



TECHNIQUES TO ACCELERATE NOISE MAPPING CALCULATIONS FOR LARGE AREAS AND CITIES

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Abstract

Noise mapping has become an important tool and starting point to integrate the noise aspect in all technical and political decisions. Unfortunately these noise calculations, as well as calculations of air pollution, are extremely time consuming. Following the possible ray paths and summing up all the contributions that may influence the noise level at a certain position needs hundreds of complex geometrical calculations for one receiver position – doing the same for a 10 m grid as it is needed for a noise map with acceptable accuracy sums up to millions of calculations.

It is shown how this process has been improved in the last two years. With software solutions that neglect less important contributions the speed can be increased if the decrease of accuracy caused by this simplification is controlled. The application of the method according to DIN 45687 to calculate the standard deviation describing the deviations and the related uncertainty is presented.

Another important method is to share the calculation and to use more computers to process the same model. If the software is able to apply multithreading, eight receiver points are calculated at the same time using a modern dual quad-core computers.

Last not least the application of noise calculation programs that are available as 64-Bit-versions extends the possible project size to largest dimensions that are only restricted by the used hardware.

These techniques and practical examples where they have been applied are presented.

1. INTRODUCTION

The time needed for and – taking restricted time resources into account – the quality of noise maps and action plans depend a lot on the software tools applied. If such grid calculations are performed for thousands of km² using 10 m spacing - see fig. 1 example Hesse [1] - any manual access should be avoided while the calculation is running. With many other large scale mapping projects (examples see also [2, 3]) a lot of experience could be gained about advantageous and even necessary procedures and developments. to ease and speed up handling and calculation. In the following some techniques are presented, that have proven to support these activities very efficiently and that indicate that beside the used algorithms software induced strategies play an important role. The techniques presented have been developed and are used with the software CadnaA.

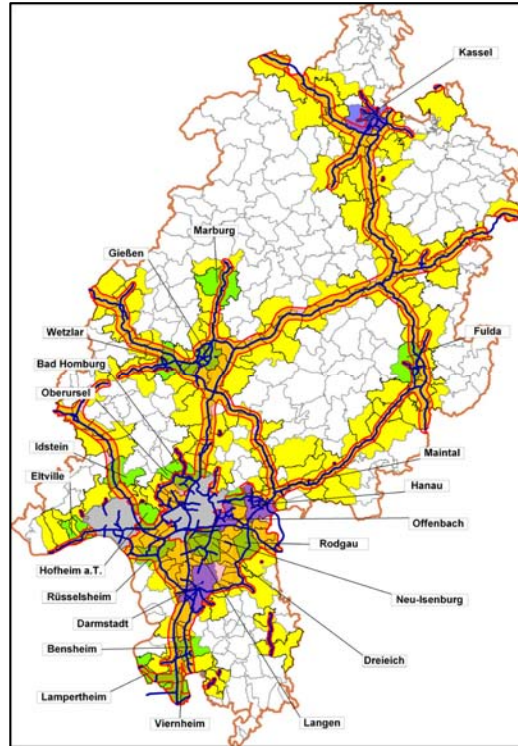


Figure 1 Noise mapping for Hesse: 1750 km main road outside agglomerations, agglomerations Wiesbaden and Frankfurt, International Airport Frankfurt.

2. CALCULATION STRATEGIES

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 geometrically. Diffracting objects and other attenuating influences are taken into account by corrections of the calculated level contribution.

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.

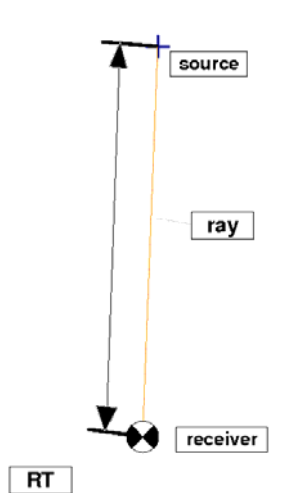


Figure 2.- Calculation of level caused by one point source at the receiver with RT.

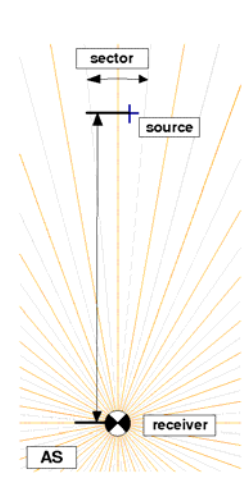


Figure 3.- Calculation of level caused by one point source at the receiver with AS.

In a certain way RT is deterministic, AS a statistic approach.

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. These RS techniques are only of negligible importance in environmental noise prediction.

3. EVALUATION OF SOFTWARE PACKAGES - CRITERIA

3.1 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.

3.2 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.

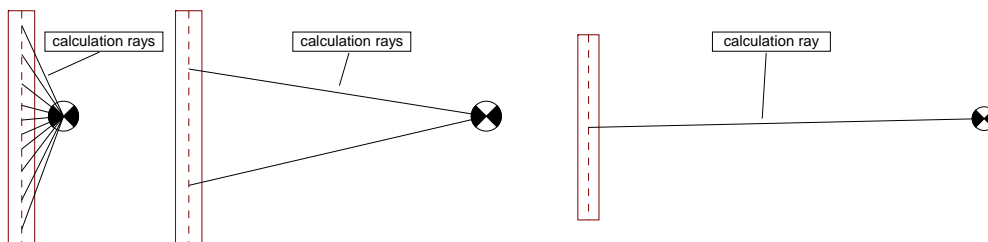


Figure 4. - Dynamic partitioning of extended sources with RT – increasing number of calculation-rays with decreasing distance

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.

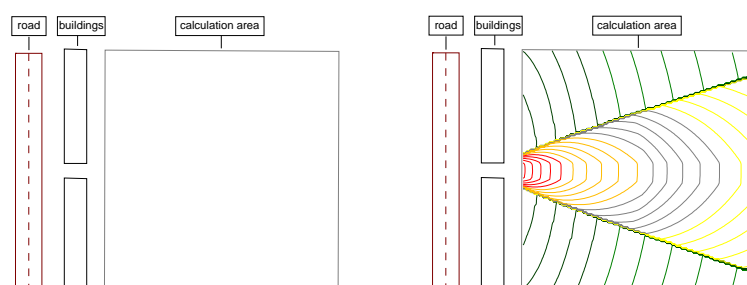


Figure 5. - Left side scenario to calculate a map in an area screened by buildings with gap. Right side result of calculation using projection method (RT)

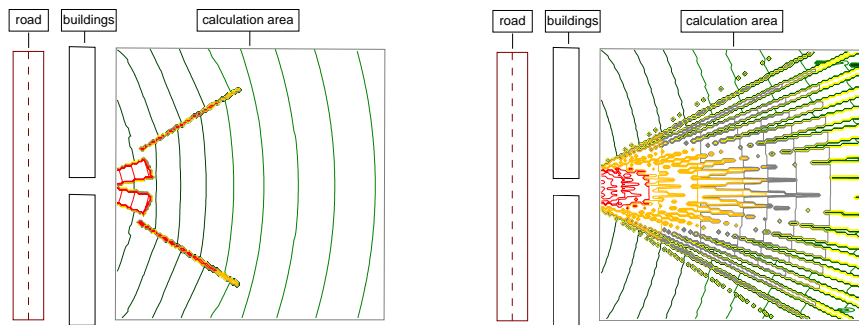


Figure 6. - Left side calculation of lines of equal level with RT without projection method.
 Right side calculation of map with AS using 100 angle sectors for 360 degree.

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 5 right shows the expected and correct result, it is obvious that the results of figure 6 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.

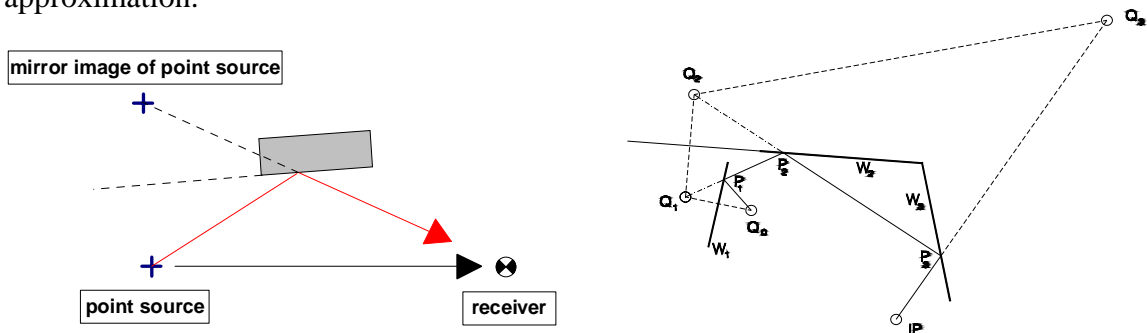
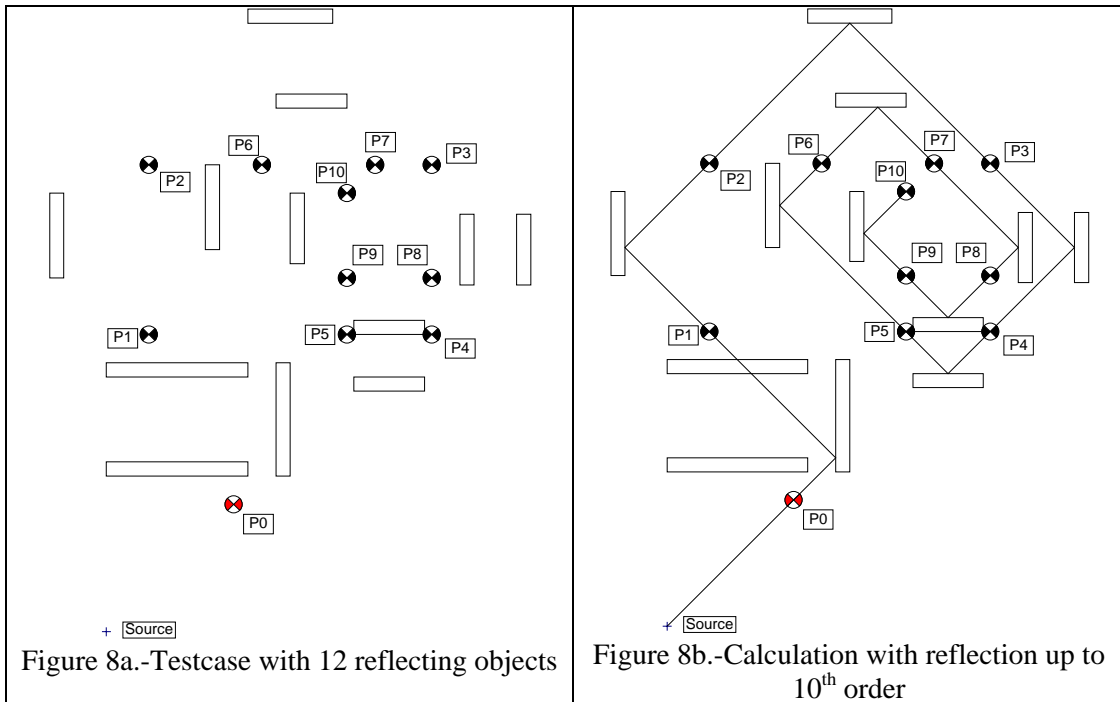


Figure 7. Construction of an image source to calculate reflections.
 Left side first order, right side third order reflection.

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 8 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 8 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.

4. 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.

5. ACCELERATION TECHNIQUES APPLIED WITH SOFTWARE CADNA/A

It depends a lot on software strategy how unnecessary or not relevant calculations can be avoided.

5.1 Search radius

A general used technique is to use a configuration parameter like “Search radius”. If the level is calculated at a receiver point then the model up to this distance is taken into account – all sources more far away are neglected. It is obvious that with such “hard” and user defined speeding techniques no absolute limit for the resulting uncertainty can be given. Even if a search radius of 3 km is used, an example can be constructed, where a slightly more than 3 km distant motorway determines the result and therefore a larger value should have been chosen.

5.2 Maximum error

Therefore more intelligent methods have been developed and integrated in CadnaA software. With the input parameter “Maximum error” a value – e. g. 0.5 dB – can be defined. Calculating the level at a receiver is now a two step procedure. With the first step the contribution of all sources inside the search radius – that can be very large – is calculated neglecting all attenuations but that caused by geometrical dispersion. These contributions are sorted and the real calculation is performed including the sources with descending order. After each adding up a new contribution the sum of the contributions of the remaining rest is compared with the defined value – if it is smaller, the calculation can be stopped, because this sum of contributions of the remaining rest is related to free field propagation and their real contribution will be smaller with large probability. Extensive tests have proven that this technique limits in fact in nearly all cases the error caused by neglect of not relevant sources to values smaller than the defined “Maximum error” value.

5.3 Specially restricted reflection and projection calculation

With CadnaA calculating in RT-mode it is possible to calculate reflections up to a defined order – in noise mapping according to the EU-Directive first order reflections are included – only for reflectors with a definable maximal distance from source and receiver. This makes it possible to restrict reflection calculation to facades directly facing the roads or behind – seen from the source – the receiver position.

A similar restriction is possible for applying the projection method – it speeds up the calculation considerably, if this projection is only applied for objects like buildings with a distance smaller than a definable value.

With software using the angle scanning strategy – this means that search rays with constant angular spacing are used starting from the immission point to find the sources – reflectors near the sources far from the receiver cannot be detected automatically.

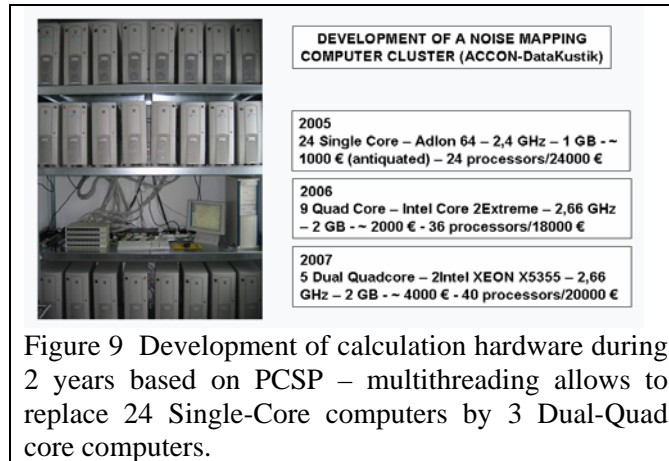
5.4 Automated shared processing

This technique is the key to overcome the problem that for noise mapping the data of the complete model must be present in the computer RAM, because read-write operations would decrease processing times too much. With PCSP (Program controlled segmented processing – the name in CadnaA) the complete area is covered with rectangular frames. To calculate the noise map inside one of these tiles, the part of the model inside this tile and inside all other tiles up to a defined search radius are loaded into the RAM, the calculation is performed and the

rectangular noise map is saved.

5.5 Multithreading

With software CadnaA a very effective step has been made by implementing this feature. All modern processors are of type dual core, quad core or even dual quad core, this means that two, four or even eight processors can be used. To use this multithreading feature, the software must support the parallel calculation with all processors by an appropriate splitting of the complete calculation in parts that are independent from one another. It is obvious that this is possible if noise maps are calculated – the calculation at one receiver is absolutely independent from the calculation at another receiver.



5.6 64-BIT- noise calculation software

Even if the calculation can be speeded up considerably using these techniques described above the problem remains that there is a restriction of totally about 2 GigaByte RAM that can be used for the data of the model – 32 Bit allows to address 4 GB, and 2 GB are necessary for operating system and administration and so another 2 GB remain for the model.

These shortcomings have been overcome by introducing 64 BIT technology in the noise calculation program CadnaA. Theoretically this is a factor of 4 billions in the addressable items, but even taking into account realistic losses for data administration the increase is tremendous. It is now possible to handle the models and grids of complete cities and even countries in one sweep. The restriction is now the total number of 16 million objects of each type – before implementation of 64-BIT-Version this number could not be reached because of limitation of addressable RAM.

It is now very comfortable if a large model is developed and all TK 25 topomaps of complete Bavaria or Baden-Württemberg can be loaded and used as background for modelling.

REFERENCES

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- [2] Noise maps Baden-Württemberg: www.lubw.baden-wuerttemberg.de
- [3] Noise maps Schleswig-Holstein: www.umweltdaten.landsh.de/laermatlas
- [4] More info about CadnaA: www.datakustik.com