4G coverage mapping with an ultra-micro drone

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***Abstract* — Drone mapping of 4G cellular network coverage is presented using an ultra-micro drone of weight less then 300 g with a 1 hour flight time. The data show a 10 dB increase in RSSI (received signal strength indication) per 100 feet (30 m) of altitude gain. This method could be broadly adopted by cell phone carriers as an economical, efficient way to map 4G network coverage over large areas.**

***Keywords* — drone, 4G**

I. Introduction

Coverage data of 4G cellular networks is usually obtained with ground vehicles and modelling. However, the advent of unmanned aerial vehicles (UAVs) provides an additional opportunity to efficiently map coverage over large areas, including remote areas with no access to ground vehicles.

We have recently described a 4G connected, internet controlled UAV with all up weight less than 300 g and 1 hour flight time, with an 80 km range.

In this paper, we demonstrate the use of this UAV to map cellular coverage over a large area, from ground level to 400 feet (120 m) height. Such a platform could have broad applications as a quiet, safe, non-invasive tool to determine 4G cellular network coverage.

II. Materials and Methods

A. Vehicle description

Details of the vehicle are presented in another paper[1]. Briefly, the system is a 600 mm flying wing with an STM32 F4 based bit flight controller running Ardupilot with GPS (Global Positioning System) and autopilot capabilities capable of complete autonomous flight, from takeoff waypoints to landings. An on-board Linux companion single board computer (Raspberry Pi Zero W) handles communication with the 4G modem and internet. The UAV can be piloted remotely via a separate 900 MHz transmitter or via the 4G internet connection over the internet.

B. 4G internet connection

A Novatel 4G modem (model # USB Universal Serial Bus 720L) interfaces with the companion computer and provides an IP connection to a cloud based Linux instance running on Amazon Web Services, which then connects to a Windows 10 computer on the ground. (The code is open source and availabe in a git repository at www.gitlab.com/pjbca/4guav).

The modem antenna is a 2 dB dipole antenna with vertical polarization, which portudes above the craft (Figure 1) so as to minimize interference from any other components.

C. RSSI recording

The Novatel firmware provides an html server to the on board computer which provides an RSSI in dBm. The RSSI is recorded continuously to a local SD card on the Linux on board companion computer, and the time stamp is used together with the log files to coordinate the craft location in 3d with less than 1 m error bar. Post flight, the RSSI and GPS coordinates are matched in software to provide a 3d coverage map.

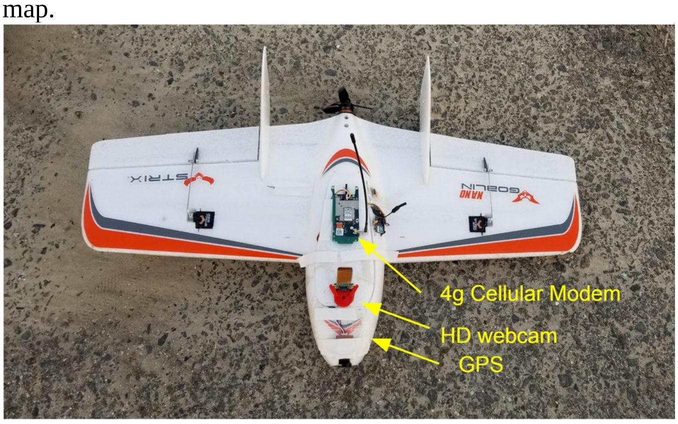

Figure 1: Picture of first generation internet connected UAV. Once this prototype successfully demonstrated proof of concept, the external components (GPS, 4G modem, camera, 5.8 GHz video transmitter) were incorporated inside the fuselage.

III. Measured signal level

A. RSSI vs. altitude

To determine the effect of altitude on RSSI, we plot RSSI vs. altitude in Figure 2. There is clearly an increase with altitude in RSSI.

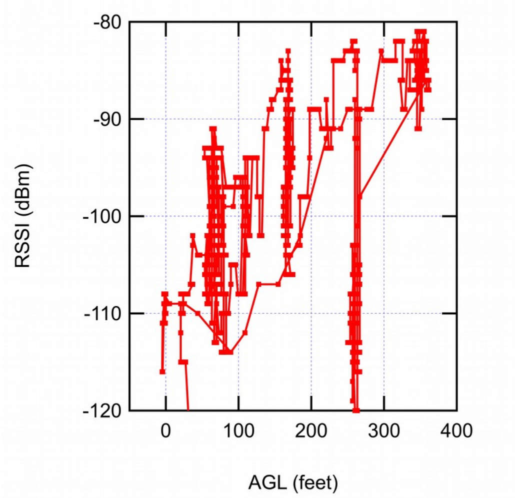

Figure 2 RSSI vs. altitude AGL (Air to Ground Level).

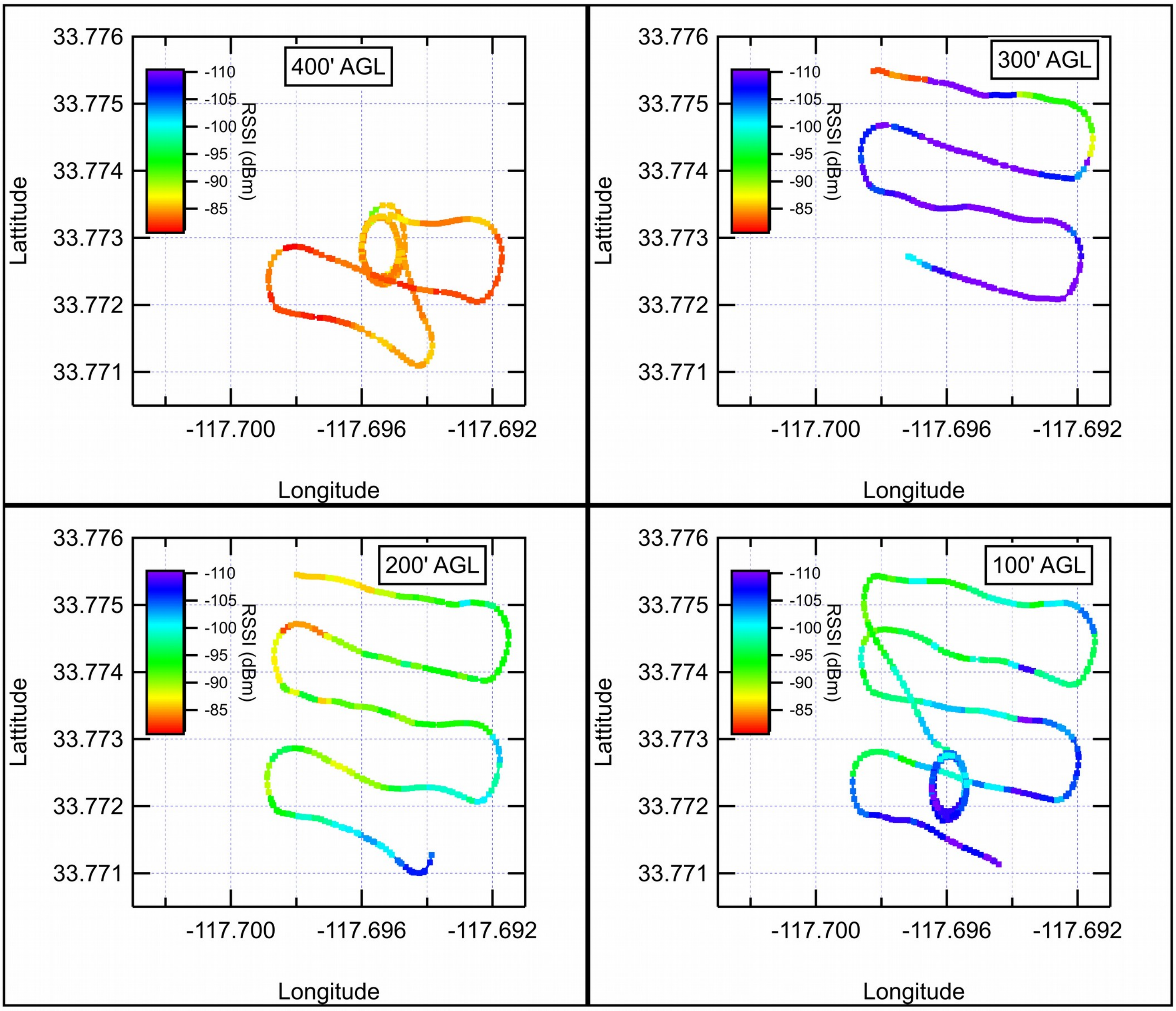

Figure 3: RSSI signal at different altitude: 100,200,300,400 feet (30,50,90,120 m) above ground level (AGL).

B. *RSSI vs. position*

The color coded RSSI vs position is shown for all altitudes in Figure 3. A square survey grid was programmed, but because of the aerodynamic properties of the craft (it could not turn at a right angle), the corners are rounded. The craft was roughly level during the flight, and the receiving antenna pattern is omni-directional in the plane of the craft. Therefore, the receiving antenna radiation pattern did not effect the results significantly.

Two trends are clear from the data. The first is that the signal increases by about 10 dB per 100 feet (30 m) increase in altitude. This may be due to the fact that the surveyed position is in a canyon. The other is that the signal is stronger in the northwest quadrant than the southeast quadrant. This may be related to the position of the cell tower.

The 300 foot (90 m) data is an anomaly (Figure 2) which is not understood at this time. Switching between different cell towers may explain the sudden change at a specific altitude for the 300 foot (90 m) data.

IV. Acknowledgements

Funding for this work was provided by the author's private finances. The design, construction, assembly, bench testing, and coding work was performed in the author’s garage. Flights were performed as an individual hobbyist under FAA rules.

V. References

[1] P. Burke, “A safe, open source, 4G connected self-flying plane with 1 hour flight time and AUW < 300 g: Towards a new class of internet enabled UAVs,” *IEEE Access*, 7(1), 67833 – 67855 (2019)