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Design of a Large-N Correlator for the SKA Low Telescope

D. Humphrey*(1), G.A. Hampson(1), J.D. Bunton(1),G.C. Babich(1) , Y. Chen(1), C. Phillips(1), D. Xinping(1),
B. Bacic(1), K.J. Bengston(1), G. Jourjon(1), A.B. Bolin(1),
(1) CSIRO, Space & Astronomy, Cnr Vimiera and Pembroke Roads, Marsfield, NSW, Australia, 2122
email: dave.humphrey@csiro.au

The Square Kilometre Array (SKA) Low telescope's correlator comprises a number of FPGA signal processing cards, 100 Gbps Ethernet (100GbE) network, and associated software [1]. The correlator is required to support a range of different operating modes, with up to 4096 dual polarisation signals being correlated, multiple subarrays, and multiple different integration parameters. In this paper we describe an efficient, flexible and expandable implementation, using commercial off the shelf components.

The SKA Low telescope operates from 50 to 350 MHz, and consists of 131072 dual polarisation antennas, organised as 512 stations of 256 antennas each. Construction has commenced, with stations coming online over the next 5 years. 300 MHz of bandwidth from each individual antenna is digitised and then groups of antennas consisting of a whole station or part of a station ("substation") are combined in a beamformer. Beams from each station or substation are then correlated in order to perform imaging. The fully digital beamformer results in a high degree of flexibility, with multiple subarrays and multiple beams for a single subarray simultaneously looking in different directions and performing different observations.

Correlation is performed on an array of Xilinx Alveo FPGA cards, connected together via 100GbE links routed by P4 network switches. The signal processing is "atomic" - it is broken into discrete frequency bands, such that a single Alveo is able to perform all correlator processing for a slice of the total telescope bandwidth [1]. The FPGA firmware makes use of the features available in recent FPGA devices, including high bandwidth memory (HBM), wide multipliers, and large internal SRAM blocks to create a flexible, power efficient and low cost correlator. The firmware design has commonalities with the SKA Mid frequency correlator [2] which will also utilise latest generation FPGA cards to deliver a flexible solution.

Atomic processing and use of COTS hardware for networking and control for the SKA correlator means that individual DSP boards can be upgraded in the future while keeping the overall correlator structure. Updates could potentially include next-generation FPGA cards from multiple vendors or GPUs. Our organisation has developed GPU and FPGA correlators for a range of projects including upgrades of the Parkes and ATCA Telescopes (see e.g. [3]), with small-N correlators migrating to GPU based solutions. The best technology for a given application depends on a range of considerations, including the cost of the hardware, power required, number of processing cards, IO requirements, and development effort. COTS FPGA cards such as the Alveo have greatly reduced the development and procurement costs for FPGA based solutions, while increased processing power and dedicated integer hardware in GPUs has reduced the performance gap with FPGAs. We provide benchmarks comparing power and bandwidth that can be processed per processing card with different technologies to give insight into the tradeoffs between the different technologies at this time.

References

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