

Prototype SKA Technologies at Molonglo:

3. Beamformer and Correlator

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Abstract

The beamformer for the new telescope will demonstrate multibeaming, pointing agility, modifiable beam shape and adaptive null steering, all of which are relevant to a future SKA. Multibeaming occurs within the primary beam of a 1m section of the line feed, with a full imaging beam and an independent fanbeam being generated. Extra fanbeams are easily added. As beamforming is electronic, the beams can be rapidly switched in meridian distance. Later stages of beamforming are digital. This allows for continuous adjustments to maintain a consistent beam shape or for adaptive null steering.

In imaging mode the FX correlator proposed is ideally suited to handle the large number (>3,000) of baselines. Two thirds of the inputs to the correlator come from a contiguous section of the line feed which allows a higher level of beamforming within the area of the imaging beam.

Beamformer

Cost constraints prevent the use of a full digital system for the ~6000 feeds in the Molonglo line feed. Instead a two stage beamformer is used. In the first stage the output of the LNAs from 9 feeds are combined in a wideband delay line beamformer. This restricts the field of view to $\pm 6^\circ$ at 1420 MHz or $\pm 27^\circ$ at 300 MHz.

The ~700 RF signals from the delay line beamformer are upconverted to a 2.5 GHz IF, bandlimited to 250 MHz. Complex IQ downconversion of the RF signal is being investigated. If this is not possible, a higher cost 500 MSamples/s converter will be used to generate a real 250 MHz signal with appropriate changes to the conversion chain. Two local oscillator (LO) signals will be supplied optically. One is a variable frequency LO to select the observing centre frequency and the other is a fixed LO for down conversion.

Details of the multi-output digital beamformer are currently being investigated. Possible implementations for the primary beam fine delay are dithered A/D clocks, polyphase filters or using additional small analog delay elements. Fan beam delays will be implemented digitally at as large a bandwidth as possible.

Correlator

The digital filterbanks use the same technology as the the ATNF 2 GHz filterbanks. It is estimated that one XC2V6000 field programmable gate array (FPGA) is needed per filterbank. See 'A 2 GHz Digital Filterbank Correlator' (this meeting) for more details.

The correlator cross-multiply-accumulate units (XMACS) are also implemented in FPGAs and operate at 125 MHz. At this speed each FPGA implements 36 XMACS, each with 1024 complex 36-bit accumulators. Two 125 MHz banks of XMACS are used to process the full 250 MHz bandwidth. About 100 FPGAs are needed to implement a full correlator for each Stokes parameter.

Spectral line observation will be implemented using decimation in the filterbank and FXF techniques. For this system 768-lag XF correlations can be implemented in each bank of the XMACS. This allows for a further 500 fold increase in resolution beyond that provided by the digital filterbank.

Optional 64 fanbeams

Beamforming within the imaging beam can be performed by summing the outputs of the digital filterbanks. Delays are already correct for the field centre and, as the filterbank outputs are narrow band, phasing of the frequency channels is sufficient to steer the beam. For a 64-beam system groups of 8 to 10 adjacent filterbank outputs are used to form 8 broad fanbeams. Corresponding broad fanbeams are then combined to form 8 fine fanbeams for a total of 64 fine fanbeams. This can be implemented in a total of 64 FPGAs. FFT beamforming is also being investigated.

