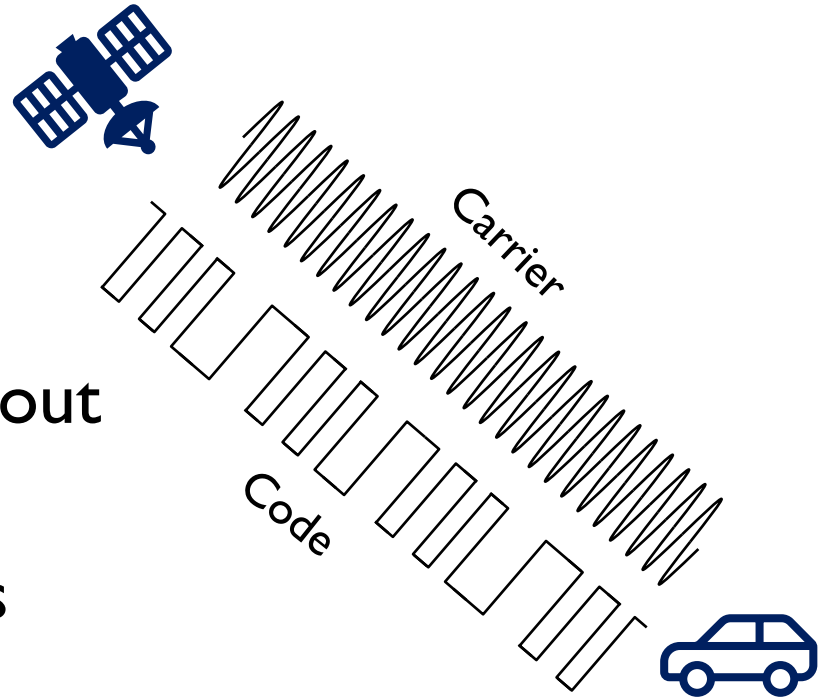


07: Signal Acquisition

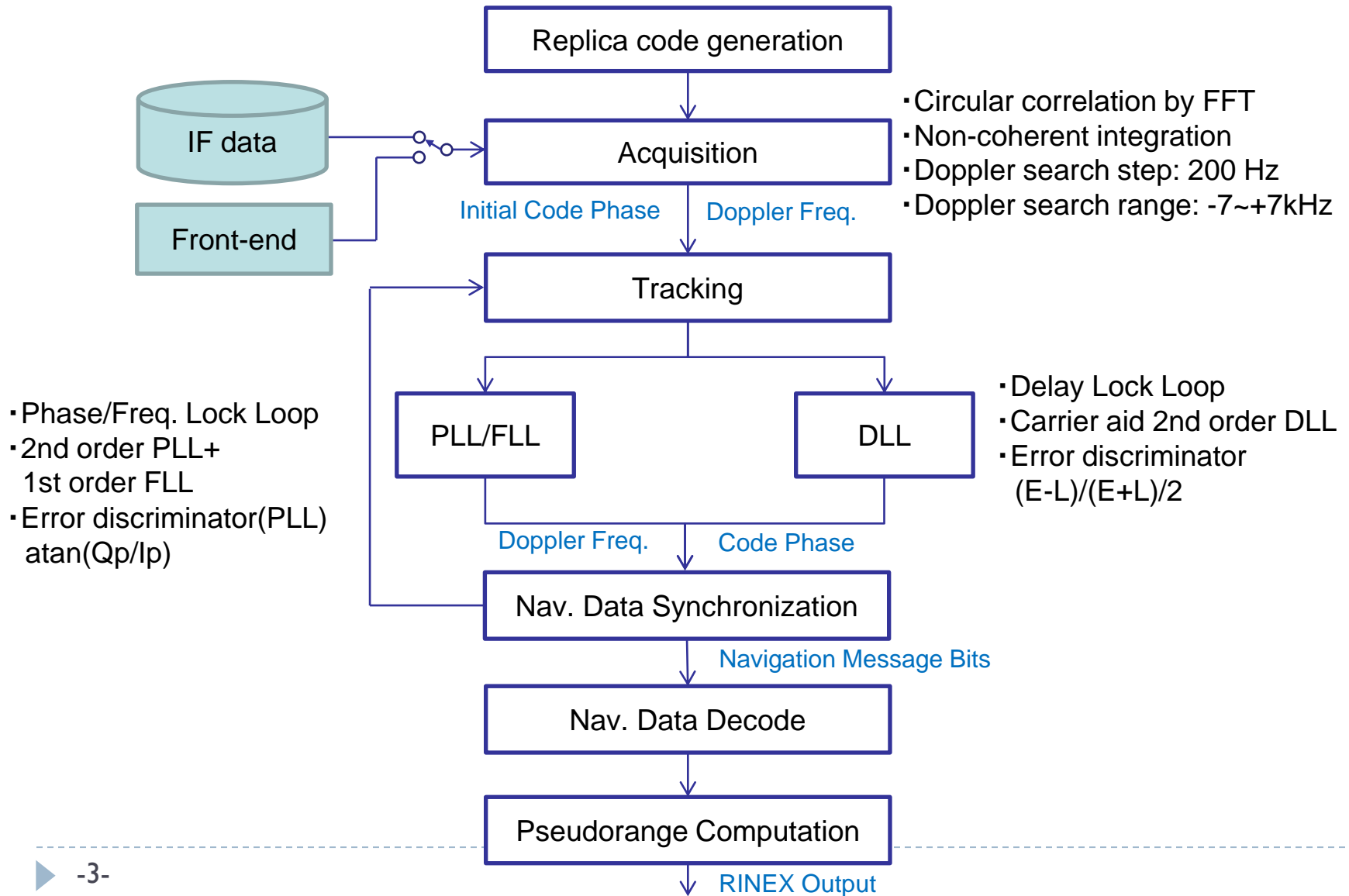
Taro Suzuki

Signal Acquisition

- ▶ Acquisition is to acquire the **approximate code-phase** and **Doppler frequency** of GNSS signals
- ▶ Tracking stage is difficult without acquisition information
- ▶ GNSS signal processing starts with signal acquisition

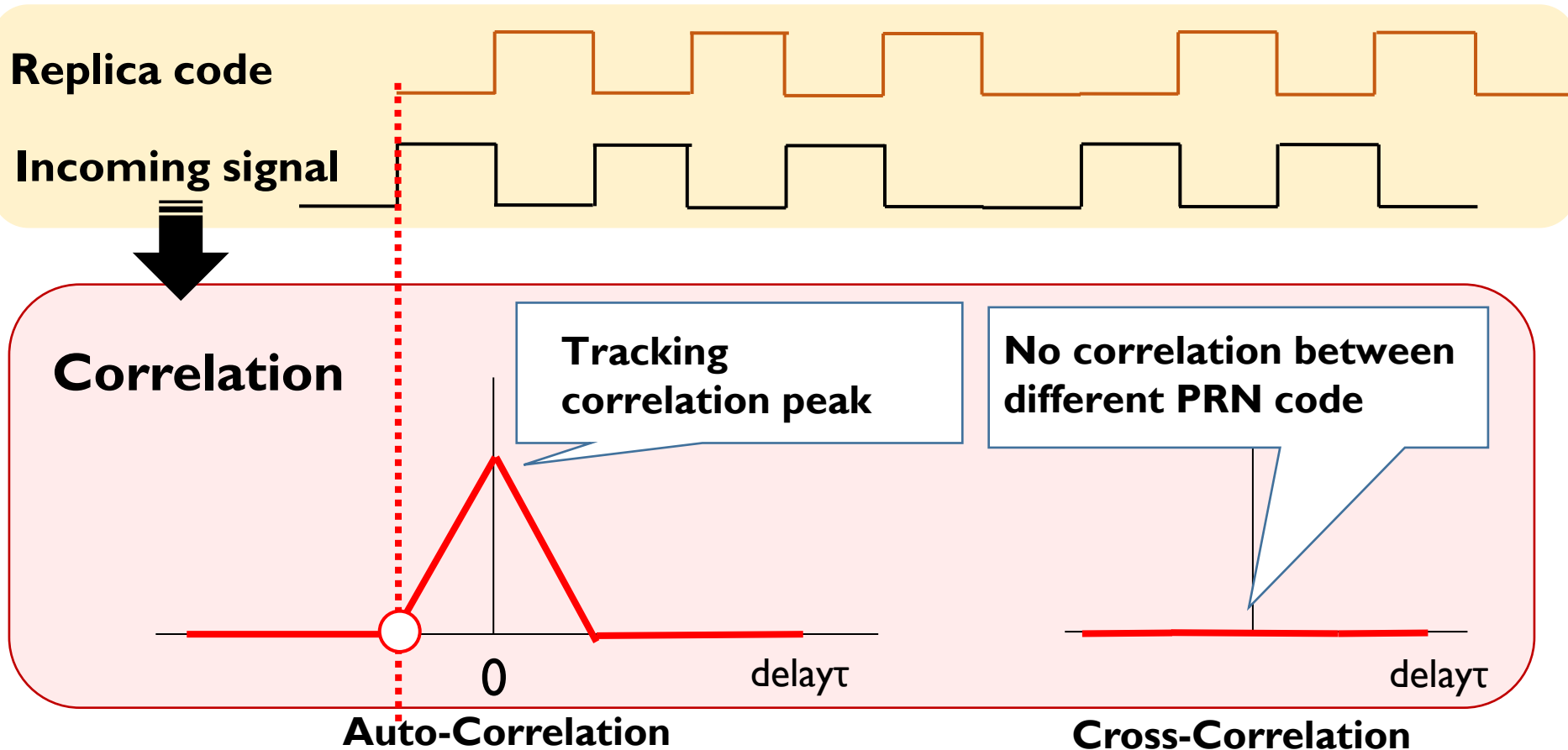


GNSS Signal Processing



GNSS Signal Correlation

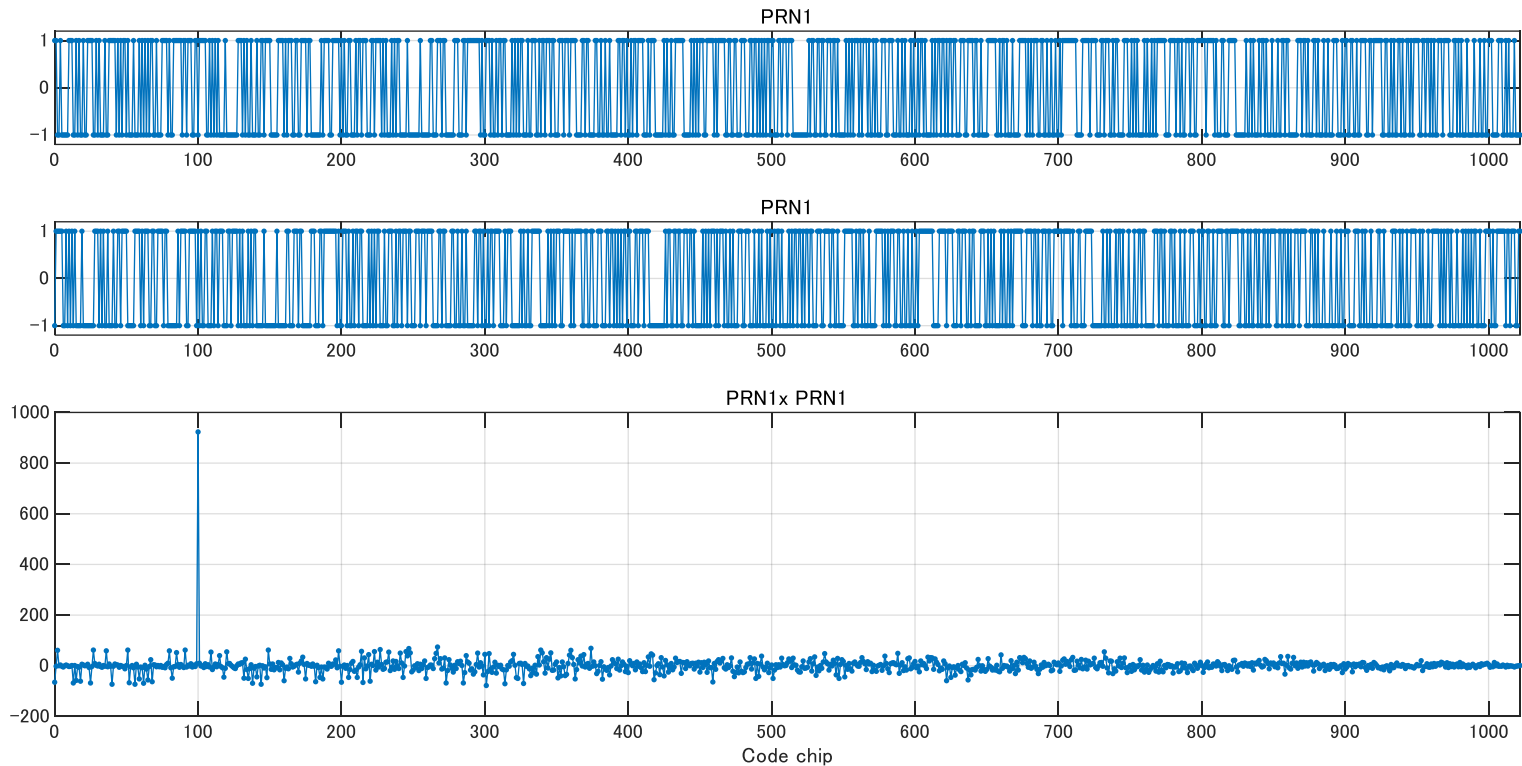
- ① Replica PRN code generation
- ② Correlation between replica code and incoming signal



Exercise 1: Auto/Cross-Correlation

▶ MATLAB

▶ /07_Signal_Acquisition/matlab/Ex1_run_correlation.m



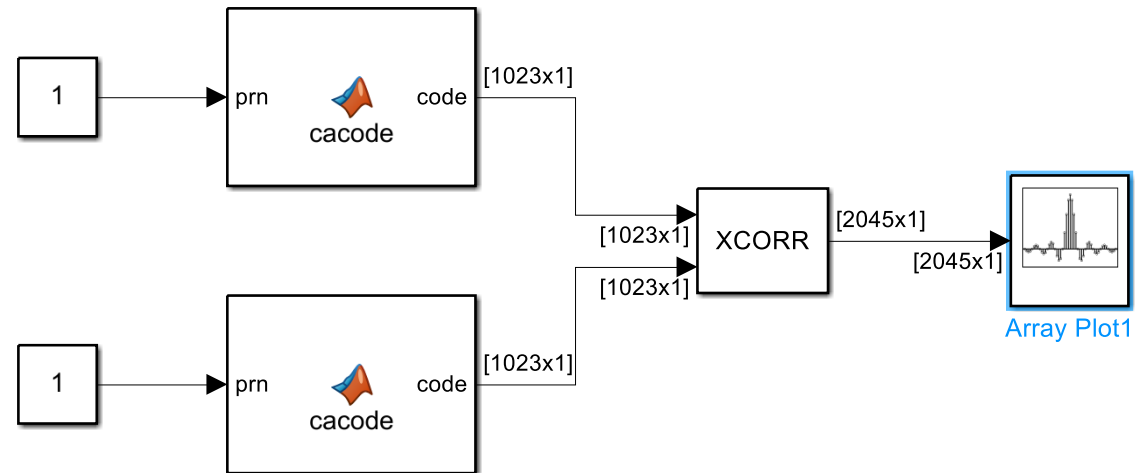
Exercise 2: Auto/Cross-Correlation

▶ Simulink

- ▶ /07_Signal_Acquisition/simulink/Ex2/correlation.slx

▶ Blocks

- ▶ MATLAB Function
- ▶ Constant
- ▶ Correlation
- ▶ Array Plot

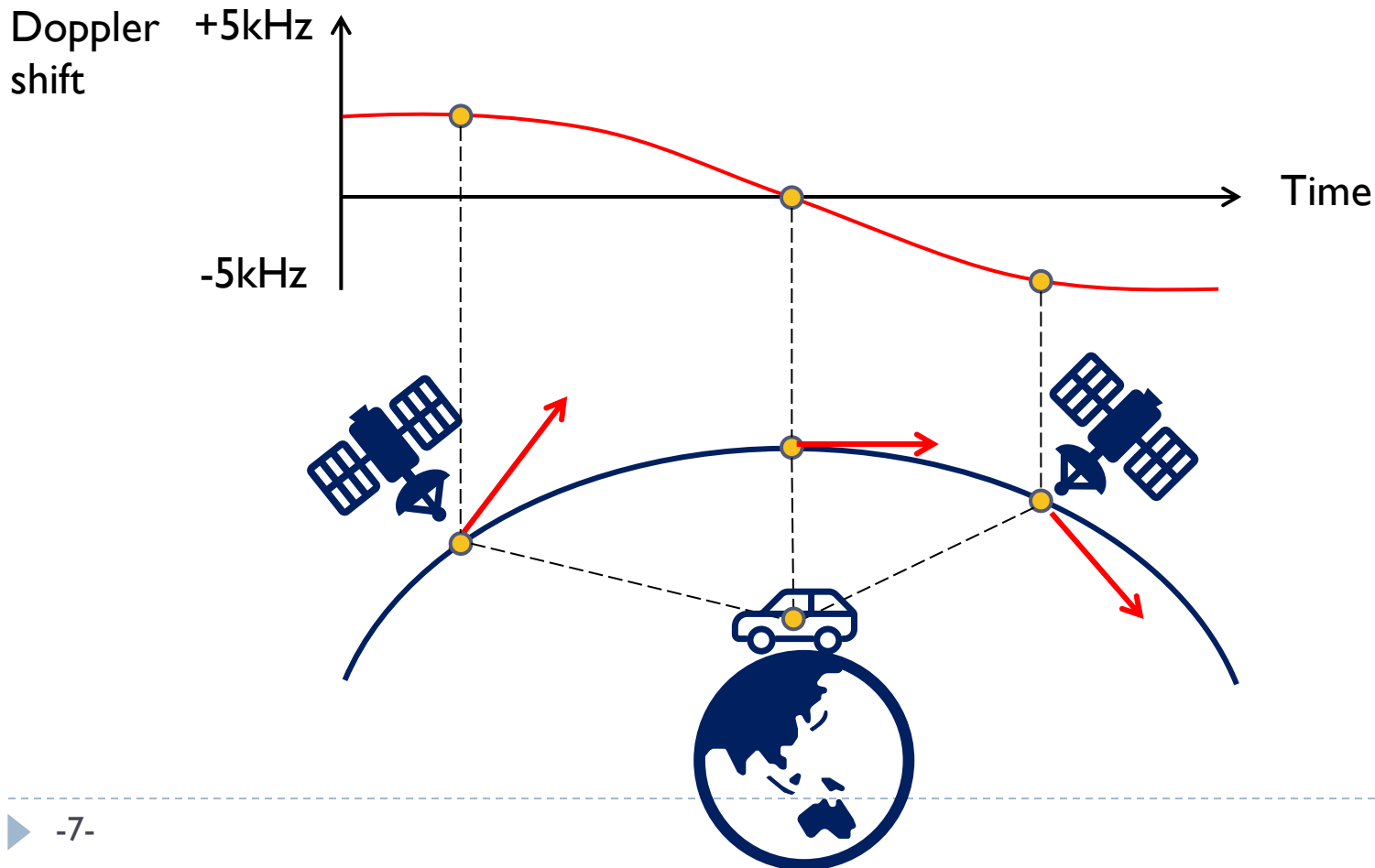


▶ Advanced challenge

- ▶ Try reversing the sign of the code using Gain
- ▶ Magnitude of correlation outputs using Magnitude Squared
- ▶ Trim cross-correlation output using MATLAB Function

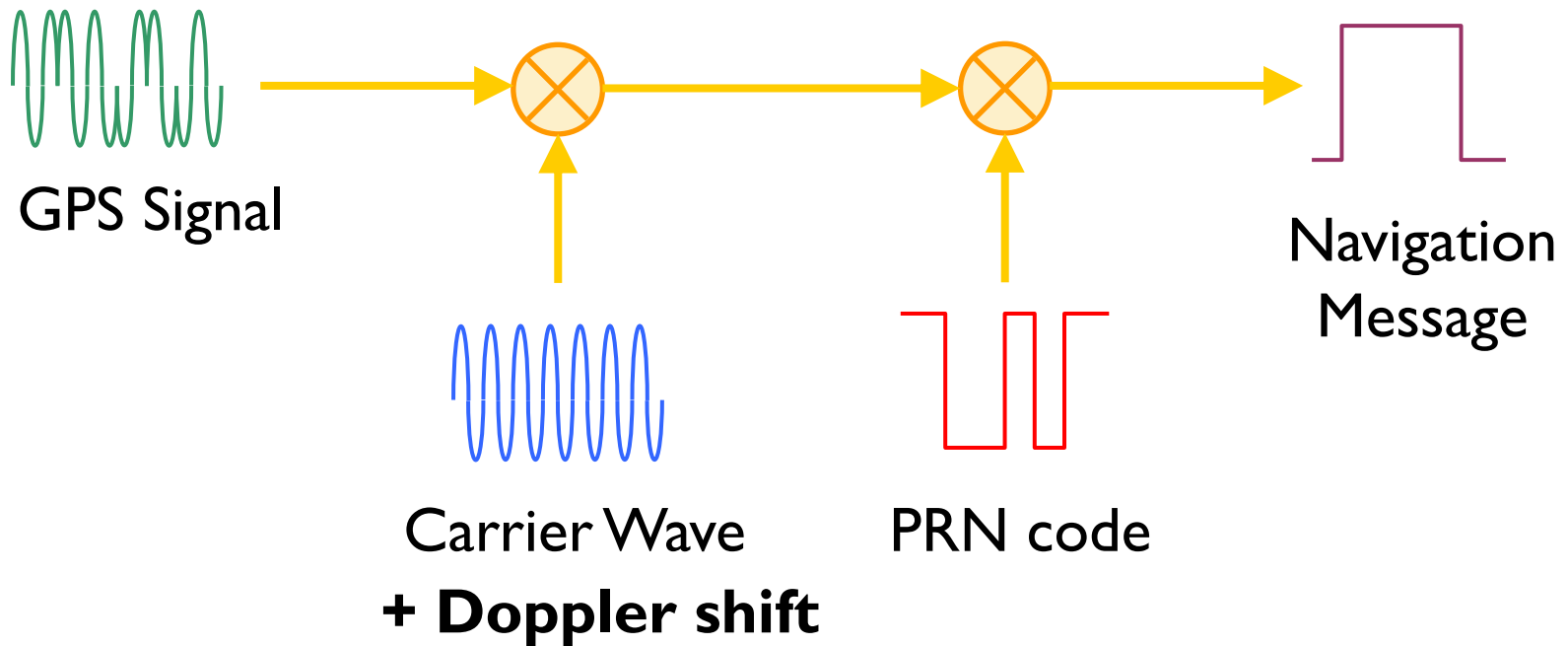
Doppler Frequency Shift

- ▶ Doppler frequency shift of approximately $\pm 5\text{kHz}$ occurs
 - ▶ Satellite motion, Receiver motion, Satellite clock drift



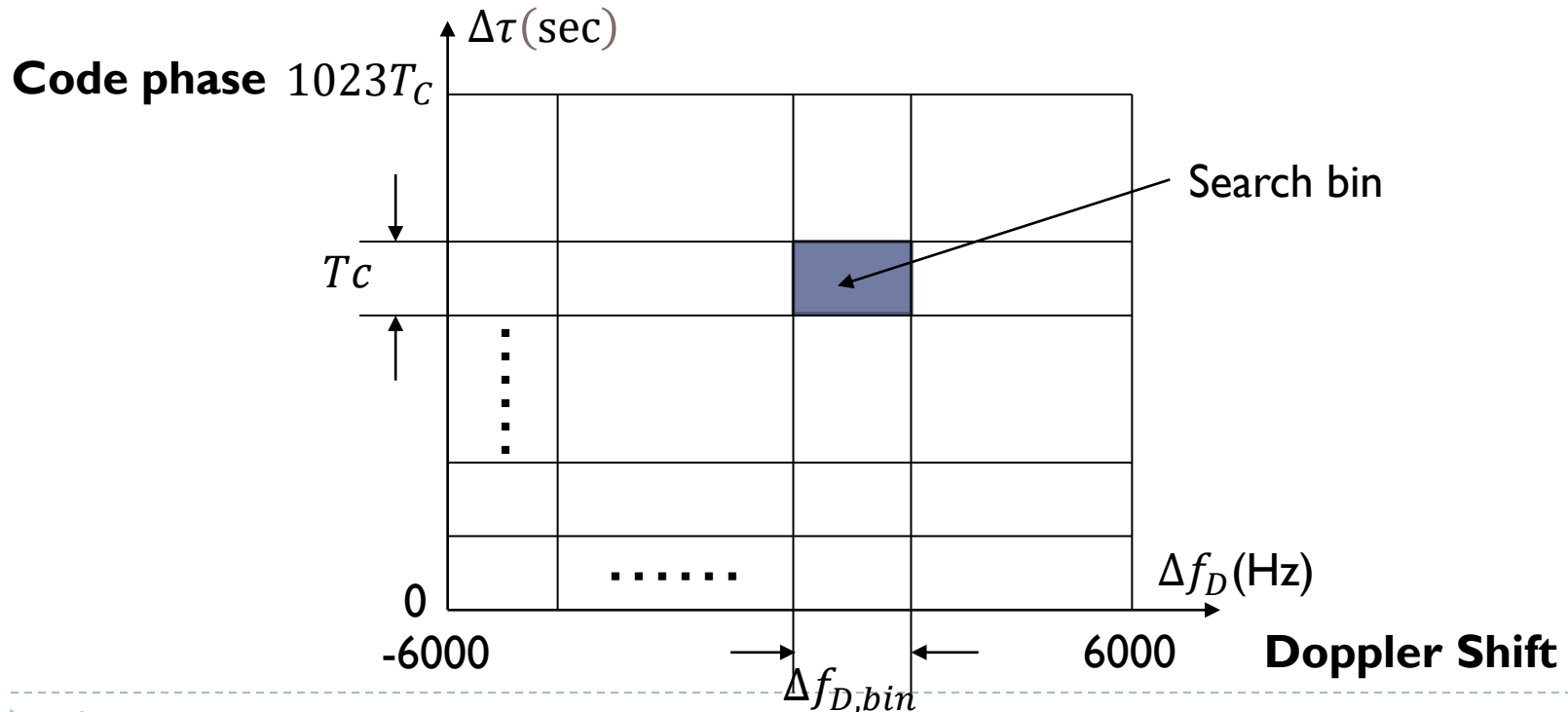
Carrier Wipe-off

- ▶ First carrier wipe-off and then correlate with the code
- ▶ Carrier contains **Doppler frequency shift**



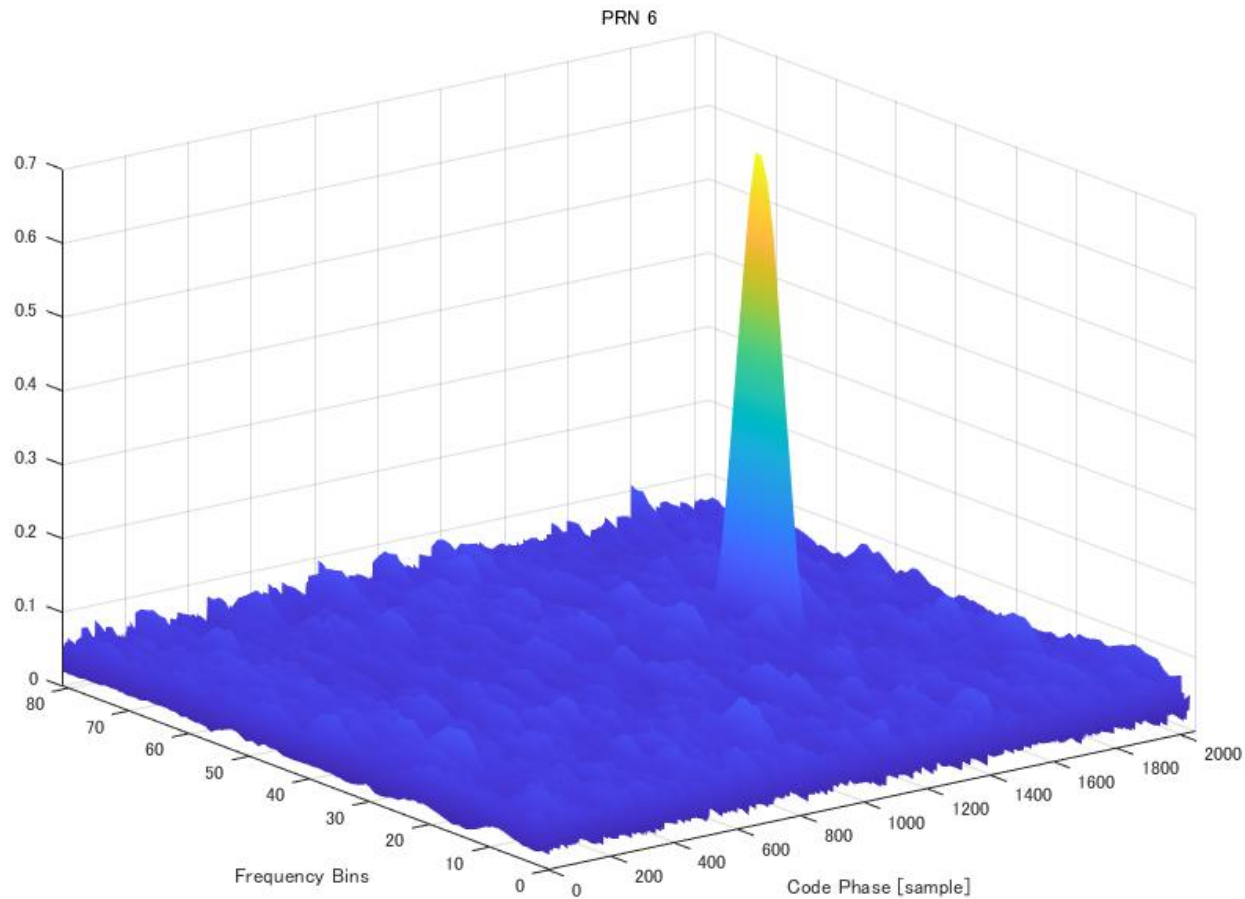
2D Search for Code Phase and Doppler

- ▶ Two things need to be estimated:
 - ▶ **Doppler frequency shift** and **code phase**
- ▶ High **autocorrelation** are obtained at the correct code phase and Doppler shift



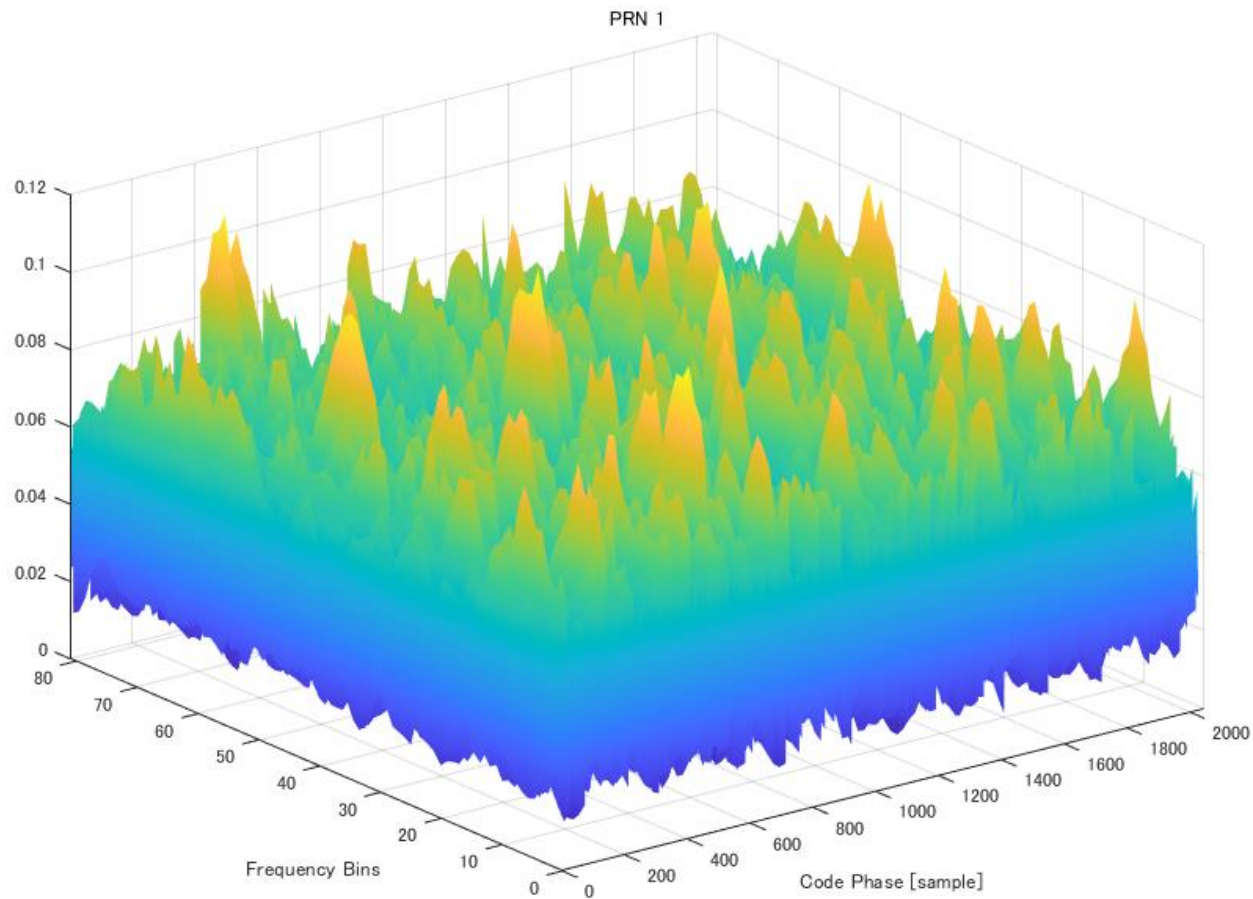
Example of Signal Acquisition (1)

▶ Auto-correlation



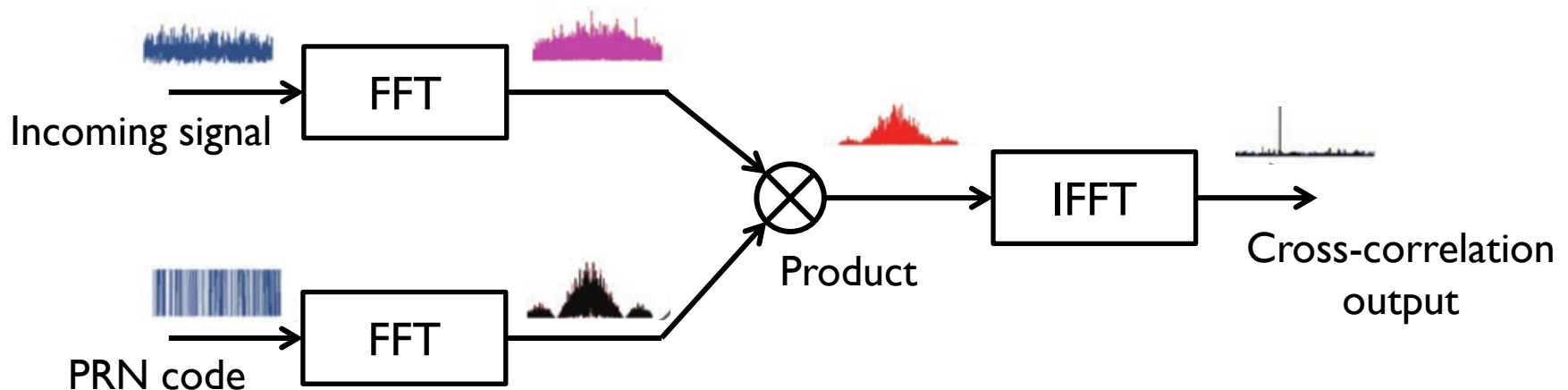
Example of Signal Acquisition (2)

► Cross-correlation

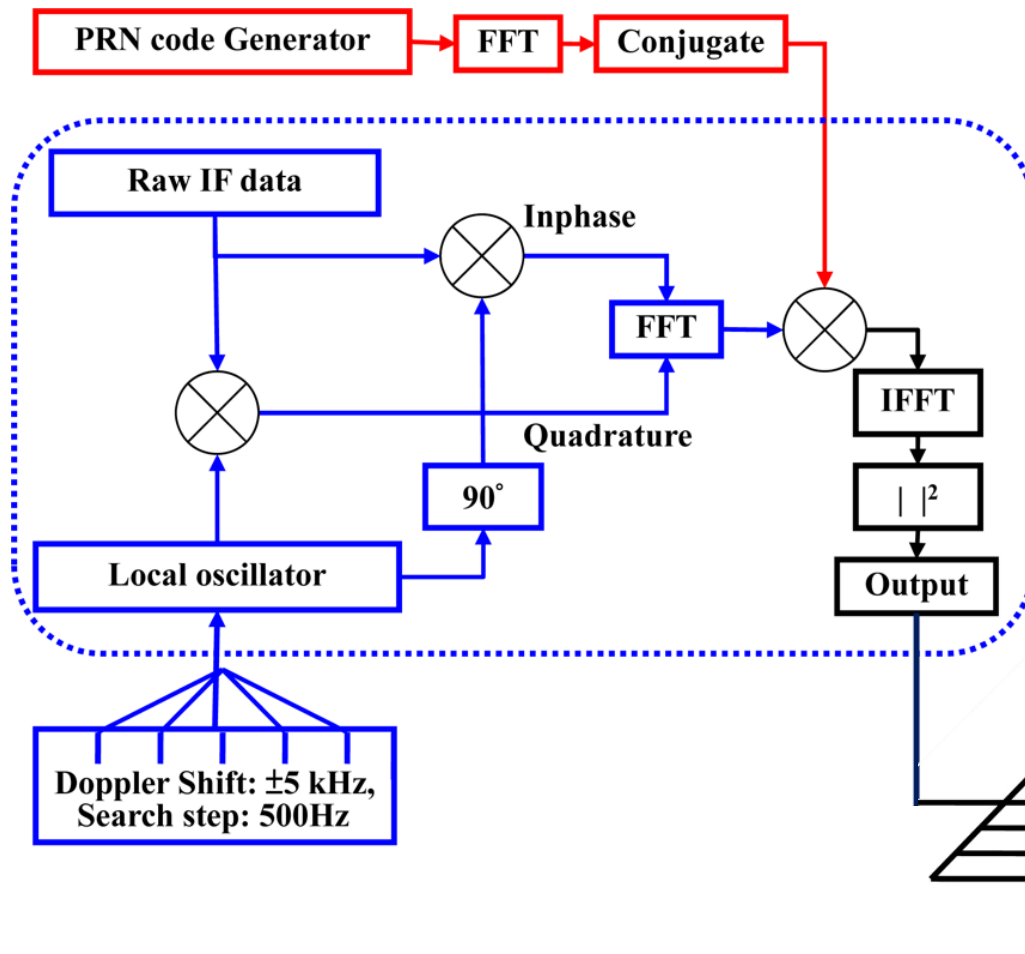


FFT-based Correlation (1)

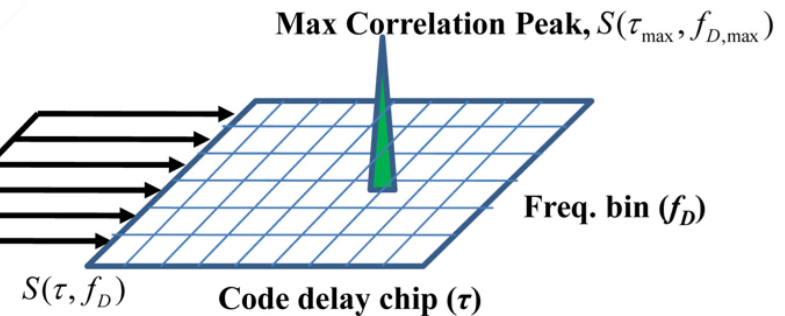
- ▶ Circular correlation / Parallel search
- ▶ Depending on the data size, it is possible to compute cross-correlation quickly and efficiently
- ▶ Suitable for software receivers



FFT-based Correlation (2)

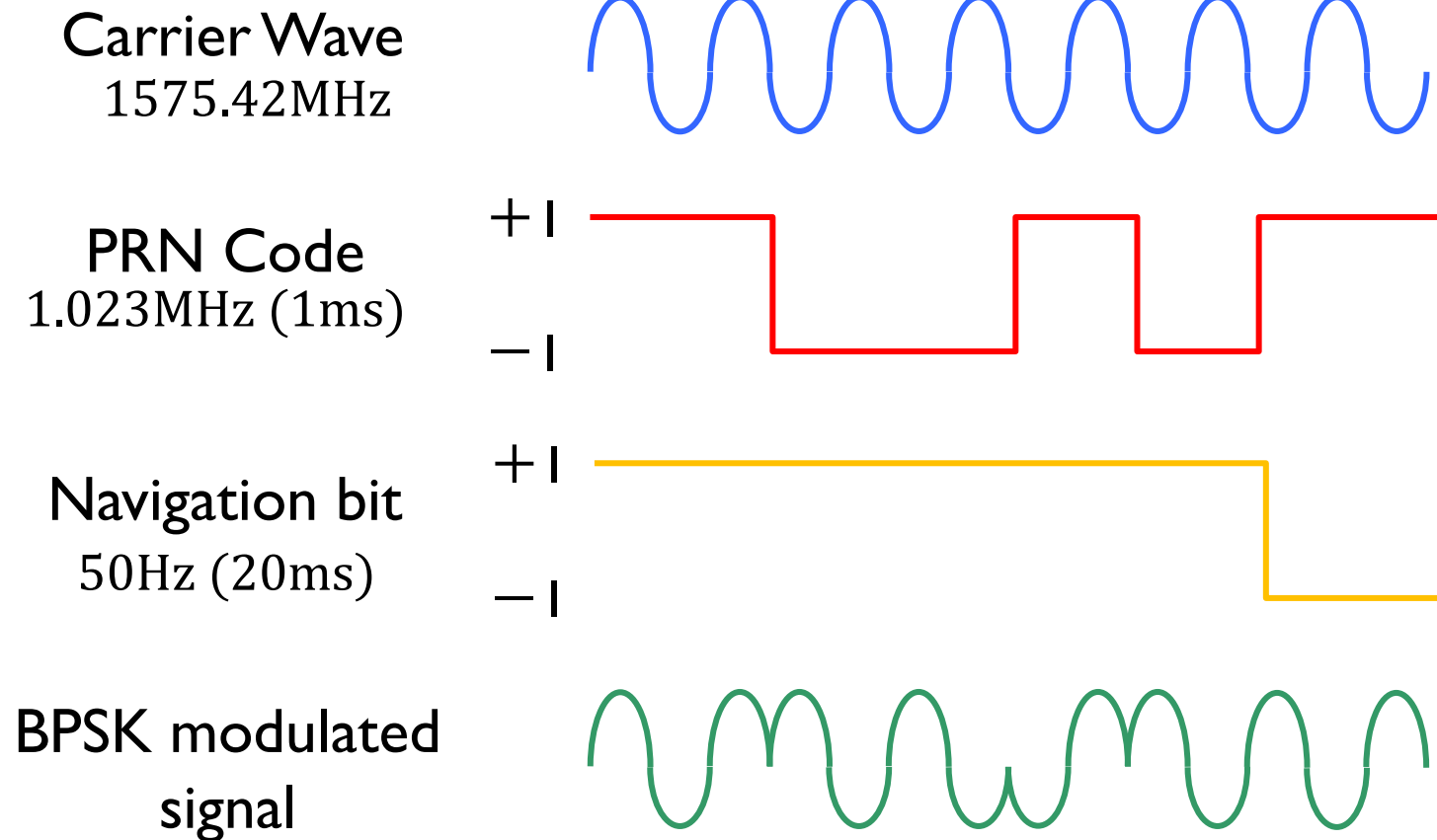


- ▶ One-dimensional search for Doppler frequency
- ▶ Carrier wipe-off
- ▶ Search Doppler frequency and code phase at peak

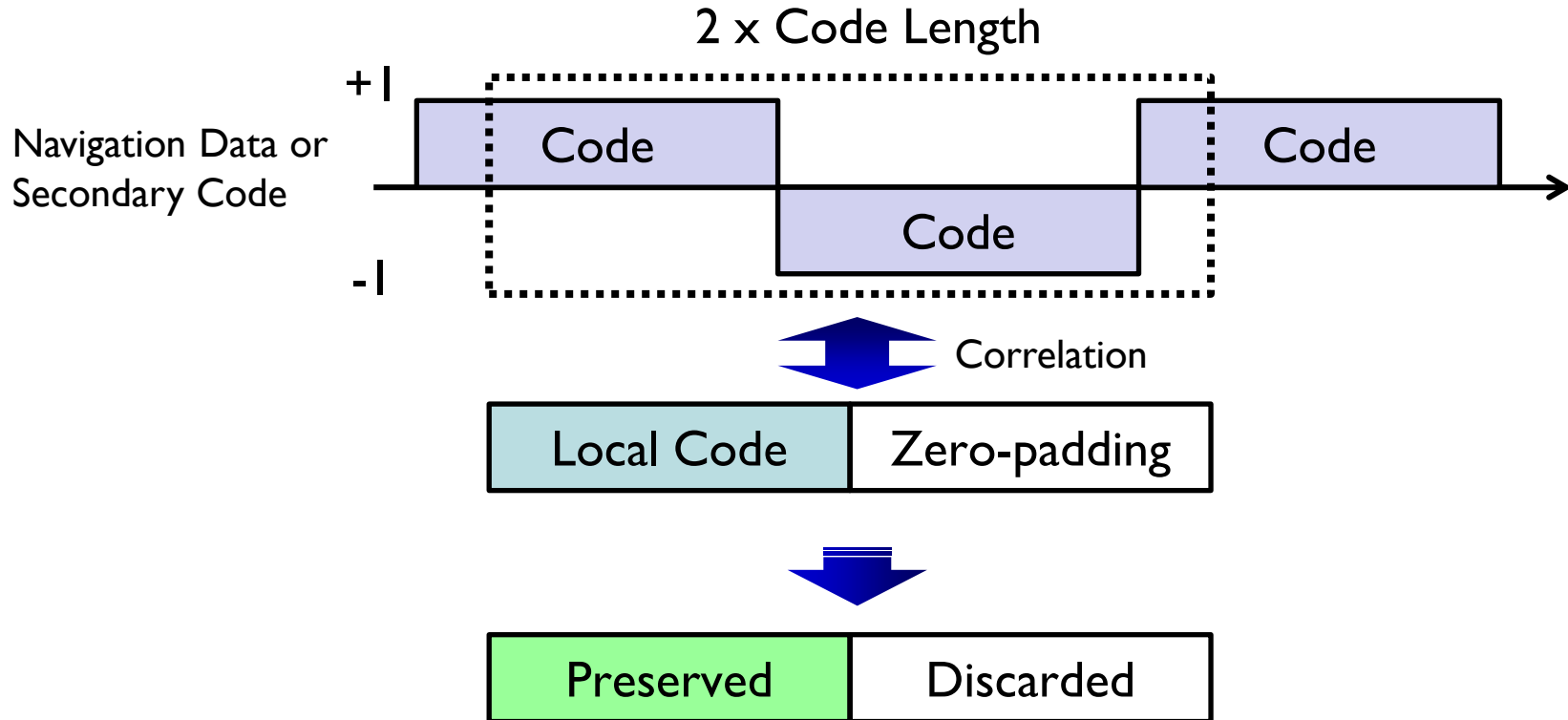


Navigation Bit Effect

- ▶ Phase changes with navigation data bits



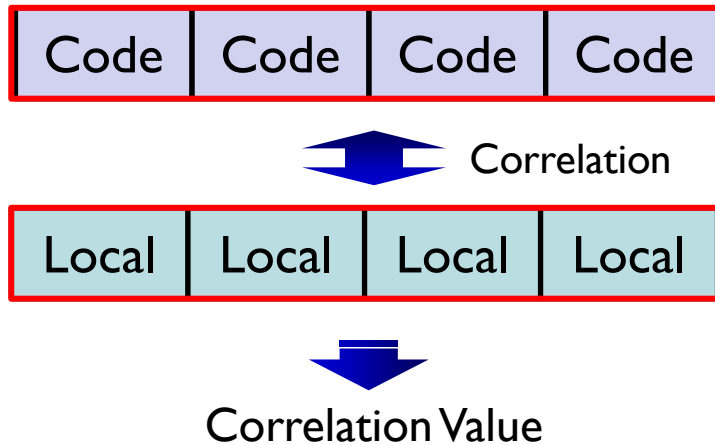
Zero-Padding



- ▶ Perfect correlation can be obtained when navigation bit is changed
- ▶ Computational cost is doubled

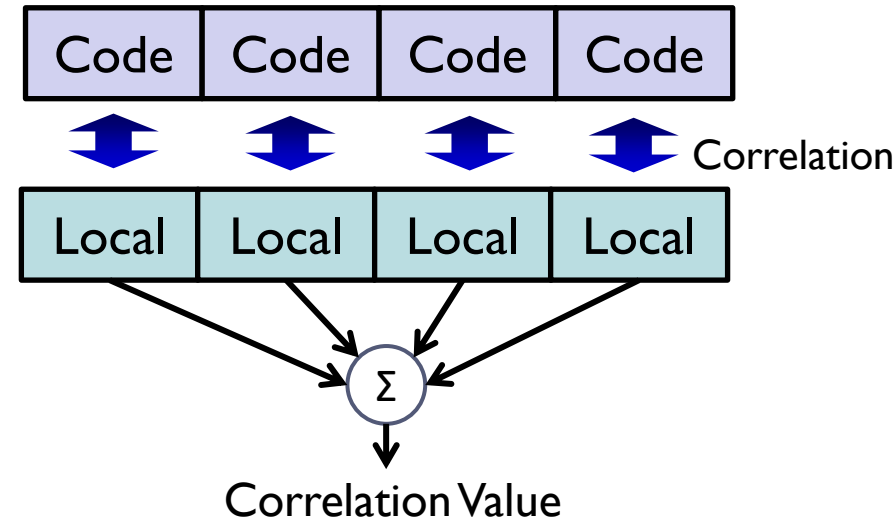
Integration

Coherent Integration



- ▶ The coherent integration is a bandpass process
- ▶ Coherent integration increases sensitivity
- ▶ Navigation bit problem

Non-Coherent Integration

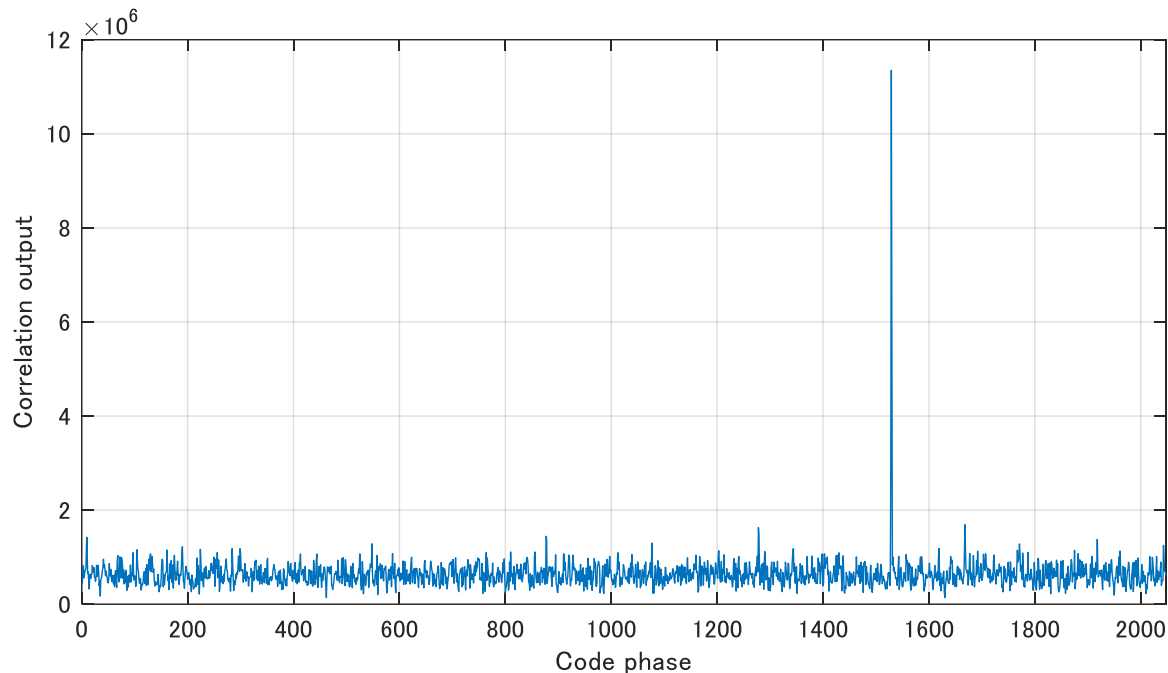


- ▶ Less sensitivity because of square loss
- ▶ Minimal effect on the phase of the navigation data bits

Exercise 3: Signal Acquisition

▶ MATLAB

- ▶ `/07_Signal_Acquisition/matlab/Ex3_run_acquisition_ID.m`
- ▶ Change integration time
- ▶ Change Doppler frequency



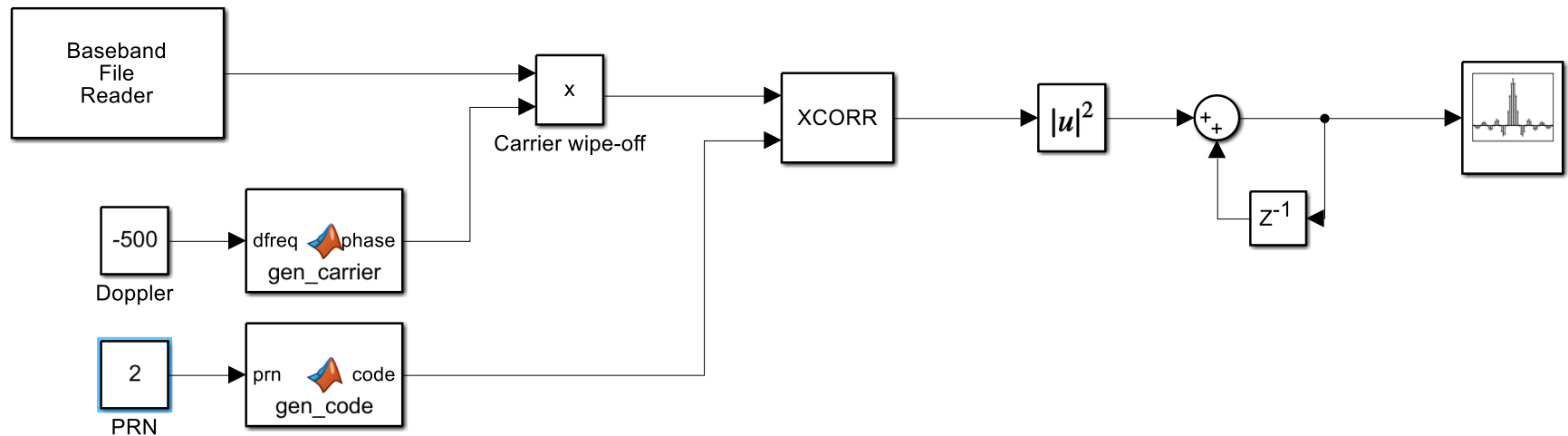
Exercise 4: Signal Acquisition

▶ Simulink

- ▶ /07_Signal_Acquisition/simulink/Ex4/acquisition_ID.slx

▶ Blocks

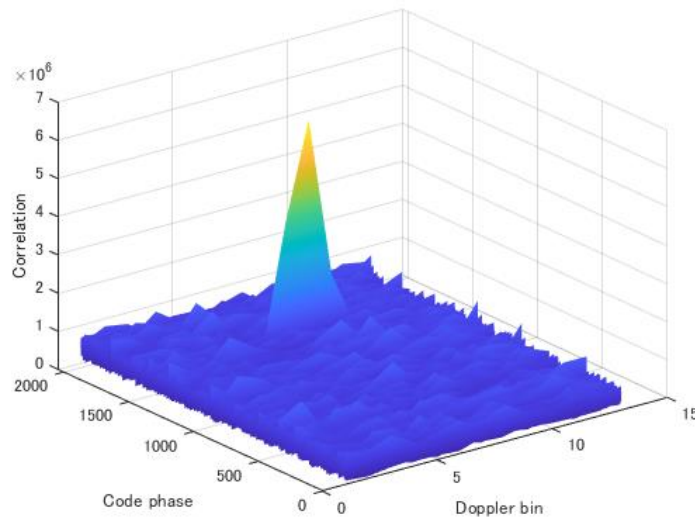
- ▶ Product, Sum, Delay



Exercise 5: Signal Acquisition

▶ MATLAB

- ▶ `/07_Signal_Acquisition/matlab/Ex5_run_acquisition_2D.m`
- ▶ Change Doppler search range/step



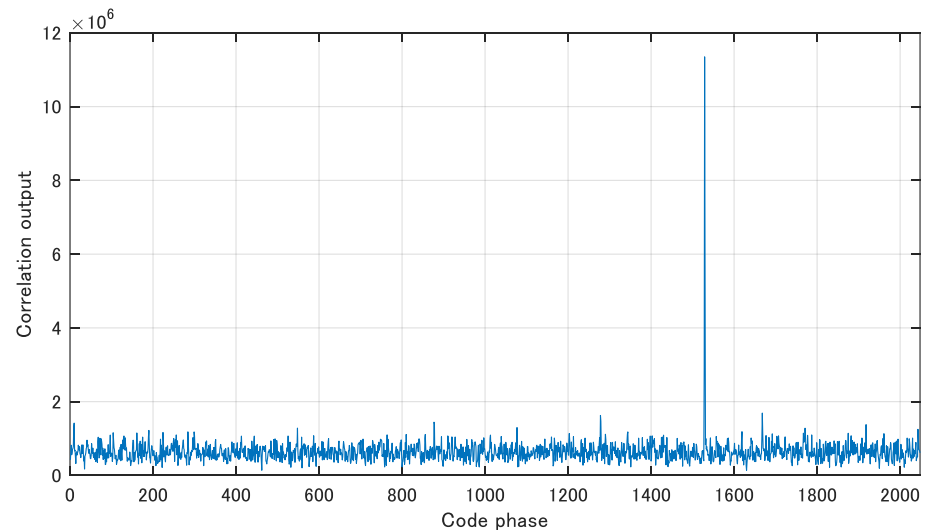
▶ Advanced challenge

- ▶ Try to acquired low-elevation satellite signal

Determination of Signal Acquisition

- ▶ In the case of a cold start, it must be determined whether the RF signal contains a certain satellite signal
- ▶ Signal acquisition (2-D search) to check for the presence of correlation peaks
- ▶ Ratio of peak to uncorrelated value

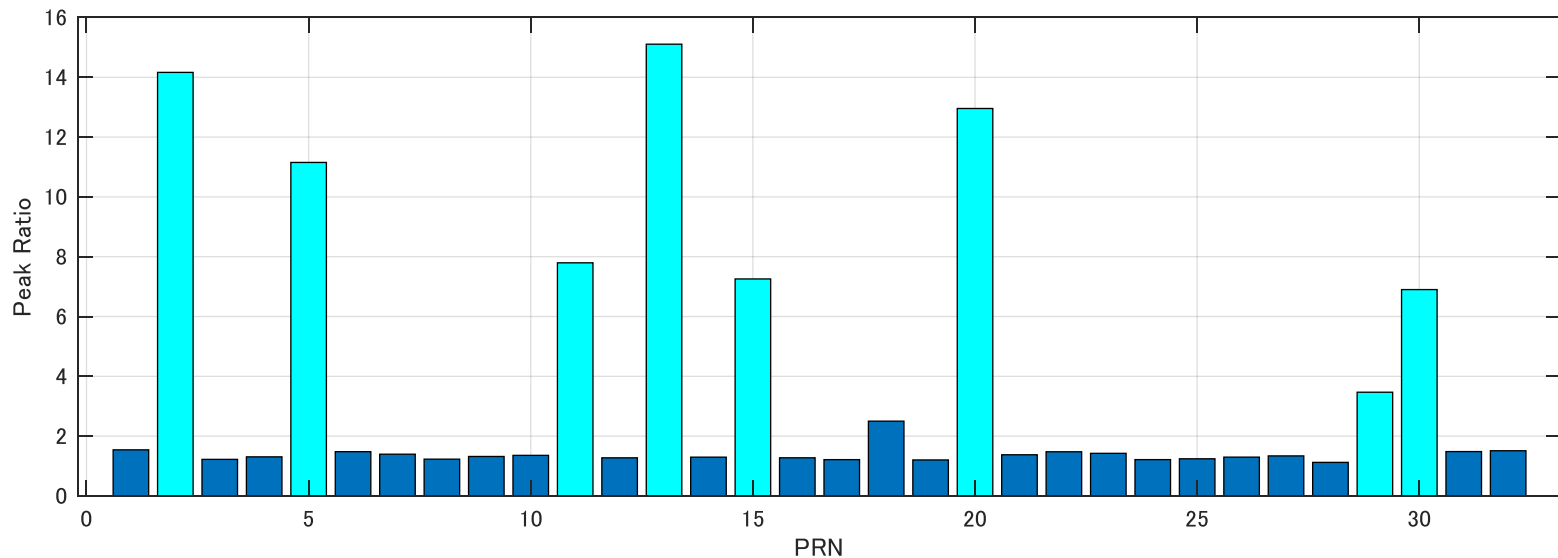
$$\eta = \frac{\text{corr}(\text{peak})}{\text{corr}(\text{uncorrelated})} > 3$$



Exercise 6: Signal Acquisition

▶ MATLAB

- ▶ `/07_Signal_Acquisition/matlab/Ex6_run_acquisition_2D.m`
- ▶ Two-dimensional search + Multiple PRN search
- ▶ Determination signal acquisition



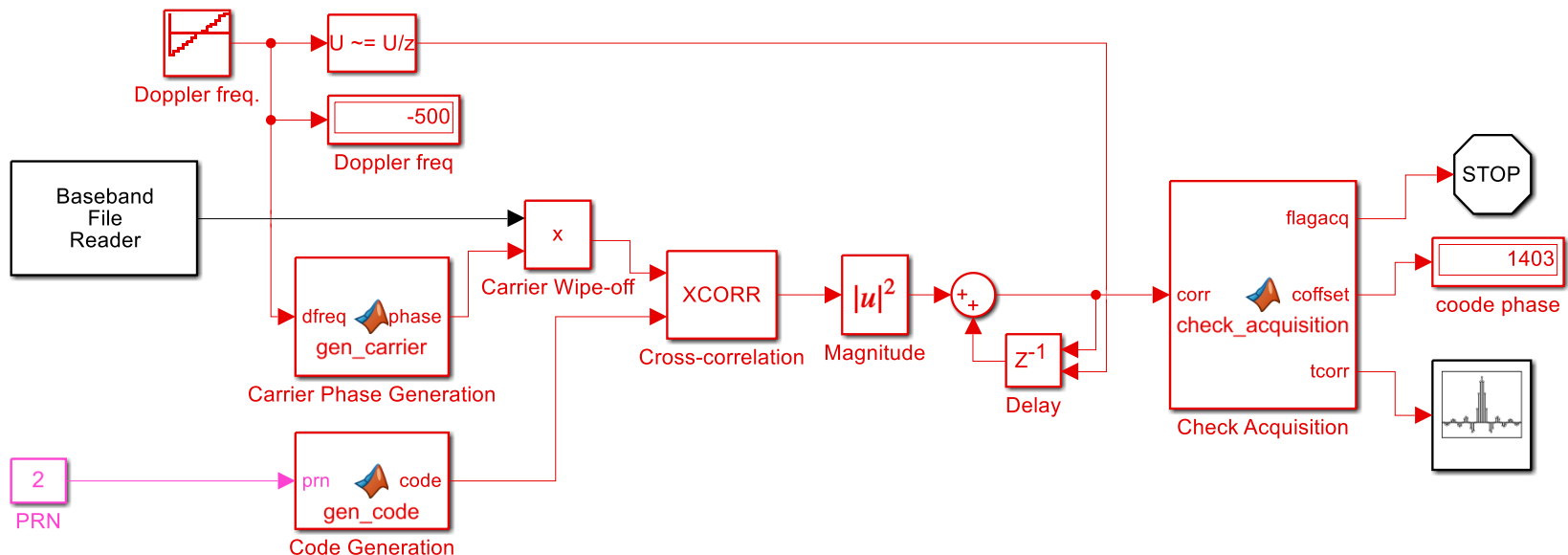
Exercise 7: Signal Acquisition

▶ Simulink

- ▶ /07_Signal_Acquisition/simulink/Ex7/correlation.slx
- ▶ Using parameter file

▶ Blocks

- ▶ Repeating Sequence Stair, Detect Change, Stop Simulation



Type of Acquisition

▶ Cold Start

- ▶ Start with no prior information whatsoever
- ▶ Signal acquisition of all satellites
- ▶ Decode navigation messages (minimum 30 seconds)

▶ Warm start

- ▶ GNSS device remembers last position, almanac, and time
- ▶ Not which satellites were in view
- ▶ Decode navigation messages (minimum 30 seconds)

▶ Reacquisition / Hot start

- ▶ Signal tracking has gone off
- ▶ Initial Doppler frequency and code phase are estimated

Signal Re-acquisition

- ▶ One satellite is temporarily blocked by an obstacle
 - ▶ Signal tracking is lost
- ▶ Receiver stores position, time, etc.
- ▶ Search around the chord phase and Doppler frequency at the time the signal is lost
- ▶ Loop lock indicator (LLI)
 - ▶ Monitor signal tracking status
 - ▶ If the signal is not tracked, it will be re-acquisition.

