Transmission of Augmentation Corrections using the Japanese QZSS for Real-Time Precise Point Positioning in Australia

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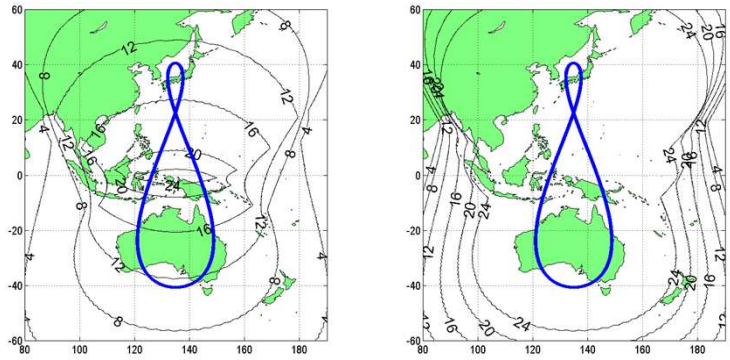
Quasi-Zenith Satellite System (QZSS)

- Phase 1: System Test
  - First satellite, QZS-1 ("Michibiki") was launched on 11 September 2010
- Phase 2: GNSS Augmentation
  - Four satellite constellation by 2018
    - 3 HEO and 1 GEO satellites
  - Availability enhancement: L1 C/A, L2C, L5 & L1C signals
  - Performance enhancement:
    - L1 SAIF: Sub-metre accuracy with integrity
    - LEX: Centimetre level accuracy
- Phase 3: RNSS
  - Seven satellites by 2023
    - 4 HEO and 3 GEO satellites
  - Independent positioning

QZS-1 satellite "Michibiki" © JAXA

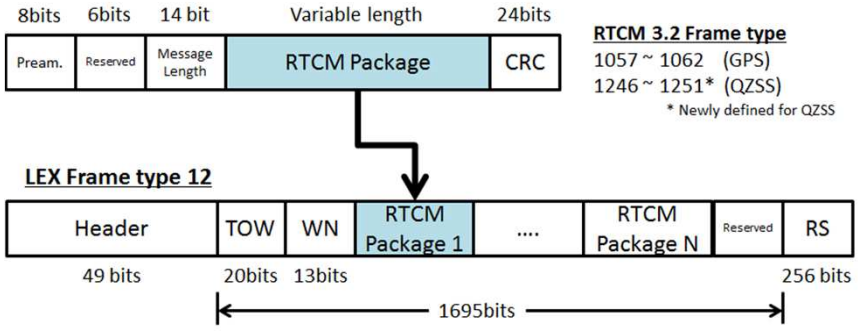
Coverage Area of QZSS



- Highly-inclined Elliptical Orbit (Blue):
  - Central longitude: 135˚ ; Orbit inclination 43˚
- Left: current visibility (2015)
  - 12 hours a day or more for most of East-Asia and Oceania
- Right: coverage with 3 HEO satellites (2018)
  - 24 hours a day over most of East-Asia and Oceania

QZSS LEX Messages for PPP

- LEX capacity: 2000bps (vs. 250bps in SBAS).
- PPP: high accuracy precise positioning using precise satellite orbit and clocks corrections.
- LEX messages for PPP: RTCM 3.2 State Space Representation (SSR) messages packaged onto LEX signal.



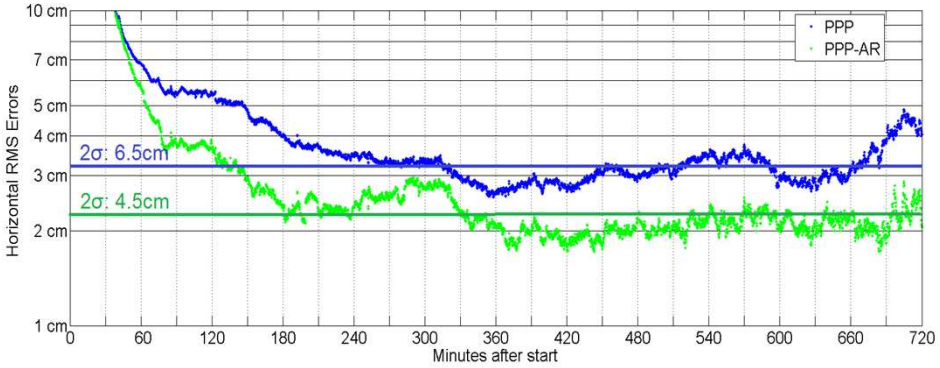
Contents of LEX Messages

	Clock	Orbit	Code bias	Phase bias	Observation
JAXA messages					
MADOCA (GPS/QZS)	GPS: 2 s QZS: 2 s	GPS: 10 s QZS: 10 s	GPS: 10 s QZS: 10 s		Generated by JAXA
MADOCA (GPS/GLO/QZS)	GPS: 2 s GPS: 2 s QZS: 2 s	GPS: 30 s GLO: 30 s QZS: 30 s	GPS: 30 s GLO: 30 s QZS: 30 s		Generated by JAXA
Tested messages…					
Low rate PPP	GPS: 5 s	GPS: 60 s			Based on CLK11
High rate PPP	GPS: 5 s	GPS: 5 s	GPS: 5 s		Based on IGS01
PPP-AR	GPS: 5 s	GPS: 5 s		GPS: 5 s	Based on CLK9B
To be tested…(in May 2015)					
PPP-AR + Iono.	GPS: 5 s	GPS: 10 s	GPS: 10 s	GPS: 10 s	+ Iono corr: 10s

Transmission Experiment: LEX Messages

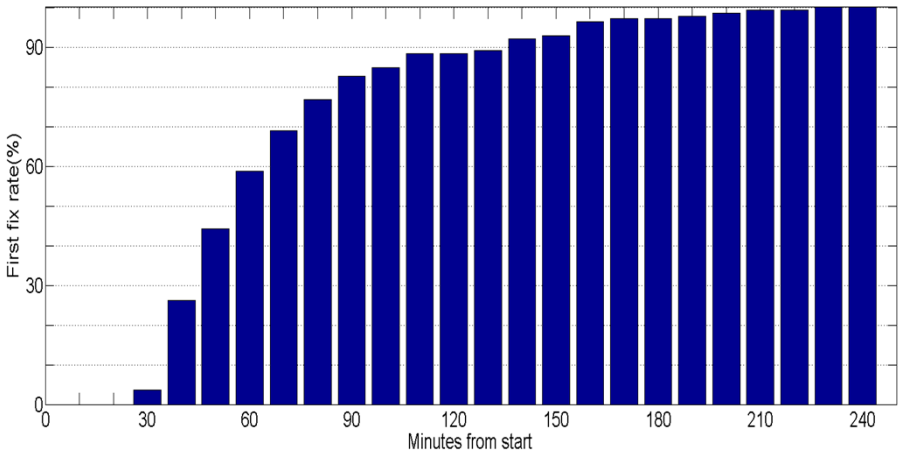
- Correction data from real-time RTCM streams
  - IGS: CLK11 and IGS01
  - CNES: CLK9B
- Correction packaged as LEX messages in RMIT University, Australia.
- Transmission to QZSS Master Control Station in Japan by standard TCP/IP commercial service for broadcast
- Real-time PPP
  - CLK11 and IGS01: float ambiguity PPP
  - CLK9B: ambiguity resolved PPP

Post-processed: PPP-float vs PPP-AR



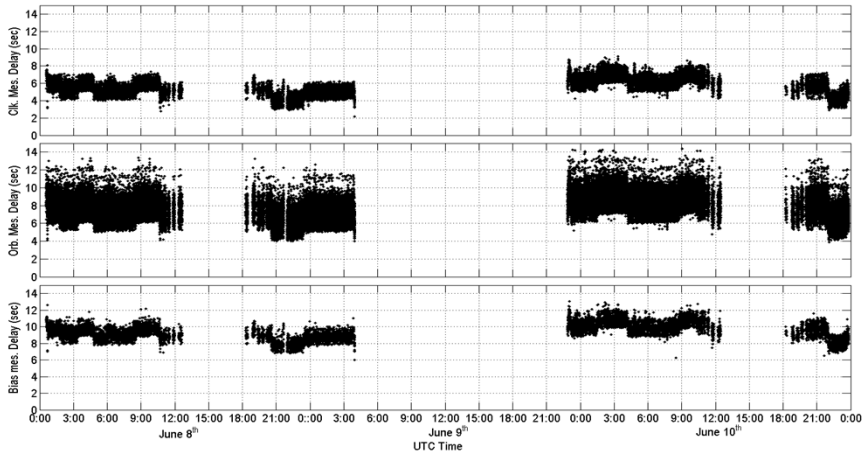
- 12-18 August and 12-18 September 2014. 10 Australian CORS stations. Total =140 solutions.
- 30% improvement in horizontal accuracy.
- Minimal improvement in heights (RMS: 13cm).

Post-processed PPP-AR: Time-To-First-Fix (TTFF)



- Partial ambiguity resolution could improve TTFF.

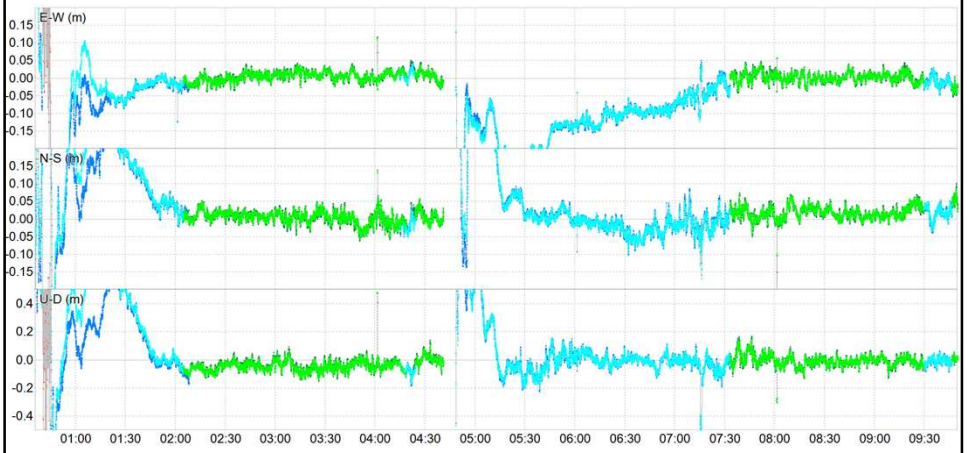
LEX Messages Delay: Real-time Transmission



	Clock	Orbit	Bias
Mean (s)	5.67	7.90	9.45
Standard dev. (s)	0.97	1.40	0.97

Real-time PPP Kinematic, Fixed Point (CLK9B)

Date: 08/06/2014



RMS (RMIT-LEX)

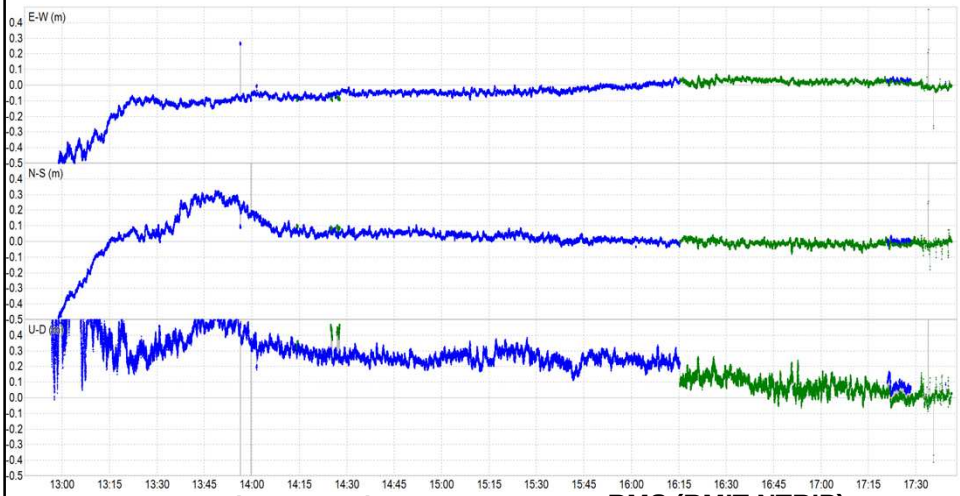
E/N/U: 1.6, 2.1, 4.9 cm

RMS (RMIT-NTRIP)

E/N/U: 1.4, 2.3, 4.8 cm

Real-time PPP Kinematic, Vehicle (CLK9B)

Date: 13/11/2014



RMS (RMIT-LEX)

E/N/U: 2.7, 2.0, 9.3 cm

RMS (RMIT-NTRIP)

E/N/U: 3.8, 1.8, 10.4 cm

Summary and Future Work

- QZSS-LEX signal is aimed at delivering cm-level positioning in the East-Asia and Oceania region.
- LEX messages for PPP and PPP-AR were generated based on global real-time corrections:
  - Satellite orbits and clocks.
  - UPD for Melbourne-Wübenna and iono-free combinations.
- Resolving ambiguities in PPP provides 30% improvement in horizontal accuracy. Convergence time is between 30 minutes to 1 hour.
- Real-time PPP-AR:
  - Accuracies: ~5 cm horizontally and ~12 cm vertically.
- Future work:
  - Experimental ionospheric corrections to assist convergence and re-convergence.
  - Transmission of Australian generated corrections for PPP-RTK.

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- French Space Agency (CNES), France
- International GNSS Service (IGS)
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- CASS Foundation, Australia

Thank you !

Outline

- Project Aim: *Transmission of a prototype "Australian-generated LEX corrections" for Precise Positioning*
  - A CRCSI-JAXA Joint Research (2013-2015)
- Introduction to QZSS
- QZSS LEX signal for Precise Point Positioning (PPP)
- Contents of the LEX messages
- Float-PPP vs ambiguity-resolved PPP
- Real-time transmission of "Australian-generated LEX corrections" for PPP-AR
- Summary and Future Work
- Acknowledgements

Modified RTCM/LEX Messages

- Clock messages:
  - Standard RTCM: 2nd order polynomial parameters for clock
  - High rate clocks, containing satellite offset only are used
- Code biases:
  - When using PPP based on iono-free combinations, code biases can be assimilated into satellite clock without loss of information
  - Only transmit code biases when receiver uses ionospheric corrections.
- Phase biases:
  - Calculate and transmit UPB corrections for Melbourne-Wübenna and iono-free combinations
  - No (official) standard messages for phase bias
  - Transmit phase biases based on the format for code biases

QZSS Signal

- Availability enhancement:
  - GPS compatible signals L1 C/A, L2C, L5 and L1C
- Performance enhancement:
  - L1 Sub-metre Accuracy and Integrity Monitoring (L1-SAIF) signal
  - L6 Experimental (LEX) Signal

Message Streams	Frequency	Encoding	Bit rate
GPS NAV messages	L1 (1575.42 MHz)	BPSK	50 bps
SBAS messages	L1 (1575.42 MHz)	BPSK	250 bps
Galileo C/NAV	E6 (1278.75 MHz)	BPSK	500 bps
QZSS LEX messages	E6 (1278.75 MHz)	CSK	2000 bps