Sensitivity Estimates for HERA

Jonathan Pober

1. Fiducial Array Parameters

Table 1: Fiducial System Parameters

Observing Frequency	150 MHz
Bandwidth	8 MHz[a]
$T_{\rm receiver}$	100 K
$t_{\rm obs}$	120 days
${t_{\rm per_day}}^b$	6 hours
Parabolic Element Size	10 m

[a] This is the cosmological bandwidth over which the universe can be considered co-eval, not the total instrument bandwidth. I assume a total instrument bandwidth running from $100 - 200$ MHz with 1024 frequency channels.
[b] This is the size of a suitable cold patch in R.A. during which science observations can be conducted.

Other relevant terms:

1. For a sky temperature model, I use $T_{\rm sky} = 569 \left(\frac{\nu}{150\ \rm MHz}\right)^{-2.5}$ K.
2. I use the following relations for a Gaussian beam model:

$$\sigma = 0.45\lambda/D \tag{1}$$

$$\rm FWHM = 2.35\sigma \tag{2}$$

$$\Omega = 1.13\ \rm FWHM^2 \tag{3}$$

3. I assume foregrounds completely contaminate all $k_{\parallel}$-modes below the baseline-dependent horizon limit plus an additive term of $0.15h\rm Mpc^{-1}$. The size of this additive term represents the spectral "unsmoothness" of the sky; its value is based on the simulations of Parsons et al. (2012). This value may be an underestimate for the larger elements considered here, since they will likely introduce more spectral structure than the PAPER dipole element beams used in the simulations.
4. This sensitivity code ignores the effect of the w-term. That is, all samples which fall in the same uv-pixel over the course of the observation period are treated as perfectly redundant. Dealing with the complications of the w term to retrieve this sensitivity is not a solved problem.

2. Dense Grid of 576 Parabolic Reflectors

The simplest array model is a dense grid of single elements. Here we consider a 24×24 grid of parabolic reflector elements, shown in the left-hand panel of Figure 1. For comparison with the sensitivity calculations of Parsons et al. 2012, this array has a redundancy metric $f/f_0 = 314521.3$.

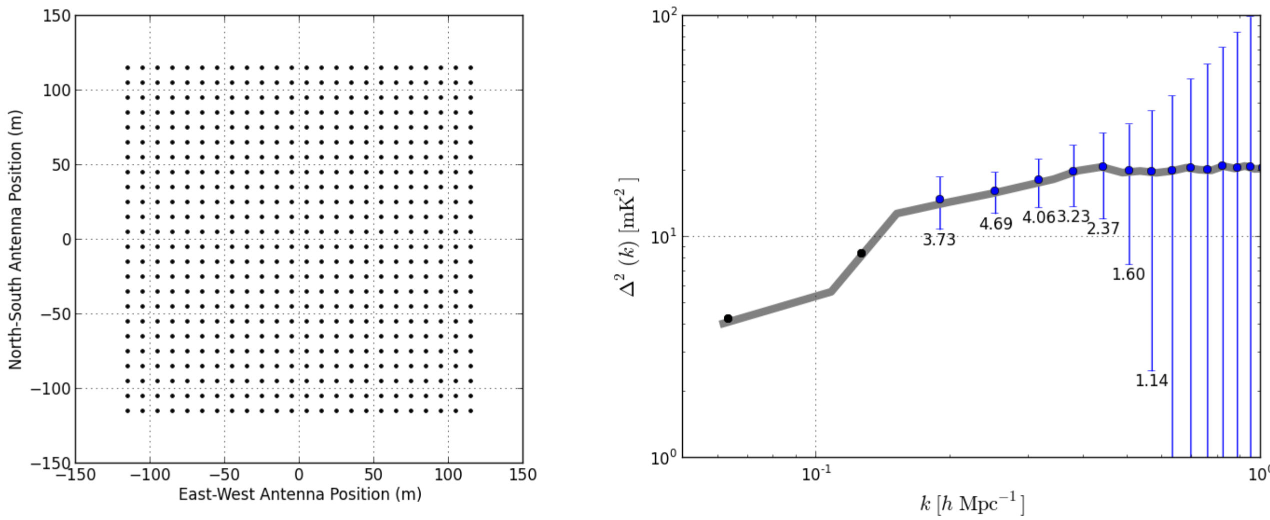


Fig. 1.— *Left*: The array configuration. *Right*: The predicted constraints using the fiducial parameters described in §1. Black points are completely contaminated by foregrounds. The numerical value below each error indicates the number of σ significance in that particular data point. The data are binned with a resolution of 0.063 hMpc^{-1}, corresponding to the $k_{\|}$ resolution of the 8 MHz band.

The size of the primary beam of these elements is assumed to divide the six hour EoR cold patch into 6 1-hour independent fields. The combined sensitivity of the measurement results in an 8.6σ detection of the EoR power spectrum.

3. Dense Grid of 1024 Parabolic Reflectors

Here we consider a 32×32 grid of parabolic reflector elements, shown in the left-hand panel of Figure 3. This array has a redundancy metric $f/f_0 = 554966.5$. The net sensitivity results in a 14.7σ detection of the EoR signal.

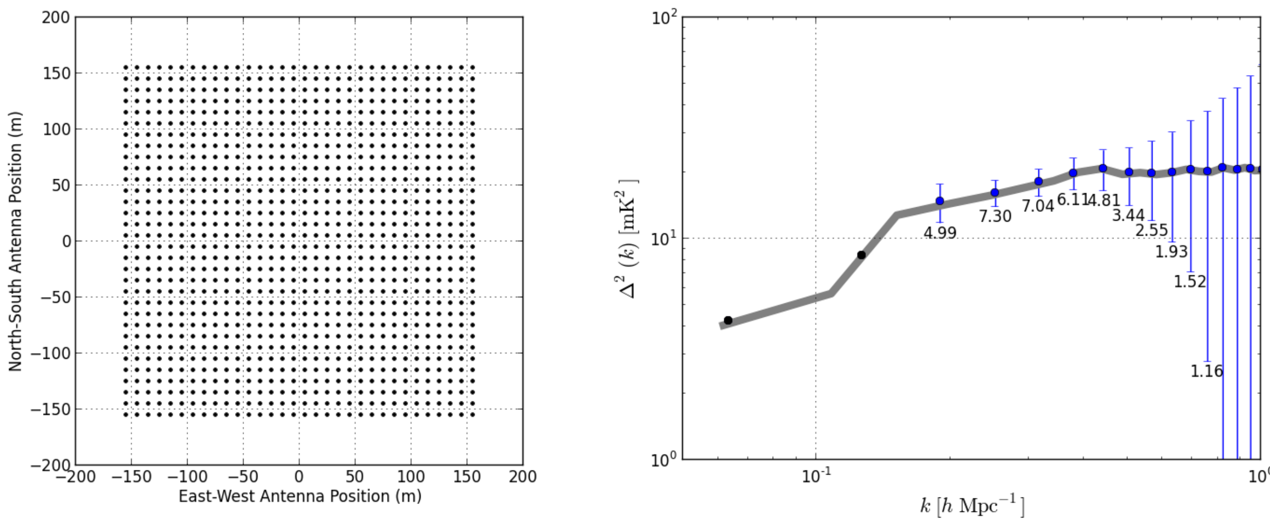
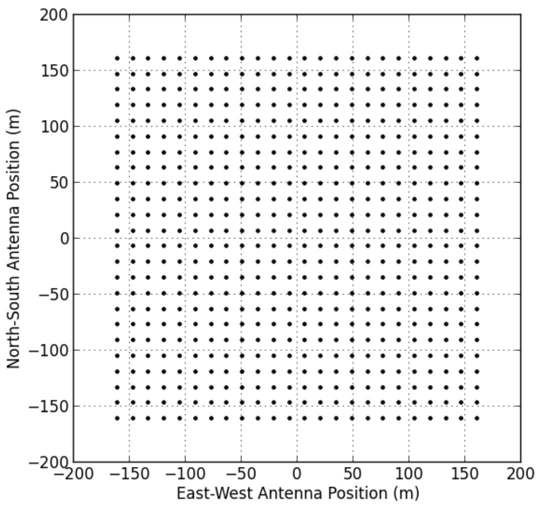


Fig. 2.— The same as Figure 1, but for a 32×32 array of parabolic elements.

4. Dense Grid of 512 14m Parabolic Reflectors

The rough effect of 14m dishes is to divide the 6-hour observing window into 12 independent 30 minute fields. Such an observation yields the following sensitivity, with a redundancy metric of $f/f_0 = 153261.5$. The overall significance of the detection is 11.7σ.



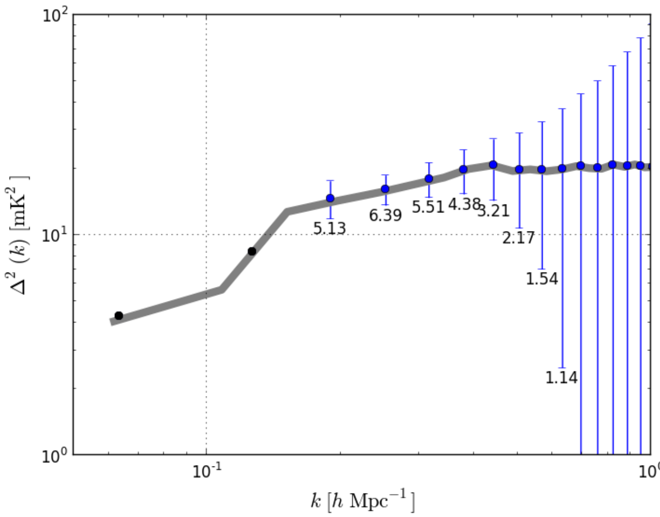


Fig. 3.— The same as Figure 1, but for a 24×24 array of 14m parabolic elements.