EDGES MEMO #492

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
HAYSTACK OBSERVATORY
WESTFORD, MASSACHUSETTS 01886

August 28, 2025

Telephone: 617-715-5533

To: EDGES group

From: Alan E.E. Rogers

Subject: Limits of reflections of FM radio signals on EDGES Global 21-cm Experiments located at Adak Island Devon Island and Western Australia

Measurements of the global 21-cm absorption signal have been made at sites in Adak Island Alaska, and near the Haughton-Mars Project Research Station (HMPRS) on Devon Island and near the Murchison Radio-astronomy Observatory (MRO) in Western Australia. These observations which cover 55 – 105 MHz rely on being able include part of the FM radio band which covers 88 to 108 MHz. The signals from FM radio stations within 2000 km have line of sight to reflections from ionized regions in the ionosphere which occur as high as 100 km from the burn up of meteors and micrometeorites. The micrometeorites are present all the time and consequently the number of FM stations closer than 2000 km need to be minimized for a good site. FM radio signals from stations beyond 2000 km can have line of sight from the satellite to the radio astronomy antenna since their orbit is above 100 km. Depending on the radar cross-section and orbit of the satellite significant FM radio reflections will need to be filtered out to avoid loss of the spectrum critical to the 21-cm measurements. This paper analyzes the FM reflections in EDGES data to aid in the choice future sites for global 21-cm observations.

1. Introduction:

Following measurements of the global 21-cm signal by EDGES (Bowman et al., 2018) with the analog electronics in a box under the antenna and digital electronics in a hut about 50m from the antenna EDGES-3 was developed with all the electronics contained inside the antenna. EDGES-3 was then deployed in Oregon for a test in 2009 and deployed on Devon Island in 2022 and then moved to the MRO in late 2022. A second EDGES-3 was installed on Adak Island and 27 days of good data was obtained from 10 December 2024 to 29 April 2025. The advantage of EDGES-3 was the ability to fully calibrate the system remotely as the Vector Network Analyzer (VNA) and also all the switches are contained inside the antenna (Cappallo et al., 2025). The amount of data obtained at Adak was limited by difficulties in maintaining operation of the generator under very wet conditions and avoiding solar emissions by limiting the data to the nighttime when the Sun was more than 20 degrees below the horizon.

2. Site locations

Table 1 lists the locations where the EDGES-3 has acquired data as well as the size of the ground plane and the orientation of the antenna.

site	latitude deg	longitude deg	antenna azimuth deg	ground plane
Skull Creek Oregon	42.387	-118.764	0	30×16m wire grid
Devon Island	75.432	-89.811	10	50x25m wire grid
MRO	-26.714	116.604	269	50x49m welded mesh
Adak	51.943	-176.599	240	50x25 wire grid

Table 1. EDGES-3 locations

The antenna azimuth is the direction between the dipole elements and is the direction of the minimum horizon gain, which is typically less than -25 dBi depending on the ground plane. The antenna gain rises from about 2 dBi at 20 degrees elevation to 6.5 dBi at the zenith at 90 degrees from the antenna azimuth at 100 MHz.

3. An example of estimated strength of FM reflection from a satellite

The expected peak strength for the reflection of 100 kw FM signal from a satellite is calculated to be about 7 K with 6 kHz resolution shown in the figures assuming:

distance of FM transmitter to satellite = 550 km
distance of EDGES to satellite = 1000 km
radar cross-section of satellite =100 m^2
EDGES gain = 6 dBi
FM transmitter gain = 0 dBi in the direction of the satellite
FM transmitter = 100 kw at 100 MHz
EDGES resolution = 6 kHz

$$pr = p_t G_t X_{sat} \lambda^2 G_{rec} / (4\pi d^2 4\pi D^2 4\pi) \quad (1)$$

where

pr is the received power
pt is the FM transmitter gain
Gt is the FM transmitter gain
Grec is the EDGES antenna gain
Xsat is the radar cross-section of the satellite
λ is the wavelength
d is the distance from the FM transmitter to the satellite
D is the distance from the satellite to the EDGES antenna

Estimated signal 7.2 degK 3489 Jansky -225 dBw/m^2/Hz

Details of the physics and geometry of the scatter along with a verification of the equation 1 is in Principles of Classical and Modern Radar Bistatic Radar (Manikas, A., 2020).

4. Sample plots

Figure 1 shows plots of the residuals of the data from Adak, Devon and the MRO without filtering of the FM reflections while figure 2 shows the residuals with filtering to remove data with reflection signals more than 2.1 sigma above the noise level in each 6 kHz frequency channel. Figure 3 shows the spectra from the test in Oregon which shows that every frequency channel has a TV signal way above the noise at an average level of about 3000 K. The time range of data in the plots are listed in table 2 below:

site	range of days
Skull Creek Oregon	2019 day 256
Devon Island	2022 day 221 - 223
MRO	2024 day 345 - 2025 day 116
Adak	2024 day 345 - 2025 day 116

Table 2. Range of days of data used in the plots
In the case of Adak data from only 27 days of the time range listed had data owing to problems with the generator.

5. Results

The data from Adak is hardly effected by reflections as the nearest FM station is in Anchorage at about 2000 km. Devon island and the MRO have about 10 FM and 30 FM stations within 2000 km respectively. The data

from the 3 sites show an average contribution of about 0.1 K, 5 K and 600 K from the FM reflections without filtering. With filtering all three sites are acceptable but with a loss of data of about 30 percent from the filtering needed for the data from the MRO. A test made at a site in Oregon found that so much of the band was filled with FM reflections from micrometeorites from about 100 FM stations within 2000 km that it was not possible to get any 21-cm data in the FM band.

5. Summary and Conclusions

While there is evidence of FM reflections from satellites the mayor source of strong reflections are from ionized regions in the ionosphere which result from the “burn up” of meteors and micrometeorites which occur at an altitude below about 100 km. This strongly suggests that the best sites for observations of the global 21-cm signals are those with the minimum number of FM radio stations within 2000 km.

The data from Adak and the MRO are reasonable sites that are not limited by FM. The site on Devon Island is marginal and the site in Oregon has too many FM radio stations within 2000 km to get any 21-cm data in the FM band. The Adak site is one of the very best available on the earth for observations of the global 21-cm signal and is probably better than can be achieved in lunar orbit or on the lunar surface without a large ground plane to avoid the reflections from strong radio sources by the lunar regolith.

References:

Bowman, J.D., Rogers, A.E., Monsalve, R.A., Mozdzen, T.J. and Mahesh, N., 2018. An absorption profile centred at 78 megahertz in the sky-averaged spectrum. *Nature*, *555*(7694), pp.67-70

Manikas, A., 2020. Principles of Classical and Modern Radar Bistatic Radar. *Department of Electrical & Electronic Engineering Imperial College London.*

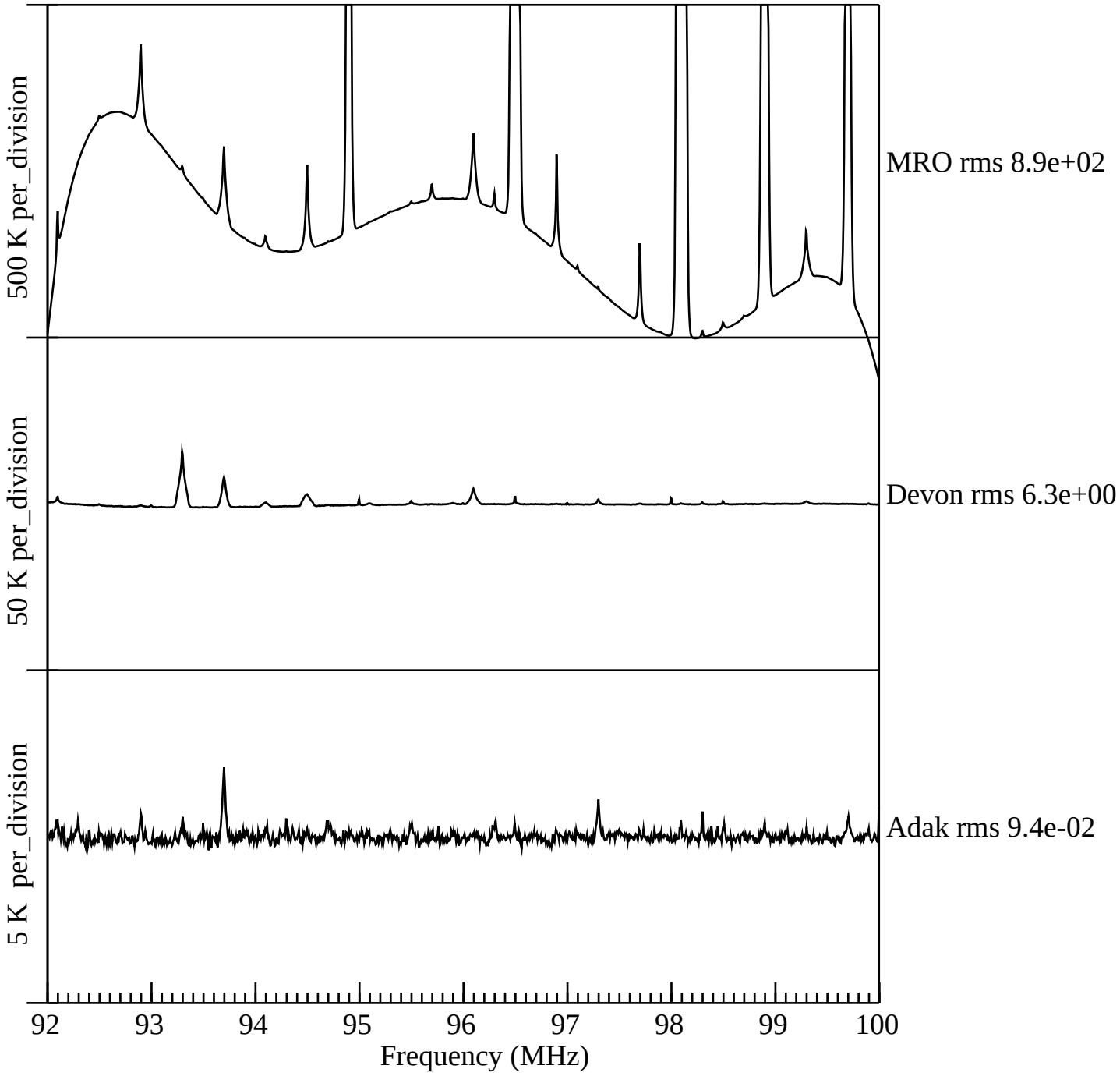

Figure 1 Data from the MRO, Devon Island, and Adak in the FM band without filtering

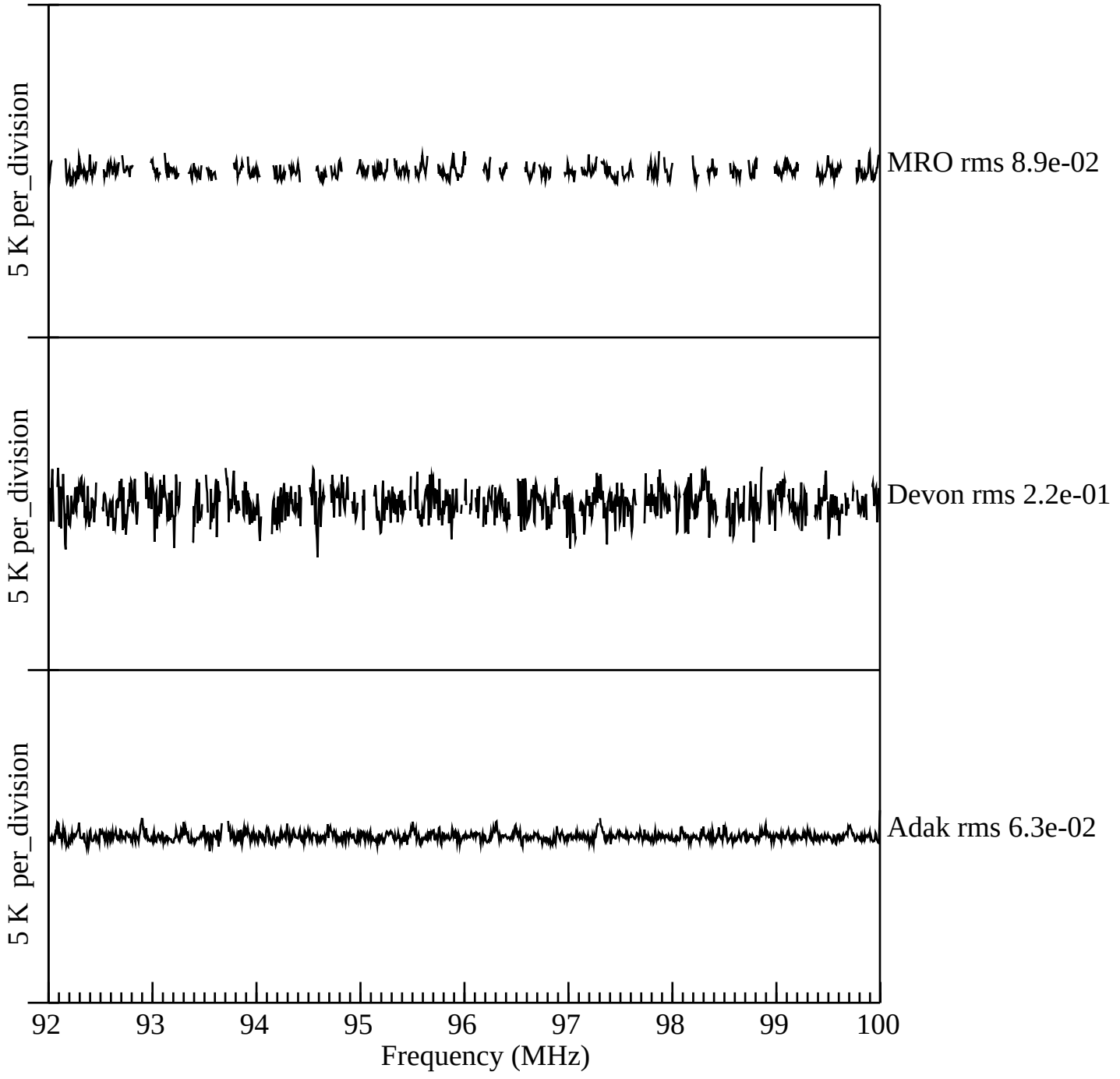

Figure 2. Data from the MRO, Devon Island, and Adak in the FM band with filtering

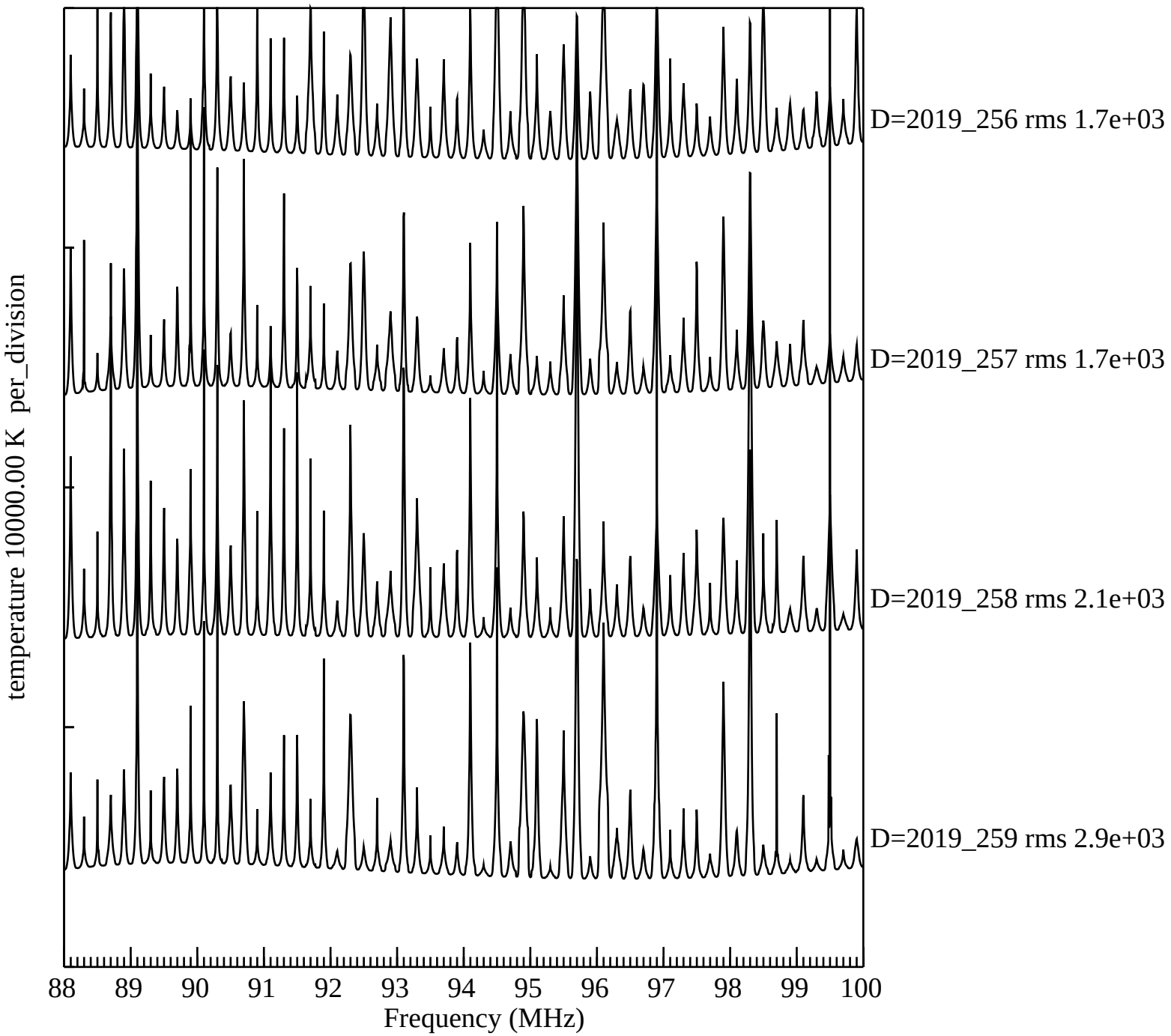

Figure 3. Data from Oregon in the FM band without filtering