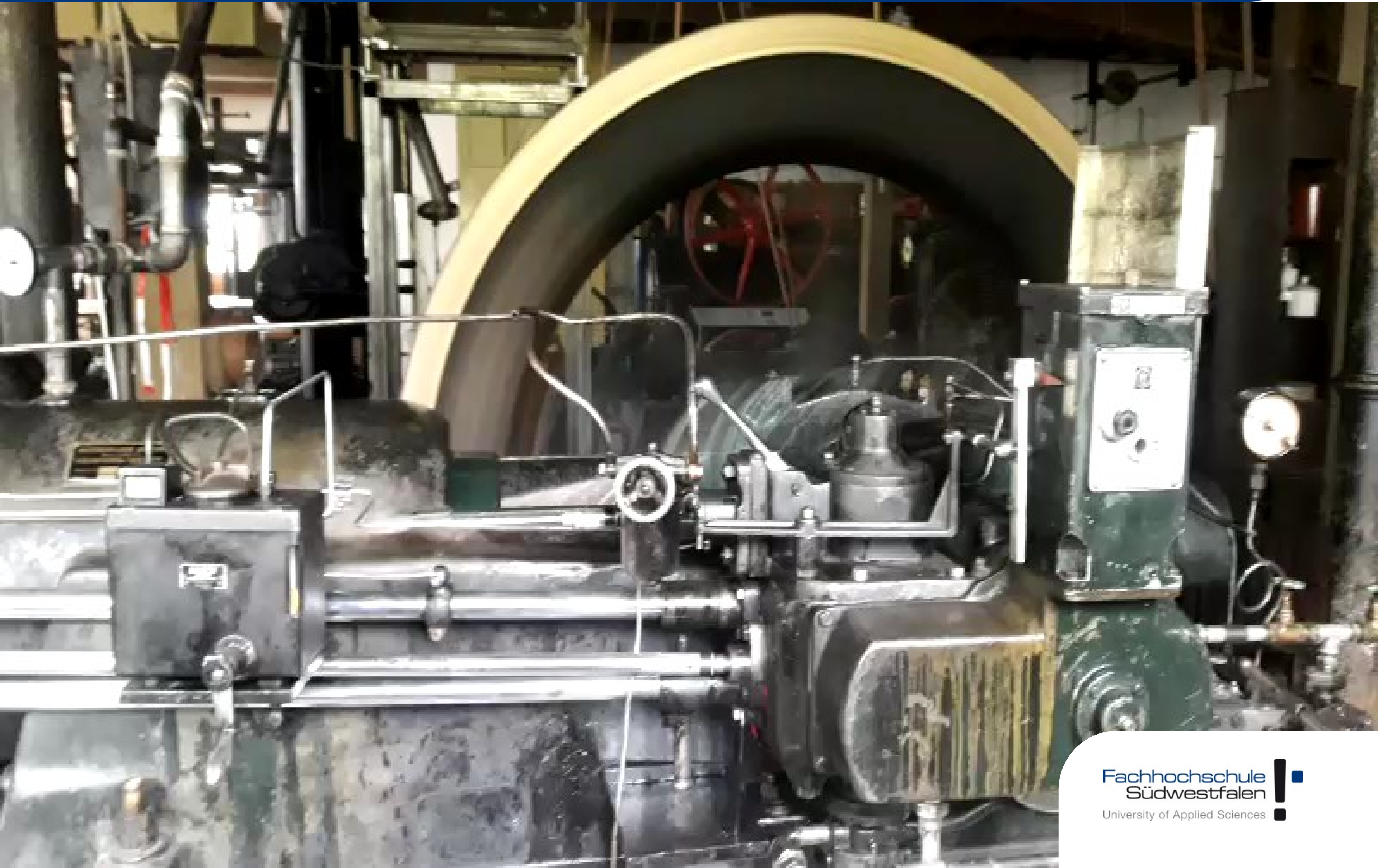
Acceleration Logging

Personal application of Ruuvi sensor



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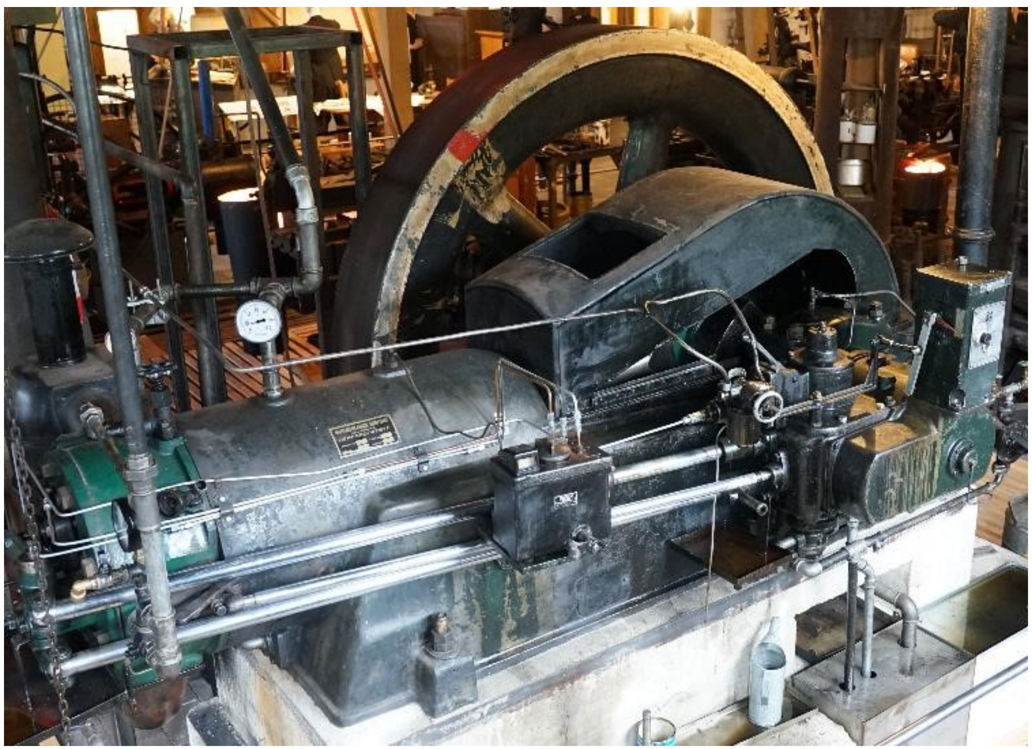
Motivation

technikmuseum freudenberg
... alles bewegt sich!

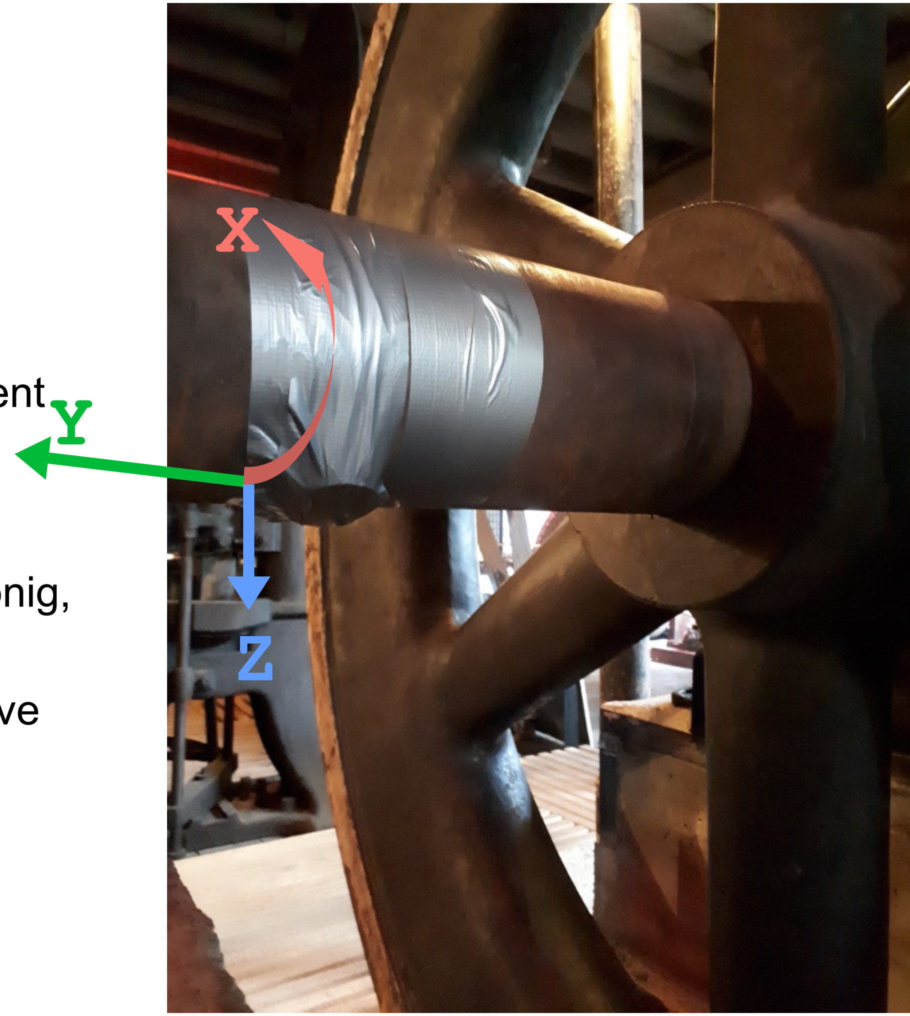
- In cooperation with Technikmuseum Freudenberg
- My hobby is operating the trains
- In 2017, the people of the museum rebuild a 70 year old Herford Stationary Diesel Engine.



Technical specification

Experimental setup

- Herford DNS Motor
- Nearly 70 years old
- Compatible to many fuels from Diesel to heavy oil.
- 75HP @ 300 revolutions per minute
- One cylinder with ~40 liter displacement
- Weight ~6200kg
- Diameter of flywheel ~2m
- Manufacturer: Motorenfabrik Hans König, Herford / Deutschland
- Placement of the Ruuvi Tag at the drive shaft.
- Sample rate streaming with 100Hz
- Resolution 12 Bit
- Scale 16G



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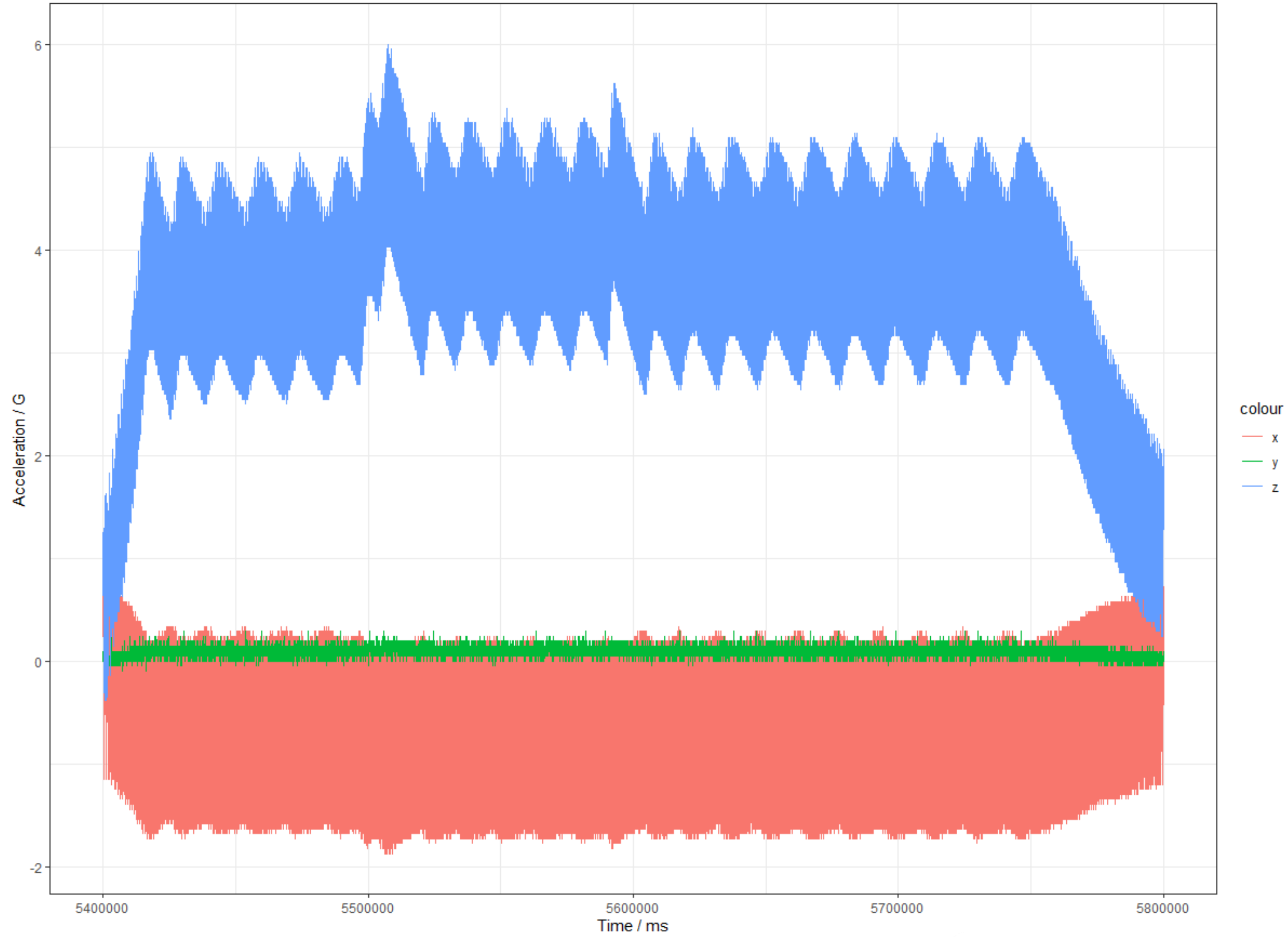
Raw acceleration data

Z: centrifugal acceleration + gravitation
Y: acceleration along the drive shaft
X: acceleration right-angled to the drive shaft + gravitation

Z and **X** acceleration consist of two components.

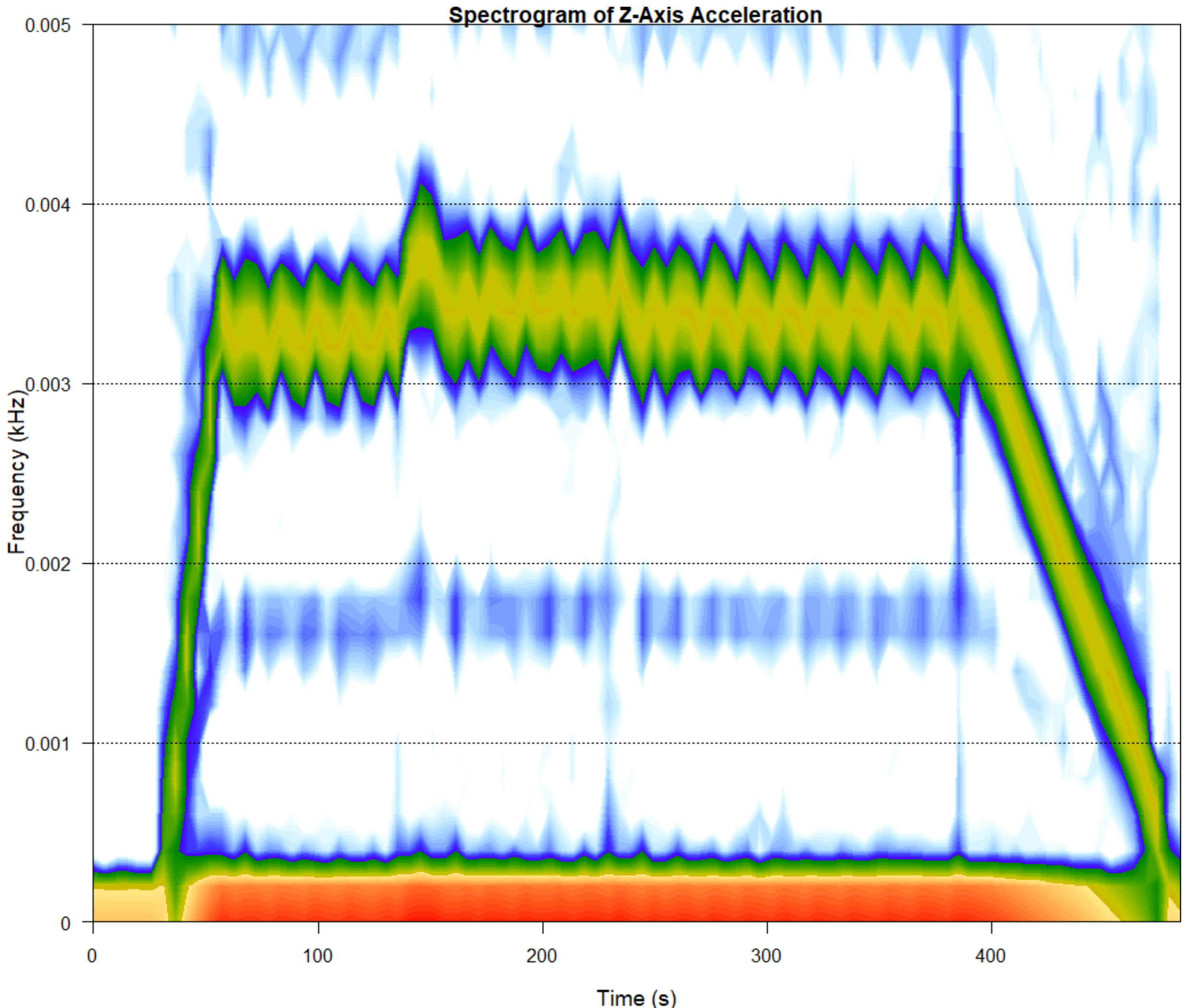


Spectrogram

The spectrogram of all axes look nearly the same.

Components can be split at ~2.4Hz using lowpass and highpass.

Engine operates at 3 to 4 revolutions per second.



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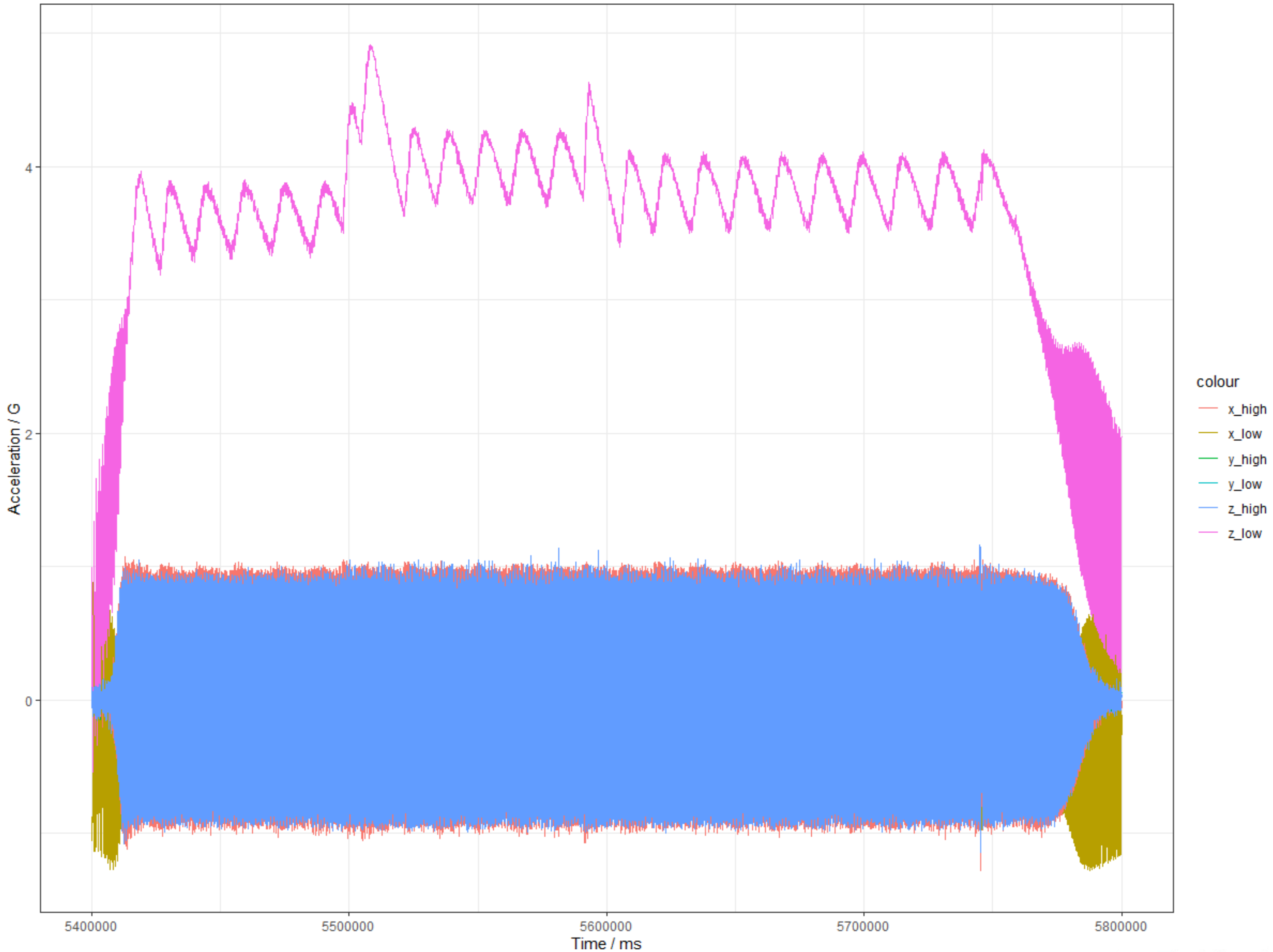
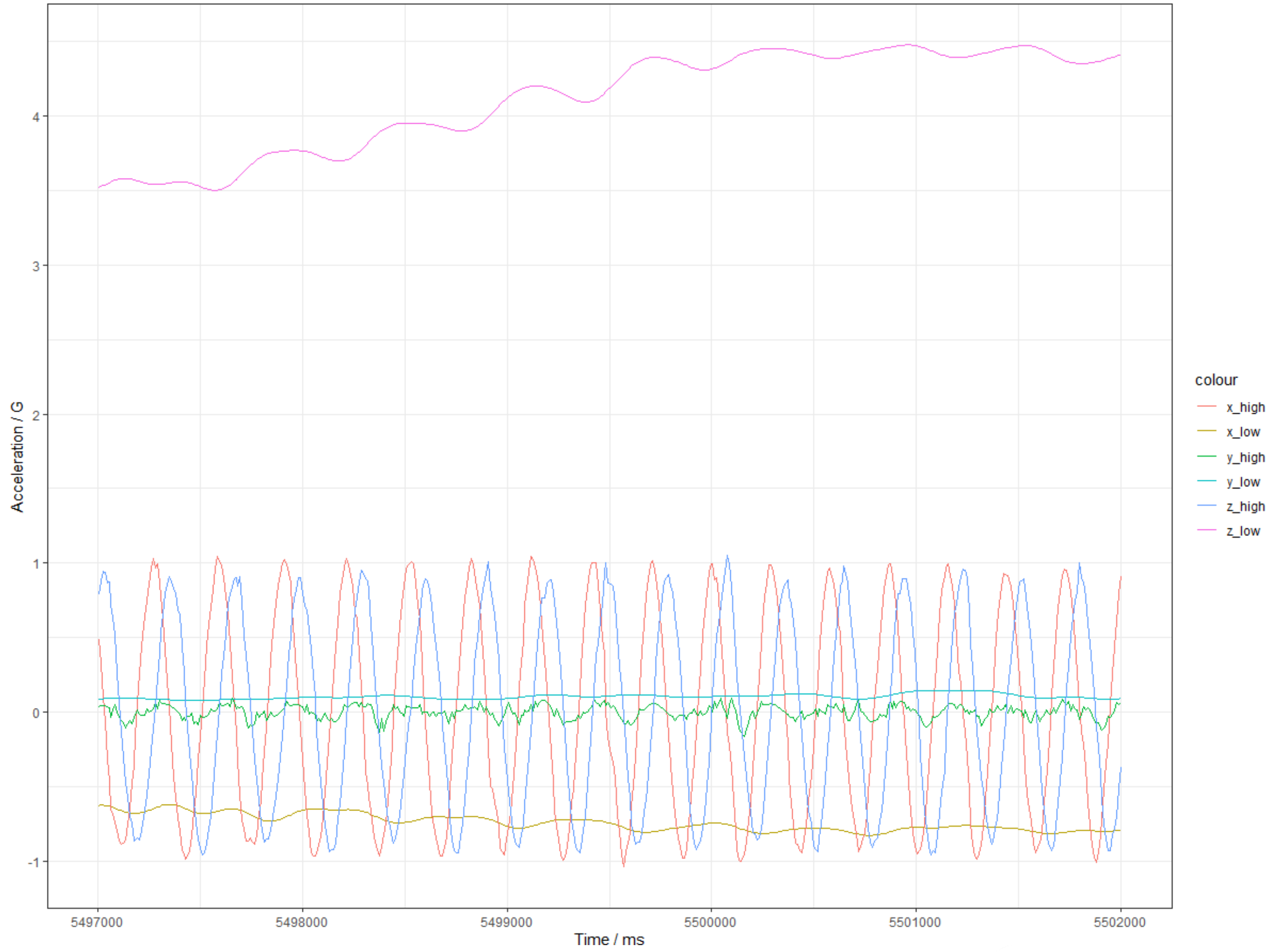
Acceleration data after split at 2.4 Hz

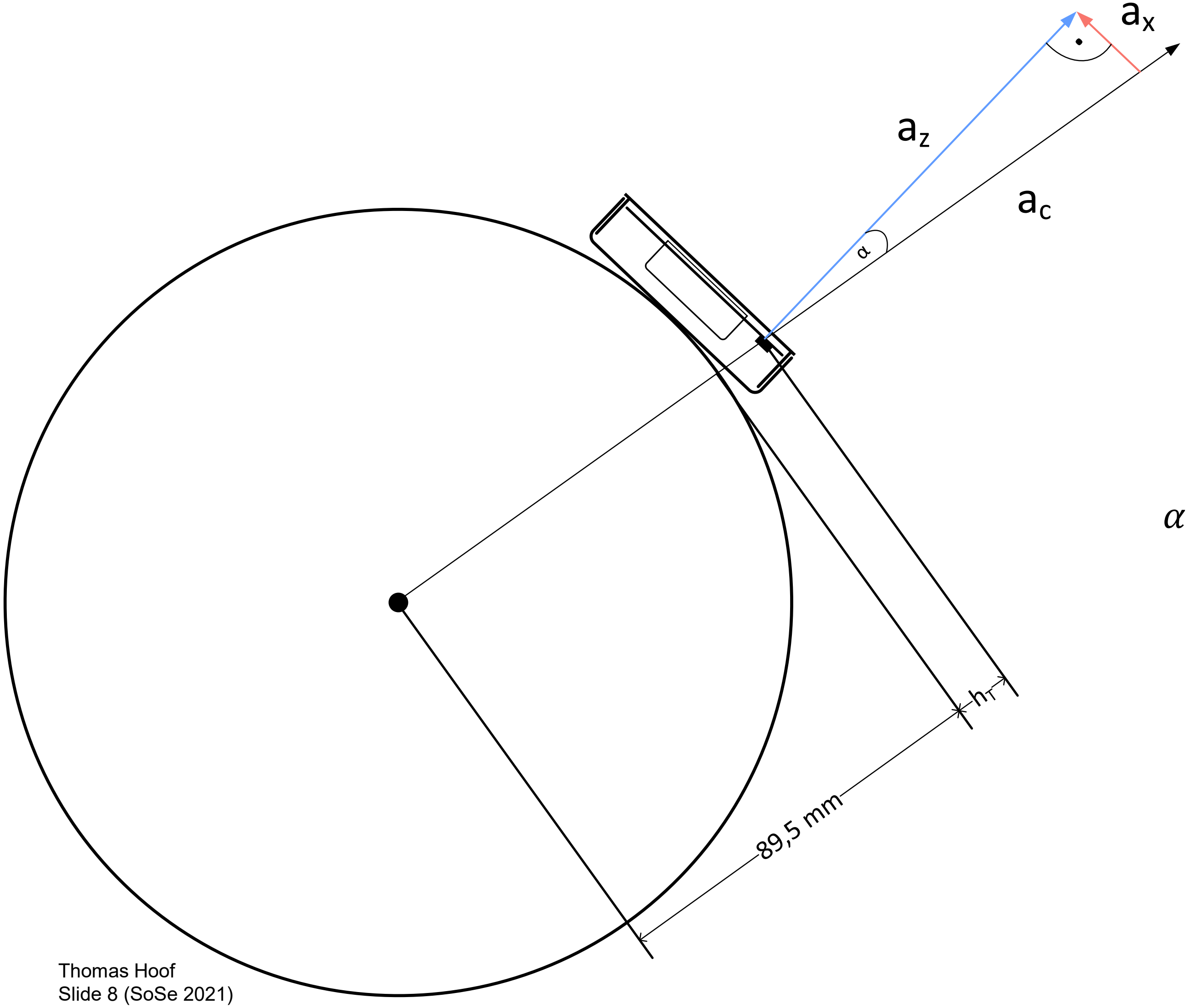


Zoom inside acceleration data

- After split at 2.4Hz
- Z_low + X_low: Components of centrifugal acceleration
- Z_high + X_high: Gravitation
- Y_low, Y_high: Acceleration along the axis of the drive shaft



Components of centrifugal acceleration



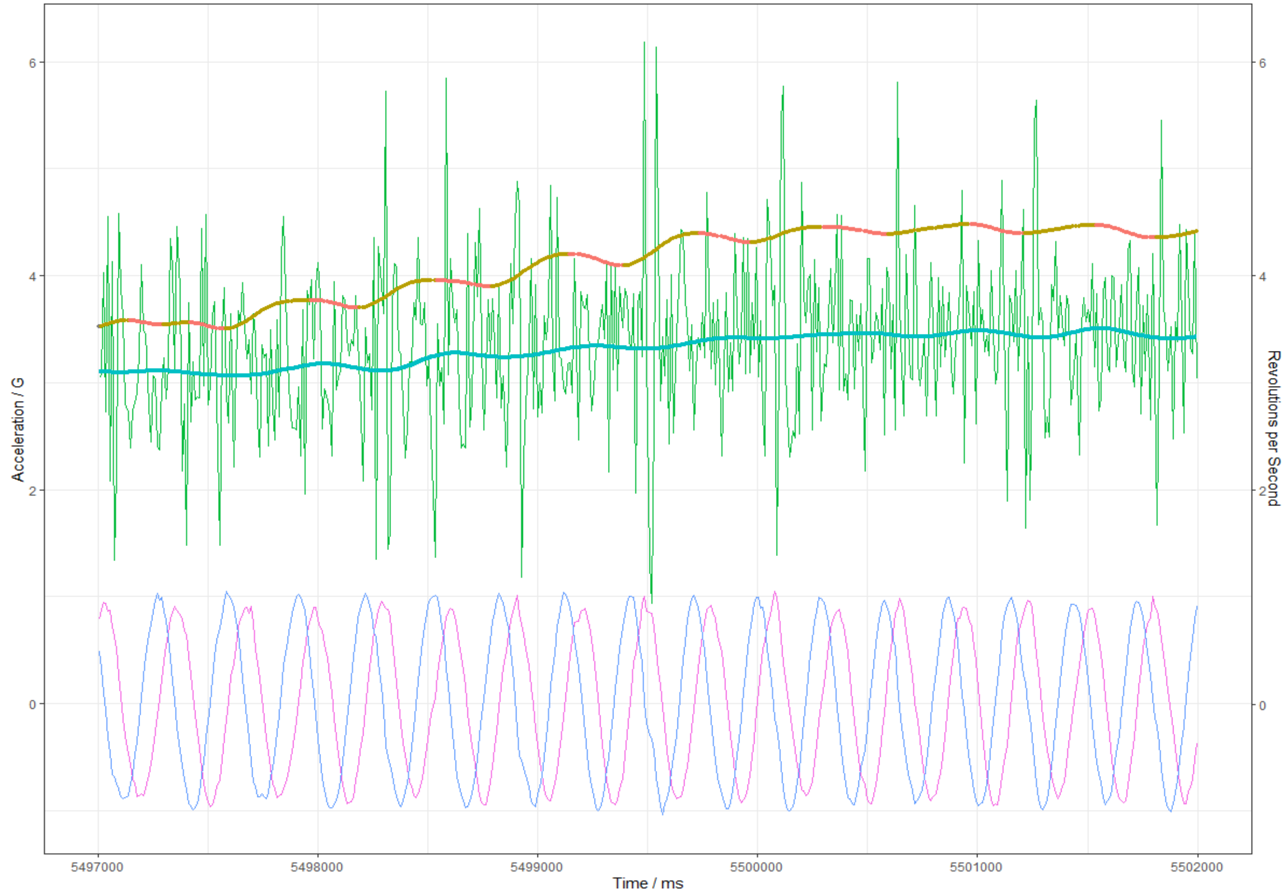
$$\alpha = \tan^{-1}\frac{a_x}{a_z}$$

$$\alpha = \tan^{-1}\frac{0.78G}{4.5G}$$

$$\alpha = 9.8°$$

Angular velocity

- Calculating angular velocity from angle and sampling time is very noisy.
- After passing through lowpass value is useful.



References: https://commons.wikimedia.org/wiki/File:Sinus_und_Cosinus_am_Einheitskreis.gif

Validation

Calculating centrifugal acceleration from angular velocity

Diameter of Drive Shaft: $d = 179mm$

Height of Ruuvi Tag: $h_T = 5mm$

$f(t{=}5501011) \approx 3.5Hz$

$$r = \frac{d}{2} + h_T = \frac{179mm}{2} + 5mm = 95mm$$

Centrifugal acceleration from components: $a_c = \sqrt{a_{x\_low}^2 + a_{z\_low}^2}$

$$a_c(t{=}5501011) = \sqrt{0.78G^2 + 4.5G^2} = 4.6G$$

Centrifugal acceleration from angular velocity: $a_c = \omega^2 \cdot r$

$$a_c = (2 \cdot \pi \cdot 3.5Hz)^2 \cdot 95mm = 46\frac{m}{s^2} \cdot \frac{1}{9.81} = 4.7G$$

References

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- signal developers (2013). signal: Signal processing. URL: http://r-forge.r-project.org/projects/signal/.
- Wickham et al., (2019). Welcome to the tidyverse. Journal of Open Source Software, 4(43), 1686, https://doi.org/10.21105/joss.01686
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