



Atacama Large Millimeter Array

Band 2+3 Receiver Technical Specifications

FEND-40.02.02.00-0048-A-SPE

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Table 1: Change Record				
Version	Date	Affected Section(s)	Change request #	Reason/remarks
A-01	2017-09-29	All	-	New document
A-02	2017-10-25		-	Few links to AD section documents fixed


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1 INTRODUCTION

1.1 Purpose


This document provides technical specifications and requirements for the ALMA Band 2+3 receiver. The receiver consists of the Cold Cartridge Assembly (CCA), Warm Cartridge Assembly (WCA), and auxiliary equipment. The noun “Band 2+3” denotes that the receiver covers simultaneously the nominal Band 2 and Band 3 frequency ranges.

1.2 Scope


The information given in this document provides a complete summary of all specifications and requirements to be met by the ALMA Band 2+3 receivers. Interface control documents are included on the Applicable Documents list and so are effectively included in these requirements.

Table 2 is the ALMA product tree at the “unit” and “item” level for the Band 2+3 receiver and its components. Band 2 product entries are used as the Band 2+3 receiver components will be installed in the “Band 2” designated locations.

Table 2: Product Tree for Band 2+3 Receiver		
Product Tree Level 3 No.	Product Tree Level 4 No.	Subassembly
40.01.02		Band 2 common optics
	40.01.02.00	General
	40.01.02.01	Warm optics/lens (if applicable)
40.02.02		Frequency band 2+3 cartridge
	40.02.02.00	General
	40.02.02.01	Cold optics (if applicable)
	40.02.02.02	Feedhorn
	40.02.02.03	Ortho mode transducer
	40.02.02.04	Cryogenic low noise amplifier
	40.02.02.05	Waveguides
	40.02.02.06	Thermal straps
	40.02.02.07	Band 2+3 support structure
	40.02.02.08	Band 2+3 protection board
	40.02.02.09	Band 2+3 cartridge wiring
	40.02.02.10	Band 2+3 cartridge electrical feedthroughs
	40.02.02.11	Band 2+3 temperature sensors
40.03.01		Dewar
	40.03.01.04	Windows & IR filters

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40.10.02		Band 2+3 First Local Oscillator
	40.10.02.00	General
	40.10.02.01	YIG Tuned Oscillator
	40.10.02.02	Active Multiplier Chain
	40.10.02.03	PLL Box
	40.10.02.04	LO Controller
	40.10.02.05	Heat Sinks
	40.10.02.06	Waveguides
	40.10.02.07	Cables and Connectors
	40.10.02.08	Directional coupler and mixer for PLL
40.11.02		Band 2+3 Warm Cartridge Assembly
	40.11.02.00	General
	40.11.02.01	Support structure (frame)
	40.11.02.02	Main wiring harness
	40.11.02.03	Room temperature RF amplifier
	40.11.02.04	Downconverter (DSB mixers, LO splitter, RF and IF hybrids)
	40.11.02.05	IF amplifiers
	40.11.02.06	Waveguides
	40.11.02.07	Cables and connectors


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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.

Table 3: Applicable Documents		
Reference	Document title	Document ID
[AD 1]	ICD: Front-end assembly monitor and control – First local oscillator	FEND-40.04.03.03-007-A-DSN
[AD 2]	ICD Band 2+3 cartridge – Dewar	FEND-40.02.02.00-40.03.02.00-B-ICD
[AD 3]	ICD Band 2+3 cartridge – FE bias module	FEND-40.02.02.00-40.04.02.00-B-ICD
[AD 4]	ICD Band 2+3 cartridge – IF switch sub-system	FEND-40.11.02.00-40.08.02.00-B-ICD
[AD 5]	ICD between WCA Connector Plate and FE WCA Harness Plate (From Band 1 Project)	FEND-40.11.00.00-40.04.00.00-A-ICD
[AD 6]	ICD Band 2+3 CCA – Band 2+3 WCA (placeholder)	FEND-40.02.02.00-40.11.02.00-B-ICD
[AD 7]	ICD FE 1 st LO And BE LO References	ALMA-40.10.00.00-56.00.00.00-E-ICD
[AD 8]	ALMA System: Electromagnetic Compatibility Requirements	ALMA-80.05.01.00-001-B-SPE
[AD 9]	ALMA Environmental Specification	ALMA-80.05.02.00-001-B-SPE
[AD 10]	Vacuum requirements for receiver components inside the ALMA Front End cryostat	ALMA-40.03.00.00-015-A-SPE
[AD 11]	ICD Antenna to Front End	ALMA-34.00.00.00-40.00.00.00-E-ICD
[AD 12]	Front End Subsystem for the 12 m Antenna Array – Technical Specifications	ALMA-40.00.00.00.001-A-SPE

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

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1.4 Reference documents


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

Table 4: Reference Documents		
Ref.	Document title	Document ID
[RD 1]	ALMA Band 2+3 Cartridge Statement of Work	TBD
[RD 2]	Band 2+3 Receiver PDR Design and Test Report	FEND-40.02.02.00-0049-A-DSN
[RD 3]	ALMA Product Tree	ALMA-80.03.00.00-001-R-LIS
[RD 4]	Front End Optics Design Report	FEND-40.02.00.00-035-B-REP
[RD 5]	ALMA Acronyms and Abbreviations	ALMA-80.02.00.00-004-R-LIS

1.1. Acronyms

A limited set of basic acronyms used in this document is given below. A complete set of acronyms used in the ALMA project can be found in [RD 5].

ALMA	<u>A</u> tacama <u>L</u> arge <u>M</u> illimeter <u>A</u> rray
AMC	<u>A</u> ctive <u>M</u> ultiplier <u>C</u> hain
FE	<u>F</u> ront <u>E</u> nd
ICD	<u>I</u> nterface <u>C</u> ontrol <u>D</u> ocument
LO	<u>L</u> ocal <u>O</u> scillator
LSB	<u>L</u> ower <u>S</u> ide- <u>B</u> and
MTBF	<u>M</u> ean <u>T</u> ime <u>B</u> etween <u>F</u> ailures
PDR	<u>P</u> reliminary <u>D</u> esign <u>R</u> eview
PLL	<u>P</u> hase <u>L</u> ock <u>L</u> oop
RF	<u>R</u> adio <u>F</u> requency
RMS	<u>R</u> oot <u>M</u> ean <u>S</u> quare
USB	<u>U</u> pper <u>S</u> ide- <u>B</u> and
2SB	<u>D</u> ual <u>S</u> ide <u>B</u> and separating

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1.5 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.

1.6 Requirements numbering

The requirements are numbered according to the following code:

[FEND-40.AA.02.00-XXXXX-YY / Z]

where:

FEND-40.AA.02.00 identifies the Band 2+3 receiver subassemblies as in [Table 2](#) and [\[RD 3\]](#):

Some general requirements apply to more than one subassembly (**AA**), in this case multiple requirements are listed, according to subassemblies product tree numbering;

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 methods:


T - test,

I - inspection,

R - review of design, and

A - analysis.

Multiple verification methods are permitted.

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2 DESCRIPTION

2.1 Equipment Definition

The Band 2+3 cartridge is one of the ten receiver cartridges that populate ALMA Front-End cryostat. It receives radiation in the 67-116 GHz frequency range in two orthogonal polarizations and down-converts the signals to intermediate frequencies between 4 and 12 GHz. All vacuum and cryogenic services are provided by the Front-End cryostat.

The Band 2+3 architecture is similar to Band 1 and deviates from that of ALMA Bands 3 through 10 receivers. The cold cartridge assembly (CCA) hosts the receiver optics and the first stage Cryogenic Low Noise Amplifiers (CLNA), whereas the warm cartridge assembly (WCA) provides not only the local oscillator power, but also houses the room temperature receiver electronics for Band 2+3, including the dual polarization 2SB downconverters.

The Band 2+3 receiver consists of the following major subassemblies, shown in the block diagram in [RD 2]:

1. Warm optics (lens) and IR filter(s), which are implemented as part of the cryostat assembly for this band.
2. Cold cartridge assembly, which includes the cartridge body, the feedhorn, OMT, CLNAs, wiring harnesses and temperature sensors, RF output waveguide, the bias protection board, and the bias supply.
3. LO, which includes the YIG oscillator, the AMC module, the digital PLL assembly and the monitor and control electronics (MCDPLL).
4. Down converter, which includes the warm IF amplifiers, passband filters (TBC), 2SB mixers, warm IF amplifiers, and the warm cartridge assembly body.

3 GENERAL REQUIREMENTS

3.1 Operation modes

The Band 2+3 receiver will be used in the following modes.

3.1.1 Operational

[FEND-40.02.02.00-00010-00 / I], [FEND-40.10.02.00-00010-00 / I], [FEND-40.11.02.00-00010-00 / 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 2+3 receiver) 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-40.02.02.00-00020-00 / I], [FEND-40.10.02.00-00020-00 / I], [FEND-40.11.02.00-00020-00 / 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 2+3 receiver 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-40.02.02.00-00025-00 / I], [FEND-40.10.02.00-00025-00 / I], [FEND-40.11.02.00-00025-00 / I]

In this mode operational power, including any bias voltages, are applied to the Band 2+3 receiver (see section [3.1.1](#), “Operational Mode”), but the RF and IF signals may not be at their nominal values. The Band 2+3 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.

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3.1.4 Transport with Antenna Transporter

[FEND-40.02.02.00-00030-00 / I], [FEND-40.10.02.00-00030-00 / I], [FEND-40.11.02.00-00030-00 / I]

This mode applies when the Band 2+3 receiver, integrated into the Front-End sub-system, is transported with the antenna on the antenna transport vehicle. In this mode, the specifications and requirements, with the exception of section [5](#), apply unless otherwise noted.

3.1.5 Transport with Front-End Service Vehicle

[FEND-40.02.02.00-00040-00 / I], [FEND-40.10.02.00-00040-00 / I], [FEND-40.11.02.00-00040-00 / I]

This mode applies when the Band 2+3 receiver, 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 [AD 9].

3.1.6 Storage

[FEND-40.02.02.00-00045-00 / I], [FEND-40.10.02.00-00045-00 / I], [FEND-40.11.02.00-00045-00 / I]

In this mode, the Band 2+3 receiver cartridges are 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. Suitable containers shall be used for the storage of the Band 2+3 receiver cartridges.

3.2 Compatibility with the ALMA Front-End sub-system

[FEND-40.02.02.00-00050-00 / I], [FEND-40.10.02.00-00050-00 / I], [FEND-40.11.02.00-00050-00 / I]

The Band 2+3 receiver design shall be compatible with other parts of the ALMA Front End sub-system. Additional details are given in the applicable ICDs listed in section [1.3](#).

3.3 Design for production

3.3.1 Technology

[FEND-40.02.02.00-00060-00 / R], [FEND-40.10.02.00-00060-00 / R], [FEND-40.11.02.00-00060-00 / R]

The Band 2+3 receiver design shall use mature technologies whenever possible.

3.3.2 Series Production

[FEND-40.02.02.00-00070-00 / R], [FEND-40.10.02.00-00070-00 / R], [FEND-40.11.02.00-00070-00 / R]

The Band 2+3 receiver 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-40.02.02.00-00080-00 / R], [FEND-40.10.02.00-00080-00 / R], [FEND-40.11.02.00-00080-00 / R]

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


3.4 Mechanical tuning

[FEND-40.02.02.00-00090-00 / R], [FEND-40.10.02.00-00090-00 / R], [FEND-40.11.02.00-00090-00 / R]

Operation of the Band 2+3 receiver shall not require the use of any mechanical tuners.

3.5 Metric dimensioning

[FEND-40.02.02.00-00100-00 / R], [FEND-40.10.02.00-00100-00 / R], [FEND-40.11.02.00-00100-00 / R]

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In general, metric dimensioning shall be used in the Band 2+3 receiver. This includes items such as fasteners and tapped holes. However, internal details of components may use imperial dimensioning and fasteners. Standard wave-guide flanges (using imperial dimensions) shall be used.

3.6 Monitor and control

It shall be possible to control and monitor the following functions of the Band 2+3 CCA and WCA via the front-end local oscillator monitor and control system.

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

3.6.1 CCA remotely controlled functions

3.6.1.1 CLNA Voltages and Currents

[FEND-40.02.02.00-00110-00 / R]

The cold LNA voltages and currents must be controlled as stated in [AD 3].

3.6.2 CCA operating parameters to be monitored

3.6.2.1 CLNA Voltages and Currents

[FEND-40.02.02.00-00115-00 / R]

The cold LNA voltages and currents must be monitored as stated in [AD 3].

3.6.2.2 Temperature

[FEND-40.02.02.00-00120-00 / R]

Temperature sensors must be provided at critical points of all temperature stages of CCA as stated in [AD 3].

3.6.3 WCA remotely controlled functions

3.6.4 Set frequency

[FEND-40.10.02.00-00110-00 / T]

This control shall be executed via digital control bits to set the coarse tune coil on the YTO. See [AD 1].

3.6.4.1 Sweep to acquire lock

[FEND-40.10.02.00-00120-00 / T]

This shall be a software function based on other remotely executable functions as described in [AD 1].

3.6.4.2 Zero integrator


[FEND-40.10.02.00-00134-00 / T]

This control shall be executed via digital control bit to open the loop and dump/zero the loop filter. See [AD 1]. This is only applicable to the LO drivers incorporating the “digital” PLL circuitry as well as the integrated M&C and “digital” PLL circuitry.

3.6.4.3 Set power level

[FEND-40.10.02.00-00140-00 / T]

This output power level shall be adjusted by programming the driver amplifier drain bias voltages in the power amplifier sub-assembly. See [AD 1].

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3.6.5 WCA Operating parameters to be monitored

3.6.5.1 PLL IF power

[FEND-40.10.02.00-00150-00 / T]

This shall be derived from the output voltage level of the IF total power detector. The detected voltage, suitably amplified and buffered, shall be available to the front-end first local oscillator monitor and control system as an analog monitor point. See [AD 1]. This monitored value will be used in conjunction with the quadrature phase detector voltage to assess whether the PLL is locked to the reference signals.

3.6.5.2 PLL reference signal power

[FEND-40.10.02.00-00160-00 / T]

This shall be derived from the output voltage level of the FLOOG total power detector. The detected voltage, suitably amplified and buffered, shall be available to the front-end first local oscillator monitor and control system as an analog monitor point. See [AD 1].

3.6.5.3 PLL temperature

[FEND-40.10.02.00-00180-00 / T]

The buffered sensor voltage shall be monitored as an analog monitor point. See [AD 1].

3.6.5.4 PLL correction voltage

[FEND-40.10.02.00-00230-00 / T]

This voltage shall be monitored as an analog monitor point. See [AD 1].

3.6.5.5 LO power level

[FEND-40.10.02.00-00270-00 / T]

The driver power amplifier drain voltage shall be monitored as an analog monitor point. See [AD 1].

4 FUNCTIONAL REQUIREMENTS

4.1 Mixer type

[FEND-40.11.02.00-00120-00 / R]

The Band 2+3 receiver shall employ any suitable mixers as the frequency-translating devices.

4.2 Mixing scheme

[FEND-40.11.02.00-00130-00 / 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)

4.3.1 RF input port

[FEND-40.02.02.00-00140-00 / R]

The nominal RF input frequency range shall be from 67 GHz to 116 GHz. Unless otherwise already specified, the following requirements shall be valid for this nominal RF band.

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4.3.2 LO frequency range

[FEND-40.10.02.00-00280-00 / R]

The LO frequency tuning range shall be from 79 GHz to 104 GHz.

4.3.3 IF output ports

[FEND-40.11.02.00-00160-00 / R]

Each polarization shall provide 16 GHz of IF bandwidth. Furthermore, each 16 GHz of bandwidth shall be evenly split into upper and lower sidebands and these IF outputs shall be centered at 8 GHz.

4.4 Polarization States

[FEND-40.02.02.00-00170-00 / R], [FEND-40.11.02.00-00170-00 / R]

The nominal polarization states shall be linear. The receiver shall separate two orthogonal polarizations, designated “polarization 0” and “polarization 1”, with each polarization available as a separate IF output as described in section [4.2](#).

5 PERFORMANCE REQUIREMENTS

Unless otherwise specified, all RF requirements for the Band 2+3 receiver are referenced to the atmospheric side of the vacuum window and consequently include contributions from the Dewar window and IR filters.

5.1 Receiver Noise Temperature

[FEND-40.02.02.00-00180-00 / T], [FEND-40.11.02.00-00180-00 / T]

The noise temperature requirements for the Band 2+3 receiver are based on the concatenation of Band 2 and Band 3 requirements and thus given in two RF frequency ranges, 67-90 GHz (original Band 2 RF range) and 90-116 GHz (original Band 3 RF range less the overlap with Band 2).

The receiver noise temperature shall not exceed the value of T_{SSB} as follows:

67-90 GHz RF frequency range:


- $\leq 30K$ over 80% of the frequency range
- $\leq 47K$ at any frequency within this RF range

90-116 GHz RF frequency range:

- $\leq 39K$ averaged over RF range 108-112 GHz
- $\leq 43K$ over 100% of the RF range

Remarks:

- An approved measurement test plan shall define the precise RF and IF frequencies at which noise performance shall be measured to verify compliance.
- The required noise temperatures shall be met when averaged over each 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.

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- The noise performance shall be measured for an operating temperature of 15 ± 0.25 K, measured at the 15K stage of the cryostat.

5.2 Image band suppression and sideband mismatch

[FEND-40.10.02.00-00290-00 / T], [FEND-40.11.02.00-00290-00 / T]

The image-band suppression shall be:

- ≥ 10 dB for 90% of the IF band (defined in section [4.3.3](#)) for any RF frequency within the nominal RF range (defined in section [4.3.1](#))
- ≥ 7 dB for the entire IF band (defined in Section [4.3.3](#)) for any RF frequency within the nominal RF range (defined in section [4.3.1](#))

5.3 Spurious Response

[FEND-40.02.02.00-00195-00 / T], [FEND-40.10.02.00-00195-00 / T], [FEND-40.11.02.00-00195-00 / T]

At any LO frequency (within the specified range of a band) the IF power due to incoherent spurious signals, generated by Band 2+3 receiver 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 Receiver IF power

5.4.1 IF Output Power

[FEND-40.02.02.00-00300-00 / T], [FEND-40.10.02.00-00300-00 / T], [FEND-40.11.02.00-00300-00 / T]

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

1. The total power in the IF frequency range (specified in section [4.3.3](#)) shall fall between -22 dBm to -32 dBm.
2. The total power in the frequency range from 10 MHz to 18 GHz shall be no more than 3 dB higher than the measured maximum in-band IF power as described in step 1) above.

These specifications follow from the requirements in [AD 4].

5.4.2 IF power variations

[FEND-40.02.02.00-00310-00 / T], [FEND-40.10.02.00-00310-00 / T], [FEND-40.11.02.00-00310-00 / T]

Within the IF band (as specified in section [4.3.3](#)), 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 IF output power variation shall not exceed 4.0 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 ≤ 3 MHz resolution.

These specifications follow from the requirements in [AD 4].

5.5 Gain compression

[FEND-40.02.02.00-00330-00 / T], [FEND-40.10.02.00-00330-00 / T], [FEND-40.11.02.00-00330-00 / T]

The large signal gain compression difference shall be less than 5 % when a 77 K load at the RF input port is replaced at the same RF input port by a 373 K load.

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5.6 Amplitude stability

[FEND-40.02.02.00-00340-00 / T], [FEND-40.10.02.00-00340-00 / T], [FEND-40.11.02.00-00340-00 / T]

The Band 2+3 receiver IF amplitude stability, measured at the IF output connectors, 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 [4.3.3](#) and [5.4.1](#)) shall be less than 4.0×10^{-7} for timescales in the range of $0.05 \text{ s} \leq T \leq 100 \text{ s}$ and 3.0×10^{-6} at 300 seconds. This corresponds to an Allan deviation of 6.3×10^{-4} and 1.7×10^{-3} respectively.

5.7 Signal path phase stability

[FEND-40.02.02.00-00350-00 / T], [FEND-40.10.02.00-00350-00 / T], [FEND-40.11.02.00-00350-00 / T]

For all frequencies within the IF passband the signal path transfer function shall maintain a phase stability:

Long term (delay drift) $\leq 22 \text{ fs}$ for $20 \text{ s} \leq T \leq 300 \text{ s}$

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 receiver.

5.8 IF Phase Variations

[FEND-40.02.02.00-00355-00 / T], [FEND-40.10.02.00-00355-00 / T], [FEND-40.11.02.00-00355-00 / T]

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 rms.

5.9 Optics

All optical performances are specified and to be verified along nominal orientations of polarization channels, as defined in sections [5.9.2.1](#). Beam patterns, including cross-polarization, 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-40.02.02.00-00360-00 / T]

The aperture efficiency factor due to the optics of the Band 2+3 receiver shall exceed 80%. This efficiency does not include any contribution related to the antenna, such as surface errors, blockage, and defocusing of antenna focal point relative to FE feed phase center.

The contribution to the aperture efficiency with 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 and
 - the field across the secondary reflector not being in phase everywhere;

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- 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_p : 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:

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

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 receiver. Individual requirements are defined for the following efficiency contributions:

5.9.1.2 Polarization efficiency

[FEND-40.02.02.00-00366-00 / T]

The polarization efficiency of the Band 2+3 optics shall exceed 99.5 %.

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

5.9.1.3 Focus Efficiency

[FEND-40.02.02.00-00368-00 / T]

The focus efficiency of the tertiary optics shall exceed 98% for Band 2+3 cartridge. This requirement simultaneously applies to both orthogonally polarized beams of a receiver.

5.9.1.4 Pointing Offset

[FEND-40.02.02.00-00269-00 / T]

The optical and mechanical design of the Band 2+3 cold cartridge shall provide the angular alignment of the optical beam to be within 3.5 mrad of the nominal direction towards the center of the subreflector, referenced to the cold cartridge 300K mounting plate. Verification of this requirement shall 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 into account measurement uncertainties, the measured angular alignment of the optical beam should be within 5.0 mrad of the nominal direction. Verification of this requirement shall be performed on each article by Test (T).

5.9.2 Polarization Requirements

5.9.2.1 Polarization Alignment

[FEND-40.02.02.00-00370-00 / 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-40.02.02.00-00390-00 / T], [FEND-40.11.02.00-00390-00 / T]

The, uncorrected cross talk between orthogonal receiver channels, RF and IF, inside the Band 2+3 receiver shall be less than -63 dB. The receiver channel is defined as the signal path starting at the RF waveguide input of the cold LNA and ending at the IF output.

5.9.2.3 Beam Squint

[FEND-40.02.02.00-00395-00 / T]

The co-alignment on the sky between the beams of the orthogonal polarization channels of the Band 2+3 receiver 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-40.02.02.00-00300-00 / T], [FEND-40.10.02.00-00300-00 / T], [FEND-40.11.02.00-00300-00 / T]

Starting from the non-operational mode, the Band 2+3 receiver shall reach the operational mode (i.e. meet all applicable specifications) within 15 minutes.

5.10.2 Stabilization time from stand-by mode

[FEND-40.02.02.00-00405-00 / T], [FEND-40.10.02.00-00405-00 / T], [FEND-40.11.02.00-00405-00 / T]

The transition from the stand-by mode to the operational mode shall take no more than 1.5 second.

5.11 LO spurious signals

[FEND-40.10.02.00-00410-00 / R, T]

Spurious Signals (coherent or incoherent) on the outputs of the LO in the WCAs shall be < -40 dBc over the range of offset frequencies from the carrier from 500 Hz to 500 kHz and < -50 dBc from 500 kHz to 12 GHz. The components harmonically related to the YTO frequency shall not exceed -20 dBc.

5.12 Phase locking

[FEND-40.10.02.00-00420-00 / T]

The Band 2+3 WCA shall reliably phase lock within 1 second to the first local oscillator reference signal over the tuning range as specified in section 4.3.2, and without phase ambiguity in any of the LO outputs.

5.13 Time to phase-switch

[FEND-40.10.02.00-00430-00 / R, T]

The Band 2+3 first local oscillator hardware shall be designed so that it could be configured to phase-switch (90° or 180°) and reach within 60° of the final phase in 1 μs.

5.14 Time for frequency-switching


[FEND-40.10.02.00-00440-00 / R, T]

The Band 2+3 WCA hardware shall be designed so that it could be configured to track frequency changes resulting from a frequency change of the FLOOG signal or the reference laser signals of 25 MHz within 10 ms.

5.15 Isolation between channels

[FEND-40.10.02.00-00450-00 / A, T]

The isolation between the two channels of the Band 2+3 WCA shall be better than 45 dB (with a goal of better than 50 dB) in the LO frequency range, as specified in section 4.3.2.

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6 MECHANICAL AND ELECTRICAL REQUIREMENTS

6.1 Mass

[FEND-40.02.02.00-00460-00 / T]

The mass of all Band 2+3 CCA components (but excluding the cartridge body itself and the warm cartridge assembly) must not exceed 2.0 kg. Details can be found in the applicable Interface Control Document [AD 2].

[FEND-40.10.02.00-00460-00 / T], [FEND-40.11.02.00-00460-00 / T],

The mass of all Band 2+3 WCA components and their support structure shall not exceed 5 kg. The LO component assembly's contribution to this specification shall not exceed 2.4 kg. Details can be found in the applicable Interface Control Document [AD 6].

6.2 Eigen-frequency

[FEND-40.02.02.00-00470-00 / A,R]

The Band 2+3 CCA shall have a first eigen-frequency of 70 Hz or greater.

[FEND-40.10.02.00-00470-00 / A,R], [FEND-40.11.02.00-00470-00 / A,R]

The Band 2+3 WCA shall have a first eigen-frequency of 30 Hz or greater.

6.3 Volume

[FEND-40.02.02.00-00480-00 / I]

The Band 2+3 CCA components shall be contained within the volume as defined in the applicable Interface Control Document [AD 2].

[FEND-40.11.02.00-00480-00 / I]

The Band 2+3 WCA components shall be contained within a volume as defined in the applicable Interface Control Document [AD 2].

6.4 Orientation

[FEND-40.02.02.00-00490-00 / A,R,T], [FEND-40.10.02.00-00490-00 / A,R,T], [FEND-40.11.02.00-00490-00 / A,R,T]

The Band 2+3 receiver 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.

6.5 Thermal Load


[FEND-40.02.02.00-00500-00 / A]

During operation or start-up, the maximum allowable thermal load to be imposed on the cryostat by the Band 2+3 cold cartridge, during operation or stand-by shall conform to the thermal loading shown in [Table 5](#)

[FEND-40.10.02.00-00500-00 / A], [FEND-40.11.02.00-00500-00 / A]

During operation the maximum allowable thermal load to be imposed on the cryostat by the Band 2+3 WCA shall not exceed 15W.

These specifications follow from the requirements in [AD 2].

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6.6 First local oscillator reference signal requirements

[FEND-40.10.02.00-00510-00 / R]

Details can be found in the applicable Interface Control Document [AD 7].

6.7 Bias requirements

[FEND-40.02.02.00-00520-00 / R]

Bias requirements for the cold cartridge assembly are defined in the applicable Interface Control Document [AD 3].

[FEND-40.10.02.00-00520-00 / R], [FEND-40.11.02.00-00520-00 / R]

Bias requirements for the Band 2+3 receiver, including CCA and WCA with LO and downconverter, are defined in the applicable Interface Control Document [AD 5].

6.8 Connectors and RF ports

6.8.1 RF Input port interface

[FEND-40.02.02.00-00530-00 / R]

The RF input port of the receiver shall comply with the requirements as described in Section 5.7 of [AD 11].

6.8.2 LO port interface

[FEND-40.10.02.00-00530-00 / R, I], [FEND-40.11.02.00-00530-00 / R, I]

The LO port interface should be standard WR-10 connector.

6.8.3 IF Output port interface

[FEND-40.11.02.00-00540-00 / R, I]

All IF output ports shall be coaxial, details can be found in the applicable Interface Control Document [AD 5].

6.8.4 First local oscillator offset generator input port

[FEND-40.10.02.00-00550-00 / R, I], [FEND-40.11.02.00-00550-00 / R, I]

Details can be found in the applicable Interface Control Document [AD 4].

6.8.5 DC Connectors

6.8.5.1 CCA bias connectors


[FEND-40.02.02.00-00560-00 / R, I]

Details for the CCA bias connector (s) can be found in the applicable Interface Control Document [AD 3].

6.8.5.2 WCA bias connectors

[FEND-40.11.02.00-00560-00 / R, I]

Details for the WCA bias connector (s) can be found in the applicable Interface Control Document [AD 5].

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7 OPERATING REQUIREMENTS

7.1 Thermal Environment

7.1.1 CCA thermal environment

[FEND-40.02.02.00-00565-00 / T]

The Band 2+3 receiver shall meet its performance requirements in a thermal environment of the cold cartridge which presents temperature variations, measured at the cold cartridge side of the thermal interface clamps as follows:

Table 5: Thermal Loading			
Cryostat Stage	Passive Heat Load	Active Heat Load	Total Heat Load
15 K Stage	95 mW	90 mW	185 mW
110 K Stage	450 mW	150 mW	600 mW

These specifications follow from the requirements in [AD 2].

An operating receiver 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.

7.1.2 WCA thermal environment

[FEND-40.10.02.00-00565-00 / A, R, T], [FEND-40.11.02.00-00565-00 / A, R, T],

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

The Band 2+3 WCA shall meet its performance requirements with an air flow of 15 l s⁻¹ or greater across the unit, in a thermal environment whose temperature is maintained in the 16 – 22 °C range and in which the maximum temperature variation is 1 °C in one hour.

7.2 Vacuum conditions

[FEND-40.02.02.00-00570-00 / 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 cold cartridge components or leaking of hermetic feed-throughs shall be compatible with the ALMA vacuum requirements for the cryostat, [AD 2] and [AD 10].

7.3 Environmental operating conditions


7.3.1 Vibration

[FEND-40.02.02.00-00580-00 / R, T], [FEND-40.10.02.00-00580-00 / R, T], [FEND-40.11.02.00-00580-00 / R, T]

The Band 2+3 receiver must survive vibration levels as specified in Appendix 1 of [AD 9]. The vertical direction being defined as perpendicular to the cartridges baseplates.

7.3.2 Acceleration

[FEND-40.02.02.00-00590-00 / R, T], [FEND-40.10.02.00-00590-00 / R, T], [FEND-40.11.02.00-00590-00 / R, T]

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The Band 2+3 cold and warm cartridges alone, with no shipping containers, must survive the following accelerations:

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

The vertical direction being defined as perpendicular to the cartridges baseplates.

7.4 Storage and shipping conditions

[FEND-40.02.02.00-00600-00 / R], [FEND-40.10.02.00-00600-00 / R], [FEND-40.11.02.00-00600-00 / R]

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

The Band 2+3 receiver must comply with [AD 9].

7.5 Electro-Magnetic Compatibility

[FEND-40.02.02.00-00610-00 / T], [FEND-40.10.02.00-00610-00 / T], [FEND-40.11.02.00-00610-00 / T]

The Band 2+3 receiver must comply with [AD 8].

8 RELIABILITY REQUIREMENTS

8.1 Continuous operation

[FEND-40.02.02.00-00660-00 / R], [FEND-40.10.02.00-00660-00 / R], [FEND-40.11.02.00-00660-00 / R]

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

8.2 Mean time to failure

[FEND-40.02.02.00-00670-00 / A], [FEND-40.10.02.00-00670-00 / A], [FEND-40.11.02.00-00670-00 / A]

The MTBF of each: cold cartridge, LO, and downconverter subsystems, shall exceed 20 years.

8.3 Lifetime

[FEND-40.02.02.00-00680-00 / R], [FEND-40.10.02.00-00680-00 / R], [FEND-40.11.02.00-00680-00 / R]

The Band 2+3 receiver shall have a minimum lifetime of 15 years.