Distribution of low frequency sound levels in rooms

Olesen, Søren Krarup; Møller, Henrik

Published in:
Proceedings of the 1998 International Congress on Noise Control Engineering, Internoise 98, November 16-18, 1998, Christchurch, New Zealand

Publication date:
1998

inter • noise 98
Christchurch NZ November 16-18

I-INCE Classification No. 25.1

DISTRIBUTION OF LOW FREQUENCY SOUND LEVELS IN ROOMS

Søren Krarup Olesen and Henrik Møller

Acoustics Laboratory, Aalborg University, Fredrik Bajers Vej 7 B4, DK-9220 Aalborg Ø, Denmark.

1. INTRODUCTION

The level of low frequency sound varies considerably with position within a room. If the geometry of the room is simple, e.g. rectangular, and the dimensions are comparable to the wave length of the sound, very well-defined and pronounced room modes exist. If the room shape is more complex or the wave length is shorter, the pattern of the sound distribution turns blurred and less pronounced, mainly due to diffusion.

Internal low frequency noise sources such as various machines, technical installations and ventilation systems are known to cause annoyance to people, but also external sources such as power plants may excite the room. Concerning the evaluation of annoyance, it is important to know the sound pressures that might occur and expose the persons in the room.

Correct measurements with a sufficient density in space would require an extensive measurement effort, so several approximate procedures and proposed standards exist, which use measurements at a limited number of predetermined positions in order to gain a single representative SPL per frequency. Some of the standards prescribe to measure in a very few positions, such as 2 or 3 points, however, due to the room modes mentioned above, the microphone placements could easily be in a minimum of the sound pressure pattern, hence the outcome SPL being severely underestimated.

The present paper will evaluate three such low frequency measurement procedures; namely 1) Guidance from the Danish Environmental Protection Agency ('GDEPA') [1], 2) Technical note from DELTA Akustik & Vibration ('TNDelta') [2] and 3) The low frequency parts of the ISO 140-3 [3].

2. METHOD

A completely reliable evaluation of the low frequency measurement procedures would require an enormous amount of control measurements in the field, since the statistical averages, variances and distributions of each procedure outcome are unknown. Such huge amounts of data would be impractical to collect. The related work by Simmons [4] relies on a limited set of measured data.

A statistically robust alternative would be to use a reliable *model* instead of actual measurements. The model used in this paper is based on the finite difference equations model (FDE), that previously have proven reliable on predicting sound pressures at low frequencies [5]. This room simulation tool is utilised in a Monte Carlo experiment in order to reveal characteristics of the three measurement procedures.

The Monte Carlo conditions

The following Monte Carlo conditions were used: 55 different rectangular rooms uniformly distributed in combinations of 2, 3, 4...11 m $\times$ 2, 3, 4...11 m $\times$ 3 m, and 101 frequency values uniformly distributed on a logarithmic scale in the range 10-100 Hz. Each of the 5555 simulations contains a number of SPL's at positions corresponding to dividing the respective rooms into cubes of $0.5 \times 0.5 \times 0.5$ m^3. The three procedures were used 50 times per frequency on each of the 55 rooms, by randomly picking SPL's from simulated points (cubes), given by the procedure.

The three measurement procedures

The three procedures had the following main requirements for microphone placement and number of measurements:

'GDEPA': If the area of the room is more than 20 m^2; 1 measurement in a corner (0.5-1 m from wall) + 2 measurements elsewhere in the room (>0.5 m from wall). If the area is less than 20 m^2; 2 measurements in corners (0.5-1 m from wall). All heights were 1-1.5 above the floor.

'TNDelta': This note was inspired by (but not similar to) a Swedish measuring procedure [6]; 2 close-to-corner positions (0.5-1 m from walls and 1-1.5 m above the floor).

'ISO 140-3': The part specified for low frequency (Annex F, >50 Hz) was followed: About 10 measurements (depending on room size) no closer than 1.5 m to surroundings and a minimum distance of 1.5 meters to neighbour measurements. Only rooms with an area above 20 m^2 were applied to this procedure.

All procedures specified energy averaging.

Additional procedures

For each room the energy was averaged over every single point in the room ('Average'). Secondly, two randomly selected corners were chosen for each room and the maximum SPL found was used ('Corners'). And thirdly, the maximum energy level in each of the rooms was found—this level was used as a *reference* in comparing the procedures.

3. RESULTS

The results of each of the measurement procedures are shown in figure 1 and figure 2.

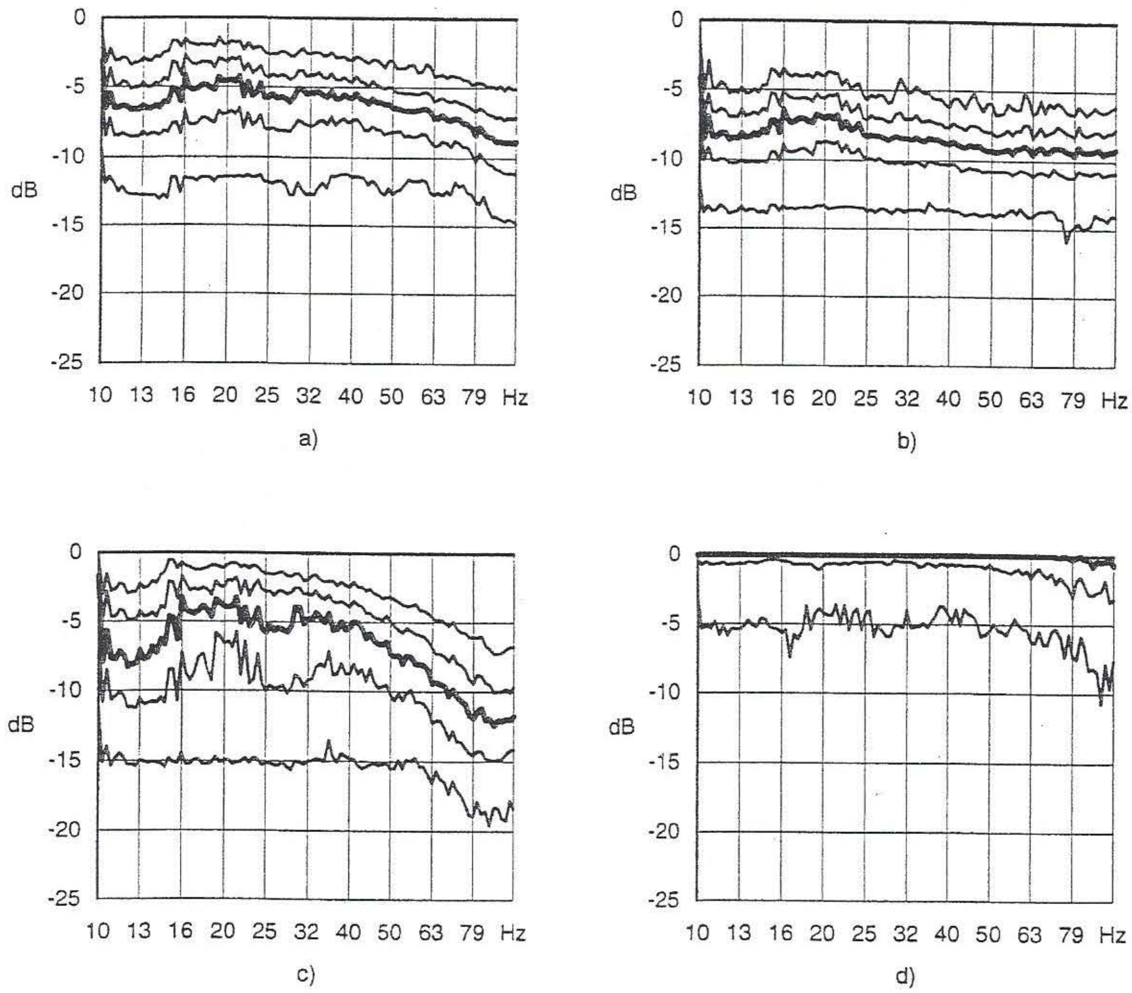

Figure 1a-d. 5, 25, 50 (median), 75 and 95% quantiles of the SPL outcome of the procedures relative to the maximum SPL found in the room. a) 'GDEPA', b) 'ISO 140-3', c) 'TNDelta' and d) 'Corners'.

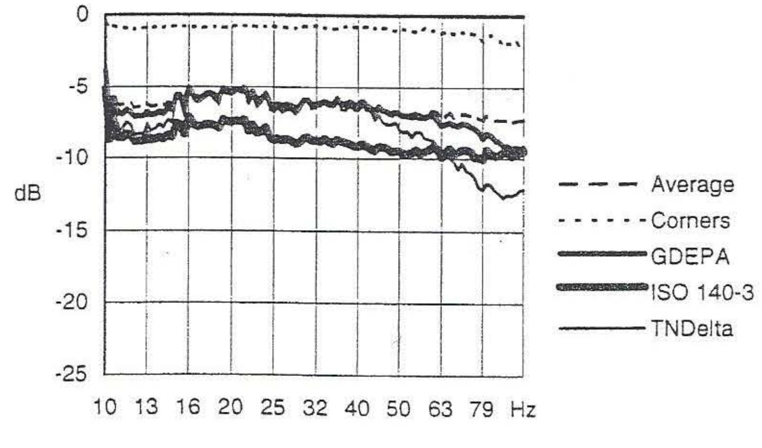

Figure 2. The mean SPL outcome of the procedures relative to the maximum SPL found in the room as a function of frequency. The 'ISO 140-3' is valid only above 50 Hz.

4. DISCUSSION

The maximum level found in a room is in general 6 dB larger than the room average ('Average'), and the prediction error made by simple averaging grows with frequency (see figure 2).

Using two randomly selected corners ('Corners') provides an average SPL closest to the maximum (only about 1-2 dB lower), and only in 5% of the cases the estimated SPL was more than 6 dB lower than the highest SPL in the room (see figure 1d and 2).

The 'GDEPA' is about 7 dB lower than the maximum SPL in general, and has a large standard deviation compared to the 'Corners'-procedure (see figure 1a). The estimated SPL's using this 'GDEPA' tend to have an increasing deviation from the maximum SPL as frequency grows.

'ISO 140-3' is about 9 dB lower than the maximum SPL in general. Due to the high number of measuring points, this is the procedure with the lowest standard deviation (except for the 'Corners'-procedure), and this is consistent within the frequency range 10-100 Hz (see figure 1b).

The 'TNDelta' follows the 'Average' and 'GDEPA' up to about 40 Hz. At higher frequencies the deviation from the maximum SPL grows rapidly with frequency. Only two measuring points are used, and since they are not completely within the corners, but are in distance 0.5-1 m to surroundings, almost any SPL may appear at such points at higher frequencies. Above 60 Hz one can in 5% of the cases expect the procedure to estimate SPL's more than 17 dB lower than the maximum SPL in the room (see figure 1c). This procedure is clearly more frequency dependent than any of the other procedures tested.

The aim of two of the forthcoming standards [1][2] for measuring noise at low frequencies is supposedly to predict the highest occurring SPL in some room. However, as the results suggest, this has not yet been accomplished.

5. REFERENCES

[1] Orientering fra Miljøstyrelsen, Lavfrekvent støj, infralyd og vibrationer i eksternt miljø, Nr. 9, (1997). (in Danish)

[2] DELTA Akustik & Vibration, Teknisk notat AV 67/96, Lavfrekvent støj, infralyd og vibrationer i eksternt miljø. (Rumakustiske forhold ved lave frekvenser), (1996). (in Danish)

[3] Dansk Standard DS/EN ISO 140-3, Acoustics - Measurement of sound insulation in buildings and of building elements, (1995). (in Danish)

[4] Christian Simmons, "Measurement of Low Frequency Sound in Rooms - A Detailed Comparison of Methods", Inter-noise 97, pp. 1371-1374, (1997).

[5] Søren Krarup Olesen, "Low Frequency Room Simulation Using Finite Difference Equations", Preprint 4422 of the Audio Engineering Society's 102nd Convention, Munich, Germany, pp. 1-8, (1997).

[6] Socialstyrelsen, "Anvisning för mätning av lågfrekvent ljud i rum", Udkast til SP-RAPPORT 1996:10, (1995). (in Swedish)