

The Problem of Predicting Noise Annoyance as a Function of Distance

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ABSTRACT

Currently, different methods exist to determine the acoustic environment – SoundScape – by means of complex procedures or measurements. The parameter yielded is the A-weighted sound pressure level. The question whether this parameter is also sufficient to describe the subjectively perceived sound quality or annoyance by environmental noises has been discussed for a long time. The aurally-adequate sound analysis uses an artificial head measurement system to record the soundfield comparable to that of human hearing. The aurally-related psychoacoustic analyses will be used to receive a better objective description of the subjectively perceived sound quality. A simple example - the so-called pass-by measurement - shows that on the one hand the change of the A-weighted sound pressure level can be calculated in dependence on distance in a relatively simple way, but on the other hand psychoacoustical parameters, particularly loudness, roughness and sharpness cannot easily be converted as a function of distance. The human hearing works as a “pattern recognition processor” which means that the spectral distribution on the one hand and the time structure on the other hand are important for the classification of a hearing event. This pattern recognition process is working widely independent of the absolute A-weighted sound pressure level.

INTRODUCTION

Acoustic environments are evaluated by our own human hearing, the sound perception mechanisms of which can be described in terms of psychoacoustic parameters, such as loudness, sharpness, roughness, and fluctuation strength. Other parameters necessary in fully capturing an acoustic environment in engineering terms are the number of signal sources (and their spatial distribution), and also the direction and speed of any movement of these sources /1/. Nevertheless, questions as to the annoyance of environmental noise cannot be satisfactorily answered by reference to these parameters alone. Both the nature of the information in the acoustic environment and the personal attitude of those hearing it greatly impact the subjective impression. Available for some years now, Artificial Head technology has proven an eminently useful tool as an objective recording system, able to weight sound in relation to the direction of sound incidence and thus be analogous to human hearing /2/. Furthermore, Artificial Head recordings, backed up by listening tests, are also able to provide aurally-accurate reproduction of acoustic environments with the aim of achieving auditory events which are directly comparable.

AURALLY-EQUIVALENT SOUND ANALYSIS

The characteristic of the outer ear enables human hearing to perceive the difference in loudness between sound events arriving at the ear from different angles of incidence. Psychoacoustic calculation methods /3/, as a function of time structure and spectral distribution, produce results which yield information of greater differentiation than is possible with A-weighted sound pressure

measurement. Human hearing may perceive a narrow-band sound source as less loud than a broadband sound source of the same A-weighted SPL. Sound sources in which SPL is greater in the higher frequency spectral ranges result in a sharpness which normally increases the annoyance of the sound. Time structures, in particular those arising through modulation, give rise to fluctuation and roughness, which in turn may cause a sound to be perceived as more apparent and also more unpleasant. Properties of this kind also partly persist when the broadband level of the sound source is reduced. Above all, human hearing can be thought of as a process of pattern recognition, able to detect certain spectral patterns and time structures irrespective of absolute SPL /4/. This means that human hearing adapts itself to a basic noise level and essentially only captures the relevant pattern in the time and frequency domains. A sound event perceived as annoying because of quite definite features arising from certain time and spectral structures will be equally unpleasant if the dB value is reduced, for example, by 3 dB.

HOW DISTANCE IMPACTS ANNOYANCE

Predictions about how distance impacts perception of an acoustic environment frequently make use of simple calculation methods, which, according to the rule of distance for sound sources, and possibly by taking account to some extent of propagation properties, are an attempt in forecasting how A-weighted SPL evolves as a function of distance. The test concept outlined below was developed for verification of this kind of calculation method in terms of psychoacoustics. The noise made by a passing passenger vehicle was used as sound event. Time signals were measured at four different positions,

at distances of 7 m, 25 m, 50 m and 100 m respectively. The time signals at these four positions were captured using an Artificial Head free-field equalized. This procedure allows both the capture of measurement data, and the subjective rating of the signals by test persons in auditory tests. Fig. 1 shows the averaged A-weighted third-octave spectra for the four measurement positions. According to the rule of distance, the value of A-weighted SPL level approximately halves as distance doubles. However, third-octave analysis is able to reveal that there is no broadband parallel shift in the spectra, but that spectral modifications are taking place.

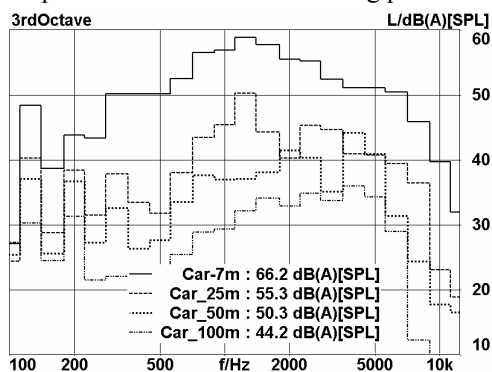


FIGURE 1. Averaged A-weighted third-octave spectrum for 4 diff. measurement positions with vehicle passing at 50 km/h

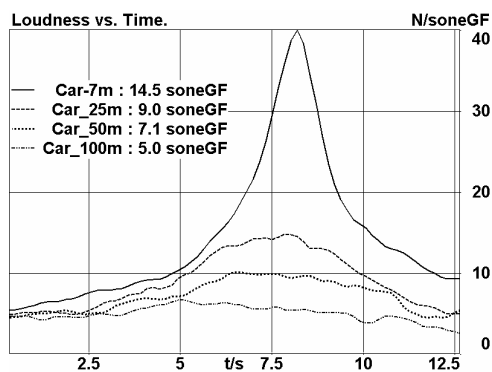


FIGURE 2. Loudness vs. time

Fig. 2 shows loudness, the spectral modifications shown in Fig. 1 are proof that the statement that loudness diminishes inversely as distance changes is not valid in this situation. Particularly striking is the change in loudness relative to the change in distance from the 25 m position to the 50 m position, which, in terms of measurement results in a reduction of 5 dB(A), but only a loudness reduction of 1.9 sone. The results are yet more significant when other psychoacoustic analyses are applied. Fig. 3 shows the sharpness curve for the four different measurement positions during the drive past. The differences observable for the 25 m, 50 m and 100 m positions are virtually zero. The average value over the observed time window is also almost constant. Fig. 4

shows the result of modulation spectral analysis, again underlining only a slight dependence on distance.

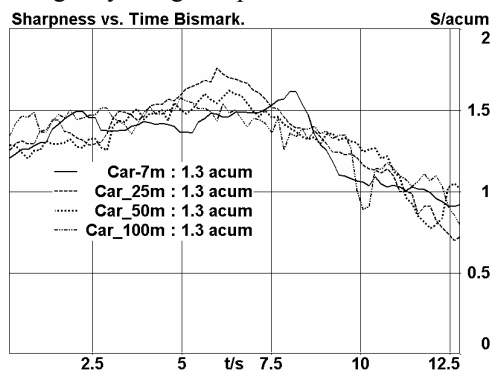


FIGURE 3. Sharpness vs. time

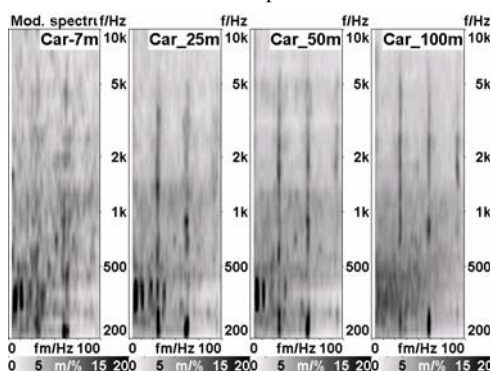


FIGURE 4. Modulation spectra vs. frequency

SUMMARY

The results of this straightforward drive-past analysis clearly underline the fact that, in terms of psychoacoustics, appropriate aurally-accurate prediction of annoyance in an acoustic environment is not possible by adding single sound sources. Simple calculation methods are shown to be inadequate to transforming psychoacoustic quantities from a sound source in the primary (near) field to the secondary (far) field. In the simplest scenario, information about the spectral changes in a noise due to distance are the minimum requirement. In complex sound situations, where a number of sound sources are distributed in space, prediction of sound quality is even more problematic, since signal components are masked by the various signal sound sources.

LITERATURE

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