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Stage acoustics for vineyard concert hall

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ABSTRACT

In rectangular concert halls all surfaces near the stage can be valuable for acoustical communication among performers, while in a vineyard hall the ceiling may become the only surface to provide early reflections back to the stage. Field measurement and subjective evaluation in a hall with adjustable overhead panels were performed regarding the effectiveness of the reflectors for various parts of an orchestra. Results of computer modeling were presented that compares various design features intended for enhancing early and late energy back to the performers. Also presented were the discussion regarding the interaction between the parameters for the musician and the parameters for the audience.

INTRODUCTION

The presence of "vineyard" style of concert halls is growing because of the dynamic atmosphere created in such a style of hall [1]. Besides normally noticed difficulties due to source directivity, problems associated with early support may arise when walls are farther away from each other in compared with a rectangular hall. Overhead reflectors become a popular solution to this problem.

This paper explored the issues of on-stage acoustics associated with vineyard halls. Various design factors employing computer simulation were analysed in attempt to better understand the design techniques to mitigate the difficulties.

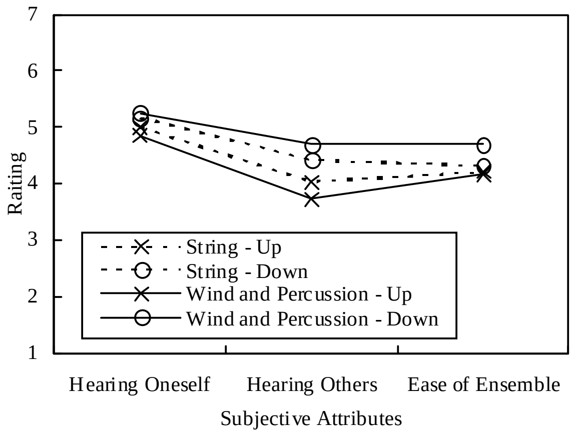


Figure 1. Subjective rating as a function of attributes comparing the configuration with the reflector arrays up position (╳) to down position (◯) and the string section (dotted lines) to the wind and percussion sections (solid lines).

EARLY ENERGY

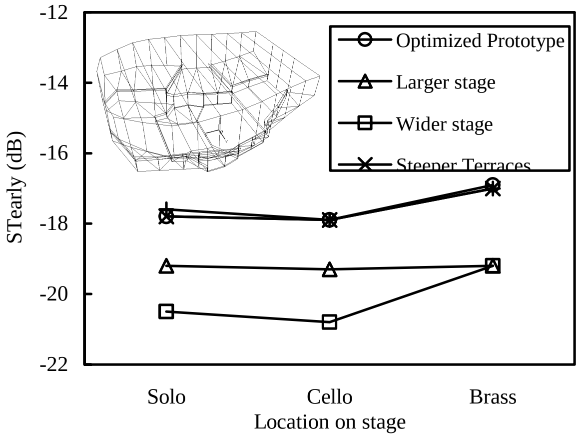
The results of some unpublished early study of field measurement and subjective evaluation in a 2,200-seat, 32-m wide multi-purpose hall [2] were presented to show how different players react differently. Arrays of triangular, adjustable overhead panels were installed over the front half portion of the stage. An oriental orchestra that used both western and eastern instruments played various orchestral pieces with the reflector arrays set to 7.5 m and 12 m high above the stage. Average early support (STearly) measured at solo and cello position for the two reflector configurations were -14.9 dB and -16.1 dB, respectively. The value at the brass position stayed nearly unchanged around -12.3 dB.

There was no statistically significant difference for attribute hearing oneself (figure 1). Lowering the reflector arrays were effective in increasing the ratings of attributes hearing others and ease of ensemble, especially for the wind and percussion sections where the sounds from one's own or nearby powerful instruments are amplified. This indicated that hearing other would potentially more important for the sections near the back. It is, however, not easy to place the reflectors low enough practically because the reflectors could be visually unpleasant, especially when there are audience seating higher than the reflectors.

Statistical perspectives

Based on the statistics of vineyard halls presented by Chen *et al*, the average volume behind the stage front line can easily reach 8,000 m^3. This volume would yield a STearly approximately 5 dB less than the optimum value based on Gade's subjective study and regression formula [3]. This was agreed by measurement taken in some vineyard halls where STearly value was approximately in the range of -19 dB to -15 dB. The halls with higher STearly data were generally the ones installed with detached overhead reflectors.

Extended study of computer simulation was performed using an optimized prototype derived from architectural dimensions of 10 halls by Chen [4] [5]. There are 9 sections of seating inside this 21,500 m^3 hall where maximum length and width are 44 m and 37 m, respectively. The 22 m wide, 240-m^2 stage of the optimized prototype was backed by an 8-m deep terrace. The stage front line was near the geometrical center on plan. The bounding wall of the 1st terrace in front of the stage was 11-m away from the stage front line. The results generally gave the approximate figure of stage support of large vineyard halls when not installed with additional reflectors. It shows that limiting the stage size, in particular the width is important. The situation was not improved by increasing the slope of the terrace or the height of terraces although high side terraces are beneficial for the audience in providing effective early reflections [5].



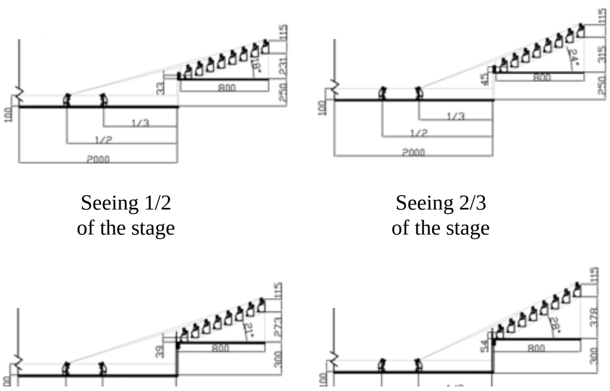


Figure 2. Simulated STearly (250 Hz through 2 kHz band) as a function of microphone location comparing an optimized hall derived from architectural dimensions of 10 halls to the halls with varying geometry of the stage.

Figure 3. Sightline analysis of seeing 1/2 of the stage (left) and seeing 2/3 of the stage (right) when the side terrace was set to 2.5 m (top) and 3.0 m (bottom) above the stage floor.

The average distance between the side terraces would be around 20 m if the stage area were kept to 240 m^2. When the height difference between the side terrace floor and the stage floor was set to 3 m, the average values of the 10 halls, 540-mm row difference would be required to see 2/3 of the stage. Higher floor difference would result in steeper terraces unless concession of sightline was made (figure 3).

The influence of width and stage position

One positive side of a vineyard hall is that the musicians at the rear of the stage would perceive softer sound from the powerful percussion and brass sections when there are no nearby surfaces to amply them. This means that a smaller difference in STearly between the brass position and the solo position is expected. Further subjective study would be extremely helpful in better understanding the consequences. Nevertheless, such a phenomenon may not be fully expressed by STearly because reflections with delays shorter than 20 ms are excluded.

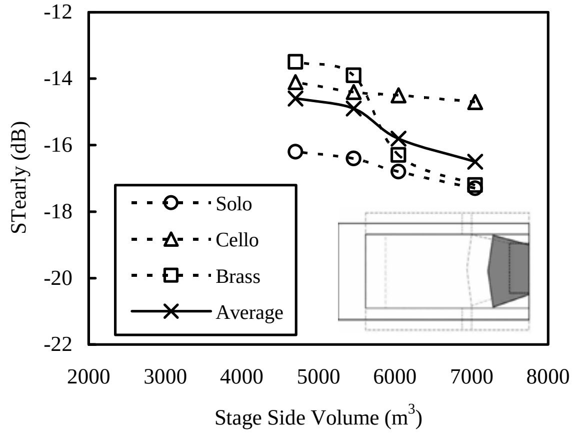


Figure 4. Simulated STearly (250 Hz through 2 kHz band) as a function of microphone location comparing 4 room configurations with varying width and stage position.

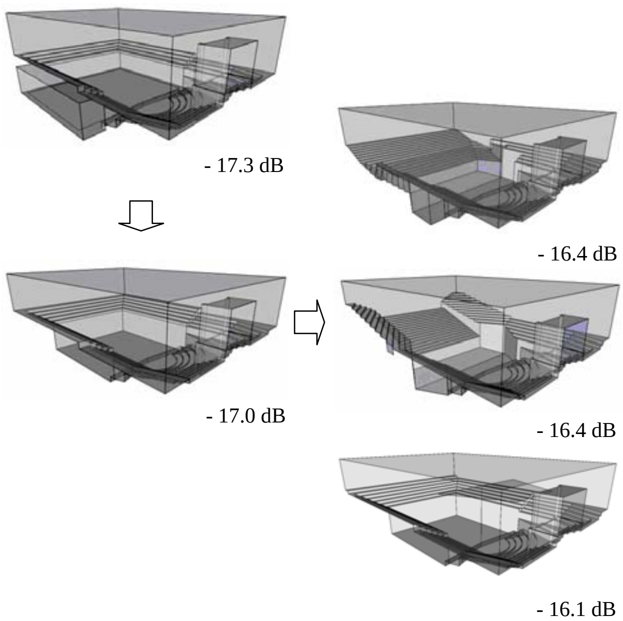


Figure 5. Deriving terraced halls (middle left and right) from the 18000 m^3, 28 m wide rectangular hall (upper left).

Computer simulation was performed comparing 4 room configurations with two widths, 24m vs. 28 m, and two stage positions, directly attached to the back wall vs. with a 6-row terrace behind the stage. The side terrace was set to 3-m above the stage floor and the maximum distance between the terraces were 20 m. The rooms were rectangular with volume set to 18,000 m^3. The two configurations with greater stage side volume were the ones with the back terrace. A 200-m^2 stage with no riser was used. It was found that ST early only decreased slightly at the solo and the Cello position. STearly at the brass position decreased significantly by adding the back terrace and widening the room.

Means to mitigate the difficulties

As shown in figure 5, the 28-m wide rectangular hall (upper left graph) was used to derive a hall with orthogonal terrace seating (middle left graph). The room width and length was increased to 32 m and 46 m, respectively, by removing the balcony overhangs. This also changed the overall proportion and shape when maintaining the same audience area and room volume.

Two vineyard terrace halls were further developed by introducing a terrace 12-m from the stage front line and 3-m above the stage floor. The side portions of the front terrace were turned diagonally towards the stage. In one hall, the side terraces set back in steps gradually when confronting with the diagonal front terraces (top right graph). Similar layout can be found in Palau de la Musica, Valencia and Auditorior Nacional de Musica, Madrid [6]. In the other hall, both diagonal portions of the front terrace were raised and merged with the side terraces, thus providing a much large reflective surfaces aiming towards the stage (middle right graph). The room height increased slightly because of the raised terraces. STearly values were also shown in figure 5. By turning balconies into orthogonal terraces as the first step, STearly increased from -17.3 dB to -17.0 dB. The values further increased slightly when introducing a terrace 12-m to the stage. An overhead panel as large as the stage was installed 10-m over the stage in the hall with orthogonal terraces (bottom right graph). The reflector yielded a STearly of -16.1 dB.

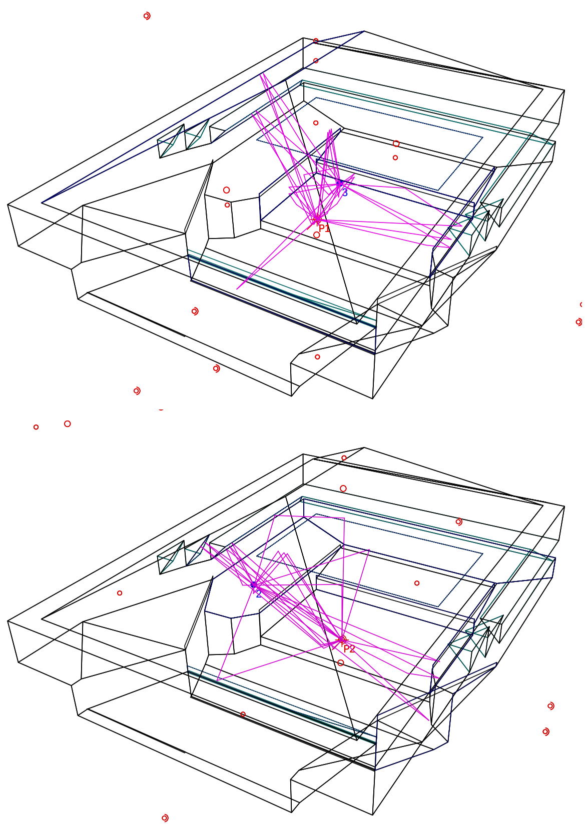


Figure 6. Ray diagrams from a violin position to a brass position (upper) and from a solo position to an audience on the side terrace (lower).

A comparison was also made between including and excluding the strong reflection from the back terrace wall when calculating STearly for the brass position using the hall with raised side terraces. STearly dramatically decreased by 1.8 dB when the reflection was excluded.

There are other architectural features that can be used to enhance early energy back to the stage, such as inclined reflectors over side terraces used in some vineyard halls and none-vineyard ones. The distance to the stage should be maintained close enough for the reflectors to be effective. Figure 6 shows ray diagrams for the 32-m hall incorporating various features to enhance early energy on stage. The upper graph demonstrated the effective reflections with 80-ms delay from the overhead panel, the bounding wall of the front terrace, the inclined reflector over the side terrace and the pitched ceiling. STearly at the solo position was -15.4 dB. This is not ideal, but within operable range [7]. While directing acoustical energy back to the stage, the above mentioned surfaces also played an important role in sending high frequency components back to the seats on the side and back terraces. The lower graph in figure 6 indicated reflection path through the bounding wall of the front terrace and the splayed, inclined reflectors on the side walls, also arrived with 80-ms delay.

LATE ENERGY

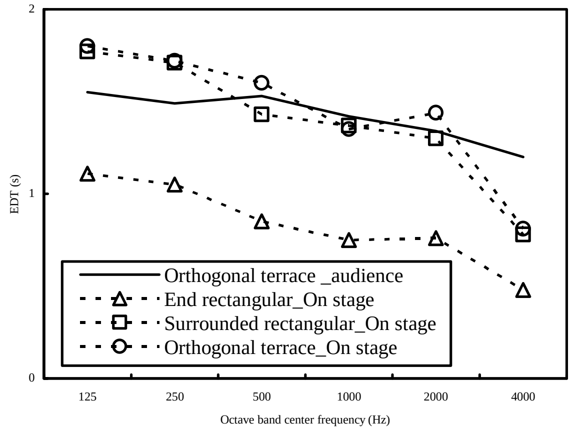


Figure 7. Simulated early decay time as a function of frequency comparing the data taken at the audience seats surrounding the stage with the data between three source-receiver combinations on stage of three 18000-m^3 halls.

Late support (STlate), early decay time measured on stage, and other parameters may all be used to represent subjectively perceived reverberant and support of one's own sound. Early decay time measured on stage with three source-receiver combinations may be one of the best parameter to represent the perceived reverberant of an orchestra. Early decay time measured on stage can be much shorter than what measured in the audience.

Figure 7 compares simulated early decay time taken at the audience seats surrounding the stage in the hall with orthogonal terraces with the data taken on stage of three 18000-m^3 halls. The value of on-stage EDT of the hall with end stage was 40 % shorter than the values of the audience. The difference was fairly small when the stage was surrounded, no matter how the geometry of the hall was.

SUMMARIES

1. Controlling the size of stage is essential although stage side wall may not provide effective reflections from or to the sounds from the players near the podium.

2. A surrounded stage provided more uniform early support than an end stage. Subjective study would be helpful in clarifying the consequence of such a phenomenon.

Early decay time on a surrounded stage could be as long as the one taken from the audience, indicating more adequate perceived reverberance for the players.

3. By applying a front terrace near the stage, inclined side reflectors, and overhead reflectors, STearly of a moderately large terraced concert hall with a back terrace of 6 to 7 rows can be greater than -16 dB.

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