Source of Image:
http://qzss.go.jp

GNSS Innovative Technology
- Introduction of Precise Point Positioning Using QZSS -

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Presentation Summary

1. Introduction of Precise Point Positioning (PPP) using QZSS

QZSS : Quasi Zenith Satellite System

Source of Image:
http://qzss.go.jp

- Service performance / Transmission signals
- Technology of precise positioning by applying satellite augmentation
- Use cases / Positioning results

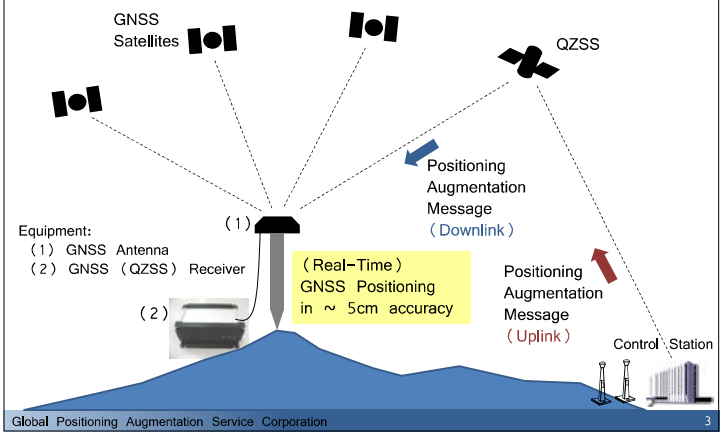
2. Evaluation on the Possibility for Utilization

Source of Image:
http://www.magellan.jp

- Introduction of the receiver/processor
- Advantages of QZSS+PPP for the measurement of Mt. Everest

Proposal Summary of QZSS Measurement

- Proposing configuration of equipment for QZSS measurement



1. Introduction of Precise Point Positioning (PPP) using QZSS

QZSS Overview

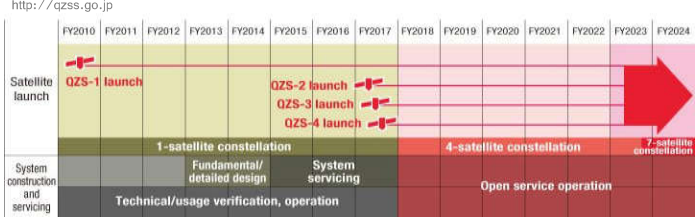
QZSS is a satellite positioning system operated by Japanese government as complementary and augmentation satellites of GPS.

Four satellites of the first constellation has already been launched, and now the final confirmation for official service is ongoing under the starting program administrated by Cabinet Office.

Source of Image:
http://qzss.go.jp

Concept

- Regional Navigation Satellite System
- Compatible with GPS satellites
- Provision of extra service signals



Transmission Signals

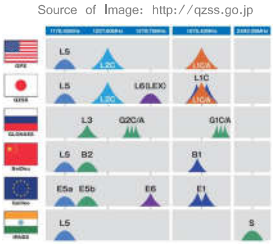
In principle signals are designed as compatible with GPS to complement it. Additionally L6 and S-band frequency bands and several services are provided as listed in orange description in the below table.

QZSS signal frequencies and services

Name	Freq.	Transmission service
L1C/A	1575.42MHz	Satellite positioning
L1C		Satellite positioning
L1S		Sub-meter Level Augmentation
		Satellite Report for DCM(*1)
L1Sb		SBAS Transmission (2020~)
L2C	1227.60MHz	Satellite positioning
L5	1176.45MHz	Satellite positioning
L5S		Positioning Technology Verification
L6	1278.75MHz	Centimeter Level Augmentation
		Positioning Technology Verification(*2)
S-band	2GHz band	QZSS Safety Confirmation (*3)
	1176.45MHz	Satellite positioning

(*1) Disaster and Crisis Management (*2) Provided from QZS-2, 3, 4.
(*3) Two-way communication service provided from GEO satellite only

Frequency Compatibility between GNSS systems
Source of Image: http://qzss.go.jp



Positioning Augmentation Service on L6

There are two channels to broadcast centimeter-level augmentation message on L6 of QZS-2/3/4 (excluding QZS-1).

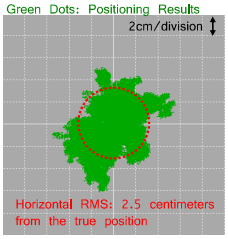
Currently, "Positioning Technology Verification" message on channel-2 can be used for global users, providing Precise Point Positioning (PPP) augmentation message.

Name	Freq.	Transmission service	Broadcasted from			
			QZS-1	QZS-2	QZS-3	QZS-4
L6	1278.75MHz	Centimeter Level Augmentation	●	●	●	●
		Positioning Technology Verification	●	●	●	●

● Currently available ● Preparing ● Planning

Positioning Example

Green Dots: Positioning Results



General GNSS accuracy is about a few meters in case of standalone positioning, and it can be improved up to centimeter-level by various method (e.g. Kinematic-GNSS, Static).

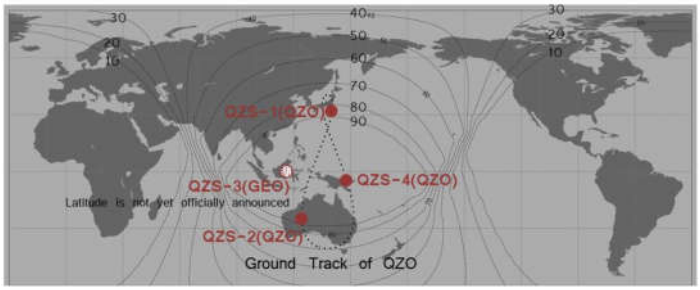
The augmentation service from QZSS also provides centimeter-level accuracy. According to evaluation results by some users, less than 5cm horizontal and less than 10cm vertical accuracy could be achieved.

Signals: L1/L2+L6 Period: 4hours Interval: 0.1second

Visibility / Availability

Four satellites constellation is consisted of three QZO (inclined geosynchronous orbit) satellites and one GEO satellite. Nepal is located within the coverage area of QZSS service.

QZS-2 has started to provide experimental service of "positioning technology verification".



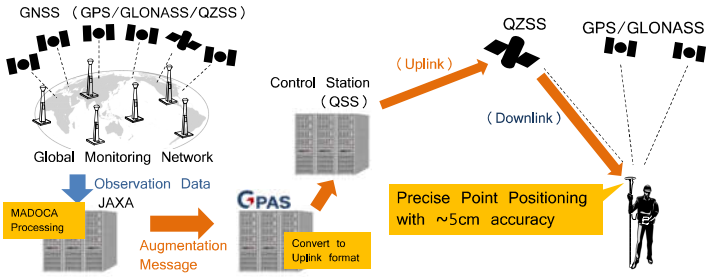
The contour shows the predicted rate of visibility for one QZO satellite over 15 degrees.

Precise Point Positioning with QZSS Augmentation

QZSS augmentation message to improve the accuracy of positioning is generated using the processing software (so called "MADOCA(*1)") with global observation data from the world-wide monitoring network. The error values in the satellite-side environment, such as orbit error, satellite's clock error, and signal biases, are estimated by MADOCA, and those are transmitted to users so that the positioning error can be corrected.

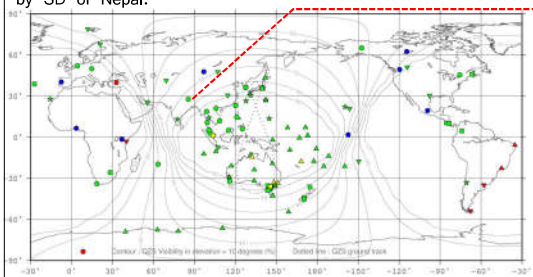
(*1) MADOCA: "Multi-GNSS Advanced Demonstration tool for Orbit and Clock Analysis" Being developed by JAXA based on their technology for estimating satellite orbit and clock corrections.

System Configuration



Demonstration CORS Network for QZSS Augmentation

Global monitoring network of MADOCA is being operated as an experiment under the international collaboration between JAXA and cooperation organizations. Currently about 90 monitoring stations are under operation including Nagarkot station provided by SD of Nepal.



Monitoring Station at Nagarkot being operated from 2013

★ QZS-1 Monitoring Station	□ Data Sharing Partner
△ Bilateral Sharing (Open to MGM-Net)	▽ Bilateral Sharing (Close to MGM-Net)
○ Hosting Sites	
Green : Under Operation	Yellow : Under Suspension
Blue : Under Construction	Red : Under Negotiation

Reference: K. Yoshikawa et al. "The Development and Demonstration of Precise Point Positioning Technology with Multi GNSS," The 60th Symposium on Space Science and Technology, September 2016

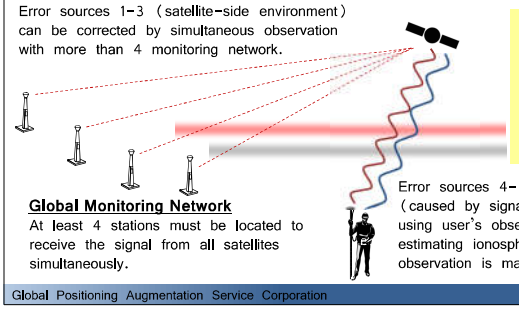
Principle of Positioning

In case of PPP method, the augmentation message provides only satellite-side error corrections, such as orbit, clock, and signal biases on satellite-side.

Other errors, such as ionosphere and troposphere should be corrected at user-side. In principle, double-frequency (L1/L2) GNSS receiver is required to estimate ionosphere error. To estimate troposphere error, a certain volume of time-series data observed by user's receiver is used.

Positioning Calculation Image

Error sources 1-3 (satellite-side environment) can be corrected by simultaneous observation with more than 4 monitoring network.

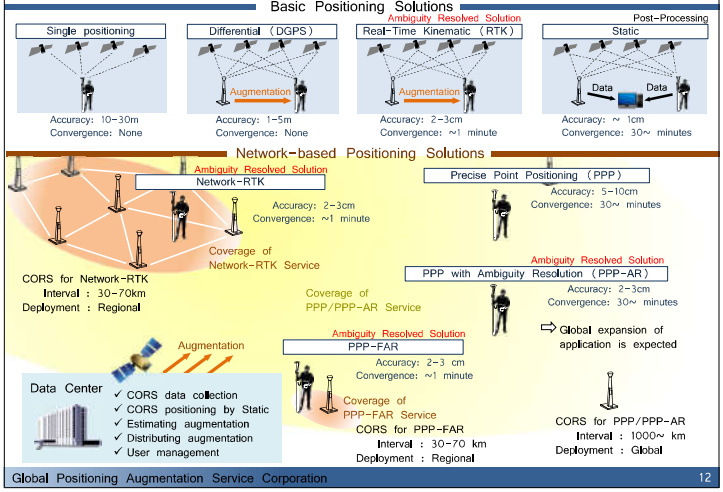


Error Sources
1. Satellite Orbit error
2. Satellite Clock error
3. Signal Biases
4. Ionosphere delay
5. Troposphere delay

Global Monitoring Network
At least 4 stations must be located to receive the signal from all satellites simultaneously.

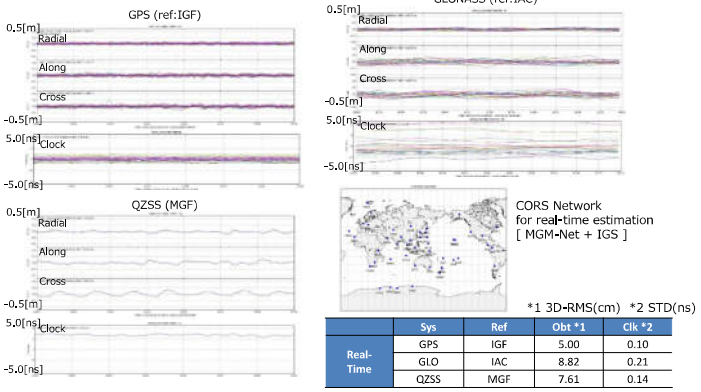
Error sources 4-5 (caused by signal delay) is corrected using user's observation data. For estimating ionosphere delay, dual-frequency observation is mandatory.

Types of GNSS Positioning Solutions



Performance of PPP Augmentation

Satisfactory performance has been confirmed for centimeter-level positioning to estimate multi-GNSS orbit / clock.



CORS Network
for real-time estimation
[MGM-Net + IGS]

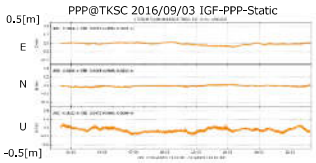
*1 3D-RMS(cm) *2 STD(ns)

	Sys	Ref	Obt *1	Clk *2
Real-Time	GPS	IGF	5.00	0.10
	GLO	IAC	8.82	0.21
	QZSS	MGF	7.61	0.14

Reference: K. Yoshikawa et al. "The Development and Demonstration of Precise Point Positioning Technology with Multi GNSS," The 60th Symposium on Space Science and Technology, September 2016

Positioning Performance of PPP

Less than 5cm RMS of horizontal accuracy, and less than 10cm RMS of vertical accuracy can be achieved by JAXA's evaluation.



PPP	AVE	STD	RMS
E	1.6 cm	2.6 cm	3.1 cm
N	1.3 cm	1.7 cm	2.1 cm
U	5.1 cm	4.8 cm	7.0 cm

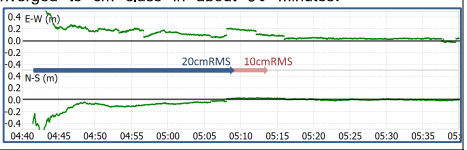
Reference: K. Yoshikawa et al. "The Development and Demonstration of Precise Point Positioning Technology with Multi GNSS," The 60th Symposium on Space Science and Technology, September 2016

Convergence Time

Due to troposphere delay, about 30 minutes of data is required to estimate the troposphere error by Kalman filter with time-series observations.

For this reason, the accuracy immediately after starting the positioning process is not stable, then it will be converged to cm-class in about 30 minutes.

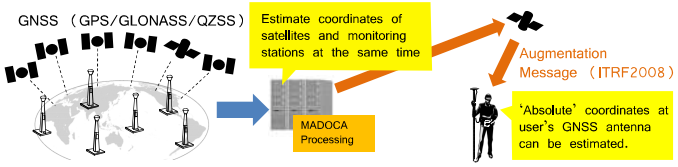
Used Satellites	GPS + QZSS + GLONASS
Convergence Time to 20cmRMS	1651 seconds
Convergence Time to 10cm RMS	1903 seconds
RMS before Convergence (10cm)	Horizontal 28.2 cm Vertical 41.7 cm
RMS after Convergence (10cm)	Horizontal 4.5 cm Vertical 4.2 cm



Estimated Position (Reference Coordinate System)

Satellite coordinates in QZSS augmentation are provided based on ITRF2008, and user's GNSS receiver should output coordinates based on WGS84 as is the case with other GNSS positioning.

In case of QZSS+PPP positioning, about 90 of world-wide monitoring stations are used for producing augmentation message (satellite orbits etc.), and the coordinates of stations are estimated with satellite's coordinates at all times, therefore, the estimated user's position does not effected by deformation of monitoring site's location. This means that PPP positioning provides "absolute" coordinates.



Generally, for precise GNSS positioning, Kinematic-GNSS method is used.

However, Kinematic-GNSS method estimates "relative" position from a reference station, therefore, there is a risk that the estimated position includes position error of reference station.

Demonstration Projects using QZSS-PPP

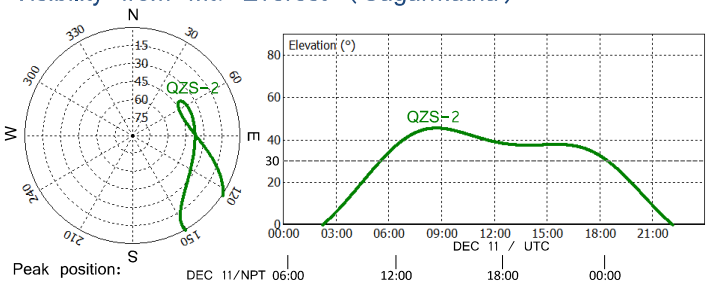
Some demonstration projects using QZSS-PPP are ongoing.

PPP solution can be utilized without the need for relative reference GNSS station around user's position. This means that PPP is available "anywhere" in the world.

The following video is past demonstration projects using PPP technology.

2. Evaluation on the Possibility for Utilization

Visibility from Mt. Everest (Sagarmatha)



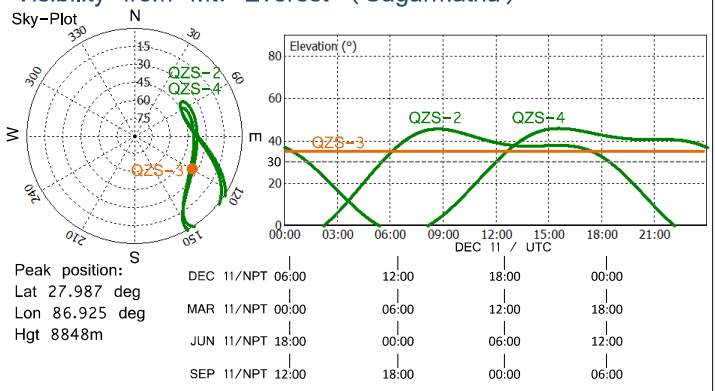
Peak position:
Lat 27.987 deg
Lon 86.925 deg
Hgt 8848m

DEC	11/NPT	06:00	12:00	18:00	00:00
MAR	11/NPT	00:00	06:00	12:00	18:00
JUN	11/NPT	18:00	00:00	06:00	12:00
SEP	11/NPT	12:00	18:00	00:00	06:00

QZS-2 can be tracked about 54% in a day above 30 degrees elevation.

Visible time is changing to about 4 minutes earlier day by day as the sidereal period of the satellite is about 23 hours 56 minutes.

Visibility from Mt. Everest (Sagarmatha)



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MAR 11/NPT 00:00 06:00 12:00 18:00
JUN 11/NPT 18:00 00:00 06:00 12:00
SEP 11/NPT 12:00 18:00 00:00 06:00

After checking out of QZS-3 and QZS-4, the visibility of one QZS satellite will be 100% above 35.4 degrees elevation. Soon those satellites will be available.

Introduction of the Receiver / Processor

To utilize "Positioning Technology Verification Service" of QZSS, at the moment, only limited product is available, because the service is just getting started and it is still verification service.

The following product (evaluation kit) is QZSS-PPP compatible receiver provided by Magellan Systems Japan, Inc.

Item	Specification (Step1 Evaluation Board)	
Supported Satellite Systems and Signals	GPS	L1, L2, L5
	QZSS	L1, L2, L5, L6
	GLONASS	G1, G2
	Galileo	E1, E5a, E5b, E5, E6
	Beidou	B1, B2
	SBAS	L1
Position accuracy	Autonomous	1.5 m (RMS) typical
	DGPS (SBAS)	< 1.0 m (RMS)
	Network RTK	
	Dynamic	< 5cm + 1ppm x BL (< 20km) (RMS)
	Static	< 0.5cm + 1ppm x BL (<20km) (RMS)
	PPP-RTK	< 10 cm (RMS)

P/N: MJ-3008-GM4-QZS

Reference: http://www.magellan.jp

Item	Specification (Step1 Evaluation Board)	
TTFF (Autonomous)	Cold start	90 sec (typical)
	Warm start	35 sec (typical)
	Hot start	12 sec (typical)
	Re-acquisition	2 sec (typical)
Output Rate	Max 100 Hz	
Interface	USB, UART, CAN, Ethernet	
Message Format	NMEA0183 Version 3.0 (Output) RTCM SC104 Version 3.1 (Input/Output)	

Advantages and Issues to be considered in case of QZSS-PPP

Advantages:

- Centimeter-level positioning is available in real-time
- No charges for receiving augmentation message as "Positioning Technology Verification" Service
- No communication-link is required except GNSS
- Absolute coordinates are measured
- No effect by deformation of reference GNSS monitoring station

Issues to be considered:

- QZSS-PPP compatible receiver is currently limited
  - cold weather prevention is mandatory
- Visible time of QZSS may be limited on Mt. Everest
- At least 30 minutes observation is required for convergence

Summary

- Four QZSS satellites have been launched and some experimental service is being provided.
- "Positioning Technology Verification" service (PPP augmentation service) has started experimentally by Global Positioning Augmentation Service Corporation from QZS-2.
- Some demonstration projects using QZSS-PPP service are ongoing.
- Absolute 10cm accuracy is available in vertical axis by applying augmentation from QZSS service, after 30 minutes convergence time.
- 54% visibility of QZS-2 above 30 degrees elevation is expected at the peak of Mt. Everest. Soon visibility will become 100% above 35.4 degrees elevation after checking out of QZS-3/4.
- One type of QZSS-PPP compatible receiver is available as an evaluation kit.

Thank you for your attention
तपाईको ध्यानाकर्सनको लागि धन्यवाद

For any inquiry or general information regarding "Positioning Technology Verification" on L6 signal of QZSS, please contact us.

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