Conceptual Design Review for the GBT 3 mm Receiver

National Radio Astronomy Observatory
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CoDR document prepared by
M. Stennes, R. Norrod, and P. Jewell
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1. Introduction

A proposal for an initial 3 mm receiver for the GBT was completed in March 2000, and appears as an Appendix. Funding and staff resources are now available for this project. This document provides additional information needed for a conceptual design review (CoDR) for the project.

The purpose of the CoDR is as follows:

- Review the scientific specifications for the receiver.
- Review the technical design presented in the proposal, together with any modifications that have been introduced in the interim.
- Define the project team, including the Project Manager, Engineer, and Scientist.
- Review the budget and project plan, including dates for the Preliminary Design Review (PDR).
- Determine the tasks to be completed by the PDR.

2. Review of Scientific Specifications

The scientific case for the receiver was presented in the proposal. This section reviews in outline form the principal scientific specifications for Module 1:

Frequency coverage:

Module 1:	68-92 GHz (some flexibility in this range, and wider tuning coverage is desirable)
(Module 2:	90-116 GHz)

Bandwidth:

Spectral Line:	Minimum: 4 x 800 MHz = 3.2 GHz (=> 4 GBT Spectrometer sections end to end.)
	Desired: 20+ GHz for spectroscopy with special, wideband correlator (e.g., for redshift surveys)
Continuum:	Minimum: 7 GHz (BW capacity of 1 analog optical fiber)
	Desired: 20+ GHz for maximum continuum sensitivity.

Noise Temperature Sensitivity: Trx $\leq$ 70 K (SSB) across tuning band.
Goal: Trx = 50 K (SSB)

Continuum Sensitivity in the absence of atmosphere:

<2mK/rt-sec (corresponds to Trx=70 K, BW=7 GHz)
Goal: ~1mK/rt-sec (corresponds to Trx=70 K, BW=20 GHz)
(The GBT is expected to have about 1 K/Jy sensitivity at 90 GHz, so that 1 mJy ~ 1 mK.)

Polarizations: Dual Linear, with option for circular for VLBI.

Number of Beams: Dual (=> 4 receivers, dual polarization and dual beam)

Beam separation:

4 beamwidths => 32 arcsec at 90 GHz (3-5 beamwidths acceptable)

Switching Modes:

Fast beam switching

NB. The scientific specification of excellent continuum sensitivity led to a practical design of a pseudo-correlation receiver, with phase switching at up to 2.5 kHz rate with <1 microsec blanking time.

Position-switching: total power with antenna position switching.

Frequency switching:

10 MHz switch at 10 Hz rate. (corresponds to ~30 km/sec velocity switch)

Tertiary beam switching: Future add-on for optimal continuum and spectral line beam switching performance. Switch between the two beams at ~10 Hz rate.

Observing modes:

Spectral line (requires total power with phase binning done by the backend)
Continuum
Polarization (using the polarization mode of the GBT Spectrometer)
VLBI (total power, circular polarization)

Calibration:

Ambient temperature blackbody load on switchable chopper wheel or vane (hot/sky calibration). Ambient loads are typically switched in for a few seconds at a time and the beginning of a scan, or sequence of scans.
Desirable: Injected cal signal from noise diode
Desirable: Hot / Cold / Sky system (ambient loads)

3.0 Technical Updates to the March 2000 Proposal

An revised block diagram of the receiver is shown in Figure 1. The changes to the receiver of design or approach that have been introduced since the proposal was written in March 2000 are as follows:

- We plan to relocate the RF bandpass filters. Placing them outside of the second magic tees will reduce the number of components to be gain- and phase-matched, thereby easing the task of gain and phase balancing.
- Dividing the RF continuum band into three sub-bands is being considered. Doing so would give users some spectral information.
- Circular polarization over a limited frequency band (for VLBI) will be provided by means of a removable polarizing plate.
- The OMTs will not be fabricated at the NRAO Machine Shop. We plan to have them made as part of the ALMA production run at either the University of Arizona, or at J&E Precision Tool, Inc.
- The block diagram does not show an explicit design for the continuum detector system. This may be developed in collaboration with the Ka-band receiver project, which may use a similar receiver design to the 3 mm Rx.

The following are open technical issues or design alternatives to be discussed at the CoDR:

- Consider merits of shifting the frequency coverage to a single module of ~85-115 GHz. Some observatories, notably UMass, have traditionally opted to cover only the high end of the band (as much as 80-115 GHz). This covers the majority of important spectral lines including all CO isotopes, CN, CS, HCN, HCO^+, SiO, and many others, but forfeits some important species such DCN and DCO^+ that lie below 75 GHz. A receiver covering ~80-115 GHz would cover the best continuum window, which is ~80-100 GHz.
- Consider a 20 GHz wide IF.
- The biphase modulator from Pacific Millimeter may not be able to cover Module 1's full 30% bandwidth. The best that PM has done for the MAP project is 26%. In addition PM does not have an existing design that is centered on our band. Other sources are being considered.
- Placement of both LNAs ahead of the biphase modulator to reduce Trx.
- Using higher switch rates, and placement of the second LNA outside the second tee.
- How best to create circular polarization for VLBI.
- Continuum detection and baseband processing.
- Vacuum window technology.
- Segmenting the RF continuum path.
- Design of a tertiary reflector and chopping system.

4. Project Organization

There will be three, key management positions for the project:

Project Manager: Roger Norrod

Responsibilities: Supervise project as a whole, including budget and staff management. Overall responsibility for delivering project and ensuring that scientific specifications are met. Organizes review meetings.

Project Engineer: Mike Stennes

Responsibilities: Detailed engineering design and construction. Lab testing of receiver, engineering documentation.

Project Scientist: Phil Jewell (possibly to be replaced by the GBT 3 mm Program Scientist, when hired)

Responsibilities: Set scientific specifications and, in collaboration with the project team, ensure that proposed design will meet those specifications. Participate in lab testing and direct the receiver commissioning on the telescope. Aid in the preparation of documents for design reviews. Coordinate / write users manual for the receiver.

5.0 Project Plan

The project plan through laboratory completion of Module 1 of the receiver has is shown in Figure 2. Module 2 (90-116 GHz section) will be built as a separate phase to be incorporated into the same cryostat at a later time. (This will involve downtime for the receiver, but it can probably be done mostly during the summer months when the 3 mm receiver will not be in use.)

The following major milestones for Module 1 of the project have been identified:

Conceptual Design Review	29 May 2001
Preliminary Design Review	7 September 2001
Critical Design Review	1 July 2002
Lab Test Review	6 December 2002
Install Receiver on GBT	15 December 2002
Receiver commissioned	15 January 2003

6.0 Preliminary Design Review Objectives

By the time of the PDR, a preliminary system design encompassing all major elements of the receiver should be completed. At least one feasible solution should be presented for all engineering requirements. (The detailed design may be refined prior to the CDR.) Issues and alternative approaches that were unresolved or left for further study at the time of the CoDR should be resolved by the PDR. Schedule and budget should be refined for the PDR, and the final project team should be in place. Coordination issues across the required disciplines and working groups should be understood and agreed.