MIST Memo 41

Test Calibration Data of the MIST Instrument

Erika Hornecker
McGill University
erika.hornecker@mail.mcgill.ca

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1 Description

Initial calibration data for the MIST instrument were processed and graphed. This was automated with a Python script.

Each binary data file contains around 30 min of measurements. The data are broken down into 3 major groups which we will call group 'a', group 'b', and group 'c'. For each group, the first 8 columns of the array contain information on the iteration, time, and case of the data ("IT+time+case"), as such:

0: IT (iteration)
1: Year
2: Month
3: Day
4: Hour
5: Minute
6: Second
7: Case

Group 'a' is an array of S11 measurements at 0 dBm, in which the DUT is the receiver input. The array is of size $(5 \times (8 + Nv))$, where the first 8 columns are the IT+time+case as seen above, and Nv is the number of frequency points. The 5 rows are:

a[0,8::] frequency array in MHz (the datatype is complex, but for the frequency it must be made real)
a[1,8::] S11 of open
a[2,8::] S11 of short
a[3,8::] S11 of load
a[4,8::] S11 of receiver input

Temperature measurements captured during group 'a' measurements are stored in the 'at' array. The array is of size $(1 \times (8 + 4))$, where the first 8 columns are the IT+time+case, followed by temperature measurements from 4 different thermistors. In order, these 4 thermistors measure temperatures at the ambient load (inside the receiver), the VNA 50 Ohm load (inside the receiver), the internal antenna simulator (inside the receiver), and externally.

Group 'b' is an array of S11 measurements at -40 dBm, in which the DUT is the LNA. Group 'b' is formatted like group 'a', the only difference being the DUT. Temperature measurements captured during group 'b' measurements are stored in the 'bt' array, which is formatted like the 'at' array.

Group 'c' is an array of spectra of size $((Ns + 1) \times (8 + Nv))$, with the first 8 columns the IT+time+case,

Nv the number of frequency points, and Ns the number of spectra. The rows are organized by spectrum, with column c[:,7] indicating the case as such:

c[:,7]==31 Spectrum of receiver input
c[:,7]==32 Spectrum of ambient load
c[:,7]==33 Spectrum of ambient load + noise source

Data are collected for each of these cases consecutively in spectral cycles (one cycle contains a spectrum from each case). In the current version, each binary data file contains 40 spectral cycles. The frequencies (in MHz) are stored in c[0,8::], and the spectra for cases 31, 32, and 33, are contained in c[:,8::].

Temperature measurements captured during group 'c' measurements are stored in the 'ct' array, which is of size $(Nc \times (8+4))$ with 8 being the IT+time+case, followed by 4 temperature measurements as described above. Temperature is measured for each spectral cycle such that the total number of rows, Nc, is the number of spectral cycles.

2 Results

In the following figures we show the data in a typical binary data file from the MIST instrument. In this particular case, the device under test (DUT) connected to the receiver input was a long shorted cable implemented on a PCB. The external thermistor measured the temperature of this cable.

The S11s of the device at the receiver input and the LNA were calibrated using the corresponding measurements of the open, short, and 50-ohm load. In the future, a second layer of S11 calibration should be applied, which uses measurements of known VNA standards measured at the receiver input. We did not apply this second layer for this memo.

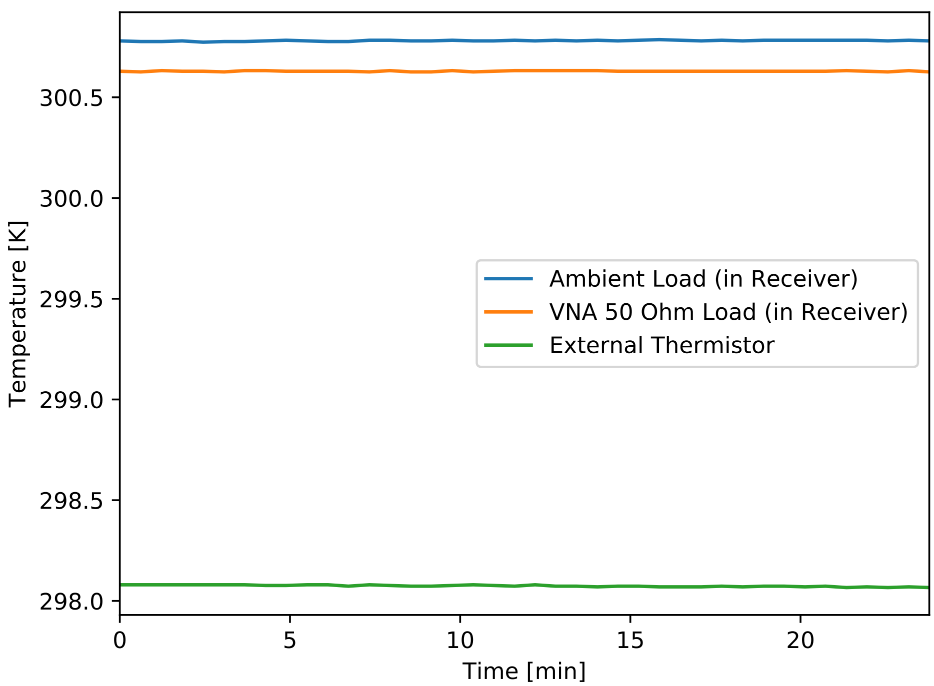


Figure 1: Graph of temperature as a function of time, plotted from the ‘ct’ array. The external thermistor was attached to the shorted cable connected to the receiver input. Note that the thermistor measuring the temperature at the internal antenna simulator was not connected, and therefore is not plotted.

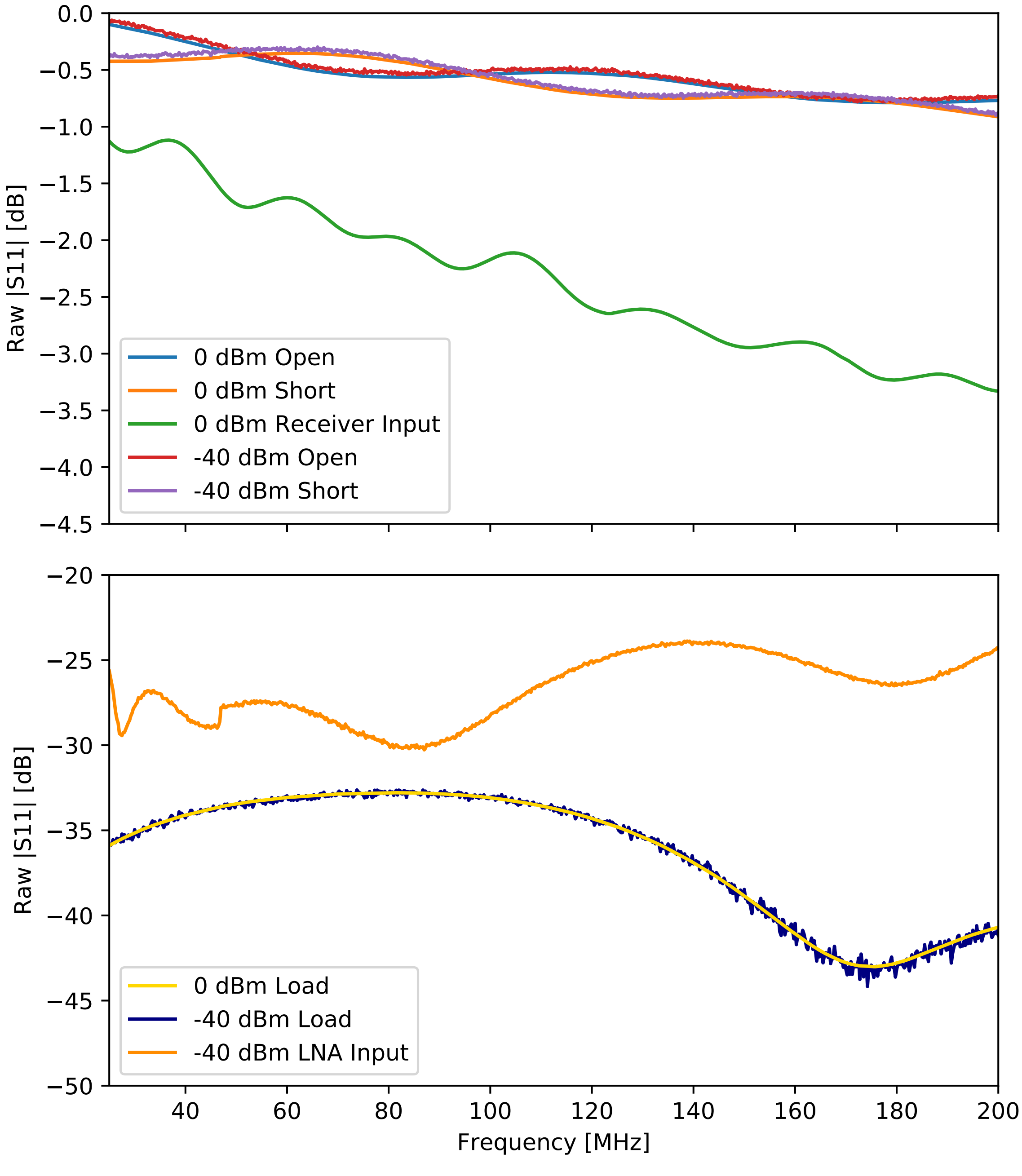
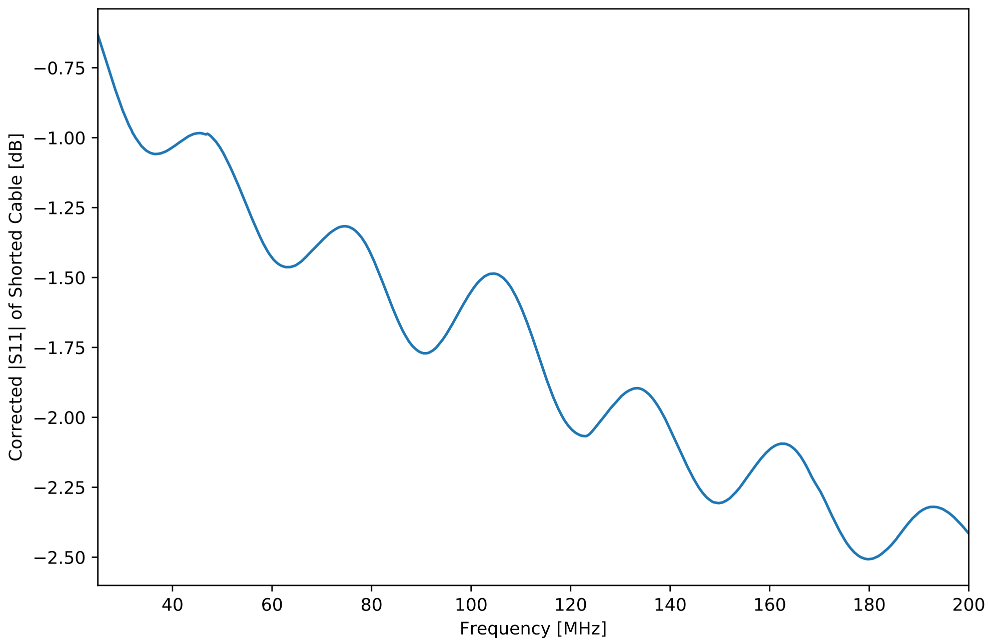
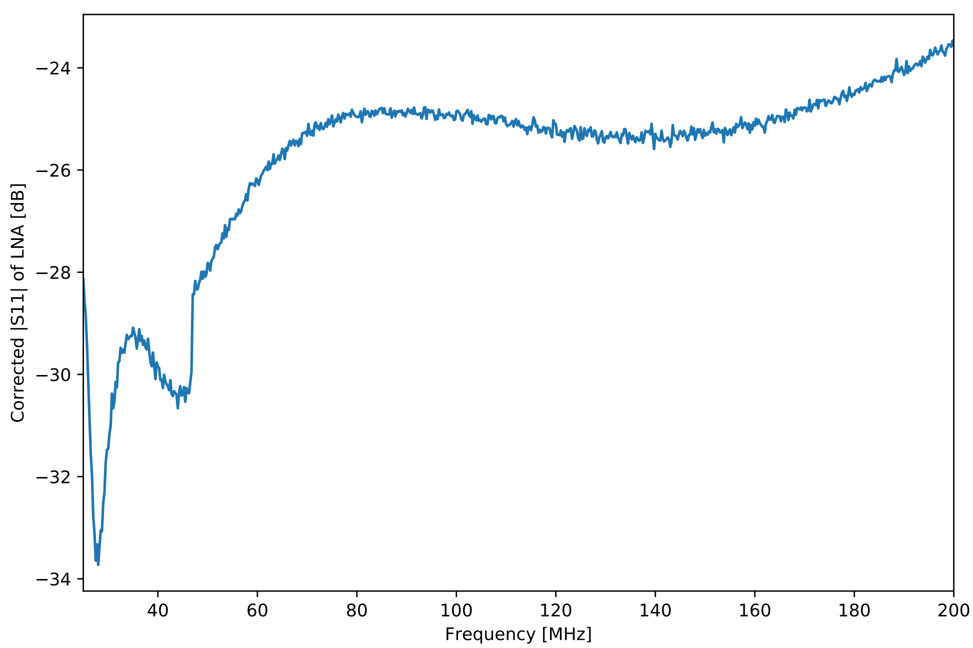


Figure 2: Raw $|S11|$ at 0 dBm (DUT is the receiver input) and -40 dBm (DUT is the LNA). The magnitude of the measured S11 (i.e. $|S11|$) was computed by using the formula: $20 \times log_{10}(abs(S11))$.



(a) Corrected $|S11|$ of the receiver input (in this case a shorted long cable).



(b) Corrected $|S11|$ of the LNA.

Figure 3: Corrected $|S11|$ for both the receiver input and the LNA. The S11 of the receiver input/LNA was calibrated using the measurements at 0 dBm/-40 dBm of the open, short, and 50-ohm load VNA standards located at the receiver front end. The magnitude of the corrected $S11$ was then computed using the same formula as in Figure 2.

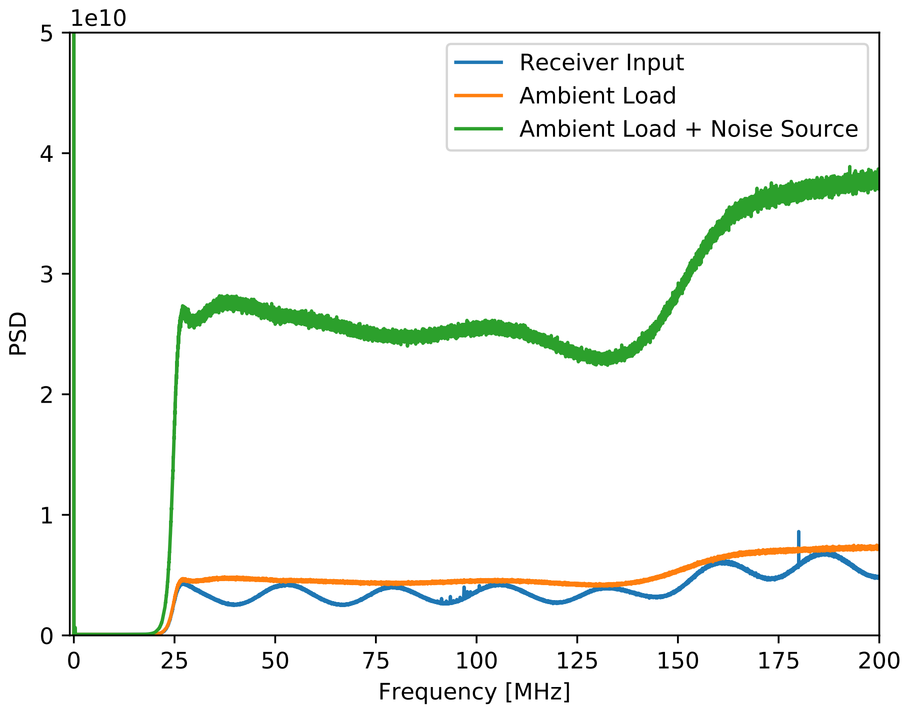
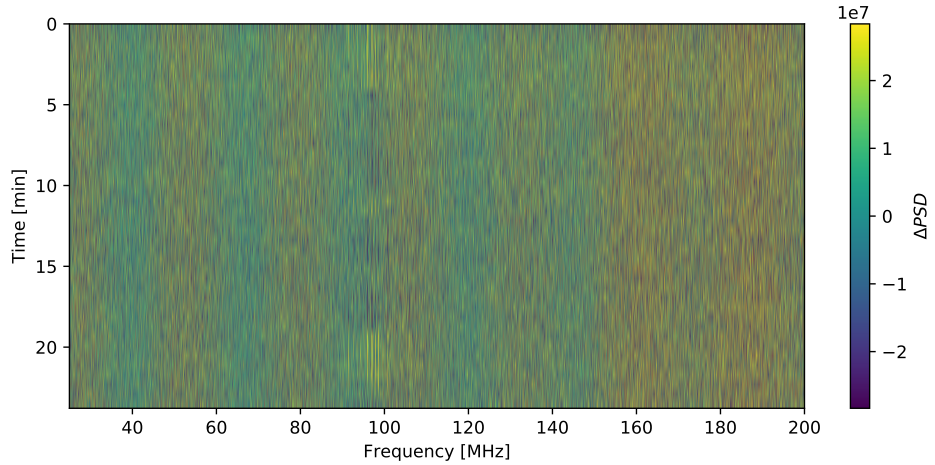
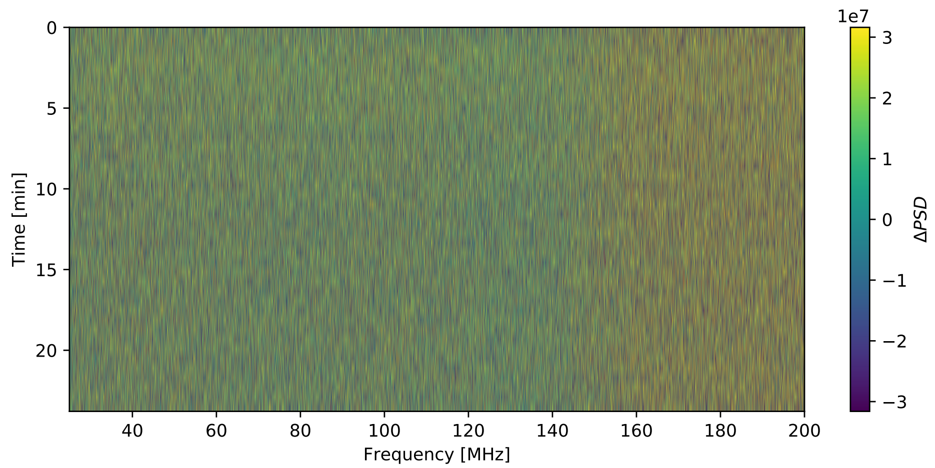


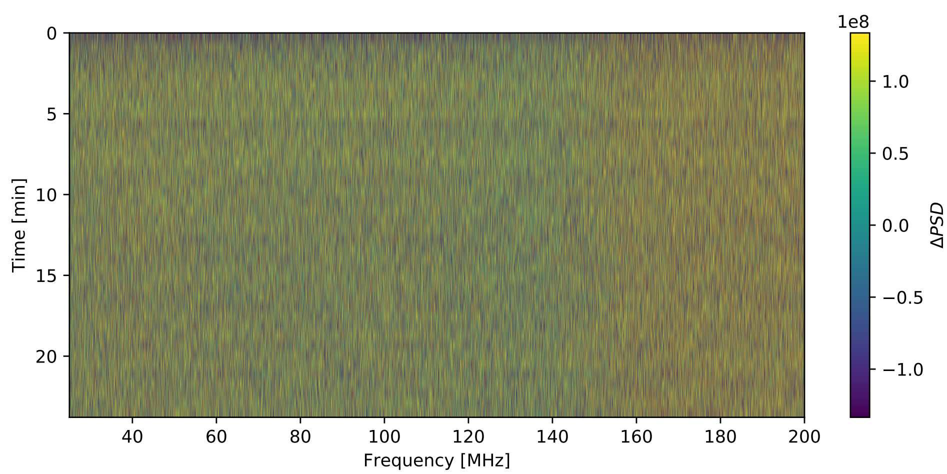
Figure 4: Spectra for all three cases from the first spectral cycle, shown as the power spectral density (PSD) versus frequency.



(a) Receiver Input



(b) Ambient Load



(c) Ambient Load + Noise Source.

Figure 5: Differences between spectra and the median spectrum of the dataset. The range of the color scale was optimized by saturating the FM band frequency range.

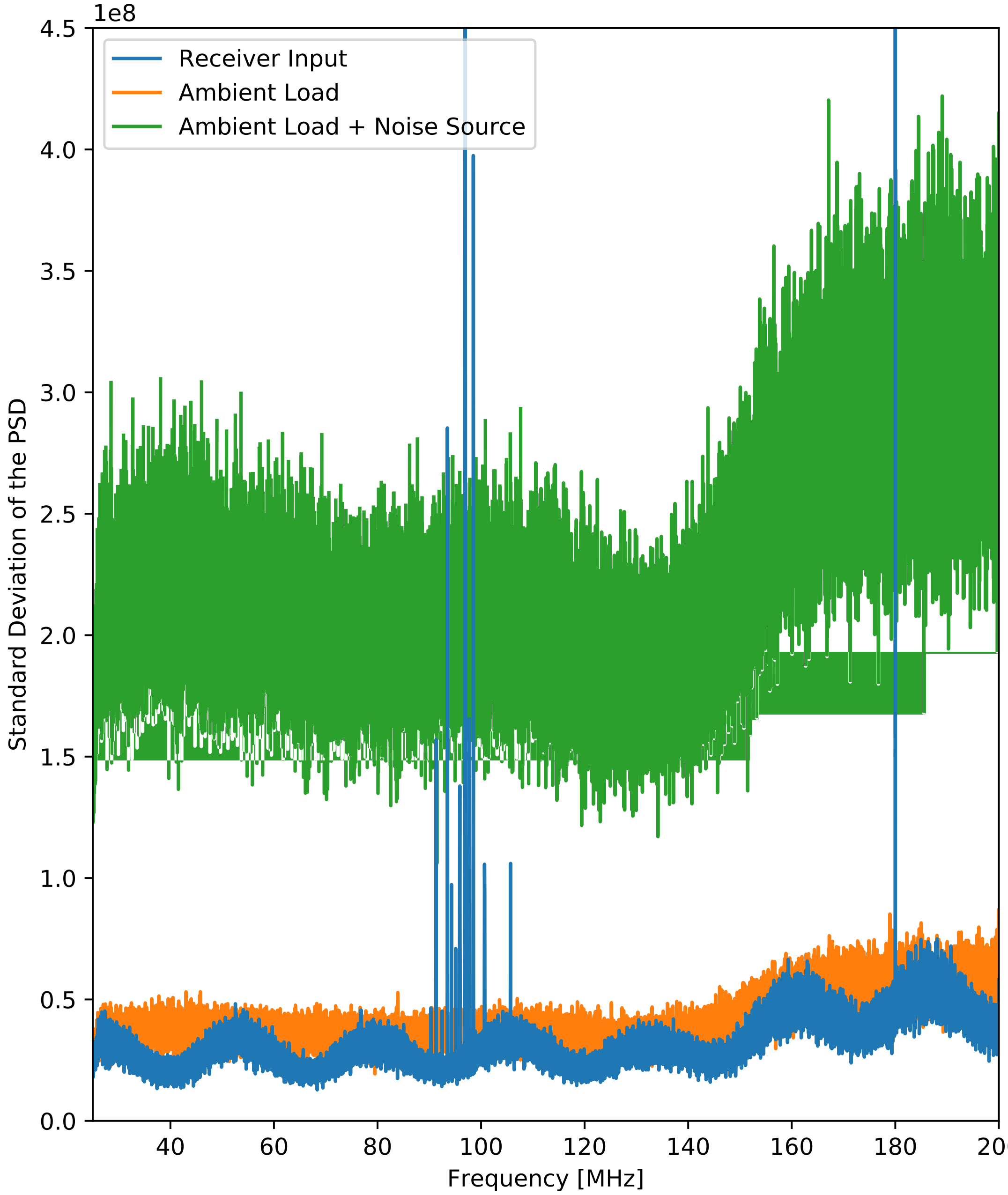


Figure 6: Standard deviation of a single PSD as a function of frequency, which was computed empirically from the scatter of all the data from the same input switch position.