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A-weighted sound pressure level as a loudness/annoyance indicator for environmental sounds – Could it be improved?

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Abstract

A system is introduced with the purpose of showing how an auditory perception system may be built up to include the basic quantities on loudness domain. The quantities are the critical bands, the power law, and the weighting. The power law seems to be the most crucial basis for hypothesizing a loudness function. It has been shown that the power law could be applied as such by assuming the auditory perception system to have two essentially different stimuli: the intensity (sound pressure level) and pure pressure. These physically different quantities seem to be combined in the root of the power law, and in this study the roots are determined from equal-loudness contours. A loudness function is derived on the basis of this finding. By adding the weighting, a method has been constructed for assessing loudness. After defining the weighting, the equal-loudness contours are constructed and are seen to be virtually identical to the contours in ISO 226. It has also been found that the equations for deriving the contours in this standard and in the new ISO 226 may be incorrect, because there is no definition of a sensible loudness function. Finally, it is deduced that the derived weighting must be unequivocal for an auditory perception system (depending solely on the otologically representative group). Finally, the A-weighting (as part of an A-weighted sound pressure level) as such is reasonably similar to the weighting derived in this study. Therefore, this weighting is not the main problem when assessing sounds in respect to loudness. The A-weighting is thus chosen as the weighting for the indicator derived in the study for assessing environmental sounds.

Keywords: A-weighted sound pressure level; Loudness; Equal-loudness contours; Environmental sounds

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1. Introduction

The main problem concerning frequency weightings seems to be how (or to what extent) the A-weighted sound pressure level indicates the human response (e.g. loudness and annoyance) to environmental sounds caused by living, transport, etc. A similar question related to weighted sound pressure levels in general, and the low frequency range in particular, seems to concern the C-weighting, which has already been adopted as a limit value in some regulations in the Nordic Countries when assessing low frequency noise.

To be a reliable environmental noise annoyance indicator, the A-weighted sound pressure level should also be an adequate loudness indicator, because annoyance and loudness originate from the same auditory perception system. However, this seems not to be the case. Contrary to the A-weighted sound pressure level, loudness has a well-defined experimental basis and, e.g. the loudness assessing method ISO 532B [1] has been shown to be superior to any weighted sound pressure level in respect to loudness, resulting in heavy criticism of the A-weighted sound pressure level. Perhaps the strongest and most quoted of this criticism has come from Hellman and Zwicker [2], who claimed that the A-weighting is in fact inversely related to both loudness and, by deduction, to annoyance. Twenty years on, however, the A-weighted sound pressure level is still the most widely used sole predictor of annoyance caused by environmental sounds.

In order to give a broader perspective to frequency-weighting problems, a basic loudness system was constructed in this study. The system consists of three characteristics (elements) seen to be of crucial importance to the auditory perception process: the critical bands, the power law (and the definition of "phon" because this is strongly related to the loudness function), and finally the weighting. It seems that neither of the first two has so far been taken seriously into account, when studying the suitability of weighted sound pressure total levels for assessing environmental sounds and comparing weighted levels with real loudness.

In this study the aim is to evaluate what roles the above quantities should play in an auditory perception system, and to see how the defined elements may interact. It should, however, be emphasized that the following terms "loudness" or "auditory perception system" are more nominal than closely related to a real, subjective, hearing process studied in depth in serious psychoacoustic research. Moreover, subjective test data when constructing the system was strongly rejected. The entire test material was taken directly from equal-loudness contours [3] and from Japanese experimental findings [4–6]. Finally, supportive calculation examples were taken from Hellman and Zwicker [2].

Finally, although the A-weighted sound pressure level has been strongly criticized, it is accepted worldwide as sufficiently adequate – at least as a measure of annoyance caused by environmental sounds. Therefore, it is not realistic to replace this indicator wholly with another that has totally different numerical values, construction and structure, as has been done elsewhere, e.g. with a loudness-level meter. Instead, one should ask whether the A-weighted sound pressure level (calculation) could be improved to better relate to the actual loudness. This question is answered in this study.

2. Fundamental elements

In the following, the author has taken the liberty to use quite freely some of the concepts usually involved in serious hearing and loudness research. The basic quantities cited above have been "postulated" from reviewing only a few earlier papers and studies. The