Influence of Hall Geometry on Balance : example of an orchestra rehearsal room

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INFLUENCE OF HALL GEOMETRY ON BALANCE - EXAMPLE OF AN ORCHESTRA REHEARSAL HALL

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ABSTRACT

The balance between the instrument groups of an orchestra is an aspect of acoustics that is, from a musical point of view, an important factor for the acoustics of a concert hall. This paper gives an overview of recent investigations that have been performed on balance. In order to focus on the hall and stage geometry (that can be influenced by the acoustician), the first investigations have been carried out with an omnidirectional source and have been presented at ISRA2019 [1]. This paper focuses on the changes of a real stage in an orchestra rehearsal hall, a stage that was originally very large.

In order to improve the musicians conditions, the stage size is decreased and stage walls are added. The results show that the reduced stage layout in combination with other measures has a positive effect on early reflections and loudness. Although it was not a specific intention at the time, the changes also influence the balance, especially on stage.

1. INTRODUCTION

The orchestral balance, being the sound level differences between the instrument groups at a listeners and/or conductors position, is introduced and explained in [1].

From a musical point of view orchestral balance is an important acoustical aspect of a concert hall. Although it is quite clear that the conductor's position is under influence of direct sound and decrease of distance, the information the conductor receives is crucial in order to instruct the different instrument groups to get the best performance in the hall: at the listener positions that usually are under much less influence of the direct sound and decrease with distance.

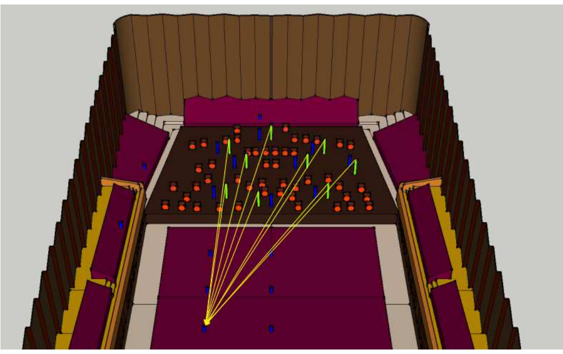

Figure 1. The concept of balance.

This orchestral balance can be presented in graphs of G from several sources (being the middle of instrument groups) at a specific microphone position.

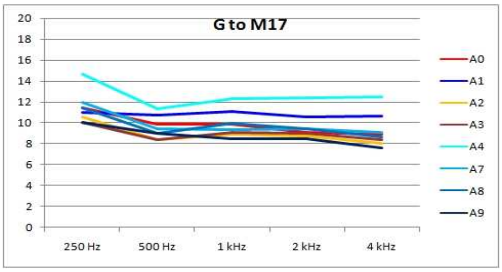

Figure 2. Example of the calculated balance at a conductors position.

It is also possible to look at balance in a single-number parameter in the form of the Range of G or G_{80} (the spread between the minimum and the maximum at a certain position). For that, we have two possibilities:

-the average Range per position: first the Range per position is calculated, and from that the average over all positions is taken;

-the maximum Range that occurs in a certain configuration at a certain position.

In figure 2, the Range (500-1kHz) is about 4 dB.

It is expected that the Range of Strength G could be a good indication for the quality of balance. The smaller the Range at a certain position, the better. Or: the more agreement between conductors position and average listener position, the better.

In [1] it is shown that the balance shows certain sensitivity to geometrical changes in calculations as well as in measurements. These investigations have been done with omnidirectional sources at the middle of instrument groups.

Of course the directivity of instrument groups, the orchestra seating arrangement and the sound power level of the different instruments have influence on the balance, but it has been shown that the hall geometry is also of great importance, on stage as well as at the listeners positions.

2. THE ORCHESTRA REHEARSAL ROOM

In the '80's a professional orchestra rehearsal room was built in MCO (Radio Music Centre), in the middle of the Netherlands. According to the wishes of the then chief conductor, the stage got large dimensions in order to accommodate especially large and rather exotic orchestra arrangements for composers like Mahler and Messiaen. The stage measured 19.5 x 16m, having an area of 312 m². The average concert hall stage area lies around 220 m². Behind the stage is tribune with 4 rows for the choir, so the large stage is really intended for the orchestra, not including the choir.

The hall itself has a rectangular shape of 45 x 21 x 17m

(l x w x h) and therefore volume of about 16,000 m³. There were no additional stage walls, but there were 3 rather curved reflectors above stage at a height of about 10m. The wall directly behind the stage (the wall of the orchestra tribune) is slightly curved and reflective.

The walls of the rehearsal room are made of perforated elements behind which there is in the cavity either diffusion or absorption. Only at the sides of the stage the perforation has been closed.

In front of the stage 46 very large chairs (formerly from a plane) are positioned randomly in the hall.

The rehearsal room has some variable elements:

- the reflectors can be rotated at their centre, so can either be "flat" (but still curved) or rotated until an angle of about 45º;

- along the walls, at the ceiling edges, a roll curtain can be rolled out until a length of 3m.

Usually, the reflectors were at 45º and the curtains out at half height.

Figure 3. An overview of the orchestra rehearsal room in 2017.

3. REASONS FOR CHANGING STAGE LAYOUT

Since the opening of the rehearsal hall, the musicians of the orchestra were complaining, mainly on the following aspects:

- the hall is too loud, on stage as well in the hall;

- hearing each other is very poor and inhomogeneous, especially the musicians at the rear part of the stage express that they can't hear the instruments from the front part of the stage;

- the sound of the hall is not beautiful, the hall is difficult to get "to resonate", making music cost too much effort;

- the hall lacks definition, precision and attack;

- the acoustic circumstances differ too much from the halls where the orchestra performs (Utrecht, Amsterdam).

A common remark made to in this last aspect was that the orchestra had to play less loud in the concert halls when compared to the rehearsal hall. This remark seems at odds with the first complaint, of the rehearsal hall being too loud.

4. THE MEASURES TAKEN

After measurements and a survey have been carried out, calculations have been performed and the proposal was made to make the following alterations. The limited budget of the orchestra was hereby taken into account. There were no opportunities to renovate the hall, we were asked to confine the measures to the most important aspects. In the last months of 2019 the following measures have been realised:

- a new stage layout of 18 x 12m. Due to practical reasons the depth has been increased to 13,5m;

- new reflective stage side walls of a height of 2,5m at the sides of the stage, so closer to the musicians than the walls of the hall;

- a basically flat stage rear wall (between stage and choir) instead of the curved one;

- both stage rear and side walls have a scattering shape, zick-zack for the side walls, with added laths for fine diffusion and cylinder shaped convex diffusors on the stage rear wall;

- the existing reflectors are now at a 0º position;

- about 85 second-hand chairs leftover from a theater renovation have been added to the "audience" area;

- awaiting more absorbing chairs, the roll curtains have been rolled out completely.

Figure 4. An overview of the orchestra rehearsal room in 2020.

5. THE ACOUSTICAL CHANGES

In April 2020 new measurements have been performed. The measurements consisted of RT and IR measurements. The sources of the IR measurements were at the middle of 10 instrument groups including the choir. All instrument groups have also a microphone position, at 1m from the source. Added to that are microphone positions in the hall and at the choir tribune. In all there are 190 source - microphone combinations.

The measurements have been performed with an omnidirectional source. The equipment as well as the positions are comparable to the measurements in 2017. The positions on stage have been changed with the stage layout. In both occasions the orchestra furniture was present on stage.

5.1 Reverberation Time

Table 1 gives an overview of the measured reverberation times in 2017 and in 2020, after the refurbishment.

RT [s]	*125 Hz*	*250 Hz*	*500 Hz*	*1k Hz*	*2k Hz*	*Av. 125 - 2k Hz*
2017 curtains half	2.5	2.4	2.1	2.2	2.1	2.3
2020 curtains up	2.4	2.4	2.3	2.3	2.2	2.3
2020 curtains down	2.2	2.0	1.8	1.8	1.8	1,9

Table 1. Measured reverberation times in 2017 and 2020

5.2 Loudness

The average loudness in the "audience" area has been reduced from +7.3 dB to +5.9 dB (500-1kHz). This is a little bit more than theoretically expected for a diffuse sound field, probably due to the position of the added absorption (chairs).

The average loudness on stage has not significantly decreased (from +11,1 dB to +10.9 dB), but this is combined with a decrease in average distance between source and microphone positions from 8,1m to 7,3m. So sitting closer to one another did not result in a higher loudness.

The average strength of early reflections (G_{5-80}) has slightly increased from +6,7 to +7,1dB.

5.3 Other parameters

The average C80 on stage at source-microphone distances of at least 5m distance has been increased from +1.6dB to +3.1dB. Even so has the average center time Ts been reduced from 111ms to 87ms.

5.4 Impulse responses

The measured impulse responses are much more regular in reflections patterns. Lack of reflections between the direct sound and reflections are filled.

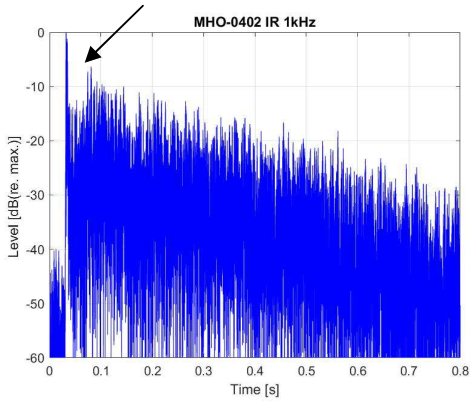

Figure 5a. Measured impulse response from 1st violins to trumpets **2017** with missing early reflections

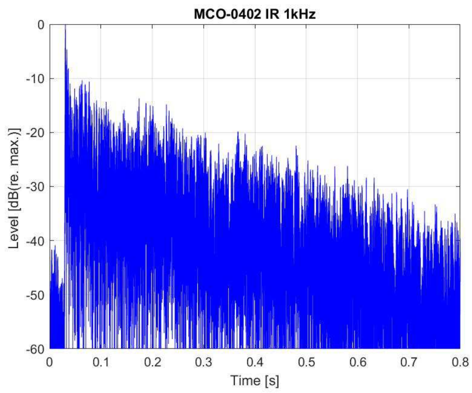

Figure 5b. Measured impulse response from 1st violins to trumpets **2020** early reflections added.

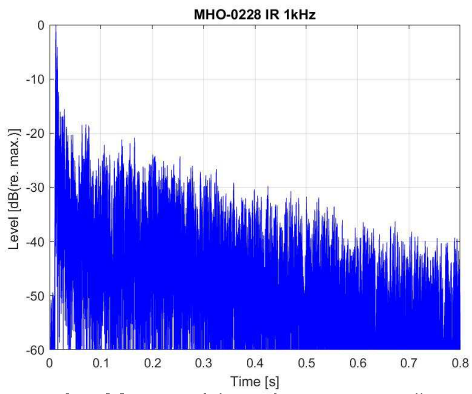

Figure 6a. Measured impulse response from trumpets to alto violins **2017** with very low strength of reflections.

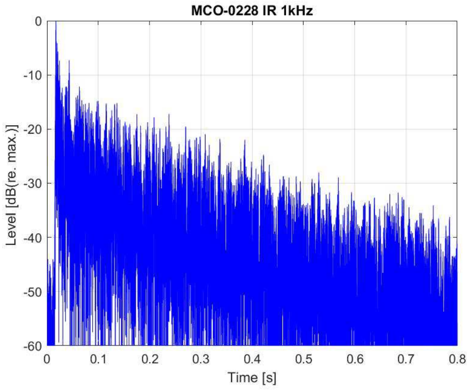

Figure 6b. Measured impulse response from trumpets to alto violins 2020 with increased strength of reflections.

5.5 Listening

Listening at an orchestra rehearsal revealed a somewhat unexpected increase in sound quality. Especially the strings showed more liveliness and brilliance. This large difference in sound quality was somewhat unexpected in relation to the relatively low amount of measures being taken.

But the rehearsal still was perceived as being somewhat on the loud side. It might be that the musicians did not addept yet to the new circumstances and are so much used of playing with power in their rehearsal room, that adaption needs a longer period of time.

6. BALANCE ON STAGE

When starting this project in 2017, the concept of balance for orchestra stages and/or concert halls was not completely on our mind yet. Nonetheless we already had performed a lot of measurements especially on stage. This made it possible afterwards to incorporate our thoughts on balance [1] and compare measurements from 2017 with the measurements from 2020.

The range of G at the conductors position from the different instrument groups has not changed a lot.

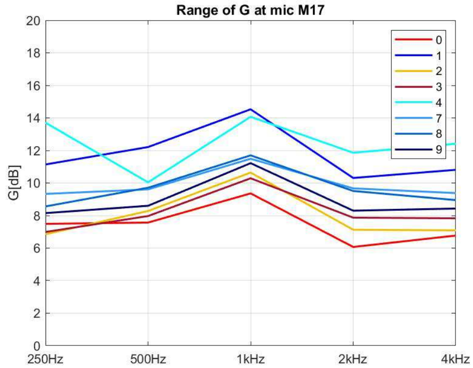

Figure 7a. Measured balance of G **2017** at conductors position

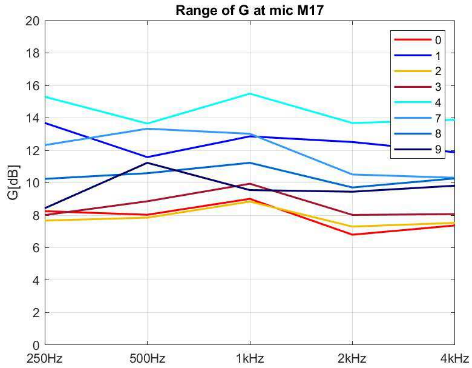

Figure 7b. Measured balance of G **2020** at conductors position

Source 4 (being the 1st violins) is in 2020 significantly closer to the conductor as in 2017, and with not a lot of shielding from other musicians, the influence of the direct sound will get louder. This might be an explanation why the 1st violins stand out in the range of balance, more than in 2017.

When going back further on stage, the Range of Balance in G clearly reduces between 2017 and 2020. The graphs below show the measured range of G at mic position 28, being the position of the alto violins (in an American arrangement) before and after refurbishment.

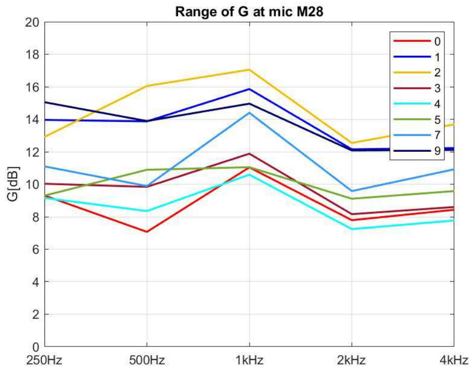

Figure 7a. Measured balance of G **2017** at the alto violin position

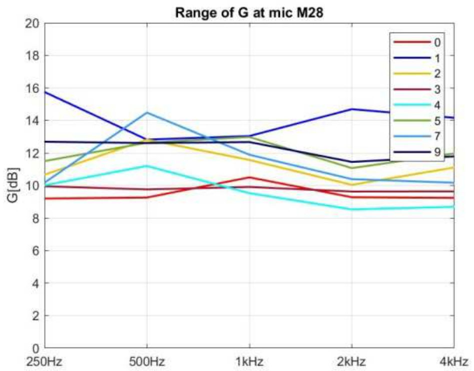

Figure 7b. Measured balance of G **2020** at the alto violin position

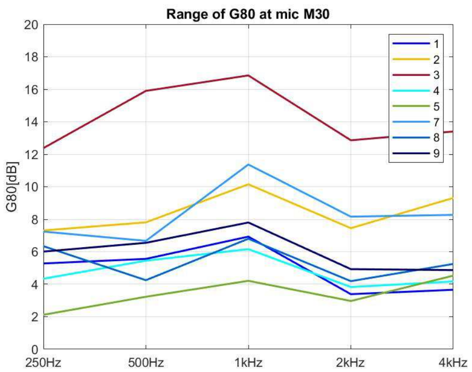

Figure 8a. Measured balance of **G80 2017** at the timpani position

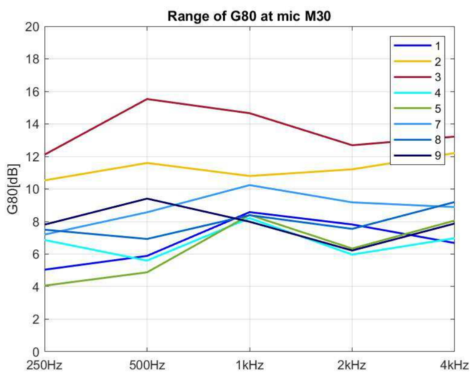

Figure 8b. Measured balance of **G80 2020** at the timpani position

Even further back on stage, at the timpani position, the difference was even larger, here the difference is seen well at the G_{80}, being the Strength G measured over the first 80ms.

At average, the range of G measured on stage in this rehearsal room has reduced from 6.5 to 5.7 dB.

The maximum range of G on stage at the position of the bass players has been reduced from 9.7 to 7.8 dB.

All in all, the differences on stage have been reduced, especially at the rear of the stage. This should have a positive effect on the problem that musicians at the rear of the stage cannot hear the musicians at the front.

Graphs from measured G vs. distance on stage show a similar conclusion that the differences on stage have decreased: the distances have reduced and so has the Range of G, without getting louder in general.

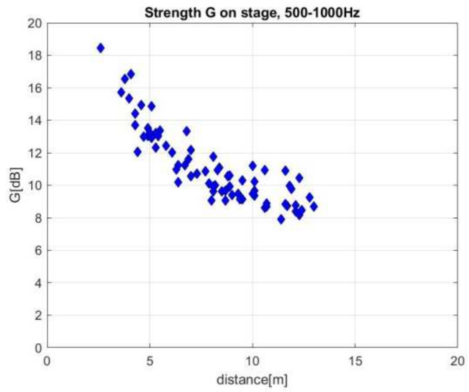

Figure 9a. Measured strength G **2017** vs distance at the stage

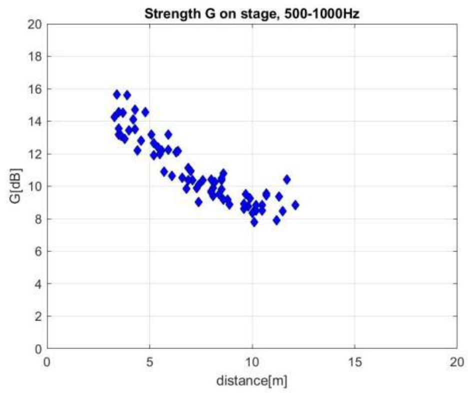

Figure 9a. Measured strength G **2017** vs distance at the stage

7. BALANCE IN THE "AUDIENCE AREA"

In 2017 there have not been made enough measurements for a good representation of the balance in the "audience area" of the hall. In 2020 these measurements have been performed.

The measured average Range of Balance G in the "audience area" is 2.7 dB. This is not as low as has been measured in concert halls like Arnhem (1.5 dB), but the amount of chairs in a hall of this volume is with ca. 130 really low, the floor in front of the stage is relatively empty. This will lead to stronger reflections over the reflective floor, which might increase differences from position to position.

Figure 10 shows the measured balance in the middle of the "audience area"

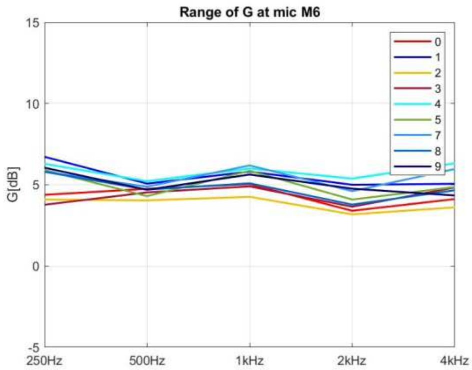

Figure 10. Measured balance **2020** in the "audience area"

8. CONCLUSIONS

The concept of balance refers to the balance between instrument groups at a certain receiver position and the possibility for a conductor to evaluate this balance.

In this paper we have applied the concept of balance to a real case; the renovation of the stage environment in MCO rehearsal hall.

It was found that the acoustical improvements in this hall, as measured and as perceived, coincide with the reduction of the Range of G and G_{80}.

The balance as meant in this paper seems an interesting aspect of room acoustics that could explain defects in acoustical quality and might help to improve the acoustical quality of a hall.

The next step will be to take the directionality of the orchestra instrument groups as well as their sound power into account. It will be interesting to investigate what their influences are and how they combine with certain aspects of the stage surrounding. The investigations will continue by means of calculations as well as measurement.

9. REFERENCES

[1] M. Lautenbach: "The Influence of Hall Geometry on Balance," *Proc. of the International Symp. on Room Acoustcis*, 2019.