sub-Kilometre scale studies of the Ionospheric Phase Screens at the SKA-Low site, using MWA extended baselines

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The ambitious scientific goals of SKA require a matching capability for calibration of the instrumental and atmospheric propagation contributions as functions of time, frequency and position. The development of novel calibration algorithms to meet these requirements is an active field of research. In this work we aim at characterising these, focusing on the spatial and temporal structure scales of the ionospheric effects; ultimately, these provide the guidelines for designing the optimum calibration strategy.

We used empirical ionospheric measurements at the site where the SKA-Low will be built, using MWA Phase-2 Extended baseline observations and the station-based LEAP calibration algorithm. We have done this via direct regression analysis of the ionospheric screens and by forming the full and detrended structure functions. We found that 50% of the screens show significant non-linear structures at scales >0.6km that dominate at >2km, and 1% show significant sub-minute temporal changes, providing that there is sufficient sensitivity. Even at the moderate sensitivity and baseline lengths of MWA non-linear corrections are required at 88 MHz during moderate-weather and at 154 MHz during poor weather, or for high SNR measurements. Therefore we predict that improvements will come from correcting for higher order defocusing effects in observations with MWA Phase-2, and even more so with new developments in MWA Phase-3. Because of the giant leap in sensitivity, the correction for complex ionospheric structures will be mandatory on SKA-Low, for both imaging and tied-array beam formation.

We applied these corrections to the same MWA data, using the Image Domain Gridding in WSClean, and demonstrated that the same results were observed when imaging; thus antenna-based (as opposed to array-based) direction-dependent corrections have a significant impact on the image quality and should be implemented, even for the limited length of the MWA extended baselines.