VLBA Sensitivity Upgrade Memo #10

Proposal to Upgrade the 22 GHz Receivers on the VLBA Antennas

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The following text is the proposal that was submitted on October 13, 2006 to NRAO upper management for the upgrade of the eleven VLBA 22 GHz receivers. The project was approved in November 2006 with a scheduled completion date of December 2007.

SUMMARY:

We propose replacing the LNAs in the current VLBA 22 GHz receivers with new amplifiers of a more advanced design. This upgrade is expected to increase the sensitivity of the instrument in the 22 GHz band by about 30%, which cuts the integration time or bandwidth required to reach a given sensitivity by more than 60%. The 22 GHz band is one of the two most heavily used bands on the VLBA so the improved sensitivity will benefit many users. It is especially important for expected efforts to measure the Hubble constant using water masers in galactic centers as was done for NGC4258. An upgrade to the 22 GHz receiver was one of the recommendations of the 2004 report, "Mapping the Future of VLBI Science in the U.S." The upgrade will take one year from the start of project and will cost $299K. Costs are about evenly split between new hardware, manpower to do the project, and a new receiver evaluation rack. The new manpower and test rack are required to do the project in one year without impacting the EVLA construction schedule.

JUSTIFICATION:

The technology of low noise cryogenic amplifiers has advanced significantly since the VLBA receivers were designed in the 1980s. Five of the 22 LNAs on the VLBA (two per receiver for dual polarization) have been upgraded to the KH design with MAP style amplifiers but these devices used older technology chips. An upgrade to the latest Cryo 3 devices can reduce the receiver temperatures of these systems by 5K. The other 17 LNAs are the original design. They can be improved by an average of 27K. The average system temperature in winter conditions of the non-KH systems is 89K which is projected to be reduced to approximately 62K for a 30% improvement.

One of the potentially most important science projects that will benefit from this upgrade is the effort to measure distances to several galaxies using H_2O masers in a manner similar to what was done with NGC4258. Such a project would attempt to measure the Hubble constant more accurately than has been done so far. Many of the parameters of modern cosmology are constrained by observations such

as those of the microwave background, but depend in their value on knowledge from elsewhere of the Hubble constant. An accurate measurement of the Hubble constant would have a direct impact on our understanding of cosmology. The candidate masers are weak and of finite bandwidth, so such observations will be sensitivity starved. Increasing the bandwidth is not an option for spectral line work. Other than increasing the collecting area, improving the sensitivity of the receivers is the only way to improve the chances of success and is a motivation to make this long-desired upgrade now.

Of course the above project is just one example. All other 1 cm science will also benefit. The 1 cm band is one of the two most popular bands on the VLBA (along with 20 cm), accounting for 16% of all observing time in the last three years. Upgrading the 22 GHz receivers on the VLBA was one of the recommendations of the Taylor/Lonsdale committee in their 2004 report, "Mapping the Future of VLBI Science in the U.S."

PROJECT DETAILS

Amplifiers:

The 22 GHz upgrade will involve replacing the two LNAs in each receiver package with modern InP amplifiers from the CDL. The first stage of each amplifier will use the latest Cryo 3 devices. The original feeds and polarizers will be retained because replacing them with EVLA designs would require an entirely new receiver package, creating an additional expense. The packaging for the new amplifiers is somewhat different from the old amplifiers so new wiring and waveguide parts will be needed. Additional circuits will be needed to protect the amplifiers.

The construction plan is to have the CDL build the amplifiers and send them to Socorro. In Socorro, the amplifiers and other required hardware will be installed in the receivers and the receivers will be tested. It is expected that the CDL can provide the amplifiers at a rate of about two per month so the 22 required for the ten VLBA sites plus spare receiver could be available in about a year.

Staff:

The current EVLA schedule and the associated Front End staffing profiles cannot accommodate an additional 11 receivers in one year. Bearing the additional projected work load in mind, the additional 11 receiver modifications could readily be accommodated by one qualified individual who is retained specifically for this effort. This individual will be responsible for parts acquisition, receiver modification and receiver testing, and performance to schedule. The most expeditious hiring method for this activity is an employment placement service that can supply an employee with the requisite skills and abilities. This additional staffing will insure that the project can be completed successfully in

one year with minimal impact to ongoing operations, activities and commitments.

Laboratory Space:

There will be receivers for 6 EVLA bands under development during 2007, each requiring a couple of benches. So lab space needs to be considered, but should not be a problem. The required work space for this project can be realized by commandeering the workspace that has historically been used by college student work activities. The only additional issue is the reconfiguration that will be required to provide for cooling down the receivers (simple task).

Test Equipment:

The availability of required test equipment is a key element in the success of any technical program. The 22 GHz receivers will be test verified using the new EVERETT (Expanded VLA Enhanced Receiver Evaluating Test Terminal) receiver evaluation racks of which currently there are two. Beginning FY2007, the Front End Group is scheduled to produce four EVLA receivers per month based on the current EVLA schedule. With this amount of activity in mind, increasing our receiver production commitments by 25% is adventurous at best.

One suggestion is to test the VLBA 22 GHz receivers by a swing shift when the EVERETT racks are not being used. Given the EVLA receiver delivery schedule, both of the EVERETT racks will, in all likelihood, be in use at any given time. Once the test equipment has been reconfigured, it must be given time to stabilize prior to re-calibration and testing. Breaking down a test setup and reconfiguring for swing shift testing and then breaking down that configuration and reconfiguring to recommence day shift testing is poor engineering practice and is to be avoided.

Acquiring an additional EVERETT test rack is the best solution and creates a win-win situation for both VLBA and EVLA. The benefits to both short term and long term receiver testing efforts are tremendous: no impact to either schedule in the short term and higher delivery rate capabilities in the long term.

Cryo Shop:

We should not lose sight of the fact that all completed receivers must be sent to the Cryo Shop at the EVLA site prior to fielding them. The Cryo Shop performs the independent leak checks and final cool down verification for each receiver. The Cryo Shop is subject to the same EVLA schedule commitments as is the Front End Group, along with non-scheduled receiver maintenance activities. Nonetheless, the Cryo Shop has stated that they can support this task.

Plan Implementation:

All modified receivers would be installed 12 months after receipt of contract for the effort. The first article should be completed within the first three months of the start of the program schedule, with the remaining 10 receivers completed in the following nine months.

For a 12 month plan, allowing for the time required for shipping both ways, for the time that each receiver must be in the lab, and for the three month startup, it is impractical to maintain a continuous 10 station capability at 22 GHz throughout the project by only working on, or shipping, the current "spare". However various viable scenarios have been identified that provide for intermittent periods of ten station capability during which, with dynamic scheduling, the demand for 22 GHz observing can be serviced. The simplest is to have two receivers either in transit or in the lab most of the time on a staggered schedule. As each is put back on the array, the next is not taken out for a week or so during which ten station observing is possible. That will be the default scheme, although alternatives might get exercised as experience is gained. In any case, efforts will be made to keep gaps in ten-station observing at 22 GHz to less than two months, and to support any required fixed schedule projects such as a global session.

COST AND MANPOWER:

A spreadsheet with a detailed cost breakdown was provided with the original proposal, but is not included in this public memo. The sums for top level elements were $90K for parts, $103K for labor, and $105K for the new test rack. The cost for the amplifiers is the full cost to CDL, including labor and is included in the parts costs.

The project will be carried out by the Socorro Operations Electronics Front End Group under the guidance of Charles (Chuck) Kutz II, Group Leader. Craig Walker will be the contact person for operations and scientific oversight.

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