Preliminary Design Review Summary, 3mm Receiver

The content and order of topics in the PDR meeting held in Green Bank on October 2, 2001 followed the agenda which was published on October 1, 2001 by R. Norrod. For a detailed and comprehensive treatment of the review topics, the reader is referred to the PDR report that was published on September 25, 2001 and available at http://www.gb.nrao.edu/~rnorrod/3mmRx/PDRreport.pdf. The purpose of this note is to highlight the significant discussions from the PDR which led to changes to the plan, or have resulted in the assignment of action items to the attendees of the review.

Review of Specifications

Frequency Coverage:

The goal for module 1 remains at 68-92 GHz, though it was acknowledged that the performance will be optimized for the 70-90 GHz band, and that some degradation outside of this range for spectral line work would be acceptable. An accurate estimation of this potential degradation was not available at the time of the PDR, because several of the components to be purchased are non-standard, and performance data does not exist.

Receiver performance, in both continuum and spectral line modes, will not be compromised within the 70-90 GHz band. Outside this range, where we wish to provide for spectral line observing only, there will be some degradation with respect to channel leakage, receiver gain stability, and system noise temperature. In the event that a choice must be made between optimizing spectral line performance at the low end (68-70 GHz) and the high end (90-92 GHz), we will choose the former, as the 90-92 GHz range can be better served by module 2 (90-116 GHz) which will be a simpler total power heterodyne receiver, and will not be subject to the limitations of the pseudo-correlation architecture.

Bandwidth:

Spectral Line: Specifications for spectral line bandwidths have not been changed since the CoDR, though there were some new frequency conversion schemes presented at the PDR that show possible ways to achieve as much as 20 GHz of instantaneous bandwidth. A final decision on provisions for future wideband spectrometer use is pending results of current investigations by Norrod and Stennes. Please refer to section 2 of the "Resolution of CoDR Technical Issues" in this memo for more information regarding frequency conversion.

Continuum: The continuum detection bandwidth goal remains at 20 GHz, however, during the PDR, Ed Wollack raised the concern that the low-frequency end of the spectrum (70-76 GHz) may suffer from high levels of atmospheric noise (due to oxygen line) and that detection of these frequencies may not improve the sensitivity of the receiver. Stennes and Jewell will look into this.

Beam separation:

Early reports stated that 3-5 beamwidths spacing is acceptable. At the PDR, it became clear that the smaller beam spacings are preferred, for achieving the best cancellation of the atmosphere when observing point-like sources. As a goal, we will try to achieve a beam spacing of 3-4 beamwidths. During the PDR meeting, Sri presented two types of corrugated feedhorn designs. The first was a linearly tapered design, modeled after the GBT 12-15.4 GHz feed. Sri identified it as a good candidate for scaling to 68-92 GHz. The aperture for this feed would be 11.8 wavelengths at 80 GHz, and would give 5.2 HPBW beam separation. Sri's second feed is a compact design with a 7.5 wavelength aperture. The beam separation in this case would be 3.5 HPBW at 80 GHz. There was much discussion about the choice between these two feed designs. The compact feed allows closer beam spacing, but does not perform as well as the conventional linearly tapered horn in terms of cross-polarization and beam-squint. The phase center travel (with frequency) is greater for the compact horn, but subreflector movement can compensate for this. At the meeting, it was decided that R. Norrod would investigate the beam-squint and cross-pol issues further, and provide the group with recommendations (a set of requirements). These requirements would then be compared to the predicted performance of Sri's feedhorn designs, and a choice would be made. A short time after the PDR, Roger completed his investigation and reported that the compact horn would give satisfactory performance. We've chosen Sri's compact horn design for the GBT 3mm receiver. An added benefit of the compact horn design is that it is easier to provide a good impedance match to the throat section, which may result in a lower return loss as compared to the linear tapered horn.

Calibration:

An ambient temperature blackbody load on a switchable chopper wheel is planned, but there is concern about the possible saturation of LNAs when the feeds are viewing a 300 Kelvin load. M. Stennes will measure the compression point of the LNA. Results from these test will likely influence our choice of amplitude calibration method. A semi-transparent vane calibration may be a better choice.

Resolution of CoDR Technical Issues

1. *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.*

It was decided that we would continue with the original plan: The continuum band will be 70-90 GHz. The benefits of shifting the continuum window to 80-100 GHz with a separate receiver module did not outweigh the cost/complexity issues. Ed Wollack raised the concern that atmosphere noise may limit the usefulness of continuum detection of the lower portion of the 70-90 GHz band. Stennes and Jewell will investigate, and follow with a recommendation.

2. *Consider a 20 GHz wide IF.*

Several methods for achieving wide-band IFs were presented at the PDR. All were based on a mixer assembly quoted by Spacek Labs. Their mixer assembly offers conversion of the 68-92 GHz RF band to an IF in 2-26 GHz with 40 dB of image rejection. A final decision on a frequency conversion scheme is waiting on results of an investigation by Norrod and Stennes. They are evaluating the current availability and (near) future prospects of wide-band correlators from various research groups.

3. *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.*

PM is willing to create a new modulator design for this project without additional cost or schedule impact. There's a risk that there will be some degradation at the band edges (68-70 GHz and 90-92 GHz) for spectral line mode. The degradation will be evident as an increase in Trx and increased leakage of one beam into the other.

4. *Placement of both LNAs ahead of the biphase modulator to reduce Trx.*

If both LNAs are placed between the tees, they will be located ahead of the biphase modulator to minimize Trx. However, the final decision on where to place the second LNA will not be made until several components have been tested. We intend to investigate the possibility of placing the second LNA *after* the second tee (See next paragraph).

5. *Using higher switch rates, and placement of the second LNA outside the second tee*.

We plan to increase the maximum switching rate from 2.5 kHz to 10 kHz. The placement of the second LNA is still under discussion. Having the second LNA outside the differencing assembly will make phase and gain balancing easier, resulting in more effective cancellation of 1/f gain fluctuations of the first LNA. However, when the second amplifier is placed outside the differencing assembly, we would be relying on the phase switching to reduce its 1/f noise. It is not clear at this time how effective this technique will be. Testing will be required.

6. *How best to create circular polarization for VLBI?*

We plan to use a removable quarter-wave plate. It was noted in the PDR that a quarter-wave plate will not produce high quality circular polarization for the entire receiver band. Instead, it will be optimized for the standard VLBI band, 86.1-86.4 GHz.

7. *Continuum detection and baseband processing*.

The use of CalTech's baseband processing design is under negotioation.

8. *Vacuum window technology*.

Crystalline quartz with matching layers is preferred [20]. Tony Kerr pointed out that it would be advantageous to minimize the size of the quartz window. The maximum clear aperture diameter of a quartz window is 4.5 inches, based on the available size of quartz material. Tony also pointed out that large windows, being comparatively thicker, are more difficult to "match" with layered dielectric coatings. Therefore, by minimizing the diameter of the quartz window, we will reduce the required thickness and thus achieve the best impedance match (minimize reflections) over a broader frequency range.

9. *Segmenting the RF continuum path*.

The 70-90 GHz band has been tentatively divided into three equal parts, each approximately 7 GHz wide. However, as mentioned earlier in this memo, we may increase the lower frequency limit if it's found that sky noise is significant (Stennes and Jewell).

Thacker recommended having provisions for having additional RF outputs, essentially bypassing the second magic tees in the differencing assembly. Ideally, the auxiliary outputs would be activated remotely. Alternatively, the receiver could be reconfigured by removing and istalling waveguide.

10. *Design of a tertiary reflector and chopping system*.

The initial outfitting will not include tertiary reflectors, but will include a "chopping" wheel capable of a variety of rotational modes. There is a concern about the possibility of saturating the second LNA when using a 300 Kelvin blackbody calibrator. Stennes plans to measure the compression point of MAP amplifiers, and follow with a recommendation.

Components

Amplifier

The most promising candidate is the MAP W-band amplifer, or its "broadband" variant. John Webber also mentioned the existence of an E-band prototype. Stennes and Webber will investigate.

Kerr recommended that we measure amplifier gain compression in two ways: one with a CW tone as the input signal, and another with white noise as the input. He stated that there may be a significant difference between the two results.

Biphase Modulator

Webber asked for return loss data on the PMP biphase modulators, and suggested the use of isolators if needed.

LO System

Thacker suggested that we consider the use of PLOs rather than a step-recovery diode approach for generating fixed-frequency LO signals.

Optics

A preliminary optics dsesign, comprised of an ellipsoidal cylinder and a flat mirror, was presented by Sri.

OMT

Our plan is to use Ed Wollack's OMT design for this receiver, but at this time, it's not known whether or not the W-band design (now in production) will work well at frequencies as low as 68 GHz. The first production units are now being tested by Wollack and others, and we're waiting on the results. If the W-band OMT does not perform well at our frequencies, we will have to scale the OMT design in order to optimize its performance over our frequency band. At the PDR, it was noted that the results of these OMT tests will have a strong influence on the project schedule. Stennes will contact Grammer and Wollack to check on status and outlook of OMT tesing.

Costs

Webber advised us to increase the cost estimates for miscellaneous waveguide by $2K, and to double the allotment for connectors, temp sensors, thermal shields, and miscellaneous components.

Software Development

At the PDR, Richard Prestage stated that the project schedule items 83-85 seemed reasonable, but that the elapsed time should be 1 month. Richard also suggested that we add another task to the schedule for IF Manager development, called "Ancillary Software Modifications" with 1 month elapsed time. Finally, he recommended that the elapsed time of item 87 be increased to 1 month.

Near Field Testing

Webber suggested that we consider using the ALMA near field test range to evaluate the GBT 3mm optics, and volunteered to provide more details at a later date.