

Attachment B : ANALYSIS

An Analytical Comparison of Radiated Emissions Test Facilities

Clark Vitek
EMC Staff Engineer
CKC Laboratories, Inc.
5473A Clouds Rest
Mariposa, CA 95338

ABSTRACT

Radiated Emissions measurements are usually required to be performed on a facility that meets the Normalized Site Attenuation (NSA) and receive antenna scan height requirements of ANSI C63.4 and CISPR 22. However, often times preliminary measurements for the purpose of frequency identification or engineering and troubleshooting are performed at fixed scan height indoor semi-anechoic facilities or free space facilities. Free Space facilities, in particular, have been put forth as a possible future alternative standard to OATS for certification measurements. An analytical comparison of the relative merits of these different types of facilities is presented.

INTRODUCTION

The benefits of a utilizing a free space test environment to reduce measurement uncertainty for radiated immunity tests are largely acknowledged in the revision of IEC 1000-4-3 (IEC 801-3, Second Edition)^[1]. Previous works by other authors have fully detailed the benefits of a fixed height free space environment compared to the fixed height semi-anechoic for maintaining field uniformity during immunity testing.^[2] It has been suggested that the improved field uniformity of a free space environment may also yield improvements in measurement uncertainty and test repeatability for radiated emissions tests^{[3],[4],[5],[6],[7]} and such facilities may also be used for certification testing of intentional radiators in accordance with ETSI standards^[8]. The purpose of the analysis detailed in this paper was to compare three commonly used types of test facilities to promote an understanding of the fundamental characteristics inherent to each for FCC Part 15 or CISPR 22 type radiated emissions tests : 1) An ideal open area test site (OATS) utilizing a 1-4m receive scan height, 2) a fixed-height semi-anechoic facility, and 3) a fixed-height free space facility.

BACKGROUND

Previous works have produced detailed models for Equipment Under Test (EUT) employing both loop and dipole radiators for the free space environment^[9]. The Effective Free Space Distance model selected for use in the analysis of this paper is consistent with that earlier work and was specifically chosen to maintain continuity with the model for Normalized Site Attenuation (NSA) as it appears in ANSI C63.4 Tables 1 and 2.^[10] The concept of using effective free space distance to model Normalized Site Attenuation (NSA) was suggested in [11] and the models employed for this paper produce

exactly the same results for NSA as Table 1 and 2 of ANSI C63.4 (1992) when the same geometries are assumed.

On an OATS site, the maximum signal received by an receive antenna scanned from 1-4 meters occurs at the point of minimum effective free space distance. The following equations can be used for the computation of effective free space distance on an OATS :

For Vertical polarity, the effective free space distance on an OATS is as follows :

$$D_{eff} = \frac{D_1^3 D_2^3}{R^2 \sqrt{D_1^6 + D_2^6 + 2 D_1^3 D_2^3 \cos[\mathbf{b}(D_2 - D_1)]}} \quad (1)$$

For Horizontal polarity, this effective distance is given by :

$$D_{eff} = \frac{D_1 D_2}{\sqrt{D_1^2 + D_2^2 + 2 D_1 D_2 \cos[\mathbf{p} - \mathbf{b}(D_2 - D_1)]}} \quad (2)$$

where D_1 and D_2 are the direct and indirect path lengths in meters, and $\beta = 2\pi/\lambda$. In Free Space, the effective free space distance is equal to D_1 , the direct path length.

The equation for Normalized Site Attenuation (NSA) that produces the same results as contained in ANSI C63.4 Tables 1 and 2 is as follows :

$$NSA = \frac{R_s \cdot R_L}{R_s + R_L} \cdot \frac{I \cdot D_{eff}}{Z_0} \quad (3)$$

where λ is the wavelength in meters, D_{eff} is the minimum effective free space distance, R_s and R_L are the source and load impedances of the measurement system (usually 50 ohms), and Z_0 is the characteristic impedance of free space (120π ohms).

ANALYSIS OF NSA OVER TEST VOLUME OCCUPIED BY TABLE TOP EQUIPMENT

For the analysis presented below, the EUT test volume is constructed around an assumed 2 meter diameter turntable. The source of emissions from the equipment is analyzed from 0.4m below the table top height to 0.7m above the table top height. Note that on an OATS

Attachment B : ANALYSIS

site this corresponds to transmit heights between 0.4m and 1.5m above ground since the table top is usually located at 0.8m above ground. The heights are stated referenced to the table top for consistency because in the free space model considered, there is no ground plane.

The following heights and positions were included in the analysis in an effort to bound the front half of the volume that would be occupied by the EUT :

NSA Analysis Positions :

- Front Position : 3 meters from Receive Antenna
- Middle Position : 3.5 meters from Receive Antenna
- Side Position : 4.123 meters from Receive Antenna

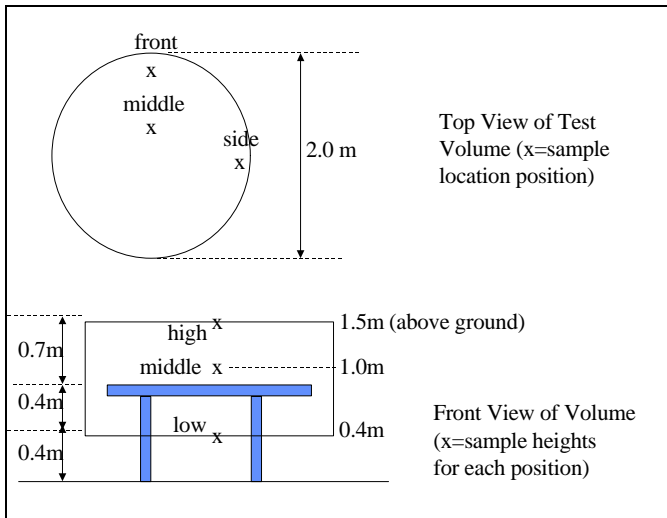
NSA Analysis Heights:

- 0.4m below table top (0.4m above ground)
- 0.2m above table top (1.0m above ground)
- 0.7m above table top (1.5m above ground)

Note that only the front half of the EUT volume is considered since an EUT would normally be rotated during the performance of the measurements and it is assumed that any emissions from the back half of the turntable would be maximized when the EUT is rotated to the front half. Also, note that the exact center position is not considered since this distance (4m) is very close to the same distance obtained from the side positions for the small turntable considered (4.123m).

Figure 1 Illustrates the construction of the Normalized Site Attenuation model.

FIGURE 1 : NSA MODEL CONSTRUCTION



ANALYSIS RESULTS

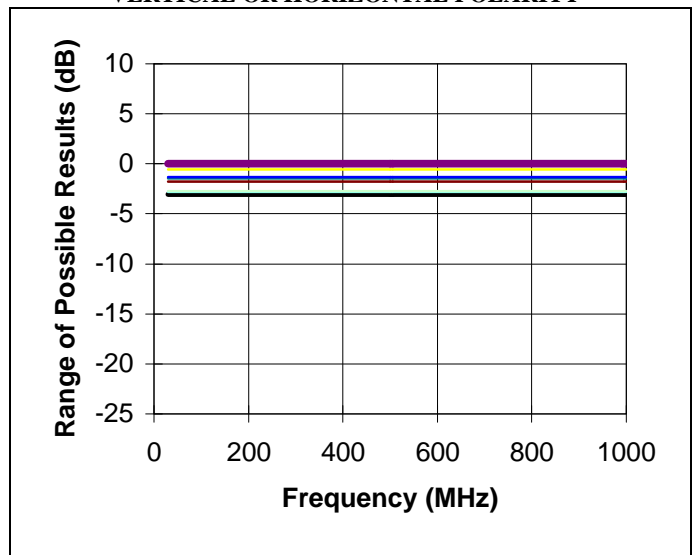
The above described analysis was performed by the use of an Excel spreadsheet to perform the multiple calculations. The results are presented to compare the range of possible results obtained at the receive antenna based on the different source locations within the test volume. The baseline values (0 dB) on these charts are the ideal

isotropic 3 meter free space result. Each of the following plots contains nine traces, one for each of the analyzed positions and heights. However, all traces may not be visible due to the scale of the plots and the fact that some traces may lay over others. The primary purpose of this presentation is to illustrate the minimum to maximum range of possible results obtained over the relatively small test volume analyzed.

CONCLUSIONS

Analysis of Normalized Site Attenuation suggests that for certification measurements in the future the fixed height free space environment most closely bounds the range of possible results over frequency, polarity and emissions source location within the EUT volume. This would suggest that lower measurement uncertainty and better test repeatability would be achievable in a standard free space environment than with the existing OATS standard. The tighter bound of possible results presented over the test volume in Free Space means that the maximum emissions obtained will be less sensitive to placement of equipment under test, variation of cable location, and operator introduced errors such as improper variation of scan antenna height over all turntable angles, frequencies and polarities to be investigated. With respect to the present day practice of using a fixed height semi-anechoic chamber to generate a frequency list for further a full scan height investigation, the analysis suggests that this practice could introduce a potentially large additional uncertainty through the use of a fixed height to perform the pre-scan and frequency selection.

FIGURE 2 : RANGE OF POSSIBLE RESULTS BASED ON ANALYSIS OF NORMALIZED SITE ATTENUATION FIXED (1.5m) FREE SPACE CHAMBER 3 METER TEST DISTANCE, 30 MHz - 1000 MHz VERTICAL OR HORIZONTAL POLARITY



Attachment B : ANALYSIS

FIGURE 3: RANGE OF POSSIBLE RESULTS BASED ON ANALYSIS OF NORMALIZED SITE ATTENUATION OATS SITE, 1-4m RECEIVE SCAN HEIGHT 3 METER TEST DISTANCE, 30 MHz - 1000 MHz VERTICAL POLARITY

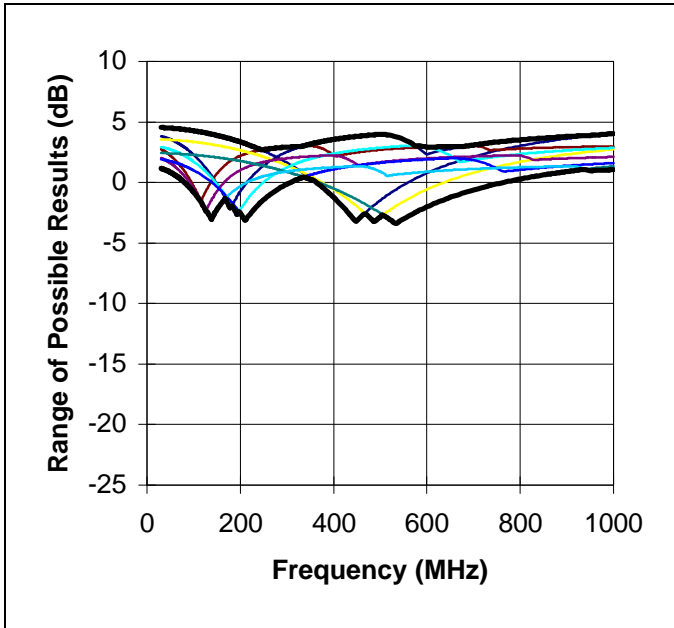


FIGURE 5: RANGE OF POSSIBLE RESULTS BASED ON ANALYSIS OF NORMALIZED SITE ATTENUATION FIXED 1.5M RECEIVE HEIGHT SEMI-ANECHOIC 3 METER TEST DISTANCE, 30 MHz - 1000 MHz VERTICAL POLARITY

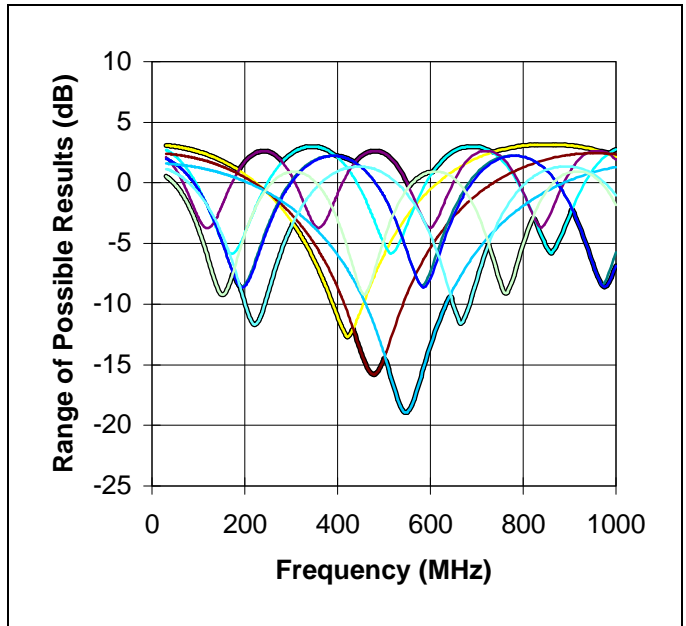


FIGURE 4: RANGE OF POSSIBLE RESULTS BASED ON ANALYSIS OF NORMALIZED SITE ATTENUATION OATS SITE, 1-4m RECEIVE SCAN HEIGHT 3 METER TEST DISTANCE, 30 MHz - 1000 MHz HORIZONTAL POLARITY

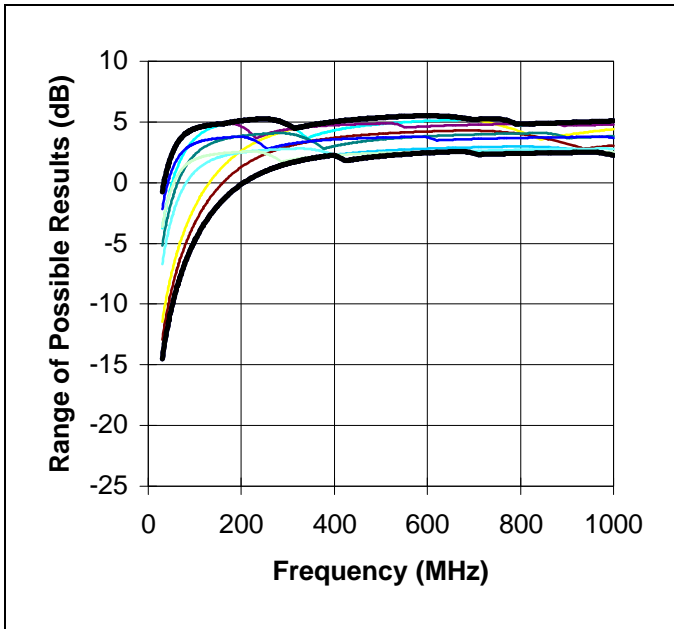
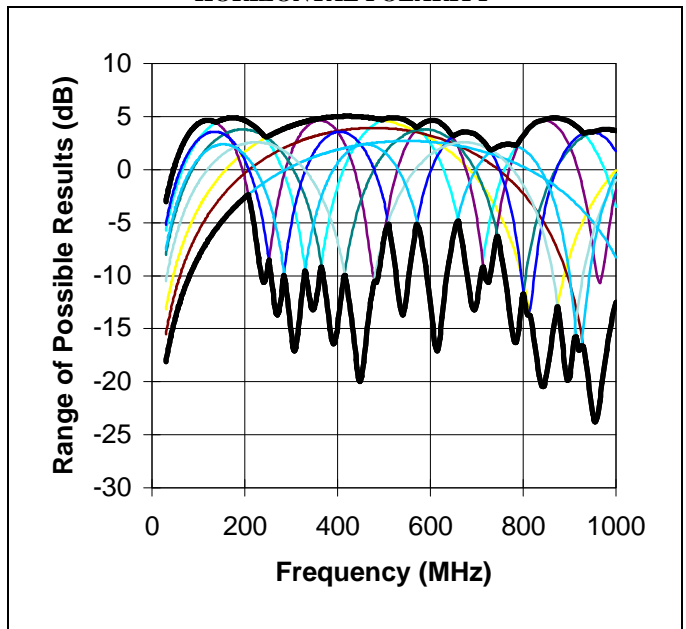


FIGURE 6: RANGE OF POSSIBLE RESULTS BASED ON ANALYSIS OF NORMALIZED SITE ATTENUATION FIXED 1.5m RECEIVE HEIGHT SEMI-ANECHOIC 3 METER TEST DISTANCE, 30 MHz - 1000 MHz HORIZONTAL POLARITY



Attachment B : ANALYSIS

GHz”, ISBN 1-55937-212-5, Copyright 1992 by the Institute of Electrical and Electronics Engineers.

REFERENCES

[1] IEC 1000-4-3 (1995), “Electromagnetic Compatibility (EMC), Part 4: Testing and Measurement Techniques, Section 3: Radiated, radio-frequency, electromagnetic field immunity test”, Copyright 1995 International Electrotechnical Commission (IEC), Rue de Varembe, Geneva, Switzerland. This standard has also been published with some modifications as a European Norm entitled EN61000-4-3 (1996).

[2] Heinrich Garn, Wolfgang Mullner, and R. Kresmer, “A Theoretical and Experimental Investigation of Field Homogeneity in Absorber lined Chambers for Radiated Susceptibility tests according to IEC 801-3 Second Edition”, IEEE 1994 International Symposium on Electromagnetic Compatibility, pages 138-143.

[3] Frank B.J.Leferink, Dick J Groot-Boerle, Ben R.M Puylaert, “OATS Emission Data Compared with Free Space Emission Data”, IEEE 1995 International Symposium on Electromagnetic Compatibility, pages 333-337, August 1995, Atlanta, Georgia.

[4] Roger A. McConnell and Clark Vitek, “Calibration of Fully Anechoic Rooms and Correlation with OATS Measurements”, IEEE 1996 International Symposium on Electromagnetic Compatibility, pages 134-139, August 1996, Santa Clara, California.

[5] Detlef Ristau and Diethard Hansen, “Correlation of Fully Anechoic to OATS Measurements”, ITEM Update 1996, pages 78 - 83, Copyright 1996, R&B Enterprises, West Conshohocken, PA.

[6] Clark Vitek, “Free Space Chambers for Radiated Emissions Measurements”, EE – Evaluation Engineering, May 1997 issue, pages 150 – 161, Copyright 1997, Nelson Publishing.

[7] CENELEC SC210/WG4 FAR STANDARD “prEN50147 Part 3 : Emissions Measurements in Fully Anechoic Chambers”, draft October 1997. Committee Co-Chairs : Anton Kohling and M.J. Alexander.

[8] ETS 300 220, “Radio Equipment and Systems ; Short Range devices technical characteristics and test methods for radio equipment to be used in the 25 MHz to 1000 MHz frequency range with power levels ranging up to 500 mW”. European Telecommunications Standards Institute (ETSI), October 1993. This reference is provided as an example of dozens of ETSI standards that accept free space measurements for intentional radiators and spurious emissions.

[9] Heinrich Garn, “Radiated Emission Measurements in Completely Absorber Lined Anechoic Chambers without Groundplanes”, IEEE 1989 International Symposium on Electromagnetic Compatibility, pages 390-393, Denver, Colorado.

[10] ANSI C63.4 (1992), “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

[11] Smith, A.A, German, R.F., and Pate, J.B., “Calculation of Site Attenuation from Antenna Factors,” IEEE Transactions on Electromagnetic Compatibility, Volume EMC-24, No. 3, August 1982.

[