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A multiple-beam CLEAN for imaging intra-day variable radio sources

I. M. Stewart, D. M. Fenech, T. W. B. Muxlow

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The CLEAN algorithm, widely used in radio interferometry for the deconvolution of radio images, performs well only if the raw radio image (dirty image) is, to good approximation, a simple convolution between the instrumental point-spread function (dirty beam) and the true distribution of emission across the sky. An important case in which this approximation breaks down is during frequency synthesis if the observing bandwidth is wide enough for variations in the spectrum of the sky to become significant. The convolution assumption also breaks down, in any situation but snapshot observations, if sources in the field vary significantly in flux density over the duration of the observation. Such time-variation can even be instrumental in nature, for example due to jitter or rotation of the primary beam pattern on the sky during an observation. An algorithm already exists for dealing with the spectral variation encountered in wide-band frequency synthesis interferometry. This algorithm is an extension of CLEAN in which, at each iteration, a set of N `dirty beams' are fitted and subtracted in parallel, instead of just a single dirty beam as in standard CLEAN. In the wide-band algorithm the beams are obtained by expanding a nominal source spectrum in a Taylor series, each term of the series generating one of the beams. In the present paper this algorithm is extended to images which contain sources which vary over both frequency and time. Different expansion schemes (or bases) on the time and frequency axes are compared, and issues such as Gibbs ringing and non-orthogonality are discussed. It is shown that practical considerations make it often desirable to orthogonalize the set of beams before commencing the cleaning. This is easily accomplished via a Gram-Schmidt technique.

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