Radio Interferometer Array Point Spread Functions

David Woody
Owens Valley Radio Observatory, Big Pine, CA 93513 USA

The new generation of large-N arrays will produce very high quality images and optical imaging criteria can be used to evaluate their performance. The Point Spread Function, PSF, widely used to evaluate optical telescope performance is also a valuable metric for characterizing the performance of interferometer array configurations. The statistical properties of the PSF including the effect of missing UV data are derived as a function of the number of antennas and array magnification, defined as the ratio of the primary beam width from an individual element to the synthesized beam width. The effect of earth rotation synthesis on the PSF is also calculated and the merits of various configuration strategies are discussed in terms of their PSFs.

Pseudo-random arrays whose large-scale average distribution match an idealized continuous antenna distribution but are randomly distributed on smaller scales have been shown to produce good PSFs. The small-scale difference between the actual discrete distribution and the idealized continuous distribution produces far sidelobes in the PSF. It is shown that the statistical distribution of the sidelobes, $\mathbf{s}$, of pseudo-random arrays of $\mathbf{N}$ antennas with sparse UV coverage is given by $\mathbf{P(s) = N\exp(-Ns)}$. The average sidelobe is $\mathbf{1/N}$ and the standard deviation is $\mathbf{1/N}$ when the single antenna measurements are included in the formulation of the PSF. The expected peak sidelobe for a pseudo-random array with a magnification $\mathbf{mag}$ is $\mathbf{s_{max} \approx 2\ln(mag)/N}$. It is predicted that optimization can reduce the peak sidelobe to $\mathbf{s_{max,opt} \approx \left(2\ln(mag) - \ln(N)\right)/N}$. Pseudo-random arrays provide a benchmark against which proposed configurations can be compared.

The PSF of several sample arrays are evaluated. The distribution of sidelobes for sensibly designed arrays is shown to closely follow the above theoretical distribution. An optimization procedure is developed that produces configurations with peak sidelobes close to the expected limit given above. The optimized arrays have a smooth progression from small peaks near the center of the PSF and to the largest peaks at the edge of the primary beam. A plot of the peak sidelobe as a function of the radial distance from the center of the PSF is a simple and useful method for evaluating the PSF of large-N arrays.