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Thesis abstract

Water Vapour Radiometers for the Australia Telescope Compact Array

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In the millimetre wavelength regime of the electromagnetic spectrum used in radio astronomy, poorly mixed pockets of precipitable water vapour cause a change in the refractive index of the atmosphere, thereby inducing an excess path that the signal must travel through. This results in a phase delay for antennae receiving an astronomical signal. In an interferometer such as the Australia Telescope Compact Array (ATCA), variations in phase delay between the antennae thus lead to degradation in the image quality obtainable due to signal decorrelation. This phase fluctuation induced noise increases both with frequency and baseline length. It therefore also puts upper limits on the usable length of baselines without experiencing significant decorrelation, thus limiting the spatial resolution of the interferometer.

We have developed Water Vapour Radiometers (WVRs) for the ATCA that are capable of determining excess path fluctuations by virtue of measuring small temperature fluctuations in the atmosphere using the 22.2 GHz water vapour line for each of the six antennae. By measuring the line of sight variations of the water vapour, the induced path excess and thus the phase delay can be estimated and corrections can then be applied during data reduction. This reduces decorrelation of the source signal. I demonstrate how this recovers the telescope's efficiency and image quality as well as how this improves the telescope's ability to use longer baselines at higher frequencies, thereby resulting in higher spatial resolution.

The design process of the WVRs is discussed, including a review of three other WVR systems for comparison with our system design. A detailed site characterisation is provided with emphasis on millimetre observing conditions and it is determined to what extent WVRs can improve telescope data. A thorough examination of the frequency space used for the WVRs follows in order to avoid and detect radio frequency interference of both terrestrial and orbital origin. A detailed description of the WVR hardware design is given and concludes with a detailed account of the atmospheric modelling and water vapour retrieval mechanisms I have developed. The thesis concludes with a list of future opportunities and developments to improve the existing WVR system.

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