



**Atacama  
Large  
Millimeter /  
submillimeter  
Array**

## **Band 5 Cartridge Technical Specifications**

FEND-40.02.05.00-001-C-SPE

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<b>Prepared By: Name(s) and Signature(s)</b>	<b>Organization</b>	<b>Date</b>
P. Yagoubov	ESO	
G. H. Tan	ESO	
J.Barkhof	NOVA	
<b>Approved By FE IET Name and Signature</b>	<b>Organization</b>	<b>Date</b>
K.S. Saini	NRAO	
P. Yagoubov	ESO	
<b>Approved By Regional Manager Name and Signature</b>	<b>Organization</b>	<b>Date</b>
W. Wild	ESO	
<b>Approved By JAO Name and Signature</b>	<b>Organization</b>	<b>Date</b>
Nick Whyborn	JAO	

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## Change Record

Version	Date	Affected Section(s)	Reason/remarks
A	2005-05-12	All	First document release
B	2012-06-14	All	Major update based on <a href="#">FEND-40.02.05.00-0127-A-CRE</a>
B05	2012-11-30	5.9.1.1.3	Added new requirement on pointing offset <a href="#">FEND-40.02.05.00-0127-B-CRE</a>
B	2013-01-28	2.1	Minor editorial change in block diagram
C	2016-02-16	1.3  4.3.1, 4.3.2, 5.1, 5.2  6.1  6.5  5.4.2  7.2  7.1.1	Update references to latest documents  Changed according to FEND-40.02.05.00-0254-D-CRE Extended RF band  Changed according to FEND-40.02.05.00-0264-C-CRE Increase of mass  Changed according to FEND-40.02.05.00-0286-A-CRE Thermal Load  Changed according to FEND-40.02.05.00-0285-B-CRE IF Power Variation  Changed 15K stage temperature range  Reference to the ICD between CCA and first LO instead of the numeric values of the frequency range.

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## 1. INTRODUCTION

### 1.1. Purpose

This document details the specifications and requirements for the ALMA Band 5 cartridge.

### 1.2. Scope

The information given in this document provides a complete summary of all the specifications and requirements to be met by the ALMA Band 5 cartridges. The document is accompanied by Interface Control Documents.

The following table details the ALMA product tree [RD1] at the “unit” and “item” level for the Band 5 cartridge and its components.

<i>PT level 3 / “unit”</i>		<i>PT level 4 / “item”</i>		
<i>Product No.</i>	<i>Product Name</i>	<i>Product No.</i>	<i>Product Name</i>	<i>Remarks</i>
40.02.05.00	Band 5 cartridge			
		40.02.05.01	Band 5 cold optics	
		40.02.05.02	Band 5 LO injection	
		40.02.05.03	Band 5 SIS mixers	
		40.02.05.04	Band 5 quadrature hybrids	
		40.02.05.05	Band 5 cryogenic IF amplifiers	
		40.02.05.06	Band 5 electrical protection board	
		40.02.05.07	Band 5 mechanical structure	Not part of this technical specification
		40.02.05.08	Band 5 cartridge wiring and cabling	
		40.02.05.09	Band 5 cartridge hermetic electrical feed-throughs	
		40.02.05.10	Band 5 cryogenic multiplier	Not part of this technical specification
		40.02.05.11	Band 5 temperature sensors	
		40.02.05.12	Band 5 warm IF amplifiers	

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### 1.3. Applicable documents

The following documents are part of this document to the extent specified herein. If not explicitly stated otherwise, the latest issue of the document is valid.

<i>Reference</i>	<i>Document title</i>	<i>Document ID</i>
[AD1]	Front End Sub-System for the 12 m-Antenna Array Technical Specifications	<a href="#">ALMA-40.00.00.00-001-A-SPE</a>
[AD2]	ICD Band 5 cartridge – Dewar	<a href="#">FEND-40.02.05.00-40.03.01.00-C-ICD</a>
[AD3]	ICD Band 5 cartridge – FE bias module	<a href="#">FEND-40.02.05.00-40.04.02.00-A-ICD</a>
[AD4]	ICD Band 5 cartridge – IF switch sub-system	<a href="#">FEND-40.02.05.00-40.08.01.00-C-ICD</a>
[AD5]	ICD Band 5 cartridge – First LO	<a href="#">FEND-40.02.05.00-40.10.05.00-C-ICD</a>
[AD6]	ICD Band 5 cartridge – Warm cartridge assembly	<a href="#">FEND-40.02.00.00-40.11.00.00-B-ICD</a>
[AD7]	ALMA System: Electromagnetic Compatibility Requirements	<a href="#">ALMA-80.05.01.00-001-B-SPE</a>
[AD8]	ALMA Environmental Specification	<a href="#">ALMA-80.05.02.00-001-B-SPE</a>
[AD9]	ALMA Product Assurance Requirements	<a href="#">ALMA-80.11.00.00-001-D-GEN</a>
[AD10]	Vacuum requirements for receiver components inside the ALMA Front End cryostat	<a href="#">FEND-40.03.00.00-015-A-SPE</a>
[AD11]	ICD WCA Connector Plate - Front End WCA Harness Plate	<a href="#">FEND-40.11.00.00-40.04.00.00-A-ICD</a>
[AD12]	ICD Antenna – Front End	<a href="#">ALMA-34.00.00.00-40.00.00.00-E-ICD</a>

In the event of a conflict between the applicable documents mentioned above and the contents of this specifications and requirements document, the contents of this document shall take precedence.

### 1.4. Reference documents

The following documents contain additional information and are referenced in this document.

<i>Reference</i>	<i>Document title</i>	<i>Document ID</i>
[RD1]	ALMA Product Tree	<a href="#">ALMA-80.03.00.00-001-Q-LIS</a>

### 1.5. Acronyms

A list of the acronyms used in this document is given below.

<b>ALMA</b>	Atacama Large Millimetre Array
<b>CDR</b>	Critical Design Review
<b>DSB</b>	Double sideband
<b>EMC</b>	Electromagnetic compatibility
<b>FE</b>	Front End
<b>ICD</b>	Interface Control Document
<b>IF</b>	Intermediate Frequency
<b>IPT</b>	Integrated Product Team
<b>LO</b>	Local Oscillator
<b>MTBF</b>	Mean Time Between Failures
<b>PDR</b>	Preliminary Design Review
<b>RF</b>	Radio Frequency
<b>SIS</b>	Superconductor-Insulator-Superconductor
<b>SSB</b>	Single sideband
<b>2SB</b>	Sideband separating

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## 1.6. Verb Convention

"Shall" and "must" are used when a specification or provision is mandatory. The verbs "should" and "may" indicate a specification or provision that is not mandatory.

## 1.7. Requirements numbering

The requirements are numbered according to the following code:

[FEND-40.02.05.00-XXXXX-YY / Z]

Where:

**FEND-40.02.05.00** identifies the 'Front End – Band 5 cartridge' as in [RD1];

**XXXXX** is a consecutive number 00010, 00020, ... (the nine intermediate numbers remaining available for future revisions of this document);

**YY** describes the requirement revision. It starts with 00 and is incremented by one with every requirement revision;

**Z** describes the requirement verification method(s). Where T stands for test, I for inspection, R for review of design and A for analysis. Multiple verification methods are allowed.



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## 2. DESCRIPTION

### 2.1. Equipment Definition

The Band 5 cartridge is one of the receiver cartridges which populate the Front End dewar. As an illustration, a generic block diagram of the Band 5 cartridge is presented in Figure 1. It should be noted that this is only a generic diagram of a 2SB mixing scheme. The actual cartridge block diagram, in line with the functional requirements given in chapter 4 of this document, is to be proposed by the institution responsible for its design.

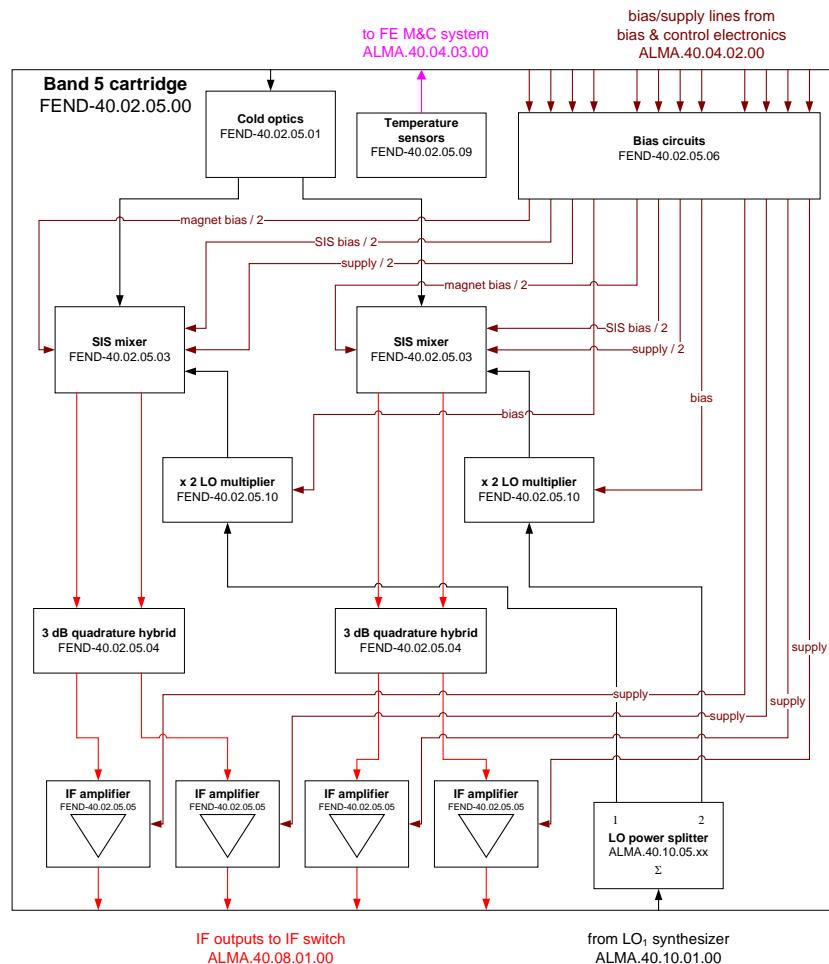
For the purposes of these requirements, the cartridge includes the cold optics (feed horn, mirrors, polarizing grids), components needed to couple the LO to the mixers, IF amplifiers, sensors for monitoring and any type of necessary interconnects.

It does not include the basic cartridge body itself, components of the LO subsystem, the Band 5 cryostat window and IR filters, support electronics for mixer and amplifier bias supply, nor any attenuators or conditioners needed for solar observation. All these components are delivered as part of and under the responsibility of other ALMA Work Elements.

Although the cartridge body itself is not part of this Work Element the mechanical mounting of all components depicted in Figure 1 so that the requirements mentioned in this document are met is part of this Work Element.

All vacuum and cryogenic services are provided by the front end dewar.

Figure 1, Band 5 generic block diagram



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### 3. GENERAL REQUIREMENTS

#### 3.1. Operation modes

The Band 5 cartridge will be used in the following modes.

##### 3.1.1. Operational

[FEND-40.02.05.00-00010-00 / I]

This mode is applicable during the normal observations with ALMA Front End sub-system. In this mode electrical power is applied to the Front End (and also to the Band 5 cartridge) with all active signal levels at nominal values. All specifications and requirements in this document apply to this mode, unless otherwise stated explicitly.

##### 3.1.2. Non-Operational

[FEND-40.02.05.00-00020-00 / I]

In this mode, electrical power is not applied and signal levels are not at their nominal levels. This mode also applies when the Band 5 cartridge is switched off (even if the Front End is powered up). For this mode, all specifications and requirements of this document shall apply, with the exception of section 5, and unless otherwise noted.

##### 3.1.3. Stand-by

[FEND-40.02.05.00-00025-00 / I]

In this mode operational power, including any bias voltages, are applied to the Band 5 cartridge (see section 3.1.1, “Operational Mode”) and the corresponding warm cartridge assembly respectively, but the RF and IF signals may not be at their nominal values. The Band 5 FE LO is not phase locked in this mode. For this mode, all specifications and requirements of this document shall apply, with the exception of section 5, and unless otherwise noted.

##### 3.1.4. Transport with the antenna transporter

[FEND-40.02.05.00-00030-00 / I]

This mode applies when the Band 5 cartridge, integrated into the Front End sub-system, is transported with the antenna on the antenna transport vehicle. For this mode, all specifications and requirements of this document shall apply, with the exception of section 5, and unless otherwise noted. This mode differs from the non operational mode in the environmental operating conditions [AD8].

##### 3.1.5. Transport in the service vehicle

[FEND-40.02.05.00-00040-00 / I]

This mode applies when the Band 5 cartridge, integrated into the Front End sub-system, is transported on the Front End service vehicle. For this mode, all specifications and requirements of this document shall apply, with the exception of section 5, and unless otherwise noted. This mode differs from the non operational mode in the environmental operating conditions [AD8].

##### 3.1.6. Storage

[FEND-40.02.05.00-00045-00 / I]

In this mode the Band 5 cartridge is stored completely assembled. This mode differs from the non-operational mode in the environmental conditions and the lack of monitoring and control signals. For storage, the same specifications and requirements as for the non-operational mode apply, unless otherwise stated. A suitable container might be used for the storage of the Band 5 cartridge assembly.

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### **3.2. Compatibility with the ALMA Front End sub-system**

[FEND-40.02.05.00-00050-00 / I]

The Band 5 cartridge design shall be compatible with other parts of the ALMA Front End sub-system, especially the receiver optics and cryostat. Details are given in the applicable ICDs listed in section 1.3.

### **3.3. Design for production**

#### **3.3.1. Technology**

[FEND-40.02.05.00-00060-00 / R]

The Band 5 cartridge design should use mature technologies whenever possible.

#### **3.3.2. Series production**

[FEND-40.02.05.00-00070-00 / R]

The Band 5 cartridge design shall impart a high degree of consideration toward reducing the production and assembly costs. Complexity of the design and mechanical structures shall be simplified wherever possible.

#### **3.3.3. Standard parts**

[FEND-40.02.05.00-00080-00 / R]

Standard, unmodified commercially available components should be used whenever possible.

### **3.4. Mechanical tuning**

[FEND-40.02.05.00-00090-00 / R]

Operation of the Band 5 cartridge shall not require the use of any mechanical tuners.

### **3.5. Metric dimensioning**

[FEND-40.02.05.00-00110-00 / R]

In general, metric dimensioning shall be used in the Band 5 cartridge. This includes items such as fasteners and tapped holes. Standard wave-guide flanges (using imperial dimensions) may be used.

## **4. FUNCTIONAL REQUIREMENTS**

### **4.1. Mixer type**

[FEND-40.02.05.00-00120-00 / R]

The Band 5 cartridge shall employ SIS mixers as the frequency-translating devices.

### **4.2. Mixing scheme**

[FEND-40.02.05.00-00130-00 / R]

Each polarization channel shall have dual-sideband separating (2SB) type down conversion scheme, making for a total of four IF outputs, each corresponding to a particular polarization and side band combination.

### **4.3. Frequency Coverage**

(Note that this section applies to the operational mode.)

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#### 4.3.1. RF input port

[FEND-40.02.05.00-00140-00 / R]

The nominal RF input frequency range shall be from 163 GHz to 211 GHz.

Unless otherwise specified the following requirements shall be valid for this nominal RF band.  
Some requirements also apply for the extended RF range of 158 GHz to 211 GHz

#### 4.3.2. LO input port

[FEND-40.02.05.00-00150-00 / R]

The LO input port frequency range shall be from 166 GHz to 203 GHz.

#### 4.3.3. IF output ports

[FEND-40.02.05.00-00160-00 / R]

Each polarisation shall provide 8 GHz of IF bandwidth. Furthermore, each 8 GHz of bandwidth shall be evenly split into upper and lower sidebands and these IF outputs shall be centred at 6 GHz.

### 4.4. Polarization States

[FEND-40.02.05.00-00170-00 / R]

The nominal polarization states shall be linear. The cartridge shall receive two orthogonal polarizations, designated “polarization 0” and “polarization 1”, with each being converted to two separate IF outputs as described in section 4.2.

## 5. PERFORMANCE REQUIREMENTS

Unless otherwise specified, all of the RF requirements for the Band 5 cartridge performance are referenced to the atmospheric side of the vacuum window and thus include contributions from dewar windows and IR filters, either as fabricated for the test dewar, or standard issue ALMA windows and filters.

### 5.1. Cartridge Noise-Temperature

[FEND-40.02.05.00-00180-00 / T]

The following table shows the required noise temperature performance for the Band 5 cartridge. It must take into account all the noise contributions up to the cartridge IF output ports.

The cartridge noise temperature shall not exceed the values of  $T_{SSB}$  as follows:

The single sideband noise temperature shall be:

-  $\leq 55\text{K}$  over 80% of the nominal RF frequency range (section 4.3.1).

$\leq 75\text{K}$  in the extended RF range (section 4.3.1). Remarks:

- The required noise temperatures shall be met when averaging over the full IF band, (as defined in section 4.3.3).
- The noise temperature shall be calculated from measurements according to the Rayleigh-Jeans law.
- SSB noise temperatures must be corrected for residual image response.
- The noise performance shall be measured for an operating temperature of  $4 \pm 0.25\text{ K}$ , measured at the 4 K stage.
- The noise temperature includes LO noise contribution as specified in section 7.1.3.

### 5.2. Image band suppression and sideband mismatch

[FEND-40.02.05.00-00190-00 / T]

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The image band suppression shall be:

- $\geq 10$  dB for 90% of the IF band (section 4.3.3) for any RF frequency within the nominal RF range (section 4.3.1).
- $\geq 7$  dB for the entire IF band (section 4.3.3) for any RF frequency within the extended RF range (section 4.3.1).

### 5.3. Spurious response

[FEND-40.02.05.00-00195-00 / T]

At any LO frequency (within the specified range of a band) the IF power due to incoherent spurious signals, generated by Band 5 cartridge only, shall be at least 10 dB below the nominal noise power in any 2 GHz bandwidth. Spurious signals shall occupy less than 0.1% of the nominal IF bandwidth as specified in section 4.3.3.

### 5.4. Cartridge IF power

#### 5.4.1. IF output power

[FEND-40.02.05.00-00200-00 / T]

With a 300 K load at the RF input of the cartridge, the output power for each of the cartridge IF outputs shall comply with the following requirements:

- The total power within the IF band (as specified in section 4.3.3), shall be in the -32 to -22 dBm range. (The power levels shall be measured at the IF outputs of the warm cartridge assembly that houses the second-stage (warm) IF amplifiers.)
- The total IF power in the 10 MHz to 18 GHz shall not be more than 3 dB higher than the measured maximum in-band IF power as described earlier.

These specifications follow from the requirements in [AD4].

#### 5.4.2. IF power variations

[FEND-40.02.05.00-00210-00 / T]

Within the IF band (as specified in section 4.3.3), the IF output power variation shall not exceed 7.0 dB peak-to-peak across the whole IF band when measured with a 100 MHz resolution.

In any 2 GHz portion of the IF band, the corresponding IF output power variation shall not exceed 5.0 dB peak-to-peak when measured with a 100 MHz resolution. In any 31 MHz portion of the IF band, the corresponding IF output power variation shall not exceed 1.35 dB peak-to-peak when measured with a  $\leq 3$  MHz resolution.

These specifications follow from the requirements in [AD4].

### 5.5. Gain compression

[FEND-40.02.05.00-00230-00 / T]

The large signal gain compression shall be less than 5 % between the situation that a 77 K load is placed at the RF input port and the situation that a 373 K load is placed at the same RF input port.

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### 5.6. Amplitude stability

[FEND-40.02.05.00-00240-00 / T]

The IF amplitude stability, measured at the IF output connectors of the warm cartridge assembly that houses the second-stage IF amplifier and the local oscillator chain, shall comply with the following requirement:

The Allan variance,  $\sigma^2(2, T, T)$ , of the IF output power in the total IF band (specified in section 4.3.3) must be less than  $4.0 \times 10^{-7}$  for timescales in the range of  $0.05 \text{ s} \leq T \leq 100 \text{ s}$  and  $3.0 \times 10^{-6}$  at  $300 \text{ seconds}$ . This corresponds to an Allan standard deviation of  $6.3 \times 10^{-4}$  and  $1.7 \times 10^{-3}$ , respectively.

Note that this amplitude stability must be achieved when using the first local oscillator chain supplied by the ALMA project.

### 5.7. Signal path phase stability

[FEND-40.02.05.00-00250-00 / T]

For all frequencies within the IF pass-band the signal path transfer function shall maintain the following phase stability:

Long term (delay drift)  $20 \text{ s} \leq T < 300 \text{ s} : 7.1 \text{ fs}$

The delay drift requirement refers to the 2-point Standard Deviation with a fixed averaging time,  $\tau$ , of 10 seconds and intervals,  $T$ , between 20 and 300 seconds. The signal path shall include all components between the RF window and the IF outputs of the warm assembly that houses the second-stage IF amplifier and the local oscillator chain. The required phase stability excludes any contribution from the local oscillator chain.

### 5.8. IF Phase variations

[FEND-40.02.05.00-00255-00 / T, A]

This applies to any 2 GHz portion of the IF band, as specified in section 4.3.3. After possible correction for a unique linear slope in the IF band (over 2 GHz), in any 31 MHz portion, the deviation from the average IF phase (over the same 31 MHz portion) shall be less than  $4.5^\circ$  rms.

### 5.9. Optics

All optical performances are specified and to be verified along nominal orientations of polarisation channels, as defined in Sections 5.9.2.1. Beam patterns, including cross-polarisation, shall be measured with the test source's E-vector aligned to cryostat radial and tangential directions.

#### 5.9.1. Beam Performance

##### 5.9.1.1. Aperture Efficiency

[FEND-40.02.05.00-00260-00 / T]

The aperture efficiency factor due to the optics of the Band 5 cartridge shall exceed 80%. This efficiency does not include any contribution (e.g. due to surface errors, blockage, defocusing of antenna focal point relative to FE feed phase center) related to the antenna.

The contribution to the aperture efficiency with the FE assembly is split into the following components:

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- Taper efficiency  $\eta_t$ : factor expressing the signal power loss due to 1) non-uniform amplitude distribution over the secondary reflector and 2) the field across the secondary reflector not being in phase everywhere;
- Spillover efficiency  $\eta_s$ : fraction of the total power that is radiated by the tertiary optics, intercepted and collimated by the secondary reflector;
- Polarization efficiency  $\eta_p$ : factor expressing the signal power lost in cross-polarized fields over the antenna aperture plane;
- Focus efficiency  $\eta_f$ : factor expressing the signal power loss due to focus errors, both radial as well as axial, of the tertiary optics relative to the secondary reflector.

The requirement can be summarized by the following expression:

$$\eta_t \cdot \eta_s \cdot \eta_p \cdot \eta_f = \eta_{ap\_FE} > 80 \%$$

The ohmic losses of all tertiary optics and feeds are included in the Trx as specified in section 5.1 and do not contribute to an aperture efficiency degradation.

This requirement simultaneously applies to both orthogonally polarized beams of the cartridge. Individual requirements are defined for the following efficiency contributions:

#### **5.9.1.1.1. Polarization Efficiency**

[FEND-40.02.05.00-00266-00 / T]

The polarization efficiency of the Band 5 optics shall exceed 99.5 %.

This requirement simultaneously applies to both orthogonally polarized beams of a cartridge. (Note that this is equivalent to a maximum of -23 dB integrated cross polarization power relative to the total integrated irradiated power).

#### **5.9.1.1.2. Focus Efficiency**

[FEND-40.02.05.00-00268-00 / T]

The focus efficiency of the tertiary optics shall exceed 98% for Band 5 cartridge. This requirement simultaneously applies to both orthogonally polarized beams of a cartridge.

#### **5.9.1.1.3. Pointing offset**

[FEND-40.02.05.00-00269-00 / T]

The opto-mechanical design of the Band 5 cold cartridge shall provide the angular alignment of the optical beam to be within 3.5mrad of the nominal direction towards the center of the subreflector, referenced to the cold cartridge 300K mounting plate. Verification of this requirement to be performed by Analysis (A).

Direction of the optical beam center is defined by the direction of the best fitting Gaussian to the measured far-field beam pattern. Taking account of the measurements uncertainties, the measured angular alignment of the optical beam should be within 5.0mrad of the nominal direction. Verification of this requirement to be done on each article by Test (T).

### **5.9.2. Polarization requirements**

#### **5.9.2.1. Polarisation alignment**

[FEND-40.02.05.00-00270-00 / R]

Nominal orientation of the major axis of the “Polarization 0” channel polarization ellipse shall be aligned with the radial direction of the cryostat. Nominal orientation of the major axis of the “Polarization 1” channel polarization ellipse shall be orthogonal to the radial direction of the cryostat.

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#### **5.9.2.2. Cross talk between orthogonal polarization receiver channels**

[FEND-40.02.05.00-00290-00 / T]

The, uncorrected, cross talk between orthogonal receiver channels, RF and IF, inside the Band 5 cartridge shall be less than -63 dB. The receiver channel is defined as the signal path starting at the RF waveguide input of the SIS mixer and ending at the IF output.

#### **5.9.2.3. Beam Squint**

[FEND-40.02.05.00-00295-00 / T]

The co-alignment, on sky, between the beams of the orthogonal polarization channels of the Band 5 cartridge shall be less than 1/10 of the Full Width at Half Maximum (FWHM) of the primary beam.

### **5.10. Stabilization time**

#### **5.10.1. Stabilization time from non-operational mode**

[FEND-40.02.05.00-00300-00 / T]

Starting from the non-operational mode, the Band 5 cartridge shall reach the operational mode (i.e. meet all applicable specifications) within 15 minutes.

#### **5.10.2. Stabilization time from stand-by mode**

[FEND-40.02.05.00-00305-00 / T]

The transition from the stand-by mode to the operational mode shall take no more than 1.0 s.

## **6. MECHANICAL AND ELECTRICAL REQUIREMENTS**

### **6.1. Mass**

[FEND-40.02.05.00-00310-00 / T]

The mass of all Band 5 cartridge components (but excluding the cartridge body itself and the warm cartridge assembly) must not exceed 2.45 kg. Details can be found in the applicable Interface Control Document [AD2].

### **6.2. Eigen frequency**

[FEND-40.02.05.00-00320-00 / T]

The Band 5 cartridge shall have a first eigen-frequency of 70 Hz or greater.

### **6.3. Volume**

[FEND-40.02.05.00-00330-00 / I]

All Band 5 cartridge components shall remain within a volume of Ø170 mm x 475 mm, measured from the cartridge mounting flange.

Details can be found in the applicable Interface Control Document [AD2].

### **6.4. Orientation**

[FEND-40.02.05.00-00340-00 / A,R,T]

The cartridge shall meet all performance requirements over a range of gravity vectors from 0 to 90 degrees. This rotation occurs about the axis of the antenna elevation-bearing.

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## 6.5. Thermal Load

[FEND-40.02.05.00-00350-00 / A]

During operation or start-up the maximum allowable thermal load to be imposed on the cryostat by the Band 5 cartridge, during operation or stand-by shall confirm to the values as defined in [AD2].

## 6.6. Bias requirements

[FEND-40.02.05.00-00360-00 / R]

Details can be found in the applicable Interface Control Document [AD3].

## 6.7. Connectors and RF ports

### 6.7.1. RF input port interface

[FEND-40.02.05.00-00370-00 / R]

The RF input port of the cartridge shall comply with the requirements as described in section 5.7 of [AD12].

### 6.7.2. LO input port interface

[FEND-40.02.05.00-00380-00 / R, I]

Details can be found in the applicable Interface Control Document [AD5].

### 6.7.3. IF output port interface

[FEND-40.02.05.00-00390-00 / R, I]

All IF output ports shall be coaxial, details can be found in the applicable Interface Control Document [AD4].

### 6.7.4. Bias connectors

[FEND-40.02.05.00-00400-00 / R, I]

Details for the bias connector (s) can be found in the applicable Interface Control Document [AD3].

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## 7. OPERATING REQUIREMENTS

### 7.1. Local Oscillator

For details refer to the applicable Interface Control Documents [AD5].

#### 7.1.1. LO input port

[FEND-40.02.05.00-00420-00 / T]

The LO frequency range of the local-oscillator signal is as specified in [AD5].

#### 7.1.2. LO power requirement

[FEND-40.02.05.00-00430-00 / A,T]

The Band 5 cartridge shall meet its performance requirements when supplied with an available local oscillator signal as specified in [AD5]. This subsection does not apply to the non-operational mode.

#### 7.1.3. LO sideband and phase noise

[FEND-40.02.05.00-00440-00 / T]

Sideband noise refers to the noise accompanying the LO at frequency offsets within the IF band of the mixer in the normal operating RF frequency range. The Band 5 cartridge shall meet its performance requirements when supplied with a local oscillator with sideband noise not exceeding  $10 \text{ K}/\mu\text{W}$ . This subsection does not apply to stand-by and non-operational modes

Further information can be found in the relevant ICD [AD5].

#### 7.1.4. LO amplitude stability

[FEND-40.02.05.00-00450-00 / T]

The Band 5 cartridge shall meet its performance requirements when supplied with a local oscillator with amplitude stability as described in the ICD between the Band 5 cartridge and the first LO [AD5]: The Allan variance,  $\sigma^2(2, T, T)$ , of the Band 5 first local oscillator output power shall be less than  $9.0 \times 10^{-8}$  for  $0.05 \text{ s} \leq T \leq 100 \text{ s}$  and less than  $1.0 \times 10^{-6}$  for  $T = 300 \text{ s}$ .

### 7.2. Thermal Environment

[FEND-40.02.05.00-00460-00 / T]

The Band 5 cartridge shall meet its performance requirements in a thermal environment which presents temperature variations, measured at the cartridge side of the thermal interface clamps as follows:

Stage	Stage temperature	Max. variation 1 min.
4 K	< 4 K	2mK (peak to peak)
15 K	10 K – 18 K	15mK (peak to peak)
110 K	70 K – 130 K	100mK (peak to peak)

These follow from the thermal environment details provided in [AD2].

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An operating cartridge must be able to withstand an increase in temperature to ambient (20° C) with a rate of less than 1 degree/minute in a dry environment only without damage. This section does not apply to storage or transportation modes.

### 7.3. Vacuum conditions

[FEND-40.02.05.00-00470-00 / R, T]

(Note that this subsection does not apply to any of the transport or storage modes)

All specifications shall be met in a vacuum environment. Any out-gassing of cartridge components or leaking of hermetic feed-throughs shall be compatible with the ALMA vacuum requirements for cryostat [AD2], [AD10].

### 7.4. Environmental operating conditions

#### 7.4.1. Vibration

[FEND-40.02.05.00-00480-00 /R,T]

The Band 5 cartridge must survive vibration levels as specified in Appendix 1 of [AD8]. The vertical direction is defined as perpendicular to the cartridge baseplate.

#### 7.4.2. Acceleration

[FEND-40.02.05.00-00490-00 / R,T]

The Band 5 cartridge alone, with no shipping container, must survive the following accelerations:

- 4 g shock load in the vertical direction
- 3 g shock load in the horizontal direction

The vertical direction is defined as perpendicular to the cartridge baseplate.

### 7.5. Storage and shipping conditions

[FEND-40.02.05.00-00500-00 / R]

(Note that this section only applies to the storage mode)

The Band 5 cartridge must comply with [AD8].

### 7.6. Electro-Magnetic Compatibility

[FEND-40.02.05.00-00510-00 / T]

The Band 5 cartridge must comply with [AD7].

### 7.7. Monitoring and control

(Note that this section does not apply to the storage mode.)

#### 7.7.1. Mixer voltages and currents

[FEND-40.02.05.00-00520-00 / R]

The mixer voltages and currents shall be monitored as stated in [AD3].

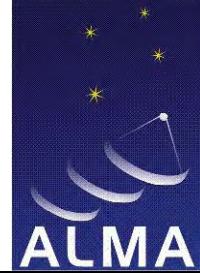
#### 7.7.2. Magnet currents

[FEND-40.02.05.00-00530-00 / R]

The magnet currents shall be monitored as stated in [AD3].

#### 7.7.3. Temperature

[FEND-40.02.05.00-00540-00 / R]

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Temperature sensors shall be provided at critical points of all temperature stages as stated in [AD3].

#### **7.7.4. Removal of trapped flux**

[FEND-40.02.05.00-00550-00 / R]

Means shall be provided to remove flux trapped in the SIS junctions.

## **8. RELIABILITY REQUIREMENTS**

### **8.1. Continuous operation**

[FEND-40.02.05.00-00560-00 / R]

The cartridge shall be designed for continuous use. It shall not require any periodic maintenance.

### **8.2. Mean time between failure (MTBF)**

[FEND-40.02.05.00-00570-00 / A]

The MTBF of the cartridge shall exceed 20 years.

### **8.3. Lifetime**

[FEND-40.02.05.00-00580-00 / R]

The Band 5 cartridge shall have a minimum lifetime of 15 years.