Sound Propagation in Workrooms

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Introduction

Sound propagation in workrooms can be calculated with a mirror image method including scattering according to a proposal of Kuttruff and Jovicic. The basis for the selection of this method as the standardized procedure in germany was an investigations where the spatial sound decay produced by a constant radiating omnidirectional source was measured in about 150 industry halls, large offices and other working rooms [1]. Comparing spatial sound decay curves that have been calculated with 15 different calculation methods with the measured ones gave the best accuracy with the above mentioned method.. Therefore the method was standardized [2] and has been applied in many cases successfully for more than 10 years.

The sound level in rather reverberant rooms is the energetic sum of a tremendous lot of reflections – it is obvious that the deterministic calculation of all these contributions is a challenge even with the fastest computers. In the VDI 3760 approach this problem was solved using the following simplified method. A point source radiating constant and omnidirectional in octave or 1/3 octave bands is assumed and the levels are calculated with receivers located at distances from 1 m to 10 m with 1 m spacing, 12 m to 20 m with 2 m spacing and 24 m to 40 m with 4 m spacing aso. To speed up the calculation the room is assumed to be box shaped, and the absorption coefficient in each frequency band is spatially averaged for each of the 6 inner surfaces walls, floor and ceiling. If the sound level is calculated at a receiver for an existing distribution of sound sources, the level contributions of all these sources are determined by a simple arithmetic addition of the LW of the source and the distance dependent level decrease taken from the sound decay curve.

The advantage of the method is that rather complex source distributions can be taken into account. With the software Cadna-SAK machines and technical facilities of any size are defined as box shaped structures. Based on the two values emission sound pressure level LpA and sound power level LWA – according to the European machine directive - the machine surface is – virtually - covered by a grid of point sources. The program allows to calculate the sound distribution presented as noise map and the sound pressure level at all defined work places and other specified positions. Walls and ceiling can completely or partially be covered with absorbing materials selected from a library of merchandized and therefore available products.

Shortcomings and possible improvements

The method described is powerful and straightforward – nevertheless many open questions remain if noise reduction methods shall be evaluated to improve a given situation. The main problem is that only the mean absorption of a wall or ceiling is taken into account – therefore reduction measures like the absorbent covering of a wall adjacent to a noisy machine are undervalued with respect to level decrease. Another point is the correct inclusion of source directivity – from physics and experience we know that directivity vanishes in the spatial level distribution the more reverberant a room is. Last not least the diffraction over large structures or even with screens applied for noise reduction reasons is not taken into account with the VDI 3760 approach.

In a research project funded by the BAuA [3] the possibilities to include or approximate these effects have been investigated.

The local distribution of absorption can be taken into account by calculating the real reflection point – this needs the determination of each ray from each source separately, and the concept of a uniform spatial sound decay cannot further be applied.

A loudspeaker radiating with directivity was used to measure the spatial sound decay curve in different directions in industrial halls, then the source directivity was included in the mirror image calculation and the measured and calculated results have been compared. The results show a rather good agreement.

If sound propagation outside is calculated – e. g. according to ISO 9613-2 – the diffraction over barriers is taken into account using an adapted Maekawa formulation. The same can be done with rays in rooms, but now it's a real 3-dimensional problem. For reflected rays the path from the mirror image has to be used, and it is obvious that it makes no sense to regard sharp rays if many diffraction processes have occurred. The concept was to apply the mentioned diffraction calculation up to an order n1 of reflection, and for higher orders to neglect barriers and objects as before. To get the necessary information a transportable barrier has been developed and the spatial sound decay curve crossing the barrier has been measured in many halls.

Figure 1 shows an example of a comparison measured and calculated sound decay curves with and without barrier if the diffraction calculation is included up to increasing orders. These and other results prove that it's generally a good approximation of reality if the rays up to 2nd reflection order are included in the screening calculation.

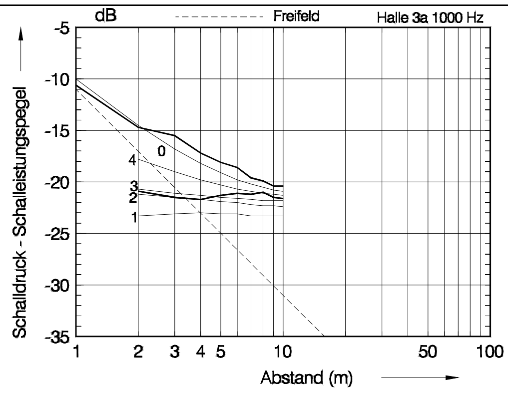

Figure 1: Bold curves measured with and without barrier – thin curves calculated – best agreement with calculation of diffraction up to 2nd order

Software realisation

In a special test compilation of the software Cadna/R [4] – a follow up of the former Cadna-SAK – some of these investigated strategies have been implemented.

Up to an order N1 diffraction calculation is applied. Two planes vertical to one another and containing the mirror source and the receiver are defined – one of these planes is vertical to the reference surface (ground).

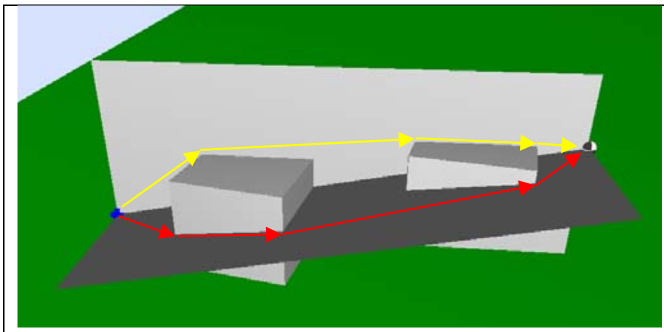

Figure 2: The straight ray from mirror source to receiver is part of the two planes that are used to define the shortest path around the objects.

With special algorithms the shortest path from source to receiver taking into account all objects for each of these 2 planes is determined – only the shortest path is used to calculate the diffracted energy.

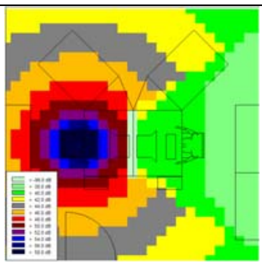

Figure 3: Calculation of the noise distribution caused by a speaking person with barrier 2m high between two workplaces and absorption at walls and ceiling..

Up to another order N2 the real ray tracing is applied – for each ray the reflection point is known and so up to this order the local distribution of absorption is taken into account.

It shall only be mentioned that these calculations – that have to be applied for each couple source receiver – are extremely time consuming. This is especially the case for the calculation of grids to get noise maps.

But on the other side this technique opens a fantastic new world of evaluation and reduction of noise including practical reduction measures.

Figure 3 shows an example for a little office. Figure 4 is a large office with reflecting ceiling and screens of 2 m height.

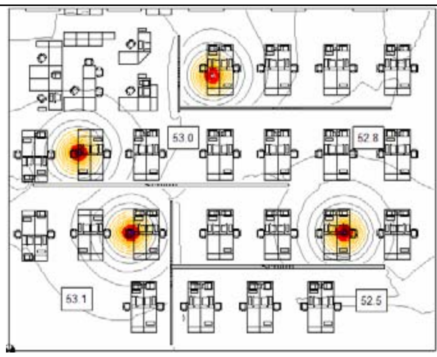

Figure 4: Level distribution –2m screens, but refl. ceiling

Figure 5 shows the same example with absorbing ceiling.

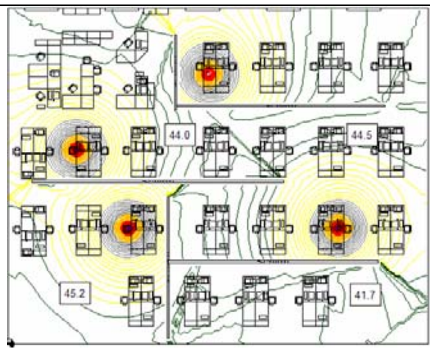

Figure 5: Level distribution – 2m screens and absorbent ceiling

Applying these methods noise levels can be evaluated realistically and based on practically available solutions. They will be improved step by step to cover all the areas of application where noise levels have to be evaluated, controlled and reduced.

Literature

[1] Probst., W.: Schallausbreitung in Arbeitsräumen II,(Sound propagation in workrooms), Fb 673 der BAuA,1993

[2] VDI 3760: 1996: Berechnung und Messung der Schallausbreitung in Arbeitsräumen, Beuth Verlag, Berlin

[3] Probst, W.: Schallausbreitung in Arbeitsräumen III, Fb 841 der BAuA, Dortmund 1999

[4] CadnaR: Program for noise prediction in rooms, DataKustik GmbH (www.datakustik.de)