Evaluation of Actual Performance of PPP in Urban Areas Using Pocket SDR

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Background(GNSS Usage)

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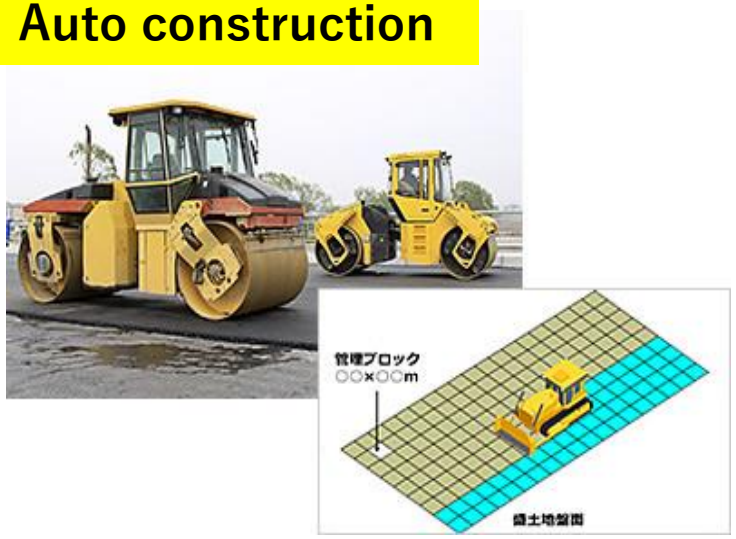
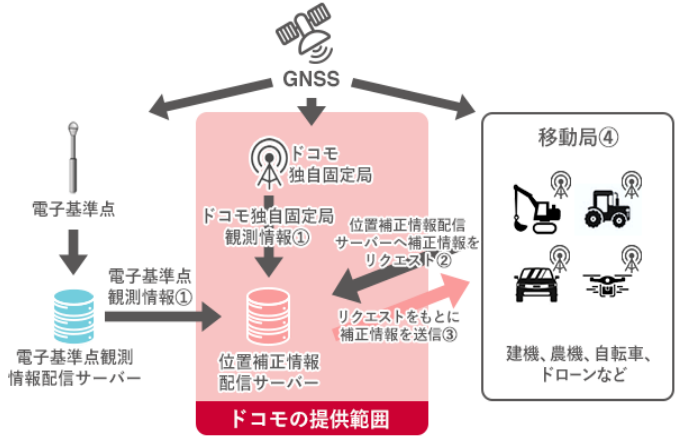
ITS

Auto construction

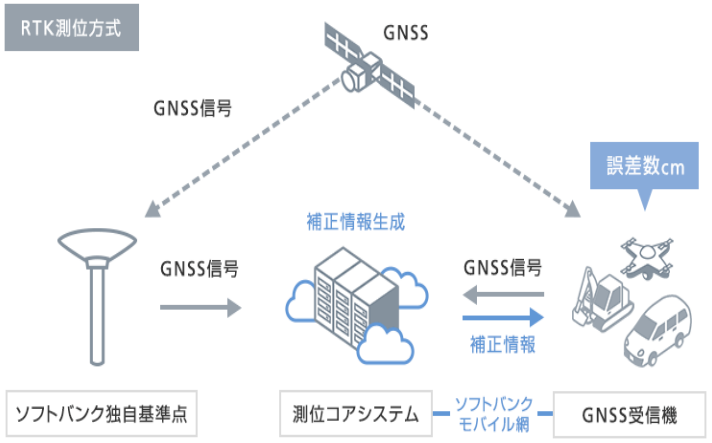


UAV

Correction data Services(JAPAN)

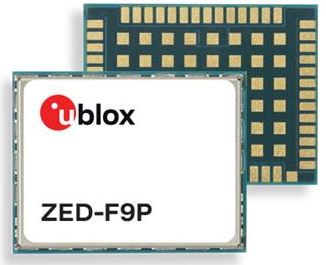


docomo



Softbank

Low cost receiver



PPP VS RTK (Real-time processing)

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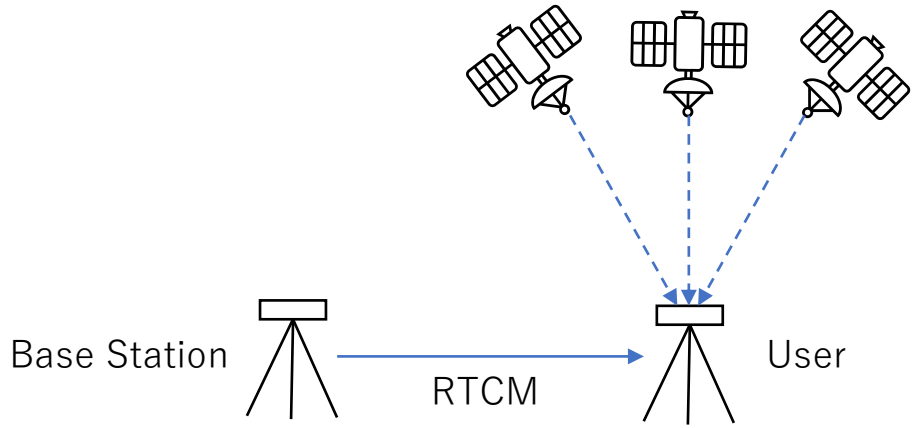
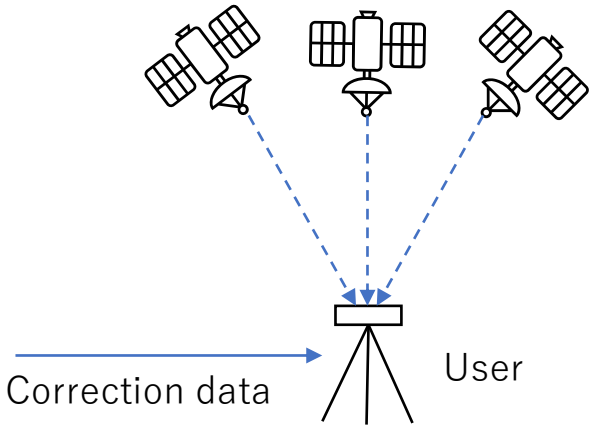
RTK



-Base station is needed (With Internet)
  Pseudorange, Carrier phase,
  Precise position at Base station
-Instantaneous cm-level position(<10km)
-High density CORS network or VRS

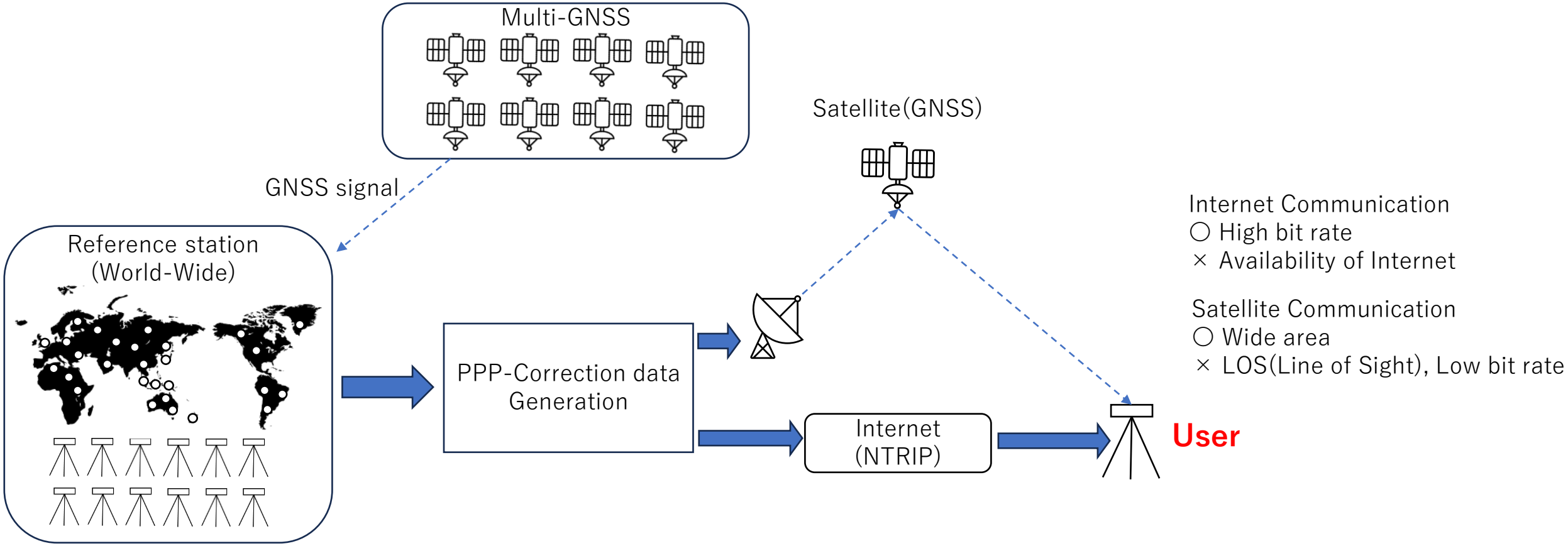
PPP



-Single Station
-Convergence time(～30 minutes)
-Correction data
  Orbit and Clock correction, Code phase bias…
- No geographical limitations

How to get the correction data(Orbit and Clock correction) in real-time?
How is the availability of correction data?

Correction data(via Satellite)



MADOCA-PPP, Galileo HAS, BDS PPP-B2b use satellite for distributing the correction data.

Unknown the availability satellite communication.
(Satellite visibility which transmit correction data, Decoding rate in actual environment)

Correction data(via Satellite)

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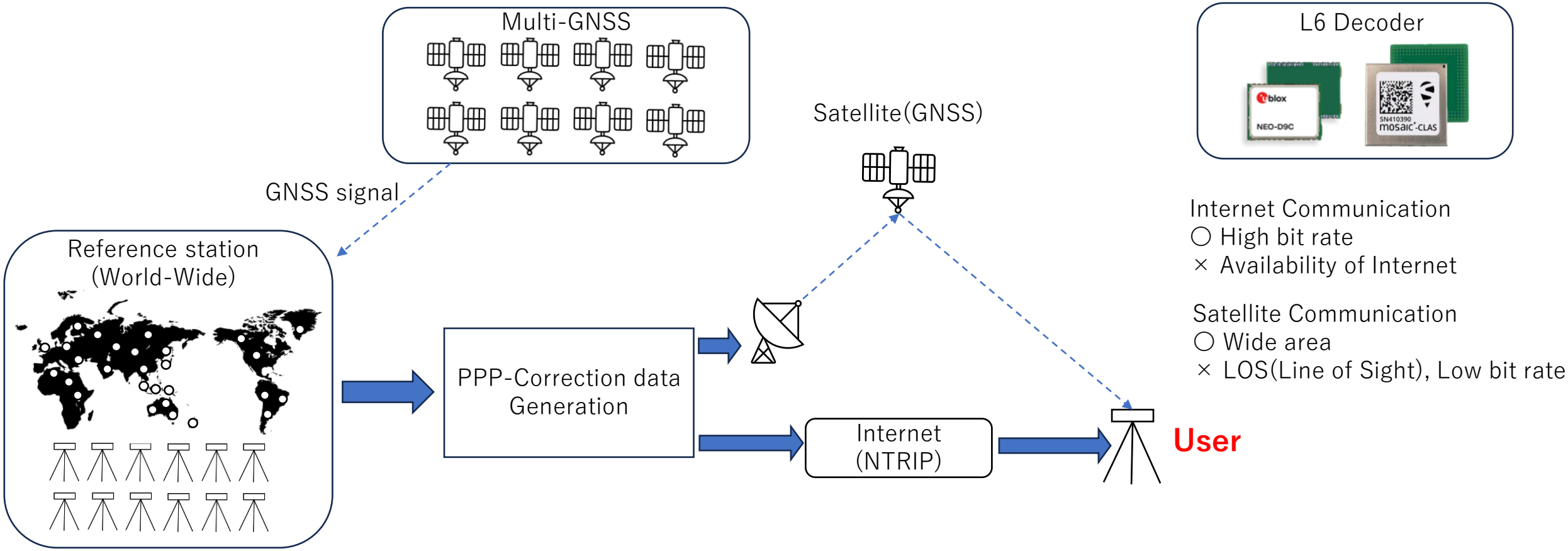

A few GNSS receiver can decode correction data(U-blox D9C…)

→We try to decode correction data and perform PPP in actual environment using GNSS-SDR!

Goal of our study

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Objective

Using GNSS-SDR(Software Defined Radio),
Evaluate the availability of correction data in actual environment and PPP suing decoded correction data.

- RF front-end and Software：Pocket-SDR developed by Mr. Tomoji Takasu
  Cheap, compact and Support Almost all GNSS signal.
  Software is written in Python3 in a very compact way.

-Actual environment：Open-Sky/ Multipath environment(Static)/ Multipath environment(Kinematic)

-PPP service：MADOCA-PPP

-PPP software：MADOCALIB(Ver：1.0b)
MADOCALIB was developed based on RTKLIB version 2.4.3 b34.(Add function of decoding L6 message)

MADOCA-PPP

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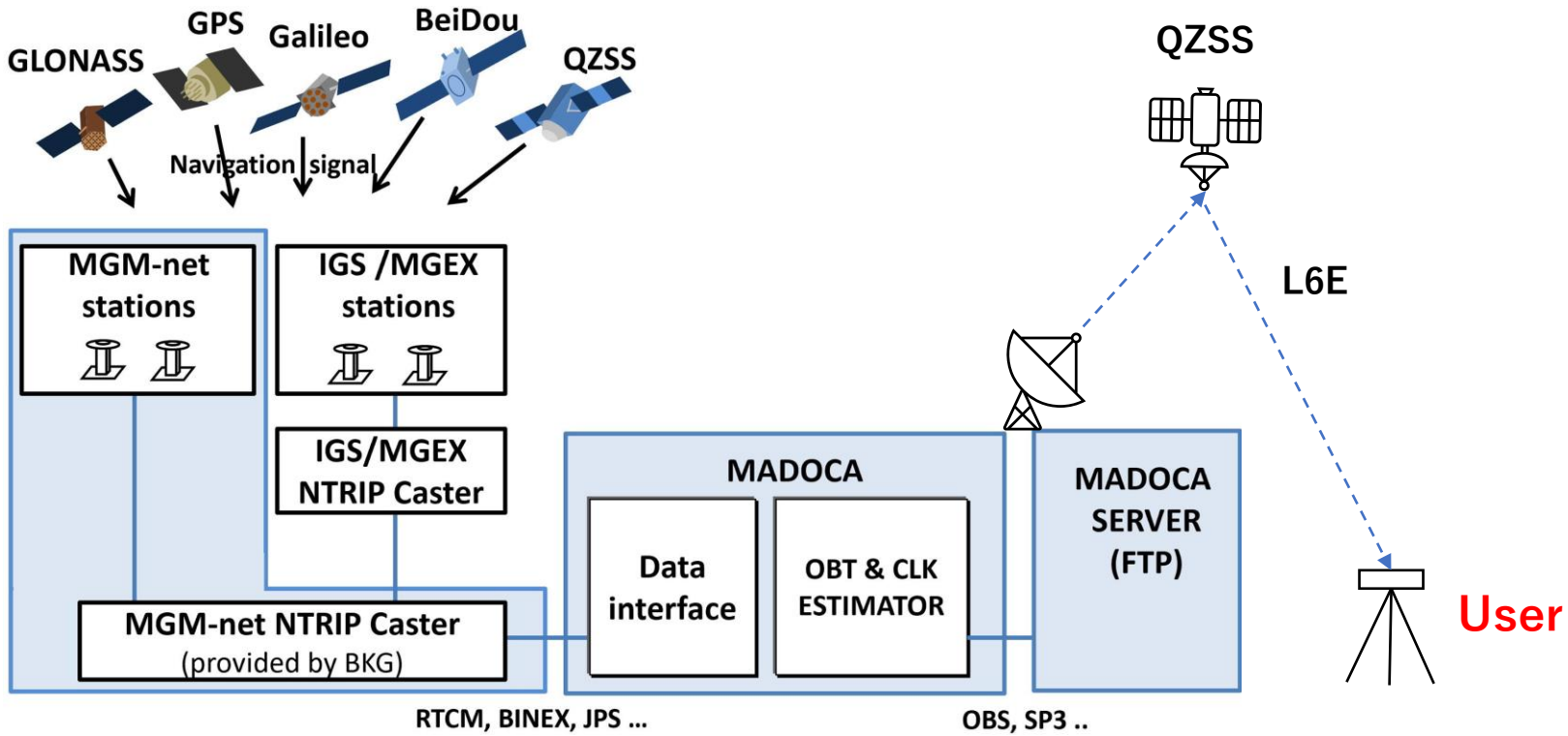
MADOCA：Multi-GNSS Advanced Orbit and Clock Augmentation



※Kawate, K., Igarashi, Y., Yamada, H., Akiyama, K., Okeya, M., Takiguchi, H., ... & Kogure, S. (2023). MADOCA: Japanese precise orbit and clock determination tool for GNSS. Advances in Space Research, 71(10), 3927-3950.

-Provide precise orbit&clock error and code/phase bias using via QZSS (L6E signal).
-GPS/QZSS/Galileo/GLONASS are supported in real-time.

MADOCA-PPP(Compact SSR)

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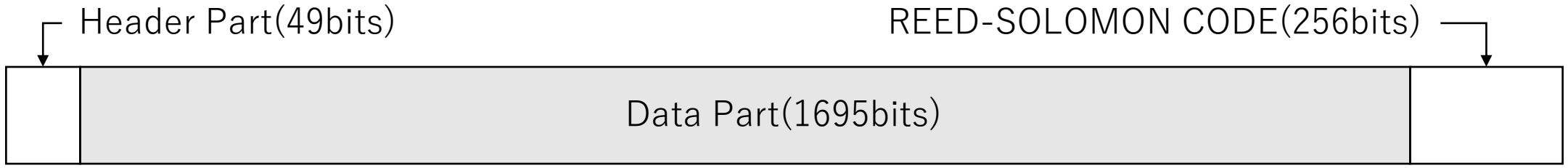
L6E Navigation Message



-2000bits(2kbps)
  Header Part(49bits)+Data part(1695bits)+ REED-SOLOMON CODE(256bits)=2000bits
-Using code shift keying (CSK) modulation
-Reed-Solomon error correction
-All QZSS satellites transmit L6 Message(J02,J03,J04,J07)

Message content & Interval

Message Name	Nominal Update Interval [s]
SSR MASK	30
GNSS Orbit Correction	30
GNSS Clcok Correction	5
GNSS Satellite Code Bias	30
GNSS Satellite Phase Bias	30
GNSS URA	30

MADOCA-PPP(Compact SSR)

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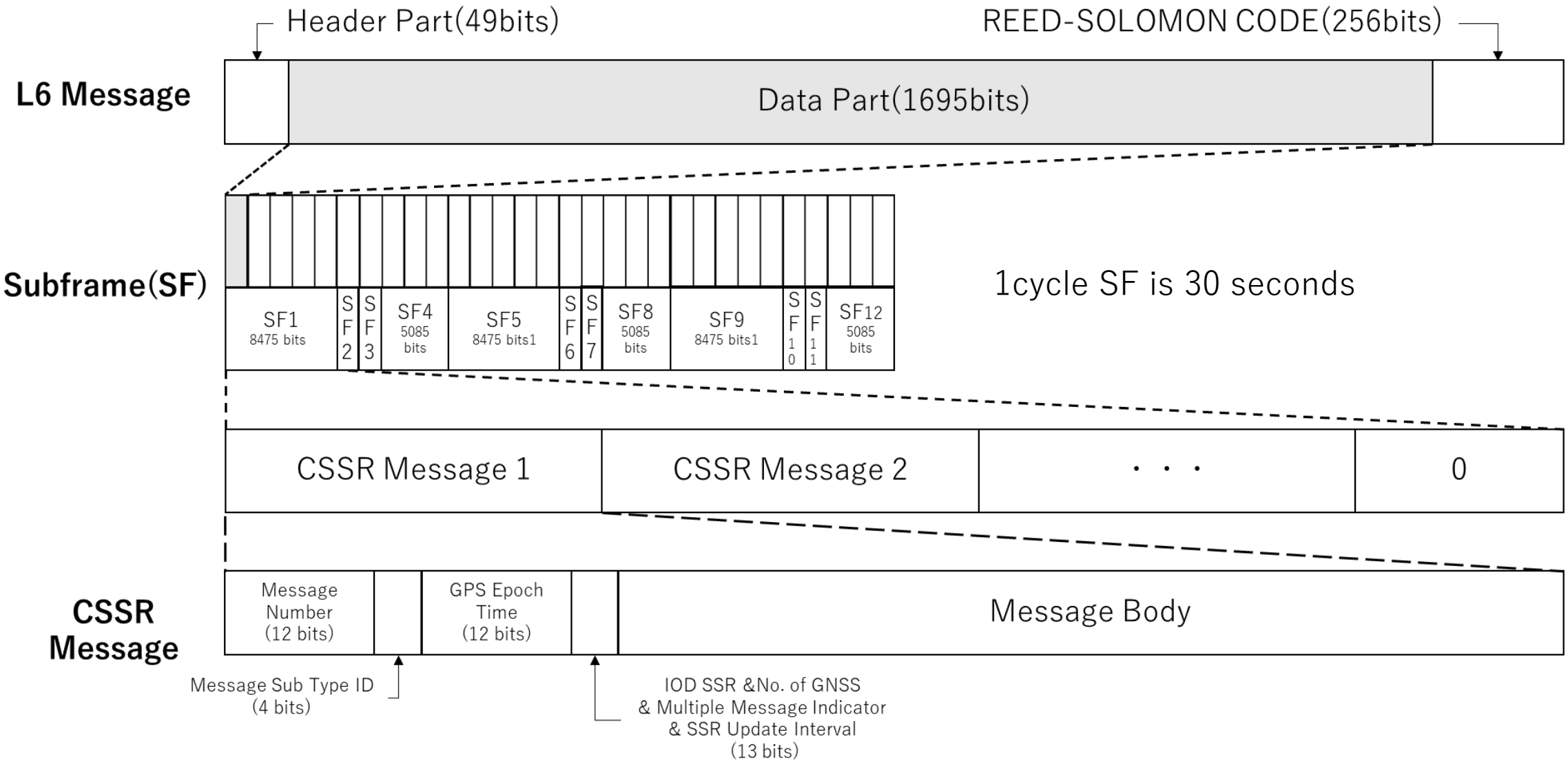

Pocket-SDR

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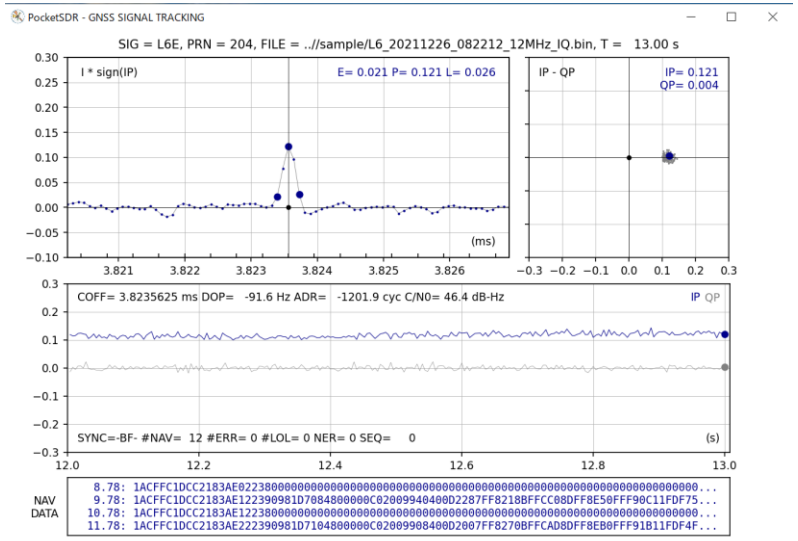
- The RF front-end device have 2-CH Maxim MAX2771 GNSS RF front-end.
  CH1：GNSS L1 band (1525–1610 MHz)
  CH2：GNSS L2/L5/L6 band (1160–1290 MHz)
  TCXO： 24.000 MHz
  Sampling frequency：＜24 MHz

※https://github.com/tomojitakasu/PocketSDR

-Software attached with Pocket-SDR is written in Python 3,
Analysis IF Data, Acquisition, Tracking, Navigation Data Decoding.

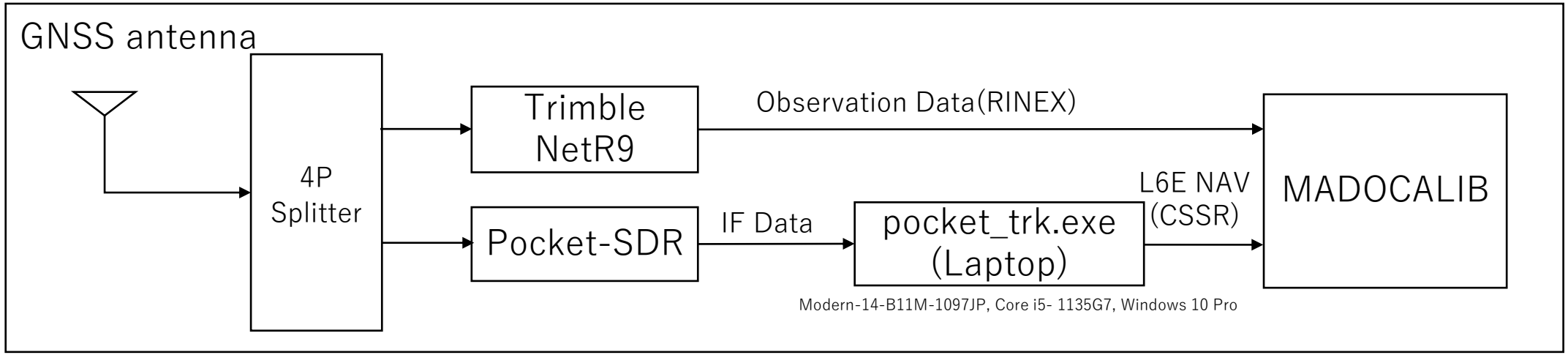
GPS	L1C/A,L1C,L2C,L5
QZSS	L1C/A,L1C/B,L1S,L1C,L2C, L5,L5S,L6D,L6E
GALIELO	E1B/C, E5a, E5b, E6B,E6C
BDS	B1I, B1C, B2I, B2a, B2b, B3I
GLONASS	L1C/A, L2C/A, L3OC
NavIC	L5-SPS
SBAS	L1C/A, L5



※T.Takasu, An Open Source GNSS SDR: Development and Application, IPNTJ Next GNSS Technology WG, Feb 21, 2022

Flow of this study and parameter setting

Flow of decoding Navigation message and PPP



Parameter of MADOCALIB

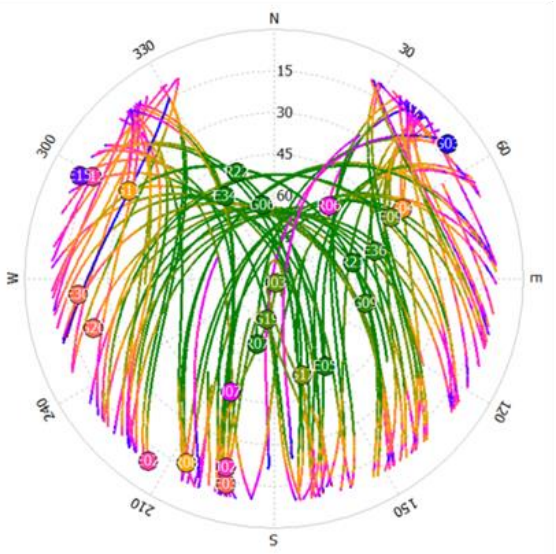
Mask Elevation	**15 degrees**
Minimum SNR	**32 dB-Hz**
Code phase measurements	**Tracked**
Carrier phase measurements	**Tracked**
Satellites	**GPS/QZSS/GALILEO/GLONASS**
GNSS Frequency	**1Hz**

Ionosphere delay ：Iono Free combination(L1/L2,G1/G2,E1/E5a)
Troposphere delay：Estimate ZTD

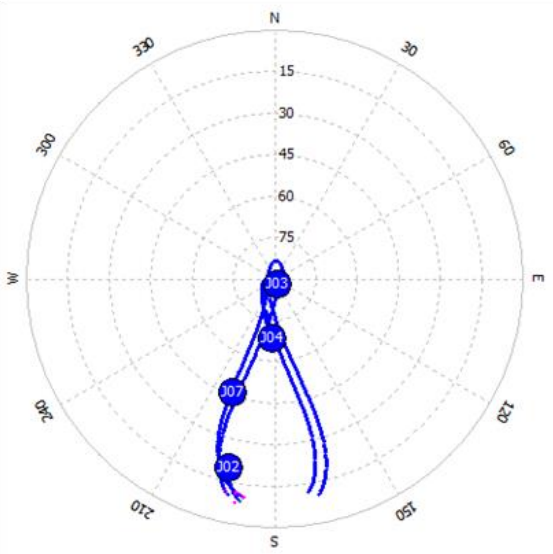
Test environment(Open Sky)

The experiment started at 6:00:00 (GPST) and ended at 23:59:59 on June 6, 2023
-Tracking J02, J04, J07.

L1 SNR

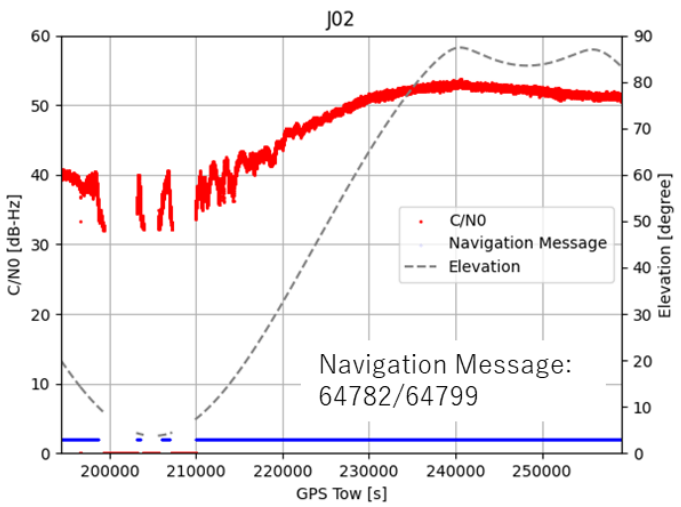


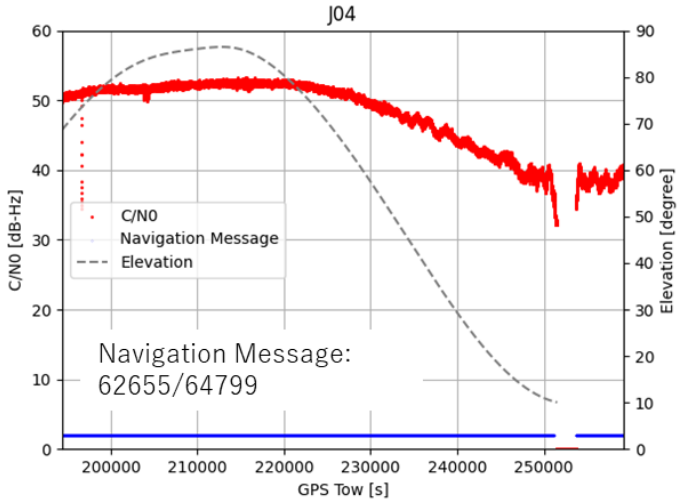
QZSS placement
in the sky at 06:00:00 (GPST)

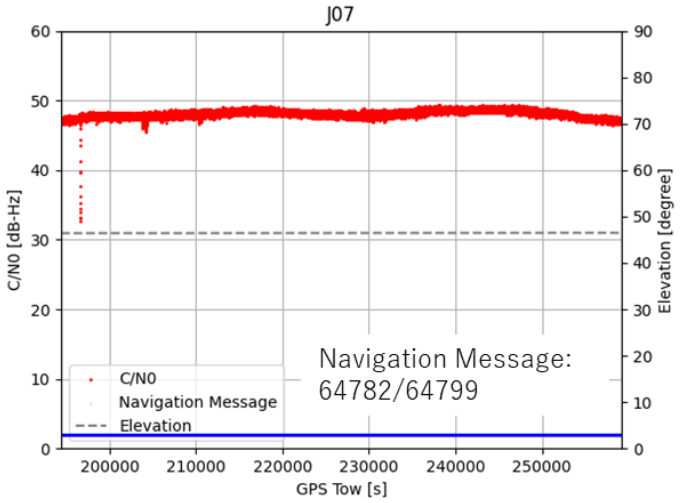


Experiment site

C/N0 and decode rate



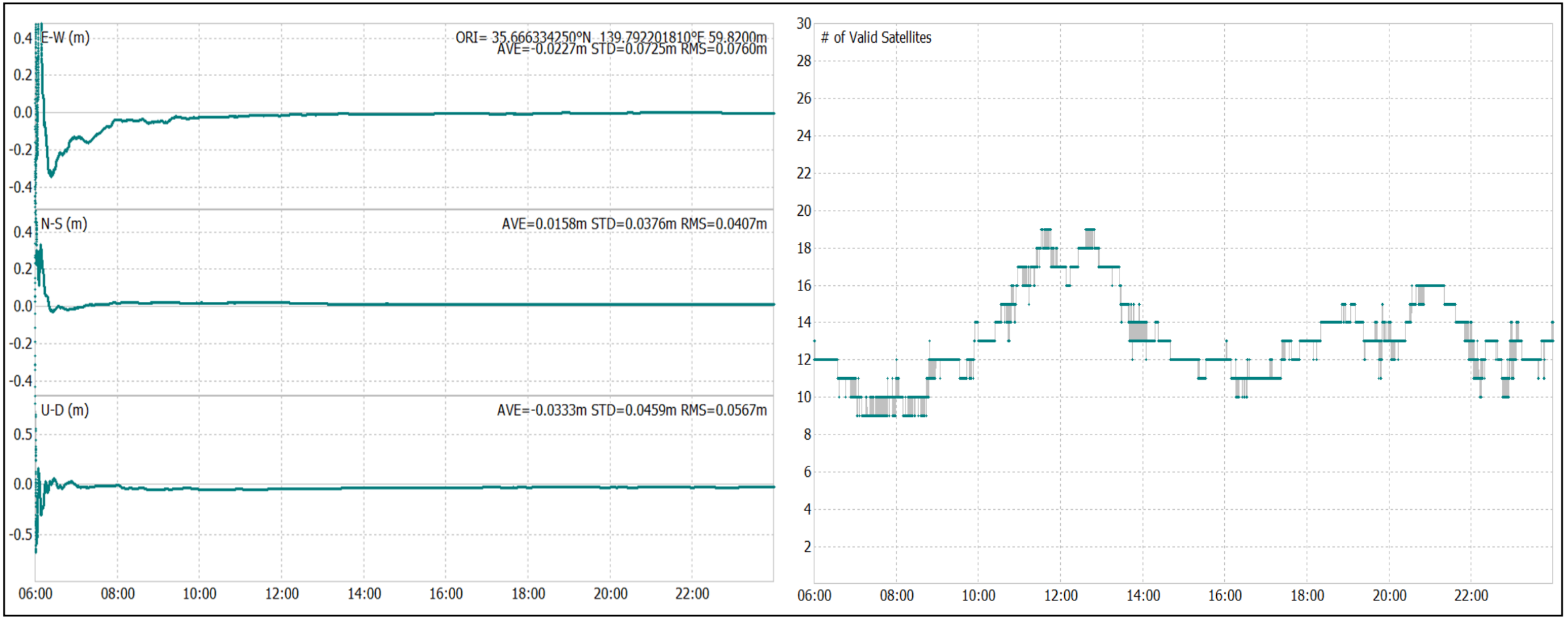




-At low elevation angles (particularly below 15°),
C/N0 was low and the decoding of navigation messages was not possible.

-At approximately 196606 s (GPS Tow),
C/N0 was low and
the navigation message was not decoded in J04 and J07
→PC temporarily ran out of power.

Result of MADOCA-PPP

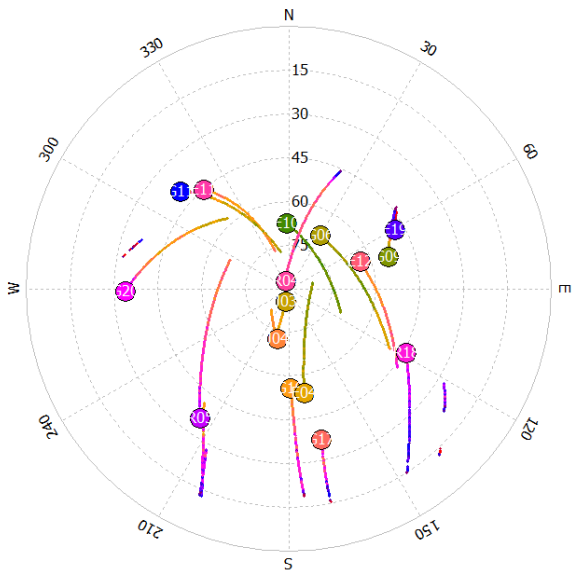


The navigation messages of J07 were used for PPP

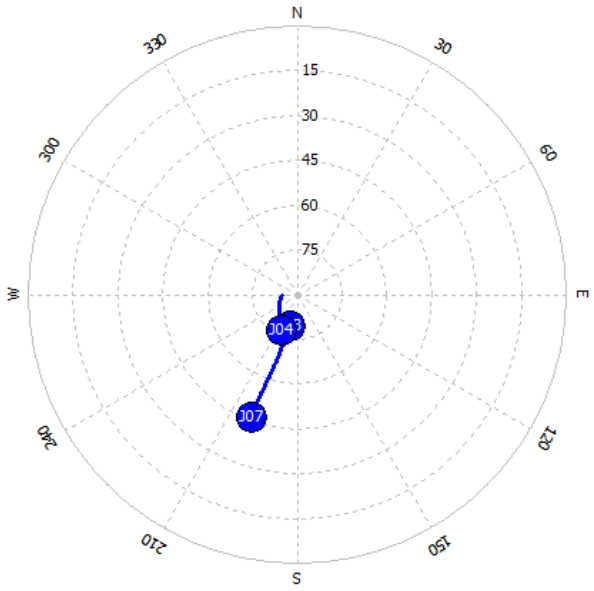
Test environment(Multipath)

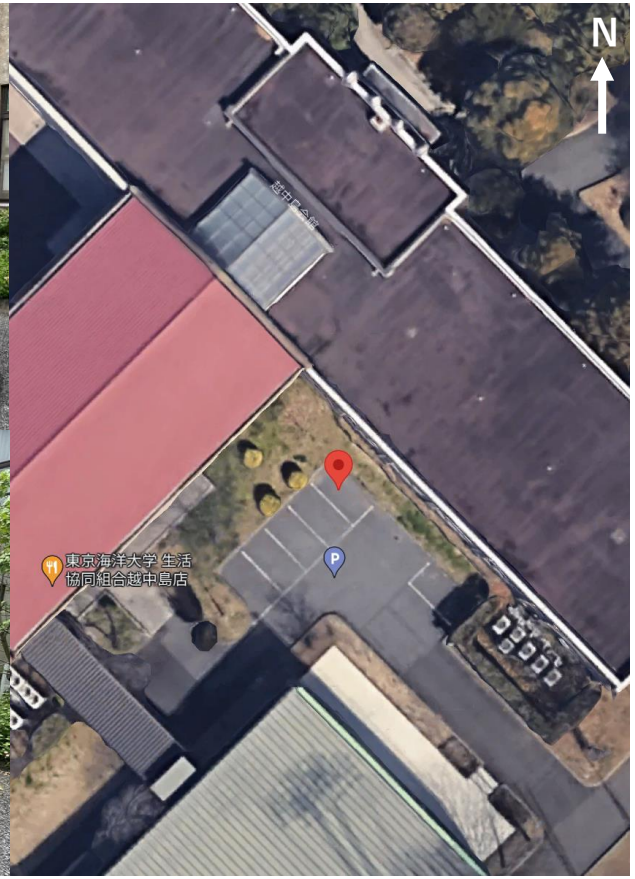
The experiment began at 5:10:00 (GPST) and ended at 06:40:00 on June 27, 2023.
-Tracking J03, J04, J07.

L1 SNR

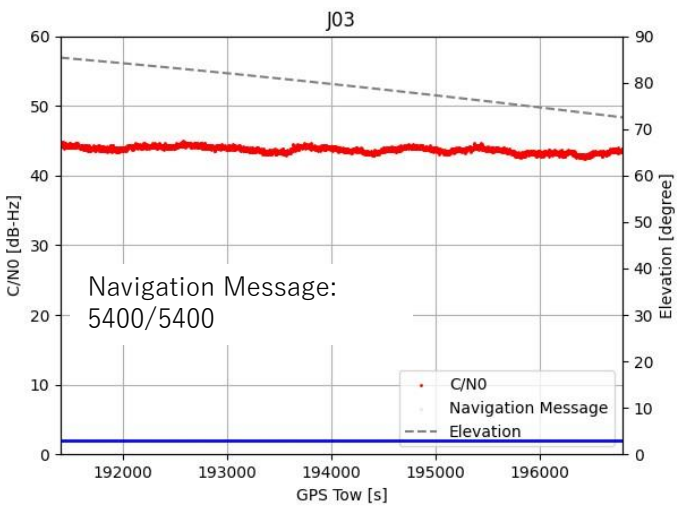


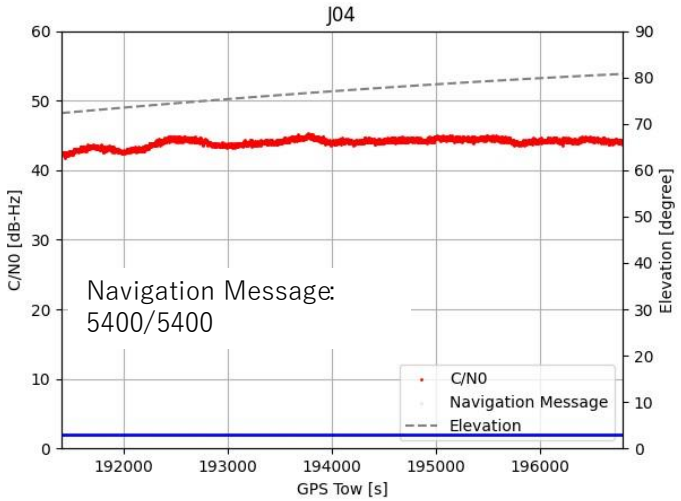
QZSS placement
in the sky at 05:10:00 (GPST)

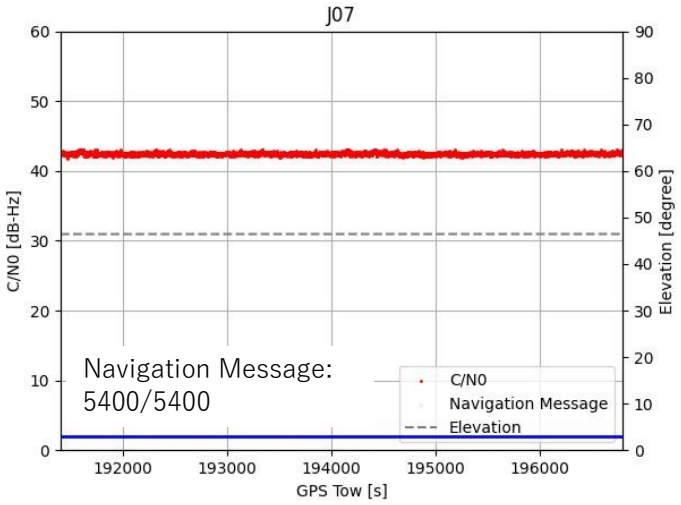




C/N0 and decode rate

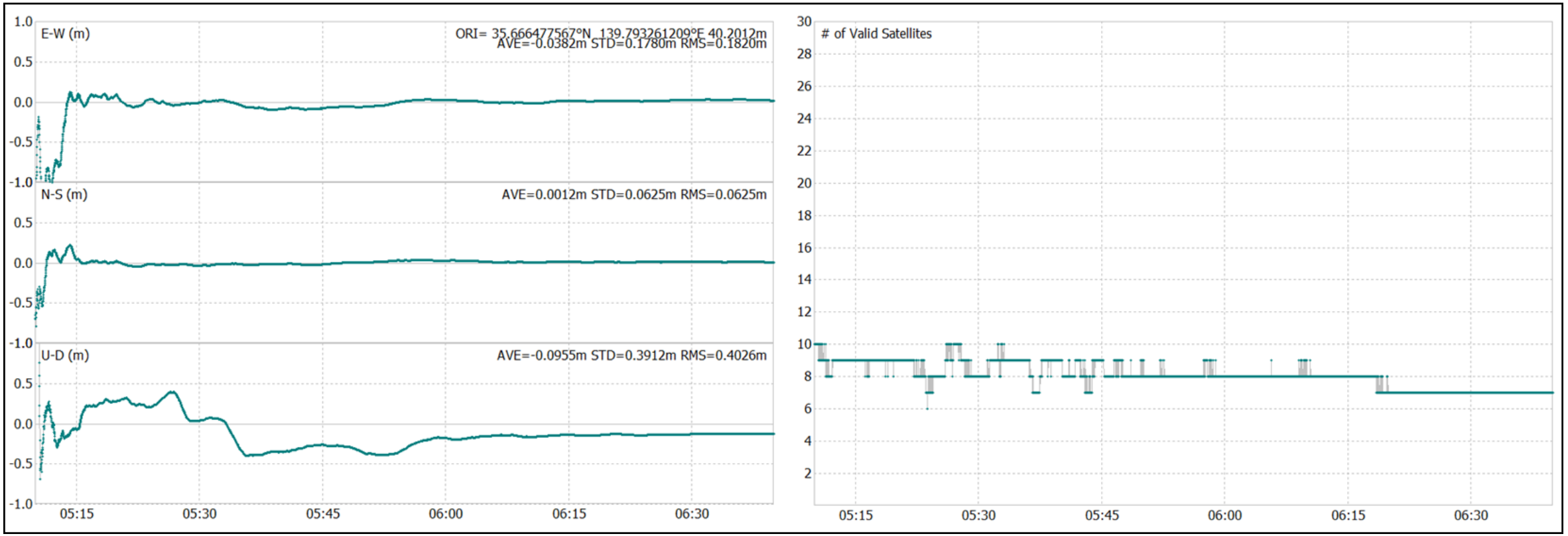






-C/N0 was lower than that in the open-sky condition.
Use of different GNSS antennas,
Installation on the roof of the car,
Multipath environments

Result of MADOCA-PPP



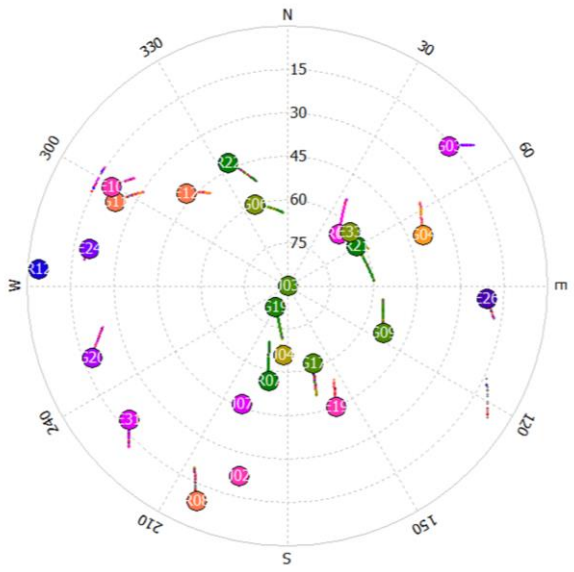
The navigation messages of J07 were used for PPP

-Accuracy of MADOCA-PPP is degraded compared to Open Sky.

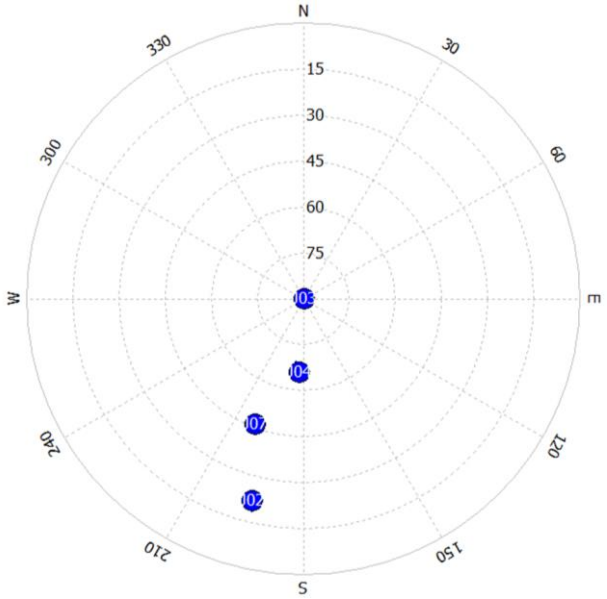
Test environment(Multpipath)

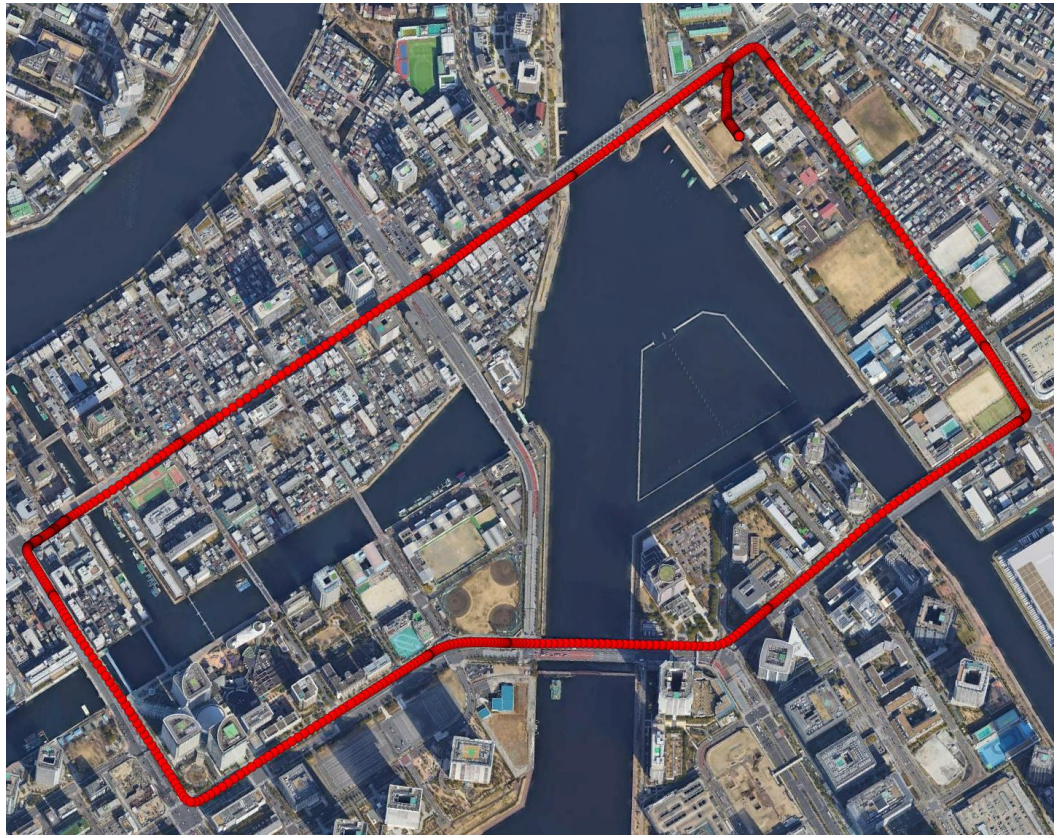
. The experiment began at 5:10:00 (GPST) and ended at 05:34:35 on June 14, 2023.
-Tracking J03, J04, J07.

L1 SNR

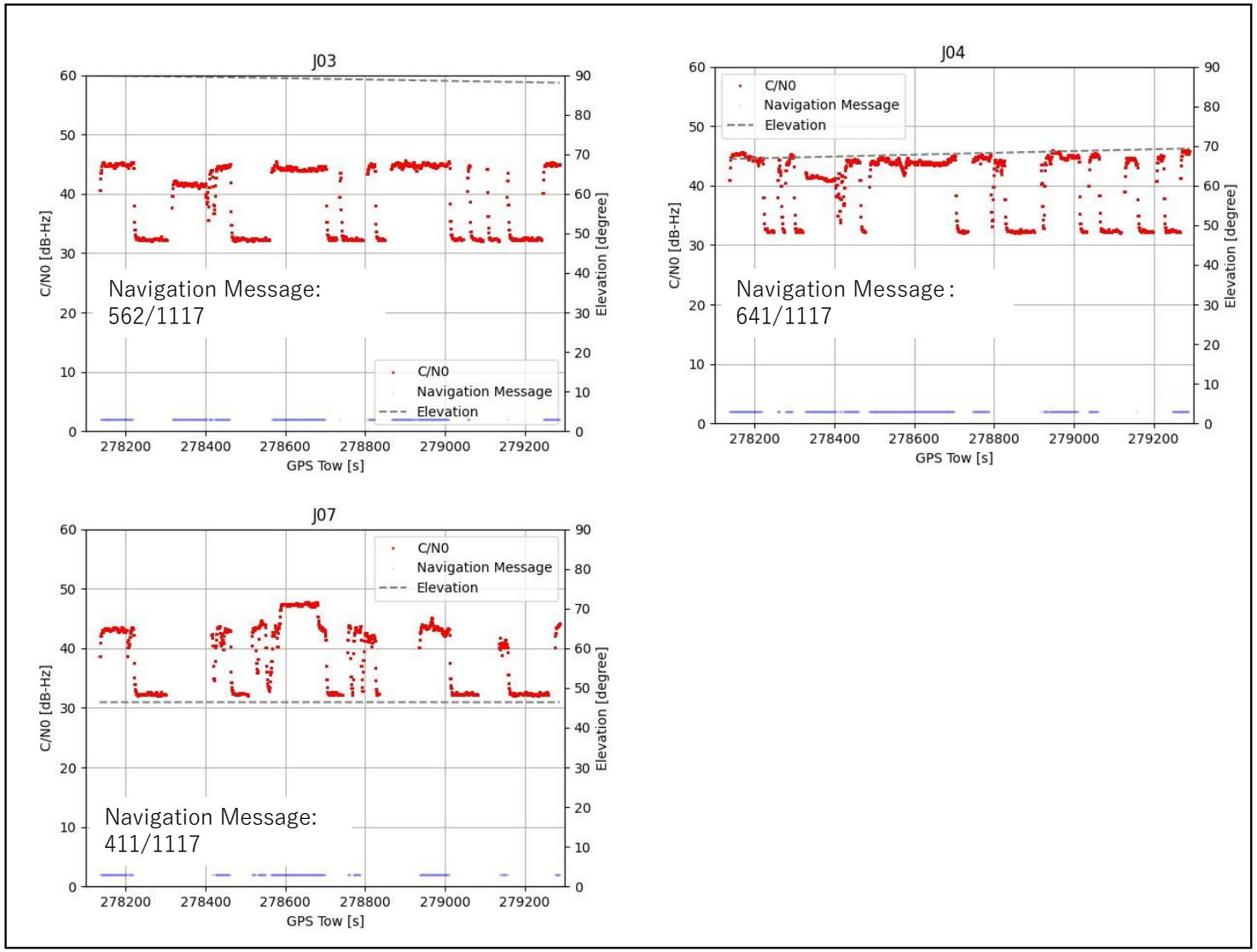


QZSS placement
in the sky at 05:10:00 (GPST)





C/N0 and decode rate



Conclusion

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・We tracked the L6E signal, decoded navigation messages include MADOCA messages, and estimated the precise position in realtime processing using Pocket-SDR.

・We investigated the availability of L6E signal navigation messages in the real-world.
Under open-sky conditions： The performance of Pocket SDR was excellent
Multipath environments：Some problems such as re-tracking occurred.
→Expected to improve in the future owing to the ease of using the user's unique algorithms, which is one of the features of this software.

Future work

・Comparison of commercial GNSS receiver which can track L6/E6 signal.
・Evaluation of decoding rates in various scenario.