EDGES MEMO #101

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To: EDGES Group

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Subject: Simulation of the removal of the foreground and ionosphere

Using the model of Galactic foreground as a sum of components as in Liu et al.

$$S(f) = (1/N) \sum_{i=0}^{N-1} \sum_{j=0}^{2} a_{ij} \left(f / f_{ref} \right)^{-\alpha_j + \delta\alpha_j} + n_i(f)$$

Where f_{ref} is 150 MHz.

j	α	$\sigma(\delta\alpha)$	$\langle a \rangle$ K	Component
0	2.8	0.1	335	Synchrotron
1	2.15	0.01	33	Free-free
2	2.5	0.5	71	Discrete sources

Simulation trials wave made with N=300, a_{ij} chosen from the magnitude of a Gaussian random number generator with average given in the table and $\delta\alpha$ chosen from a Gaussian random number with sigma values given in Table 1 above.

$S(f)$ is computed for each MHz from 50 to 100 MHz and independent noise is added to each frequency based on a system noise temperature multiplied by 3 for the EDGES switch cycle and divided by the square root of the integration time times 10^6. Assuming an EoR signature of

$$ce^{-d(f-f_c)^2}$$

where c = -100 mK

f_c = 70 MHz

d = 0.69/8 for 16 MHz full width at half power

the simulated data was analyzed using weighted least square using the following parameters

$$P_j = \left(f / f_{ref} \right)^{-\alpha'_j + \left((\sigma'_j)^2 / 2 \right) \log(f / f_{ref})} \qquad j = 0,1,2$$

$$P_3 = 1$$

$$P_4 = \left(f / f_{ref} \right)^{-2}$$

$$P_5 = \left(f / f_{ref} \right)^{-4.5}$$

$$P_6 = e^{-d(f-fc)^2}$$

Parameter 0,1,2 represent the Galactic foreground, P_3 represents a first order correction for instrumental error, P_4 and P_5 represent the emission and absorption of the ionosphere. While choosing $\sigma'_j = \sigma_j$ and $\alpha'_j = \alpha_j$ will result in the best performance this choice doesn't realistically represent the variation in Galactic foreground so tests were made of the sensitivity to the differences.

The results for the signal to noise of EoR detection are as follows:

Integration time	10 days
Average SNR	17
Average SNR with ionosphere	13

The results for the sensitivity to bias which result from the difference between the assumed values of α and σ are as follows:

j	$\Delta\alpha = 0.1$		$\Delta\sigma = 0.1$	
0	58	2	20	4
1	10	0	3	0
2	10	0	20	2

Table 2 Bias in the EoR signature in mK which results from a change in assumed α or σ. First column in each case is without added parameters for ionosphere.

These results show that while the introduction of additional parameters needed for the ionosphere these parameters also help "soak-up" error in the assumed foreground.

While Liu et al[1] show that higher order terms may be required to obtain the 21-cm signature this analysis shows that is may still be possible to look for the presence of an assumed signature with high signal to noise in a relatively short integration time on the assumption that absolute calibration can reduce the number of parameters to account for instrumental systematics to a small number.

Figure 1 shows the residuals to a fit for the foreground plus 21-cm absorption in a simulation without receiver noise for a frequency range 30 to 150 MHz. This illustrates that the 21-cm signature is not easily absorbed in the monotonically decreasing terms needed to characterize the foreground. While currently no single antenna can cover the 5:1 frequency it may be possible to combine calibrated spectra from separate systems to improve the detection of a global 21-cm signal.

[1] Liu, Pritchard, Tegmard and Loeb "Global 21 cm Signal Experiments: a Designer's Guide" arxiv 1211.3743.

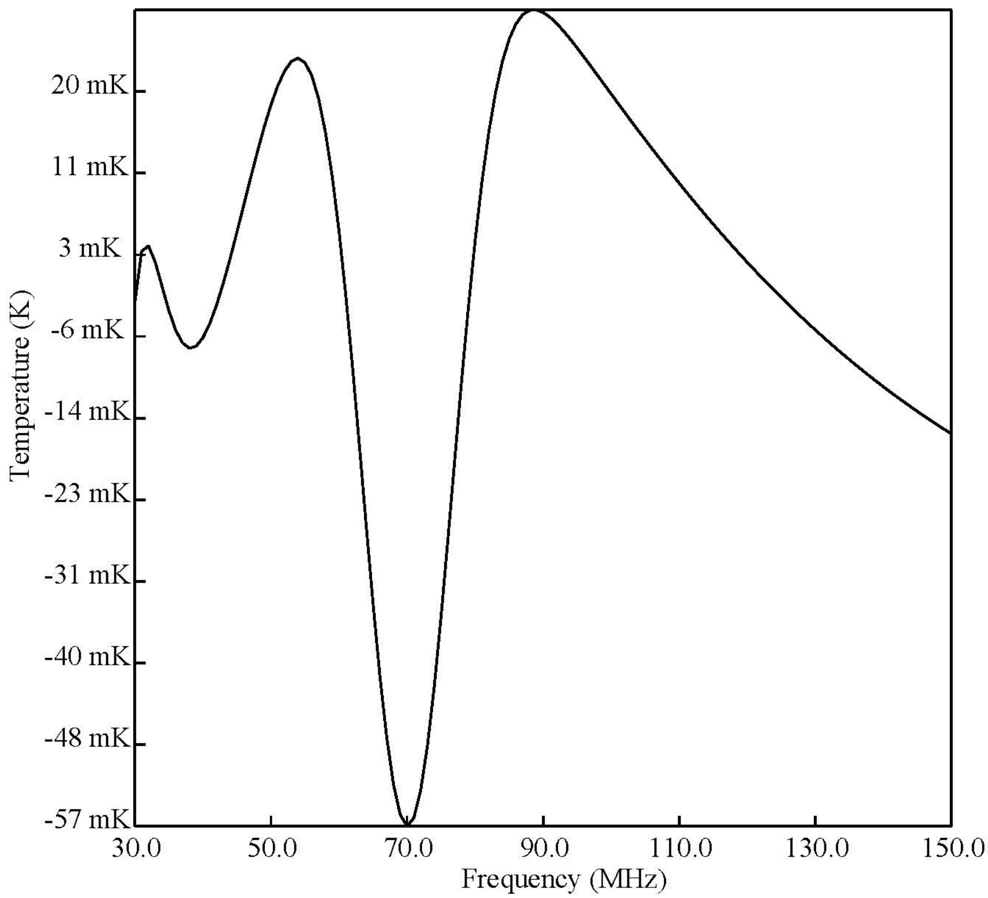

Figure 1.

Simulation of 21-cm signature after removal of foreground.