Noise Prediction based on Measurements

Wolfgang Probst

DataKustik GmbH, Gewerbering 5, 86926 Greifenberg, E-Mail: wolfgang.probst@datakustik.de

Introduction

Starting point for the calculation of noise levels at a receiver position are generally the emission values - these are in most cases the sound power levels – of sources. They may be derived from technical parameters like traffic flows or speeds, but at the end emission levels must be known for all sources. Based on methods like ISO 9613-2 or others the partial levels caused by all sources at a receiver are determined and the wanted sound pressure level is calculated by summing up all these partial levels energetically. A lot of investigations have been undertaken to improve the accuracy of such calculations and nowadays computer based noise prediction has become the most important tool to check the acceptability of planned projects with respect to noise and to evaluate possible noise reduction measures if acceptable limits are exceeded. Calculations are by far more powerful to control the noise exposure of residents in noise affected areas than measurements because they can be related to representative time periods even if these are months and years and they give a strong link between the technical parameters that can be influenced and the unwanted noise exposure of residents.

Nevertheless it can be advantageous in some cases to install noise monitoring stations and to measure noise levels additionally. This may increase the acceptance of the determined noise levels by the residents, allows to check the validity of assumed input parameters and the calculation method and may in some cases even be used to update the applied computer model. In the last years monitoring stations have even been used in some cases to avoid a detailed investigation of input parameters and to do a sort of "back calculation" of emission values from such measurements. Using simple linear equation algorithms it is even possible to update receiver levels in larger areas or on complete noise maps and it is not surprising that mainly authors associated with suppliers of measurement equipment push such solutions ([1] – [5]). Words like "Reverse Engineering", "Inverse Engineering" or "Dynamic Noise Mapping" are used to label such techniques, but at the end it is all based on the same – a replacement of modelling with detailed input data by the measurement of sound levels.

The application of such methods may in many cases be justified, but it is recommended to weight thoroughly pros and cons before deciding about a costly monitoring system and to check the uncertainties if measured sound levels are used as input parameters for a larger noise map. It can be questioned if the detailed data of flight paths and movements at an airport can be replaced by the input from one station and the railway traffic in a city from two stations as it is mentioned in [3].

Measurement based noise calculations – the principles

Generally the sound level L_i at a receiver i is calculated from the sound power level $L_{W,j}$ of a source j from an equation like

$$L_{W,j} - A_{ij} = L_i \qquad (1)$$

where A_{ij} comprises all attenuations on the propagation path. This equation can also be expressed as

$$10^{-A_{ij}/10} \cdot 10^{L_{W,j}/10} = 10^{L_i/10} \qquad (2)$$

or

$$a_{ij} \cdot E_j = I_i \qquad (3)$$

As (3) defines a linear equation system, the sound power levels L_W of N sources can be determined in many cases if minimum N sound levels L are measured and if the transfer factors a have been derived from the model.

With two sources and two receivers this equation can be written

$$\begin{pmatrix} a_{11} & a_{21} \\ a_{21} & a_{22} \end{pmatrix} \cdot \begin{pmatrix} E_1 \\ E_2 \end{pmatrix} = \begin{pmatrix} I_1 \\ I_2 \end{pmatrix} \qquad (4)$$

The simple scenario figure 1 with 4 sources and 4 receivers shall be used to demonstrate the principle.

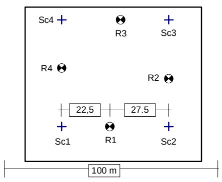

Figure 1: 4 sources Sc und 4 receivers R.

We attach the sound power levels 100, 97, 94 und 91 dB to Sc1 – Sc4, perform a propagation calculation and assume in the following that we only know the receiver levels and recalculate the sound power levels. Varying a receiver level at R4 and calculating again shows the error in L_W resulting from this error in the measured L.

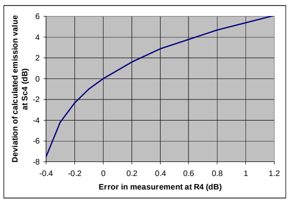

Figure 2: Deviation of „back-calculated" emission value

This very simple example shows the principally existing problem – even errors of some 0.1 dB with the measured level can cause considerable deviations in the "back-calculated" emission or in the noise map in the relevant area.

Direct use of measurements to update a noise map

In practical cases if a noise map shall be updated using measured results the following procedure can be used.

We assume N sources and N receivers, where a "source" can also be a group of sources of any complexity, if changes in emission values dL_W are always the same for all subsources of a group and the angular radiation pattern therefore remains constant. A receiver value can be the energetic mean value of any number of receivers.

Step 1: Creating the computer model with a best possible choice of emission values.

Step 2: Calculating N noise maps for the same calculation area – each of them with another one of the sources j. The levels of these source related maps are $L_{map,j}$

Step 3: Performing calculation and registration of all partial levels L_{ij} (Level caused by source j at receiver i)

Step 4: Measurement of levels L_i (total level caused by all sources at receiver i)

Step 5: Solving the linear set of equations (5) to determine the necessary corrections for the sources sound power levels $dL_{W,j}$

$$\sum_j (10^{L_{ij}/10} \cdot 10^{dL_{W,j}}) = 10^{L_i/10} \qquad (5)$$

Step 6: Adding arithmetically the correction $dL_{W,j}$ to each of the noise maps and summing these up.

$$L_{map} = 10 \cdot \lg \sum_j 10^{\left(L_{map,j} + dL_{W,j}\right)/10} \qquad (6)$$

Practical application for road networks

In practise it is not a simple task to apply these strategies to update noise maps for agglomerations by using monitoring stations. As it is indicated with figure 2 above, variations of some tenth of a dB may cause differences of more than 5 dB in the calculated maps especially in the areas with lower levels. Doubling the traffic flow is equivalent to a correction of 3 dB – therefore little deviations in the measured levels can change the noise map equivalent to considerable changes in traffic flows.

The problems increase if monitoring positions are influenced by more than one dominating source each. Application of the described or similar strategies to separate these influences is only possible and requires that the source emission is changed by the calculated correction $dL_{W,j}$ related to all directions without any change of the angular radiation pattern. If larger parts of the road network are taken as one source as it was done in some of the reported cases to reduce the necessary monitoring positions the accuracy of the resulting noise map must be questioned.

If monitoring stations shall be used to update noise maps it is recommended to locate them near the main noise sources. This minimises problems and reduces uncertainties

Application for industrial sources

ISO 8297 offers a method to determine the sound power level from industrial plants by measurements performed with receiver positions on a closed line fencing the plant. But the result is only the emission as a single number information – it is in many cases sufficient to determine the resulting noise levels in distances by far larger than the extension of the plant, but the level distribution nearby depends on the location and the directivity-pattern of the really radiating sources on the area.

In [5] the application of "Reverse Engineering" in such cases is described and recommended. But this must be even more questioned as with road sources. The problem is that industrial sources are determined by very complex propagation situations, and with respect to the radiation into the far field it makes a big difference if a omnidirectional radiating building surface is assumed or if the real radiating openings and attached sources like motors, pumps and stacks are modelled.

In all these cases a thorough view to accuracies is necessary. For the standards describing the measurement of sound power levels of machines the application of the GUM approach to determine the uncertainty of the procedure is mandatory – the same should be done if techniques are used where the acoustic emission is determined from some measured values outside the plant using the techniques described above.

Literatur

[1] Manvell, D. et al: SADMAM – Combining Measurements and Calculations to Map Noise in Madrid. InterNoise 2004, Prague

[2] Manvell, D. et al.: Reverse engineering: guidelines and practical issues of combining noise measurements and calculations, InterNoise 2007, Istanbul

[3] Reiter, M. et al: Optimizing localization of noise monitoring stations for the purpose of inverse engineering applications. Acoustics'08, Paris 2008

[4] Comeaga, D. Et al: Reverse engineering for noise maps with application for Bucharest city, InterNoise 2007, Istanbul

[5] Stapelfeldt, H. et al: Reverse Engineering – Improving noise prediction in industrial noise impact studies, EuroNoise 2009, Edinburgh