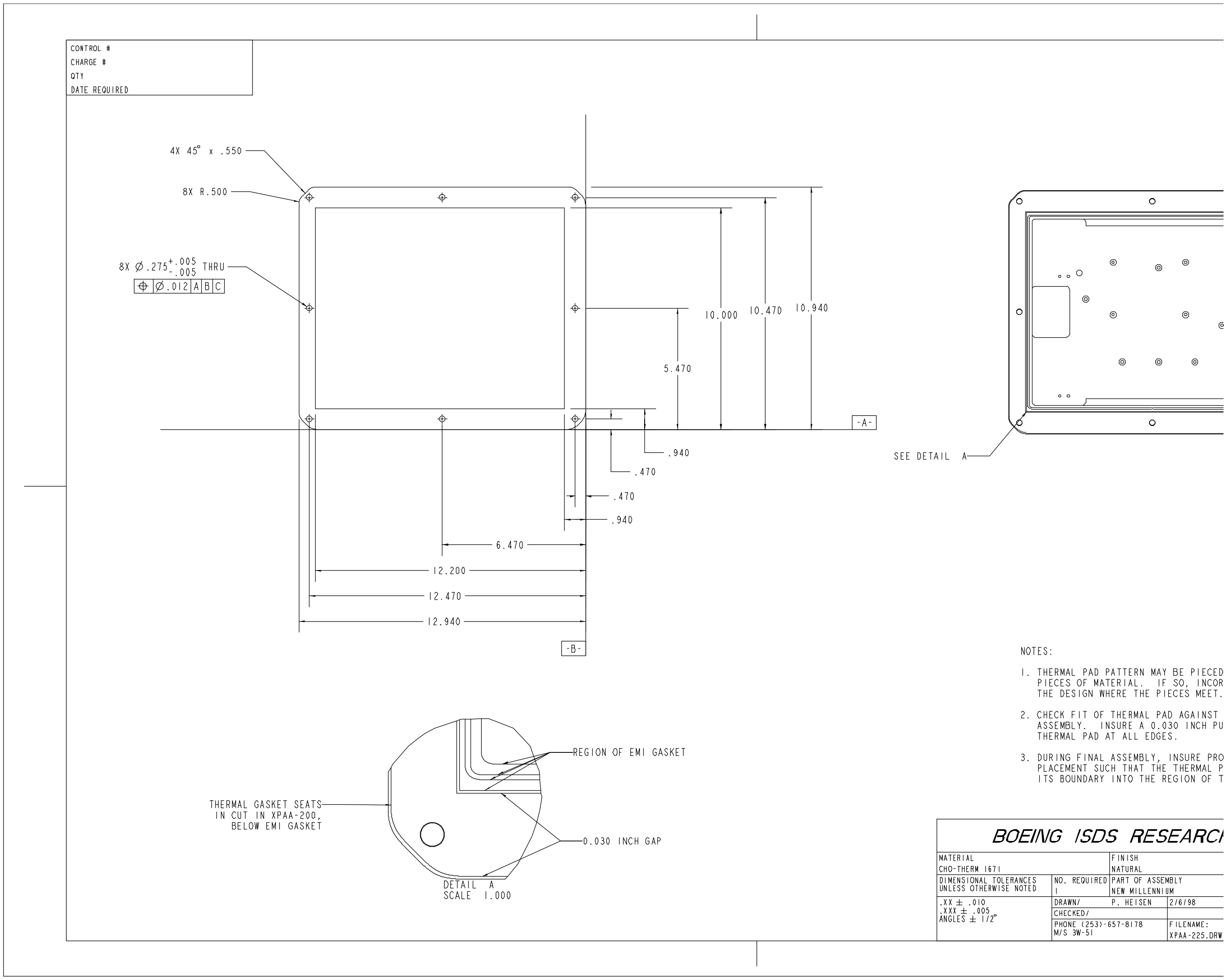
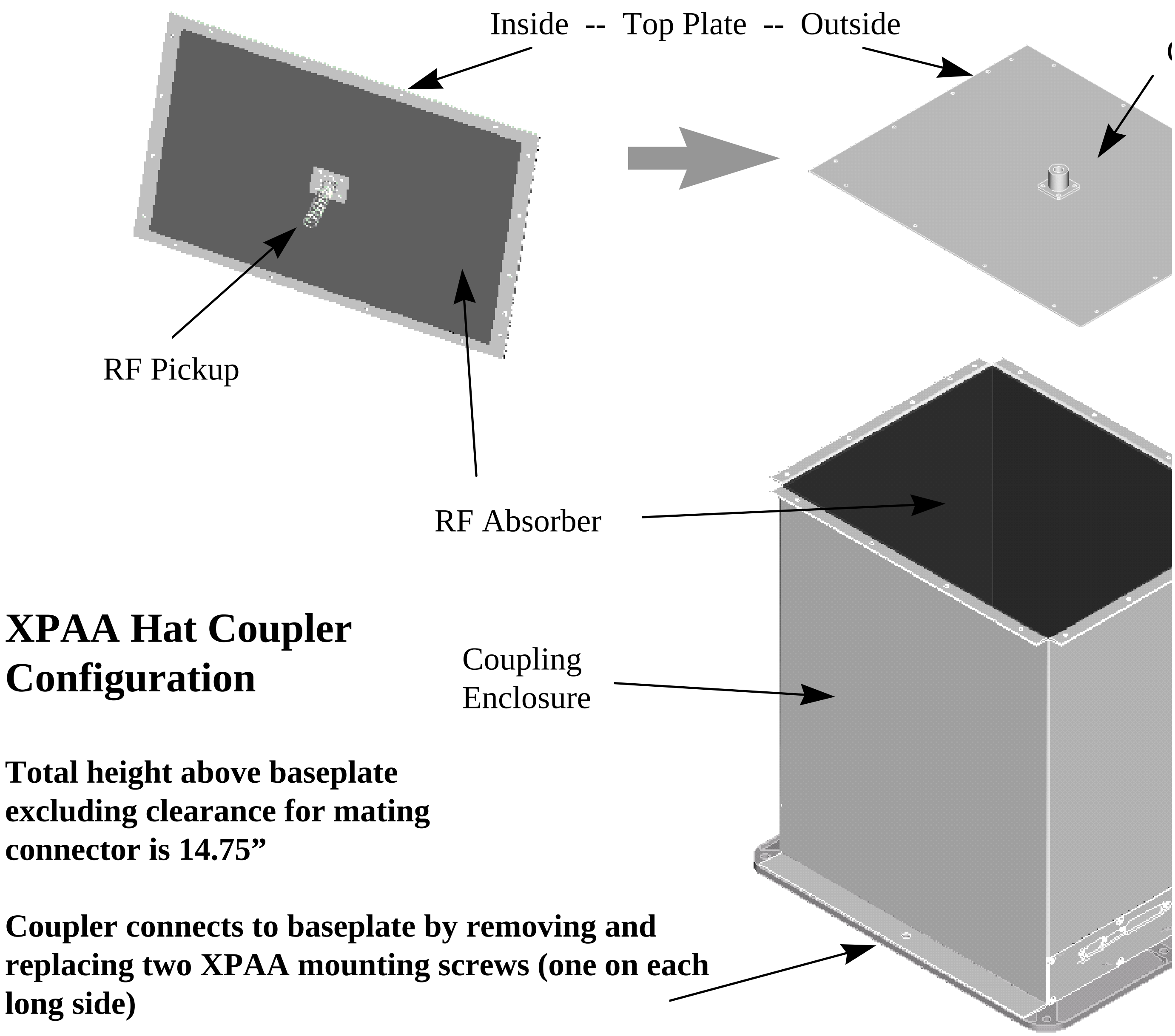


Figure 8-3. Test Hood



Abbreviations and Acronyms

^{o}C	degree Celsius
A	ampere
C&DH	command and data handling
dB	decibel
dBm	
dc	direct current
EIRP	effective isotropically radiated power
EMI	
EO-1	Earth Orbiter-1
ESN	essential services node
FPGA	field programmable gate array
FME	
GHz	gigahertz
ICD	interface control document
in-lb	inch-pound
kg	kilogram
LVPC	low voltage power supply
mA	milliampere
Mbps	megabytes per second
MCM	multi-chip module
MLI	multilayer insulation
mm	millimeter
mW	milliwatt
NASA	National Aeronautics and Space Administration
NES	
NMP	New Millennium Project
RF	radio frequency
RFI	radio frequency interference

RSN	remote services node
QPSK	quadriphase shift key
SMA	
SOW	statement of work
TBD	to be determined
TTL	transistor-transistor logic
UART	universal asynchronous receiver-transmitter
V	volt
Vdc	volt direct current
XPAA	X-Band Phased Array Antenna
W	watt
WAIM	
WARP	Wideband Advanced Recorder/Processor