MMA Memo 163:
A Strawman Optics Layout for the MMA Antenna

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Abstract

A strawman design for the overall optics layout and receiver cabin space of the MMA antenna is proposed. Sufficient detail is provided so that design of the receiver and its feed system can proceed. The MMA Antenna Working Group would like comments as to the adequacy of this concept.

Introduction

The purpose of this memo is to document the current ideas of the MMA Antenna Working Group with respect to the overall optics layout and receiver cabin space for the MMA antenna. We would like comments from the other MMA working groups, especially the receiver group, as to the suitability of this concept. The current concept is shown in Figure 1 below, and the dimensions are given in Table 1. It is likely that some of the details will change as the antenna design proceeds and we will issue updated versions as necessary. Some of the considerations which have led to this concept are discussed below.

Choice of Cassegrain Geometry

The proposed geometry is a minimum-blockage Cassegrain geometry. This choice is driven primarily by the desire for low antenna noise (to match the low atmospheric opacities available on the 5000m site in Chile) and for high aperture efficiency. The minimum blockage aspects of the design include supporting the quadrupod legs at the edge of the reflector and making the diameter of the subreflector equal to the diameter of the hole in the center of the primary reflector. The use of the Cassegrain focus avoids additional reflectors and their unavoidable contributions to the system temperature. Another advantage of the Cassegrain focus is that it is easy to have more than one feed at a time looking at the subreflector. This is necessary, for example, if one wishes to monitor the atmospheric total power fluctuations at one frequency in order to correct for atmospheric phase fluctuations at another frequency.

Choice Of F/D And Magnification

The choice of 0.38 for the primary F/D is driven primarily by the close packing (short interferometer baseline) requirement. With this value of F/D, and with space provided behind the subreflector for a nutator, the antennas can be placed on a baseline of length 1.29 D without possibility of collision at elevation angles greater than 19°.5. At an elevation of 0° the shortest baseline without possibility of collision is 1.35 D.

The location of the secondary focus is chosen 1.5 m below the vertex of the primary to allow plenty of space in front of the receiver for the various selectable quasi-optical devices (so called "widgets") that have been proposed. Examples of these devices include calibration devices, circular polarizers, solar observing devices, dual frequency reflectors and a beam directing reflector for the 30 GHz receiver which will be mounted off to the side of the mm/submm receiver.

The magnification of the Cassegrain optics is chosen as that value which makes the diameter of the subreflector equal to the hole in the middle of the primary, with the hole in the primary being just large enough to pass the beam at 30 GHZ, the lowest frequency of operation of the telescope. This hole will also be large enough to accommodate a possible future 3x3 focal plane array at a frequency of 90 GHz or higher. This geometry provides the minimum possible central blockage (0.4% unweighted blocked area). However, if a feed arrangement is selected for the receiver in which an active feed is looking at the subreflector from an off-axis location, this hole in the primary may not be large enough, depending on how far off-axis the feed is located and its frequency. In this case there will be no problem in making the hole larger, at the expense of a small increase in central blockage. If the primary hole is increased it would be logical to increase the subreflector diameter as well because this would decrease feed size. However, before increasing the subreflector diameter above the size proposed here, it will be necessary to investigate subreflector nutation requirements more carefully than we have done so far.

Possible Feed Arrangements

Several feed systems can be considered to provide the seven or more receiving bands proposed for the mm/submm receiver. Desired bands currently include 85, 110, 160, 235, 340, 475 and 665 GHz plus locations for perhaps two future-expansion bands. Selection of the best system will depend on details of the receiver design. The geometry proposed here should be compatible with any of the systems, except for a possible need to increase the size of the hole through the primary. Four possible systems are summarized below.

1. Off-axis Feeds. This is the feed system used on the BIMA antennas and is the system preferred by the MMA receiver group in MMA Memo No 143. The feeds are clustered as close together as feasible in the middle of the dewar. Advantages include simplicity and the ease of having more than one feed looking at the subreflector for phase calibration by total power fluctuation measurement. Disadvantages include a possible need for a larger hole in the primary mirror, crowding of the receivers in the dewar and of the "widgets"; above the dewar, degraded polarization purity and a small increase in spillover noise. If the subreflector is truncated to avoid the spillover the outer part of the primary is under-illuminated degrading the close packing performance. None of these disadvantages are so serious as to preclude the use of this system.
2. Movable Dewar. The dewar is moved (rotation or linear motion) so as to bring the observing feed on-axis. This solves all of the disadvantages of the off-axis system but at the expense of an undesirable mechanism to move a massive dewar. Another possible advantage is that a single on-axis "widget"; could be used for all bands.
3. Cooled Rotating Beam Director. Here an on-axis rotating reflector (cooled for high sensitivity) directs the beam to the active feed in the dewar. It solves the problems of the off-axis system but at the expense of a cooled reflector moving mechanism. An additional disadvantage is the difficulty of having more than one feed at a time looking at the subreflector .
4. Rotating Asymmetric Subreflector. This is the feed geometry used on the VLA and VLBA. Its advantages include no aberration or excess spillover and well separated feeds. Disadvantages include degraded polarization, a more complicated subreflector moving mechanism and probably the need for a larger hole in the primary.

Receiver Mounting

The receiver cabin below the central cone will be made of insulated steel and it should be possible to mount receiver equipment to any point on the walls. The central cone will probably be fabricated from CFRP and will not be suitable for direct mounting of receiver equipment. Metal support structure, run up from the walls of the cabin, will be provided to any point in the cone where it is required. The cabin door is approximately the largest that can be provided based on structural considerations and it is possible that detailed analysis will require a reduction in its height.

Conclusions

A strawman design for the overall optics layout of the MMA antenna is proposed. Sufficient detail is provided so as to allow design of the receiver and its feed layout to proceed. There is still sufficient flexibility in the antenna design to allow changes to most of the dimensions in this proposal provided that changes are identified soon.

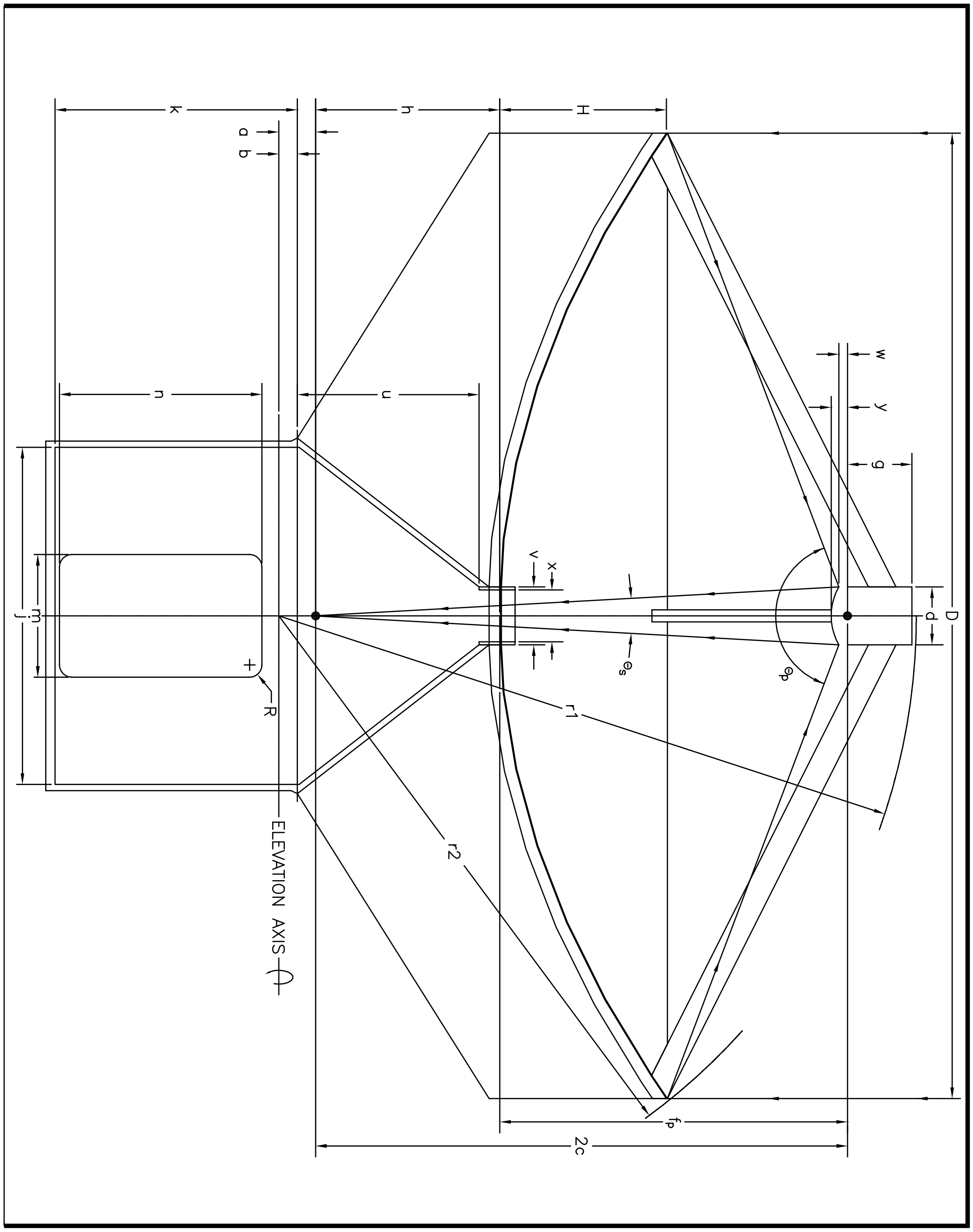

Figure 1: MMA Optical Configuration, Version 1.

D	Primary Aperture	8,000 mm	315.0 inches
f_p	Focal length of primary	3,040.38 mm	119.7 inches
	f_p/D of primary	0.38	0.38
d	Secondary aperture	530.86 mm	20.90 inches
	Final f/D	8.39	8.39
	Magnification factor	22.08	22.08
$theta_p$	Primary angle of illumination	133.36 deg	133.36 deg
$theta_s$	Secondary angle of illumination	6.83 deg	6.83 deg
2c	Distance between primary and secondary foci	4,564.0 mm	179.7 inches
H	Depth of primary	1,316.0 mm	51.8 inches
r1	Tipping structure apex radius (1” clearance) [close packing 1.36 D]	5,433.0 mm	213.9 inches
r2	Tipping structure dish radius (1” clearance) [close packing 1.28 D]	5,114.0 mm	201.3 inches
h	Distance from vertex to secondary focus	1,524.0 mm	60.00 inches
a	Distance from elevation axis to focus	304.8 mm	12.00 inches
b	Distance from elevation axis to base of center cone	152.4 mm	6.00 inches
g	Distance from primary focus to top of quadrapod	533.4 mm	21.0 inches
x	Clear aperture at receiver cabin window	480.06 mm	18.9 inches
	Center cone base inside diameter	2,844.80 mm	112 inches
u	Center cone height	1,506.22 mm	59.3 inches
v	Center cone and primary surface inside diameter	530.86 mm	20.90 inches
j	Receivercabininsidewidthanddepth(square)	2,794.0 mm	110 inches
k	Receiver cabin inside height	2,006.60 mm	79.0 inches
m	Receiver cabin door width	1,016.0 mm	40.0 inches
n	Receiver cabin door height	1,676.4 mm	66.0 inches
R	Receiver cabin door fillet	101.6 mm	4.0 inches
w	Distance from primary focus to edge of secondary mirror	114.414 mm	4.5045 inches
y	Distance from primary focus to front face of secondary mirror	197.772 mm	7.7863 inches

Table 1: Dimensions of MMA Optical Configuration, Version 1.