VARIABLE CONTROL OF THE ROOM RESPONSE IN PERFORMANCE HALLS BY NATURAL OR ELECTRONIC MEANS

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1 INTRODUCTION

Depending on the user profile of a performance hall the reflection patterns and the reverberation field or in other words the overall acoustic properties must be designed purposeful. For acoustically different performances variability is required, which can be achieved by applying variable acoustic means or nowadays more and more by electronic enhancement systems.

In the last years two different performance halls have been opened with quite different user profiles, but in both cases with the demand of acoustic variability:

The Ukrainian based Kharkov Organ hall of the Regional Philharmonic with only about 500 seats was opened with a brand new Schuke organ on August the 19th 2016. The hall is designed for performing organ and choir music on one hand and orchestra repertoires on the other. Here acoustic variability can be achieved by natural means.

The Turkey based large Presidential Theatre in Ankara for more than 2000 visitors was opened in September 2016 and designed for reproducing sound reinforced (including speech) events on one hand, on the other hand theatre, opera and symphonic orchestra performances will happen. Here electronic means enables the wanted acoustic variability.

For both halls the realized different approaches for the acoustic design will be described, compared and discussed.

2 KHARKOV REGIONAL PHILHARMONIC ORGAN HALL

2.1 Background, Room Acoustic Targets and Design

The Kharkov Regional Philharmonic (Ukraine) is going to be reconstructed and already a new building was erected and inaugurated, housing a concert hall with 500 seats and used especially for organ and choir music. The room acoustic properties thus have been designed for organ music, but the hall is as well regularly used for symphonic orchestra music.

So an acoustic variability is necessary in order to ensure suitable conditions for both kinds of music presentation. This concerns not only variability of reverberation time, but as well enabling essential mutual hearing for the orchestra on stage.

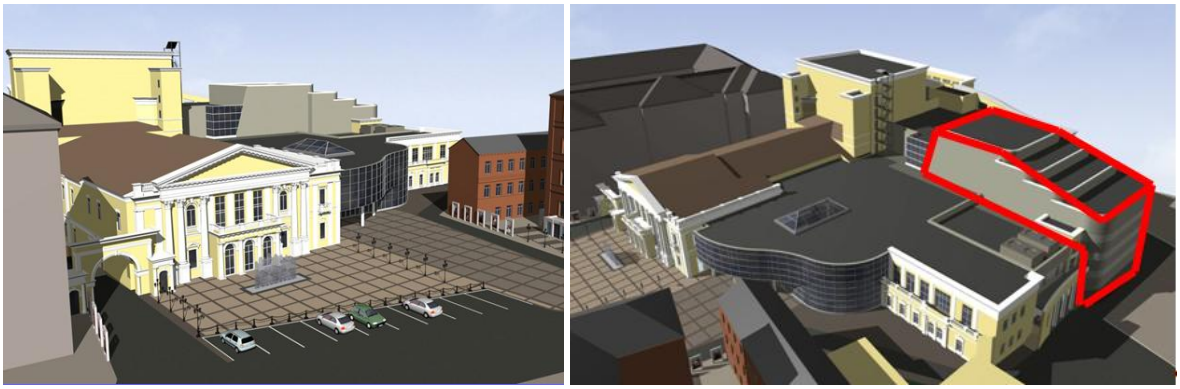

Figure 1: Architectural Renderings (© Rabinowitsch Architects) of the Kharkov Regional Philharmonic building ensemble of; right: The building with the organ hall is marked in red

In the starting phase of the project a room acoustic design had to be developed, describing a suitable inner shell of the hall inside an already existing raw building construction of 11,000 m³ volume.
A number of 500 audience seats had to be realized economically. In the design process it was found that the integration of technical devices (HVAC, lighting bridge, etc.) enables a hall of max. 8.000 m³ inside the raw building. This leads to a volume index of 16 m³/seat, which enables sufficiently high reverberation times for organ music. The development of the primary shape of the hall with secondary structures results in the following model:

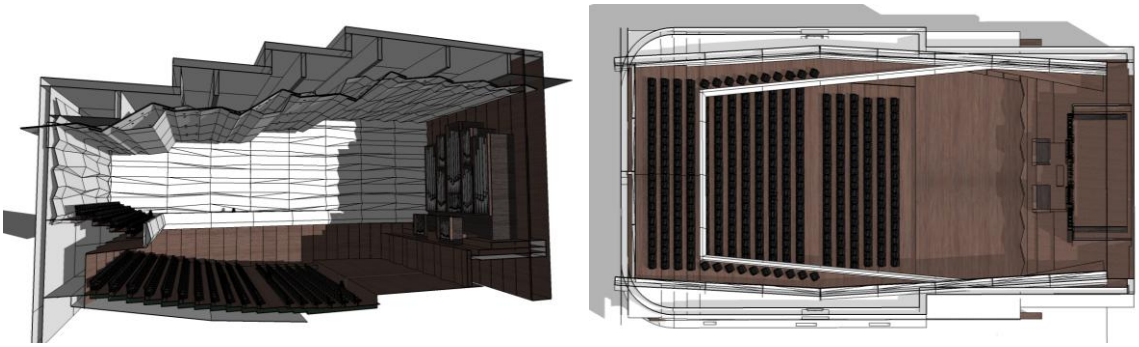

Figure 2: Model of the hall; left: View into the longitudinally opened hall, right: top view into opened hall

Regarding the volume of 8.000 m³ according standard literature [1] the target reverberation time is in the range of 2.7 s for organ and choir music to 1.8 s for orchestral performances:

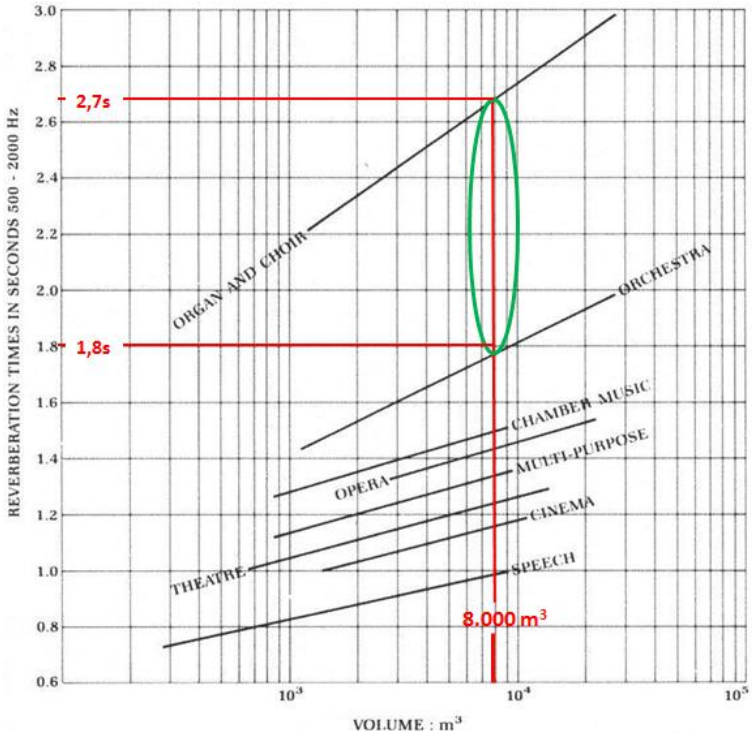

Figure 3: Target reverberation time depending on volume and purpose (© Russell Johnson), with marks in red and green representing the Kharkov Organ Hall

For acoustic variability a moveable plafond of approx. 100 m² area was designed. High efficient absorption is placed on top of the plafond and at the ceiling soffit above. Sound getting into these absorption areas is only enabled if the plafond is lowered from the ceiling; if it is at highest (parking) position right in the height of the ceiling soffit the absorptive areas are covered completely.

The lowering of the moveable plafond decreases reverberation time significantly, whilst on the same hand early reflections are generated back into the orchestra, strengthening essential mutual hearing.
For supporting the sound traveling in the hall's volume for the needed prolonged reverberation time and diffusing the sound field a secondary structure cladding the walls was developed as shown in figure 4 (right). This structure leads 2/3 of the sound energy upwards into the void under the ceiling, 1/3 downwards into audience and musicians.

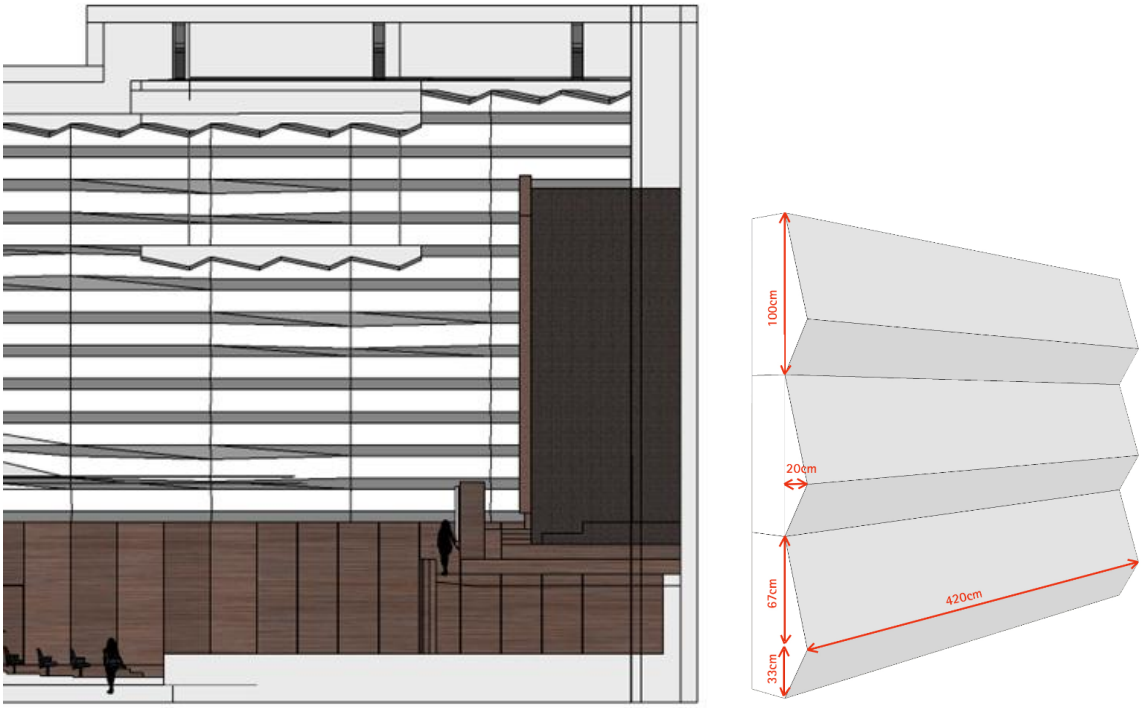

Figure 4: left: Detailed lateral view on stage with organ an moveable plafond, right: Detailed sketch of the secondary structure at the walls

Based on the above described design a simulation model was built for room acoustic investigations:

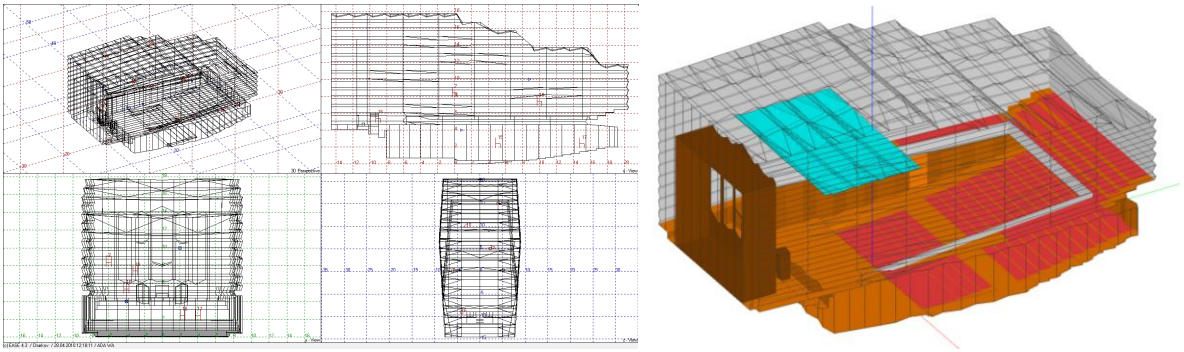

Figure 5: EASE simulation model, left: wire frame model, right: rendered view with lowered plafond

The simulations done in EASE-AURA showed that reverberation times can be expected on site laying inside the targeted range (see Fig. 3). In the highest position of the plafond right under the ceiling soffit sufficient high reverberation times are in the upper half of the targeted range. With the lowered plafond a significant reduction of the simulated reverberation times occur, with values in the lower half of the targeted range.

2.2 Results after construction completed

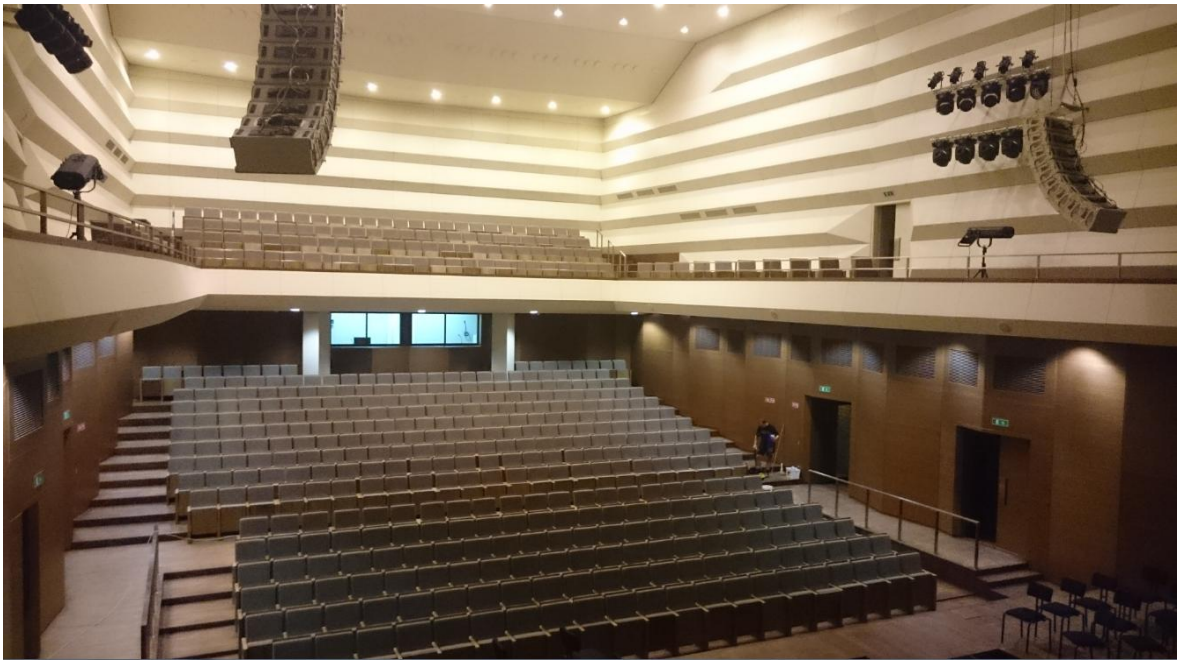

Figure 6: Photography of the hall after completion, view from organ balcony towards audience stalls and balcony

After completion on site room acoustic measurements in the unoccupied hall have been done with dodecahedron excitation on stage and organ balcony. On stage musicians' seats and other orchestra equipment was placed during measurements. All relevant positions of the moveable plafond have been taken into account for measurements.



Figure 7 a/b/c: View towards the ‚Schuke' organ with the plafond in front in high (left), medium (middle) and low position (right)

The high position is used for pure organ and choir music presentation. The medium position, which still enables a full view on the organ, is used during orchestra performances. The low position is only for special purposes, e.g. orchestra rehearsals or speech events.

On the next page the results of the reverberation time measurements for all plafond positions are shown:

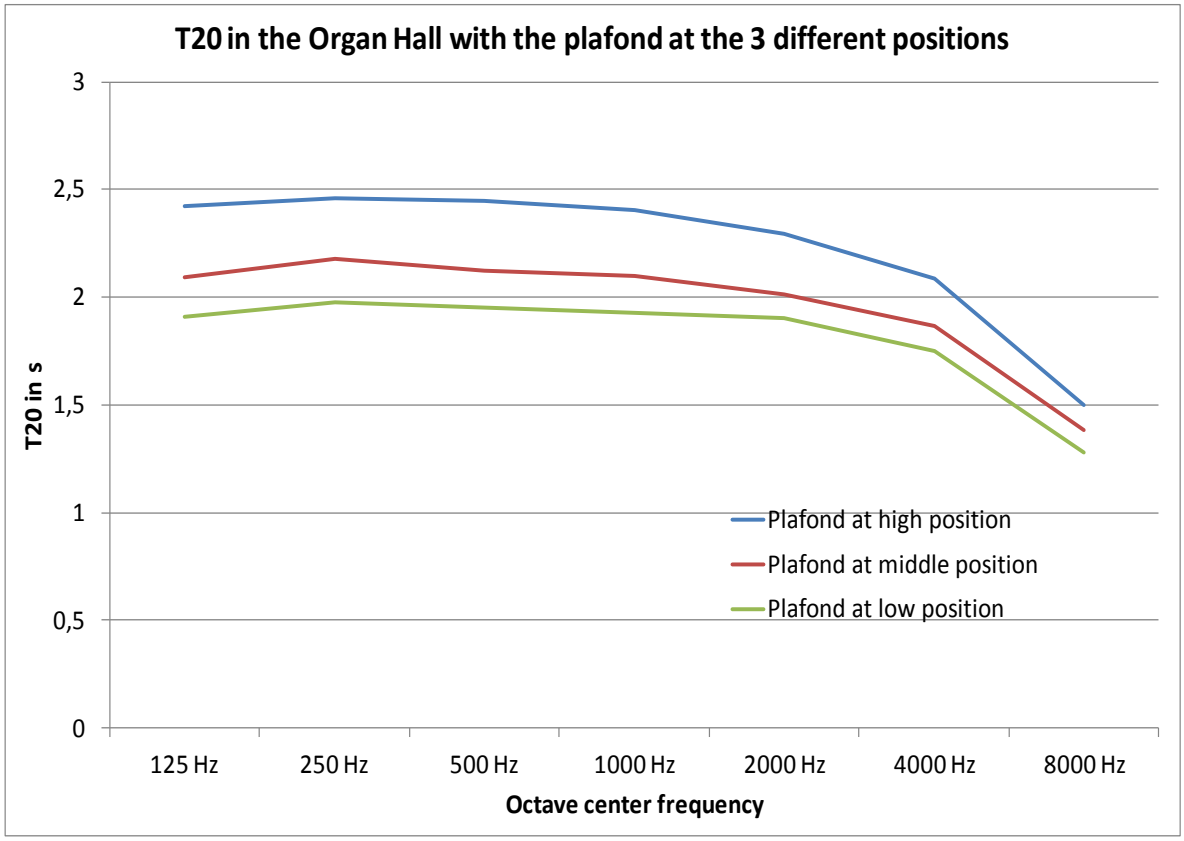

Figure 8: Measured reverberation times for the 3 plafond positions

It can be seen in the above figure that with the **plafond in high position** (blue line, absorption disabled) the mid frequency reverberation time is about 2.4 s. It may be remarked here that due to special kind of seating no significant reduction of reverberation time will happen in the occupied case, but instead higher values can be expected for pure organ music presentation when the stage is complete empty (no musicians' seats and other orchestra equipment as present during measurements).

In the **middle position of the plafond** (red line) a decreasing of the reverberation time is happening with values now about 2.1 s in the mid frequency range. This means a reduction about 3/10 s, which is a very good result, and can easily be heard subjectively. It may be remarked here that in case of orchestra musicians present on stage a slight furthermore reduction of reverberation time can be expected.

At **low position of the plafond** (9 m above stage) a reduction of another 2/10 s happens with reverberation times in the mid frequency range about 1.9 s.

So for all kind of music presentations the hall offers suitable reverberation times. As well other room acoustic measures have been investigated. So e.g. the clarity C_{80} and support measures are significantly higher in case of lowered plafond.

Subjectively musicians, audience and critics gave positive feedback for all kind of music presentations in the Kharkov Organ hall.

3 ANKARA PRESIDENTIAL THEATRE

3.1 Background, Room Acoustic Targets and Design

The Presidential Theatre in Ankara is a venue for sound reinforced events (including speech) on one hand, on the other hand theatre, opera and symphonic orchestra performances are happening. For the latter purpose a professional concert shell is part of the stage technical equipment. The volume of the hall (excluding the huge stage house and the void above the ceiling plafonds) is roundabout 16,000 m³. With its 2040 seats (stalls: 1264 seats, balcony 1: 432 seats, balcony 2: 344 seats) the volume index is 7.84 m³/seat, which is inside the desired tolerance range of 5...8 m³/seat and thus close to the upper limit of the established guide values, here for multipurpose halls.

By comparing figure 3 it is obvious that reverberation times of 1.9 s are needed here for symphonic purposes, 1.4 s for typical multipurpose theatre (speech and music), 1.3 s for drama theatre and 1.1 s for speech and electro acoustical reinforced purposes.
So an acoustic variability is necessary in order to ensure suitable conditions for all kinds of presentations. The first architectural plannings proposed a variability by mechanical means: Turnable elements with reflective and absorptive surfaces to be installed at the side walls of the hall. By simulation it was shown that this would lead to only 2/10 s variability of reverberation time. Regarding the above described range of necessary reverberation time variability, 2/10 s must be judged as insufficient.

So it was decided to realize an electronic system for room acoustic enhancement of the hall. In order to ensure a theatre-typical ‘natural’ (not electronically enhanced) reverberation field and considering the fact that reverberation time cannot be shortened by electronic means, the target reverberation time for the ‘natural’ acoustics in the hall had been set to 1.3 s in the mid frequency range. This is close to the shortest value of the above explained range and subjectively not too dry, but still allowing very good speech intelligibility indices for sound reinforced speech events. Higher values for reverberation time, up to 2 s, will be generated by a modern electronic enhancement system with a high number of loudspeakers at the walls, the ceiling and balcony soffits. Any sound sources on stage and proscenium will be captured by microphones flown from the upper machinery devices on stage.

The hall has been modeled in EASE 4.4 for room and electro acoustic investigations, the model is shown below:

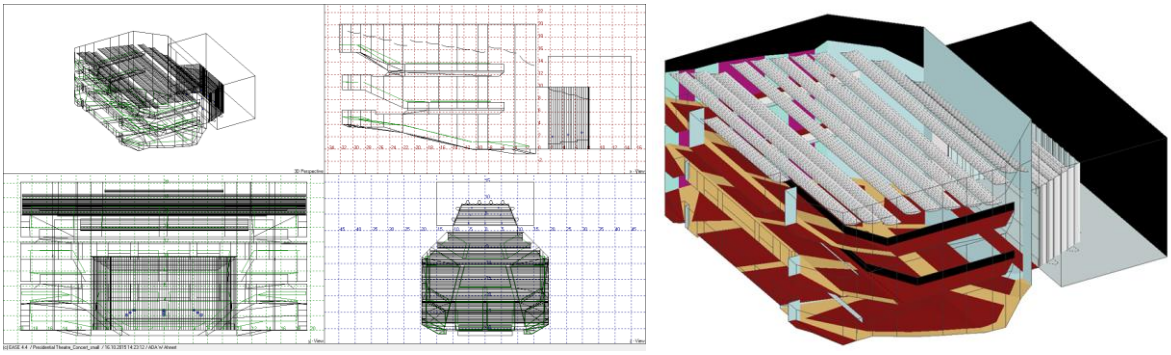

Figure 9: EASE model of the theatre hall with the concert shell and schematic stage house, left: wire frame views, right: rendered isometric view

The design of proscenium side walls, the ceiling plafonds and the wall claddings has been developed for the wanted ‘natural’ acoustic properties in order to get advantageous reflection patters, especially avoiding any theater hole in the middle stalls and to enable the target reverberation time. In the following figure some details of investigations and solutions are shown:



Figure 10: left: Exemplary EASE ray tracing for checking lateral reflections at proscenium side walls avoiding any theatre hole in the mid stalls, middle: photography of proscenium side wall structuring, right: module sample of a QRD-scattering structure, which has been installed in a high number along the walls in all levels



Figure 11: Photography of the hall after completion, view from stage through portal opening into the hall

Regarding all commercial products for electronic acoustic enhancement the final choice was to implement an 'Astro Spatial Audio'-System [2]. It is based on WFS algorithms developed by Fraunhofer IDTM in so-called 'Object based' design using a 'SARA' 3D audio engine.

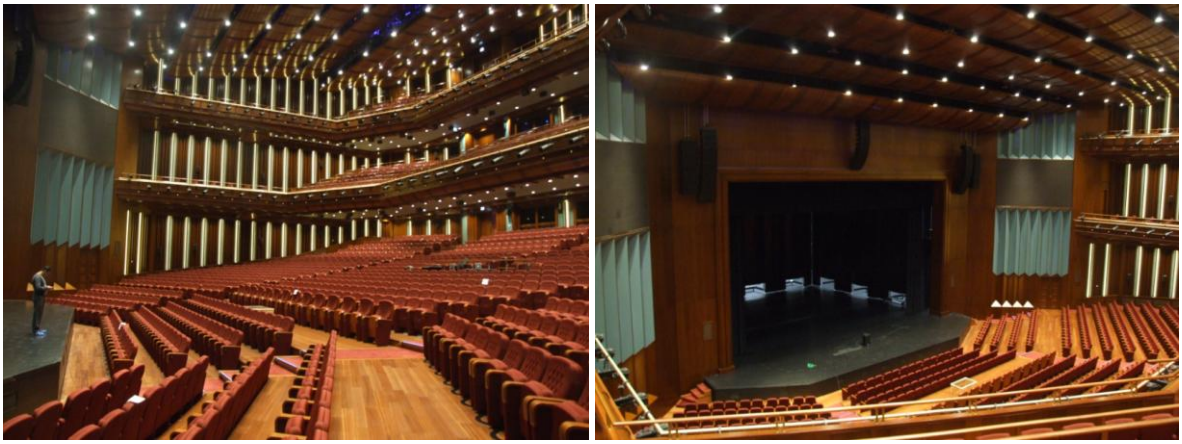

Figure 12: Photographs of the hall after completion, left: view from left wall in the hall, right: view from 1st balcony towards stage

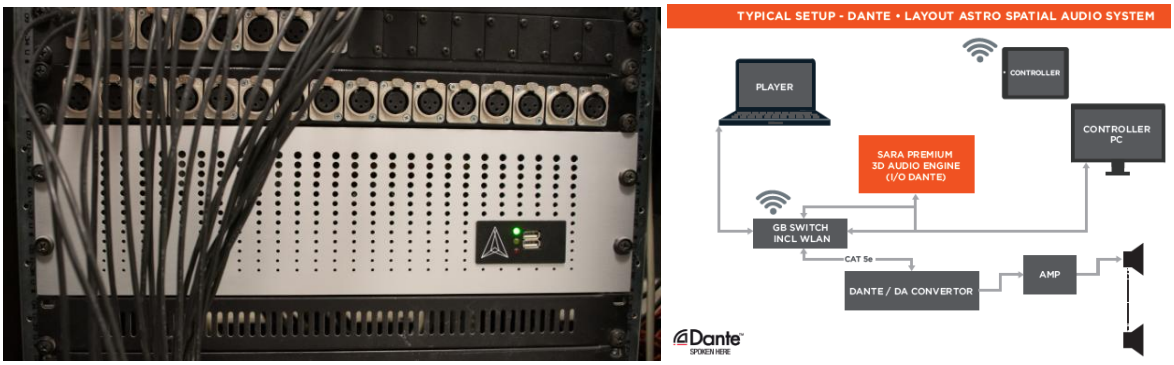

Figure 13: left: Photograph of the 'Astro Spatial Audio' main frame processor, right: Schematic block diagram of the system (© Bjorn van Munster / Astro Spatial Audio)

The 'Astro Spatial Audio'-system feeds a huge number of loudspeakers installed at the walls (as well the main line array loudspeaker systems at the portal opening), the ceiling and balcony soffits as shown by plan and section views as follows:

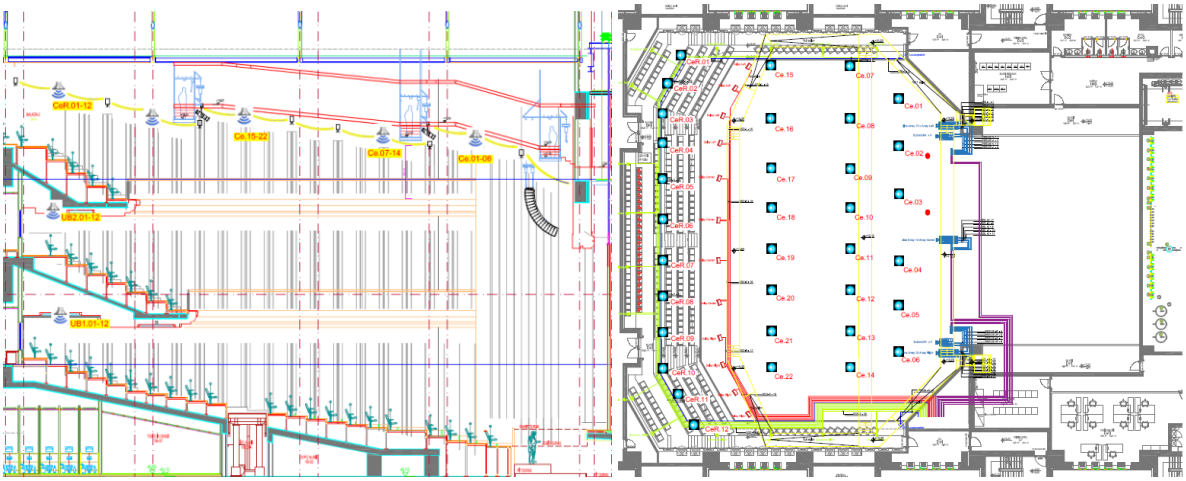

Figure 14: Loudspeakers for the electronic enhancement system, left: longitudinal section view with the yellow marked loudspeaker axes at the ceiling and balcony soffits, right: plan view with the blue marked loudspeakers at the main ceiling

After completion on site room acoustic measurements in the unoccupied hall have been done with dodecahedron loudspeaker excitation on stage inside the concert shell with the closed orchestra pit. For measurements all provided presets of the 'Astro Spatial Audio'-System have been taken into account. The next figure shows the results of the reverberation time measurements for 'natural' acoustics and all presets of the enhancement system, additionally the situation with open stage (no concert shell) and enhancement system 'off' (excitation by main sound system) has been measured:

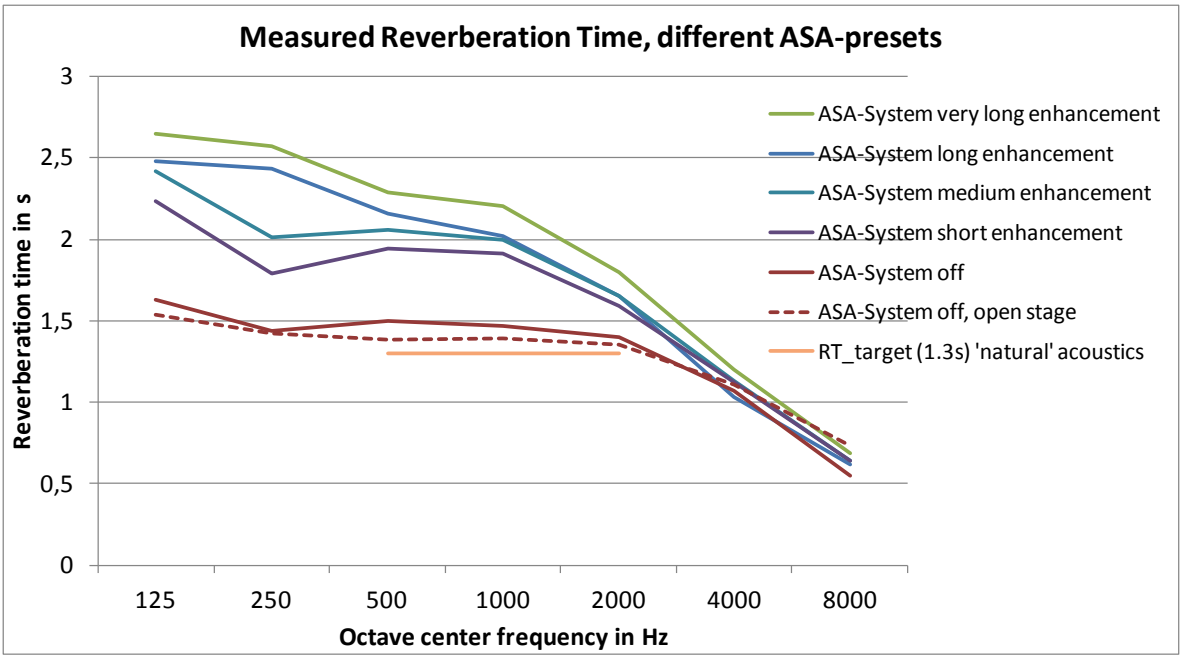

Figure 15: Measured reverberation times for 'natural' acoustics and all presets of the enhancement system (solid lines represent results with concert shell on stage, the dashed lines

The 'natural' acoustics reverberation time is approx. 1.45 s in the mid frequency range in case with the concert shell on stage, without any orchestra equipment on stage.
Slightly lower values have been measured with open stage (no concert shell) and excitation by main sound systems. It may be remarked here that in the occupied case a slightly reduction of reverberation time will happen.
Depending on the preset of the 'Astro Spatial Audio'-System, the enhancement leads to prolonged reverberation times as wanted for all music presentation performances.

Besides room acoustic enhancement and prolongation of the reverberation time the 'Astro Spatial Audio'-System is used in the Ankara Presidential Theatre hall for performing 3D-audio scenes of all kind.

4 REFERENCES

1. T. Behrens, W. Ahnert: Neubau eines Saals für Orgelmusik in Kharkov/Ukraine, Fortschritte der Akustik DAGA 2017 (2017)
2. https://www.astroaudio.eu/