Towards an Optimal Sound Insulation by Auralization and Computational Prediction Methods

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Introduction

"How will it sound?" Quite a simple question, but often the answer given by an acoustics expert is just a rating number, e. g. the weighted sound reduction index. Maybe some acoustical expert will 'hear' these numbers, but most people hear with their ears only. There is a way to provide for a hearing experience with their own ears: Auralization. The complex acoustics behind these bare rating numbers is revealed via loudspeaker or headphones. Today auralization – using properties of building parts measured in a laboratory – is a useful tool in room or building acoustical consulting. But how should a building part with maximum acoustical comfort be designed? What should be the aims of development?

Principle of Auralization

In general an auralization system consists of three parts [1]. The first part is a sound source, usually an anechoic or a semi-anechoic recording. The second one is a transfer function calculated by more or less complex simulation programs. All the physics, how the sound waves travel from the source to the ear of a listener, is described by this transfer function. Finally a signal processing is needed which calculates the resulting sound from the sound source and the transfer function (Figure 1).

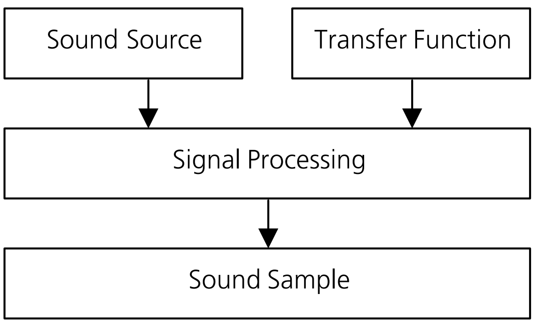

Figure 1: Block diagram of an auralization system.

Current building-acoustical requirements for products

In Germany a building part is often only required to have a weighted sound reduction index (R'_w or R_w) greater than a certain number. Therefore the aim in the development departments is large R_w-values. However, this can be counterproductive. After some 'improvements' in the above sense a manufacturer received many complaints. This could be explained by a test with auralized sounds for both the original and the 'improved' building parts (A and B), which were presented to many skilled and unskilled listeners. As stimulus road traffic noise of an inner-city road with five vehicles per minute was used. Despite of the 8 dB R_w-difference between both parts the answer to the question "Which part sounds better?" was in no case the part with the higher weighted sound reduction index (see Table 1). Obviously, the weighted sound reduction index was not a sufficient measure for acoustical comfort.

Part	Weighted sound reduction index	Which part sounds better?
A	53 dB	100 %
B	61 dB	0%

Table 1: Answers of skilled and unskilled listeners to the question "Which part sounds better?" for two building parts using road traffic noise as stimulus.

Auralization as part of the development process of new products

Using auralization for marketing purposes only does not use its full potential. In fact it may be of great value in the development process. In the first step, which defines the objective acoustical target values (Figure 2), only a line for the sound reduction index of a wall versus frequency must be drawn on a sheet of paper. Auralization makes this line audible and offers the possibility to compare several different lines with respect to subjective acoustic comfort. At this stage it is an aid for defining the right target.

The development of products can be further improved with simulation programs like LAYERS [2]. They may be used to determine the sound reduction of constructions without building any prototype. The results of these calculations can also be auralized and compared with target values. A prototype needs only to be built as soon as the comparison is satisfying. The advantages over the often used trial-and-error-procedure are obvious: more transparency, less costs, faster progress and subjective control of acoustic comfort during the whole process.

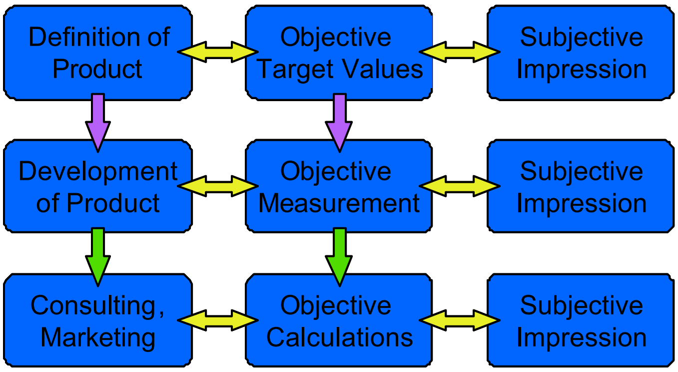

Figure 2: During each step of development a new product, auralization delivers a subjective impression of the acoustical comfort.

Computation of Sound Reduction

The above mentioned program LAYERS has been frequently used for the computation of sound reduction. Building parts composed of up to 100 homogeneous layers can be treated. Different types of layers (solid, fluid, porous, membrane, thin plate, elastic) are implemented. For periodic structures like brick walls a preparatory homogenization of inhomogeneous layers has to be carried out [3, 4]. The layers are infinite, therefore all effects due to the lateral dimensions of real walls are not considered. They have to be estimated subsequently. Figure 3 shows the result of a computation of the sound reduction index of a five-layer safety-glass pane compared with measured values.

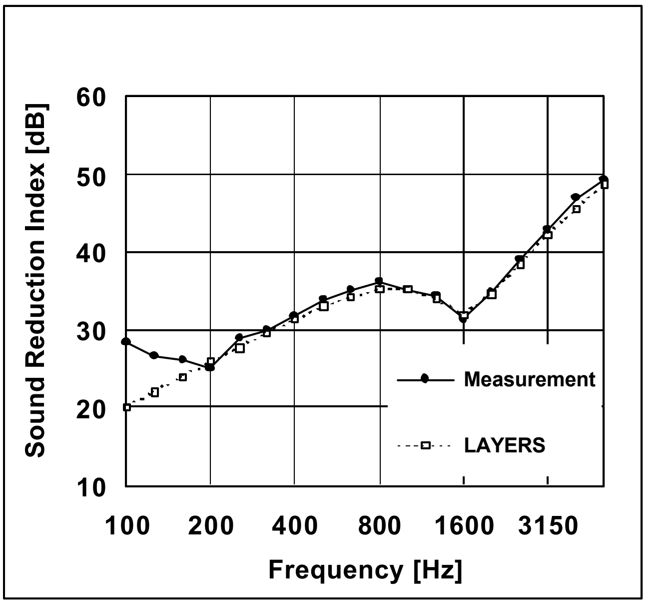

Figure 3: Measurement and computation of the sound reduction index of a five-layer safety-glass pane [2].

The excellent match (except for the lowest frequencies) shows that the results of LAYERS can be used for virtual prototyping of compound systems. A recent application was the optimization of external thermal insulation composite systems (ETHICS) with polystyrene or highly porous recycling-glass foams as thermal insulation layer.

Conclusions

Meanwhile a virtual development of building products by auralization programs and sound-reduction prediction methods is practible on a PC. The emphasis should be much more on a high degree of acoustical comfort of the user of a building rather than on a large sound-reduction-index numbers. Comfort is only incompletely described by objective criteria, e. g. personal preference and the characteristics of the exciting sound are also important parameters. With auralization and computation tools these aspects can be integrated into the development process.

References

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