Constraining the ionospheric effect on EoR observation with the SKA1-Low Telescope

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The Cosmic Dawn (CD) and Epoch of Reionization (EoR) are crucial epochs in the phase transition of the early universe. A promising method for probing these epochs is the detection of the redshifted 21 cm signal from neutral hydrogen. However, the detection of this faint 21 cm signal is very challenging due to the bright astrophysical foreground, instrumental effects, and Earth's ionosphere. To understand and quantify these contaminants, an end-to-end simulation pipeline is necessary to deal with synthetic observations. An extensive amount of research has been done to quantify this excess noise to recover the 21 cm power spectrum. This excess noise is often attributed to systematics, which primarily constrains the upper limits of the CD/EoR power spectrum measurements. One of the potential sources of the excess noise is the residual ionospheric phase errors, which remain even after calibrating the effect of the ionosphere. This work investigates the impact of the Earth's ionosphere on observations of the redshifted 21 cm signal from the EoR using the SKA1-Low AA4 telescope. The SKA1-Low, a highly sensitive next-generation interferometer, is designed to detect the 21 cm power spectrum precisely. Through detailed simulations employing both the catalogue-based source model and Kolmogorov turbulence model of the ionosphere, we quantify the level of residual direction-dependent errors (DDEs) or the residual ionospheric refractive shifts required to extract the target signal. Our study demonstrates how residual DDEs caused by ionospheric effects can significantly impact on the extraction of 21 cm signal. We establish tolerance levels for the "median ionospheric offset" (MIO), demonstrating that calibration accuracy of the order of $\theta\mathrm{MIO} \lesssim 0.1''$ is essential for unbiased estimation of the cosmological power spectrum. This work highlights the critical need for developing and implementing robust ionospheric calibration algorithms for future SKA1-Low observations to extract the target signal from the CD/EoR precisely. Here, we present our results from simulations of how the DDEs affect the extraction of the target EoR signal.