Polarization calibration of low-frequency radio telescopes (E2/SC4)

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Description:
The state of polarization of radio sources such as the percentage, type and angle of polarization convey significant astrophysical information. However, determination of polarization information (polarimetry) with a low-frequency phased array telescope depends on multiple steps of calibration and modelling, each of which demands high precision and is challenging. Firstly, low-frequency phased array telescopes are electronically steered such that the primary beam is dependent on the pointing direction. Secondly, unlike single-pixel dish telescopes, a phased array telescope has antenna elements that mutually couple.

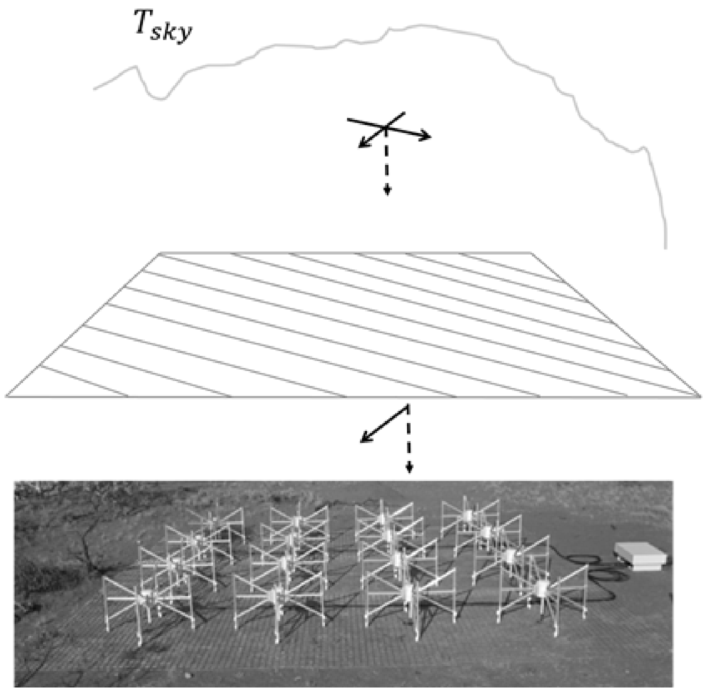
These factors complicate efforts to repeatably and accurately model the array beam over all frequencies and pointing directions for polarimetry. Finally, calibration of the phased array telescope for polarimetry requires constraining the phase and/or delay between the dual polarized antenna, which in the case of the Murchison Widefield Array (MWA) are orthogonally polarized dipoles (called "X" and "Y"). Here, we call this quantity X/Y phase. We note that similar considerations apply to the next generation low-frequency radio telescope, the low-frequency Square Kilometre Array (SKA-Low).

X/Y phase calibration is not critical in intensity-only observation or imaging. In this case, the X dipoles may be calibrated separately from the Y dipoles using an unpolarized sky model. The relative phase between the two dipoles is not critical. However in polarimetry, the polarization angle and type of polarization cannot be correctly inferred without proper X/Y phase information. Astronomical calibration of X/Y phase could be achieved by observing a bright source with well-known polarization properties. However, such sources are less well-characterized at low frequencies and do not transit at zenith such that calibration of X/Y phase is dependent on the quality of the beam model. It is highly desirable that the X/Y calibration be separated from the beam model to minimize uncertainties and systematic errors.

The objective of the project is to explore methods to calibrate X/Y phase by direct measurement on site and devise the most appropriate technique given the conditions and constraints of the telescope operation in Murchison Radio-astronomy Observatory (MRO). The physical mechanism that gives rise to the direction-independent delays between the X and Y dipoles in the MWA is no different than that which produces the X and Y delays separately.

They primarily depend on the relative group delay due to the electronic signal chains and the cable lengths. For a single MWA X/Y dipole, this quantity is measurable directly by injecting in-phase RF signals into the dipoles and measuring the X/Y phase at the MWA correlator. For the MWA tile (an entity of 4x4 dual polarized dipoles), the signal should be simultaneously fed into all elements.

This requires further considerations and proper engineering to ensure that the method of injection and measurement is easily deployable, is repeatable and minimizes potential interference at the MRO.



MWA tile receiving a polarized radiation