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Comparison of Methods to Evaluate Semi-anechoic Chamber Performance

Understanding how to evaluate a 3-m semi-anechoic chamber is critical for the adequate control of chamber performance.

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Procurement of a state-of-the-art 3-m semi-anechoic chamber requires a thorough understanding of the two methods commonly used to evaluate chamber performance. The first method compares chamber performance to a theoretical model that employs free-space antenna factors, and the second method directly compares a chamber to the measured performance of a near-ideal open area test site (OATS). Both of these methods were used to evaluate a state-of-the-art chamber, and their advantages and disadvantages are discussed. This article also explains how chamber performance is currently unregulated because the accepted interpretation of ANSI C63.5-1988[1] allows a chamber to be directly compared to an unspecified OATS.

Chamber Performance

The performance of a 3-m semi-anechoic chamber is usually determined by performing a normalized site-attenuation (NSA) measurements series and comparing them to a reference standard.[2-4] To obtain NSA, site attenuation must first be measured. This is accomplished by connecting a signal generator to a transmit antenna. Next, a receive antenna is connected to a receiver and placed 3 m from the transmit antenna. Site attenuation in decibels (dB) is determined by subtracting the maximum voltage measured by the receiver from the voltage measured when the cables are connected together while the receive antenna height is varied from 1 to 4 m. Finally, NSA (dB) is obtained by subtracting the free-space antenna factors (dB/meter) from the site attenuation (dB).

A 3-m Semi-anechoic Chamber

NSA measurements were recently performed in a state-of-the-art 3-m semi-anechoic chamber. The inside of the chamber was 8.5m long, 5.2m wide, and 5.3m high. It was equipped with high-performance 24-in. hybrid absorber and a 2-m diameter turntable. Both the turntable and the receive antenna were located along the centerline of the chamber.

The chamber's worst-case NSA occurred in the 30-200 MHz frequency range when the biconical antennas were vertically polarized and the transmit-antenna height (ht) was set to 1.5 m. The NSA measurements are compared in Figure I to a theoretical NSA calculated using free-space antenna factors. These antenna factors were measured using the standard site method5with the antennas horizontally polarized (ht = 2 m), the receive-antenna height (hr) varied from I to 4 m, and the horizontal distance between the antennas (d) set to 10 m. The measurement was performed on a near-ideal OATS equipped with an uncovered 50 X 80-m ground plane. However, the result was reasonably accurate free-space antenna factors because the standard site method properly accounted for the ground-plane reflection. This method also yields equivalent results when the measurement is performed on a more modest ground plane, which will be discussed later. The NSA in Figure I was measured with the transmit antenna placed at the center, front, left, and right of the turntable as specified in ANSI C63.4-1992.4The chamber is acceptable for 3-m emission testing because the measurements in Figure 1, as well as all of the other required NSA measurements from 30 to 1000 MHz, are within ±4 dB of the corresponding theoretical NSA.

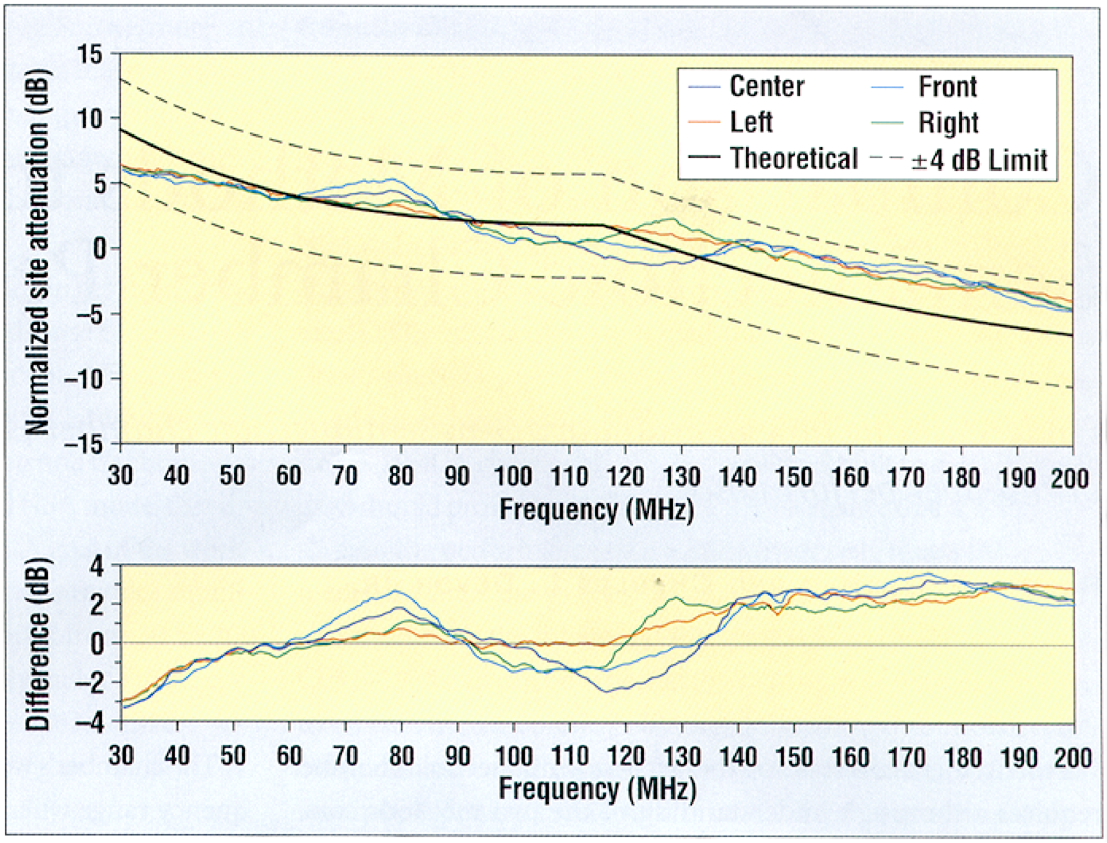

Figure 1. Comparison of normalized site attenuation (NSA) measured in a semi-anechoic chamber to theoretical NSA calculated using free-space antenna factors, vertical polarization (h_t = 1.5 m, h_r = 1-4 m, d = 3 m, 30-200 MHz).

The curves from 140 to 200 MHz in Figure 1 are significant. Although the largest difference between the theoretical and measured curves occurs over this frequency range, the difference between the measured curves is relatively small. This behavior suggests a significant error associated with the theoretical NSA model. To investigate this possibility, a similar NSA measurement was performed on the near-ideal OATS. The result, shown in Figure 2, is compared to the theoretical NSA from Figure 1. Because the ground plane on the near-ideal OATS is extremely large and the measurement error is small, the difference between the measured and theoretical curves in Figure 2 is mainly the result of the effects neglected by the theoretical model. These effects include the l/r2 and 1/d radiation terms, the mutual coupling between the antennas, the mutual coupling between the antennas and the ground plane, and the nonuniform illumination of the receive antenna. If the chamber NSA measurements in Figure I were directly compared to the NSA measured on a near-ideal OATS in Figure 2, the differences would be smaller. Such a direct site-to-site NSA comparison is shown in Figure 3.

The maximum differences between the measured and theoretical NSA in Fig 1 are 3.7 dB and -3.3 dB, whereas the maximum differences in Figure 3 are only 1.7 dB and -3.0 dB. Similar results occur for the other 30-200 MHz measurements, summarized in Table I, and for the horizontal and vertical NSA measurements from 200 to 1000 MHz. The smaller differences demonstrate the advantage of a direct site-to-site comparison. This advantage, however, is negated by several disadvantages.

NSA Reference Standards

The question as to whether a theoretical model or a measurement on a near-ideal OATS provides the best NSA reference standard has been rigorously debated during the last 20 years. The major advantage of the measured NSA reference or direct site-to-site comparison is that it can provide the greatest accuracy of the two methods as seen in Figures I and 3 and Table 1. However, the NSA reference must be measured on a near-ideal OATS with an extremely large ground plane, such as the 50 X 80-m ground plane used for the measurements in Figure 3. This ground plane must be located on a large, level, obstruction -free area and be well connected electrically to the surrounding earth. The near-ideal OATS also must not be covered by any structure that prohibits measurements during adverse weather conditions. Such a site is expensive and of limited usefulness for purposes other than NSA measurements.

The performance of the near-ideal OATS must also be rigorously verified. Furthermore, to achieve the greatest possible accuracy, the same antennas, antenna masts, cables, and instrumentation must be used for both the chamber and the OATS measurements. Moreover, the placement of the cables, positions of any ferrite cores, and the locations where the cables penetrate the ground plane must also be identical in the chamber and on the OATS. Cabling is critical because of the coupling between the vertically polarized antennas and the sections of the cables that are parallel to the antennas.

The greatest advantage to using a theoretical NSA reference is that the free-space antenna factors (employed by the theoretical NSA model) can be measured on a modest OATS with a much smaller ground plane. An example of such a site is a 7 x 14-m ground plane constructed of paper-barrier insulating foil placed in a parking lot.5 Another advantage is that the requisite antenna factors are determined from a horizontal site-attenuation measurement in which the cables are orthogonal to the antennas. This orthogonality virtually eliminates the sensitivity to cable position, the need for ferrite cores, and the importance of the location where the cables penetrate the ground plane. The only disadvantage of the theoretical NSA reference is that the total measurement error is larger, which is the result of the effects neglected by the theoretical model that were described earlier. The total error is typically less than ±2 dB for horizontal 3-m NSA measurements from 30 to 200 MHz, and all 3-m horizontal and vertical NSA measurements from 200 to 1000 MHz. However, vertical 3-m NSA measurements from 30 to 200 MHz may exhibit a maximum total error of ±3 dB as shown in Figure 2. Both the theoretical model and the direct site-to-site comparison are specified in current ANSI C63 standards.

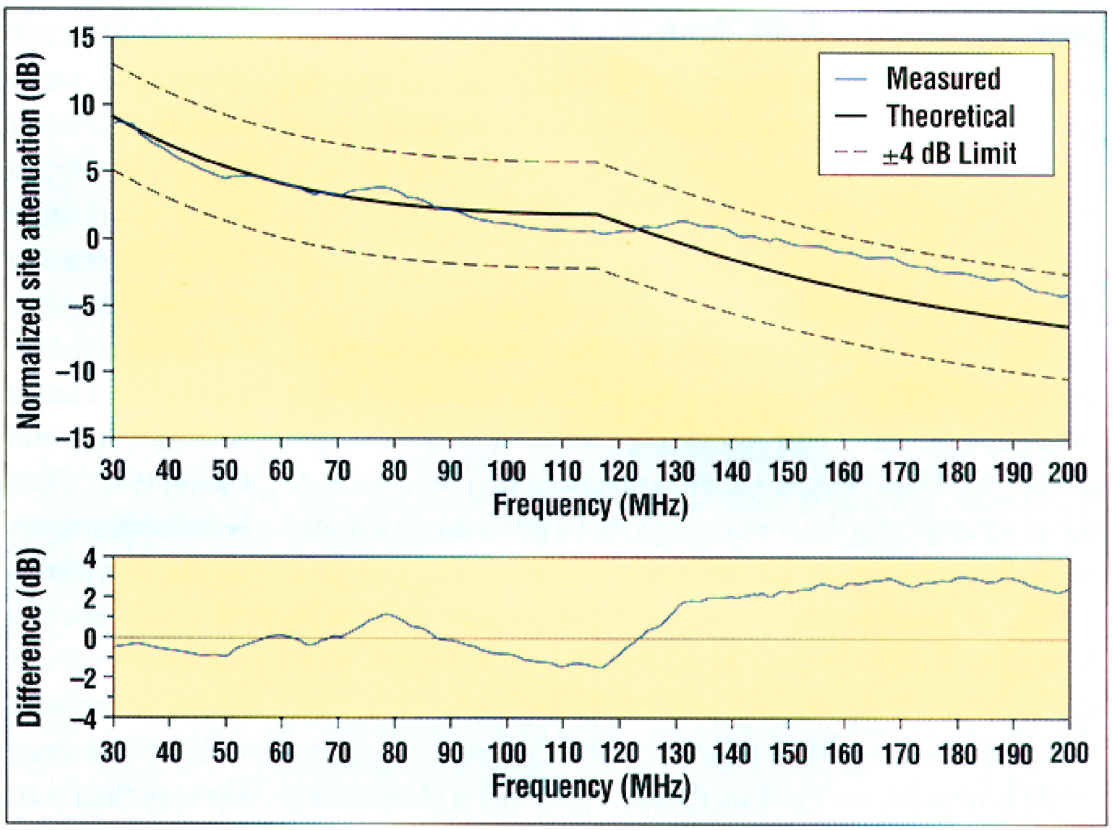

Figure 2. Comparison of normalized site attenuation (NSA) measured on a near-ideal OATS to theoretical NSA calculated using free-space antenna factors, vertical polarization (h_t = 1.5 m, h_r = 1-4m, d = 3 m, 30-200 MHz).

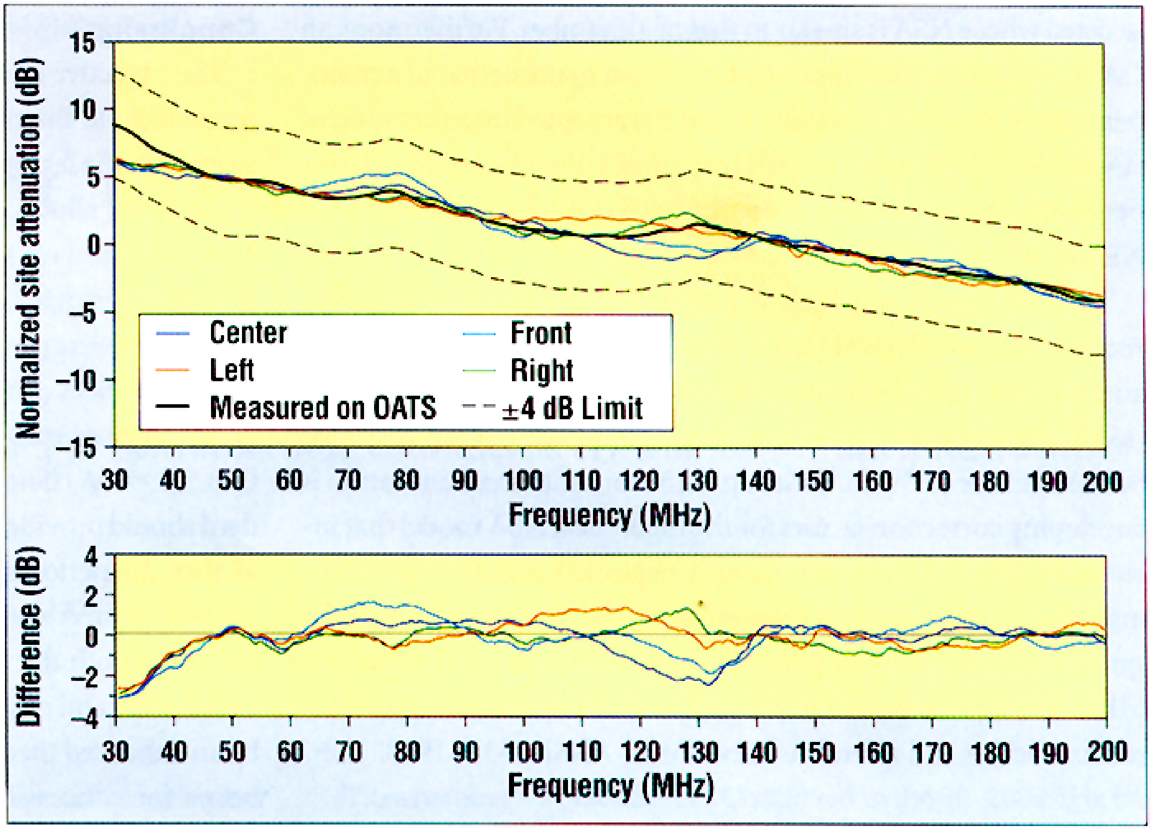

Figure 3. Direct site-to-site comparison of normalized site attenuation (NSA) measured in a semi-anechoic chamber to NSA measured on a near-ideal OATS, vertical polarization. (h_t = 1.5 m, h_r = 1-4 m, d = 3 m, 30-200 MHz).

ANSI C63.4 and ANSI C63.5

ANSI C63.4-1992[4] states that a test site is acceptable for emission measurements if it provides NSA within ±4 dB of the theoretical NSA calculated using antenna factors that are measured according to ANSI C63.5-1988.' According to Section 4.1 of ANSI C63.5-1988, these antenna factors should be free-space antenna factors. This section specifies that antennas must be calibrated in a geometry where near-field and mutual-coupling effects are negligible. Such a calibration results in free-space antenna factors. The intent of ANSI C63.5-1988 is again stated in Section 5.1, which explains why the standard site method should only be used to determine antenna factors that most nearly approximate the results obtainable in free space.

Soon after publication of ANSI C63.4-1992, it became apparent that it is quite difficult to design and build a semi-anechoic chamber that provides measured NSA within ±4 dB of the theoretical NSA calculated free-space antenna factors. An interpretation of ANSI C63.5-1988 was subsequently developed that allowed antennas to be calibrated using the same polarization, antenna heights ANSI, and separation used for the chamber NSA measurements.
The result became known as geometry-specific antenna factors. However, this interpretation is questionable because it relies upon wording that permits the use of special geometries in unusual situations. It also produces measurements that exhibit significant near-field and mutual-coupling effects, which contradict the requirements in Section 4. 1.

Unfortunately, this interpretation of ANSI C63.5-1988 has been accepted by the Federal Communications Commission (FCC) and become the industry standard. Worse yet, it is actually a direct site-to-site NSA comparison in disguise.[6] When chamber performance is compared to a theoretical model that uses geometry-specific antenna factors, the chamber NSA is actually being directly compared to the measured NSA of the OATS where the antennas were calibrated! More importantly, ANSI C63.5-1988 does not specify the near-ideal OATS that must be used to achieve an accurate site-to-site NSA comparison.

C63.5-1988 contains no specific requirements for the OATS to which a chamber is compared because its objective was not to allow direct site-to-site NSA comparisons. Consequently, many OATS can be measured from which one can be selected whose NSA is similar to that of a chamber. Furthermore, an OATS can be modified to produce NSA that matches that of a chamber. Hence, it must be concluded that the accepted interpretation of ANSI C63.5-1988 offers no effective control of semi-anechoic chamber performance because chamber NSA can be compared to the NSA of an unspecified OATS.

	Maximum NSA Difference (dB) from 30 to 200 MHz			
	Horizontal Polarization		Vertical Polarization	
	$h_t = 1.0$ m	$h_t = 2.0$ m	$h_t = 1.0$ m	$h_t = 1.5$ m
Theoretical	+2.2, −1.6	+2.1, −1.5	+3.6, −3.5	+3.7, −3.3
Measured on OATS	+0.9, −1.9	+1.2, −1.3	+1.8, −3.5	+1.7, −3.0

Table I. Comparison of normalized site attenuation (NSA) measured in a semi-anechoic chamber to theoretical NSA calculated using free-space antenna factors and NSA measured on a near-ideal OATS (hr = 1-4 m, d = 3 m).

This unfortunate situation should be remedied in the future. The recently published ANSI C63.5-1998 requires the use of free-space antenna factors and does not allow direct site-to-site NSA comparisons.' Furthermore, ANSI Accredited Standards Committee C63, Subcommittee 1, Working Group 1- 15.6 on Antenna Calibration is developing correction factors for the theoretical NSA model that include the effects that were previously neglected. A goal of the working group is an enhanced theoretical model that provides significantly improved accuracy for biconical antennas from 30 to 200 MHz. A future version of ANSI C63.4 will likely include these correction factors and reference a revision of ANSI C63.5-1998.

Procurement Specification for a Now Semi-anechoic Chamber

A new chamber should be designed and built to meet all current and proposed standards. Such was the case for the state-of-the-art 3-m semi-anechoic chamber discussed in this article. As shown in Figure 1 and Table 1, it provides NSA from 30 to 200 MHz that is within ±4 dB of the theoretical NSA calculated using free-space antenna factors. This is the requirement specified in ANSI C63.5-1998 and the intent of ANSI C63.5-1988. The chamber also meets the accepted interpretation of ANSI C63.51988 because its NSA from 30 to 200 MHz (Figure 3 and Table I) is within ±4 dB of the NSA measured on a near-ideal OATS. All horizontal and vertical chamber NSA from 200 to 1000 MHz also meet both of these requirements. Therefore, a 3-m semi-anechoic chamber that meets ANSI C63.5-1998 should also meet both the intent and the accepted interpretation of ANSI C63.5-1988.

If a 3-m semi-anechoic chamber meets ANSI C63.5-1998, it can also be expected to meet the requirements that would be imposed by an enhanced theoretical model. This is because chamber NSA errors usually add to the theoretical model errors and an enhanced model should provide reduced errors at each frequency. Since the state-of-the-art chamber is within ±4 dB of the theoretical model in ANSI C63.4-1992, it can be expected to be even closer to an enhanced model. Another result of this error addition is that a chamber with NSA that is within ±4 dB of the theoretical model usually exhibits better overall performance than a chamber that only meets the requirements of a direct site-to-site NSA comparison. An examination of the NSA data in Figures I and 3 and Table I reveals that this is the case for the state-of-the-art chamber from 30 to 200 MHz.

Conclusion

The objective of ANSI C63.5-1988 is to compare the NSA of a semi-anechoic chamber to a theoretical NSA calculated using free-space antenna factors. However, the accepted interpretation of ANSI C63.5-1988 allows chamber NSA to be directly compared to the NSA measured on any unspecified OATS. Therefore, semi-anechoic chamber performance is currently unregulated. Even if the near-ideal OATS were properly specified, the greater accuracy of the direct site-to-site NSA comparison would be negated by its disadvantages. Adequate control of chamber performance is achieved with ANSI

C63.5-1998. A chamber that is designed and built to meet this standard should provide state-of-the-art performance that is better overall than the performance of a chamber that only meets the requirements of a direct site-to-site NSA comparison. Such a chamber should also meet both the intent and the accepted interpretation of ANSI C635-1988 and can be expected to meet any requirements imposed by an enhanced theoretical NSA model. Improved control of chamber performance will occur if the enhanced theoretical NSA model is incorporated into a future version of ANSI C63.4 as anticipated.

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