Hearing-adequate Description of a Soundscape Based on Standardized Measurement Procedures

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Introduction

Regarding the soundscape the following approach is needed: the overall effects of noises – those generated by nature, by men, directly or indirectly - need to be observed in the context of the sensitivities of the human beings living in that said soundscape. An important task herein consists in the description of the sound events situated within the soundscape according to the requirements of its measurement technology. As it is well known the diminishing of the quality of life through the acoustical ambience may not be registered alone by way of the A-weighted sound pressure level. With regards to the complex signal processing within human hearing at least equally complex procedures of analysis are required such as psychoacoustics puts them at the engineer's disposition in form of quantities as loudness, sharpness, roughness etc. At this point it becomes an issue that, except for the loudness of stationary noise, no generally accepted calculation procedures have been specified by way of binding standards and norms. Until now no other measurement quantities in order to describe noise annoyance in addition to the existing A-weighted sound pressure level can be requested by government regulations. On the other hand it is actually possible to deduce parameters based on known, standardized procedures of measurement and analysis, which approach the given psychoacoustic quantities more readily and thus allows a greater quality of assertion with regards to noise annoyance than the mere regarding of the A-weighted sound pressure level or of the energy-equivalent sound pressure level respectively. In utilizing standardized third-octave filters as well as sound pressure level meters with a variable - markedly lower than the FAST weighting – integration time several psychoacoustic quantities of susceptibility may be approximated quite well.

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 for 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 narrowband 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.

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 [5]. 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.

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 [6].

Judgment of Noise

- Which sound source is responsible for the annoyance? (selection)
- Which signal attributes like modulation or specific patterns in the time and frequency domain are creating annoyance? (psychoacoustics)
- What kind of attitude and expectation has the listener? (psychological aspect)
- The human hearing adapts to average level and becomes more sensitive for any changes in the time and frequency domain

Example: Take-off Airplane

We have used a binaural recording of a take-off of an airplane which produced an acceptable A-weighted sound pressure level, but caused by some modulations in the higher frequency spectrum a specific roughness is clearly detectable. Figure 1 shows the modulation spectrum of the left and the right artificial head ear signal. You can clearly see a modulation with around 80 Hz in the frequency range between 1000 and 2000 Hz.

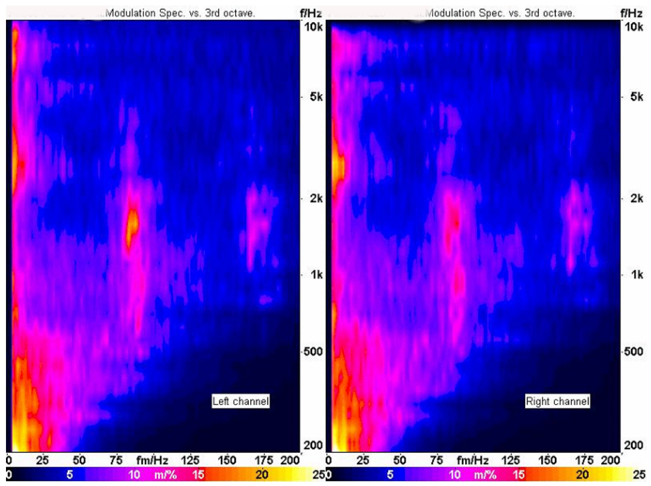

Fig. 1: Modulation spectrum vs. frequency

Figure 2 shows the A-weighted sound pressure level during the take-off and in comparison to the contribution of the frequency range between 1400 Hz and 1900 Hz, but with a shorter integration time of 2 ms.

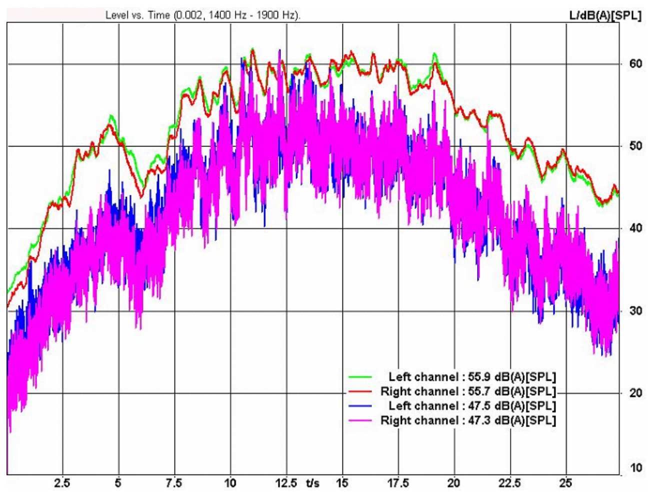

Fig. 2: A-weighted level and selected level (1400 - 2900 Hz)

Figure 3 shows the same as figure 2, but only a smaller time range to get a better information about the strong modulation in this frequency range. At the peak level of this complained frequency range it is very close to the total A-weighted sound pressure level.

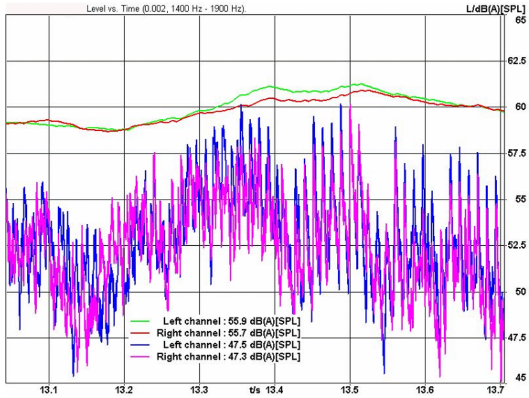

Fig. 3: Zoom of Fig. 2.

Conclusion

"Sound quality is most definitely in the mode... except for one important area. Environmental noise, where A-weighted equivalent level (L_{Aeq}) continues its convenient dominance.

This is the great contradiction in our approaches to noise. When we want to sell something we make it sound good. But when we want an environmental criterion we suppress all the sound quality by averaging over long periods and take no account of what it actually sounds like. We rate intermittent noise in the same way as we rate continuous noise. We suppress low frequencies. We suppress the information carried by fluctuations. We throw out the recognized subjective contributors to sound quality, whilst assuming that those exposed to the noise have brains like buckets of water. Our legislators and decision makers must relinquish the comfort given them by L_{Aeq} criteria, behind which they hide at the first mention of noise. It is time to send them a clear message: **Put some quality into environmental criteria.** [7]" An "intelligent" use of existing measurement tools like level meter with variable integration time and third octave analyzer can help to cover the lack of standardization.

References

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