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Comparison of various procedures for the assessment of prominent discrete tones using a large number of sound samples

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This paper deals with the comparison of the procedures from the standards ISO 1996-2 and DIN 45681 as well as the two procedures (TNR and PR) from ISO 7779.

In the first section, characteristic features of the procedures (e.g. signal analysis parameters, degree of automation and characteristics of the prominent discrete tone analysis) are described.

In the second section, the procedures are applied to approximately 70 sound samples. In addition to natural sounds (e.g. from machines), synthetic sounds (e.g. peak in a trough) are used as well. The results are then compared to the assessment of these sounds by human subjects. The results of the comparisons are to be discussed, with special attention paid to cases where significant deviations occur.

The third section deals with the results of the comparisons with reference to requirements for a standard (e.g. robustness, precision).

Overall it was determined that none of the procedures investigated provides optimal results for all sound samples.

1 Introduction

Aiming at seeking one procedure for all purposes of prominent tone detection and assessment four existing procedures are compared using 72 sound samples. These sound samples derive from 5 different sources.

Set 1: 10 industry, 2 wind power plants

Set 2: 10 industry, 10 wind power plants

Set 3: 5 wind power plants

Set 4: 20 unknown (industry and artificial)

Set 5: 7 industry, 1 wind power plant, 6 artificial

Reference for these comparisons is the assessment of the sound samples by test persons, most of them experts in acoustics.

After a brief comparative description of the four procedures the requirements for a standard procedure are going to be discussed. The comparison of the results of the different procedures for the 72 sound samples is based on these requirements.

2 Description of Procedures

The four procedures which are compared in this paper are based on two concepts:

- Tone to Noise Ratio (TNR)
- Prominence Ratio (PR)

The procedures are from the following standards

- 1) DIN 45681:2002 (TNR)
- 2) ISO 1996-2 (TNR)
- 3) EN ISO 7779:2001/prA2:2006 (TNR)
- 4) EN ISO 7779:2001/prA2:2006 (PR)

All the procedures lead to one measure, the level ΔL , for the description of the prominence of a tone.

The first step is in all cases to make a spectrum from the sound. Therefore the standards possess different rules:

DIN 45681: narrowband spectrum, A-rated
 $1.9 \text{ Hz} \leq \Delta f \leq 4 \text{ Hz}$

ISO 1996-2: narrowband spectrum, A-rated
 $\Delta f < 5\%$ of critical band width

ISO 7779: narrowband spectrum, unrated
 $\Delta f < 1\%$ of f_t (frequency of the tone)

The overall procedure can be separated in two parts, one part for the detection of a tone in a sound (spectrum), and another part for the calculation of the prominence (ΔL) of the tone.

Only DIN 45681 contains a procedure for a full automatic detection of tones in a sound (spectrum).

Some comparing aspects regarding the calculation of the prominence:

- Target of design:
 - DIN 45361 environmental noise
 - ISO 1996-2 environmental noise
 - ISO 7779 occupational noise
- Critical bandwidth:
 - DIN 45361 “Zwicker” - Formula
 - ISO 1996-2 approximation to “Zwicker”
 - ISO 7779 “Zwicker” - Formula
- Positioning of the critical band with respect to tone frequency:
 - DIN 45361 geometrical
 - ISO 1996-2 arithmetical
 - ISO 7779 arithmetical $\leq 500 \text{ Hz}$
geometrical $> 500 \text{ Hz}$
- Lowest tone frequency:
 - DIN 45361 90 Hz
 - ISO 1996-2 50 Hz
 - ISO 7779 89.1 Hz

- DIN 45681 and ISO 1996-2 are appropriate to varying tone frequencies, ISO 7779 is not.

Only DIN 45681 allows a full automatic monitoring. ISO 1996-2 needs two parameters, one, whether the tone frequency is constant or varying, a second one describing the roughness of the spectrum. Due to the purpose of the ISO 7779 (Measurement of airborne noise emitted by information technology and telecommunication equipment) ISO 7779 starts with a listening to the noise. In the TNR – procedure of ISO 7779 an unambiguous definition of which narrow band is part of the tone is missing. If the tone is found by hearing, the calculation of the prominence with the PR – procedure of ISO 7779 will be completely defined.

Remark:

One aim within the last revision of DIN 45681 was a harmonization with ISO 1996-2, but also ISO 7779 and ANSI S1.13 had been taken into account.

3 Requirements for a Standard Procedure

Which are the criteria that qualify a procedure as a standard procedure?

- The procedure shall always supply a result (independent from the quality of the result)
- The mean difference of the calculated ΔL to the "nominal" values shall be as small as possible
- The standard deviation of the differences of the calculated ΔL to the "nominal" values shall be as small as possible
- No calculated ΔL should be very far from the "nominal" value

Criterion a) is obligatory. In the case, that c) and d) are sufficiently fulfilled, a misfit of b) can easily be solved by a simple addend.

4 Comparison for Numerous Sound Samples

4.1 Overview

All comparisons are based on narrow band spectra which were generated by FFT analysis according to the specification of the different standards. The standard procedures were transformed into computer programs to execute the calculations of ΔL as automatically as possible.

DIN 45681 and ISO 1996-2 incorporate a frequency dependent masking index in their calculation of ΔL and the assessment of ΔL under the aspect of annoyance is independent from the frequency of the tone. In ISO 7779 it is vice versa. Therefore a frequency dependent masking index was calculated from the ΔL to annoyance relation of ISO 7779 and this masking index was included in the calculation of the ΔL values that are shown in chapter 4.3.

In accordance to the principles of the assessment that less than no annoyance is impossible and that more than strong annoyance is impossible too there is a low cap of 0 and a high cap of 13.5 for the calculated ΔL , which were used for the comparison of the calculated ΔL to the assessed values.

Because only the DIN 45681 contains a procedure to find the tones in the spectra, this procedure was also used for the other standards. A glance on the spectra showed us that the procedure worked well.

4.2 Assessments by Test Persons

The weakest point in the comparisons is the assessment of the sound samples by test persons. Only one set of sound samples was assessed by a large number of acoustic experts from different institutes. All the other sets of sound samples have only been assessed by about 12 test persons (by the majority acoustic experts) from one institute.

The sound assessment did not take place under laboratory conditions and the adjustment of the sound samples to equal sound level was not perfect.

The assessments were based on a scale of annoyance from 0 to 5 (set 1) or 0 to 6 (set 2 to 5) with 0 meaning no annoyance. The 75% percentiles were taken as results of the assessments. In a first step the results for set 1 were multiplied with 6/5, and then all the results were transformed from the annoyance scale to a ΔL scale.

A typical standard deviation of the sound assessment on the basis of ΔL was about 2 dB.

4.3 Results

The following figures show the difference between the calculated ΔL and the assessed ΔL for the 12 sound samples of set 1. This set has been chosen for some more detailed information as it is the one with the most reliable assessment by test persons.

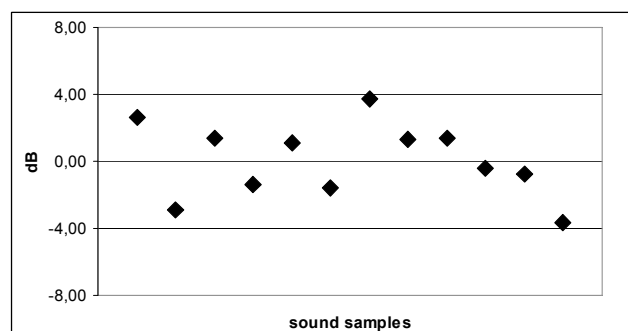


Fig. 1 DIN 45681 calculated - Assessed

Mean value of the differences:	0.1 dB
Standard deviation of the differences:	2.2 dB
Maximum of the differences:	3.8 dB
Minimum of the differences:	-3.6 dB

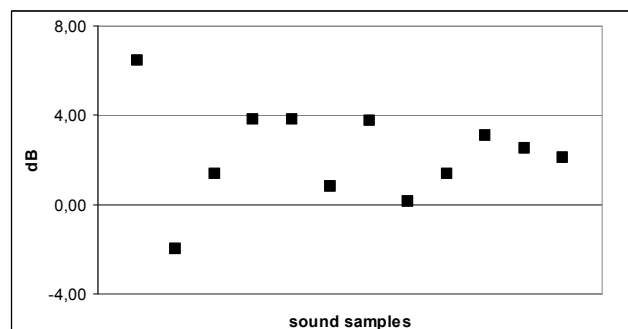


Fig. 2 ISO 1996-2 calculated - Assessed

Mean value of the differences:	2.3 dB
Standard deviation of the differences:	2.2 dB
Maximum of the differences:	9.1 dB
Minimum of the differences:	-2.0 dB

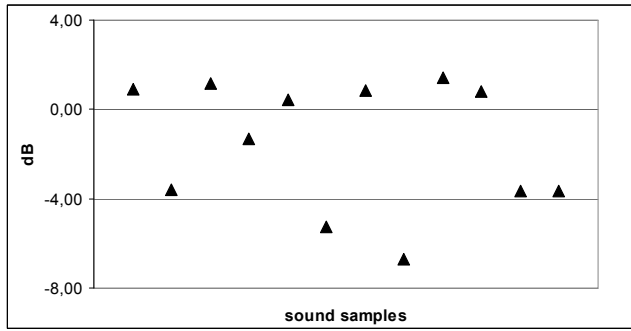


Fig. 3 ISO 7779 (TNR) calculated - Assessed

Mean value of the differences: -1.6 dB
 Standard deviation of the differences: 2.9 dB
 Maximum of the differences: 1.4 dB
 Minimum of the differences: -6.7 dB

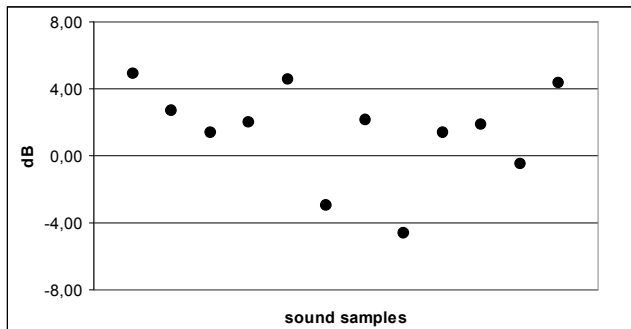


Fig. 4 ISO 7779 (PR) calculated - Assessed

Mean value of the differences: 1.4 dB
 Standard deviation of the differences: 2.9 dB
 Maximum of the differences: 4.9 dB
 Minimum of the differences: -4.6 dB

The overall results based on all 72 sound samples are shown in Table 1.

Description of the differences	DIN 45681	ISO 1996-2	ISO 7779 (TNR)	ISO 7779 (PR)
Mean	0.8	1.9	-3.0	0.8
Standard deviation	3.8	3.6	6.0	3.9
Maximum	7.0	8.5	8.4	8.4
Minimum	-8.4	-7.8	-10.1	-10.2

Table 1 Statistic data including all 72 sound samples

It should be noted that the ISO 7779 (TNR) procedure in 40 % of the sound samples does not find a prominence of a tone, whereas the other procedures find a prominence of a tone.

4.4 Discussion of the Results

The results show, that DIN 45681 and ISO 1996-2 are rather similar with reference to the calculated ΔL . The higher mean difference of ΔL from ISO 1996-2 to the assessed values is less relevant (see 3).

The problems of the TNR – procedure of ISO 7779 may partially be caused by the calculated masking index (see 4.1).

Although the PR – procedure from ISO 7779 is quite different to the procedures of DIN 45681 and ISO 1996-2 the statistic results are very similar.

5 Conclusion

The results show that the TNR - procedures of DIN 45681 and ISO 1996-2 may be a good basis for the design of a unified procedure for the detection and assessment of prominent tones. Special aspects of ISO 7779, ANSI S1.13 and recent papers should also be taken into account. Furthermore it should be discussed whether an advantage could be taken of an additional PR – procedure.

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