Difference between using 2 and 4 meter receiver height in railway noise prediction

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Summary

In the Nordic countries a receiver height of 2 m has often been used when calculating noise levels over large areas for socio-acoustic surveys, but within the EU 4 m is used. Here results are presented for railway noise calculations at both heights in 1459 points across several areas in Sweden. The average difference in equivalent level is 2.5 dB higher at 4 m height than at 2 m, which in turn leads to 10 % – 40 % less predicted annoyance if the exposure is calculated at 4 m.

1 Introduction

Within the Swedish research program “Train Vibration and Noise Effects” (TVANE) [1, 2] a large number of noise calculations have been performed both at a height of 2 m (Nordic standard) and 4 m (EU Environmental Noise Directive standard) above the ground. This paper describes the differences between the two approaches, both in statistical terms and the theoretical explanations in a few example cases. The impact on estimated annoyance is also briefly investigated.

2 Calculated equivalent and maximum levels

When calculating the noise level from railway traffic the receiver height is of great importance. During detailed investigations it is possible to take the different heights of buildings with several floors into account, but in large noise mapping endeavours it is more efficient to use a standard height. For Swedish conditions 2 m is often used, but for the EU Environmental Noise Directive (END) noise mappings a height of 4 m is advised. Therefore it was decided to work with both heights in the TVANE project.

Within TVANE five different areas were selected for calculations and questionnaire surveys: Falköping, Töreboda, Kungsbacka, Alingsås and Sollentuna. The calculations were performed using the Nordic method revised 1996 [3] in a total of 1459 points up to 350 m¹ from the railway, and were based on digital maps including height information of the terrain, buildings and the railway embankment. Specular reflections of order 1 were included, which was thought to be enough since the areas mostly consisted of detached houses and no street canyons. The traffic flow varied from 10 to 34 trains per hour at peak traffic for the different areas.

Fig. 1. Histogram of differences in equivalent level between 2 m and 4 m receiver height.

¹ A few receiver positions were more distant, up to 450 m from the track.

As expected the calculated noise levels are slightly higher at 4 m receiver height as compared to 2 m. The histogram of the differences in equivalent level can be found in Fig. 1, and the difference versus distance to the railway can be found in Fig. 2, the overall mean difference is 2.5 dB. There are differences up to 11 dB, and as can be seen in Fig. 2 those extreme points occur at all distances from the railway. There is a slight trend of decreasing differences at longer ranges, which is visible in Fig. 2 where the dotted line is the least squares linear regression.

After investigating the receiver points where the differences are large and making calculations in a few test cases it was found that the large differences occur almost exclusively at receiver points where screening is important, either from noise barriers or other buildings.

Fig. 2. Difference in equivalent level between 2 m and 4 m receiver height vs. distance from source.

The difference in the maximum level (time weighting F) are more pronounced than for the equivalent level, which is partly due to the method which specifies an incremental search for the position of the noisiest train passage which gives the

highest noise level. This method needs to be simplified by the program manufacturer to reduce the necessary calculation time, and different programs use different approaches. Part of the difference may also be attributed to numerical problems related to finding the relevant rays in a 3D environment, and possibly to program errors. The difference in maximum level is plotted versus the equivalent level in Fig. 3, where it is clear that receiver positions where the difference is large for the equivalent level the same is true for the maximum level.

Fig. 3. Difference in equivalent and maximum level between 2 m and 4 m receiver height.

3 Screening and ground effect

By making a few example calculations for flat ground and a low source (no embankment) both with the Nordic method from 1996 [3] and the newer Nord 2000 [4] it was clear that the difference in ground effect between 2 and 4 m height was 1 – 3 dB (more in individual frequency bands), and could not explain the higher differences even at long ranges. In other words screening by terrain, buildings or sound barriers is what differs.

Therefore a set of calculations were made using the Nord 2000 method [4] with a screen and two receivers at 2 and 4 m height respectively. The resulting difference is plotted versus distance from the screen in Fig. 4, where the screen height is 4 m above the top of the rail and the distance from the track to the barrier is 15 m. Note that very close to the barrier the difference is as high as 10 dB in this example. This is reasonable from a theoretical perspective since the closer the receivers are to the barrier the larger the difference in diffraction angle becomes. It should be noted though that if reflections between the barrier and the receiving façade are included the difference decreases. It decreases even more if scattering and higher order diffraction are taken into account. Therefore it is reasonable to expect differences between 2 and 4 m height from field measurements to be less than the calculated values in Fig. 2.

Fig. 4 Difference in equivalent level at 2 and 4 m height behind a screen vs distance behind the screen using the Nord 2000 method.

4 Discussion

Since the calculated noise levels are higher at 4 m above ground than at 2 m the annoyance measured at a certain equivalent or maximum interval such as 55 – 60 dB will be reduced if 4 m receiver height is used. In the TVANE study one of the questions in our questionnaire was the ISO standardized annoyance question [5]. Evaluating the proportion of annoyed respondents for different receiver heights in the area Sollentuna gives approximately 40 % less annoyance at low levels which decreases to about 10 % less annoyance for high levels. In other words the effect would make comparisons between surveys based on 2 m receiver height noise calculations difficult to compare with those based on 4 m.

This difference is important to keep track of when comparing different studies, or when performing meta-analysis of many studies. The effect may be as large as more well known problems in comparing studies; such as different annoyance scales and difference between noise indicators such as $L_{Aeq,24h}$ VS L_{DEN} .

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