Reverberation Chambers

Design and Construction Considerations for Aerospace and Military Test Requirements

ETS-LINDGREN®
An ESCO Technologies Company

REVERBERATION CHAMBERS: DESIGN AND CONSTRUCTION CONSIDERATIONS FOR AEROSPACE AND MILITARY TEST REQUIREMENTS

Reverberation chambers are used primarily for evaluating the emissions and immunity of electronic devices at high field strengths, such as 7200 V/m from 4 to 6 GHz for Category L of DO-160. Compared with other test methods, reverberation chambers offer the advantages of lower cost, higher field-to-input power ratios and the ability to accommodate large complex arrangements of test systems and devices. This type of chamber can be used for both pre-compliance and radiated testing to standards including MIL-STD-461E/F/G, IEC 61000-4-21, and RTCA DO-160E/F/G. The robust reverberation chamber construction can easily handle the high field strengths required by today's military and aerospace test standards.

Reverberations chambers operate by using their interior surfaces to reflect internally radiated RF fields. One or more rotating paddles, or tuners, are used to change the cavity boundary conditions. The changing boundary conditions results in the movement of the modal peaks throughout the chamber volume. This creates fields having statistical isotropy and field homogeneity over a large working volume. Statistical theory can be used to show that the field measured at one point can be used to predict the maximum field at any other position.

Advanced tuner designs ensure fast settling times and maximum throughput during mode tuning tests. Mode stirred (continuous rotation) measurements can also be performed in the chamber where permitted by the test standard.

The reverberation chamber has intrinsic properties of isotropy and homogeneity that provide several unique features for testing. Assuming proper configuration and a given uncertainty level, field measurement results will be the same regardless of where in the chamber they are taken. In addition, reconfiguration of the equipment under test (EUT) will have minimal effect on those measurements if the coupling mechanism is unaffected. EUT measurements compared between different reverb chambers with different sizes will be the same once the relevant chamber corrections and uncertainties are considered. The benefits are high measurement repeatability and test result reproducibility.

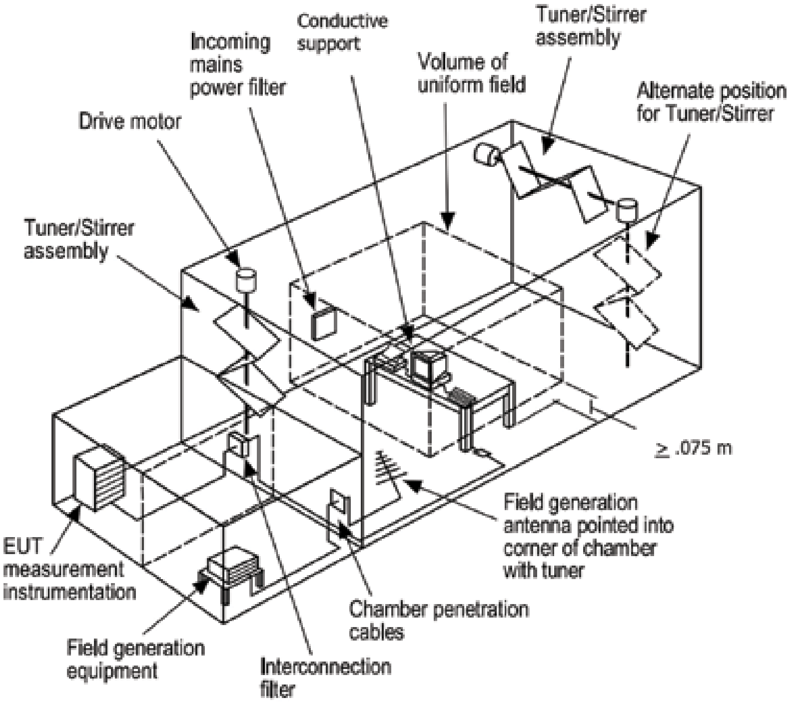
Adding to the appeal of reverberation chambers is that very high field strengths can be generated using less power than required by other test environments, especially in cases where the added DUT losses are minimal. The benefit is that less expensive amplifiers can be used without sacrificing performance. Reverberation chambers are well suited to simulate the complex EMC of cavities such as computer rooms, medical equipment rooms, aircraft avionics bays and vehicle engine compartments. A well designed and installed reverberation chamber simulates all wave polarizations and incidence angles during a full test.

When considering the installation of a new reverberation chamber for critical military and aerospace test applications, following is a basic primer to optimize the return on your investment.

Chamber Design

While there are many standard size reverberation chambers available on the market, it is often more cost effective to work with an experienced RF shielding supplier to design a chamber that meets your exact test needs, i.e. accommodates the products you want to test and to what specific standards. An experienced RF shielding supplier can work with you to determine the correct chamber volume for achieving the desired frequency range, select interior finishes to optimize the mode density and Q-bandwidth as well as recommend the right antenna and amplifier combination for field strength requirements. Depending on the area of installation and/or testing required, seismic considerations may be required, such as bracing of the chamber and additional structural support to meet seismic zone 4 requirements for any installation located in California.

Following is a typical reverberation chamber layout taken from RTCA DO-160G.



Layout as shown in RTCA DO-160G

Typical Reverberation Chamber Layout

NOTES:

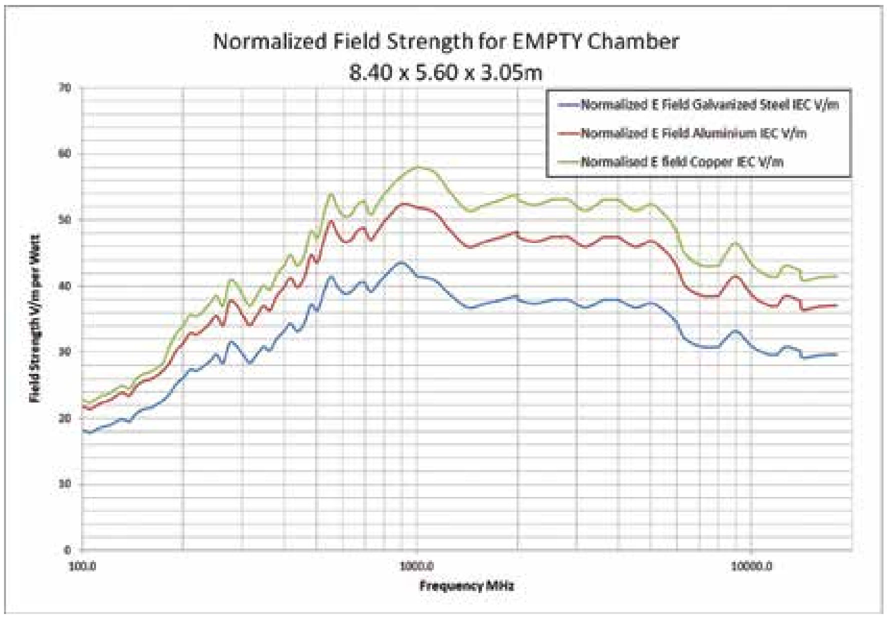
(1) Working volume must be at least .75 meter (or l/4) from any chamber surface, field generating antenna, or tuner assembly.

(2) The chamber should remain free of any unnecessary absorbing materials. Items such as wooden tables, carpeting, floor covering, or ceiling tiles should not be used. Exposed light fixtures are also a source of potential loading. For new chambers, it is recommended that an evaluation of the chamber be conducted prior to installation of any support equipment other than doors, vents, and access panels.

Chamber Materials

Unlike conventional EMC test chambers, reverberation chambers may utilize different material for the interior and exterior surfaces. For example, interior shielding panel surfaces of reverberation chambers are lined with copper to increase the Q, which increases the cavity field strength. The outside shielding panel surface is typically steel to provide the RF shielding performance required while also being a cost effective material. The interior floor may be lined with yet another different material. For example, floors may be lined with aluminum for durability purposes. This is especially important to consider when testing heavy items, such as military vehicles or when equipment traffic in and out of the chamber is high.

Following is a simulation for expected normalized field strength for the DO-160 method comparing galvanized, aluminum and copper in a reverberation chamber of the size noted. The materials used directly impact the chamber performance.



Chamber Construction

Optimal chamber construction consists of shielded modular panel sections that are assembled with a clamping system into a self-supported enclosure. Sheets of galvanized steel (ideally 28-gauge) are laminated to a high-density particle and/or plywood board core. Panels are joined together with an extruded “hat” and “flat” and “cove” clamping system to provide uniform and consistent pressure contact against the shielded panel mating surfaces. These structural clamping sections should be zinc plated to resist corrosion and joined with self-taping zinc plated fasteners spaced four inches on center to ensure a secure shield. An alternative construction method using single skin folded sheets (PAN form) is also in common use. This lends itself well to galvanized steel and aluminum chambers.

To maintain electrical isolation, a dielectric vapor barrier and underlayment should be placed beneath the shielded floor panels. Counter-sunk floor screws should be used in the clamping system to ensure a smooth floor surface. With this type of construction, modular or PAN formed panels can be converted into a ferrite-lined and/or conventional absorber-lined anechoic chamber if requirements change. These shielding solutions deliver high performance attenuation over a broad frequency range while providing the flexibility to create a new environment should a lab’s test needs change.

Typical Shielding Performance

Magnetic Field	20 dB @ 1 kHz / 56 dB @ 10 kHz / 100 dB @ 200 kHz
Electric Field	≥ 100 dB from 200 kHz to 50 MHz
Plane Wave	≥ 100 dB from 50 MHz to 1 GHz
Microwave	≥ 100 dB @ 10 GHz

Important Chamber Components: Doors, Tuners and Others

RF Shielded Doors

There are many types of shielded doors available for reverberation chambers. From manually operated swing opening type doors to fully automatic, push button type slide opening doors, selecting the ideal door type for your application may be complicated. How often will you open/close the door? How heavy are the items you will test? Are they heavy enough to drive into the chamber or require a cart to be rolled into the chamber? In this case, for example, a sliding door may be preferred since the door threshold will be lower, i.e. recessed or flush with the floor of the chamber. The recessed channel required of swinging doors work well for personnel entry, but may not be appropriate when the EUT are large in size or are heavy in weight.

Tuners

Tuners are typically made of large aluminum reflecting sheets supported on either a rigid box (truss) frame or a single spine and are designed to provide the efficient reflecting surfaces necessary for use in a RF reverberation chamber. Most tuners can be computer controlled using a positioning controller. The controller provides a digital display of the angular position and can be used to control the speed and position of the tuner in both the stirred or tuned mode operation. Ideal tuners feature the following important characteristics:

- **Robust Lightweight Construction**
- **Short Settling Time**
- **Efficient RF Scattering**
- **Sized to Match Chamber Size**
- **Cross Section Based on Operating Frequency**
- **Synchronous or Stepper Motor**
- **Suitable for Tuned and Stirred Mode Operation**

Other mode stirring methods are in use, like frequency stirring, but some of these techniques are not covered in the current standards.

Others

Of course, no test is complete without antennas, positioners and software. After the "heavy lifting" noted above with the chamber design and construction, care should also be paid to these key components. Not only do these components need to work together, they may also be long lead items. Ask for recommendations from the chamber supplier on the optimal antennas and positioners required. You'll want antennas with broad enough performance, for example, to lessen your downtime in substituting one antenna for another for a specific test requirement. Ask for software options that provide the greatest flexibility and convenience with test report writing capabilities, etc. Most companies will provide software training to lab personnel and management to expedite the test proficiency of your staff; require this training be included with a sales proposal for a new reverberation chamber.

Certification Testing

As with any type of RF shielded enclosure, it is essential to perform certification testing of the chamber after installation is completed. A shield verification test is typically performed in general accordance with the test methods of MIL-STD-285 and IEEE-299 at four frequencies up to 10 GHz plane wave field. The shielding performance should be guaranteed prior to the installation of system components such as the antenna, RF cabling, etc. In addition, a reverberation validation test per DO-160F/G (100 MHz to 18 GHz in an empty chamber) should be performed. A complete test report should be provided and kept on file to document performance of the chamber.

More Than Just a Metal Box

A vertically-integrated test solution supplier ensures that all components of the chamber work together seamlessly. This creates one point of contact for the project and reduces the risk and liability when relying on a third party supplier. Control over manufacturing allows a vertically-integrated test solution supplier to tailor product performance to specific test applications and efficiently support your future operational requirements. Protect your long term investment by discussing your current and future test expectations with your potential supplier. Review the qualifications of your supplier, ask for customer references, evaluate maintenance services provided, and document the supplier's financial capabilities to complete the project in a timely manner. Keep in mind that a well designed, manufactured and installed reverberation chamber is more than just a "metal box".

"Products are designed and tested to ensure that they will operate reliably throughout its life cycle within its intended installation site or electromagnetic environment. In many cases, products designed to perform a specific function or number of functions in a particular environment are may also be integrated into systems performing these functions fulfilling a wide variety of applications across a number of unrelated industries, and platforms. The most common scenario is the use of commercial off the shelf (COTS) equipment being integrated into military applications. Variations between the intended electromagnetic environment and the newly proposed installation environment can be significant, and can pose serious product design risks.

It is important to understand these electromagnetic environmental effects (E³) differences, and to mitigate design risks before seeking product certification. This infographic provides a comparison of the most common military, aerospace, and commercial EMI test standards to reveal potential risks and qualification gaps."

Jeff Viel
Chief Electrical Engineer and General Manager of NTS Plano

EMI/EMC Testing

The following is courtesy of NTS. For additional information, or to see the infographic "EMI/EMC Requirements Comparison" in its entirety, please visit the NTS website at www.nts.com.

EMI/EMC Testing Categories

Immunity/Susceptibility Tests

Evaluates the potential operational effects of a product when exposed to a series of specific platform based environments. Includes:

- Radiated Susceptibility/Immunity Tests (Electric and Magnetic)
- Conducted Susceptibility/Immunity Tests (Voltage and Current)
- Surges, Switching Transients, Lightning
- Power Quality (Drops, Sags, Variations)

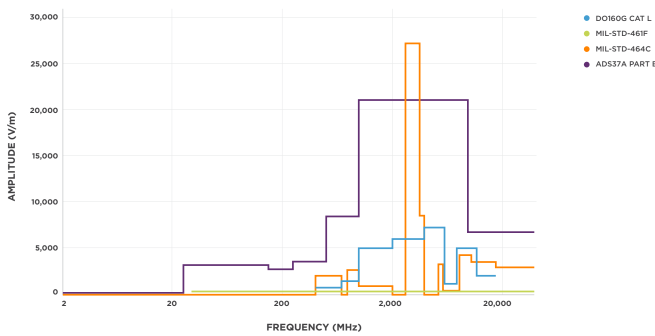
Emissions Tests

Ensures that proper EMI design controls have been implemented (based on existing platform emissions levels), to prevent operational interference of nearby equipment.

- Radiated Emissions Tests (Electric and Magnetic)
- Conducted Emissions Tests (Voltage and Current)
- Power Quality (Harmonics, Power Factor)

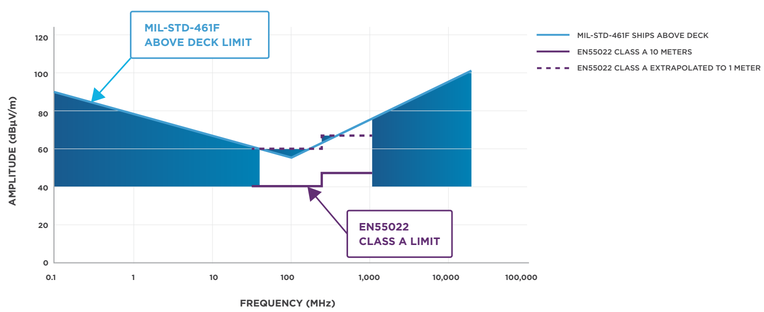
Radiated Susceptibility Comparison

Differences in radiated susceptibility across different standards are found in amplitude, frequency range, step size, and modulation.



Radiated Emissions Electric Field Comparison

Common areas of difference include frequency range, measurement distance, and resolution.



Need additional assistance? ETS-Lindgren can help! Contact your local ETS-Lindgren representative, phone us at +1.512.531.6400, or visit our website at www.ets-lindgren.com.

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