EDGES MEMO #265

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To: EDGES Group

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Subject: Foreground and beam chromaticity contribution to lowband spectra

Figure 1 of memo 203 shows the lowband1 residuals with 4 polynomial terms removed from 72 to 97 MHz for the lowband1 receiver on the original 10×10m ground plane. Figure 1 shows the results of a similar analysis for the lowband1 receiver on the extended ground plane. The data is from 2016_251 to 2017_098. In both cases there are significant and similar changes with Galactic hour angle.

In the case of the 10×10m ground plane there are large changes in the beam correction model with changes in the soil dielectric and conductivity but in the case of the extended ground plane changes in the soil dielectric and conductivity are not large enough to make a significant difference to the beam correction. Simulations of the effect on beam corrections with soil parameters are listed in Table 1. Figure 2a and 2b simulated the residual spectra for the first case. The parameters changed include the addition of changes to the spectral index, β, and the spectral curvature, γ, added to the Haslam map. Of these changes the largest effect is from the addition of spectral index curvature at the level of $\gamma \sim 0.2$. However, the effect on the spectral residuals with 4 terms removed is very small. The effect of changes in β and γ on the foreground model assuming a frequency dependent beam is also very small.

	reference		new					Average	note
Fig	ε	σ	ε	σ	β	γ	Case	rms mK	
2	3.5	2e-2	13	1e-1	-	-	A	4	
3	3.5	2e-2	3.5	2e-2	0.1	0	A	1	
4	3.5	2e-2	3.5	2e-2	0	0.2	A	1	
5	3.5	2e-2	3.5	2e-2	0.1	0	B	0.1	1
6	3.5	2e-2	3.5	2e-2	0	0.2	B	0.6	2

Table 1. Effect of beam chromaticity (case A) and Foreground (case B) on change in soil, and spatial structure in spectral index (β) and spectral index curvature (γ). Average rms is rms for each 4 hour block over GHA with 2 hour spacing. 72 to 97 MHz.

Note 1: spectral index changed by 0.05 at Galactic latitude magnitude of 20 degrees.

Note 2: Spectral index curvature changes by 0.2 at Galactic latitude magnitude 20 degrees.

Higher order structure in the foreground has very little effect on the beam correction but has a significant on the observed spectra.

If the next higher order term beyond "gamma" is introduced

$L_n T = T_0 + \beta \ln f + \gamma (\ln f)^2 + \delta (\ln f)^3$ where

T = sky temperature

β= spectral index

γ = "gamma" or curvature in spectral index

This spatial structure is dependent on the antenna beam is given in Table 2 for different antennas and locations.

Antenna	Location	Average rms (mK)
Blade	MRO	40
Blade	Oregon	40
Monopole	MRO	34
Isotropic	MRO	36

Table 2. Effect of spatial structure δ = 0.1 for magnitude of Galactic latitude less than 5 degrees. Residuals for 4 polynomial terms removed for 62 to 97 MHz.

Figure 3 shows the simulated residuals to a 4 term polynomial fit for δ = 0.1 spatial structure. The "delta" structure was chosen to produce a result in changes with some similarity to what is observed.

Table 3 shows the values of spectral index and gamma obtain from the lowband1 data using a 3-term fit.

GHA (hrs)	β	γ
0	-2.453	-0.07
2	-2.474	-0.08
4	-2.511	-0.08
6	-2.557	-0.05
8	-2.578	-0.01
10	-2.575	-0.00
12	-2.572	-0.01
14	-2.566	-0.01
16	-2.546	-0.03
18	-2.513	-0.06
20	-2.469	-0.07
22	-2.447	-0.07

Table 3. Spectral index and gamma from lowband1 data. 4 hour averages at each GHA. Extended ground plane 2016_251 to 2017_098.

These results imply that values of gamma are smaller and have less negative bias than those in Figure 10 of Oliveira-Costa et al. (2008).

Figure 6 shows the lowband1 data residuals with 4 polynomial terms removed from 52-97 MHz. Figure 7 is a simulation as in Figure 5 but with frequency span extended to cover 52-97 MHz. Again, this shows how foreground spectral structure extending to a higher order term could explain the observed residual spectrum when 4 polynomial terms are removed.

Conclusions:

The dependence of residual lowband1 spectra with 4-term polynomial removed on Galactic hour angle could be due to fine spectral structure from sources close to the Galactic plane. This region is already known to have large variations in the spectral index and the curvature in the spectral index or "gamma" term of Figure 10 of Oliveira-Costa et al (2008). While simulations show that gamma structure is removed with a 4-term polynomial structure in the next order ("delta") is not removed and results in significant changes in the residuals when the Galaxy is "up". If there is significant frequency structure in the sources in the galactic plane we may be limited by this structure when the Galactic plane is in the antenna beam. If this is the case, improvements like a larger ground plane and a less frequency dependence of the antenna beam will be limited. In this case, the next step might be to improve the foreground model using a combination of EDGES and imaging array data.

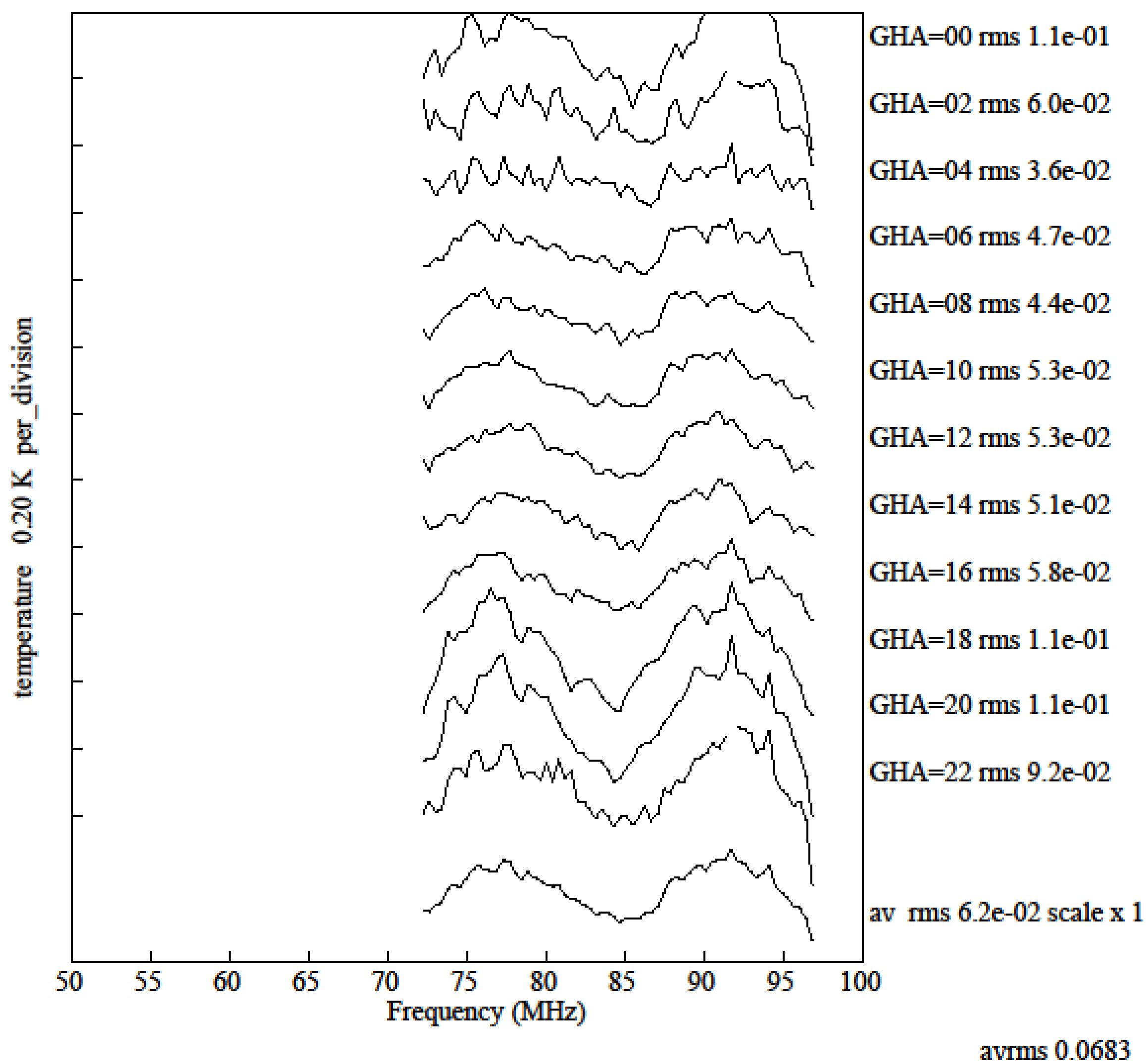

Figure 1. Lowband1 on extended ground plane residuals to 4 term polynomial.

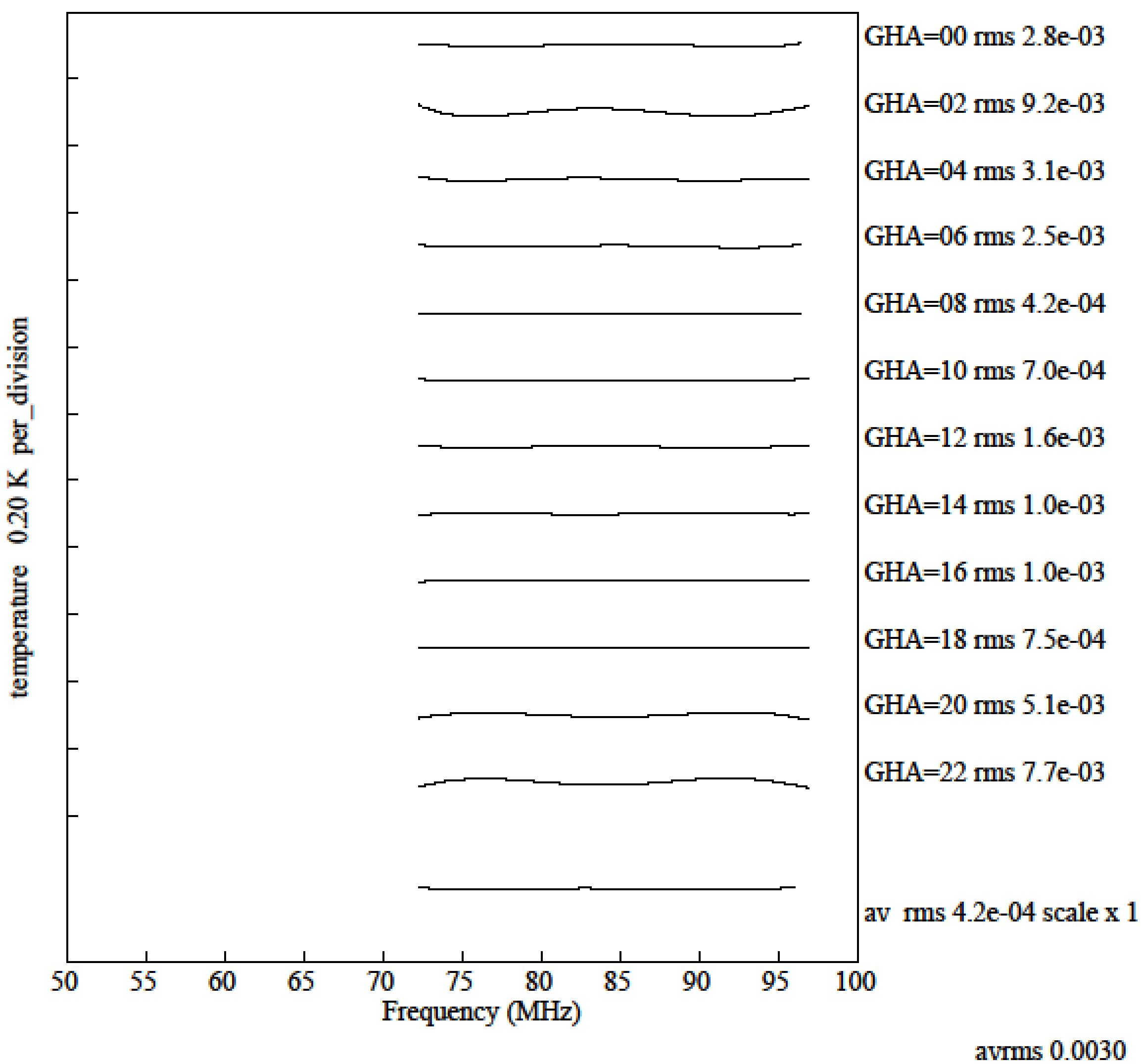

Figure 2a. Simulated residuals for change in soil with 4 term polynomial removed.

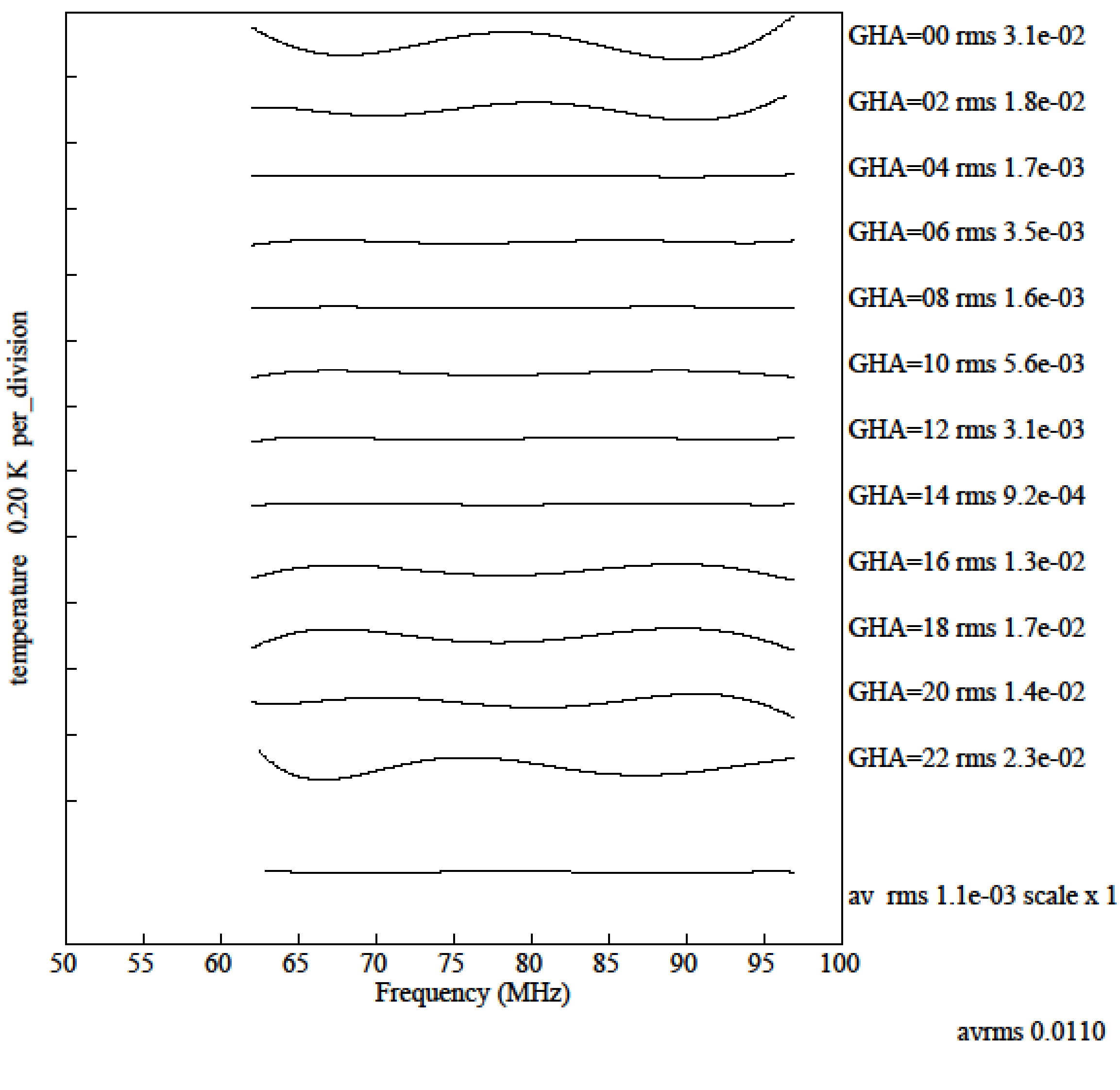

Figure 2b. Effects over larger frequency range.

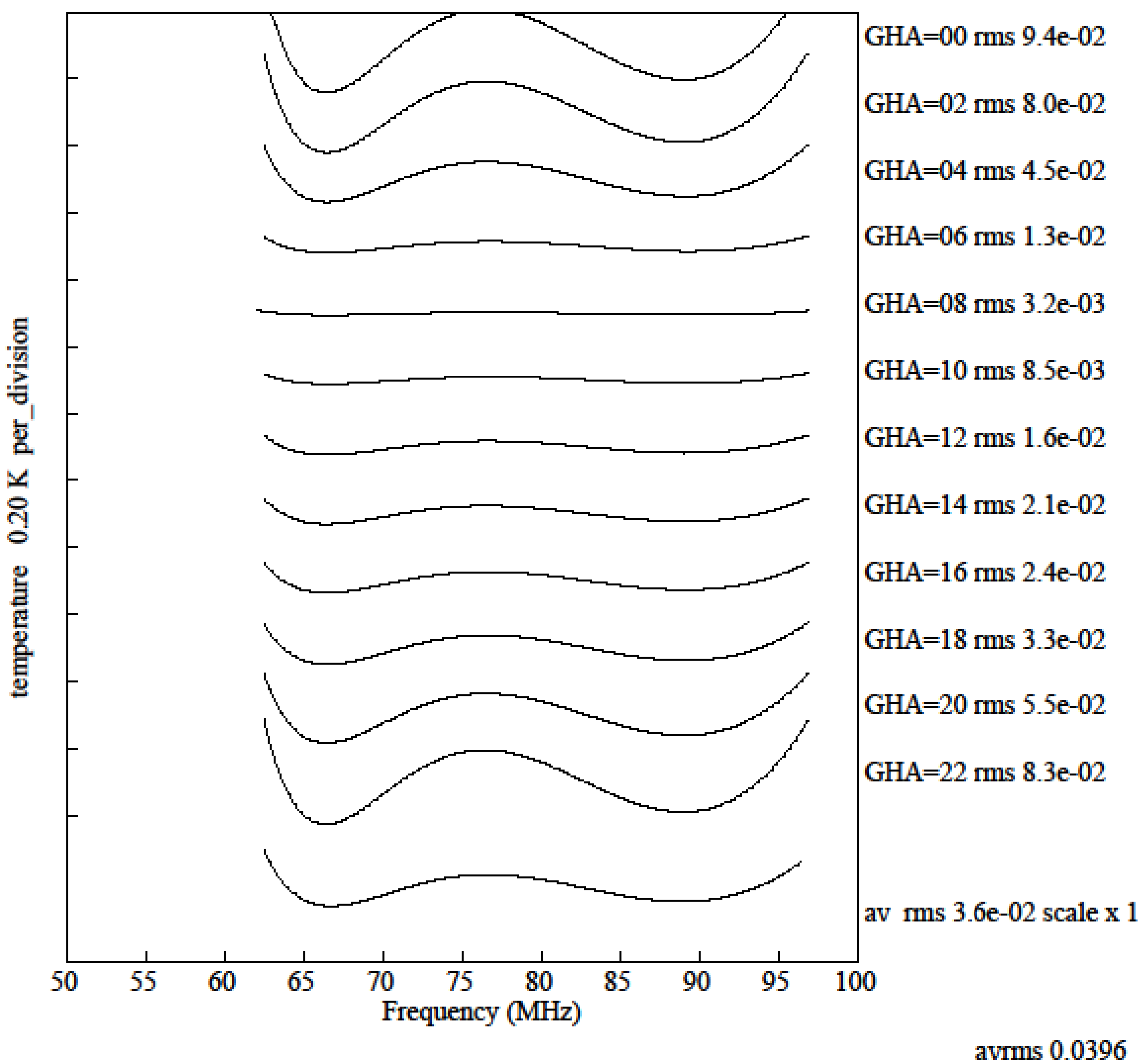

Figure 3. Simulated residuals with 4 term polynomial removed for δ=0.1 within 5 degrees of equator.

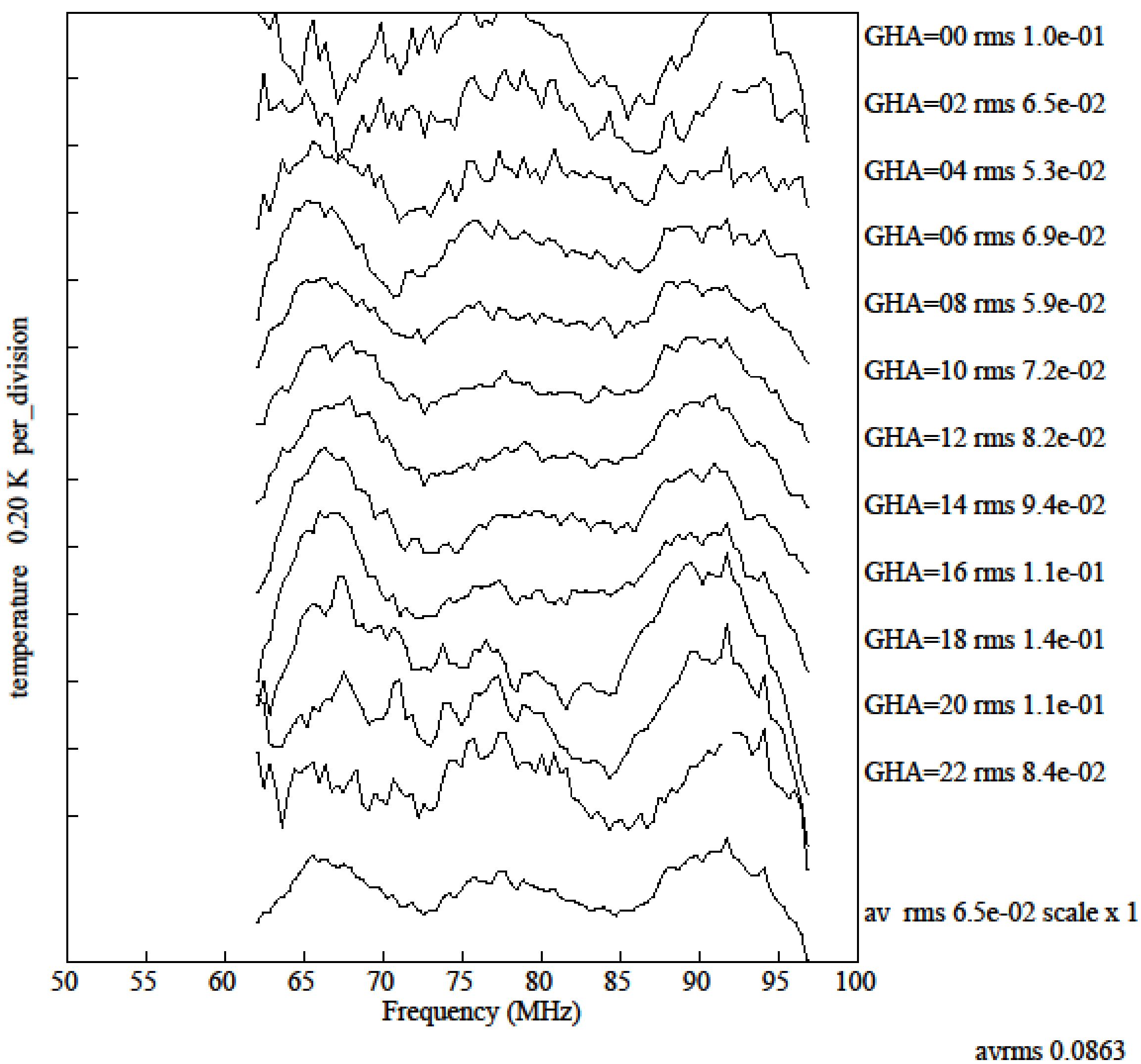

Figure 4. Lowband1 residuals with 4 polynomial terms removed.

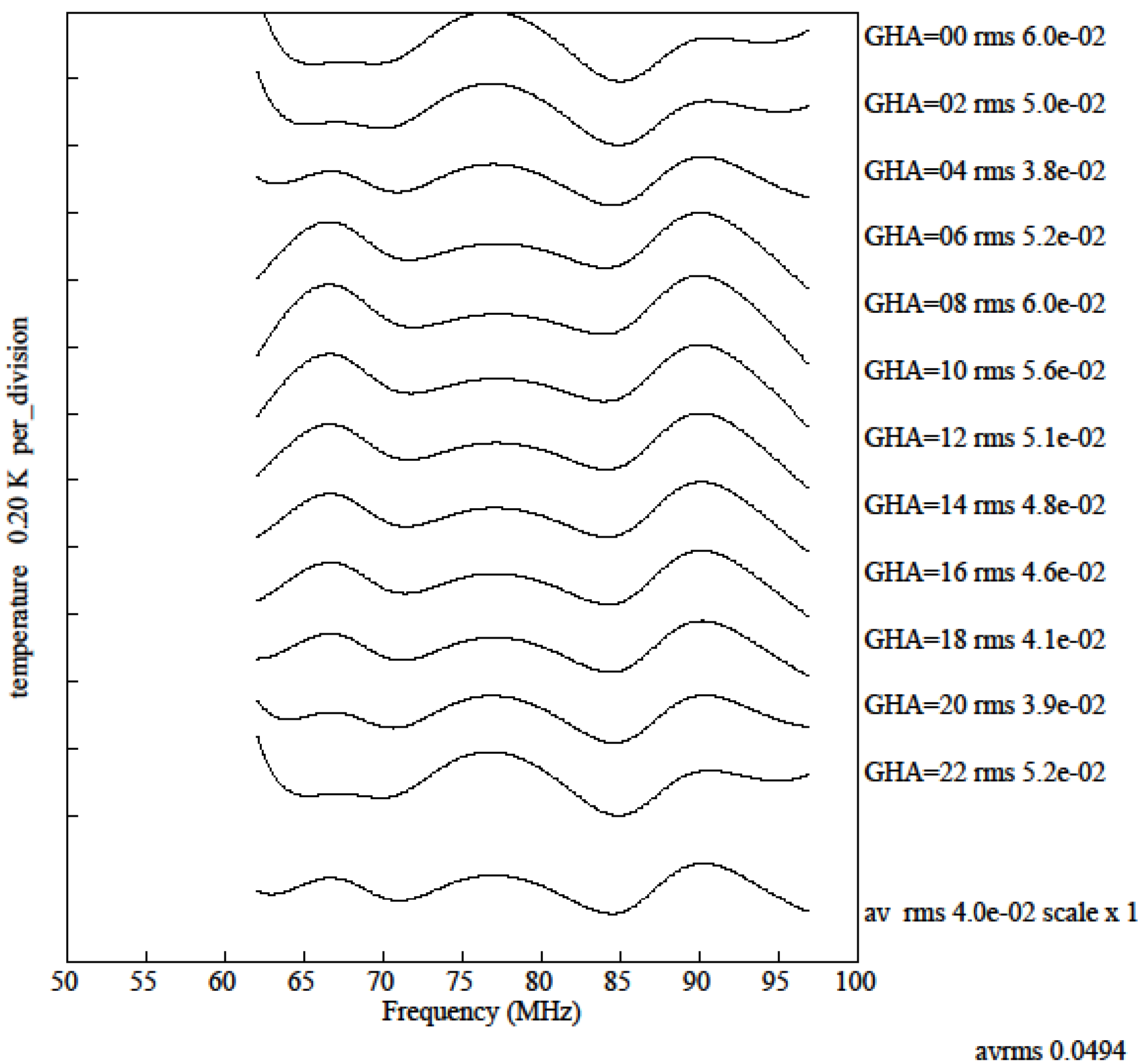

Figure 5. Simulated residuals with 0.5 K absorption at 78 MHz with 19 MHz FWHP τ=7 is added to the simulation shown in Figure 3 for comparison with lowband1 residuals shown in Figure 4.

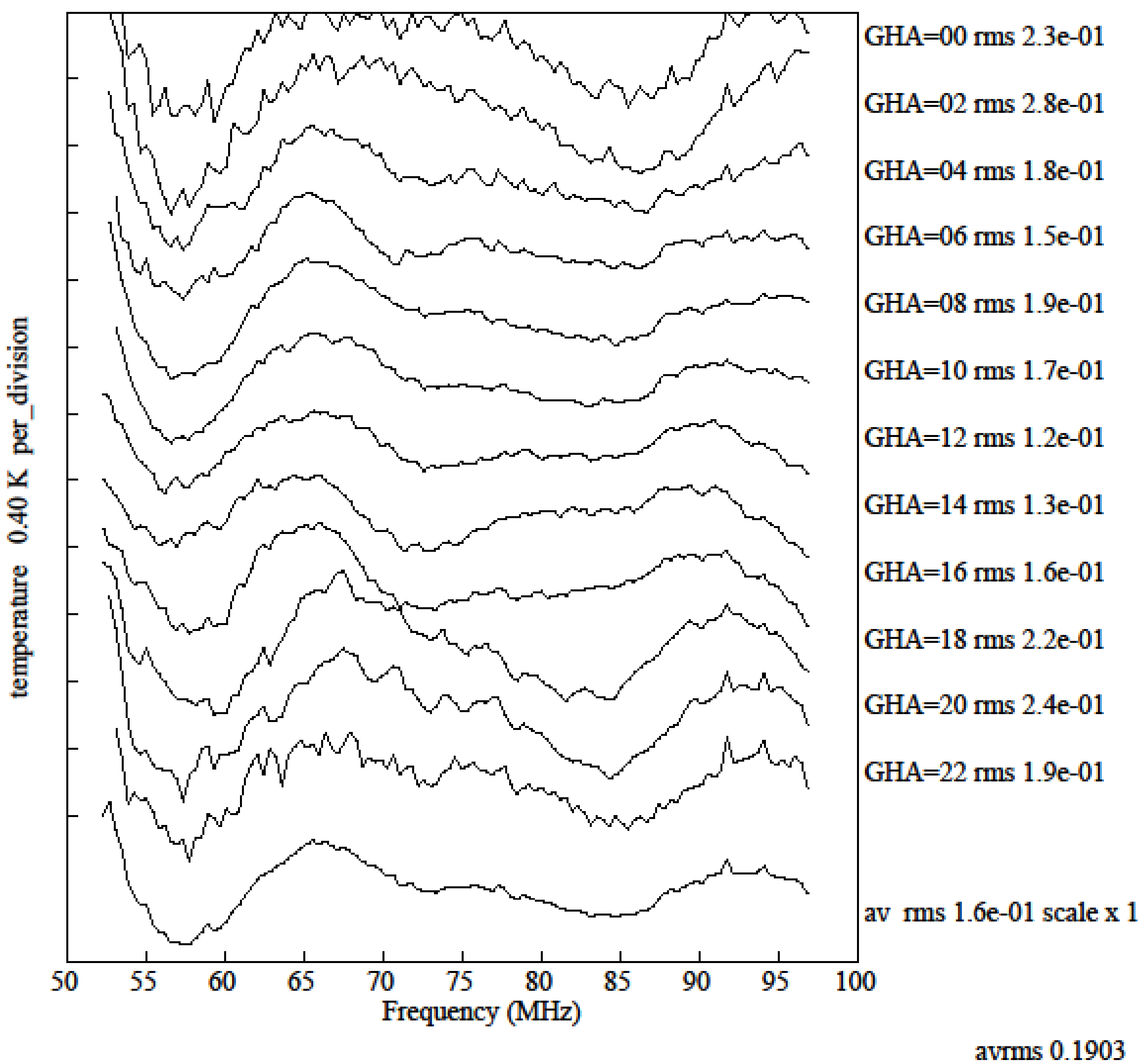

Figure 6. Lowband1 data residuals with 4 polynomial terms removed.

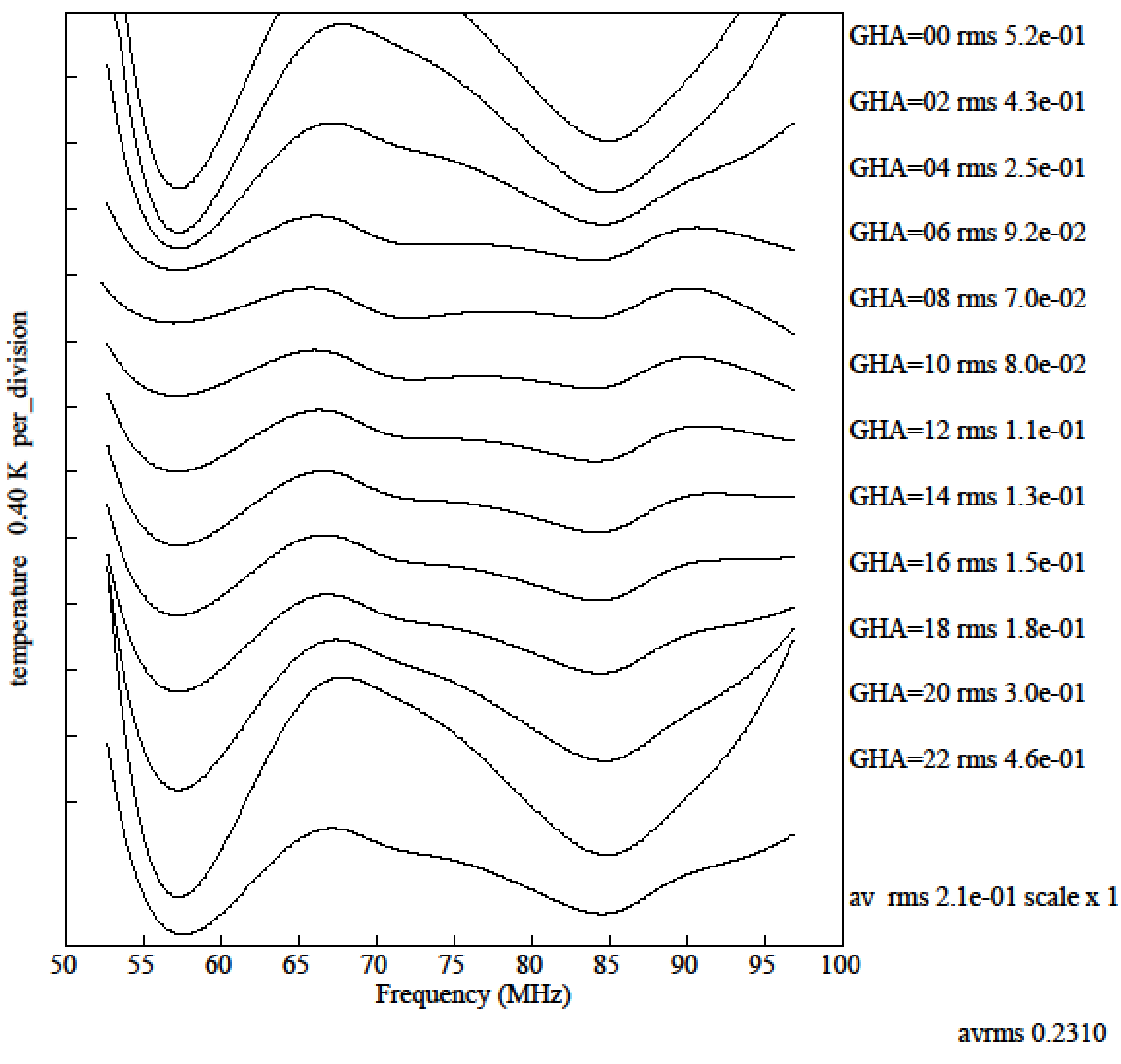

Figure 7. Simulation with added signature as in Figure 5 over larger frequency range for comparison with lowband1 data residuals shown in Figure 5.