Report: EVLA FE System and Feed Cone Design Review Panel

This report on the findings of the EVLA FE PDR Review Panel is based on a top level presentation of the design plans conducted on February 12 and 13 at Socorro. The purpose of the review was to answer 3 principal questions:

1. Are the top level performance requirements complete and adequate?
2. Have the correct design solutions been selected for study and development during the EVLA design phase: Are there important alternate solutions that are not being studied?
3. Has an adequate procurement plan been identified for the subsystem?

Members of the Review Panel attending were the following:

German Cortes, NAIC
Eugene Lauria, CDL
Roger Norrod, GBT
Bruce Veidt , HIA
Peter Napier, Project Manager
Rick Perley, Project Scientist
Jim Jackson, Hardware Systems Engineer
Gareth Hunt, Software Systems Engineer
Terry Cotter, LO/IF Task Leader
Paul Lilie, Receivers/Feeds Task Leader
Bill Sahr, Monitor and Control Task Leader
Jim Ruff, Antenna Task Leader

The Review report is divided into five parts: I) Comments from the Panel Review, II) Comments during the open meeting presentation, III) Questionnaire inputs, IV) Conclusions, and

V) Letters.

Part I. Comments from the Panel Review

-- The 2:1 bandwidth ratio required of the OMTs is optimistic. Is performance attainable? Will band edge degradation be acceptable? Should you consider ATA design?

-- The BW ratio also causes waveguide in the receivers to be used close to cutoff frequency where the waveguide resistance will go up. Increased resistance will result in higher receiver temperatures.

-- Trapped or unwanted modes may occur in the OMT because of discontinuities at the transition to the feed. The resulting resonances will cause nulls or "suckouts" accross the band. Making the OMT longer will make the suckouts smaller, but there may be more of them.

-- The proximity of the high frequency feeds to the large L and S band feeds may cause shadowing. Define the correct criteria for non- shadowing such as the relationship between the edge of the feed and edge of the subreflector, spread of aperture with phase error, and electrical isolation of wavelengths beyond the beam.

Detailed calculations need to be made to confirm that the significant axial defocusing of the L and S band feeds and the lateral translation of the L band feed do not cause unacceptable loss of performance. Don't forget the spillover effects of the L band translation.

-- L-band FAA radar in Roanoke causes saturation of the receiver at the GBT and filters had to be installed. Why doesn't the comparable radars in Albuquerque at 1310 and 1330 MHz cause saturation of the VLA L-band receivers? Should this discrepancy be understood in designing the new L-band feed? Propagate RFI through the L-band design and look for nonlinearities.

-- The proposal to reduce cost for the upper frequencies through use of block mixers as proposed by Bob Hayward should be reviewed carefully and adopted if possible.

-- Finding dewar window material that will hold a vacuum and have a suitably low dielectric constant will take some time; start early. Extra insulation on the dewar may help.

-- Have you adequately reviewed the design for RFI intermods?

-- S-band isolators don't work because of the physics of the devices. Because of this it may be necessary to used balanced amplifiers at S-band.

-- Coordinate construction closely with CDL. Low frequency devices may require a new wafer from TRW for LNA fabrication.

-- S-band must be mapped across the band; one point is not adequate.

-- Develop specifics for M&C requirements. Avoid special requirements like disabling monitoring during a slew: complex and robust are incompatible.

-- Need spillover implications for L-band.

-- What are scientific requirements for power stability?

-- Divide the system specification between elements of the design. What are the overall bandpass ripple and flatness requirements and what are budgets for separate elements to achieve them?

-- Use holography to find centroid of subreflector and avoid off center illumination which would degrade the image. [Note: Rick Perley presented holography measurement results at a VLA Test Meeting Feb 21 that show Ant 8 and others have off center illumination. According to an ALMA paper by Mark Holdway, doing so changes the baseline and introduces a phase gradient as well as degrading the image. Rick's measurements on Ant 8 confirm the predicted impact on phase gradient.]

-- Pay attention to port-to-port isolation in feeds. What is specification for polarizatin stability? How will reflection of feeds impact polarization?

-- Procurement: Decide the design for the L-band feed very soon. It is needed for test antenna in Q2 2003.

-- Procurement: Need criteria for build or buy.

Part II. Comments from open meeting.

Feeds design

-- Is the center frequency band dip in L-band performance tuneable so that it can be moved out of the way for certain experiments?
Commenter would prefer optimization of feed at 1.3 - 1.4 GHz.

-- What is cross polarization of compact (62") L-band feed horn? Is the polarization constant with time?

-- What is the performance of S-band at bandedges?

Feed cone and feed fabrication

-- Save feed ring space by using one dewar for two or more high frequency receivers?

-- Use RFI caulk or tape on cone segments?

-- Side slope of segments should follow ray.

-- Attach cup for Q-band horn at bottom flange and make it RFI and weather tight.

OMT design

-- 0.2 dB of insertion loss at ambient will cause 5% loss in G/T.

Feeds production

-- Feed heaters cause debris in feeds: need to paint, service?

-- Need calibrator to verify orthogonality and ellipticity (see letter in Part V.)

-- Need to pay careful attention to QA during production of feeds.

High frequency receivers

-- Lower bottom end of Q band to 38 GHz to balance bandwidth ratios between Ka and Q.

-- 28 GHz LO planned for use with Ku-band will need adequate shielding.

Low frequency receivers

-- Why is temperature stability needed for post amps?

-- Do we need a total power stability specification?

-- Slide 6 has error in polarizer lengths.

-- Slides 10 up have error in OMT operating temperature specification.

-- Uniformity needed in spectral response of noise diodes from antenna to antenna? Would need adjustable attenuator? Why are cals taken at bench now different when measured again on the antenna?

-- InP LNAs don't work below 3 GHz.

-- Slide on C band receiver needs more development.

-- Why is installation of cal couplers after the OMT? ATNF inserts their couplers in feeds.

Solar design

-- How will the dynamic range be transferred to accomodate solar?
Observer, signal detection?

-- Use PIN diodes for S-band isolator?

-- EVLA design must replace function of existing system as a minimum.

-- What is the recovery from saturation?

WVR

-- Are we convinced that usefulness in operation justifies the expense? What percentage of observing time will WVRs actually provide useful data?

-- Is data rate provided for in M&C design?

Monitor and Control design

-- Plan for outgassing of circuit boards installed in dewar. Also, provide for memory after "power on" with non-volatile components.
See Wes Cramer for experience in this area.

-- Monitor continuosly and straighten out differences in software to keep hardware operation simple.

RFI

-- The strategy after 1st stage should be to avoid RFI. Avoiding is not the same as excision and both are needed.

-- Consider the use of special filters, but avoid cooled filters.

-- Can't split stages of Bradley's LNAs.	One reviewer points out that if you split the stages *without* 90-degree couplers to convert back to single-ended then you have to have very similar filters.

-- Consider use of FE filters for different IF BW like in current system.

-- Is the plan to clock the MIB only when transferring data overkill?

-- Need to know signal level below 3rd order intercept point which will avoid intermodulation interference.

Part III. Questionnaire inputs

-- What are the MIB requirements for the 4 m and 90 cm wavelength band receivers?

-- For de-icing the feed windows, would it be better to heat directly rather than using the current indirect heat lamp system? A different methology would eliminate lamp maintenance and the problem with debris falling from the lamp onto the feed.

Part IV. Conclusions

1. Are the top level performance requirements complete and adequate?	a. Some additional specification recommended for total power stability.
b. What are minimum requirements at band edges?

2. Have the correct design solutions been selected for study and development during the EVLA design phase: Are there important alternate solutions that are not being studied?
a. 2:1 bandwidth ratio for OMTs may be impossible to achieve.
b. More modeling is needed for bandedges, especially S-band.
c. Trapped modes for OMTs need to be better understood.
d. Consideration of Hayward's modified block mixer proposal for high frequency bands is recommended.
e. The performance of L-band in the presence of strong external RFI needs to be verified.
f. Need to check more carefully for shadowing at the higher frequency bands.

3. Has an adequate procurement plan been identified for the subsystem?
a. Need to plan immediate procurement of new L-band feed for installation on test antenna Q2 2003.
b. Need criteria for build vs. buy.

Part V. Letters.

Dear Rick and Peter,

Here is a more specific description of the polarized "cal" source that I suggested would improve the calibration and day to day operation of vla/vlba type antennae. It is based upon over three decades of using a similar device on the UMRAO 26-meter. The suggestion is to illuminate the feed horns with a highly linearly polarized, broad-band signal source. At Michigan, we have used a noise diode at the input of a small broad band antenna mounted at the vertex of the 26-meter. The high purity linear polarization is achieved using a polarizing grid, consisting of closely spaced metal strips. Our original design was to depend upon the waveguide feeding the small antenna to determine the orientation of the electric vector, but my paranoia about possible multi-moding in a multi-octave device (we are currently using this polarization source over the range 4.5 - 25 GHz) led to the installation of the polarizing grid. The absolute accuracy of our PA ref (by the grid) is estimated to be 0.15 deg. We use a miniature replica (approx 1-ft square aperture) of the Bell Labs "sugar-scoop" antenna to get the broad band performance (the design specs were from an old article in the Bell Labs Journal). The source antenna could actually be considerably smaller -our original design was to achieve an effective Ta of 10-degrees at our prime-focus feeds using an argon discharge tube: the noise diodes typically give us a Ta of over 100K at their peak frequency). Incidentals: we protect the grid/antenna assembly from weathering using a thin sheet of a fiberglass like material used in radomes (we used Rexolite in the past but it broke down after several years of exposure to sun light); the noise diode is fed by a constant current source, but we have made no attempt to temperature stabilize the diode; also we have found no problems modulating the supply current at our (Dicke) switching frequency (near 100Hz) in cases where horn switching is not available. In a vla/vlba system, the polarized source could be mounted in a small hole in the sub-reflector located at the center of the sub-reflector (as seen by the feed horn on the feed horn ring). This portion of the sub- reflector otherwise simply reflects emission from the feed horn back into the feed horn - an area that is already shadowed by the sub-reflector. I have not investigated the dimensions but I am guessing that it could fit next to the P-band horn hole on the current VLA sub-reflectors.

Uses of this polarized cal source:

1. Brief observations of the calibrator while looking at the cross-correlation between R & L would immediately determine the phase difference zero- point. Note that as the sub-reflector rotates to illuminate different feed horns, the absolute PA (defined in the local alt-az coordinates) will rotate as well, but this is a trivial correction that can be built into the analysis software. A similar calibration could also be achieved by injecting broad band cal signals at the appropriate place in the mode-conversion network associated with each feed/receiver. The advantage of this external system is that only a single source need be fabricated and maintained for each antenna (not 8). Also the plumbing in the cooled part of the systems can be made simpler (no

extra directional couplers and noise sources (or switches) are needed.

2. Even a fixed PA signal (for each horn) gives one some degree of calibration and performance verification of the complete feed-horn -> back-end chain. A complete characterization of the feed systems (ellipticity and the orthogonality of any residual response to linear polarization) can be determined if the polarized cal source is rotated (through at least 180 deg). This would be useful for the initial commissioning phase, but would also be valuable for subsequent calibration as the equipment ages. I would not envision this mode of use for routine linear pol observations, but for precision circular polarization, such a calibration ability would be invaluable. Also for particular experiments (e.g. wide field maps) where cross-pol leakage is especially important, an observer could identify optimal frequencies where the feed systems operated better than average.

Aside from these obvious uses, an external noise has turned out for us to be very useful in the day-to-day operation of an "on all the time" facility. If a malfunction is suspected, the operation of the entire signal chain can be quickly verified. Also, since the Ta of the signal is comparable to our strongest sources (e.g. Cas A), the linearity of the system can be measured to a fraction of a percent by simply leaving the polarized cal signal on during an observation of our standard low level cal signal.

I hope that these ideas are helpful.

Sincerely,

Hugh (Aller)