ACOUSTICAL ANALYSIS OF THE ORPHEUM THEATRE

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Introduction

Extensive acoustical measurements and analyses were carried out in the Orpheum Theatre (Vancouver) for Aercoustics Engineering Ltd. as part of studies to develop plans for renovating the theatre. Measurements were made both on stage and for a number of locations in the audience seating area. Complete sets of measurements were repeated to evaluate the effects of the existing over-stage reflectors and an under-balcony electro-acoustic enhancement system. The measurements quantified problems associated with focusing effects and the different conditions found under a large balcony overhang. The measurements are compared with similar results found in other large halls.

Measurements were made with our RAMSoft-II computer-based measurement system that uses an MLS signal and Fast Hadamard Transform techniques to calculate impulse responses. The impulse responses were filtered into octave bands and a dozen different acoustical quantities were calculated while in situ at each measurement position in the hall. For these measurements, three different source positions on stage and 15 receiver positions in the audience area of the hall were used.

Comparison of Hall-Average Measurements

Initial analyses compared mean values of the principal acoustical measures with average values from other large halls. Figure 1 compares the mean RT values from the Orpheum Theatre with the range of Mean RT values from 11 other large halls. Also shown are the hall-average EDT values versus frequency from the Orpheum Theatre. While mid-frequency RT values are intermediate to those of other halls, at the lowest octave band the Orpheum RT value is longer than in the other halls. The mean EDT value is a little less than the RT value, indicating decays are not completely linear and the hall will sound somewhat less reverberant than indicated by the measured RT values.

Sound levels as measured by the relative level or strength (G) are shown in Figure 2. The mean measured G values are comparable to the lowest of the other 11 halls at mid- and high-frequencies.

Mean values of C80, a measure of the clarity or the balance between clarity and reverberance, were intermediate to those of other halls. Similarly, mean values of measurements of the lateral energy fraction, LF, suggested that spatial impression in the Orpheum Theatre would be in the middle of the range of values found in other halls.

Variations with Source-Receiver Distance

The acoustical quality of a hall can also be assessed by the spatial homogeneity of various measures. Figure 3 compares the variation of 1000 Hz RT and EDT values with source-receiver distance. While the RT values are reasonably constant with distance, EDT values decrease quite dramatically towards the rear of the hall. EDT values from seats under the balcony were consistently lower than

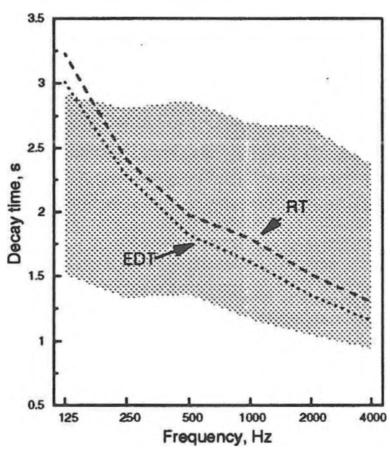

Figure 1. Mean RT and EDT in the Orpheum Theatre compared to the range of hall-average RT values from 11 halls.

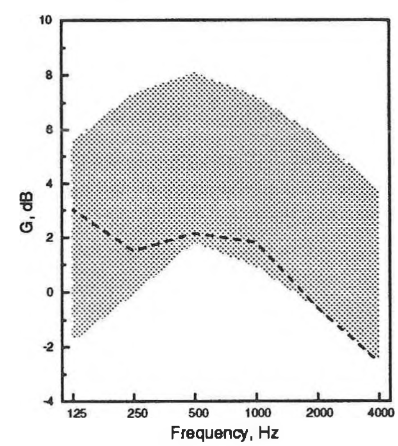

Figure 2. Comparison of mean G values in the Orpheum Theatre and the range of mean G values from 11 halls.

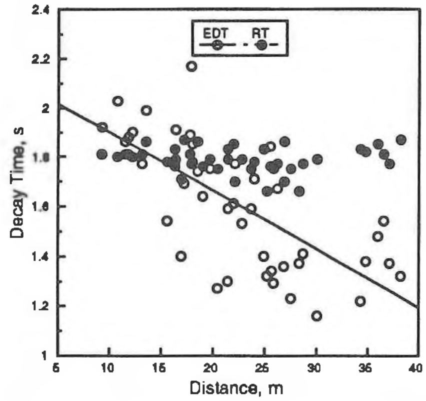

Figure 3. RT and EDT decay times versus distance at 1000 Hz.

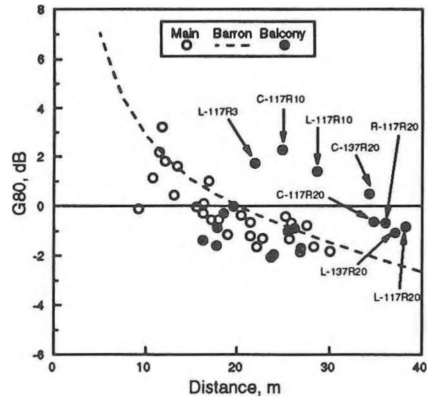

Figure 5. G80 values versus distance at 1000 Hz.

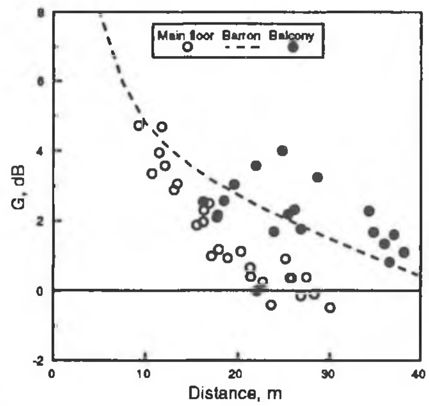

Figure 4. G values versus distance at 1000 Hz.

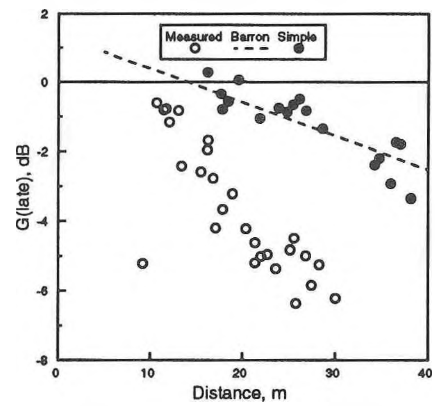

Figure 6. G(late) values versus distance at 1000 Hz.

EDT values measured at seats in the balcony.

Figure 4 plots 1000 Hz G values versus source-receiver distance. Main floor seats under the balcony are about 2 dB lower than predicted by Barron's revised theory[1]. Some seats in the balcony have G values in close agreement with Barrons's theory while others exceed the theoretical prediction. This is illustrated by the plot of G80 values (the relative level of the first 80 ms of the impulse responses) versus distance in Figure 5. Here most measurements both in and under the balcony agree quite well with Barron's theory. Eight measurements at Balcony seats are approximately 2 dB greater than the theoretical prediction. These results are due to focussed reflections from various curved areas of the ceiling. Further unusual results are seen for the G(late) values shown in Figure 6. Here the relative level of the late arriving sound is significantly lower and decreases more rapidly with distance under the balcony.

Particular Effects

At some locations, the focusing effects of the ceiling (that influenced the G80 results in Figure 5) were even more significant. Impulse responses showed very strong reflections and G80 values exceeded the theoretical prediction by over 5 dB at 1000 Hz. At these locations, image shifts were so audible that the soloist appeared to be located in the ceiling of the hall.

Particular efforts were made to identify the effects of an array of over-stage reflectors. Complete sets of measurements (3 source positions by 15 receiver positions) were made both with and without the reflectors in place. Plots of G80 values versus frequency were compared for each measurement location. Some main floor seats in front of the balcony showed small increases in 4000 Hz early sound levels. On-stage measurements at some positions also showed effects of these reflectors.

The hall has an electro-acoustic enhancement system to increase sound levels under the balcony. In its present state, this system was found to be quite ineffective. The under balcony G(late) values shown in Figure 6 suggest that an ideal enhancement system should increase the late arriving sound levels so that they are more equivalent to those in other areas of the hall.

Reference

1. M. Barron and L.-J. Lee, Energy Relations in Concert Auditoria. I, J. Acoust. Soc. Am., Vol. 84, pp. 618-628 (1988).