EDGES MEMO #129

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Subject: Sensitivities of EDGES-2 to instrumental error

The sensitivity of the EDGES-2 to sources of instrumental error is estimated based on the S11 from the installation in November 2013. The results are based on generating a 300K signal at 150 MHz with spectral index of 2.5 based on the calibration data made at 25°C.

An estimate of the sensitivity is made by perturbing the analysis of the following categories:

1] Smoothing of the calibration data using least squares fitting of polynomials and Fourier series
2] Temperatures of hot, cold loads, noise wave calibration cables and antenna
3] Loss estimates
4] VNA errors
5] Electronics temperature based on the calibration at 35°C

The measure of the error is given as a residual to a fit using the first five basis functions which are scale, ionospheric emission, ionospheric absorption, constant ground noise, and the spectral index derivatives gamma plus an EoR signature of 20 MHz full width at half power centered at 150 MHz. The data and calibration is weighted from 100 to 185 MHz.

parameter	Change	rms (mK)	Bias (mK)	Comments
nfit4	37→27 terms	9	3	Antenna S11 smoothing
nfit3	27→17 terms	2	1	LNA S11 smoothing
nfit2	27→26 terms	7	-5	Other S11 smoothing
nfit2	27→28 terms	1	1	Other S11 smoothing
nfit 1	27→17 terms	2	1	Calibration table interpolation
wfit	6→7 terms	3	1	Noise wave smoothing
cfit	7→6 terms	3	3	Calibration smoothing
thot	298→308 K	1	0	Hot load temperature
tcold	298→308 K	2	-2	Cold load temperatures
tcab	298→308 K	3	-30	Noise wave cable
tant	298→308 K	2	2	Antenna temp for loss
lh	0.05→0 dB	1	-1	Hot load loss
balun loss	10% reduction	2	16	
ant loss	Reduce to zero	1	4	
db corr	0.005 dB	2	17	VNA amplitude bias
delaycorr	2ps or 0.1°	10	16	VNA phase bias
electronics	+ 1° C	10	-73	Scaled from cal at 35° C
electronics	+ 1° C	5	-40	120-180 MHz
electronics	+ 1° C	1	-3	130-170 MHz EoR 10 MHz

Table 1. Estimates of instrumental error

The most significant instrumental errors are those which produce fine frequency structure. This structure is primarily the result of the delay in the antenna S11 which is about 20 ns at 150 MHz. Added to this is about 4ns 2-way delay in the transmission line from the antenna to the LNA. As a result of this delay biases in S11, errors in loss estimates and changes in the LNA input impedance result in structure on scale of 40 MHz. For example Figure 1 shows the residuals in the case of a 10% error in balun loss.

The calibration constants of scale, offset, and noise wave values along with LNA S11 change with temperature. The values in Table 1 are for 1 degree derived from the calibration data at 25 and 35° C. The effect on the EoR estimate for a signature of 20 MHz width can be reduced by limiting the frequency range and drops dramatically for a EoR signature width of 10 MHz. Not shown in Table 1 are the effects of the change in antenna S11 with temperature for which is assumed that the temperatures coefficients derived prior to installation will suffice. Instead just the effects of a bias in VNA amplitude and phase are given.

Conclusions

If the S11 errors are under 0.005 dB in amplitude and 0.1° in phase and the electronics can be held to within about 0.2 K it may be possible to set new limits on an EoR signature for widths up to about 20 MHz. A more stable environment as well as "in situ" calibration of the electronics along with automated measurements could be used to substantially reduce the instrumental errors. In principle this could be accomplished with a VNA and matrix of mechanical switches to connect the VNA to the antenna, LNA, hot, ambient loads, VNA calibration kit and noise wave calibration cables. The switch matrix would also connect the LNA to the antenna, calibration loads and cables.

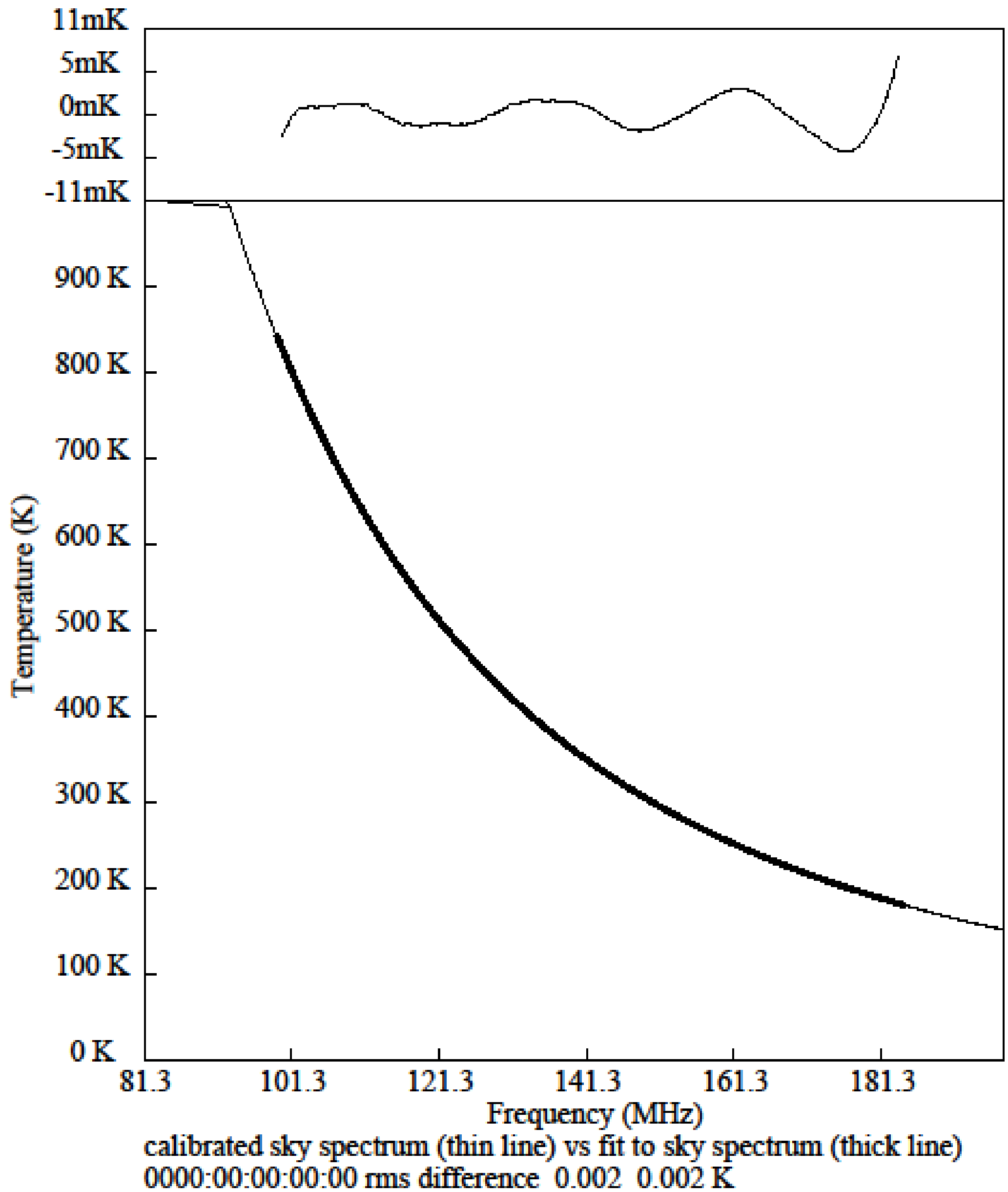
11mK
5mK
0mK
-5mK
-11mK
900 K
800 K
700 K
600 K
500 K
400 K
300 K
200 K
100 K
0 K
Temperature (K)
81.3
101.3
121.3
141.3
161.3
181.3
Frequency (MHz)
calibrated sky spectrum (thin line) vs fit to sky spectrum (thick line)
0000:00:00:00:00 rms difference 0.002 0.002 K

Figure 1.