EDGES MEMO #046

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To: EDGES Group
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Subject: Theoretical noise for 3-position switching using Acqiris DP310

Switching from antenna to a load and then to a load plus noise calibration allows the antenna temperature to be estimated from

$$T_A = \left[\frac{p0 - p1}{p2 - p1}\right] T_{cal} - T_{load} \tag{1}$$

where $p0 = (T_A + T_R)\, g$

$p1 = (T_L + T_R)\, g$

$p2 = (T_L + T_{cal} + T_R)\, g$

where T_A = antenna temperature
T_L = load temperature
T_R = receiver noise temperature
g = receiver gain

If the system is linear the relation of equation (1) is independent of the bandpass and any constant additive noise which is present in the total power of each switch position. The noise in T_A can be estimated from the noise in the spectra from each switch position. Since the noise in each position is independent of the noise in another position the total noise is the square root of the squares of the individual noise components:

$$\Delta T_A = \left[(T_A + T_R)^2 \sigma_0^2 + \frac{(T_A - T_L - T_{cal})^2 (T_L + T_R)^2 \sigma_1^2}{T_{cal}^2} + \frac{(T_A - T_L)^2 (T_{cal} + T_L + T_R)^2 \sigma_2^2}{T_{cal}^2} \right]^{1/2} \tag{2}$$

where σ_0, σ_1 *and* σ_2 are the fractional noise in each switch position. If equal times are spent in each position and $T_{cal} >> T_L$

$$\Delta T_A \approx \sigma \left[(T_A + T_R)^2 + (T_L + T_R)^2 + (T_A - T_L)^2 \right]^{1/2} \tag{3}$$

where $\sigma = (bT/3)^{-1/2}$

b = resolution bandwidth (Hz)
T = total integration (s)

Parameters used by dp310	
T_{cal}	400 K
T_L	300 K
T_R	50 K
Sample rate	420 Ms/s
Number samples / FFT	32,768
Number spectral points	16,384
Number FFT blocks per integration period	5120
Integration time	0.4 s per switch position
Real time	~ 10 s per switch position
Window function	Blackman – Harris
Frequency spacing	12.817 kHz
Frequency resolution (Blackman – Harris)	26 kHz
Effective integration Fraction for Blackman – Harris	0.5
Calculated rms noise for $T_A = 10^3$	24 K
26 kHz resolution and 30 seconds real time	
(For T_A= 500 K the rms noise is 11 K)	
Calculated rms for 24 hours realtime and smoothing to 1 MHz	72 mK

In summary the EDGES system has increased noise as a result of the following factors:

1] 96% of the time the data is being transferred and processed so noise is increased by a factor of 5

2] Each FFT is windowed to obtain very high rejection of the resolution sidelobes this increases the noise by $\sqrt{2}$

3] For the 400 K calibration noise is increased by a factor of about 1.3, depending on the antenna temperature, compared with a much stronger calibration.