STARS
SATELLITE TECHNOLOGY
FOR ADVANCED
RAILWAY SIGNALLING

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GSA, Prague

STARS
WP4 – Data Post-processing

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European Global Navigation Satellite Systems Agency

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Agenda:

- Scope and structure
- Main objectives of WP4
- Railway environment characterization
- Conclusion

Scope

To use collected data, selected methods and wide range of SW tools (partly existing, partly developed) for:

- Processing of collected raw data
- Building up Reference data set
- Data analysis for detection of local effects disturbing GNSS SIS
- Railway environment characterization

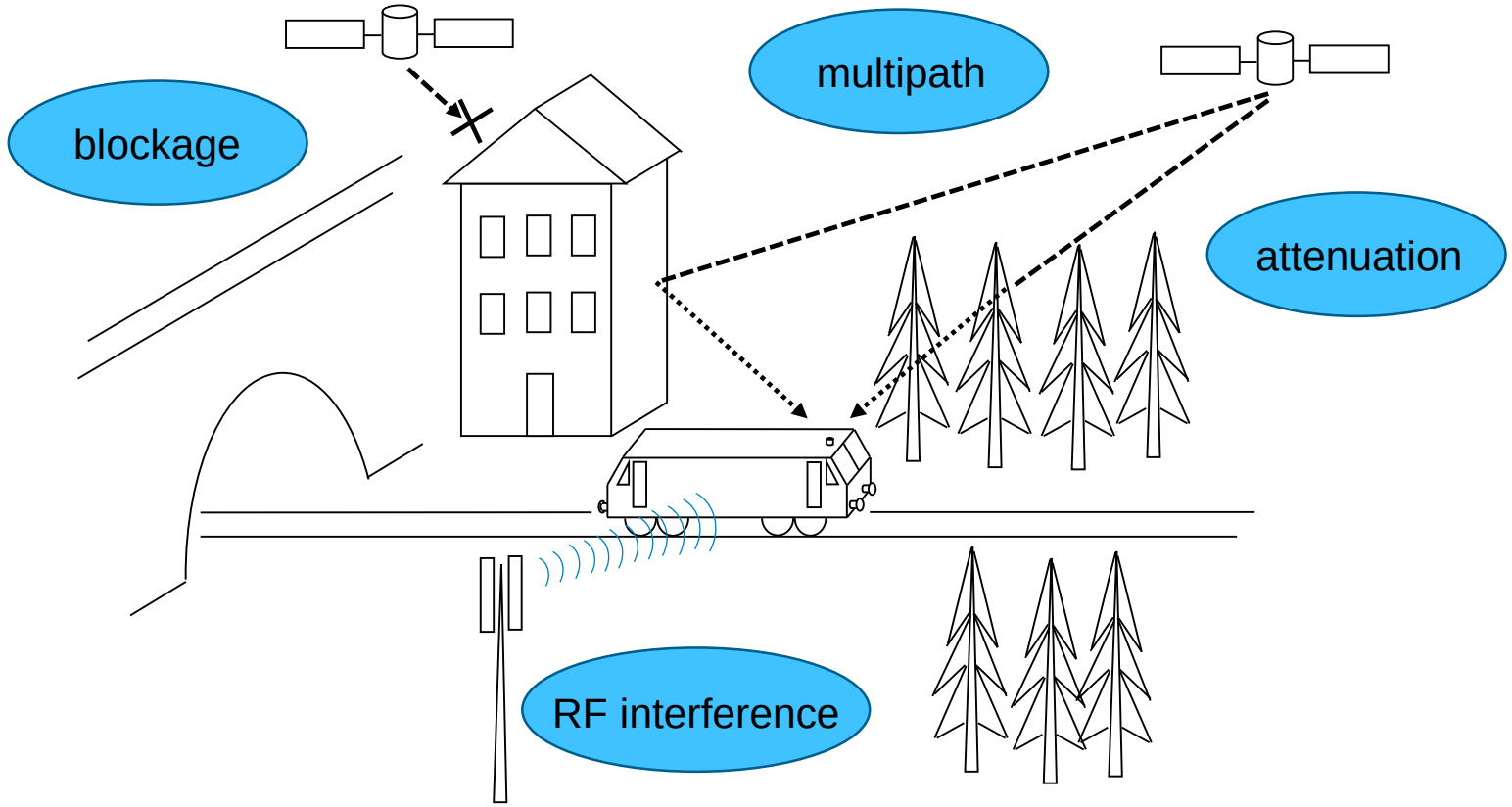
Structure

- Task 4.1: Selection and provision of tools and methods for data analysis
- Task 4.2: Post-processing and analysis of field data
- Task 4.3: Railway environment characterization

Main objectives

- Railway environment characterization

  The reason is: High impact of local effects on GNSS SIS



Main objectives

- SW tools and methods for data processing and analysis
- Processing of raw data from measurement campaigns
- Reference data set
- Analyses focused on detection of local negative phenomena
- Railway environment characterization

SW tools and methods for data processing and analysis

Survey and selection of suitable SW tools and methods for:

- Clearing, splitting, merging, checking and conversion of data obtained in WP3, e.g. raw data from GNSS receivers, data from RF signal recording instruments
- PVT calculation for different modes of solution, different constellations and signals
- Reference position calculation based on Ground Truth position, i.e. GNSS independent position by different odometry systems and track axis database
- Detection of negative local phenomena (multipath, RF interference, sky visibility mask) on measured data set

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Processing of raw data from measurement campaigns

Main goal of raw data processing: preparation of inputs for further analysis

- Manipulation of GNSS receivers' raw data
- Manipulation of Ground Truth data
- Calculation of Ground Truth reference position of GNSS antenna on a train
- PVT calculation of GNSS antenna position for different modes of solution (code phase standalone, EGNOS), different constellations (GPS, Galileo) and signals (L1,E1,L5,E5)
- PVT calculation of GNSS antenna position based on RTK solution (GPS, Glonass, L1,L2)
- Conversion of RF I/Q samples from RPSs into open format

Note: Software used for PVT calculation: PPSDK(Septentrio), RTKLIB(T.Takasu), SPRING(ESA, TAS-F)

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Reference data set

Measured raw data from WP3

Reference data set

- Receivers' raw data
- GT based reference position of GNSS antenna
- PVT data
- RF spectrum and I/Q samples
- GNSS supporting data
- Pictures of track surrounding from measurements

Google Cloud repository

Data manipulation and calculations based on methods and tools selected in WP4:

- Calculation of GT based reference position of GNSS antenna on a train
- Splitting, checking, conversion etc. of raw GNSS data, RF data
- PVT calculations
- Video data processing
- Processing of GNSS supporting data (IGS and EDAS)

Note: Reference data set is subject of D4.2

Main objectives

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Analyses focused on detection of local negative phenomena

To detect reliably local negative phenomena => various methods from different domains selected and used:

- Comparison in position domain (GPS L1 standalone, EGNOS, GT and GNSS RTK references)
- Receiver raw data analyses (pseudoranges, AGC, C/N_0, CMC, SSE etc.)
- RF data analyses (various correlators, RF I/Q sample histogram, PSD)
- Sky visibility mask evaluation (panoramic camera figures)
- GNSS availability analysis from perspective of different constellations

Methods indicate generally irregularities in GNSS performance or indicate local phenomenon

Software scripts developed in Matlab, Octave, Python or Excel

Analyses outputs

Common data outputs in ASCII format:

- GPS time
- Evaluation Symptom
- Analyzed Parameter Value

} mandatory parameters

- optional parameters

Analyzed parameter value (APV)

- analog value, calculated or evaluated parameter in analysis
- not provided by some methods (e.g. evaluation of multipath by receiver)

Evaluation symptom (ES)

- scalar value, indicates impact strength of local effect on GNSS performance
- resulting from comparison of APV and threshold(s) or directly from GNSS receiver
- input for railway environment characterization

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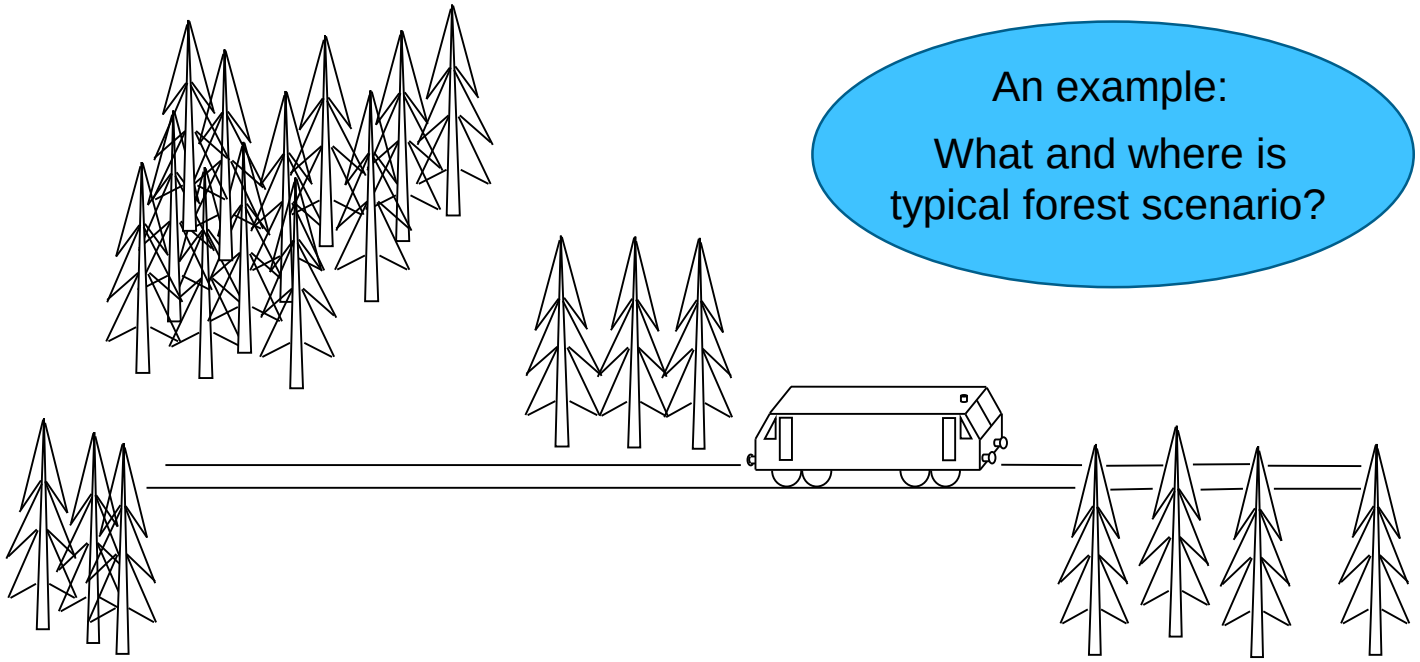
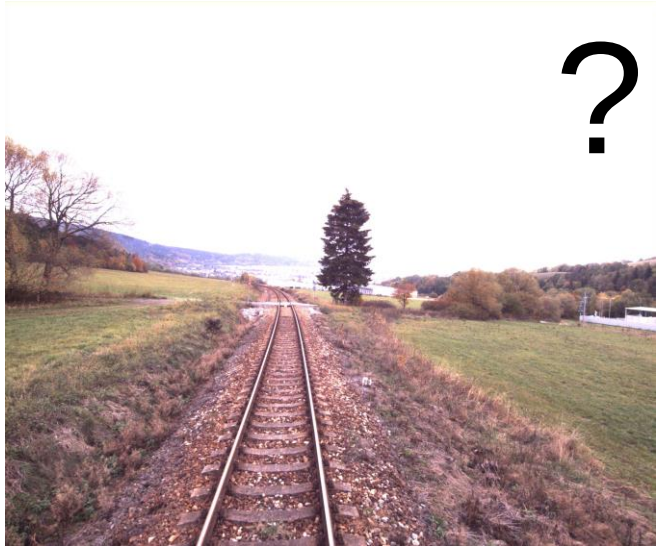
Railway environment characterization

How to characterize inhomogeneous environment?

No way to simply distinguish typical scenarios of railway environment
(due to changing relative position of obstacle and satellites, surface reflectivity, attenuation, different obstacle size and distance from a track,…)





Railway environment characterization

Three parameters introduced for characterization of environment along a track:

- MultiPath Level (MPL)
- RF Interference Level (RIL)
- Sky Visibility Factor (SVF)

Outputs of different analyses (methods) contribute to one or more parameters:

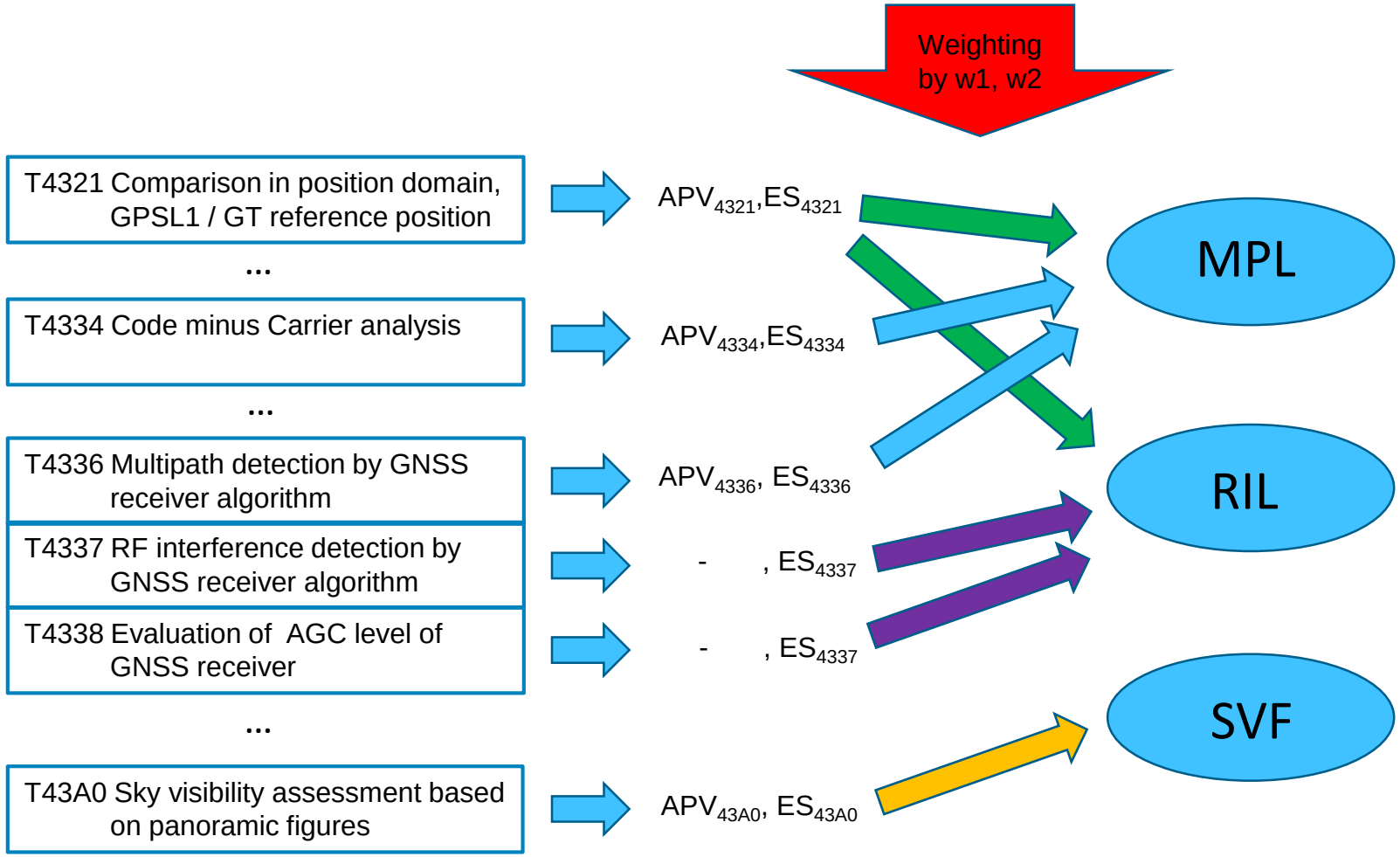
$$MPL(t) = \frac{w1_{4331} \cdot w2_{4331} \cdot ES_{4331}(t) + w1_{4332} \cdot w2_{4332} \cdot ES_{4332}(t) + \ldots + w1_{43xy} \cdot w2_{43xy} \cdot ES_{43xy}(t)}{n(t)}$$

$$RIL(t) = \frac{w1_{4333} \cdot w2_{4333} \cdot ES_{4333}(t) + w1_{4337} \cdot w2_{4337} \cdot ES_{4337}(t) + \ldots + w1_{43wz} \cdot w2_{43wz} \cdot ES_{43wz}(t)}{n(t)}$$

$$SVF(t) = \frac{area\ of\ clear\ sky\ view\ (t)}{area\ of\ whole\ figure\ (t)}$$

Weighting of method outputs according to method efficiency and output magnitudes.

Railway environment characterization



Railway environment characterization, analysis and evaluation

Measurements in railway environment typical to all three test tracks analyzed

- ASTS, Sardinia - clear sky view, a railway station in countryside, vicinity of a military airport
- AZD, South Bohemia - forest
- SIE, Switzerland - mountains, a city railway station

MPL, RIL and SVF values compared and evaluated with respect of HNSE

HNSE calculated for GPS L1 standalone and EGNOS position solutions by SPRING, RTKLIB, PP-SDK

MPL and RIL calculated and analyzed for GPS L1,L5 and Galileo E1,E5a signals

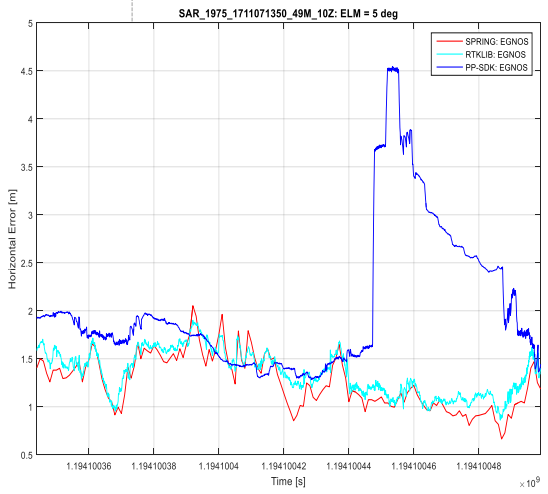
Other parameters (train speed, SV number, DOP) analyzed and evaluated for better understanding values of MPL, RIL and SVF, also vizualization of estimated position and Ground Truth position employed

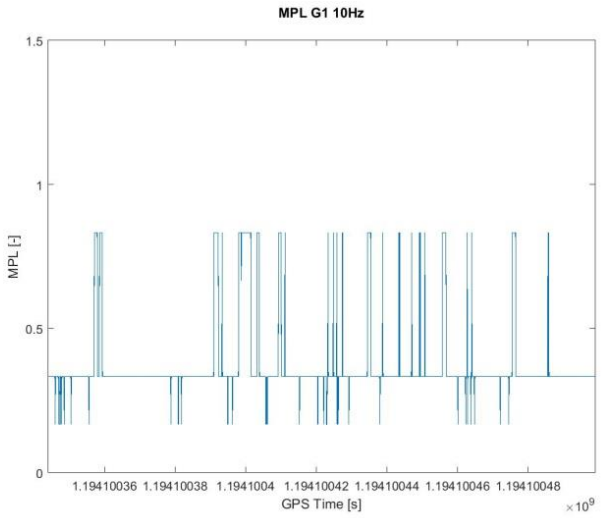
STARS WP4

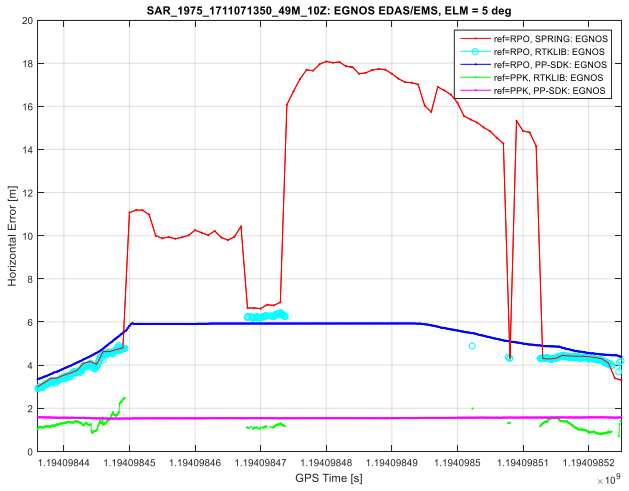
Railway environment characterization analysis and evaluation

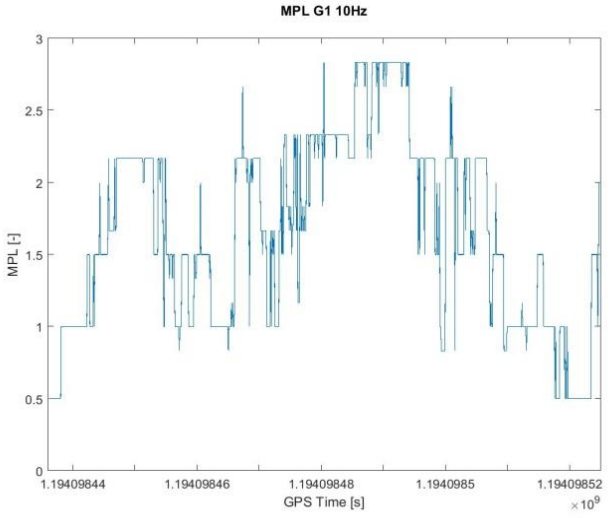
- Clear sky view
  (ASTS, Sardinia test track)

- A station in countryside
  (ASTS, Sardinia test track)



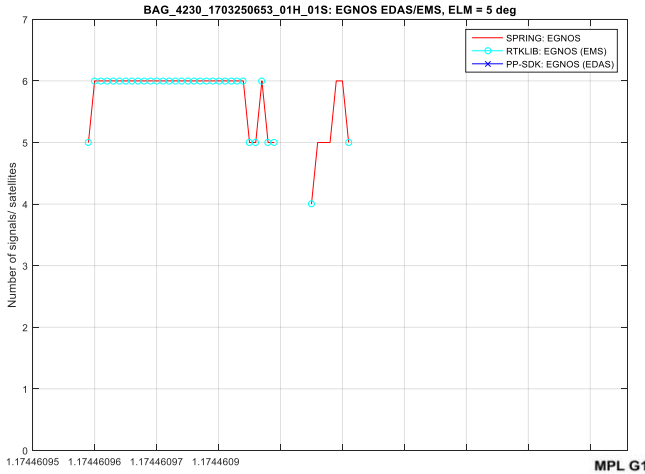


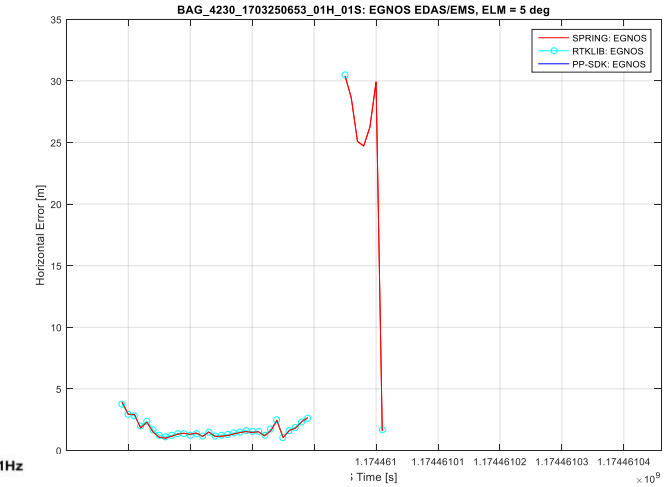


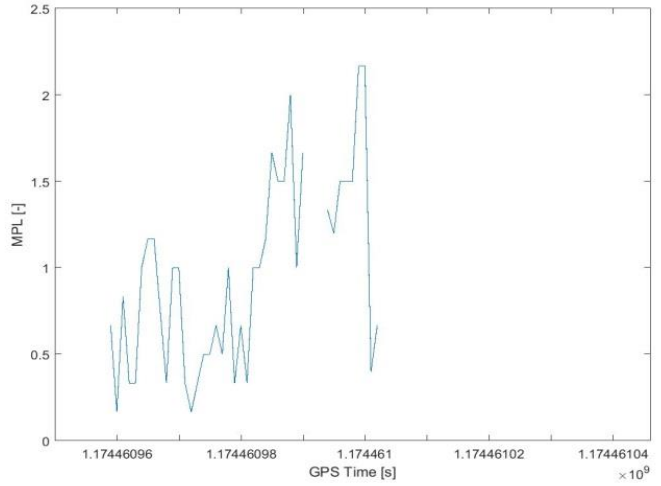


Railway environment characterization, analysis and evaluation

- Mountains
  (SIE, Switzerland test track)

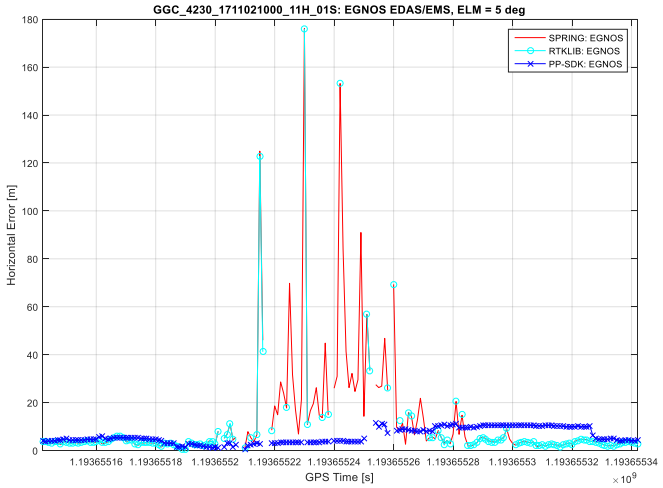


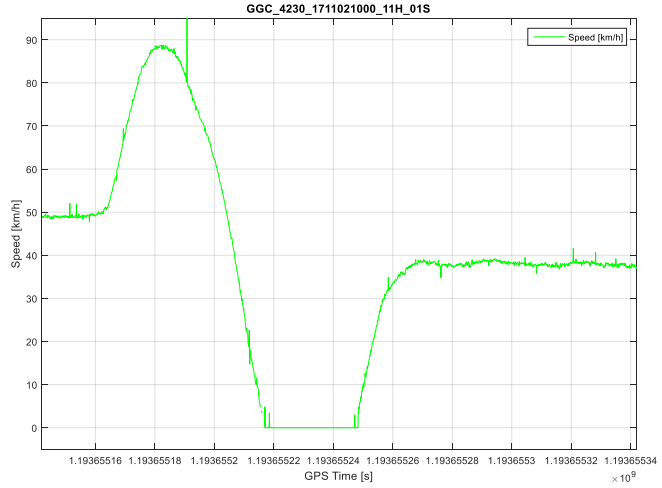


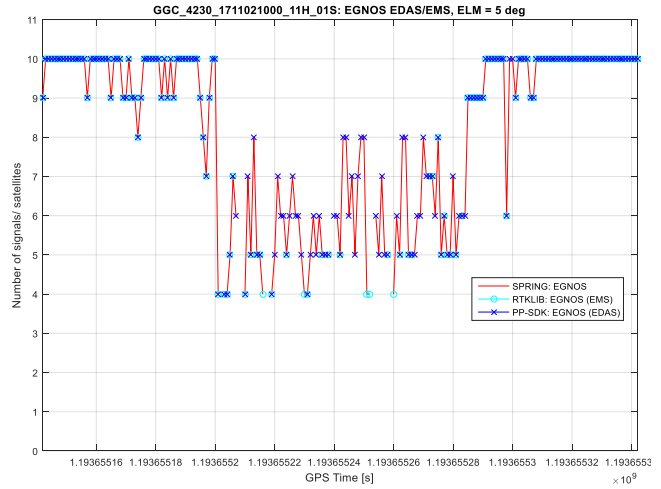


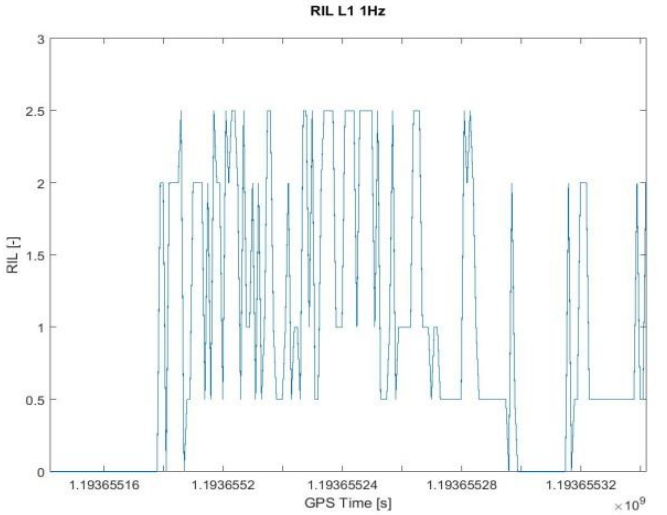
Railway environment characterization, analysis and evaluation

- Acceleration from a station (SIE, Switzerland test track)



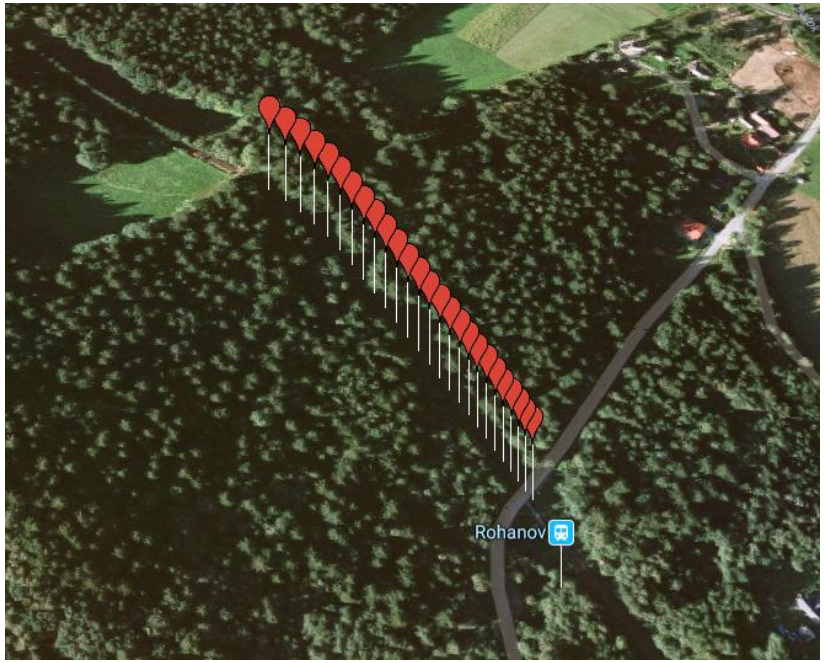


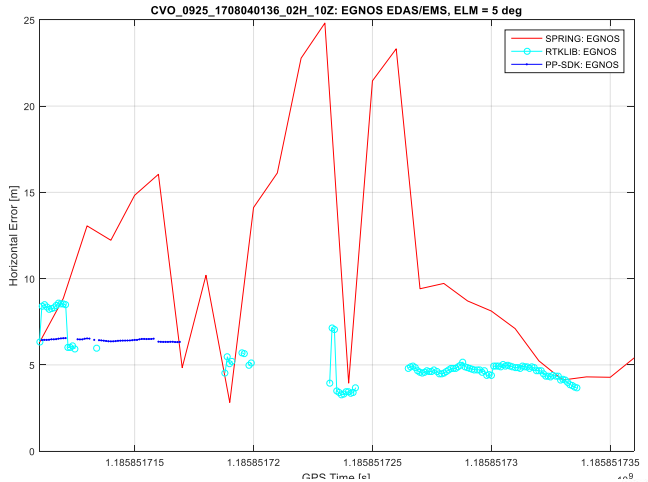


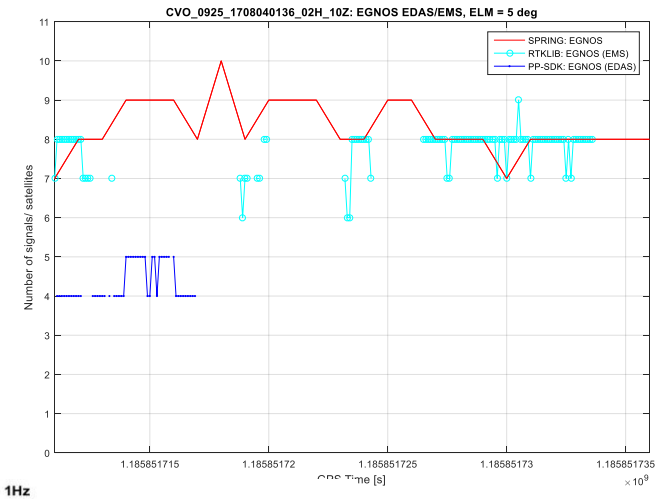


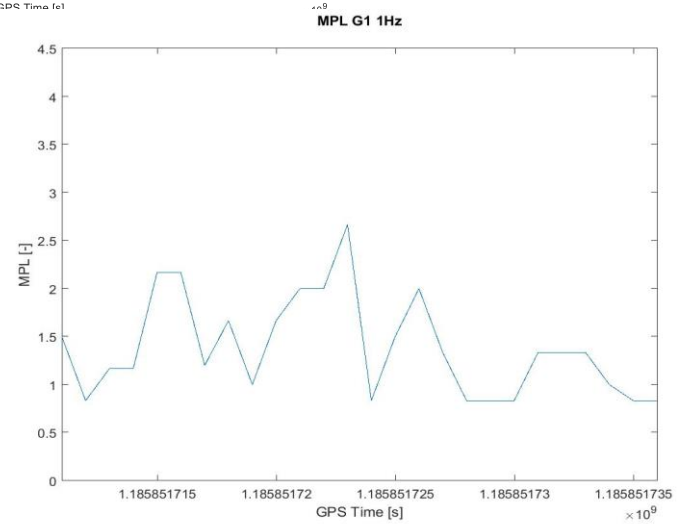
Railway environment characterization, analysis and evaluation

- Forest, normal case
  (AZD, South Bohemia test track)



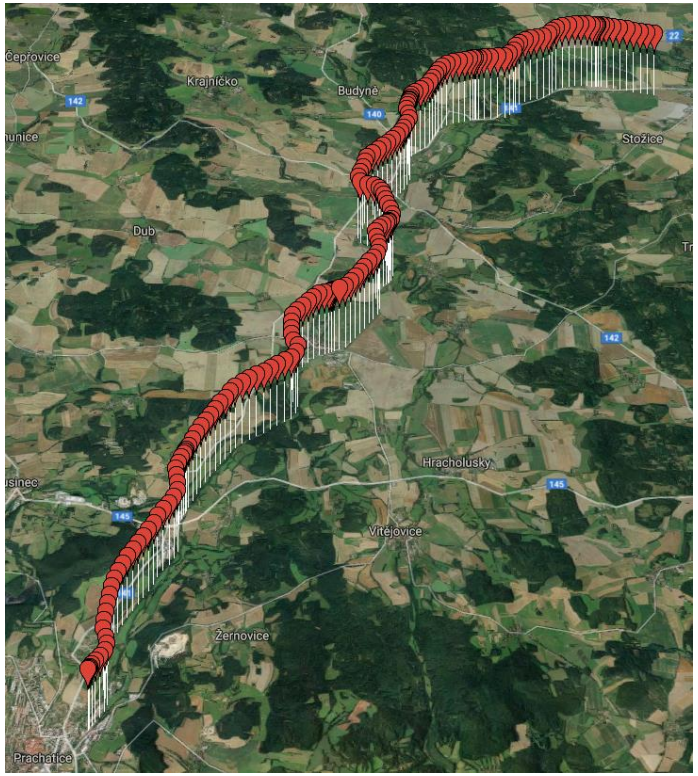


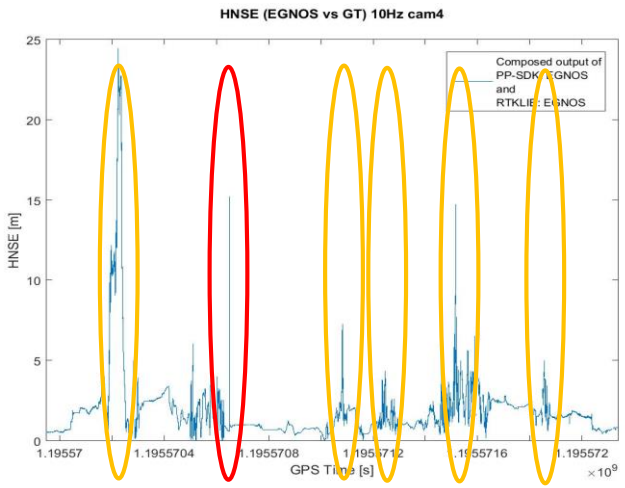


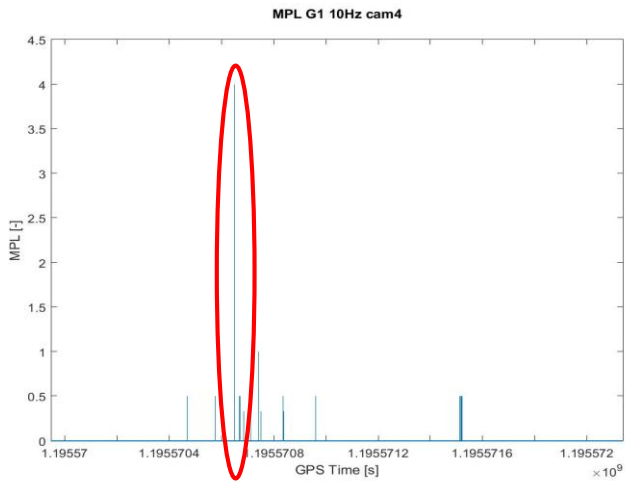


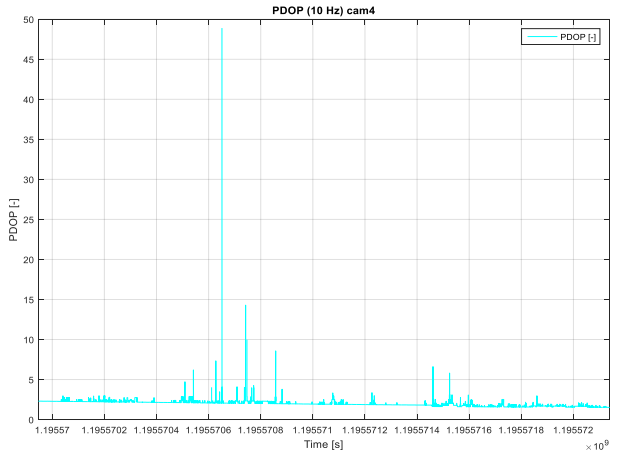
Railway environment characterization, analysis and evaluation

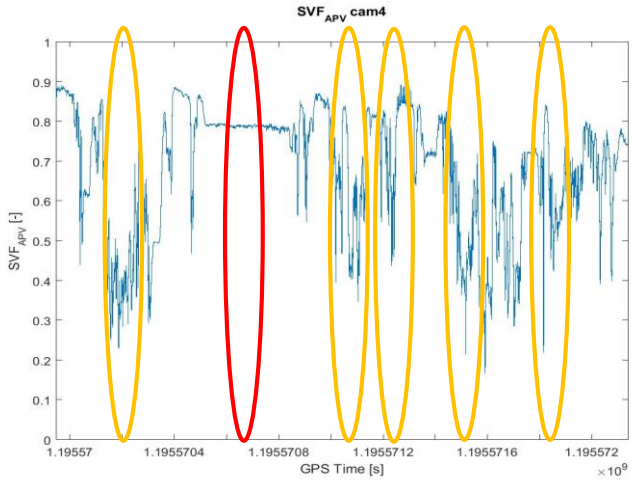
- Camera measurement (AZD, South Bohemia test track)











Conclusion

- Strong correlation between MPL, RIL, SVF and HNSE => characterization approach and developed methodology can be considered correct
- Higher multipath level detected in a forest and in railway stations (mainly during train standstill) => multipath can be detected and excluded by the techniques used in characterization process, other techniques (dynamic model), measures (suitable area for GNSS use), on board sensors (standstill detection)
- RF interference caused by on board source observed => RF domain techniques proposed in characterization process should be implemented, careful installation design of RF components on a train is required, strong outside the train interferers will require measures or on board sensor support according to effect duration
- Sky visibility is crucial factor for sufficient GNSS performance => GNSS deployment under specified conditions (MOPS for railway), on board sensor support if necessary

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Thank you!

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