MEASUREMENTS AND STUDY ON VARIABLE ACOUSTICS IN PERFORMANCE SPACES

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1 INTRODUCTION

Auditoriums built specifically for classical music, contemporary music or conference uses have seldom enough users in order to be in effective use, especially in smaller communities. When building new auditoria it is a very attractive approach to house different user groups in the same space. In order to fulfil the various needs of different user groups the auditorium should be able to transform acoustically.

2 VARIABLE ACOUSTICS

If an auditorium is to meet the requirements of different user groups, as from classical orchestras to rock concerts, the space should be versatile and variable. In order to be truly variable acoustically an auditorium needs extensive variable elements that can be easily changed. In this section the different acoustical requirements for user groups are briefly introduced and the main means of achieving them presented.

2.1 Acoustic Requirements for Different Purposes

Traditionally the acoustics in multi-purpose auditoriums were designed either as a compromise between the different uses or focusing on one use and letting the other ones suffer [2]. It is clear that the same space cannot be satisfactory for both classical music and rock concerts without extensive variability.

Classical music is one of the extremes regarding acoustics in a multi-purpose auditorium. Long reverberation time and a highly diffuse soundfield are requirements for a good concert hall. Further there should be a large amount of lateral reflections. These requirements translate to a large volume in proportion to the seat count in the hall.

Electrically reinforced contemporary music usually needs far shorter reverberation time than classical music. The short reverberation time gives more room for controlling the sound field created by the PA-system and makes it easier to keep the sound pressure level on an acceptable level. Lateral reflections are not as essential as for classical music but the sound-field should be diffuse enough to avoid problems such as audible echoes.

For drama or conference use the main goal for an auditorium is speech intelligibility. Early reflections are essential for good speech intelligibility for speaker not using sound reinforcement systems. But where lateral reflections are vital for classical music the direction of the reflections doesn't affect the speech intelligibility.

2.2 Methods for Achieving Variability

There are several different methods for achieving variability of the acoustics in an auditorium. The methods can be divided into the two maingroups variable absorption and variable volume [1]. These two are briefly introduced in this section. Except for these two, variability in the sound field in an auditorium can be achieved by electronic systems, this study is concentrating on traditional way of varying the acoustics and these systems are not covered.

2.2.1 Variable Absorption

The most common way to achieve variability of the acoustics in an auditorium is bringing more sound absorbing material to a reverberant room. As an easy and cost effective method curtains and banners can be exposed for events where shorter reverberation time is needed[1 2].

Variable absorption can also be realized with retractable absorbing panels that are visible when shorter reverberation time is needed. The panels can be for example of the turning type where one side is covered with absorbing material and the other side reflective[1].

2.2.2 Variable Volume

Another way of altering the acoustic environment in a space is to change the volume. As a result of adding volume to an auditorium without adding any absorption the reverberation time will be longer. The volume is often increased by opening doors to surrounding spaces. These are often referred to as “reverberation chambers” or “Coupled Volumes” [1 2].

Another way of varying the volume of an auditorium is simply raising and lowering the ceiling or moving walls. These methods require heavy mechanics and are therefore often expensive solutions.

For classical concerts, auditoriums with flytowers usually have an orchestral shell which isolates the stage from the flytower. The shell is changing the acoustics by isolating the stage house from the auditorium and ensuring that the sound from the orchestra is reflected into the auditorium and not absorbed in the stage house. An orchestral shell is actually a combination of variable volume and absorption, the latter because usually the alternative to the shell is heavy curtains that absorb sound effectively.

3 MEASUREMENTS

Even though there are several examples of collected data from concert halls, there are very little measured values from auditoriums with variable acoustics available. Especially comparison between different types of variability is hard to find.

Two Finnish multi-purpose auditoriums were measured in different configurations of the variable elements. In this section the methods and equipment used for measuring the halls and the halls themselves are introduced.

3.1 Measurement method

The measurements were carried out as described by Gade in *Acoustical Survey of Eleven European Concert Halls* [4]. In order to get a representative average of the impulse response in the auditorium 3 source positions on the stage and 3 receivers on stage and 3-6 in the audience were used, summing up to 18-27 combinations of sources and receivers.

As the source an omnidirectional loudspeaker consisting of 12 loudspeaker elements in a dodecahedron casing was used. In order to imitate the directional characteristics of a human for measurements of speech intelligibility a small 2-way loudspeaker (Genelec 1029A) was used.

The recording hardware consisted of an omnidirectional condenser microphone capsule AKG CK 92 and output module AKG SE 300 B output module or an AKG 414 B-ULS condenser microphone. The microphone was connected to a USB-soundcard Marian UCON CX. For the measurements the WinMLS 2004 software was used with a logarithmic sweep as signal, except for the speech intelligibility measurements where a MLS-signal was used.

Figure 1 shows one example of a measured impulse response in Sibelius Hall in Järvenpää. In this particular measurement the source was placed where at the typical soloist position[4] and the the receiver point almost in the middle of the audience area.

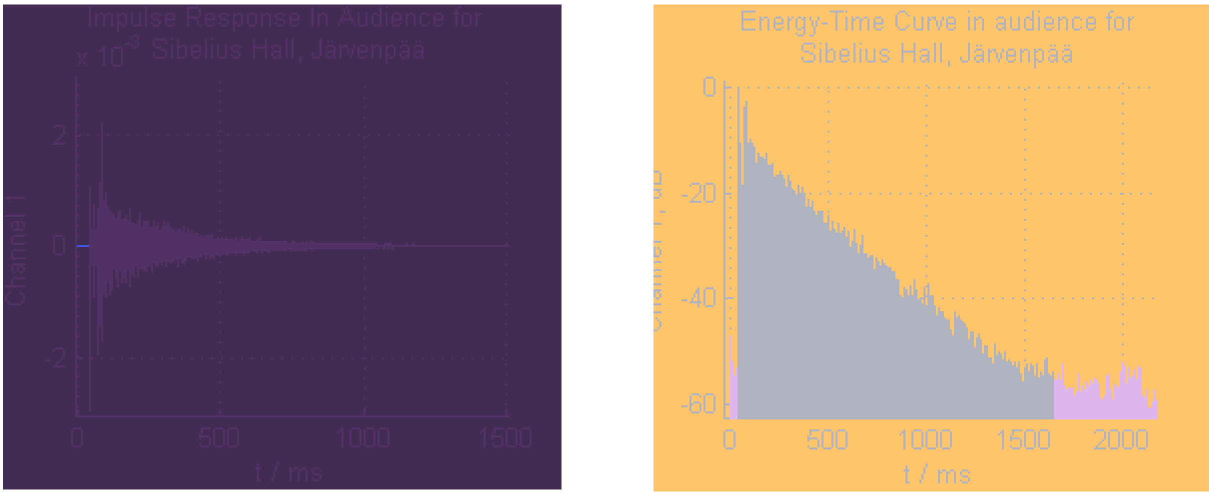


Figure 1: Impulse response and energy-time curve for source position 1 and receiver position 2 in Sibelius Hall in Järvenpää with a concert configuration where the stage is hard and the hall is without absorption.

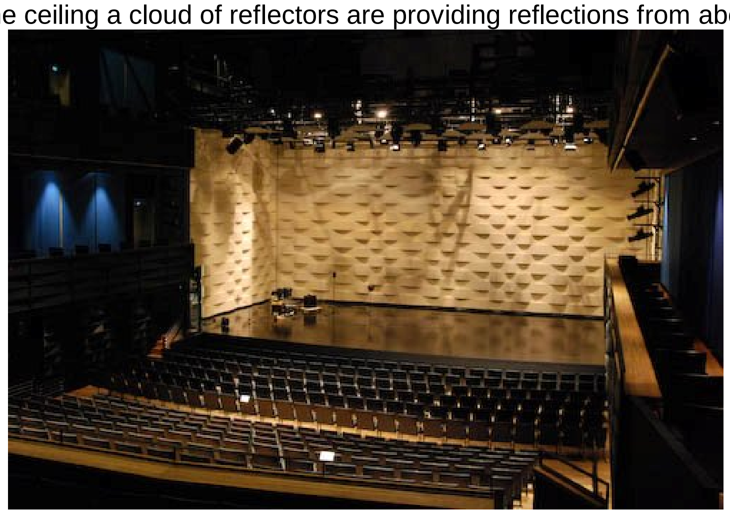
3.2 Auditoriums Measured

3.2.1 Vanaja Hall

Vanaja-hall is a new multipurpose auditorium of shoebox layout completed in the fall of 2007 located in the city of Hämeenlinna. In concert mode the auditorium have about 700 seats on the floor and the two balconies. The use of the auditorium is everything between symphonic music with a 100 musician orchestra to concerts with reinforced music.

The variability in Vanaja hall consist mainly of retractable absorbing curtains. The main variable element in the hall is four double curtains which can be extended down 3m from the ceiling. Further most of the side walls can be covered with curtains.

For classical music a wall forming a shell with variable absorption is placed on the stage. Suspended from the ceiling a cloud of reflectors are providing reflections from above the orchestra.



Picture 1: Vanaja Hall in Hämeenlinna with orchestral shell and banners exposed on the side wall

3.2.2 Sibelius-hall

In the Järvenpää-building completed in 1987 is the Sibelius hall with 574 seats. The hall is asymmetrical with on side partial fanshape and the other shoebox. The sidewalls provide some diffusion especially near the front of the stage. All the seats are placed on the floor and there are no balconies in the hall.

The variable acoustics in Sibelius hall consist of turnable panels on the sidewalls. The panels have one side reflective and the other absorbing. For concert configuration the rotatable wall sections on the stage,back wall and suspended ceiling form a shell for the orchestra.

Picture 2: Sibelius Hall in Järvenpää with orchestral shell and absorbing panels exposed on the side walls.

4 RESULTS

Almost all analysis on the measurements described in section 3 were done with the Matlab-application IRMA (Impulse Response Measurement Application) written by Timo Peltonen from Akukon Consulting Engineers[7]. Only the speech intelligibility was analyzed with WinMLS 2004.

In this section is presented few of the usual parameters for a concert hall. The main focus in this study is the variability of the acoustic environment in the auditorium, therefore instead of showing only the absolute values also the change in percent or dB is showed.

The average for the conventional hall parameters reverberation time (T20), early decay time (EDT) and clarity (C50, C80) were calculated for different configurations of the halls[5]. Because the halls are used in addition to music performances for conferences and other speech programme the speech transmission index (STI, RASTI) were also calculated for the halls[6].

4.1 Hall parameters

Average values for different configuration of the variable acoustics are shown for the hall parameters in Vanaja Hall in Hämeenlinna and Sibelius Hall in Järvenpää for reverberation time in

Figure 2 and Clarity C80 in Figure 4. The change in percent for reverberation time in percent is shown in Figure 3 and the change in dB for Clarity C80 in Figure 5.

The average values for the hall parameters and speech intelligibility is summed up in Table 1.

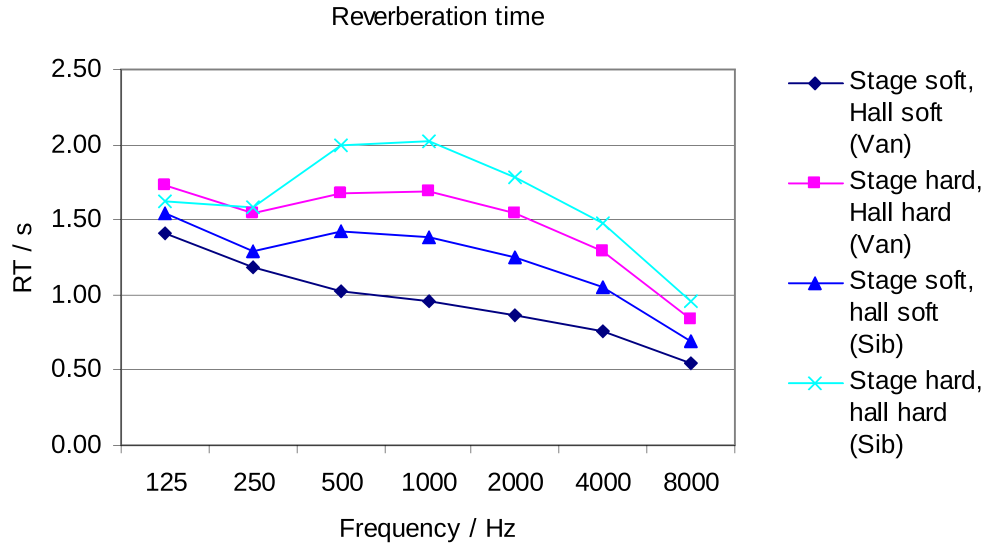


Figure 2: Reververation (T20) time for Vanaja Hall (Van) and Sibelius Hal (Sib) in all hard and all soft configurations of the variable acoustics.

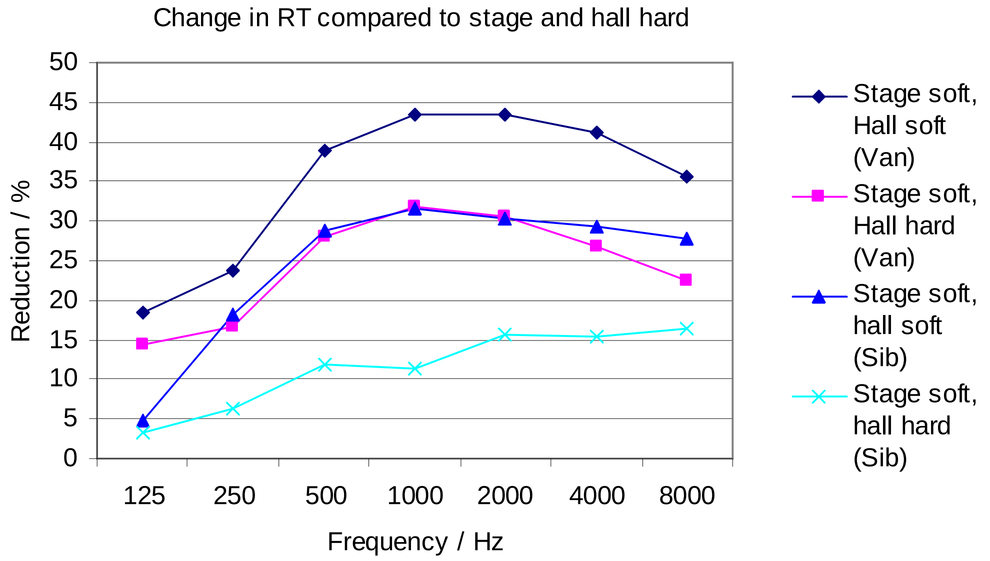


Figure 3: Change in percent of reverberation time for Vanaja Hall (Van) and Sibelius Hall (Sib) compared to halls hard i.e. in concert configuration.

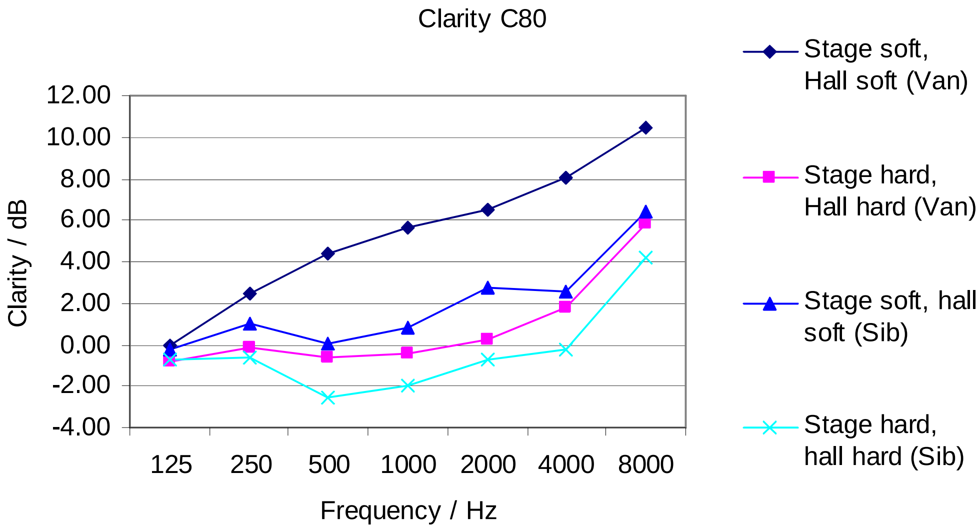


Figure 4: Clarity C80 in Vanaja Hall (Van) and Sibelius Hall (Sib) in different configurations of the halls.

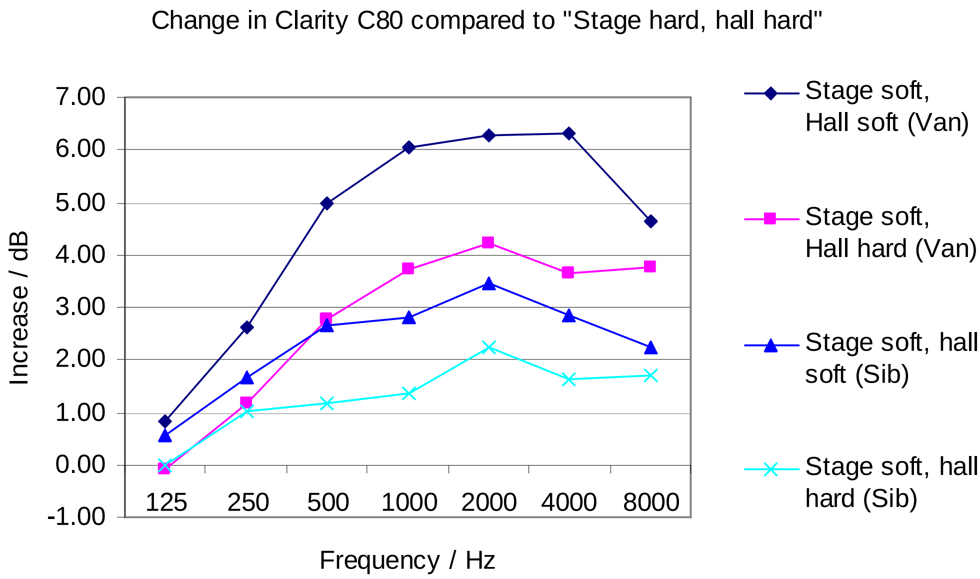


Figure 5: Change in Clarity C80 in Vanaja Hall (Van) and Sibelius Hall (Sib) in different configurations of the halls.

	hard		soft	
	Vanaja	Sibelius	Vanaja	Sibelius
Reverberation time (mid)	1.7 S	**2.0** s	1.0 s	**1.4** s
Bass-Ratio	1.0	**0.8**	1.3	**1.0**
Early Decay Time (mid)	1.7 S	2.0 s	0.9 s	1.4 s
Treble-Ratio	0.8	0.8	0.8	0.7
Clarity C50(mid)	-3.0 dB	-5.0 dB	2.5 dB	-2.0 dB
Clarity C80(mid)	-0.5 dB	-2.3 dB	5.0 dB	0.4 dB
Speech Transmission STI	0.59	0.53	0.69	0.61
Speech Transmission RASTI	0.55	0.48	0.70	0.58

Table 1: Hall parameter for Vanaja Hall in Hämeenlinna and Sibelius Hall in Järvenpää in hall all hard and all soft.

5 CONCLUSIONS

As the results in section 4 shows both adding absorption by curtains and rotating panels with absorbing material can effectively reduce the reverberation time in an auditorium. Even though the Vanaja Hall has a bigger overall volume the reduction in reverberation time is bigger. The Sibelius hall has got approximately half of the side walls covered with absorbing material in soft mode. Vanaja hall in turn have most of the side walls covered with absorbing banners, except for the balcony fronts, in soft mode. It is difficult to fit absorbing as much absorbing panels on the walls as retractable banners. In order to achieve true variability in an auditorium a combination of different variable elements should be implemented. Banners alone on the side walls or suspended from the ceiling are more suitable for tuning the acoustics instead of truly varying it for different purposes.

Reverberation time and clarity is certainly telling much of how the variable elements change the sound-field in an auditorium. They are still not describing how the spatial impression is changed due to adding absorbing material into the auditorium.

6 REFERENCES

1. H. Möller, A. Ruusuvuori, O. Salmensaari, O. Lindfors. Designing Halls With Variable Acoustics, Proc. B-NAM 2008, 17-19.8.2008, Reykjavik
2. Kahle Acoustics and Altia Acoustique, Acoustic Brief of Philharmonie de Paris (2006), http://www.kahle.be/articles/programme-acoustique86D33.pdf
4. A. C. Gade, Acoustical Survey Of Eleven European Concert Halls, The Acoustic Laboratory - Technical University of Denmark, Report No. 44 (12-27) (1989)
5. International Standard, Acoustics – Measuremen of the reverberation time of rooms with refernce to other acoustical parameters, ISO 3382:1997(E)
6. International Standard, Sound System Equipment – Part 16: Objective rating of speech intelligibility by speech transmission index CEI/IEC 60268-16:1998
7. T. Peltonen, A Multichannel Measurement System for Room Acoustics Analysis, M.Sc. Thesis, Laboratory of Acoustics and Audio Signal Processing, Department of Electrical and Communications Engineering, Helsinki University of Technology 2000