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To: Paul Vanden Bout

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Subject: GBT Receiver Development

Following the Q-band array receiver currently under construction, the next four GBT receiver development projects, in priority order, are:

1. Fully Sampled Focal-Plane Array Receivers

This research effort, led by Rick Fisher and Rich Bradley, is developing array feeds, receivers, and correlators which extract all of the information in or near the focal plane of a telescope. The primary goals for radio astronomy are (1) multi-beam receivers that fully sample the sky with arbitrarily close beam spacings and (2) the ability to measure and correct for large-scale reflector deformations. Array feeds are our best hope for radically improving both the quality and speed of imaging with single-dish telescopes such as the GBT. The main technical challenges are economically forming many beams from a large number of small elements and approaching the noise performance of single-beam receivers with distributed amplifiers.

The feasibility of forming closely spaced beams has already been demonstrated with a 19-element array on the 140-ft telescope. The next step is to use better RF amplifiers and measure aperture efficiency, spillover temperature, and mutual coupling between the elements. At least two beam-forming designs are being considered: (1) Direct combination of signals at RF or IF using phase shifters and power combiners will be most appropriate for wideband applications where the properties of the antenna reflector are well known. (2) Full cross-correlation of the signals from all elements in the array is feasible with narrower bandwidths, say, less than 100 MHz. This permits optimization of complex array element signal weights in post-processing so that the reflector surface deformations and the optimum balance between aperture illumination and spillover are not required a priori.

A reasonable minimum effort for this project would be a half-time technician and about $20K per year for parts. Cryogenic development and beam-combiner prototypes would go faster with $30K per year and more technician help. After three or four years of research it may be possible to design a competitive cm-wave array receiver for the GBT.

2. Wideband Magnetic Isolators in a 26–40 GHz Receiver

A 26–40 GHz receiver on the GBT would complement the 40–52 GHz Q-band receiver in covering the atmospheric window between the water and oxygen lines. It would be used to detect the CO $J = 1 \rightarrow 0$ line from galaxies and quasars in the redshift range $1.9 < z < 3.4$ corresponding to the epoch of peak AGN activity and possibly star formation. It would also be used as a continuum receiver in the 30–33 GHz frequency range, the clearest part of this atmospheric window.

There are at least three options for covering this large fractional bandwidth: (1) Build two circularly polarized receivers with smaller bandwidths. This is the "traditional" solution for the NRAO. (2) Build a single linearly polarized receiver covering 26–40 GHz. This would make VLBI and observations of linear polarization more difficult, but would be acceptable for most CO and continuum observations. (3) Build a single circularly polarized receiver covering 26–40 GHz. This option is the most desirable but has not been tried because there is a severe impedance mismatch of the circularly polarized feed near the band edges. John Webber recently suggested that a wideband Faraday-rotation isolator of the type built by Neal Erickson might be used to isolate the RF amplifier from this mismatch. Neal Erickson advised John that his full band Faraday rotation type isolator should work cold, with a loss below 0.2 dB, which means a contribution to the system temperature of less than 0.7 K. John concluded "It will be a little work to get one going, but it seems quite feasible."

Such isolators might also be valuable for covering frequencies above 70 GHz on the GBT and on the MMA.

3. 3 mm Receiver

Ken Kellermann has applied for funding to build a 3 mm receiver intended for VLBI on the GBT. If this is approved, the NRAO should modify the basic VLBI receiver to make it useful for single-dish spectroscopy and continuum observations. For example, a beamswitching scheme or nutating tertiary would be needed to cancel atmospheric emission fluctions for continuum use. A large instantaneous bandwidth is needed for continuum sensitivity, and a large tuning range is needed to cover as many spectral lines as possible.

4. Conventional Multibeam Receivers

A seven-beam continuum receiver operating at $\lambda \approx 2$ cm would be useful for mapping extended continuum sources (e.g., nearby spiral galaxies), repeatedly surveying the Galactic plane to discover active compact objects and stars by their radio outbursts, and mapping small ($\Delta T/T \sim 10^{-6}$) fluctuations in the cosmic microwave background.