Some Comments on Sampling, Antenna Spacings, and Uniform Aperture Illumination

Wm. J. Welch
BIMA

1. Introduction

The general scheme for measuring short-spacing interferometer data that is planned for the MMA is a method known as "mosiacing", as outlined by Cornwell, MMA memo no. 24, and further developed in Cornwell et al (1993). This uses scanning or multiple pointing of the interferometer antennas during tracking to extend the uv coverage of close pairs into the circle of radius D, one antenna diameter. This extension will then overlap the uv coverage provided by single dish maps made by individual interferometer antennas. For source declinations that are sufficiently different from the latitude of the observatory, baseline foreshortening will readily bring antenna separations to the minimum separation of one antenna diameter. However, for declinations near the observatory latitude, the needed minimum spacing can only be achieved by close antenna spacing, as long as observations are done at the highest possible elevations.

In an earlier memo, MMA no. 64, James Lamb discussed spacing constraints for the MMA antennas. He noted that among existing millimeter antennas the smaller units used would have some difficulty in being spaced closely enough to enable good sampling of the shorter spacings. He nevertheless suggested that a separation as small as 1.1 diameter might be possible without collisions between the antennas.

Uniform illumination of the antenna aperture is expected to improve the spatial spectral coverage. This note considers briefly the importance of aperture illumination to the quality of the short spacing sampling. We also add a little to Lamb's discussion of the problem of antenna separation.

2. The Effect of Aperture Illumination

In the spectral, or uv, plane, the effective uv coverage that results from the multiple pointing is the ordinary visibility function convolved with the single antenna spectral function. Lamb's figure 5 shows the overlap of the single antenna spatial spectrum with that of the convolved shortest interferometer spacing. He considers two separations, one for 1.1D and one for 1.3D. His spectral function is for a typical 11 db illumination taper. The spectral distribution for uniform illumination is the following well-known function.

$$\Psi_u(S/D) = 2/\pi[sin^{-1}\sqrt{1-(S/D)^2} - (S/D)\sqrt{1-(S/D)^2}] \qquad (1)$$

where S is the separation and D is the dish diameter. In Figure 1 we show the spectral responses for both Lamb's 11 db taper and for the uniform illumination of the same aperture. Both the single dish and minimum separation responses are shown for both illuminations for a separation of 1.2D. The uniform case is the solid line and the tapered case is the dashed line. The overlap is better for the uniform case, but only by a small amount.

3. Antenna Separation

The antenna separation in Figure 1 is 1.2D, and it is clear that if it were as large as 1.5 or 1.6, the overlap in the spectral functions would be poor, regardless of which illumination were used. Looking over the structures of existing millimeter antennas, Lamb concluded that 1.25D and possibly even 1.1D might be achieved. While this conclusion seems to fit the larger of the millimeter telescopes, it seems somewhat optimistic for the smaller ones, including the strawman 8m design for the MMA.

Lamb took the most conservative view that the separation would be such that there would be no possibility of collision between neighboring antennas. It is clear that in the antenna design, consideration should be given to mount structures that could permit separations as small as 1.1D or 1.2D with no danger of collision. However, this may be difficult, and it may be worth considering the option of having the antennas close enough that near the horizontal limits a collision would be possible. Limit switches in both hardware and software could be used to keep the antennas apart.

4. Discussion

As regards the illumination of the aperture, there seems to be only a small advantage in spectral sensitivity in selecting the uniform illumination over a more conventional taper. An illumination approaching uniform is possible through the use of shaped reflectors or lenses (Galindo, 1964;Hudson et al, 1987). However, there are some penalties in this choice that probably outweigh the small spectral advantage discussed here. The choice of shapes is sensitive to the feed pattern, and a change of that pattern with possible receiver upgrades will degrade the advantage. For the same reason, the aperture coupling is more frequency dependent. The shaping generally results in a severely limited field of view. This limitation in the optics makes it difficult to use a chopping secondary or to later add even a small focal plane array. It also restricts the options in coupling to multiple receivers. The gain improvement that comes with the shaping is typically small. For example, Hudson et al (1987) reported an improvement in aperture efficiency from .69 to .84 with the use of a shaping lens on one of the BIMA 6m antennas at 85.5 GHz. More recently, an efficiency of about .77 has been achieved with a feed at the tertiary focus of a conventional parabola/hyperbola Cassegrain system on one of the BIMA telescopes (Lugten ,1994). This is nearly as high as for the shaped system with none of the disadvantages listed above. Since the spillover is on the sky, there is no relative penalty on background pickup compared to the more uniformly illuminated case.

The more important effect is the actual antenna separation. A separation as small 1.2D or even 1.1D is desirable. It would be best if the mount design could allow such a small separation with no possibility of collision. If small separation without collision is not possible, some thought should be given to ways in which the antennas could be protected by means of hardware and software limits. A tight array of BIMA 6m antennas has been operated with a minimum spacing of 1.25D. At this separation, collision is possible, and a system of contact wires mounted at the edges of the reflector and along the feed legs has been used to protect the antennas. No damage resulted from this operation. However, simple problems such as a failure of one antenna to continue tracking could possibly stall the whole array.

5. References

1. Cornwell, T. J. 1984, MMA memo no. 24
2. Cornwell, T. J., Holdaway, M., and Uson, J. 1988, A&A 271, 697.
3. Galindo, V., 1964, IEEE Trans. AP, AP-21, 403.
4. Hudson, J. A., Plambeck R., and Welch, W. J. 1987, Radio Science, 22,1091
5. Lamb, James , 1990, MMA memo no. 61
6. Lugten, J. 1994, Proceedings of the European Workshop on Low Noise Quasi-optics, Bonn, 12Sept-13Sept.

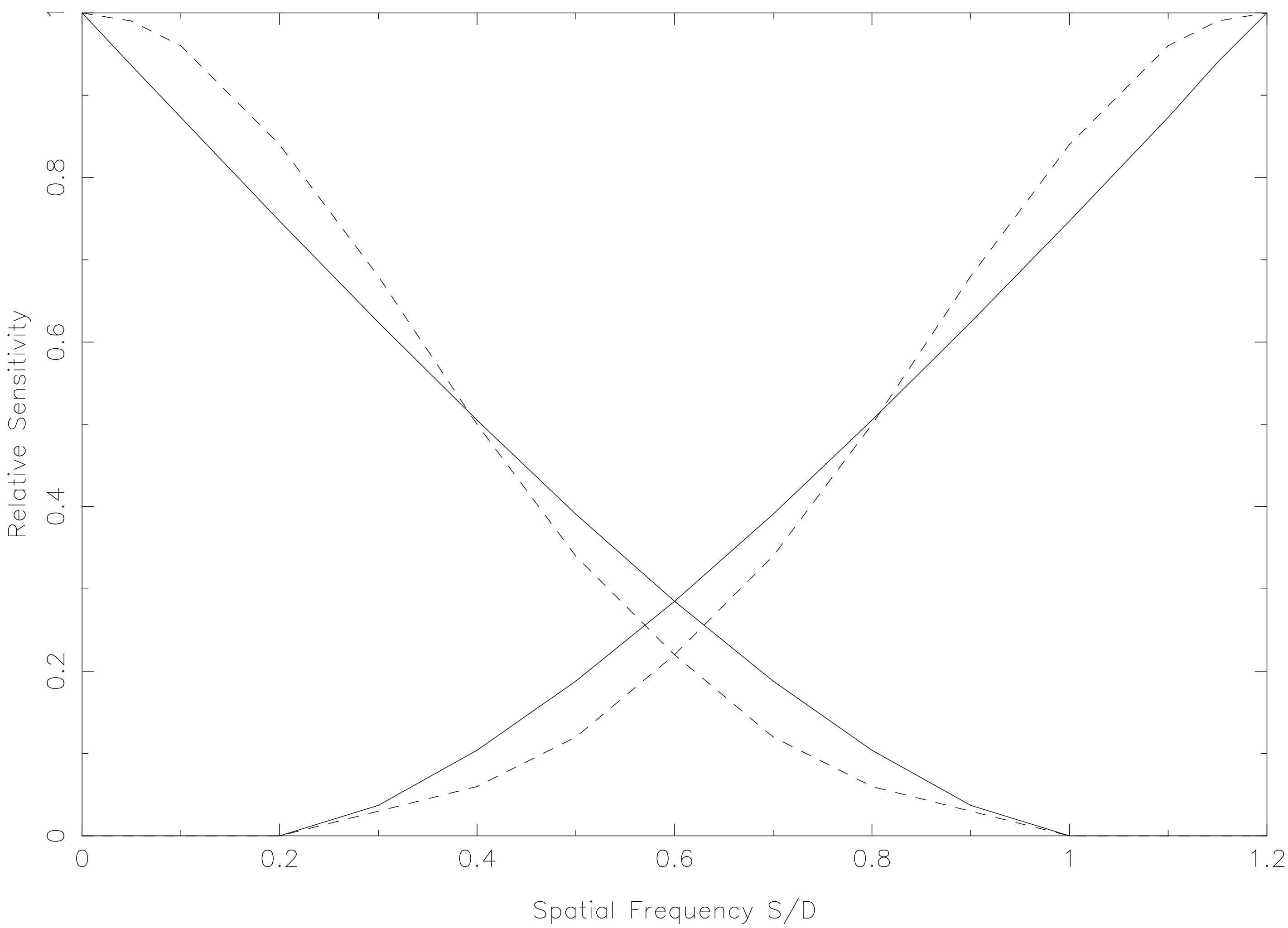

Fig. 1.— Spectral responses of the single-dish and minimum array spacing. The minimum antenna separation is 1.2 times the dish diameter. The solid curves correspond to uniform illumination, and the dashed curves correspond to an 11db aperture taper.