MASSACHUSETTS INSTITUTE OF TECHNOLOGY
HAYSTACK OBSERVATORY
WESTFORD, MASSACHUSETTS 01886
March 30, 2021 EDGES Memo #389

VHF Ny Ålesund Radio Survey

Devin Huyghebaert and Juha Vierinen

March 2022

1 Introduction

A radio interference and site suitability survey in Svalbard was conducted between 9th of March and 16th of March. The main sites to be surveyed were located around Ny Ålesund. A measurement was also conducted at the EISCAT radar site near Longyearbyen.

The purpose of the survey is to evaluate the suitability of the Ny Ålesund area for the location of the EDGES-3 instrument, to reproduce the epoch of reionization signature performed on the southern hemisphere. The most important band of frequencies to investigate is between 50-150 MHz. The amount of meteor scatter, and the amount of local interference are both of interest. Soil conductivity, the elevation blockage, and the flatness of the ground are also of importance.

While the Ny Ålesund area is protected in terms of radio equipment above ≈1 GHz, no such protection exists for lower frequencies. There exists e.g., an ionosonde transmitter (≈1-16 MHz) within the Ny Ålesund settlement area, located near the Zeppelin observatory cable car station. Most of the local communications are conducted using ≈172 MHz FM radio. There are two repeater stations on top of the mountains Scheteligfjellet and Zeppelinfjellet to increase the range for this band. The air traffic control for the Ny Ålesund airport provides Aerodrome Flight Information Service (AFIS) at frequencies 123.9 MHz and 121.5 MHz. It is expected that there are not very many powerful sources of emission within the 50-150 MHz band nearby.

The main purpose of this report is to outline the key findings of the radio survey and provide recommendations for a future EDGES site. The equipment we had with us was useful for identifying sites that are not suitable in terms of radio interference, but only an instrument with identical functionality to the EDGES instrument itself would be able to exhaustively determine if a site meets the requirements. For example, with the setup used, measurements in the millikelvin range were unobtainable. The survey was conducted during the winter, so the ground was frozen and covered with snow, information about site suitability was mainly obtained based on discussions with the local site staff.

2 Equipment

The following equipment were brought to perform the survey:

- PC based network analyzer Signal Hound BB60C.
- Dell rugged PC, with extra EU power plug
- 80 meters of RG213U (N-N)
- 20 meters of RG58 (N-N)
- 10 meters of RG58 (BNC-BNC)
- A full spare set of cables
- NanoVNA portable network analyzer
- 2 $\times$ 12V lead acid batteries, 1.2 Ah on the smaller battery
- Battery box with pre-amplifier inside
- 2 $\times$ ZFL-1000LN+ pre-amplifiers
- External 8 TB hard drive for backup of measurements
- Assortment of connectors and tools.
- Diamond D130-J discone antenna 25-1250 MHz [3]
- Personal PC laptops
- Carbon fiber camera tripod for mounting the discone antenna

The system was tested at UiT before leaving for Ny Ålesund. This was to determine if the setup would function for the test. Measurements were made in the parking lot of the Siva Innovasjonssenter Tromsø, with a picture of the setup shown in Figure 1.

A pre-amplifier box was quickly designed and assembled for the measurements. The amplifier box can be seen in Figure 1 as the black plastic box below the antenna. A block diagram of the setup is shown in Figure 2. This pre-amplifier was determined to be required for making measurements at the thermal noise level of the system, as the spectrum analyzer had a system noise temperature of $\approx$ 3000 K. Future improvements would include making the system resistant to RFI through a conductive casing, though aspects of the current design proved useful for the field test, including the ability to power on and off the pre-amplifier using a switch on the front of the case.

The details for the pre-amplifier (ZFL1000LN+) can be found at the link: `https://www.minicircuits.com/pdfs/ZFL-1000LN+.pdf`. Based on the specifications, the amplifier as a noise figure of 2.9 dB and $\sim$ 20 dB gain with the 12V battery used.

Figure 1: Test setup at UiT.

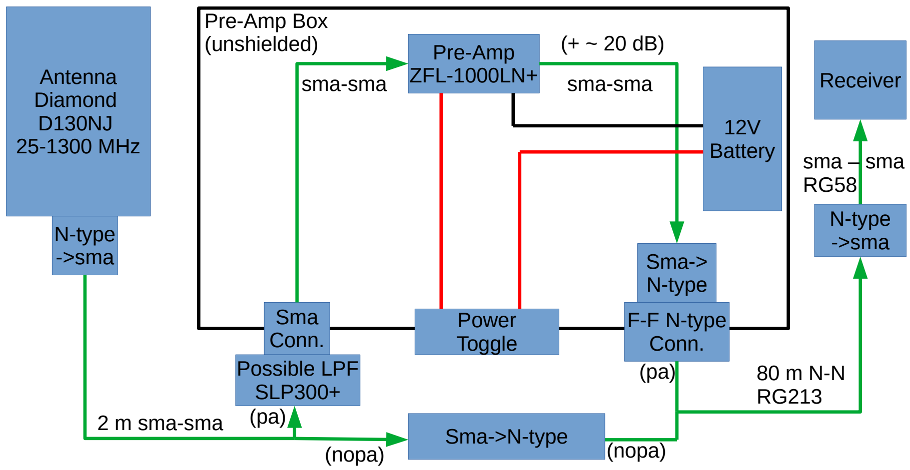


Figure 2: Block diagram of test setup with and without pre-amplifier. The tests were performed without the low pass filter (LPF).

2.1 Receiver characterization

We assume that the noise temperature measured can be given by the following equation:

$$T_{\mathrm{m}} = T_{\mathrm{an}} + (T_{\mathrm{amp}} + GT_{\mathrm{ant}})L + T_{\mathrm{amb}}(1 - L), \tag{1}$$

where T_{m} is the measured power, T_{an} is the spectrum analyzer noise temperature, T_{amp} is the preamplifier noise temperature, G is the gain of the preamplifier, $L = P_{\mathrm{out}}/P_{\mathrm{in}}$ is the cable loss for the ≈ 80 m long feed line, and T_{amb} is the ambient noise temperature (about 273 K).

The T_{an} term was measured by adjusting the "ref-level" setting on the analyzer, and finding that below -50 dBm, the noise floor power level was no longer reduced from -115 dBm in a 100 kHz bandwidth. The terms G, T_{amp}, and cable loss L were measured using a network analyzer. These terms are likely to have changed somewhat during the measurements due to discharging of the battery, and up to 40 K changes in ambient temperature.

Vector network analyzer measurements of the antenna S11 and the long cable loss (S12) are shown in Figure 10. Note that the antenna is not very well matched below 90 MHz, but there is a region where the antenna functions relatively well at 50 MHz and 70 MHz.

2.2 Equipment on site

The Ny Ålesund site is fairly well stocked with equipment, which can be rented out from the Norwegian Polar Institute (NPI) or directly from Kings Bay. For this trip we rented from NPI and asked to use:

- 2 × snow scooter
- 2 × snow mobile outfit
- VHF radio
- sledge

A listing of equipment available for rental can be obtained from the institute. For example, it is possible to hire a boat for a summer deployment for transport of people and equipment.

The pricelist for NPI equipment can be accessed at: (`https://varekatalog.npolar.no/Varekatalog.pdf`), while the pricelist for Kings Bay can be accessed at: (`https://kingsbay.no/wp-content/uploads/2022/02/Prisliste-2022-Engelsk_v3.pdf`). Note that it is 780 nok per hour for a driver and/or polar bear watch during day, 4-8pm 1145 nok, 1925 nok otherwise (night and weekend). It is possible to have someone in the group do polar bear watch, but they require a rifle permit (described in next section).

For shipping gear to Ny Ålesund, a guideline for shipping cargo is available online at: (`https://nyalesundresearch.no/research-and-monitoring/researchers-guide/cargo/`).

For getting to locations nearby Ny Ålesund, it is possible to rent boat for drop-off and pick-up, rather than full day. For a full day of boat operations (8 hours, including driver) it is $\sim$ 11,000 NOK. The boat can reach land assuming the conditions are okay (no cliffs), and holds around 8 passengers.

Kings Bay also has heavy equipment for rental, and if needed, it would be best to ask them directly about getting equipment to remote locations.

2.3 Rifle permit

We also requested to rent two polar bear rifles and a safety course on how to use said guns. However, we learned upon arrival that polar bear rifles are available only to those with a permit. For foreigners this permit can be obtained through application to the Svalbard governor. For Norwegian residents, this permit is only available through their local police district. For future trips to Svalbard, it is advisable to obtain this permit in advance of the trip, as going out into the field without a guide that is able to carry a rifle is not allowed. **The application process takes at least three weeks** if the application is made in Svalbard, and 6-7 weeks if the application is made in Tromsø. Most likely these timelines are underestimates of the true wait times.

The availability of Ny Ålesund staff to act as polar bear guards is limited. It may however be possible to hire students with the appropriate permit from the University of Svalbard. **This needs to be planned well in advance of a measurement campaign, as field work is not possible without a polar bear guard**.

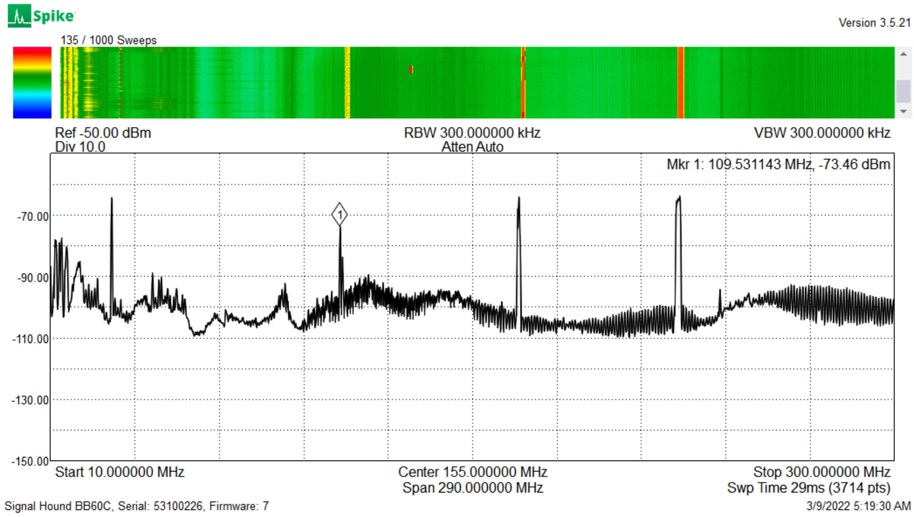


Figure 3: Outside test of Diamond wideband antenna with laptop within 2 meters. The antenna is located outside of the EISCAT Svalbard radar building. The incoherent scatter radar next to the discone antenna was not transmitting. The 109.5 and 110.3 MHz signals are for the Longyearbyen airport

3 Measurements

3.1 Longyearbyen

The first test was performed at the (European Incoherent Scatter Scientific Association) EISCAT Svalbard Radar (ESR) site outside Longyearbyen on the afternoon of 2022-03-08. The equipment was setup inside and tested before doing a test outside the EISCAT building. A pre-existing discone antenna at the site was also connected to check for interference, and showed a very noisy environment in the VHF band. When the wideband Diamond antenna was connected to the Signal Hound receiver within 2 meters there was clear interference from the laptop (e.g., Figure 3).

Outside the EISCAT building tests were performed without and with the pre-amplifier attached. A picture of the setup is shown in Figures 4. The spectrum measured without the pre-amplifier connected is shown in Figure 5. The two signals in the 30-60 MHz band are the MST radar and the meteor radar in the Adventdalen value floor, approximately 1 km from the measurement site. The 109.5 MHz and 110.3 MHz signals are the airport instrument landing service beacons. More information about the airport radio navigation and communication services can be found here: `https://ais.avinor.no/no/AIP/View/112/history-no-NO.html`. The EISCAT radar itself operates at 500 MHz, but it was not on at the time of the interference measurement.

The test at EISCAT Svalbard served as a valuable test of the system and

Figure 4: Picture of setup at Svalbard EISCAT. The large antenna on the right was not transmitting at the time of experiment. The center frequency for this radar is 500 MHz.

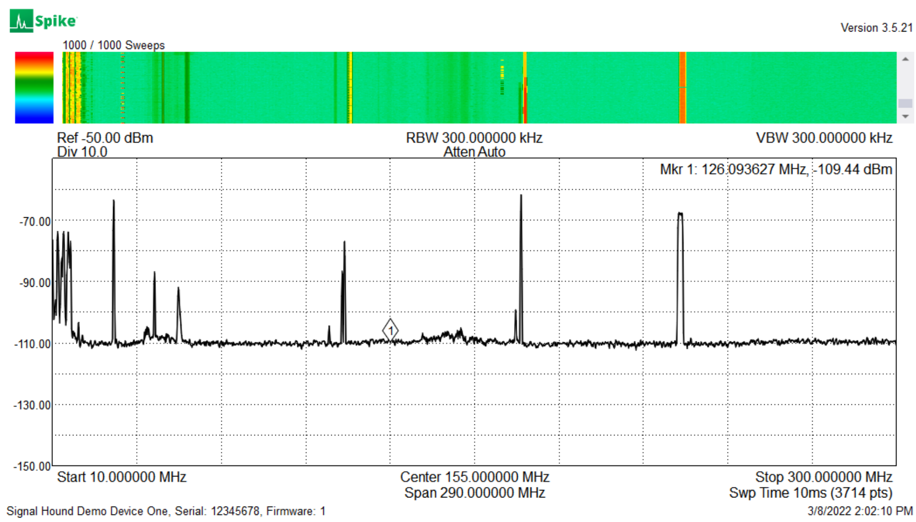


Figure 5: Spectrum measurement at ESR without pre-amplifier and with ∼ 80 m of RG213 coaxial cable for feedline. The system noise temperature of the spectrum analyzer is approximately 3000 K, which corresponds to -110 dBm within a 300 kHz bandwidth. The two peaks between 30 and 60 MHz are the meteor radar and the MST radar at the bottom of the Adventdalen valley. The 109.5 and 110.3 MHz signals are the instrument landing service beacons for runways 10 and 28 of the Longyearbyen airport. The broad band noise between 130-160 MHz is most likely radio noise present on the site.

Figure 6: Example test setup for measurements inside the Ny Ålesund settlement, near the miniature steam train. The picture on the right is the location that showed the least amount of interference within the town site.

setup in the polar conditions. It was determined that dealing with the 80 m of RG213 coaxial cable would be a problem in the field. In Ny Ålesund an empty cable spool was found for the coaxial cable, which greatly reduced the time needed for setting up the system in the field.

3.2 Ny Ålesund

3.2.1 System Test

A test of the system was performed in the town of Ny Ålesund upon arrival. There is an area around Ny Ålesund that is considered safe from polar bears, essentially the town site. Without a rifle permit and rifle the research is restricted to this area. The most promising location inside the town site was located at the GPS coordinates: 11.933402°E, 78.926139°N, 10 ft. altitude.

For the site visits in the field, we determined it would be best to disassemble and re-assemble the antenna. This reduced the possibility of losing antenna parts during the trip. This did end up requiring an extra $\sim$ 10 minutes for the setup of the antenna.

There were 3 external locations where spectra and IQ measurements centered on 100 MHz were taken on March 11, 2022. The Zeppelin observatory also had data taken, though it was expected to be a noisy environment due to the many instruments situated in the vicinity. The locations tested are shown in Table 1.

Site	GPS Lon	GPS Lat	altitude
1. Corbelle station	12.157245° E	78.900986° N	87 ft.
2. Geopol cabin	11.475479° E	78.95096○ N	100 ft.
3. Kjaerstranda cabin	11.450739° E	78.914920° N	10 ft.
4. Zeppelin Observatory	11.88905° E	78.90674° N	1558 ft.

Table 1: Locations of the measurements external to the Ny Ålesund town site.

3.2.2 External Sites

The agenda for March 11 that was relatively closely followed is listed below. Measurements were made at the first 3 locations listed in Table 1. At each of the sites 5 minutes of IQ were taken centered at 100 MHz, and the spectra were also measured from 10-300 MHz using the Signal Hound.

- Get snowmobiles 8:30-9:30 (1 h)
- Go to French station (Corbelle) 9:30-9:45 (0.25 h)
- Measure at French station 9:45-10:30 (0.75 h)
- Go to Kvadehuken 10:30-11:30 (1 h)
- Field lunch 11:30-12:30 (1 h)
- Make measurements 12:30-14:30 (2 h)
- Go back 14:30-15:00 (0.5 h)

A Measurement procedure for each of the sites was devised, and is listed below.

- Unspool antenna cable (15 minutes)
- Setup tripod and amp box (5 mins)
- No person next to antenna!
- First no amp, save spectrum (100 kHz bandwidth, 10-300 MHz frequency range), set reference level as low as it will go without overload (5 mins)
- Connect amp
- Repeat measurement (5 mins)
- Raw IQ (5 mins) 100 MHz ± 20 MHz
- Pack up (15 mins)

Figure 7: Example test setup for measurements outside of town in the field.

Figure 8: Picture of Second cabin past Kvadehuken.

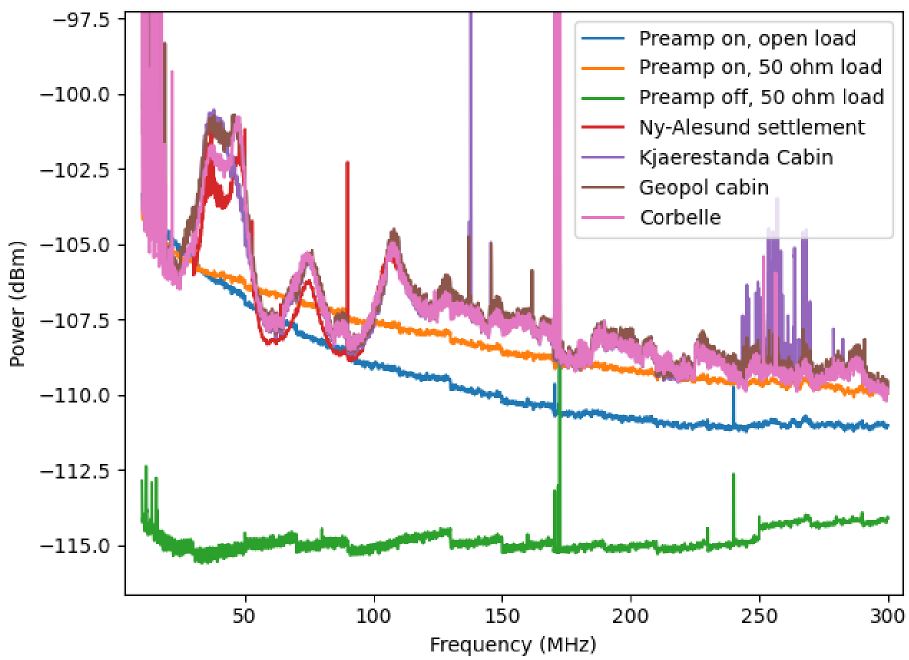


Figure 9: Combined spectra measurements taken with the spectrum analyzer in sweep mode with a 100 kHz resolution bandwidth. All measurements were done with the same gain setting on the analyzer. The that the power-stepping behaviour is a feature of the spectrum analyzer. The measurement within the Ny Alesund settlement shown with a red line was taken with a more narrow frequency range (30-109 MHz) in order to avoid receiver overloading due to the 172 MHz handheld signals. Due to this reason, the red line has a different receiver filter setting on the analyzer and the power levels deviate from the other measurements.

Some in the field pictures of the setup are provided in Figures 7 and 8.

These sites were much more radio quiet than in town, allowing the measurements to be made much more close to the actual noise floor. The spectra measurements at the sites are shown in Figure 9.

There were connector issues causing a ≈ 0.15 dB a ripple in the spectrum measurements. This is most likely due to snow and ice getting into the connectors. In order to defrost the connectors, hot air had to be blown into the connectors. This hypothesis is supported by the fact that the same setup had significantly less ripple in a measurement that was conducted at a above freezing point outdoor temperature on the next day.

At the Geopol cabin, there were also some signals in the 90-95 MHz range, which where evident in the measurements. The source of this noise was determined to be due to the laptop being very close to the feed line. In later tests, we were able to reproduce this noise by placing the laptop close to the cable. We were also able to reduce this noise when the laptop was moved 50 cm away from the feed line to an undetectable level in the roughly 10 second averaged spectrum analyzer power plot.

To further measure the system noise, measurements were made with a 50 ohm load on the pre-amplifier box in town. This helped determine the thermal noise floor of the system. Measurements of the system noise level are also shown in Figure 9.

4 Results

In Figure 9 both measurements with and without the antenna are included. The green trace shows the signal level without power to the pre-amplifier. The blue line shows the signal level with a 50 ohm load used instead of the antenna. The orange trace shows an open coaxial cable used as a load for the input to the pre-amplifier. These serve to characterize the system without an antenna connected.

The other traces show the signal levels with the antenna connected for the 3 locations investigated outside of town on March 11. There are small differences in the traces, though the trends are similar. The antenna characteristics are not consistent across the full frequency band, and therefore this could be the reason for the system thermal noise varying with frequency (open vs 50 ohm load). The small fluctuations in the field measurements are likely due to snow getting in the connectors and the subsequent icing when removing the snow. These fluctuations were not seen in measurements at warmer temperatures.

For fine measurements of the noise temperature down to mK scales, a setup with a more well matched fixed antenna, and continuous calibration is required. From the green trace, with the system fully connected and the pre-amplifier turned off, the spectrum measured by the Signal Hound spectrum analyzer is not smooth. This is likely due to the sweep settings of the analyzer, where the step function behaviour at certain frequencies is not evident in the recorded IQ data from the device. It is recommended to take IQ data for the full spectrum in subsets in the future to investigate the noise behaviour.

Another issue with the measurement was the antenna S11 across the VHF spectrum. For use in the 50-100 MHz range modifications are required to the antenna (e.g., `http://www.farr-research.com/Papers/ssn488.pdf`) to obtain a reasonable S11. The variation in the signal between 50-100 MHz is believed to be due to the antenna characteristics. Future measurements should make the modifications to the antenna that are listed in the document, or use a better tuned antenna to these frequencies. One possible simple modification would be to simply increase the lengths of the antenna rods – we unfortunately did not have the materials and equipment available on site to make these modifications.

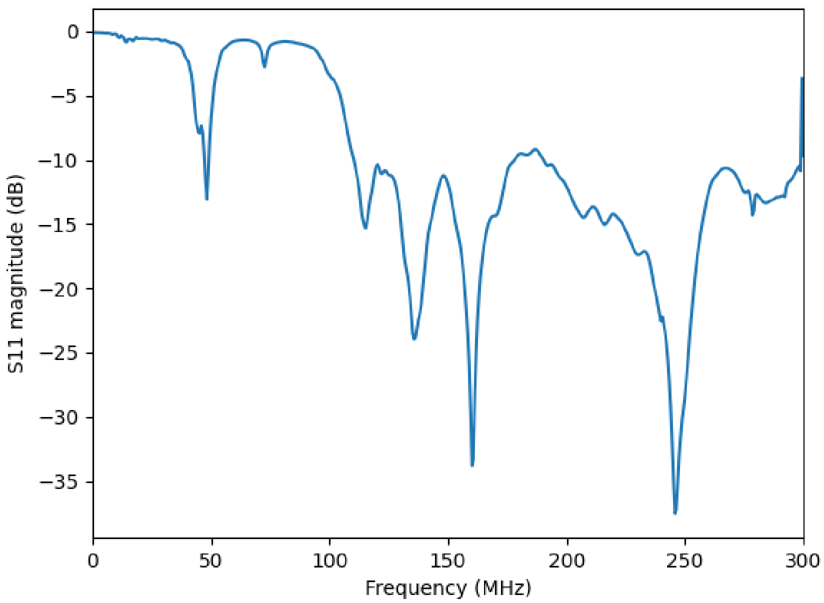
Nonetheless, the sites outside the townsite of Ny Ålesund do show promise for low noise measurements in the VHF band. Locations with radio links on the 170 MHz frequency band are shown in Figure 11. One site that was not investigated with the RFI measurement setup is shown as the blue 'X'. This is a possible setup location. Due to weather and insufficient time, it was unable to be looked at, though a local mentioned that there they were unable to use their radio in that location. The ground is also relatively flat. Pictures are provided in Section 4.3.1.

4.1 Meteor scatter

We obtained 375 seconds of complex baseband voltage at each of the explored sites. This was done using the IQ recorder utility of the Signal Hound. A center frequency was 100 MHz and the sample-rate was 40 MHz. The data files contain I and Q inteleaved as little-endian 16-bit integers. The filter on the spectrum analyzer is relatively sharp, providing a passband with approximately 27 MHz of bandwidth. In order to calibrate the raw voltage measurements, a measurement of the terminated input was taken. The calibration is only good roughly to within 3 dB or so. Plots of forward scatter meteor detections are shown in Appendix A.

One point of specific importance is the analysis settings when looking for meteor scatter. The e-folding time of a typical specular meteor trail echo is of the order of 0.1 seconds. This means that longer temporal averaging will cause reduce the ratio of the scattered power to system noise. Similarly, the spectral widths will be comparable to the spectral widths of FM radio station signals on these time scales. Radio stations playing music or speech with more frequent moments of silence will have on average more narrow spectral widths, allowing a larger signal to noise ratio to be obtained with narrow frequency bins. In order to optimize for detectability of meteor scatter in the measurements, several different frequency and time bin widths were tested, and values of 12.2 kHz and 0.19 s were selected. However, no systematic optimization was done to maximize detectability.

Note that the antenna performance for these measurements is best at the top end of the frequency band at 110 MHz. Regardless of this, meteor scatter was also observed on the lowest frequencies as well, but the noise power was lower there.



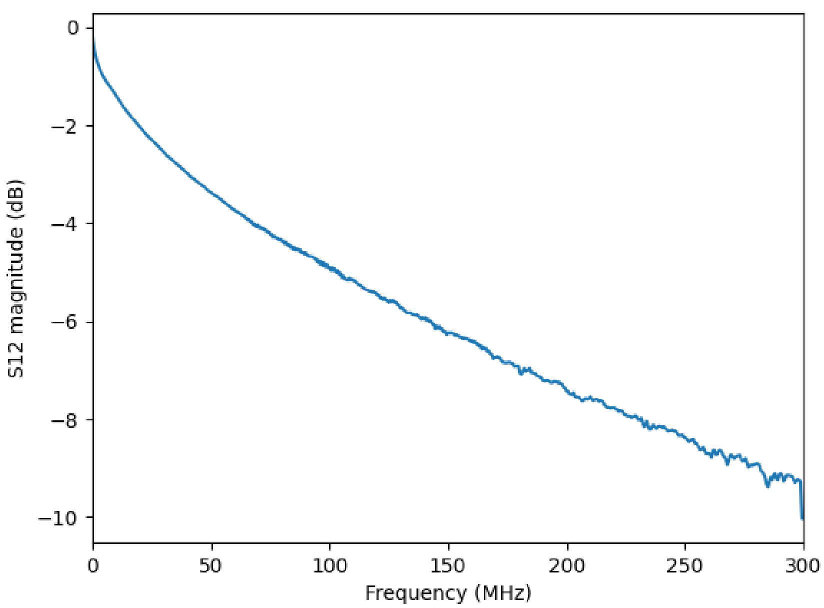


Figure 10: Top: S11 measurement of the Diamond D130-J discone antenna using a 2 meter cable. Bottom: S12 measurement of the 80-m RG-213 cable used for the RFI measurements.

Figure 11: Locations with radio communication on the 170 MHz communication frequency. The red 'X' denote locations of the 170 MHz repeater stations. The blue 'O' denote the locations of the tests made outside the townsite. The red 'o' show the locations where communications have been made on the 170 MHz radio band in the field. The blue 'X' shows a potential promising location for the receiver. A local of Ny Ålesund has stated that there is no radio reception there. Pictures of this "sandbar" area are provided in section 4.3.1.

In order to remove the ripple due to presumably iced up cable connectors, a background subtraction was performed on the measurements, removing the mean power of each frequency as a function of time. This was done separately for 37.5 second segments of measurements. What still remains on the top end of the band is a slight undulation of the background noise floor. This is most likely due to mechanical oscillations in the antenna due to the strong wind present at all measurement times.

4.2 Soil Measurements and Information

The area around Ny Ålesund is a relatively well studied area in terms of soil composition. Several measurements of soil conductivity exist [2, 1]. Based on these studies, it appears that the best season is late summer, when the soil is melted and wet.

Soil samples were retrieved from the three RFI measurement sites outside the Ny Ålesund townsite. These were stored in ziplock bags and will be sent back with the analyzer.

4.3 Site Suitability

Based on EDGES Memo 383, the site requirements are as follows:

1. Site in Northern hemisphere
2. Less than 200 transmitters in the 50 – 120 MHz band within 2000 km of the site with more than 50 km to the nearest transmitter in the 50 – 120 MHz band
3. maximum horizon, over a significant fraction of the sky, should have elevation less than 15 degrees
4. minimum distance from buildings with unfiltered computer equipment LED lights etc. 500m to prevent RFI in the 50 -120 MHz band from switching circuitry
5. maximum ground tilt of less than 1 degree over an area of 100x100m surrounding the antenna
6. maximum height of object within 50m of antenna 1m
7. maximum height of object within 100m of antenna 5m and no wire fence within 100m of antenna
8. maximum height of object within 200m of antenna 10m
9. Flattened area of at least 30x30m to within +/- 5 cm peak deviation from flatness and clear of bushes, mounds of gravel or any objects higher than 10 cm out to 25m from the center of 30x30m area

Site	1	2	3	4	5	6	7	8	9	10	11
1. French Site	x	?	x	x	?	x	x	x	?	?	x
2. Kvadehuken Cabin 1	x	?	x	x	?	x	x	x	?	?	x
3. Kvadehuken Cabin 2	x	?	?	x	?	x	x	x	?	?	x

Table 2: The different sites and whether they meet the conditions in Memo 383. Many of the land requirements will require additional work to flatten the ground. A proper survey of the region will be needed to determine the elevation changes in fine detail. That stated, all three sites look promising for flatness, though it is difficult to determine how flat the ground is in the winter with snow cover.

10. 30x30m for antenna should be even enough so that the wire grid can be tensioned to lay on ground as in memo 310 Figure 1 without separation from the ground of more than 1 cm.

11. food/gas and lodging (with internet) within 120 miles and road or boat access to within 100m of antenna

Table 2 indicates if the sites visited meet these criteria or not. A question mark indicates that it is unknown if the criteria can be met. The ground was mostly covered by snow, so surveying the ground with a sufficiently high accuracy was not possible.

4.3.1 English Bay (Engelskbutka)

One promising location for a site that we found is called Engelskbukta, which translates from Norwegian to English Bay. The location of this area is 78.82N, 11.93E. A satellite map is shown in Figure 12. The Norwegian Polar Institute provides a relatively accurate topographic map of the area, which can be found here: `https://toposvalbard.npolar.no/?lat=78.84042&long=11.98425&zoom=7&layer=map`.

While it was not possible to obtain measurements at the this location, it is the most promising site for a few reasons. The ground appears to be quite flat from the obtained pictures shown in Figure 13. It is also only slightly above sea level ($\sim$ 2 m in some places). The ground should be relatively well saturated with salt water, providing a sufficiently conductive ground for measurements. The proximity to the sea will most likely thaw the ground during summer months faster, further increasing the soil conductivity.

The location also has easy access to the sea for deployment of the instrument and should be sheltered from radio interference due to the surrounding mountains. This could not be verified on this expedition due to uncooperative weather conditions. A local employee of King's Bay did mention that they are unable to make radio communications in the area - even from the repeater stations located nearby Ny Ålesund.

The locations that were measured for radio interference do not have pictures of the regions during summer conditions to complement the measurements.

There is therefore a risk that these regions will require more groundwork - a potential issue with obtaining an experiment and deployment permit.

4.3.2 Zeppelinfjellet Observatory

Measurements were also made at the Zeppelin observatory station. This was a very radio noisy area, with the VHF communication repeater ($\sim$ 172 MHz) situated in the vicinity, as well as many different measurement devices.

5 Conclusions

The site survey in Ny Ålesund gives an indication that the region is reasonably radio quiet outside of the settlement area in the 50-150 MHz frequency range. However, detectable meteor scatter scatter is present at all sites tested. This most likely originates from distances of 1000 km away or further.

A promising location for a future deployment of an EDGES system is the Engelskbukta region, which is towards southeast of the settlement area, on the other side of the mountain range. This region is outside of the reach of the Ny Ålesund VHF handheld radio repeater range, and likely to be best shielded from local interference originating from the research station. This region is also naturally relatively flat and in close proximity to sea water that is likely to increase the soil conductivity.

One possible thing to note is that during the summer months, the sun is above the horizon 24 hours per day. This may be an issue due to solar radio bursts, which can extend to the 50-150 MHz frequency range. The ionospheric electron density will also be higher during the day time.

References

[1] Julia Boike, Olaf Ippisch, Pier Paul Overduin, Birgit Hagedorn, and Kurt Roth. Water, heat and solute dynamics of a mud boil, spitsbergen. *Geomorphology*, 95(1-2):61–73, 2008.

[2] Julia Boike, Inge Juszak, Stephan Lange, Sarah Chadburn, Eleanor Burke, Pier Paul Overduin, Kurt Roth, Olaf Ippisch, Niko Bornemann, Lielle Stern, et al. A 20-year record (1998–2017) of permafrost, active layer and meteorological conditions at a high arctic permafrost research site (bayelva, spitsbergen). *Earth System Science Data*, 10(1):355–390, 2018.

[3] Everett G Farr, Leland H Bowen, and David R Keene. Resistively loaded discones for uwb communications. *Sensor and Simulation Notes*, 2004.

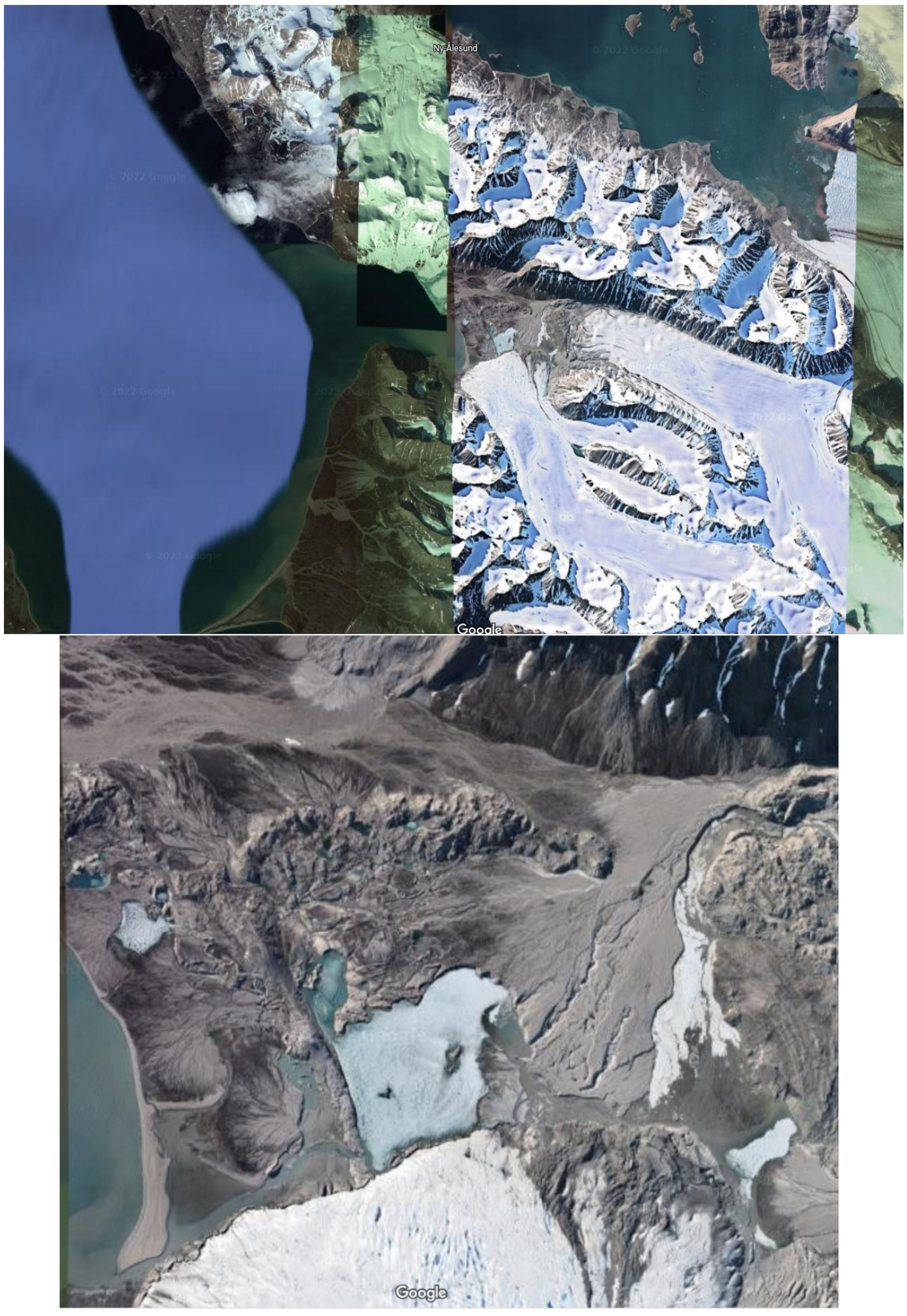
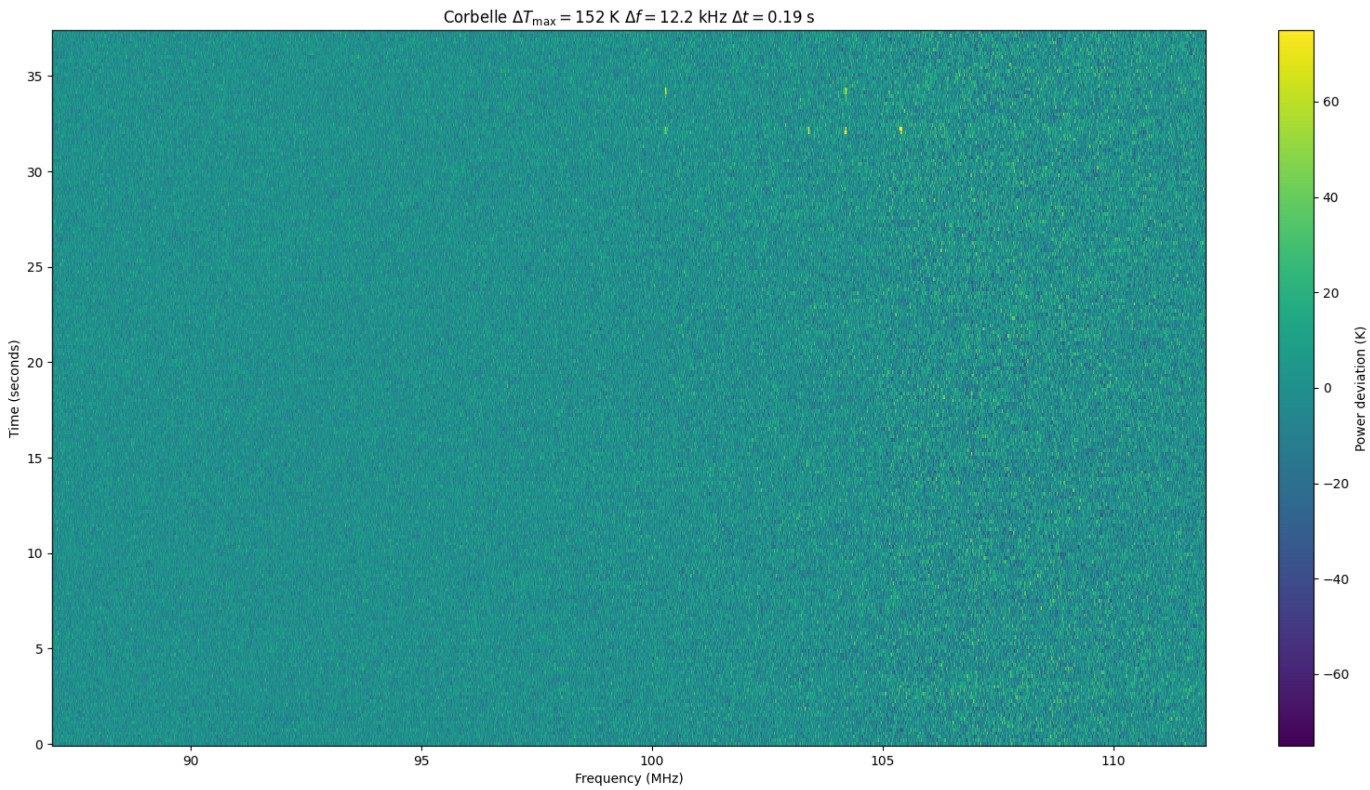


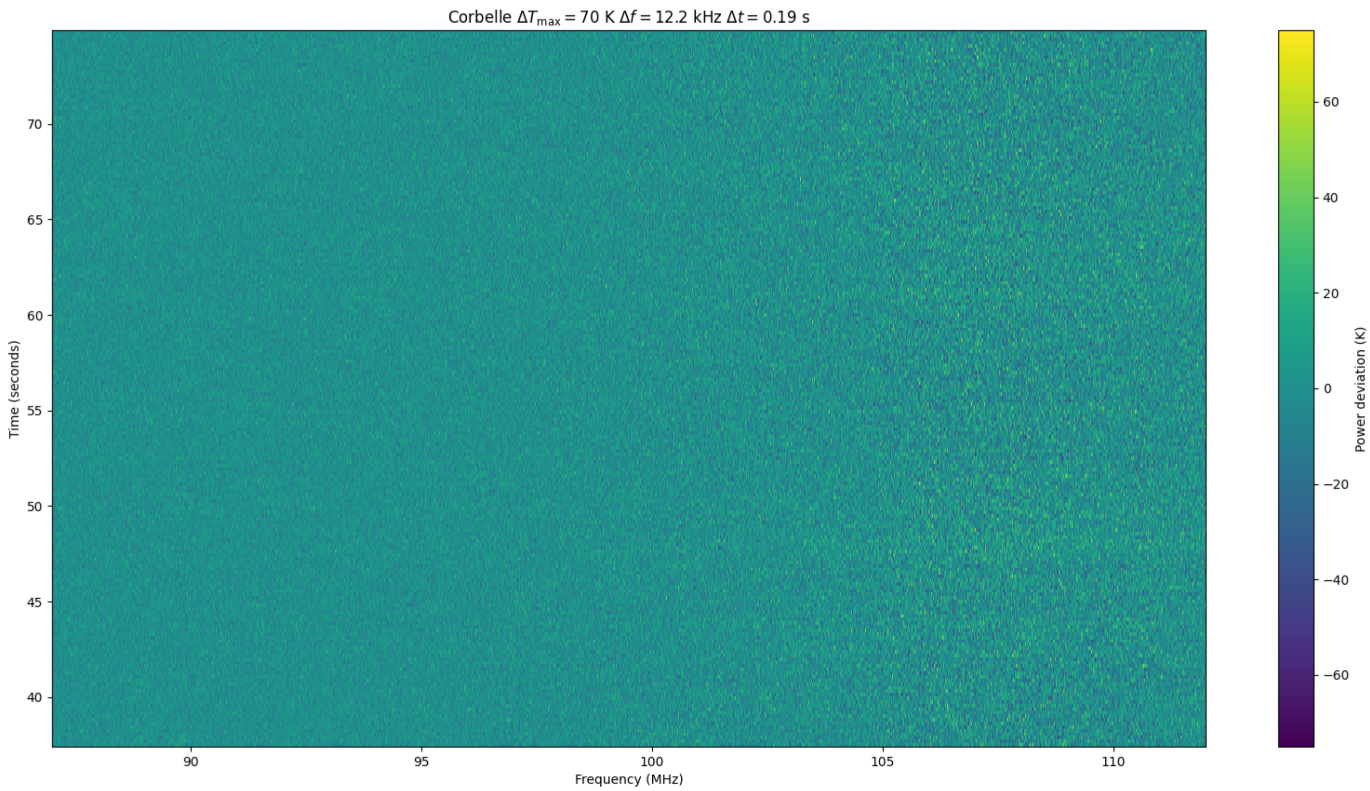
Figure 12: Zoomed out region of sand bar potential receiver location.

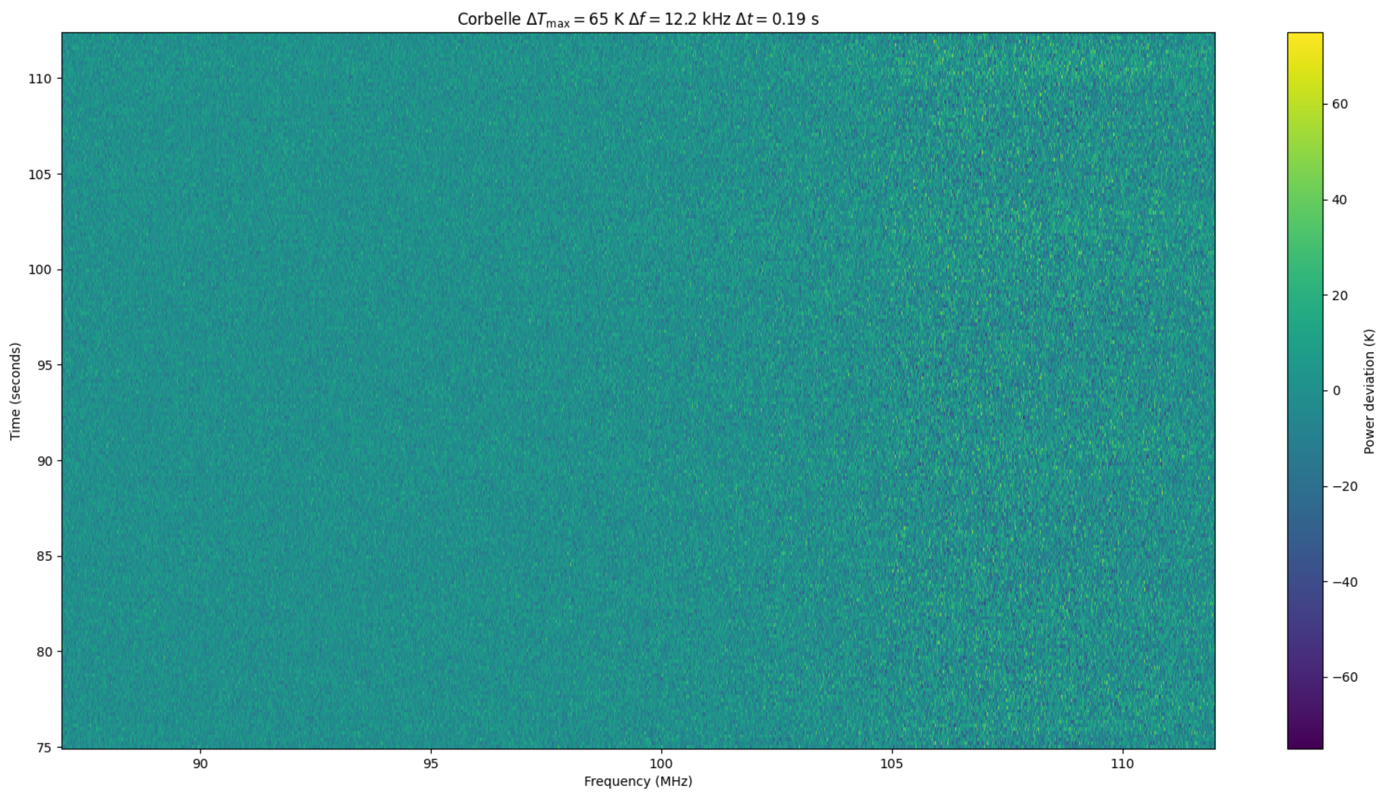
Figure 13: Pictures of the Engelskbutka region (Credit: Svein Torgar Oland of NPI).

A Meteor scatter

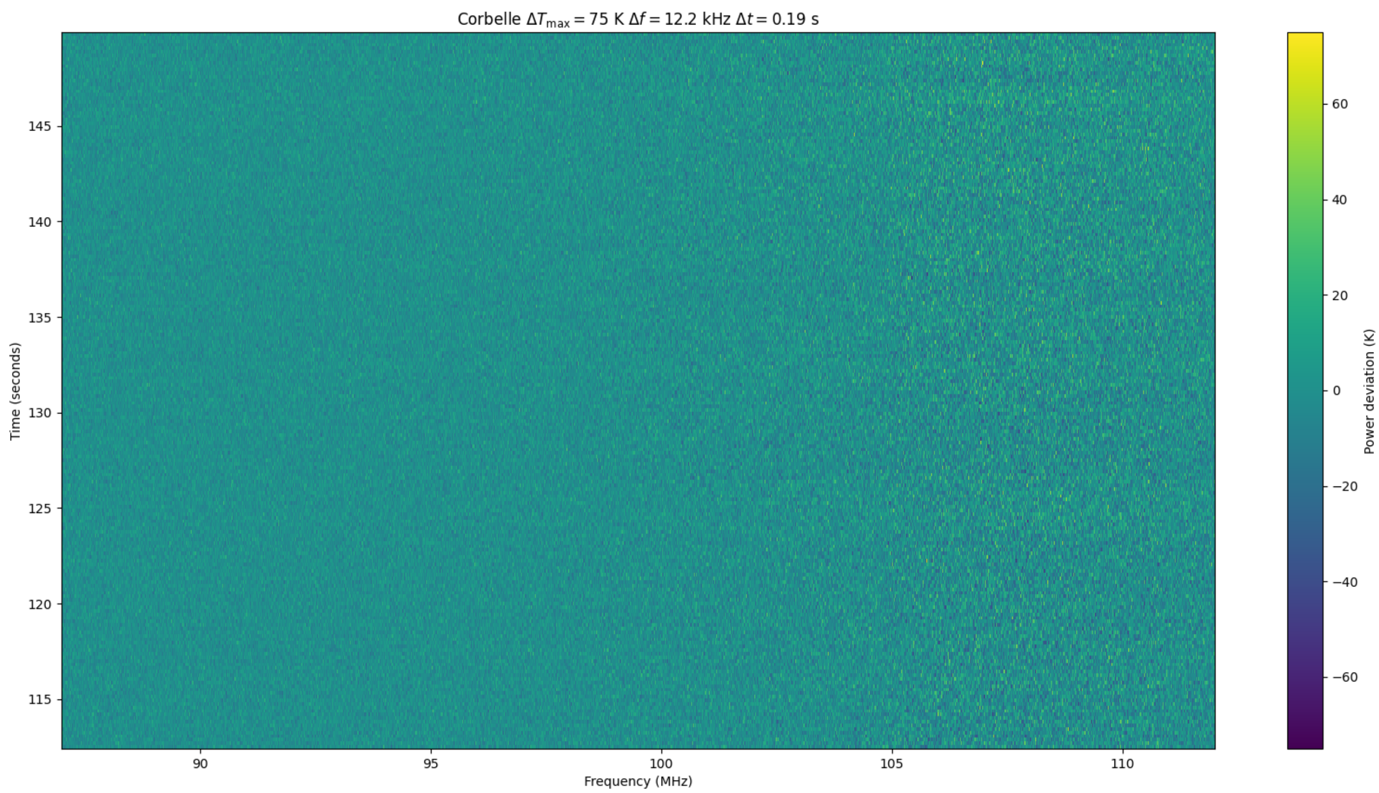
A.1 Corbelle station

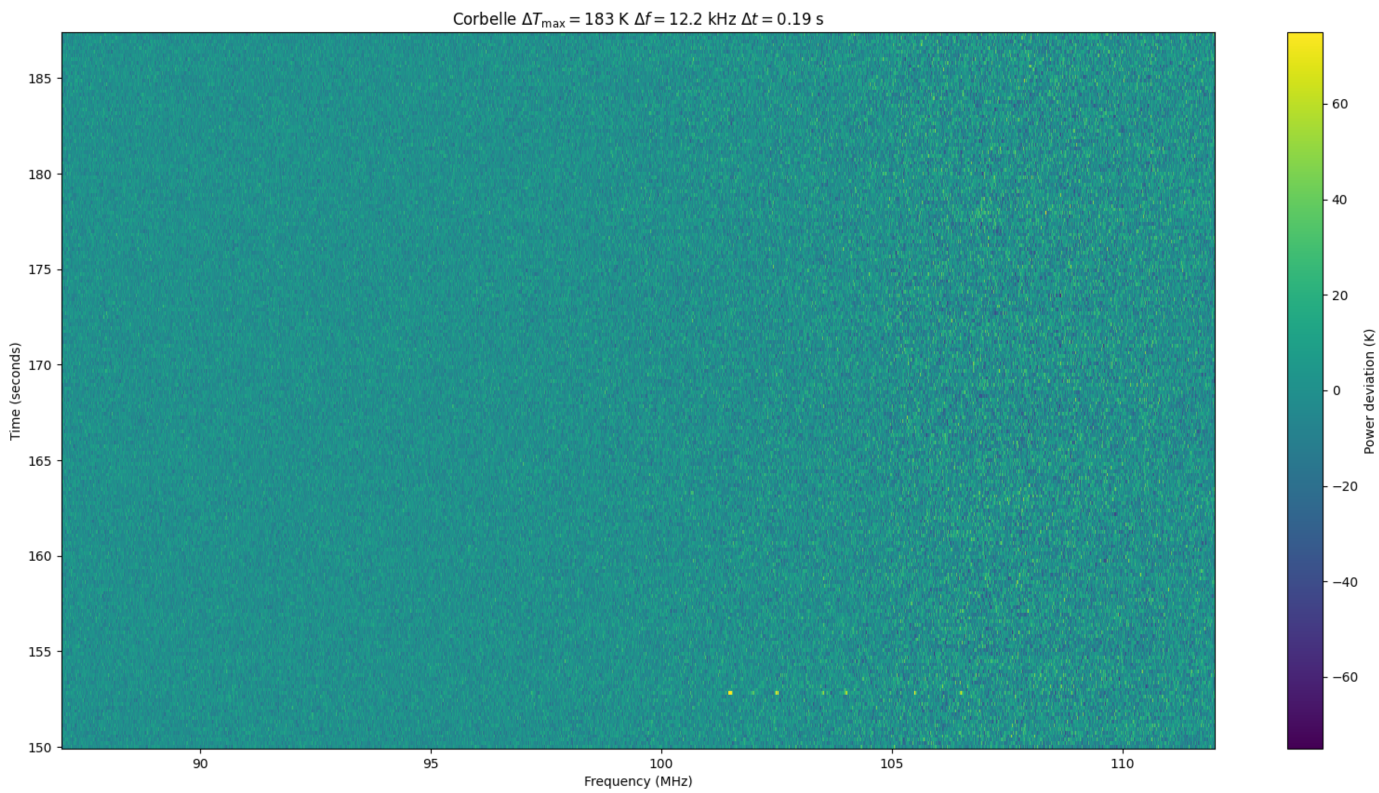



Corbelle $\Delta T_{\max} = 70$ K $\Delta f = 12.2$ kHz $\Delta t = 0.19$ s
Time (seconds)
70
65
60
55
50
45
40
90
95
100
105
110
Frequency (MHz)
Power deviation (K)
60
40
20
0
−20
−40
−60

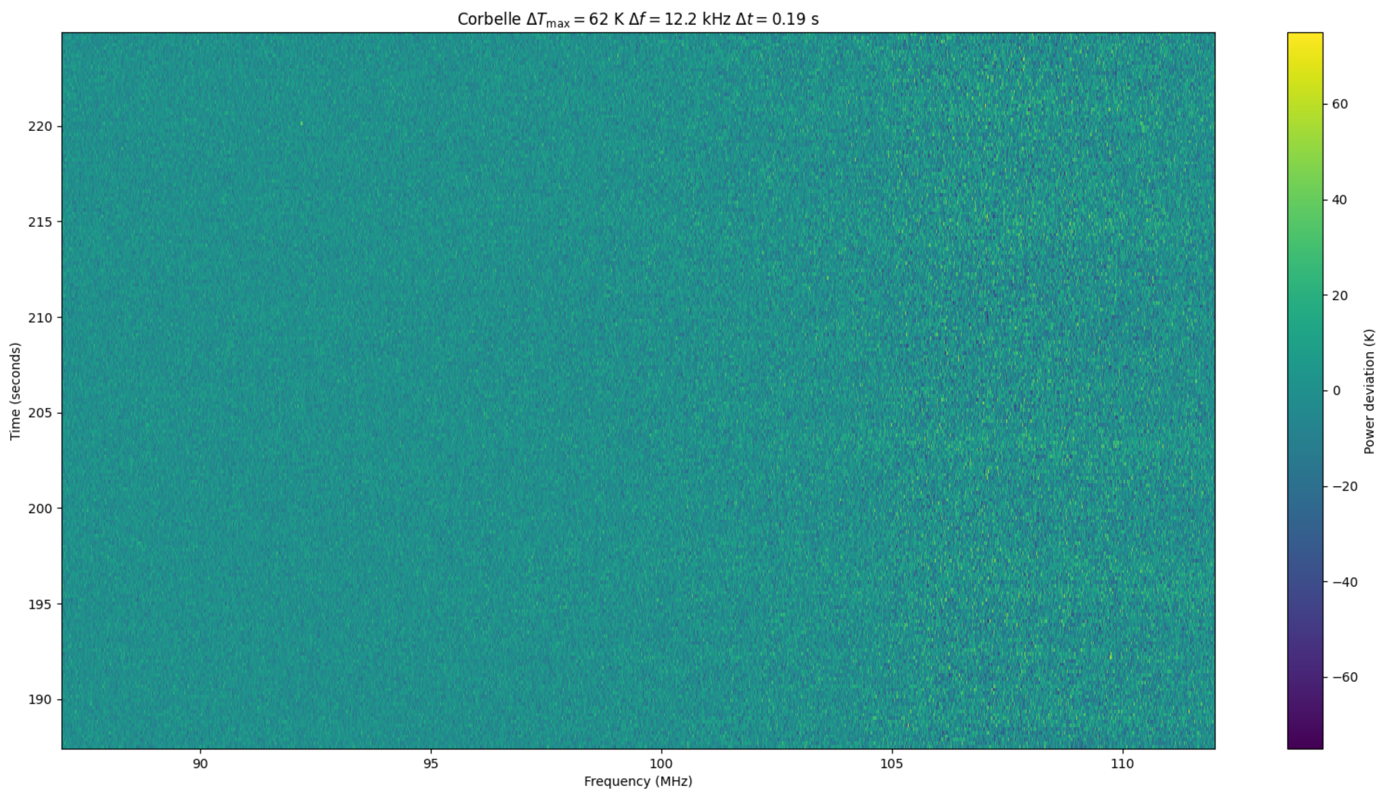


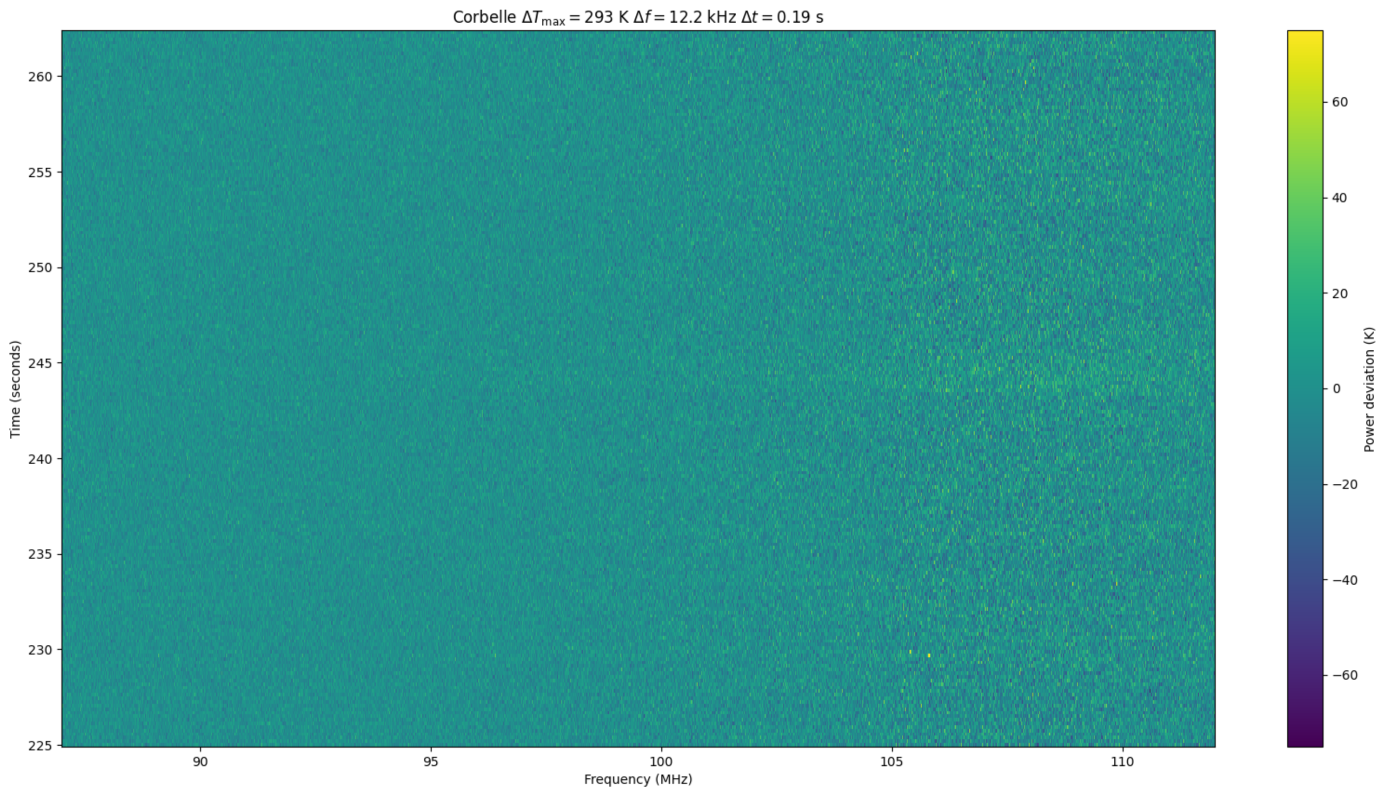
Corbelle $\Delta T_{\max} = 65$ K $\Delta f = 12.2$ kHz $\Delta t = 0.19$ s
Time (seconds)
Frequency (MHz)
Power deviation (K)
110
105
100
95
90
85
80
75
60
40
20
0
−20
−40
−60

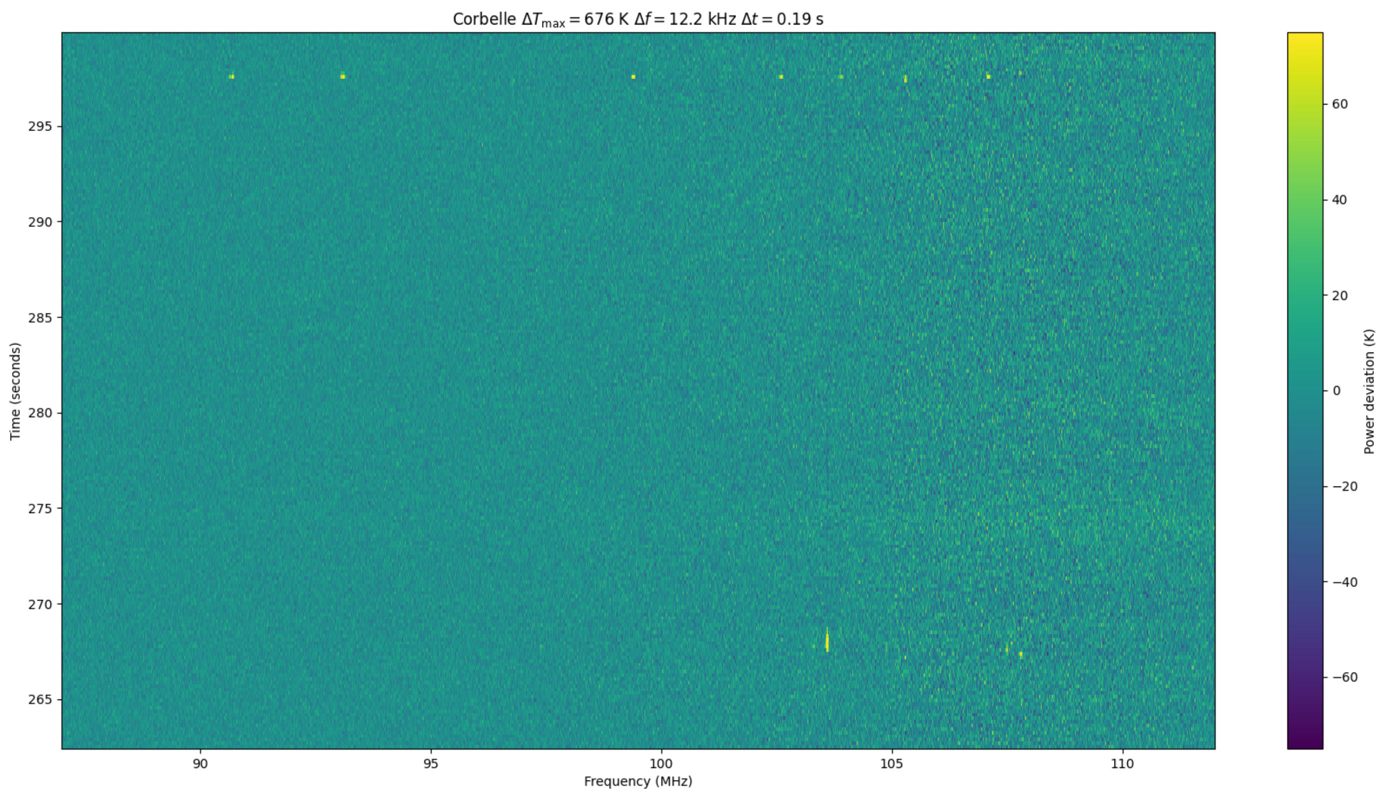

Corbelle $\Delta T_{\rm max} = 75$ K $\Delta f = 12.2$ kHz $\Delta t = 0.19$ s
Time (seconds)
145
140
135
130
125
120
115
Frequency (MHz)
90
95
100
105
110
Power deviation (K)
60
40
20
0
−20
−40
−60

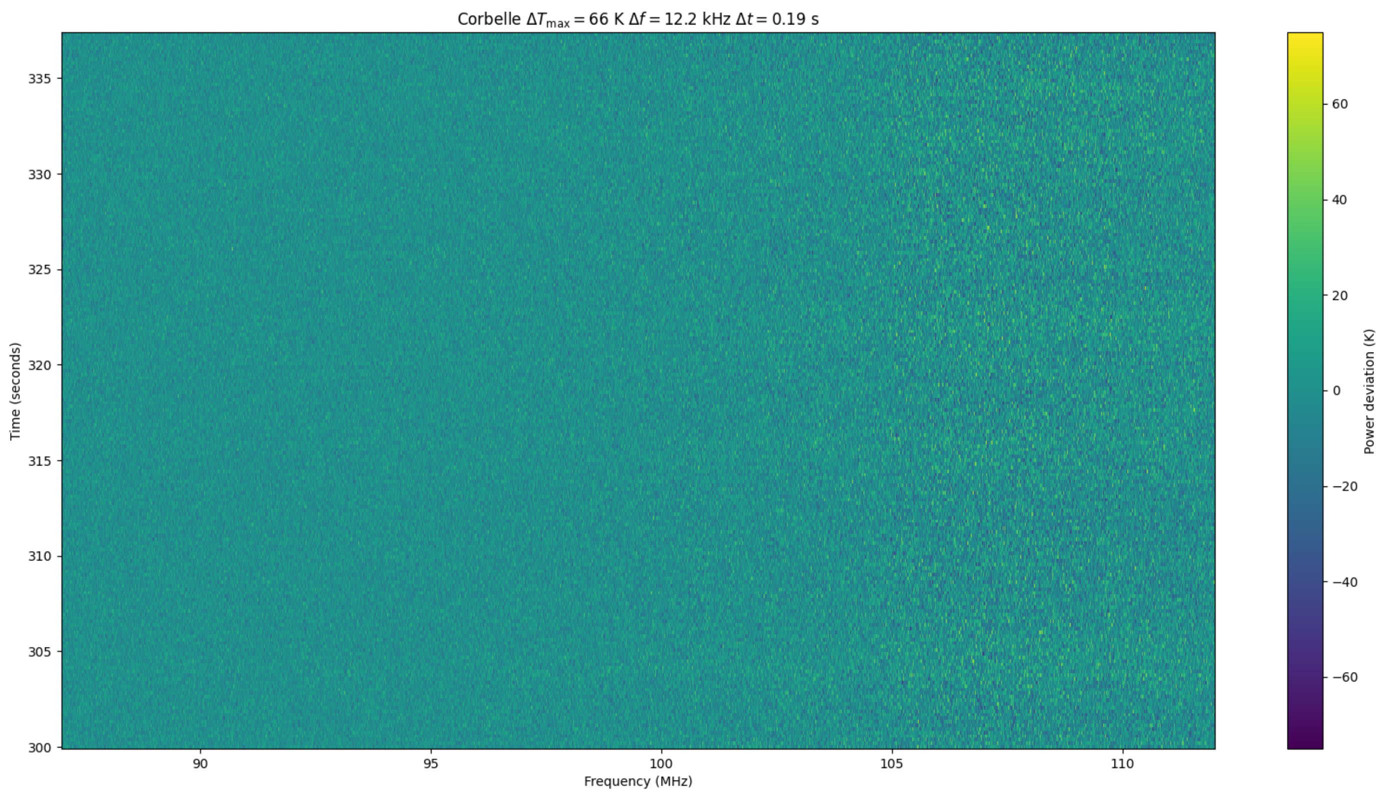


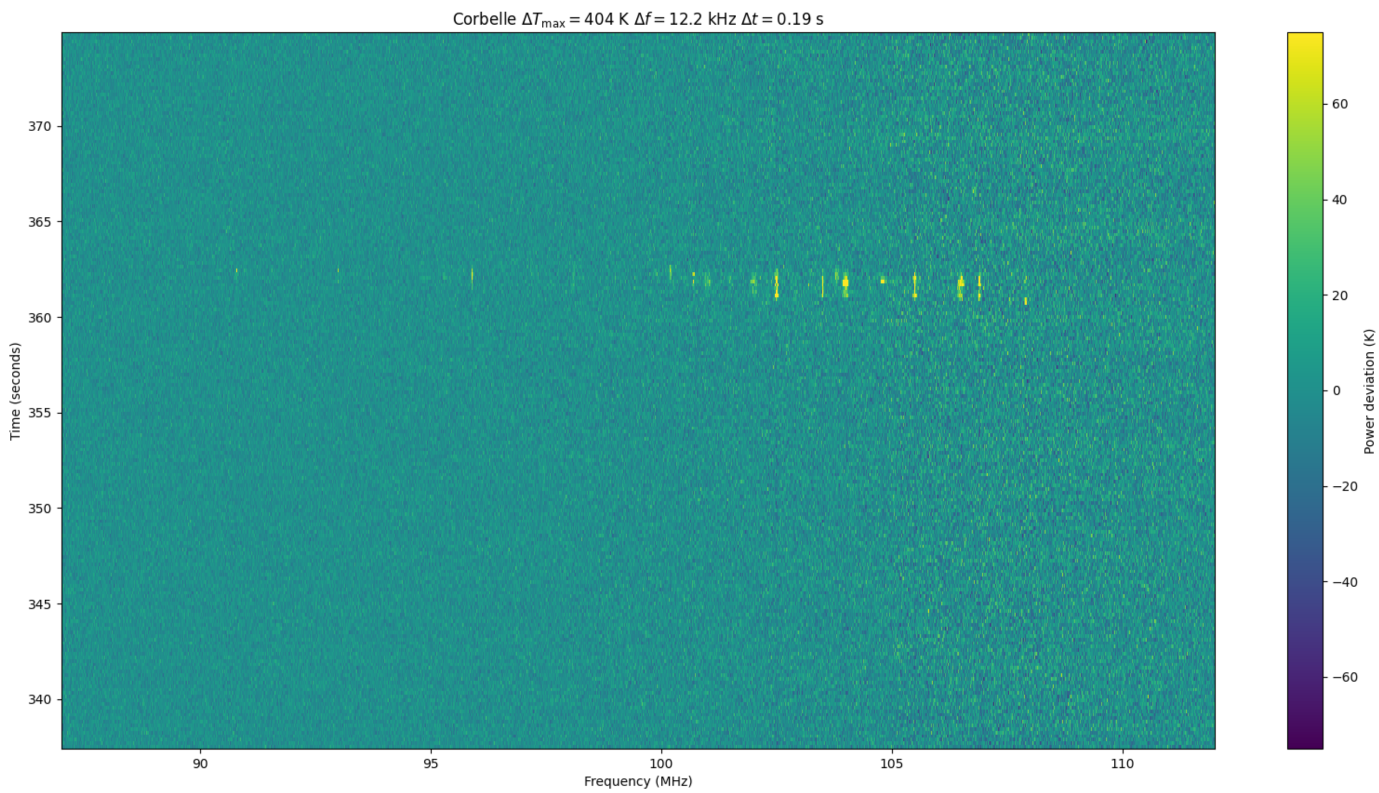
Corbelle $\Delta T_{\max} = 183$ K $\Delta f = 12.2$ kHz $\Delta t = 0.19$ s
Time (seconds)
185
180
175
170
165
160
155
150
90
95
100
105
110
Frequency (MHz)
Power deviation (K)
60
40
20
0
−20
−40
−60


Corbelle $\Delta T_{\max} = 62$ K $\Delta f = 12.2$ kHz $\Delta t = 0.19$ s
Time (seconds)
Frequency (MHz)
Power deviation (K)
190
195
200
205
210
215
220
90
95
100
105
110
60
40
20
0
−20
−40
−60


Corbelle $\Delta T_{\mathrm{max}} = 293$ K $\Delta f = 12.2$ kHz $\Delta t = 0.19$ s
Time (seconds)
Frequency (MHz)
Power deviation (K)
260
255
250
245
240
235
230
225
90
95
100
105
110
60
40
20
0
−20
−40
−60

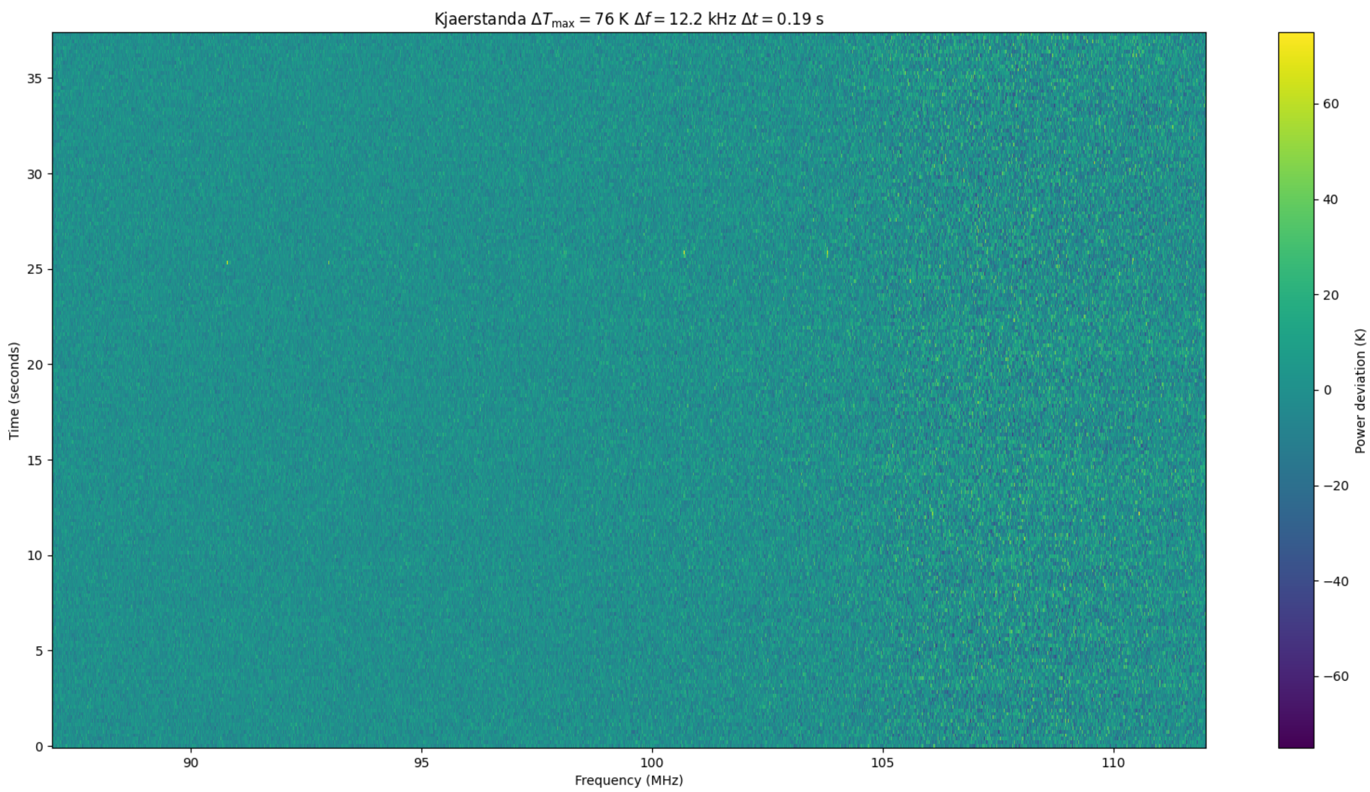

Corbelle $\Delta T_{\mathrm{max}} = 676$ K $\Delta f = 12.2$ kHz $\Delta t = 0.19$ s
Time (seconds)
Frequency (MHz)
Power deviation (K)
295
290
285
280
275
270
265
90
95
100
105
110
60
40
20
0
−20
−40
−60

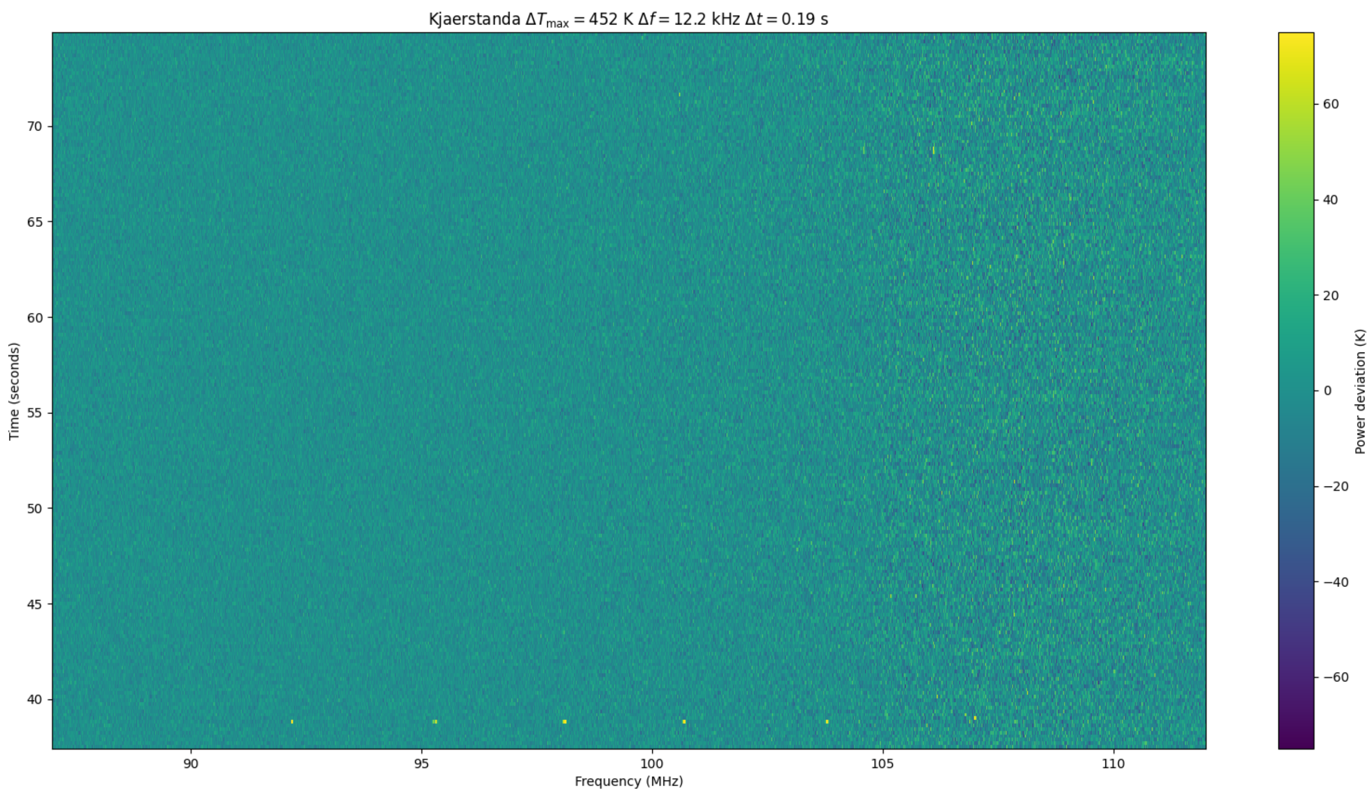

Corbelle $\Delta T_{\mathrm{max}} = 66$ K $\Delta f = 12.2$ kHz $\Delta t = 0.19$ s
Time (seconds)
Frequency (MHz)
Power deviation (K)

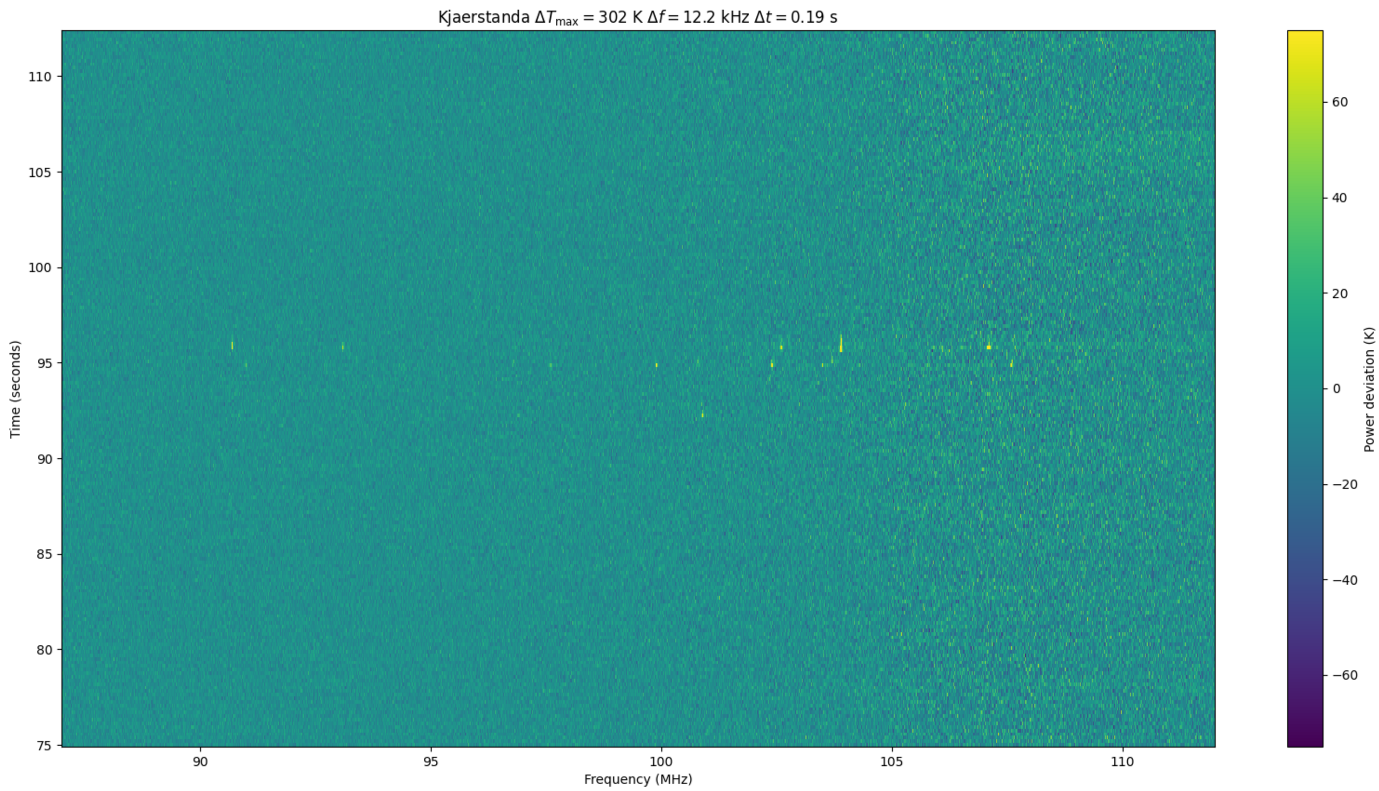


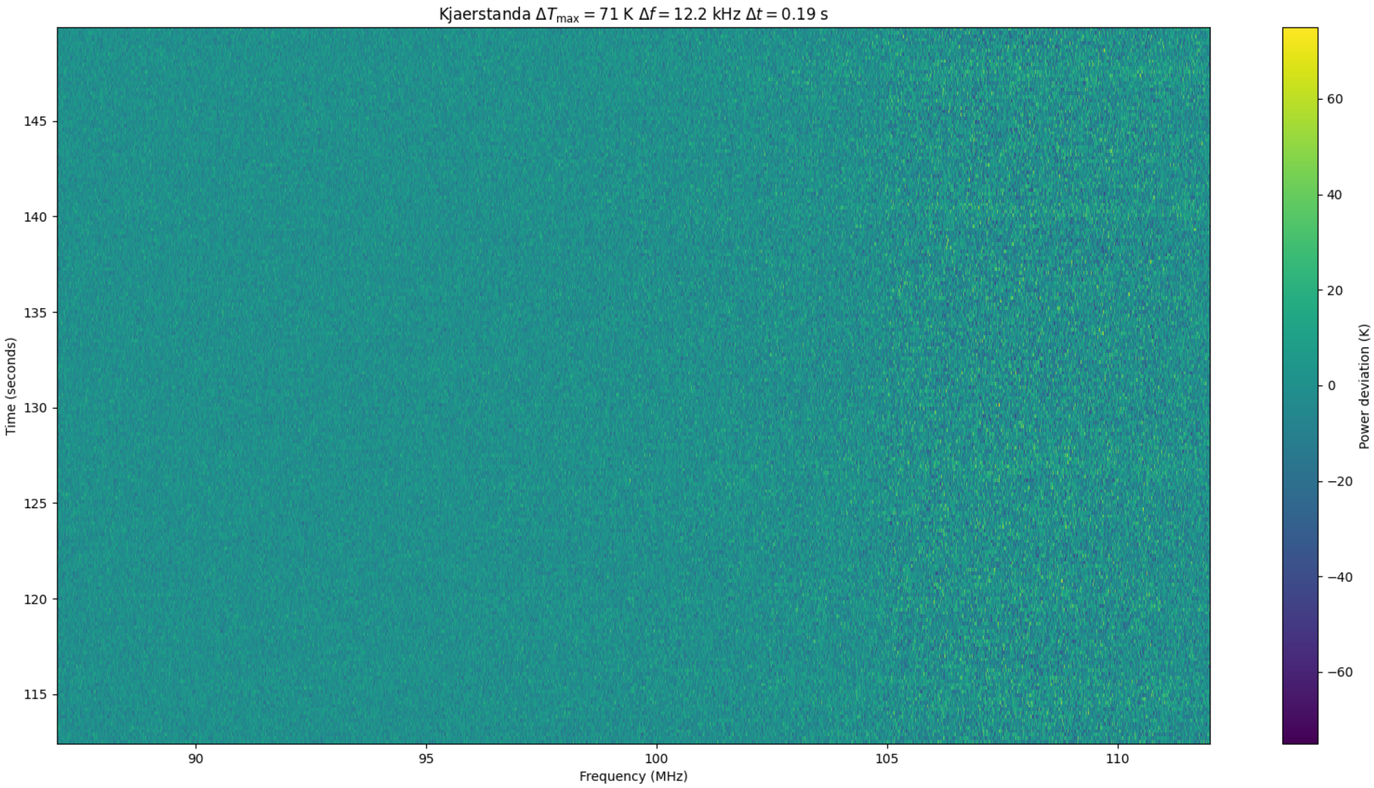
Corbelle $\Delta T_{max} = 404$ K $\Delta f = 12.2$ kHz $\Delta t = 0.19$ s
Time (seconds)
Frequency (MHz)
Power deviation (K)

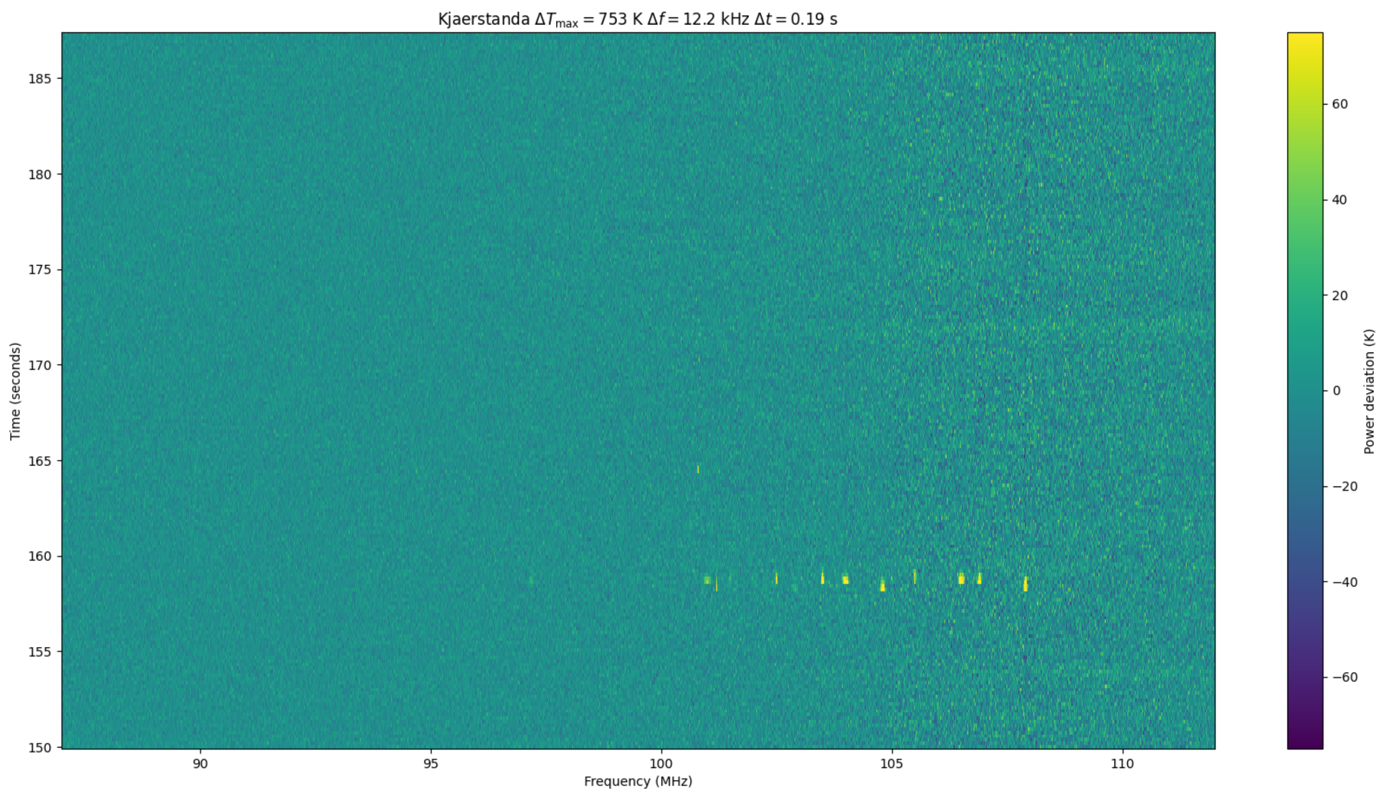
A.2 Kjaerestand Cabin

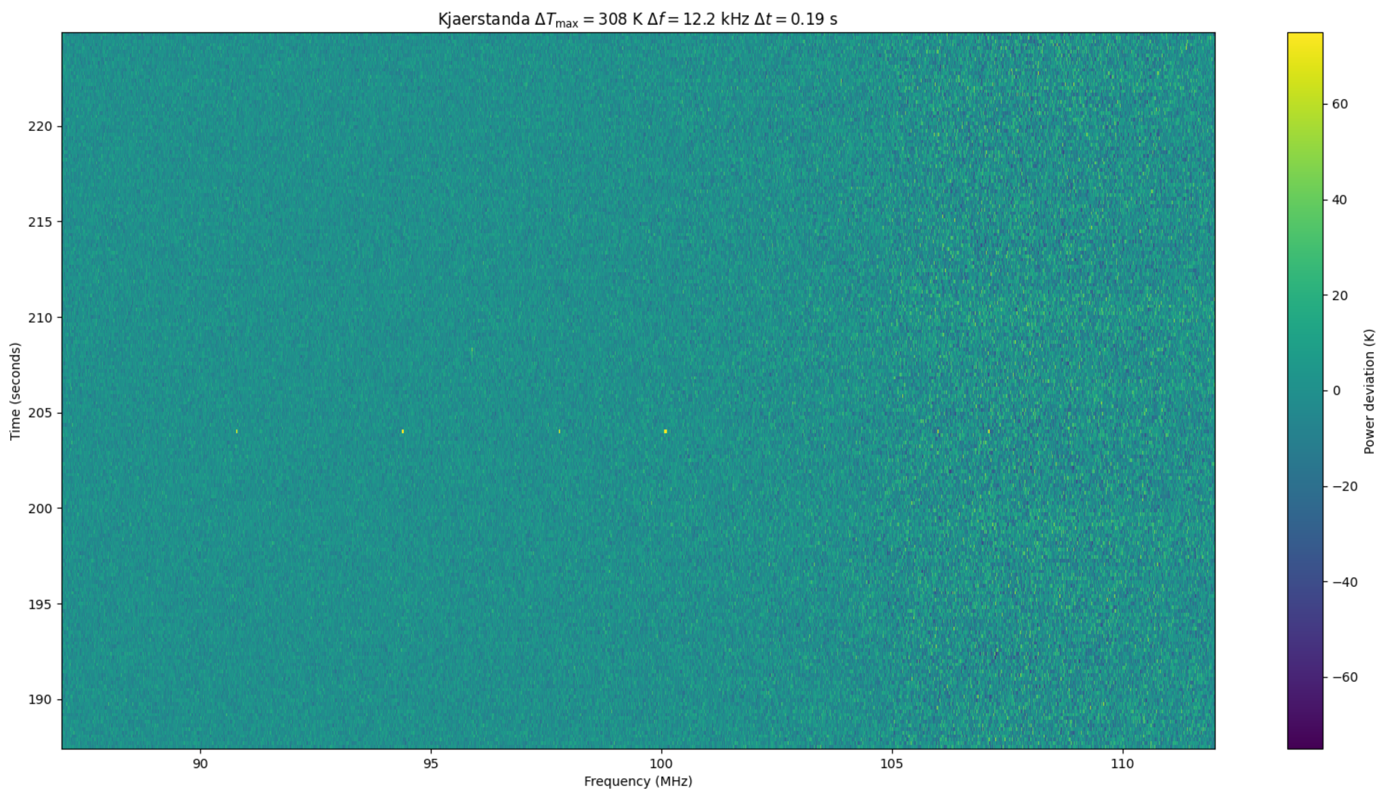



Kjaerstanda $\Delta T_{\max} = 452$ K $\Delta f = 12.2$ kHz $\Delta t = 0.19$ s
Time (seconds)
70
65
60
55
50
45
40
90
95
100
105
110
Frequency (MHz)
Power deviation (K)
60
40
20
0
−20
−40
−60

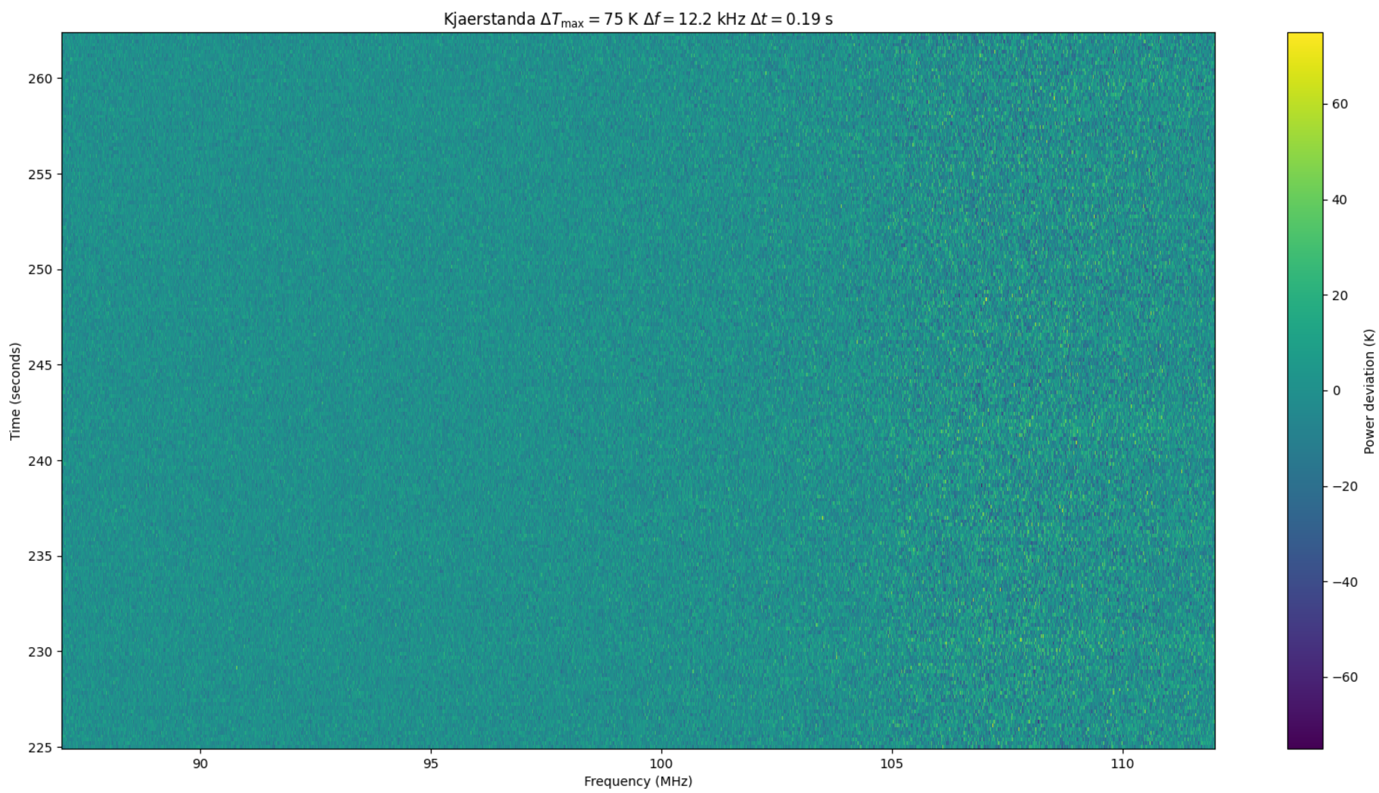

Kjaerstanda $\Delta T_{\max} = 302$ K $\Delta f = 12.2$ kHz $\Delta t = 0.19$ s
Time (seconds)
110
105
100
95
90
85
80
75
Frequency (MHz)
90
95
100
105
110
Power deviation (K)
60
40
20
0
−20
−40
−60


Kjaerstanda $\Delta T_{\mathrm{max}} = 71$ K $\Delta f = 12.2$ kHz $\Delta t = 0.19$ s
Time (seconds)
145
140
135
130
125
120
115
90
95
100
105
110
Frequency (MHz)
60
40
20
0
−20
−40
−60
Power deviation (K)

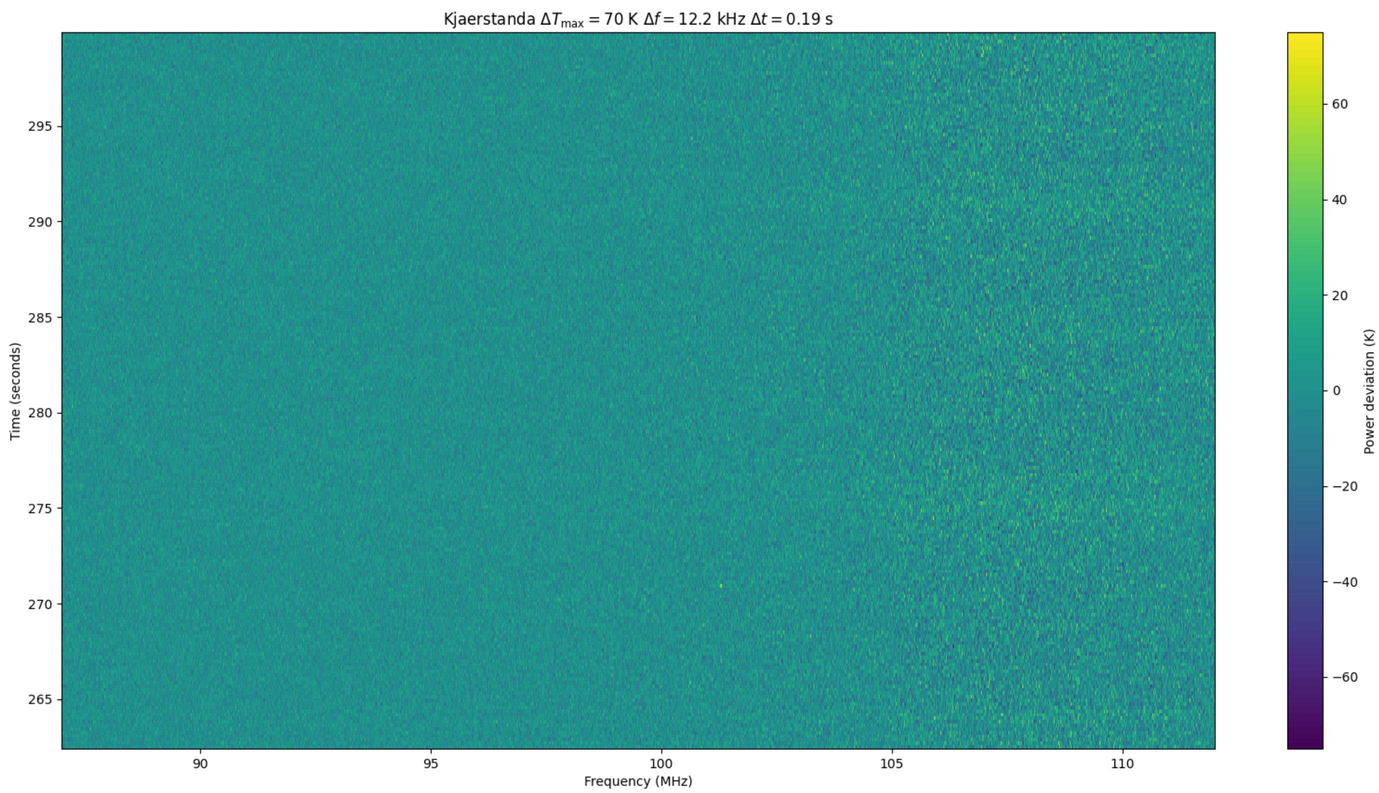

Kjaerstanda $\Delta T_{\max} = 753$ K $\Delta f = 12.2$ kHz $\Delta t = 0.19$ s
Time (seconds)
Frequency (MHz)
Power deviation (K)
185
180
175
170
165
160
155
150
90
95
100
105
110
60
40
20
0
−20
−40
−60

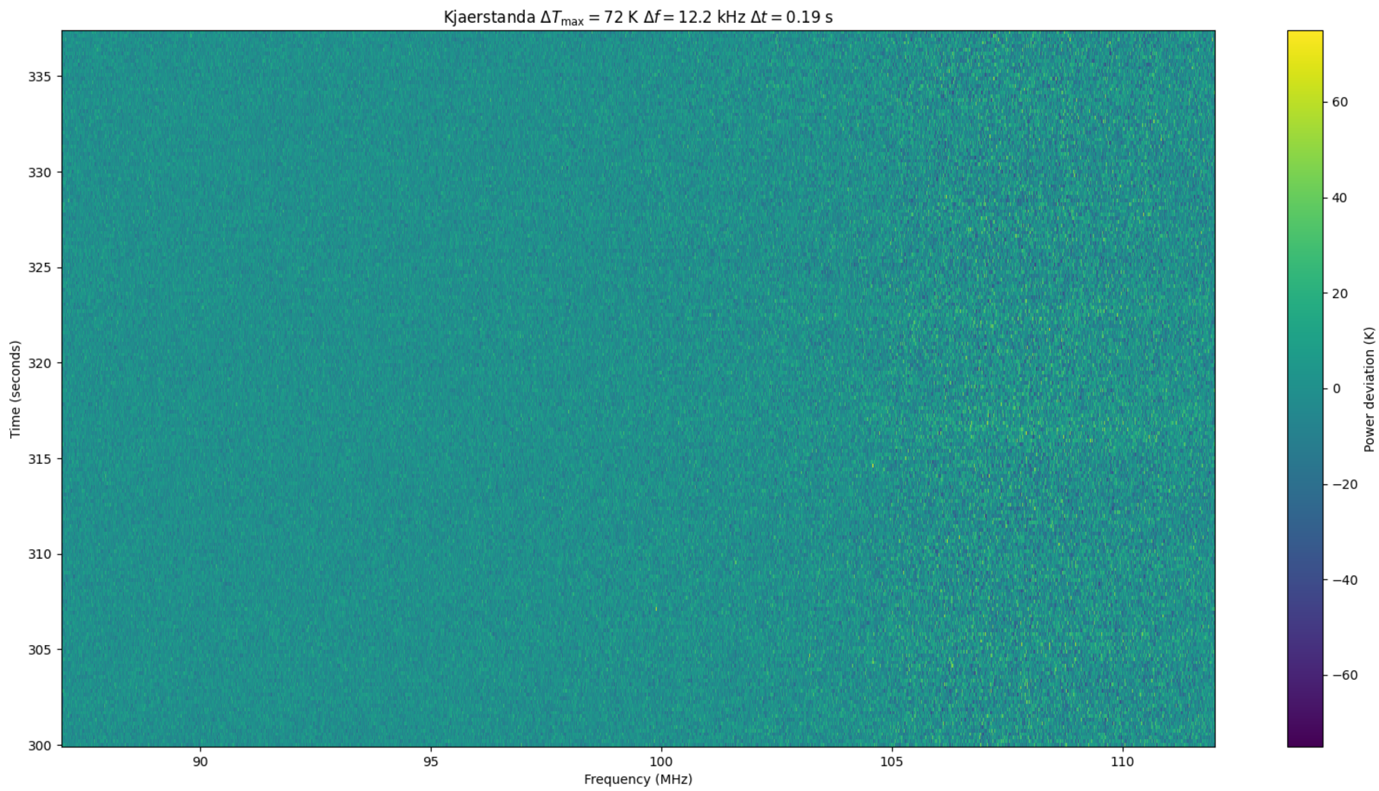


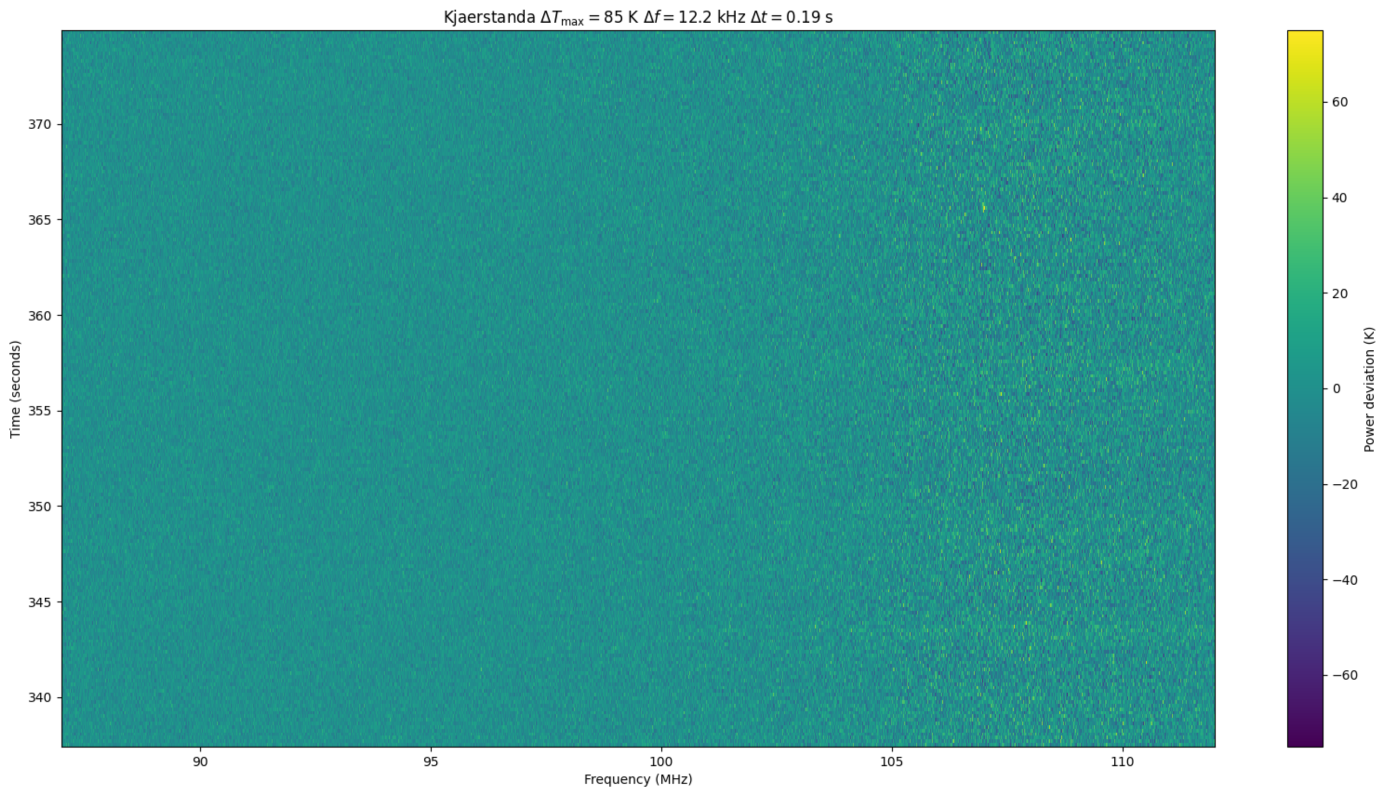
Kjaerstanda $\Delta T_{\max} = 308$ K $\Delta f = 12.2$ kHz $\Delta t = 0.19$ s
Time (seconds)
Frequency (MHz)
Power deviation (K)



Kjaerstanda $\Delta T_{\max} = 75$ K $\Delta f = 12.2$ kHz $\Delta t = 0.19$ s
Time (seconds)
260
255
250
245
240
235
230
225
90
95
100
105
110
Frequency (MHz)
60
40
20
0
−20
−40
−60
Power deviation (K)

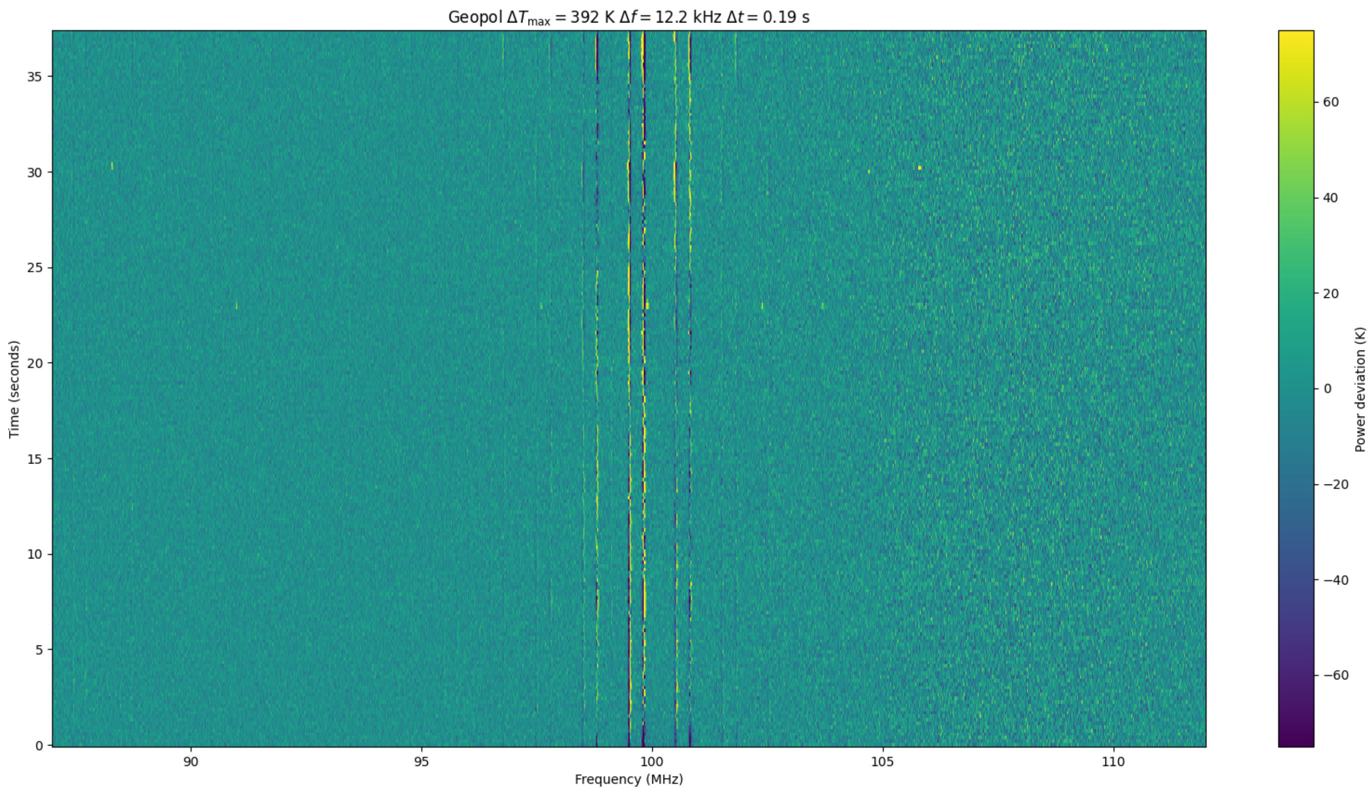

Kjaerstanda $\Delta T_{\max} = 70$ K $\Delta f = 12.2$ kHz $\Delta t = 0.19$ s
Time (seconds)
295
290
285
280
275
270
265
90
95
100
105
110
Frequency (MHz)
60
40
20
0
−20
−40
−60
Power deviation (K)


Kjaerstanda $\Delta T_{\max} = 72$ K $\Delta f = 12.2$ kHz $\Delta t = 0.19$ s
Time (seconds)
Frequency (MHz)
Power deviation (K)
300
305
310
315
320
325
330
335
90
95
100
105
110
60
40
20
0
−20
−40
−60



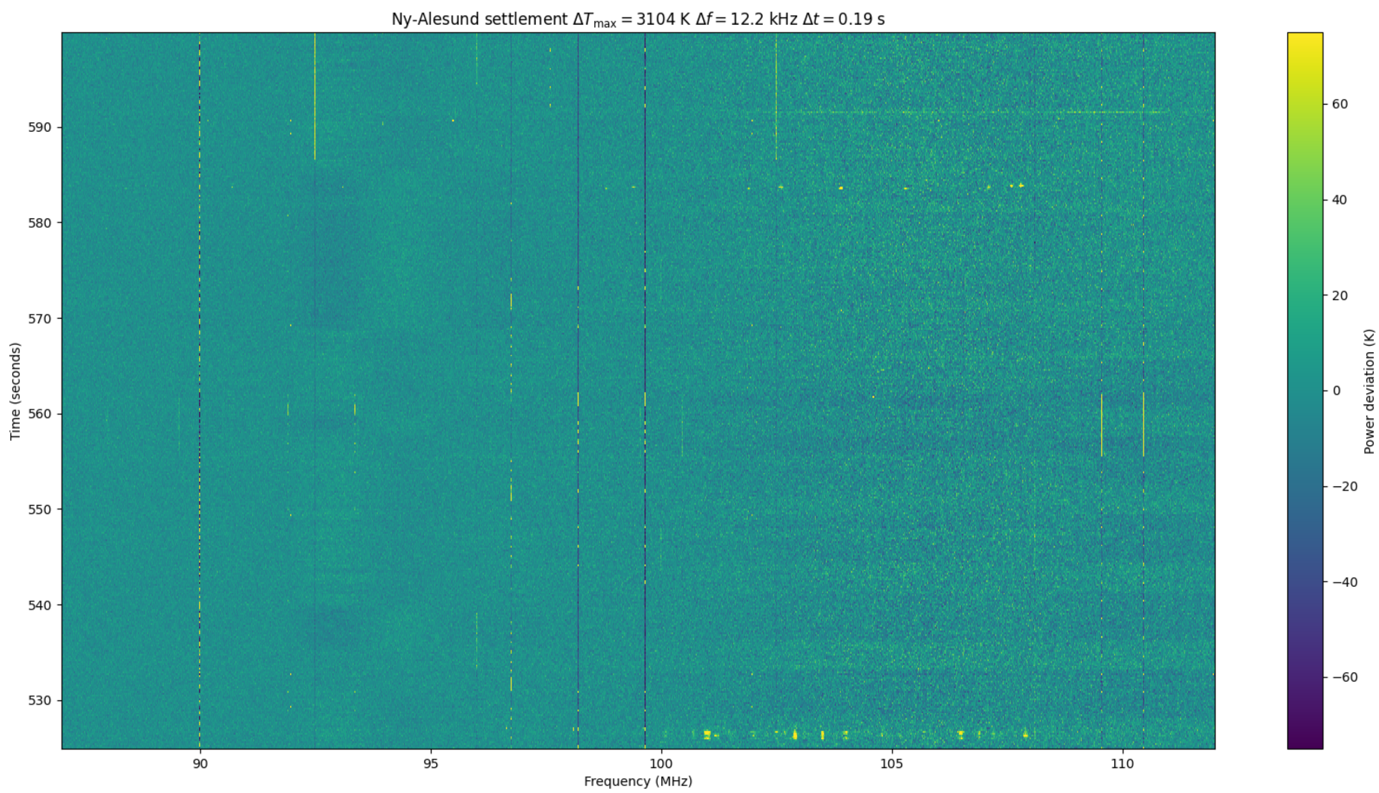
A.3 Geopol cabin

These measurements were problematic due to noise originating from the measurement computer, which was placed too close to the feed line. The measurements did however show a similar number of meteor scatter events, as seen by the single figure included below.



A.4 Ny Ålesund settlement

The Ny Ålesund settlement contains significantly more radio interference. However, the noise floor itself was not significantly raised with respect to the background noise measured further away from the settlement. The detectability of meteor scatter was nearly similar to the more quiet locations further away from the station. For example, in the figure shown below, there are two clear meteor forward scatter events.



Ny-Alesund settlement $\Delta T_{max} = 3104$ K $\Delta f = 12.2$ kHz $\Delta t = 0.19$ s
Time (seconds)
590
580
570
560
550
540
530
90
95
100
105
110
Frequency (MHz)
60
40
20
0
−20
−40
−60
Power deviation (K)