Measurements in opera houses: comparison between different techniques and equipment

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Abstract: In room acoustics many objective parameters to quantify subjective impressions have been introduced. These quantities can be measured by using a wide variety of powerful tools and equipment. The results can be influenced by the measurement techniques and instruments used. Furthermore the results also depend on the position and condition of the hall in which the measurements are made.
With the aim of obtaining a procedure to qualify a room, and in particular an opera house, which will give comparable and reproducible results anywhere else, an extensive measurement campaign was made. In this paper some of the results of the measurement campaign are presented. Comparisons were made both between different tools (real-time analyzer, DAT, PC-board, sources) and between different techniques (stationary, impulsive, pseudo-random).

INTRODUCTION

Measurements in room acoustics can be made by using a wide variety of powerful tools and equipment. The number of combinations of tools, equipment, techniques and methods could be very large. The results are influenced by these different settings but it is not clear if the differences are important or not. The results also depend on the position and condition of the hall in which the measurements are made. The aim of this research is to find a procedure to qualify an opera house, which will always give comparable and reproducible results. The procedure takes into account the measurement techniques, the equipment, the measurement positions and the condition of the audience and the stage. In the measurement campaign, comparisons were made both with different settings and different conditions of the stage and pit (e.g. empty, with the presence of orchestra tools and/or musicians). In this paper only the comparisons between different techniques and equipment are reported.

EXPERIMENTAL MEASUREMENTS

Measurements were made with the following instruments: 2 omnidirectional dodecahedron loudspeakers, 2 binaural microphones, 2 computer-based MLS measurement systems, a real-time spectrum analyzer, a DAT recorder and 2 impulsive sound sources (pistol and balloons). Almost any combination of these instruments was checked, although in the following only the most relevant comparisons are reported.
Furthermore, different post-processing techniques of the same experimental results were attempted; the number of possible combinations was thus increased. Most of the comparisons were made in two halls.
In more detail, the following comparisons were made:

- Measurement of the reverberation time with the standard interrupted-noise method and with the backward-integration of the impulse response.
- MLS measurement of the impulse response with the two available systems and with synchronous/asynchronous correlation.
- Measurement of the impulse response with impulsive sources (pistol shots, explosion of balloons).
- Use of two different loudspeakers, one of which has an optional electronic equalization circuit.
- Use of two different binaural microphones (on the same dummy head).

The attempt was made to maintain all the other variables unchanged when checking the effect of each of the above possibilities. Furthermore, for each comparison a highly significant acoustical parameter was chosen, although the whole set of parameters was computed for each measurement setup. The measurements were repeated with various source and receiver positions, but great care was taken to ensure that these positions remained absolutely unchanged among the different measurement sets. All the instruments employed are claimed to be in accordance with the ISO 3382 standard.
Figure 1 shows the comparison between the reverberation times measured with the real-time analyzer (interrupted-noise method) and with the backward integrated impulse responses: these were obtained both with the MLS technique and with pistol shots. Figure 2 shows the comparison between the signal-to-noise ratios obtained with the two MLS systems and two impulsive sources (balloons and pistol shots).

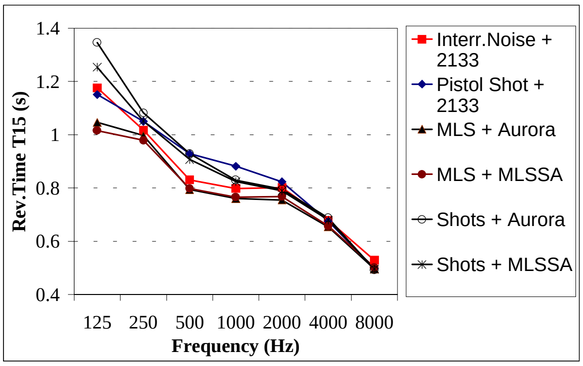

Figure 1: Comparison between the reverberation times measured with the interrupted-noise method and with the backward integrated impulse responses (hall 1).

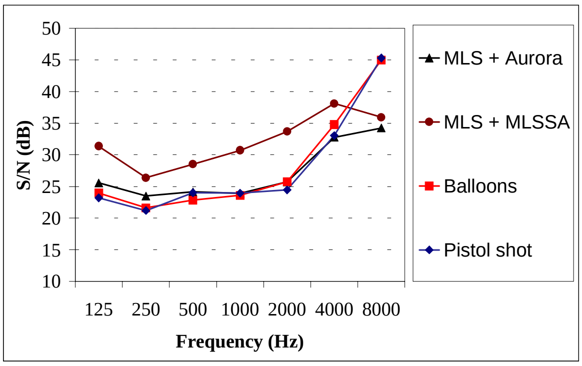

Figure 2: Comparison between the signal-to-noise ratios of different measurement techniques (hall 2).

DISCUSSION AND CONCLUSIONS

From the measurement results the following considerations can be made:

- In the calculation of the reverberation time the major differences are not between stationary or impulsive techniques but between stationary or impulsive sources. This mean that the results obtained with MLS impulsive techniques are closer to the results obtained with the stationary interrupted noise than to those obtained with a pistol shot or an explosion of a balloon.
- The differences between the two available MLS systems are not of great importance. The measurements based on the MLSSA board seem to have a better signal to noise ratio than those obtained by using the software Aurora with a standard Sound Blaster PC board. The comparison between the MLS direct measurements (synchronous correlation) and the measurements made after DAT recording of the noise (asynchronous correlation) gave the same results. The MLS system based on the Aurora software has the advantage of permitting direct binaural measurements. As the results of the two MLS systems can be processed with both software tools, it was checked that the computation algorithms are perfectly interchangeable.
- The measurement of the impulse response with impulsive sources (pistol shots, explosion of balloons) gave comparable results with the other techniques. With pistol shots there are frequent problems in the calculation of the parameters at low frequency. The signal to noise ratio with impulsive sources is usually smaller than the MLS noise, particularly at low frequencies.
- The results obtained by employing two different loudspeakers, one of which with an electronic equalization of the spectrum, are the same at the medium frequencies. The sources with the equalization gave slightly higher clarity and lower reverberation time at high frequencies. In some cases the non-equalized source permits the calculation of the parameters at a lower frequency than the equalized source. The substantial coincidence of the results with two sources having a great difference in frequency response means that the time-domain acoustical parameters are quite robust. But when listening to the measured impulse responses, both directly or after convolution with anechoic signals, the effect is dramatically different: this means that the commonly accepted set of acoustical parameters does not properly include the characterization of the frequency response of the system. A new class of frequency-domain acoustical parameters is needed.
- The employment of two different binaural microphones (on the same dummy head) gave comparable results. One of the microphones, equipped with very small capsules, gave a higher clarity at high frequencies but had a lower response at low frequencies.

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