Single Human Body and Human Crowds RCS

In the recent years, due to the integration of electronic devices into everyday life there is an increasing public concern about the impact of electromagnetic wave on the human body. In this paper we will simulate the effect of electromagnetic wave on the human body and human crowds.

WIPL-D Software suit offers great tools for general 3D electromagnetic (EM) simulation in real life geometries and smart options to reduce number of unknowns and simulation time. This product also provides a library of homogenous dielectric and metallic human phantoms with adjustable phantoms' size, positions, shape, gender and so on.

Dielectric and metallic models of human body

In our investigations, we have used a homogenous dielectric (Figure 1) and metallic human body (Figure 2) in the frequency range from 2 GHz to 10 GHz. The relative dielectric constant and specific electrical conductivity for surface tissue of human body are in range from 5 to 50 and 0.02 S/m to 10 S/m at the considered frequency range, respectively.

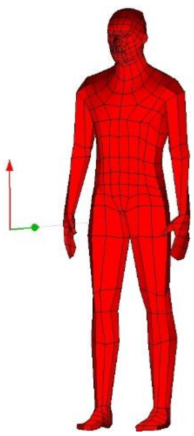

Figure 1. Dielectric human body

The skin depth is between 2mm at 10GHz and 60mm at 2GHz. Because of the small skin depth at higher frequencies, the most efficient simulation model of the human body proved to be metal model with losses included in form of distributed loadings. By using the metallic models with distributed loadings the number of unknowns is greatly reduced (compared to the case of the dielectric model), without reducing the accuracy of the simulation.

Dielectric model of human body is simulated at 2 GHz while the metallic model with distributed loadings is simulated at 2 GHz and 10 GHz. In all examples we set the same properties of materials. The relative dielectric constant and specific electrical conductivity are 35.5 and 1.36 S/m. The surface impedance for distributed loadings which is used in the simulations is Rs=36.6 Ohm and Xs=-16 Ohm. Both models are illuminated with a plane wave with electric field parallel to the human body.

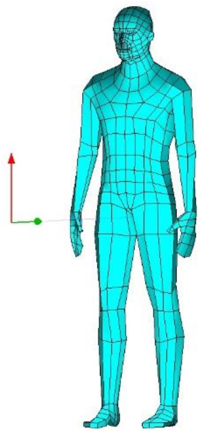

Figure 2. Metallic human body with distributed loadings

Calculated near filed for both models (dielectric and metallic) at 2GHz and metallic model at 10 GHz are shown in Figures 3, 4 and 5, respectively.

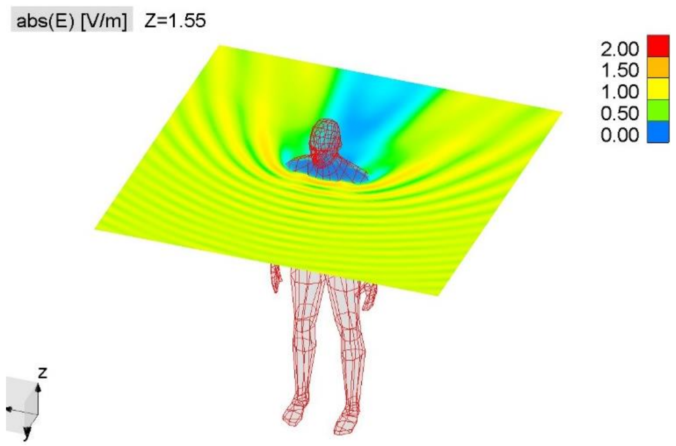

Figure 3. Near field for dielectric model at 2 GHz

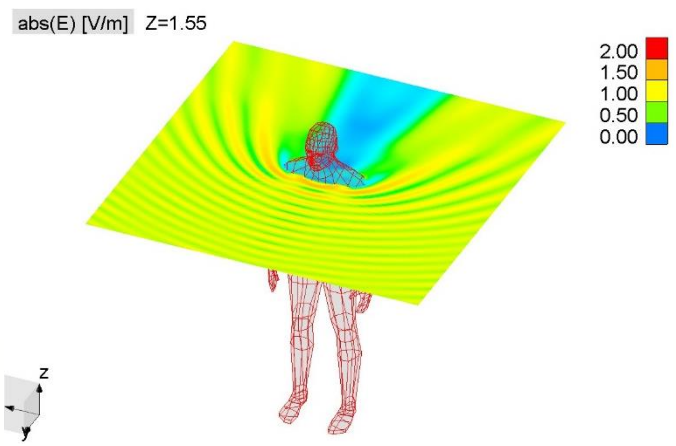

Figure 4. Near field for metallic model with distributed loadings at 2 GHz

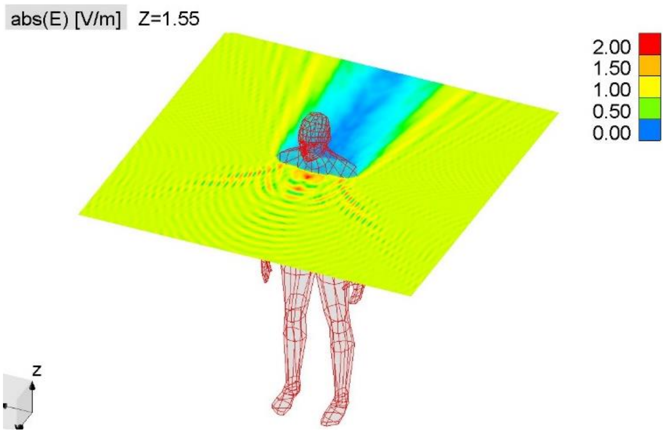

Figure 5. Near field for metallic model with distributed loadings at 10 GHz

Additionally, by using part of the smart features available in WIPL-D such as shadow, we have reduced number of unknowns for both models. We have used total shadow with 60% reduction at 2 GHz and 40% reduction at 10 GHz, which results in reducing number of unknowns more than 1.7 times at both frequencies. Distribution of the near filed for dielectric model at 2 GHz and metallic model at 2 GHz and 10 GHz after the smart reduction are shown in Figs 6-8.

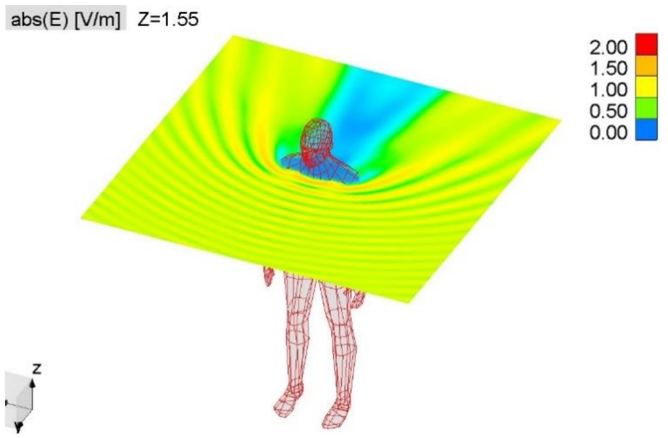

Figure 6. Near field for dielectric model after smart reduction at 2 GHz

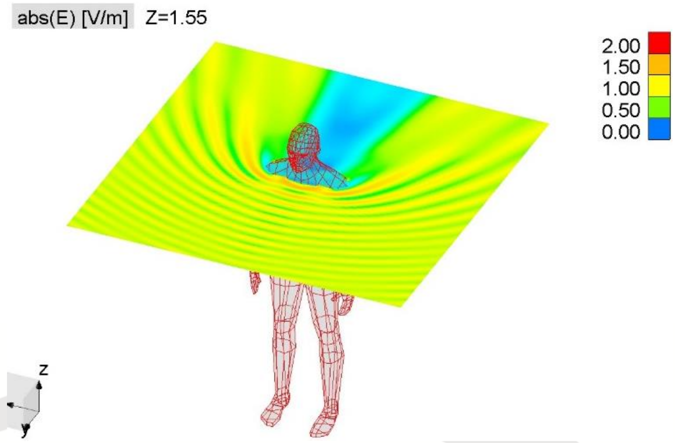

Figure 7. Near field for metallic model after smart reduction at 2 GHz

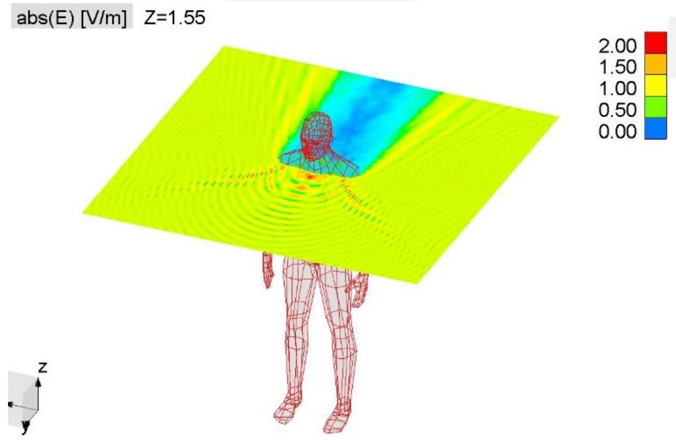

Figure 8. Near field for metallic model after smart reduction at 10 GHz

Number of unknowns and simulation time, for both models at 2 GHz and 10 GHz with and without the smart reduction, are summarized in Table 1. Computer configuration used is standard desktop PC with increased RAM and single inexpensive GPU card added for the matrix inversion speed up:

Intel® Core™ i7-7700 CPU @ 3.60 GHz with 64 GB RAM and NVIDIA GeForce GTX 1080 GPU card.

CPU is used for matrix fill, while GPU is used for matrix inversion.

Table 1. Number of unknowns and simulation time with and without smart reduction at 2GHz and 10GHz.

Model	*Number of unknowns*		*Simulation time [sec]*	
	2 GHz	10 GHz	2 GHz	10 GHz
Dielectric model	13,774	461,662	21*	
Metallic model	6,887	83,493	8	463*
Dielectric model with reduction	7,888	239,192	14	
Metallic model with reduction	3,944	46,432	4	119*

* The matrix inversion was done by using GPU Solver

Human crowds

In this section, we have analyzed a few models of human crowds with properly distributed (Figure 9) and random positions of human bodies (Figure 10). Number of human body for each group is 49. Operating frequency is 0.9 GHz. Number of unknowns and simulation time for both models are given in Table 2.

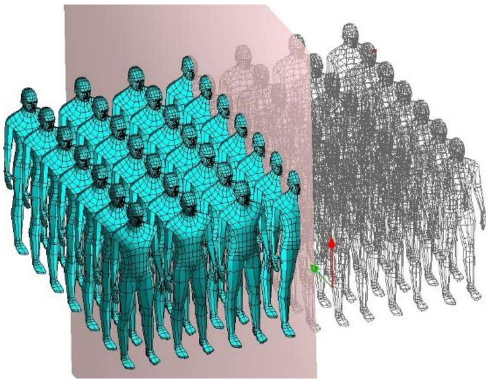

Figure 10. Metallic human crowds with distributed loadings with properly distributed positions of human bodies

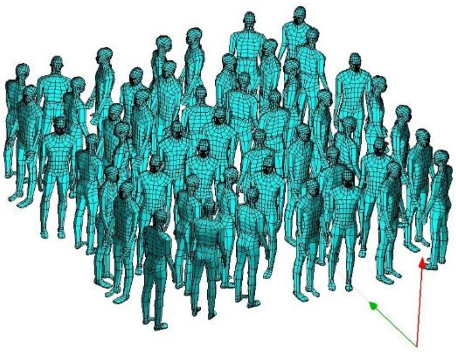

Figure 11. Metallic human crowds with distributed loadings with random positions of human bodies

Table 2. Number of unknowns and simulation time with and without smart reduction at 2GHz and 10GHz

Model	*Number of unknowns*	*Simulation time [sec]*
Properly distributed positions of human bodies	70,756	997*
Random positions of human bodies	131,614	6,048*

* The matrix inversion was done by using GPU Solver

Distribution of the near field for model with random positions is shown in Figure 12.

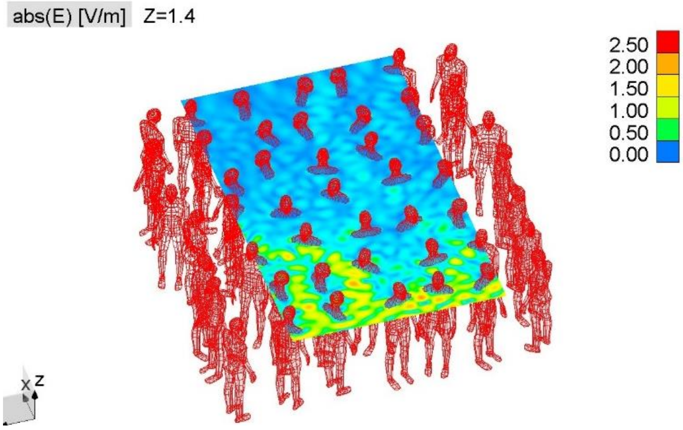

Figure 12. Near field for model with random positions of human bodies at 0.9 GHz.

Solvable in maximum 1 day using WIPL-D

In all examples, we have observed problems that could be solved in 1 day using WIPL-D. Depending on the computer architecture, typical values of the number of unknowns solvable in under one day are:

- 100,000 unknowns with regular quad core PC,
- 500,000 unknowns with inexpensive GPU added,
- 1,000,000 unknowns with GPU cluster with 10 nodes,
- 3,000,000 unknowns using Domain Decomposition Solver with 20 cores PC.

Usage of symmetry planes can double/quadruple number of humans without increasing the number of unknowns.