VLB ARRAY MEMO No. 22

VLBA Memo No P. J. Napier 8/26/80

A Possible Feed System For the VLBA Antenna

Introduction: This memo describes a possible feed system for the VLBA antenna which will allow operation of the antenna at 330 Mhz, 610 Mhz, 1.4-1.7 Ghz, 2.2 Ghz, 5 Ghz, 8.85 Ghz, 10.7 Ghz, 15.4 Ghz, 22 Ghz and 43 Ghz. There are three main features of the design:

(1) Remote Operation. Since it is important to minimize the operating manpower at the antennas it is important that frequency changing require a minimum of hardware changes on the antenna. An offset Cassegrain reflector geometry, similar to the VLA, is proposed, with all feeds between 610 Mhz and 43 Ghz inclusive located at the secondary focus. Frequency changes over this frequency range will simply require rotation of the subreflector about the main reflector axis, as is done at the VLA. The reflectors will be shaped for high efficiency. The 300 Mhz feed will be located at the primary focus. It can be located on axis if the subreflector is removed, or off axis, at the edge of the subreflector, if reduced performance is acceptable.

(2) Large Subreflector. A much larger than usual subreflector is proposed. This will reduce subreflector diffraction loss at the lower frequencies and allow all feeds to be smaller, simpler to design and less expensive. The reduced feed size will allow the feeds to be arranged in a smaller circle around the main reflector axis so that the circular cross polarization problem, present in the VLA antennas, is reduced. Also the smaller feeds will prevent the subreflector being in the near field of the feeds. A 3.66 m diameter subreflector is proposed.

(3) Dual Frequency Feeds. Since 9 frequencies must be accommodated at the Cassegrain focus, dual frequency feeds are used whenever possible to make more efficient use of space. The dual frequency feeds will also be valuable for special experiments such as verifying general relativity by measuring apparent source movement during occultation.

The Feed Elements: The high performance dual frequency feed recently developed by JPL (Williams and Withington, 1979; Williams et al, 1979) is suitable for the 1.55/5.0 Ghz, the 2.2/8.8 Ghz, the 10.7/22 Ghz and the 15.4/43 Ghz frequency ranges. The JPL and VLBA subreflectors subtend very nearly the same angle (32.7^o and 30.5^o respectively) so that an almost identical design, scaled for frequency, can be used. This dual frequency feed works on the principle that when the length of a horn of fixed flare angle is made sufficiently long, the increasing phase error in the horn aperture prevents the radiation pattern from getting any narrower and the beamwidth of the horn is determined only by the flare angle. If a dual frequency horn is operated in this "beamwidth saturation" mode at both frequencies, its radiation patterns will be very nearly the same at both frequencies. The second feature of the JPL design is that at the lower frequency the horn corrugations are in the range $\frac{\lambda}{4}$ to $\frac{\lambda}{2}$, whilst at the upper frequency they are in the range λ (2N-1)/4 to λ(2N/4) where N=2 or 3.

For the 600 Mhz feed it is proposed to use a single ring of 600 Mhz helices. This feed is chosen because, for a given maximum aperture diameter, an annular aperture distribution has the narrowest beam-width of any circularly symetric distribution. This is therefore the smallest possible feed. Although the spillover efficiency is low, this is made up for by having cryogenics available at the Cassegrain focus. If a room temperature receiver were used at the prime focus it is estimated that the system temperature would be 1.78 times the system temperature of a 600 Mhz cryogenic receiver.

The 300 Mhz feed at the prime focus will be a scalar or Claven feed with total aperture efficency approximately 50%. If it is located 1.83m off axis at the edge of the subreflector a gain loss of 2dB can be expected and coma aberation will increase the first sidelobe level by 10 dB.

Proposed Feed Layout. Figures 1 and 2 show the proposed Cassegrain Geometry and feed layout.

System Performance. The shaped reflector system should provide uniform illumination in the aperture of the main reflector with a -14dB illumination on the edge of the subreflector. This will keep the low frequency feeds to a manageable size and allow an almost direct scaling of the JPL dual frequency feed design. The shaped main reflector should not give significant gain loss at 300 Mhz. For this reason the difference between the shaped main reflector and its best fit parabola should not exceed 1.8cm rms (for the VLA this difference is 0.97 cm rms). The main reflector surface accuracy will be .044 cm (λ at 43 chz). A reasonable goal for the subreflector accuracy is 0.^{15}012cm, giving a combined surface rms of .046 cm. Table 1 shows the aperture illimination efficiency and the surface accuracy efficiency to be expected across the range of observing frequencies.

(b) Subreflector Diffraction Table 1 gives estimates of the energy lost due to subreflector diffraction with a - 14 dB edge illimination on the subreflector (Rusch, 1963)

(c) Spillover Efficiency Table 1 gives estimates of the fraction of the feed energy incident on the subreflector. For the dual frequency feeds these are taken from (Williams and Wittington, 1979) and for the 600 Mhz feed they are computed from the theoritical radiation pattern of a circular array of 20 helices, each helix having 15 turns

(d) Blockage. A reasonable goal for total blocked area, including the blockage of the 3.66 m diameter subreflector is 7%. This gives a blockage efficiency of .86 in a uniformly illiminated reflector.

(e) Phase Efficiency The nominal phase center of the Cassegrain geometry, as shown in fig 1, is 1.7 m in front of the main reflector vertex. Since the dual frequency horns have their phase centers at their throats, it will be necessary to refocus the subreflector. With a Cassegrain magnification of 5.2, this should not result in significant loss of phase efficiency.

(f) Sidelobes. A 25 m circular aperture with uniform illimination and or 3.7 m diameter circular blockage at its center has a first sidelobe level of -13.7 dB. Feed leg blockage will increase this further at some angles. However, for most VLBI observations, this high first sidelobe level is not expected to be a problem. The VLA antennas have sidelobes of this level.

(g) Polarization. Since the feeds of this VLBA antenna are somewhat closer to the main reflector axis than they are on the VLA antenna, the circular polorization problem present on the VLA antennas (Napier and Austinec, 1977) will be slightly reduced. A separation between the circularly polarized beams of 0.047 beamwidth can be expected. In general this should not be a problem since most VLBI sources will be confined to the antenna axis. At the highest observing frequency pointing problems will cause a circular polarization uncertainty of approximately 3%.

Frequency	Esurf	Eillum	Ediff	Espil	E Block	Ephase	Emisc	Etotal
600 Mhz	1.0	.95	.87	.64	.86	.98	.95	.42
1.5 Ghz	1.0	.98	.92	.90	.86	.98	.95	.65
5.0 Ghz	.99	.99	.96	.90	.86	.98	.95	.68
10.7 Ghz	.96	.99	.99	.90	.86	.98	.95	.68
22 Ghz	.84	.99	.99	.90	.86	.98	.95	.59
43 Ghz	.50	.99	.99	.90	.86	.98	.95	.35

Table 1. Predicted Feed Performance

Esurf = Surface Accuracy Efficiency

Eillum = Aperture Illimination 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.

References

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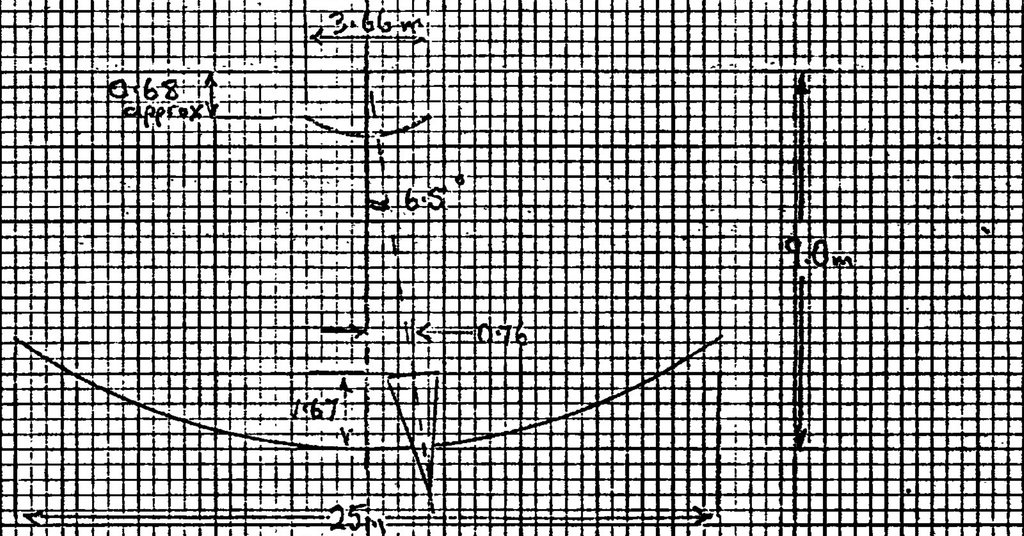
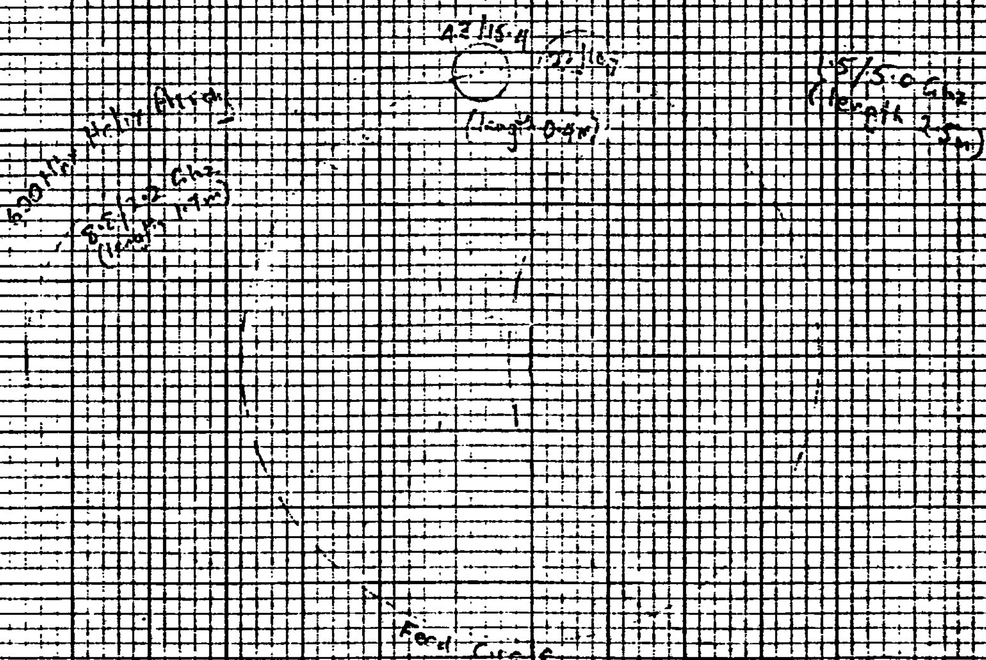


Fig 1 Proposed Cassegrain Geometry



Scale: 1cm = 20cm

Fig 2 Proposed Feed Layout