# Reduction of railway noise by diffracting elements on a low height noise barrier

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**Abstract.** Recently, the use of diffraction has gained interest as an additional means to reduce railway noise. In this paper, we describe a test setup of a diffractor on a low height (1 m) noise barrier. The noise barrier was kept as low as possible to allow an open view from and to the train. The presented measurements show that the overall reduction of this combination (a low noise barrier and the tested diffractor) is 4-7dB far away from the track, depending on the microphone position and distance of the diffracting element to the train. This illustrates the great potential of diffractors to mitigate railway noise without blocking the line of sight.

**Keywords:** Diffractor, Railway noise.

## 1 Introduction

In the Netherlands, there is a great demand for noise reducing measures to fulfill the noise legislation and to reduce the annoyance of traffic noise. In recent years the focus to reduce railway noise has mainly been on the application of rail dampers, rail roughness control and noise barriers. Although noise barriers are a common noise measure, they can lead to complaints or objections as they do not fit well into the surroundings. Hence, there is a need for new, alternative, noise measures.

In this line of thought, diffractors have gained interest as a means to effectively reduce railway noise without blocking the view to and from the train as high noise barriers do. Diffractors contain acoustically resonating elements (cavities) which deflect the sound waves propagating over the noise barrier in an upward direction. In doing so, a region of reduced sound pressure level behind the diffractor is obtained. In this paper, we, M+P, Prorail, 4Silence and the University of Twente, present the results from a pilot project to test a diffractor on a low noise barrier near an instrumented test-track in Susteren, the Netherlands. Goal of this project was to test the noise reduction of the system and to gain knowledge to be used for upcoming legislation of diffractors to mitigate railway noise. The method to experimentally assess the acoustic performance of the system is based on pass-by measurements of various trains. In the measurement setup, the diffractors were positioned on top of a low noise barrier, with additional noise absorbing material added to the noise barrier. The system is shown in Figure 1.

**Fig. 1.** Diffractor on top of a low noise barrier.

Microphones were positioned near the track at 7.5, 15 and 25 m away from the center of the closest track at various heights (1.2, 2, 3 and 5 m) and sound was recorded for a large number of passing trains. The measurements were analyzed with respect to train-type, speed and number of lorries. The measurement setup is shown in Figure 2.

**Fig. 2.** The test setup.

In addition, the performance of the diffractor has been simulated theoretically using the finite element method. The calculated difference between the sound pressure level for a simulation without and for one with diffractors, yield the ‘measured’ reduction of the diffractor on the low noise barrier.

# 2 Experiments

## 2.1 Test setup

The tested diffractor was placed along the railway track over a length of 100 meters. The diffractor's height was 1.10 meter above the upper surface of the rail. The front side of the diffractor is at 4.77 meter from the center line of the track. The total width of the construction is 1.08 meter. To determine the noise reduction, microphones were positioned along two sections; one section behind the diffractor and one reference section without a low noise barrier and diffractor. The railway track should obviously be the same for both sections. This was verified as follows. The track consist of ballasted track with concrete sleepers. At both sections we measured the track decay rate and the rail roughness. The results of these measurements show that the track decay rate and the rail roughness at both sections is comparable and no correction to compensate for differences in noise emission is needed. During the measurements a reference microphone close to the track was placed near each section. The results at these microphones confirm that the noise emission at both sections are almost identical.

We performed pass-by measurements. Microphones were placed at three distances from the center of the nearest track at 7.5m, 15m and 25m, as mentioned; one set along the reference section (no diffracting element) and one set behind the diffractor. Four microphone heights were used at 1,2m, 3m, 4m and 5m. A schematic representation of the measurement set up is given in Figure 3.

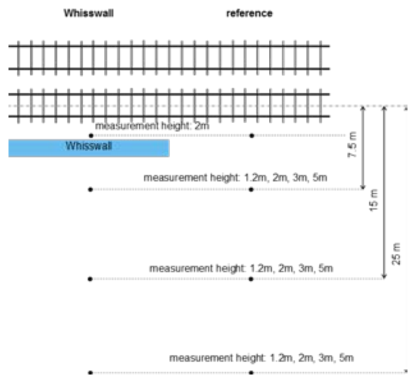


**Fig. 3.** Schematic representation of the measurement setup (The diffractor is indicated here by the term Whisswall).

During each pass-by we recorded the A-weighted sound level in third octave bands, the vehicle speed, the vehicle type and the number of cars. From this we calculate the equivalent sound level over the time that the train is in front of the microphone. Per train pass-by, this results in an equivalent sound level, both in third octave levels and total sound level, for each microphone position, together with the vehicle speed at the reference section and at the section with the diffractor. The measurements were performed two times; shortly after installation and one year after the installation. During the last session only a limited number of microphones were used. We have performed measurements for trains running on the track closest to the diffractor but also for trains running on the track further away.

### 2.2 Results

We determined the noise reduction of the diffractor by calculating the difference between the sound level at the reference section and the section with the diffractor. The average noise reduction is obtained by calculating the average difference over all pass-by's. This results in 24 results: 3 microphone distances, 4 microphone heights and the 2 tracks. The results are displayed in Figure 4. The blue bars are the reduction results for the nearest track, the yellow bars are the reduction results for the farthest track. The error bars indicate the value for the standard deviation. These results were previously published in [1].

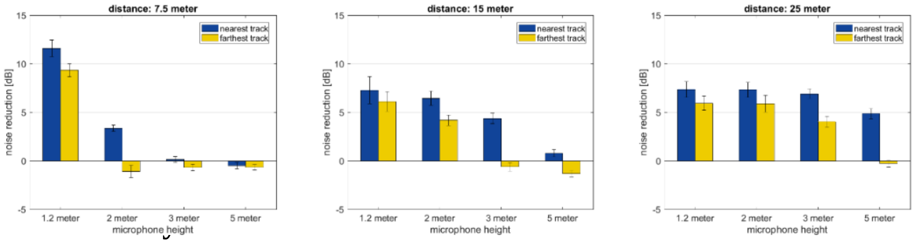


**Fig. 4.** Average noise reduction measured for the diffractor per microphone height and distance. The error bars indicate the standard deviation.

In general, we can conclude from Figure 4 that the diffractor can achieve a significant noise reduction. At 25 meters from the track a noise reduction over 5 dB is achieved for the closest track. The results for the farthest track show a similar behavior. The largest noise reductions are found on the lower microphone positions. The noise reduction of the diffractor is larger when it is placed closer to the sound source, but still a significant reduction is obtained when the diffractor is placed further away from the track.

Figure 5 shows the noise reduction in third octave bands for the diffractor at 15 meters distance from the nearest track. The left diagram shows the results for the nearest track, the right diagram shows the results for the farthest track. For the lower microphone positions, we observe a broad band noise reduction up to 10 dB in certain frequency bands. As the microphone height increases the noise reduction decreases in most frequency bands. For the results at the farthest track we observe a broad band increase of the noise at 5 meters height which is in line with the working principle of the diffracting element. The diffractor is tuned to be effective in certain frequencies. The reduction for these frequencies is measured at the lowest microphone heights. For higher microphones, this noise reduction shifts to a lower frequency.

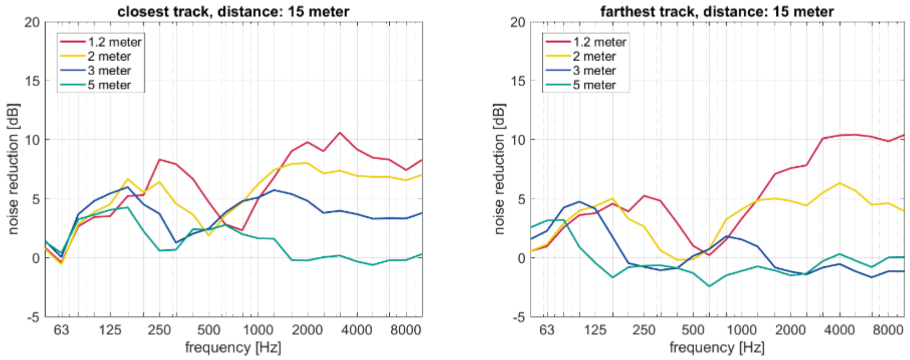


**Fig. 5.** Noise reduction of the diffractor in third octave bands

The noise measurements were repeated one year after installation at a limited number of microphone positions at 25 meters distance from the track. The resulting noise reductions are shown in figure 6. The noise reductions one year after installation are very similar as the noise reduction shortly after installation. For the track nearby, we observe a small increase in the noise reduction. The noise reduction for the farthest track is somewhat less than the noise reduction directly after installation.

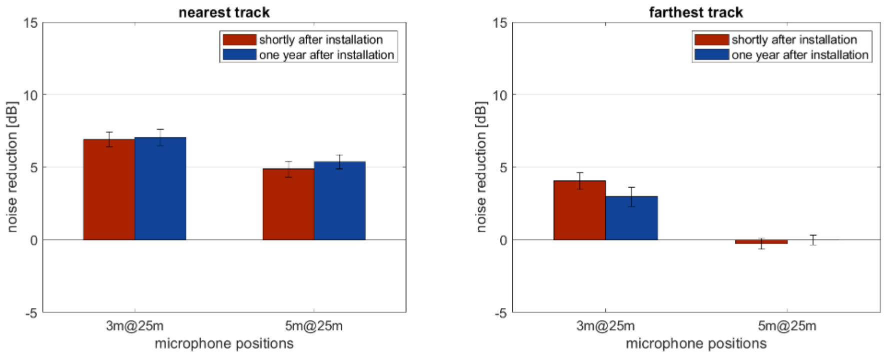


**Fig. 6.** Noise reduction in the far field for the diffractor shortly after installation and after one year

## 3 Theory

Alongside the experimental results, we simulated the test setup using finite elements. Figure 7 shows the computational domain used in the simulation. For practical/computational reasons, we restricted ourselves to simulations up to 7.5 m from the track. A similar model without diffractor was used as a reference model. A stationary sound source was assumed at the wheel/rail interface, whose position is shown in Figure 7. The noise reduction was calculated by the difference in sound pressure level between the reference situation and diffractor situation.

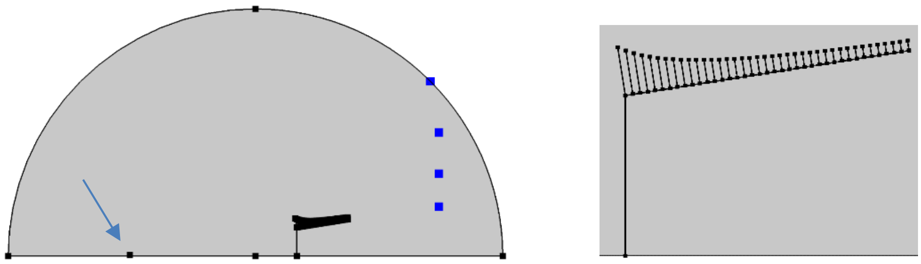

**Fig. 7.** The computation domain used in the simulation. The blue dots indicate the microphone positions (at 7.5 m from the track, 1.2, 3, 4 and 5 m high). The arrow points to the power sound source.

To illustrate the diffracting effect, Figure 8 shows the calculated sound pressure levels at 250 Hz, 500 Hz, 1000 Hz and 2000 Hz. Especially at 500 Hz, which is a frequency that is within the working range of the current diffractor design, a large deflection of sound can be observed. This deflection is seen to continue to about 2000 Hz.

Figure 9 shows the calculated reduction as a function of frequency at the various microphone positions. A large reduction is indeed predicted, especially for the low microphone positions. The large increase in reduction can be seen to start from about 400 Hz. After this frequency, individual resonance peaks for each of the resonators can be distinguished. (The current diffractor is designed to deflect sound from 400 Hz until 2000 Hz, using quarter wavelength cavities having depths of 21 cm to 4.3 cm). The combination with the noise screen is also seen to induce a region of larger reduction between 100 and 200 Hz at the low microphone position.

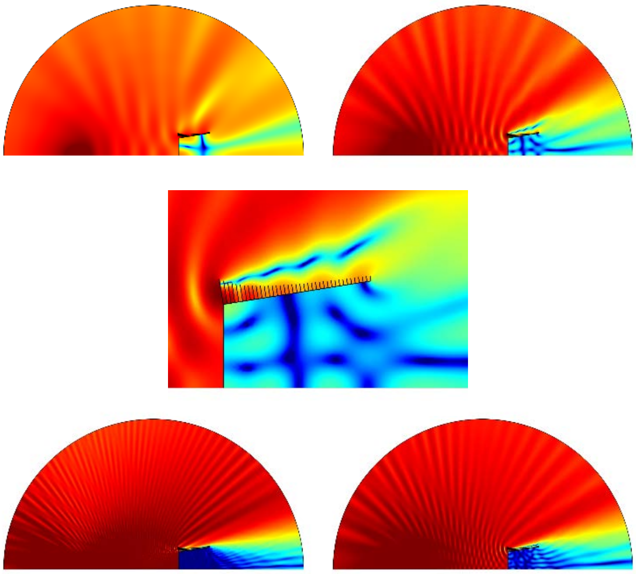

**Fig. 8.** Sound pressure level distribution at 250 Hz, 500 Hz, a detail near the diffractor at 500 Hz, 1000 Hz and 2000 Hz

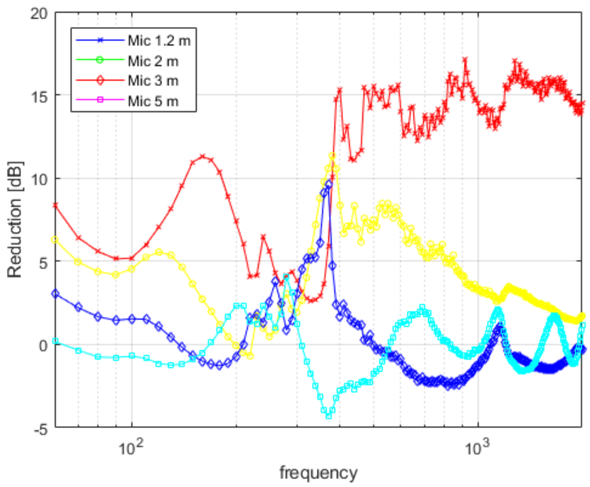


**Fig. 9.** The reduction as a function of frequency for the various microphone positions (@7.5 m distance from the track).

# 4 Comparison and conclusion

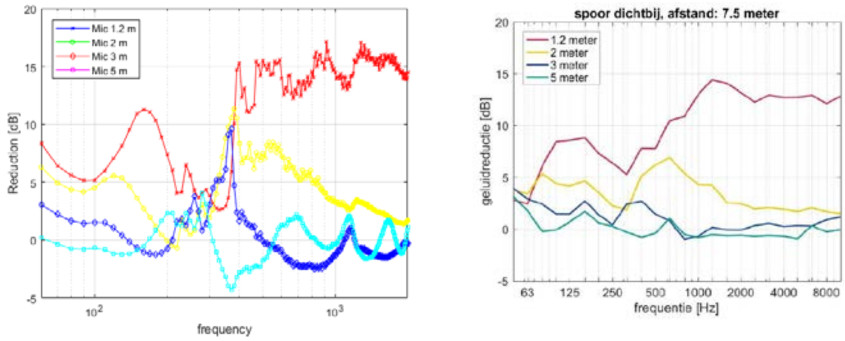


**Fig. 10.** Noise reduction induced by the diffractor; theory (left) and experimental (right).

Figure 10 shows the comparison in reduction based on theory (up to 2000 Hz) and experiment. Although the theoretical results have not been binned to the one-third octave bands, the trend and overall reduction values of theory and experiment are quite similar. For the lowest microphone position, reduction values close to about 12.5 dB are seen at the higher frequencies and a sharp increase in reduction is seen from about 400 Hz. Also the small increase in reduction near 100 Hz is observed in theory and experiment. The increase of simulated sound pressure levels at the higher microphone positions is less prominent in the experiments.

Based on the results shown in this paper, one can conclude that significant noise reduction of railway noise can be achieved by a diffracting element alongside the track. A conclusion that is confirmed by both measurements and theory.

## References

1. Wout Schwanen, Ysbrand Wijnant and Nils Yntema: Whisswall, a sound diffractor on a low height noise barrier: experimental testing. GTL congres, Hoevelaken, 2018