About Speech Intelligibility depending on different Sound Insulations

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1 Summary

In a former study within the framework of the DEGA recommendation "'Schallschutz im Wohungsbau - Schallschutzausweis"' theoretical considerations were made on the basis of the calculated loudness of received noise emitted from neighbouring dwellings. Among other things this served as a basis for the predefinition of the grading and increment for the different classes of noise protection.

The recommendation also includes a list of verbal descriptions of the subjective perception of (typical) sounds in housing space and speech from neighbouring living areas. In another table the perception descriptions are rudamentary linked with the levels of noise protection. However, application in planning practice is usually difficult, as these experimental data are only correct under special conditions, which have so far not been sufficiently investigated.

The research in hand starts here. The perception of different situations of sound insulation shall be experimentally investigated under controlled conditions. Thereby, the speech intelligibility is first investigated with sample tests for different sound insulations.

In the first part we are describing the performed hearing tests and show first results. The aim is the verification of the expressions of the list based on the measured intelligibility for as real as possible situations.

The second part aims to create a correlation between intelligibility and sound insulation at a specific initial level in the emitting room.

Aspects of loudness especially the labels of loudness and the level of sound protection is more closely considered.

2 Introduction

While developing the different classes of noise protection we concluded for noise and speech that the grading should have a increments of ca. 5 dB. Based on th efollowing hypothesis: Doubling the loudness of the perceived signal from an neighbouring dwelling is a substantial increase of noise protection.

This hypothesis leads in the end to the grading and the levels closely matched the more practicaly developed levels of the noise protection in other countries.

We now are interested in testing the reliability of our findings with more typical descriptions of the quality of the perceived sound insulation. Normally one of the major disturbances is speech from the nearby dwelling. Even more problematic is understanding what is spoken in a neighbouring dwelling. In the DEGA recommendation there is a table describing different insulation qualities. One important factor hereby is the degree of speech intelligibility. This table is more or less a summary of experiences and it is not clear under which circumstances the description will be realistic. Maybe it holds for a typical average situation. But if we want to develop the noise insulation or even judge the noise insulation quality of a certain situation we should know the certain needs and circumstances. So if we want to specify a table or formula for calculation we apparently should find a relation between the amount of sound insulation and the speech intelligibility. Here we want to describe our approach to inspect the relation between speech intelligibility and sound insulation. Because we found in earlier work that the background level is also an important factor, we chose the background level as a parameter. We decided to determine the speech intelligibility by simulating the sound insulation between two dwellings and present the speech with loudspeakers to listeners in a sound treated booth.

3 Experimental setup

- As stimulus we used the sentences of the *Oldenburger Satztest* spoken by untrained speakers and normalized to a level of $L_{AF,eq} = 70\,\text{dB}$ at 1 m distance. This corresponds to raised speech.

- The used R_w are depicted from measured curves of the sound insulation. So the frequency characteristics vary slightly from curve to curve.

- As background level we select *brown noise* which decreases $-6\,\mathrm{dB}$ per octave to higher frequencies. The levels of the brown noise were $L_{AF,eq} = 15, 20, 25\,\mathrm{dB}$.

3.1 Generating the signals

The used sound insulations are displayed in figure 1. There were steps of 5 dB in R_w.

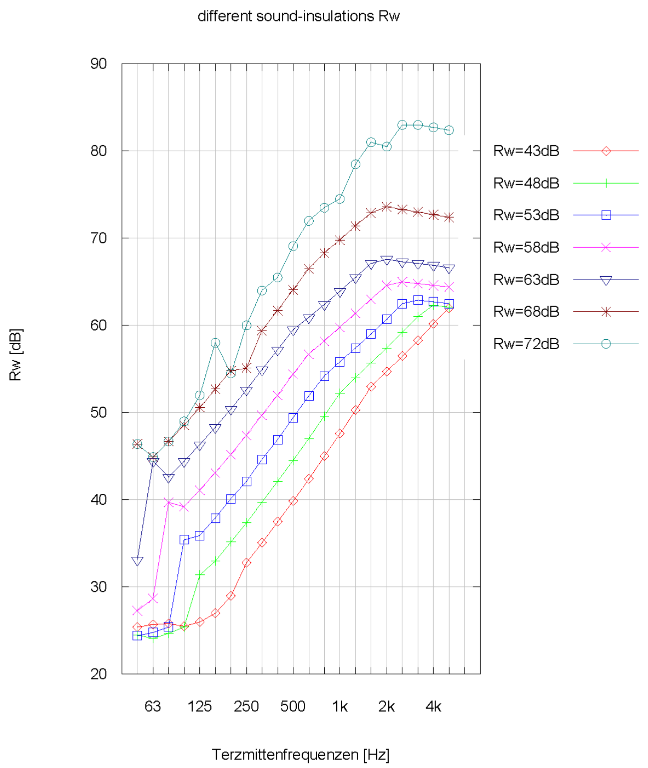

Figure 1: *Used R for simulation the level of the speech transferred to a wall between dwellings*

The following calculation procedure was used:

(A) recording the sentences and normalization to $L_{A,eq} = 70\,\mathrm{dB}$

$\Downarrow$

(B) filtering with sound insulation spectrum (R')

$\Downarrow$

(C) adding the background noise

$\Downarrow$

(D) presenting the signals via loudspeaker in a booth

$\Downarrow$

(E) recording how much sentences and words are correctly identified

The loudness and the level of the speech and the background noise is shown in figure 2

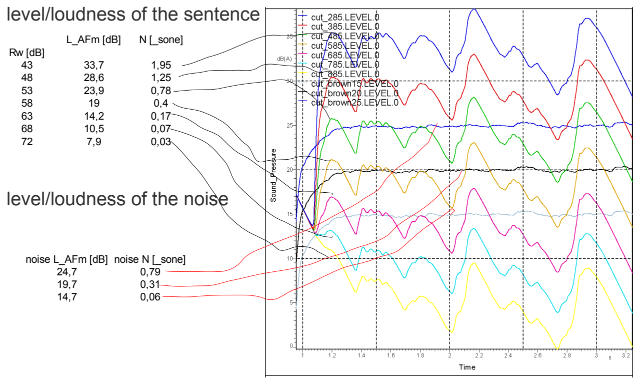

Figure 2: *Loudness and level of the an exemplary sentence: Kerstin bekommt elf rote Schuhe*

3.2 Presenting the signals

The signals were presented via loudspeaker in a sound treated booth. The listener was seated in a distance of 1 m from the speaker at an angle of $10\,^{\circ}$ to the loudspeaker. The level was controlled with a microphone in the distance of 10 cm from the right ear of the listener. The listener had to repeat the sentence which was registered by an experimenter.

4 Results

The results are shown in figure 3. The results for the whole sentences and the words of a sentence are shown separately.

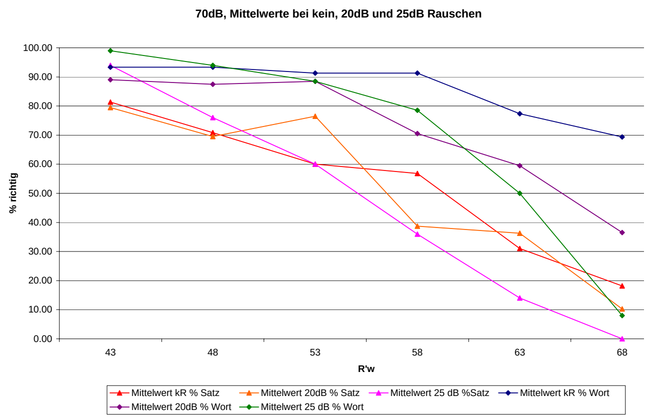

Figure 3: *Results of the Speech intelligibility tests*

The score for the correctly identified words or sentences is shown on the abscissa, the R'_w is shown on the ordinate and corresponds to a decreasing speech signal. The points with equal background level are connected with lines only for a better visualisation. What the data points show, is the decreasing speech intelligibility seen with higher sound insulation. The point of main interest is the 50%-point. It became clear is, that if the speech intelligibility falls beyond this point, the sense of the sentence could normally not be understood. If the score is higher than 80% the sense of a sentence may be followed, because there is typically a certain redundancy of the words in one sentence. Hence, the used 5-word sentences do not contain any redundancy.

The subjective description of the speech intelligibility may be as follows:

*ge*90%**:** sentence clearly understandable

50%: sentence sense unclear, single words understandable

35%: speech audible, seldom words understandable

15%: tere may be speech detected

≤10%: no speech detectable

5 Discussion

The identification score of the sentences without interfering noise reaches the interpolated 50% value at ca. $R'_w = 54\,\text{dB}$. If there is interfering noise of $L_{Aeq} = 20\,\text{dB}$ the 50% value is found at $R'_w = 57\,\text{dB}$. With interfering noise of $L_{A,eq} = 25\,\text{dB}$ the 50%-point is found at $R'_w = 59\,\text{dB}$.

As the psychometric function for the speech intelligibility of the word, it is easier to identify the 50%-point. But this point is not reached for the Situation without interfering noise. Most of the words could be identified correctly at a sound insulation of $R'_w = 68\,\text{dB}$ which is expected, as long as the loudness of the formants is higher than the hearing threshold. With increasing background noise the 50% point ist reached at lower sound insulations. The 20 dB noise leads to 50% score for $R'_w = 65\,\text{dB}$ and the 25 dB noise to $R'_w = 63\,\text{dB}$. Looking also at the 80%-score the results are as the following table shows:

	50%	80%
no noise	$\geq R'_w = 68\,\text{dB}$	$R'_w = 62\,\text{dB}$
20 dB noise	$R'_w = 65\,\text{dB}$	$R'_w = 55\,\text{dB}$
25 dB noise	$R'_w = 63\,\text{dB}$	$R'_w = 57\,\text{dB}$

The results may be interpreted in a way, that a significant increase of the speech intelligibility takes place, when the increments in sound insulation ΔR are higher than 5 dB up to nearly 10 dB.

The results show that a significant increase in speech intelligibility (here from 50% to 80%) is reached for steps of the sound insulation greater than $\Delta R' = 5\,\text{dB}$. The increment are also dependant of the background noise level: the lower the background level the higher the necessary $\Delta R'$ to reach the 80% score starting at the 50% point.

6 Visualisation of the results

We also analysed the loudness of some test signals to show their relation to the threshold. Therefore we used the *s*i-vision software which is able show the loudness of a signal while hearing it (figure 4). For this paper we chose a time clip with a vowel after being filtered equivalent to a Wall with $R'_w = 43\,\text{dB}$. The black line over the light blue represents the loudness of the noise background which is here determined by the hearing threshold. The tonal components (red impulses) were found in the signal which is represented by the green area. Without background noise the formants of the vowel are well above the hearing threshold.

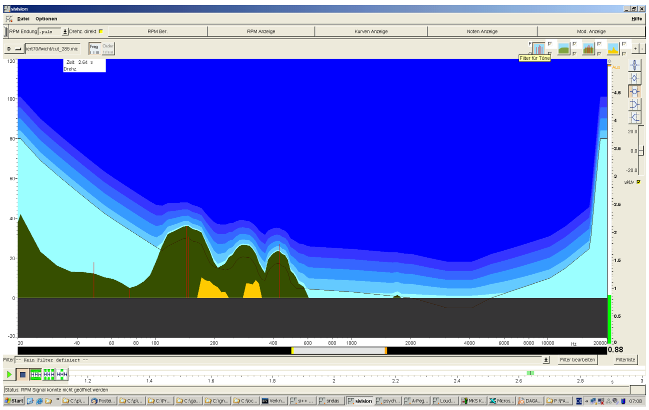

Figure 4: *Loudness of the speech signal through a wall with $R'_w = 43\,dB$ without background noise*

The brown noise with a level of $L_{A,eq} = 25\,\text{dB}$ leads after the same analysis to the representation shown in figure 5

Adding the background noise to the speech being filtered equal to a wall with $R'_w = 53\,\text{dB}$ the formants of the vowel are still above the loudness of the noise (figure 6). The intelligibility score was 65% for the sentence.

Filtering the speech equal to a wall with $R'_w = 63\,\text{dB}$ leads to a intelligibility score of 15% (see figure 7). In this situation the speech is hardly noticeable.

In this representation the heard impression of the

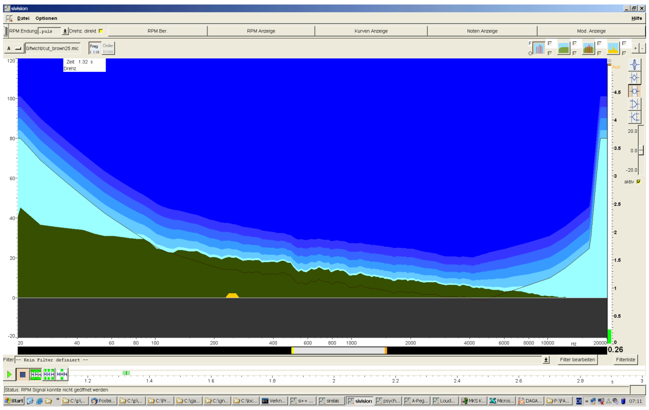

Figure 5: *Loudness of the background noise with* $L_{A,eq} = 25\,dB$

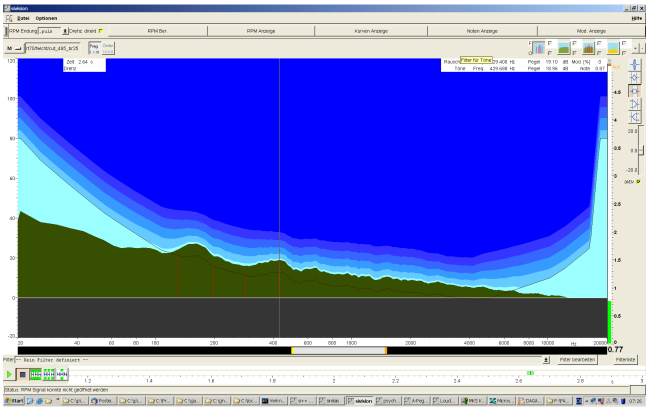

Figure 6: *Loudness of the speech signal through a wall with* $R'_w = 53\,dB$ *with background noise at* $L_{A,eq} = 25\,dB$*, 65% intelligibility of the sentence*

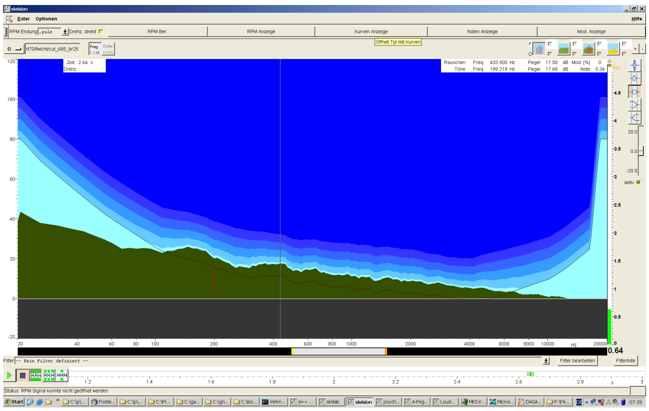

Figure 7: *Loudness of the speech signal through a wall with* $R'_w = 63\,dB$ *with background noise at* $L_{A,eq} = 25\,dB$*, 15% intelligibility of the sentence*

sounds corresponds to the depicted loudness of the sound.

7 Conclusion

At this point of the investigation the need for more data to get more systematic results becomes apparent. Experiments of the speech intelligibility tests show, that the sentence material we used was not perfectly suited. We found that normalization the level of the test sentence is not sufficient because of the varying loudness of varying loudness of singular word in one sentence. Also the speakers had different speed of pronunciation. So the experiments have to be repeated with better material.

On the other hand the experiments show, that the basic approach will lead to results, which can be used for a table with a subjective description of the perceived speech intelligibility. While determining the loudness of the speech signals it will be possible to add further acoustical terms to this table.

References

[Kötz, Moll] Kötz, W.-D. und Moll, W. "'Wie hoch sollte die Luftschalldämmung zwischen Wohnungen sein?"', Bauphysik 10 (1988), Heft 3, Seite 71–76.

[Gösele] Gösele, K. "'Zur Festlegung von Mindestanforderungen an den Luftschallschutz zwischen Wohnungen"', Bauphysik 10 (1988), Heft 6, Seite 165–172.

[Brand, Kollmeier] Brand, Th. und Kollmeier, B. "'Efficient adaptive Procedures for thereshold and concurrent slope estimates for psychophysics and speech intelligibility tests "', JASA 111 (6), Juni 2002, Seite 2801–2810.

[DIN 45631] DIN 45631 "'Procedure for calculating loudness level and loudness"' (Weißdruck 1991), Hrsg.: Deutsches Institut für Normung e.V., Beuth Verlag GmbH, Berlin.

[DIN 4109] DIN 4109 "'Schallschutz im Hochbau"' (Weißdruck November 1989), Hrsg.: Deutsches Institut für Normung e.V., Beuth Verlag GmbH, Berlin.

[VDI-4100] Verein Deutscher Ingenieure: VDI-Richtlinie 4100 "'Schallschutz von Wohnungen"' (Weißdruck September 1984), Beuth Verlag GmbH, Berlin.

[Zwicker] Zwicker, E., "'Psychoakustik"', Springer-Verlag, Berlin Heidelberg New York 1982.