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To: EDGES Group

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Subject: Tests of Galaxy calibration using low and high band data

The "Galaxy calibration" method uses the data taken near transit of the Galactic center to remove or identify systematics in the data taken well away from transit of the Galactic Center. The ratio of the sky noise for "Galaxy up" to "Galaxy down" is about 3 for the blade dipole at latitude -26.7° so that many instrumental errors like an error in antenna S11 are magnified by a factor of 3 in the "Galaxy up" data. The Galaxy calibration for the high band has been discussed in memos 172, 171, 145, 55 and 48. The problem with Galaxy calibrations is that the frequency dependence of antenna beam or chromaticity tends to dominate the "Galaxy up" spectra. This is especially a problem for the relatively small low band ground plane as discussed in memos 195, 192, 189, 188, 187, 186, 185, 184.

In this memo the Galaxy calibration method is used in simulation and on low band data to separate the effects of systematic errors in beam chromaticity modeling from calibration errors.

Simulations using 5 physical terms and frequency coverage from 51 to 99 MHz. Beam correction using best current model with dielectric 3.5 and conductivity 1e-2 S/m as reference are given in Table 1. The column labeled "Diff" is the rms of the "Galaxy down" spectrum minus one third of the "Galaxy up" spectrum.

Test	Up (mK)	Dn (mK)	Diff (mK)	Notes
CMB subtracted	48	19	33	1
Modified map	190	14	70	2
Shift to due North	130	16	34	3
Change to infinite	1700	200	710	4
Change to cond. 5e-2	400	74	190	5
Change to cond. 2e-2	130	20	58	6
Change to cond. 5e-3	99	13	43	7
Change to no beam corr.	1300	120	500	8

Table 1. Simulated effect of changes in beam correction.

Notes:

1] Change due to subtraction of the CMB from the Haslam map before scaling to 50 to 100 MHz assuming beta = -2.5

2] Using map with spectral from 408 and 45 MHz maps. (see memo #200).

3] Change of azimuth from -6° to 0°

[4-8] changes in beam parameters

Simulations of changes in S11 and other instrumental factors are given in Table 2.

Test	Up (mK)	Dn(mK)	Diff(mK)
Change to no loss	72	39	25
Changed ant. S11 by 0.1 dB	190	72	15
Changed ant. S11 by 30 ps	43	18	6
Changed S11 from day 342 to day 289	17	5	5
Changed S11 fit from 9 terms to 10 terms	17	6	0.5

Table 2. Simulated effects of instrumental parameters.

These show that in general S11 errors and changes in loss models have a much smaller effect on the "Galaxy calibrated" spectra labeled as diff. On the other hand the effects of error in the beam model are large, mainly as a result of its limited size of 9.8×9.9 m. However it may still be possible to improve the low band results using Galaxy calibration.

Figures 1,2 and 3 show the results of applying the "Galaxy calibration" to low band data taken from 2015_286 to 2016_139 using a 4 hour window at GHA=0 and 8 hour window at GHA=10 hrs. The plots are the residuals to a 5-term fit to scale, spectral index, spectral curvature, ionospheric absorption and ionospheric emission from 51 to 99 MHz. The lowest plot is the residual spectrum from GHA=10 minus one third of the residual spectrum from GHA=0. The results are dependent on the beam model and while it's difficult to know which beam model is accurate the relative smoothness of the difference suggests that some of the systematics are instrumental. The difference between Figure 3 and Figure 2 below 55 MHz is probably due to the larger contribution of the ionosphere in the daytime.

Test	Up (mK)	Dn (mK)	Diff (mK)
Change to infinite	96	13	36
Change to no beam corr.	160	17	62
Shift to due North	10	4	4
Change to no loss	36	29	19
Change ant. S11 by 0.1 dB	65	28	12
Change ant. S11 by 30 ps	351	147	43

Table 3. Simulated effects at high band 102-198 MHz 5-terms removed.

A comparison of simulated effects at high band listed in Table 3 show that the sensitivity to beam effects from the finite ground plane are lower by a factor of about 2 in units of a fraction of the sky noise. On the other sensitivity to instrumental parameters, especially S11 phase is larger than at low band by a factor of 2 or more in units of a fraction of the sky noise.

Figure 4 shows results of "Galaxy calibration" applied to the high band over the same period for comparison with the low band. The ratios rms for low over high for Up, Dn and Diff are 2.8, 3.8 and 4.3 respectively compared with the sky noise ratio of 5.6 which suggest larger instrumental errors at high band. Some of this may be due to the larger sensitivity to S11 and loss. The quasi periodic in the high band difference spectrum comes mainly from the Galaxy up spectrum. In the high band the effects of S11 and loss do not scale perfectly with sky noise ratio.

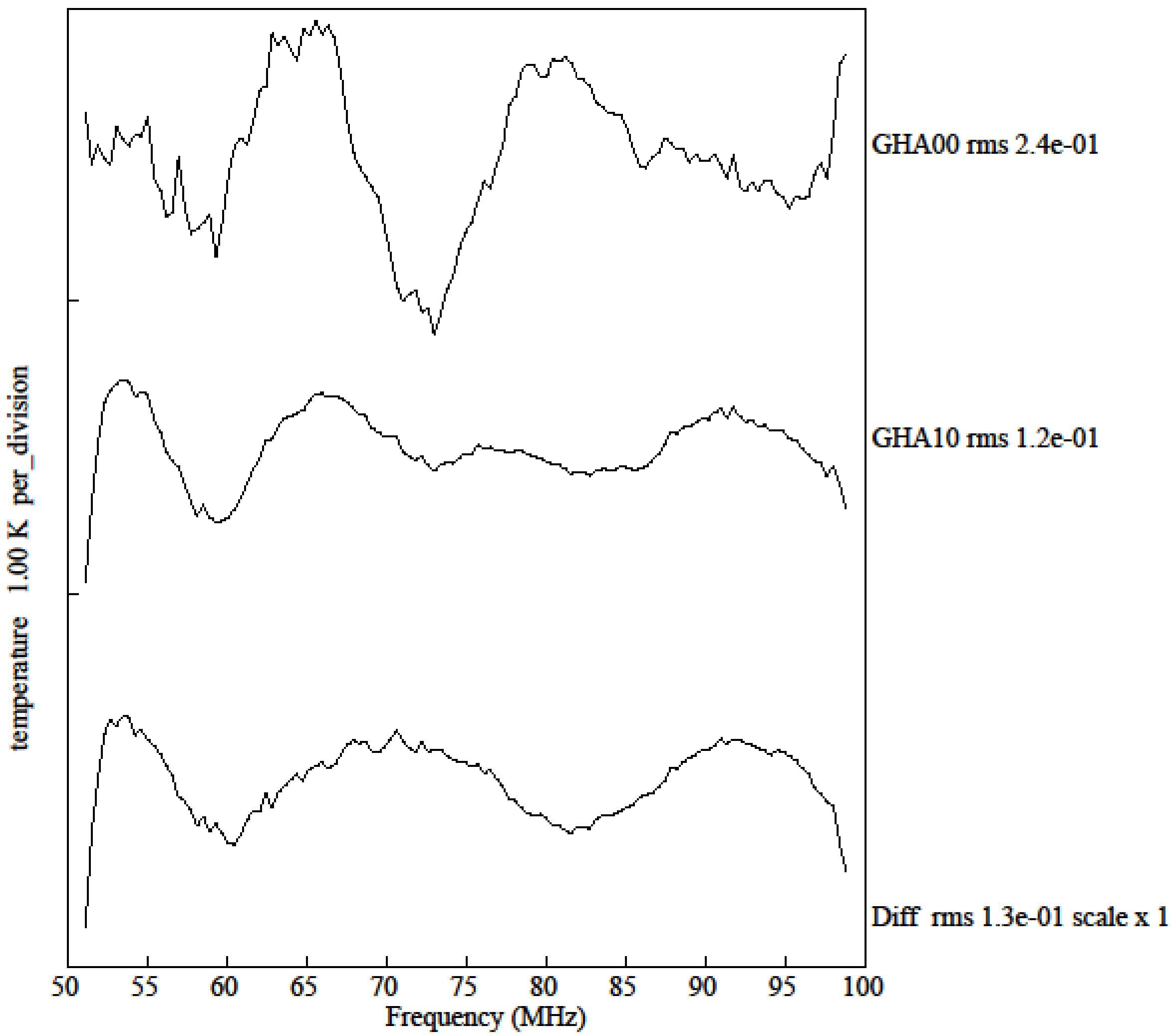

Figure 1. Galaxy up (GHA00), Galaxy down (GHA10) using GF beam with dielectric 3.5 and conductivity 1e-2.

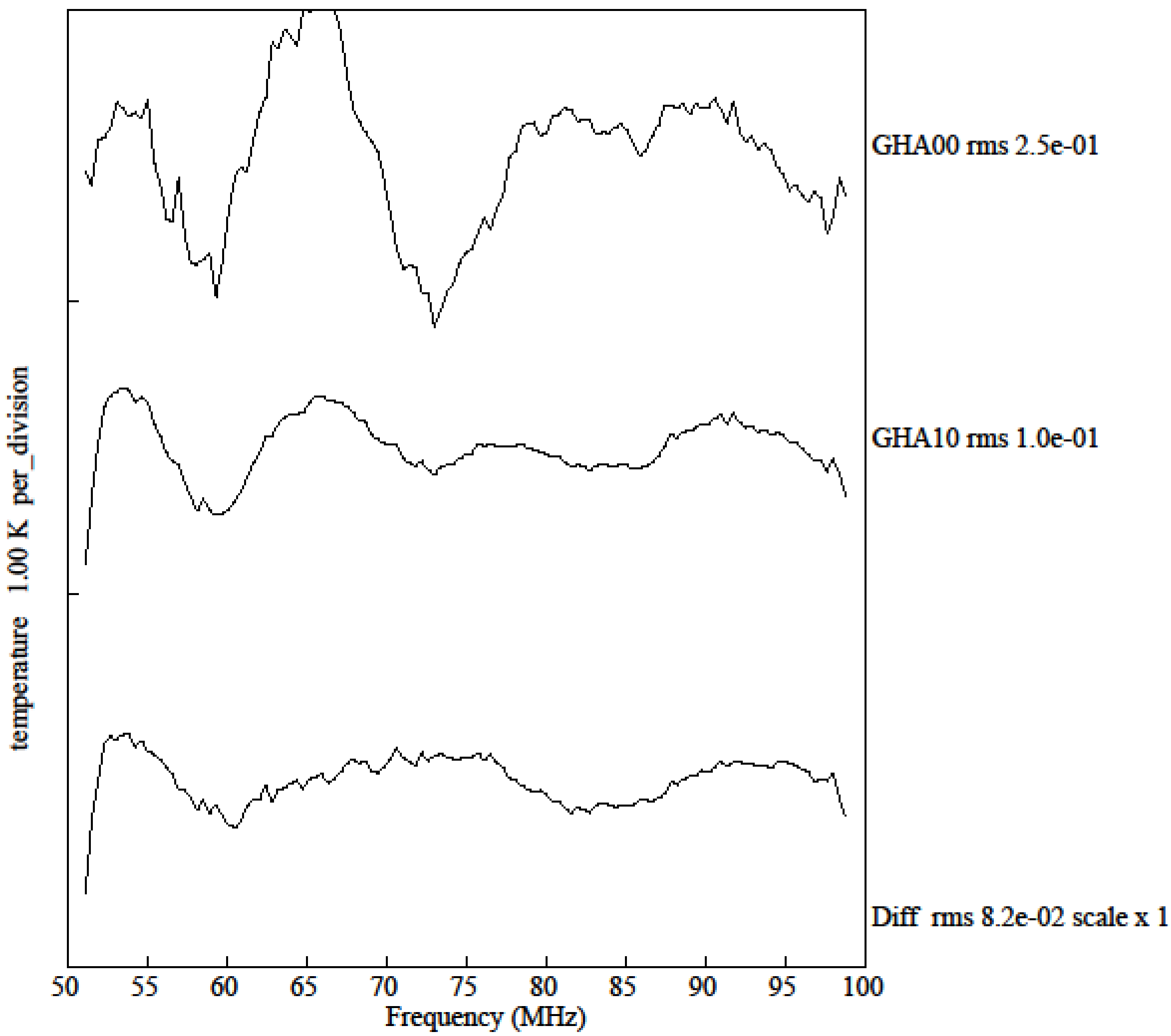

Figure 2. Galaxy up (GHA00), Galaxy down (GHA10) using GF beam with dielectric 3.5 and conductivity 2e-2.

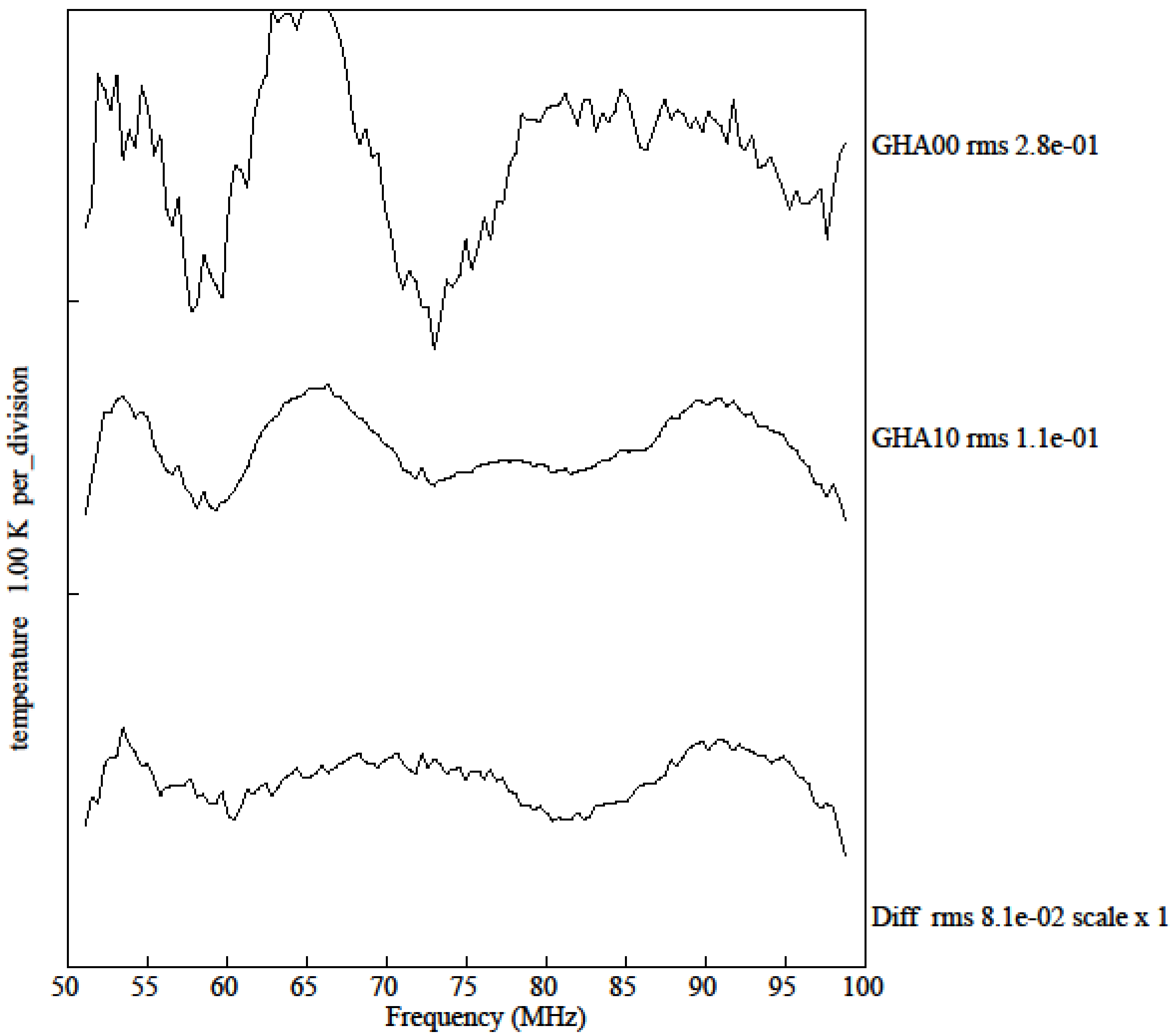

Figure 3. Same as Figure 2 for nighttime data only.

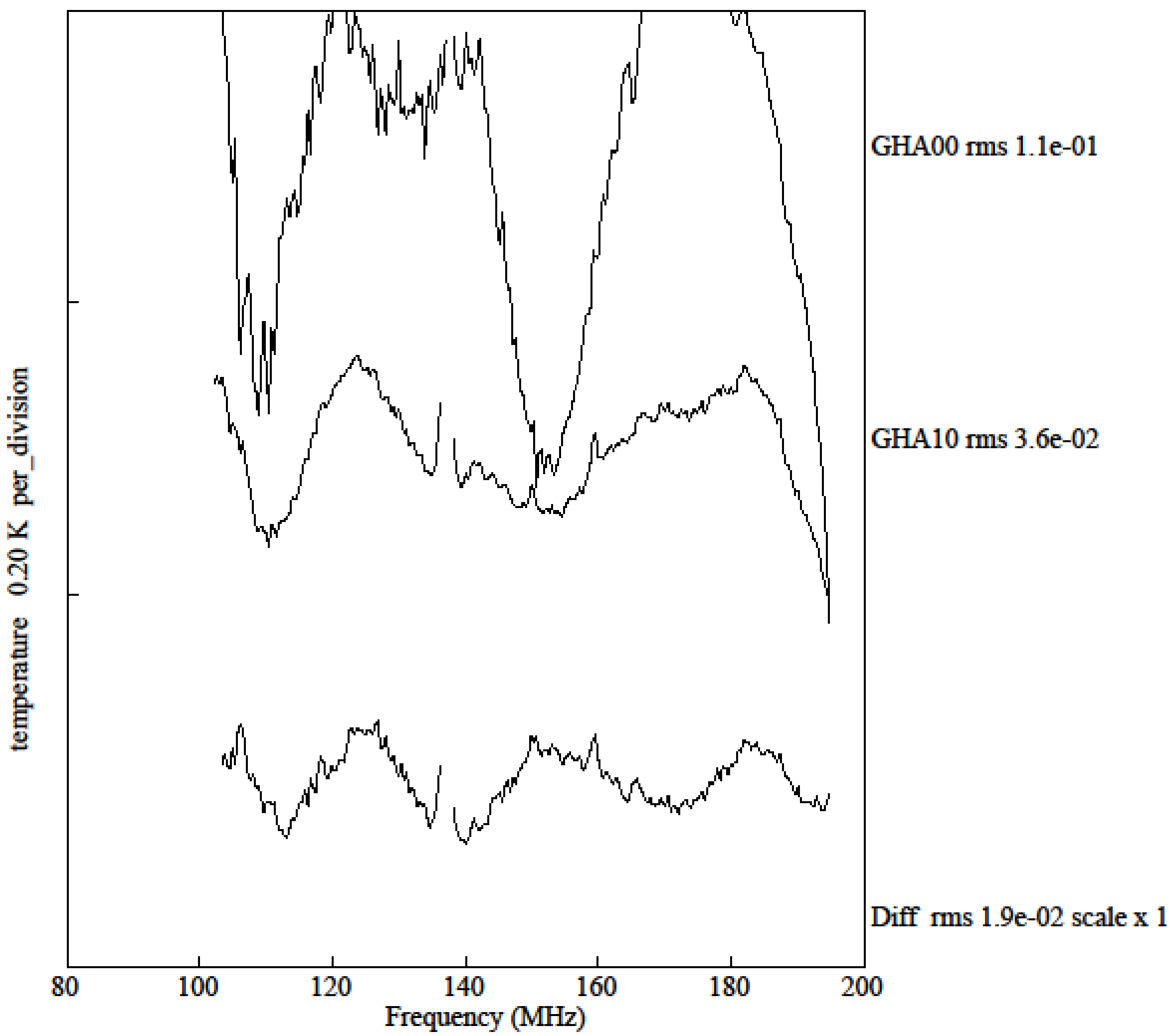

Figure 4. High band 102-195 MHz nighttime data. 5 physical terms removed. GF beam correction using dielectric 3.5 and conductivity 1e-3.