Previous results on the evaluation of the influence of sound level meter case in diffuse field

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In order to evaluate the influence of sound level meter cases on measurements, scattering around a 3D model is evaluated using Boundary Element Method. Using an iterative procedure to solve the coupled structural-acoustic problem, the free field correction curves are obtained for various angles of incidence and for random incidence. Case deviation is then obtained by comparison against the results of a reference microphone.
The results under free-field conditions reveal that the influence of case can be relevant at the middle frequency range, with deviations that can exceed ± 0.5 dB in some situations. Under diffuse-field conditions the deviation at middle frequency is not so large although it may reach ± 0.13 dB. From 10kHz the calculations show that the deviation increases significantly for both free-field an diffuse field conditions, with values between −1.5dB and 2 dB. Further research is needed to confirm this fact experimentally.

1 Introduction

It is already known that the presence of instruments can influence measurements. This is especially true in radiation experiments, where the instrument body is surrounded by the same medium in which measurement is carried out. In Acoustics, this influence is usually negligible at low frequencies, where instrument dimensions are very small compared with the wavelength, but for the high frequency range, scattering around instruments becomes relevant and may influence measurements.

Following the path of previous work [1] the purpose of this text is to present a preliminary study of case influence by means of 3D simulation. The free-field correction curves of a typical sound level meter (SLM) geometry are evaluated numerically with an open source implementation of the boundary element method based on Juhl [2]. The membrane movement has been taken into account using an iterative process to solve the structural-acoustic problem with a maximum error of 0.001 dB. The influence of the case is extracted by comparing the pressure received by the SLM against that received by a reference microphone.

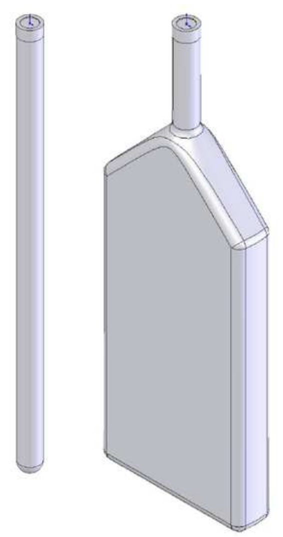

Figure 1: The two 3D models used to evaluate the influence of the SLM case.

2 Correction Curves Calculation

Figure 1 shows the geometries that have been examined. The first one corresponds to the reference microphone, a B&K4180 model mounted on a 25cm long rod which is ended by a hemispherical cap. The second one corresponds to a typical SLM case geometry. For this first study a general model has been chosen and no comparison is made between different model properties.

2.1 Free-field conditions

A plain wave is calculated as it approaches to the instrument with a given angle of incidence. The instant sound pressure received by the instrument it is calculated from the diaphragm movement using a parabolic weighting of the sound pressure over the membrane. As in previous works [1], the coupled structural-acoustic problem is solved by the iterative procedure described in Juhl [2]. The pressure received by the device is compared with the pressure when the instrument is absent. In this way, the free-field correction curve can be obtained from expression,

$$\Delta L = 20 \log_{10} \left(\frac{p}{p_0} \right), \quad (1)$$

where p is the rms pressure received by the instrument and p_0 is the rms pressure at the centre of the membrane when the instrument is absent. Free-field correction curves can be obtained for several angles of incidence.

The influence of the case material has been already studied in [1], demonstrating that the case can be considered perfectly rigid with no loss in accuracy. This consideration has been followed to perform the present evaluation.

2.2 Diffuse-field conditions

To obtain the diffuse-field correction curve, diffuse conditions were approximated by a set of plain waves coming from all directions. Of course this could be only valid if the distribution of the directions is perfectly uniform. The difficulty of achieving a random direction distribution is equivalent to the difficulty of picking a random set of points on the surface of a sphere.

It is incorrect to select spherical coordinates θ and ϕ from two uniform distributions $\theta \in [0, \pi)$ and $\phi \in [0, 2\pi)$, since the area element $d\Omega = \sin\phi d\theta d\phi$ is a function of ϕ, and points chosen in this way will be "crowded together" around the poles of the sphere. This effect can be seen in the left graph of figure 2.

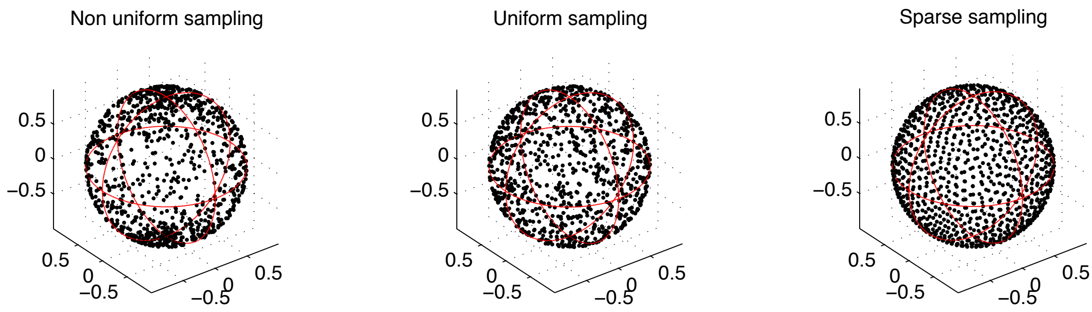

Figure 2: Representation of different sampling methods.

One method [3] for choosing points uniformly distributed over a sphere, consist of choosing u and ϕ two uniformly distributed random variables within the intervals $u \in [-1, 1]$ and $\phi \in [0, 2\pi)$. In this way,

$$x = \sqrt{1-u^2}\cos\phi, \quad (2)$$
$$y = \sqrt{1-u^2}\sin\phi, \quad (3)$$
$$z = u, \quad (4)$$

are the Cartesian coordinates of a set of points which are uniformly distributed over the sphere surface (see the middle graph in figure 2) and the pair (θ, ϕ) describes a set of uniformly distributed directions. However, due to the uniform sampling, a high number of points are needed to achieve a good representation of all directions. For this reason an iterative algorithm was implemented to scatter the points over the sphere surface.

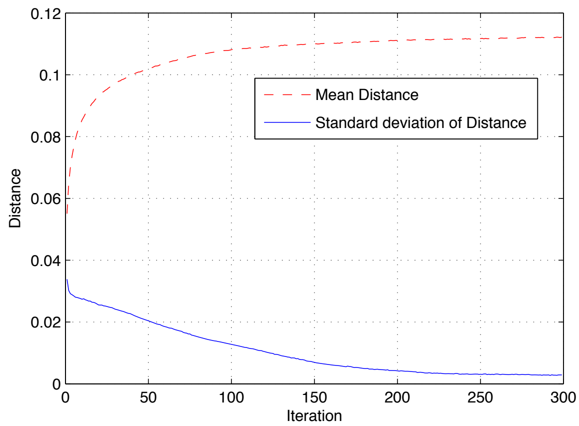

Figure 3: Evolution of the mean distance between nearest points and of the standard deviation of it along the number of iterations.

Inspired by electromagnetism, a repulsion force, which depends inversely on the squared distance, is assumed to act between the sample points. By allowing the points to move freely on the surface of the sphere, the sample set will scatter over the surface until arriving at a some sort of equilibrium (see right graph in figure 2). The resulting maximisation of the distance between nearest points is shown in figure 3, which is simultaneous with the decreasing of the standard deviation of the distance between nearest points.

2.3 Results

In figure 4 the results of the calculations for the B&K4180 microphone are presented for several angles of incidence and for random incidence.

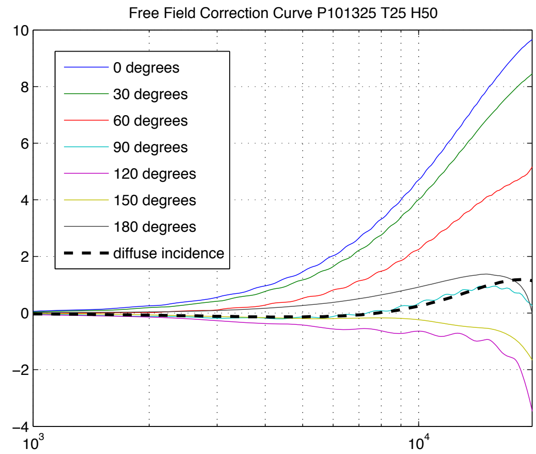

Figure 4: B&K4180 free-field correction curves for different incidence angles and for random incidence.

The results agree with the typical correction curves of 1/2 inch microphones. The deviation increases smoothly with frequency presenting its maximum value at normal incidence. These curves fit with the results presented in [1, 2, 4] for B&K4180 microphone. The diffuse-field correction is smooth and presents a maximum value of 1.3 dB at around 18kHz.

In the figure 5 the results of the calculations for the considered SLM model are presented for several angles of incidence and for random incidence.

No previous data is available to verify the validity of the SLM results but only mesh resolution problems are expected since the only difference between microphone and SLM calculations is the mesh geometry. The effects of the non-uniqueness problem were overcome using the combined Helmholtz integral equation formulation proposed by Schenck [5].

There are clear differences between SLM and reference microphone correction curves. The deviation for the SLM model is rougher, presenting several local minima and maxima.

Ruling out convergence problems, these differences among the microphone correction curves must be caused by the SLM case.

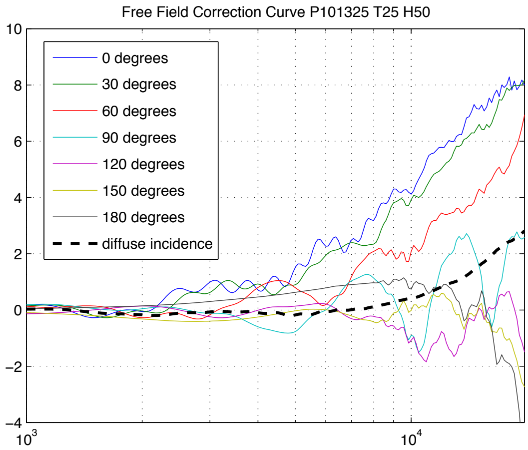

Figure 5: SLM model free-field correction curves for different incidence angles and for random incidence.

3 Case Correction Curves Calculation

Normally the firmware in SLM devices includes both free-field normal incidence and diffuse-field correction curves. The device offers a choice of correction curves that can be used to compensate for the presence of the instrument. However, to the best of our knowledge, the correction values used by the SLM are not those of the SLM, but rather the correction curves of the microphone. This goes against the IEC recommendation 61672:2002 [6], which states that correction factors should be provided by manufacturers to account for the presence of the SLM. If the corresponding factors are not used, then another source of uncertainty is added to the SLM measurements, a source which has been already identified as the case factor [7].

If we compare the pressure received by the SLM with the pressure received by the reference microphone, case correction curves can be obtained. These curves correspond to the values that should be subtracted from the SLM reading (which has been obtained from the microphone correction curves) to achieve the real value for sound pressure in the absence of the instrument. The case correction curves can be calculated from previous results simply by,

$$\Delta L_{\mathrm{CASE}} = 20\log_{10}\left(\frac{p_{\mathrm{SLM}}}{p_{\mathrm{MIC}}}\right), \qquad (5)$$

where p_{SLM} is the rms sound pressure received by the SLM, and p_{MIC} the is the pressure received by the reference microphone.

In figure 6 the case correction curves are presented for various incidence angles and for random incidence.

Below 10 kHz, under free-field conditions, the deviation fluctuates practically inside the interval ±0.5 dB. Each incidence presents its own configuration of maxima and minima, with no apparent correlation between them. The deviation is quite a bit lower under diffuse-field conditions, presenting a maximum value of 0.15 dB, which may be negligible for the most applications.

However, above the 10 kHz barrier, the deviation due to case increases abruptly, presenting values between -1.5 dB and 2dB under free-field conditions, and a maximum value of 1.5 dB for the diffuse-field. These deviations are significant enough to merit further research.

4 Discussion

The results in the middle frequency band may be considered negligible in some situations and for some purposes, but not in others. When the correction is ignored, an expanded uncertainty factor of around 0.4dB is added, depending on the frequency band in which it is evaluated. Case correction also depends on the SLM geometry and, as shown in [1], a specific geometry can be designed to slightly affect case correction while maintaining the volume of the device.

The accuracy of numerical simulations can be compromised by the resolution of the mesh. Using 6 nodes per wavelength as rule of thumb, about 350 nodes per meter are needed to achieve results up to 20kHz, which corresponds to approximately 3mm between nodes. Due to computational limitations, the current study was performed using a distance between nodes of around 6mm. This may imply a certain lack of accuracy for the high frequency (from 10kHz). For that reason, further work is needed to increase the mesh resolution and to corroborate the results achieved.

5 Conclusions

The free-field and diffuse-field correction curves of both a reference microphone and a SLM model have been obtained numerically by means of the boundary element method. The diffuse-field conditions have been approximated by a combination of plain waves, which been uniformly distributed in all directions. The case influence has been then extracted by comparison against the reference microphone curves.

Under free-field conditions, the results show a moderate influence in the middle frequency range, presenting a maximum value of around 0.5dB, which may be neglected in some circumstances. Above 10kHz, a strong deviation was found for both free-field and diffuse field conditions. Further research is needed to corroborate these results in the high frequency range.

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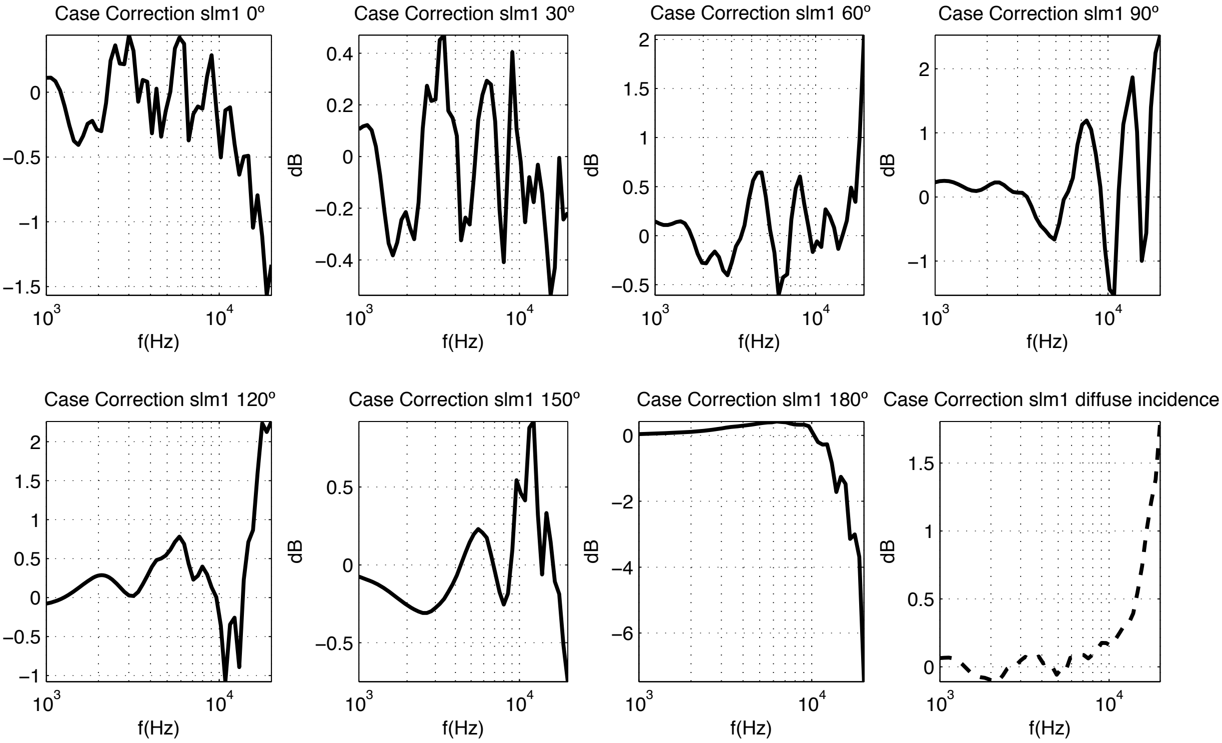

Figure 6: Case correction curves of the SLM model.

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