

# Navigation Signals In Space

Vlaamse Ruimtevaart Industrie

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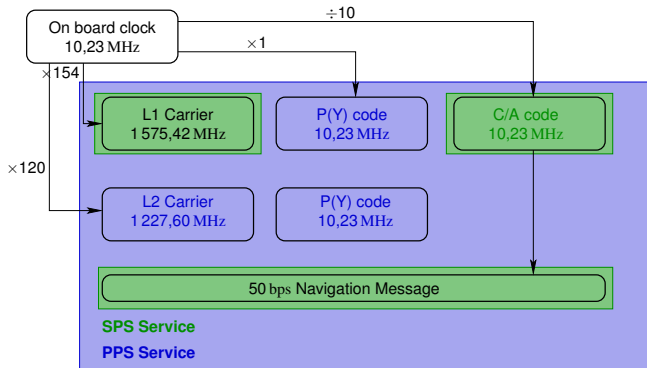
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# GPS Navigation Signals

- Current GPS Positioning Services
  - GPS offers 2 navigation services



- Very **limited accuracy** guaranteed by US DoD
- SPS service is **free of charge** for everyone



# GPS Navigation Signals

- Information transmission from SV to Rx
  - based on properties of PRN codes
    - similar to noise but with deterministic character
    - cycle-and-add property
    - high degree of auto-correlation
    - insensible for cross-correlation
  - data bits contained in navigation message
  - technique applied is Direct Spread Spectrum System
    - PRN code used as spreading code for navigation message
    - causes fast phase transitions in the carrier frequency
    - spreading of energy over a large bandwidth before transmission
    - @reception  $\Rightarrow$  de-spreading by multiplication spreading code
    - re-concentration of energy in limited bandwidth
    - extraction of information bits above the noise floor

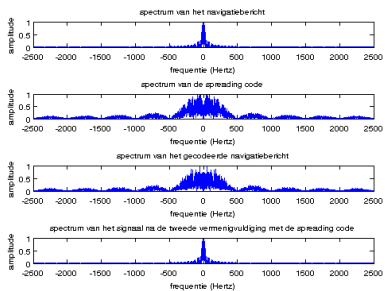
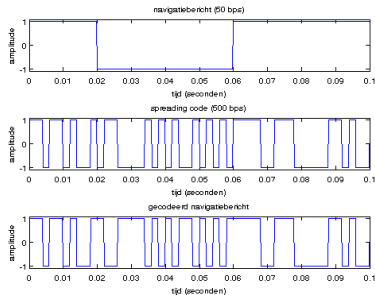


# GPS Navigation Signals

- Information transmission from SV to Rx
  - based on properties of PRN codes **high chipping rate**
    - similar to **noise** but with **deterministic character**
    - **cycle-and-add** property
    - high degree of **auto-correlation**
    - insensible for **cross-correlation**
  - data bits contained in **navigation message** **low data rate**
  - technique applied is **Direct Spread Spectrum System**
    - PRN code used as **spreading code** for navigation message
    - causes **fast phase transitions** in the carrier frequency
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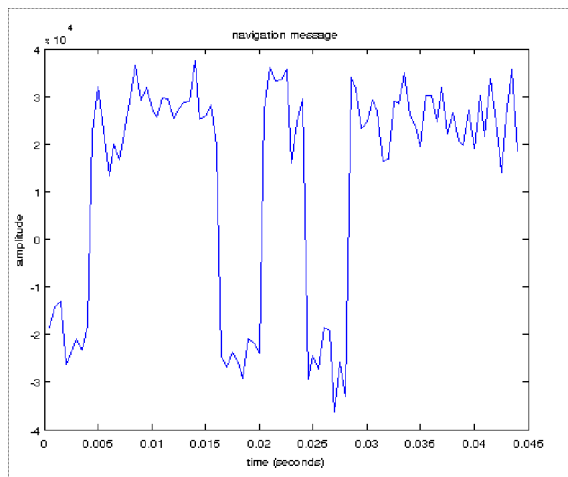


# The GPS (de-)spreading operation



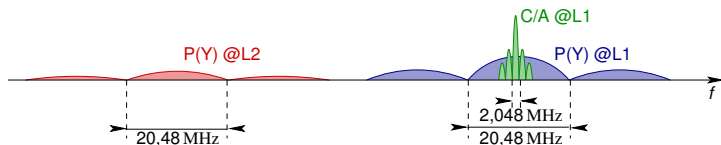
# The GPS (de-)spreading operation

- Leads to demodulation of Navigation Message



# Current GPS spectrum

- BPSK Modulation of C/A & P(Y) code on L1 & L2
  - Binary Phase Shift Key since modulation constellation consists of 2 possible values  $+0^\circ$  and  $+180^\circ$
  - **chipping rate** of C/A 1,023 MHz (P(Y) 10,23 MHz)



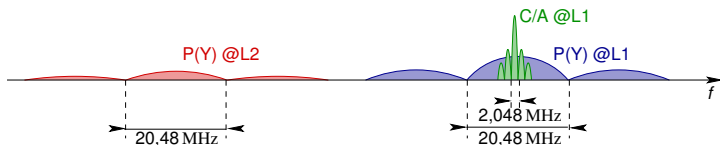
- Main error sources in current GPS

- **ionospheric delay** on single frequency systems 5 m
- **multi-path** error 0,5 m  $\rightarrow$  2 m



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# How to be better than GPS ?

- Identify technical & legal/political shortcomings of GPS
  - Technical : Precision, Integrity, Availability & Continuity of Service
  - Non-technical : European dependence on foreign military system, no legal guarantee, US domination of world wide navigation, ...
- Technical limitation of current GPS system
  - Based on direct spread spectrum system
    - determines number of codes, amount of multi-path, difficulty to jam, reliance of data-demodulation
    - main parameter is processing gain<sup>1</sup>  $G_P = \frac{B_t}{B_i}$
    - DSSS : longer spreading code increases process gain, but limited by memory and processing power of Rx

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<sup>1</sup>bandwidth of wide frequency spectra versus baseband information bandwidth



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# Galileo Signals

- Positioning Services

- Open Service (OS) : free for use, similar to GPS-SPS
- Commercial Service (CS) : guaranteed performance level
- Public Regulated Service (PRS) : only for governmental use
- Safety of Life Service (SoL) : high degree of integrity
- Search And Rescue Service (SAR) : for distress situations

- Galileo Spectrum

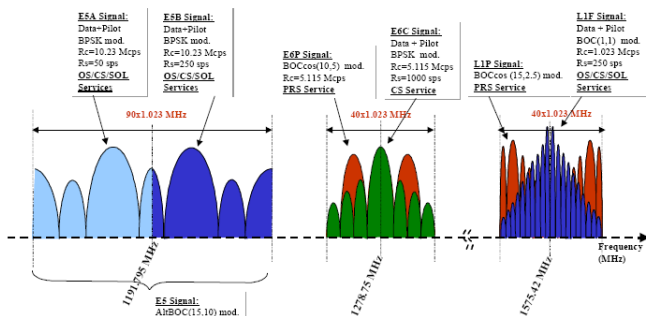


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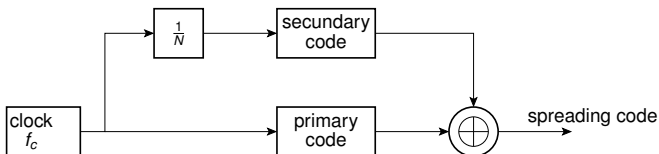
## Galileo Spectrum



# Galileo Spreading Codes

## ● Spread Spectrum Code

- constructed in two steps of a **layered spreading code**
  - construction of a **primary code**
  - Manchester coding of primary code with a **secondary code**



- spreading code characteristics (E1 frequency)

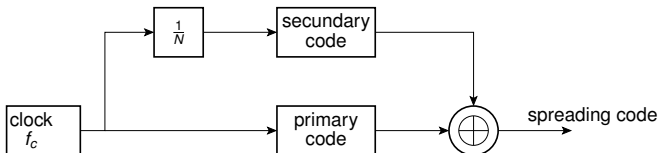
	$C_{E1-A}$	$C_{E1-A}$	$C_{E1-A}$
service	Public Regulated Service	Open Service	Open Service
period full code	10 ms	4 ms	200 ms
length primary code	25 575 chips	4 092 chips	8 184 chips
length secondary code	1 chip	1 chip	25 chips
chipping rate	2,557.5 MHz	1,023 MHz	1,023 MHz



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# Galileo Signals

- Galileo multiple signals and carriers provide
  - provides more open signals and 2 PRS signals per satellite
  - codes transmitted for different services on different carriers allow ionospheric error reduction
  - higher chip rate increases transmission bandwidth  $\Rightarrow$  better multi-path reduction and lower thermal noise
  - longer codes lead to complexer hardware and need advanced techniques for acquisition
  - use of pilot and data channels allow for continuous tracking under more severe conditions (lower tracking threshold)



# Galileo Segment and Differentiating Concepts

- Constellation characteristics

- GPS

- nominal constellation of 24 satellites/6 orbital planes
- is oriented towards mid-latitudes
- military operated GNSS

- Galileo advantages

- larger constellation of 30 SVs/3 orbital planes/higher altitude
- better coverage for higher latitudes (Atlantic crossing for aviation, Scandinavian countries)
- civil operated GNSS with guarantee for safety, coverage, CoS and availability
- BOC modulation allow for 3 separate signals
- combination of different frequency band

- Galileo disadvantages

- applied techniques are more complex
- more complicated front-end



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# Conclusion

- Galileo is setting a benchmark
  - introduces **new coding system** and spectral separation of services/signals
  - signals with **larger bandwidth** with better noise characteristics
  - clever usage of available **spectrum**
- GPS **modernisation** will lead to a similar system
- USA and Europe will collaborate to offer a combined **hybrid GPS-Galileo Rx**
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# Thanks

- Stijn CEYSSENS, *Studie en ontwerp van een software Galileo ontvanger*, Lieutenant, 157 Polytechnical Promotion, RMA 2007.



## Questions ?

