Simulation of Electromagnetic Shielding

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 very important. Importance is especially expressed if electrical device we try to protect is very sensitive on 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 occurring very challenging issue.

There are applications with device, placed inside some kind of conductive material shell. In order to minimize interference field inside the shell, shell thickness is usually few times larger than skin depth. This means, that field on outer surface of the shell is much larger than field on inner surface of the shell. According to this, if we want to obtain accurate results, large field variation over short distance should be properly analyzed.

Since analytical solution for spherical shield is known, we will simulate spherical shell. Modeling and simulating of this shell is obtained in WIPL-D Pro software and these results are compared with Mie series analytical results.

The aim of this paper is to obtain shielding efficiency of such device and to show that such shielding device can be very accurately modeled by using surface integral-equation formulation (SIE) Method of Moments (MoM), built in WIPL-D Pro.

Models

Conductive spherical shell illuminated by a plane wave was modelled and simulated in WIPL-D Pro (Figure 1).

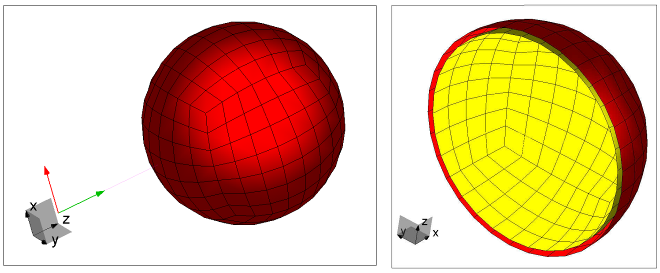

Figure 1. WIPL-D Pro model of the conductive shell illuminated by plane wave and the cross section view of the shell

Outer radius of the shell is 1 m while shell thickness is 5 cm. Frequency is 3 MHz. Shell is made of conductive material with parameters $\varepsilon_r = 1$ and $\mu_r = 1$. Cavity inside the shell is filled by air. RMS of the electric field of incident plane wave is 1 V/m. WIPL-D Pro simulation parameter Integral accuracy is set on “Normal” (Integral accuracy “Normal” is grade used by default and it is sufficient for most of the problems; in average, according to this grade, number of integration points used in calculation of MoM matrix elements, is slightly greater than the order of current expansion). The second order of current approximation has been used over all elements in the models.

Results

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

Conductivity has been varying in order to obtain different skin depths. Three different skin depths were considered: 5 cm (equal to shell thickness), 2.5 cm (half of shell thickness) and 1.25 cm (quarter of shell thickness). Corresponding conductivities are 33.77 S/m, 135.09 S/m and 540.38 S/m, respectively. Electric field on z-axes is shown in Figs. 2-4.

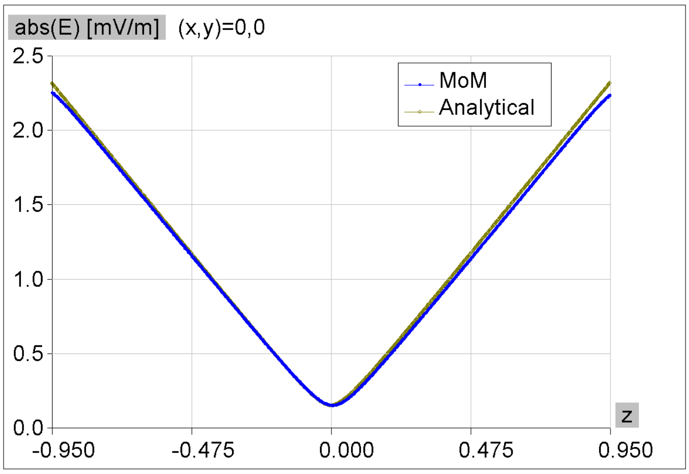

Figure 2. Electric field inside the cavity for skin depth equal to shell thickness

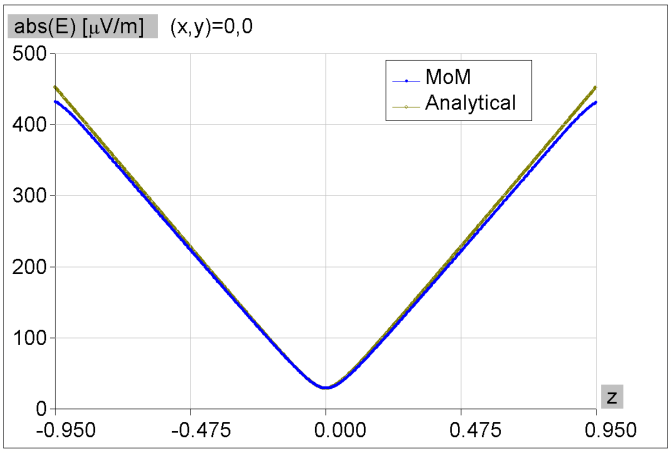

Figure 3. Electric field inside the cavity for skin depth equal to half of shell thickness

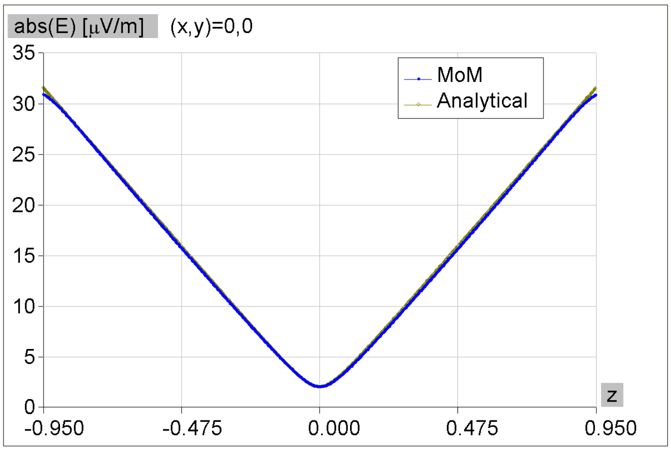

Figure 4. Electric field inside the cavity for skin depth equal to quarter of shell thickness

If we decrease skin depth to 0.625 cm, which is eighth of shell thickness, conductivity will be increased to 2161.51 S/m. In this case, the grade for Integral accuracy should be increased to “Enhanced 2”. This was done in order to stabilize result. Near field is shown in Figure 5.

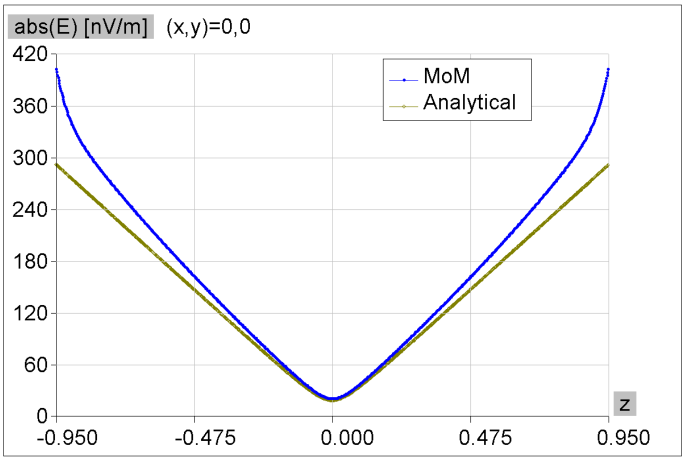

Figure 5. Electric field inside cavity for skin depth equal to eighths of shell thickness. Integral accuracy parameter set to “Enhanced 2”

Model – Shell with Additional Surface

In the model with conductivity of 2161.51 S/m, along very short distance between outer and inner shell surface, field differs about e^8 times. This is huge difference between field levels in the spherical cavity and the outer space. Because of so large difference in field levels, propagation of numerical error through the walls of the shell appears. In order to eliminate this numerical error theorem of surface equivalence will be used.

In WIPL-D Pro, we added a fictitious dielectric filling the cavity (with dielectric properties the same as air). We set calculation of near field inside this fictitious dielectric. By setting calculation of near field just in this added domain, we actually set calculation of near field by using theorem of surface equivalence.

For the sake of better modeling of the EM field inside the spherical cavity, one more surface between outer and inner shell surface has been added (Fig. 6).

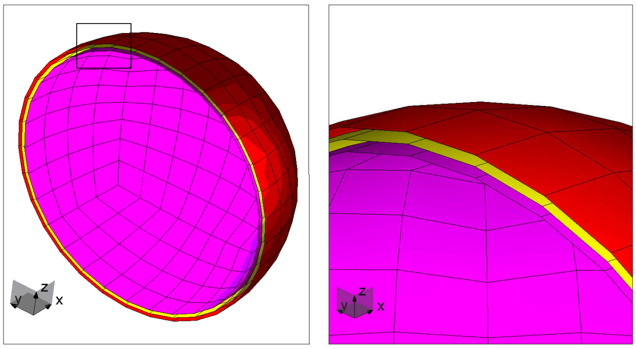

Figure 6. Cross section and detail of the shell with additional surface

Results – Shell with Additional Surface

By adding this middle surface, number of unknowns is increased for 50% comparing to original model. Nevertheless, with the additional surface, very good field approximation in the shell and accurate results for the field inside cavity are obtained. Electric field on z-axes, inside the cavity, is shown in Fig. 7.

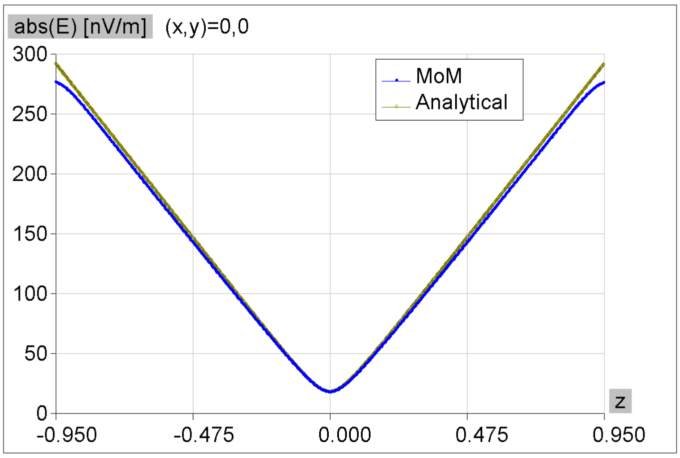

Figure 7. Electric field inside cavity for skin depth equal to eighths of shell thickness. 3 surfaces were used. Integral accuracy is set to “Enhanced 2”

Ratios between magnitude of incident electric field and magnitude of electric field in the center of cavity, with conductivity and skin depth are presented in Table 1.

Table 1. Skin depth, conductivity and ratio between incident field and field at the center of cavity

Skin Depth [cm]	*Conductivity [S/m]*	*Electric Field Ratio [dB]*
5	33.77	16.3
2.5	135.09	90.5
1.25	540.38	113.9
0.625	2161.51	154.6

Computational Platform and Simulation Time

The models were simulated on standard desktop computer Intel® Core™ i7 CPU 950@3.07 GHz with 8 GB RAM. Every model was simulated in less than a minute and a half.

Conclusion

We started from lower conductivity values, since such values give us greater skin depth. After that, we simulated numerically complicated models with higher conductivity.

Results obtained by using MoM SIE implemented in WIPL-D software and applying theorem of surface equivalence show high accuracy even in case when skin depth is significantly less than thickness of conductive walls.

Observing Fig. 5, we see that it is possible to obtain acceptable results if higher level of integration is used, even in the case when skin depth is equal to just eighths of shell thickness.

Almost perfect matching between analytical solution and solution obtained by simulating the model in WIPL-D Pro software occurred, although field level inside the cavity was more than 150 dB below the field level of incident wave (Fig. 7).