Qualification of laboratories for sound power determinations

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Introduction

The sound power is the major descriptor for the sound emission of technical sources. It is usually determined by standardised methods e.g. the diffuse- or the free-field method. In most cases, the sound pressure is measured on an enveloping surface and the sound power is calculated under the assumption of a free sound field. The application of this method requires a certain quality of the sound field which is tested by standardised procedures. There are, at current, several methods standardised to test the quality of a free sound field. Within a cooperation with Bosch and Siemens Household Appliances (BSH), PTB now had the possibility to compare the different methods for the qualification of free-field environments. The first investigated method is the qualification procedure according to annex A of ISO 3745 [1] or ISO 26101 [2]. These test results could be compared to results from another testing institute obtained for one room. It was furthermore very interesting to compare the performance of flat panel rooms with other rooms where the lining is made of wedges. Additionally, the room correction K_2 according to ISO 3744 [3] was determined on several box-shaped surfaces. The rooms were three newly erected highly absorbing rooms with flat panel absorbers of about 35 cm thickness and a perforated metal plate cover.

1/*r*-measurements

By this method, it is tested whether the sound pressure drops by 6 dB per doubling the distance from a point source. This test is usually performed on five paths in anechoic or hemianechoic chambers according to ISO 3745, annex A [1] or according to ISO 26101 [2]. These standards define the test parameters and the tolerated deviations from the ideal 1/*r*-behaviour. The tolerated deviations are ±1.0 dB for an anechoic room and ±2.0 dB for a hemianechoic room at medium frequencies. They are larger at higher and lower frequencies. The result of this test is a maximum distance from the source for each path where all points on this path are inside the standardised tolerance. This results then in a general performance evaluation for a volume inside a measurement chamber. Nevertheless, this test procedure is not really linked to a sound power determination. It is especially not possible to derive an uncertainty component for sound power level determinations due to the remaining room reflections.

PTB's test setup and details of the measurement procedure are given in [4]. A special multisine test signal is used in combination with an FFT-measurement. The measurement microphone is moving during the measurement using a cable car. The integration length is 1 cm up to 4 kHz and 1 mm for the higher frequencies. The test is performed twice, once with the source off to determine the background noise and once with the source turned on.

A typical sound pressure level as a function of distance is shown in Figure 1. It can be seen, that the background noise is well below the source signal and that there are some minor reflections leading to a standing wave superposed to the free wave. The amplitude of the standing wave increases slightly with increasing distance to the source.

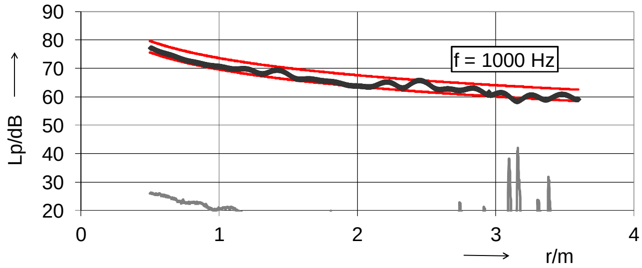

Figure 1: Measured sound pressure level as a function of the distance from a point source (black) with tolerance range (red) and background noise (grey)

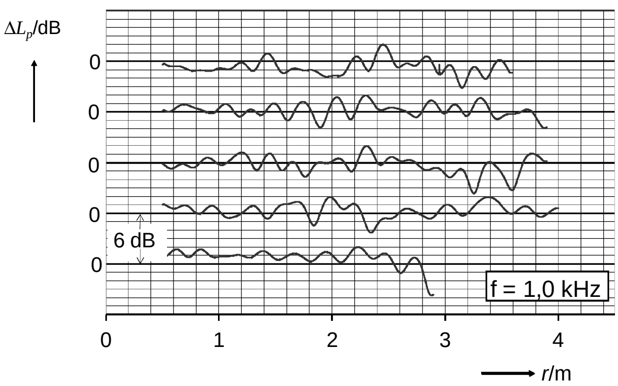

Figure 2: Normalised sound pressure levels for 5 paths

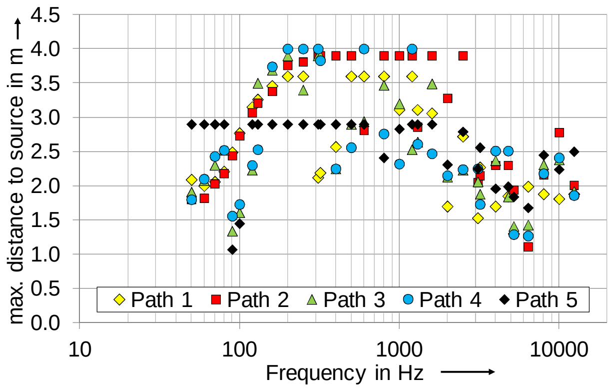

Figure 3: Maximum distances from the source on different measurement paths within a testroom where all points up to this maximum are inside the tolerances

Figure 2 shows the deviations to the ideal 1/*r*-behaviour for five different paths in one measurement chamber. The five paths show a very similar behaviour which means that the absorbent lining is homogeneous. For each of these paths, a distance is determined where the test results leave the tolerance for the first time. An overview on these maximum distances for one room is found in Figure 3. It turns out that the desired measurement distance of 1 m from the source qualifies for all paths and investigated frequencies in this room.

In view of the very small tolerances and the detailed results it is always an interesting question whether the results can be repeated. The two upper curves in Figure 4 and Figure 5 show repeated measurements. They were originally repeated due to the occurence of an acoustic perturbance e.g. indicated by a needle at 2.4 m in the upper curve in Figure 4. Except for these perturbances the curves show an excellent repeatability, even for a frequency of 10 kHz (Figure 5).

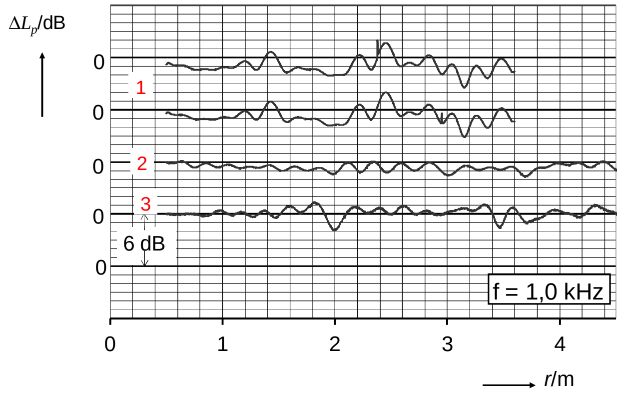

Figure 4: Deviation to the ideal free-field behaviour. Repeated measurements in flat panel room (1), room with absorber wedges (2) and room with absorber wedges covered by perforated metal plate (3)

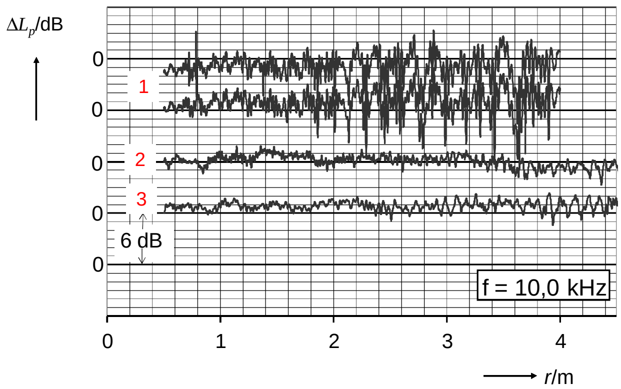

Figure 5: Normalised sound pressure levels. Repeated measurements in flat absorber room (1), room with absorber wedges (2) and room with absorber wedges covered by perforated metal plate (3)

Figure 4 and Figure 5 show furthermore the comparison between the flat panel room under test and two other rooms of similar size with wedges. Obviously, the rooms with wedges show a smaller amount of reflections, especially at 10 kHz.

Within the cooperation, BSH furthermore provided data of 1/*r*-measurements performed by another test institute in one of the rooms. Since the use of the paths towards the upper corners of the room and the location of the source in the centre of the room is prescribed in ISO 3745 annex A, measurements could be compared to each other. For this comparison one has to keep in mind that the exact location of the paths is not identical for both measurements. Under these circumstances test results are similar for a frequency of 400 Hz in terms of the amplitude of the standing wave (Figure 6). This means that the maximum distance to the source would be pretty much identical despite the differences in the details. For a frequency of 4 kHz, results from PTB and the other test institute are discrepant due to a different spatial sampling (Figure 7). Whereas PTB uses 1 cm, the other institute used 10 cm which is the minimum spatial resolution given in [1].

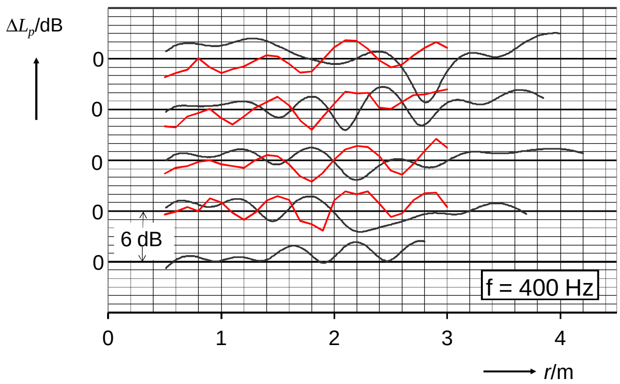

Figure 6: Deviation to the ideal free-field behaviour. Results from different test institutes, PTB (black) with a spatial resolution of 1 cm and another test institute (red) with a spatial resolution of 10 cm.

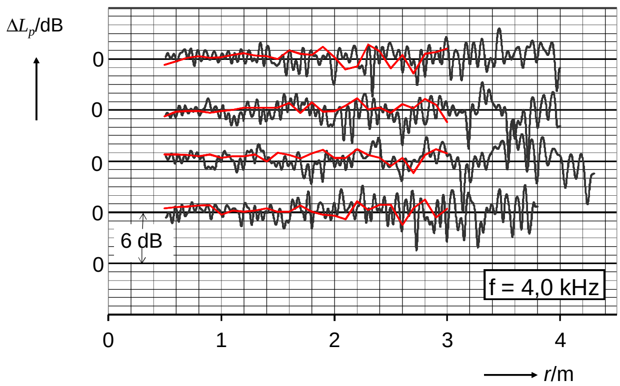

Figure 7: Deviation to the ideal free-field behaviour. Results from different test institutes, PTB (black) with a spatial resolution of 1 cm and another test institute (red) with a spatial resolution of 10 cm.

Determination of K_2

Starting point is the assumption that the sound pressure of the direct sound field from a source and the sum of all remaining reflections can be energetically added.

$$p_\Sigma^2 = p_{\mathrm{dir}}^2 + p_{\mathrm{diff}}^2 \qquad (1)$$

The underlying idea is that the reflections constitute a diffuse sound field. The equation for the sound power *P* in the diffuse sound field is

$$P = \frac{p_{\mathrm{diff}}^2}{\rho c} \frac{A}{4} \quad (2)$$

with the equivalent absorption area A and the density ρ and sound speed in air c. The same sound power is assumed for the free sound field

$$P = \frac{p_{\mathrm{dir}}^2}{\rho c} S \quad (3)$$

with the enveloping surface S. Combining all these equations leads to

$$P = \frac{p_{\Sigma}^2}{\rho c} S \left(\frac{1}{1 + 4\,S / A} \right) \quad (4)$$

from which the environmental correction

$$K_2 = 10 \lg \left(1 + \frac{4\,S}{A} \right) \mathrm{dB} \quad (5)$$

is derived [3]. This correction should vanish in an ideal free field and assume positive values in normal rooms. Unfortunately, the value of K_2 depends on the exact shape of the measurement surface, the microphone positions on this surface, on the size of the surface, on the position of the measurement surface inside the measurement room and on the sound source itself. The determination of K_2 thus does not qualify a room in general but a combination of all the mentioned parameters. The advantage in comparison to the $1/r$-measurement is that it is linked to the sound power and not to the field quantity sound pressure.

An aerodynamic reference sound source was used for the tests. One sound power determination was performed in the hemianechoic room at PTB. A second measurement was performed in the test rooms at BSH and the difference in the sound power levels is then used to calculate K_2. Measurements at PTB and at BSH were performed with the same analyser, microphone and measurement positions in relation to the source. Measurement setups included the six-point-array on a reflecting floor with an additional reflecting wall and the nine-point-array on a reflecting floor. The K_2 – values are close to 0 dB, as expected (Figure 8).

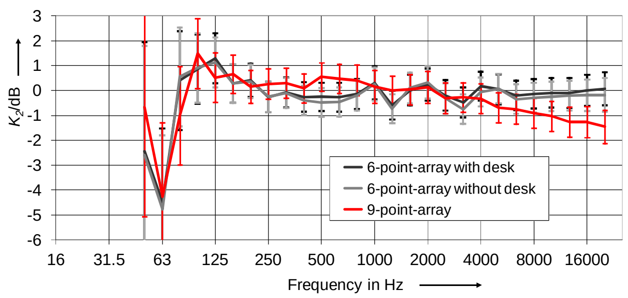

Figure 8: Room correction K_2 with and without a desk inside the test room

There was one additional measurement performed where a special control desk with a supervising person was in the measurement chamber. The desk has an absorbing surface and is especially designed for its purpose. The K_2 resulting from a surface average of the sound pressure level is not much influenced by this additional obstacle (Figure 8). Individual sound pressure levels show larger deviations in particular for frequencies below 250 Hz (Figure 9).

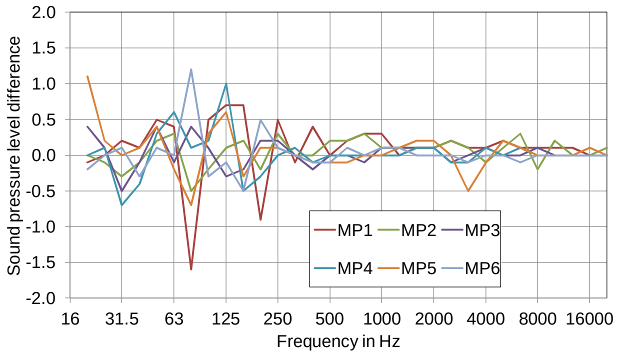

Figure 9: Difference of sound pressure levels at different microphone positions (MP) with and without a special control desk with absorbent lining in the test room

Conclusion

The new test rooms at BSH qualify according to ISO 3745 as hemianechoic rooms for the desired measurement distance of 1 m and can thus be used for sound power determinations. PTB´s measurement setup shows an excellent repeatability for the $1/r$-measurement. Results of another test institute show qualitatively the same behaviour as long as the spatial sampling rate is sufficient. K_2 assumes values between 0 and 1 dB except for the very low frequencies where negative K_2 – values are observed. Since the theory assumes the superposition of a free and a diffuse sound field, it can hardly be applied in highly absorbing rooms. It is therefore recommended to use a K_2 of 0 dB, also because the test of ISO 3745 has been passed.

Both methods lead to the conclusion that the rooms can be used for sound power determinations. A new European research project coordinated by PTB will deal among other topics with the qualification of highly absorbing rooms for sound power determinations.

Acknowledgements

Thanks to Wolfgang Harbich from BSH for the close cooperation.

References

[1] ISO 3745:2012 *Acoustics - Determination of sound power levels and sound energy levels of noise sources using sound pressure - Precision methods for anechoic rooms and hemi-anechoic rooms*

[2] ISO 26101:2012 *Acoustics - Test methods for the qualification of free-field environments*

[3] ISO 3744:2010 *Acoustics - Determination of sound power levels and sound energy levels of noise sources using sound pressure - Engineering methods for an essentially free field over a reflecting plane*

[4] Bethke, C., Wittstock, V.: *Technical aspects in the qualification of free-field environments*. Proceedings of NAG/DAGA09 on CDROM, Rotterdam, March 2009