James Dyson Foundation Undergraduate Bursary 2018/19
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Project Report
Design of a RF System for Performing Trilateration of a Rocket

Cambridge University Spaceflight is a student society that builds and launches high power rockets. Our latest project, Martlet 4, is being designed to reach an altitude in excess of 20 km in a bid to claim the altitude record for a UK built amateur rocket, which currently stands at 10.3 km. In order to verify this, a system able to accurately measure the maximum altitude reached by the rocket is required.

In industry systems that can carry out these tasks with a high level of accuracy are commonplace, however for a student team such solutions are prohibitively expensive. Therefore low-cost commercial of the shelf technology must be utilised to carry out such measurements.

My project aimed to build and test a system able to estimate the 3D position of a rocket to within 50 m under any combination of the following operating conditions:

- Maximum Range - 30 km
- Maximum Velocity - 686 m/s (Mach 2)
- Maximum Acceleration - 16 g

Figure 1 – Martlet 3

RF localisation is resilient to large changes in acceleration and velocity and capable of working over long distances. The system proposed for this project employs this method of range finding. The proposed system architecture is shown in figure 2 below. Here time of flight (TOF) measurements are performed by the system allowing the position of the rocket to be esitmated by trilateration.

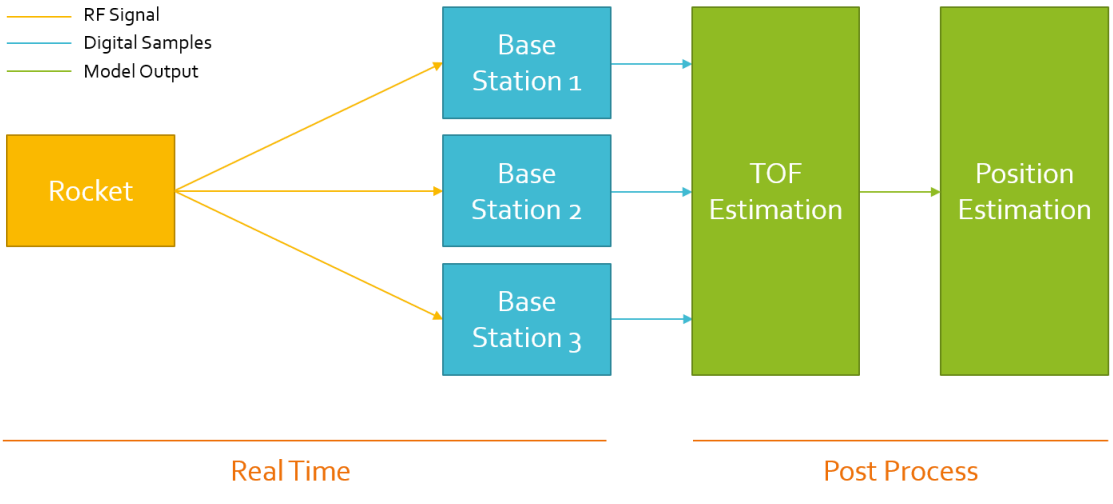

Figure 2 – System Design

The base stations are designed around the LimeSDR, a low-cost software defined radio (SDR). Figure 3 below shows a completed base station consisting of a LimeSDR, timing reference, mini-PC and power supply.

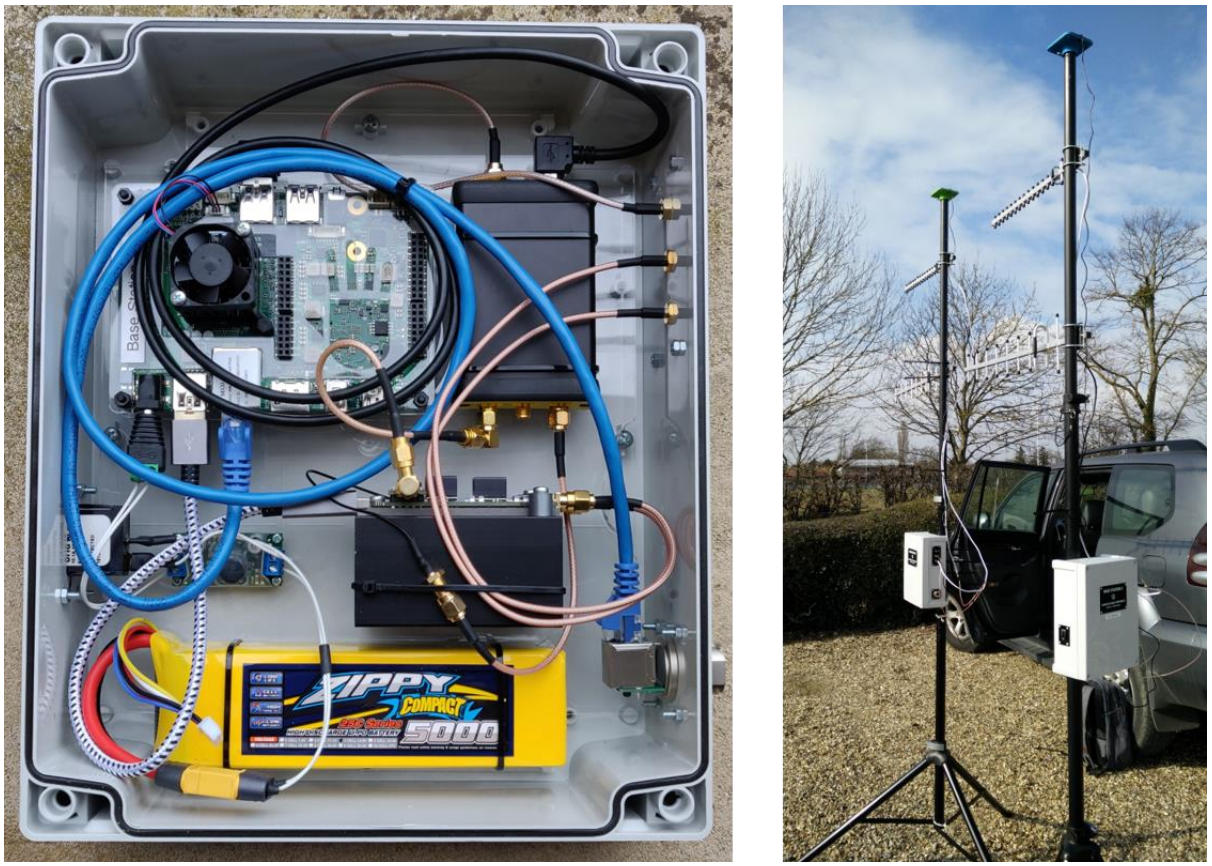

Figure 3 – Completed Base Station

In order to test the ability of the system to perform TOF measurements, we attempted to measure the TOF between two static base stations over a distance of 180m outside. This was conducted on the Pembroke Playing fields and the true position of each base station was measured using a GPS.

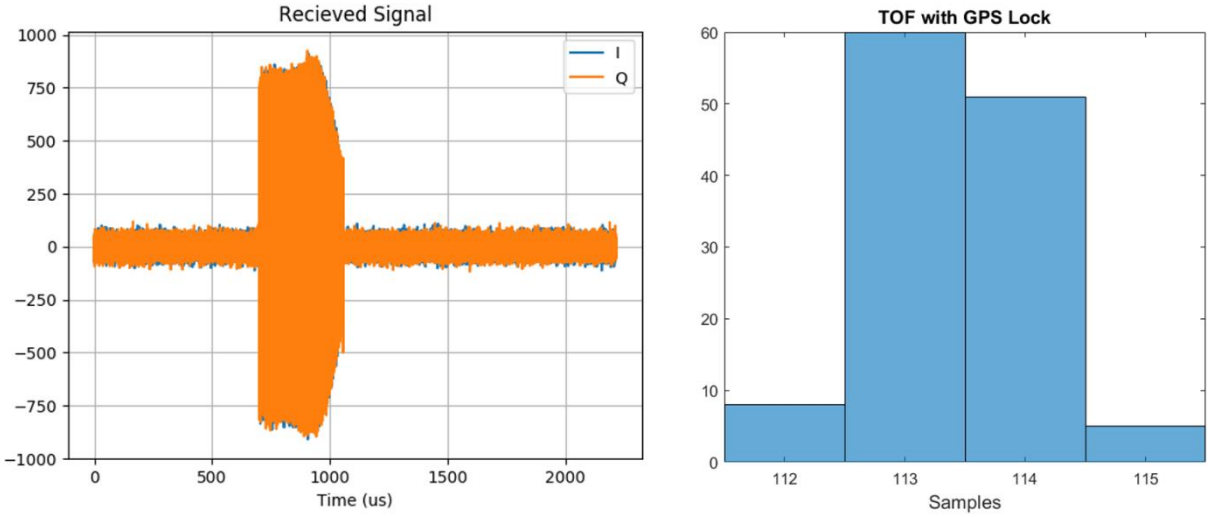

Figure 4 – Received Signal

Figure 4 above shows the received waveform and a histogram of the measured TOF between the two base stations during initial outdoor testing. It can be seen that the TOF can in fact be measured reliable to an accuracy of 20m.

Further field testing went on to show that the system would in fact be able to reliably determine the TOF to this accuracy at a range of 175 km and speeds of up to Mach 2, outperforming the initial design requirements. An algorithim was also written to produce a 3D position estimate using the measurements of a number of base stations.