All-Sky synthesis imaging for optimum transient detection in Radio Astronomy

Peeyush Prasad*[(1)], Stefan J. Wijnholds, [(1)] and R.A.M.J Wijers[(2)]
(1) ASTRON, PO Box 2, 7990AA, The Netherlands.
(2) University of Amsterdam, The Netherlands. Email: prasad@astron.nl

We present the imaging subsystem of the AARTFAAC interferometric array, an All-sky monitor for detecting short term (seconds to minutes) transient activity of celestial radio sources in near real time. We optimize point source sensitivity, and reduce sidelobe confusion noise to significantly enhance transient detectability. The resulting images have a dynamic range of ~2000:1 with a 1 sec/90kHz integration at 60 MHz. They are confusion noise limited in few tens of seconds due to the ~1deg Point Spread Function (PSF) of the instrument making the array the most sensitive dedicated transient detector at low frequencies.

The co-planar array carries out continuous transit drift scans in snapshot imaging mode and extracts fluxes from all detected sources in a timeseries of images for transient detection. The requirements for adequate flux and position calibration in the face of ionospheric and instrumental variations are met by a real-time calibration system (Prasad et. al, A&A, 568, 2014, A48). The imaging is complicated by the all-sky field of view and the low frequencies of operation (30-80 MHz) of the array, which results in several non-thermal point and diffuse sources of high brightness temperature within an image. These need to be adequately deconvolved to recover the weaker sources reliably, in order to enhance the transient detection sensitivity of the instrument.

We apply a spatial filter on the diffuse Galactic emission, with subtraction of model visibilities of other bright sources. The real-time latency requires a gridding of the observed Fourier space visibilities, in order to use an FFT to transform them to the image domain. These operations, however, lead to image artifacts, and require us to derive weighting, tapering and a Grid Convolution Function to optimize point source sensitivity, and to reduce sidelobe confusion. The array spatial configuration can change with observations, requiring its own optimization. Fig. 1 (left) shows an All-sky DFT image with no taper and natural weighting. Emission is dominated by a few bright point sources and the Galactic plane, with weaker sources not visible. Fig. 1(middle) shows the resulting 2D PSF around the phase center, after applying a Gaussian taper to the shortest baselines. This reduces the close-in ringing due to the spatial filter by ~10dB, compared to applying no taper. Fig. 1(right) shows the same timeslice after filtering diffuse and brighter point sources with the optimized PSF.

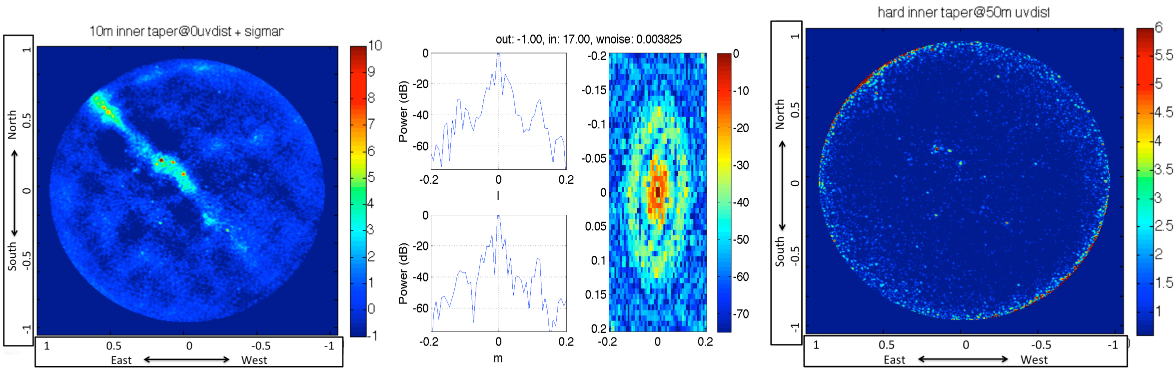

Fig. 1: (left) All-sky DFT image, (middle) Optimized PSF and profile, (right) Processed image with spatial filtering and optimized PSF. All plots are in (l,m) coordinates.