# COMPARATIVE STUDY OF THE DIFFUSERS CHARACTERISATION METHODOLOGIES

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## ABSTRACT

In the last years, several scattering coefficients have been proposed with the intention of completely characterising the effectiveness of diffusers. There are also several methods or techniques that must be carried out in order to obtain these parameters. In the present work we present the preliminary results of a comparison of the classical methods and the most recently proposed ones.

## INTRODUCTION

Several authors have proposed scattering coefficients in order to completely characterising the effectiveness of diffusers. However, it is still not clear which is the most appropriate one for this purpose. The idea is to obtain a coefficient that completely characterises the way in which the diffuser scatters the incident sound, as the absorption coefficient characterise the way in which a material absorbs the sound.

If the scattering coefficient is only needed to use it in "room acoustics simulation programs" based on the geometrical acoustics this coefficient needs only to evaluate the energy reflected in a non-specular way. This is due to the way these programs take into account the scattering. In practice, the scattering coefficient is taken into account in this programs as follows: when an acoustic ray hits a surface with (frequency-dependant) scattering coefficient greater than zero, a random number, between 0 and 1, is generated. If this number is smaller than the scattering coefficient a random direction ray is added to the whole set of considered rays. However, Farina [1] has proposed an improvement for these techniques that seems in close agreement with the experimental results.

If the final purpose is to predict the diffusion degree inside a room it is, at this moment, a non-sense question through lack of models that taking into account the geometry, absorption and scattering coefficients can predict this important characteristic of the sound field.

The actually employed methods for measuring the scattering coefficients can be separated in two groups. The most recent methods have been proposed by Mommertz and Vorlander ([2]) and permit to obtain directly the energetic scattering coefficient and they are based on the fact that scattered sound is non-coherent and can be separated repeating impulse responses measurements of a particular system while the diffuser is rotated. There are two variants of this method. One of them is carried out at a reverberation chamber and the other in free field. The other group of methods evaluates the different scattering coefficients from the scattering polar pattern. Apart from the holographic methods, these techniques consist in measuring the reflected sound pressure for several reflection angles. For this purpose the impulse response must be obtained, using MLS or other techniques, moving the microphone on a semicircumference (or on a hemisphere if the diffuser is a bi-directional one) centered in the middle point of the object under test [3]. Appropriate windowing of the signal obtained permits to evaluate the sound pressure reflected in each direction. Obviously, the complete characterisation of the diffuser is performed if the incidence angle is also varied from –90 to 90 degrees. However, as far as we know, the most common technique evaluates only the normal incidence.

The fundamental disadvantage of the Mommertz-Vorlander methods is that the only parameter that can be obtained is the so-called energetic scattering coefficient. This coefficient compares the energy reflected in a diffuse way with the total reflected energy, assuming that the energy reflected in a diffuse way is incoherent. Namely:

$$\delta \equiv \frac{E_{diffuse}}{E_{total}} = \frac{E_{incoheren}}{E_{total}} \tag{1}$$

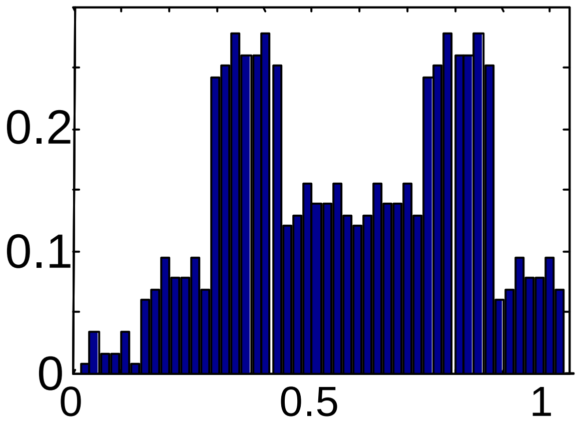
where E is the Energy of the sound wave.

This parameter can be also obtained using the classical characterisation methods. As we have commented above, these methods permit to obtain the scattering polar patterns. From the patterns, one can separate the energy reflected in a diffuse way since it is the correspondent to measures out of the specular zone. However, this kind of measurements suffer from the problem that the relative levels within the polar response are dependent on the relative distances between the acoustic source, the diffuser and the microphone, unless the source and microphones are in the far field. The far field is a semi-infinite zone where the relative patterns area equal at any point. In other words, the scattered polar response is independent of the distance to the diffuser. The advantage of the classical method is that they permit to obtain all the scattering coefficients proposed [4].

In [5] we perform a comparative study between the two classical methodologies of measurement of the scattering coefficients of a diffuser. The scattering coefficients have been obtained for the diffuser and for a flat surface with the same dimensions. We discuss the results for the different scattering coefficients in both the two cases evaluating the dispersion power of the diffuser. Figure 2 illustrates the results presented in that paper. Our present idea is to compare that results with the obtained by means of the Mommertz-Vorlander method carried out in a reverberation chamber.

In both the two cases the diffuser evaluated is a wooden difractal one measuring 1 x 2'5 m. (figure 2 shows the diffusers profile). The diffuser has been designed in order to disperse the sound from 400 Hz to 7000 Hz.

Figure 1. Diffuser profile.



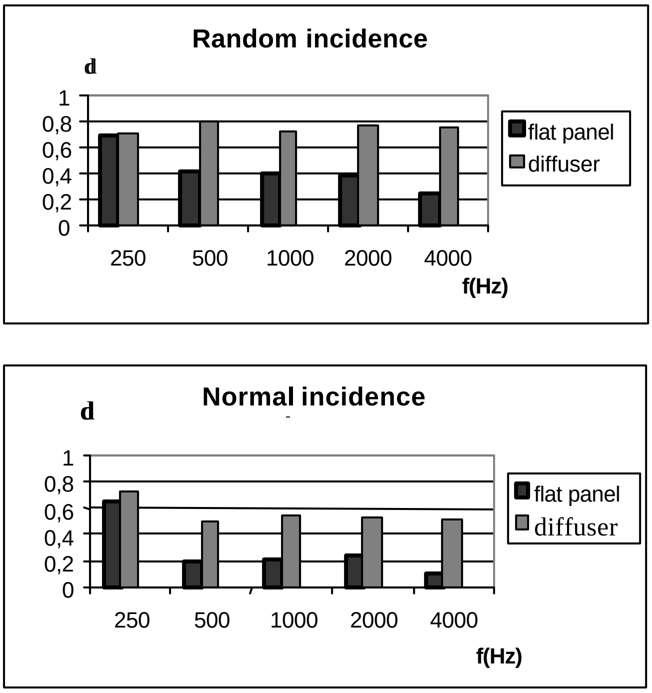




Figure 2.

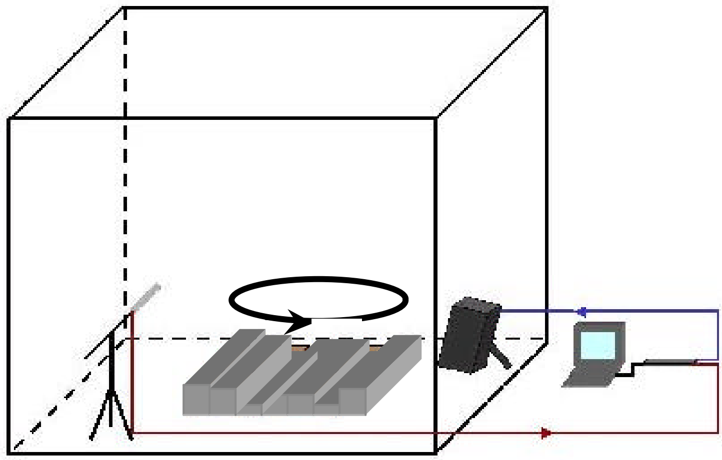
Energetic scattering coefficient. Values obtain considering random incidence (top figure) and considering only normal incidence (bottom figure). The plots correspond to the diffuser and to a flat panel of the same dimensions.

## MOMMERTZ-VORLANDER METHOD

The experimental set-up is illustrated in figure 3. The diffuser is inserted into the reverberation chamber. The impulse response is obtained by means of the software Aurora (MLS module) running in a PC that previously is connected to a sound source and to several microphones.

Figure 3

Experimental Set-up



We have obtained the impulse response rotating the diffuser 72 times with a step of 5 degrees. After that, one must perform a phase-locked addition of all the impulse responses obtaining the impulse response for a "virtual" room. (See Figure 4).

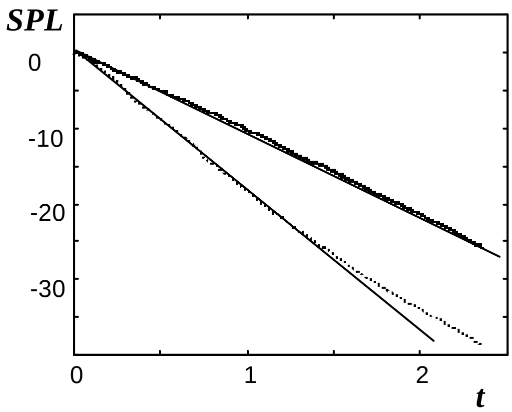



Figure 4.

Sound pressure level vs time. Integrated impulse responses for the reverberation chamber (solid thick line) and for the "virtual" room (dotted line), obtained by means of the phase locked average of several impulse responses at the reverberation chamber rotating the diffuser. The thin lines correspond to the theoretical straight lines that may be observed in a perfect diffuse field.

Assuming that the phase locked average removes the sound reflected in a specular way, because of its intrinsic coherence, the scattering coefficient can be obtained as follows:

- The original reverberation chamber absorption can be obtained by means of the Sabine equation from the measurement of the reverberation time in the empty chamber, i.e.:

$$A_c = \frac{0.162\ V}{RT_1} \tag{2}$$

where $A_c$ is the absorption of the chamber walls in metres , V is the chamber volume in cubic metres, and $RT_1$ is the reverberation time in seconds.

- In a similar way the absorption of the diffuser can be obtained from the measurement of the reverberation time in the chamber with the diffuser inside.

$$A_d = \frac{0.162\ V}{RT_2} - \frac{S - S_d}{S} A_c \tag{3}$$

where $A_d$ is the absorption of the diffuser in metres, S is the total area of the chamber walls, Sd is the area of the diffuser surface, and $RT_2$ is the reverberation time in seconds for that configuration. The absorption coefficient, $\alpha$, can be easily obtained dividing $A_d$ by $S_d$. In the following we neglected the area of the diffuser in the calculus of the walls absorption, i.e.

$$\frac{S - S_d}{S} \approx 1 \tag{4}$$

- In the case of the "virtual" room the total absorption is:

$$A = A_c + A_d + A'_d \tag{5}$$

where Ad is the usual diffuser absorption, and $A'_d$ is the diffuser pseudo-absorption. Equation 4 can be written as follows:

$$A = A_c + S_d\,(\alpha + \alpha') \tag{6}$$

where $\alpha'$ is the quotient between the energy reflected in a non specular way, i.e. incoherently, and the total reflected energy. It can be shown that:

$$\alpha' = \frac{E_{incoh}}{E_{inc}} = \frac{E_{ref}}{E_{inc}}\,\frac{E_{incoh}}{E_{ref}} = (1-\alpha)\,\delta \tag{7}$$

Considering equations 5 and 7, and taking into account the known reverberation time of the "virtual" room, one can obtain the scattering coefficient as follows:

$$\delta = \frac{1}{S_d(1-\alpha)}\left[\frac{0.162\ V}{RT_3} - A_c - A_d\right] \tag{8}$$

However, the diffuser edges must not produce any additional scattering in order to obtain coherent values for this parameter. So, edge effects can invalidate the measures. In our case, as the diffuser can not be altered into a round sample, we decide to obtain the scattering coefficient of the diffuser by means of the comparison of the reverberation time in two "virtual" rooms. The first one is the usual one, and the second is the one obtained rotating the diffuser covered by a flat wood surface with almost the same acoustic absorption of the diffuser wood. We will assume that the flat panel cover has a scattering coefficient almost null.

## PRELIMINARY RESULTS

As usual, when the reverberation time is needed for any purpose, one must chose among the practical definitions of the reverberation time. One can select EDT, RT20, or another common definition. In perfectly diffuse fields it does not matter. But in these "virtual" rooms this parameters take different values. Figure 4 illustrates how the integrated impulse responses in these rooms are not straight lines.

The preliminary results for the scattering coefficient of the diffuser sow some mismatch (see figure 5). For almost the whole effectiveness rank of the diffuser $\delta$ is bigger than one. This effect is smaller if the reverberation time considered is RT20, but still clear for high frequencies.

Nevertheless, the results permit to distinguish two frequencial ranks. The first one, for low frequencies, corresponds to the rank in which the diffuser do not scatters the sound. The second one corresponds to the rank of effectiveness of the diffuser. Remember that the diffuser has been designed in order to scatter the sound from 400 Hz to 7000 Hz.

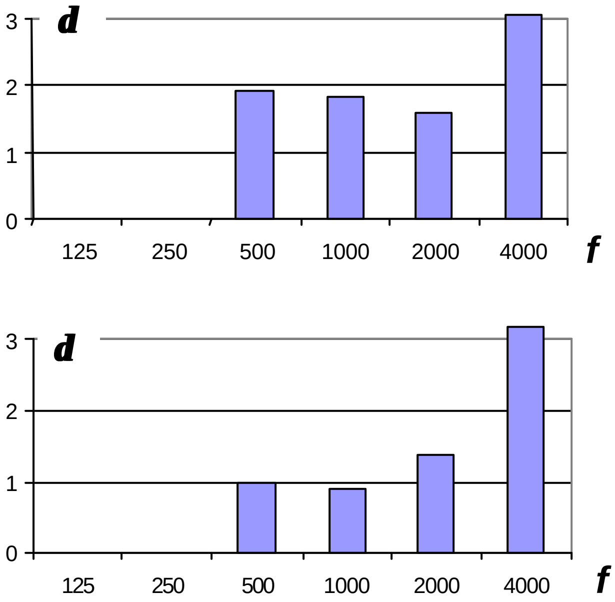



Figure 5

Energetic scattering coefficient obtained by means of the Mommertz and Vorlander method using EDT (top) and RT20 (bottom)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