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Towards FPGA-based Prototype FPA Beamformer for the Expanded GMRT

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The Expanded GMRT (eGMRT) [1] is a proposal for enhancing the scientific capabilities of the Giant Metrewave Radio Telescope (GMRT). The three expansions proposed as part of the eGMRT are - increasing the field of view, increasing the angular resolution and improving the sensitivity to the extended radio emission [1]. In this talk, we would focus on FPGA-based prototype Focal Plane Array (FPA) beamformer development used for increasing the field-of-view. A prototype is being developed as part of the capability building exercise to understand the challenges in designing a real-time multi-beam beamformer. A typical FPA beamformer needs correlation for calculating the complex weights and a beamformer to compute the weighted sum of the inputs. As part of this project, we have calculated the computational complexity of implementing FPA beamformer in real-time and the various tradeoffs at the architectural level. The major challenge for the beamformer is a large computation and I/O (input-output) requirement. The current designs developed for the prototype use real-time correlation and beamforming. The computational requirement is dominated by the correlation operation for which the number of operations increases quadratically with the number of inputs. A variant of the prototype has been implemented and tested with offline correlation and real-time beamforming. In parallel with the prototype development, system-level simulation is being carried out as a test reference.

Currently, multi-beam beamformers with narrow (32 MHz) and wide (300 MHz) bandwidth are designed for the prototype using the CASPER (Collaboration for Astronomy Signal Processing and Electronics Research) methodology. The beamformer design with 16-element and 4 independently steerable beams has undergone preliminary testing with the 144-element ASTRON FPA operating in the L-band. The overall test setup along with the analog and down-conversion counterpart of the beamformer was characterized prior to the testing. The characterization includes testing the effects of external interference and system gain and phase stability. We have developed software tools to check the functioning of the various beamformer elements of the FPA and to carry out data quality checks from the digitized time-series which is acquired from the FPGA through the 10 Gigabit interface. A free-space test range has been developed at the GMRT with a 3m parabolic reflector as radiating antenna. Beamsteering experiments are carried out using this test range with FPA in the aperture array mode. The test results from these experiments are described.

For the final prototype consisting of 144-inputs and 30 independent beams, the total size of the system and the power requirement would be crucial in deciding the implementation platform. We are evaluating contemporary signal processing platforms which can be interfaced directly with the RF and analog counterparts of the beamformer. The talk would also discuss the plans to extend the number of elements and beams using scalable architecture which would lead to the final prototype beamformer for the eGMRT.

1. Patra et al., “The Expanded Giant Metrewave Radio Telescope”, October 2018, Under Review.