Methods for the Calculation of Sound Propagation

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Introduction

The development of methods to calculate sound propagation has become an enormous push by the noise mapping activities following the requirements of the European directive. Many experts discuss the need of more accurate predictions, but neglect in many cases the decrease of precision that may be the consequence of more and more detailed input parameters. The following is a little summary of the authors experience with the activities in this field.

Scientifically based models

Figure 1 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.

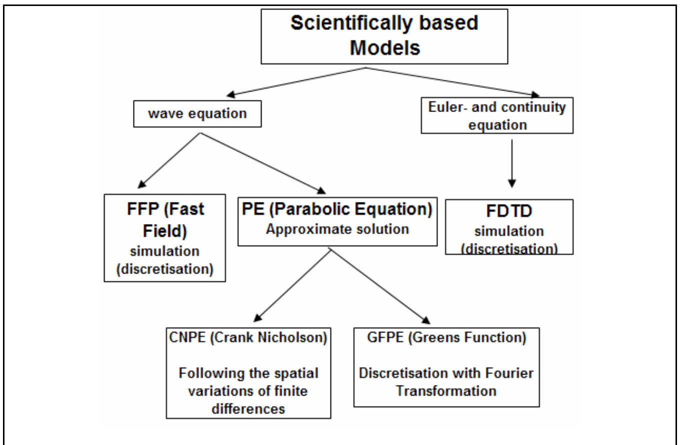

Figure 1: Scientifically based methods

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.

Engineering models

For such problems engineering models are used, that are based on the calculation of rays or particle tracks represen-ting the sound propagation from sources to the receiver. Figure 2 shows an attempt to sort standardized procedures and even well known software packages that can be applied.

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 end results.

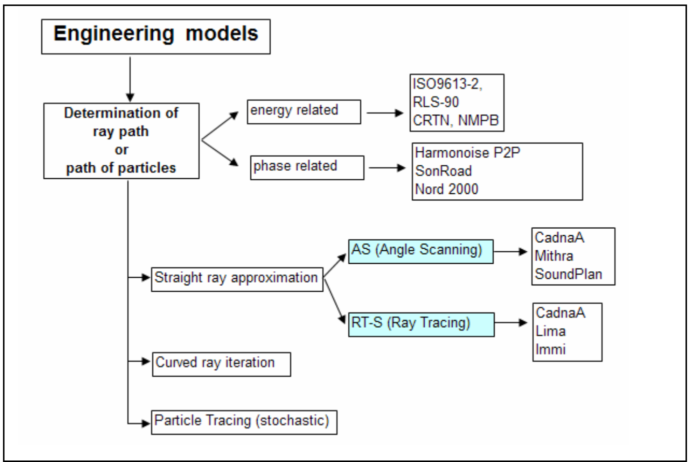

Figure 2: Engineering models.

The importance of physical phenomena influencing sound propagation depend on the task or the specific application. If a certain phenomena 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 may even be more important than accuracy in such cases.

For detailed analysis of noise problems with road traffic, railway noise and industrial noise the type of source radiation, ground effects, diffraction around objects and reflections – all this many times and in combination between source and receiver – have to be taken into account.

The existing models used to control legal requirements like RLS-90, Schall03 and ISO 9613-2 are all based on energetic superposition of incoherent sounds – interference effects are not included. This simplifies the calculation enormous, but may cause some deviations of calculated from measured levels in frequency bands if only few correlated sources radiate or with a source and a single reflecting surface nearby. With the newer models Harmonoise, Nord 2000 and SonRoad phase relations are taken into account.

The first mentioned engineering models use basically straight rays to connect sources – and mirror sources – with receivers. Nevertheless bended rays around upper and lateral edges of barriers can be taken into account. To find the possible ray paths two main software strategies are used. These two main principles are shown in figure 3 and 4.

With the mostly used ray tracing technique all sources and mirror sources are connected with the receiver by straight ray paths. Extended sources can be subdivided in smaller elements using the projection method, where the gaps between objects are exactly taken into account, as it is shown in figure 3. Another method is to draw rays subdividing the full 360° around the receiver in constant angle segments and to search for sources in all these segments.

Both methods have their pros and cons, and in the following only the most important differences shall be mentioned.

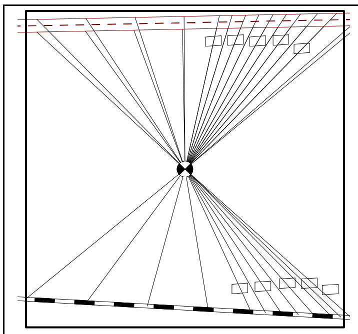

Figure 3 Road and railway calculated with RT-D

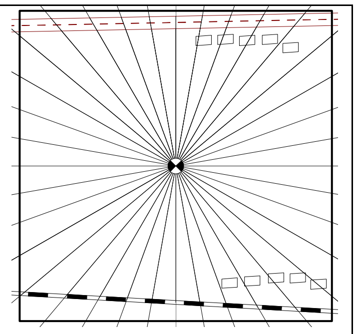

Figure 4 Road and railway calculated with AS

In the framework of noise mapping the calculation times are relevant and such calculations need always a balancing of accuracy and time expenditure. Reflection calculation – especially to find the relevant mirror source positions – is extremely time consuming, and therefore only the important reflectors near the sources and near the receivers can be taken into account. With RT methods it is possible to restrict the reflection calculation to a definable maximal distance from source and receivers. With AS methods this is only possible with respect to receivers. With a parameter setting “reflection depth” the splitting up of a search ray all the times an object is crossed must be restricted to very few objects – reflections near sources far away can not be found automatically.

The advantage of AS methods is a very quick reflection calculation in spaces without objects – this is the case if the level caused by a road canyon with facades at both sides has to be calculated at these facades. Using a small reflection depth of 0 or 1 makes it possible to calculate even up to high orders in acceptable times. But the price is that even important reflectors near sources far away are not detected without manual access.

If meteorologic influences shall be taken into account more precisely, it is necessary to model the atmosphere with spatial varying properties. Generally a layered atmosphere with vertical gradients of temperature and wind speed is used to get the vertical sound speed profile. With conditions the possible ray path is constructed step by step in an iterative process. The geometric attenuation is calculated from the spreading of two rays at the receiver position related to their incosed angle at the source. Another method is to construct the path of particles radiated from the source in directions that are randomly distributed. The energy at the receiver is determined by summing up the number of particles crossing a small control volume.

The advantage of these two methods is the inclusion of meteorological influences, but this is payed with a lot of problems that are important in smaller scales like the subdivision of extended sources with neighboured objects , screening in combination with reflection and others.

These and a lot of other aspects have to be taken into account if strategies and methods are developed. The physical model to simulate reality is one side of the coin – the other side is the strategy to force a computer to organize this job with a given project in the best way. The two aspects are not independent and therefore a cooperation of acousticians and experts in software techniques is the best condition to solve such problems .

In some publications and standards more scientifically based methods are used as “reference methods” that shall be used to “calibrate” the engineering models. Such approaches are only acceptable if the uncertainty of these reference models has been proven to be superior by comparison of calculated and measured results. And even such comparisons are only reliable if first the calculation is performed by one group and then the measurements are made by another group.

References

[1] Long version of manuscript “Methods for the calculation of sound propagation”: www.datakustik.com/papers