electromagnetic modeling of composite metallic and dielectric structures

Influence of a Fence Located Between Communicating Drones

This application note outlines two scenarios involving the drones and a fence acting as an obstacle for communication between them. The focus of this application note is on pure electromagnetic topics related to physical layer of communication link between the drones. Each scenario discussed here contains three drones. In the first scenario the drones communicate above a flat ground plane including a metallic fence made from wires modeled as WIPL-D *Wire* entities. The second scenario contains drones, ground plane, and a metallic fence made from wires modeled using WIPL-D bilinear surfaces (the *Plates*).

The aim of this application note is to show a change in S-parameters between drone antenna ports varying the relative position of the fence and keeping the initial order of the drones the same. It is assumed that the drones can be approximated as pure dielectric structures. In all cases the ground plane is approximated with flat infinite PEC plane. The operating frequency is 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 Pro Model of The Drone

The model of a drone used was available in one of the standard CAD file formats. The model was imported in WIPL-D Pro CAD software and converted to the WIPL-D Software native format (Figure 1). It is assumed that the drone dielectric material has the following properties: ε_r=2.2 and tanδ=0.03. A simple, wideband monopole antenna mounted on the top of the drone has been added to the model (Figure 1). A small dielectric area located just below the monopole antenna has been replaced with a metallic surface (Figure 1) acting as an electrical ground for the monopole. The model of the drone includes a payload (Figure 1) which is in this case a camera made of a material same as the one assumed for the drone.

Figure 1. Meshed model of the drone with the monopole and the payload in WIPL-D Pro

Scenarios with Fence as The Obstacle

Two scenarios with drones are explained here. Each scenario involves three drones above a PEC plane.

Scenario 1 is shown in the Figure 2. The dimensions specifying positions 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. The fence is located between drones #2 and #3. The metallic wire fence is modeled with WIPL-D *Wire* entities. A building element is a WIPL-D *Wire* entity with the radius of 3 mm. The fence is approximately 2 meters high and 4 meters wide.

The drones are 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 numerated as presented in Figure 2. In the scenarios 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.

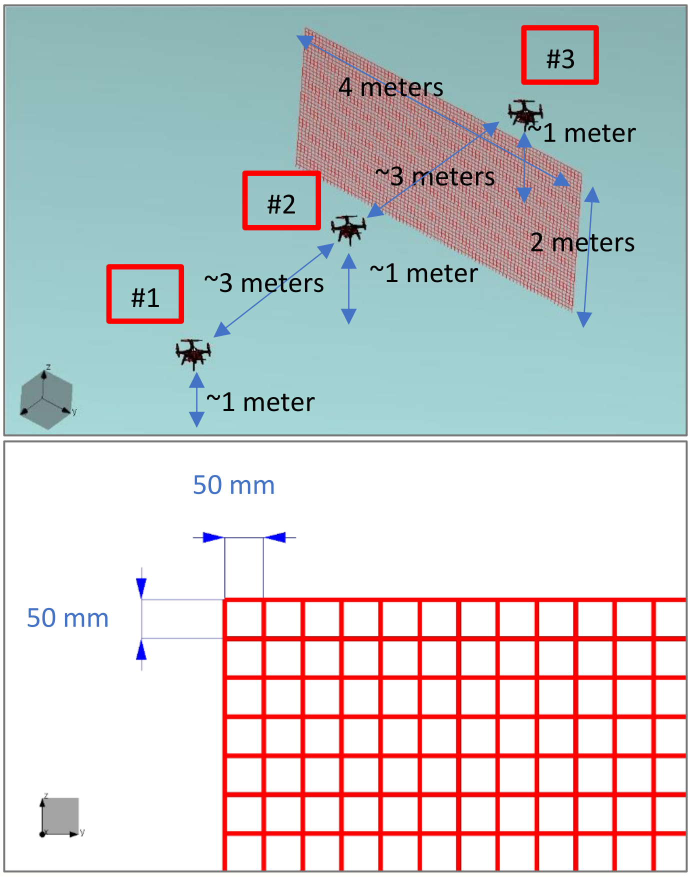

Figure 2. Drones above PEC with *Wire* entities fence with dimensions of the *Wire* entity fence grid cell

Scenario 2 is shown in the Figure 3. 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 2* wire fence is modeled using *Plate* entities. Details regarding fence modeling using *Plate* entities are shown also in Figure 3 including the mesh of the fence grid and significant dimensions.

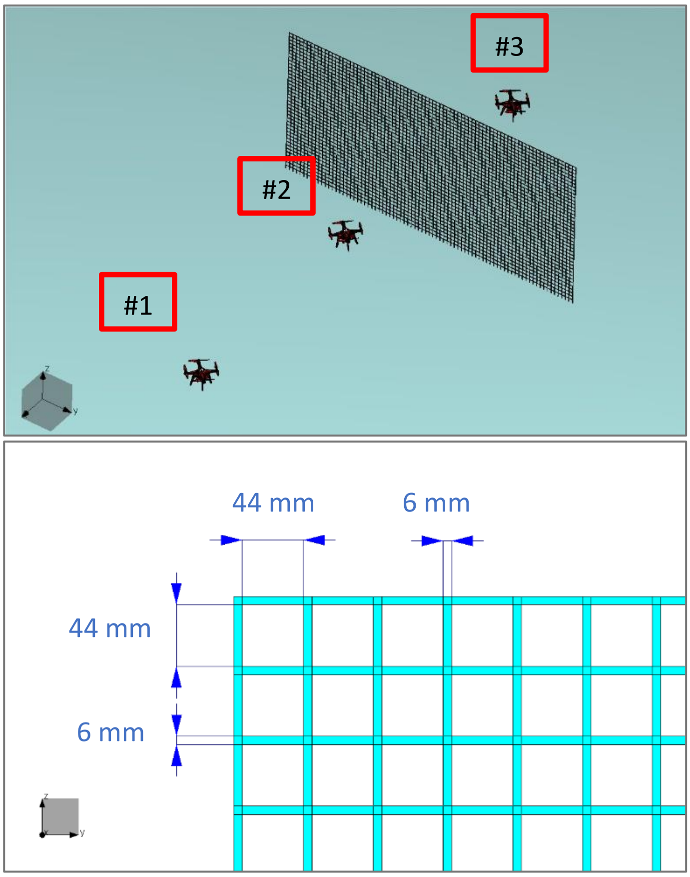

Figure 3. Drones above PEC with *Plate* entities fence and dimensions of the *Plate* entity fence grid cell

Changing Relative Fence Position with WIPL-D Sweeper

A bird's eye view is used for explaining locations of the drones and the location of the fence (Figure 4). The relative positions of the drones and non-ideal line formation is the most clearly seen in the Figure 4. In order to hold the same relative positions of the drones and change the position of the fence, the parameter XPos is introduced. The parameter determines x coordinates of the fence and has been varied from -1 meter to 1 meter in 11 points. Three positions of the fence obtained with varied XPos parameter are also displayed in Figure 4.

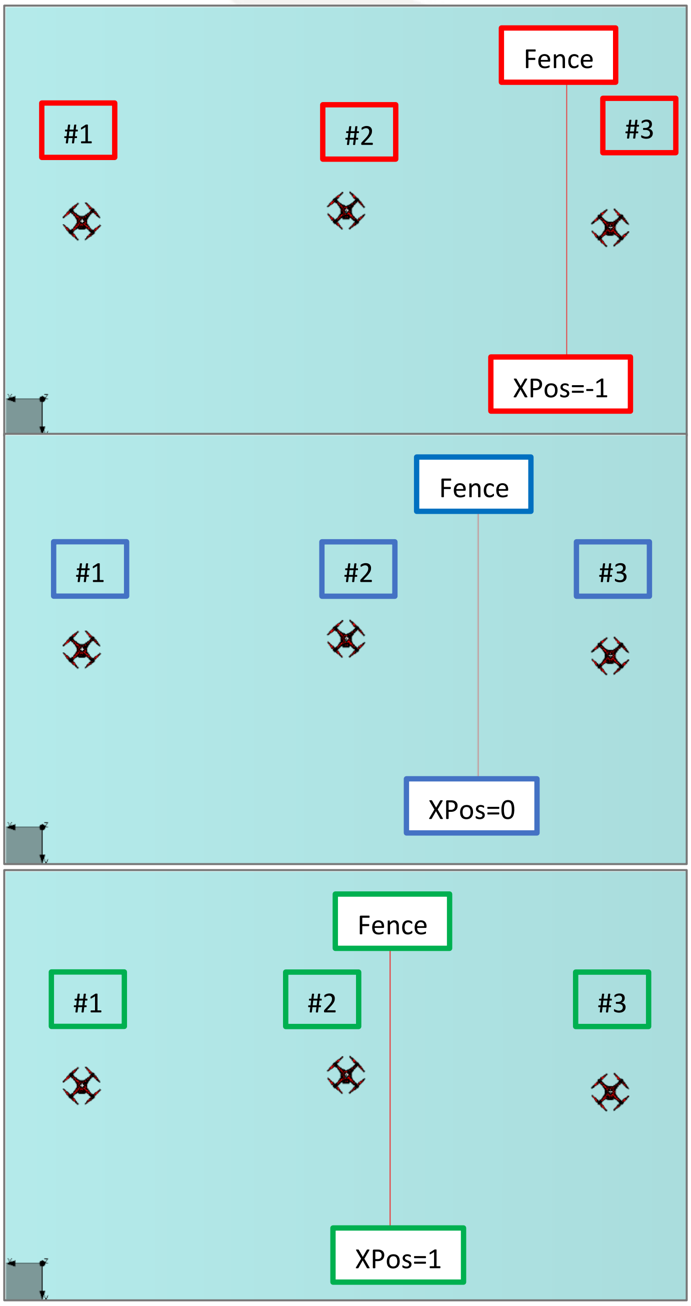

Figure 4. Drones and three position of the fence

Simulations and Results

All scenarios are simulated at 2.4 GHz. The S-parameters between communicating drones are calculated for each of 11 positions.

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

Number of elements, number of unknowns, and simulation times per position of the fence are presented in Table 2. Matrix fill-in and matrix inversions were performed on GPU cards.

S-parameters (S_{21} and S_{32}) calculated for each position of the fence in the *Scenario 1* and *Scenario 2* are compared in Figure 5 and Figure 6.

Table 1. Workstation used for carrying the simulations

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

Table 2. Number of elements, number of unknowns, and simulation time per position of the fence

Model	Number of elements	Number of unknowns	Simulation time per fence position
Scenario 1	51,241	112,516	51 minutes
Scenario 2	57,883	135,400	58 minutes

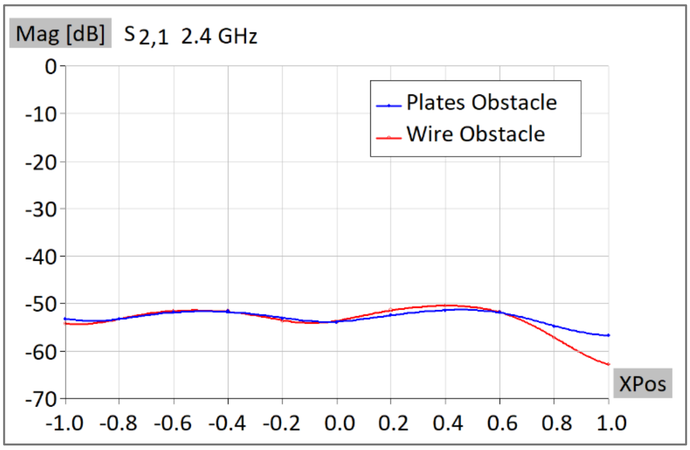

Figure 5. S_{21}-parameters for different positions of the fence obstacle

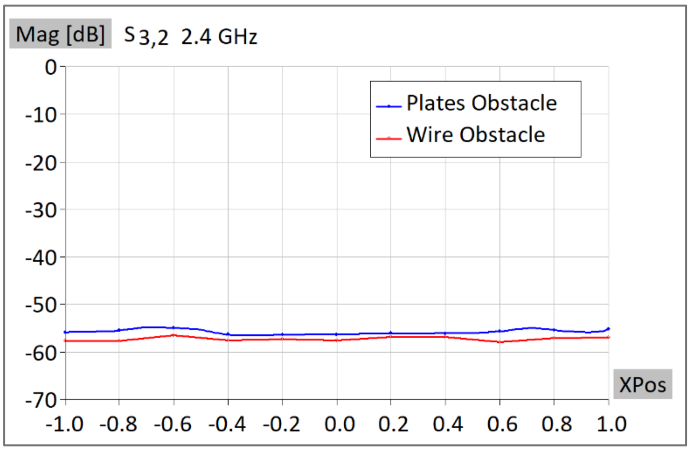

Figure 6. S_{32}-parameters for different positions of the fence obstacle

Conclusion

Real-life scenarios with three drones communicating at 2.4 GHz were investigated focusing on pure electromagnetic topics related to the physical layer of communication link between the drones. Both scenarios encompass the drones above ground plane which is approximated with an infinite PEC plane and a metallic wire fence which has been introduced between two of the drones. The difference between the scenarios 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. In the particular case considered here, the variations of calculated S-parameters are not more than ±5 dB. It should be noted that the influence of the relative position of the fence is small. Furthermore, the way of modeling the fence has negligible effect. In the other words, the preferable fence modelling could be the one which uses *Wire* entities as it requires smaller number of unknowns and reduced computational resources without significant loss of accuracy.

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.