EDGES MEMO #145

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To: EDGES Group

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Subject: Using Galactic noise variation to extract EoR revisited

A method of using the Galactic noise variation was first examined in memo 48. While this method has been revisited from time to time only the recent EDGES-2 data from 2014 days 108 to 126 has a level of instrumental stability to put this method to a serious test. Assuming the calibrated spectra from “Galaxy down” to be

$$Gd = gf^{(Sd+\gamma d \ln(f))} - g\tau_d f^{-2+Sd} + T_{ed}\tau_d f^{-2} + eor \qquad (1)$$

Where g = Galaxy down strength at 150 MHz

f = frequency normalized to 150 MHz

S_d, γ_d = Galaxy down spectral index, and gamma (the derivative of S_d)

τ_d = ionosphere opacity at 150 MHz

T_{ed} = effective electron temperature

And a similar expression for “Galaxy up” replacing g with a times g and another set of constants $S_u, \gamma_u, \tau_u, T_{eu}$ where a is the ratio of “Galaxy up” to “Galaxy down” at 150 MHz. The ratio, a, can be determined from the weighted average of the ratio G_u/G_d or just the ratio at 150 MHz.

If we now take the difference spectrum

$$S_{diff} = G_d - G_u/a \qquad (2)$$

We get

$$S_{diff} \simeq d - g\left(\tau_d f^{-2+S_d} - (\tau_u/a) f^{-2+S_u} + (T_{ed}\tau_d - T_{eu}\tau_u/a) f^{-2}\right) + eor(1-1/a) \qquad (3)$$

Where

$$d = gf^{S_d}(\ln f)^2(\gamma_d - \gamma_u) \qquad (4)$$

For small differences the difference spectrum can be fit with 5 parameters

$$S_{diff} \simeq Af^{S_d} \ln(f) + Bf^{S_d-2} + Cf^{-2} + Df^{S_d} (\ln(f))^2 \quad (5)$$

which represent the systematic effects of the uncertainty of the combination of the Galaxy and the ionosphere.

Figure 1 shows the residuals to a 4 parameter fit, omitting the D term which accounts in the difference of the curvature of the spectral index, γ. The bottom spectrum is the average for the individual results for the 12 days plotted above. The spectrum is limited to 110 to 165 MHz. The limit on the high end is needed to avoid the region where the beam shape was strongly influenced by the presence of the LNA box (see Figure 2) which had to be placed on the antenna baseplate. The integration time for each “Galaxy up” and “Galaxy down” period for each day was 1 hour. The sensitivity to an EoR signature was judged by adding Gaussian EoR signature of 10 MHz full width at 150 MHz and corresponding EoR parameter for a total of 5 parameters in the weight least squares fit. A SNR of 10 was achieved for a signature of 180 mK. For a 20 MHz wide EoR signature 350 mK was needed for an SNR of 10. This result implies that we need a total of about 100 days integration to detect or set a limit on a 20 mK EoR signature of 10 MHz width. Further this assumes an absence of systematics. The “Galaxy up” data in this short test was during the day so it may be possible to eliminate the parameters, B and C which account for the ionosphere if the Galaxy up and Galaxy down data can be acquired between about 10 pm and 5 am local time.

Test of longer integration time and RFI excision

The Galaxy up Galaxy down or galaxy ratio method enables a way of removing RFI, solar emission and large ionospheric perturbations which are relatively weak and are not east to identify. Galaxy ratio difference spectra from equation 2 made from 1 hour integration of RFI filtered calibrated data be fit using the function of equation 5 and the rms residuals used to eliminate difference spectra contaminated with low level RFI. It is better to average 1 hour rms filtered difference than to use long integration times before deriving the difference spectra. In practice, using the limited EDGES-2 data currently available I was able to reach rms levels of about 16 mk from a total of 40 hours data after excision of some difference spectra smoothed to a resolution of 1 MHz shown in Figure 3. For the Galaxy up/down ratio of about 2.5 any EoR signature in the residuals would be reduced by the factor of $(1-1/a)=0.6$ times a factor which accounts for the degree to which the 5 parameters of equation 5 soak up a signature. For a Gaussian of 5 MHz width at 130 MHz this factor is about 0.7 for a combined factor of 0.4.

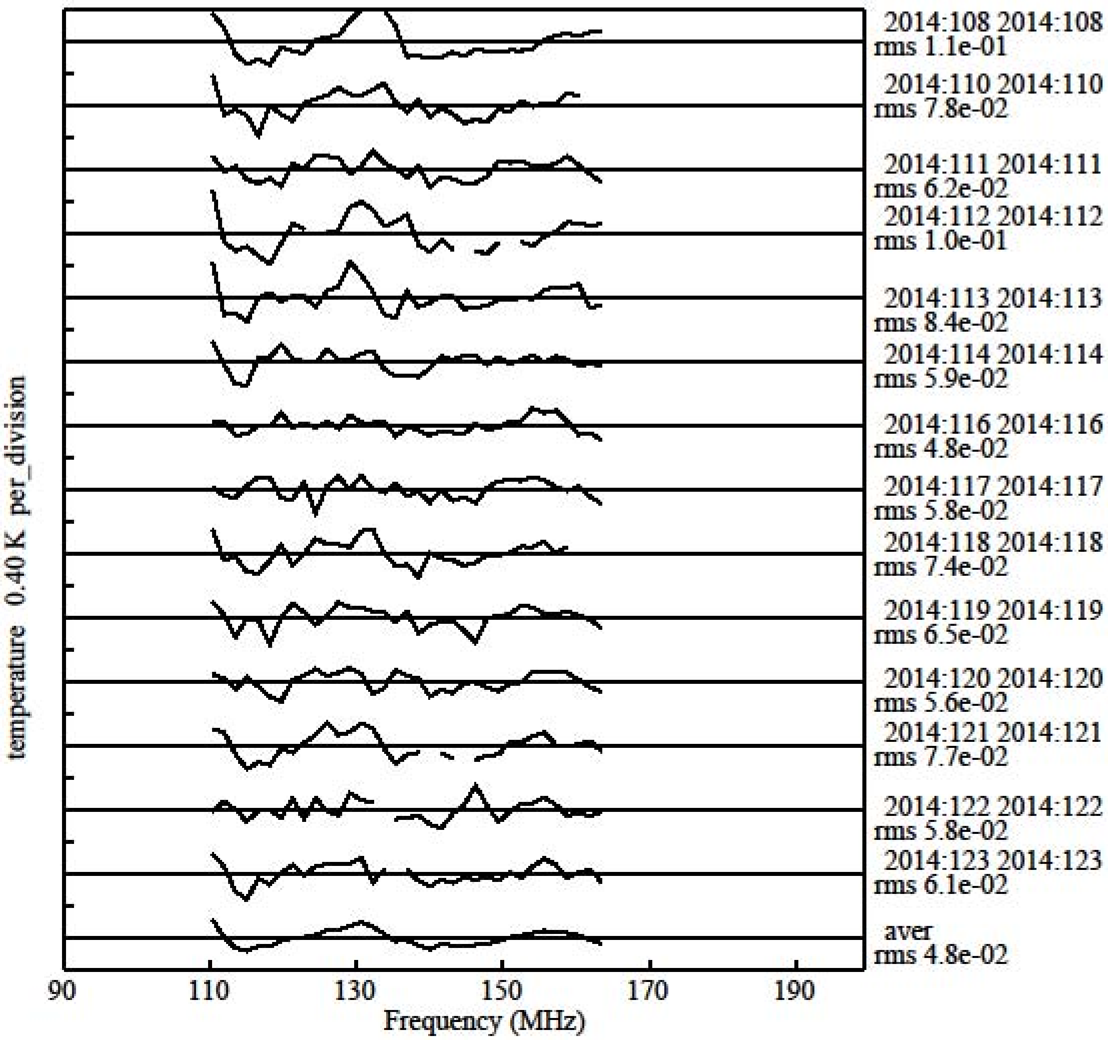

Figure 1. Difference spectra for each day along with average. The values of rms deviation from a constant are given in K. The rms for the average is 48 mK.

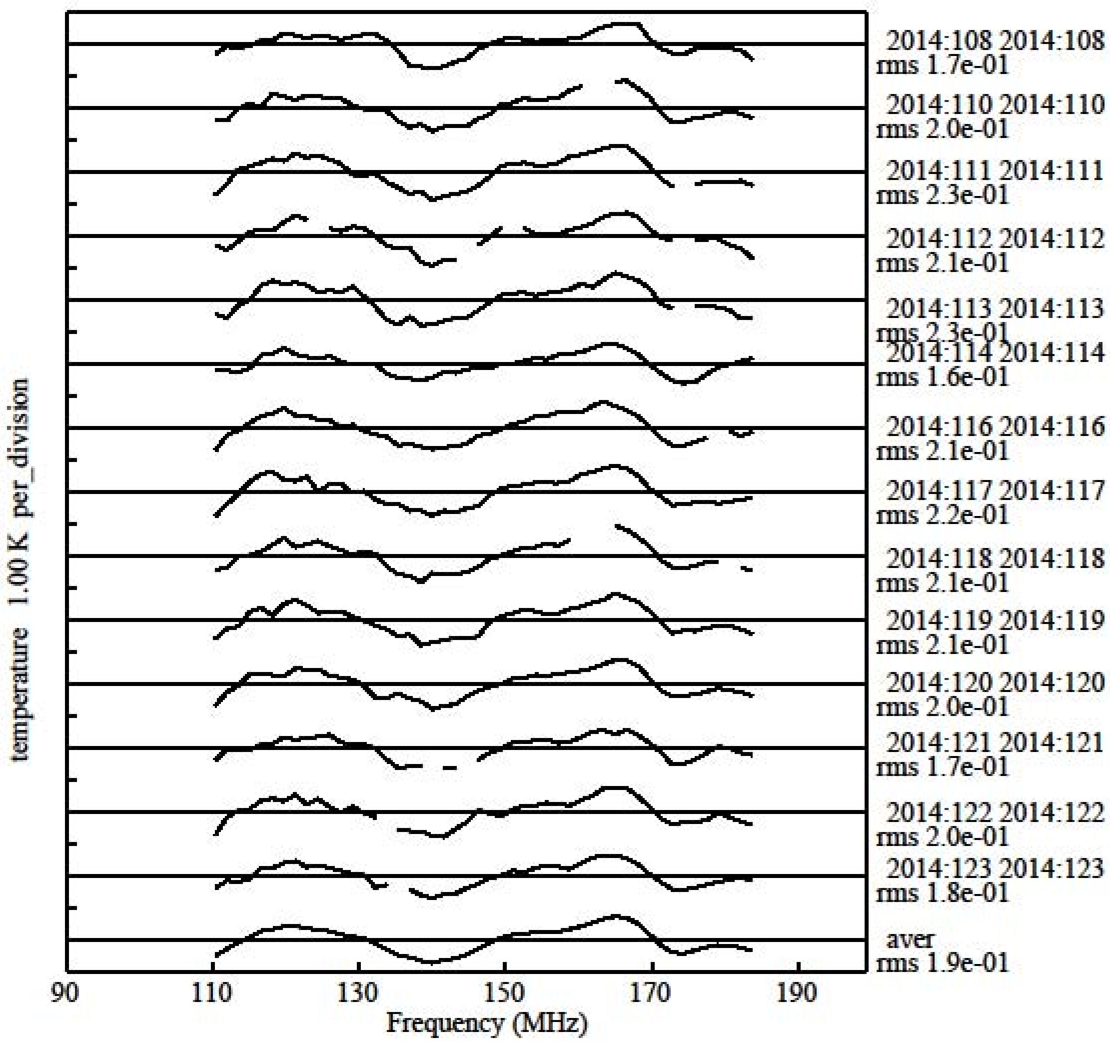

Figure 2. Same as Figure 1 with a wider frequency coverage showing the effect of the frequency dependence introduced by the LNA box.

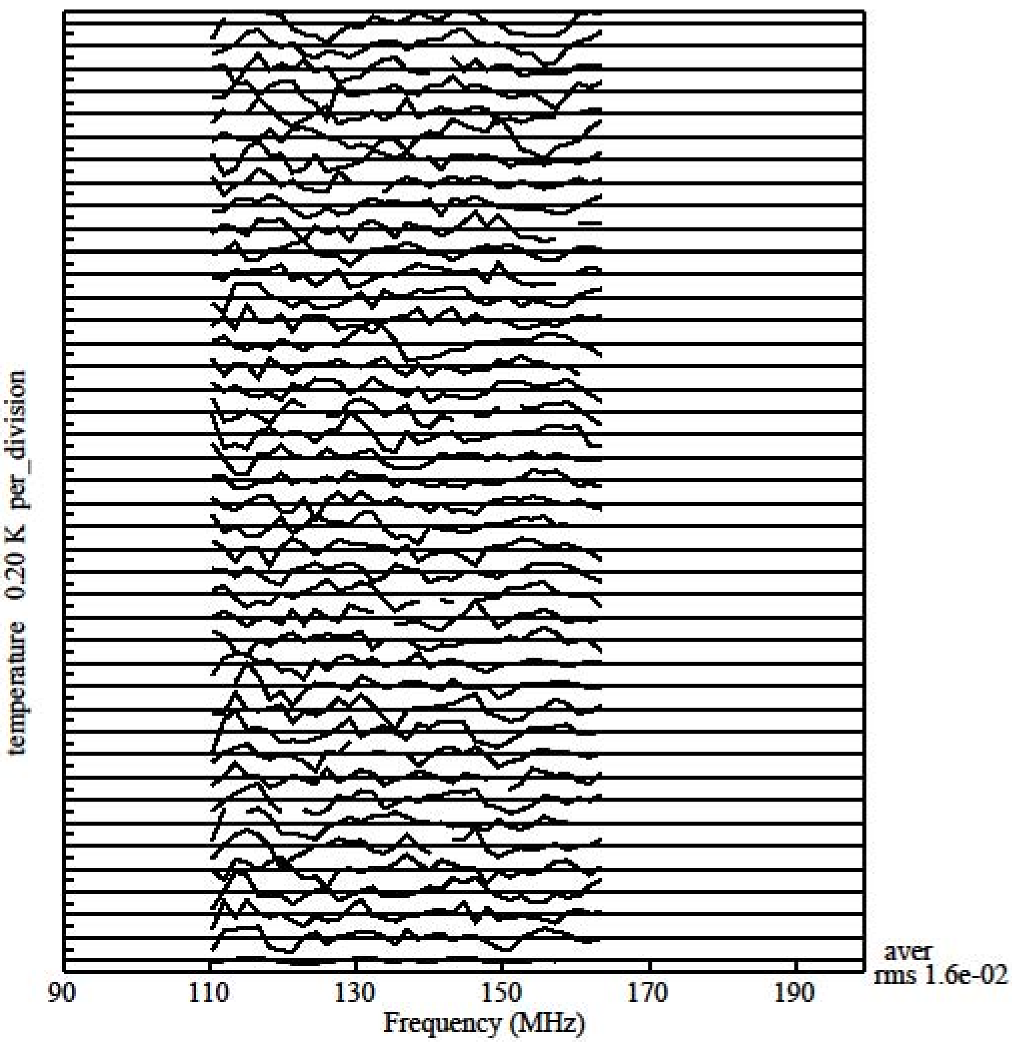

Figure 3. A residual level of 16 mK in average reached after some difference spectra. Total integration 40 hours. Resolution 1 MHz.