A Time-Domain Beam-former with Integrated Correlator for Rapid Calibration of Antenna Arrays

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We present an architecture for a scalable and reusable self-calibrating time-domain beam-former using general purpose FPGA boards. We use tried-and-tested hardware platforms including the iBOB, iADC, and BEE2, which enjoy extensive development support and have a significant user community.

Previous beam-former designs generally focused on maximizing the utility of the FGPA resources in terms of the number of inputs and simultaneous beams, and did not dedicate resources for calibration. While external correlators can be used to calibrate the beam-former, calibration difficulty increases when the correlator and the beam-former have significantly different signal paths. At the Allen Telescope Array (ATA), for example, the correlator and beam-former utilize independent frequency tunings and share little back-end hardware.

We have modified the previously-reported beam-former design to include a correlator in the beam-former firmware. Although this correlator consumes FPGA resources, it enables automated, rapid, and accurate calibration of the antenna amplitudes and phases for the beam-former by ensuring that the calibration is performed entirely within the beam-former signal path. This system has been deployed at the ATA, and is scalable for use with a large number of antennas.

The real-time calibration of antenna phasing using the built-in correlator is particularly relevant to the SKA. The primary beam response is the product of the antenna voltage patterns for each correlation, and will modulate the phase and amplitude of sources away from the pointing center. For an SKA phased-array station beam, atmospheric fluctuations make the complex-valued station beam time-variable. Even for a clean voltage pattern with low level sidelobes from a single antenna, the complex sidelobe pattern will vary with time due to pointing errors, which cause a time varying illumination which can be calibrated during imaging.