Different Simulation Scenarios Involving Unmanned Aerial Vehicles (UAVs)

Unmanned aerial vehicles (also known as drones) have become a common part of our life. Controlled by human operators and\or artificial intelligence, they are frequently used in commercial, military, intelligence, security etc. purposes. This application note outlines three scenarios involving the drones. The focus here is on pure electromagnetic topics related to physical layer of communication link between several drones.

All scenarios considered here contain three drones. In the first scenario the drones communicate above a flat ground plane. The second scenario, in addition to the drones and the ground plane, includes a fence made of metallic wires. The fence is modeled with WIPL-D *Wire* entity. Finally, the third scenario is very similar to the second. It contains drones, ground plane and a fence made of metallic wires which are in this scenario modeled using WIPL-D bilinear surfaces (the *Plates*). The aim is to show a change in S-parameters between drone antenna ports resulting from a presence of the fence. It is assumed that the drones are made from a dielectric material. In all cases the ground plane is approximated with flat infinite PEC plane. Frequency band used for communication is around 2.4 GHz.

All the simulations will be carried out using **WIPL-D Software, a full wave 3D electromagnetic Method-of-Moments based software** which applies Surface Integral Equations.

WIPL-D Drone Models

The model of a drone was imported in WIPL-D Pro CAD software through one of the standard CAD file formats (Figure 1). It is assumed that the drone is made from a dielectric material. The properties of the dielectric material are: ε_r=2.2 and tanδ=0.03.

A simply wideband monopole antenna is mounted on the top of the drone (Figure 1). It is used for communication between the drones. In order to enable electrical ground for the monopole, a small area located just below the antenna is metallized (Figure 1).

The model of the drone contains also a payload (Figure 1) which is in this case a camera made of a material same as the one assumed for the drone.

The meshed model of the drone with the antenna and the payload i.e., the model converted to WIPL-D native format, is shown in Figure 2.

Drone Scenarios

Three scenarios with drones are explained in this section. Each scenario involves three drones above a PEC plane. The scenarios were being modified using WIPL-D Pro and WIPL-D native format files.

Scenario 1 is shown in the Figure 3. The dimensions significant for understanding locations of the drones are outlined in the same figure. The distance between two adjacent drones is about 3 meters, while the altitude of all of the drones is about 1 meter.

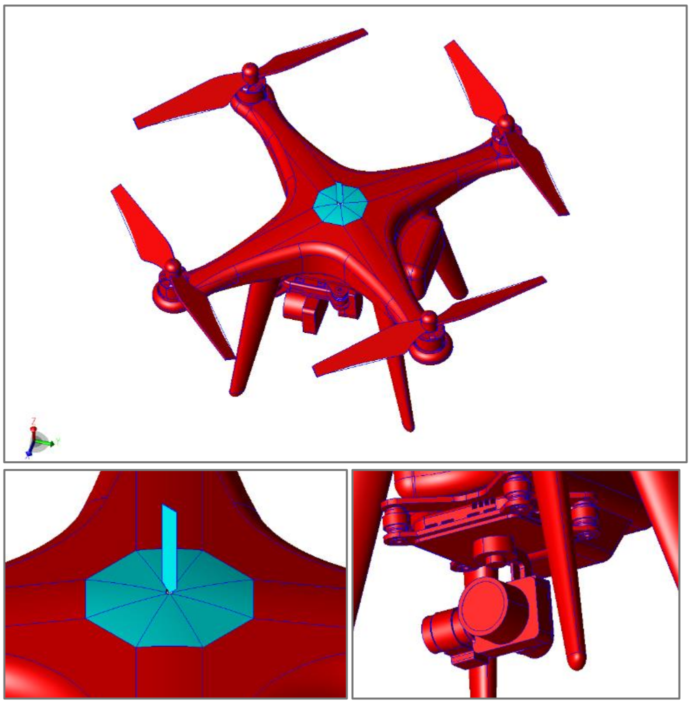

Figure 1. The model of the drone, the monopole antenna and the payload in WIPL-D Pro CAD

Figure 2. Meshed model of the drone in WIPL-D Pro

It can be seen that drones fly in a column (so called, the line formation). However, the column is not ideal as each drone is offset and rotated a bit. The drones are marked numerated as presented in Figure 3. In the scenario considered here the first drone is the leader and is followed by other drones. The communication exists only between a pair of neighboring drones, i.e., #1 and #2, and #2 and #3.

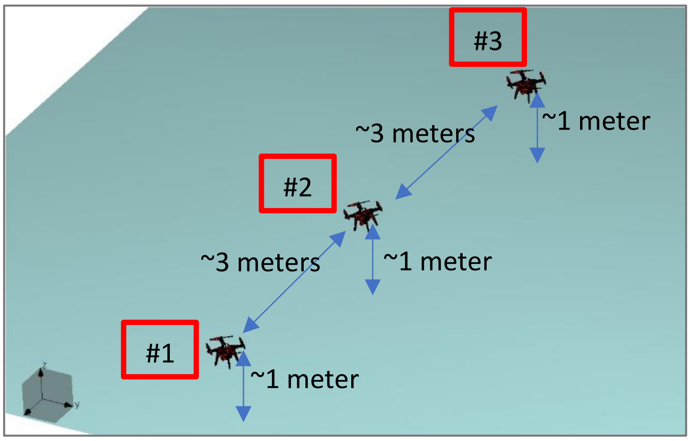

Figure 3. Drones above PEC - *Scenario 1*

Scenario 2 is shown in the Figure 4. It is similar to the first scenario. However, the main difference is in the presence of a metallic wire fence modeled with WIPL-D *Wire* entities. The fence is located between drones #2 and #3. The dimensions required for understanding positions of the drones and the size of the fence can be found in the Figure 4. The distance between the fence and the second drone is 1.5 meters, the same as the distance between the fence and the third drone. The fence is approximately 2 meters high and 4 meters wide. The other dimensions are the same as shown in the Figure 3.

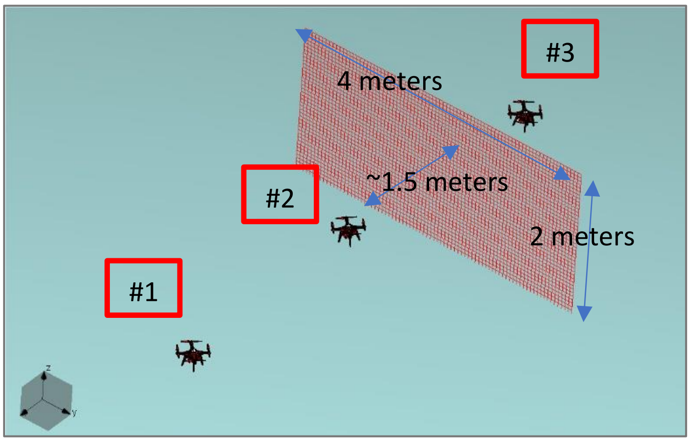

Figure 4. Drones above PEC with *Wire* entities fence - *Scenario 2*

The fence is modeled as a finite metallic wire grid. The wire used to model the fence is a WIPL-D *Wire* entity with the radius of 3 mm. A single fence cell is a square with side length of 50 mm as shown in the Figure 5.

Scenario 3 is shown in the Figure 6. The main difference with respect to the *Scenario 2* is in modeling of the metallic wire fence which is now modeled using bilinear surfaces. Using WIPL-D terminology, in *Scenario 3* wire fence is modeled using *Plate* entities. Details regarding fence modeling using *Plate* entities are shown in Figure 7 including the mesh of the fence grid and significant dimensions.

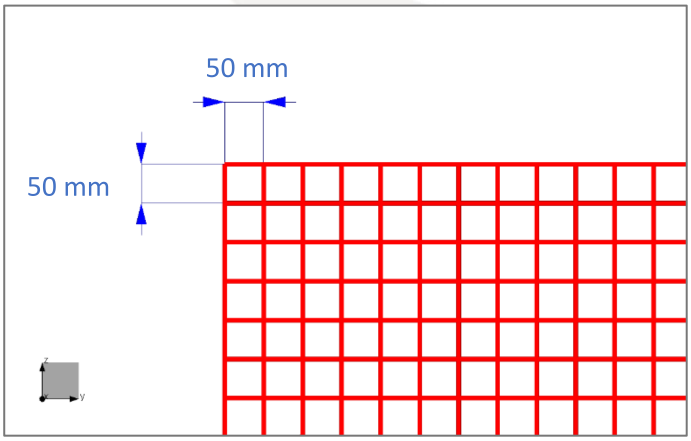

Figure 5. Dimensions of the *Wire* entity fence grid cell

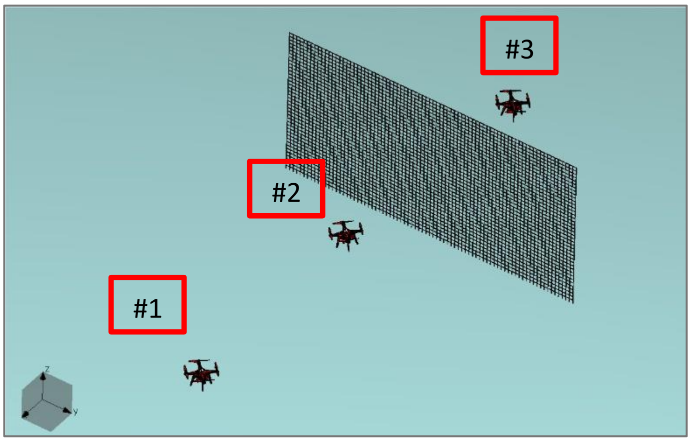

Figure 6. Drones above PEC with *Plate* entities fence - *Scenario 3*

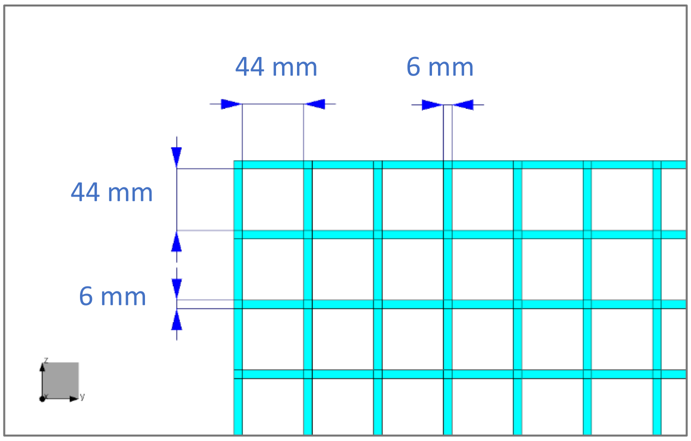

Figure 7. Dimensions of the fence grid cell modeled with *Plate* entities

Simulations and Results

All scenarios are simulated from 2.35 GHz to 2.45 GHz at 5 frequency points. The results of interest are S-parameters between communicating drones.

The modelling and the simulations were performed on a computer with hardware specifications outlined in Table 1.

Table 1. The workstation used

Hardware	Description
Processor	Intel® Xeon® Gold 6248R CPU @ 3.00GHz 3.00 GHz (2 processors)
RAM	768 GB
GPU	NVIDIA GeForce RTX 3080 (2 cards)

Number of elements, number of unknowns, and simulation times per frequency are presented in Table 2. Matrix inversions were performed on GPU cards.

Table 2. Number of elements, number of unknowns, and simulation times per frequency

Model	Number of elements	Number of unknowns	Simulation time per frequency
Scenario 1	38,361	97,444	62 minutes
Scenario 2	51,241	113,524	1 hour 51 minutes
Scenario 3	57,883	136,408	1 hour 55 minutes

S-parameters (S_{21} and S_{32}) calculated in the *Scenario 1*, *Scenario 2*, and *Scenario 3* are compared in Figure 8 and Figure 9.

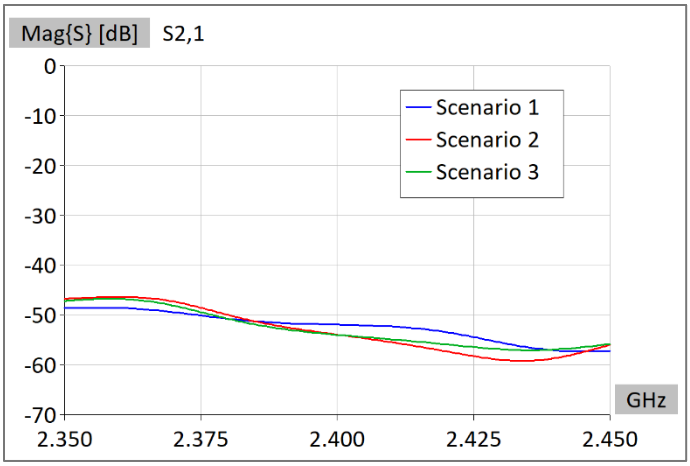

Figure 8. S_{21}-parameters

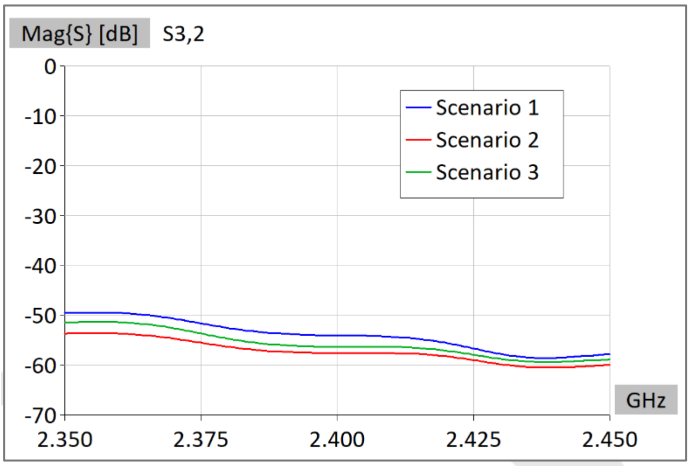

Figure 9. S_{32}-parameters

Conclusion

Real-life scenarios with three drones (UAVs) communicating at frequency band around 2.4 GHz were investigated focusing on pure electromagnetic topics related to the physical layer of communication link between the drones. The first scenario serves as a reference and encompasses the drones above ground plane which is approximated with an infinite PEC plane. In remaining scenarios, a metallic wire fence has been introduced between two of the drones. The difference between the later is in the method used to model the wire fence.

From the simulation results It can be clearly seen that presence of the fence influences S-parameters between drones' antennas ports. Also, the way of modelling the fence influences the results.

All the simulations were carried out using **WIPL-D Software, a full wave 3D electromagnetic Method-of-Moments based software** which applies Surface Integral Equations. According to the simulation times, it can be concluded that all simulations were performed in an efficient manner and that WIPL-D software can be used successfully for the analysis of drone related scenarios.