# The VLA Upgrade Project Memo Series

## Number 2

## *The UHF/VHF Prime Focus Systems For the Future VLA Upgrade*

*R. Sramek*

21 July 1995

*Returning the Instrument to the State of the Art*

National Radio Astronomy Observatory

# THE UHF/VHF PRIME FOCUS SYSTEMS FOR THE FUTURE VLA UPGRADE

R. Sramek

July 21, 1995

A meeting to discuss the UHF/VHF systems for the VLA Development Project was held on Monday, June 26, 1995, in the A.O.C. auditorium. Below are my notes of this meeting; they do not necessarily reflect the time order of the meeting, but are grouped by topic.

In order to provide a focus, the discussion concentrated on the engineering problems associated with providing continuous coverage from 75 to 1200 MHz. The receivers, the feeds, R.F.I., and the mechanical constraints imposed by the VLA antennas were considered. If a feasible plan can be developed, production of a VHF/UHF prototype system on one or more VLA antennas by the end of 1996 will be considered.

We started with some general discussion of feeds for the VLA.

The VLA antennas are shaped reflectors which differ from a true paraboloid by about 1 cm; therefore there is no exact prime focus (P. Napier). The focus of the best fit paraboloid lies about 55 cm behind the average position of the subreflector for the Cassegrain focus. Since the subreflector focus travel is only +\- 15 cm, we will need to add about 40 cm to the focus travel to place the subreflector at the prime focus (J. Ruff). Another 50 cm of travel will be needed to allow room for the UHF feed and receiver. So we will have to add at least 90 cm of subreflector focus travel if we want to expose the prime focus in this way.

Other options to expose the prime focus include shifting the subreflector laterally, tilting it to one side, or, if we rebuild the subreflector, have it open like a clam shell. The cost of the VLBA subreflector was about $35k per antenna plus $200k in non-recurring engineering. The VLBA antennas have +\- 30 cm of travel to allow prime focus operation.

Adding 90 cm of additional travel to the subreflector, or any of the other approaches to expose the prime focus will require modification of the FRM and the quadrupod legs. The only way to avoid this is to accept the poor beam shape and aperture efficiency associated with operating the feed at an out of focus position, as we do now. This would be especially damaging in the 800 to 1200 MHz band.

Rough cost estimates are approximately $500k to raise the quadrupod plus $150k to extend the travel of the FRM (materials only, for full array). Since we don't yet have a design, these estimates are highly uncertain. We need to check if we can still fit the antennas into the AAB if we raise the quadrupods. The FRM for the VLBA cost about $120k each.

The modifications to the FRM and quadrupod legs, plus the addition of feed positioning mechanisms and receivers at the apex, will all add weight at the end of a long moment arm. A mechanical analysis of the quadrupod and backup structure should be done to study what effect these modifications will have on Cassegrain pointing and the reflector shape as a function of elevation.

The Cassegrain L-band feed was also discussed (J. Campbell). The performance of the current feed/polarizer on the VLA deteriorates rapidly below 1280 MHz. Also there is factor of two increase in Tsys at moderate elevation angles owing to significant far side lobes with this feed.

A new feed design for the VLA upgrade covers the range 1200 MHz to 1750 MHz. It is a very large feed but will fit on the existing feed ring with all of the other planned receiver systems. However, in length it will extend through the vertex room floor unless we provide a lens. A solid dielectric lens will weigh a couple tons; a compound lens like the one on the present feed will not be broad band, although it is not known how far this design can be pushed. Since the subreflector is in the near field of the L-band feed, a lens is also needed to provide a phase correction.

If we were to install a larger subreflector we could get good performance at a lower frequency for the same size feed mouth. However, this would add to the required focus travel distance of the subreflector, add to the weight at the apex, add to the overall cost, and make it more difficult to achieve the required rigidity in the structure.

Although the new L-band feed design is specified to work to 1200 MHz, it is important to calculate how badly the performance of the feed/antenna system fails as we go to lower frequencies. If we still have reasonable performance at 1100 MHz or 1050 MHz, we might avoid building one of the prime focus systems.

The current 75 MHz and 327 MHz feeds probably raise the system temperature at L-band by about 10% (D. Bagri), although this number is uncertain. For the proposed systems, this effect may be present at all bands, and may depend on frequency in some complex manner. The acceptable level is not established (10% was too high for the All Sky Survey), but may be in the range 10% to 20% (D. Frail). Special consideration should be given to S-band, our most sensitive proposed band.

Array feeds were discussed (Fisher). These could provide either Cassegrain or prime focus illumination of the main reflector. In principle the array feed could be distributed on the subreflector or off-axis on the main dish. If only a single beam is formed with the array feed, a full correlator would not be needed; only an amplitude and phase adjustment would be needed for each element. However, this amplitude and phase would have to be adjusted with observing frequency. The array feed probably needs a few more years of development before we should consider it for the VLA upgrade. It is however, an approach that should be watched.

Balanced amplifiers should be considered for VHF/UHF receivers (R. Bradley). They offer a good impedance match over a wide frequency range and a 3 dB improvement in dynamic range.

A 600 to 1000 MHz prototype is being developed for the GBT with $T_{amp}$ = 4.5 K. Compact Peltier coolers (200 K ?) or closed cycle Sterling coolers (70 K, 4 W, $15k now, but probably going down in price) are available. At a physical temperature of 70 K, the GBT amplifiers would only suffer a X2 increase in $T_{amp}$.

It is possible to build feeds with reasonable impedance match over a bandwidth ratio (BWR) of 2:1. However, a dipole in a cavity (0.9 wavelength diameter) will not give an optimal illumination pattern over this range. We would best keep the BWR below 1.3 with this feed. However, this would require 6 feeds to cover 240 MHz to 1200 MHz. A scalar feed (about 3 wavelengths diameter) could be used with a BWR of 1.5 at the higher frequencies. If we loosen the spec for the dipole feed to allow BWR 1.5; we will need only 4 feeds for the 240 MHz to 1200 MHz range. This would allow one feed to be attached to each quadrupod leg. The receiver and possibly a compact refrigerator could be attached behind each feed.

A possible receiver plan would then be:

| Band | BWR | Feed | Rcvr |
|---|---|---|---|
| 240 - 360 MHz | 1.5 | dipole | ambient |
| 360 - 540 MHz | 1.5 | dipole | ambient |
| 540 - 800 MHz | 1.5 | scalar | cooled |
| 800 - 1200 MHz | 1.5 | scalar | cooled |

The conical sinuous feed could possibly offer a compact design that would have a reasonably constant illumination pattern over a BWR of 1.5. A more compact low frequency feed would allow us to better hide the feed/rcvr package against the feed leg and minimize their impact on the Cassegrain systems; also it would lower the weight.

The 75 MHz to 240 MHz feeds could be end fed whip antennas that fold against the quadrupod legs when not in use. These antennas could be trap loaded for use at a few discrete bands. Other than this, these would be like the existing 75 MHz feeds. They would continue to be low performance feeds, using the subreflector as a ground plane. This is a compromise. If we were ever to build a free-standing meter wavelength array, the 75 to 240 MHz band might be done there.

We need to learn more about the RFI environment in the 240 to 1200 MHz range. Statistics on the frequency of RFI might help define the band edges. A program to monitor this frequency range at the VLA site would be useful.

Participants:

Jim Ruff
Jon Thunborg
Peter Napier
Rick Perley
Dick Sramek
Jack Campbell
Gerry Petencin
Durga Bagri
Larry Beno
Clint Janes
Dale Frail
Bill Erickson (U Md)
Rich Bradley (NRAO/CV)
Srikanth (NRAO/CV)
Rick Fisher (NRAO/GB)