ETH
Eidgenössische Technische Hochschule Zürich
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Assessment of high-rate GPS using a single-axis shake table

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Introduction

Project:

→ Study the applicability of high-rate GNSS for seismology

Kinematic GPS L1/L2 measurements (100Hz) with static antenna

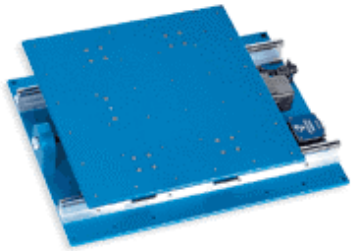
Zero-baseline and very short baseline (~5m)

→ Correlations and noise level

Kinematic GPS L1/L2 measurements (100Hz) with 1D shake table

Very short baseline (~5m)

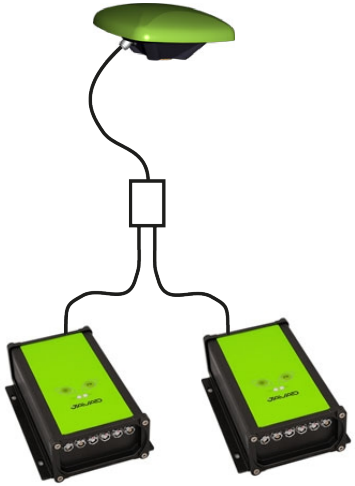
→ Dynamic characteristics of the GPS receiver



Kinematic GPS Measurements with 100Hz

Zero-Baseline

- Carrier phase noise
- Internal receiver errors



Kinematic RMS:

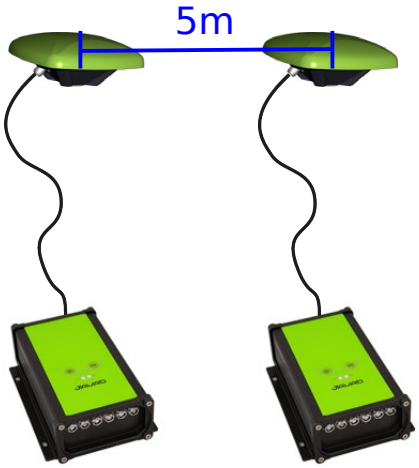
East = 0.4 [mm]

North = 0.6 [mm]

Up = 0.9 [mm]

5m Baseline

- Multipath
- Different antenna characteristics



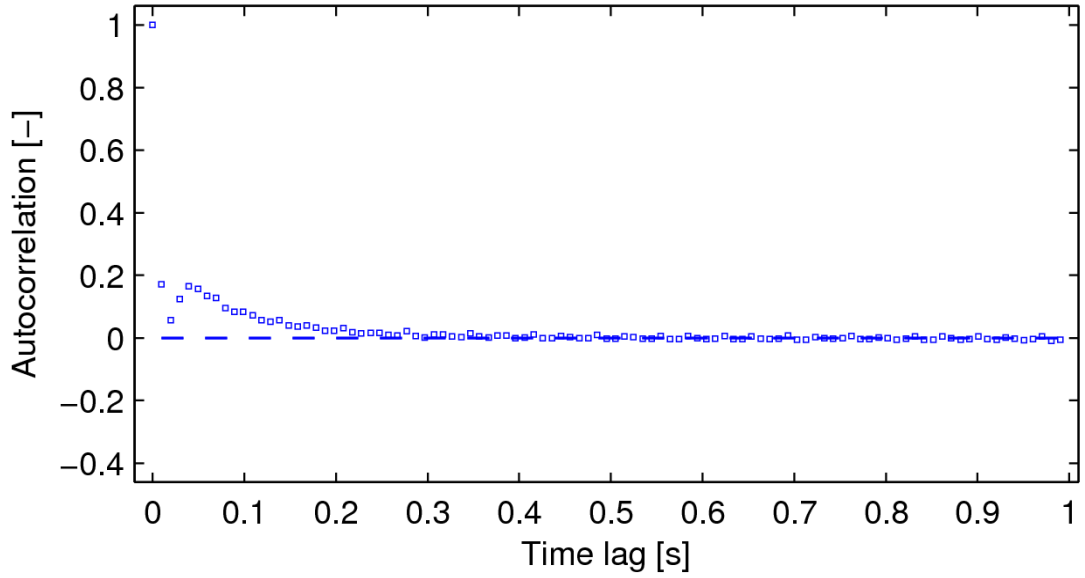
Kinematic RMS:

East = 2.4 [mm]

North = 3.2 [mm]

Up = 5.9 [mm]

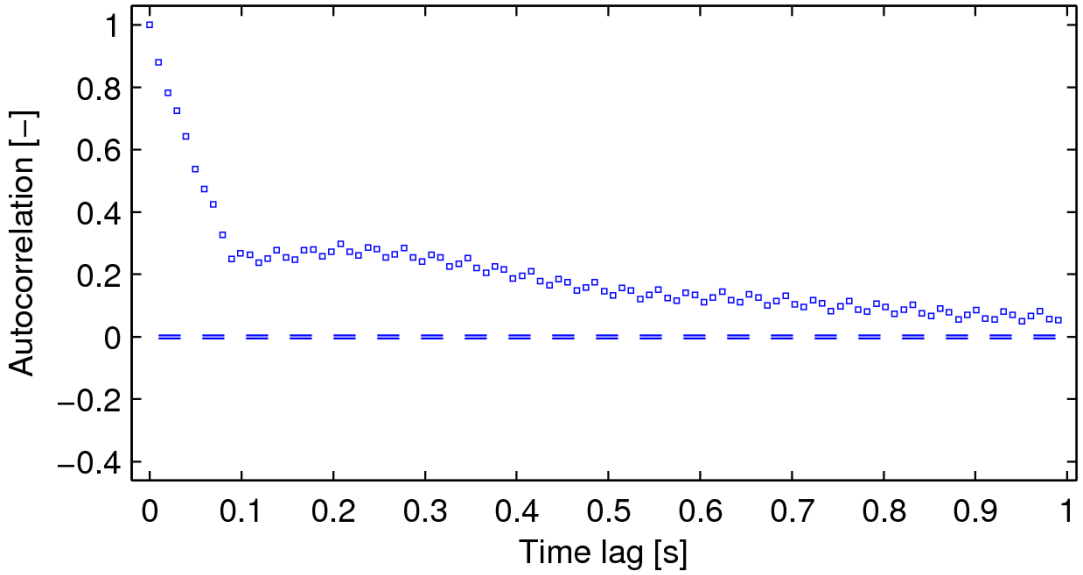
Position Correlations: Zero-Baseline L1



CA/L1

PLL = 50 Hz (0.02 s)

DLL = 5 Hz (0.2 s)



PLL = Phase-locked loop

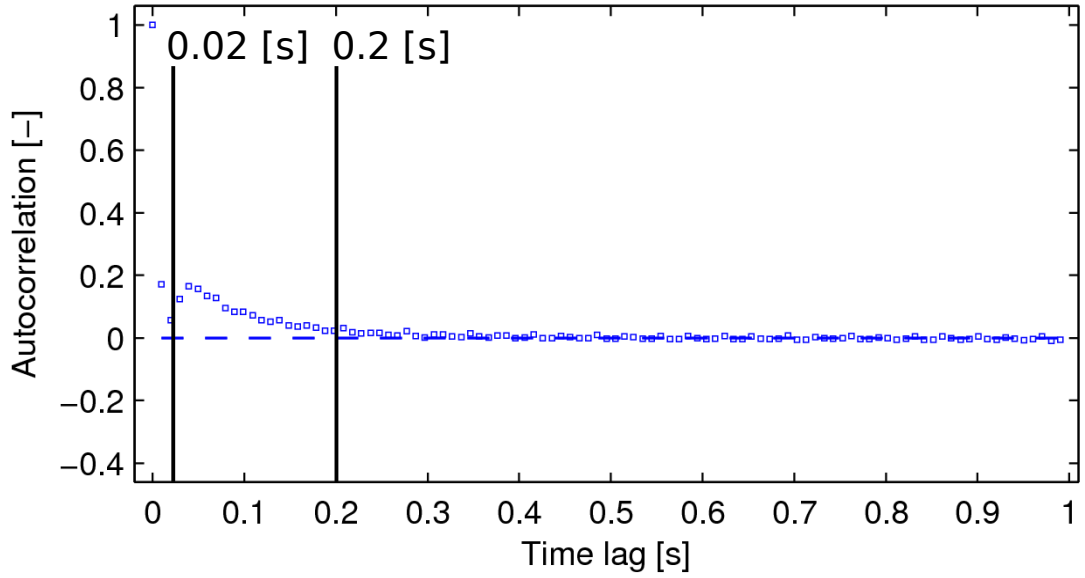
DLL = Delay-locked loop

CA/L1

PLL = 10 Hz (0.1 s)

DLL = 1 Hz (1 s)

Position Correlations: Zero-Baseline L1



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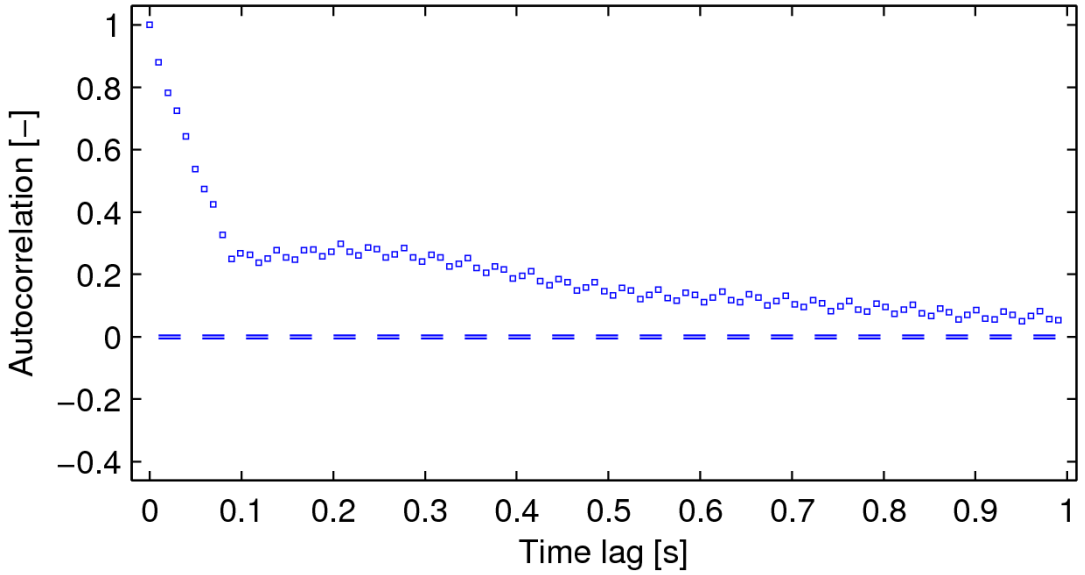

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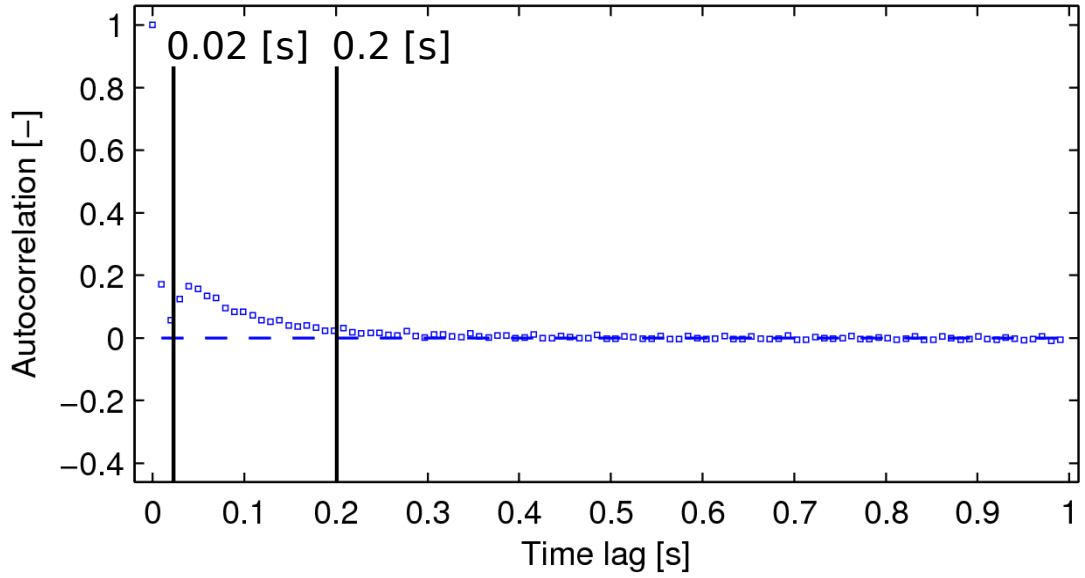

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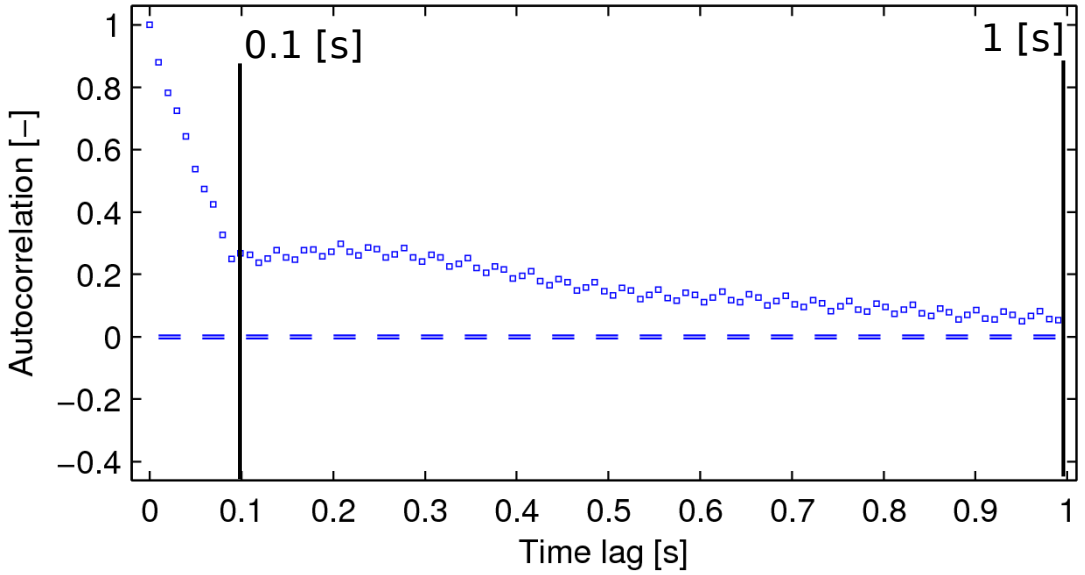
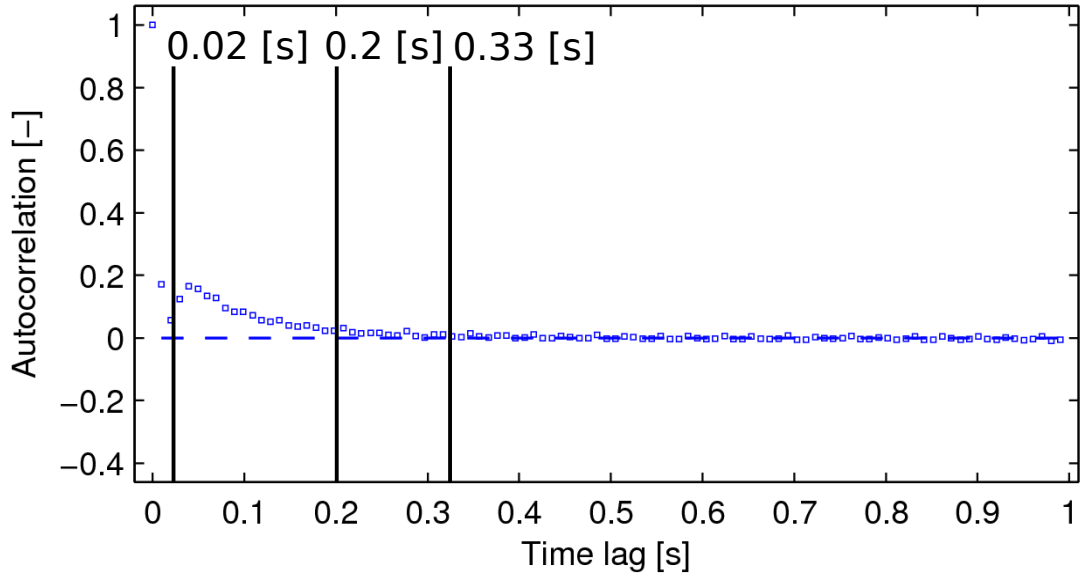


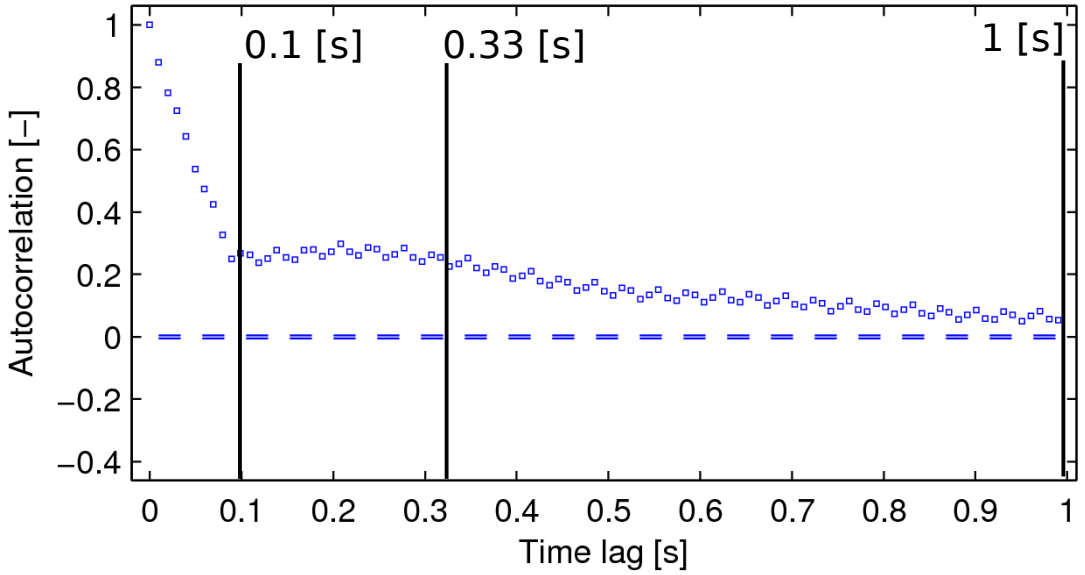
CA/L1

PLL = 10 Hz (0.1 s)

DLL = 1 Hz (1 s)

Position Correlations: Zero-Baseline L1





CA/L1

PLL = 50 Hz (0.02 s)

DLL = 5 Hz (0.2 s)

P/L1

PLL = 3 Hz (0.33 s)

DLL = 3 Hz (0.33 s)

PLL = Phase-locked loop

DLL = Delay-locked loop

CA/L1

PLL = 10 Hz (0.1 s)

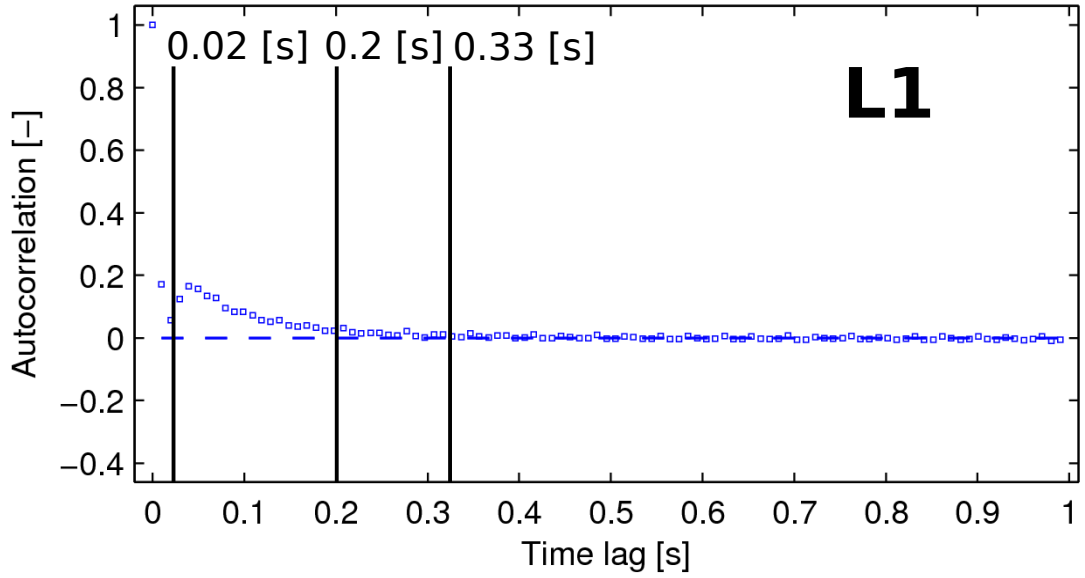
DLL = 1 Hz (1 s)

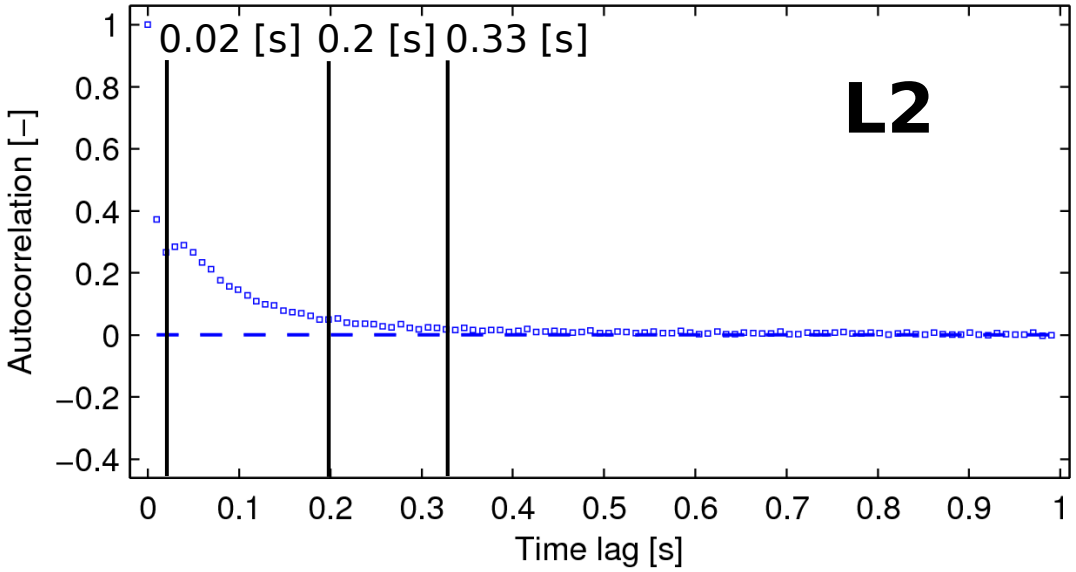
P/L1

PLL = 3 Hz (0.33 s)

DLL = 3 Hz (0.33 s)

Position Correlations: Zero-Baseline L1/L2





CA/L1

PLL = 50 Hz (0.02 s)

DLL = 5 Hz (0.2 s)

P/L1

PLL = 3 Hz (0.33 s)

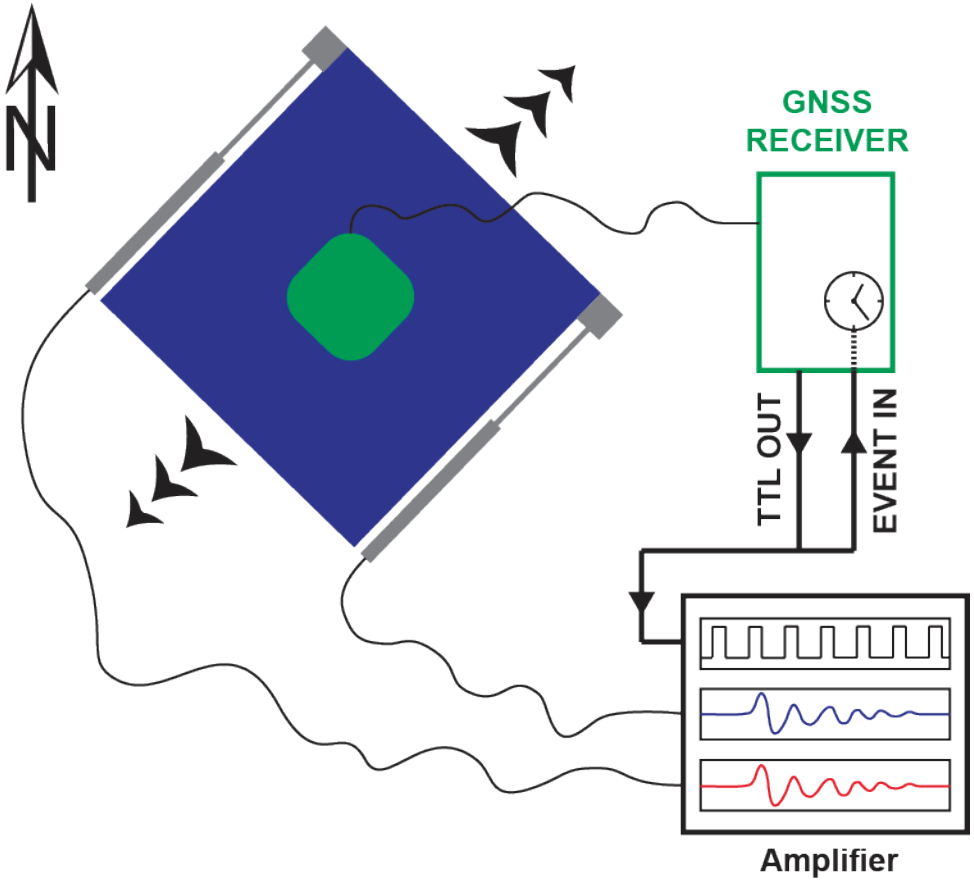
DLL = 3 Hz (0.33 s)

P/L2

PLL = 3 Hz (0.33 s)

DLL = 3 Hz (0.33 s)

Shake Table - Schematic Overview



Shake Table

- max. acceleration = 2.5 [g]
- max. velocity = 0.4 [m/s]
- max. frequency = 20 [Hz]
- max. amplitude = 7.5 [cm]

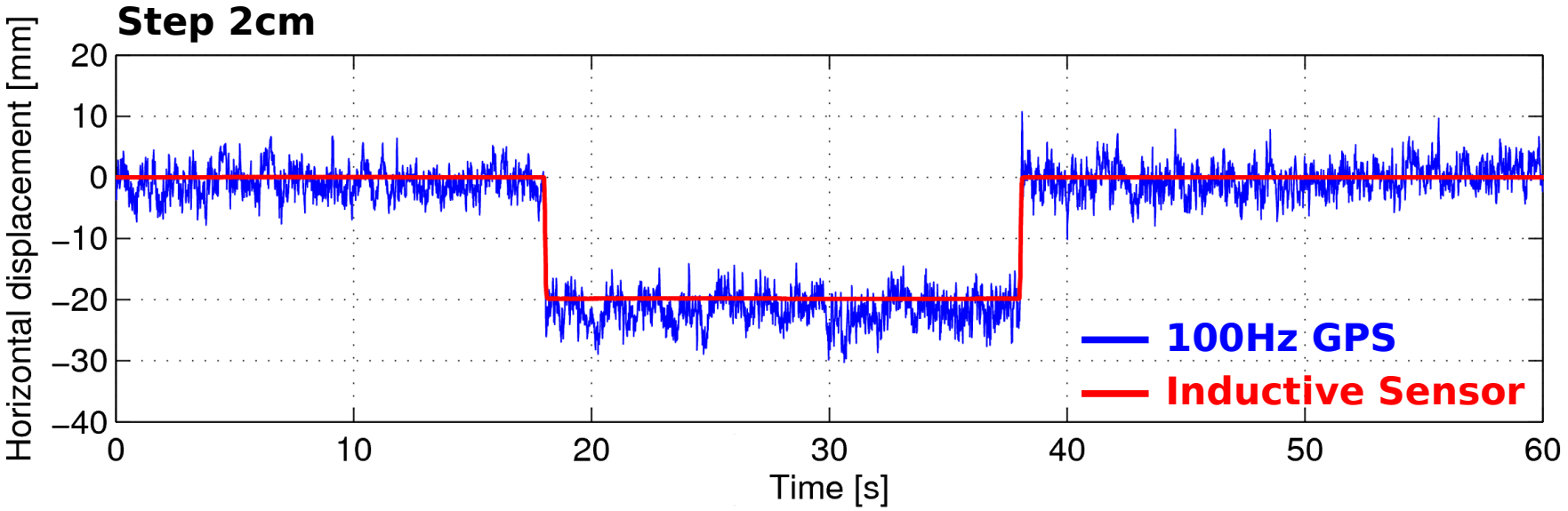
Inductive Sensors

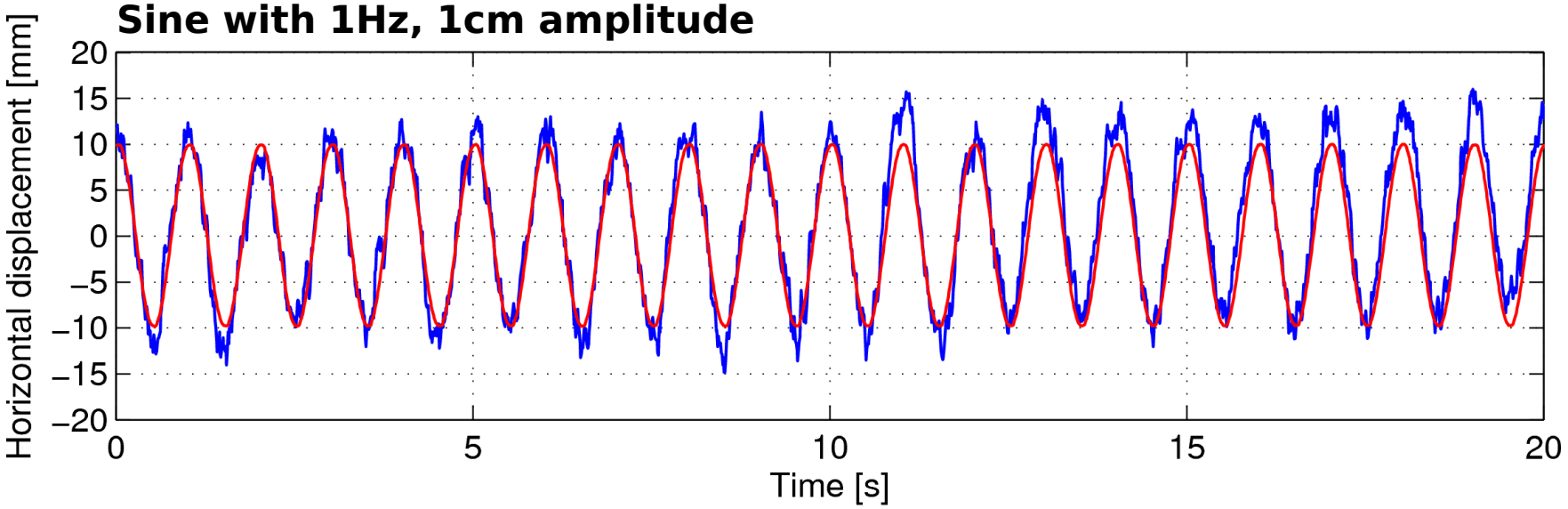
- resolution = 0.006 [mm]
- sampling rate = 2.4 [kHz]
- time synchr. < 0.4 [ms]

Total Uncertainty:

< 0.1 [mm]

First Tests with the Shake Table



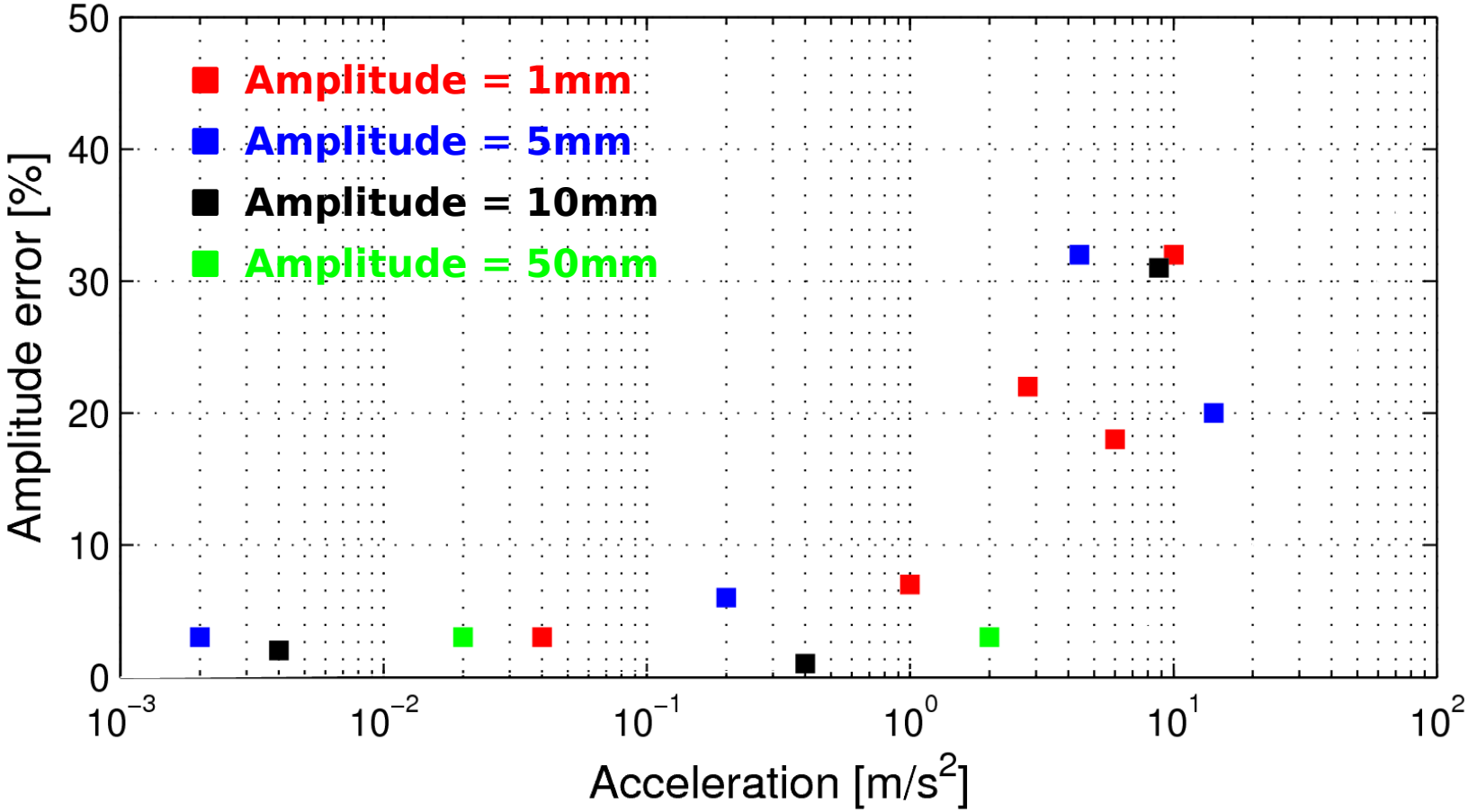


Sine Oscillations

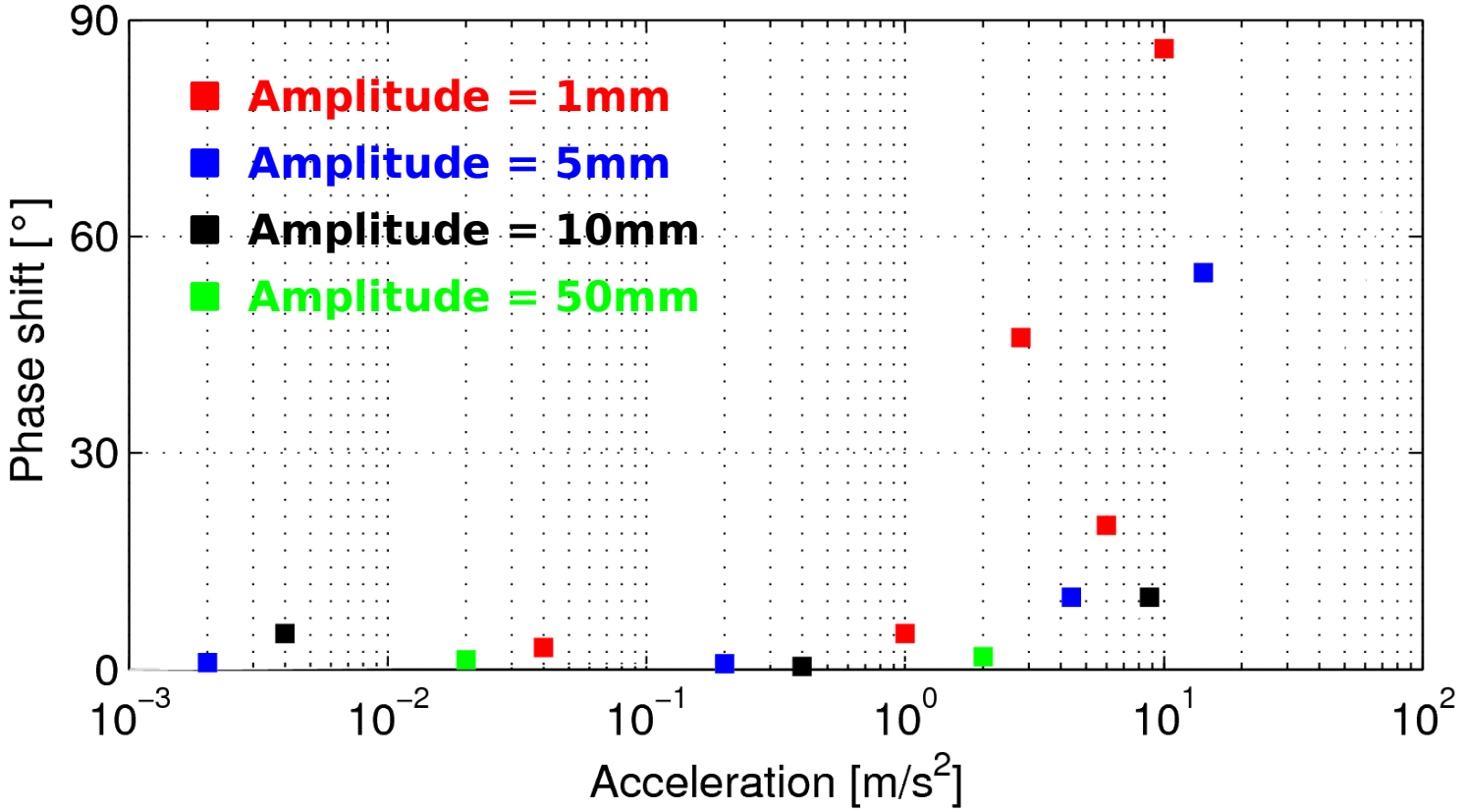
Frequencies: 0.1 – 20 [Hz]

Amplitudes: 1 – 50 [mm]

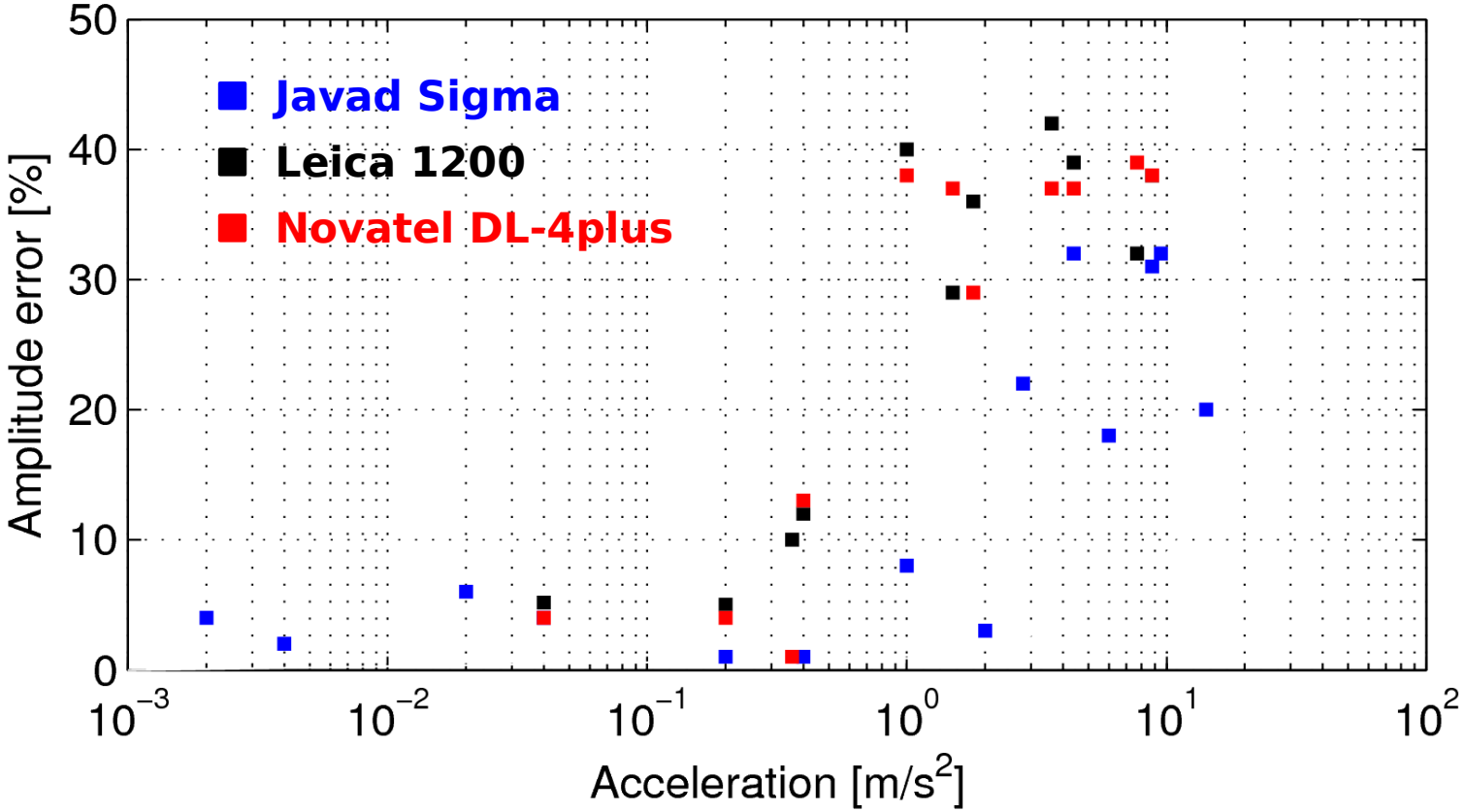
→ acceleration dependent amplitudes and phases



Sine Oscillations – Phase Shift

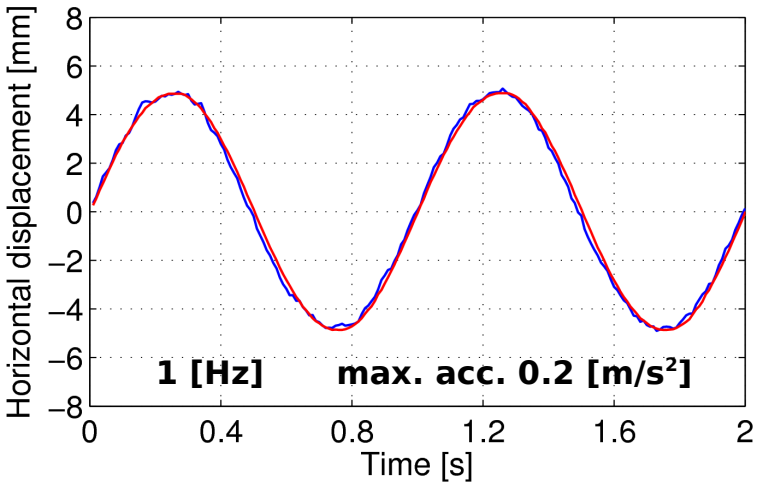


Sine Oscillations – Different Receivers

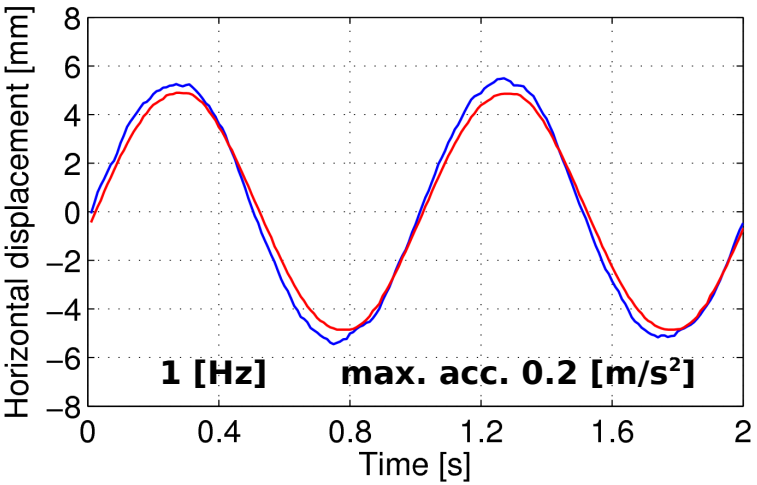


Sine Oscillations (5mm Amplitude)

PLL = 50Hz, DLL = 5Hz



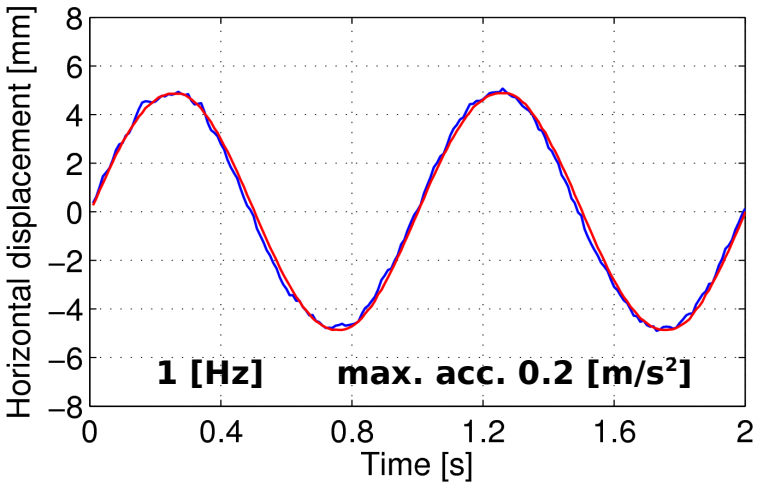
PLL = 10Hz, DLL = 1Hz

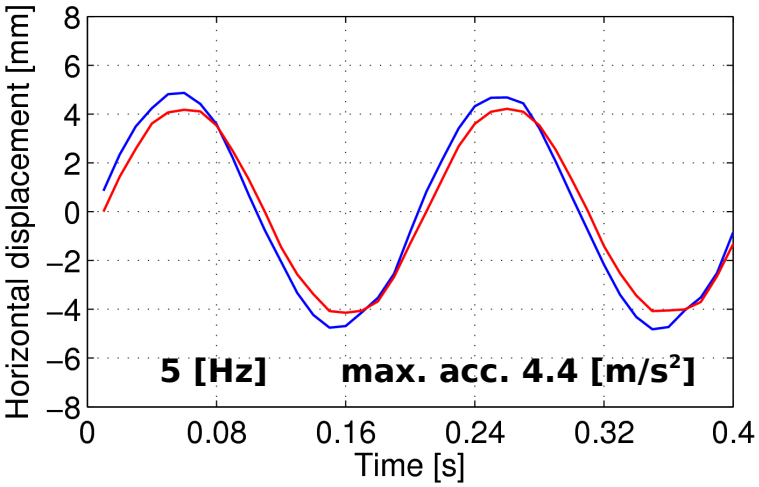


100Hz GPS **Inductive Sensor**

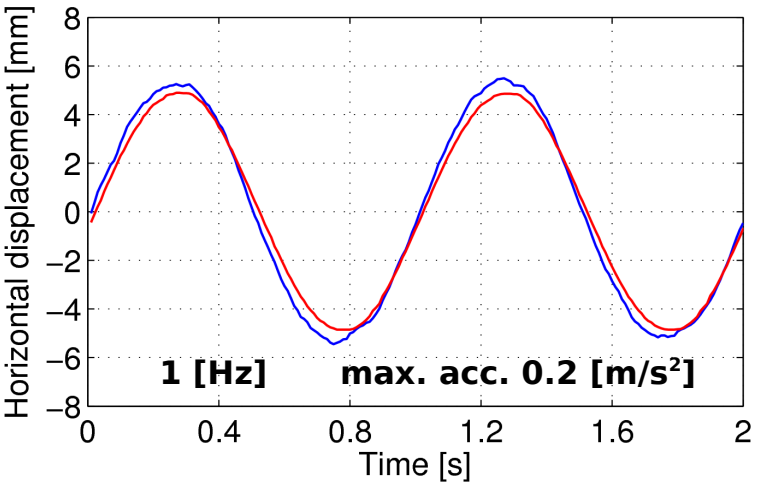
Sine Oscillations (5mm Amplitude)

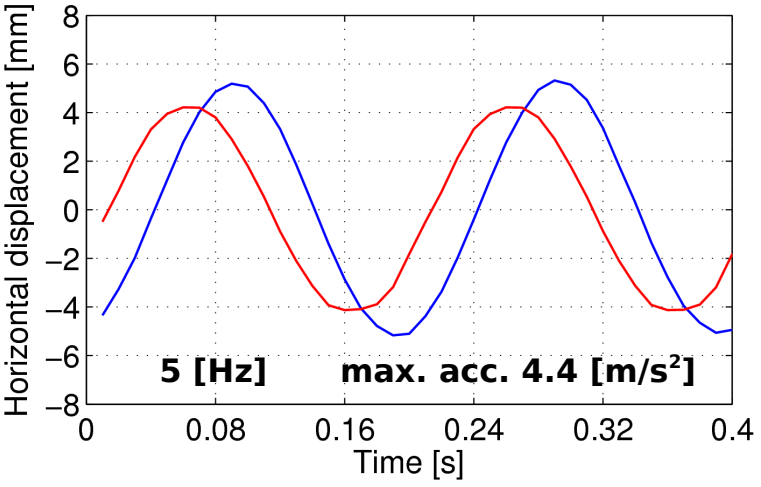
PLL = 50Hz, DLL = 5Hz





PLL = 10Hz, DLL = 1Hz



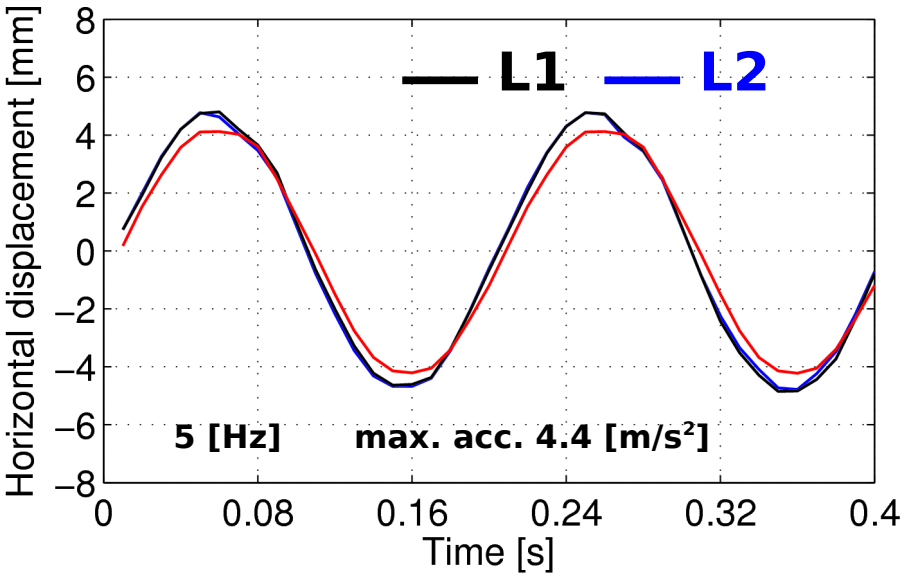


100Hz GPS **Inductive Sensor**

Sine Oscillations (5mm Amplitude)

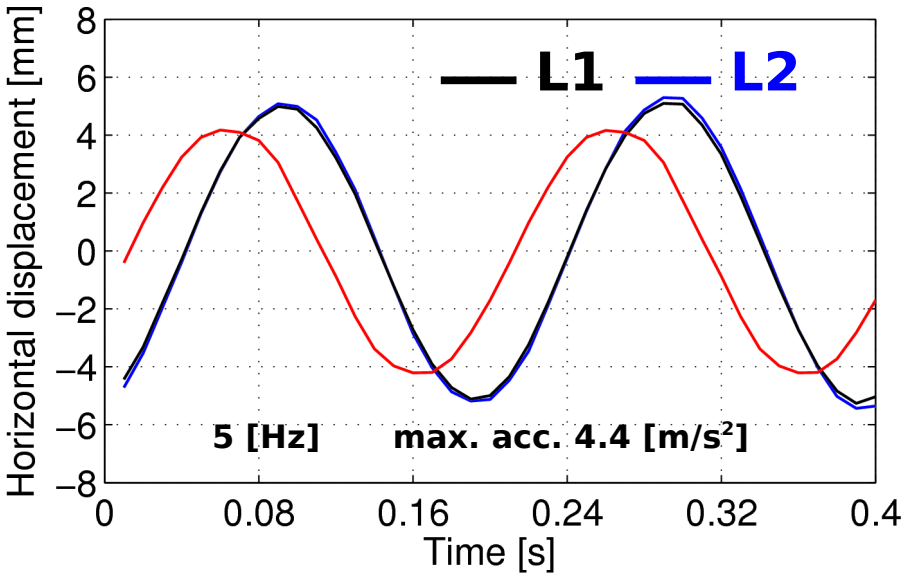
CA/L1 PLL = 50Hz, DLL = 5Hz

P/L2 PLL = 3Hz, DLL = 3Hz

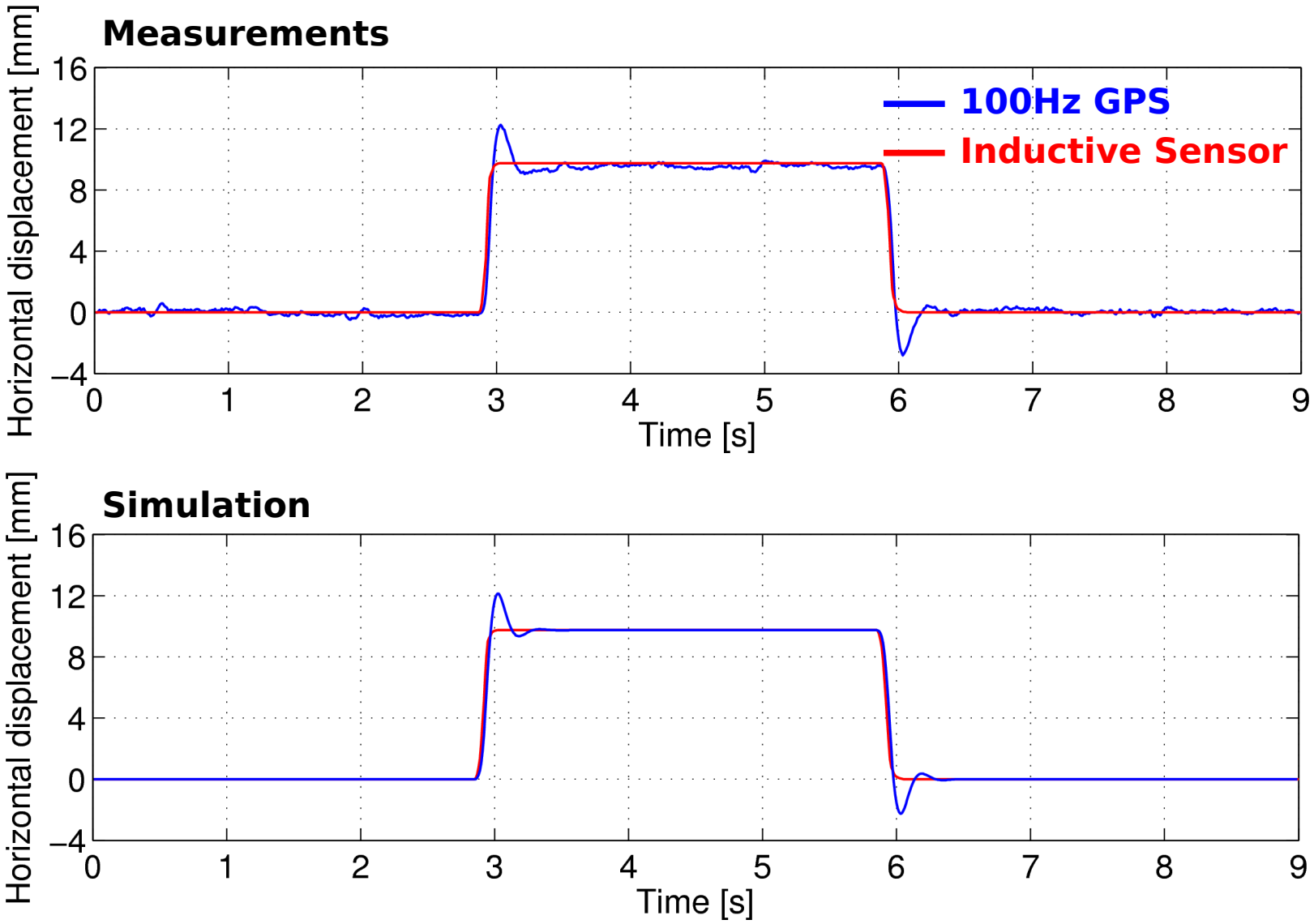


CA/L1 PLL = 10Hz, DLL = 1Hz

P/L2 PLL = 3Hz, DLL = 3Hz



Receiver Transfer Function – 2nd Order



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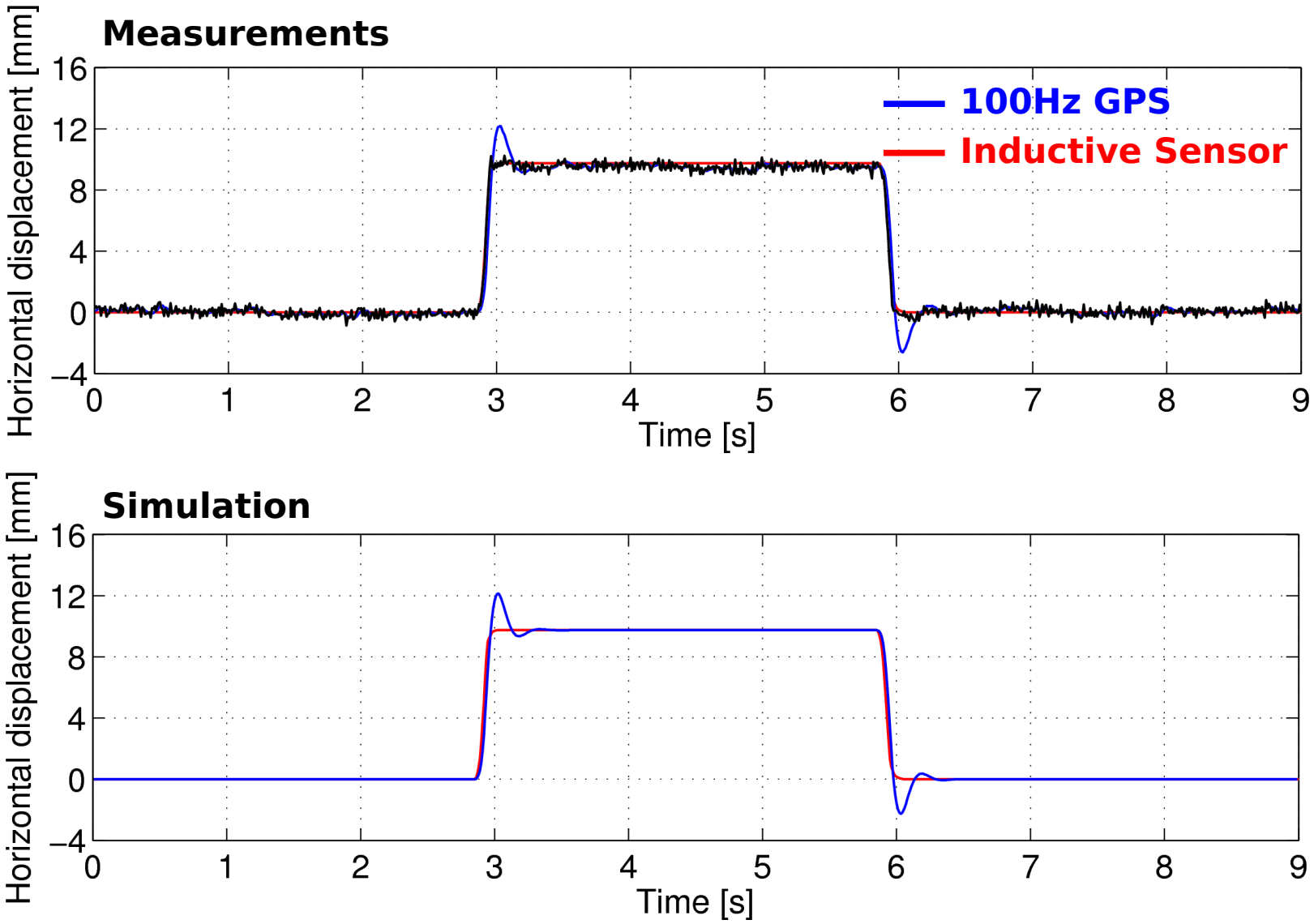
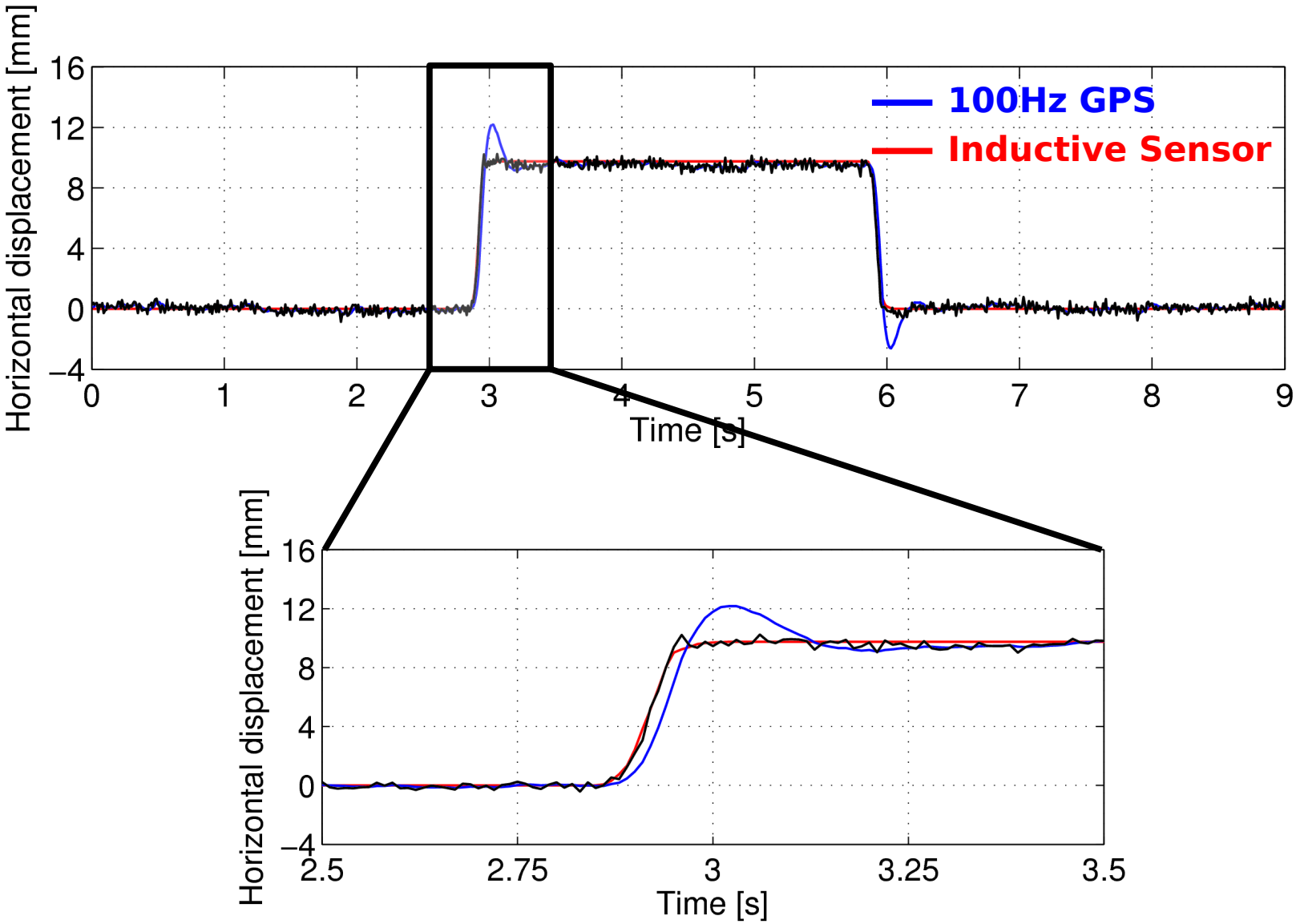
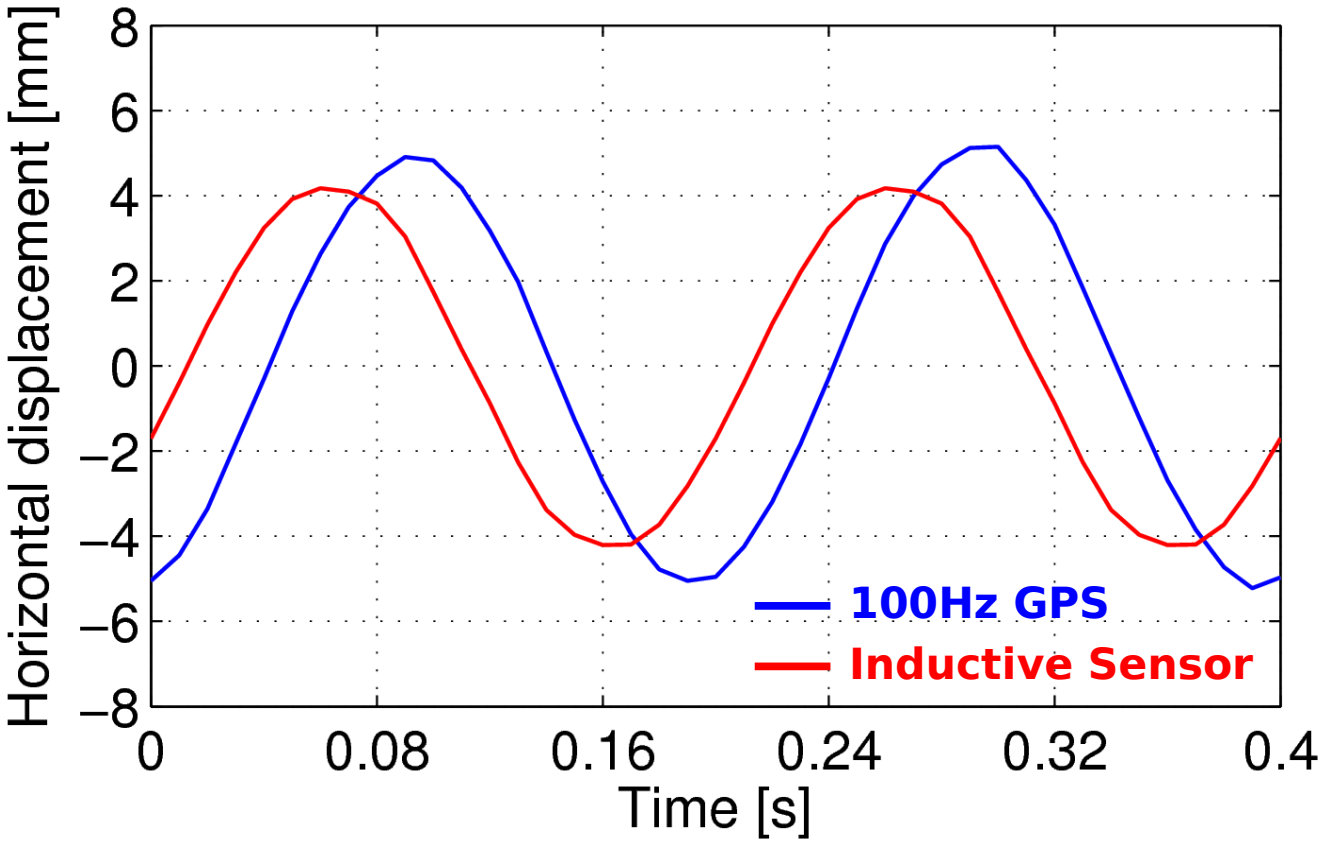


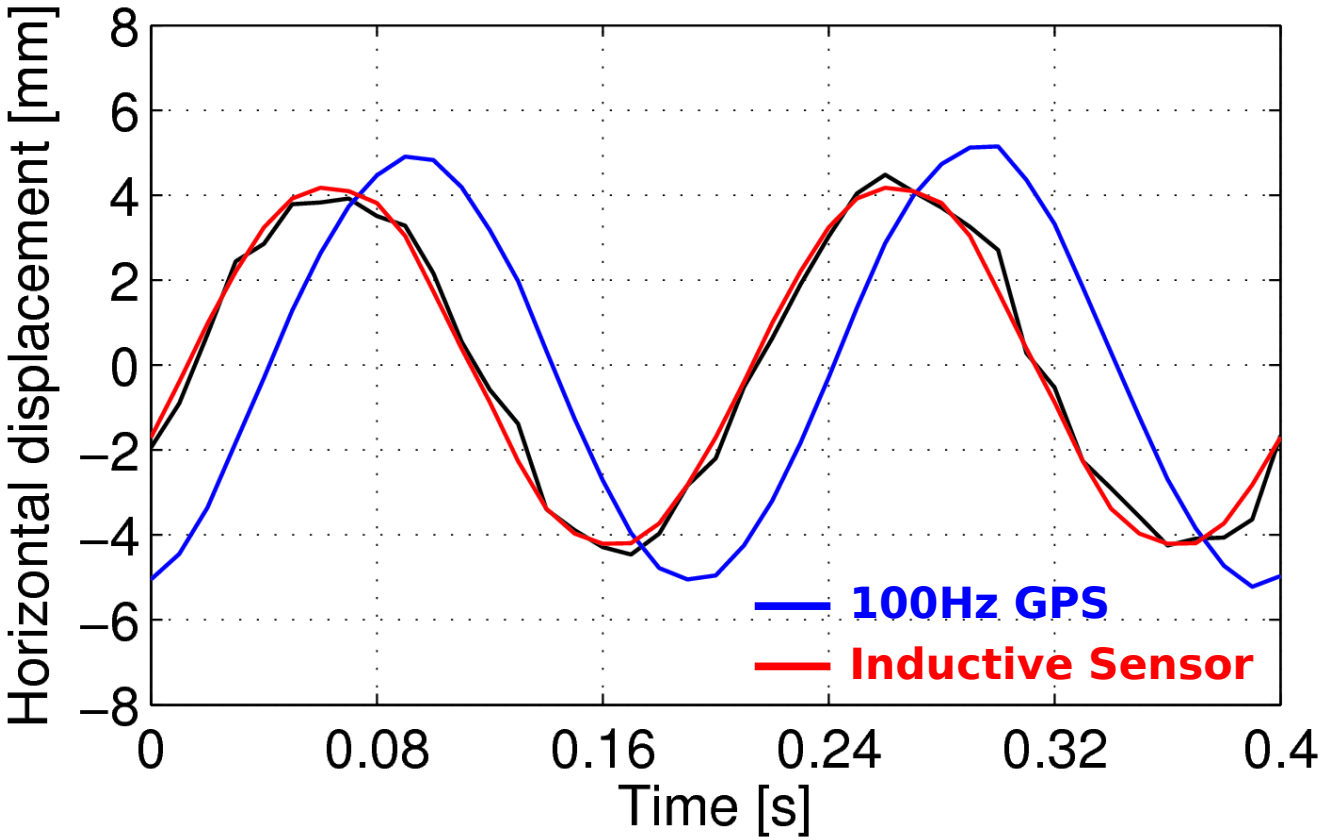
Receiver Transfer Function – 2nd Order



Receiver Transfer Function – 2nd Order



Receiver Transfer Function – 2nd Order



Conclusions

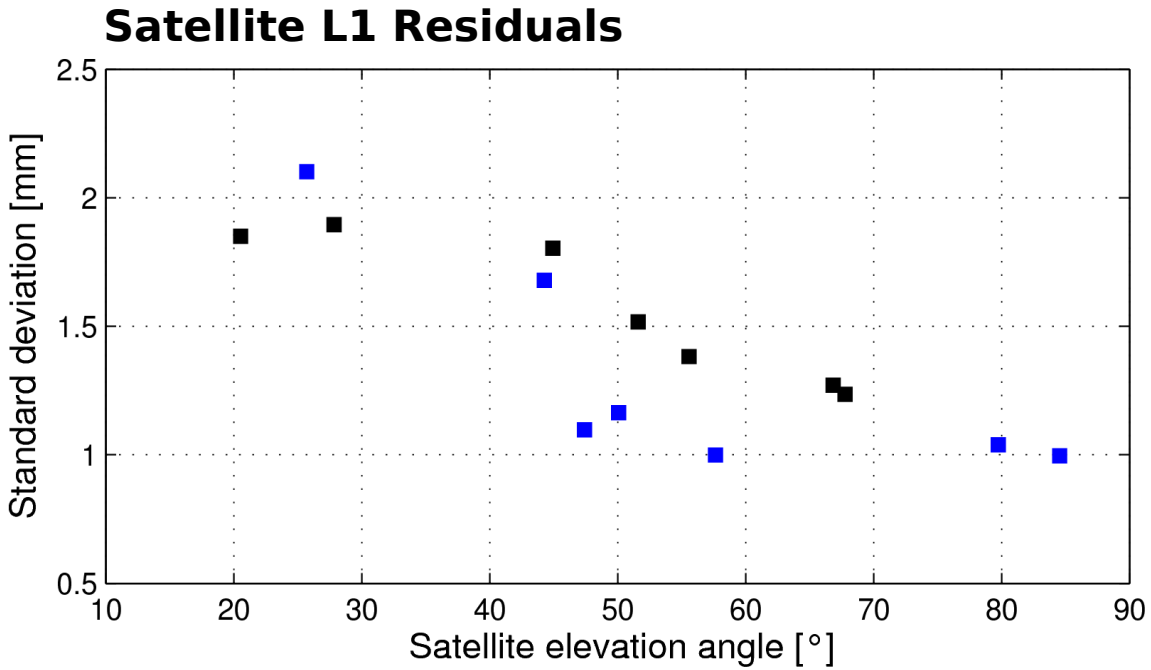
- Tracking loop parameters directly influence the noise level and position correlations
- Accuracy of dynamic GPS measurements depends on acceleration and tracking loop parameters
- Similar behaviour of the L1 and L2 signals
- Minimization of the errors by inverse filtering

Next Steps

- Longer baseline (~100km)
- Problem of loss of lock
- 3D Robot for larger amplitudes

THANK YOU FOR YOUR ATTENTION

High-Frequency Noise: 5m Baseline



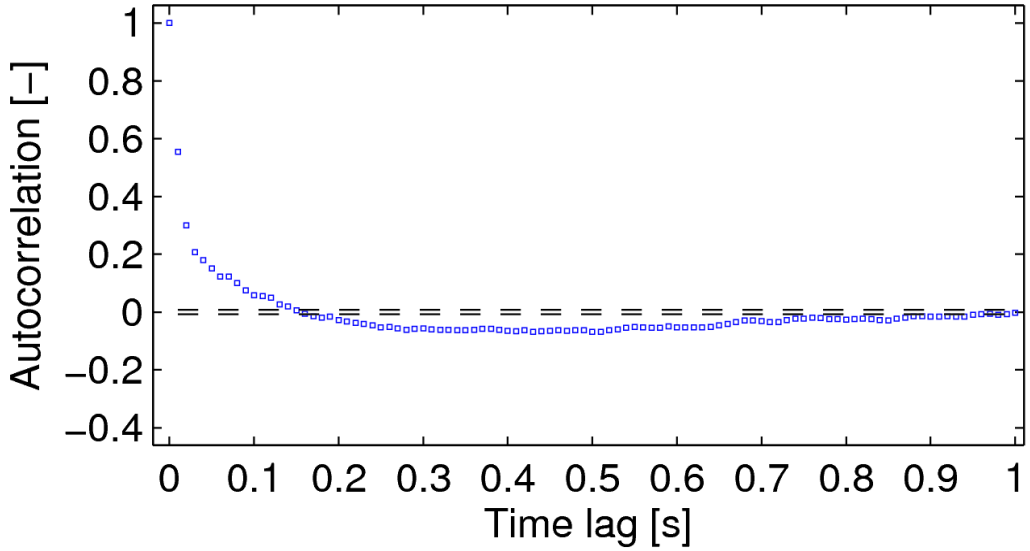
PLL = 50Hz, DLL = 5Hz

PLL = 10Hz, DLL = 1Hz

RMS for kinematic coordinates:

PLL = 10Hz, DLL=1Hz	**PLL = 50Hz, DLL= 5Hz**
East = 1.8 [mm]	East = 1.9 [mm]
North = 1.9 [mm]	North = 3.6 [mm]
Up = 3.8 [mm]	Up = 5.0 [mm]

Position Correlations: 5m Baseline



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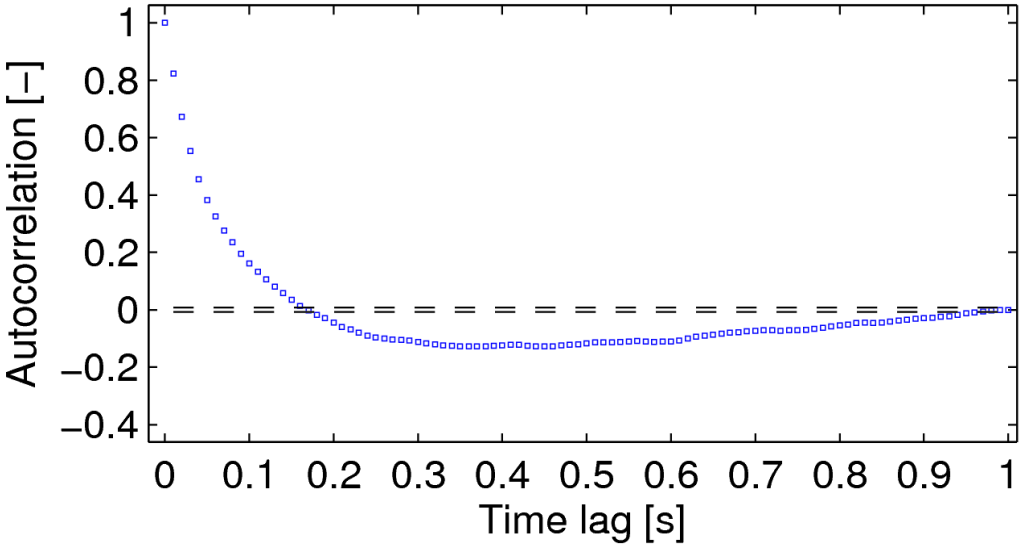

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