MMA Memo 172: Comments on Minimum Sidelobe Configurations

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Abstract

L.R. Kogan's (1997) minimum sidelobe configurations are discussed in the framework of the debate between ring-like and filled array configurations for the MMA. If multiple configuration imaging will be standard for the MMA, we predict the filled, minimum sidelobe configurations will result in superior imaging of complex objects. If single configuration imaging will be standard for the MMA, simulations have shown that ring-like configurations will result in superior imaging of complex objects. Therefore, a strategy for the use of the configurations (ie, predominantly multiple configuration imaging or single configuration imaging) must be developed.

L.R. Kogan (1997) has developed a computer algorithm which finds an array configuration which produces a zenith snapshot point spread function (PSF) with minimum sidelobes along radial slices at certain azimuth angles. MMA Memo 171 describes the algorithm and presents the optimized array configurations for different numbers of antennas.

Other interferometric array optimization methods seek to obtain uniform Fourier plane coverage within a circular region of the Fourier plane (Keto 1996), or subject to the constraint that the antennas lie within a circular region in the antenna plane (Cornwell, 1986). These optimizations result in ring-like arrays, the Fourier plane density is a flat function of (u,v) distance with a sharp cutoff at the maximum baseline and an overdensity of very short baselines at roughly 3.14 * ArrayDiameter / N. (This minimum baseline is not even as short as in the case of the VLA even though there are more MMA antennas, which is perceived as problematic. One can obtain shorter baselines, but at the expense of introducing non-uniformities into the Fourier plane coverage.) The sharp cutoff at the edge of the (u,v) coverage is seen by some to be the main advantage of these array configurations, as the array has the maximum possible sensitivity on the longest baselines, which have the lowest visibility amplitudes. However, the sharp cutoff also results in very large near-in PSF sidelobes (about 15% of the PSF peak). The sharp cutoff is somewhat assuaged by long tracks which reduce the worst sidelobes to about 10%, but this is still much higher than the sidelobe level of Kogan's arrays.

For small numbers of antennas, Kogan's algorithm produces ring-like arrays (given an initial ring-like array). However, when there are as many as 32 or 40 antennas, Kogan's algorithm produces filled arrays. This can be understood if we consider two different origins of PSF sidelobes: non-uniform Fourier plane coverage within the sampled region of the (u,v) plane, and the envelope of the Fourier plane sampling (ie, the sharp cutoff in the case of the ring-like arrays). Both Keto and Cornwell have demonstrated that a ring-like array will minimize the size of the (u,v) gaps within some region of the (u,v) plane. For small numbers of antennas, the sidelobes due to these gaps in the (u,v) plane will be larger than the sidelobes due to the sharp cutoff at the maximum sampled baseline inherent in the ring. so Kogan's algorithm favors ring arrays for small numbers of antennas. For large numbers of antennas in a ring-like array, the gaps in the (u,v) plane will be very small, and the PSF sidelobes will be dominated by the shape of the sampling envelope, the ringing caused by the sharp cutoff in the (u,v) plane. Hence, Kogan's algorithm rearranges the antennas such that the cutoff is smoothed out and the sidelobes are no longer dominated by the sampling envelope. IE, to minimize the sidelobes in a 40 element MMA configuration, the algorithm produces a filled array, which produces a centrally condensed, or naturally tapered, Fourier plane coverage (see also Holdaway, 1996). For longer (u,v) tracks, the PSF sidelobes will be dominated by the sharp (u,v) cutoff with even smaller numbers of antennas since earth rotation is more effective at filling in the holes than it is at softening the sharp (u,v) cutoff at most declinations.

A possible disadvantage of the filled array is that it produces a lower resolution beam as compared to a ring-like array, given the same maximum baseline. This is not necessarily a strong disadvantage if the suite of array configurations are designed with this in mind.

Which of these Fourier plane coverages is superior? This depends strongly on the type of objects which will be observed by the MMA and the observing strategy which will be employed. Unpublished simulations indicate that for single configuration imaging of large, complex objects, the ring-like arrays produce better images than the filled arrays. This is primarily due to the superior very short baseline coverage which the ring-like arrays have. When the antennas are constrained to lie on a ring, each antenna's nearest neighbor will, on average, be much closer than when the antennas are merely constrained to lie within a circle.

I posit that for complex objects, the minimum sidelobe (ie, filled) configurations will yield superior images when multiple configuration imaging is employed to fill the increased central gap in the (u,v) coverage. If single configuration imaging is required (ie, the large configurations also have enough short baselines to produce acceptable images for even large objects), the ring-like arrays will yield superior images.

References

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