Simulations of Advanced Signal Processing Techniques for Remote Sensing

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Outline

- Simulation Tools
- (Not So Hard)ware
- Example 1: Correlation Function
- Example 2: Sideband Splitting
- Example 3: Phase-Locked Loops
- Summary

Simulation Tools Already Exist

- Ocean Surface Scattering Monte Carlo
  - Elfouhaily wave spectrum
  - Sub-meter integration cells on surface
  - Spacecraft-altitude receiver
  - Optimized for multi-node processing (but no MPI)
  - Recently added polarization

- Software receiver
  - Easy to implement new processing algorithms
  - Test concepts on real data

Modern (Not So Hard)ware

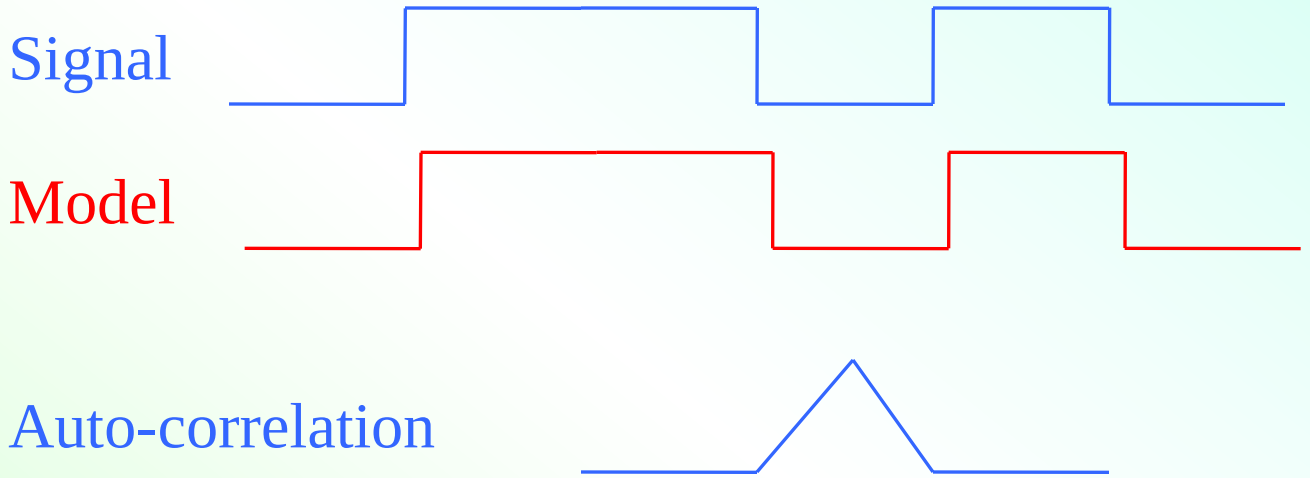
- Many receiver functions are now reconfigurable
  - Especially true for flight receivers
  - Non-standard processing possible
  - Receiver modifications “just” a software upload

⇒Time is right to search for creative new processing schemes

- Three Examples
  - Modified correlation function
  - Bandpass filtering
  - Phase-locked loops

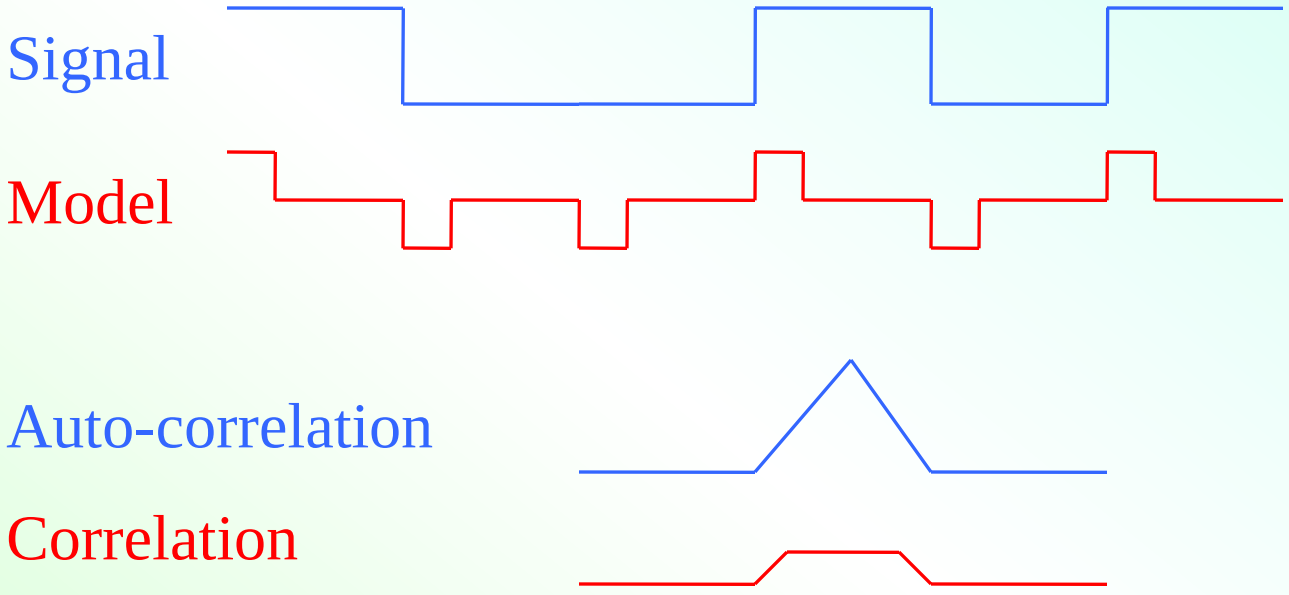
Example 1: Modified correlation function

- Model is usually a close replica of the signal

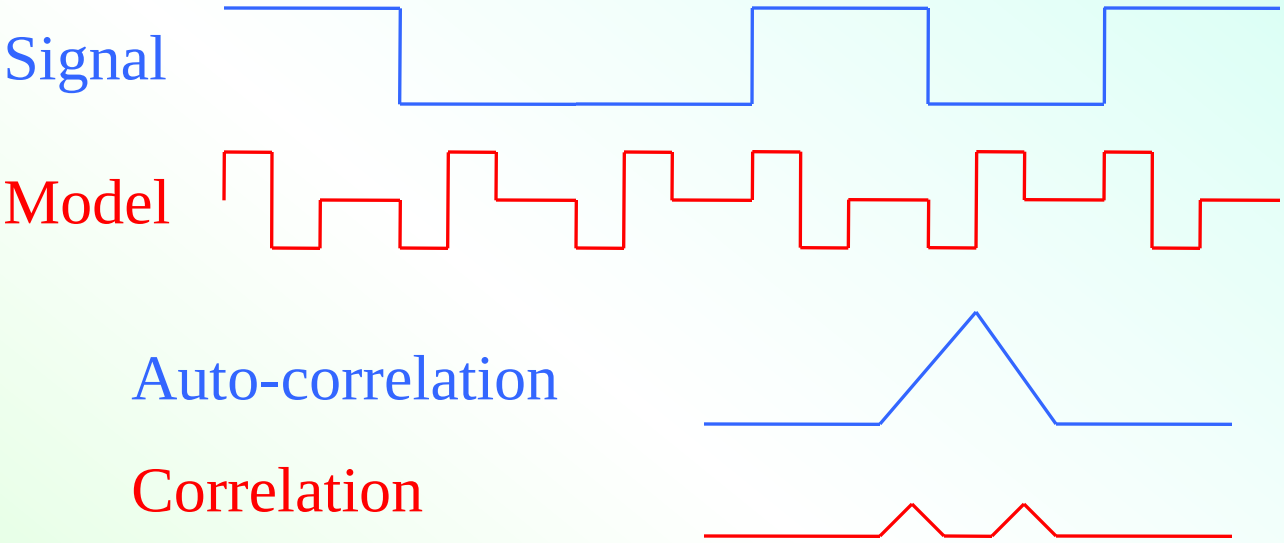


Example 1: Modified correlation function

- Correlation functions can blank, or negate signal

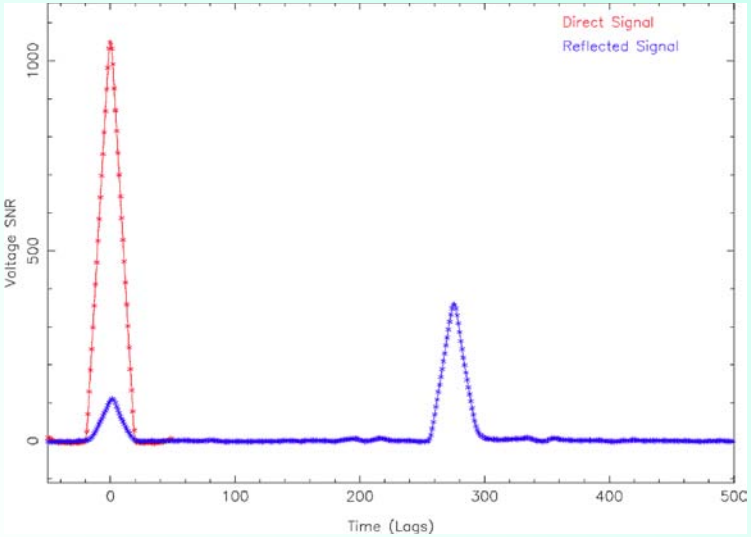


Delta-dot Chipping Function



- Novel correlation functions, but lower SNR
- Must account for finite bandpass

- Aircraft data over ocean
- GPS C/A code
- Standard processing



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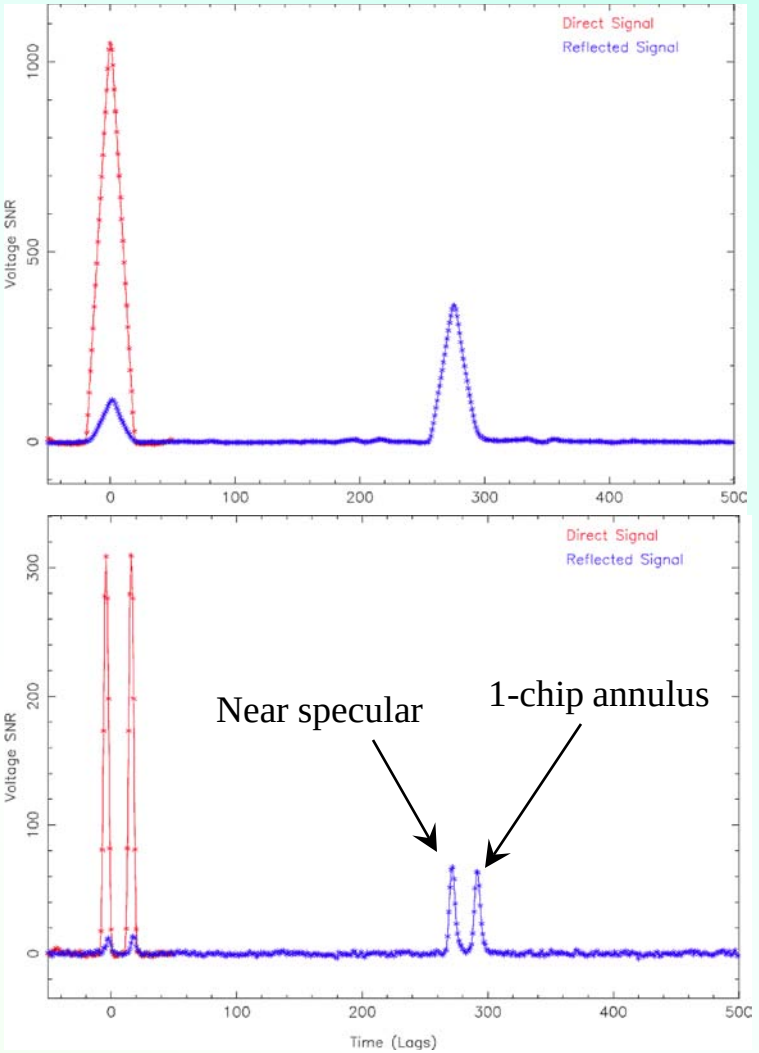


- Non-standard correlation function
- Narrower correlation function
  But lower SNR (don't win)
- Smaller surface footprint
  - Better spatial resolution
  - Coherence may be better
  - Differences between peaks

Example 2: Sideband splitting

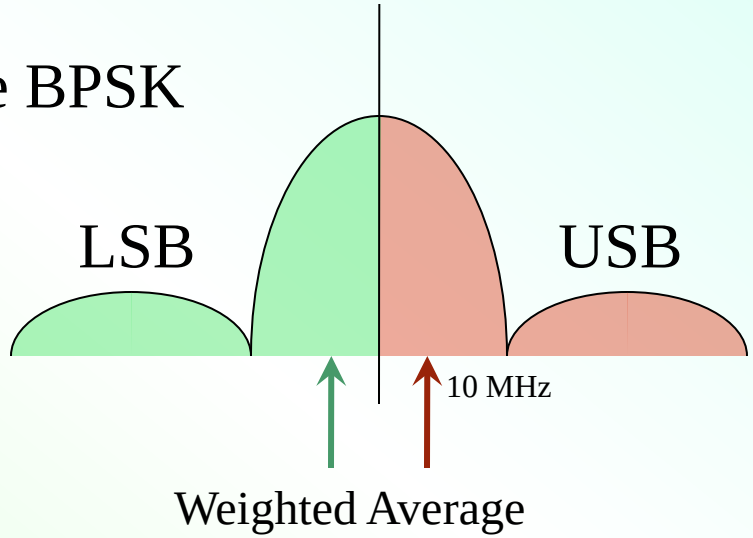
- Filter model into upper/lower sidebands
- Correlate each with unfiltered data
- Resulting waveforms at 2 different frequencies

$\Rightarrow$ Phase Delay $= \Delta\phi / \Delta\nu$

- Precision same as fitting to model waveform
- No model waveform needed

Example 2: Sideband splitting

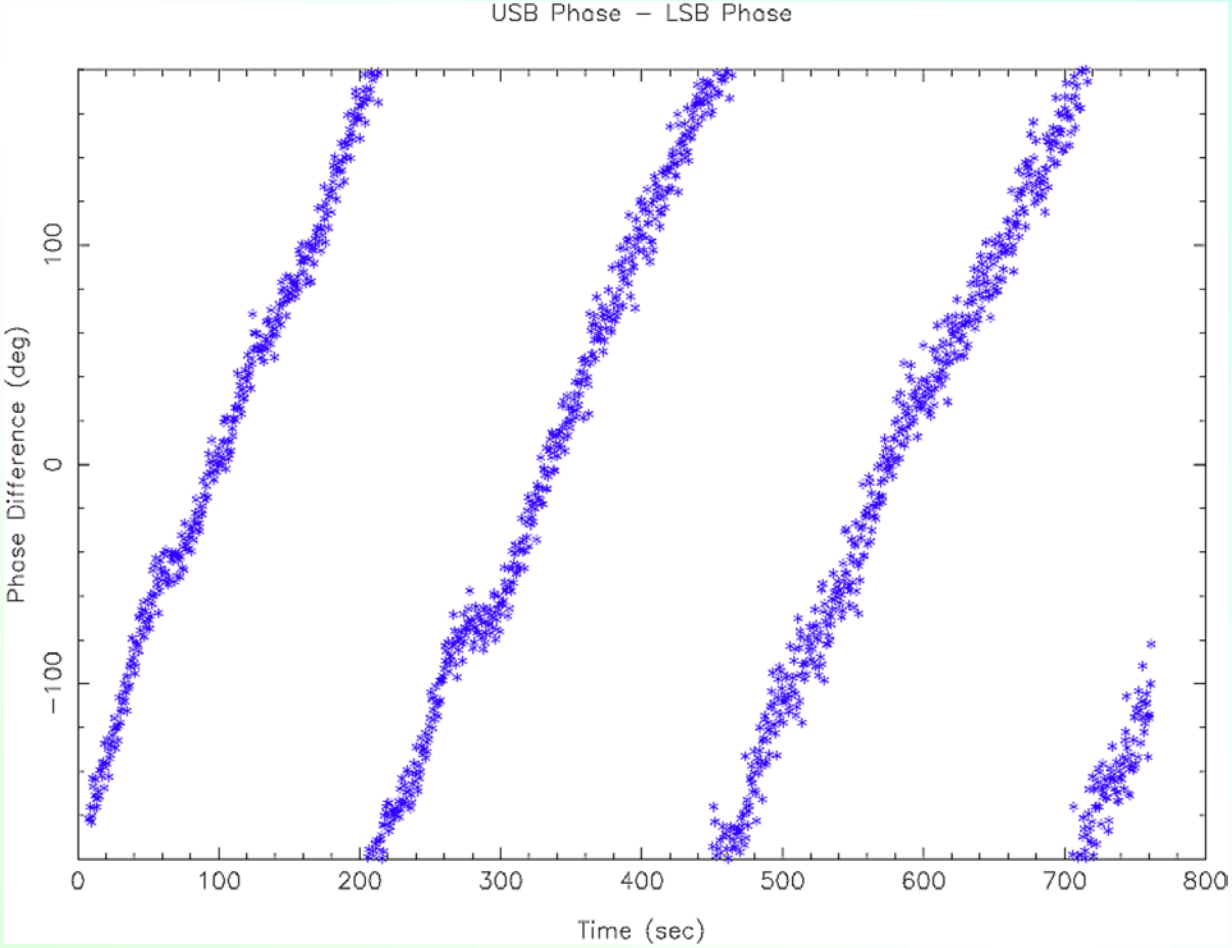
GPS P(Y) code BPSK



- BOC signals better
  - Power at bandpass edges

Example 2: Sideband splitting

Aircraft data



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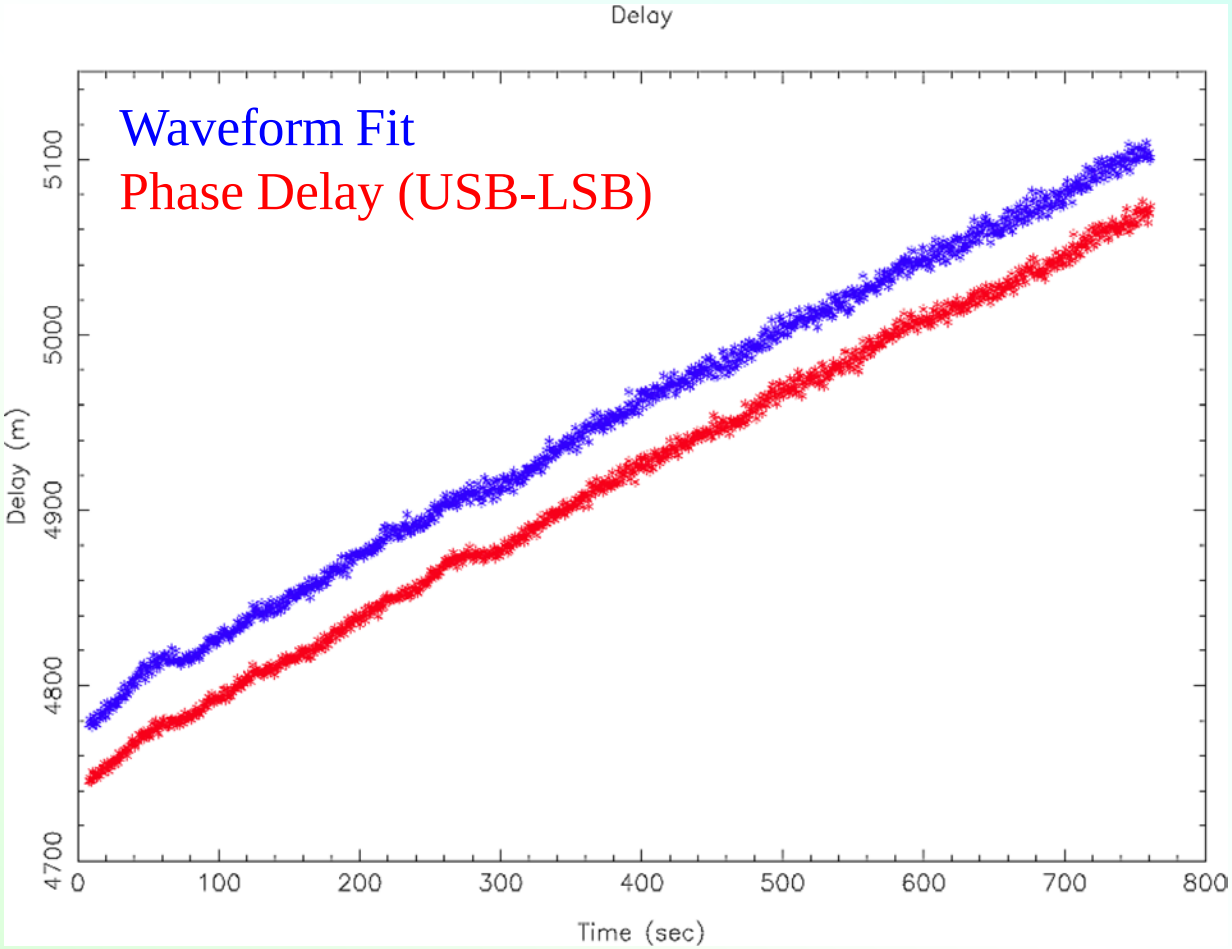

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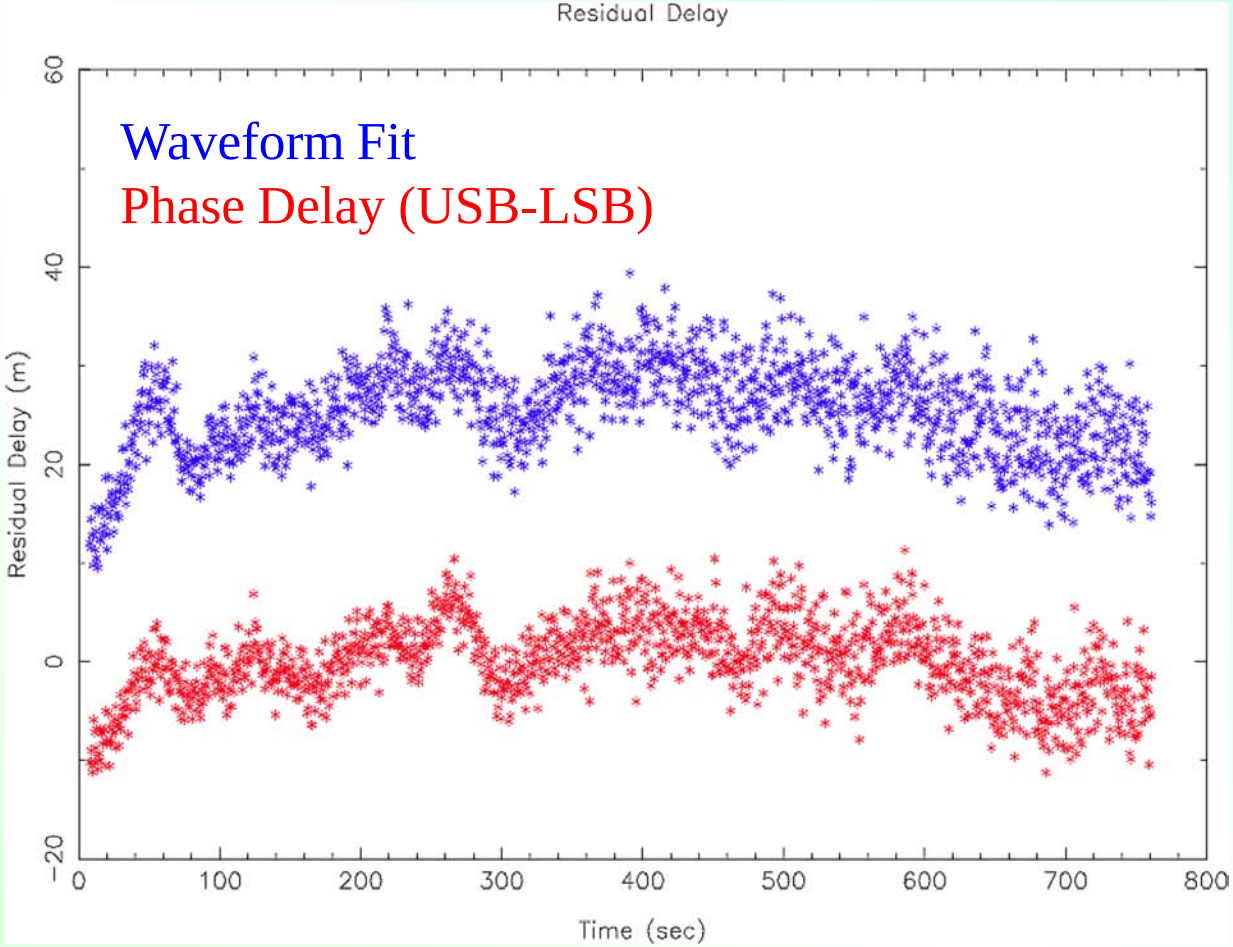


Example 2: Sideband splitting

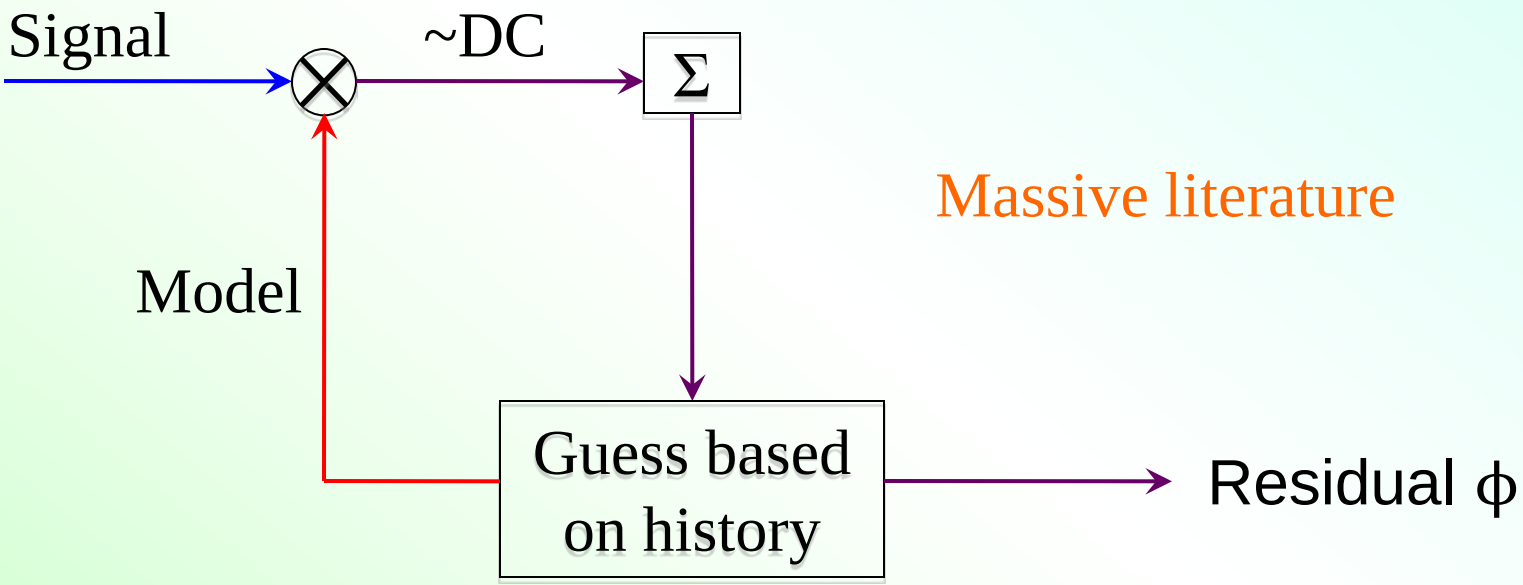
- Phase-Delay observable is available

- No precision improvement over waveform fitting, but:
  - May be easier to process onboard
  - May have better accuracy (?)
  - BOC signals have power on bandpass edges

Example 3: Phase-Locked Loops

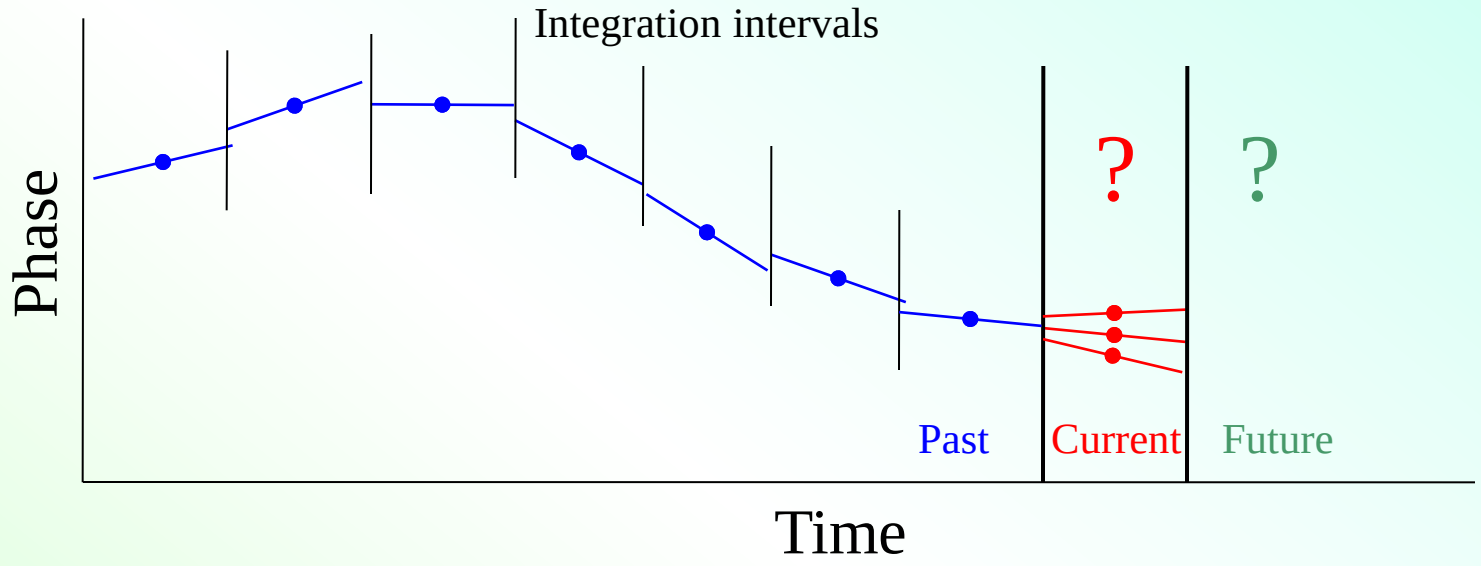
What are PPLs really? (in tracking loops)

⇒ Efficient guess at model phase based on past signal history



Massive literature

Example 3: Phase-Locked Loops



Assumptions

- Signal low-frequency peaked
- Stable signal amplitude
- Initiated with “acquisition”

Example 3: Phase-Locked Loops

PPL Properties

- One guess
  - A bad guess or two => loose lock, tracking stops
- Asymmetric in time
- Locally stable, globally unstable

Example 3: Phase-Locked Loops

PPL Properties

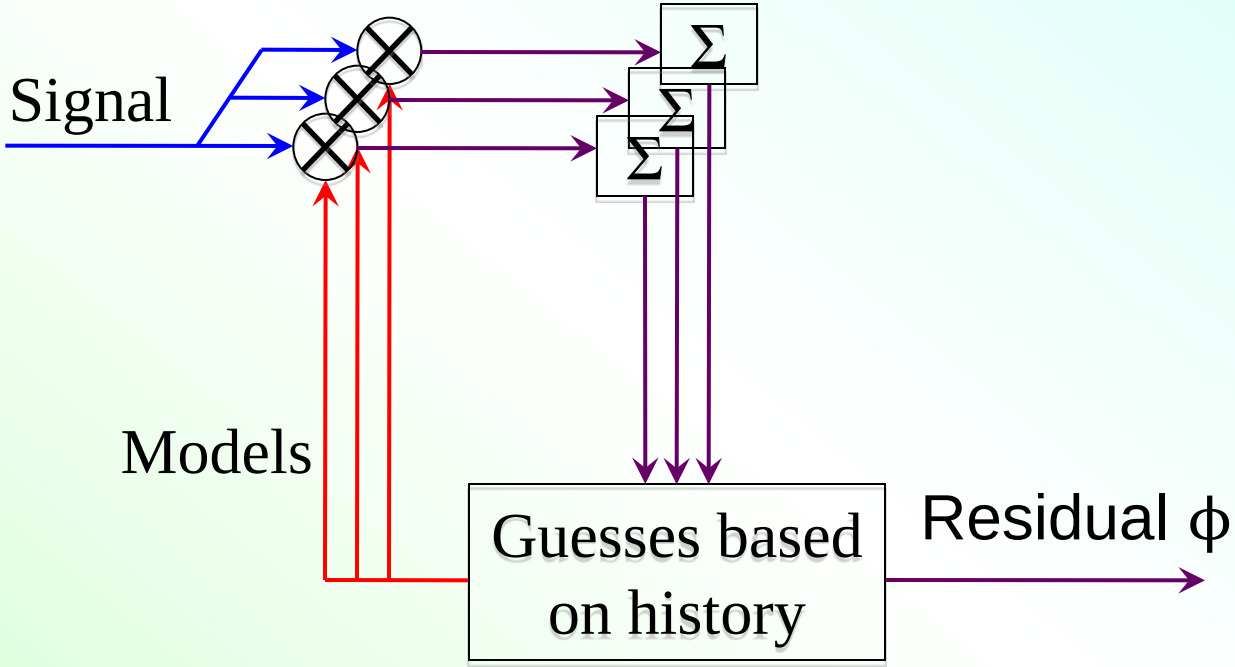
- One guess
  - A bad guess or two => loose lock, tracking stops
- Asymmetric in time
- Locally stable, globally unstable

What if acquisition is permanent!

- No PLL
- No loss of lock (no lock)
- Requires lots of hardware

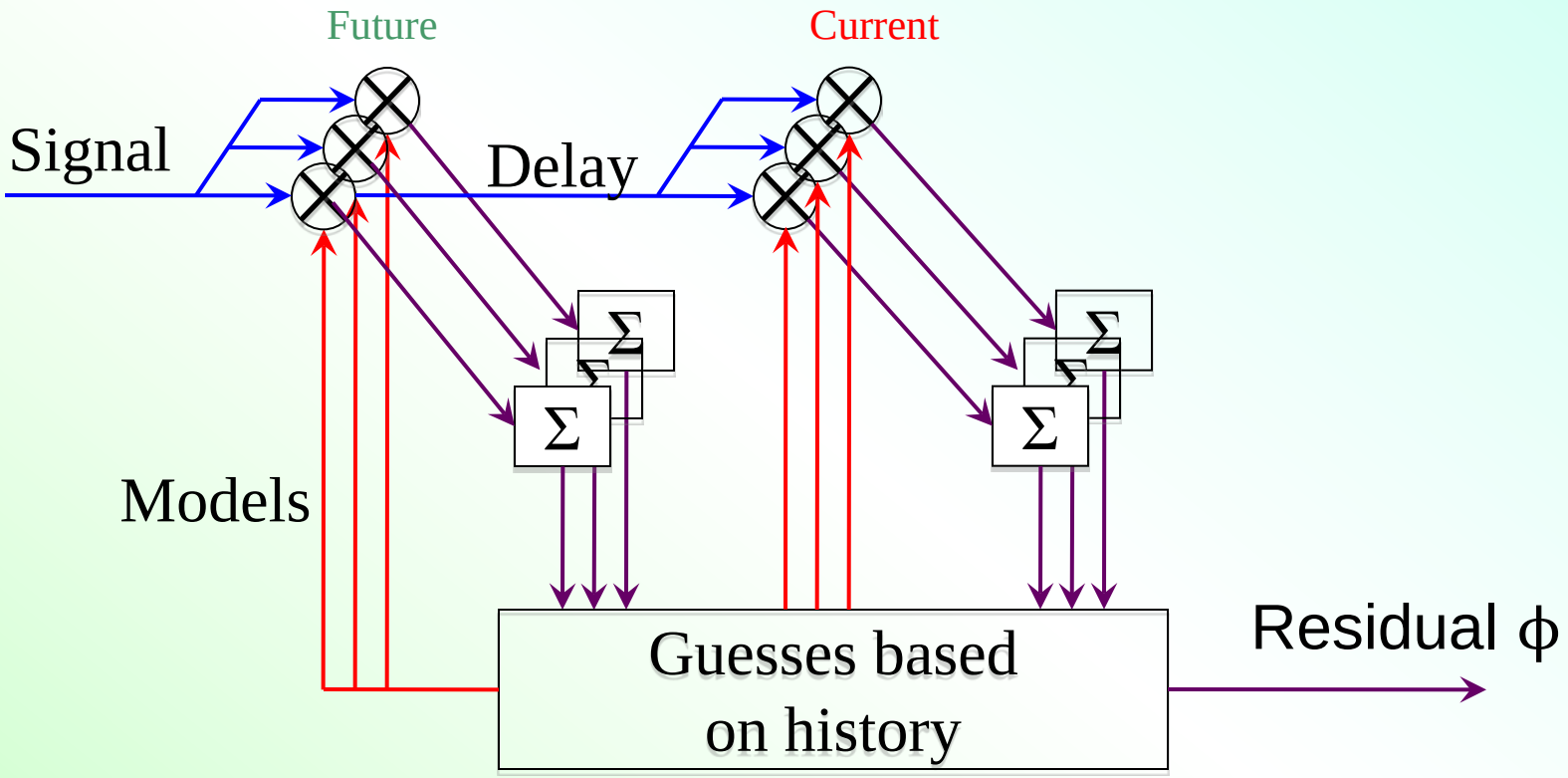
Example 3: Phase-Locked Loops

Try more guesses

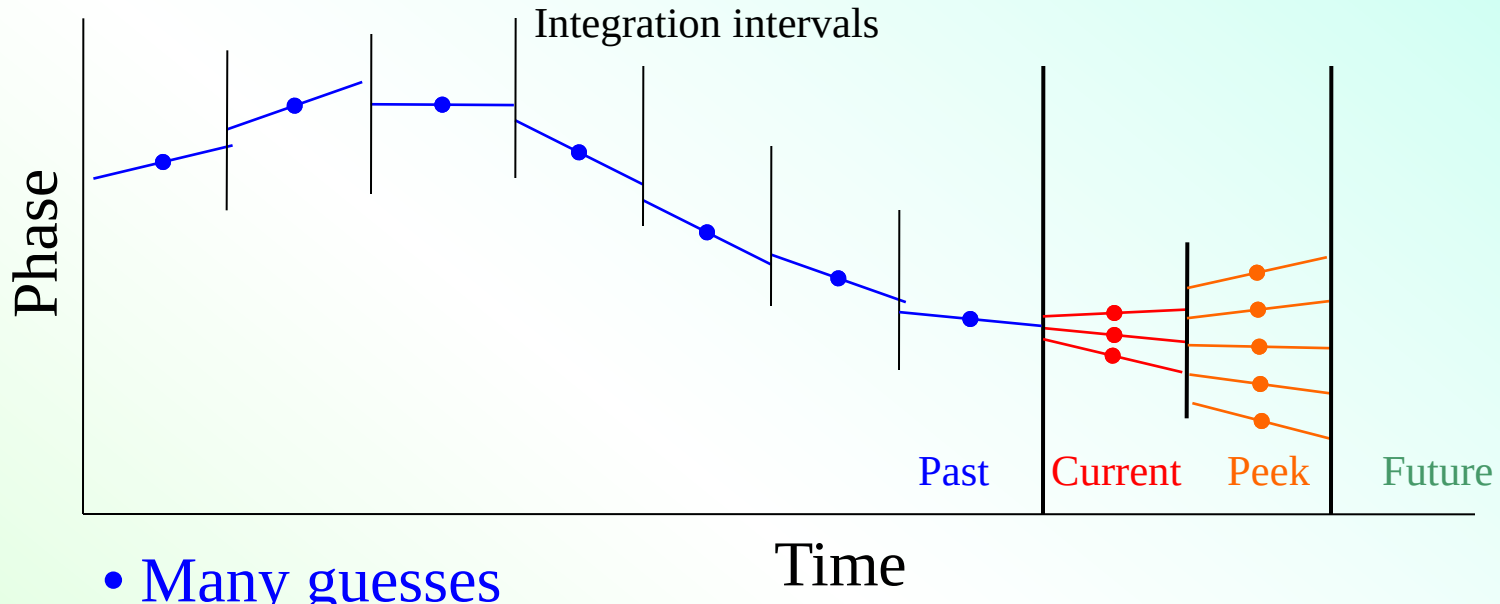


Example 3: Phase-Locked Loops

Look ahead



Example 3: Phase-Locked Loops



- Many guesses
  => Much more likely to get it right
- Have past, current, and future results
  => Symmetrizes time
- More stable, lower SNR threshold
- No Literature / Theory

Summary

Modern Digital Signal Processing

- Hardware capability/cost improving dramatically
- Many DSP ideas with GNSS-R applications
- Presented 3 diverse possibilities
- BOC signals ripe for ideas