The Implementation of GNU Radio Blocks for Decoding Long-lasting Frames in Mobile Underwater Acoustic Communications

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GNU Radio Conference
September 18, 2018

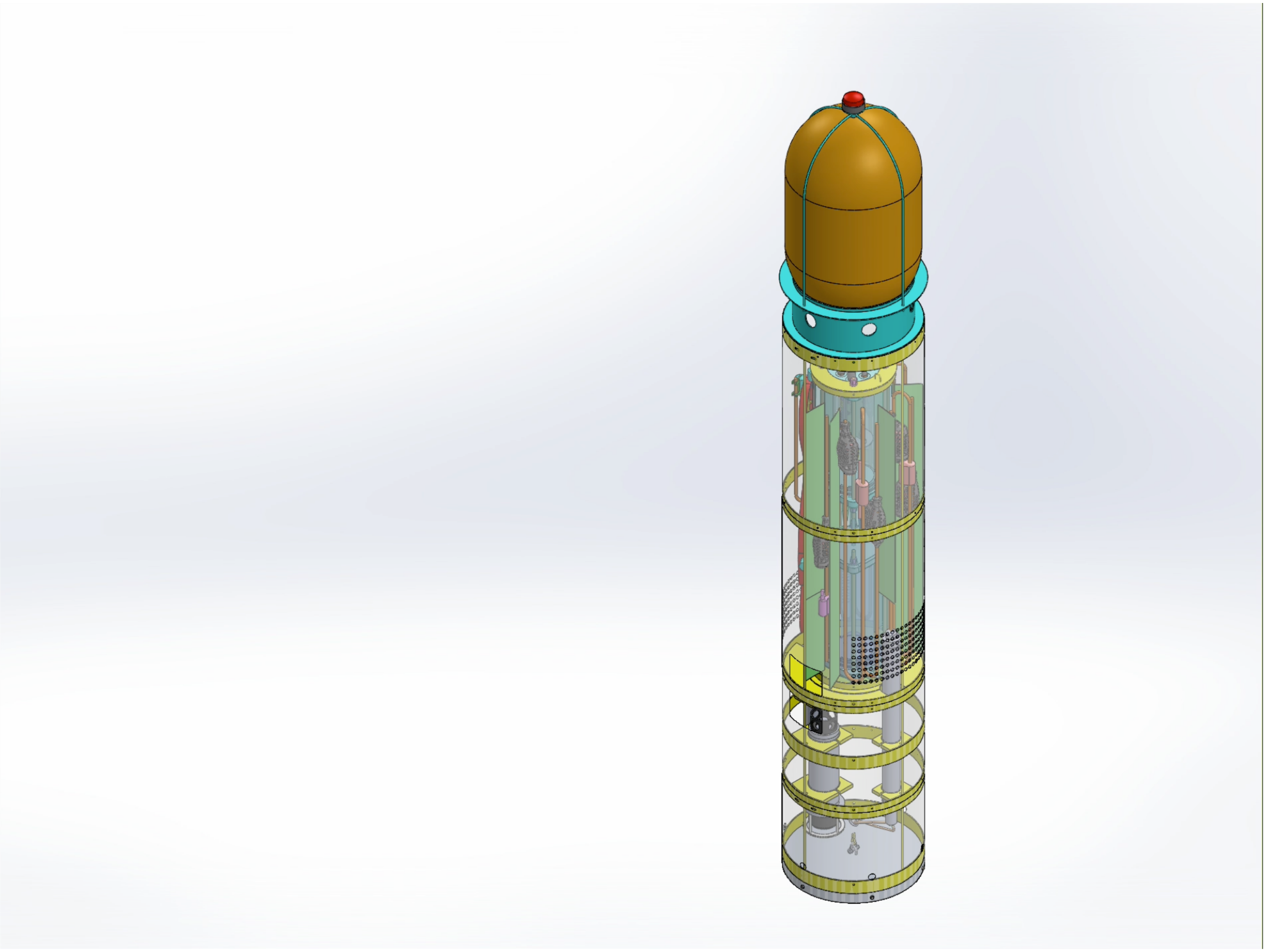
Outline

- Why?
- Background
- High level design
- Performance

Why underwater communications?

- Monitoring and surveillance of coastal waters
- Submarine activity sensors
- Autonomous undersea vehicles
- Underwater robots
- Submerged airplane locator beacons

Monitoring and surveillance node

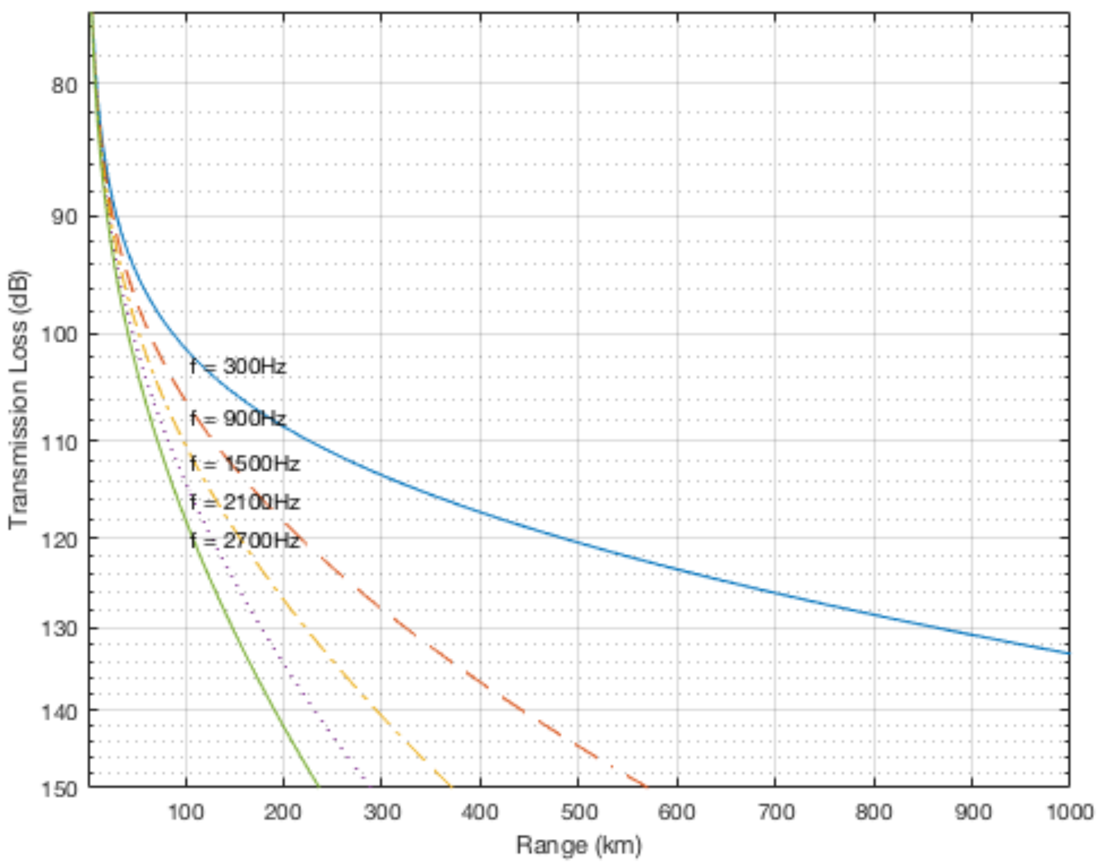


BACKGROUND ON UNDERWATER COMMUNICATIONS

Acoustic waves

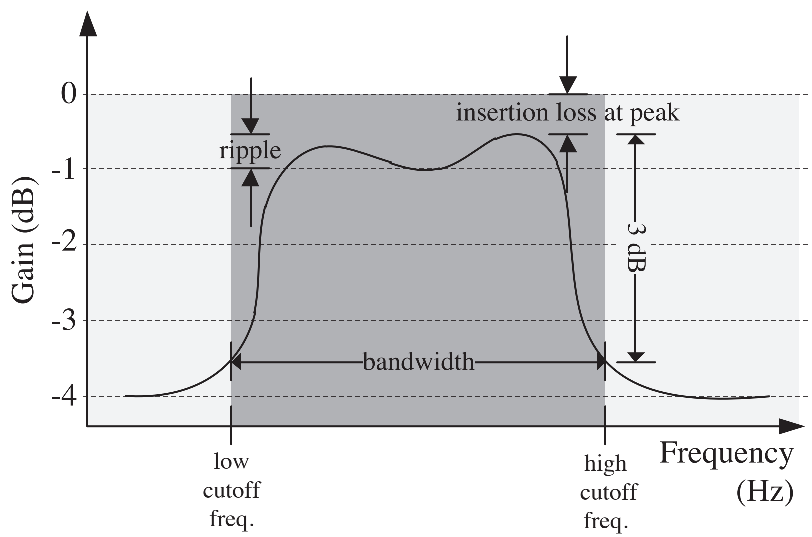
- Why? Radio waves suffer from high attenuation in water
- Low propagation speed signal (1500 m/s)
  - Long distances, delays counted in minutes
- Impairments
  - attenuation
  - numerous sources of noise
  - when mobile, Doppler effect

Attenuation at selected frequencies

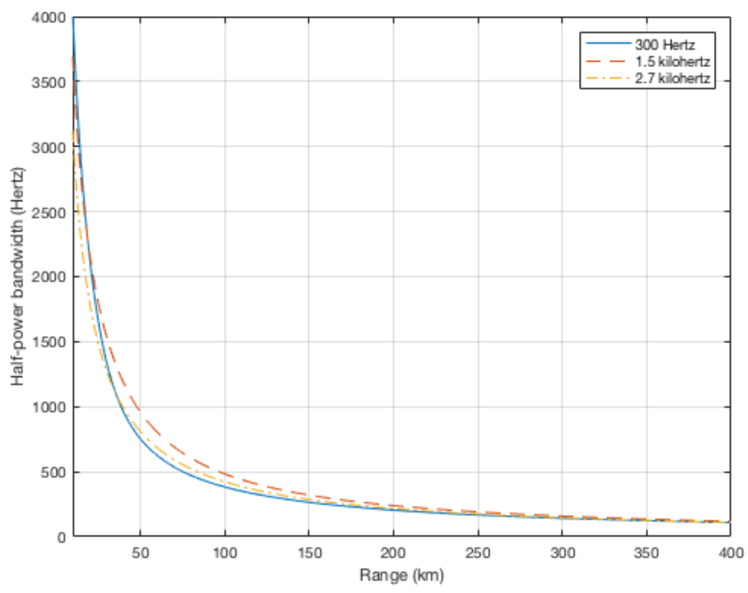


Half-power bandwidth

Difference between high cutoff and low cutoff frequencies

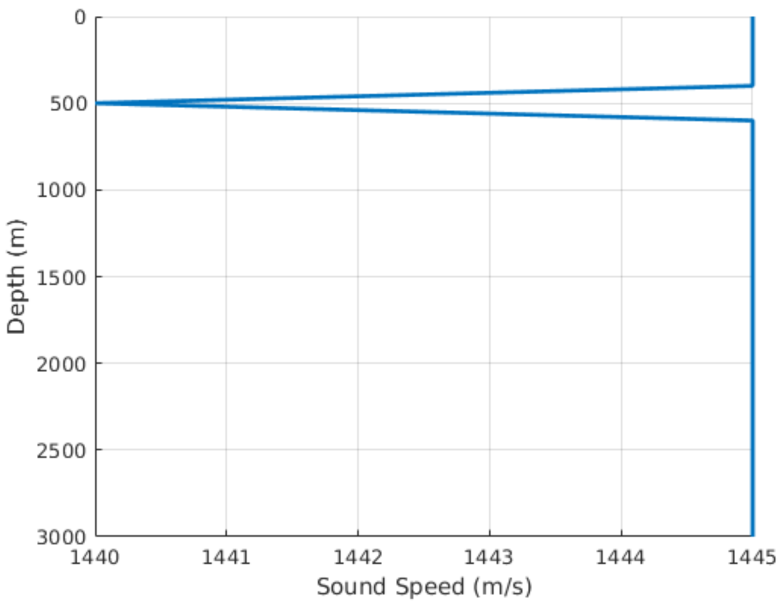


For selected low frequencies

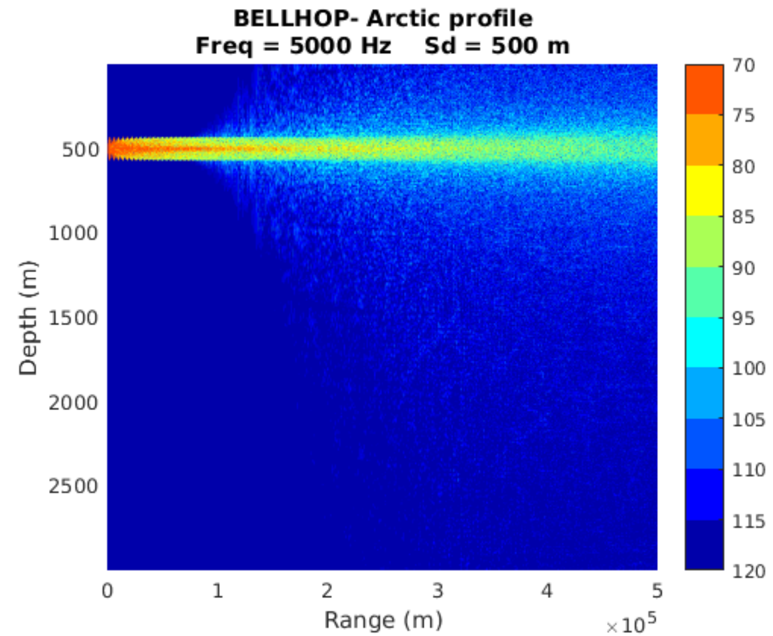


Propagation

Sound Speed Profile

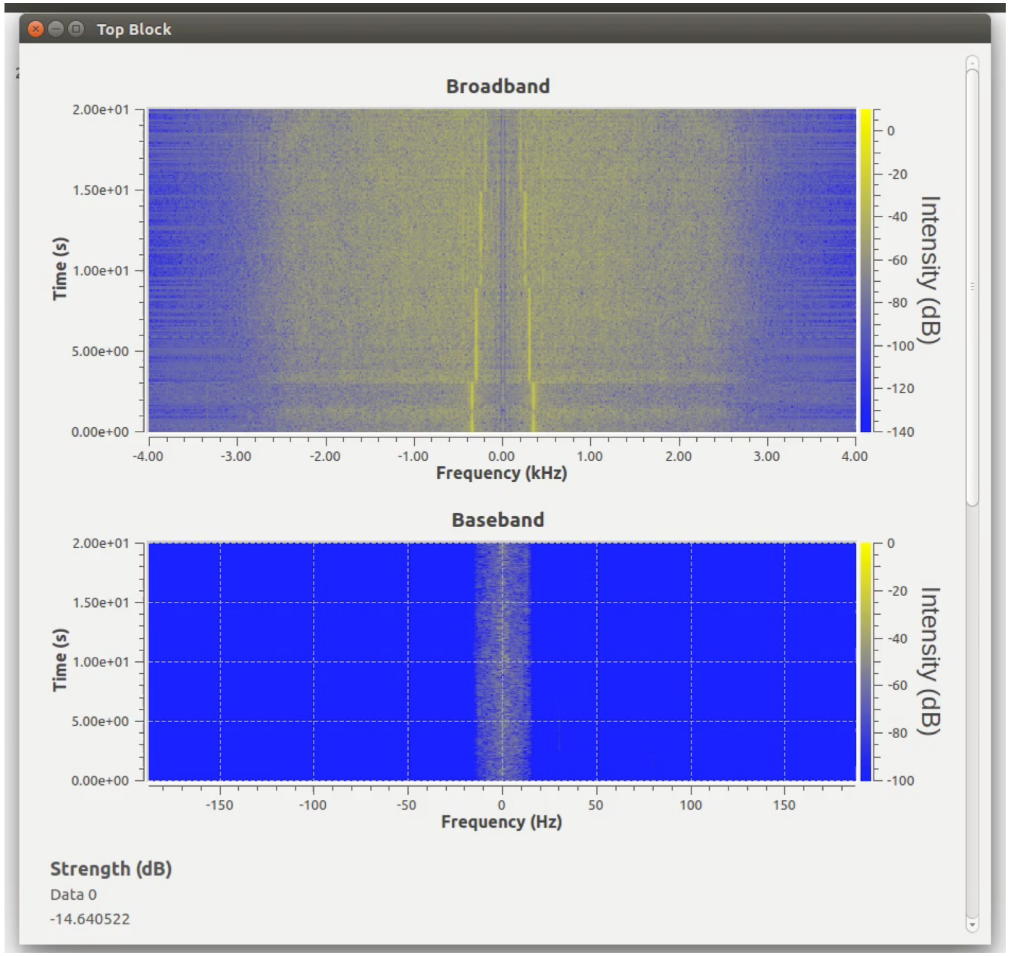


Waveguide: acoustic energy propagates without interaction with sea surface or sea bed



Open-water trial

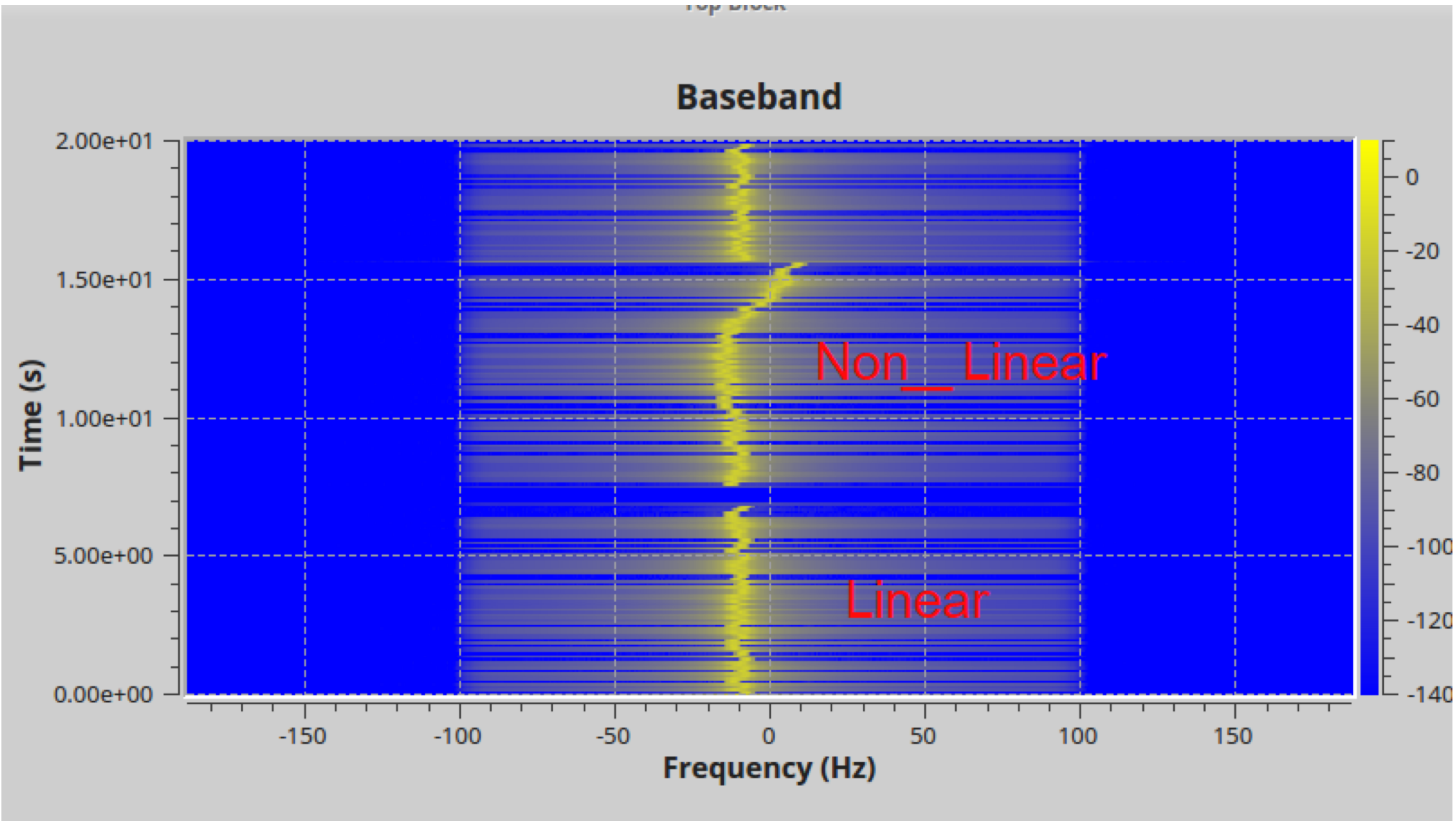
Noisy channel example (carrier @ 270 Hz)



Doppler effect

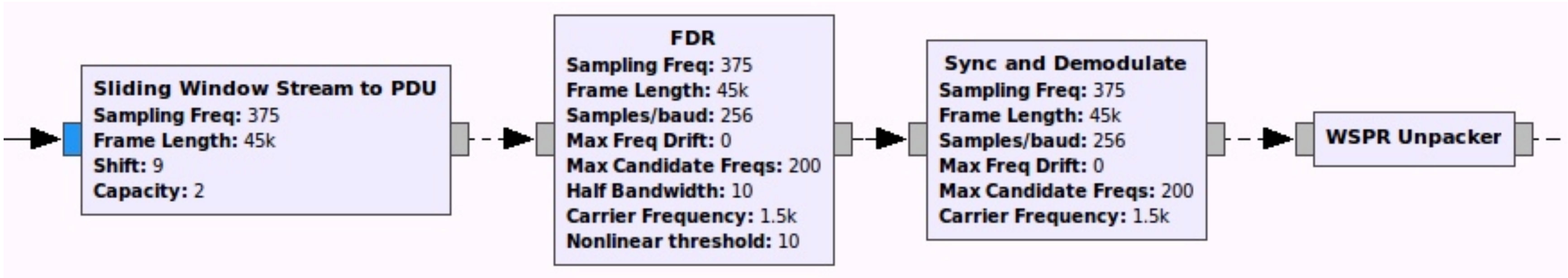
$$f_{\Delta}(t) = f_0 \frac{v(t)}{c} \text{ Hz}$$

Doppler effect on long-lasting frames

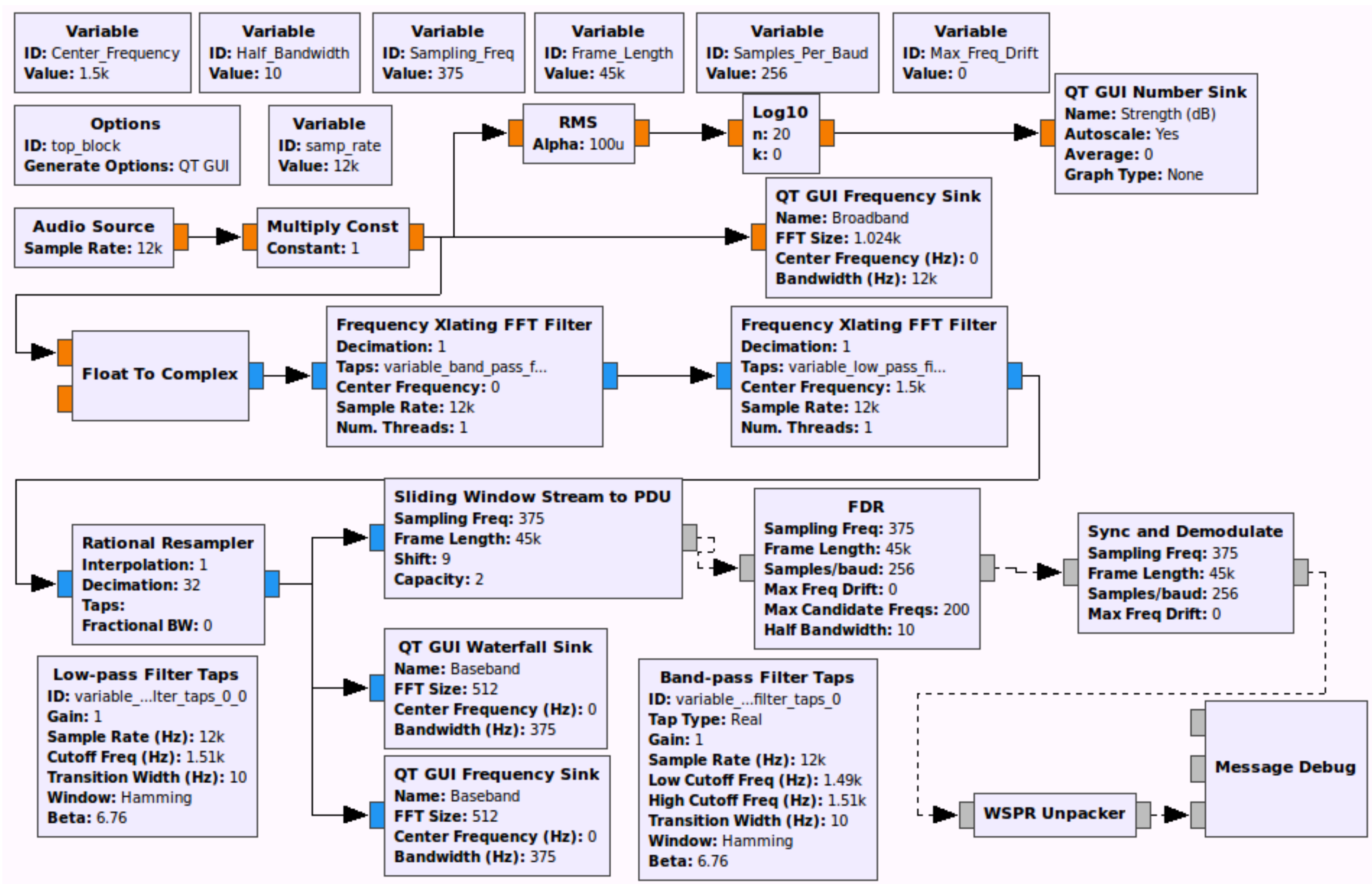


HIGH LEVEL DESIGN

New GNU Radio blocks



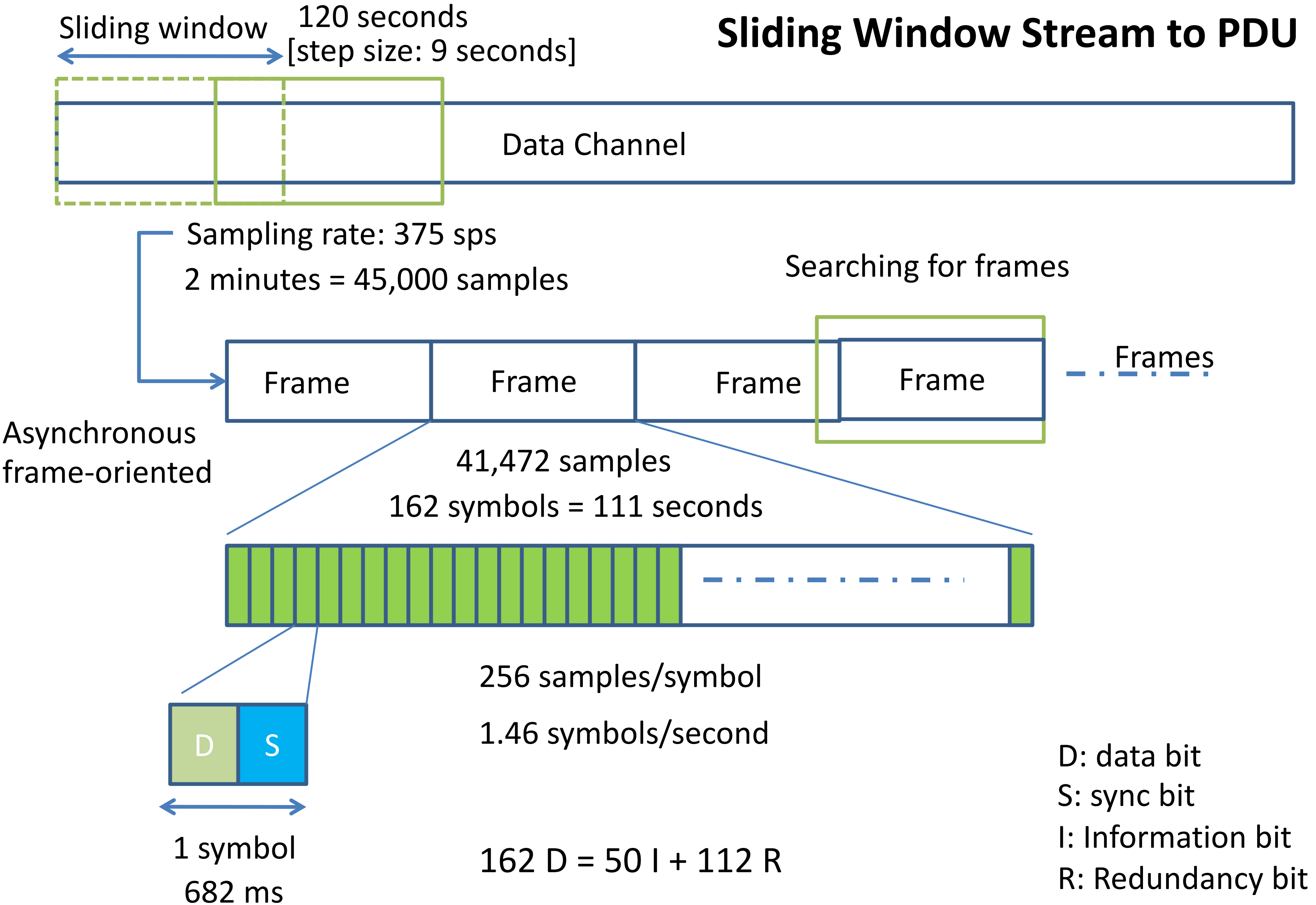
Flow graph of audio decoder



Protocol: Highlights

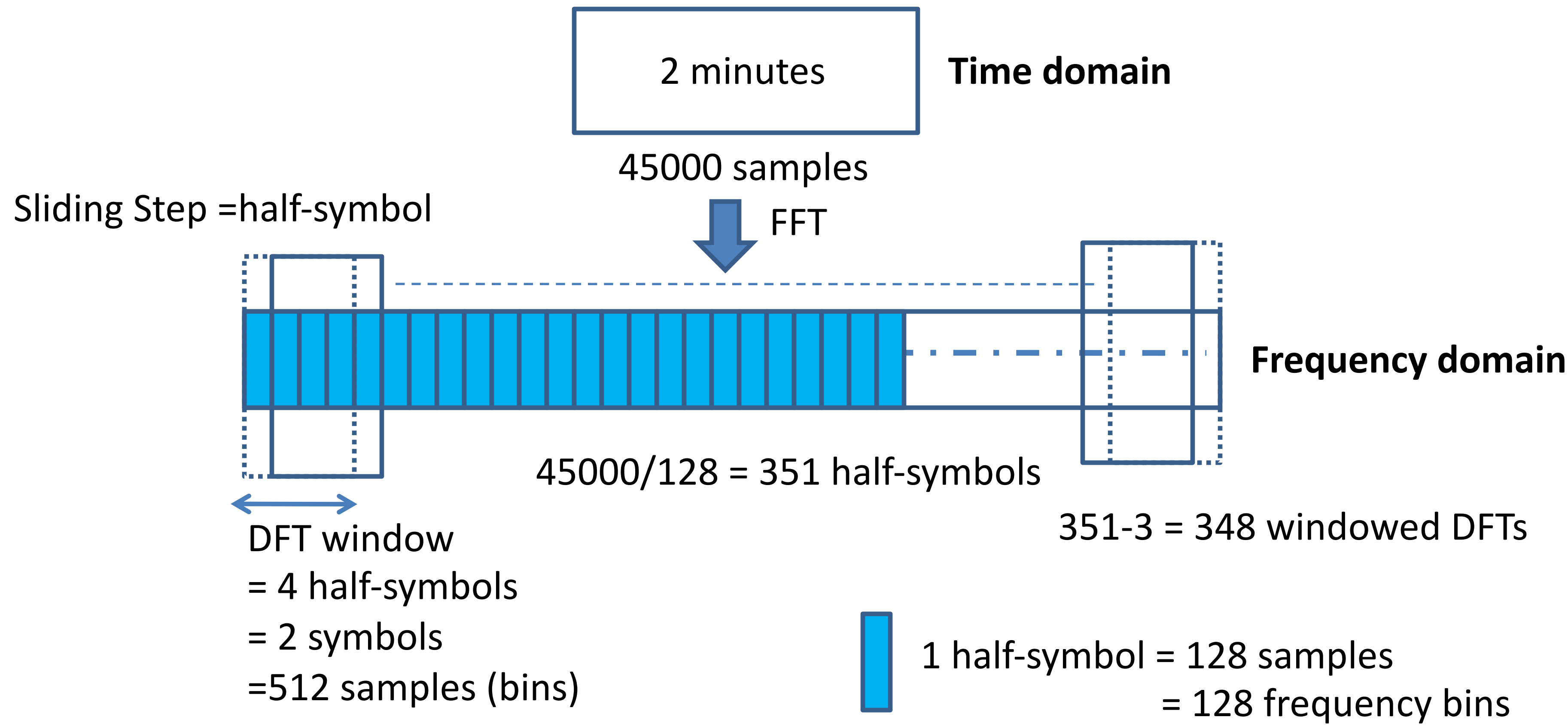
- 4-Frequency-shit keying modulation
- Narrow bandwidth (6 Hz)
- Convolutional FEC
  - 300% redundancy
  - Probabilistic decoding
- Built on [GNU Radio conf. ‘17]: only constant or linearly variable Doppler shifts
  - Doppler shift as a first degree polynomial
- <u>New extension: Nonlinearly variable Doppler shift</u>

Sliding Window Stream to PDU



Data rate = 50 bits / frame duration = 50 / 111 = 0.45 bps

FDR (Frequency Domain Representation)



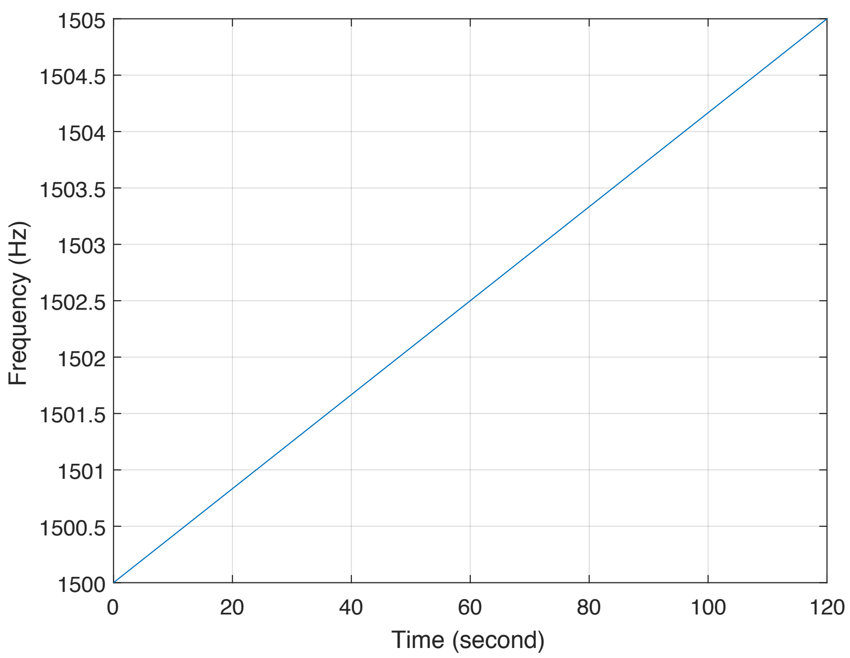
- A frequency becomes a candidate when there is a local SNR maximum.
- For each candidate frequency, measure the correlation of the spectrum power around frequency index with the sync bits.

Doppler effect (1)

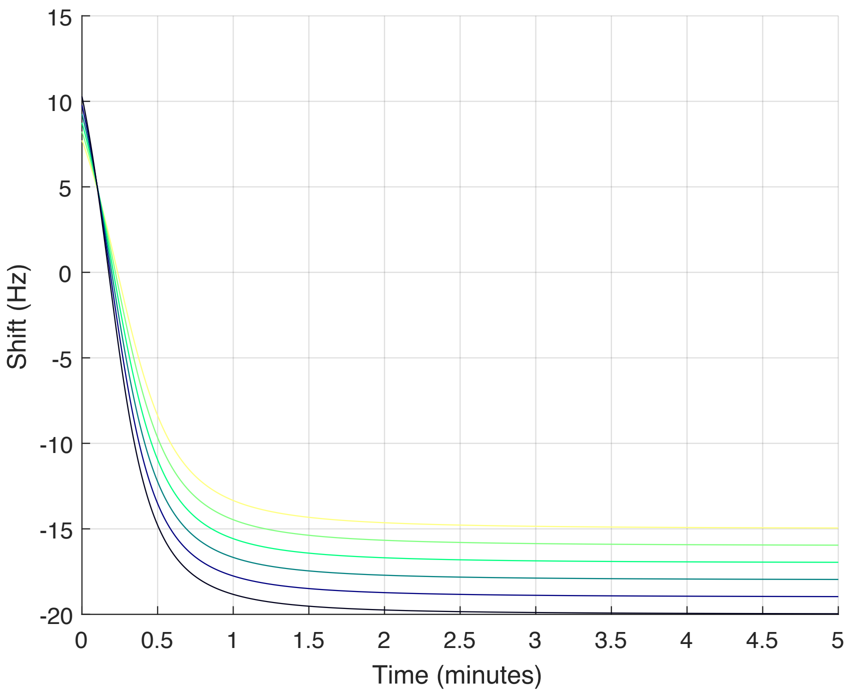
- Cause frequency drifts during frame reception
- Can be
  - Absent or constant
  - Variable: linearly or nonlinearly

Doppler effect (2)

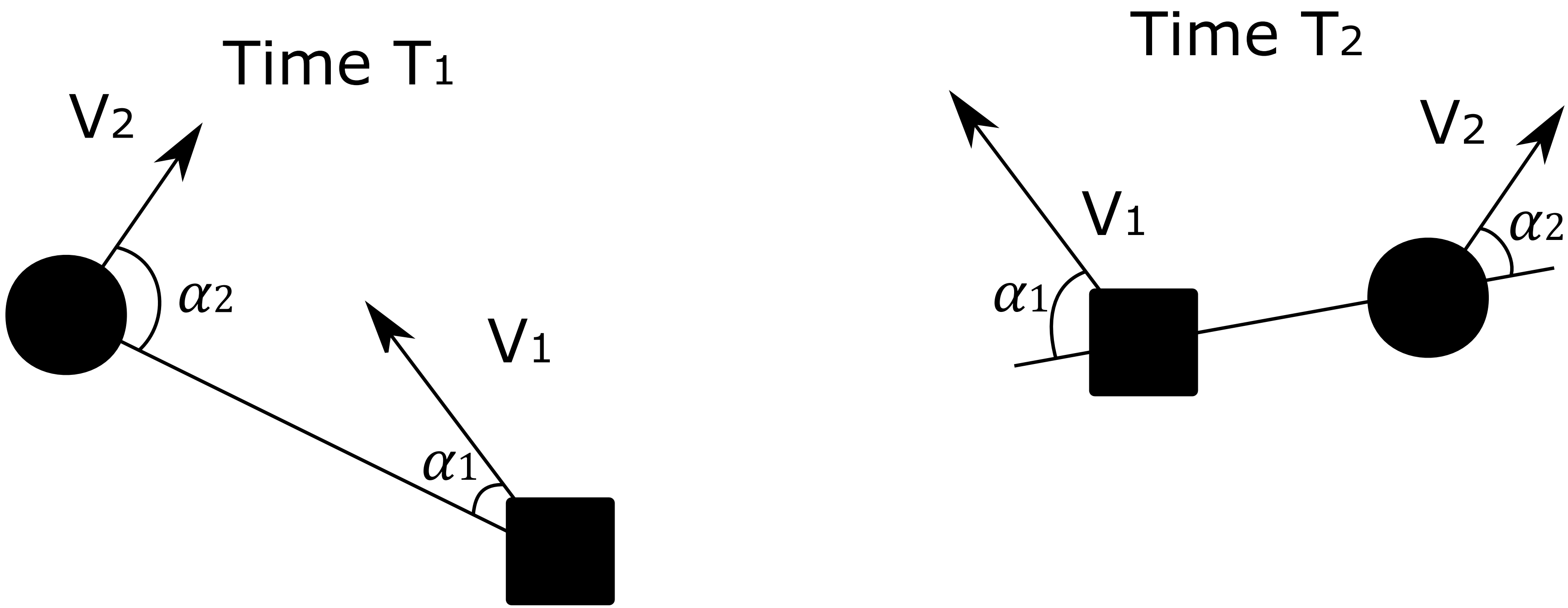
Linear



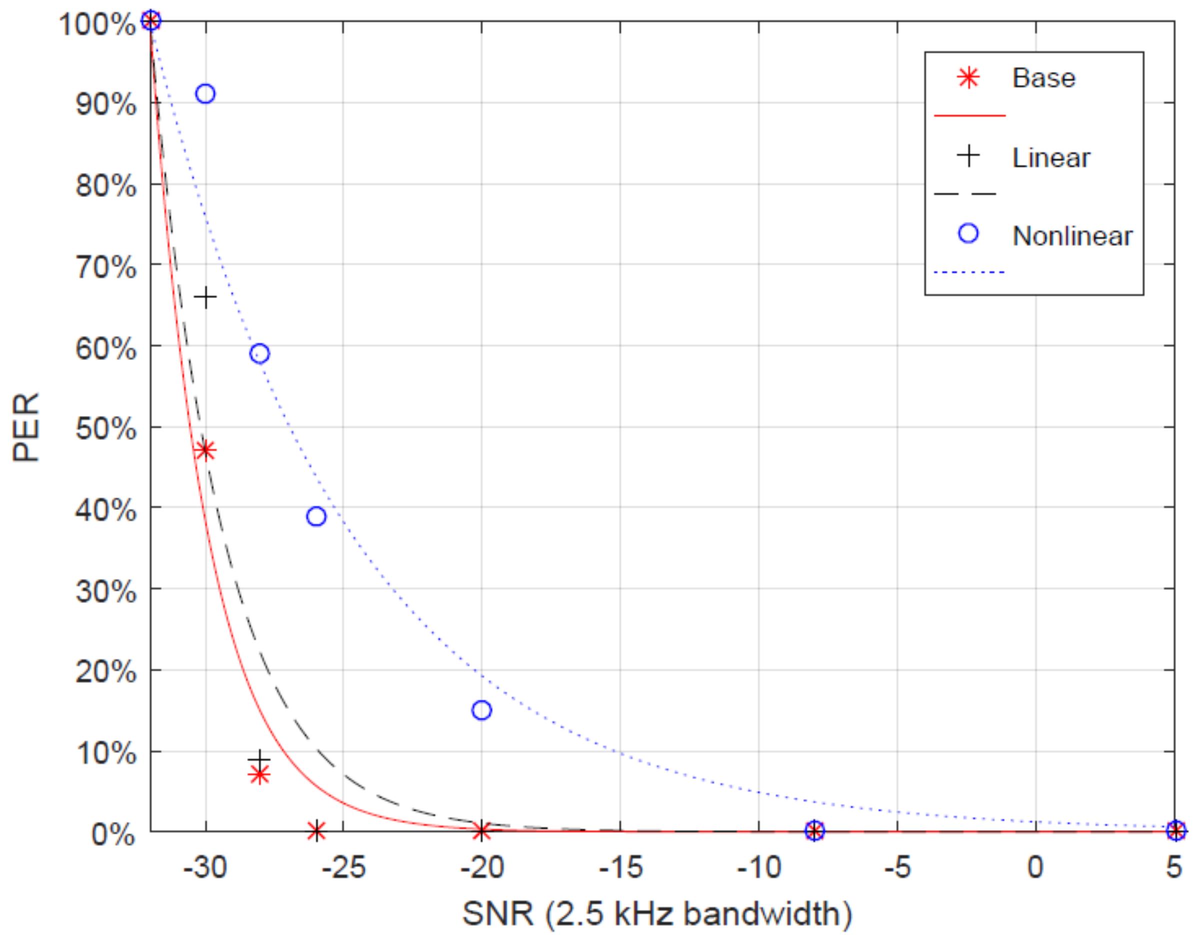
Nonlinear



Representation of trajectories



Performance: PER vs SNR



PER versus SNR for base case (no Doppler shift), linear Doppler shift case and nonlinear Doppler shift case.

Acknowledgements:

Evangelos Kranakis and Steven Porretta (Carleton University)
Stéphane Blouin (DRDC Atlantic Research Centre)

GitHub

https://github.com/michelbarbeau/gr-uwspr

THANK YOU!