

Balance Measurements in Four Canadian Theatres

John O'Keefe
Aeroustics Engineering Limited
Toronto, Ontario

Introduction

A proscenium arch theatre is fundamentally different from a concert hall in many ways, not the least of which is acoustics. The classical concert hall has a single distributed sound source, the orchestra, in the same acoustic space as the audience. A theatre has two sound sources in acoustically dissimilar rooms - the singers on stage and instrumentalists in the orchestra pit. The audience is in yet another dissimilar acoustic space. Therein lies the unique aspect of theatre acoustics: the balance that must be struck between singers on stage and the instrumentalists in the orchestra pit. To date, this has received little attention in the literature.

Trained operatic singers develop a fifth formant, one more than a typical speaker¹. The formant is centred around 2500 to 3000 Hz and is the principle mechanism by which a single singer is able to project over the formidable forces of an orchestra. Poor acoustic coupling between the pit and the audience chamber also works to the singer's benefit.

Measured Balance is a simple logarithmic ratio of sound emanating from the stage to sound from the pit. Values greater than zero indicate that the sound from the stage predominates. Optimum balance may lie in the range of +2dB, although there have been no subjective studies as yet to substantiate this.

Measurement Procedure

Measurements were performed in four unoccupied theatres. These are the Royal and McPherson Theatres, both in Victoria, Saskatoon Centennial Auditorium and the former O'Keefe Centre, now known as the Hummingbird Centre. More information on these theatres may be found in ref. 2. Directional and omnidirectional sound sources were used on stage and in the pit, respectively. The source locations are similar to those employed by Barron³. Measurements were performed at ten different seating locations in each theatre.

Balance ratios were calculated in 1/3 octave bands according to:

$$B_t = 10 \log \left(\frac{\int_0^t P_{stage}^2(f, \tau) d\tau}{\int_0^t P_{pit}^2(f, \tau) d\tau} \right) + K(f) \quad (1)$$

Where t is time and $K(f)$ is the frequency dependant difference (in dB) between the directional and omni-directional sound sources. Three different temporal integrands were chosen: 10 ms (Direct), 50 ms (Early) and ∞ (Steady State).

Results

The most demonstrative interpretation of the measurements came in the form of the 50 ms Balance ratios, please see Figure 1. Note how low frequency balance is much lower on the orchestra level. In many proscenium arch theatres, the sound is thought to be best on the balcony. This may suggest one reason why.

The measurement survey suggests the following trends:

- (i) Low frequency balance favours the pit for listeners on the orchestra level. For listeners on the balcony level, low frequency balance is about even.
- (ii) At high frequencies, in the range of the singers' formant, the balance curve dips in favour of the orchestra pit. Also, at high frequencies the directional orientation of the stage source influences the balance. There is no significant difference between the balcony and the orchestra levels for either of these effects.
- (iii) Lowering an orchestra pit effects direct sound much more than early or late reflected sound.

Conclusions

Low frequency balance is typically better on balconies than it is on orchestra levels and is most likely influenced by the seat dip effect. A high frequency reduction of balance has been measured on both the balcony and orchestra levels and is likely to be exacerbated in occupied rooms by an interference effect known as the head dip phenomenon⁴.

References

- [1] SUNDBERG, J. 'The acoustics of the singing voice', Proc. 15th ICA, Vol. 3, pp 39-44 (1995)
- [2] O'KEEFE, J., 'Measurement of Stage to Pit Balance in Four Proscenium Arch Theatre', Proc. IOA Vol. 19 Part 3 Auditorium Design at the Millennium, pp 145-151 (1997)
- [3] BARRON, 'Auditorium Acoustics and Architectural Design', E & F Spon, London, (1993)
- [4] MOMMERTZ, E. 'Attenuation of sound passing over audience at grazing incidence' 125th ASA Mtg, Ottawa, Canada (1993)

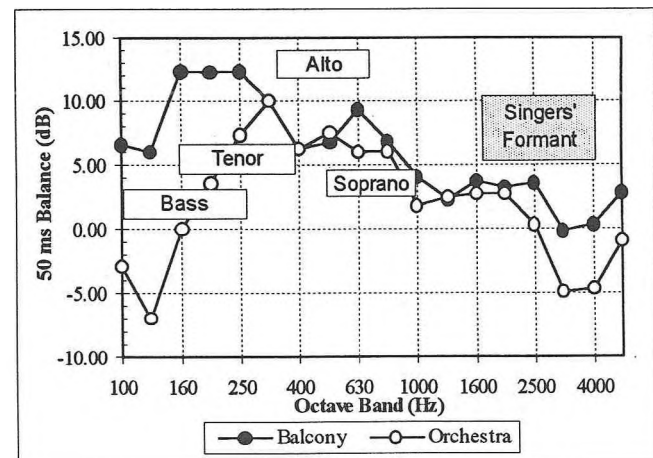


Figure 1 50 ms Balance (B50) measured in The Royal Theatre, Victoria, B.C. Also shown in the graph are the approximate ranges of the four singing groups and the range of the singers' formant.