CORRECTION OF A STRONG SEAT-DIP IN THE TEATRO ARGENTINO OF LA PLATA IN ARGENTINA

Gustavo Basso[1*]
[1] IPEAL, Facultad de Artes, Universidad Nacional de La Plata, Argentina

ABSTRACT

The Teatro Argentino de la Plata was inaugurated in 1999, and the acoustic quality of the Ginastera Hall received various unfavourable comments from musicians, critics and the general audience. The lack of bass frequencies, low sensation of envelopment and a flat, distant sound were highlighted. After carrying out a lot of acoustical measurements and developing a digital model of the Hall, the analysis showed, on the main floor level, a deficit of acoustical energy in the first 100ms after the direct sound, insufficient lateral energy, and a strong seat-dip. To correct those problems a new acoustical canopy, made with a distributed array of rectangular panels, was placed over the pit. The situation improved substantially, but there was still a minor seat-dip in the stalls. When a new restauration was undertaken in 2016, which included the replacement of the seats in the stalls, it was seen as an opportunity to fix the residual seat-dip problem. This paper briefly describes the action of the new canopy and the criteria for choosing the new seat model and the acoustic measurements taken before and after placing the canopy and replacing the seats.

Keywords: *Opera theatre, main floor acoustics, seat-dip.*

1 INTRODUCTION

The new Teatro Argentino de La Plata was inaugurated in 1999, after the destruction of the former building by a fire in 1977. The Sala Ginastera, the building's opera hall, has a wide main floor surrounded by three levels of large balconies. Its capacity is almost 2000 people [1].

[*]*gusjbasso@gmail.com*

After its inauguration, audiences agreed that, although the sound was quite good at the upper levels, the acoustics on the main floor suffered from a lack of bass frequencies, producing low listener envelopment and the overall feeling was a flat and distant sound. Measurements from the stalls showed a lack of acoustical energy in the first 100 ms after the direct sound, insufficient lateral energy and a strong seat-dip. As a result of this diagnosis, it was decided to modify the temporal and spatial structure of the early reflections focused on the audience by installing a new canopy over the pit, the main objective of which was to fix the problems detected in the main floor without changing the acoustical quality at the upper levels [2]. One of the intervention's main goals was to eliminate or minimize the strong seat-dip perceived in the stalls. This short text focuses on the actions taken with the aim of fixing the seat-dip problem.

2 INITIAL DIAGNOSTICS

In March 2011, a complete set of acoustic measurements was made, based on the ISO-3382 standard [3]. The diagnosis was completed with the results of opinion polls on the sound perceived by musicians, critics and the public, and simulations in a digital model of the hall. The main outcome of the measurements was that, on the main floor, the acoustic field did not have enough early energy and the first main reflection appeared too late, between 60 and 75 ms after the direct sound. To make matters worse, in the centre of the main floor the Lateral Energy Fraction was only 14%, well below the minimum recommended by the specialized literature. As an example, Figure 1 shows a clear absence of early reflections from 5 to 70 ms after the arrival of the direct sound, which could explain the lack of envelopment in the stalls.

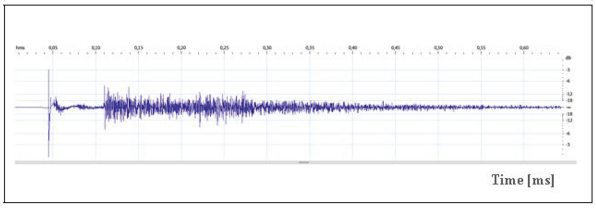

Figure 1. Impulse response measured near the centre of the main floor (from [2]).

Due to the acoustic differences between the lower and upper levels, the average indicators, such as the Bass Ratio, the Bass Level Balance and the Bass Index, did not offer useful information about the main floor. Neither did the extensions of these indicators towards the octave bands centred around 63 and 32 Hz [4].

After the analysis of the measurements in numerous specific source/receiver pairs, it was concluded that the lack of early lateral energy was the main factor that differentiated the stalls from the upper levels, a conclusion that could also be extrapolated in relation to the deficit of bass sounds.

2.1 Seat-dip on the main floor

A strong deep seat-dip was perceived by the audience on the main floor, with minimal variation between different positions[1]. As an example, Figure 2 shows the prominent spectral minimum at 118 Hz that appeared 30 ms after the arrival of the direct sound.

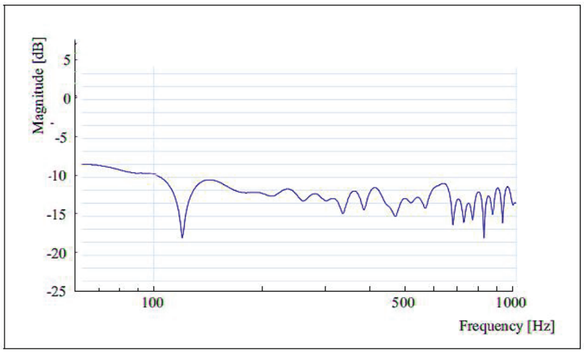

Figure 2. Early establishment of the seat-dip of 118 Hz in the centre of the main floor. A 40 ms Hamming window was used.

[1] Opinion poll participants followed the usual procedure: they listened to an orchestra standing up, and then sat down. Almost all of them reported a noticeable decrease in the loudness and presence of the bass sound when doing so.

2.2 Effect of the diffraction grating associated with the seat rows

The cause of the seat-dip in the stalls was clearly the action of the diffraction grating of the rows of seats located in front of the measurement point. The original seats in the hall were, until their replacement in 2016, made of metal and plastic with seats, backrest and armrests covered with heavy textile material. The main seat-dip attenuation, calculated for the interference between the direct sound and the wave path under the seat going through the back-rest's underpass, was at a frequency of 110 Hz [5-6].

Depending on the horizontal angle of arrival, which in the stalls of the Sala Ginastera varies between 0 and 50º, it is expected to find seat-dip frequencies between 104 and 120 Hz.

2.3 Time evolution of the seat-dip

The early establishment of the seat-dip does not necessarily imply that it will be perceived; the valley must be maintained over time. In the case of the measurements carried out on the stalls of the Sala Ginastera, the spectral minimum was retained for a large amount of time, far exceeding 200 ms in all cases. Figure 3 shows a time-frequency graph near the centre of the main floor in which the evolution of the impulse response between 20 and 200 ms after the arrival of the direct sound, segmented into 20 ms intervals, can be seen [7]. The minimum at 118 Hz not only lasts for the first 200 ms but is still present throughout the entire signal development.

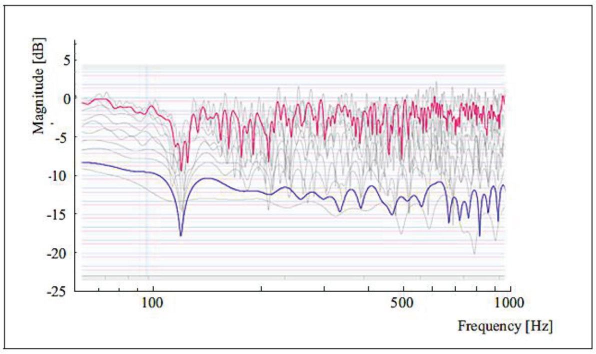

Figure 3. Temporal development of the seat-dip in the centre of the main floor measured at 20 ms intervals. In blue, impulse response at 40 ms; in red, at 200 ms.

The perceived seat-dip does not seem to be associated with its early appearance but rather with its permanence over time. The lack of recovery of the spectral valley could be related to the absence of low-frequency early reflections reaching the main floor with elevation angles greater than 10º.

3 ACOUSTIC FIELD CORRECTION

3.1 New acoustic canopy

To fix the acoustical issues detected on the main floor, early lateral reflections within the first 80 ms after the arrival of the direct sound needed to be produced. Consequently, it was decided to place a canopy over the pit, which had to meet the following conditions:
1. Cover the main floor acoustically with reflections within the first 80 ms in a homogenous way.
2. Increase the amount of lateral energy on the main floor.
3. Maintain the acoustic quality of the upper levels of the hall.
4. Raise the angle of arrival of the early reflections to reduce the seat-dip in the main floor.
6. Improve the Support and the Early Ensemble Level for the musicians on the stage.
A traditional canopy, made up of large reflective pieces of wood or other material, could not meet all these requirements at the same time. Therefore, it was decided to make a 17.5 x 5 m canopy built of 1.6 x 1.6 m square convex panels to approximately cover the area over the pit, with a panel density of 50% (Figure 4) [2].

Figure 4: The new canopy in position during a concert of Beethoven's *Missa Solemnis*, October 2011.

[2] The description of the canopy design can be seen in reference [2].

A new set of comprehensive measurements was carried out in March 2012. Figure 5 shows the impulse response taken in the same position as Figure 1 after installing the canopy.

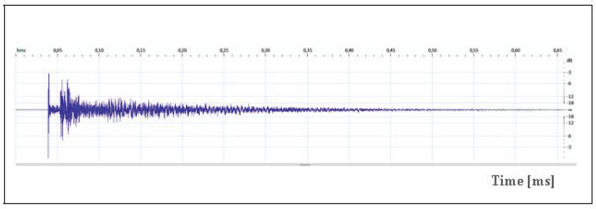

Figure 5: Impulse response measured near the centre of the main floor with the new canopy in place.

It was concluded that:
1. The lack of early energy on the main floor was fixed.
2. The amount of lateral energy on the main floor was significantly increased. As an example, in the centre of the main floor the value rose from 14 to 35%. The origin of this change was mainly the greater number of lateral reflections coming from the front of the balconies after being reflected by the canopy.
3. The bass frequency Strength G, below 300 Hz, was increased by 3 dB on average.
4. The acoustic quality at the upper levels did not show any appreciably change.
Regarding the perception of the seat-dip, the situation improved remarkably. However, when the hall was full, a slight decrease in low frequency was still perceived. According to the analyses carried out, it was possibly caused by the obstruction of the underpass by the large seat placed in the down position (e.g. occupied).

3.2 Seat replacements

To carry out maintenance tasks and solve some problems with the stage machinery, the Sala Ginastera was closed between 2016 and 2023. During this period, which included the Covid-19 pandemic, it was decided for non-acoustic reasons to replace the seats. The author, in charge of the acoustic consultancy, decided to take advantage of this situation to further improve the acoustic quality of the hall in general and the stalls in particular. The new seats are less absorbent and their design, with a higher underpass and a shorter seat, increase the minimum seat-dip frequency to 129 Hz and reduce the differences between the unoccupied seat (seat in an upright position) and occupied seat (seat in a horizontal/down position).

3.3 Disappearance of the perceptual seat-dip

The Sala Ginastera reopened in April 2023 and, both empty and full, no perceptual seat-dip was reported.
Figure 6 shows the seat-dip evolution of the impulse response between 20 and 200 ms after the arrival of the direct sound in the same position as in Figure 2.

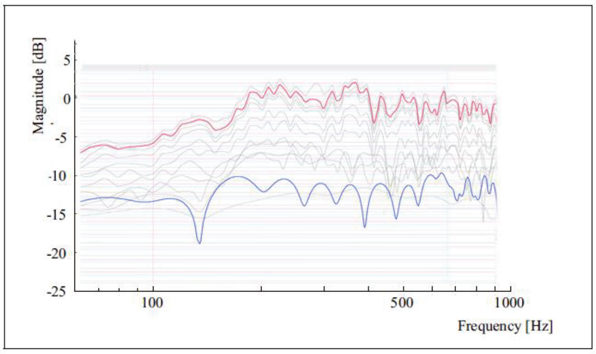

Figure 6: Temporal development of the seat-dip in the centre of the main floor measured in 2019. In blue, impulse response at 20 ms; in red, at 200 ms.

The rapid temporary recovery of the seat-dip aligns well with the opinions of the audience.

4 CONCLUSIONS

After the installation of the canopy and the replacement of the seats, the sound field in the stalls of the Sala Ginastera appears more enveloping, the basses are richer and the sensation of "flat sound" has disappeared. At the same time, the strong seat-dip on the main floor is no longer noticeable. In summary, the overall quality of the hall has been improved after an intervention focused mainly on adjusting its early acoustical field.

5 ACKNOWLEDGMENTS

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