

**MASSACHUSETTS INSTITUTE OF TECHNOLOGY
HAYSTACK OBSERVATORY
WESTFORD, MASSACHUSETTS 01886**

January 21, 2025

Telephone: 617-715-5533

To: EDGES group

From: Alan E.E. Rogers

Subject: Settings for processing figure 5 of memo 466 and effects of FM reflections from the moon

The details of the setting used in memo 466 are given below.

1] antenna beam (see memos 300, 313, 362 and 406 for details of antenna)

file: azelq_box_perf_48_2e-2.txt

feko script: genbox7 gapin 0.018 -gap2 0.066 -diag 0.734 -hgt 0.88 -side 0.953 -swid 900 -bhgt 0.1511
-rpipe 0.5 -rcon -0.25 -wcon 0.02 -rpb 0.25 -hh 0.54 -sigma 2e-2

antenna azimuth: 269 deg

2] receiver calibration (see memo 303 for path of VNA to LNA and memo 423 for calibration filtering)

file: specs_210opt.txt

script: docal_210opt

amb hot open short spectra from: 2023_210

ant amb hot open short s11 from: 2023_210_03

s11 parms: ps = 33 ps rs = 49.962 ohms len = 4.45 diel = -0.9 loss = -92.0

-tcold 303 -thot 392 -wtmode 1 -lmode -1 -tant 303 -tcab 303 -cfits 7 -wfits 9 -nfits 7 -nfits 37

3] antenna s11 (see memo 411 for antenna s11 averaging and VNA failure in 2023)

script: s11ant286.csv

data from: 2023_286_15 with ps = 33 rs = 49.930

4] RFI filtering (see memos 137, 173, 244, 250, 307, 418, and 445)

c-code: acqplot7amooncm -rfi 2.1 -nrft 2 -maxrmsf 50 -maxfm 2000 -sunlim -20 -sunmin -90

5] smoothing (see memo 40 and memo 129 for list of nfit parameters)

c-code acqplot -smooth 8 and edges3 -nfit4 12 -smooth -8

A test of the effect of the reflections of FM radio from the moon is studied in memos 53, 244 and 250. This study is extended to include to study of the data from EDGES-3 data taken in WA in 2024.

center MHz	SNR	amp K	width MHz	# terms	rms1 mK	rms2 mK	Moon limits
77.3	37	0.61	22.3	4	78	22	none
77.0	33	0.58	22.6	4	74	23	-1
77.3	34	0.57	22.3	4	73	23	5
77.0	33	0.58	22.7	4	73	23	20
77.0	35	0.59	22.6	4	75	22	30

Table 1. The 21-cm absorption parameters using tau = 4 57-104 MHz and rms threshold 0.22 K

Table 1 shows results of adding a limit of the moon's elevation to the grid search for the 21-cm absorption in figure 5 of memo 466 absorption results in the first entry. Based on the added limits on the moon's elevation which results in less data being used there is very little change in the result.

While the moon is known to reflect FM radio signals these reflections are relatively weak since the satellite population has increased reflections from satellites have become stronger and more frequent. The increase in reflections of FM radio signals from day 217 of 2018 to day 217 of 2023 is studied in memo 424.

Another occasional source of FM radio reflections are meteor shower events but these are brief and usually strong enough that the fit to the data exceeds the rms filter threshold, whose values are in the last column of tables 1 and 2 of memo 466, so that data from these events is not accepted . All of the sources of FM reflections can be filtered with rfi settings of rfi=2.1 and nrfi=2. Settings of rfi=2.5 and nrfi=4 were used in processing of data from Devon Island described in memo 419. The best settings are a compromise between making the rfi threshold which is in units of statistical sigma low enough to remove the FM but not low that significant noise results from reduced amount of data used in average used for the overall acceptance of data blocks.

Table 2 shows the results of processing 61 days of data from EDGES-3 at the WA over a range of GHA from 6 to 18 hours for which the sun is more than 20 degrees below the horizon. Various choices of FM filter parameters are used to illustrate the effects of the rfi threshold, and the number of adjacent channels used in the iterative RFI excision process defined in memo 137. 4 physical terms are used to remove the foreground and beam correction has been applied.

MODE	-rfi	-smooth	-nrfi	comments
0	2.1	2 24 kHz	0	nrfi > 0 needed to remove adjacent channels
1	2.1	2 24 kHz	2	good suppression of FM
2	3.5	2 24 kHz	2	rfi threshold too high to remove FM
3	1.8	2 24 kHz	2	rfi slightly too low leaving some channels with no data
4	1.8	2 24 kHz	2	MODE 3 with moon below horizon
5	2.1	2 24 kHz	2	MODE 1 with moon below horizon

Table 2. FM filtering parameters sun 20 degrees below the horizon GHA 6-18 4 physical terms

Plots of the tests of the filter parameters listed in Table 1 are shown in Figure 1 and can be compared with the plots from EDGES-2 from 2016_252 to 2017_094 in memo 250. Very strong signals in the FM band like occasional reflections from aircraft are removed by the maxrmsf 50 maxfm 2000 settings. Another source of strong FM reflections seen by EDGES-3 were from the Geminids on 14 December 2024 and Quadrantids meteors on 13 January 2025. Figure 2 shows the residuals in Figure 1 using smooth parameter value 8 to smooth to a resolution of 391 kHz.

In summary with the large increase in FM reflections since 2017 make it even harder to separate FM reflections from the moon from other sources of FM reflections but overall the effect of FM reflections on the 21-cm absorption amplitude is still under 50 mk with good filtering.

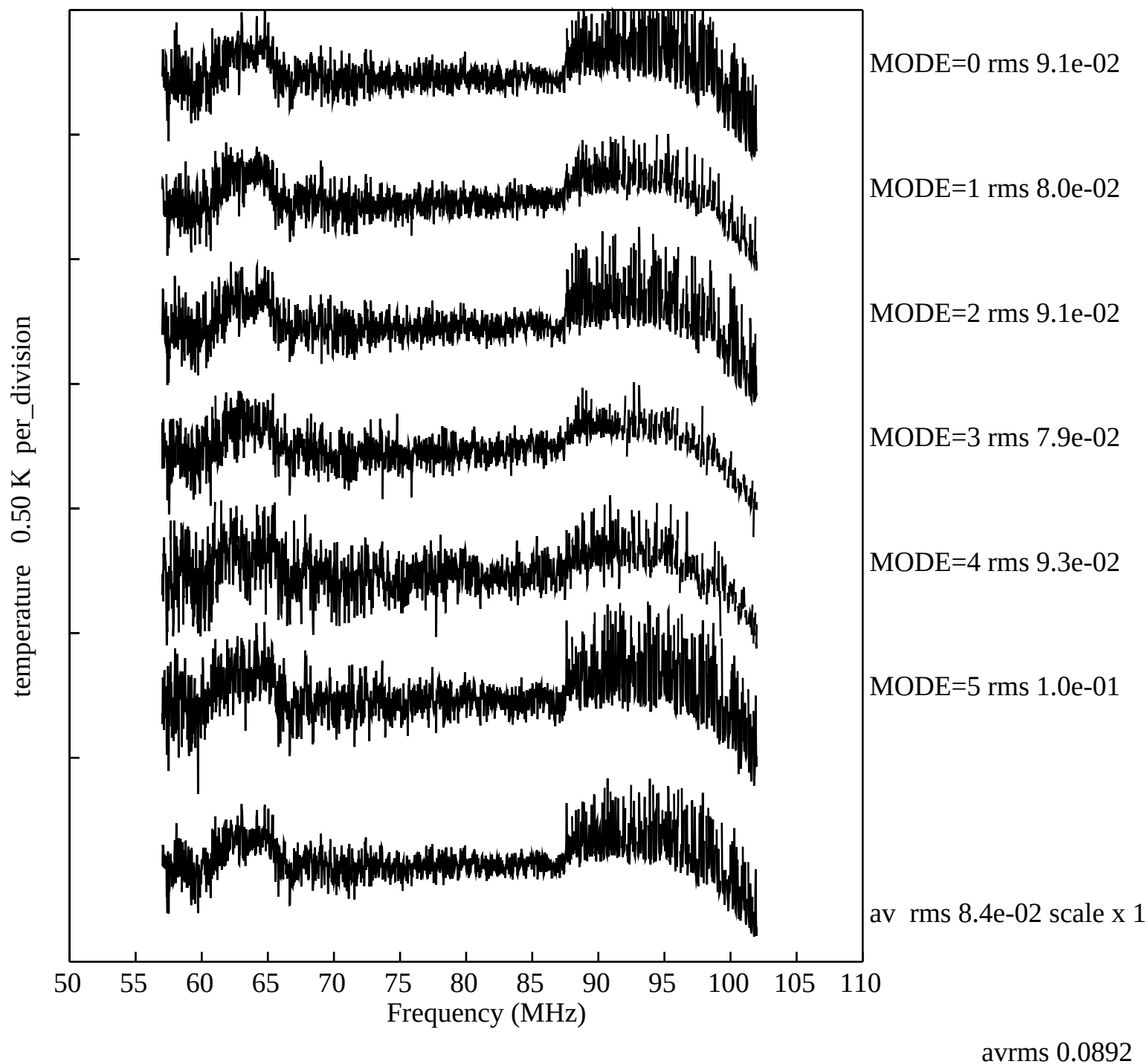


Figure 1. EDGES-3 in WA from 2024 day 300 to 360 using RFI selections in table 2.

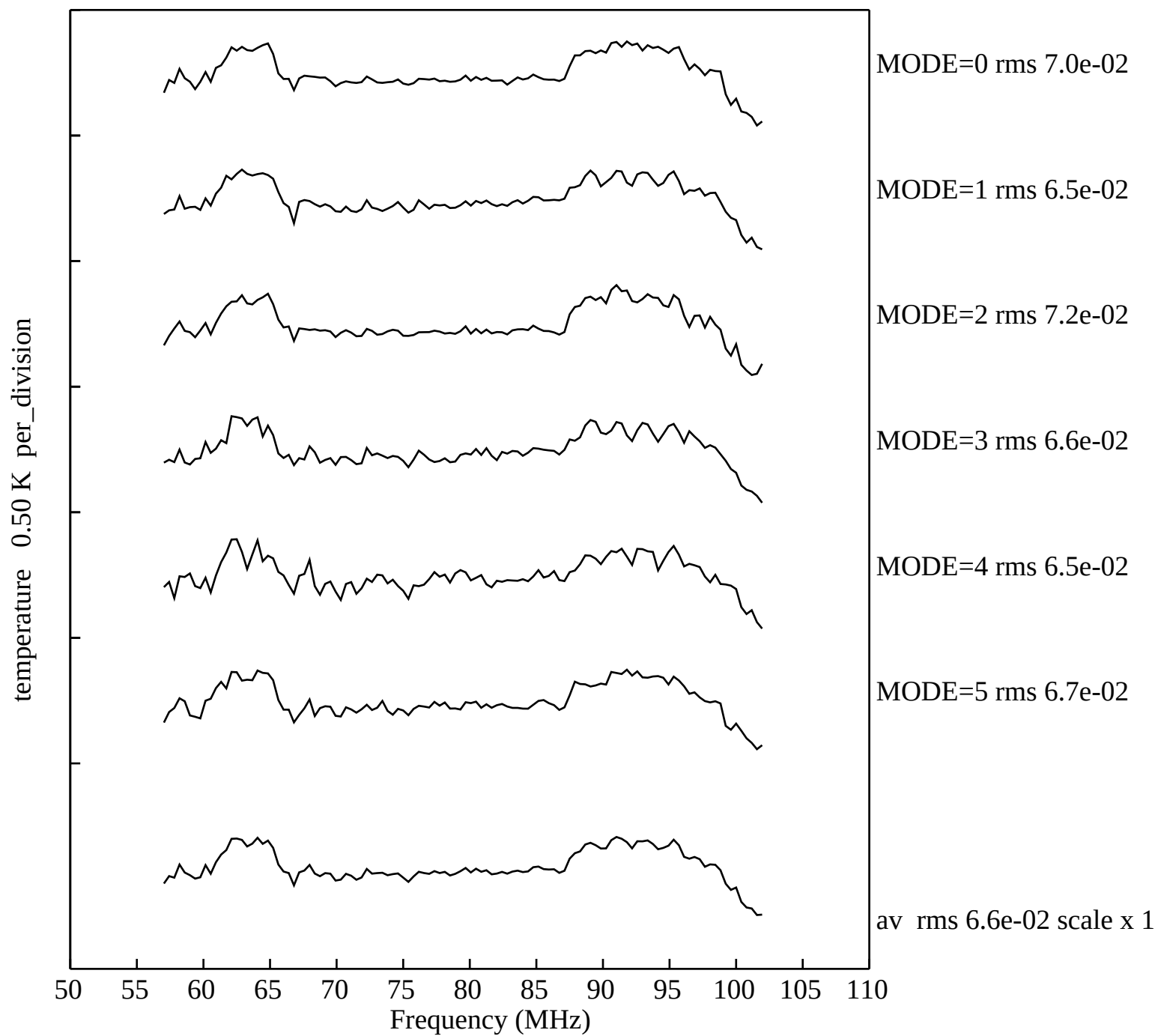


Figure 2. Residuals using smooth parameter of 8 to smooth to 391 kHz resolution.