EDGES MEMO #121

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
HAYSTACK OBSERVATORY
WESTFORD, MASSACHUSETTS 01886

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Telephone: 781-981-5400
Fax: 781-981-0590

To: EDGES Group

From: Alan E.E. Rogers

Subject: Lab tests with long integrations

In order to extend the lab tests described in memo 120 to longer integrations and to signal levels closer to the sky temperature at 150 MHz a 7 dB attenuator was added to the output of the 1565 K filament source. This brings the artificial antenna temperature down to about 500 K and reduces the reflection coefficient to about -18 dB at 150 MHz. Reducing the antenna temperature improves the sensitivity making it easier to set lower limits on any spurious signals, which might be present in the EDGES electronics, in a reasonable time.

To process this data only the calibration data from 80 to 195 MHz and the artificial antenna data from 110 to 190 MHz was used. The antenna S11 data was taken from the S11 measured directly from the filament source reduced by 14 dB to account for the 7 dB attenuator. Figure 1 shows the results from 7 days of antenna data, 6 hours each of hot and ambient loads and 3 hours each of open and shorted cable. S11 data was taken with the Hp85047A/8753C VNA at power levels of 0 dBm for all except the LNA for which the power level alas -30 dBm to avoid saturation effects. S11 averaging times were 4 minutes. The data was processed using the method described in memo 113. The following smoothing was applied:

The fit to S11 of hot, ambient, open/shorted cable and antenna used a 27 term Fourier series and the fit to the LNA S11 used a 14 term Fourier series. The noise waves were fit with a 6 term polynomial and the calibration scale and offset were fit using a 4 term polynomial.

The antenna data was fit using the first 5 basis functions listed in memo 94. As noted in memo 94 these are sufficient to "soak-up" the systematics of EDGES-2. The rms residual was 3.3 mK compared with 8 mK for a single days data. The rms of 3.3 mK is close to the theoretical noise for the current EDGES realtime processing which is about 40% efficient owing to the additional time taken by the FFT processing. The "calibrated" spectrum is not flat and at the level of 1575 K of the filament because the final correction involving the correction for the 7 dB loss was omitted on the assumption that the artificial antenna, which in this case was the filament source plus the 7 dB attenuator, had zero loss.

To test the ability to detect an EoR signature Figure 2 shows the residuals to after adding a 30 mK Gaussian of 20 MHz full width at half maximum to the 7 day average of 3 position switched spectra and then processed in exactly the same way.

The EoR signature is seen and the residuals to the fit are 5 mK. If the EoR basis function for a 6 parameter fit is added the residuals drop back to the 3.3 mK and the SNR of the detection is 11.

Table 1 below gives the SNR for other widths of the EoR signature centered at 150 MHz. These results used the 9 basis functions of memo #118 but the results are almost identical when only the first 6 basis functions of memo #118 are used.

	7 day integration		26 day integration	
EoR signature width	signal mK	SNR	signal mK	SNR
10	19.9	14	22.9	22
20	20.7	11	23.5	18
30	20.0	6	25.7	12
40	17.3	3	29.6	7
50	12.0	1	36.6	5

Table 1. Simulations of EoR detection by adding 30 mK signal to data from “artificial” antenna.

The results in table 1 show that while the expected width of about 50 MHz will be hard to detect it should be possible to place limits on the EoR signature out to a Δf of 30 MHz which corresponds to a Δz of 1.9. The results of this lab test could be optimistic because the S11 of the filament source is very smooth whereas the S11 of the EDGES-2 antenna has more structure. The rms residuals to the fits whose results are given in table 1 were 3.3 and 2.3 mK for the 7 and 26 day integration respectively. The theoretical rms for the 26 days integration was 1.5 mK. At least part of the reason for not reaching the theoretical noise level is due to some residual RFI which leaked into the connection between the artificial antenna and the LNA in the very high noise environment of the Haystack control room. The noise in the uncalibrated data after removing a polynomial with 7 terms decreases from 4.3 to 3.0

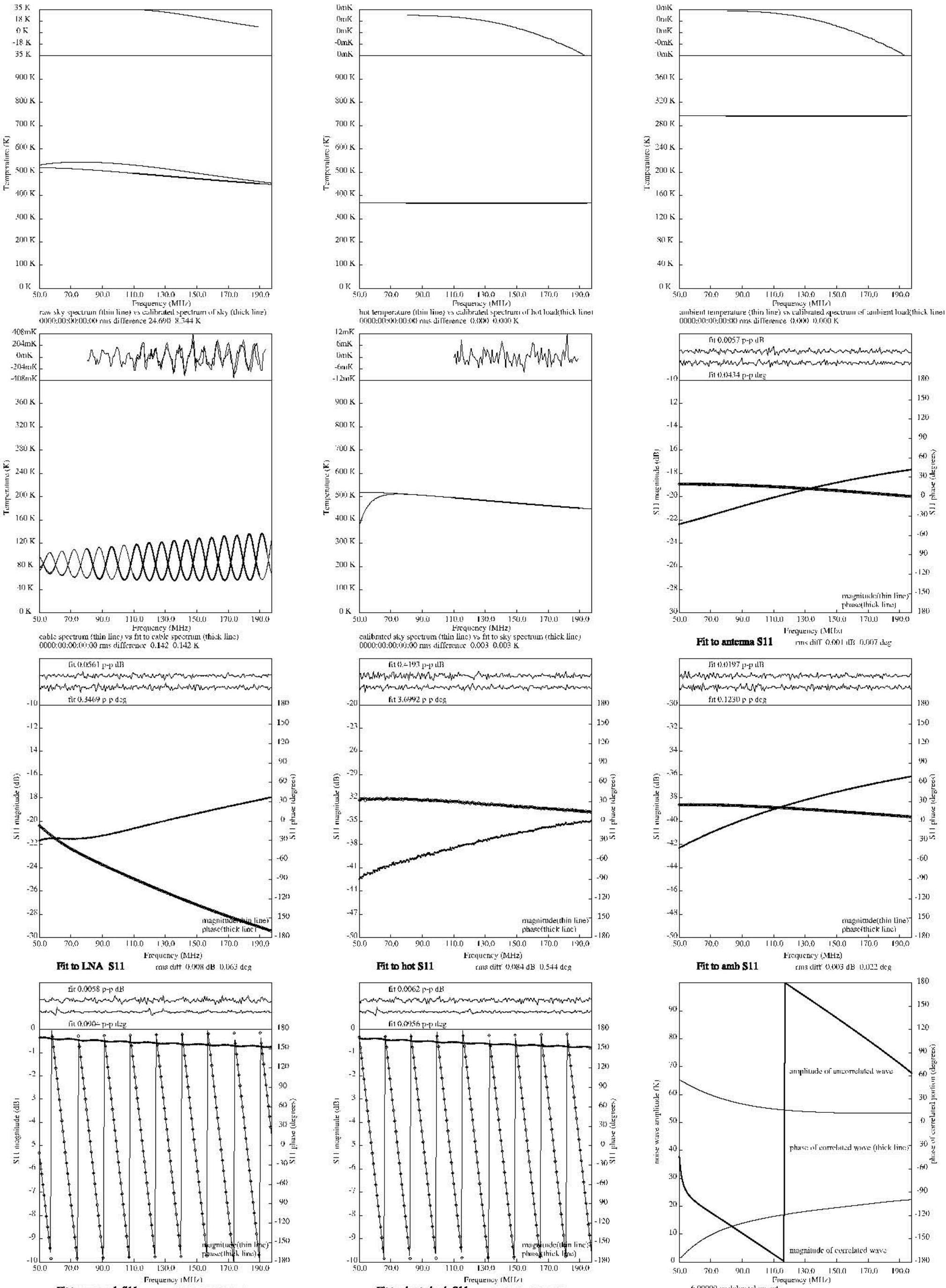

Figure 1. Plots of the S11 data and spectra. The residuals to the fits are shown with an expanded scale at the top of each plot.

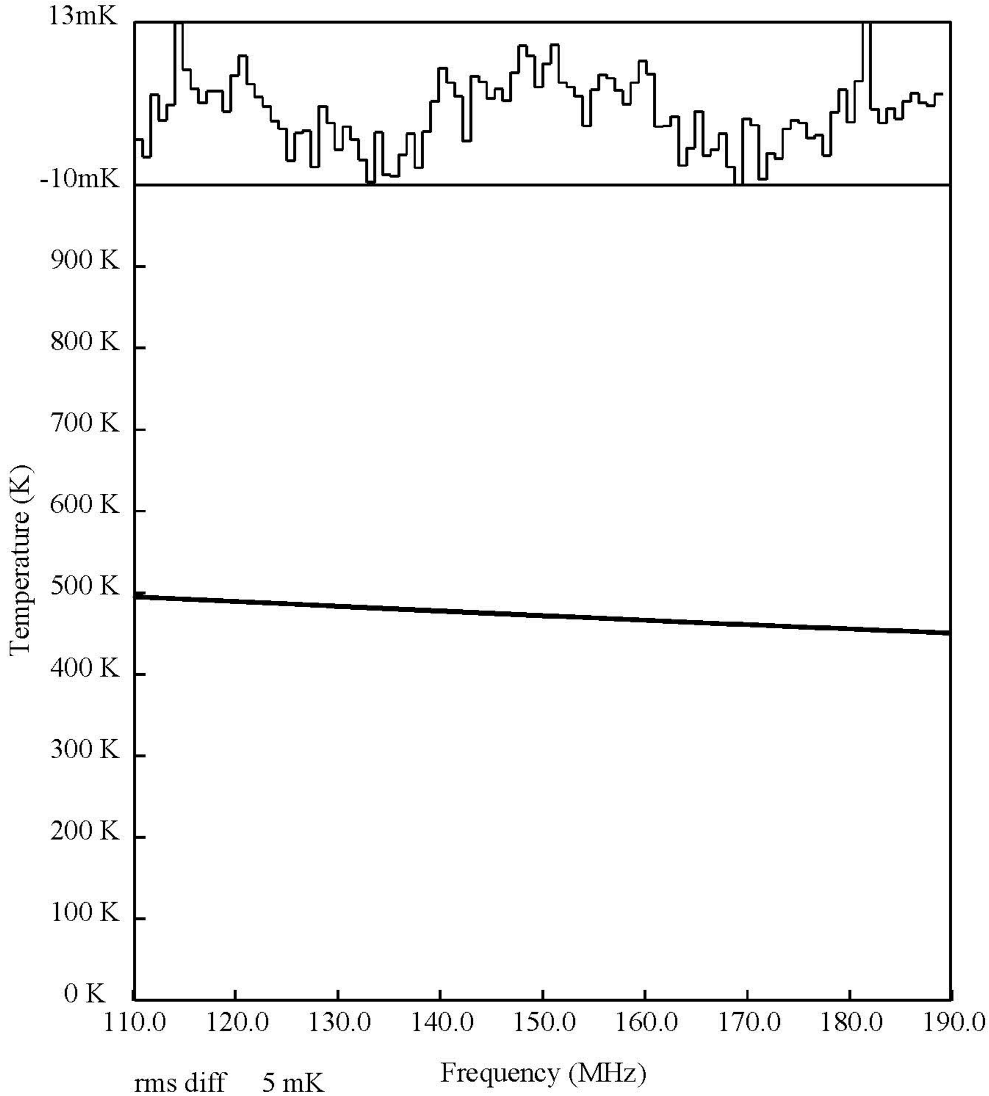

Figure 2. The calibrated antenna spectrum to which an EoR signature has been added. This signature is seen in the residuals at a reduced level because of the signature is absorbed in the basis functions needed to remove the instrumental systematics.