# Influence of scattering coefficient on the prediction of room acoustic parameters in a virtual concert hall.

# INFLUENCE OF SCATTERING COEFFICIENT ON THE PREDICTION OF ROOM ACOUSTICS PARAMETERS IN A VIRTUAL CONCERT HALL

Louena Shtrepi [a)], Sönke Pelzer [b)], Monika Rychtáriková [b), c)], Arianna Astolfi [a)]

[a)] *Politecnico di Torino, Department of Energetics, 10129 Torino, Italy*
[b)] *Aachen University, Institute of Technical Acoustics, 52056 Aachen, Germany*
[c)] *K.U. Leuven, Laboratory of Acoustics and Thermal Physics, 3001 Heverlee, Belgium*

**Abstract**: The scattering coefficient is one of the most important input parameters in room acoustics simulations. Together with absorption coefficient they belong to main descriptors of interior surface properties in the calculation process based on ray or radiosity method algorithms. This paper investigates the influence of scattered sound on the objective room acoustical parameters in the example of a virtual concert hall. Six different alternatives were simulated, where scattering coefficients s = 10, 30, 50, 60, 70 and 90 % respectively, were applied to the interior surfaces of the ceiling, side and rear walls. Analysis has been performed by studying the results of objective room acoustical parameters predicted by simulations done in the software Catt-Acoustic®.

## 1 Introduction

Developers of software for room acoustics prediction aim on reliability of calculated results, confirmed by sufficiently good fit with measurements. The scattering coefficient, among other parameters, enhances prediction accuracy and in many cases it is an essential component in an accurate model. This is valid mainly when simplifying the geometrical construction of 3D models in order to reduce modeling and calculation time. In the first Round Robin test in 1995 [1] it has been proven, that simulations with consideration of sound diffusion give more accurate values on the most important acoustical parameters. With an increased interest in auralized sound, based on room acoustic simulation a greater emphasis on diffuse reflection has been leant as well.

In recent years, two different measures of sound diffusion were introduced with somewhat different applications: the first one called *scattering coefficient* gives the quantity of scattered reflections, and the other one called *diffusion coefficient* is intended for evaluation of the quality of sound diffusers. A scattering coefficient is a measure of the amount of sound scattered in a different direction from the specular reflection and it plays an important role particularly in the late response. Using the diffusion coefficients in geometric room acoustic models is likely to produce incorrect results [2]. Thus, the more appropriate quantity to be used in simulation software is the random incidence scattering coefficient, rather than the uniformity diffusion coefficient [3].

## 2 Simulations

In this research, simulations were performed in the software Catt-Acoustic [4], that combines the Image Source Model (ISM) for calculation of the early reflection, and special ray-tracing with randomized Tail-corrected Cone-tracing (RTC) for full detailed calculation. Diffuse reflections in the late part are handled by randomizing the direction of reflected rays according to so called Lamberts distribution [5].

## 2.1 Description of the case study

The case study represents the project of a small music concert hall with about 480 seats, designed by ONLECO s.r.l., Turin, Italy. Its geometry is similar to a 'shoe box' characterized by a volume of $V$=2376m$^3$ and a total area of the interior surfaces $S$=1600m$^2$ with a simple rectangular planimetry (17 x 30m x maximal height of 7m) and a tilted audience area (Fig.1). It is slightly non symmetric and the stage position is not central to the symmetry axis. The stage has a simple geometry and is elevated from the floor plane of 0.8m (5.5 x 13.5m).

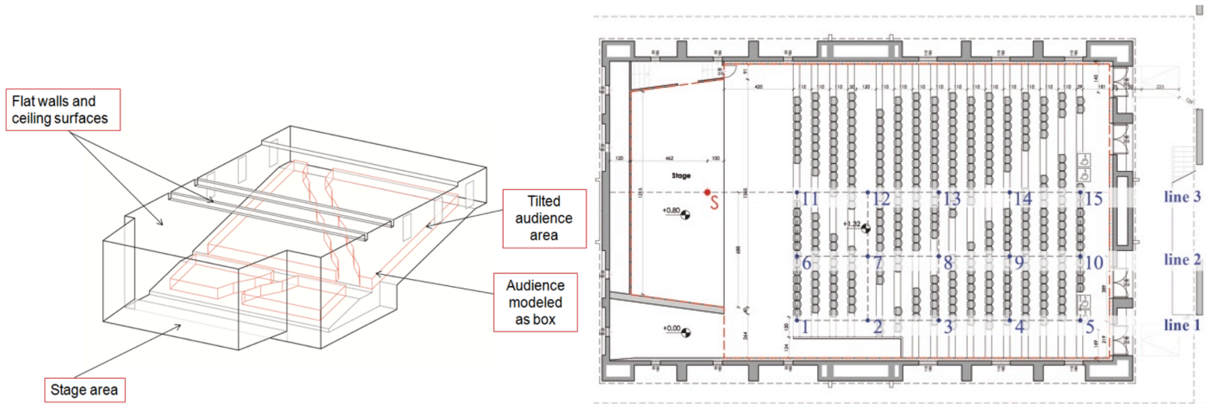


**Figure 1.** Hall's 3D model (left) and Set-up (source and receivers positions) as used in the simulation (right)

## 2.2 Simulation set-up

The 3D model was first designed with CAD software and the geometry of the hall was simplified in order to reduce the simulation time, though without compromising the resemblance to the real space it represents. The audience area was modeled as a volume of 0.8m height identified as a "box".

The same set-up of source and receivers was used in the six different simulation models. A simple omni directional source, with a sound power level of 90dB, was placed in the center of the stage at 1m distance from the front border, at 1.5m above the stage floor and far enough from the side walls to make sure the preservation of the source's features. Fifteen listener positions were simulated considering a crossed evenly spaced array distribution of 3.8m x 4.3m, and extended to one of the two symmetric halves of the audience area. The receivers were positioned at a height of 1.2m from the floor level under each seat (0.4m above the "box" upper plan).

The hall was considered in an unoccupied state. The material properties such as sound absorption and scattering coefficient were defined for each octave band frequency and assigned according to the project documentation and the simulation system was designed so that standard objective parameter values were typical of those found in real halls, and within the ranges recommended by the standard ISO 3382-1 [6].

Six simulations were performed varying the scattering coefficient values of the side and rear walls, and ceiling (s=10, 30, 50, 60, 70, 90%). The absorptive characteristics of the hall were kept the same in all scenarios. To enable the comparison between alternatives, the same boundary conditions such as absorption of materials, temperature and humidity of the interioe air were considered for all the simulations, and the same settings (transition order, number of rays), type of source and receiver, and source-receivers' positions were kept (Fig.1-right).

## 2.3 Evaluation parameters

Assessment of the case study-concert hall has been done with a respect to room acoustic parameters as defined in the ISO 3382-1 [5]. The following parameters were predicted for each model: Reverberation time ($T_{30}$), Early Decay Time (*EDT*), Clarity ($C_{80}$), Strength (*G*), Definition ($D_{50}$) and Lateral Energy Fraction (LF), and the analysis was performed by studying the results of this objective room acoustical parameters versus the changing values of scattering coefficients on one hand (Fig. 3), and versus source to receiver distance and distance from lateral walls on the other hand (Fig. 2).

## 2.4 Results

Figure 2 shows values of $T_{30}$, $C_{80}$ and *G* concerning three degrees of scattering values: 10%, 50% and 90% (representing the low, medium and high diffusion respectively). In the presented graphs averages of octave bands 500-1000 Hz in each receiver position are given.

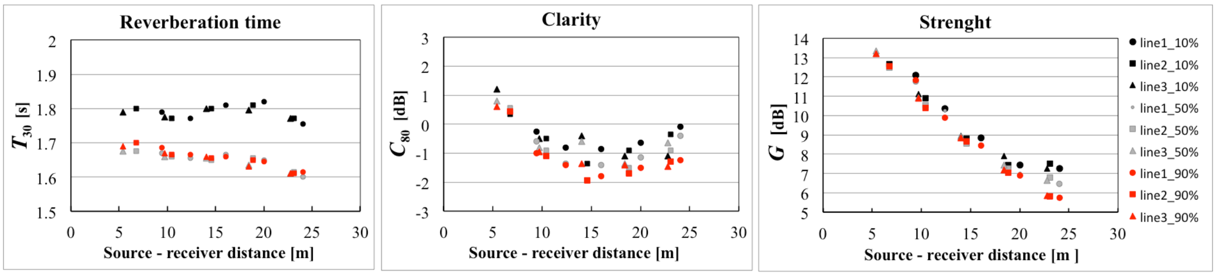


**Figure 2.** $T_{30}$, $C_{80}$ and G values versus source to receiver distance

The dependence of each parameter on source to receiver distance is shown for each of the three cases of scattering coefficients. The data are organized for each receivers' row and the symbols (circles, squares and triangles) show results for each "line" (see Fig.1) depending on the distance from the side walls; and third, each color (black, grey and red) give information on how the parameter changes in the same position or row when the scattering coefficient values increase.

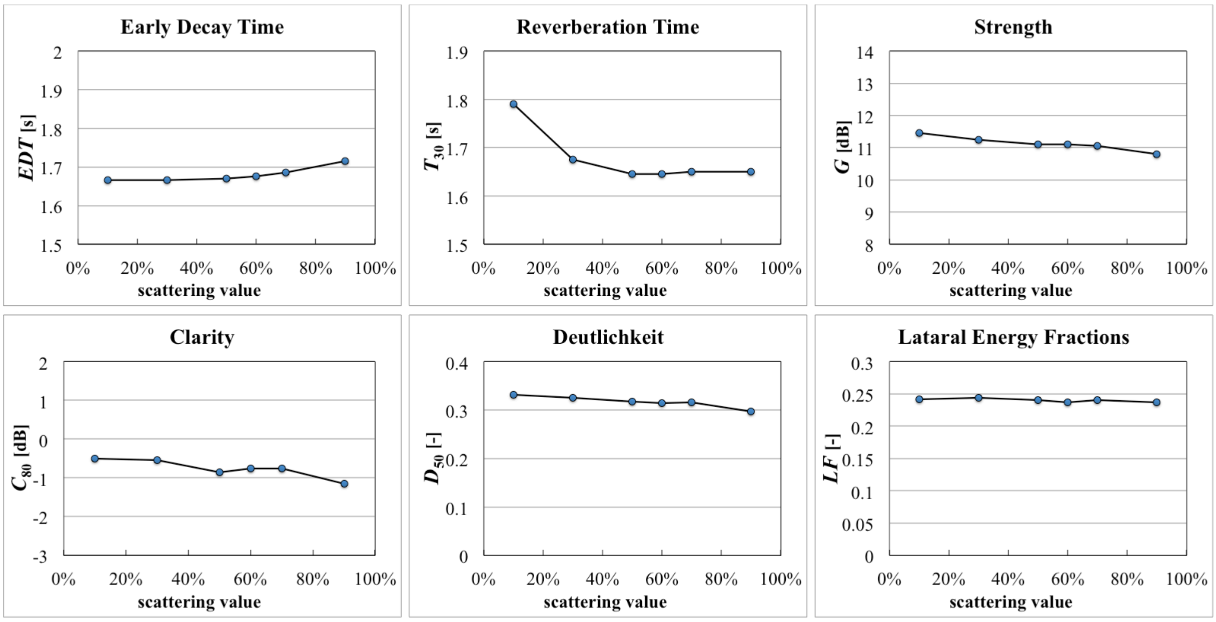


**Figure 3.** Parameters values versus scattering

Figure 3 shows the behavior of each parameter as depending on scattering value from 10% to 90%. Shown results (Fig.3) are averaged values of all the receiver positions for octave bands as prescribed in the ISO 3382-1.

## 3 Conclusions

In this study six alternatives in a virtual hall model have been simulated, based on six different values of scattering coefficient applied on a ceiling, side and rear walls. It can be concluded that values of acoustical parameters are mainly dependent on the distance between source and receiver. However some slight differences caused by the distance from the lateral walls were found for $C_{80}$. The influence of scattering on $G$ and $C_{80}$ values can be noticed in the last row positions (Fig.2). It has been found that higher values of scattering cause lower values of $T_{30}$, $C_{80}$, $G$ *and* $D_{50}$. It turned out that scattering has no influence on *LF* and *EDT* values (Fig.3).

Based on this preliminary study, future works may lead to the investigation of the objective acoustical parameters in a larger number of halls, and not only by simulations in other available acoustical predicting tools.

## References

[1] Vorländer, M. (1995): International round robin on room acoustical computer simulations*,* Proc. 15th ICA, Trondheim, Norway, 689-692.

[2] Cox, T. J., Dalenbäck, B-I. L., D'Antonio, P., Embrechts, J. J., Jeon, J. Y., Mommertz, E. and Vorländer M. (2006): A tutorial on scattering and diffusion coefficients for room acoustic surfaces, Acta Acustica, 92, 1-15.

[3] ISO 17497: Acoustics - Measurement of sound scattering properties of surfaces – Part 1: Measurement of the random-incidence scattering coefficient in a reverberation room.(ISO 17497-1 2004); Part2: Measurement of the directional diffusion in a free field (DIS 2007).

[4] CATT-Acoustic® v 8.0. Unlimited education/research version, Laboratorium Bouwfysica, K.L. Leuven, BE: http://www.catt.se

[5] Kuttruff, H. (2000): Room Acoustics, 4th ed., Spon, New York.

[6] ISO 3382: Acoustics - Measurement of room acoustic parameters - Part 1: Performance spaces (ISO 3382-1:2009).