Today’s Subjects

• GPS Signal Acquisition
  – Doppler frequency bins

• Acquisition methods:
  – Serial Search Acquisition
  – Parallel Frequency Space Search Acquisition
  – Parallel Code Space Search Acquisition

• Coherent acquisition
Acquisition Process
The Problem

• The GNSS signal can be received only when:
  – The frequency of the local carrier replica matches the frequency of the carrier in the received signal
  – The PRN replica code is well aligned in time to the PRN code in the received signal

• There are number of parameters, that influence how precisely these signals must mach

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Incoming signal → \times \rightarrow \times \rightarrow \text{Integrator} \rightarrow (\cdot)^2 \rightarrow \text{Correlation result}
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- Carrier wave replica
- PRN code replica
GPS Signal Acquisition

• **Purpose of acquisition:**
  – Find satellites (signals) visible to the receiver
  – Estimate coarse value for C/A code phase
  – Estimate coarse value for carrier frequency
  – Refine carrier search result if it is needed for the chosen tracking (receiver) design

• **Acquisition in high sensitivity receivers might also find bit boundaries**

• **The search space can be reduced if the receiver has some apriory knowledge about visible GNSS signals**
Carrier Frequency Acquisition
Doppler Shift

• ~5kHz maximum Doppler shift is created due to satellite motion (when satellite is moving directly towards/away from the receiver)

• The Doppler value and sign depend on the angle between signal line of sight vector and satellite’s motion vector

• Receiver motion also creates a Doppler offset: 1.46Hz per each 1km/h

• Again, the Doppler value and sign depend on the angle between signal line of sight vector and this time receiver motion vector
Doppler Shift

- Receiver oscillator offset will also cause a Doppler effect: 1.575kHz/1ppm
- Offsets of oscillators for GPS are typically from ±1ppm to ±3ppm, but ±0.5ppm devices are also introduced (2008)

- Therefore the total maximum Doppler shift is roughly +/-10kHz
- Receiver must search in this 20kHz band for visible GPS (GNSS) signals
How Carrier Acquisition Works

Correlation

Incoming carrier

Generated carrier
Doppler Frequency Bins

• The whole frequency search band is divided into frequency bins
• The size of a frequency bin depends on the desired integration time and the desired maximum SNR loss due to frequency mismatch
• Commonly used Doppler frequency bin size for acquisition is 500Hz
• This gives a total of 41 different frequencies to be tested for a band of 20kHz
C/A Code Acquisition
How Code Acquisition Works

**Incoming code**

**Generated code**

**Correlation**
The step depends on desired correlation (SNR) loss due to missaligned spreading code phases.

Typical step for GPS is $\frac{1}{2}$ of a chip.
Length Of Signal For Acquisition

• Minimum 1 spreading code sequence should be used, else the PRN properties are degraded: min 1ms for GPS

• The total signal length should be m*codeLength, where m is an integer >0

• When m is >1
  – The SNR is improved
  – Data bit transitions can destroy integration result
  – Acquisition takes longer because:
    • The signals to be process are longer
    • The frequency step must be reduced – more bins to check
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Acquisition Techniques
Serial Search Acquisition

- A straight-forward method of acquisition
  - Search all possible combinations of code phase and carrier frequency

![Diagram of serial search acquisition process](image-url)
Output From A Serial Search Acquisition

No GPS signal for given PRN

GPS signal is present for given PRN
Serial Search Acquisition

- Total number of combinations to search:
  - 41 different carrier frequencies
  - 2046 different C/A code phases
  - Total $41 \times 1023 \times 2 / 2 = 41943$ combinations (bins)

- The calculations for each of the combinations are quite simple therefore it is easy to implement in hardware

- The high number of combinations makes the method very slow, especially for high sensitivity signal acquisition
  - Multiple correlators to increase acquisition speed
Parallel Frequency Space Search Acquisition

- Lower the number of code phase and carrier frequency combinations to be searched:
  - Parallelize one of the two search dimensions – frequency
  - Use a Fourier transform to detect carrier in a single step
Output From Parallel Frequency Space Search Acquisition

No GPS signal for given PRN

GPS signal is present for given PRN
Parallel Frequency Space Search Acquisition

- Total number of combinations to search: \(1023 \times 2 / 2\)
- Each of the combinations is computationally demanding because of the use of the Fourier transform
- The efficiency of this method depends on the speed of the used Fourier transform implementation
- Frequency search resolution depends on signal length: the longer the signal, the finer is the resolution
Parallel Code Space Search Acquisition

- Parallelizes the code space dimension – use circular correlation
Output From Parallel Code Space Search Acquisition

No GPS signal for given PRN

GPS signal is present for given PRN
Parallel Code Space Search Acquisition

• Total number of combinations to search: 41
• Each of the combinations is very computationally demanding because of the intense use of a Fourier transformations
• The efficiency of this method depends on the speed of the used Fourier implementation
• Method can yields high code phase resolution (one sample res.) per single search step
Acquisition Of Weak Signals
Weak Signal Acquisition

• Results from several search cycles are combined to detect weak signals
• The process is an extension of the basic acquisition:
  – Coherent integration period is increased
  – Non-coherent integration period is increased

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Weak Signal Acquisition

- Weak signal acquisition increases the number of search steps
- Parallel hardware operations are used to increase search speed
- Bit transition is a problem
- Carrier frequency error can destroy the integration result
- Next generation GNSS signals will have longer spreading codes and data less signals to aid weak signal acquisition (and tracking)
Non-Coherent Acquisition

- Non-coherent acquisition snapshot/video was made by student group 1049 (2005)
Signal Detectors
Signal Detectors

- Compare main peak to noise floor
  - TH can be precomputed
  - Noise floor is not constant

- An alternative solution is to compare main peak to the second highest peak, which is not closer than one chip to the main peak

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Questions and Exercises