Improvement of the GPS Performance in Urban Canyon Using QZSS

GNSS Workshop

Bangkok, Thailand

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Motivation

◘ Background

One of the Key technologies for ITS is GNSS
QZSS will be launched in summer of 2010.
QZSS would bring large benefits to users especially in urban canyon…
East Asia has a huge population.

◘ Viewpoints in this study

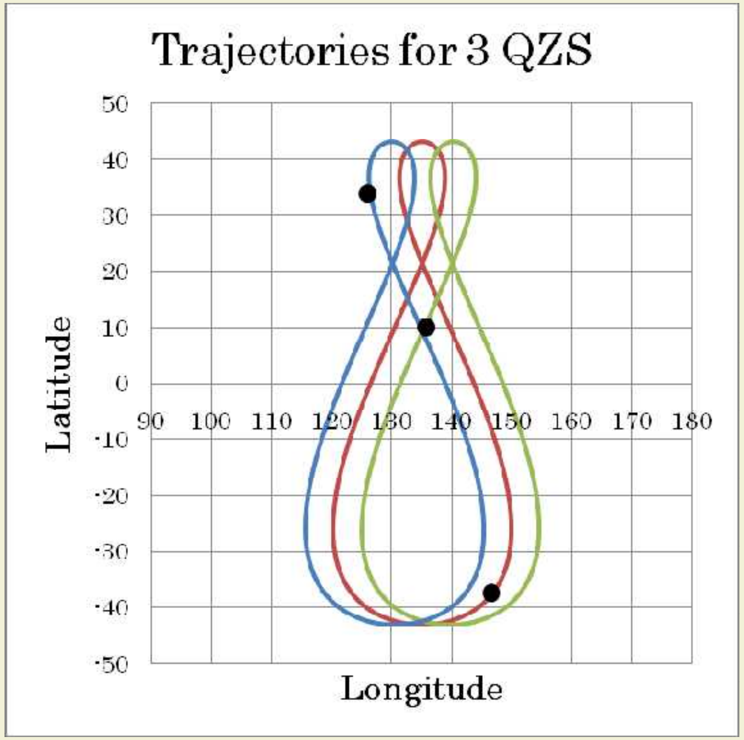
It is important for us to show the performance of the **combined GPS-QZSS**.
Both stand-alone and RTK service are introduced.
There is no problem under open sky… but **under urban canyon** ?

↓

The objective of this paper is to show the benefits by QZSS in large Asian cities.

Satellite Constellation

- The GPS configuration used is GPS YUMA almanac of GPS week 488 2009. The date is January 1st in 2009.
- The QZSS configuration used is the most likely constellation referring to the article by JAXA.



Software Based Simulator

- The software simulator generates pseudo-range and carrier-phase. Several errors are considered in this simulation.

* *Tracking Errors* (based on the equation)

* *Ephemeris (inc. clock) Errors* (deduced from the difference between IGS final and ephemeris

* *Ionospheric Errors* (deduced from the difference between dual-frequency based and broadcast model)

The solar activity is very low at present.
The ionospheric errors in 2008 < One-fifth of those in 2001

Multipath Errors ?

- Multipath reflection effect is not considered.

* Very complicated.

* The effect of urban canyon could be simulated to some degree by considering mask angle because the influence of large DOP is dominant in urban canyon.

* Since even low-cost receiver is going to have a better correlation technique, the long-delayed strong multipath will be reduced in the near future. Low-cost receiver has already used the advantage of robust Doppler frequency.

Robust Doppler Aiding Performance (low-cost high-sensitivity receiver)

This place is surrounded by many high-rise buildings in Tokyo

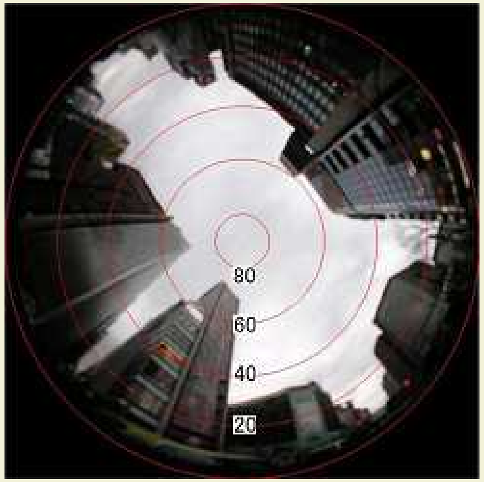
Only Pseudo-range

Pseudo-range + Doppler aiding

Doppler aiding is quite effective to reduce multipath errors but good satellite constellation is still required to maintain good performance.

Effects of Urban Canyon

- As a configuration of obstacle, mask angle is used. Different mask angles are set at 15, 30 and 45 degrees.
- From the real configuration in the dense urban area in Tokyo, the rate of interrupted sky is mostly from 0.6 to 0.7. When we set the mask angle 45 degrees, the rate of interrupted sky is 0.75 (30 degrees: 0.57, 15 degrees: 0.31).



3 lanes in each way
The rate of interrupted sky ≈ 0.6

Typical case of masking condition in Tokyo

Scenarios

- Each scenario uses a different model and mask angles.
- Interval is 30 seconds. Period is 1 day.
- Performance criteria: **NVS, DOP, Stand-alone Positioning**

Constellation for each scenario

	Constellation
Scenario1	**GPS**
Scenario2	**GPS + 3QZS**
Scenario3	**GPS + 6 QZS**

Locations of selected cities

	Latitude	Longitude
Beijing	**39.55**	**116.26**
Seoul	**37.32**	**126.58**
Tokyo	**35.68**	**139.90**
Shanghai	**31.06**	**121.22**
Bangkok	**13.45**	**100.32**
Singapore	**1.17**	**103.51**
Sydney	**-33.53**	**151.10**

Number of Visible Satellites

Mask: 45 degrees   max/min/1day average

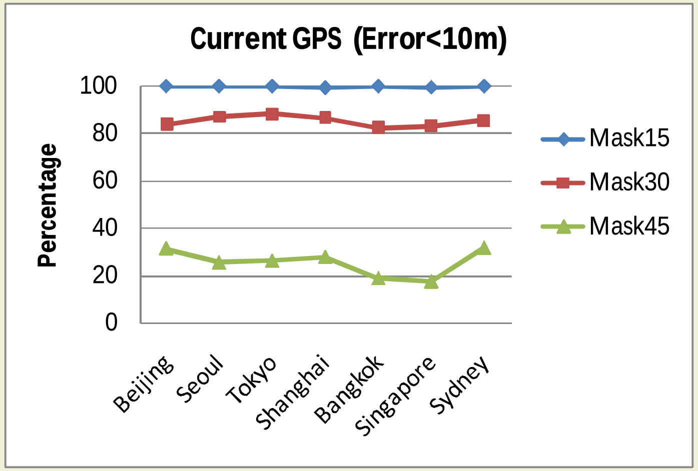
	GPS	GPS+3QZS	GPS+6QZS
Beijing	7/ 1/ 3.1	9/ 2/ 4.7	10/ 4/ 6.2
Seoul	6/ 1/ 3.0	8/ 2/ 4.7	9/ 4/ 6.4
Tokyo	6/ 1/ 3.1	8/ 2/ 4.8	9/ 4/ 6.4
Shanghai	6/ 1/ 3.1	8/ 3/ 4.8	9/ 4/ 6.4
Bangkok	5/ 0/ 2.6	7/ 1/ 3.8	9/ 2/ 5.7
Singapore	4/ 1/ 2.6	6/ 1/ 3.6	7/ 2/ 4.9
Sydney	6/ 1/ 3.1	7/ 2/ 4.5	9/ 3/ 5.8

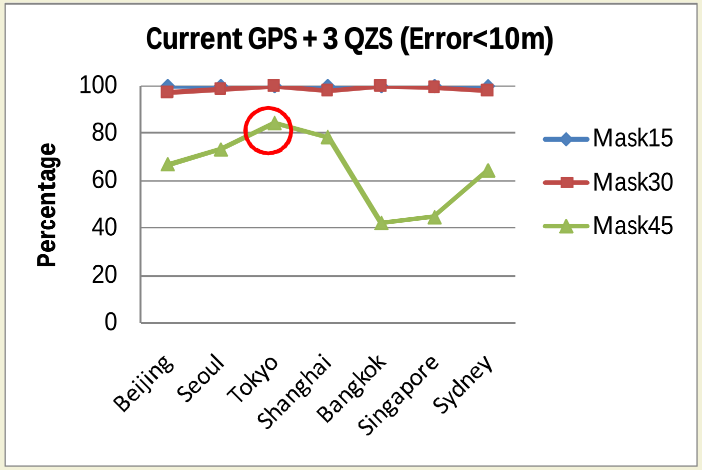
Mask: 30 degrees   same manner

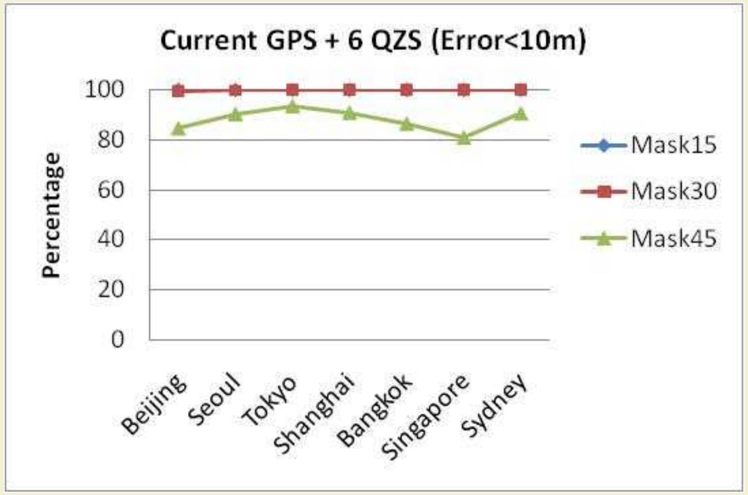
	GPS	GPS+3QZS	GPS+6QZS
Tokyo	7/ 3/ 5.1	9/ 5/ 7.1	10/ 6/ 7.8
Bangkok	8/ 3/ 5.2	10/ 5/ 7.4	13/ 8/ 9.8
Singapore	7/ 2/ 4.8	10/ 4/ 7.3	13/ 7/ 10.1

Stand-alone Positioning Performance

Percentage meets with horizontal errors is below 10 m.







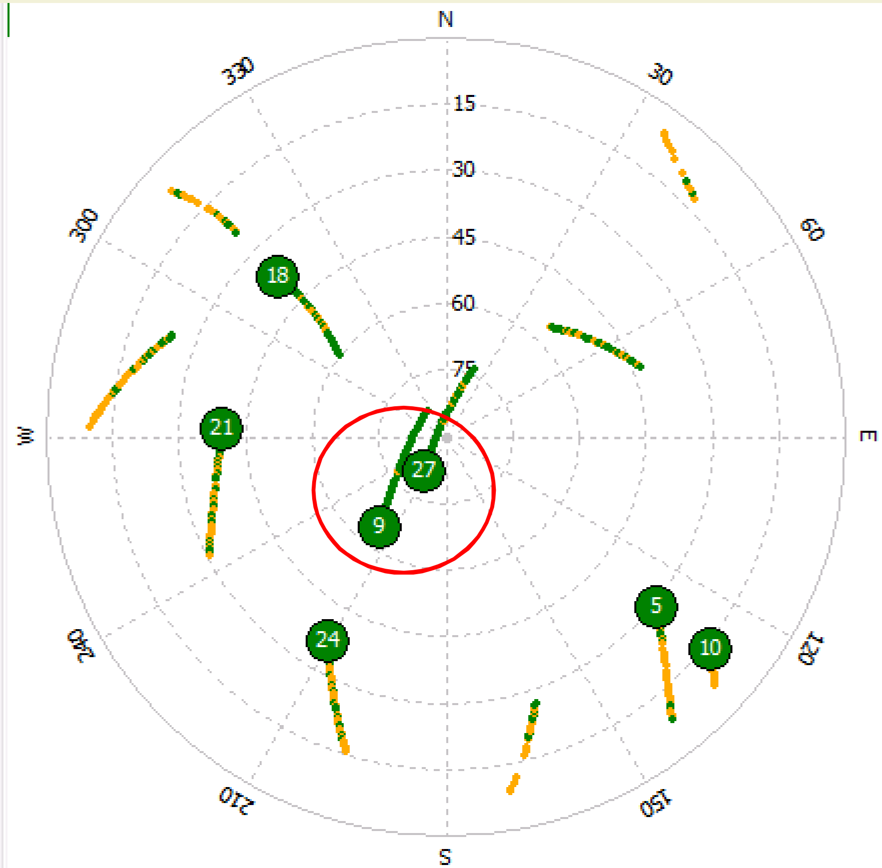
RTK Test in Urban Canyon

- **Objective: Predict performance of QZSS in urban canyon using GPS (+GLONASS) raw data.**

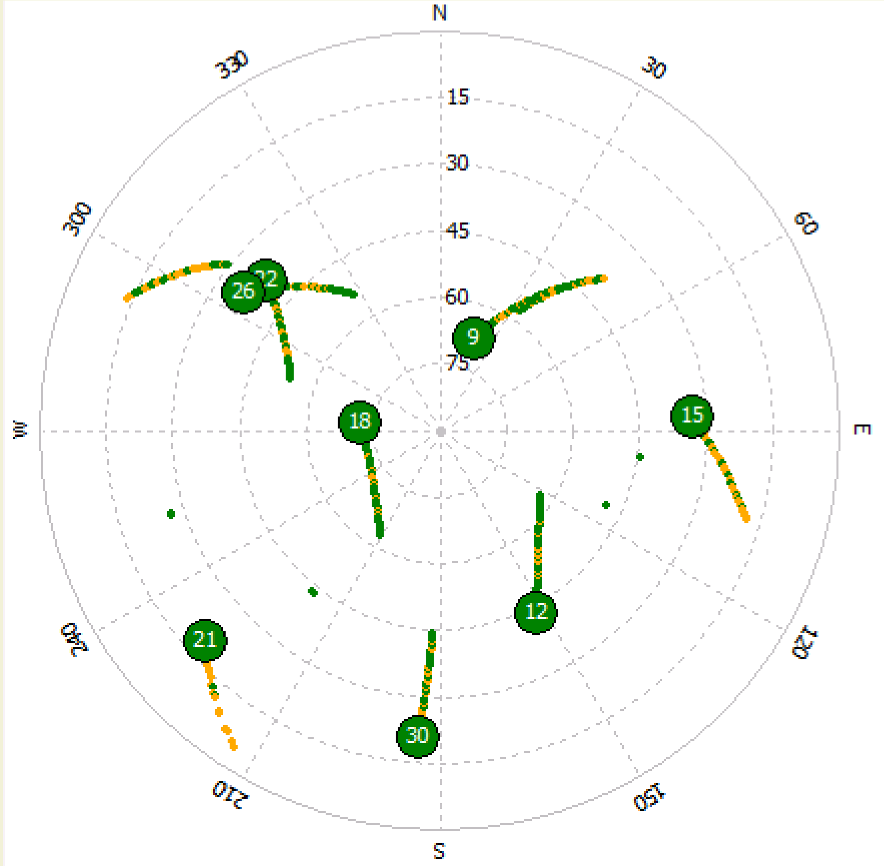
* 2009/12/26 (2 periods/ 23+26min)
* Relatively Good Constellation
* Dense Urban Canyon (Tokyo)
* Car (OEM5 + GPS702/ 5Hz)
* RTKPOST 2.3.0 by T. Takasu

Set of Equipments

Constellation (Period1 , Period2)



Period 1

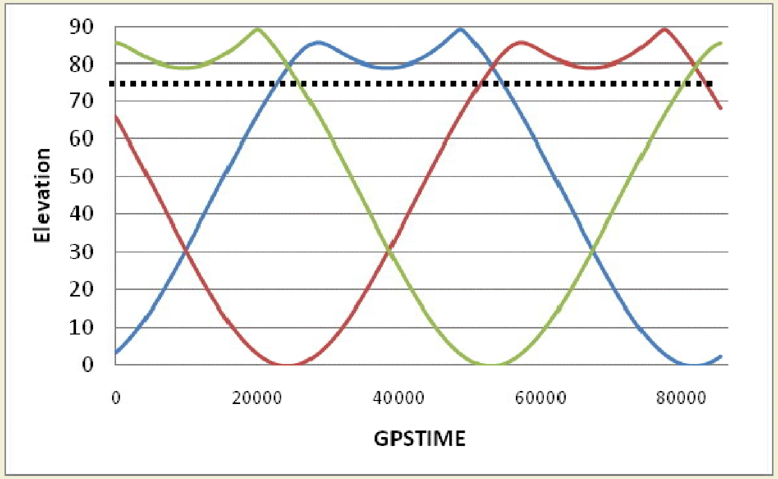


Period 2

How can we predict QZS contribution?

Average NVS	Period1	Period2
Mask15	9.3	9.0
Mask30	7.7	8.0
Mask45	3.3	5.6
Mask60	3.0	3.3
Mask75	1.4	0

Average NVS (>Ele75) : 1.1



24 hours Elevation in Tokyo (3 QZSs)

Assumption

Constellation in Period 1 → "GPS + 3 QZSs"

RTK Results

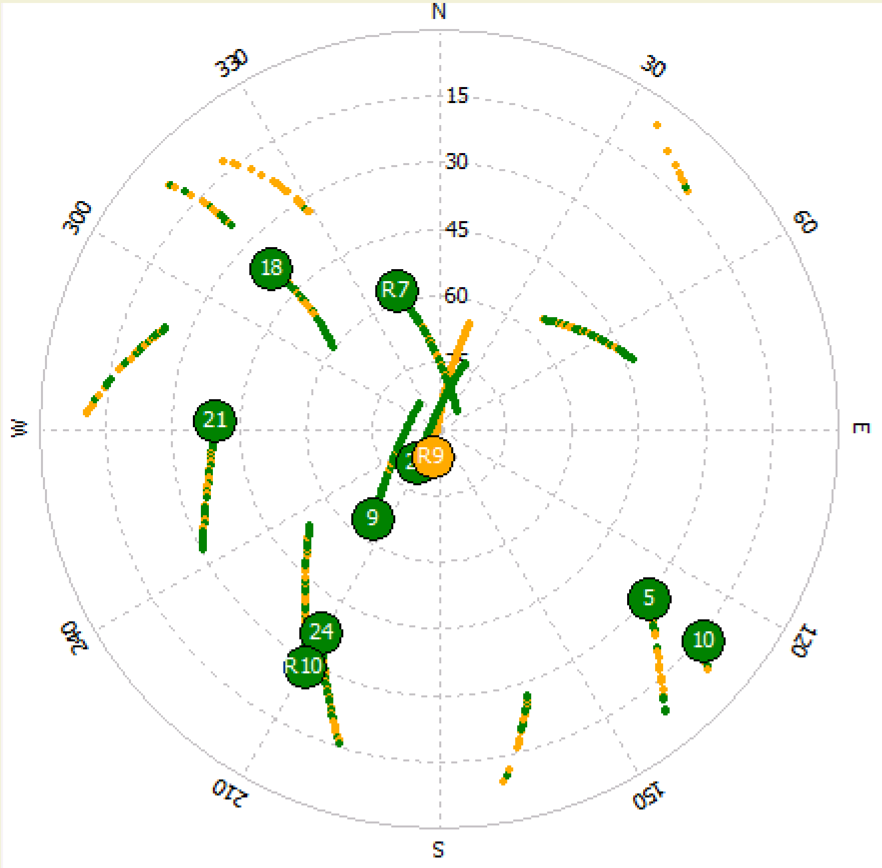
		Instantaneous	Fix and Hold
Period 1 (Mask15)	FIX FLOAT	27.4% 20.1%	35.1% 11.3%
		Period 1: Total Epochs = 6900	
Period 2 (Mask15)	FIX FLOAT	23.1% 23.2%	27.2% 17.9%
		Period 2: Total Epochs = 7900	

NVS in High-Elevation : Period1 > Period2

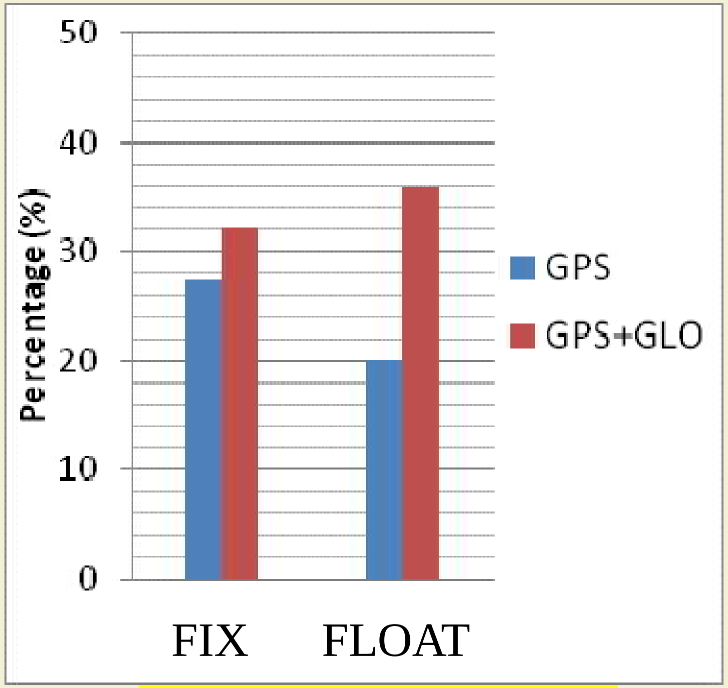
RTK performance in dense urban area : Period1 > Period2
QZS will be effective for RTK in the dense urban area

GPS + GLONASS

- Instantaneous
- Mask 15



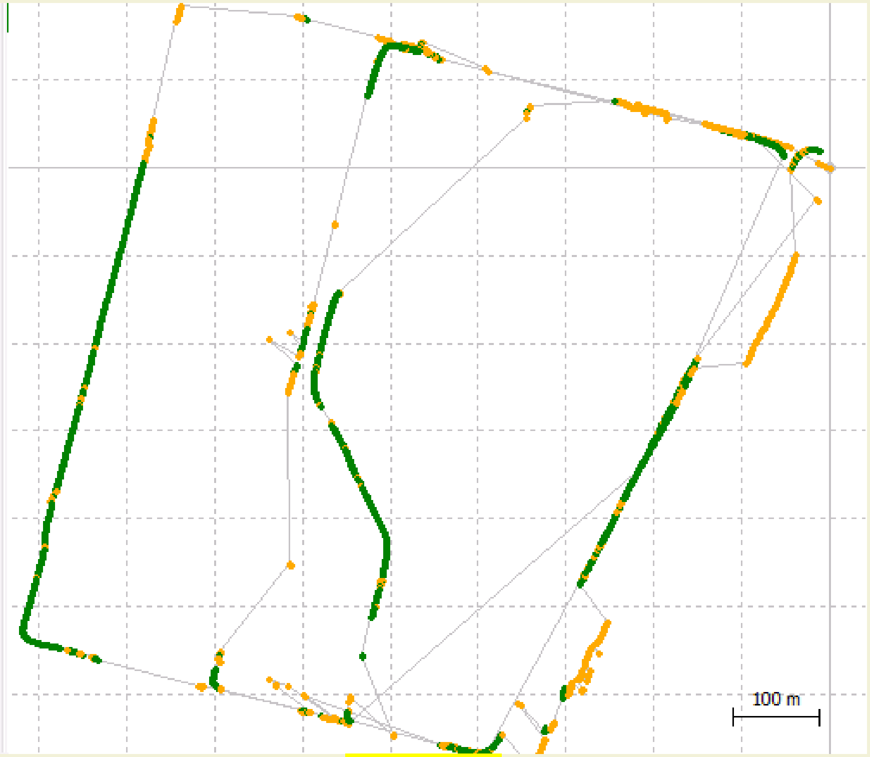
Period 1



Period 1: 6900 Epochs

Horizontal Results

Green: FIX   Orange: FLOAT



GPS

GPS+GLONASS

Summary

- The performance of general stand-alone positioning in large Asian cities is analyzed for different scenarios of the present GPS and combined future GPS-QZSS system.
- The results show that adding QZS clearly improves the availability and positioning performance in selected large Asian cities.
- In east Asia, QZS stays at high elevation for a long time. Even at low latitudes including Bangkok and Singapore, QZS stays at medium elevation for a long time.
- It is expected that RTK performance in urban canyon will be improved effectively by adding 3QZSs.

Thank you for your attention