PROCEEDINGS of the
International Symposium on Room Acoustics

15 to 17 September 2019 in Amsterdam, Netherlands

Acoustical Design of the Blue Whale Auditorium in Buenos Aires

Gustavo BASSO[1]

[1] IPEAL, Facultad de Bellas Artes, Universidad Nacional de La Plata, Argentina

ABSTRACT

The "Blue Whale" Auditorium in Buenos Aires opened in 2015. Designed to be the headquarters of the National Symphony Orchestra of Argentina, its goal was to become the city's main space for symphonic music. The architectural program posed several challenges from an acoustic point of view, as 2,000 people had to be accommodated in a square space into which none of the usual architectural typologies fit properly. It was decided, therefore, to place in this space an "ad-hoc" hall, whose shape is far from traditional. The design centred around three main premises: to achieve an enveloping acoustic field, by generating a large number of lateral reflections within the Haas limit; to establish an adequate triple-slope reverberation decay; and to combine reflective and diffusing surfaces to attain a similar acoustic field through the entire audience area. This work details the design process of the Auditorium, during which the final shape was deduced from the established acoustic premises.

Keywords: Symphonic Auditorium, Acoustical Design, Early Reflections

1 INTRODUCTION

The Blue whale Auditorium of the Kirchner Cultural Centre, designed to be the headquarters of the National Symphony Orchestra of Argentina in Buenos Aires, opened in 2015. The architectural brief stated that that the building had to accommodate 2,000 people and an orchestra of 100 musicians in a square of side 45 m (the area reserved for the theatre can be seen in Figure 1). None of the usual architectural typologies fit properly into this space: it was not long enough for a "shoebox" type room; a fan-shaped hall would not have had enough lateral energy; and an arena would not have provided the desired spatial homogeneity.

Figure 1: Square space of 45 m side designated to accommodate the hall

It was decided, therefore, to place an ad-hoc hall in this site, with a shape that was far from traditional. The design centred around three main premises: to reach an enveloping acoustic field with, at the same time, great sound clarity; to achieve a homogeneous acoustic field through the entire

[1] gusjbasso@gmail.com

audience area; and to establish an adequate reverberation decay.

To fulfil the initial condition, a first reflection was required that was as close as possible to the direct sound, with a delay not exceeding 30 ms in most of the seats [1] [2]. It was also essential to provide a large number of significant lateral reflections within the first 150 ms with intensity and delay near the upper limit of Haas [3]. An early acoustic field with a dense and well-distributed texture was sought, but at the same time it was important not to produce echoes, spectral colorations or perceptible changes in the location of the acoustic source [4] [5]. The second condition required an adequate blend of reflecting and diffusing surfaces. Too much diffusion would have precluded the necessary reflections required in order to achieve an immersive acoustic field but, conversely, an insufficient or misplaced diffusion would have prevented the homogeneous distribution of the acoustic energy [6] [7]. The acoustic absorption was reduced to only the strictly necessary; just the amount provided by the seated audience and the empty seats. Condition three implied a sound field with a large reverberation and, simultaneously, very good clarity. The choice made, therefore, was a triple-slope reverberation decay; the first part dominated by the early reflections, the second part by the total volume of the hall, and the third part by the reinjection of acoustic energy from external reverberation chambers.

2 DESIGN PROCESS

2.1 Deciding the shape of the hall

The final shape was deduced from the three aforementioned premises following an iterative process. The main early reflections were analysed, using Catt-Acoustic software, from all source-receiver (SR) pairs. Nine source positions and 85 receiver positions were used in the calculations. The shape and location of the interior surfaces were arranged in such a way that the sequence of early reflections was retained, as far as possible, close to the modified upper limit of the Haas scheme. After 16 complete iterations, a geometric design was achieved that allowed the desired pattern of early reflections to be maintained in 90% of the seats calculated. Figure 2 shows two stages of the iterative process for an SR pair.

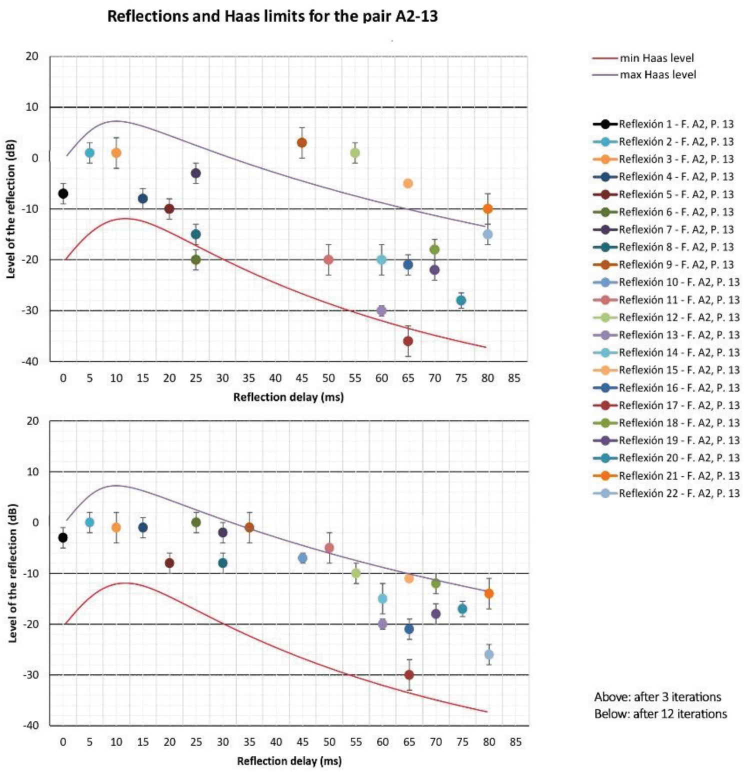

Figure 2: Main non-frontal early reflections in the Haas scheme for the A2-13 pair (source in the centre of the stage, receiver near the centre of the main floor). Above at the beginning of the iterative process, below at an advanced stage of the process, The sound power of the source was modified between the simulations

The appropriate incidence direction of each SR pair was set in order to maximize the non-correlated lateral energy. Figure 3 shows the shape of the plan view that was reached at the end of the iterative process.

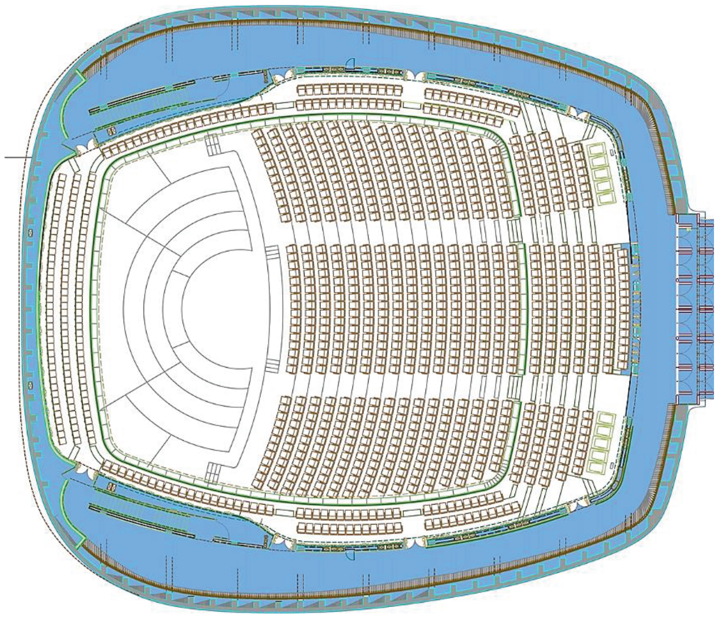

Figure 3: Plan view of the final design. Its shape does not fit any of the traditional typologies; it is too wide to be a shoebox, and the stage at one end and the absence of terraces mean it cannot be considered an arena either

Two levels of balconies were included to produce strong broadband reflections on the main floor, as can be seen in Figure 4.

2.2 Selection of the inner surfaces

The appropriate proportion and location of the reflecting and diffusing surfaces were key factors when designing the hall. Too much diffusion wouldn't have produced the necessary reflections to achieve an immersive acoustic field but, on the other hand, a deficient or ill-disposed diffusion would have prevented the even distribution of the energy and the hall would have become spatially uneven. The acoustic absorption had to be reduced to the strictly necessary: the seated audience or the empty seats. Figure 4 shows the disposition on the inner surfaces.

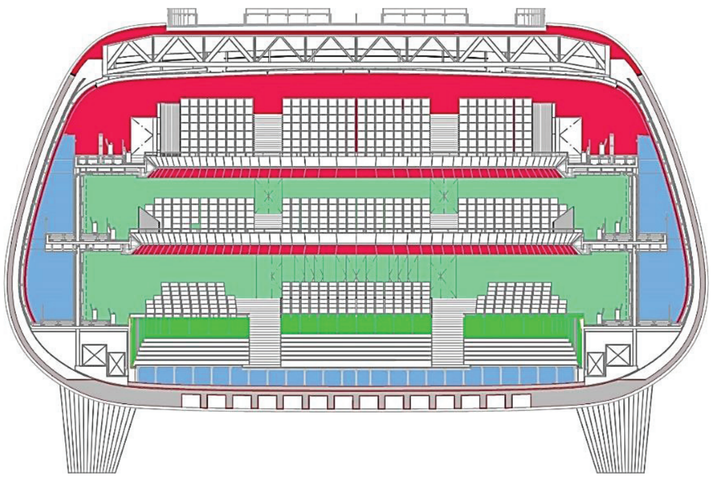

Figure 4: Cross section of the hall showing the distribution of some of the acoustic devices: reverberation chambers in blue, diffusive surfaces in green and reflective surfaces in red

2.3 Reverberation

A proper reverberation curve was another key factor considered in the design. Once the general shape was established and the diffusing and reflecting surfaces were arranged, a triple-slope decay with a Reverberation Time T30 of 2 s at medium frequencies was chosen. Rooms with a single exponential slope, which follow the model proposed by Sabine at the beginning of the 20th century, must choose between a global acoustic field with high reverberation and little clarity or low reverberation and great clarity. The triple slope was chosen to maximize both features: the first part determined by the early reflections, the second by the global inner reverberation, and the third by the reinjection of energy from the coupled acoustical chambers that surround the hall (that can be seen in Figure 4). The integration of variable devices, mainly the large articulated reflector over the stage, would allow regulation of the crossing point between the first two exponential reverberation slopes.

2.4 Outcomes of the digital simulation

Following simulation in CATT-Acoustic, the space was considered satisfactory in relation to the values of the parameters defined by the standard ISO-3382 [8]. Es an example, Figure 5 shows the spatial distribution of the Strength G on the main floor.

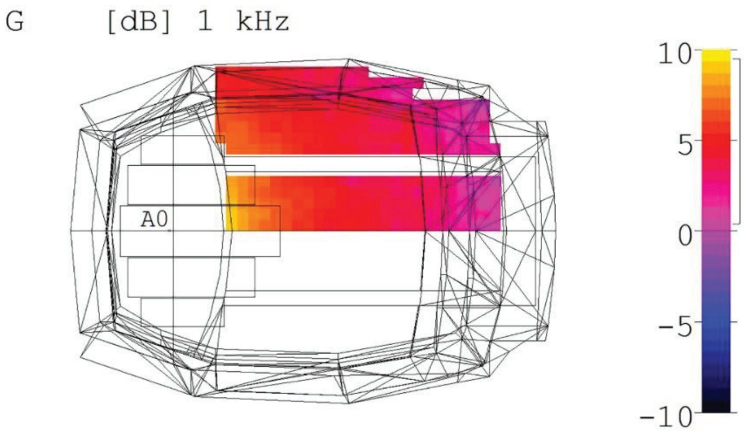

Figure 5: Strength values at 1000 Hz obtained with an omnidirectional source on the centre of the stage. The spatial distribution of the energy on the main floor can be seen

With regard to the early field, Figures 6 to 7 display some of the outcomes obtained: Figure 6 shows the dense texture of early reflections that appear at one seat on the middle of the main floor and Figure 7 shows the simulated impulse response at the same seat.

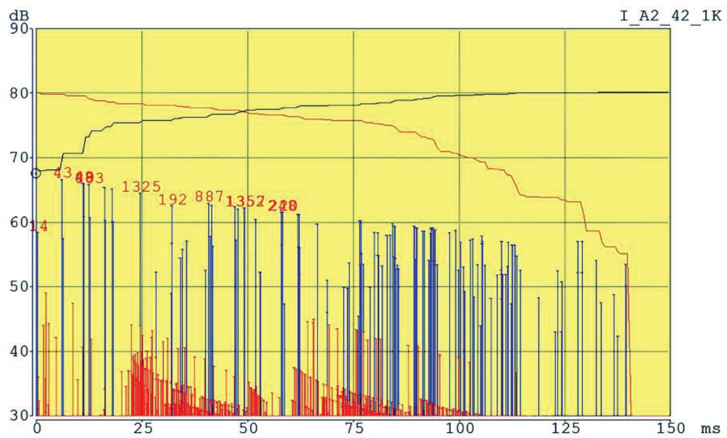

Figure 6: Reflectogram for the SR pair A2-42 at 1000 Hz from the final design. The temporal texture of the reflections can be seen in the first 150 ms

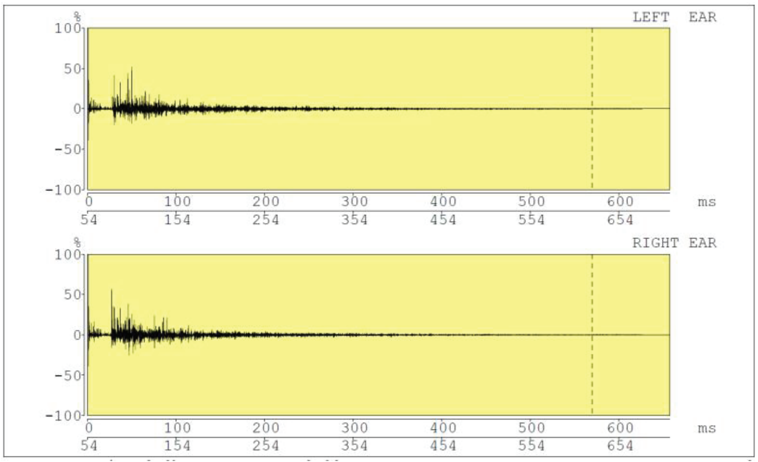

Figure 7: Impulse response for the SR pair A2-42 simulated in Catt-Acoustic

The final design was considered acoustically satisfactory based on the three premises defined at the beginning of the process.

3 CONSTRUCTION, FINAL ADJUSTMENTS AND MEASUREMENTS OF THE HALL

Once the design stage was completed, the construction of the hall began. All materials and relevant details were controlled from the acoustic point of view. The absorption of the main wall coverings and the seats, occupied and non-occupied, was measured in a certified acoustical laboratory. Special attention was paid to avoid extra absorption at low frequency caused by the assembly structures. During the building process, periodic acoustic measurements were made to monitor the evolution of the work and, eventually, correct any deviation as soon as possible.

The final adjustments of the movable devices, such as the acoustical canopy, the stage risers, the curtains that surround the hall and the coupling of the reverberation chambers, were made with the participation of the National Symphony Orchestra of Argentina. Acoustical measurements were also carried out to test the efficacy of the acoustical predictions made during the design process.

3.1 Acoustical measurements under ISO-3382 Standard

During March and April 2016, a complete set of acoustic measurements based on the ISO-3382 Standard [8] was carried out by placing an omnidirectional speaker and several microphones in the same places that had been used in the digital model during the design stage (Figure 8).

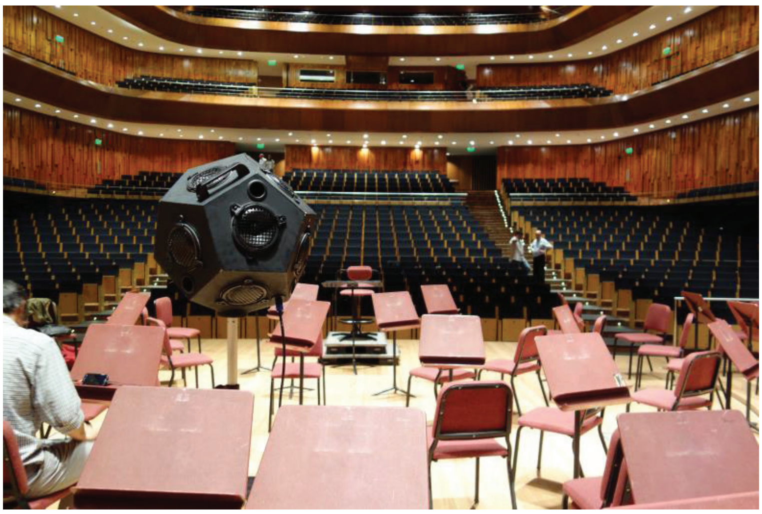

Figure 8: Dodecahedral speaker used in the 2016 measurements (IADAE)

Some of the outputs of the measurements, made under a specific arrangement of the variable devices, can be seen in Table 1 and in Figure 9.

Table 1. Global acoustical parameters under ISO-3382. Unoccupied hall

Acoustical Parameters	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
EDT [s]	2.22	2.03	1.91	1.82	1.62	1.42
T30 [s]	2.41	2.20	2.1	1.96	1.72	1.62
C80 [dB]	-2,3	1.7	2,4	2.8	3.2	3.4
Ts [ms]	183	186	136	116	91	87
LF	0.34	0.31	0.28	0.25	0.22	0.23

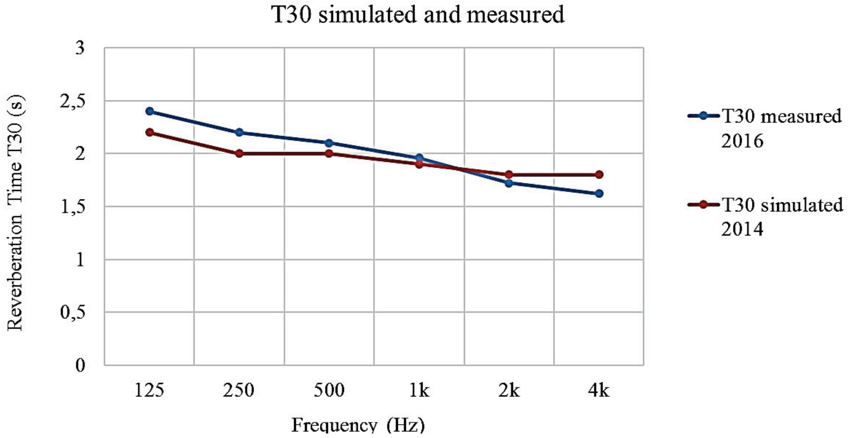

Figure 9: Global reverberation time T30 measured in 2016 (blue line) and simulated during the design stage (red line). The unoccupied hall was arranged with the reverberation chambers closed, the curtains of the stage unfolded and the acoustic reflector in its flat configuration at a height 11 m

3.2 Early energy measurements

In order to verify the effectiveness of the acoustic design, regarding the creation of strong lateral reflections on the main floor, in 2019 a set of spatial measurements was made. A first-order Ambisonic microphone was used (Figure 10) and the data was processed using the O3A Core plugin from Blue Ripple Sound Limited.

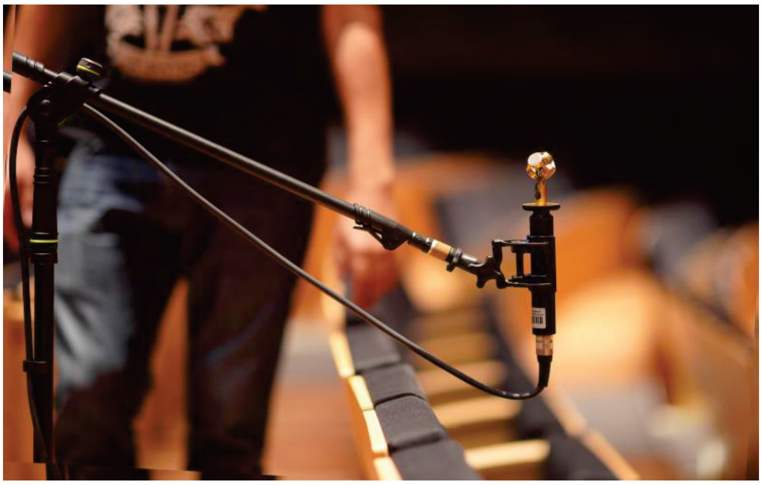

Figure 10: First-order Ambisonic microphone used in the 2019 measurements (property of the National University of Quilmes)

The results of the spatial measurements fit quite well with the predictions for the main reflections detected, as can be seen in the example shown in Figures 11 and 12. Some discrepancy was found in the frequency domain; although the measured reflections were mainly broadband reflections, they showed some differences with those simulated in the low frequency region.

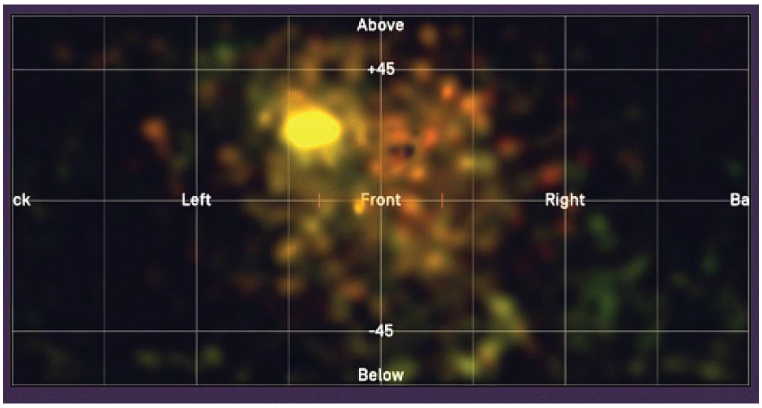

Figure 11: Strong broadband reflection measured with the Ambisonic microphone and analysed with the O3A Core plugin. It has a delay of 62 ms after the direct sound

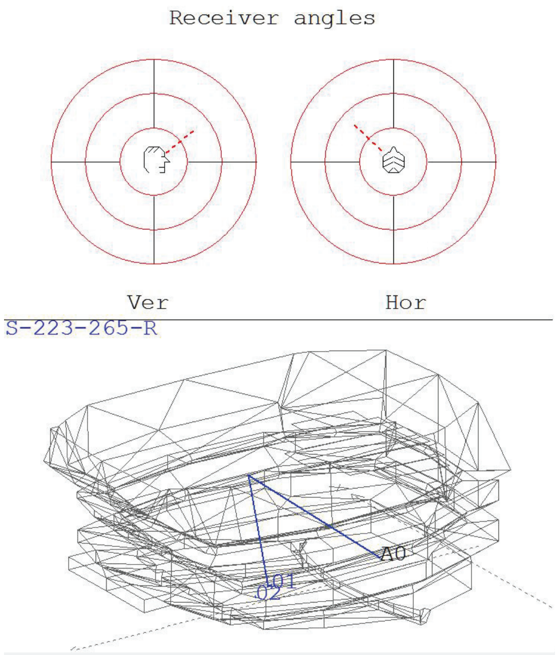

Figure 12: Origin of the reflection showed in Figure 11 as predicted during the design stage for the SR pair A0-02. It has a delay of 61 ms after the direct sound

Figure 13: The finished hall

4 CONCLUSIONS

This work shows the process applied to design the acoustic field of the Blue Whale Auditorium, in which the current tools used to predict the acoustic behaviour of a space are good enough to design a large auditorium for symphonic music. In this case, these tools were applied to a non-traditional shape optimized to reach three concurrent acoustical objectives: to achieve an enveloping acoustic field, to produce adequate reverberation decay and to distribute the acoustic energy uniformly. The acoustic measurements made according to ISO-3382 in the finished hall did not show significant deviations in relation to the predictions. The same can be said of the spatial measurements made with an Ambisonic system. The "Blue Whale" auditorium opened in May 2015 and has become a central pillar of musical life in Buenos Aires.

ACKNOWLEDGEMENTS

The author acknowledges Eng. Rafael Sánchez Quintana, the authorities of the Centro Cultural Kirchner and the research teams of the projects “Acústica de Espacios no Convencionales. Música para Sitios Específicos/UNLP” and “Sistemas Temporales y Síntesis Espacial de Sonido en el Arte Sonoro/UNQ" of the National Universities of La Plata and Quilmes, Argentina.

REFERENCES

1. Beranek, L. Subjective Rank-orderings and Acoustical Measurements for Fifty-Eight Concert Halls. Acta Acustica, 89 (2003), 494-508.
2. Beranek, L. L. (2016). Concert hall acoustics: Recent findings. The Journal of the Acoustical Society of America 139 (2016), 1548-1556.
3. Haas, H. The Influence of a Single Echo on the Audibility of Speech. J. Audio Eng. Soc. 20 (1972), 145-159.
4. Kahle, E. Halls without qualities - or the effect of acoustic diffusion. Proceedings of the Institute of Acoustics: Auditorium Acoustics, Hamburg, Germany, October (2018), 4-6.
5. Pätynen, J., Tervo, S., Robinson, P., and Lokki, T. Concert halls with strong lateral reflections enhance musical dynamics. Proceedings of the National Academy of Sciences of the United States of America 111(12) (2014), 4409-4414.
6. Green, E., and Kahle, E. Dynamic spatial responsiveness in concert halls. Proceedings of the Institute of Acoustics: Auditorium Acoustics, Hamburg, Germany, October (2018), 4-6.
7. Blauert, J. Conceptual Aspects Regarding the Qualification of Spaces for Aural Performances. Acta Acustica united with Acustica 99 (2013), 1-13.
8. ISO 3382-1:2009. Acoustics - Measurement of Room Acoustic Parameters—Part 1: Performance Spaces, Intl. Org. for Standardization, ISO, Geneva, Switzerland (2009).
9. Hochgraf, K., Sacks, J., and Markham, B. The model versus the room: Parametric and aural comparisons of modeled and measured impulse responses. The Journal of the Acoustical Society of America 141(5) (2017), 3857.