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New Techniques in Noise Prediction

Wolfgang Probst

DataKustik GmbH, D-86926 Greifenberg Gewerbering 5, Germany

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ABSTRACT

Noise prediction methods must include the mathematical description of many physical phenomena influencing sound propagation. More scientific based methods approximate the solution of the wave equation with given boundary conditions, while the engineering methods simulate the wave propagation by geometrically defined rays. The first mentioned scientifically based methods are powerful to investigate certain effects as propagation in a layered atmosphere or diffraction over a complex barrier in a simple and clear defined environment, while the engineering methods are clearly superior in realistic complex scenarios like industrial facilities or built up areas in cities with thousands of traffic sources. The techniques applied have been improved in the last years and an example of such an improvement is presented and explained.

INTRODUCTION

Noise prediction has become an important tool to support environmental control. Its power is the completeness of an acoustical model – the link between the technical parameters that can be influenced and the resulting noise exposure of people opens many possibilities to evaluate alternatives in planning processes and to optimise a project taking cost – effect relations into account. Sometimes people prefer measurements because they don't trust calculations, but such measured sound pressure levels show only a spotlight and give no information about the influence of the relevant parameters.

Especially in Europe these techniques got an enormous push by the activities around the European Directive about Environmental Noise 2002/49/EC – noise maps for thousands of km² for cities, main roads, railways and airports have been produced and action plans have been developed. As a consequence many people are discussing about extending these calculation techniques to take more and more phenomena into account, that are known to influence sound emission and propagation.

It is a never ending discussion between experts about the best way to adapt sound calculation methodologies to the continuously increased power and performance of computers and two main positions can be encountered in this debate.

The first group are those who apply the noise prediction software in their daily work – these are consultants, environmental engineers responsible to check legal issues or experts for noise working in acoustic groups of large companies. They are interested that the calculation method is precise, simple to use and transparent. Precise means that different experts calculating the same problem get the same result. Transparent means that all the algorithms used are clearly described and that it is possible to retrace a calculation and to find the reason for unexpected results. Due to these requirements any overhead in input data and calculation algorithms must be avoided.

The second group are experts interested in research and development. They argue that the accuracy of the methods must be continuously adapted to the state of the art and that more and more detailed data shall be used and more phenomena should be covered by the method.

It is not easy to find an optimal solution for these splitted positions, and as a result many new calculation methods appear that are nothing else but a variation of still existing methods with some more details taken into account.

Figure 1 shows the principle. The observable phenomena can be explained by certain physical models, and based on these models algorithms can be developed to predict the influence of the phenomena on the evaluation parameter. A complete set of such models and algorithms is combined in a sort of standard and transformed to software. Driven by the above mentioned group 2 there is a tendency to integrate more and more phenomena, to use more fine frequency bands and to apply more complex calculation methods. Unfortunately this tends to decrease precision and transparency of the methods.

From experience we know that a balance between all three aspects – accuracy, precision and transparency – is necessary. What we don't want is a software like a black box that applies a certain not published calculation strategy. What is needed are three important steps to provide a calculation method according to the state of the art.

Step 1: The calculation method itself should be standardized – this requires a clear and unambiguous description. The standardization process ensures that interested groups will be included in the process of development, opens the technical contents to critics of other experts and allows to integrate experiences during a draft phase. .

Step 2: Parallel to the development of the standard measures of quality assurance should be developed. An example is the german DIN 45 687 /1/ where these necessary measures are described. They include test problems with acceptable result intervals. The quality assurance of the calculation method allows it to be integrated in any software platform available on the market.

Step 3: After finalisation of steps 1 and 2 the methodology can be implemented in any software package – thanks to quality assurance it can remain the responsibility of each software developer to prove and certify the correct implementation of such a standardized method.

In some countries the software realisation itself was financed centrally and distributed – this suppresses competition and the quality of such software products should be warning enough not to follow this road with a dead end.

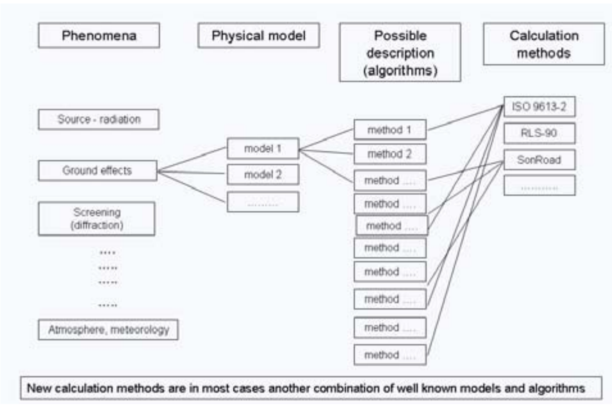

Figure 1. The structure behind a calculation methodology

SCIENTIFICALLY BASED MODELS

Figure 2 gives an overview to more or less scientific based methods, that are based on approximate solutions of the wave equation or on a simulation of the particle movements by separating the medium in small volume elements.

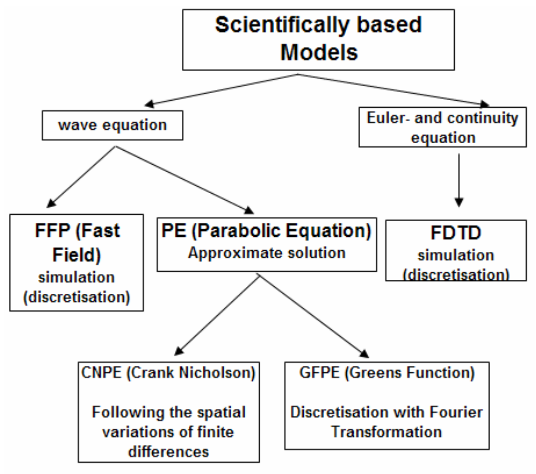

Figure 2 Scientifically based methods

These methods are generally used to investigate special problems in detail, but are in most cases too complex and therefore time consuming to be used for prediction of noise levels with complex scenarios. The influence of layered atmosphere on large scale propagation or the diffraction around a complex object are typical tasks where such methods can – or even must – be applied, but they cannot be used to calculate the noise distribution in a city or the level caused by an industrial facility with complex technical sources at residential areas nearby.

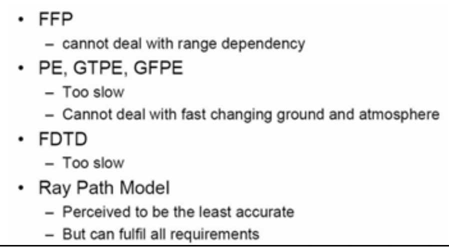

Figure 3 Some aspects of scientifically based models /2/

Figure 3 gives some critical remarks about the limited usability of these methods in practical cases of noise prediction.

But these methods can be used to study the influence and the consequences of special parameter combinations and to transform the relations found to better applicable empirical algorithms.

ENGINEERING MODELS

For such problems engineering models are used, that are based on the calculation of rays or particle tracks representing the sound propagation from sources to the receiver. Figure 4 is an attempt to classify these procedures and some standards and guidelines based on them.

If pros and cons are discussed, the phenomena that influence sound propagation must be taken into account.. It is well known that sound propagation is influenced by the vertical temperature profile, but neglecting this influence in RLS-90 must not give less accurate results if sound levels caused by road traffic are determined at the nearby facades. This is one of the main problems in the development of new calculation methods – to find a justified balance and not to increase the complexity without benefits in the accuracy of the final results.

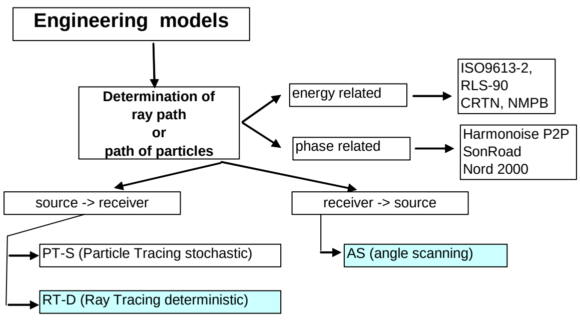

Figure 4 Standard engineering models

The importance of physical phenomena influencing sound propagation depend on the task or the specific application. If a certain phenomenon is not taken into account with a given calculation method it is always possible to construct a scenario where errors of 10 dB and more are produced neglecting this special influence. Therefore it is necessary to define the range of application and to study thoroughly the priorities before a method is created or modified. More complexity needs more detailed input information and reduces transparency and the possibility to validate the calculation.

Calculation methods used to control legal requirements should be very precise – different experts should get the same results with a given problem. Precision and transparency – or traceability - may even be more important than accuracy in such cases.

WHAT PHENOMENA SHOULD BE INCLUDED

The main influences – geometric dispersion, air absorption, reflection and diffraction – are simulated in all calculation models and must not be discussed.

With some approaches like CONCAWE /3/, NORD 2000 /4/ and Harmonoise/Imagine /5/ meteorological effects have been included. The result can easily be seen if the normalized sound pressure level from a little piece of road is plotted versus distance source – receiver. Normalized means that the sound pressure level calculated only with geometric dispersion and air absorption is subtracted from the result arithmetically.

Figure 5 shows the influence of meteorology on sound propagation calculated with the European Harmonoise method. S1 – S5 are the meteorological stability classes that are related to the coverage of the sky with clouds – this method is used internally to estimate the vertical temperature gradient. The ground is porous and therefore absorbent in this case.

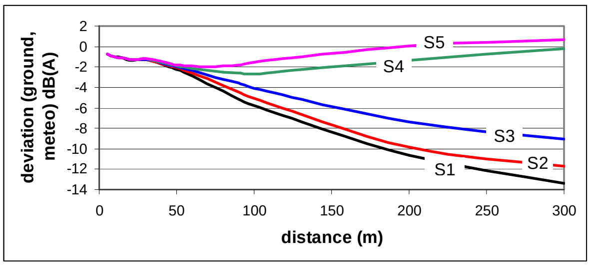

Figure 5 Normalised propagation in dependence of distance calculated with Harmonoise – influence of meteo classes

The influence of wind direction according to Harmonoise is shown in figure 6. The windspeed was assumed to be 10 m/s.

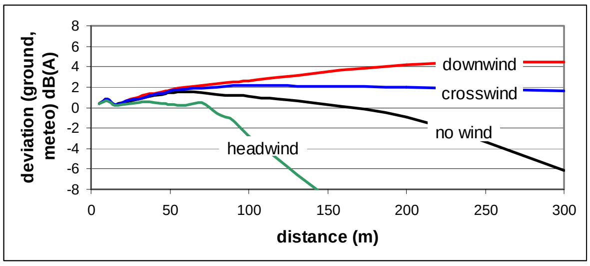

Figure 6 Normalised propagation in dependence of distance calculated with Harmonoise – influence of wind direction

It can be questioned if the influence of meteorological conditions should be taken into account if legal requirements shall be controlled. The calculation for different conditions with a weighted average at the end makes it difficult to retrace unplausible results and transparency will be reduced. Comparisons of noise maps calculated with different meteorological conditions show only negligible differences – decisions like necessary actions to reduce the noise are practically not influenced.

Another aspect separating existing engineering models in two groups is the way how ground effects and generally reflections are calculated. In some energy based models like ISO 9613-2 /6/ the ground effect is a simple correction derived from acoustic properties of the ground and the geometry source – ground – receiver. In other phase related models like Harmonoise, NORD 2000 and SonRoad /7/ direct sound and ground reflection are superposed taking into account their relative phase. To avoid very crude level jumps due to sudden changes of ground properties an averaging by the technique of Fresnel-zone weighting is applied.

But all these relatively complex improvements use up a lot of computer performance for an intended improvement of the calculation of free sound propagation only. It should be questioned if it would not be better for the accuracy of the final results in realistic scenarios if the calculation of free propagation of sound above ground would be kept as simple as possible and more practically observed problems would be included in such engineering models.

For the calculation of industrial noise in most countries the methodology ISO 9613-2 is applied. The sound emission of the sources is quantified using the sound power level L_W and the sound pressure level at the receiver is calculated subtracting different attenuations A. As it is shown in figure 7 for one source at an industrial building and one receiver position, the attenuation values can be separately calculated, written into the protocol and subtracted one after the other. This simple procedure makes the calculation transparent and easy to control.

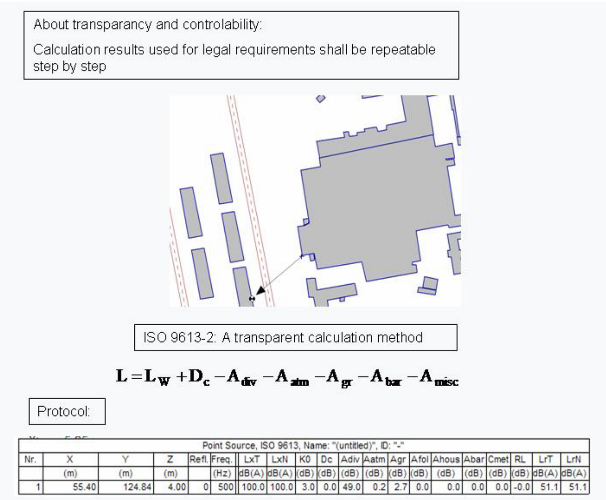

Figure 7 Calculation of the noise level caused by one source by subtracting different attenuation terms.

Reflections are taken into account by using the mirror image method. A problem arises if the reflection is caused by a curved surface as it is the case with tanks, silos or other cylindrical shells. This is one of the problems mentioned above that are important but not generally solved in ISO 9613-2. In the following a solution is presented /8/ that has been implemented in a software package /9/ since years and can be recommended generally to be included in one of the next revisions of ISO 9613-2.

Figure 8 shows the scenario with source S in a distance ds from the cylindrical surface and the receiver in a distance dr.

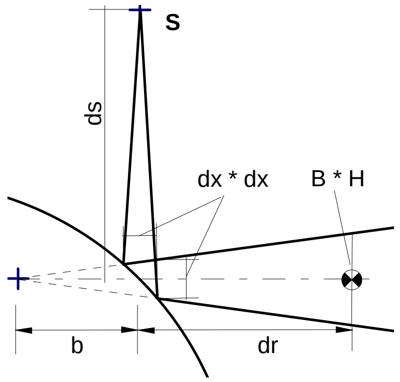

Figure 8 Geometrical relations if a ray is reflected at a cylindrical surface

The ray cone with bredth dx hits the surface and the opening angle is increased by the curvature of the reflecting surface. Due to this widening of the ray cross section the distance b of the mirror image source behind the surface is not ds (as it would be with a plane reflector), but can be calculated with

$$b = \frac{R \cdot d_s \cdot \sqrt{1-k^2}}{R \cdot \sqrt{1-k^2} + 2 \cdot d_s} \qquad (1)$$

R radius of cylinder
k distance of incident ray from center divided by R
d_s distance of source from reflection point

The level caused by the reflected sound alone at the receiver can be calculated in the usual way replacing the cylinder by the tangential plane, but an additional attenuation A_{curv} has to be taken into account

$$A_{curv} = 10 \cdot \lg\left(1 + \frac{2 \cdot d_s \cdot d_r}{R \cdot (d_s + d_r) \cdot \sqrt{1-k^2}}\right) dB \qquad (2)$$

This technique allows the seamless integration of reflections at curved surfaces into engineering models like ISO 9613-2. Figure 9 is an example where the sound radiated by a road is reflected by a cylinder and increases the level at the receiver.

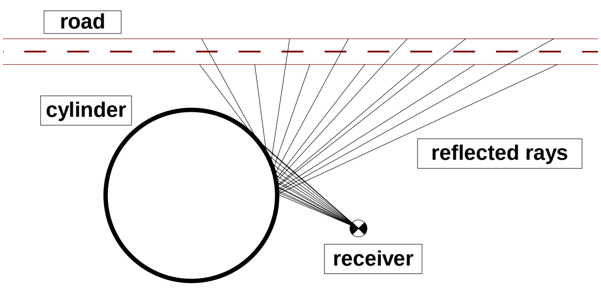

Figure 9 Sound radiated by a road reflected at a cylinder.

The presented geometrical ray based approximation is accurate as long as the radius of the cylinder is large relative to the wavelength.

This is only one example for special calculations that can easy be integrated if the calculation models applied are not too sophisticated.

REFERENCES

Do not use footnotes. The paragraph format is 0.5cm hanging indent. References may be cited in either the alphabetical Harvard system as (Author, 2009) or using numerical references with the citation in square brackets [1] with the references in numerical order. Examples are as follows:

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