

Modern measurements optimised diffusion & electronic enhancement in a large fan shaped room

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Abstract: Pronounced side wall echoes had to be reduced prior to the installation of an electronic enhancement system in a large post war theatre. 1:48 scale model testing suggested that traditional diffusion might not solve the problem. A crescent shaped diffuser was developed using a BEM optimisation routine. Modern acoustical measurements provided an interesting assessment of a difficult room.

The Hummingbird Centre (formerly O'Keefe Centre) in Toronto, Canada, opened in 1960. Typical of its age, it seats 3,100 in a broad 21° fan shaped plan. Not surprisingly, given its size and shape, the acoustics have been lamented since it opened. Modern acoustical measurements provide an informative corroboration of these complaints.

Like other theatre of the post war era, Reverberation Times (RT) are in the appropriate range (.12 s) and, as expected, do not vary much throughout the hall. In other words, the designers were successful with the acoustical parameter of paramount concern at the time. Unfortunately, that's all that can be said for the room. Early Decay Times (EDT) are significantly lower than the RT and vary almost to the point of disbelief. One set of measurements was performed with a directional source, following a procedure similar to Barron¹. In orchestra level seats in front of the balcony, the average EDT for the central source was 1.24s, for the lateral it was 0.73 s; a difference of 0.5s. Difference limen for reverberance is usually taken as $.01s^2$. One seat on the balcony had an EDT of 0.24 s. (central and lateral broadband average).

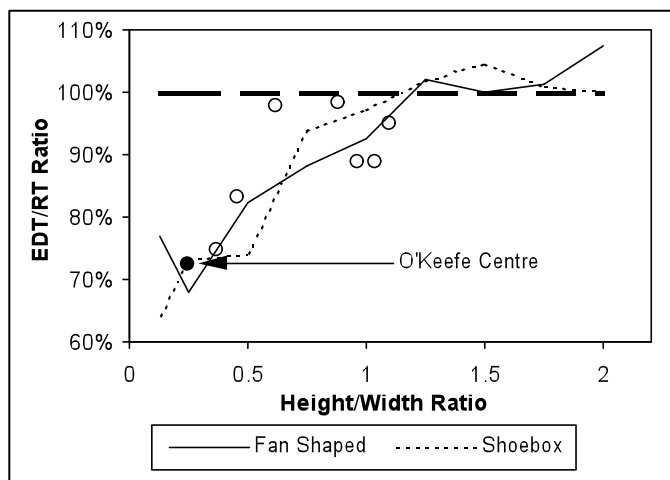


FIGURE 1 A computer model experiment (dashed and solid lines) suggests that height/width ratio influences effective reverberance. Circles indicate EDT/RT measured ratios in halls similar to the model.

rations for halls that match the very simple geometry implied by the computer model experiment⁴. The fan shaped geometry of the Hummingbird Centre implies that the Height/Width ratio is low at most seats, particularly the ones near the back of the room. The computer model experiment suggests that this may explain why the EDTs are so low.

As might be expected for these short EDTs, 80 ms Clarity is fairly high. Early energy levels (G80) however are below average for a theatre or opera house. Late energy (Glate), is extremely low. For a shoebox shaped concert hall Glate is usually in the range of 0 dB. For a proscenium arch theatre it's often in the range of -1 to -5 dB. In the Hummingbird Centre Glate ranged from -10 dB at the front of the room to -15 dB and lower at the back.

Taken in this context, it's not surprising that the room has been plagued by echoes. One of the more pronounced echoes was off the side wall. It had never been a problem in the past because the side walls reflect very little energy from the stage. The proposed electronic enhancement system design however called for 62 loudspeakers on both

These measurements are all the more interesting when placed in the context of a renovation study for another theatre opened in the same year, Vancouver's Queen Elizabeth Theatre. (QET) The EDTs in this room are also much shorter than the RT. One suggestion was that this might have been a result of the QET's geometry; very wide with a low ceiling³. A computer model experiment indicates that this may indeed be the case. In the experiment, impulse responses were predicted for nine versions of two six-sided boxes, one fan shaped and the other shoebox. The height of each box was increased as a percentage of its mean width. The height to width ratio was found to have a strong influence on the EDT/RT ratio; what one might call the reverberation efficiency. Results of the computer experiment are shown in FIGURE 1. Superimposed on the graph are the measured EDT/RT ratios for halls that match the very simple geometry implied by the computer model experiment⁴. The fan shaped geometry of the Hummingbird Centre implies that the Height/Width ratio is low at most seats, particularly the ones near the back of the room. The computer model experiment suggests that this may explain why the EDTs are so low.

side walls. Each speaker was to be individually addressable for multi-media presentations and each one would be capable of producing what can only be described as a head-spinning echo.

DIFFUSION

The design challenge was formidable. How does one introduce acoustical diffusers onto the flat, yet very elegant side walls and make them look like they belong there? Three possible diffusers were proposed, each including a loudspeaker for the enhancement system and based on stepped prime number theory diffusion. The intention was to fit the diffusers into the lattice of 0.3 x 1.2 m recesses in the side walls. Two took the shape of a long right angle triangle with the loudspeaker at one end, the third was a flattened triangle with the loudspeaker in the middle. The latter was the poorest diffuser but best suited the architectural solution. At this point, diffuser optimisation⁵ was explored. The result was a crescent shaped diffuser that fitted in with the architect's concept of a "basket weave" that would thread in and out of the cherry wood side walls. The improvement generated by the optimisation was limited to 630 Hz and higher, as shown in Figure 2, where the surface scattering is characterised by a standard deviation diffusion parameter⁵. The 630Hz limit was probably due to the limitation placed on the diffuser depth of 0.3 m. Cursory echo detection listening tests suggested that this frequency range was appropriate. The improvement above 630 Hz is significant and leads to much more even scattering - see Figure 3.

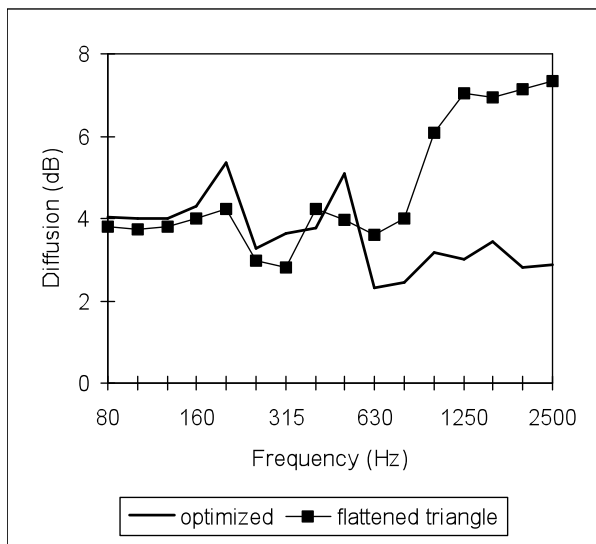


FIGURE 2 Diffusion spectrum for the optimised and flattened triangles.

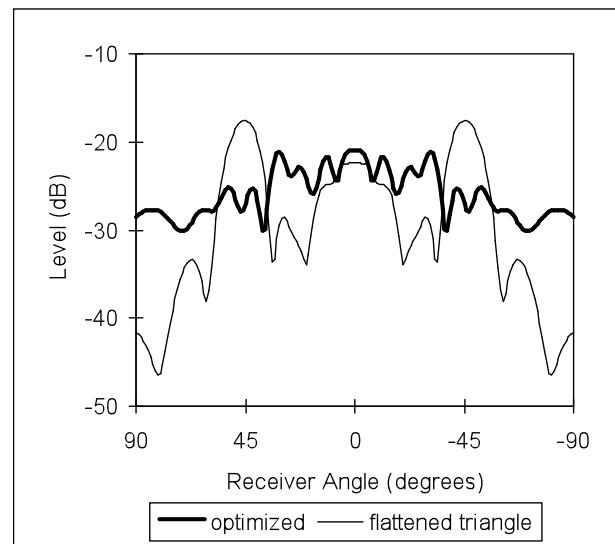


FIGURE 3 Diffusion response for the optimised and flattened triangles.

ENHANCEMENT SYSTEM

The electronic enhancement system consisted of four LARES mainframes⁶ fed from two microphones located above and in front of the stage. 293 front ported two way loudspeakers were installed in the ceiling, on the proscenium arch and along the side and back walls. EDTs, Strength and Spatial Impression have all improved considerably. The renovated room and, in particular, the enhancement system have been well received by the owners and their tenants, including the National Ballet and the Canadian Opera Company.

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