A K-Band Spectroscopic Focal Plane Array for the Robert C. Byrd Green Bank Radio Telescope

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Abstract

This paper presents the design and current status of a K-Band Focal Plane Array (KFPA) for the Green Bank Telescope (GBT). The prototype array will go online with 7 independent dual-polarized beams, but the design target is a fully-populated instrument with approximately 60 beams on the sky. This project presents a number of technical challenges, including the architecture of a cryostat capable of supporting 60 independent receivers, design of high-performance components that fit behind the aperture of a compact feedhorn, and stable transmission of the large-volume of receiver data from the telescope to a remote building for back-end processing.

1. Summary

The GBT, built by the National Radio Astronomy Observatory (NRAO) and located in West Virginia in the center of the National Radio Quiet Zone, is the worlds largest fully-steerable radio telescope. It has a 100-meter diameter unobstructed aperture using offset Gregorian optics, and has a 3-foot wide focal plane that lends itself naturally to large-format arrays. However, until recently the telescope's suite of instruments consisted entirely of single-pixel radiometers or dual-beam pseudo-correlation receivers. Fortunately, array receivers are becoming the new standard as the NRAO commissions a 64-element W-Band bolometer array known as MUSTANG and begins the development of the telescope's first heterodyne array at K-Band, the topic of this presentation.

The K-Band Focal Plane Array will be a spectroscopic instrument capable of rapidly mapping large regions of the sky in Ammonia and numerous other chemical species. While the cryostat and supporting subsystems, such as M&C and LO distribution, are being designed for a ~60-element array, the initial prototype instrument will be populated with 7 elements. Each dual-polarized element, or "pixel" will consist of a complete independent receiver chain from cold electronics to back-end. No compromise will be made in system noise temperature or bandwidth, the sensitivity of each pixel for spectral line mapping will be the same as it is for the observatory's existing single-beam K-Band receivers on the GBT and VLA.

The optics will consist of compact, corrugated feedhorns at room temperature, packed closely in a hexagonal arrangement. The feedhorn aperture measures 3.45 inches across, defining the pixel's cross section behind which the rest of the front-end electronics must fit. Following the feedhorn inside the cryostat is an input thermal gap, circular-to-square transitions, a phase shifter, an OMT, isolators, a noise-source/calibration-coupler module, cryogenic low-noise amplifiers, and output thermal transitions. In order to minimize development time, the electromagnetic components and cryogenic LNAs are all either preexisting or scaled versions of preexisting components.

Outside the cryostat is a multifunction MMIC module which performs all the remaining amplification, channel selection, downconversion, and leveling in the front-end. It has been designed to make the most efficient use of the available IF bandwidth in the back-end for a 7-element array. In order to retain enough data to be scientifically useful, this will involve multiplexing information from two pixels onto a single IF fiber channel, while maintaining the 1.8 GHz IF bandwidth that can currently be processed with the existing back-end. Operating the larger 60-element array will require an upgrade to the IF Transmission System on the GBT and the back-end electronics, an improvement that will be instantly useful for this array and pave the way for a whole suite of new large-format imaging cameras on the GBT.

2. Conclusion

The K-Band Focal Plane Array is the first of a new class of heterodyne instruments for the GBT, sampling the full width of the focal plane of the telescope with low-noise receiver elements in order to realize a massively accelerated imaging and mapping capability. The presentation will review the science case for such an instrument, the design decisions that led to the current architecture, the limitations imposed by the telescope's auxiliary systems, and how these limitations might be addressed in the future.