Calibrating Radio Arrays without Visibilities Using the E-field Parallel Imaging Calibration (EPICal)

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Next generation cosmology-driven radio interferometry arrays will require thousands of antenna elements to achieve the survey speed necessary for Epoch of Reionization and Dark Ages science, as well as enabling sensitive radio transient searches. The computational complexity of traditional correlators (FX and XF) scales as the number of antennas squared, and will quickly approach the petaFLOPS regime in the coming decades, making the correlator a dominant cost of these instruments, or prohibiting development altogether. Direct imaging correlator architectures promise to alleviate the large-N problem by performing a spatial Fast Fourier Transform of the electric field stream in real time, which scales as N log(N) rather than N^2, as discussed in a companion talk describing the E-field Parallel Imaging Correlator (EPIC) software. However, when using these types of correlators, antenna calibration becomes extremely important, as visibilities are never formed and the complex gains must be applied in real time. I will present a model-dependent method for calibration which does not use visibilities, but instead correlates antenna voltages with a single output image pixel. This method scales only as the number of antennas, accounts for complex sky models, and produces results equal in quality to traditional visibility-based calibrations. Furthermore the algorithm places no restriction on the antennas — accounting for both irregular spacing and non-identical primary beams. This technique will further enable E-field imaging correlators as a competitive option for the coming decades of radio interferometry. An implementation of this calibration (EPICal) is available and integrated into the EPIC software repository.