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Direction Dependent corrections for MWA and the implications for SKA and very long baselines

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The Ionosphere is a complex turbulent media, which throws up some significant challenges in calibration. The major issue is that the solution along one line of sight, to a suitable calibrator or cluster of calibrators, is not correct for another line of sight. This direction dependence (DD) could become the largest computational challenge to the SKA Data Processing. This is because all the contributions from all the directions in the sky, in principle, need to be solved simultaneously or sequentially. We have developed an innovative, simplified approach, which breaks this log-jam and allows embarrassingly-parallel processing of the calibration directions called Low-frequency Excision of Atmosphere in Parallel: LEAP [1]. We report on the LEAP outcomes for MWA, demonstrating a solution for the DD issue for reasonably compact instruments with dense ground coverage and wide fractional frequency.

As LEAP operates on the visibilities it can `refocus' data considered unusable, and provide scientifically valid data. We are quantifying the gains as a function of frequency, with a particular focus on the required calibrator density. MWA Phase-2 has extended the baselines to 6km, and the DD calibration approaches used for MWA Phase-1 GLEAM are no longer adequate.

The by-product of LEAP calibration is a measure of the (differential) ionospheric surface over the array, across a wide field of view; for the lowest frequencies of MWA this is more or less the whole visible sky. This measurement samples the surface at fine scales with high angular and time resolution, these being the most intractable component and which pose the major challenge for future instruments. The surfaces are predominately linear over the 6km of MWA and are stable over two minutes, but in many cases they are non-linear and change rapidly.

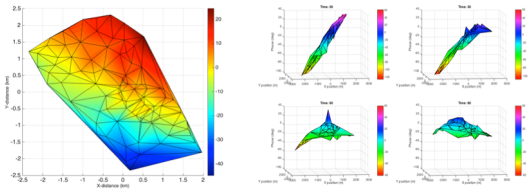

Figure 1: *Phase surfaces as seen in one dataset for different directions. One shows a near linear surface stable over time, the other phase surface is highly non-linear and rapidly varying.*

We will discuss the application of LEAP to various SKA requirements in calibration, in particular the real-time beam-forming where rapid solutions with no model dependence are mandatory. LEAP fulfils this role and its application is a focus of active study.

References

[1] M. Rioja, R. Dodson, T. Franzen, "LEAP: an innovative direction-dependent ionospheric calibration scheme for low-frequency arrays", MNRAS, 478, 2337