EVLA Front-End Systems Critical Design Review

The review was held in the AOC Auditorium, Socorro NM, and at the VLA site, April 24th-25th 2006.

Review panel members:

Roger Norrod, Head of the GBT Microwave Group, Green Bank, WV.
Ganesan Rajagopalan, Head, Electronics Dept, Arecibo, NAIC.
Neil Roddis, Receivers Group Leader, Jodrell Bank Observatory, UK.
Ed Wollack, Senior Scientist, Goddard Space Flight Center, NASA.

Charge to the review panel

Mark McKinnon, EVLA Project Manager, charged the review panel to answer the following questions and to submit a written report addressing these questions and any other important issues that were identified by the panel.

- **Are the detailed requirements for the front ends complete and adequate?**
- **Will the designs selected for implementation meet the requirements?**
- **Are interfaces to other subsystems defined adequately and completely?**
- **Has adequate attention been given to the production, testing, and maintenance of the front ends?**

The review panel's response to these questions is given below, together with their comments on technical aspects of the EVLA Front-End upgrade.

Are the detailed requirements for the front ends complete and adequate?

Overall the panel felt that the definition of the requirements for the project was comprehensive and realistic. However, there was some concern that there is not yet any experience of the RFI conditions in the new wide bands, especially L-, S -, C-, and X-bands. This throws into question the adequacy of the headroom specifications. We recommend that RFI surveys be performed urgently in order to quantify the extent of the problem if there is one.

Will the designs selected for implementation meet the requirements?

For the most part the designs selected appear to meet the requirements of the project, allowing hardware production to proceed in most areas. OMT design is the major area of concern. The panel was very impressed with the design of the new L band OMT; in particular the return loss, phase balance and isolation all look very good and the treatment of the trapped modes is excellent. However, noise performance clearly needs attention before going to mass production. The OMT designs are a serious concern because the unresolved issues with the L band design impact on dewar design and on the S and C band designs. These are also delaying the decision as to which type of OMT to use at X band. Hence, the review panel suggests that more resources, manpower, hardware and test infrastructure, be applied to the L band OMT development work. Furthermore, the panel recommends actively seeking advice from other groups with experience in OMT design and production. Although the panel has been reassured that the OMT design is not holding up the EVLA common dewar design we nevertheless see success in this area as crucial to meeting the project goals. In view of the criticality of the OMT design there is an appendix at the end of this report which deals exclusively with OMT design issues, and offers some suggestions in respect of the design and its evaluation.

Other design issues include the waveguide window for L band, which appears to have limited manpower resource dedicated to it. The review panel suggests that a selection of appropriate window materials be identified and tested radiometrically and mechanically.

Programmable equalizer design is required urgently in order to be able to complete T304 design.

Are interfaces to other subsystems defined adequately and completely?

Most of the interfaces to other subsystems were thought, by the review panel, to have been well defined. A few minor areas of concern were identified.

We are concerned about the interface between power supplies and low noise front ends, and suggest that the voltage clamping default should be made safe for InP devices; special case clamping should be provided for the higher power devices. In addition the panel recommends that bias card output voltage adjustment ranges should be limited to avoid device damage. Consultation with CDL is recommended to define these voltages.

The panel recommends the adoption of a common grounding scheme for the front end systems, so they are all built to the same specification. This should be summarized in a configured drawing.

Has adequate attention been given to the production, testing, and maintenance of the front ends?

In our view the production program looks very demanding, and is hampered by the need to maintain the existing systems using the same staff. Furthermore, the impression of the panel was that a considerable amount of time is being spent by engineers doing management and organizational tasks that could be taken on by others, thereby freeing the engineers to concentrate more of their time on development. At this stage of the program technical issues need to be given a very high priority in order to meet the production schedule. The EVLA front end schedule needs to be updated to reflect the interim system work. There is some indication that coordination between groups or within groups could have been improved in the past. (For example, we note that the delay in the production of the card cages and/or monitor/control modules has caused interim receiver installation with older card cages.) The review panel suggests that consideration be given to early production of one of the better defined receivers, in order to concentrate on final systems rather than interim. This could be done in parallel with OMT development. It seemed unclear whether sufficient in-house resources are available for the assembly work on the Q and Ka band down converters.

We support the decision to buy the parts in advance: this is economically desirable because of quantity discounts, and is necessary to aid meeting the tight production schedule. We advise inspection and test of components within the warranty period. Selective cryogenic testing of critical components is recommended; if necessary other cryogenic testing facilities within NRAO should be explored. Out-sourcing some of the assembly work to VLBA sites is clearly attractive to make best use of manpower, but we urge that some level of testing be performed by the assemblers to reduce the potential for re-work.

The review panel was impressed with the laboratory test systems, and particularly appreciated the axial ratio measurements and the quick noise measurements with the Scalar Network Analyzer. We suggest that there should be a test plan and check list for each receiver, together with a test record archive for each receiver. These should include laboratory tests and telescope tests. We commend the scientific staff for testing systems early on the telescopes so that design issues are identified and corrected as soon as possible. This is seen as a priority.

We were impressed by the cryogenic systems developments.

We were also impressed with the water vapor radiometer work but agree with the decision to delay this project for the time being.

Conclusions and recommendations

Overall the panel felt that the definition of the requirements for the project was comprehensive and realistic, and that for the most part the designs selected appear to meet the requirements of the project, allowing hardware production to proceed in most areas. Also, most of the interfaces to other subsystems have been well defined. The production program looks very challenging, and the need for production staff to maintain existing systems is a problem; advanced purchase of parts was seen to be desirable both economically and to help meet the production schedule. The panel was impressed with the efficiency of the cryogenic developments. Receiver front end test facilities were also seen to be well thought out and effective. Clearly the completion of the design of the L band OMT is crucial to the program; further technical discussion is detailed in the appendix to this report.

A number of recommendations have been made by the review panel in the detailed sections above; these include the following.

- Perform an RFI survey on-site.
- L band OMT: apply more technical resources.
- L band OMT: investigate noise contributions (see appendix).
- L band OMT: seek advice from other groups with OMT design experience.
- Further investigation of waveguide window material.
- Expedite programmable equalizer design.
- Review clamping and limiting of bias card output voltages.
- Adopt and document a common grounding scheme.
- Where feasible, reduce management and organizational burden on engineers.
- Consider early production of one of the better defined (e.g., Ka band) receivers.

Appendix: Panel comments and suggestions on the L band OMT design and manufacture

The prototype L-band OMT displays impressive performance, and the assembly of the second unit now under way will provide some indication of how well it can be reproduced. It was completely advisable to design the prototype unit as was done to allow adjustment during tests, but attention to mass manufacturing issues at this stage of development could be of large benefit. Consultations with mechanical engineers or other groups who have produced similar units should be sought. Dip-brazing of the aluminum structure could be considered, but potential issues with this technique include the achievable precision and the surface roughness of a finished assembly. Electroforming of the shell around machined ridges (as was done on the VLBA/VLA 1.3-1.8 GHz OMT) is another possibility. It may be that a bolted assembly proves to be the preferred solution, but the robustness under multiple thermal cycles should be investigated. Contact between the ridges and the shell may need to be improved using high-pressure contacts, indium seals, or other means. Adequate compression of the flange interfaces upon cooling with bevel washers, or similar arrangement, should be verified. With the current use of materials and fasteners it is unclear at this point if this aspect of the mechanical design has an impact on the electrical performance.

Difficulties with cooling the prototype L-band front-end have slowed the development. Experience with similar systems indicates these problems are solvable, and the panel recommends concentration on doing so in the short-term. Use of additional temperature sensors to evaluate the cold strap efficiency, radiation shields, and refrigerator capacity should prove useful in understanding the design in it present state of development. The use of a LN2 precool system for the OMT might also be considered.

A compilation of a loss budget for the OMT structure, which summarizes where possible the experimentally validated data, may prove useful in tracking down the excess noise. In particular, we would recommend summarizing the loss of the quadridge structure, hybrid, interconnecting cables, connectors, thermal break gap, and losses to mode conversion. Comparison to the modeled expectation for a perfect-E structure with lossless joints would provide a useful figure of merit. Although only representative of the structure performance, it could facilitate conveying what is anticipated and where the dominate gains might be realized by increasing the level of integration in the structure. For example, one possibility discussed by the review panel was the use of a superconducting hybrid with integrated -30dB calibration coupler. Measurement of the OMTs response (with and without the coaxial elements) with a shorted input or similar is recommended to understand the loss.

Another suggestion, in consideration of the noise contribution of the OMT, is to plate the brass OMT probes with >3 skin-depths of high-conductivity copper, gold, or silver. Experience shows that this could potentially save several kelvins.