

Measurement of the surface scattering coefficient: comparison of the Mommertz/Vorlander approach with the new Wave Field Synthesis method

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Abstract

This paper is about the experimental determination of the surface scattering coefficient, which is theoretically defined as the ratio between the acoustic energy diffusely reflected from an infinite surface and the total reflected energy (diffuse + specular). Two experimental methods have been tested in free field conditions: the Mommertz/Vorlander approach, based on repeated impulse response measurements taken rotating in small angular steps the surface under test, and the Wave Field Synthesis approach, in which the surface is steady, but many microphone positions are sampled along a straight line.

After a brief theoretical explanation of the two methods, some experimental results are presented. From these data, it comes out that the Mommertz/Vorlander method is quite unstable, and requires very large samples of the surface under test, as any minor edge effect can ruin completely the results. Instead, the WFS approach appears to be much more robust, and produces values of the scattering coefficient which are optimal for today's room acoustics programs.

The future investigations on this topic, with the description of a novel, third measurement method, will conclude the paper.

Introduction

The acoustic scattering properties of uneven surfaces are considered 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 are optimal for a given case.

Although most room acoustic computer models allow for the introduction of frequency-dependent scattering coefficients (usually in octave bands), there is not yet an unique definition of an "ideal diffuser", nor a standardized measurement method for characterising objectively the scattering properties of existing surfaces. Two international working groups are indeed proceeding to the creation of two measurement standards: AES is normalizing the measurement of the reflection uniformity of single objects (the related quantity is referred as diffusion coefficient), whilst ISO is normalizing the measurement of a diffuse-field scattering coefficient s .

None of the two quantities being standardised complies exactly with the intrinsic definition of the scattering coefficient employed in today's room acoustic programs (and the confusion is increased by the fact that this quantity is usually indicated as "diffusion coefficient" in these programs, although it is much more similar to the ISO scattering coefficient than to the AES diffusion coefficient).

Furthermore, it must be clear that different implementations of the scattering physical mechanism inside different computer programs cause the need for different values of the scattering coefficient to be introduced in each program, for ensuring maximum similarity with experimental results.

Being more explicit, some computer programs treat the diffuse energy as being re-irradiated uniformly (with constant intensity in all directions), whilst other are treating the diffuse energy as being re-irradiated according with the Lambert cosine model. Furthermore, in some programs the edge scattering from border of surfaces is treated explicitly, in others this is included with the surface scattering (by increasing the scattering coefficient).

The fact is that, when considering the reverberant field in more-or-less diffuse rooms, these implementation differences tends to smear, and in practice the only great difference is between programs that only allow for specular reflections and programs that take into account (in one way or another) the not-specular reflections causing diffusion. And the experience of two round-robin tests [1,2] demonstrated that the latter produce far better results. It was also evident that, for computing acoustical parameters in diffuse rooms, the actual values of the scattering coefficient are not critical; any value between 0.1 and 0.9 produces substantially the same results in most cases.

This fact covered the problem of careful definition of the scattering coefficient, and of the lack of a standardised measurement technique.

On the other hand, in free-field cases it appeared evident that the scattering properties of materials affects strongly the behaviour of the reflected sound: this regards noise screen for roads and railways, sound absorbing floors, orchestra shells for outdoor performances, etc.

And in free field cases there is not any statistical reverberant tail, which mixes the things together, smearing the differences among different implementations. For this reason, the author is mainly interested in numerical simulation of the reflected sound field, including scattering, in free field cases (or, better, in the first reflection case). The implementation of numerical modelling of scattering made by the author is described in another paper [3], here only the measurement techniques are described in detail. First the scattering coefficient will be defined (in a way which complies substantially with the ISO definition), and then the experimental results obtained with two different measurement techniques will be presented.

The first measurement technique is the free-field version of the Mommertz/Vorlander method [4]. It must be recalled that these authors presented two similar methods, one for reverberation room measurements, the other for free-field (or, better, first reflection) conditions: the first is actually being evaluated by ISO as the basis for the new measurement standard, whilst the second was subjected till now to very little interest by the scientific community.

The second method is based on the Wave Field Synthesis approach, and it was first compared with the AES measurement method [5], demonstrating very little agreement (but the two quantities are definitely different).

The theory of these two methods will be presented hereafter, and then some experimental results will be discussed. Unfortunately, as the two measurement campaigns were conducted in different times, it was not possible to make a direct comparison of the scattering coefficient of the same diffusing panels.

Theory: the Mommertz/Vorlander free field method

First we need to define the scattering coefficient s . According to the ISO approach, it is defined as the ratio between the reflected energy which is being diffused and the total reflected energy (diffuse + specular):

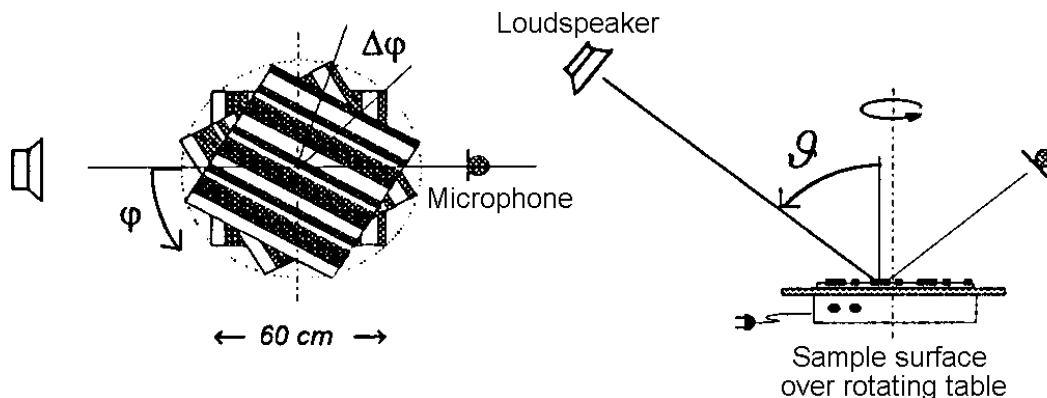
$$s = \frac{E_{\text{diff}}}{E_{\text{tot}}} = \frac{E_{\text{diff}}}{E_{\text{spec}} + E_{\text{diff}}}$$

As it is not easy to measure the diffuse energy, the method is based on the measurement of the specular energy. The hypothesis is that the specular energy comes from a coherent reflection (or phase-locked), whilst the diffuse energy is incoherent (or random-phase). This opens the possibility to average-out the random-phase, incoherent component by measuring many reflected impulse responses coming from a surface which is moved after each measurement.

The easiest movement is rotation, thanks to a rotating table placed under the panel, which of course makes sense only if the geometry of the surface is not rotationally-symmetric.

This assumption can be criticised in many ways: smooth, convex surfaces are known to produce very good “diffusion”, but for example an hemisphere will have no random-phase variation with rotation. Furthermore, many commercial diffusing panels are designed for providing strong scattering only in one plane, and for them it would be more appropriate to translate the surface in one direction instead of rotating along an axis orthogonal to the surface.

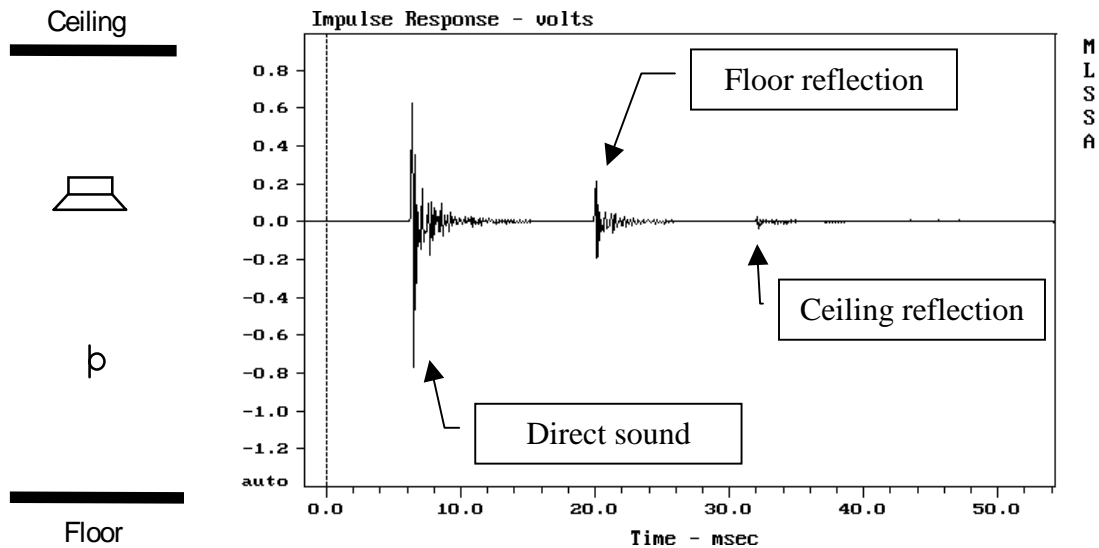
Nevertheless, the method is basically implemented as depicted in the following picture:



A loudspeaker is generating the direct sound, which impinges on the diffusing panel with a certain incidence angle ϑ . A microphone, placed along the theoretical specular reflection path, samples the reflected sound.

If the measurements have to exclude the border effects, the surface sample must be very large. In this case, instead, it was required to characterise commercial panels of limited size, including the border effect, so the experiments were conducted on samples measuring 600x600 mm. Furthermore, these materials are usually placed over a smooth, specular surface. So the measurement were made in the same conditions, over a large, reflecting floor.

In practice, the impulse response measurement were made thanks to a MLSSA system, and the following picture shows a preliminary test made without any diffusing panel on the floor, in normal incidence.



It can be seen easily that the direct sound, the reflected impulse and the first subsequent spurious reflection from the ceiling can be easily separated in the time domain.

The Mommertz/Vorlander method is based on FFT post-processing of the measured impulse response. First of all, a reference measurement is made in true free field, with the microphone placed in axis on the speaker, at the same distance as the total reflection path during the measurements on the panels. Of course, the time arrival of this free-field reference measurement must be coincident with the time arrival of the reflected impulse during the panel measurement, so that the same time window can be used for both cases.

The impulse response is repeated many times (typically 72, rotating the panel at 5° steps). Then only two impulse responses are retained: the first one, called IR_{tot}, is simply the first measurement done. The second one, called IR_{spec}, is given by the average of all the 72 measurements (it is a linear average of the sample values of the time-domain impulse response): it is assumed that this phase-locked averaging process completely destroys the incoherent reflection, leaving only the coherent (and thus specular) part.

After this is done, the FFT is taken over the selected portion of each IR, extracting the spectrum of the reflected sound. These spectra are equalized by dividing for the spectrum of the reference measurement made in free field.

At this point, it is easy to compute, at each frequency, the absorption coefficient α from the two IRs:

$$\alpha_{\text{tot}} = 1 - \frac{|\text{FFT}(\text{IR}_{\text{tot}})|^2}{|\text{FFT}(\text{IR}_{\text{ref}})|^2} \quad \alpha_{\text{spec}} = 1 - \frac{|\text{FFT}(\text{IR}_{\text{spec}})|^2}{|\text{FFT}(\text{IR}_{\text{ref}})|^2}$$

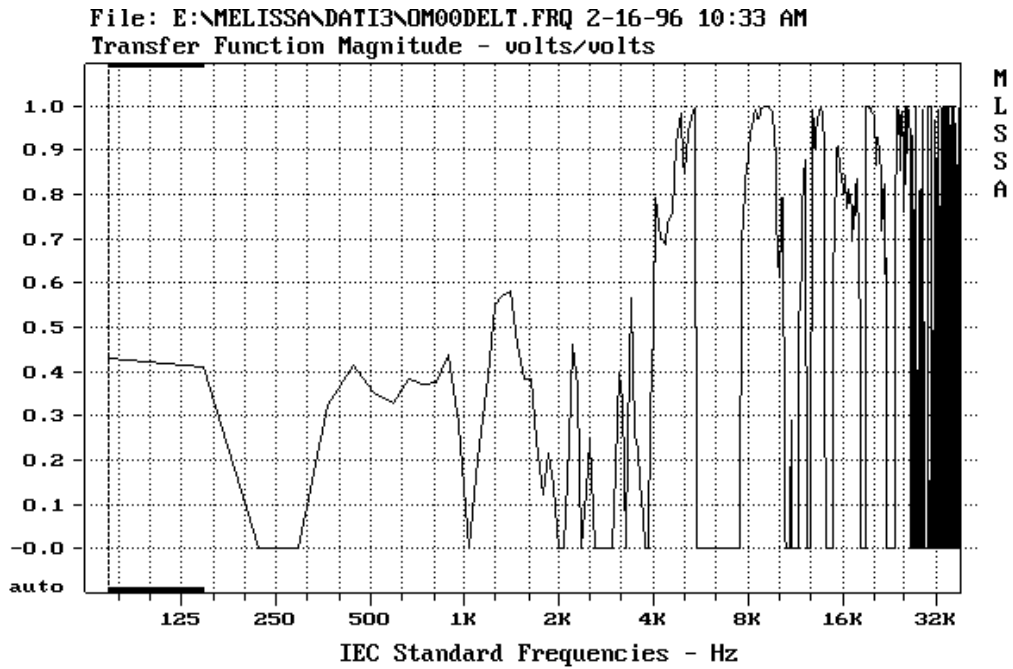
As the specular reflected energy is usually less than the total reflected energy, it should always happen to be that $\alpha_{\text{spec}} > \alpha_{\text{tot}}$.

Recalling the definition of the scattering coefficient s , and considering the fact that the specular reflected energy is the factor $(1 - s)$ of the total reflected energy, we obtain:

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

which should always be bounded between 0 and 1.

The computation of the above formula can easily be done within the MLSSA software, displaying directly on the screen the result in the form of the spectrum of s , as shown in the following picture.

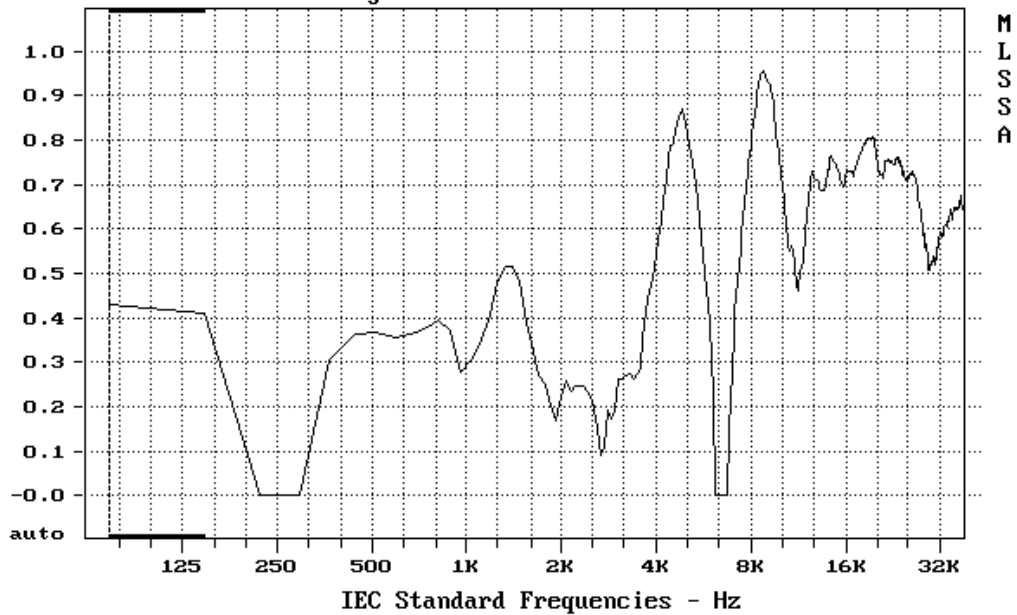


CURSOR: y = 0 x = 37735.8475 (512)

FREQUENCY DOMAIN MENU: Go View Reference Acquisition Setup Transfer Macro QC
 Overlay Calculate Printer DOS Units Library Info Exit
 F1 for Help MLSSA: Frequency Domain

As shown, the spectral behaviour is very irregular, and the values often exceed the interval (0..1). The things are much better after one-third octave averaging, as shown here.

File: E:\MELISSA\DATI3\OM00DELT.FRQ 2-16-96 10:33 AM
 Transfer Function Mag - volts/volts (0.33 oct)



CURSOR: y = 0.643844 x = 37735.8475 (512)

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In any case, the spectral behaviour is very irregular, with deep valleys and peaks. The things are partially compensated by repeating the measurement with different incidence angles, and averaging the results in a unique random-incidence scattering coefficient.

It must be noted, however, that the same problems happen also for the measurement of the absorption coefficient. Although the first-reflection method was normalized by AFNOR (S-031/89) and is being employed by ISO as a basis for the standard devoted to the characterization of the sound absorption of noise screens and absorbing floors, it is well known that this method only works for flat, wide and even surfaces, as clearly shown in [6] and [7]. Any attempt of employing the impulsive method for the measurement of the absorption coefficient of very uneven surfaces causes the same problems depicted above regarding sound scattering: highly uneven frequency response, which can be solved only taken many measurement in different points and averaging.

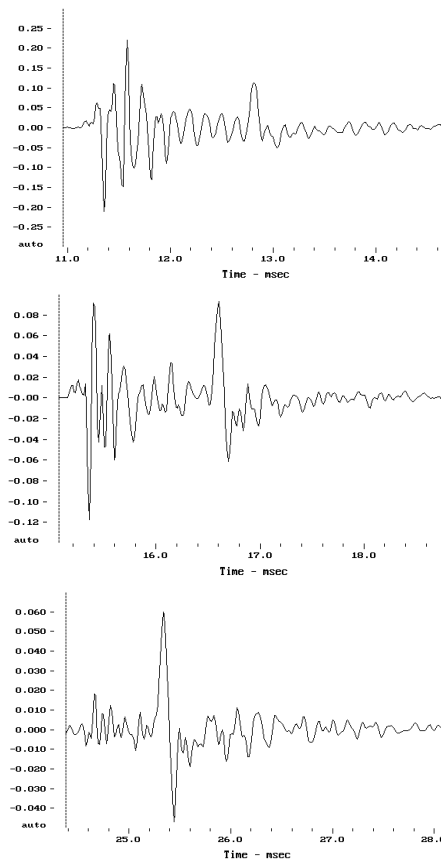
Despite the problems evidenced (which are certainly caused also by the choice of employing a very little surface), the Mommertz/Vorlander method was employed for the comparative study of 6 different diffusing panels.

Experiments: the Mommertz/Vorlander free field method

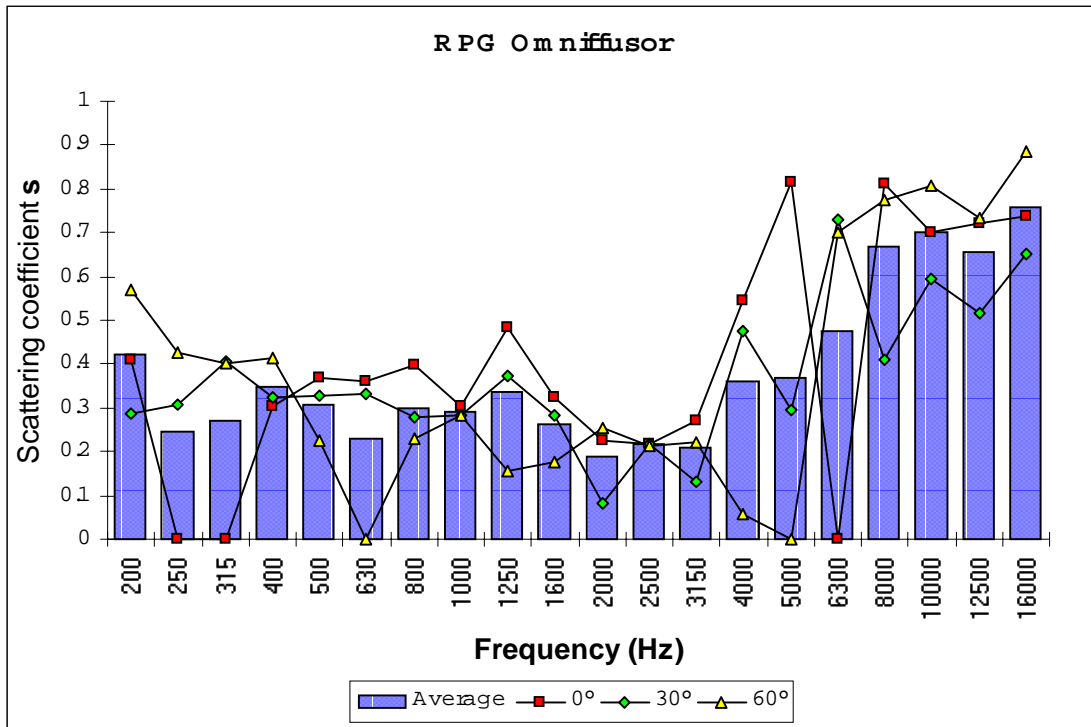
The following picture shows the laboratory where the experiments were performed. It is a quite large building, so that the reflections coming from lateral walls can easily be windowed out from the impulse response. The loudspeaker was suspended thanks to a steel frame, as it resulted that any minor vibration of the transducers during the measurement can cause averaging-faults, which are inherent with the MLS method.



The measurements were made on 6 different panels, with three incidence angles for each panel: 0° , 30° and 60° . Usually the response varies a lot with the incidence angle, as shown from the picture below, which compares the impulse responses of an RPG Omniffusor at the three angles:



Of consequence, also the single-angle values of the scattering coefficient are quite different, as shown from the following picture:

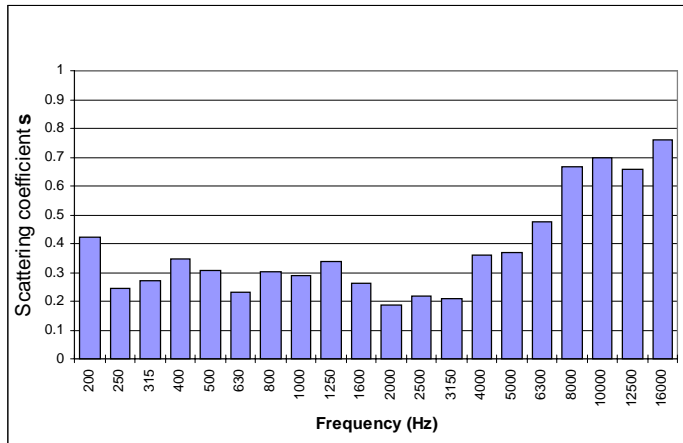


The averaged values appear much more stable, so here only the random-incidence averaged results will be presented for the other panels.

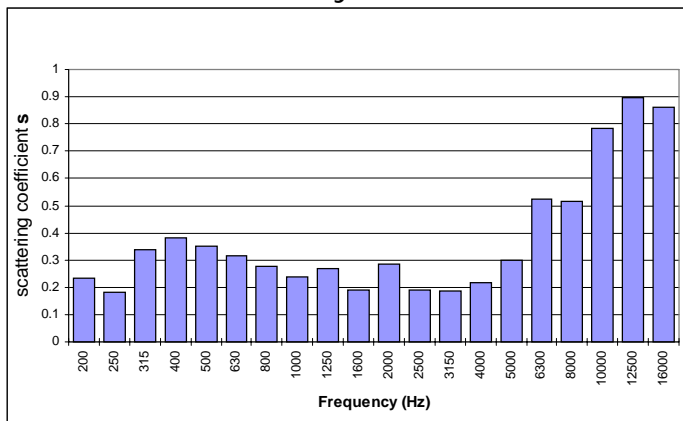
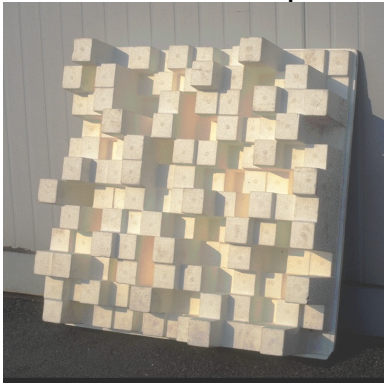
The choice of the test surfaces was governed partially from availability of commercial products (kindly provided by RPG Diffusors Inc.). On the other side, two “reference” surfaces were tested: a flat, smooth panel (with theoretically no scattering behaviour), and a home-made scattering surface made with egg containers (pressed heavy carton). All the panels had the same size (600x600 mm), and were mounted in such a way that their upper surface was always at 400mm above the floor.

The following table shows the surfaces under test, and the corresponding results obtained from the measurement.

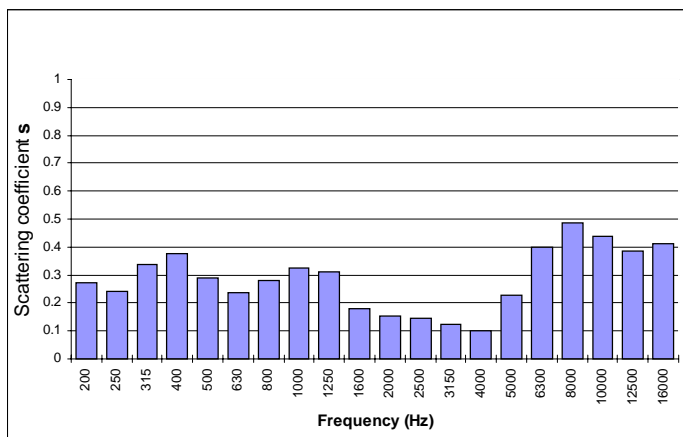
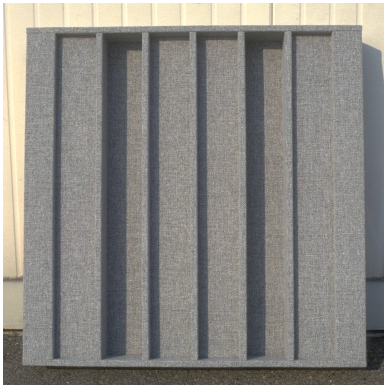
Commercial diffusor RPG Omniffusor®



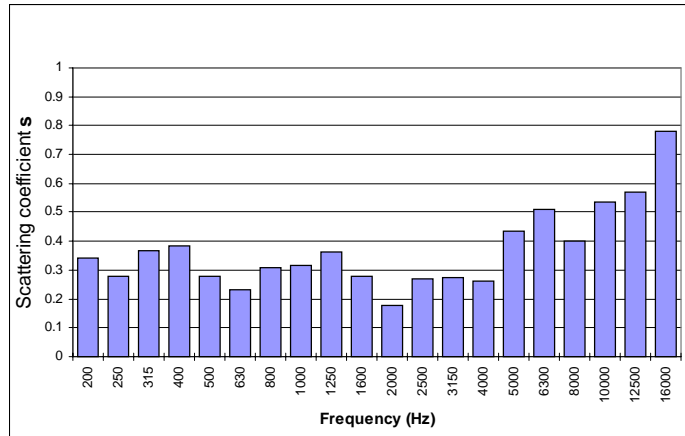
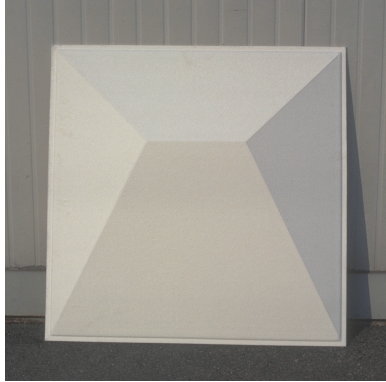
Commercial diffusor RPG Skyline®



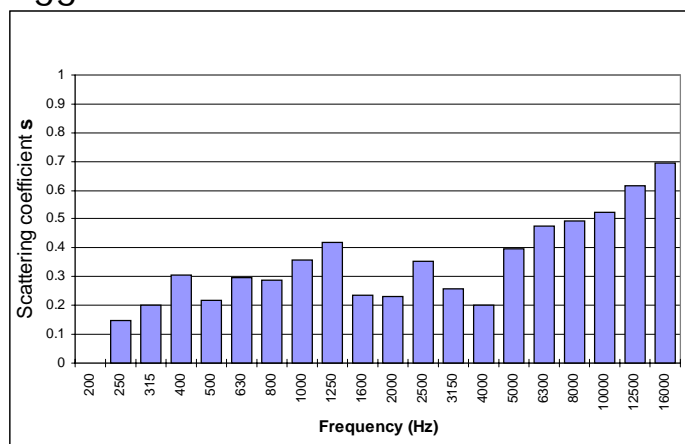
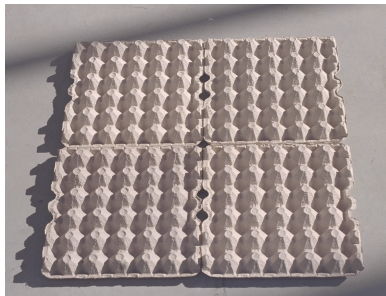
Commercial diffusor RPG Abffusor®



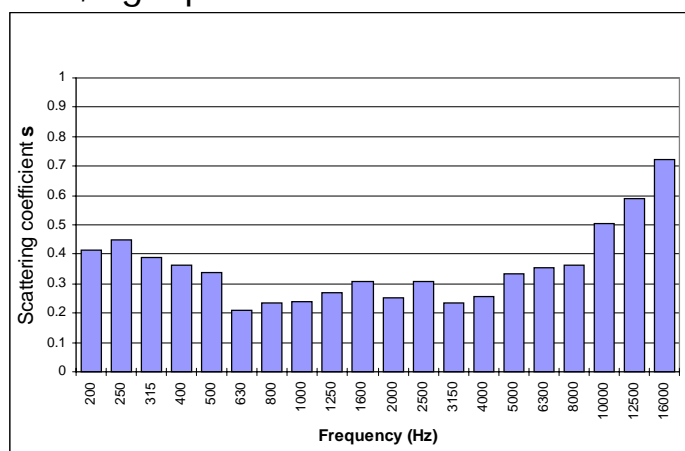
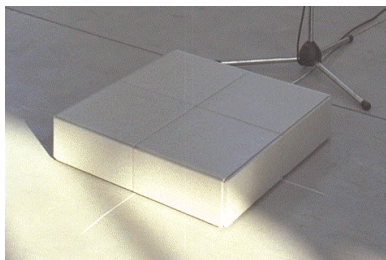
Polyester fiber absorbing panel



Egg containers



Flat, rigid plate



The observation of the results obtained for all the six panels suggests that the measured values of the scattering coefficient have no evident relationship with the

true acoustic phenomena. In practice, it resulted that there is more scattering from the flat reference surface (evidently due to the border effects) than from heavily corrugated surfaces.

In conclusion, it resulted that the implementation of the Vorlander/Mommertz method to small surfaces was substantially a failure, and the author abandoned this method in favour of alternative techniques.

The Wave Field Synthesis (Analysis) approach

Wave Field Synthesis was initially developed at the Tech.University of Delft as a technique for producing synthetic sound fields, thanks to linear arrays of loudspeakers [8]. More recently, the technique was folded back to the analysis of complex sound fields, being renamed Wave Field Analysis [9]. In this second application, a large number of impulse responses are measured with a single microphone, repeatedly placed in subsequent positions along a straight line, with constant spacing.

After the impulse responses are measured, an image is formed plotting the magnitude of the signal along a vertical line for each microphone in terms of darkness of the pixels. This graphing technique is common in other fields, such as underwater acoustics or medical imaging. Important information can then be obtained applying to such images proper data processing techniques, the most simple being windowing and filtering, going up to deformations and synthetic focusing.

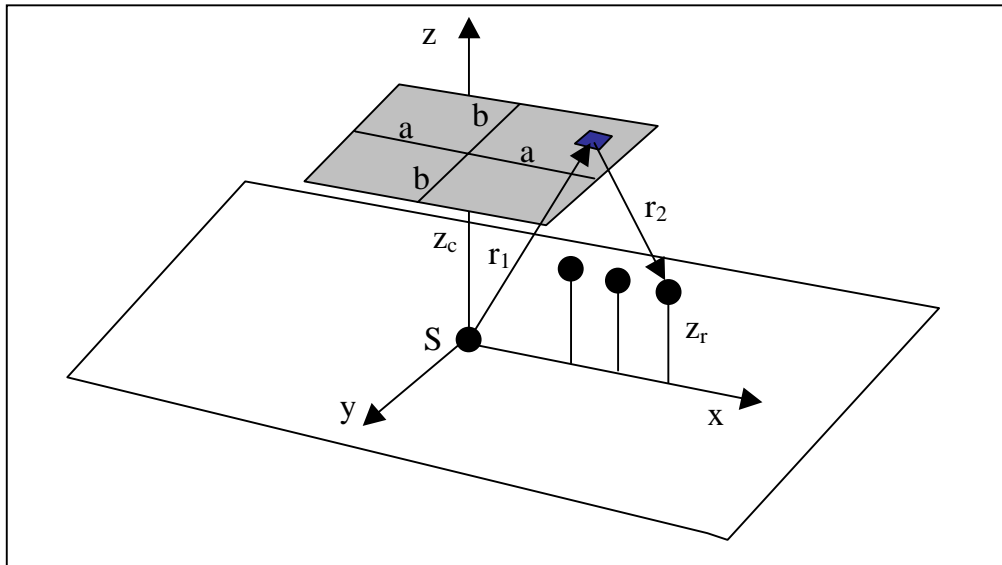
In the case of a diffusing panel inserted in a flat surface, this technique evidences the scattered wavefronts from the specularly reflected one, as the first has more curvature than the latter [10]. In principle, this different curvature could be used for separating the two sound fields (specular and diffused), and this would enable the direct computation of the ISO scattering coefficient.

So it was decided to employ a data acquisition technique based on the WFS approach, with a microphone moving along a straight line instead of along a hemicircumference. As it will be explained in the following paragraphs, this made it possible to obtain a better understanding of the reflected sound field than what can be seen by energetic polar plots.

Experimental apparatus for the WFS method

A low-cost experimental setup was employed for this work. The experiment was conducted in a large, untreated room: the elimination of unwanted reflections was obtained by time windowing of the measured impulse responses.

The geometry of the testing facility is schematically represented in the following picture.



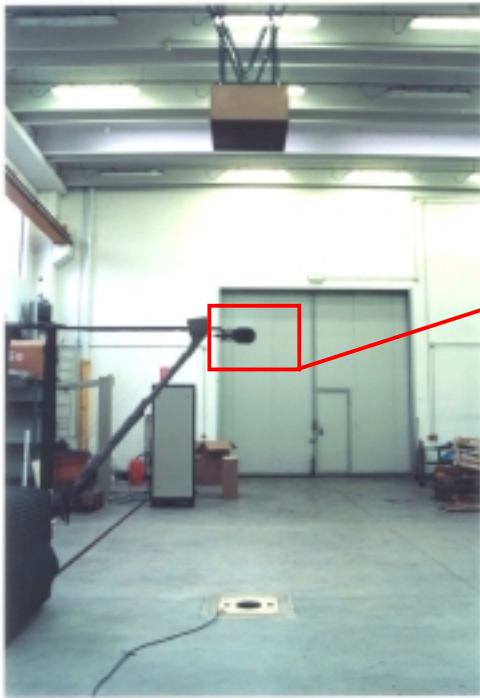
A single, wide-band loudspeaker was mounted flush on the floor, in which a proper niche was created. The diffusing panel was suspended just above it, at an height z_c of 3.65 m.

A Soundfield pressure/velocity microphone was moved along a line, at an height z_r over the floor of 1.98 m, passing under the diffusing panel, thanks to a light carriage and a rotating board which acted as drum, over which a cable was folding pulling the carriage. A rail embedded in the floor ensured linear movement of the microphone. The advancement step was 27.91 mm, and 255 microphone positions were measured.

The impulse response measurements were conducted with a PC equipped with an Echo Layla board (capable of simultaneous acquisition of up to 8 channels, at 20 bit, 48 kHz), directly interfaced with the rotating board. The software employed for the measurements was Aurora 3.0 [11], running under CoolEditPro v. 1.2. A Cool Edit macro ensured automatic, unattended operation (the whole measurement procedure takes more than three hours).

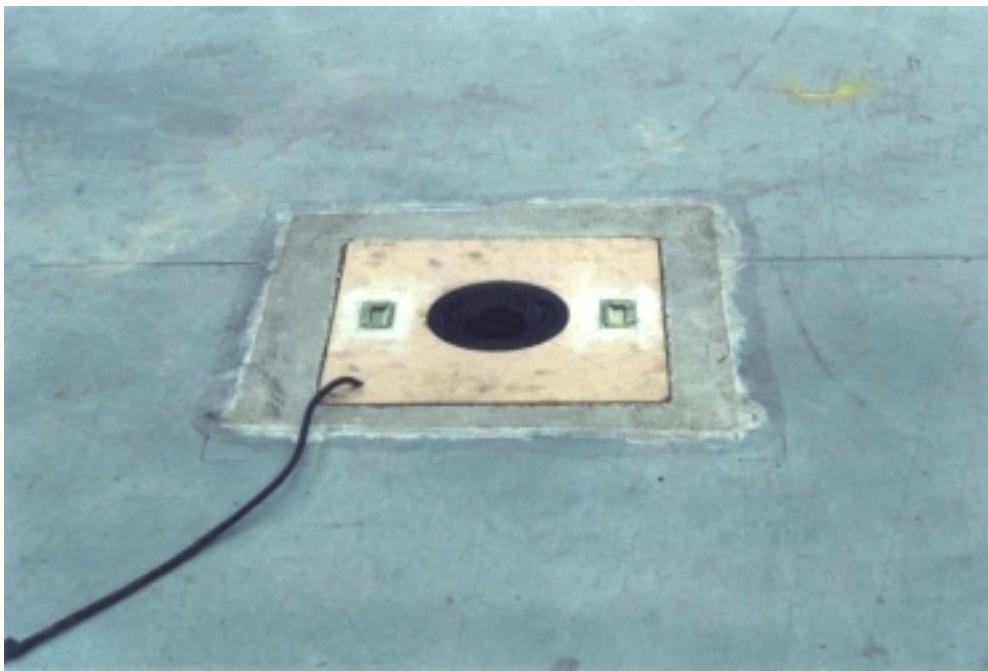
Each impulse response measurement was constituted of 16 repetitions of the MLS-16A signal (Maximum Length Sequence of order 16). The deconvolution was based on the synchronous average of the latter 15 sequences, as the first one served to bring the system in steady state.

The following 4 pictures show the overall setup, the loudspeaker, the microphone, the rotating board and the suspended panel. As shown, it was attempted to reduce the unwanted reflections from the carriage by covering it with a thick coat of sound absorbing material, which gained it the surname of “sheep”.



Particular of the Soundfield microphone

Experimental apparatus – Overall view



Particular of the loudspeaker inserted in the floor



Particular of the rotating board with the cable folding around the drum.



The diffusing panel (named GALAV2) on the reflecting floor.

Thanks to the employ of a Soundfield MKV microphone, in each microphone position 4 impulse responses were measured simultaneously, coming from the 4 B-Format output connectors of the microphone. The first channel is the omnidirectional pressure (W), and the other three channels are the Cartesian components of the particle velocity (XYZ). This makes it possible, in principle, to measure the three-dimensional sound intensity; nevertheless, only the pressure channel results were employed for the subsequent computations till now. In the future, a more robust true intensimetric analysis will be conducted on the acquired data, instead of employing the squared pressure in place of the true acoustic intensity.

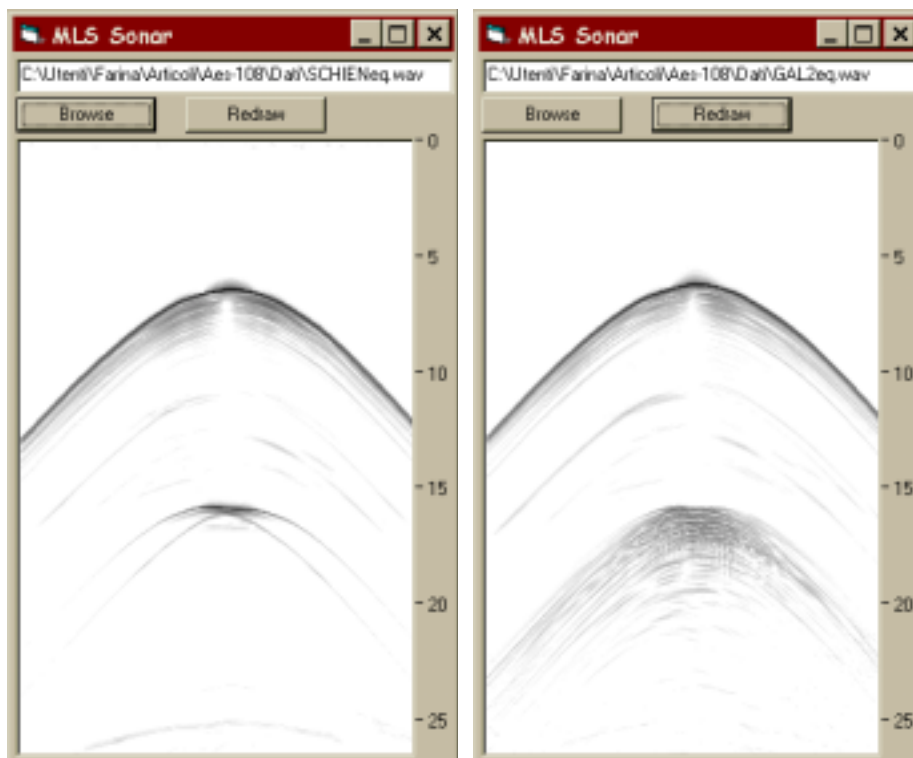
It was also possible, thanks to the advanced digital signal processing tools included in Aurora, to apply a proper filtering to the measured impulse responses, for “sharpening” the time signature of the loudspeaker. This was possible thanks to the module which computes the Nelson/Kirkeby inverse filter of the loudspeaker response [12], computed selecting the direct wave in the microphone located exactly above the loudspeaker. After the computation of the inverse filter, it was applied by convolution to the whole sequence of 255 impulse responses, obtaining the deconvolution of the loudspeaker signature to an almost perfect Dirac’s delta function.

As the Kirkeby’s filtering demonstrated to be very effective, this processing was systematically employed for all the measurements.

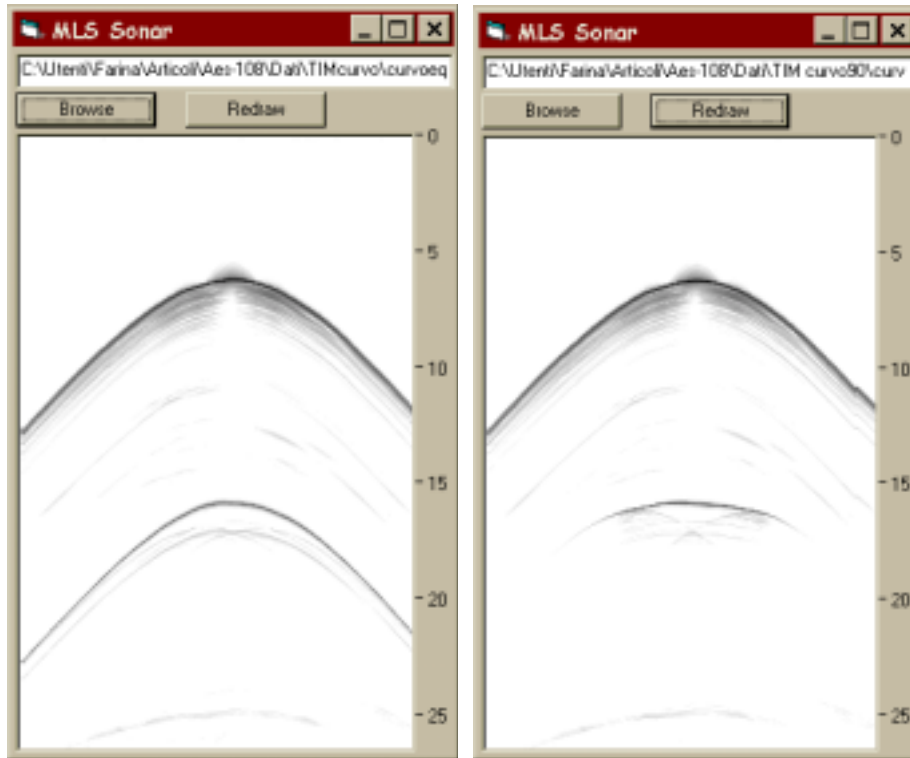
Results from the tests on three diffusors

In the following, the results obtained with three different diffusing panels are presented. The first one is a square, flat, smooth panel, made of heavy wood (MDF) and measuring 0.715 x 0.715 m. The second has the same size and is made of the same material, but has evident diffusing properties at medium frequency due to its construction as a sequence of cavities of different depth (it is visible in fig. 7). The third is a hemicylindric surface, also made of smooth wood (marine plywood), measuring 2m x 0.9m. It was measured in two perpendicular directions: the direction of maximum scattering, that is perpendicularly to the cylinder axis, and the orthogonal one (moving the microphone along the cylinder’s axis), which exhibits much lower spreading of the reflected sound.

The following 4 pictures show the WFS representations of the measurement on these three panels: the response of the hemicylinder is repeated also along its minimum scattering direction (along the cylinder axis).



Reference flat panel (Left) and Schroeder-type diffuser (right)



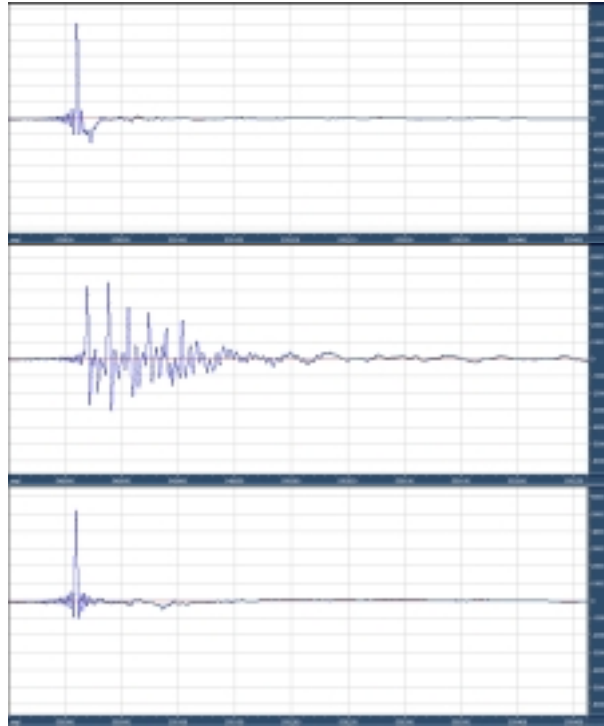
Hemicylinder tested along maximum (left) and minimum (right) scattering directions

The next step in processing the experimental results was the separation of the direct sound from the reflected waveform. This was possible employing the WFS theory for computing proper spatial windows, and applying them to the above results, setting to zero all the data points outside these windows.

This process is possible on a simple geometrical basis, as the computation of the travelled distance translates easily in the corresponding time lag over the impulse response of each microphone.

After the windowing, it is possible also to “listen” separately at the direct and reflected sound. The first is always the same for all the measurements, whilst the second reveals the nature of the reflected sound. In fact, the flat panel produces a short impulse (but somewhat smeared for the border effect), the diffusing panels responds with a smooth and long signal, having little impulsive character, and the curved surfaces produces a very sharp peak, without any sort of tail. This different behaviour is evident looking at the following picture, which shows the enlarged portion of the reflected waves for the central microphone.

For the subsequent analysis, the windowed portions were octave-band filtered and the sum of the squared sample values was taken as an estimate of the acoustic intensity of the direct and reflected waves.



Waveform of the reflected signals
Flat panel (above), diffusing panel (middle), curved panel (below)

Estimation of the ISO scattering coefficient

The definition of the scattering coefficient given here is very pragmatic: we search for the value of the scattering coefficient (and of the absorption coefficient, at once) which, inserted in a simplified formulation of the reflection (specular, diffuse, and border effect) produces numerical results in optimal agreement with the experimental ones.

The new definition resembles the Sabine's absorption coefficient definition: α_{SAB} is defined as the numerical value which, inserted in the Sabine's equation, makes the numerical estimation of the reverberation time to be coincident with the measured value of it.

Similarly, we shall define the scattering coefficient s as the numerical value which, inserted in the simplified formulation given hereafter, makes the numerical simulation of the sound field to be maximally similar to the experimental results.

Like the Sabine's equation, which only describes a very specific case (a diffuse field in a reverberant room), also the following theory only applies to a specific case of very simple reflection/diffusion. In general cases, a room acoustic program will be needed for properly modelling multiple reflection/diffusion paths in complex geometries.

The test case considered here is a free, rectangular panel (dimensions $2 \cdot a \times 2 \cdot b$), suspended above a point sound source, and above a row of microphones, which is substantially a case corresponding to the above described experiments.

At each microphone position, the total diffused energy which comes back from the panel can be computed as:

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

In which s_{loc} is the local value of the scattering coefficient, which can vary due to the increase of the scattering coming near to the edges of the panel. In practice, s_{loc} increases over the normal value of s only starting from a distance d from the border of the panel equal to half wavelength ($\lambda/2$), and it reaches its maximum value (1) at the border itself, following this linear equation:

$$s_{loc} = 1 - (1 - s) \cdot \frac{d}{\lambda/2}$$

Due to the variation of s_{loc} , the analytical computation of the above integral is not easy, so it was decided to perform it numerically, inside an Excel spreadsheet. The surface of the panel was divided in 11x11 cells, and from each cell a local contribution to the diffused energy is computed for each microphone.

Furthermore, for the little number of microphones which are within the specular zone, a specular reflected intensity also arrives (apparently being generated at the mirror image source, which is at an height $2 \cdot z_c$):

$$I_{spec} = \frac{W \cdot (1 - \alpha) \cdot (1 - s_{loc})}{4 \cdot \pi \cdot \left[(2 \cdot z_c - z_r)^2 + x_r^2 \right]} \quad (9)$$

After summation of the two intensities, a column of 255 theoretical reflected intensities is obtained, and this is compared with the column containing the experimentally measured values of the reflected intensity.

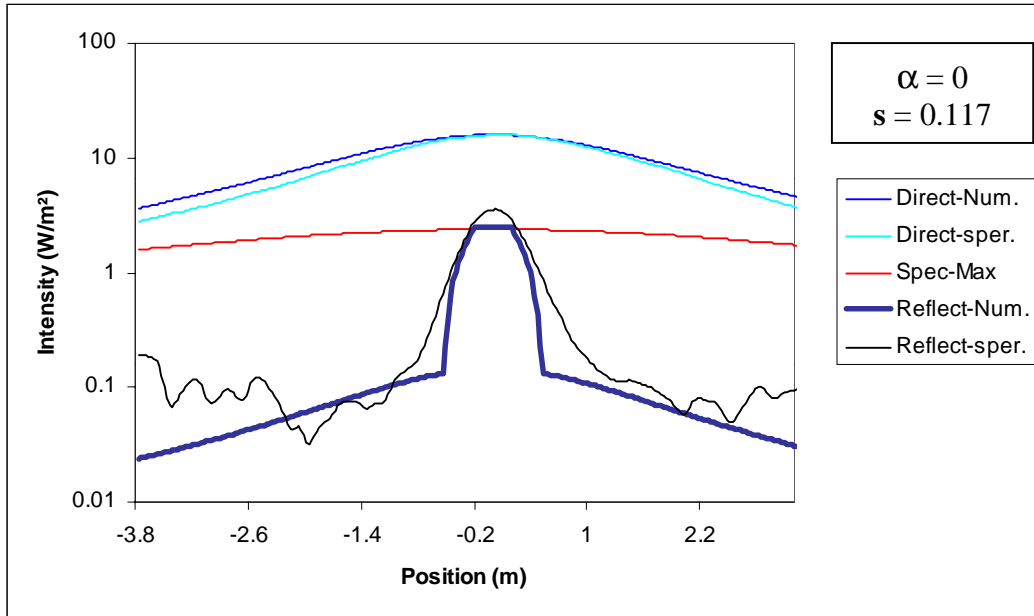
First of all, the value of the emitted sound power W is adjusted so that the intensity of the direct wave, for the central microphones, assumes exactly the same value as measured. Then the Excel's solver function is employed, for automatically optimising the values of α and s which cause the numerical results to maximally match the experimental data. This process takes some minutes, and after the optimisation is concluded it is possible to compare graphically the results.

This table reports the values of the scattering coefficients and the absorption coefficients, at the frequency of 1 kHz, obtained by the best-fitting procedure outlined above.

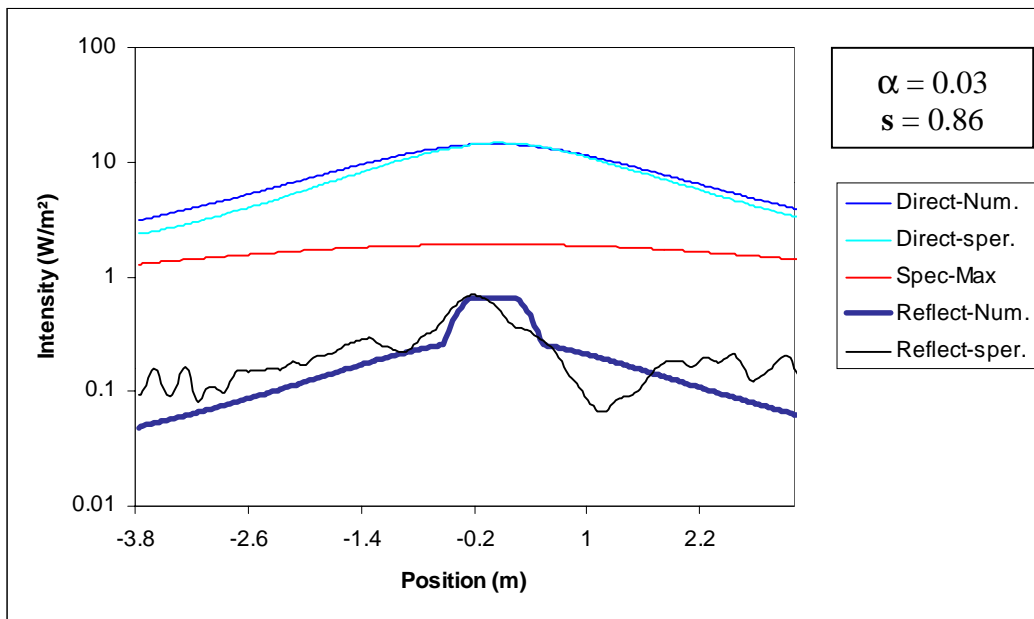
Parameter	Flat Panel	Schroeder diffuser	curved panel	curved panel (90°)
α	0	0.03	0.286	0.76
s	0.117	0.86	1	0.20

It can be seen how the curved panel, along its major dimension, behaves as a not-diffusing surface, but it appears to have a much greater absorption coefficient, as the energy is being spread on sides, and thus the specular reflection has lower amplitude than what's expected for a flat surface. This fact already shows that serious errors can arise if the curved panel is modelled as a flat panel with "average" values of α and s . Also along the maximum scattering direction, the reduction in the amplitude of the specular reflection caused by the geometrical spreading of the reflected sound causes an "apparent" sound absorption coefficient: this again show that the formulation presented here produce strange result for curved surfaces.

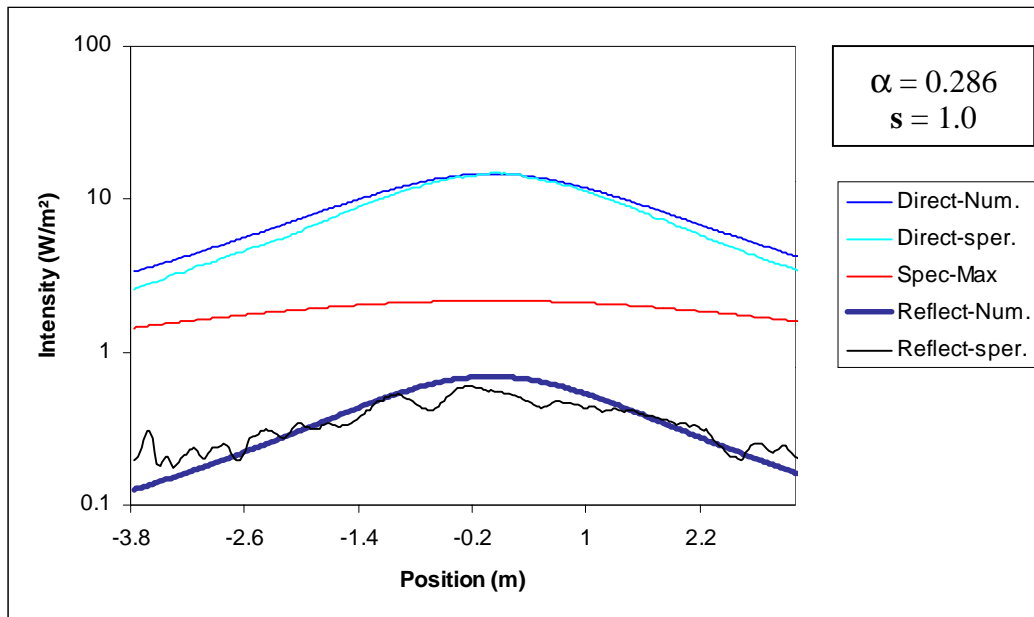
The following 4 pictures show the results obtained for the three already described panels (the curved panel is again considered twice, both along maximum and minimum diffusion directions).



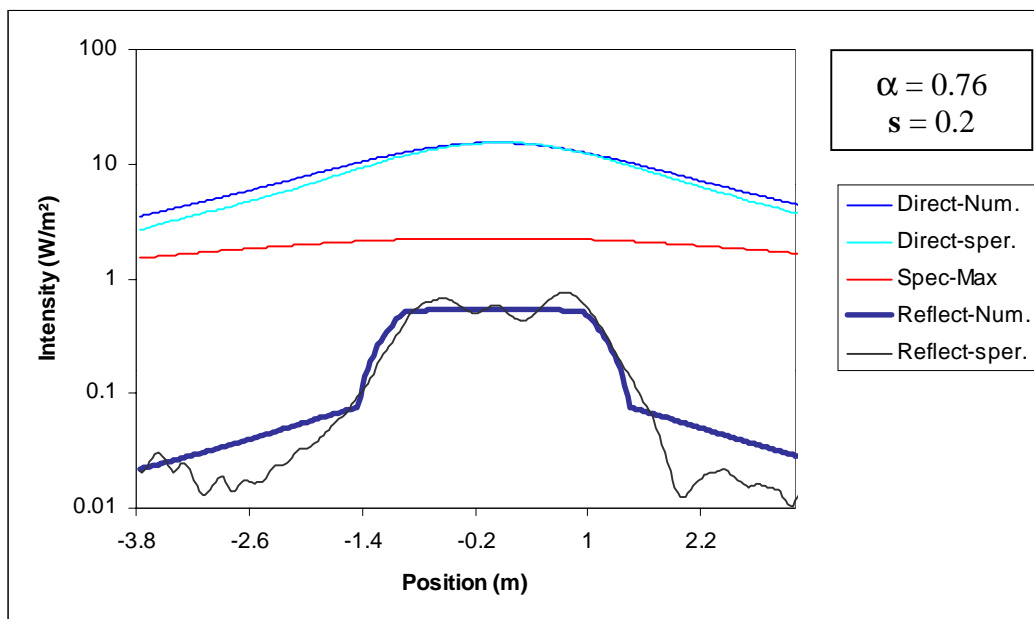
Matching between numerical and experimental data – Flat Panel



Matching between numerical and experimental data – Schroeder-type diffusor



Matching between numerical and experimental data – Curved Panel



Matching between numerical and experimental data – Curved Panel at 90°

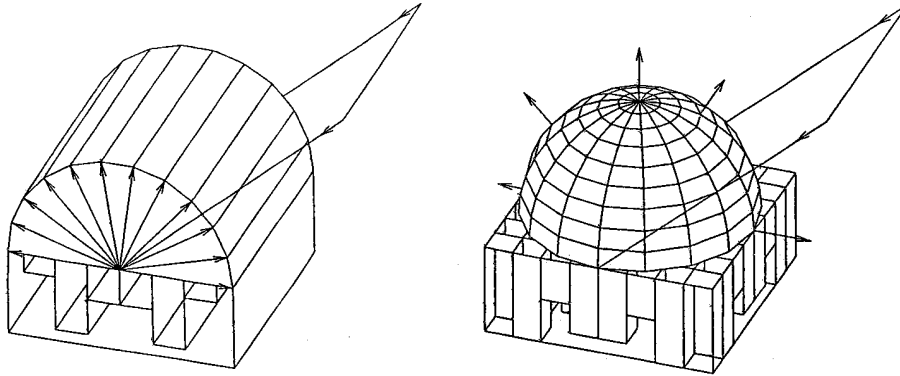
These results show clearly that the numerical formulation given here for the reflected sound field (including specular, scattered and edge diffracted contributions) can be made to adhere strictly with the experimental results.

Nevertheless, it is obvious that the scattering properties of surfaces which are inherently very different along the two orthogonal directions cannot be described accurately with a single value of α and s , but none of the actually employed room acoustics programs makes it possible to take into account for these effects, and so only an “average” value of the scattering coefficient can be assigned for characterising these not-isotropic surfaces.

Conclusion and future work

The results obtained with the two measurement techniques reported here are not completely satisfactory. The Mommertz/Vorlander approach revealed to work very badly for small samples, and the WFS approach is suitable only for panels which are substantially isotropic.

In most cases, instead, the scattering panels are designed to work more “cylindrically” than “spherically”, as shown from these two pictures:



Cylindrical diffusion (left) and spherical diffusion (right)

If these effects have to be properly modelled by room acoustics programs, it will be required to develop more sophisticated formulations for emulating the scattering phenomena within the framework of geometrical room acoustics (ray or beam tracing).

In this sense, the AES diffusion coefficient is defined in such a way that it can characterise both kinds of diffusing panels in a consistent way, but it suffers of its inherently qualitative nature (it is related to the uniformity of the reflected sound, not to the amount of energy moved from the specular behaviour to the diffuse one).

Furthermore, the AES measurement technique (which was not discussed here) is interesting for the capability of displaying graphically the actual angular plots of the reflected energy.

The future work will be based on the application of the ISO definition of the scattering coefficient and of the method proposed here for estimating the values of s and α by a best fitting procedure, but starting from a data set collected following the AES method instead of WFS.

This means that many impulse responses have to be measured, moving the microphone over an arch (or better over an hemisphere) instead of along a straight line. An enhanced treatment of spatial propagation will be needed (a sort of WFS in cylindrical or spherical coordinates, instead of Cartesian) for applying the spatial filters required for the extraction of the reflected impulse response.

Thereafter, provided that an enhanced numerical formulation of the reflected sound is made available (capable of describing not-isotropic scattering with a simple formulation), the best-fitting procedure will be applied for estimating the scattering and absorption coefficients.

It must be clear that, following this proposal, what will be measured are the “free field” scattering and absorption coefficients, suitable for computations made outdoors or indoor relating to the first reflections. In general, these coefficients are different from the “diffuse field” values: this is well known for the absorption coefficient, but for extension it should be the same also for the scattering coefficient.

Continuing in the comparison, it must be recalled that some room acoustic programs require as input the free-field absorption coefficient of the materials, as they employ the same deterministic equations for following the whole history of each ray (not-hybrid programs). On the other hand, there are programs that compute the reverberant tail with diffuse field statistical formulations (thus they require Sabine's absorption coefficients), whilst only the first reflections are treated deterministically (hybrid programs): usually these programs ask for the Sabine's coefficient, and possibly adjust it internally for the first reflection treatment.

The relationship between free field and diffuse field absorption coefficient was recently investigated [13], employing again a "best-fitting" technique for defining the optimal value of the absorption coefficient which fits better in different computation schemes.

So it can be concluded as a general remark that the proper values (of scattering and absorption) to be introduced in any computing box depends on what is within the box, and that different conceptual definitions can be given for each parameters, relating to different approaches. It is quite reasonable to think that, as it is now for the absorption coefficient, we shall end with two or three different definitions and standards also for the scattering coefficient: one will be the reverberant-room, diffuse field, random incidence coefficient (the one which is being standardised by ISO), a second one will be the free-field coefficient obtained with the impulse response method following the Mommertz/Vorlander approach evaluated in this paper (for large samples, of course), a third one could be the best-fitting approach also evaluated here, with the annotation that the fitting can be done with reference to different numerical models, and so this scattering coefficient should be named after the numerical model which is being best-fitted.

Comparative studies, as the one reported in [13] for the absorption coefficient, will be required for deriving general rules relating the different scattering coefficients together.

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