Baseline Redundant Array With LWA-OVRO (BRAWL)

Concept development notes

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1 Introduction

The *Baseline Redundant Array With LWA-OVRO (BRAWL),* is a proposed 127-element interferometric array that will be co-located with the Long Wavelength Array (LWA) at Owens Valley Radio Observatory (OVRO). BRAWL follows the footsteps of the PAPER and HERA telecopes, that exploit redundancy to improve calibration and to target uv-modes of interest. Unlike PAPER and HERA, BRAWL will be targeting the period between the Dark Ages and the Epoch of Reionization, which is referred to as "Cosmic Dawn" or the "Epoch of X-ray heating" (EoX); that is, measurement of the 21-cm emission line at redshifts between 10-40.

This memo details the results of simulations of sensitivity, made with the `21cmsense` package (Pober et. al. [REF]). The code has been modified to allow looping over multiple redshifts, and to allow redshift to be added as a command-line parameter which is parsed to compute frequency parameters.

2 Input models and parameters

Power spectra model A. Fialkov has run some initial simulations for the expected 21-cm signal over $7 < z < 40$, for a range of k values between 0.0-1.6 (Figure 1), which are used as an input for `21cmsense`. These power spectra (PS) are for a 'bleak' model and the signal is likely stronger. Note that there is noise at lower k due to cosmic variance in the data cube used.

Antenna array For antenna placement, we are using a hexagonal-packed 127-element array with 10-m spacing (Figure 2). While for some k modes closer spacing would be preferable, mutual coupling between antenna elements is of concern.

Antenna parameters We assume the use of an LWA gain antenna, with the approximation that the gain is a constant 9 dB over the frequency range covered (beam solid angle of $\pi/2$). For compatibility with `21cmsense`, this is expressed as a 2D Gaussian with beamwidth $\pi/8$, and the parameter `dish_size_in_lambda` is set to 2. Ideally, we would use antenna parameters as modelled from an EM package; this is worth looking into at a later date.

System temperature The system temperature is given by

$$T_{sys} = T_{rx} + T_{sky}(\nu),$$

where T_{rx} is the receiver temperature, and is set to 500 K, and using a sky model

$$T_{sky} = T_0 \lambda^{2.55}$$

with $T_0 = 60$. The sky model thus gives a temperature of 1369 K at 88 MHz, increasing to 21288 K at 30 MHz. Using a more realistic sky model (i.e. based upon LEDA observations) would be advantageous for future simulations.

Table 1: Simulated signal-to-noise ratios for BRAWL, over $15 < z < 25$.

Redshift	Pessimistic	Moderate	Optimistic
15	1.00×10^{-1}	1.68×10^{-1}	3.41
16	1.24×10^{-1}	2.05×10^{-1}	5.85
17	1.48×10^{-1}	2.40×10^{-1}	8.41
18	1.15×10^{-1}	1.86×10^{-1}	6.37
19	8.31×10^{-2}	1.38×10^{-1}	2.28
20	1.71×10^{-1}	2.84×10^{-1}	1.01
21	2.91×10^{-1}	4.78×10^{-1}	1.82
22	2.89×10^{-1}	4.62×10^{-1}	1.60
23	1.99×10^{-1}	3.23×10^{-1}	1.11
24	1.12×10^{-1}	1.82×10^{-1}	6.18×10^{-1}
25	5.00×10^{-2}	8.27×10^{-2}	2.82×10^{-1}

Observation parameters Default parameters are used elsewhere in the code. This corresponds to 180 days of 6-hour drift-scan observations. A cosmological bandwidth of 8 MHz (redshift range that is co-evaluated) is used. Both conservative and optimistic models for the foreround wedge are presented.

3 Results

Using `21cmsense`, we computed the expected signal-to-noise ratio for the A. Fialkov PS model, under 'conservative' and 'optimistic' foreground removal models. Following from Pober et. al., consevative is defined as the foreground wedge extending $0.1\,\mathrm{h\,Mpc^{-1}}$ beyond horizon limit, and optimistic is defined as the foreground wedge extending only into the FWHM of the instrument's primary beam.

Simulations suggest that a $> 5\sigma$ detection of the PS can be made over the redshift range $16 \leq z \leq 18$. The conservative model suggests that foreground 'avoidance' only will not result in SNR levels high enough for detection, meaning that a foreground model is required. The minimally-redundant LWA-OVRO array would therefore be required for foreground characterization.

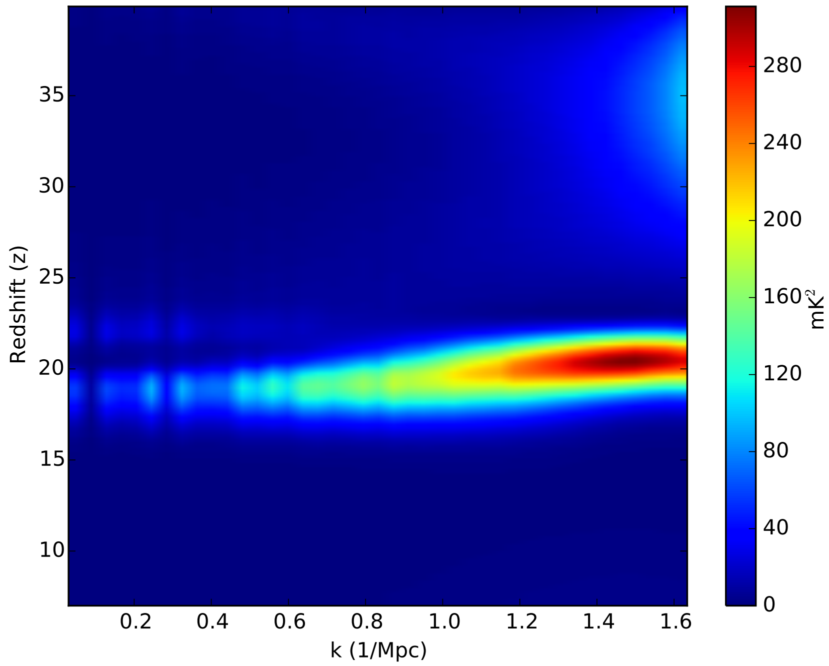

Figure 1: Simulated 21-cm power spectrum (preliminary).

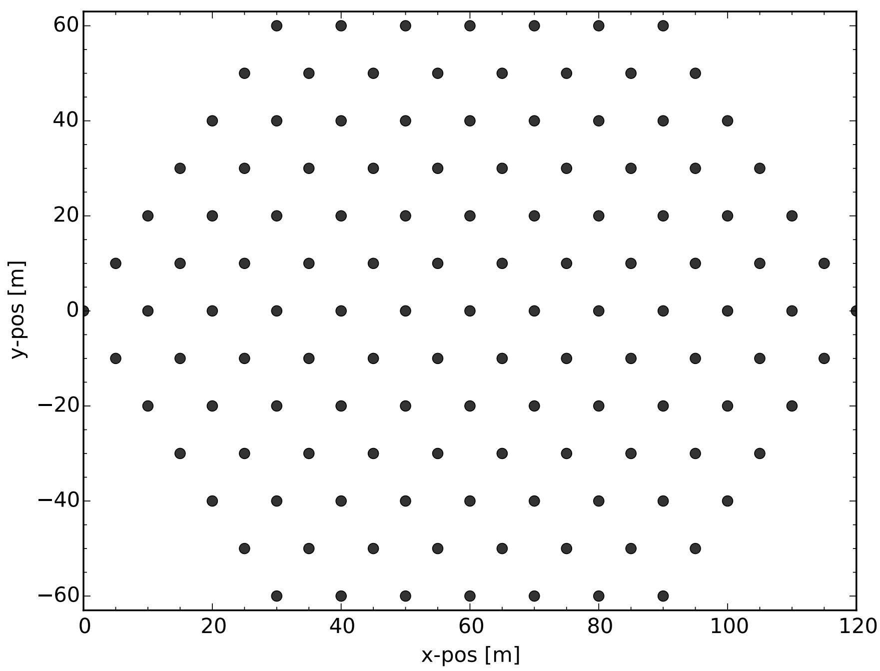

Figure 2: Antenna positions for the proposed BRAWL instrument.

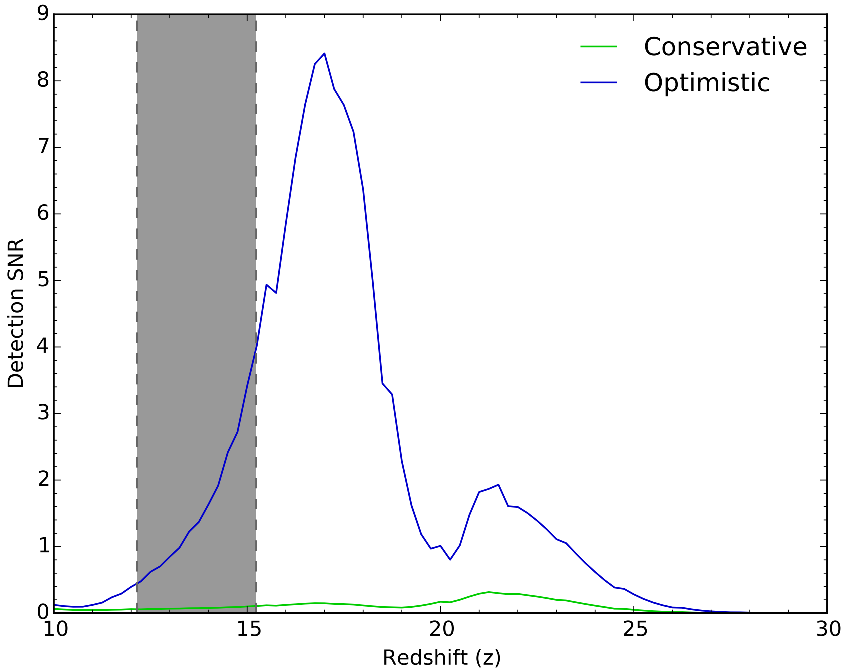

Figure 3: Simulated signal-to-noise ratio (SNR) for power spectra as a function of redshift. The shaded area corresponds to the FM radio band, over which RFI is a significant impediment to astronomical observations..