VLB ARRAY MEMO No. 59

A REVISED PROPOSAL FOR A FEED SYSTEM FOR THE VLBA ANTENNA

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## INTRODUCTION

In a previous report[1] a concept for a feed system for the VLBA antenna was presented. Further study of the problem has shown several deficiencies in this concept. The Jet Propulsion Lab dual frequency feed has insufficient bandwidth to support both 21cm and 18cm (H and OH) observations from a single lower band output. Also, because of the phase error needed in the aperture, the feed aperture is relatively large. This, together with the complicated waveguide network needed for the lower band port makes the the feed expensive. Finally, significant development work would be needed to make the feed work at frequencies where the ratio between upper and lower frequency bands is different to the prototype JPL S and X Band. In this new proposal, instead of the JPL dual frequency feed, individual corrugated horns will be used for each frequency with dual frequency capability being obtained, where necessary, by using dichroic reflectors of the type developed at JPL[2] and the VLA[3]. A second problem with the previous proposal was the design goal of keeping the 610Mhz feed at the Cassegrain focus. Further study has shown that the helix-array feed would have lower efficiency than expected due to mutual coupling problems and would cause aperture blockage for the other Cassegrain feeds. In this proposal the 610Mhz feed will be permanently mounted in the middle of the subreflector. The subreflector drive mechanism and the feed legs will be designed to allow the subreflector to be driven up until the 610Mhz feed is sufficiently close to the primary focal point.

Modifications to the original proposal[1] are detailed below.

## The Cassegrain Geometry.

The proposed shaped Cassegrain geometry is show in Figure 1. A large subreflector of diameter 3.18m is used to keep the feeds and feed circle as small as possible. The geometry is optimized so that aperture blockage due to the subreflector and feed system are equal. The feeds are arranged in a circle of radius 85cm around the main reflector axis, with the secondary focal point being 1.67m in front of the main-reflector vertex. The 610Mhz feed is located at the center of the subreflector and the 327Mhz feed is mounted at the side of the subreflector.

## The Feed Elements

A circle approximately 0.5m in diameter in the middle of the subreflector is shadowed by the subreflector itself. A 610Mhz feed, of either the Clavin or crossed double dipole type, can be permanently located in this area without significantly effecting the performance of the cassegrain feeds. The subreflector will have to be capable of moving axially to place the phase center of the 610Mhz feed within 10cm of the prime focal point, to reduce defocussing loss to less than 5%.

The feed for 18 to 21cm wavelength will be a hybrid-lens feed of the VLA type[4], scaled to provide the smaller aperture needed to illuminate the subreflector which subtends an angle of $\pm 13.1^{\circ}$. The feeds for the 7 frequency bands from 13cm to 0.7cm wavelength will be corrugated horns all scaled exactly according to wavelength from the same design. This approach has the advantage of low risk, since the design of corrugated horns is well established[5]. The corrugated horn has high performance in terms of spillover efficiency and cross polarization. The prototype feed design[5] gives the following parameters; phase error in aperture 0.2λ, horn aperture 6.04λ, horn length 19.2λ, corrugation depth 0.25λ, corrugation width 0.2λ, corrugation period 0.25λ, number of corrugations 76. This horn has a 14dB taper at the edge of the subreflector with a spillover efficiency of 93%. The table in Figure 1 shows the outside dimensions for the horns. All horns have their apertures in the same plane. The 1.3 cm and 0.7cm wavelength horns feed into the same cryogenic dewar requiring the 0.7cm feed to be stretched to the same length as the 1.3cm feed using single mode circular waveguide. All other Cassegrain feeds will feed directly into their own dewars allowing the orthomode junction to be cooled for best noise performance. Circular polarization will be obtained by using a quarter-wave waveguide phase shifter of the VLA L Band type for the lower frequency bands and quasi optical quarter-wave plates of the Greenbank type at the higher bands. For the higher bands, the feeds will be mounted directly onto the cryogenic dewars. The Cassegrain vertex room will be designed to provide convenient access to the higher frequency dewars which will be approximately 3.8m above floor level.

Dual frequency operation will be provided for the 13cm and 3.6cm wavelength feeds using a combination of dichroic and ellipsoidal reflectors. If dual frequency operation between frequency bands higher than this is needed, there is room around the feed circle to provide for additional reflectors.

System Performance

Since the 610Mhz feed is at the prime focus the shaped main reflector must deviate from a parabola by as little as possible. The VLA shaped geometry produces uniform illumination from an 11.5dB illumination taper on the edge of the subreflector. The VLA main reflector deviates from a parabola by 0.97cm rms. The VLBA antenna will be more shaped to produce uniform illumination from a 14dB subreflector taper. The deviation from a parabola is not known for the VLBA antenna, but a reasonable design goal would be 1.2cm rms. This will result in a gain loss of 9% at 610Mhz which is bearable. Table 1 shows the expected feed performance for all bands. The low phase efficiency for the 327Mhz feed results from its off-axis location. If this efficiency is unacceptable, it can be manually mounted on the subreflector whenever 327Mhz is scheduled.

The spillover efficiencies in Table 1 are reasonable goals for the prime focus feeds. The 1.5Ghz feed spillover is estimated from VLA experience and the spillover efficiencies for the corrugated horns are taken from Reference 5.

The subreflector support structure should be designed to minimize blockage. A total blocked area of 7%, including the blockage of the 3.18m diameter subreflector is a reasonable goal. With this much blockage the worst first sidelobe level should be approximately -15dB (the estimate of -13.7dbm in the previous proposal[1] was too pessimistic).

As described in the previous proposal[1] the circular polarization performance of the antenna will be degraded by the assymetric geometry. Circular polarization measurements will be made even more difficult because the feeds themselves are circularly polarized.

## Cost

The proposed feed system has been costed based on VLA experience.

It is assumed that all feeds will be designed and developed in house and built in quantity by outside machine shops. This is a safe approach since all feed components have been previously built at NRAO either at the VLA or at Greenbank. Testing will be done on a rented antenna range by the VLBA Feed Engineer.

| | | |
|---|---|---|
| Development Cost: | Build 1 prototype of each feed at twice the production cost. | $K 150 |
| | 3 Man Years Engineering | |
| | ½ Man Year Drafting | |
| Construction Cost: | | $K |
| | 327Mhz Feed | 2 |
| | 610Mhz Feed | 2 |
| | 1.5Ghz Feed | 13 |
| | 2.2Ghz Horn | 11.7 |
| | 5.0Ghz Horn | 3.6 |
| | 8.4Ghz Horn | 1.8 |
| | 10.7Ghz Horn | 1.8 |
| | 15Ghz Horn | 1.5 |
| | 22Ghz Horn | 1.5 |
| | 44Ghz Horn | 1.5 |
| | Polarizers | 8 |
| | Dichroics | 10 |
| | Windows, Waveguides etc. | 4 |
| | Pattern Measurement, VSWR Test | 10 |
| | | 72.4 |
| | Amortize $150K development over 10 ant | 15 |
| | Cost per antenna | 87.4K |

During construction need 1 feed engr full time.
Subreflector cost: Budgetry estimate from Milliflec Inc.,

| | |
|---|---|
| NRE and NRT | 50 K |
| Each subreflector | 20 K |

Refrences

1. P. J. Napier, "A Possible Feed System for the VLBA Antenna, "NRAO VLBA Memo No. 22, August 1980.
2. D. A. Bathker, "Dual Frequency Dichroic Feed Performance," Proceedings 26th Meeting Avionics Panel, AGARD, Munich, Germany, November 26-30, 1973.

3. S. Weinreb, M. Balister, S. Maas, P. Napier, "Multiband Low-Noise Receiver for a Very Large Array, IEEE Trans., MTT-25, Nov 4, April 1977, pp 243-248.

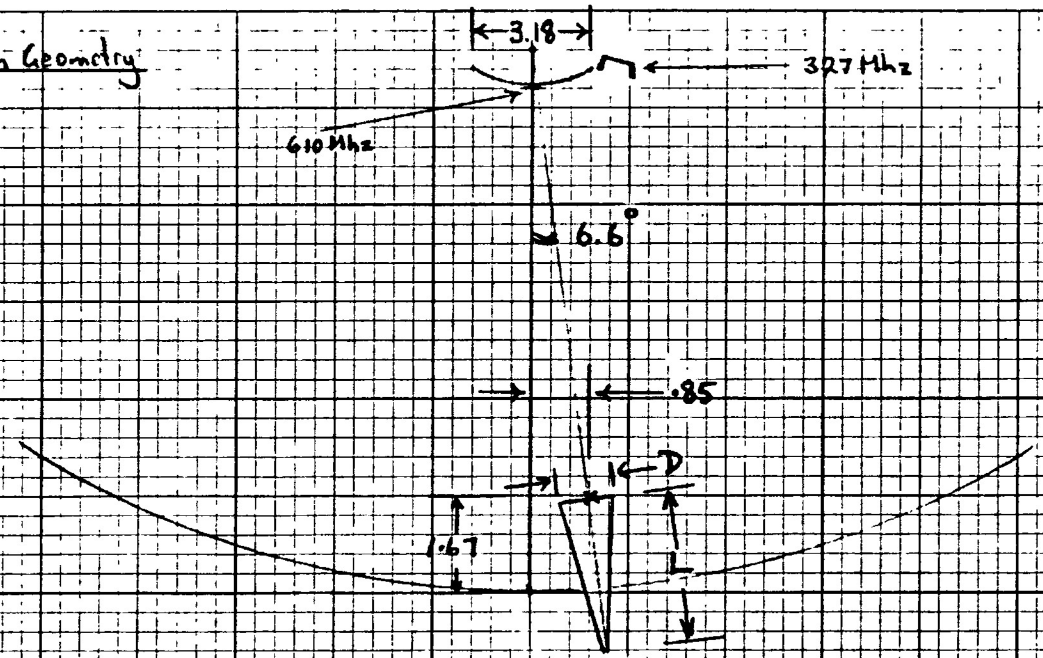
4. J. J. Gustincic, P. J. Napier, "A Hybrid Lens Feed For The VLA," Digest of the IEEE International Symposium (Stanford: IEEE Antennas and Propagation Society) p361, 1977.

5. B. Thomas, " Design of Corrugated Horns, "IEEE Trans., Vol AP-26, No 2, March 1978, pp 367-372.

| Frequency | Esurf | Eillum | E Diff | Espil | E Block | Ephase | E Misc | E Total |
|---|---|---|---|---|---|---|---|---|
| 327Mhz | .97 | .78 | 1.0 | .78 | .86 | .63 | .95 | .31 |
| 610Mhz | .91 | .78 | 1.0 | .78 | .86 | .95 | .95 | .47 |
| 1.5Ghz | 1.0 | .95 | .90 | .85 | .86 | .98 | .95 | .58 |
| 2.3Ghz | 1.0 | .99 | .93 | .93 | .86 | .98 | .95 | .69 |
| 5Ghz | .99 | .99 | .95 | .93 | .86 | .98 | .95 | .69 |
| 84Ghz | .98 | .99 | .98 | .93 | .86 | .98 | .95 | .71 |
| 10.7Ghz | .96 | .99 | .99 | .93 | .86 | .98 | .95 | .70 |
| 15Ghz | .92 | .99 | .99 | .93 | .86 | .98 | .95 | .67 |
| 22Ghz | .84 | .99 | .99 | .93 | .86 | .98 | .95 | .61 |
| 44Ghz | .50 | .99 | .99 | .93 | .86 | .98 | .95 | .36 |

Table 1. Predicted Feed Performance
Esurf = Surface Accuracy Efficiency
Eillum = Aperture Illumination Efficiency
Ediff = Subreflector Diffraction Efficiency
Espill = Feed Spillover Efficiency
Eblock = Blockage Efficiency
Ephase = Phase Efficiency
Emisc = Efficiency due to miscellaneous effects eg VSWR efficiency, loss in the feed and its window.

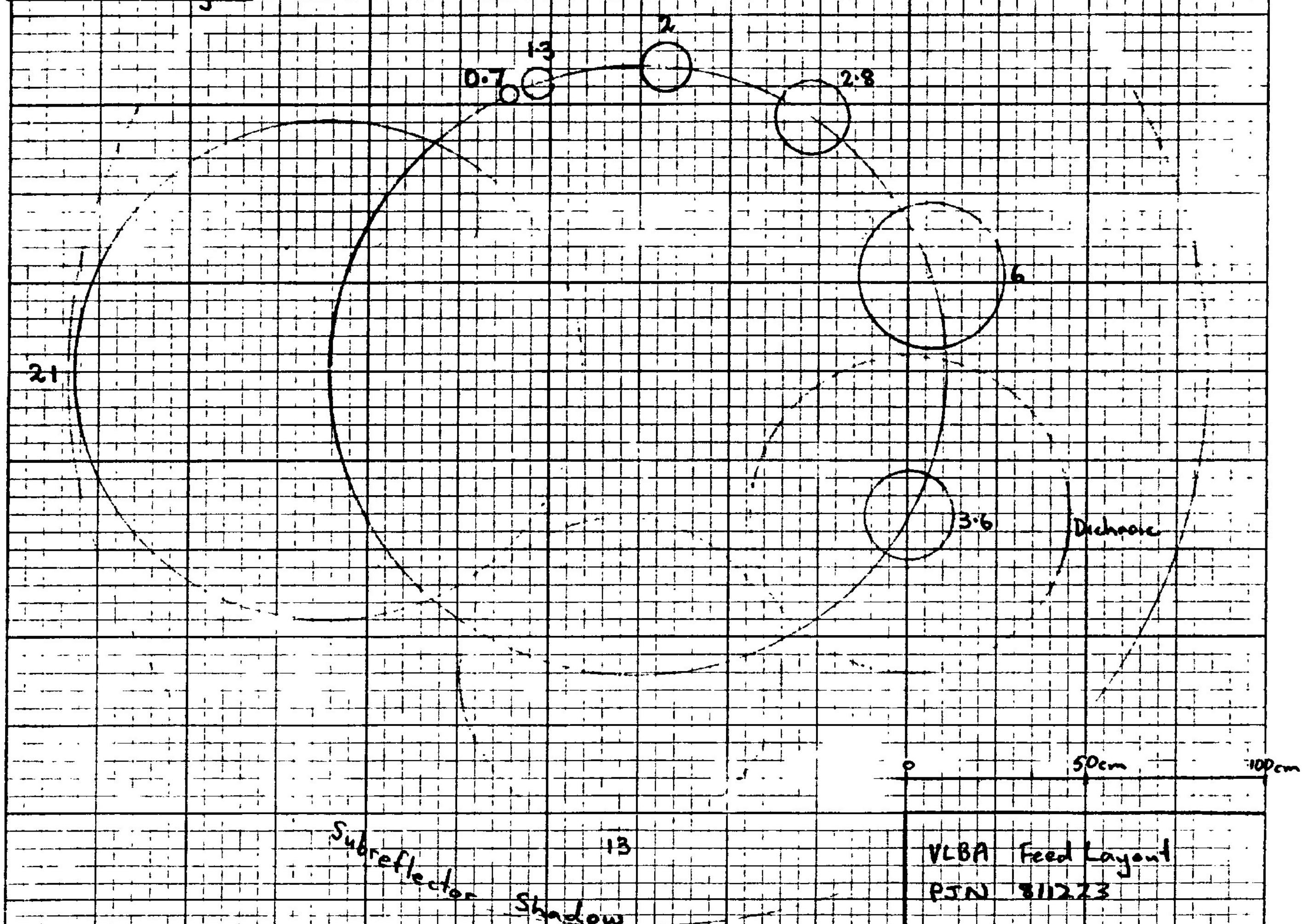
## Cassegrain Geometry




| $\lambda_{cm}$ | 92 | 49 | 21 | 13 | 6 | 3.6 | 2.8 | 2.0 | 1.3 | 0.7 |
|---|---|---|---|---|---|---|---|---|---|---|
| $D_{cm}$ | PF | PF | 142 | 90 | 41 | 24 | 19 | 14 | 9 | 5 |
| $L_{cm}$ | PF | PF | 228 | 256 | 119 | 71 | 56 | 41 | 27 | 16 |

PF = Prime Focus

## Feed Circle Layout




VLBA Feed Layout
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