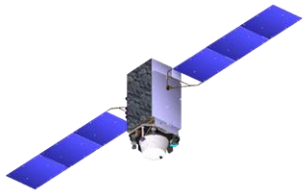
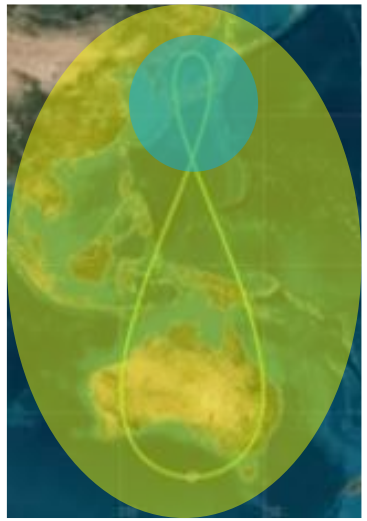
Recent Activity of International Standardization for High-Accuracy GNSS Correction Service



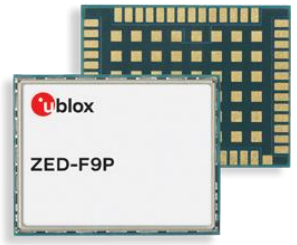


Dr. Rui Hirokawa (Mitsubishi Electric Corporation)

June 27, 2019
Standards and Interoperability of Precise Point Positioning Services
Workshop on the Applications of Global Navigation Satellite Systems, Suva, Fiji

Age of Open High-Accuracy GNSS positioning

- ✓ Open PPP/PPP-RTK correction services are available.
- ✓ Low cost dual-frequency receivers are available in the mass-market.
- ✓ Open High-Accuracy GNSS Positioning would be commodity in the middle of 2020.



u-blox F9P

Broadcom BCM47755

Interoperability between correction services and receivers becomes highly important.

List of Open Satellite-Based High-Accuracy GNSS Correction Service

System	Service	Satellite	Status	Signal	Data Rate	Format
QZSS CLAS	PPP-RTK	IGSO/GEO	Operational (2018-)	1.278GHz (L6D)	2,000bps	Compact SSR
QZSS MADOCA	PPP	IGSO/GEO	Experimental (2017-)	1.278GHz (L6E)	2,000bps	RTCM SSR
Galileo HAS	PPP	MEO	Development (2021-)	1.278GHz (E6b)	500bps	Compact SSR as starting point
GLONASS	PPP	MEO/IGSO	Development (2020?)	1.207GHz (L3)	?	?
Beidou 3	PPP	GEO	Development (2020?)	1.207GHz (B2b I/Q)	1,000bps	?
Austrian SBAS	PPP	GEO	Development(2023-)	1.5GHz (L)	?	?

CLAS Applications

Centimeter level positioning accuracy, anywhere, anytime

Agriculture

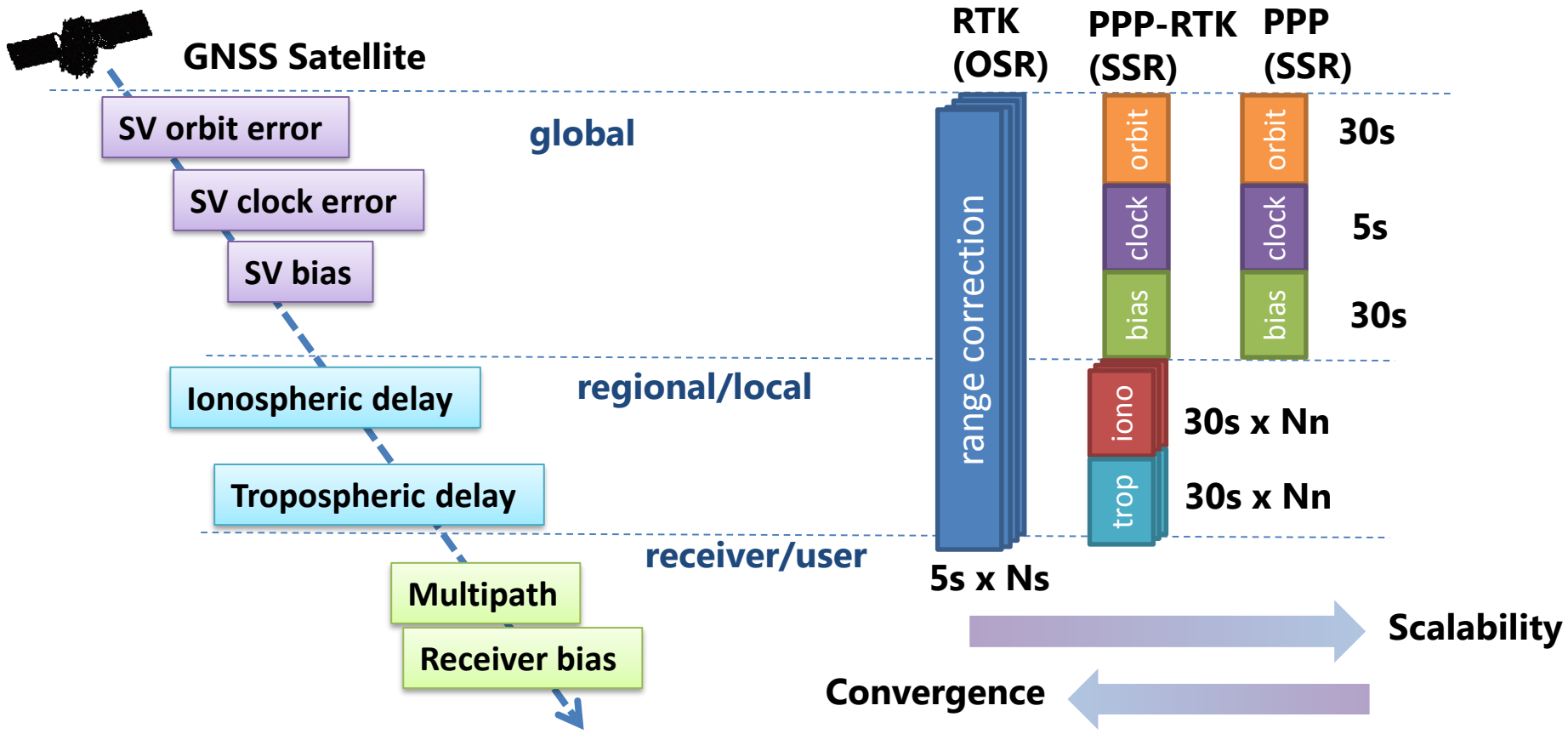
Automobile (ADAS)

Construction & Survey

Train management

Concept of State-Space Representation(SSR)

- ✓ The range measurements include the errors from different sources.
- ✓ In SSR, each corrections are separately estimated and transmitted based on each dynamics.



OSR: observation-space representation
SSR: state-space representation

Ns: number of stations
Nn: number of sub-network/grids

Advantage of SSR

- ✓ The scalability is major issue of conventional RTK/network-RTK.
- ✓ By applying SSR, the total data-rate can be reduced considerably (<0.1%).
- ✓ The correction data can be broadcasted
  (no requirement for mobile communication line like VRS)

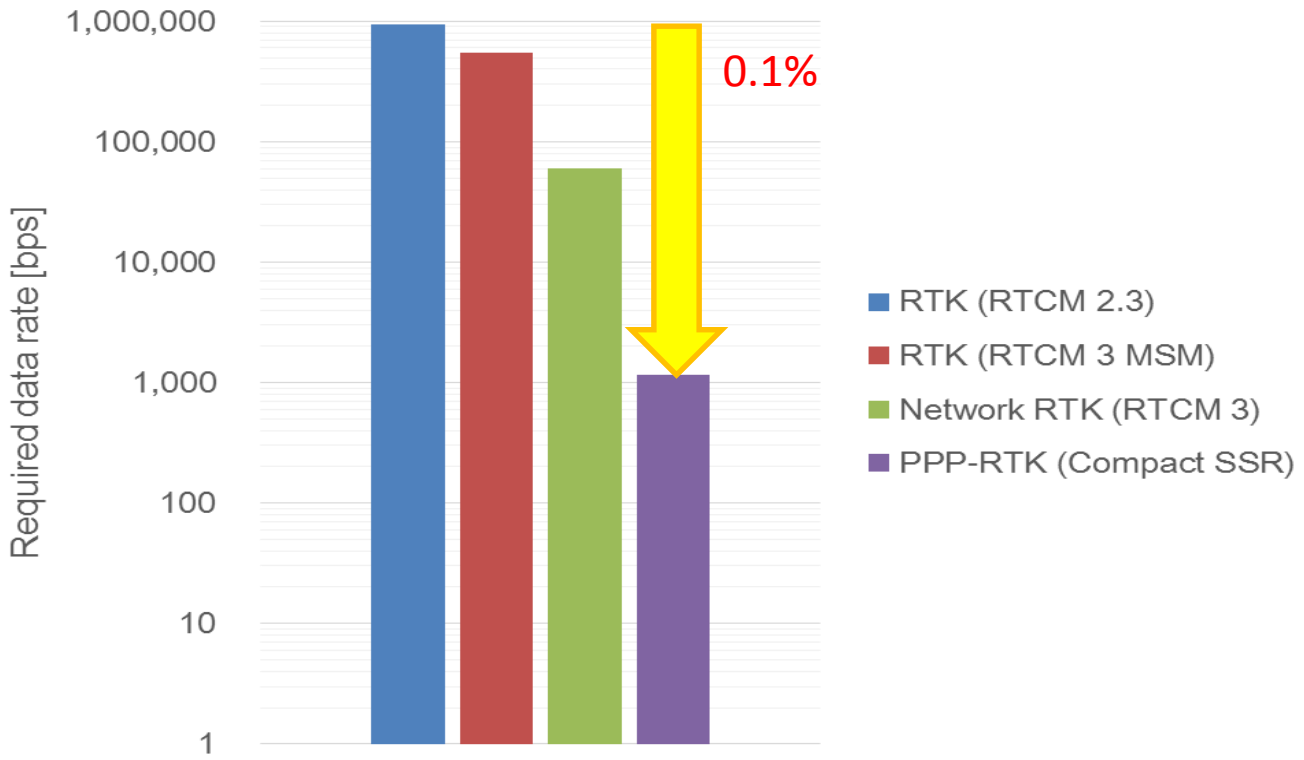


Fig.2 required data rate for nationwide high accuracy correction service

Tab.1 Parameters for nation-wide RTK service

item	Value
Number of GNSS	3
Number of satellites	14
Number of signals	3
Service area	400,000 [km^2]
Baseline (PPP-RTK)	50 [km]
Baseline (Network-RTK)	40 [km]
Baseline (RTK)	20 [km]
Update interval	5 [sec]

Open standard for high-accuracy GNSS

- RTK/Network RTK and PPP are standardized in RTCM SC-104.
- An open standard for PPP-RTK, Compact SSR proposed in Sep. 2015 as RTCM proprietary message (MT4073), applied for QZSS CLAS (defined in IS-QZSS-L6).
- 3GPP working to define the standard for mobile communication (LTE/5G).
- Other parties such as Geo++, Sapcorda are also preparing SSR based proprietary format.

#	Type	Publisher	Application	Status
1	RTCM 3 (2004-2011)	RTCM	RTK/NRTK PPP	Open standard (RTCM 3 standard, under development)
2	Compact SSR (2015)	Melco	PPP/PPP-RTK	Open standard (RTCM 3 proprietary: MT4073)
3	LPP (2019)	3GPP	RTK/NRTK PPP/PPP-RTK	On proposal for PPP-RTK (based on RTCM SSR/Compact SSR)
4	SSRZ	Geo++	PPP/PPP-RTK	Not available (under development) (RTCM3 proprietary: MT4090)
5	SAPA	Sapcorda	PPP/PPP-RTK	Not available (under development)

SSR standardization in RTCM SC-104

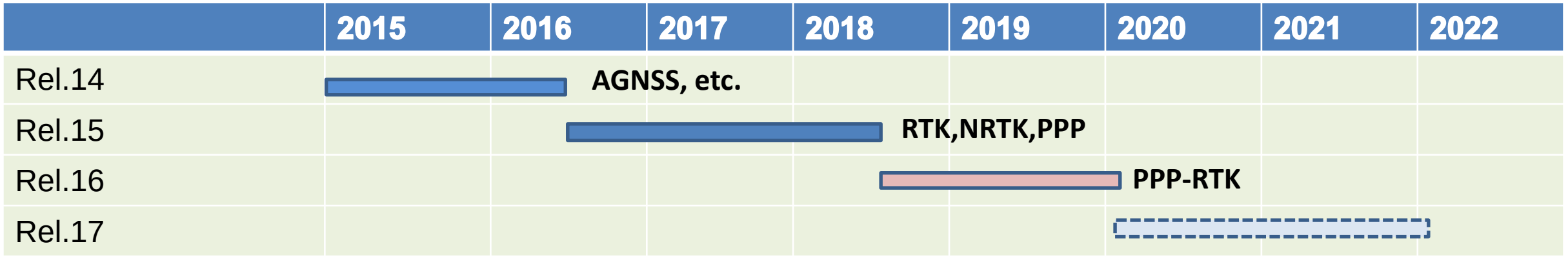
- SSR standardization is still on-going in RTCM SC-104, there is no progress since Feb. 2011.
- The Stage-2 messages for phase bias and VTEC are on proposal phase.

Stage	Type	Application	Status
1	Orbit/Clock/ Code bias/URA	Code PPP	• GPS/GLONASS in RTCM 3.1a5 (Feb. 2011) • On proposal for GAL/BDS/QZS/SBAS
2	VTEC Phase bias	SF-PPP PPP-AR	• On proposal
3	STEC/Tropo	PPP-RTK	(TBD)
4	Compression	PPP/PPP-RTK	(TBD)

Standardization in 3GPP

- The high-accuracy GNSS positioning is demanded for LTE/5G, 3GPP started to define the format based on open-standard.
- In Rel.15, RTK,NRTK,PPP were standardized based on RTCM 3.
- Melco/u-blox/ESA proposed the PPP-RTK messages based on Compact SSR, accepted as Work Item for Rel.16 (March 2019):

  Define extensions of LPP protocol to support GNSS SSR (PPP-RTK support) based on the "Compact SSR" definitions specified for QZSS



Concept of Compact SSR

- ✓The first open format supporting the atmospheric correction
- ✓Compatibility with existing RTCM-3 standard (Message Type 4073)
- ✓Compactness of presentation for satellite base broadcasting service (<=2,400bps)
- ✓Supporting the quality indicator to calculate the protection-level [1]

Tab.3 Compact SSR Messages

Group Name	Sub-Group Name	Message Type
Common Correction	Mask	4073, 1
	GNSS Orbit Correction	4073, 2
	GNSS Clock Correction	4073, 3
	GNSS Combined Orbit/Clock Correction	4073,11
	GNSS Satellite Code Bias	4073, 4
	GNSS Satellite Phase Bias	4073, 5
	GNSS Satellite Code and Phase Bias	4073, 6
	GNSS URA	4073, 7
Local Correction	STEC correction	4073, 8
	Gridded Correction	4073, 9
Service	Service Information	4073, 10

69 satellites (32 GPS, 7 QZS, 30 Galileo) with 3 signals/satellite
Interval: 5sec for clock, 30sec for others

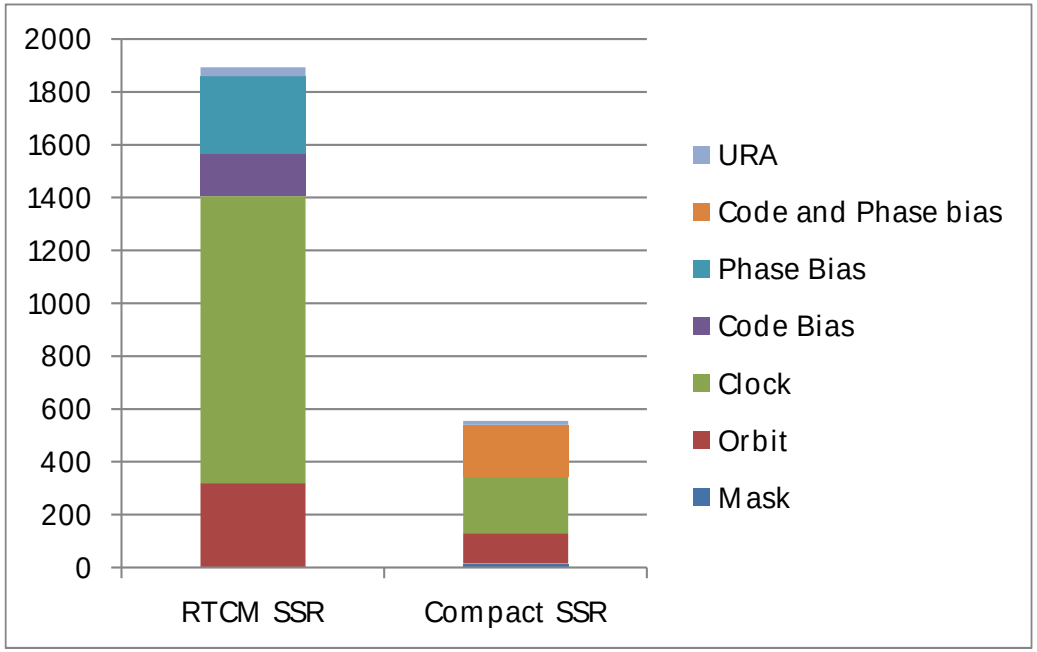


Fig. 3. Required data rate (bps) for a global PPP service

[1] “Design of Integrity Function on Centimeter Level Augmentation Service (CLAS) in Japanese Quasi-Zenith Satellite System”, ION-GNSS+ 2016

Format definition in Galileo HAS

Ignacio Fernandez-Hernandez, “Galileo High Accuracy Service and its importance for mobility applications”, INTERGEO, Frankfurt, 16 Oct 2018

HAS DEFINITION

- High accuracy (PPP) corrections provided in the Galileo E6-B signal component:
  - Satellite orbits
  - Satellite clock corrections
  - Code biases for multi-frequency
  - Signal/correction quality information
  - Phase biases (to be confirmed)
  - Ionosphere in EU (to be confirmed)
- Corrections will for Galileo (E1, E5a, E5b, E6, E5 TBC) and GPS (L1, L2, others TBC), and in the future potentially for other GNSS.
- Global coverage when fully operational. Partial coverage before. EU always included.

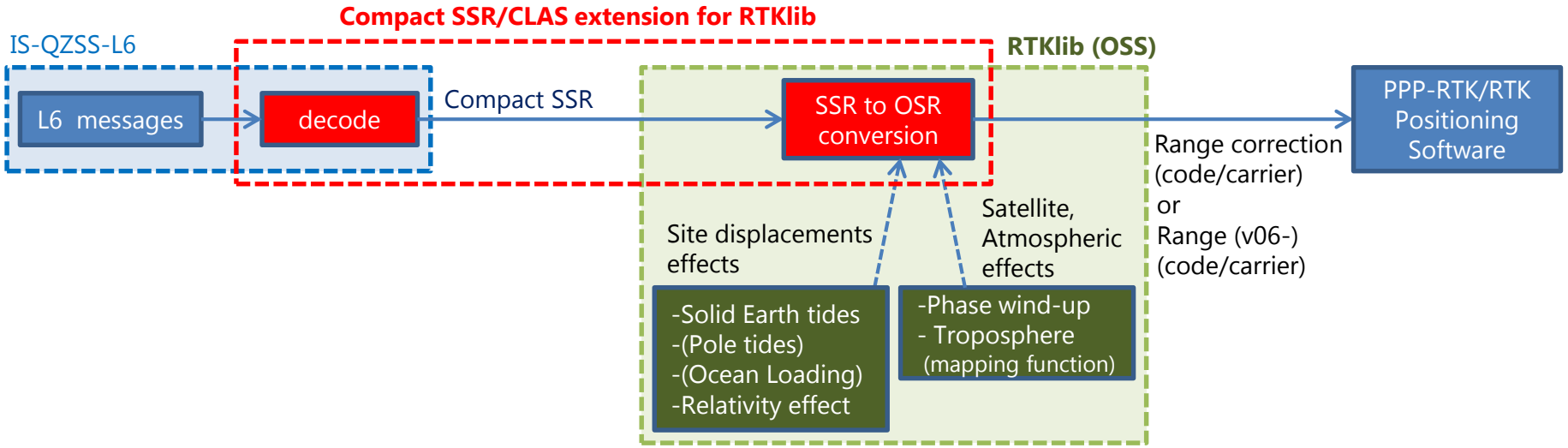
- HAS data will be transmitted openly, for free, and through an open standard format. **RTCM CSSR used as starting point.** Format currently under definition.
- "user error of less than two decimetres". This depends on user receiver, algorithm and environment.
- Support HAS via terrestrial networks is under consideration.

Sub Type	Sub Type Name	No. of Bit
1	Compact SSR Mask	37 + 60 x Nsys
2	Compat SSR GNSS Orbit Correction	25 + (51 or 49) x Nsat
3	Compact SSR GNSS Clock Correction	25 + 15xNsat
4	Compact SSR GNSS Satellite Code Bias	25 + 11 x Ncode x Nsat
5	Compact SSR GNSS Satellite Phase Bias	25 + 17 x Nphase x Nsat
6	Compact SSR GNSS Satellite Code and Phase Bias	28 + 28 x Nsig x Nsat
7	Compact SSR GNSS URA	25 + 6 x Nsat
8	Compact SSR TEC Correction	25 + 34 x Ngrid

- Galileo HAS plan to use an open standard, Compact SSR as starting point.
- EC/GSA and CAO Japan started to discuss to maintain the inter-operability between Galileo HAS and QZSS CLAS.

CLAS Test Library: CLASLIB

- Based on the request from major GNSS receiver manufacturers, “CLAS Test Library (CLASLIB)”, an open source software toolkit for CLAS is developed [1].
- It is available from QSS Web site.
  http://sys.qzss.go.jp/dod/en/downloads/download.html?TECH_ID=3.
- It is based on RTKLIB and GSILIB, and it includes:
  1. Manual
  2. Compact SSR to OSR converter
  3. Post processing analysis tool using PPP-RTK (submission in form is necessary)



[1] “CLASLIB: An Open-source Toolkit for Low Cost High-precision PPP-RTK Positioning”, ION-GNSS+ 2019

Future Enhancement

- ✓ Service Information
  - Four types of service information messages plan to be defined
- ✓ More Effective Compression
  - More effective compression based on adaptive length bit assignment plan to be applied on Compact SSR SubType 12.
- ✓ Authentication
  - The authentication for SBAS has been studied recently.
  - The concept of authentication for PPP-RTK correction will be presented in ION GNSS+ 2019 [1].
- ✓ Integrity
  - Compact SSR supporting the basic integrity feature to estimate the protection level [2].
  - Standardization is progressing in RTCM SC-134 for safety critical applications such as Automotive, Rail.

[1] “A Message Authentication Proposal for Satellite Based Nation-wide PPP-RTK Correction Service”, ION-GNSS+ 2019
[2] “Design of Integrity Function on Centimeter Level Augmentation Service (CLAS) in Japanese Quasi-Zenith Satellite System”, ION-GNSS+ 2016

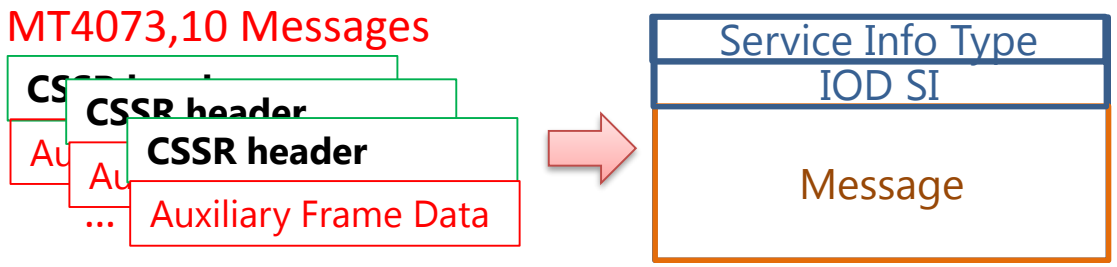
Service Information

- Some slowly changing or constant information could be useful for users.
- In Compact SSR, the Service Information Message (ST10) is defined a slow virtual stream (6-50 bps) to send the service information.
- The four Service Information messages plan to be defined.

Specification of Compact SSR

Part	Type	Standalone	Combined
Satellite	Clock	SubType 3	SubType 11
	Orbit	SubType 2	
	Code Bias	SubType 4	SubType 6
	Phase Bias	SubType 5	
Local (Troposphere, Ionosphere)	Functional	SubType 8	SubType 12 *1
	Gridded	SubType 9	
Service Information	SubType 10 *1	(defined in [1])	

*1 experimental



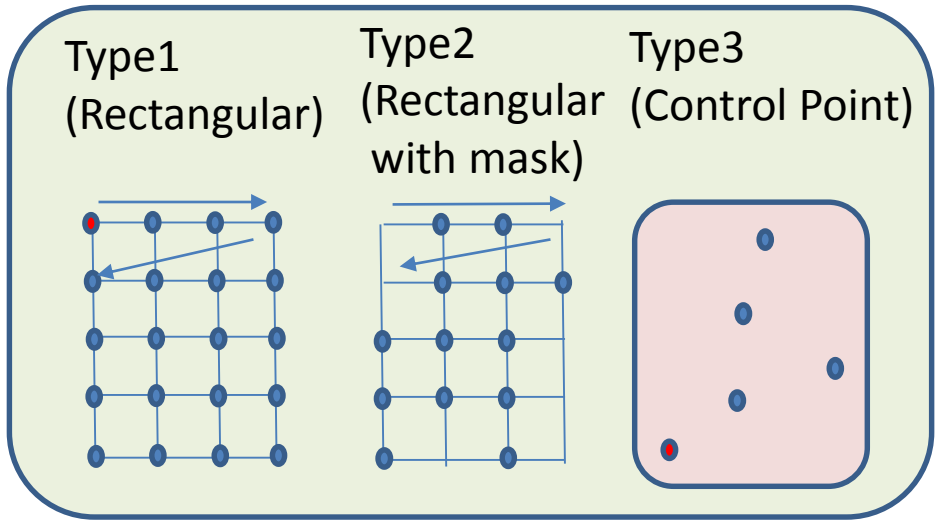
Specification of Service Information message [1]

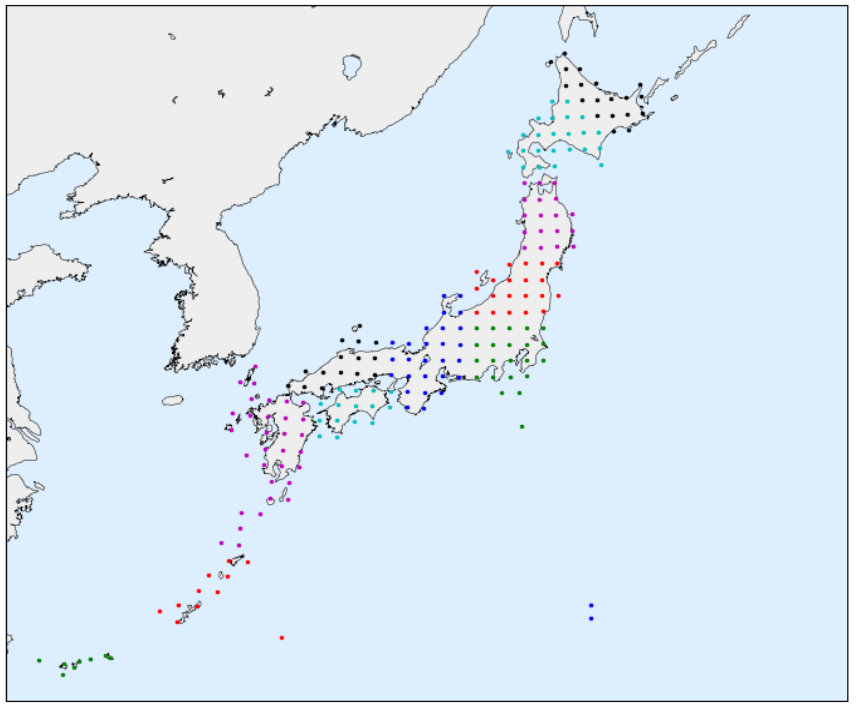
Type	Message Name
1	Service Provider Information
2	Service Operation Information
3	Grid Definition Information
4	Coordinate Transformation Information

[1] “Specification of Service Information Messages for Compact SSR” (draft)

Grid Definition Information

- The grid coordinates should be defined for atmospheric correction.
- The grid coordinates are defined in ICD for CLAS. In stream definition could also be useful.
- The idea proposed ”Concept for RTCM SSR Messages for Stage 3”, RTCM SSR WG, 2016
- A highly flexible and efficient grid definition message proposed in 3GPP by u-blox, Melco (May 2019)
- Three different types of grids can be mixed.
- 212 grids for CLAS can be transmitted using 6bps slow virtual stream within 4 minutes





The location of grids for CLAS (212 grids)

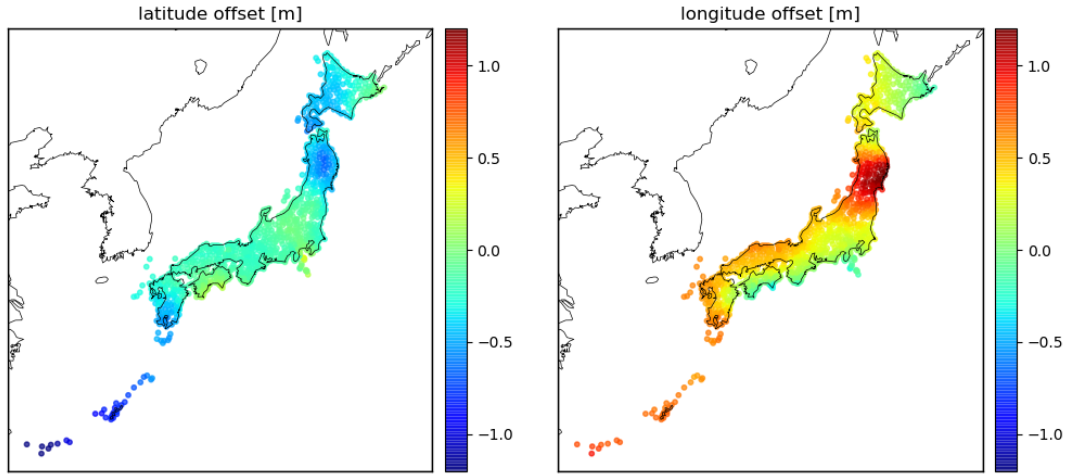
Coordinate Transformation Information

- The position derived from CLAS is based on the dynamic datum of current epoch.
- The mapping coordinates are based on static datum, JGD2011.
- The difference between these coodinates is more than 1.5m, drifting upto 10cm/year.

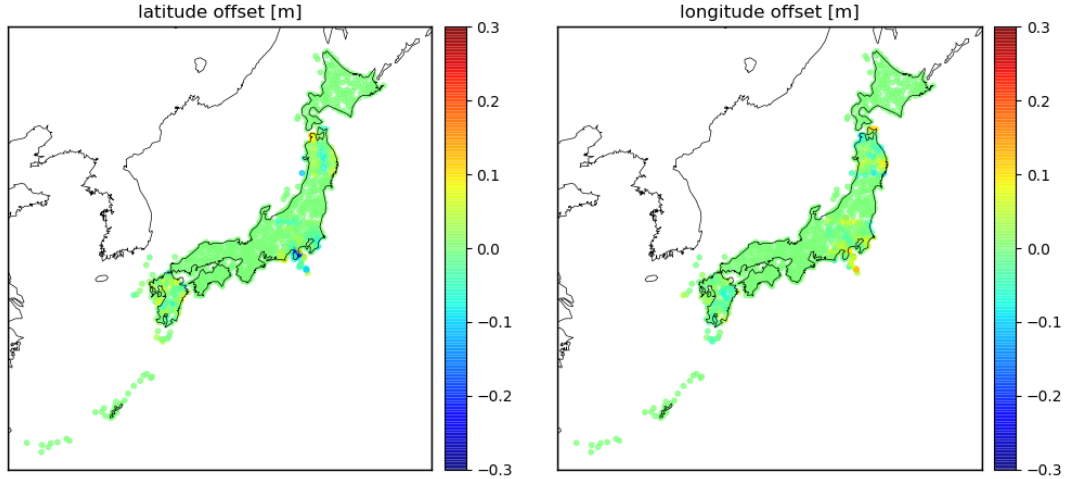
- A highly efficient coordinate transformation information is defined for Service Information Message of Compact SSR.

offset = [functional model] + [grid based residual]

- Expected accuracy after compensation is 3cm (rms).
- The message can be sent in the virtual slow stream of 6bps within 15minutes.



After transformation



Conclusion

- The recent activities in RTCM and 3GPP to define the open standard for high-accuracy GNSS positioning were introduced.
- Compact SSR, a flexible and efficient open format for PPP/PPP-RTK is introduced with the future enhancement plan.
- The continuous effort to maintain the inter-operability between services and receivers are highly important.