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Development of an Optimized Real-Time Radio Transient Imager for LWA-SV

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Modern radio astronomy is driven towards an upward trend in the size and computational capacity of the conventional FX correlators, primarily by the requirements of sensitivity, field-of-view and resolution. Next-generation radio telescopes (viz. HERA, SKA, PUMA etc.) will require large-N correlators with significantly higher computational and storage requirements. One of the key scientific objectives of modern radio telescopes is to understand the physics of radio transient phenomena and to explore the space weather environment on other sun-like stars that harbour exoplanets. Real-time imaging at high temporal resolution is ideal for the detection and localization of Fast Radio Bursts (FRBs) and stellar flares/CMEs. Here, we present a generic correlator implementation to reduce the computational requirements for these science cases with our E-field Parallel Imaging Correlator (EPIC : [4]) based on the Modular Optimal Frequency-Fourier (MOFF : [3]) mathematical formalism for direct Fourier imaging. EPIC works by gridding the electric fields from individual antennas and spatially Fourier transforming it to the sky image on-the-fly, while conventional correlators spatially sample the sky by synthesizing an aperture through cross-multiplication of all antenna voltage pairs. Thus EPIC introduces a reduction in computation scaling from $O(n_a{}^2)$ to $O(n_g log_2 n_g)$ (where n_a is the number of antennas and n_g is the number of grid points) [1] and produces very high time resolution images in real-time.

EPIC is implemented on a GPU-accelerated architecture and integrated with a high-performance streaming framework, Bifrost [2]. It was successfully deployed and tested on the Long Wavelength Array station [1] located at the Sevilleta National Wildlife Refuge (LWA-SV) in New Mexico, USA. The LWA-SV is a compact array consisting of 256 dual-polarization active dipole antennas arranged in a pseudo-random pattern with an elliptical footprint operating in the frequency range of 10-88 MHz.

EPIC is composed of multiple kernels/modules that perform various functionalities making use of some of the standard signal processing blocks of Bifrost. However, the original implementation was not particularly optimized and significant work has been done to improve its performance to increase the real-time operating bandwidth. We have performed CUDA-level code optimizations to one such module that performs voltage gridding based on a high-speed gridding algorithm [5] and improved its speed of operation by a factor of three. In this talk, I will present some of our recent optimization results and highlight the current efforts towards a real-time transient detector and RFI-mitigation pipeline to bolster the science capabilities of the subsequent versions of EPIC.

References

[1] James Kent *et* al., "A real-time, all-sky, high time resolution, direct imager for the long wavelength array," *Monthly Notices of the Royal Astronomical Society*, **486**, 4, July, 2019, pp. 5052–5060, doi: 10.1093/mnras/stz1206.

[2] Miles D. Cranmer *et* al., "Bifrost: A Python/C++ Framework for High-Throughput Stream Processing in Astronomy," *Journal of Astronomical Instrumentation*, **06**, 4, July, 2017, pp. 1750007, doi: 10.1142/S2251171717500076.

[3] Miguel F. Morales, "Enabling Next-Generation Dark Energy and Epoch of Reionization Radio Observatories with the MOFF Correlator", *Publications of the Astronomical Society of the Pacific*, **123**, 14, October, 2011, pp. 1265–1272, doi:10.1086/663092.

[4] Nithyanandan Thyagarajan *et* al., "A generic and efficient E-field Parallel Imaging Correlator for next-generation radio telescopes," *Monthly Notices of the Royal Astronomical Society*, **467**, 01, May, 2017, pp. 715–730, doi: 10.1093/mnras/stx113.

[5] Romein J. W., 2012, in Bannerjee U. , Gallivan K., eds : *Proceedings of the 26th ACM international conference on Supercomputing*. ACM, ACS, New York, pp. 321.