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COMPARISON OF ACOUSTIC MEASUREMENTS IN TWO DIFFERENT AUDITORIA WITH HYBRID RAY TRACING/IMAGE METHOD MODEL PREDICTIONS.

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1. INTRODUCTION

Computer modelling of auditorium acoustics has developed several forms largely based on the image source method and the ray tracing method. In the image source method a reflection is simulated by the construction of an image source on the opposite side of a surface. The response of a receiver is then the sum of contributions from many image sources. Once image sources are constructed a visibility check is required since some image sources may not contribute to a receiver's response. This visibility check is often the most time consuming process in this method. In the ray tracing method sound is modelled by sending energy rays around a room and collecting them at a receiver point. The ODEON computer model used in this study uses a hybrid ray tracing/image source method, which uses a shortened ray tracing to perform the visibility check. It also has further modifications regarding calculation of the reverberant tail and the modelling of diffusion.

A previous study compared hybrid ray tracing/image source method results to scale model measurement results [1]. This paper presents comparisons of measurements made in two real halls with computer model results. The results presented are part of a continuing validation process involving comparisons of several auditoria.

2. DESCRIPTION OF AUDITORIA

The two halls used in this investigation were the 'Limerick University Foundation Building' (LUFB) main hall and the 'High Wycombe Entertainment Centre' (HWEC) hall. Plan views of both halls with source and receiver positions are shown in figures 1 and 2. Both halls were designed and built recently and therefore full architectural drawings were available.

The LUFB hall is fan shaped with two side balconies near to the stage front. It is mainly used for lectures (with a public address system) and for concerts. It has a seated capacity of approximately 1000.

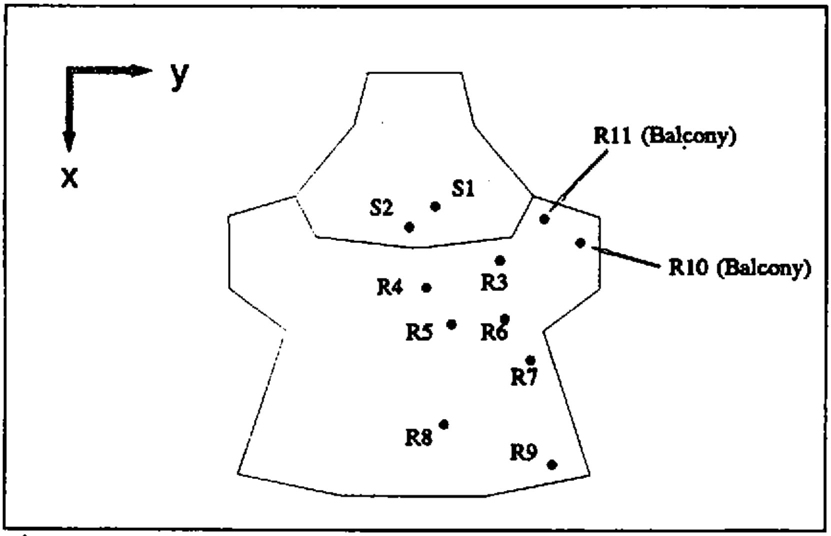

Figure 1 LUFB Source and Receiver positions.

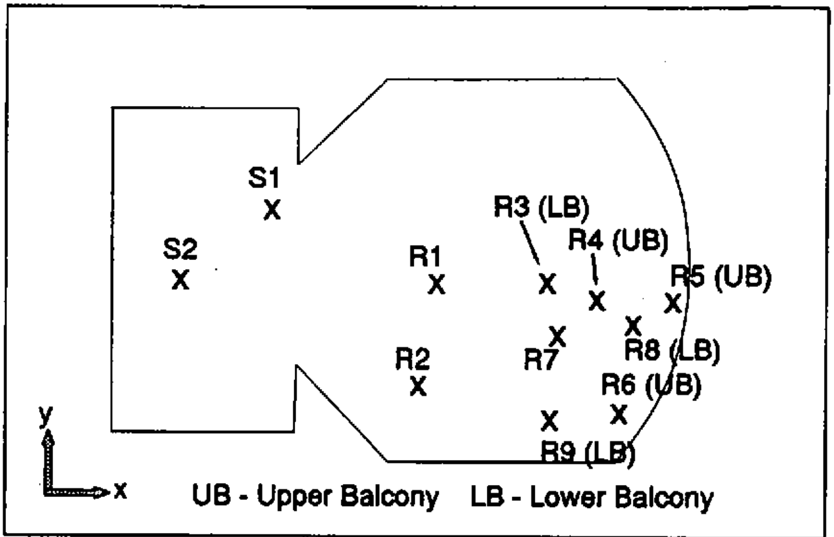

Figure 2 HWEC Source and Receiver positions.

The HWEC hall is used mainly for plays and musicals and has two large balconies at the back of the hall. It contains a public address system that is used with artificial reverberation for performances. It also has a seated capacity of approximately 1000. Measurements were made in both halls with the public address and artificial reverberation systems switched off.

3. DESCRIPTION OF MODELS

For the LUFB model the material absorption coefficients were taken from standard coefficients supplied with ODEON. For the HWEC model, most material absorption properties were given by the architects.

In ODEON, the degree of scattering a surface produces is controlled by a probability weighting for the direction of reflection from the surface. This probability weighting can vary between 0.0 and 1.0 and is known as the diffusion coefficient. A diffusion coefficient of 0.0 produces a purely geometrical reflection whereas a value of 1.0 will mean the reflection angle will vary according to Lamberts distribution. Due to a lack of available data on the diffusion characteristics of surfaces, diffusion coefficients of 0.7 and 0.1 were chosen for seating and wall surfaces respectively. These values have produced good results in previous comparisons with scale models [1]. However, surface diffusion properties in scale models and full size halls are likely to be different and future comparisons will vary this parameter.

The number of rays used in the predictions was 8,000 and 10,000 for LUFB and HWEC respectively. The 'maximum reflection order' was set to the maximum of 200. The 'desired final reflection density' was set to 200 /ms. All smoothing was set to 'OFF'. ODEON version 2.0 was used for all predictions.

4. COMPARISON AND DISCUSSION OF SELECTED RESULTS

4.1 Reverberation Time

Predicted and measured reverberation times at single positions in each hall (S1R8 in LUFB, S1R3 in HWEC) are shown in Fig.3. Despite being taken at single positions they represent the general relationship found between prediction and measurement throughout both halls. Both predictions produced reverberation times generally above those measured with their closest results occurring in the 500 Hz band. At low frequencies higher reverberation times would be expected due to the finite size of the surfaces.

Fig.4 shows reverberation times in the 1 kHz band against source/receiver position for LUFB. For both halls the predicted times were much more variable with position and generally higher than those measured. The effect of varying the ODEON transition order

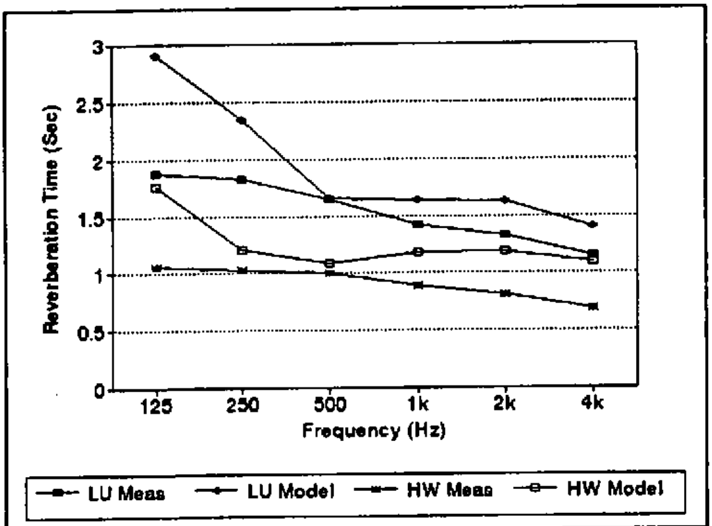

Figure 3 Measured and modelled T60 at single positions in LUFB and HWEC.

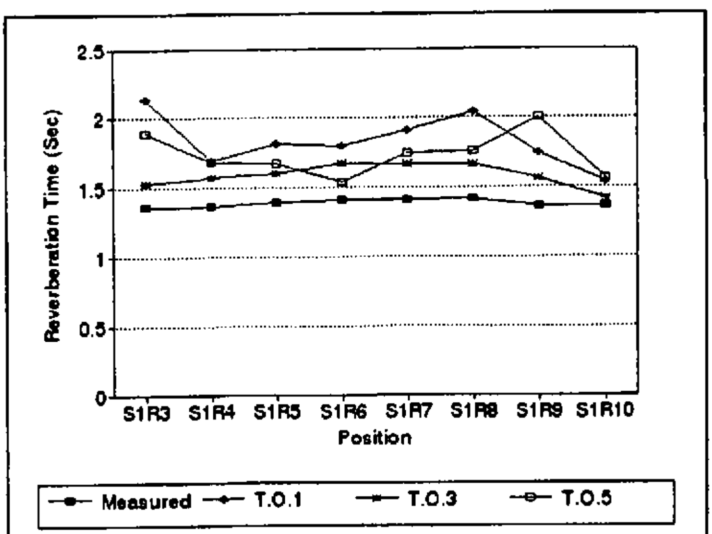

Figure 4 LUFB T60 at 1000 Hz. Showing variation of transition order.

on the reverberation time predictions is shown in Fig.4. In both rooms the models with transition order equal to 3 produced the most accurate results with the least variance. The models with transition orders set to 1 and 5 gave more variable results. This was unexpected for a transition order of 1.

Although not presented graphically, the Sabine reverberation times in the 1 kHz band calculated by ODEON were 1.1 sec for LUFB and 0.9 sec for HWEC. These values are closer to those measured than those calculated with full ray tracing. This suggests the real halls were more diffuse than modelled. In both halls the accuracy of the reverberation time predictions increased slightly with source to receiver distance.

4.2 Clarity Index (C80)

C80 predictions and measurements at 1 kHz are shown for LUFB in Fig.5. The clarity index is more sensitive to early reflections than reverberation time. With the reverberation time predictions being too high, the C80 values are also expected to have notable errors. In common with previous work [1], the Clarity Index at receivers nearer to the source was generally predicted better with a lower transition order of 1. Receivers further from the source were usually modelled better with a higher order of 3 or 5. All models generally calculated the positional variations well. At certain positions in both halls all used transition orders gave high Clarity Index values that were not measured. For instance, S2R4 in LUFB, this effect could be caused by reflections from small surfaces, which have an exaggerated influence in ODEON. Destructive interference in the real hall, which is not considered in the energy based ODEON model, could also contribute. A transition order of 5 produced slightly higher values of Clarity Index than a transition order of 3, this also agrees with previous studies. It is interesting that even with a low transition order of 1 positional differences due to geometrical effects in the hall were still predicted reasonably well.

4.3 Early Lateral Energy Fraction (ELEF')

Lateral energy measurements were performed with a pressure figure-of-8 microphone, which enabled a direct comparison with the values calculated by ODEON. So far, lateral energy measurements have only been measured at HWEC. These are shown in Fig.6. In these comparisons a low transition order of 1 produced markedly different results to the two higher orders used and agrees better with the measurements.

4.4 Relative Level

Fig.7 shows measured and modelled levels at 1 kHz against source/receiver position for HWEC. The relative levels shown are referenced to the level at position S1R1. For both halls varying the transition order had little effect on the level predictions. Source/receiver positions with a strong direct component in their response - such as S1R1, S1R2, S1R3 and S1R7 in HWEC - produced the most accurate predictions. This also occurred in LUFB where more positions had a strong direct component. Positions S1R4 and S1R8 produced level predictions significantly higher than those measured. These are thought to be due to

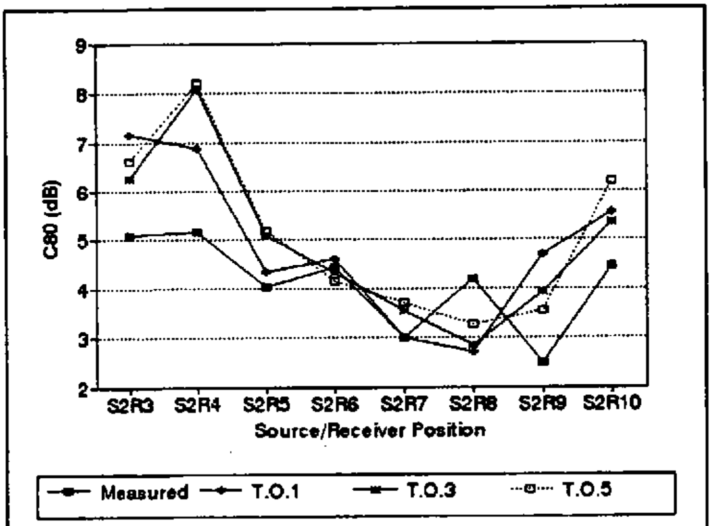

Figure 5 LUFB C80 at 1000 Hz. Showing variation of transition order.

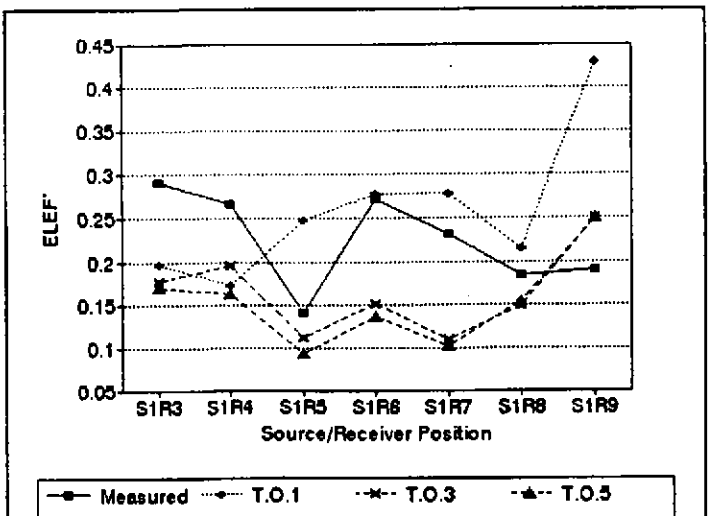

Figure 6 HWEC ELEF' at 1000 Hz. Showing variation of transition order.

a combination of exaggerated reflections from small surfaces in ODEON and possible local interference in the measured responses, which would not be predicted by the energy based ODEON model. Positions with weak direct components - such as S1R5 and S1R6 in HWEC - still had levels predicted within ± 1 dB.

5. SIGNIFICANCE OF RESULTS

The selected results presented in this paper are part of a wider survey that compares computer modelling with real hall measurements in several halls. So far only two halls have been measured - further measurements will be made in different halls in the coming year. A previous study [1] has compared several hybrid ray tracing/image source models to 1:50 scale model measurements. However, there are important differences between these two validation studies. For instance, with scale models there are usually only a few different materials used and the absorption properties of these are known accurately. Scale model surface diffusing effects are also likely to be very different from those in real halls.

6. REFERENCES

[1] Y W LAM,'On the Modelling of Auditorium Acoustics, Part II : The Validation of a Hybrid Computer Model', Submitted to JASA for publication (1993)

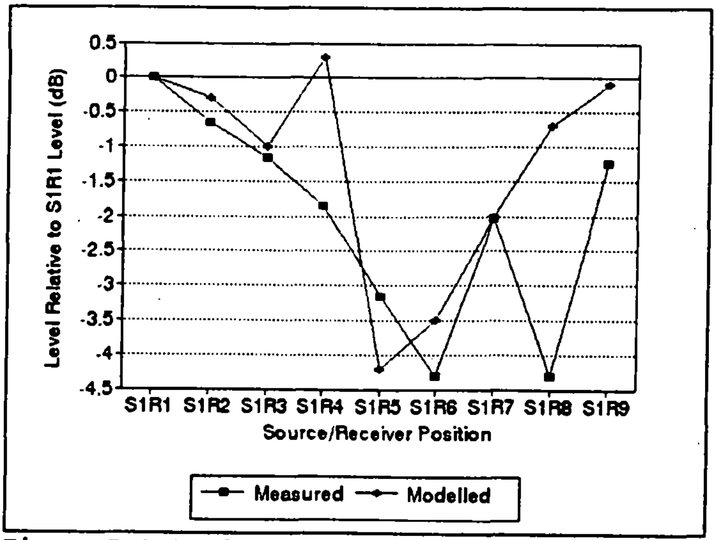

Figure 7 HWEC level relative to S1R1 level at 1000 Hz.