L-band Antenna Element Design for a Cryogenic Phased Array Feed on the Green Bank Telescope

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Brigham Young University and the National Radio Astronomy Observatory have been collaborating for the last several years on the development of a high sensitivity imaging phased array feed (PAF) for the Green Bank Telescope. A PAF is a phased array antenna configured as a reflector feed, rather than an aperture antenna with direct view to the sky. Broadband digital beamforming is used to create an image with many pixels over a relatively wide field of view (several half power beamwidths), potentially leading to significantly greater scientific observation capability than traditional single pixel horn feeds and enhancing the value of world-class telescopes like the100 meter GBT.

Because observation time on the GBT is highly competitive and the telescope is in great demand by astronomers around the world, previous PAF prototypes have been tested on a smaller 20-meter dish at the NRAO facility in Green Bank, WV. As PAF prototypes and signal processing hardware have matured, efforts are now underway to prepare for PAF tests on the GBT. For feed design, the dish f/d (or equivalently, the dish opening angle) is a critical parameter. Our design procedure for the antenna elements and array configuration uses a complex cost function based on the G/T, bandwidth, and field of view of the array and reflector system. Since the active impedances presented by the array to front end amplifiers depend on the beamformer coefficients used to form astronomical images, and the beamformer coefficients depend on the secondary patterns of each element in the far field of the reflector, the element optimization process incorporates reflector characteristics into the final element design.

While previous PAF prototypes developed at BYU have been optimized for the 20-Meter Telescope with a focal length to diameter ratio (f/d) of 0.43, the prime focus GBT optics has an effective f/d of 0.7, which means that the dish opening angle is smaller, the feed illumination pattern must be narrower and more directive, and a larger PAF aperture size is required. Earlier PAF prototypes have an element spacing of 0.6 wavelengths. If this spacing were used for a PAF optimized for the GBT, more array elements would be required to properly illuminate the GBT reflector. Due to signal transport infrastructure limitations on the GBT, however, in the near-term no more than 19 dual polarization elements can be supported. In order to keep the PAF to 19 elements and still properly illuminate the GBT reflector, we have designed a new PAF configuration with wider element spacing. Using numerical simulations, we have found that 0.7 wavelength spacing is optimal. This spacing does not lead to significant sensitivity loss relative to 0.6 wavelength spacing, yet achieves a larger field of view (defined by the largest beam steering angle away from the reflector boresight that maintains a sensitivity within 1 dB of the boresight beam). Array elements have been designed for optimal active impedance matching, broad bandwidth, and wide field of view for this element spacing and taking into account the GBT optics configuration. The new array design is currently in fabrication, and we anticipate testing the full PAF with cryogenics on the GBT in 2013.