Are Fully Anechoic Chamber Emission Measurements in Compliance with the Standards?

Authors: Toralf Jahn, Dr. Diethard Hansen
EURO EMC SERVICE (EES) Dr. Hansen GmbH, D-14513 Teltow, Germany
Phone: +49 3328-430 141, homepage: http://www.euro-emc-service.de

Abstract

In a recent article we have shown, good correlation between 3 m Fully Anechoic Lined Chambers (FALC) and 10 m Open Area Test Site (OATS) results for radiated emission testing between 30 and 1000 MHz [1 in German]. Naturally this corresponding correlation is only valid if the correct theoretical / experimental conversion factors are used. In the following we demonstrate how to use and derive these factors. Of course the same limitations apply to the fully anechoic 3 m test facility as for any other 3 m site regarding Equipment Under Test (EUT)-size and near field problems in the lower frequency range. The detailed investigations have been carried out in a thesis at the Berlin institute of technology (TFH), 1995 by the first author [2].

1. Advantages using 3 m fully anechoic chambers

OATS measurements are known to be affected by all different types of ambience. In chambers there is shielding which protects both ways (emissions and immunity). Testing computers and other ITEs on an OATS it is often very difficult to find the emissions from the device at background interference levels which might be 50 dB higher than the limit. Turning on and of the EUT is not a good idea because of booting. Furthermore there are also numerous time varying interference sources e. g. mobile telephones. All this seems to be solved in a 10 m semi anechoic chamber, however certainly not in a cost effective manner. Such facilities could easily call for a multi million pound investment. Unfortunately such chambers require additionally special buildings because of antenna height scan considerations. Does it really make sense to test a small EUT like a telephone set in a huge chamber which could easily accommodate an automobile on the turn table?

A 3 m FALC (with absorbing floor) in contrast to OATS and 10 m semi anechoic chambers (with reflecting floors) only require a normal room height (3.3 m) for installation and will cost ca. 100.000,- Pound Sterling.

Analysing the measurement procedure (30 - 1000 MHz, receiving antenna height scan 1-4 m and turn table rotation of 360° at each of the 16.167 frequencies - 60 KHz steps) on such reflecting ground planes which are fully compliant with CISPR 16-1 and ANSI C63.4, respectively, leads to typical test times of up to 11 hours. In reality hardly any test house can afford this.

In FALCs this height scan of the receiving antenna is basically not necessary, because there is no indirect signal path which could introduce a phase problem by cancellation of the fields at a certain antenna height and frequency for a given test distance. This results in typical test times below 1,5 h. A further advantage is to use these fully lined facilities directly for immunity measurements at 3 m distance. There is no need to cover any ground plane and consequently waste time in setting up the EN 61000-4-3 test. There is also no need to consider height dependent antenna factors because of the quasi free space environment. These antenna factor changes over reflecting floor are known to be in between 2 - 6 dB, depending on the choice of antennas [3]. It is also interesting to know, that ETS 300xxx standards for radio type approvals recognise the fully anechoic chamber approach. It becomes clear from the above mentioned, that the only criteria to accept a FALC as an alternative emission test facility is it's successful correlation to the normalised site attenuation (NSA) at the 27 specified test frequencies in various locations of the given test volume. Let us consequently now look at how to derive the appropriate conversion factors.

2. Calculation of the conversion factors

For simplification we will only consider the horizontal polarisation case. The complete analysis is given in [2]. The international literature [4, 5] confirms the findings in [2], however using a slightly different approach.

The standardised test facility for radiated emission measurements is an OATS with metallic ground plane. The schematic of an OATS is given in fig. 1. The EUT and the receive antenna have a fixed distance of d. The EUT is positioned at constant height h1. The antenna receives the direct signal via the path dd and the reflected signal from the ground by di. To determine the conversion factors is necessary to analyse the ratio of field strengths at the receive antenna. Due to the strong impact of the individual field strength with the corresponding phase angle on the resulting field strength Eges it is useful to switch to the complex plane (fig. 2). Ed and Ei are the electromagnetic waves hitting the receive antenna by the direct path dd and the indirect path di. The resulting field strength is Eges. With:

$$
\begin{aligned}
2\pi &= 2\alpha + 2\varphi \\
\alpha &= \pi - \varphi \\
\alpha &= \pi - \left(\varphi d - \varphi i\right)
\end{aligned}
$$

equation 1

To determine ♑d:

$$\frac{d_d}{\lambda} = \frac{\varphi_d}{2\pi}$$

$$\varphi_d = \frac{2\pi * d_d}{\lambda}$$

equation 2

From the Fresnel equations we find the reflection factor of -1 for horizontal polarisation. Consequently the indirect wave, in the case of horizontal polarisation, is phase shifted by π. Therefore:

$$\frac{d_i}{\lambda} = \frac{\varphi_i \pm \pi}{2\pi}$$

$$\varphi_i = \frac{2\pi * d_i}{\lambda} \pm \pi$$

equation 3

Inserting equation 2 and 3 into 1 results in ♋:

$$\alpha = \frac{2\pi}{\lambda}(d_i - d_d)$$

equation 4

Ed, Ei and Eges form a triangle. With the Cos-theorem we find:

$$\left|\underline{E}_{ges}\right|^2 = \left|\underline{E}_d\right|^2 + \left|\underline{E}_i\right|^2 - 2 * \left|\underline{E}_d\right| * \left|\underline{E}_i\right| * \cos\alpha$$

equation 5

This is the resulting field strength. Now we search for the conversion factor U to transform the 3 m FALC test results (no reflecting ground) into the 10 m test result (with reflecting ground). To simplify this we assume a half wave dipol as radiation source. This results in:

$$\left|\underline{E}_{ges}\right|^2 = \left|\frac{7 * \sqrt{P_s}}{d_d}\right|^2 + \left|\frac{7 * \sqrt{P_s}}{d_i}\right|^2 - 2 * \left|\frac{7 * \sqrt{P_s}}{d_d}\right| * \left|\frac{7 * \sqrt{P_s}}{d_i}\right| * \cos\alpha$$

$$\left|\underline{E}_{ges}\right| = 7 * \sqrt{P_S} * \sqrt{\frac{1}{d_d^2} + \frac{1}{d_i^2} - 2 * \frac{1}{d_d * d_i} * \cos\alpha}$$

equation 6

The conversion factor U between sites with reflecting ground and the corresponding total field strength Eges and those without reflecting ground with the corresponding field strength from the FALC EV is given in the next equation, where dV is the test distance in the FALC.

$$U = \frac{\left|\underline{E}_{ges}\right|}{\left|\underline{E}_{V}\right|} = \frac{7 * \sqrt{P_S} * \sqrt{\frac{1}{d_d^2} + \frac{1}{d_i^2} - \frac{2}{d_d * d_i} * \cos\alpha}}{7 * \sqrt{P_S} * \frac{1}{d_V}}$$

$$U = \frac{\left|\underline{E}_{ges}\right|}{\left|\underline{E}_{V}\right|} = d_V * \sqrt{\frac{1}{d_d^2} + \frac{1}{d_i^2} - \frac{2}{d_d * d_i} * \cos\alpha}$$

equation 7

It becomes evident, the characteristic of the radiation source is cancelled. The conversion factor U depends on the geometry of the test site. Table 1 shows this factor aU for the 3 m FALC and the 10 m OATS with h1 = 1 m, h2 = 1 - 4 m for horizontal antenna polarisation.

3. Checking the conversion factors

To check the resulting conversion factors we calculated the NSA of the 3 m FALC and used the conversion factors to compare the results with the specified NSA of the 10 m OATS. The agreement is excellent.

Additionally we tested the findings in a FALC 7 m x 3 m x 4 m lined with ferrites and using a 3 m diagonal test distance. The diagram 1 shows the FALC to be within the +/- 4 dB NSA criteria. To prove this with real EUTs we refer to [1] within the internationally well known error bounds (+/- 6 to +/- 12 dB) comparing accredited 10 m OATS.

It is important to highlight the possibility to correctly apply these factors also to the 30 m OATS (EN 55011: 10/97 ISM group 1, class A). This implies in principle to be able to process and correlate the FALC measurement results, after finishing the test, to any other test distance.

4. Is the 3 m test distance with reflecting ground an alternative?

EN 55022, class B for ITE equipment permits to use a 3 m test distance with reflecting ground. To convert to the standard 10 m distance, 10 dB should be subtracted. This is permitted in spite of considerable, known measurement errors. Converting a 3 m test result to a 10 m test distance under class A is not permitted.

EN 55011 requires 10 m or 30 m test sites with reflecting ground plane. This means, using a 3 m absorber chamber with reflecting ground, for EN 55011 is not in accordance with the standards. It is understood that subtracting 10 dB as a general rule leads to considerable errors. Taking the NSA table for various test distances of 3, 10 and 30 m according to CISPR 16-1 and ANSI C63.4/1992, respectively, shows the following values for broad band antennas (h1 = 1 m, h2 = 1 to 4 m):

Comparing 10 m nominal distance results to 3 m actual distance, both with ground plane				
frequency	NSA 10 m (dB)	10 m- value minus 10 dB	NSA 3 m (dB)	final test result
30 MHz horiz.	29,8	19,8	15,8	4 dB too high
180 MHz vert.	1,8	-8,2	-1,3	6,9 dB too low

This means even for ideal sites the deviation is 6,9 dB. In the worst case there is an additional 8 dB error of the site even for sites perfectly fulfilling the +/- 4 dB NSA criteria. The maximum error could be as high as 15 dB!

The same errors result from using a 10 m OATS instead of 30 m OATS and subtracting 10 dB from the measurement result.

Comparing 30 m nominal distance results to 10 m actual distance, both with ground plane				
frequency	NSA 30 m (dB)	30 m-value minus 10 dB	NSA 10 m (dB)	final test result
30 MHz horiz.	47,8	37,8	29,8	8 dB too high

This means, even for ideal sites the deviation is 8 dB. In the worst case there is an additional 8 dB error of the site even for sites perfectly fulfilling the +/- 4 dB NSA criteria. The maximum error could be as high as 16 dB!

This phenomena does not exist in FALCs using the above mentioned individual conversion factors.

Conclusions

Fully anechoic lined chambers offer cost effective, technically correct and compliant alternative solution to the classical OATS or semi anechoic chambers with reflecting ground plane. The FALC must be prudently designed and the individual conversion factors must be correctly incorporated into the emission software. Numerous round robin tests with real EUTs, including cables, have demonstrated the equivalence (or even better) of the test results with the classical OATS reference procedure.

Literature

[1] Diethard Hansen, Stefan Mößler: „Normgerecht ist nicht gleich Normengerecht“ EMV-ESD Ausgabe 4/97

[2] Toralf Jahn: „Untersuchung über die Vergleichbarkeit von Messungen der elektromagnetischen Feldstärke in Absorbermeßhallen und auf Freifeldern“ Diplomarbeit TFH-Berlin (Feb. 1995)

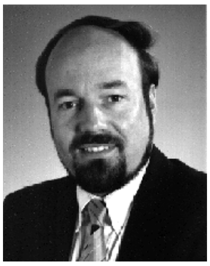
[3] Martin J. Alexander: „Measurement Good Practice Guide No 4, Calibration and Use of EMC Antennas“; National Physical Laboratory, Teddington, Meddlesex, United Kingdom TW11 0LW; ISSN 136-6550; (April 1997)

[4] Roger McConnell, Clark Vitek: „Calibration of fully anechoic rooms and correlation with OATS measurement“, IEEE International symposium on EMC, Santa Clara USA (Aug. 1996)

[5] Detlef Ristau, Diethard Hansen: „Correlating Fully Anechoic to OATS Measurements“ 13th Wroclaw Symposium and Exhibition on EMC (June 1996)

Toralf Jahn is an EMC engineer at EURO EMC SERVICE (EES) DR. Hansen GmbH, Teltow, Germany since 1995. The conversion algorithm was engineered during his master thesis at TFH Berlin. Prior to his employment with EES he worked as a radio and EMC approval and test expert for Robert Bosch GmbH Berlin in the field of mobile communications. His special interest includes radiated phenomena, antenna calibration and CE radio type approval testing.

Dr. Diethard Hansen is the president of the EES company group. EES is specialising as an accredited test lab and certification body in the following areas: EMC, TTE, LVD, Radio, Automotive, Medical as well as Machinery. EES has world wide branch offices serving the clients additionally with consulting, training and R&D (EES EMC test product division).
Dr. Hansen received his BS EE and Economics from Esslingen and his MS as well as PhD from TU Berlin and has been engaged in EMC and NEMP for more than 15 years in North America and Europe. He has published over 130 professional papers around the world and is listed as inventor on more than 35 patents including the GTEM cell and the EUROTEM. He is an active member in the international EMC standardisation and a lead auditor for EMC in the German accreditation system. Dr. Hansen is a member of the board of the European Association of Competent Bodies.



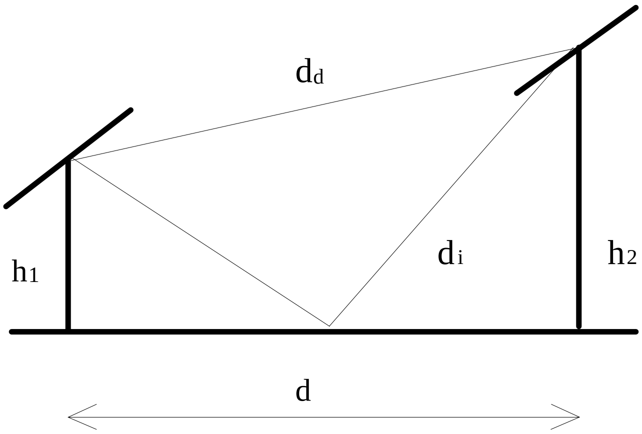


Fig.1: Geometry and schematic of the OATS

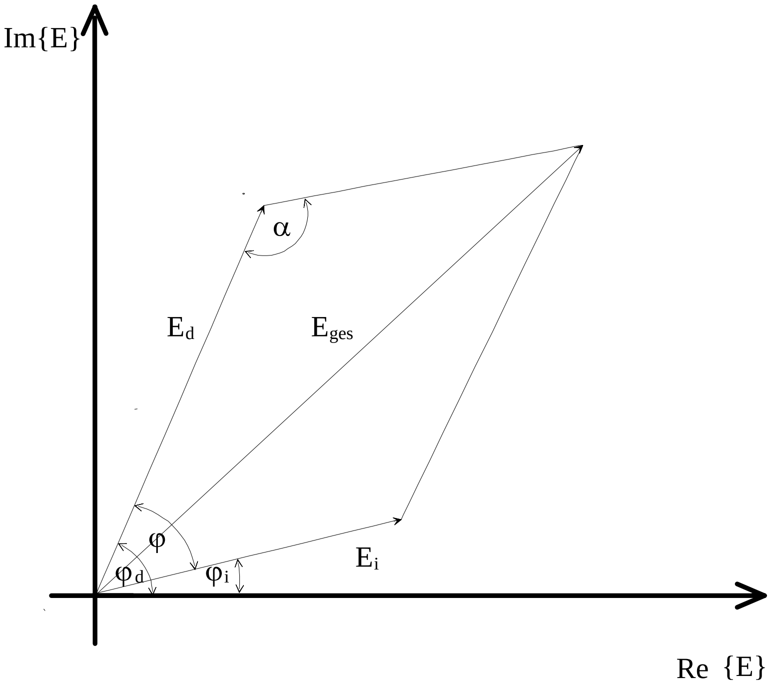


Fig.2: Received field strength in the complex plane

f [MHz]	aU [dB]
30	-17,7
35	-16,4
40	-15,4
45	-14,4
50	-13,5
60	-12
70	-10,8
80	-9,8
90	-8,9
100	-8,2
120	-7
125	-6,8
140	-6,2
150	-5,8
160	-5,6
175	-5,3
180	-5,2
200	-5,08
250	-4,86
300	-4,75
400	-4,63
500	-4,58
600	-4,55
700	-4,54
800	-4,63
900	-4,77
1000	-4,72

Table 1: Conversion ratio aU for 3 m FALC and 10 m OATS (h_1 = 1 m, h_2 = 1 to 4 m, horiz.)

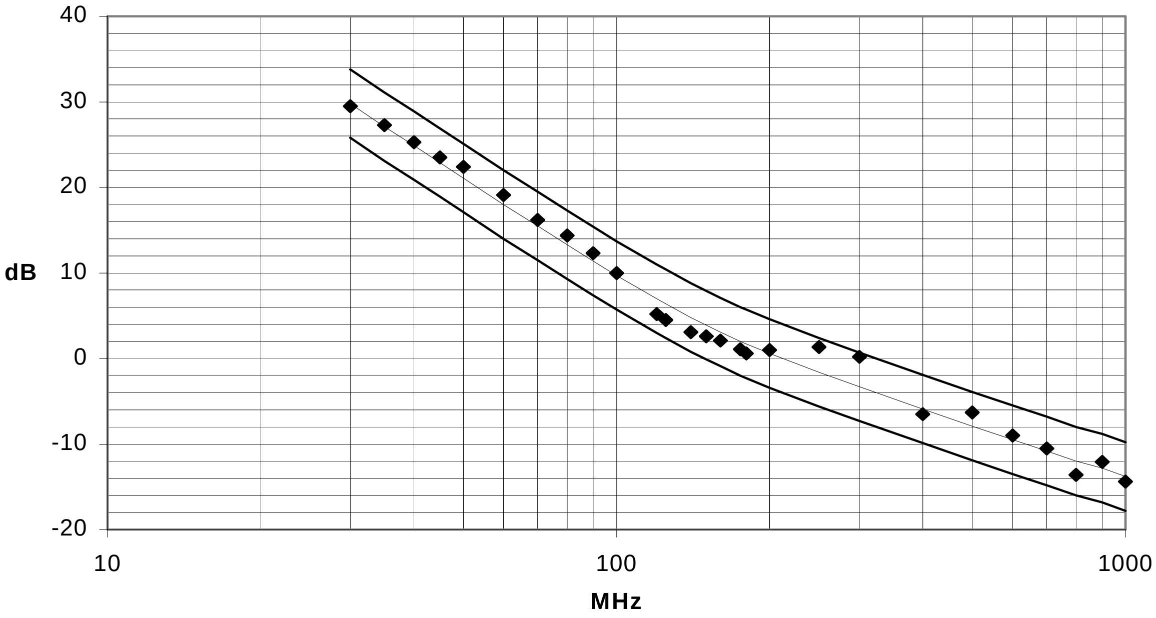


Diagram 1: Measured NSA in the 3m FALC in comparison with the norms of the 10m OATS