Accurate Analysis of Electromagnetic Shielding Problems using MoM SIE Method

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***Abstract* – Calculation of shielding efficiency of a conducting spherical shell using MoM SIE based code is presented in this paper. Theorem of surface equivalence is used in order to minimize propagation of numerical error through the walls of the shell. Accuracy is further improved by using advanced matrix equilibration and special integration methods for highly accurate evaluation of MoM matrix elements. Simulation results are compared with analytical solution. Very good agreement is obtained, even in cases when field inside the cavity is more than 260 dB below the level of incident field.**

***Index Terms* — Shielding efficiency, method of moments, theorem of surface equivalence, matrix equilibration, singularity extraction, singularity cancellation.**

1. Introduction

The purpose of electromagnetic shielding is to reduce electromagnetic field inside the area under protection. In this paper we are focused on shielding which is performed by enclosing the area under protection by a conducting shell. As analytical solution for spherical shell is well known [1], we considered spherical shell.

In order to achieve significant reduction of interference field inside the shell, thickness of its walls would be few times larger than skin depth [2]. That means, that field on outer surface of the shell is much larger than field on inner surface, and that for accurate results large field variation over short distance should be properly analyzed.

Analysis of spherical shell with high shielding efficiency by using MoM SIE and surface equivalence theorem implemented in WIPL-D software package [3] is presented in [4]. Very good agreement between analytical results and EM simulation is noticed for shielding efficiencies up to about 110 dB. If an additional surface is used in shell modeling, it is shown that shielding efficiency of up to 150 dB can be successfully simulated.

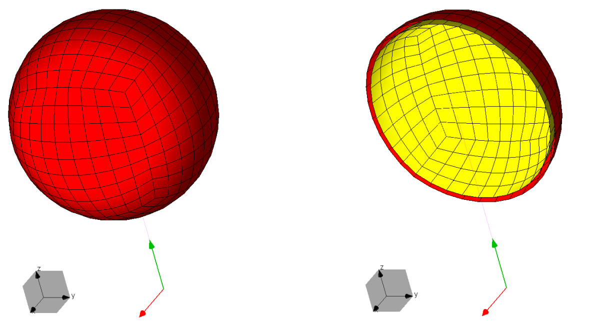
In this paper we simulated conducting shell with significantly higher shielding efficiency. In order to obtain accurate results for so demanding problem, solver used in [4] is improved by introducing the new method for matrix equilibration [5] and advanced integration techniques [6, 7] for highly accurate evaluation of MoM matrix elements.

Description of the problem under consideration is given in Section II. Simulation results as well as its comparison with analytical results are presented in the Section III.

2. Problem Description

The model which analysis is presented in the paper is spherical shell illuminated by a θ-polarized plane wave incoming along *z*-axis. Outer radius of the shell is 1 m, and shell thickness is 5 cm. Frequency of interest is equal to 3 MHz. Effective value of the electric field of incident plane wave is 1 V/m.

WIPL-D model of analyzed structure is shown in Figure 1.



a) Model of the shell b) Shell cross section

Fig. 1. WIPL-D model of the conductive shell illuminated by plane wave.

Shell is made of conductive material which relative permittivity and permeability are both equal to 1. Model is simulated with four different values of material conductivity: 2161.51 S/m, 4323.02 S/m, 8646.04 S/m and 12969.06 S/m. Thickness of the shell for these conductivities is equal to 8, 16, 32 and 48 skin depths, respectively.

Result of interest is electric field on z-axis inside the cavity, i.e. for $-0.95\ m < z < 0.95\ m$.

3. Simulation Results

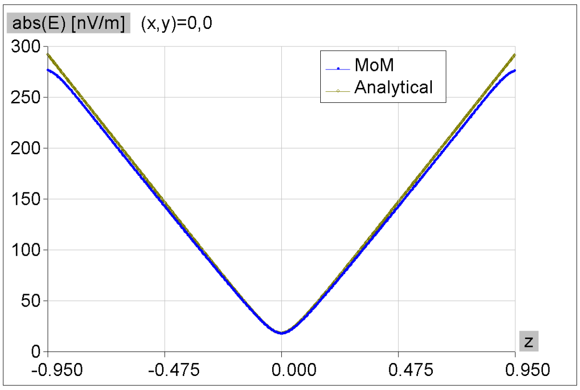
Before we present simulation results of described problem let us remind about the models which solution is shown in [4]. It is shown that very accurate results for EM field inside the shell can be obtained for all shell thicknesses lower than or equal to 4 skin depths. When shell thickness becomes higher than 4 skin depths additional surface between inner and outer shell surface should be added for high accuracy. After adding of this middle surface, highly accurate results are obtained for shell thickness of 8 skin depths, where shielding efficiency is about 150 dB. Shielding efficiency is calculated as ratio between electric field outside of the shell and field in the center of the shell.

All models presented in this paper are created without the additional surface. On the other side, the lowest shell thickness presented in this paper is equal to 8 skin depths.

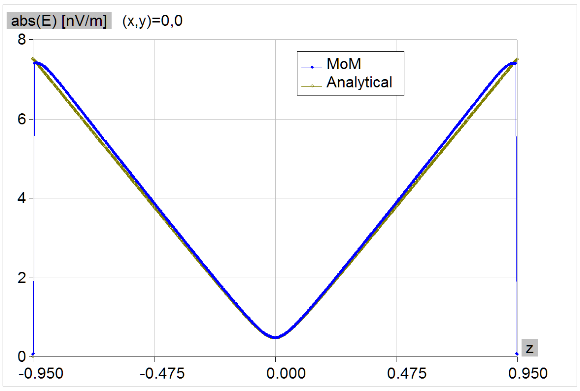
Highly accurate simulation of these very challenging problems is achieved by introduction of:

- Advanced matrix equilibration to balance source/field quantities in SIEs and basis/test functions in MoM solution [5].
- New generation of integral methods for highly accurate evaluation of MoM matrix elements that combines singularity extraction technique [6] and singularity cancellation techniques [7].

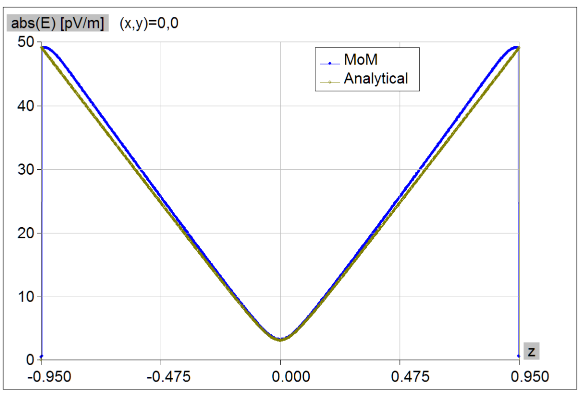
Electric field inside the shell along *z*-axis, for different thicknesses of the shell is given in the Figure 2.



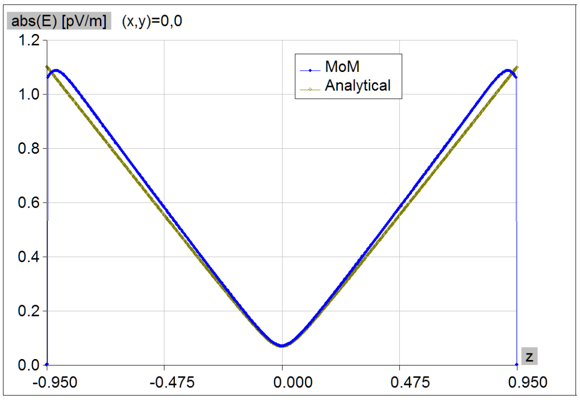
a) Shell thickness equal to 8 skin depths



b) Shell thickness equal to 16 skin depths



c) Shell thickness equal to 32 skin depths



d) Shell thickness equal to 48 skin depths

Fig. 2. Electric field inside the cavity for different skin depths.

From the diagrams shown in Figure 2 we can see very good agreement between analytical solution and MoM SIE results. This agreement is achieved despite the fact that field inside the shell is dramatically lower than incident field.

Shielding efficiency for different skin depths is given in Table 1.

TABLE 1

Conductivity [S/m]	Shell Thickness in Skin Depths	Shielding Efficiency [dB]
2161.51	8	154.6
4323.02	16	186.2
8646.04	32	230.14
12969.06	48	263.13

4. Conclusion

Results presented in the paper show that described method which is based on MoM SIE, application of theorem of surface equivalence and advanced techniques for matrix equilibration and highly accurate integration, enable very accurate analysis of electromagnetic shielding problems.

Almost perfect agreement between simulated and analytical results is obtained for problems with shielding efficiency of more than 260 dB.

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