CES Research Report
Southern Illinois University Carbondale
Reliable Wireless Communications in Aircraft and Other Challenging Environments
Researchers: Xiangwei Zhou
Students: Feixiang Zhang (PhD student) and Shanglei Li (Ph.D. student)

**Project Description**

The evolution of wireless communication technologies in terms of data rate and quality of service enables their use in many different industries. However, existing wireless communication systems are not specifically designed for aircraft or other challenging environments. The deployment of wireless communications in aircraft is a challenging task, which must meet very high standards for reliability [1], which is also the case in other challenging environments. For safety-critical applications, the connections should be close to 100 percent reliable. Meanwhile, for other applications such as maintenance and diagnosis, the connections still need to be reliable enough with a cost-effective solution. To address the above design and implementation issues, we study novel techniques for reliable wireless communications in challenging environments.

**Objectives**

The environment in aircraft is very different from where conventional wireless communication systems operate. The objective is to understand the operational environment in aircraft, including channel propagation model and communication node distribution. The details are as follows.
*Channel propagation:* The environment inside aircraft is heavily reverberant because of metal materials and the special fuselage structure. To characterize the resonant environment, ray tracing techniques [2] are applied and signal propagation characteristics at different parts of the aircraft can be determined. By properly modeling the channel propagation, we are able to address the system design and performance analysis in future researches.
*Node distribution:* Due to the special structure of aircraft, the installation of communication nodes including their antennas is always restricted. Combining the results of the channel propagation in aircraft and possible locations of communication nodes, the physical topology of the communication network can be determined.

**Industrial Relevance**

Electrical wiring in aircraft has become more and more complex nowadays. According to [3], the total number of wires in an Airbus A380-800 is around 100,000, and they are 470 kilometers in total length and 5700 kilograms in total weight. The use of wiring brings a number of issues in terms of weight, cost, safety, and maintainability. It is therefore desirable for aerospace industry to replace wired interconnections with wireless connections in aircraft. With the proposed research on reliable wireless communications in aircraft, the complexity and life-cycle cost of electrical wiring in the state-of-the-art aircraft will be greatly reduced. As it is easier to provide redundancy with wireless connections, flight safety can be improved as well. Furthermore, aircraft weight reduction will save fuel cost and result in environmental benefits. Similarly, the use of wireless communications in other environments such as hazard detection systems is also preferred and thus has attracted a lot of attention.

**Project Outcomes**

To design reliable wireless communication systems for various applications, we study applying ray tracing method to radio propagation prediction in 3-D restricted spaces in the project. Applying ray tracing method to 3-D restricted spaces is challenging, not only because of the stringent requirement on precision, but also due to the explosive computation amount with tiny improvement in accuracy. In this project, we propose a unique algorithm for propagation prediction with transmission and reflection in restricted spaces. By using binary labels to record propagation history, this algorithm can be implemented with parallel computing. As a result, we are able to handle a large computation amount for 3-D restricted spaces in an acceptable time duration. Afterwards, our ray tracing method in restricted spaces is employed to simulate radio propagation in the cargo compartment of aircraft. Figure 1 shows the ray paths of 4 selected rays after 100 reflections in the cargo compartment. And Figure 2 shows the accumulative energy density of single dipole transmitter antenna in the cargo compartment. We also provide guidelines for receiver deployment based on our simulation results. By combining the propagation simulation results of all the employed transmitters, the receiver capabilities of different positions can be seen in Figure 3. In this project, the simulation code can cater to different materials, different antennas, different cargo loads, and different required precisions. Furthermore, in consistency with the geometric structure of the COLLADA model, the proposed radio propagation method can also be applied to a large database, including aircraft and other challenging environments.

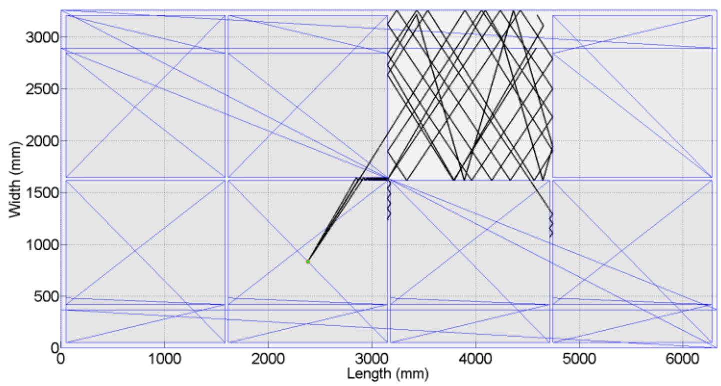


Figure 1. Paths of 4 rays after 100 reflections in the cargo compartment.

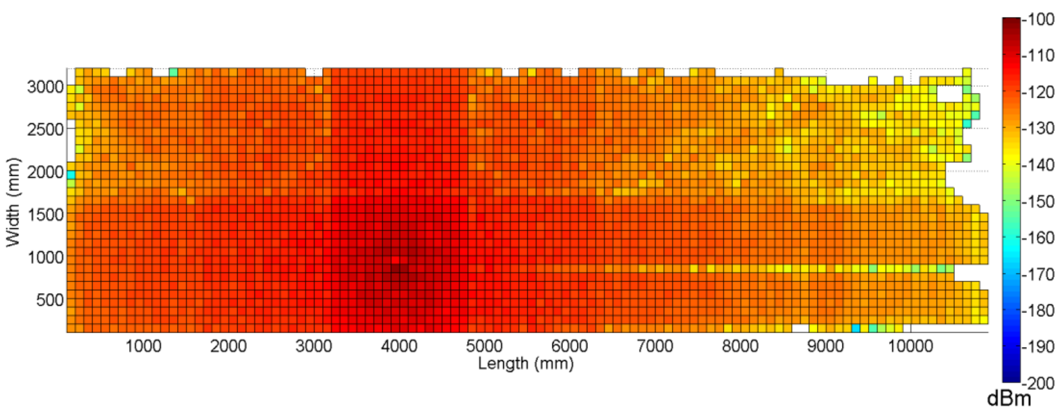


Figure 2. Accumulative energy density of dipole transmitter antenna in the cargo compartment.

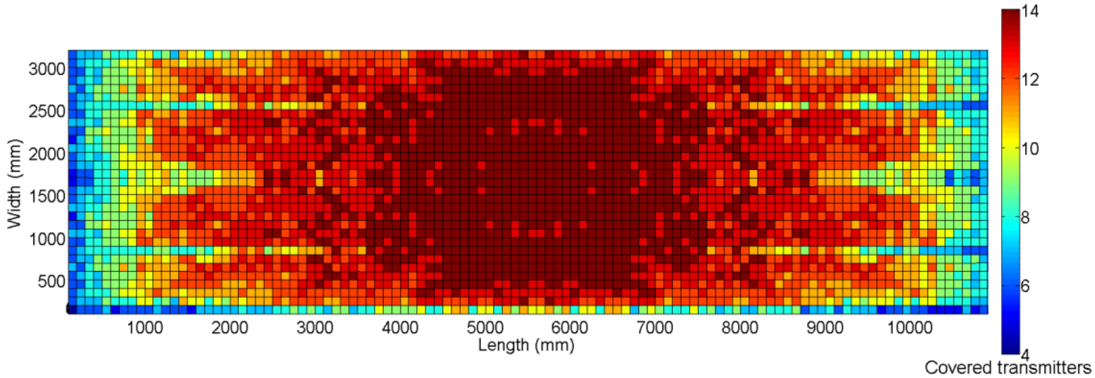


Figure 3. Receiver capabilities of different positions when threshold is -140 dBm in the cargo compartment.

## Research Team

Xiangwei Zhou is an Assistant Professor at SIU, Feixiang Zhang is a current Ph.D. student at SIU, and Shanglei Li was a Ph.D. student at SIU and now he is with Link Engineering Company.

## References

1. RTCA/DO-160G, "Environmental Conditions and Test Procedures for Airborne Equipment," RTCA, Inc., Dec. 8, 2010.
2. C. J. Debono, R. A. Farrugia, and K. Chetcuti, "Modelling of the wireless propagation characteristics inside aircraft," *Aerospace Technologies Advancements*, T. T. Arif, ed., InTech (2010): pp. 361-378.
3. R. Zakrzewski, "Protected spectrum for wireless avionics intra-communications," *Passive Wireless Sensor Technology Workshop, ISA Communications Division Symposium*, June 6, 2012.