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To: EDGES group

From: Alan E.E. Rogers

Subject: The effects of reflections earth's FM stations from the moon on EDGES-3 data

The effects of FM reflections were examined in memo 468 using data from EDGES-3 in WA from 2024 day 300 to 360. In this memo we use data from 2025 day 1 to 344.

The presence of FM needs to be filtered out to avoid an increase in the calibrated antenna temperature in the FM band which covers 87.5 to 108 MHz. The presence of FM is seen in all the EDGES data because FM stations within 3,000 km have a line of site to the region 100 km above the FM transmitter tower, where micrometeorites and meteors burn-up and produce ionized regions which reflect the FM signals from the FM transmitter to the EDGES antenna. In addition reflected signals from satellites, and the moon can reach the antenna via a reflected path depending on the geometry. Also occasional reflections of nearby FM stations from aircraft are possible and very strong if there is a FM station within 100 km but those seen in figure 2 of memo 47 and in figures of memos 52, 58, 75, 144, and 213 are mostly too frequent to be from aircraft and are most likely from sporadic E reflections from ionized regions of the ionosphere.

The key memos on FM signals are 227, 250, 310 , 400, 424, 468, 469, 490 and 492. Figure 1 shows plots of the FM from 80 to 110 MHz seen every tenth day from day 1 to day 331 of 2025 without smoothing for a resolution of 6 kHz and rfi threshold of 3 sigma. The plots have 7 loglog terms removed with no limit on the rms threshold. These results show significant FM carrier signals at a level of about 4K, when averaged over a day, on days 51 and 171 which are the result of a meteor event on these days. Similar tests shown in figure 2 and 3 made on all days with an rms threshold of 0.31 K which limits the number of days to 34 show no strong events since these are excluded by the threshold. The weaker reflections at the level of about 200 mK are seen in the average which drops from 170 to 160 mK when data with the moon below 1 degree elevation is excluded from the average.

days covered	time range	sun limit	moon limit	av rms K	rms of av K	Figure
1 to 331 in 10 day steps	0 – 24 UT	none	none	0.20	0.39	1
1 to 334 in 1 day steps	0 – 24 UT	none	none	0.17	0.30	2
1 to 334 in 1 day steps	0 – 24 UT	none	1 deg	0.16	0.29	3

Table 1. Results of the average FM spectrum with and without moon elevation limit

Owing to the strength of the FM signals from micrometeorites and satellites it is difficult to determine the contribution from the reflections from the moon even after using a threshold on the rms to eliminate the FM reflections from the strong meteor events. However in order to minimize the effects of RFI an rfi threshold of 2.1 sigma is found in memo 468 to provide a good rejection of all FM.

An estimate of the effect of FM reflection from the moon on the global 21-cm absorption is made using an rfi threshold of 2.1 sigma. The results of the grid search listed in table 2 and an eyeball judgment of the “bump up” at 88 MHz in figure 4c of about 50 mK along with the 60 mK and 80 mK increase in the 21-cm amplitude in table 2 case a to b and table 2 case c to case d .

An effect of 60 mK is in reasonable agreement with what is expected for the strength of FM reflections from the moon from antenna on earth. The geometry, radar equation and parameters of the reflection is studied in memo 244 and a result of 15 mK. Changing the EDGES gain from 1 to 4 and increasing the wavelength from 3 to 3.3 m in memo 244 brings the result up to 70 mK which is close to 100 mK measured by the MWA given the effects discussed in memo 244.

frequency MHz	SNR	amp K	width MHz	rms1 mK	rms2 mK	range MHz	smooth scale	moonlim deg	case
78.2	33	0.55	20.9	56	33	60 - 102	4	90	a
78.3	26	0.49	20.9	55	38	60 - 102	4	1	b
78.1	26	0.57	20.9	52	22	60 - 104	8	90	c
78.1	21	0.49	20.9	47	24	60 - 104	8	1	d

Table 2. Results of the grid search for rms threshold of 0.5 K with 5-terms

The cause of the reflection can be identified using the characterized by making the tests listed in table 3. A closer examination of the data along with an estimate of the expected reflections from satellites indicate that the strong FM reflections of short duration are most likely to be from STEVE (Strong Thermal Emission Velocity Enhancement) events and not from reflections from satellites as suggested in memo 424 which are not likely to produce a reflection as short as 10 seconds. Short bursts of the FM and amateur radio signals are discussed in memo 404 as being from “Sporadic E” which are probably due to STEVE events which may also have been observed by the Jicamarca radar (see reference).

Source	memos	duration	Rate of occurrence	Strength over 100 kHz channel	number of carriers
micrometeorites	310 311	2 – 10 sec	about 10 per hour	5-500 K	5 - 50
meteors	469	6 -12 hours	30 per year	200-20000 K	5 - 22
STEVE events	404	3 – 60 sec	needs solar activity	~ 4000 K	~ 10
satellites	424	few minutes	16 per day	~ 100-1000 K	~ 50
Space station	424	90 minutes		> 1000 K	~ 50
moon	250 468	continuous	need moon up	50-80 mK	~ 100

Table 3. Reflected FM range 88-108 0.2 spacing in US 88.5 0.1 spacing in EU and Australia

A test of the occurrence of the “short bursts” is shown in Figure 5 which shows data from 2025 day 171 from 3.13 to 3.15 and 16.20 to 16.22 UT in 0.01 hour steps. These time ranges for which the FM spectra changes on the time scale of 0.01 hours and are daytime and nighttime respectively. Most of the FM on day 171 shown in figure 1 occurs from 3.8 to 4.5 hours is from a meteor event.

In summary the relatively weak reflections of FM signals from the moon and micrometeorites need to be filtered out with rfi threshold and the data average with moon up should be tested to check its effect on the final global 21-cm results. EDGES also shows that short bursts occur at daytime and nighttime and their occurrence increases with solar activity.

References: Study of waves observed in the equatorial ionospheric valley region using Jicamarca ISR and VIPIR ionosonde Pablo Martin Reyes 2017

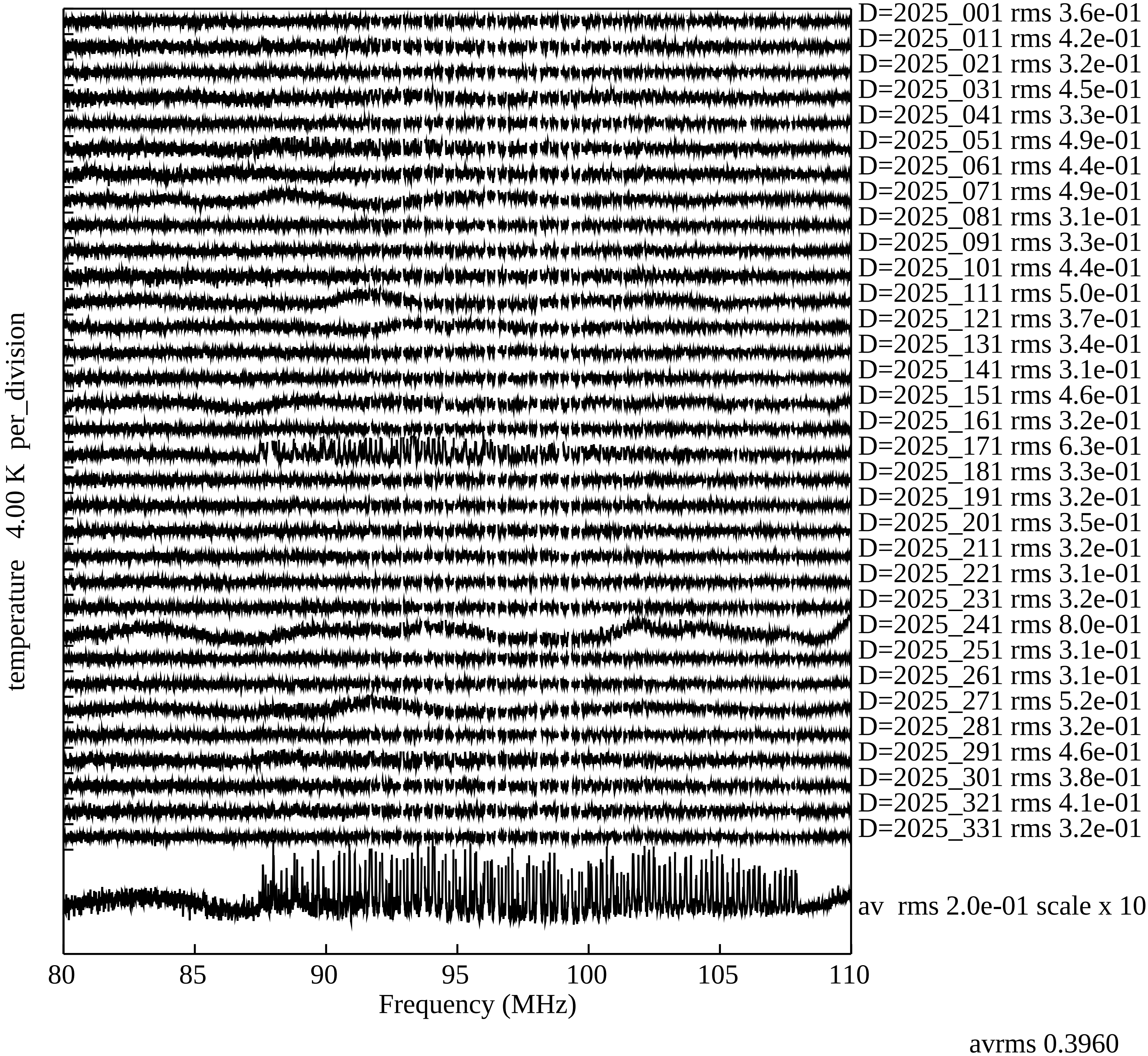

Figure 1. Residuals of spectra from the WA for every tenth day of 2025 day 1 to 331

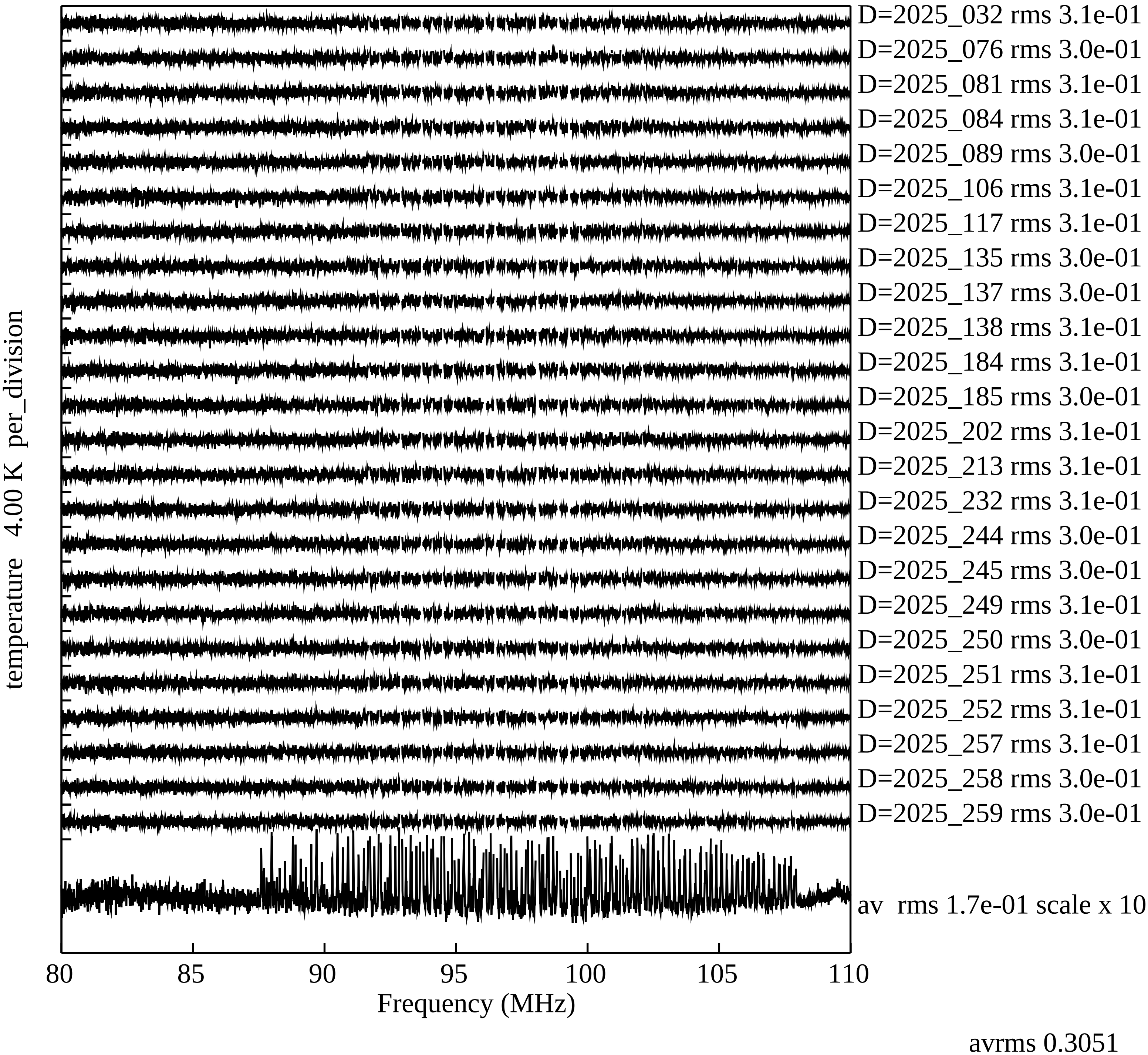

Figure 2. Residuals of 2025 days 1 to 341 with rms threshold less than 0.31 K

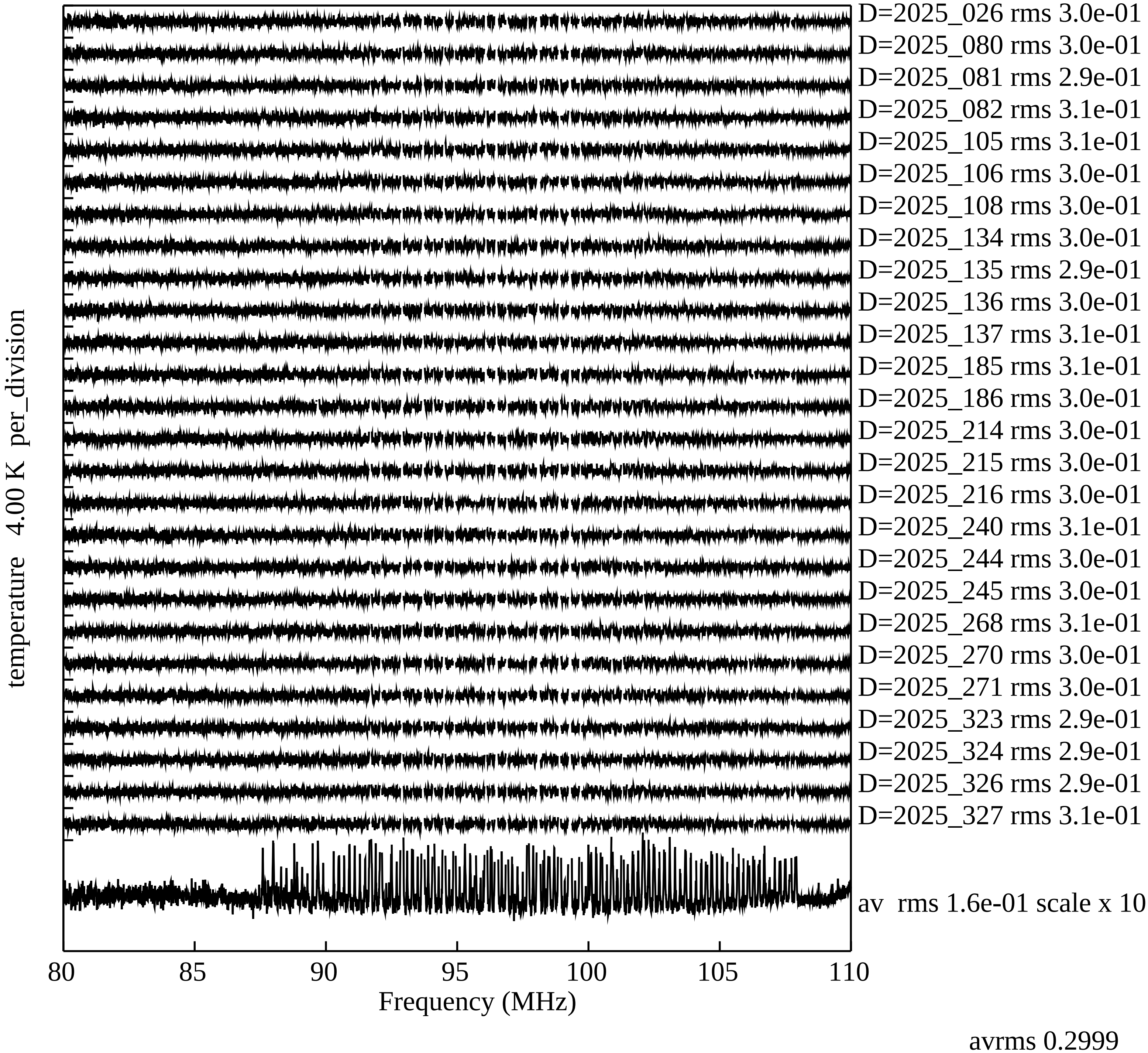

Figure 3. Residuals of 2025 days 1 to 341 with rms threshold less than 0.31 K and moon below 1 degree

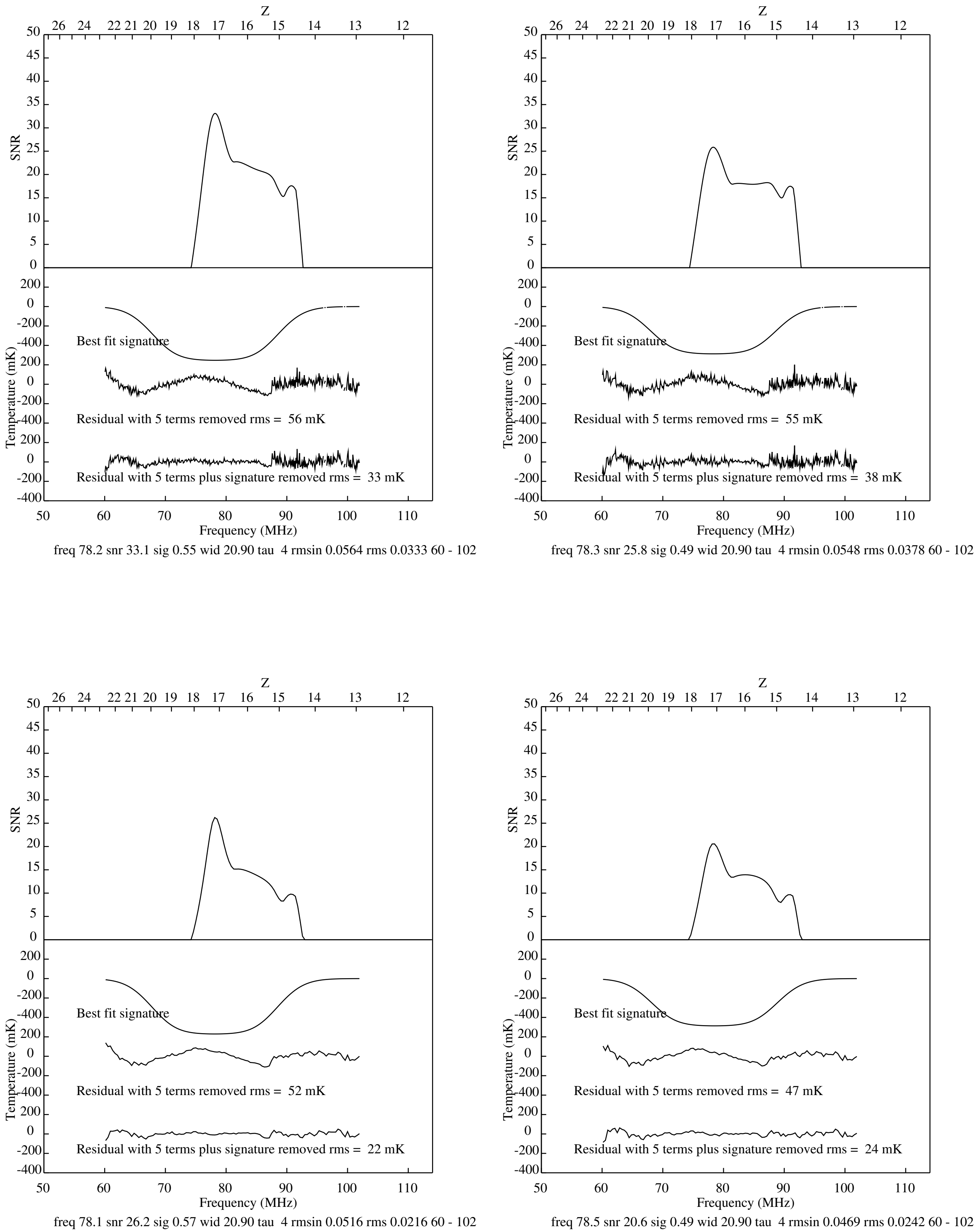

Figure 4. Plots of the global 21-cm results in table 2 for cases a to d

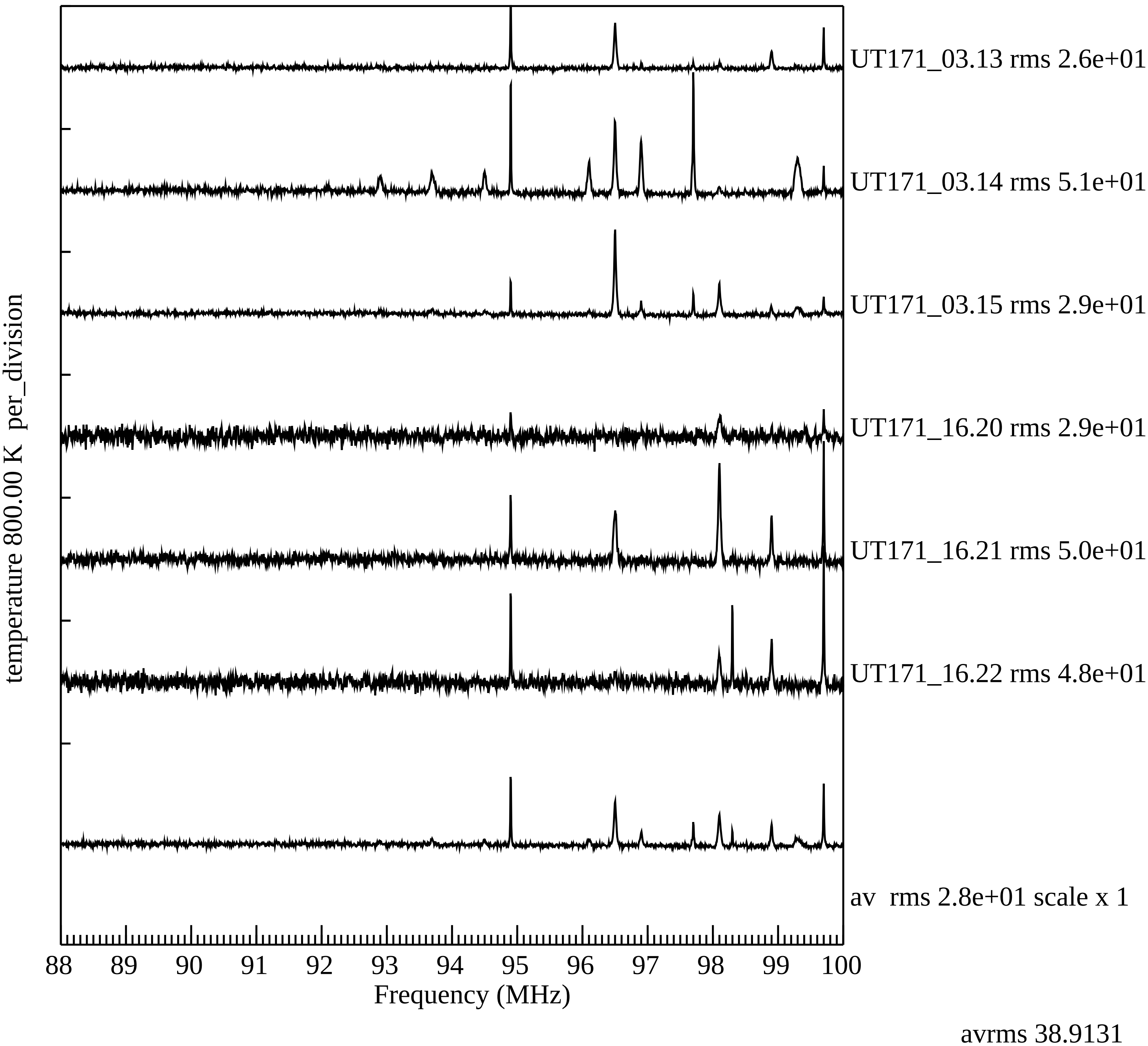

Figure 5. Residuals for 2025 day 171 with 6 kHz on fine time scale without rfi excision