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IMPACT OF PLANTS ON THE PROTECTION EFFECT OF NOISE BARRIERS

M Weber Basler & Hofmann AG, Consulting Engineers, Zurich, Switzerland
P Angst Rutishauser Ing., Consulting Engineers, Zurich, Switzerland

1 INTRODUCTION

As traffic noise has increased, noise barriers have been built along numerous roads and railways in recent years and decades to protect local residents. They can reach considerable heights, so that 5 - 6 metres are by no means infrequent today.

However, these high noise barriers also increase the impact of new effects that can be neglected in the case of upper edges of “normal height”. One of these effects is that due to plant screens on the protective effect of the barrier (**Fig. 1**). This has hitherto been neglected. However, increasing complaints are heard from local residents about poor protection and newly occurring ambient noise in the case of high barriers. In contrast, when shrubs are planted along noise barriers, their noise-reducing effect is praised, although this phenomenon has not been proven so far.

As there are no meaningful data on these effects, it was decided to base the studies on a selective analysis of the situation with the use of suitable measuring equipment.

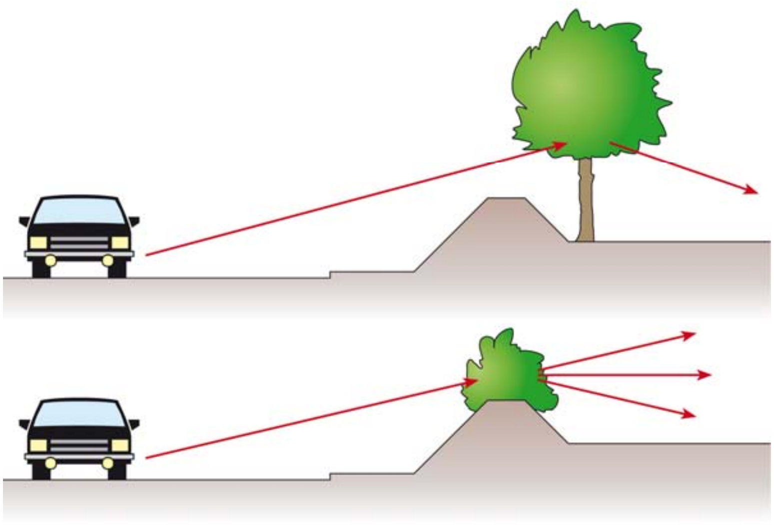

Fig. 1 *Standard situation for reflections from trees and scatter by shrubs*

2 OBJECTIVE

To delimit the objectives, the studies will be restricted to situations in which the reflecting trees project above the barrier. Suitable measurement and calculation methods will be used to quantify the effect of plant screens on the impact of noise barriers and a specific evaluation procedure will be presented.

3 MEASURING AREA

To carry out the measurements, a typical model situation at a motorway access point in Zurich, which satisfies the requirements of the study in an optimal way, was evaluated. When the western Zurich bypass was built, the relevant motorway section was reconstructed (with a link to the new by-pass). A residential zone with detached houses is located in the immediate vicinity of the motorway, separated from it by a green strip. This zone was screened before and after the construction work by a high earth barrier whose effect is additionally reinforced by the low-lying position of the road. Between the barrier and the buildings, a group of trees project clearly above the noise barrier. To the north and south, the area is skirted by forest edges (**Fig. 2**).
The shape of the noise protection barrier was slightly changed by the road reconstruction, resulting in a somewhat improved protective effect (**Fig. 3**). When the construction work was completed (and even before the by-pass was opened), sporadic reflections from the trees were noted.

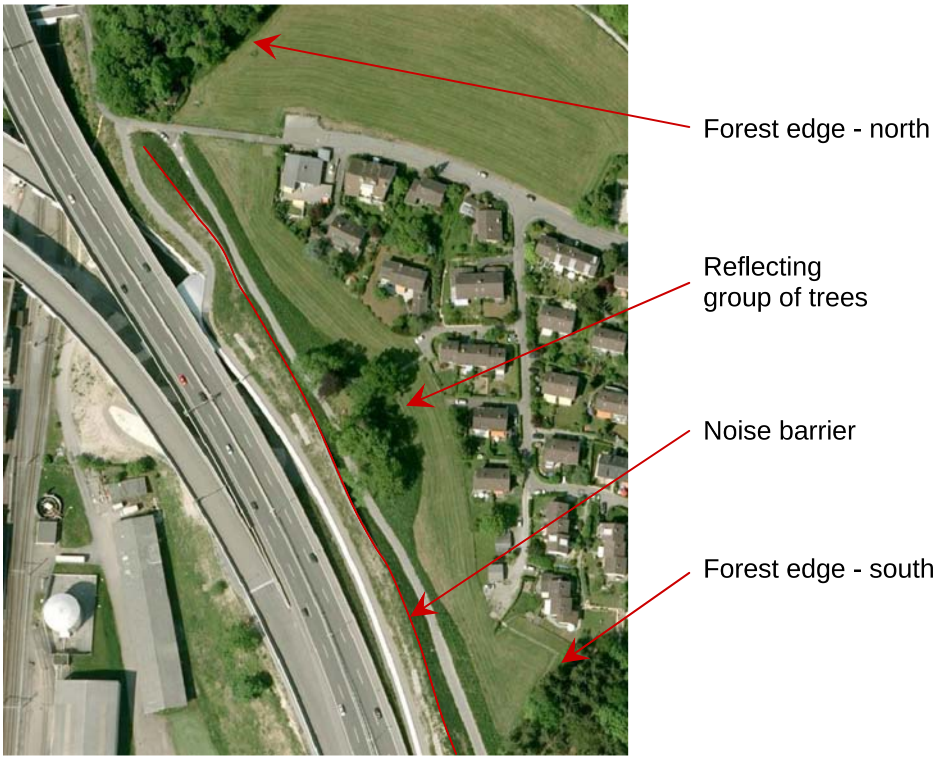

Fig. 2 *Site view*

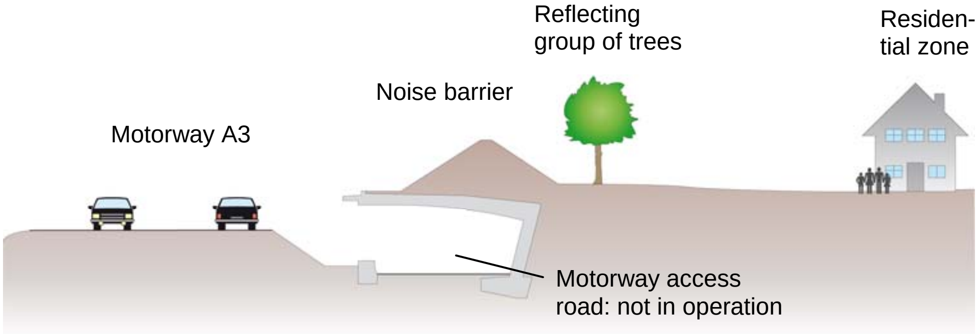

Fig. 3 *Cross section*

Two plant zones were seen as possible reflection areas, namely the group of trees in the centre of the area and the forest edges skirting either side of it.
Earlier noise measurements made within the scope of the motorway project had already shown divergences in the results which indicated the effect of reflections from the plant screens.
At the time the measurements were made, the traffic ran only on the previous main route of the motorway. The access ramps and by-pass were not yet in operation. The measurements were made in stable, sunny weather with little wind within a single day.

4 METHODS

As there is currently an almost total lack of theoretical approaches to quantifying reflections from plant screens, the selected approach is based principally on data obtained from selective comparative calculations performed on a computer model.
In defining the measurement methods, we focused on the parallel application of several techniques in order to analyse the phenomenon from different angles. To simplify matters, no meteorological data was acquired or evaluated.

Method 1: Use of the acoustic camera

- Although the measurement of the road traffic noise with the "camera" technique does not yield any direct noise data, it does indicate where and with what intensity the noise is reflected from the plant screens.
- Recordings of gunshots show the paths and intensity of the respective noise reflections.
- The measurements made with the acoustic camera also allow the differences in frequency patterns of the reflections to be read off.

Method 2: Noise grid with comparative calculation

- Parallel measurements were made at a point on the noise barrier and a reception point in the screened area. The screening effect of the noise barrier was then determined from the difference between them, taking into account the air and ground attenuation and the reduction of propagation. The measurement at each reception point lasted 3 minutes. This duration proved to be sufficient in preliminary experiments. Both during the measurement and in the evaluation, care was taken to ensure that the results were not distorted by interference.
- A comparison of the measured and calculated data was used to check whether local differences are produced by the diverse nature of the planted areas.

Method 3: Comparison of measured/calculated frequency data

- **-** If it is assumed that some frequencies are reflected from the planted areas more strongly than others; this should have an effect on the frequency characteristic at the reception points. A comparison of measured and calculated spectra should show if this is the case.

5 RESULTS

5.1 Acoustic camera – road traffic noise

The graphics can be used to visualise the reflecting areas at trees and forest edges both as a total load and distributed among individual frequency ranges. However, the dynamic range of the acoustic camera is limited to about 8 dB. Accordingly, only the intensity differences can be shown, but not the absolute noise levels.
Figures 4 and **5** show that the low and high frequencies are not reflected to the same extent.

Fig. 4 *Photo from the acoustic camera; frequency range 400 – 1000 Hz*

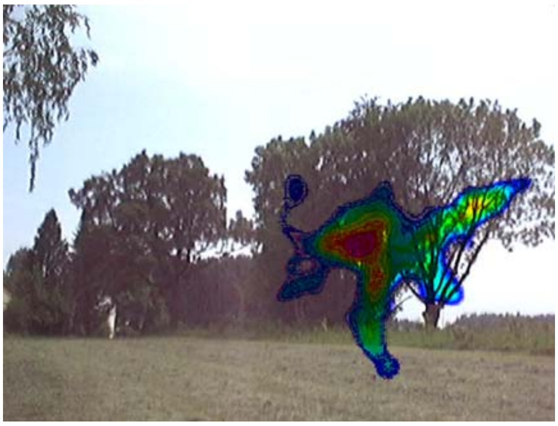

Fig. 5 *The acoustic camera; frequency range > 2000 Hz*

The measurements showed that the reflection intensities were significantly higher than those of the noise deflected at the barrier crown. However, no quantitative statements can be derived from this about the effect of the reflections on the total noise level.
The graphical evaluations of the traffic noise measurements allow the following conclusions to be drawn:

- Low frequencies tend to be reflected from the lower parts of the trees. These reflections are, in the main, concentrated strongly on the centre (trunk, lower branches).
- High frequencies tend to be reflected from the crown or the whole tree. They are much more strongly scattered than the low frequencies.

5.2 Acoustic camera – gunshot results

Gunshots were fired on the street-side foot of the noise barrier. The obstructive effect was consequently higher than for the traffic noise. Some of the measurements, therefore, showed the noise intensities from the reflections to be higher than those from the direct noise. **Figure 6** shows the three distinct sections of the noise characteristic of a gunshot event.

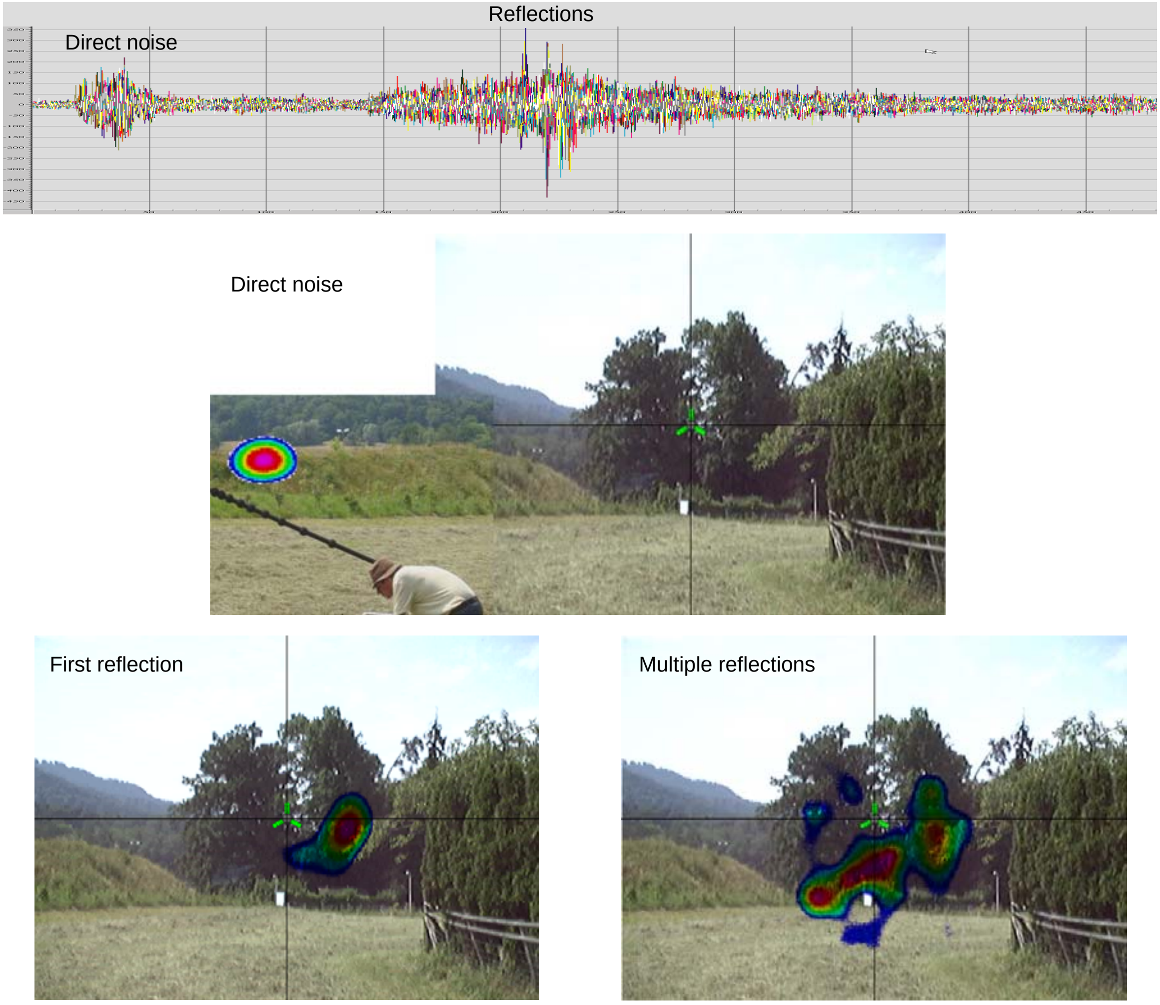

Fig. 6 *Gunshot event with noise level characteristic*

Both the graphical interpretation of the gunshot recordings and the analysis of the noise level characteristics show that the reflections from individual trees and forest edges could represent a significant share of the total emissions. Both experimental configurations produced similar results. The precondition for this is effective screening of the direct noise. The most important results may be summarized as follows:

- In the event of strong screening of the direct noise, the reflected emissions could be of the same order of magnitude as the direct noise.
- If the reflecting trees are in the direct line-of-sight between source and emission site, the share of reflections may be greater than in the case of lateral reflection emissions.
- The frequency distribution of the reflected noise is broader than that of the direct noise.
- The principal determining factors at the forest edges are the obstructive effect of the noise barrier and the character of this edge (dense or sparse, height of the trees).

5.3 Grid measurement of traffic noise

The noise level measurements were carried out at nine cross-sections perpendicular to the motorway at a spacing of 10 m between each cross-section. For each cross-section, a measurement point was placed every 3 m in addition to a reference microphone on the barrier crown. On the basis of test measurements, each measurement interval was set at 3 minutes. In addition, the emissions for all measurement points were calculated by the Cadna programme on the basis of the Stl-86+ model. This allowed the noise-level differences between each measurement point and the corresponding reference microphone to be determined by measurement and calculation.

A comparison of the calculated and measured differences shows that the former are smaller than the latter at most points. This means that the effect of the noise protection is better than expected. This phenomenon may have various causes, such as the effect of the soil. However, this study focuses on the distribution of these relative differences or divergences over the measured area.

The distribution of these relative divergences produces the pattern shown in **Fig. 7**, from which two clear tendencies can be derived:

- In the area close to the road, the values tend to be positive and decline with increasing distance (green → red)
- The values increase from north to south (green → red)

This result is interesting because the northern part with the group of trees is clearly distinct from the southern part without trees. We can conclude that the reflections from the tree crowns can raise the noise level by 1 - 2 dB.

Another significant pattern is shown by the divergences in the area close to the motorway. Here, the measured values are higher (by about 3 - 4 dB) than the calculated ones throughout when compared with the generally lower calculated values in the rest of the area. This effect cannot be attributed unequivocally to the reflections from the trees. The effect of deflection at the obstacle edge is likely to be at least as significant.

The precondition for noticing such effects is good screening of the direct noise by about 10 to 15 dB.

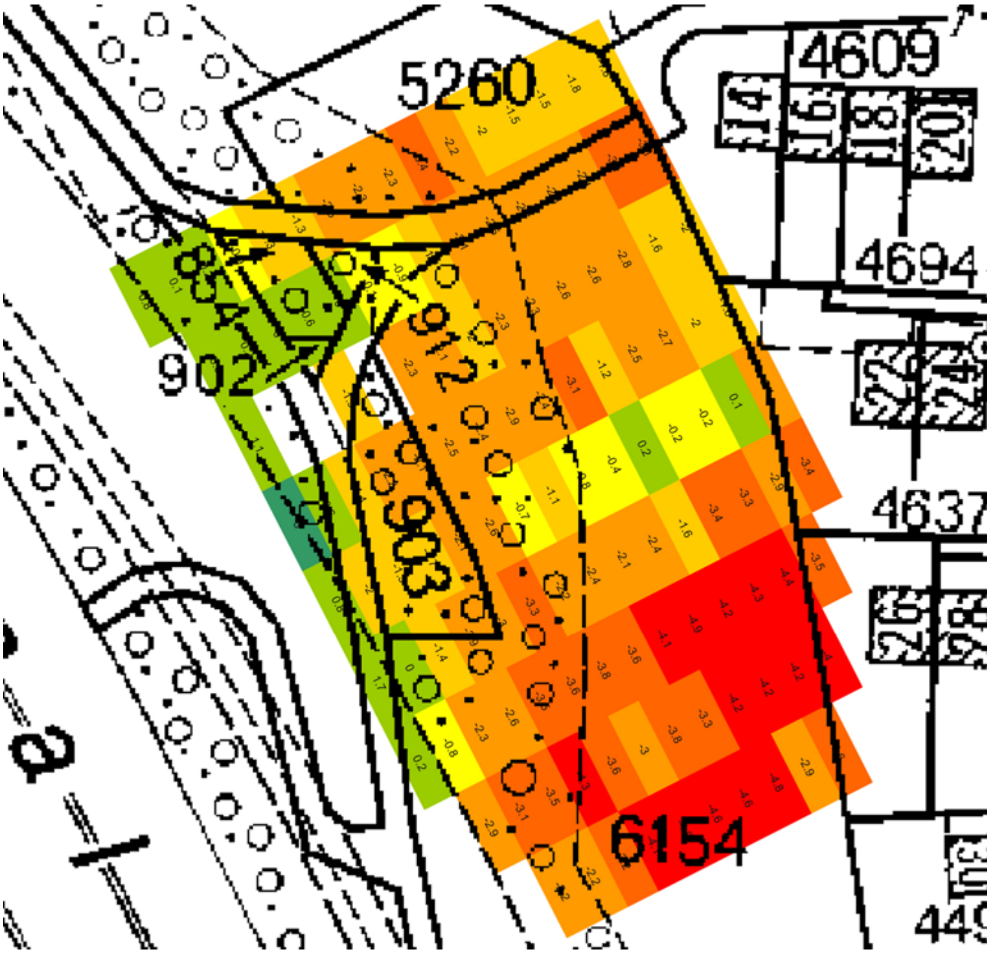

Fig. 7 Relative differences

5.4 Frequency comparison

The frequency evaluation of the grid measurements leads to further interesting results, but these cannot be attributed unconditionally to the reflections. Rather, sensitivity considerations show that soil effects are likely to have a dominant impact on the frequency characteristic. The calculated and measured spectra parallel to the motorway are compared in **Fig. 8**. This shows clearly that between 250 and 800 Hz as well as above 2 kHz, the measurements yield higher frequency components than the calculations. The divergences in the centre frequency range are likely due to the high correction values for the soil effect produced by the calculation based on the Son Road model. However, the reflections do contribute to the increased values in the upper frequency range.

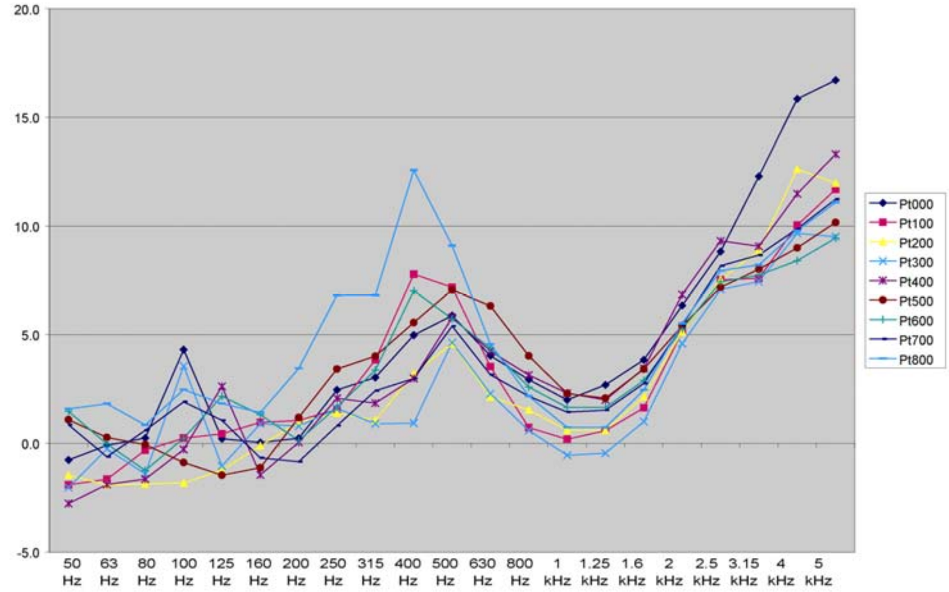

Fig. 8 *Difference between measured and calculated frequency spectra for a series of points parallel to the motorway*

A comparison of the normalised frequency spectra on the cross section perpendicular to the motorway yields no direct evidence for the effect of reflections either (**Fig. 9**). Only between 160 and 500 Hz does the frequency characteristic diverge from the average for individual points in the area close to the motorway. However, this can hardly be explained by the effect of reflections.

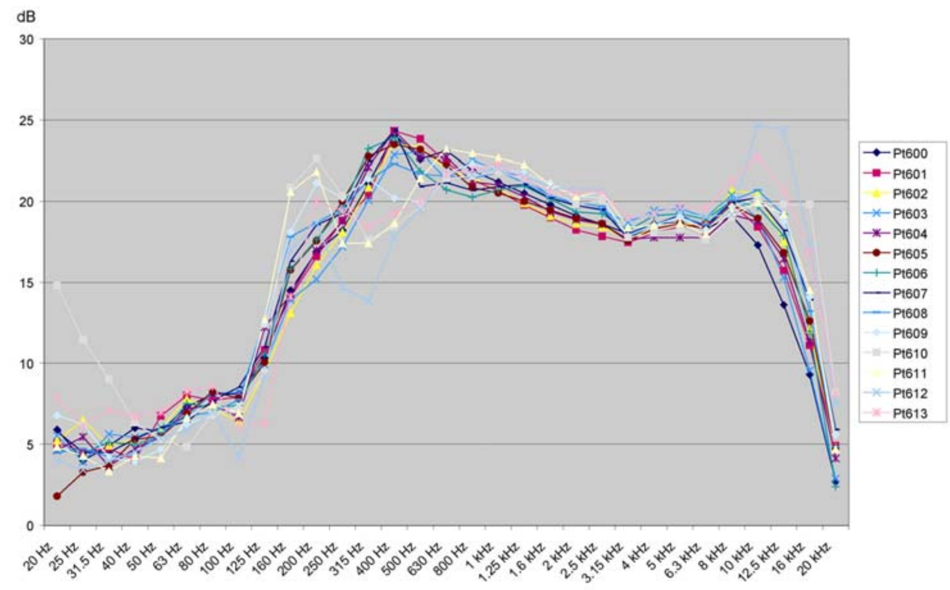

Fig. 9 *Normalised spectra for points on an axis perpendicular to the motorway*

6 CONCLUSIONS

Reflections from trees are audible and measurable. They can have a negative impact on noise emissions if the direct noise is screened by an obstacle (earth barrier, noise barrier etc.).
First estimates from the measurements show that with a screening effect of about 8 to 15 dB, a rise in noise level from 1 to 2 dB can be observed, i.e. the reflected noise level is about 10 - 15 dB lower than the direct noise with no obstacle. In the near area behind the noise barrier, noise level increases of about 3 to 4 dB can also be measured. These are, however, probably only partially due to reflections from the plant screen.
An evaluation of the gunshot data showed that a significantly higher effect of the reflections from the plant screen can be expected in individual cases. The camera recordings also show that the perennial parts of the trees (trunks, thick branches) are significantly involved in the reflection.

7 OUTLOOK

The measurements yielded initial indications for the locations, degree and frequencies of reflections from trees. Further studies are necessary to obtain well-founded statements about the effect of the size of groups of trees and forest edges (height, length, depth, density) as well as the type and shape of the trees and shrubs. In this context, the following points should be considered:

- The measurements should be repeated in the same place in winter (condition without leaves)
- Measurements should be made at comparable locations with similar reflection problems
- Measurements should be made under "laboratory conditions". It should be determined whether the effect of (movable!) plants could be measured with a noise barrier and constant artificial noise sources.