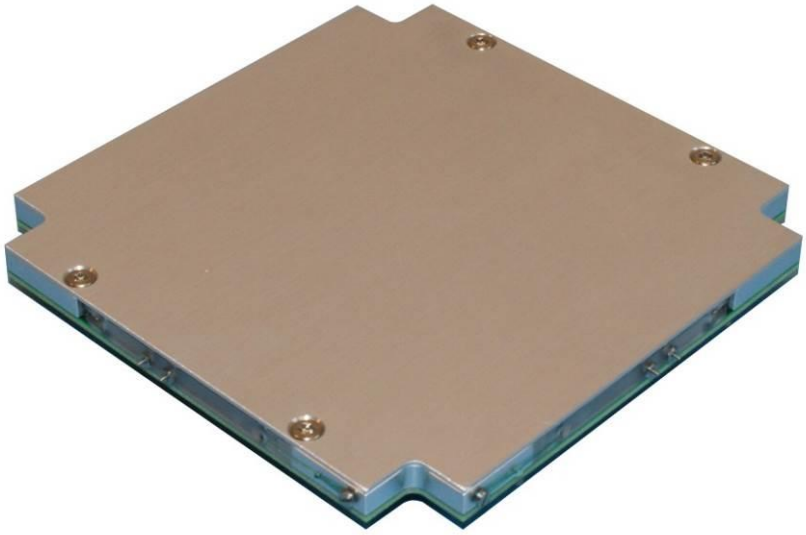
Antenna System User Manual

ISIS.ANTS.UM.001



Issue 1.44

Release information

Written by:	R. Fernandez	2014-08-20
Checked by:	R. Barnhoorn A. Dominguez	2014-09-16
Approved by:	R. Fernandez	2014-09-24

Distribution List:

Change log

Date	Issue	Modified by	Section / Pages Affected	Reason for Change
2011-11-01	1.0	R. Fernandez	All	Document Released
2012-02-22	1.1	R. Fernandez	§2	Antenna safety manual (ISIS.ANTS.SM.001) integrated into User manual
		V. Karunanithi	All	5.0V version of the Antenna System incorporated to the User Manual
2014-04-30	1.2	R. Barnhoorn	§6.2.9, §6.2.10, §6.2.11 and §6.2.12	Update of deploy antenna with override command description
2014-08-20	1.3	R. Fernandez	All	Update for revision D of the hardware. Annex E (system configuration) moved to Test Report
2014-10-29	1.4	M. Alvarez	§6.2.15	Update of deployment antenna status command

Applicable Documents

AD01			
AD02			
AD03			
AD04			
AD05			

Reference Documents

RD01			
RD02			
RD03			
RD04			
RD05			

TBD/TBC/TBW

TBD/TBC/TBW	Responsible	Action	Page

Disclaimer

The contents of this document are subject to the relevant provisions in the contract concluded between the parties. ISIS – Innovative Solutions In Space B.V. (“ISIS”) shall not be liable, in full or in part, for any damage arising out from the application or use of any product or circuit described herein, in case such application or use are carried out in a manner not in line with the instructions and warranties provided in the User Manual, Safety Manual, product information sheets or any other document provided by ISIS upon the delivery of the product (“Documents”). Further, ISIS shall not be liable for any damage caused by any use which exceeds the function(s) of the product, or does not conform to such function(s) as described in the Documents. ISIS shall not be liable for any damage arising from a use which is not carried out in a manner conforming to acceptable practices in the aerospace industry.

ISIS warrants that the product is supplied after relevant tests had shown the product is in good order and functioning, as far as these tests may indicate and predict product functionality.

List of Acronyms

1/2/3U	1-Unit, 2-Unit, 3-Unit; commonly referring to the singles and multiples of the commercially available CubeSat sizes
ANTS	ISIS Deployable Antenna System
ANTS-EM	Electrical model of the ISIS Deployable Antenna System without RF or mechanical function
AIV	Assembly, integration, verification
COTS	Commercial off the shelf
COM	Centre of Mass
EGSE	Electrical Ground Support Equipment
EMC	Electro-Magnetic Compatibility
EMI	Electro-Magnetic Interference
EPS	Electronic power system
ESD	Electrostatic discharge
I^2C	Inter integrated circuit communication bus used to control the Antenna system.
ISIS	Innovative Solutions In Space BV.
MGSE	Mechanical Ground Support Equipment
RF	Radio Frequency
RH	Relative Humidity
LED	Light emitting diode.
N/A	Not Applicable
TBC	To Be Confirmed
TBD	To Be Determined
TBW	To Be Written
UM	User Manual
VNA	Vector network analyser
UHF	Ultra High frequency (400-470MHz within this context)
VHF	Very High frequency (136-170MHz within this context)

Table of Contents

Table of Figures

Table of Tables

1 Introduction

The AntS provides a configurable antenna deployment system with a configurable user interface. The AntS can house up to four antenna elements which may be tuned for typical VHF and UHF frequencies in use by nano satellites as requested by the end user. The antennas may be configured for various RF antenna configurations (i.e 4 x monopole, 2 x dipole or 1 x turnstile) and are deployed under user command by a redundant control mechanism.

1.1 Purpose and Scope of Document

This document provides all information required to use and handle the ISIS Deployable Antenna System (AntS) Rev D properly.

This document is valid until it is declared obsolete or replaced with a succeeding version. Changes with respect to the previous version will be clear from the revision. As this document may be updated without prior notice, it is advised to check the ISIS website "www.isispace.nl" or ask us for the latest version at "support@isispace.nl" before using this document as reference.

1.2 Shipment contents

Please check the contents of the shipment case for completeness and damage during shipment. The shipment should typically contain the following items:

Item	Quantity	Check
Protective Case	1	
ISIS Antenna System (AntS) module	1	
Printed User Manual	1	
Printed Acceptance test results	1	
Omnetics male connector with cable (Omnetics reference A28000-009)	1	
RF cable with SSMCX/MMCX connector	2	
HDRM assist pins	2	
HDRM burn wire puller	1	
Burn wire refurbishment set		
HDRM burn wires	4	
HDRM burn wire fasteners M1.4	4	

Table 1-1 Shipment Content Check-list

1.3 Specification

Parameter	Typical Value	Comments
Environmental Characteristics		
Qualified operational temperature range	-20 to +60°C	
Storage temperature range	-50 to +85°C (RH<60%)	
Electrical Characteristics		
Supply Voltage	3.0V to 3.6V (3.3V nominal) 5.0V (on customer request)	
Typical current consumption (antennas stowed)	9mA @ 20°C	

Parameter	Typical Value	Comments
Typical current consumption (antennas deployed)	8mA @ 20°C	
Typical deployment current (for each element)	0.56A @ 3.3V 0.30A @ 5.0V	
Typical deployment duration (per antenna at temp >0°C)	<3s	
Safety Time limit	30s	
Physical Characteristics		
Dimensions (Main)	98 x 98 mm	
Dimensions (Extending fasteners)	102 x 102 mm	
External height	6 mm	
Internal envelope	3.0 mm	
Weight	89 grams	
RF Characteristics		
Antenna Return Loss at resonance frequency (with antenna deployed)	< -10dB	

Table 1-2 Ants Overall Specification

2 Handling and Storage

2.1 Handling

Note that the AntS is sensitive to Electro Static Discharge (ESD).

2.1.1 Electrostatic discharge ESD

CAUTION

The printed circuit board can be damaged by electrostatic discharge. Do not touch any of the boards unless it is absolutely necessary. If you must handle them, wear a grounded wrist strap and take other antistatic precautions. Wear a grounded wrist strap any time you must handle the board.

2.1.2 Exposed Voltages

WARNING

Handling the board with an active power supply connection is not recommended. The board itself could be damaged and there is a possibility of electric shock hazard

In the event of Emergency, disconnect the power supply and proceed, if required, with first aid activities.

2.1.3 Current Limit protection

CAUTION

Ensure that over-current protection to a level of 1A is present when connecting to external power supplies.

2.1.4 Operation Conditions

CAUTION

The AntS is supplied ready for deployment. Performing any mechanical operations altering the physical state of the system may impede deployment reliability.

Limit the number of connector mating cycles to less than 50 (about 10 cycles are used during functional testing)

CAUTION

Limit the number of connector mating cycles to less than 50 (about 10 cycles are used during functional testing)

CAUTION

The AntS is supplied with final functional test results. Operating it outside its prescribed operating conditions may impede functionality.

The resistors used to burn the wires holding the antennas withstand a limited amount burn cycles. Each resistor can tolerate a maximum of 100 burn cycles or a cumulated burn time of 300s. If stressed over these rating, the burn resistors must be refurbished by ISIS.

CAUTION

The AntS is supplied pre-tuned to the ordered frequency range on a standard 3U ISIS mechanical structure. Mounting the AntS on a different structure (especially with custom deployables) may change the resonance frequency range.

WARNING

The use of protective glasses is encouraged whenever the ANTS is being manipulated.

The deployment system might be inadvertently activated leading to serious personal injury.

CAUTION

This system is intended for INDOOR use only and should not be operated outdoors as the board electronics might be damaged.

Ensure that the system is always operated within its qualification temperature range: -20 to +60°C [RD01]

WARNING

Some components on the AntS (such as the burn resistors on the bottom side of the PCB) will get very hot during operation.

Handling the system while this part of the system is active may lead to minor injury.

2.2 Storage

CAUTION

Store the ANTS inside a sealed ESD bag and in an environment controlled area.

The absolute maximum ratings for storage temperature are from -50 to +85°C with a Relative Humidity <60%

2.3 Disposal

WARNING

This product contains materials that can be harmful for the Environment and as such it should not be disposed of with conventional waste but treated according to WEEE regulations (UE Directives 2002/96/EC and further amendments) and brought to an appropriate recycling facility.

3 Functional Description

3.1 General Description

The main functionality of the antenna system is to deploy the stowed antennas so that the antennas can be used for RF transmissions. A few of the concepts the system uses will be explained below.

3.1.1 Arming and disarming

In order to prevent the antennas from accidentally deploying, the system has an armed and disarmed state. The deployment systems for the antennas can only be activated when the system has been armed. The antenna system can be armed using an I^2C command.

3.1.2 Antenna deployment switches

The deployment system of each antenna is equipped with a switch. The function of this switch is to detect whether the antenna is deployed or undeployed (also referred to as stowed). The switches are connected to both microcontrollers in the antenna system, which allows their status to be read out using I^2C.

3.1.3 Activation safety time limit

In order to prevent the deployment systems from being active too long a safety time limit has been built into the system. Having the deployment system active too long could result in damage to the deployment system itself, which would prevent reuse. Reuse might be required if it's unclear whether the antenna has deployed or not and another deployment attempt has to be performed. The safety limit is also in place to prevent the deployment systems from draining the satellite's batteries when accidentally activated for too long.

3.1.4 Activation tracking

For each deployment system the following information is stored in the microcontroller:

- How many times has the deployment system of the antenna been activated
- How long in total has the deployment system been active. This is added up over multiple activations.

This information is available from the microcontroller upon request and can be used to determine how long it took for antenna to deploy. Please note that this information is lost whenever the microcontroller experiences a reset.

3.2 Power Conditioning and Distribution

There are two redundant power connections on 9pin connector.

3.3 Grounding Scheme

There are three redundant ground connections on 9pin connector with common system ground used.

3.4 Electrical Description

The AntS electrical architecture is described in Figure 3-1 for the non-RF components. The whole deployment system is composed of two fully redundant microcontroller based systems. Antennas are deployed by burning a wire as described above. Antenna status (stowed or deployed) is measured using switches. One I^2C repeater is used for each data bus in order to provide better isolation and robustness of the I^2C bus. Two temperature sensors are present on the board.

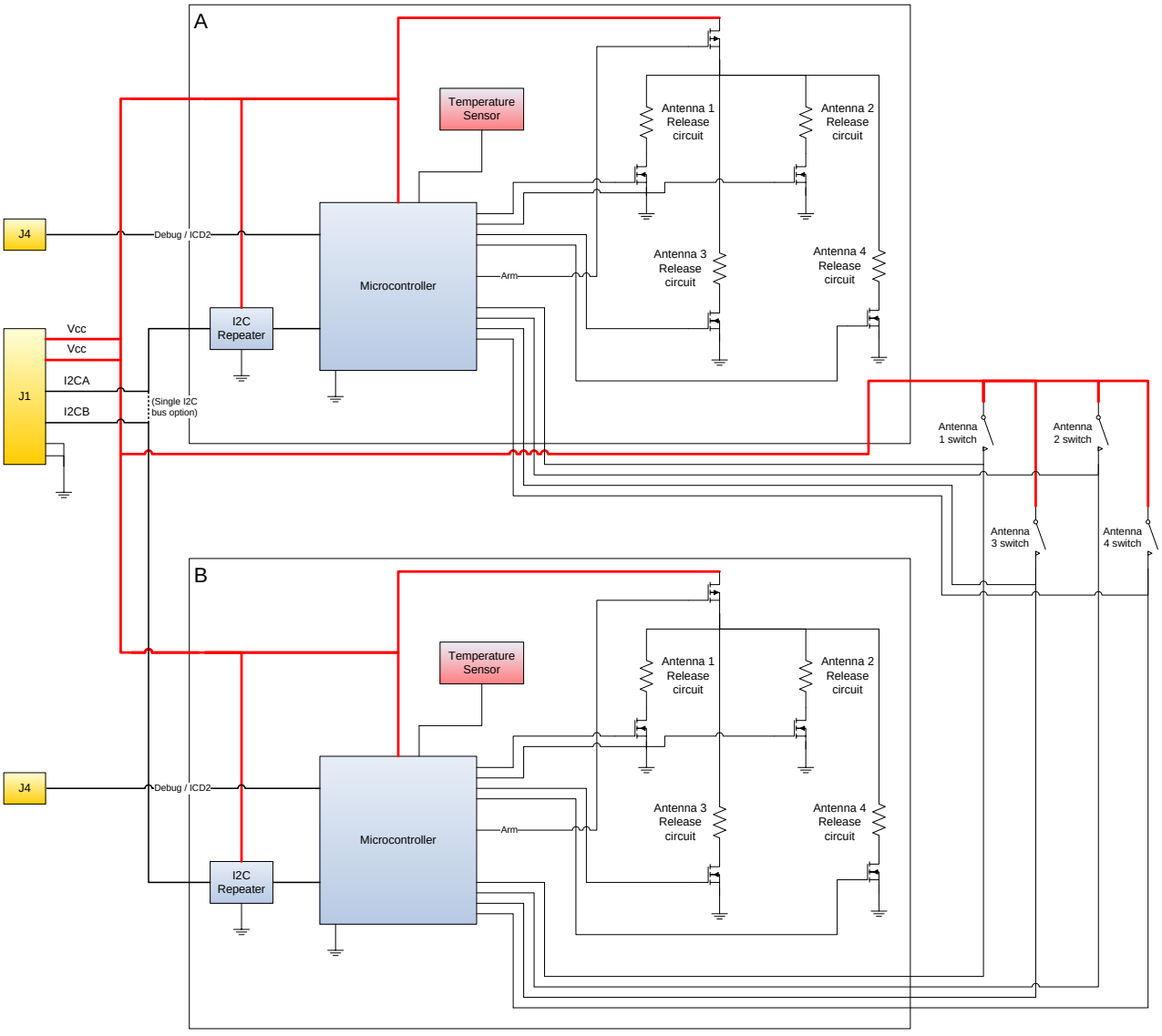


Figure 3-1 AntS Electrical block diagram (no RF)

3.5 RF Description

Figure 3-2 shows the RF components of the AntS. Depending on the antenna configuration option, different components are used on the PCB as described in Table 3-1.

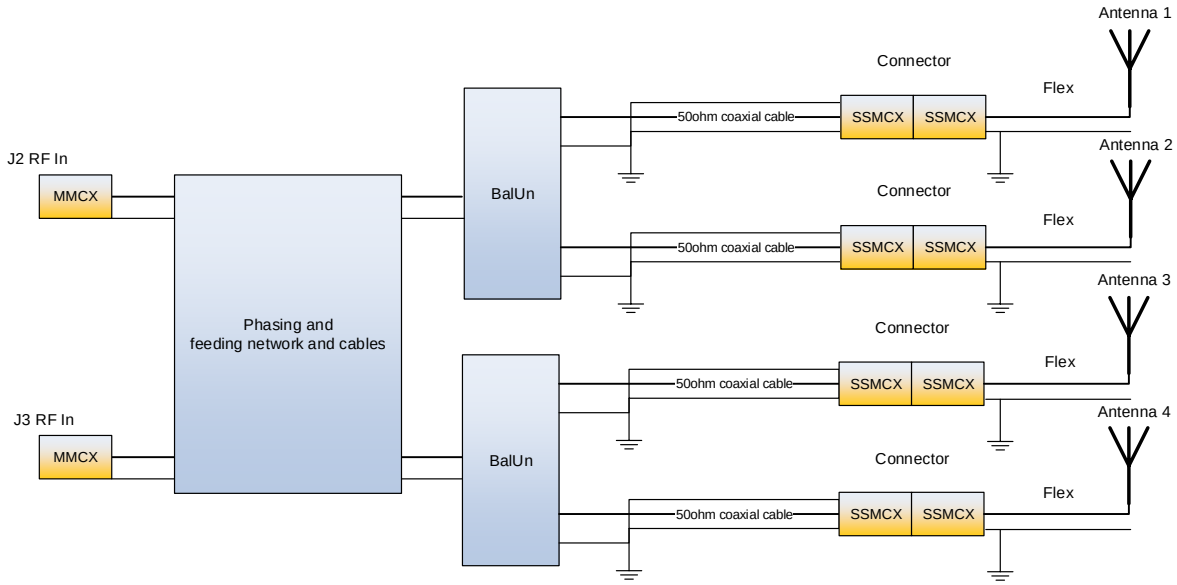


Figure 3-2 Ants RF block diagram

RF Configuration	90Deg phase shifter	RF Ports	Polarization	Elements in use	Number possible per AntS
UHF Turnstile	In use	J2 or J3	Circular	4	1
VHF Turnstile	In use	J2 or J3	Circular	4	1
UHF Dipole	Not Used	J2 or J3	Linear	2	2
VHF Dipole	Not Used	J2 or J3	Linear	2	2
UHF Monopole	Not Used	Flex Connectors	Linear	4	4
VHF Monopole	Not Used	Flex Connectors	Linear	4	4

Table 3-1 AntS RF Configurations

For the turnstile configurations the antenna may be configured for right hand (default) or left hand circular polarization depending on the physical connection of the phasing cables. For the dipole and turnstile configurations, phasing lines and baluns are implemented on the AntS Motherboard. For the monopole configuration, the antennas are fed directly from the flex-rigid PCB and no RF components are used on the AntS Motherboard. Note that combinations of UHF and VHF dipoles and monopoles are possible to be implemented on a single AntS PCB but the effect of the custom configurations on the resonance tuning needs to be taken into account during the tuning process.

3.6 Mechanical Description

The ISIS Antenna System (AntS) design is fully compatible with the CubeSat standard as defined by CalPoly and compatible with ISIS & Pumpkin CubeSat structures. When delivered the AntS is already fully assembled and nearly all fasteners are locked with torque and Epoxy (3M Scotchweld 2216). Exceptions are the fasteners holding down the cover lid and the fasteners which need to be accessed by the customer to allow

integration with the customer satellite.

The antenna system consists of up to four antenna elements which are rolled-up and stowed inside the antenna housing. An aluminium bracket creates an enclosure in which the antenna is stowed and contains a Polycarbonate lid to release and deploy the antenna in orbit (Figure 3-3, centre red circle).

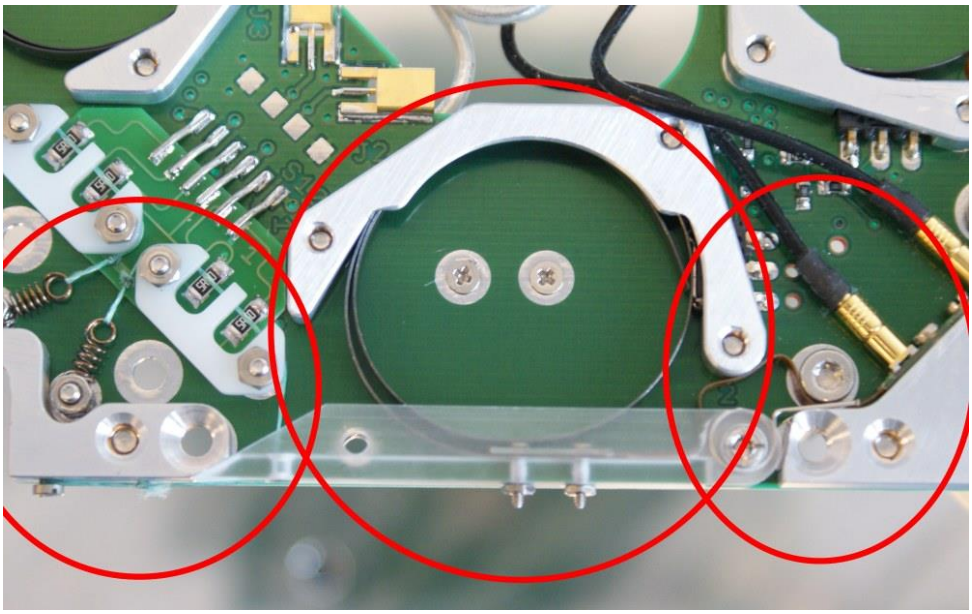


Figure 3-3 Modular Antenna Box

The Antenna elements are made out of a NiTi-alloy based shape memory alloy in order to reduce the required antenna envelope in stowed configuration. The antenna is connected to a SSMCX connector through a flex-rigid PCB (Figure 3-3, right red circle).

The lid is kept close with a spring tensioned burn wire which is made from dyneema wire. The wire is routed over a set of redundant resistors which can be heated on command, which melts the wire and releases the lid (Figure 3-3, left red circle).

The dimensions of the antenna system as viewed from the side are provided in the mechanical drawings in Annex D. The overall height of the AntS is build up by a 1mm PCB, 4.1mm mechanical parts and an aluminum lid of 0.8mm (which is delivered as standard with every unit shipped) for a total of 5.9mm. CAD models of the entire AntS may be delivered on request.

4 Interfaces

4.1 Electrical interface

The Ants is powered by a 3.3V supply (5V on customized boards) from the satellite EPS. During the brief period of antenna deployment the AntS requires approximately 2W of electrical power. After deployment the system may be permanently switched off by the satellite EPS to save power.

The burn time required per antenna element deployment at 20ºC is typically less than 3s. For deployment at very high temperature this would be shorter (<2s at 80ºC) while for very cold temperatures this would be longer (<6s at -40ºC). Note that these measurements were done at ambient pressures where the heat from the resistors would also be removed from the application area of the wires by convection which would not be applicable for the case of the AntS operating in a vacuum. It is therefore expected that the burn times given are conservative estimates.

Connector J1 is the interface for providing the power and data to the Antenna system (see Figure 4-5). Please find the pin-out in the Table 4-1 below.

Connector	Pin	Name	Level	Remarks	Wire color*
J1	1	Vcc	3.3V nominal (min 3.0V, max 3.6V) 5.0V (on customized boards)	Positive supply voltage	Black
	2	SDA_A	0-3.3V nominal (5V tolerant)	I2C data A	Brown
	3	GND		Ground	Red
	4	SDA_B	0-3.3V nominal (5V tolerant)	I2C data B	Orange
	5	GND		Ground	Yellow
	6	Vcc	3.3V nominal (min 3.0V, max 3.6V) 5.0V (on customized boards)	Positive supply voltage	Green
	7	SCL_A	0-3.3V nominal (5V tolerant)	I2C clock A	Blue
	8	SCL_B	0-3.3V nominal (5V tolerant)	I2C clock B	Violet
	9	GND		Ground	Gray

* Corresponds to the wire color of the Omnetics Bi-lobe male connector reference A28000-009.

Table 4-1 J1 pinout

Note that there are 2 separated I^2C buses (it is possible to connect them together onboard the AntS with a 0ohm resistor, please contact us for this option). The AntS has one electrical ground only (RF, power, mechanics).

J1 is a female Omnetics Bi-Lobe dual row 9 pins connector (type AA, female SMT, reference A29100-009). It is a high quality MIL-DTL-32139 qualified connector. The pin numbering is shown in Figure 4-1.

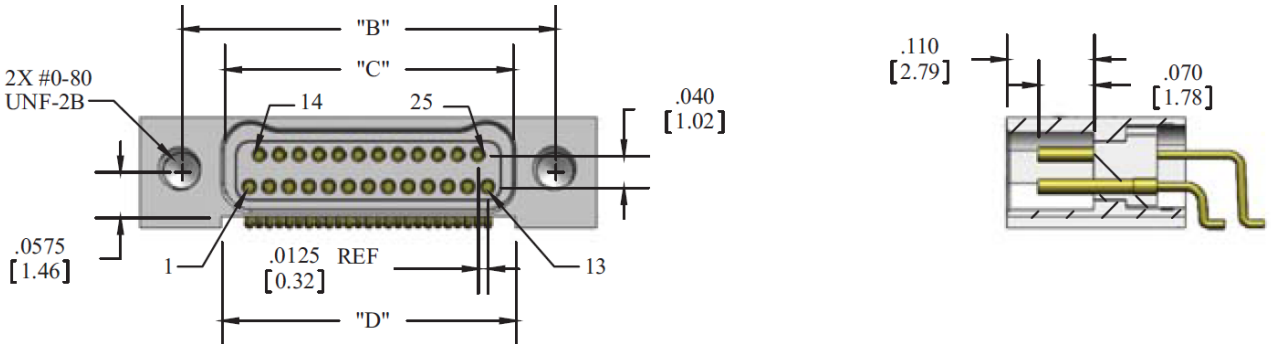


Figure 4-1 Omnetics Bi-Lobe type AA pin numbering (figure shows a 25 pin connector but the 9 pin version is used)

The Ants is provided with a male Omnetics Bi-Lobe dual row 9 pins connector (type WD, male pre-wired, 18 inches wire length, Colour Coded IAW MIL-STD-681, reference A28000-009). The wire thickness is AWG30 as shown in Figure 4-2.

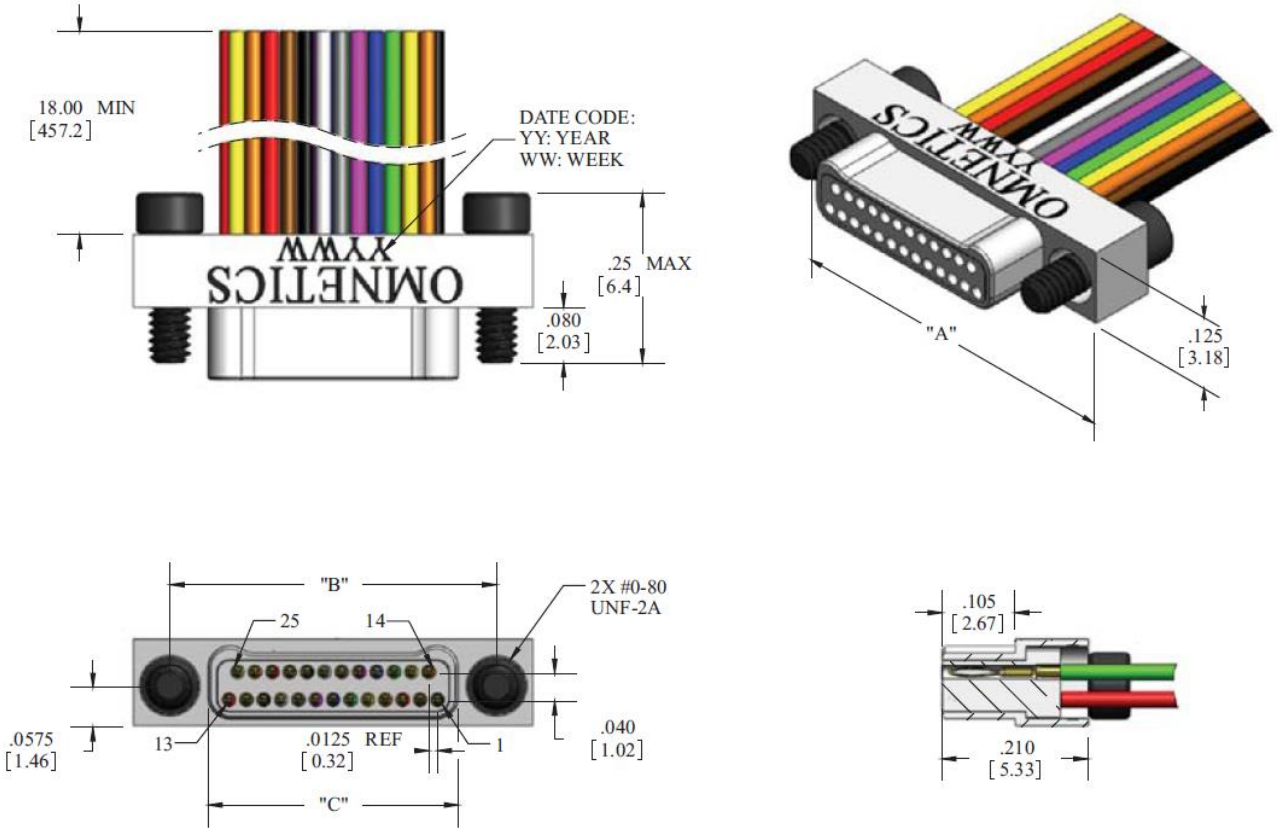


Figure 4-2 Omnetics Bi-Lobe type WD pin numbering (figure shows a 25 pin connector but the 9 pin version is used)

Please take great care while mating and de-mating J1. Refer to §5.1.3 "Connector Mating/De-mating" for further information regarding the proper mating and de-mating of the system connectors.

4.2 RF interface

The RF circuit of the AntS is interfaced by means of 1 to 4 MMCX or SSMCX female coaxial connectors dependant on system configuration (one for the turnstile antenna configuration, two for the dual dipole configuration and four for the monopole configuration.). These connectors are J2 and J3 (see Figure 4-4). For the turnstile antenna configuration, the signal is provided through either J2 or J3 keeping the unused output terminated. The additional output is used for testing purposes at ISIS only.

Note: using the internal test connector for connecting a turnstile antenna to a satellite radio system will lead to a dysfunctional antenna system).

The RF impedance of all connectors is 50 ohms with a S11 of less than -10dB (with the AntS mounted on a satellite structure and antenna deployed). The maximum RF power handling on all RF ports is 2W.

Note: Do not transmit any radio signals to the antenna systems when all antennas are not deployed (in this case there may be almost a full reflection of the power at the RF input).

J2	J2.1	RF in/out		50 ohm
	J2.2	GND		RF ground (at same potential as power ground)

Table 4-2 RF Connector pinouts

The type of connectors used on the AntS is the MMCX edge mount jack (female). In the configuration of one to four independent monopole antennas the interface to the antenna elements may be done by user defined cables which may be connected directly to the SSMCX connectors on the flex-rigid PCB's as is visible in Figure 4-4.

Please take great care while mating and de-mating J2 and J3. Refer to §5.1.3 "Connector Mating/De-mating" for further information regarding the proper mating and de-mating of the system connectors.

4.3 Data interface

The data interface's hardware characteristics are listed in Table 4-3 below. For the command interface specification, please refer to §6

Parameter	Typical Value
Bus logic low-level input voltage	0 - 1 V DC
Bus logic low-level output voltage	0.47 – 0.6V DC
Bus logic high-level voltage	2.3 - 3.3 V DC
Supported I^2C modes	Standard-mode (up to 100 kbits/sec) Fast-mode (up to 400 kbits/sec)
Supported address types	7 bits (10 bits on request)
I^2C node type	Slave only
I^2C general call supported	Yes

Table 4-3 I^2C specifications

Note: Because of the use of I^2C repeaters to provide bus isolation, the low-level output voltage cannot have a value of 0V, but typically a value of 0.5V.

For more details on the I^2C bus timings and operations, please refer to the *I2C-bus specification and user manual* from Phillips – NXP (UM10204, Rev. 03, 19 June 2007, http://www.nxp.com/documents/user_manual/UM10204.pdf).

Note: Since each microcontroller can be commanded separately, it is technically possible to initiate two antenna deployment in the same time using microcontroller A and microcontroller B. The power consumption is 4W in this case. Although the AntS will not be damaged, this is not the recommended mode of operation. Be sure that this case does not happen when sending antenna deployment command and/or that the EPS can handle 4W.

4.4 Mechanical Interface

The ISIS AntS is designed to be mounted onto either the ISIS CubeSat structure or the Pumpkin CubeSat structure. However both structures require a different mounting configuration. For mounting the AntS module to an ISIS CubeSat structure it requires four M2.5x10 CSK Torx screws. The mounting holes for mounting the structures top/bottom panel are used for mounting the AntS module (Figure 4-3, red dots). In case of custom structures it is advised to use the ISIS CubeSat structure mounting pattern.

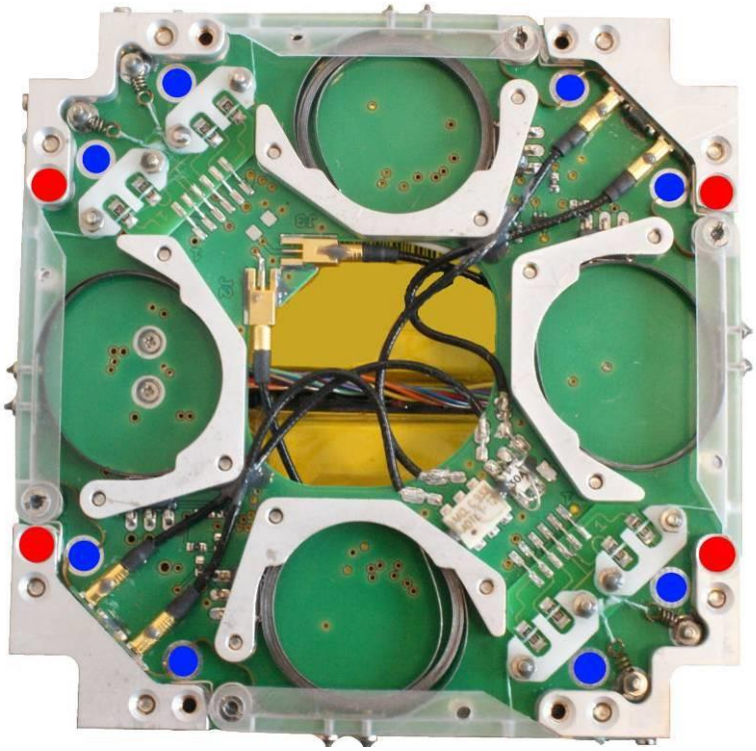


Figure 4-3 ISIS & Pumpkin CubeSat structure mounting points on the AntS module

The ISIS AntS module is also compatible with the bottom panel of the Pumpkin rev D CubeSat structure. This however requires a modification to the bottom panel of this structure (Annex C). The AntS module is fastened to the Pumpkin structure bottom panel with eight M2.5x6 Cylinder Hex bolts with nuts (Figure 4-3, blue dots).

Due to the electrical components on the bottom (internal) side of the AntS module, the internal envelope height is determined at 3.0 mm (Annex D). For safety reasons it is recommended that the dynamical envelope for the module is 5.0 mm.

Figure 4-5 and Figure 4-4 show the location of the main electrical components on the top side and bottom side of the AntS.

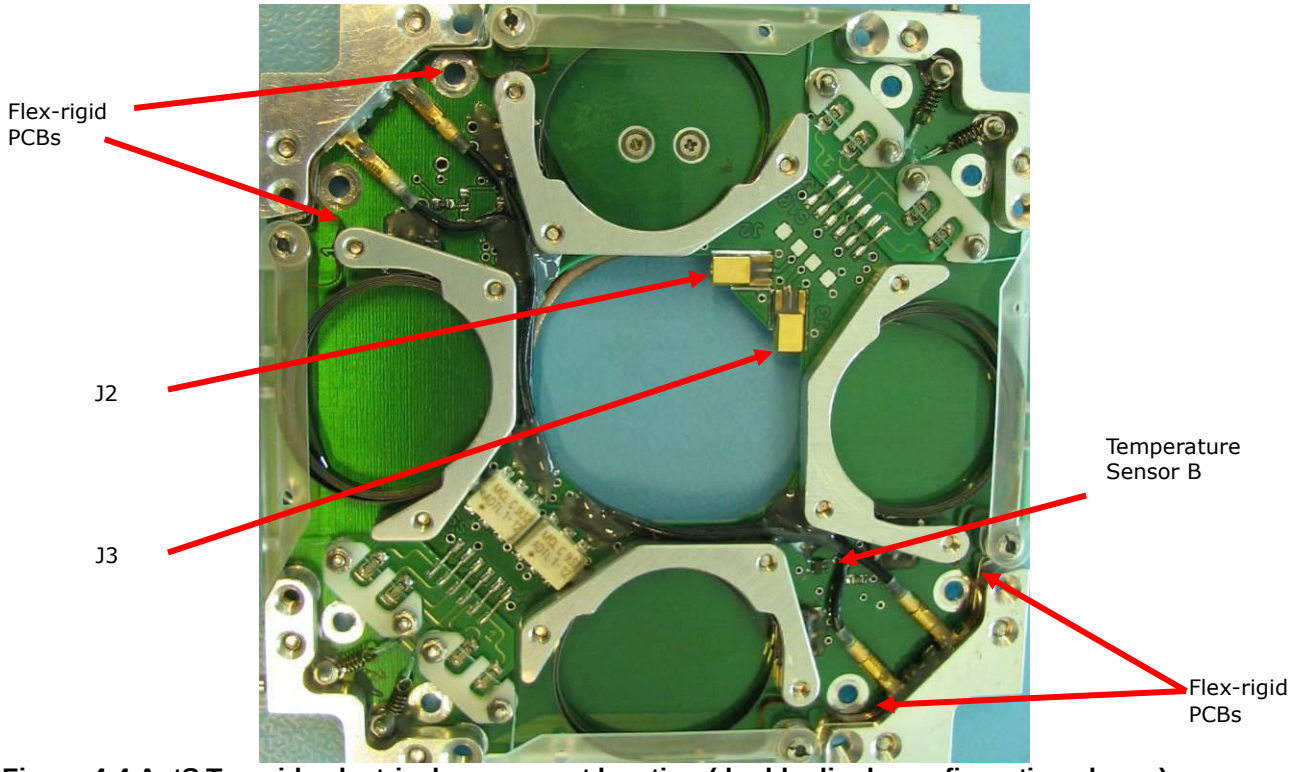


Figure 4-4 AntS Top side electrical component location (double dipole configuration shown)

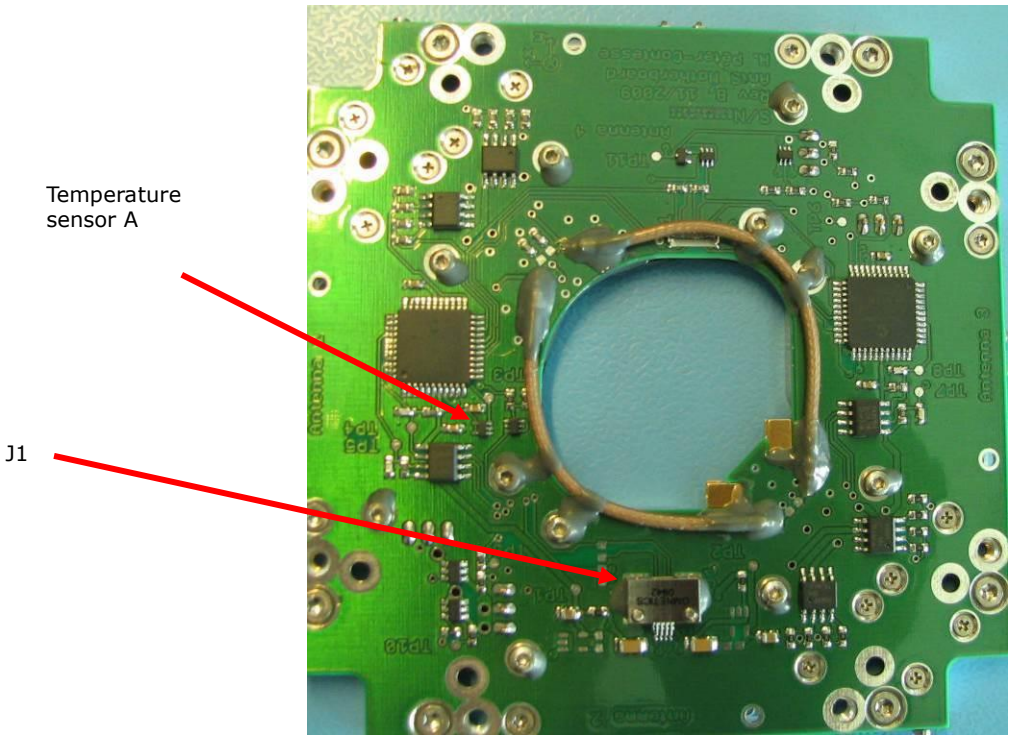


Figure 4-5 AntS Bottom side electrical component location (picture shows a double dipole configuration)

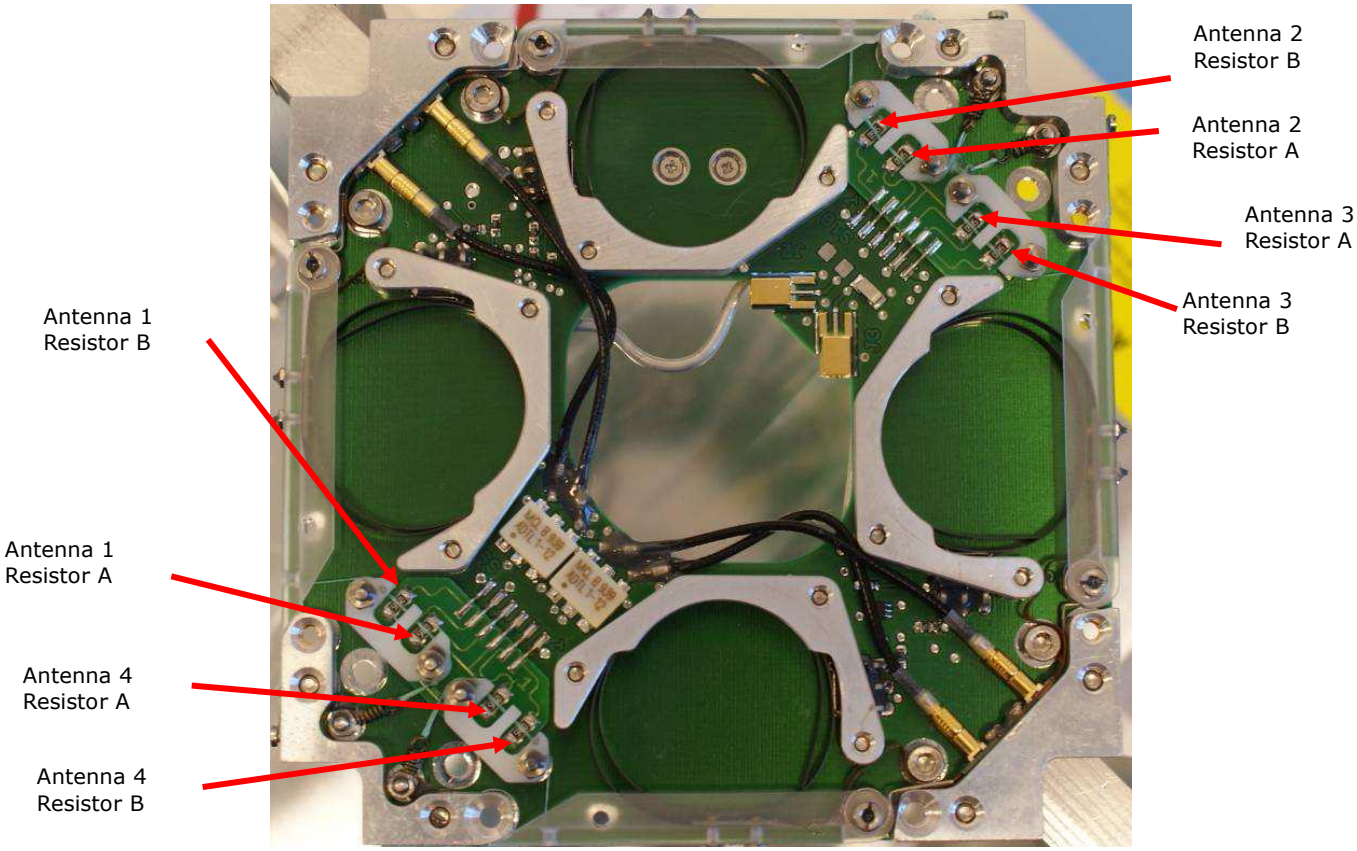


Figure 4-6 Burn Resistor reference

5 Detailed Description of Operations

5.1 Assembly instructions

5.1.1 Mounting ANTS into the Satellite structure

When mounting the ISIS AntS module to any CubeSat structure it is advised to perform the following steps:

1. Remove the AntS module from the ESD bag.
2. Remove the top panel from the module.
3. Mount the module to the structure top/bottom (Note: proper axis alignment) (Annex D)
    a. For ISIS STS use 4x M2.5x10 CSK Torx.
    b. Custom STS with AntS main mounting use 4x M2.5x10 CSK Torx.
    c. Pumpkin STS use modified STS bottom panel with 8x M2.5x6 Cylinder Hex screws with nuts (not included).
4. Connect the Omnetics connector/cable (J1) to the system bus (refer to section 4.4).
5. Connect the RF connector(s)/cable(s) to the satellite radio transceiver and the AntS (Refer to Figure 5-9 and Figure 5-10).
6. Confirm the proper routing of the flex-rigid PCB (Figure 5-1).

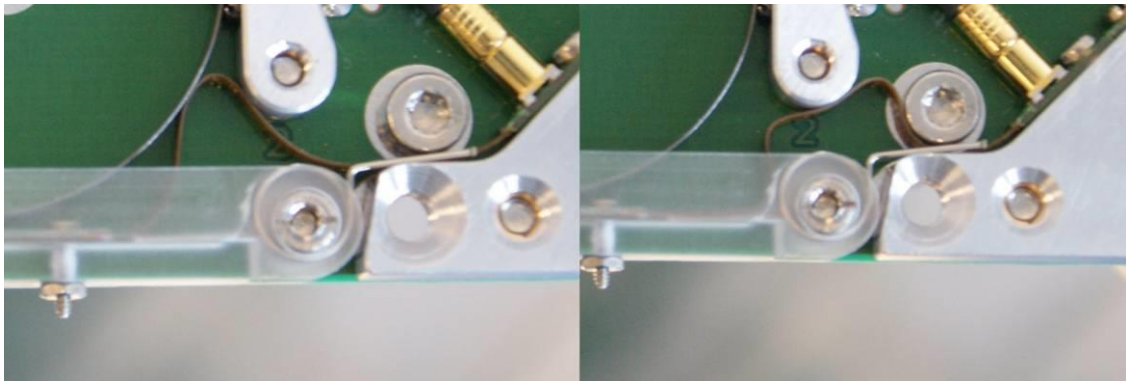


Figure 5-1 Left: improper routing of flex-rigid PCB; right: proper routing of flex-rigid PCB

7. Mount the top panel.
8. (Perform functional testing & wire refurbishment).
9. Remove the top panel.
10. Loosen the STS fasteners.
11. Apply torque (0.7 Nm) and Epoxy on the structure mounting fasteners.
12. Mount the top panel and apply torque (0.7 Nm) and Epoxy on the fasteners.

5.1.2 Burn wire refurbishment

After performing a full functional burn test, the burn wires need to be refurbished by

performing the following steps:

1. Remove the top panel from the AntS module.
2. Inspect resistors visually.
3. Remove the old burn wire remains.
4. Close the antenna lid with the HDRM assist pin and stow the antenna (Figure 5-2).

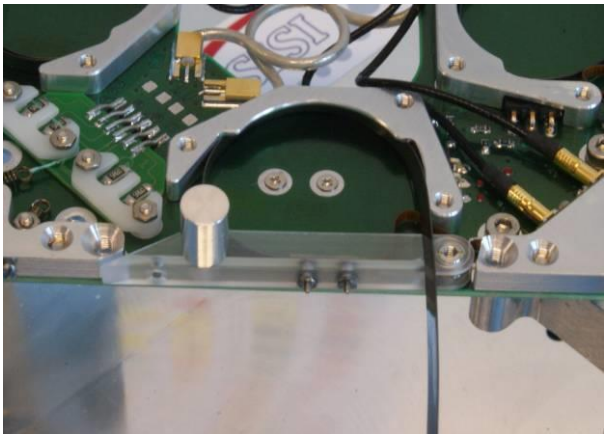


Figure 5-2 Fixing lid with HDRM assist pin

5. Mount the small loop side of the wire to the pull spring with tweezers (Figure 5-3).

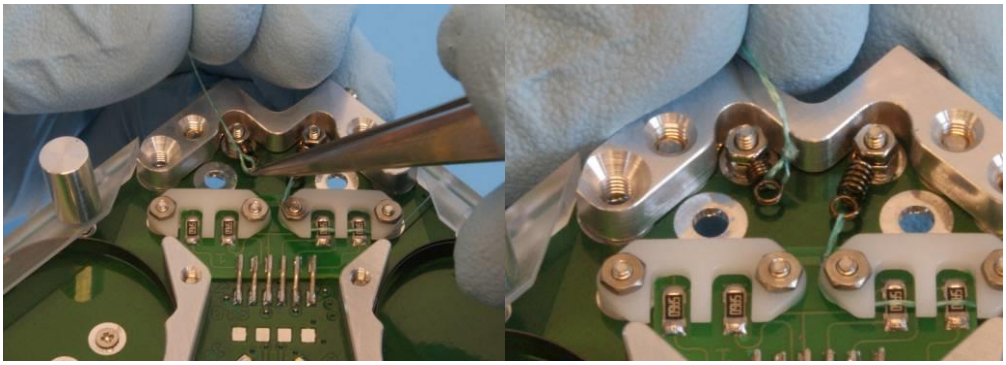


Figure 5-3 Mounting burn wire to pull spring

6. Align the wire over the resistors (Figure 5-4).
7. Route the burn wire through the exiting hole.

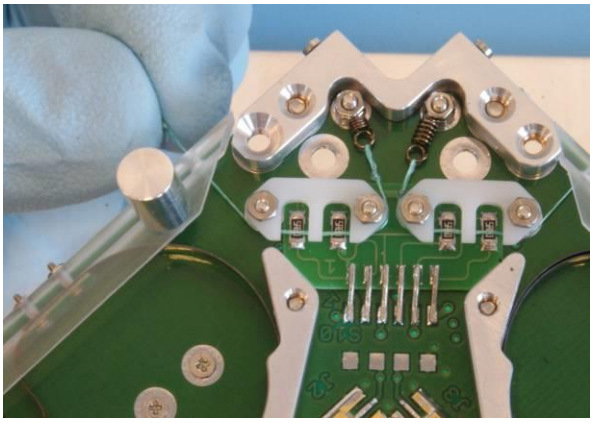


Figure 5-4 Alignment of HDRM burn wire

8. Use the wire puller MGSE to align the mounting screws with its mounting hole (Figure 5-5).

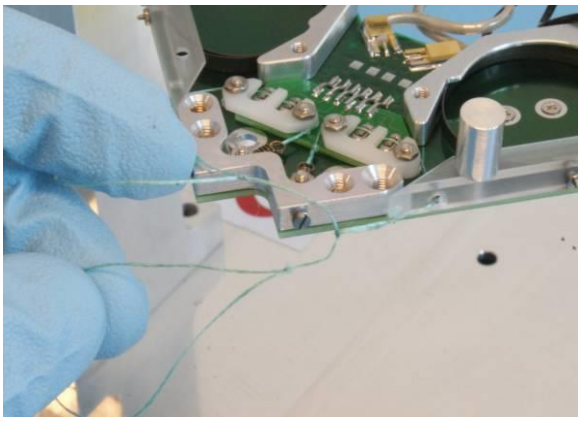


Figure 5-5 HDRM Burn wire with wire puller

9. Fasten the screws (M1.4) with 0.07 Nm torque (and apply Epoxy (Only for final flight preparation - Refer to Figure 5-6).
10. Remove the wire puller.
11. Inspect the burn wire, the pull spring and the flex-rigid PCB (Figure 5-1) before closing the top panel.

Figure 5-6 Final External epoxy on burn wire

5.1.3 Connector Mating/De-mating

5.1.3.1 Omnetics Main Connector - J1

Please take great care while mating and de-mating J1. The simultaneous use of 2 screw drivers (hexagonal, ball-ended, 1.3mm/0.050inch tip, for example Farnell reference 3106159) is strongly recommended in order to screw-unscrew while keeping the connector faces parallel to each other (see Figure 5-7 and Figure 5-8). If only one screwdriver is available sequentially turn each fastener half a turn at a time to achieve the same result.

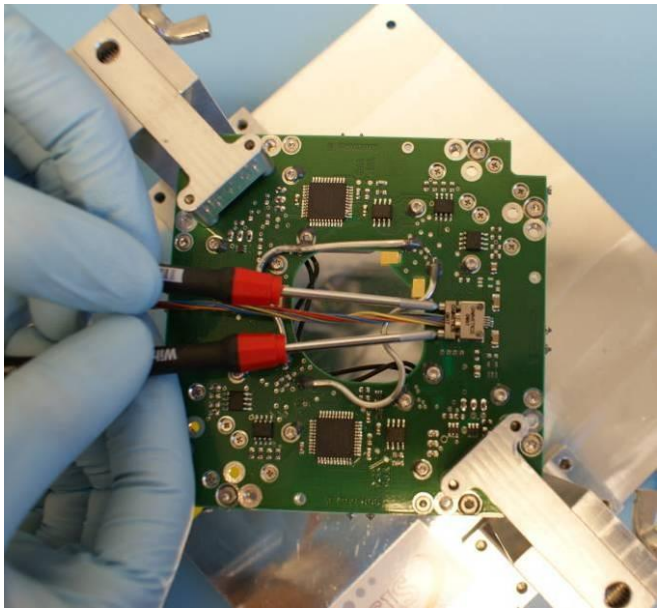


Figure 5-7 Mating of the main connector

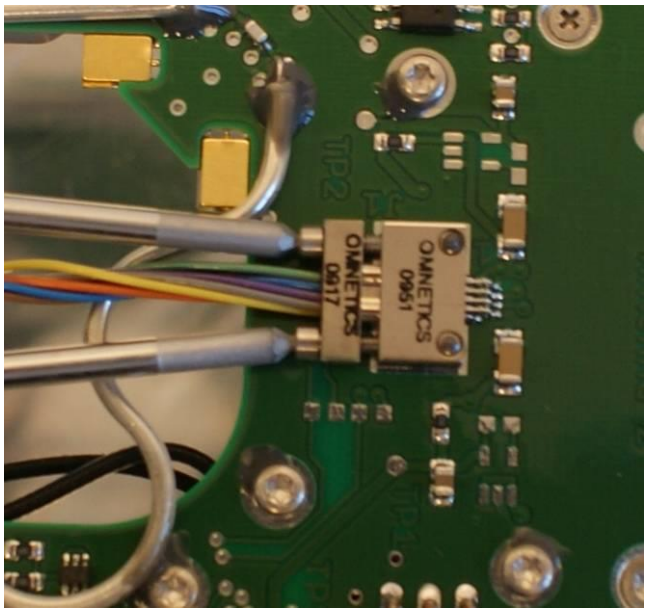


Figure 5-8 Detailed view of main connector mating

5.1.3.2 RF Connectors – J2 / J3

To mate or de-mate RF connectors it is recommended to physically support the connector during the process to prevent damage to the PCB (see Figure 5-9 and Figure 5-10).

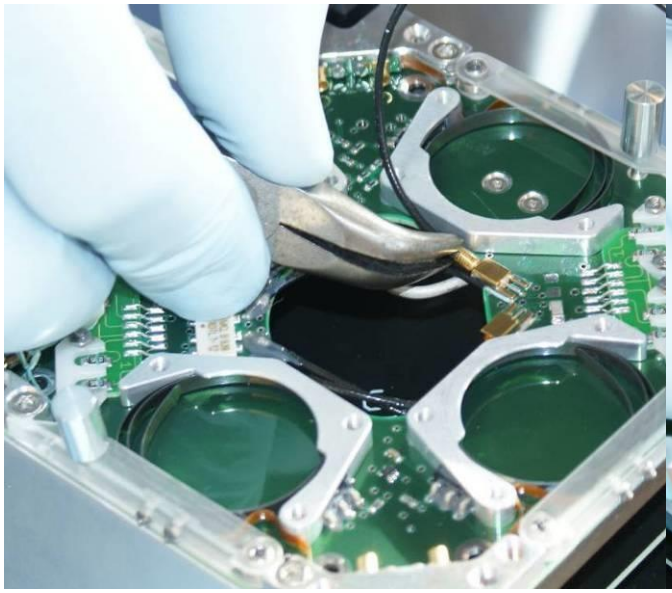


Figure 5-9 Mating of J2 for turnstile and dipole configurations

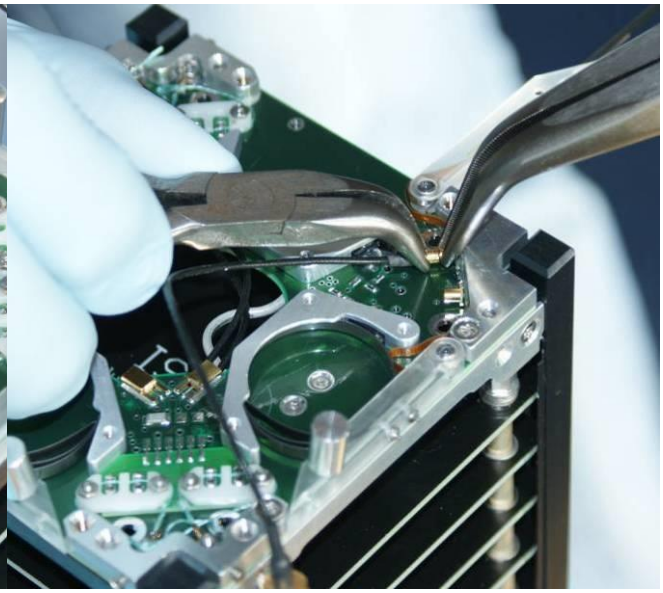


Figure 5-10 Mating of flex-rigid PCB connector for monopole configurations

5.2 RF Operations

5.2.1 RF resonance tuning

In order to measure the antenna resonance frequency the AntS must be mounted on a satellite structure that is representative of the final satellite flight configuration and the S11 return power measured over a valid frequency range with a vector network analyzer. Other appendages like other antenna systems or deployable solar panels and/or sensors need to be incrementally introduced to the final system level resonance measurement to determine if they have an effect on the resonance frequency or not.

Keep in mind that the adjacent elements of the total antenna system may have a pronounced influence on the measurements. This is especially true for antenna elements on opposite sides of the structure (180º) but is also true for elements adjacent to the antenna element under test. (90 º 270 º). As far as possible the final operational configuration should be replicated during the measurement as well as any frequency tuning of the elements that may be performed. This type of tuning must also be done incrementally in small steps.

Open Air Antenna measurements in the VHF and UHF frequency ranges may be influenced a lot by the surroundings in which the measurements are done. Personnel touching the measurement setup or even walking by the setup may influence the measurements. As a rule of thumb these types of measurements are therefore best done in an area 5 to 10 wavelengths away from reflecting material or personnel.

For delivery of ISIS ANTS to clients a basic pre-tuning of the resonance frequency is performed on a standard ISIS structure. As the influence on a single antenna between very small and very large structures has been found to be small, the pre-tuning is typically performed on a "middle sized" structure namely the ISIS 2U structure. No effects of other appendages are taken into account during the pre-tuning. In case of special request from customers, the antennas are tuned on 1U, 2U or 3U structure.

While it is possible to tune the resonance frequency of AntS upwards by reducing the antenna element lengths, it needs to be done very carefully as tuning in the opposite direction by increasing the element lengths are not possible (other than fitting the AntS with new antenna elements). It should also be noted that having multiple antennas on one AntS changes the resonance frequency relative to that measured for a single element. In general the procedure for antennas with multiple elements is to tune the first element to a frequency slightly lower than the wanted final frequency with all other elements stowed (i.e. not influencing the measurement). The next step is to sequentially tune the resonance of the other antenna elements as close as possible to that of the first before connecting them together to form the final antenna. If further tuning of the resonance frequency is required it should be done by shortening all elements as close as possible to the same lengths between subsequent measurements.

The following should be taken into account if these measurements are to be performed by a client:

- A good quality VNA with valid calibration status should be used.
- The influence of the final satellite structure should be taken into account during the measurement.
- The satellite structure should not be supported on a structure with metal in it (like a metal table) during this measurement.
- Be sure to disconnect ESD grounding before doing the measurement.
- The measurement area should be set up such as to limit the influence of reflections from metal objects or people within 3-5 wavelengths (refer to
- Figure 5-11).
- The VNA should be connected to the antenna under test by a long piece of good quality cable (~6 to 8m).
- The VNA should be calibrated at the end of the connecting cable with the correct connecting connectors (MMCX or SSMCX) to ensure valid measurements.
- Measurements should only be performed without personnel within 3-5 wavelengths of the antenna.
- Measurements should only be performed after the antenna elements are physically stable as movement may influence the measurement.
- If measurements on long elements are performed it may be necessary to support the elements in their flight configuration by non-conducting materials like wood or plastic.
- Cut off short portions of elements if necessary (as a guide the change rate of resonance frequency may easily exceed 4MHz/mm)
- Cut off the corners (~1mm) of each antenna element to prevent possible sharp edges sticking into the PCB or antenna lid material increasing friction during deployment (this has been measured to have no major influence on antenna resonance)

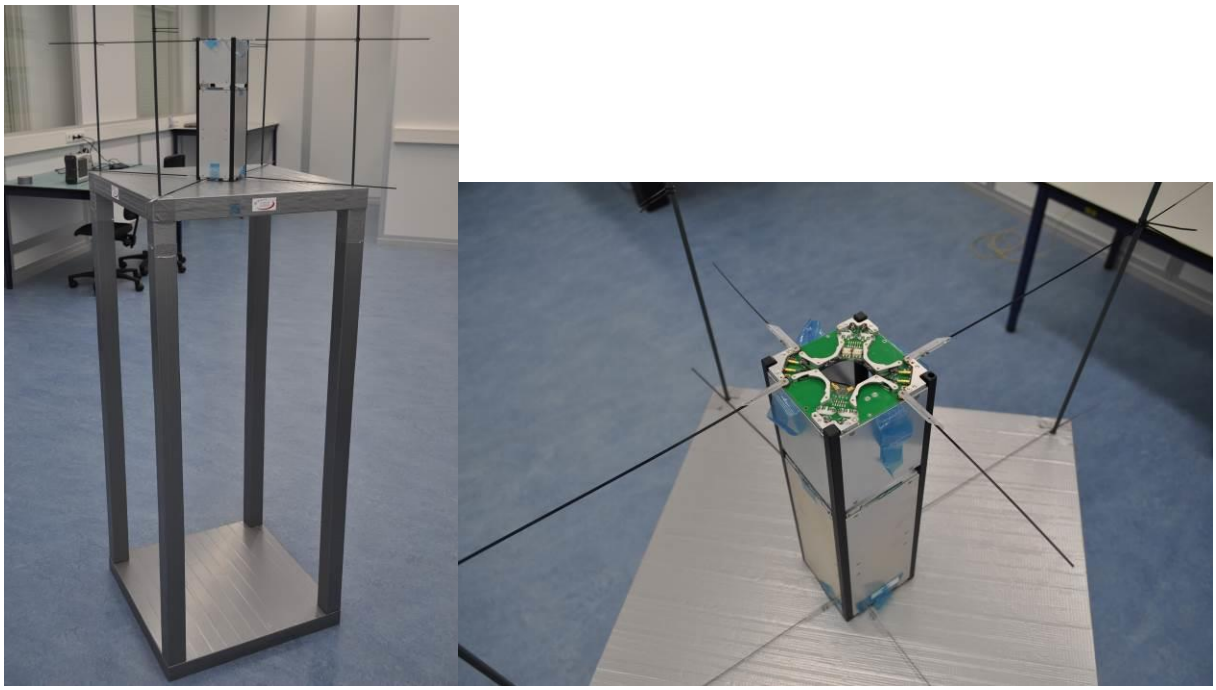


Figure 5-11 Antenna resonance tuning setup

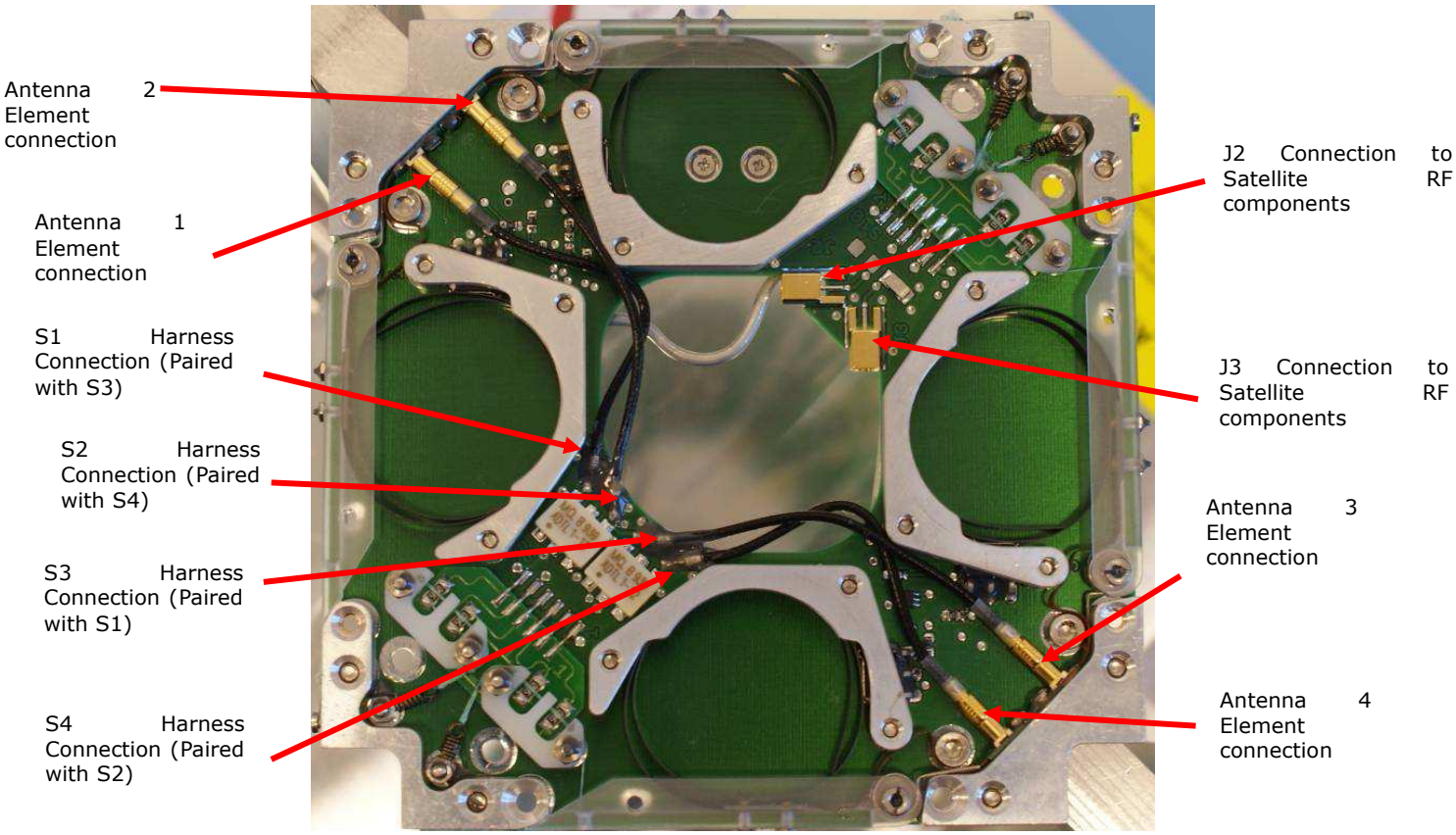


Figure 5-12 RF Connection Reference

Tuning Summary

1. Set up an open area with little or no reflective (metal) material within 5-10

wavelengths

2. Connect the VNA good quality cable of 5-10 wavelengths in length and calibrate to the end of the cable for S11 (amplitude) measurements.
3. Mount the antenna system on a representative satellite structure
4. Stow all antenna elements except one and connect the VNA directly to this element
5. Slow tune the resonance point upwards by clipping short portions (typically 5-10mm) of the element until a point about 20% lower than the required frequency point have been reached. (note the centre of the S11 resonance dip as well as the -10dB bandwidth carefully for future reference)
6. Stow the element under test and deploy the antenna element intended for connection as the other side of the eventual dipole.
7. Connect the VNA to this element and tune to within 1MHz of its dipole partner.
8. Stow this element and repeat the process for the other dipole.
9. Connect one dipole at a time to its respective phasing network (S1,S3 connected to elements 1, 3 and fed through J2; S2,S4 connected to elements 2, 4 and fed through J3) and repeat the S11 measurement through the dipole phasing network with the other dipole stored.
10. If required tune the dipole upwards for the final frequency by trimming both elements a similar short piece at a time (~5mm at a time)
11. Stow the dipole and repeat the dipole tuning for the other dipole
12. Do a final measurement with both dipoles deployed to not potential influence on each other.

5.2.2 RF Radiation patterns

The final radiation pattern of the AntS can only be measured while mounted on a representative final satellite structure. In order to be accurate this test also needs to be performed in a specialized test chamber by qualified personnel. This test is not included in the standard offering of the AntS. ISIS can perform this test or assist with this test at additional cost. The various antenna configurations as delivered have been simulated in the Feko electromagnetic software package for typical standard ISIS mechanical structures. Two examples of these simulations are presented below. More detailed simulation results are available on request.

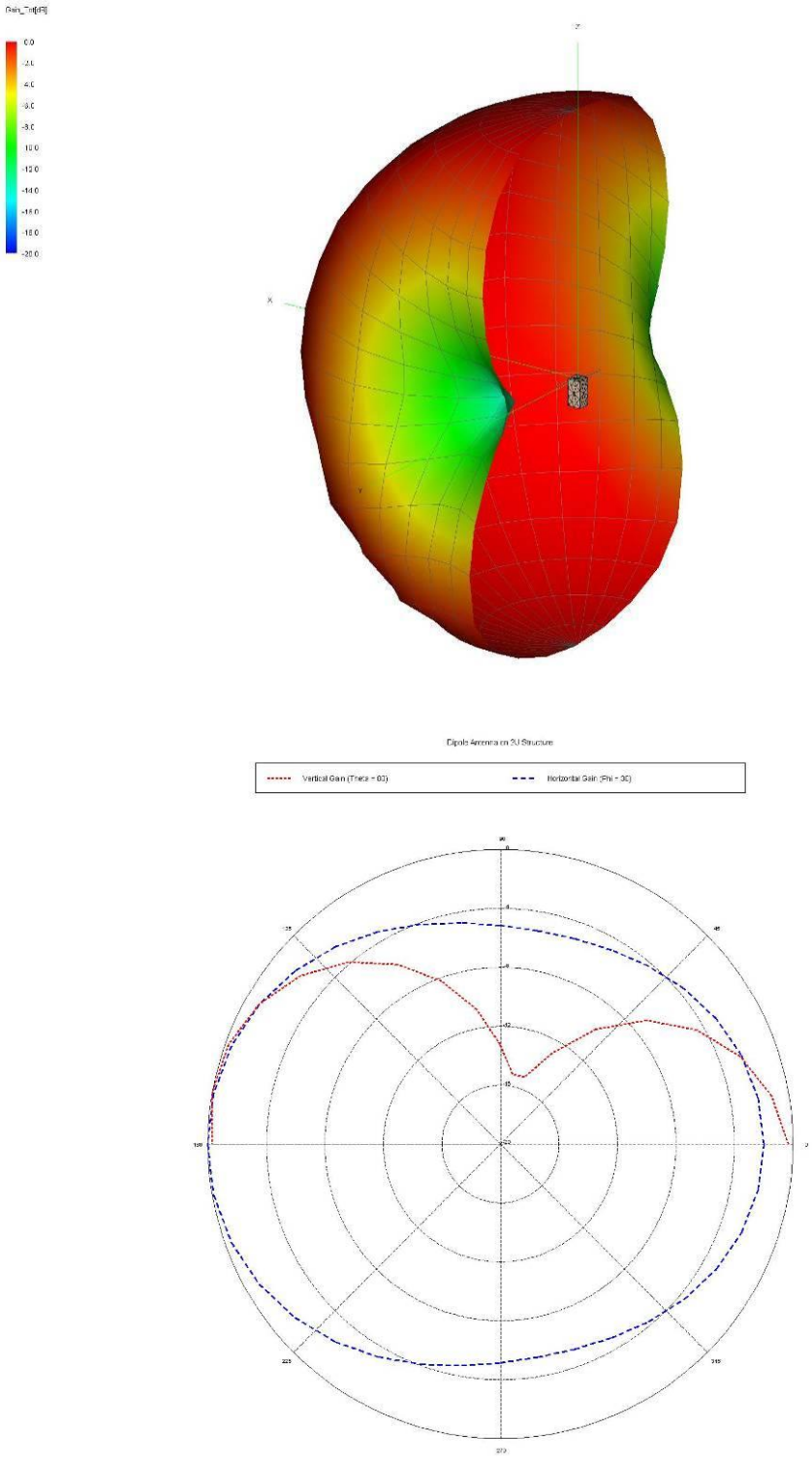


Figure 5-13 Radiation pattern of UHF Dipole mounted on 2U structure

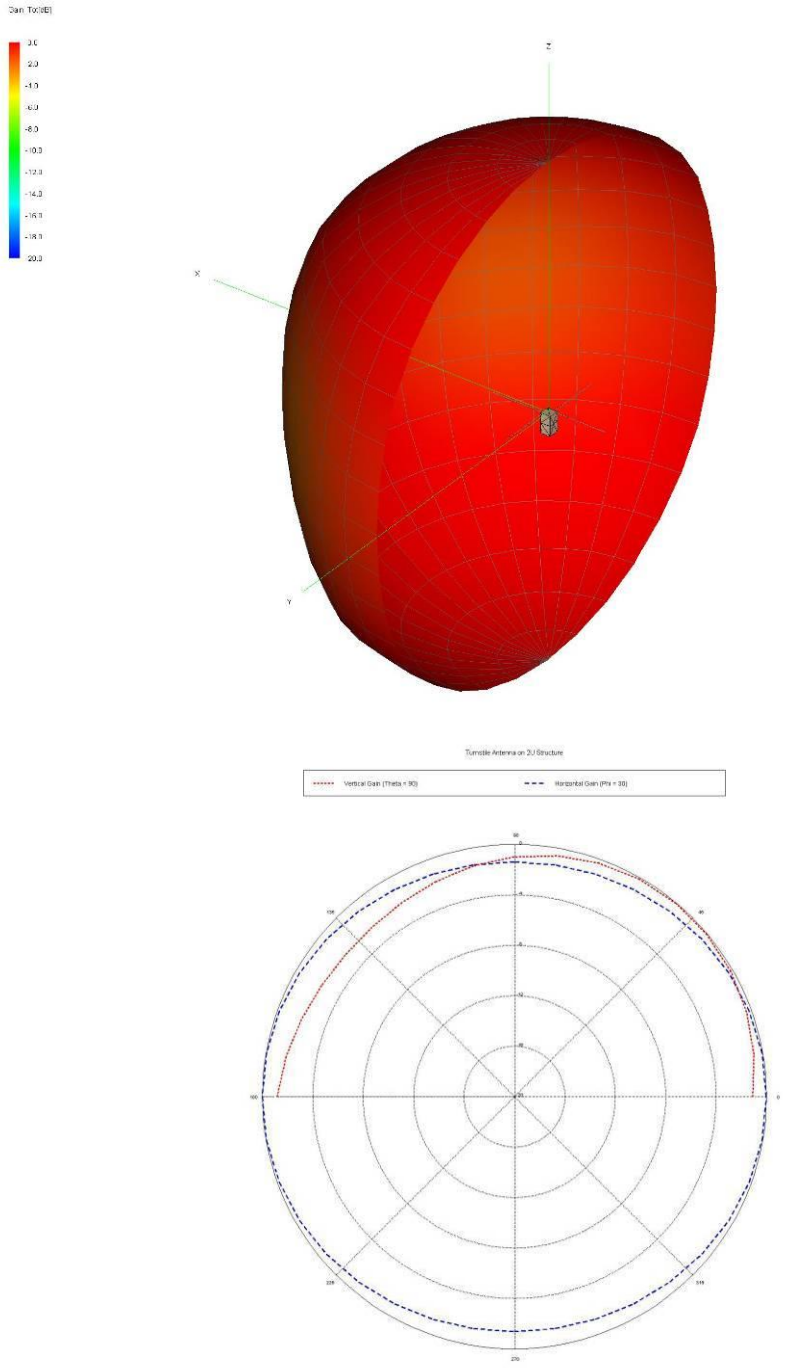


Figure 5-14 Radiation pattern of VHF turnstile mounted on 2U structure

As can be expected from electromagnetic theory for most dipole antennas the radiation pattern is that of a linear antenna with two nulls corresponding roughly with the antenna physical axis. The depth of these nulls is in the order of -20dB and may lead to fading in the down/uplink signals for a spinning satellite.

For a turnstile antenna configuration the result is a circularly polarized pattern with an omnidirectional characteristic and without nulls.

5.3 Nominal Operation Instructions

5.3.1 Deployment scenarios

There are two deployment scenarios possible for each antenna: nominal and override.

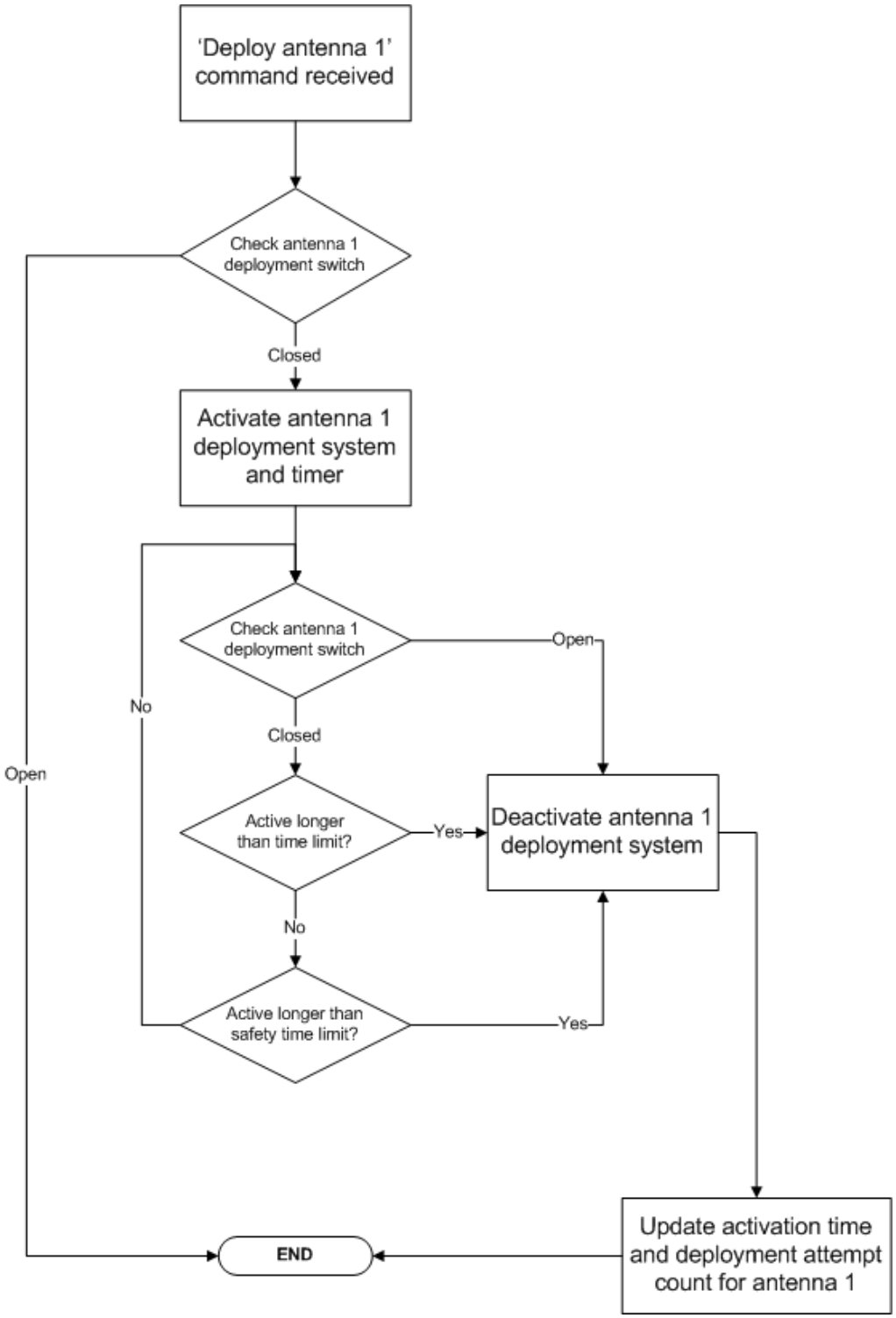


Figure 5-15 Nominal antenna deployment scenario

The flow diagram for the nominal scenario is shown in Figure 5-15. The antenna's deployment system will only be activated if that antenna's deployment switch is currently indicating that the antenna is still undeployed. The deployment system will then be activated until either of the following three cases occurs:

- The deployment switch belonging to the antenna indicates the antenna is currently deployed
- The antenna's deployment system has been active for the amount of time that was specified in the I^2C command the satellite issued to the antenna system
- The antenna's deployment system has been active for the amount of time that has been set as the safety time limit.

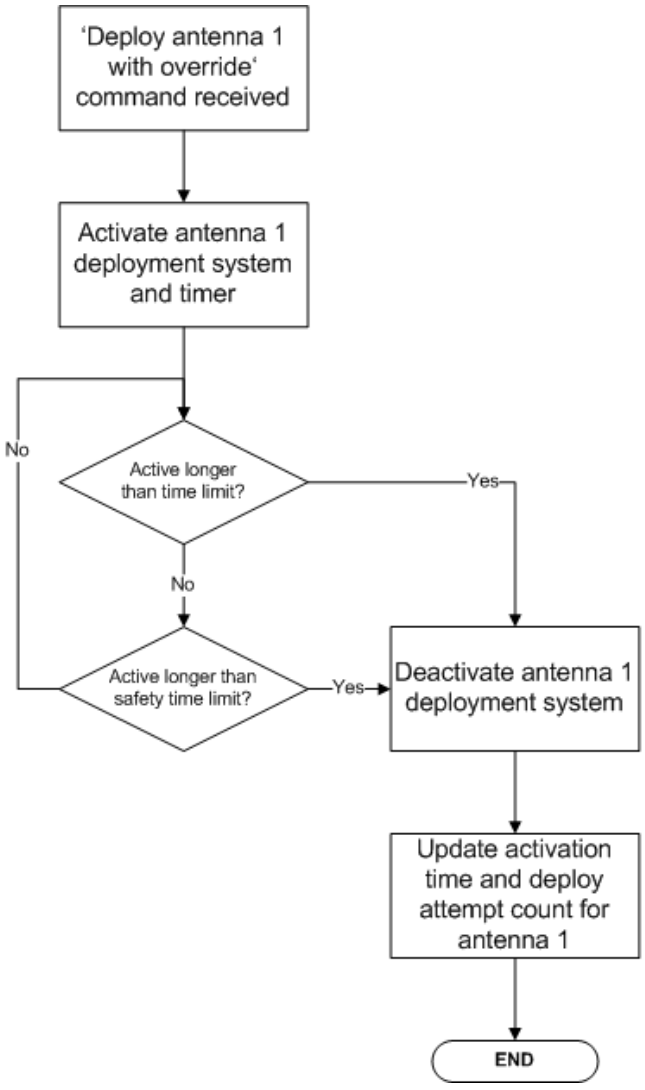


Figure 5-16 Antenna deployment scenario with override

The flow diagram for the override scenario is shown in Figure 5-16. The override scenario is the in principle the same as the nominal scenario, except for the fact that the antenna's deployment switch is ignored. This means that the deployment system will be activated regardless of whether the deployment switch indicates if the antenna is deployed or undeployed. The deployment system will be activated until either of the

two following cases occurs:

- The antenna's deployment system has been active for the amount of time that was specified in the I^2C command the satellite issued to the antenna system
- The antenna's deployment system has been active for the amount of time that has been set as the safety time limit.

Examples of when the override scenario can be used:

- The readout of the antenna's deployment switch is considered to be unreliable, e.g. flickering or the readout indicates a deployed antenna when the antenna is still stowed
- The deployment switch indicates the antenna has been deployed but judging by other evidence, e.g. antenna pattern, it is not so another activation of the antenna's deployment system is required.

5.3.2 Typical use case

Below you will find a typical use case for the antenna system. In this use case we have assumed that the satellite's on-board computer (or equivalent) is in control of deployment of the antennas. Each step in the use case scenario can be completed using the appropriate I^2C commands from the section 4.5.

1. Arm antenna system
2. Either
    a. Send deployment commands for each antenna
    b. Send command to start automated sequential antenna deployment
3. Poll antenna system's deployment status to see when deployment is complete
4. Get deployment activation times from antenna system
5. Disarm antenna system

It is advisable to include at least the antenna deployment status in the satellite's telemetry downlink.

6 Command Interface Description

6.1 Description

The ISIS Antenna System contains the following functionality:

- Reporting antenna deployment status
- Arming and disarming the antenna system
- Deployment of individual antennas
- Automated sequential antenna deployment
- Storage and reporting of activation count and total activation time
- Reporting system temperature

Please note that all the commands are available on both the A and B microcontroller. Since these are completely separate and independent, commands sent to the A side microcontroller will not affect the B side microcontroller. For example, arming the antenna system through the A side microcontroller will only allow the A side microcontroller to deploy the antennas.

Commands can have responses (return values). These responses need to be retrieved from the controller using a separate data transfer (master read) following the data transfer that contained the command (master write). The response of a command will be generated at the time of reception of the command and not at the time the response is retrieved from the transceiver. This applies for example to the commands of the antenna system to measure the telemetry values: the measurements are performed when the command is received by the antenna system. The response to a command will be available until another command that has a response is executed. The commands are listed in the following section.

Please find the format specification for all the commands below

Command Name	Command Code
Name of the command	Command code in binary

Description

Extended description of the command.

Parameters

[000 – 000] format

Specification of the parameters required after the command.

Response

[000 – 000] format

Specification of the response that the antenna system will generate for this command.

The parameter and response descriptions contain specifications per byte or sequence of bytes. There can be several parameters or responses associated with a command and each have its own specification. Please note that parameters always start at byte 001, as byte 000 contains the command code. These specifications contain the following items:

6.1.1 Parameter / response length

This specifies the length and the location in the byte sequence of the parameter or response of the command. Several examples are provided below to explain the possible options.

[001 - 001]

Parameter / response has a fixed length of 1 byte and is located in byte 001

[001 - 020]

Parameter / response has a fixed length of 20 bytes and is located in bytes 001 through 020

[001 - 020*]

Parameter / response has an arbitrary length between 1 byte and 20 bytes and is located in the corresponding number of bytes starting at byte 001

6.1.2 Format specification

This specifies the format of the byte(s) of the parameter or response. Several examples are provided below to explain the possible options.

0000xxxx	The four most significant bits contain zeroes, while the four least significant ones contain the relevant bits
xxxxxxxx 000000xx	All bits of the first (and least significant) byte are relevant, while of the second byte only the two least significant bits are relevant
n/a, binary	All bits in all the bytes are relevant and are interpreted as binary content, i.e. no interpretation will take place
n/a, ASCII	All bits in all the bytes are relevant and are interpreted as ASCII content, specific interpretation depends on the command
_ _ _ _ _ _01	The two least significant bits have the specific value of '01', while the other bits can be either a 1 or a 0 (don't care)

6.2 Telemetry and Command Definition

6.2.1 Reset

Command Name	Command Code
Reset	10101010

Description

Performs a reset of the microcontroller

Parameters

None

Response

None

6.2.2 Arm antenna system

Command Name	Command Code
Arm antenna system	10101101

Description

Arms the antenna system. The system needs to be armed to be able to deploy antennas.

Parameters

None

Response

None

6.2.3 Disarm

Command Name	Command Code
Disarm antenna system	10101100

Description

Disarms the antenna system. This command will deactivate any active antenna deployment systems and terminate an ongoing automated sequential antenna deployment before disarming the system. The antenna system will only be able to deploy antennas once it has been armed again.

Parameters

None

Response

None

6.2.4 Deploy antenna 1

Command Name	Command Code
Deploy antenna 1	10100001

Description

Attempt to deploy antenna 1 by activating the deployment system for antenna 1.. The deployment mechanism will remain activated until:

- The deployment of antenna 1 is detected using the corresponding deployment switch
- The deployment system has been active for the specified amount of time
- The deployment system has been active for the amount of time specified in the safety timeout

This command will not be executed when:

- The antenna system has not been armed
- Another antenna deployment system is currently active
- The antenna's deployment switch indicates the antenna is deployed
- An automatic sequential antenna deployment is in progress

Parameters

[001 - 001] n/a, binary

The maximum activation time for the deployment system in seconds. The minimum value is 0 and the maximum value is 255 seconds. Please note that if a value of 0 is specified, only the safety timeout will be taken into account.

Response

None

6.2.5 Deploy antenna 2

Command Name	Command Code
Deploy antenna 2	10100010

Description

Attempt to deploy antenna 2 by activating the deployment system for antenna 2. The deployment mechanism will remain activated until:

- The deployment of antenna 2 is detected using the corresponding deployment switch
- The deployment system has been active for the specified amount of time
- The deployment system has been active for the amount of time specified in the safety timeout

This command will not be executed when:

- The antenna system has not been armed
- Another antenna deployment system is currently active
- The antenna's deployment switch indicates the antenna is deployed
- An automatic sequential antenna deployment is in progress

Parameters

[001 - 001] n/a, binary

The maximum activation time for the deployment system in seconds. The minimum value is 0 and the maximum value is 255 seconds. Please note that if a value of 0 is specified, only the safety timeout will be taken into account.

Response

None

6.2.6 Deploy antenna 3

Command Name	Command Code
Deploy antenna 3	10100011

Description

Attempt to deploy antenna 3 by activating the deployment system for antenna 3. The deployment mechanism will remain activated until:

- The deployment of antenna 3 is detected using the corresponding deployment switch
- The deployment system has been active for the specified amount of time
- The deployment system has been active for the amount of time specified in the safety timeout

This command will not be executed when:

- The antenna system has not been armed
- Another antenna deployment system is currently active
- The antenna's deployment switch indicates the antenna is deployed
- An automatic sequential antenna deployment is in progress

Parameters

[001 - 001] n/a, binary

The maximum activation time for the deployment system in seconds. The minimum value is 0 and the maximum value is 255 seconds. Please note that if a value of 0 is specified, only the safety timeout will be taken into account.

Response

None

6.2.7 Deploy antenna 4

Command Name	Command Code
Deploy antenna 4	10100100

Description

Attempt to deploy antenna 4 by activating the deployment system for antenna 4. The deployment mechanism will remain activated until:

- The deployment of antenna 4 is detected using the corresponding deployment switch
- The deployment system has been active for the specified amount of time
- The deployment system has been active for the amount of time specified in the safety timeout

This command will not be executed when:

- The antenna system has not been armed
- Another antenna deployment system is currently active
- The antenna's deployment switch indicates the antenna is deployed
- An automatic sequential antenna deployment is in progress

Parameters

[001 - 001] n/a, binary

The maximum activation time for the deployment system in seconds. The minimum value is 0 and the maximum value is 255 seconds. Please note that if a value of 0 is specified, only the safety timeout will be taken into account.

Response

None

6.2.8 Start automated sequential antenna deployment

Command Name	Command Code
Start automated sequential antenna deployment	10100101

Description

Attempt to sequentially deploy all the antennas present on the system, without intervention. This command will start at the antenna with the lowest number and attempt to deploy it. After this attempt has finished, the system will automatically move on to the next antenna and attempt to deploy that. This process will continue until deployment of all the antennas present on the system has been attempted.

This command is similar to sequentially executing an 'Deploy antenna' command for each antenna present on the system.

The antenna deployment system for each antenna is activated until:

- The deployment of the antenna is detected using the corresponding deployment switch
- The deployment system has been active for the specified amount of time
- The deployment system has been active for the amount of time specified in the safety timeout

This command will not be executed when:

- The antenna system has not been armed
- Another antenna deployment system is currently active
- An automatic sequential antenna deployment is in progress

Parameters

[001 - 001] n/a, binary

The maximum activation time for each deployment system in seconds. The minimum value is 0 and the maximum value is 255 seconds. Please note that if a value of 0 is specified, only the safety timeout will be taken into account.

Response

None

6.2.9 Deploy antenna 1 with override

Command Name	Command Code
Deploy antenna 1 with override	10111010

Description

Attempt to deploy antenna 1 by activating the deployment system for antenna 1. This command ignores the corresponding deployment switch that indicates deployment of antenna 1. The deployment mechanism will remain activated until:

- The deployment system has been active for the specified amount of time
- The deployment system has been active for the amount of time specified in the safety timeout

This command will not be executed when:

- The antenna system has not been armed
- Another antenna deployment system is currently active
- An automatic sequential antenna deployment is in progress

Parameters

[001 - 001] n/a, binary

The maximum activation time for the deployment system in seconds. The minimum value is 0 and the maximum value is 255 seconds. Please note that if a value of 0 is specified, only the safety timeout will be taken into account.

Response

None

6.2.10 Deploy antenna 2 with override

Command Name	Command Code
Deploy antenna 2 with override	10111011

Description

Attempt to deploy antenna 2 by activating the deployment system for antenna 2. This command ignores the corresponding deployment switch that indicates deployment of antenna 2. The deployment mechanism will remain activated until:

- The deployment system has been active for the specified amount of time
- The deployment system has been active for the amount of time specified in the safety timeout

This command will not be executed when:

- The antenna system has not been armed
- Another antenna deployment system is currently active
- An automatic sequential antenna deployment is in progress

Parameters

[001 - 001] n/a, binary

The maximum activation time for the deployment system in seconds. The minimum value is 0 and the maximum value is 255 seconds. Please note that if a value of 0 is specified, only the safety timeout will be taken into account.

Response

None

6.2.11 Deploy antenna 3 with override

Command Name	Command Code
Deploy antenna 3 with override	10111100

Description

Attempt to deploy antenna 3 by activating the deployment system for antenna 3. This command ignores the corresponding deployment switch that indicates deployment of antenna 3. The deployment mechanism will remain activated until:

- The deployment system has been active for the specified amount of time
- The deployment system has been active for the amount of time specified in the safety timeout

This command will not be executed when:

- The antenna system has not been armed
- Another antenna deployment system is currently active
- An automatic sequential antenna deployment is in progress

Parameters

[001 - 001] n/a, binary

The maximum activation time for the deployment system in seconds. The minimum value is 0 and the maximum value is 255 seconds. Please note that if a value of 0 is specified, only the safety timeout will be taken into account.

Response

None

6.2.12 Deploy antenna 4 with override

Command Name	Command Code
Deploy antenna 4 with override	10111101

Description

Attempt to deploy antenna 4 by activating the deployment system for antenna 4. This command ignores the corresponding deployment switch that indicates deployment of antenna 4. The deployment mechanism will remain activated until:

- The deployment system has been active for the specified amount of time
- The deployment system has been active for the amount of time specified in the safety timeout

This command will not be executed when:

- The antenna system has not been armed
- Another antenna deployment system is currently active
- An automatic sequential antenna deployment is in progress

Parameters

[001 - 001] n/a, binary

The maximum activation time for the deployment system in seconds. The minimum value is 0 and the maximum value is 255 seconds. Please note that if a value of 0 is specified, only the safety timeout will be taken into account.

Response

None

6.2.13 Cancel deployment system activation

Command Name	Command Code
Cancel deployment activation	10101001

Description

Deactivate any deployment systems that are currently active, and terminate ongoing automated sequential antenna deployment. This command only has effect when the system has been armed and a deployment system is currently active or an automated sequential antenna deployment is currently ongoing.

Parameters

None

Response

None

6.2.14 Measure antenna system temperature

Command Name	Command Code
Measure antenna system temperature	11000000

Description

Measures the temperature as reported by the temperature sensor on the antenna system. Please note that each microcontroller connects to its own temperature sensor.

Parameters

None

Response

[000 – 001] 000000xx xxxxxxxx

Raw 10 bits measurement of the temperature. Please refer to Annex A. for the conversion table.

6.2.15 Report deployment status

Command Name	Command Code
Report deployment status	11000011

Description

Report the deployment status of the antenna system. This status contains information for each antenna as well as system level information.

Parameters

None

Response

[000 – 001] xxxxxxxx xxxxxxxx

Format of the deployment status information:

	bit 7							*bit 0*
MSB	A1S	A1T	A1B	0	A2S	A2T	A2B	IG
LSB	A3S	A3T	A3B	INDB	A4S	A4T	A4B	ARM

AxS

1 - This antenna's deployment switch indicates this antenna is NOT deployed

0 - This antenna's deployment switch indicates this antenna is deployed

AxT

The latest deployment system activation for this antenna was stopped because:

1 - a time limit was reached (specified time or safety time limit)

0 - a reason other than reaching a time limit

AxB

1 - This antenna's deployment system is currently active

0 - This antenna's deployment system is currently NOT active

INDB

1 - The antenna system independent burn is currently active.

0 - The antenna system independent burn is currently NOT active.

IG

1 - The antenna system is currently ignoring the antenna deployment switches

0- The antenna system is currently NOT ignoring the antenna deployment switches

ARM

1 - The antenna system is currently armed

0 - The antenna system is currently NOT armed

6.2.16 Report antenna 1 deployment activation count

Command Name	Command Code
Report antenna 1 deployment system activation count	10110000

Description

Reports the number of times the deployment system for antenna 1 has been activated since the last reset of the microcontroller.

Parameters

None

Response

[000 – 000] xxxxxxxx

The number of deployment system activations. This number has a minimum value of 0 and a maximum value of 255.

6.2.17 Report antenna 2 deployment activation count

Command Name	Command Code
Report antenna 2 deployment system activation count	10110001

Description

Reports the number of times the deployment system for antenna 2 has been activated since the last reset of the microcontroller.

Parameters

None

Response

[000 – 000] xxxxxxxx

The number of deployment system activations. This number has a minimum value of 0 and a maximum value of 255.

6.2.18 Report antenna 3 deployment activation count

Command Name	Command Code
Report antenna 3 deployment system activation count	10110010

Description

Reports the number of times the deployment system for antenna 3 has been activated since the last reset of the microcontroller.

Parameters

None

Response

[000 – 000] xxxxxxxx

The number of deployment system activations. This number has a minimum value of 0 and a maximum value of 255.

6.2.19 Report antenna 4 deployment activation count

Command Name	Command Code
Report antenna 4 deployment system activation count	10110011

Description

Reports the number of times the deployment system for antenna 4 has been activated since the last reset of the microcontroller.

Parameters

None

Response

[000 – 000] xxxxxxxx

The number of deployment system activations. This number has a minimum value of 0 and a maximum value of 255.

6.2.20 Report antenna 1 deployment activation time

Command Name	Command Code
Report antenna 1 deployment system activation time	10110100

Description

Reports the total amount of time the deployment system for antenna 1 has been active since the last reset of the microcontroller. Please note that this value is cumulative, i.e. it sums the activation times for separate deployment system activations.

Parameters

None

Response

[000 – 001] xxxxxxxx xxxxxxxx

The cumulative activation time of the deployment system in 50 ms steps. The minimum value for this time is 0 and the maximum value is 65535. To obtain the activation time in seconds, divide this number by 20.

6.2.21 Report antenna 2 deployment system activation time

Command Name	Command Code
Report antenna 2 deployment system activation time	10110101

Description

Reports the total amount of time the deployment system for antenna 2 has been active since the last reset of the microcontroller. Please note that this value is cumulative, i.e. it sums the activation times for separate deployment system activations.

Parameters

None

Response

[000 – 001] xxxxxxxx xxxxxxxx

The cumulative activation time of the deployment system in 50 ms steps. The minimum value for this time is 0 and the maximum value is 65535. To obtain the activation time in seconds, divide this number by 20.

6.2.22 Report antenna 3 deployment system activation time

Command Name	Command Code
Report antenna 3 deployment system activation time	10110110

Description

Reports the total amount of time the deployment system for antenna 3 has been active since the last reset of the microcontroller. Please note that this value is cumulative, i.e. it sums the activation times for separate deployment system activations.

Parameters

None

Response

[000 – 001] xxxxxxxx xxxxxxxx

The cumulative activation time of the deployment system in 50 ms steps. The minimum value for this time is 0 and the maximum value is 65535. To obtain the activation time in seconds, divide this number by 20.

6.2.23 Report antenna 4 deployment system activation time

Command Name	Command Code
Report antenna 4 deployment system activation time	10110111

Description

Reports the total amount of time the deployment system for antenna 4 has been active since the last reset of the microcontroller. Please note that this value is cumulative, i.e. it sums the activation times for separate deployment system activations.

Parameters

None

Response

[000 – 001] xxxxxxxx xxxxxxxx

The cumulative activation time of the deployment system in 50 ms steps. The minimum value for this time is 0 and the maximum value is 65535. To obtain the activation time in seconds, divide this number by 20.

Annex A. Temperature sensor conversion factor

The sensor used is the LM94022 with GS=10. Accuracy is about ±2°C. The value returned by the temperature measurement command is the raw data from the microcontroller ADC:

- Vout = Vcc/1023 *Raw_data. The nominal value for Vcc is 3.3V.
- See table below for the relationship between Vout and the measured temperature.

Temp (DegC)	Vout (mV)
-50	2616
-49	2607
-48	2598
-47	2589
-46	2580
-45	2571
-44	2562
-43	2553
-42	2543
-41	2533
-40	2522
-39	2512
-38	2501
-37	2491
-36	2481
-35	2470
-34	2460
-33	2449
-32	2439
-31	2429
-30	2418
-29	2408
-28	2397
-27	2387
-26	2376
-25	2366
-24	2355
-23	2345
-22	2334
-21	2324
-20	2313
-19	2302

Temp (DegC)	Vout (mV)
1	2089
2	2079
3	2068
4	2057
5	2047
6	2036
7	2025
8	2014
9	2004
10	1993
11	1982
12	1971
13	1961
14	1950
15	1939
16	1928
17	1918
18	1907
19	1896
20	1885
21	1874
22	1864
23	1853
24	1842
25	1831
26	1820
27	1810
28	1799
29	1788
30	1777
31	1766
32	1756

Temp (DegC)	Vout (mV)
51	1547
52	1536
53	1525
54	1514
55	1503
56	1492
57	1481
58	1470
59	1459
60	1448
61	1436
62	1425
63	1414
64	1403
65	1391
66	1380
67	1369
68	1358
69	1346
70	1335
71	1324
72	1313
73	1301
74	1290
75	1279
76	1268
77	1257
78	1245
79	1234
80	1223
81	1212
82	1201

Temp (DegC)	Vout (mV)
101	986
102	974
103	963
104	951
105	940
106	929
107	917
108	906
109	895
110	883
111	872
112	860
113	849
114	837
115	826
116	814
117	803
118	791
119	780
120	769
121	757
122	745
123	734
124	722
125	711
126	699
127	688
128	676
129	665
130	653
131	642
132	630

Temp (DegC)	Vout (mV)
-18	2292
-17	2281
-16	2271
-15	2260
-14	2250
-13	2239
-12	2228
-11	2218
-10	2207
-9	2197
-8	2186
-7	2175
-6	2164
-5	2154
-4	2143
-3	2132
-2	2122
-1	2111
0	2100

Temp (DegC)	Vout (mV)
33	1745
34	1734
35	1723
36	1712
37	1701
38	1690
39	1679
40	1668
41	1657
42	1646
43	1635
44	1624
45	1613
46	1602
47	1591
48	1580
49	1569
50	1558

Temp (DegC)	Vout (mV)
83	1189
84	1178
85	1167
86	1155
87	1144
88	1133
89	1122
90	1110
91	1099
92	1088
93	1076
94	1065
95	1054
96	1042
97	1031
98	1020
99	1008
100	997

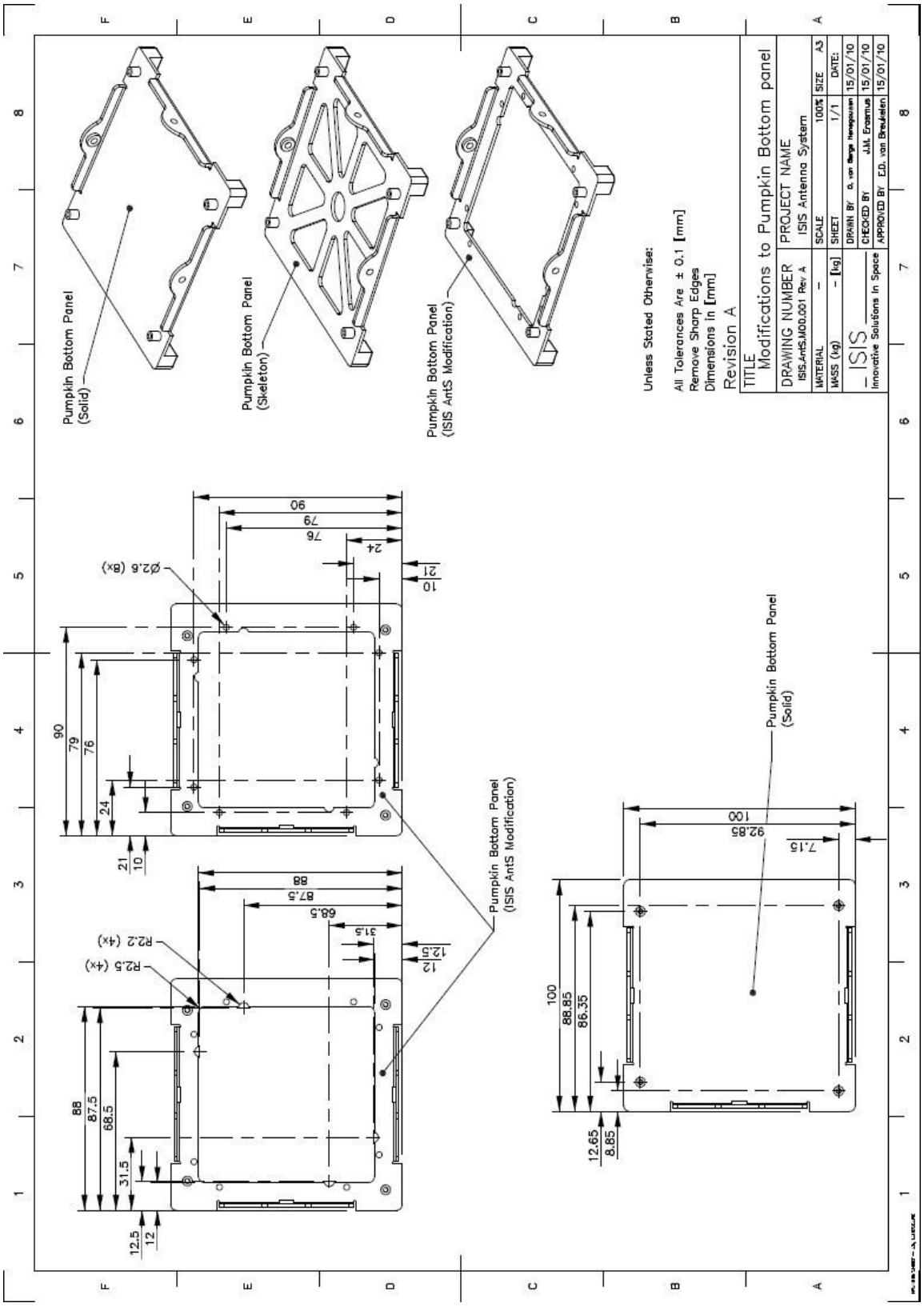
Temp (DegC)	Vout (mV)
133	618
134	607
135	595
136	584
137	572
138	560
139	549
140	537
141	525
142	514
143	502
144	490
145	479
146	467
147	455
148	443
149	432
150	420

Table 6-1 Vout vs measured temperature conversion table

Annex B. AntS Typical Functional Testing

1. Perform manual deployment by removing external burn wire fastener (#10x)
2. Perform burn sequence testing without burn wires (confirm switch override required)(x2x)
3. Perform full functional test burning of burn wires (1x max)
4. Mount on structure
5. Check Antenna resonance frequencies
6. Optimise Resonance tuning (optional)
7. Measure antenna radiation patterns (optional)
8. Thermal cycling (optional)
9. Final deployment test(optional)

Annex C. Pumpkin bottom panel Modifications



Annex D. AntS Envelope Spec sheet