ALMA Memo 584

Proposed ALMA Correlator VLBI, Phased Sum, and Pulsar Support

By
R. Escoffier, J. Webber, R. Lacasse, A. Saez, J.Greenberg

Abstract

The proposed support for VLBI, phased sum (beam forming), and pulsar observations in the ALMA 64-antenna correlator is presented in the hope of eliciting comment from the ALMA community.

Introduction

The purpose of this document is to describe the support to be provided by the ALMA correlator for:

- VLBI operation
- Phased summation
- Pulsar observations

The specification for the correlator mandates that “hooks” be provided for these options so that they could be considered late in the correlator design cycle and not slow the initial system development. The correlator design and fabrication is now sufficiently far along that consideration of these items is appropriate.

Presentation of correlator group intentions at this time is made in the hope of eliciting comment from the ALMA community as to the appropriateness of the support planned. Additional information may be found in drawing CORL-60.00.00.00-060-A.PLA.

The ALMA correlator is built in 4 identical but independent quadrants. The descriptions below will consider only a single quadrant. The architecture of the correlation section of the correlator includes thirty-two 64-by-64-by-2 (two for the two 2 GHz IF channels processed in a quadrant) correlator-circuit matrices referred to below as “planes” that multiply all 64 antenna signals by all 64 antenna signals.

VLBI and phased sum support

A provision to supply an output consisting of summed antenna output signals was built into the ALMA correlator. Such a summation output may carry the signal from a single antenna or be the sum of 2 or more phased antennas of the ALMA array. A 64-bit program include/exclude mask is used to determine which of the 64 possible antenna signals to include in the sum. One possible use of the summed output will be to drive a VLBI terminal.

The support discussed below will require the design and fabrication of a new card or box to accept the sum output cables from each plane and process them (filter, sample, convert to analog, etc.) as required, in addition to firmware and software modifications.

As the correlator design presently exists, each of the 32 correlator planes in one quadrant of the system provides outputs for 4 signal summations, two for each of the 2 GHz IF channels (basebands) in the quadrant. Each of the 4 summation outputs has an independent include/exclude mask. The precision of each of the summation outputs is 8 bits and the output format is LVDS (low voltage differential signaling, a standard for high speed digital communication).

Use of only a single summed output for each 2 GHz IF channel in the quadrant will be assumed in the following discussion, although hardware to process both outputs per baseband can be provided if this is considered desirable.

As with normal correlator operation, two modes of operation for phased summation will be presented, one for frequency division mode and another, more general mode, to be used in a modified time division configuration.

Frequency division mode

One quadrant of the ALMA correlator contains 32 planes. In a full 2 GHz bandwidth frequency division mode, such as mode 7 (see correlator mode definitions in ALMA memo 556), a quadrant will generate 64 independent 62.5 MHz bandwidth phased summation outputs (32 for each of two basebands). These sub-band summation outputs cannot be combined in any meaningful way with each other since they are developed from different frequency bands within the full 2 GHz correlator input.

The phased summation logic being proposed will provide a crossbar switch so that any 8 of the 64 independent 62.5 MHz sums can be selected for output. Both digital and analog versions of all 8 selected sub-bands will be available (see figure 1, below). In this figure, the output of the analog sum hardware would be eight 8-bit digital signals with a 125 MHz clock rate and eight 62.5 MHz bandwidth analog signals.

With this type of phased sum operation, the results produced in the normal correlator output (lags) would be valid.

Time division mode

Another mode of operation for the phased sum would need a sort of hybrid system configuration between a frequency division mode and a time division mode. In this configuration, the filter bank cards would be in bypass mode as if supporting a time division observation, but the station cards would be programmed as if supporting a frequency division mode. Such a system configuration would allow the full bandwidth the ALMA digitizer outputs to flow through unchanged to the summation logic located on the correlator cards (except, of course, that only the 2 MSBs of each 3-bit digitizer sample would be present and the delay lines in the station logic of the correlator would be available to remove the array geometric delays). Since the system would be in a non-standard configuration, the normal correlator output (lags) for the antennas included in the summation output would be meaningless (other possible non-summation sub-arrays would work normally, however).

Collection of the summation of phased (2-bit) antenna signals from all 32 planes of a correlator quadrant in this mode results in a broadside output of a full 2-GHz bandwidth sum (with each plane sum supplying every 32nd sample of the 2-GHz sum). The phased summation logic being proposed would then use this full 2 GHz summed output to drive two 2-GHz digital filters (one for each baseband). The filters could be programmed to select any band pass up to 1 GHz wide within the 2 GHz input for final output. Both analog and digital versions of the filter outputs would be available (see figure 2). In this figure, the output of the analog sum hardware would be two 8-bit broadside output digital signals demultiplexed over 16 lines (i.e., sixteen 8-bit outputs for each baseband, each output carrying every 16th sample of the full 1 GHz bandwidth) of 125 MHz data rate each and two analog outputs up to 1 GHz in bandwidth.

For VLBI support, standard VLBI data rates are not easily obtainable from the ALMA correlator system 125 MHz clock. Remedying this will require either use of the analog output (driving filters and digitizers in the VLBI terminal) or some method to convert clock rates (either some clock rate change logic or a digital-to-analog/digitizer re-sample stage) not shown in the figures.

The system as described should thus be able to support any standard VLBI or e-VLBI bandwidths up to 1 GHz. Extension to the full 2 GHz ALMA IF channel bandwidth is possible if this is considered desirable.

Pulsar support

Support for pulsar observations will be provided by the generation of a blanking signal for correlator chips in the system to restrict correlation to any selected portion of a target pulsar's period. A mathematical model of the pulsar period will be generated within the correlator using both computers and hardware to track the pulsar phase. Implementation of pulsar blanking is entirely in software and firmware; no additional hardware is required.

Initial goal for the pulsar phase model accuracy will be to track the pulsar phase to within 1/256 of the pulsar duration; thus, blanking resolution will be in 1/256 pulse period increments.

Because there is circuitry for the distribution of only a single blanking signal within each plane of the ALMA correlator, sub-arrays will not be possible when a pulsar observation is in progress. This single blanking term is normally used for blanking during the correlator dump operation and using it to support a pulsar observation would result in the corruption of any non-pulsar sub-array data. Pulsar observations within only a single quadrant of the correlator are possible, however, leaving the other 3 quadrants free for non-pulsar work.

To get two sets of output data simultaneously -- one with the blanking gate, and one without, a second quadrant would be necessary (the un-blanked set could, of course, be taken as a sub-array since the sub-array restriction would be lifted on its quadrant). Also, 2 or more quadrants could be used with individual blanking profiles to get results from different portions of the pulse cycle.

Any existing mode of the ALMA correlator could be used for pulsar work. For mode performances (like spectral resolution) see the correlator mode definitions in ALMA memo 556.

Correlator mode considerations

Some of the fundamental characteristics of the ALMA correlator must be taken into account in planning for pulsar support. Time control is fundamental to a pulsar observation and the two basic modes of the correlator, time division mode and frequency division mode, handle time in different ways.

Time division mode

In time division mode, a 1 milli-second swatch of input samples from a given antenna into the correlator is subdivided into 32 data packets. Each packet contains 125,000 contiguous samples (1/32 of 1 milli-seconds worth of data from a 4 GHz sample stream). Each sample in a packet is a 4 GHz sample and so it represents a 250 ps time interval. Each of the 32 packet outputs from a station card drives one of the 32 correlator planes in the system where the clock rate is lowered to 125 MHz. Thus, 1 msec of input samples at 4 GHz input clock rate is divided into 32 parallel 1 msec packets of 125,000 samples each with a 125 MHz clock rate.

At the boundary between two 1 msec system cycles (i.e., between two consecutive packets) in a given plane, a time discontinuity of 31/32 msec in the packet sample stream occurs. This discontinuity should not present a problem but the model parameters generated throughout the system must take it into account. In the end, correlation results (lags) from all 32 planes are added together.

Frequency division mode

In frequency division mode, a correlator plane processes true 125 MHz samples (produced by the digital filter bank) instead of 4 GHz samples on a 125 MHz clock, so each sample represents an 8 nsec time interval. Also, the center frequency of a 62.5 MHz sub-band within the full 2 GHz correlator input being processed may vary from plane to plane (requiring a slightly different pulsar phase to be tracked in each plane). While this may be useful to aid in the de-dispersion of the pulsar, the CCC must take into account the sample rate and sub-band frequency for a given plane in computing model parameters for an LTA.

Model generation

Pulsar phase model tracking will be done at 3 levels in the correlator.

- The CCC will compute high precision model parameters for each LTA microprocessor every 10 seconds(?) using ALMA system wide timing signal as a reference.
- LTA Microprocessors will use the CCC supplied model parameters in a moderate precision model tracker to periodically update the phase term in a 2-parameter hardware polynomial model tracker on the correlator cards.
- The correlator card hardware model generator will track the pulsar phase of input samples from clock to clock using the 125 MHz system clock.

The 8 most significant bits of the hardware phase model will address a 256x1 RAM which will in turn supply the pulsar blanking signal. The RAM will contain the profile of the pulse in terms of which parts of a pulsar cycle to discard and which part to use for correlation. This pulsar blanking signal developed by the RAM will be ORed with the normal 1 msec internal system cycle blanking signal. The contents of this RAM will be loaded prior to the start of the observation.

There will have to be an integration count (Vs) counter that the LTA microprocessor can read to supply the CCC with integration counts for each correlation results dump.

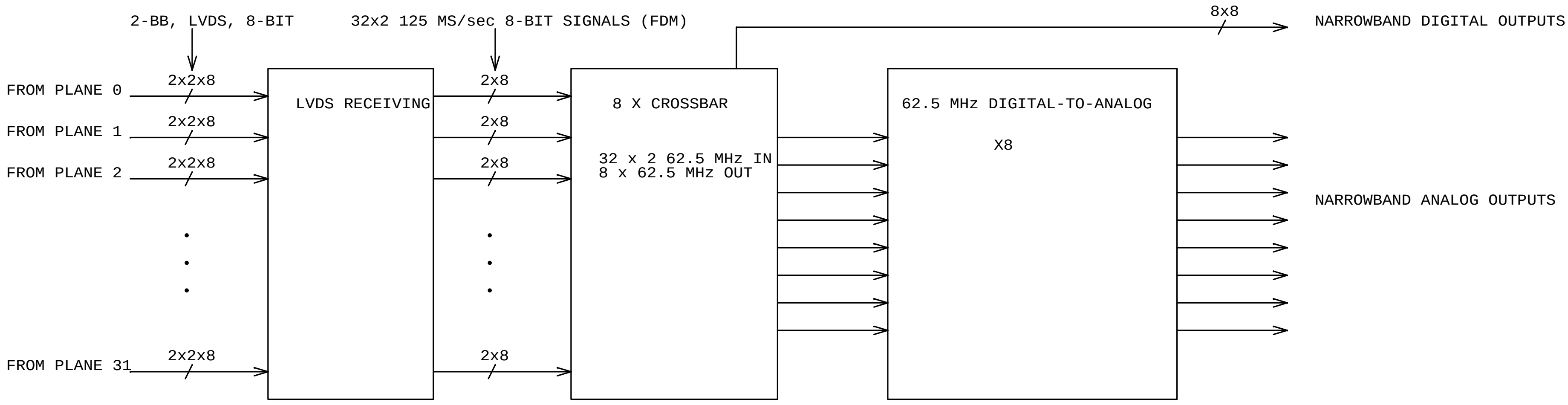

FIGURE 1 BLOCK DIAGRAM OF PHASED SUMMATION LOGIC (FREQUENCY DIVISION MODE)

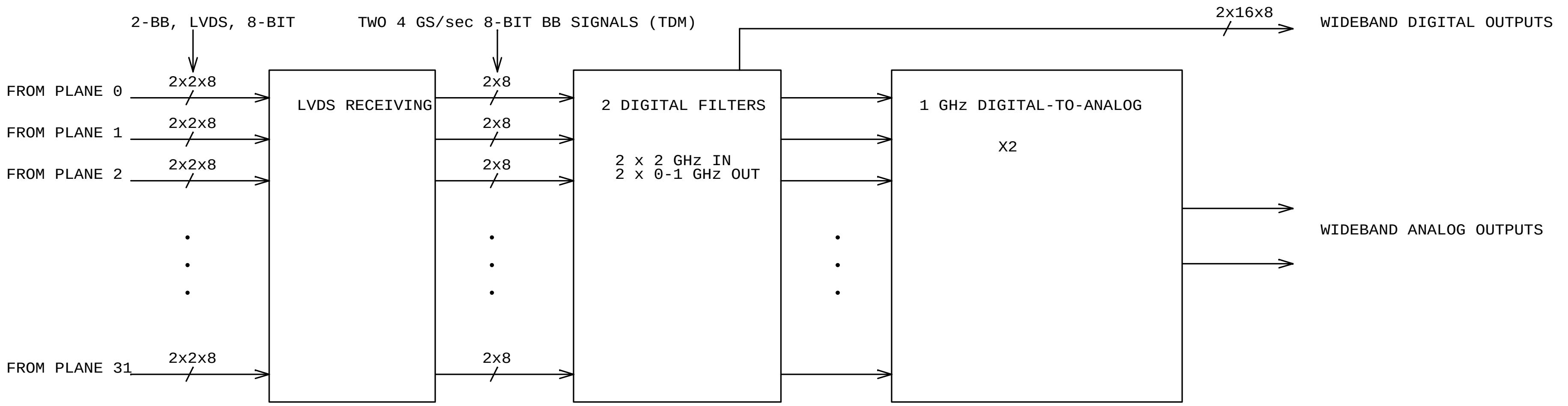

FIGURE 2 BLOCK DIAGRAM OF PHASED SUMMATION LOGIC (TIME DIVISION MODE)