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An Accelerated Signal Tracking Module Using a Heterogeneous Multi-GPU Platform for Real-time GNSS Software Receiver

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Kwi Woo Park[1], Sangwoo Lee[2], Min Joon Lee[3], Sunwoo Kim[2] and Chansik Park[1]

[1]Dept. of Electronics Engineering, Chungbuk National University, Korea
[2]Dept. of Electronics and computer Eng., Hanyang University, Korea
[3]Agency for Defense Development, Korea

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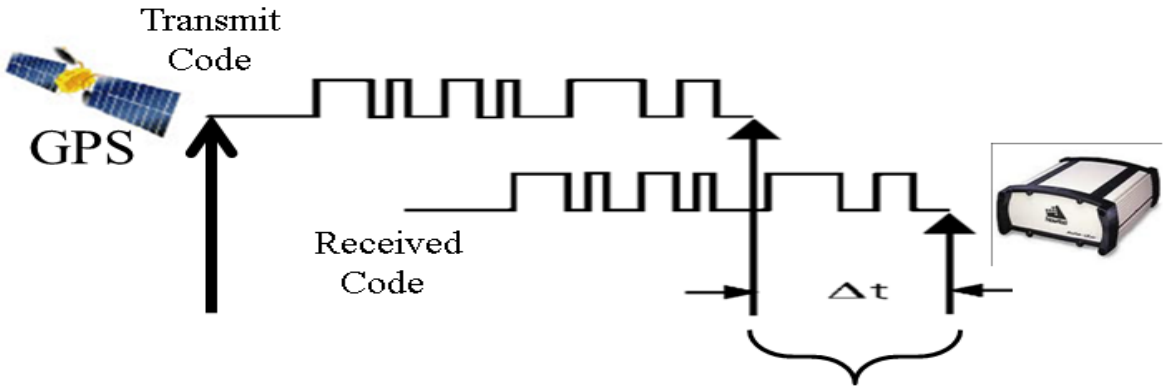
GNSS(Global Navigation Satellite System)

Concept of GNSS

Navigation Message

Satellite ≡ Transmitter

Receiver



Wave propagation delay → range

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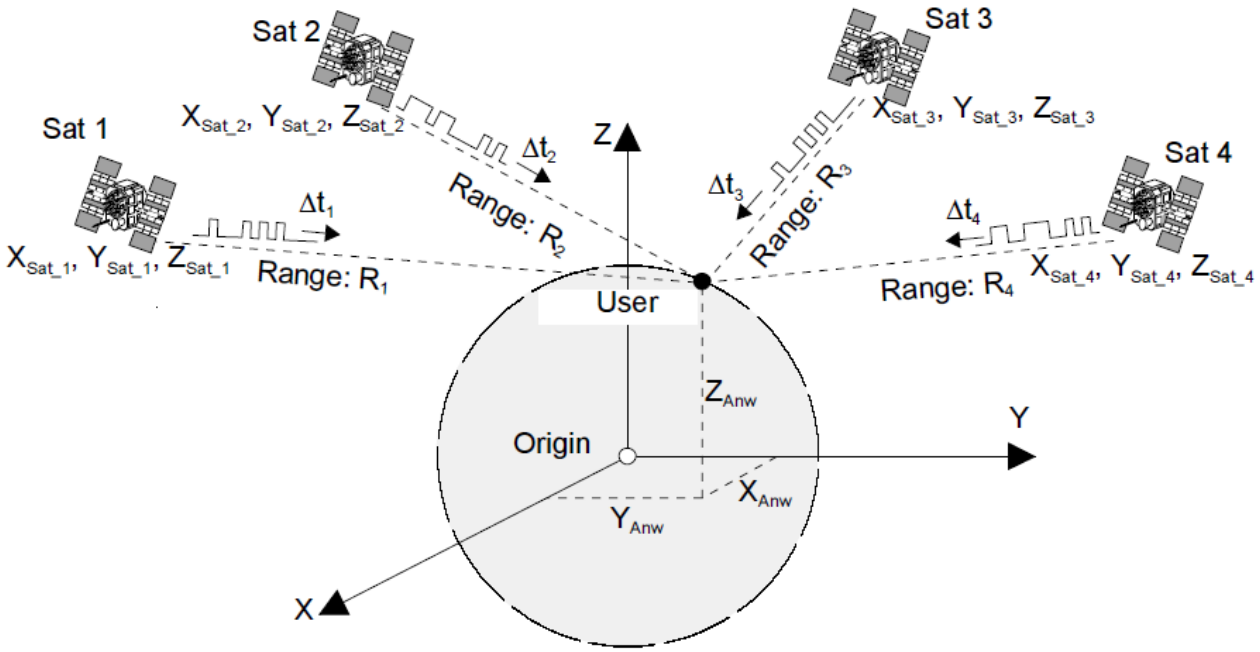
GNSS(Global Navigation Satellite System)

Positioning

- Measurements
  - Speed of light * (Rx time – Tx time) → Range
  - Navigation msg → Ephemeris → Satellite position(Tx time)

- If #Measurements >= 4?



Multi-constellation

Operation plan of GNSS

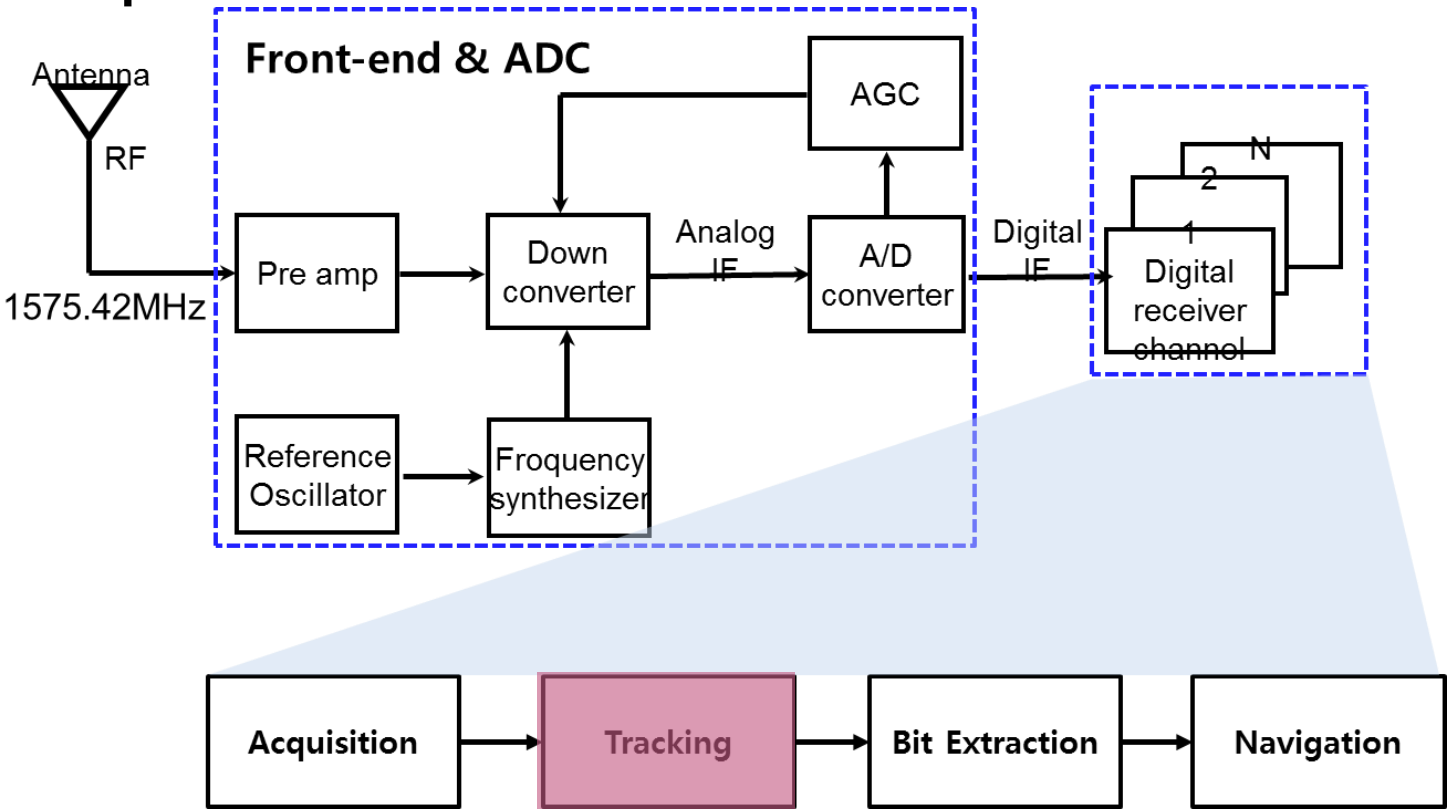
	L1 band(1575.42Mhz) E1 band(1575.42Mhz) G1 band(1598.0625 ~ 1605.275) B1(1561.098Mhz)				L2 band(1227.60Mhz) E6 band(1278.75Mhz) G2 band(1242.9375 ~ 1248.625) B3(1268.52Mhz)				L5 band(1176.45Mhz) E5 band(1191.795Mhz) B2(1207.14Mhz)	
GPS	L1 C/A	L1C	L1 Pcode	L2 Mcode	L2C		L2 Pcode	L2 Mcode	L5	
Galileo	E1 OS		E1 PRS		E6 CS		E6 PRS		E5a	E5b
GLONASS	G1 OF	G1 SF	G1 OC	G1SC	G2 OF	G2 SF	G2 OC	G2 SC		
BeiDou	B1-I		B1-Q		B3-I		B3-Q		B2-I	B2-Q

Closed service
Underdevelopment
Open service

- Channel reconfiguration → Software-Defined Radio
- SDR → CR(Cognitive Radio) → Jamming detection & Avoidance

GNSS SDR(Software-Defined Radio)

Concept of SDR

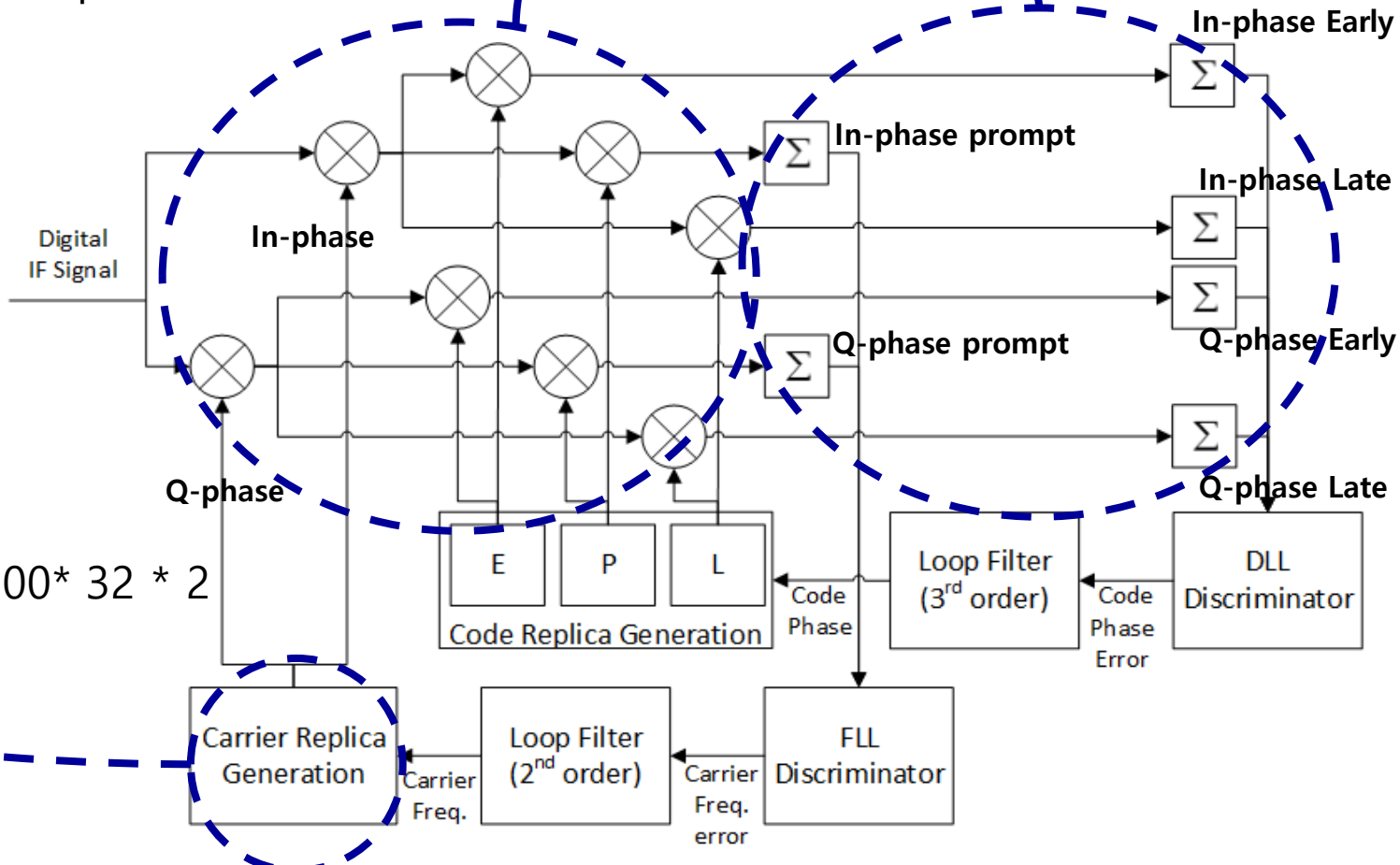


- Software Receiver(S/W) → Parallel computing using GPU
- Signal tracking have a heavy computational load

Signal Tracking Loop

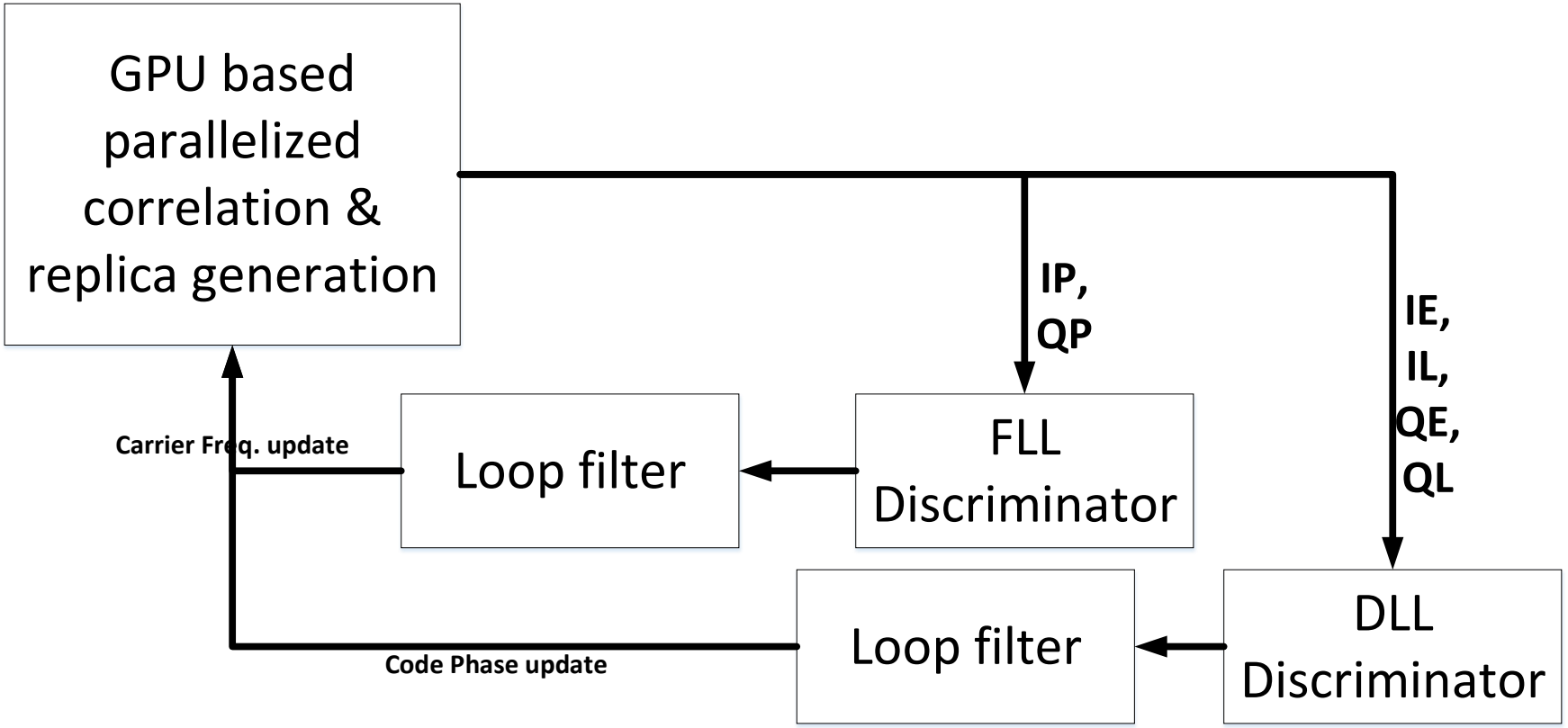
Example – 1msec signal integration

- Sampling Rate : 32MHz
- Quantization bit : 16bit
- #Channels : 32
- #Correlator per channel : 6
- Multiplier : 32000* 32 * 8
- sum : 32000* 32 * 6
- Cos() : 32000* 32 * 2



Parallelized signal tracking

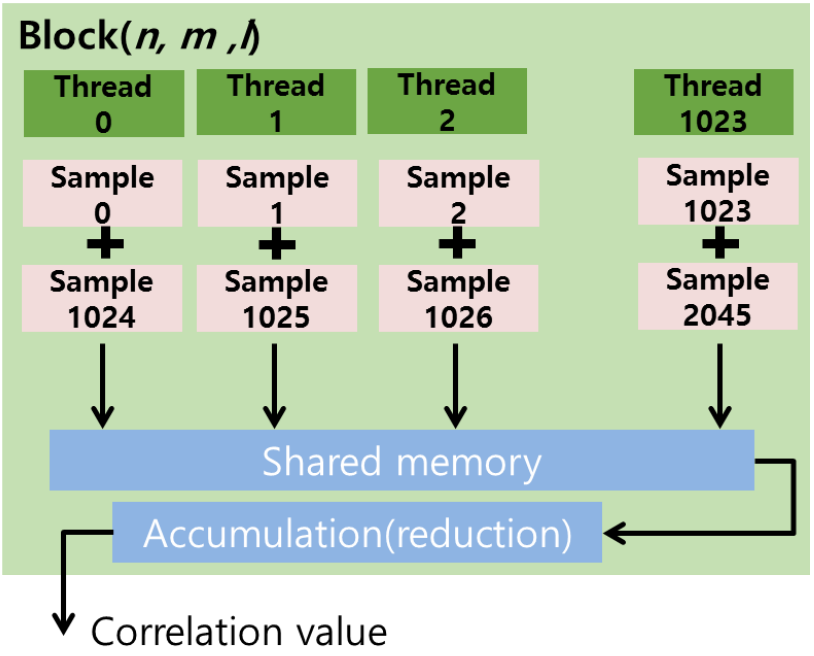
- Correlation, Replica generation is parallelized
- Correlation values(IE, IP, IL, QE, QP, QL) are computed by hundreds of threads and blocks in parallel based on GPU



Parallelized signal tracking

Correlation kernel[1]

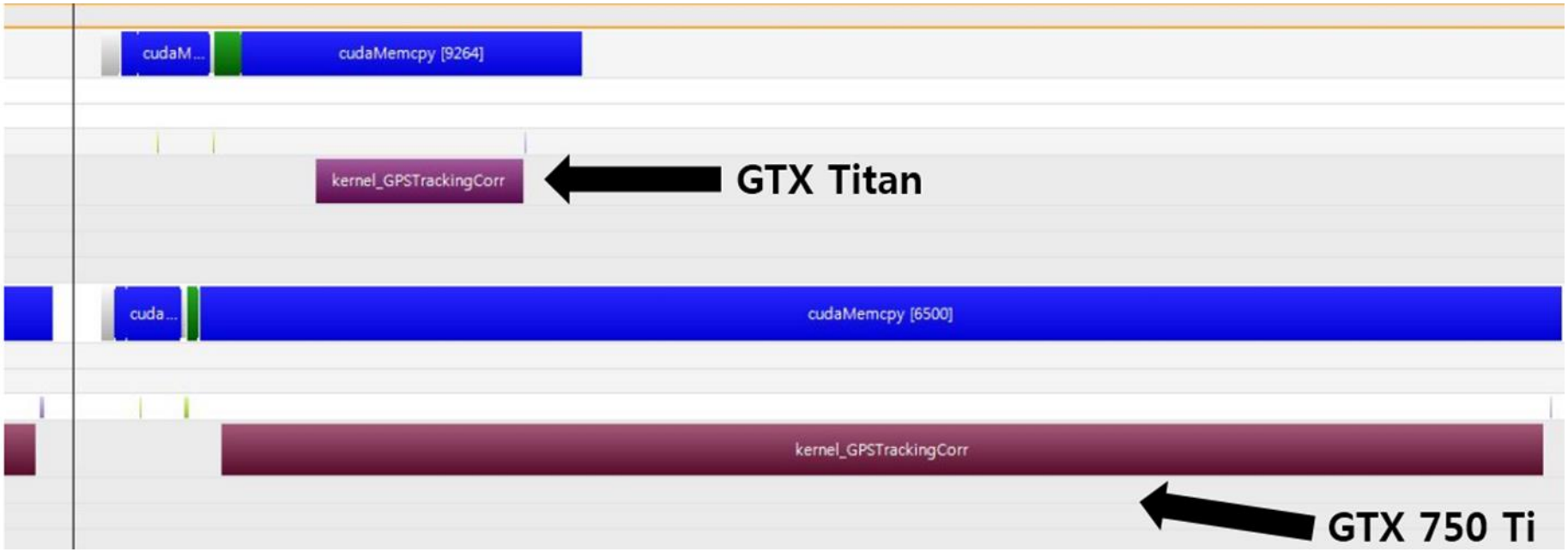
- Computation using block and thread
- Block : number of correlators = #Channels x 6(IE, IP, IL …)
- Thread : maximum thread is 1024 per block



Load balancing for multi-GPU platform

Multi-GPU and Load balancing

- Load imbalanced example
- All processor wait for the “slowest” one



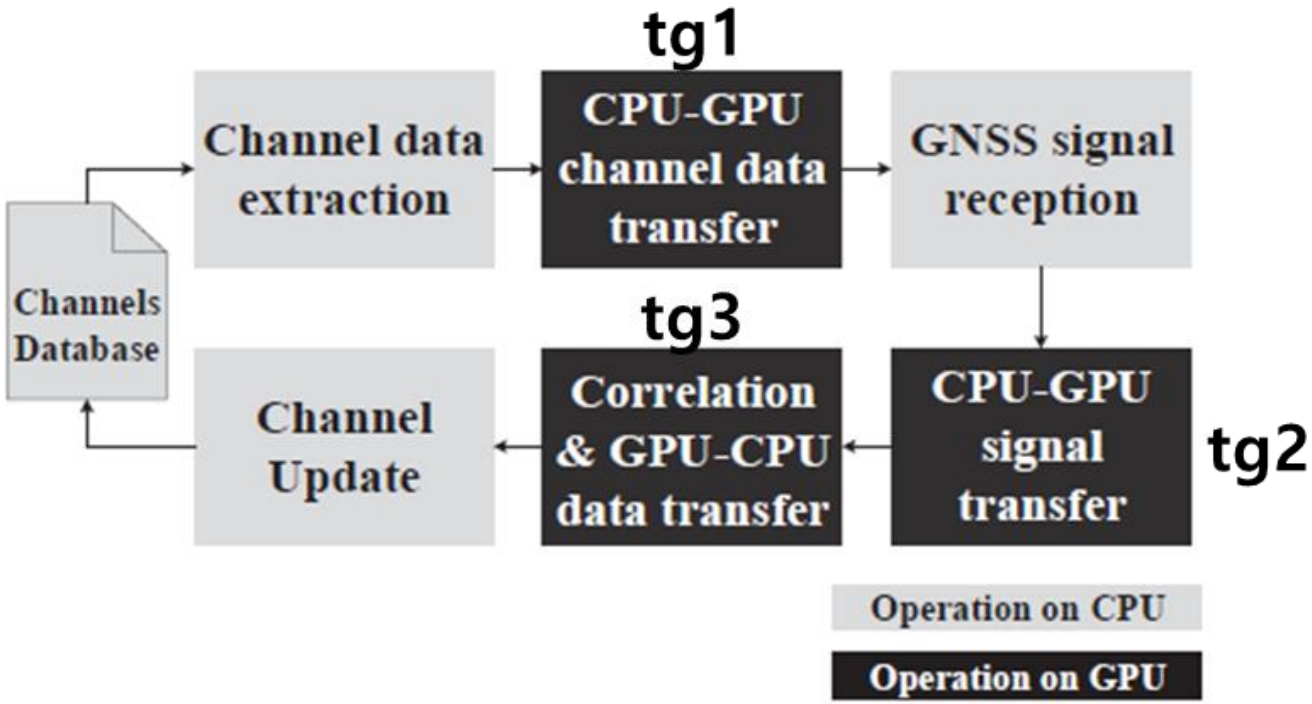
Load balancing for multi-GPU platform

Model based load balancing

- To estimate the operation time of signal tracking per channel

Signal tracking is sliced and measured by Nsight profiler*

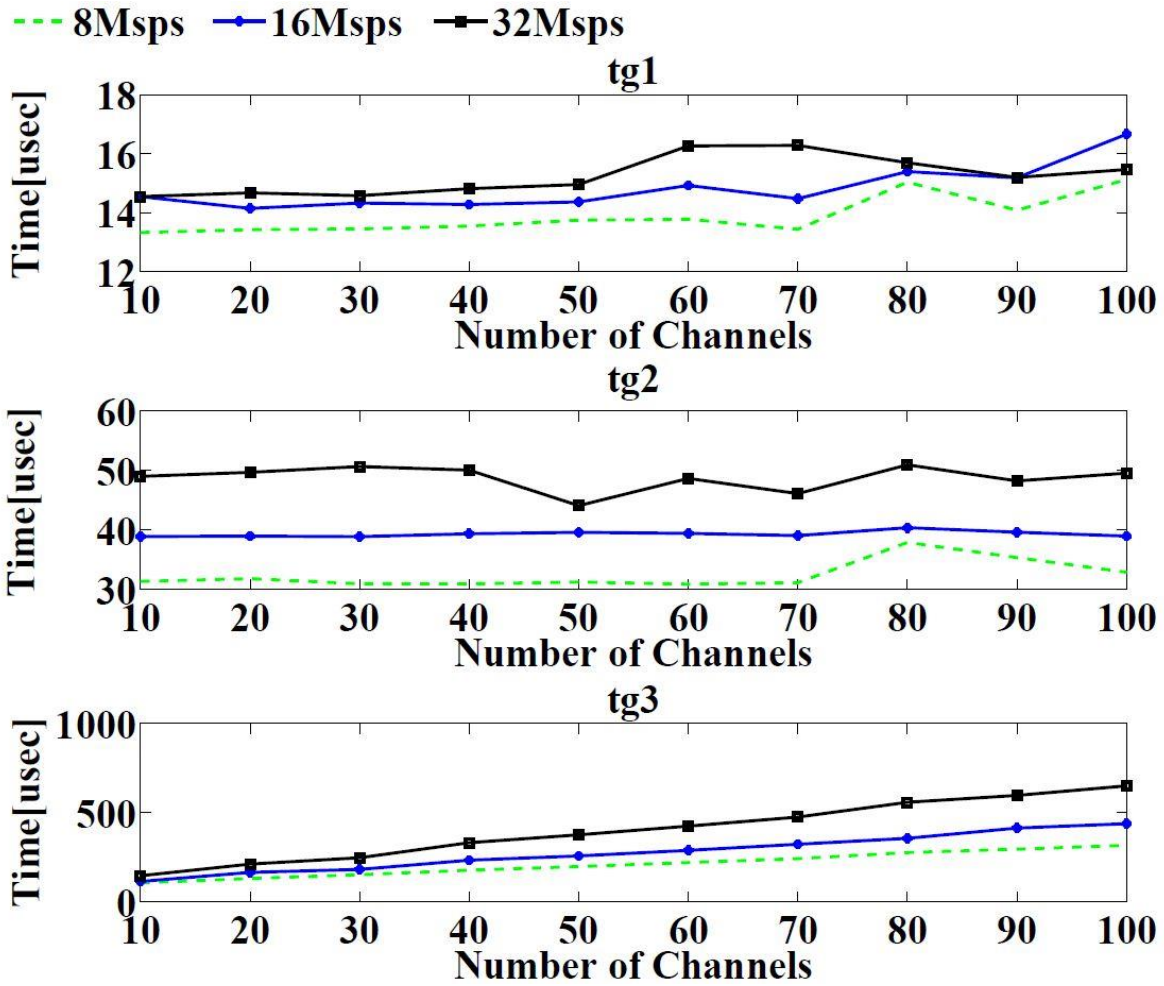
- Operation time of 3 phase in GPU(tg1, tg2, tg3) is measured



Load balancing for multi-GPU platform

Analysis of operation time

- Operation time check with sampling rate and channels
- Using same GPU(GTX Titan)



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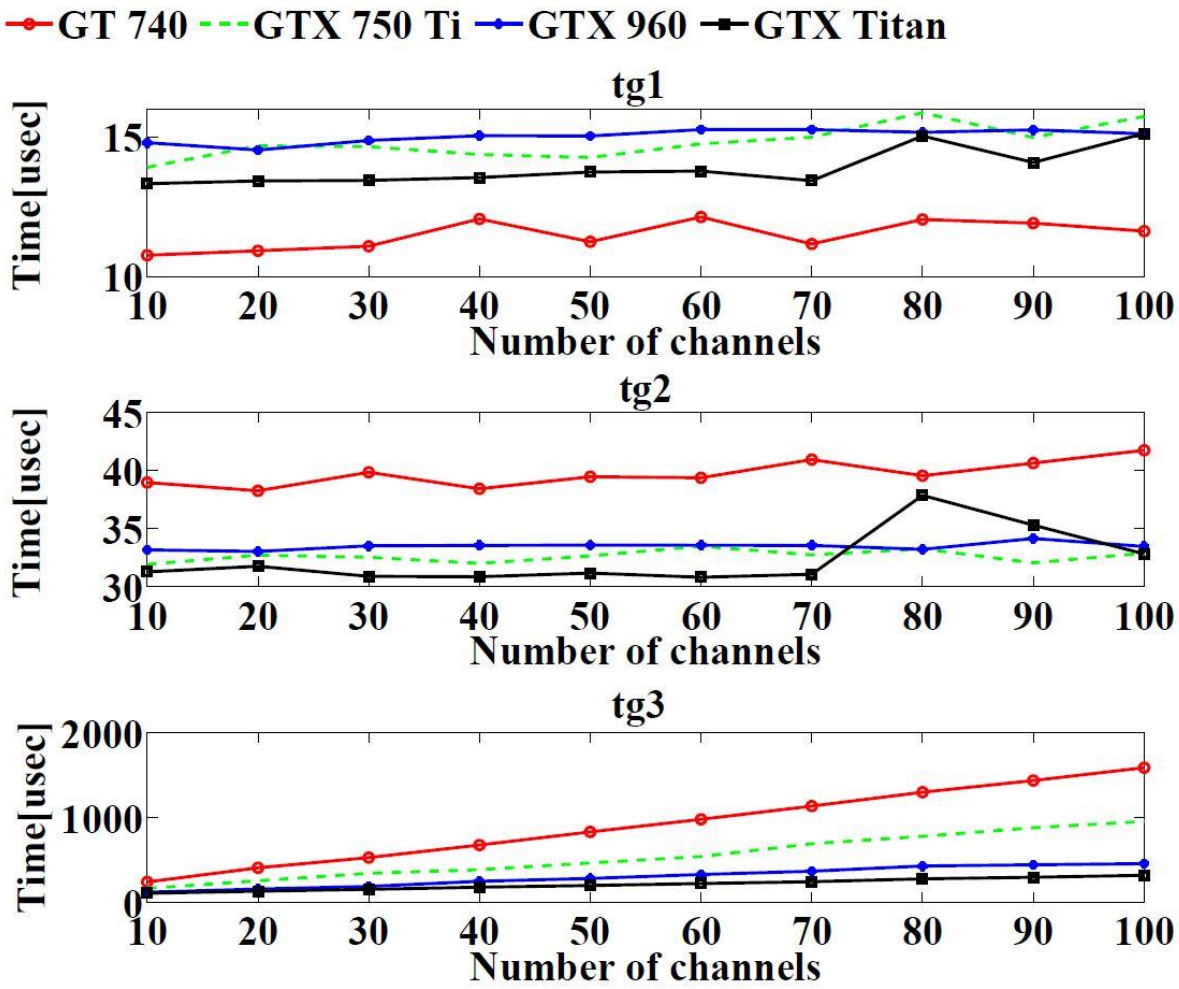
Load balancing for multi-GPU platform

Analysis of operation time

- Operation time check with 4 kinds of GPU and channel
- Using 8 MSPS Signal



Type	#Cores
GTX Titan	2688
GTX 960	1024
GTX 750Ti	640
GT 740	384

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Load balancing for multi-GPU platform

- Tg1 is near-constant value
- Tg2 have a relation only with the sampling rate
- Tg3 is increased with the sampling rate and number of correlation, but decreased with the number of CUDA cores

$$\hat{\mathbf{t}}_\mathbf{g} = \mathbf{H}\mathbf{p}$$

where

$$\mathbf{H} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & N_S & 1 & 0 \\ \frac{N_S N_C}{N_O} & \frac{N_S}{N_O} & \frac{N_C}{N_O} & 1 & 0 & 0 & 0 \end{bmatrix},$$

$$\mathbf{p} = \begin{bmatrix} p_0 & p_1 & p_2 & p_3 & p_4 & p_5 & p_6 \end{bmatrix}^T,$$

$$\hat{\mathbf{t}}_\mathbf{g} = \begin{bmatrix} t_{g1} & t_{g2} & t_{g3} \end{bmatrix}^T$$

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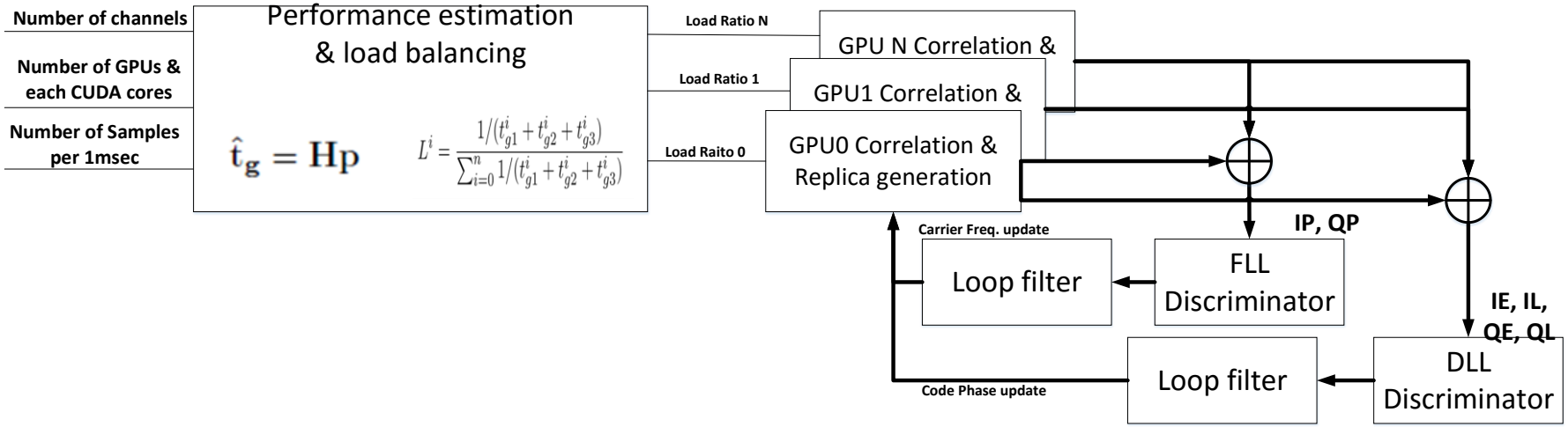
Load balancing for multi-GPU platform

Load ratio of *i*-th GPU

- Tg1 ~ Tg3 is estimated by proposed mode

$$L^i = \frac{1/(t^i_{g1} + t^i_{g2} + t^i_{g3})}{\sum_{i=0}^{n} 1/(t^i_{g1} + t^i_{g2} + t^i_{g3})}$$

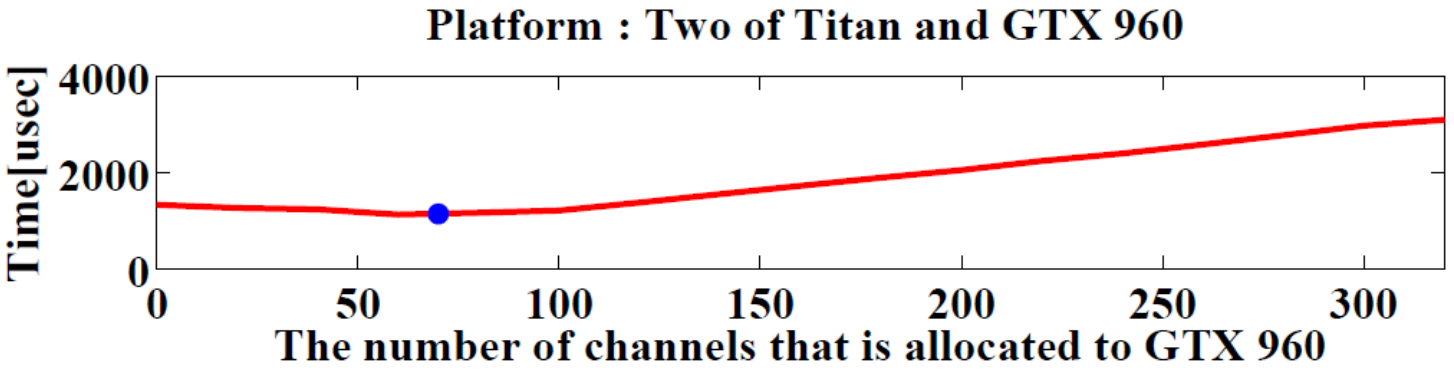
Multi-GPU based signal tracking overview

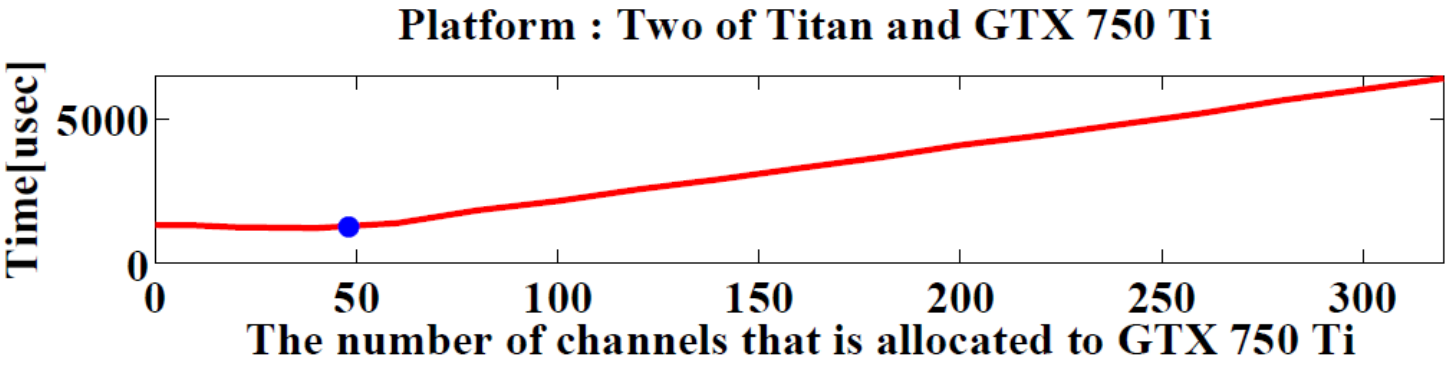


Results of Experiments

Load balancing test

- Using GPS signal(32 GPS satellites * 10 times and 32 MSPS)
- 0 to 320 channels are allocated GTX 960 or GTX 750





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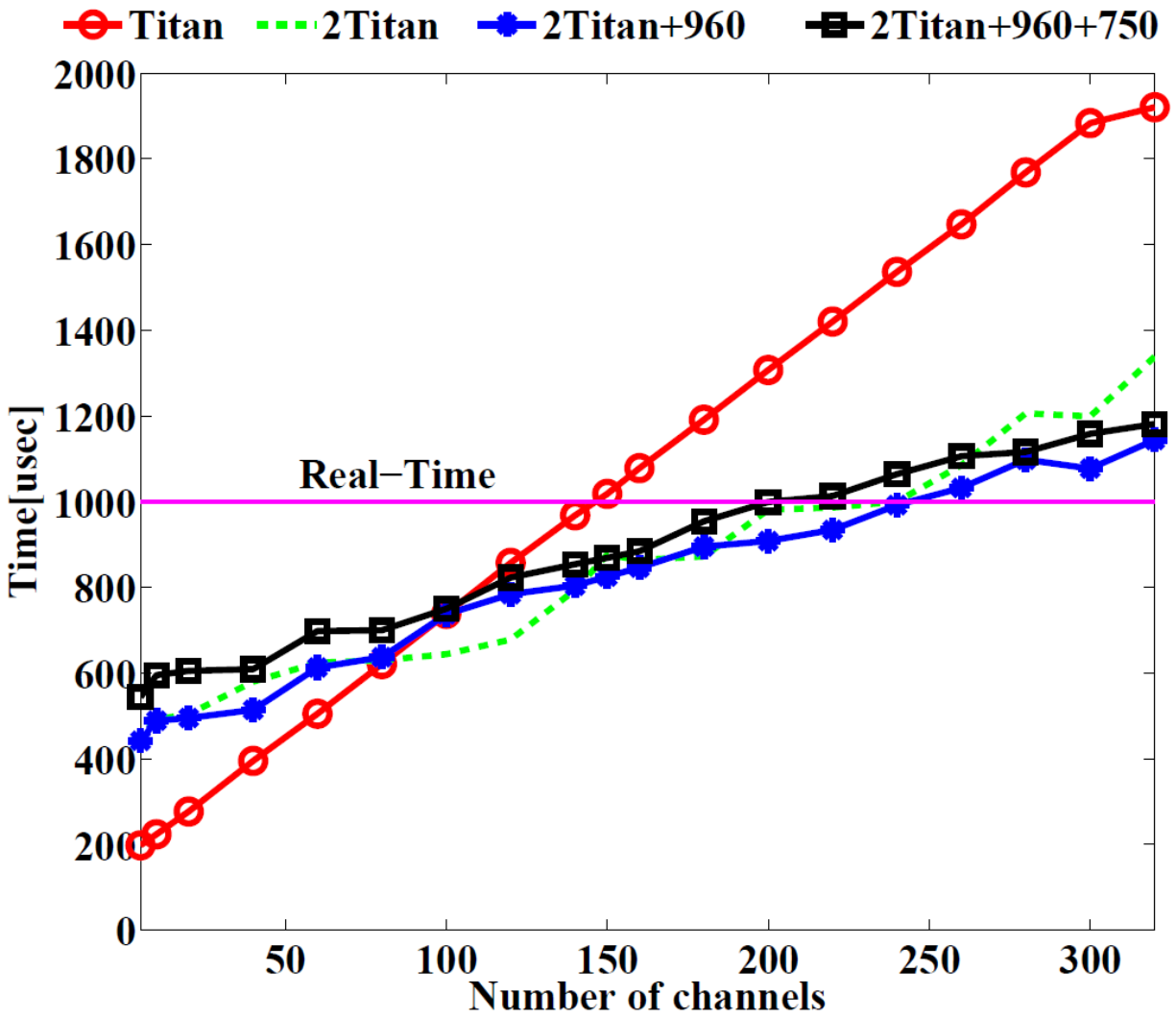
Results of Experiments

Signal tracking operation time



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Conclusion

Summary

- An accelerated signal tracking loop for GNSS software receiver was designed using multi-GPU platform
- To solve bottleneck problems, we proposed a model based load balancing method
- As a results, about 250 channels is computed in real-time on 3 kinds of GPU platform(two GTX Titan and one GTX 960)

Plan

- To use multi-GPU, overhead consideration
- Acceleration signal acquisition module using GPU or multi-GPU

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Q&A

Thank you

Kwi Woo Park : zumbox@cbnu.ac.kr

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