Room Acoustic Design of the Queensland University of Technology Creative Industries Precinct Phase 2 (CIP2)

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ABSTRACT
The QUT Creative Industries Precinct Phase 2 (CIP2) co-locates the music, dance, performance and visual arts portfolios of the Creative Industries Faculty in a mixture of new-build and adaptive re-use of heritage structures. The acoustic design of CIP2 was of primary importance to the overall building performance and posed significant design challenges. The room acoustic design of CIP2 included design of two professional-quality recording studios, a large rehearsal/performance room, three interdisciplinary "black box" studios and several small rehearsal/practice rooms. The recording studios were designed to Dolby 5.1 standards, which involved challenges in fitting the required number of functional spaces into the available building area while maintaining the early-reflection control requirements of the Dolby guidelines. Ray-tracing design tools were used to develop the studio layouts taking into account the constraints of symmetry, favourable room ratios and the early-reflection requirements of the Dolby guidelines. Some studio spaces were façade-located which added challenges in controlling reflections and façade noise break-in. Additional flexibility in use was achieved by including variable-acoustics within studio live rooms via hinged panels.

1. INTRODUCTION
Queensland University of Technology (QUT) has recently moved into the new Creative Industries Precinct Phase 2 (CIP2) building at the Kelvin Grove campus. CIP2 is a new-build facility co-locating the music, dance, performance and visual arts portfolios of the Creative Industries Faculty into a single site, replacing several buildings split across QUT's Kelvin Grove and Gardens Point campuses as well as an external recording studio facility in Newstead.

Located within CIP2 are multiple studio spaces including a large ensemble rehearsal/performance room, small rehearsal/practice rooms, two recording studio complexes ("Studio A" and "Studio B", each consisting of multiple control, live and isolation rooms), three large interdisciplinary "black box" studios, three dance studios with sprung dance floor and four drama rehearsal spaces, with visual arts studios and gallery spaces accommodated in reused heritage structures formerly part of the Kelvin Grove army barracks.

The acoustic performance of CIP2 was key to the success of the entire project and required careful acoustic design to achieve the desired performance outcomes.

This paper focusses on the room acoustic design of the CIP2 facility, with special emphasis on the design of the recording studios and the large orchestral rehearsal room.

2. ACOUSTIC PERFORMANCE REQUIREMENTS
For the recording studios, the control rooms were designed to meet Dolby 5.1 standards (Dolby 2003), which have requirements for control of room reverberation, with a spectrum shape tolerance as shown in Figure 1. The reference RT is based on the room volume. The Dolby standards also require all early reflections within 15 ms of the direct sound to be at least 10 dB below the direct sound level over the frequency range 1 kHz to 8 kHz. The Dolby guidelines require a minimum room size of 30 m^2 floor area, with a room volume less than 300 m^3; ideally the control room should be symmetrical.

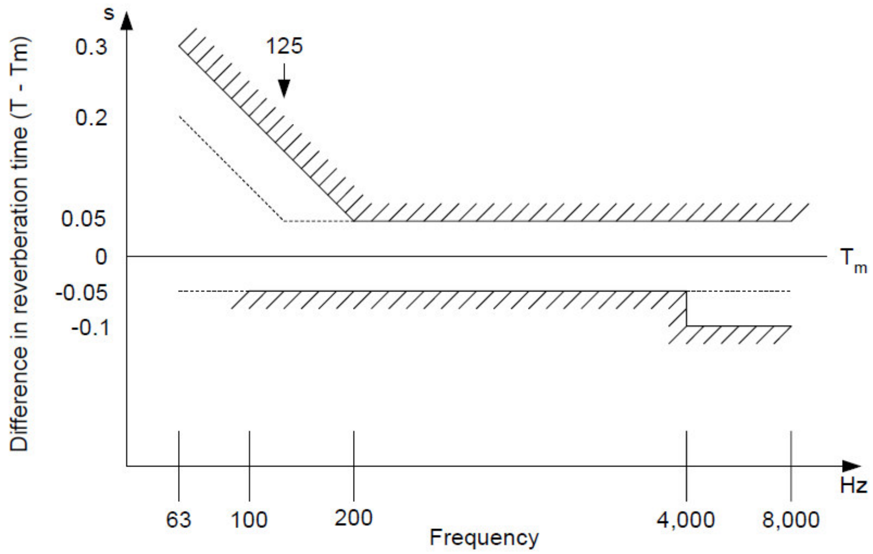

Figure 1 Required frequency spectrum shape for Dolby 5.1 standards, adapted from Dolby 2003

Benchmarking measurements of the existing QUT studio complex at Doggett Street in Newstead were also taken, in particular to quantify the existing background noise levels within the studios and the noise levels from rack-mounted studio outboard equipment. This resulted in a background noise level target of NR20 for the recording studios and the large rehearsal/performance room, with a target of NR25 set for the smaller rehearsal/practice rooms. Although these are higher than recommended by the Dolby standards, these were agreed with the end-users of the studios.

3. ROOM ACOUSTIC DESIGN

3.1 Space Planning of Recording Studios

The overall design for CIP2 essentially consists of two buildings joined by a connecting atrium – the eastern side is a 6-storey office building with single-height floor spacing, while the western side consists of four large structural "boxes" which contain three levels of double-height studio spaces.

This meant that each recording studio complex had to fit within a 15.6m x 12.4m structural box, while keeping the minimum room size and symmetry requirements for the control rooms to meet the Dolby standards, as well as providing usable live rooms and isolation rooms. This posed a challenge in providing the required number of functional spaces.

Previous Arup studio projects had largely used "template" control room and live room designs. These have the advantage of having repeatable, standardised acoustics for control rooms (a plus for multi-location organisations such as broadcasters) but are less spatially efficient and would not allow the required number of functional rooms to fit in the available space.

This required several iterations of space planning, but eventually resulted in a layout that provided control rooms of the required shape/size and symmetry requirements, with isolation and live rooms fitted into the "interstices" between the control rooms. This resulted in some irregularly-shaped rooms, including an 8-sided live room in one recording studio (Room 522), as shown in Figure 2:

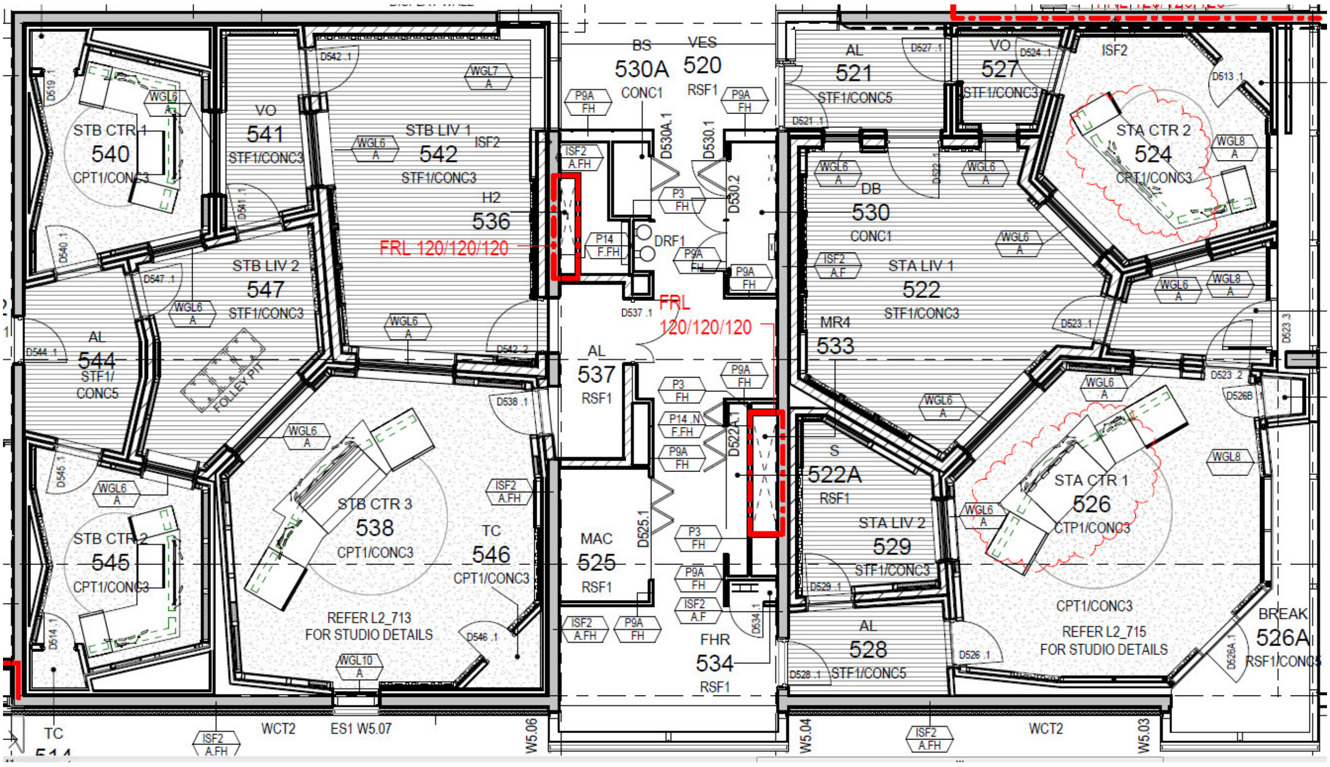

Figure 2: Developed Studio A and Studio B Layouts

Control room and live room dimensions were designed to meet the Dolby standards as well as, where possible, within the Bolt area of "favourable" shape ratio (Length/Width/Height) regions (Bolt 1946), which was achieved for all rooms except the two smallest control rooms (which are intended as more-"educational" spaces) and the large rehearsal room (which is sufficiently large that modal behaviour is less-important), as shown in Figure 3:

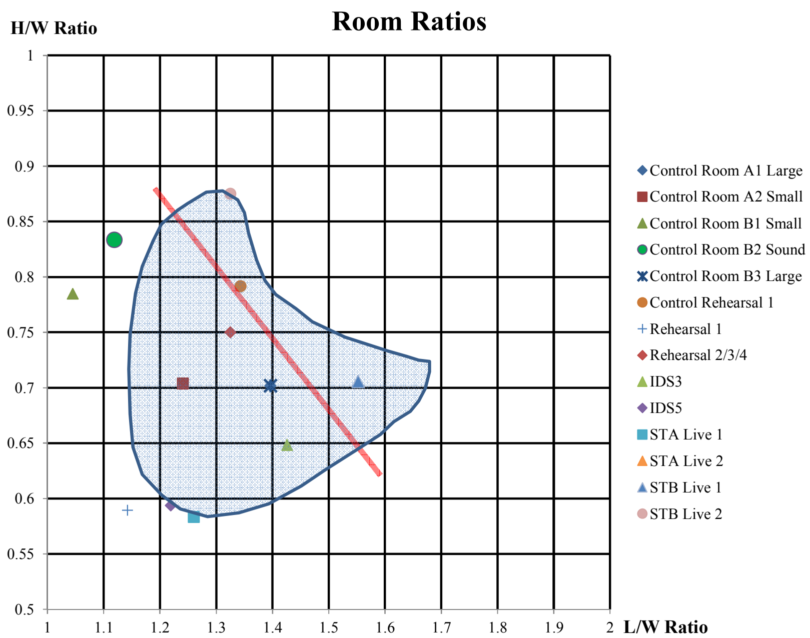

Figure 3: Room Ratios (L,W,H) for Music Spaces with the Bolt area (Bolt 1946) shaded in blue

3.1.1 Symmetry and Shaping of Control Rooms

Raytracing scripts were used to design control rooms using the Reflection Free Zone (RFZ) approach (D'Antonio and Konnert 1984), shaping the side walls of the control rooms so that no geometric reflection could arrive at the listener position within a 15 ms time window (i.e. a >15 ms Initial Time Delay Gap). The largest control rooms (intended as surround sound rooms with 5.1 or 7.1 speaker setups) were sized so as to achieve a >15 ms RFZ, with the first (side wall) reflection arriving at the listener at approximately 15 ms. Note that height differences and the surface finishes of materials will increase the achieved ITDG compared to the purely "geometric" ITDG discussed here.

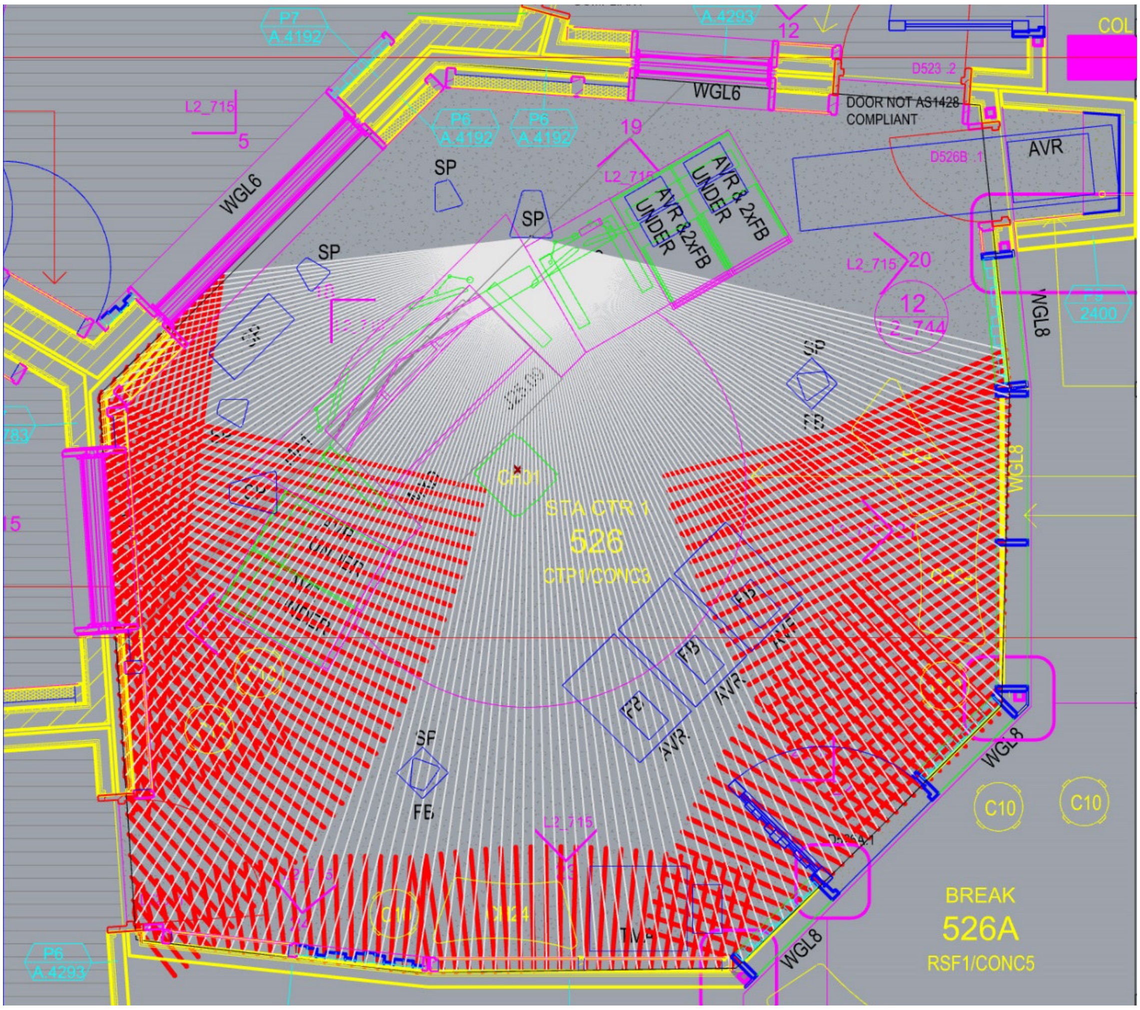

Figure 4: 15 ms reflection delay envelope from right channel (160° dispersion angle) for large control room, showing direct sound (white), first reflections (red) and listener position on edge of RFZ

The predicted decay curves for a large control room are shown in Figure 5, showing the achieved ITDG of just over 15 ms (~17 ms). Note that the strongest early reflection (at ~22 ms delay) is from the opposite side of the room because the room boundary contributing to the ~17 m/s "near wall" ITDG is highly-absorptive.

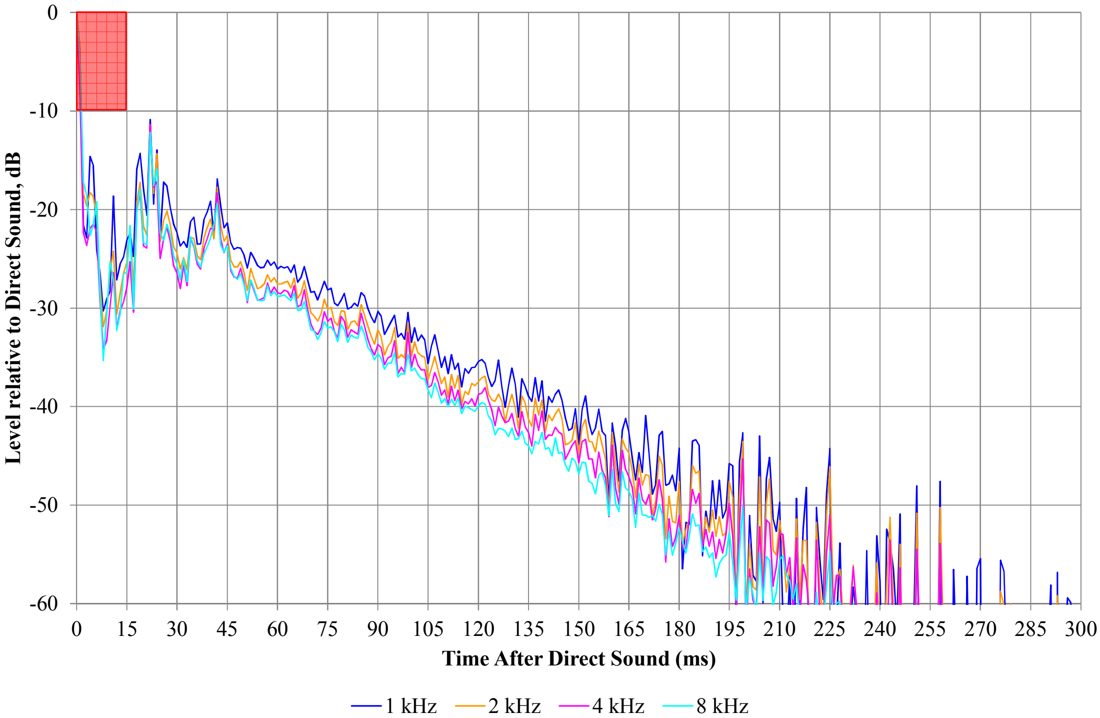

Figure 5: Predicted decay curves for large control room. Dolby early reflection control region is shaded in red.

For the two smallest control rooms, the physical size of these rooms was too small to allow a geometric RFZ and an ITDG of 15 ms was achieved by use of absorptive finishes and by angling the rear wall of these control rooms with an “anhedral” shape to redirect the rear wall reflection away from the listener. These rooms were not completely symmetrical due to the incorporation of isolated cupboards to house rack-mounted studio equipment out of the room in order to allow the noise floor in the control room to be reduced below the existing Doggett Street studios, which have equipment located in-room.

Figure 6 Angled rear wall used to achieve 15 ms ITDG in small control rooms

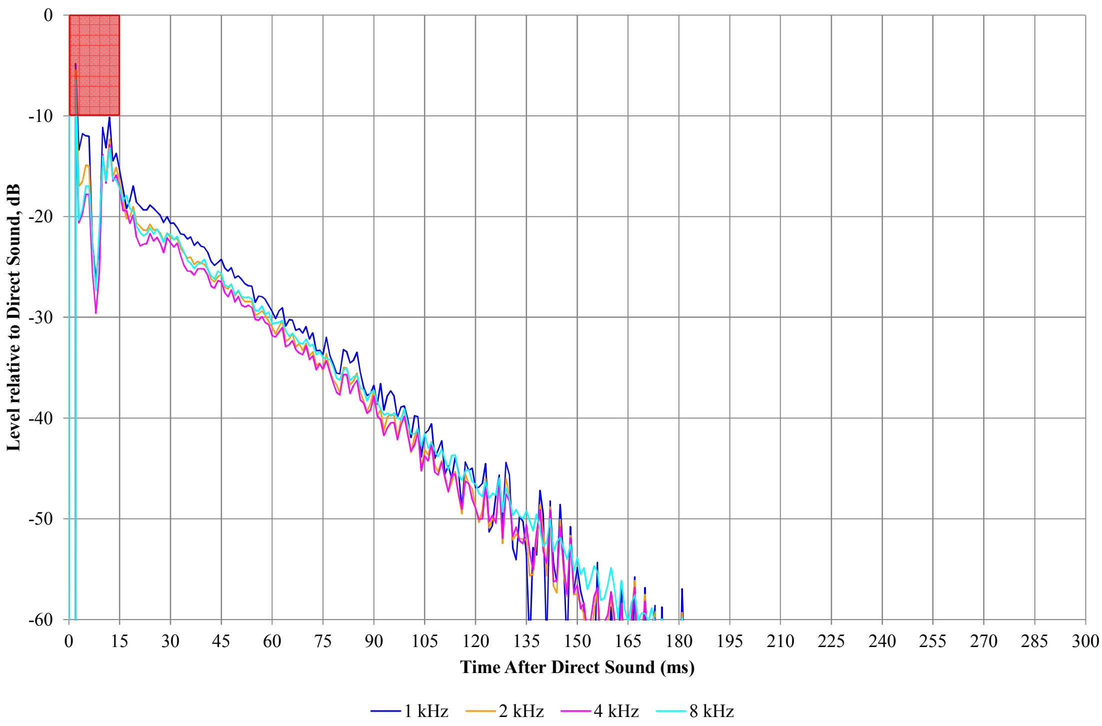

Figure 7: Predicted Decay Curve of Small Control Room. Dolby early reflection control region is shaded in red.

3.2 Room Acoustic Design of Control Rooms

The control rooms were generally designed to have an acoustically-absorptive "sending end" adjacent to the source loudspeakers to provide a clear aural image via early reflection control, and providing controlled diffuse late room response to prevent aural fatigue in long mixing sessions that can occur with absorptive finishes behind the listener (Davis and Davis 1980).

Both control rooms in Studio A were located on the southern façade of CIP2 overlooking the Brisbane CBD, and there was an architectural desire to maximise the use of glazing in these control rooms. This posed challenges in achieving symmetry in these rooms and in controlling late reflections. In particular, for the large control room in Studio A, an access door to the trafficable airgap between the building façade and the secondary glazing was located at the rear of the room. A Perspex diffusive finish (based on a Quadratic Residue Diffuser QRD sequence) was designed to be located in front of this door to prevent strong reflections back to the mixing desk from this access door.

The architectural concept for the recording studios used extensive amounts of timber. Low-frequency absorption was incorporated by using a panel-type absorber with a thin (3mm) hardboard panel in front of 150 mm of 32 kg/m³ glasswool insulation. In addition, some sections of walls were used as cable reticulation paths with no insulation in the cavity, which would nevertheless provide some incidental low-frequency absorption. Laboratory testing during construction required a revision in the amount of low-frequency absorption as the basis-of-design product was no longer readily available in Australia and the manufacturers' recommended alternate product did not provide the required absorption.

Figure 8: Panorama of large Control Room showing acoustic finishes

Broadband absorption at low level (below 2400 mm) was implemented as 100 mm faced polyester absorption material covered by a 6 mm perforated timber facing. This treatment was painted black as shown in Figure 8 The acoustic specification required a minimum acoustic transparency (defined as the % reduction in the random-incidence absorption coefficient of an absorber behind the facing compared to the unfaced absorber), which was confirmed by laboratory acoustic testing during the construction stage. At high level (above a 2400 mm datum line on the studio walls and on the ceiling) polyester absorption with no perforated timber facing was used. Areas of timber diffusion (a modified QRD sequence) were used at the rear of the room.

Figure 9 compares the measured vs predicted reverberation in a typical control room:

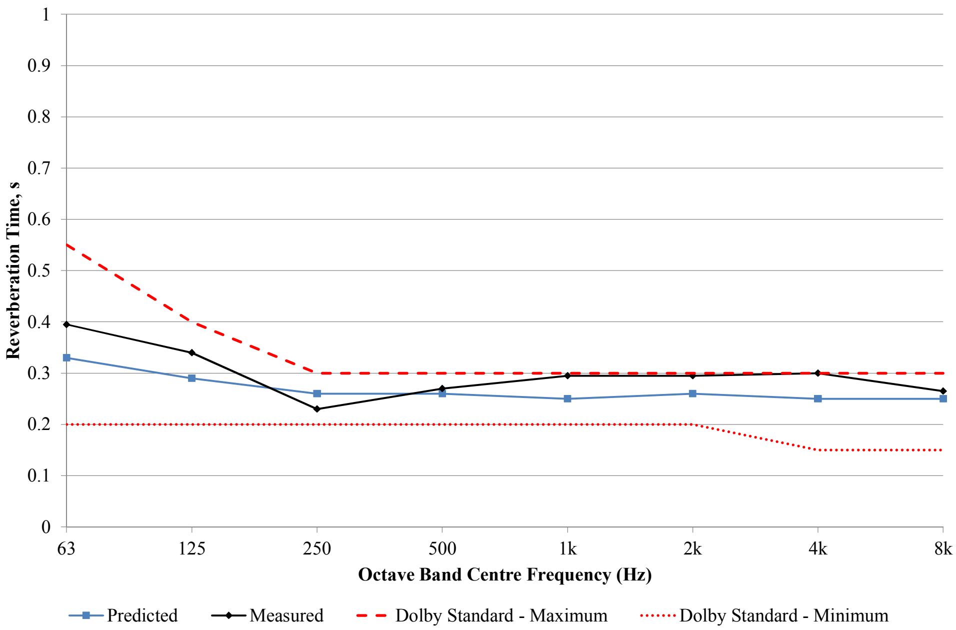

Figure 9: Typical measured-vs-predicted reverberation, Typical Studio Control Room

The predicted room response (from an Odeon model of the studios) is generally close to the measured room response, although the measured spectrum is slightly "brighter" with higher reverberance at high frequencies. This is likely due to be from the polyester insulation used on site not performing as per the design documentation (potentially due to dust on site fouling the pores of the insulation), as this was also apparent in laboratory random-incidence tests of absorption delivered to site. The room acoustics of all studio spaces will be retested following cleaning of finishes by the contractor, which will hopefully provide more clarity on why the apparent site performance of the absorption product was less than anticipated from the manufacturers' own test data.

3.3 Room Acoustic Design of Live Rooms and Isolation Rooms

The approach for the room acoustic design of the live rooms and isolation rooms was to provide a series of spaces with complementary room acoustic conditions to allow users of the studios flexibility in recording in different acoustic environments. This is because the entire CIP2 building is connected by a high speed production data network, allowing content to be streamed in real time between studios and control rooms, and hence it is possible for a mixing session in a control room to be using content recorded in a different studio (or even one of the performance studios elsewhere in the building). The different room acoustic conditions provided ranged from essentially-"dead" isolation rooms with a mid-frequency RT of 0.15 s, up to the large live rooms with a mid-frequency RT of 1.1-1.2 s.

To provide a neutral acoustic for recordings, the frequency response of each live room was designed to be as flat as practicable. For additional flexibility, the largest live room in each studio incorporates several hinged acoustic panels that can be swapped between absorptive or diffusive to allow the mid-frequency RT to be varied between 0.7 s and 1.2s.

Figure 10 Views of Recording Studio Live Rooms, showing hinged reversible panels and room finishes

3.4 Room Acoustic Design of Ensemble Rehearsal/Performance Room

The largest rehearsal room at CIP2 is intended for use as a rehearsal room for orchestra/concert band as well as a performance space for small ensembles with an audience of up to 100 loose seats on a flat floor. A tertiary usage is as an additional recording space, since it has the highest room reverberation of any of the music spaces at

QUT. A dedicated control room (albeit not fully designed to meet the Dolby standards) is provided adjacent to the rehearsal room. The room is designed to be “bright” (rising RT with frequency) when unoccupied in order to provide flat reverberation with a modest bass rise when occupied.

A suspended ceiling of several raked ceiling panels acts as an ensemble reflector, with a diffusive finish (based on a Quadratic Residue Diffuser sequence) improving the tone quality of overhead reflections compared to a plane surface by reducing colouration; this diffusive finish is extended down the rear wall of the room, while the side walls have a timber batten diffusive finish based on a Primitive Root Diffuser sequence in order to redirect energy away from the specular reflection direction and improve the spaciousness of the room.

Figure 11: Large Rehearsal/Performance Room

The secondary glazing of the rehearsal room is set-out in a “zigzag” shape to provide some redirection of sound and low-frequency diffusion. A curtain track around two sides of the room allows for the room acoustics to be adjusted from a mid-frequency RT (unoccupied) of 1.55 s down to 0.45 s. The measured and predicted RT range in the large rehearsal/performance room is shown in Figure 12.

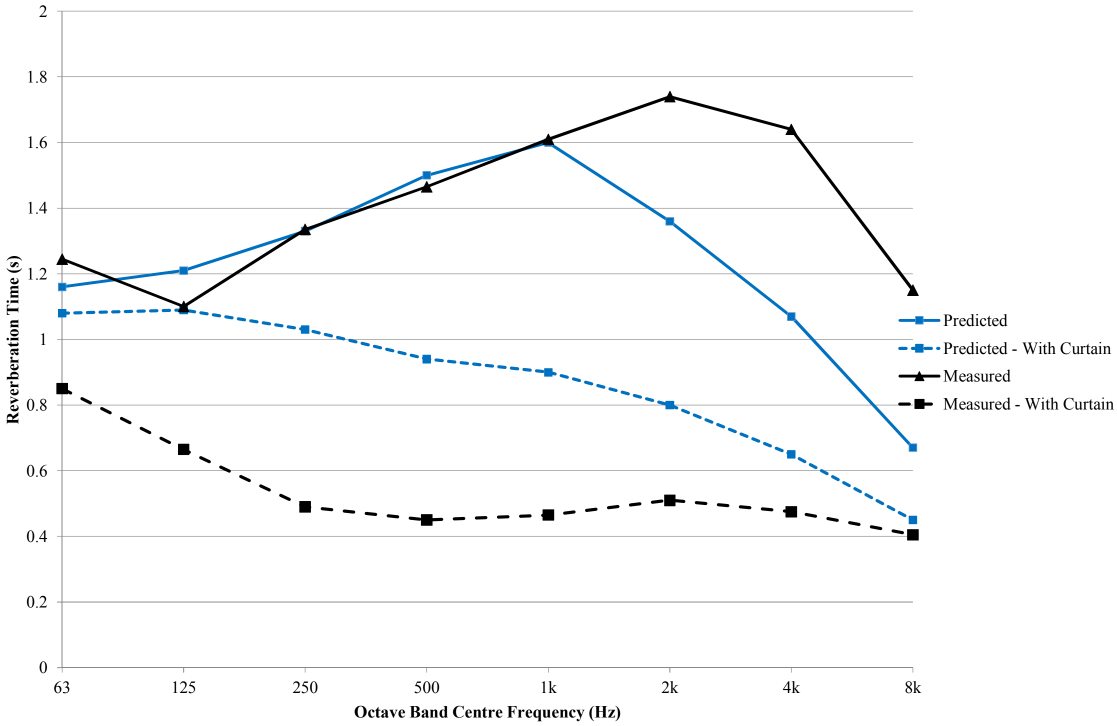

Figure 12: Comparison of Measured Vs Predicted Results, Large Rehearsal Room

As with the control rooms, the large rehearsal room is slightly “brighter” than predicted; this is likely due to the absorptive and diffusive ceiling finishes absorbing slightly less at high-frequencies compared to absorption data from previous projects. In particular, the laboratory test results for the diffusive finishes at QUT absorb less sound at high-frequencies than previous tested diffusive finishes. This may be due to the use of larger-size elements in the profile which reduces the incidental absorption due to edge effects and/or small gaps between elements.

The installed curtain area is higher than the basis of design, which allows a greater variation in RT compared to the original design and provides additional flexibility for users of the room.

CONCLUSIONS

The Queensland University of Technology Creative Industries Precinct Phase 2 project has provided end users with a highly-flexible creative arts building with initial feedback from end users being positive.

The project offered significant challenges in locating multiple functional spaces in a constrained area while still providing professional-quality room acoustics. In particular, the façade-located control rooms of the recording studios successfully integrate the stringent room acoustic requirements with a fully-glazed wall to provide external views, believed to be unmatched by any comparable spaces in Australia.

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