Testing different fitting functions on Simulated and actual Spectra for Beam chromocity analysis

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Introduction:

The analysis done in this report is to support the content in the low-band beam paper. The beam pattern of the low band blade antenna over the real ground is modelled using 3 softwares FEKO, HFSS-IE and CST-I. To quantitatively assess the effectiveness of each of the beam solutions, we convolve them with scaled Haslam Sky map (40-100 MHz) and compare each simulated spectra with the actual lowband data between the days: 2015_286 to 2016_015.

The data and simulated spectra are fitted with following foreground models:

- LogLog - 3,4,5 terms
- LinLog - 3,4,5 terms
- Polynomial - 3,4,5 terms

Loglog - 5 terms

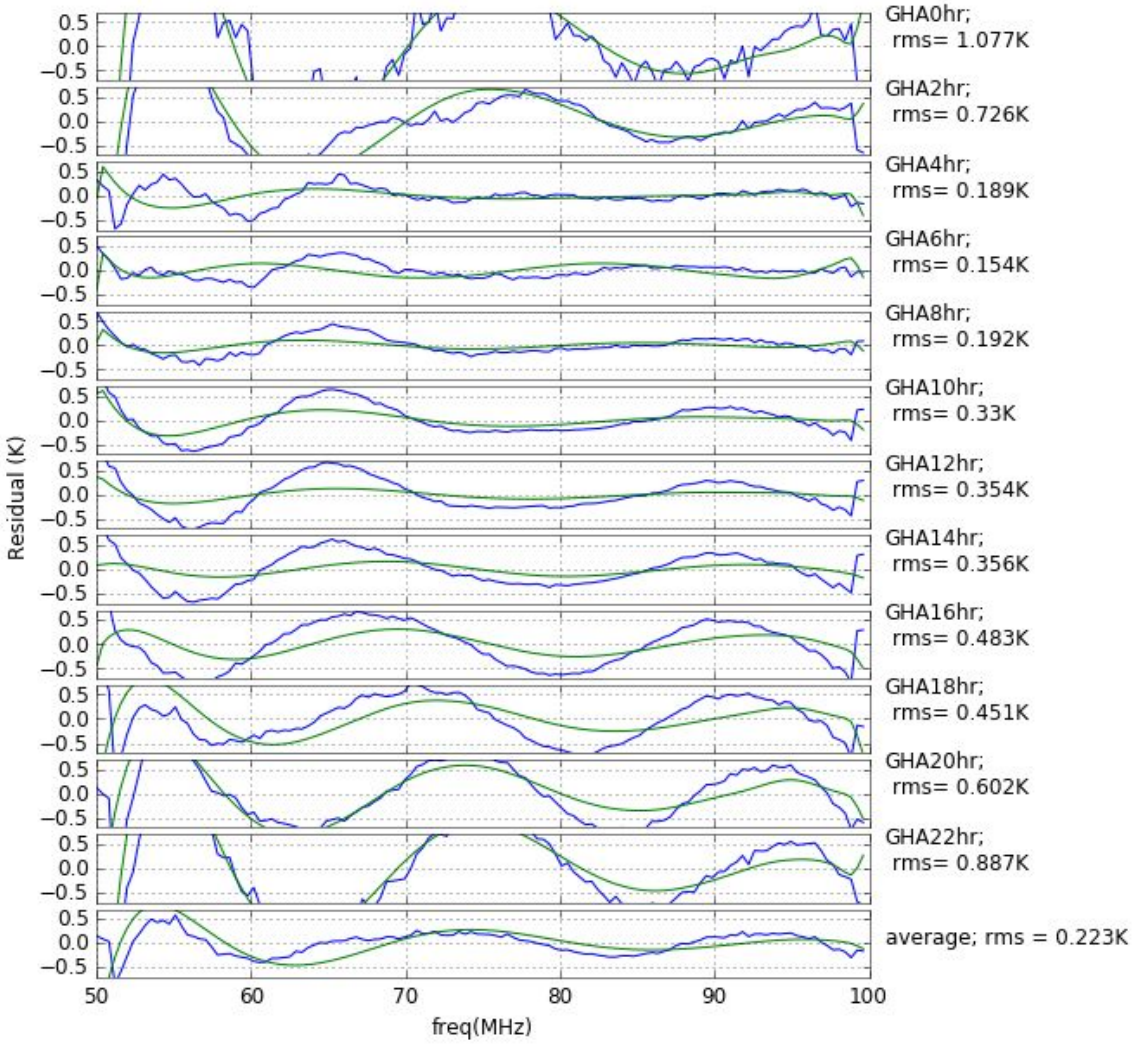


Fig1: Comparison of residues from the simulated feko (green) and collected (blue) lowband spectra for different Galactic Hour Angles.

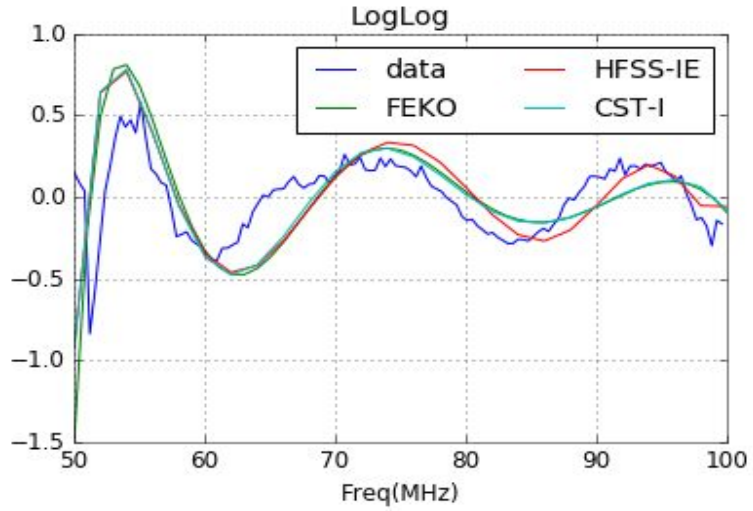


Fig2: The time averaged residues vs Freq for the different simulated spectra and the actual low-band data.

Linlog - 5 terms

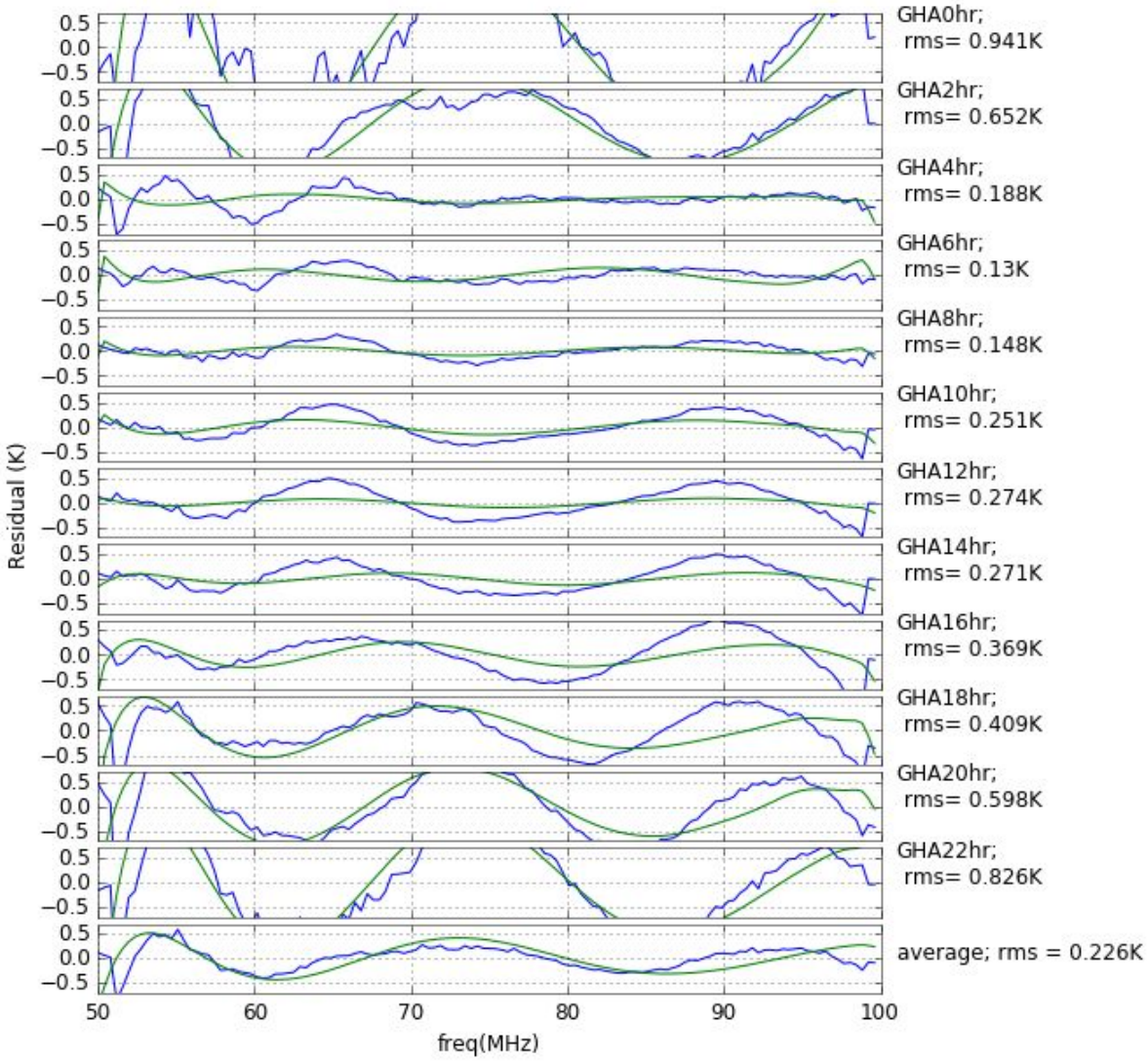


Fig3: Comparison of residues from the simulated feko (green) and collected (blue) lowband spectra for different Galactic Hour Angles.

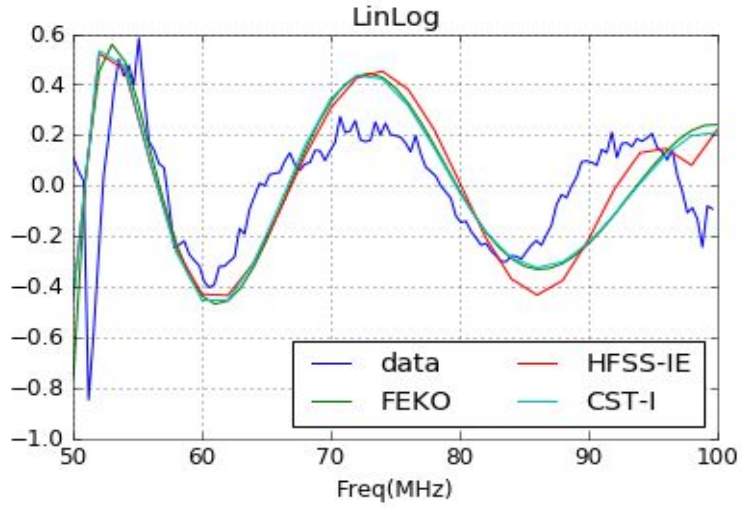


Fig4: The time averaged residues vs Freq for the different simulated spectra and the actual low-band data.

5 term polynomial

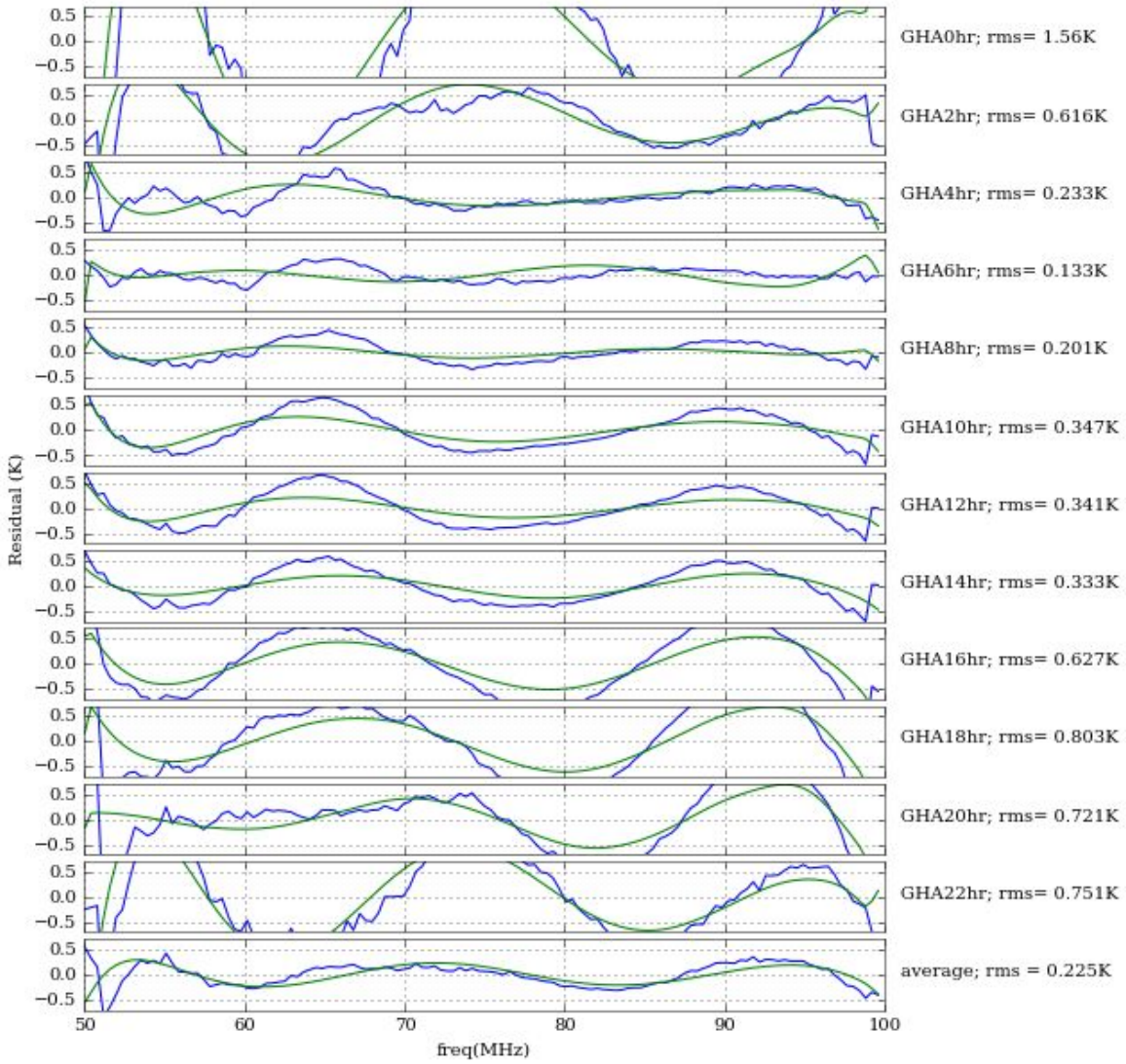


Fig5: Comparison of residues from the simulated feko (green) and collected (blue) lowband spectra for different Galactic Hour Angles.

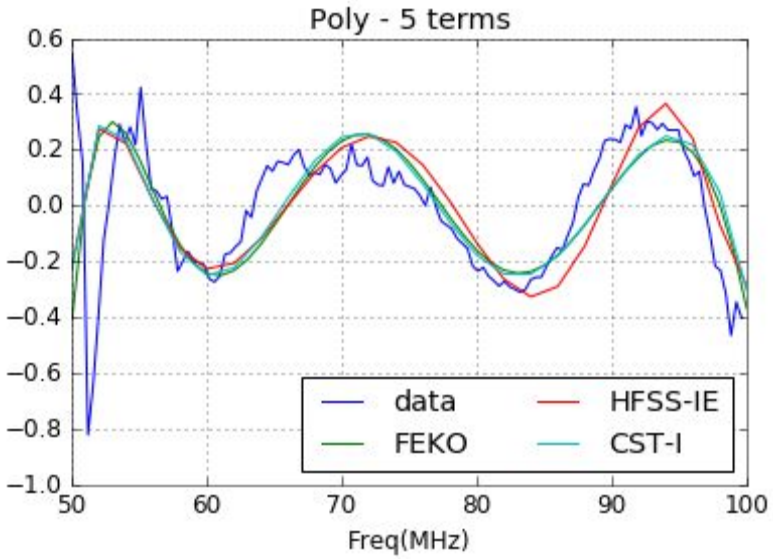
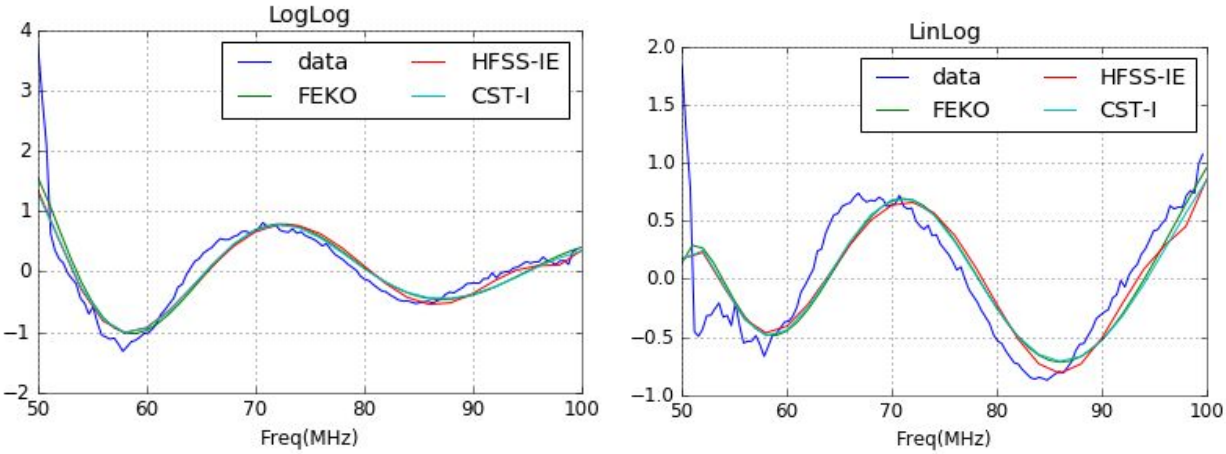


Fig6: The time averaged residues vs Freq for the different simulated spectra and the actual low-band data.

Effect of varying the no.of terms used for each of the models:

a.) 4 terms



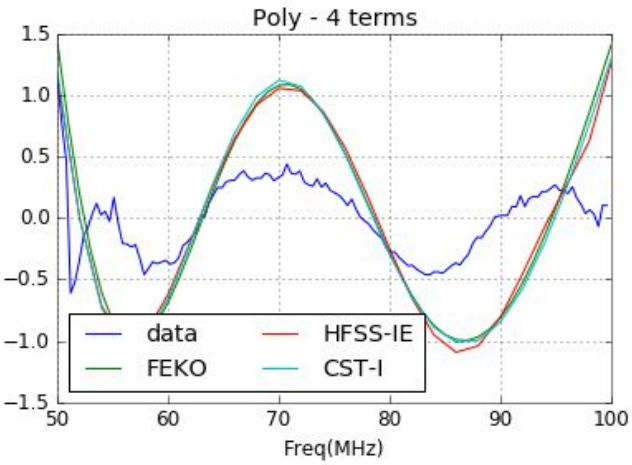


Fig 7: Residues of different time averaged simulated spectra and actual low-band data to 4 term a.) Loglog model, b.)Linlog model and c.) Poly model

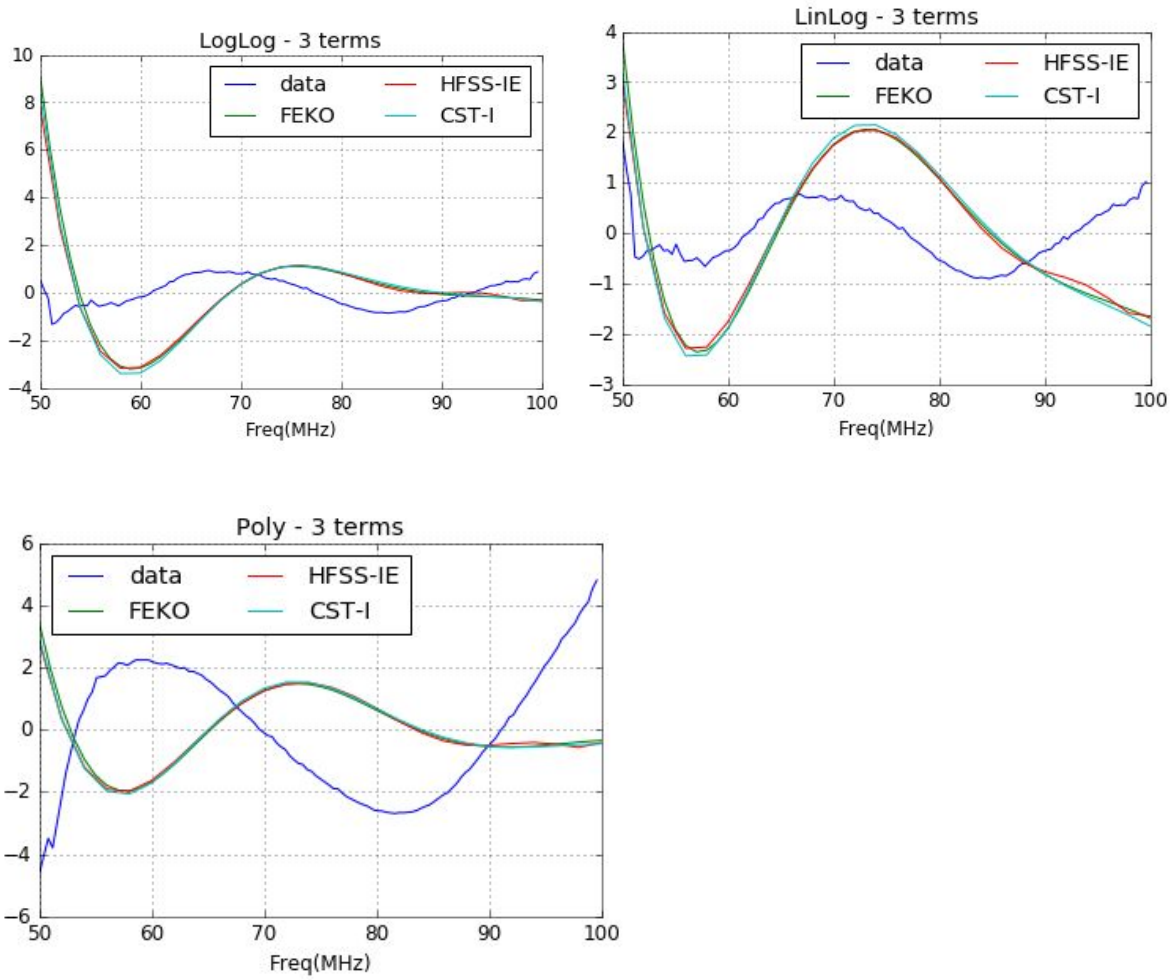


Fig 8: Residues of different time averaged simulated spectra and actual low-band data to 3 term a.) Loglog model, b.)Linlog model and c.) Poly model

Inferences:

- From Figures 1&3, Linlog and Loglog fit to the data don't show a broad flattening at GHA 20 hr around 60 MHz.
- The LinLog and LogLog fits to the simulation spectra captures the variations in the residues of the actual data at high galactic latitudes better.
- Some of the persistent features (over all GHAs) in the data remain in all the fits.
- For 5 terms, the poly fit does slightly better in terms of capturing the time averaged residues.
- On reducing the no.of terms to 4, the Linlog and Loglog still result in residues that match well. But in the case of the polynomial fitting, there is a large difference between the data residues and simulated spectra residues.
- The 3 terms does not model the data well in any of the cases.

Changing the Spectral index used in scaling the sky map from 408 MHz.

Seen in figure 7 and 8, the Simulated spectra don't capture the variation in the residues of the actual data. One idea to improve this is to use a different spectral index while scaling the HASlam map from 408 MHz. For the previous plots, a spectral index of -2.5 was used. In the following plots, a new curve “CST-I-2p6” is added. This corresponds to CST beam convolved with the Sky map that was scaled with -2.6.

a.) Linlog fit

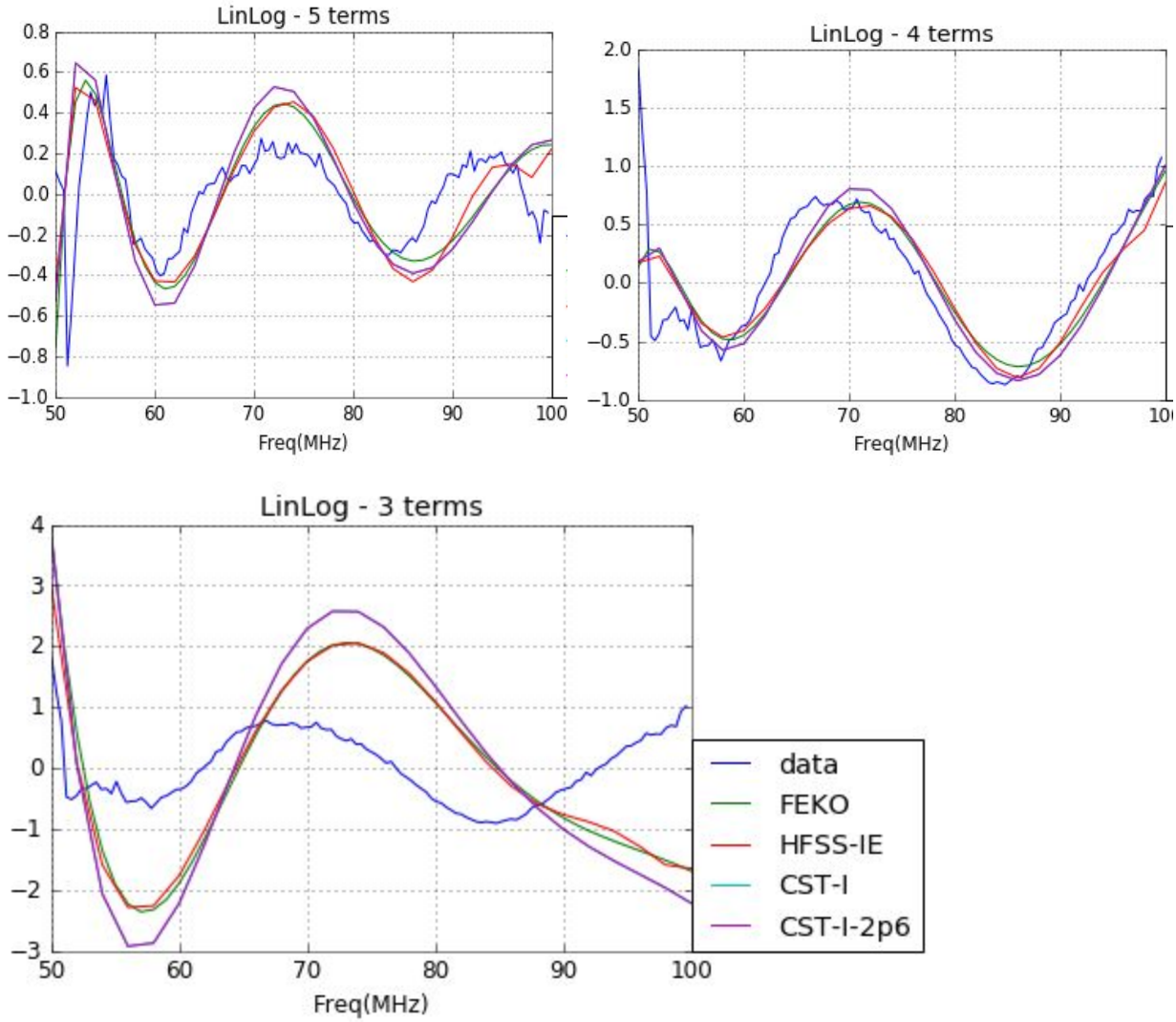


Fig 9: Residues of different time averaged simulated spectra and actual low-band data to a.) 5 term, b.) 4 term c.) 3 term Linlog model. The simulated spectra CST-I-2p6 was generated by using Haslam sky map that was scaled with -2.6 instead of -2.5.

b.) Loglog Fit

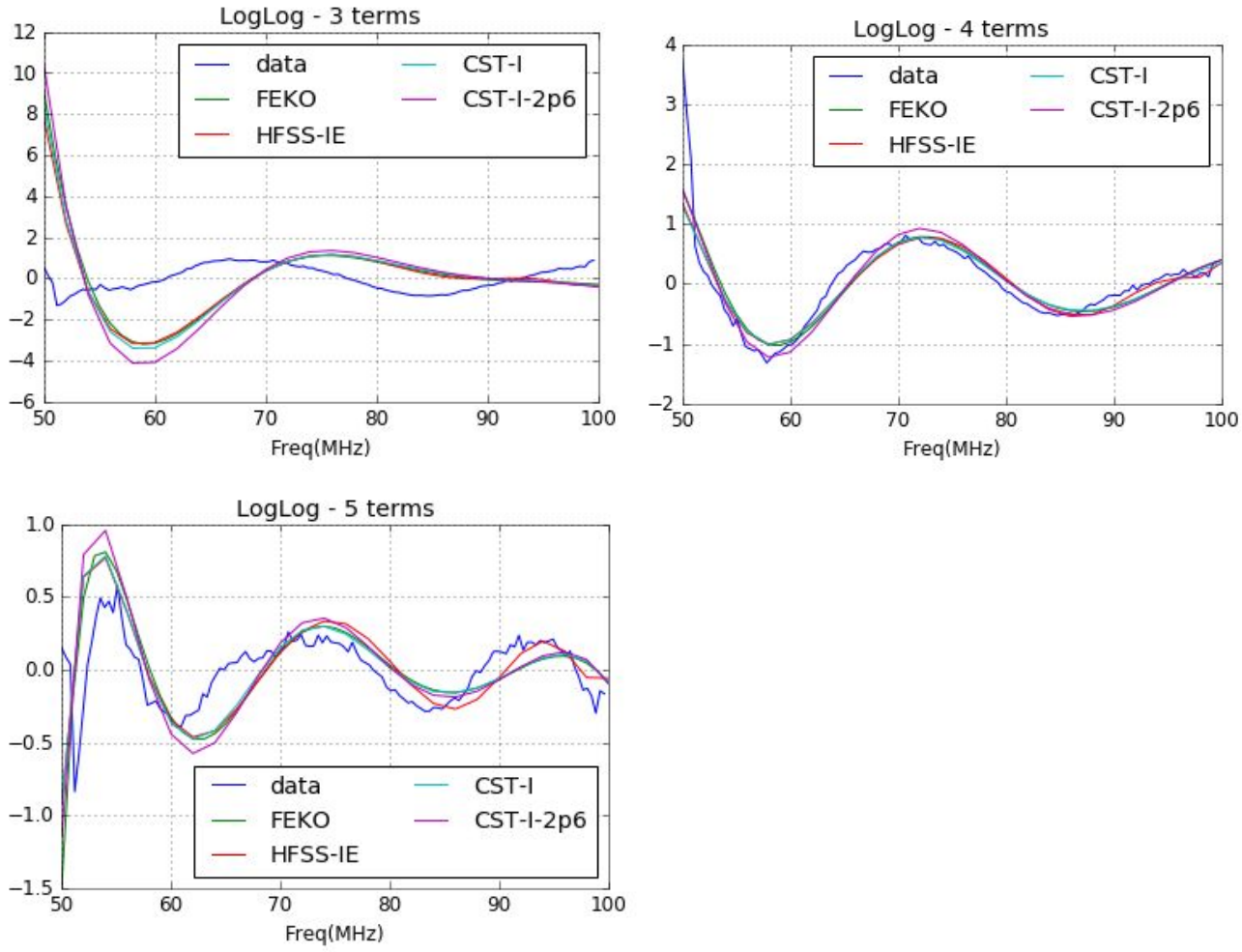


Fig 10: Residues of different time averaged simulated spectra and actual low-band data to a.) 5 term, b.) 4 term c.) 3 term Loglog model. The simulated spectra CST-I-2p6 was generated by using Haslam sky map that was scaled with -2.6 instead of -2.5.

c.) Polynomial fit

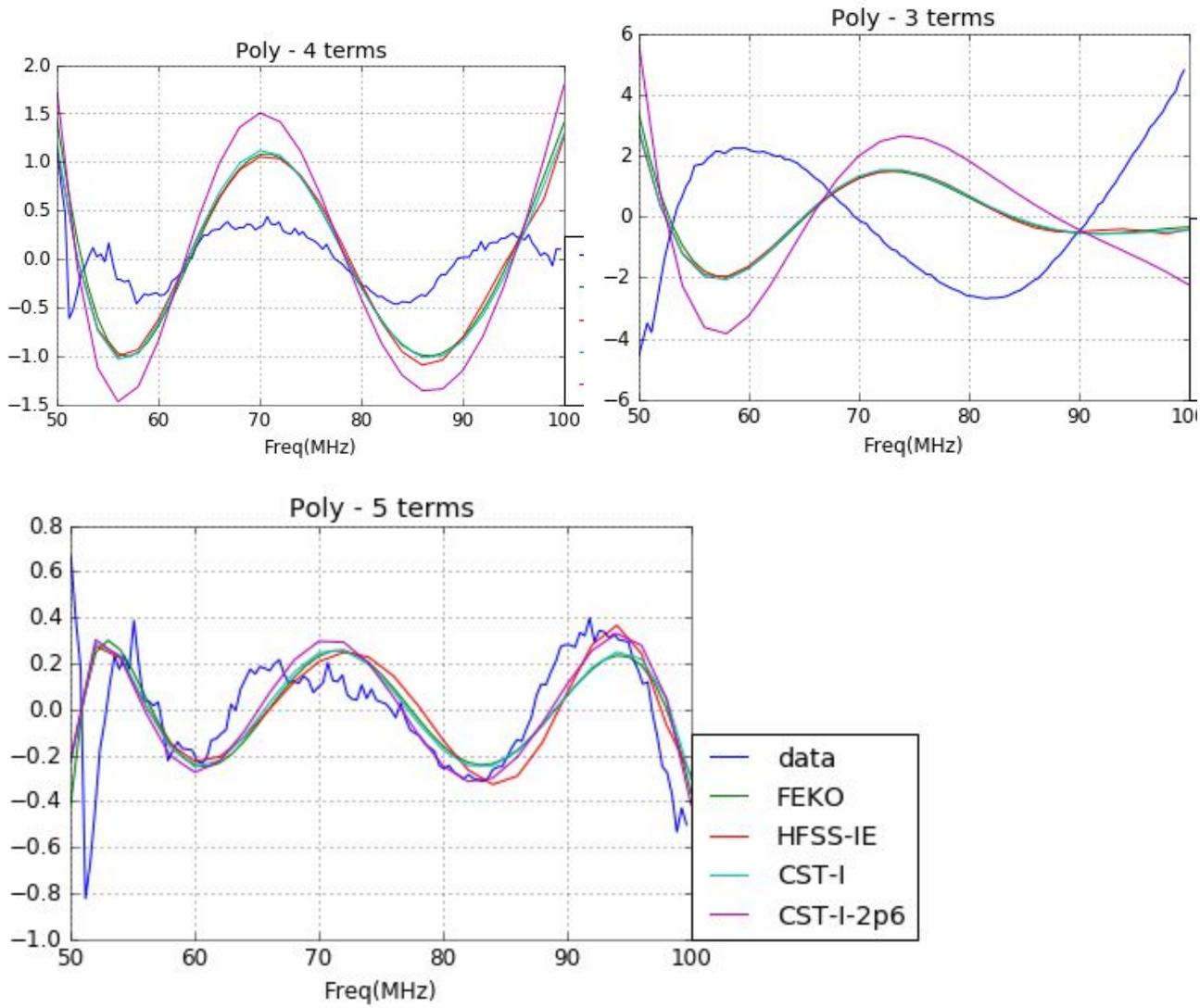


Fig 10: Residues of different time averaged simulated spectra and actual low-band data to a.) 5 term, b.) 4 term c.) 3 term polynomial model. The simulated spectra CST-I-2p6 was generated by using Haslam sky map that was scaled with -2.6 instead of -2.5.

Remarks

- The different scaling didnt change the residues much for the 4 and 5 term fits of any of the modelling cases
- For the 3 terms it only it caused more deviation from the actual residues of the data.

To explain the discrepancy between the time averaged residues obtained from the data and simulated spectra while using a lower order fit as seen in figures 7 and 8(Linlog or loglog or Poly); we investigate the residues over time (over GHA) as shown below:

Loglog fit - 3 terms

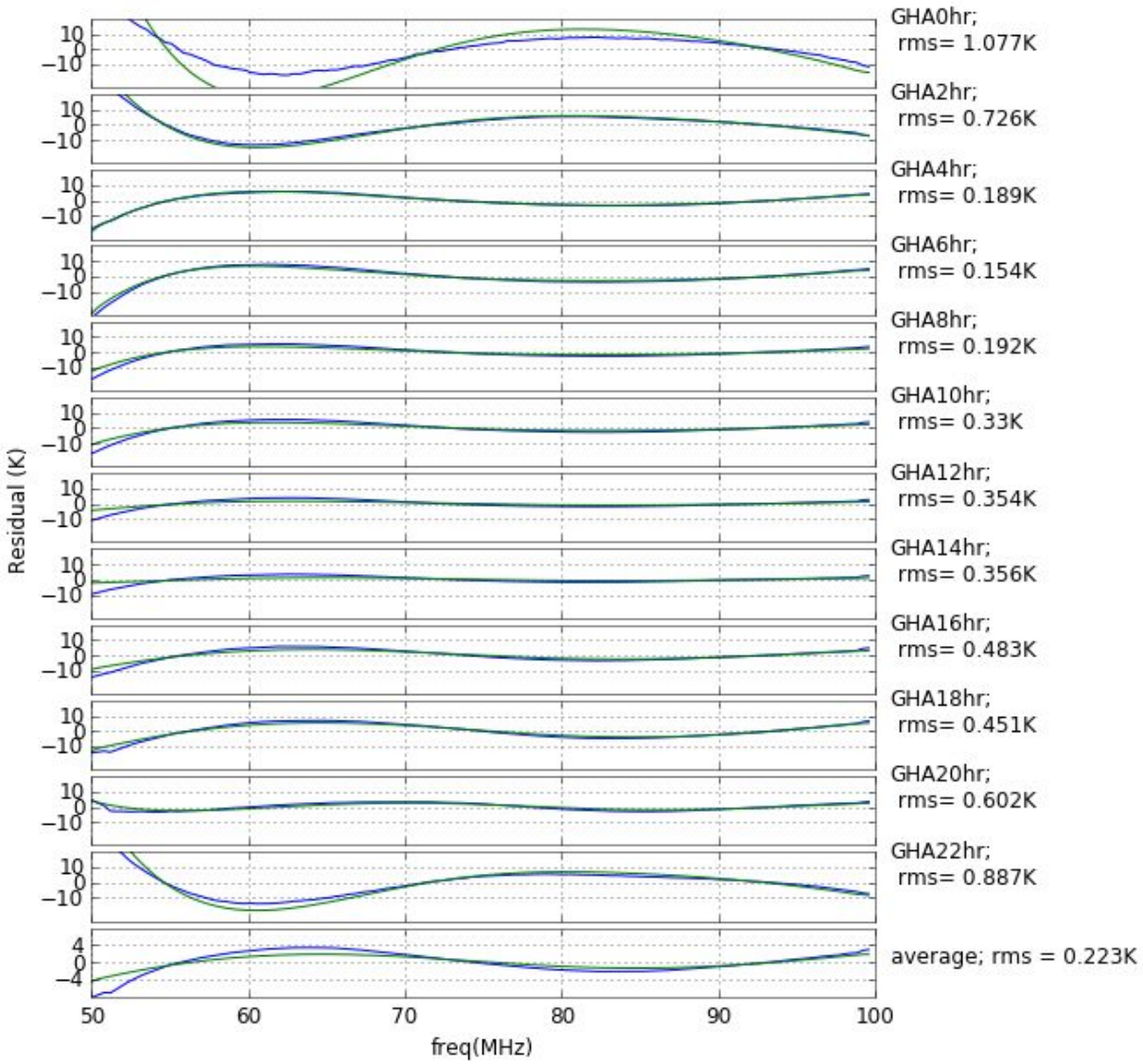


Fig11: Comparison of residues after fitting a 3 term loglog fit to the simulated feko (green) and collected (blue) lowband spectra for different GHAs. The maximum deviation between the two residues is seen in bins- GHA 0 & GHA22

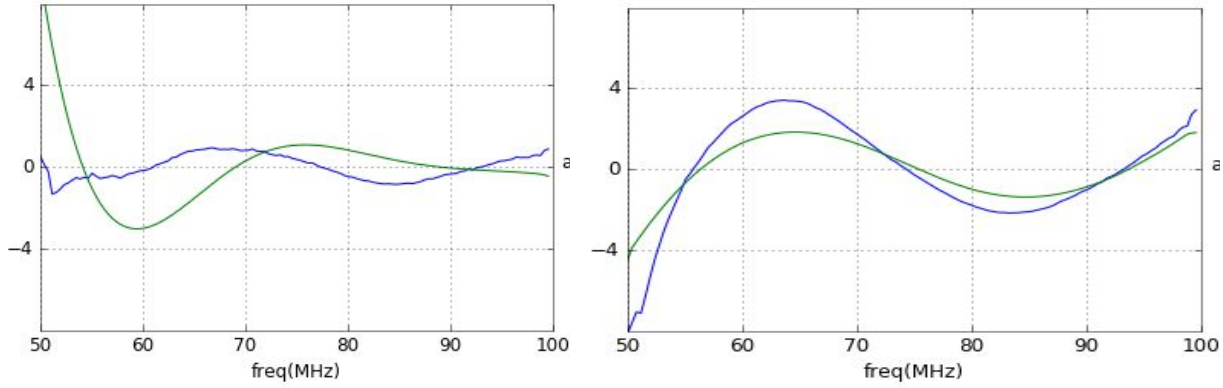


Fig 12: Time averaged residues of the simulated spectra and actual low-band data to 3 term loglog fit (left) using all the residues (right): excluding the residues in GHA bins 0 & 22

Linlog fit - 3 terms

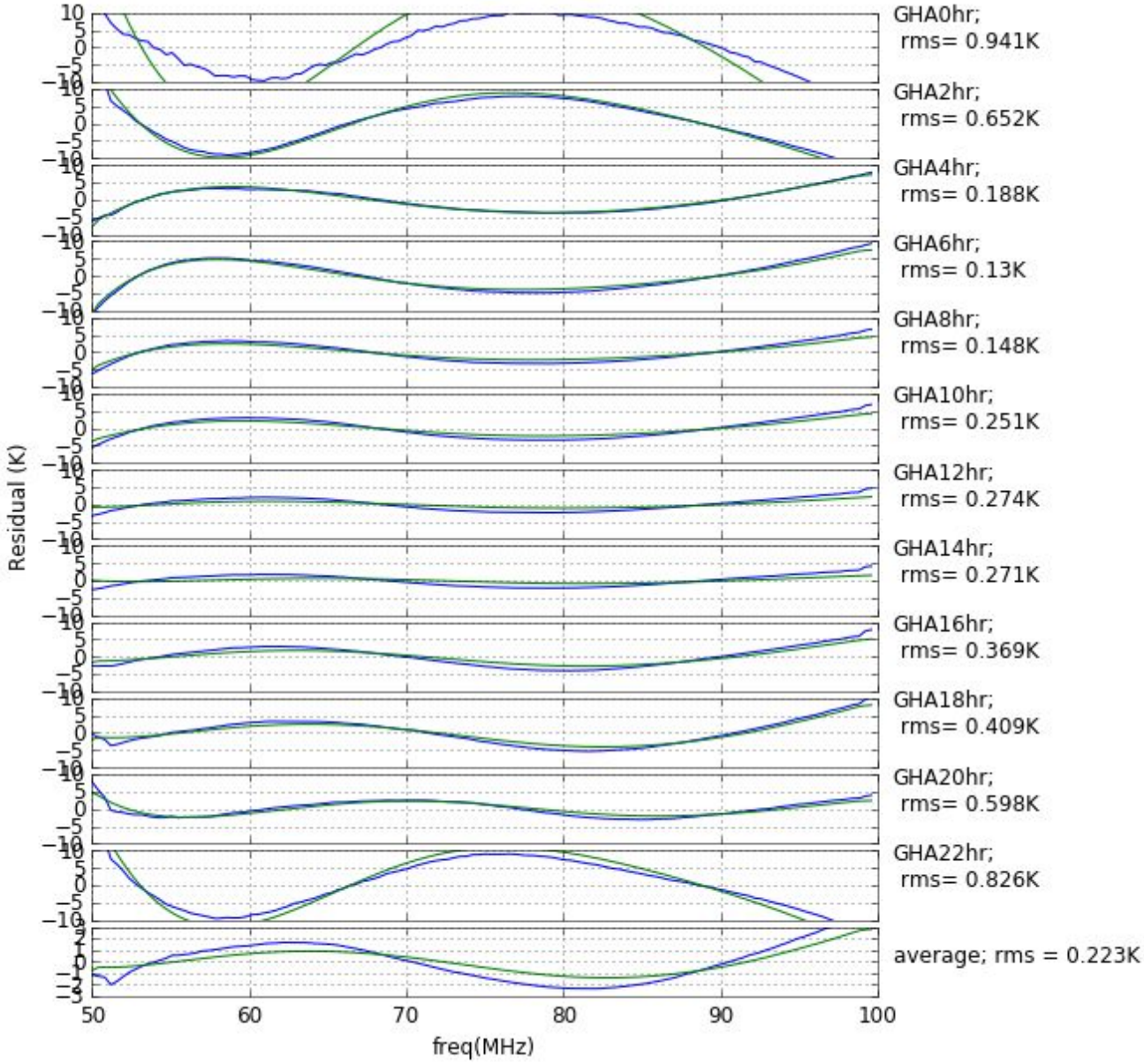


Fig13: Comparison of residues after fitting a 3 term linlog fit to the simulated feko (green) and collected (blue) lowband spectra for different GHAs. The maximum deviation between the two residues is seen in bins- GHA 0 & GHA22

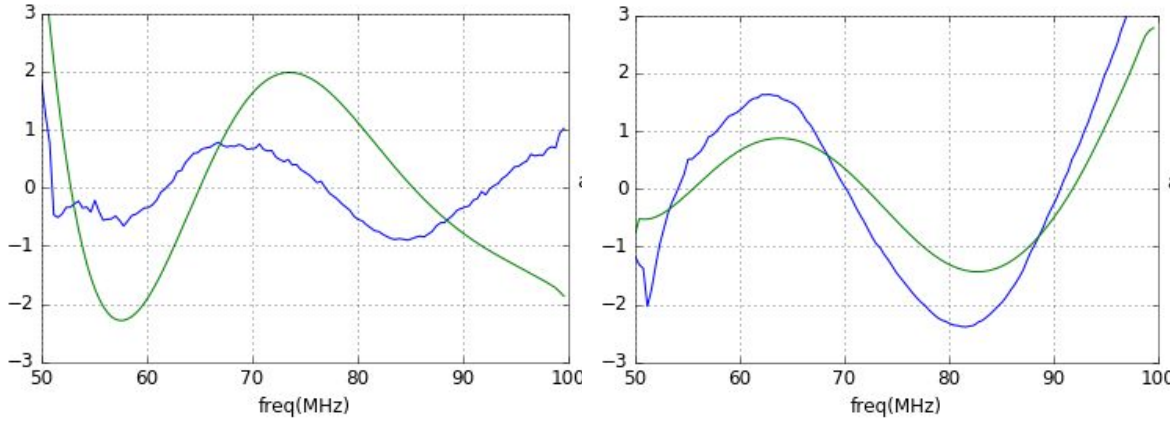


Fig 14: Time averaged residues of the simulated spectra and actual low-band data to 3 term linlog fit (left) using all the residues (right): excluding the residues in GHA bins 0 & 22

Polynomial fit - 3 term

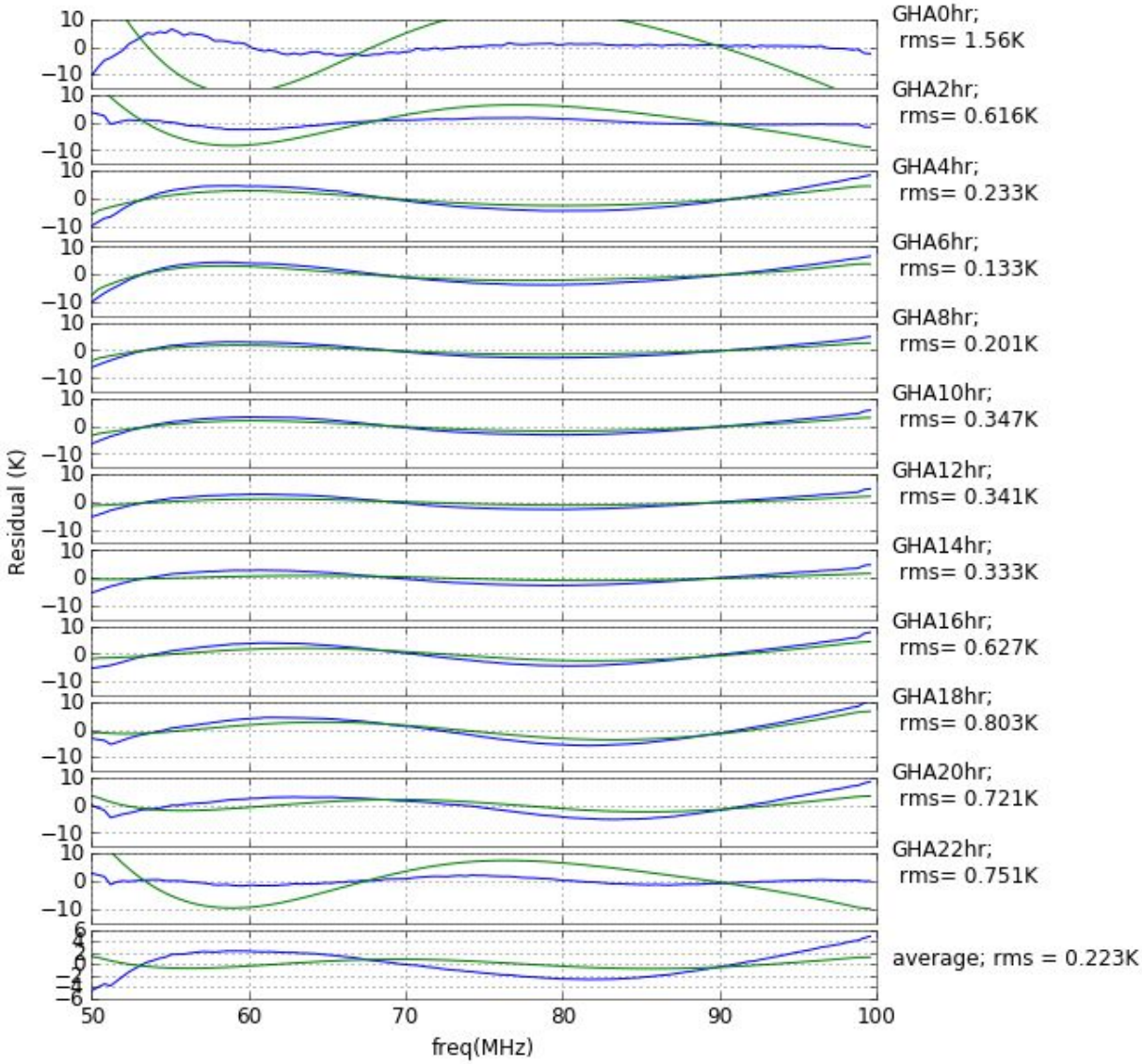


Fig15: Comparison of residues after fitting a 3 term polynomial fit to the simulated feko (green) and collected (blue) lowband spectra for different GHAs. The maximum deviation between the two residues is seen in - GHA 0,GHA2 & GHA22

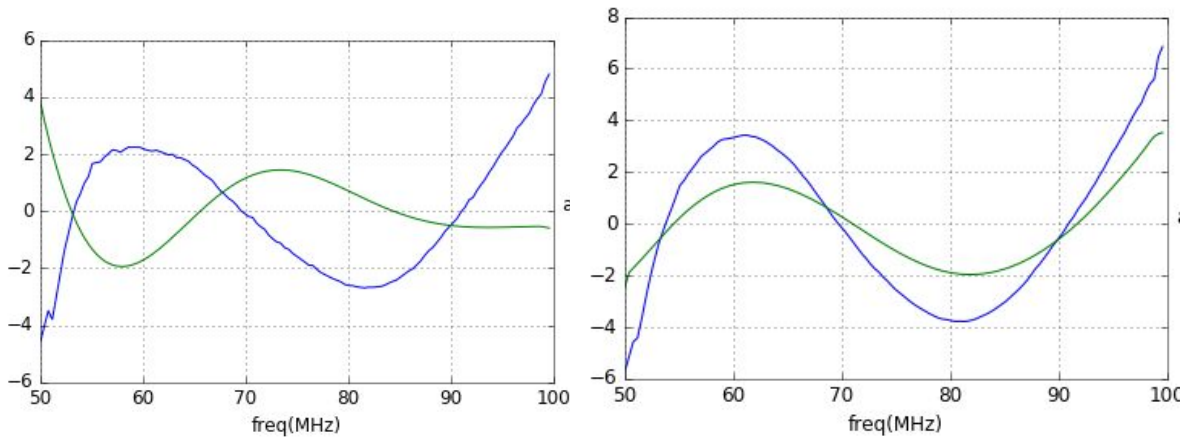


Fig 16: Time averaged residues of the simulated spectra and actual low-band data to 3 term polynomial fit (left) using all the residues (right): excluding the residues in GHA bins 0,2 & 22

Inferences

- On looking at the residues of the simulated and actual data over time, we can see better agreement between the two even for low order fits (3 terms).
- It was the discrepancy when the galactic center is the beam that causes the discrepancy in the averaged residues.
- By omitting those residues in the average residue calculation, we get between agreement
- The sky model I used was Haslam sky map scaled with -2.5 spectral index. But from Mozdzen et al 2018, we saw that for 40-100 MHz, at LST =18hr, the spectral index is about -2.46. Could that explain the difference? Because we see Figures 11,13,15 that at GHA 0 the simulated residues is higher in temperature.

In all the above plots that show the residues varying over GHA; the simulated spectra used was that given by Alan. Because the residues generated from my simulation spectra doesn't agree with that of the data at certain GHAs even i use a 5 term fit as shown below:

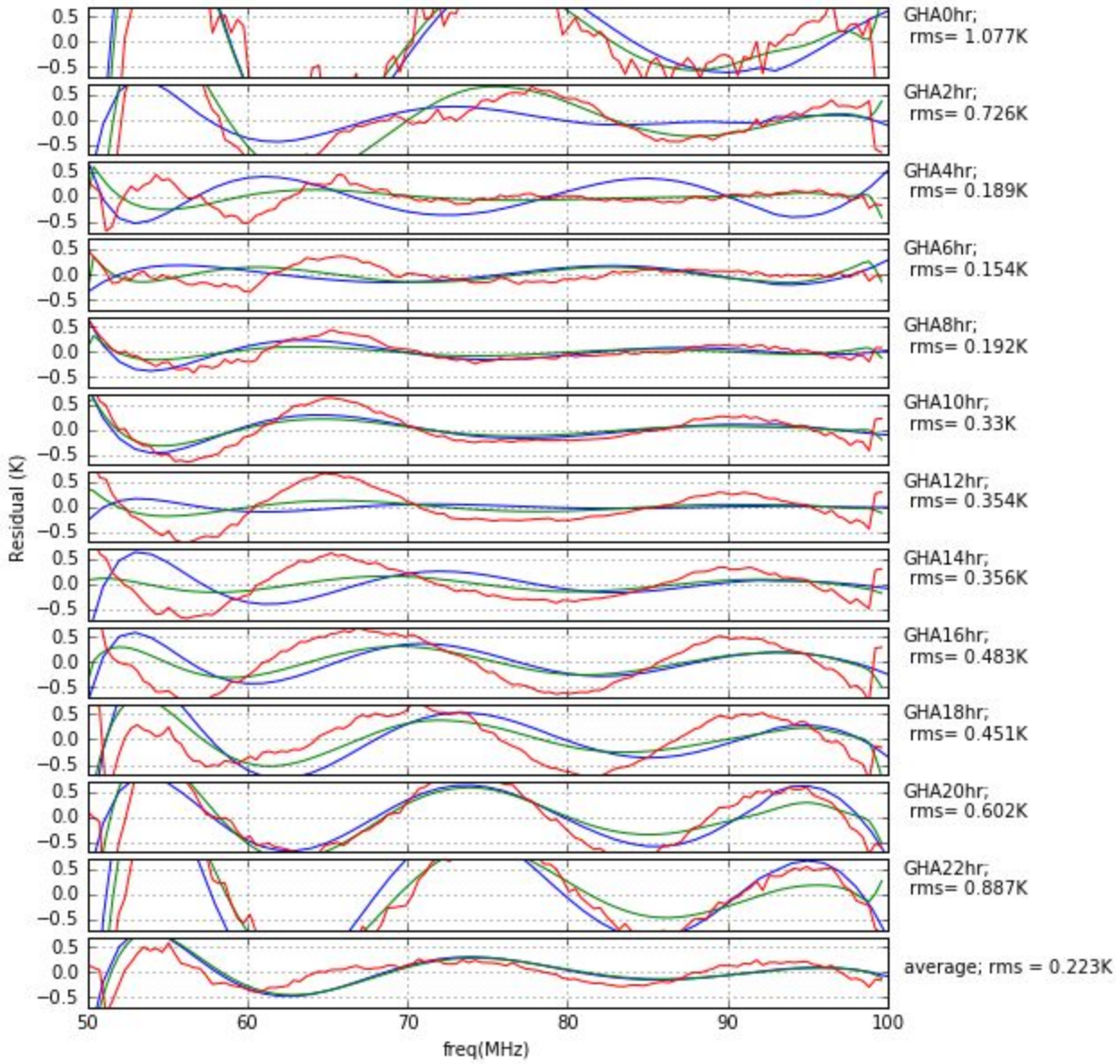


Fig17: Comparison of residues after fitting a 5 term loglog fit to the simulated feko Nive (Blue), simulated feko Alan (green) and collected (red) lowband spectra for different GHAs.

But the time averaged residues from my simulated spectra agree well with data and Alan's simulated spectra shown in the last subplot in fig 17 and in the plots in the first section.

To understand the difference better, I plot the actual spectra and data (not residues) over GHA for few frequency points as shown below:

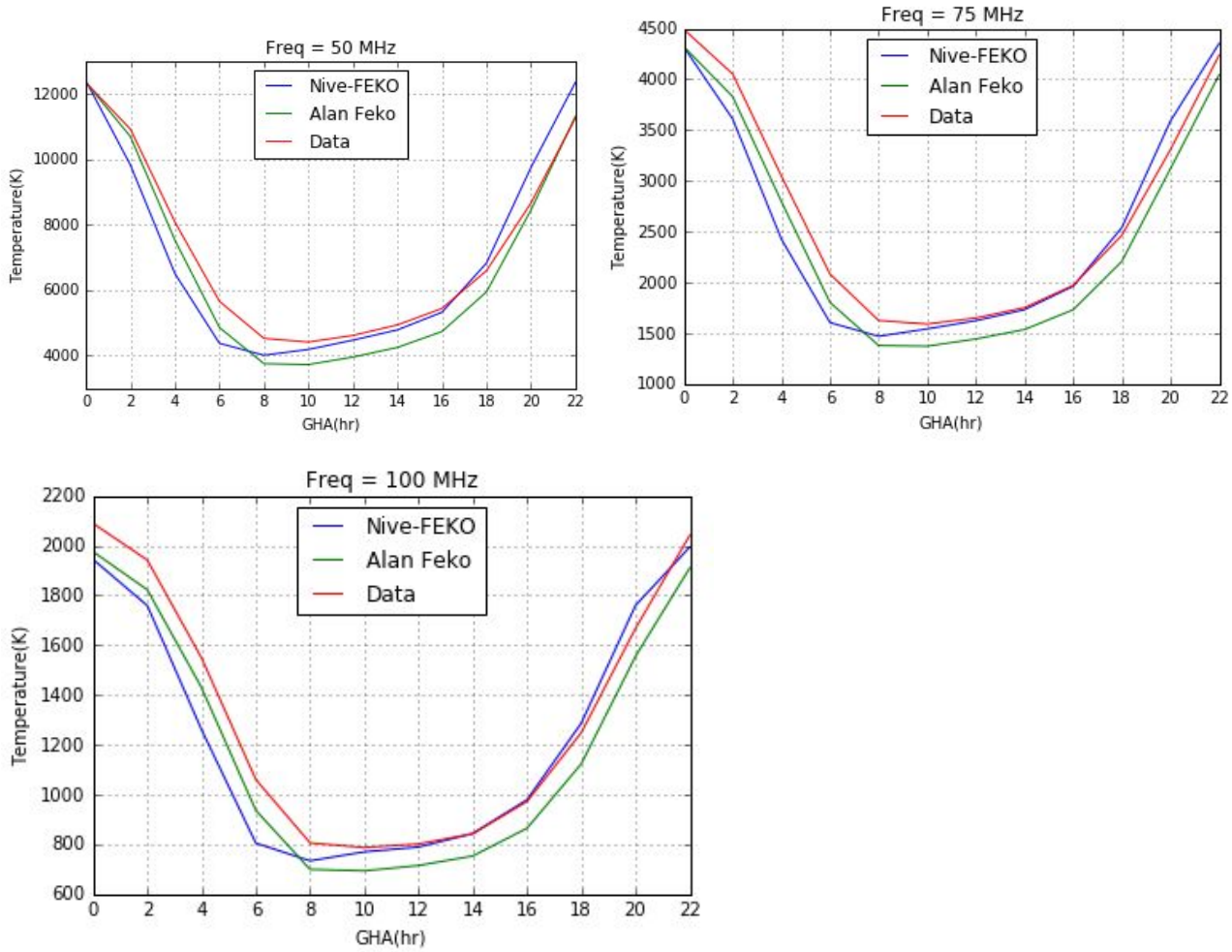


Fig18: Simulated spectra (Mine & Alan's) and actual data versus GHA at a.) 50 MHz, b.) 75 MHz and c.)100 MHz

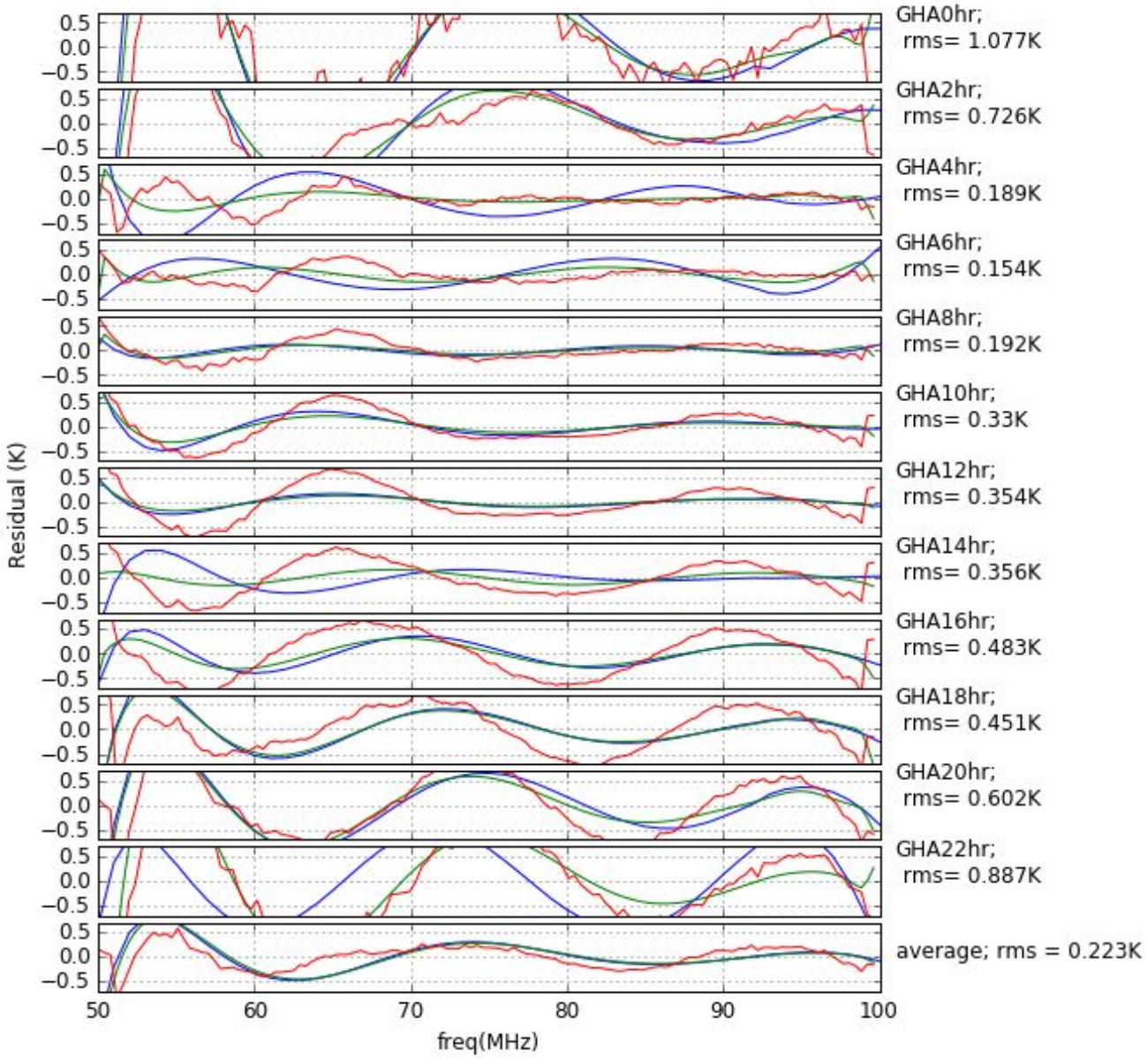


Fig19: Comparison of residues after fitting a 5 term loglog fit to the simulated feko Nive (Blue), simulated feko Alan (green) and collected (red) lowband spectra for different GHAs. This is different from fig 17 in terms of the averaging done for the 2 hour GHA bins. The averaging is centered around the numbers indicated instead of beginning at it

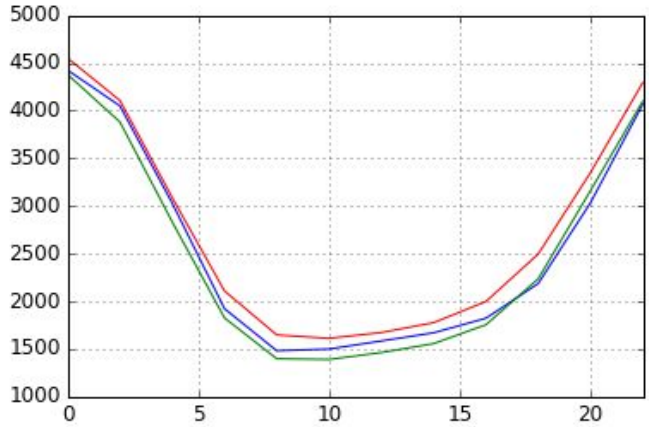


Fig20: Simulated spectra (Mine & Alan's) and actual data versus GHA at 75 MHz

After a discussion with Alan, we realised that the soil conductivity value used in Memo 118 or in Alan's FEKO model was 1e-3S/m instead of 2e-2 S/m.
So I re ran FEKO simulation with the same sigma value and below are the plots

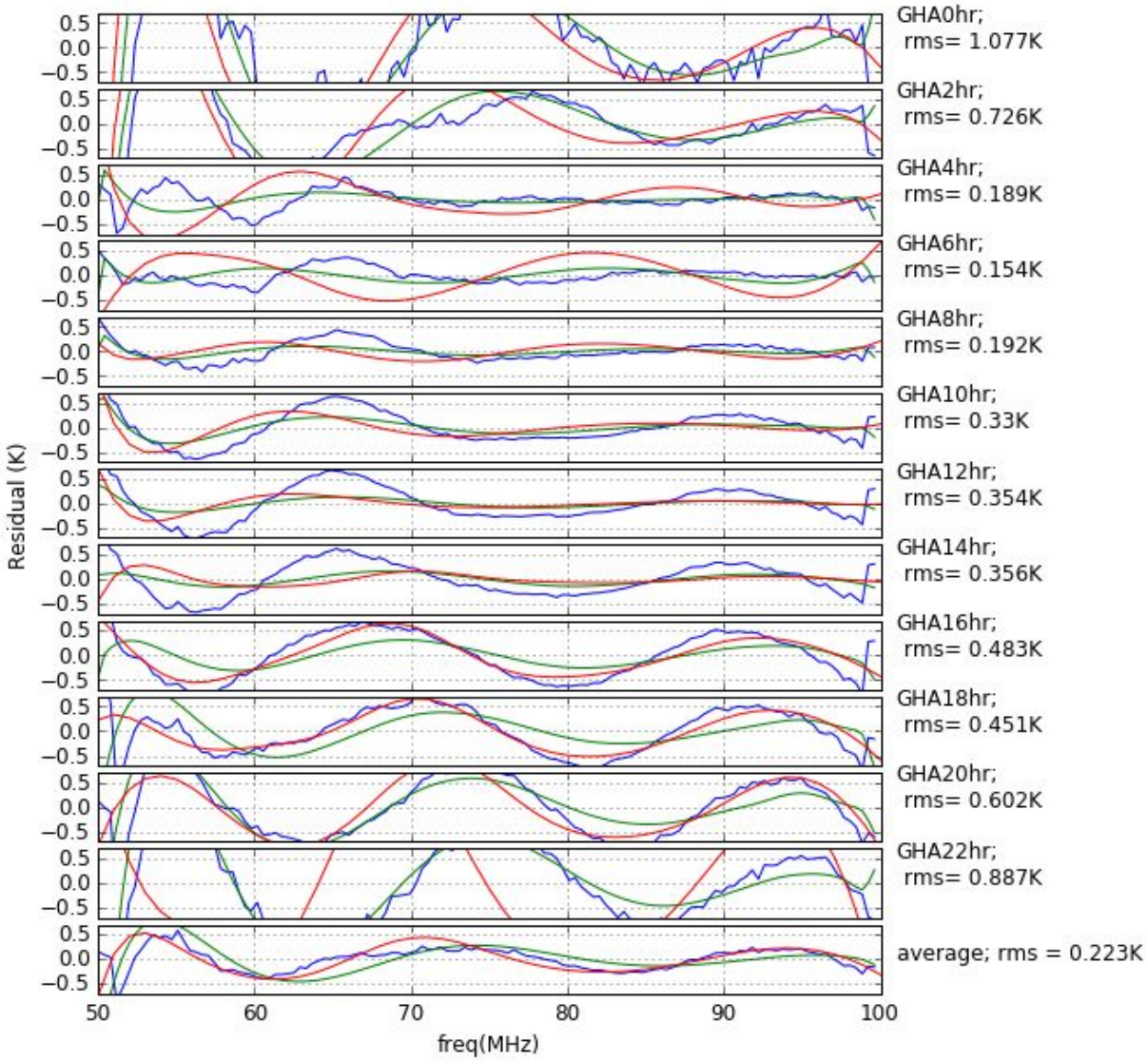


Fig21: Comparison of residues after fitting a 5 term loglog fit to the simulated feko Nive (red), simulated feko Alan (green) and collected (blue) lowband spectra for different GHAs. The averaging is centered around the numbers indicated instead of beginning at it

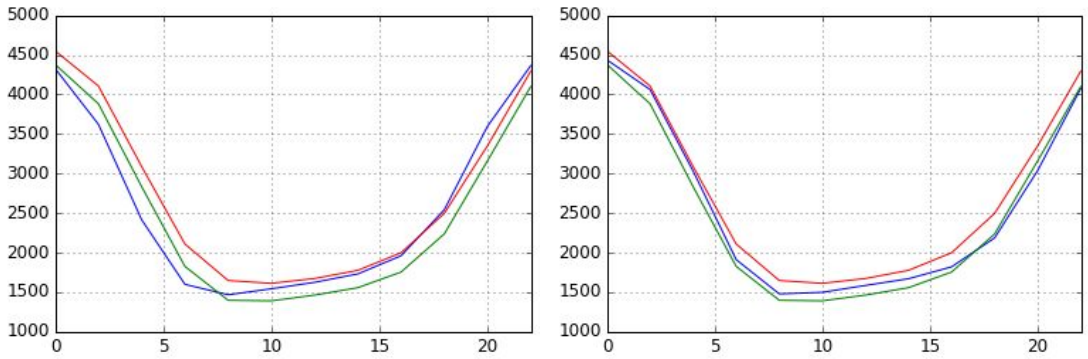


Fig22: Simulated spectra (Mine & Alan's) and actual data versus GHA at 75 MHz. Left : Averaging for GHA0hr begins at 278 deg longitude. Right: Averaging for GHA0hr begins at 293 deg longitude.

Inferences:

- On looking at the last subplot in figures 19 and 21, it is clear that Alan's FEKO model also used sigma = 2e-2 S/m
- The discrepancies in the residues over time between the mine and Alan's could be just due to difference in averaging or data selection issues.
- The differences were reduced when I began averaging data in my GHA0 bin from 293 deg instead of 278 deg

Different soil properties

To assert that the EDGES soil properties included in the beam simulations capture the variation in the actual data accurately, additional simulations were carried out using different types of soil. The beam solutions from these additional models were used to generate more simulated spectra and they were compared with actual data.

The different standard soil properties were taken from the following website:
https://pe2bz.philpem.me.uk/Comm/-%20Antenna/Info-905-Misc/soildiel.htm#magdry

Soil Type	**Relative permittivity**	**conductivity/ tan delta**
EDGES	3.5	0.02 S/m
Sandy soil (dry)	2.55	$\delta = 0.016$
Loamy Soil (dry)	2.48	$\delta = 0.014$
Clay soil (dry)	2.44	$\delta = 0.04$

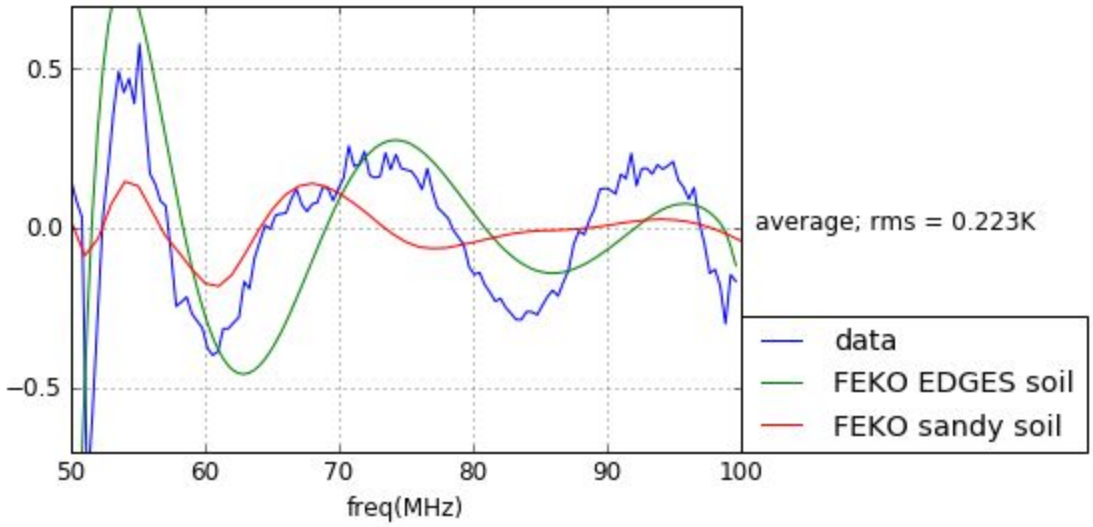


Fig23: Time averaged residues of the simulated spectra with edges soil (green), sandy soil (red) and actual low-band data to 5 term loglog using the residues over all GHAs.

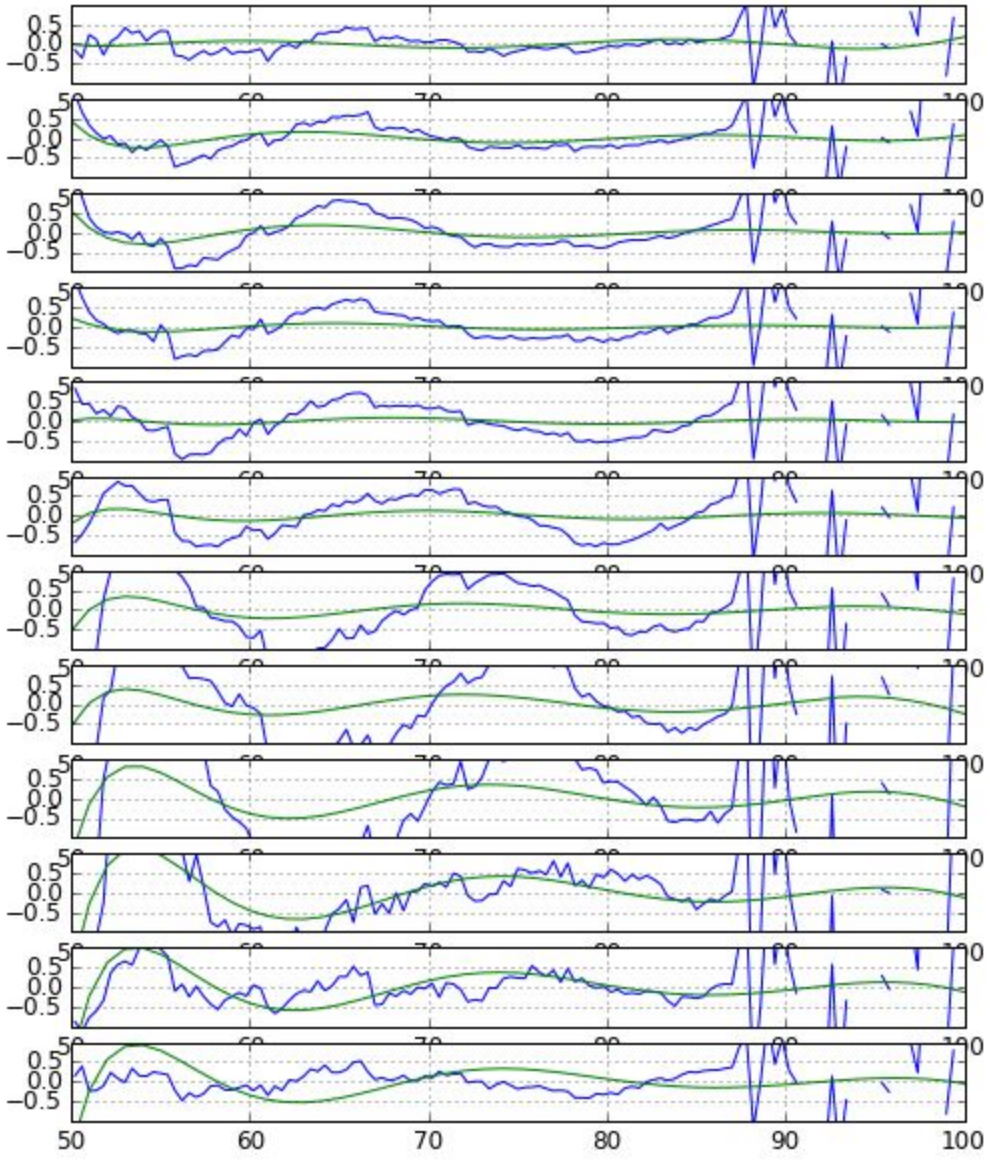


Fig 24: Comparison of residues after fitting a 5 term loglog fit to the simulated feko Nive (green), and receiver calibrated data but binned and rfi exercised by me (Blue) lowband spectra for different LSTs.

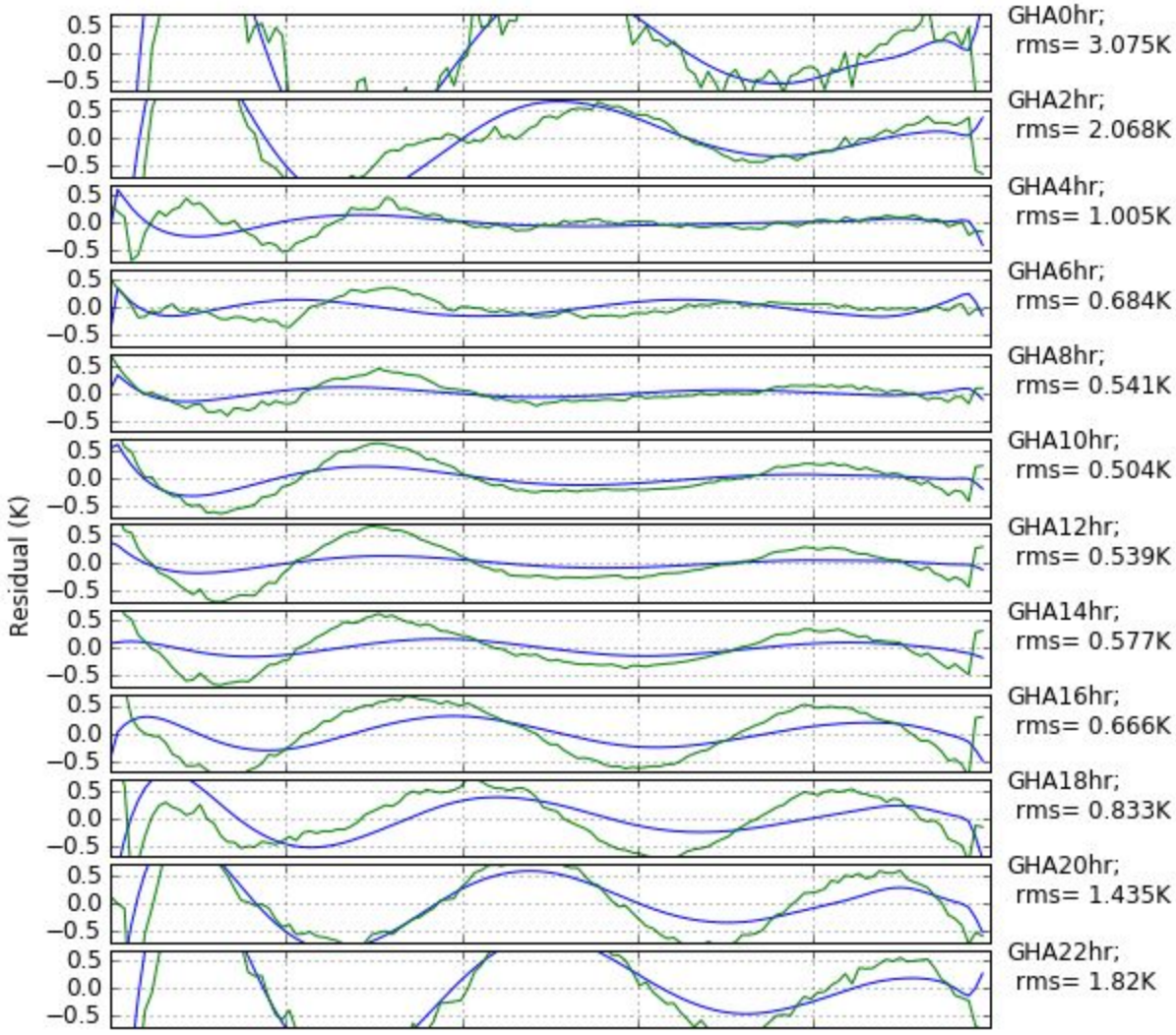


Fig 25: Comparison of residues after fitting a 5 term loglog fit to the simulated feko Alan (Blue), and processed data by Alan(Blue) lowband spectra for different GHAs.

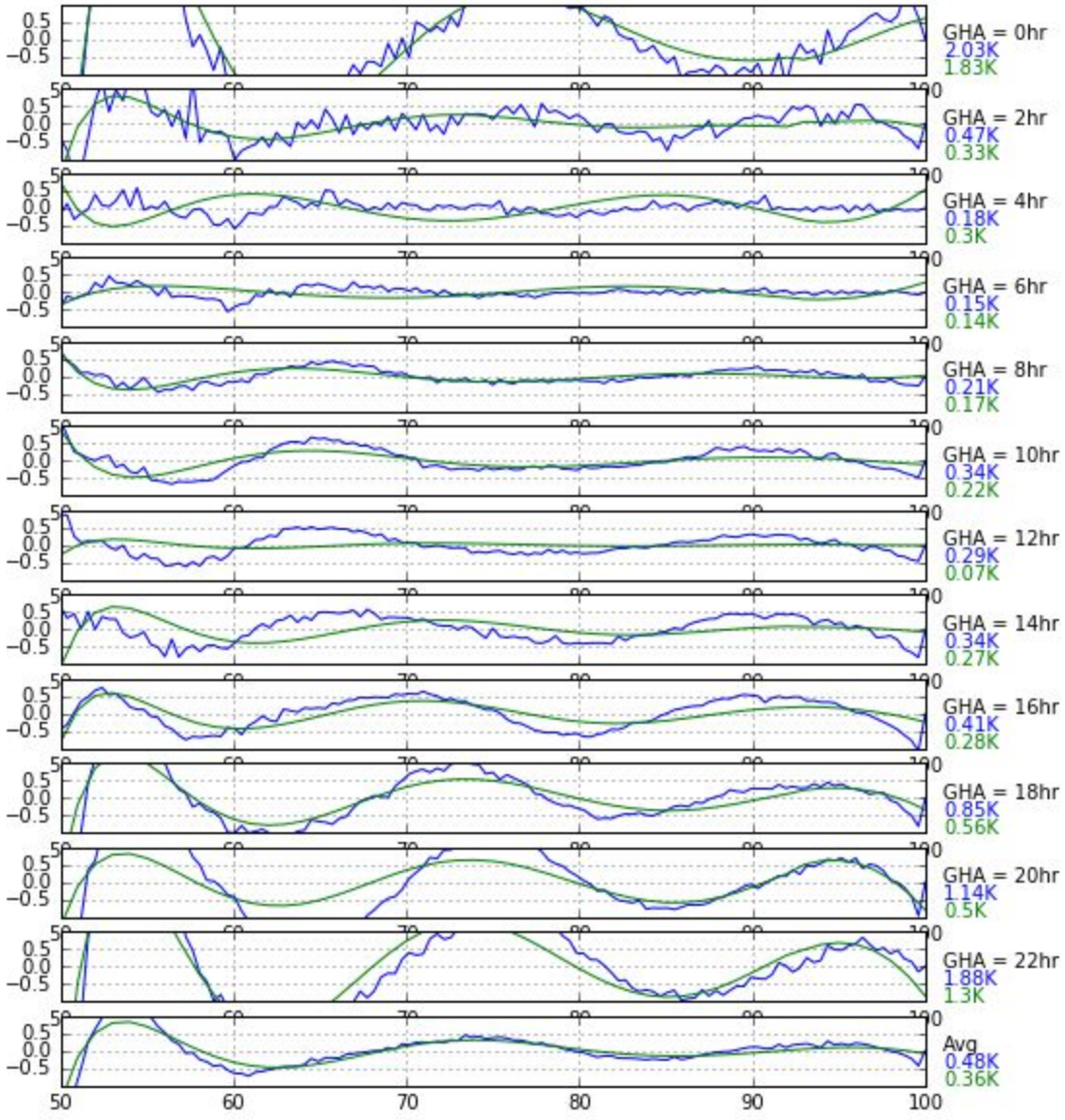


Fig 26: Comparison of residues after fitting a 5 term Loglog fit to the simulated feko (Green), and processed old ground data (Blue) for different GHAs.

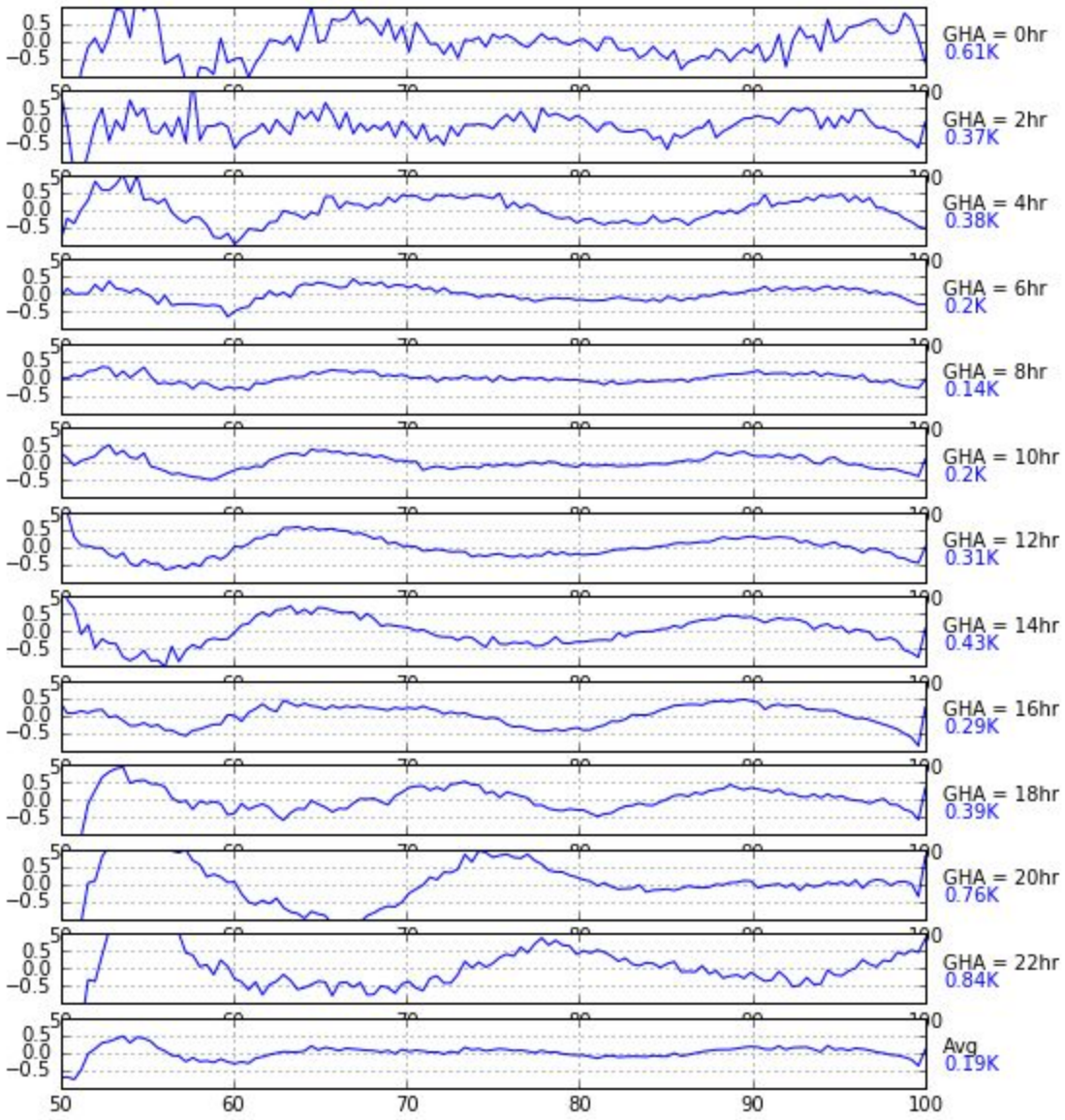


Fig 26b: Difference of the residues after fitting a 5 term Loglog fit to the simulated spectra and processed old ground data for different GHAs.

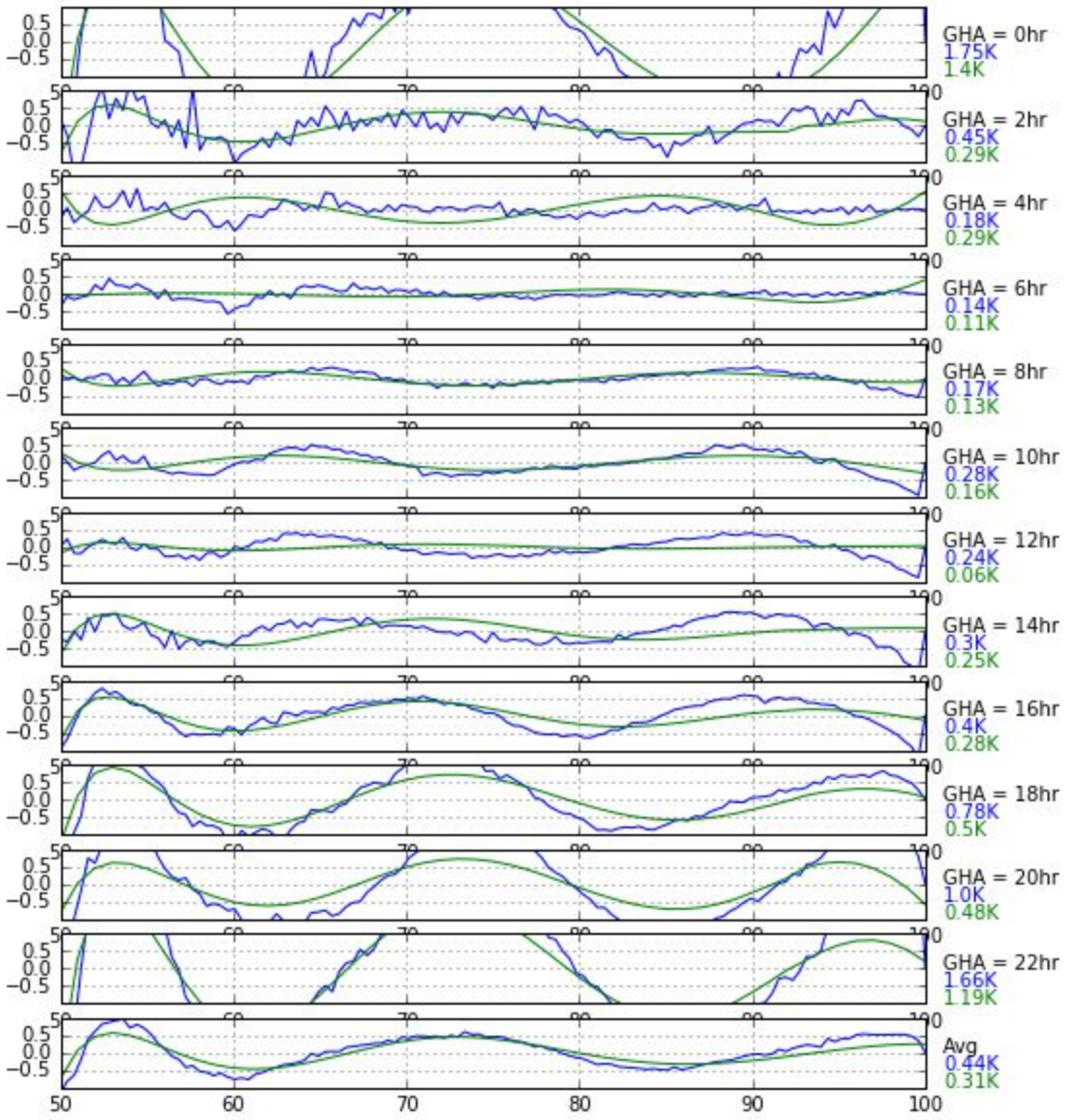


Fig 27: Comparison of residues after fitting a 5 term Linlog fit to the simulated feko (Green), and processed old ground data (Blue) for different GHAs.

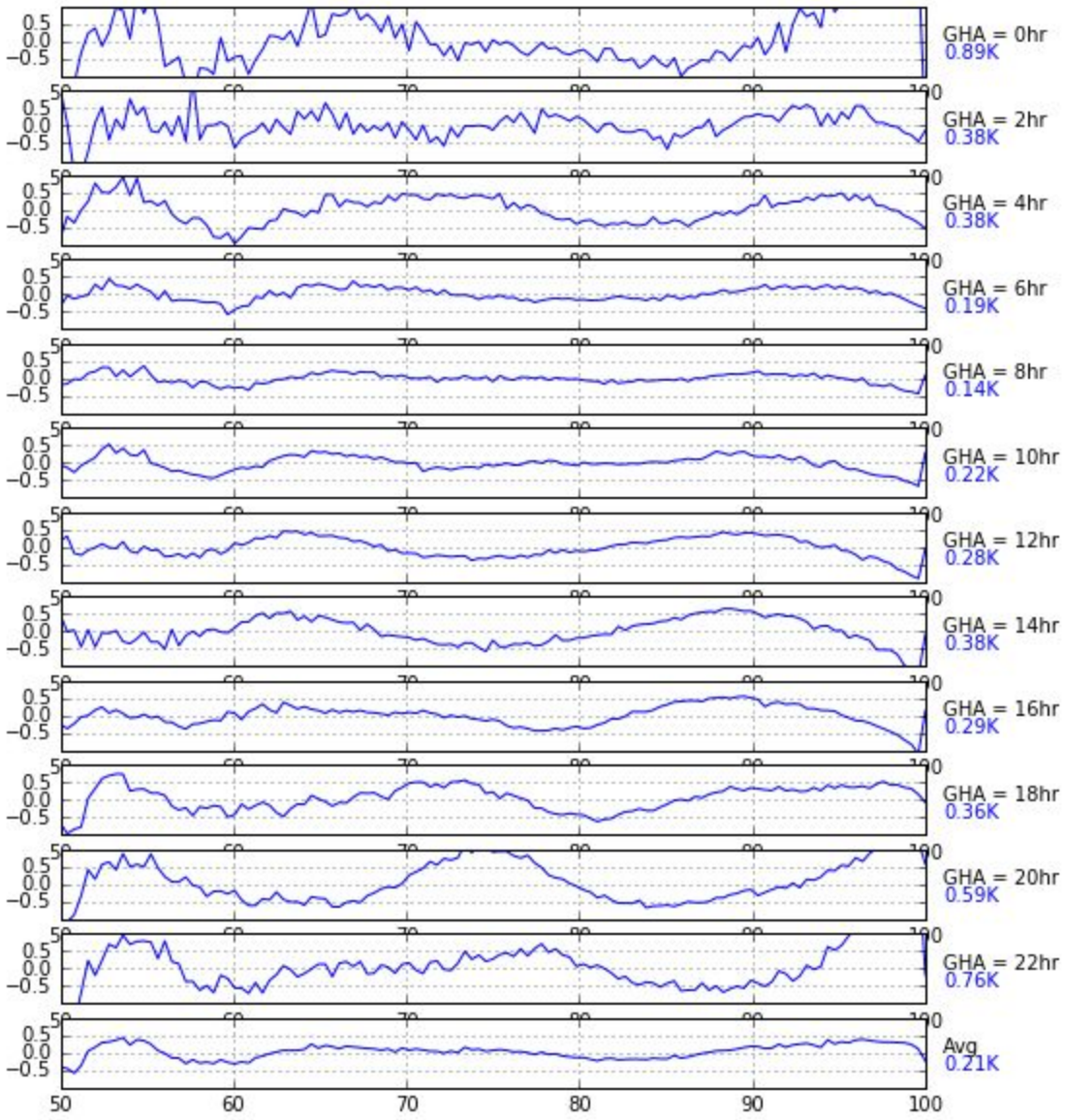


Fig 27b: Difference of the residues after fitting a 5 term Linlog fit to the simulated spectra and processed old ground data for different GHAs.

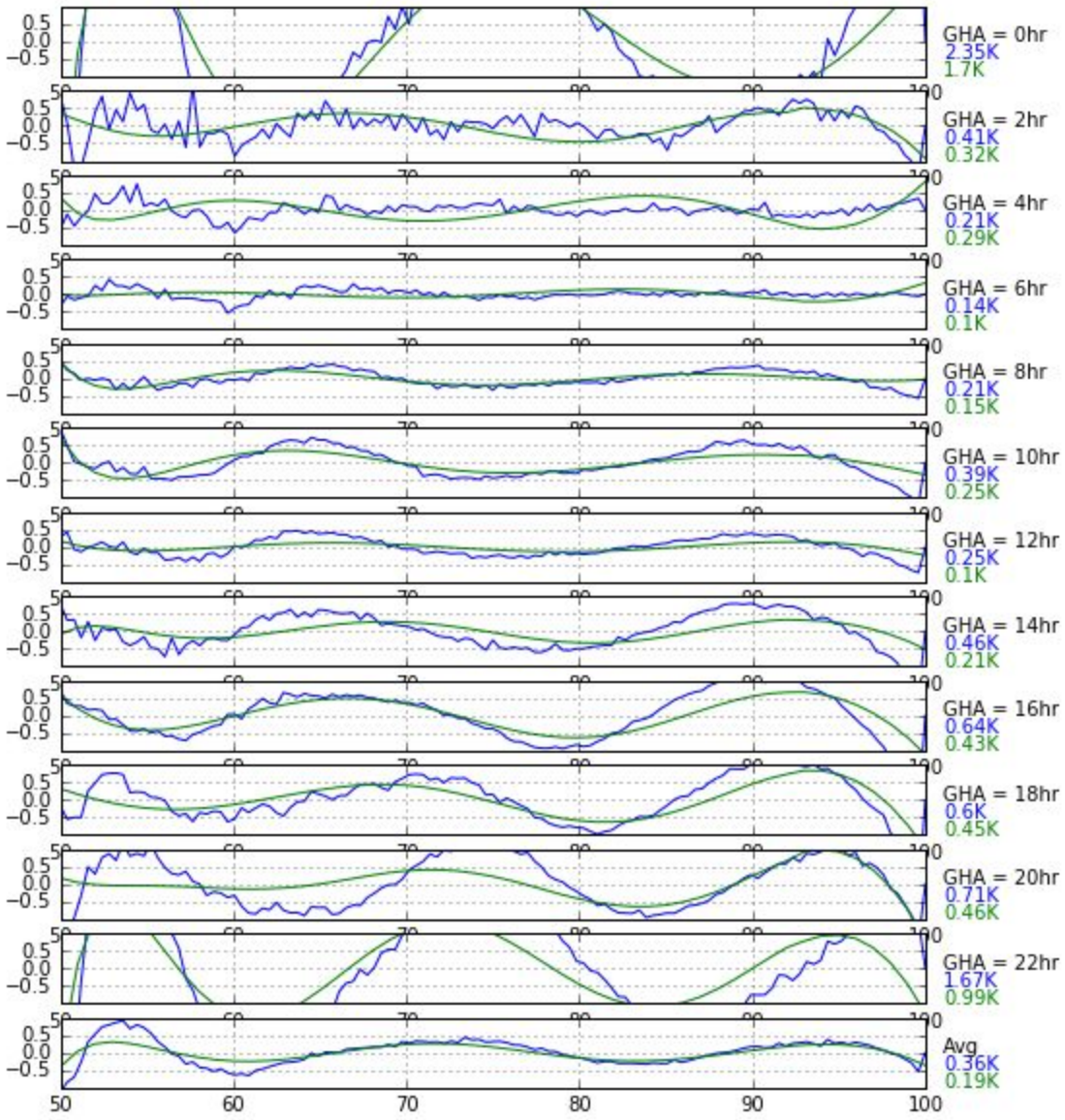


Fig 28: Comparison of residues after fitting a 5 term polynomial fit to the simulated feko (Green), and processed old ground data (Blue) for different GHAs

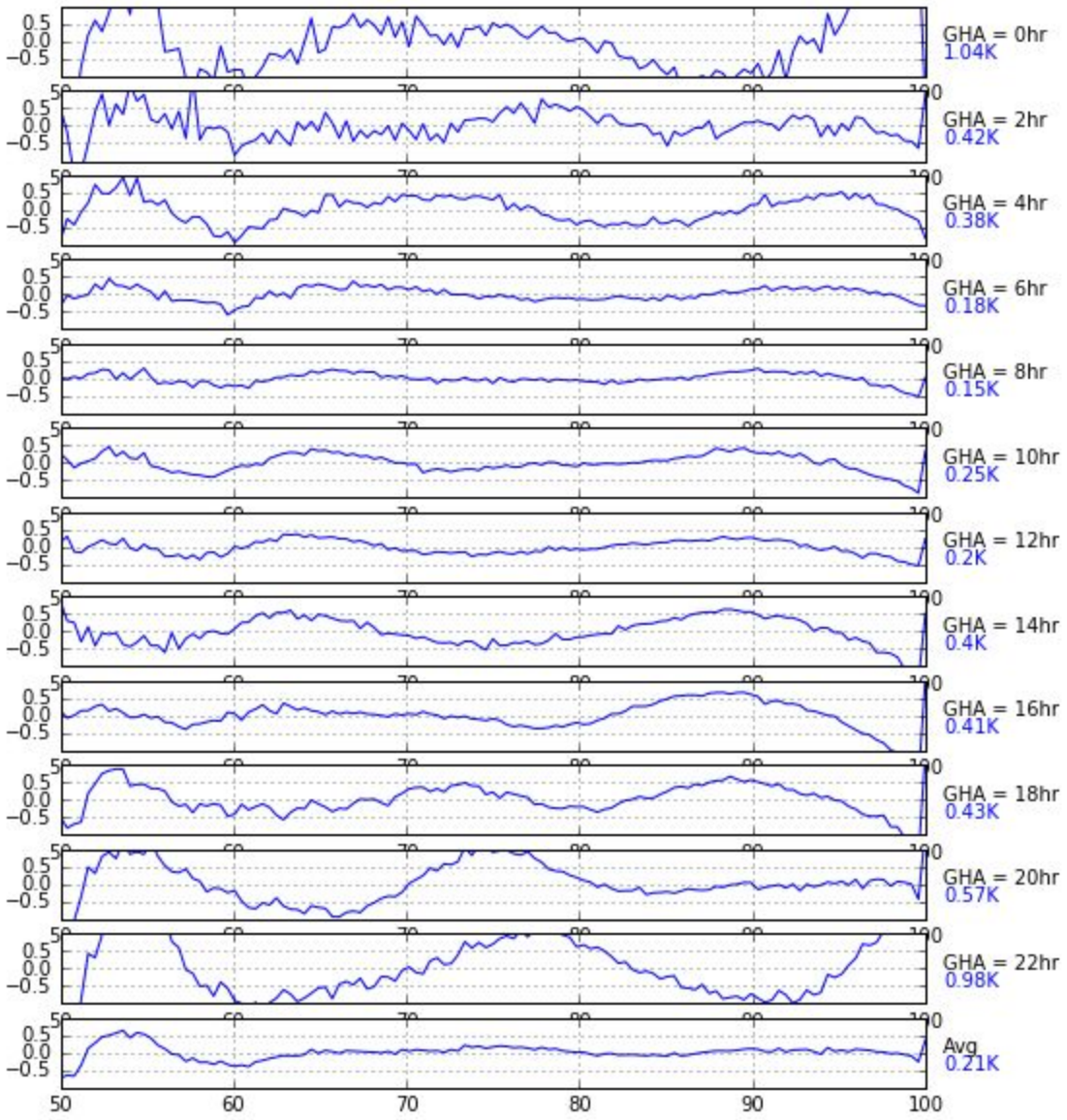
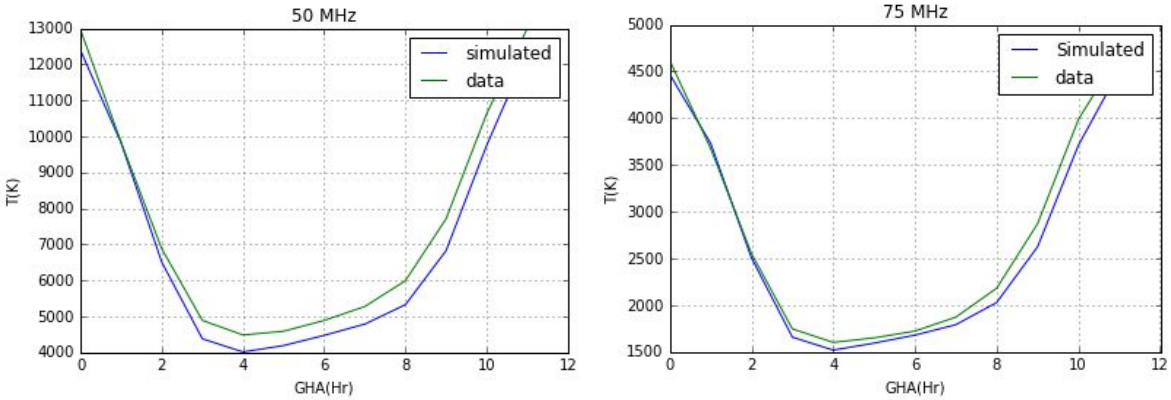


Fig 28b: Difference of the residues after fitting a 5 term polynomial fit to the simulated feko and processed old ground data for different GHAs



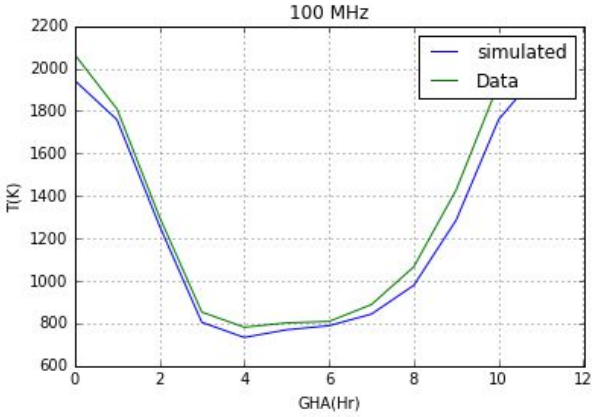


Fig29: Simulated spectra and actual data versus GHA at 50MHz, 75 MHz and 100 MHz.

Analysing Extended Ground Plane

We have data from days 2016_258 to 2017_017 and 2017_077 to 2017_094

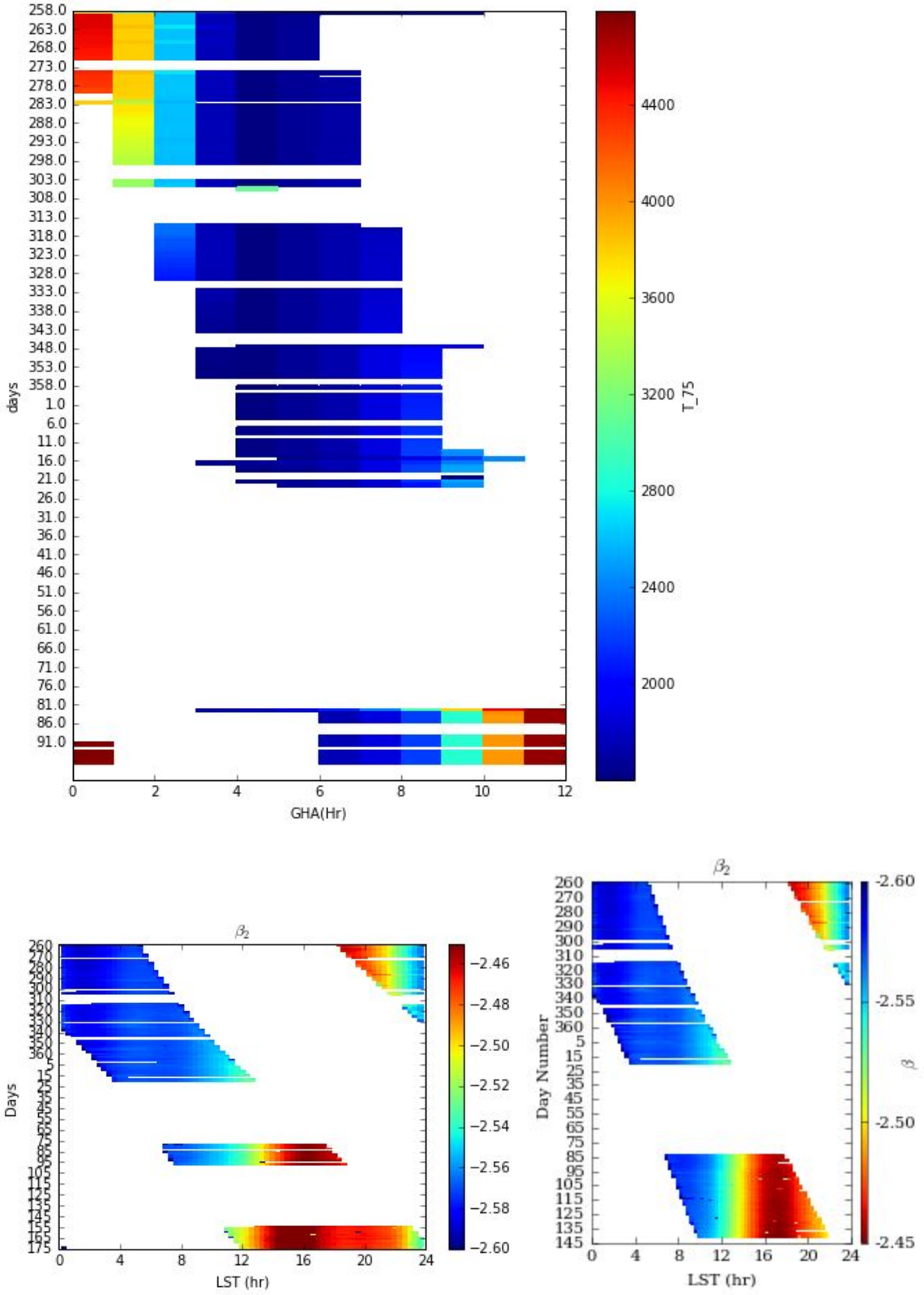


Figure30: Waterfall plot of the sky temperature at f = 75MHz. All the available data is shown. The overall change in sky temperature between days 2017_077 to 2017_095 was also noted in our spectral index analysis. Hence we used Low2 data.

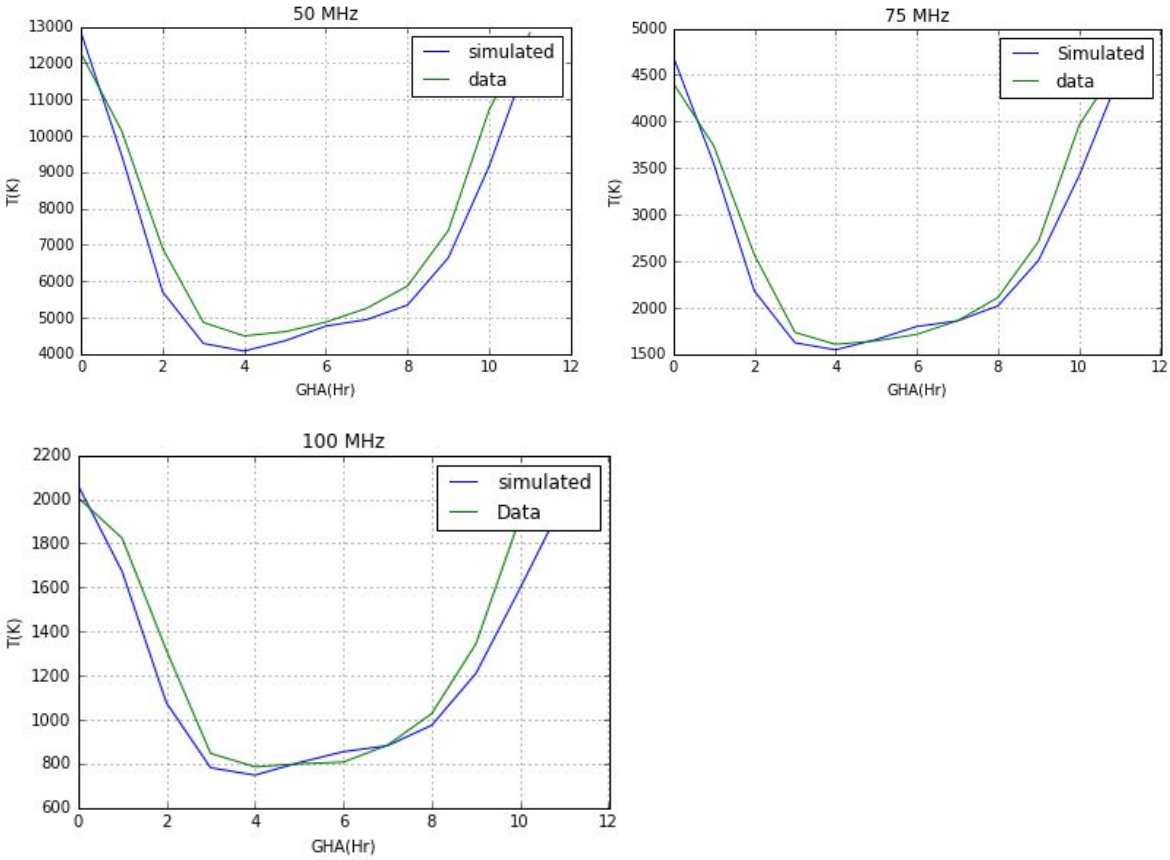


*Fig31: Simulated spectra and actual data versus GHA at 50 MHz, 75 MHz and 100 MHz. *Must check the simulated spectra convolution**

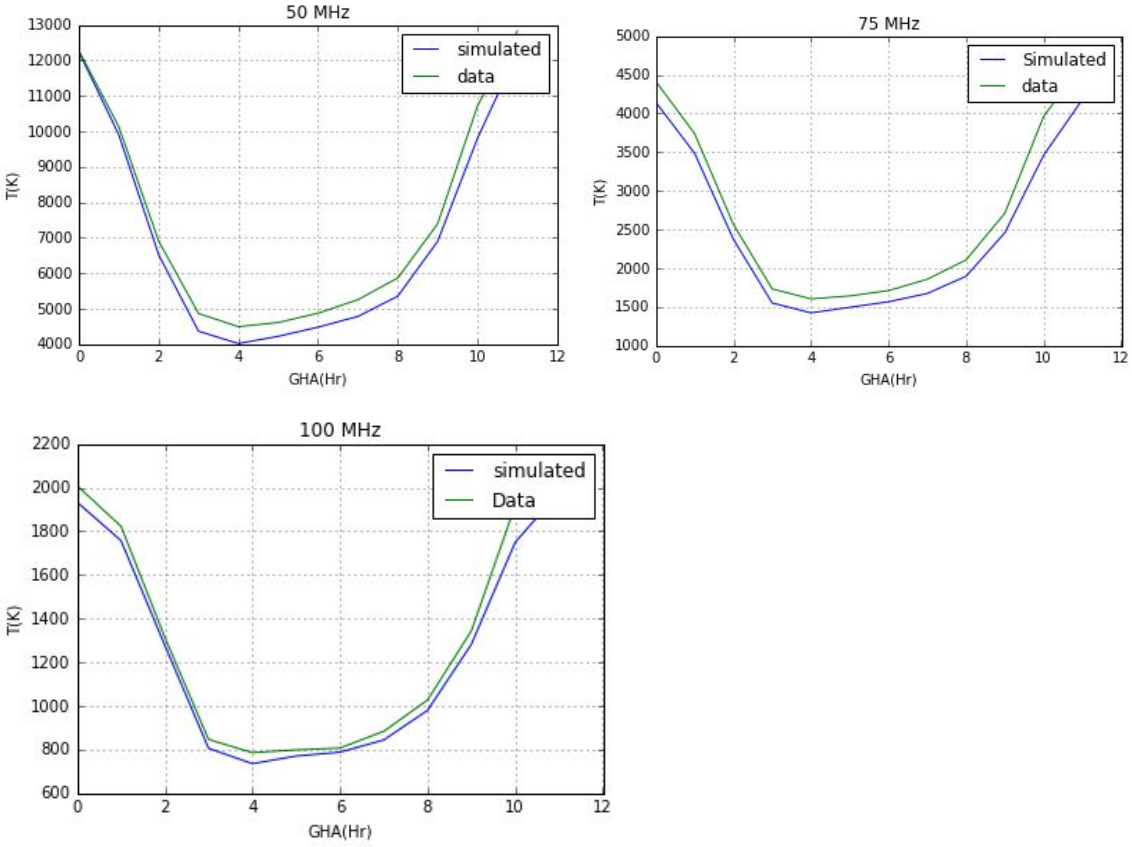


Fig31b: Simulated spectra and actual data versus GHA at 50 MHz, 75 MHz and 100 MHz.

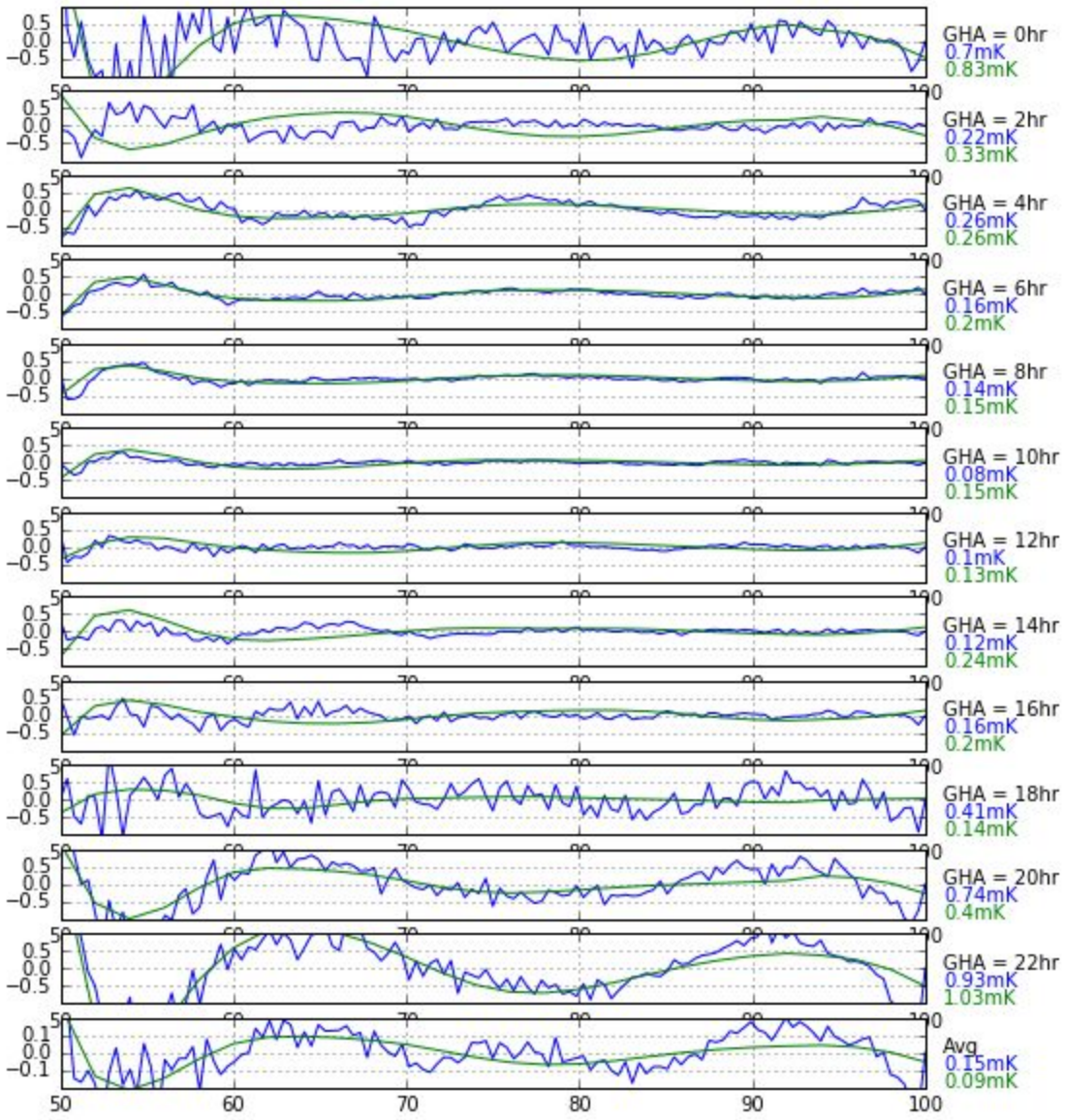


Fig 32a: Comparison of residues after fitting a 5 term Loglog fit to the simulated feko (Green), and processed New ground data (Blue) for different GHAs.

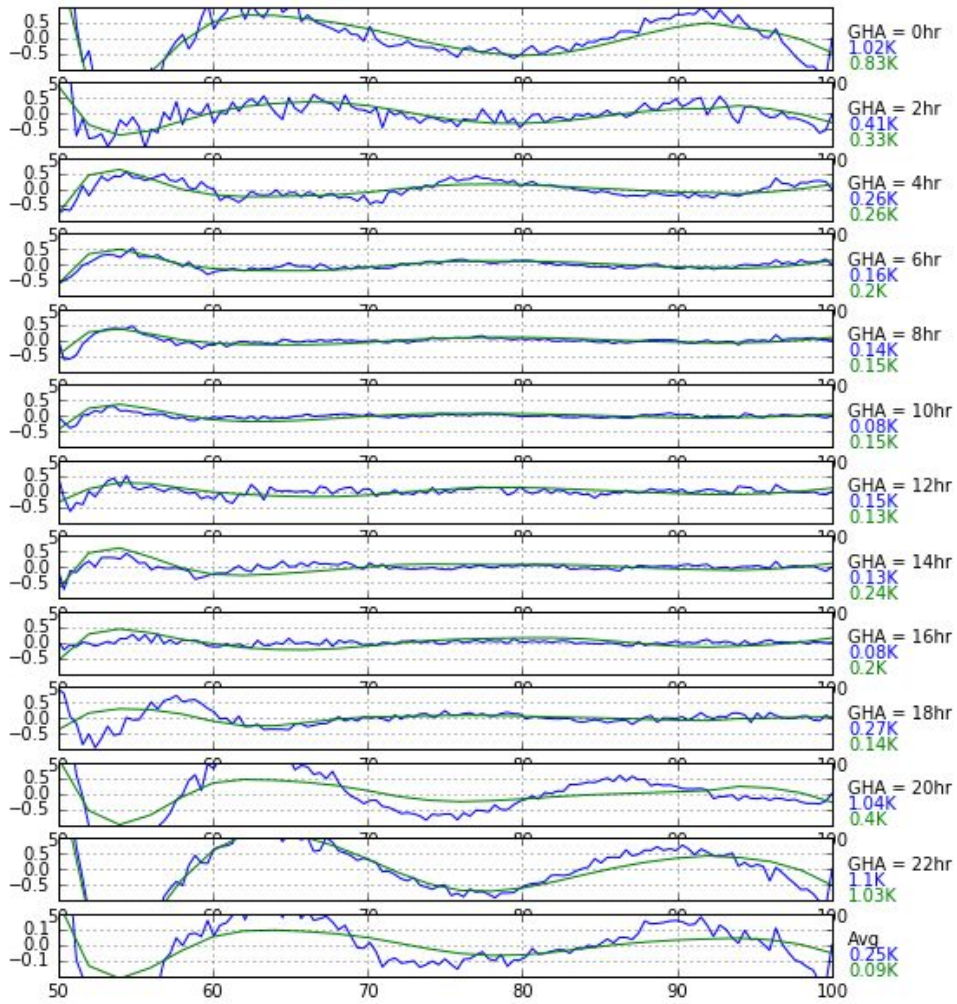


Fig 32b: Comparison of residues after fitting a 5 term Loglog fit to the simulated feko (Green), and processed New ground data (Blue) for different GHAs. Adding more days between 2017_082 and 2017_142. There is better agreement at GHA=0hr.

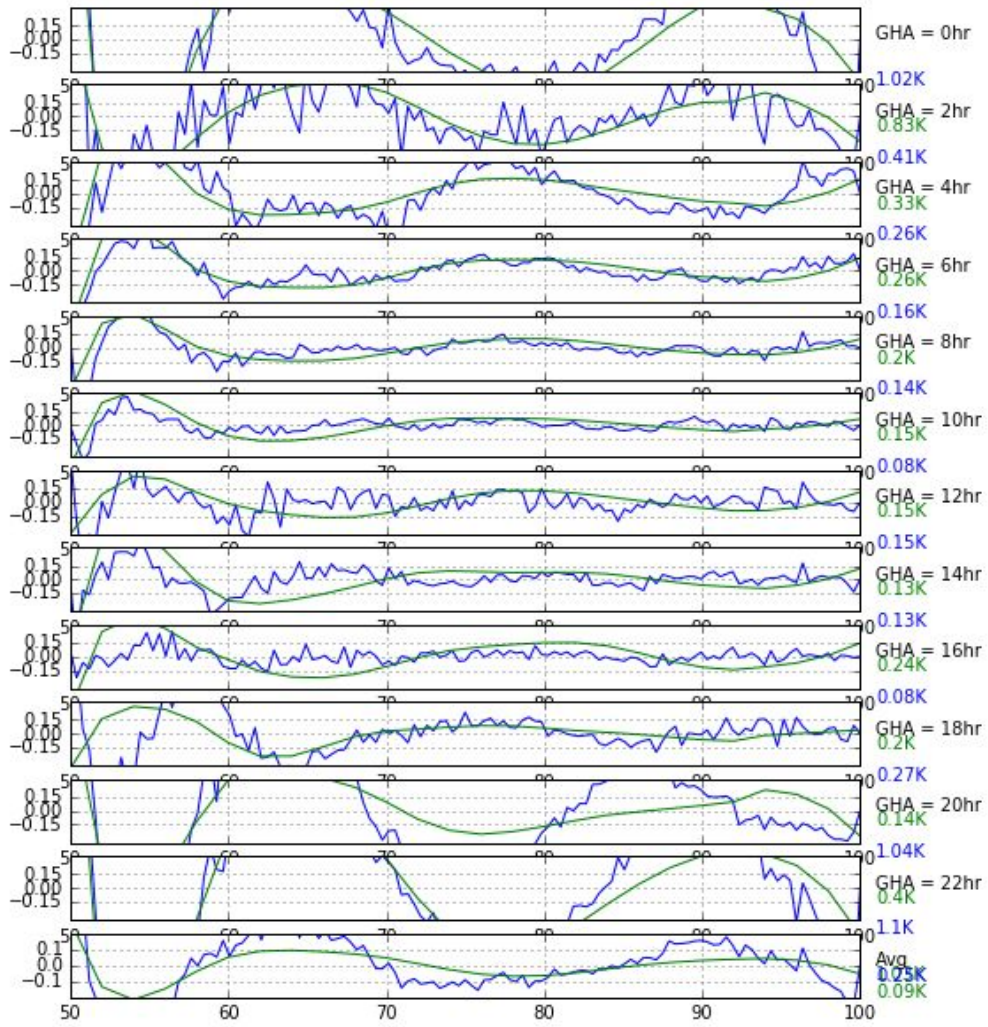
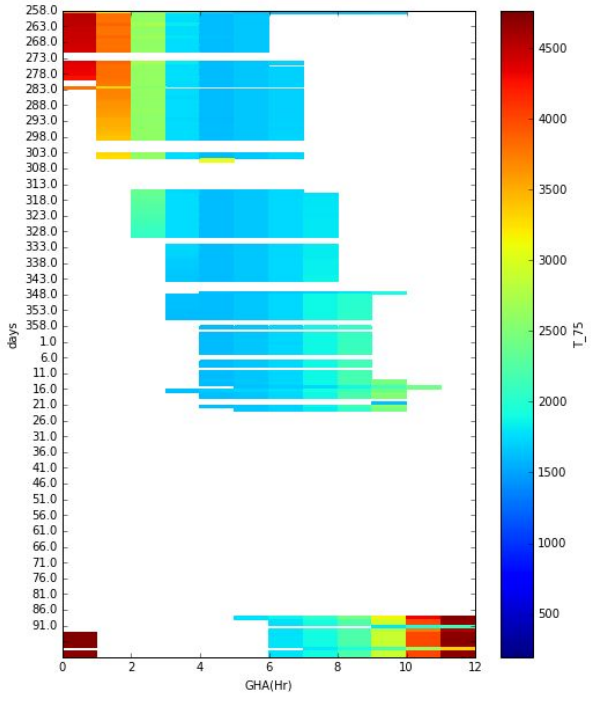


*Fig 32c: Comparison of residues after fitting a 5 term Loglog fit to the simulated feko (Green), and processed New ground data (Blue) for different GHAs. Adding more days between 2017_082 and 2017_142. There is better agreement at GHA=0hr. *ZOOMED IN**



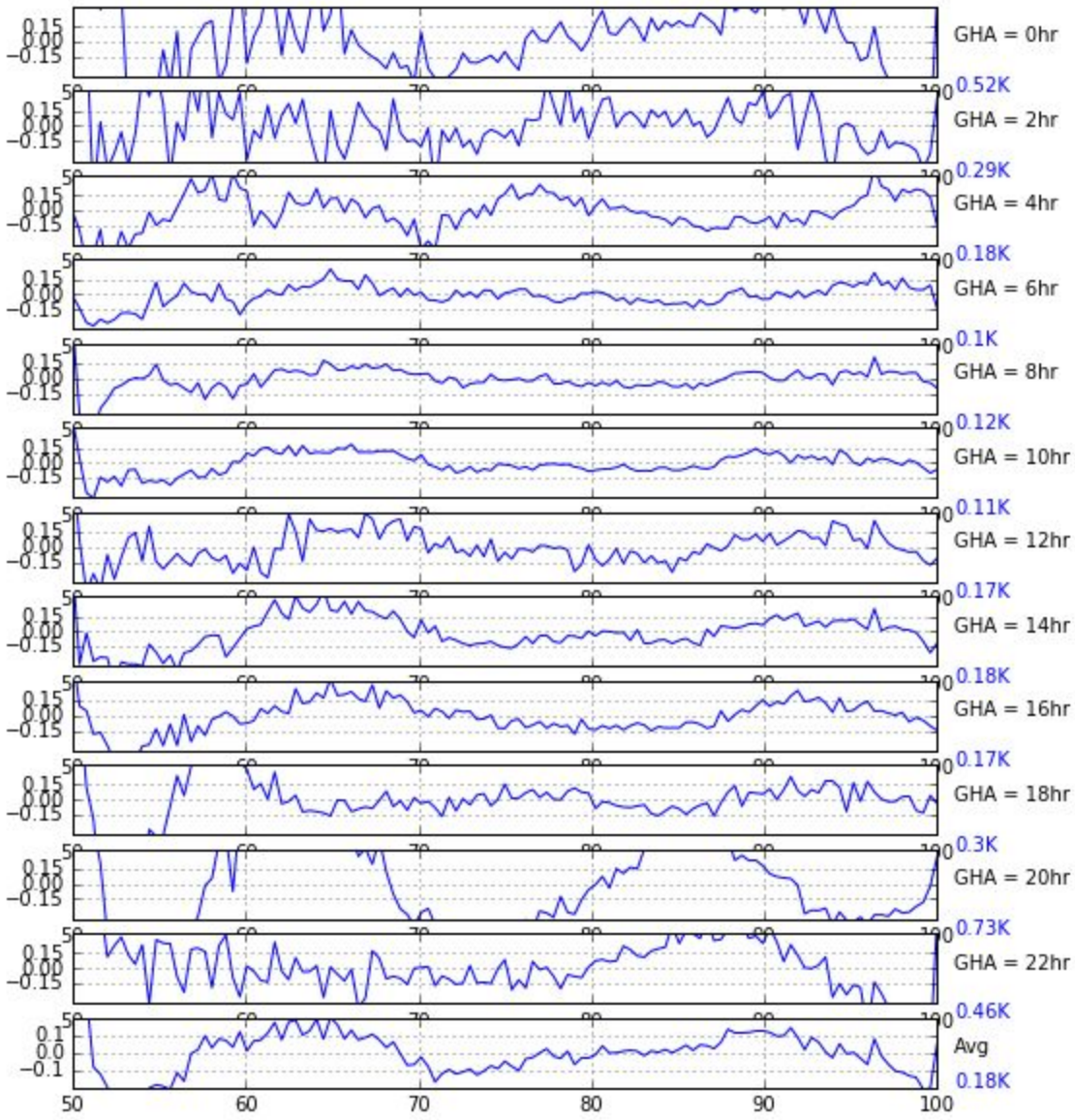


Fig 32d: Difference of the residues after fitting a 5 term Loglog fit to the simulated spectra and processed New ground data for different GHAs.

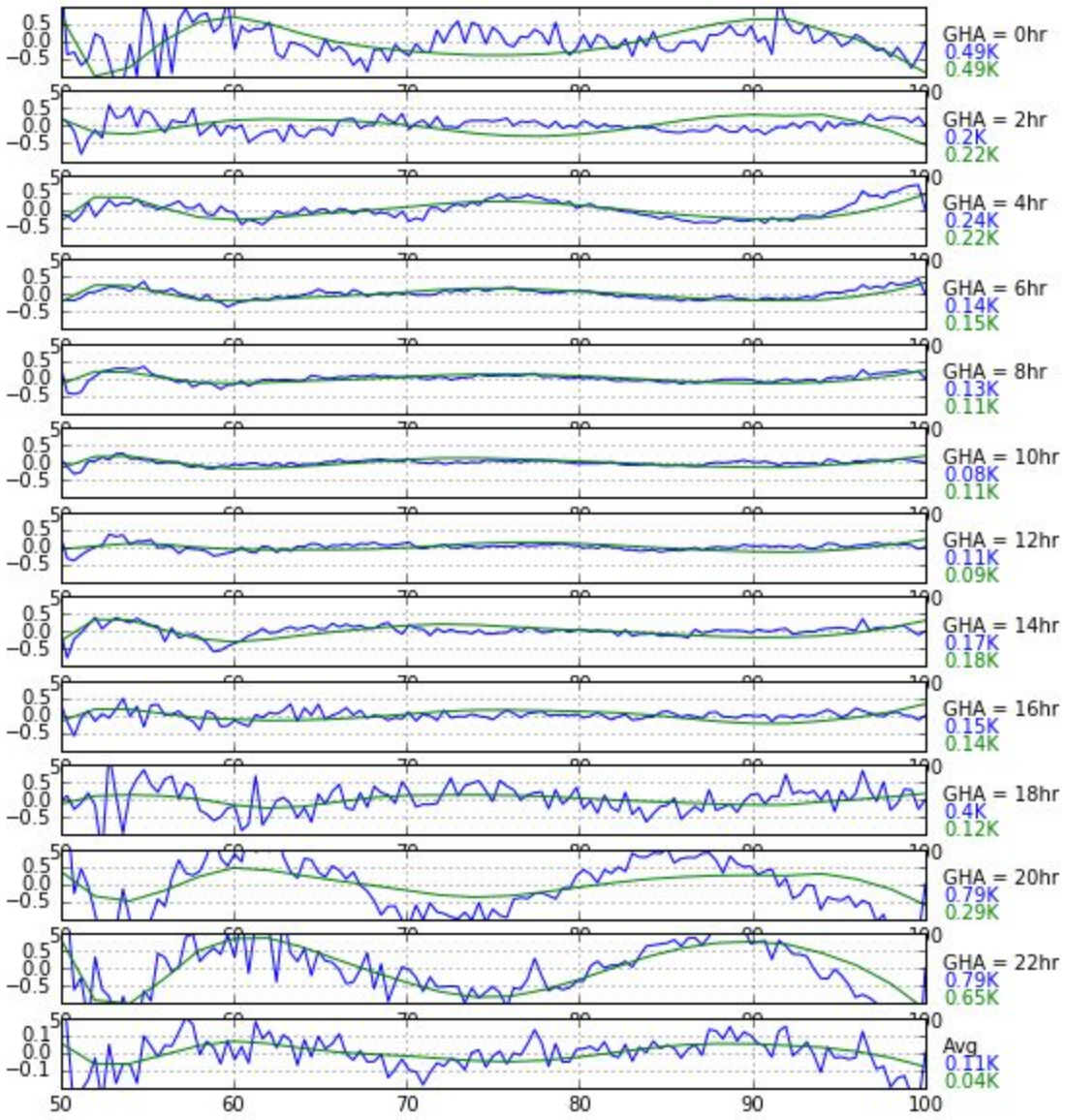


Fig 33a: Comparison of residues after fitting a 5 term Linlog fit to the simulated feko (Green), and processed New ground data (Blue) for different GHAs.

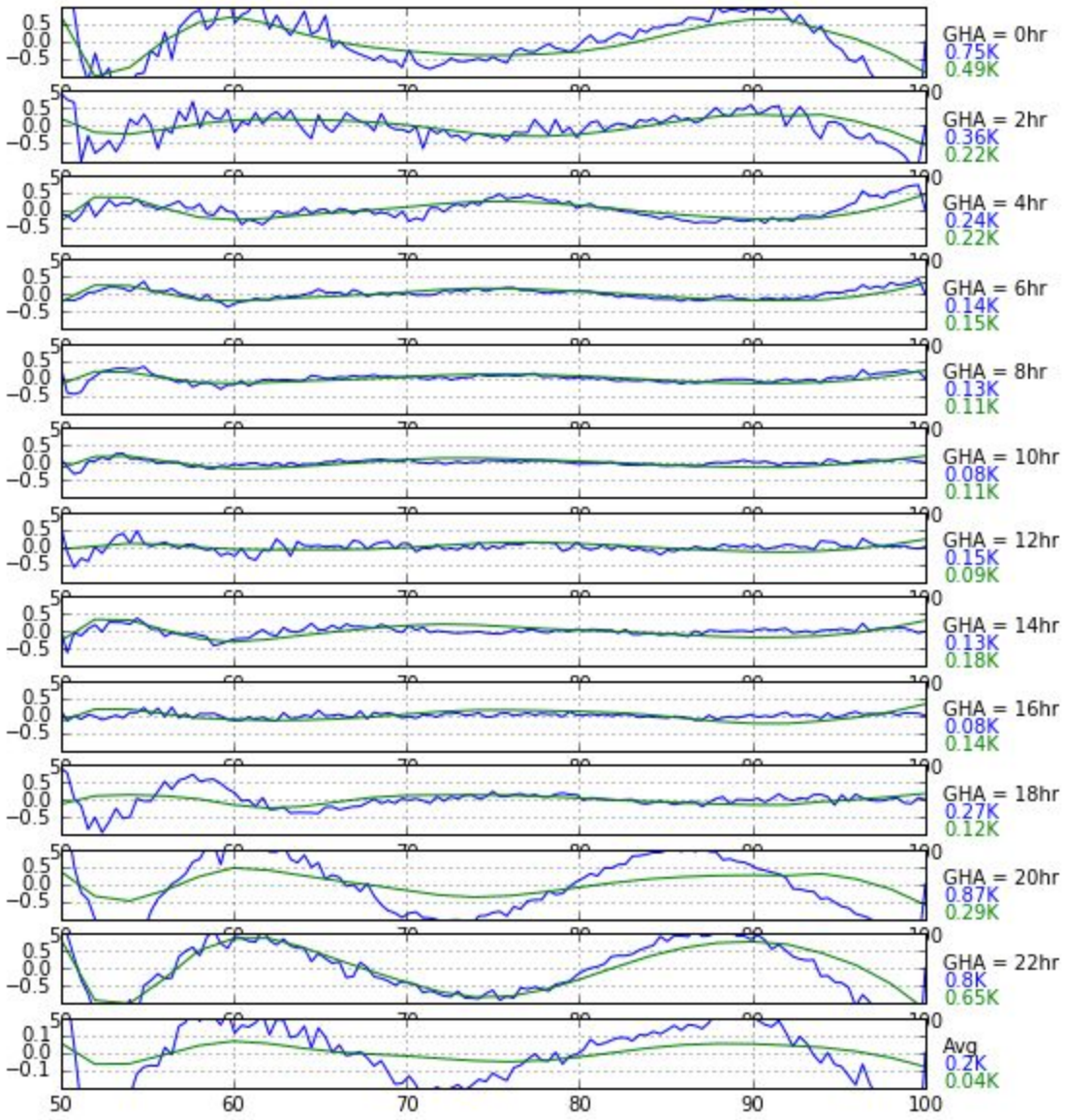


Fig 33b: Comparison of residues after fitting a 5 term Linlog fit to the simulated feko (Green), and processed New ground data (Blue) for different GHAs. Adding more days between 2017_082 and 2017_142. There is better agreement at GHA=0hr.

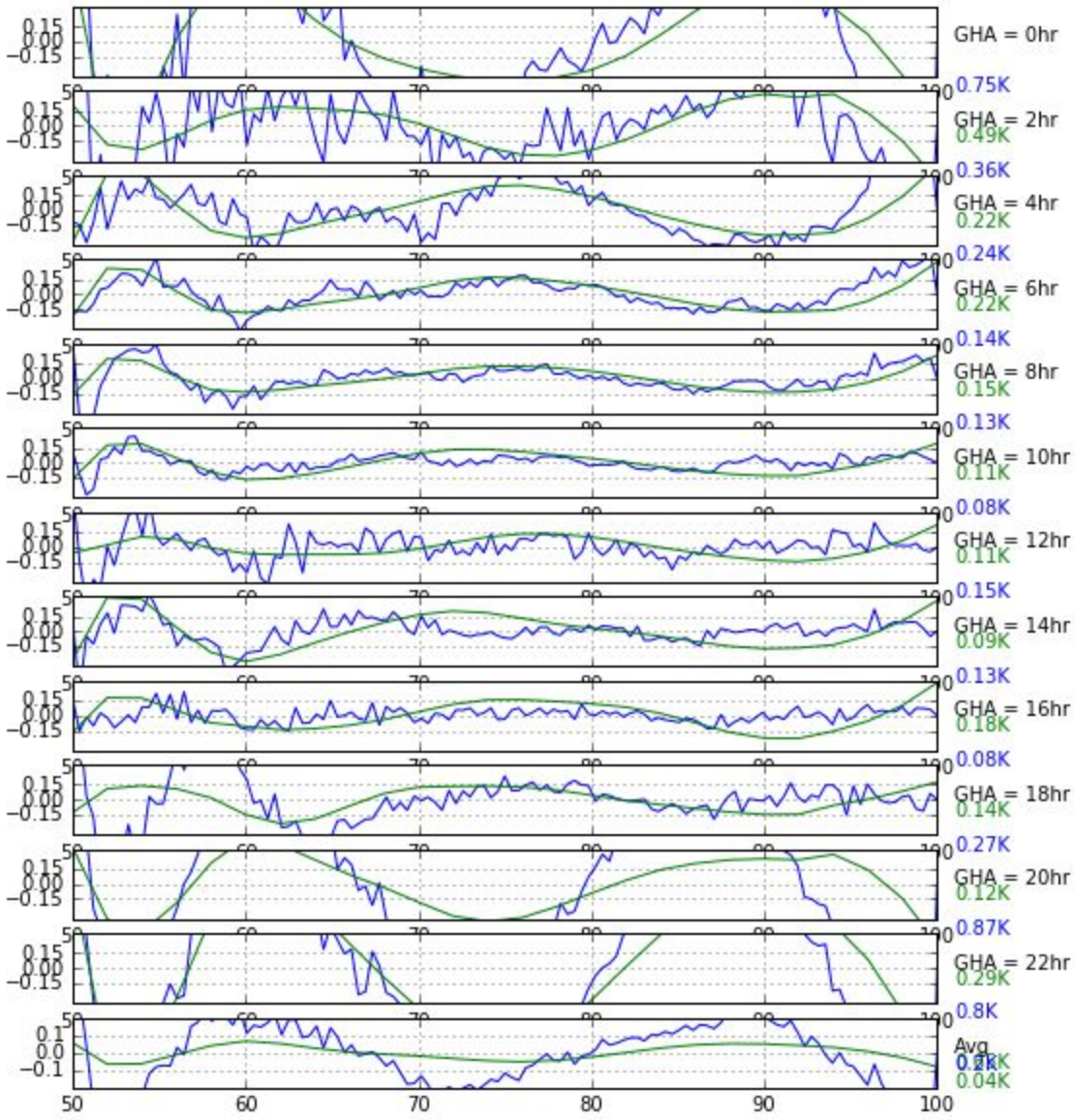


*Fig 33b: Comparison of residues after fitting a 5 term Linlog fit to the simulated feko (Green), and processed New ground data (Blue) for different GHAs. Adding more days between 2017_082 and 2017_142. There is better agreement at GHA=0hr. *ZOOMED IN**

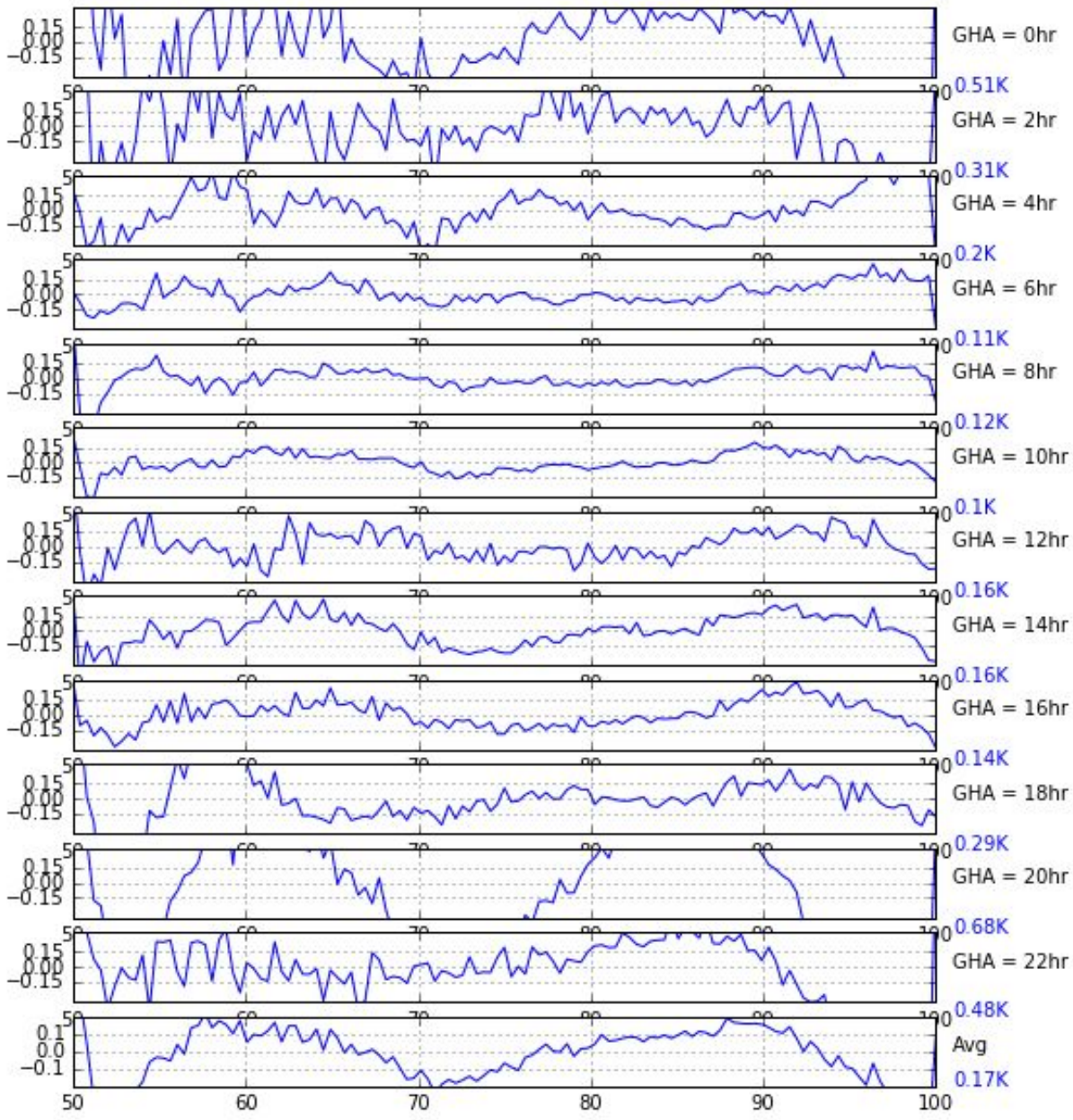


Fig 33d: Difference of the residues after fitting a 5 term Linlog fit to the simulated spectra and processed New ground data for different GHAs.

Changes in Average RMS

Ground Plane	***Loglog***			***Linlog***		
	Diff RMS (mK)	***Data RMS (mK)***	***% Diff***	***Diff RMS (mK)***	***Data RMS (mK)***	***% Diff***
10m X 10m	*190*	*480*	*39.5%*	*210*	*440*	*47.7%*
30m X 30m	*180*	*250*	*72%*	*170*	*200*	*85%*