mmA Antenna Memo No. 2

Minimum Spacing Constraints for MMA Antennas

James W. Lamb
National Radio Astronomy Observatory
Tucson, Arizona

Introduction

Production of mosaic images requires that the antennas in the array be placed close together so that the u-v coverage of the array overlaps the u-v coverage of a single element of the array. This places some strict requirements on the antenna structure. For example, the design of an enclosure which does not prevent antennas from being closely spaced is difficult and it becomes desirable to design an antenna which does not require an enclosure for protection. The closest spacing should also not cause mechanical interference between antennas even if one or more antennas should malfunction and point in the wrong direction. This note looks at some geometrical constraints on spacing.

Calculation of Minimum Spacing

In general, an antenna will sweep out an ellipsoidal volume with dimensions determined by the points most distant from the two axes. For a symmetrical antenna with intersecting azimuth and elevation axes (Fig. 1) the ellipsoid becomes spherical, with some radius *R*. Following the diagram, *D* is the aperture diameter, *f* is the primary focal length, and *a* is the distance of the elevation bearing behind the primary vertex. In a real antenna, there will be some structure beyond the prime focus, but that will be ignored in this analysis.

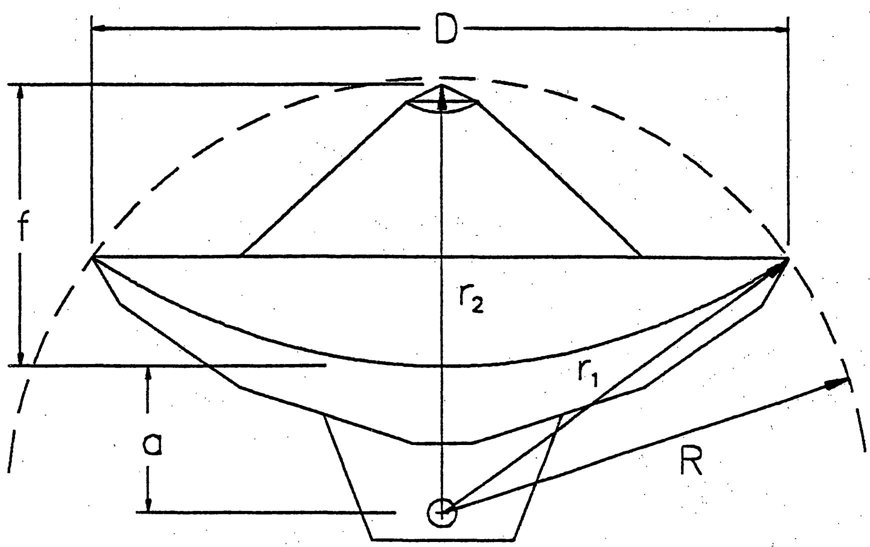

Figure 1. Definition of parameters used in the text for a symmetrical antenna.

The only arrangement which allows the minimum spacing $R = D/2$ is where the elevation axis is in the aperture plane. The focal ratio must then lie in the range:

$$0.125 < f/D < 0.603$$

It is more usual, however, for the elevation support to be behind the aperture plane, and generally behind the primary vertex. From Fig. 1, it may be seen that the most compact arrangement for a given a is obtained by choosing a focal ratio such that r_1 and r_2 are equal. Fig. 2 shows how the optimum focal ratio depends on the distance of the elevation axis behind the primary vertex (normalized to the aperture diameter), and Fig. 3 gives the corresponding radius of the volume swept out by the antenna. If a 9m spacing was required for the 8-m antennas, the elevation axis would have to be less than 0.96m behind the primary and the focal ratio would be 0.44. A spacing of 10m would indicate an axis to vertex distance of 1.84m, and a focal ratio of 0.40.

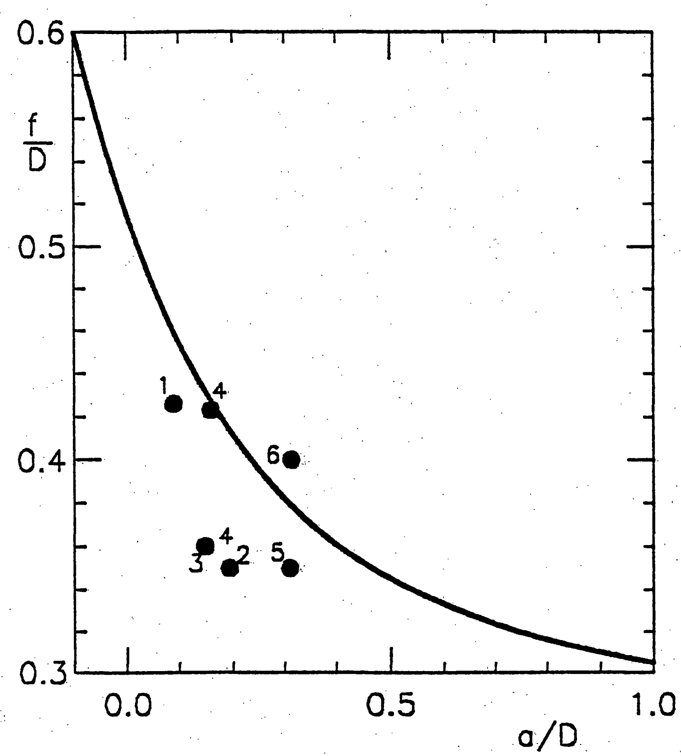

Figure 2. Dependence of optimum focal ratio on normalized distance from vertex to elevation axis. Points correspond to designs in Table I.

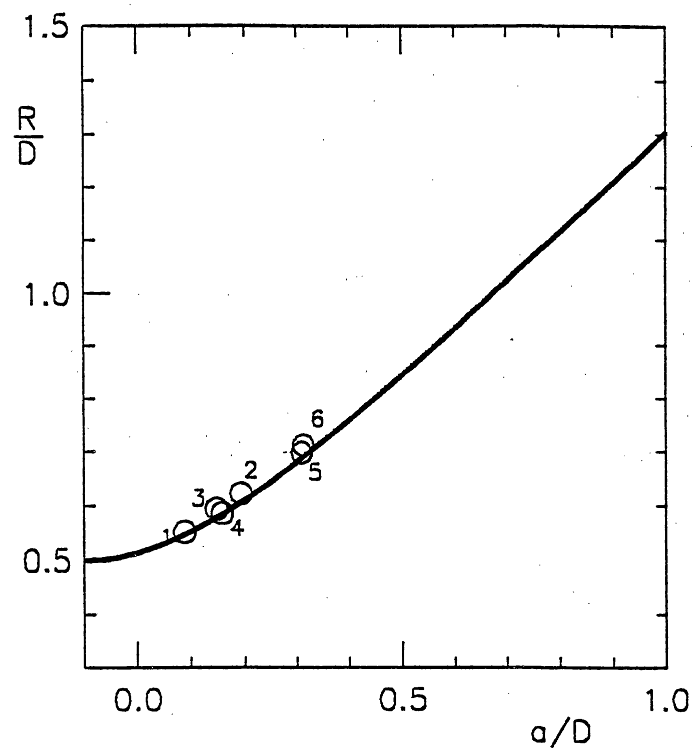

Figure 3. Minimum radius swept out by antenna. Points correspond to designs in Table I.

Other Considerations

Obviously, there are other structural and optical factors which influence the choice of *f* and *a*. In the present concept for the MMA antennas (Fig. 4, MMA Memo No. 52), the secondary focus is well behind the primary vertex so that it is in an easily accessible receiver room in the mount. This requires that the f-ratio is kept small to place the secondary focus as far down as possible. The radius of the mount needs to be as large as possible to provide receiver accommodation, but that requires *a* to be large if the antenna is to point at the horizon. Some lower elevation limit greater than 0° would reduce this conflict.

Other aspects of the design will also be important. For example, the distance *a* will also be restricted by the design of the backing structure which may not allow the bearings to be close to the vertex while maintaining the required structural properties.

Comparison With Other Designs

Closest packing has not generally been a driving force in the design of antennas, though in some cases, such as the JCMT, the f-ratio of the primary has been determined by the need to minimize the size

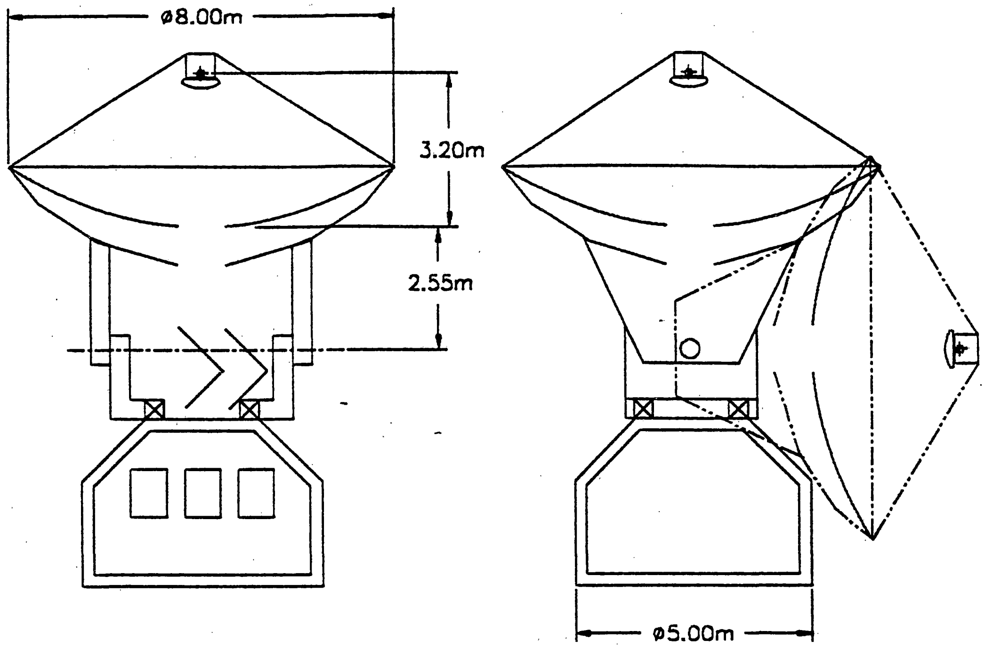

Figure 4. Concept MMA antenna design (Lamb and Payne, MMA Memo No. 52).

(and cost) of an enclosure. It is, nevertheless, interesting to compare some existing designs with the optimum strategy described above. Table I shows the relevant parameters for the antennas. The sample is determined by which drawings were readily available rather than an attempt to be truly representative. Also on the Table is the straw-man design for the MMA antennas (Fig. 4). A major consideration in that design was to locate the elevation axis far enough from the vertex so that the antenna could be pointed at the horizon without touching the mount which contains the receivers.

	DESIGN	D (m)	f (m)	a (m)	f/D	a/D	r_1/D	r_2/D
(1)	NRAO 65-m	65	27.70	5.7	0.426	0.088	0.552	0.514
(2)	IRAM 30-m	30	10.50	5.8	0.350	0.193	0.623	0.543
(3)	JCMT 15-m	15	5.40	2.2	0.360	0.147	0.594	0.507
(4)	NRAO 12-m	12	5.08	1.9	0.423	0.158	0.586	0.582
(5)	SMT 10-m	10	3.50	3.1	0.350	0.310	0.699	0.660
(6)	MMA 8-m	8	3.20	2.5	0.400	0.313	0.685	0.713

Table I: Geometrical parameters for some antenna designs.

In Fig. 2, the points represent the designs listed in Table I. They apparently do not lie very close to the optimum curve. Despite this, the designs do not depart very far from the minimum value of R, as shown in Fig. 3, since R is not a very sensitive function of the f-ratio. Clearly, the most important parameter is a/D. Generally, this is smaller for large antennas for several reasons. Firstly, the mass and dynamical considerations are more critical to large antennas and it is therefore important to keep the rotation axes close to the center of gravity of the primary reflector to minimize the moment of inertia and counterweights. Secondly, the receiver accommodation does not scale with antenna size, but is almost constant. Thirdly, large antennas are often built with a wheel and track mounting rather than the central bearing used in small antennas. The larger spacing between elevation axle mounting points makes it easier to minimize a.

Discussion and Conclusions

When a closely packed array of antennas is required, the most conservative approach is to design the antennas so that they do not touch each other under any circumstances. This means not only that the antennas do not run the risk of damage, but also that one defective antenna does not "lock" all the other closely packed elements if it becomes "frozen." The most critical parameter in achieving this aim is the elevation axis to primary vertex distance, a. From existing designs, it appears that a closest spacing of $1.25D$ may be achieved reasonably easily, but spacings as low as $1.10D$ could be possible but difficult.

Fig. 5 shows the single-dish and minimum array spacing spatial sensitivities for two minimum spacings. In practice, the effective spacing may be reduced, at least in one dimension by a cosine elevation factor. Simulations of the production of mosaic images should investigate spacings between $1.1D$ and $1.3D$.

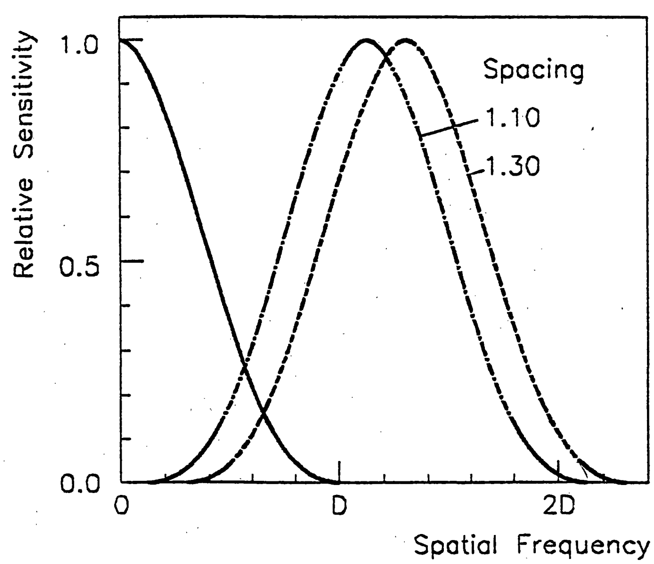

Figure 5. Single-dish and minimum array spacing spatial sensitivities, assuming an 11 dB taper and no central blockage.