Time-Synchronized GNSS/IMU Data Logging from Android Smartphone and its Influence on the Positioning Accuracy

ION GNSS+ 2021

Session B4b: Applications of GNSS Measurements from Smartphones

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Outline

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- Embedded Sensor aiding
- GNSS/IMU Logger
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Smartphone GNSS Positioning

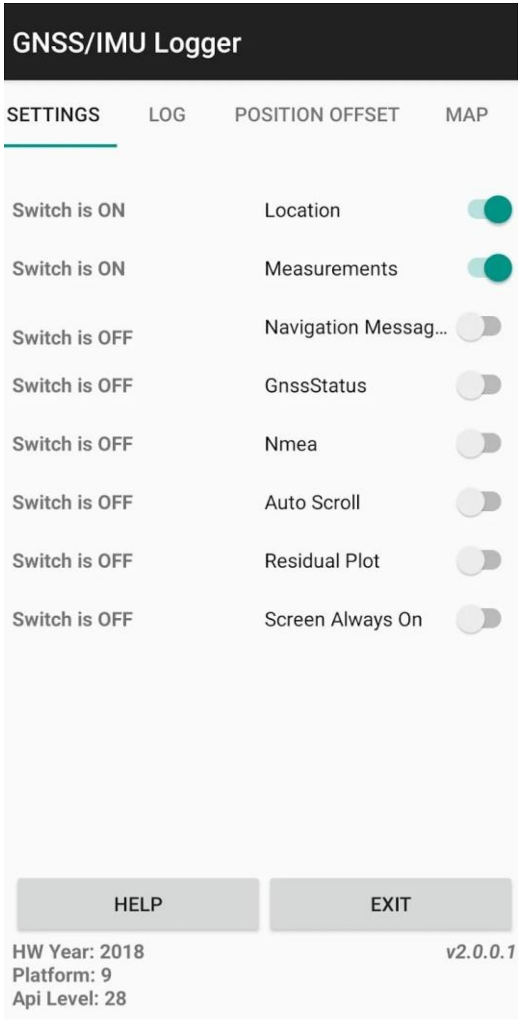
- Despite the latest innovation in Smartphone GNSS carrier phase positioning, there are still key limiting factors which need to be addressed before full scale use of Smartphones in high precision applications.
- The existing GNSS algorithms can only provide float solutions with the GNSS measurements from the Smartphone [1] – [6].
- To enhance the position accuracy, it needs an external aiding from additional sensor.

Embedded Sensor Aiding

A Word about GNSS/INS Logger...

https://play.google.com/store/apps/details?id=com.ista.android.apps.location.gps.gnsslogger

GNSS/IMU Logger



- GNSS/IMU Logger (latest version 2.0.1)
- Log RINEX file
  - GPS/GALILEO/BEIDOU
  - Support Dual Frequeny
- Log GPS Time-Synchronized IMU Data
  - Accelerometer
  - Gyroscope
- Provided real - time Code Minus Carrier (CMC) plot to monitor tracking capabilities
- Provides real - time clock offset between SystemClock and GnssClock

Time Synchronization Approach and Implementation

Basic Approach – Time Synchronization

GNSS/IMU Logger

Rinex Logger
Uses GNSSClock for timestamp

Sensor Logger
Uses SystemClock for timestamp

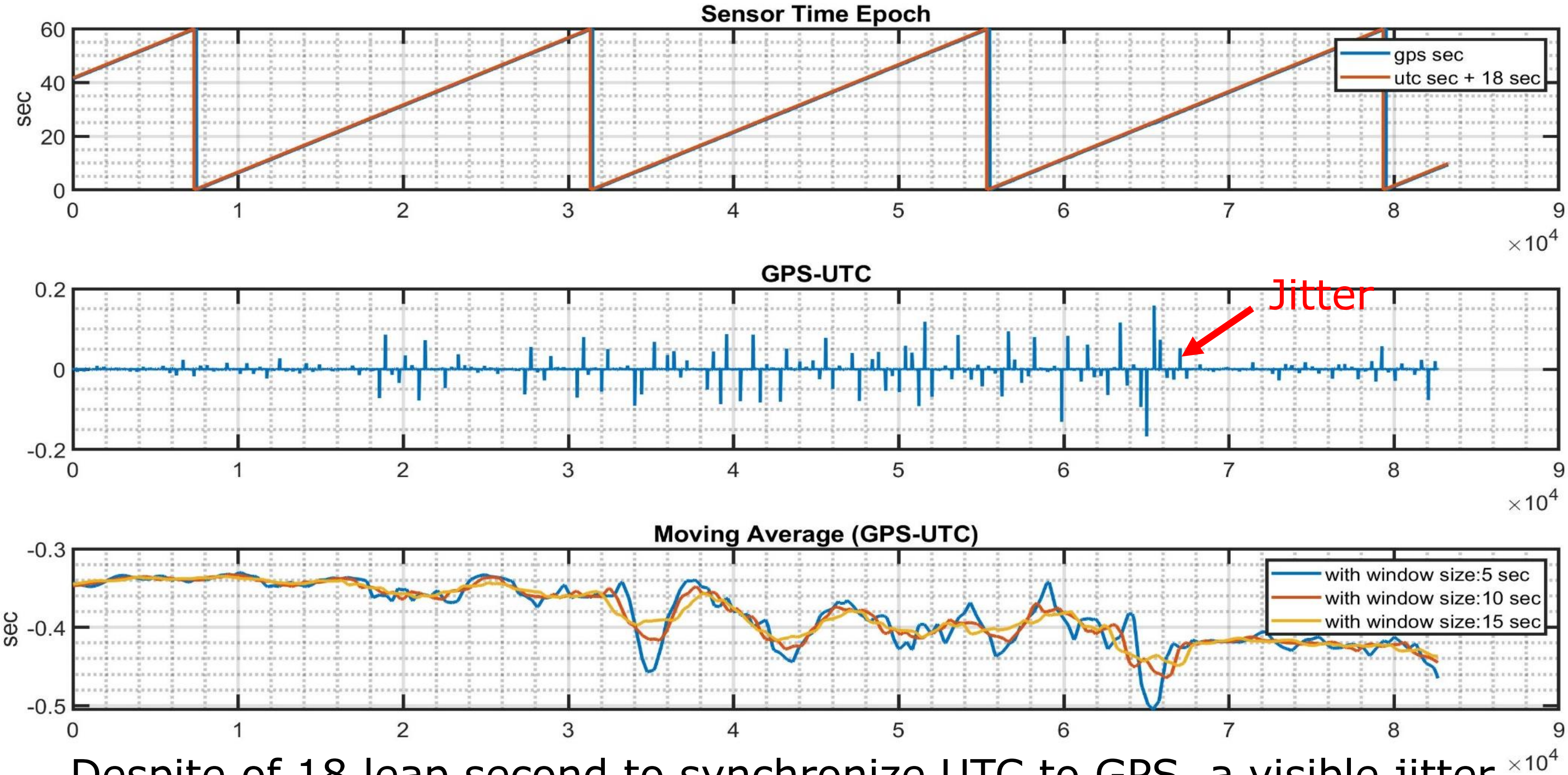
Calculate Clock offset and adjust SystemClock counter in Sensor Logger

Goal is to synchronize SystemClock to GPS Time. Currently, the SystemClock is synchronized to UTC via Network/Wi-Fi.

Need for Time Synchronization - I

- The GNSS measurements from the smartphone are ‘GnssClock’ driven, and GPS time tagged. Whereas the ‘SystemClock’ is used to timestamp the IMU measurement.
- Although, the ‘SystemClock’ get synchronized to the UTC time via network provider, one can often encounters a small timing error between the sampling instances of the GNSS and IMU measurements.
- System time is affected by users, broadcast, and network, so the time may jump backward or forward unpredictably.
- The impact of data timing errors in integrated navigation systems may cause a bias in the forward acceleration during the transfer alignment of a strap-down INS.

Need for Time Synchronization - II



Despite of 18 leap second to synchronize UTC to GPS, a visible jitter can be seen in the second plot. To damp this jitter from GPS-UTC, a moving average filter with window size 30 sec was implementedSmartphone : Xiaomi MI8

SystemClock

elapsedRealtimeNanos

Added in API level 17

```
public static long elapsedRealtimeNanos ()
```

Returns nanoseconds since boot, including time spent in sleep.

Returns	
`long`	elapsed nanoseconds since boot.

https://developer.android.com/reference/android/os/SystemClock#elapsedRealtimeNanos()

GnssClock

getElapsedRealtimeNanos

Added in API level 29

```
public long getElapsedRealtimeNanos ()
```

Returns the elapsed real-time of this clock since system boot, in nanoseconds.

The value is only available if `hasElapsedRealtimeNanos()` is `true`.

Returns	
`long`	

https://developer.android.com/reference/android/location/GnssClock#getElapsedRealtimeNanos()

GnssClock

GnssLog Format - RAW sentence (Cont')

Google

Field name	Description
AccumulatedDeltaRangeState	GnssMeasurement#getAccumulatedDeltaRangeState()
AccumulatedDeltaRangeMeters	GnssMeasurement#getAccumulatedDeltaRangeMeters()
AccumulatedDeltaRangeUncertaintyMeters	GnssMeasurement#getAccumulatedDeltaRangeUncertaintyMeters()
CarrierFrequencyHz	GnssMeasurement#getCarrierFrequencyHz()
CarrierCycles	GnssMeasurement#getCarrierPhase() Deprecated in API level 28 (Android P in 2018)
CarrierPhase	GnssMeasurement#getCarrierPhase() Deprecated in API level 28 (Android P in 2018)
CarrierPhaseUncertainty	GnssMeasurement#getCarrierPhaseUncertainty() Deprecated in API level 28 (Android P in 2018)
MultipathIndicator	GnssMeasurement#getMultipathIndicator()
SnrInDb	GnssMeasurement#getSnrInDb()

Carrier phase

Inter-Signal Biases

Chipset timestamp in Android time scale (used to sync IMU measurement)

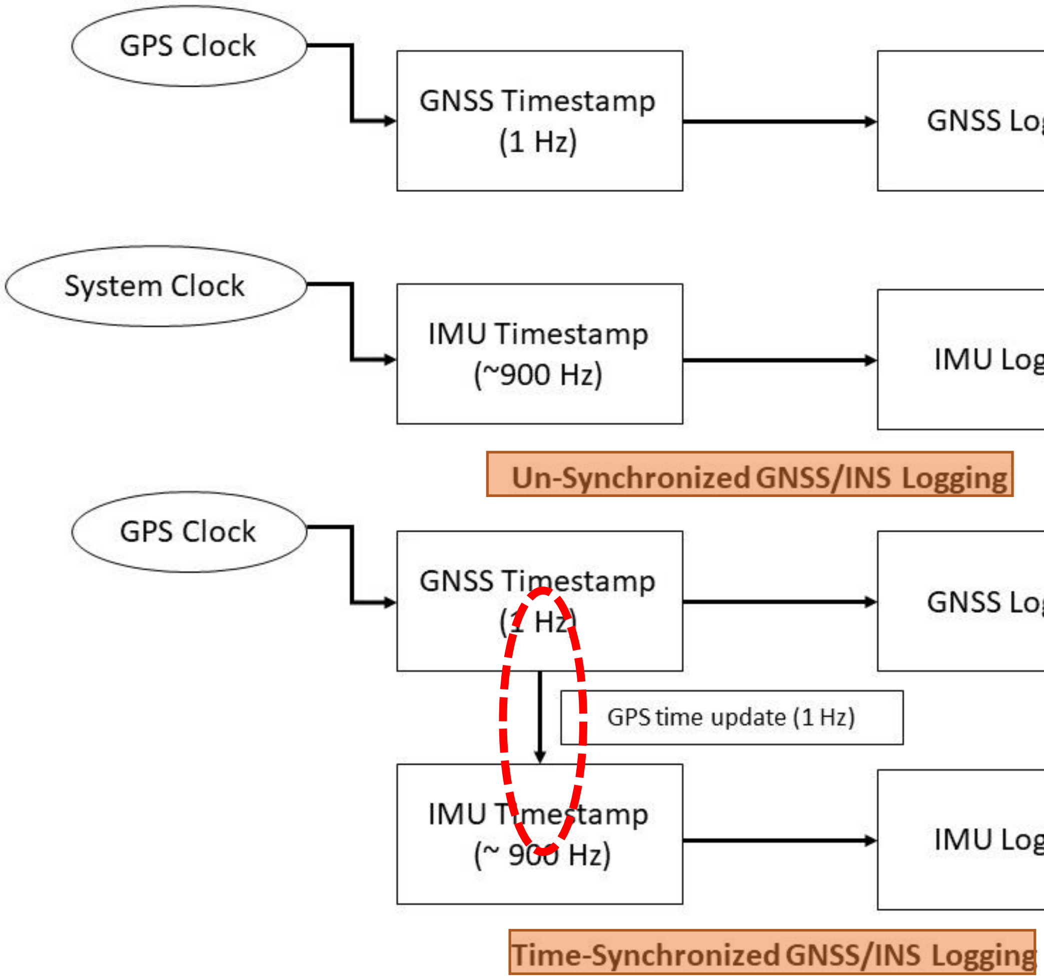
Field name	Description
ConstellationType	GnssMeasurement#getConstellationType()
AgcDb	GnssMeasurement#getAutomaticGainControlLevelDb()
BasebandCnoDbHz	GnssMeasurement#getBasebandCnoDbHz() Added in API level 30 (Android 11 in 2020)
FullInterSignalBiasNanos	GnssMeasurement#getFullInterSignalBiasNanos() Added in API level 30 (Android 11 in 2020)
FullInterSignalBiasUncertaintyNanos	GnssMeasurement#getFullInterSignalBiasUncertaintyNanos() Added in API level 30 (Android 11 in 2020)
SatelliteInterSignalBiasNanos	GnssMeasurement#getSatelliteInterSignalBiasNanos() Added in API level 30 (Android 11 in 2020)
SatelliteInterSignalBiasUncertaintyNanos	GnssMeasurement#getSatelliteInterSignalBiasUncertaintyNanos() Added in API level 30 (Android 11 in 2020)
CodeType	GnssMeasurement#getCodeType() Added in API level 29 (Android 10 in 2019)
ChipsetElapsedRealtimeNanos	GnssClock#getElapsedRealtimeNanos() Added in API level 29 (Android 10 in 2019)

19 More details: [5][6]

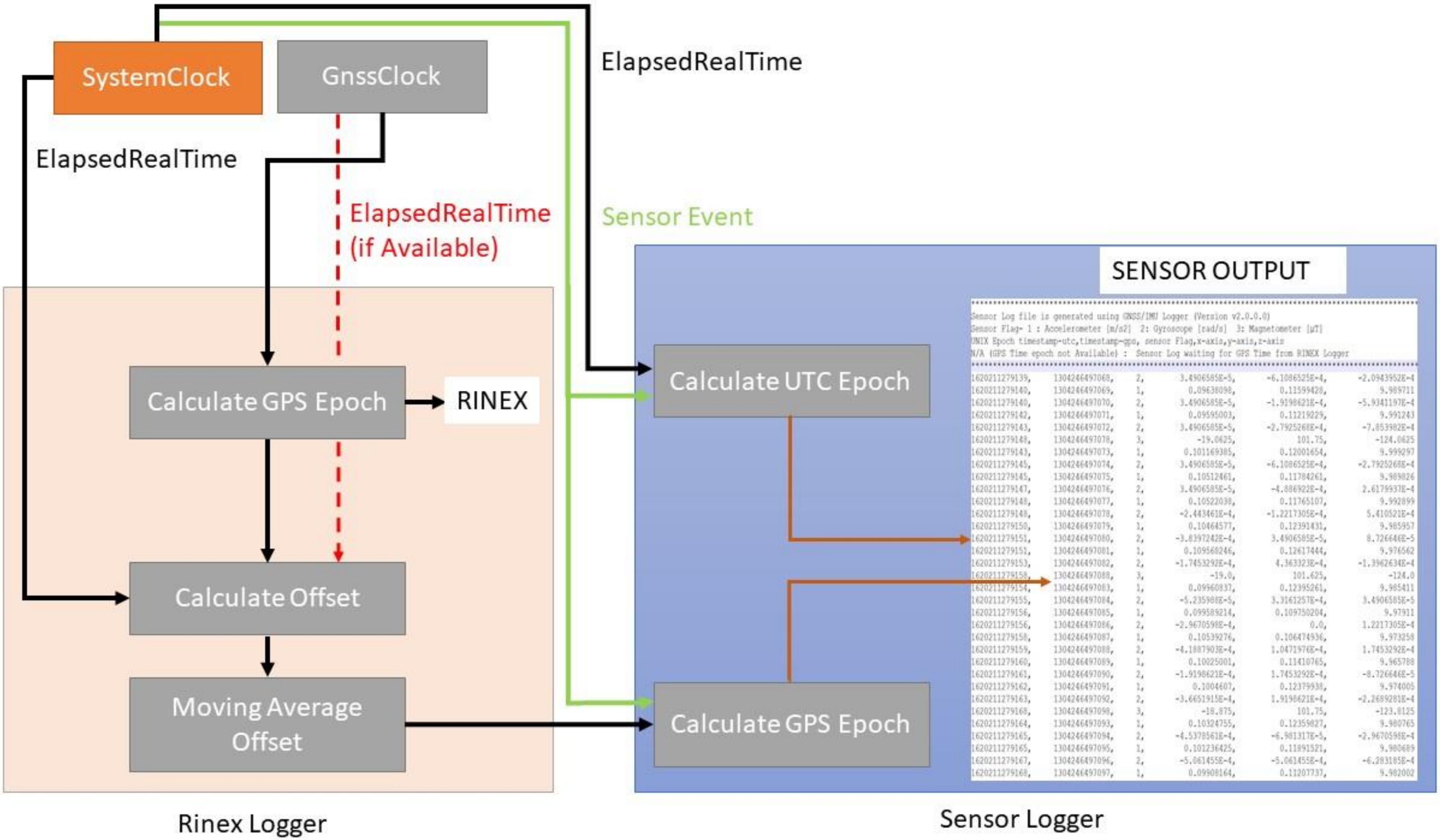
Google at ION GNSS+ Virtual 2020

https://developer.android.com/reference/android/location/GnssClock#getElapsedRealtimeNanos()

Un-Synchronized vs Synchronized GNSS/INS Logging



Implementation



Measurement setup and Analysis

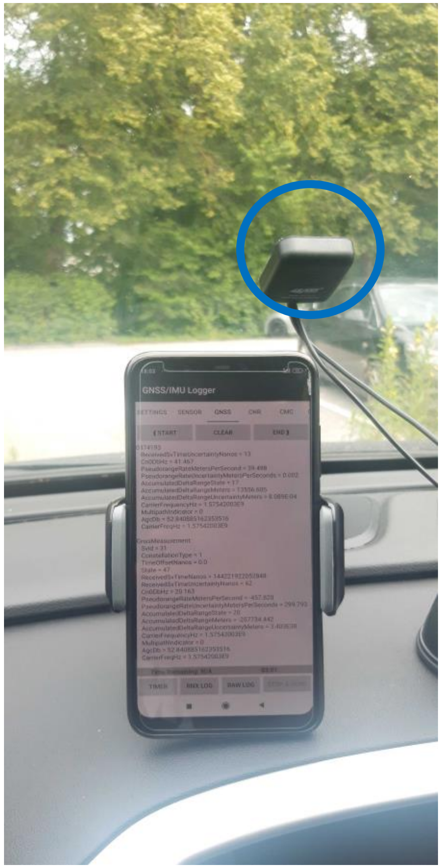
Setup - I

- Smartphone Xiaomi MI8
  - Inside the car with Amplifier (GPS L1)
- Configuration
  - RTK/INS Processing with Novatel Inertial Explorer

Receiving antenna

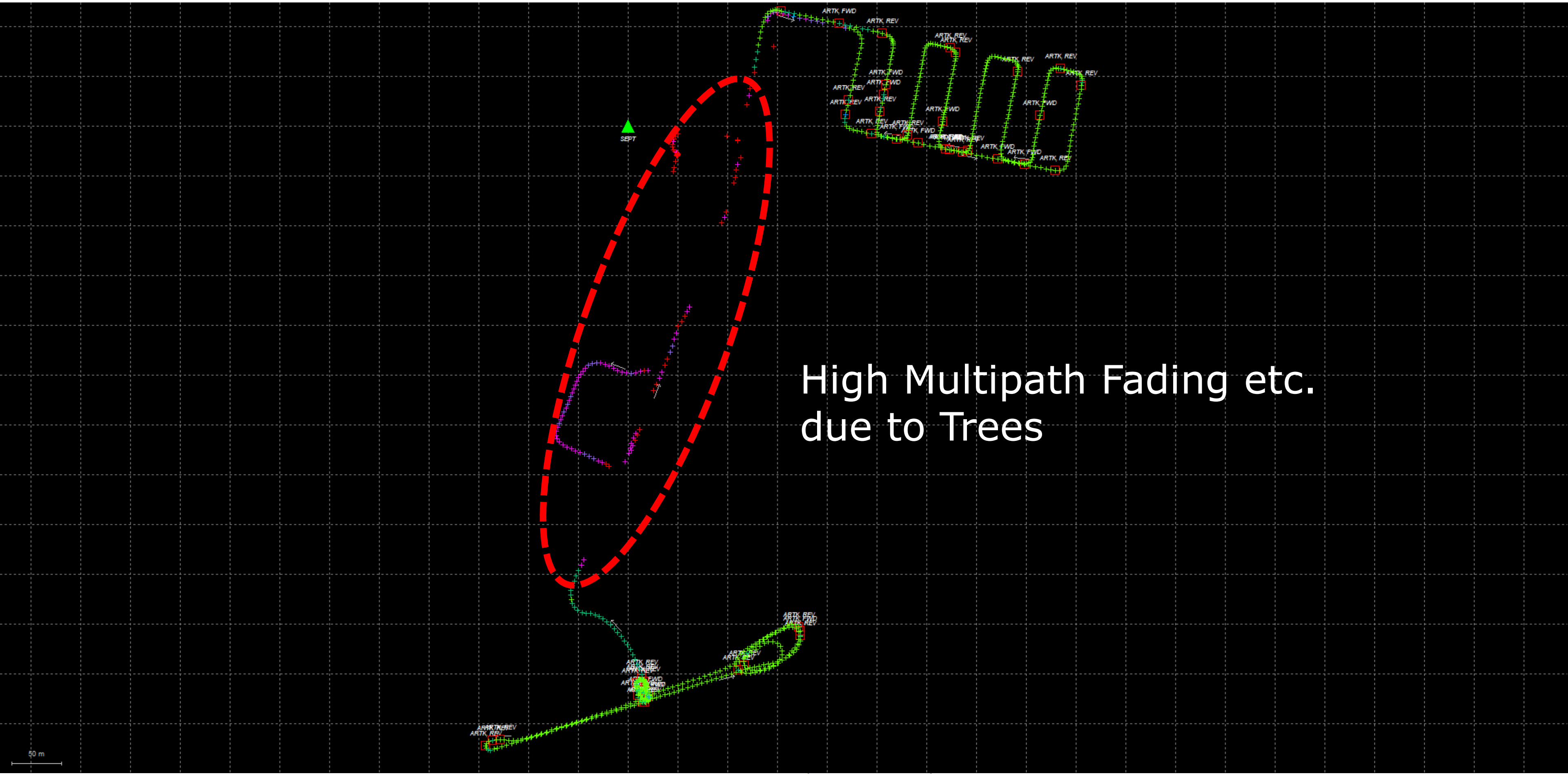
Roof Top

Retransmit antenna



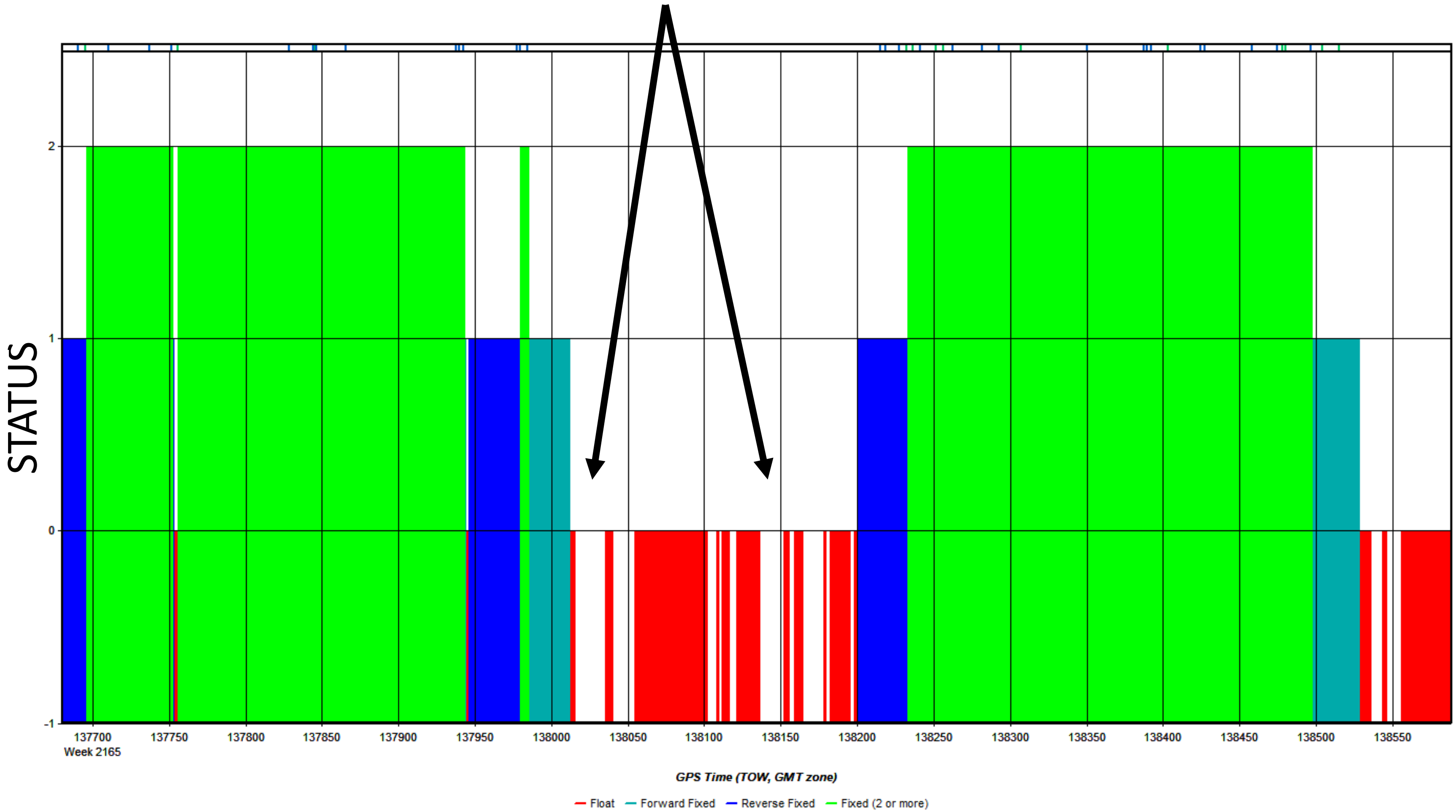
Inside Car

RTK only - Trajectory



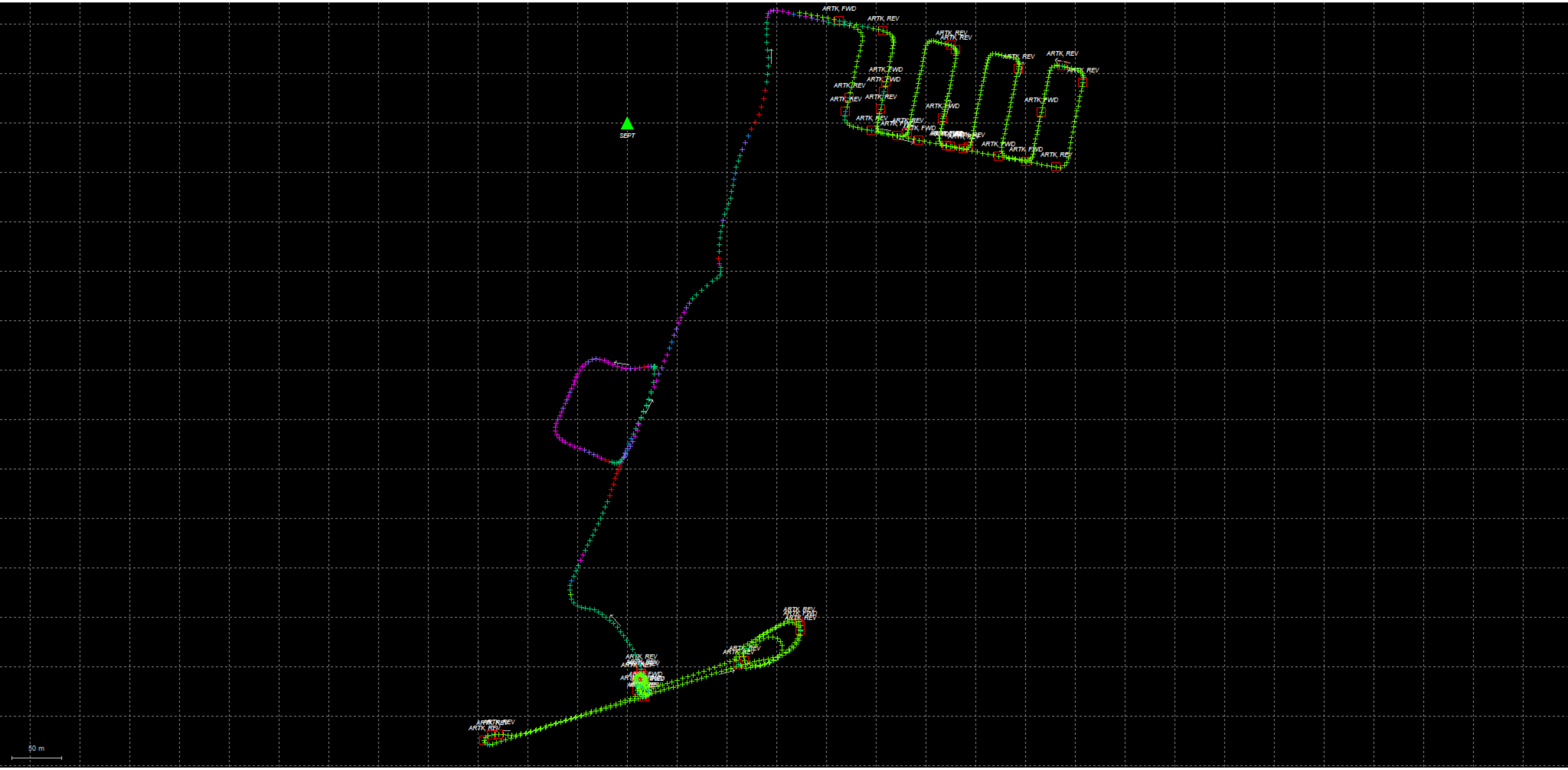
RTK only – Ambiguity Status

Data gap due to no GNSS caused by trees

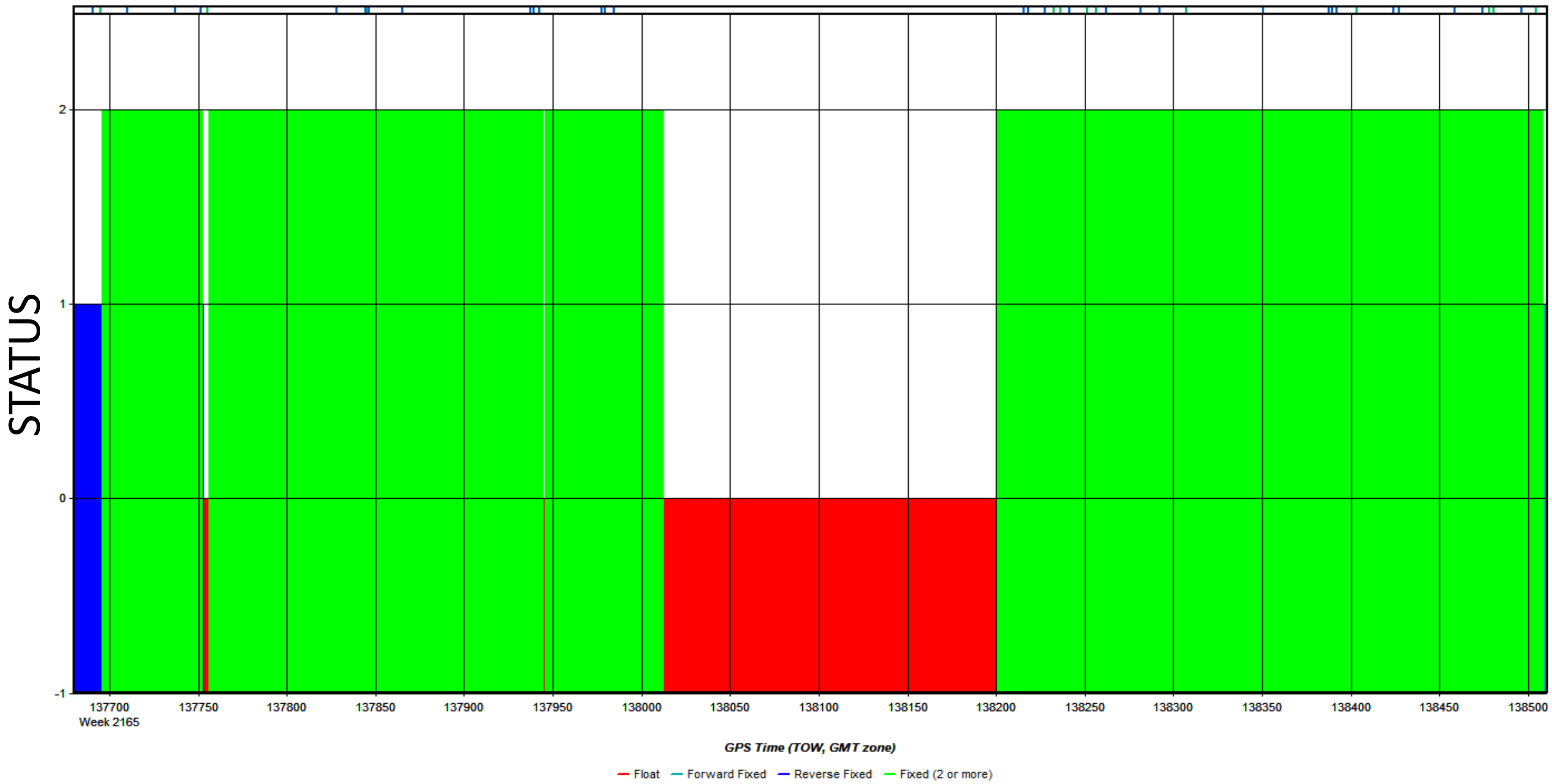


Float Forward Fixed Reverse Fixed Fixed

RTK/INS (Loosely Coupled) – Trajectory



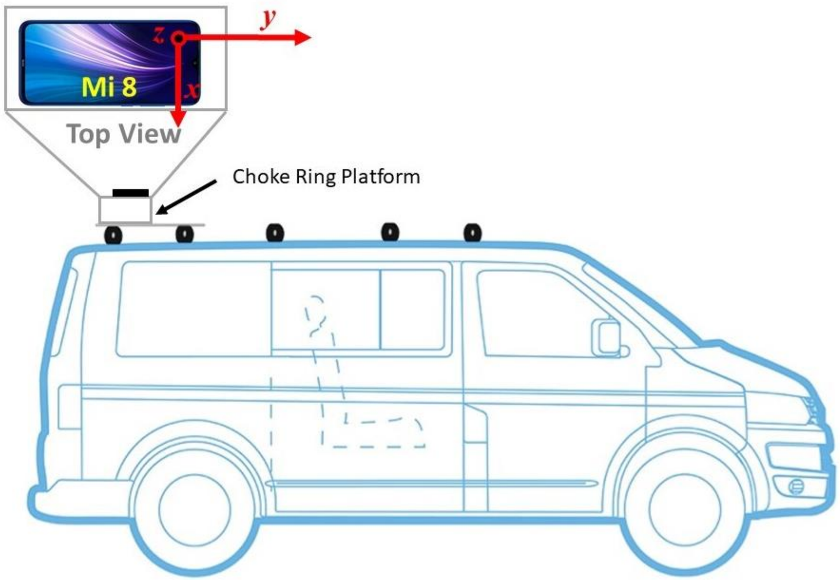
RTK/INS (Loosely Coupled) – Ambiguity Status



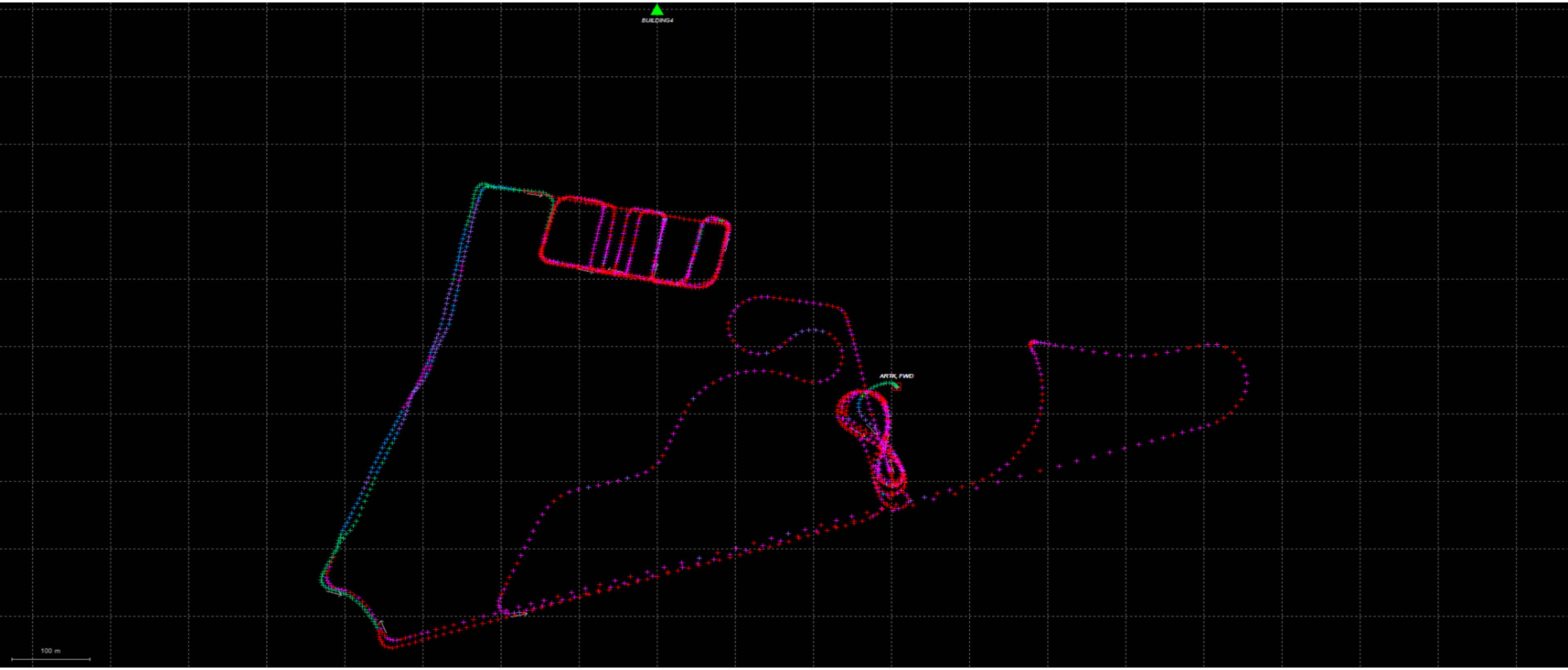
Float Forward Fixed Reverse Fixed Fixed

Setup - II

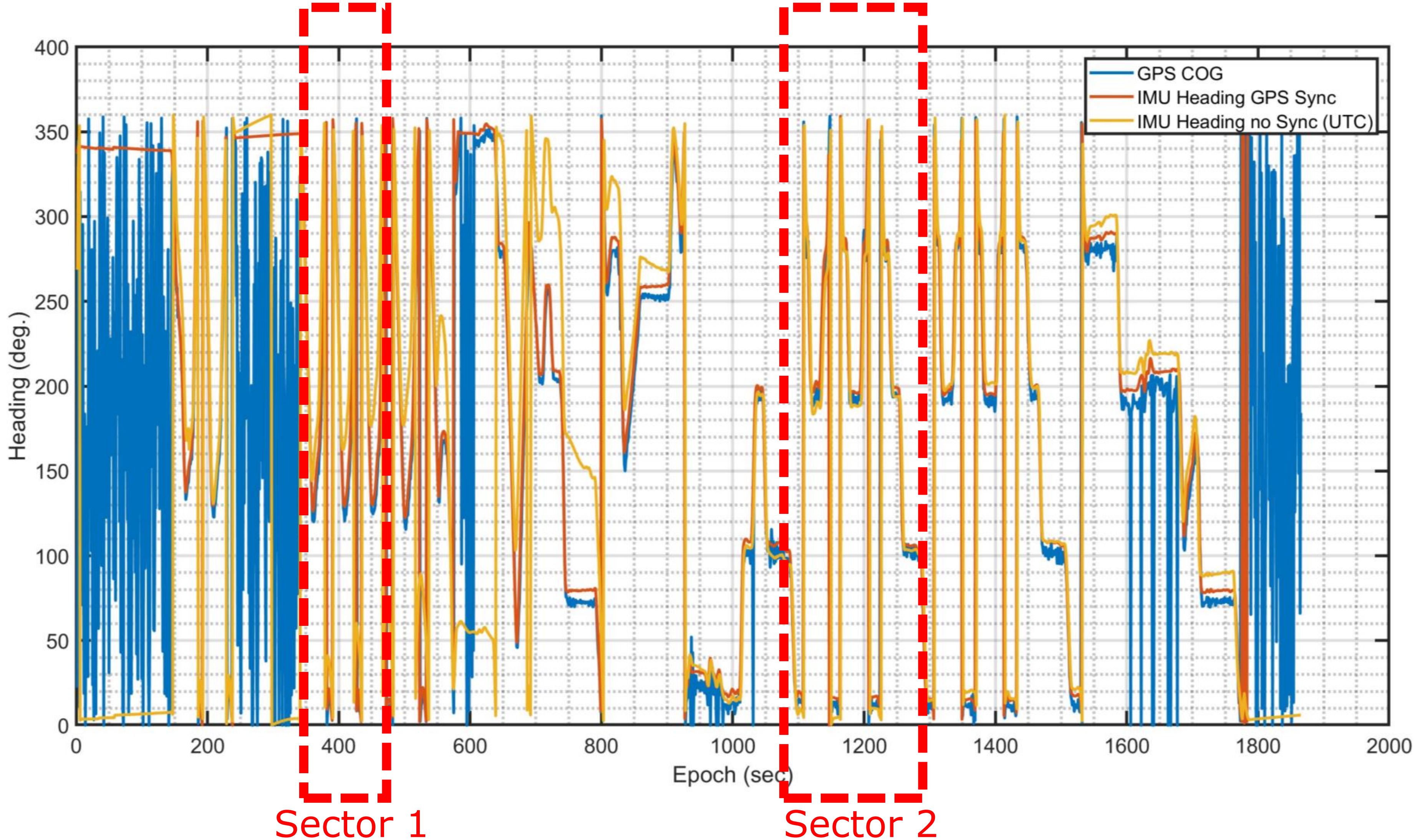
- Smartphone Xiaomi MI8
  - Roof Top with Choke Ring
- Configuration
  - RTK/INS Processing with Novatel Inertial Explorer
  - No Lever-arm correction applied (needed)
  - Smartphones was horizontally placed



RTK/INS - Trajectory

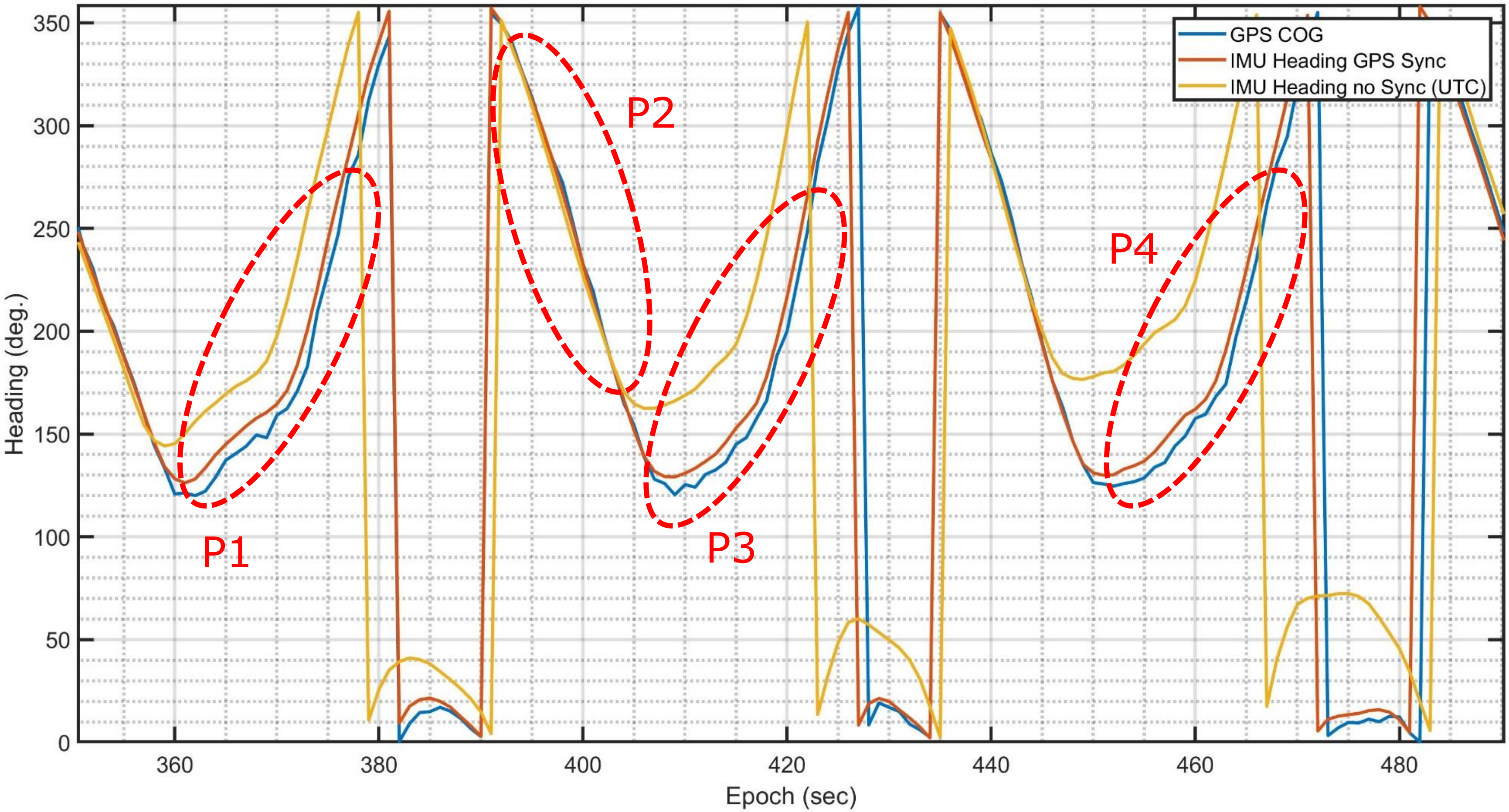


IMU Heading



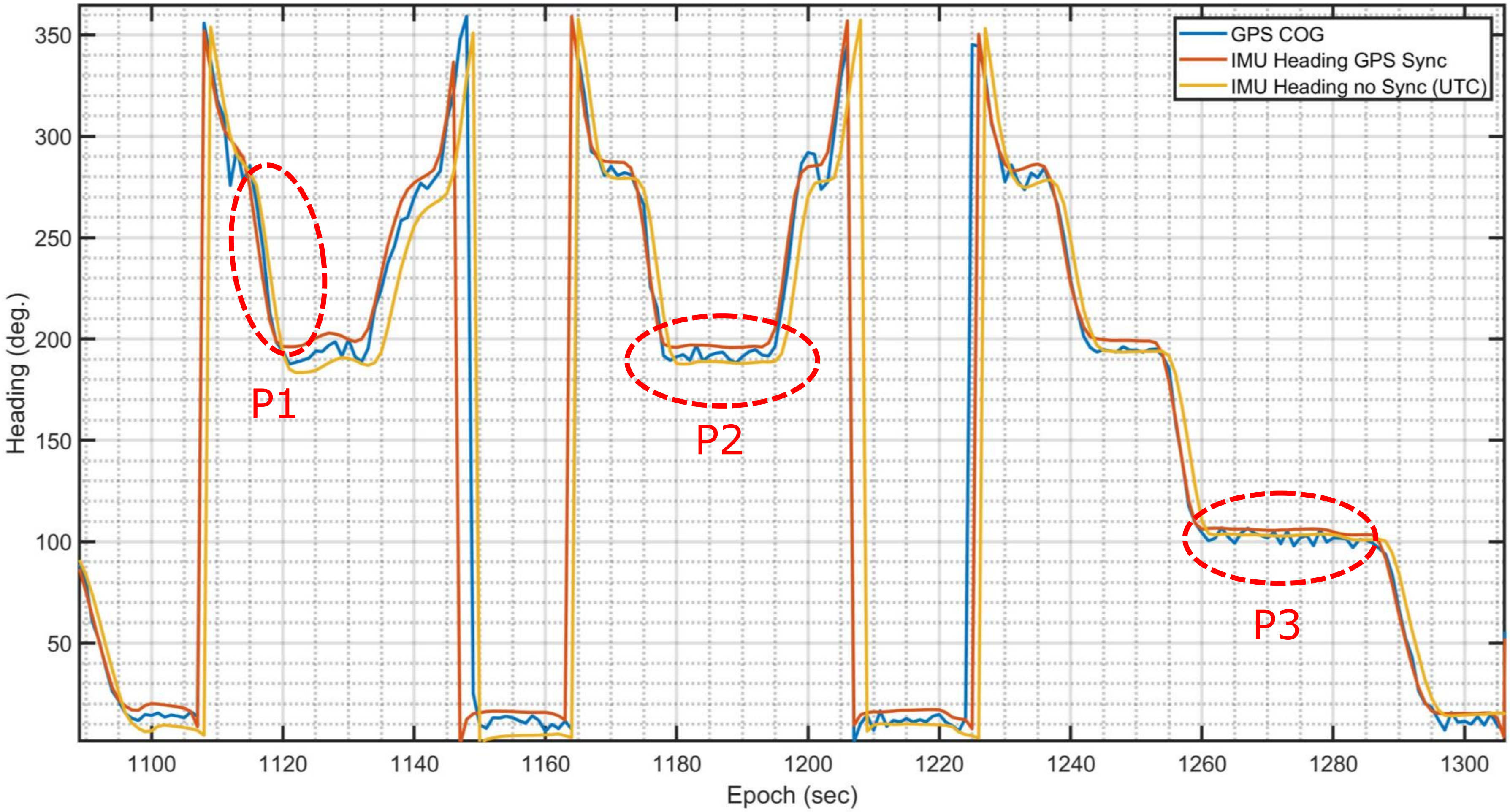
GPS COG
IMU Heading GPS Sync
IMU Heading no Sync (UTC)
Heading (deg.)
Epoch (sec)
0
50
100
150
200
250
300
350
400
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Sector 1
Sector 2

Sector 1



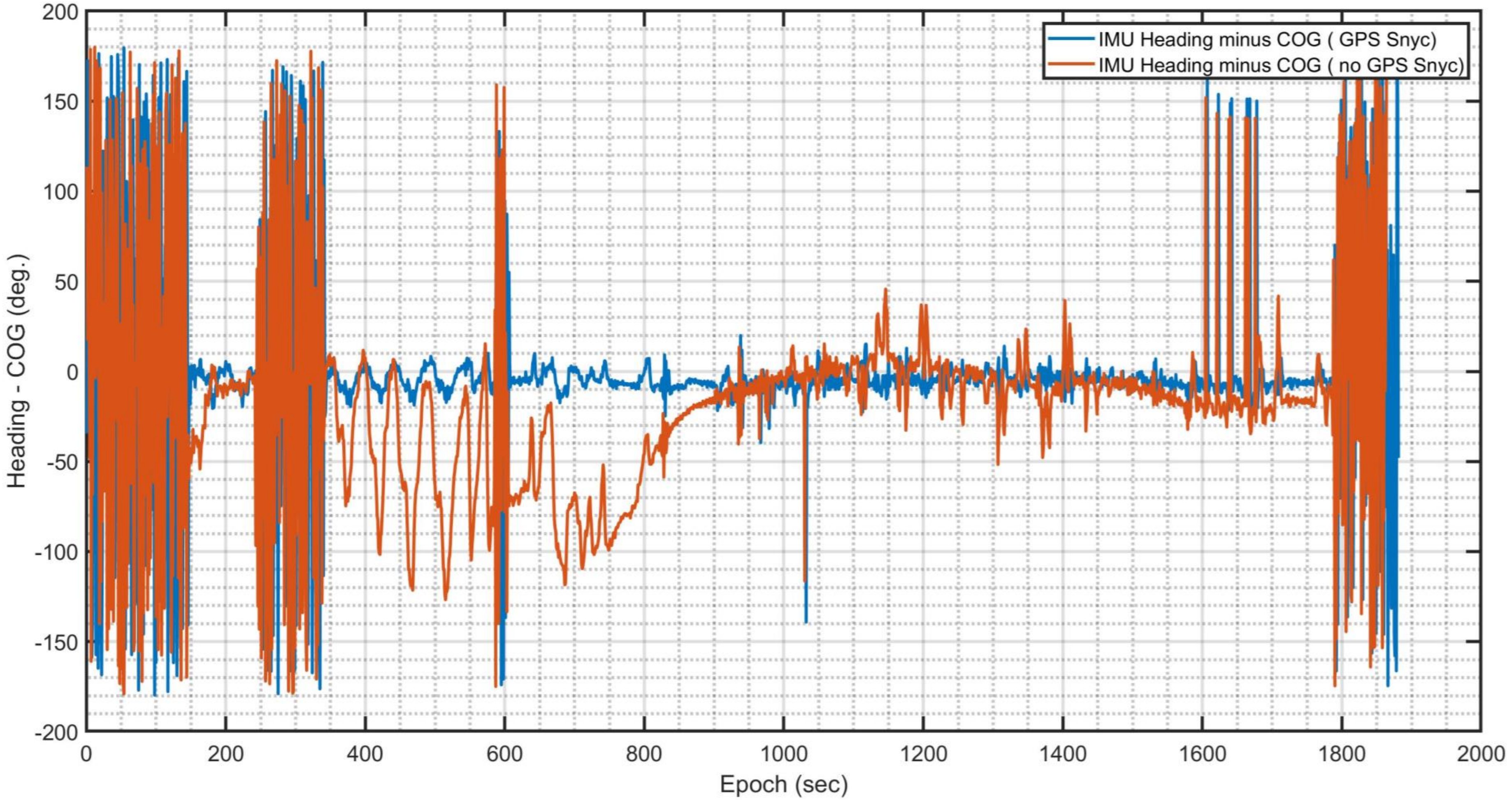
GPS COG
IMU Heading GPS Sync
IMU Heading no Sync (UTC)
P1
P2
P3
P4
Heading (deg.)
Epoch (sec)
0
50
100
150
200
250
300
350
360
380
400
420
440
460
480

Sector 2



GPS COG
IMU Heading GPS Sync
IMU Heading no Sync (UTC)
Heading (deg.)
Epoch (sec)
350
300
250
200
150
100
50
1100
1120
1140
1160
1180
1200
1220
1240
1260
1280
1300
P1
P2
P3

IMU heading minus COG



Conclusion

- IMU data logged with Smartphone is good enough to be processed with GNSS Measurements
- With good quality GNSS measurement, the IMU data can enhance the Ambiguity fixing
- GnssClock.ElapsedRealTimeNano is not available before Android API 29
    - GnssClock is more precise but can be implemented in with Latest Android Version Only
    - Additionally, Not all the Smartphone with Android API > 29 provide this value
        - Xiaomi MI8 does not provide the value (API 29)
        - Huawei Mate20X does provide the value (API 29)
- GPS time Synchronized IMU data provide more precise Heading as compared to non synchronized IMU data.

References

[1] Sharma H, Schütz A, Pany T.(2018) Preliminary Analysis of the RTK Positioning using Android GNSS Raw Measurements and Application Feasibility for the Trajectory Mapping using UAV's” Proceedings of the 31st International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GNSS + 2018), Miami, Florida September 2018 , pp.432-444.

[2] Sharma H, Schütz A, Pany T. (2018), Qualitative Analysis of Smartphone GNSS Raw Measurements and Effect of Duty Cycling on the RTK Positioning”, NAVITEC 2018, Netherlands

[3] Sharma H, Schütz A, Pany, T.(2019) Emulating the Smartphone GNSS receiver to Understand and Analyse the Anomalies in RTK Positioning using GNSS Raw Measurements Proceedings of the 2019 International technical Meeting of the Institute of navigation, Reston, Virginia, January 2019, pp.577-582

[4] Sharma H, Bochkati M, Pany T.(2019) Influence of the Multipath Mitigation on Precise Positioning with Smartphone Raw GNSS Measurements Proceedings of the ISGNSS 2019, Jeju, South Korea

[5] Sharma H, Bochkati M, Pany T. (2019) Researchers Achieve 1-2cm level Accuracy with Commercial Smartphone Inside GNSS, 2019

[6] Darugna F, Wübbena J B, Wübbena G, Schmitz M, Schön S, Warneke A (2021) Impact of robot antenna calibration on dual-frequency Smartphone-based high-accuracy positioning: a case study using the Huawei Mate20X. GPS Solutions 25, 15

Thank You for Listening !

For question, please write me at Himanshu.sharma@unibw.de