Indoor Wi-Fi Antenna at 2.4 GHz

Wi-Fi represents technology which is widely used in wireless local area networking, the most common frequency bands used being 2.4 GHz and 5.8 GHz. This application note presents use of the WIPL-D software suite for the calculation of near field in a room where Wi-Fi antenna operating at 2.4 GHz is located.

WIPL-D Pro CAD and WIPL-D Pro models and simulation setups will be presented. The efficiency of **Method-of-Moments (MoM)**, a numerical method implemented in WIPL-D solver will be explained. Furthermore, *Smart reduction,* a reduction of current expansion orders will be explained. The results obtained without any reduction and the results with the reduction applied will be presented and compared. In addition, the results will be compared with the near field calculated when the Wi-Fi antenna is in the free space. Details regarding the simulation time and other relevant computation data will be presented.

MoM Efficiency

WIPL-D software uses very **sophisticated higher order basis functions** (HOBFs) together with quadrilateral meshing. This means that the mesh elements are quads, as opposed to commonly used triangles, and that the basis functions are higher order polynomials, not simple linear (rooftop) functions. Hence, for the case where a current distribution over a surface is approximated using HOBFs, the current distribution can have considerably higher dynamic than in the case where the same number of rooftops is used. Owing to this efficiency, significantly larger structures are quickly simulated on relatively inexpensive workstations. Application of HOBFs is entirely automatic, although the user can increase the accuracy of the approximation.

Smart Reduction of Expansion Order

The *Smart reduction* is a feature which is very suitable for antenna placement problems. It is based on adaptive reduction of current expansion order over parts of the model which are distant from the antenna or in shadow. Applying *Smart reduction*, the **number of unknowns can be significantly reduced**, while **very good accuracy** of calculated radiation pattern or coupling between multiple antennas is preserved. Decreasing expansion orders usually requires increasing *Integral accuracy*, a WIPL-D numerical kernel parameter.

WIPL-D Models

The model of Wi-Fi antenna located inside of the room was created using WIPL-D Pro CAD (Figure 1). WIPL-D Pro CAD is a CAD tool suitable both for creating models from the scratch or importing various CAD formats. The former have been used to create the model of the antenna located in room, the utilization of several built-in primitives from WIPL-D Pro CAD pallet help creating the simulation scenario a couple of minutes.

The dimensions of the room are L=5 m, W=4 m, and H=3 m. The room was modeled using cuboid primitive. It is considered that the walls are made of the bricks with dielectric permittivity of 4.5. Only one surface (between the room interior and the bricks) was modeled. Wi-Fi antenna is given in the form of the thin half-wave dipole. The dipole is moved from the wall for a quarter of a wavelength. The dipole is positioned in such manner that two symmetry planes can be applied.

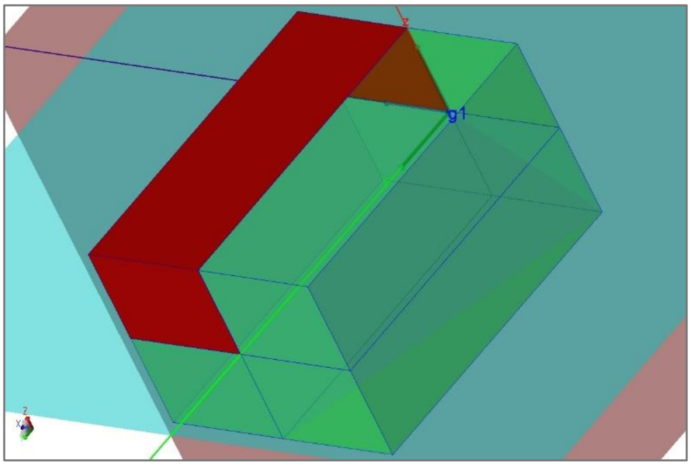

Figure 1. CAD model of the room.

The operating frequency is 2.4 GHz. Meshing of this electrically large structure was efficiently carried out as *Max Patch Size* parameter was modified from 2 wavelengths to 1.83 wavelengths. The meshed model, which is actually the model obtained after converting WIPL-D Pro CAD model to WIPL-D Pro, is shown in Figure 2.

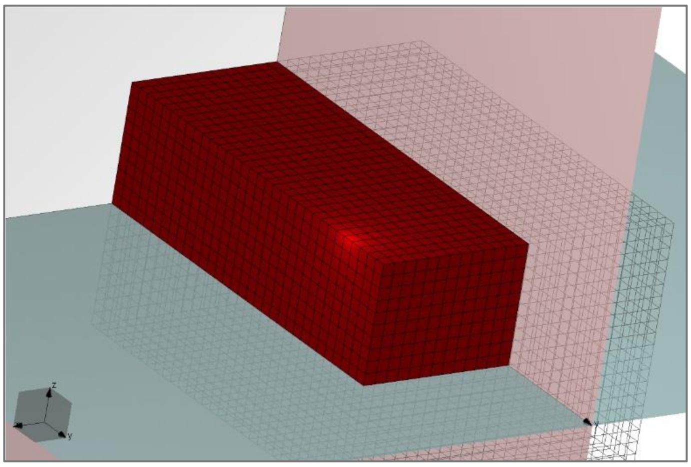

Figure 2. WIPL-D Pro (meshed) model of the room.

Results and Simulations

The first simulation was the calculation of the near field of a Wi-Fi antenna inside of the room with no reduction applied. The second simulation was calculation of the near field of the same antenna – room scenario with antenna placement reduction of 70% applied. The other simulated models represent models of the Wi-Fi antenna simulated in the free space.

The near field distributions within the room calculated with and without the antenna placement reduction are compared in Figure 3. The results are very similar which implies that the model with the antenna placement reduction is highly accurate and can be used successfully for further calculations instead the full model.

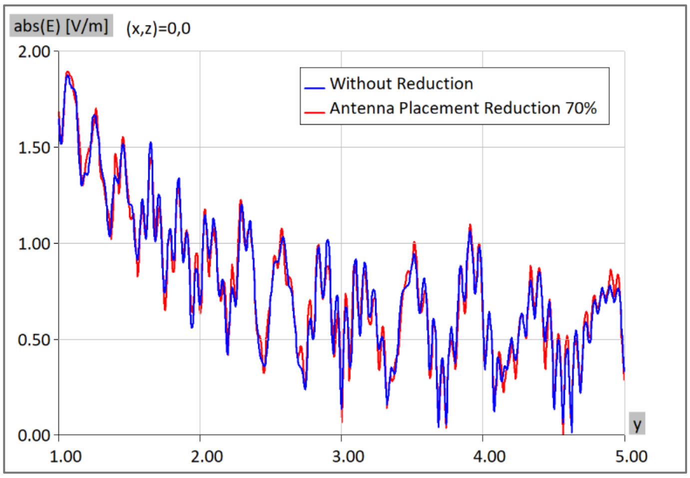

Figure 3. Comparison of near field distributions-models with and without the reduction. The near field is obtained within the room.

Calculated 2D near field distributions with the reduction applied are presented in Figures 4-7. The distribution inside of the room is plotted in 501x501 points. For z = 0 m (which is equal to 1.5 meters above the floor) the distribution is shown in Figure 4, while the distribution in the free space for the same coordinate is shown in Figure 5. Near field distribution inside of the room for z = 0.75 m (which is equal to 2.25 meters above the floor) is shown in Figure 6, and the corresponding field distribution in the free space for the same coordinate is shown in Figure 7.

Computer used for these simulations is Intel® Core™ i7-7700 CPU @ 3.60 GHz with 64 GB RAM. Matrix inversion was performed on a GPU card (GeForce GTX 1080). Number of unknowns, computer memory required and simulation times are listed in Table 1. Presented simulation times mainly consist of time required for matrix fill and for matrix solution.

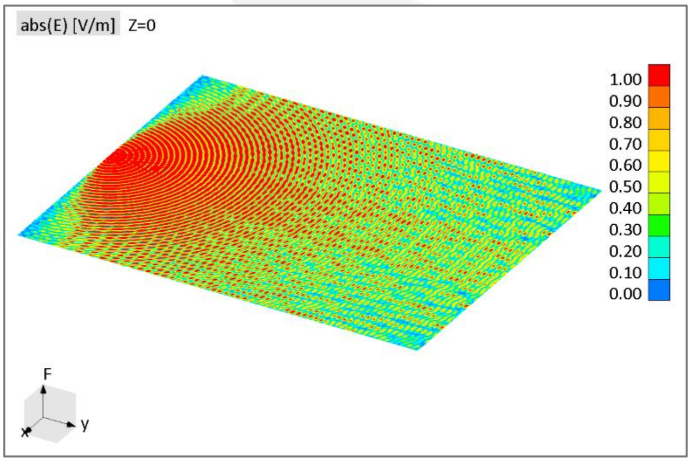

Figure 4. 2D near field distribution inside of the room-z = 0 m.

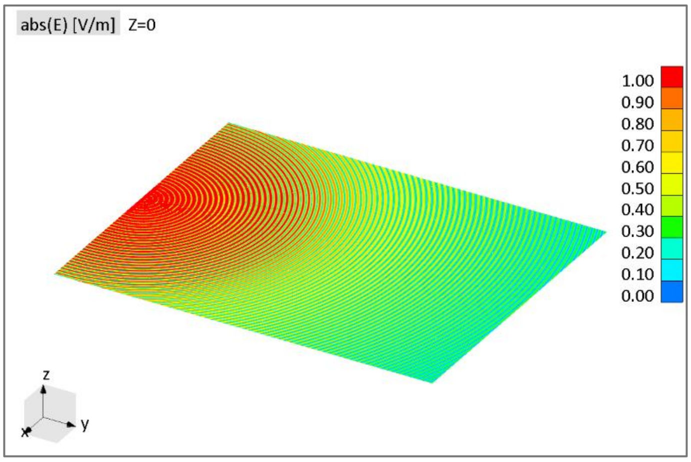

Figure 5. 2D near field distribution. Wi-Fi antenna in free space-z = 0 m.

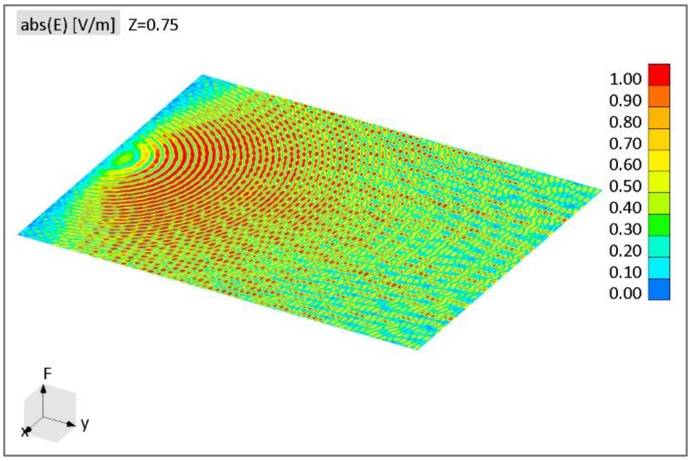

Figure 6. 2D near field distribution inside of the room-z = 0.75 m.

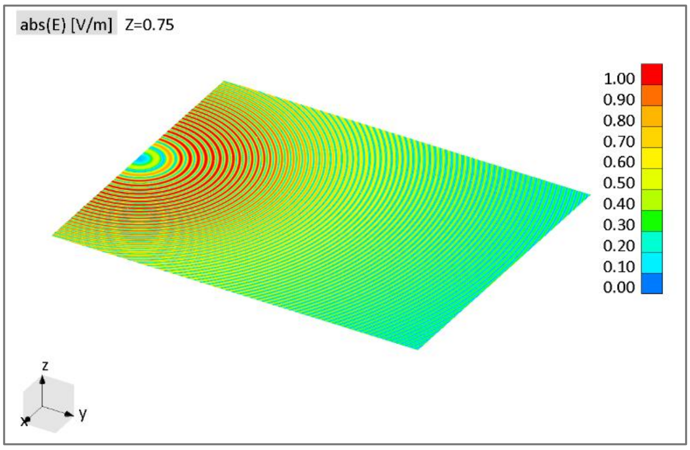

Figure 7. 2D near field distribution. Wi-Fi antenna in free space-z = 0.75 m.

Table 1. Number of unknowns, computer memory required and simulation time

Model	Number of unknowns	Memory [GB]	Simulation time [hours]
Model without reduction	143,426	153.3	2.03
Model with the reduction	71,446	38.0	0.22

Conclusion

Near field results obtained after simulating the models of Wi-Fi antenna positioned inside the room with brick walls are presented. In addition, near field results for model of Wi-Fi antenna in free space are also presented. After applying optimal meshing parameters, model of a Wi-Fi antenna was firstly simulated without any reduction, while the second simulation was preformed with *smart reduction* applied. All models were simulated very fast on a “standard”, “inexpensive” workstation.

With *smart reduction*, applied the number of unknowns **decreases about 2 times** (the computer memory requirement **decreases about 4 times**), while the simulation time **decreases about 9 times**. The time saving feature comes without noticeable changes in values of the calculated near field.

All calculations give theoretically expected results. When compared with free space results, it is clear that the results obtained for antenna located within a room contain the reflections from the walls.