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PERFORMANCE PREDICTION OF 3 METER SEMI-ANECHOIC CHAMBER BETWEEN 30 AND 200 MHZ TAKING INTO ACCOUNT THE NEAR FIELD EFFECT

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Abstract : This paper addresses EMI (ElectroMagnetic Interference) chamber performance in the frequency range between 30 and 200MHz, which is where chambers exhibit their deficiencies. The difference between attenuation in an open area test site (OATS), called Normalized Site Attenuation (NSA) and this same measure in the test chamber gives the performances. The European EN50147-2 [1] and American ANSI C63-4 standards [2] authorize a maximum deviation of ± 4 dB. Numerical modelling enables us to identify performances and thus optimise the chamber. In this work, we propose a whole new chamber modelling with a boundary condition taking into account the reflectivity of ferrite tile. Also we focus on antenna modelling because of the significant mutual coupling effect in this frequency range, unlike other previous works [3,4,5] which consider electrically small antennas.

I. INTRODUCTION

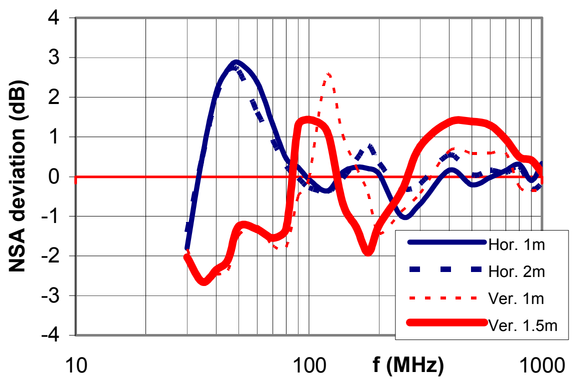

Fig.1. NSA deviation measurement for horizontal and vertical polarization in a 3 meter semi-anechoic chamber.

If EMS (Electromagnetic Susceptibility) performances are directly dependent on the antenna used, due to the directivity which defines the field uniformity area. The EMI performances are directly dependent on the chamber design and absorber performance.

The relative isotropy of the antennas and the ratio of the wavelength to the dimensions of the chamber at the low frequencies define the maximum NSA deviation in comparison with an OATS (fig.1).

If no object is in the near field zone of each antenna, each one can be defined as an equivalent punctual source. In these conditions, NSA values are independent of the antennas used. This consideration is right for fully anechoic chamber as done by the MIRA [3] where one of the calibration antennas has to be smaller than 40cm [6].

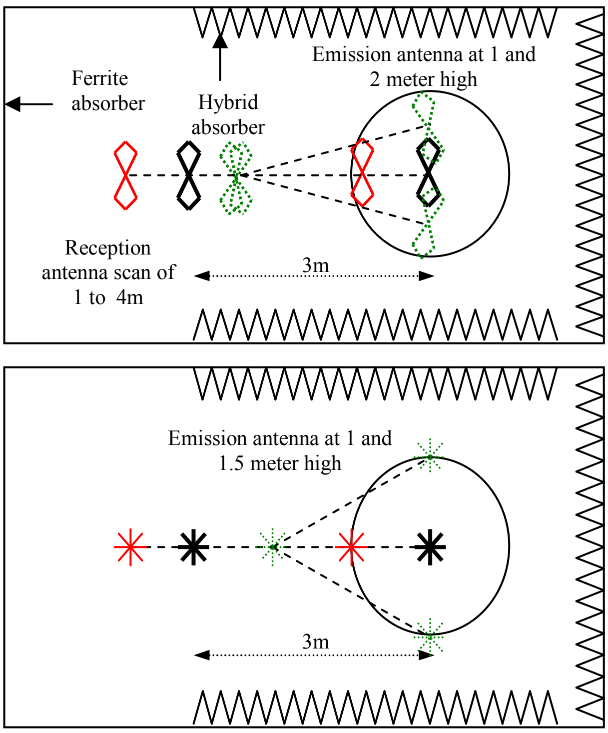

Fig.2. NSA measurements in the quiet zone of a semi-anechoic chamber for horizontal and vertical polarizations.

In the case of 3 meter measurements in a semi-anechoic chamber and for low frequencies (fig.2), theoretical and experimental approaches [7,8] show the significant influence of antennas on measurements because antennas used for qualifying the chamber are electrically large (resonant dipoles to 200MHz or broadband biconical antennas).

II. NEAR FIELD EFFECT

To quantify the error due to the near field effect, two theoretical approaches can be compared. The first one, the Smith, German and Pate formulation (SGP) [9], uses a geometrical approach, so sources (antennas) are punctual. Two paths are considered: a direct path and a reflected one on the metallic plane. For 3 meter measurements, the near field effect is not considered in this approach.

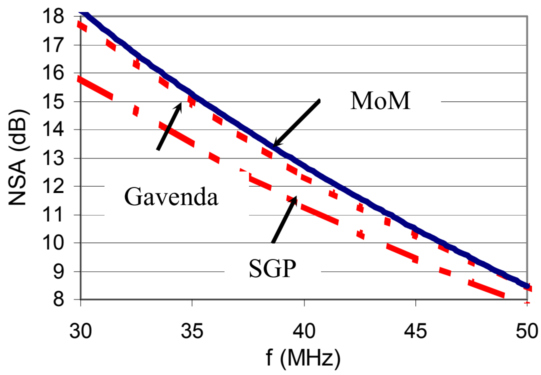

Fig.3. Theoretical NSA for 3m measurements in horizontal polarization (height of 1m) for the different methods.

The second one, the empiric Gavenda formulation [8] takes into account the near field effect specifically for a resonant dipole. This model shows a deviation up to 2dB in comparison with the SGP model (fig.3). A rigorous simulation with the Method of Moments (MoM), appropriate to define the wire structure of dipoles, shows the same results as Gavenda's model.

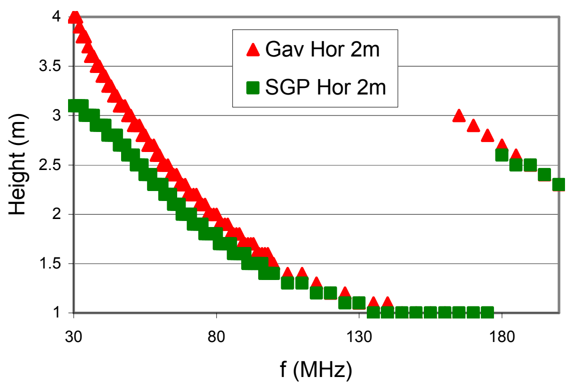

Fig.4. Heights of receiving antenna for minimum transmission loss in horizontal polarization (height of 1m).

The other difference due to the near field is the height of the minimum transmission loss which is different between the SGP and Gavenda model (fig.4) [7].

The attenuation prediction of a 3 meter test chamber over the frequency range 30 to 200 MHz needs both modelling absorbers and the antennas used (in our case, biconical antennas) to take into account the near field effect and the height dependency to have a rigorous performance prediction of the chamber.

III. SELECTION OF ELECTROMAGNETIC SOFTWARE

The most difficult problem in chamber simulation is linked to the computational requirements due to the large dimensions of the structure in ratio to the wave length and to the modelling of the different elements (the antennas and the absorbers). Particular care has to be taken to simplify the models without compromising accuracy.

A study was made to determine among several methods (MoM, FDTD and TLM), the one most appropriate for this type of structure. Each of these methods has different advantages in our simulations. Classical time domain approaches (TLM, FDTD) are interesting in the case of a broadband study and for modelling the frequency dependency of absorber material. Frequency MoM methods are appropriate for the simulation of wire antennas and large homogeneous volume (interface only meshing).

An electromagnetic software which uses the « Transmission Line Matrix » method (TLM) was finally chosen to simulate the chamber because unlike the classical time domain method, it can easily define biconical antennas as shown in the next paragraph.

IV. TLM MODEL

An important study was made in the modelling of biconical antennas and absorbers to reduce the simulation time of the semi-anechoic chamber with good accuracy in the case of the TLM method.

IV.1. Absorbers

Compliant chambers are most of the time lined with ferrite absorbers or hybrid absorbers (ferrite tiles covered with pyramidal foam absorbers), depending on the frequency band of operation.

IV.1.1. Ferrite absorbers

The ferrite absorbers by their high permittivity (ε_r=12.8) and permeability (fig.5) impose fine spatial meshes, and a small time step Δt defined by the Courant Frederich Levy criterion (Eq. 1).

$$\Delta t \leq \frac{1}{\frac{c}{\sqrt{|\varepsilon_r \mu_r|}} \sqrt{\frac{1}{\Delta_x^2} + \frac{1}{\Delta_y^2} + \frac{1}{\Delta_z^2}}} \quad (1)$$

With, Δt : the time step (s)
Δx, Δy, Δz : the spatial mesh dimensions (m)

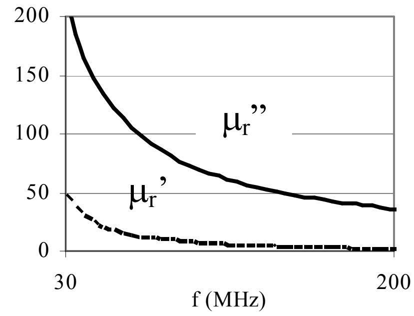

Fig.5. Relative permeability of FE30Z ferrite tiles (real and imaginary part).

Reflectivity is very dependant on the angle of incidence and the polarization (fig.6) and the modelling of the absorber needs to conserve this dependency.

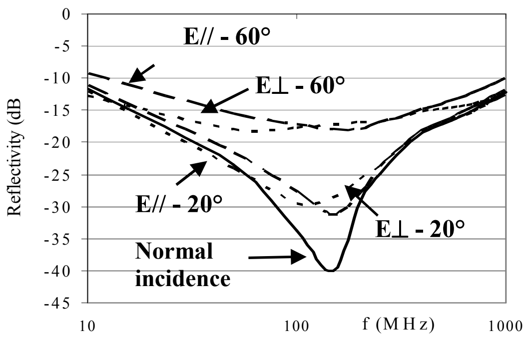

Fig.6. Reflection coefficient of 6.7mm thickness ferrite tiles with a metallic support for normal incidence (solid line: simulation with the limit condition, squares: measurements).

In the case of this absorber, for all incident angles, the refraction angle is near the normal, because of the electromagnetic parameters of the ferrite. In this case, the refracted wave in the ferrite can be considered normal at the air ferrite interface (fig.7), i.e. φ can be considered equal to 0.

With this last approximation, the reflectivity of metal backed ferrite tiles can be defined by a one dimensional meshing model in the thickness of ferrite. This will slightly change the angular dependency of the complex reflection coefficients, but this change is very small. Theoretically, this approximation makes an error of less than 0.1dB in amplitude and 0.5° in phase.

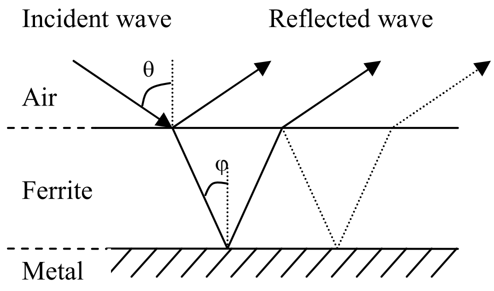

Fig.7. Ferrite tile reflectivity principle.

For this reason, we purposed to model ferrite only by a 1D model in the thickness, usable in the case of a time domain volumetric meshing. To simplify the calculation, this 1D model can be defined only by a boundary condition.

This boundary condition is defined at the air ferrite interface. In the case of TLM is a frequency-dependent surface impedance of a ladder network (fig.8) for both polarizations (E field perpendicular and parallel to the air/ferrite interface) [10].

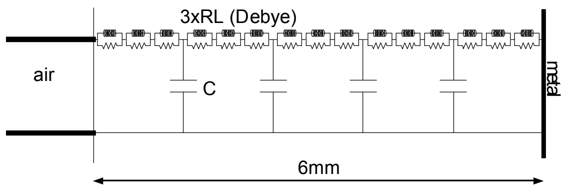

Fig.8. Equivalent 1-D TLM electric circuit for electromagnetic modelling of ferrite tiles.

To take into account the frequency (f) dependence of the ferrite permeability (μ), we used a three order Debye model (i.e. 3 poles of resonance) (eq.2) [11], the ferrite permittivity is constant in the frequency band.

$$\mu = \mu_0 - \sum_{n=1}^{3} \frac{\Delta\mu_n}{\left(1 + i\, f / f_n\right)} \quad (2)$$

with fn : frequency of pole n.
$\Delta\mu_n$: permeability step of pole n.

The rungs of the ladder are capacitors C representing the dielectric properties of the ferrite; the uprights are three RL resistance-inductance networks representing the three order Debye model of magnetic properties (fig.8).

Unlike Dawson's ferrite model [12] which is based on measured reflectivity, the one proposed is defined with the electromagnetic parameters of ferrite, and takes into account the incidence angle and the polarization of the electromagnetic wave. The limitation of this model is the effect of the holes and gaps in the ferrite absorber which are not taken account. In our case the typical gap is of 0.2mm so the effect is a small shift of the resonance. The hole of 10mm diameter in the center of half tiles reduced reflectivity at the resonance especially in normal incidence and the screws have no effects [5].

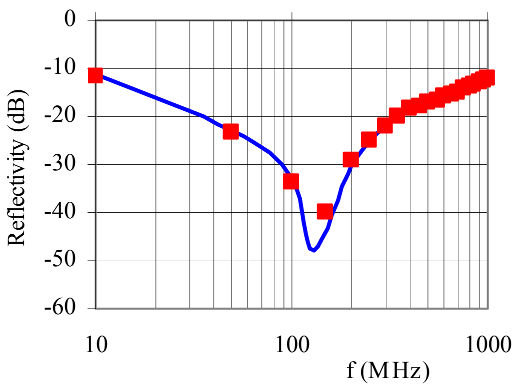

Fig.9. Reflection coefficient of 6.7mm thickness ferrite tiles with a metallic support for normal incidence (solid line: simulation with the limit condition, squares: measurements).

The reflectivity simulation of ferrite tiles up to 200MHz needs meshing in λ/10 or 150 mm with this boundary condition unlike the 1mm in the case of classical TLM meshing. The stability criterion of Courant-Frederich-Levy (CFL) imposes a maximum temporal step which is multiplied by a factor of up to 150. This last parameter and the decrease in the number of meshes significantly reduce the simulation time, the total error induced in the reflectivity being lower than 1dB (fig.9).

IV.1.2. Pyramidal absorber

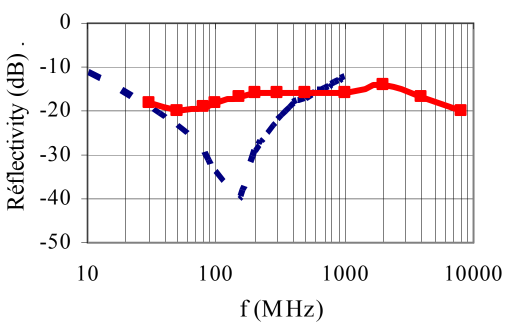

Fig.10. Typical normal incidence reflectivity of ferrite tiles (dotted line) and 50 cm hybrid absorber (solid line).

The low carbon loaded pyramid in the case of a hybrid absorber makes it quasi transparent in the band studied, but preponderant for frequencies above 1GHz. Pyramidal absorbers modify reflectivity mainly at the ferrite frequency resonance (~250MHz) (fig.10). Pyramidal absorbers can be modelled by an anisotropic multilayer model [13] with an error lower than 5% for frequencies up to 1GHz.

IV.2. Biconical antennas

Theoretical approaches have been subject to some intrinsic error due to mutual coupling between antennas used to validate semi-anechoic chambers. For this reason, the NSA prediction needs to simulate the complete structure of the antennas used, in our case biconical antennas.

The biconical antennas used, made by Seibersdorf (PBA 320) are especially designed for NSA measurements [7] : The balun has been designed to minimize the height dependency of the antenna factor with an excellent phase symmetry but not for adaptation. The impedance presented by the balun to the wires is stable on the frequency band and is equal to 100Ω.

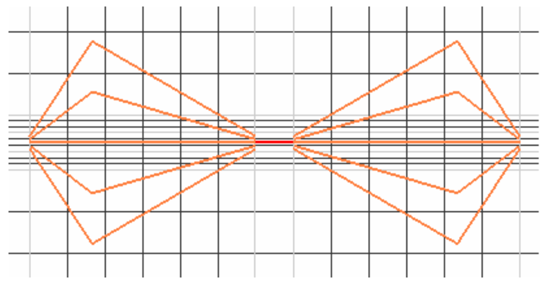

Fig.11. Meshing of the biconical antennas

With a specific numerical treatment for wire structures [14], the inclination of the biconical antenna wires can be modelled without an excessive increase in the number of meshes in comparison with a conventional volume meshing technique (fig.11). The diameter of the wire and the coupling between the different wires which are very influential on the mismatch of the antenna, were taken into account.

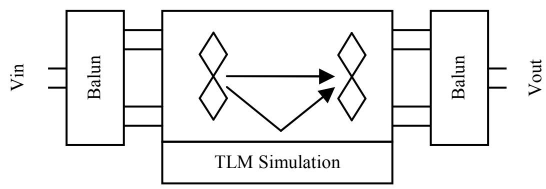

Fig.12. S-parameters model for transmission between biconical antennas.

The problem of this approach is to simulate the scan of the received antenna from 1 to 4m by finite steps. We have chosen a 10cm step to achieve sufficient accuracy.

NSA (dB) values have been deduced directly from the space losses, SA (Site Attenuation), and the antennas factor given by the ANSI C63.4 standard [2] (Eq. 3).

$$NSA = Vin - Vout - DAF \quad (3)$$

Vin and Vout (dBV): Respectively the input voltage of the emission antenna and the maximum output voltage of the reception antenna.

DAF (dB) : Dual Antenna Factor. Sum of the antennas factor

In our simulations, the transmission parameters are defined by the scattering parameters of the balun and the simulation results of the wires in its environment (fig.12) for 100 Ω impedance sources (impedance presented by the balun).

To verify the antenna modelling and mutual coupling, simulation and NSA measurement results have been compared for the two polarizations (vertical, horizontal) and for the two heights of the emission antenna in the case of a distance of 3 meters.

In this case, with a deviation between simulations and measurements lower than +/- 0.75dB, the antenna model can be considered valid.

V. CHAMBER PREDICTION

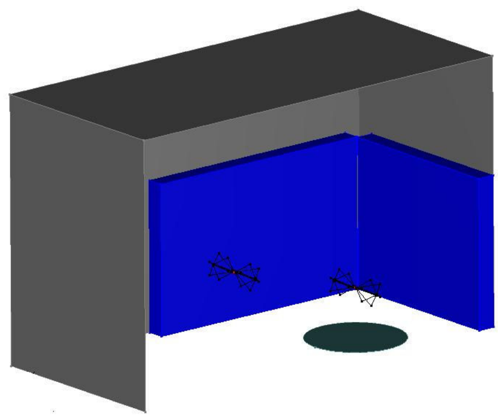

Fig.13. Cut of a chamber's model for one position of the received antenna in horizontal polarization.

To validate our model, the NSA deviation in the quiet zone of a 3 meter compliant semi-anechoic chamber has been studied (fig 13).

The chamber under investigation was 8.9m long, 5.9m high and 7.1m large. The test volume is a cylinder of 2m diameter and 2m high.

The difference between simulation results and measurements has been compared to this real chamber for all the positions and gives a good performance prediction with an accuracy of 1dB for the two polarizations (fig.14-15) especially at critical frequencies.

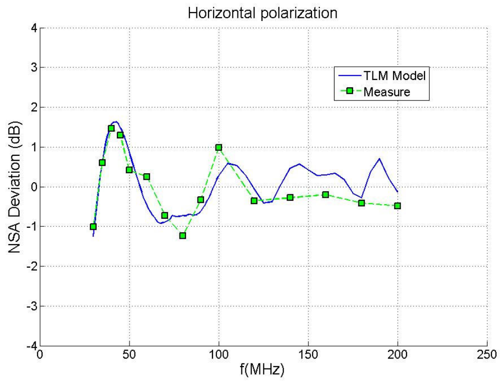

Fig. 14. NSA Deviation for horizontal polarization for 1m height of the emission antenna.

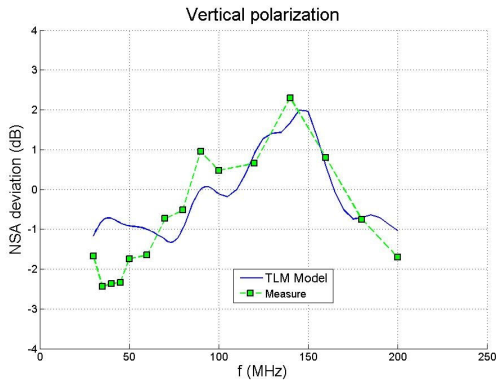

Fig. 15. NSA Deviation for vertical polarization for 1m height of the emission antenna.

This TLM model has been improved for other dimensions of semi anechoic chamber and gives with the same accuracy, the NSA deviation of the test volume.

VI. CONCLUSION

In this paper, we have presented a new efficient TLM model of NSA measurements. This model takes into account the near field effect existing for the frequency band between 30 and 200MHz especially for 3 meter semi-anechoic where this effect is significant. The solution has been to model the biconical antennas used to validate the chamber.

This model has been optimized in terms of computer requirements with the utilization of a new boundary condition for modelling the metal back ferrite tile reflectivity.

Also this TLM model allows us to optimize the design of the whole room, considering the location of the absorbers, and the dimensions and location of the quiet zone, by a performance prediction and a better understanding of the field distribution in the chamber.

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