Acoustical Renovation of The Orpheum Theatre, Vancouver, Canada

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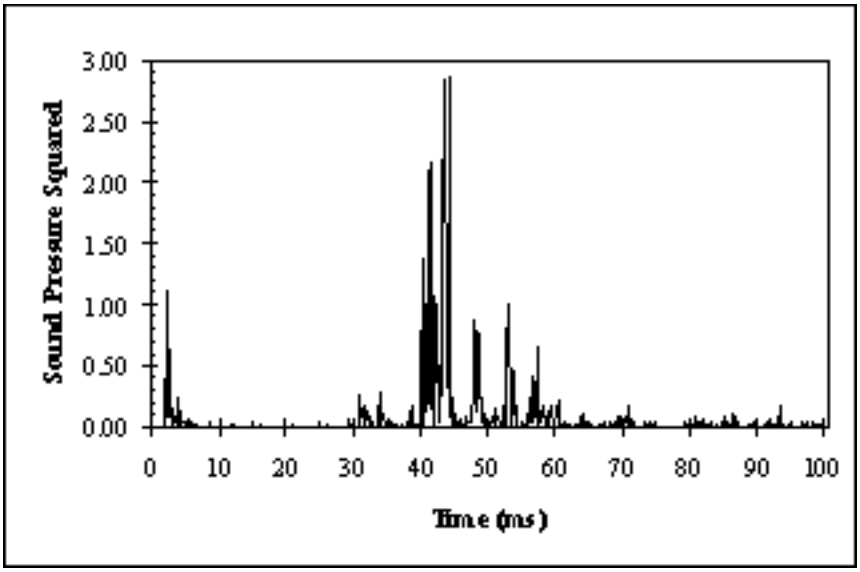
Abstract: The Orpheum Theatre is a 2800 seat vaudeville house that was renovated for the Vancouver Symphony in the 1970s. Funds ran out prior to completion and some problematic conditions remained for the following fifteen years. Perhaps the most significant was an image shift heard on the balcony. This and a number of other issues have been addressed with: a complete set of stage and audience measurements in the full scale room; experiments with a 1:48 small scale model; and listening tests using anechoic music convolved with the full scale binaural impulse responses.

Original Full Scale Measurements

A full set of acoustical measurements was performed in the room before and after the renovation. Binaural and omni-directional audience measurements were performed with the RAMSoft system[1]. Stage measurements were also performed and have been documented elsewhere[2]. In all cases, the auditorium was unoccupied. Compared with thirteen other North American concert halls[3], The Orpheum's reverberance is about average, or slightly below. The mid-frequency (250 Hz - 2 kHz) Early Decay Time is 1.77 seconds. Clarity is slightly above average. Compared to the other 13 halls, Strength is at the lower end of the scale, primarily because of the room's size and the long balcony overhang. At 35 m, The Orpheum is a fairly wide concert hall. One would expect it therefore to have a low Early Lateral Fraction (ELF). That, fortunately is not the case. The ELF is about average compared to the other halls, slightly less than 0.20. Underneath the long balcony overhang the early reflected energy levels are really not much different from the levels measured on top of the balcony, as expected. There is however a very clear difference in late energy, which agrees with Barron's findings in British auditoria[4]. Interestingly, there is little difference between EDTs above and below the balcony.

In the 1970s, there was an attempt to solve this problem with microphones placed above and in front of the stage. The sound from these positions was played through loudspeakers located in the under balcony ceiling. It appears that the system never worked out as planned, most likely due to a lack of gain before feedback.

Focusing and image Shift in The Balcony



The most obvious aberration in The Orpheum is the *image shift* heard in the front part of the balcony. Image shift is an effect where the singer or soloist on stage has an acoustical image that seems to locate them somewhere else. In the case of The Orpheum, voices and instruments appeared to originate somewhere in the ceiling. As a consequence of this effect, the balance between different orchestra sections varied significantly depending on where one sat in the balcony. Measurements at a location where this was a particular problem indicated that two reflections from the ceiling appeared to be at fault, the first at 39 ms and the other at 46ms. Broadband time domain analysis of the full scale measurements indicated that the reflections were about 2dB louder than the direct sound. Windowed spectral analysis however demonstrated that at frequencies below 1kHz, the energy of the reflections is actually about 10 dB greater than the direct sound. Moreover, for frequencies below 300 Hz, the energy of the reflections is some 20dB greater than the direct sound.

Existing literature on image shift could not be directly applied to this situation. A series of binaural impulse responses were created wherein the level of the reflections were gradually reduced. These were then convolved with anechoic music. The results of this test suggested that the total energy of the combined reflections must not exceed the energy of the direct sound, otherwise an image shift would occur. The onset of image shift seemed to occur very suddenly. These results were later confirmed using synthesised fields in an anechoic room[5].

A 1:48 Plexiglas scale model of the existing Orpheum Theatre was built and tested using the MIDAS system. An impulse response measured in the model is shown in Figure 1. Note the double reflection in the 40-45 ms range. A number of experiments were carried out, first to determine the validity of the model then to test the effectiveness of different types of convex ceiling components. To quantify the performance of the different reflectors, the following measurement parameter was developed:

$$\text{Level\_re : direct} = 10 \log \left\{ \int_{t}^{t+5ms} p^2(t) \Big/ \int_{0}^{5ms} p^2(t) \right\}$$

This is a broadband quantifier, effectively limited to 2 kHz (full scale) by the 1/8" microphone in the 1:48 model. The acceptance level for this parameter was set at 0 dB. The first convex reflector tested fell far short or the 0 dB criterion (Please see Figure 2) A number of convex reflectors of various radii were then tested, both short and long. The optimum radius was 4.6 m, full scale. Results for this reflector are shown in Figure 3.

In the summer of 1995, a number of changes were made to The Orpheum:

1. A large 4.6 m radius, convex reflector was hung beneath the perimeter of the ceiling.
2. The disused enhancement system underneath the balcony was repaired and its microphones moved from in front of the proscenium arch to locations above the middle of the balcony.
3. Silencers were installed to reduce Heating Ventilation and Air Conditioning (HVAC) noise.
4. One of the two rows of Plexiglas stage reflectors installed in the 1970s was removed[2].The image shift has been completely eradicated. Late energy underneath the balcony has been improved as have the Early Decay Times. There is no problem with gain before feedback. The renovations have been well received by owners and users alike.

References

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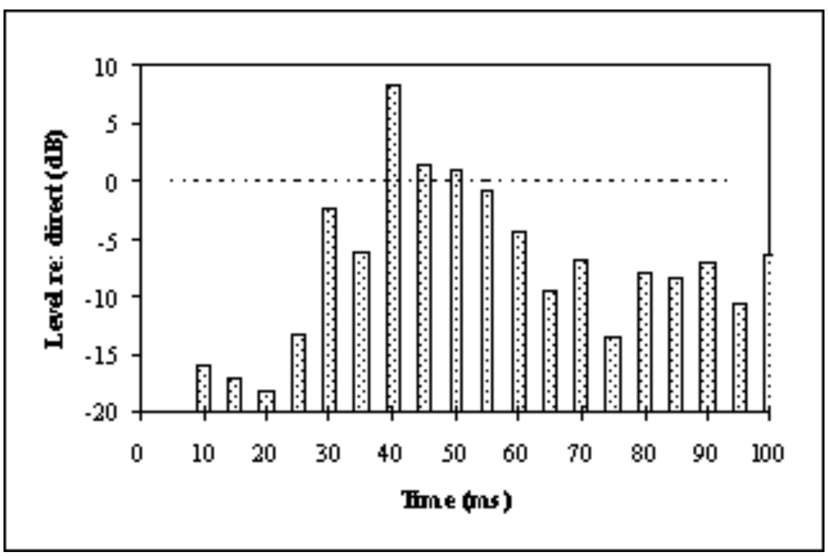

Figure 2 Same as Figure 1 in 5 ms bins as described above. Successful design required all bins less than 0 dB.

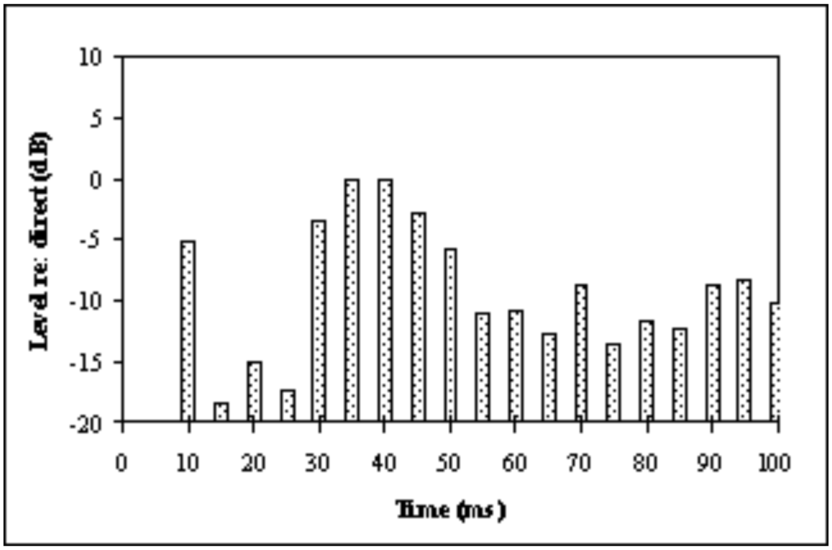

Figure 3 A convex reflector with a radius of 4.6 m reduced the 40 ms reflection(s) to the requisite 0 dB

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