Modeling and Analysis of an Anechoic Chamber

P. T. Benkő, J. Pávó
Department of Broadband Infocommunications and Electromagnetic Theory
Budapest University of Technology and Economics, H-1521 Budapest, Hungary

Abstract — In this paper we present the modeling and analysis of an anechoic room in a wide frequency band (30–1000 MHz). The method is based on the segmentation of the problem into two sub-problems: first, the unit cell of the periodic wall absorber structure is analyzed, and the equivalent surface impedance is determined, which is used in the second sub-problem, during the analysis of the chamber having the equivalent surface impedance on the walls. The goal of the space segmentation is to separate the calculation of the geometrically complex absorber structure from the electrically large chamber analysis. Both sub-problems are solved using finite element method, however, the chamber is divided into different space regions for the calculations at high frequencies. The presented method is used for the optimization of a low-cost absorber structure, and for the design of an anechoic room for electromagnetic compatibility (EMC) tests.

I. INTRODUCTION

Electromagnetic compatibility is an emerging problem during the design of electronic devices. Standard test procedures are defined in national and international standards to ensure the interoperability of such devices. The tests are performed in special rooms, i.e. anechoic chambers, that have absorber material on the walls to provide low reflection coefficient.

Full-wave analysis of anechoic chambers require huge computer resources, because

1. the absorber structure is relatively complex, and requires a dense mesh near the wall, and

2. the chamber is electrically large at high frequencies, resulting a fine mesh the analysis domain.

To reduce the necessary computer memory and time for the analysis, we divide the problem into two sub-problems:

1. A unit cell of the periodic absorber structure is analyzed, and the equivalent surface impedance is determined.

2. The formerly calculated equivalent surface impedance is applied as homogeneous boundary condition for the chamber, and the room is analyzed either directly (at lower frequencies), or using spatial decomposition (at higher frequencies).

Our goal is to calculate the electric field distribution in the anechoic chamber.

II. MODELING THE ABSORBER

Absorbers applied on the walls of anechoic chambers are usually conical shape, ferrite based structures, that are rather expensive. In this paper, we investigate another configuration using ferrite and graphite-painted paper (Fig. 1), however, the method is not limited to the given geometry, but can be used for arbitrary periodic structures.

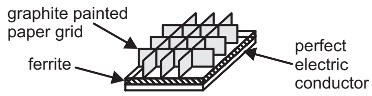

Fig. 1. Investigated absorber structure

A. Calculation of Equivalent Surface Impedance

The electromagnetic field distribution is calculated for the unit cell using finite element method, assuming an incident plane wave propagating normal to the plane of the absorber basis. The equivalent surface impedance on the basis of the absorber can be calculated from the resulting field using transmission line approximation (Fig. 2).

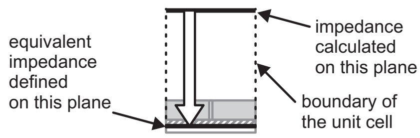

Fig. 2. Equivalent surface impedance is calculated using transmission line approximation

B. Approximate Function of the Surface Impedance

Although the equivalent surface impedance can be calculated at arbitrary frequencies using relatively small computer resources, it is many times more efficient to determine an approximate function for further calculations.

During the calculations, we used Fourier-series as approximate function of the periodic extension of the calculated impedance points, however, other approximations are also applicable. To avoid Gibbs-oscillations, we have extended the input data set by mirroring the calculated surface impedance points on the upper limit of the frequency domain (Fig. 3).

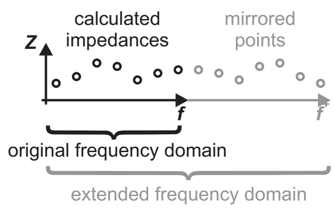

Fig. 3. Extension of frequency domain for the determination of the approximate function of the equivalent surface impedances

The approximate function has particular importance in case of ferrite-based structures, where the magnetic loss tangent can be singular (the real part of the magnetic permeability can be zero), which may cause numerical instability.

II. ANALYSIS OF THE CHAMBER

The finite element analysis of the chamber is performed using homogeneous boundary conditions: the above calculated surface impedance is applied on the walls of the room. A transmitting antenna is located in the chamber, and the electric field distribution is calculated. For the evaluation of the room, standards usually specifies a maximum deviation compared to free-space configurations (radiation boundary condition on the walls) in a given 'test volume' of the chamber.

A. Analysis at Low Frequencies

Analysis at lower frequencies is straightforward (Fig. 4). The required computer resources are within a tolerable range up to a given frequency, where a model dimensions are getting too large for a reasonable mesh size. Although this limit varies from application to application, our investigations showed that the typical maximum model size where the entire region is modeled is in between 500 and 800 cubic wavelengths.

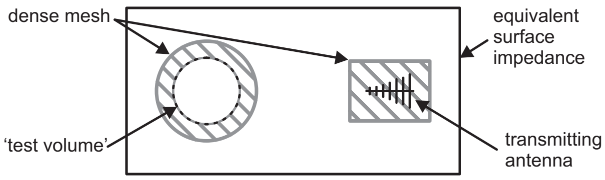

Fig. 4. Analysis at low frequencies require dense mesh near the transmitting antenna and the 'test volume'

It is essential to generate a dense mesh near the transmitting antenna and in the 'test volume' to have reliable numerical results.

B. Analysis at High Frequencies

At higher frequencies, where the model size can reach several thousands of cubic wavelengths, three regions are formed in the chamber (Fig. 5) that are linked by Green's functions representing the free-space propagation between them:

1. *Region 1:* volume including the transmitting antenna, having radiation boundary conditions on each face.
2. *Region 2:* thin 'shell' near the wall of the room, having radiating boundary condition in the inner faces, and the calculated equivalent surface impedance on the outer faces.
3. *Region 3:* 'test volume', having radiating boundary conditions on each face.

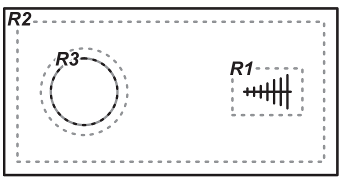

Fig. 5. Three regions are formed in the anechoic chamber for calculations at high frequencies

The field distribution in each region can be calculated using relatively small computer resources. The free-space between the regions is not discretized, that would otherwise significantly increase the size of the problem.

The field distribution in the 'test volume' is calculated using superposition (Fig. 6):

1. The field of the transmitting antenna is calculated in Region 1.
2. The field of the transmitting antenna is linked to Region 2, as the incident field on the wall of the chamber. The reflected field is calculated.
3. The field reflected from the wall of the chamber is linked to Region 1, and Region 1 is analyzed again.
4. Step 2. and 3. are repeated iteratively, until the fields converge.
5. The field of the transmitting antenna is linked to Region 3, and the field distribution is calculated. This part of the resulting field is considered as the 'direct' component.
6. The field reflected from the wall of the chamber is linked to Region 3, and the 'test volume' is analyzed. This part of the resulting field is considered as the 'reflected' component.
7. Direct and reflected field components are added in Region 3 resulting the net field distribution is the 'test volume'.

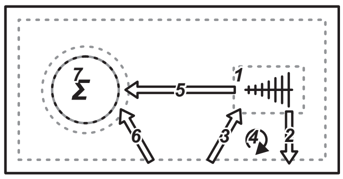

Fig. 6. Coupled calculation scheme for analysis at high frequencies

III. RESULTS

The above described method was applied for the calculation of the electric field distribution in an anechoic chamber. The results were compared to free-space field values to evaluate the performance of the chamber.

Numerical results are shown in Fig. 7. The performance of the chamber is acceptable at higher frequencies. Behaviour at lower frequencies should be improved using the above descried method for optimization.

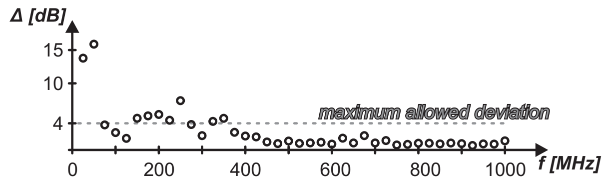

Fig. 7. Calculated maximum deviation from the free-space field values ($\Delta = E_{anechoic} / E_{free-space}$) in the 'test volume' of the anechoic chamber

IV. REFERENCES

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