Single-number rating of façade insulation

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1 Introduction

Sound quality is one of the main factors of comfort in dwellings, and it is described in internationally standardised terms of sound insulation. Legal regulations in many countries therefore require sound insulation of new designed buildings to be predicted beforehand. In practice building engineers deal with single number ratings of sound insulation quantities. The method of transforming the frequency-dependent sound insulation in single number ratings can be criticised because the reference curve is not always appropriate for modern constructions. Particularly low frequencies are problematic. In R'w, for instance, frequencies below 100 Hz and above 3150 Hz are not taken into account. Especially low Frequency traffic noise is not correctly represented. It is thus possible that differing sound insulation curves come up with same single number ratings. Also there is no means to recall the frequency dependent shape of the insulation from the single number rating, because the necessary information was lost during the transformation.

For a discussion of single number ratings it may be interesting to have a comparison on the influence of different façades on psychoacoustic parameters like loudness or sharpness, which are important factors for the rating of annoyance of outdoor noise inside buildings. In this paper the calculation of sharpness and loudness with a tool for auralisation of airborne sound insulation is presented.

2 Auralisation of airborne sound insulation

An algorithm for the auralisation of airborne sound insulation was developed and implemented. It allows modelling of the influence of sound transmission paths through building structures and of the receiving room. One-third octave band sound insulation data of building products are used as input data to synthesize a transfer function from the source room to the receiving room. Any desired monophonic signal can be processed with this transfer function to obtain the sound impression in the receiving room. The auralised sound gives a natural binaural impression both concerning loudness and coloration. A block diagram of the algorithm is shown in Fig. 1. The values of the standardised level difference are considered as a filter for the sound pressure for every single path (5 in total) and are convolved with the head related transfer functions for the appropriate directions (see Fig. 2 and Fig. 3) and delayed according to the position of the listener in the receiving room. The summation of the five paths results in a direct sound in the receiving room, which is assumed to originate from 5 point sources in the middle of each wall.

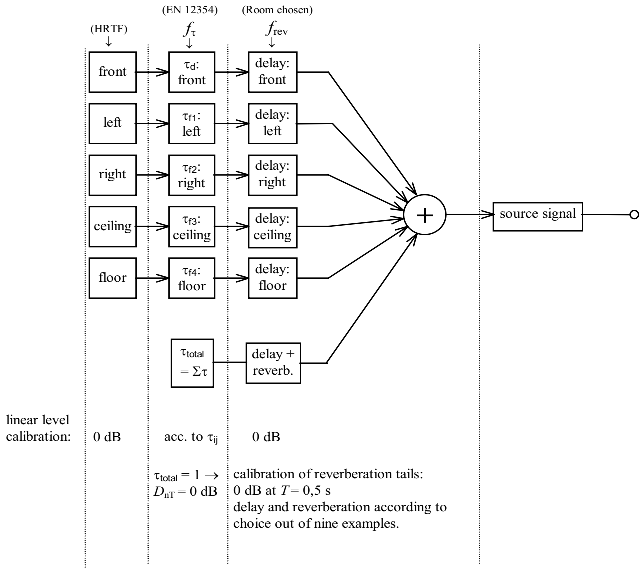

Fig. 1: Block diagram of the auralisation

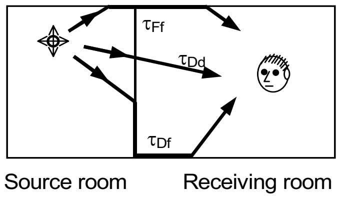

Fig. 2: Transfer paths

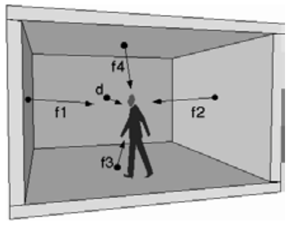

Fig. 3: Situation in the receiving room

To model the characteristics of the receiving room, a measured binaural room impulse response is processed in a way, that the direct sound is cut out and after a multiplication with the energetic sum of the five transfer paths the direct sound calculated as above is inserted. This results in a binaural transfer function from the source room to the receiving room, which can be used to process arbitrary monophonic signals.

In the case of façade sound insulation the sound source is modeled in free field and the transmission paths are considered in the same way as in room-to-room situation. The receiving room is accounted for as described above.

2.1 Verification

The auralisation was verified regarding the level differences in source and receiving room by carrying out a measurement of the original and the auralised signal over a PC soundcard. Fig. 4 shows the differences between the standard level difference which was used for the auralisation and the one which was measured.

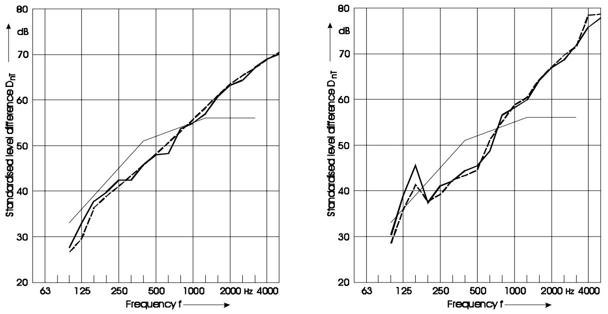

Fig. 4: Standardized level differences used for the auralisation (dashed) and measured from auralised signals (solid)

However the exact reproduction of psychoacoustic parameters has not been considered. For this purpose, at real room situations the sound insulation must be measured and recordings of signals in source and receiving room have to be carried out. The auralised sound signals in the receiving room then have to be compared with the recordings according to the psychoacoustic parameters.

3 Example for the calculation of psychoacoustic parameters

As a starting point synthesized sound signals were compared by evaluation of some psychoacoustic parameters. The most important are assumed to be loudness and sharpness [2]. Three facades with nearly equal single numbers were simulated and sound signals in the receiving room for outdoor noise from a passing freight train at an L_{eq} of 92 dB(A) were auralised. Fig. 5 shows the curve of the standardized level differences. Situation 2 and 3 only differ at high frequencies, which introduces a higher sharpness in the auralised signal for Situation 2. At lower frequencies Situation 1 differs from Situation 2 and 3 which may have an effect in the calculation of the loudness.

Situation	$R'_{w,45°}$	Level(A) [dB(A)]	Loudness [soneGD]	Sharpness [acum]
Source		92,33	99,5	1,31
Sit. 1	46,1	44,57	4,1	0,71
Sit. 2	46,5	44,17	5,0	0,80
Sit. 3	46,7	44,68	5.0	0,70

Tab. 1 A-weighted level , Loudness and Sharpness

3.1 Results

Tab. 1 shows the the A-weighted level, the sharpness (von Bismarck) and the loudness for the auralised signals. From each 2 values for the left and right channel one value was derived by calculating the geometric mean value for the sharpness and the arithmetic mean value for the loudness [3]

3.2 Discussion

As can be seen, the sharpness between Situation 2 and Situation 3 differ slightly but noticeable which is caused by the gap in the sound insulation at higher frequencies. The just noticeable difference for the sharpness can be assumed as app. 10% [3]. The sharpness of Situation 1 and Situation 3 are equal. If only high frequencies were considered the sharpness of Situation 1 should be lower compared to Situation 3, but the lowpass character of Situation 1 up to 400 Hz increases the sharpness..

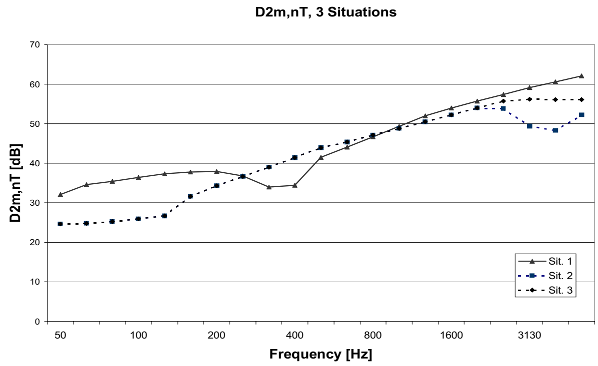

Fig. 5: DnT of Sit. 1 - Sit. 3, Sit. 2 and Sit. 3 are equal except for high frequencies

The loudness for Situation 2 and Situation 3 are equal but differ from Situation 1, which is because of the different overall shape of the insulation curve. The small gap in the insulation around 400 Hz gives the greatest contribution to the loudness in Situation 1 whereas in Situation 2 and 3 a broad band of lower frequencies produces a higher loudness. The just noticeable differences are app. 10% according to [2].

4 Summary

With an algorithm for the auralisation of airborne sound insulation it is possible to carry out comparisons between different building products not only by their single numbers but also by calculated psychoacoustic parameters, which must be taken into account when it is dealt with the annoyance of e.g. traffic noise.
Also it is possible to carry out listening tests, where subjective criteria come into play, which are difficult to obtain from measurements. For instance the influence on subjects during work, disturbance of privacy or effects during sleep can be evaluated. The signals needed for these tests are easily produced.
A further verification of the correct reproduction of psychoacoustic has to be done by comparison between recorded signals at real situations and auralised signals of the simulated situations.

5 References

[1] Vorländer, Thaden : „Auralisation of Airborne Sound Insulation in Buildings“, Acustica united with acta acustica 86 (2000) No. 1, p. 70-76

[2] Zwicker, Fastl : Psychoacoustics, Springer, Berlin 1990

[3] Klemenz, Fels : Zur Berechnung psychoakustischer Größen mehrerer Schallquellen, DAGA 2002, Bochum