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To: EDGES group

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Subject: 21-cm absorption from Devon Island using better RFI filtering

An absorption search using data from Devon Island over a wider frequency can be obtained using the filtering techniques developed in memo 418 to improve the results from the 2023 deployment of EDGES-3 at the MRO.

Preliminary absorption searches on the data from Devon Island are shown in Figure 3 of memo 397 which covers 68 to 110 MHz and in Figure 4 of memo 402 which covers 65 to 95 MHz. With improved RFI filtering a result consistent Bowman et al. 2018 which covers 64 to 98 MHz can be obtained and Figure 1 shows the result of an absorption search using 30 minute blocks of all available data from 2022 days 221 223 224 225 226 227 228 229 230 231 232 233.

The first stage filter thresholds were set to -maxrmsf 100 -maxfm 100 -rfi 2.5 -nrfi 4. The second stage rms threshold was set to 0.37 and 5 loglog polynomial terms were used for the foreground and systematics.

A subtraction of the EDGES 2018 result with tau 7 center frequency 78 MHz and width 19 MHz is shown in Figure 2. This shows a reduction in the rms from 204 to 185 mK prior to adding the absorption parameters and a best fit to a weaker absorption with a larger rms residual help fit the systematics. This test adds confidence that the EDGES 2018 21-cm absorption is also present in the data from Devon Island. For a valid “subtraction test” it is important to ensure that exactly the same dataset is used following the subtraction and that any rms thresholds do not change the dataset.

The potential of the Devon Island site for a future deployment depends on avoiding the large RFI which was present in the August 2022 deployment. If the RFI is due to Polar cap sporadic-E it could also be present in the arctic winter as reported by MacDougall et al. 2000.

The source of the RFI at Devon Island is unknown but could be from the scattering of power line noise by polar cap sporadic E layers in the ionosphere. Figure 3 of memo 402 shows that the added noise is present over all 24 hours and is even a little stronger when the Sun is below the horizon from about 4 to 8 hours UTC so the noise is not being received directly from the Sun.

Figure 3 shows that there is little change with time of day when 3 physical terms are removed to take out the effects of changes in ionospheric absorption. It also shows a slight increase in rms when the when the Sun is below the horizon which makes it unlikely that any of the RFI is directly from the Sun.

Figure 4 shows that there are changes in the ionospheric absorption with time of day and changes from day to day in Figure 5. Some of the changes are from solar activity which is not strong enough to have been filtered out and while the obvious solar activity seen in the waterfall plots of the data when the

Sun is above the horizon have been excluded changes in the noise directly from the Sun are hard to identify in the waterfall plots and have not been excluded.

Figure 6 shows that the effects of RFI are relatively large on day 227 compared with day 226. A closer examination of the data from 11 to 14 UTC on day 227 shows that the noise has a spectral index closer to 1 and is most likely from the Sun.

With the exception of some times like from 11 to 14 UTC on day 227 the plots are consistent with the noise being from distant power line noise scattered from irregularities in the ionosphere but the lack of change with UTC or day in the absence of solar activity seen in the waterfall plots implies that any scattering from the ionosphere must be from relatively stable irregularities produced by winds. Figure 6 compares different days at the same UTC times.

Figure 7 compares the residuals with 5 physical terms removed for different days and includes data taken on days 232 and 233 to check for the source of RFI from the electronics built into the batteries. The results of these tests indicate that noise in the DC power is not a source of local RFI although a change is seen when powered by external Lead-Acid batteries instead of the LiFePo battery. This change was most likely due to a change antenna s11 for this data. The spectra with batteries inside the antenna box on day 233 in Figure 7 are not significantly different from the spectra taken using the external LiFePo batteries. See memo 396 for details of the tests made on days 232 and 233.

A FM radio carrier at 90.1 MHz 105.1 and other FM carriers are seen in most of the data, including data when the Sun is below the horizon. The 90.1 MHz FM carrier could be from Mary River mine which is about 560 km from HMP and 105.1 MHz could be from Resolute Bay.

Figure 8 is a sample spectrum from Devon Island which shows that the spectrum which is uncalibrated and has 37-terms removed is far from being just Gaussian noise and has FM carriers and "spiky" unidentified components. The added noise in Figure 8 from whatever is the true source of the spiky noise is only about 10 K out of the 1900 K at 75 MHz expected from the sky noise but its contribution to the systematics which limit the measurement of the global 21-cm signal is very large.

A search for local RFI was made during the occupation but nothing was found. It is possible that very strong power-line noise from the region around Resolute, which is only 165 km away, could reach the antenna via a diffracted path but these would need to be extremely strong to overcome the path loss.

Another possible source of noise in the arctic is from the ionosphere itself. EDGES-2 measured the electron temperature at the MRO and obtained temperatures around 800 K (Rogers et al. 2015) but Walker and Rees 1968 report electron temperatures as high as 3000K in the Aurora and if the Aurora emission tends to be "spiky" emission from the ionosphere might be the source of the RFI so this needs further study.

In summary the RFI present in the data from the Devon Island HMP site has FM carrier signals which must be from distant sites and noise which could be from both distant and nearby sources. Based of the literature it is not clear if the HMP site will be free of RFI during the winter.

References:

MacDougall, J.W., Jayachandran, P.T. and Plane, J.M.C., 2000. Polar cap Sporadic-E: part 1, observations. *Journal of Atmospheric and Solar-Terrestrial Physics*, *62*(13), pp.1155-1167.

Rogers, A.E., Bowman, J.D., Vierinen, J., Monsalve, R. and Mozdzen, T., 2015. Radiometric measurements of electron temperature and opacity of ionospheric perturbations. *Radio Science*, *50*(2), pp.130-137.

Walker, J.C.G. and Rees, M.H., 1968. Ionospheric electron densities and temperatures in aurora. *Planetary and Space Science*, *16*(4), pp.459-475.

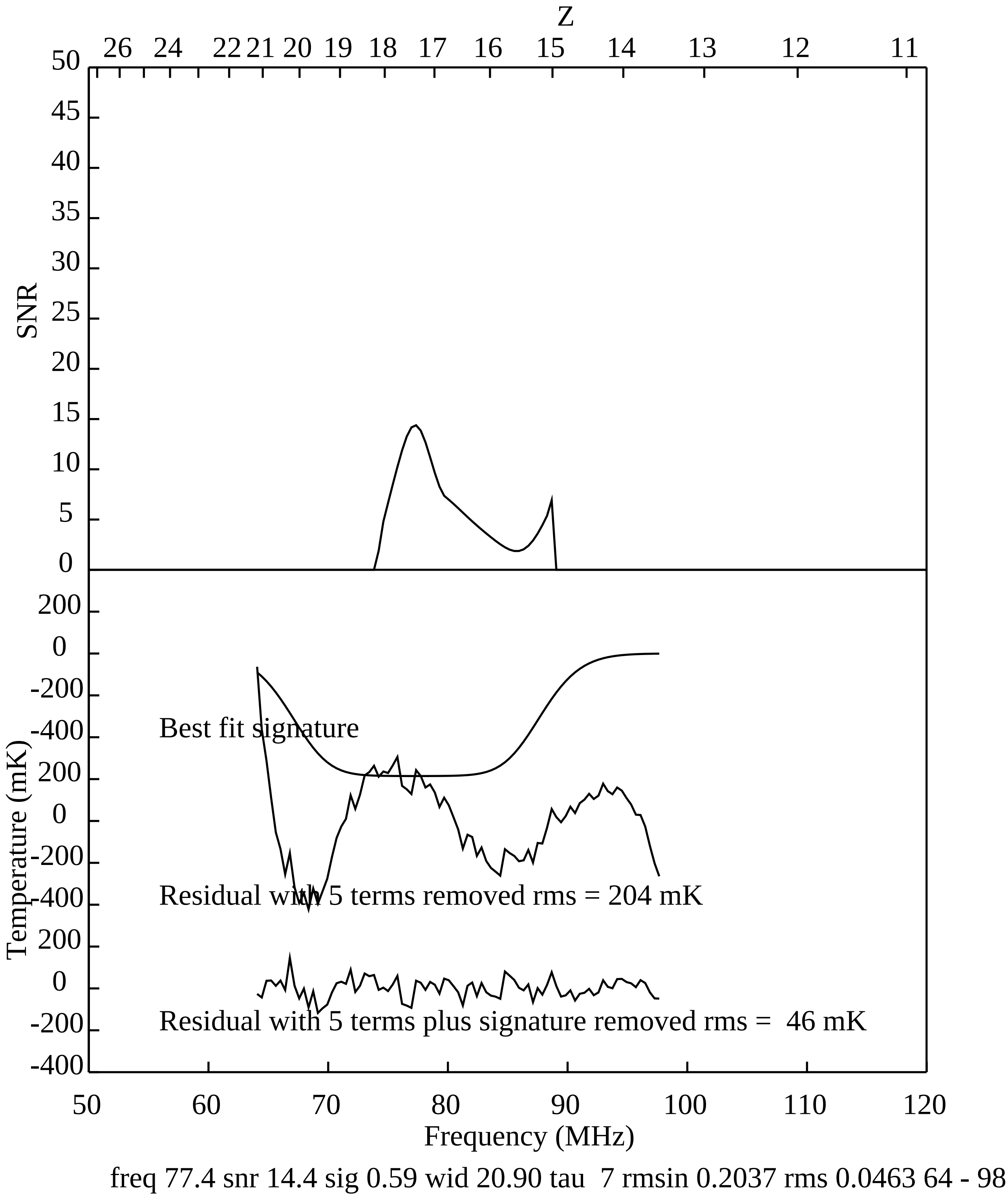

Figure 1. Results of grid search for absorption using 5 loglog polynomial terms.

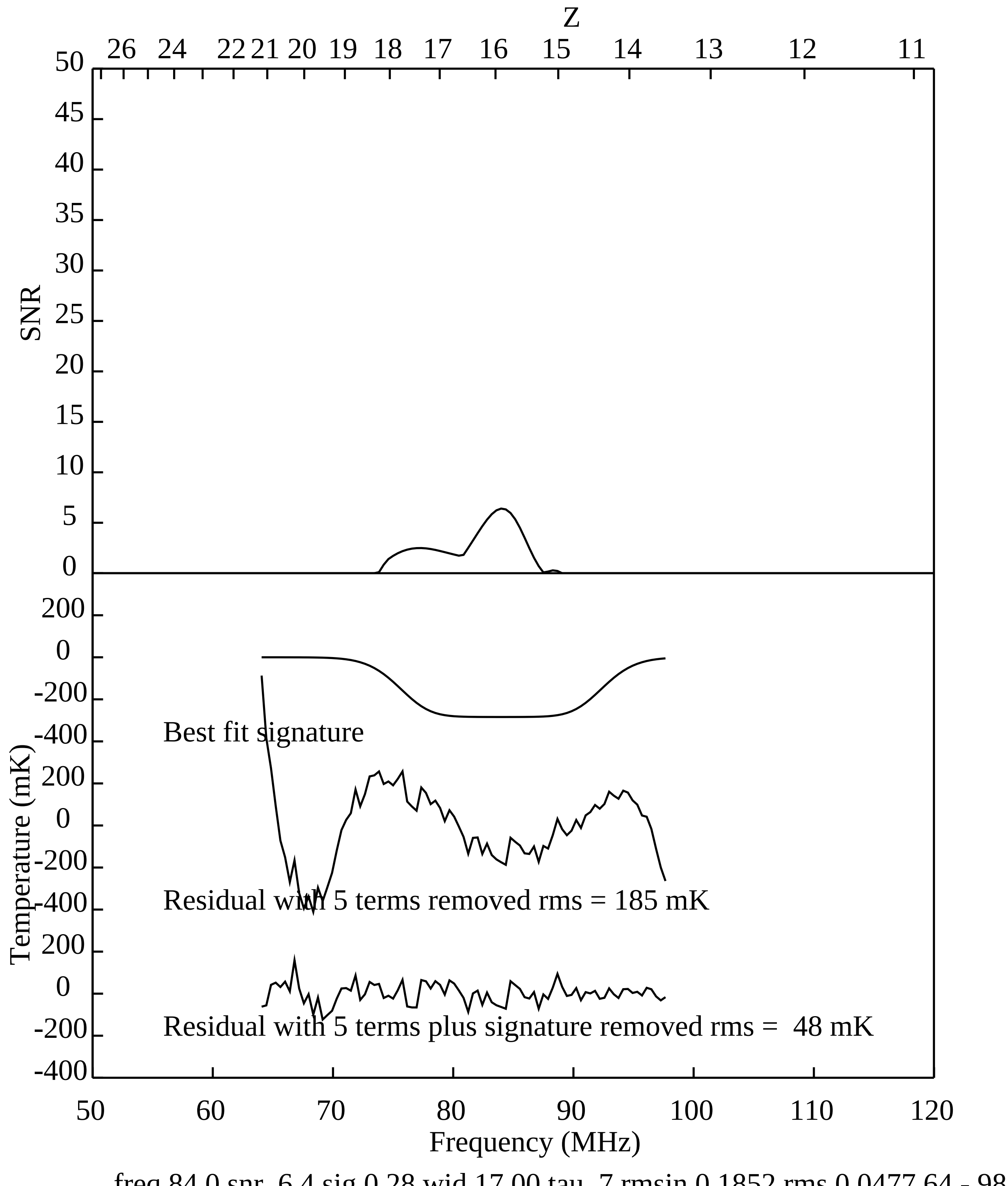

Figure 2. Results of grid search following subtraction of the EDGES-2 2018 result.

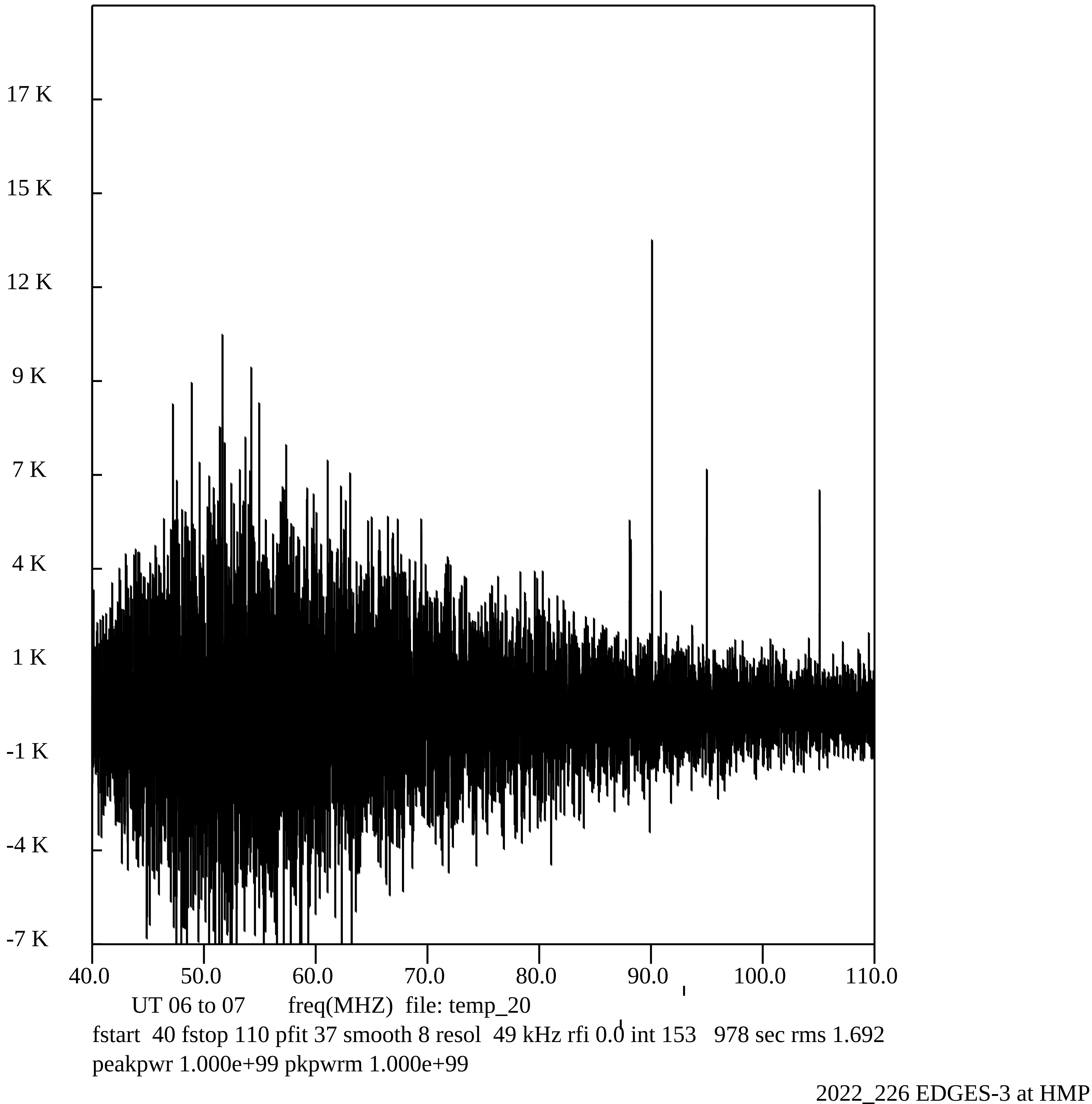

Figure 8. Spectrum for 2022_226 6 to 7 hrs UTC from EDGES-3 at Devon Island with FM carriers at 90.1 and 105.1 MHz.