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# A-POSTERIORI AURALIZATION OF THE EFFECT OF NOISE BARRIERS

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## ABSTRACT

Noise-reduction measures are usually evaluated by means of physical data which arise from complex regulations. For political decision-makers and persons affected by noise such data, e.g., dB(A) values, often prove inadequate illustrating the effect of a particular measure. To solve this problem a method is presented which is capable of making the noise signals audible which are present before and after erecting a noise barrier, solely based on signals recorded after constructing the barrier. To this end a combination of binaural technology with sound propagation calculations from commercial programs is employed. Among other things, the method facilitates an auralization of the effect of a hypothetical removal of the barrier. In an aural demonstration for politicians and local residents the method was accepted, and the residents, who initially doubted the effect of the noise barrier, were finally convinced of its usefulness. In principle, the method is not limited to an a-posteriori verification of noise barriers. It can be applied to a-priori auralizations as well as to other noise-reduction measures.

## 1. PROBLEM

The basis for planning and realizing noise-reduction measures are standards and guidelines where physical data is used. Such data (mostly dB(A) values) often mean very little to humans who are permanently exposed to noise. These people judge their own noise situation according to the socio-economic context and on individual factors (e.g., emotional components). This problem became even more serious in a concrete situation where a noise barrier along a main road with six lanes and two light-railway tracks has already been erected. The local residents, who had initially approved the barrier, were dissatisfied with the resulting situation. To solve these psychological problems a method has been devloped which renders an auditory comparison of the sound field situation before and after building the noise barrier. Such a method enables listeners to gain an impression of the effect of the measure based on their actual hearing sensation.

## 2. AURALIZATION

For an auditory comparison of the situations before and after the implementation of a noise-reduction measure, the acoustical changes caused by the measure need to be known. To this end the sound propagation is calculated conforming to the applicable regulations (such as, in Germany: [6], [2], [4], [5]). Such computations show sound pressure levels for the immitted noise which are calculated for different frequency bands (octave bands) and sound field situations. These levels are commonly used for specifying noise barriers. For a before-and-after comparison level differences are relevant. Therefore the immitted noise level before and after implementing the noise-reduction measure are subtracted from one another. These complex calculations are supported by existing commercial sound-propagation programs, which take into account various characteristics of noise sources, transmission paths, and different receiver positions.

To auralize the data resulting from these calculations, the sound field must be reproduced as authentically as possible. For achieving this the directional information in the noise is particularily relevant. Binaural technology is an adequate means for recording noise signals while preserving this directional information. This technology allows the recording of signals inside the human ear canal, i. e., signals as modified by the human pinna. When presenting such signals to listeners via headphones after proper equalization, they will receive the same signals which would have been received by their ears at the recording end [1]. In practice dummy heads with typical external-ear characteristics are used as recording equipment.

Fig. 1 shows how binaural technology and the sound propagation calculation are combined in order to achieve an auralization of the effect of sound-reduction measures. The level differences of the immitted noise at one particular location are used to design a filter which simulates the auditory effect of the measure under consideration. This filter is used to filter the binaural signals recorded at the location of reference. As an output of the filtering process binaural signals are rendered which reflect the sound field after the implementation of the noise-reduction measure. If these binaural signals and the original recordings are presented alternately, a direct (A/B) auditory comparison of the noise situation with and without the measure becomes possible.

## 3. RESULTS

The auralization method was applied to make the effect of an already con-

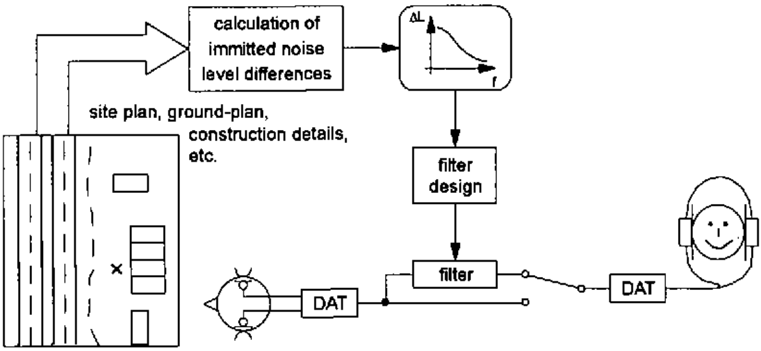


Fig. 1: Auralization of noise-reduction measures

structured noise barrier, as described in section 1, audible. In cooperation with the people affected by the noise, binaural recordings at particular locations were performed. For these locations the immitted noise level differences (for octave bands) were calculated using a sound-propagation program. These calculations were based on data on the terrain, the site and the construction plans of the noise barrier already in place, according to regulations applicable in Germany ([4], [5]). The resulting filter transfer functions reflect the increase of the immitted sound levels under the assumption that the noise barrier had been removed. As expected in the example of the noise barrier, the increase is much more pronounced in the higher frequency region than in the lower one (15 dB and 2 dB respectively, at one location). Basically, the curves show the inverted insertion loss of the noise barrier. Yet, strictly speaking, the curves represent the (inverse) sound pressure level differences at one specific location, because the calculations take into account various specific sound field modifications, such as reflections, attenuations, diffraction, the relative positions of noise sources and recording locations. The designed filter was implemented on a hardware signal processor and then used for the auralization. During the demonstrations to politicians and local residents the people affected by noise confirmed that the noise signals matched their experience in reality. The demonstration convinced the local residents, who initially doubted that the barrier had any significant effect, of its usefulness.

## 4. DISCUSSION

The auralization method, as presented here, uses binaural technology for an authentic reproduction of the sound field, in which, among other perceptual features, the directional information in the signals is preserved. As described, the auditory effect of the noise barrier at one location is simulated by filtering the recorded signals with a single transfer function. In other words, the calculated sound pressure level differences are averaged across all the directions of sound incidence (azimuth and elevation) and over all the sound source distances. In general, not just the sound pressure level depends on the direction of incidence but also the insertion loss, i.e. the sound pressure level difference. Taking this into account, the calculation of immitted sound level differences could be carried out separately for different directions of incidence. After this the sound sources, i.e. noise sources and reflections, had to be auralized separately and then superposed. These extensive efforts could be avoided in the case of the auralization of the noise barrier as reported in this paper. In a first approximation the insertion loss due to the barrier does not depend on the direction of incidence and a worst-case assumption has been applied. Yet, a thorough evaluation as to the extent to which the auralized conditions actually differ perceptually from the natural ones, has been left for a future investigation.

## 5. FINAL REMARKS

Successfully applying a new auralization method has shown its usefulness for making the perceptual effect of noise-reduction measures audible. Aural demonstrations proved the acceptance of the method to politicians as well as to people affected by noise. In principle, the method can also be used for a-priori auralizations, as well as for other noise-reduction measures. In any case, the method presents an effective technical tool for an auditory examination of planned or already implemented noise-reduction measures - at least for the particular case of noise barriers. Its use for planning purposes may support the cost-benefit analysis and reveal the deficiencies of certain measures at an early stage of planning. Employing this method, the people who are actually effected by the noise can be better integrated into the planning, decision making and evaluation processes.

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