# Radiated Emissions Site Selection Considerations

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*Several key issues must be considered when comparing OATS to semi-anechoic chambers.*

Electromagnetic compatibility (EMC) testing and certification has become an integral part of product regulatory compliance. In particular, EMC has exploded onto the compliance scene, propelled by regulations such as the European Union Directive 89/336/EEC. This increased demand for EMC compliance in the 90s has resulted in a significant expansion in the number of test sites performing radiated emissions tests. Whether you are considering building a test site or enlisting the assistance of an independent laboratory, there are a few key issues to consider when comparing open area test sites to semi-anechoic chambers. This article explores some of the pros and cons of using both technologies, including construction and maintenance costs, test repeatability, measurement accuracy and site productivity.

## Open Area Test Sites

The traditional test site for conducting radiated emissions measurements has been an open area test site (OATS). Due to the abundance of such sites, a majority of radiated emissions compliance testing is still performed at OATS. However, the rising popularity of cellular phones, pagers and overall expanded use of additional radio frequency bands in the 90s have made it increasingly difficult to conduct emissions tests using OATS because of the increased presence of ambient emissions.

An ideal open area test site is defined as a perfectly flat, infinitely large, continuous ground plane having infinite conductivity and located in free space. "Free space" is defined as an open area that is free of objects which can reflect electromagnetic waves, including buildings, electric lines, fences, trees, hills, etc. All test sites strive to be as near to ideal as possible. Obviously, there are no sites in the world that are "ideal" and most OATS have site imperfections.

Standard OATS are typically uncovered facilities. The use of partially and/or fully enclosed, weather-protected open area test sites has gained popularity. Recommended construction practices for standard and weather protected OATS are provided in ANSI C63.7-1992, the American National Standards Institute (ANSI) Guide for Construction of Open-Area Test Site for Performing Radiated Emission Measurements.

A standard OATS with a turntable has an obstruction-free area formed by an ellipse as shown in Figure 1. Weather-protected OATS are defined in ANSI C63.7-1992 as:

*Type 1*—A structure that encloses the equipment under test (EUT), the receiving antenna and the space between.

*Type 2*—A structure that encloses *only* the EUT.

*Type 3*—A structure enclosing instrumentation or test personnel outside the obstruction-free ellipse.

## Semi-anechoic Chambers

Recent technological improvements in radio wave absorbing materials have afforded large-scale, indoor semi-anechoic chambers that provide an alternative environment for EMC testing. Because EMC semi-anechoic chambers begin as shielded metallic enclosures offering 100 dB of RF attenuation, they "block out" all ambient emissions from the surrounding area. These shielded enclosures are lined with radio frequency (RF) absorbing materials, thereby simulating a free space environment above the ground plane through the absorption of RF signals not directly coupled to the receiving antenna.

## Qualifying Test Sites

Every site used for radiated emission compliance measurements, be it an OATS or a semi-anechoic chamber, must be constructed to eliminate, reduce or reliably control reflected energy from adversely affecting the measurements. The most common measure of the performance of a test site is a normalized site attenuation (NSA) test. The NSA test is specified in the 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 (ANSI C63.4-1992). It should be noted that ANSI C63.4-1992 allows an OATS to be evaluated for NSA through a single measurement location using several discrete frequencies, while a semi-anechoic chamber is required to be evaluated using swept frequencies and five distinct locations that define the volumetric area intended to be occupied by the EUT. When a test volume is evaluated, the distribution of the NSA values for the five locations is a factor in test repeatability. The use of swept frequencies as opposed to distinct or "spot" frequencies provides a broader and more uniform view



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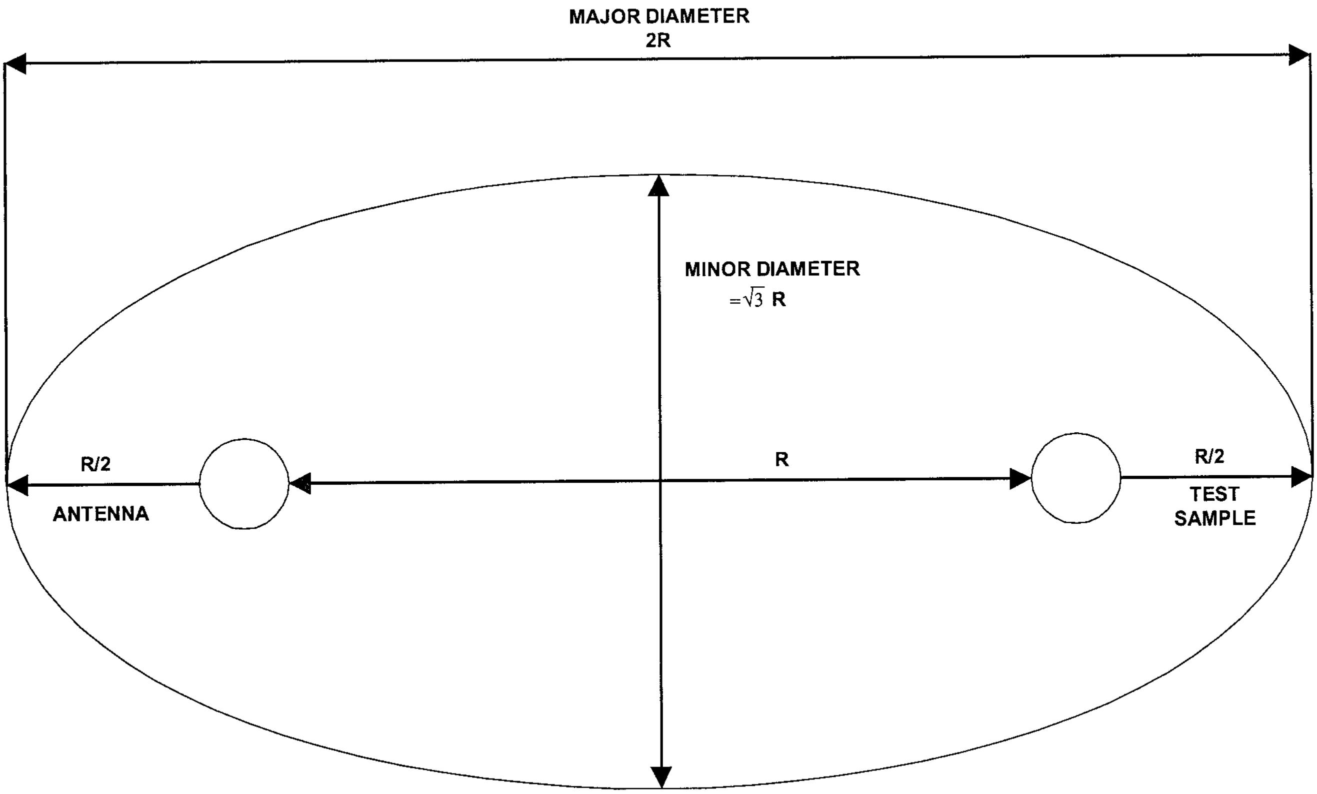


***Figure 1.*** *Obstruction-free Area for OATS with a Turntable.*

of the site performance. Proposals are being considered that would require weather-protected OATS to be evaluated using this volumetric method.

An NSA test is a measure of the transmission characteristics of a test site between the point where the equipment under test is located and the receiving antenna. The performance of a site, as judged by the NSA test, is considered acceptable when measured values are within +/- 4 dB of the theoretical ideal site values specified in ANSI C63.4. This validation procedure should be run at least once a year for a standard OATS or semi-anechoic chamber and twice a year for weather-protected OATS. While the transmission characteristics of a site are important, this one test does not adequately define the quality of a particular test site. The test repeatability, measurement accuracy and productivity at the test site will also depend on a number of other factors, including the existing RF ambient and weather conditions.

## Construction and Maintenance Costs

Initial start-up costs for constructing a standard OATS are the lowest of all the various test sites. Generally, a standard OATS only requires an obstruction-free terrain and a mesh or metal ground plane. A weather-protected OATS has the same basic features as a standard OATS, but is generally more expensive due to the additional costs associated with a Type 1, 2 or 3 enclosure. Semi-anechoic chambers are the most expensive options in terms of construction costs because of the need for a host facility, and other costs incurred from shielding, anechoic material and fire protection.

Maintenance costs for an OATS depend on the weather conditions present at the test site. Because they are exposed to weather, equipment used to automate testing in a standard OATS (e.g., power sources, masts, turntables) need to be maintained on a regular basis. Types 1 and 2 weather-protected OATS can have maintenance costs associated with removal of snow, ice, or water from the protective covering. In addition, the RF transparent material used should be periodically cleaned to remove contamination, such as any airborne particulate material. Weather-protected OATS also require more frequent normalized site attenuation measurements (every 6 months) as recommended in ANSI C63.7-1992. Other than the annual NSA test, the cost of the host building essentially covers the maintenance of a semi-anechoic chamber.

## Test Repeatability

Climate can affect radiated emission measurements when testing is done at an OATS. Although many OATS may be covered so they can be used in any weather condition, variations in temperature and humidity can affect test repeatability.

The construction materials used in the protective cover can influence test repeatability at a weather-protected OATS. Materials such as

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painted or unpainted wood and nylon can retain moisture. Consequently, high humidity, recent rain or snow can affect the moisture content of the construction materials, thereby causing changes in the reflective properties of the materials, which can adversely affect test repeatability.

Extreme temperature and humidity can also affect the operation of the EUT, especially for mechanical equipment. The operation of a printer, for instance, may be different in cold temperatures. Except for adverse weather conditions (snow, rain, etc.), changes in humidity and temperature will have relatively little effect on test repeatability in a standard OATS.

RF ambients can also affect test repeatability at standard or weather-protected OATS (Figure 2). A wide variety of test methods and protocols can be used to measure emissions in the presence of RF ambients, such as reducing the measurement bandwidth to separate the EUT emission from an ambient signal. Although reducing the receiver bandwidth is a common practice when working in high RF-ambient conditions, extra precautions should be taken to ensure that the reduced bandwidth does not adversely affect the measured amplitude of the emissions from the EUT.

Test repeatability in semi-anechoic chambers housed in temperature- and humidity-controlled host facilities is generally greater than in standard or weather-protected OATS. However, chambers employing open cell absorbers are more susceptible to variations in humidity than chambers employing closed cell absorbers.

Hybrid chambers—semi-anechoic chambers designed to operate below 1 GHz and up to 18 or 40 GHz—consist of two types of RF absorbing materials which are impedance matched or "tuned" to each other to reduce the reflection coefficient at the boundary between the materials. To achieve RF absorption performance below 1.5 GHz, ferrite tile is used. Foam absorbers are generally used for higher frequency ranges above 1.5 GHz, since using them for lower frequencies is impractical because their absorber profiles would have to be very large.

Foam absorbers (anechoic cones or wedges) are generally made from polyethylene, polyurethane, polystyrene or other polymer materials. Each of these base materials has distinct advantages and disadvantages that can affect test repeatability. Polystyrene is a closed-cell design that is unaffected by changes in humidity, therefore offering the most stable performance of the three types. Polyethylene and polyurethane are open-cell materials similar to a sponge in the sense that they allow air to pass through the cells, or "breathe." Consequently, even small humidity changes within a chamber can adversely affect the reflective properties of the polyethylene- and polyurethane-based absorber performance and degrade test repeatability. Polystyrene-based absorber designs offer improved test repeatability and increased physical endurance, but generally cost more.

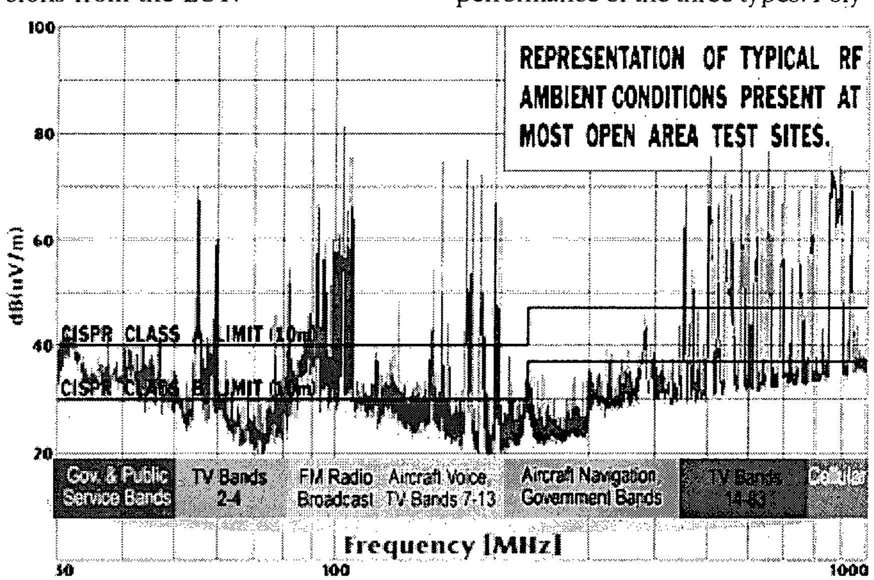


***Figure 2.*** *Typical RF Ambient Condition Present at OATS.*

## Measurement Accuracy

Measurement accuracy of a test site will depend on a variety of factors including measurement instrument accuracy, quality of the ground plane construction, potential weather-related reflections (objects or enclosures at OATS), RF ambients (at OATS) and test procedures used to contend with those ambients.

Measurement accuracy of any measurement site will be affected by the quality of the ground plane. ANSI C63.7-1992, Annex B recommends smoothness based on the Rayleigh criterion. This mathematical criterion illustrates the fact that the less flat the ground plane, the more likely phase cancellation can occur. Special consideration must be given to the ground plane construction at an OATS that must account for ground plane shift as a result of erosion. Ground planes in Types 2 and 3 weather-protected OATS are also more susceptible to weather conditions since they are exposed.

Semi-anechoic chambers and Type 1 weather-protected OATS provide protective covering for the ground plane. The desired flatness is more likely to be achieved in a chamber than at an OATS because the ground planes in semi-anechoic chambers are made of machined components.

Any object in the vicinity of an OATS (Figure 1) has the potential of adversely affecting the accuracy of measurements taken at an OATS. Moisture buildup can cause surfaces on protective enclosures at Types 1 and 2 weather-protected OATS to become more reflective, significantly altering measurement accuracy. Measurements made during or immediately following adverse weather conditions (e.g., snow, rain, and high humidity) can be significantly affected by the presence of moisture on enclosure materials or any other object in the vicinity of the OATS.

Semi-anechoic chambers inherently have some reflections since the ferrites and absorbers are not perfectly lossy dielectric materials. However, these reflections are constant and can therefore be measured and accounted for during normalized site attenuation testing. Further, unless chambers are exposed to high moisture content, their performance should remain relatively unaffected, particularly in chambers where closed cell absorbers are used.

Making reasonably accurate measurements in the presence of RF ambients at standard and weather-protected OATS also requires thorough measurement protocols, including testing at different times (often late in the evening) when occurrence of RF ambients may be reduced. Other options include changing the measurement distances or receiver resolution bandwidths of the frequency to compensate for the present ambient conditions. Even with these extra steps, if the emission bandwidth from the EUT is too close to the RF ambient, it still may not be possible to measure with any reasonable degree of confidence at that particular OATS.

One of the most critical steps in accurately measuring emissions in the presence of RF ambients on an OATS is the implementation of preliminary measurements performed in an enclosed, semi-anechoic pre-compliance chamber or at a greatly reduced distance (e.g., 1 meter) on an OATS. The EUT is commonly tested first in a pre-compliance 3-meter chamber, where a "qualitative" emissions measurement is taken, or at a greatly reduced distance (e.g., 1 meter) on an OATS. This catalogs the emission frequencies used for the final "quantitative" EUT compliance measurements to determine if the emissions exceed the permitted limit. Any difficulty in discriminating emissions from RF ambients present during the preliminary measurements at an OATS usually results in those emissions not being measured at all.

## Site Productivity

Site productivity is often measured by the number of tests completed in a day, and is dependent upon the measurement procedures and the hardware and software being used. There are significant trade-offs between accuracy and repeatability, and site productivity. Most productivity losses are attributed to weather conditions and RF ambients present at standard and weather-protected OATS. In addition, procedures such as pre-scans in a compact chamber and conducting final measurements at an OATS can reduce productivity. However, any OATS employing thorough methods to ensure accurate measurements can usually complete an average of one RF emissions test during an 8-hour shift. With their ambient-free environments, semi-anechoic chambers are able to double that productivity.

## Conclusion

Selecting an appropriate design when building or selecting a suitable radiated emissions test site requires careful consideration of several key factors, including operating and construction costs, test repeatability, measurement accuracy and site productivity. Inherent trade-offs exist between the initial costs and test repeatability, measurement accuracy and site productivity for the different types of OATS, as well as between OATS and semi-anechoic chambers. When choosing to use or construct an OATS, careful consideration must be given to the measurement procedures used to evaluate products and their impact on site productivity, measurement accuracy and repeatability.

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