# ACA Spectrometer
# Technical Specifications and Requirements

ALMA-64.00.00.00-0005-D-SPE

Version: D

2022-11-28

| **Prepared By:** | **Organization** | **Date** |
|---|---|---|
| ACA Spectrometer Team: | | |
| Jongsoo Kim | KASI | |
| Manabu Watanabe | NAOJ | Manabu Watanabe デジタル署名者 : Manabu Watanabe 日付 : 2022.11.28 19:57:28 +09'00' |
| **Approved By:** | **Organization** | **Date** |
| Takafumi Kojima (Development Program Manager) | NAOJ | |
| Seiichi Sakamoto (EA-IET Lead) | NAOJ | |
| (Observatory System Engineer) | JAO | |
| John Carpenter (Observatory Scientist) | JAO | |
| **Configuration Control Board Approval:** | **Organization** | **Date** |
| (CCB Secretary) | JAO | |
| **Released By:** | **Organization** | **Date** |
| Alvaro Gonzalez (ALMA-EA Operations Manager) | NAOJ | |

# Change Record

| Version | Date | Affected Section(s) | Change Request # | Reason/Initiation/Remarks |
|---|---|---|---|---|
| A | 2017-01-27 | All | Draft A | First draft |
| A1 | 2018-11-01 | All | | Comprehensively revised to accommodate RIDs from PDR reviewers |
| A2 | 2018-11-16 | All | | NDW: various changes, formatting & corrections |
| A3 | 2018-11-21 | All | | Update based on telecon on 20th / 21st . |
| A4 | 2018-11-26 | Tables 1-6<br>6.2<br>All<br>5.2.4 | | Put footnotes at Tables 1-6<br>Rewrite the synchronization requirement<br>Do cosmetic format changes or minor modifications<br>Change of sensitivity loss from 1% to 5% |
| A5 | 2019-02-22 | 5.2.4<br><br><br>Tables 1-6 | | Change the title of the subsection from “sensitivity loss” to “quantization loss” and quote 12% in [AD03] as the requirement of the maximum quantization loss.<br>All the footnotes related to the quantization loss are removed. |
| A6 | 2019-03-08 | 5.2.4 | | The subsection title is changed from “quantization loss” to “sensitivity loss.” The loss is reduced from 12% to 2.1%. The verification method is changed from R to A. |
| A | 2019-03-14 | Cover page | | Signature matrix edited |
| B | 2019-05-06 | | | Revision after release of version A |
| B1 | 2019-05-06 | 4.3.2<br>5.2.4<br><br>5.2.6<br>6.3.3 | | Insert subsection titled “Electronics environment”<br>Make modification of the contents of the subsection “Quantization levels of input data”<br>Insert subsection titled “Output data format”<br>Clarify that there is no option to synthesize the frequency response from the ACA Correlator |
| B2 | 2019-06-17 | 5.2.3 | | Include the maximum output data rates |
| B3 | 2019-09-26 | 5.1.4 | | Include footnote on nutator. |
| B4 | 2019-10-09 | 2.3<br><br>4.4.4<br>4.5.2 | | Add [RD 09] in the list of reference documents and quote [RD 09] in 5.2.6<br>Put an explicit value, 20.2 kW<br>Change of wording |
| B5 | 2019-10-15 | 6.2 | | Restate synchronization based on “metaframe bit” and [RD10] is included. |
| B.6 | 2019-11-25 | 2<br>7.4 | | TN-NAOJ:<br>ICD lists are now integrated into AD list (RID-1254).<br>Changed the title of section 7.4 (RID-1259). |
| B.7 | 2019-11-26 | 7.5 | | TN-NAOJ: Replaced “MTD” with “MDT” (RID-1258). |

| | | | | |
|---|---|---|---|---|
| B.8 | 2020-01-06 | 5.1.5<br><br><br>5.1.4 | | JK_KASI:<br>The requirement of the spectral dynamic range is changed as suggested in RID-1291<br>In response to RID-444, remove the footnote added in B.3<br>In response to RID-1207, the requirement is revised. The dump time columns in Table 1, 2, 3, and 7 are removed. |
| B.9 | 2020-05-27 | 5.2.7 | | In response to RID-1204, Jongsoo added the subsection 5.2.7 Non-linearity correction |
| B.10 | 2020-06-10 | | | Jongsoo made a version B to be released. |
| C.1 | 2020-11-09 | 5.2.5 | ALMA-64.00.00.00-0033-A-CRE | JK added sensitivity loss due to imperfect delay correction |
| C | 2020-12-21 | 5.1.3 | | In response to the CRE, JK changed the requirement number CORL-64.00.00.00-0030-00/R to CORL-64.00.00.00-0035-00/R |
| D.1 | 2022-11-28 | 5.1.4 | ALMA-64.00.00.00-00xx-A-CRE | The minimum integration duration was relaxed to 4ms from 1ms for auto correlations in TDM mode. |
| D | 2022-11-28 | | | Edit for the version D to be released. |

# Table of Contents

# 1 INTRODUCTION

## 1.1 PURPOSE

This document summaries the specifications and design requirements for the ACA Spectrometer. Many of the requirements are derived from ALMA project requirements and ACA Correlator requirements, and restated in this document. The rest of them are specific to the ACA Spectrometer.

# 2 RELATED DOCUMENTS AND DRAWINGS

## 2.1 APPLICABLE DOCUMENTS

The requirements in the following documents are applicable to the ACA Spectrometer unless indicated otherwise. In the case of a conflict between this document and the following documents then this one takes precedence.

| No | Document Title | Reference |
|---|---|---|
| AD 01 | ALMA System General Safety Design Specification | ALMA-10.08.00.00-003-B-SPE |
| AD 02 | ALMA System: Electromagnetic Compatibility (EMC) Requirements | ALMA-80.05.01.00-001-B-SPE |
| AD 03 | ALMA System Technical Requirements | ALMA-80.04.00.00-005-C-SPE |
| AD 04 | ALMA Environmental Specification | ALMA-80.05.02.00-001-B-SPE |
| AD 05 | ALMA System: Electrical Design Requirements | ALMA-80.05.00.00-005-C-SPE |
| AD 06 | ALMA Power Quality (Compatibility Levels) Specifications | ALMA-80.05.00.00-001-C-SPE |
| AD 07 | Standard for Plugs, Socket-outlets, and Couplers | ALMA-80.05.00.00-004-B-STD |
| AD 08 | ALMA Product Assurance Requirements | ALMA-80.11.00.00-001-D-GEN |
| AD 09 | Interface Control Document Between Back End and ACA Spectrometer | ALMA-50.00.00.00-64.00.00.00-D-ICD |
| AD 10 | Interface Control Document Between Site (AOS Technical Building) and ACA Correlator | ALMA-20.01.02.00-62.00.00.00-C-ICD |
| AD 11 | Interface Control Document Between ACA Correlator and ACA Spectrometer | ALMA-62.00.00.00-64.00.00.00-A-ICD |

| | | |
|---|---|---|
| AD 12 | Interface Control Document Between ACA Spectrometer and Computing / ACA Spectrometer Control (ASC) subsystem | ALMA-64.00.00.00-70.44.00.00-B-ICD |

## 2.2 REFERENCE DOCUMENTS

| No | Document Title | Reference |
|---|---|---|
| RD 01 | ALMA Documentation Standards | ALMA-80.02.00.00-003-G-STD |
| RD 02 | ALMA Product Tree | ALMA-80.03.00.00-001-R-LIS |
| RD 03 | ACA Correlator Structural Analysis Report (including Seismic Supporting Structure) | Not ALMA doc. |
| RD 04 | ALMA Scientific Specifications and Requirements | ALMA-90.00.00.00-001-A-SPE |
| RD 05 | ALMA System Design Description | ALMA-80.04.00.00-002-D-SPE |
| RD 06 | Observational Modes Supported by the ALMA Correlator | ALMA memo 556 |
| RD 07 | 64 Antenna Correlator Specifications and Requirements | ALMA-60.00.00.00-001-B-SPE |
| RD 08 | Technical Specification For the Design and Manufacturing of the ALMA NUTATOR SYSTEM | ALMA-35.03.00.00-002-B-SPE |
| RD 09 | Science Data Model Binary Data Format written by M. Pokorny and J. Pisano | Version 2.0 |
| RD 10 | ACA Spectrometer Module Timestamping Accuracy | CORL-64.00.00.00-0021-A-REP |

## 2.3 ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| ACA | Atacama Compact Array |
| AD | Applicable Document |
| ALMA | Atacama Large Millimeter/submillimeter Array |
| AOS | Array Operation Site |
| ASC | ACA Spectrometer Control |
| ASM | ACA Spectrometer Module |
| BDF | Binary Data Format |
| COTS | Commercial Off-The-Shelf |
| DRX | DTS Receiver |
| DRXP | DRX board with PCI-express bus interface |
| DTS | Data Transmission Subsystem |
| EMC | Electro-Magnetic Compatibility |
| FDM | Frequency Division Mode |
| GPU | Graphic Processing Unit |
| ICD | Interface Control Document |
| JAO | Joint ALMA Observatory |
| KASI | Korea Astronomy and Space Science Institute |
| LRU | Line Replaceable Unit |
| M&C | Monitor and Control |
| MDT | Mean Down Time |
| MTBF | Mean Time Between Failures |
| NAOJ | National Astronomical Observatory of Japan |
| PCI | Peripheral Component Interconnect |
| RD | Reference Document |
| RFI | Radio Frequency Interference |
| RMS | Root Mean Square |
| TDM | Time Division Mode |
| TP | Total Power |

## 2.4 REQUIREMENTS NUMBERING

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

**[CORL-64.00.00.00-XXXXX-YY / Z]**

Where:
**CORL** is the project code for correlator documents as defined in [RD 01];
**CORL-64** represents the level 1 hierarchy for the ACA Spectrometer as defined in [RD 02]
**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(Z1, Z2,…..)** describes the requirement verification method(s), where **A** stands for analysis of subsystem or product, **I** for inspection, **R** for review of design and **T** for test.

All requirements in this document trace to the Top Level requirements to pass data from the ACA Spectrometer to the ALMA computing system.

## 2.5 VERB CONVENTIONS

"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. "Will" is used to express a declaration of purpose on the part of the design activity.

## 2.6 ORDER OF PRECEDENCE

In the event of conflict between the text of this document and applicable documents, the following order of precedence shall apply:

1. This document
2. Applicable document

# 3 DESCRIPTION

The ACA Spectrometer shall provide auto-correlation and cross-antenna correlation outputs of digitized data streams from the four ACA TP antennas. It will largely replace the functionality of the ACA Correlator for the TP antennas. It should support all the observing modes provided by the 64-input Correlator and the ACA Correlator. Compared with the ACA Correlator, the ACA Spectrometer will provide a better signal-to-nose ratio of the auto-correlation outputs due to its 32-bit floating-point calculation, better flexibility to implement new capabilities for future upgrade due to its high-level software nature, and easy development and maintenance due to its use of COTS.

Figure 1 represents a high-level view of the ACA Spectrometer and its interfaces to the ALMA system [AD 09, AD 10, AD 11 & AD 12]. The red and blue boxes are the pre-existing facilities and the orange boxes are to be added. The hardware components that form part of the ACA Spectrometer are M&C computers, module servers, two network switches, and data acquisition (DRXP) cards installed in each module server. The optical signal splitters belong to the Backend. Signals from antennas go through the optical signal splitters where they are split into two paths; one path goes to the ACA Correlator and the other to the ACA Spectrometer. In this way the ACA Spectrometer can operate independently of the ACA Correlator.

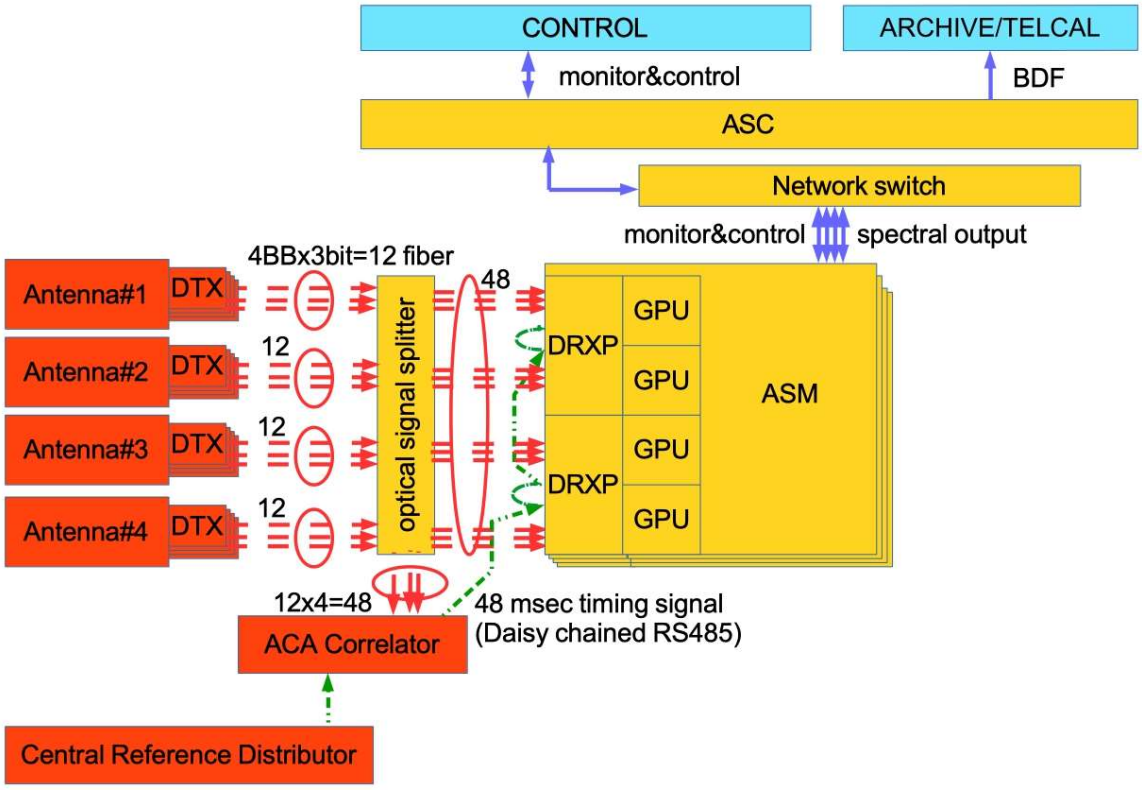


**Figure 1 High-level view of the ACA Spectrometer and its interfaces to ALMA. The new components to be installed for the ACA Spectrometer are indicated by orange boxes: M&C computers, module servers, optical signal splitters, and network switches. Arrows indicate network data flow (blue), optical signals (red), and analog timing signals (green). The optical signal splitters allow the ACA Spectrometer to operate independently of the ACA Correlator. The 48 ms timing signal is delivered to the DRXP cards through a daisy-chained RS-485 cable.**

# 4 GENERAL REQUIREMENTS

## 4.1 OPERATION MODES

The ACA Spectrometer shall be used with the following modes.

### 4.1.1 Operational and Test

[**CORL-64.00.00.00-00020-00/I,R**]
The Operational mode applies during normal observations with the ACA Spectrometer. In this mode, all the specifications and requirements described in this document shall apply, unless otherwise stated. Test mode is the same as Operational mode except that valid data may not be available. The Operational or Test mode is also termed “on”.

### 4.1.2 Non-Operational

[**CORL-64.00.00.00-00030-00/I,R**]
The Non-Operational mode for the ACA Spectrometer identifies the state in which the ACA is neither Operational mode nor Test mode. The Non-Operational mode is also termed “off”.

## 4.2 SAFETY REQUIREMENTS

[**CORL-64.00.00.00-00040-00/R**]
The ACA Spectrometer design shall be in compliance with ALMA System General Safety Design Specification ([AD 01]).

### 4.2.1 Seismic requirement

[**CORL-64.00.00.00-00050-00/R**]
The ACA Spectrometer system and optical signal splitters shown in Figure 1 shall be installed at the existing four computer racks in the AOS building. The racks and their support structure with the added mass shall satisfy the ALMA seismic requirements ([AD 04]). Additionally, the distribution and masses of the spectrometer hardware in the ACA correlator racks shall be consistent with the analysis in [RD 03].

### 4.2.2 Emergency requirement

[**ALMA-64.00.00.00-00055-00/R**]
A remote shutdown method of the ACA Spectrometer shall be implemented as a part of the M&C system for regular operations. It is not required to have an emergency stop button.

## 4.3 OPERATING CONDITIONS

### 4.3.1 Start up time

**[CORL-64.00.00.00-00060-00/R]**
The ACA Spectrometer shall perform pre-defined startup procedure and self tests within 15 minutes after applying power. Automatic power up sequence shall be provided, if necessary, to insure restoration to normal operation without manual on-site intervention.

### 4.3.2 Electronics environment

**[CORL-64.00.00.00-00080/R]**
The design of the ACA Spectrometer electronics shall comply with the applicable electronics design requirement [AD 05].

### 4.3.3 Altitude

**[CORL-64.00.00.00-00090-00/I,R]**
The operating altitude of the ACA Spectrometer shall be 0 – 5200m.

### 4.3.4 Thermal environment

**[CORL-64.00.00.00-00100-00/I,R]**
The ACA Spectrometer shall meet all of its operational performance requirements at ambient temperatures between 10 °C and 28 °C. In Non-Operation mode, the ACA Spectrometer shall survive at ambient temperatures of -30 °C to 40 °C ([AD 04]).

### 4.3.5 Relative humidity

**[CORL-64.00.00.00-00110-00/I,R]**
The ACA Spectrometer shall meet its performance with a non-condensing relative humidity between 20% and 80%.

### 4.3.6 EMC

**[CORL-64.00.00.00-00120-00/R,T]**
Electromagnetic radiation from the ACA Spectrometer electronics shall be in compliance with project EMC and RFI standards ([AD 02]).

### 4.3.7 Storage and shipping condition

For storage mode, the same specifications and requirements as for non-operational mode apply, unless otherwise stated.

[**CORL-64.00.00.00-000150-00/R**]
The ACA Spectrometer modules shall meet ALMA environmental requirements in the on modes (both Operational and Test modes) and shipping requirements in the Non-Operational mode ([AD 04]).

## 4.4 ELECTRICAL AND MECHANICAL REQUIREMENTS

The interface between the ACA Correlator and the ACA Spectrometer are described in [AD 11], and the ACA Spectrometer shall meet the following electrical and mechanical requirements.

### 4.4.1 Mass

[**CORL-64.00.00.00-00160-00/I,R**]
The mass requirement shall comply with the one described in [AD 10].

### 4.4.2 Physical volume

[**CORL-64.00.00.00-00170-00/I**]
All the hardware components except the cables of the ACA Spectrometer shall be installed in the pre-existing four computing racks in the AOS building. The rearrangement of the existing computers and auxiliary equipment in the racks are allowed ([AD 11]).

### 4.4.3 Electric power

[**CORL-64.00.00.00-00172-00/R**]
The electrical power requirements of the ACA Spectrometer shall be in accordance with [AD 10].

[**CORL-64.00.00.00-00180-00/T**]
The total maximum amount of electric power required for the four computing racks in the AOS building is [AD 10], which takes into account of the pre-existing computers for the ACA Correlator, rack-mountable hardware components for the ACA Spectrometer and all other equipment.

### 4.4.4 Thermal load

[**CORL-64.00.00.00-00190-00/I,R**]
The maximum thermal load from the consumption of electric power in the computer racks in terms of calorific value is 20.2 kW [AD 10].

## 4.5 MONITOR AND CONTROL REQUIREMENTS

[**CORL-64.00.00.00-00200-00/R**]
Monitor and control capabilities at the level of LRUs shall be provided to check the status of and to diagnose the ACA Spectrometer equipment in the event of failure.

### 4.5.1 Overheating requirement

[**CORL-64.00.00.00-00210-00/I,R**]
Temperatures of critical equipment shall be sensed and reported to the M&C system. A drop-off in power of the equipment shall be handled directly or at least internally to the subsystem for the sake of damage control.

# 5 FUNCTIONAL REQUIREMENTS

## 5.1 ALMA OVERVIEW REQUIREMENTS

### 5.1.1 IF bandwidth

[**CORL-64.00.00.00-00220-00/R**]
The input bandwidth per baseband pair (dual polarization) per antenna shall be 2 x 2 GHz. The total number of the baseband pairs per antenna and total bandwidth per antenna shall be 4 and 16 GHz, respectively.

### 5.1.2 Spectral resolution

[**CORL-64.00.00.00-00230-00/R**]
The ACA Spectrometer shall provide all the spectral resolutions offered in the observation modes in Table 1-7 at the end of this document.

### 5.1.3 Spectral windows

[**CORL-64.00.00.00-0035-00/R**]
The ACA Spectrometer (as the ACA Correlator) should support the capability to process 64 spectral windows per baseband pair for the future.

### 5.1.4 Minimum integration time

[**CORL-64.00.00.00-00240-00/R**]
The ACA Spectrometer should provide minimum integration times of 4 msec for a TDM and 32 msec for FDMs of auto-correlation, and 96 msec for a TDM of cross-correlation.

### 5.1.5 Spectral dynamic range

[**CORL-64.00.00.00-00241-00/R**]
The spectral dynamic range shall be 20000:1. Here the spectral dynamic range is defined as the ratio of the peak spectral line amplitude to the RMS noise in the spectrum.

### 5.1.6 Spectrometer products

[**CORL-64.00.00.00-00250-00/R**]

The ACA Spectrometer shall generate products, with two digitized data streams from a baseband pair of one antenna, $X_iX_i^*$ or $Y_iY_i^*$ for single polarization, $X_iX_i^*$ and $Y_iY_i^*$ for dual polarization, and $X_iX_i^*$, $Y_iY_i^*$, $X_iY_i^*$ and $Y_iX_i^*$ for full polarization. For the calibration purpose of the TP antennas, it shall generate $X_iX_j^*$, $Y_iY_j^*$, $X_iY_j^*$, $Y_iX_j^*$ for only TDMs. Here, $X_i$ and $Y_j$ represent Fourier transformed polarized streams detected with the horizontal X direction of i-th antenna and the vertical Y direction of j-th antenna, respectively, and a sign * is a notation for the complex-conjugate operation. The i and j indices cover from 1 to 4 of the four TP antennas.

## 5.2 REQUIREMENTS SPECIFIC TO THE ACA SPECTROMETER

### 5.2.1 Number of antennas

[**CORL-64.00.00.00-00260-00/R**]
The ACA Spectrometer shall process the digitized IF signals from four ACA TP antennas.

### 5.2.2 Number of correlations

[**CORL-64.00.00.00-00270-00/R**]
The numbers of auto-correlations including cross polarization products per baseband pair per spectral window per antenna shall be 1 for single polarization, 2 for dual polarization, and 4 for full polarization. The number of cross-correlations per baseband pair per spectral window shall be 24 (= 6 (number of pairs from 4 antennas) x 4 (full polarization products)).

### 5.2.3 Quantization levels of input data

[**CORL-64.00.00.00-00290-00/R**]
The quantization levels of input data should be eight levels (3-bit digitization).

### 5.2.4 Maximum output data rates

[**CORL-64.00.00.00-00300-00/R**]
The TDM modes for the ACA Spectrometer with 1 m sec dump time in Table 1-3 generate a maximum output data rate from the ACA Spectrometer. The maximum output data rate shall not exceed 17 MB/sec.

### 5.2.5 Sensitivity Loss

[**CORL-64.00.00.00-00305-00/A**]
The sensitivity loss of the ACA Spectrometer should be smaller than 2.1%. (There is an additional 4% loss due to the 3-bit sampling at the antennas.)

[**CORL-64.00.00.00-00308-00/A**]
The sensitivity loss of the ACA Spectrometer due to imperfect delay correction shall be smaller than 1%.

### 5.2.6 Output data format

[**CORL-64.00.00.00-00310-00/R,T**]
The ACA Spectrometer shall deliver its output data in the BDF. The details of the format are described in [RD 09].

### 5.2.7 Non-linearity correction

[**CORL-64.00.00.00-00320-00/R,T**]
A total power measurement based on 3-bit digitized signal with nonlinearity correction shall have less than 1 % error relative to the measurement of an analogue power meter over a dynamic range of 10 dB.

# 6 COMPATIBILITY REQUIREMENT

## 6.1 INPUT OPTICAL INTERFACE

[**CORL-64.00.00.00-00340-00/I,T**]
The ACA Spectrometer shall get digitized signals through 48 optical fiber cables from four ACA TP antennas. The detailed requirements of the input optical interface are described in [AD 09].

## 6.2 CLOCK AND REFERENCE SIGNAL

[**CORL-64.00.00.00-00350-00/R,T**]
The ACA Spectrometer shall be synchronized to the ALMA system based on a so-call “metaframe bit” in incoming DTS data streams, which is turned on 1 only for every 48 msec (see details in [RD10]).

## 6.3 COMPATIBILITIES WITH 64-ANTENNA CORRELATOR

### 6.3.1 Correlator/Spectrometer modes

[**CORL-64.00.00.00-00360-00/R**]
The ACA Spectrometer shall provide auto-correlation modes listed in Tables 1-6, most of which are the same as the modes provided by the 64-antenna Correlator using Tunable Filter

Bank in terms of bandwidth and channel resolution (see Table 1-7 in [RD 06] which supersede the mode tables in [RD 07]). In order to support a top-level requirement of 1 msec output rate of auto-correlation ([AD 03]), the lowest resolution modes in Tables 1-3 support a minimum dump time of 1 msec. The ACA Spectrometer shall provide cross-correlation modes listed in Table 7 for calibration purpose, which are newly added modes.

### 6.3.2 Channel-averaging factors

[**CORL-64.00.00.00-00370-00/R**]
The ACA Spectrometer shall provide the capability for the channel-averaging (also known as spectral averaging) with binning factors = 2, 4, 8, 16, 32, 64.

### 6.3.3 Frequency profile synthesis

[**CORL-64.00.00.00-00370-00/A,R**]
The ACA Spectrometer shall be implemented with an option to synthesize the frequency response profile of the 64-input Correlator with a window function. However, there is no need to synthesize the frequency response profile of the ACA Corrector, because the frequency responses from the ACA Correlator and Spectrometer are basically same. It shall also generate its own frequency response profile.

# 7 RELIABILITY AND MAINTENANCE REQUIREMENTS

## 7.1 LINE REPLACEABLE UNITS (LRUS)

[**CORL-64.00.00.00-00390-00/I**]
LRUs shall be used as far as possible and will include the ASC, ASM, power suppliers and cooling fans of the ASC and ASM, GPU cards, and DRXP cards. All of them are COTS except the DRXPs.

## 7.2 MEAN TIME BETWEEN FAILURES (MTBF)

[**CORL-64.00.00.00-00400-00/A**]
The top level requirement of the availability of the Array in [AD 03] shall be larger than 85% with a goal of 95% for the steady ALMA operations. Assuming that 1/3 of the TP Array down time is due to the ACA Spectrometer and half of the down time is due to the hardware failures of the ACA Spectrometer, the total time to repair the failed hardware in a year is 1/3 * 1/2 * 0.05 * 24 hours * 365 days/year = 73 hours / year.

Consequently, and assuming that the average time to execute a hardware repair is 2 hours + 12 hours = 14 hours, a minimum MTBF for the ACA Spectrometer against hardware failure shall be 14 hours / (73 hours/year) = 0.2 year.

## 7.3 LIFETIME

[**CORL-64.00.00.00-00410-00/A**]
The lifetime of the ACA Spectrometer shall be more than 15 years.

## 7.4 FAILURE DIAGNOSIS AND REPLACEMENT

[**CORL-64.00.00.00-00420-00/A,R**]
The failure diagnosis and software maintenance shall be done remotely. The failure diagnosis program shall not exceed one hour. The replacement of LRUs should be done with two persons for one hour. The adequate preparation of spare LRUs shall be provided to meet the lifetime of the ACA Spectrometer.

## 7.5 MAINTENANCE

[**CORL-64.00.00.00-00430-00/A,R**]
The ACA Spectrometer should need the overall maintenance once a year during the ALMA maintenance period, and the MDT shall not exceed 1 day. The ACA Spectrometer should have simple regular maintenance once a month, and the MDT of the monthly maintenance shall not exceed 1 hour.

**Table 1*.** Auto-correlation mode chart with one baseband pair for single polarization

| Mode # | Number of sub-channel filters | Total BW [MHz] | Number of Spectral Points | Spectral Resolution [kHz] | Velocity Resolution at 230 GHz [km/s] |
|---|---|---|---|---|---|
| 1 | 32 | 2000 | 8192 | 244 | 0.32 |
| 19 | 32 | 2000 | 4096 | 488 | 0.64 |
| 38 | 32 | 2000 | 2048 | 976 | 1.28 |
| 2 | 16 | 1000 | 8192 | 122 | 0.16 |
| 20 | 16 | 1000 | 4096 | 244 | 0.32 |
| 39 | 16 | 1000 | 2048 | 488 | 0.64 |
| 53 | 16 | 1000 | 1024 | 976 | 1.28 |
| 3 | 8 | 500 | 8192 | 61 | 0.08 |
| 21 | 8 | 500 | 4096 | 122 | 0.16 |
| 40 | 8 | 500 | 2048 | 244 | 0.32 |
| 54 | 8 | 500 | 1024 | 488 | 0.64 |
| 4 | 4 | 250 | 8192 | 30 | 0.04 |
| 22 | 4 | 250 | 4096 | 61 | 0.08 |
| 41 | 4 | 250 | 2048 | 122 | 0.16 |
| 55 | 4 | 250 | 1024 | 244 | 0.32 |
| 5 | 2 | 125 | 8192 | 15 | 0.02 |
| 23 | 2 | 125 | 4096 | 30 | 0.04 |
| 42 | 2 | 125 | 2048 | 61 | 0.08 |
| 56 | 2 | 125 | 1024 | 122 | 0.16 |
| 6 | 1 | 62.5 | 8192 | 7.6 | 0.01 |
| 24 | 1 | 62.5 | 4096 | 15 | 0.02 |
| 43 | 1 | 62.5 | 2048 | 30 | 0.04 |
| 57 | 1 | 62.5 | 1024 | 61 | 0.08 |
| 25 | 1 | 31.25 | 8192 | 3.8 | 0.005 |
| 58 | 1 | 31.25 | 2048 | 15 | 0.02 |
| 68 | TDM | 2000 | 256 | 7813 | 10.2 |

*All the observing modes supported by the ACA Spectrometer have data streams sampled with the Nyquist time interval.

**Table 2*.** Auto-correlation mode chart with one baseband pair for dual polarization

| Mode # | Number of sub-channel filters | Total BW [MHz] | Number of Spectral Points | Spectral Resolution [kHz] | Velocity Resolution at 230 GHz [km/s] |
|---|---|---|---|---|---|
| 7 | 32 | 2000 | 4096 | 488 | 0.64 |
| 8 | 16 | 1000 | 4096 | 244 | 0.32 |
| 26 | 16 | 1000 | 2048 | 488 | 0.64 |
| 44 | 16 | 1000 | 1024 | 976 | 1.28 |
| 9 | 8 | 500 | 4096 | 122 | 0.16 |
| 27 | 8 | 500 | 2048 | 244 | 0.32 |
| 45 | 8 | 500 | 1024 | 488 | 0.64 |
| 59 | 8 | 500 | 512 | 976 | 1.28 |
| 10 | 4 | 250 | 4096 | 61 | 0.08 |
| 28 | 4 | 250 | 2048 | 122 | 0.16 |
| 46 | 4 | 250 | 1024 | 244 | 0.32 |
| 60 | 4 | 250 | 512 | 488 | 0.64 |
| 11 | 2 | 125 | 4096 | 30 | 0.04 |
| 29 | 2 | 125 | 2048 | 61 | 0.08 |
| 47 | 2 | 125 | 1024 | 122 | 0.16 |
| 61 | 2 | 125 | 512 | 244 | 0.32 |
| 12 | 1 | 62.5 | 4096 | 15 | 0.02 |
| 30 | 1 | 62.5 | 2048 | 30 | 0.04 |
| 48 | 1 | 62.5 | 1024 | 61 | 0.08 |
| 62 | 1 | 62.5 | 512 | 122 | 0.16 |
| 31 | 1 | 31.25 | 4096 | 7.6 | 0.01 |
| 63 | 1 | 31.25 | 1024 | 30 | 0.04 |
| 69 | TDM | 2000 | 128 | 15600 | 20.4 |

* All the observing modes supported by the ACA Spectrometer have data streams sampled with the Nyquist time interval.

**Table 3*.** Auto-correlation mode chart with one baseband pair for full polarization

| Mode # | Number of sub-channel filters | Total BW [MHz] | Number of Spectral Points | Spectral Resolution [kHz] | Velocity Resolution at 230 GHz [km/s] |
|---|---|---|---|---|---|
| 13 | 32 | 2000 | 2048 | 976 | 1.28 |
| 14 | 16 | 1000 | 2048 | 488 | 0.64 |
| 32 | 16 | 1000 | 1024 | 976 | 1.28 |
| 15 | 8 | 500 | 2048 | 244 | 0.32 |
| 33 | 8 | 500 | 1024 | 488 | 0.64 |
| 16 | 4 | 250 | 2048 | 122 | 0.16 |
| 34 | 4 | 250 | 1024 | 244 | 0.32 |
| 17 | 2 | 125 | 2048 | 61 | 0.08 |
| 35 | 2 | 125 | 1024 | 122 | 0.16 |
| 51 | 2 | 125 | 512 | 244 | 0.32 |
| 18 | 1 | 62.5 | 2048 | 30 | 0.04 |
| 36 | 1 | 62.5 | 1024 | 61 | 0.08 |
| 52 | 1 | 62.5 | 512 | 122 | 0.16 |
| 66 | 1 | 62.5 | 256 | 244 | 0.32 |
| 37 | 1 | 31.25 | 2048 | 15 | 0.02 |
| 67 | 1 | 31.25 | 512 | 61 | 0.08 |
| 70 | TDM | 2000 | 64 | 31250 | 40.8 |

* All the observing modes supported by the ACA Spectrometer have data streams sampled with the Nyquist time interval.

**Table 4*.** Multi-resolution mode chart with one baseband pair for single polarization

| Mode # | Minimum size of correlation | Number of sub-channel filters | Bandwidth [MHz] | Number of Spectral Points |
|---|---|---|---|---|
| 2 | 1/2 | 16 | 1000 | 8192 |
| 3 | 1/4 | 8 | 500 | 8192 |
| 4 | 1/8 | 4 | 250 | 8192 |
| 5 | 1/16 | 2 | 125 | 8192 |
| 6 | 1/32 | 1 | 62.5 | 8192 |
| 25 | 1/32 | 1 | 31.25 | 8192 |

* All the observing modes supported by the ACA Spectrometer have data streams sampled with the Nyquist time interval.

**Table 5*.** Multi-resolution mode chart with one baseband pair for dual polarization

| Mode # | Minimum size of correlation | Number of sub-channel filters | Bandwidth [MHz] | Number of Spectral Points |
|---|---|---|---|---|
| 9 | 1/2 | 8 | 500 | 4096 |
| 10 | 1/4 | 4 | 250 | 4096 |
| 11 | 1/8 | 2 | 125 | 4096 |
| 12 | 1/16 | 1 | 62.5 | 4096 |
| 31 | 1/16 | 1 | 31.25 | 4096 |

* All the observing modes supported by the ACA Spectrometer have data streams sampled with the Nyquist time interval.

**Table 6*.** Multi-resolution mode chart with one baseband pair for full polarization

| Mode # | Minimum size of correlation | Number of sub-channel filters | Bandwidth [MHz] | Number of Spectral Points |
|---|---|---|---|---|
| 16 | 1/2 | 4 | 250 | 2048 |
| 17 | 1/4 | 2 | 125 | 2048 |
| 18 | 1/8 | 1 | 62.5 | 2048 |
| 37 | 1/8 | 1 | 31.25 | 2048 |

* All the observing modes supported by the ACA Spectrometer have data streams sampled with the Nyquist time interval.

**Table 7.** Cross-correlation mode chart with one baseband pair for dual and full polarizations. These modes also provide auto-correlation results.

| Mode # | Spectral modes | Total Bandwidth [MHz] | Correlation products | Number of Spectral Points | Minimum dump time [msec] |
|---|---|---|---|---|---|
| 81* | TDM | 2000 | XX*, YY* | 128 | 96 |
| 82* | TDM | 2000 | XX*, YY*, XY*, YX* | 64 | 96 |

*Newly added modes. There are no corresponding modes in the mode charts of the 64-input Correlator.