Band 7 Cartridge Technical Specifications

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Change Record

Version	Date	Affected Section(s)	Change Request #	Reason/Initiation/Remarks
A	2004-01-14	All	None	New Document
B	2007-05-09	Various	None	Document has been updated because of release of "Front-End Sub-System for the 12 m-Antenna Array Technical Specifications", ALMA-40.00.00.00-001-A-SPE
		Section 5.2	FEND-40.02.07.00-092-A-CRE	Relaxation of image rejection ratio
		Section 5.4.2	FEND-40.02.07.00-093-A-CRE	Relaxation of requirements on power level across IF band
C	2007-11-27	Section 5.2	FEND-40.02.07.00-092-B-CRE	Modification of image rejection ratio requirement
		Section 5.4.2	FEND-40.02.07.00-144-A-CRE	Added foot note with clarification
		Section 5.5	FEND-40.02.07.00-144-A-CRE	Changed specification to original value as defined in version A of this document
		Section 5.8.1	FEND-40.02.07.00-095-B-CRE	Updated to reflect CRE and reworded for clarification
		Section 5.8.2.3	FEND-40.02.07.00-144-A-CRE	Rewording of requirement
		Section 7.1.4	FEND-40.02.07.00-144-A-CRE	Added foot note to raise incompatibility between old LO specification and Band 7 Cartridge requirement as defined in this document
		Section 7.4.1	FEND-40.02.07.00-144-A-CRE	Clarification of requirement
D	2008-07-15	Section 5.8.1.2	FEND-40.02.07.00-160-A-CRE	Following CRE the polarization efficiency minimum value is increased to 99,5 %
		Section 5.8.2.1	FEND-40.02.07.00-160-A-CRE	Angle of Absolute Polarization Alignment adjusted to accommodate improved optics design
		Section 5.8.2.2	FEND-40.02.07.00-160-A-CRE	Angle of Relative Polarization Alignment adjusted to accommodate improved optics design
		Section 4.4.2	FEND-40.02.07.00-160-A-CRE	Documented the chain of angular coordinates defining the Pol0 position angle, as resulting from a) new optics for improved X-pol; b) inconsistency in cartridge drawings

E	2010-05-07	Section 1.3	None	Updated [AD 5] from version A to B
		Section 1.4	None	Updated [RD 2] from version A to E
		Section 4.4.2	None	Editorial
		Section 5.4.1	None	Editorial, IF output power range included
		Section 5.8.2	FEND-40.00.00.00-211-A-CRE	Polarization orientation changed to an "absolute" definition
		Section 5.8.2.1	FEND-40.02.07.00-253-A-CRE	Tolerance of angle of absolute polarization alignment relaxed from 2° to 4°
		Section 5.8.2.2	FEND-40.00.00.00-211-A-CRE FEND-40.02.07.00-253-A-CRE	Tolerance of angle of absolute polarization alignment relaxed from 2° to 4°
		Section 6.3	FEND-40.02.07.00-099-A-CRE	Updated volume dimensions to match [AD02] version B
		Section 6.5	None	Editorial, thermal load table inserted
		Section 7.1.4	None	LO stability requirement updated to be in agreement with [AD 5] version B

TABLE OF CONTENTS

1. INTRODUCTION

1.1. Purpose

This document summarizes the specifications and requirements for the ALMA Band 7 Cartridge.

1.2. Scope

The information given in this document provides a complete summary of all the requirements that must be met by the ALMA Band 7 Cartridges delivered to the project. This document is accompanied by Interface Control Documents for this Band 7 Cartridge.

The following table shows a partial view of the ALMA product tree [RD3] at levels 3 and 4 for the Band 7 Cartridge and its components.

PT level 3		*PT level 4*		
Product No.	*Product Name*	*Product No.*	*Product Name*	*Remarks*
40.02.07.00	Frequency Band 7 Cartridge			
		40.02.07.01	Band 7 cold optics	
		40.02.07.02	Band 7 LO injection	
		40.02.07.03	Band 7 SIS mixers	
		40.02.07.04	Band 7 quadrature hybrids	
		40.02.07.05	Band 7 IF amplifiers	
		40.02.07.06	Band 7 protection board	
		40.02.07.07	Band 7 support structure	Not part of this technical specification
		40.02.07.08	Band 7 Cartridge wiring	Includes sensors for monitoring
		40.02.07.09	Band 7 Cartridge electrical feed-throughs	
		40.02.07.10	Band 7 cryo frequency multiplier	Not part of this technical specification
		40.02.07.11	Band 7 temperature sensors	
		40.02.07.13	Band 7 Warm IF amplifier	

1.3. Applicable documents

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

Reference	*Document title*	*Document ID*
[AD1]	ICD Cartridges – Warm Cartridge Assemblies	FEND-40.02.00.00-40.11.00.00-A-ICD
[AD2]	ICD Band 7 Cartridge - Dewar	FEND-40.02.07.00-40.03.01.00-B-ICD
[AD3]	ICD Band 7 Cartridge - Band 7 bias circuits	FEND-40.02.07.00-40.02.07.06-B-ICD
[AD4]	ICD Band 7 Cartridge – IF switch sub-system	FEND-40.02.07.00-40.08.01.00-A-ICD
[AD5]	ICD Band 7 Cartridge – Band 7 First Local Oscillator	FEND-40.02.07.00-40.10.07.00-B-ICD
[AD6]	ALMA System: Electromagnetic Compatibility (EMC) Requirements	ALMA-80.05.01.00-001-B-SPE
[AD7]	ALMA Environmental Specification	ALMA-80.05.02.00-001-B-SPE
[AD8]	Vacuum Requirements for receiver components inside the ALMA Front End cryostat	FEND-40.03.00.00-015-A-SPE
[AD9]	ICD between Antenna and Front-End	ALMA-34.00.00.00-40.00.00.00-D-ICD

In the event of a conflict between applicable documents mentioned above and the contents of this document, the contents of this document shall be considered as a superseding requirement.

1.4. Reference documents

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

Reference	*Document title*	*Document ID*
[RD1]	ALMA Front End Sub-System Technical Specification	FEND-40.00.00.00-001-A-SPE
[RD2]	ALMA Band 7 Cartridge Production Statement of Work	FEND-40.02.07.00-075-E-SOW
[RD3]	ALMA Product Tree	ALMA-80.03.00.00-001-N-LIS
[RD4]	Improvement of the Band 7 Cartridge Cross Polarization	FEND-40.02.07.01-002-A-DSN

1.5. Acronyms

A limited set of basic acronyms used in this document is given below.

ALMA Atacama Large Millimeter Array
CDR Critical Design Review
DSB Double-SideBand
FE Front End
ICD Interface Control Document
IF Intermediate Frequency
IPT Integrated Product Team
LO Local Oscillator
MTBF Meantime between Failures

PDR	Preliminary Design Review
RF	Radio Frequency
SIS	Superconductor-Insulator-Superconductor
SSB	Single-SideBand
2SB	SideBand separating

1.6. Verb Convention

"Shall" is used whenever a specification expresses a provision that is binding. The verbs "should" and "may" express non-mandatory provisions.
"Will" is used to express a declaration of purpose on the part of the design activity.

1.7. Requirements numbering

The requirements within the present document are numbered according to the following code:

[FEND-40.02.07.00-XXXXX-YY / Z(ZZ)]

Where:

FEND-40.02.07.00 identifies the 'Front End – Band 7 Cartridge' as based on [RD3];

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(ZZ) 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.

2. DESCRIPTION

2.1. Equipment Definition

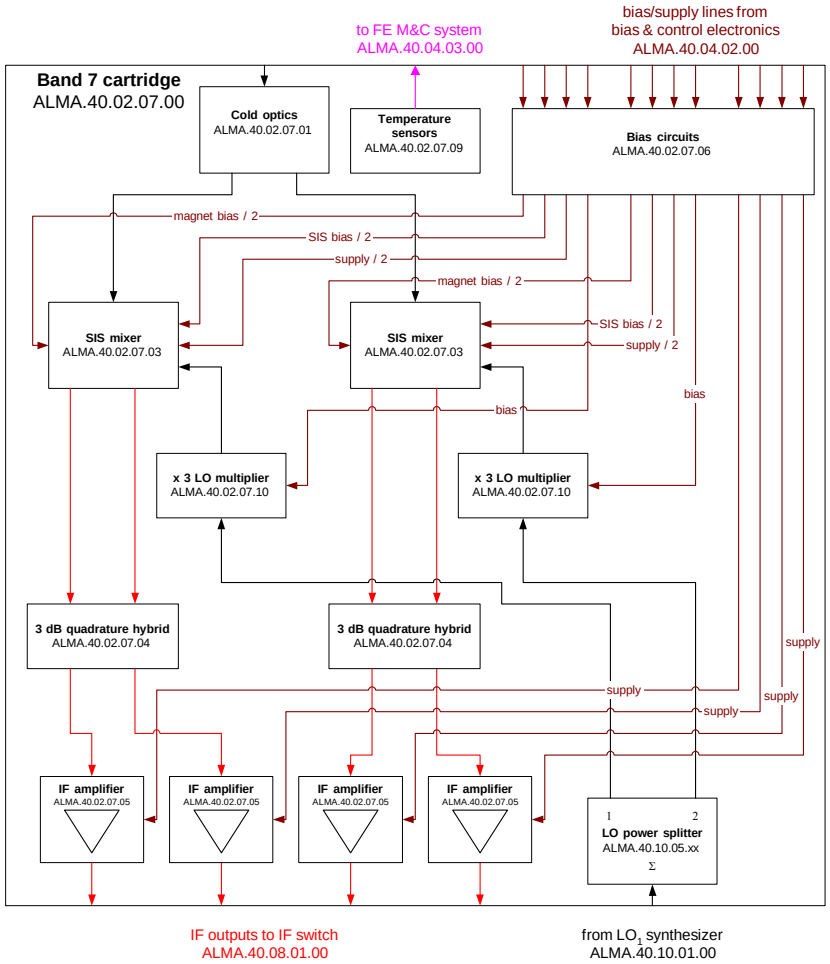
The Band 7 Cartridge is one of the receiver cartridges which populate the front end dewar. As an illustration, a generic block diagram of the Band 7 Cartridge is presented in figure 1. It should be noted that this is only a generic diagram of a 2SB mixing scheme. The actual cartridge block diagram, in line with the functional requirements given in chapter 4 of this document, is the responsibility of the Contractor.

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 7 cryostat window and IF 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 7 generic block diagram



3. GENERAL REQUIREMENTS

3.1. Operation modes

The Band 7 Cartridge shall be used according to the following modes.

3.1.1. Operational

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

3.1.2. Non-Operational

In this mode electrical power is not applied and signal levels are not at nominal values. For this mode, the specifications and requirements in all sections of this document shall apply, with the exception of section 5 and unless otherwise noted.

3.1.3. Stand-by

In this mode operational power, including any bias voltages at normal operational level (see Operational mode, section 3.1.1.), is applied to the Band 7 Cartridge and warm cartridge assembly, respectively, but RF and IF signal levels are not at nominal values and the Band 7 1st local oscillator is not phase locked. For this mode, the specifications and requirements in all sections of this document shall apply, with the exception of section 5 and unless otherwise noted.

3.1.4. Transport with the Antenna Transporter or in the FE Service Vehicle

This mode is applicable, when the Band 7 Cartridge as part of the front end sub-system is transported with the antenna on the antenna transport vehicle. For this mode, the specifications and requirements in all sections of this document shall apply, with the exception of section 5 and unless otherwise noted. A suitable container in which the Band 7 Cartridge is placed might be used for this storage mode to meet the requirements imposed.

3.1.5. Storage

In this mode the Band 7 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 in which the Band 7 Cartridge is placed might be used for this storage mode to meet the requirements imposed.

3.2. Compatibility with ALMA front end sub-system

[FEND-40.02.07.00-00050-00 / I]
The Band 7 Cartridge design shall be compatible with other products within the ALMA front end sub-system, especially the receiver optics and cryostat design. Details as given in the applicable ICDs.

3.3. Design for production

3.3.1. Technology

[FEND-40.02.07.00-00060-00 / R]
The Band 7 Cartridge design shall use mature technologies.

3.3.2. Series production

[FEND-40.02.07.00-00070-00 / R]
The Band 7 Cartridge design shall give a high degree of consideration to reduction of production and assembly costs. Complexity of the design and mechanical structures shall be simplified wherever possible.

3.3.3. Standard parts

[FEND-40.02.07.00-00080-00 / R]
Standard, unmodified commercially available components shall be used where possible.

3.4. Mechanical tuning

[FEND-40.02.07.00-00090-00 / R]
No mechanical tuning shall be employed during operation.

3.5. Metric hardware

[FEND-40.02.07.00-00110-00 / R]
All hardware used in the Band 7 Cartridge, including but not limited to fasteners, tapped holes, etc., shall be metric where possible.

4. FUNCTIONAL REQUIREMENTS

4.1. Mixer type

[FEND-40.02.07.00-00120-00 / R]
The Band 7 Cartridge shall employ a SIS mixer as the frequency translating device.

4.2. Mixing scheme

[FEND-40.02.07.00-00130-00 / R]
Each polarization channel shall be dual-sideband separating (2SB) with both sidebands supplied per polarization. Both polarization channels shall have the same mixing scheme.

4.3. Frequency Coverage

This section does not apply to the non-operational mode.

4.3.1. RF input port

[FEND-40.02.07.00-00140-00 / R]
The RF input frequency range shall be 275 GHz to 370 GHz.
Operation in the range 370 GHz to 373 GHz, equivalent to a local oscillator frequency in the range 362 GHz to 365 GHz, with degraded performance shall be feasible. This degraded performance defined as:

- Cartridge noise performance as defined under section 5.1;
- All other performance requirements defined in chapter 5 of this document do not apply for this extended frequency range.

4.3.2. LO input port

[FEND-40.02.07.00-00150-00 / R]
The LO input port frequency range shall be 283 GHz to 365 GHz.

4.3.3. IF output port bandwidth and centre frequency

[FEND-40.02.07.00-00160-00 / R]
Each frequency channel shall provide 8 GHz total IF bandwidth per polarization according to the following requirements:

- 4 GHz dual-sideband, (2SB) upper and lower sideband, centred at 6.0 GHz

4.4. Polarization

4.4.1. Polarization States

[FEND-40.02.07.00-00170-00 / R]
The nominal polarization state of the Band 7 Cartridge optics shall be linear.

4.4.2. Polarization Configuration

[FEND-40.02.07.00-00175-00 / I, R]
For all frequency bands the Cartridge shall receive two orthogonal polarizations, designated “Polarization 0” and “Polarization 1”, with each one converted to two separate IF outputs for the 2SB mixing scheme.

The nominal orientation of the major axis of the "Polarization 0" channel polarization ellipse is detailed below, as results from:

- a modification of the cartridge cold optics to improve the cross-polarization performance;
- a recently discovered inconsistency in cartridge body drawings

All angles are degrees, with the ***trigonometric sign convention***, ***looking towards the subreflector***.

Document	From	To	Angle
FEND-40.00.00.00-024-E-DWG	+X cryostat axis	Cartridge/cryostat dowel pin (6.35mm)	+15 °
FEND-40.03.000.00-105-C-DWG Release 3	Cartridge/cryostat dowel pin (6.35mm)	Dowel holes for cartridge structure (3.17mm)	-16 °
New cold optics polarization diplexing design study	Dowel holes referencing 4k optics	Pol 0 E vector	+37,45 °
Total	**+X cryostat axis**	**Pol 0 E-field orientation**	**+36,45 °**

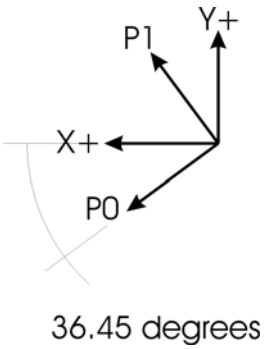


Figure 1. Cryostat reference frame, P0 and P1 E-field vectors. Looking *from* cartridge *towards* subreflector.

5. PERFORMANCE REQUIREMENTS

5.1. Cartridge Noise Performance

[FEND-40.02.07.00-00180-01 / T]
The following table shows the required noise temperature performance for the Band 7 Cartridge. The cartridge noise performance is referred to its quasi optical RF input port. It includes the noise contributions from dewar windows and IR filters, either as fabricated for the test dewar, or standard issue ALMA windows and filters. 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:

Requirement	
T_{SSB} over 80% freq. range	*T_{SSB} at any RF frequency*
147 K	219 K

Remarks:

- Frequency and frequency range in the table above as specified in section 4.3.1.
- The required noise temperature as given in the table above shall be met when averaging over the IF frequency range as specified in section 4.3.3. of this document.;
- In the frequency range 370 – 373 GHz a relaxed receiver noise temperature of less than 300 K (SSB) is allowed.
- The noise temperature shall be calculated from the measurements according to the Rayleigh-Jeans law.
- The noise performance shall be measured for an operating temperature of 4 ± 0.25 K at the mixer block.
- SSB noise temperatures shall be corrected for true single side band response, i.e. corrected for the residual image response.
- The stated cartridge noise temperatures are based on a LO noise contribution as specified in section 7.1.3.

5.2. Image Band Suppression

[FEND-40.02.07.00-00190-01 / T]
For a SSB or 2SB mixing scheme the image band suppression (for any LO frequency in the range 283 GHz – 362 GHz) no more than 10% of the measured points for the image gain shall be above - 10dB and no more than 1% above -7dB. The 10% (resp. 1%) fraction is to be applied globally to all LO frequencies for one combination of polarization and sideband.

5.3. Spurious response

[FEND-40.02.07.00-00195-00 / T]
At any LO frequency (within the specified range of a band) the IF power due to incoherent spurious signals, generated internally by the Band 7 Cartridge only, shall be at least 10 dB below the nominal noise power in any 2 GHz bandwidth (see section 5.4.1.). These incoherent spurious signals shall occupy less than 0.1% of the nominal IF bandwidth (see section 4.3.3.).

5.4. Cartridge IF output

5.4.1. IF output power

[FEND-40.02.07.00-00200-01 / 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 bandwidth, as specified in section 4.3.3, shall be in the -32 dBm to -22 dBm range.
- The total power in the IF frequency range 10 MHz to 18 GHz shall not be more than 3 dB higher than the measured maximum in-band IF power as described above.

Remarks:
-These power levels must be measured at the IF outputs of the warm cartridge assembly that houses the warm IF amplifier and the first local oscillator chain.
These specifications follow from the requirements in [AD4].

5.4.2. IF power variations

[FEND-40.02.07.00-00210-00 / T]
Within the IF band, variations from the average IF power over the whole IF band as specified in section 4.3.3 shall be less than[1]:

- 5.0 dB peak to peak in any 2 GHz portion of the IF band, as specified in section 4.3.3.
- 7.0 dB peak to peak across the whole IF band, as specified in section 4.3.3.

5.5. Gain saturation

[FEND-40.02.07.00-00230-01 / 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..

5.6. Amplitude stability

[FEND-40.02.07.00-00240-01 / T]
The IF amplitude stability, measured at the IF connectors on the output flange 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, $\sigma^2(T)$, of the IF output power in the IF band (specified in section 4.3.3) shall be less than 4.0×10^{-7} for T in the range of 0.05 s $\leq T \leq$ 100 s and 3.0×10^{-6} for T = 300 seconds.
  This corresponds to an Allan standard deviation of 6.3×10^{-4} and 1.7×10^{-3}, respectively.

Remarks:

[1] The requested performance might be obtained by the use of an equalizer. This equalizer shall have uniform characteristics among cartridges, in other words the use of an equalizer which is tuned for each cartridge is not allowed.

-This stability must be achieved when using the ALMA first local oscillator chain.

5.7. Signal path delay / phase response

5.7.1. Signal path delay stability

[FEND-40.02.07.00-00250-01 / 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 s ≤ T < 300 s : 7.1 fs

The delay drift requirement refers to the 2-point Standard Deviation with a fixed averaging time, τ, 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.

5.7.2. IF Phase variations

[FEND-40.02.07.00-00255-00 / A, T]
The following applies to any 2-GHz portion of the IF band pass. After a possible correction for a unique (over the 2-GHz) linear phase slope, in any 31-MHz portion, the deviation of the IF phase from the average (in that 31-MHz portion) shall be less than 4.5°rms.

5.8. Optics

5.8.1. Beam Performance

5.8.1.1. Aperture efficiency

[FEND-40.02.07.00-00260-00 / A]
The aperture efficiency factor due to the optics of the Band 7 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 centre) related to the antenna.

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

- Taper efficiency η_t: factor expressing the signal power loss due to non-uniform amplitude distribution over the secondary reflector
- Phase efficiency η_p: factor expressing the signal power loss due to the field across the secondary reflector not being in phase everywhere;
- Spillover efficiency η_s: fraction of the total power that is radiated by the tertiary optics, intercepted and collimated by the secondary reflector;
- Polarization efficiency η_x: factor expressing the signal power lost in cross-polarized fields over the antenna aperture plane;
- Focus efficiency η_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:

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

The ohmic losses of all tertiary optics and feeds are included in the T_{rx} 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:

5.8.1.2. Polarization efficiency

[FEND-40.02.07.00-00266-00 / AT]
The polarization efficiency of the tertiary optics system shall exceed 99,5 % for the Band 7 Cartridge. This requirement simultaneously applies to both orthogonally polarized beams of a cartridge.

5.8.1.3. Focus efficiency

[FEND-40.02.07.00-00268-00 / AT]
The focus efficiency of the tertiary optics system shall exceed 98 % for the Band 7This requirement simultaneously applies to both orthogonally polarized beams of the cartridge.

5.8.2. Polarization requirements

5.8.2.1. "Polarization 0" channel Alignment Accuracy

[FEND-40.02.07.00-00280-00 / T]
Orientation of the major axis of the "Polarization 0" channel polarization ellipse shall be aligned to within 4 degrees of its nominal position as defined in section 4.4.2.

5.8.2.2. "Polarization 1" channel Alignment Accuracy

[FEND-40.02.07.00-00285-00 / T]
Orientation of the major axis of the "Polarization 1" channel polarization ellipse shall be orthogonal to within 4 degrees of the "Polarization 0" nominal position as defined in section 4.4.2.

5.8.2.3. Cross Talk between Orthogonal Polarization Channels

[FEND-40.02.07.00-00290-00 / T]
The, uncorrected, cross talk between orthogonal receiver channels, RF and IF, inside the Band 7 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.

5.8.2.4. Beam Squint

[FEND-40.02.07.00-00295-00 / AT]
The co-alignment, on sky, between the beams of the orthogonal polarization channels of the Band 7 Cartridge shall be less than 1/10 of the Full Width at Half Maximum (FWHM) of the primary beam.

5.9. Stabilisation time

5.9.1. Stabilisation time from non-operational mode

[FEND-40.02.07.00-00300-00 / T]
Starting from the non-operational mode, the front end shall reach the operational mode (meet all applicable specifications) within 15 minutes.

5.9.2. Stabilisation time from stand-by mode

[FEND-40.02.07.00-00305-01 / T]
From the stand-by mode, the operational mode shall be reached within 1 second.

6. MECHANICAL AND ELECTRICAL REQUIREMENTS

6.1. Mass

[FEND-40.02.07.00-00310-01 / T]
The cartridge, including all components as presented in figure 1 of this document, but not including the cartridge mechanical structure (cartridge body, Prod. ID 40.02.07.07) itself, shall not exceed a mass of 2.4 kg. Details can be found in the applicable Interface Control Document [AD2].

6.2. Eigen-Frequency

[FEND-40.02.07.00-00320-00 / A]
The cartridge, including all components as presented in figure 1 of this document, shall have a first eigenfrequency of 70 Hz or higher.

6.3. Volume

[FEND-40.02.07.00-00330-00 / I]
All Band 7 Cartridge components, with the exception of the warm IF amplifiers, as presented in figure 1 of this document shall remain within a volume of ∅169 mm x 455 mm, measured from the cartridge mounting flange. Details can be found in the applicable Interface Control Document [AD2].

6.4. Orientation

[FEND-40.02.07.00-00340-00 / T]
The cartridge shall meet all performance requirements over a range of gravity vectors from 0 to 90 degrees. This rotation occurs about the antenna elevation-bearing axis.

6.5. Thermal Load

[FEND-40.02.07.00-00350-00 / A]
The maximum thermal load presented 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	40 mW	45 mW
15 K Stage	115 mW	15 mW	130 mW
110 K Stage	700 mW	150 mW	850 mW

This requirements follows from [AD2].

6.6. Bias requirements

[FEND-40.02.07.00-00360-00 / 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-40.02.07.00-00370-00 / R]

The RF input port of the cartridge shall comply with the requirement as described in section 5.7 of [AD9].

6.7.2. LO input port interface

[FEND-40.02.07.00-00380-00 / R, I]
The mixer LO input port shall comply with the applicable Interface Control Document [AD5].

6.7.3. IF output port interface

[FEND-40.02.07.00-00390-00 / R, I]
All IF output ports shall be equipped with connectors as described in the applicable Interface Control Document [AD4].

6.7.4. Bias connectors

[FEND-40.02.07.00-00400-00 / R, I]
Details for the bias connector (s) can be found in the applicable Interface Control Document [AD3].

7. OPERATING REQUIREMENTS

7.1. Local Oscillator

7.1.1. LO input port

[FEND-40.02.07.00-00420-00 / T]
The LO frequency signal range is 283 GHz to 365 GHz.

7.1.2. LO power requirement

[FEND-40.02.07.00-00430-00 / T]
The Band 7 Cartridge shall meet its performance requirements when supplied with an available local oscillator signal as specified in [AD5].
This subsection does not apply for the non-operational mode.

7.1.3. LO sideband noise

[FEND-40.02.07.00-00440-00 / T]
Sideband noise refers to noise accompanying the LO at frequency offsets within the IF band of the mixer in the normal operating RF frequency range. The Band 7 Cartridge shall meet its performance requirements when supplied with a local oscillator with sideband noise not exceeding 10 K/μW.
This subsection does not apply for the stand-by and non-operational modes.

7.1.4. LO amplitude stability[2]

[FEND-40.02.07.00-00450-00 / T]
The Band 7 cartridge shall meet its performance requirements when supplied with a local oscillator with amplitude stability as described in the ICD between the Band 7 Cartridge and the first LO [AD5]: The Allan variance, $\sigma^2(T)$, of the Band 7 first local oscillator output power shall be less than 9.0×10^{-8} for $0.05\ s \leq T \leq 100\ s$ and less than 1.0×10^{-6} for $T = 300\ s$.
This subsection does not apply for the stand-by and non-operational modes.

7.2. Thermal Environment

[FEND-40.02.07.00-00460-00 / T]
The cartridge shall meet its performance requirements in a thermal environment which presents temperature variations, measured at the cartridge side of the thermal interface clamp 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	80 K – 130 K	100mK (peak to peak)

The operating cartridge shall withstand an increase of temperature to ambient temperature of 20° C without damage to the equipment.
This subsection does not apply for the transport modes and for the storage mode.

7.3. Vacuum conditions

[FEND-40.02.07.00-00470-00 / R]
All Specifications shall be met in a vacuum environment.
The out gassing of the cartridge components shall be compatible with the ALMA cryostat specifications as stated in [AD2] and [AD8].
This subsection does not apply for the transport modes and for the storage mode.

7.4. Environmental operating conditions

7.4.1. Vibration

[FEND-40.02.07.00-00480-00 / R, T]
The Band 7 Cartridge shall survive vibration levels as specified in Appendix 1 of [AD7].

7.4.2. Acceleration

[FEND-40.02.07.00-00490-01 / R, T]
The Band 7 Cartridge shall comply with the following survival specification:

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

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

7.5. Storage conditions

[FEND-40.02.07.00-00500-00 / R]
The Band 7 Cartridge shall comply with [AD7]. This section applies only to the storage mode.

7.6. Electro-Magnetic Compatibility

[FEND-40.02.07.00-00510-00 / T]
The Band 7 Cartridge shall comply with [AD6].

7.7. Monitoring and control

This section does not apply to the storage mode.

7.7.1. Mixer voltage and currents

[FEND-40.02.07.00-00520-00 / R]
Mixer voltage and currents shall be monitored as stated in [AD3].

7.7.2. Magnet currents

[FEND-40.02.07.00-00530-00 / R]
Magnet currents shall be monitored as stated in [AD3].

7.7.3. Temperature

[FEND-40.02.07.00-00540-00 / R]
Temperature sensors shall be provided at critical points of all temperature stages as stated in [AD3].

7.7.4. Removal of trapped flux

[FEND-40.02.07.00-00550-00 / R]
Means shall be provided to remove trapped flux in the SIS junctions.

8. RAMS REQUIREMENTS

8.1. Continuous operation

[FEND-40.02.07.00-00560-00 / R]
The cartridge shall be designed for continuous use. It shall not require any periodic maintenance.

8.2. MTBF

[FEND-40.02.07.00-00570-00 / A]
The MTBF of the cartridge shall exceed 20 years.

8.3. Lifetime

[FEND-40.02.07.00-00580-00 / R]
The Band 7 Cartridge shall have the same minimum lifetime as the front end sub-system, this being 15 years.