



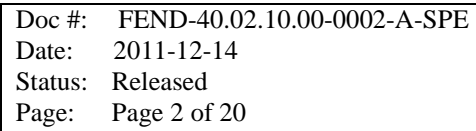
**Atacama  
Large  
Millimeter /  
submillimeter  
Array**


## **Band 10 Cartridge Technical Specifications**

FEND-40.02.10.00-0002-A-SPE

Version: A  
Status: Released  
2011-12-14


<b>Prepared By: Name(s) and Signature(s)</b>	<b>Organization</b>	<b>Date</b>
Y. Uzawa	NAOJ	2011-12-14
<b>Approved By Name and Signature</b>	<b>Organization</b>	<b>Date</b>
Y. Uzawa	NAOJ	
<b>Approved By FE System Engineer Name and Signature</b>	<b>Organization</b>	<b>Date</b>
K. S. Saini	NRAO	
P. Yagoubov	ESO	
<b>Approved By IPT Name and Signature</b>	<b>Organization</b>	<b>Date</b>
S. Thacker	NRAO	
G. H. Tan	ESO	
<b>Approved by Regional Manager Name and Signature</b>	<b>Organization</b>	<b>Date</b>
S. Iguchi	NAOJ	
<b>Approved By JAO Name and Signature</b>	<b>Organization</b>	<b>Date</b>
R. Bhatia		

[illegible]


	<b>ALMA Project</b> <b>Band 10 Cartridge</b> <b>Technical Specifications</b>	Doc #: FEND-40.02.10.00-0002-A-SPE Date: 2011-12-14 Status: Released Page: Page 3 of 20
--	--	--

## TABLE OF CONTENTS

<b>1. INTRODUCTION .....</b>	<b>5</b>
1.1. PURPOSE .....	5
1.2. SCOPE.....	5
<b>2. RELATED DOCUMENTS .....</b>	<b>5</b>
2.1. APPLICABLE DOCUMENTS .....	5
2.2. REFERENCE DOCUMENTS .....	6
2.3. ACRONYMS .....	6
2.4. VERB CONVENTION .....	7
2.5. REQUIREMENTS NUMBERING .....	7
<b>3. DESCRIPTION.....</b>	<b>7</b>
3.1. EQUIPMENT DEFINITION .....	7
<b>4. GENERAL REQUIREMENTS .....</b>	<b>8</b>
4.1. OPERATION MODES.....	8
4.1.1. OPERATIONAL .....	8
4.1.2. NON-OPERATIONAL .....	8
4.1.3. STAND-BY.....	8
4.1.4. TRANSPORT WITH THE ANTENNA TRANSPORTER.....	8
4.1.5. TRANSPORT IN THE FRONT END SERVICE VEHICLE .....	8
4.1.6. STORAGE.....	8
4.2. COMPATIBILITY WITH THE ALMA FRONT-END SUB-SYSTEM .....	9
4.3. DESIGN FOR PRODUCTION .....	9
4.3.1. TECHNOLOGY.....	9
4.3.2. SERIES PRODUCTION.....	9
4.3.3. STANDARD PARTS.....	9
4.4. MECHANICAL TUNING .....	9
4.5. METRIC DIMENSIONING.....	9
<b>5. FUNCTIONAL REQUIREMENTS.....</b>	<b>9</b>
5.1. MIXER TYPE.....	9
5.2. MIXING SCHEME .....	9
5.3. FREQUENCY COVERAGE .....	10
5.3.1 RF INPUT PORT .....	10
5.3.2 LO INPUT PORT .....	10
5.3.3 IF OUTPUT PORTS .....	10
5.4. POLARIZATION STATES .....	10
<b>6. PERFORMANCE REQUIREMENTS.....</b>	<b>10</b>
6.1. CARTRIDGE NOISE-TEMPERATURE.....	10
6.2. IMAGE BAND SUPPRESSION AND SIDEBAND MISMATCH .....	11
6.3. SPURIOUS RESPONSE.....	11
6.4. CARTRIDGE IF POWER .....	11
6.4.1. IF OUTPUT POWER .....	11
6.4.2. IF POWER VARIATIONS .....	11
6.5. GAIN COMPRESSION.....	11

	<b>ALMA Project</b> <b>Band 10 Cartridge</b> <b>Technical Specifications</b>	Doc #: FEND-40.02.10.00-0002-A-SPE Date: 2011-12-14 Status: Released Page: Page 4 of 20
--	--	--

6.6.	AMPLITUDE STABILITY .....	12
6.7.	SIGNAL PATH PHASE STABILITY .....	12
6.8.	IF PHASE VARIATIONS .....	12
6.9.	OPTICS.....	12
6.9.1.	BEAM PERFORMANCE.....	12
6.9.2.	POLARIZATION REQUIREMENTS .....	13
6.10.	STABILIZATION TIME.....	14
6.10.1.	STABILIZATION TIME FROM NON-OPERATIONAL MODE .....	14
6.10.2.	STABILIZATION TIME FROM STAND-BY MODE.....	14
<b>7.</b>	<b>MECHANICAL AND ELECTRICAL REQUIREMENTS .....</b>	<b>15</b>
7.1.	MASS .....	15
7.2.	EIGEN FREQUENCY .....	15
7.3.	VOLUME .....	15
7.4.	ORIENTATION .....	15
7.5.	THERMAL LOAD.....	15
7.6.	BIAS REQUIREMENTS.....	15
7.7.	CONNECTORS AND RF PORTS .....	16
7.7.1.	RF INPUT PORT INTERFACE .....	16
7.7.2.	LO INPUT PORT INTERFACE .....	16
7.7.3.	IF OUTPUT PORT INTERFACE.....	16
7.7.4.	BIAS CONNECTORS.....	16
<b>8.</b>	<b>OPERATING REQUIREMENTS .....</b>	<b>17</b>
8.1.	LOCAL OSCILLATOR.....	17
8.1.1.	LO INPUT PORT .....	17
8.1.2.	LO POWER REQUIREMENT .....	17
8.1.3.	LO SIDEBAND AND PHASE NOISE .....	17
8.1.4.	LO AMPLITUDE STABILITY .....	17
8.2.	THERMAL ENVIRONMENT.....	17
8.3.	VACUUM CONDITIONS.....	18
8.4.	ENVIRONMENTAL OPERATING CONDITIONS.....	18
8.4.1.	VIBRATION .....	18
8.4.2.	ACCELERATION .....	18
8.5.	STORAGE AND SHIPPING CONDITIONS.....	18
8.6.	ELECTRO-MAGNETIC COMPATIBILITY.....	18
8.7.	MONITORING AND CONTROL.....	18
8.7.1.	MIXER VOLTAGES AND CURRENTS .....	18
8.7.2.	MAGNET CURRENTS .....	19
8.7.3.	TEMPERATURE.....	19
8.7.4.	REMOVAL OF TRAPPED FLUX.....	19
<b>9.</b>	<b>RELIABILITY REQUIREMENTS.....</b>	<b>20</b>
9.1.	CONTINUOUS OPERATION .....	20
9.2.	MEAN TIME TO FAILURE .....	20
9.3.	LIFETIME.....	20

	<b>ALMA Project</b> <b>Band 10 Cartridge</b> <b>Technical Specifications</b>	Doc #: FEND-40.02.10.00-0002-A-SPE Date: 2011-12-14 Status: Released Page: Page 5 of 20
--	--	--

## 1. INTRODUCTION

### 1.1. Purpose

This document details the specifications and requirements for the ALMA Band 10 cartridge.

### 1.2. Scope

The information given in this document provides a complete summary of all the specifications and requirements that must be met by the ALMA Band 10 cartridges delivered to the project. The document is accompanied by Interface Control Documents for this Band 10 cartridge.


The following table provides a partial view of the ALMA product tree (RD01) at the “unit” (level 3) and “item” (level 4) for the Band 10 cartridge and its components.

<i>PT level 3 / “unit”</i>		<i>PT level 4 / “item”</i>		<i>Remarks</i>
<i>Product No.</i>	<i>Product Name</i>	<i>Product No.</i>	<i>Product Name</i>	
40.02.10.00	Band 10 cartridge			
		40.02.10.01	Band 10 cold optics	
		40.02.10.02	Band 10 LO injection	
		40.02.10.03	Band 10 SIS mixer	
		40.02.10.04	Band 10 cryogenic IF amplifiers	
		40.02.10.05	Band 10 protection board	
		40.02.10.06	Band 10 support structure	
		40.02.10.07	Band 10 cartridge wiring	
		40.02.10.08	Band 10 electrical feedthroughs	
		40.02.10.09	Band 10 cryo frequency multiplier	Not part of this requirements document
		40.02.10.10	Band 10 temperature sensors and heaters	
		40.02.10.11	unused	
		40.02.10.12	unused	
		40.02.10.13	Band 10 Warm IF amplifier	

## 2. RELATED DOCUMENTS

### 2.1. 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.

	<b>ALMA Project Band 10 Cartridge Technical Specifications</b>	Doc #: FEND-40.02.10.00-0002-A-SPE Date: 2011-12-14 Status: Released Page: Page 6 of 20
--	--	--

<i>Reference</i>	<i>Document title</i>	<i>Document ID</i>
[AD01]	Front-End Sub-System for the 12 m-Antenna Array Technical Specifications	FEND-40.00.00.00-001-A-SPE
[AD02]	ICD Band 10 cartridge – Dewar	FEND-40.02.10.00-40.03.01.00-A-ICD
[AD03]	ICD Band 10 cartridge – Band 10 bias Module	FEND-40.02.10.00-40.04.02.00-A-ICD
[AD04]	ICD Band 10 cartridge – IF switch sub-system	FEND-40.02.10.00-40.08.01.00-A-ICD
[AD05]	ICD Band 10 cartridge – Band 10 first LO	FEND-40.02.10.00-40.10.10.00-A-ICD
[AD06]	ICD cartridges – Warm cartridge assembly	FEND-40.02.00.00-40.11.00.00-A-ICD
[AD07]	ALMA System: Electromagnetic Compatibility Requirements	ALMA-80.05.01.00-001-B-SPE
[AD08]	ALMA Environmental Specification	ALMA-80.05.02.00-001-B-SPE
[AD09]	ALMA Product Assurance Requirements	ALMA-80.11.00.00-001-C-GEN
[AD10]	Vacuum requirements for receiver components inside the ALMA Front End cryostat	FEND-40.03.00.00-015-A-SPE
[AD11]	ICD Antenna – Front-End	ALMA-34.00.00.00-40.00.00.00-D-ICD

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.

## 2.2. 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>
[RD01]	ALMA Product Tree	ALMA-80.03.00.00-001-O-LIS
[RD02]	ALMA Front-End Optics Conceptual Design Report	FEND-40.01.00.00-003-A-REP
[RD03]	ALMA Band 10 cartridge Statement of Work	FEND-40.02.10.00-003-A-SOW

## 2.3. Acronyms

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

<b>AD</b>	Applicable Documents
<b>ALMA</b>	<u>A</u> tacama <u>L</u> arge <u>M</u> illimeter <u>A</u> rray
<b>CDR</b>	<u>C</u> ritical <u>D</u> esign <u>R</u> eview
<b>DSB</b>	<u>D</u> ouble <u>s</u> ide- <u>b</u> and
<b>EMC</b>	Electromagnetic compatibility
<b>FE</b>	<u>F</u> ront- <u>E</u> nd
<b>ICD</b>	<u>I</u> nterface <u>C</u> ontrol <u>D</u> ocument
<b>IF</b>	<u>I</u> ntermediate <u>F</u> requency
<b>IPT</b>	<u>I</u> ntegrated <u>P</u> roduct <u>T</u> eam
<b>LO</b>	<u>L</u> ocal <u>O</u> scillator
<b>MTBF</b>	<u>M</u> ean <u>t</u> ime <u>b</u> etween <u>f</u> ailures
<b>NAOJ</b>	National Astronomical Observatory of Japan
<b>PDR</b>	<u>P</u> reliminary <u>d</u> esign <u>r</u> eview
<b>RD</b>	Reference Document
<b>RF</b>	<u>R</u> adio <u>f</u> requency
<b>SIS</b>	<u>S</u> uperconductor- <u>I</u> nsulator- <u>S</u> uperconductor

	<b>ALMA Project Band 10 Cartridge Technical Specifications</b>	Doc #: FEND-40.02.10.00-0002-A-SPE Date: 2011-12-14 Status: Released Page: Page 7 of 20
--	--	--

**SSB**      Single side-band  
**2SB**      Side-band separating

## 2.4. 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.

## 2.5. Requirements numbering

The requirements are numbered according to the following code:

**[FEND-40.02.10.00-XXXXX-YY / Z]**

Where:

**FEND-40.02.10.00** identifies the 'Front-End – Band 10 cartridge' as in [RD01];

**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.

## 3. DESCRIPTION

### 3.1. Equipment Definition

The Band 10 cartridge is one of the ten receiver cartridges that populate the Front-End cryostat. It receives radiation in the 787 - 950 GHz frequency range in two orthogonal polarizations and down-converts the signals to intermediate frequencies between 4 and 12 GHz.

The Band 10 cartridge work-package includes the cold optics (feed horn, mirrors, polarizing grids), SIS mixers, isolators, components required to couple the LO into the mixers, IF amplifiers (cold and warm), temperature sensors, heaters and component interconnects. Other ALMA work-packages will supply the cartridge body, the LO subsystem (including cold frequency nonuplers), cryostat window/infrared blocking filters and the DC support electronics. These deliverable items shall be integrated into the Band 10 cartridge and the assembly tested as a whole. All vacuum and cryogenic services are provided by the Front-End cryostat

	<b>ALMA Project</b> <b>Band 10 Cartridge</b> <b>Technical Specifications</b>	Doc #: FEND-40.02.10.00-0002-A-SPE Date: 2011-12-14 Status: Released Page: Page 8 of 20
--	--	--

## **4. GENERAL REQUIREMENTS**

### **4.1. Operation modes**

The Band 10 cartridge will be used in the following modes.

#### **4.1.1. Operational**

[FEND-40.02.10.00-00010-00 / 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 10 cartridge) with all active signal levels at nominal values. All specifications and requirements in this document apply to this mode, unless otherwise stated explicitly

#### **4.1.2. Non-Operational**

[FEND-40.02.10.00-00020-00 / 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 10 cartridge is switched off (even if the Front End is powered up), and signal levels are not at nominal values. Unless otherwise noted, in this mode, all specifications and requirements of this document, with the exception of section 6, apply.

#### **4.1.3. Stand-by**

[FEND-40.02.10.00-00025-00 / I]

In this mode, operational power, including any bias voltages are applied to the Band 10 cartridge (see section 4.1.1, “Operational Mode”) and the corresponding warm cartridge assembly respectively, but the reference signals may not be at their nominal values. The Band 10 FE LO is not phase locked in this mode. Unless otherwise noted, in this mode, all specifications and requirements of this document, with the exception of section 6, apply.

#### **4.1.4. Transport with the antenna transporter**

[FEND-40.02.10.00-00030-00 / I]

This mode applies when the Band 10 cartridge, integrated into the Front-End sub-system, is transported with the antenna on the antenna transport vehicle. Unless otherwise noted, in this mode, all specifications and requirements with the exception of section 6, apply. This mode differs from non operational mode in the environmental operating conditions [AD08].

#### **4.1.5. Transport in the front end service vehicle**


[FEND-40.02.10.00-00040-00 / I]

This mode applies when the Band 10 cartridge, integrated into the Front-End sub-system, is transported on the Front-End service vehicle. Unless otherwise noted, in this mode, all specifications and requirements with the exception of section 6, apply. This mode differs from the non operational mode in the environmental operating conditions [AD08].

#### **4.1.6. Storage**

[FEND-40.02.10.00-00045-00 / I]

In this mode the Band 10 cartridge is stored completely assembled. This mode differs from the non-operational mode in the environmental operating conditions and lack of monitoring and control signals. For storage, the same specifications and requirements as for the non-

	<b>ALMA Project Band 10 Cartridge Technical Specifications</b>	Doc #: FEND-40.02.10.00-0002-A-SPE Date: 2011-12-14 Status: Released Page: Page 9 of 20
--	--	--

operational mode apply, unless otherwise stated. A suitable container might be used for the storage of the Band 10 cartridge assembly.

In normal operation conditions, the band 10 cartridge is either “operational” or in “stand-by”.

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

[FEND-40.02.10.00-00050-00 / I]

The Band 10 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 [AD02 through AD06].

## **4.3. Design for production**

### **4.3.1. Technology**

[FEND-40.02.10.00-00060-00 / R]

The Band 10 cartridge design should use mature technologies whenever possible.

### **4.3.2. Series production**

[FEND-40.02.10.00-00070-00 / R]

The Band 10 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.

### **4.3.3. Standard parts**

[FEND-40.02.10.00-00080-00 / R]

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

## **4.4. Mechanical tuning**

[FEND-40.02.10.00-00090-00 / R]

Operation of the Band 10 cartridge shall not require the use of any mechanical tuners.

## **4.5. Metric dimensioning**

[FEND-40.02.10.00-00110-00 / R]

All hardware used in the Band 10 Cartridge, including but not limited to fasteners, tapped holes, etc., shall be metric where possible. However, the internal details of components may use imperial dimensioning and fasteners. Standard wave-guide flanges (using imperial dimensions) may be used.

# **5. FUNCTIONAL REQUIREMENTS**


## **5.1. Mixer type**

[FEND-40.02.10.00-00120-00 / R]

The Band 10 cartridge shall employ SIS mixers as the frequency-translating devices.

## **5.2. Mixing scheme**

[FEND-40.02.10.00-00130-00 / R]

	<b>ALMA Project</b> <b>Band 10 Cartridge</b> <b>Technical Specifications</b>	Doc #: FEND-40.02.10.00-0002-A-SPE Date: 2011-12-14 Status: Released Page: Page 10 of 20
--	--	---

The Band 10 mixers shall be of the double-sideband (DSB) type.

### 5.3. Frequency Coverage

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

#### 5.3.1 RF input port

[FEND-40.02.10.00-00140-00 / R]

The RF input frequency range shall be from 787 GHz to 950 GHz.

#### 5.3.2 LO input port

[FEND-40.02.10.00-00150-00 / R]

The LO input port frequency range shall be from 799 GHz to 938 GHz.

#### 5.3.3 IF output ports

[FEND-40.02.10.00-00160-00 / R]

Each polarization shall provide 8 GHz of IF bandwidth. Each eight GHz of bandwidth shall be double-sideband (DSB), centred at 8.0 GHz.

### 5.4. Polarization States

[FEND-40.02.10.00-00170-00 / R]

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 5.3.3. The nominal polarization states shall be linear.

## 6. PERFORMANCE REQUIREMENTS


Unless otherwise specified, all of the RF requirements for the Band 10 cartridge performance are referenced to the atmospheric side of the vacuum window and include the contribution from the warm optics assembly. Any applicable contributions from the cryostat vacuum window and IR filters (either as provided by the project for the test cryostat, or standard issue ALMA windows and filters) are included.

### 6.1. Cartridge Noise-Temperature

[FEND-40.02.10.00-00180-00 / T]

The following table details the required noise temperature performance for the Band 10 cartridge.

<i>Requirement</i>	
<i><math>T_{DSB}</math> over 80% of the frequency range</i>	<i><math>T_{DSB}</math> at any frequency within The RF band</i>
230	344

	<b>ALMA Project Band 10 Cartridge Technical Specifications</b>	Doc #: FEND-40.02.10.00-0002-A-SPE Date: 2011-12-14 Status: Released Page: Page 11 of 20
--	--	---

Remarks:

- The frequency ranges of the bands in the table above are specified in section 5.3.1 of this document.
- The required noise temperatures shall be met when averaging over the full IF band, (as defined in section 5.3.3).
- The noise temperature shall be calculated from measurements according to the Rayleigh-Jeans law.
- The noise performance shall be measured for an operating temperature of  $4 \pm 0.25$  K, measured at the 4 K stage.
- The stated cartridge noise temperatures are based on a LO noise contribution as specified in section 8.1.3.

## 6.2. Image band suppression and sideband mismatch

[FEND-40.02.10.00-00190-00 / T]

For a DSB mixing scheme the side-band ratio between upper and lower side bands shall be 3 dB or less across 80% of the combined IF and LO frequency ranges specified under sections 5.3.3 and 5.3.2.

## 6.3. Spurious response

[FEND-40.02.10.00-00195-00 / T]

At any LO frequency (within the specified range of a band) the IF power due to incoherent spurious signals 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.

## 6.4. Cartridge IF power

### 6.4.1. IF output power

[FEND-40.02.10.00-00200-00 / 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 5.3.3) 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 may house the second-stage (warm) IF amplifiers.)
- The total power in the 10 MHz to 18 GHz shall not be more than 3dB higher than the measured maximum in-band IF power as described earlier.

These specifications follow from the requirements in [AD4].


### 6.4.2. IF power variations

[FEND-40.02.10.00-00210-00 / T]

Within the IF band (as specified in Section 5.3.3), the IF output power variation shall not exceed 6.0 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 peak-to-peak variation shall not exceed 4.0 dB peak-to-peak when measured with a 100 MHz resolution. These specifications follow from the requirements in [AD04].

## 6.5. Gain compression

[FEND-40.02.10.00-00230-00 / T]

	<b>ALMA Project Band 10 Cartridge Technical Specifications</b>	Doc #: FEND-40.02.10.00-0002-A-SPE Date: 2011-12-14 Status: Released Page: Page 12 of 20
--	--	---

The large signal gain compression caused by the exchange of RF load temperatures of 77 and 373K shall be less than 5 %.

## 6.6. Amplitude stability

[FEND-40.02.10.00-00240-00 / 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 IF band (specified in sections 5.3.1 and 5.3.3) 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  $3.0 \times 10^{-6}$  for  $T = 300 \text{ s}$ .
- 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.

## 6.7. Signal path phase stability

[FEND-40.02.10.00-00250-00 / 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 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 amplifier and the local oscillator chain. The required phase stability excludes any contribution from the local oscillator chain.

## 6.8. IF phase variations

[FEND-40.02.10.00-00255-00 / T, A]

This applies to any 2 GHz portion of the IF band, as specified in section 5.3.3. 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.

## 6.9. Optics


### 6.9.1. Beam performance

#### 6.9.1.1. Aperture Efficiency

[FEND-40.02.10.00-00260-00 / T]

The aperture efficiency factor due to the optics of the Band 10 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:

	<b>ALMA Project Band 10 Cartridge Technical Specifications</b>	Doc #: FEND-40.02.10.00-0002-A-SPE Date: 2011-12-14 Status: Released Page: Page 13 of 20
--	--	---

- 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 6.1 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:

#### **6.9.1.1.1. Polarization efficiency**

[FEND-40.02.010.00-00266-00 / T]

The polarization efficiency of the Band 10 optics in the FE assembly shall exceed 99.5%. This requirement simultaneously applies to both orthogonally polarized beams of a cartridge. (Note that this is equivalent to -23 dBc integrated cross polarization performance)

#### **6.9.1.1.2. Focus efficiency**

[FEND-40.02.010.00-00268-00 / T]

The focus efficiency of the tertiary optics system shall exceed 98 % for the Band 10 Cartridge.

This requirement simultaneously applies to both orthogonally polarized beams of a cartridge.

### **6.9.2. Polarization requirements**

#### **6.9.2.1. “Polarization 0” channel Alignment Accuracy**

[FEND-40.02.10.00-00280-00 / T]

Orientation of the major axis of the “Polarization 0” channel polarization ellipse shall be aligned to within 2 degrees of the radial direction of the cryostat.

#### **6.9.2.2. “Polarization 1” channel Alignment Accuracy**


[FEND-40.02.10.00-00285-00 / T]

Orientation of the major axis of the “Polarization 1” channel polarization ellipse shall be orthogonal to within 2 degrees of the radial direction of the cryostat.

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

[FEND-40.02.10.00-00290-00 / T]

The, uncorrected, cross talk between orthogonal receive channels, RF and IF, inside the Band 10 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.

	<b>ALMA Project Band 10 Cartridge Technical Specifications</b>	Doc #: FEND-40.02.10.00-0002-A-SPE Date: 2011-12-14 Status: Released Page: Page 14 of 20
--	--	---

#### **6.9.2.4. Beam Squint**

[FEND-40.02.10.00-00295-00 / T]

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

### **6.10. Stabilization time**

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


[FEND-40.02.10.00-00300-00 / T]

Starting from the non operational mode, the Band 10 cartridge shall reach the operational mode (i.e. meet all applicable specifications) within 15 minutes.

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

[FEND-40.02.10.00-00305-00 / T]

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

	<b>ALMA Project</b> <b>Band 10 Cartridge</b> <b>Technical Specifications</b>	Doc #: FEND-40.02.10.00-0002-A-SPE Date: 2011-12-14 Status: Released Page: Page 15 of 20
--	--	---

## 7. MECHANICAL AND ELECTRICAL REQUIREMENTS

### 7.1. Mass

[FEND-40.02.10.00-00310-00 / T]

The total mass of all Band 10 cartridge cooled components (but excluding the cartridge body itself and the warm cartridge assembly) must not exceed 2 kg. Details can be found in the applicable Interface Control Document [AD02].

### 7.2. Eigen Frequency

[FEND-40.02.10.00-00320-00 / A,R,T]

The Band 10 cartridge shall have a first eigen-frequency of 70 Hz or greater.

### 7.3. Volume

[FEND-40.02.10.00-00330-00 / I]

The diameter of the cartridge components should not exceed that of the cartridge plate on which they are mounted (TBC, this is D = 169 mm for the 4 K plate, 169.5 mm for the 15 K plate, and 170 mm for the 110 K plate. Ø170 x 475 mm, measured from the cartridge mounting flange. Details can be found in the applicable Interface Control Document [AD02]

### 7.4. Orientation

[FEND-40.02.10.00-00340-00 / 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. Flexure of components mounted on the cartridge-body shall not cause the cartridge beam coupling efficiency to vary by more than 2 % over the same range.

### 7.5. Thermal Load

[FEND-40.02.10.00-00350-00 / A]

During operation or start-up the maximum allowable thermal load to be imposed on the cryostat by the cartridge, during operation or stand-by shall confirm to the following:


Cryostat Stage	Passive Heat Load	Active Heat Load	Total Heat Load
4 K Stage	5 mW	36 mW	41 mW
15 K Stage	95 mW	67 mW	162 mW
110 K Stage	600 mW	250 mW	850 mW

This specification follows from the Interface Control Document [AD02]

### 7.6. Bias requirements

[FEND-40.02.10.00-00360-00 / R,T]

Details can be found in the applicable Interface Control Document [AD03]

	<b>ALMA Project Band 10 Cartridge Technical Specifications</b>	Doc #: FEND-40.02.10.00-0002-A-SPE Date: 2011-12-14 Status: Released Page: Page 16 of 20
--	--	---

## 7.7. Connectors and RF ports

### 7.7.1. RF input port interface

[FEND-40.02.10.00-00370-00 / R]

The RF input port of the cartridge shall comply with the requirements as described in section 4.2.3. of [AD01].

### 7.7.2. LO input port interface

[FEND-40.02.10.00-00380-00 / R, I]

The mixer LO input ports shall be rectangular waveguide.

Details can be found in the applicable Interface Control Document [AD05].

### 7.7.3. IF output port interface


[FEND-40.02.10.00-00390-00 / R, I]

All IF output ports shall be coaxial, details can be found in the applicable Interface Control Document [AD04].

### 7.7.4. Bias connectors

[FEND-40.02.10.00-00400-00 / R, I]

Details for the bias connector (s) can be found in the applicable Interface Control Document [AD03].

	<b>ALMA Project</b> <b>Band 10 Cartridge</b> <b>Technical Specifications</b>	Doc #: FEND-40.02.10.00-0002-A-SPE Date: 2011-12-14 Status: Released Page: Page 17 of 20
--	--	---

## 8. OPERATING REQUIREMENTS

### 8.1. Local Oscillator

For further details refer to the applicable Interface Control Documents [AD05]

#### 8.1.1. LO input port

[FEND-40.02.10.00-00420-00 / T]

The LO frequency range of the local-oscillator signal is 799 GHz to 938 GHz.

#### 8.1.2. LO power requirement

[FEND-40.02.10.00-00430-00 / A,T]

The Band 10 cartridge shall meet its performance requirements when supplied with an available local oscillator signal as specified in [AD05]. This subsection does not apply to the non-operational mode.

#### 8.1.3. LO sideband and phase noise

[FEND-40.02.010.00-00440-00 / 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 10 cartridge shall meet its performance requirements when supplied with a local oscillator with sideband noise not exceeding 20 K/μW. This subsection does not apply to stand-by and non-operational modes

Further information can be found in the relevant ICD (Band 10 Cartridge to first LO [AD05])

#### 8.1.4. LO amplitude stability

[FEND-40.02.10.00-00450-00 / T]

The Band 10 cartridge shall meet its performance requirements when supplied with a local oscillator with amplitude stability as described in the ICD between the Band 10 Cartridge and the first LO [AD05]: The Allan variance,  $\sigma^2(2, T, T)$ , of the Band 10 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  $T = 300 \text{ s}$ .

### 8.2. Thermal Environment


[FEND-40.02.10.00-00460-00 / T]

(Note that this subsection only applies to the operational mode.)

The Band 10 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 [AD02].

	<b>ALMA Project Band 10 Cartridge Technical Specifications</b>	Doc #: FEND-40.02.10.00-0002-A-SPE Date: 2011-12-14 Status: Released Page: Page 18 of 20
--	--	---

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.

### 8.3. Vacuum conditions

[FEND-40.02.10.00-00470-00 / R]

(Note that this subsection does not apply to either 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 [AD02] and [AD10].

### 8.4. Environmental operating conditions

#### 8.4.1. Vibration

[FEND-40.02.10.00-00480-00 /R,T]

The Band 10 cartridge must survive vibration levels as specified in Appendix 1 of [AD08].

The vertical direction is defined as perpendicular to the cartridge base plate.

#### 8.4.2. Acceleration

[FEND-40.02.10.00-00490-00 / R]

The Band 10 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 base plate.

### 8.5. Storage and shipping conditions

[FEND-40.02.10.00-00500-00 / R]

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

The Band 10 cartridge must comply with [AD08]

### 8.6. Electro-Magnetic Compatibility

[FEND-40.02.10.00-00510-00 / T]

The Band 10 cartridge must comply with [AD07].


### 8.7. Monitoring and control

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

#### 8.7.1. Mixer voltages and currents

[FEND-40.02.10.00-00520-00 / R]

The mixer voltages and currents must be monitored as stated in [AD03]

	<b>ALMA Project Band 10 Cartridge Technical Specifications</b>	Doc #: FEND-40.02.10.00-0002-A-SPE Date: 2011-12-14 Status: Released Page: Page 19 of 20
--	--	---

#### **8.7.2. Magnet currents**

[FEND-40.02.10.00-00530-00 / R]

If required by the mixer design, the currents flowing in the suppression magnet must be monitored, see [AD03]

#### **8.7.3. Temperature**


[FEND-40.02.10.00-00540-00 / R]

Temperature sensors shall be provided at critical points of all temperature stages, see [AD03].

#### **8.7.4. Removal of trapped flux**

[FEND-40.02.10.00-00550-00 / R]

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

	<b>ALMA Project</b> <b>Band 10 Cartridge</b> <b>Technical Specifications</b>	Doc #: FEND-40.02.10.00-0002-A-SPE Date: 2011-12-14 Status: Released Page: Page 20 of 20
--	--	---

## **9. RELIABILITY REQUIREMENTS**

### **9.1. Continuous operation**

[FEND-40.02.10.00-00560-00 / R]

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

### **9.2. Mean time to failure**

[FEND-40.02.10.00-00570-00 / A]

The MTBF of the cartridge shall exceed 20 years.

### **9.3. Lifetime**

[FEND-40.02.10.00-00580-00 / R]

The Band 10 cartridge shall have a minimum lifetime of 15 years.