Interdisciplinary Division of Aeronautical and Aviation Engineering
航空工程跨領域學部

THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

NLOS Detection and Compensation using a Vector Tracking-based GPS Software Receiver

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Outline

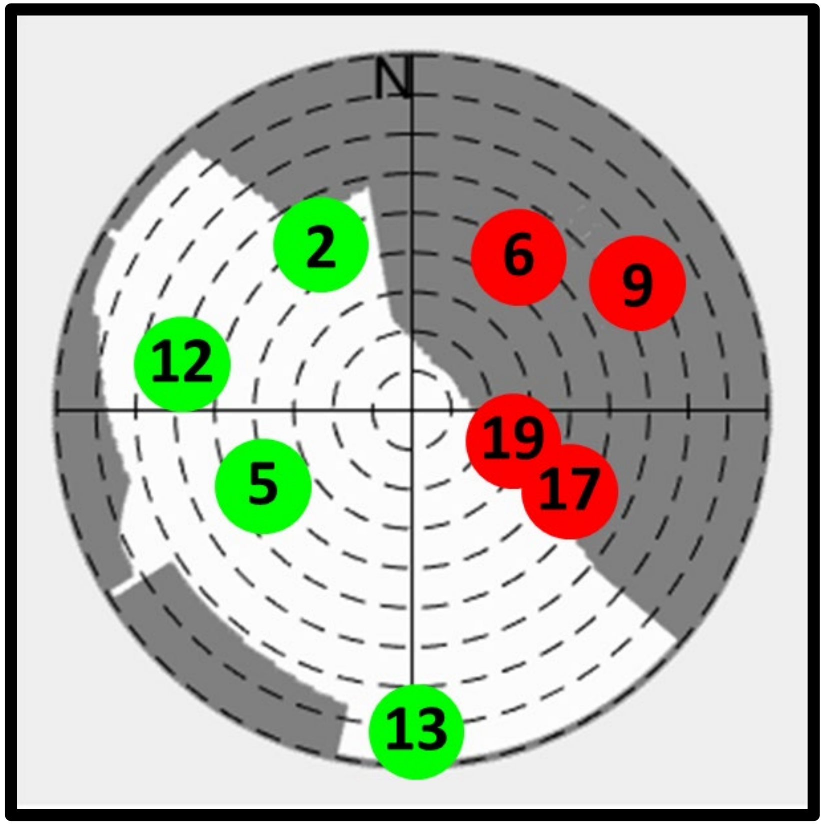
1 Background and Motivation

2 Vector Tracking-based NLOS Detection and Correction

3 Experimental Results and Analysis

4 Conclusion and Future Work

1. Background and Motivation



Sky-plot with building boundary information in an urban area in HK

Problem in urban areas

- Multipath effect
- None-line-of-sight (NLOS) reception

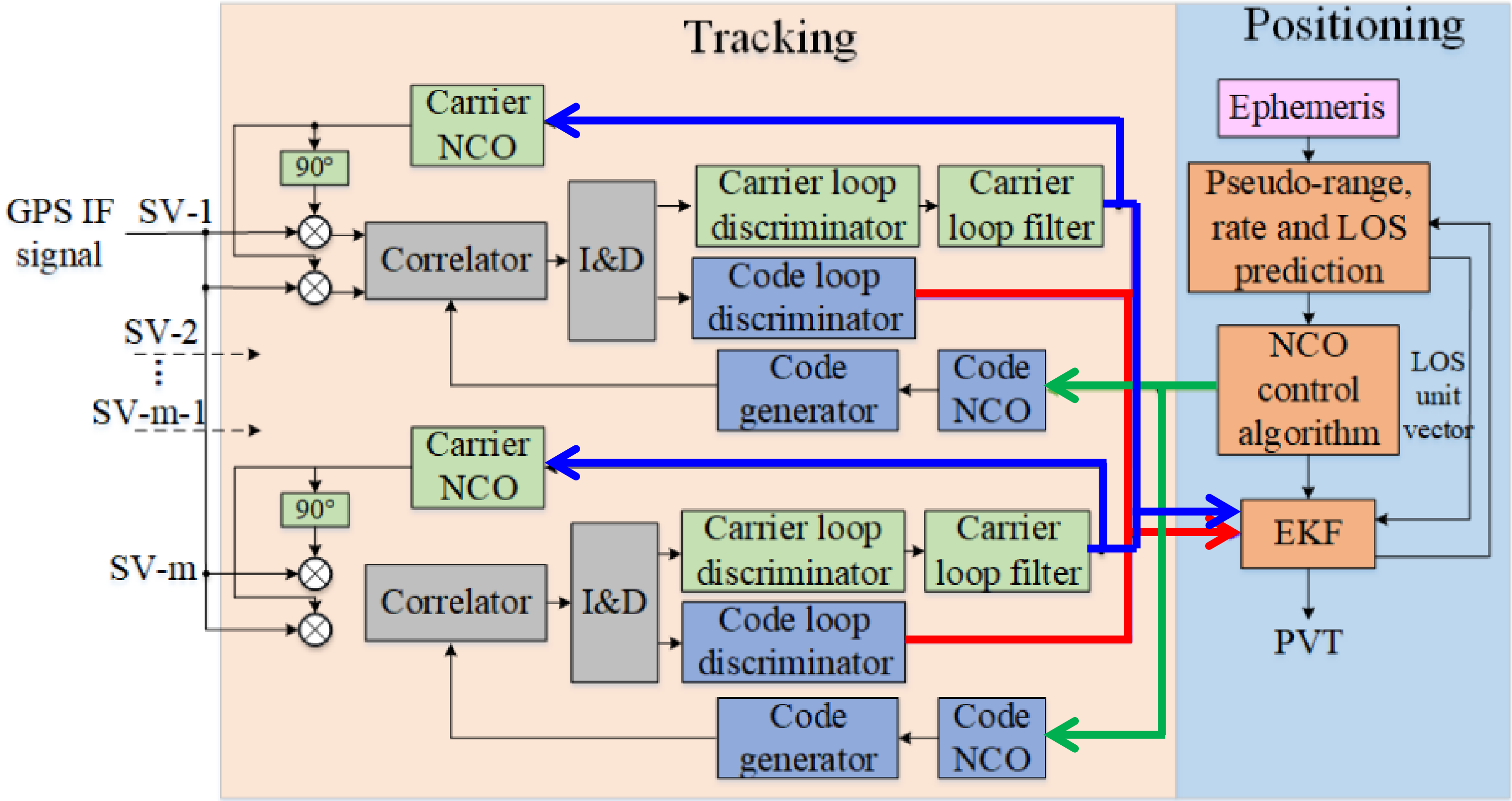
1. Background and Motivation

Solution

TABLE I Techniques Dealing With NLOS Reception

Category	Techniques
Mitigation	Antenna design, e.g., choke-ring antenna
	Consistency checking, e.g., pseudorange residual, navigation solution
	Kalman filter-based innovation filtering
Detection	Hardware-based techniques, e.g., array antenna, dual-polarization antenna, sky-pointing camera, 3-dimentional light detection and ranging (3D LiDAR)
	Machine learning technique, e.g., elevation angle
	3D building model
Correction	Ray tracing-based 3D mapping-aided (3DMA) GNSS positioning, Vector tracking loops (VTL)

2. VTL-based NLOS Detection and Correction



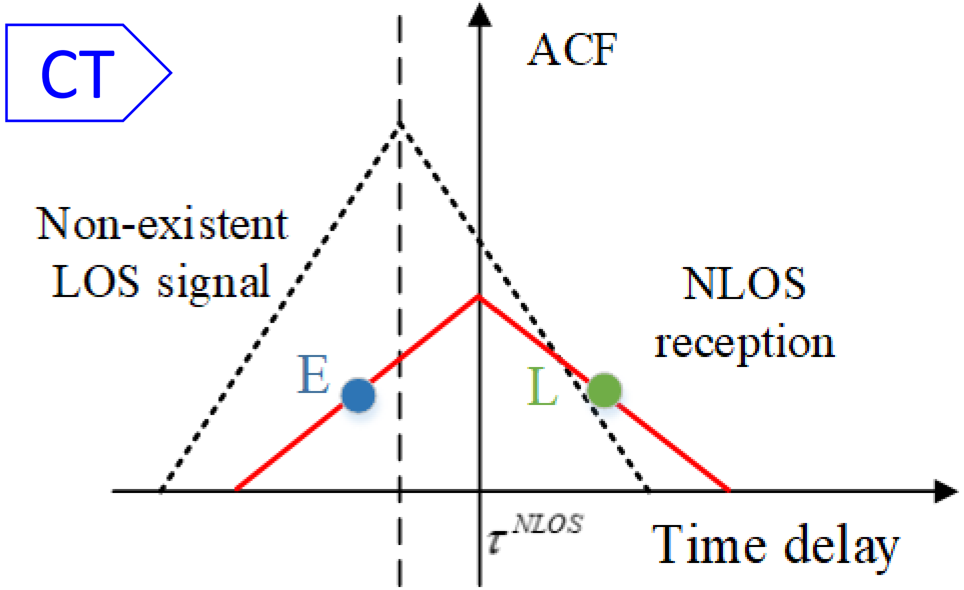
- □ VDLL + 2nd-order PLL
- □ Code NCO

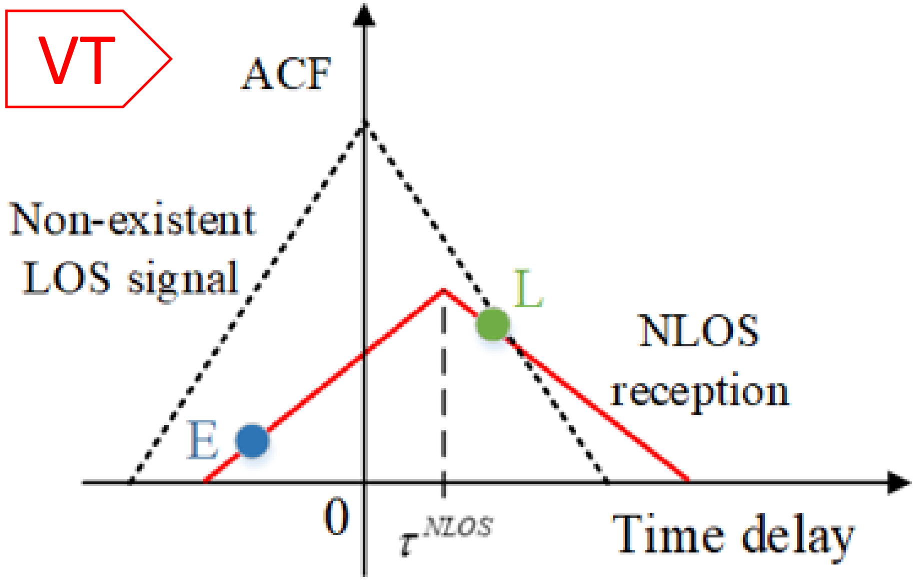
$$f_{code,k}^{m} = f_{CA}\left(1-\frac{\hat{\rho}_k^m-\hat{\rho}_{k-1}^m}{c\cdot T_0}\right)$$

$$\hat{\rho}_k^m = \left\|\mathbf{p}_k - \mathbf{p}_k^m\right\| + \delta\hat{\rho}_{sv,c}^m + \delta\hat{\rho}_I^m + \delta\hat{\rho}_T^m - \delta b_k$$

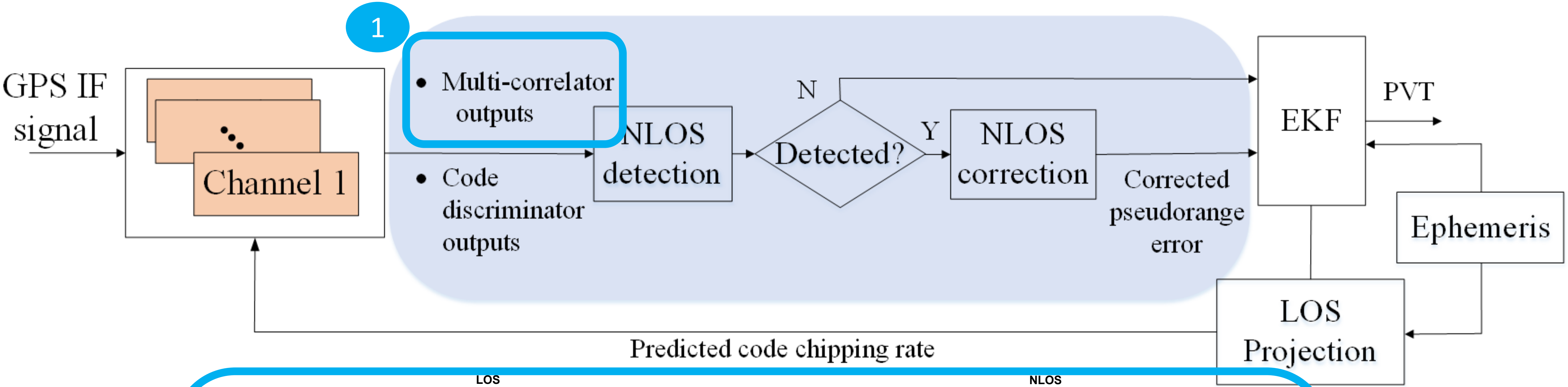
2. VTL-based NLOS Detection and Correction

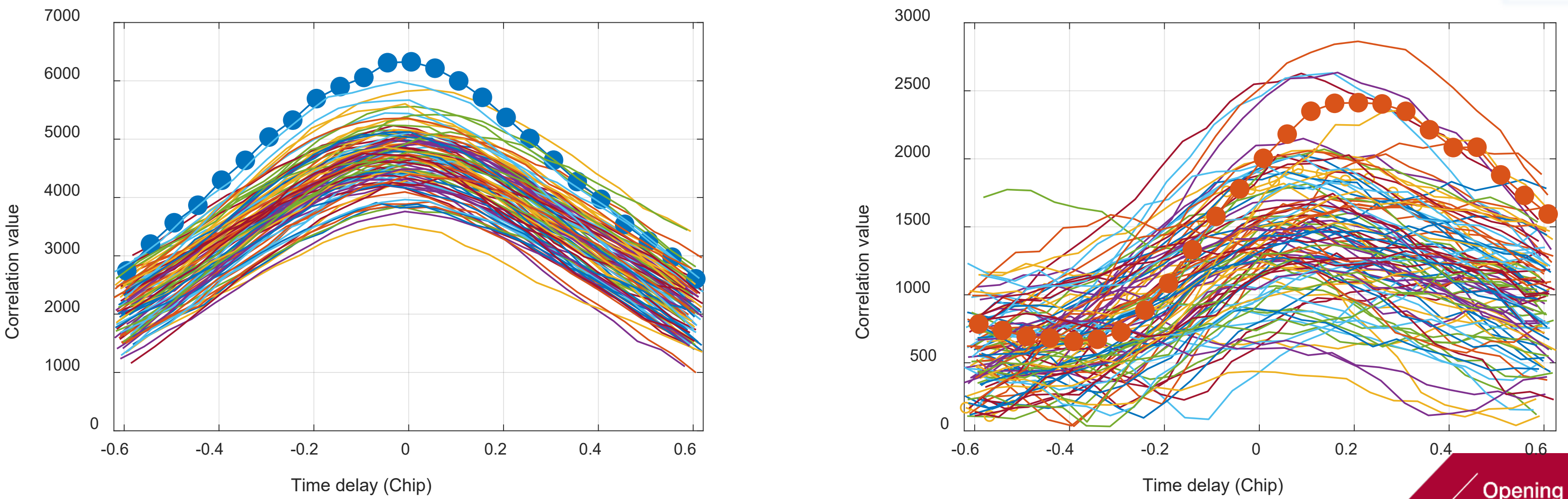
Why is VTL capable of detecting and correcting the NLOS reception?



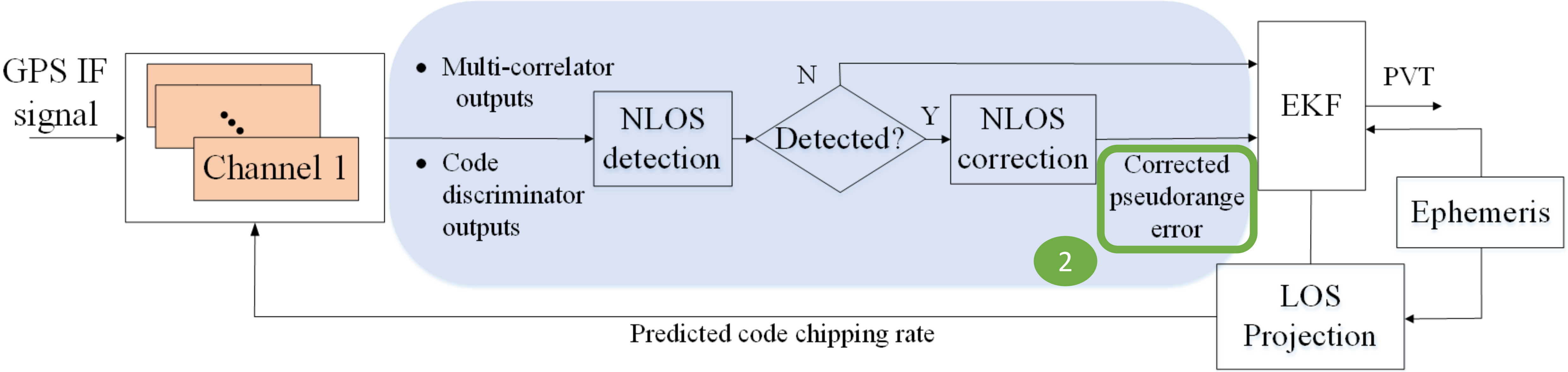


2. VTL-based NLOS Detection and Correction


1
GPS IF signal
Channel 1
• Multi-correlator outputs
• Code discriminator outputs
NLOS detection
Detected?
N
Y
NLOS correction
Corrected pseudorange error
EKF
PVT
Ephemeris
LOS Projection
Predicted code chipping rate



2. VTL-based NLOS Detection and Correction

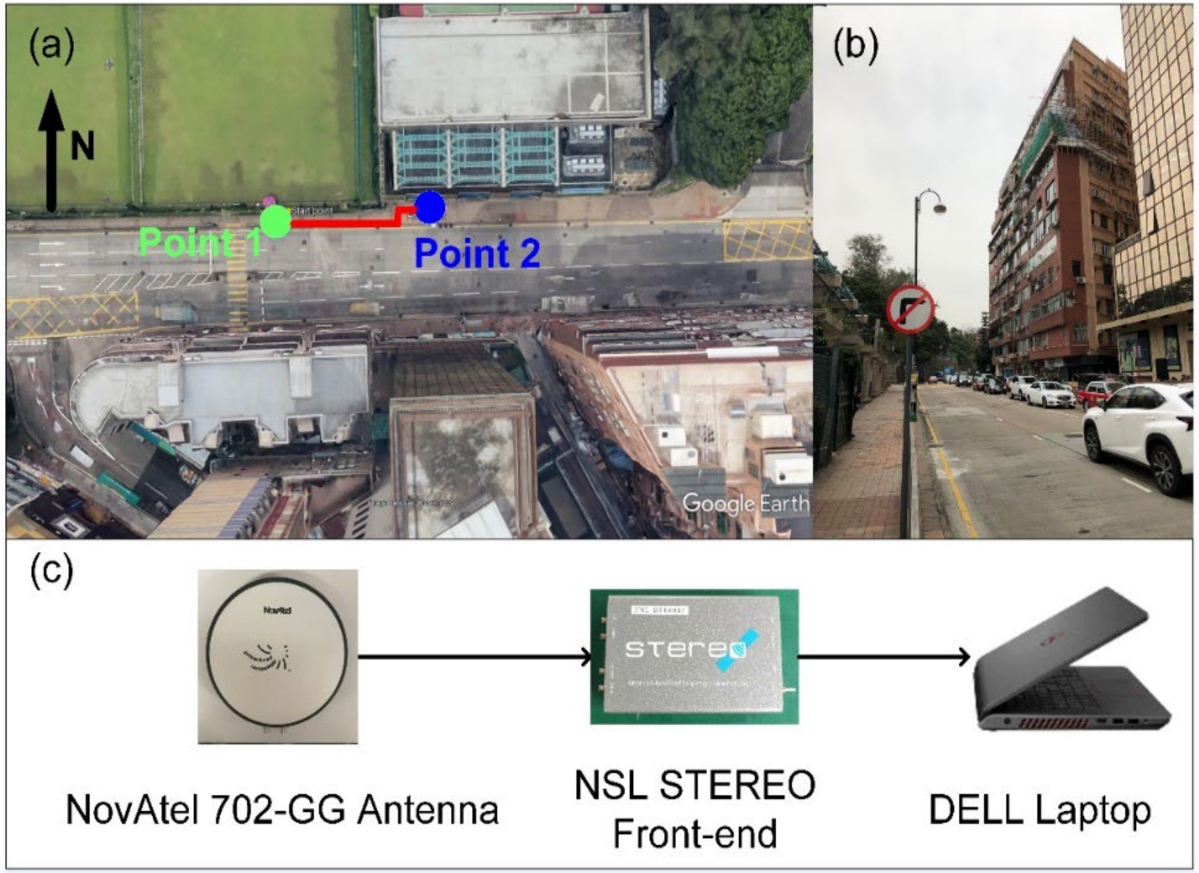


$$\Delta\rho_c^j = \left(\boxed{\Delta\tau^j} + \boxed{\tau_{corr}}\right)\cdot\frac{c}{f_{CA}}$$

Code discriminator outputs

Code discriminator outputs averaged over 50 consecutive values

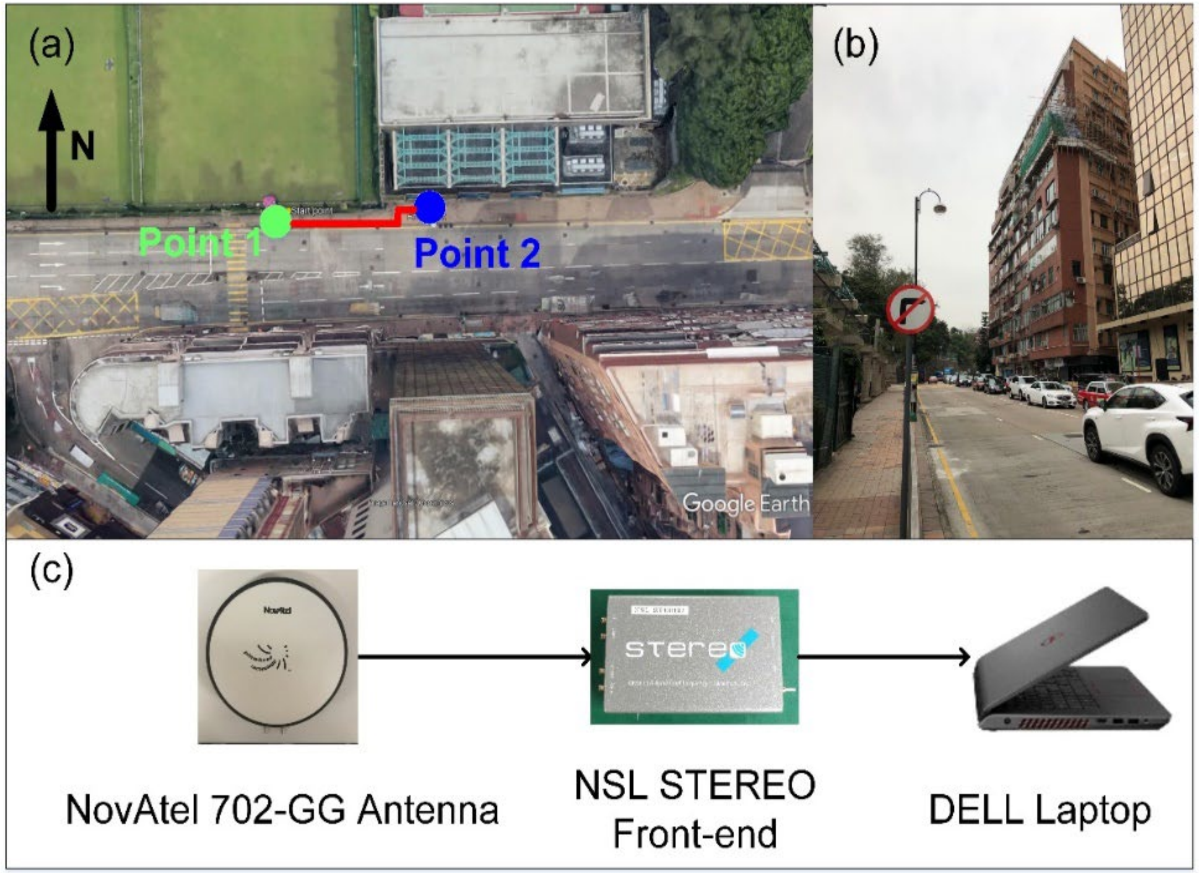
3. Experimental Results and Analysis



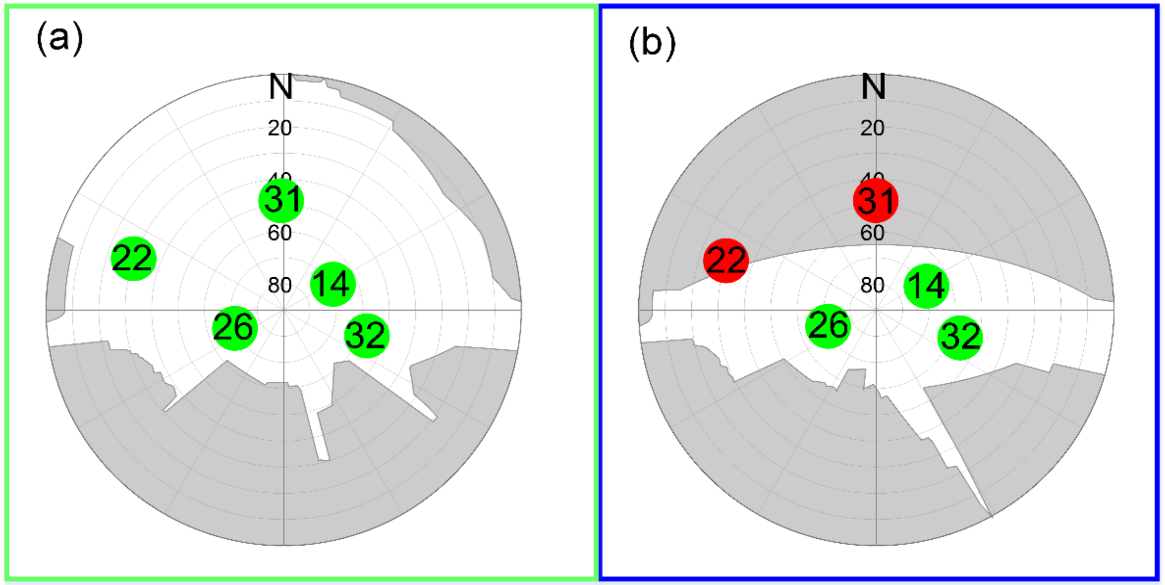
Front-end	Model	NSL Stereo
	Constellation	GPS L1
	Sampling rate & IF	26 MHz, 6.5 MHz
	Bandwidth	2 MHz (Double sided)
SDR [1]	Correlator numbers and spacing (chip)	Normal mode: 3, 0.5 NLOS detection mode: 25, 0.05
	Pre-detection integration (PDI)	1 ms
	Measurement update interval	20 ms
	PLL bandwidth	20 Hz

[1] B. Xu and L.-T. Hsu, "Open-source MATLAB code for GPS vector tracking on a software-defined receiver," GPS Solutions, vol. 23, no. 2, 2019.

3. Experimental Results and Analysis



Experimental environment and set-up

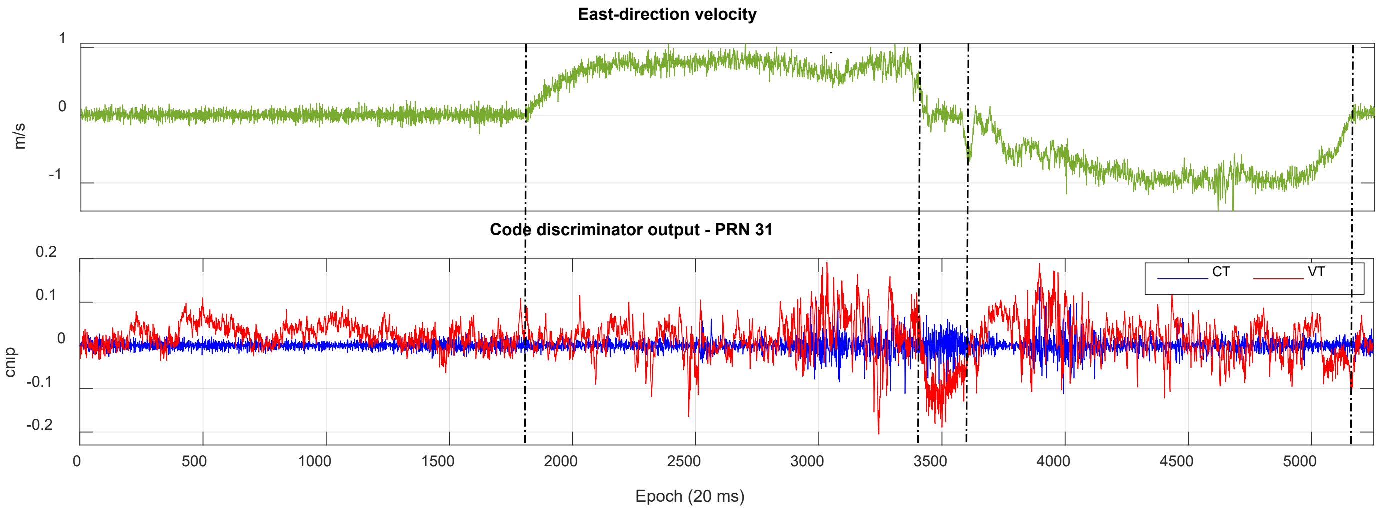


Point 1

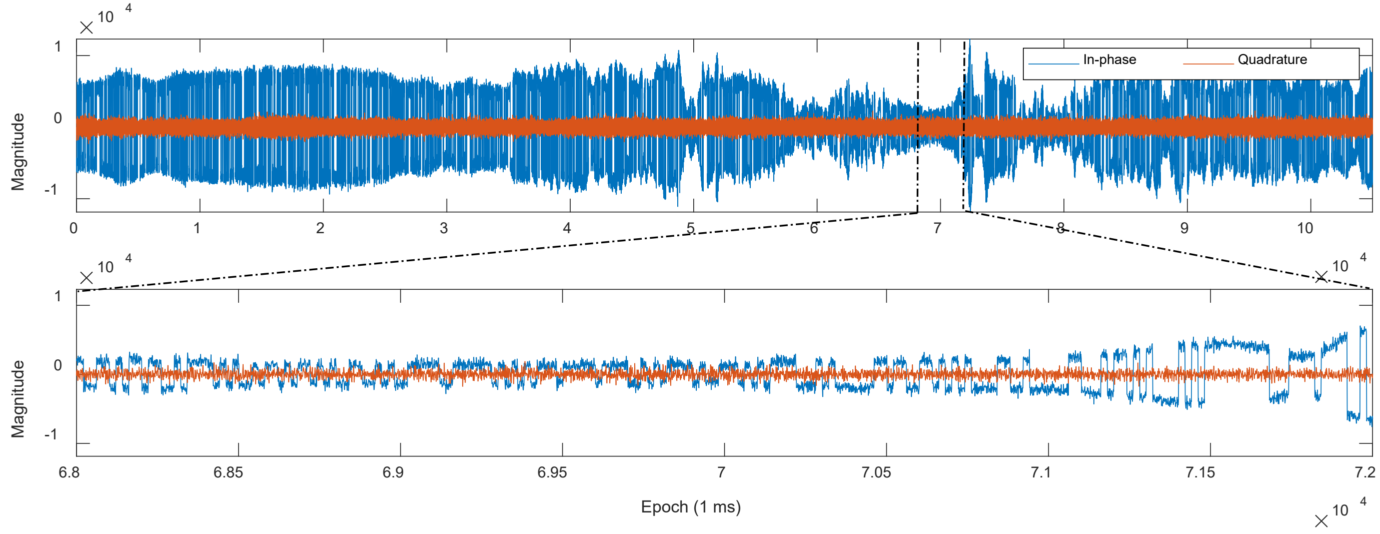
Point 2

Sky-plot with building boundary information

3. Experimental Results and Analysis



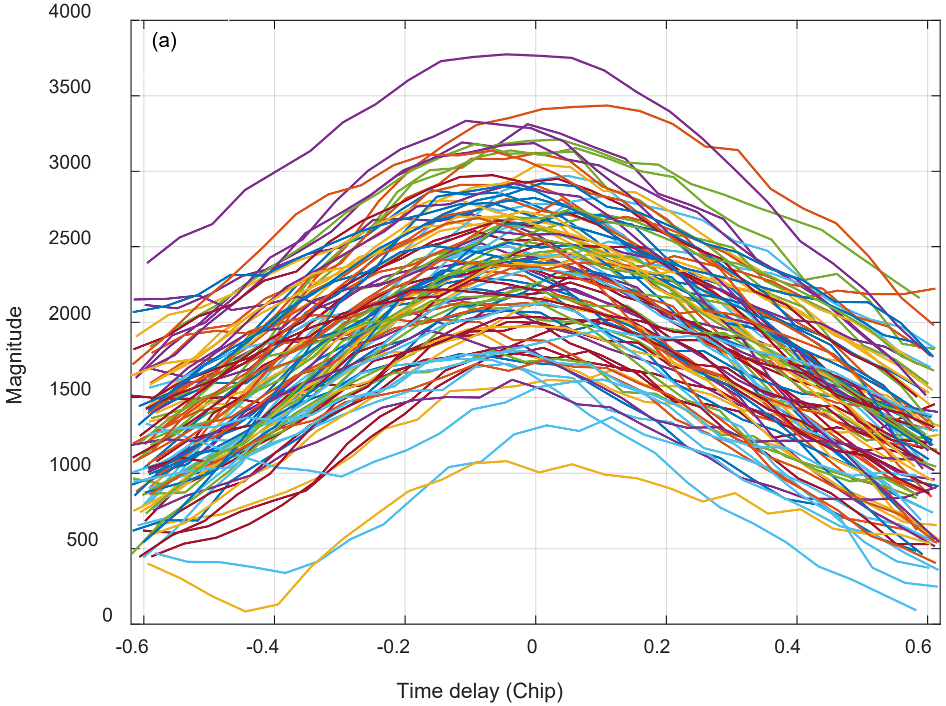
- Code discriminator outputs



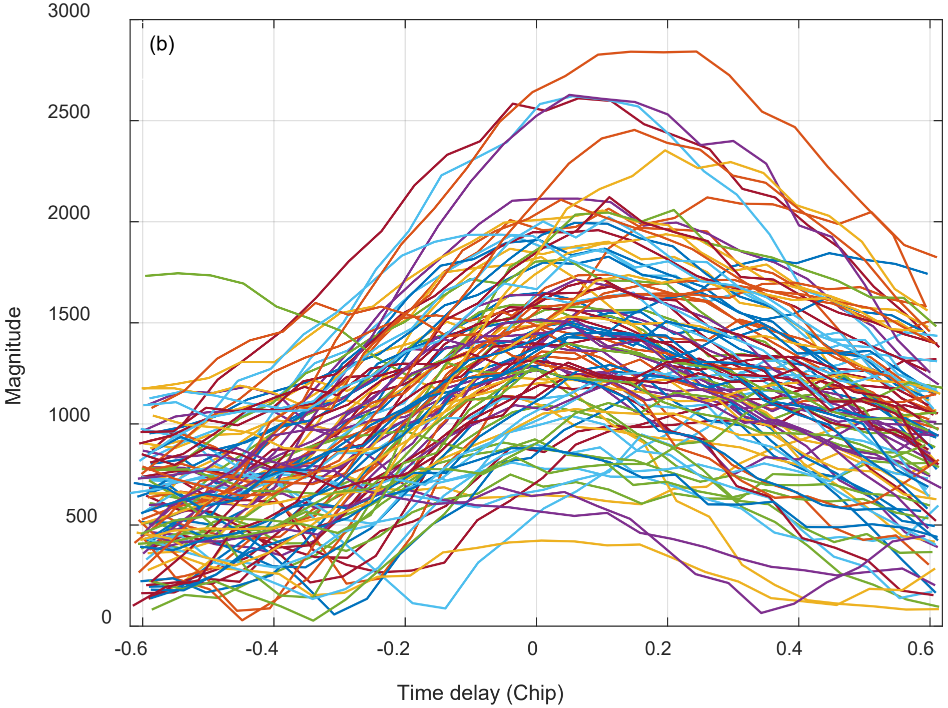
- Prompt correlation

3. Experimental Results and Analysis

- Multi-corrector outputs:



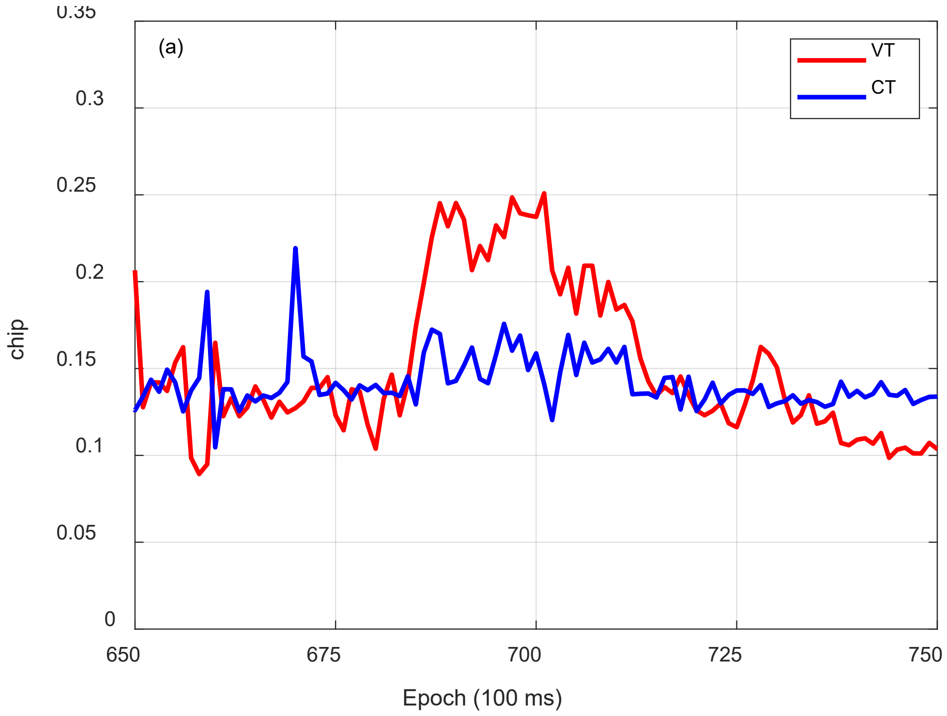
CT



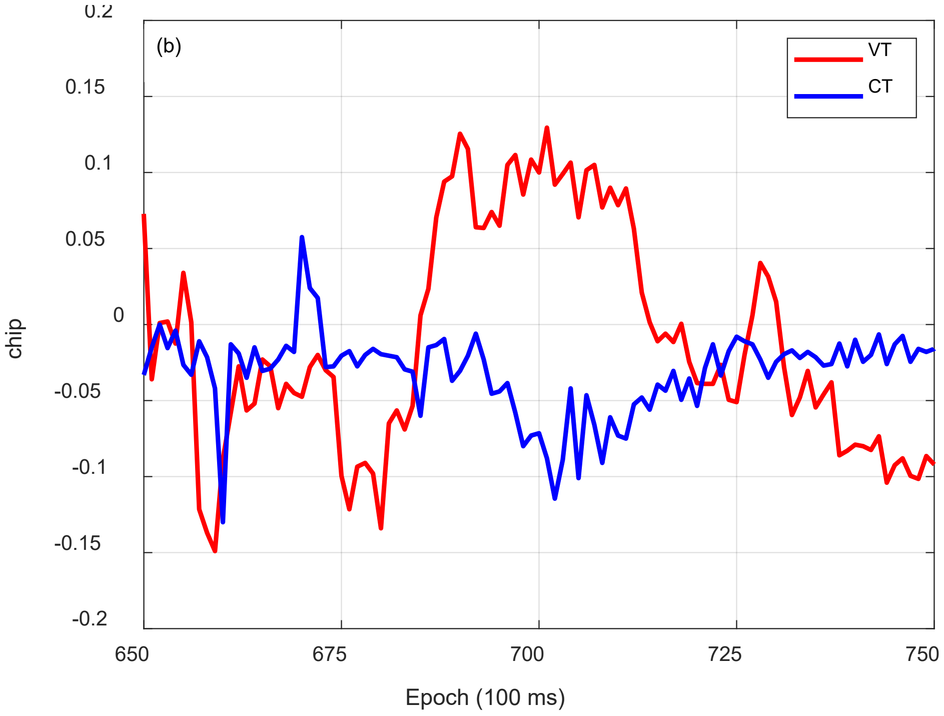
VT

3. Experimental Results and Analysis

- Multi-corrector outputs:



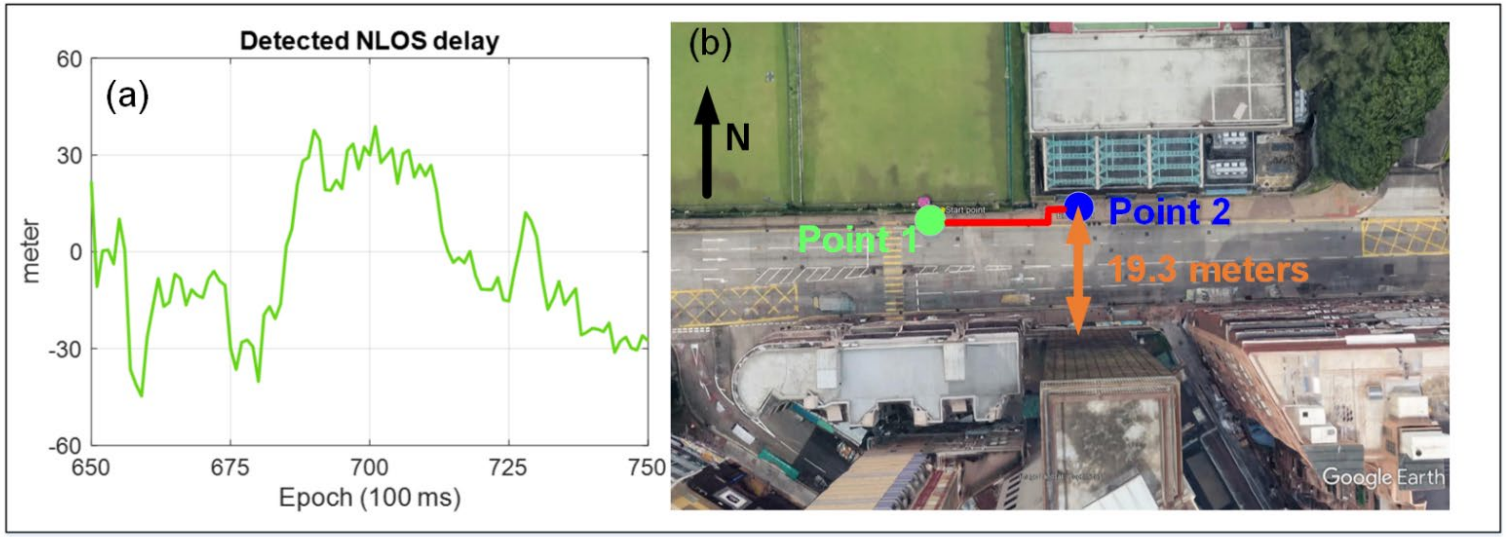
Variance



Mean

3. Experimental Results and Analysis

- Extracted NLOS delay:



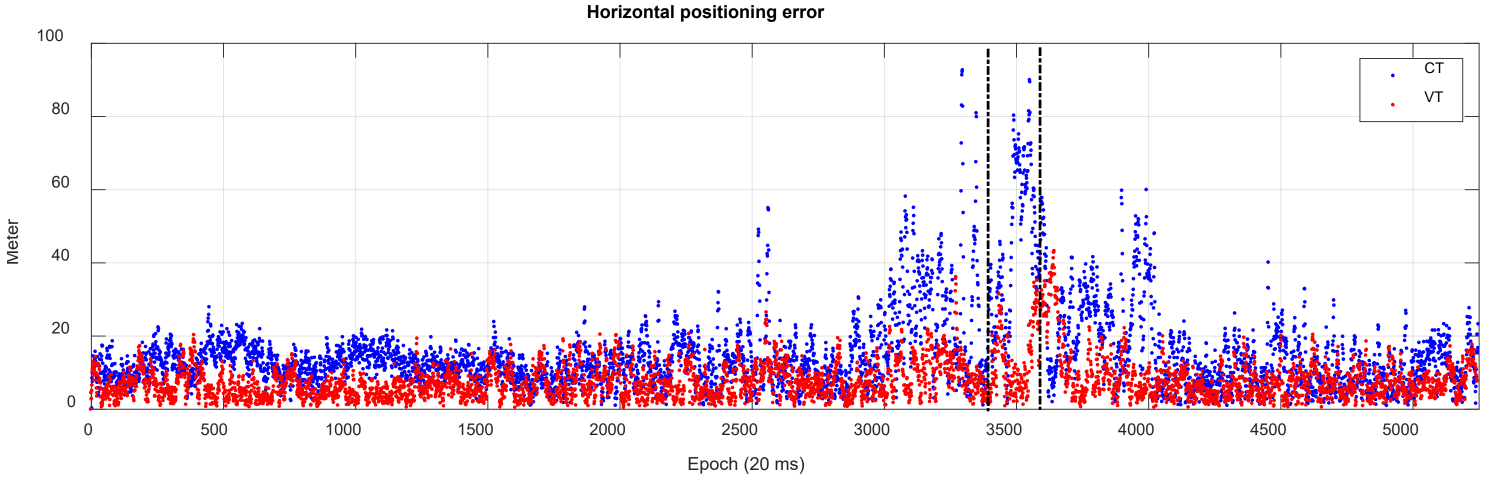
- NLOS pseudorange delay model [2]:

$$\gamma = \alpha \sec\theta_{ele}\left(1+\cos 2\theta_{ele}\right) \longrightarrow 26.8\ \text{m}$$

[2] L.-T. Hsu, "Analysis and modeling GPS NLOS effect in highly urbanized area," GPS Solutions, vol. 22, no. 1, 2018.

3. Experimental Results and Analysis

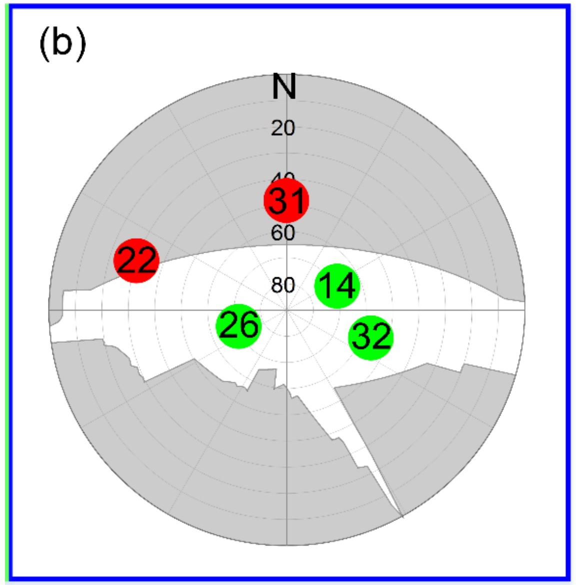
- NLOS correction results:

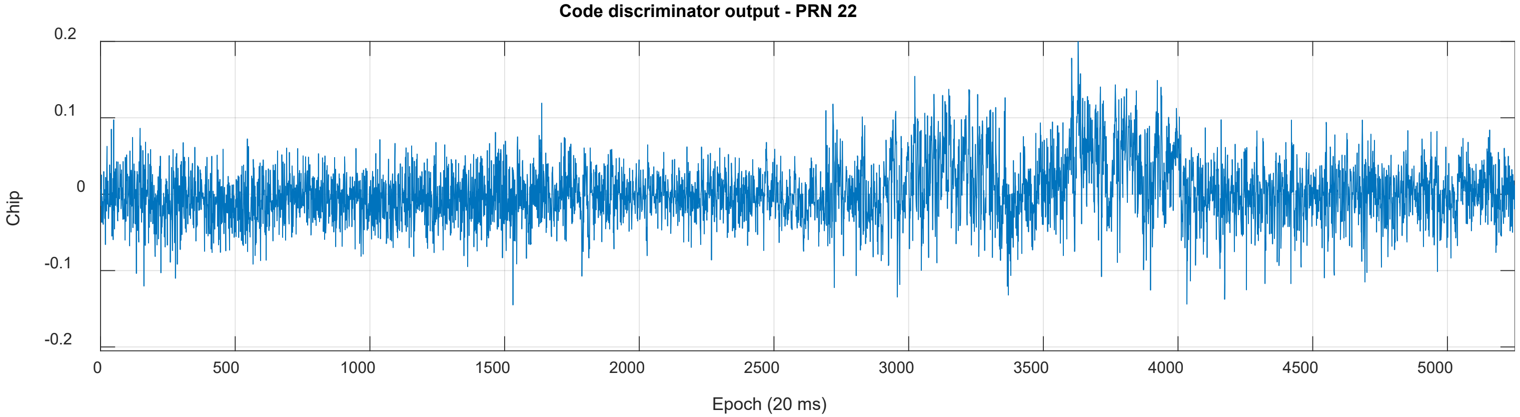


Epochs	1~1800	1800~3400	3400~3600	3600~5200
VT	6.43	8.39	13.64	8.47
CT	12.14	16.22	45.41	14.67

3. Experimental Results and Analysis

- PRN 22:





- Near the building boundary
- Diffraction region [3]

[3] Wang L., Groves, P. D., and Ziebart, M. K., "GNSS shadow matching: improving urban positioning accuracy using a 3D city model with optimized visibility scoring scheme," NAVIGATION, Vol. 60, No. 3, 2013, pp. 195-207.

4. Conclusion and Future Work

- Conclusion:
  - ➢ Vector tracking is capable of detecting and correcting the NLOS reception at the signal processing level without any additional aiding.
- Future work:
  - ➢ Give the principle of the proposed method mathematically
  - ➢ Multipath detection and correction