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ALMA Receiver Subsystem Top-level Requirements and Specifications

- DRAFT 1.3 – 19 May 2000 W. Wild, J. Payne

1. Introduction

1.1 General

This document describes the top-level requirements and specifications for the ALMA receiver subsystem. It is based on the document *ALMA Receivers: Specifications adopted* (by U.S. Division Heads), written by L. D'Addario. We distinguish between top-level requirements and specifications as follows:

- **ALMA Receiver Subsystem Top-level Requirements**: these are the specifications which have immediate influence on the scientific capabilities of ALMA, such as frequency bands, IF b/w, noise temp, stability etc. The top-level requirements are of concern to the future scientific users of ALMA, and a change would affect the scientific goals of ALMA.
- **ALMA receiver egineering specifications**: they describe details of the receiver subsystem which have no direct influence on the scientific capabilities but are important engineering specs. Examples are IF interface specs (e.g. power level), breakdown of noise contributions, cool down time etc. A necessary change would not affect the scientific capabilities of ALMA. In any case, changes with an influence on interfaces will be discussed with and must be approved by the relevant groups.

1.2 Major changes

The major changes to earlier versions of the ALMA receiver subsystem specifications are:

- Receiver specific monitor/control system (including software) included in receiver subssystem, with a clear interface to the ALMA monitor and control bus
- LO components inside the cryostat included in the receiver subsystem
- 4 GHz IF bandwidth as a fall back position for the initial bands
- definition of some terms
- band 3 starts tentatively at 86 GHz (before 89 GHz)
- WVR operation not required with band 1

1.3 Definition of the receiver subsystem

The receiver subsystem accepts the focused beam from the antenna's secondary reflector over a selected band of frequencies. It amplifies and converts this band to an intermediate frequency band in several channels (typically differing in polarization and/or sideband), and delivers the IF signals as outputs. It accepts as inputs local oscillator signals at the appropriate frequencies and levels to accomplish the conversion. It includes:

- RF optics as required to couple the subreflector beam to its first electronic element,

- amplifiers and mixers of the RF-IF signal path (separately for each band required to cover the overall frequency range), including any components needed to couple the LO signal to each mixer,
- local oscillator components within the cryostat. The interface is the feedthrough into the cryostat, at a frequency around 100 GHz for the option II LO system,
- vacuum system and cryocoolers needed to achieve the appropriate operating temperatures for certain components, along with related thermal insulation and mechanical supports,
- bias and control circuits to support the RF-IF amplifiers and mixers,
- devices to select the desired frequency, including IF band switching and any required tuning or adjustment of amplifiers and mixers as a function of frequency,
- a computer monitor/control system (including software), allowing remote control of all functions and providing extensive remote diagnosis capability, with a clearly desined interface to the general ALMA moncitor and control bus,
- a water-vapor monitoring radiometer operating simultaneously with all frequency bands except band 1, and
- calibration devices that are built into or placed immediately in front of the receiver optics.

It does not include the following elements, which belong to other subsystems:

- any local oscillator components outside the cryostat,
- general power supplies (which are part of the common infrastructure), and
- calibration devices located outside the receiver cabin (including any built into the subreflector).

1.4 Definition of terms

- **Receiver**: this is the receiver subsystem as defined in 1.3 . It provides space for 10 cartridges.
- **Band**: this is the range of RF frequencies which is received in dual linear polarization and defined in Table 1.
- **Frequency channel**: this is one receiving chain which receives one polarization within the specified band. A band has two channels.
- **Cartridge**: a device insertable into the main dewar, receiving RF frequencies within one specified band in dual polarization, containing optics, mixers, IF amplifiers, LO components. Receives the RF from external optics, accepts an LO signal at TDB frequency and power, and delivers IF signals.
- **ICD:** Interface Control Document. The document which specifies interfaces between subsystems and parts within a subsystem.

2 Document references

2.1 Applicable documents

The following documents form part of this specification document to the extent specified herein. In the case of conflict between documents referenced herein and the contents of this specification, the contenct of the specification shall be considered a superseding requirement.

Antenna/Receiver ICD No. 1

Antenna/Receiver Cabin Equipment Rack ICD No. 10

2.2 Reference documents

Project Book
ALMA memos
Report of the ALMA Scientific Advisory Committee: March 2000 meeting

3 Receiver top-level requirements

3.1 Frequency coverage

The ALMA receiver subsystem will cover all the available atmospheric frequency windows between 30 GHz and 950 GHz. The range shall be covered in 10 bands with HFET or SIS devices as follows:

Table 1: Frequency bands for ALMA

Band	from (GHz)	to (GHz)	Input device type
1	31.3	45	HFET amplifier
2	67	90	HFET amplifier
3	86*	116	SIS or HFET (TBD)
4	125	163	SIS mixer
5	163	211	SIS mixer
6	211	275	SIS mixer
7	275	370	SIS mixer
8	385	500	SIS mixer
9	602	720	SIS mixer
10	787	950	SIS mixer

*extension of band 3 down to 86 GHz is being investigated

3.2 Polarization

3.2.1 Polarization states

Simultaneous reception of two orthogonal polarizations is required, with each converted to (one or more) separate IF output(s). The nominal polarization states may be selected separately for each band so as to minimize the receiver noise temperature; that is, either linear or circular is acceptable as the nominal polarization.

Detailed specifications on polarization performance are under study.

3.2.2 Maximum non-orthogonality

At any frequency within the receiver's tuning range, the polarization states of the two channels should conform to a maximum non-orthogonality of TBD (~ -20 to -25 dB), measured at the optical entrance to the receiver subsystem.

(Remark: This specification affects the accuracy with which total intensity (not polarization) can be measured when cross-polarized correlations are not computed, thus enabling the frequency resolution of the correlator to be doubled.)

3.2.3 Maximum polarization mismatch

The maximum polarization mismatch between any pair of antennas in the array shall not exceed TBD (~ -20 dB).

3.3 Optical coupling to the telescope

Under study, shall be maximized.

3.4 Receiver noise performance

The noise temperature measured at the dewar input window to the cartridge shall not exceed 10 hf/k for SSB response or 5 hf/k for DSB response at any one frequency within the band (with h and k being the usual physical constants).

[detailed break down of noise contributions within cartridge: TBD]
[how to measure the noise temperature: TBD]

3.5 Sidebands

Each frequency channel may be DSB, SSB or 2SB. An attempt shall be made to optimize the overall sensitivity for both spectral line and continuum observations. SSB and 2SB channels shall provide at least 10 dB image band suppression.

3.6 IF bandwidth

The ALMA IF system and correlator will be designed for an IF bandwidth of 8 GHz per polarization and two polarizations (i.e. a maximum of 16 GHz IF per antenna). Each frequency channel shall provide 8 GHz total IF bandwidth. In case this cannot be achieved for the initial bands within the project schedule constraints or with the required sensitivity, the IF bandwidth per polarization shall not be less than 4 GHz.

3.7 Simultaneous operation of bands

Astronomical observations will be done in only one frequency band at any one time (no dual frequency observations). The water-vapor monitoring radiometer shall operate simultaneously with bands 2 to 10, but not with band 1 which can ~~operate~~ without the water-vapor monitoring radiometer. In order to allow fast phase switching, band 3 shall be ready for operation at all times.

3.8 Receiver stability

Specifications on receiver phase stability and gain stability (including 1/f noise) are under study. These are in addition to, and independent of, stability specifications imposed on the LO and on the antenna structure. A preliminary suggestion for a gain fluctuation limit is:
1e-4 rms over a 1 sec interval. A complete specification should give the limit as a function of time interval over a wide range. Phase stability should generally be better than that required of the LO system.

3.9 Receiver calibration

Specifications on overall calibration are under study by several groups (U.S. Calibration & Imaging group, European Observational Concept & Calibration group, receiver WBS 4.8.1: Receiver calibration system,). The specifications for the receiver calibration accuracy (as part of the overall calibration requirements) need to be seen in the context of a system wide calibration concept and strategy. In any case, an effort shall be made to reach the best receiver calibration accuracy possible.

3.10 Water vapour radiometer

The receiver shall include a radiometer for measurement of water vapor along the signal path, using the 183 GHz line. This instrument shall operate simultaneously with the selected astronomy band (except band 1), illuminating the subreflector so as to produce a beam on the sky that is offset from that of an astronomy channel by no more than 10 arcmin. It must include all necessary LO sources and signal processing. Its outputs shall be digital total power measurements in each of [TBD] frequency channels at [TBD list of frequencies], along with calibration measurements that allow each to be reduced to an antenna temperature.

Specifications on water vapour radiometer sensitivity are under study.

3.11. Solar observing and safety

No components shall be damaged if the receiver input is illuminated by 0.3 W/cm^2 of solar optical and infrared radiation. Provisions shall be taken to allow observations of the sun.

4 Receiver engineering specifications

4.1 Selection of (pre-set) observing band

Selection and operation of a (pre-set) observing band shall be possible in less than 1.5 sec. This provides support for fast phase-switching. The reselection of a particular frequency band at a particular antenna shall result in pointing changes not to exceed 0.2" (repeatability of selection mechanisms), and phase changes not to exceed (TBD).

4.2 Narrow-band frequency switching

Changing between two frequencies within .03% of each other (30 MHz at 100 GHz, 285 MHz at 950 GHz) and in the same band shall require no more than 10 msec (goal of 1 msec). This provides support for narrow-band frequency switching.

4.3 Selection of new observing band

Selecting and tuning a new band shall require no more than 15 min. This allows for warmup of components and reaching thermal equilibrium. A shorter time is desirable.

4.4 Frequency changes within a band

Changing between frequencies more than .03% apart and in the same band shall not require more than (TBD) min/sec.

4.5 IF interface

The IF shall be delivered in the range from 4 to 12 GHz, at a nominal power spectral density of [TBD, tentatively -30] dBm/GHz when the antenna temperature at the receiver input is 290 K. There will be four such signals to support 2SB, dual-polarization receivers; SSB or DSB receivers will use only two of them. If the instantaneous bandwidth B of one IF channel is 4GHz<B<=8 GHz, the center frequency should be 8.0 GHz; if B=4.0 GHz, then the center frequency should be 6.0 or 10.0 GHz. More detailed specs will be part of an ICD.

[4.6 IF passband ripple: TDB]

[4.7 LO range and power

LO tuning range, min. output power vs frequency]

[4.8 LO interface

At the feed through to dewar at a frequency of (TBD) and a power level of (TBD)**]** On cartridge

4.9 Dewar size and mass

The maximum size and mass of the dewar as well as mechanical interfaces with the antenna are specified in ICD #1 Antenna/Rreceiver interface.

[4.10 Optics: beam quality, alignment tolerances etc: under study]

4.11 Cryocooling

- temp stages: 4, 12-15, and 70 K
- stability for each stage: 4K <2 mK in 1 min, 12-15 K under study,
  70 K <0.5 K in 1 min
- max thermal load for each stage: under study (by 1 June, JP)
- max thermal load for each cartridge: under study (by 1 June, JP)
- operational requirements:
  - # of bands switched on: max 3 + WVR
  - what mounted where:
    4K cartridge optics, SIS mixers, first IF amps
    12-15K second IF amps, HFETs (bands 1 and 2, possibly 3)
    70K LO multipliers or photomixer
  - dewar cooldown time: max 24 h. goal of 12 h]