EDGES MEMO #056

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
HAYSTACK OBSERVATORY
WESTFORD, MASSACHUSETTS 01886

January 8, 2010

Telephone: 781-981-5407
Fax: 781-981-0590

To: EDGES Group
From: Alan E.E. Rogers and Judd D. Bowman
Subject: Current limits of EDGES performance using DP310

1] EoR step

An EoR step or ramp is modeled with a sine wave from $+\pi/2\ to\ -\pi/2$ during the "ramp" and has a value of +50 mK at frequencies below the ramp transitioning to -50 mK at frequencies above the ramp. For this case, the rms deviations from a polynomial is given in the table below.

# terms	Full width of ramp MHz			
	5	10	20	40
1	48	48	48	48
7	13 (13)	12 (11)	9 (7)	4 (2)
11	10	8	5	1
15	9	6	3	0.3

The numbers in parentheses are for a linear ramp. The problem is that while a polynomial "soaks-up" instrumental effects it also quickly "soaks-up" the EoR signature as the number of terms increases and as the ramp becomes more gradual.

The current level of performance using Galactic calibration analysis is shown in figure 1 for data taken at Boolardy. The rms fit to a 7 term polynomial is 10 mK with aggressive excision of data (~ 15 percent excised) with strong RFI and exclusion (~21 percent excluded) of frequencies with any RFI. In addition the region from 147-153 MHz has been excluded. At this level of performance we might expect to see the EoR if the ramp occurs over a frequency range of less than 20 MHz and has an amplitude of 100 mK peak to peak. If the "step" is only 50 mK we probably wont see it unless it occurs over a very small range of a redshift. There is an apparent signal around 150 MHz which could be due to RFI but this is not yet clear given the sensitivity of the spectrometer based on the DP310.

Also with smoothing to 3 MHz resolution a feature appears at about 190 MHz which might be from the sky but more likely is digital TV. A search for the best fit to the EoR signature and a corresponding significance test can be made by calculating the residuals to a 4 parameter fits of scale, offset, redshift and range of redshift over which the EoR occurs or equivalently by adding the parameterized EoR signature to the polynomial used to fit the spectrum.

2] The influence of the Sun

The quiet Sun is about 10^{-21} wm^{-2} Hz^{-1} at 150 MHz which corresponds to an antenna temperature of about 100 K at 150 MHz at zenith. Thus the Sun has a significant influence on the spectrum and hence we should probably not use data with the Sun above the horizon.

3] Rain on the antenna

Rain on the antenna has a large effect on the spectrum producing an upturn at about 205 MHz as seen on day 258.

4] RFI excision

Transient RFI is removed by elimination portions of the time when signals are present.

There are several reasons for excision:

a) Continuum bursts from lightening or other broadband sources. For this a threshold is set on the total power integrated over the entire spectrum.

b) Strong narrowband signals. For this a threshold is set on the peak signal within the resolution of the spectrum.

c) Weaker signals of various bandwidths.

For this a threshold is set on the signal to rms noise level, where the signal is the average over a specified bandwidth and the noise is calculated from a region of bandwidth adjacent to the signal averaging region.

The regions included for these "weaker" signals are the FM band, the 150 MHz satellite band and the digital TV bands centered at 177.5, 184.5, 191.5 MHz. [In Australia the TV bands are spaced 7 MHz apart]. I was able to find the following digital TV assignments in the acma.gov.au database:

177.5 MHz 82 kw EIRP TVW7 Bickley (Nr. Perth)

Ant. 134 at -32:00:34 116:04:57

184.5 MHz 5 kwEIRP Morawa (Nr. Geraldton)

Ant. 60 m at -29:19:05 115:52:40

The Morawa site is only about 250 km from Boolardy. The 177.5 MHz (Ch. 6) digital TV first shows up in the EDGES data on day 266 (23 Sep 09) and the 184.5 MHz (Ch. 7) first appears on day 281.

As previously mentioned other reasons for the excision or elimination of blocks of data in time are periods when the antenna could be wet and when the Sun is above the horizon. In practice, we cannot eliminate all the data when RFI is present as in a location like Boolardy there is always some RFI present so that the RFI that remains after excision has to be removed by excluding frequencies with RFI. This procedure should work well for narrow band signals but cannot be expected to work for broad band signals like those of digital TV. A possible solution might be to have simultaneous data from an antenna with high gain on the horizon in order to define those times when the broadband signals are

significant. To some extent the presence of significant power in the FM band can be used as a "proxy" for propagation conditions for which digital TV might be a problem.

5] Potential enhancements to EDGES

1] Move to a more remote location away from digital TV stations

2] Add separate RFI detector

3] Eliminate daytime observations

4] Return to using a more spectrally efficient spectrometer like the AC240. [It is not clear the 12-bit ADC is needed once the time periods with strong RFI have been removed.]

5] Increase the size of the ground plane.

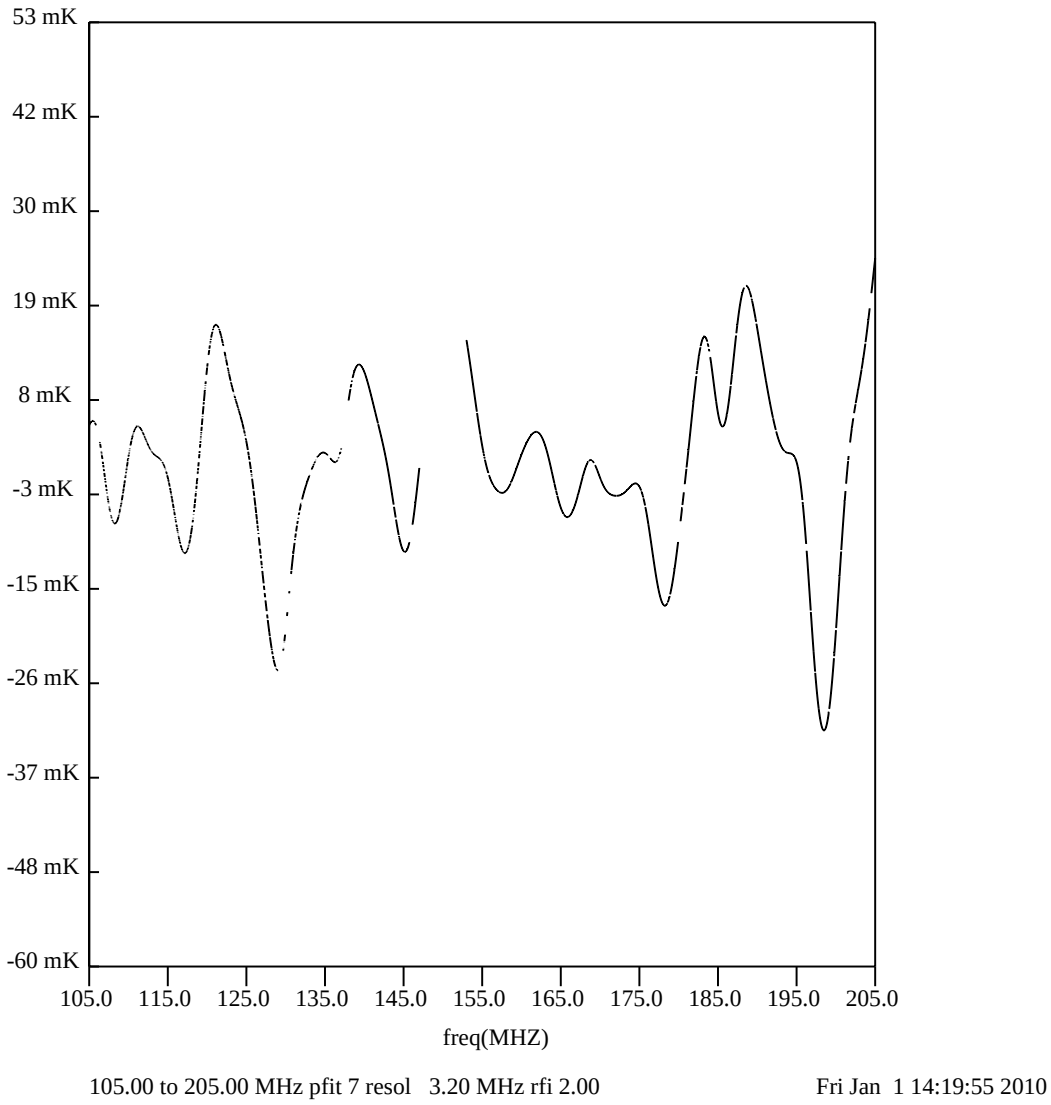

Figure 1. Spectrum after removing 7 term polynomial. Blank portions in the spectrum are regions excluded by RFI.