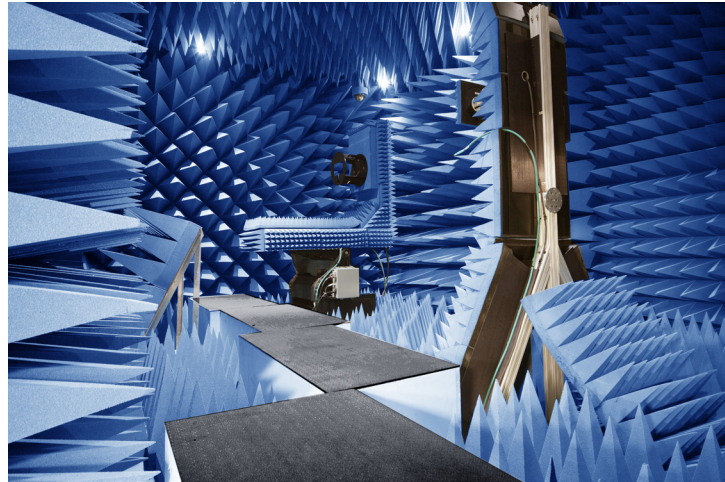


Multi-Purpose Tapered Chamber at the National University of Singapore Enables Far-Field and Spherical Near-Field Test Measurements Over an Extended Frequency Range

Complicated antenna measurements are now possible at the new Temasek Laboratories (T-Lab) of the National University of Singapore (NUS). ETS-Lindgren's unique tapered chamber, a critical research tool at the new facility, was designed and installed for educational research purposes to enable both far-field and spherical near-field antenna measurements over an extended frequency range of 200 MHz to 18 GHz.



T-Lab is the culmination of a long-standing collaboration between the NUS and the Defense Ministry of Singapore. The new S\$42 million building housing the tapered chamber provides a central location for T-Lab's state-of-the-art research in aeronautical and biomedical sciences, including nanotechnology, mechanobiology, electromagnetics, information security, and signal processing.

When the University and Defense Ministry were ready to expand their test and measurement capabilities to include precise antenna measurements, ETS-Lindgren provided the solution with a custom tapered antenna test chamber in a unique L-shape. The turn-key solution included the design, manufacture, installation,

integration, and calibration of the chamber as well as the hardware and software required for performing high-accuracy antenna testing. The tapered RF-shielded anechoic chamber is fully-lined on the walls, ceiling and floor with anechoic absorber materials.

Based upon the NUS specification, ETS-Lindgren provided a cost effective solution that combined a spherical near-field system with a far-field system to enhance the capabilities of the T-Lab. This combination allows test engineers to perform a much more detailed analysis of antenna measurements as compared to having only a far-field or near-field system. In addition,

the software provides aperture transformation, holographic analysis, as well as multiple corrections.

Unlike traditional tapered chambers that have a square base pyramidal tapered section, the T-Lab tapered chamber has a conical section for its entire length. This unique chamber could not have been built without ETS-Lindgren's capability to cut the anechoic absorber material into complex shapes. The full conical tapered chamber has no transitions from square to octagonal to conical as in traditional tapered chamber designs. The result is a chamber where the source positioning is minimized across the range, providing excellent performance for frequencies above 2 GHz.

**Tapered (L-Shaped) Chamber
Technical Specifications**

- Non-shielded tapered section measures 8.0m long enclosed within a rectangular shielded section of 10.8m x 4.3m x 4.3m (35'-5" x 14'-1" x 14'-1").
- Rectangular shielded section measures 8.0m L x 5.0m W x 4.3m H (26'-2" x 17'-4" x 14'-1") nominal dimensions.
- Overall external chamber dimensions are 16.14m x 8.1m x 4.5m (52'-11" x 26'-5" x 14'-8") nominal.
- Quiet zone is 1.5m in diameter, capable of supporting an antenna under test (AUT) of 70 kg (155 lbs).
- AUT Roll/Mast/Offset/Azimuth/Elevation positioner assembly provided includes adjustable height source, motor control electronics, data acquisition and processing software.
- One Series 201, dual-leaf RF shielded door measure 1.83m x 2.13m (6' x 7'), located on the rectangular section for access to AUT and positioner system.
- One RFD-100, single leaf RF shielded door measure 1.21m x 2.13m (4' x 7'), located on the tapered section for access to the measuring antennas.
- Chamber floor supports pressure equal to the maximum floor loading of the installation site (7.5 kN/sq m (157 lbs/sq ft) and includes a 0.3 cm (1/8") thick dielectric floor underlay, polyethylene vapor barrier and vinyl floor tile.

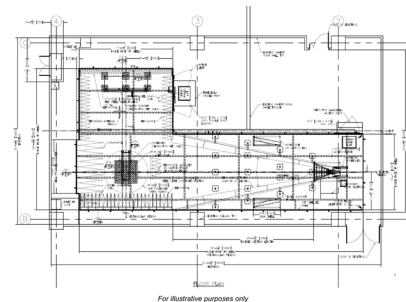
- Waveguide air vents, 30.6cm x 30.6cm (12" x 12"), are located in the chamber ceiling and feature a fixed flange for welded mounting.
- Power line filters provided are dual-line, UL listed, 30 amp 50/60 Hz for lighting, outlets and the AUT.
- Fiber optic light system includes four light emitters per feed, for a total of eight emitters in the rectangular section.
- Antennas provided include Model 3106B with for measurements over the frequency range of 200 MHz to 2 GHz with an air polarization mechanism for rotation and Model 3164-05 quad-ridged horn antenna for measurements over the frequency range of 2 GHz to 18 GHz.
- Accessories provided include penetrations, connector panels, shielded waveguide penetrations as well as a Desiccant dehumidifier package that includes supply and connection of ductwork to the chamber's waveguide air vents.
- Model 4340 digital CCTV system includes two RF shielded camera units with 22x digital zoom, pan and tilt, image capture, color monitor, computer control, network switch, and 30m video cable.
- Non-shielded control room provided was designed to support management and control of the acquisition and analysis of measurement data.
- Supply and installation provided of all wiring, conduits, wiring

devices, lighting fixtures, switches, receptacles, filters, isolation transformers, distribution panels, breakers, and fuses.

Chamber RF Shielding Performance

- 100 dB at 200 kHz RF – Magnetic field
- 100 dB from 200 kHz to 50 MHz – Electric field
- 100 dB from 50 MHz to 1 GHz – Plane Wave
- 100 dB at 10 GHz – Microwave

Unique L-Shaped Chamber Configuration



Anechoic Absorber Treatment

Anechoic treatment of the chamber includes 100% coverage of all wall and ceiling surfaces in addition to the floor. ETS-Lindgren's unique engineering and manufacturing process ensures excellent agreement between computed and measured performance. This excellent agreement has been documented between predicted performance and actual measured free-space NSA data.

ETS-Lindgren is the only absorber manufacturer that tests every piece of absorber that we manufacture. Each piece of absorber was tested per IEEE Standard 1128-1998 in the range of 30 MHz to 5 GHz. Two NRL arches, designed to perform RF absorber reflectivity testing from 800 MHz to 18 GHz, were used to verify material performance.

Absorber provided was manufactured and tested at ETS-Lindgren's 11,148 sq m (120,000 sq ft) manufacturing facility in Durant, Oklahoma - the world's largest - capable of producing over 10.5 million board feet of absorber per year.

Key absorber features include:

- Compact-sized shielded enclosure with fully anechoic testing capability.
- Full coverage with curvilinear, wedge and pyramidal shape polyurethane absorber. Partial coverage provided with rigid walkway absorber.
- RF power handling capable of >600 V/m
- Material composition is high performance combustion limiting polyurethane made from urethane foam impregnated with a dielectrically matched conductive carbon and water-soluble fire retardant ingredients.

- Non-hygroscopic substrate composition is moisture resistant, resulting in optimal mechanical and RF performance over the life of the absorber as well as constant electromagnetic properties regardless of changes in moisture levels.
- Fire retardant capability was tested in accordance with industry standards such as NRL Report 8093 (Tests 1, 2 and 3), UL 94 HBF, and others.

Operation and Maintenance Training

ETS-Lindgren provided hands-on training at the NUS facilities upon project completion. Topics included general information on EMC testing principles as well as a review of basic organization and functioning of the antenna measurement system equipment. Design and flow schematics, system function, operation and troubleshooting were topics discussed in lectures and demonstrated using the tapered chamber and instrumentation.

Maintenance training provided included all aspects regarding maintenance of the system and utility interfaces, including system design as well as operation and diagnosis of potential equipment malfunction.

About ETS-Lindgren

ETS-Lindgren is an international manufacturer of components and systems that measure, shield, and control electromagnetic and acoustic energy. The company's products are used for electromagnetic compatibility (EMC), microwave, wireless and Magnetic Resonance Imaging (MRI) testing, electromagnetic field (EMF) measurement, radio frequency (RF) personal safety monitoring, and control of acoustic environments.

Headquartered in Cedar Park, Texas, ETS-Lindgren has manufacturing facilities in North America, Europe and Asia. The company is a wholly owned subsidiary of ESCO Technologies, a leading supplier of engineered products for growing industrial and commercial markets. ESCO is a New York Stock Exchange listed company (symbol ESE) with headquarters in St. Louis, Missouri. Additional information about ETS-Lindgren is available at www.ets-lindgren.com. Additional information about ESCO and its subsidiaries is available at www.escotechnologies.com.