



HOW TO EVALUATE THE ACCURACY OF A NOISE MAP

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ABSTRACT

The German standard DIN 45 687 presents a method how to evaluate the accuracy of a noise map. The best possible accuracy or the “truth” is defined by a standardized or otherwise exactly described calculation procedure. Each deviation from the exact calculation caused by acceleration techniques or other methods to reduce calculation times produces uncertainties after systematic errors have been eliminated. These uncertainties can be determined using a double-tracked calculation with and without such approximations for a small subset of receiver points. The test is only valuable if the reference condition is clearly defined and comparable carried out with different software packages. The conditions that should be met are discussed.

INTRODUCTION

Software packages usable for calculation and detailed analysis of complex industrial noise problems as well as for noise mapping purposes according to the Directive 2002/49/EC /1/ simulate the sound propagation from source to receivers by replacing the more or less complex wave field by geometric defined propagation rays. The shortcomings caused by this approximation are partially compensated with special techniques, but these are in some cases not standardized and therefore open for interpretation. For the potential user who wants to decide about the product best fitted to his needs it is difficult to get a more or less objective overview about the capabilities of all the available products on the market. Taking into account the complexity of the issue it is not astonishing that even people using a certain software package for many years are not aware of the uncertainties associated with the calculated results.

The German standard DIN 45687 /2/ was developed to improve this situation. The calculation guidelines or standards applied with a software package are regarded as the “truth”, and any software bugs or even deviations caused by numeric approximations are treated as errors. Calculation methods must be described transparent and clear step by step that they can be included in the quality assurance system according to DIN 45687.

But even DIN 45687 is based on simple test cases and does not help to reveal the used approximation processes applied with a software product. Unfortunately nearly all researchers on the field of sound propagation focus on complex models like FFP (Fast Field Programme) or PE (Parabolic Equation) or try at least to include atmospheric propagation conditions and ground effects in geometric ray models – the improvement of the methods applicable for practical purposes and used all over the world for noise prediction is in many cases unattended and limited to an interchange of empiric equations between national methods.

In the following some of these problems are revealed and it is – necessarily with only some examples developed with software CadnaA /3/– shown how test cases can be constructed to get more insight into the inner procedures of a software package. The method of DIN 45687 to determine the accuracy of a calculated noise map is presented.

NUMERIC METHODOLOGIES

In the following only software packages are dealt with that can be used to calculate the noise levels in detail for practical industrial problems with complex sources and environments as well as for large scale noise mapping even in agglomerations. Complex methods solving the wave equation or simulating the sound propagation by discretising the propagation medium are not

included, because they play a negligible role in practical applications.

The two different strategies Ray Tracing (RT) and Angle Scanning (AS) are used. It shall be mentioned that these names are used in the context of this paper – different expressions are used elsewhere.

Ray Tracing is used in most of the commercially available software packages. The possible ray paths between sources and receivers including direct rays and reflected rays are found by looping over all sources for each receiver – or vice versa – and constructed geo-metrically. Diffracting objects and other attenuating influences are taken into account by corrections of the calculated level contribution. The level at a receiver is the result of summing up the level contributions of all sources. Here are differences between the softwares – for large scale noise mapping calculation times may be unacceptable to include all sources, so only the relevant sources are included. But the strategies to decide about negligible sources are quite different and therefore cause quite different uncertainties. This is an important point to focus on if different packages are compared.

Angle Scanning works different – the 2D-angle of 360 degree around the receiver point where the level shall be calculated is partitioned in equal angle sectors – e.g. 100 sectors of 3,6 degree each – and one search ray in the axis of each sector starting from the receiver is used to find the relevant sources. Generally the point sources inside a sector are projected to the axis and the emission of the parts of extended sources like roads inside the sector is attached to the intersection with the axis.

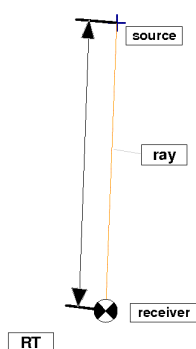


Figure 1.- Calculation of level caused by one point source at the receiver with RT.

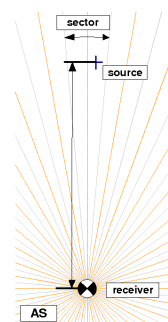


Figure 2.- Calculation of level caused by one point source at the receiver with AS.

In a certain way RT is deterministic, AS a statistic approach. It shall only be mentioned that the AS approach can from principle also be used starting from the source and searching for receivers – but this technique was not used in well known and commercially offered packages.

Random Search (RS) is a further methodology to calculate noise based on ray techniques. The directions of the rays – or particles - sent out from each source are distributed randomly, and if such a ray intersects a control volume around the receiver, it is counted. The number of counts for each receiver volume is a measure of the sound energy and the basis to calculate the level. While in RT and AS the geometric spreading dependent on distance is included as a correction, it is replaced in RS by the relative number of counts for each receiver. It is obvious that the necessary dynamic or difference between maximal and minimal levels is an important criterion for the necessary calculation time to get a statistically significant number of counts at receivers with minimum exposure. These RS techniques are only of negligible importance in environmental noise prediction.

EVALUATION OF SOFTWARE PACKAGES - CRITERIA

User Friendliness

User friendliness is a property that is often undervalued. It is not only a “nice wrapping”, but an important issue with respect to avoiding errors (technically) and savings of time and money (commercially). DIN 45687 addresses this aspect – a clear structured graphical interface, easy usable different views including 3D presentations and the presentation of calculation rays even

in 3D is invaluable to control a model and the calculation.

A short bill of important features:

- Graphic interface with windows that can be moved and modified in size (the project should always be visible)
- Direct call of all graphical features and back to the project with one click (otherwise control of inputs is too elaborate and will often not be done)
- Easy callable graphic presentation of calculation rays to selectable receivers (also necessary to facilitate control of projects)
- “Orthogonal programming” sounds technically, but is important with respect to simple and multiple use of modelled scenarios. The implementation of a new feature – e.g. a calculation method – should not influence any of the existing methods. It should further be possible to use the geometrical model including sources with different calculation methods. If the noise caused by a road is calculated with CRTN (UK), why not recalculating it with the German RLS-90 without input of a new RLS-90 road? This gives the program user the possibility to compare the results based on complete city models with minor adaptations.

There are a lot of program supported features that make much easier – but they are not seen at a first glance. It is necessary to ask for each product someone familiar with its use to work on the same little project or task to see how things are used and handled.

Calculation- and Simulation Strategies

As it was mentioned above, the calculation via ray paths between sources and receivers is an approximation of the real world where a wave field sweeps over the environment between sources and receivers. The following strategies are used and must be implemented correctly to get reliable results.

- **Correct sub partitioning of extended sources**

If the noise caused by an extended source is calculated, the latter must be partitioned in small elements with an extension smaller than half (or another portion depending on the standard used) of the distance.

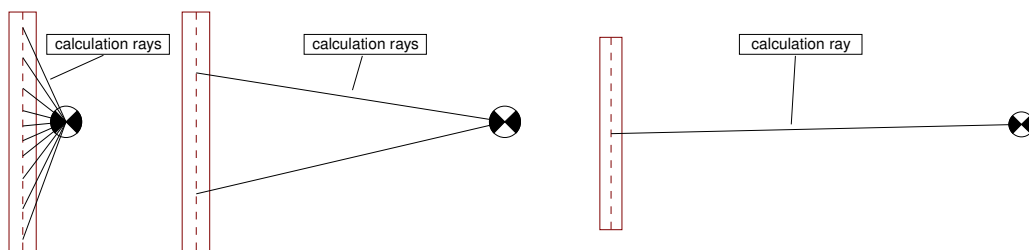


Figure 3. - Dynamic partitioning of extended sources with RT – increasing number of calculation-rays with decreasing distance

With AS methods the angle sector must be configured small enough to fulfil these requirements.

- **Different propagation conditions must be taken into account**

With automatic partitioning (RT) or constant angle steps (AS) the angles between adjacent calculation rays may be too large and the resolution may be too poor to calculate the exact energy contribution caused by the energy transfer through gaps between objects (e.g. buildings with gaps between them).

The solution is to use projection method with RT and small angle sectors with AS.

The correct calculation can easily be controlled by using a configuration shown in figure 4.

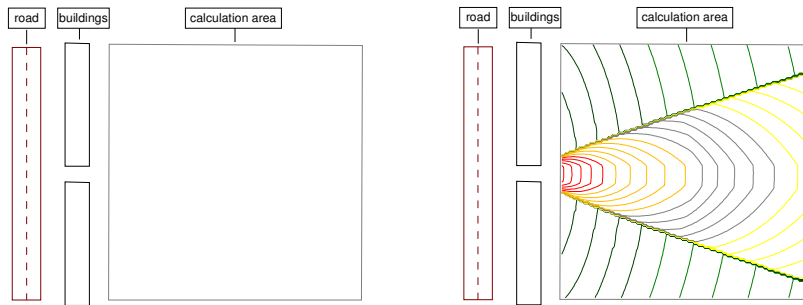


Figure 4. - Left side scenario to calculate a map in an area screened by buildings with gap. Right side result of calculation using projection method (RT)

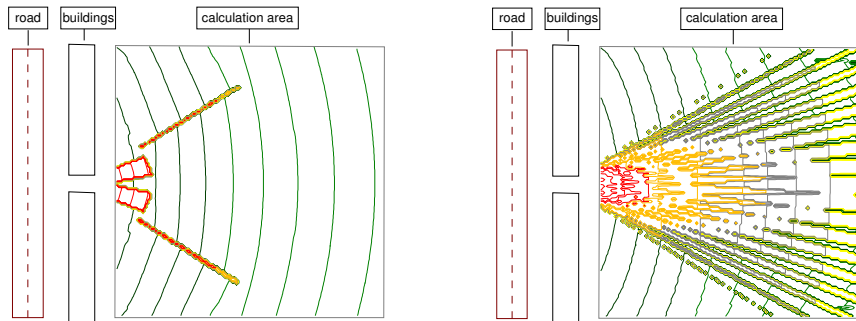


Figure 5. - Left side calculation of lines of equal level with RT without projection method. Right side calculation of map with AS using 100 angle sectors for 360 degree.

Projection method is a two step procedure where in the first step the gap is projected to the extended source to get exactly the part contributing to the immission. In the second step the extension of each subpart is compared to the distance and – if it is too large – it may be partitioned further. The pattern of the lines of equal level are a sensitive tool to encounter wrong results. While figure 4 right shows the expected and correct result, it is obvious that the results of figure 5 are wrong. These strange patterns are not only a visual shortcoming – they indicate unphysical level jumps and therefore unacceptable deviations.

- **Reflections up to the declared order must be calculated correctly**

Reflections are generally calculated using the mirror image method – this means that smooth reflecting surfaces are assumed and where this is not the case this solution is used as an approximation.

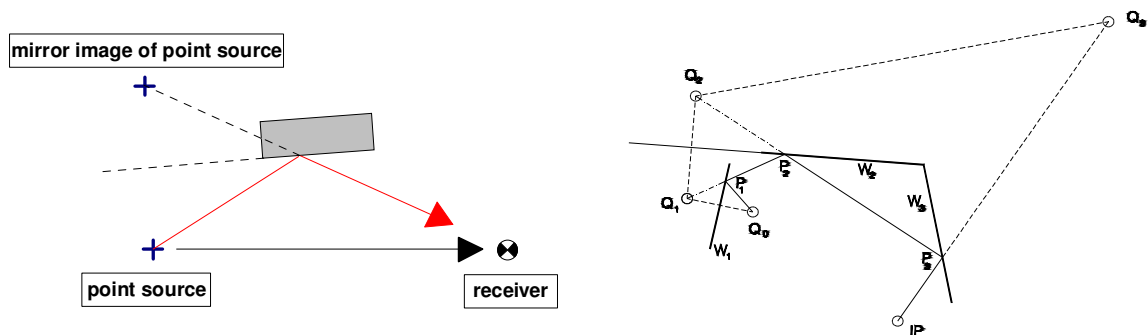
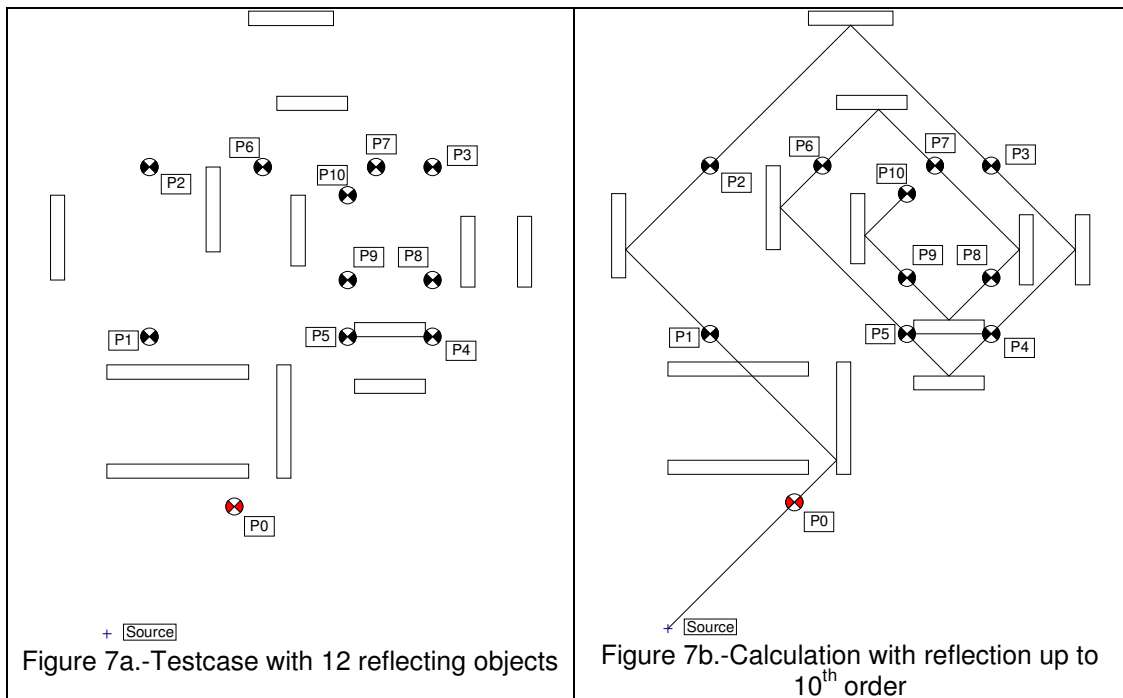


Figure 6. Construction of an image source to calculate reflections. Left side first order, right side third order reflection.

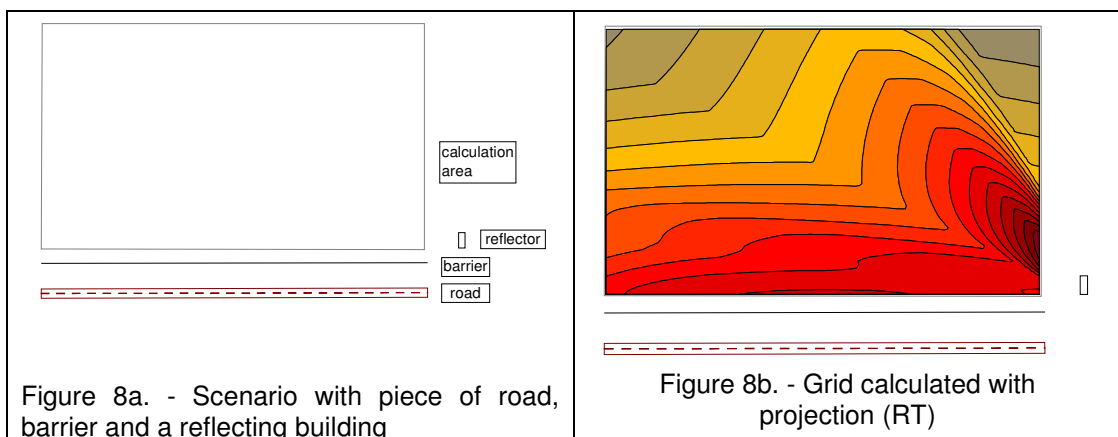
In cases of noise abatement in industry it is often necessary to calculate higher order reflections because the receiver position is screened and can only be reached by reflected rays. It is necessary that all possible rays are completely calculated – otherwise the result may be erroneous and there is no possibility to decide about the uncertainty characterizing the result.

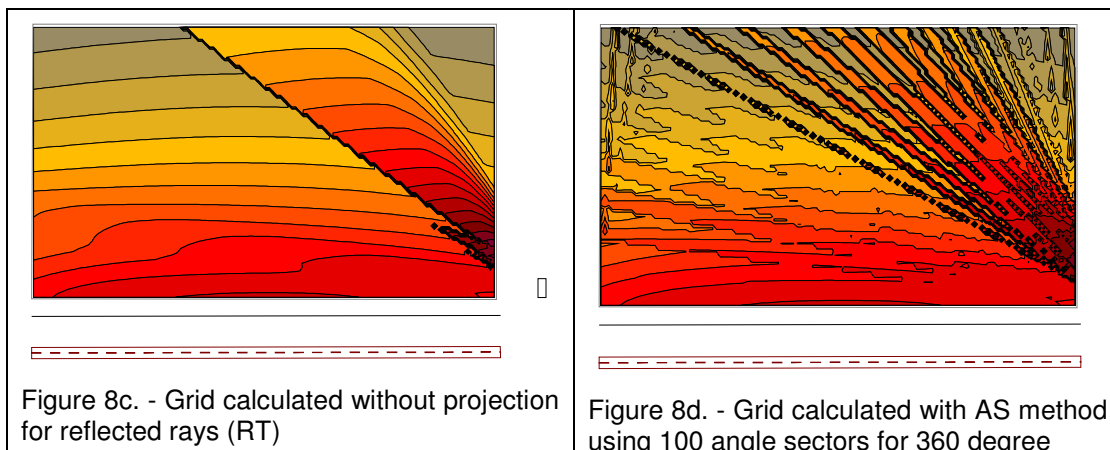
Figure 7 shows a scenario that can be used to test if a software package is able to calculate reflections up to the 10th order correctly.



With the scenario shown in figure 7 the level is calculated for 10 receiver points. Starting with a calculation without reflections, the calculated reflection order is increased by one in each step. The results of each calculation are entered in columns of a table– the level jump by increasing the reflection order shows clearly if the reflected energy is calculated correctly.

To calculate the correct contribution of noise from extended sources like roads or railways radiated into screened areas, it is necessary to use the projection method even for the reflected sound.





THE UNCERTAINTY ACCORDING TO DIN 45687

Software for large scale noise mapping must apply certain acceleration procedures – otherwise it would not be possible to calculate the noise of a larger city in acceptable times. Such techniques are to restrict the maximum search radius for sources around the receiver, to apply the time consuming projection method and the calculation of reflections only up to a maximum distance from source or/and receiver. If a larger noise map with such special acceleration settings shall be calculated the following procedure is used:

- minimum 20 fixed receiver points are distributed statistically over the complete area
- the level at these points is calculated with a “reference configuration” where no acceleration techniques are applied
- then the planned acceleration configuration is applied and the calculation is repeated
- the deviations are sorted – the 10 % and the 90 % limits define the interval of uncertainty.

The technique is powerful and shows an estimate for the uncertainty interval if – and that is the problem – if it is really true that no approximations have been used in the reference configuration. If a software uses a less accurate reference configuration, the calculated uncertainty interval will be smaller. Experience shows that it is necessary to standardize this reference setting – otherwise a fair comparison of software packages is not possible.

CONCLUSIONS

The overall uncertainty of noise maps due to the application of acceleration techniques can be evaluated by calculating at a restricted number of receivers twice – once with and once without acceleration techniques. A statistical analysis of the differences according to DIN 45 687 shows the uncertainty interval due to the application of these acceleration methods.

But this is not sufficient. Many effects and methods like reflection, diffraction and combinations are handled approximately and these approximations implement uncertainties that are not encountered by the DIN procedure. Test problems are shown that allow to inspect software packages and to find out if these effects are handled correctly.

REFERENCES

- [1] Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise
- [2] DIN 45687 Acoustics - Software products for the calculation of the sound propagation outdoors - Quality requirements and test conditions, 2006-05
- [3] CadnaA – Software for the calculation and evaluation of environmental noise, Datakustik GmbH, D-86926 Greifenberg, Germany