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Signal Processing in the SKA Low Correlator and Beamformer

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SKA is rapidly approaching the commencement of the first construction phase, which for SKA-Low will consist of 512 stations of size 35-40 m each containing 256 dual polarisation log-periodic antennas. Stations receive frequencies in the range 50 to 350 MHz and are distributed up to 65 km apart. The antennas in an SKA1-Low station work together to act in an analogous manner to a dish, however they have the ability to electronically form multiple simultaneous beams in any direction as the output of all antennas is digitised.

In this paper we describe the implementation of the signal processing stages in the SKA Low Correlator and Beamformer system. This system, which we have called Perentie, receives an aggregate of 6Tbps of digitised station data and calculates three output products, as shown in Figure 1. The first output is 500 pulsar search beams, visibilities for imaging, 16 pulsar timing beams (which can also be reformatted to be VLBI beams).

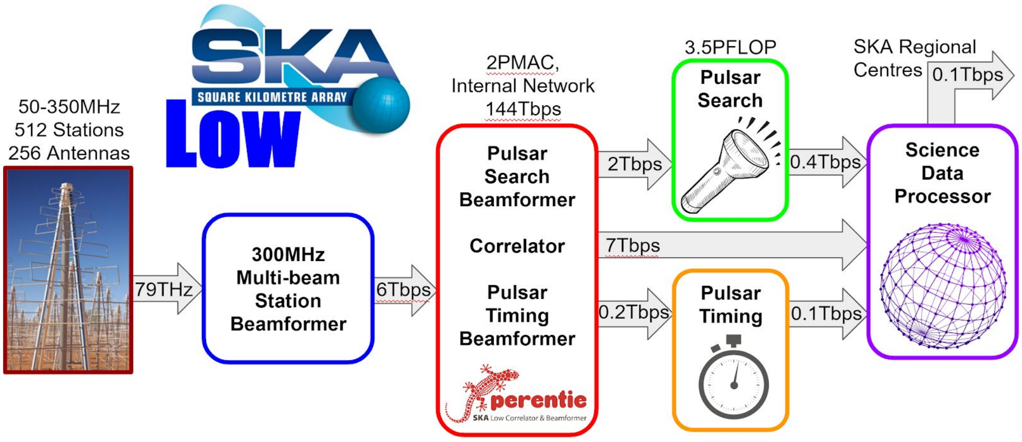

Figure 1. Perentie system signal processing and external interfaces

The Perentie system requires approximately 2 Peta Multiply-Accumulates and an internal network of 144 Tera-bits-per-second to produce these outputs [1]. In addition tight implementation requirements on power consumption, physical size, reliability and cost direct the solution towards Field Programmable Gate Arrays (FPGAs). FPGAs are ideal for low power consumption, high data rate and physically compact solutions. High data rates and huge volumes of data necessitate the use of High Bandwidth Memory (HBM) enabled FPGAs.

Three major signal processing dominate the compute (filterbanks, correlator and beamforming), however there are additional functions to make an operational astronomy instrument. These include signal monitoring, data delays, wavefront correction, Doppler shift, Radio Frequency Interference (RFI) flagging and polarisation corrections. A bit exact Matlab data model enables verification of the implementation against the operating system. Engineering subarrays to allow separation of operational instrument and engineering tests. In this paper we will present the Perentie architecture as well as details of the current system prototype.

References

[1] G. Hampson et. al., “Accelerating astronomy using Atomic COTS”, RadioNet Workshop on Future Trends in Radio Astronomy Instrumentation, Bonn, Germany, 22 September 2020.