Sound pressure distribution in rooms at low frequencies

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SOUND PRESSURE DISTRIBUTION IN ROOMS AT LOW FREQUENCIES

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Abstract

The sound pressure distribution at low frequencies is investigated in a wide range of rooms, using a finite difference equation model. The results are used to compare the validity of three measurement procedures at low frequencies. The procedures predicted in general sound pressure levels slightly larger than a pure room average, but severely lower than the maximum levels in the particular room.

1 Introduction

The level of low frequency sound and noise 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 ducts 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 dip 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.

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 [3] 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 [4]. This room simulation tool is utilised in a Monte Carlo experiment in order to reveal characteristics of the three measurement procedures.

2.1 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 $\times$ 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.

2.2 The three measurement procedures

The three procedures had the following main requirements for microphone placement and number of measurements:
'GDEPA': If area of 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 height were 1-1.5 above the floor.
'TNDelta': This note was inspired by (but not similar to) a Swedish measuring procedure [5]; 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 50-5000 Hz was followed: 10 measurements no closer than 1.5 m to surroundings and a minimum distance of 1.5 meter to neighbour measurement. Only rooms with an area above 20 m^2 were applied to this procedure.
All procedures specified energy averaging.

2.3 Additional procedures

For each room the energy was averaged over every single point in the room ('Average'). Secondly, a randomly selected corner was chosen for each room ('Corner'). 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 procedures in 2.2 and 2.3 are shown in figure 1 and figure 2.

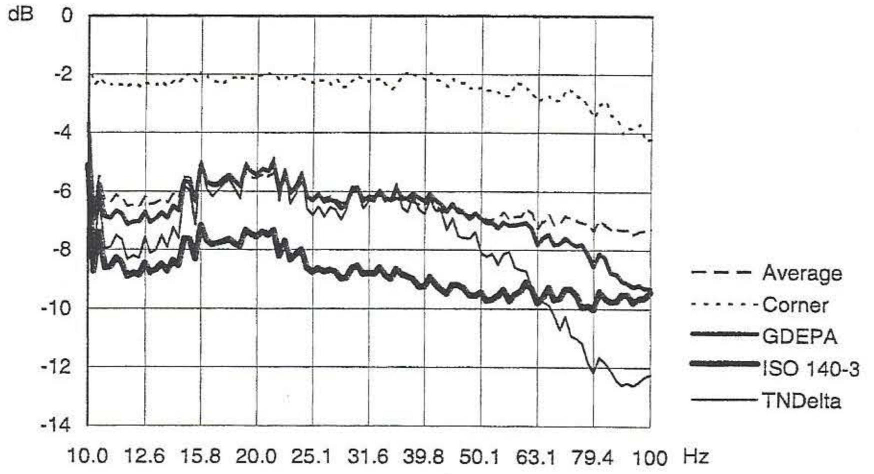

Figure 1. The average SPL outcome of the procedures relative to the maximum SPL found in the room, as a function of frequency. The ISO 140-3 graph is valid only above 50 Hz.

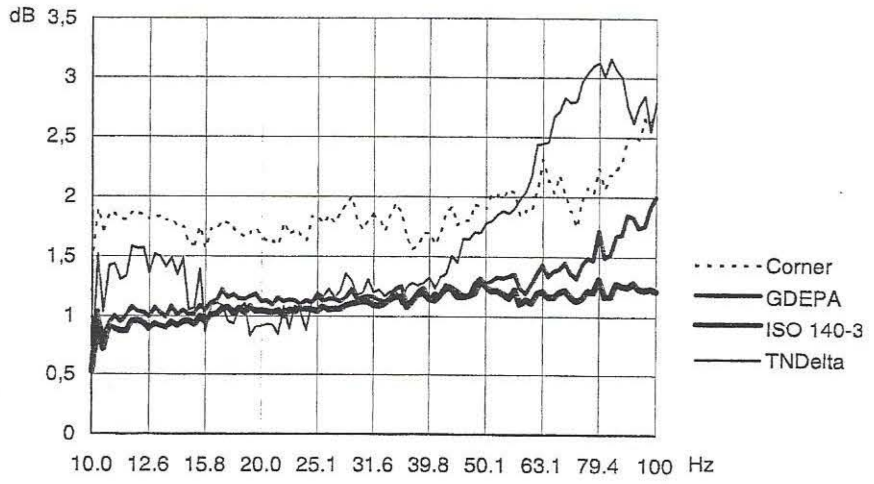

Figure 2. The standard deviation of the procedures, as a function of frequency. The ISO 140-3 graph is valid only above 50 Hz.

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.
Using a single randomly selected corner ('Corner') provides an average SPL closest to the maximum, and the standard deviation is still comparable to the other procedures.
The 'GDEPA' is constantly about 4 dB lower than the random corner SPL and gives in general a low standard deviation independent of frequency.
'ISO 140-3' specified measuring points at least 1.2 m in distance from the surroundings, resulting is SPL's approximately 2 dB below the average and as much as 10 dB below the maximum SPL. Due to the high number of measuring point, this is the method with the lowest standard deviation, and this is relatively frequency independent.
The 'TNDelta' follows the average and 'GDEPA' up to about 40 Hz. At higher frequencies both the divergence from the maximum SPL and the standard deviation grows with frequency. Only two measuring points are used, and since they are not totally within the corner, but are in distance 0.5-1 m to surroundings, one can expect almost any SPL to occur at such points at higher frequencies. At frequencies above 60 Hz a completely randomly selected at-corner point would be preferable.

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 quite been accomplished.

5 References

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