Optimizing Low Frequency Array Design

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Detecting the Epoch of Reionization (EoR) through power spectrum analysis is a working goal of a number of low frequency radio experiments. The discovery of foreground dominated regions in Fourier Space prompted many "foreground avoidance" techniques to conduct analysis in regions of Fourier Space free of foreground signals. This region of Fourier space dominated by foreground is the so called "Foreground Wedge." The wedge is created primarily by the spectral structure imprinted by the imperfect sampling of the electric field by the instrument, this is influenced by the antenna design, and array configuration among other effects. The mixing of Fourier modes due to these effects causes ordinarily spectrally smooth foregrounds to bleed or leak into higher k modes. Theoretically it should be possible to build an array which perfectly samples the electric field and therefor has no wedge, in practice, reality intrudes. Here we attempt to quantify the amount of perfection needed to avoid a wedge altogether. We investigate the extent of the wedge influenced by antenna placement and coverage of the (u, v) plane. We make use of the PRISim simulator, the Fast Holographic Deconvolution (FHD) and Error Propagated Power Spectrum with Interleaved Observed Noise (ϵppsilon) analysis packages to conduct simulations of various arrays' expected power spectra. Our analysis shows a correlation between the fractional dynamic range of an array's (u, v) coverage and the amount foreground wedge leakage. We find that below a certain threshold, arrays exhibit a minimal amount of foreground contamination in the wedge. Using this threshold we define a metric for array response (combining beam and antenna position) which allows us to quickly evaluate arrays for foreground contamination level without need for a complete instrument simulation. We compare this metric directly to the outputs of FHD and ϵppsilon to verify the accuracy of the expected contamination. Using this metric we propose several array configurations which provide suitably low foreground leakage to enable high quality imaging. High quality imaging will allow for high fidelity image cubes of cosmic evolution through the EoR via the 21cm line.