2nd URSI AT-RASC, Gran Canaria, 28 May – 1 June 2018

Blind calibration techniques for radio astronomical arrays

Stefan J. Wijnholds
Netherlands Institute for Radio Astronomy (ASTRON), Oude Hoogeveensedijk 4, 7991 PD, Dwingeloo, The Netherlands
Dept. of Electrical and Electronic Engineerings, Stellenbosch University, Stellenbosch, South Africa

1. Abstract

Radio astronomical arrays usually consist of many receiving elements to meet the resolution and sensitivity requirement demanded by the application. Calibration of the individual receive paths in these systems is crucial to the performance of these instruments. This is normally done by constructing a source model of the brightest sources in the observed scene based on sky catalogs. After initial calibration, an image is constructed and, if needed, the source model is updated. This updated source model can then be used to further improve the calibration. This iterative process is referred to as self-calibration.

This approach usually gives excellent results but is also known to produce erroneous results when the initial source model is too inaccurate. Such situations may occur when there is an unexpected unknown source, such as a transient source or radio frequency interference, or when a new instrument is commissioned that opens up a hitherto unexplored frequency range. In such cases, blind calibration may help to bootstrap the self-calibration process. Blind calibration techniques are calibration methods that work without an a priori model of the observed scene.

In this tutorial, I present an overview of blind calibration techniques used to calibrate radio astronomical arrays. I start with redundancy calibration, which was developed in the early 1980s to calibrate the Westerbork Synthesis Radio Telescope (WSRT) by exploiting the regularity of its array configuration. Fuzzy redundancy, which exploits the availability of almost redundant baselines in dense irregular array, is a natural extension of redundancy calibration. More recently, a number of blind calibration methods have been proposed that work for arbitrary array configurations. These techniques either work by optimizing the contrast in the observed scene or by exploiting the sparsity in the observed scene. The techniques in the latter category appear to be quite robust to large instrumental errors and have an interesting connection with regular self-calibration techniques that start from an initial sky model. This connection led to a number of new insights in the robustness of self-calibration to poor initial source models.