IoT Scenario Within an Aircraft Apartment

The operating environment an **Internet of Things (IoT)** system is usually complex and includes the presence of some obstacles e. g. furniture for an indoor scenario. A typical example of such a scenario could be a modern traveling environment onboard a luxury aircraft which includes a passenger inside an aircraft apartment and several pieces of furniture. On the one side of an IoT link is a **traveler with a cellphone**, and on the other side is a **warning sensor located in a locker compartment** intended to warn the passenger if an object is forgotten inside a locker. The cellphone antenna is modeled as a printed dipole inside the phone housing, while the sensor hardware is simplified to an inverted-F antenna (IFA). The operating frequency of this IoT warning system is assumed to be approximately 2.40 GHz.

This application note illustrates the calculations of S-parameters for the two antennas and how S-parameters change if the position of the sensor is moved. Therefore, only the coupling between the antenna required to analyze radio link budget will be considered.

All simulations will be carried out using **WIPL-D Software**, **a cutting-edge full wave 3D electromagnetic Method-of-Moments based software.** It will be shown that calculations are very efficient providing high accuracy in reasonable simulation time.

WIPL-D Models

A CAD file of the large aircraft was imported to WIPL-D Pro CAD software and prepared for simulations. A model of luxury flight apartment with a passenger and pieces of furniture is presented in Figure 1.

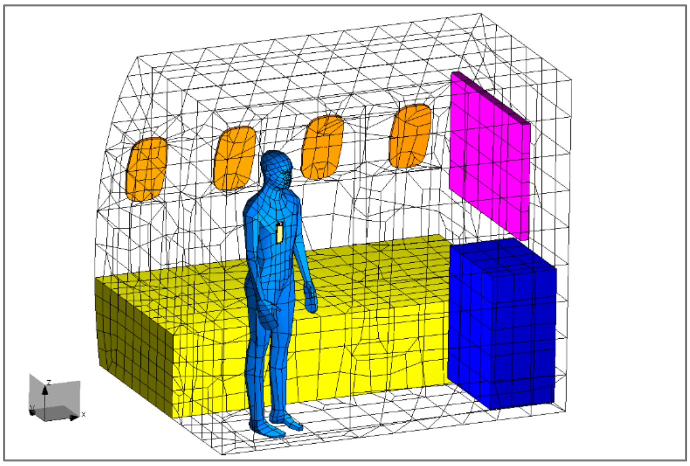

Figure 1. The model of the apartment with traveler phantom, a cellphone, and a sensor (the sensor is not shown in the figure)

The passenger is modeled through a human phantom with the cellphone located at the chest and presented as a yellow box (it should not be mixed with the bed). The model of the apartment environment includes metallic walls which are presented in transparent wire frame, dielectric windows in orange. A magenta box represents a monitor, yellow box stands for a bed, while a blue box models a locker. A sensor IFA is located inside the blue box. The apartment walls were modeled using PEC metallic surfaces as presented in Figure 2. Only the communicating devices are shown for clarity in Figure 3.

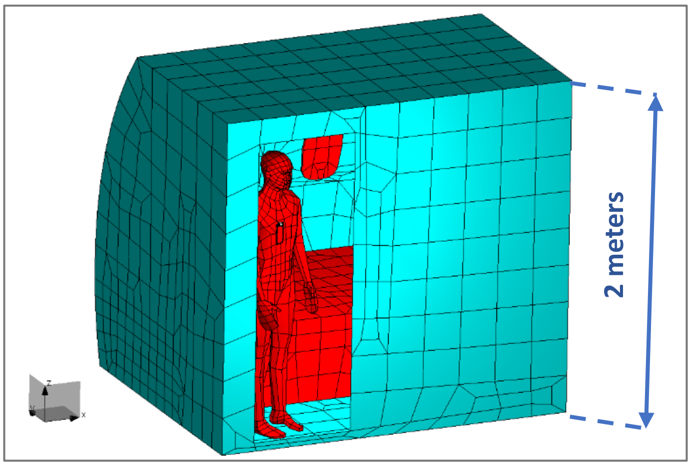

Figure 2. Metallic walls and height of the apartment

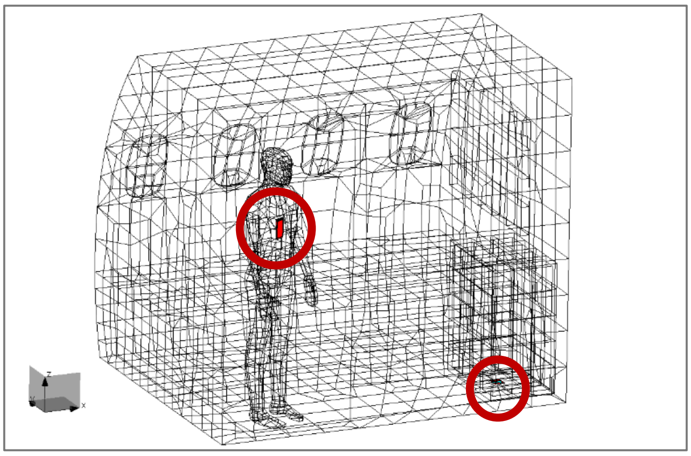

Figure 3. Communicating devices

The simplified cell-phone model is shown in Figure 4. On the left-hand side, the exterior of the phone is presented – it has a form of a dielectric box. The interior is represented on the right-hand side. The printed circuit board (PCB) is approximated with a finite PEC plane. The dipole antenna is located adjacent to the PCB.

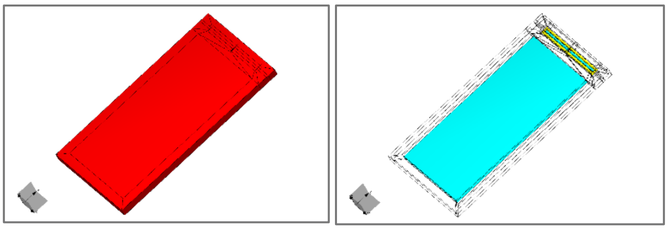

Figure 4. The model of the cellphone and its interior

The model of the IFA representing the sensor within the locker is shown in the Figure 5.

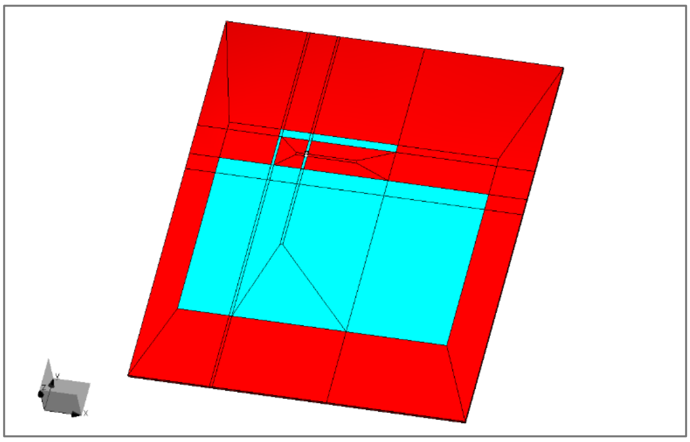

Figure 5. IFA representing the sensor

This apartment model contains several models of dielectric objects, a list of the objects and electrical properties of corresponding materials can be found in Table 1. The properties of the materials are for the illustration purposes only.

Table 1. Applied materials

Object	Er	TgD
Human phantom	100	0 (Sigma = 3 [S/m])
Window glass	2	0.0025
Apartment walls	PEC	
Bed	4	0.00025
Monitor	PEC	
Locker	3	0.000667
Cellphone case	3	0

Simulations and Results

All the projects were simulated in the frequency range from 2.350 GHz to 2.535 GHz.

Dipole antenna from Figure 4 has been simulated as located in a phone corresponding to Figure 4, while IFA from Figure 5 has been simulated as radiating in free space. The simulations have been carried out at 21 frequency points. The calculated S-parameters are shown in Figure 6. **Both simulations are very fast as they take no more than a couple of minutes as the problems' sizes require not more than 2,000 unknowns.**

After confirming that matching of both antennas is acceptable, simulations of the complete scenario between 2.40 GHz and 2.41 GHz at 21, 11, and 6 frequency points were performed. The results are presented in Figure 7. The aim of these simulations was to determine optimal number of frequency points in the 2.350 GHz to 2.535 GHz band. It can be concluded that applying 6 frequency points enables result which is smooth enough, i.e. the frequency step of (2.41 GHz-2.40 GHz) / (6-1) = 2 MHz is optimal. This means that for frequency band from 2.350 GHz to 2.535 GHz, 94 frequency points are required. The apartment scenario simulations were performed with WIPL-D *Smart reduction* feature set to 50% and numerical kernel parameter *Integral accuracy* set to *Enhanced 2*.

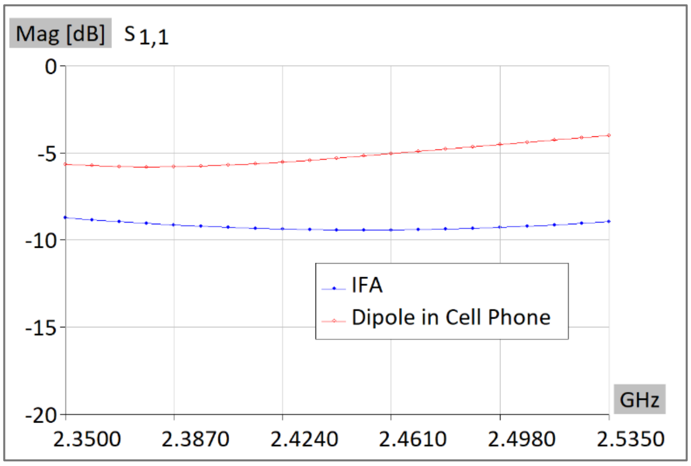

Figure 6. S-parameters for IFA and dipole in cell phone

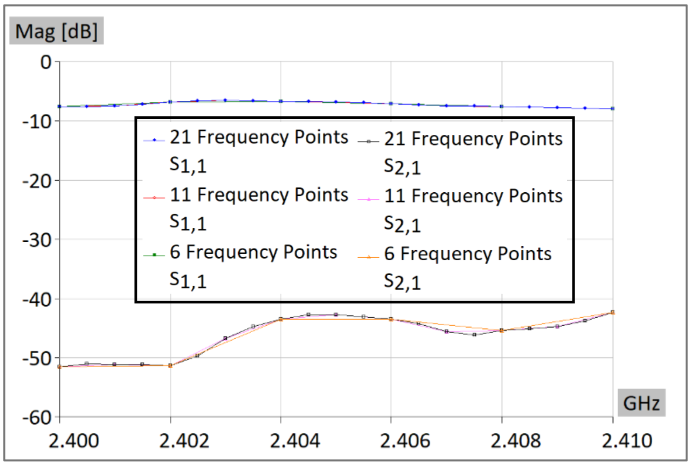

Figure 7. S-parameters between 2.40 GHz and 2.41 GHz

In addition, results of apartment simulation with furniture containing two communicating devices were compared with appropriate S-parameters of IFA and the dipole within the cell phone. The comparison of the results is presented in Figure 8.

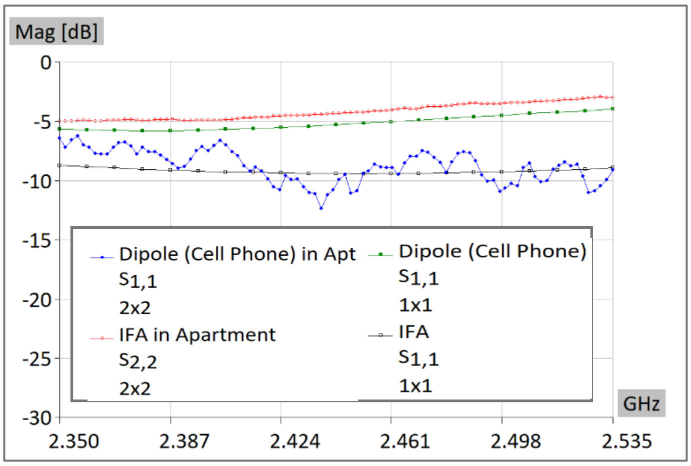

Figure 8. Comparison of S-parameters

It can be concluded that the matching of the antennas is almost not affected when they operate in this particular IoT scenario.

S-parameter representing transmission between two antennas located within the apartment is shown in Figure 9. The average coupling between the antenna in the frequency range is approximately -44 dB which can be used in a preliminary link budget calculation.

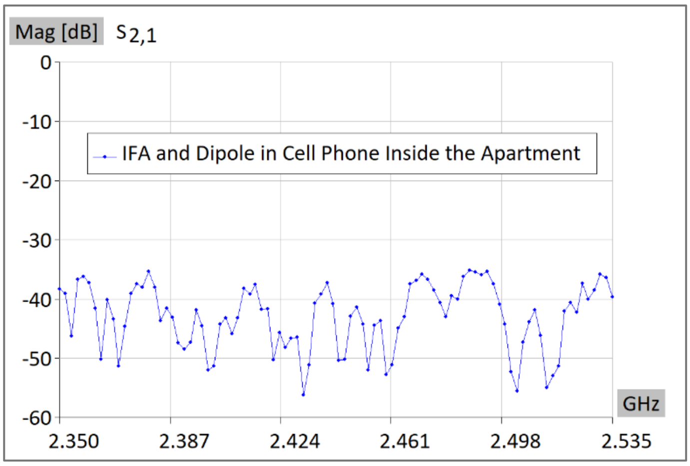

Figure 9. Transmission between IFA and the dipole within the cell phone

S-parameters representing transmission between two antennas located within the apartment when IFA is moved along x axis with a space resolution of 6 mm are presented in Figure 10. It can be concluded that the link budget remains almost unchanged for the specified movement of the sensor antenna.

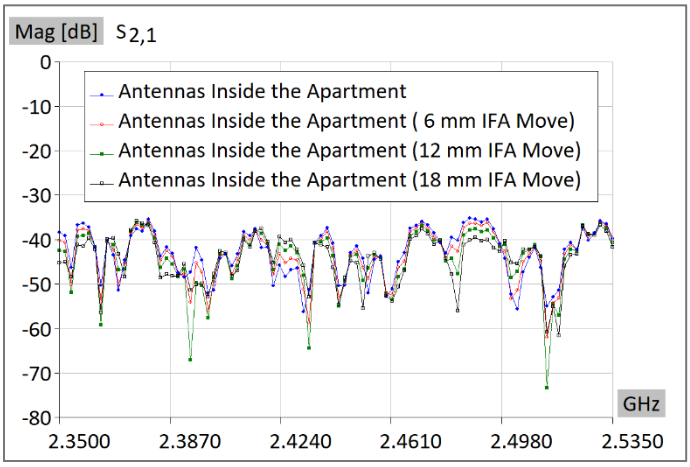

Figure 10. Transmission between two antennas when IFA is moved along x axis

Computer hardware used for simulations is presented in Table 2.

Table 2. Computer used in the simulations.

Hardware	Description
CPU	Intel® Xeon® CPU E5-2650 v4 @ 2.20GHz 2.20 GHz (2 processors)
RAM	256 GB
GPU	4 cards: Nvidia GeForce GTX 1080 Ti

Number of unknowns and simulation time per frequency for antenna inside the apartment project are presented in Table 3. Matrix fill was performed on CPU. Matrix solution was performed using GPU cards.

Table 3. Number of unknowns and simulation times for simulated scenario

Project	Number of Unknowns	Simulation Time per Frequency
Antennas within the apartment with obstacles	118,082	~19 minutes

Conclusion

A typical IoT scenario was simulated using WIPL-D, a full wave MoM based software. The IoT scenario contains two antennas communicating in 2.350 GHz-2.535 GHz frequency band, a traveler with cellphone, and the airplane apartment interior including the apartment walls and furniture. Only electromagnetic (EM) aspects of this scenario were considered.

It was shown that all simulations were successfully carried out using **WIPL-D Software, a full wave 3D electromagnetic Method-of-Moments based software which applies Surface Integral Equations.** Unlike common practice to simulate such a scenario applying various asymptotic solvers, WIPL-D full-wave MoM based solver, can be successfully used to simulate such a realistic scenario as simulation time per frequency is only about 19 minutes.