TTT4180 Technical Acoustics - Assignment 0

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Introduction

This report describes the equipment and methods used for the recording assignment in the Technical Acoustics course (TTT4180). Furthermore, it presents the results in form of computed values attained using the recording. Finally, it provides a discussion of the results as well as difficulties encountered in the process.

1 Material and Methods

1.1 Recording Site

The site chosen for this assignment was the intersection by Studentersamfundet, where the main sound sources are street vehicles or just traffic noise in short.

The microphone was setup pointing directly to the intersection, where the closest point of sound generation was roughly 4m away (Fig. 1). Some of the sounds recorded are from sources up to 50m and more away from the microphone.

The recording took place on Sunday, 12th September 2021 between 12:45 and 13:45. The weather was overcast with a slight wind, a temperature of around 11°C, and no precipitation.

Figure 1: Recording Site Setup

1.2 Soundscape

The main component in the traffic noise is the sound the tires emit while driving on the concrete roads. This is a steady sound for which the intensity increases mostly with higher travelling speeds of the vehicles, if we neglect the tire type and its condition.

In addition to that there's the rumbling noise of combustion engines. The major contributors to the perceived loudness of their sound are the size of the cylinders, the RPMs, and the attenuation from the exhaust pipes.

Aforementioned would likely be categorized as low-frequency noise, especially when the cars are driving slow with low RPMs. This is the case for many of the passing vehicles in the recording. Occasionally there are also mid/high-frequency sounds, like the screeching of brakes or the honking of car horns.

1.3 Equipment

The main setup consisted of a handheld recorder with an external microphone connected by cable.

The microphone model used was a Behringer ECM8000 condenser microphone. Even though the wind was not strong, the windscreen was used preventively.

The external microphone was connected to the input of the digital recorder Zoom H5 (Serial No. 212698) with an XLR cable. The recorder was set to a sampling rate of 48kHz with 24-bit resolution.

The calibrator Brüel & Kjær Type 4230 (Serial No. 1719650) was used for the generation of the reference recordings. It provides 94dB at 1kHz. With this calibration source the gain of the recorder was tuned to match roughly −6dB.

Although the recorder was transported in the provided hard case for protection, the position of the analog gain knob had changed from the calibration before and after the recording. This results in some uncertainty of the calculated SPLs, which is further adressed in Section 3.3.

1.4 Calibration

With the recordings generated by calibrator signal the digital values can be transformed to pressure values in Pascal. To achieve this the formulas for sound pressure level (SPL)

$$p_{rms} = 10^{(SPL/20)} p_0 \tag{1}$$

and the digital root-mean-square (RMS)

$$x_{rms} = \sqrt{\frac{1}{N} \sum x^2 [n]} \tag{2}$$

are used to generate a scaling factor. Multiplying this scaling factor to the sampled signal $x[n]$ results in the digital values now expressing the measured, calibrated pressures values. This can be written as

$$p[n] = \frac{p_{rms,cal}}{x_{rms,cal}} x[n], \tag{3}$$

where $p_{rms,cal}$ and $x_{rms,cal}$ are the RMS values of the calibrator recording and $x[n]$ are the digital values from the 24-bit WAV-file recording.

1.5 Computation

After using the reference recording to compute the pressure values, it was possible to further analyze them by the usual methods including the Fast Fourier Transform (FFT), 3rd octave bands, and A-weighted 3rd octave bands.

Python was used as the programming language of choice. The code written provides a small CLI interface to trigger the computations for the values of interest.

2 Results

The following results were produced from a 30min piece of the recording. Due to difference in the gains before and after the recording, the values are given with a *pre* and *post* suffix, indicating calibration with the reference before and after recording respectively.

SPL total is calculated using the RMS values of the recording.

$$\begin{aligned} L_{p,pre} &= 74.3 \text{ dB} \\ L_{p,post} &= 75.1 \text{ dB} \end{aligned} \tag{4}$$

SPL for sequences are computed for the time constants of 1s and 0.125s. The full recording was sliced into pieces according to the time constants. And then the SPLs were calculated for every slice, which results in the plots given by the Figures 2 and 3.

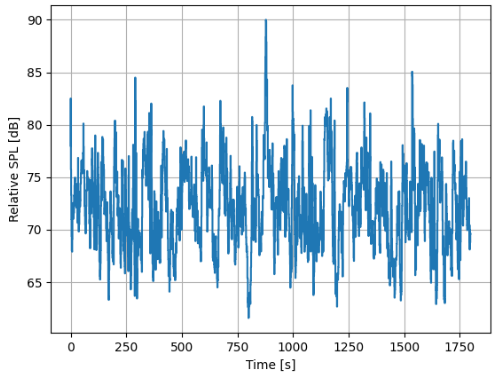

Figure 2: Time series of SPL with time constant set to 1s

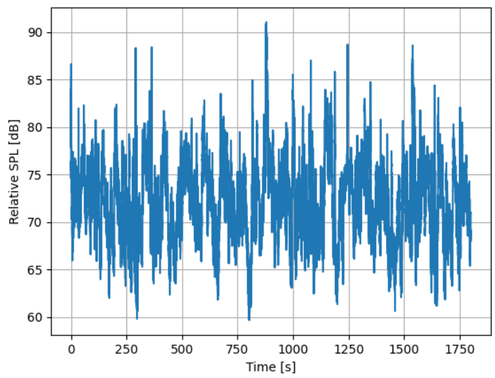

Figure 3: Time series of SPL with time constant set to 0.125s

A-weighted SPL total is computed from the 3rd octave band power spectrum adjusted with the corresponding weighting [1]. The spectrum is shown in Fig. 4. And the total SPLs correspond to

$$\begin{aligned} L_{p,pre} &= 68.2 \text{ dBA} \\ L_{p,post} &= 69.1 \text{ dBA} \end{aligned} \tag{5}$$

Power Spectrum attained with the FFT can be seen in Fig. 4. It shows a spectrum with constant bandwidth of 1Hz. Summing up all the SPLs from that spectrum then results in

$$\begin{aligned} L_{p,pre} &= 74.3 \text{ dB} \\ L_{p,post} &= 75.1 \text{ dB} \end{aligned} \tag{6}$$

3rd octave bands spectrum is also displayed in Fig. 4. The spectrum was generated from the FFT spectrum by using a table of low-, mid-, and upper-frequencies of the bands [2]. The total SPL calculated from this spectrum is then given by

$$
\begin{aligned}
L_{p,pre} &= 74.3 \text{ dB} \\
L_{p,post} &= 75.1 \text{ dB}
\end{aligned}
\tag{7}
$$

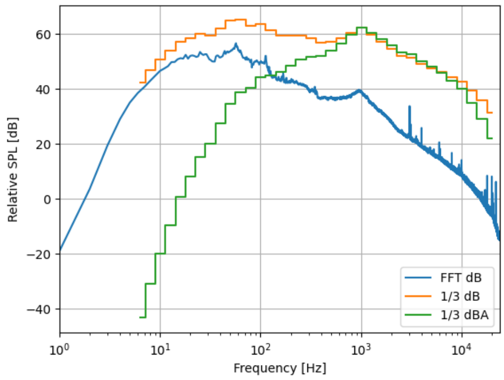

Figure 4: Power Spectrum for the FFT, 3rd octave bands, and the A-weighted 3rd octave bands using the pre-recording reference for calibration

3 Discussion

3.1 Recording Site

Initially, it was planned to record the emitted noise from a construction site. This turned out to be more difficult than expected. On the first day of recording, which was a Friday, it was raining heavily. This resulted in the recording being dominated by rain sounds.

In addition to that, it's highly reliant on the type of construction that's currently ongoing. There were a number of construction sites as possible candidates. But on the following Saturday most of them had a reduced work force and didn't produce a lot of sounds worth recording.

For those reasons, we have chosen to switch to the backup plan of recording a traffic intersection.

3.2 Clipping

With setting the gain of the recorder to correspond to −6dB using the 94dB source and the maximum of the recorder being at +6dB it allows recording SPLs up to 106dB. Even though this is quite loud, there still was one event that caused clipping in the recording, which was a loud motorcycle passing by.

3.3 Recorder

Although being careful during transport and handling of the recorder, the gain knob was moved after recording the reference from the calibration source. Because it is unknown at which point during the recording this happened, there's uncertainty in the validity of the computed values.

The difference between the computed values is approximately 0.8dB. This corresponds to a relativ error of roughly 1%, which is significant.

3.4 Post-Processing

The most prevalent issue to overcome was the amount of available RAM. Loading a 30min recording and then storing and plotting manipulated copies, like calibrated signal and power spectrums, quickly filled up the available 8Gb of RAM. Enlarging the virtual RAM and being more thoughtful about resource usage, helped to minimize this issue. Allowing to run the code with the complete recording.

Additionally, it had to be ensured that the code did not take on the complexity of $\mathcal{O}\left(n^2\right)$. As this resulted in extremely long computation times when using the full 30min recording.

4 Conclusion

The recording session shows that the noise from traffic intersection ocurres mostly in the lower frequencies. At least if accumulated over time, the high-frequency content is overshadowed by the low-frequency sounds.

Despite the fact that the power-spectra suggest close to no power in the high frequencies, those sounds, like the screeching of brakes, are personally perceived a lot more intrusive than the steady low frequency sounds of the passing vehicles.

Although having the visuals to relate the sounds to is helpful, it should be possible working with an unattended recording. Working solely with a time series of sound levels on the other hand is more challenging. This is mainly due to not being able to relate the sound levels to past experiences. For example, if we have a recording, it's possible to listen to the sounds that are questionable and possibly identify the source. Which would not be the case using sound levels only.

5 References

References

[1] (2019). *A-Weighting Table | Acoustics Engineer*. [online] Available at: https://acousticalengineer.com/a-weighting-table [Accessed 05. October 2021]

[2] Engineering ToolBox, (2010). *Octave Band Frequencies*. [online] Available at: https://www.engineeringtoolbox.com/octave-bands-frequency-limits-d_1602.html [Accessed 05. October 2021]