EFFECTS OF ANTENNA PRIMARY BEAM ERRORS IN MOSAIC IMAGING WITH APERTURE SYNTHESIS TELESCOPES

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Abstract

Astronomical imaging using aperture synthesis telescopes require deconvolution of the point spread function as well as calibration of instrumental and atmospheric effects. Antenna pointing errors and rotation of azimuthally asymmetric antenna power patterns lead to time varying gains which also vary across the field of view. With improved sensitivities of the various next generation radio telescopes, there is a need to correct for such errors during image deconvolution. In this paper, we discuss imaging dynamic range limits due to these effects and the algorithmic and computing challenges ahead with an emphasis on mosaic imaging.

1. Summary

The antenna power pattern is azimuthally asymmetric for most antennas used for aperture synthesis in radio astronomy. For azimuth-elevation mounted antennas, the power pattern also rotate on the sky as a function of the Parallactic Angle. This results in time varying gains which change across the main lobe of the primary beam. The azimuthal asymmetry is much stronger in the side lobes of the power pattern. Sources in the direction of the side lobes therefore experiences almost 100% variation in the antenna forward gain as a function of time. With the increased sensitivity of the new instruments like EVLA and ALMA, deconvolution of sources in the first side lobe will be necessary to achieve sensitivity limited imaging even for simple fields. Hence, even for single pointing imaging, it is necessary to develop image deconvolution algorithms that correct for such time varying primary beam effects.

Mosaic imaging is necessary for sources which are larger than the antenna primary beam. This will typically be the case for high frequency interferometers like ALMA which are under construction. Since such observations require multiple pointing typically separated by half the size of the primary beam main lobe, there is significant flux in the direction of the half-power point of the primary beam and side lobe for most pointing. The time varying gains due to the rotation of the azimuthally asymmetric antenna power patterns therefore constitute a first order effect for mosaic imaging. Time varying antennas gains will also appear for both single pointing and mosaic observations due to time varying antenna pointing errors.

Correction of such direction and time dependent effects will be crucial in achieving sensitivity limited imaging performance with higher sensitivity synthesis telescopes being planned or under construction. The data volume from these telescopes is also going to be much higher. It is therefore important to develop efficient imaging deconvolution and calibration techniques which can solve and correct for such effects. In this paper, via simulations we will discuss the various errors that could limit the imaging dynamic ranges of the next generation telescopes and the progress made towards development of new efficient algorithms which can potentially improve the imaging performance in comparison to the conventional algorithms.