EDGES MEMO #071

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Subject: Effect of antenna beam pattern on the detectability of EoR

The simulations in memo 70 did not include the effects of the change in beam pattern with frequency. One of the difficulties with a broadband antenna is the effect of the ground plane. In order to obtain a beam pattern for which the zenith gain pattern at the high frequency end retains similar shape to that at lower frequencies the ground plane needs to be close to the dipole. However the closer the dipole is to a ground plane the more difficult it is to obtain a broadband match. In the case of the "fourpoint" antenna the optimum height was found to correspond to 0.32 wavelengths at the high frequency end of its response and increasing the height beyond this value improves the match but flattens the beam so that the maximum gain is no longer at the zenith.

In order to evaluate the effect of the change of beam with frequency on the shape of the measured spectrum the beam was convolved with all sky map of Haslam et al. and the resulting fit with 4 term polynomial of the form

$$T(f) = \sum_{n=0}^{n=3} f^{-2.5+n}$$

The rms of residuals to this fit for a frequency range of 50 to 100 MHz are shown in figure 1 as a function of LST for the latitude of Boolardy. It should be noted that for much of the LST range when the Galaxy is down the rms is acceptably low. Changing the azimuth orientation of the antenna doesn't have much effect on the general trend. A northern latitude is slightly better. If the antenna height is reduced by a factor of 2 the peak rms drops from 80 to 1 mK.

To simulate the effect of the beam pattern change on the EoR detection the beam pattern was convolved with the all sky map in simulations similar to those of memo 70. To simulate the effect of an uncertainty in the sky map the sky map for the model and the data were taken from different LST. Otherwise nothing else was changed and the same functions and corresponding 9 parameter fit were used in the solution. Selecting an LST with the Galaxy down as data and Galaxy up as a model (or vice-versa) limited the EoR detection to an EoR width of 5 MHz but a change in LST over several hours in a range when the Galaxy is needed to significantly reduce the EoR detection width given in Table 2 of memo 70. As a consequence the change in beam pattern with frequency of current EDGES antenna (see memo 69) may not be a limiting factor.

Added note: If the antenna follows the expected functional form of the ground reflection on the antenna gain as

$$\left[\sin\left(2\pi h\left(f/c\right)\sin el\right)\right]^2$$

Where h is the antenna height, f is the frequency, c is the propagation velocity and el is the elevation then the change of antenna temperature with frequency, $T\left(f\right)$ is limited to even multiples of n or

$$T\left(f\right) = af^{-2.5} + bf^{-0.5} + cf^{1.5} + df^{3.5} + ...$$

Limiting the polynomial to these terms improves the ability to separate on EOR signature from the variations in the calibrated spectrum which result from the change in beam pattern. Figure 2 shows the rms residuals (bottom curves) and EoR amplitudes (top curves) for a fit with 4 polynomial terms plus an EoR Gaussian with 20 MHz full width at half power centered at 75 MHz. The thick and thin curves are for 90 and 96 cm antenna height respectively. The frequency range covered was 50 to 100 MHz.

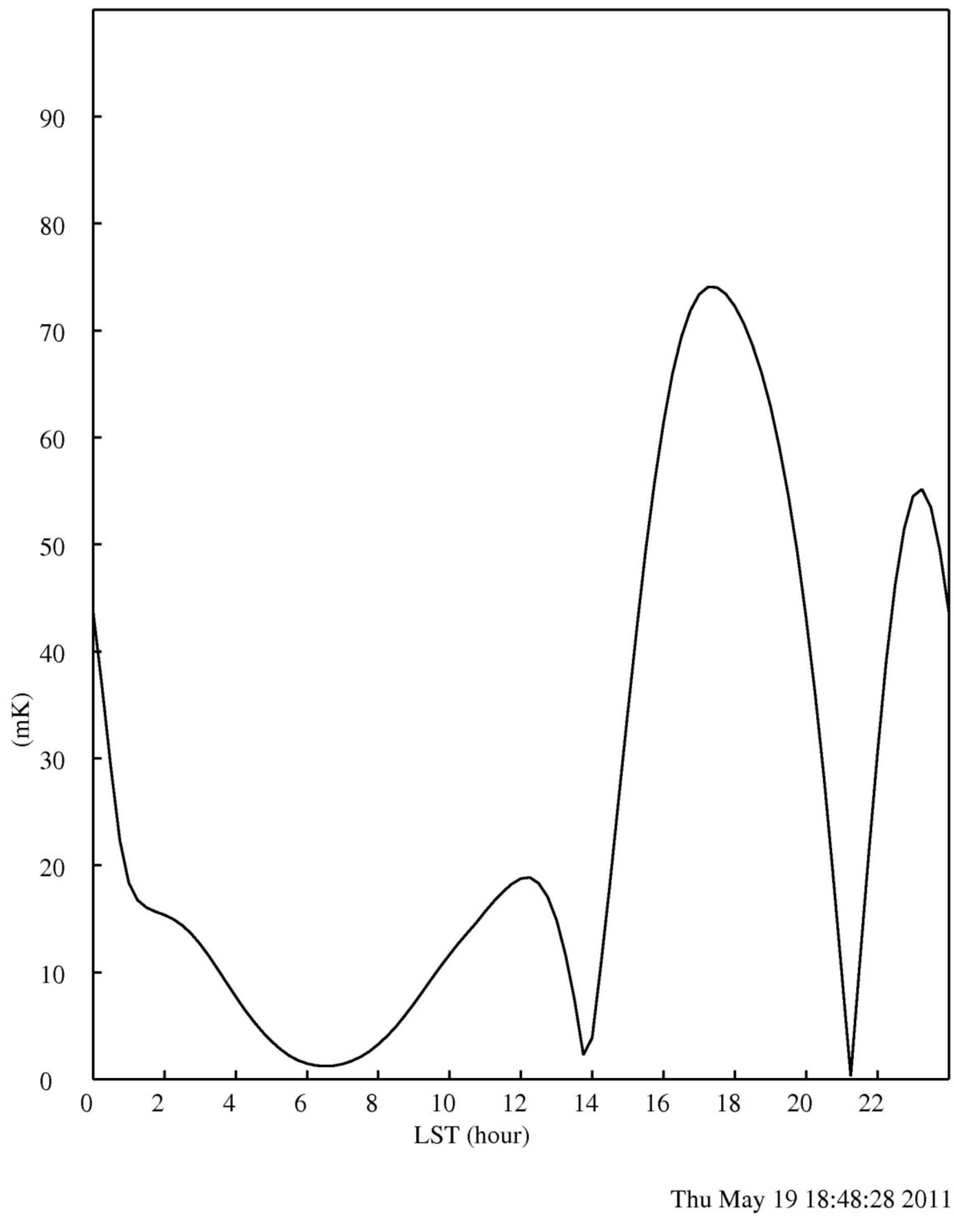

Figure 1. The rms residuals after removal of a polynomial from the frequency dependence of the antenna temperature from the change in beamshape.

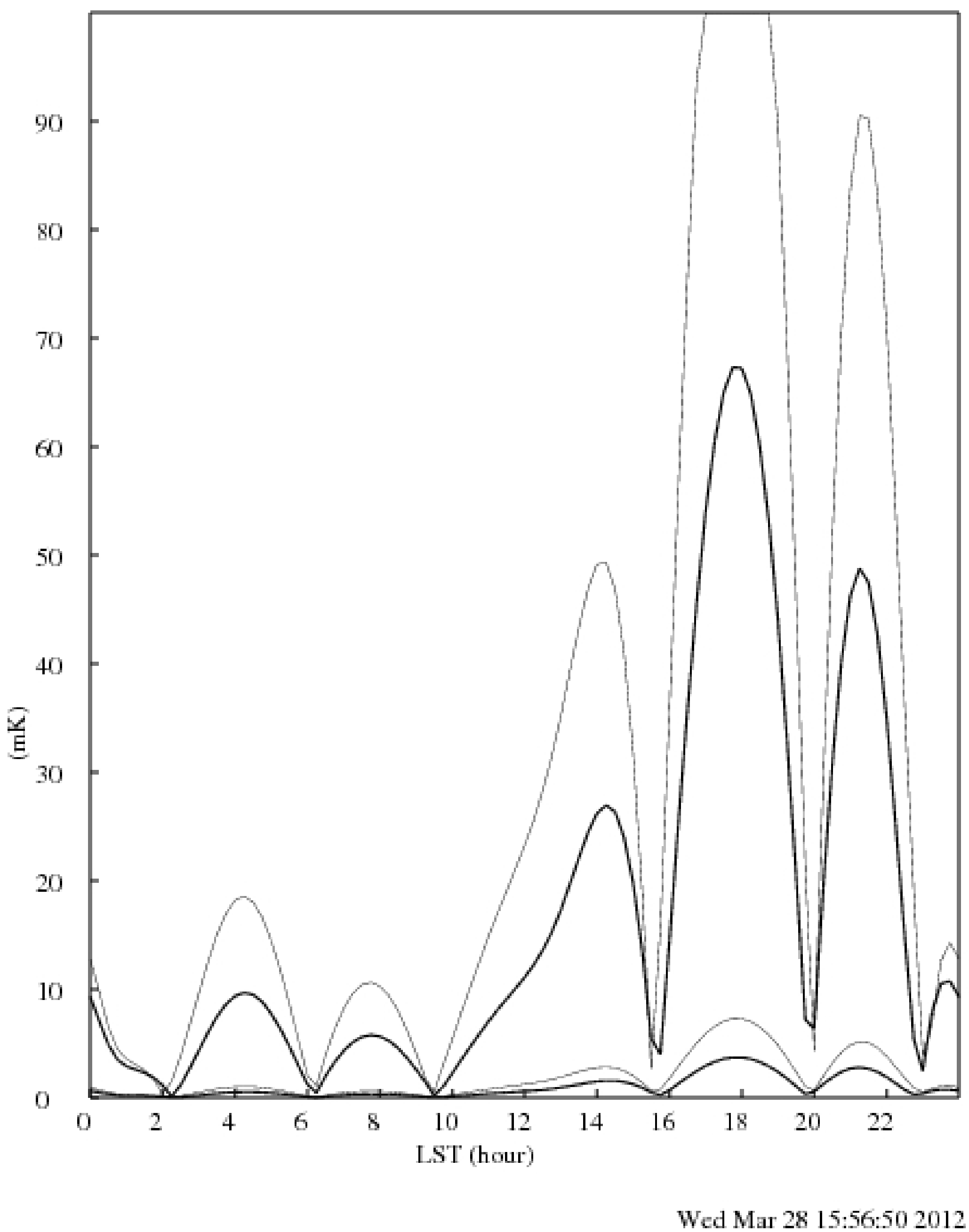

Figure 2. The rms residuals after removal of 4 term polynomial in the lower curves. Upper curves are amplitude of EoR term (see text).