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An Introduction to UTS Anechoic and Hemi-Anechoic Chambers

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ABSTRACT

Anechoic chambers are specialist yet foundational facilities in audio, acoustics and vibration valued for their precision and performance but limited in availability due to their unique design, high construction costs, and ongoing operational and maintenance demands. As industry interest in accurate acoustic testing grows, a gap remains between this demand and the readiness of accessible laboratory environments. This paper addresses that gap by presenting the capabilities and some example applications of the fully anechoic and hemi-anechoic chambers at the UTS Tech Lab facility at the University of Technology Sydney (UTS). By summarising key performance attributes and highlighting use cases in product testing, research, and benchmark dataset creation, we aim to promote awareness and encourage professional utilisation through inter-university, industry, government, and multidisciplinary collaborations.

1 INTRODUCTION TO ANECHOIC AND HEMI-ANECHOIC CHAMBERS (IN ANZ)

An acoustic anechoic chamber is a purpose-built facility designed to replicate free-field conditions by suppressing acoustic reflections and isolating the interior from external noise and vibration. These environments are indispensable for accurate sound measurement, underpinning research in acoustics, psychoacoustics, and product development. By enabling precise studies of sound emission, propagation, and perception, anechoic chambers have advanced both experimental methodologies and industrial testing practices.

The qualification of such facilities is governed by international standards. ISO 26101-1:2021 specifies methods for verifying whether spaces satisfy the criteria of anechoic or hemi-anechoic conditions, using discrete-frequency (pure tone) and broadband tests with omnidirectional sources. Here, an anechoic space is defined as a volume qualified as a free sound field, while a hemi-anechoic space is a volume above a reflecting plane that meets the same free-field criteria. A free sound field refers to a sound field in a homogeneous, isotropic medium free of boundaries (ISO/TR 25417:2007, 2.17). In addition, background noise is defined as the sum of all signals other than the one under investigation, including contributions from airborne sound, structure-borne vibration, and electrical noise in instrumentation. The frequency range of qualification is expressed as contiguous one-third-octave bands from the lowest to highest qualified frequencies. In practice, once a chamber has been qualified, its use is governed by application-specific standards. ISO 3745:2012, for example, defines precision methods for sound power measurements in anechoic and hemi-anechoic rooms, prescribing explicit tolerances on deviations from the inverse square law and requiring qualification over a frequency range of 100 Hz to 10 kHz.

In Australia and New Zealand, the availability of high-performance anechoic facilities has historically been limited, with only four major chambers reported in operation in 2010, as documented in Table 2 of (Day Design Pty Ltd, 2010). Over the past fifteen years, however, the number of laboratories has more than doubled, with nine now operating across universities and research institutes in 2025. Among these is the facility at the University of Technology Sydney (UTS), housed within UTS Tech Lab in Botany—a location selected for its accessibility to Sydney Airport and nearby industrial precincts, supporting agile collaboration between academia and industry. The UTS Acoustics Lab houses full and hemi-anechoic chambers - a rare combination that distinguishes it within Australia and New Zealand - alongside complementary reverberation rooms, transmission loss suites, and a hearing test room. The facility is equipped with advanced instrumentation and co-located with additional laboratories, including vibration, large-scale structural testing, and an antenna chamber.

2 KEY ATTRIBUTES OF UTS ACOUSTIC ANECHOIC FACILITIES

The UTS anechoic and hemi-anechoic chambers enable full and half-space free-field acoustic simulations and are constructed using a robust “box-in-a-box” design, suspended on arrays of very stiff springs to achieve high-level vibration isolation. Both chambers are built from heavy brick and concrete and fitted with specially sealed acoustic doors to minimise airborne sound transmission. Internally, they are lined with long, non-flammable foam wedges extending 900 mm from the walls, ceiling, and (in the anechoic chamber) the floor, to absorb sound and minimise reflections. Designed to meet international standards including ISO 26101 and ISO 3745, the facilities support a wide range of advanced acoustic testing applications. The hemi-anechoic chamber, in particular, offers an exceptionally large volume and double-height ceilings, enhancing low-frequency performance and providing a spacious free-field region.

2.1 UTS Anechoic Chamber

The anechoic chamber at the UTS Acoustics Lab provides a fully free-field environment for precision acoustic measurements. It contains over 1300 foam wedges, each 900 mm in length, achieving a cut-off frequency of 89 Hz. As shown in Fig. 1, the bare room dimensions are 6.46 m × 4.66 m × 7.00 m, with a total volume of 211 m³. The usable space between the wedges and above the wire floor is 4.46 m × 2.66 m × 4.60 m, yielding a usable volume of 55 m³. The background noise level was measured at 16.9 dBA on 24 March 2020 using a Brüel & Kjær Type 2250 sound level meter with a Type 4189 ½” free-field microphone. Free-field conditions were verified on 23–24 March 2020 across five microphone traverses (Zhu, 2020a), in accordance with ISO 26101 and ISO 3745. The qualification covered 21 one-third octave bands with centre frequencies from 100 Hz to 10 kHz, confirming compliant radii of up to 2.6 m along the oblique traverses (T1–T3 in Figure 1) and 1.7 m along the horizontal traverses (T4–T5). The chamber was also commissioned in 2019 by IAC Acoustics (Australia) Pty Ltd, with acoustic testing performed by Acoustic Dynamics in accordance with ISO 3745:2003. The results demonstrated conformity with the inverse-square law across all traverses up to 2.6 m, the limit of the measurement range, except for one traverse at 100 Hz that was compliant up to 2.0 m (Acoustic Dynamics, 2019a).

The free-field condition of the anechoic chamber was further measured by Reza Ghanavi and A/Prof. Densil Cabrera from the University of Sydney on 8–9 October 2019, covering an extended frequency range of 1/3-octave band centre frequencies from 80 Hz to 20 kHz (Cabrera and Ghanavi, 2019). The results show that the UTS anechoic chamber generally satisfies the qualification criteria outlined in ISO 26101:2017, with compliance observed across most traverses and frequency bands. However, non-compliance was identified in two of the four traverses at higher frequencies (16 kHz and 20 kHz), indicating localised deviations from the inverse square law. While the chamber meets the standard testing requirements—which primarily focus on the 100 Hz to 10 kHz range in 1/3-octave bands—care should be taken when conducting research or bespoke testing involving higher frequencies. Additional acoustic treatment or calibration may be necessary to ensure accurate results in these extended frequency ranges.

In addition to the free-field condition previously discussed, a background noise level of 16.9 dBA was measured on 24 March 2020 using a Brüel & Kjær Type 2250 sound level meter, equipped with a Type 4189 ½” free-field microphone. Background noise includes all signals not associated with the target measurement, such as airborne sound, structure-borne vibration, and electrical noise from the instrumentation. In this case, the measured background noise level was primarily influenced by the self-generated noise of the instrumentation system, rather than by the acoustic properties of the chamber. According to Section 4.8 of the manufacturer's manual (Brüel & Kjær, 2013), the typical broadband self-generated noise for single-range operation is 16.6 dBA, comprising 14.6 dBA from the microphone and 12.4 dBA from electrical components. For measurements requiring a lower minimum dynamic range, a low-noise measurement system should be employed. For example, a low-noise measurement system—such as one incorporating a low-noise microphone like the GRAS 40HF—may be used to more accurately verify the background noise level at the time of measurement.

2.2 UTS Hemi-Anechoic Chamber

The hemi-anechoic chamber is tailored for acoustic measurements over a fully reflecting plane, simulating real-world operating conditions. It contains 2132 foam wedges extending 900 mm from the walls and ceiling, with a cut-off frequency of 89 Hz. The bare room dimensions are 9.22 m × 6.90 m × 6.29 m, with a total volume of 400 m³. The usable space above the hard floor is 7.22 m × 4.90 m × 5.29 m, yielding a usable volume of 187 m³. The background noise level was measured at 17.1 dBA on 7 April 2020 using a Brüel & Kjær Type 2250 sound level meter with a Type 4189 ½” free-field microphone. This value was primarily influenced by the self-generated noise of the instrumentation system. Free-field conditions were verified on 6–10 April 2020 across five microphone traverses (Zhu, 2020b), each extending 5.2 m, in compliance with ISO 26101 and ISO 3745. The qualification covered 21 one-third octave bands with centre frequencies ranging from 100 Hz to 10 kHz.

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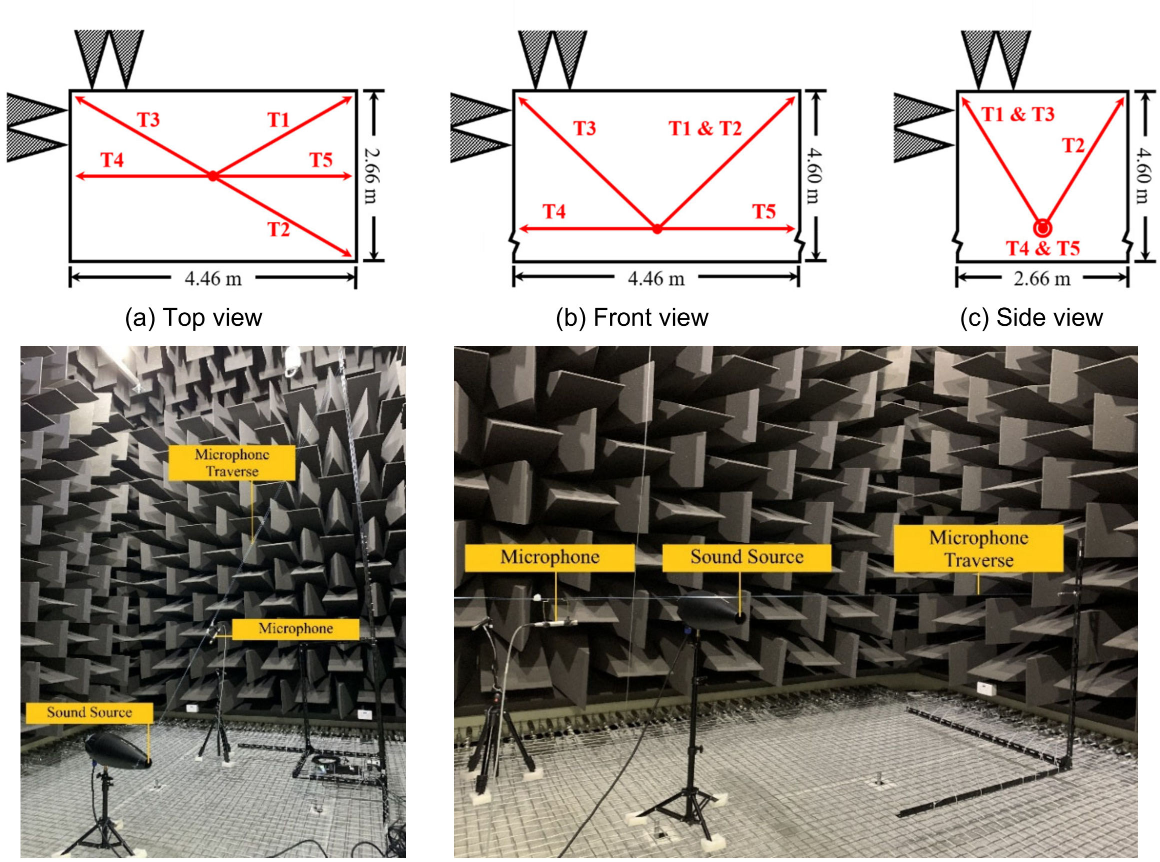


(a) Top view (b) Front view (c) Side view

(d) Traverse 2 (e) Traverse 5

Figure 1: Measurements on the anechoic room at UTS with microphone traverses (Zhu, 2020a). (a–c) Geometry of the UTS full anechoic chamber, showing the test sound source (red dot) and five microphone traverse paths (T1–T5) used for inverse square law measurements. (d) Setup of a microphone traverse directed toward an upper corner of the chamber. (e) Setup of a microphone traverse on a horizontal plane, perpendicular to a wall.

The chamber was also commissioned by IAC Acoustics (Australia) Pty Ltd, with Acoustic Dynamics undertaking acoustic qualification testing in accordance with ISO 3745:2003. The testing assessed free-field performance by quantifying deviations from the inverse-square law across five measurement traverses extending up to 5.6 m from the source. Results confirmed anechoic compliance over one-third octave bands from 100 Hz to 16 kHz to a measurement radius of 5.2 m. Four traverses maintained compliance to 5.6 m, being the end of those traverses, while the fifth traverse achieved compliance to 5.2 m, being the end of that traverse.

3 USE CASES IN PRODUCT TESTING, RESEARCH, AND BENCHMARK DATASET CREATION

The UTS anechoic and hemi-anechoic chambers support a wide spectrum of acoustic testing, consultancy, and research activities. The facilities enable both standardised product evaluation and advanced investigations that demand precisely controlled sound and vibration fields. They also play an increasingly important role in generating benchmark datasets that contribute to the broader acoustics and signal processing research community worldwide.

3.1 Standard Product Testing

Commercial testing services are performed in accordance with applicable Australian and international standards, supporting industry partners in regulatory compliance and acoustic product development. For example, laboratory verification was conducted for GHD Pty Ltd (Newcastle office, Australia) on a custom-designed, low-cost dodecahedron loudspeaker used for measuring internal building acoustic parameters (Robertson, 2022). The facility also supported SiteHive Pty Ltd through the calibration and validation of a MEMS-based device developed for real-time construction noise monitoring in outdoor environments (Cooper-Woolley et al., 2022). The Goodear acoustic shield, designed to improve hearing protection for musicians, has been assessed within the chambers through sound level measurement and acoustic performance testing (UTS Tech Lab, 2024). In addition, the chambers are used by Daikin Australia for sound power and sound pressure measurements of various air-conditioning units (UTS Tech Lab, 2022). Together, these case studies demonstrate how the chambers support industry-driven contract testing, enabling reliable and traceable acoustic characterisation of emerging products and technologies.

3.2 Research and Development Support

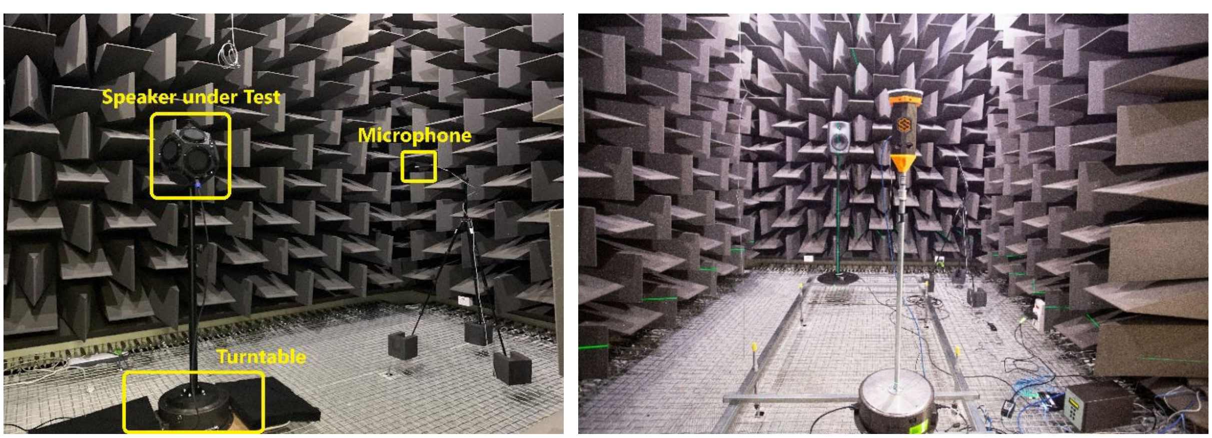
The chambers also support experimental research that depends on repeatable and well-defined acoustic boundary conditions. Example audio and acoustic research projects include the realisation and characterisation of advanced acoustic sources, such as parametric ultrasonic loudspeakers (Zhong et al. 2020), directional loudspeaker arrays used for multizone sound field reproduction (Zhao et al. 2022), a broadband point-source loudspeaker designed for chamber qualification (Ghanavi and Cabrera 2021), and non-contact acoustic field sensing enabled by refracto-vibrometry (Xiao et al. 2024). The facilities further provide controlled environments for high-sound-pressure-level exposure in environmental acoustics research (Halkon et al. 2025; Yang et al. 2025), fine-resolution measurement spaces for micro-scale investigations, such as termite movement behaviour studies (Mandal et al. 2025), and experimental validation of ultrasonic manipulation methods for levitated objects (Akbarzadeh et al. 2025). Collectively, these activities demonstrate the essential role of the chambers in advancing controlled validation of acoustic models and enabling innovation in acoustic transduction, materials, and structural design, while supporting the generation of high-quality experimental datasets across frontier acoustics research domains.

3.3 Benchmark Dataset Creation

The UTS anechoic and hemi-anechoic chambers also play an increasing role in the development of high-quality benchmark datasets that support acoustics and audio signal processing research. Recent work includes the creation of a room impulse response database for multizone sound field reproduction, captured across diverse loudspeaker and receiver geometries under rigorously controlled acoustic conditions (Zhao et al. 2022). These datasets are disseminated to enable reproducible evaluation of spatial audio algorithms, sound field control methods, and machine-learning-based reconstruction techniques.

Future initiatives will broaden dataset generation to meet emerging research demands. Potential areas include professional musical instrument radiation measurements, anthropometrically diverse head-related transfer function (HRTF) capture campaigns, large-scale multilingual speech recording in controlled environments, and professionally collected sound and vibration profiles targeting specific industrial applications. These datasets aim to foster advances in machine audition and multimodal sensing for industrial monitoring (Ni et al. 2022; Liu et al. 2022), promote technology translation into sector-specific use cases (Zhang et al. 2025; Kong et al. 2022), and collectively contribute to the development of global audio foundation models (Kong et al. 2020; Liu et al. 2024) for environmental understanding (T. Xiao et al. 2023; F. Xiao et al. 2023) and audio content generation (Zhang et al. 2024; Fan et al. 2023).

Collectively, these activities reinforce the chambers' value as a national infrastructure asset that delivers reference-quality data, supports open science, and strengthens the development and benchmarking of next-generation sound reproduction, spatial audio, and speech processing systems.



(a) GHD speaker test (b) SiteHive multi-sensor device test

Figure 2: Example use cases for product testing in UTS anechoic and hemi-anechoic chambers. (a) GHD speaker test (Robertson, 2022), and (b) SiteHive multi-sensor device test (Cooper-Woolley et al., 2022).

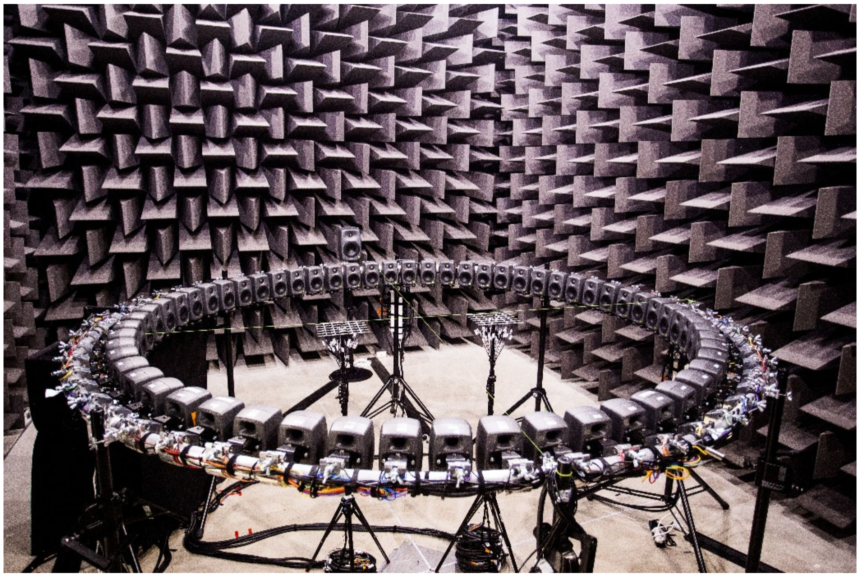


Figure 3: Example experimental configuration supporting research and development activities and benchmark dataset creation. Dedicated multichannel loudspeaker and microphone arrays were deployed for multizone sound field reproduction evaluation and dataset acquisition (Zhao et al. 2022).

4 CONCLUSIONS

This paper has presented the commissioning results and example applications of the fully anechoic and hemi-anechoic chambers at University of Technology Sydney. Verified compliance with ISO 3745 and ISO 26101 demonstrates that both facilities deliver the controlled acoustic conditions required for precision measurement. Their current use encompasses standardised product testing, research that relies on accurate sound field characterisation, and the early stages of structured dataset development. Some examples of the kinds of projects which have been conducted within the chambers have been included for readers' review. Continued work will focus on broadening measurement capability and formalising dataset creation processes, supporting reproducible research and enabling wider professional access through collaborative engagements which are encouraged.

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