# Comparison between measurements of the scattering and diffusion coefficients

A. Farina[1], L. Tronchin[2]

[1]*IED, University of Parma, 43100 Parma, Italy*

[2]*DIENCA-CIARM, University of Bologna, 40136 Bologna, Italy*

In this paper the results of a wide comparative experiment are presented. 14 different small-sized scattering panels were tested making use of the new method based on the Wave Field Synthesis [1]. From the experimental raw results, with proper processing, both the scattering coefficient [2] and the diffusion coefficient [3] can be derived.

The octave-band spectra of these two coefficients are compared for each panel. As expected, it resulted that it is generally difficult to find a stable relationship between the two coefficients. The WFS method proved of consequence its value, being capable of yielding both coefficients from the same measurement results.

On two panels, the measured values were cross-checked with other measurement methods. It resulted that the diffusion coefficient is almost the same as the value obtained by the AES-standard method, whilst the scattering coefficient is much less correlated with the value measured, on a large continuous surface, with the Mommertz/Vorlander method. This difference was explained considering that the WFS method is applied to a single panel, where border effects are predominant (particularly at low frequency), and these effects are instead minimized making use of a large continuous surface.

## DIFFUSION AND SCATTERING COEFFICIENTS

The acoustical scattering properties of uneven surfaces are judged to be very important for proper numerical simulation of the sound propagation in enclosed spaces. Furthermore, many diffusing panels are on the market nowadays, and it is not easy for the acoustical designer to specify what kind of panels is optimal for a given case. There are no standardized measurement methods. Furthermore, two different approaches are followed by AES and ISO Committees, which are confusing in some way the meaning of diffusion and scattering properties.

## THEORY:1 MOMMERTZ-VORLÄNDER METHODOLOGY

The first method of measuring scattering was developed by Mommertz and Vorländer and it's called free-field scattering measurements method. The scattering coefficient is defined as:

$$s = \frac{E_{diff}}{E_{tot}} = \frac{E_{diff}}{E_{spec} + E_{diff}}$$

therefore, after FFT post-processing of the measured IR (obtained rotating the panel at 5° steps in 72 angles), extracting the spectrum of reflected IR, for each frequency the absorption coefficient is:

$$a_{tot} = 1 - \frac{|FFT(IR_{tot}|^2}{|FFT(IR_{ref}|^2}; \; a_{spec} = 1 - \frac{|FFT(IR_{spec}|^2}{|FFT(IR_{ref}|^2}$$

from which the scattering coefficient is obtained:

$$s = \frac{E_{spec}}{E_{tot}} = \frac{a_{spec} - a_{tot}}{1 - a_{tot}}$$

The direct and reflected sound can be simply obtained by time-windowing the IRs, as in the following figure

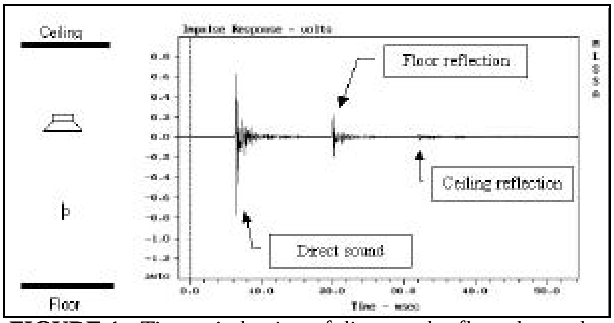


**FIGURE 1.** Time-windowing of direct and reflected sound

## THEORY: 2 WAVE FIELD SYNTHESIS METHODOLOGY

Since the scattered wavefronts have more curvature than the specularly reflected one, the WFS approach can easily separate the two wavefronts. The data acquisition setup consists of a soundfield microphone moving along a straight line instead of a hemi-circumference. For each microphone position, the total diffused energy coming from the panel is calculated.

$$I_{diff} = \int_{y=-b}^{b} \int_{x=-a}^{a} \frac{W \cdot z_c}{4 \cdot \pi \cdot r_1^3} \cdot \frac{(1-\alpha) \cdot s_{loc}}{2 \cdot \pi \cdot r_2^2} \cdot dx \cdot dy$$

whilst the specular reflected intensity coming from the panels and measured only in those positions of the microphone within the specular zone, is:

$$I_{spec} = \frac{W \cdot (1-\alpha) \cdot (1-s_{loc})}{4 \cdot \pi \cdot \left[ (2 \cdot z_c - z_r)^2 + x_r^2 \right]}$$

The estimation of ISO scattering coefficient is therefore obtained simply minimizing the difference between numerical calculations and experimental measurements.

**FIGURE 2.** Setup of the acoustical apparatus for the measurements with the Vorlander-mommertz free field method

## ANALYSIS AND RESULTS FROM MEASUREMENTS

Different panels were analyzed, and the scattering coefficient was measured as reported. Specialized software was developed, and all the 255 IRs measured with WFS approach were fitted in only one waveform. Direct and reflected sound were separated by software, and analyzed.

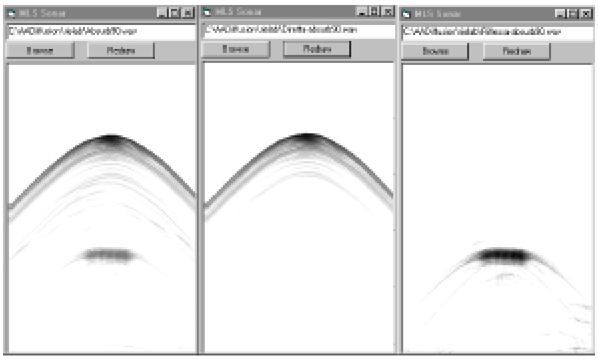

**FIGURE 3.** Polar plot: Whole IRs, (left) direct (center), reflected sound (right)

From experimental data, polar plot were obtained. The spectra of both direct and reflected sound from numerical formulation were compared with measurements; absorption and scattering coefficient were obtained minimizing differences between numerical and experimental data, by meaning of a worksheet solver. The procedure was repeated for octave frequencies, from 125 to 16000 Hz.

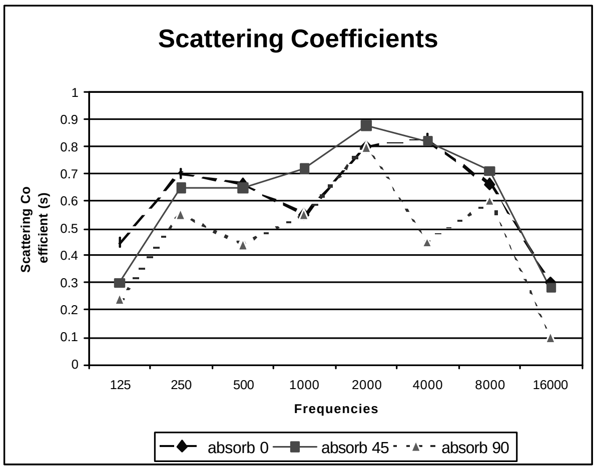


**FIGURE 4.** Scattering coefficient for different angles on incident sound


## ACKNOWLEDGMENTS

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## REFERENCES


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