Development of an Ultrasound Level Meter Suitable for Practical Use in Occupational Health

Moritz Wächtler[1], Christoph Kling[1], Andrea Wolff[2]
[1] *Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, e-mail: moritz.waechtler@ptb.de*
[2] *Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (IFA), St. Augustin*

Introduction

The number of workplaces exposed to airborne ultrasound is increasing due to the growing usage of ultrasound techniques such as welding and cutting. Since German law requires that all possible hazards in the workplace be assessed, it is important that ultrasonic noise be measured as well. However, the sound level meters currently available are very limited in terms of their applicability to ultrasonic frequencies. Therefore, as part of a project at PTB in collaboration with IFA, a sound level meter with an extended range covering audible as well as ultrasonic frequencies is being developed.

Why is measuring ultrasound so difficult, anyway?

- Audio devices such as analog-to-digital converters are often optimized for the audible frequency range. In the ultrasonic frequency range, however, their sensitivity is often inadequate, resulting in poor signal-to-noise ratios. In addition, signals may be disturbed by electric interferences emitted by the device itself.
- Digital signal processing algorithms cause an increased computational load due to the higher sampling rates of the signals.
- In ultrasonic fields, sound pressure strongly depends on the location, making it difficult to capture a source's sound field with a reasonable effort.
- Obstacles in the path of the sound waves (microphone protection grid, device case, operator) have a large impact on the sound pressure. This means the mere act of measuring in the sound field causes it to change significantly.

Ultrasound level meter

This project aims to develop an ultrasound level meter suitable for practical use in occupational health. The scope of the project comprises the following elements (among others).

Formulating requirements

The requirements for the ultrasound level meter are partly based on the international standard for sound level meters [1], yet some requirements need to be expanded to include the ultrasonic frequency range. In addition, some of the meter's requirements were derived from a directive on ultrasonic noise in the workplace [2]. The following aspects of the meter are of particular interest for its application to ultrasound in the workplace:

- Temporary independence from mains power supply,
- Electromagnetic compatibility (of particular interest due to the strong electromagnetic exposure of some workplaces),
- The meter's microphone can be detached from the device and mounted on a microphone holder, thus reducing the acoustical influence of the case and the operator.
- Directivity patterns of the microphone in use need to be taken into account. Detailed requirements will be formulated during the course of the project.
- Linearity at high sound pressure levels with the operating range being between 70 and 150 dB SPL,
- Ultrasound frequency weightings:
  - U-weighting [3]: A low-pass filter designed to suppress ultrasonic components during measurements of audible sound,
  - AU-weighting [2]: A concatenation of the A-weighting, as known from conventional sound level meters, and the U-weighting filter.

  The use of these filters may seem contradictory within the scope of this project, as its goal is to measure ultrasonic components. However, the AU-weighted sound level has become an important measure for the assessment of sound exposure in the workplace [2], which is why it needs to be included in the software.
- Time weightings: fast, impulse, EQ, peak
- Display of a fast Fourier transform, particularly useful for identifying inaudible spectral components
- A fractional-octave filter bank with mid-frequencies ranging up to at least 40 kHz. Support of 1/12, 1/3 and 1/1 octave filters.

Development of software

A software program for calculating, displaying and recording sound levels is being developed using the Python programming language. The time curve of the

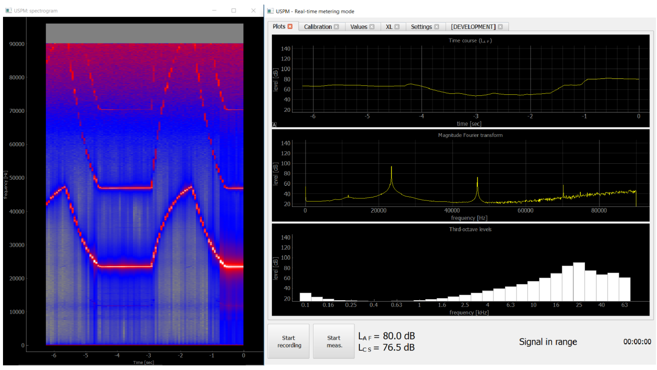

Figure 1: Graphical user interface of the software being developed.

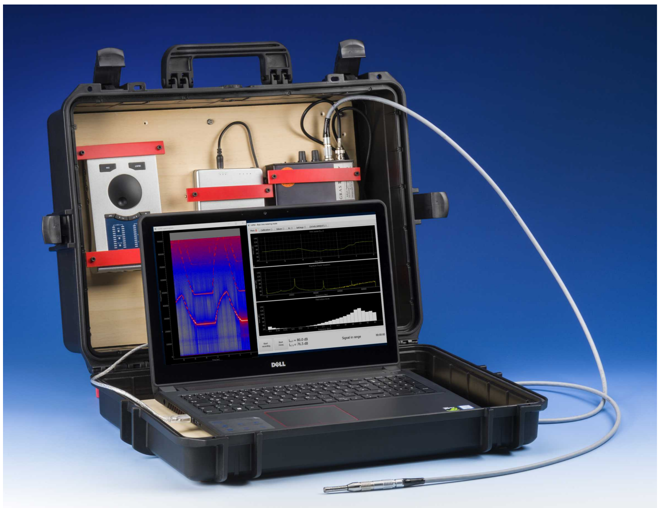

Figure 2: The assembled prototype of the ultrasound level meter.

sound levels, the fast Fourier transform, the fractional octave levels and a running spectrogram can be monitored via a graphical user interface (Figure 1). The software supports two basic modes of operation: a real-time metering mode as well as an offline mode that allows the user to analyze previously recorded sound files. Due to the higher sampling rates, the analysis of digital signals requires much more processing power than in sound level meters that cover only the audible frequency range.

Selecting, testing and assembling hardware components

The prototype of the sound level meter consists of a laptop computer, an analog-to-digital converter, a power module, a microphone preamplifier and a quarter-inch microphone cartridge, all of which are contained in a solid and portable case (Figure 2). The device can be powered using rechargeable batteries, making it temporarily independent from the mains power. Specialized test rigs at PTB allow the components to be checked concerning their compliance with the requirements formulated.

As an example of such an evaluation test, Figure 3 compares the sensitivities of a quarter-inch microphone cartridge as a function of frequency, measured once with and once without the protection grid. The use of the grid leads to a more pronounced maximum and a reduced sensitivity to higher frequencies.

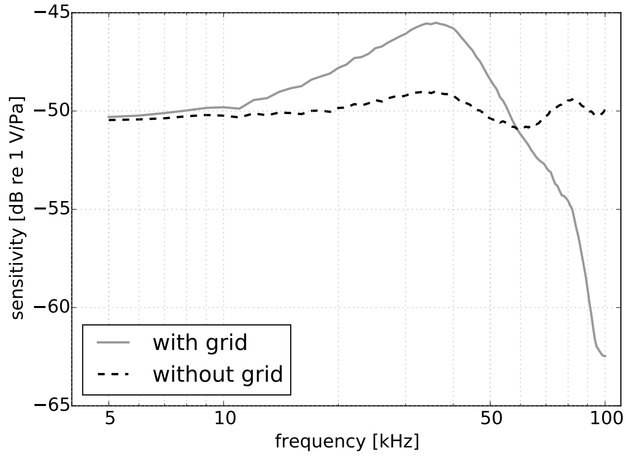

Figure 3: Sensitivity of a quarter-inch microphone cartridge as a function of frequency, measured with and without the protection grid.

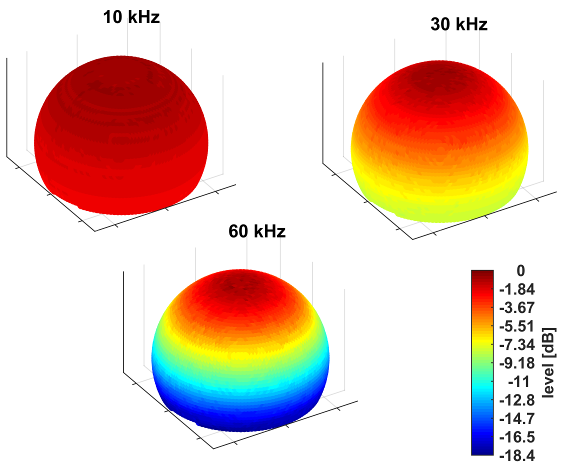

Figure 4: Directivity patterns of a quarter-inch microphone cartridge (without the protection grid) recorded at different frequencies.

As a further example, the directivity patterns of a quarter-inch microphone cartridge (without the protection grid) are shown in Figure 4. The microphone was located in the center of the spherical measurement surface that had a radius of 0.7 m; the membrane was facing upwards. The maximum sound pressure level was normalized to 0 dB for each of the spheres. It can be seen that the directivity patterns become more pronounced as the frequency rises; that is, the dependence of the sound pressure level on the direction of incidence increases.

Outlook

During the remainder of the project, the following procedures for the practical use of the ultrasound level meter will be developed:

Development of a practical measurement procedure

Ultrasonic sound fields are characterized by the highly heterogeneous spatial distribution of their sound pressure levels. That is, the sound pressure strongly depends on the location and the direction of incidence (as can be seen from the results in Figure 4). In addition, even small obstacles cause significant changes in the measured sound pressure levels (Figure 3). For this reason, the development of a systematic measurement procedure is of great importance. Two points are crucial: first, finding an optimal compromise between uncertainty and measurement effort; second, causing as few disruptions to the working process as possible.

Development of a calibration procedure

Sound level meters need to be checked on a regular basis. To this end, an acoustical calibration procedure is needed. In this project, an acoustical free-field calibration procedure will be developed for the purpose of periodically checking the ultrasound level meter.

Acknowledgements

This project is funded by the TransMeT program of PTB. We would like to thank:

- Andreas Schmidt for designing and constructing the case interior,
- Marvin Rust for conducting the measurements of the directivity patterns and the analysis of the results,
- Robert Schöneweiß for his helpful comments on the conference poster,
- Vinay N. Krishnan for his valuable advice on Python programming.

References

[1] IEC 61672-1:2013: Electroacoustics – Sound level meters – Part 1: Specifications.

[2] VDI 3766:2012-09: Ultraschall - Arbeitsplatz - Messung, Bewertung, Beurteilung und Minderung (Ultrasound - Workplace - Measurement, assessment, judgement and reduction).

[3] IEC 61012:1990: Filters for the measurement of audible sound in the presence of ultrasound.