Glenn Leembruggen:

Profession
Acoustic and Electro-Acoustic Engineer

Professional Associations
Fellow of Institute of Acoustics (UK)
Member of:

- Associate of Sydney University
- Audio Engineering Society
- Australian Acoustical Society
- Associate Member Acoustical Soc. America
- Australian Assoc. of Acoustic Consultants

Standards Committee
IEC Maintenance team for 60268-16 (Measurement of intelligibility by Speech Transmission Index

SMPTE B Chain 25CSS

Awards

2014 AVIA Award Best Installation under $500,000 for St Andrews Cathedral

2013 Merit Award SMPTE for Journal paper

2013 AVIA Award Best Installation under $500,000 for Chatswood Outdoor Cinema

2012 AVIA Award For outstanding engineering work at the Grand Concourse at Sydney's Central Station.

1998 Audio Designer of the Year
by popular vote at Entech Awards for Technical Brilliance

1995 Audio Engineering Society Inc Achievement Award for the design of the new sound system for Court 2 of the High Court of Australia.

1994, 1993 & 1990 Hi Fi Loudspeaker of the Year Award for the design of hi fi loudspeakers.

1993 Audio Engineering Society Inc Achievement Award for the design of the new sound systems for the Parliamentary Chambers in the Australian Parliament House.

The sound of speech and music is where science meets art and humanity;

When it is good, it can greatly enhance our human experience.

So why is sound so often poor?

Both the delivery of wanted sound and the attenuation of unwanted sound are all too often taken for granted. Architects, clients and users are often unaware that many everyday situations present difficult challenges for the delivery of speech and music with sufficient clarity and intelligibility, tonal naturalness and freedom from echoes and feedback.

Glenn Leembruggen is one of the world's leading experts in the acoustic design of sound systems for important buildings that have demanding requirements for music and speech amplification.

Glenn's holistic understanding of the interdependence of architecture, acoustic environment, sound systems and sound quality brings great value to projects. His approach to acoustic design is unusual, combining knowledge of music, high-level acoustic and electrical theory, practical application and measurement skills along with a high listening acuity.

Along with thirty years of experience, Glenn holds a degree in electrical engineering and has undertaken postgraduate studies in acoustics, achieving High Distinctions.

In recognition of his work and support of the Audio and Acoustics program at the University of Sydney, Glenn was appointed an Associate of the Architecture and Design Faculty at Sydney Uni.

His current research areas are measurement and prediction of speech intelligibility, prediction of acoustical absorption behaviour and low frequency transmission loss, loudspeaker array design and the optimisation of sound in listening rooms.

Glenn has presented a number of papers at international conferences on the prediction of speech intelligibility, the design of innovative loudspeaker solutions for problem spaces and acoustic absorption systems. He has authored three journal papers and is a member of the IEC maintenance team for the IEC standard relating to the measurement of speech intelligibility by STI.

Publications and Papers

Journal papers:

"Increasing Robustness in the Calculation of the Speech Transmission Index from Impulse Responses" Cabrera Lee Leembruggen and Jimenez. *Journal of Building Acoustics* Vol 21 No 3 · 2014.

Speech Transmission Index for the English Language Verified Under Reverberant Conditions with Two Binaural Listening Methods: Real-Life and Headphones. Morales, Dance, Shield, Leembruggen,. *Journal Audio Engineering Society*, Volume 62 Issue 7/8 July 2014

"Further Investigations into the Interactions Between Cinema Loudspeakers and Screens" *Motion Imaging Journal* SMPTE Nov/Dec 2012. co-authored with Brian Long, Roger Schwenke and Peter Soper.

"Three unusual loudspeakers for the High Court of Australia" Leembruggen, *Journal Audio Engineering Society*, May 2000

"The design and commissioning of sound reinforcement systems for the Australian Parliament - a holistic approach" Leembruggen, Connor, *Journal Audio Engineering Society*, October 1996

"A new method of characterising driver linearity" Scott, Kelly, Leembruggen, *Journal Audio Engineering Society*, April 1996

Conference papers

"On The Importance of The Speech Spectrum to the STI Calculations" co-authored with Lorenzo Morales (principal author) IOA Reproduced Sound Conference 2013

"Can you Rely on STI" co-authored with David Gilfillan. IOA Reproduced Sound Conference 2012:

"Preliminary validation of the STIr male for the English language: co-authored with Lorenzo Morales (principal author) IOA Reproduced Sound Conference 2012.

"Raising the Tone of the Debate" co-authored with David Gilfillan. IOA Reproduced Sound Conference 2011

"The cone of an ancient New Zealand tree inspires the acoustic design for the New Zealand Supreme Court" co-authored with Mark Hanson. IOA Reproduced Sound Conference 2011

"Does 1/3rd octave equalisation improve the sound in a typical cinema?" co-authored with Philip Newell. IOA Reproduced Sound Conference 2011

"Is the X Curve Damaging Our Enjoyment of Cinema? co-authored with Philip Newell and David Gilfillan. SMPTE Conference Sydney 2011

"Comparison of measured and predicted sound absorption properties of polyester fibre insulation using an unusual plane wave tube" co-authored with David Gilfillan. IOA Reproduced Sound Conference 2010

"Further Investigations into Improving STI's Recognition of the Effects of Poor Frequency Response on Subjective Intelligibility" co-authored with Marco Hippler and Peter Mapp 128th AES Convention London 2010

"Exploring ways to improve STI's recognition of the effects of poor tonal balance on speech intelligibility" Co-authored with Marco Hippler. IOA Reproduced Sound Conference 2009

"Watt did they just announce? "A novel approach to intelligible announcement delivery Sydney Central Station" co-authored with David Gilfillan. IOA Reproduced Sound Conference 2009

"Hybrid Line Arrays - a viable alternative" co-authored with Ambrose Thompson and David Gilfillan. IOA Reproduced Sound Conference 2009

"Doof and Intelligibility: Does Bass Do It You?" co-authored with Tony Stacey. IOA Reproduced Sound Conference 2007

"Is SII any better than STI in recognising the effects of poor tonal balance on intelligibility" IOA Seminar on Intelligibility 2006

"Unusual Beam Steered Array Loudspeakers: Holistic Solutions for Courts and Parliaments" IOA Reproduced Sound Conference 2005

"Should the STI Matrix be reloaded" co-authored with Tony Stacey. IOA Reproduced Sound Conference 2003

"A computational method analysis and design of acoustic absorbers and low frequency transmission loss" co-authored with Stuart Colam. IOA Reproduced Sound Conference 2003

"Speech intelligibility predictions and measurements - making the ends meet" co-authored with Paul Malpas and Sam Wise. IOA Reproduced Sound Conference 2002

Major Projects - Parliamentary

NT Parliament House Darwin

Design and commissioning of new sound system (as one of the Principals of sister company ICE Design) of a highly engineered bespoke electro-acoustic system for bot h the Chamber and the public galleries providing robust speech intelligibility. The downward beam-steering loudspeaker array assemblies now allow members to effortlessly understand each other when speaking.

NZ Parliament House

Design and commissioning of new sound system for the House of Representatives debating chamber. To meet strong architectural, acoustic and sound quality requirements, a number of bespoke hybrid loudspeakers were developed and installed. Each of the six loudspeakers serving the chamber floor comprised of three beam-steered arrays hybrid of three line arrays.

A refined version of the automatic equalisation algorithm (see Aust Parliament) was used to maximise the acoustic gain of the system for the 100 or so microphones.

The sound quality and speech intelligibility were impressive!

NSW Legislative Assembly

Design of loudspeaker system to provide a high degree of speech intelligibility in a noisy working environment housed in a Heritage protected space. All loudspeakers were to have minimal heritage impact, whilst overcoming constraints of sight lines, and high ceiling and diverse audience areas. Special steered loudspeakers were designed in conjunction with NSW Govt. Architects.

Solomon Islands Parliament

Design and commissioning of sound system for the debating chamber in the parliament building. The circular chamber with its vaulted ceiling presented strong acoustic challenges, which were addressed using beam-steered line array loudspeakers and a modicum of acoustic treatment. The final sound quality and speech intelligibility were excellent, belying the small budget that was available for the system.

All of the following parliamentary projects were characterised by the following issues:

- The sound systems were required to deliver loud, extremely intelligible, natural sounding voices, with excellent immunity from feedback.

- Challenging acoustic environment, both in terms of architectural room acoustics and noise levels.
- Need to accommodate strict architectural, heritage and physical constraints.
- Systems were also required for public galleries which needed to have absolutely minimal sound spill back into the members' area of the chamber.

Australian Parliament House, Canberra

Design and commissioning of sound systems for the House of Representatives, Senate and Great Hall, to deliver. Cabaret-style music amplification was also required in the Great Hall.
Glenn's solutions included the design of beam-steered line-array loudspeakers utilising both cone and horn speakers driven by complex signal processing. Glenn also developed an equalisation method to minimise feedback for the large number of microphones in the House of Representatives and Senate using calculations based on acoustic measurements.

Glenn also specified remedial acoustic treatment for House of Representatives public galleries.

City of Sydney Council Chambers, Town Hall

Design of loudspeaker system to deliver a high degree of speech intelligibility to councillors in a heritage listed reverberant room with a high ceiling and minimal acoustic treatment. Special beam-steered loudspeakers were designed in conjunction with the architects.

Courts

New Zealand Supreme Court

The Supreme Court is New Zealand's highest court, and a new, visually-striking orb-shaped building was opened in 2010. Glenn was the project director for the architectural acoustic and sound system design. The historic High Court room was also restored for hearings and moot court applications, for which architectural acoustic treatment and beam-steered arrays were physically integrated with the furniture and fittings in the room.

This beautiful egg-shaped shaped courtroom initially provided a strong design challenge as its elliptically domed surfaces would cause sound to focus at specific points in the room. This focusing would create strange and uncomfortable sounds with speech for both talkers and listeners. Given that the primary purpose of this room is speech, this focussing would have caused grave problems for court proceedings.

One solution to prevent the sound focusing problem would have been to use a huge amount of acoustic absorption on the curved walls and ceilings. However, this approach would render the ambience of the room too dead and would not provide a sense of space or grandeur. Another solution is diffusion, which was the best option, as it retained the ambience of the space, despite involving complex designing of large surface areas.

In response to the acoustic requirement for diffusion, architects Warren and Mahoney created spiral-wrapped bands of diamond shaped and angled timber panels that look similar to the NZ Kauri cone.

The courtroom effectively has three 'zones' of these spiral shaped panels. The lowest band is reflective and flat to provide some natural reflections for speech; the mid-band is diffusive, with angled panels and low frequency absorption, while the uppermost band provides acoustic absorption to control reverberation times in the room. The skylight consists of a series of glass blades angled for acoustic diffusion, arranged in a floral motif.

Glenn also led the commissioning of the courtroom sound system, which uses eight bespoke beam-steered line-array loudspeakers, custom engineered to meet architectural and acoustic requirements.

Queens Square Law Courts Sydney

Design and commissioning of architectural room acoustics and sound systems for some thirty courts in the refurbishment of this large complex. Included in the complex are the Supreme Court, Federal Courts and the High Court of Australia.

High Court of Australia (1993 -2009)

Design of new sound systems for Courts 1, 2 and 3 in Canberra and Sydney.
The combination of softly spoken judges, strict architectural requirements, difficult acoustic environments and the locations of talkers and listeners, were strong challenges to delivering high-intelligibility and natural-sounding speech re-enforcement free of feedback. Part of the solution for Canberra was the joint design with the architect of innovative loudspeakers, two of which were clad in stone.

Commonwealth Law Courts, Adelaide

Design of sound reinforcement systems for twenty-two high technology court rooms where the conflicting requirements of architecture, acoustic gain, source localisation and video-conferencing needed to be accommodated. These courts all incorporate Glenn's innovative loudspeaker design concept utilising beam-steered array loudspeakers mounted in the ceiling to produce very natural sounding speech with unusually high acoustic gain and intelligibility.

Transport

Central Station Sydney

- Design and commissioning of time-sequenced beam-steered loudspeaker system for twenty three platforms to facilitate simultaneous announcements on island platforms. Our solution included development of novel algorithm to automatically adjust the announcement volume in response to ambient noise levels.
- Design and commissioning of announcement sound systems for acoustically difficult subterranean spaces in this complex building, with high background noise and reverberation. The goal of this work was to deliver high speech intelligibility without the need to install acoustic treatment in the concourses and pedestrian tunnels.
- Design and commissioning and innovative sound system for the Grand Country Concourse at Central Station. The reverberation time of this space is 5 seconds, and satisfactory speech intelligibility had never been possible. Our solution finally allows good speech clarity to be delivered to all areas in this heritage listed space. Acoustic Directions was given an AVIA award for the engineering work associated with this system.

Sydney Suburban Stations

- Design and commissioning of Proof of Concept sound systems for platforms using three different types of announcement systems to assess the performance of each system with respect to speech intelligibility on the platforms and noise spill to nearby residents.
- Preparation of specification for time-sequenced digital PA system for planned roll-out to suburban stations over the next five years.

Waratah Carriages for CityRail Network

- Design and specification of acoustic aspects of th e audio system for new generation of carriages for CityRail Network. This work was undertaken for Thales Australia, the provider of the systems and will result in quantum improvement in speech intelligibility for passengers, both with live and recorded announcements.
- Provision of expert advice to RailCorp regarding the performance of proposed hearing loops in the carriages. This advice was required to achieve an agreement with the carriage builder about the system's required specifications.

Glenfield to Leppington Rail Link Stations and Shellcove station

Design and commissioning of sound and hearing loops systems for two stations and stabling yard.

Benchmarking of speech intelligibility performance on platforms and concourse.

Wynyard and Town Hall Stations

Rescue of the sound quality and intelligibility of poor sound quality at these busy city underground stations. The poor quality was due to i) the original acoustic design which was grossly inadequate for the difficult acoustic environments at these stations and ii) a lack of proper acoustic commissioning.

Worship

St Andrew's Cathedral Sydney

Design and commissioning of sound system to deliver highly intelligible speech and amplified contemporary music. This system won a 2014 AVIA award.

St Paul's Cathedral Melbourne

Design and commissioning of new sound system for Cathedral using distributed beam-steered array loudspeakers. The system was installed as part of the cathedral restoration and was ultimately deemed the most significant aspect of the restoration!

St. Mary's Cathedral, Sydney

Rescue and re-commissioning of a beam-steered, full frequency range loudspeaker system, requiring architectural integration with structural columns.

Toongabbie Baptist Church

Acoustic design of large church auditorium to control breakout of music noise and to enhance sound quality within the space.

Figtree Anglican Church, Wollongong

Design of sound isolation, architectural acoustics and sound system for a large church that emphasises both congregational singing and contemporary music.

Christian City Church Oxford Falls

Architectural acoustic design of worship and performance space to enhance envelopment of congregational singing whilst retaining clarity of speech and live contemporary music.

Shire Christian Centre

Design of building envelope to contain noise from rock-music and architectural acoustics to enhance music performance and congregational singing.

Wollongong Salvation Army

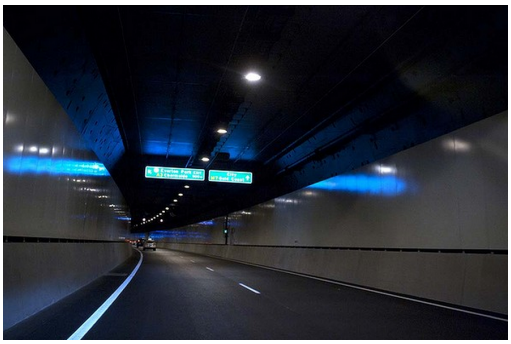
Preparation of acoustic standards and requirements document for the Army's proposed regional worship facility. Review of builder's design.

Christ Church Cathedral Newcastle

Design of distributed full frequency range tapered line array sound system to deliver high speech intelligibility in a large reverberant church.

Road Tunnels

Brisbane Airport Link Tunnel



Electro-acoustic design, modelling and commissioning for UGL of emergency evacuation PA systems for vehicular tunnel and pedestrian egress passages. The final systems delivered remarkable sound quality and speech intelligibility for such a hostile acoustic environment.

Measurements of STI and post-processing according to IEC standard 60268-16.

Sporting

Melbourne Cricket Ground 2006

Design and commissioning of main arena loudspeaker system required to deliver high quality speech and music to 80,000 people.

After undertaking the concept design and acoustic modelling of the sound system in the main bowl for the successful tenderer Rutledge Engineering, Acoustic Directions was then engaged to provide the detailed design and to execute the complex commissioning work to optimise sound clarity, speech intelligibility and music enjoyment.

Among the benefits that Acoustic Directions brought to this project was a steered bass loudspeaker array whose unusual radiation pattern substantially overcame the wide variation in the distance from listener seats to the loudspeakers, enabling a much more consistent distribution of sound at low frequencies.

Sydney Olympic Park 1999/2000 and 2009

- Design and specification of large outdoor public address and hearing loop systems, along with distribution and control networks utilising a Cobranet system, for the 2000 Olympic Games site.
- Audit of existing site-wide system and preparation of User Requirements to form the basis of a new systems

Docklands (Telstra) Stadium, Melbourne 1998

System and loudspeaker component design of stadium loudspeaker system required to deliver high quality speech and music to 55,000 people. This system was benchmarked some three years later by Acoustic Directions in order to support a variation claim for the builder and was found to still be meeting its design performance requirements.

Corporate and Residential

239 Great North Rd Fivedock

Acoustic design and testing of flooring and window systems to meet council and BCA requirements

Silkwood Residential Tower Surry Hills Sydney

Appointed during construction phase after the incumbent acoustic consultant was removed. Provision of acoustic advice to accommodate as-built conditions, and design and testing of acoustic constructions to ensure the apartments complied with the Australian BCA and the City of Sydney codes.

Remembrance Retirement Village Wagga Wagga

Acoustic design of entire complex to meet BCA and noise codes

163 Elizabeth St

Design to DA stage of high-rise residential and corporate building for property developer.

Macquarie Bank

- Advice regarding improvement of the sound quality and comfort of the speech in large meeting rooms.
- Design of sound system for conference room to achieve extremely natural sound quality and high intelligibility for video conferences with a large number of participants.

NRMA Boardroom

Design of modifications to boardroom audio system to deliver natural sounding speech, free of feedback and with the capacity for high quality video and tele-conferencing.

NAB House Corrs Lawyers

Design of noise masking system for large office area.

Noise Emissions from Entertainment Venues

Tamworth Regional Council

Acoustic advice and noise monitoring to assist with successful presentation of outdoor rock concerts at night held in the ground of AELEC (Australian Equestrian & Livestock Events Centre)

Exchange Hotel Darlinghurst

Design of acoustic box-in-box structure to prevent sound from live bands reaching residents immediately sharing a party wall.

Acoustic monitoring of noise levels, advice and reporting which resulted in the elimination of long standing noise complaints and allowing the venue to trade to the satisfaction of the owners.

World Cup 2010 FIFA Fan Fest (Darling Harbour)

- Preparation of acoustic noise modelling in SoundPlan software and DA report for live outdoor screening catering for 20,000 people held between 8 pm and 6 am.
- Provision of continuously attended noise monitoring at three sites for the month-long event.

Empire Hotel and Beach Haus Potts Point

Expert witness acting for City of Sydney: Activities included noise measurements, acoustic calculations, reporting and attendance at Land and Environment Court.

The Bourbon Potts Point

Appraisal of noise impact of proposed outdoor terrace for residents of nearby apartments, for submission to City of Sydney.

Sailors Restaurant Rose Bay

Appraisal of noise impact of proposed outdoor dining and bar terraces undertaken nearby residents for submission to Woollahra Council.

Paddington Reservoir

Assessment of noise impact of proposed events at the reservoir at residents some 20 m away, and preparation of strategies to mitigate the noise and enhance the sound quality at events. Prediction of patron noise levels was a major component of this work.

Manly Wharf Hotel

Preparation of noise impact assessment for outdoor patron areas, for presentation and discussion at OLGR compulsory conference.

Shore Club Manly

Design of the hotel's building envelope to ensure break-out of music noise from nightclub and lounge complies with noise criterion at nearby residents. Design of architectural acoustic finishes to enhance patron enjoyment of music and reduce noise spill. Preparation of report for DA application.

Sugar Mill Hotel Kings Cross

Acoustic design of the hotel's building envelope for DA to contain noise from nightclub and lounge music. Preparation of DA report, requiring a high level of detail to satisfy City of Sydney's concerns that this development would not have a noise impact on the area.

ARQ Sydney

Acoustic design of building envelope and patron areas to prevent noise breakout and enhance sound quality in entertainment areas.

Mean Fiddler Hotel (Rouse Hill)

Advice to prospective hotel purchaser about noise exceedances at residents from patrons and achieving compliance with council codes by means of a large acoustic barrier.

Major Projects - Broadcast and Recording

ABC (Australian Broadcasting Corporation) TV Facility, Sydney

Design and testing of architectural acoustics for major TV studios, voice booths and audio control and monitoring rooms (including Dolby 5.1 room).

Sydney Opera House Recording Studio

Design of:

- structures to prevent transmission of low frequency noise from Studio recording area to the audio control room.
- architectural acoustic treatment for audio control room in the recording facility.