GBT K Band Focal Plane Array
Critical Design Review
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Final Report

Panel Members: Gopal Narayanan (U.Mass), Ed Wollack (NASA/GSFC), James Aguirre (U.Penn), Mark Heyer, Committee Chair (U.Mass)

Summary:
The NRAO staff has made significant progress in the testing and debugging of designed critical components required for the full 7 element system. Measurements gathered from the single pixel receiver both in the lab and on the telescope demonstrate that these individual components meet the established specifications with regards to noise, gain, frequency range, pixel-to-pixel isolation, and feed horn efficiency to achieve the stated science goals. Unexpected features revealed by the tests are now understood and affected components have been redesigned to resolve these problems. To date, there are no technical impediments within these designed components that would preclude the next phase to construct the full 7 pixel KFPA system. However, there are several key components that still require definition or further testing prior to the full assembly of the array. A high and immediate priority should be given to a thermal and wire harness design for the dewar. In addition, the communications protocol between the GBT Monitor & Control system and the frontend needs to be established and prototyped for debugging. The panel remains concerned about the input match to the integrated down converters that could affect the spectral baseline stability. The data pipeline has a design but no prototype that could be evaluated. Given the development times for software, the M&C interface and data pipeline are likely critical path items for its effective use by observers.

The focus of the group should be on the completion of a new and outstanding 7 pixel instrument for the GBT that will be highly valued by the user community. The consideration of design issues in the context of future, larger arrays should not impede the progress to complete the 7 pixel KFPA.

Review Aims

Did the single K-Band pixel demonstrate satisfactory performance as the prototype of the seven pixel instrument?
Measurements gathered in the lab and as part of the two campaigns on the telescope have demonstrated the EM components meet the specifications defined for the instrument with regards to receiver noise, gain, polarization, pixel-to-pixel isolation, feed efficiency.

Is the final design of each component in compliance with the system specification?

- Where there are final designs and built prototypes that allow for testing, the

components are in compliance based on the data presented at the CDR.

- Two critical components require design and prototyping
  - Thermal design for dewar: The full design of the dewar can not be considered complete without accommodations for heat dissipated by the devices. The positions and wrapping of heat straps and wire harnesses for DC biasing and monitoring, must be included in the packaging of pixels within the dewar. Likewise, the routing of cabling must be specified to allow installation and service access for the full 7-pixel instrument.
  - Communication protocol between GBT M&C and instrument : The current descriptions are only schematic. This is not a difficult problem yet its implementation is critical to the integration of the KFPA with the GBT control system and its effective use by observers.

Is there any component that may compromise the instrument's scientific objectives?

- There are several concerns related to the input match from the LNA output to IDM as these may impact baseline stability. What is the return loss at the IDM? What are the effects of gravity on the sliding waveguide interface section? More tests are required to quantify these effects. An overall reduction of the reflection coefficient of elements in this region (or termination of standing waves by an ferrite isolator) could reduce risk in this aspect of the design.
- The generation of I.F. spurs by the down converter is well understood, and design modifications of the IDM are defined. Implementation of these changes are limited by available technician time and may place some risk to complete full system
- Gore-Tex membrane. How would fluttering of this membrane ahead of the feeds impact baseline stability? Can this be measured in the lab or demonstrated by analysis to be negligibly small?

Are the compromises for expansion and decisions to simplify the design justified given the schedule and GBT turret constraints?

The committee strongly endorses the compromises that have been made to simplify the design to remain on schedule. While the 7 pixel array is a pathfinder for larger focal plane arrays at K or W band, it is also an important science instrument. Therefore, its development and progress to deployment should not be slowed by designs and implementations that in some cases, will not readily scale with more pixels. The committee strongly encourages the team to focus on the completion of the 7 pixel system and getting this onto the telescope.

Is the schedule achievable, budget and spending reasonable?

There were not any detailed presentations of the budget. Based on summary costs to date and allocated funding, the KFPA program appears to be on-schedule and on-budget.

The committee commends the Project Manager for his oversight of this program. He has kept the program on schedule with reasonable costs. Moreover, from an external viewpoint,

this program has been characterized by transparency of information and decision making. It has sought and received input from the community. The KFPA wiki page (and the NRAO public wiki in general) has been a valuable asset for anyone to keep informed of the project status.

Are there any obvious critical path items that will compromise the program?

We believe the two major software components are the critical path items to full deployment to the user community.

- As noted above, the M&C interface to the instrument and communication protocol has not been fully described. While there are not any strong real-time requirements for the system, the small amount of control and monitoring still needs to be implemented. Until there is a full design and working prototype, this component is unproven and its completion date can not be reliably determined. The primary concern is that delays in the implementation of the interface can impact the schedule for testing other components.
- Data Pipeline: The software pipeline scope and priorities are appropriate. The gridding steps/algorithms are already established. However, there is bookkeeping, data editing, and user feedback at various pipeline steps that need to be coded and verified. The committee strongly urges the development of a software simulator that can verify the process while spawning new feedback/data editing tools. Verification with the simulator can greatly reduce the complexity of debugging the pipeline when fed with real data at the telescope. It is not essential that the data from a 7 pixel array be processed with parallel computing systems. If this adds significant complexity to the development, then the parallelized version of the pipeline can be delayed or simply not implemented.

As defined by the observing-mode document, is the pipeline development and data analysis reasonable in its approach? Are there any other modes to be considered?

On-the-Fly (OTF) Mapping places the largest demands on the pipeline given the data rates and gridding of data into a spectroscopic data cube. More importantly, it should be the preferred/default mode as this provides the best image fidelity. The pipeline should therefore emphasize the processing of OTF data. Other modes may be considered as a subset of OTF mapping as these require many of the same processing steps and could also use the pipeline. The KFPA is a spectral line instrument. NRAO should maintain its focus on the processing of spectral line data and the corresponding observing modes. The initial observing modes should be kept simple yet effective – even at the cost of reduced flexibility for observers. With experience of use, more innovative data collection modes can be developed later. At this point in time, a reliable spectral line OTF pipeline should be the goal. An appropriate amount of time has been left in the schedule in early 2010 for the integration and test of the instrument and pipeline. The committee suggests that software development may be aided at this stage by the solicitation of shared-risk observing modes to bring the experience of seasoned observers to bear.