Portland, Oregon
NOISE-CON 2011
2011 July 25-27

Validation of calculation methods for sound propagation outdoors

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Different calculation methods exist that include meteorological and ground effects. It is important to know how accurate these methods are and if the loss in precision and transparency is justified by an adequate improvement if such effects shall be predicted. Measurements have been undertaken that can be used to check the uncertainties and to evaluate and rank the deviations between calculated and measured levels.
In the frame of the European CNOSSOS-EU project it is planned to compare the methods ISO 9613-2, NMPB 2008, Harmonoise and some others. The noise levels produced by a uniformly radiating sound source are measured at receivers at different distances. The same scenario is modeled and the levels are calculated with these above mentioned methods. The comparison of calculated and measured levels is an effective method to qualify a calculation method and to optimize the selection of default parameters to be used.

1 INTRODUCTION

Noise calculation methods are an important part of national noise policies and in most cases the starting point of local and even large scale programs of noise mitigation. It is important to see the calculation of noise not as a concurring procedure to measurements. The relation between parameters defining acoustically the sources and the environment and the resulting noise impact elsewhere must be clarified by measurements. If many of such exercises with measurements have been performed it is obvious that relations encountered between measured noise levels and system parameters should preferably be expressed mathematically to avoid further measurements in cases where such relations exist. The calculation method is nothing else but a summary of many measurements undertaken by the acoustic community and therefore in many cases more representative than an individual measurement that is more or less a snapshot. This is especially true for parametrizable sources like roads traffic where noise levels averaged over longer periods like days, nights or even years are the important indicator to be compared with certain limiting values.

If the comparison of calculated noise levels with legally fixed requirements decides about acceptance or rejection of a planned project it is obvious that the calculation method itself and its implementation in different software-platforms should produce absolutely identical results with the same input data. This needs two different steps. The first step is to describe the method clear

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and unambiguously – at best to fix it in a standard – so that there is no need for interpretations or other open issues. A high level of precision means that different experts applying the method should produce the same results if they calculate the noise levels for the same scenario. For all calculation methods used to check legal requirements the precision of method is a very important property. The uncertainty – this means the deviation from results obtained with an ideal measurement – or other way round the accuracy is also important, but only at second position behind the precision. A further important aspect is simplicity and transparency – this is necessary to find the reasons for unexpected results and to retrace a calculation in such cases.

In the past 15 years some methods have been developed with the intention to include more physically observable influences. Examples are NORD 2000 and Harmonoise/Imagine. These methods calculate a coherent superposition of direct rays and ground reflection and apply the Fresnel Zone Construction to take all possibly reflecting surface elements into account. Another important point is meteorology – the well known effect that with different temperature and wind speed gradients the long range sound propagation is not (RLS-90, CRTN) or only roughly with respect to the yearly average (ISO 9613-2) included in the conventional models. With NORD 2000 and Harmonoise different meteorological classes are taken into account and the calculation has to be performed for these classes separately to get the final result by calculating the weighted average.

It is difficult to weigh the pros and cons of all these different approaches, and therefore it was decided to make some comparisons with test cases. The following shall only describe the procedure with some examples – these comparisons will be extended by far more to be able to rank the different properties and shortcomings depending on the tasks to be performed. The methods ISO 9613-2[1] and NMPB 2008[2] are used as representatives of relatively simple and straightforward engineering models, the method Harmonoise integrated as a P2P model[3] as representative for these mentioned new approaches with phase related superposition of ground reflection and different meteorological classes. All three method have been integrated in the software-platform CadnaA[4] .

2 PROPAGATION ABOVE FLAT TERRAIN

2.1 Comparison of the three methods

Figure 1 shows the simple scenario. The source is alternatively a line source (for ISO 9613-2 and Harmonoise) or a piece of road (for NMPB 2008) of length 1 m – the receivers are arranged along a straight line in a height of 2 m above ground. The source height is 5 cm above ground.

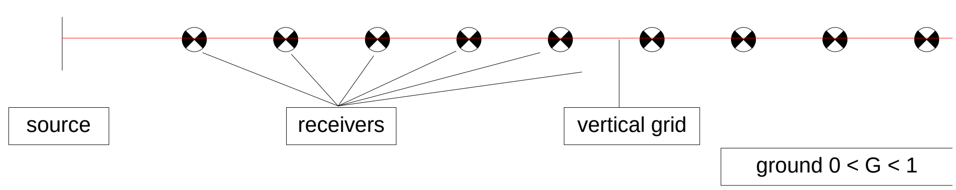

Figure 1. Scenario to calculate propagation above flat terrain.

The emission of the source is a normalized A-weighted spectrum typical for road traffic (according to NMPB 2008 for road surfaces “non drainant”).

Table 1. Normalized A-weighted frequency spectrum (octave bands).

Frequency (Hz)	125	250	500	1000	2000	4000	Total
LWref A-weighted)	-20.6	-13.3	-6.9	-2.8	-7.4	-15.3	0.0

Fig. 1 – 4 show the calculated results on a vertical grid for the 3 methods, where Fig. 3 show these results for very unfavorable and Fig. 4 for very favorable propagation conditions calculated with Harmonoise. These vertical grids show that the differences are restricted to a relatively thin layer above ground.

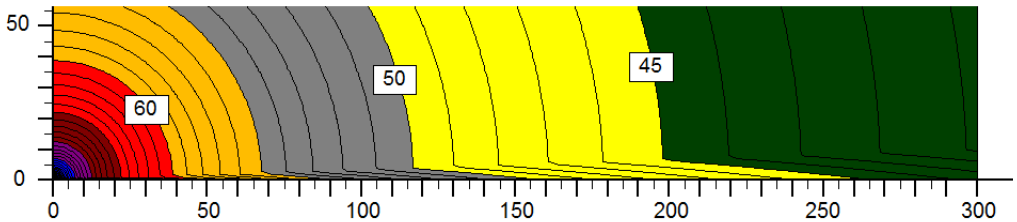

Figure 2. ***ISO 9613-2, reflecting ground (G = 0).***

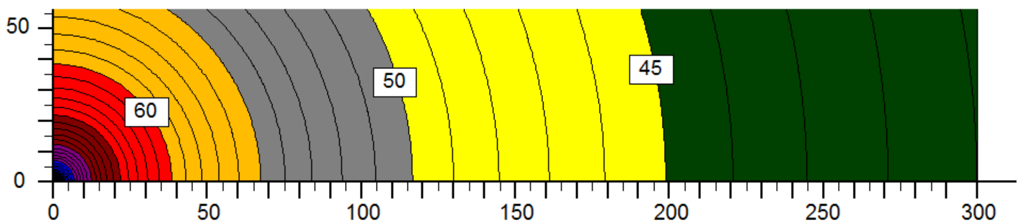

Figure 3. NMPB 2008 homogene or favorable, reflecting ground (G = 0).

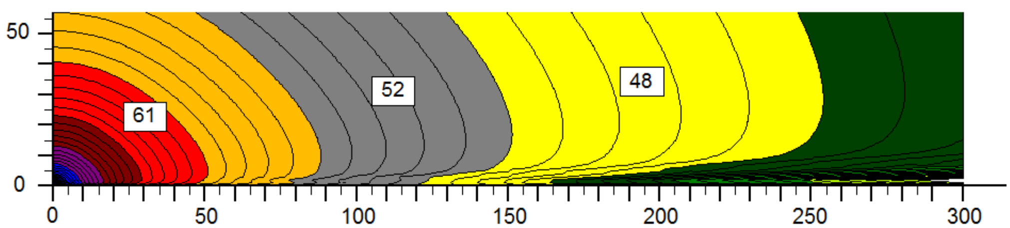

Figure 4. Harmonoise Stability Class S1, reflecting ground (G = 0).

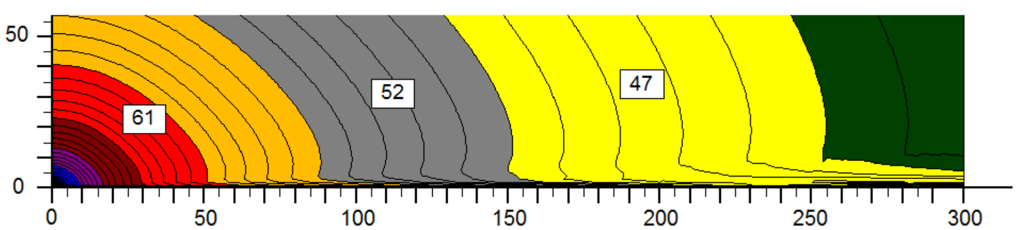

Figure 5. Harmonoise Stability Class S5, reflecting ground (G = 0).

The main differences occur at low heights above ground. Therefore receiver points are located in a height of 2 m above ground (figure 1) to investigate the dependence of levels from distance. The source height was 2 m above ground (different from the vertical grids above, where the source height was 0.05 m (according to height of road source in NMPB 2008).
The pure geometric attenuation from a point source in free field was extracted from the results by applying a correction according to

$$dLA_{calc}(r_i) = L_{calculated} - L_{WA} + 11 + 20*\log(r_i/1m) \qquad (1)$$

where r_i is the distance source – receiver in m at position i. This values dLA show the influence of ground, meteorology and air absorption.

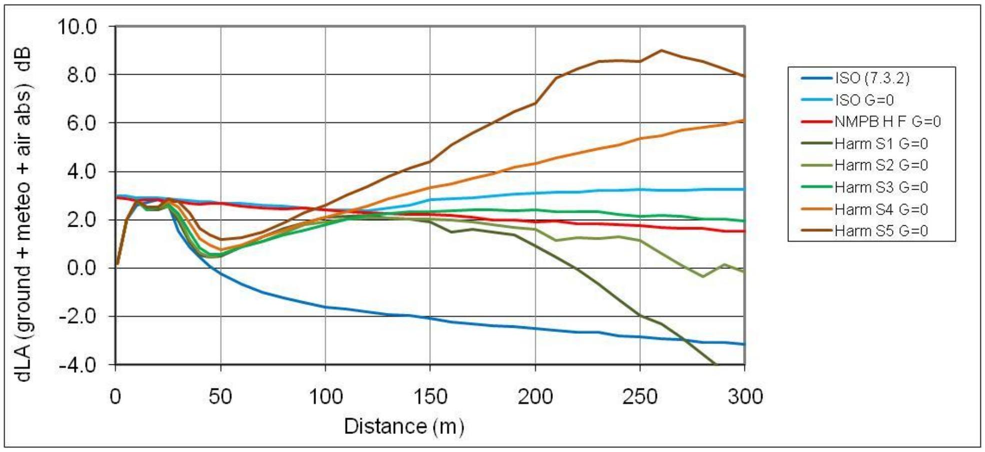

Figure 6. Ground absorption coefficient G=0 (reflecting, 20000 kRayl with Harmonoise)

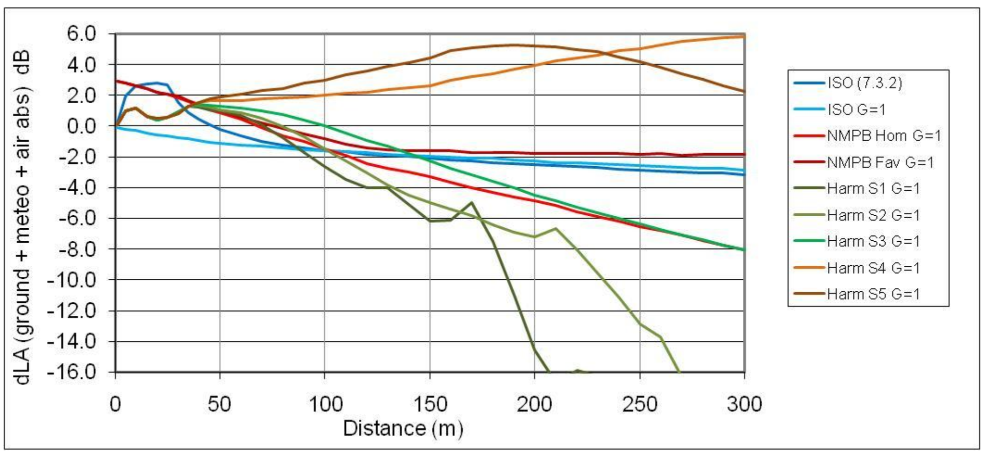

Figure 7. Ground absorption coefficient G=1 (porous, 200 kRayl with Harmonoise)

2.2 Comparison with measurements

Measurements have been performed above flat ground.

Figure 8. Source with L_{WA} = 125 dB(A)

The sound power level of the source $LW_{Source}(k)$ in each frequency band k has been determined in a reverberation room according to ISO 3745. The normalized A-weighted levels comparable to the calculated ones and related to the same reference frequency spectrum table 1 $LW_{ref}(k)$ are determined by

$$dLA_{meas}(r_i) = 10 * \lg \sum_k \left(10^{(L_{meas}(k,r_i) - LW_{Source}(k) + LW_{ref}(k))/10}\right) + 11 + 20 * \lg \left(\frac{r_i}{m}\right) \quad (2)$$

The following diagram shows the propagation curves based on measurements and calculations and normalized as described above. These plotted values dLA show again the combined influence of ground, meteorology and air absorption on the A-weighted level of road traffic sound emitted by a point source.
This meteo-influence dLA shall be used in all cases in a standardized way for further assessments and evaluations.

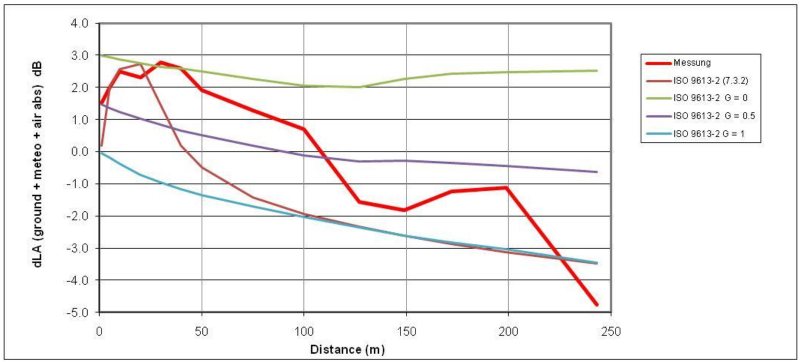

Figure 9. Meteo-influence dLA measured and calculated according to ISO 9613-2

From the deviations of calculated and measured levels

$$\Delta_i = dLA_{calc}(r_i) - dLA_{meas}(r_i) \qquad (3)$$

at all distances the mean deviation $\overline{\Delta}$ and the standard deviation $\sigma(\Delta)$ can be determined.
This diagram is only an example to show the principle. To check the uncertainty of the method only the parameter set according to observation during measurement shall be used in further investigations of that type.

The mean and standard deviation of the differences between calculated and measured levels have been determined without any weighting at this stage. It is clearly questionable if another rule for the importance of different distances may be better – but this is a task for later decision if more standardized measurements have been made.
The absolute value of the absolute mean value plus standard deviation may be used to rank the degree of agreement of calculated with measured curves.

3 PROPAGATION ABOVE TERRAIN WITH VARYING GROUND HEIGHTS

The flat ground of Fig.1 is further replaced by different ground profiles. For free propagation it is sufficient to use a narrow ramp with varying ground heights to study its influence on the propagation pattern.

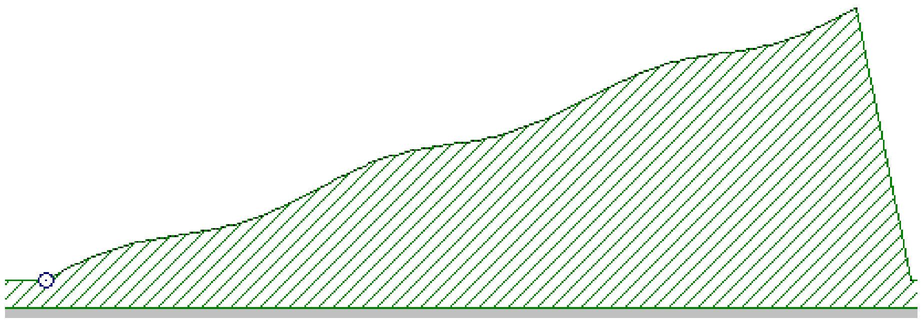

Figure 10. Ramp with sinusoidally varying ground height

The ramp is extended from x = 0 to 300 m horizontally and the ground height varies according to

$$z = x/3 + 3*\sin(2*pi*x/100) \qquad (4)$$

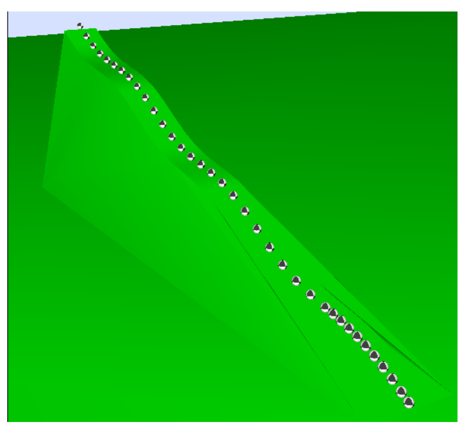

Figure 11. Receivers 2 m above varying ground

The results of the calculation of the level distribution along a line with constant height of 2 m above the varying ground are shown in the following diagram. To normalize the levels according to Eq. (1) the 3d-distance source-receiver was applied.

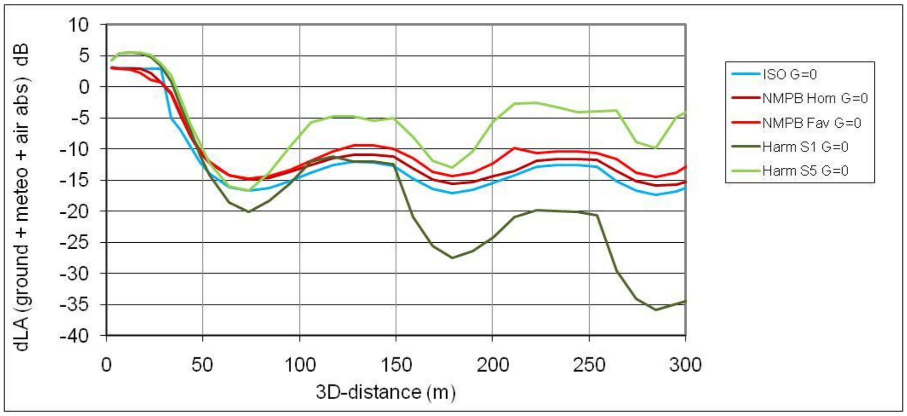

Figure 12. Normalized levels versus 3d-distance with reflecting ground (G = 0, 20000 kRayl)

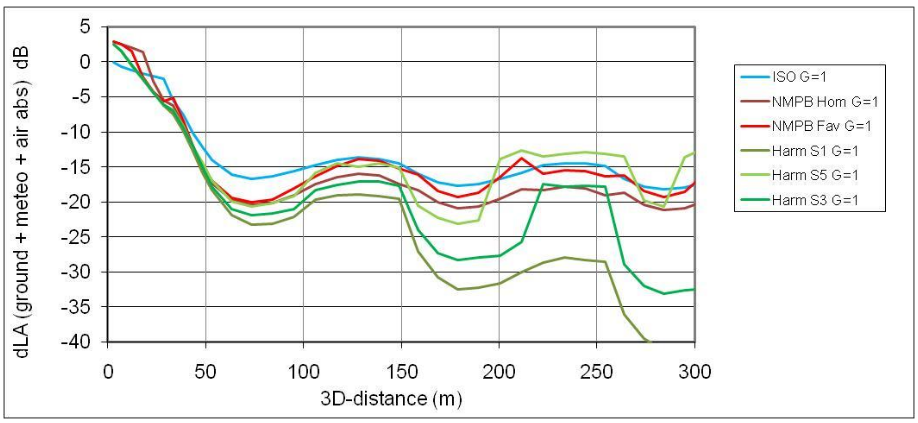

Figure 13. Normalized levels versus 3d-distance with porous ground (G = 1, 200 kRayl)

This test case with varying ground height shows an enormous increase of calculation times with Harmonoise. This is not further surprising if the complex calculation of the ground influence mentioned above is taken into account.

4 TEST CASES WITH SIMPLE BUILT UP SCENARIOS

All published test cases from Harmonoise/Imagine report HAR32TR_040922_DGMR20 have been used to create models and to calculate the levels at the defined receiver point as well as on a grid with 30000 m². One of these models with calculated results is shown in Fig. 14 – 17.

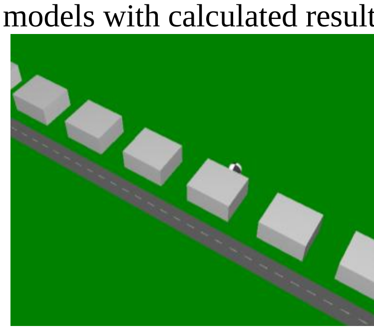

Figure 14. Equally spaced buildings 8 m high at one side of the road

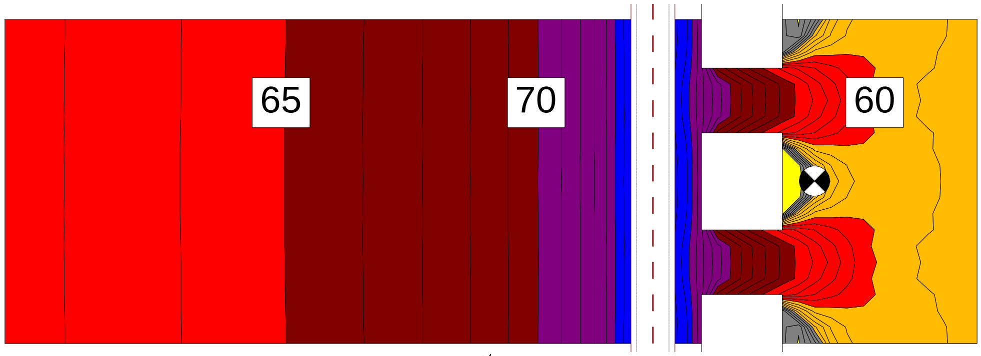

Fig. 15. ISO 9613-2, refl. 1st O., calculation time 1 second*

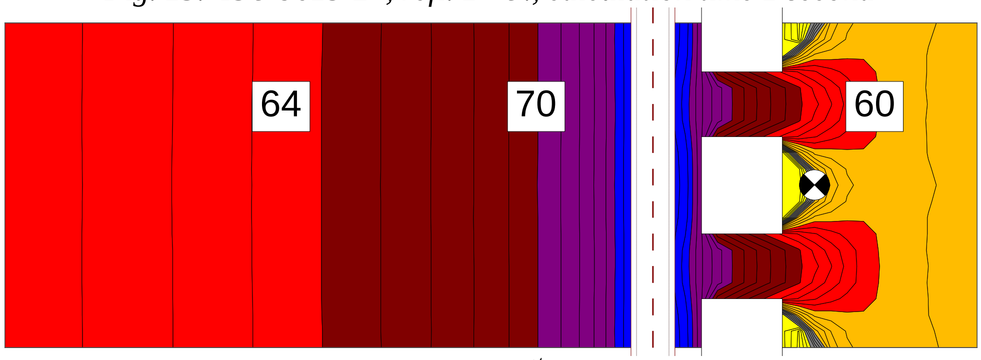

Fig. 16 NMPB 2008 homogene, refl. 1st O., calculation time 1.2 second

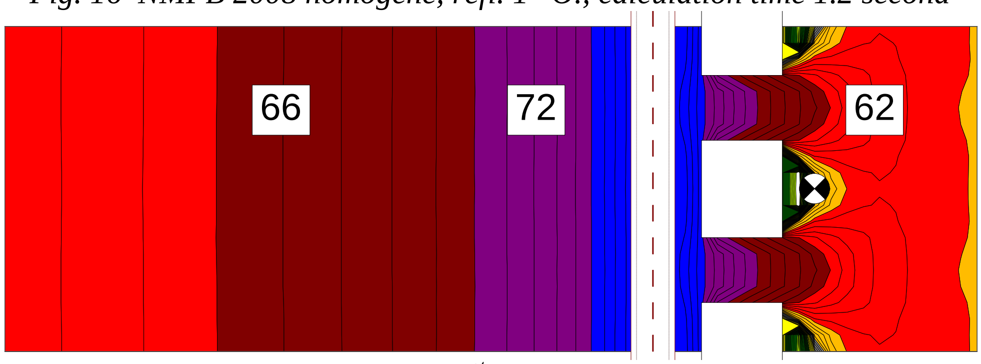

Fig. 17 Harmonoise S3, refl. 1st O., calculation time 54.2 second

These test cases have shown, that levels calculated with Harmonoise for stability class S3 are about 1 - 2 dB higher than those calculated with ISO 9613-2 or with NMPB for homogenous condition, if the receiver is not screened from the source. In cases with screening the differences are very large – Harmonoise calculates levels up to 30 dB lower than ISO 9613-2 or NMPB 2008. The differences in calculation time are obvious. Even with these more simple test cases calculation with Harmonoise takes up to 50 times more calculation time than with the other two methods. But this may be the necessary price for a more accurate result. The planned comparisons will show if this can be justified.

5 FURTHER INVESTIGATIONS

It is planned to investigate more detailed the influence of complex propagation conditions in built up areas like cities. The source system shown in figure 8 is completely installed on a pick up and can be operated while the car is moving. This allows to investigate thoroughly the sound propagation through tunnels, galleries, over barriers and in street canyons and to find out the best compromise to model such facilities and to include them in the propagation calculation.

Fig. 18 Source system installed on a pick up

6 REFERENCES

1. ISO 9613-2: 1996, "Acoustics – Attenuation of sound during propagation outdoors, Part 2: General method of calculation", *International Standardization Organization*.
2. *Road noise prediction, 2:NMPB 2008- Noise propagation computation method including meteorological effects*, Sétra report, April 2009.
3. Dirk Van Maercke, "PROGRAMMING THE POINT–TO-POINT PROPAGATION MODEL". Document reference HAR34TR-041124-CSTB01, 2004 (applied P2P Version 2.020 April 2011)
4. CadnaA – Software for Noise Prediction (www.datakustik.com)