OPERA HALL ORCHESTRA PIT ACOUSTIC

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Abstract

Within the last few years, we have used the "virtual orchestra" to measure acoustic conditions within the orchestra pit, and in particular, the connection between the pit and the parterre in two different opera orchestra pits, The Finnish National Opera and The Bolshoi Theater Historic stage in Moscow.

The paper will first of all describe the measurement system and setup, the actual measurements and discuss the results and the implications on design.

INTRODUCTION

The loudspeaker orchestra - a measurement system consisting of a large array of sources on stage was initially proposed in IOA Auditorium Acoustics in 2008[1].

In our case, that is for opera houses, the system offers a better method of investigating the acoustic connection between both the orchestra pit and the audience between the vocalist on stage and the audience as it uses a setup of semi-directional loudspeakers as compared to normal room acoustic investigations where an omni-directional loudspeaker is used.

The original measurement method and its refinements have been described in references [1] – [11] and the measurements in the Finnish National opera has previously been presented in [12].

Both the Finnish National Opera and the Bolshoi Opera was reported to have some acoustic challenges, regarding both the orchestra pit and stage, and more precisely the projection of sound from both pit and stage.

The “Virtual orchestra system” was used to get directional impulse responses from both these halls and based on the analysis of the direction impulse responses, improvement suggestions were presented.

The challenge with the original Virtual Orchestra setup is, from a consultant point of view, the high number of loudspeakers. So, one of the challenges for the Bolshoi measurements was to reduce to total amount of loudspeakers and instead move the loudspeakers in the pit and on the stage. For the measurement a total of 4 small Genelec loudspeakers were used together with 2 medium size studio monitors, borrowed on site and one omnidirectional loudspeaker for direct reference to ISO 3382-1 parameters

2 THE FINNINSH NATIONAL OPERA

The Finnish National Opera is a horseshoe-type opera house opened in 1993. The medium-size theatre seats a combined audience of 1350 at the stalls and three tiers of balconies. The main stage has equally sized rectangular side and back wings, and a fly-tower. The floor plan and side section drawing are shown in Fig. 1. The orchestra pit accommodates a typical opera orchestra, and there is no overhang below the stage. A prominent feature of the side walls of the auditorium is that most of the overall surface consists of audience doors. They are angled so that they do not provide any natural early reflection patterns to the audience. Another feature of acoustic significance is that the balcony fronts are essentially smooth and tilted down towards the audience. This creates some focusing effects, which are mainly heard when the sound reinforcement system is used. Despite these observations, the acoustic conditions of the hall in general were found pleasing for the performers as well as audience since the inauguration, but also left room for improvements in the future.

A major renovation took place in 2007, when the stage mechanics and most of the audio-visual infrastructure were replaced. At the same time, the pit was enlarged to remove the pit overhang. Also, the sidewalls in front of the proscenium opening were altered. The intention of this modification was to enhance early reflections from the singer and provide better support for the orchestra. The general impression after the renovation was that the acoustics was improved, but the hall could still benefit from further improvements for some issues: missing clarity of the singers inside the auditorium; balancing the orchestra and singers; uneven sound and low brilliance of the strings inside the audience area; and, local sound focusing inside the audience area.

In 2015, the seats in the entire hall were scheduled to be replaced, and the orchestra shell was changed. This renovation also opened a possibility for further acoustical modifications, and it was decided to commission investigation of the acoustic conditions in order to suggest improvements for the opera house. The renovation of the seats required the conventional measurement reverberation time and other basic objective parameters in the opera house. For learning more on the room-acoustic features of the venue, we conducted spatial impulse response measurements with the loudspeaker orchestra. These measurements were studied by applying recently introduced analysis methods for evaluating the acoustics through spatiotemporal visualizations and planning the conceivable modifications based on those findings.

The measurements points are shown in Figure 1.

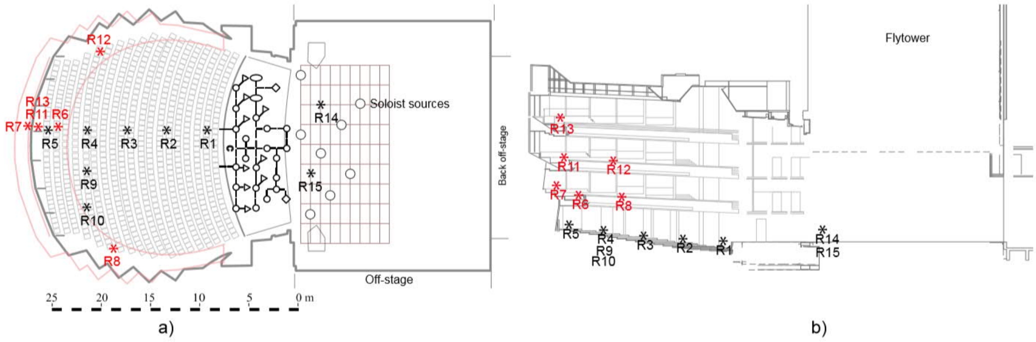

Figure 1: Measurement points in the Finnish National Opera

Measurement results

The visualizations show the accumulation of the spatial sound energy over time. Each of the outward expanding curve accumulate the directional energy from the initial direct sound to 5, 10, 20, 30 (bolded), 40 ms etc. up to 200 ms. The outermost red curve represents the spatial distribution of the entire impulse responses. Note that the curves are averaged over source positions included in each visualization. Detailed description of the visualization technique are presented in [5].

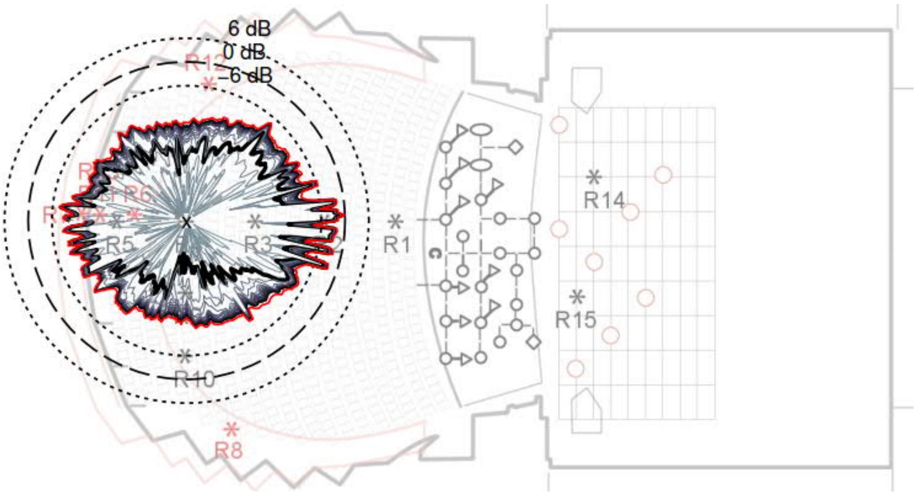

Figure 2: Reciever R4 X-Y direction, Stage sources only

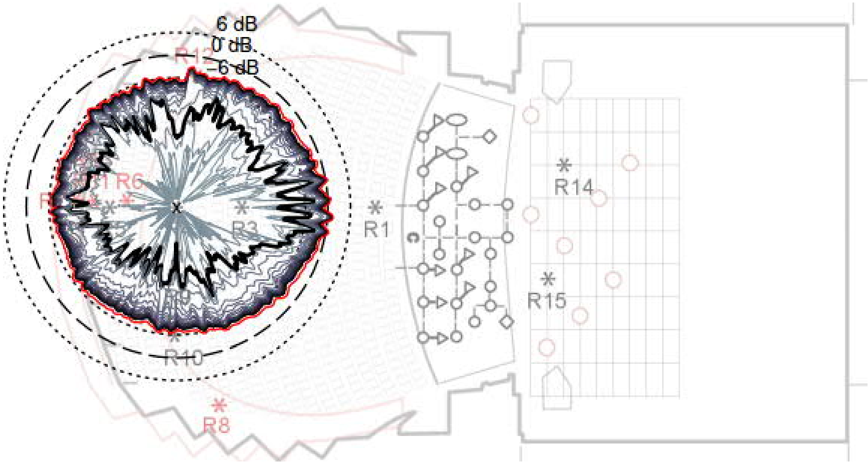

Figure 3: Receiver R4 X-Y direction, pit sources only.

As can be seen from Figs. 2 and 3, there is very little early lateral reflections (within the initial 30 ms; thick black curve) from the area around the proscenium. For the sources on the stage the few spikes outside the source positions suggests that the proscenium provides distinct reflections with only certain soloist positions. In the lateral plane (X-Y direction) from the pit we see that the example receiver position has a line-of-sight into only few source positions, and the unobstructed direct sound is shown as the strong spikes in the respective directions. Both for the stage sources and for pit sources there are quite strong reflections from the rear of the hall, which is expected due to the curved geometry.

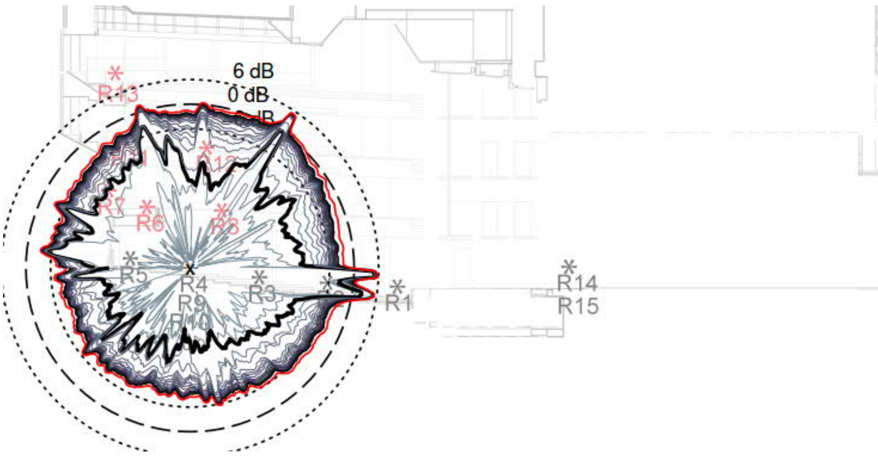

Figure 4: Receiver 4, X-Z direction, pit and stage sources

When inspecting the X-Z plane, it can be seen quite clearly that there is a very strong overhead reflection from the flat ceiling in front of the orchestra pit.

3 THE HISTORIC HALL OF THE BOLSHOI THEATER IN MOSCOW

The Historic Hall of the Bolshoi Theater is one of the most famous opera venues in the word. The original building for the Bolshoi Theatre was build opened in 1825 and has been reconstructed several times since then. The last major reconstruction was between 2005 and 2011. In this reconstruction, all technical systems in the building was renewed but hall itself was essentially renovated, no geometric changes was made, except for some changes of the orchestra pit railing.

The problems reported are mainly concerning the sound on the parterre, in particular the front parterre. The orchestra is perceived as “not clear, detached, poor balance”. Also the soloists are not perceived clearly. It should however be clear that this concerns only the parterre. No such problems are reported from the balconies.

Measurement setup

As the equipment had to be flown to Moscow, it was necessary to narrow down the measurement setup, which led to using only 4 small directional loudspeakers, 2 mid-size studio monitors borrowed from the Bolshoi Theater and one omni-directional source for standardized measurements.

An ambisonic microphone, the CoreSound Tetra mic was used for spatial measurements and a DPA 4006 omni-directional microphone as extra references. The loudspeakers were placed in the pit (S1.1…S1.7) and on stage (S2.1…S2.3) as can be seen from Fig. 5.

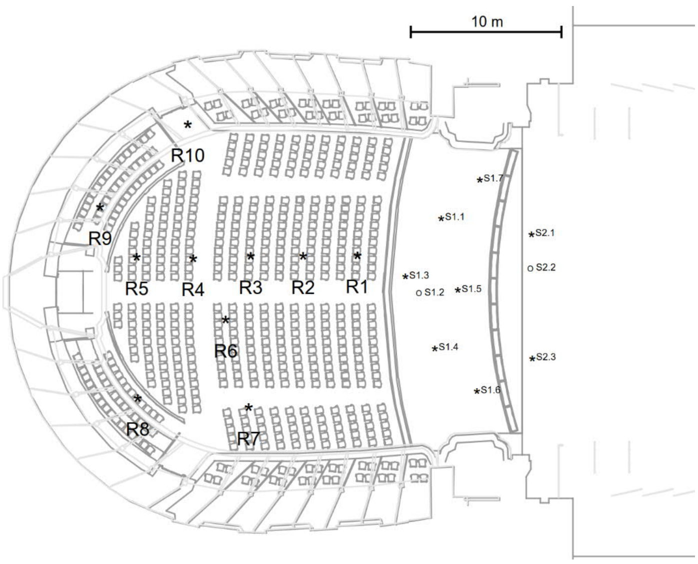

Figure 5: Source and reciever positions in the Historic Scene of the Bolshoi Theater

Evaluation of the measurements

The spatial room impulse responses pointed to some apparent problems with the projection between both the stage and the orchestra pit and the parterre. From the X-Y plane (lateral plane) shown in Fig. 6, it is clear that very little early lateral reflections reach the listener positions on the parterre. What is also clear is that the diffraction from the orchestra pit railing is very low in energy.

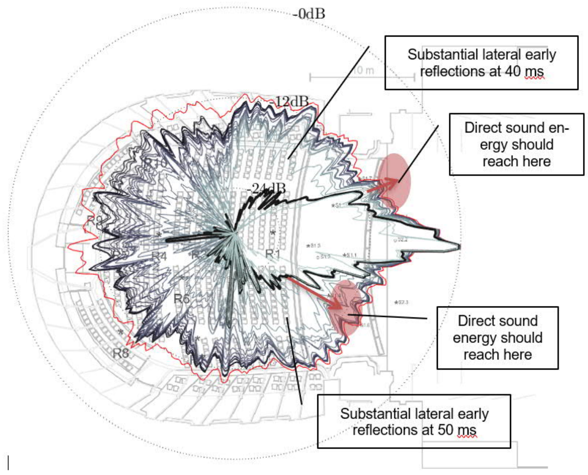

Figure 6: Example of measured spatial impulse response, X-Y axis: Receiver position R2; orchestra pit sources.

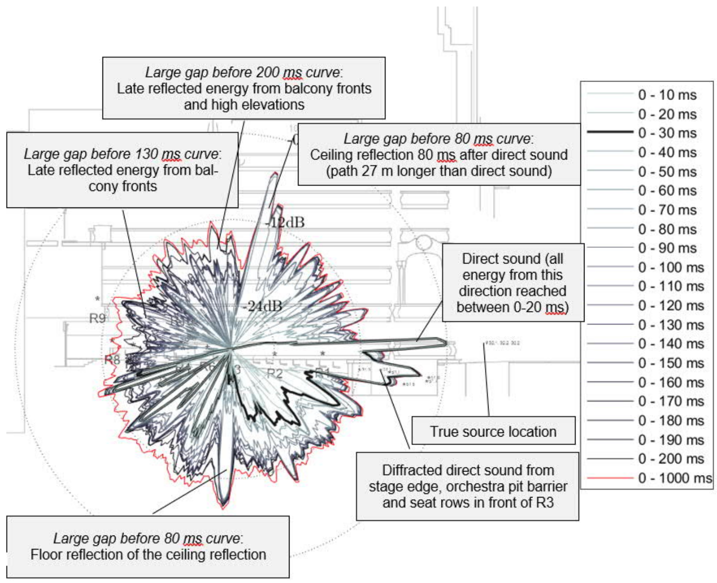

Figure 7: Example of measured spatial impulse response, X-Z axis: Receiver position R3, Source S2.2 (omni-directional source)

As can be seen from Fig. 7, there is a very strong ceiling reflection from some source positions. This can almost be heard as discrete reflections (in the empty hall between ceiling and floor)

4 DISCUSSION

The work shows, from a technical point of view, that it is possible to use a downscaled version of the virtual orchestra to investigate foremost reflection- and projection-related problems in opera houses. The directional speakers provide a possibility to simulate the natural directional characteristics of the orchestra and, to moderate extent, the singers on stage, whereas the use of an omni directional source, makes it possible investigate pure geometric patterns in the hall.

The microphone used in the Bolshoi measurements is essentially a standard Ambisonic microphone, but our measurements show that the precision of the microphone is suitable for measuring spatial impulse responses that can be feasibly analyzed in 3-D.

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