Universität der Bundeswehr München

GPU Based GPS Signal Generator: Low Cost and High Bandwidth Alternative

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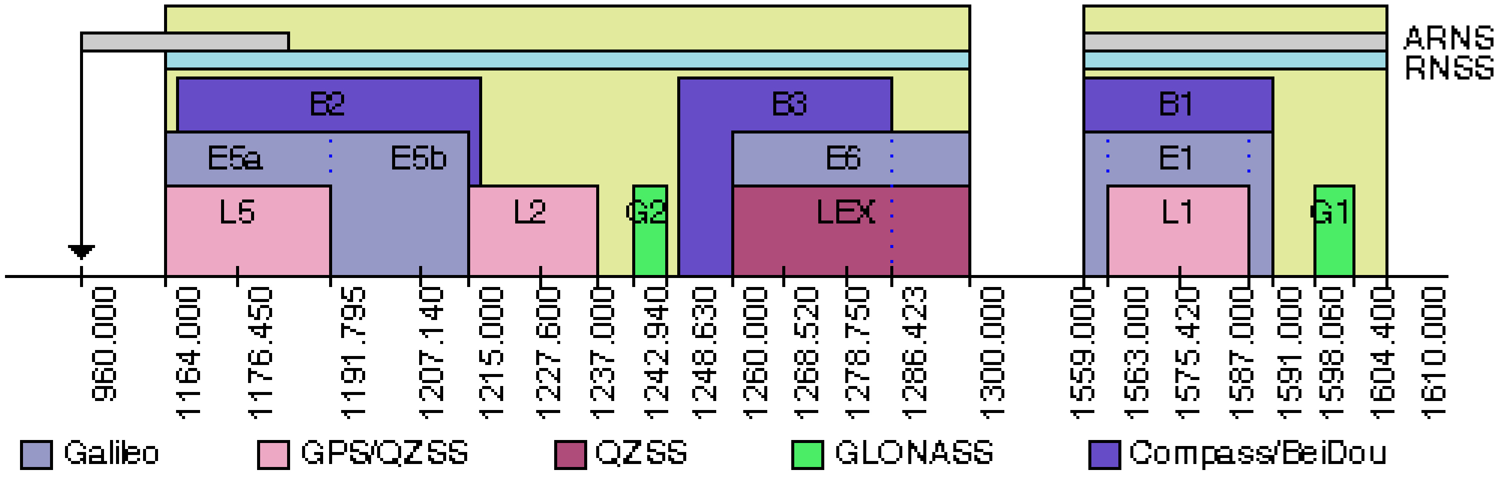
GPS, Galileo and other Global Navigation Satellite Systems (GNSS)



GNSS	GPS	Galileo	GPS	GPS	Galileo	GPS
Service	L1 C/A	E1 OS	L1C	L2C	E5ab	L5
Modulation	BPSK	CBOC	TMBOC	BPSK	AltBOC	BPSK
Components	1	2	2	2	4	2
Code Length	1023	4092	10230	1023/767250	10230	10230
Code 2 Length	0	0/25	0/1800	0	10/20	0

GNSS Signals and Principles

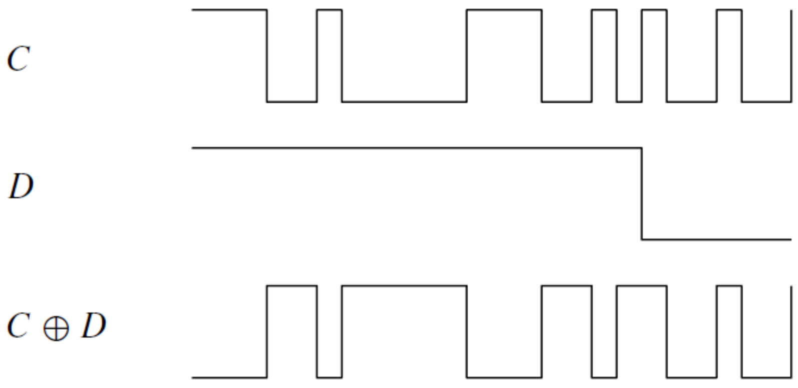
- General signal:

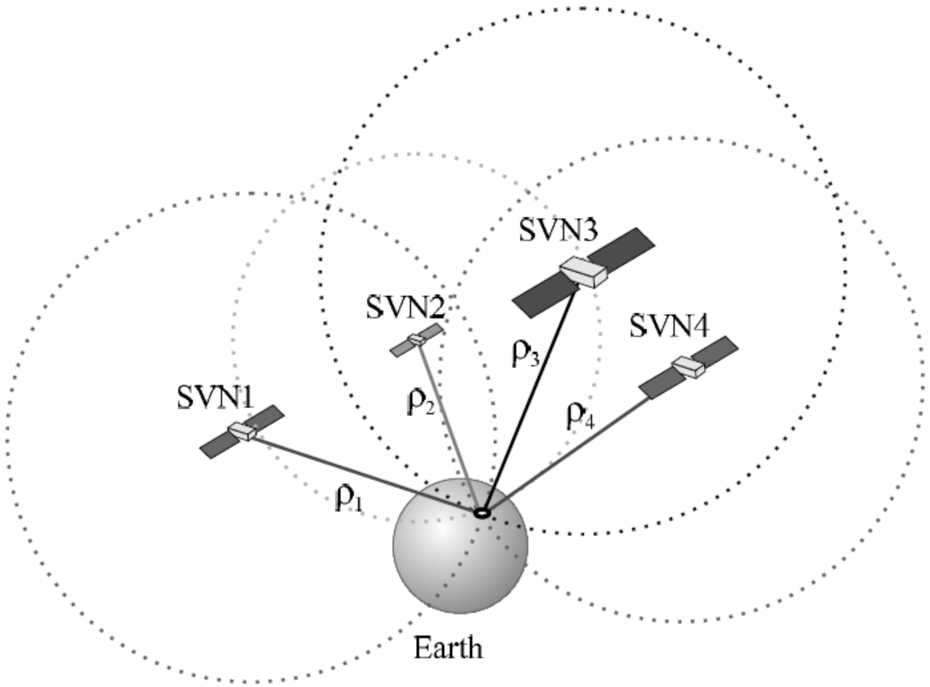
$$s(t) = A\sin(2\pi ft + \varphi)$$

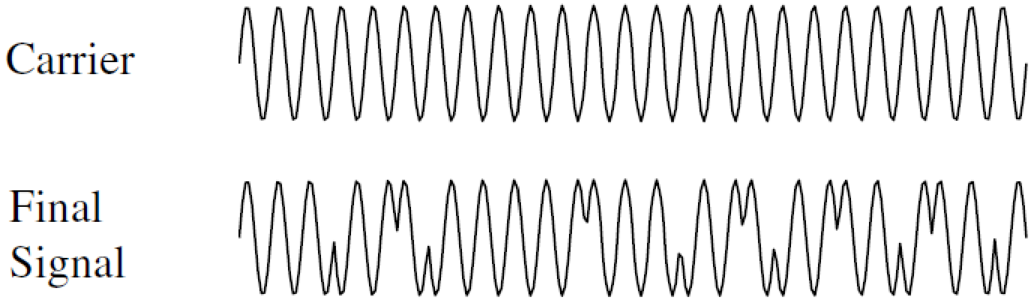
- GNSS signals:

$$s_{L1C/A} = \sum_{p=1}^{m} A_p D_p C_p \cos(2\pi f_p)$$

$$s_{E1OS} = \sum_{p=1}^{m} A_p (D_p C_{bp} S_b - C2_{cp} C_{cp} S_c)\cos(2\pi f_p)$$



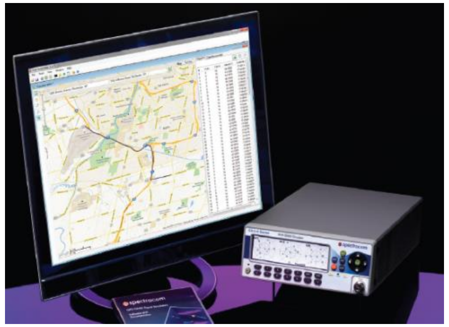




GNSS Signal Simulators

Spirent GSS9000

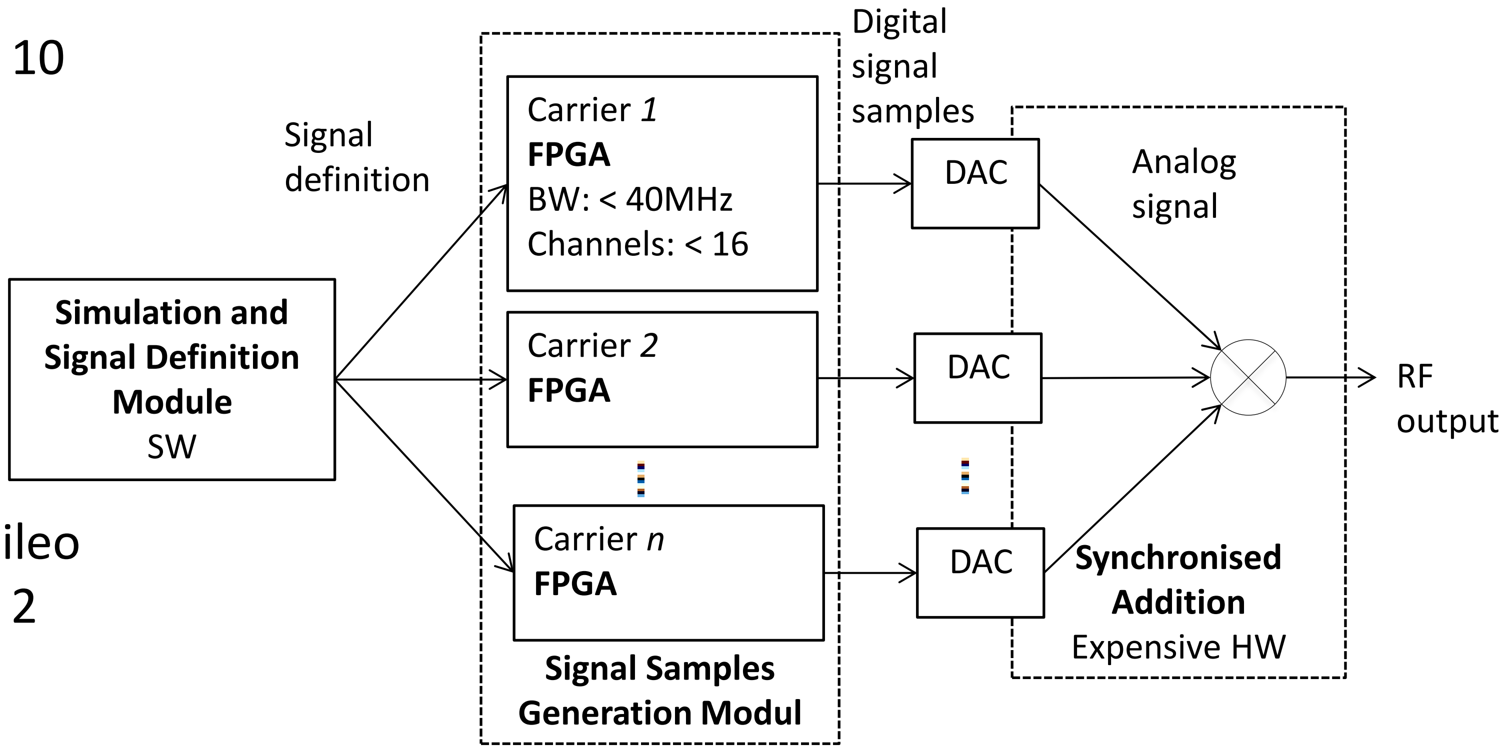
Services: All
Frequency bands: 10
Channels: 160



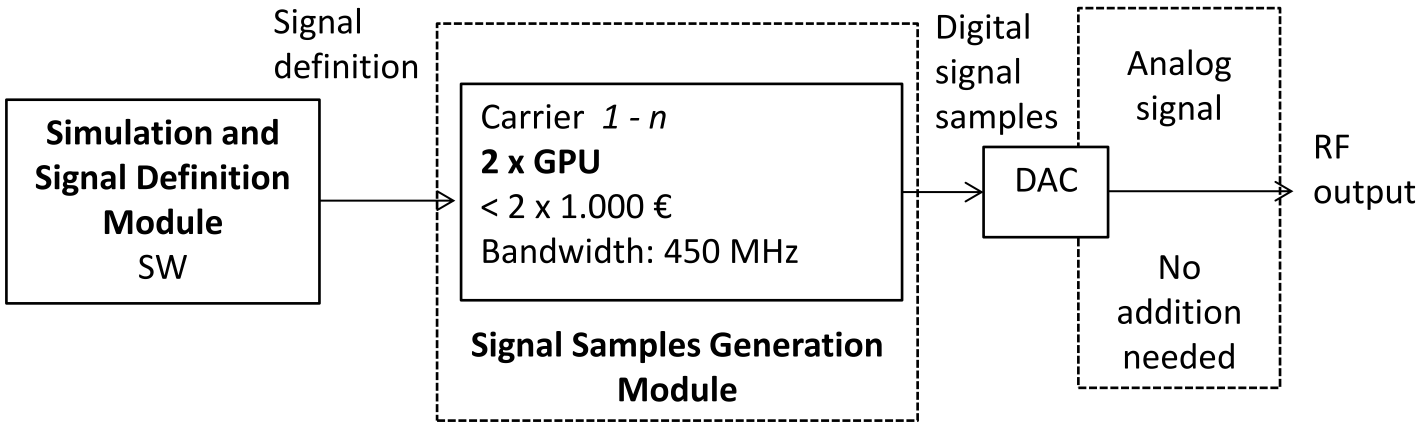
Spectracom GSC-62

Services: GPS, Galileo
Frequency bands: 2
Channels: 48

Nyquist-Shanon: $F_S > 2BW$



GPU Based GNSS Signal Simulator

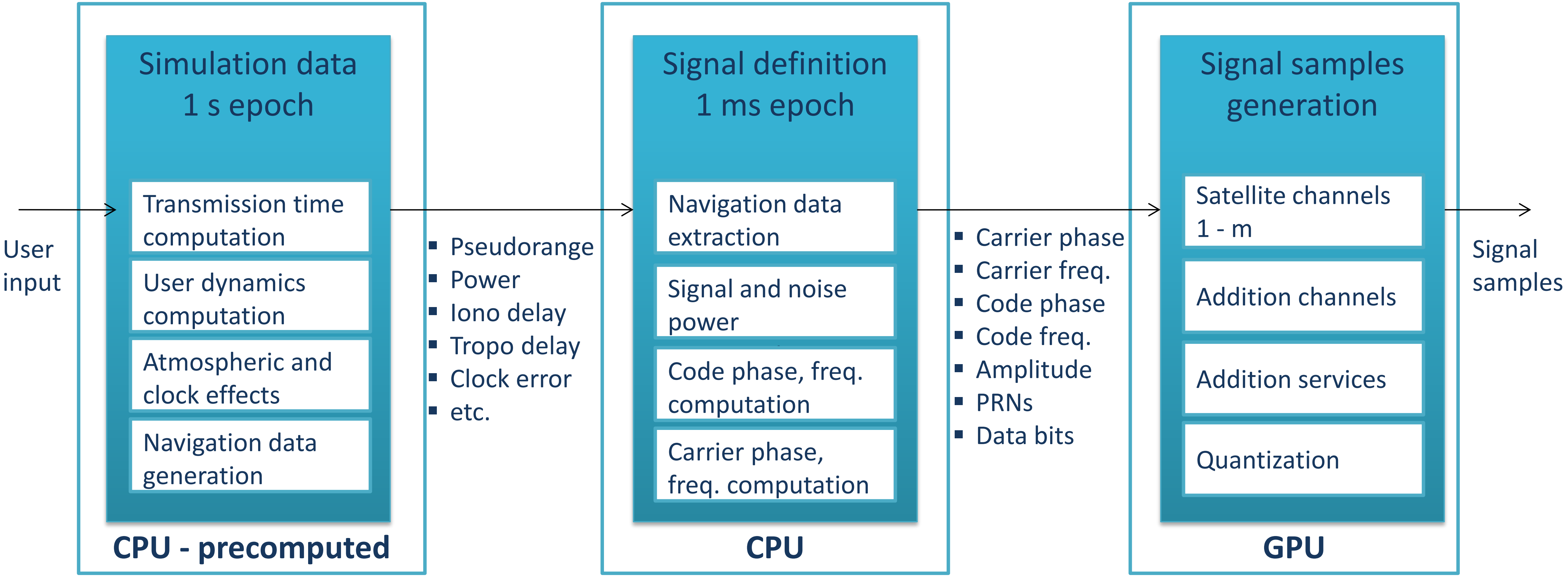


Services: GPS, Galileo, …
Frequency bands: all in 1 broad band
Channels: 84 (2 GPUs)

2x NVIDIA GeForce GTX Titan Black
C.C. 3.5 – Kepler GK 110
15 SMXs, 2880 cores

Gaming PC
ASUS Rampage IV
Intel Core i7-3970X
Corsair Vengeance,
12800 MB/s

Simulator Internal Structure

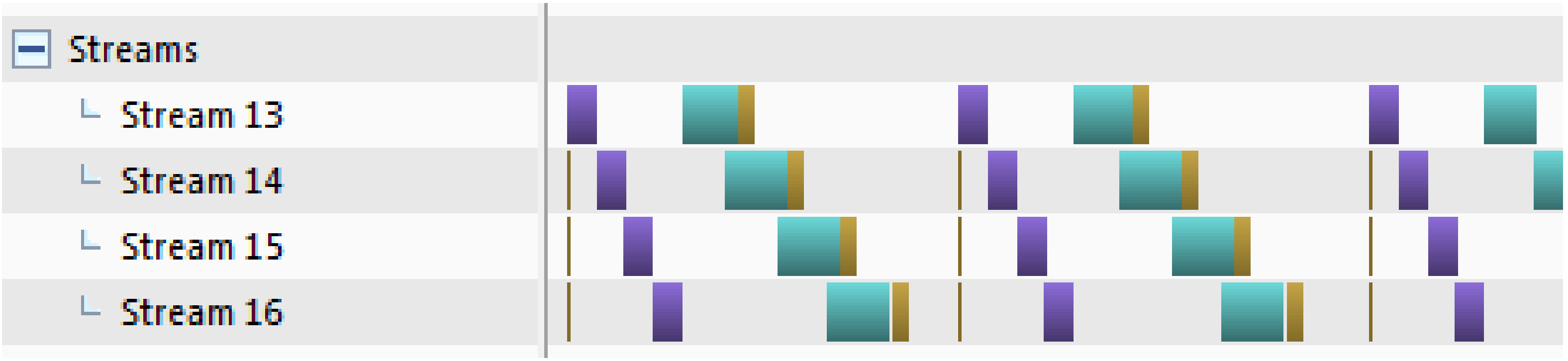


Parallelization and Optimization: CUDA C/C++

- SMs and beyond: get it all run in parallel
  - Data transfer host <-> device
  - Parallelization over SMs of a GPU and multiple GPUs
  - Data transfer to DAC-Board
- SM intern: one kernel for each signal service
  - Parallelization over cores of a SM
  - Carrier wave generation
  - Shared memory and GPU memory concept
  - Addition of services, quantization of signal

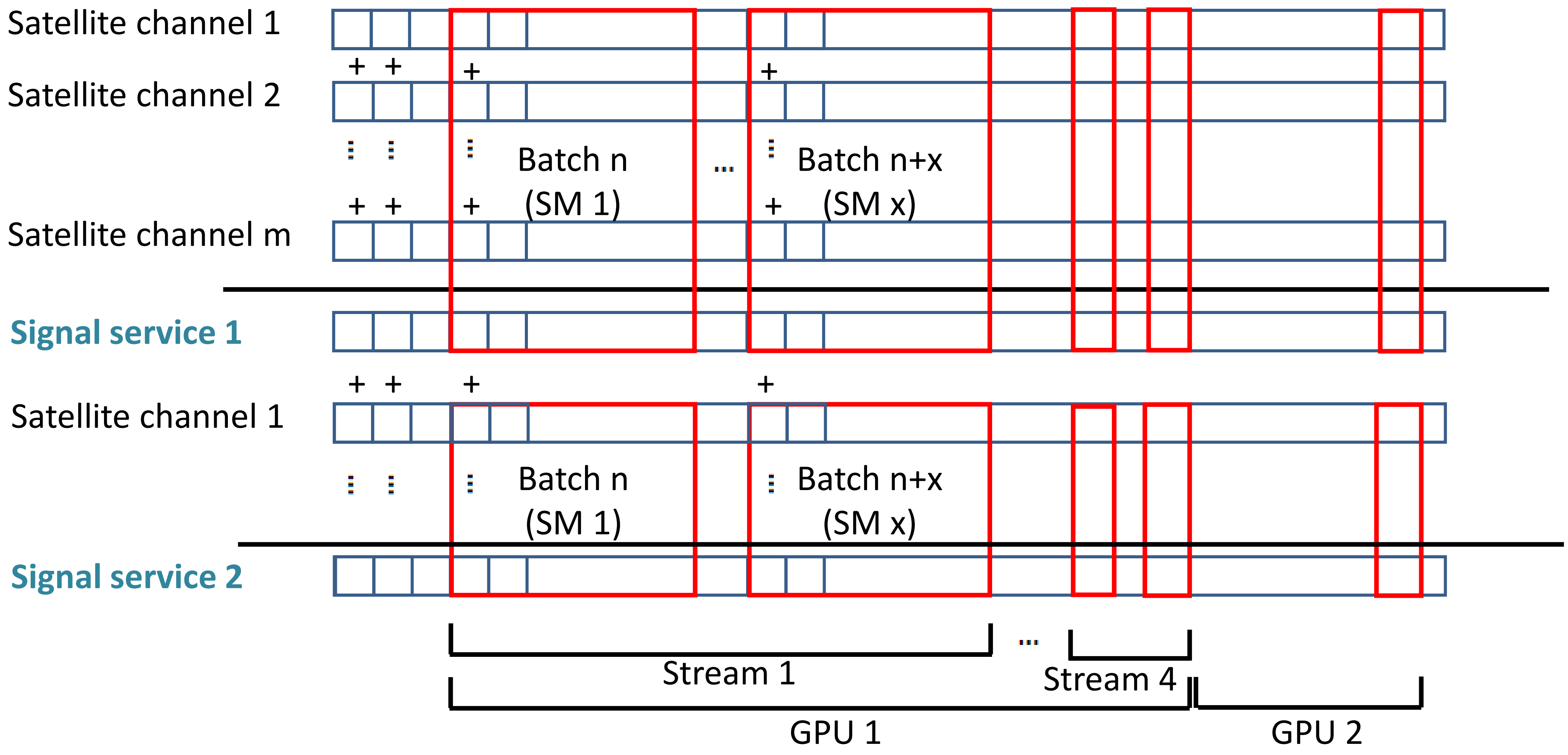
Data Transfer CPU <–> GPU

- Transfer of generated samples GPU -> CPU
  - Theory: PCIe x16 v.3.0: 16 GB/s, host memory speed: 12.8 GB/s
  - Reached: 11.6 GB/s to DAC-board specific buffer (6 MB per transfer)
  - Alternative: GPUDirect RDMA
- Transfer of fixed signal parameters CPU -> GPU
  - Reached: 6 GB/s – (23 kB per transfer)



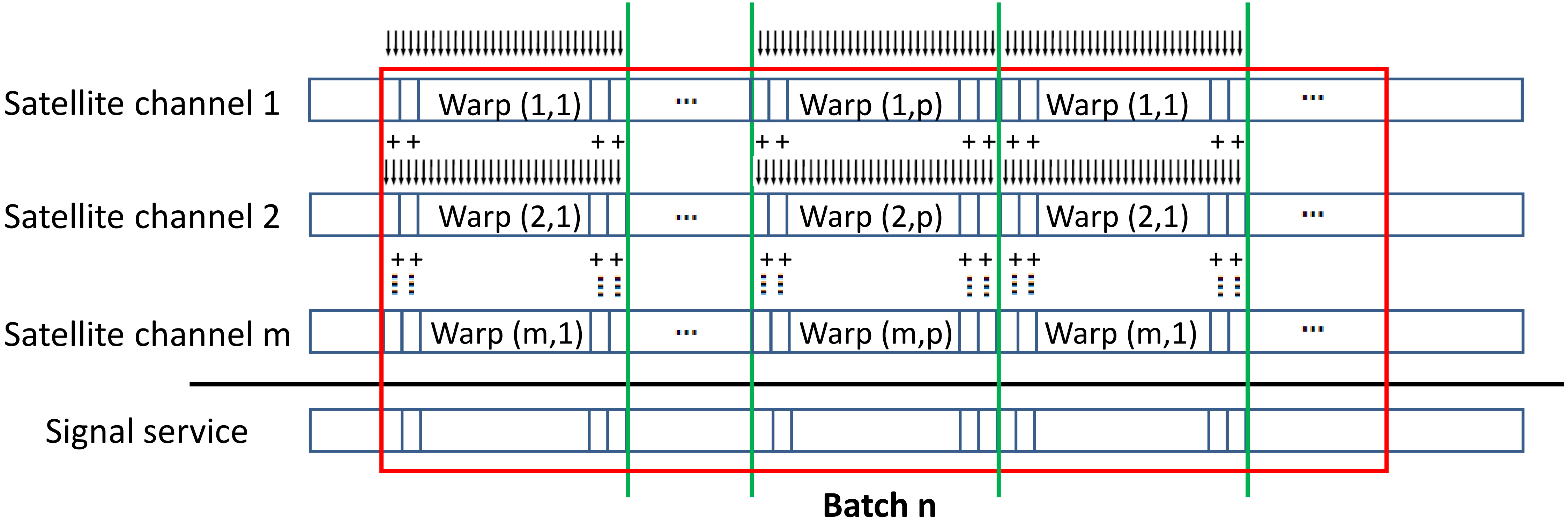
Violet: L1 C/A, Blue: E1 OS, Brown: Data transfer

Parallelization over SMs of a GPU and over Multiple GPUs



Parallelization over Cores of a SM

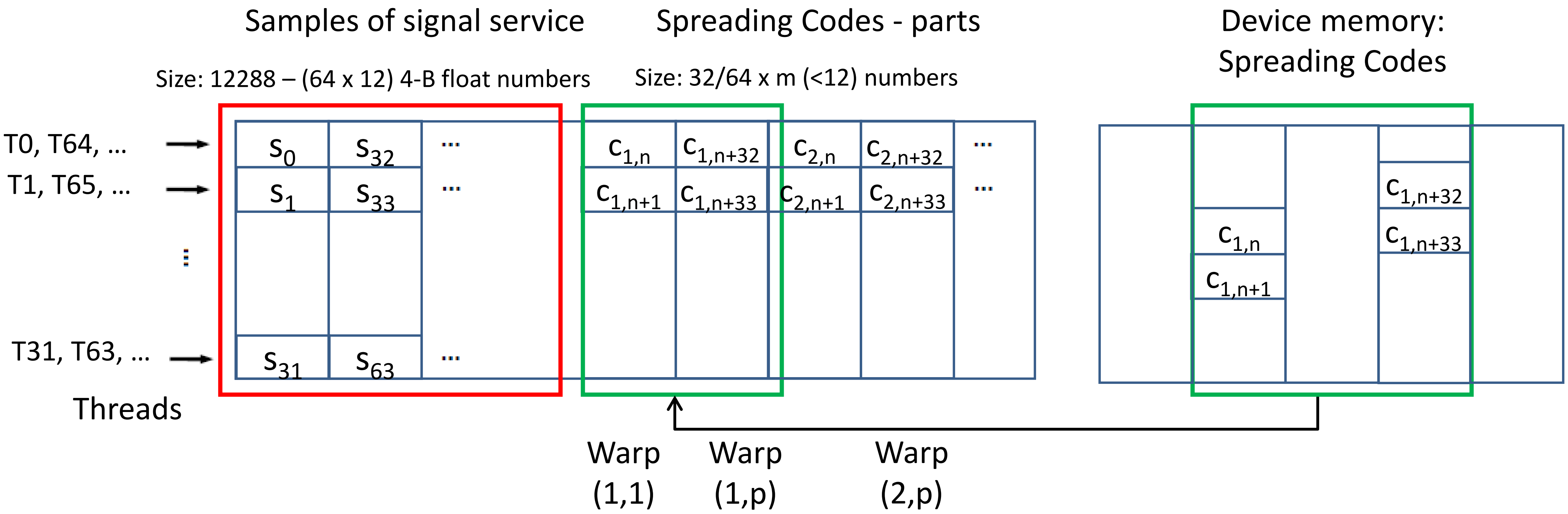
- CUDA block of threads: (m, p x 32)
- Where m * ((p +1) * 32) > max. # warps per kernel



Carrier Wave Generation: Instruction Throughput

- Carrier wave generation
  - SFUs on GPU: sin and cos in one clock cycle
    - Limited number of SFUs
    - Special modulation schemes: AltBOC
  - Conventional approach in digital signal generation: Lookup table
    - Shared memory: no alignment of access within warp
    - Registers: too big

SM Shared Memory Usage



- Parts of PRN sequences reloaded successively
- Addition to signal stream in device memory and quantization

Digital Signal Precision

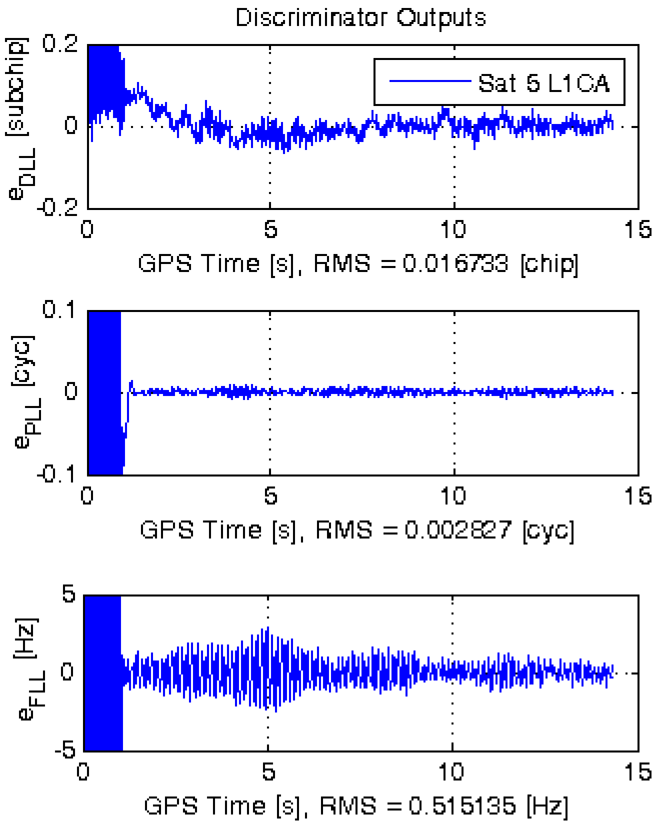
1. Signal samples precision [bits]
   - Float: 23 (100%), double: 52 (30%)
2. Carrier, code phase (NCO) resolution
   - Float: limited, uint +ulong: OK
3. Time from start of simulation
   - Precision carrier: 13 bits
   - Float: insufficient
   - double: 1 week of highest SR

Signal Samples Precision	**Value Range**	**Bits**
Satellite channels [#]	12 - 168	4 - 8
Relative signal power [dBW]	-205, -150	2 – 9
Carrier wave resolution [cycle]	1.2E-4 - 6.4E-18	13 - 21

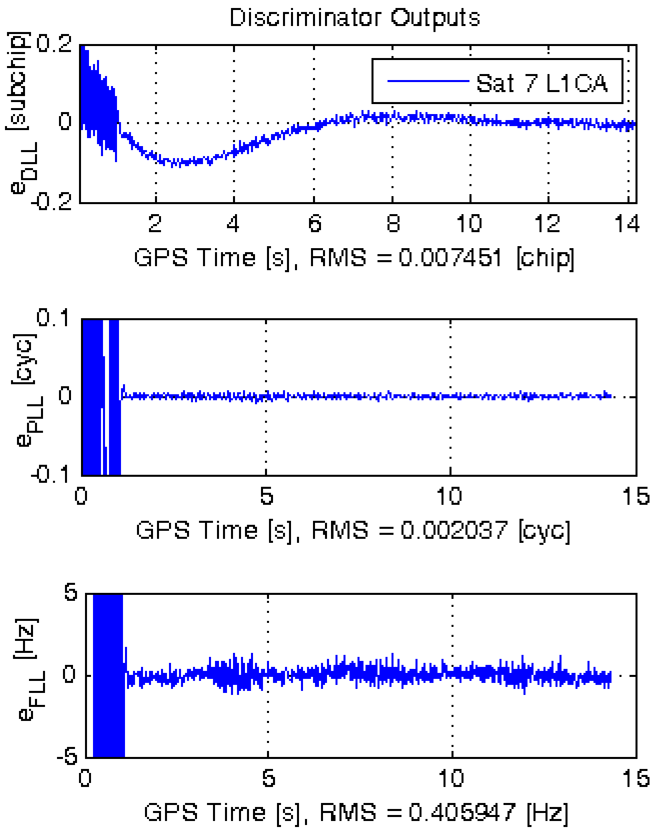
NCO Resolution Phase Step: 64 th.	**Max. value**	**Bits x.y**	**Bits x.y**	**Δ_f broad band**	**σ_t min. error**
Carrier freq. [cyc]	*.322*	*0*	*32*	0.23 Hz	0.1 Hz
Carrier phase [cyc]	0.999	0	32		--
C freq. [chip]	2.864	16	48	3.5e-6 Hz	0.001
C [chip]	63.99	16	48		--

Verification

- Verification: Institute’s own scientific CPU-based software receiver IpexSR

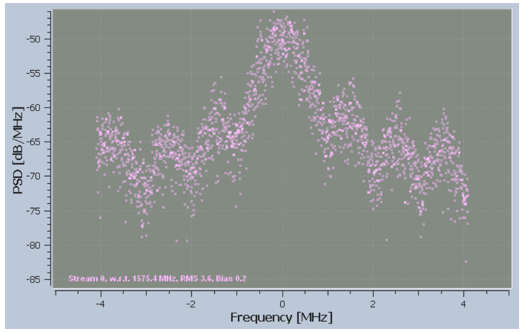


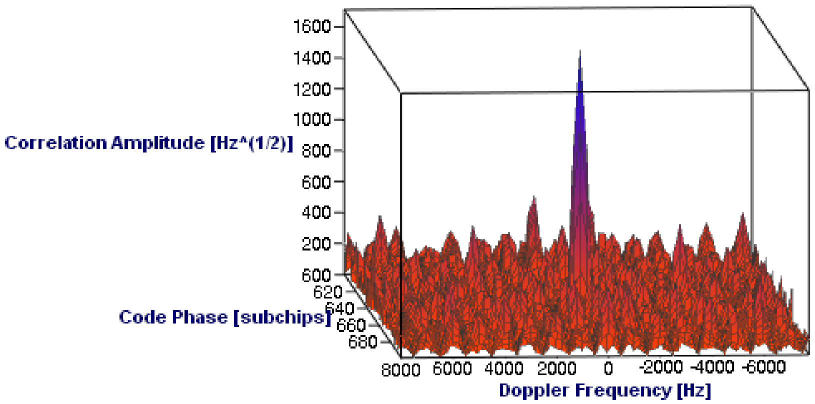
Float samples, float NCO



Float samples, fixed point NCO

Acquisition: PRN 1

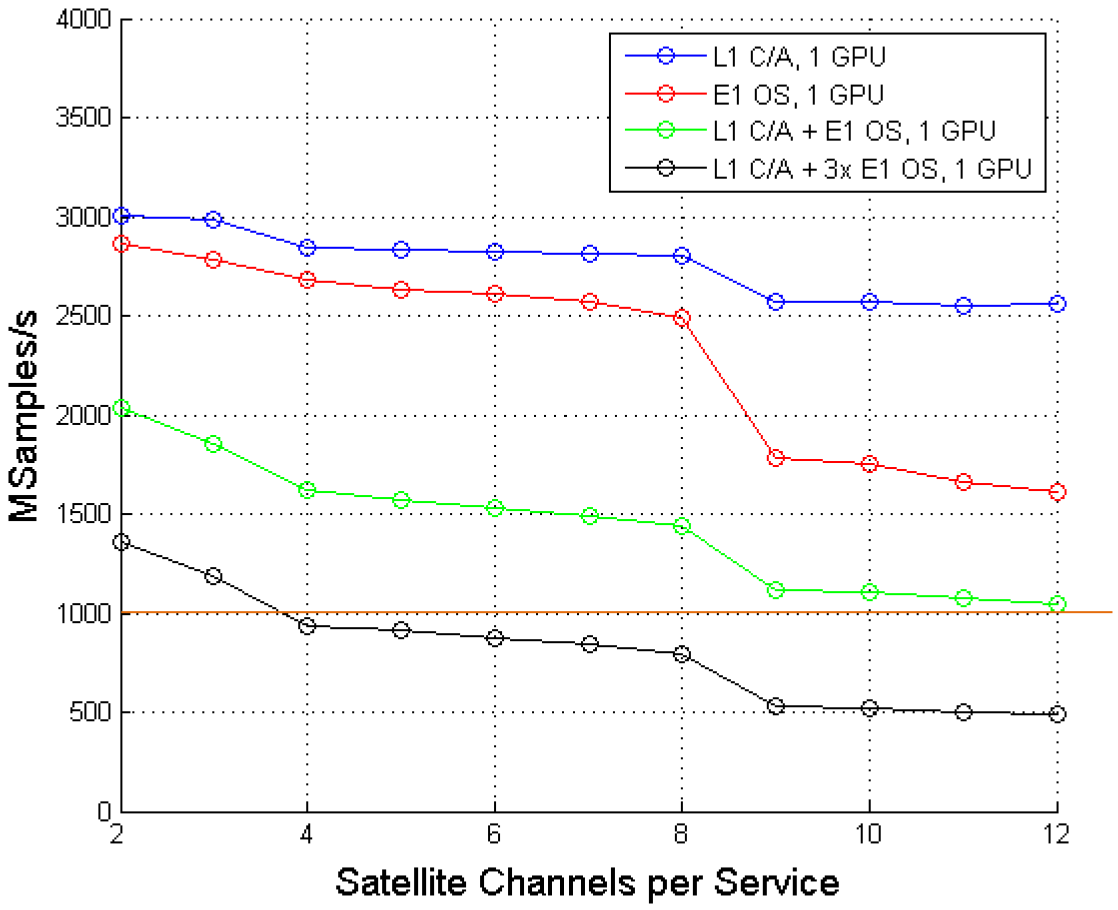




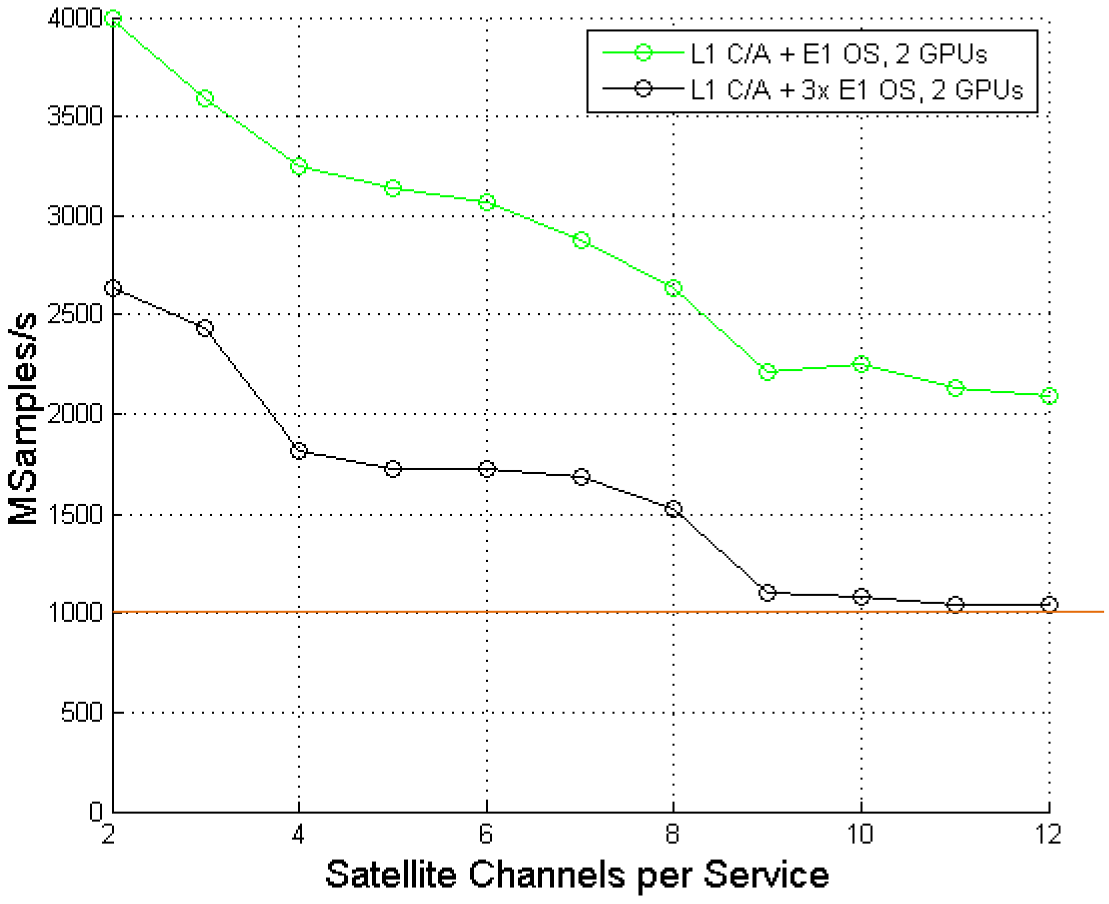
Power Spectrum Density

Real-Time Performance

Sample Generation Rate: 1 GPU



Sample Generation Rate: 2 GPUs



Summary

- Benefits
  - Flexible – satellite channels, signal services vs. # GPUs
  - Low-cost mass market components for digital part
  - Full GNSS bandwidth in real time
  - Future progress:
    - GPUdirect RDMA
    - Fast evolution of GPU technology
    - Double precision units (Quadro, Tesla)
- Challenges
  - High bandwidth DAC for PCIe
  - GPUdirect RDMA for DAC-board
  - High bandwidth upconversion

Thank you

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