HOW TO INFLUENCE ENVIRONMENTAL NOISE
BASED ON PSYCHOACOUSTIC PARAMETERS

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1 - ABSTRACT

Typically, environmental noise situations result from a number of spatially distributed sound sources. Each sound source can be described in terms of psychoacoustic parameters; but the annoyance due to a given individual sound source cannot be described only in terms of these psychoacoustic parameters. The annoyance due to a sound source depends on the personal attitude of the listener. Predicting sound quality in a complex sound situation arising from the superpositioning of a number of sound sources is very complicated unless the signal processing involved in human hearing is taken into account. Firstly, with two sound sources, both of which are causing a high degree of annoyance, the superposition of the two sound sources again results in a situation of high annoyance. However, the total of perceived annoyance depends on the location of the two sound sources relative to the listener. Secondly, it is possible for an existing sound source of high annoyance to be masked by a second sound source of good sound quality. For example, the subjectively perceived impulsiveness of individual sound sources can be reduced by adding noise of a comfortable sound quality [1]. Accurate description of an environmental noise situation in terms of noise annoyance requires us to apply our knowledge about binaural signal processing, psychoacoustics and the cognitive aspects of human hearing.

2 - INTRODUCTION

Economic growth goes hand in hand with increasing demands for mobility and transport. To ensure a high quality of life, future growth will need to take account of how environmental noise effects both people and the environment itself. More than 50% of the people living in the EU feel annoyed by traffic noise, or are worried about the direct effect it could have on their health and well-being. Any improvement in the quality of environmental noise would have a direct, positive impact on the quality of life and the environment. Targeted engineering of acoustic data would also increase safety. Achieving an adequate reduction of the human harm caused by traffic noise demands pathbreaking, innovative approaches. In the past, European countries have introduced regulations towards a radical reduction of A-weighted sound pressure level in a passby drive test. To meet the future limit of 71dB(A), car manufacturers are currently making high investments. Yet increasingly stringent regulations have failed to reduce the annoyance effect due to traffic noise: the level of annoyance has actually increased. This is one of the reason for the EU-project SVEN (Sound Quality of Vehicle Exterior Noise) [2] to get a better understanding between sound emission and perceived sound quality.
Any radical improvement in this area can only be achieved if the noise created by traffic is engineered to take account of the special factors involved in our aural sensation and perception. This necessitates a multidimensional approach, integrating subjective evaluation, the sensation of annoyance and physiological effect. We are advocating here an approach which, alongside the limited A-weighted sound pressure level benchmark, is focused on aurally-equivalent engineering. This not only contributes to achieving a product identity sound, but will ensure the continued social acceptance of the motor vehicle.

While being a highly-responsive measuring system, the human auditory apparatus lacks an adequate long-term memory. Once our hearing has perceived a sound event to be unpleasant and disturbing, this impression is retained, even if the noise is reduced in terms of sound pressure level (adaptation of human hearing) [3]. Consequently, once sensitized to a given pattern of sound event, our hearing is practically powerless to inform us about any general change in sound quality or annoyance through noise.

It is at this point that all conventional measuring parameters and analysis techniques can help no further. This situation has resulted in a new approach involving aurally-accurate sound measurement, where the special characteristics of the human auditory apparatus are taken into account [4].

In the past, efforts to take account of the specific properties of human hearing have brought forth psychoacoustic rating quantities, aimed at producing a description of how noise is subjectively evaluated [5].

3 - FROM THE SOUND EVENT TO A HEARING EVENT

Fig. 1 is a schematic diagram of the process involved in sound perception, directly applicable to environmental noise.

![Fig. 1: The process of sound perception [6]](image-url)
Sound engineering of environmental noise

Sound engineering [7] generally requires
- a general definition of the term „sound quality“
- applicability testing of existing measurement and analysis techniques
- taking account of the requirements of affected individuals, and, in consequence, the special characteristics of the human hearing
- the development of calculation techniques and describing variables, leading to objectification of subjective noise rating in terms of reproducible testability.

The enterprise of linking the various dimensions of sound event capture will eventually result in a definition of the term „sound quality“. However, practice has shown that a definition of terms of this kind is no straightforward matter. This is because sound quality is determined by a large number of different parameters (see fig. 2). Alongside the more familiar actuating variables, such as SPL, duration of exposure, spectral composition and time structure, also included are spatial distribution of sound sources and information content, plus the hearer’s subjectivity.

**Sound Quality Parameters**

All previous attempts at standardizing the term „sound quality“ have failed. In what follows, the term „sound quality“ is to be understood as the degree to which the sum of all the individual demands made on an auditory event are satisfied [8]. Generally, we can say that sound quality is negative when sound events lead to auditory events perceived to be unpleasant, annoying, or disturbing, or produce negative associations or sounds uncharacteristic of the product. Similarly, sound quality is positive if auditory events are not perceived as such, produce no disturbance, result in a pleasant auditory impression or create positive associations in relation to the product.

![Fig. 2: Parameters affecting sound quality](image-url)
The first step towards engineering environmental sounds is by adequately processing acoustic signals using aurally-equivalent measurement and analysis techniques. This is currently being achieved in large sectors of the automobile industry through the application of Artificial Head technology. Alongside aurally-accurate recording, this technology provides the following advantages in aural monitoring of sound [9]:

- sound uniquely defined
- unlimited archiving
- repeatable as often as required
- no environmental distraction
- direct A/B comparison
- spatial impression

Also required to arrive at a global evaluation of sound quality is a fundamental knowledge about the psychoacoustic properties of human hearing, combined with the cognitive aspects and source-related weighting (see fig. 3).

![Fig. 3: Variables applying for subjective rating of noise comfort level](image)

Only an approach which takes account of the all aspects described here can result in adequately engineered environmental noise, achieving auditory events perceived at least as non-disturbing, if not actually pleasant.
The first application is based on a measurement with an Artificial Head positioned in a garden of a house close to an airport. Three different takeoffs of planes were recorded and analysed. Fig. 4 shows the A-weighted level and in comparison the loudness during time of these different planes. There is a significant difference with respect to the A-weighted level and the loudness between the three planes, but the loudness representation correlates better to the subjective evaluation by listening tests of these three planes. During the listening tests the different noise pattern was observed. The plane with lower level has had a stronger modulation and some stronger tonal components. This is well represented with a prominence ratio analysis at fig. 5 and with the modulation spectrum analyses at fig. 6. Such a noise pattern could stronger contribute to the annoyance of the sound although at lower loudness. A further important objective parameter for the subjective perceived annoyance could be the change of loudness or A-weighted level in dependence on time. As the human hearing is able to adapt to a sound situation a sound event with a small increase of loudness in dependence of time could create a lower annoyance in comparison to a shorter sound event with a high change of loudness during a short time slot.

![Fig. 4: Airplane, A-weighted level and loudness](image1)

![Fig. 5: Airplane, prominence ratio analysis](image2)

![Fig. 6: Airplane, modulation spectrum vs. frequency](image3)
Application two shows the results of an Artificial Head recording of a pass-by recording of a sporty car. The recording was done with four Artificial Heads at different distances to the car. That means (fig. 7) that the A-weighted level and the loudness will decrease in dependence of distance. But the disturbing pattern of the sporty car represented by the prominence ratio analysis at fig. 8 will not be changed in such a significant way in dependence on the distance.

Fig. 7: Pass-by at different locations, A-weighted level and loudness
Fig. 8: Pass-by, prominence ratio analysis

5 - REFERENCE

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