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GPS Signal Acquisition

GPS Signals And Receiver Technology **MM11**

Darius Plaušinaitis

dpl@gps.aau.dk

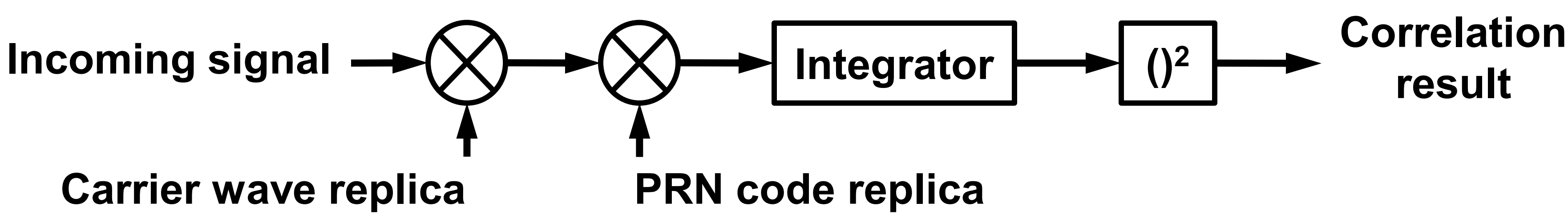
Today's Subjects

- 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



GPS Signal Acquisition

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- 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

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- ~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

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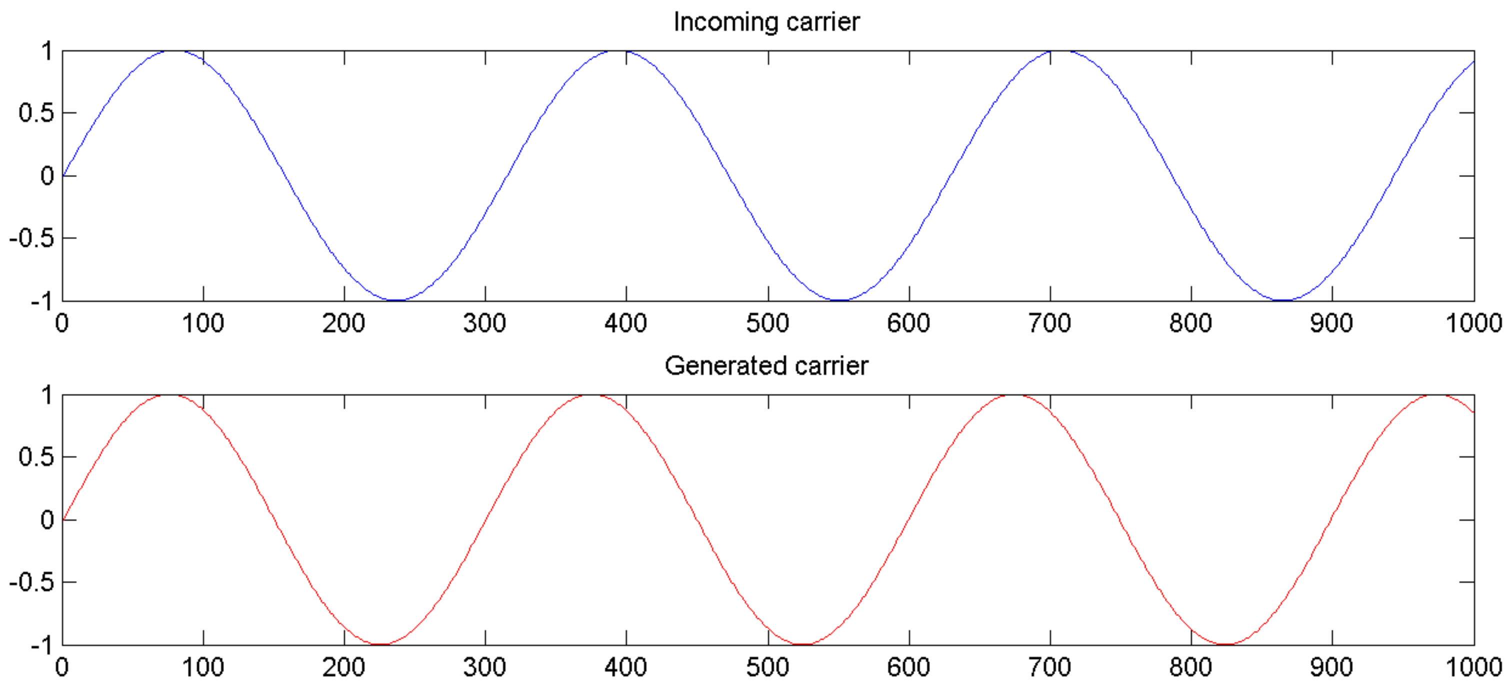
- Receiver oscillator offset will also cause a Doppler effect: 1.575kHz/1ppm
- Offsets of oscillators for GPS are typically from ±1ppm to ±3ppm, but ±0.5ppm devices are also introduced (2008)

- 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 ● 1

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 missmatch
- 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

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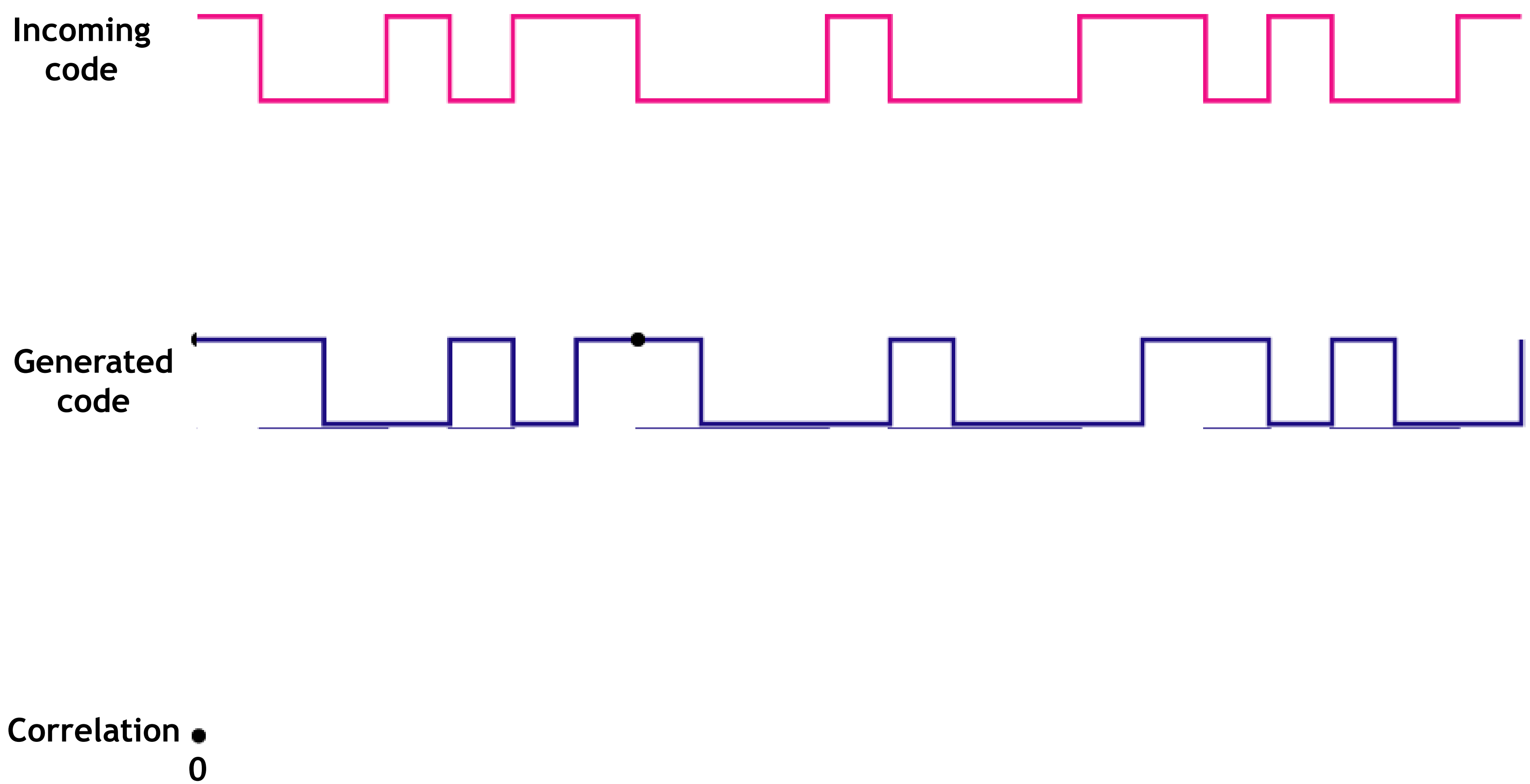
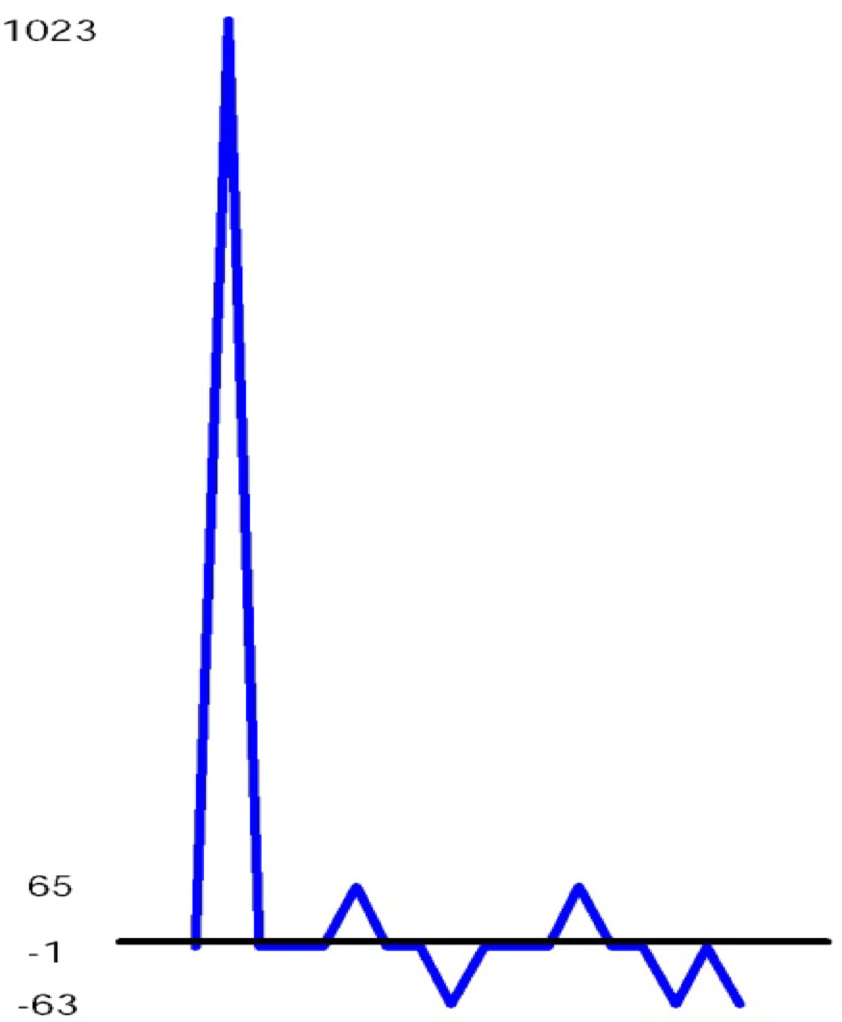


Code Phase Search Step

- The step depends on desired correlation (SNR) loss due to missaligned spreading code phases
- Typical step for GPS is ½ 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

Important Details

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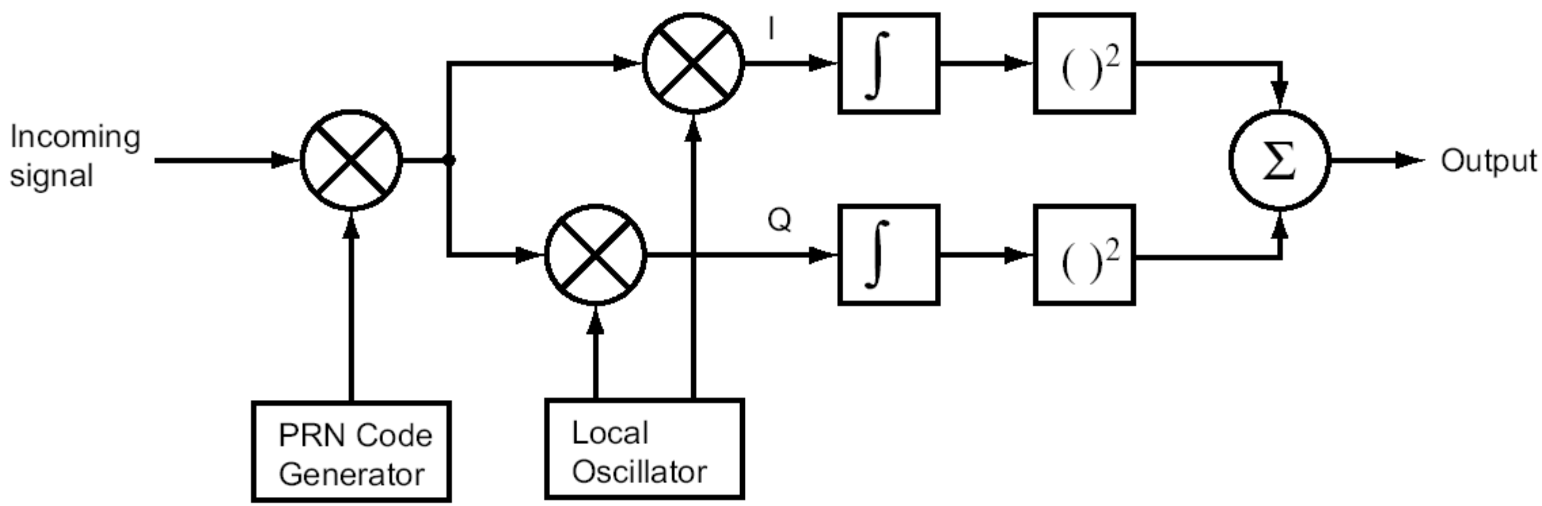
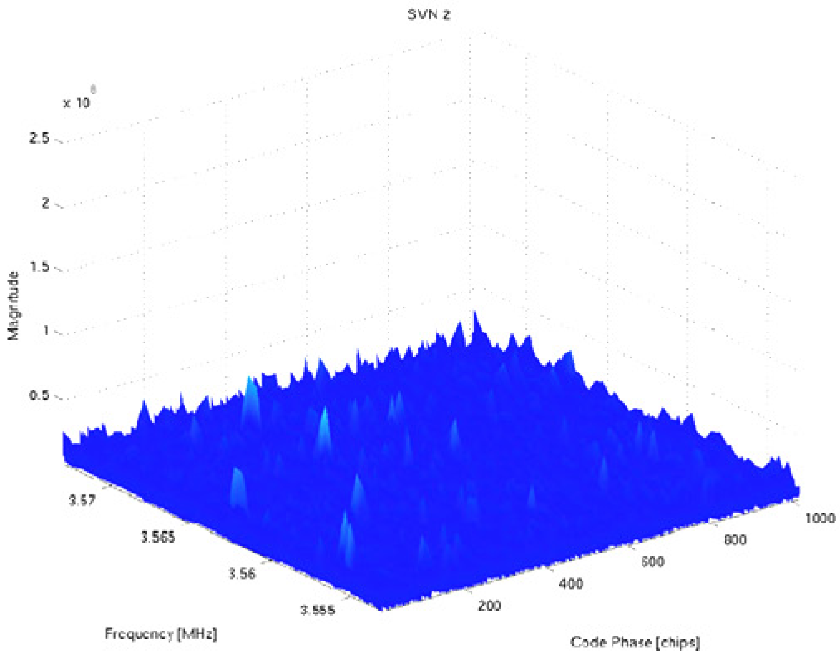
Acquisition Techniques

Serial Search Acquisition

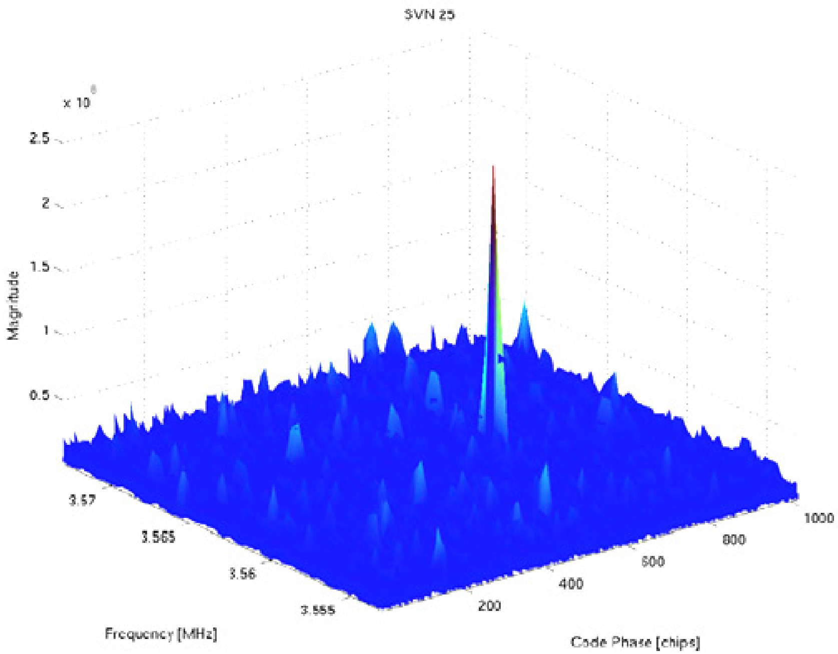
- **A straight-forward method of acquisition**
  - **Search all possible combinations of code phase and carrier frequency**



Output From A Serial Search Acquisition



No GPS signal
for given PRN



GPS signal is present
for given PRN

Serial Search Acquisition

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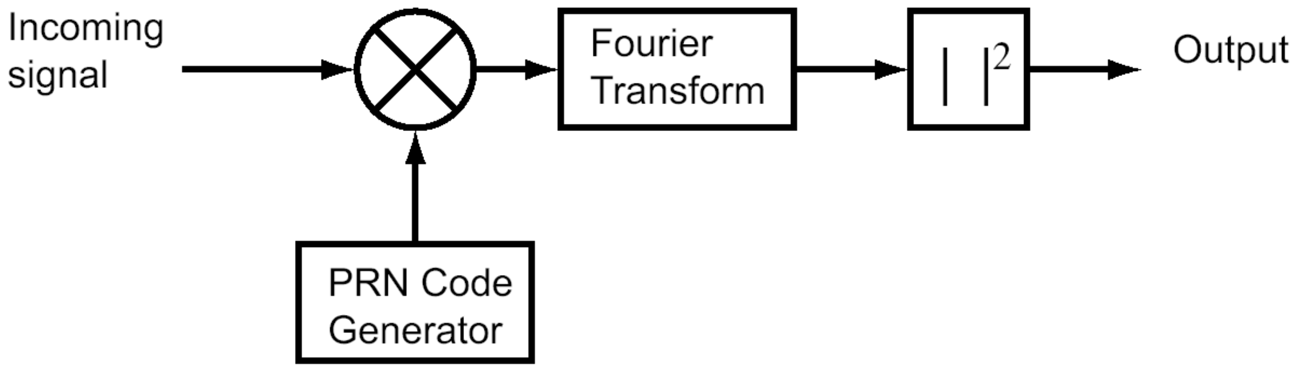
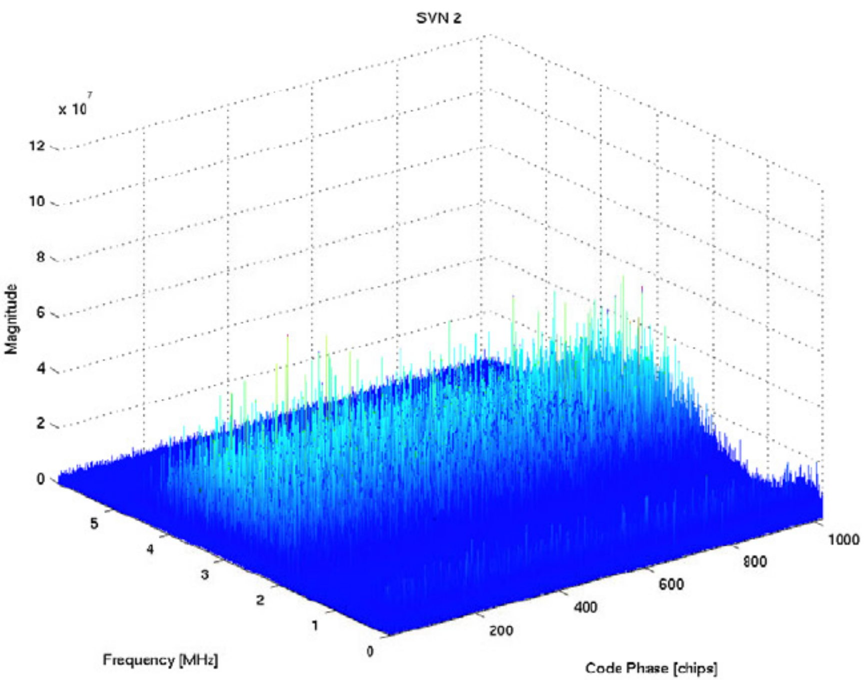
- Total number of combinations to search:
  - 41 different carrier frequencies
  - 2046 different C/A code phases
  - Total 41 x 1023*2/2 = 41943 combinations (bins)
- The calculations for each of the combinations are quite simple therefore it is easy to implement in hardware
- The high number of combinations makes the method very slow, especially for high sensitivity signal acquisition
  - Multiple correlators to increase acquisition speed

Parallel Frequency Space Search Acquisition

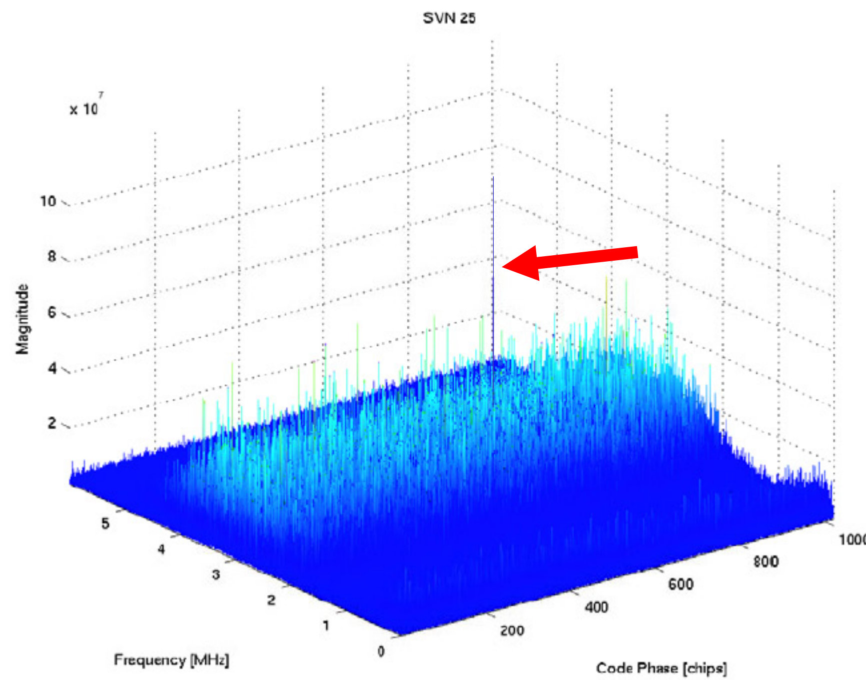
- **Lower the number of code phase and carrier frequency combinations to be searched:**
  - **Parallelize one of the two search dimension – frequency**
  - **Use a Fourier transform to detect carrier in a single step**



Output From Parallel Frequency Space Search Acquisition



No GPS signal
for given PRN



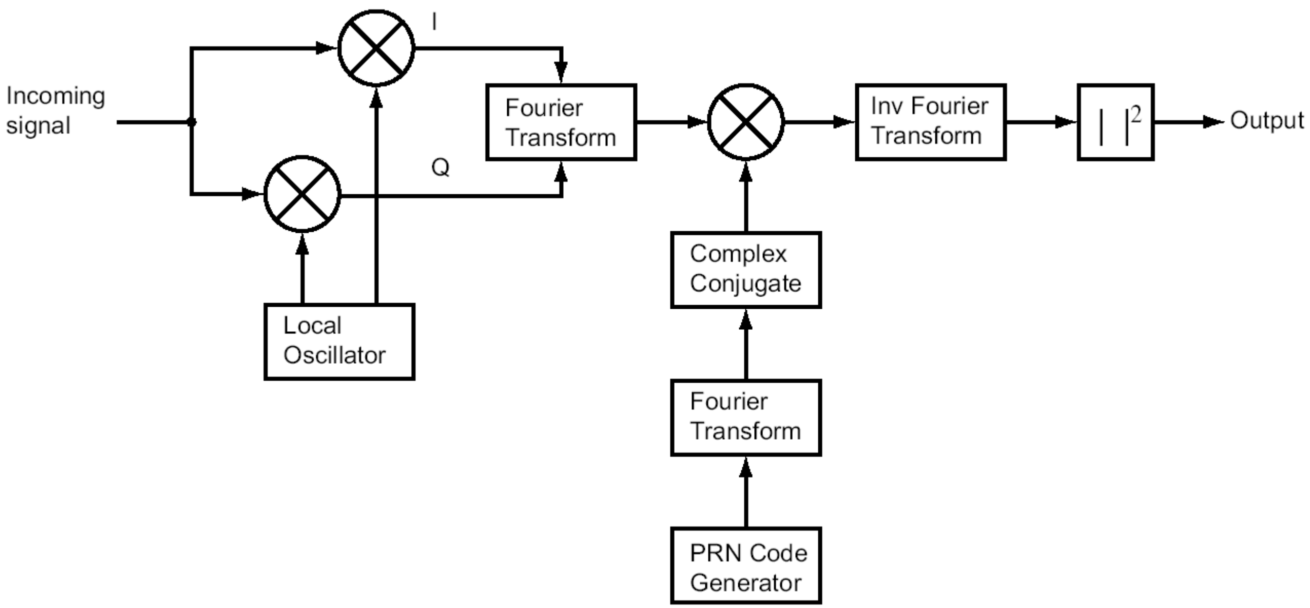
GPS signal is present
for given PRN

Parallel Frequency Space Search Acquisition

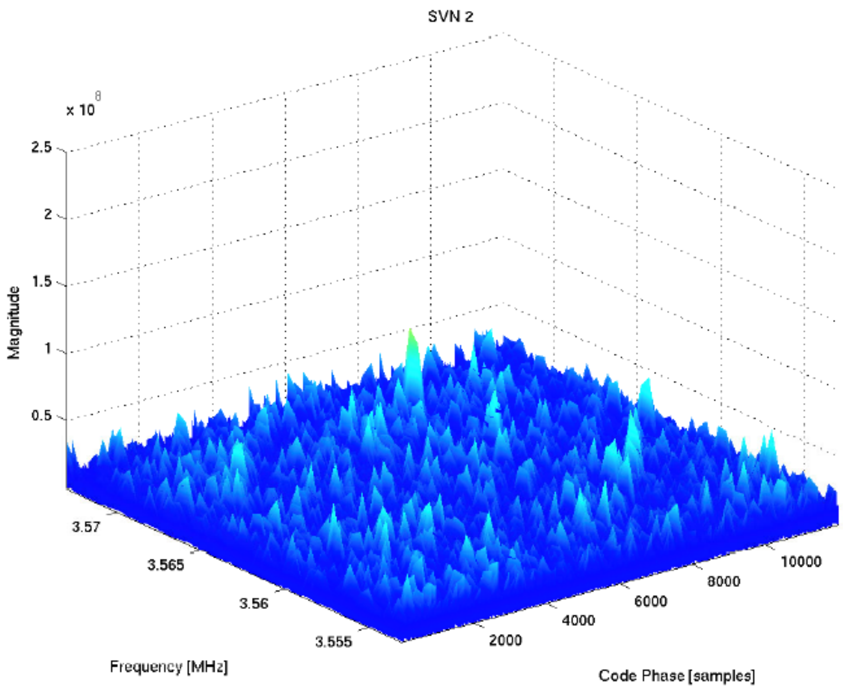
- Total number of combinations to search: 1023*2/2
- Each of the combinations is computationally demanding because of the use of the Fourier transform
- The efficiency of this method depends on the speed of the used Fourier transform implementation
- Frequency search resolution depends on signal length: the longer the signal, the finer is the resolution

Parallel Code Space Search Acquisition

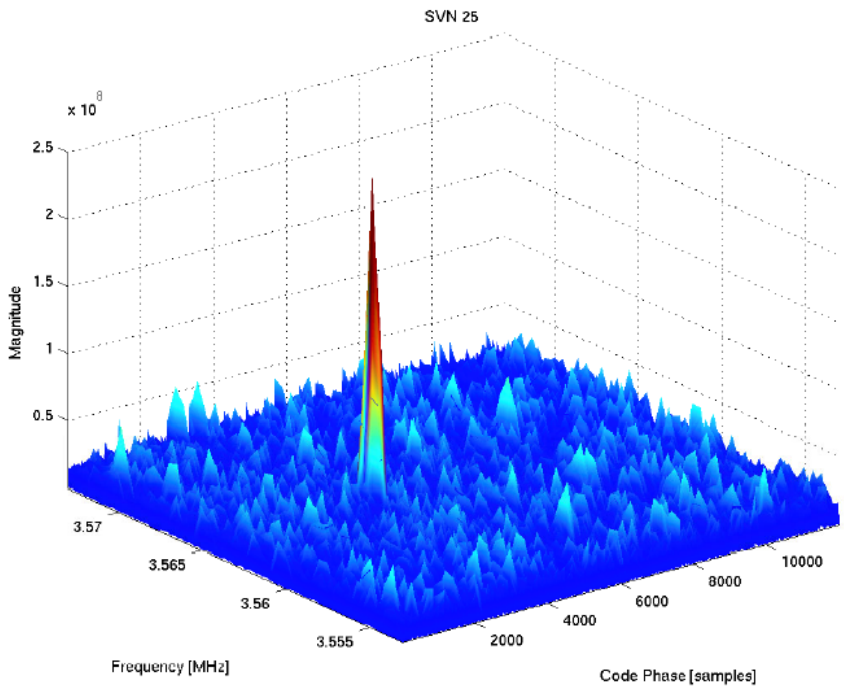
- **Parallelizes the code space dimension – use circular correlation**



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

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- 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 extendion of the basic acquisition:
  - Coherent integration period is inreased
  - Non-coherent integration period is increased

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Weak Signal Acquisition

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- 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

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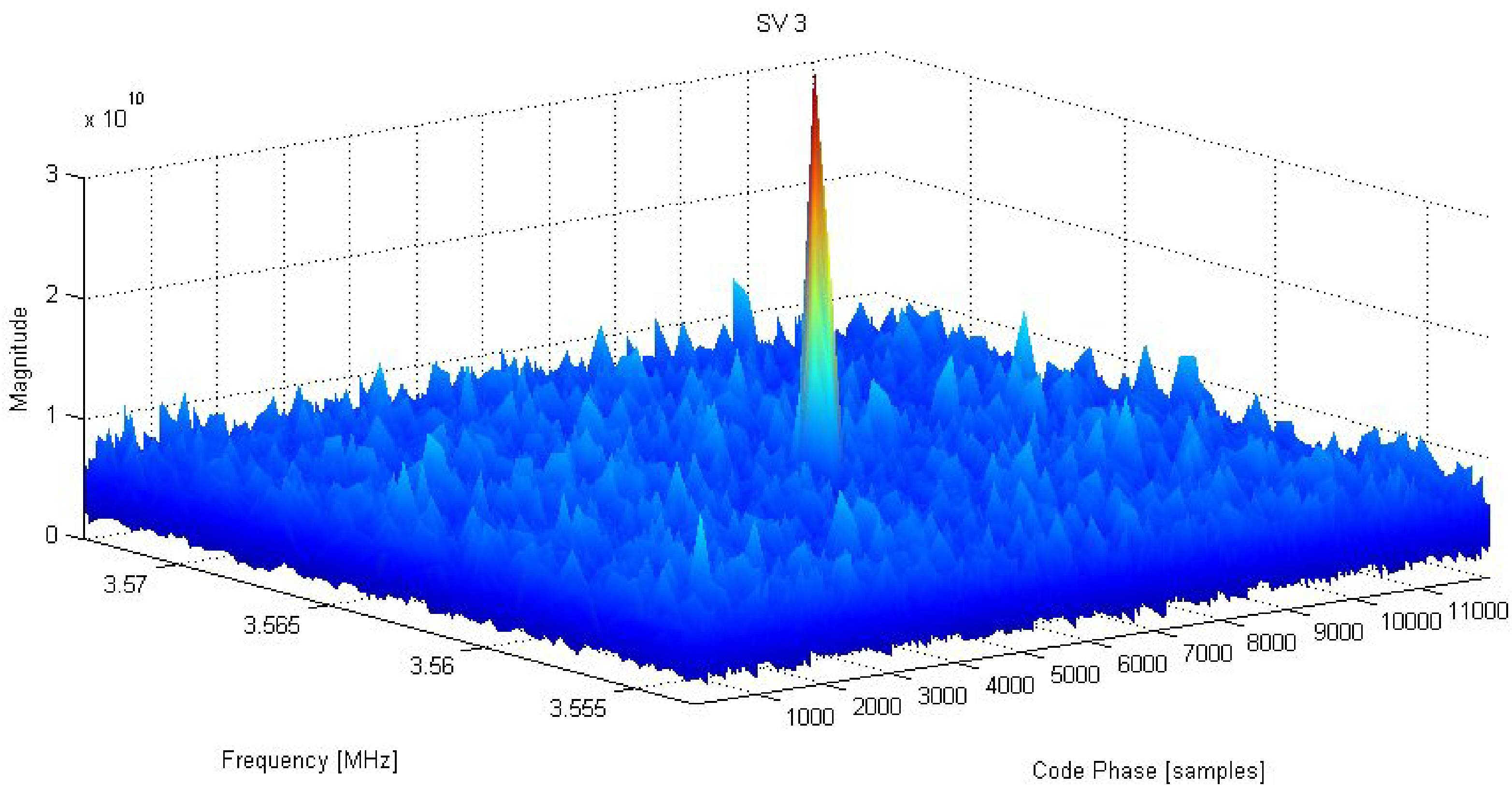
- Non-coherent acquisition snapshot/video was made by student group 1049 (2005)



Signal Detectors

Signal Detectors

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

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

Questions and Exercises

MM11 Exercises

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