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To: EDGES Group
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 Subject: EDGES data analysis

1] Spectrum calibration and bandpass removal

The EDGES radiometric spectrometer takes spectra in 3 switch positions.

Sw posn.	
0	Ambient load
1	Ambient load + calibration noise
2	Ambient load + antenna input

If the effects on mismatch are ignored

$$p_0 = g(T_L + T_R)(1 + n_0) \tag{1}$$

$$p_1 = g(T_L + T_R + T_{cal})(1 + n_1) \tag{2}$$

$$p_3 = g(T_A + T_R)(1 + n_2) \tag{3}$$

where

p_0, p_1, p_2	are the power spectra
g	frequency dependent gain or bandpass
T_L	Ambient load temperature
T_R	Total receiver noise
T_{cal}	Calibration noise
T_A	Antenna temperature
n_0, n_1, n_2	Gaussian noise = $(b\tau_i)^{-1/2}$
b	Resolution bandwidth (Hz)
τ_i	Integration time (sec)

From equations 1,2,3

$$\begin{aligned}
T_A &= T_{cal} (p_2 - p_0) / (p_1 - p_0) + T_L \\
&= \frac{T_{cal} \mathfrak{g}(T_A - T_L + n_2(T_A + T_R) - n_0(T_L + T_R))}{\mathfrak{g}(T_{cal} + n_1(T_L + T_R + T_{cal}) - n_0(T_L + T_R))} + T_L \\
&= \left[(T_A - T_L) + n_2(T_A + T_R) - n_0(T_L + T_R) \right] \\
&\times \left[1 + n_1(T_L + T_R + T_{cal})T_{cal}^{-1} - n_0(T_L + T_R)T_{cal}^{-1} \right]^{-1} + T_L \tag{4} \\
&\approx T_A + n_0 \left((T_L + T_R)(T_A - T_L)T_{cal}^{-1} - (T_L + T_R) \right) \\
&+ n_1(T_L + T_R + T_{cal})(T_A - T_L)T_{cal}^{-1} + n_2(T_A + T_R) \\
&\approx T_A - n_0(T_L + T_R) + n_1(T_A - T_L) + n_2(T_A + T_R) \\
&\text{when } T_{cal} \gg T_L
\end{aligned}$$

If the total time for a 3 position switch cycle is T and f_0, f_1 and f_2 are the fractions of time spent in each position the noise in a measurement of T_A is

$$\begin{aligned}
&\left[(f_0 b T)^{-1} (T_L + T_R)^2 (f_1 b T)^{-1} (T_A - T_L)^2 + (f_2 b T)^{-1} (T_A + T_R)^2 \right]^{1/2} \\
&\approx (5/2)^{1/2} b^{-1/2} T^{-1/2} \left(T_A^2 + T_L^2 + 2(T_A - T_L)^2 \right)^{1/2}
\end{aligned}$$

when TR is small and f_0, f_1 and f_2 are 2/5, 1/5, 2/5 respectively. For example if $T_A = T_L = 300\text{K}$ and $T = 30$ sec ($b = 122$ kHz)

$$\Delta T_A \text{ rms} \sim 550 \text{mK}$$

If the results of 100 cycles (~ 1 hour) are averaged and the resolution is smoothed to 1 MHz the rms noise is reduced to approximately 20 mK.

2] RFI reduction

There are a number of options for RFI reduction. The most extreme is to excise any cycle which has any spectral point above 10 sigma. A less extreme approach is to exclude spectra channels which exceed 10 sigma or some other fixed threshold.

3] Processing method

- a. Perform calibration on each cycle using equation (4)
- b. Search for 10 sigma deviations in residuals to sliding polynomial fit of n terms over m spectral points. Mark rfi channels and save rfi spectrum separately.
- c. Remove cable ripple by fitting ripple period plus polynomial if in absolute mode.
 - cable x (x = cable length in ft)
- d. Correct for cable attenuation
- e. Correct for antenna VSWR and balun loss
- f. Calculate VSWR if in VSWR mode
- g. Remove polynomial with n terms
 - control – npoly n (default 0)
- h. Plot waterfall with max scale of 10^nK

control –water n

For averages

- i.* Average results of each cycle keeping rfi removed points separate for plotting in blue. Also estimate noise for each spectral point.
- j.* Remove bestfit polynomial from average
- k.* Smooth over n spectral points
Control: - smooth n (default 0)
- l.* Set linear plot scale max and min
Control: - lin max_min (default 0-0)
- m.* Convert to fractional units if desired
Control – ppm 1 (default 0)

The steps c thru c are controlled by the keyword “cor”

- cor 1 EOR mode – no cable correction
- cor 2 EOR mode – corrects for cable
- cor 3 absolute antenna temperature
- cor 4 - not used
- cor 5 VSWR mode – returns reflection coefficient