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2aAAa3. Active acoustics and sound reinforcement at TUI Operettenhaus, Hamburg: A case study
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TUI Operettenhaus is a proscenium theater with one balcony which is host to drama, musical theater, and concerts. The venue hosts different sound reinforcement systems for different shows, and now has a permanent active acoustic system. The physical acoustics are very dry as is appropriate for modern theater with spatial sound reinforcement, and the active acoustic system allows the reverberation time to be extended as appropriate for different performances. The active acoustic system can also pass through signals to it's speakers for spatial surround reproduction. The installation of the active acoustic system in an older building posed many challenges. This case study presents the challenges that were overcome during installation, the integration of the active acoustic system with sound reproduction, and the measured performance of the system.

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Introduction

The first performance venue at the site of Operettenhaus, Hamburg was built in 1841 for horseback riding (dressage) and named Circus Gymnasticus. The venue has been rebuilt and renovated many times. It was most recently rebuilt after World War II, and continues to be renovated from time to time. Since 2007 it has been named TUI Operettenhaus and seats 1350. It is host to conferences, drama, musical theater, and concerts.

The mid-band physical reverberation time is 0.8 seconds as is appropriate for speech performances such as conferences and drama\textsuperscript{1,2,3}. Because of the benefits of having a widely-variable reverberation time\textsuperscript{4} an active acoustic system was installed in 2012 to provide longer reverberation times useful for acoustical musical performances and for theatrical effect. As Barron\textsuperscript{5} points out, the “use of a single space for both speech and music is usually not possible without electronic assistance.” The active acoustic system chosen was Constellation manufactured by Meyer Sound Laboratories. It was installed by Stage Entertainment, who is also the owner of the venue.

Active Acoustic System

The acoustics of a room can be controlled both actively and passively. Absorption can be added or subtracted from the room, sometimes with rotating panels or moving curtains. Moving ceilings or doors to coupled spaces may be used to control the cubic volume\textsuperscript{5,6}. These methods will be referred to as “passive” because they control the rate at which sound is removed from the room. Alternatively, microphones, signal processing, and speakers may be used to add early reflections and reverberation to the room. Increasing the level between the microphones and speakers increases the reverberation time, raises the reverberant level in the room, and is therefore analogous to reducing the effective absorption. Adding reverberation to the signal between the microphones and speakers increases the resulting reverberation time without increasing the reverberant level in the room, and is therefore analogous to increasing the cubic volume\textsuperscript{7}. This method will be referred to as “active” because it controls the rate at which sound is added back into the room. Using an active acoustic system can result in significantly less renovation to an existing building, or a new building with significantly less cubic volume made of lower weight materials. Because of these advantages, using an active acoustic system could possibly result in earning Leadership in Energy and Environmental Design (LEED) credits\textsuperscript{1}.

The Constellation system uses the Variable Room Acoustic System (VRAS) algorithm invented and patented by Mark Poletti of Industrial Research Limited (IRL). The VRAS processor uses a unitary reverberation algorithm which can provide a uniform increase in reverberation time versus frequency, and a gain-before-feedback which increases with the number of decorrelated microphone and speaker channels\textsuperscript{8,10}. Poletti has shown that when reverberation is added between microphones and speakers the reverberation time gain is:

\[
\frac{T_{\text{result}}}{T_{\text{physical}}} = \frac{\alpha}{\left(1 + \alpha\right) - \sqrt{\left(\frac{\alpha - 1}{2}\right)^2 + \alpha k^2}}
\]

Where \(T_{\text{result}}\) is the resulting reverberation time using the active acoustic system, \(T_{\text{physical}}\) is the reverberation time of the physical room, \(k^2\) is the coupling constant, and \(\alpha\) is the ratio of the reverberation time in the processing to the physical reverberation time: \(\alpha = T_{\text{processing}}/T_{\text{physical}}\). Thus the resulting reverberation time in the room is not necessarily the same as the reverberation time of the processor. In fact, one can make multiple settings with the same resulting reverberation time by using different coupling constants and processor reverberation times. Even though these settings will have the same resulting reverberation time, they may be different in other qualities such as Early-Decay-Time, Clarity, Strength, etc. The VRAS algorithm has been found to meet or exceed these predictions for reverberation time increase\textsuperscript{11,12}.

System Design

The system consists of: speakers and microphones distributed throughout the venue, analog-to-digital and analog-to-digital interfaces distributed throughout the building, and centralized digital signal processing. Where speakers are far from listeners, a low density of higher power speakers is used. Where speakers are close to
listeners, a higher density of lower power speakers is used\cite{12}. Where ceilings are high, hanging cardioid microphones are used. Where ceilings are low, a higher density of omnidirectional microphones is used. The same signal processors used to provide reverberation can also matrix surround sound and other spatialized audio signals to the same speakers. The system design is shown in Figure 1.

![Figure 1. System Design: Ceiling (upper left), Under-Balcony (upper right), Section (lower left), Legend (lower right). Devices are not to scale.](image-url)

This project came about at exceptionally short notice. Although the idea of installing Constellation in the Operettenhaus had been discussed with Sound Designer Peter Hylenski, there were less than 6 weeks from the green light to completion. Meyer Sound engineers designed the system, and the integration was divided between the theatre and show owners Stage Entertainment, who installed the loudspeakers and microphones, and Amptown System Company who installed the D-Mitri digital audio platform that hosts the Constellation system. As soon as the installation was complete it underwent exhaustive testing followed by calibration and tuning by Meyer Sound engineers.

The D-Mitri system is split into 4 separate locations to facilitate easier installation. CAT 6 cables provide the necessary interconnects.

The building presented many challenges, and there were several minor design changes to accommodate undocumented structural elements discovered during the installation. Meyer Sound worked closely with all concerned to ensure the changes could be accommodated. The system was delivered on schedule.

**Performance**

The reverberation time versus frequency for the physical reverberation and the various active acoustic settings is shown in Figure 2.
Figure 2. Reverberation time versus frequency for the physical reverberation and the various active acoustic settings

REFERENCES