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NORMALIZED SITE ATTENUATION MODELING OF INDOOR FACILITIES USED FOR ELECTROMAGNETIC COMPATIBILITY TESTING

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Abstract: *Models of Anechoic and semi anechoic chambers for electromagnetic compatibility tests are proposed. Normalized site attenuations in the frequency range of 30 to 1000 MHz in both cases are determined using full electromagnetic simulation in HFSS software environment. The received results can be used as a reference in the validation tests of anechoic and semi anechoic facilities.*

Key words: *Electromagnetic compatibility, Normalized site attenuation, Anechoic and Semi anechoic chambers.*

1. INTRODUCTION

Normalized site attenuation (NSA) measurement is a basic procedure for anechoic indoor facilities validation tests. NSA measured values over the specified frequency band are than compared with the reference values of so called "ideal" anechoic chamber and the deviations should satisfy the requirements of the standard. The validation procedures for the frequency ranges of 30 to 1000 and 1000 to 18000 MHz are described in detail in the ETSI recommendation ETSI 102.321. V1.1.1. [1]. The described validation procedure can be applied mainly for full anechoic facilities, when all side walls, celling and floor are covered with radio absorbers in order to eliminate signal reflections over the operational frequency range. The validation procedures for semi anechoic chambers with perfectly conductive metal floor are still not well defined. In this paper models of ideal anechoic and semi anechoic chambers are proposed and using full electromagnetic simulation it is possible to determine normalized site attenuation values and to investigate the influence of floor reflections on antennas patterns (respectively on antenna factors) and on radio channel attenuation. Data for 3 m ideal semi anechoic chamber normalized site attenuation are presented for specific frequencies in the frequency range 30 to 1000 MHz.

2. NORMALIZED SITE ATTENUATION FOR IDEAL ANECHOIC CHAMBER

In an ideal anechoic chamber, any reflections from the camera walls are fully eliminated and only direct signal pass between the reference antenna and device under test can be considered. The radio channel attenuation is strictly proportional to distance square. According to the standard verification procedure two similar adjustable half wave dipole antennas are needed for NSA measurement. Antennas are tuned precisely for any of the test frequencies. Transmit antenna is situated into the specific points

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within camera working area and the receiving antenna in the standard reference antenna position. Half wave dipole antenna in resonance have strictly defined gain of 1.64 (2.14 dB) and respectively strictly defined antenna factor (AF). The NSA than can be easily calculated by subscribing antennas AFs from signal channel loss. In that way NSA do not depends from the type of antennas used for verification. Standard NSA measurement test set up is shown on Fig. 1.

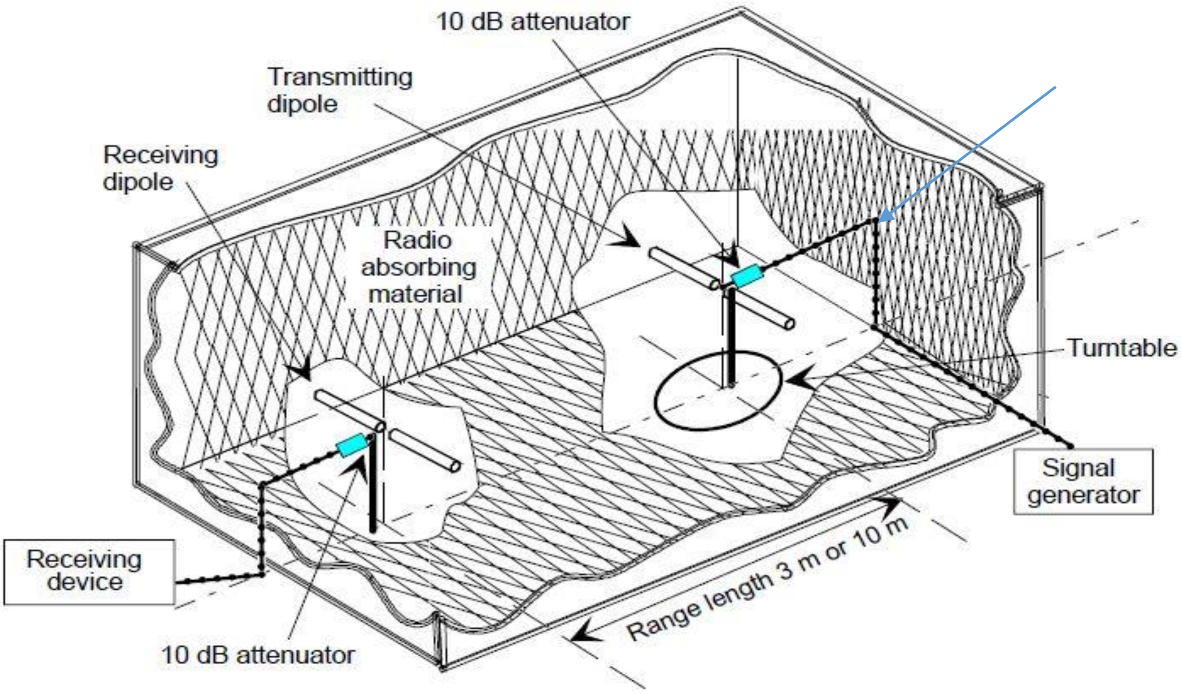


***Fig. 1.** NSA measurement standard test set up according to ETSI102.321 V1.1.1*

The tunable reference antennas are connected to the receiver and generator through the coaxial cables and 10 dB attenuators in order to guarantee the best matching especially for the lower part of the frequency band (below 100 MHz). Cables are equipped with ferrite beads to suppress parasitic radiation which can cause measurement errors. The transmit antenna is set in six defined points within the camera operation area which normally has form of a 1.4 X 1.4 m, 1.5 m above the camera floor. Tests for each one of the test points and for specific frequency need to be done for vertical and horizontal antennas orientation. Standard range lengths are usually 3 or 10 m.

According to the standard verification procedure NSA measurement needs to be done in two steps. In the first step coaxial cables are connected directly via attenuators pads and “in-line” adapter and the signal voltage measured by the receiver is marked as V_{direct}, Than cables are connected to the antennas inputs and the voltage V_{site} is measured. NSA can be calculated as:

$$NSA[dB] = V_{direct}[dB\mu V] - V_{site}[dB\mu V] - AF_t - AF_r - AF_{tot} \tag{1}$$

where AF_t and AF_r are antenna factors of the transmit and receive antennas and AF_{tot} is a mutual coupling correction factor (for frequencies below 80 MHz). The measured NSA values are compared with the NSA values for the “ideal” anechoic chamber for any specific frequency, positions and orientations of antennas. According to the standard the deviations should not exceed $\pm 4dB$.

NSA of an "ideal" anechoic chamber can be determined by the transmit and receive signal voltage in one "ideal" radio channel according to the equation shown below:

$$V_{site\ id}[dB\mu V] = E_{site\ id}[dB\mu V(m^{-1})] - AF[dB(m^{-1})] \quad (2)$$

From another side signal strength of transmitted signal can be calculated using transmit antenna factor TAF as:

$$E_{site\ id}[dB\mu V(m^{-1})] = V_{direct\ id}[dB\mu V] + TAF[dB\mu V(m^{-1})] \quad (3)$$

TAF can be expressed by AF as it is shown in [2]:

$$TAF[dB(m^{-1})]=20logF[MHz] - AF[dB(m^{-1})] - 20logr[m] - 32 \quad (4)$$

where r is the chamber range. Then:

$$V_{site}[dB\mu V]=V_{direct}[dB\mu V]+20logF[MHz] - AF - 20logr[m] - 32\text{-}AF \quad (5)$$

and

$$V_{direct}\text{-}V_{site}=-20logF[MHz] + 2AF[dB(m)^{-1}] + 20logr[m] + 32 \quad (6)$$

Having in mind equation (1) for the "ideal" NSA we have:

$$NSA_{ideal}[dB]=V_{direct}\text{-}V_{site} - 2AF = -20logF[MHz] + 20logr[m]+32 \quad (7)$$

Using equation (7) it is easy to calculate NSA_{ideal} for any frequency in the frequency range of 30 to 1000 MHz or 1000 to 18000 MHz and for any anechoic site range 3 or10 m.

3. "IDEAL" ANECHOIC CHAMBER MODELING

As it was shown above NSA of an "ideal" anechoic chamber can be easily calculated by (7). But it is not so easy for semi anechoic chambers since the attenuation in the signal channel depends strongly from the floor reflections. Antenna patterns (respectively AF) are also affected by the reflections and are frequency dependent. So, it is difficult to deliver the equation for NSA_{ideal} in case of semi anechoic environment which to be like the one done above. To investigate the problems connected with the NSA in semi anechoic chambers, we propose to use a model for full electromagnetic simulation of the signal propagation in the chamber and then to calculate the NSA for different frequencies and different antenna orientations. As a first step we shall investigate anechoic chamber model to compare the received by simulation NSA values with that calculated by (7) in order to verify the model consistency. Model of 3 m "ideal" anechoic range for full electromagnetic simulation by HFSS (High Frequency Structure Simulator) software is shown on Fig. 2. Models of half wave resonance dipole antennas are used to receive and transmit electromagnetic signals. Antennas are 1.5 m above the chamber floor. The anechoic chamber is modeled as radiation box covered with PML

(Perfect Matched Layer), to guarantee full reflections suppression. NSA of the ideal anechoic chamber is calculated by simulated radio channel loss $|S_{21}|$, which represents direct pass transmission coefficient.

Antenna factors are calculated by simulated antenna gain at specific frequency according to the equation [2]:

$$AF[dB(m^{-1})] = -29.78 + 20logF[MHz] - G_A[dB] \quad (8)$$

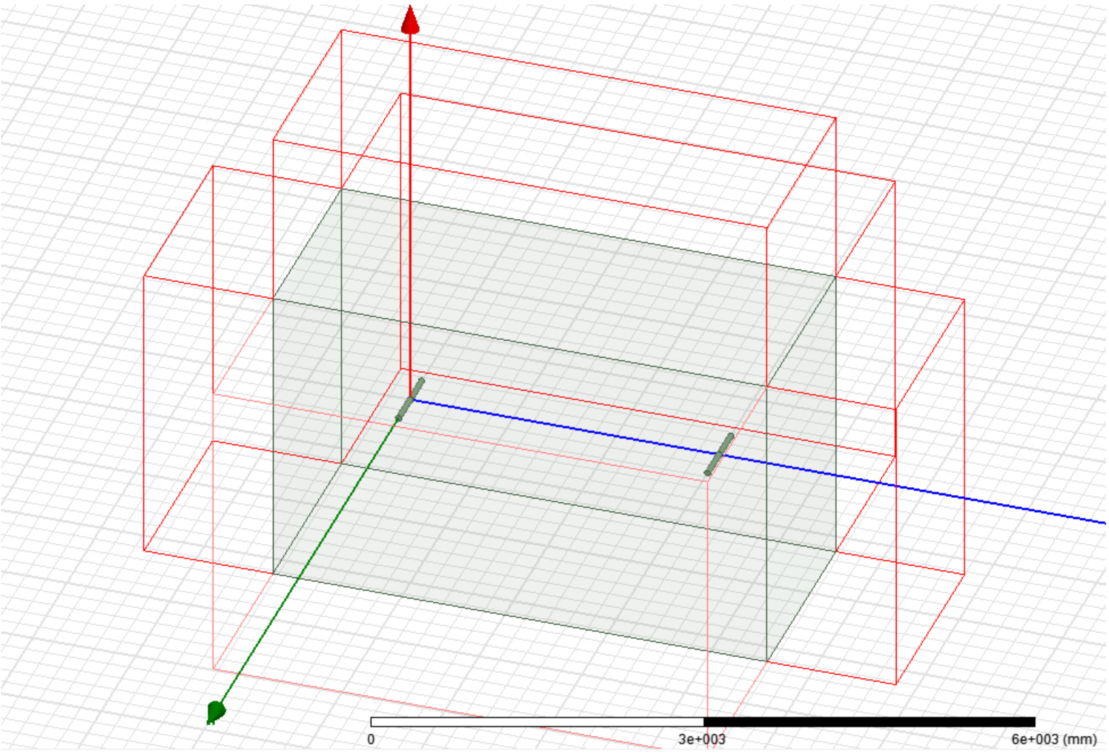


Fig. 2. *"Ideal" anechoic chamber model used for full electromagnetic simulations*

Then NSA of "ideal" anechoic chamber can be calculated as:

$$NSA_{ideal}[dB] = |S_{21}|[dB] - 2AF[dB(m^{-1})] \quad (9)$$

Simulated values of NSA_{ideal} are compared with the values calculated by (7) in Table 1.

Table 1

$F[MHz]$	$\|S_{21}\|[dB]$	$AF[dB(m^{-1})]$	$NSA_{ideal}[dB]$ 3m		
			Simulated	Calculated by (7)	$\Delta[dB]$
30	57.5	23.8	9.9	12	+2.1
100	18.8	8.6	1.6	1.5	-0.1
200	23.57	13.94	-4.31	-4.5	-0.19
500	31.57	21.4	-12.03	-12.4	-0.37
700	-33.4	24.32	-15.24	-15.4	-0.16
1000	-37.25	27.85	-18.47	-18.5	-0.03

As it can be seen the simulated results are very close to the calculated by (7) ones. It proves the proposed method which will be used below for semi anechoic chamber behavior investigation.

4. "IDEAL" SEMI ANECHOIC CHAMBER MODELING

Semi 3 m anechoic chamber model is shown on Fig. 3. It is like the described above full anechoic chamber model. The only difference is that the camera floor is modeled as perfect conductive surface.

NSA deviations in case of semi anechoic environment compared to full anechoic chambers are supposed to be caused by two main reasons: first is reflections from the conductive floor which can change the signal pass attenuation and second antennas patterns (respectively antenna gain and AF) changes due to reflections from the ground (conductive chamber floor). Example of antenna pattern deformations due to reflections are shown on Fig. 4. The described above deviations are frequency dependent and depends of antenna orientation and range distance. It is expected the antenna pattern deviations to be bigger for horizontal antenna orientation and for lower frequencies within the operative range.

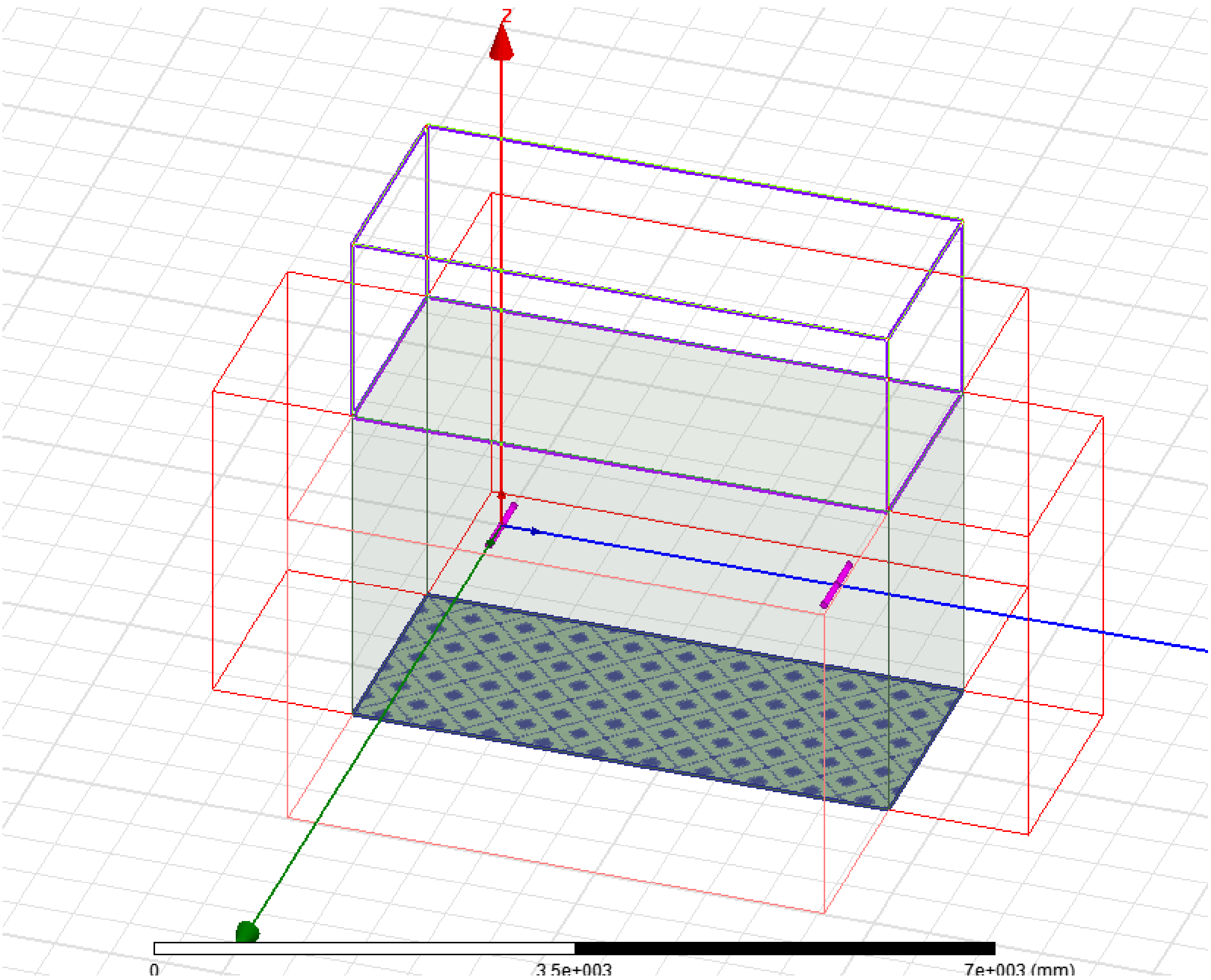
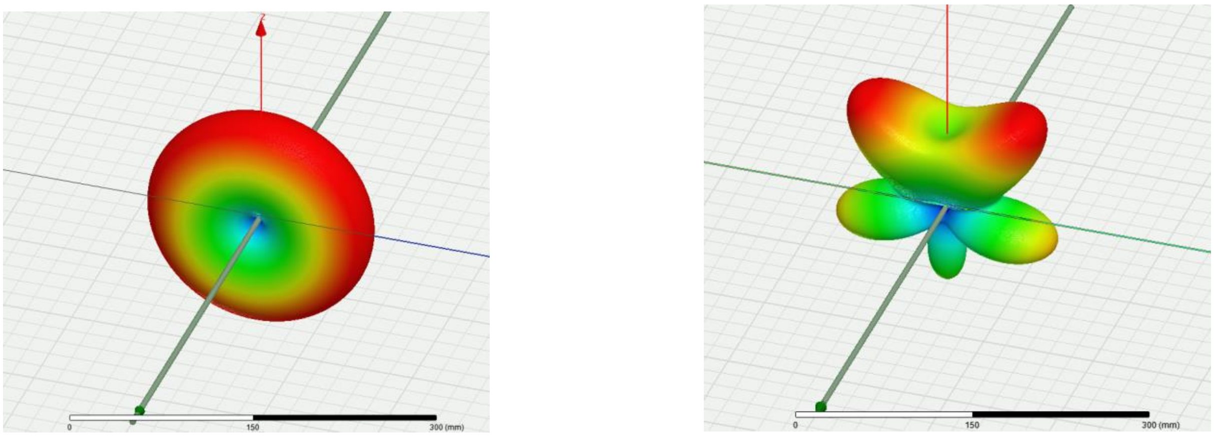


Fig. 3. *"Ideal" 3m semi anechoic chamber model*



a) $AF = 13.94dB(m^{-1})$ b) $AF = 14.57dB(m^{-1})$

Fig. 4. *Simulated 3D antenna patterns for resonant half wave reference dipole antenna at 200 MHz, horizontal polarization, height above ground 1.5 m:*

a) in ideal anechoic chamber, b) in ideal semi anechoic chamber

Ideal semi anechoic NSA values are delivered from the simulations in the way identical to the described above procedure for full anechoic chamber. The calculated NSA values for ideal semi anechoic chamber are shown in the Table 2. As it can be seen from the Table 2 the NSA values are different for different polarizations (different antenna orientations) since the influence of the conductive floor is polarization dependent. Deviations from NSA_{ideal} calculated from (7) are shown for comparison.

Table 2

$F[MHz]$	$\|S_{21}\|[dB]$		$AF[dB(m^{-1})]$		$NSA_{ideal}[dB]$ 3 m				
	H	*V*	*H*	*V*	*Ideal (7)*	*H*	Δ	*V*	Δ
30	62	51.88	26.45	23.45	12	9.1	**+2.9**	4.98	**+7.02**
100	12.86	23.2	8.85	6.27	1.6	-5.1	**+6.7**	10.66	**-9.06**
200	22.08	22.1	17.42	14.02	-4.31	-12.76	**+8.45**	-5.34	**+1.03**
500	36.7	30.86	22.8	21.8	-12.03	-8.9	**-3.13**	-12.74	**+0.71**
700	39.86	34,45	25.7	24.9	-15.24	-11.54	**-3.7**	-14.35	**-0.89**
1000	37.52	35.17	29.8	28	-18.47	-21.9	**+3.43**	-20.83	**-1.07**

5. CONCLUSIONS

Proposed models used for full electromagnetic simulations of the signals propagating within "ideal" anechoic and semi anechoic EMC compliance test facilities can be successfully used for NSA_{ideal} determination taking into account real shape of the antenna patterns and floor reflections. Simulated NSA_{ideal} for full ideal anechoic chamber are close to the calculated values using the proposed exact equation (7) which proves the proposed model consistency. Full electromagnetic simulations of an “ideal” semi anechoic chamber makes possible the calculated NSA_{ideal} values to be used as reference in practical validation tests in the 30 to 1000 MHz frequency range held by the similar test procedure as it is described in [1]. As it can be seen from the results NSA_{ideal} values for semi anechoic chamber depend strongly of antenna (polarization) orientation, which is due mainly to the ground reflections, which influence strongly antenna patterns polarization dependably. Deviations from full anechoic chamber NSA_{ideal} values are bigger for the lower part of the frequency range and especially for frequencies below 100 MHz, since the influence of the conductive ground is more severe. This influence at all is more significant for horizontal orientation of antennas. In the frequency range above 300-500 MHz and especially for vertical antenna orientation the deviations in the NSA_{ideal} values between full anechoic and semi anechoic chambers are relatively smaller which states for the possibility to use in case of semi anechoic facility the same verification procedure as it is proposed in [1].

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