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A NEW, COST EFFICIENT METHOD FOR THE MEASUREMENT OF SOUND BARRIER INSERTION LOSS

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1. Introduction

Sound barriers are commonly applied for noise control in railway aplications. The effect of the barrier is given by the insertion loss of the barrier, i.e. the difference between spectra with and without a barrier present. Conventional sound barrier insertion loss measurements require a long sample barrier in order to do the measurement accurately. A decrease of the length of the sample barrier will have a positive effect on the cost-efficiency of the measurement but will harm the results of the measurement. In the framework of the Euroécran project (a research project of a consortium of European railway companies and sound barrier manufacturers (NS, FS, SNCF, BASE, APREA and TNO) which aims at the optimisation of sound barriers for high speed trains and freight trains) a new measurement technique has been developped by NS Technical Research. With this technique it is possible to do insertion loss measurements on short sound barriers. This paper describes the functioning of this measurement technique.

2. Sound propagation over a barrier

Sound propagation over a barrier can be characterised by three mechanisms: diffraction, transmission and reflection between barrier and train. This is illustrated in figure 1.

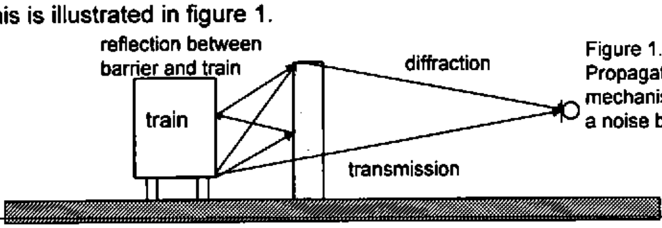

Figure 1. Propagation mechanisms over a noise barrier.

The reflection path is basically caused by diffraction of reflected sound. A barrier can be designed in such a way that the contribution of the transmitted and reflected sound can be ignored compared to the diffracted sound. In the remaining part of this paper it is assumed that only the diffraction contributes to the propagation over the barrier. When considering a short barrier, the vertical edges of the barrier will also contribute significantly to the total sound propagated over the barrier. The diffraction from the vertical edges can be suppressed by measuring with a microphone array which has highly directional characteristics.

3. Theory of microphone arrays

The theory of microphone arrays is discussed here briefly, for a detailled treatment the reader is referred to the literature [1].

A sound wave that incides from a certain direction causes time delays between the microphones in the array. Consequently, if the signals from all array microphones are given a proper, position dependent, delay the array can be steered in a certain direction. After this delay, all microphone signals are summed thereby causing an amplification of the signal from the desired direction and a reduction of the signals from all other directions. This processing is mathematically described as:

$$s(t)=\frac{1}{\sum_{n}\alpha_{n}}\sum_{n=1}^{N}\alpha_{n}p_{n}(t-\tau_{n})$$

where p_n is the time signal registrated by the n^{th} microphone, τ_n is the applied delay for the n^{th} microphone and α_n is a weighting factor for the n^{th} microphone. The weighting factors α_n, the total number of microphones in the array (N) and the spacing between the microphones control the directivity of the array. The directivity pattern of a microphone array is characterised by a main lobe with decreasing side lobes. Applying this concept to measurements on a sound barrier, one should design a system, such that the main lobe only covers the central part of the sound barrier and the vertical edges of the barrier fall outside this main lobe. Typical reductions of signals outside the main lobe are in the order of 20 dB.

4. Simulations

Simulations, with the Pierce diffraction theory, have been performed to evaluate the measurement technique. The simulation setup is as follows. A point source is positioned 5 meters behind a short noise barrier (length of the barrier 30 meters). The microphone array is positioned 25 meters in front of the barrier and consists of 8 microphones, with a spacing of 0.30 meter. A weighting function (a squared cosine over the outer microphones) has been applied to the microphone signals. The effect of this weighting function is that the side lobes of the array are suppressed, thereby improving the directional sensitivity of the array. Figure 2 shows the simulated insertion loss for a measurement with a single omnidirectional microphone (drawn 20 dB raised) and the insertion loss for a measurement with a microphone array, both for a short barrier. Furthermore, the insertion loss of an infinitely long noise barrier is drawn.

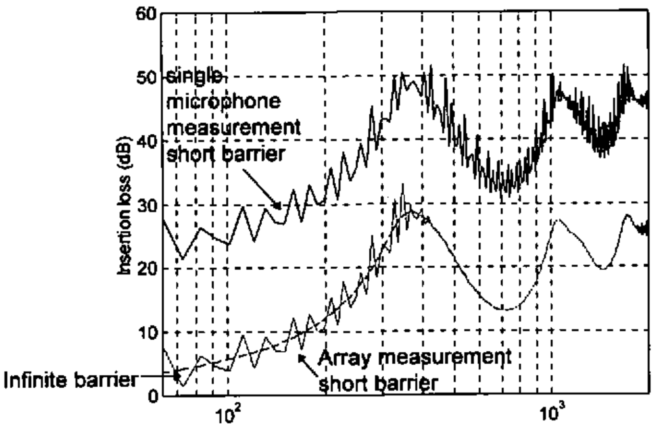

Figure 2. Simulated Insertion Loss for infinite barrier and short bar rier with a single microphone and an array.

The figure clearly shows that a short barrier has a strongly fluctuating insertion loss compared to the infinite barrier. The application of a microphone array reduces these large fluctuations and it demonstrated that the insertion loss measured with an array matches the insertion loss of an infinite barrier in a large frequency range. This proves that the diffraction from the vertical edges of the short barrier is strongly suppressed by the directivity of the array. Simulations also showed that the proposed method is robust. It has been varified by simulation that the method is rather unsensitive to disturbances in:

- the position of the microphones
- amplifier gain
- the focus point

Additionally, the effect of adding noise to the microphone signals is relatively small, but a signal-to-noise ratio of 30-40 dB is recommended.

5. Measurements

In order to test the method in practice, some field measurements have been performed. A microphone array was designed such that the directivity pattern in the octave bands 250-2000 Hz was approximately the same (microphone spacings of 0.70, 0.35, 0.18 and 0.09 m were used, N=8 microphones, 80% cosine-square taper). This particular array design causes a minimum reduction of 25 dB for directions beyond the vertical barrier edges. The insertion loss of an existing noise barrier has been measured on a high speed line near the Belgian-French border. The noise barrier was made of two concrete plates, each with a tilt angle with respect to the horizontal (10 and 15 degrees), the total height of the barrier was 4.5 meter and the track side of the barrier was covered with absorbtive material. The results of the measurements are shown in figure 3. In this figure the insertion loss measured on a short barrier with an array is shown together with the calculated insertion loss of an infinitely long barrier. Comparison of the results shows that there is good agreement between simulation and measurement of the insertion loss.

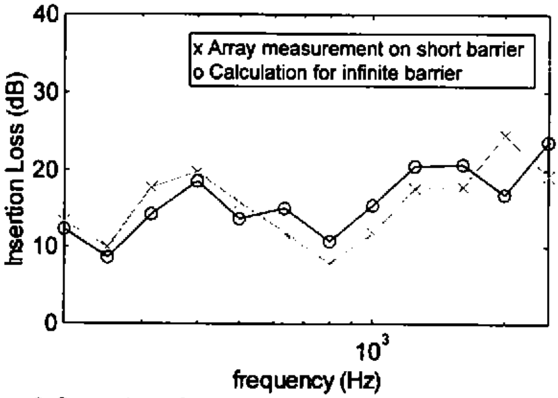

Figure 3. Comparison of measured insertion loss of a short barrier and calculated insertion loss for an infinite barrier.

6. Conclusions

From the preceeding sections, it can be concluded that the proposed method is very well suited for insertion loss measurements on short barriers. It has been shown that there is good agreement between the measured insertion loss with an array on a short barrier and the calculated insertion loss of an infinitely long barrier.

References

1. Boone, M.M., Design and development of a synthetic acoustic antenna for highly directional sound measurements (Delft University of Technology, GEBO Tekst, Zoetermeer, 1987).