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Digitization and Digital Filtering for 16 GHz On-sky Bandwidth Analysis with ALMA

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Extended Abstract

An upgrade to the current ALMA system is being studied in Europe, North America and East Asia with the main goals of doubling the instantaneous bandwidth and enhancing the spectral resolution and the sensitivity. We describe here the approach followed by the Bordeaux group to design the new digitizers and new digital filters which are required for the ALMA upgrade while retaining the current system infrastructure. Our work has been supported by ESO through the 2013 and 2016 Calls for Proposal and should lead to on-site demonstration in the years to come, for an effective upgrade in the early 2020's.

A full digital back-end for 16 GHz on-sky bandwidth analysis seems feasible using state-of-the-art technology. This solution would simplify the ALMA calibration sessions and would increase the system reliability and versatility. Several possibilities are considered to upgrade the current ALMA digitizers. The first one consists in a direct digitization of the full 4-12 GHz IF using an ADC that can be operated at 24 GSps. Another approach consists in using a multi-rate digitization architecture requiring for instance two clocks at 8 and 12 GHz to sample the 4-8 GHz and 6-12 GHz overlapping sub-bands, respectively. In any case, an additional digital filtering stage is required to replace the analog frequency conversion which operates from 4-12 GHz to 2-4 GHz in the current back-end. Then, an analog to digital converter with a resolution of 4 bits or more would be necessary to optimize the sensitivity and to relax the front-end flatness constraint across the IF band.

Upgrading the correlator bandwidth requires to design new digital filters taking advantage of the most recent FPGA devices. One of our study objectives is to consider the different options for partitioning the required digital signal processing between the back-end and the correlator subsystems. This partitioning impacts directly the data transmission through the optical fiber and the correlator versatility. On the back-end side, the exact digital signal processing will depend on the selected digitization scheme. On the correlator side, we favor a design combining an overlapping polyphase filter bank followed by a tunable filter bank (TFB) similar to the current TFB subsystem. We have shown that a single large FPGA is adequate to extract 32 tunable 125 MHz wide sub-bands. Our first studies are based on DSP mathematical models and available FPGA resources.

The status of our ongoing studies will be presented at the time of this meeting. This will include, ADC evaluation, digital signal processing model, preliminary board architecture, FPGA chip quantity needed for production and preliminary costing.