State of the Art Signal Acquisition using a GPU

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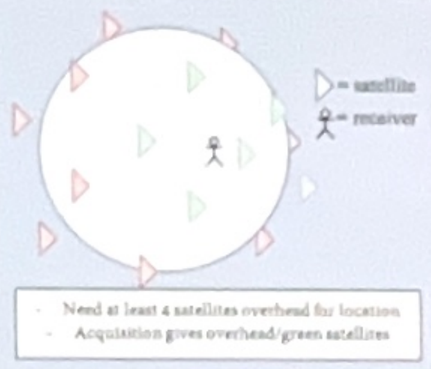
Background

Introduction:

- GPS needs to know the satellites that are overhead (signal acquisition)
- Offline signal acquisition and satellite monitoring rely on CAF (Cross Ambiguity Function) generation
- CAF generation is extremely computationally expensive and time-consuming



Objective:

- Speed up L1 C/A CAF generation through optimizations and the GPU

The Received Signal:

- Each satellite's signal, $x(t)$ or $e^{j2\pi ft}$, has a unique PRN (pseudo-random noise) code, $c(t)$, in binary format
- Satellite transmits the signal replica or $c(t)x(t)$, but we receive $c(t)x(t) + n(t)$ where $n(t)$ is noise and $n(t) \gg c(t)x(t)$
- The received signal is also shifted in time, τ, and frequency, f_d
- $y(t) = c(t+\tau)e^{j2\pi(f_c+f_d)t} + n(t)$ where $y(t)$ is the received signal
- Sum for all t in the signal for correlation
- Repeat for all possible time delays, τ, and Doppler shifts, f_d

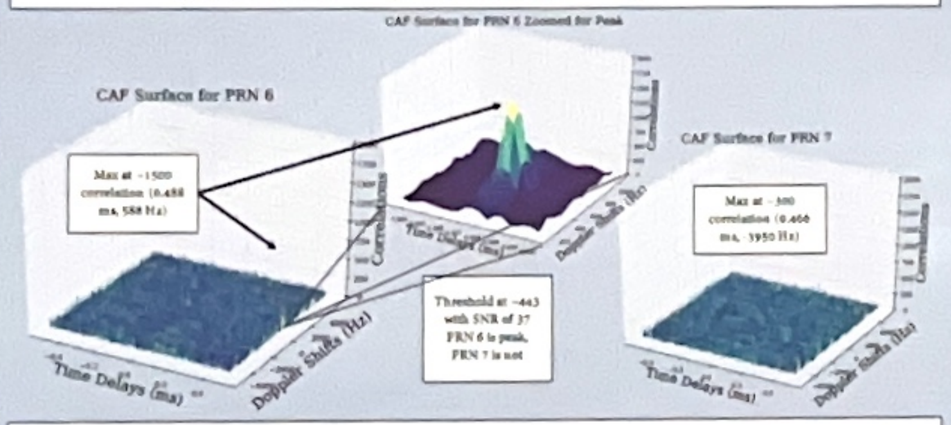
CAF Generation:

$$\sum_{t=1}^{T} y(t)e^{-j2\pi(f_c+f_d)t}c(t+\tau) = \sum_{t=1}^{T} c(t+\tau)^2 + n(t)c(t+\tau)$$

$$= IFFT\left(FFT(y(t))\overline{FFT(c(t)e^{-j2\pi(f_c+f_d)t})}\right)$$

Peak Detection:

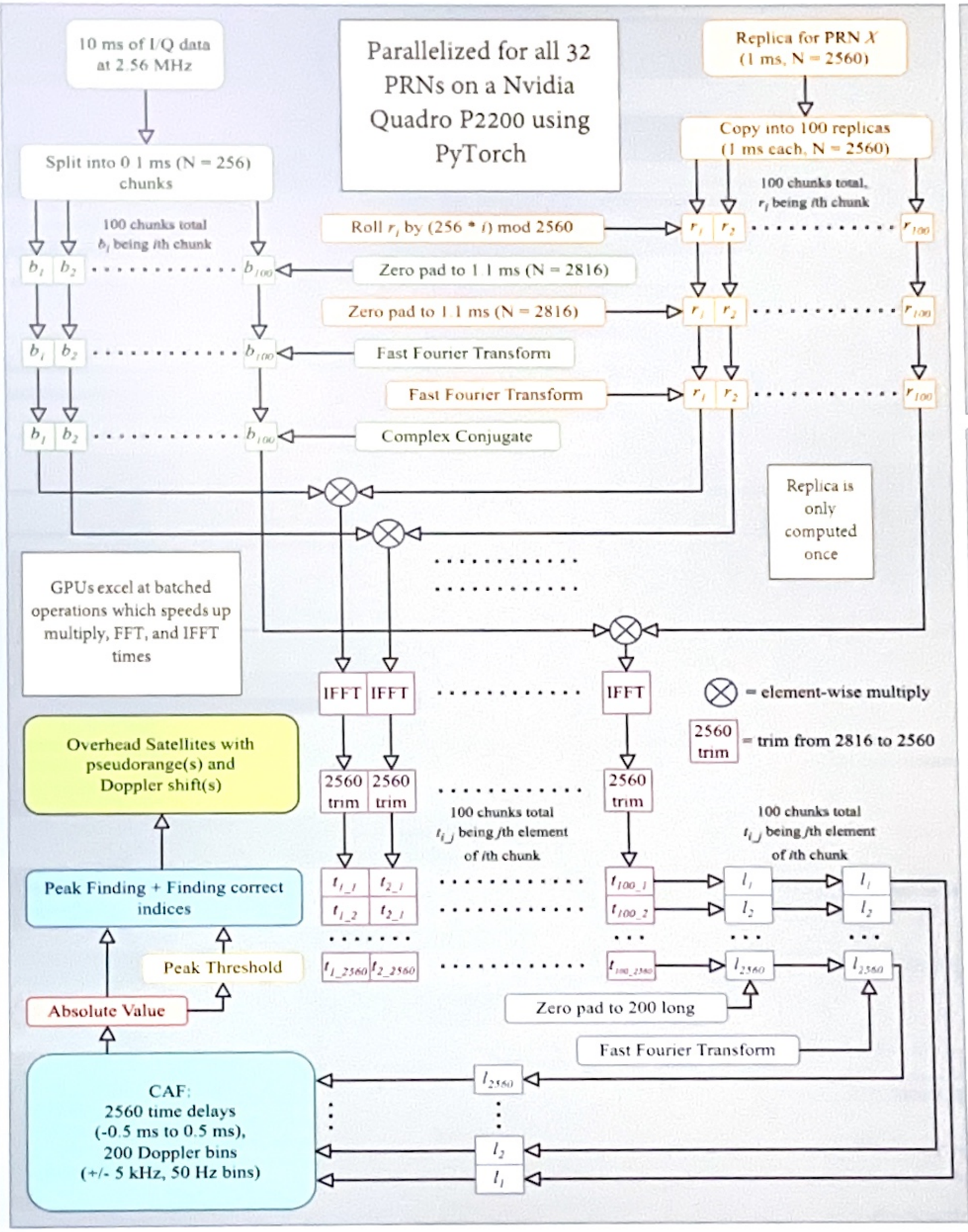
$$Threshold = \sqrt{SNR(noise \cdot \Delta t) + noise}$$



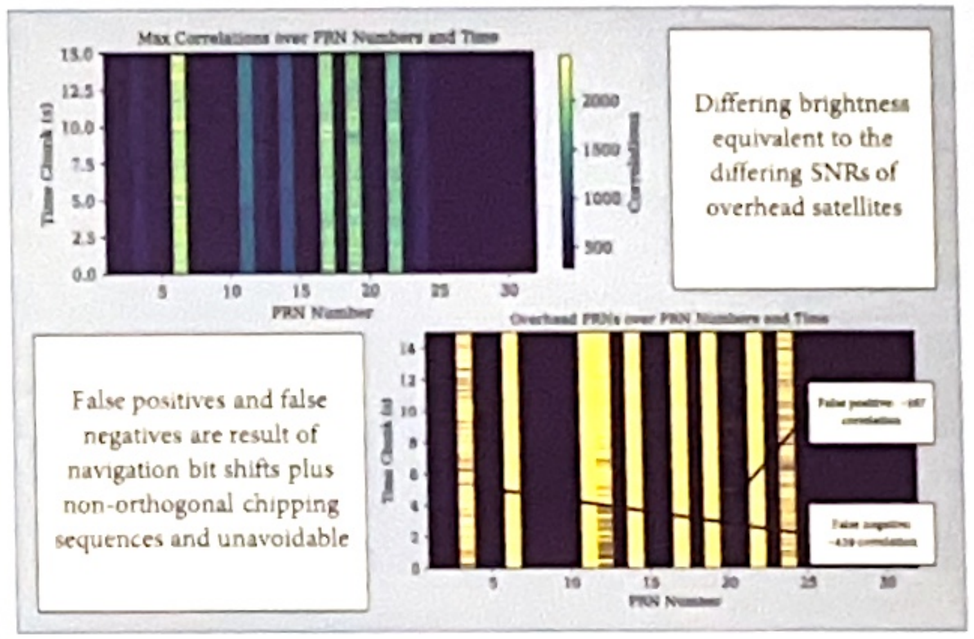
Overhead Satellites:

- If a peak exists for some τ, f_d then there is a satellite overhead

Methodology



Results



Differing brightness equivalent to the differing SNRs of overhead satellites

False positives and false negatives are result of navigation bit shifts plus non-orthogonal chipping sequences and unavoidable

Step	Time (ms)
Preprocessing	0.130 ms
Multiply	0.662 ms
IFFT	4.108 ms
FFT	4.781 ms
Magnitude	2.648 ms
Threshold	0.481 ms
Identification	1.748 ms
CAFs	9.832 ms
Acquisition	14.78 ms

20 times speed up!
100 FPS live data display!

Conclusion/Future Work

Conclusion:

- Successfully lowered 300 ms (typical CPU implementation) to 15 or 10 ms
- Nearly instantaneous signal acquisition and completely real-time CAF generation
- No loss in coherent integration time and high pseudorange/Doppler shift resolution

Future Work:

- Improve data export functionality (12 Gb/s)
- Combination of acquisition and tracking

First (startup) steps takes disproportionate times

Step	Multiplier
Preprocessing	5.1 (~0.66 ms)
Multiply	3.6 (~2.39 ms)
IFFT	2.8 (~11.35 ms)
FFT	3.3 (~15.64 ms)
Magnitude	4.0 (~10.61 ms)
Threshold	191.1 (~91.71 ms)
Identification	21.7 (~37.91 ms)
CAFs	3.1 (~30.24 ms)
Acquisition	10.6 (~171.02 ms)