EDGES MEMO #183

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To: EDGES Group

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Subject: Spectral structure at the low end of low band

The rms residuals of low band given in memo 182 are at a level of about 150 mK with 5 terms removed. This is higher than expected by scaling the high band rms of 16 mK from memo 182 with 5 terms removed by a spectral index of -2.6 which gives about 100 mK. Most of the structure in the residuals are at the low end. The effect of the application of the loss correction for the balun and ground plane loss using the results given in memos 180 and 181 is shown in Figures 1 and 2 which compare the residuals to a 3 term fit in the frequency range 51 to 70 MHz. The effect of loss is the largest in this range and the test shows a decrease in rms by a factor of 4. This test along with the knowledge that the balun correction reduces the rms in the high band over its full 100-190 MHz range results in some confidence that the correction is being applied correctly. However the application of the correction does not improve the rms over the full low band range of 51 to 95 MHz.

Figure 3 shows substantial structure in the rms residual to a 5 term fit from 51 to 85 MHz remains after the balun and ground loss corrections have been applied. Figure 4 shows that this structure is reproduced with correct ratio, below 70 MHz in the residuals to a 5 term fit with the Galaxy up which indicates that the remaining structure below 70 MHz is not from the foreground but could be from errors in the antenna S11, receiver calibration, and imperfect correction of the balun or ground loss. Unfortunately it cannot be used to distinguish between these error sources.

Figure 5 shows the rms residuals to 5 term fits made at GHA 6, 8, 10, 12 and 14 hours. It is noted that there is some structure at 10 and 12 hours not evident at the other Galactic hour angles. Checks were made that show that residuals are not significantly affected by whether beam correction or balun and ground loss corrections are made or not. A similar test was done on the high band data which shows no discernable structure in the range 122 to 170 MHz and no significant difference between the residuals at GHA of 6, 8, 10, 12 and 14 hours. The origin of this structure is not known but could possibly be due to a weak resonance in the ground plane. When more data over a wider range of days is available it should be possible to distinguish between a resonance and a signature in the foreground or some other cause.

Another potential cause of high residuals, especially at the low end of low band, is the accuracy of the terms in the physical model which are linear approximations to

$$S = af^{-2.5+b+c\log f}\exp\left(-d/f^2\right)+ef^{-2}$$

S = spectrum

f = normalized frequency

a = scale

b = correction to spectral index

c = “gamma”

d = ion absorption

e = ion emission

Using the approximation that

$$f^{\alpha} \simeq 1 + \alpha \log f$$

$$\text{and } \exp(\alpha) \simeq 1 + \alpha$$

$$\text{we get } S = af^{-2.5}\left(1 + \mathrm{b}\log f + \mathrm{c}(\log f)^2\right)\left(1 - d/f^2\right) + ef^{-2}$$

giving the terms for a, b, c, d and e

$$f^{-2.5}, f^{-2.5}\log f, f^{-2.5}(\log f)^2, f^{-4.5}, f^{-2}$$

We have ignored the term $\alpha^2/2$ and higher which for the ionospheric absorption can be significant at 50 MHz since $\alpha \approx 5\times10^{-2}$ during the day and $\alpha^2/2 \approx 10^{-3}$ or 8 Kelvin out of 8,000K. However simulations and tests on the data using the log of the spectrum to fit the data show that approximations should be good enough at night. Fitting to the log of the spectrum is not perfect either since the added term for the ionosphere emission now requires an approximation

$$\log(a+\alpha) \approx \log a + \alpha/a$$

Tests on the data and simulations also show that for 6 terms the polynomial $f^{-2.5+i}$ may give lower residuals whereas for less than 5 terms the physical terms give lower residuals. When 6 terms are used with the physical model the added function is $f^{-2.5}(\log f)^3$ which represents the next term in a logarithmic polynomial expansion of the spectral index of the foreground.

			Residual mK	
Index	gamma	Ion	4 terms	5 terms
0.2	0	0	1	0
0	0.3	0	22	2
0	0	2	33	3
0.2	0.3	2	62	6
-	0	0	2	0

Table 1. Simulation of error in approximations.

The table above shows the effect of the approximation in the physical model by simulating a Galaxy down spectrum from 51 to 95 MHz using the exact expression and processing using the approximation. The first three column show the deviations of the spectral index, gamma and ionosphere respectively. The unit for the ionosphere are in percentage opacity at 150 MHz. The last row shows the effect of a foreground consisting of equal contributions with spectral index of -2.0 and -3.0. The results in the table show that the effect of the approximation are only significant with large gamma and daytime ionosphere and when fewer than 5 terms are removed.

Figures 6 and 7 show the nighttime spectra for high and low band with beam correction, balun correction and ground loss correction with 2 terms removed. From these plots it is clear that the spectral shape below about 65 MHz is very different from that expected from the foreground. The drop off below 65 MHz is steep and most likely due to effects of the ionosphere or ground loss. It is reasonably well corrected in Figure 8 by applying the ground upper loss curve in memo 179 instead of applying one quarter of the ground loss. But this loss corresponds to about a 1 percent increase in loss from 65 MHz down to 50 MHz. It might be in agreement with the curve in Figure 3 of memo 88 if the shape was closer to that of figure 2 in memo 88. Another test was made to try and distinguish between larger than the expected ground loss and effects of the ionosphere. Figures 9 and 10 show 3 term fits to both day and night data. The 3-terms are scale, spectral index and ionospheric absorption. The rms residuals for daytime the data in Figure 10, which used the larger ground loss used in Figure 8, are lower than those in Figure 9 which used a ground loss of one quarter of that of upper curve in memo 179. Another indication that the ground loss is larger than expected is the ratio of daytime to nighttime ionosphere obtained from the ionospheric absorption fitted to the data in Figure 9 are much lower than the expected ratio of about 5 to one.

It is also noted that the 3-term residuals in Figure 10 are increased with enhanced ground loss correction when the Galaxy is up raising the possibility that beam effects from the reduced size of the ground plane need to be considered.

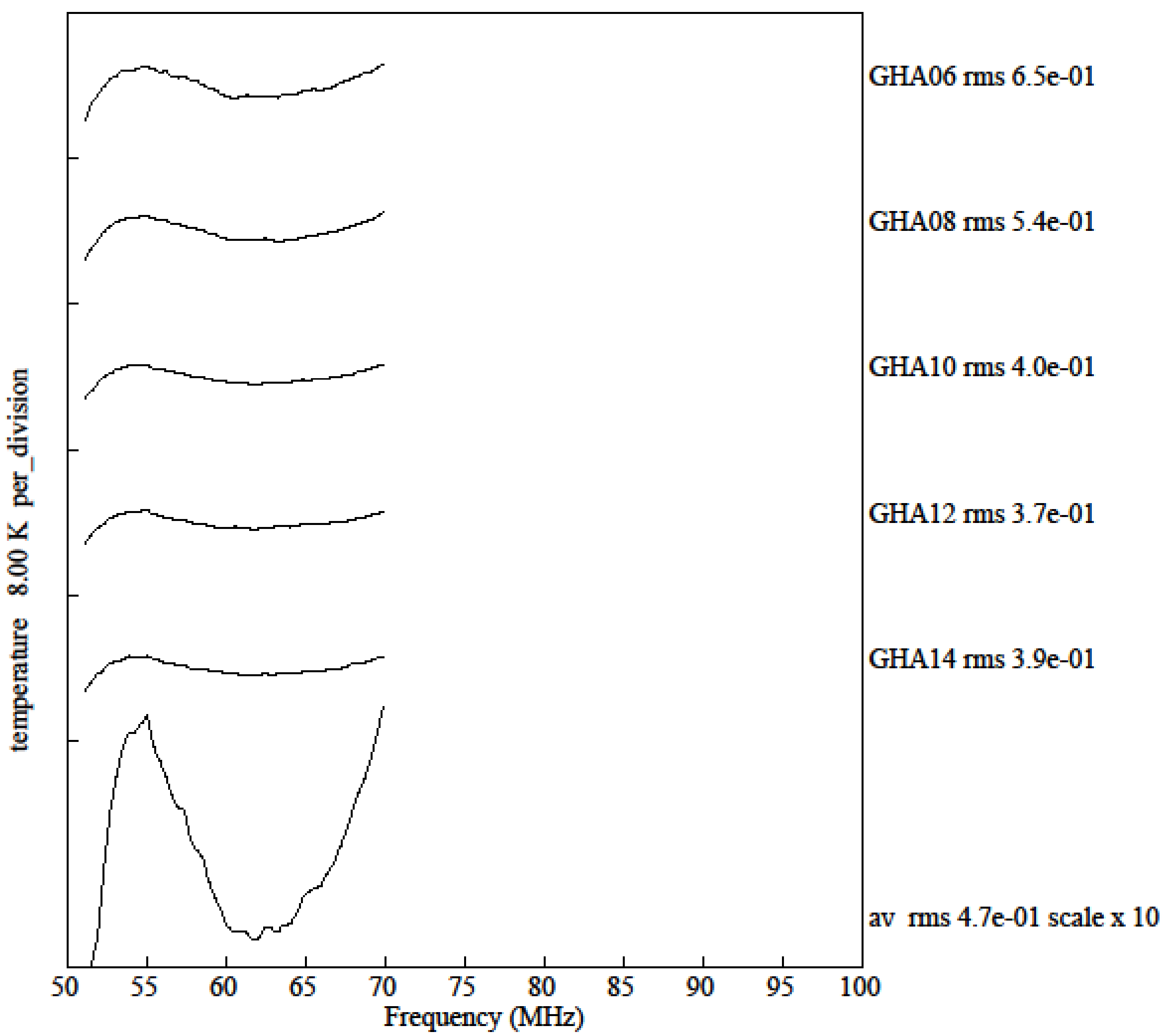

Figure 1. Residuals with 3 terms removed without correction for balun loss.

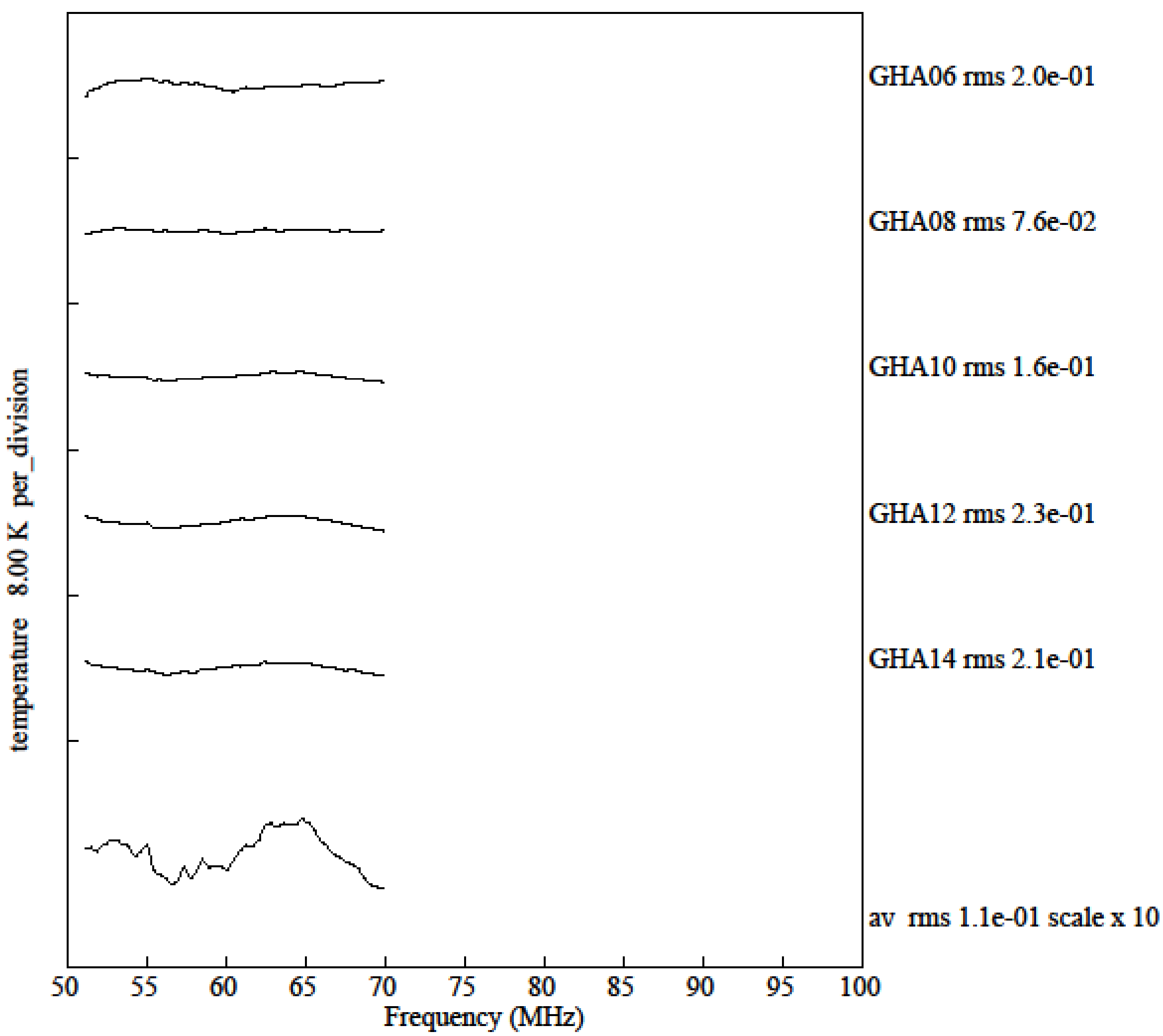

Figure 2. Residuals with correction for balun loss.

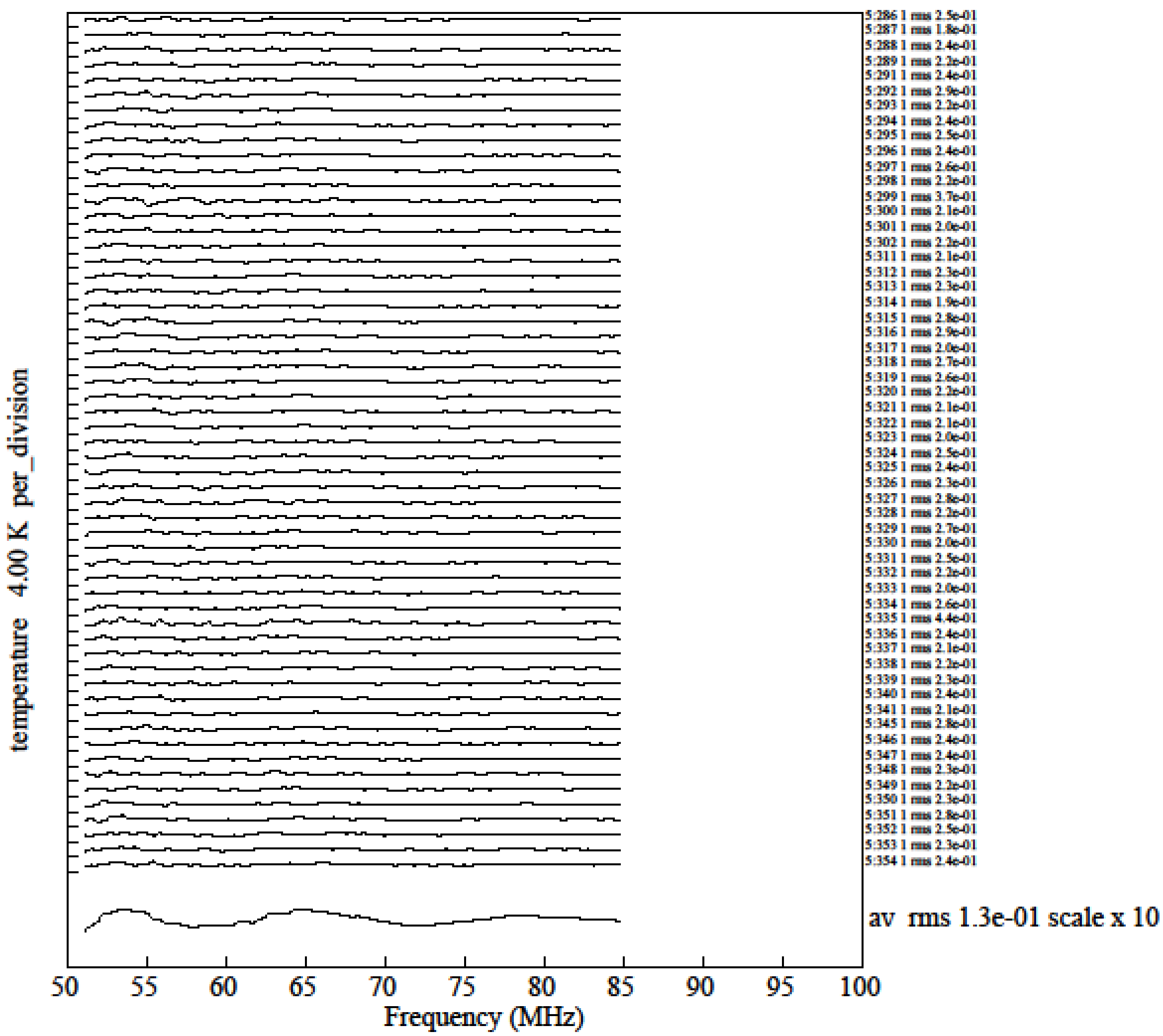

Figure 3. Residuals to 5 term fit from data taken at GHA of 10 hours.

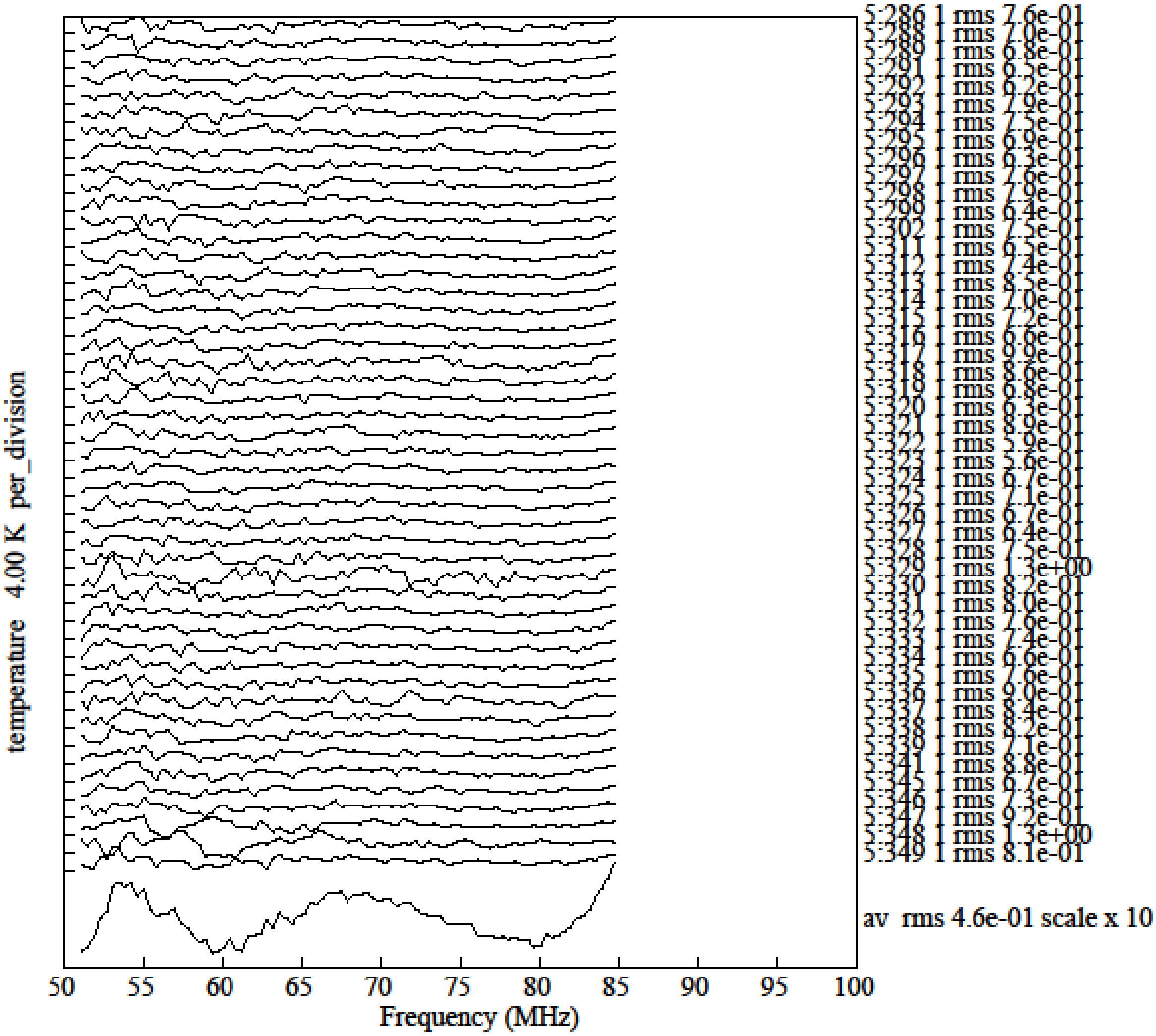

Figure 4. Residuals to 5 term fit from data at Galactic center transit.

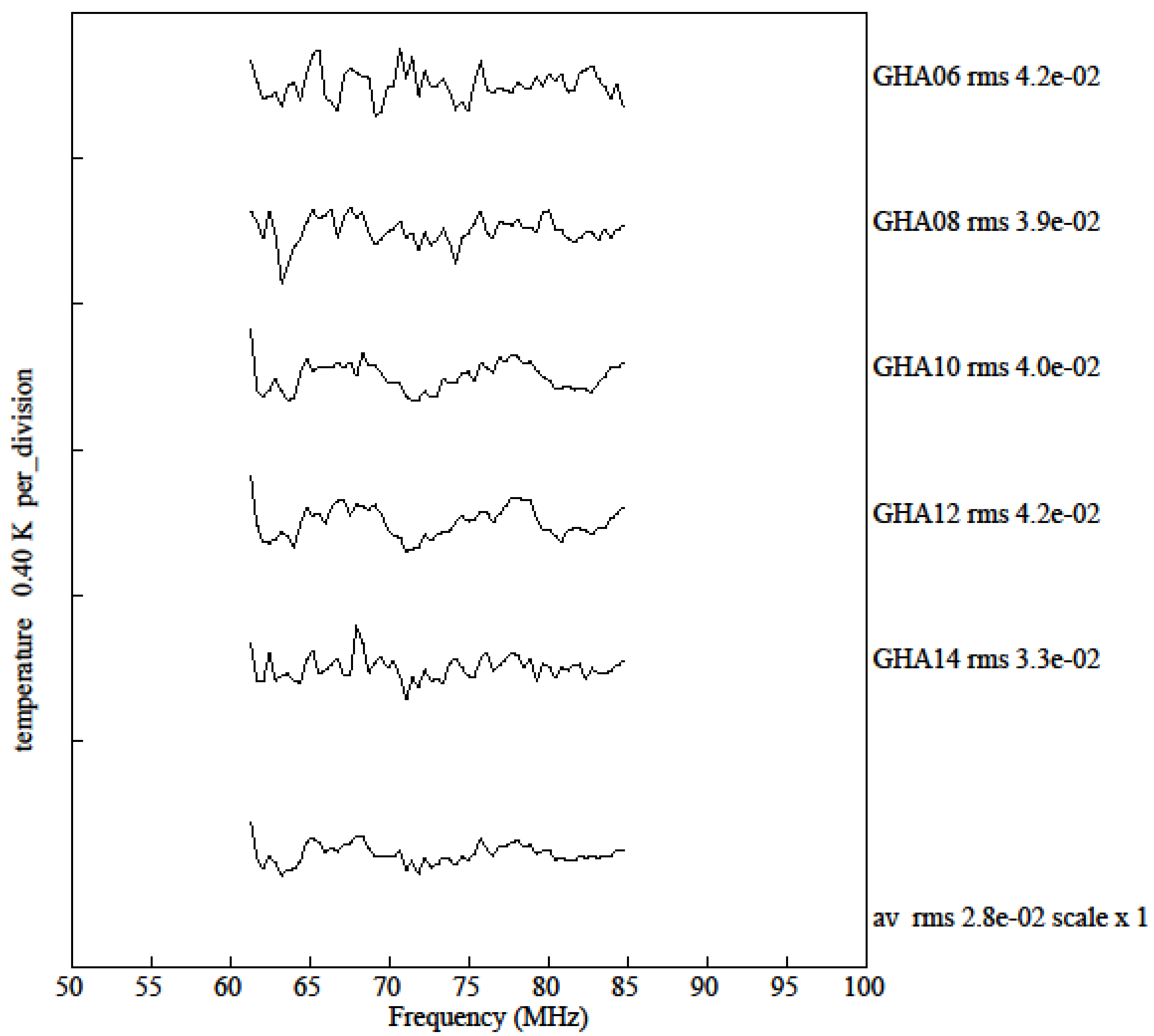

Figure 5. Residuals to a 5 term fit for a range of Galactic hour angles.

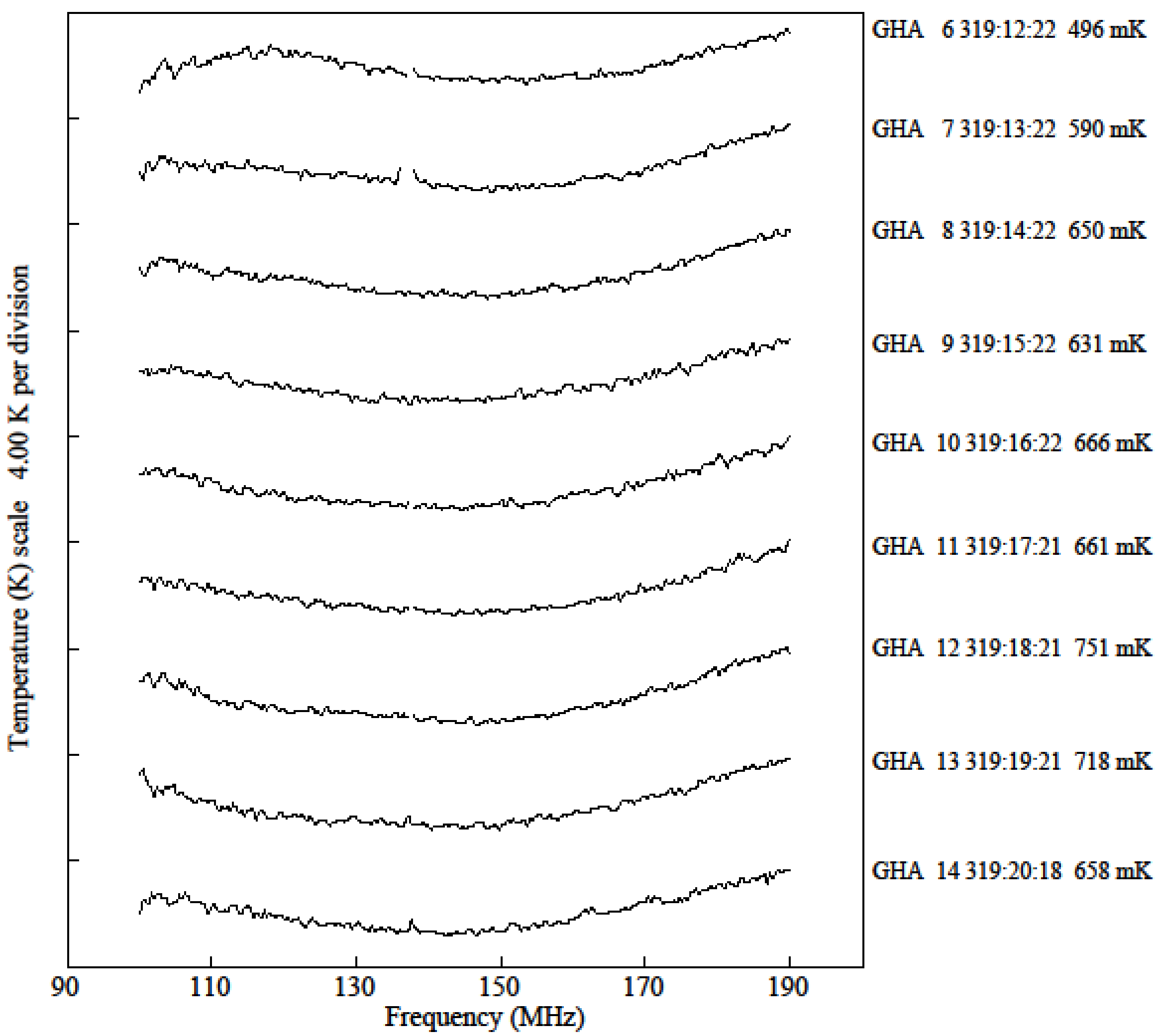

Figure 6. Residuals to a 2 term fit with beam, balun and ground loss correction.

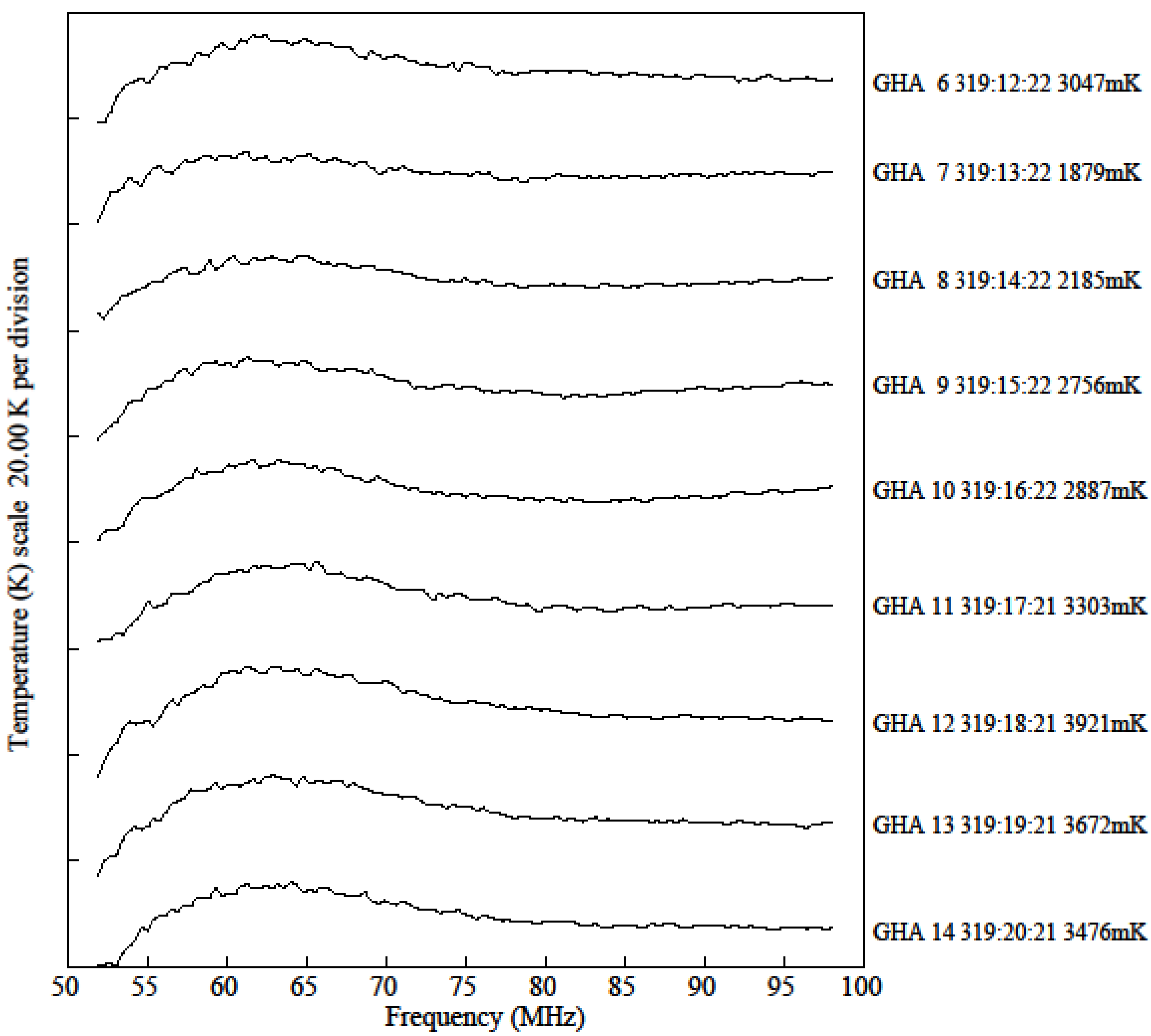

Figure 7. Residuals to 2 term fit with beam, balun and ground loss correction.

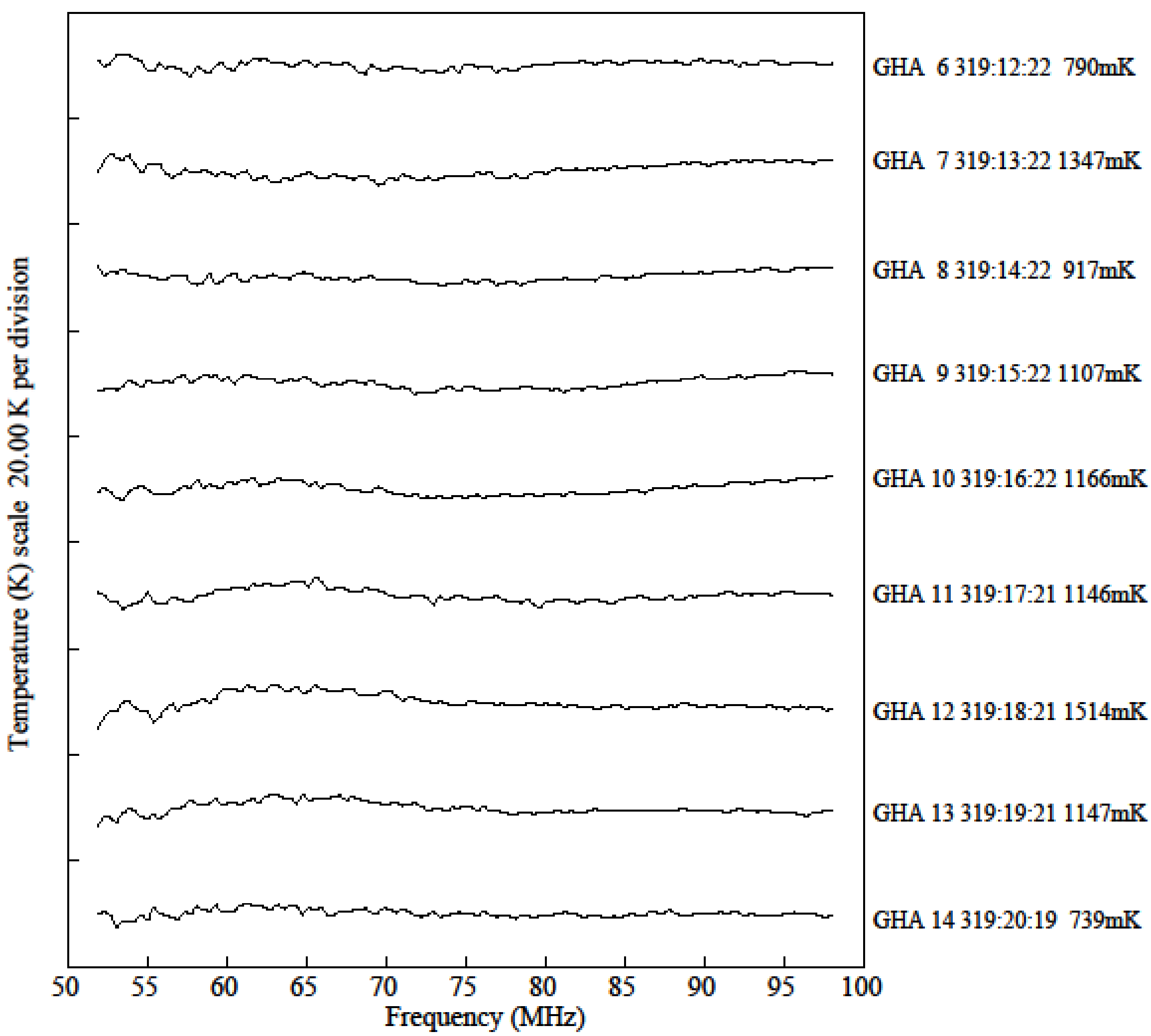

Figure 8. Residuals to 2 term fit with beam, balun and enhanced ground loss correction.

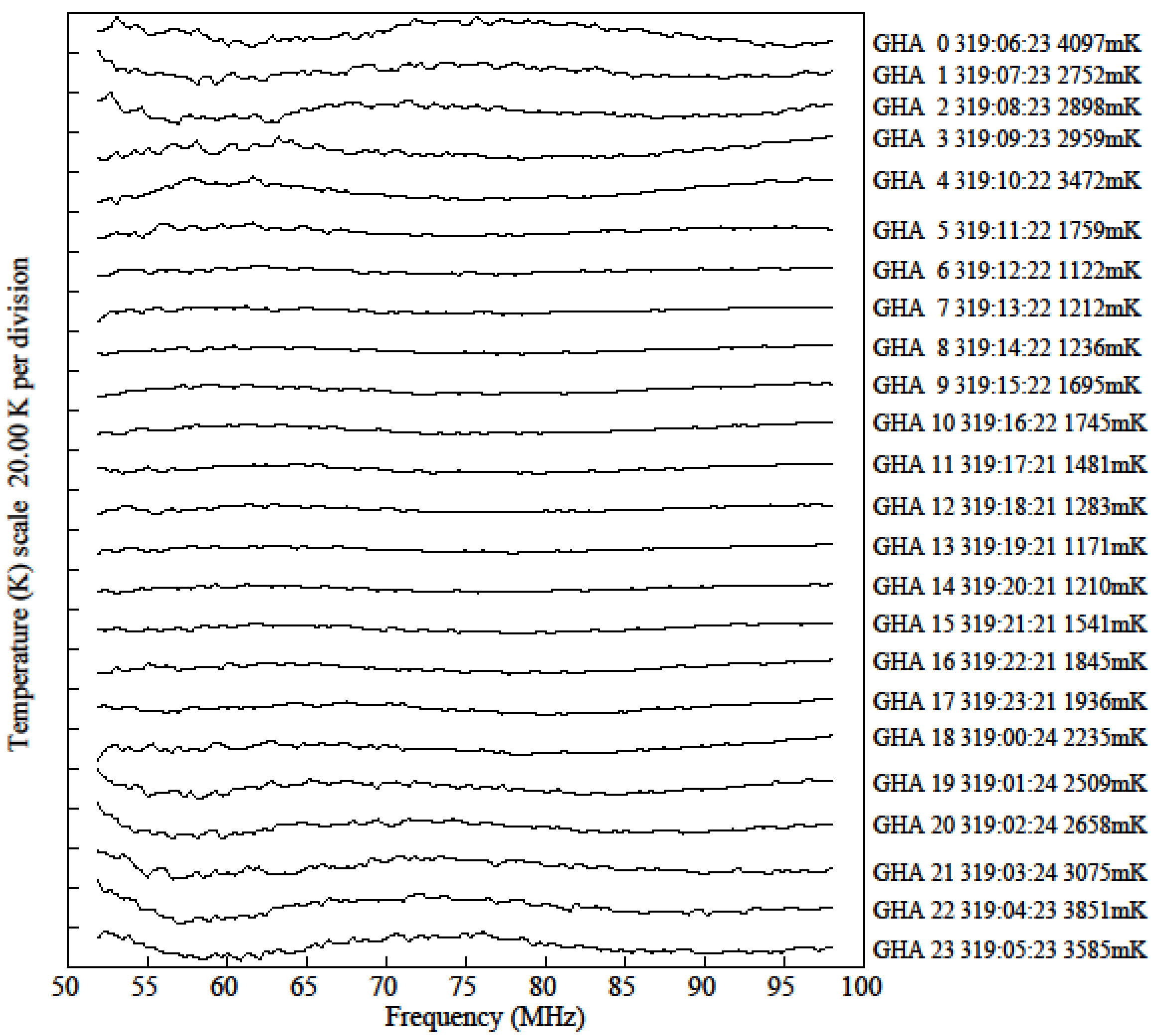

Figure 9. Residuals to 3 term fit.

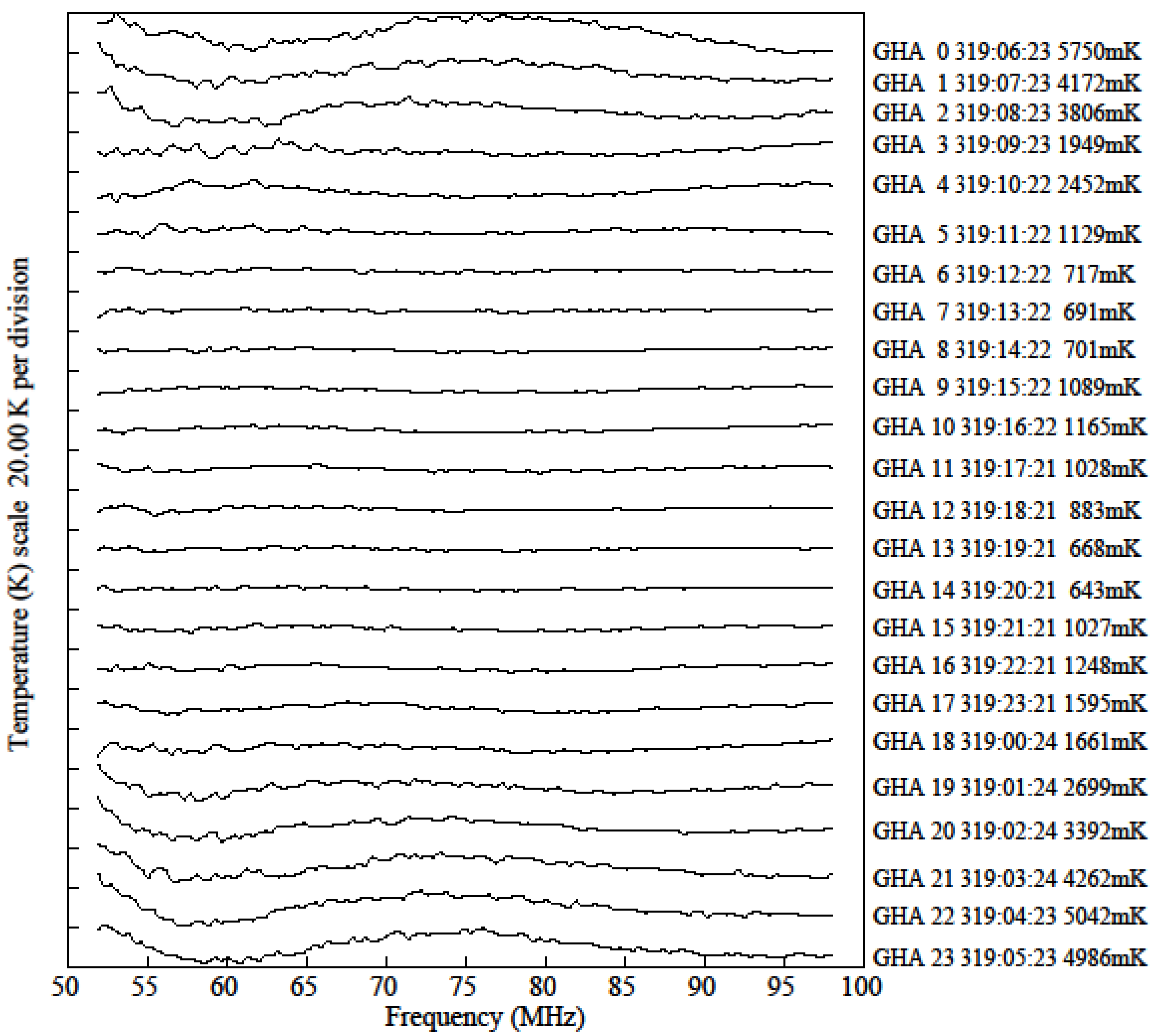

Figure 10. Residuals to 3 term fit with enhanced ground loss correction.