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Antenna Characterization and RFSoC Digital Back End Development for the ALPACA Phased Array Receiver

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The Advanced L-band Phased Array Camera for Astronomy (ALPACA) [2] is a cryogenic astronomical imaging phased array in development at Cornell University, Brigham Young University, for the Green Bank Observatory. This instrument is a fully cryogenically cooled 69-element dual-polarized broadband dipole array with a digital signal processing back end for real-time beamforming and calibration. An instantaneous processing bandwidth of 305 MHz with 40 full-Stokes beams can be tuned from 1.3-1.72 GHz. Design and development for the antenna array, cryostat and low noise amplifiers, RF over fiber signal transport, and the digital back and are largely complete and the receiver is in the fabrication stage.

Digital back end development is based on the Collaboration for Astronomy Signal Processing and Electronics Research (CASPER) framework. CASPER is an international effort with the objective to develop open-source hardware and software tools for the design and development of radio astronomical instrumentation. The hope is to minimize time between instrument conception and commissioning and reducing the time and cost to upgrade an instrument. Reducing *time-to-science* can be achieved using CASPER hardware and tools supporting modularity, flexibility, and design reuse [1].

We will present the integration of Xilinx RF system-on-chip (RFSoC) based digitizers into to the CASPER toolflow. This includes capabilities for sampling, digital down conversion, 100 GbE, multi-tile and multi-board synchronization and new resources for the development of real-time signal processing for radio astronomy instrumentation using CASPER and RFSoC. For array calibration, output voltage correlation, channelization, beamforming, and imaging, ALPACA will use a heterogeneous two stage channelizer architecture. First stage processing is done by 12 Xilinx RFSoC FPGAs implementing an oversampled polyphase filter bank channelizer. The coarse frequency channels are packetized and transmitted via 100 GbE to a cluster of 25 GPU processing nodes (two NVIDA A10 GPUs per node) for beamforming and preparing coarse and fine spectrometer science data products.

The antenna elements have been tested with the RF over fiber signal transport and RFSoC digital signal processing. The antenna Y factor method was used in a remote location to avoid RFI sources with microwave absorber and cold sky to assess the radiation efficiency of the antennas. The system was measured with the uncooled antenna and front end. Results for the antenna radiation efficiency were extrapolated to cryogenic temperatures and the radiation efficiency appears to be adequate for the final system to meet intended performance requirements.

References

[1] J. Hickish, et. al., "A Decade of Developing Radio-Astronomy Instrumentation using CASPER Open-Source Technology," *Journal of Astronomical Instrumentation*, **5**, 4, December 2016, pp. 1641001, doi: 10.1142/S2251171716410014.

[2] M. C. Burnett, K. F. Warnick, B. D. Jeffs, et al.,"Design and development of a wide-field fully cryogenic phased array feed for Arecibo," *2020 XXXIIIrd General Assembly and Scientific Symposium of the International Union of Radio science (URSI GASS)*, 2020, pp. 1–4, doi: 10.23919/URSIGASS49373.2020.9232378.