This report includes the findings of the EVLA FE PDR Review Panel and the response by the Task Leader. The report 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
im 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. The original findings are designated by a ">" and the responses follow.

> 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?

1. There are three lines of attack: Paul Lilie is working on a short quad-ridge OMT, a group in CV is working on a completely symmetric OMT, and the fallback is scaling and optimizing the ridge profile for the traditional QR OMT, as the Australians have done.

To Paul's knowledge, the ATA intends to use crossed log-periodic feeds. For a cassegrain antenna these would be impractically long.

See also 3, below.

> -- 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.

2. The lower band-edge will be at 1.1 times the cutoff frequency of the circular waveguide input to the OMTs for L, S, and C bands. This waveguide is very short as the feed is bolted directly to the front end. The quad-ridge waveguide in the OMT will be working well above cutoff, and its loss, which increases across the band, will predominate. The dissipation loss of the OMT is estimated to be less than 10 mB, and it will be cooled.

Raising the lower band-edge further above cutoff would allow more propagating modes at the high end of the band.

> -- 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.

3. In circular waveguide, the TM01 cutoff occurs at 1.31 times the cutoff of the dominant TE11 modes. Therefore, any bandwidth above 1.31:1 will involve multiple modes. In the quad-ridge structure, some of these modes may be trapped, that is, able to propagate in the quad-ridge section, but cut off near where the ridges end. At those frequencies where the length of the propagating region is a multiple of a half-wavelength, a high-Q resonance will be possible. If there is coupling from the desired TE11 modes to these trapped modes, a suck-out will occur. These may be unavoidable. The CV group's OMT design reportedly assumes this intermode coupling is due to discontinuities and asymetries in the OMT, and aims to avoid them.

The (first order) chain of reasoning is thus:

a. The size of the subreflector drives the size of the feeds.

b. The size of the feed circle then determines the number of feeds which can be accommodated, dominated by the size of the L, S, and C band feeds.

(We can't afford to replace the subreflector and/or move the feed circle.)

c. The desired frequency range, divided by the number of feeds, gives the frequency range that each feed (and front end) must cover.

d. The only type of OMT we believe capable of covering this range (2:1) is the quad-ridge design.

d1. An undesireable feature of this design may be the presence of several very narrow "suck-outs", of the order of 1.5 dB deep and 1 MHz wide.

d2. These suck-outs will be at known frequencies, which will probably differ by a few MHz from antenna to antenna.

d3. It may be possible to tailor the location of these suck-outs somewhat to avoid sensitive regions of the spectrum.

f. Alternative OMTs (~1.5:1 maximum frequency range) would require abandonment of ~~40% of the spectrum below X-band.

Therefore, go with quad-ridge OMT.

> -- 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.

4. Sri and Ed Szpindor are making these calculations.

> -- 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.

5. Possibly we have not seen this here because it is far enough outside normal observing band. Dan Mertely is Surveying RFI levels at the VLA, and "headroom" is kept in mind throughout the signal chain design.

> -- 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.

6. This proposal is now part of the plan.

> -- 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.

7. Dan Mertely and Ed Szpindor are investigating these materials.

7a. The comment about extra insulation may refer to placing a foam piece under the window to reduce condensation; if so, we are experimenting with the idea on K-band feeds.

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

8. Not yet, but we're working on it.

> -- 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.

9. Dan Mertely is investigating this.

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

10. Coordination is being done.

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

11. Noted.

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

12. Agreed.

> -- Need spillover implications for L-band.

13. Agreed.

> -- What are scientific requirements for power stability?

14. See 15, below.

> -- 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?

15. These specifications are now in the project book. They have been divided between subsystems to a reasonable extent.

> -- 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 Holdaway, 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.]

16. Not really a design issue for this PDR, but it sounds like a good thing to do.

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

17. Isolation will be maximized to the extent that it does not degrade performance. Again, this may be dominated by OMT performance.

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

18. Proceeding, on track.

> -- Procurement: Need criteria for build or buy.

19. Agreed. However, must be done on a case-by-case basis, weighing all factors.

>
> 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?
> Commentor would prefer optimization of feed at 1.3 - 1.4 GHz.

20. Performance will be made more uniform across the band.

> -- What is cross polarization of compact (62") L-band feed horn?

> Is the polarization constant with time?

21. This will probably be dominated by the performance of the OMT. It should be dependent only on the dimensions of metal structures and so quite stable.

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

22. Performance at the edges of any band has not been specified in detail. We are starting to look into this now.

> Feed cone and feed fabrication
>
> -- Save feed ring space by using one dewar for two or more
> high frequency receivers?

23. We do not plan to do this. The only bands having feed diameters smaller than the dewar diameter are Ka and Q. Putting these in one dewar would save only about 4" in the ~240" circumference. This would allow making the L-band feed larger in diameter or moving its axis closer to the feed circle, but the gain in performance would be small. It would also eliminate one refrigerator. It would require a complete redesign and rebuild of the existing Q-band front ends, which otherwise would not require internal modification.

> -- Use RFI caulk or tape on cone segments?

24. This will be investigated.

> -- Side slope of segments should follow ray.

25. Presumably so feed cone roof does not increase blockage.

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

26. Jim Ruff's feed mountings will take RFI and weather-tightness into account. Feed pattern considerations are being addressed. See 4, above.

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

27. Insertion loss will be minimized to the extent

practicable. 0.2 dB *at ambient* would be even worse than 5%, however most of the loss ahead of the LNAs is cooled.

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

28.   Noted.

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

29. The nearly-on-axis horn described in part V would be difficult to include in our rotating subreflector, which has the 327 MHz feed in the center. With an array, these parameters can be verified by astronomical observations.

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

30.   Agreed.

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

31. Benefit gained would not outweigh the burden of re-designing the existing Q-band receivers.

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

32. Noted. LO shielding and feed-through will require careful attention.

> Low frequency receivers
>
> -- Why is temperature stability needed for post amps?

33. A stable ambient temperature will be required to meet system stability goals. There is no plan to temperature-stabilize the post amps beyond this.

> -- Do we need a total power stability specification?

34. This is in the project book.

> -- Slide 6 has error in polarizer lengths.

35. These lengths were scaled from the existing VLA L-band OMT, for lack of a better estimate. They will be corrected when EVLA OMT designs are firmer.

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

36. This will be corrected.

> -- 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?

37. Cal values should be reasonably uniform. However, the expense of an adjustable attenuator would not be justified. It could make them identical at one frequency, but there would still be individual idiosyncracies (including a contribution from the attenuator) making them differ at other frequencies. It must be noted that the wide bandwidth of these receivers will require that frequency-dependent cals will have to be measured and applied.

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

38. Marian Pospieszalski will take this into consideration in designing the amplifiers.

> -- Slide on C band receiver needs more development.

39. Details will be added.

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

40. Earlier insertion introduces an asymetry in the feed which can influence cross-polarization performance, etc. Additionally, the use of individual couplers is of use in the solar observing mode.

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

41. Paul Lilie plans that: The observer will determine in advance when solar mode should be used. While in solar mode, changes in, say, step attenuators will be done by command of the observing system, so that all antennas change state together, and the observing system knows that state. How it decides to make these changes is not addressed here.

> -- Use PIN diodes for S-band isolator?

42. Perhaps this question refers to an idea to use a cooled isolator and pin-diode switch if 20-dB couplers were substituted for the current 30-dB. (This would reduce the noise coupled from ambient temperature.) This scheme will probably not be needed as it looks possible to retain the 30-dB couplers.

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

43. Agreed.

> -- What is the recovery from saturation?

44. This will be measured, but is fast compared with slew times.

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

45. Defending a decision to build the WVRs is not part of this PDR. The EVLA involvement is simply not to preclude use of the WVRs.

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

46. Yes

> 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.

47. Agreed. However, it may prove impractical to mount the boards inside the dewar, making this point moot.

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

48. Agreed.

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

49. Agreed.

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

50. Special filters will no doubt be needed, but we don't know enough about the RFI environment and observers' needs to specify them at this stage. We will not design so as to obviate the possibility of their inclusion.

Cooled filters are awkward in some ways, esspecially if they must be switched in and out. But they also have advantages--improved performance, temperature stability, avoid long, lossy transmission lines.

> -- 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.

51. Noted. In-band responses of "identical" filters will probably be sufficiently similar, but cabling would have to be phase-matched.

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

52. IF bandwidths in the current system are set by IF filters; the front ends are "wide open".

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

53. Yes. Data transmission from the Front Ends to the MIB, however will be by means of the SPI bus, this will be clocked only during data transfers.

> -- Need to know signal level below 3rd order intercept point which

> will avoid intermodulation interference.

54. I would put this, "We need to specify the signal level
below which intermods are acceptable." (Since there are always
intermods, though they may be hundreds of dB "down".)

> Part III. Questionnaire inputs
>
> -- What are the MIB requirements for the 4 m and 90 cm wavelength band
> receivers?

55. Less than the cryogenic receivers since we will not
monitor baises or cryogenic parameters.
>
> -- 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.

56. Yes, but it's too hard to do, as the windows are very poor
thermal conductors, being thin and dielectric.

> Part IV. Conclusions
>
>   1. Are the top level performance requirements complete and
> adequate?
>   a. Some additional specification recommended for total power
> stability.

57.   See reply 15, above.

>   b. What are minimum requirements at band edges?

58.   See 22, above.

>   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.

59.   We are confident that the bandwidth can be achieved,
however, see
3, above, for caveats.

> b. More modeling is needed for bandedges, especially S-band.

60. See 22, above.

> c. Trapped modes for OMTs need to be better understood.

61. Agreed. We're working hard on it.

> d. Consideration of Hayward's modified block mixer proposal
> for high frequency bands is recommended.

62. Agreed. See 6, above.

> e. The performance of L-band in the presence of strong
> external RFI needs to be verified.

63. Agreed. See 5, above.

> f. Need to check more carefully for shadowing at the higher
> frequency bands.

64. Agreed. See 4, above.

>
> 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.

65. Agreed. See 18, above.

> b. Need criteria for build vs. buy.

66. Agreed. See 19, above.

>
> 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)

67. See 29, above.

For the panel,

Clint