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The Acoustic Camera as a valid tool to gain additional information over traditional methods in architectural acoustics.

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Abstract

The use of beamforming systems in architectural and building acoustic areas, to describe the acoustic field and localize construction irregularities, start to be frequent. These systems offer the possibility to measure the acoustic characteristics of a room, and localize with accuracy reflections and airborne sound transmission paths between rooms.
This study case presents a variety of acoustic measurements carried out with a 3D beamforming system, emphasizing the results of the reverberation time measurements and comparing them with those given by a sound level meter type 1. All the measurements have been accomplished in two adjacent halls with similar dimensions following the ISO 3382.

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Keywords: Acoustic Camera; Beamforming; sound localization; architectural acoustics; new measurement methods

1. Introduction

The use of different simulation techniques during the building or renovation process of enclosed spaces meant for speech and musical events is extended between architects and acousticians in order to obtain an overview of the acoustic characteristics of the room in question. Each of these simulation techniques has its advantages and limitations. The "In situ" measurements are those considered most reliable due to the difficulty to calculate various

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aspects of the reality as air absorption, materials absorption and diffusion coefficients inherent to field measurements [1].

The beamforming is a new technique that offers the possibility to cover partially the gap of the simulation programs, with "in situ" measurements, offering a visual overview of the acoustic field of an interior. The vast field of applications of beamforming have been presented in the last 20 years, mainly related with the industry [2, 3], but the field building and architectural acoustics has been introduced at the same time that a new technique using 3D- microphone array around 10 years ago [3,6,7,8,9].

The aim of this study is to identify the Acoustic Camera as a valid tool for architectural and building acoustics purposes, comparing the results obtained with this technic with the results obtained with a sound level meter type 1, adding some extra valuable results, as visual airborne transmission path localization.

2. Experimental procedure

2.1. Measurement objects

To reach the goal of this study, the acoustic characteristics of two empty rooms, 13,5m x 12,5m x 3,5m, separated by a movable wall - were analyzed. The rooms are used for meetings, congresses, symposiums, weddings and other events. The multipurpose character of the rooms poses a challenge when the time comes to decide how to design the acoustics of the rooms. Particularly reaching ideal acoustic characteristics desired for music and/or for speech depending on the function to be held is a big challenge. In the case of the two rooms under study, the decision was already taken by the acoustic designer who had chosen to treat the roof of one of the rooms ("Conrad") with a not covered absorption material (Basotect®).

2.2. Measurement set-up

2.2.1. Sound Level Meter

Following the ISO standard suggestions (ISO 16283-1:2014, ISO 717-1, ISO 3382) the apparent sound reduction index (R') and the reverberation time (T20) were measured using a sound level meter. To carry out the apparent sound reduction index measurement, ten measurements and one sound source position were chosen and marked on the floor of each room. These positions are distributed randomly covering the whole surface of each room.

The reverberation time was measured in four measurement points in each room. The sound source used for this purpose was a starting pistol.

2.2.2. Beamforming system: Acoustic Camera

As a complementary method to those suggested by the ISO standards, a 3D-microphone array was used to measure both rooms. This system use beamforming algorithms on the 3D Model [4] of the rooms. For the measurements, a 120-channel spherical and acoustically transparent microphone array with a diameter of 60cm was used.

By the measurements carried out with the array, a 30 second logarithmic sweep (20Hz - 20kHz) was played over a dodecahedron loudspeaker and recorded at 192kHz (sampling rate). The advantages of using a sine sweep for room and building acoustics purposes have been presented by Barré et al [6]. Post-processing was carried out in the software NoiseImage, where a room impulse response was calculated from the recorded sweep. Based on the room impulse response, reverberation time and other relevant parameters were calculated. Furthermore, the impulse response was used for a visual analysis of (early) reflections and leakages in the movable wall.

3. Results

3.1. Sound Level Meter

3.1.1. Reverberation Time

The results showed a notable decrease in reverberation time, especially in lower and middle frequencies - Figure 1.

The results obtained with the sound level meter showed a higher absolute error in lower frequencies than in higher frequencies. Nevertheless, the absolute error of the measurements done is less than 2% in those measured in room “Arnold” and around 6.5 % in room “Conrad”.

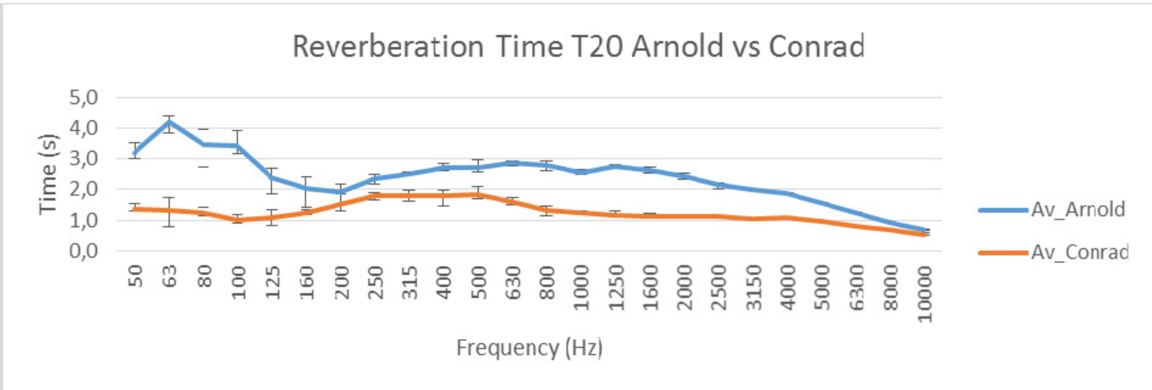

Fig. 1. Reverberation Time in both rooms, with the absolute error for each third-octave band – Sound Level Meter.

3.1.2. Apparent Sound Reduction Index

The sound insulation effect of the movable wall between both rooms was measured and calculated following the ISO standards. The results showed an apparent sound reduction index of 32dB. The abrupt diminution of the index in the frequency range of 600Hz - 800Hz stems from insulation effects by the movable wall – Figure 2.

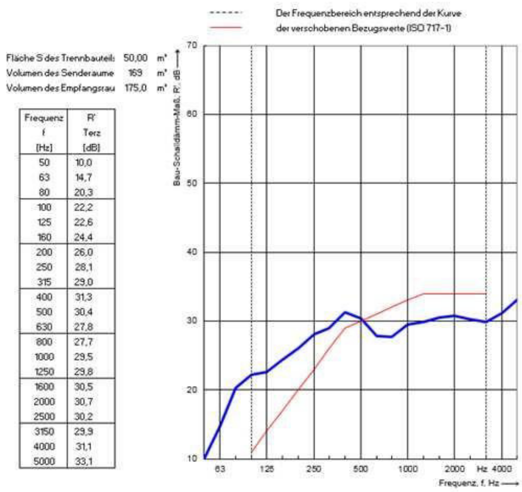

Fig. 2. Detail of the Apparent Sound Reduction Index report of the movable wall.

3.2. Beamforming system

3.2.1. Reverberation Time

The results obtained with the beamforming system shown similar results to those measured with the sound level meter, besides the coherence of the measurements with microphone array is higher than the coherence of the measurements with the sound level meter, having with the beamforming system an absolute error of the average of the measurements done of 5% in those measured in room "Arnold" and 3 % in room "Conrad". Besides the absolute error of the measurements in the frequency range, is notable higher in the frequencies below 200Hz and in the frequencies above 8 KHz – Figure 3.

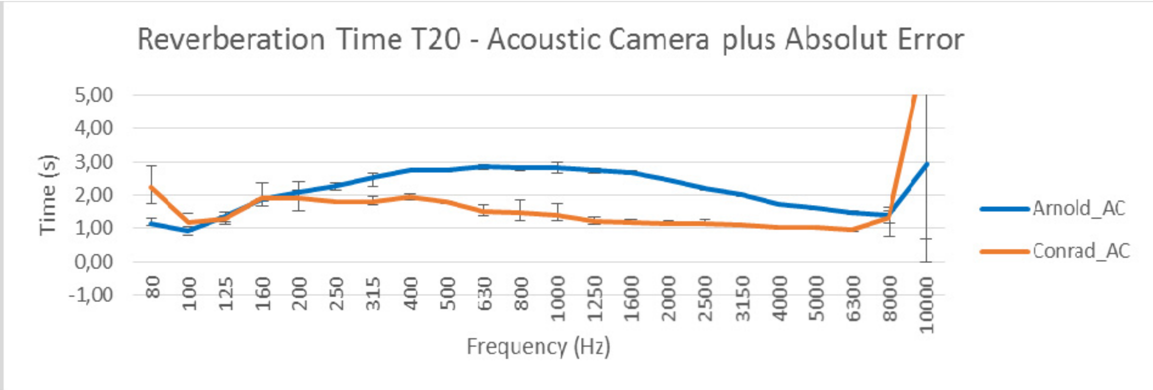

Fig. 3. Reverberation Time in both rooms, with the absolute error for each third-octave band – Acoustic Camera.

The comparison of the results given by both methods is shown in the figure 4, where the difference of the reverberation time values for the central frequencies is minimum. The biggest difference is appreciated in the frequency range below 200 and above 8 KHz.

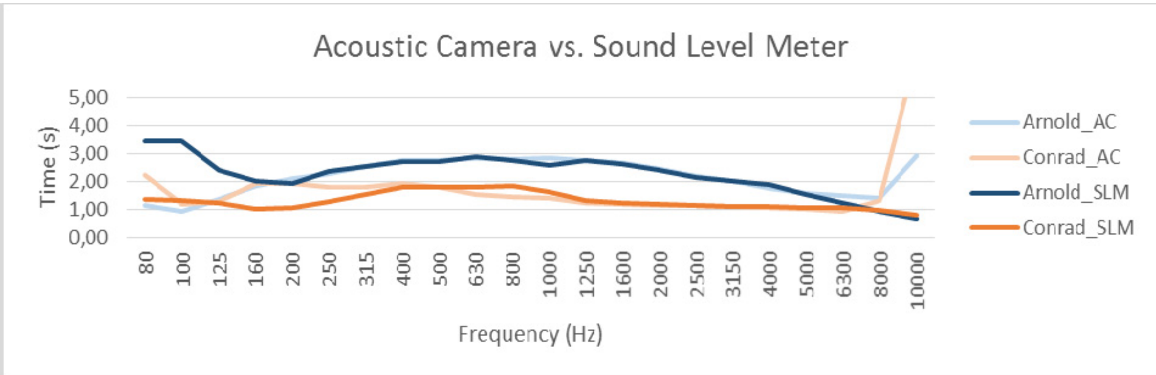

Fig. 4. Comparison of the Reverberation times measured with both methods.

3.2.2. Analysis of Reflections

Localizing early reflections in a room is crucial for a better understanding of the room's acoustics and – in conclusion - to be able to manipulate (redirect or eliminate) it to the desired effect.

The effect of the acoustic treatment of the room is seen directly in the acoustic maps. One example is the third reflection shown in figures 5(a) and 5(b). Figure 5(a) (room "Arnold") shows a more focused and louder reflection than figure 5(b) (room "Conrad") where the acoustically treated room absorbs most of the energy.

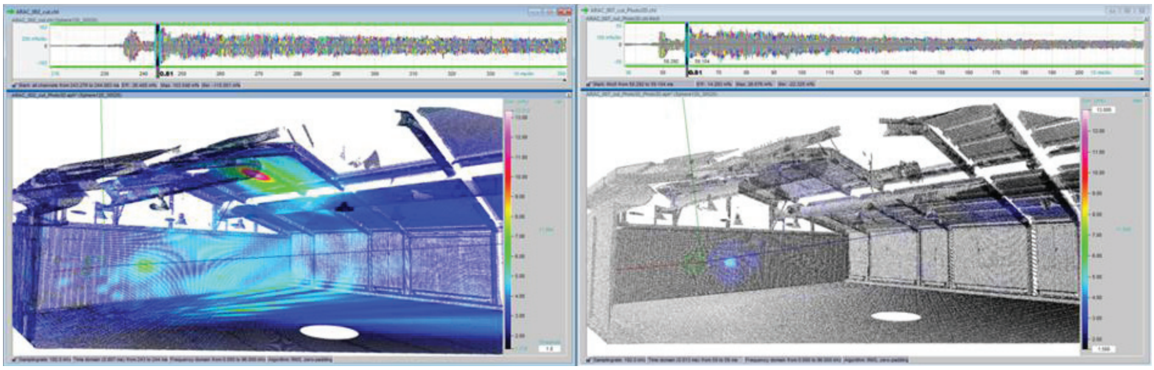

Fig. 5. Third reflection (a) room Arnold (b) room Conrad – with absorbent material.

3.2.3. Leakages

Detecting sound leakages is one of the harder and rather tedious jobs in room and building acoustics. Such leakages often stem from mistakes committed during the building design phase or even during the building process itself. There are numerous technics to carry out leakage tests but all of them are very time consuming.

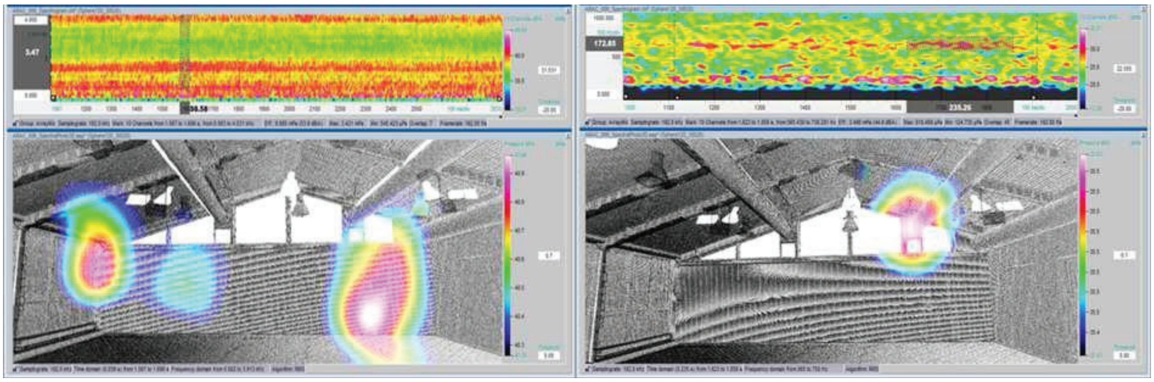

Fig. 6. (a) General analysis wide-frequency-band (b) detail frequencies between 400Hz-800Hz

Using the Acoustic Camera helps simplifying this process to a single measurement and the results are quickly and clearly displayed as shown in figure 6(a). Here the end of the movable partitioning wall at the left side and the door are identified as the weaker parts of the wall.

As shown in the results of the Apparent Sound Reduction Index, in the frequency range between 600 and 800Hz the R' decreases abruptly. When analyzing this frequencies with the post-processing program, The Spectrogram shows a higher energy in this frequency range, when it is mark, the sound source is localized at the end of the ventilation tube, up to the movable wall Figure 6(b).

4. Conclusion

The Acoustic Camera has proved to be a valid and helpful tool for room and building acoustics purposes. The comparison between the reverberation times measured with either system confirms the high reliability of the measurements results. Nevertheless, there is still room for improvement in the lower frequencies ranges (<200Hz), and in frequencies above 8 kHz. For the other acoustic parameters, even though the results are promising, a more detailed research similar to the presented in this paper must be carried out.

Using a beamforming system as a complementary tool to a sound level meter helps shedding light on the results given by the sound level meter.

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