EDGES MEMO #048

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Revised July 27, 2009

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To: EDGES Group

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Subject: Using Galactic noise variation to extract EoR signatures

The EDGES data analysis has been based on the assumption that the antenna response varies slowly with frequency. In this case, the H-line EoR signature will be detectable if it varies more rapidly with frequency than the antenna response. In the simulations of memo 1 it was shown that an EoR signature consisting of a 10 MHz wide ramp at 125 MHz will appear in the residuals to fitting a 9-term polynomial from 100 to 220 MHz. However, part of the EoR signature is absorbed in the polynomial so that only about half the amplitude remains in the residual. The loss the signature gets worse as the EoR ramp increases in width or the number of terms in the polynomial increases. An alternate method of looking at this problem suggested by the CORE group, is to look for the EoR in the spectral slope (or spectral index) of the antenna response.

It has also been suggested that the variation of galactic noise might be used to separate out the EoR signature.

If we assume that the antenna temperature measured by the 3-position switching method is dominated by the sky noise we have

$$T_A' = g\left(T_{EoR} + T_g f^{-\beta} + T_b\ f^{-\beta}\right)$$

$$T_A = g\left(T_{EoR} + T_b\ f^{-\beta}\right)$$

where T_A' is the antenna temperature with "Galaxy up"

T_A is the antenna temperature with "Galaxy down"

g is the antenna "efficiency" variation mostly due to changes in impedance match

T_g is Galactic noise associated with the Galactic plane

T_b is the isotropic background noise

β is the spectral index

If we now take

$$T_A - \alpha T_A' = gT_{EoR}\left(1-\alpha\right)$$

where $\alpha = T_b \big/ \left(T_g + T_b\right)$

We have largely removed the contribution from the background. After the subtraction a polynomial fit is still required because:

1. There are other contributions to the antenna noise, like the ground pick-up.
2. The spectral index for the galactic and extragalactic noise is not quite the same.
3. The EDGES system is not to be perfectly linear

This method was tested by taking the data from days 33 through 41 reported in memo #47 for UT time ranges of 18 to 05 hours for T_A' and 6 to 18 hours for T_A. The factor α was taken as the ratio of the minimum to maximum of the spectrum of the two UT time ranges or α can be chosen to minimized the rms of the difference spectrum. Prior to taking the difference of spectra the RFI was removed from each spectra by fitting a 11 term polynomial, excluding frequencies with RFI, and then adding back the polynomial.

Figure 1 shows the difference $T_A - \alpha T_A'$ and figure 2 shows $T_A - \alpha T_A'$ (where α ~0.6) after removal of a 5 term polynomial and smoothing to 5 MHz resolution. The rms of the spectrum in figure 2 is 35 mK and is dominated by system noise. Improvements in system noise are expected to result from the use of a more powerful CPU processor to speed-up the FFT calculations which currently dominate.

Simulations of an EoR ramp centered at 125 MHz with widths of 10 and 20 MHz analyzed with 2.5 and 5 MHz resolution respectively are given in table 1. The entries are the peak to peak values of the EoR signature remaining after removal of a polynomial covering 105 to 205 MHz.

	EoR signature	
#terms	10 MHz / 2.5 MHz	20 MHz / 5 MHz
1	1.0	1.0
2	0.9	0.8
3	0.7	0.5
4	0.6	0.4
5	0.6	0.3
6	0.5	0.2
7	0.4	0.15
8	0.4	0.10
9	0.4	0.10
10	0.3	0.06
11	0.2	0.04

An alternate approach, explored by Judd Bowman is to take the difference of the spectra for the “Galaxy up” and “Galaxy down” in order to first obtain a measure of the antenna loss due to mismatch so that the spectra can be corrected for this loss. A variant on this method is to calculate

$$T_{sky}\left(1-\alpha\right)T_a'/\left(T_a'-T_a\right)=T_{sky}+T_{EoR}$$

where T_{sky} is an estimate of the antenna temperature without mismatch losses and

α = average of T_a/average of T_a'

Application of the formula above largely removes the variation due to mismatch at the expense of multiplying the noise by a factor of $2\alpha/\left(1-\alpha\right)$ compared with using the uncorrected average of the Galaxy up plus Galaxy down. As before we will still need to remove a 5 term polynomial to remove the imperfections in the linearity, ground pick-up etc. A result similar to that of figure 2 was obtained after removing a polynomial. However it was found that it was best to perform the polynomial removal before multiplying by T_{sky}.

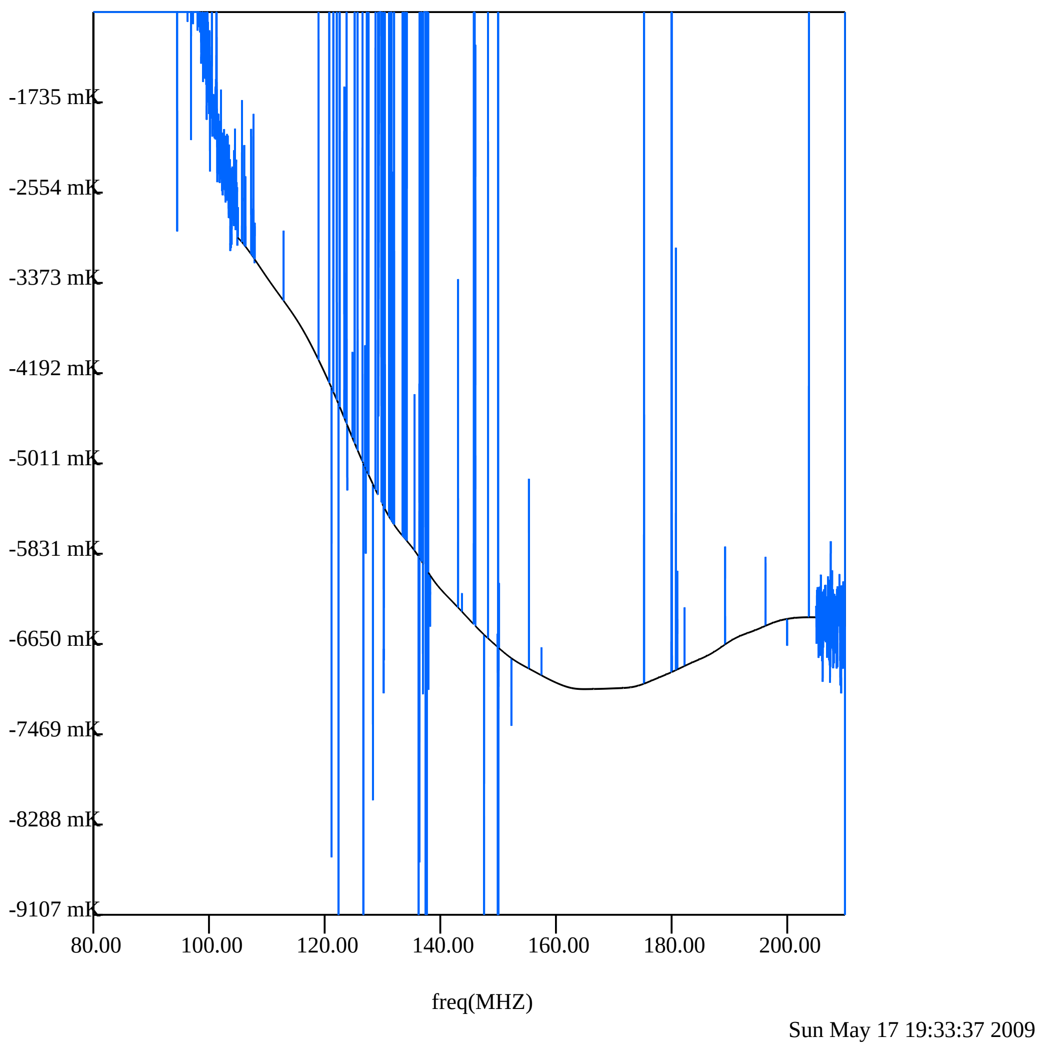

Fig. 1 Difference spectrum. The blue lines are frequencies excluded due to the presence of RFI.

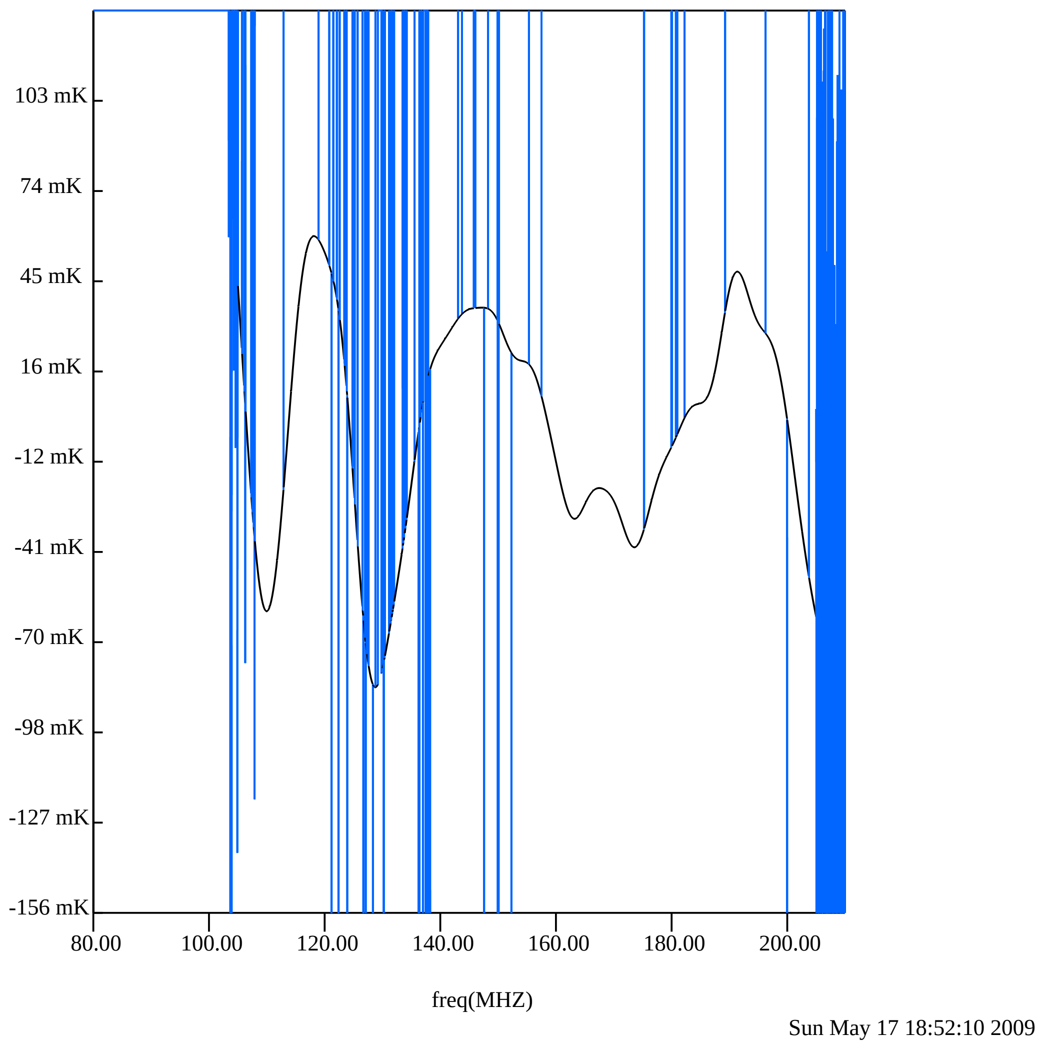

Fig. 2 Difference spectrum after removal of 5 term polynomial.