Errors Incurred Using a Dummy Head to Make Omni-directional Room Acoustics Measurements

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INTRODUCTION

Most auditorium acoustics measurements require the use of an omni-directional microphone; others are binaural and require the use of a dummy head. This paper presents some aspects of investigations using a dummy head to make omni-directional measurements. Data from three different concert halls, using both techniques, were used to examine the differences between the two. The halls used were Mechanics Hall in Worcester, Massachusetts, Massey Hall in Toronto, and two configurations of the John Aird Centre Recital Hall in Waterloo, Ontario.

EXPERIMENTAL METHOD

The omni-directional microphone impulses were obtained using RAMSoft II [1], while the binaural impulses were obtained using BRAM (Binaural Room Acoustics Measurement software). Both are computer based measurement systems developed at the National Research Council of Canada. Both produce impulse responses for a maximum length sequence signal, using a Fast Hadamard transform process. The integrated impulses from the dummy were added on a simple energy basis. The RAMSoft II software calculates 12 acoustical quantities including: reverberation time, RT (-5 to -30 dB), early decay time, EDT (0 to -10 dB), clarity-early/late energy ratio, C80 (80 ms early time period), and relative level, G (level re. free field level at 10 m). All the measures were obtained in the six octaves from 125 to 4000 Hz. The omni-directional microphone was a half-inch B&K microphone and the dummy head was a B&K type 4128 head and torso simulator with internal microphones.

RESULTS

Consider first the differences between hall average measurement results from the dummy head and the omni-directional microphone system. The average differences, dummy head - omni, for EDT are plotted versus octave band frequencies for the three halls and are shown in Figure 1. The differences tend to be small (within 0.1 s) which could be due to errors in accurately re-positioning the source and receiver. Bradley [2] showed that moving the receiver by only 30 cm can induce a variation of over 0.1 s at low frequencies and 0.05 s at high frequencies. Since the two measurements were made at different times and with different receivers, significant variations in the positions are quite plausible. At the higher frequencies, where the width of the head becomes a significant fraction of the wavelength, the directionality of the head will become a factor and thus contribute to the differences. Another problem is that the dummy head measurements averaged two positions that are 15 cm apart, i.e. the spacing of the ears. This will also contribute to the observed differences. On a seat-by-seat basis, the differences are larger. Differences of up to 0.4 s at mid frequencies and 0.8 s at low frequencies were found at individual seat locations in one hall.

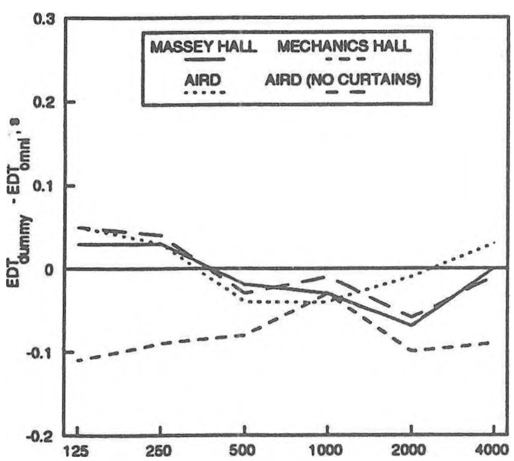

Figure 1. Average differences over entire hall of $EDT_{dummy} - EDT_{omni}$.

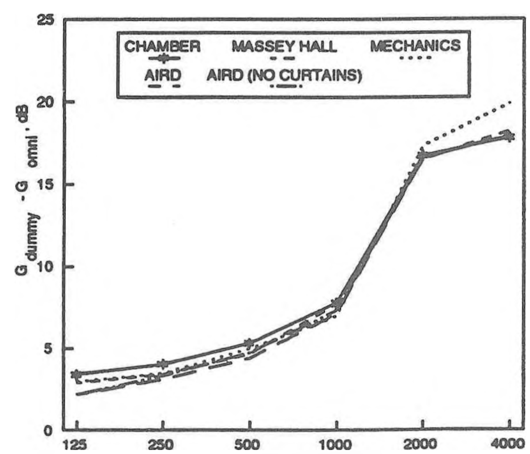

Figure 2. Average differences over entire hall of $G_{dummy} - G_{omni}$.

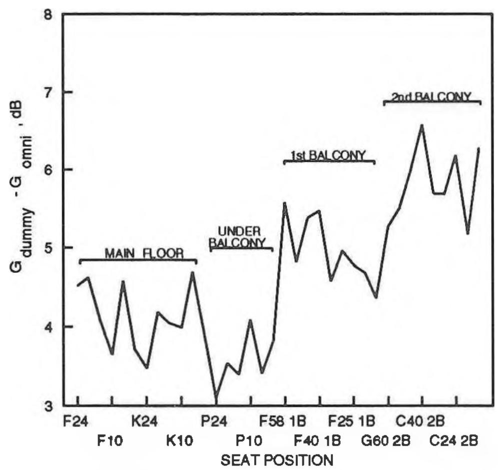

Figure 3. Seat-by-seat differences of G for Massey Hall at 500 Hz.

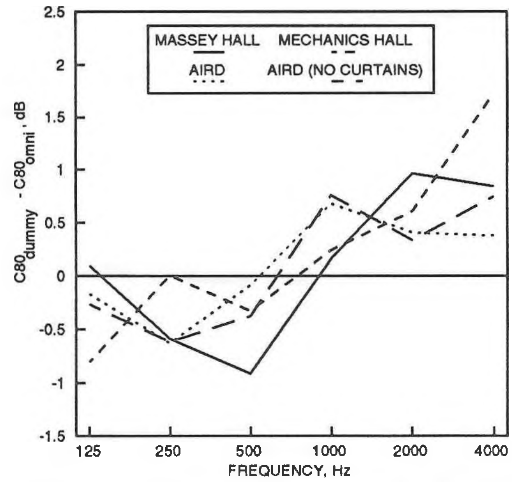

Figure 4. Average differences over entire hall of C80 dummy -$C80_{omni}$.

A graph of the average differences of G versus frequency is shown in Figure 2, and the effect of the directionality of the head is quite apparent. Along with the hall differences, the measured differences of the dummy head and the omni-directional microphone in a 250 m^3 reverberation chamber at the National Research Council are shown. In the 125 Hz octave, the difference is about 3 dB, which corresponds to a doubling of energy. The energies of the two ears were added together, and therefore at lower frequencies where the head is less directional, the energy should be twice that of the omni-directional microphone. At higher frequencies, the directionality of the head is a larger factor and is not a simple doubling of energy. The differences from the hall data results follow the form of the reverberation chamber measurements. The differences range from 3 dB in the low octave to between 15 and 20 dB in the 4000 Hz octave. There is also a noticeable spread of differences between the halls, about 1 dB in the lower octaves and up to 2 dB in the highest octave.

A plot of the differences in G versus seat position for the 500 Hz octave for Massey Hall is shown in Figure 3. The curve is shifted above zero due to the average directionality effects of the dummy head at 500 Hz, shown in Figure 2. The major variations are shown to be related to specific areas in the hall that would change the significance of the dummy head directionality. The dummy head would be more sensitive to sound arriving from the side, thus these locations might make these more prominent. These areas are under the balcony and in the balconies where the receiver is significantly above the source. On a seat-by-seat basis, Figure 3 shows that these differences are as large as 3 dB.

The differences of C80 versus frequency for the two measuring techniques are shown in Figure 4. At the low frequencies, the differences are in accordance with the expected re-positioning errors [2] which are about 1 dB for source/receiver differences of 30 cm. At the higher frequencies, differences of about 0.5 dB would be expected [2], but once again the directionality of the head will also play a role. The seat-by-seat differences are large - from 1 dB to over 7 dB at 4000 Hz in one hall. These differences are probably due to directionality effects of the head but it is not clear that this is the only effect.

CONCLUSIONS

The directionality of the dummy head plays a very important role and causes differences in all of the above measured quantities. On an average basis for an entire hall, the differences are not very large, but are significant. It may be possible to apply an average correction to account for some of the systematic differences. This is obvious with G values (as seen in Figure 2) but for the other measures it will require further work. However, the individual differences can be much larger. At some locations these differences would be greater than typical differences between halls. These differences can vary as much as 3 dB, as seen in Figure 3. Therefore, the two techniques cannot be used to give precisely the same results.

REFERENCES

1. Halliwell, R.E., and Bradley, J.S., "RAMSoft II: A Computer-Based Room Acoustics Measurement System", Presented at Baltimore meeting of the ASA, May 1991, J. Acoust. Soc. Am., Vol. 89, No. 4, Pt. 4, p.1897 (1991).
2. Bradley, J.S., Gade, A.C., and Siebein, G.W., "Comparisons of Auditorium Acoustics Measurements as a Function of Location in Halls", Presented at Ottawa meeting of the ASA, May 1993, J. Acoust. Soc. Am., Vol. 93, No. 4, p2265 (1993).