Investigation of Scattering Coefficient of Everyday Furniture

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Introduction

In recent years, the scattering coefficient has been more and more integrated in room acoustics computer simulation as it significantly improves the precision and accuracy of simulation results [1,2]. The scattering coefficient offers a handy description of diffuse reflections of the sound field: it is defined as the ratio of the non-specularly reflected sound energy to the totally reflected energy [3]. The measurement method has already been developed and standardized by ISO [4]. Nowadays, the available scattering coefficient data are mainly related to architectural surfaces with different patterns and structures [5]. A lot of effort has also been put on the determination of numerical methods for calculating this coefficient beforehand [6,7]. Despite all, investigation on common objects has rarely been performed and there is still a lack of scattering coefficient data, especially for items that are commonly present in closed spaces, such as chairs, desks, bookshelves. This aspect is of primary interest particularly for environments, such as classrooms, churches or concert halls, where furniture constitute a large part of the total scattering surface.

This paper presents a preliminary study for improving the accuracy of room acoustics computer simulations by quantifying the influence of pieces of furniture on the sound field reflections in terms of scattering. Acoustical measurements in a real furnished room are carried out and afterwards compared with subsequently simulation results.

Scale Model Measurement Setup

Measurements have been performed in the scale model reverberation chamber at the Institute of Technical Acoustics in Aachen. The scale model has a volume of approximately 1 m^3 and a surface area of 6.07 m^2. The diffusion in this room has been improved by using three PVC diffusers hanging on the ceiling. Measurement devices include a turntable with a flat base (having a scattering coefficient in accordance with the ISO Standard [4]), two sound sources (a cylindrical loudspeaker for low frequencies and a piezoelectric dodecahedron for high frequencies) covering a frequency range of 1-80 kHz, two ¼" precision microphones and an audio interface with 192 kHz sampling frequency. A sweep was used as test signal and 72 measurements (with 5° turntable angular steps) for three different source-receiver positions were performed. Because of strong air absorption, the measured reverberation times at high frequencies become very similar. Moreover, several time variances effects, such as small steady changes in air temperature or humidity, result in a severe decrease of the measured reverberation time, especially at high frequencies. For these reasons, only results up to 50 kHz (5 kHz for the real scaled frequency) will be shown, since the data in the range 50-80kHz are affected by a significant error.

Samples under investigation

Several pieces of furniture have been built in a scaled version model with ratio 1:10 (see Figure 1). Samples are made up of balsa wood and reflect the design of common real objects. In this first study only results associated with chairs and desks will be presented.

Figure 1: Scaled pieces of furniture (scale 1:10).

Four different spatial configurations have been investigated (Figure 2). In a first layout, a matrix of 48 chairs has been placed in a squared recess. The sitting height of the chairs has been mounted flush with the height of the recess, in order to avoid border effects [8]. A wooden grid has been used for realizing a faster and precise spacing between samples.

In a second configuration, 12 desks have been placed in a three rows matrix inside a squared recess in order to reproduce the exact layout of a real lecture room. No spacing has been left between the desks.

In a third configuration, 24 chairs have been added to the desks configuration.

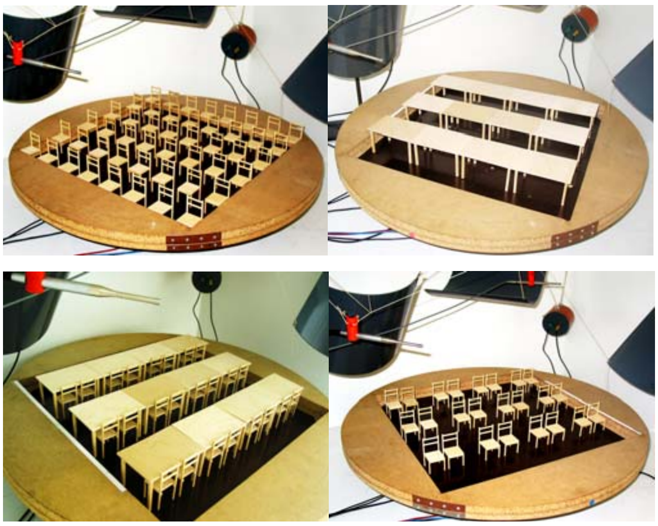

Figure 2: Furniture configurations under investigation.

In a fourth configuration, desks have been removed and only 24 chairs, in a "paired" placing, have been measured. Resulting scattering coefficients are showed in Figure 3.

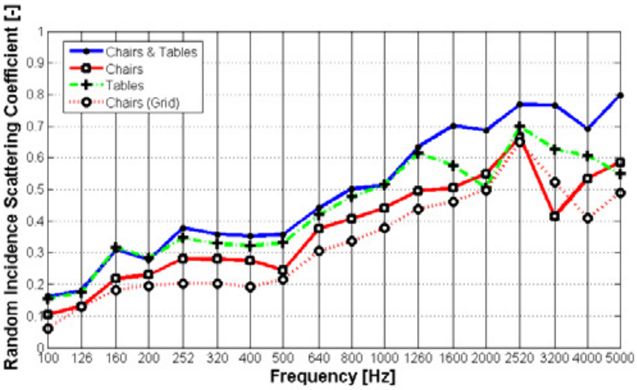

Figure 3: Measured scattering coefficient (four configurations).

Real Environment Measurements

Measurements have been carried out in the lecture room G4 at RWTH Aachen University. This room has an approximate square shaped footprint with a surface area of 510 m^2 and volume of 520 m^3. It contains 60 chairs and 30 desks, which constitute the main scattering area together with the ceiling. Seven microphone positions were chosen, all located in between the last two desks rows. A dodecahedron speaker, located approximately on the teacher desk position, was used as sound source. The measured reverberation time was 0.8 s.

Simulation

An acoustic simulation of the lecture room has been execute with the hybrid room acoustics simulation software RAVEN [9]. This software uses a real-time hybrid method that combines deterministic image sources to ensure an exact localization of sound sources with a stochastic ray tracing algorithm for determining the late reverberant sound field. The simulation model consisted of 147 polygons, a fourth order image source setup and thirty thousand ray tracing particles for each frequency band. Figure 3 shows a screenshot of the running simulation. The scattering coefficient data measured in the third configuration (see Figure 2) have been used for describing the area occupied by desks and chairs.

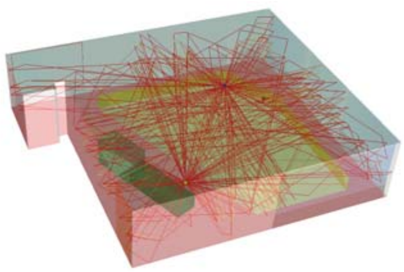

Figure 4: Lecture room simulation (one source, two receivers).

Results and Conclusions

A comparison between the decay curves as obtained from measurements and from the simulation is depicted in Figure 5. The decay curves exhibits high similarities in each frequency band, except for some ripples present in the measured decay curves. The use of measured values of scattered coefficient in the computer simulation improved significantly the precision of results, thus confirming the importance of using proper values for scattering surfaces.

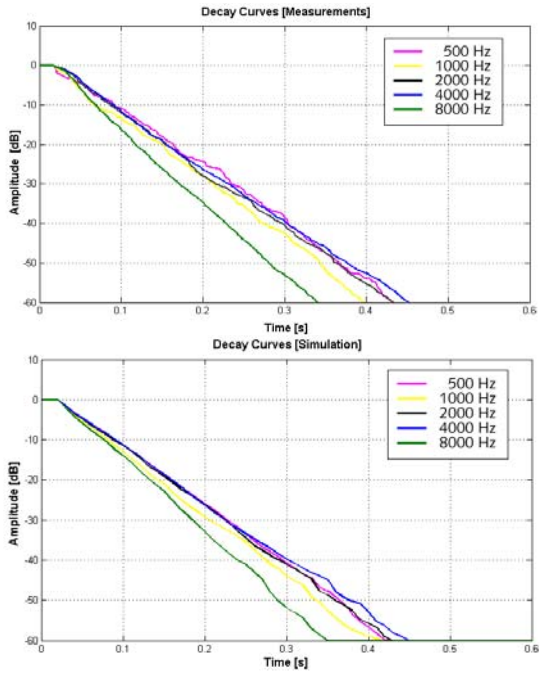

Figure 5: Measured and simulated decay curves.

Future perspectives include further investigations on several surfaces, the creation of a scattering coefficient database, as well as an analysis on the influence of the scattering coefficient on listeners perception.

References

[1] Bork,I., A comparison of room simulation software – The 2nd round robin on room acoustical computer simulation. Acustica united with Acta Acustica **86** (2000) 943-956.

[2] Lam, Y.W., A comparison of three diffuse reflection modelling methods used in room acoustics computer models. J. Acoust. Soc. Amer. **100** (1996) 2181-2192.

[3] Vorländer, M. et al., Definition and measurement of random-incidence scattering coefficients, Applied Acoustics **60** (2000), 187-199.

[4] ISO 17497-1, Acoustics – Measurement of the sound scattering properties of surfaces – Part 1:Measurement of the random-incidence scattering coefficient in a reverberation room. 2004.

[5] Jeon, J.Y. et al., Development of scattering surfaces for concert halls, Applied Acoustics **65** (2004), 341-355.

[6] Kosaka, Y. et al., Numerical examination on scattering coefficients of architectural surfaces using the boundary elements method, Acoust., Sci. & Tech. **26**, 2 (2005).

[7] Embrechts, J.J. et al., Calculation of the random-incidence Scattering Coefficients of a Sine-Shaped Surface, Acustica united with Acta Acustica **92** (2006), 593-603.

[8] Gomes, M., et al., Aspects of the sample geometry in the measurement of the random-incidence scattering coefficient, Forum Acusticum, Sevilla (2002).

[9] Schröder, D. et al., Hybrid method for room acoustic simulation in real-time, ICA, Madrid (2007).