EDGES MEMO #268

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
HAYSTACK OBSERVATORY
WESTFORD, MASSACHUSETTS 01886

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Telephone: 617-715-5533
Fax: 781-981-0590

To: EDGES Group

From: Alan E.E. Rogers

Subject: Cancellation of 3-position switch noise bias

Memos 18, 46, 147, 176 and 230 discuss the 3-position switch. The noise bias in the switch can be removed, to first order, as follows:

Currently the spectral data is converted to temperature using

$$T = T_{cal}\left(pa - p\ell\right)/\left(pc - p\ell\right) + T_{load}$$

where pa = power on antenna

$p\ell$ = power on load

pc = power on load plus internal noise cal

T_{cal} = fixed temperature assumed for noise cal

T_{load} = fixed temperature assumed for load

T_{cal} and T_{load} can be any value as long as the same values are used for the first stage processing of data from the field and data from the calibration in the laboratory.

From a Taylor expansion

$\left(1+n\right)^{-1} = 1 - n + n^2 - n^3 + n^4 ...$ so that if n is the fractional Gaussian noise

$$\left\langle \left(1+n\right)^{-1} \right\rangle = 1 + \left\langle \sigma^2 \right\rangle + \left\langle \sigma^4 \right\rangle +$$

$$= 1 + c + 3c^2 +$$

where c is the noise fraction

$$c = \left(p\ell^2 + pc^2\right)a^2 / \left(pc - p\ell\right)^2$$

where $a = \left(bt\right)^{-1/2}$

where b = resolution bandwidth

t = integration time for pc and $p\ell$ which are assumed to be equal.

In the current software

$b = 6.10$ kHz

$t = 6.71$ seconds

To first order the 3-position switch bias is corrected by multiplying by (1+c) so that

$$T = T_{cal}\left(1+c\right)\left(pa - p\ell\right)/\left(pc - pl\right) + T_{load}$$

For a large noise cal $c \sim \left(bt\right)^{-1} \sim 2.5\times10^{-5}$ for receiver1 $c \sim 6\times10^{-5}$

The value of c doesn't depend on the backend as long as the noise contribution of the backend contribution is small.

A test of the effects on the lowband1 data were made by processing the calibration and the field data using the first order correction.

freq (MHz)	SNR	amp (K)	width (MHz)		
78.1	37.4	0.53	18.7	51-99	No bias correction
78.5	37.0	0.55	18.8	51-99	With bias correction
78.5	37.0	0.55	18.8		

Table 1 lowband1 data 2016_250 - 2017_095

The effect in this case is very small. Another test is made using simulated data in which the length of the data in each switch cycle is changed between the calibration and the data taken in the field. This might be the case if there is an increase in FFT processing efficiency so that more data is processed in a switching cycle without speeding up the switching cycle. Not speeding up the switching period is desirable due to the dependence of the limited lifetime of the mechanical switch on the number of cycles.

A simulation is made in which $c = 2.5\times10^{-5}$ for calibration is dropped to $c = 2.5\times10^{-4}$ for the data. The result is a 33 mK residual with correction shown in Figure 1 compared with 55 mK residual (1 term removed) without correction shown in Figure 2. Figure 2 shows a clear systematic in addition to the noise for the 24 hour integration.

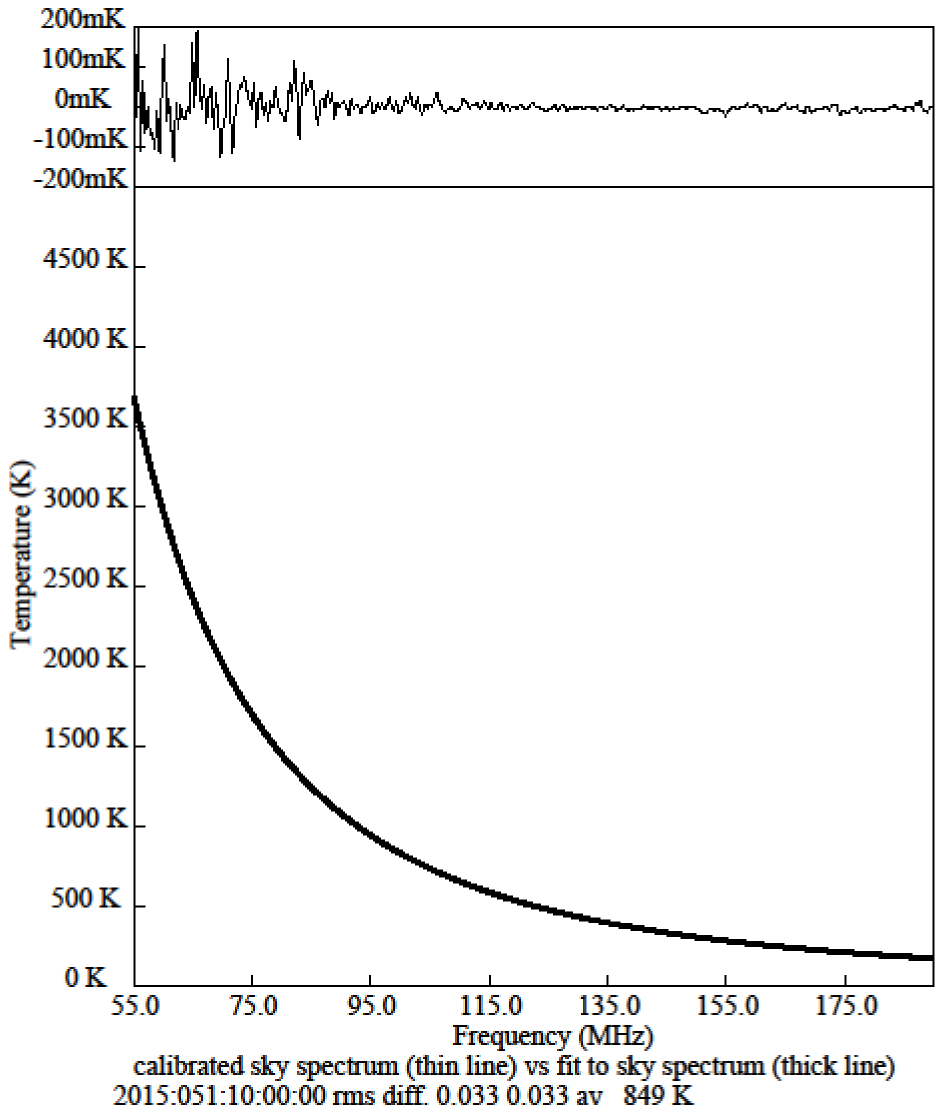

Figure 1. Simulated data with bias correction.

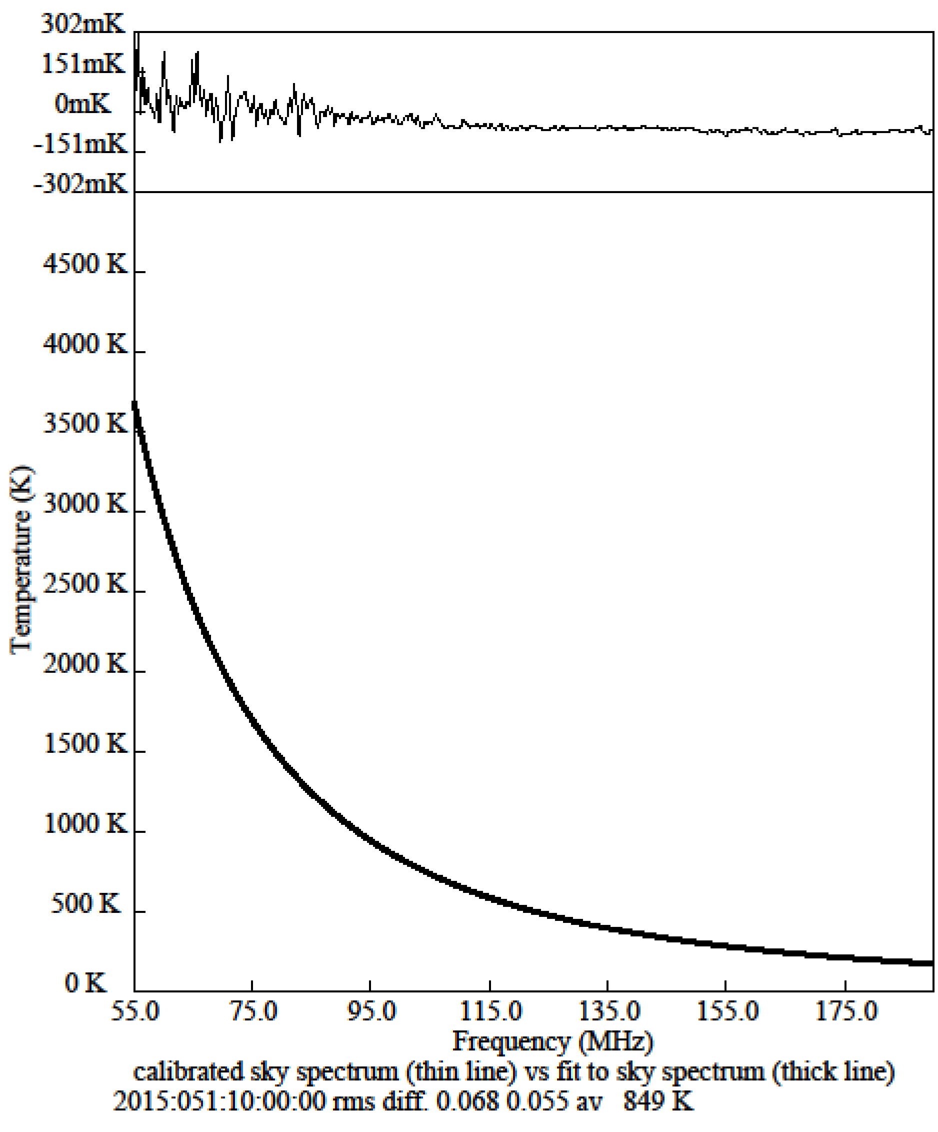

Figure 2. Without bias correction.