A LARGER SUBREFLECTOR FOR THE VLA

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1 INTRODUCTION

One of the areas of investigation for the VLA Upgrade Design Study is the use of a larger subreflector on the VLA antenna (Perley, VLA Upgrade Memo # 4). Advantages of a larger subreflector include a reduction in feed size, making it easier to fit an increased number of feeds around the feed circle and, at L Band, improved sensitivity and frequency coverage. Disadvantages of a larger subreflector include cost, weight, the need to replace all feeds, the increased focus travel required to expose the prime focus and a need to modify the existing quadruped structure. The purpose of this note is simply to examine the limits placed on subreflector size and location by the VLA optics design and to provide some examples to aid the designers of the new system. Detailed consideration of the advantages and disadvantages listed above will be the subject of future reports.

2 THE VLA SHAPED CASSEGRAIN GEOMETRY

The VLA asymmetric shaped Cassegrain geometry is shown in Figure 1. For ease of comparison with the VLA antenna construction drawings, all dimensions in this report are given in inches. The edges of any subreflector suitable for use with the symmetric VLA primary reflector must lie on the cone defined by the rays which reflect from the edge of the primary towards its apex. This cone is the cone EIM in Figure 1 and has a half angle of 67.801'. To determine the overall dimensions and location of a new subreflector one simply locates its edge at the appropriate point, call it K', on the edge ray IM to give the desired maximum subreflector radius (see Figure 2). The new total ray path length, P, is then given by P=MK' +K'B. New locations for the axis intercept, F', and short edge, G', are then found by forcing all new total path lengths to equal P. Using the known shape of the symmetric primary reflector, the complete profile of the new subreflector can be determined in this way by forcing all ray paths to have total path length P. Note that this procedure can also be used to design a subreflector with its secondary focal point in a new location. Thus, if required, the diameter and height of the feed circle could be changed.

3 EXAMPLES OF LARGER SUBREFLECTORS

We will give some examples of larger subreflectors. These examples, as well as the current subreflector, are shown in Figure 2.

The first example is the largest subreflector which will fit between the legs of the existing quadruped structure. In principle, the maximum allowable subreflector radius is at the point L, the intersection of lines IM and JN in Figure 1. Note that spherical wave blockage is not increased by having the subreflector edge very close to the quadruped leg. Blockage is determined by the optical properties of the symmetric primary reflector and the location of the quadruped on it, not by the size or location of the secondary reflector. However, it would be unwise to locate the subreflector edge at point L because this provides no allowance for tolerance build-up in the quadruped. Examination of the VLA K band subreflector settings shows that some antennas require the subreflector to be raised by as much as 1.8 in compared to the average. This could be an indication that the quadruped, due to tolerance build-up, is sitting low on these antennas. Therefore, we will chose a maximum subreflector size which provides a 2.0 in clearance to the nominal quadruped surface above it. The maximum radius of this subreflector is 70.3 in.

The second example is the largest subreflector which will just fit within the 78 in radius of the unpanelled area in the middle of the primary. This subreflector would not increase plane wave blockage but would require the legs of the quadruped structure to be moved further apart.

The properties of these subreflectors are shown in Table 1. To show how dimensions vary, also included in Table 1, but not shown in Figure 2, is a subreflector with maximum radius 64.9 in.

Table 1. Properties of 4 Possible VLA Subreflectors

	Current Subreflector	**Subreflector with max radius 64.9 in**	**Largest subreflector fitting between quadruped legs**	**Largest subreflector fitting inside unpanelled area**
Diameter (in)	92.5	117.6	127.2	140.7
Total angle (degrees) Subtended from feed	18.1	23.2	25.2	28.1
Magnification	8.5	6.6	6.1	5.5
Intercept on primary Axis (in)	333.8	325.7	322.7	318.6
Long edge radius and Depth (in)	50.9, 16.5	64.9, 18.9	70.3, 19.6	78.0, 20.7
Short edge radius and Depth (in)*	41.68, 20.28	52,7, 23.8	56.9, 25.1	62.7, 26.9
Feed tilt angle (deg)	8.3	8.5	8.7	8.8
Total path length (in)	774.6	758.6	752.6	744.3

*Edge depths measured with respect to the intercept on the primary axis

An offset shaped Cassegrain geometry has no simple expression for Cassegrain magnification. However, for comparison purposes a value for magnification, M, is included in Table 1 which, in analogy to a classical Cassegrain geometry, is calculated as:

M= tan(0.25*Full angle subtended by Primary)/tan(0.25*Full angle subtended by secondary)

For comparison, the subreflector on the VLBA antennas has a diameter of 125.8 in, subtends a full angle of 26.3 * and has a magnification of 5.9.

4 CONCLUSIONS

Three examples of possible larger subreflectors for the VLA have been provided to indicate the range of parameters to be expected. A detailed study of the advantages and disadvantages of a larger subreflector needs to be made. In particular, because of the difficulty of fabricating a large asymmetric subreflector to the precision required, and because of the modifications required to the existing quadruped, focus-rotation mount and feeds, the cost is likely to be high. A full diffraction analysis of both the existing subreflector and the larger subreflector must be made to quantify the expected improvements in L band performance. Additionally, changing the subreflector size will modify the aperture illumination provided by the shaped geometry. This effect needs to be quantified.

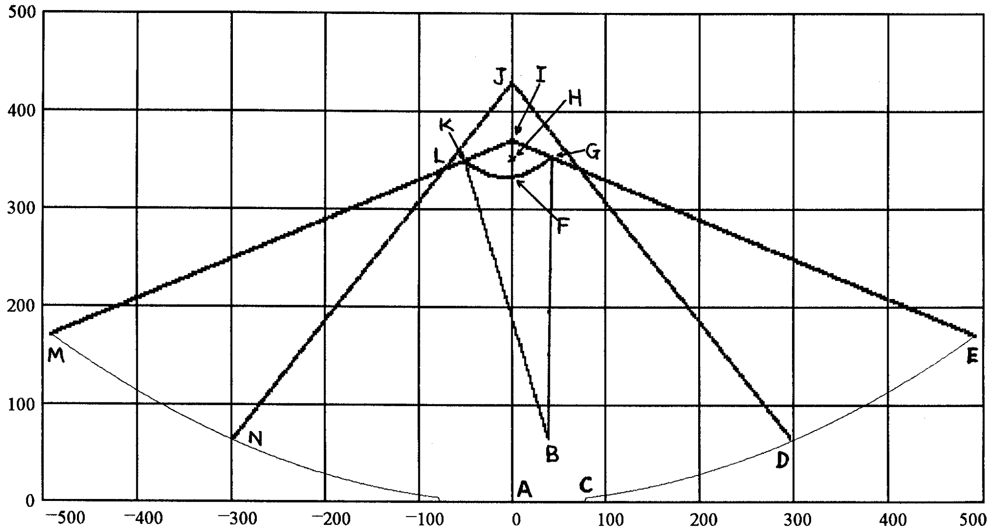

Figure 1. VLA Cassegrain geometry. The lines DJ and NJ are the nominal inside surfaces of the quadruped legs (locations provided by R. Broilo) and the lines BGE and BKM are the rays which travel from the edge of the primary reflector to the secondary focus. The coordinates of the labeled points are as follows:

A. Primary reflector vertex	0,0	I. Intersection of edge rays	0,371.086
B. Secondary focus	38.4,66.0	J. Virtual intersection of quadruped legs	0,430.66
C. Radius of unpanelled area	78.0,4.334	K. Long edge of subreflector	-50.855,350.331
D. Bottom of quadruped inside surface	297.246, 65.82	L. Intersection of edge ray with quadruped leg inner surface	-72.707,341.417
E. Primary reflector edge	492.126,170.268	M. Primary reflector edge	492.126,170.268
F. Intersection of secondary surface and primary axis	0,333.80	N. Bottom of quadruped inside surface	-297.246,65.82
G. Short edge of subreflector	41.678,354.079	Angle AIE. Edge ray angle	67.801 deg
H. Best fit prime focus for primary	0,354.33		

* Note: The VLA asymmetric subreflector is specified in VLA Specification A13620N1. The values for the subreflector edge shown here are the exact geometric optics edges and are slightly larger than the values in Spec.A13620N1 which are given only on a 0.5 in rectangular grid. The origin of coordinates for the profile given in Spec. A13620N1 is (0,333.708).

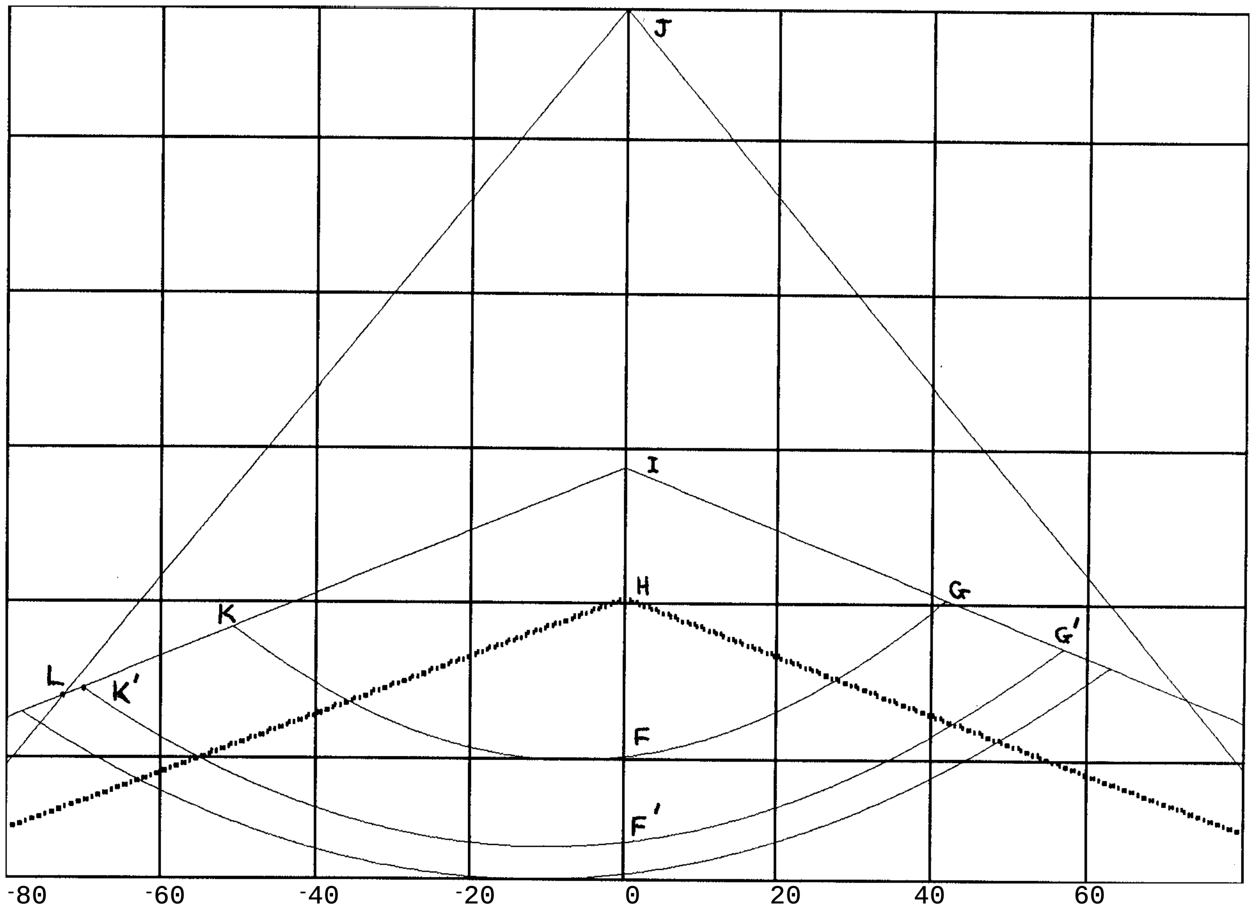

Figure 2. The current subreflector and two larger subreflectors. The labeled points correspond to the points shown in Figure 1. The vertical origin of coordinates has been shifted to the location of the intercept on the primary axis of the current subreflector. Also shown as point H is the location of the best-fit primary focal point and the rays from it to the edge of the primary reflector. The subreflector profiles are correct only at the two edge points and on the primary axis. The curved profiles shown are smooth second-order curves fitted through these three points.