ARCHITECTURAL ACOUSTICS DESIGN OF THE GOLD COAST CITY COUNCIL CHAMBERS

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Abstract

This paper reviews the design challenges and development of solutions to the room acoustics design of the Council Chambers in the new Civic Focus building of the Gold Coast City Council. The proposed design incorporated a double concave light well and a concave main wall facing the Councillor seating positions with significant areas of glass behind them. Additionally, for a number of seating positions, the Councillors would be speaking with their backs to the Chambers Public Gallery.

Preliminary analysis of the space indicated the likelihood of significant sound focusing and flutter echo problems for the Chambers with the prospect of poor speech intelligibility for listeners. A 3D computer model of the Chambers was created and geometric ray tracing was used to investigate the behaviour of sound source propagation in the space, concentrating on the Councillor locations as the source positions with other Councillors and the Public Gallery as the receiver locations of interest. An analysis was undertaken of the sound reflection sequences in the Chambers considering the audibility of echoes and the provision of useful early reflected sound energy to enhance speech intelligibility at all the listener locations.

The development of surface features and treatments to solve the design issues within the imposed constraints and the outcomes of the design will be discussed.

Introduction

A Council Chambers for Councillors to use for public and private meetings was proposed as part of an overall redevelopment program for a municipal council on the Gold Coast, Australia.

A design goal for the Chambers was good conditions for unaided speech. This paper describes the acoustic design issues, the development of acoustic treatments and the outcomes of the design.

Description of Chambers

The proposed Chambers design had a number of features unfavourable to achieving a good outcome for speech communication. Foremost among these was:

- the basic concave shape of the lower section of the room
- this shape facing large glazed (sound reflective) areas
- a double concave forming the atrium

Figure 6 shows an overhead perspective view of an outline of the Chambers with these features highlighted. Figure 7 shows a preliminary rendered drawing of the Chambers and the seating arrangement.

Another feature of the design impacting speech intelligibility was the fact that Councillors in the main section of seating were speaking away from (had their backs to) or, at best, were side on to the Public Gallery.

Design Issues

The shape of the Chambers was not conducive to accurate modelling of reverberation characteristics in the Chambers since an inherent assumption of these models is a diffuse sound field. Instead an approach was used which looked at the usefulness to speech intelligibility of reflected sound energy, minimising problematic reflections and maximizing useful reflected sound energy.

Figure 1 depicts the two perceptual boundaries in terms of the level and delay of reflected energy relative to the direct sound at a listener.

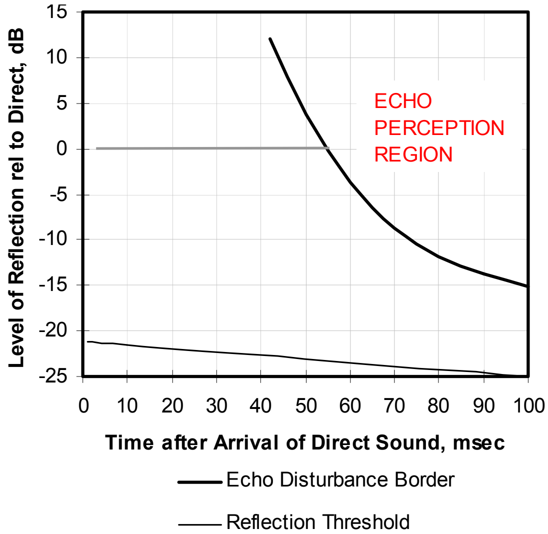


Figure 1 Perceptual Boundaries

Figure 1 highlights the importance of both the delay and the relative level of the reflected sound energy but it does not provide guidance on sound colouration or background noise effects.

For good speech intelligibility at the most remote seating position from a talker, 18 metres in the case of the Chambers, a background noise in the range of NR 32 to NR 38 is desirable. As can be seen in the figure below, however, if a listener is at the back of a talker then a level reduction in the important speech frequencies around 2 kHz occurs [1]. The reduction in level is in the order of 12 dB.

Consequently to maintain good speech intelligibility the background noise level needs to further reduce by this same amount to maintain the approximately equivalent speech signal to noise ratio at the listener. For this reason a background noise level target of RC20 to RC30 was specified.

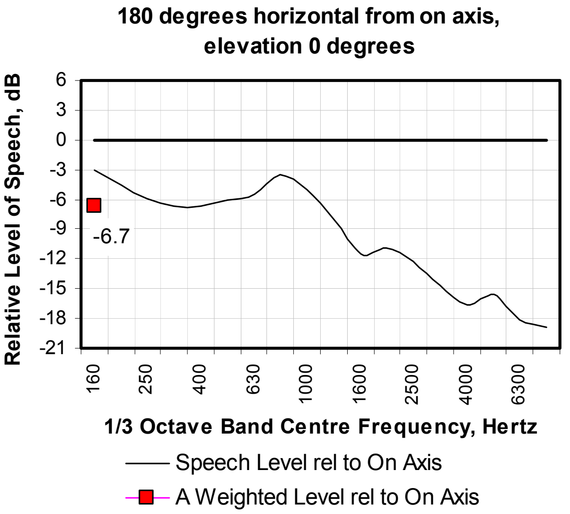


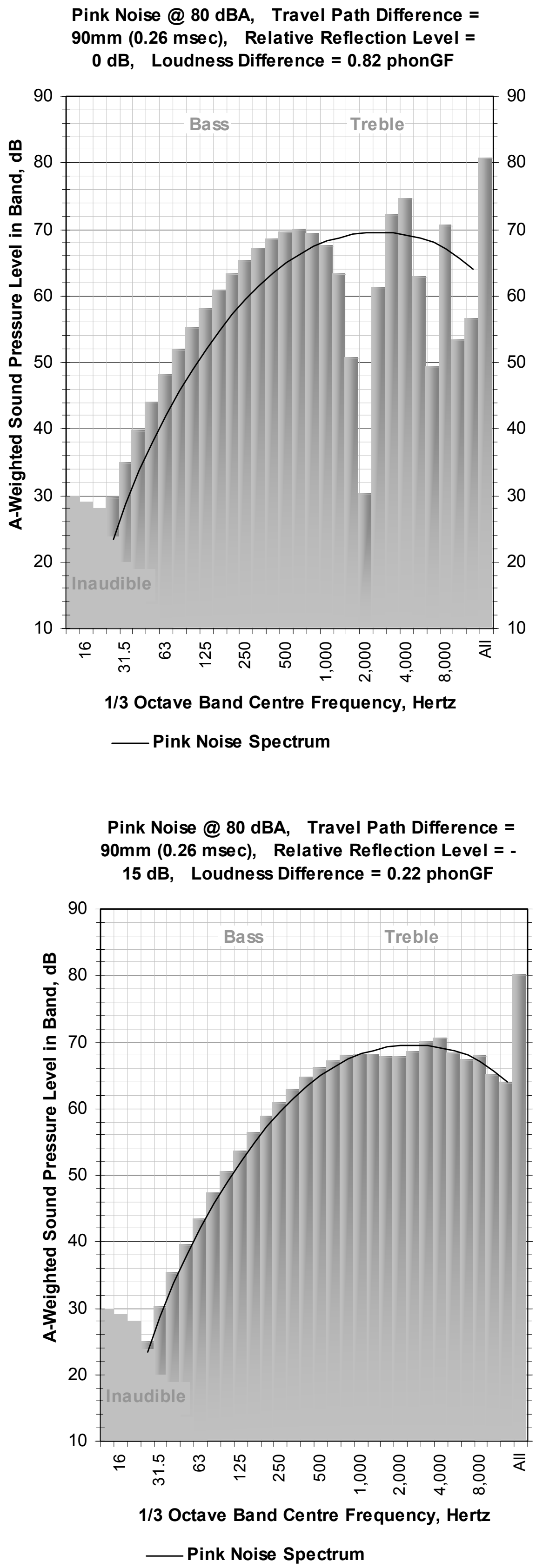
Figure 2 Speech Level behind a Talker

Although a reflection with characteristics within the echo avoidance region will prevent an echo problem it may still cause the sound heard to be coloured. This is due to the coherent addition of the direct and reflected sound energy. Figures 3a and 3b show the effect on sound spectrum of a reflection with a short delay (path length difference 90mm) relative to the direct sound for two conditions:

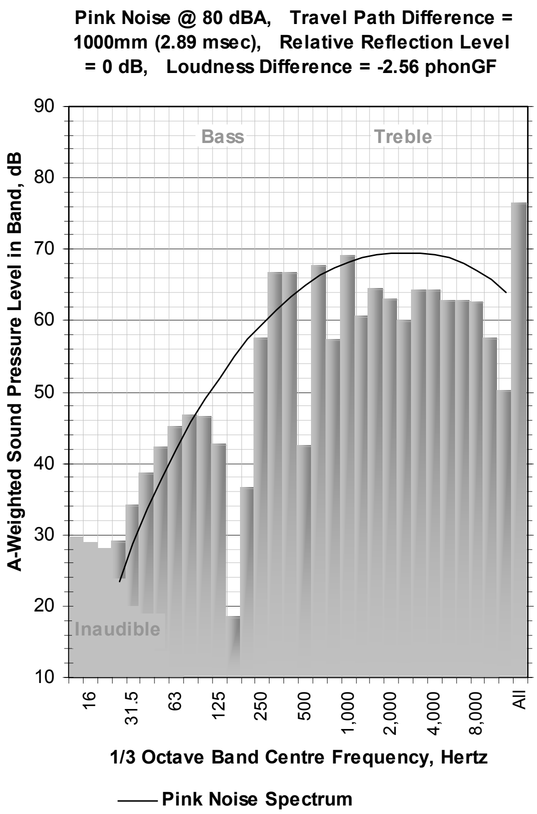
- a reflection at the same level as the direct sound
- a reflection -15 dB down relative to the direct sound

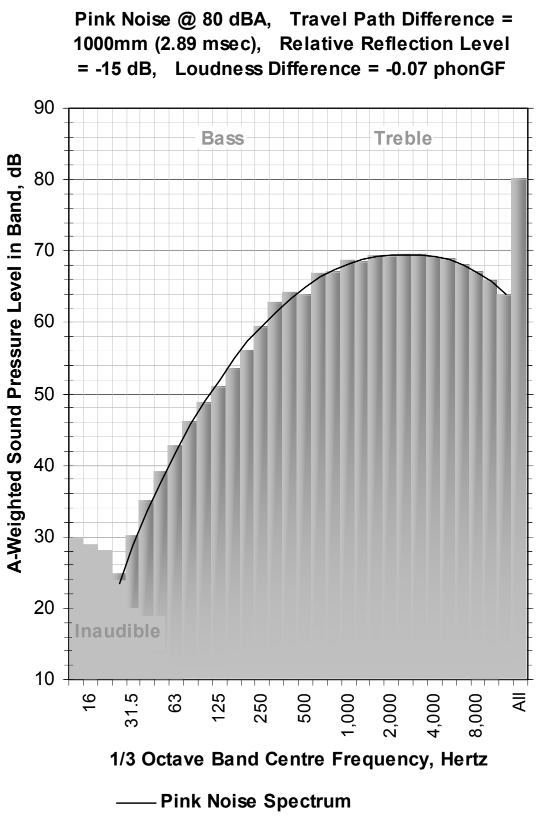
Figures 4a and 4b show the effect for a longer difference between the direct and reflected sound travel paths (1000mm). The spectrum modification is relative to the pink noise spectrum (black line).

The figures show that lowering the relative level of the reflection reduces its effects on the sound spectrum.



Figures 3a/b Reflection Spectrum Effects





Figures 4a/b Reflection Spectrum Effects

Early reflections, occurring within 50 milliseconds of the direct sound (travel path difference of 17 metres), provide useful reinforcement of speech. A recent study confirmed the importance of early reflections for achieving good conditions for speech in rooms and found early reflections can increase the effective signal-to-noise ratio by up to 9 dB [2].

Finally, reverberation time, a measure of how quickly sound energy is removed from a room, needs to be adequately short to reduce the chance of decaying sound energy masking the direct sound from a talker or loudspeakers. A reverberation time of less than one second at mid frequencies is desirable [3].

Summarising these acoustic design issues:

- Good speech intelligibility requires an adequately low background noise level with a neutral spectrum, free of fluctuations over time
- Early reflected sound energy is useful to enhance speech.
- Reflected sound energy has potential to cause sound colouration.
- Delayed reflected sound energy at sufficient level has the potential to cause echo disturbance and masking of speech.

Design Analysis

A 3D computer model of the Chambers was created and geometric ray tracing was used to investigate the behaviour of sound source propagation in the space, concentrating on the Councillor locations as the source positions with other Councillors and the Public Gallery as the receiver locations of interest.

Figure 5 below shows the effect of sound propagating in the double concave atrium after 9 reflections. It can be seen that sound energy has not dissipated and a flutter echo would be expected.

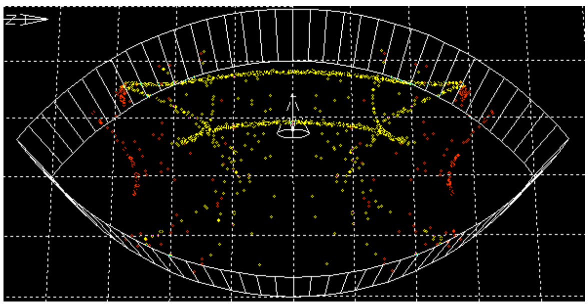


Figure 5 Atrium Reflection Study

Modelling also showed that there was sound focusing at the main Councillor seating due to the concave wall and that this focusing occurred at greater than 50 milliseconds delay.

Design Solutions

Some of the most detrimental effects of strong early reflections can be minimised by the use of surfaces that scatter sound, sound dispersive surfaces, and by surfaces that combine scattering and absorption. The sound energy is spread out, or redirected, in space so that reflected energy is lower in level at any given listening location, reducing colouration and echo effects.

Simply adding sound absorption into the Chambers may have reduced the negative effects of sound colouration and echo, however, this would not have assisted speech intelligibility and it is likely that the Chambers would have been fatiguing to be in for any length of time.

By spreading out the reflected sound energy, sound diffusion treatment allows the generation of a more diffuse soundfield, reducing the variability between listening locations, reducing frequency interference effects and smoothing out the reverberation response.

Modelling showed that the vertical first reflection zones centred on the head height of talkers were the most significant in terms of acoustic treatment. For these areas, where feasible to implement, a novel sound diffusive, but reflective, treatment was selected. The purpose of the treatment was to disrupt the sound focussing effect of the concave wall and provide a multitude of early, low level, lateral reflections at listening positions.

The modelling also showed that it would be useful to add a reflector to the Public Gallery to direct early reflected sound energy towards the Gallery instead of this sound energy propagating back into the Chambers.

The ceiling above the main Councillor seating and the central air-conditioning riser at the rear of the Mayors seat were also curved to allow early reflections between Councillor seating and also from these seats to the Public Gallery.

To avoid flutter echo problems developing in the atrium this upper zone was treated with absorptive finishes (ceiling and walls). Figures 8a/b show the finished Chambers.

Outcomes

Listening tests undertaken in Chambers have confirmed the validity of the design approach. Despite the air-conditioning noise levels being substantially above the design specification, the Chambers sounds very neutral and speech intelligibility at all listening locations within the Chambers are very good. There are no audible flutter echoes.

I am advised that Councillors can no longer mutter asides to their colleagues and assume speech privacy!

References

[1] National Research Council of Canada Research Report 104 “Detailed Directivity of Sound Fields Around Human Talkers”, December 2002.
[2] Bradley JS, Sato H, Picard M., “On the importance of early reflections for speech in rooms” JASA. 2003 Jun; 113(6):3233-44.
[3] Australian Standard AS2107

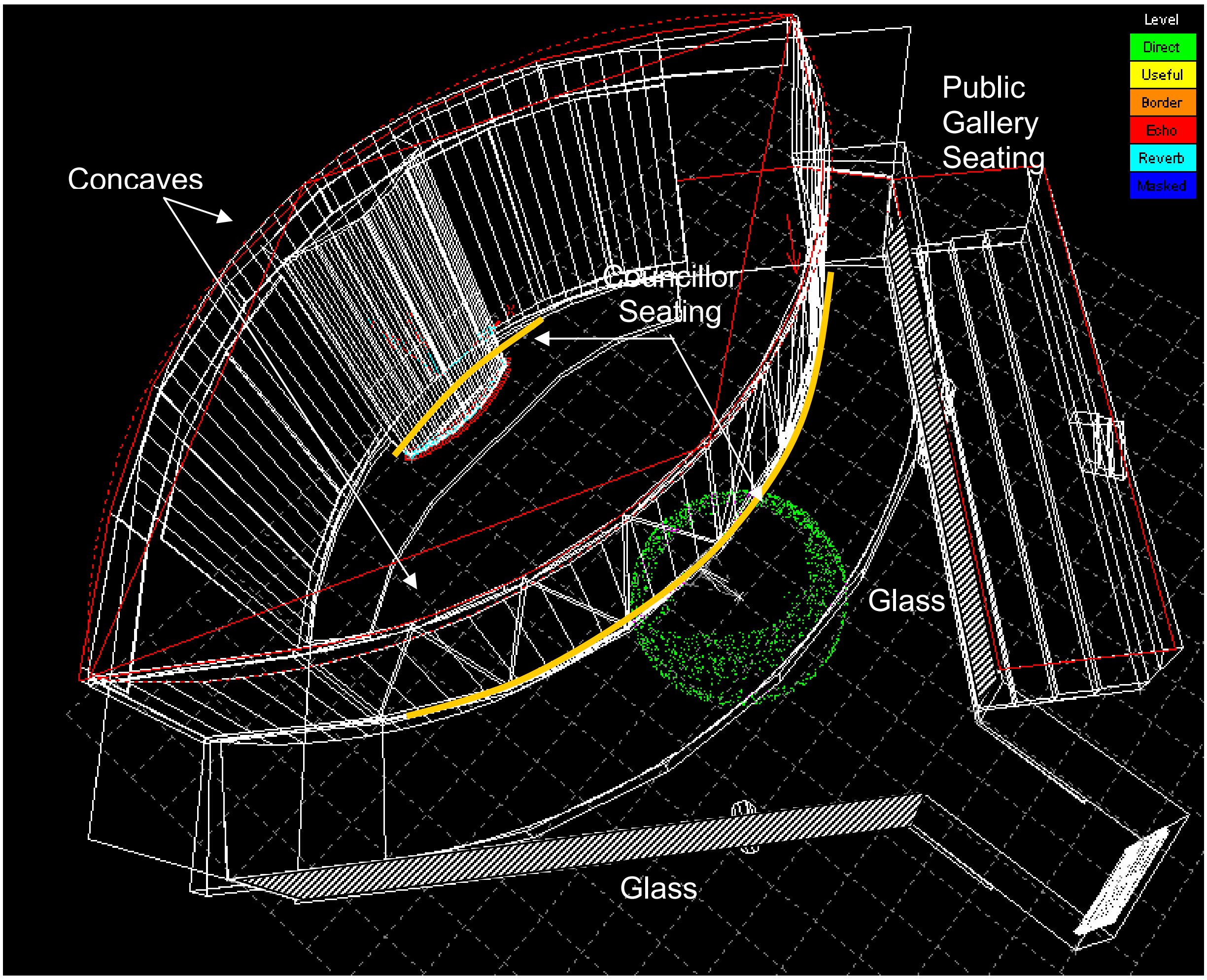


Figure 6 Chambers Outline Perspective showing Main Features

Figure 7 Early Stage Design (pre acoustic design input)

Figures 8a/b Completed Council Chambers – Views from Entry and towards Public Gallery from side