Application Note

Drone Testing: Everything About the Radio Link

Azimuth Channel Emulator

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1. Overview

This application note talks about some of the factors that affect the reliability of the critical radio link of a drone, the challenges associated with testing this radio link, and some solutions to improve and simplify testing.

2. Introduction

A simple radio-controlled flying object is called an unmanned aerial vehicle, or drone. The new generation of drones has been renamed to reflect the devices' increased sophistication: "unmanned aircraft systems," or UAS, refers not only to the drone vehicle itself but includes the control system (e.g., a ground control station or GCS), the specialized data link, its cameras or other payloads, and all related support equipment.

Once considered a niche market, UAS now represent the fastest-growing sector of the aviation industry, with sales expected to top $1.9 billion by the end of 2020[*1]. Consumer interest in nonmilitary drones is rising, driven by the seemingly limitless applications they offer not only for recreational purposes but in industry, law enforcement, energy and power, manufacturing, infrastructure, media and entertainment, agriculture, and research.

Figure 1: Drone being used for commercial applications

*1: Barbara Booth, "Is It Time to Buy Your Kid a Drone for Christmas?" CNBC, December 22, 2014. http://www.cnbc.com/id/102280825.

Unmanned aircraft systems are regulated by the national aviation authority of the respective country. Nonmilitary (e.g., hobbyist, commercial) drone use in the United States is regulated by the Federal Aviation Administration (FAA), but currently there is a lack of clear and consistent state and federal regulations. While the FAA has started approving commercial drone permits[*2], new rules clarifying drone use in public areas and national airspace are expected to come from the FAA in 2015, with clarifications that address issues of aircraft and emergency-responder safety, privacy, data protection, and liability. The European Aviation Safety Agency (EASA) has already established a new regulatory approach for remotely piloted aircraft.

The UAS industry's exponential growth is mainly driven by innovations making the drones both easier to use and more functional while at the same time bringing down per-unit costs. For instance, today's drones can be controlled from a ground control station or handheld device miles away. Capable of carrying live-streaming cameras and traveling at high velocities, the drones allow users to capture everything from search-and-rescue operations to solar farm inspections to real-time reportage in remote or dangerous areas.

2.1 The Critical Data Link

Naturally, the connection enabling the transfer of data between the radio controller and the drone is highly critical. Testing and refining that connection is of prime importance to manufacturers of drones, drone components (e.g., modem radios), and drone applications, given the numerous factors affecting performance: the long-distance connection, with low received power and a high propagation delay; the Doppler effect, due to velocity; and natural and constructed signal scatterers and obstacles in the multipath environment.

Figure 2: Drone with camera being used in multipath environment.

*2: Clay Dillow, "FAA approves more than 1,000 commercial drone permits."
http://fortune.com/2015/08/09/faa-commercial-drone-permits/

Drones currently available on the market can go at a maximum speed of approximately 30 mph, with a maximum distance of about one mile, though that is changing rapidly with higher capability drones.*3 The uplink connection from the drone to the controller has an average throughput of 1.5 Mbits/sec (in the case of drones sending real-time video data) and a downlink throughput of about 300kbits/sec, mainly used to send control information.

3. Radio Characteristics of Drones

For long-distance control, civilian drones use a Wi-Fi connection (2.4 and 5.9 GHz) with a MIMO spatial diversity link between the drone and the remote controller. Spatial diversity helps mitigate the effects of a multipath environment and challenging radio conditions, and to improve the robustness of the connection, especially when the drone is at the edge of the coverage region. The most common configuration uses two antennas at both ends.

3.1 Antenna Shadowing

Depending on the orientation (location of the antennas and the separation between them), the strength of the received signal power at the two antennas could be either similar or drastically different. In the case of drones, the two antennas are usually located on opposite arms of the machine, under the rotors, as shown in the figure below. This antenna topology can lead to instances where one antenna is shadowed for specific mobility paths.

Figure 3: Antennae locations

*3: "Sony tests 'superfast' commercial drone." http://www.bbc.com/news/technology-34057002

For instance, consider a drone rotating on its axis at a fixed distance from a remote controller with a direct connection (i.e., line of sight component). For a brief time, each antenna will be alternately hidden by the body of drone. The resulting in power drops as shown graphically below.

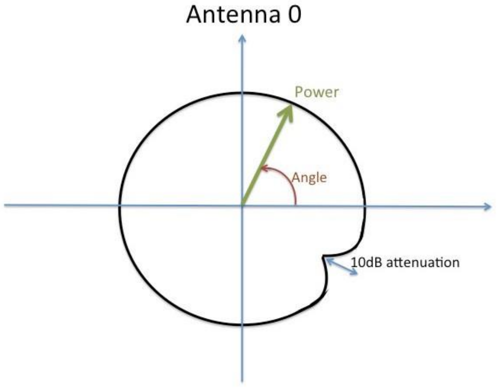

Figure 4: Ant0 received power during one rotation of the drone on itself

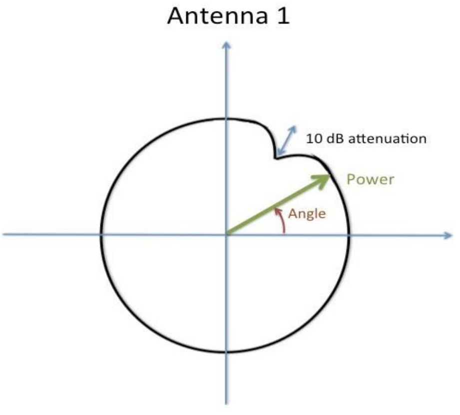

Figure 5: Ant1 received power during one rotation of the drone on itself

A drop in the received power can be observed (for each antenna) when the body of the drone comes between the remote controller and antenna; the dip in power depends on the actual drone (e.g., engineering, materials) and the scenario (e.g., distance, surroundings). This is where the advantage of diversity becomes obvious; at no single point of time will both the antennas be shadowed out.

3.2 Impact of Tilt

The received signal power at each antenna of the drone is also affected by the tilt angle—the angle of the drone in relation to the horizontal plane.

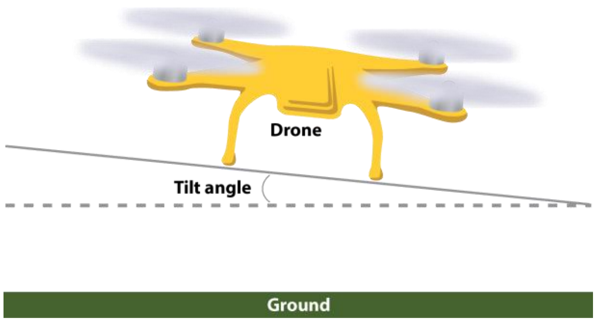

Figure 6: Tilt angle

3.3 Antenna Pattern

In addition to the challenges mentioned earlier, the antennas on the remote controller can also affect the overall robustness of the link between the controller and the drone. Although the drone's antennas may both be omnidirectional, this is usually not the case with the radio controller, which usually uses directional antennas, as shown on the figure below. Their 30-to-40-degree beams make them very sensitive to variations in the orientation of the controller and the position of the drone. When the drone and the controller are not aligned, the reliability of the radio link declines.

Figure 7: Remote controller antenna beams

Thus, the drone's design, controller, and mobility all have an impact on the reliability of the critical radio link. This, combined with the inherent effects and impairments of any wireless environment, make the radio link between the drone and controller extremely susceptible and sensitive to a variety of potentially performance-degrading factors.

4. How Can You Test Drones Efficiently?

So far, we've learned that a number of factors can degrade the link between the drone and the controller: the specifics of the antennas of the drone and the remote controller, the location and orientation of the drone's antennas, the mobility of the drone, the multipath fading environment, and objects that might cause shadowing. The impact of specific, individual effects on performance can't be tested in the field. This, combined with the logistical challenges of testing drones in the field (e.g., cost, regulations, etc.) make it impossible to rely on just field testing. There is a critical need for solutions that can help move some of this testing to the lab.

A channel emulator can be used to re-create the different elements of drone environment: multipath, velocity, propagation delay, received power per antenna (alternatively, the path loss), noise, and other factors. Since a channel emulator is controllable, so is the radio environment it creates. You can therefore test the effect of individuals influencers.

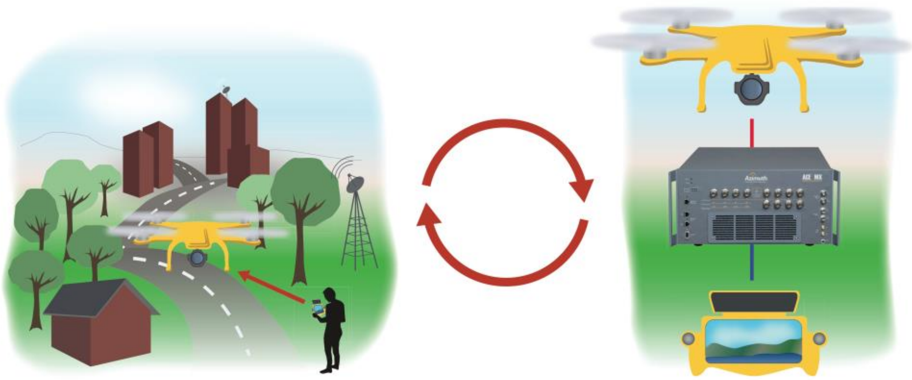

Figure 8: Using a channel emulator to replicate field conditions

In addition to testing for specific effects, you can also test the performance of the drone for traditional functional tests like rate vs. range (RvR) and rate vs. noise (RvN), which extend well for real-world scenarios such as the performance of the drone as the drone moves away from the controller (RvR) or as the signal-to-noise ratio (SNR) of the link deteriorates (RvN).

3.1 Replay Flight Tests: From Field Tests to the Lab

Drive tests (or "flight tests") are commonly used by drone companies for troubleshooting, software improvement, and benchmarking. Complicated and time consuming, these drive tests yield results that are not repeatable. Thus, it is hard to compare sets of flights, even if they occurred in the same location in seemingly similar conditions. Any number of factors will have changed—the degree and type of interference, weather and wind conditions, drone height, controller orientation, velocity, drone and controller position—and the tests are impossible to replicate precisely.

This can be addressed by using Azimuth's Field-to-Lab capability, which allows you to re-create field environments in the lab by feeding logs from the radio modem on the drone and controller and into the channel emulator, as shown in the figure below.

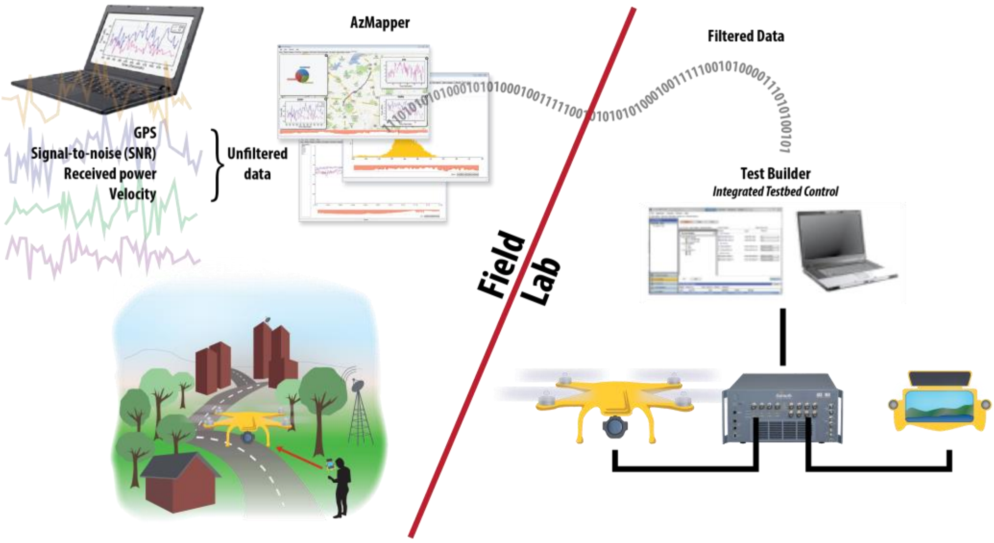

Figure 9: The Field-to-Lab process: Testing drones in the lab using recorded field conditions

This allows you to re-create field tests quickly, easily, efficiently, and accurately. Not only does this allow you to test drones in exact field conditions, it also allows you to test drones under modified field conditions by overriding specific parameters or effects—for example, using the power variation seen on the field but with a less punishing multipath fading environment.

5. Summary

In this application note, we covered some of the effects that have an impact on the robustness of the radio link between the drone and the controller, and the challenges with testing drones in the field. We then discussed some solutions for testing drones in the lab using Azimuth's channel emulation and Field-to-Lab capabilities.

Specifications are subject to change without notice.

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