1-26.5 GHz interference measurement with the new RFI system at Yebes Observatory

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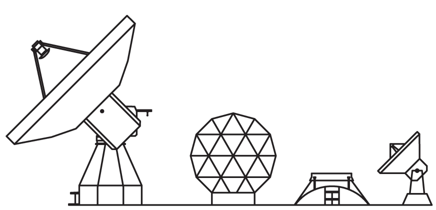
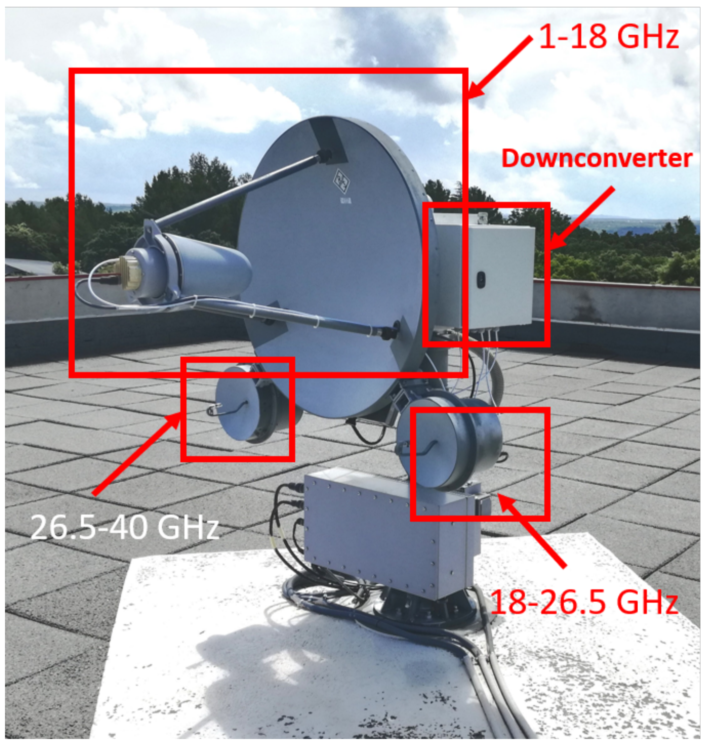
IT-CDT 2019-13
Observatorio de Yebes
Apdo. 148, E-19080
Guadalajara SPAIN



Contents

1 Introduction

During the month of May some RFI measurements have been carried out with the new RFI system in Yebes Observatory. The system consist of a set of three antennas, a downconverter located in the rooftop of the building and an spectrum analyzer located in the laboratory. More details are found in CDT Technical report 2019-12.



2 Measurement setup and calibration process

The instrumentation used is the following:

- 20 Hz-40 GHz Keysight spectrum analyzer, model FSEK30.
- 10 MHz-40 GHz Rhode & Schwarz signal generator.
- RF coaxial cables.
- PC and Matlab software.
- GPIB-Ethernet Prologix controller.

The calibration process carried out follows the next steps:

- **To obtain the gain of each subband** (G_L, G_M, G_H)**:**

  The RF signal generator (at the rooftop) along with a coaxial cable 'A' (used also in the next step) is connected to the each of the antenna's output, and it generate a pulse that makes a sweep over each subband. The spectrum analyzer located at the laboratory collects the data in a max hold mode. With that, it is measured the chain which consist of the sum of the downconverter, the input cables and the 36-m cable that carries the output signal to the laboratory.

  After that, the signal generator along with the same cable 'A' used in the previous step is connected directly to the spectrum analyzer. The same sweep with the same configuration used in the previous step is performed in order to subtract the data collected in the previous step to the data of this one. At that point we have obtained the gain of the chain between the preamplifier output and the input of the spectrum analyzer for each subband.

- **To obtain the gain of each antenna** $(Gant_L, Gant_M, Gant_H)$ **and preamplifier** $(Gamp_L, Gamp_M, Gamp_H)$**:**

  These insformation has to be transferred from the theoretic data in the datasheet to Matlab. Only the low band preamplifier was measured in the laboratory, so in this case the data is the real one.

- **To Convert the power measured (dBm) into spectral densisty flux** $(dBW/m^2 \cdot Hz)$**:**

  This equation is derived from the effective area and the flux.

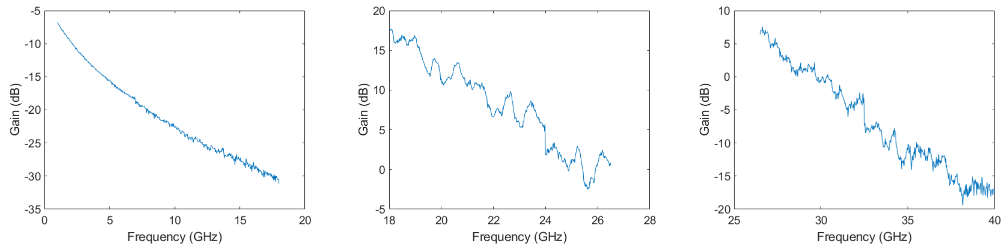
$$\begin{aligned} S[dB_{W/m^2 \cdot Hz}] = P_m[dBm] - 30 - G_{LNA}(dB) - 10\log(\mathrm{RBW}[Hz]) - \\ -10\log(G_{rx}) + 20\log(10^6) + 20\log(f[MHz]) - 158.54 = \\ = P_m(dBm) - G_{LNA}(dB) - 10\log(\mathrm{RBW}[MHz]) - \\ -G_{ant}(dB) + 20\log(f[MHz]) - 128.54, \end{aligned}$$

  where the P_m is the measured power with the analyzer, G_{LNA} is the gain of the whole chain from the output of the antenna up to the input of the analyzer $(G_{[L|M|H]} + Gamp_{[L|M|H]})$, RBW is the resolution bandwidth of the analyzer and G_{ant} is the gain of the antenna $(Gant_{[L|M|H]})$. Thus, the spectral density power flux (spectral pfd) is obtained at the antenna input.

3 Calibration measurements

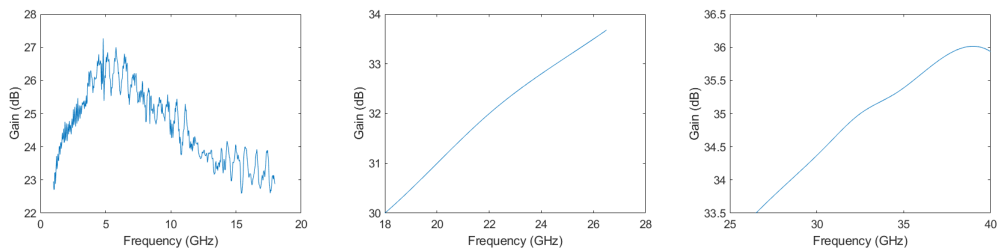
The different measured gains of each subband $(G_{[L|M|H]})$ between the antenna output and the analyzer input are shown in Figure 1.

The gain of each antenna $(Gant_{[L|M|H]})$ and preamplifier $(Gamp_{[L|M|H]})$ are shown in Figures 2 and 3 repectively.



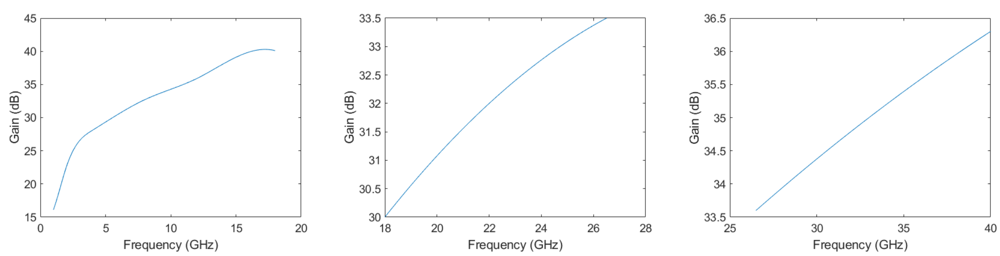
(a) Low band (b) Mid band (c) Upper band

Figure 1: Gain of each subband between antenna's output and the input of the analyzer ($G_{[L|M|H]}$).



(a) Low band (b) Mid band (c) Upper band

Figure 2: Gain of the preamplifier of each subband.



(a) Low band (b) Mid band (c) Upper band

Figure 3: Gain of the antennas of each subband.

4 Postprocessed data

The data collected from the analyzer is taken by a GPIB-Ethernet device, and the data is processing afterthat with Matlab. The data is saved in a "txt" file.

An app has been done to read, process and plot the data of interest. The interface is shown in figure 4.

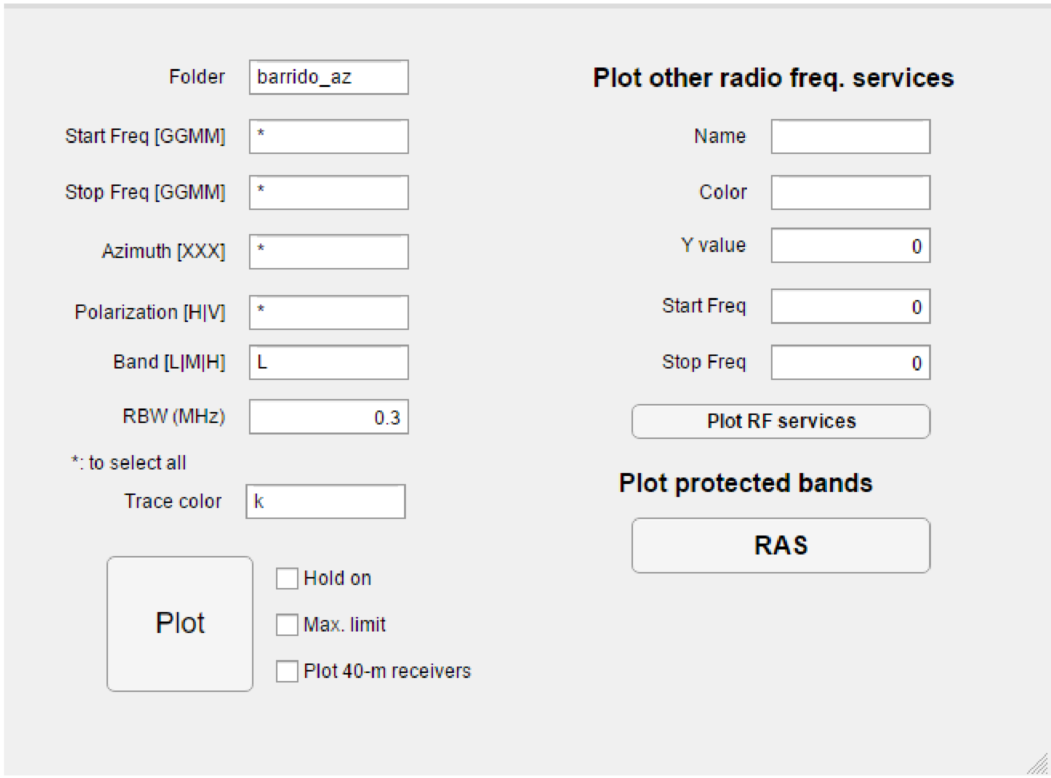


Figure 4: Matlab app interface

The way to proceed is to organized the ".txt" files in folders with an specific name structured as following:

[GGMM]-[GGMM]-az[XXX]-pol[V| H]-[L| M| H].txt

where GGMM (the two first numbers show the Gigaherzt and the last two the Megahertz) is the start and stop frequency, for example if the analyzer has measured from 1.5 to 2.5 GHz, at 300 azimuth degrees, in vertical polarization and in the downconverter is set to the low band, the file name is "0150-0250-az300-polV-L.txt". In case that the measurement is done in a sweep way, the azimuth has to be "999" Appart from plotting the RFI signal, the max limit permitted for non protected bands, as well as the protected ones can be plotted and the RAS-bands where Yebes has receivers (the 40-m ones).

An example with all the options plotted is shown in Figure 5. In that figure the 40m-receivers are plot in blue, and the protected subbands are plotted in red over the spectrum (such as the range between 1 an 2 GHz). The maximum limit threshold of +88.8 $dB(\mu V/m)$ is obtained in pfd units per Hz with the equation (4)

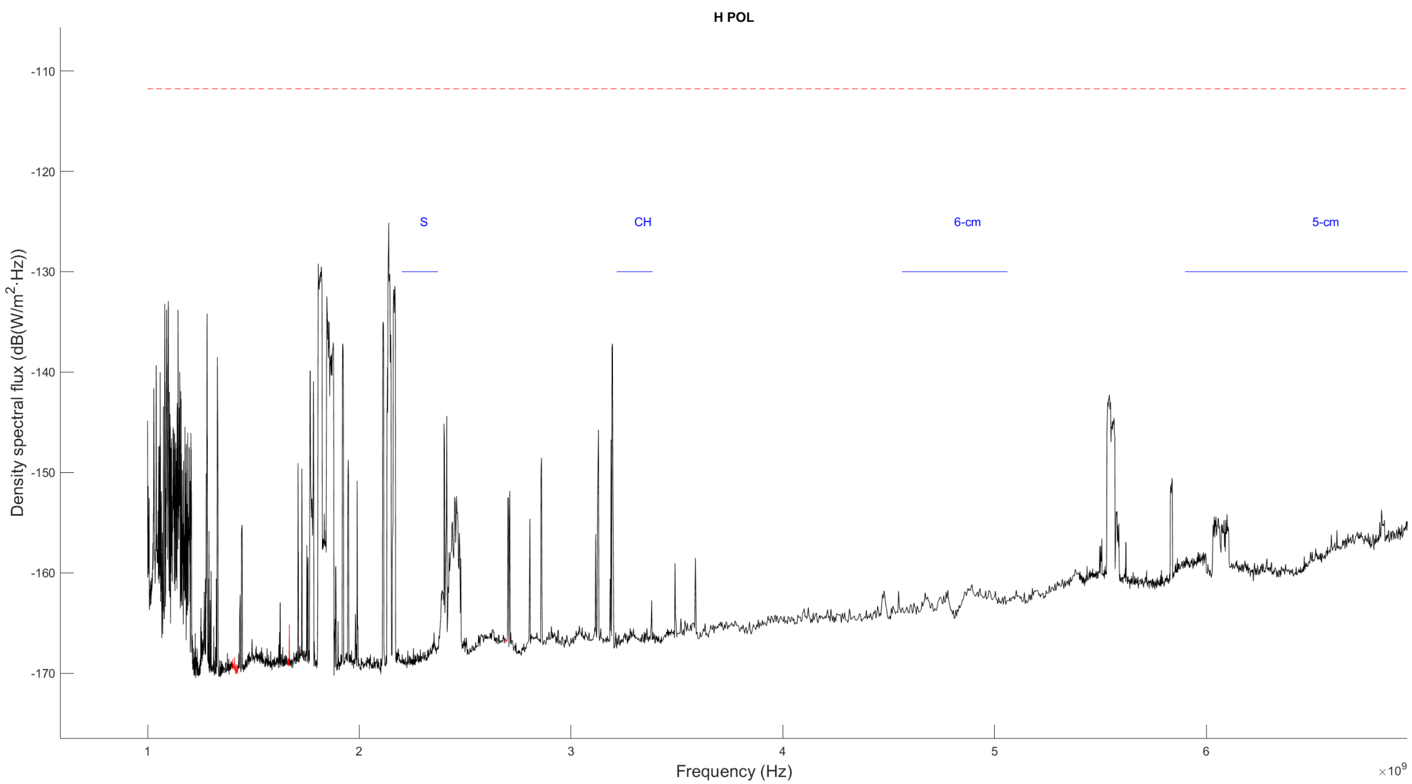


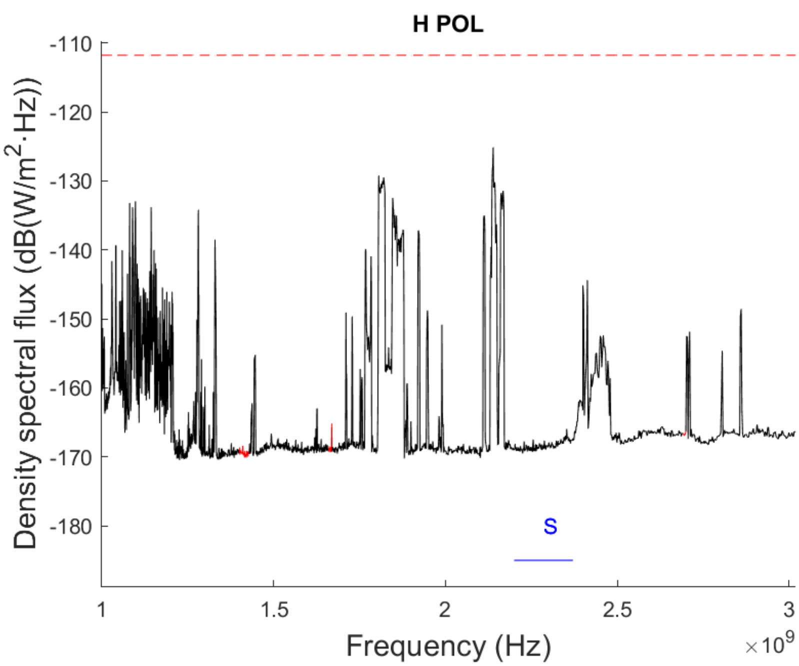
Figure 5: 1-6 GHz RFI spectrum example.

$$S[dB_{W/m^2 \cdot Hz}] = E_{\mathrm{rx}}\left[\mathrm{dB}_{\mu\mathrm{V/m}}\right] - 145.8 - 10 \cdot log(RBW[Hz]) \tag{1}$$

5 Results

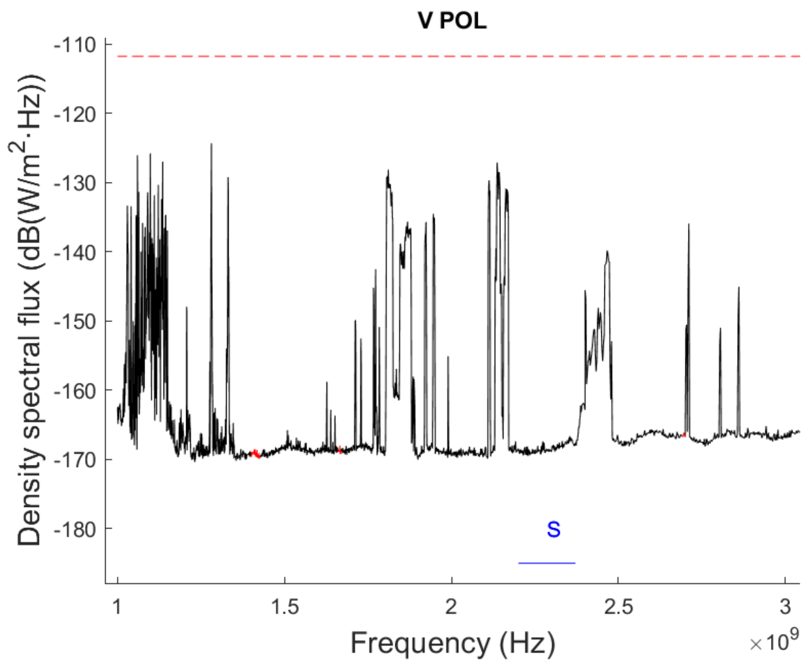
Several measurement every 1 GHz were taken in order to cover the frequency range from 1 to 26.5GHz with a reasonable resolution. A 360-degrees sweep is done in azimuth in 5 degrees step with an integration time of 15 seconds (the hole azimut range in a total time of 2500 sec). And a fixed elevation of 1 degree to point to the skyline, from where the terrestrial interferences come from. The RBW was set to 300 kHz.

The spectrum up to 26.5 GHz is shown but in several graphs with more detail and in both polarizations. The different bands of the 40-m receivers are plotted in blue, and in red the protected bands for RAS. Limit for the non-protected bands is plotted in dash line.

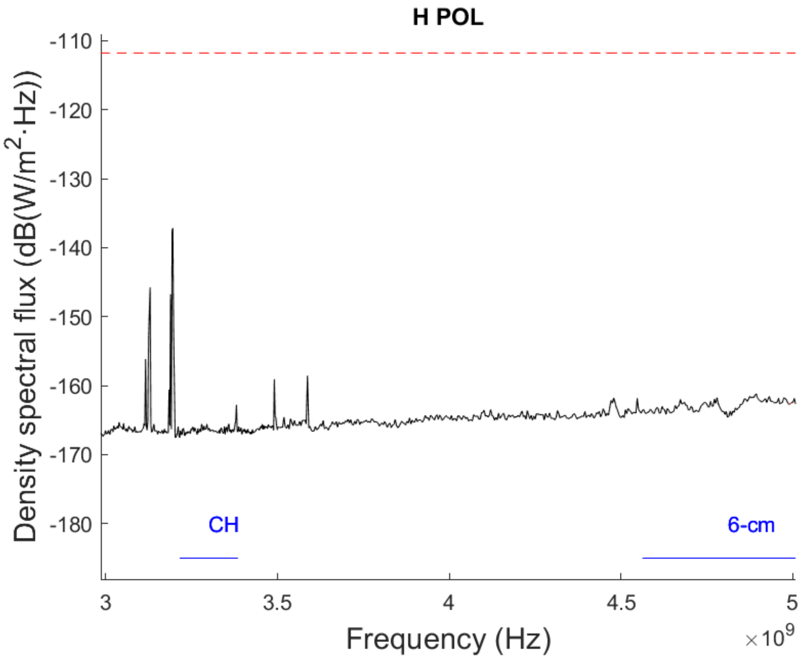


6 Conclusions

Some notes to be taken from the data:



- The different bands inside the spectrum analyzer has no been cancelled with the calibration as a consequence of the poor resolution the calibration has (only 500 points over 18 GHz for the worst case (L)). This problem will be fixed in a future in order to get more precised data.
- Upper part of the spectrum shows a rising noise floor. This is due to have applied the equation (section 2) to the whole spectrum (mainly this slope is due to the cable losses). The optimum way to do that should be to apply only the conversion into the real signals because the noise floor is related to the sensibility and no conversion has to be applied.
- The most polluted band is the lowest one up to 3 GHz approximately and also the 9 GHz for vertical polarization.
- There is not any interference in the protected bands for RAS, or at least not so intense that this system could detect it.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-140
-150
-160
-170
-180
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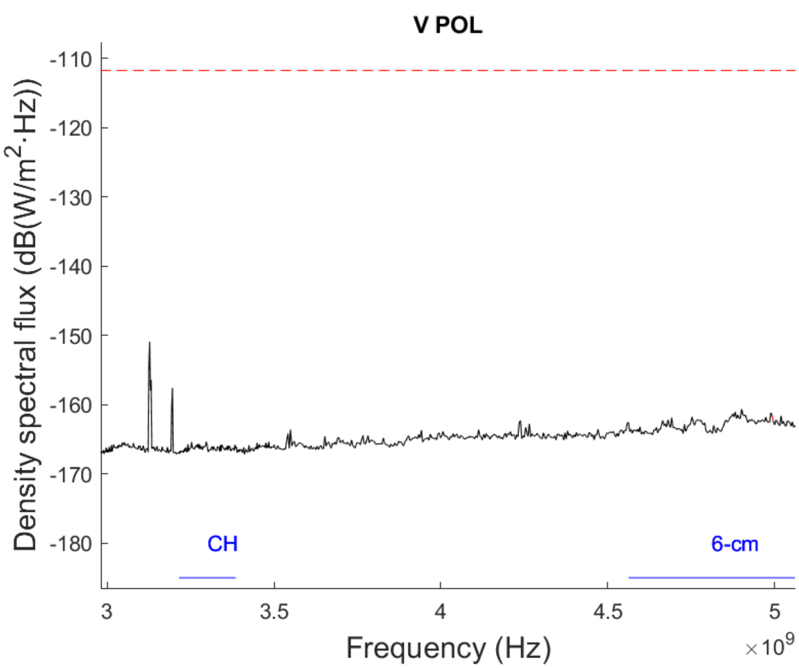
6-cm
3
3.5
4
4.5
5
Frequency (Hz)
×10^9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Density spectral flux (dB(W/m^2·Hz))
CH
6-cm
3
3.5
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4.5
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Frequency (Hz)
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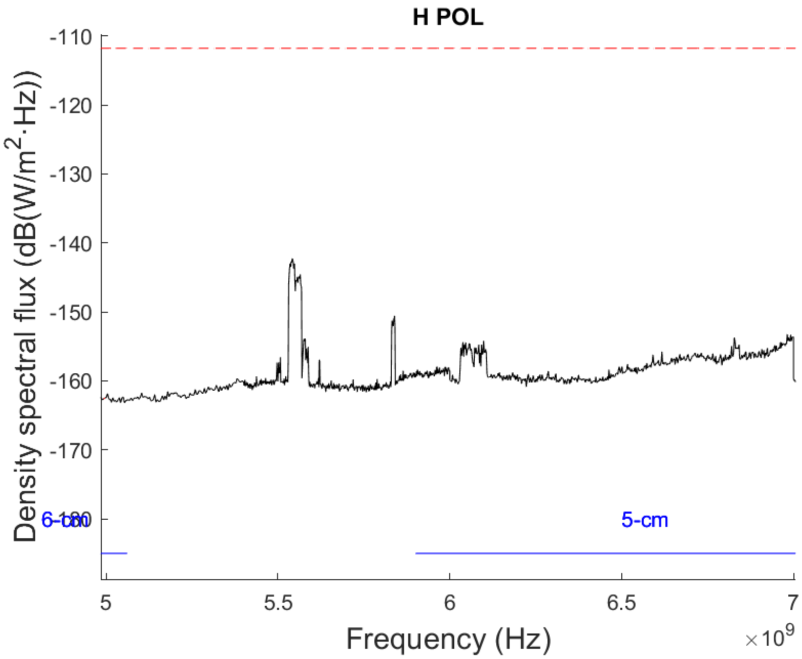
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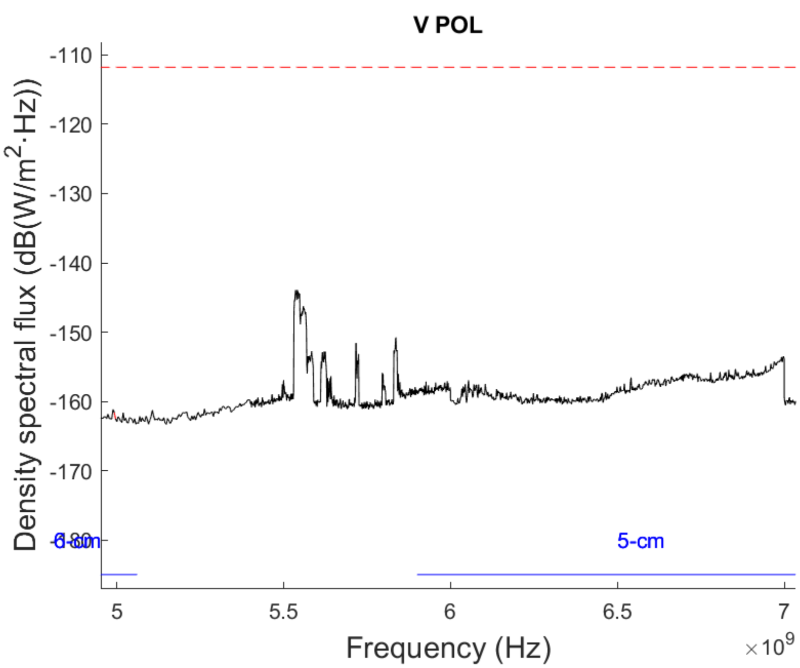
-180
6-cm
5-cm
Density spectral flux (dB(W/m²·Hz))
5
5.5
6
6.5
7
Frequency (Hz)
×10⁹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5-cm
Density spectral flux (dB(W/m²·Hz))
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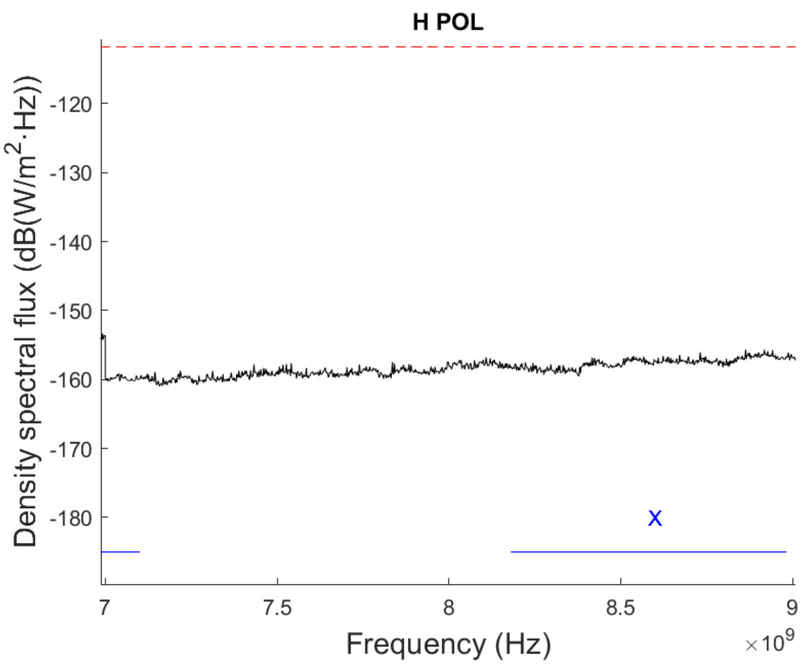
6.5
7
Frequency (Hz)
×10⁹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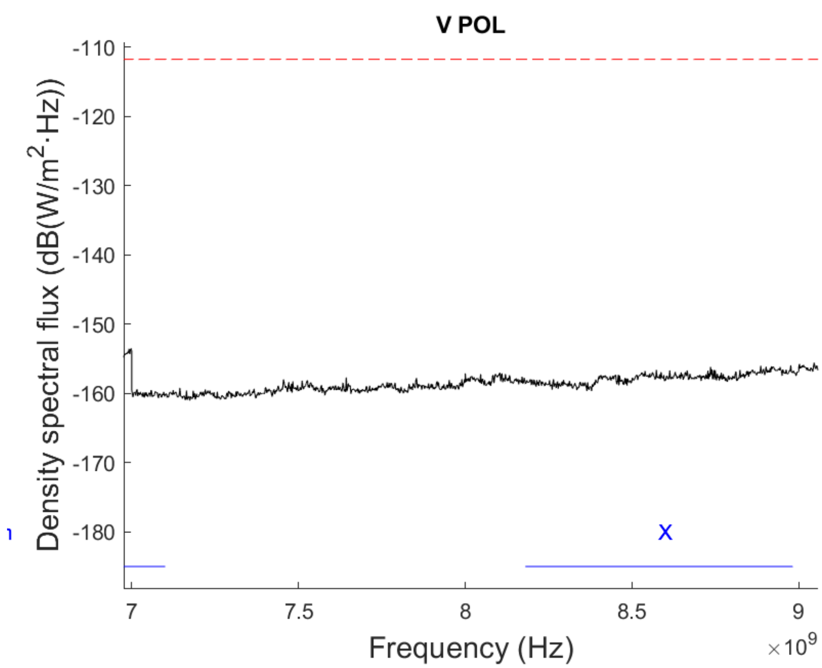
-180
X
7
7.5
8
8.5
9
Frequency (Hz)
×10^9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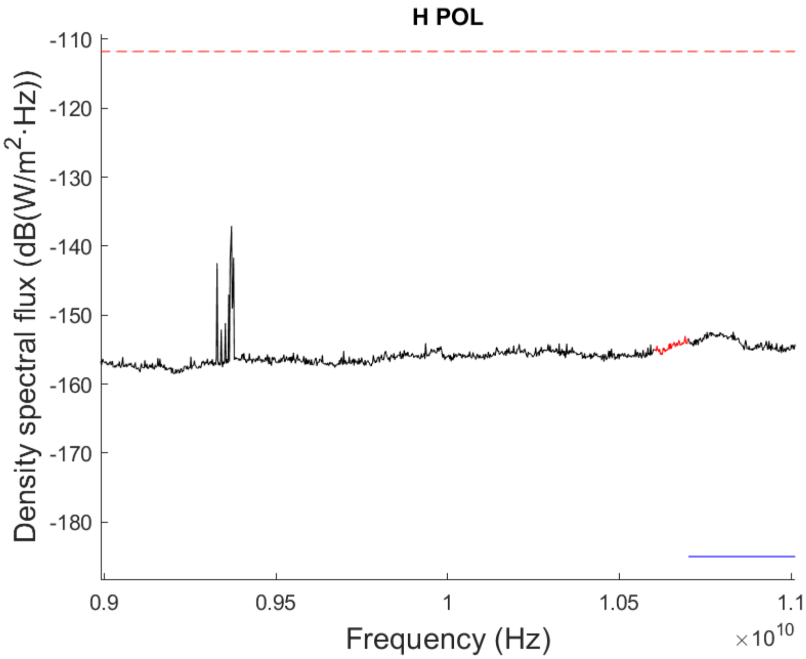
8
8.5
9
Frequency (Hz)
×10^9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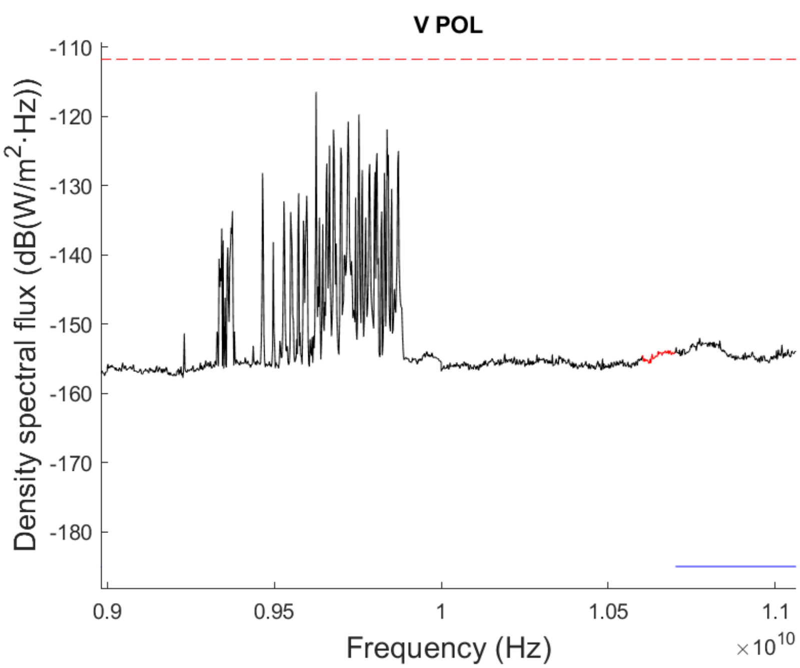
0.95
1
1.05
1.1
Frequency (Hz)
×10^{10}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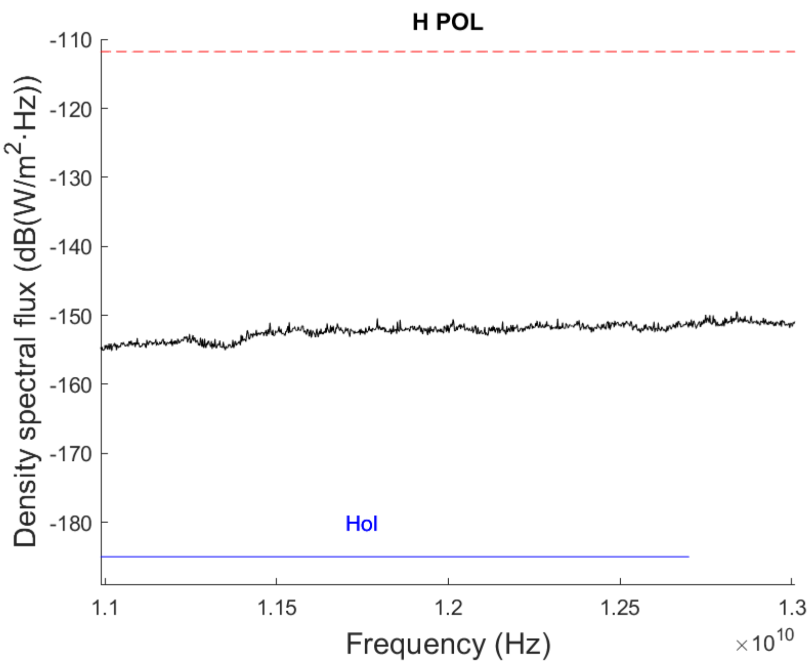
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Density spectral flux (dB(W/m^2·Hz))
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-180
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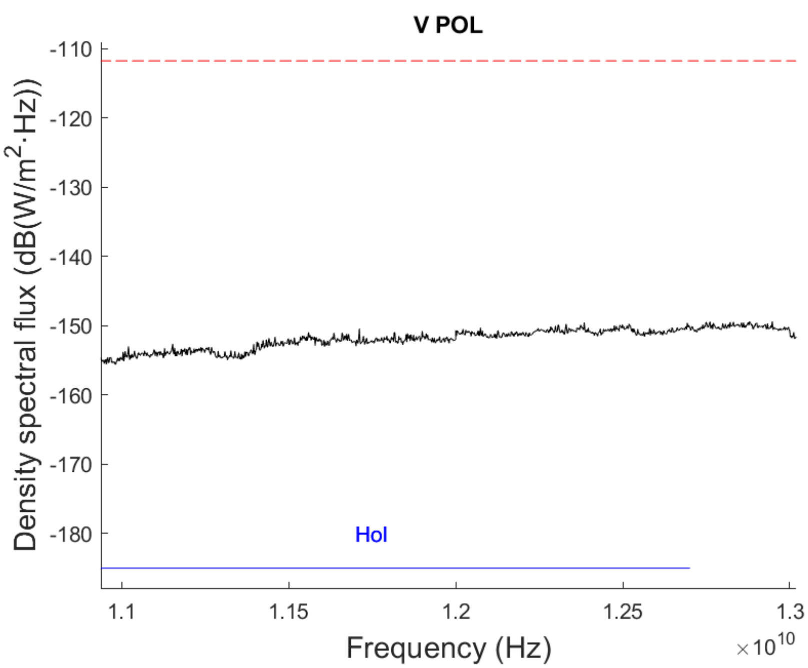
1.2
1.25
1.3
Frequency (Hz)
×10^{10}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Density spectral flux (dB(W/m^2·Hz))
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-120
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Hol
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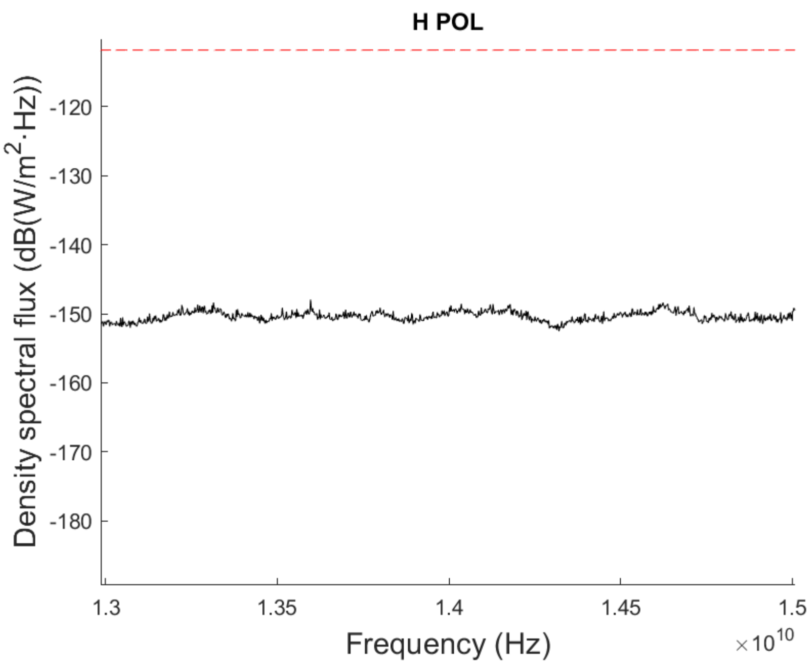
1.15
1.2
1.25
1.3
Frequency (Hz)
×10^{10}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Density spectral flux (dB(W/m²·Hz))
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-160
-170
-180
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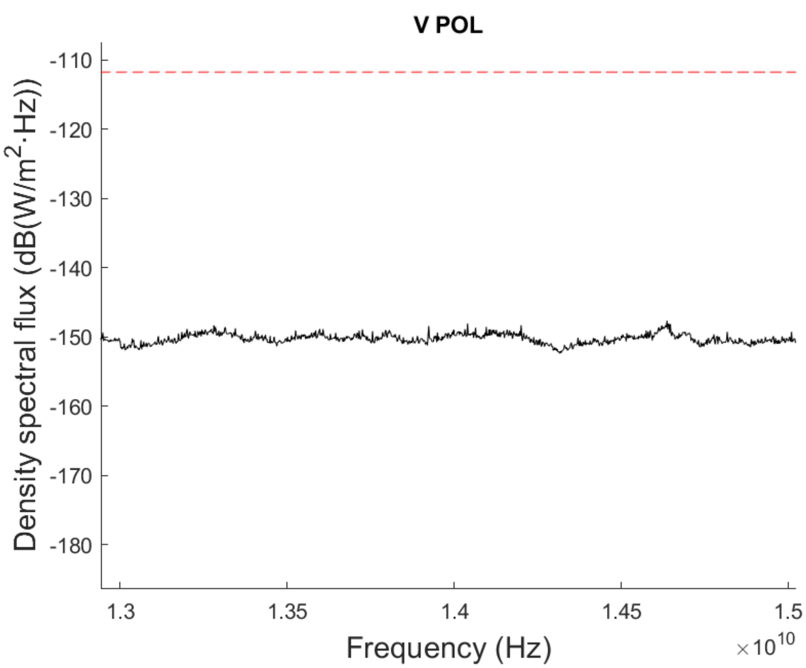
1.35
1.4
1.45
1.5
Frequency (Hz)
×10^10


V POL
Density spectral flux (dB(W/m²·Hz))
-110
-120
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-180
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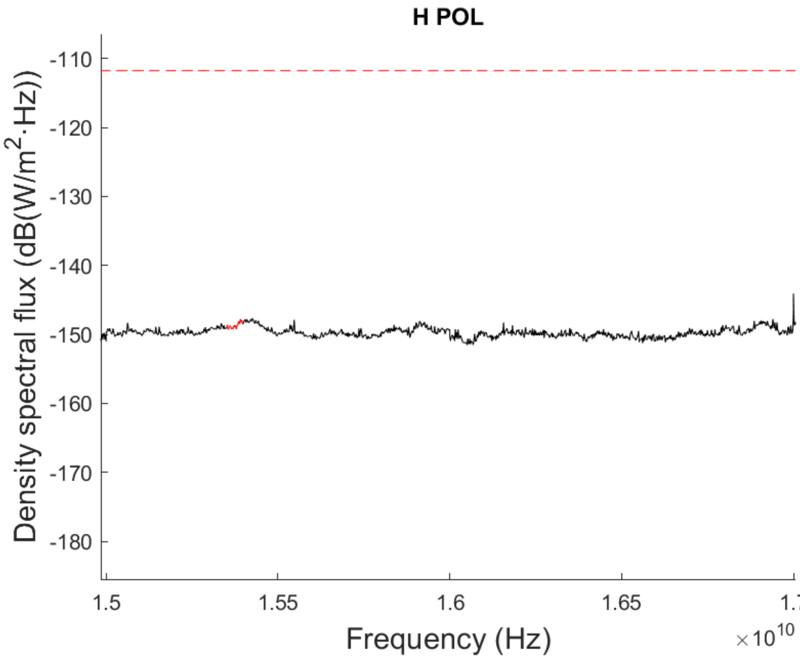
1.35
1.4
1.45
1.5
Frequency (Hz)
×10^10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Density spectral flux (dB(W/m^2·Hz))
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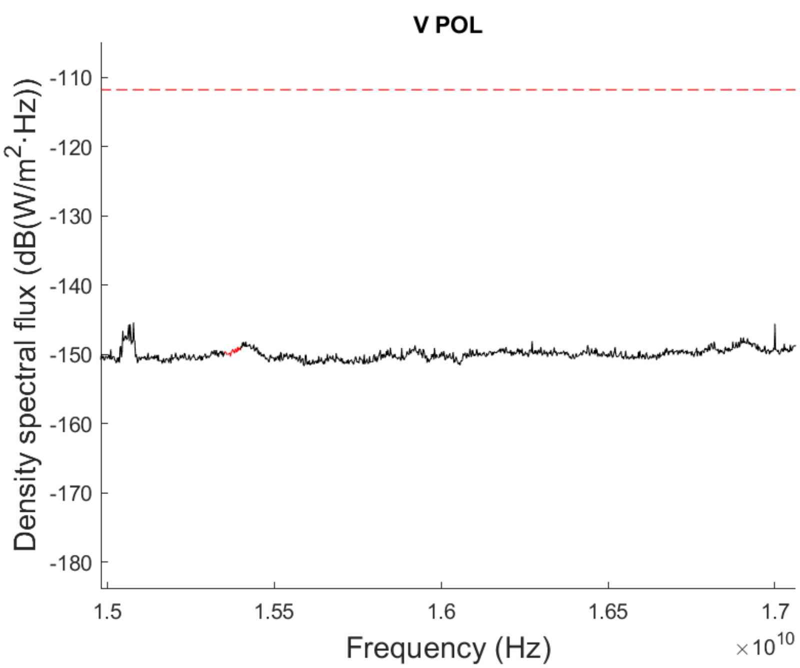
1.6
1.65
1.7
Frequency (Hz)
×10^{10}


V POL
Density spectral flux (dB(W/m^2·Hz))
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-120
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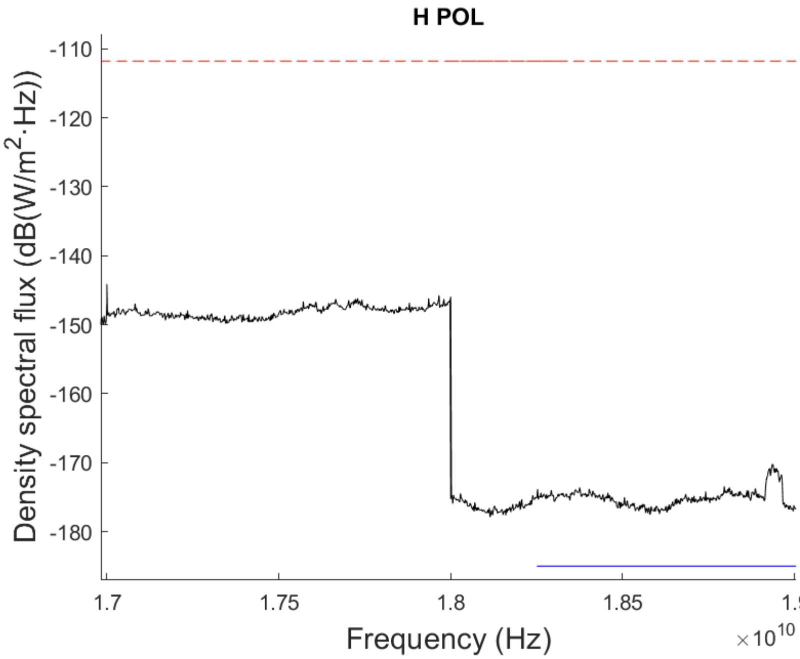
1.65
1.7
Frequency (Hz)
×10^{10}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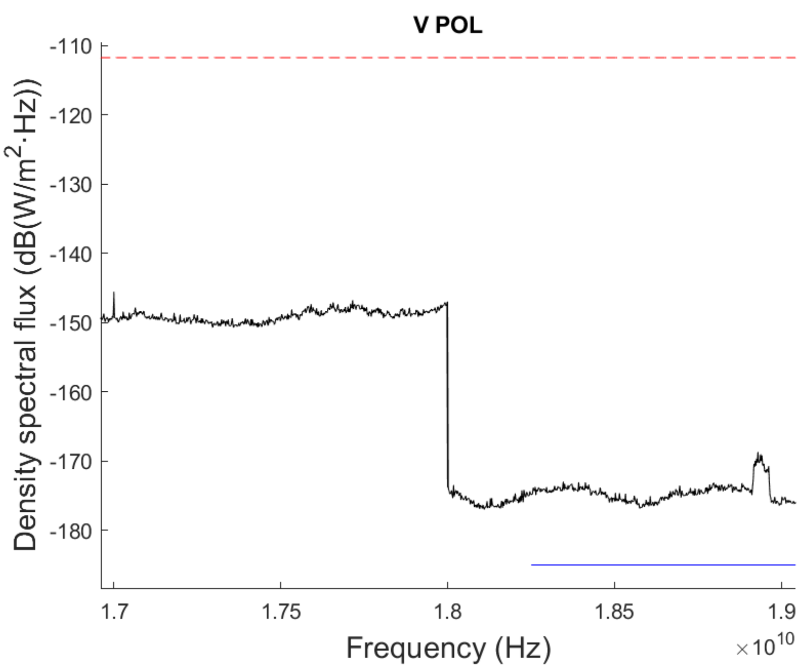
Frequency (Hz)
×10^{10}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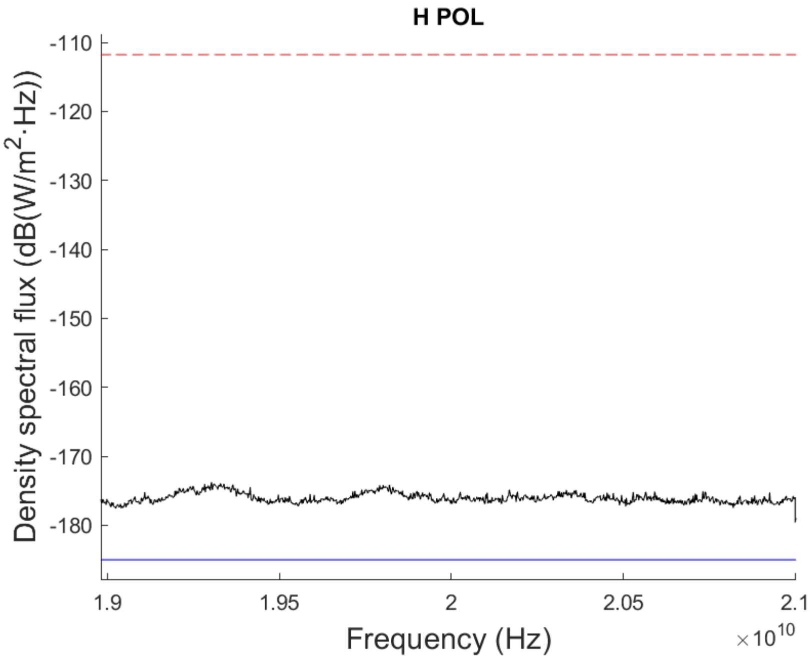
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Frequency (Hz)
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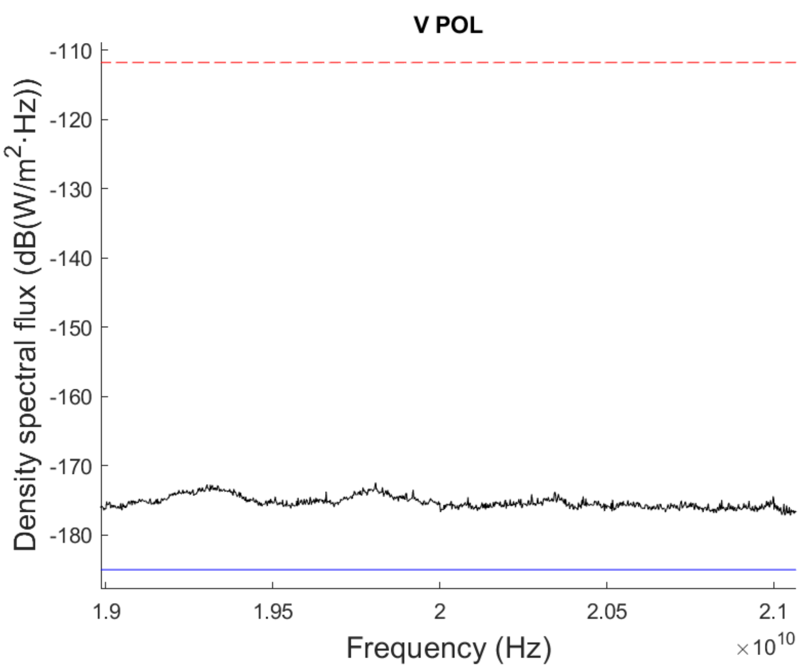
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Frequency (Hz)
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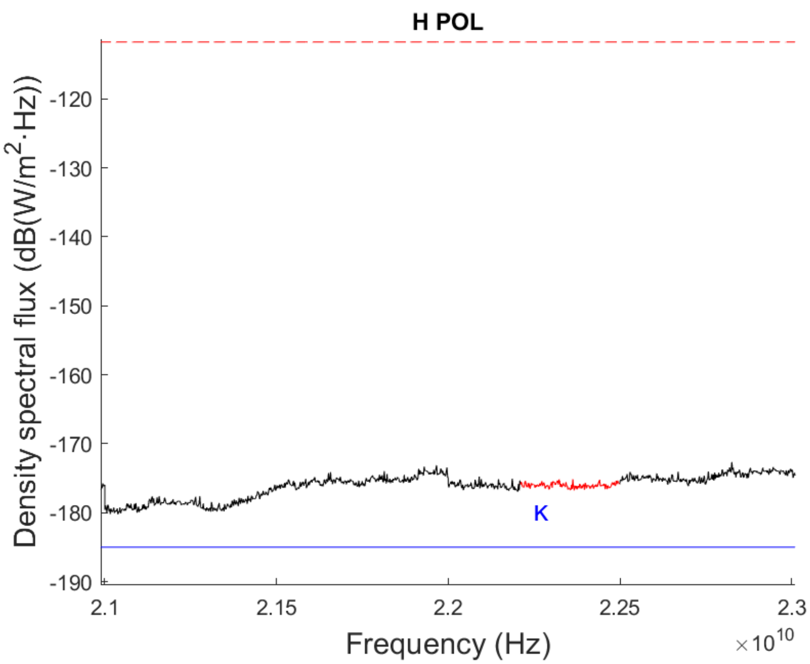
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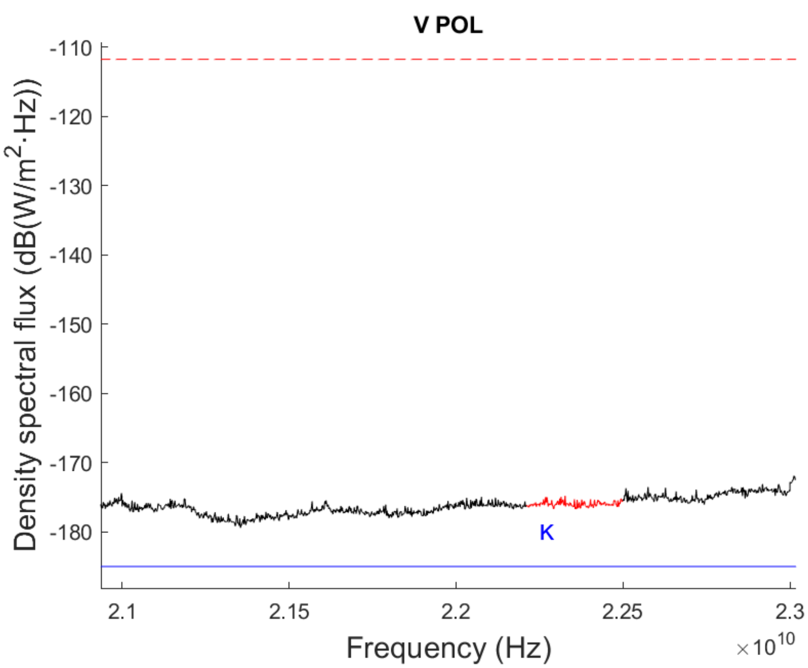
2.3
Frequency (Hz)
×10^{10}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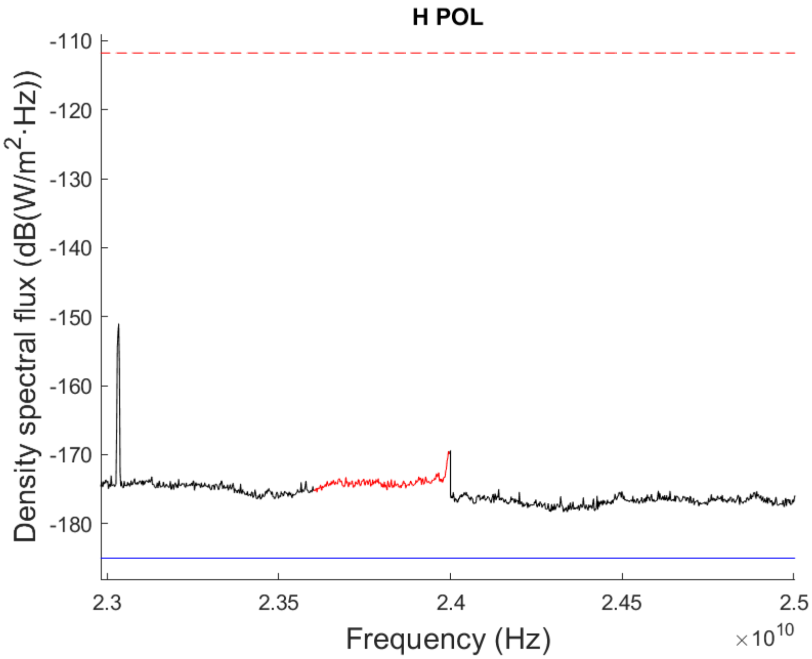
Frequency (Hz)
×10^{10}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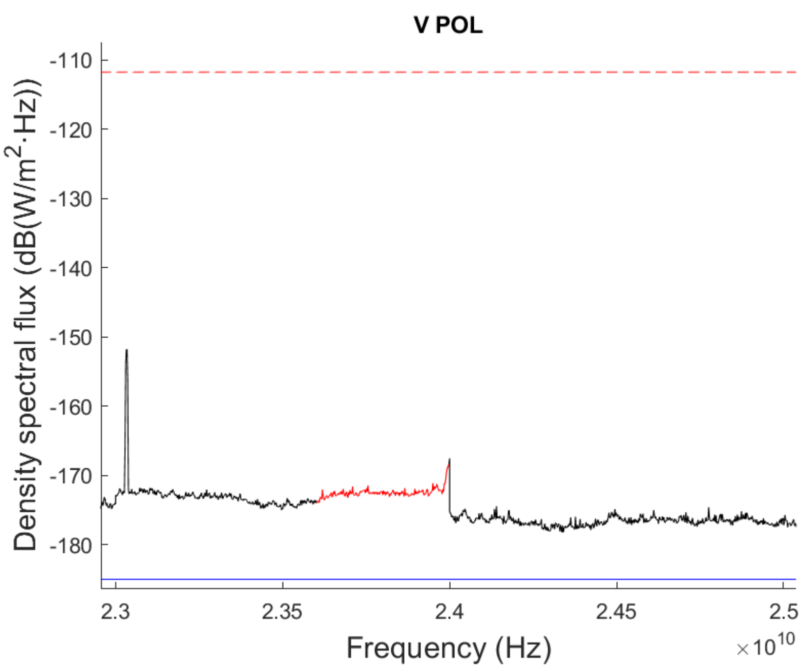
Frequency (Hz)
×10^{10}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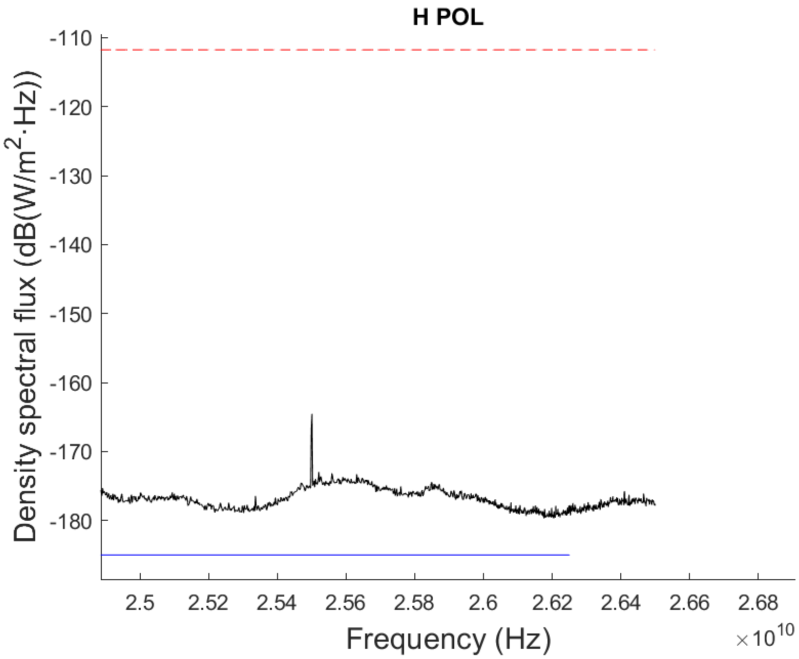
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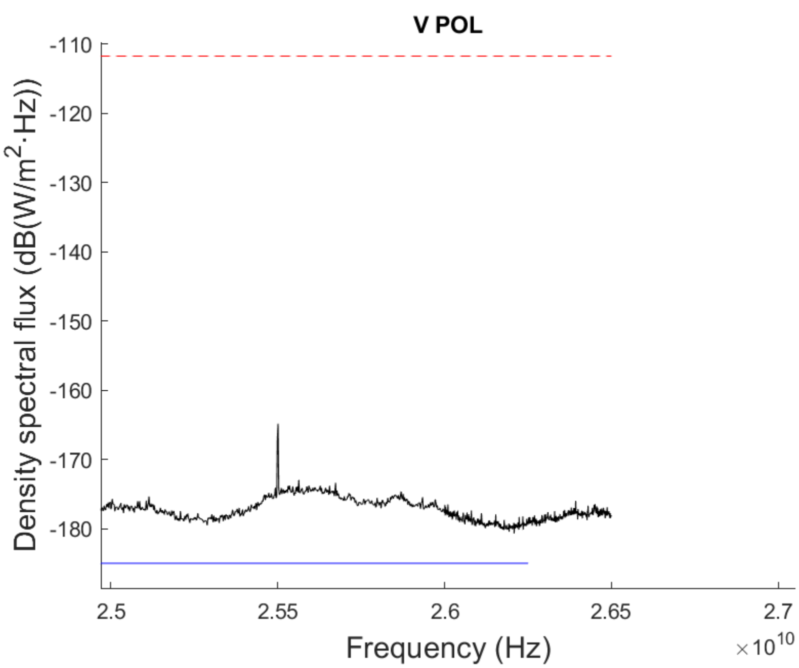
×10^{10}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Frequency (Hz)
×10^{10}