EM Shielding of Conductive Spherical Shell

Electromagnetic shielding represents the process of reducing the electromagnetic (EM) field by blocking the field using barriers made of conductive and/or magnetic materials. The exact purpose of EM shielding is to protect devices from the undesirable coupling between interior and exterior space of the device.

Testing of shielding efficiency of a device is rather important. Importance is especially expressed if electrical device we try to protect is very sensitive to interferential fields. Thus, small field propagation inside protected space is required. According to this, accurate numerical analysis of such problems must be performed. Consequently, this kind of analysis is very challenging EM problem

In this application note 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 rigorously 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 application note we have 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 of the new method for matrix equilibration [5] and advanced integration techniques [6, 7] for highly accurate evaluation of MoM matrix elements.

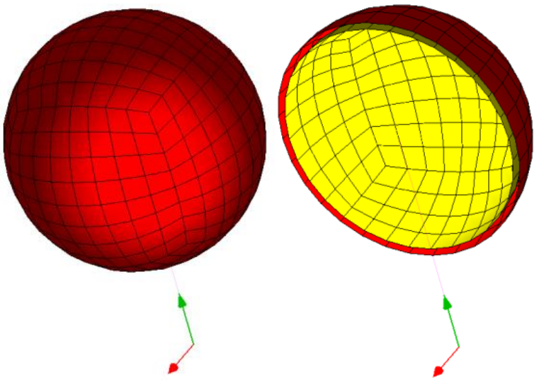
Problem Description

The model which analysis is presented in the application note 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 the simulated structure is shown in Figure 1.

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, 11.3, 16 and 19.6 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.



a) Model of the shell **b) Shell cross section**

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

Simulation Results

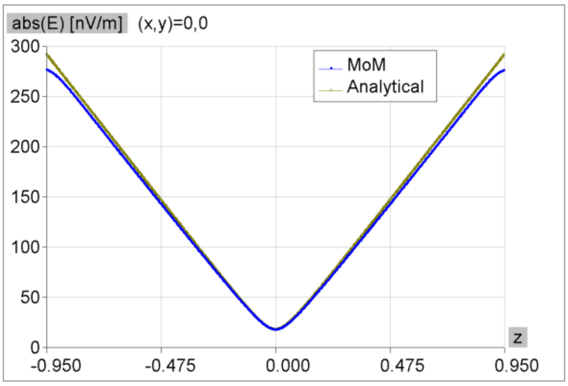
Before we present simulation results of the described problem let us remind about the models which solution is shown in [4]. It is shown that very accurate results for EM field inside the shell can be obtained for all shell thicknesses lower than or equal to 4 skin depths. When shell thickness becomes 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 here are created without the additional surface. On the other side, the lowest shell thickness presented is equal to 8 skin depths.

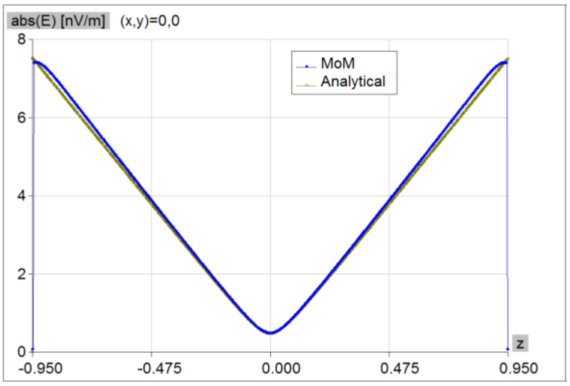
Highly accurate simulation of these very challenging problems is achieved by introduction of:

- 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].

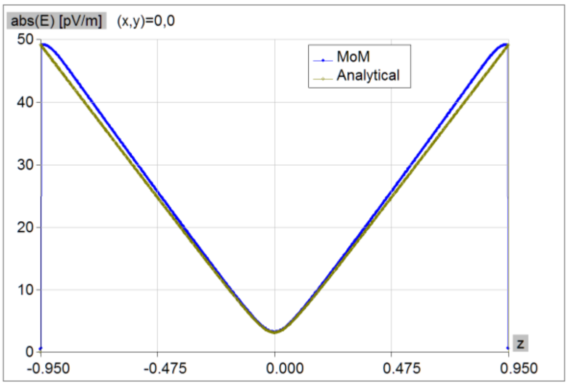
Electric field inside the shell along z-axis, for different thicknesses of the shell is given in the Figure 2.



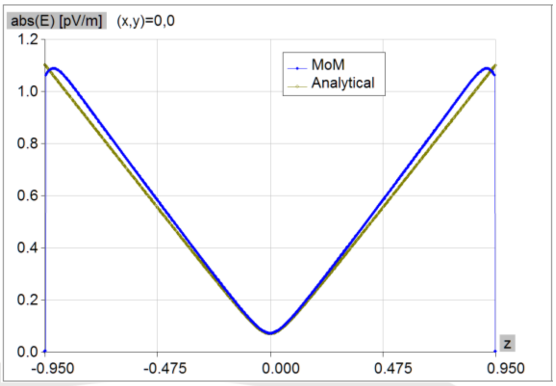
a) **Shell thickness equal to 8 skin depths**



b) **Shell thickness equal to 11.3 skin depths**



c) **Shell thickness equal to 16 skin depths**



d) **Shell thickness equal to 19.6 skin depths**

Fig. 2. WIPL-D model of the conductive shell illuminated by plane wave.

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. Shielding efficiency versus shell thickness

Shell Thickness in Skin Depths	**Shielding efficiency [dB]**
8	154.6
11.3	186.2
16	230.14
19.6	263.13

Conclusion

Results presented in the application note show that WIPL-D software package can be used for 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. If such an outstanding field suppression is not sufficient, the approach for [4] should be used. Shell wall should be subdivided into two dielectric materials with identical EM properties. Additional layer brings tremendous improvement to the suppression level that can be simulated.

All the models described here are simulated at standard desktop PC with low number of unknowns, in just a few seconds.

References

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