EDGES MEMO #432

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To: EDGES group
From: Alan E.E. Rogers
Subject: Summary of EDGES-3 results from the WA from 2023 day 54 to 298

This memo is an update of the results documented in memo 423 which cover the results from day 54 to day 210 (29 July 2023). Since late July EDGES-3 has continued to acquire data which gives a result consistent with the 2018 absorption.

This analysis used the same “weighted least squares grid search” software used for the EDGES-2 data with the changes described in memo 303 to account for the VNA path to the LNA used in the automated calibration described in memo 361 and instrumental calibration error sensitivities summarized in memo 368. One very important change was made in March to improve the VNA accuracy achieved in the field was a rapid cycling from device to calibration Short Open Load, as described in memo 411, to get more accurate S11 measurements in the changing environment of the deployment in the field. Measurements of the temperature coefficient of the handheld VNA used in EDGES-3 are described in memo 416.

Figure 1 shows effect of antenna S11 measurements, which were made almost every day, on the residuals using simulated data with calibration on day 210 and antenna S11 on day 155 without any added 2018 feature. The residuals are shown with 4 physical terms removed to emphasize the changes for each measured antenna S11. The antenna S11 measurements that are used for processing are made as listed in Table 1 below:

Day range	antenna S11 day used	comments
54 to 98	70	
99 to 149	99	
150 to 199	155	
200 to 224	263	
225 to 234	286	
235 to 262	263	
263 to 284	277	period without cover
285 to 298	286	

Table 1. Choice of antenna S11 used in data processing for absorption feature

The choices of which antenna S11 to use for each day of data were checked by looking at the residuals for each day and for blocks of 10 days and making a reasonable choice based on physical events like the installation of brackets to maintain a stable separation of the antenna boxes and a period when the cover was blown off the antenna and was later put back on with a strap to keep it from being blown off again.

Figure 2 shows the result of processing each day with a single block of the nighttime data within a range of GHA from 4 to 20 hours with the appropriate selection of antenna S11 from table 1. All data used the calibration from day 210. The feature search used 5 loglog polynomial terms.

Figure 3 shows the result of processing each day with up to 1 hour blocks of nighttime data in the GHA range from 6 to 19 hours with the appropriate selection of antenna S11 from table 1. All data used the calibration from day 210. The feature search used 5 loglog polynomial terms.

Figures 4 and 5 show the results from the processing schemes used in Figures 2 and 3 without any beam correction which show that when a 48x48m ground plane is used errors in the knowledge of the sky model and the beam chromaticity are not the major source of systematic error. The beam chromaticity used was derived using FEKO and assumed a soil dielectric of 3.5 and a conductivity of 2e-2 S/m. A change to a conductivity of 2e-3 made only a 20mK change in feature amplitude in the results in Figures 2 and 3.

Center MHz	SNR	amsK	width	rmsin mK	rms mK	S/m
78.1	28.0	0.43	20.2	87.4	17.2	2e-3
78.1	29.0	0.44	20.9	87.0	17.2	2e-2
78.1	25.3	0.48	20.9	64.8	21.8	2e-3
78.1	25.6	0.50	20.9	64.7	22.1	2e-2

Table 2 change of soil conductivity for result shown in Figures 2 and 3

The major source of systematics are from errors in S11 as discussed and tested in memo 423. As discussed in memo 423 the EDGES-3 and EDGES-2 midband data get lower residuals with a flattening parameter of tau = 4.

Figures 6 show plots of the estimates errors of the fits shown in Figure 2 using the delta Chi-squared boundaries of 95% confidence outside the red and 99% confidence in the black and only 1% probability in the white. However, bare in mind that the residuals are not perfectly Gaussian and have some systematics. The algorithms used in this method are described in memo 272. A full Bayesian analysis written by Steven Murray and tested by Nivetida Mahesh and Akshatha Konakondula Vydula (see ref.) is being prepared to analyze EDGES-3 data.

In summary the 21-cm absorption results obtained at the WA using EDGES-3 are consistent with those obtained with EDGES-2. While the two systems are similar EDGES-3 has the electronics built into the antenna which eliminates the need for a balun and the added loss associated with a balun. EDGES-3 is designed for a remote deployment. Further development is planned to reduce the power consumption and improve the S11 measurement accuracy to the level that can be achieved with the most accurate “benchtop” VNAs.

Reference:

Murray, S.G., Bowman, J.D., Sims, P.H., Mahesh, N., Rogers, A.E., Monsalve, R.A., Samson, T. and Vydula, A.K., 2022. A Bayesian calibration framework for EDGES. *Monthly Notices of the Royal Astronomical Society*, *517*(2), pp.2264-2284.

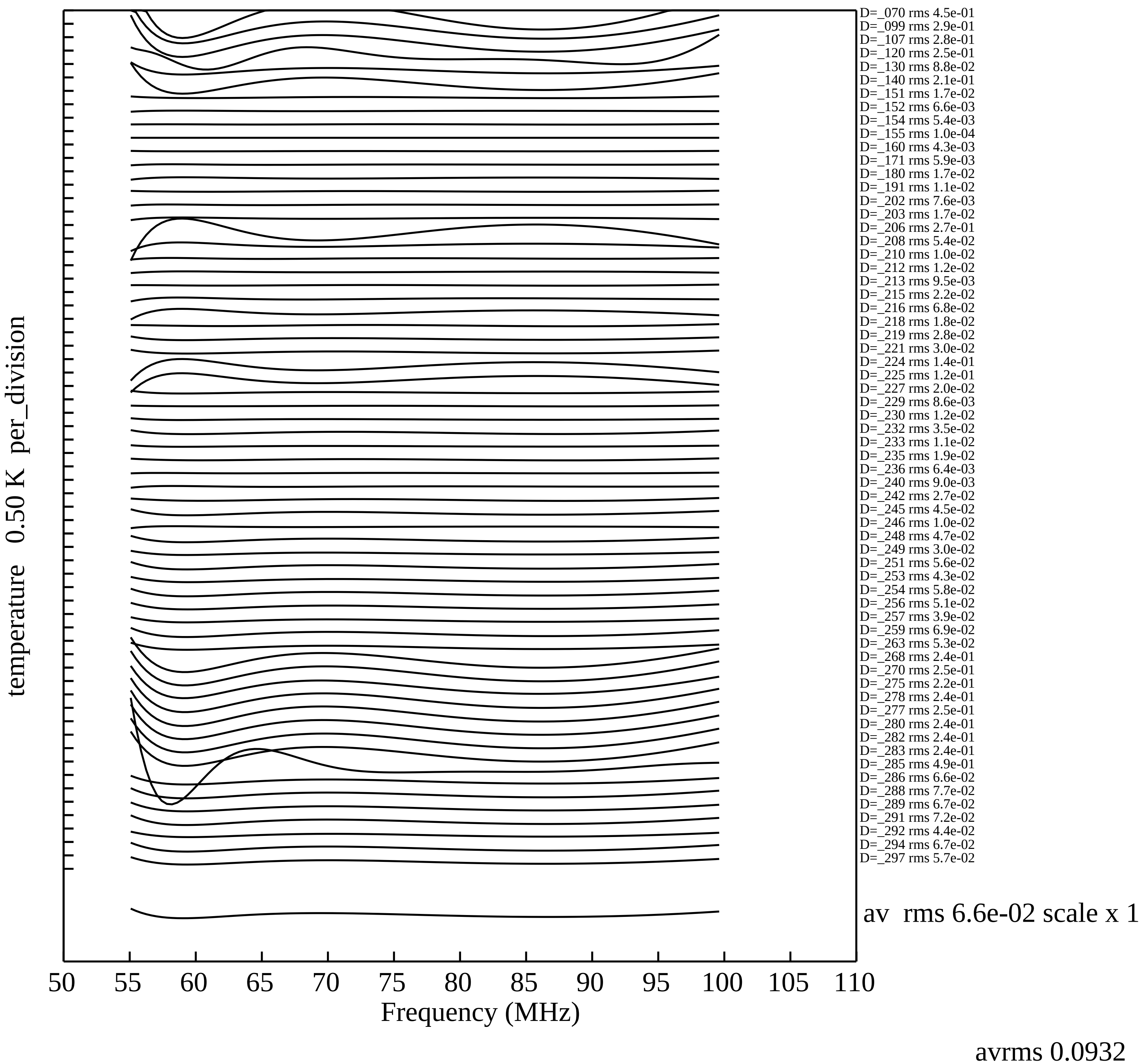

Figure 1. Effects of the changes in antenna S11 on the days listed along with 4-term rms residuals.

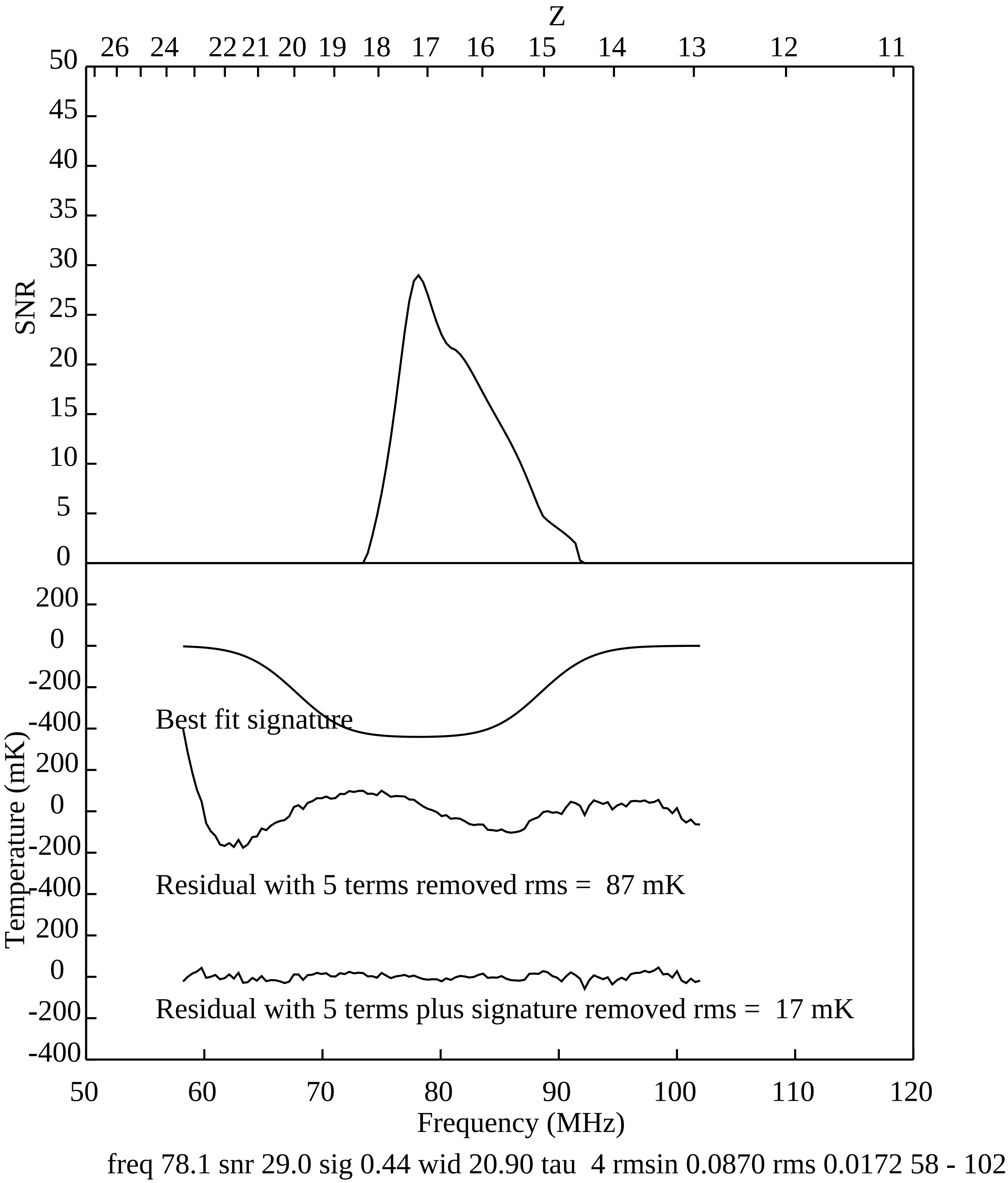

Figure 2. Absorption feature from single nighttime blocks of data from 2023_054 to 2023_398.

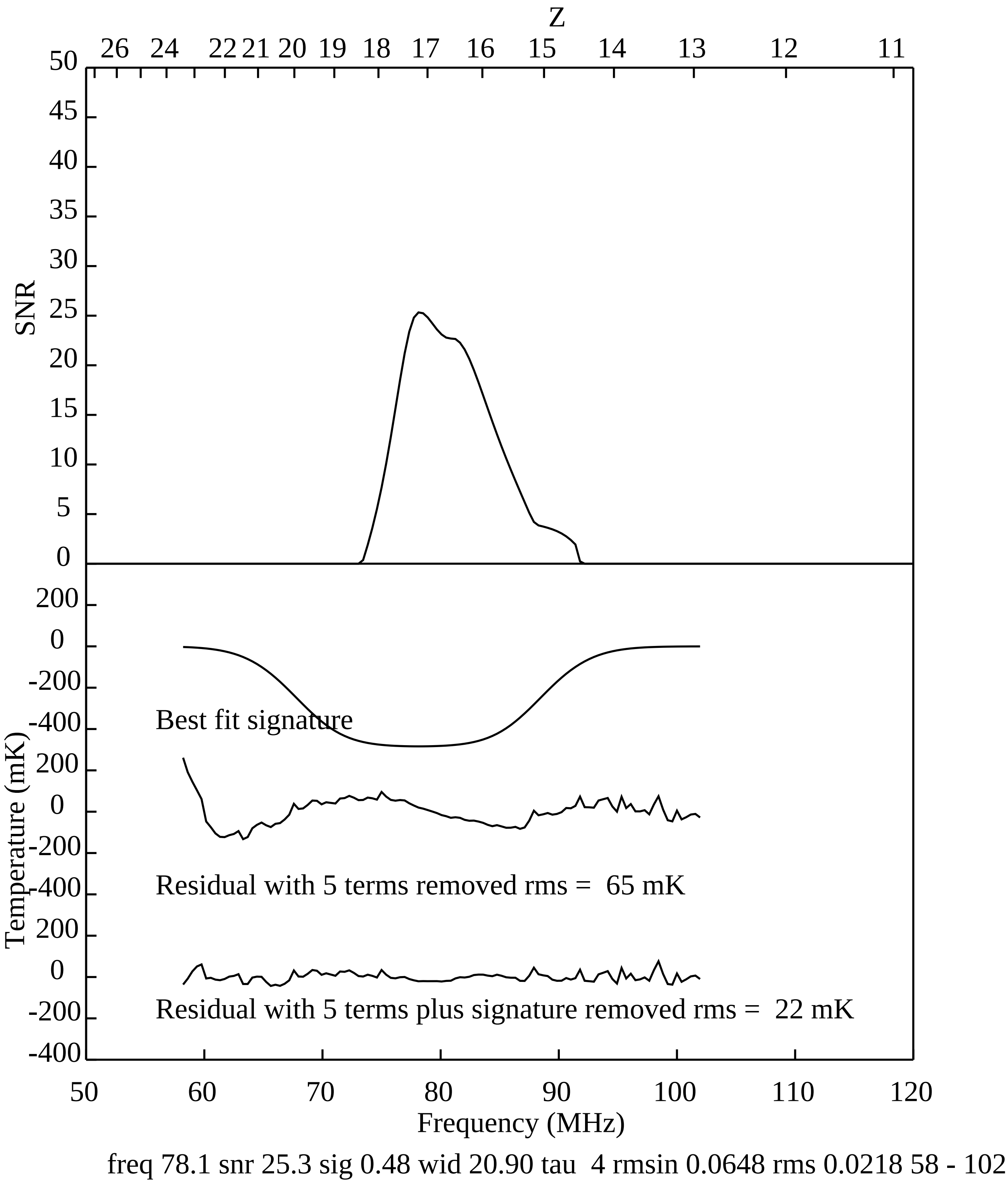

Figure 3. Absorption feature from multiple nighttime blocks of data from 2023_054 to 2023_398.

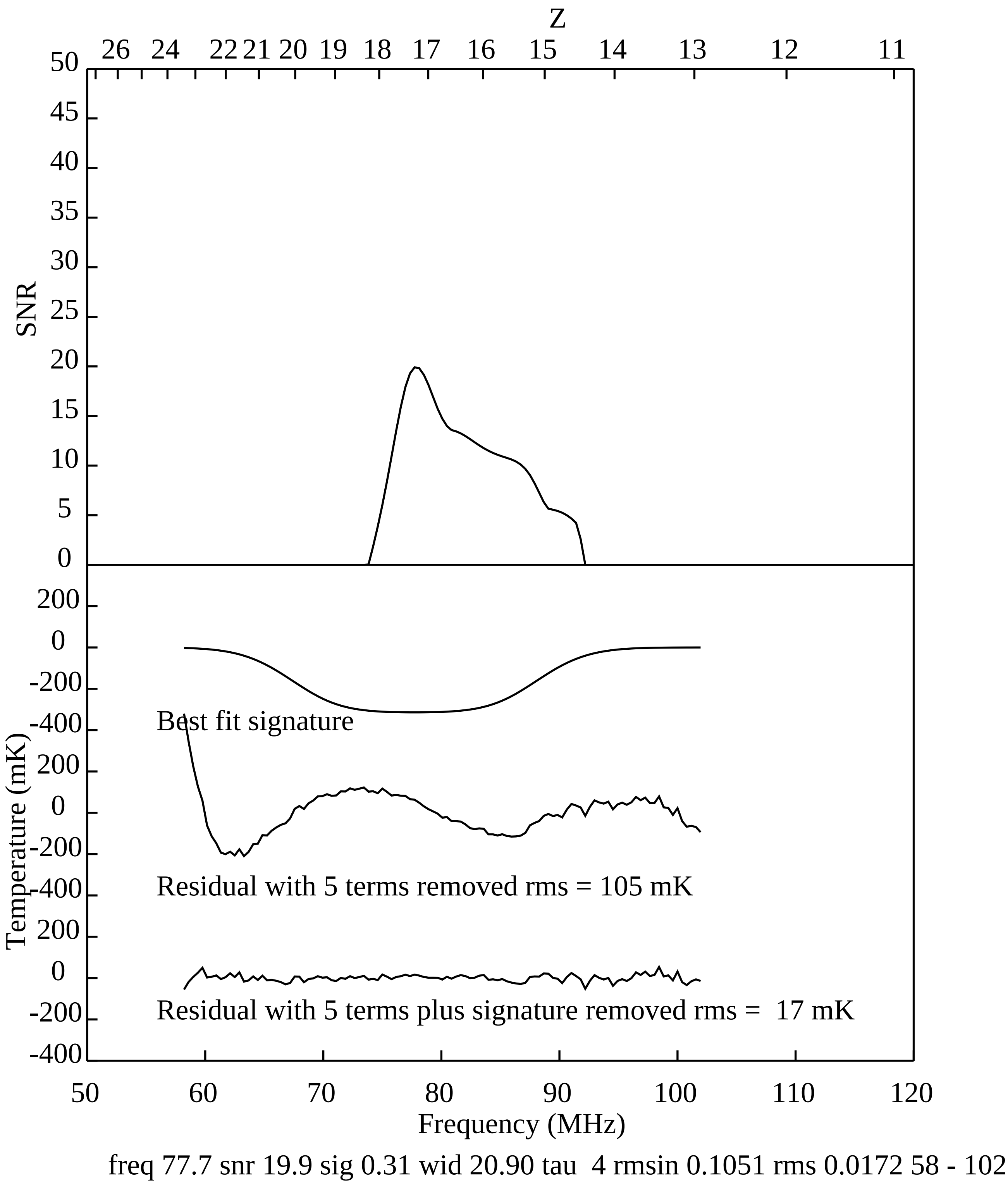

Figure 4. Same processing as in figure 2 without beam correction.

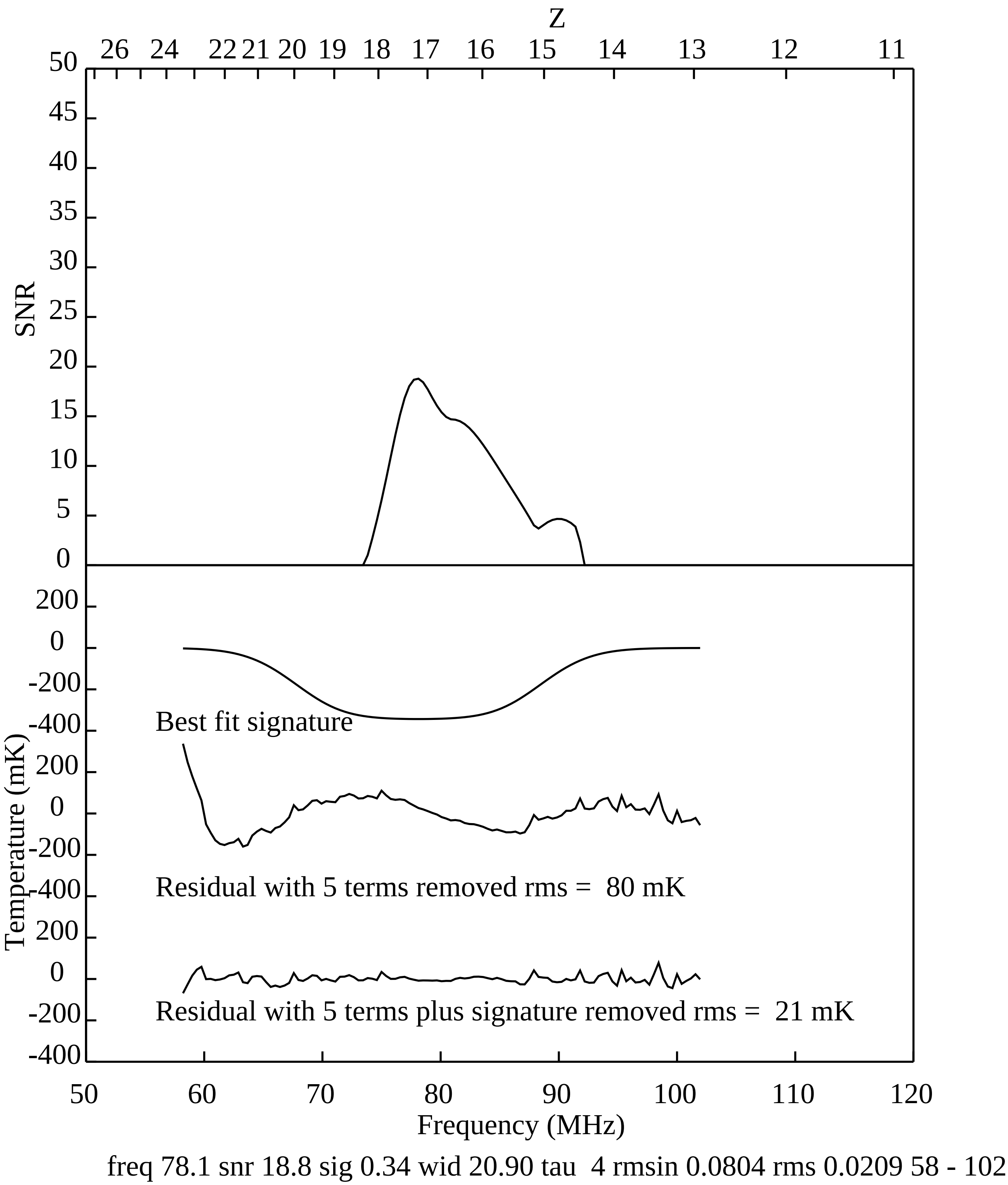

Figure 5. Same processing as in figure 3 without beam correction.

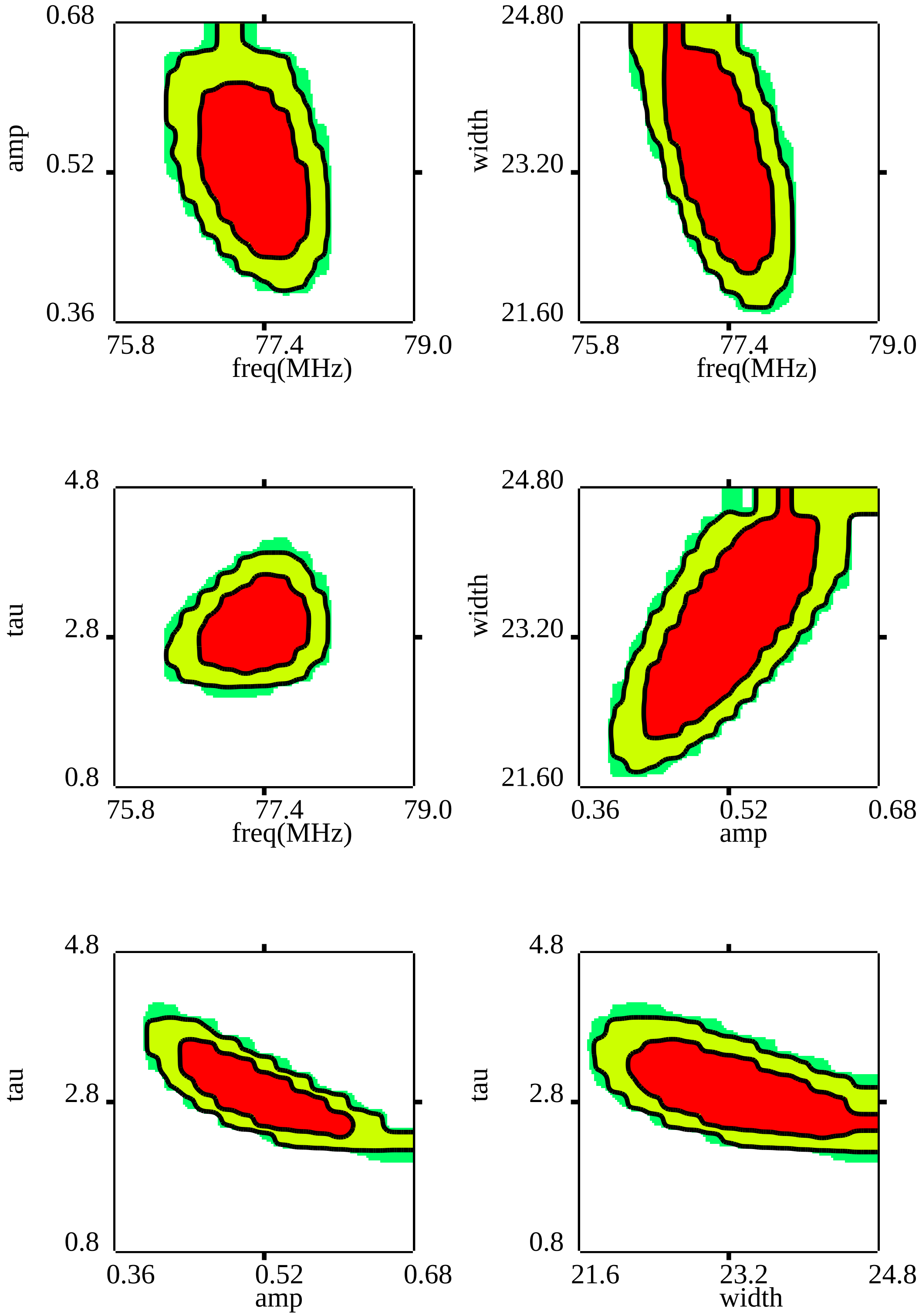

Figure 6. Chi-squared boundary error estimates for data in Figure 2.