The influence of single scattering objects for room acoustic measurements

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Introduction

The uncertainty of room acoustic measurements is influenced by a variety of influence factors such as noise [3], directivity of the loudspeaker [4] or temperature changes [5]. This study approaches to the question if and to which extend the presence of the measurement operator in an empty auditorium has an influence on the evaluated room acoustic parameters.
For room acoustic measurements according to ISO 3382 [1], several sender-receiver combinations has to be measured to describe a room. It is common practice that the measurement operator who moves the microphones is not leaving the room during the measurements, but to save time moves a few meters away. The body of the person is a scattering object that might introduce new reflections, diffraction or shadowing of existing reflections. Thus the impulse response and the evaluated parameters might change.
The knowledge about the effect of scattering objects on room acoustic parameters is also important for room acoustic simulations. It indicated to which level of detail part of the room (such as pillar or furniture) has to be modeled to obtain reliable results.

Measurement Setup

The measurements have been conducted in the general assembly hall of RWTH Aachen University. The auditorium is mainly used for lectures and classical concerts and has a rectangular shape, a volume of 5500 m³ and 600 seats. The dodecahedron loudspeaker was placed on the stage at the position of the soloist. A life-sized dummy of an adult person was used as scattering object. It was placed in the middle of the audience area and three line arrays of microphones were installed around it (see Figure 1).

Array A is positioned behind the scattering object in one line with object and loudspeaker modeling a shadowing effect. This construction simulates the situation when the measurement operator stands in line of sight between source and receiver during the measurement. Six microphones with distances from 0.6 m to 3.4 m from the dummy allow an analysis regarding different microphone-scatterer distances.
The second array, named B, is installed perpendicular to the source-scatterer axis in one line with the scattering object. This scenario represents the situation when the measurement operator stands next to the microphone. In this configuration the scattering object might shadow some reflections from the side wall or cause some new reflections or scattering.
The third array (C) is placed between scattering object and source, simulating the measurement operator standing behind the measurement microphone. In this situation the dummy might change the sound filed due to new reflections and shadowing of reflections form the back. All tree line arrays are used simultaneously.

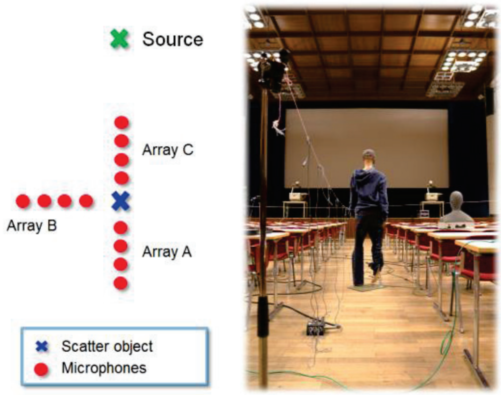

Figure 1: Overview of the measuring arrangement on the left side and photo of the measurement on the right.

The measurements were performed with and without the scattering object in the middle to analyze the differences in detail. The measurement session consists of 7 parts, where during every part the condition if the scattering object is present or not, is changed. The first four parts last one hour each and the last three parts half the time.
The two different conditions are fragmented on purpose, to distribute long term time variances of the room or the measurement system (i.e. temperature changes in room or equipment) equally on both conditions. This way long term changes don't have an influence on the analysis.
During the measurements no persons were present in the auditorium. The measurements when persons were in the auditorium to place or remove the scattering object are excluded from the analysis.

A measurement script started the acoustic measurement, measured temperature and relative humidity using 8 sensors distributed in the room and saved the results. After a short break of a few seconds the procedure starts all over again, providing around 150 measurements per hour. The large number of repetitions in each measurement part allows a statistical analysis that distinguishes between the scattering object and other factors of random measurement uncertainty.

The measurements and the room acoustic parameter evaluation have been done using the ITA-Toolbox, an open source toolbox for Matlab [2]. Measurement, equipment and evaluation are compliant with ISO 3382-1 [1].

Results

Figure 2 shows the evaluated reverberation time T_{20} for the 500 Hz octave band at two different microphone positions. In the upper part, it can be seen that the two different configurations can clearly be separated from each other. The scattering object shows a reproducible influence for this microphone position (object 2.5 m behind the microphone) that is clearly larger than the remaining random fluctuations. The relative difference between the two configurations is <

3%. Figure 2 bottom shows the same analysis for a different microphone position (object 2.6 m in front of microphone). The differences between the two configurations are unclear and in the same order of magnitude as the fluctuations in one measurement part.
These two results are typical for all occurring results. However, they are not typical for the microphone positions. There is no detectable correlation between the results and location of the microphones, distance to the scattering object or frequency band.

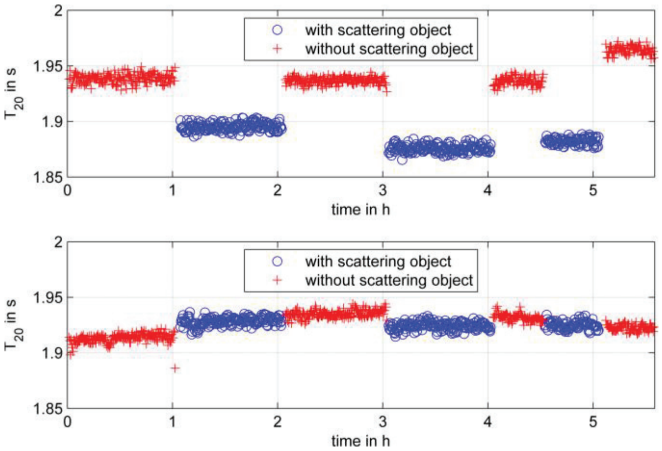

Figure 2: Reverberation time T20 over the measurement period of .5 hours. The measurements with scattering object present are marked with (blue) circles and without wit (red) crosses.

ANOVA Analysis

The analysis of variances (ANOVA) compares the mean value and the variances of two groups of data and states if these two groups are different or if they are random samples from the same population. The presence of the scattering object is the independent variable and defines the two groups for the dependent variable – the reverberation time T_{20}.

In a first step a one-way ANOVA was applied to every microphone position and every frequency band separately to investigate if the scattering object has an effect. Figure 3 shows the results. The different arrays are arranged in three blocks, where every horizontal row represents one microphone position. From bottom to top (in each block) the distance from microphone to scattering object increases from about 0.2 m to up to 4 m. On the x-axis the center frequencies of the octave band filters are shown. The colors indicate the significance ($p < 0.01$) of the scattering object on the reverberation time (green for significant, red for insignificant).
For the lowest frequency band of 62.5 Hz the scattering object has no influence in most cases. The high uncertainty of the ambient noise in low frequencies causes fluctuations that are larger than the scattering object.
The majority of the remaining bands show a significant effect of the dummy. The few band-microphone combinations that show no effect don't indicate a systematic dependence on the frequency band or the distance to the scattering object.
It seem that the microphone array perpendicular to the source-scatterer axis (B) show more insignificant results.

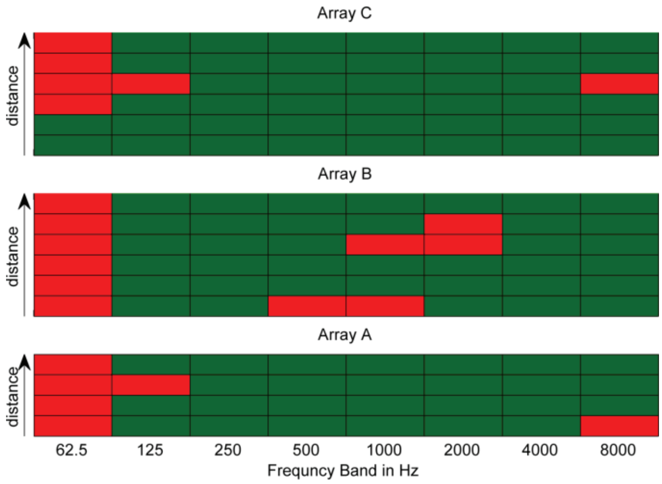

Figure 3: Results for the ANOVA analysis for every microphone position and frequency band. Significant effects of the presence of the scattering object are marked in green and insignificant in red.

Conclusion

The measurements showed a clear effect of a human scattering object in an auditorium on the reverberation time $T_{20.}$ The ANOVA showed a significant effect ($p<0.01$) for the majority of frequency bands and microphone positions.

However, the mean difference between the two situations is smaller than the just noticeable differences for reverberation time (5%). For standard room acoustic measurement the relevance of this error is rather low and compared with other influences the result in uncertainty is of same of higher magnitude. For lateral fraction with emphasis on the strong early reflections, however, the effects of the scatterer are not yet known, which is under investigation in next steps.
For measurements where the focus is on precision of the results, the measurement operators should not stay around the microphone.
For smaller rooms such as reverberation chambers the error is expected to increase.

References

[1] ISO 3382-1: Acoustics – Measurement of room acoustic parameters – Part 1: Performance spaces. International Organization for Standardization (2009).

[2] ITA-Toolbox. A MATLAB Toolbox for the needs of acousticians, http://www.ita-toolbox.org/ (2015)

[3] Guski M., Vorländer M., Comparison of Noise Compensation Methods for Room Acoustic Impulse Response Evaluations, Acta Acustica united with Acustica 100 (2014), 320-327

[4] Knüttel1 T., Witew I. B. and Vorländer M., Influence of "omnidirectional" loudspeaker directivity on measured room impulse responses, Journal of the Acoustical Society of America, Vol. 134 (2013)

[5] Guski, M. and Vorländer, M., Uncertainty of room acoustic parameters caused by air movement and temperature changes. DAGA 2014 (2014)