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Stage acoustics, further development of parameter $LQ_{7\text{-}40}$

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Abstract
Since a few years a lot of research focussed for better understanding the acoustics on a stage of a concert hall for symphonic music with respect to the ease of playing ensemble and the way the conductor hears the orchestra. As a result of a study in Danish Concert halls dr A. Gade developed the Early and Late Support. These parameters seem very valid with respect of the musicians hearing themselves. To better understand the way musicians hear each other the $LQ_{7\text{-}40}$ has been proposed, a parameter which compares the very early reflections with the late early and late reverberant sound. Measurements on a grid of source and receiver positions show how the sound energy is transferred over the stage from one musician to the other. In 10 concert halls these measurements have been carried out. For 7 Dutch halls the results of $LQ_{7\text{-}40}$ have been presented at Internoise in Ottawa. The study with respect to these parameters is extended to different time windows. In this paper the results of this study will be presented. The benefit of the parameter to chart and fine tune the acoustics of a stage and orchestra pit will be elucidated as well as a proposal for the best time window to take into account.

Keywords: Stage acoustics, LQ, Internoise 2010.

1 Introduction

To better understand the impact of early reflections on the stage environment and thus the influence of reflecting surfaces close to the musicians the $LQ_{7\text{-}40}$ is proposed [1]. The $LQ_{7\text{-}40}$ compares the very early reflections energy (7 to 40 ms) to the total amount of energy after 40 ms. In 2009 measurements have been carried out in 7 concert halls in the Netherlands [2,3], among other, $LQ_{7\text{-}40}$, C_{80} and ST_{early} have been presented. The $LQ_{7\text{-}40}$ is measured on a grid over the stage, where the source positions and receiver positions represent the different music sections of the orchestra. In total 4 source positions and 10 receiver positions have been distinguished (fig 1). For the ST_{early} measurements have been performed at receiver positions in front and next to the same 4 source positions (fig. 2). The INR for all measurements was at least 45 dB what is a guarantee for their reliability.

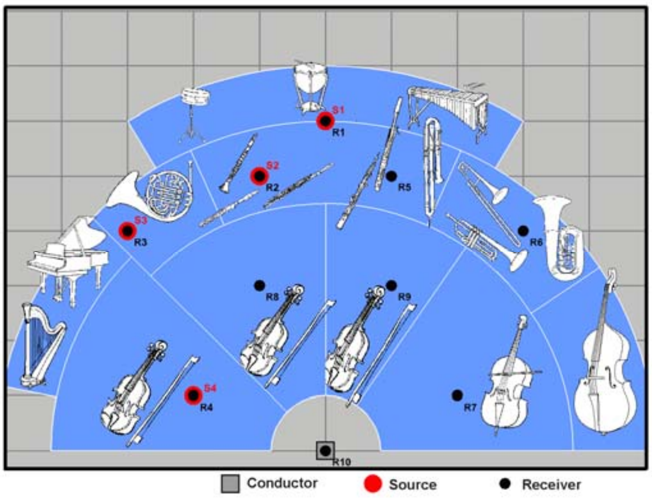

Fig 1: Measurement grid with source (4) and receiver positions (10) on a common stage of a concert hall for symphonic music

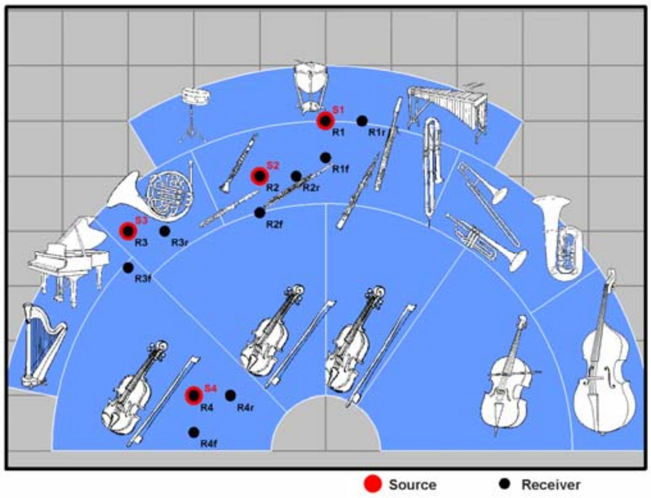

Fig 2: Measurement grid with source (4) and receiver positions at 1 meter distance on a common stage of a concert hall for symphonic music

2 Further developments

In this paper the limits of the interval 7 ms to 40 ms is motivated. As these limits for the time interval for the LQ is mainly based on literature [4] the data for the different concert halls have been further analysed with respect to the choice of these lower and upper limits.
The average of the octave bands with mid-frequency of 500, 1000 and 2000 Hz was used in earlier studies. However in ISO 3382-1 the mean value of 500Hz and 1000 Hz is proposed. In this paper, the values for LQ_{7-40} measured in the different concert halls averaged over the frequency bands 500/1000 Hz, according to ISO 3382-1, are compared with the values averaged over the frequency bands 500/1000/2000 Hz. Furthermore, a closer look has been taken on the individual results for different source positions and the conductor's position. Also an extra result is added for one concert hall where a canopy is introduced and the seats have been refurbished.

3 Time intervals

The information gathered is analysed more in detail with respect to the time interval. By starting the interval at 7 ms the reflections of all the really nearby surfaces are excluded. The effect of the floor indicates a limit of ≥ 5 ms to filter out the direct sound. The earliest reflection from the rear wall of all halls comes in at 10 ms. To be able to include this reflection into the useful early reflections, the lower limit should not exceed 10 ms. Figure 3 shows the difference between LQ for the different lower time window limits of 5, 7, and 10 ms, normalised to the average of all the halls. It is shown that differences between the halls in LQ is not much influenced by the choice of the lower time window limit.

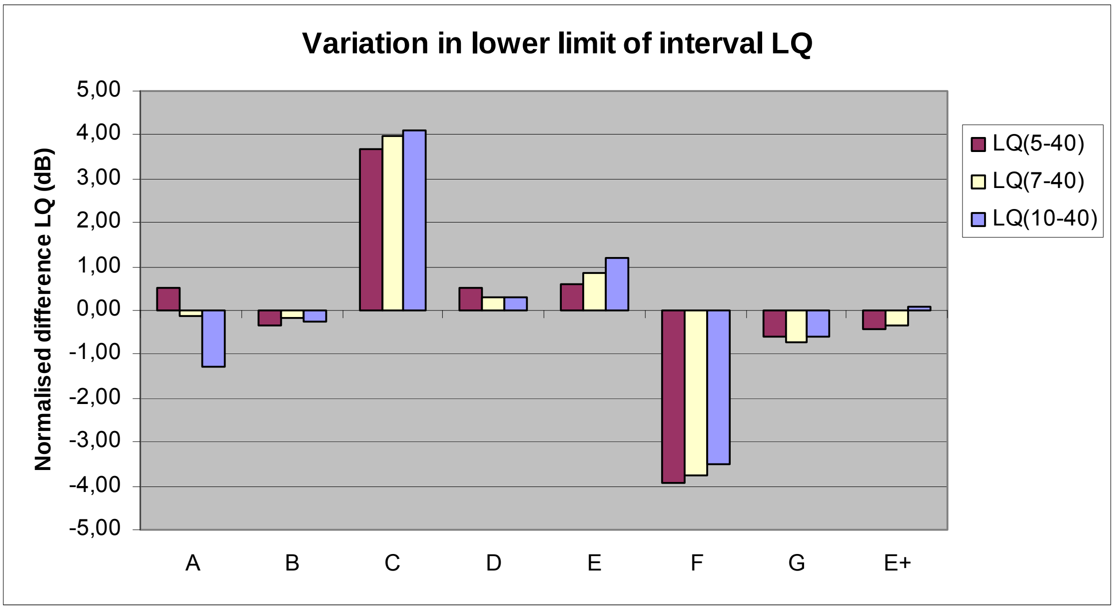

Fig 3. Difference of the value for the stage acoustic descriptor with varying lower limit of LQ interval.

The upper limit of the time window for useful early reflections is varied from 35 to 40, 50 and 80 ms. The lowest value of 35 ms refers to the integration time period for the perception of direct sound. The highest values refer to the more common values for useful sound in terms of intelligibility of speech (50 ms) and music (80 ms). Figure 4 shows the difference between LQ for the different upper time window limits of 35, 40, 50 and 80 ms, normalised to the average of all the halls. It is shown that differences in LQ between the halls are influenced by the choice of the upper time window limit. It seems that hall C remains to have the highest LQ for any choice of upper limit. But the difference between hall A (good reputation) and hall F (bad reputation) seems to change stretching the upper limit. For LQ_{7-80} hall F even has a higher value than hall A. This may indicate that the upper limit of 80 ms is too high, as is already frequently referred too in literature for the hearing ensemble.

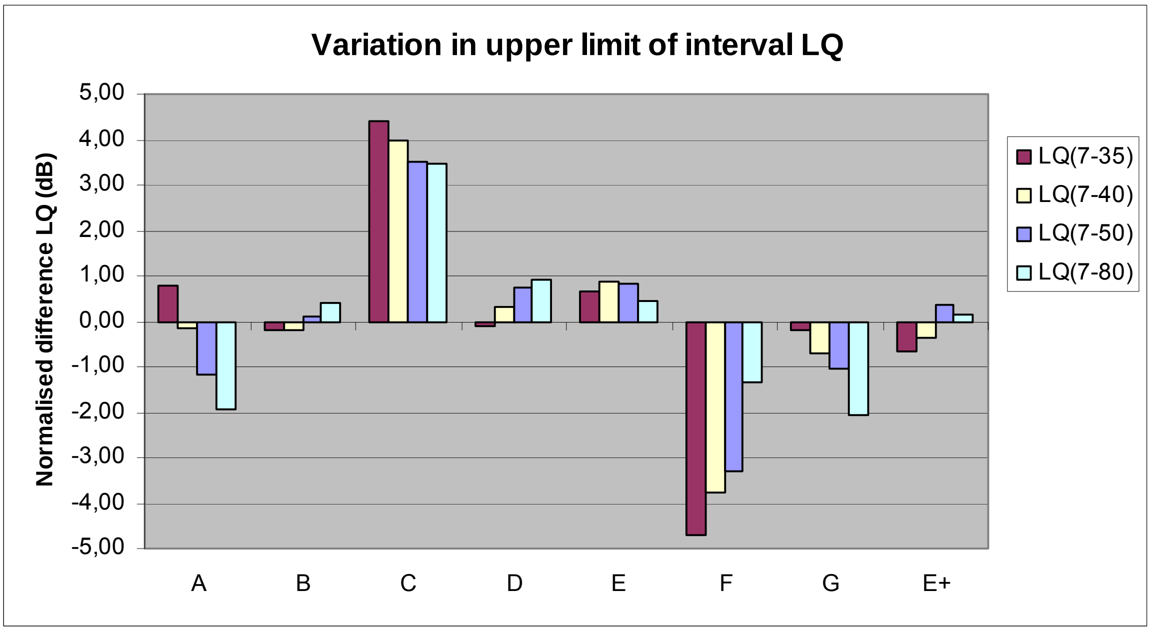

Fig 4. Difference of stage acoustic descriptor with varying upper limit of LQ interval.

From this we may conclude that there is no reason to change the time window of 7 to 40 ms.

4 Frequency averaging

The averaged values of all source positions over three frequency bands varied between +0.9 dB to -8.3 dB, indicating that the parameters can be useful to determine the quality of the early reflections on a stage of a concert hall for symphonic music (fig 5). The averaged values determined for the mean value of the octave band of 500 and 1000 Hz only differ slightly from the mean value of the octave band of 500 to 2000 Hz. So is decided to use the average of 500 and 1000 Hz.

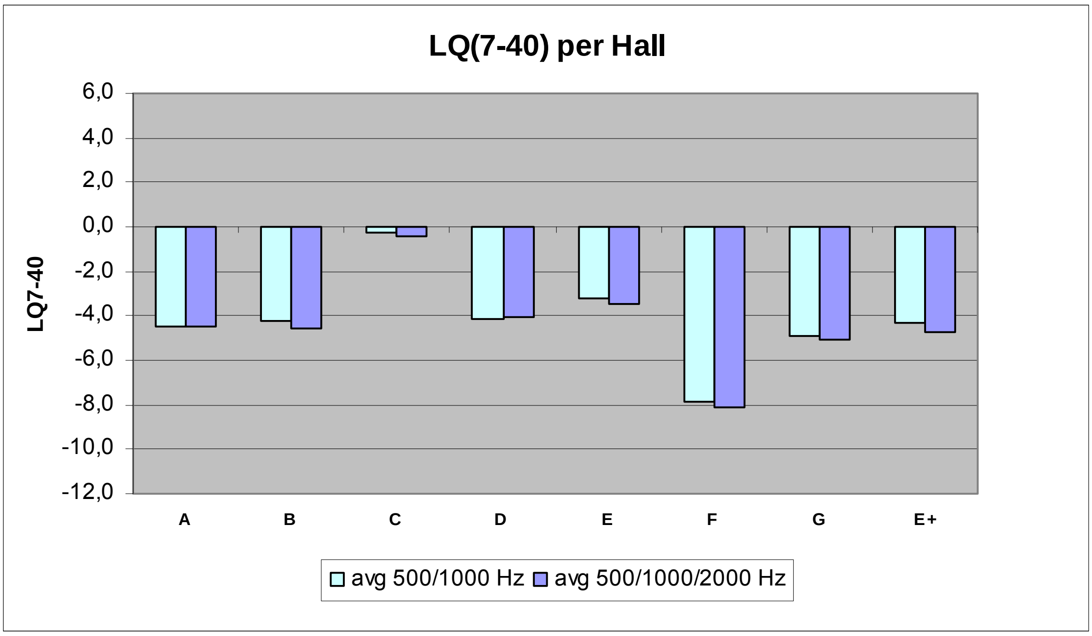

Fig 5. Averaged values for $LQ_{7\text{-}40}$ for different frequency averages

5 Other findings

The stage boundary properties responsible for the early reflections are the horizontal surrounding surfaces (wall, balcony edge), the diffuseness of these surfaces and the presence of reflectors. In concert hall A, E and G no reflectors or canopies are applied. Concert halls A and G do not have surrounding walls. In concert hall D and F there is no organ behind the stage. From the interviews it became clear that the student's orchestra playing the same piece of music in all the halls judged the acoustics on the stage of the halls A, B and C as very good [3]. This was confirmed by the conductor. Hall F was judged as the hall with the poorest stage acoustics of all. The concert halls A, B and C were the best judged halls with respect to the acoustics on the stage, although the difference with the other halls was minor. This is more or less confirmed by the averaged value for $LQ_{7\text{-}40}$ per source position averaged over all receiver positions (figure 6).

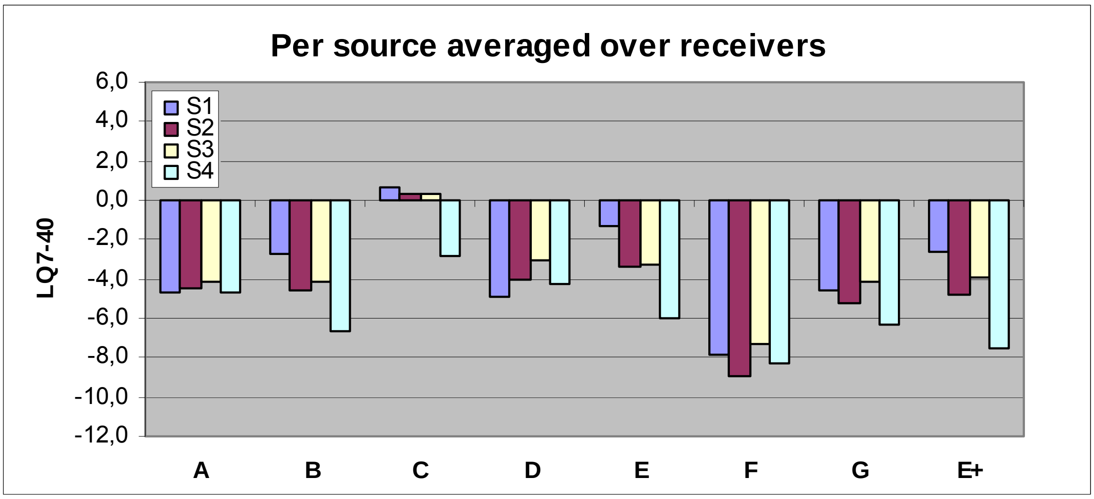

Fig 6. Averaged $LQ_{7\text{-}40}$ over the source positions

The differences are more pregnant at the receiver position of the conductor (see figure 7). The relatively low value for $LQ_{7\text{-}40}$ at the conductors position for source S4 (violins and celli) indicates the lack of early reflections from these sections, what is easy to understand taking into account the fact that because of the short distance the necessity of the early reflections is less. However the results as shown in fig 7 also indicate that there is a substantial difference in early reflections supporting percussion and wind in the concert halls with boundary.

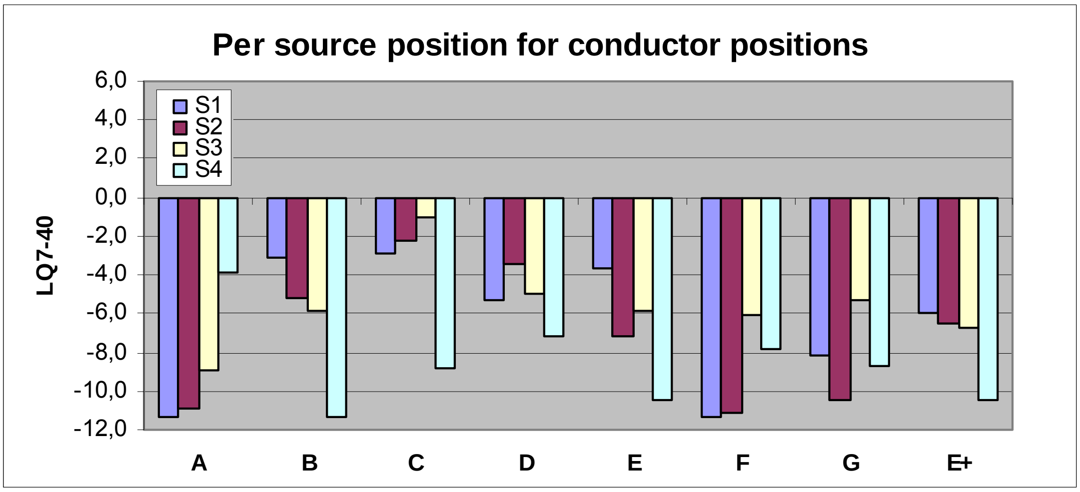

Fig 7. Averaged $LQ_{7\text{-}40}$ at the conductor's position.

To be able to understand the variation of the parameter $LQ_{7\text{-}40}$ we also compared the mean values for all sources with the average value of C_{80} and ST_{early}. For the C_{80}, the same measurement positions were used as indicated in figure 1. For the ST_{early}, the 1 meter distance measurement positions of figure 2 were used. For this we took the difference of the value in one concert halls with the averaged value for all halls for all three quantities. The result of this operation is presented in fig 8. The graph shows clearly the difference between concert hall C and concert hall F. In general the stage of concert hall C is judged as a very clear stage. The quantity LQ_{7-40} is clearly more distinctive then the other parameters. Main reason for this effect is probably the shape of the balcony front around the stage. With respect to this detail Hall C distinguishes it self form the others.

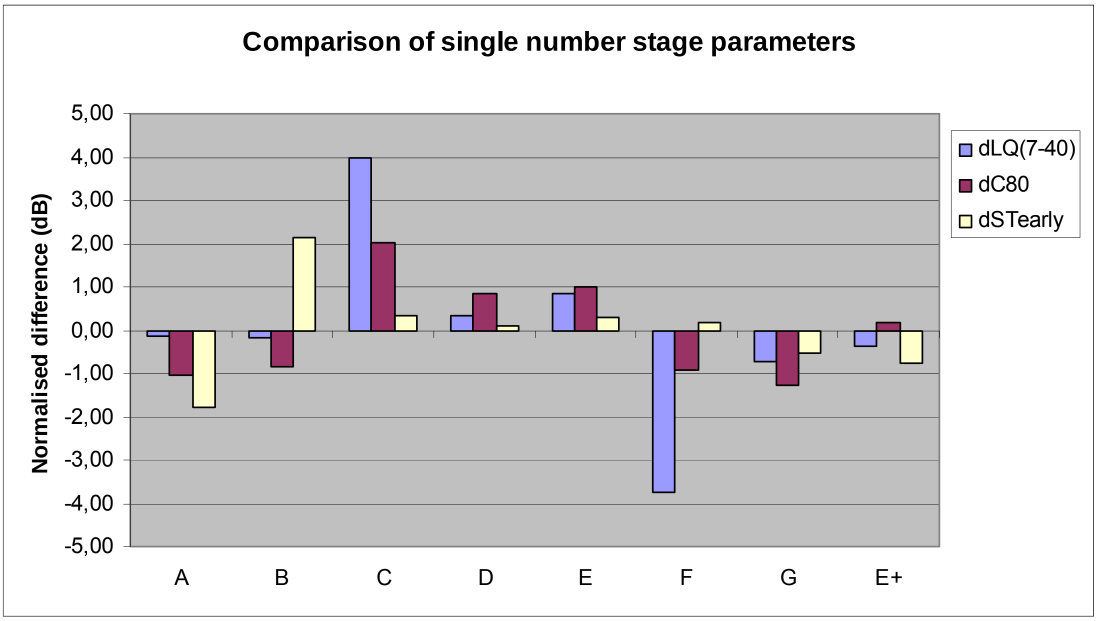

Fig 8. Difference of different stage acoustic descriptor

6 Conclusions

Based on the analysis of the measurement results carried out on the stages in 7 concert halls in the Netherlands we can conclude that the time interval of 7 to 40 ms is the correct one. This confirms most findings as summarized by Dammerud [4]. The data for the 7 concert halls are not distinctive enough to be convincing the parameter can be used to fine tune the acoustics of an orchestra environment. It is not clear whether this is because the acoustic quality of the stages measured did not differ enough. However Hall C scores high with respect to the parameter and is generally judged as a very clear stage. The effect of introducing a canopy in concert hall E is not expressed in the value of LQ_{7-40} as besides an increase of the early energy also the late energy seems to be increased as a change of the acoustics of the hall.

Acknowledgments

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