Correlating Fully Anechoic Chamber to Open Area Test Site Measurements by the Normalized Site Attenuation

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Abstract

The performance of a fully anechoic chamber (FAC) for radiated emission (RE) measurements has been evaluated using the normalized site attenuation (NSA). To do this, the antenna factor (AF) of a set consisting of nearly identical antennas has been calibrated at an open area test site (OATS). Appropriate correlation factor (CF) between the chamber and the OATS has been calculated. Results show that the performance of the chamber is fairly good with respect to the ANSI-limit except 41～66 MHz for vertical polarization and near 900 MHz for horizontal polarization.

Key words : correlation, normalized site attenuation, radiated emission, open area test site, fully anechoic chamber

Ⅰ. Introduction

Since radiated emission (RE) measurements have been made at the OATS, considerable efforts have been focused on overcoming the ambient noise problem at the OATS. One of the attempts is to use a fully anechoic chamber (FAC) [1]～[4]. Suitability of the FAC to RE measurements is also verified by evaluating the normalized site attenuation (NSA) of the FAC [5]～[7]. This approach is originated from the evaluation method of the OATS specified in [8],[9].

In [6], it is reported that the results of the theoretical emission model for the correlation of the FAC to OATS are better than ±4 dB according to ANSI/IEEE C63.4 [8]. Moreover, a draft document for RE measurements in FACs has been proposed [10]. In this paper, we use the same approach proposed in [6], [10]. The method correlating FAC to OATS measurements using the NSA is briefly described and it will be applied to a specific FAC, i. e., an immunity chamber for the IEC 61000-4-3 immunity test [11] installed at the Korea Research Institute of Standards and Science (KRISS). Measured results are compared with the ANSI limits of ±4 dB and a few concluding remarks summarize this chapter.

Ⅱ. Theory

2-1 The CF between FAC and OATS Measurements

In this paper, it is assumed that the inner space of the chamber is free space. This means that there are no reflected waves inside the chamber. Therefore, fields of the chamber due to an electrically small dipole are easily obtained. In calculating a correlation factor (CF) between the FAC and OATS, the near field-terms in the field expressions of the small dipole are accounted. It is noted that ANSI/IEEE C63.4 [8] does not take into account near-field effects for tuned dipoles, since they are included in the calculation of the mutual impedance correction.

The CF is defined as

$$C_{co}^{M-N} = 20\log\frac{|E_{\text{OATS}}|_N}{|E_{\text{FAC}}|_M} \tag{1}$$

where $|E_{\text{OATS}}|_N$ and $|E_{\text{FAC}}|_M$ are the electric field strengths at an N m-OATS and in an M m-FAC, respectively. Note that the field strengths at the N m-OATS should be calculated in specified height range of the receive antenna corresponding to the measurement distance.

Fig. 1 shows C_{co}^{3-3} for both horizontal and vertical polarizations. It can be observed in Fig. 1 that the CFs with and without near-field terms lead to difference of as much as 1.0 and 0.8 dB for horizontal and vertical polarizations, respectively.

2-2 The Normalized Site Attenuation

The NSA measuring method is described in detail in [8],[9]. An equation which implies basic measurement procedures is given by [8]

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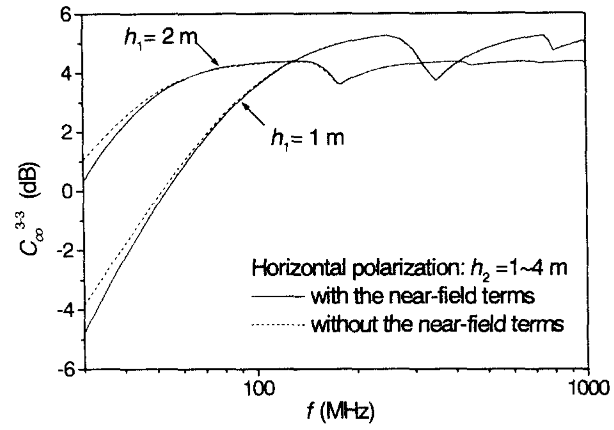
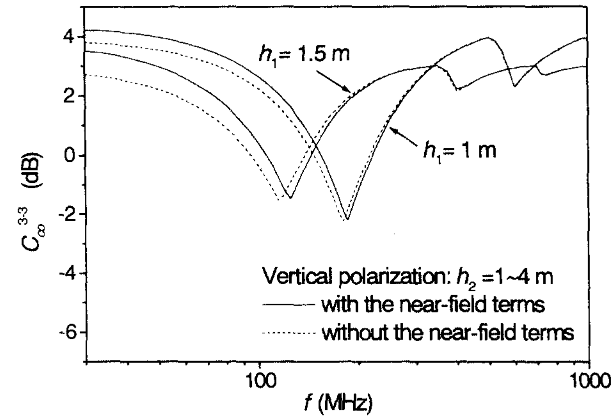


(a)



(b)

Fig. 1. Calculated correlation factor C_{co}^{3-3} for (a) horizontal and (b) vertical polarizations.

$$NSA_{\text{OATS}} = V_{\text{Direct}} - V_{\text{OATS}} - AF_T - AF_R - \Delta AF_{TOT} \quad (2)$$

where NSA_{OATS} = NSA measured at the OATS,

V_{Direct} = the reading of voltage with the two cables disconnected from the transmit and receive antennas and connected to each other via an adapter,

V_{OATS} = the reading voltage with the coaxial cables reconnected to their respective antennas and the maximum signal measured with the receive antenna scanned in height,

AF_T = antenna factor (AF) of the transmit antenna,

AF_R = AF of the receive antenna,

ΔAF_{TOT} = mutual impedance correction factor.

If the NSA is measured in the chamber, the similar equation for evaluating the NSA can be expressed by

$$NSA_{\text{FAC}} = V_{\text{Direct}} - V_{\text{FAC}} - AF_T - AF_R - \Delta AF_{TOT} \quad (3)$$

where

NSA_{FAC} = NSA measured in the FAC,

V_{FAC} = the reading voltage with the coaxial cables connected to their respective antennas and with the receive antenna placed at a fixed height in the chamber. It is assumed that all other terms in (3) are identical to those in (2). This implies that the AFs both at the OATS and in the FAC are assumed to be same each other even though they depend on the test facility. The received voltages V_{OATS} and V_{FAC} have the following relation using the CF defined in (1)

$$C_{co}^{M-N} = V_{N,\text{OATS}} - V_{M,\text{FAC}} = |E_{\text{OATS}}|_{N,\text{dB}\mu\text{V/m}} - |E_{\text{FAC}}|_{M,\text{dB}\mu\text{V/m}} \quad (4)$$

Inserting (4) into the two equations, (2) and (3), and taking difference between the two resultant equations give

$$NSA_{N,\text{OATS}}^{e} = NSA_{M,\text{FAC}} - C_{co}^{M-N} \quad (5)$$

Therefore, the NSA measured in the M m-chamber $NSA_{M,\text{FAC}}$ can be converted into an equivalent NSA at the N m-OATS $NSA_{N,\text{OATS}}$ by (5). The superscript 'e' indicates 'equivalent' and it denotes the corresponding NSA is not for an actual OATS but for a chamber.

Note that all terms in (2) and (3) are expressed in dB. Careful observation of (2) and (3) gives us two facts of importance: One fact is for ΔAF_{TOT}. Since we use two broadband antennas instead of two resonant dipoles for measuring the NSA in the chamber, we assume that there is no mutual coupling between transmit and receive antennas, i. e., $\Delta AF_{TOT} = 0$. The other is for determining the AF_s, AF_T and AF_R. We measured the AFs using the Standard Site Method (SSM) detailed in [12].

Ⅲ. The NSA Measurement System. in the FAC

Fig. 2 illustrates the system for measuring the NSA in the chamber. The FAC has been installed for the purpose of the RF immunity test according to IEC 61000-4-3 [11]. The FAC with the dimension of 8.36 m (L) × 5.94 m (W) × 3.00 m (H) has 19 mm-thick ferrite grid absorber backed by a metal plane on its six walls.

Ⅳ. Results and Discussion

4-1 Dependence of the NSA on the Receive Height

To investigate the dependence of the NSA on the receive height, the transmit antenna is positioned at a fixed height $h_1 = 1.5$ m. Then height of the receive antenna h_2 varies by 0.95, 1.2, 1.5, 1.8, and 2.1 m, respectively, above the floor of

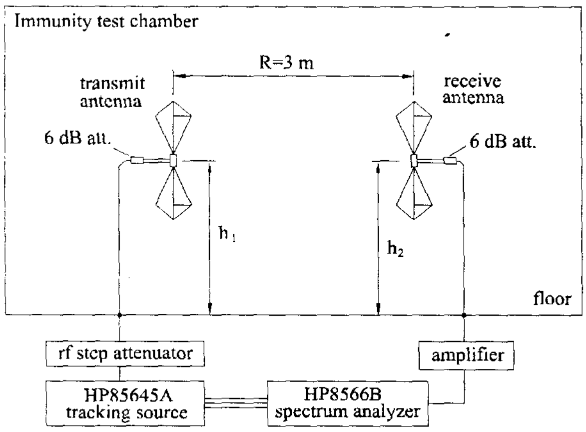


Fig. 2. The NSA measurement system in the chamber.

the chamber. The procedure to obtain the NSA of the chamber which is equivalent to the values of the OATS is as follows:

(a) Measure the voltage readings $V_{\rm FAC}$ and $V_{\rm Direct}$ by the system shown in Fig. 2.

(b) Calculate the measured NSA of the chamber $NSA_{\rm FAC}$ by substituting appropriate values into (3). Note that $AF_T = AF_R$ and $\Delta AF_{TOT} = 0$.

(c) Convert $NSA_{\rm FAC}$ into $NSA^{e}_{\rm OATS}$ using (5). Here, $NSA^{e}_{\rm OATS}$ is the NSA of the chamber which is equivalent to the NSA of the OATS.

(d) Compare $NSA^{e}_{\rm OATS}$ with the ANSI-limit to make a decision whether the chamber complies with the requirement of alternate test sites [8].

Fig. 3 shows the dependence of the NSA in the 3 m-immunity chamber on the receive height for horizontal polarization. The NSA falls within ±4 dB-limit in the frequency range of 30~300 MHz, while it deviates from the +4 dB-limit by 1.8 dB for $h_2 = 1.5$ m in 889~907 MHz-frequency range. However, the NSA complies with the ANSI-limit for $h_2 = 0.95$, 1.2, 1.8, and 2.1 m. Since the transmit antenna is fixed at the height of 1.5 m during the experiment, this means the symmetrical configuration of the transmit and receive antennas with respect to the chamber height H heavily affects the horizontally polarized fields in the chamber.

The dependence of the NSA in the 3 m-immunity chamber on the receive height for vertical polarization is shown in Fig. 4. The dependence on the receive height reaches up to 1.7 dB in 30~1,000 MHz-frequency range. It is noted that the NSA deviates from the ANSI-limit by a factor of 1.1 dB in the frequency range of 41~58 MHz.

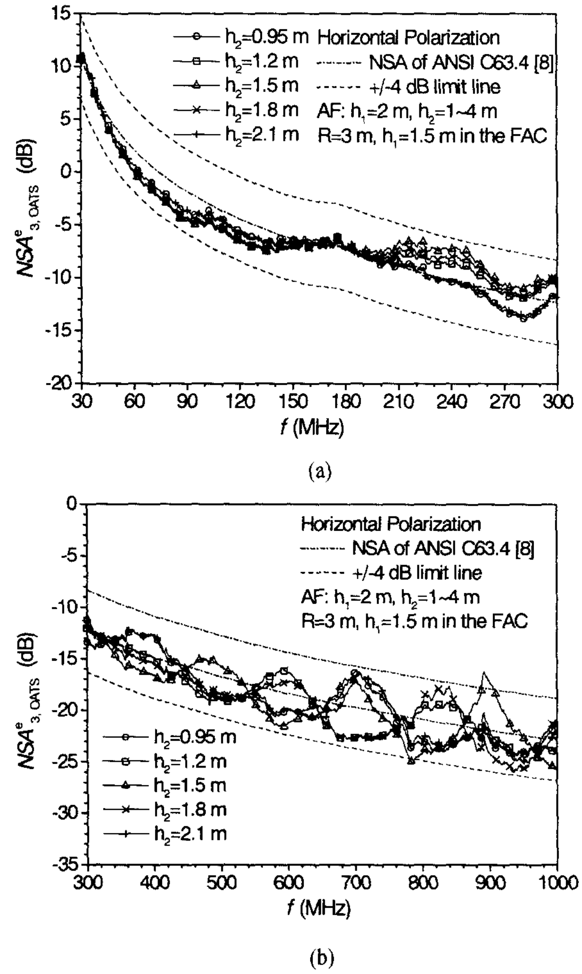


Fig. 3. The dependence of the NSA of the chamber on the receive antenna height for horizontal polarization. The AF measured under the condition of $R = 3$ m and $h_1 = 2$ m is used. (a) 30 MHz~300 MHz, (b) 300 MHz~1,000 MHz.

4-2 The NSA for Accounting a Test Volume

To take into account the volume of an equipment under test (EUT), the transmit antenna has been placed at various points within the test volume with both horizontal and vertical polarizations. It is assumed that the EUT does not exceed a volume of 1.0 m depth, 1.5 m width, 1.5 m height with the periphery greater than 1.0 m from the closest material, i. e., the grid ferrite absorber, that may cause undesirable reflections. Detailed measurement method is found in [8]. The graphical illustrations are not given here because the NSA behavior with respect to the test volume is quite similar to those regarding the receive height shown earlier. However, results show that the

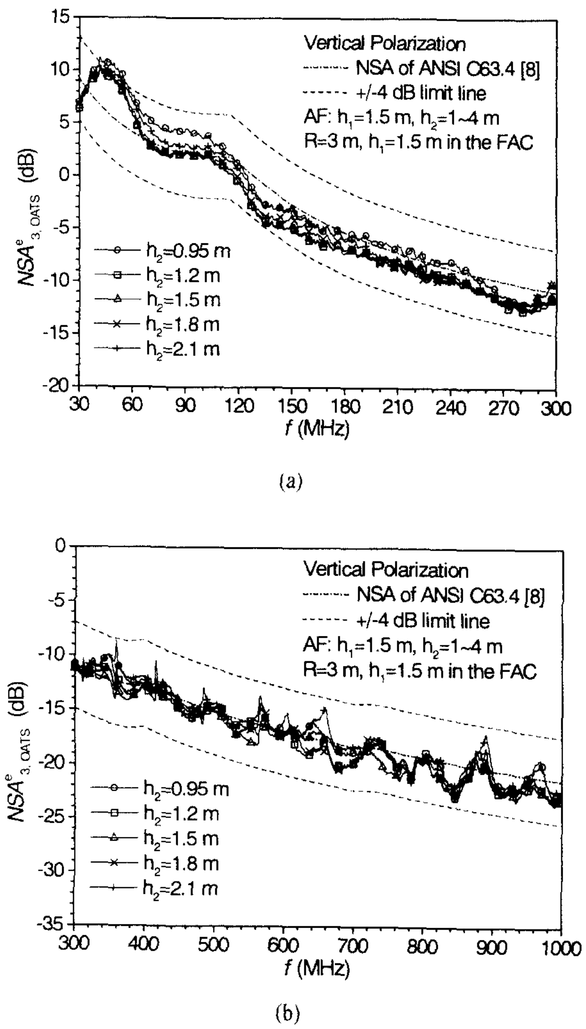


Fig. 4. The dependence of the NSA of the chamber on the receive antenna height for vertical polarization. The AF measured under the condition of $R=3$ m and $h_1=1.5$ m is used. (a) 30 MHz~300 MHz, (b) 300 MHz~1000 MHz.

performance of the chamber is fairly good with respect to the ANSI-limit except in 41 ~66 MHz-frequency range for vertically polarized case and near 900 MHz-frequency for horizontally polarized case.

V. Conclusion

In this paper, the performance of an FAC for RE measurements has been evaluated using the NSA. To do this, the AF of a set consisting of nearly identical antennas has been calibrated in advance at the OATS. Appropriate CF between the chamber and the OATS has been calculated. The distance between the transmit and receive antennas during the AF calibration and the NSA measurement in the chamber keeps constant as 3 m.

Results show that the performance of the chamber is fairly good with respect to the ANSI-limit except in extremely low frequency range for vertically polarized case and in extremely high frequency range for horizontally polarized case. These preliminary results will serve as a basis for further works to verify the RE measurements in the chamber.

References

[1] S. Roleson, "Practical statistical correlation of an rf absorber lined chamber and open area EMI test site", *IEEE Intl. Symp. Electromagn. Compat.*, USA, Aug. 1991, pp. 429-431.

[2] R. A. McConnel and C. Vitek, "Calibration of fully anechoic rooms and correlation with OATS measurements", *IEEE Intl. Symp. Electromagn. Compat.*, USA, Aug. 1996, pp. 134-139.

[3] D. Zhu and K. Y. Chok, "Modeling and correlation of radiated emissions generated in a fully anechoic chamber and at an OATS", *IEEE Intl. Symp. Electromagn. Compat.*, USA, Aug. 1998, pp. 147-152.

[4] L. Farber, "Statistical correlation between field strengths at an open area site and in an absorber-lined chamber", *IEEE Intl. Symp. Electromagn. Compat.*, USA, Aug. 1985, pp. 622-629.

[5] D. Hansen and D. Ristau, "Comparing the measurement results in a fully anechoic chamber (FALC) to those on four different OATS", *EMC'98 Symposium*, Wrozlaw, Poland, June 1998, p. 206.

[6] D. Ristau and D. Hansen, "Correlating fully anechoic to OATS measurements", *EMC'96, Symposium* Wrozlaw, Poland, June 1996, pp. 402-405.

[7] F. B. J. Leferink, D. J. Groot-Boerle, and B. R. M. Puylaert, "OATS emission data compared with free space emission data", *IEEE Intl. Symp. Electromagn. Compat*, Atlanta, GA, Aug. 1995, pp. 333-337.

[8] ANSI/IEEE C63.4: Methods of measurement of radio-noise emissions from low-voltage electrical and electronic equipment in the range of 9 kHz to 40 GHz, *American National Standards Institute*, 1992.

[9] CISPR 16-2, Specification for radio disturbance and immunity measuring apparatus and methods, Part 2: Methods of measurement of disturbances and immunity, *International Electrotechnical Commission, International Special Committee on Radio Interference (CISPR)*, Aug. 1999.

[10] Draft prEN50147-3: *Electromagnetic Compatibility Basic*

Emission Standard Part 3: Emission Measurements in Fully Anechoic Rooms.

[11] IEC 61000-4-3: Electromagnetic compatibility (EMC), Part 4: Testing and measurement techniques- Section 3: Radiated, radio-frequency, electromagnetic field immunity test, *International Electrotechnical Commission*, 1995.

[12] ANSI C63.5-1998, American National Standard for Electromagnetic Compatibility-Radiated Emission Measurements in Electromagnetic Interference (EMI) Control-Calibration of Antennas (9 kHz to 40 GHz), *American National Standards Institute*, Dec. 1998.

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