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THE INFLUENCE OF EXCITATION TYPE ON REVERBERATION TIME MEASUREMENTS

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Abstract: *The goal of this paper is to compare the results of reverberation time measurements obtained with different sound sources (both loudspeakers and other types of excitation) using the impulse response measurement method. Loudspeakers of different directivity and size were used (including a subwoofer) in order to determine the possible influence of these properties on the results of measurements. Other types of excitation were inflated balloons of different sizes, pistol shots, firecrackers, hand claps etc. The spectral content and the obtained sound pressure level of each source were investigated in order to find the limits of the source itself.*

Key words: reverberation time, sound source, excitation type

1. INTRODUCTION

Reverberation time is one of the most important parameters in architectural acoustics. It is regarded as the predominant indicator of acoustical properties [1]. There are other acoustical parameters of a room, for example early and late energy ratios, lateral energy fractions, relative sound pressure level etc. But nevertheless, reverberation time is considered to be the most important one, giving a rough estimation of how a certain room will serve its purpose in terms of intelligibility or pleasantness. There are a number of different methods for measuring the reverberation time. These are: interrupted noise method, integrated impulse response method, simple response to an impulsive source, burst method. Another paper deals with the different methods of measuring reverberation time and the possible differences and/or problems with various methods [2].
The measurement chain always consists of a sound source, a receiver in form of a microphone, a room which produces various reflections and couples the source and the receiver, and a device for recording / analyzing the incoming sound on the receiver side. The microphone is a less critical part of the equipment, the demand on it is to be omni-directional, at least in the frequency range considered for the measurements. This can be easily achieved using even a less expensive electret microphones. The most critical part is the sound source because it has to fulfill certain demands.

2. THE DEMANDS ON THE SOUND SOURCE

The demands on the sound source [1] can be summarized as follows:

- omni-directivity (or as close to it as possible)
- sound pressure level high enough to provide a minimum required dynamic range (at least 45 dB for techniques without synchronous averaging).

Furthermore, it is recommended that pistol shots and balloon bursts should be avoided because of their lack of repeatability.
These demands clearly indicate that an omni-directional loudspeaker would be the best type of sound source for use in reverberation time measurements. Nevertheless, in certain situations such measurements cannot be properly performed, e.g. if only a real, directional loudspeaker is available, or even when there are no loudspeakers at all. The goal of this paper is to compare the most common sound sources used for reverberation time measurements and to comment on the results obtained from these measurements.

2. EXCITATION TYPE

The following sound sources were used for comparison:

1. An omni-directional loudspeaker ZEA – OS 1 Max
2. A Yamaha MSP5 near-field monitor
3. A TOA 38-SD sound reinforcement loudspeaker
4. A Yamaha SW10 active subwoofer
5. Balloons of various sizes (inflated from 80 to 160 cm in circumference)
6. Pistol blanks 6 mm and 8 mm

Although it is common to measure the reverberation time in octave frequency bands with center frequencies from 125 Hz to 4 kHz, the frequency range for this paper was extended to center frequencies of 62.5 Hz and 8 kHz as well.

The time and frequency characteristics of the impulsive sound sources have been described previously [3] with the conclusion that 6 mm and 8 mm pistol blanks as well as standard-size balloons (80 cm in circumference) provide enough sound pressure level to fulfill the requirement on the dynamics to be greater than 45 dB if the noise level in the room of interest is reasonably low. All three sources provide similar spectral content, however, the 6 mm pistol blank lacks in low frequency content compared to 8 mm blank and the balloon (which has the richest low frequency content).

Fig.1. The omni-directional sound source (on the right).

The loudspeakers were chosen to represent 4 typical scenarios for measuring the reverberation time: an omni-directional loudspeaker, with or without a subwoofer, a big passive box used for sound reinforcement (nominal power of 360 W) and a small active near field monitor with lower sensitivity but easily portable. In order to observe the differences the best way possible, the subwoofer was driven as a single sound source with the cutoff frequency set to 120 Hz. Fig.1 shows the omni-directional loudspeaker and the other three loudspeakers are shown in fig.2 to show the differences in their size and shape.

Fig.2. From top to ground: the near-field monitor, the subwoofer and the sound reinforcement loudspeaker.

3. MEASUREMENT SETUP

The measurements were made in three acoustically very different spaces, and more measurements are planned to be performed in additional spaces. As this paper is trying to reveal certain limitations of different excitation types, it was necessary to try to find acoustically different positions in a given space and to observe possible differences between those positions, as stated in [1].

The first room was an acoustically treated listening room having the dimensions of 10,2 m x 7,1 m x 3,2 m and a room volume of 230 m^3. Its plan view with the indicated sound source and microphone positions is shown in fig. 3. It's interior is shown in fig. 4.

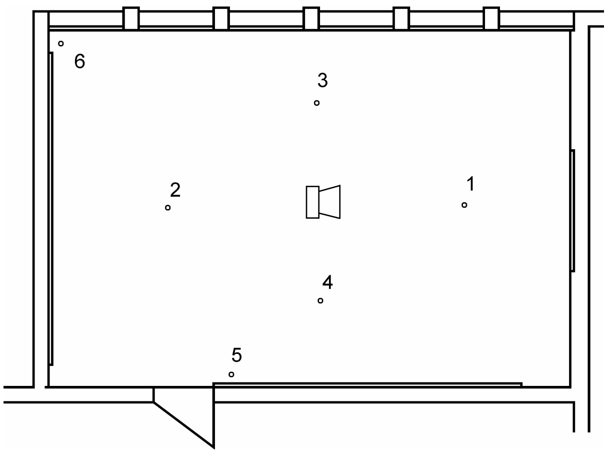

Fig. 3. Plan view of room 1.

Fig. 4. Interior of room 1.

The second room was a reverberant corridor paved with marble, which has the purpose to connect some lecture rooms, but also serves as an art gallery. It is a long and relatively tight L-shaped space with a staircase which connects the corridor with a lower level hall, thus making a coupled room system. It was chosen because it's volume is not significantly bigger than the volume of the first room, but the acoustic finishing differs a lot. The plan view with the indicated sound source and microphone positions is shown in fig. 5. Fig. 6. shows the interior of the described corridor.

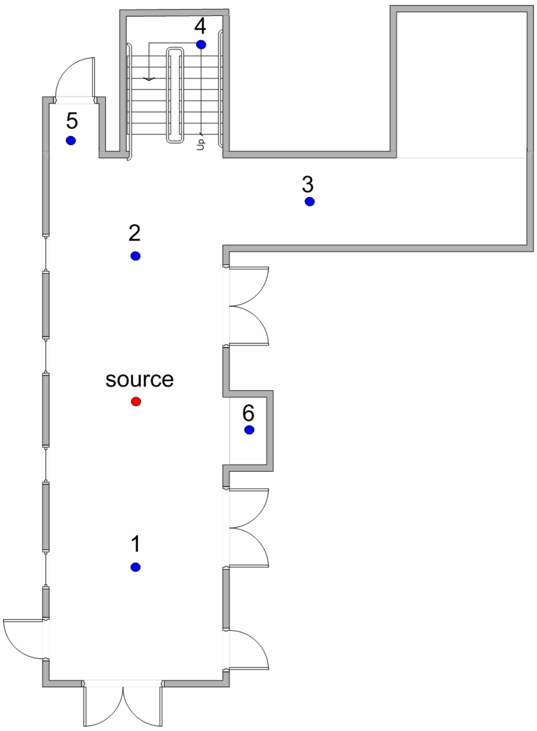

Fig. 5. Plan view of room 2.

The third measurement location is a part of the ongoing measurements performed in large spaces. To be more precise, it is a newly built drama theatre having the room volume of 3130 m^3. The plan view of the theatre is shown in fig. 7 and its interior in fig. 8.

Fig. 6. Interior of room 2.

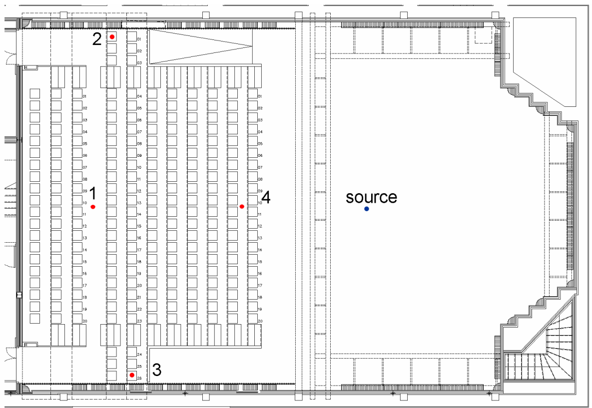

Fig. 7. Plan view of room 3.

Fig. 8. Interior of room 3.

All measurements were done by calculating the reverberation time from the integrated impulse response, which was either measured using the exponential sine sweep signals fed to the loudspeakers, or just recorded to an audio file as the response to impulsive sound source excitation. The ARTA software [4] was used for measuring the integrated impulse response and for calculating the reverberation times. An average of 4 measurements was used to increase the signal to noise ratio. As for the impulsive sources, pistol shots were recorded with the same microphone used for previous measurements and then analyzed with the same software in order to compare the sources in as similar conditions as possible.

3. RESULTS

The reverberation times shown below were calculated from the integrated impulse responses. The 60 dB decrease of the sound pressure level was approximated from the decay between -5 dB and -35 dB from the referent level of 0 dB, as described in [1]. Fig. 9. shows an example of the energy decay curve for room 1, position 1, omni-directional loudspeaker and frequency range of 62.5 Hz and 8 kHz. The dynamic range of the sources can be easily compared for every octave band, as well as the possibility to excite the room at low frequencies which was altogether the most critical part of the measurements.

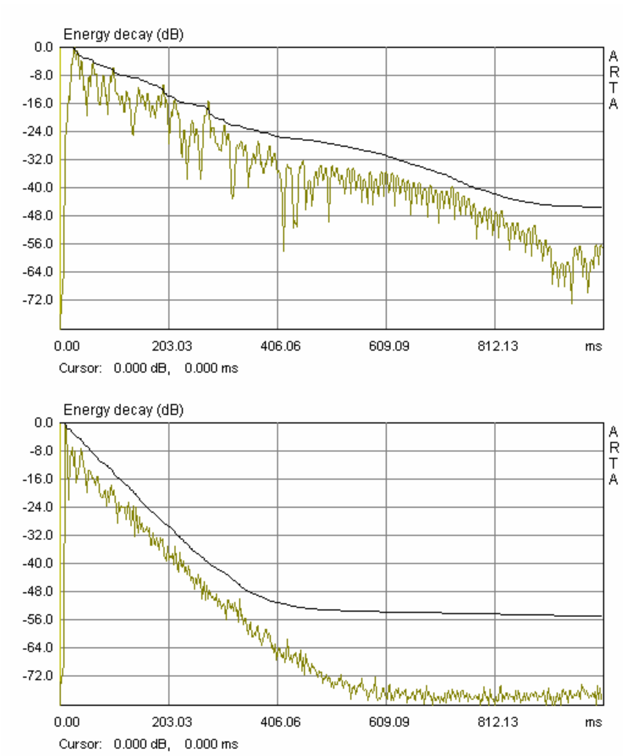

Fig. 9. Energy decay curve for room 1, position 1, omni-directional source and 62.5 Hz (upper) / 8 kHz (lower).

Some results for room 1 are shown in figs. 10. to 12. The results obtained using the subwoofer should be taken into account only for 63 and 125 Hz because of it's cut-off frequency. The measurement results show a rather good matching, except at the lowest frequency band. The subwoofer has the best dynamic range and it's reverberation time doesn't vary much compared on various positions, in contrast to other sources (compare fig. 10. and fig. 12.).

Some results for room 2 are shown in figs. 13. to 15. In this room, two types of balloons were used, a smaller (80 cm circumference), and a bigger (120 cm circumference). As this room is more difficult to excite, the differences in results for various sound sources differ much more as well. The low frequency portion has again proved to be the most problematic. For example, Fig. 13. shows a wide variation of the measured reverberation time at 63 Hz, but after that, the variations are much smaller. The directivity of the MSP5 and the small balloon shows the only bigger deviation. Fig. 14. shows the results for position 3 which was not in line of sight looking from the source. The balloons and the MSP5 could not excite this position in the room at low frequencies enough to get a trustworthy result. The results of the measurements made using the TOA 38-SD loudspeaker also deviate from the ones made using the omni-directional source. Fig. 15. shows the results in position 4 where room coupling is emphasized the most. Again, most sources could not provide sufficient excitation in this position at low frequencies.

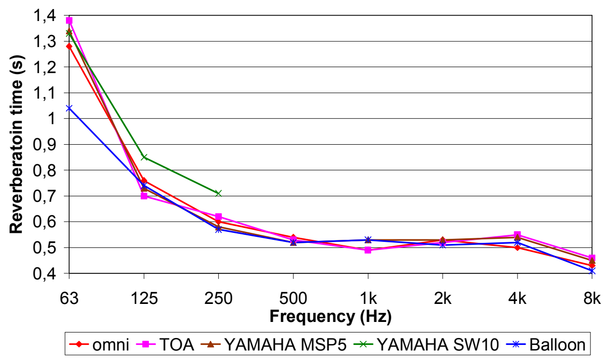

Fig. 10. Reverberation time for room 1, position 1.

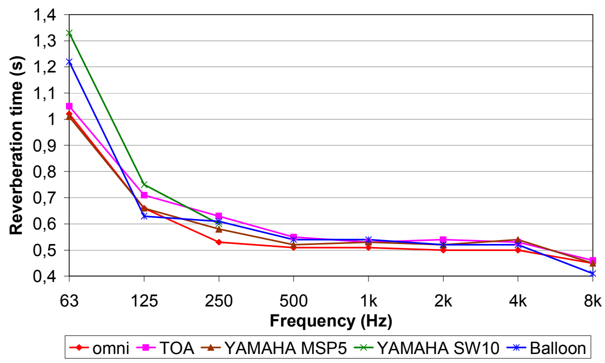

Fig. 11. Reverberation time for room 1, position 2.

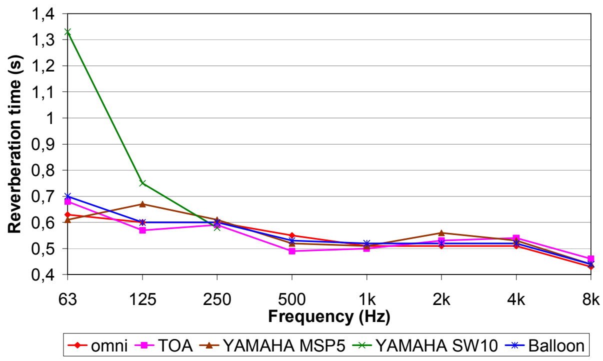

Fig. 12. Reverberation time for room 1, position 3.

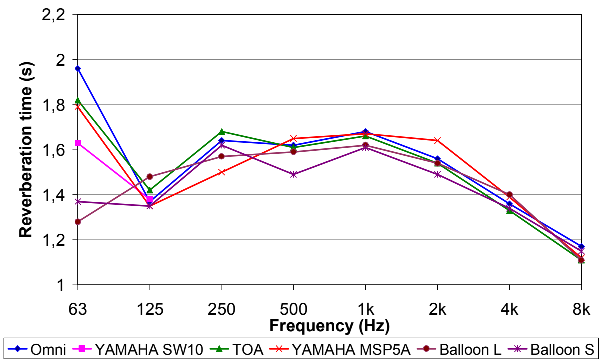

Fig. 13. Reverberation time for room 2, position 1.

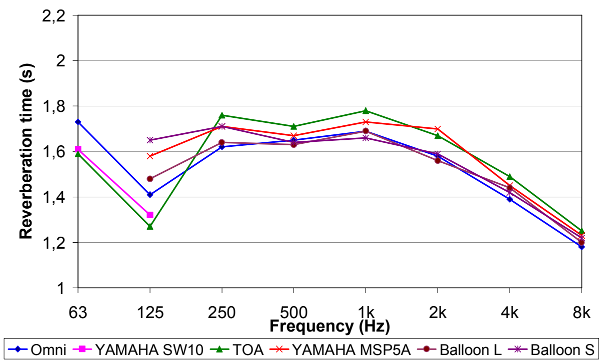

Fig. 14. Reverberation time for room 2, position 3.

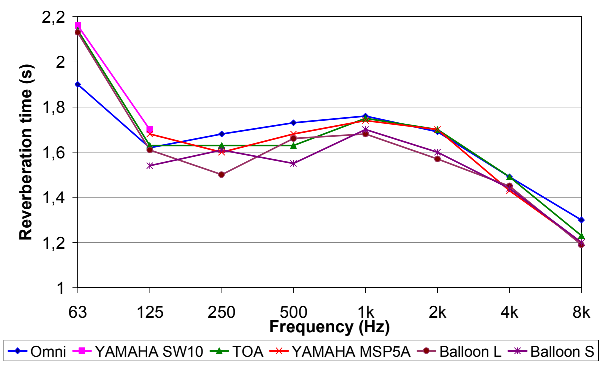

Fig. 15. Reverberation time for room 2, position 4.

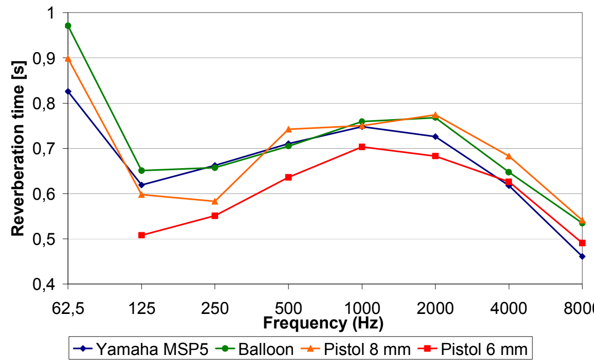

Fig. 16. Reverberation time for room 3, position 1.

Room 3 is the space where the biggest deviations between the results can be expected because of its size. The results shown in Fig. 16. confirm this assumption. Two calibers of pistol blanks were used as excitation. It is obvious that the smaller caliber blank cannot provide a satisfying result at all, while the bigger caliber blank can excite the room properly only at middle and high frequencies. The low frequency results are also very questionable because of the rather small dynamic excitation range for all the sources.

4. CONCLUSION

The collected results are a part of an ongoing testing having a goal to determine the influence of excitation type and the measuring method on the results of reverberation time. Although there is a common agreement that omni-directional loudspeakers are the best choice for this type of acoustic measurements, it is often not possible to use them. The results shown also for other sound sources show that some of them can also be used for the measurements, depending on the sound pressure level (i.e. the dynamic range) they are able to provide, the measurement space (its volume, shape, absorption surfaces), and the required precision.

Although the impulsive sound sources cannot ensure repeatable measurements, the results obtained in this manner do not vary much from the results obtained from repeatable measurements. It is obvious that pistol blank of smaller caliber (6 mm) do not provide enough dynamics to excite a large room at low frequencies. Balloons, however, prove to be the best choice, especially the ones of larger size and higher air pressure.

For the largest spaces, the use of an explosive device of some kind (a small caliber cannon, a balloon filled with a mixture of acetylene and oxygen, a can containing a chunk of calcium carbide in reaction with water, etc.) has been proposed to serve as the excitation. However, this course of action has not yet been realized due to costs and safety reasons.

Directional speakers have proved to be sufficient for measurements in smaller rooms. However, if the room has an irregular shape or its surfaces are very reflective, the results are again significantly different from the ones obtained using the omni-directional speaker as a referent source.

ACKNOWLEDGMENT

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