Feasibility Study of Using UAVs as GNSS Satellites

Daniel Maier, Dominik Dötterböck, Ronny Blum,
Thomas Kraus, Thomas Pany

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Introduction

Investigate and determine the performance of current and new GNSS signals

Computer simulation

- Easy to realize
- Flexible
- Low costs
- Simplification of the System
- Neglecting the total complexity

Open-Field-Test

- High degree of reproducing the reality
- Reliable results
- Complex infrastructure
- Hardware intense
    - Plenty of tuning

Concept

Building pseudo satellite using

- UAV

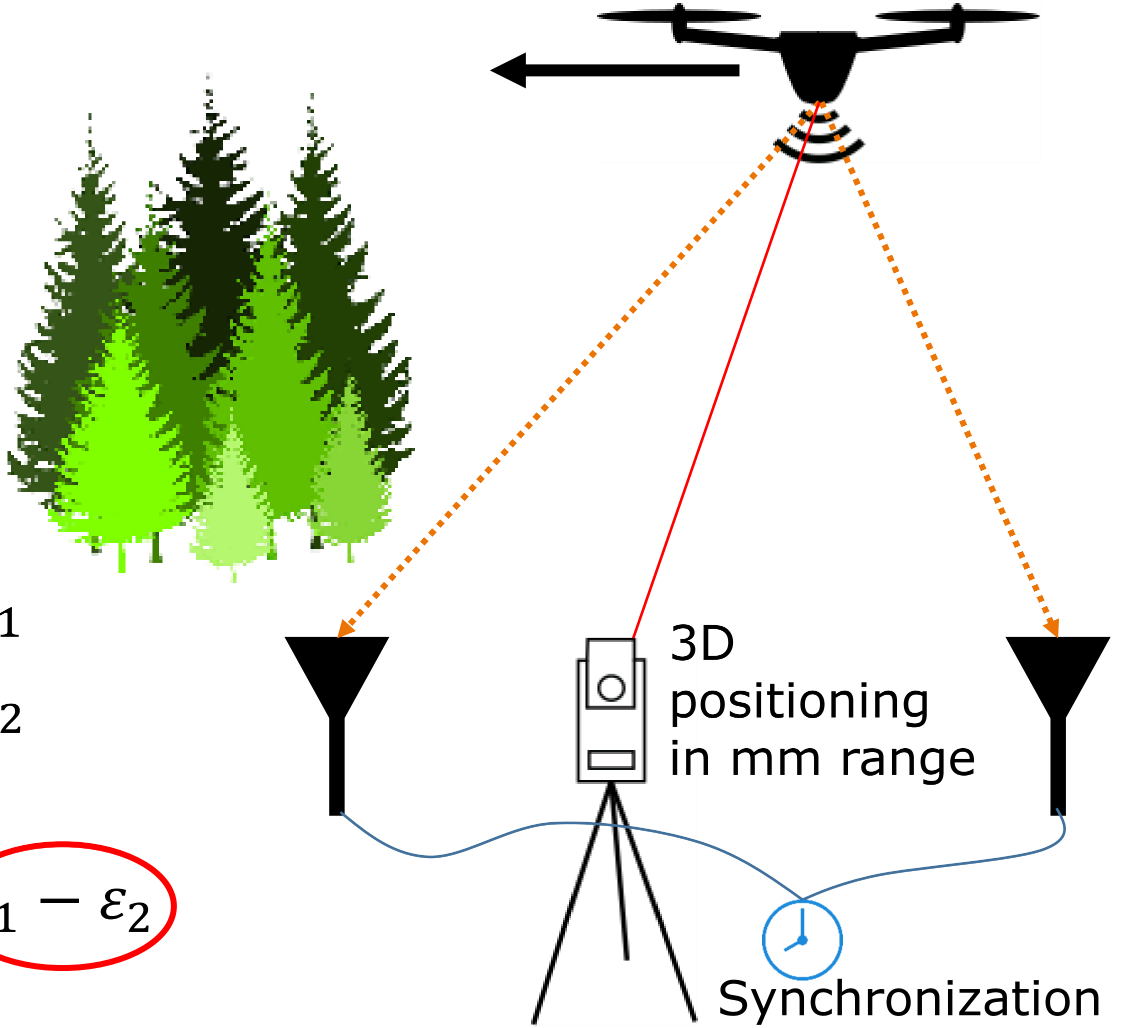
and

- Software Defined Radio (SDR)

Concept

Multiple case studies for different
- GNSS-Signal structures
- Authentication methods

under
- Jamming or
- Spoofing



$$P_1 = \rho_1 + c(dr_{sv} - dt_r) + \varepsilon_1$$
$$P_2 = \rho_2 + c(dr_{sv} - dt_r) + \varepsilon_2$$

$$P_1 - P_2 = \rho_1 - \rho_2 + \varepsilon_1 - \varepsilon_2$$

Objectives

- Analysis of multipath effects
- Optimization of signal modulation
- Characterizing the channel coding behavior in shadowed regions
- Optimizing of GNSS signals and receiver algorithms
- Investigating the robustness of actual and future Galileo signals to jamming and spoofing

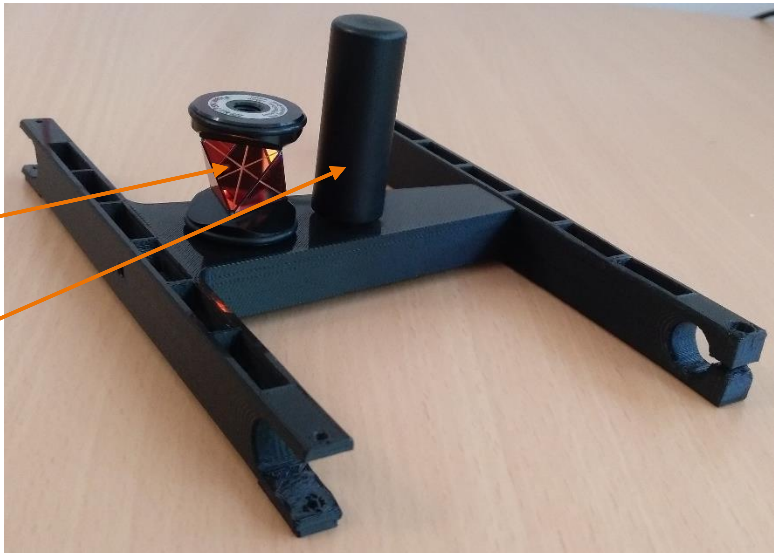
UAV

Drone

- Vendor DJI
- Model S1000+
- Max. payload ~6kg
- Flight duration 10-17min
- IMU, GPS and Compass stabilized

Using 3D printed parts for the mounting of

- SDR (NI USRP 2950R)
- 360° Reflector (Leica GRZ101)
- Helix antenna (Maxtena M1516HCT-P-SMA)



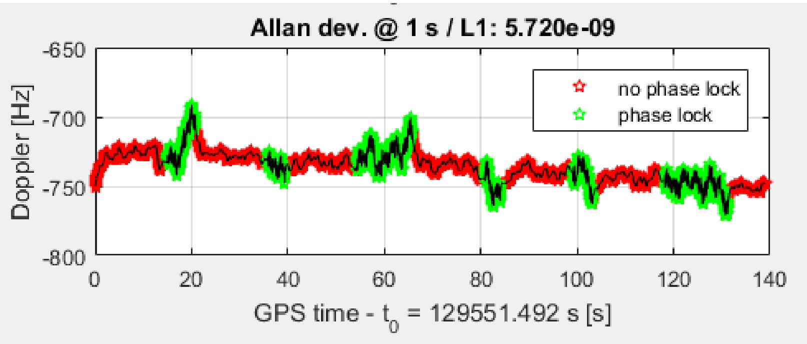
UAV Payload

Software Defined Radio

- Vendor: National Instruments
- Model: USRP 2950R
- DAC: I/Q sample rate 200 MS/s
- 120 MHz bandwidth
- TCXO and OCXO
- FPGA Xilinx Kintex 7

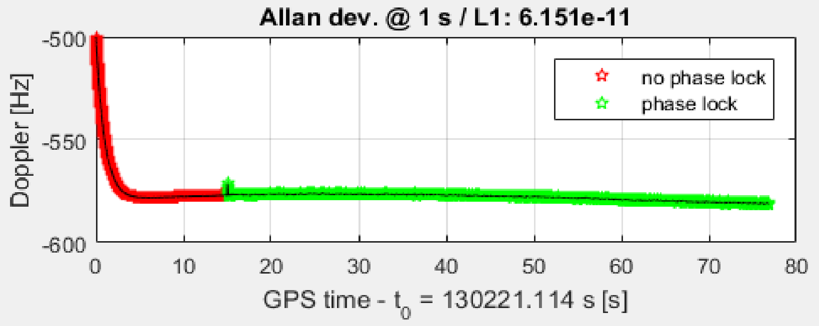
TCXO, OCXO and Atomic Clock

TCXO



OCXO

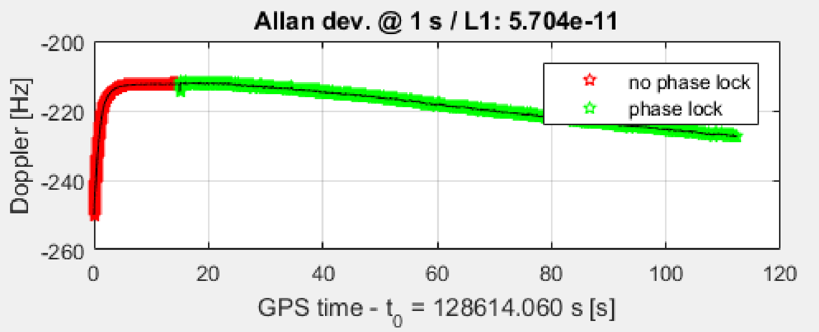
- ADEV 1E-11 at 1s



Atomic Clock

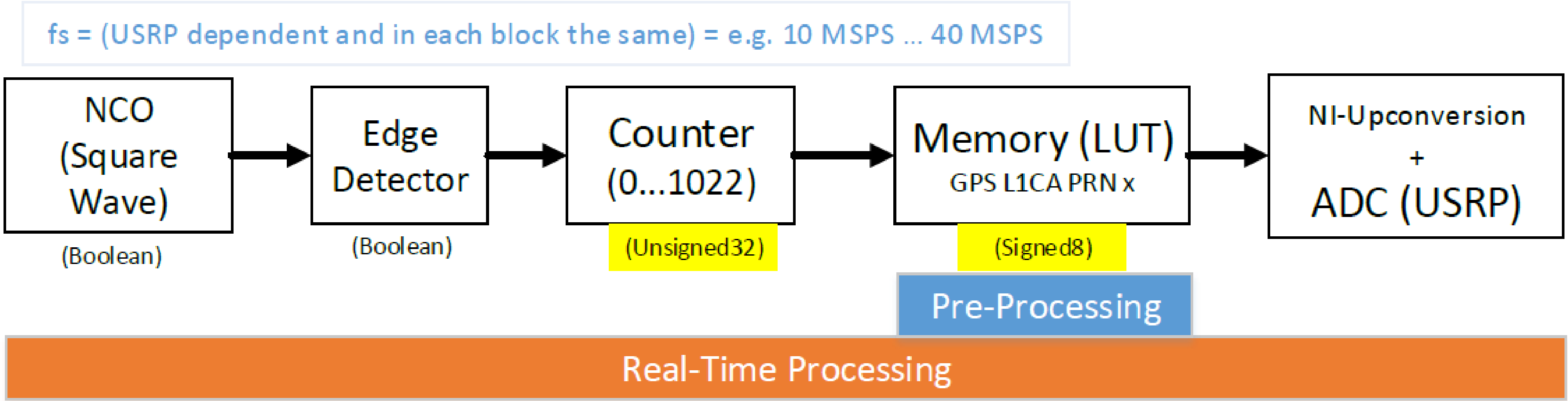
Symmetricom

XPO Rubidium Oscillator



FPGA

- LabVIEW 2016
- Use of NI LabVIEW library
  - Square Wave Generator as NCO
- Edge Detector provides one pulse for counter
- Look-Up-Table (LUT) containing the PRN code
- Native NI code used for up-conversion and transmission



fs = (USRP dependent and in each block the same) = e.g. 10 MSPS … 40 MSPS

NCO (Square Wave) (Boolean) → Edge Detector (Boolean) → Counter (0…1022) (Unsigned32) → Memory (LUT) GPS L1CA PRN x (Signed8) → NI-Upconversion + ADC (USRP)

Pre-Processing

Real-Time Processing

USRP 2950R Standalone Mode

USRP 2950R is not supposed to work in a Standalone mode.

Bypass this regulation with the use of

- Laptop with ‘Express Card’ slot
- NI ExpressCard-8360
- ExpressCard MXI Cable
- Battery for power

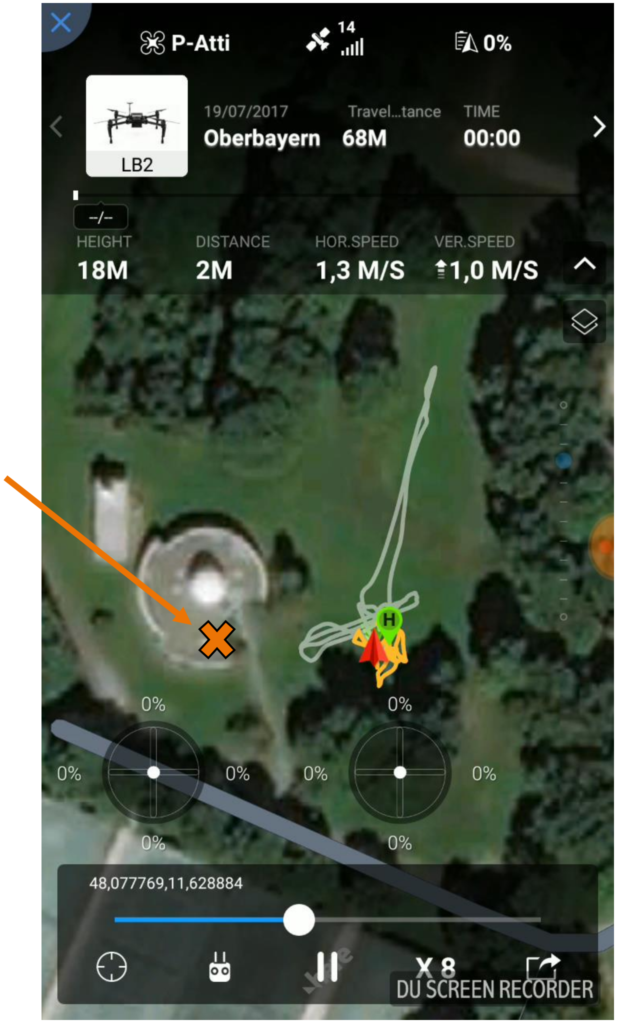
1. Connect Laptop with USRP 2950R
2. Start LabVIEW FPGA program
3. Unplug Laptop from USRP (Works only with ‘Express Card’ slot)

Positioning and Ranging

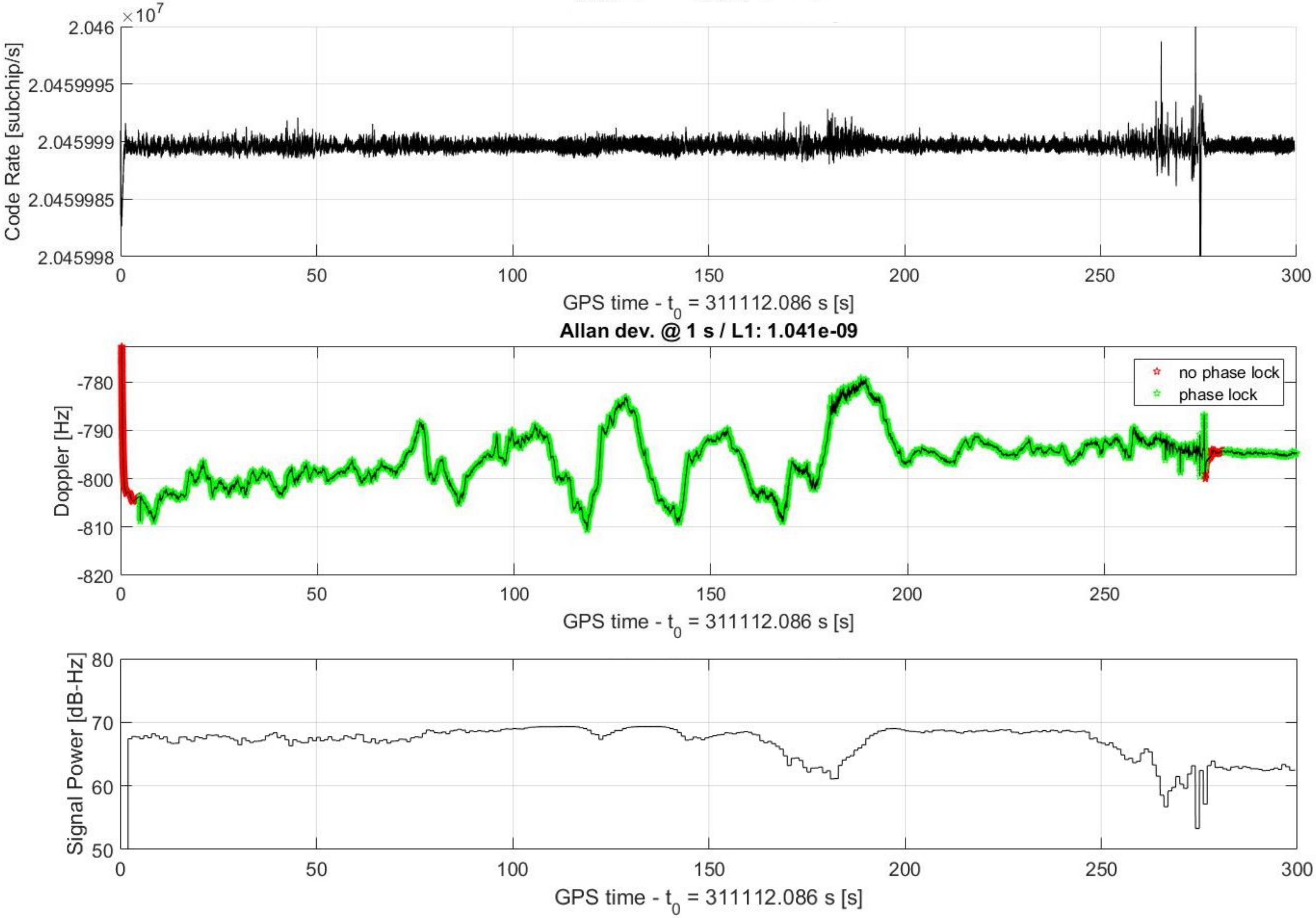
- Leica Tacheometer
- MS60
- Sub-centimeter accuracy
- Auto tracking
- Nano second timestamp of system
- Attempts to synchronize with GPS time
- Useable API

First results with single antenna

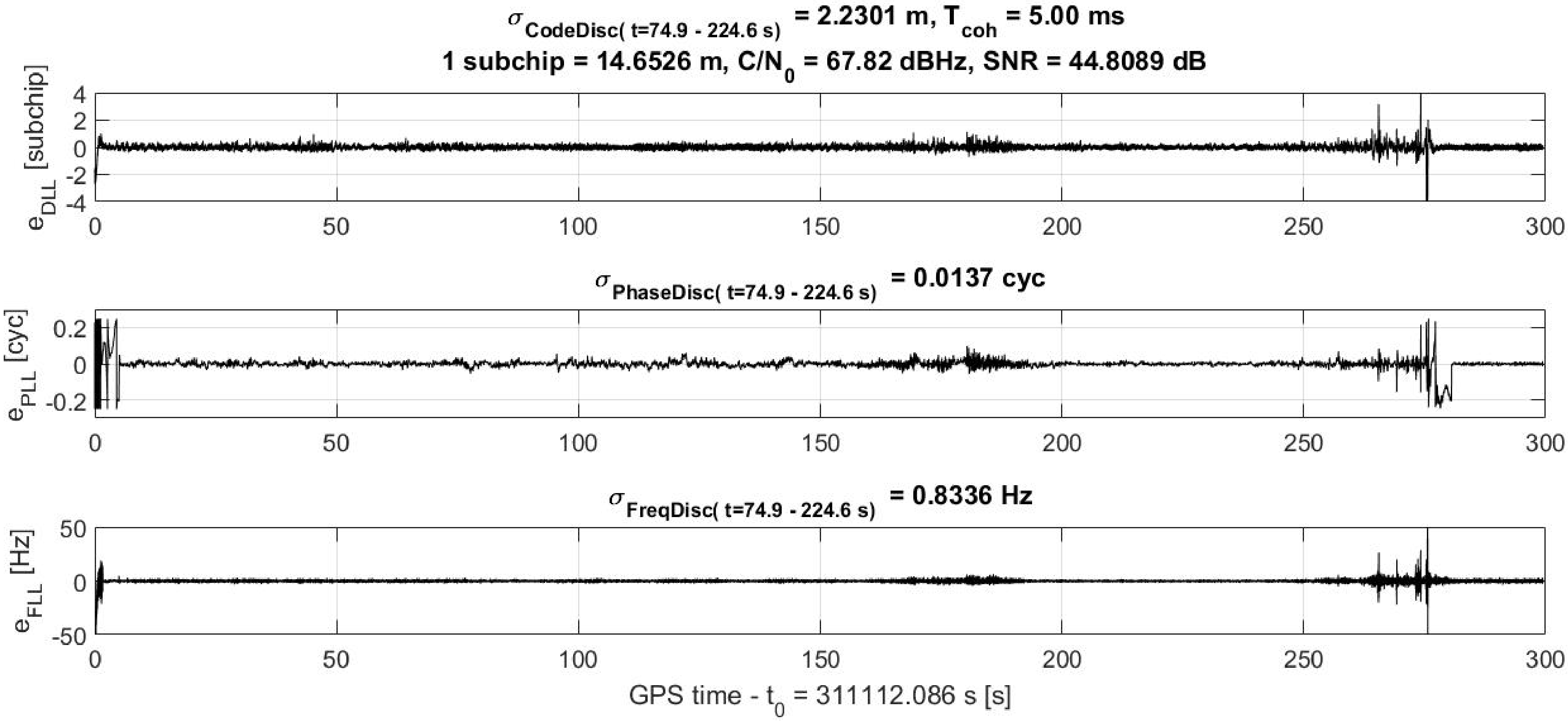
- Flight duration 5:33 min
- Start weight 8.6kg
- Signal
  - GPS PRN 1
  - Without Data Bits


Antenna Position

First results with single antenna

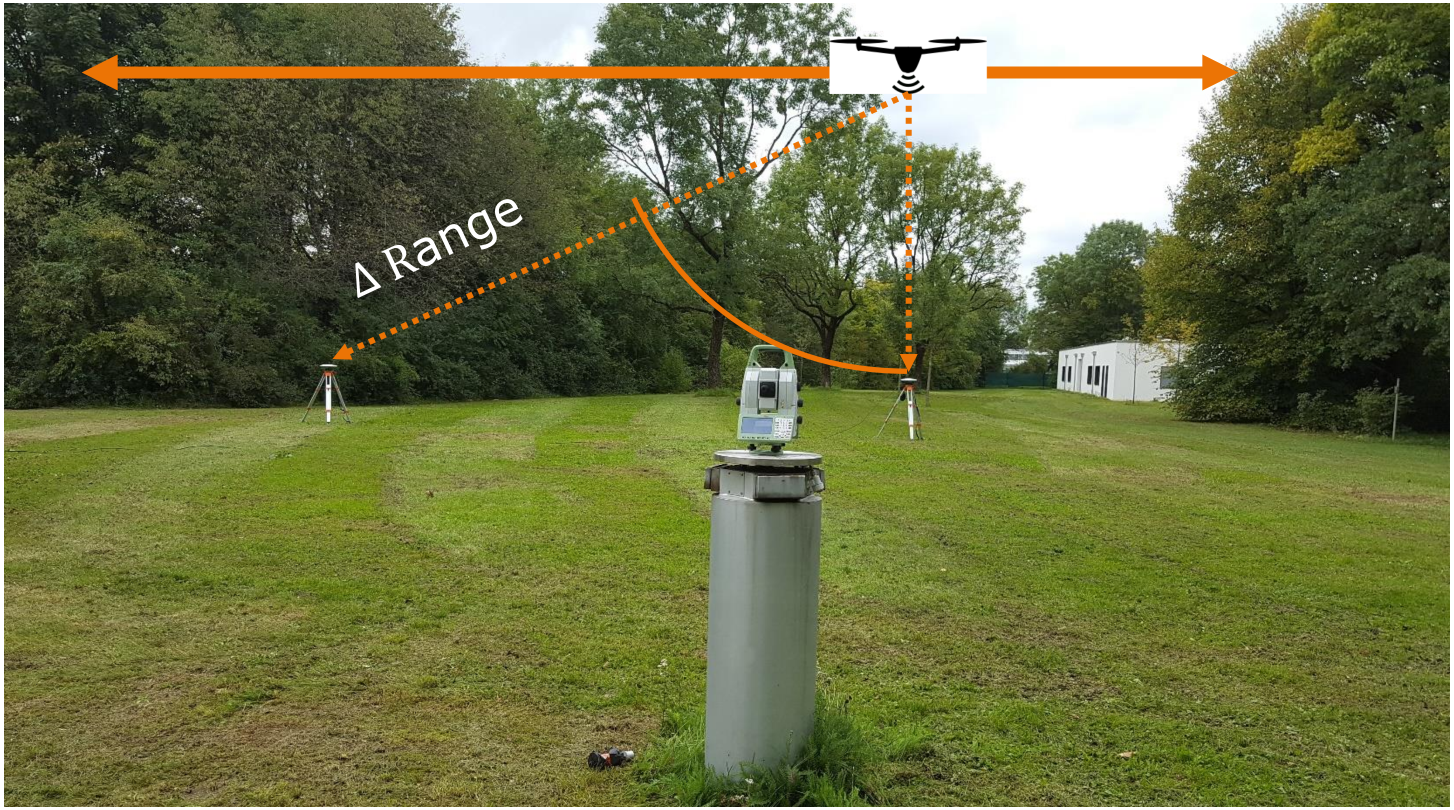


First results with single antenna



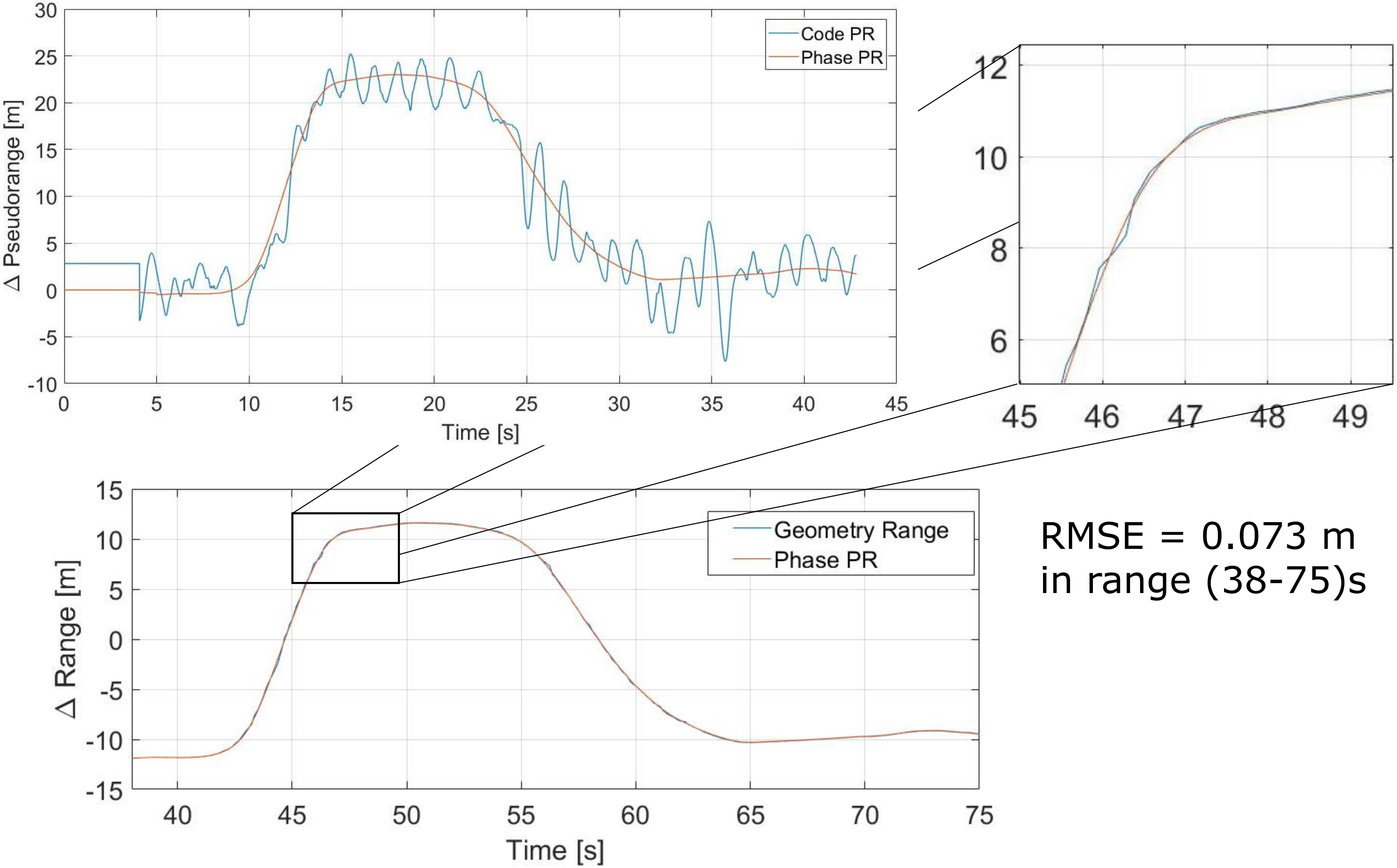
First results with two antennas

- Recording time 40 sec
- Signal
  - GPS PRN 1
  - Without Data Bits



First results with two antennas

First results with two antennas



RMSE = 0.073 m
in range (38-75)s

Summary

1. Showed that the OCXO stability is sufficient for GNSS signal generation
2. We are able to program the FPGA on the USRP to create a GNSS signal
3. The USRP can be operated in a standalone mode
4. The USRP with all necessary parts was fixed to the drone
5. We were able to send, receive and analyse GNSS signals from a flying drone
6. Compare pseudorange difference with geometric difference

Future upgrades

Our aim in the future is to enhance our testbed in order to be able to simulate complex, realistic GNSS-based navigation problems.

- Creating multiple signals and mimic a satellite constellation
- Additional antennas on poles
- More drones for constellation simulation
- Investigate the use of ‘FUSE’ Automated Smart Winch Tethering System

Contact

Daniel Maier

Institute of Space Technology and Space Applications

Universität der Bundeswehr München

Email: daniel.maier@unibw.de

Phone: +49 (0)89 6004 4374