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Simulation of Radio Frequency Power Received by a UAV Along Its Flight Path

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Abstract

A ray-tracing electromagnetic simulation using ALTAIR WinProp software was performed to calculate the 2.4 GHz power received by a UAV in flight, both from the intended controller transmitter and from a fictitious interference source of equal power located near the ground. The signal-to-interference ratio was then calculated. For the chosen example, the received power from the controller varied from -88.3 to -70.1 dBm, while the signal-to-interference ratio varied from -10.9 to +11.4 db. This work was done in support of the System-Wide Safety Project Technical Challenge 2 - Emerging Operations at NASA Langley, which is studying methods to avoid interference of UAV control and data relay signals.

Introduction

The NASA Airspace Operations and Safety Program, System-Wide Safety Project Technical Challenge 2 - Emerging Operations at NASA Langley, is studying the topic of electromagnetic interference as it affects Unnmaned Aerial Vehicles (UAV's) in flight. Currently we are studying methods of detecting and simulating interference sources with a view to inform UAV pilots of high-intensity radiation areas to avoid. Radio signals are transmitted between a UAV and its ground station both for aircraft control and for data relay. Interference, either intentional or accidental, can occur as a result of transmitted co-channel signals or noise of sufficient power. Depending on the receiver on board the UAV, there will be a minimum signal-to-interference ratio below which control and data signals become unreliable. Similarly, there will be a minimum signal-to-noise ratio below which the identification of desired signals becomes unreliable; co-channel noise transmitted from sources external to the UAV can add to the existing receiver noise and degrade the UAV receiver's signal-to-noise ratio. This paper describes a method for calculation of the received signal power and the signal-to-interference ratio at the UAV receiver while the UAV flies along a defined path. In order to demonstrate the method, a specific example has been chosen as described in the next section. The same method can be used to calculate the received noise power, given that the transmitter and receiver characteristics are known.

Simulation Method

Simulations were performed using ALTAIR WinProp software, which calculates radio frequency energy propagation, using the Intelligent Ray Tracing method. The steps necessary to complete the simulation are described in Appendix A. A model of Langley Research Center (LaRC) was first created as described in [1]. A handheld UAV controller transmitter was modeled to resemble the Futaba T18MZ, having transmitted power = 41.16 mW, frequency = 2.4 GHz, and an omnidirectional antenna pattern with gain = 1.5 dBi. The location of the controller is shown as a red dot in Fig.1; its antenna pattern as entered into the simulation is shown in Fig. 2. A fictitious interference source, located nearby (Fig. 3), was assigned the same power and radiation pattern as the T18MZ transmitter. The onboard receiver was modeled after the Futaba R7008SB, with an omnidirectional antenna pattern having gain = 2.0 dBi. Actual gain for a UAV antenna might be a dB more or less but would likely be a low number so as to detect radiation adequately from many directions.

A flight path was defined for an example UAV flight over the City Environment for Range Testing of Autonomous Integrated Navigation (CERTAIN Range) I at the Center, shown as a clockwise loop in Fig. 1, and the received power was calculated every 10 meters. The UAV's altitude varied slightly but was close to 50 meters above ground level.

The power received at the UAV from the controller and from the interference source was calculated at each designated point along the flight path. The resulting power and signal-to-interference values were then plotted.

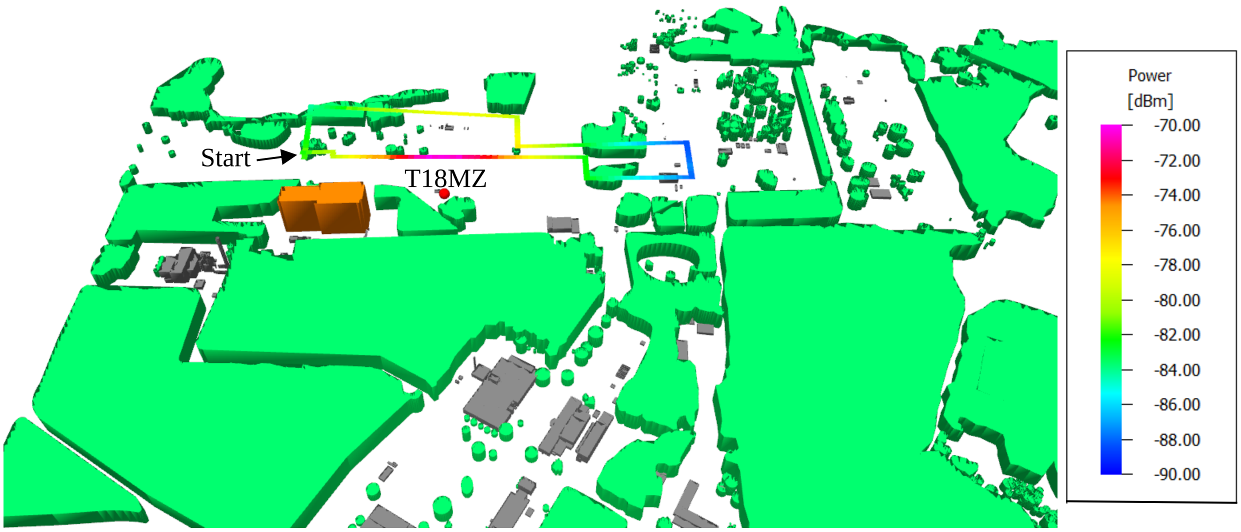

Figure 1. Received control signal power shown as a colored line along a flight path over the CERTAIN I Range at Langley Research Center, assuming a receiver gain of 2 dBi. The transmitter for the T18MZ controller is situated at the red dot.

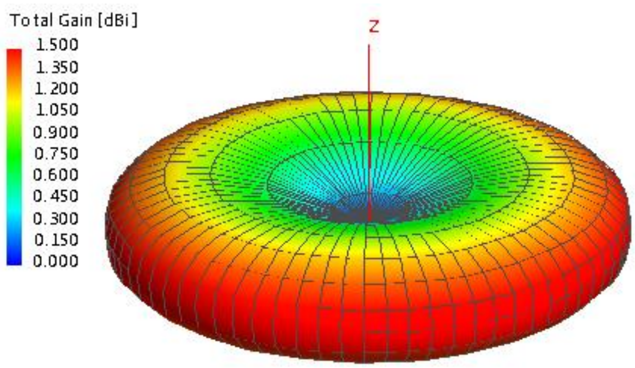

Figure 2. Antenna pattern for the T18MZ transmitter.

Results

Signal Power Received at the UAV from the Controller

As shown in Fig.1, the signal power received at the UAV varied from -88.3 to -70.1 dBm. For a receiver antenna with gain more or less than 2 dBi, a dB could be added or subtracted. As expected, the strongest signal is seen close to the controller.

Signal-to-Interference Power Ratio Received at the UAV

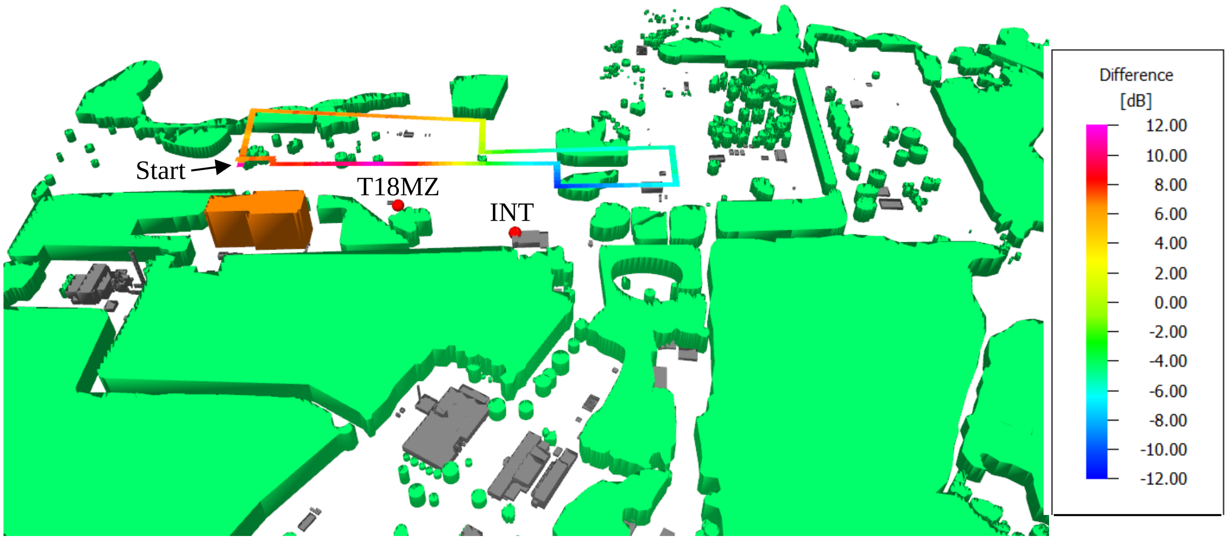

Figure 3. Received signal-to-interference ratio shown as a colored line along a flight path over the CERTAIN I Range. The transmitter for the T18MZ controller and interference source INT are situated at the red dots.

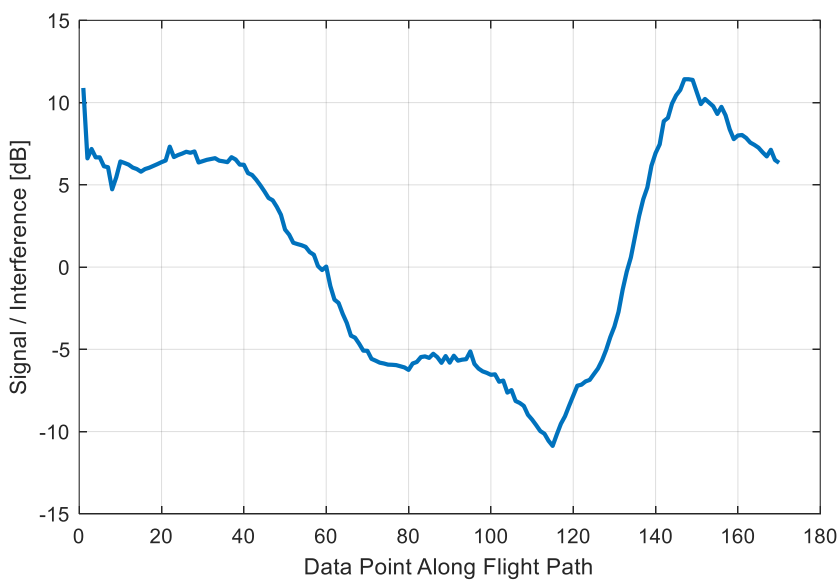

Figure 4. Received signal-to-interference ratio versus distance as the UAV flies around the loop shown in Fig. 3 over the CERTAIN I Range. Power was evaluated at 172 points with data point separation ≈ 10 m.

As shown in Figs. 3 and 4, the signal-to-interference ratio varied between -10.9 and +11.4 dB. This figure can be calculated by subtracting the interference power in dB from the controller signal power in dB without knowledge of the receiver antenna pattern. However, the transmitter pattern must be specified. As expected, the ratio is highest close to the controller and lower close to the interference source.

Conclusion

A method has been demonstrated for calculating signal power or signal-to-interference ratio along a defined flight path. Next steps include 1) characterizing the minimum allowable signal-to-interference and signal-to-noise levels for various aircraft and 2) identifying known sources of radiation that could interfere with proper operation of a UAV. In this way, a flight path may be planned to avoid hazardous interference.

Reference

[1] Mackenzie, Anne I.; Nguyen, Truong X.; Barnes, Kevin N.; and Scherner, Michael J., “Simulated Versus Measured UHF Radiated Power at LaRC Street Level,” NASA/TM-20210013542, April 2021.

Appendix A: WinProp Simulation Procedure

Given the preprocessed .oib database and an antenna pattern for each transmitter:

Start Proman > File > New Project
Simulation type = Propagation Analysis
Scenario = Urban Scenarios
Use only preprocessed databases > Select filename.oib
Polarimetric Analysis = Standard
Display Height = 0 m [doesn't matter]
[Model appears in ProMan window.]
Save Project as filename.net [.mic, .net, .nup, and .wpi files are created.]

On the left side of the ProMan window, find the Prediction Trajectories icon and mark the approximate start and stop points for the flight. [The path appears as a red line on the 2-D model.]

Project > Edit Project Parameter
- Simulation
  - In the trajectory window, click on your trajectory and correct the lat, long, height above ground. Leave roll, pitch yaw = 0°. Set resolution = 10 m, Trajectory sampling = Heights relative to ground, Distance between evaluation points = 10 m.
- Sites, Add
  - Site with Sectors, Omni Site, Az of first sector, Downtilt of all sectors
  - Add the locations of transmitting sources: lat, long, height AGL = 0 m
  - In Antenna window, define antenna for each source: Name, Enabled, Frequency, TX Power, Lat, Long, Height AGL, Directional, Saved Pattern, Gain [Site appears on model as an orange circle; antenna as a blue icon.]
- Computation
  - Intelligent Ray Tracing, Rigorous 3D IRT

Computation > Compute All
- [Calculated power values appear in PropName\AntennaName Power.fpp.]
- Values can be exported using Export Data (Planes) > Export ASCII (ALL), producing a text file with UTMX, UTMY, height, power.

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14. ABSTRACT
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