APP Correlator Modification Description

Release 1.0

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Revision Date: April 26, 2013

1. Phasing Overview

The general methods for phasing arrays of antennas are well understood. Phasing systems for several millimeter and sub-millimeter arrays including the Berkeley Illinois Maryland Array, the Owens Valley Radio Observatory array, and the Plateau de Bure array have been implemented to enable VLBI observations (Bower *et al*. 1997, Torres 2000). These systems were used in early 1.3 mm and 3 mm wavelength VLBI observations of Sgr A* (Krichbaum *et al*. 1998, Doeleman *et al*. 2001). More recent efforts focused on building a beamformer for the Sub-millimeter Array on Mauna Kea. This is now able to coherently sum all the sub-millimeter apertures on the Hawaiian summit, including the James Clerk Maxwell Telescope and the Caltech Submillimeter Observatory for VLBI work (Weintroub 2008). A similar system has been adapted for use at the Combined Array for Research in Millimeter Astronomy with the primary application being 1.3 mm VLBI of Sgr A* and M87.

2. Characteristics of the APP Implementation

- Correlator upgrades are in parallel with the existing hardware/firmware and do not affect the normal data path.
- Only relatively minor software enhancements to the ALMA code base are required.
- All of the phasing corrections are performed in the correlator and supporting computer system with no front-end or Local Oscillator modifications required.
- Development of the system is fault-tolerant in that the critical path involves minimal risk to commissioning.
- No new technical development is required for the project (i.e. APP involves a straightforward implementation of existing technologies).
- The phasing system includes a commercial hydrogen maser. This provides a high stability, spectrally pure frequency standard to ALMA for routine operations as well as VLBI.

- The ALMA Correlator can process the interferometric data for the source in parallel with the VLBI data being captured.
- Additional information is available in the following ICD's:
  - ALMA-05.11.10.49-50.00.00.49-A-ICD   ICD with Back End
  - ALMA-05.11.10.49-20.00.00.49-A-ICD   ICD with Site
  - ALMA-05.11.10.49-60.00.00.49-A-ICD   ICD with Correlator
  - ALMA-05.11.10.49-70.00.00.49-A-ICD   ICD with Computing

3. Correlator Modifications

To direct ALMA data to the Phasing Interface Cards (PIC), the correlator requires minor upgrades.

A firmware modification to the summing logic in the Correlator Cards will provide the sum of the antenna signals in the 2-bit format required by the PICs and Correlator Interface Cards (CIC). The addition of up to 64 2-bit values is representable with 8 bits which can be implemented with a tree of adder chips. The final 2-bit sum of N antennas is achieved by scaling via a lookup RAM in the Xilinx. This logic is applied to each of the 32 channels to provide the signals sent to the PIC. In the interest of testability, it will be possible to substitute pseudo-random data or an incrementing count for the sum data.

The Correlator Interface Card Xilinx personality has been modified to accept an alternate input for "antenna 64". The antenna sum will be routed to this alternate input, providing the capability of correlating the sum against any of the other 63 antennas connected to the correlator. This important test feature is useful in evaluating the effectiveness of the phasing.

Approximately 275 LVDS cables will be routed in the existing cable trays in the correlator to transport the sum signals and timing signals to the PICs. These cables are similar (except in length) to the other cables already in these cable trays which interconnect the correlator's Station and Correlator racks. The PICs will also be cabled into the multi-drop bus.

Two small modules will be added to one of the computer racks. Their purpose is to distribute Maser and GPS 1 PPS signals to the PICs to check that all PICs are correctly synchronized.

The specific actions required to integrate the PICs into the ALMA Correlator are as follows:

- The Correlator Card FPGA ASUMMID will get a revised personality. This will facilitate the formatting and testing of the output sums. This will be documented in the Computing ICD and in the CVS repository
- APP requires a Correlator Interface Card FPGA modification. This was installed before delivery of the fourth quadrant and is already documented in the CVS repository.
- Cabling modifications will be required (Sum Data to PIC, TE to PIC, 1-PPS, Multi-Drop Bus Mods): These will be described in separate installation instructions prior to the Test Readiness Review.
- A 1-PPS distributor will be provided. The schematic, BOM, PCB files and assembly drawing will be provided.

- A GPS receiver will be provided. This is a COTS item, and is documented on the system BOM.
- A PIC Power Supply Assembly is provided. An assembly and mechanical drawings will be provided.

Acronyms

ALMA	Atacama Large Millimeter/Sub-millimeter Array
APP	ALMA Phasing Project
BOM	Bill of Materials
CDR	Critical Design Review
CIC	Correlator Interface Card
COTS	Commercial Off-the-Shelf
CVS	Concurrent Versions System
FPGA	Field-Programmable Gate Array
GPS	Global Positioning System
ICD	Interface Control Document
LTA	Long Term Accumulator
PCB	Printed Circuit Board
PIC	Phasing Interface Card
PPS	Pulse Per Second
TE	Timing Event (48 milliseconds apart)
VLBI	Very Long Baseline Interferometry

References:

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