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NOISE CALCULATION STRATEGIES

Wolfgang J. Probst

ACCON GmbH and DataKustik GmbH
Gewerbering 5, D-86926 Greifenberg, Germany
Wolfgang.probst@accon.de

ABSTRACT

Different software products are offered to be applied in Noise Mapping according to Directive 2002/49/EC. These software products are generally based on one of two possible strategies to calculate the sound pressure level at a receiver point from all sources. These two strategies - the “Angle-Scanning-Method (AS)” and the “Ray-Tracing-Method (RT)” – have both their advantages and shortcomings. The AS method was mainly used for road and railway noise calculations, while the RT method was developed for general noise calculations with point-, line- and areasources. In the meantime both methods are used for all noise types, and it may be helpful for users to understand the methodical differences. To cope with all requirements existing, both methods have been implemented in the Noise Mapping Software CadnaA. The comparison of both methods show that the AS method has advantages if levels at the facades facing a road shall be calculated and reflections up to high orders caused by buildings and other reflecting objects at both sides of the road have to be included. This advantage vanishes if many diffracting objects have to be crossed between source and receiver.

The main differences of the two systems are discussed and some procedures to improve the accuracy are presented.

1 INTRODUCTION

Software packages that are designed to calculate Strategic Noise Maps according to the Directive 2002/49/EC use generally geometric methods to construct the possible ray paths between source and receiver. Two fundamentally different approaches are used – the Angle-Scanning-Method AS and the Ray-Tracing-Method RS. .The main differences and advantages as well as shortcomings are discussed with this contribution. Figures 1 and 2 show a simple scenario where both methods have been applied: A rectangular frame is built by a line source and the sound pressure level shall be calculated at a receiver point near the lower left edge.

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 (figure 1). 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 crouded with sources if this spacing is adjusted to the necessary resolution in areas with very detailed source structures.

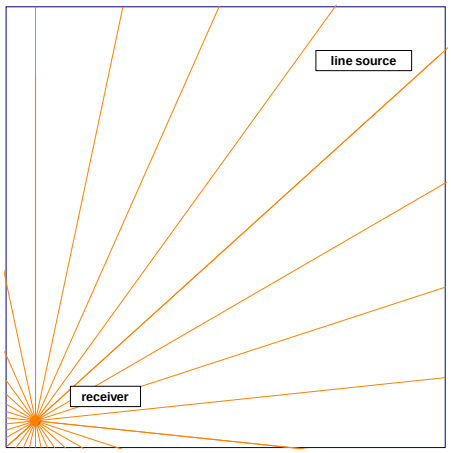

Figure 1 – Application of AS-method

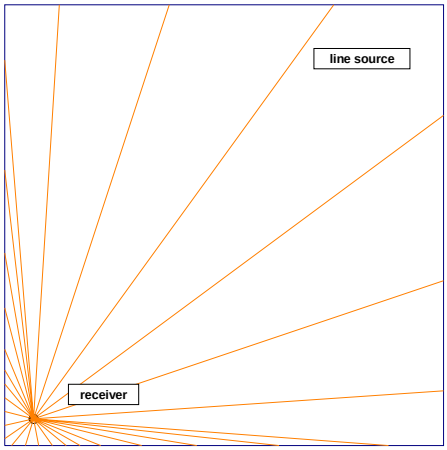

Figure 2 – Application of RT-method

2 THE RAY-TRACING-METHOD

2.1 Varying propagation conditions

With point sources the procedure is simple – for each receiver point all these point sources are used sequentially, the possible ray paths source receiver are determined and all the level contributions are summed up energetically.

Extended sources like line- or areasources are subdivided into elements so small that these can be replaced by point-sources.

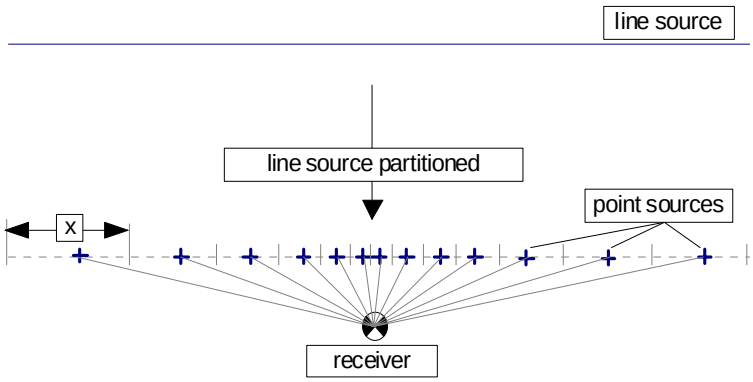

Figure 3 – Dynamic subdivisioning of an extended source (line source)

The size of the subparts depend on the distance – at large distances the extended source can be replaced by one point source and calculated with one ray, as it is shown in figure 4 at the left side. The area source with same shape and extension but next to the receiver is automatically subdivided into more elements.

With screening objects the use of one calculation ray will produce erraneous results – therefore the software produces automatically more rays as it is shown at the right side of figure 4. This is realised using a two step procedure – first the receiver is connected with the outermost points of each screening object and these lines are used to subdivide the extended source in a first step. In a second step the extension of each part is compared to the distance and subdivided further if necessary. This projection method is a type of automatically adjusted resolution. With high quality mapping software the projection can be used also for reflected rays and restricted to selectable distances from source and receiver.

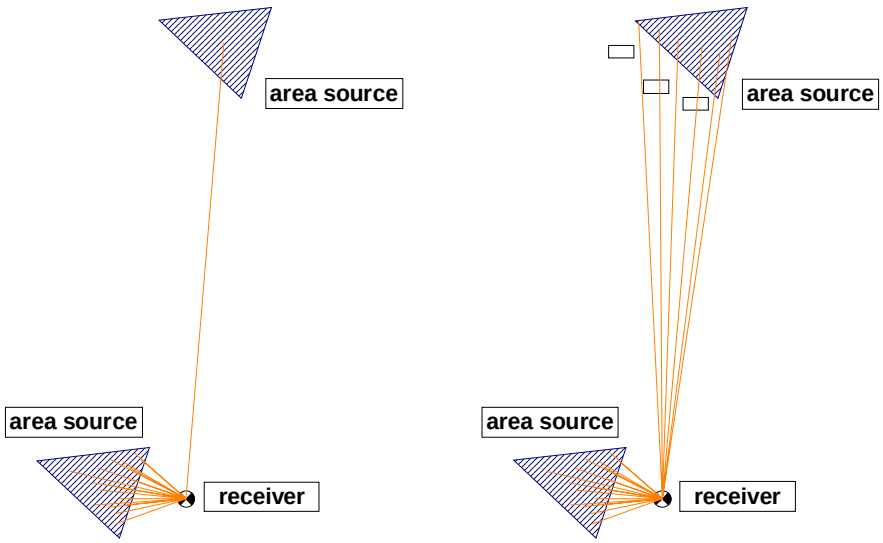

Figure 4 – Left: same propagation conditions. Right: Screening objects

2.2 Reflection

Reflections are taken into account using the mirror image method. Figure 5 shows the rays produced by a piece of road and reflected at opposite surfaces..

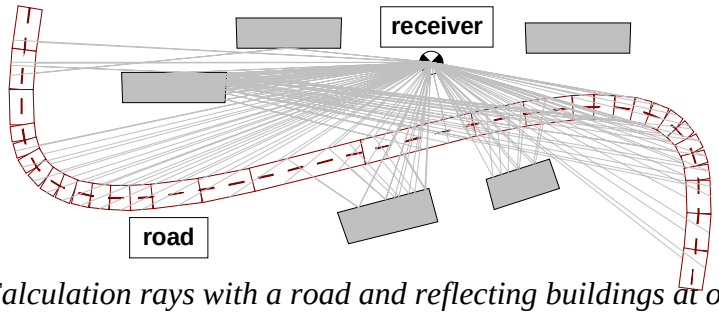

Figure 5 – Calculation rays with a road and reflecting buildings at opposite sides

With RT-method the reflected rays can be calculated up to any order by a recursive procedure – this enshures that all possible reflections are found and taken into account. Practically the number of possible rays and the necessary calculation times explode with increasing number of reflecting surfaces and with order of reflection included. In Noise Mapping with hundreds of km² agglomerated area it is impossible to calculate even more than one reflection order. High quality software will allow to restrict the reflectors taken into account to a definable distance from source and receiver.

3 THE ANGLE-SCANNING-METHOD

3.1 Varying propagation conditions

With AS the environment of a receiver is subdivided in constant angle steps. The same calculation shown in figure 4 is presented with AS method in figure 6.

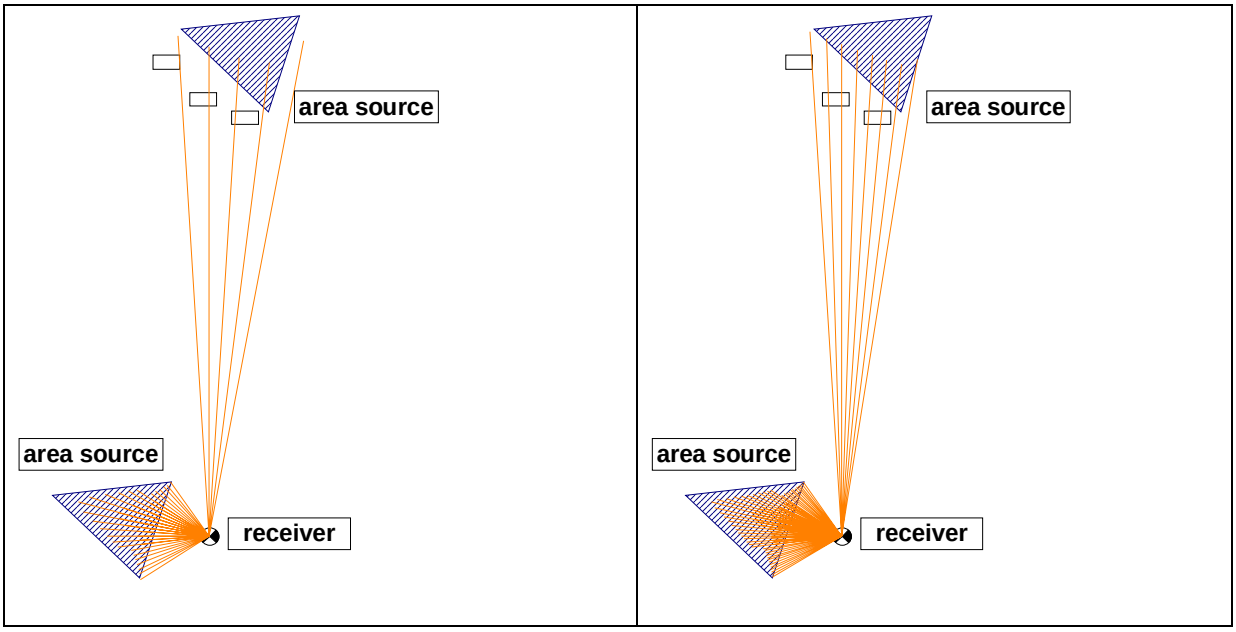

Figure 6 – AS-method with extended sources. Left: 100 rays, Right: 200 rays

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.

3.2 Reflection

There is no principal difference in the strategy how to calculate reflections – with AS the mirror image method can be used as well.

A general problem is based on the fact that the search rays start from the receiver. Each time a ray crosses a diffracting object an additional search ray reflected at this surface may be produced. The result is an exponential increase of possible rays with increasing distance from the receiver. Therefore the production of additional search rays must be stopped after a definable number of reflecting objects have been crossed. This on the other side makes it impossible to detect the effect of a reflecting object direct facing a road in the calculated noise map for an agglomeration area at the opposite side.

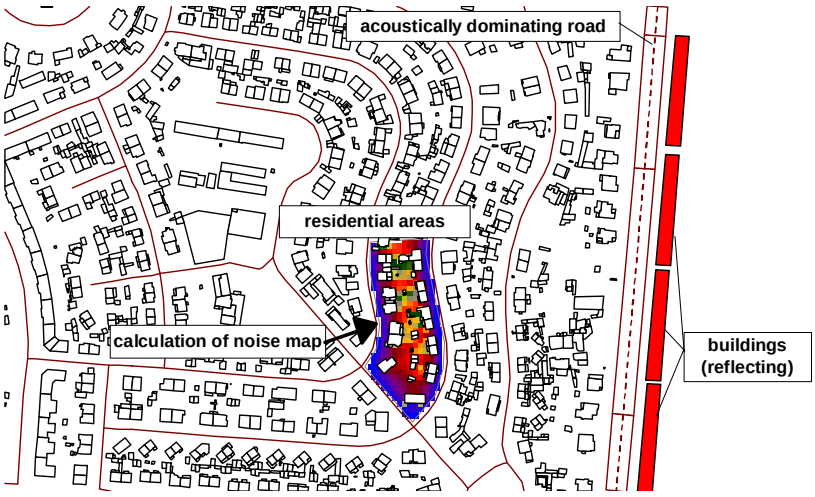

Figure 7 – Reflecting buildings at a motorway opposite to an agglomerated area

Figure 7 shows this situation – special methods must be applied with AS-calculations to get the level increase caused by the reflector in the built up area at the opposite side.

The advantage of AS-methods comes into play if multiple reflections have to be calculated at facades facing the road. If the rays propagate free and no diffracting objects have to be crossed the AS method is by far faster than the RT method.

Figure 8 shows a simple example. About 10 reflecting buildings are at each side of a road. The calculation was carried out taking into account reflections up to 8th order – it took 14 seconds using RT and a fraction of a second using AS method.

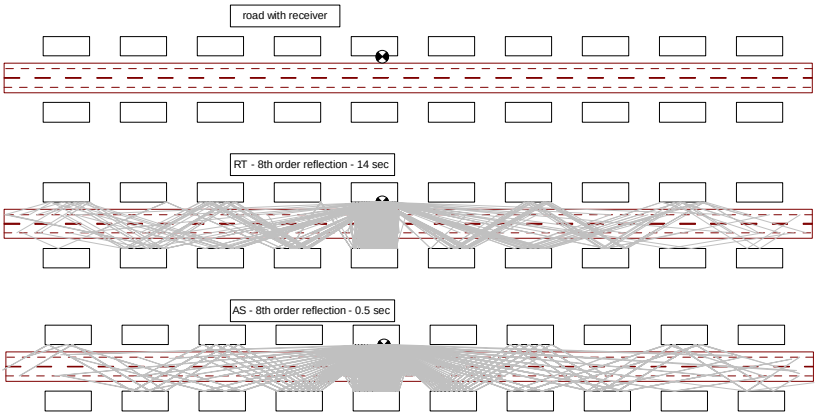

Figure 8 – Upper: road with 10 buildings at each side. Middle: RT-calc. Lower: AS-calc.

3.3 CONCLUSIONS

Ray Tracing (RT) and Angle Scanning (AS) are two methods applied in noise mapping software. RT is more exact and reflections are included in a deterministic way, that means all possible reflections are calculated up to the defined order. AS with its restricted resolution includes uncertainties, that are more or less averaged and therefore vanish with extended sources. The advantage of RT is the accuracy and precision, but the price to be payed is the

long calculation time if higher reflection orders come into play. The advantage of AS is the very fast calculation of multireflections inside road spaces, but the price is the lower accuracy in certain configurations.

The software CadnaA can calculate using both methods alternatively with the same project file – this is unique and allows to use the advantages of both methods.