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How to evaluate the accuracy of noise mapping calculations – the standardized approach according to DIN 45687

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ABSTRACT

All software packages used in Noise Mapping Projects claim to be the best solution and to calculate the most accurate results in shortest time. The German standard DIN 45 687 offers an approach to get a reliable estimate about the accuracy of a noise map and besides it allows to evaluate the differences in calculation time based on the same grade of accuracy.
Some properties of software are mandatory to perform these tests, e.g. a graphic screen presentation of all the rays included in a calculation for a defined receiver point. Two calculations are carried out for a set of receiver points – one with the best possible accuracy without using any acceleration techniques and one with the configuration settings used to calculated the noise map. The statistical analysis of the differences is an excellent measure of the uncertainty in the procedure, and the time needed to calculate in the well defined and accurate reference conditions provides a clear indication of differences of alternative possible software packages. The techniques are explained and presented using practical examples.

1 INTRODUCTION

According to the Directive 2002-49-EC [1] the noise caused by main roads, main railway lines, main airports and generally in agglomerations with more than 100000 inhabitants shall be determined and presented as strategic noise maps. These maps are the basis for further assessments of the noise distribution in residential areas and for action plans.

The directive recommends a grid spacing of 10 m for these noise maps – this means that the level has to be calculated at 10000 receiver points to get a map of 1 km². This gives an idea what tremendous lot of calculations has to be carried out if the noise maps for some 1000 km² have to be produced.

In most cases - based on the calculation standard used - extended sources like roads and area-sources are subdivided in smaller parts and these parts are then handled like point sources - therefore the problem is to calculate the noise level caused by many point sources at many receiver points. With n point sources and m receivers m * n calculations are necessary only for the direct sound. If reflections are included the number of calculations is increased again because each theoretically possible reflection produces a new image source.

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It can be stated that even with best available hardware and software technology it is necessary to use special acceleration techniques and approximations if large scale noise maps have to be calculated.

The standard DIN 45687 [2] deals with quality requirements and test conditions for software products for the calculation of the sound propagation outdoors. A software product that fulfils the quality requirements of this standard must offer a possibility to evaluate the uncertainty resulting from the use of implemented acceleration techniques.

Four steps are necessary – and should be supported by the software product – to qualify the uncertainty of a noise map calculation, where certain acceleration techniques shall be used – these steps are demonstrated with a simple example. Repeating the procedure by variation of a configuration parameter shows the influence of this parameter on accuracy on one side and on calculation time on the other side. A thorough analysis as starting point of a noise mapping project allows to optimize the procedure in relation to calculation time and acceptable uncertainty.

2 UNCERTAINTY AND ACCELERATION TECHNIQUES

All calculation methods used in noise mapping projects are based on ray techniques – this means that the propagating sound wave is approximated by geometrically exact defined rays presented by straight polygon lines. The problem is to get a sufficient high resolution to “see” the gaps between buildings, barriers and other objects and to calculate the correct amount of unscreened sound energy if the receiver point and an extended source like a road are separated by such objects with gaps between them. To cope with this problem it is necessary to distinguish between two well known software strategies - the RT (ray tracing) and the AS (angle scanning) method. With both methods extended sources like roads and area-sources are subdivided in smaller parts and these parts are then handled like point sources – therefore the problem is to calculate the noise level caused by many point sources at many receiver points.

With AS method the full viewing angle of 360 degree is subdivided in a selectable number of equal sectors and in each of these sectors the bisecting line is the ray to search for sources. Each intersection point ray - line source is included in the calculation like a point source replacing the relevant part of the line source.

With RT method the line source is intersected dynamically – parts far away are subdivided in longer, parts nearby in shorter elements.

Generally the dynamic adjustment of ray spacings used in RT method is quicker – it is easily understood that constant spacing waste time in areas sparsely crowded with sources if this spacing is adjusted to the necessary resolution in areas with very detailed source structures.

Figure 1 shows the application of the RT method if the contribution of two area sources – one nearby and one far away – is calculated. Left side there are no screening objects – the source nearby is subdivided in many little parts, for the source far away one single calculation is sufficient. With the situation left side three buildings are located in front of the area source far away and calculating only one ray would result in an arbitrary level depending whether the ray is intersected and therefore screened by the building. Therefore a two step procedure is used shown right side – first the area source is subdivided in screened and unscreened parts by “projecting” the objects to the source as they are seen from the receiver. The energy of each subpart is then attached to a relevant ray. This produces the exact energy contribution of the partially screened source at the receiver location. But it is obvious that the number of calculation rays and so the calculation time explodes with increasing number of objects between receiver and source.

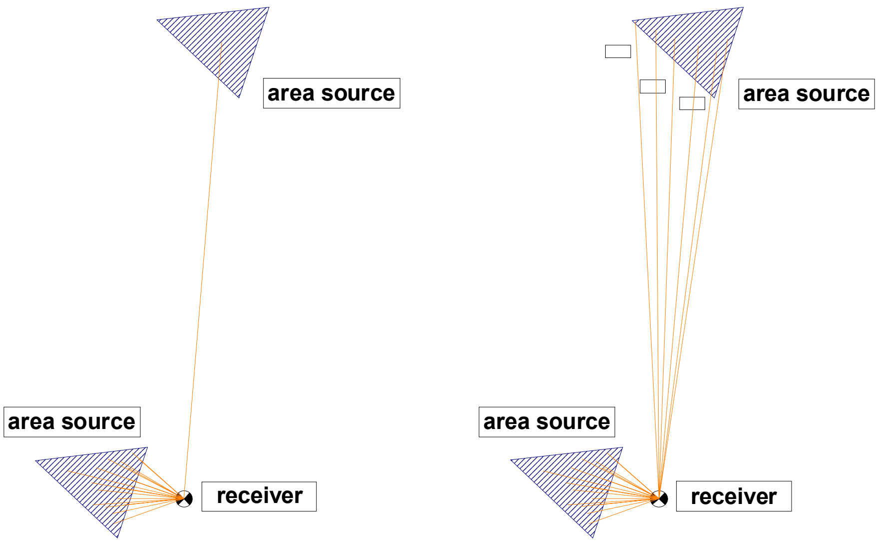

Figure 1: RT method: Left: sources unscreened. Right: far source partially screened (projection method).

Application of the projection method is quite complicated, because the receiver is connected with the edges of all objects and these rays are used for subdividing the extended source in a first step. In large scale noise mapping it is therefore an important acceleration technique to restrict the application of the projection method to distances of about 100 m from the sources and receivers. In that case the gaps between the buildings near the road are taken into account, but an unnecessary “atomizing” of the extended sources is avoided.

With the angle scanning method AS the only chance to take the gaps correctly into account is to select very small angle steps to get an acceptable resolution.

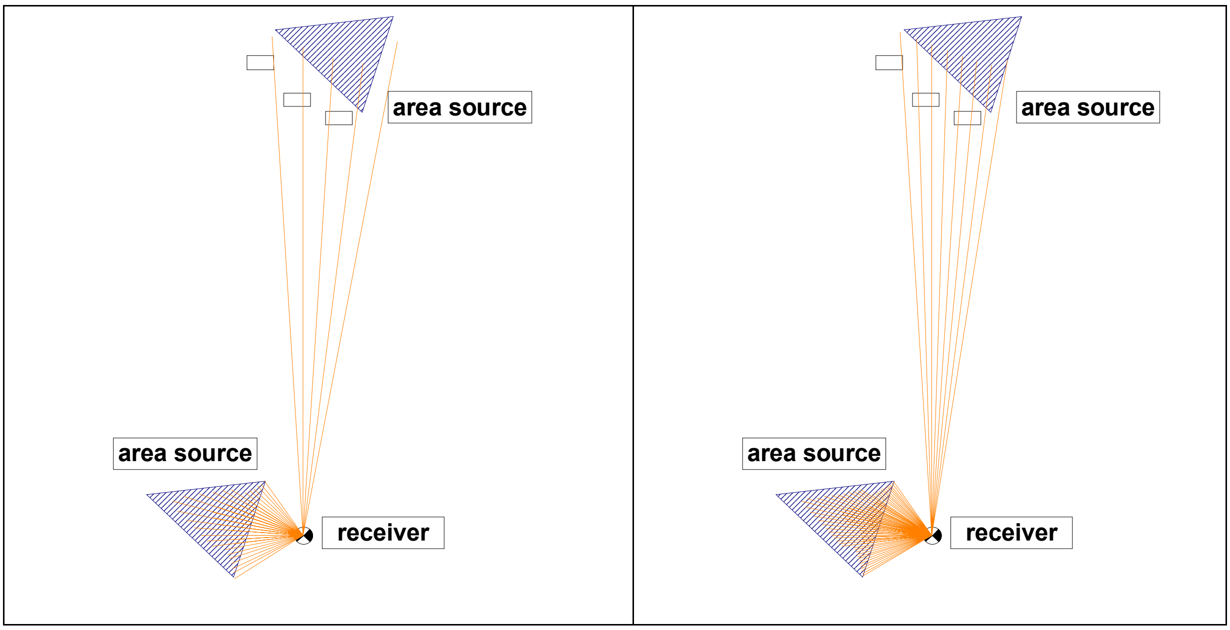

Figure 2 – AS-method with extended sources. Left: 100 rays, Right: 200 rays.

At the left side the 360 degree environment is covered with 100 equally spaced rays. It can be seen that even with this relatively high resolution one of the gaps between the buildings is not encountered – the calculated level will be too low because the energy penetrating this gap is not included. In a calculation shown at the right side 200 rays have been used and the resolution is now good enough to see all the gaps. But the area source next to the receiver is now also calculated with this tight pattern of rays – an unnecessary and time wasting procedure.

With angle scanning AS it is therefore an important acceleration technique to apply larger angle segments.

Many other methods like

- restricted search radius around the receiver where sources are included in the calculation
- restricted search radius for reflecting surfaces
- interpolation techniques

are used in noise mapping projects to reduce calculation times.

To evaluate the influence of software configuration the accuracy is related to the deviation from the exact calculation – exact means that the applied standard or guideline is fulfilled exactly. The uncertainty encountered has nothing to do with the deviation calculation – measurement. In that sense the underlying calculation method defines the "truth" – any deviations caused by neglecting sources or by applying approximations increase the uncertainty.

3 DETERMINATION OF THE UNCERTAINTY RELATED TO A GIVEN CALCULATION CONFIGURATION

The method to determine the uncertainty is a 4-step procedure.

Starting with a given project as shown in Figure 3, receiver points are distributed irregularly over the calculation area.

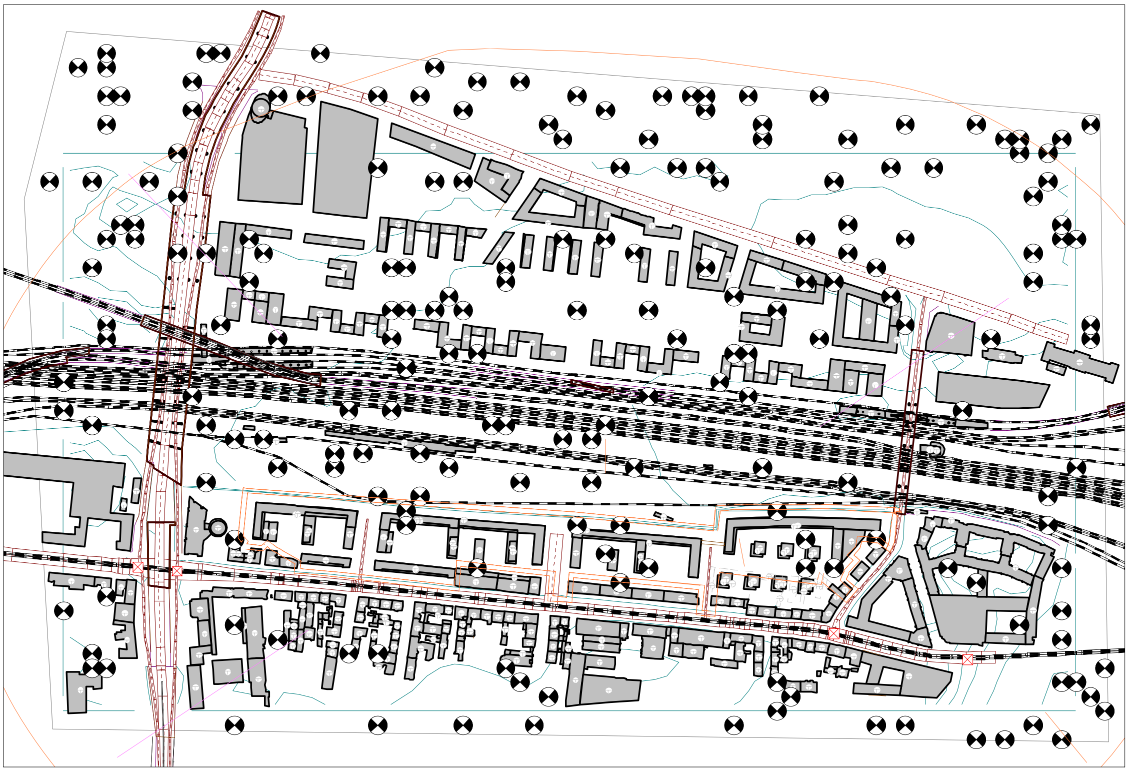

Figure 3 Built up area in the vicinity of railway tracks with 200 receivers distributed irregular (realization CadnaA [3]).

The second step is to calculate the level at all receivers without using any acceleration technique and with best possible accuracy – this is the so called reference configuration. The calculation time will be quite long – therefore only a restricted number of points is used. DIN 45687 requires a minimum of 20 points.

In the next step the calculation is repeated using exact the same program configuration that shall be applied for the noise map – in most cases the levels will be lower.

Now the differences of the two levels are evaluated statistically. The 0.1 and 0.9 Quantil define the limits of the uncertainty interval according to DIN 45687.

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Result of the analysis of uncertainties according to DIN 45687
Projekt: Railwaystation Munich 0507

Calculation configuration	Referenz	Projekt
Max. Search Radius (m)	3000	1000
Grid Interpolation	(none)	17 * 17
Proj. Line Sources	1	0
Proj. Area Sources	1	0
max. Order of Reflection	1	0
Max. Distance Source - Rcvr	3000	1000
Search Radius Src	3000	100
Search Radius Rcvr	3000	100

Statistical analysis:	
Quantil q0.1:	-1.8
Quantil q0.9:	-0.0
Mean value:	-0.6
Standard deviation	0.9
Minimum:	-4.4
Maximum:	1.7

Single values

Nr.	Coordinates			Level		
	X	Y	Z	Reference	Project	Difference
	(m)	(m)	(m)	(dB)	(dB)	(dB)
1	4466160.00	5334320.00	523.06	55.71	55.48	-0.23
2	4466660.00	5334240.00	522.17	51.82	51.36	-0.46
3	4466320.00	5334020.00	522.67	43.21	43.71	0.50
4	4465480.00	5334240.00	522.96	59.43	59.51	0.08
5	4465960.00	5333780.00	522.95	57.74	56.94	-0.80

Figure 4 Statistical analysis of uncertainties when calculating with the project configuration.

The analysis shows that in this case the applied acceleration techniques produce a systematic deviation of - 0.6 dB, this means the calculated levels are too low. The standard deviation is 0.9 dB and the uncertainty interval according to DIN 45687 is -0.8 to 0.

It shall only be mentioned that it is absolutely necessary to standardize the reference configuration, because this is the basis for the uncertainty analysis. Especially the maximum size of the angle step in the AS method and the minimum search radius for sources must be the same if the results shall be comparable.

4 CONCLUSIONS

The uncertainty analysis according to DIN 45687 can be a powerful method to determine the influence of acceleration techniques, if the reference configuration used to calculate the "true" values is better defined and standardized. The method allows to get the influence of accelerating settings on the accuracy and to decide about the best suited calculation configuration.

5 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 (www.datakustik.de)