Real-Time GNSS Software Receiver: Challenges, Status, and Perspectives

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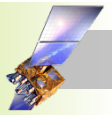
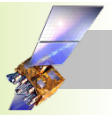


Presentation outline

- Motivation
- History
- Definition and types
- Challenges
- Status
- Outlook
- Conclusion



Motivation

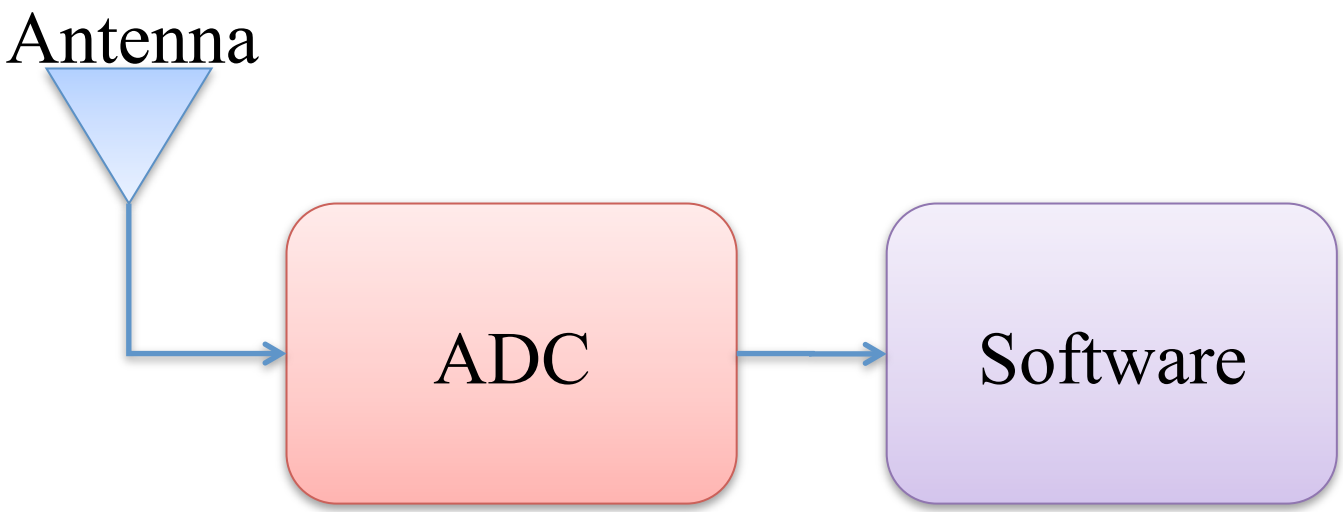
- More and more computing power available
- Use of existing resources (CPU, memory, …)
- Low cost implementation possible
- Flexible solution for research and development
- Flexibility for adapting to new signals and frequencies

Introduction

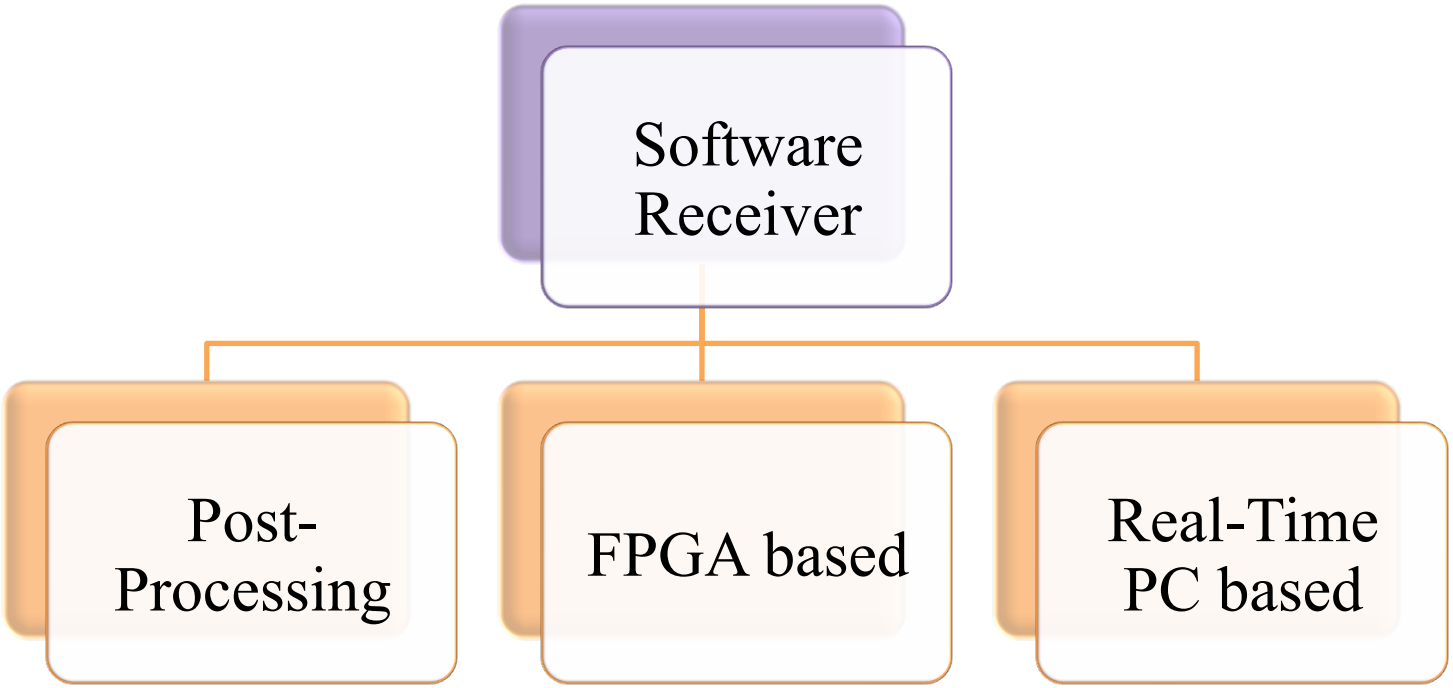
- History
  - Start in the 1990‘s: Project Speakeasy (U.S. D.o.D.)
  - 1990: Utilisation of FFT for CDMA system
  - 1996: Bandpass sampling introduced by Ohio University
  - 2001: Real-time capable software receiver for GPS L1 C/A on a DSP (Stanford University)

Software Receiver: Definition

- Base-band signal processing is performed in software
- Analog-to-digital converter (ADC) as close as possible to the antenna



Software Receiver: Types



Challenges: Data Rate

- Direct sampling
  - GPS L1 signal: 393 MB/s (1 bit quantization)
  - Challenge: High data rate

- Sub-sampling (respecting signal bandwidth)
  - GPS L1 signal: 500 kB/s (Fs = 4 MHz)
  - Challenge: Current hardware and resources limitations

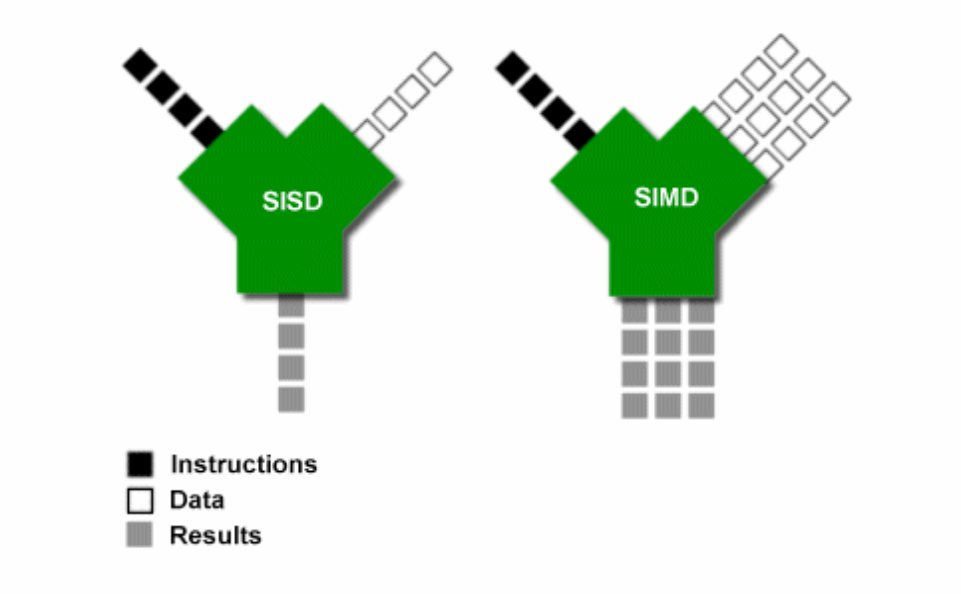
Challenges: Base-Band Processing

- Generation of local code and carrier (in real-time)
  - In hardware
    - Numerically Controlled Oscillator (NCO)
  - In software
    - CPU load for real-time generation: 3 GHz Pentium 4 @ 100%
    - Solution: pre-calculation or new methods (pseudo real-time)

- Accumulation
  - Perfomed in real-time and at sampling rate
  - Independent for every channel

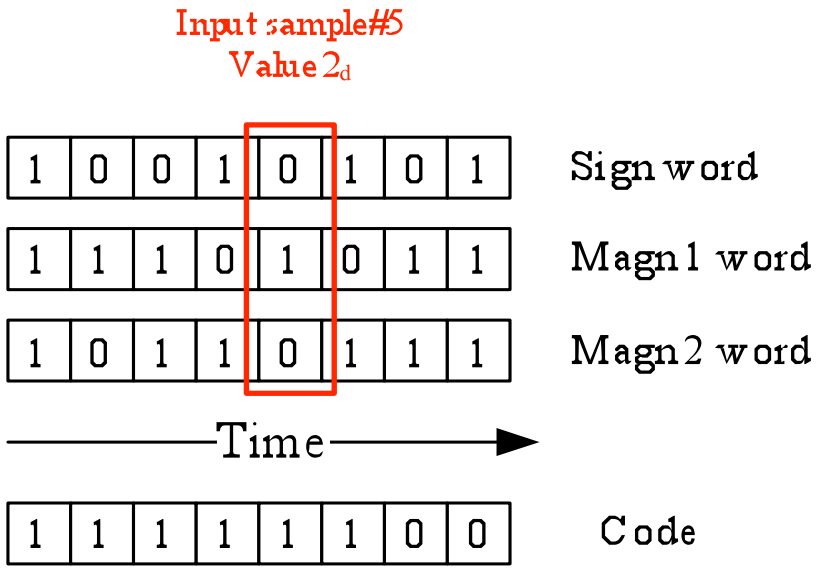
Status: Data Processing

- Single Instruction Multiple Data (SIMD) operations
  - To parallelize the operations
  - Up to 600% performance improvement claimed
  - CPU specific



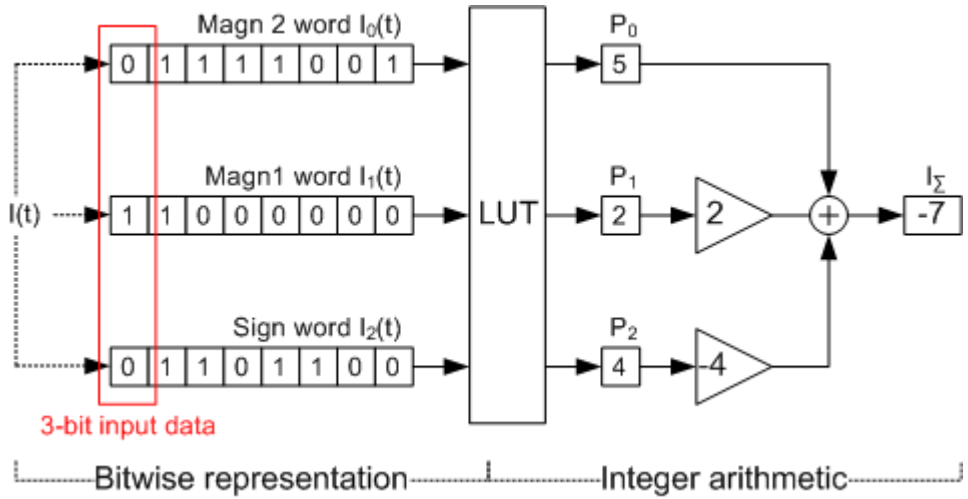
Status: Data Processing

- Bitwise operations (vector processing)
  - To parallelize the operations
  - CPU independent
  - Bit-depth dependent



Status: Data Processing

- Distributed arithmetic
  - To combine the bitwise and integer operations



Status: Code Generation

- Real-time generation not recommended
- Pre-calculate the code
  - In an oversampled representation
  - With different phase offsets
- Doppler shift?
  - Assuming Doppler frequency of 0 Hz
    - Correlation power loss of < 0.014 dB (for Doppler < 10 kHz)
- Almost all SR solutions pre-calculate the code

Status: Carrier Generation

- Needed for Doppler removal
- Real-time generation not recommended
- Pre-calculate the carrier and store in look-up tables
  - Coarse frequency grid (error compensated by phase rotation)
  - Oversampled representation
  - Zero phase or set of initial phases
- Removing the Doppler concurrently for all satellites
  - Loss (due to frequency error) compensated with partial integration and phase rotation
  - Difficult to implement

Status: Acquisition

- Serial search
  - Two dimensional search (code phase / Doppler frequency)
  - Power hungry
  - Not used in software receivers
- Parallel code / frequency search
  - Use of FFT
  - High memory requirements
  - Preferred solution for software receivers

Status: Available Software Receivers

- At university and commercial level
- Not only programming solutions but also realization of dedicated RF front-ends
- Two classes of PC-based software receivers
  - Use of commercial available ADC cards
  - Interate an ADC and an USB interface into the front-end
- Growing market for embedded solutions

Outlook

- Technical
  - Availability of higher performances in the embedded market is one of the key-driver for the development
  - Use of additional available hardware (for example GPUs)
  - Flexibility for research and development laboratories

- Market
  - Software receivers are asked (possibility to adapt to new frequencies and modulations, short time-to-market)

Conclusion

- Software receivers will become important in the next years
- Challenges still exist
- Improvements and development needed

- Working solutions (academic and commercial) exist

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