



INSTITUTE OF
SPACE TECHNOLOGY & **SPACE APPLICATIONS**

der Bundeswehr
Universität München



**Research Center
Space**
Universität der Bundeswehr München

Flying Smartphones on UAVs to Avoid Multipath for Successful Carrier Phase Ambiguity Fixing

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Agenda

- State of Research
- Experimental Setup
- Data Processing
- Results
- Conclusion

State of Research – cm-Level Positioning

- **What we want?**

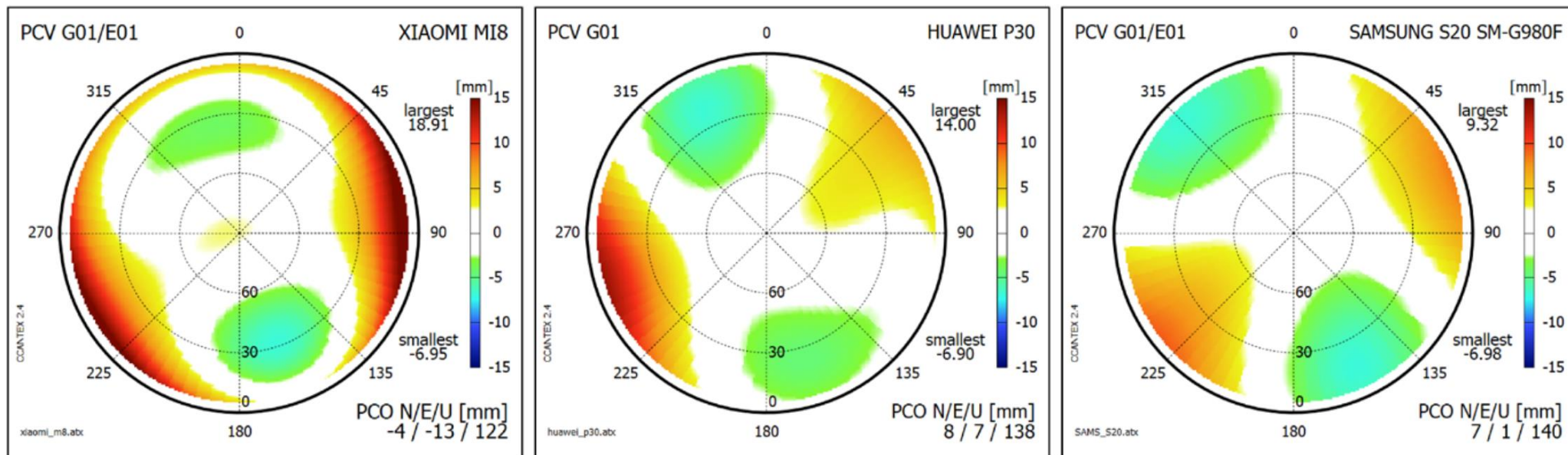
- reliable
- cm-level positioning
- with smartphones (low-cost GNSS receiver + low-cost antenna)

- **What we need?**

- Carrier-phase positioning
- with high ambiguity fixing rates
- and calibrated PCO and PCV

State of Research – cm-Level Positioning

- PCO and PCV analysis
- Azimuth and elevation-dependent C/N0 analysis

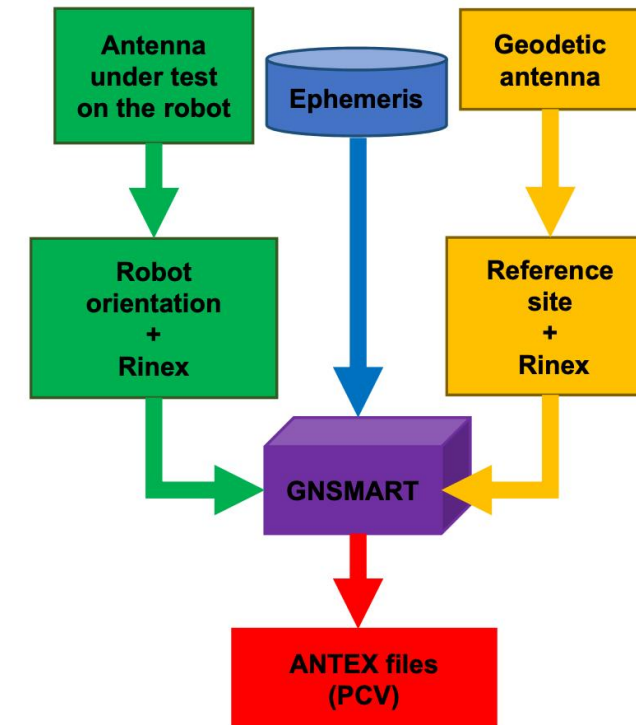
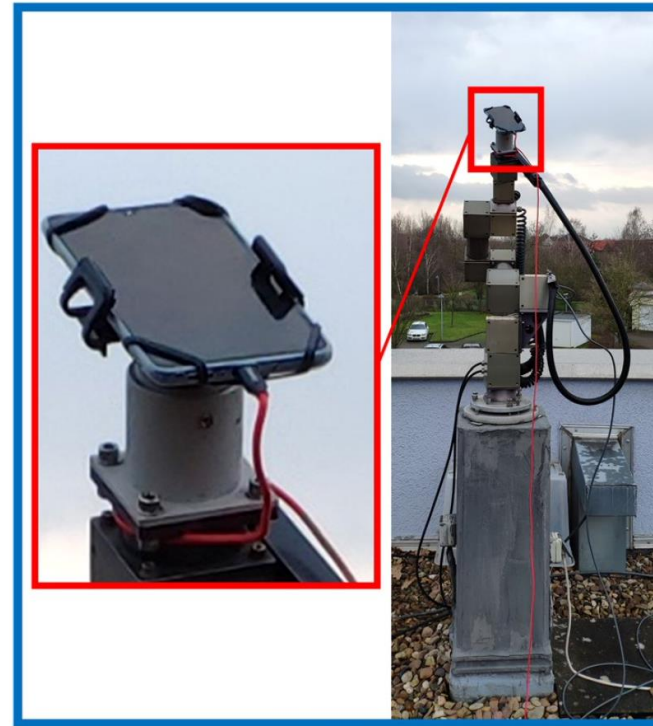


- Hesselbarth, Anja & Wanninger, Lambert. (2021). GNSS-Messungen mit Smartphones–Analyse der Beobachtungsdaten und cm-genaue Positionsbestimmung. ZfV - Zeitschrift für Geodasie, Geoinformation und Landmanagement. 3/2021. 189-197.

State of Research – cm-Level Positioning

- Robot-based PCO and PCV calibration

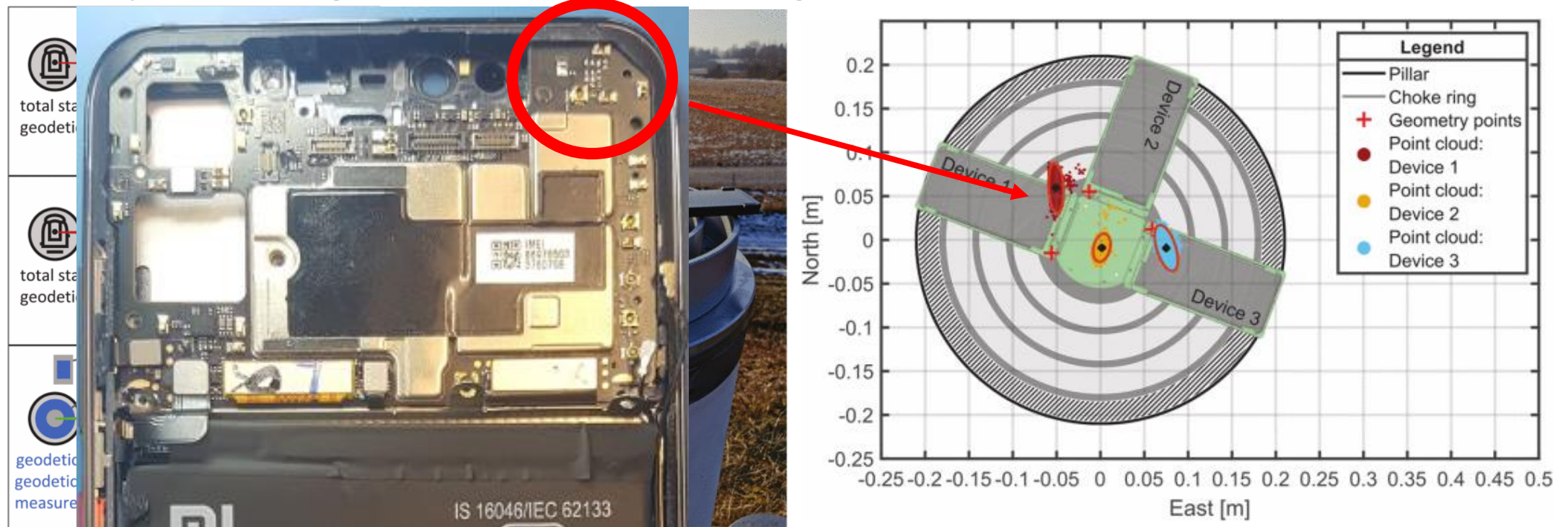
Fig. 1 From left to right: robot antenna calibration setup and simplified processing scheme of the calibration of the smartphone antenna. The Mate20X was carefully mounted, allowing the device to be continuously charged



- Darugna, Francesco & Wübbena, Jannes & Wübbena, Gerhard & Schmitz, Martin & Schön, Steffen & Warneke, André. (2021). Impact of robot antenna calibration on dual-frequency smartphone-based high-accuracy positioning: a case study using the Huawei Mate20X. GPS Solutions. 25.

State of Research – cm-Level Positioning

- Multipath mitigation with choke-ring antenna



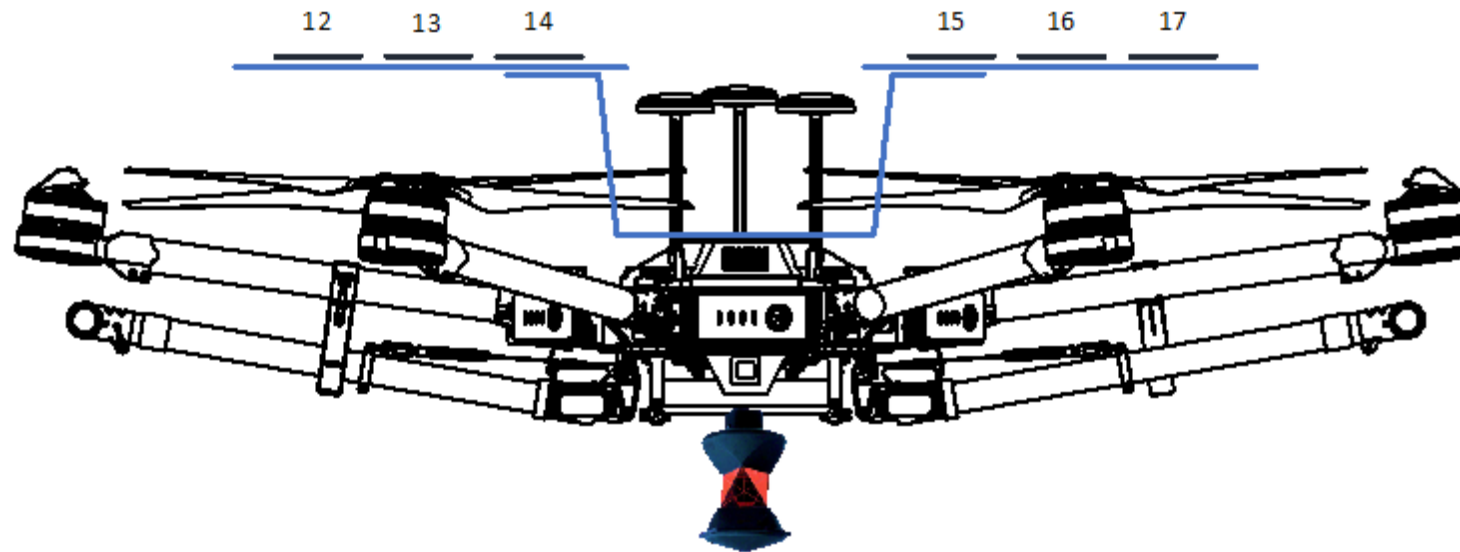
- Smartphone-based GNSS Positioning – Today and Tomorrow, Sharma, H., Bochkati, M., Lichtenberger, C. A., Pany, T., Draguna F. and Wübbena, J. B., *Inside GNSS*, Vol. 2, No. 2, March–April 2007
- Sharma, H., Bochkati, M. and Pany, T. (2019). Influence of the Multipath Mitigation on Precise Positioning with Smartphone Raw GNSS Measurements. Proceedings of the ISGNSS 2019, Jeju, South Korea.

Idea and Hypothesis

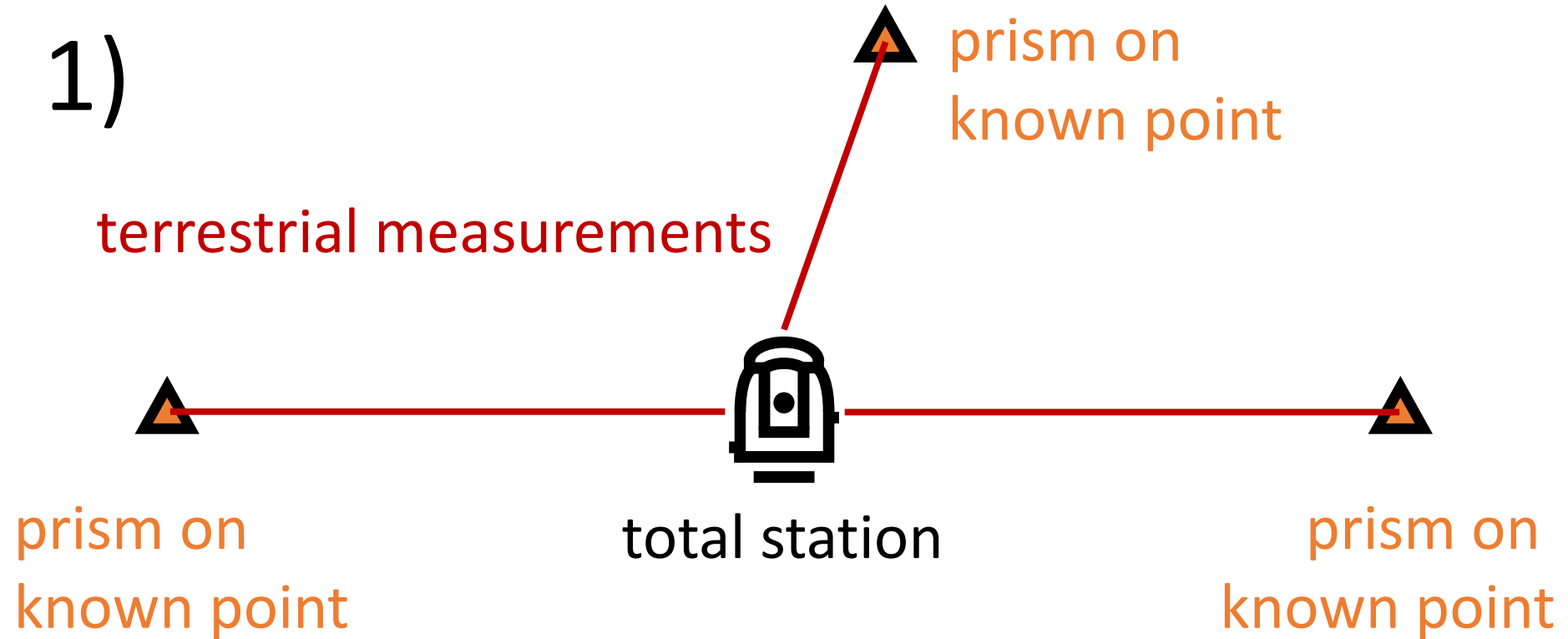
- **Idea:** mitigate (ground-) multipath and enhance C/N0 without choking antenna by „flying away“ from multipath
- **Hypothesis:**
 - Influence from multipath decreases with height over ground
 - Carrier-phase ambiguity fixing rates increases with height over ground

Experimental Setup

- Test Devices: **6 x Xiaomi Mi 8** with Broadcom BCM47755 GNSS chip
- Drone platform: DJI M600 Pro
- Terrestrial ground truth: Multistation Leica MS60

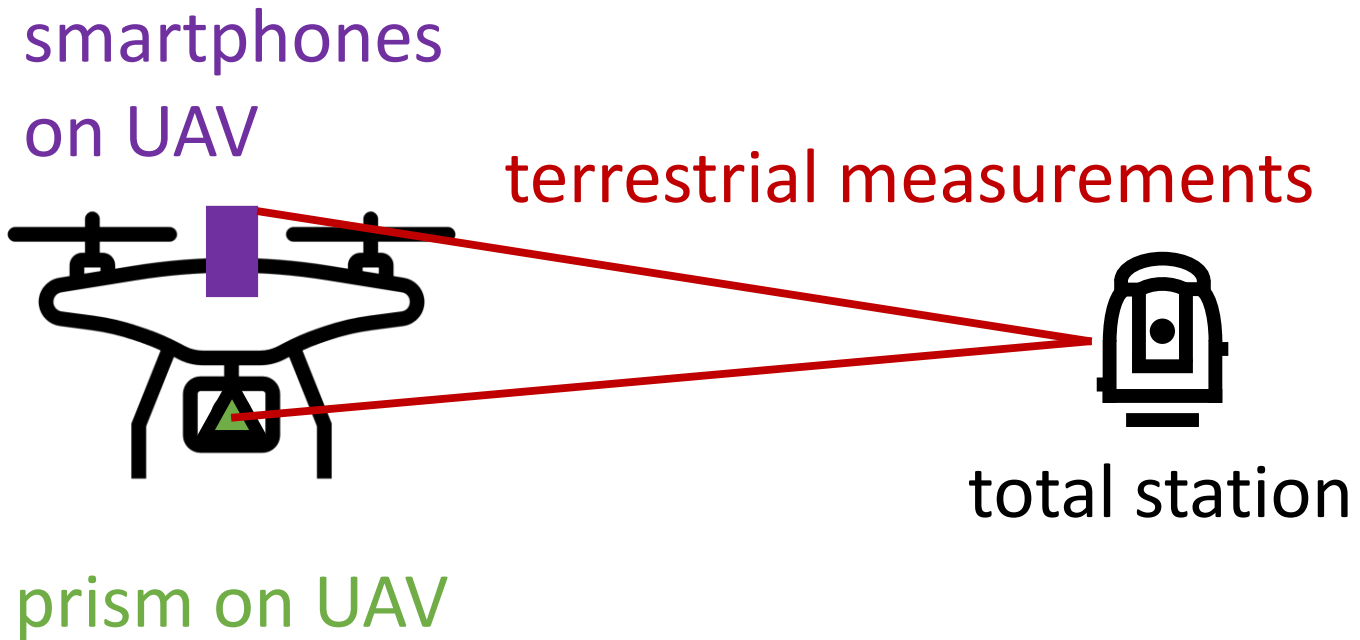


Experimental Setup



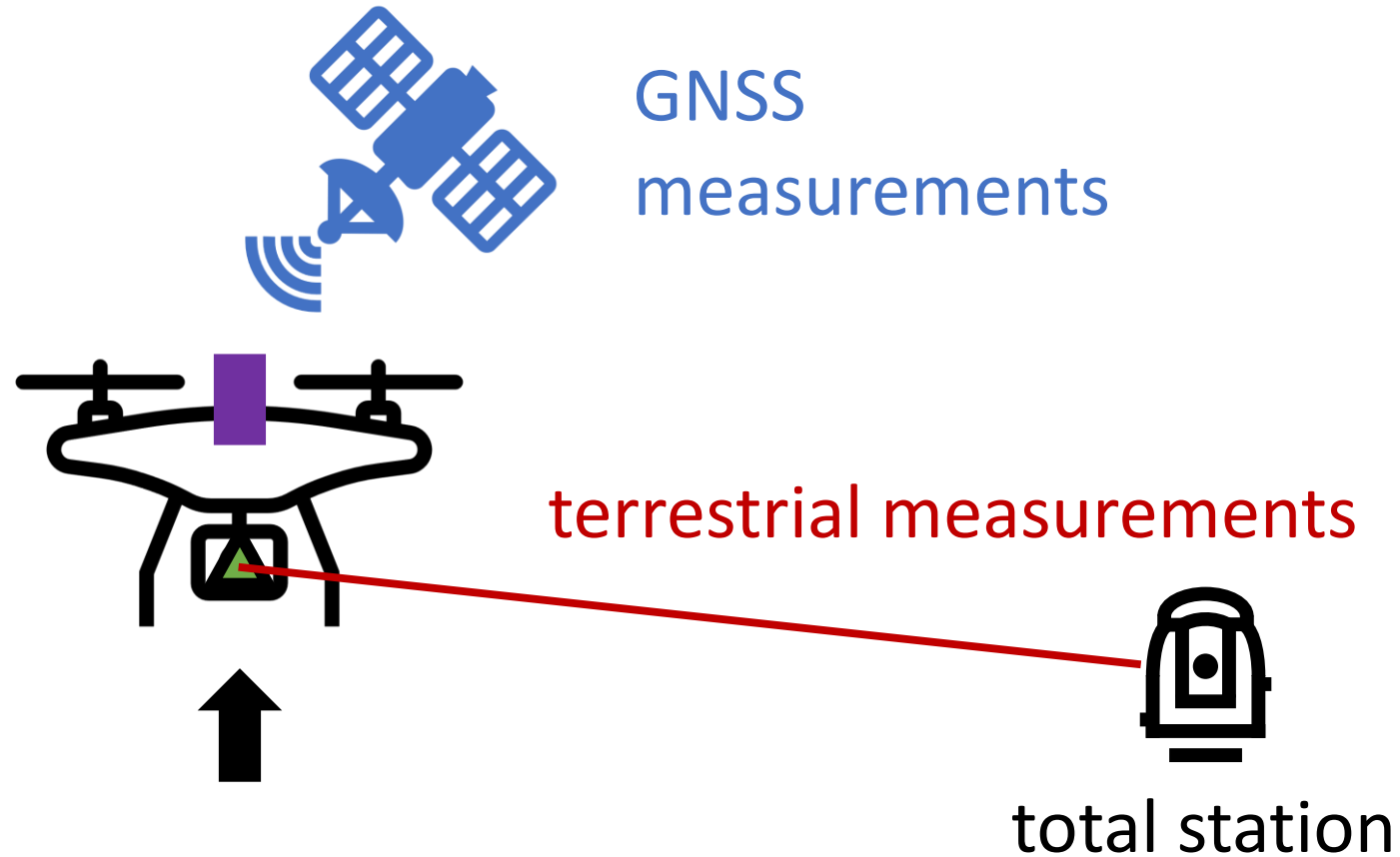
Experimental Setup

2)



Experimental Setup

3)



Experimental Setup

- Real impressions from the experiment



GNSS/IMU Logger

- Logger for time-synchronous RINEX and IMU data
- Available in Google Play Store

The image displays three screenshots of the GNSS/IMU Logger application interface.

Left Screenshot: Shows sensor data plots. The top plot is "Calibrated Accelerometer vs Time" (m/s²) and the bottom plot is "Calibrated Gyroscope vs Time" (rad/s). Both plots show data from Epoch 29078 to 30082 milliseconds. Below the plots are toggle switches for "Uncalibrated Sensor Data", "Calibrated Sensor Data", "RNX + Uncalibrated Sensor Data", and "RNX + Calibrated Sensor Data". A "Log Duration" indicator shows 00:00.

Middle Screenshot: Shows GNSS sensor data and statistics. It includes a "GNSS" tab and a list of parameters:

- SvTimeUncertaintyNanos = 28
- Cn0DbHz = 0,000
- PseudorangeRateMetersPerSecond = 241,102
- PseudorangeRateUncertaintyMetersPerSeconds = 0,050
- AccumulatedDeltaRangeState = 16
- AccumulatedDeltaRangeMeters = 0,000
- AccumulatedDeltaRangeUncertaintyMeters = 10,00E-02
- CarrierFrequencyHz = 1.57542003E9
- MultipathIndicator = 0
- AgcDb = 1.0
- CarrierFreqHz = 1.57542003E9

 It also shows "GnssMeasurement" details for Svid = 1, ConstellationType = 6, TimeOffsetNanos = 0.0, State = 0, ReceivedSvTimeNanos = 0, ReceivedSvTimeUncertaintyNanos = 11, Cn0DbHz = 0,000, PseudorangeRateMetersPerSecond = 503,985, PseudorangeRateUncertaintyMetersPerSeconds = 0,050, AccumulatedDeltaRangeState = 16, AccumulatedDeltaRangeMeters = 0,000, AccumulatedDeltaRangeUncertaintyMeters = 10,00E-02, CarrierFrequencyHz = 1.57542003E9, MultipathIndicator = 0, AgcDb = 1.0, and CarrierFreqHz = 1.57542003E9. At the bottom, it shows "Location | onLocationChanged: Location[gps 48*****", "Time Remaining: N/A", and "00:00".

Right Screenshot: Shows "Normalized Clock Offset (ms) vs Epoch" data. The plot shows a blue line for "Offset" and a red line for "Moving Average Offset". Below the plot, it displays:

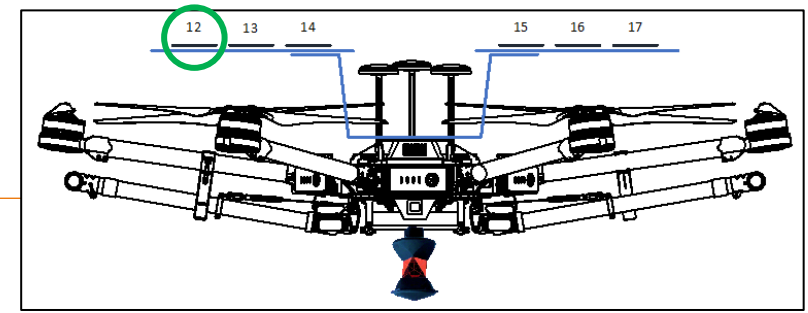
- Offset Calculation using : GPSTime : GnssClock Class, ElapsedRealTime : GnssClock Class
- Moving Average Clock Offset (ms) : -2.133
- Current Normalized Clock Offset (ms) : 3.141169
- Averaging Window (s) : 30

- ISTA-UniBw M (2021). GNSS/IMU Logger (Version v2.1.0.0) [Mobile app]. Retrieved from <https://play.google.com/store/apps/details?id=com.ista.android.apps.location.gps.gnsslogger&hl=de&gl=US>

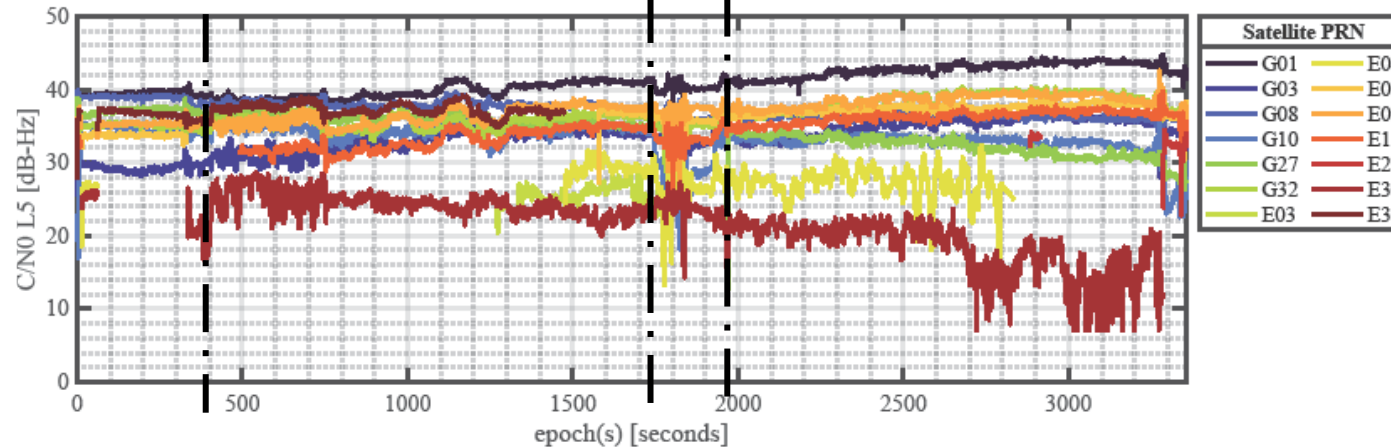
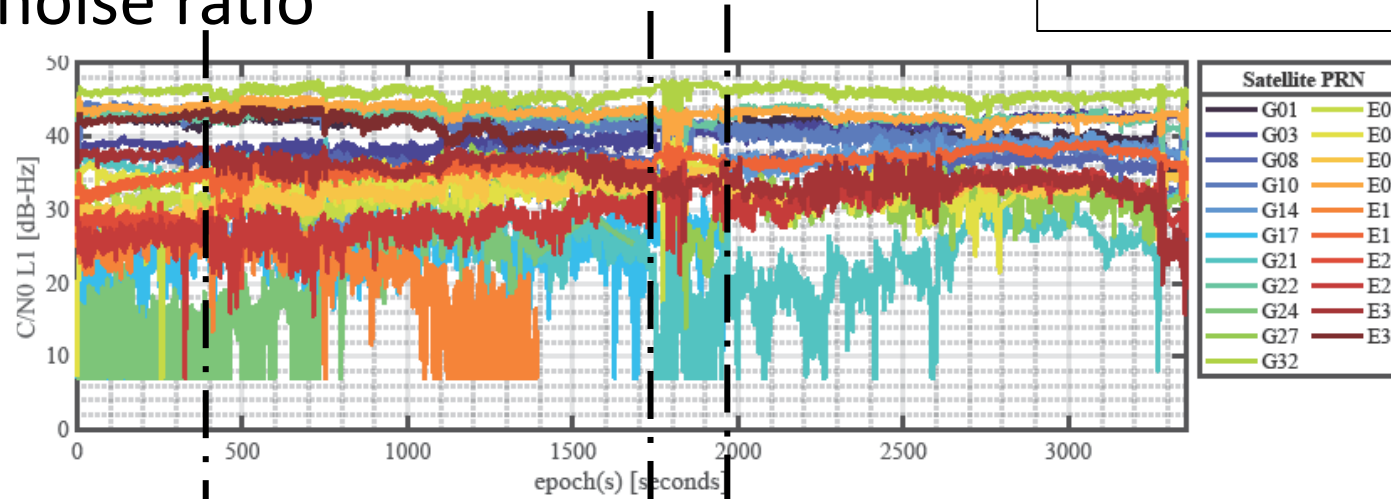
Data Processing

- Geodetic reference station (baseline < 1 km) on campus site
- Time synchronisation between terrestrial and GNSS measurements
- Code-minus-carrier (CMC) method for multipath calculation
- NovAtel Inc. Inertial Explorer (version 8.70.4301) for RTK processing

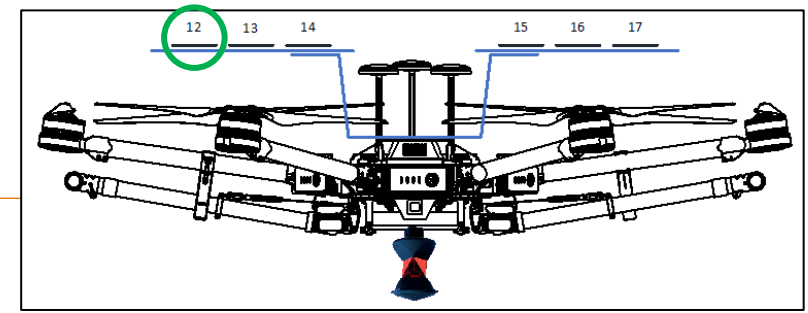
Results (Device 12, best)



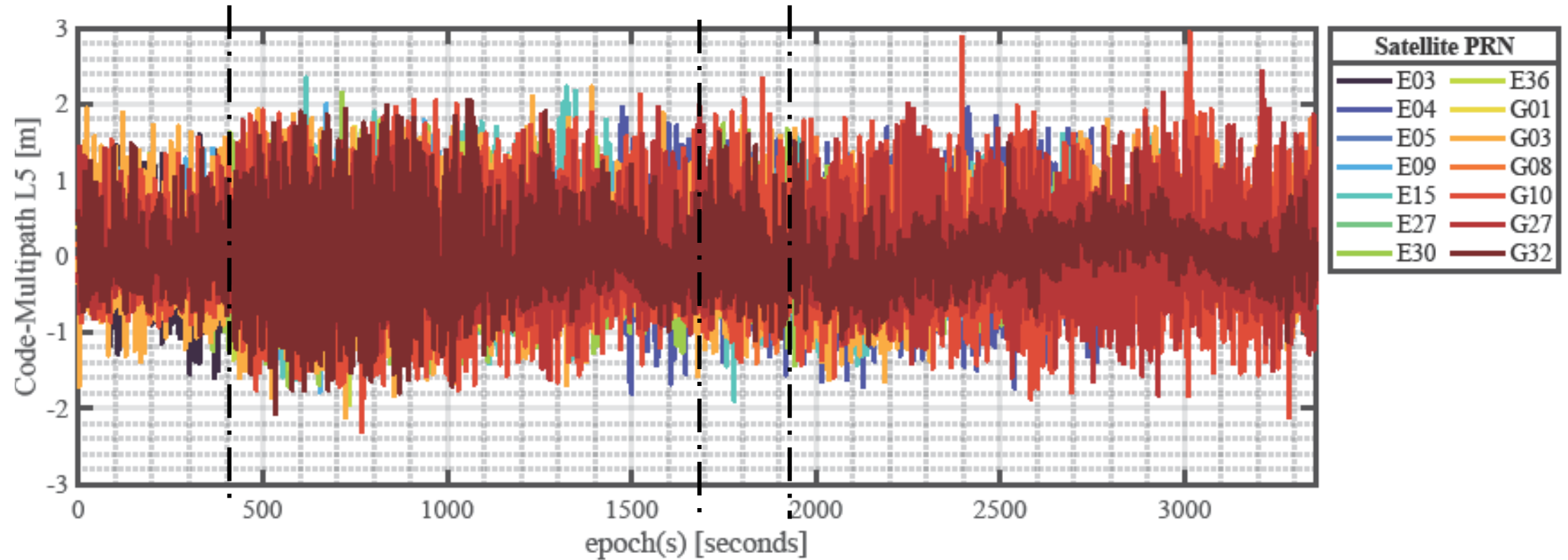
- Carrier-to-noise ratio



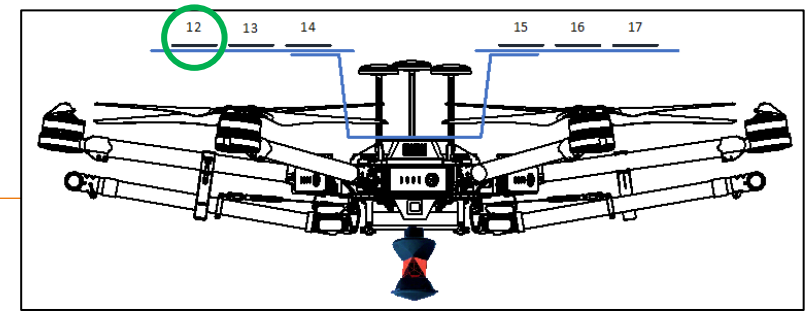
Results (Device 12, best)



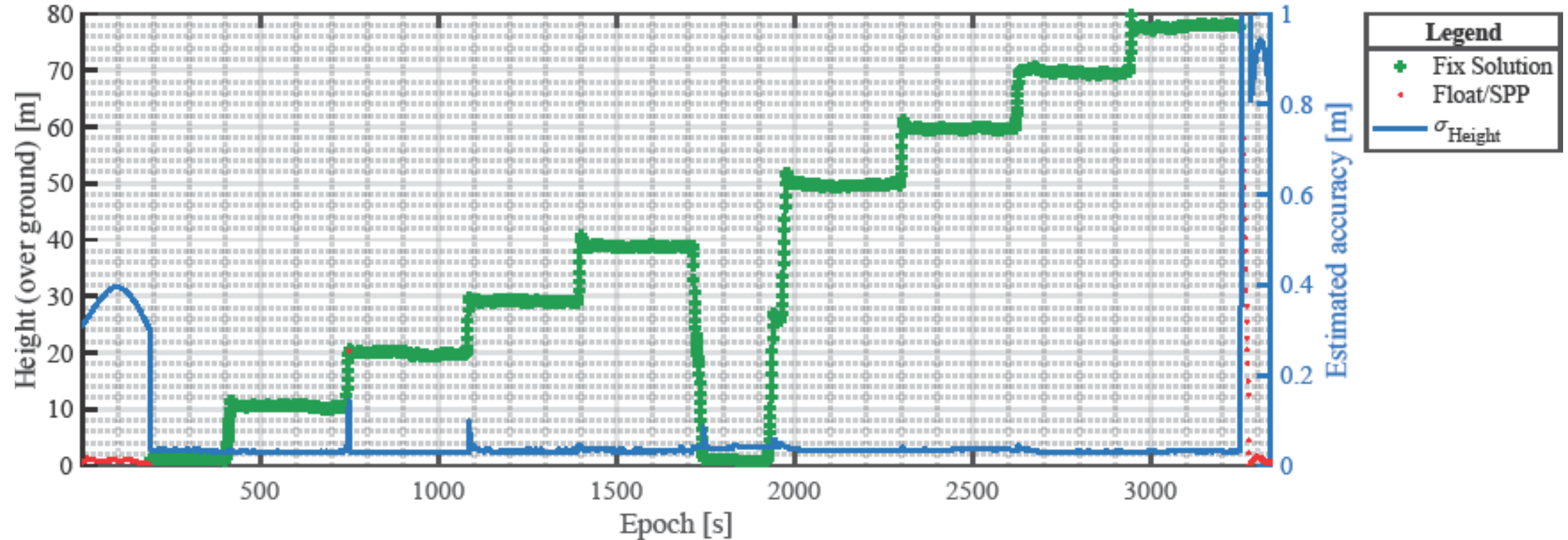
- Multipath L1



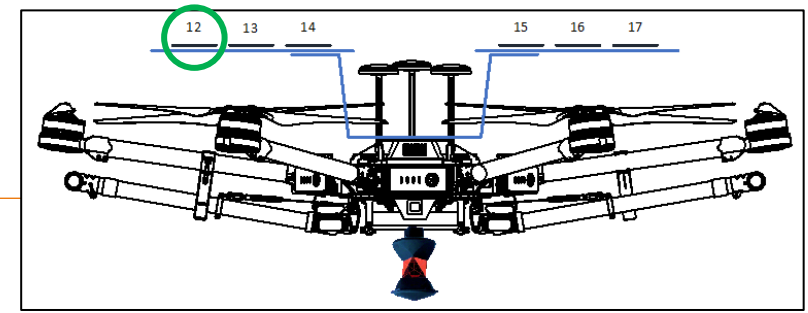
Results (Device 12, best)



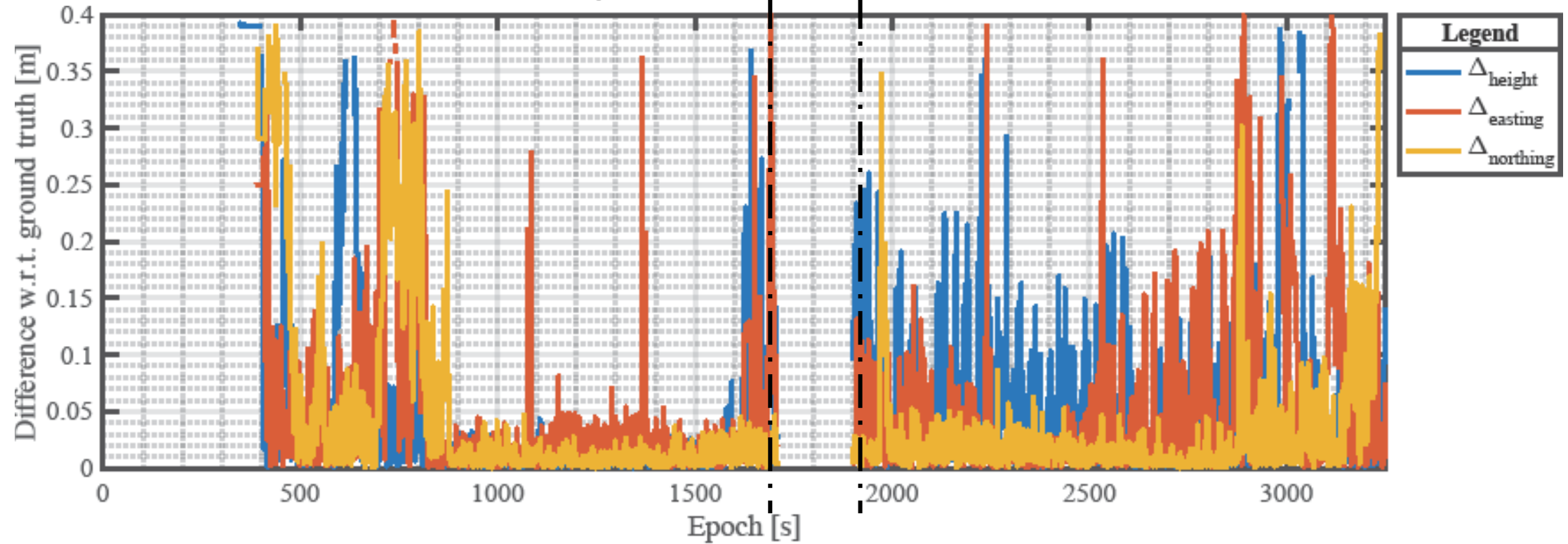
- Ambiguity fixing



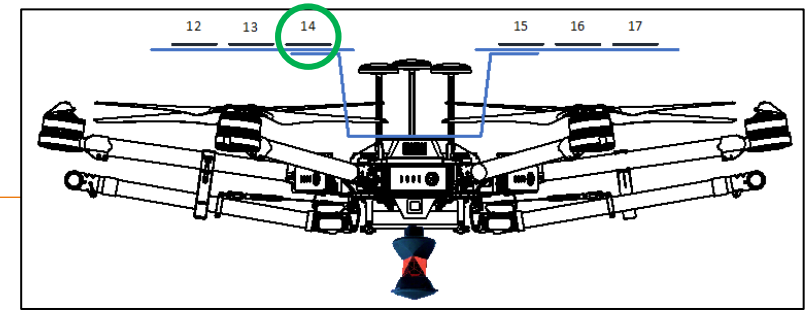
Results (Device 12, best)



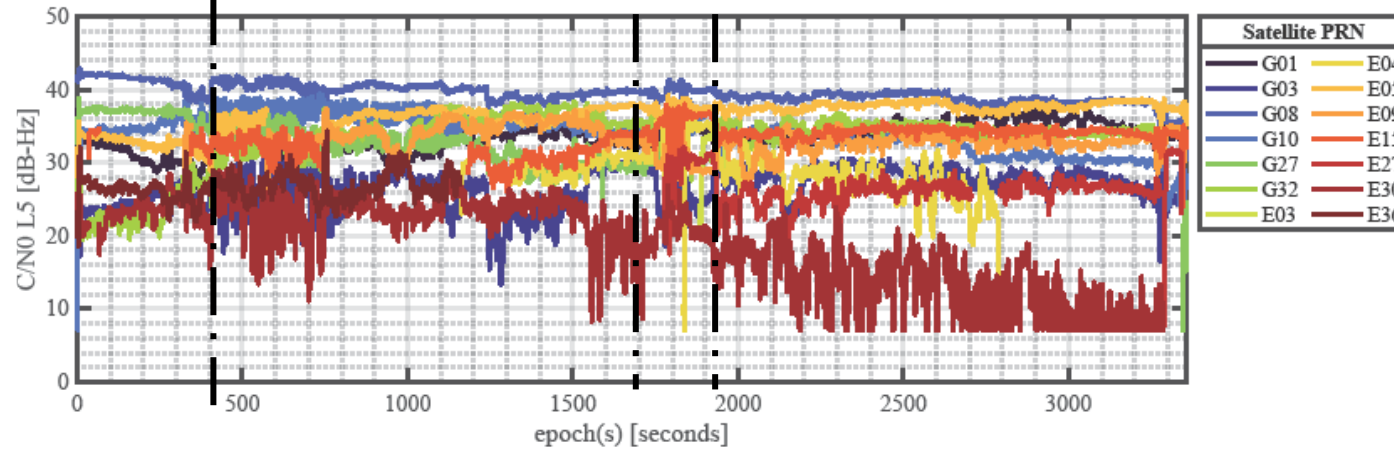
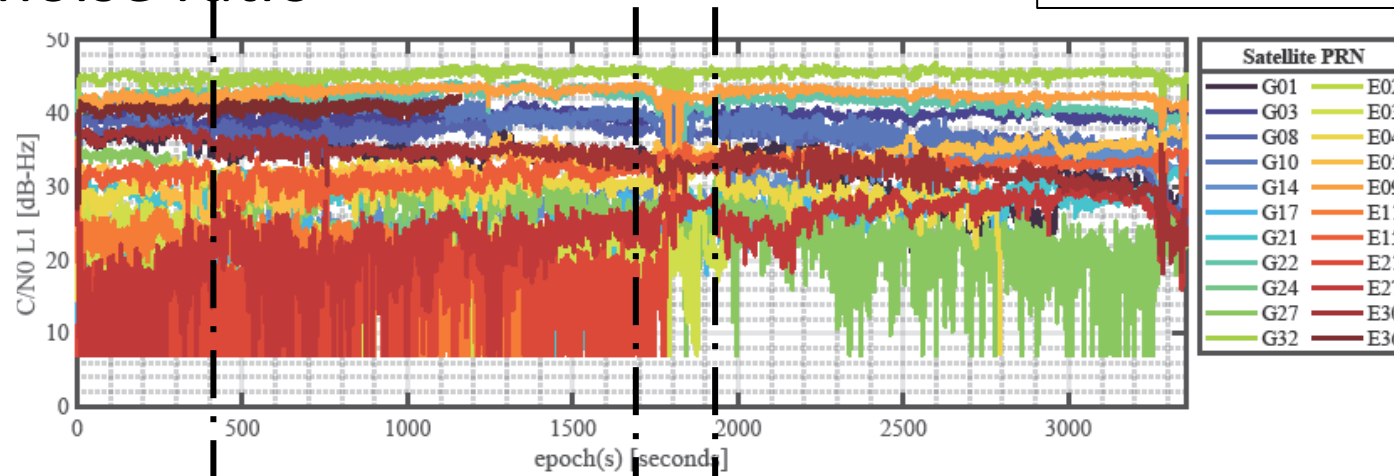
- Position difference w.r.t. ground truth



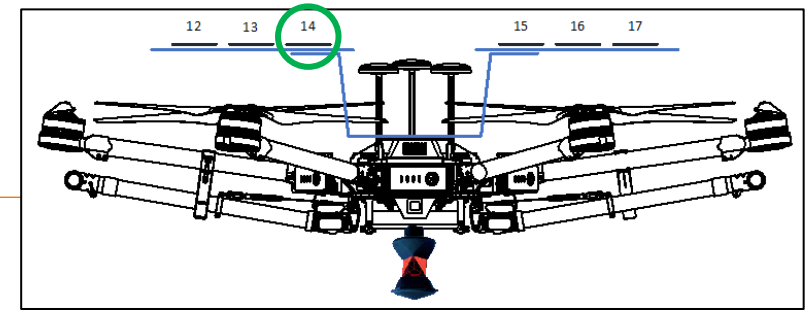
Results (Device 14, worst)



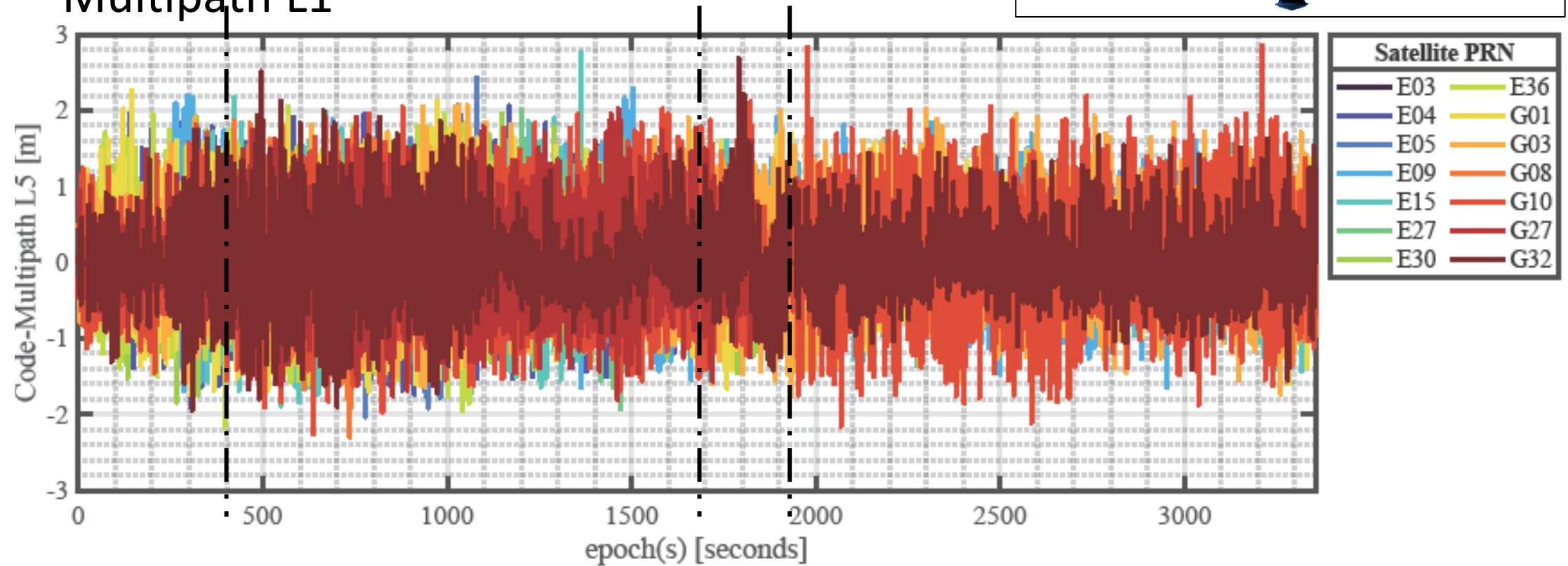
- Carrier-to-noise ratio



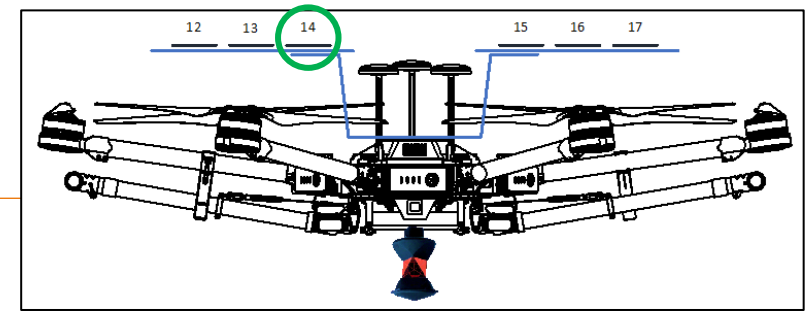
Results (Device 14, worst)



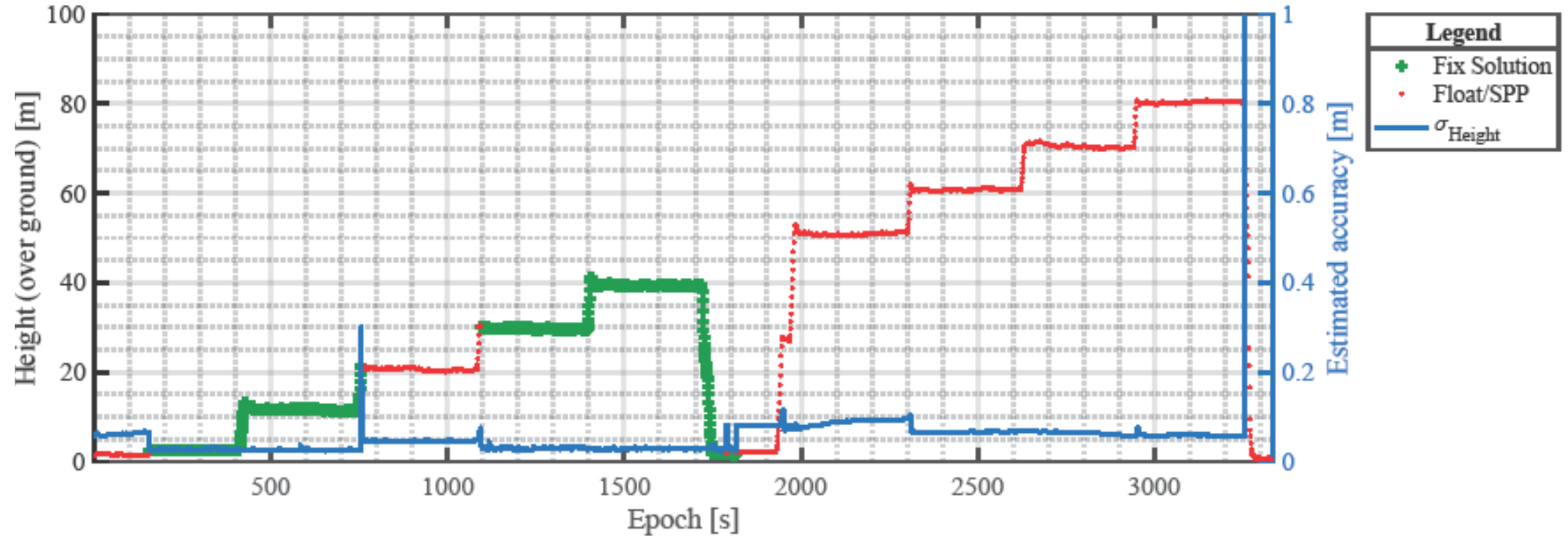
- Multipath L1



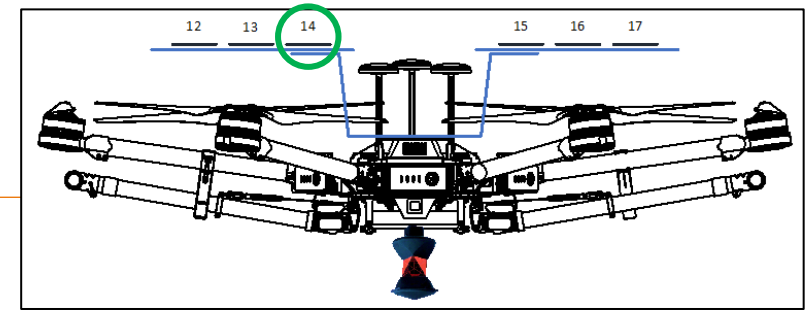
Results (Device 14, worst)



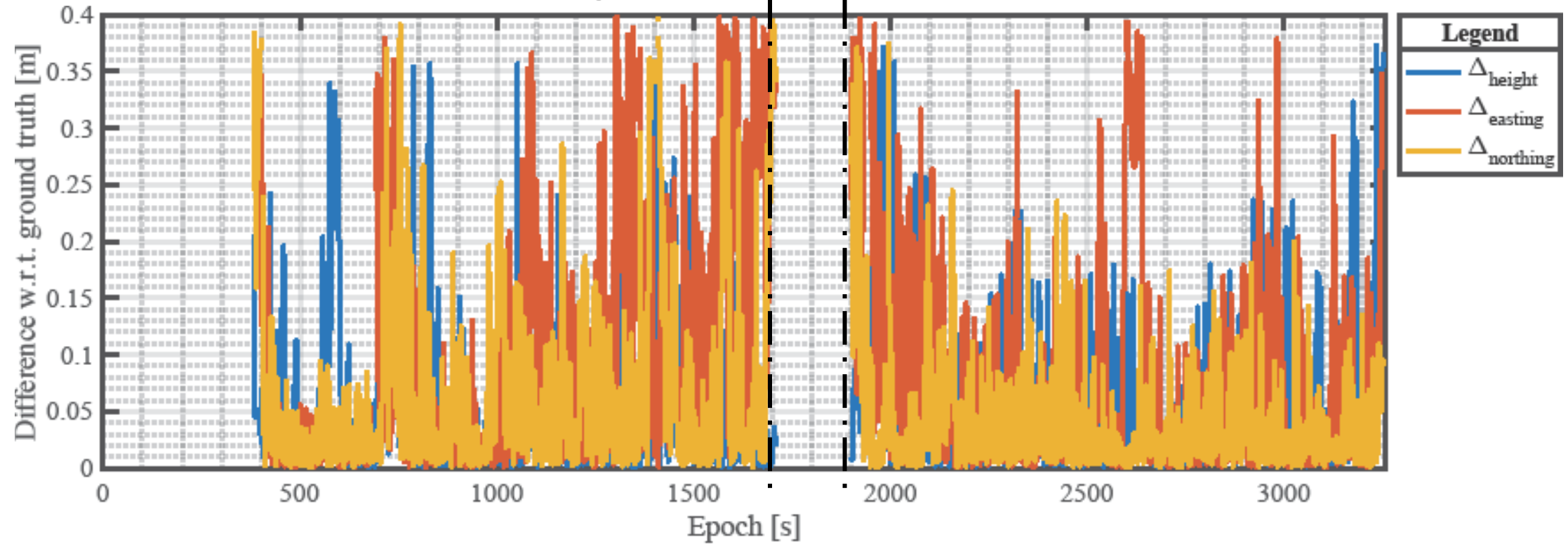
- Ambiguity fixing



Results (Device 14, worst)

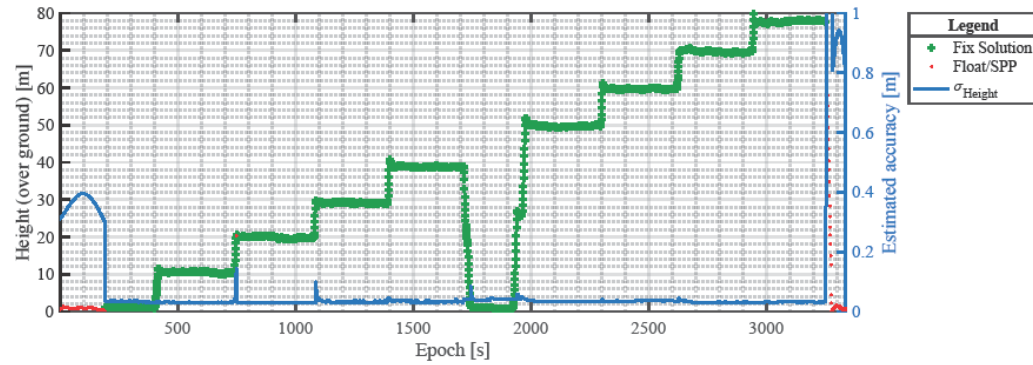


- Position difference w.r.t. ground truth

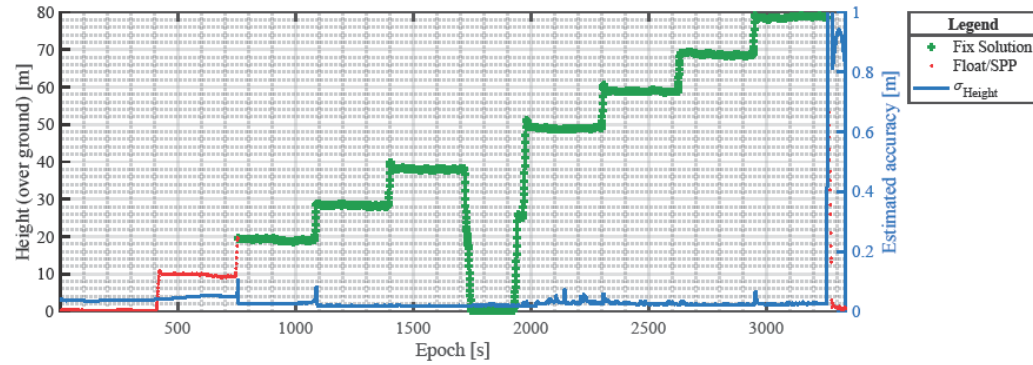


Results (Overview)

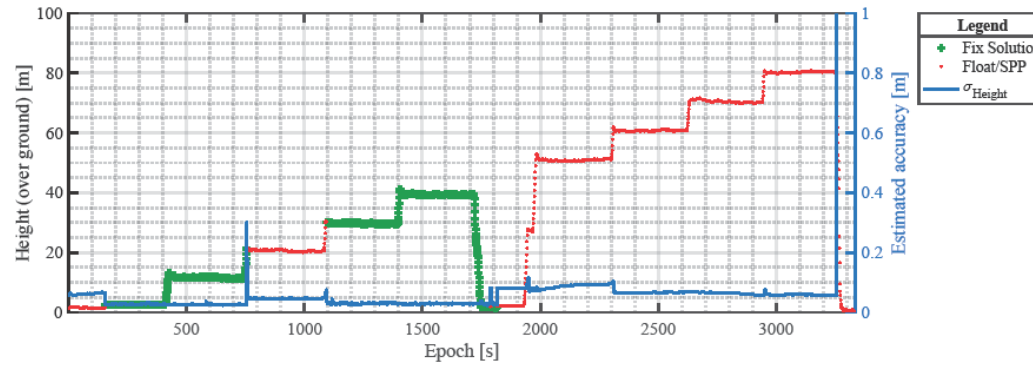
12



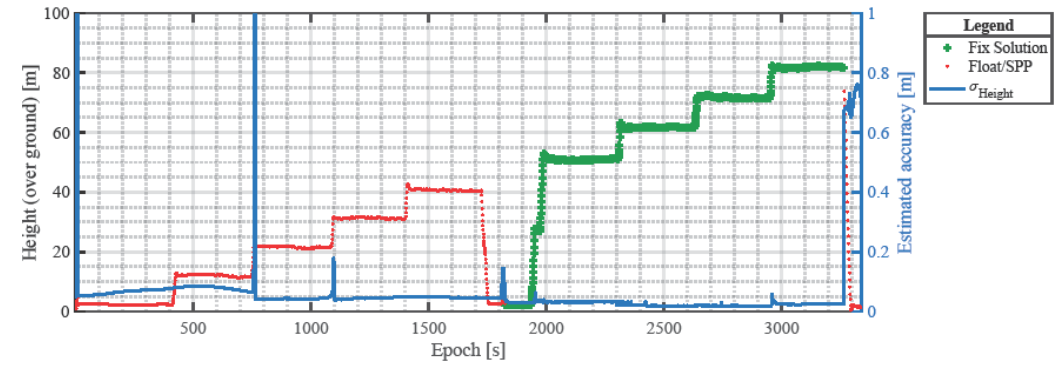
13



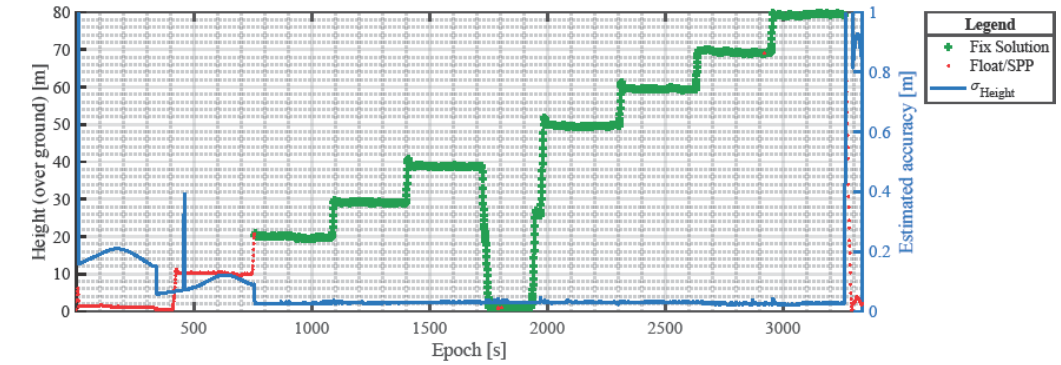
14



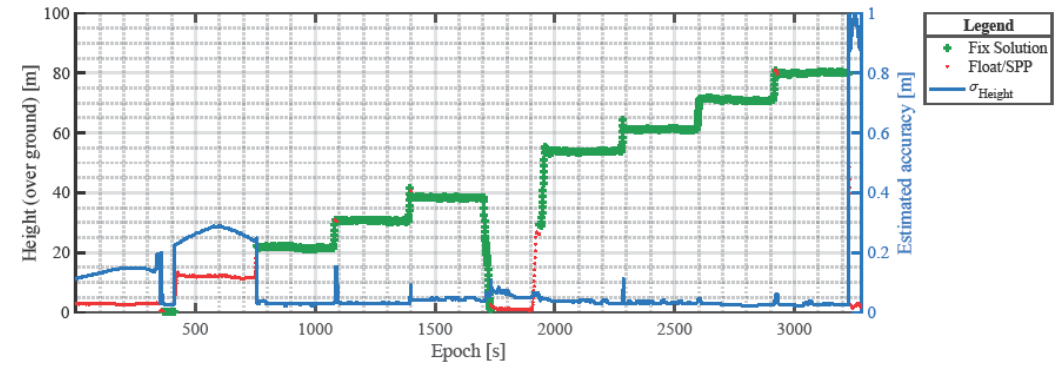
15



16



17



Results

Smartphone device		12 (best)	14 (worst)
fixing rate [%]	forward filtering	66	40
	backward filtering	26	0
	combined filtering	92	40

coordinate component	best (device 12)		worst (device 14)	
	mean	RMS	mean	RMS
Easting [m]	0.060	0.152	0.070	0.162
Northing [m]	0.065	0.134	0.072	0.140
Height [m]	0.080	0.180	0.119	0.215

Conclusion

- Multipath effect on smartphone GNSS receivers can be reduced, while the altitude increases
- No time-consuming calibration needed for adequate ambiguity fixing rates
- cm- or dm-level accuracy achieved without any hardware support (e.g. special antennas or retransmitting of signals)

Future Work

- Replace drone platform with (helium-) balloon to avoid self-jamming from drone onboard electronics
- Potential application: low-cost drones with low-cost GNSS-receivers/antennas
 - e.g. SmartMap concept: smartphone for drone control and 3D-mapping



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Project initiative based on the space
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aufgrund eines Beschlusses
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