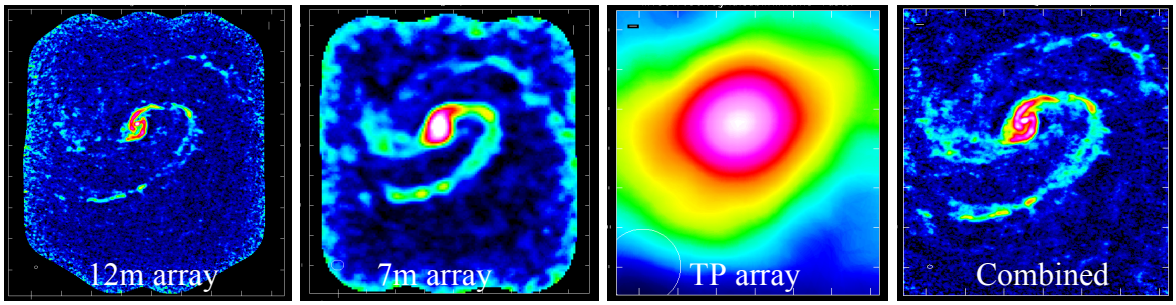
ACA Total Power Spectrometer Development

September 2016

This document describes the background and scientific/operational merit of implementing a new Total Power Spectrometer for the Atacama Compact Array (ACA). For the past years, NAOJ and the Korean Astronomical Space Institute (KASI) have been collaborating on a plan to build a dedicated spectrometer for the TP array.

Background

The ACA consists of 12 x 7-m antennas and 4 x 12m Total Power (TP) antennas. The ACA provides the uv coverage and zero spacing data that are unattainable with the 50 x 12-m array, producing scientific images that are consistent at all spatial scales. The importance of adding the ACA to the 12-m array is already demonstrated through the science verification observation of M100 (see Figure).



Objects that are extended in nature are obvious targets for adding the ACA to the 12m array data (e.g. infalling gas envelopes in proto-planetary disks, Galactic molecular clouds, SZ effect, nearby galaxies). Apart from augmenting the 12m array with the additional short spacing uv coverage, the ACA has the potential for a number of standalone science cases (ref. "ACA-Standalone Science Goals" ALMA IST, Dec 2015).

Scientific and Operational Merit of the New TP Spectrometer

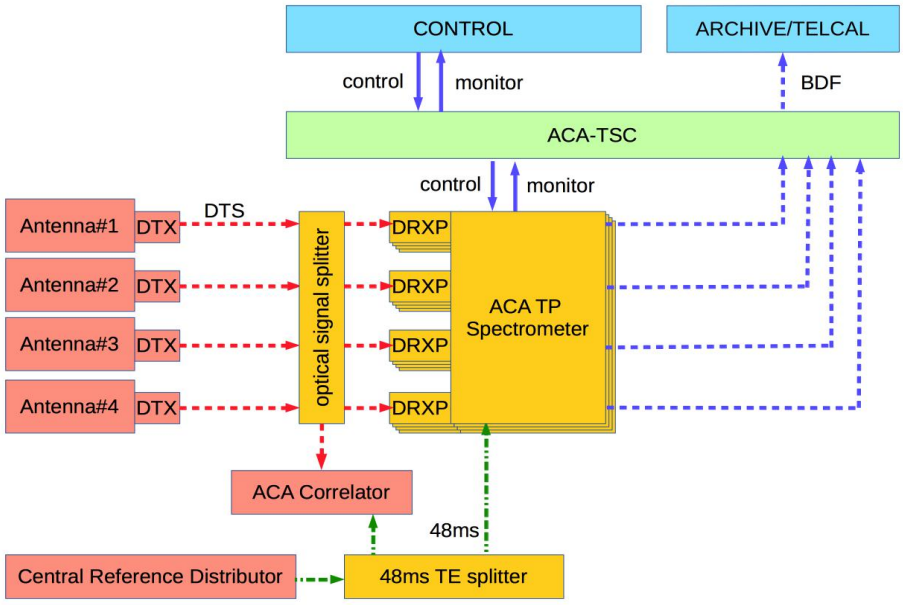
Here we describe the scientific and operation advantages of adopting a new TP spectrometer. We advocate that a dedicated TP spectrometer will bring valuable enhancements to ALMA/ACA, in terms of scientific return and improved operation efficiency.

1. **Scientific Advantage:** The original ACA correlator is designed and optimized for processing cross-correlation data from the interferometer, which means that it is not fully tuned for single dish use and all of the ALMA science specifications may not be satisfied as a consequence. To be more specific, the current FX-type ACA correlator decimates the 16-bit FFT output down to 4-bits before cross- (and auto-) correlation, an inevitable procedure that was necessary to decrease the computational load for accommodating the large number of baselines. In practice, this 4-bit decimation is not necessary for auto-correlation, since there are only four total power antennas and the resultant computation load is much lower than cross-correlating 16 antennas. Therefore, the auto-correlation portion of the data processing can in fact be improved, by separating the auto-correlation from the cross-correlation, leading to an increase in sensitivity (by eliminating the sensitivity loss due to re-quantization) and accuracy (by maintaining 16-bit quantization, and possibly upgrading to 32-bits) of the TP spectrum.

2. **Operational Advantage:** The current ACA correlator accommodates signal from both the ACA 7-m array and the 12-m TP array, often operating simultaneously for scientific use. If the ACA correlator suffers downtime due to an unforeseeable hardware/software event, then the data acquisition from both arrays will discontinue, affecting the operation of the entire ACA. Obviously, improvements in efficiency can be realized if the data acquisition from the interferometer and the total power are separated into different hardware. In addition, hardware/software architecture will become simple and thus flexible, allowing us to implement functionalities that are specific to single dish observations. Moreover, the correlator start-up time becomes shorter without the re-quantization setup mentioned above.

Specifications and Expandability

The new TP spectrometer will receive signal from the four 12-m TP antennas. It is a GPU based software spectrometer that will be installed in the ACA correlator rack at the AOS. The digital signal transmitted from the antennas will be split into two signal paths, one to the TP spectrometer and the other to the existing ACA correlator. Therefore, data from both the TP spectrometer and the ACA correlator will be available for checking the consistency. The scientific specifications of the TP spectrometer will be identical to the specifications defined for the ACA correlator.



In 2015, the ALMA Science Advisory Committee (ASAC) has identified four key paths for the future development of ALMA (ALMA 2030); (1) improvements to the ALMA Archive, (2) large bandwidth and better sensitivity receivers, (3) longer baselines, and (4) wide field mapping using (for example) a multi-beam receiver. Implementing items (2) and (4), although ambitious at present, may present a certain degree of impact to the future design of the ACA TP spectrometer. In both cases, it will be necessary to modify the data acquisition module (DRXP) to accommodate the increased number of optical input, but the change in software is predicted to be small. However, if the number of sampling bits are increased (up to 32-bits for the new design), or a Fourier Transform of a wider instantaneous bandwidth becomes necessary, the impact to hardware/software may become more substantial. NAOJ/KASI will continue to collaborate with the partner regions regarding the expansion of the ALMA telescope, and will modify the hardware/software technical specifications of the TP spectrometer if deemed necessary.