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**Title: FIRST STAGE CRYOGENIC IF AMPLIFIER SPECIFICATION (2.4-4.8 GHz)**

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# 1 General

## 1.1 Introduction

The IF amplifier units described in this document are intended for use in the Focal Plane Unit of the HIFI instrument. HIFI is the heterodyne instrument on HERSCHEL, a Far-InfraRed Submillimetre space Telescope, a collaborative project between ESA and NASA.

The Focal Plane Unit receives sub-millimetre radiation from the sky and reference signals from the Local Oscillator subsystem. It combines these signals and propagates the combined beams to heterodyne mixers, which produce Intermediate-Frequency signals. After amplification these IF signals are fed to the HIFI spectrometers for further processing. The HIFI frequency band is divided in 7 sub-bands. Each sub-band contains two mixers and IF chains to detect the orthogonal polarisations.

The IF1 amplifier units provide low noise amplification of the mixer signals and are therefore located close to the mixers. The signals from the IF1 amplifiers are fed to the IF2 box for further amplification and conditioning. In between the mixer and the IF1 amplifier two IF isolators are present: one close to the mixer and one close to the IF1 amplifier.

## 1.2 Scope

This specification establishes the requirements for the analysis, design, development, manufacturing, validation and preparation for delivery of the HERSCHEL-HIFI IF1 amplifier units, which are part of the HIFI-FPU subsystem.

The specification is fully applicable to the QM and FM/FS models of the HIFI IF1 amplifier units. The DM shall comply with the functional and interface requirements, but reduced performance is allowed, except for the IF bandwidth.

The IF1 amplifier unit specification contains an up to date and agreed description of the amplifiers. Through this document the parties involved (Yebes and SRON-Groningen) and the HIFI system have available the complete and correct information to base their work upon.

## 2 Document references

### 2.1 Applicable documents

AD1. HIFI Instrument specification, SRON-G/HIFI/SP/1998-001

AD2. Product Assurance plan for the HIFI instrument, SRON-U/HIFI/PL/1999-008

AD3. Environmental Test Levels for the IF1, FPSS-00386

### 2.2 Reference documents

## 3 Amplifier specification

### 3.1 Functional description

The first stage cryogenic IF amplifier for HIFI amplifies the signal provided by the mixer unit in the 2.4-4.8 GHz band. It is located in the cold focal plane at a temperature of about 10K. The amplifier will be used without an isolator at its input. The specifications for the amplifier given in this document are for a nominal operating temperature of 14K.

### 3.2 Performance requirements

#### 3.2.1 Frequency band

The amplifiers are designed to work in the **2.4-4.8 GHz** band.

#### 3.2.2 Noise temperature

The average noise temperature in the band shall be less than **10K (baseline)** with a goal of **5K**. The average noise is calculated as the arithmetical mean in the band with a resolution better than 200 MHz.

#### 3.2.3 Gain

The average gain of the amplifiers shall exceed **26 dB.** The ripple in the band shall be less than **±1.5 dB (baseline)** with a goal of **±1 dB**.

#### 3.2.4 Input and output return loss

**S11** and **S22** shall be **<–10 dB (baseline)** with a goal of **–15 dB** in the band.

#### 3.2.5 Stability

The amplifier shall remain unconditionally stable at all frequencies (K>1). It shall not oscillate under any combination of passive input and output impedances.

#### 3.2.6 Power dissipation

The total power dissipation shall be less than **5 mW**.

#### 3.2.7 Bias ranges

The amplifier shall operate at cryogenic temperature with **0<Vd ≤1V**, **0<Id ≤5mA** and **–11V≤Vg ≤5.9V**. At room temperature the typical values are **Vd ≤1.25V**, **Id ≤10mA** and **–11V≤Vg ≤5.9V.** Values including divider by 20 in gate.

#### 3.2.8 Gain stability

The total normalized gain fluctuations at 1Hz shall not exceed $\mathbf{3\times10^{-4}\ (Hz)^{-1/2}}$ **(baseline)** with a goal of $\mathbf{1.4\times10^{-4}\ (Hz)^{-1/2}}$

# 4 Interfaces

## 4.1 Definitions

### 4.1.1 Co-ordinate system

To define the mechanical, electrical, and thermal interfaces a local co-ordinate system is used for the amplifier unit. This local co-ordinate system does not coincide with higher level co-ordinate systems.

The local co-ordinate system is given in figure 1 and shown also in figures 2 and 3.

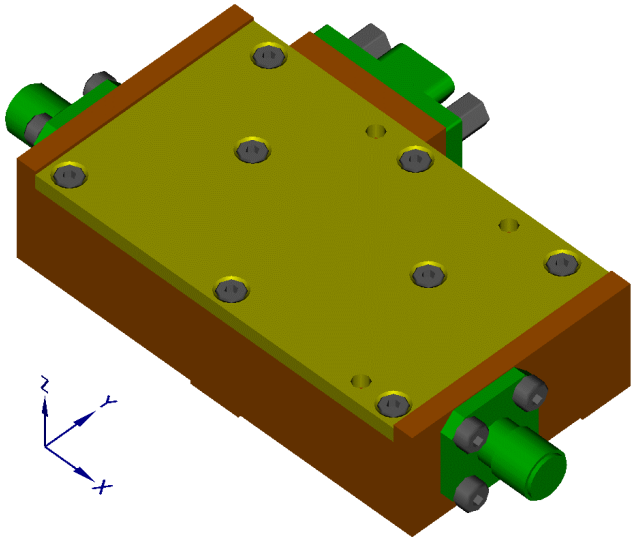



***Figure 1.-*** *Amplifier unit local co-ordinate system*

## 4.2 Structural and mechanical interfaces

### 4.2.1 Amplifier unit envelope

The amplifier unit envelope is given in figure 2. The envelope shall completely contain the amplifier unit and all parts thereof.

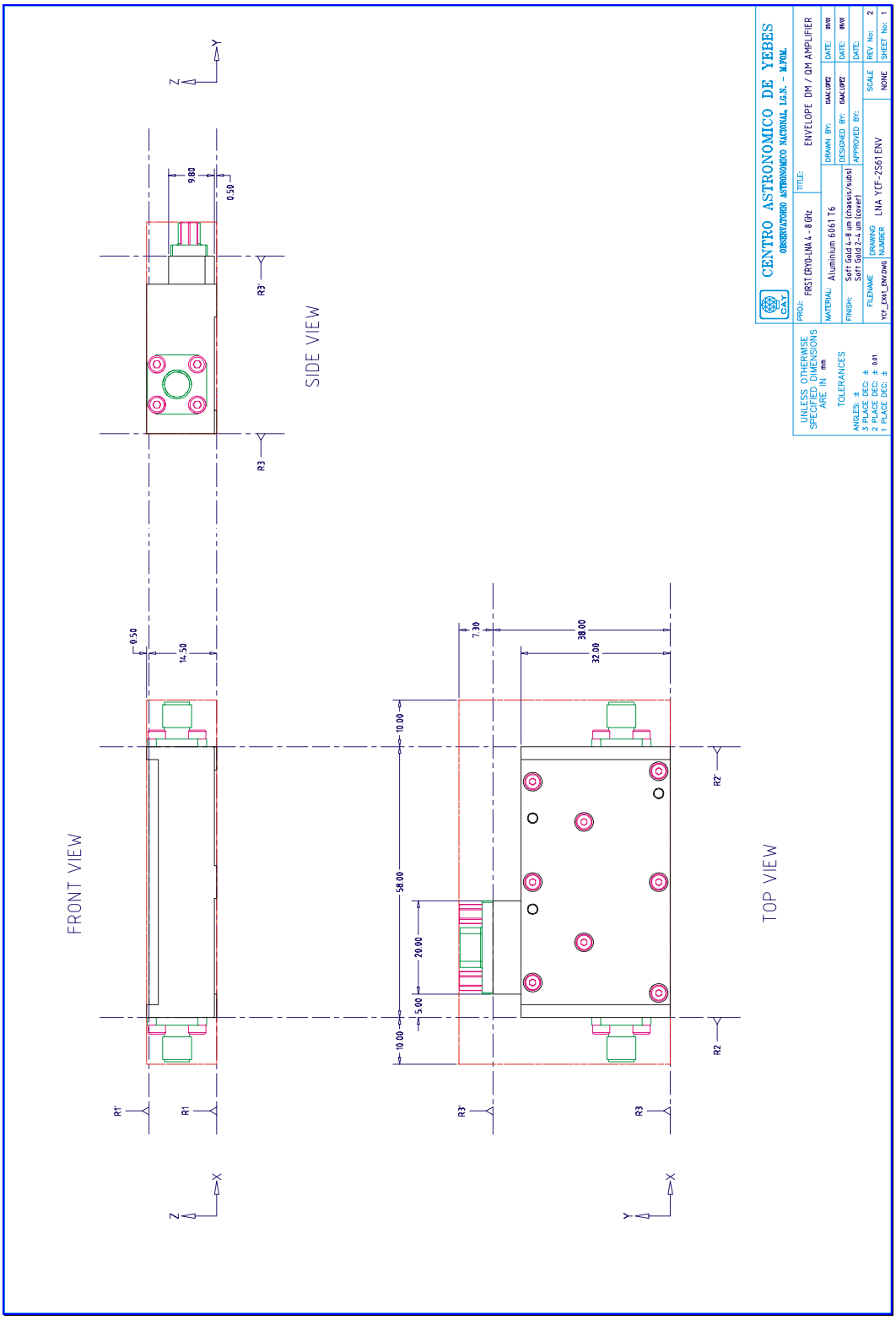



***Figure 2.-*** *Amplifier unit envelope*

### 4.2.2 Location and sizes mechanical references

The location and sizes of the mechanical reference planes are given in figure 3.

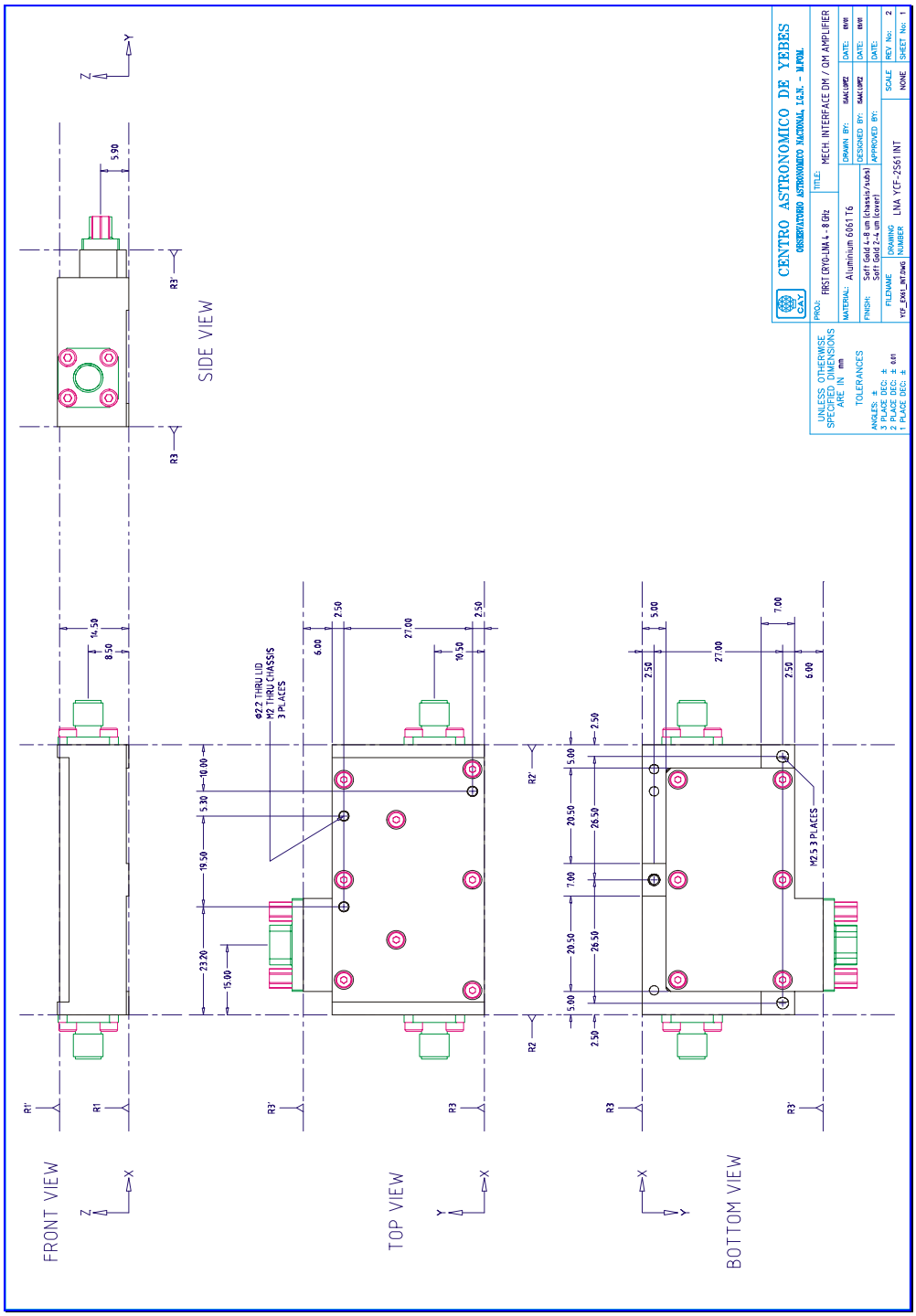



***Figure 3.-*** *Location and sizes of the mechanical reference planes*

#### 4.2.3 Mounting interface

##### 4.2.3.1 Location and sizes of screw holes

The location of the mounting screw holes is given in figure 3.

The amplifier units are mounted into the FPU with 3 stainless steel M2.5 bolts.

The screw holes of the amplifier units shall be provided with Helicoils with a length of at least 1.5 times the screw diameter.

##### 4.2.3.2 Torque level of mounting bolts

The 3 mounting bolts of the amplifier units shall be tightened with 0.70±0.05Nm. The torque level shall never exceed 0.80Nm.

##### 4.2.3.3 Materials at interface

As the mounting planes are also the thermal and grounding interface the mounting surfaces shall have either an electrodeposited gold coating or a chromate conversion coating.

##### 4.2.3.4 Flatness of interface

Because the amplifiers are mounted in an optical unit the flatness of the amplifier unit mounting plane shall be better than 10μm.

##### 4.2.3.5 Roughness of interface

The surface roughness of the interface planes should be 0.8 Ra.

#### 4.2.4 IF connector

##### 4.2.4.1 Location of the IF connectors

The location of the IF connectors is given in figure 3.

##### 4.2.4.2 IF connector type

The IF connectors shall be a female SMA connector according ESA-SCC specification 3402/002, variant 19 (the material of the chosen variant is beryllium copper, gold plated with nickel underplate, front mounting with a 4-hole flange).

For the DM and QM commercial variants of the connector are allowed.

##### 4.2.4.3 Torque level of mating connector

The male mating connector shall be tightened with 1.00±0.05 N.m. The torque level shall never exceed 1.2 N.m.

#### 4.2.5 Bias connector

##### 4.2.5.1 Location of bias connector

The location of the bias connector is given in figure 3.

##### 4.2.5.2 Connector types

The connector for the amplifier unit bias supply and monitoring shall be a 9 pins P type connector according to ESA-SCC specification 3401/029.

The screw lock assembly shall be according to ESA-SCC specification 3401-032-01-B3.

For the DM and QM commercial equivalents of the connector are allowed. The part numbers of ITT-Cannon are MDM-9PH038B-A174 for the connector and 322-9500-000 B for the screw lock assembly. The rubber gasket shall be removed from the connector, since it cannot withstand thermal cycling to cryogenic temperatures.

The nut of the screw lock assembly may be replaced by thread in the amplifier unit housing. However, the torque levels specified in paragraph 4.2.5.3 are mandatory and, if necessary, provisions have to be taken to avoid overloading the material of the amplifier unit housing.

#### 4.2.5.3 Torque levels of mounting screws

The male (chassis) mounting screws of the connectors shall be tightened with 0.35±0.02Nm. The torque level shall never exceed 0.44Nm.

The mounting screws of the mating (cable) connectors shall be tightened with 0.25±0.02Nm. This torque level shall never exceed 0.28Nm.

### 4.2.6 Mass properties

#### 4.2.6.1 Amplifier unit mass

The amplifier unit shall have a mass of less than 70 grams.

## 4.3 Electrical interfaces

### 4.3.1 IF interfaces

#### 4.3.1.1 Connector pin allocation

The connector pin allocation shall be as follows:

| **Connector J01** | | |
|---|---|---|
| Functions: amplifier unit IF signal input | | |
| Pin number | Lead name | Description |
| 1 | IFSGNL IN | IF signal input |
| chassis | GND | Amplifier ground |

| **Connector J02** | | |
|---|---|---|
| Functions: amplifier unit IF signal output | | |
| Pin number | Lead name | Description |
| 1 | IFSGNL OUT | IF signal output |
| chassis | GND | Amplifier ground |

### 4.3.2 Amplifier bias

The amplifier bias will be supplied by the FCU. This bias supply is specified in section 5.13 of the FCU specification, SRON-U/FCU/SP/2000-004. In the table below the main characteristics of the amplifier bias are given. However, the data in the above referenced document has precedence over the data given in the tables.

| **Amplifier drain voltage supply characteristics** | | |
|---|---|---|
| Parameter | Value | Remarks |
| Drain voltage range | 0…+1V (=FSR) | Commandable, constant voltage supply, drain voltage sense w.r.t. source voltage sense. |
| Absolute accuracy | +/- 0.02V | |
| Step size (setting) | ≤ 0.01V | |
| Drain Voltage Noise | <800nV $Hz^{-0.5}$ | @ 1 Hz |
| Total Drain Voltage Noise | <20$\mu V_{rms}$ | 0.1-800 Hz |

| Amplifier drain current supply characteristics | | |
|---|---|---|
| Parameter | Value | Remarks |
| Output current range | 0 … 5mA | Commandable current feedback power supply controlling gate voltage |
| Absolute accuracy | +/- 0.10mA | |
| Step size (setting) | ≤ 0.05mA | |
| Regulation bandwidth | From DC to 20Hz | 3 dB frequency for suppressing |
| Suppression of Drain Current Fluctuations * | > 25 dB | @ 1 Hz |
| Residual Drain Current Fluctuations (caused only by power supply) ** | < 8nA $Hz^{-0.5}$ | @ 1 Hz |

* This suppression is to reduce the effect of the intrinsic fluctuations of the transconductance of the transistor.

** This is the noise introduced by the power supply not taking into account the effects of the intrinsic fluctuations of the transconductance of the transistor.

**Applicable conditions**

Transconductance Range: For the nominal bias (specified and optimised for each amplifier) and operating temperature (15K) the transconductance will be 2.5-10mS (Including divider by about 20 in gate bias circuit)

**Absolute maximum ratings**

Output drain voltage/reverse current limit: 1.8V/ -1mA

Output gate voltage: -15V to 6.5V

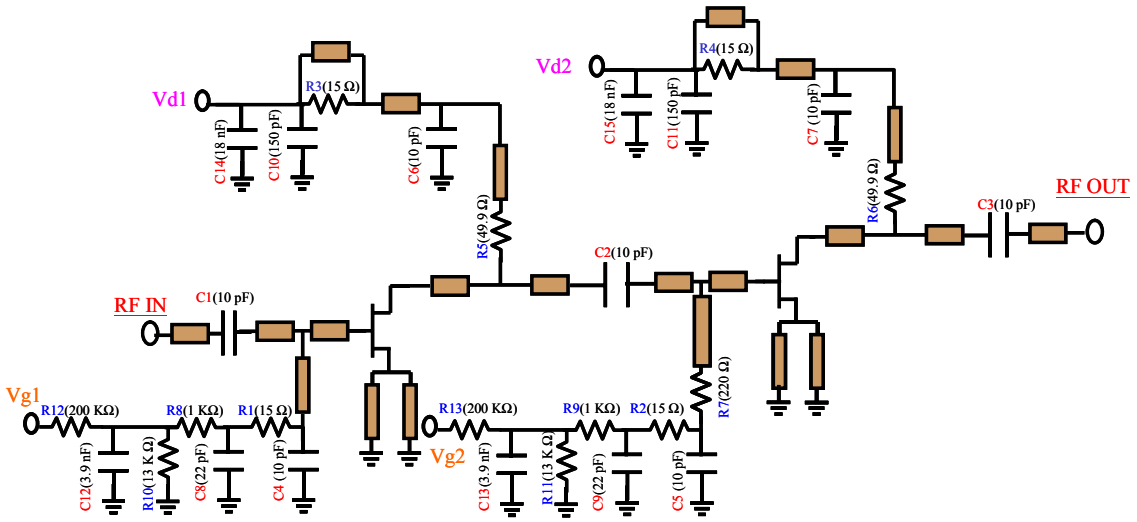
#### 4.3.2.1 Bias connector pin allocation

The connector pin allocation shall be as follows:

| Connector identity: J03 | | |
|---|---|---|
| Functions: amplifier unit bias supply and monitoring | | |
| Pin number | Lead name | Description |
| 1 | GND | Amplifier ground |
| 2 | GND SENSE | Sense circuit reference ground |
| 3 | VD1 | Drain voltage 1 |
| 4 | GND | Amplifier ground |
| 5 | VG1 | Gate voltage 1 |
| 6 | VD2 | Drain voltage 2 |
| 7 | GND | Amplifier ground |
| 8 | VG2 | Gate voltage 2 |
| 9 | GND | Amplifier ground |

#### 4.3.2.2 Bias circuit

The bias circuit for the DM amplifiers is shown in the following drawing.




## 4.4 Thermal interfaces

### 4.4.1 Thermal contact

The thermal interface of the amplifier unit to the 10K level of the mixer sub-assembly FPU is provided by the mounting interfaces (thus no extra thermal straps will be used).

### 4.4.2 Dissipation

The time-averaged dissipation budget is 5 mW per amplifier during operation (0.3 mW when not being used considering the maximum gate voltage (10V) in the amplifier being used). Note that this includes dissipation in the bias circuit plus filtering contained within the amplifier unit.

## 4.5 Grounding, bonding

The amplifier unit case is grounded to the mixer sub-assembly via the mounting interfaces. The electrical circuits will be grounded as given in the equivalent circuit diagrams. All non-used connector pins shall be connected to ground. The housing of the connectors shall be electrically connected to the unit structure. Shorting connectors shall be attached to all connectors when not connected to the FCU or equivalent electronics.

# 5 Environmental conditions

## 5.1 EMI/ESD

The amplifier unit shall be able to operate, without performance degradation, in the EMI environment that is given in SRON-U/FPU/RP/2002-001 (-69dBm in the 2-5.5 GHz band) and shall have provisions for ESD protection to a **tbd** level.

## 5.2 Radiation

The amplifier unit shall be able to operate and survive without performance degradation the radiation environment that is given in 6.1 of AD1.

### 5.3 Vibration

The vibration environment including acceptance and qualification is given in paragraph 2.1 of the **"Environmental Test Levels for the IF1"** document (AD3).

Although all the details about the environment are given in such a document, the qualification and acceptance levels for sine and random vibration are shown in this document to give us a global view of the level to be applied to the IF1 amplifier units. These levels include the amplification in the FPU structure and they are derived from the current vibration levels to be applied to the FPU base.

The qualification tests should be performed cold (<90ºC) and the acceptance ones at room temperature.

**SINUSOIDAL VIBRATION**

| **Sine qualification loads (T<90K)** | | |
|---|---|---|
| **Frequency Hz** | **Level** | |
| 5-21.3 | +/-11mm | All axis |
| 21.3-100 | 20g | Sweep rate 2 oct/min |

| **Sine Acceptance loads (Room Temperature)** |
|---|
| Not Tested |

**RANDOM VIBRATION**

| **Random qualification loads (T<90K)** | | |
|---|---|---|
| **Frequency Hz** | **Level $g^2$/Hz** | |
| 20-100 | +6 dB/oct | All axis |
| 100-500 | 0.4 $g^2$/Hz | Over all 20 grms |
| 500-2000 | -6 dB/oct | Duration 2 min/axis |

| **Random Acceptance loads (Room Temperature)** | | |
|---|---|---|
| **Frequency Hz** | **Level $g^2$/Hz** | |
| 20-100 | +6 dB/oct | All axis |
| 100-300 | 0.025 $g^2$/Hz | Over all 5.2 grms |
| 300-2000 | -6 dB/oct | Duration 1 min/axis |

### 5.4 Thermal

#### 5.4.1 Operational temperature range

The amplifier units shall operate within the performance requirements in the operational temperature range from 10K to 20K.

#### 5.4.2 Non-operating temperature ranges

##### 5.4.2.1 Thermal cycling

The amplifier units shall be able to withstand thermal cycling between room temperature and its operational temperature 50 times without performance degradation. The maximum thermal change rate is **tbd** K/min.

##### 5.4.2.2 Bake-out

The amplifier units shall be able to withstand 5 warm cycles from room temperatures up to 80ºC and extended bake-out at a temperature of 80°C for 144 hours without performance degradation.

#### 5.4.2.3 Storage and handling

The amplifier units shall be stored and handled at room temperature (15-30°C).

### 5.5 Humidity

Whenever possible the amplifiers should be stored in a dry environment. Due to the risk of ESD damage the relative humidity during assembly and integration shall be maintained above a minimum of 40 % in areas where ESD protection is a requirement. If the relative humidity cannot be maintained above 40%, work shall be stopped and the ESDS item shall be put in a protective packaging or cover. If extra precautions are required the minimum level may be raised to 50%. The preferred humidity range is 45-60%. The maximum relative humidity shall never exceed 70%. The relative humidity limits shall be verified with calibrated recording hygrometers.

## 6 Cleanliness requirements

### 6.1 Particulate

The amplifier units shall have, at delivery to the FPU subsystem, a particulate cleanliness level of less than 100ppm **(tbc)**.

### 6.2 Molecular

The amplifier units shall have, at delivery to the FPU subsystem, a molecular cleanliness of less than $10^{-7}$ g.cm$^{-2}$ **(tbc)**.

### 6.3 Bake out

The amplifier units may be baked out prior to delivery to the FPU subsystem to reduce the molecular contamination level. However, this is not mandatory as long as the contamination level is less than the requirements in paragraph 6.2.

## 7 Design requirements

### 7.1 Lifetime

The design life shall be 5 (**tbc**) years of on-ground operations and storage, followed by 4.5 years of in-orbit operations with no performance degradation to a level inferior to that given in this specification.

### 7.2 Reliability

**Tbd**

### 7.3 Mechanical

#### 7.3.1 Vent holes

Small venting holes shall be provided for the confined spaces in the amplifier unit to accommodate the rate of barometric pressure change during evacuation and pressurisation of the harbouring cryostats.

### 7.4 Identification and marking

#### 7.4.1 Connector identification

The connectors shall be identified with the numbers specified in this document. The connector identification shall be visible prior to and after mating.

#### 7.4.2 Amplifier unit

Each amplifier and isolator unit shall be permanently marked. Because of their small size, the amplifier units shall be marked with a unique serial number only. This serial number shall be consecutive for the whole program. To avoid confusion, the definition of the IF1-low serial numbers should minimize the risk that IF1 and IF1-low amplifiers are not inadvertently exchanged.

### 7.4.3 Transport/storage container

The transport/storage container shall be labelled or marked with the complete HIFI identification. This identification shall include the following items:

1. Name
2. Top assembly drawing number
3. Identification number (project / CI number / model)
4. Serial number
5. Supplier (optional).

Example:

| | |
|---|---|
| Name: | Amplifier Unit IF1-low |
| Drawing: | 322-G-7000/a |
| Id. number: | HIFI/HFPIF1/F *(CI number **tbc**)* |
| Serial number: | Y02 (tbd) |
| Supplier: | YEBES |

## 8 Unit handling

### 8.1 Handling manual

The unit shall be delivered with a manual that provides information for the safe handling of the unit in the envisaged environments and higher level units.

### 8.2 Cleanliness

The amplifier units or parts thereof shall be handled in an adequate clean environment.

At idle times the amplifier units or parts thereof shall be stored in containers or be covered by adequate material to reduce the built up of contamination, regardless the clean room class.

### 8.3 Connector mate/demate

Flight-quality connectors shall be protected against frequent mating/demating operations by connector savers. These savers shall be supplied with the amplifier unit.

A mate/demate log shall be maintained for the flight-quality connectors.

### 8.4 Transport

The amplifier units shall be shipped in dedicated transport/storage containers. These containers shall be air tight and equipped with shock indicators.

The container shall be sealed in a plastic bag in a clean environment and after that packaged in a box with shock absorbing provisions to reduce the shock and vibration levels encountered during transport (air and road).

The transport box shall be marked with the full address of the addressee and sender and the unit identification as outlined in paragraph 7.4.3.

## 9 Testing

### 9.1 Qualification testing

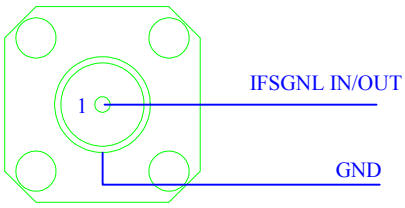
All testing will be described in the IF1 Amplifier PID.

### 9.2 Acceptance testing

All testing will be described in the IF1 Amplifier PID.

## 10 Interface Control Drawings

### 10.1 Pin allocation IF connectors J01 and J02




### 10.2 Pin allocation DC connector J03