Acoustics'08 Paris
June 29-July 4, 2008
www.acoustics08-paris.org

Experimental analysis of the acoustical behaviour of Musikverein in concert and ballet configurations

Angelo Farina[a], Daniel Commins[b] and Nicola Prodi[c]

[a]University of Parma, Via delle Scienze 181/A, Industrial Engineering Dept., 43100 Parma, Italy
[b]Commins Acoustics Workshop, 15 rue Laurence Savart, 75020 Paris, France
[c]Engineering Dept. - Univ. of Ferrara, Via Saragat, 1, 44100 Ferrara, Italy
farina@unipr.it

This paper reports about measurements performed in the famous Musikverein concert hall, in Vienna. Two different configurations of the room were tested: concert and ballroom. In the latter, the main stalls are employed as a large dancing area.

Measurements were performed with the room completely empty (no audience, no dancers), and this exacerbated the difference between the two conditions. Despite the large values of reverberation time attained in the ballroom configuration, the room revealed to provide good values for most other acoustical parameters, confirming the fame of the room, and demonstrating how it can accommodate very different requirements and fittings.

The measurements demonstrated that, albeit the acoustical properties change significantly in the two different arrangements of seats, the variation is not due to coupling with the storage volume located under the stalls, where the seats are packed during ballets.

1 Introduction

Musikverein is acknowledged as one of the best concert halls of the world, and is highly regarded for top-level symphonic performances, covering mainly classic repertory. However, following a centuries-old tradition, the hall is also employed for open-to-the-public ballets. All the seats in the main stalls are removed, and packed under the wooden floor thanks to a large, openable part of the floor. Seats on the lateral balconies stay in place, but the room becomes something completely different from the "concert hall" configuration. People who pay the ticket can enter the room and dance in the "stalls" area, while the orchestra plays on stage.

A set of detailed acoustical measurements have been performed, with the aim of evaluating the different acoustical behavior with and without the seats. Furthermore, it was attempted to assess the contribution of the air volume under the floor, as a possible "reverberant chamber", with volume and absorption significantly different when it is filled with packed seats.

This included measurement of the sound reduction index of the openable part of the floor, and measurements with accelerometers and pressure-velocity acoustical probes for determining the net energy flow through this partition.

A state-of-the-art measurement technique was employed, making use of a 24-bits digital sound system, and employing Exponential Sine Sweep signals for optimal rejection of background noise and artifacts due to nonlinearities in the transducers and to small time variance (air movement). Furthermore, a three-dimensional microphonic array was employed for measuring simultaneously sound pressure and the three Cartesian components of particle velocity, allowing for a complete energetic and vector analysis of the sound field at each measurement point.

The usage of a powerful omnidrectional sound source, carefully equalized thanks to preliminary measurements, provided a number of measured impulse responses with exceptionally wide dynamic range and frequency response, which are not only suitable for computing standard ISO-3382 acoustical parameters, but also for being employed as numerical filters for artificial reverberation of anechoic music by means of a convolution process.

The results of this experimentation did show that the main acoustical parameters vary significantly between the "concert" setup and the "ballroom" setup, the second case being much more reverberant, with larger strength.

It was expected also to see lower clarity and more diffuse sound, and instead here we got the surprise: Clarity and Lateral Fraction do not change removing the seats!

The measurements were performed without audience, but the presence of people inside the hall, either as audience during the concerts and as dancers/observers during the public ballets, should decrease the spread of the two setups, as in concert configuration the seats already provide some of the absorption even when no one is seating in them....

However, for properly assessing the acoustical effects of the occupancy, it would be necessary to repeat the measurements with the room full of people, albeit this poses severe technical difficulties due to increased background noise and time-variance.

Regarding the hypothesis that the volume under the floor has some effect on the acoustical behavior of the room, the experimental results seem to exclude that this is possible. In fact, the sliding panels covering the opening in the floor revealed to provide a significant sound insulation: even if some energy can flow in the lower volume through these panels, it becomes so weak that, when travelling back after reverberating inside this chamber, it arrives back in the main room at a level which is surely completely masked by the sound field of the main room.

And, even when the "lower" room is empty, its reverberation time is never longer than that of the main room...

Furthermore, the measurements with accelerometers and pressure/velocity probes did not reveal any difference between the behavior of this "openable" part of the floor and the surrounding "fixed" floor.

So it was concluded that the big difference in acoustical behavior is simply caused by the removal of the seats, and by changes in fittings of the stage for the two different usages of the hall.

2 Measurement technique

Multichannel impulse responses were measured, employing a state-of-the art system developed by the authors.

The measurement method employed is based on the Exponential Sine Sweep method [1]. The test signal is generated by means of a laptop computer, running Adobe Audition fitted with the Aurora suite of plugins [2,3].

The computer is connected with a professional multichannel audio interface (Motu Traveler) by means of a Firewire cable.

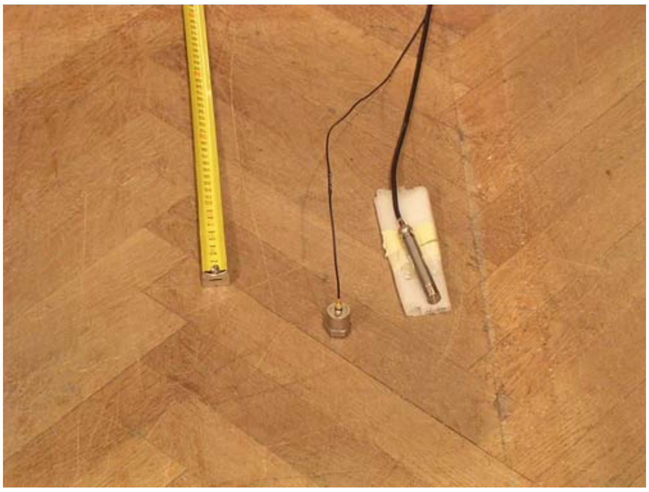
An omnidirectional loudspeaker (Lookline D-300 dodecahedron) was employed, compliant with ISO 3382 [4].

A number of different microphones were employed, including a Soundfield ST-250 three-dimensional pressure-velocity probe, and a number of omnidirectional microphones. Also accelerometers were employed, for measuring the vibration velocity on the wood panels covering the storage volume, and assessing the energy flow through them.

The following photographs show the equipment in the concert hall during the measurements.

,Fig.1 Sound Source and microphone during calibration (ballet configuration)

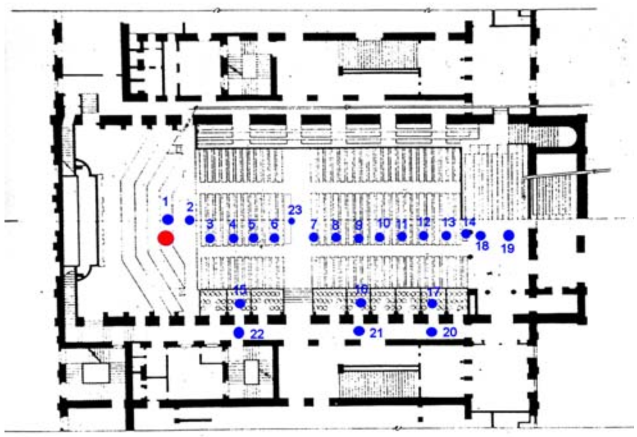
,Fig.2 Computer and audio interface (concert configuration)



,Fig.3 Accelerometer and microphone on the floor for measuring surface intensity

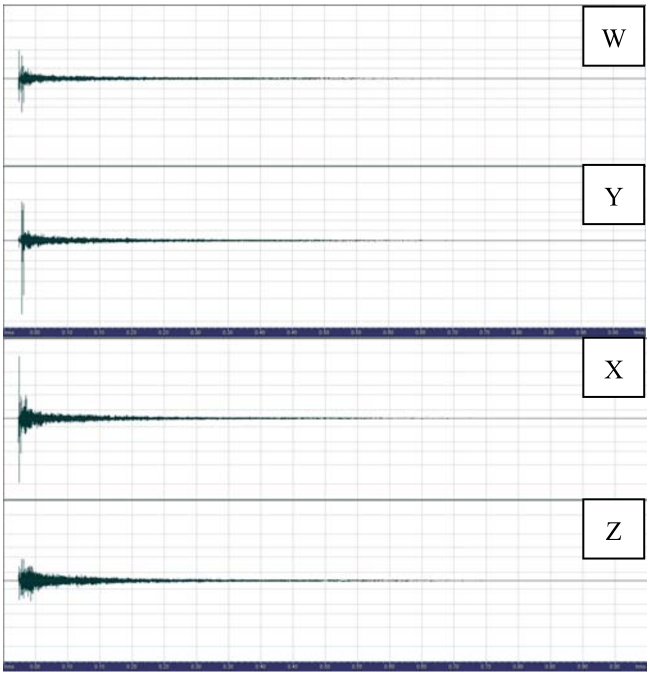
,Fig.4 Seats packed in the storage volume under the floor

The measurements were performed maintaining the source in the same position on the stage, and keeping the same measurement positions in the stalls and in balconies, both for concert and for ballroom configuration, as shown in the next figure.



,Fig.5 Position of source and measurement points

The test signal employed was an Exponential Sine Sweep, 22Hz to 22 kHz, 20s, sampling 48 kHz. The 4 channels of the Soundfield microphone were recorded simultaneously, so that, after deconvolution, a complete impulse response in 1st-order B-format, was obtained, 160000 samples long, as shown here:



.Fig.6 B-format Impulse Response

Acoustical parameters have been computed mainly by processing the first two channels (W, omnidirectional pressure, and Y, which is the figure-of-8 velocity signal along the left-right direction, for a listener having the X axis pointing to the source), by means of the Aurora plugin "Acoustical Parameters", as shown here:

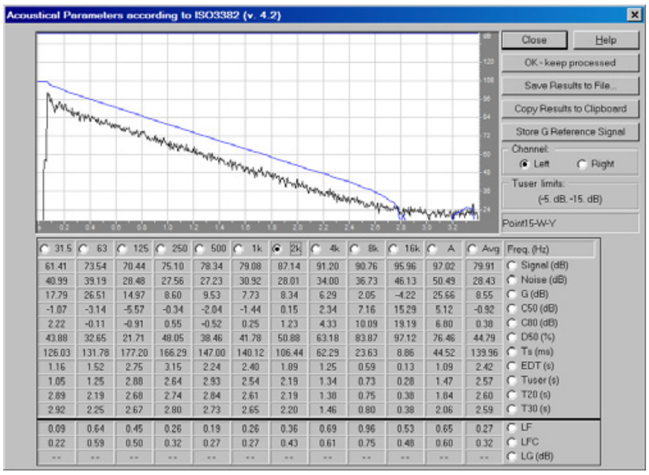


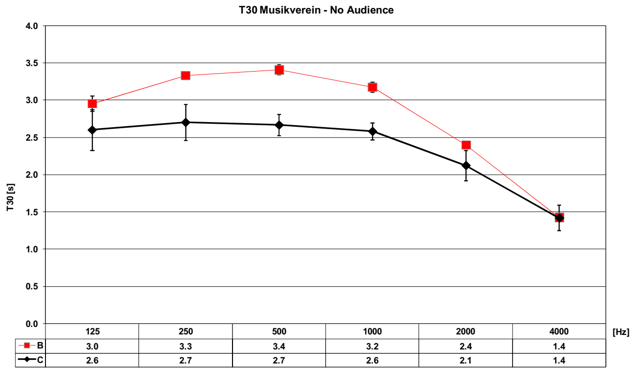
Fig.7 Computation of ISO3382 Acoustical Parameters

Other measurements performed were devoted to analyzing the coupling between the main room and the storage volume located under the stalls: an ISO-140-4 [5] airborne sound insulation measurement was performed, and the net energy flow through the wooden floor was measured by means of surface intensity (pressure with a microphone, velocity with an accelerometer).

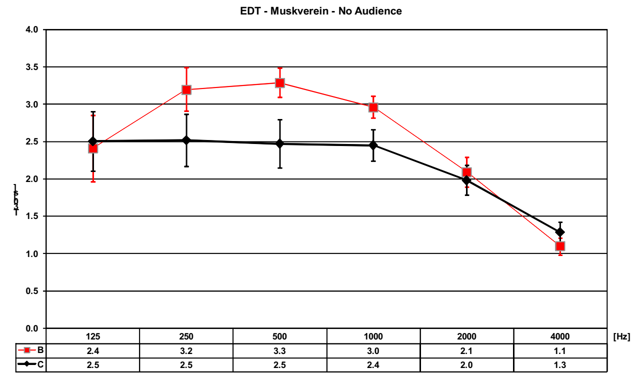
3 Experimental results

3.1 ISO 3382 parameters

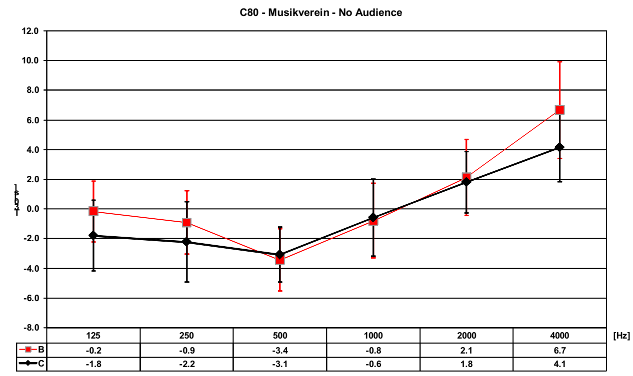
The main goal was to compare the Concert (C) and the Ballet (B) configurations. In the following figures, the most relevant acoustical parameters are compared



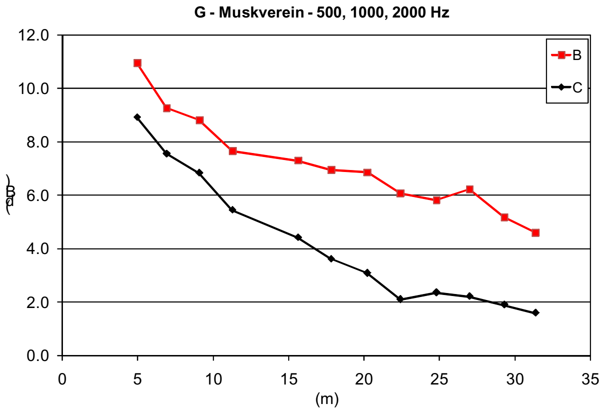
.Fig.8 Reverberation Time T30



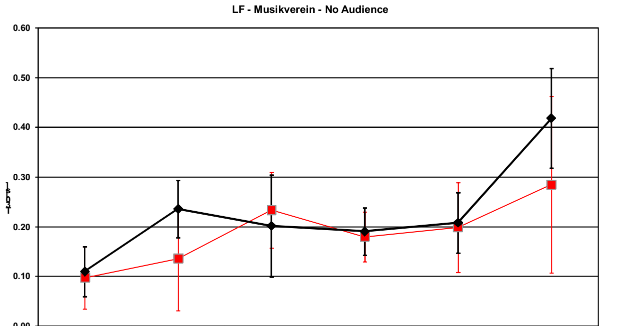
.Fig.9 Early Decay Time EDT



.Fig.10 Clarity C80



.Fig 11 Strength at mid frequencies G



	125	250	500	1000	2000	4000
B	0.10	0.14	0.23	0.18	0.20	0.28
C	0.11	0.24	0.20	0.19	0.21	0.42

.Fig 12 Lateral Fraction

It can be seen how, removing the seats for transforming the concert hall in a Ballroom, the reverberation time and Strength are changed significantly while C80 and LF remain substantially the same.

This means that, whilst a significant amount of absorbent material is removed, the peculiar properties of this concert hall, related to very diffuse sound field and good clarity despite the long reverberant tail, are maintained, ensuring that also the customers entering the Ballroom will enjoy the music.

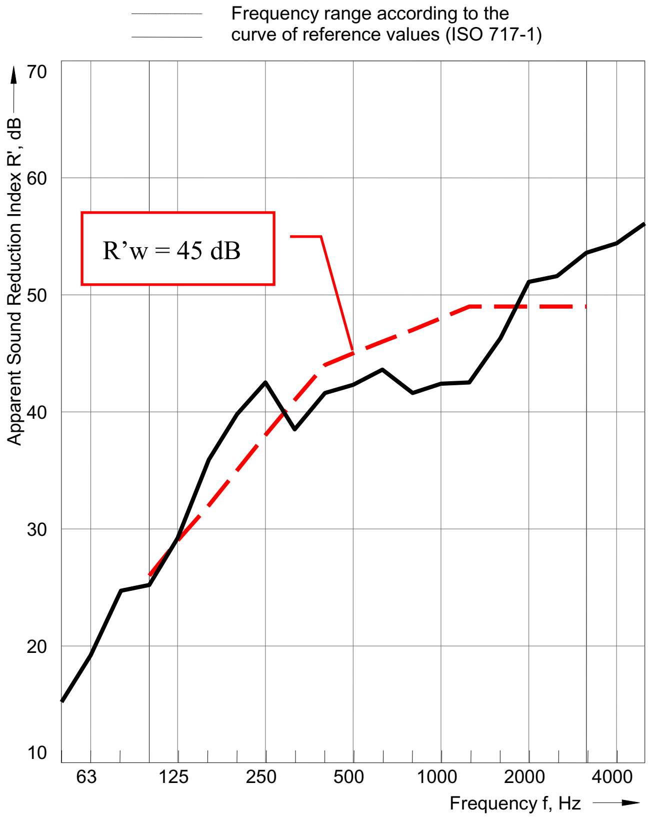
It must be remembered that the room was empty (no audience) during the measurements: adding the absorption of people has a much larger effect in the ballroom mode, when the stalls are completely unobstructed. So, the large difference in reverberation times measured with the empty room, will probably disappear almost completely with the audience.

3.2 Airborne sound insulation

One possible explanation of the fact that the room maintains good acoustical properties in Ballroom configuration was that the storage volume located under the floor in the stalls area acts as a coupled reverberant room when this volume is empty. When the volume is filled of packed seats, it does not provide anymore such an additional reverberation, compensating for the reduced amount of sound absorbing objects in the room above.

However, this can happen only if the wooden panels which cover the opening towards the storage volume are capable of allowing significant sound energy to pass through, and, after a while, to come back. In practice, the sound reduction index of these panels should be low.

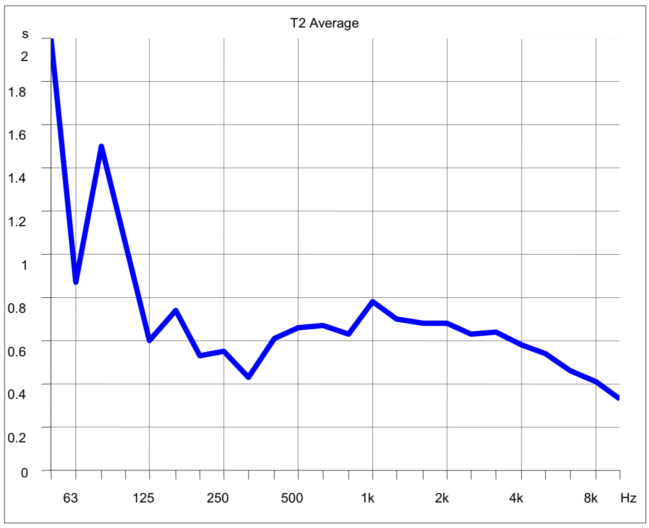
A B&K 2260 spectrum analyzer was employed for performing the airborne sound insulation test. The results are shown here:



.Fig 13 Sound Reduction Index

It can be seen that the airborne sound insulation is very good. There is too much attenuation for the sound passing through the wooden panels for getting back any significant contribution to the reverberant tail…

Furthermore, as shown here below, the measurement of the reverberation time performed inside the empty storage room revealed that this empty volume is, in realty, less reverberant than the main hall, so it is impossible that it contributes to the reverberation.

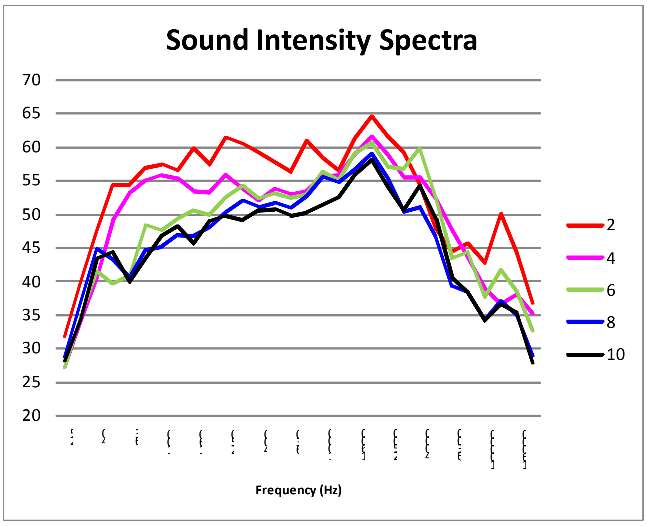


.Fig 14 Reverberation Time T30 – Storage Room

So the hypothesis that this storage volume acts as a coupled reverberation chamber has been definitely dismissed.

3.3 Surface sound intensity

By the measurement of pressure and velocity at several points on the floor, it was possible to measure the 1/3 octave spectrum of the sound intensity "flowing into" the wooden surface.
The measurements were performed along a line, at increasing distances from the sound source, passing over the folding panels which give access to the lower storage room.
Measurements were performed at 2m, 4m, 6m, 8m and 10m from the source. The points above the folding panels are those at 6m and 8m.
The following figure shows the sound intensity spectra measured in the 5 positions:



.Fig 15 Reverberation Time T30 – Storage Room

It can be see that the two points above the folding panels are almost indistinguishable from the two following points, over the normal floor. The first two points appear getting more intensity, but this happens simply because they are close to the source, where the energy density is not yet distance-independent.
So it can be seen how the folding panels are acoustically undistinguishable from the "normal" floor.

5 Conclusion

Musikverein revealed to be a quite interesting "variable acoustics" room, providing a flexible, quickly reconfigurable method for transforming the main stalls in a ballroom. This double usage is typical of the approach to music in Vienna: music does not have to be something serious and boring, music is enjoyment and something making the people to dance and stay together, having an happy time.
So, the temple of symphonic music doubles itself as a ballroom, where very popular entertainment is done.
It is wonderful to see how, despite the removal of hundredths of seats, the peculiar acoustical characteristics of the room stay unchanged: Clarity remains very high, and the decorations on side walls provide smooth reflections from everywhere, creating a very enveloping sound field.
Unfortunately it was not possible to repeat the room during its usage, with people inside. In a further step, the authors plan to simulate the effect of the audience by means of a room simulation software, carefully calibrated against the measured values in the "empty" configuration. It is expected that the presence of the audience will further reduce the spread among the two configurations of the room.

Acknowledgments

The authors want to express their gratitude to the staff and management of Musikverein, who allowed to make the measurements and cooperated actively.

References

[1] A. Farina – "Simultaneous measurement of impulse response and distortion with a swept-sine technique", 110th AES Convention, Paris 18-22 February 2000.

[2] A. Farina, F. Righini, "Software implementation of an MLS analyzer, with tools for convolution, auralization and inverse filtering", Pre-prints of the 103rd AES Convention, New York, 26-29 September 1997.

[3] A. Farina – "Aurora Plugins" – HTTP://www.aurora-plugins.com

[4] ISO/DIS 3382-1:2006 – "Acoustics - Measurement of room acoustic parameters - Part 1: Performance rooms" – International Standard Organization, Geneva, 2006.

[5] ISO 140-4:1998 – "Acoustics - Measurement of Sound Insulation in Buildings and of Building Elements - Part 4: Field Measurements of Airborne Sound Insulation between Rooms" – International Standard Organization, Geneva, 1998.