

THE DESIGN, CONSTRUCTION, AND QUALIFICATION OF A CHAMBER DEPENDS ON THE PRODUCTS IT WILL TEST.

# ANECHOIC CHAMBERS RISE FROM THE PITS

BY MARTIN ROWE, SENIOR TECHNICAL EDITOR

Tests for electromagnetic immunity and emissions work best when located far from intentional transmitters such as broadcast stations and cell towers. Testing products for emissions or immunity in populated areas requires an anechoic or semianechoic chamber to keep ambient signals from interfering with measurements. Every chamber installation is unique and is influenced by many factors, some of which can change over time.

Major factors affecting chamber design include the size of the EUT (equipment under test), the relevant standards for EMC (electromagnetic compatibility), and the building facilities. A company that manufactures handheld devices won't need a chamber as large as one that makes rack-mounted equipment or vehicles. Chambers also differ depending on whether they must comply with commercial or military standards. Chambers used exclusively for emissions tests differ from those that also host im-

munity tests. Chambers used for precompliance tests and troubleshooting rather than full-compliance tests may also differ in size and construction from those used for full-compliance tests. ("What is an anechoic chamber?" p. 36, explains how chamber components minimize signals inside the room.)

## Know what goes in

Proper chamber design starts with a knowledge of the products that you need to test. "Have a good idea of your product roadmap over the next several years, because test requirements tend to grow over time," advised Bryan Saylor, Sr. VP and GM of ETS-Lindgren. Planning for future products eases decisions about a chamber's size, turntable size, cable routing, power provisioning, and instrumentation.

National and international EMC standards significantly influence chamber size, because they often specify the distance from the antenna to the EUT: 1 m, 3 m, or 10 m. For example, CISPR 22 requires a 10-m distance for EUTs larger than 2 m<sup>3</sup> (Ref. 1). Product size affects chamber size, because a chamber must be large enough to accommodate the distance from the EUT to the antenna, plus the size of the EUT, plus the size of any internal absorber materials. Absorbers such as cones that line a chamber's walls significantly reduce the usable area.

Chambers may also accommodate other distances such as 5 m. "Some test labs will use a 5-m distance for precompliance tests because it better correlates to how an EUT will perform at 10 m than a 3-m distance," noted Peggy Girard, president of Panashield. "Some chambers are designed to accommodate a 5-m path length, but currently the FCC will only accept the chamber based on the

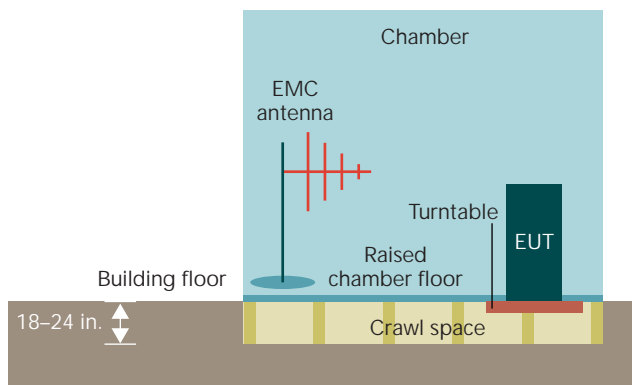


FIGURE 1. Many chambers sit inside a pit that provides space under the working floor.

3-m test data, because the agency doesn't formally recognize 5-m data in its comparison to an OATS (open-area test site).

The construction of the host building also affects chamber size, particularly height. When engineers at Northwest EMC opened a facility in June 2009 in Brooklyn Park, MN, they wanted a location close to potential customers, which ruled out an OATS. Operations manager Tim O'Shea explained that ceiling height was a critical factor, because many cities have building-height restrictions, and he needed a building with ceilings high enough to house a 10-m chamber, which can typically be 30 to 32 ft tall.

### Rising from the pit

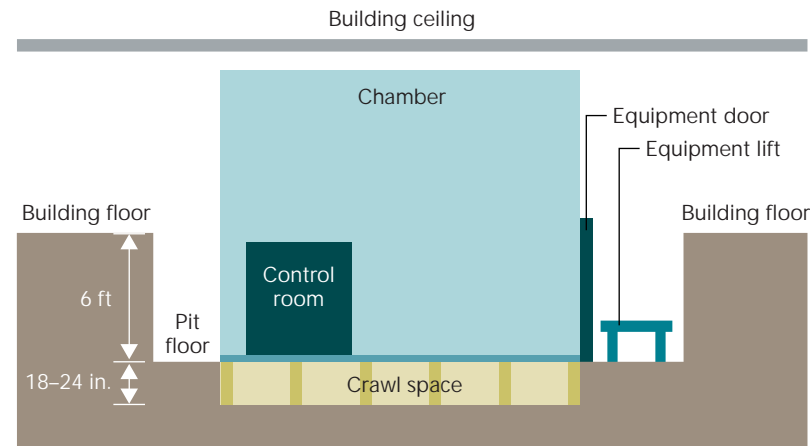
Height isn't the only consideration for a building to house an anechoic chamber. Depth counts, too. **Figure 1** shows a typical chamber with a raised working floor. The chamber floor is supported on legs because there's a pit under the floor. The pit, typically 18-in. to 24-in. deep, provides space for EUT support equipment and cable routing from the control



**FIGURE 3.** A chamber without a pit requires an equipment ramp. A swinging door lined only with ferrite tiles will clear the door opening. Courtesy of Panashield.

room to the center of the floor's turntable. The raised floor is flush with the building floor outside the chamber, which lets technicians roll equipment into the chamber.

Girard described an unusual chamber that, because of low ceilings in the building that housed it, required a "pit within a pit." **Figure 2** shows that the chamber's raised floor was actually 6-ft below the building's floor. The 6-ft pit



**FIGURE 2.** One chamber design needed a 6-ft pit to clear a building's ceiling.

was larger than the chamber, providing working space outside the chamber at the chamber floor's level. A second pit extended 18 in. below the chamber's floor to provide space for cables and turntable motors.

Pits under chambers need not be as large as the entire chamber. To save on construction costs, some companies and test labs choose to leave much of the area under the chamber floor solid and just provide conduits for cables to the EUT, turntable, and antenna. While this design costs less to dig, it minimizes flexibility. Chambers with conduits also need metal pipes for electromagnetic shielding.

Instead of having just the 18-in. to 24-in. space under their raised floors, some chambers have deeper pits under the turntable or antenna. Ghery Pettit, EMC regulatory compliance manager at Intel, chose to construct a chamber with a 6-ft pit under the antenna. That depth provides space for RF amplifiers used in immunity tests. Keeping amplifiers close to an antenna results in shorter cables that carry RF signals. "We really wanted a 7-ft pit because 6-ft isn't deep enough for

some people to stand. When we built a chamber in Dupont, WA, we dug a 7-ft pit so that anyone could stand upright in it."

Other chambers have no pits under them at all. Instead, the base of the chamber rests on the building floor, and the chamber has a raised floor under which the cables run. In that case, an equipment ramp (**Figure 3**) lets technicians roll equipment into the chamber.

Cables under a chamber floor provide power, control, and I/O signals to an EUT. RF cables connect antennas in the chamber to RF amplifiers for immunity tests or to EMI (electromagnetic interference) receivers and spectrum analyzers for emissions tests. Other cables provide power and control signals for turntables and antenna masts. Test equipment usually resides in a shielded control room close to the chamber.

### Connecting the cables

Because test equipment resides in a separate control room, all chambers need penetration panels that hold cable connectors. Cables on either side of the panels connect equipment in the control room to the EUT, turntable, and antenna inside the chamber. The control room should be located close to the portion of the chamber that holds the panels in order to minimize cable length.

For commercial EMC tests, cables that come from outside the chamber generally run under the floor. The penetration panels may be part of a chamber's walls, or they can be on the floor next to the chamber, provided there's space under the panel for cable runs. At Northwest

EMC's Brooklyn Park facility, penetration panels are located in the chamber's wall (**Figure 4**) next to the control room, but below the raised-floor's surface. At Intertek's facility in Boxborough, MA, connector panels are located on the floor of the control room (**Figure 5**). Cables then run through the pit under the floor to the center of the turntable. The raised chamber floor has panels through which the antenna cables can emerge to reach the antenna and its mast.

For military tests, cables must run on the chamber floor, because that simulates actual use. In addition, EUTs need not rotate. So, Tom Arcati, engineering specialist at Dayton T. Brown, uses chambers without pits or turntables (**Figure 6**).

That simplifies the chamber's design and makes it less expensive than chambers used for testing to commercial standards. The penetration panel is on the chamber wall, slightly above the floor. "MIL-STD 461 requires at least 10 m of cable between the antenna and EUT," said Arcati. "Power cables from the LISN [line impedance stabilization network] and the equipment must be at least 2 m long."

EUTs often need external AC or DC power, so a chamber must be wired to make power available. The AC or DC power that a chamber must support varies with how the chamber is used. Independent EMC test labs test a wide range of powered products and require more forms of power than chambers dedicated



**FIGURE 4.** A penetration panel sits below the building floor, providing access to cables that run under the chamber's raised floor. A pipe opening alongside the panel provides access for additional cables and hoses.

Courtesy of Northwest EMC.

## What is an anechoic chamber?

Anechoic chambers perform two basic functions as part of an overall EMC measurement system. They shield a test setup from ambient signals, and they absorb reflected signals generated inside.

The walls and ceiling of a chamber are lined with metal that connects to a grounded metal floor, which serves as the ground plane required by many EMC standards. The metal lining, both inside and outside the walls, attenuates signals by providing a low-impedance path to the earth ground. A typical chamber can attenuate signals by at least 100 dB.

Unintentional emissions, radiated either by the EUT or by the signals intentionally transmitted from an antenna, will bounce off the shielded walls, creating undesirable fields inside the chamber. Thus, anechoic chambers need absorbing materials to minimize reflections.

The **figure** shows a typical wall construction. The wall consists of a wood panel sandwiched between two metal layers. The inside metal layer is lined with ferrite tiles and absorber cones typically referred to as hybrid absorber, which is impedance matched to the ferrite to allow for testing across the full range from 30 MHz to greater than 40 GHz.

The ferrite tiles absorb signals up to about 1 GHz. If a chamber won't see higher frequencies, then it won't need the hybrid cones on top of the tiles. The cones, up to about 4 ft long, significantly reduce chamber size. They're typically made of carbon-loaded polyurethane foam, polystyrene foam, or fibrous material.

A chamber's raised floor is an integral part of the chamber's shielding and grounding. For radiated emis-

sions tests, the floor—made of metal and often covered with vinyl—is grounded and is attached to the chamber walls. Radiated emissions standards such as ANSI C63.4 and CISPR 22 require a grounded metal floor that simulates signals bouncing off the ground of an outdoor facility. Because the floor isn't covered with absorbing

materials, the chamber is called semi-anechoic rather than fully anechoic.

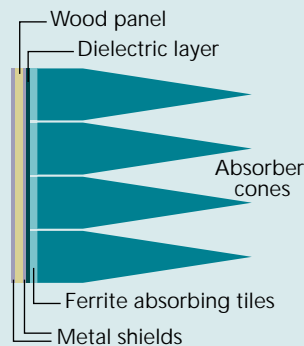
Radiated immunity standards such as EN 61000-4-3 require a partial floor coverage of absorbers between the front of the uniform field and the antenna for a 3-m path length, typically 10 ft wide by 11 ft long. Thus, absorbers must be on all six surfaces of the chamber. If a chamber is used for both commercial emissions and immunity tests, it will need removable absorbers for the floor.

Anechoic chambers used for commercial EMC emissions and immunity tests need a turntable that rotates the EUT, exposing all sides to an EMC

antenna. EUT size and weight dictates the size of the turntable. Intel's Ghery Pettit has built three anechoic chambers in his career. The first, built in 1989 and still in use, has an 18-ft diameter turntable that can support 20,000 lbs.

Standards also require tests over different frequency ranges. ANSI C63.4 and CISPR 22 originally called for frequencies from 30 MHz to 1 GHz. CISPR 16-1-4 covers frequencies from 1 GHz to 6 GHz and up to 18 GHz. Military standards such as MIL-STD-461 call for conducted tests from 30 Hz to 80 MHz and for radiated tests from above 80 MHz to 40 GHz.

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Chamber walls consist of shielding layers and absorbing materials.

to one company. The type of power also depends on national compliance standards. For example, a chamber might need 100 V for Japan, 110 V for Taiwan, 120 V for North America, and 220 V for Europe. It may need to provide power frequencies of 50 Hz, 60 Hz, or 440 Hz, single phase or three phase.

The AC mains lines that enter a chamber require filtering to minimize noise. Some chambers filter their AC voltages using a single filter for each voltage, then distribute the clean power to the equipment inside the chamber. Some EMC engineers, however, prefer to distribute the power to its load and filter it there. The choice depends on cost versus flexibility.

Because power and signal cables must connect to an EUT on a turntable, the cables must have enough slack to accommodate turntable rotations. “Most turntables have 380° of rotation,” said Saylor of ETS-Lindgren. “The turntable typically rotates  $\pm 180^\circ$  during a test.” A more expensive approach, and one that he rarely sees, uses slip rings that conduct power and signals while permitting continuous rotation.

### Designing the doors

Regardless of whether a chamber is used for commercial or military tests, it needs a door large enough to get an EUT in and out. The size and design of a door also depends on the products tested in the chamber. Size and location are important. Intel’s Pettit noted that “The door locations should minimize the distance to the turntable if the chamber will test large, heavy EUTs.”

Door location matters for more than just convenience. Saylor warned that “There are electrically good and bad places for chamber doors. If the door lacks cones, it should be as far away from the turntable as possible because it will affect the quiet zone around the turntable.”

Engineers at Northwest EMC use their chamber for radiated emissions only, and the EUTs are typically

small enough to fit on a table. Thus, the chamber has two 4-ft by 8-ft swinging doors for equipment entry and exit. The inside of the doors don’t have absorbing cones because they would interfere with the door opening in the chamber wall. The door has ferrite tiles lining its inside surface. Figure 3 shows a single door lined with ferrite tiles, but no cones,

so the door can clear the door opening. In contrast, the chamber at Intertek’s Boxborough facility has a retractable door, and thus has cones, but costs considerably more than a swinging door. Swinging door leaves can have cones over the ferrites provided the cones can clear the door opening (Ref. 2).

### Qualifying a chamber

Because anechoic chambers are shielded rooms, they must prove that they sufficiently attenuate outside signals before a manufacturer installs internal absorbers. Most EMC engineers specify that chambers attenuate outside signals by at least 100 dB. “We can build chambers that attenuate up to 120 dB for areas high in ambient signals,” said Saylor. “For most applications, 80 dB of at-



FIGURE 5. A floor-mounted panel provides power and signal cables with access to the inside of a chamber. Courtesy of Intertek.

tenuation is enough.” Remember that it is the ambient noise levels inside the chamber that count. If a chamber is in a region of relatively low ambient signals, then 80 dB of attenuation may be sufficient.

A technician will test the chamber’s shielding effectiveness by generating a signal at a known power and frequency and measuring signal strength on the other side of the wall. O’Shea explained the test procedure at Northwest EMC. “We had the transmit antenna at 26 different locations outside of the room—including the top—and moved the receive antenna along all inside seams closest to the transmit position. We checked every seam in the room.”

Technicians may also perform shield-

ing-effectiveness tests with the transmit antenna outside the chamber and the receive antenna inside. Placing the receive antenna in the chamber reduces ambient signals at the receiver, which makes the transmitted signals easier to see on a spectrum analyzer.

Following a shielding-effectiveness test, a chamber is ready for the absorbing materials. After installation, the chamber needs additional measurements around the turntable to verify its quiet zone for radiated emissions tests per IEEE C63.4 from 30 MHz to 1 GHz (Ref. 3) and per CISPR 16-1-4 (Ref. 4). For



FIGURE 6. Chambers designed for MIL-STD-461 compliance tests don’t need turntables; cables for these tests can run on the chamber floor. Courtesy of Dayton T. Brown.

radiated immunity tests, a chamber must undergo a field-uniformity test to comply with EN 61000-4-3 (Ref. 5).

### **Do this, not that**

The engineers I interviewed for this article offered some tips for building an anechoic chamber. Panashield's Girard urged an understanding of your needs. "Start by knowing what your present and future testing needs will be for your product, per international standards. Will you require radiated emissions, immunity, or both?"

O'Shea of Northwest EMC said, "Plan ahead. Look at the whole facility and how the chambers will fit into the building. Evaluate customer needs to customize room size, turntable size, door size, power requirements, etc. Don't take shortcuts in the building process or during shielding effectiveness testing because this could cause problems that are much more difficult to fix once the room is fully constructed."

Sayler of ETS-Lindgren added, "Get on the good side of your facilities people. You'll need them."

And Intel's Pettit expressed concern for AC mains power. "Have plenty of power, at least 100-A service for each voltage. Separate power feeds from the turntable to the EUT so you won't get interference." T&MW

### REFERENCES

1. Wiles, Martin, "How the Evolution of CISPR Standards Continues to Shape the Requirements for Anechoic Chambers," *Conformity*, July 2008. [www.conformity.com](http://www.conformity.com).
2. Rowe, Martin "A place for compliance tests," *Test & Measurement World*, September 2009. [www.tmworld.com/2009\\_09](http://www.tmworld.com/2009_09).
3. IEEE C63.4-2009, "American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz," IEEE, Piscataway, NJ. [www.ieee.org](http://www.ieee.org).
4. CISPR 16-1-4 Ed. 2.0, "Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-4: Radio disturbance and immunity measuring apparatus - Ancillary equipment - Radiated disturbances," International Electrotechnical Commission, Geneva, Switzerland. [www.iec.ch](http://www.iec.ch).
5. EN 61000-4-3, "Electromagnetic compatibility (EMC) -- Part 4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test," CENELEC, Brussels, Belgium. [www.cenelec.eu](http://www.cenelec.eu).