Modeling and System Development for the FLAG L-band Phased Array Feed for Large-Dish Astronomical Observations

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Wide-field phased array feeds (PAFs) are part of the next generation of receivers for astronomical observatories. Groups around the world are developing array feeds for medium to large size dish antennas. The Brigham Young University (BYU) radio astronomy group is focusing its efforts on modeling and developing new high performance PAF systems for the Green Bank Telescope (GBT) with 100-meter reflector, which is the largest fully steerable radio telescope in the world.

This presentation will report on recent progress by a collaboration between BYU and National Radio Astronomical Observatories (NRAO) on developing a Focal L-band Array Feed for the GBT (FLAG). Work is ongoing on the front end antennas, cryogenic electronics, and digital beamforming back end. We are also contributing to the development of an 8×8 cryogenic PAF in the 70-95 GHz frequency range designed by the University of Massachusetts radio astronomy group. The L-band and mm-wave feeds are targeted for demonstration experiments on the GBT within the next year.

To serve as the back end for both arrays during the engineering test phase, a 64-channel analog downconverter system with 20 MHz bandwidth was developed to mix down, filter and amplify received signals. For science observations, more bandwidth is required. A broadband real time system is in development with 150 MHz bandwidth based on 155 MHz I/Q ADCs and graphics processing unit (GPU) cards for correlation and beamforming.

Using full wave modeling tools, we have studied key effects on the performance of feeds from L-band to mm-wave frequencies. One key issue is the radiation efficiency of the L-band array feed and the influence on these parameters of beam steering and array mutual coupling. The radiation efficiency of an array antenna can be much smaller than an isolated antenna due to mutual coupling effects, and there is a variation of array radiation efficiency when the beam is steered. We have also found that for broadband array feeds, aperture efficiency decreases at the frequency where the nulls of the Airy pattern of field focused by the reflector in the plane of the array feed lie on the locations of elements in the array. This effect is independent of the antenna structure, the number of elements, and the array layout. We have quantified this behavior and showed how it influences the optimal design of element feed patterns. The long term goal of this work is to develop practical design guidelines and performance bounds on array feed receiver systems.