Using LoRa for iNav Telemetry

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This document describes the use of LoRa radio devices for telemetry from a multirotor using iNav firmware and the LTM telemetry format.

Setup

Hardware

380mm quadcopter, E45-TTL-100 LoRa device from Ebyte. The same 17cm antenna used for 3DR (433Mhz) were used with these LoRa devices (868Mhz).

Flight Controller

SPRacingF3EVO with iNav 1.8.1 (development branch) firmware `INAV/SPRACINGF3EVO 1.8.1 Nov 2 2017 / 20:00:55 (d7a974a7)`.

LoRa Configuration

Serial Speed	115200
Air Speed	19200
Power	14dBm

Table 1. Specific Settings

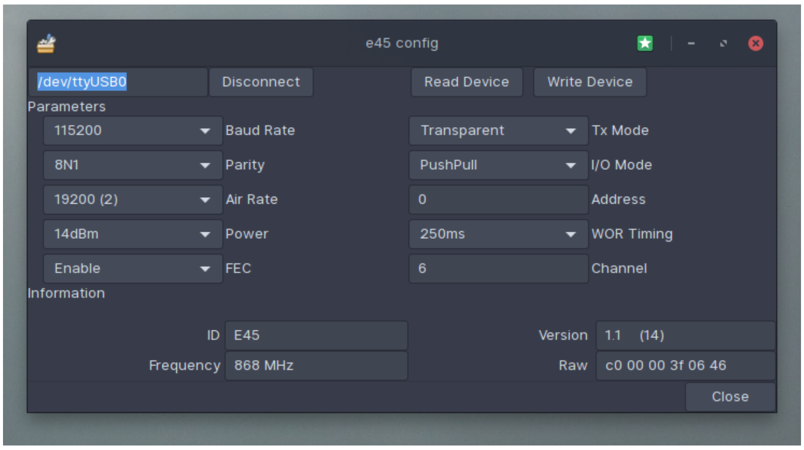


Figure 1. Device Configuration

Note: The speeds were chosen as a result of experiments and advice from members of the iNav development community in order to minimise latency.

Ground Station

mwp. The "over the air" LTM telemetry is received and logged by the the mwp ground station. The logs are displayed and analysed below.

LTM usage

LTM is a push technology (from the aircraft to the ground station). It operates at three rates:

NORMAL	Legacy rate, currently 303 bytes/second (requires 4800 bps)
MEDIUM	164 bytes/second (requires 2400 bps)

SLOW	105 bytes/second (requires 1200 bps)

Table 2. LTM Rate Settings

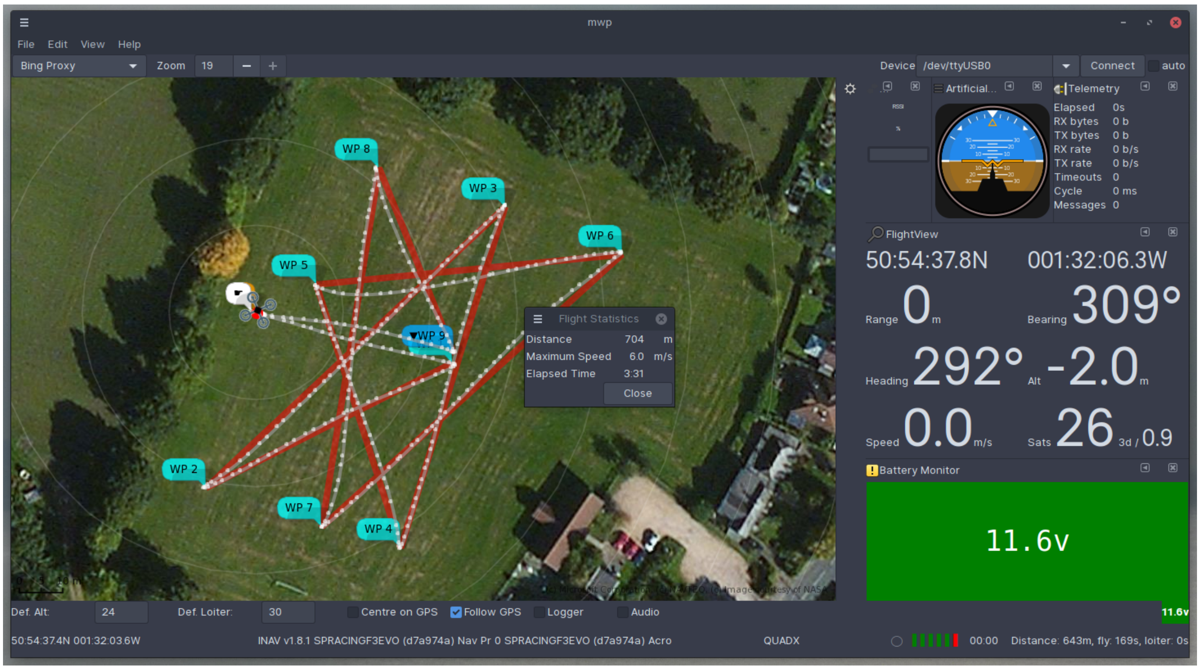
Aim

The aim was to investigate if the LoRa devices could support LTM with minimal data loss and without undesirable latency. Long range was not a consideration for this experiment (the maximum range experienced was c. 120m).

In particular, the author was interested to compare the performance to 3DR radio technology.

Experiment 1 - LTM Rates

The same short mission was flown with the LTM rate at SLOW, MEDIUM and NORMAL. Images of the data points captured is shown below. The data point distribution and density is as expected for the respective data rates.

Rate	Result
Slow	

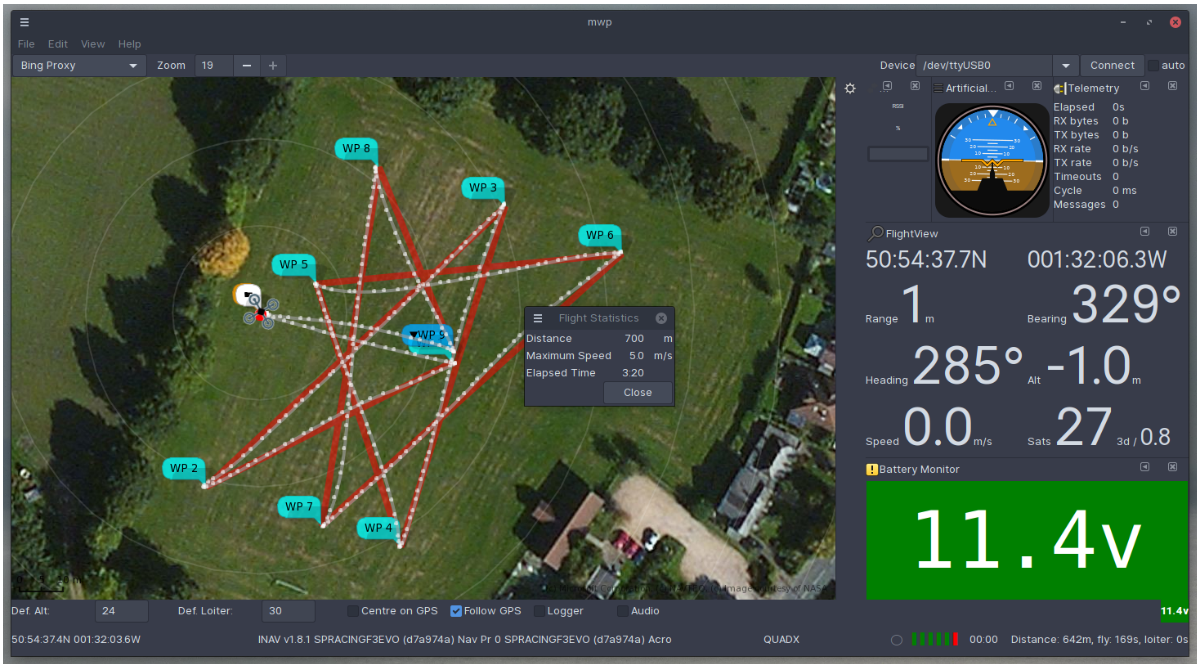
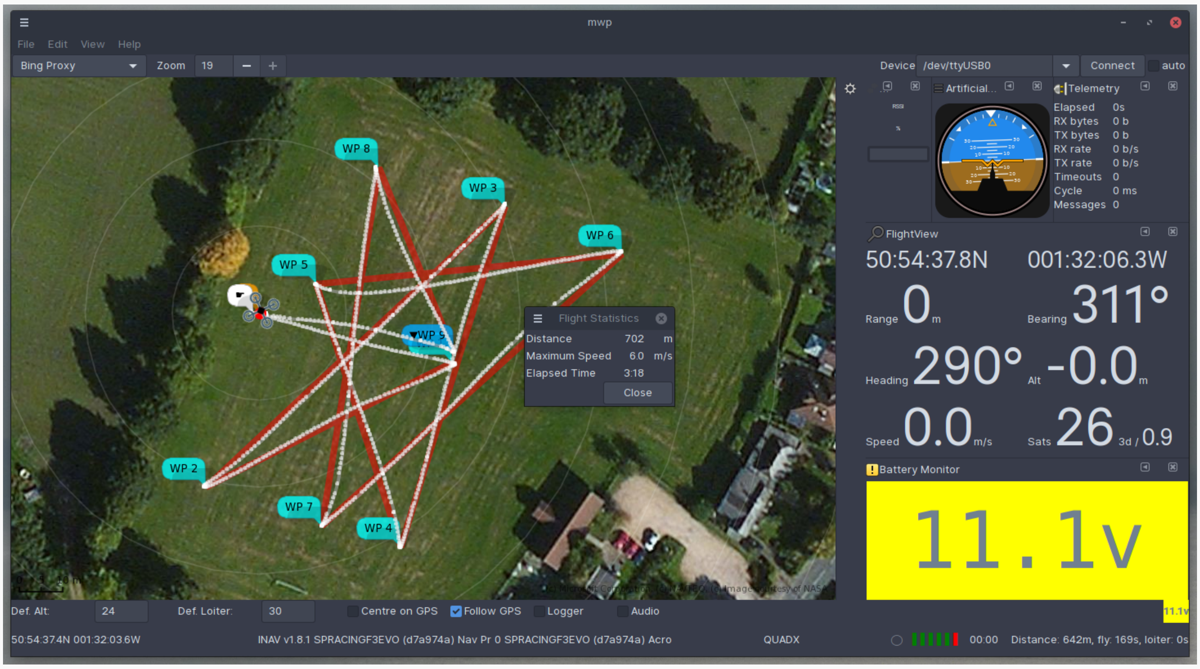
Rate	Result
Medium	
Normal	

Table 3. LTM Rate Table

The LTM protocol includes a sequence counter for `X-FRAME` messages, so it is possible to estimate packet loss. Note that we get 1 X-Frame / second regardless of LTM rate.

Slow	Expected 90, got 91 at 91 Expected 96, got 97 at 96 Expected 163, got 164 at 162 mwp_ltm_slow.log 204 samples 3 errors (1.47%)
Medium	mwp_ltm_medium.log 196 samples 0 errors (0.00%)

Normal	Expected 127, got 128 at 128 Expected 134, got 135 at 134 mwp_ltm_normal.log 192 samples 2 errors (1.04%)

Table 4. LTM Speeds and Packet loss

These packet loss rates are entirely acceptable and comparable to those experienced with 3DR. Overall, the rates available do not appear to influence packet loss.

Experiment 2 - Comparison with 3DR

In this example, the same mission is shown with 3DR and LoRa as the telemetry devices. Note that these missions were flown about a week apart.

Device	Result
3DR	

Device	Result
LoRa	

Table 5. Device Comparison

Just looking at the two images, the LoRa image looks to have a more consistent point density; this is confirmed by looking at the sequence counters and packet loss:

3DR	Expected 43, got 44 at 44 Expected 79, got 80 at 79 Expected 81, got 82 at 80 Expected 139, got 140 at 137 Expected 147, got 148 at 144 Expected 170, got 171 at 166 Expected 198, got 201 at 193 Expected 204, got 205 at 196 Expected 65, got 66 at 312 Expected 124, got 125 at 370 Expected 177, got 178 at 422 Expected 212, got 213 at 456 mwp_3dr.log 589 samples 12 errors (2.04%)
Lora	Expected 94, got 95 at 95 Expected 64, got 65 at 320 Expected 138, got 139 at 393 Expected 149, got 150 at 403 Expected 175, got 176 at 428 Expected 177, got 178 at 429 mwp_LoRa.log 566 samples 6 errors (1.06%)

Table 6. 3DR v LoRa Lost Packets

The LoRa test shows 50% of the packet loss experienced in the 3DR test.

Summary

I'm impressed; before the iNav development community started experimenting with LoRa devices, there was some concern that duty cycle and latency concerns would prevent use for meaningful telemetry. Subsequently we learned that duty cycle can be 100% as long as the power is less than 20dBm and that increasing the baud rate would reduce the latency.

One afternoon's testing is hardly conclusive, nevertheless, I'm content that the E45-TTL-100 LoRa device is an effective alternative to 3DR and HC-12 radios. The only downside is the form factor; the device is larger than the HC-12 and 3DR devices and the vertical pins are really annoying (from left to right HC-12, 3DR, E45-TTL-100).

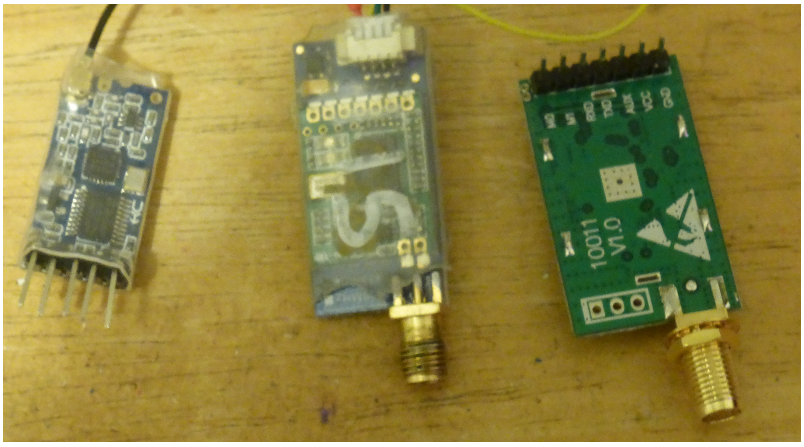


Figure 2. Device Form Factors

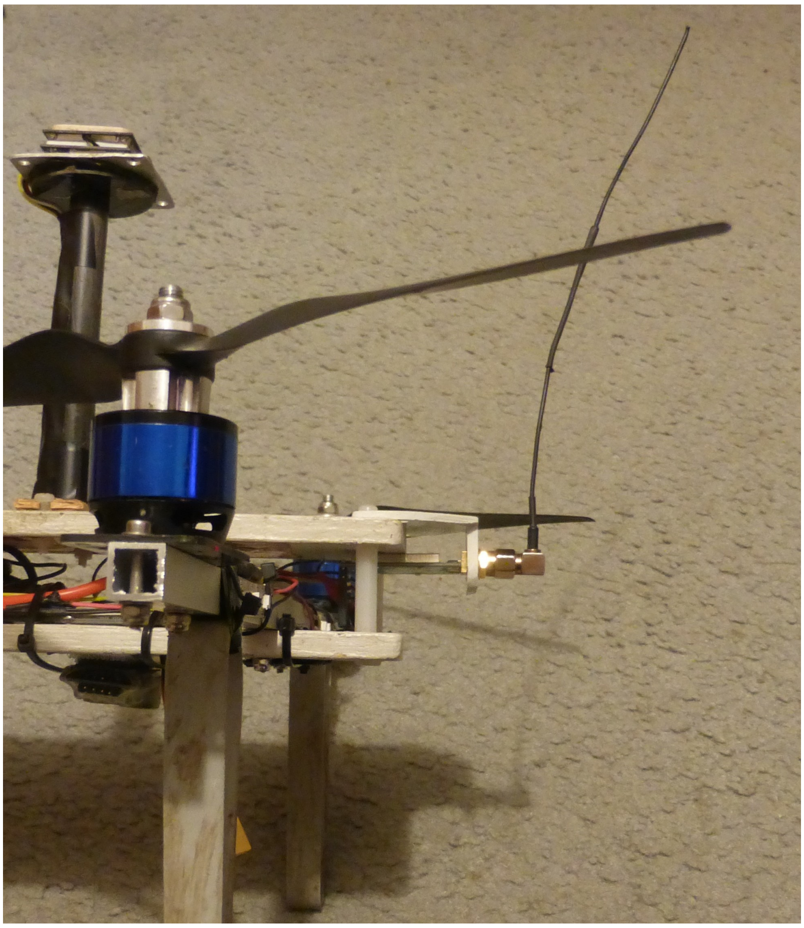


Figure 3. Aircraft Fitting

Links

[Configuration Tool for E45-TTL-100 on Linux / FreeBSD]

E45-TTL-100 Vendor Documentation
QuadMeUp's LoRa Experiments
PDF version