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The contribution on the accuracy and robustness of time synchronization in multi-constellation and multi-band GNSS receivers

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FURUNO ELECTRIC CO., LTD
Takahiko Ikeda
takahiko.ikeda@furuno.co.jp

Applications of GNSS receivers for time synchronization

- Telecommunication (DCN[*1], PMR[*2] , V2X)

  *1 Digital Cellular Network, *2 Professional Mobile Radio

- Power station (Phasor measurement, Fail detection)
- Financial transaction
- Broadcasting (Digital TV, Cable TV)
- Sensor network (Earthquake, Lightning)
- Measurement equipment
- Clock (Timestamp)

Modern GNSS Providers

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Increasing importance of GPS as information infrastructure

⇩

From GPS to GNSS era

Each country builds its own satellite positioning system

American GPS

European Galileo

Chinese BeiDou

Russian GLONASS

Regional Navigation Satellite Systems (RNSS) are also deployed and operated

Japanese QZSS

Indian NavIC

Korea Positioning System(Planning)

Multi-constellation GNSS receiver can utilize multiple GNSS

The GNSS RF signals

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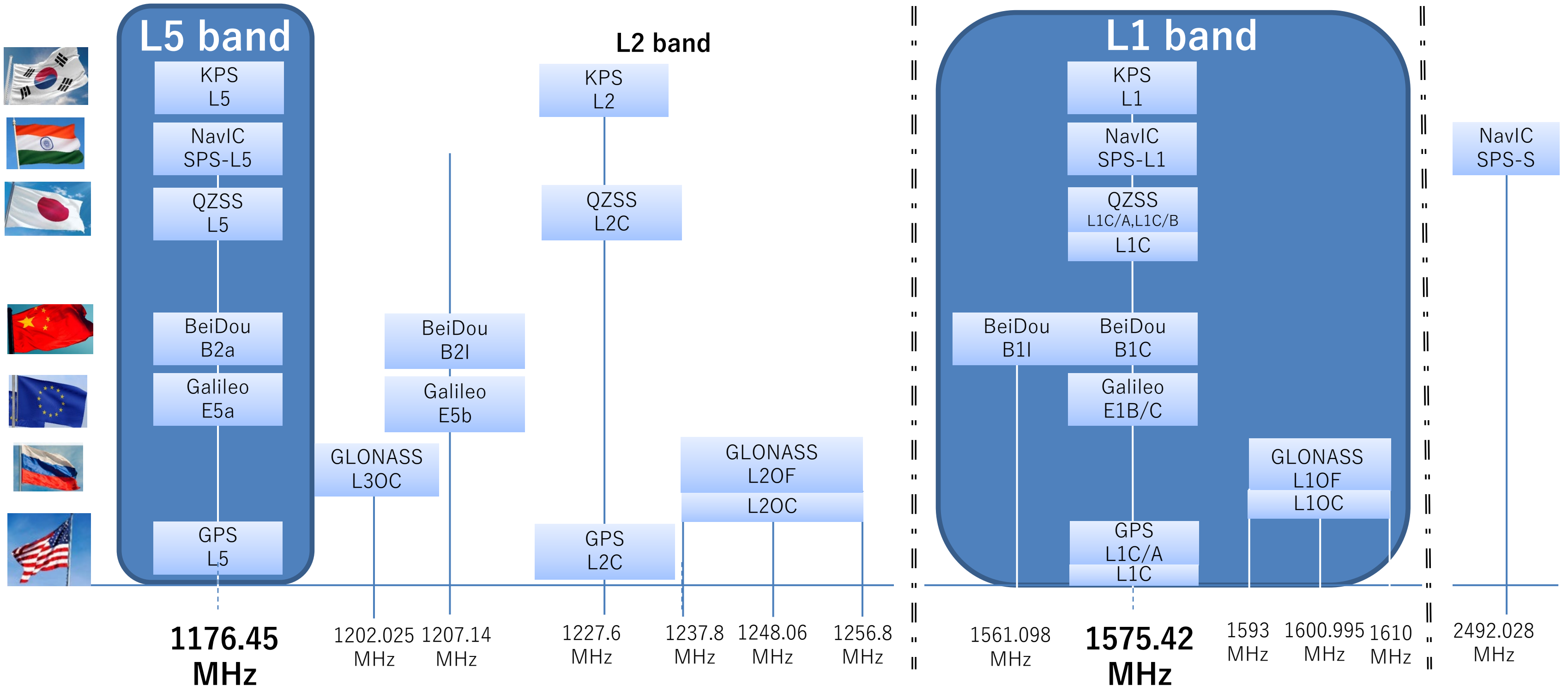
※Including signals in the broadcasting plan
※Details of the KPS signal specifications have not been disclosed
※GLONASS is based on information as of February 2022



Multi-band GNSS receiver can receive multiple GNSS frequency bands

The challenging of GNSS timing synchronization

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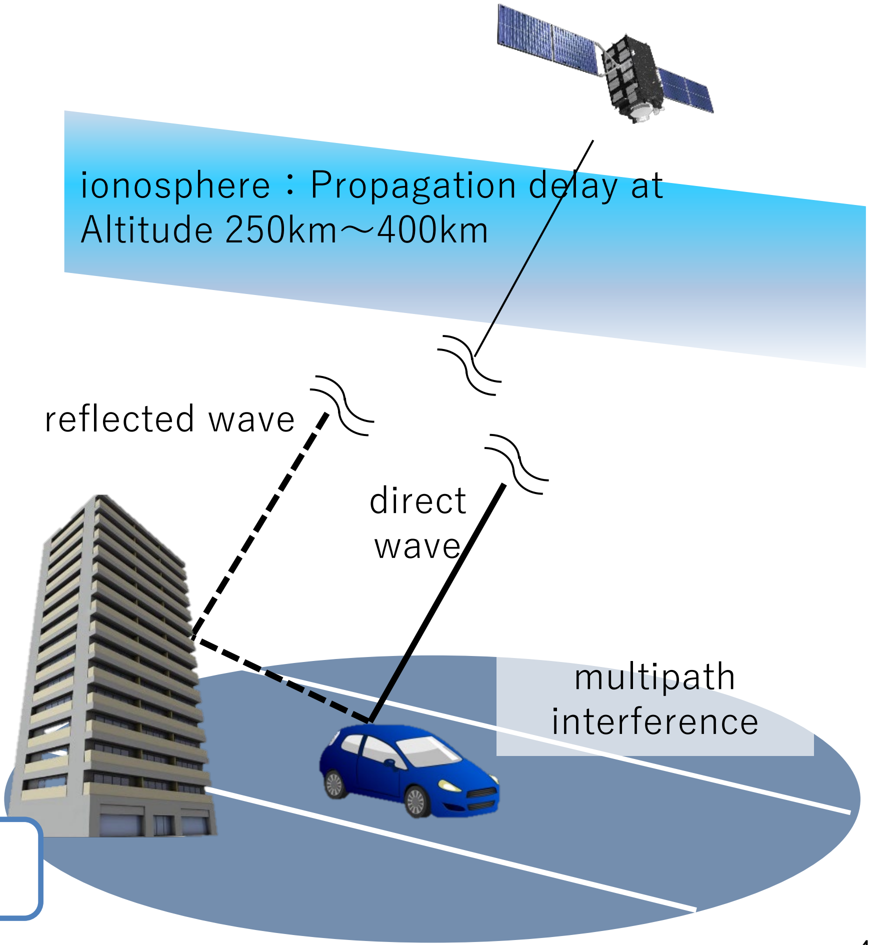
- Poor visibility (Small number of sat., Multipath)
- Environmental factors (Signal Propagation delay, Temperature)
- Usage misunderstanding (Cable delay, Wrong hold position)
- Interference
- Equipment failure (Receiver failure, Antenna failure)
- GNSS system error
- Spoofing

Some challenges can be addressed by making GNSS receivers multi-band, multi-constellation



The benefit of multi-band GNSS signal reception

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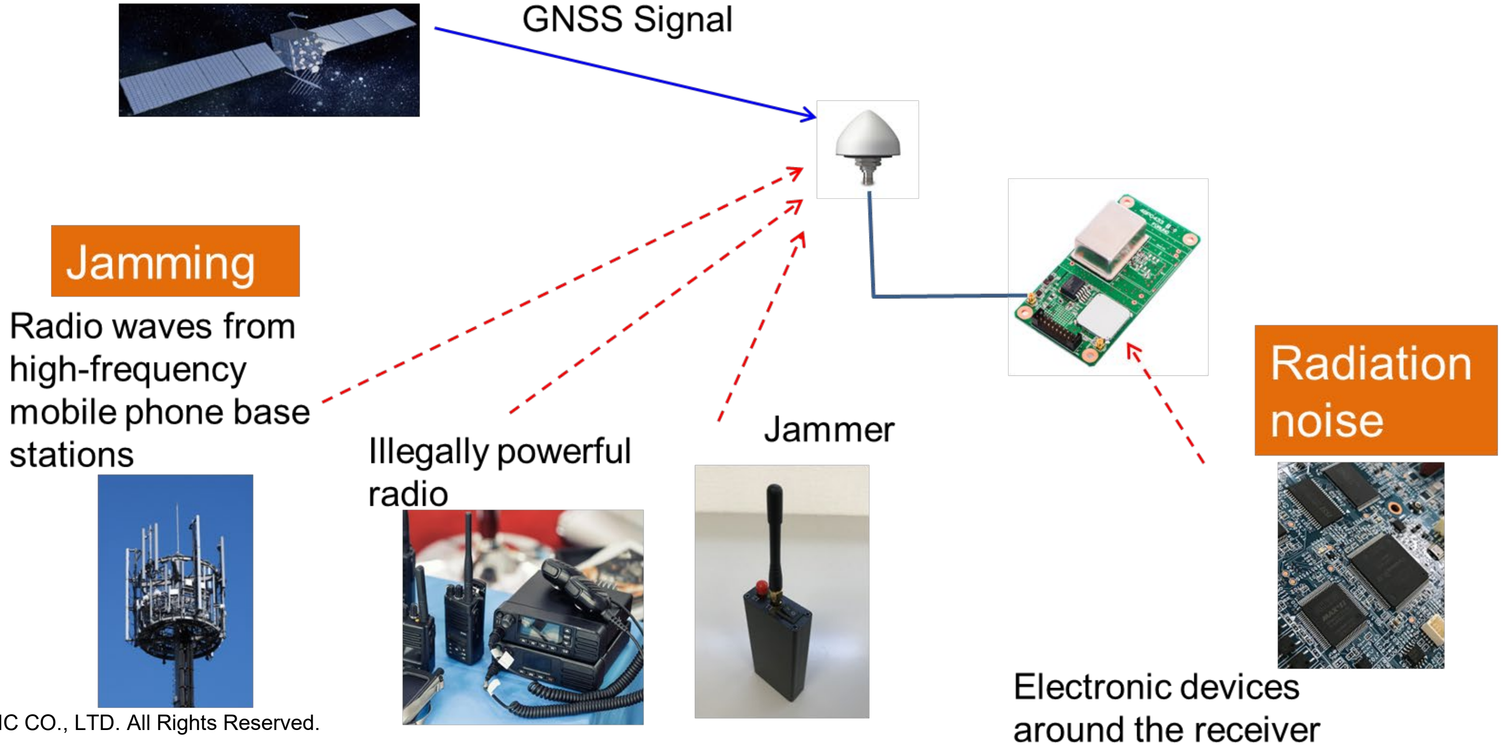
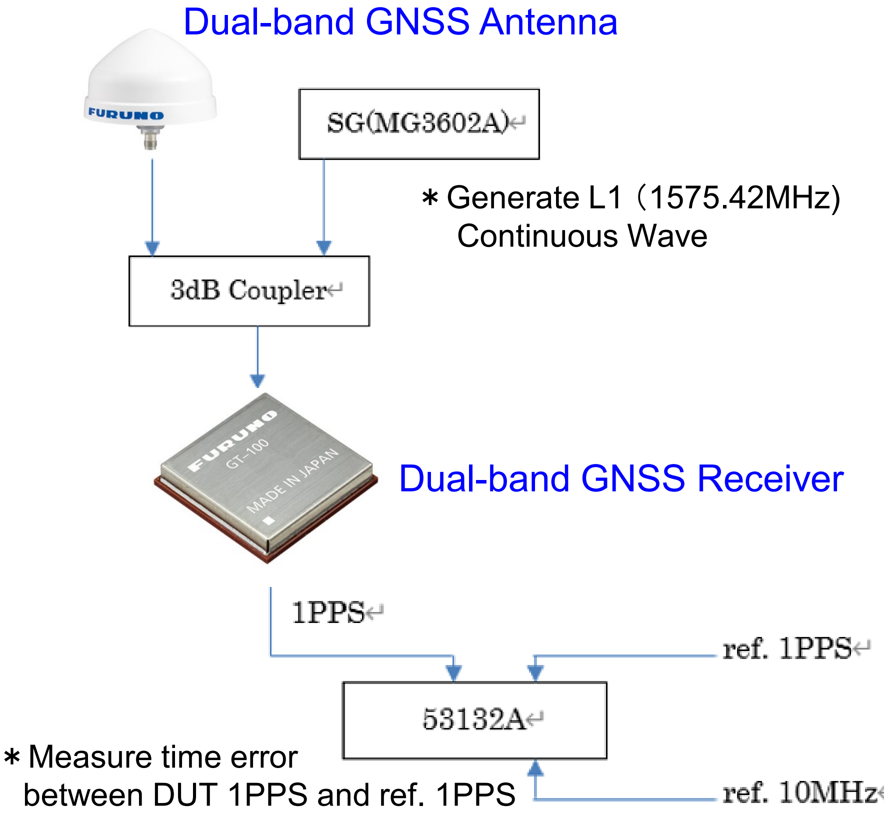
Advantages against jamming and noise

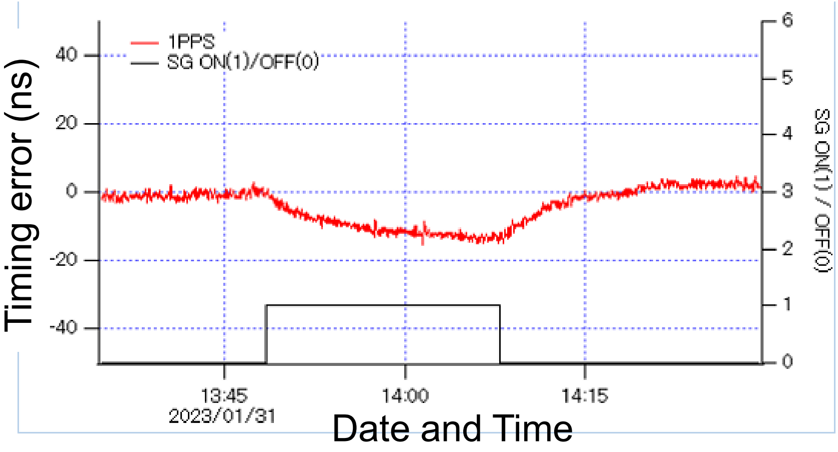
GNSS Signal is very week. It is easily interfered.
If GNSS signal is interrupted, GNSS timing output cannot be continued.

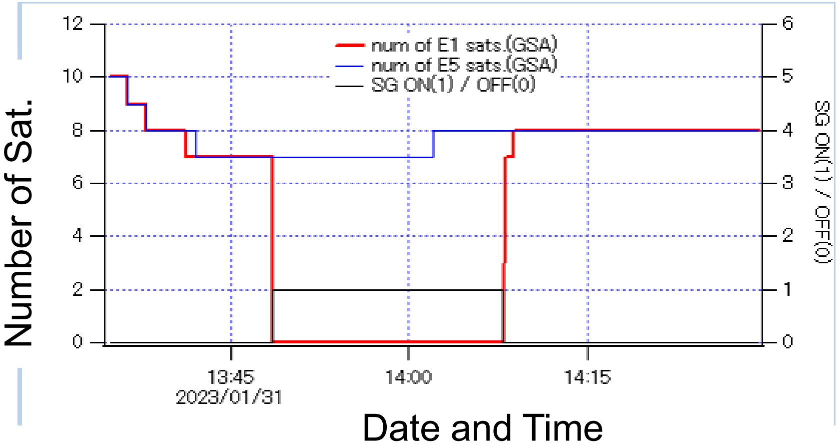


The benefit of multi-band GNSS signal reception

Case with signal interference







The benefit of multi-band GNSS signal reception

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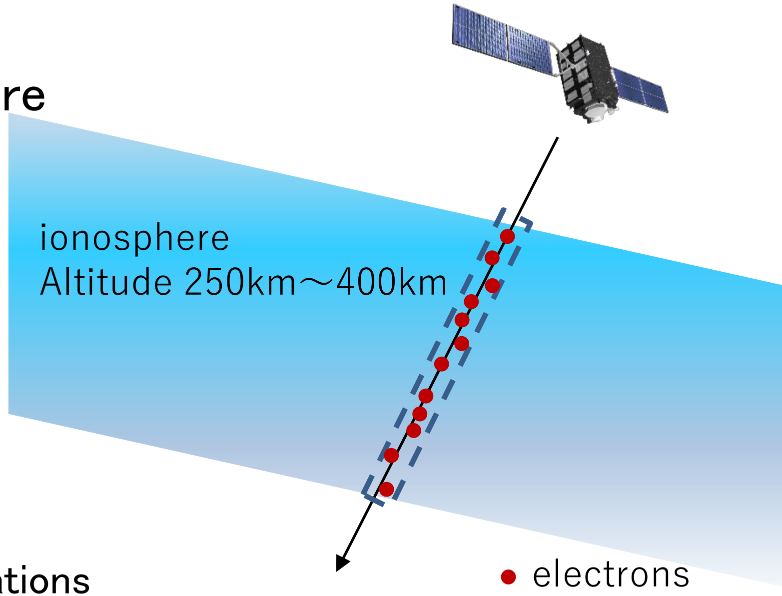
Independent correction of ionospheric delay

- Signal propagation delay through the ionosphere
  - Amount of delay generated in the ionosphere I_f [m]

$$I_f \approx \frac{40.3\ \mathrm{TEC}}{f^2}$$

f: signal frequency [Hz] (known)
TEC: total number of electrons (unknown)



- In the case of single band Elimination by the D-GPS method, etc.

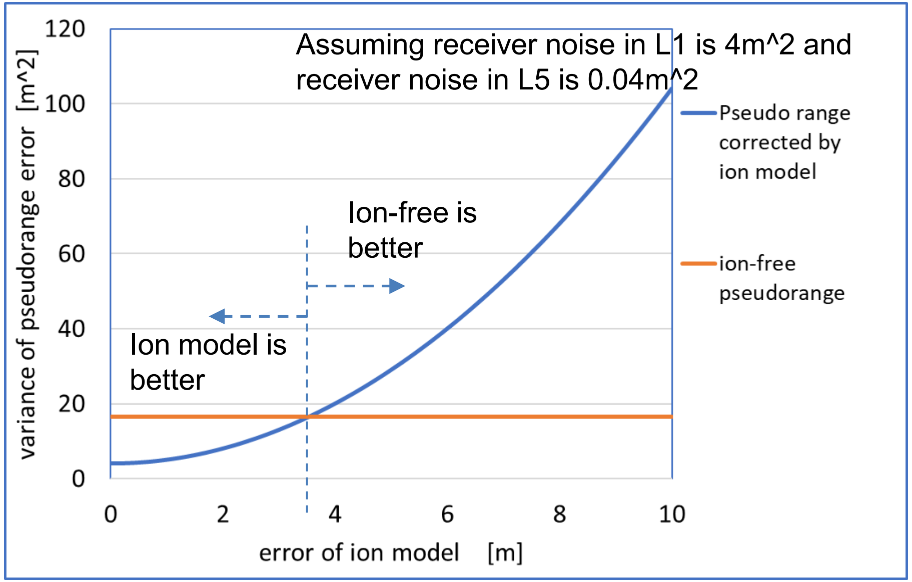
  - Use pseudoranges for ionosphere-free linear combinations
    - The only unknown for I_f is TEC, so it can be eliminated with two equations
    - Linear combination of two pseudoranges to remove ionospheric delay

Multi-band and dual-band GNSS receivers can take advantage of this ionosphere-free linearly combined pseudorange

Considerations when using ionosphere-free pseudorange

It suffers from greater receiver noise than single-band pseudorange.

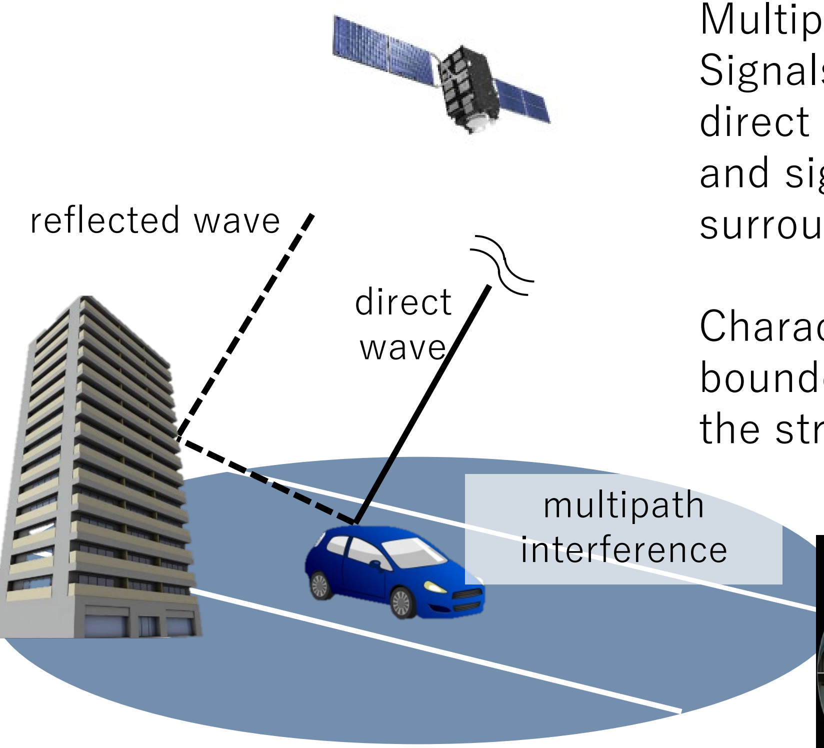
if there are ionospheric delays that cannot be sufficiently corrected by the ionospheric delay correction model, the effect of ionosphere-free pseudorange be expected.



In near future, solar activity will become more active, and there is a high possibility that local and instantaneous variations in ionospheric delay will occur.

The benefit of multi-band GNSS signal reception

Mitigation of multipath errors



Multipath(LOS)
Signals arrive via two paths: direct waves from satellites and signals reflected by surrounding structures.

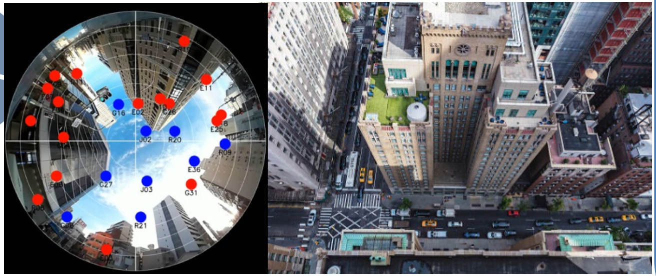
Characterized by boundedness that depends on the structure of the signal

Effect of Modernization L5 Signal Utilization

GPS L1C/A < ±150 [m]

↓

GPS L5： < ±15 [m]



The upper and lower bounds of the observation error are reduced to about <u>1/10</u> (*). Positioning and timing accuracy under <u>urban canyon</u> get better

(*)Observation error is not always reduced to 1/10 because it depends on the design of the GNSS receiver.

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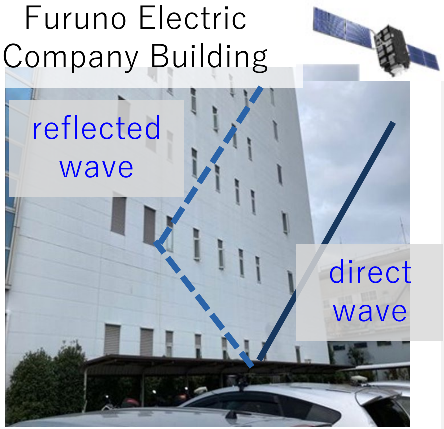
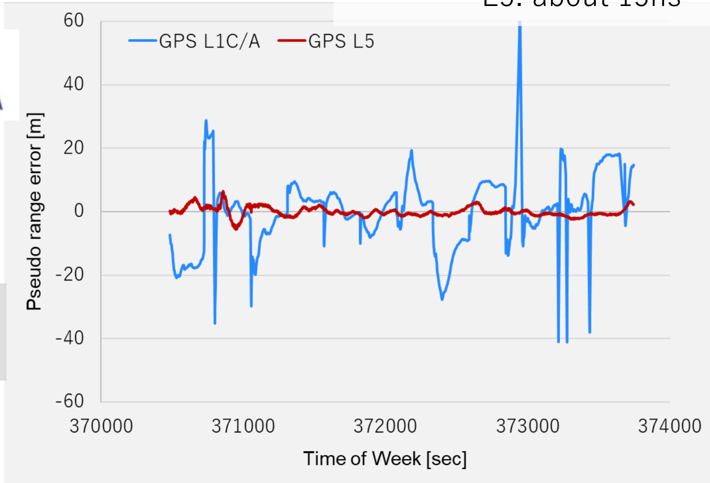
Comparison of L1 and L5 positioning results

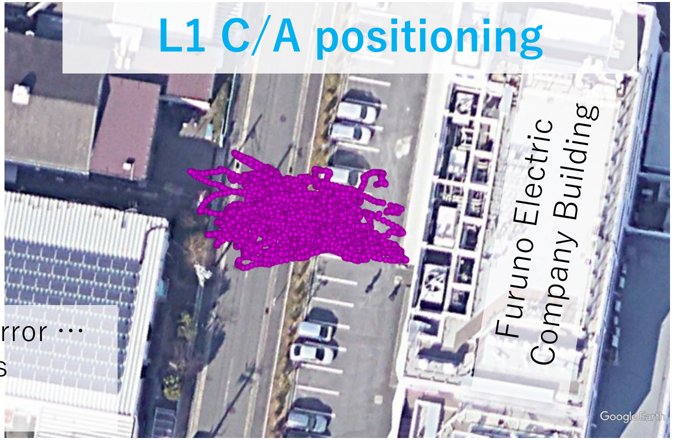
Fixed-point positioning experiment at Furuno Electric's parking lot
January 5, 2023 15:00-17:00 JST

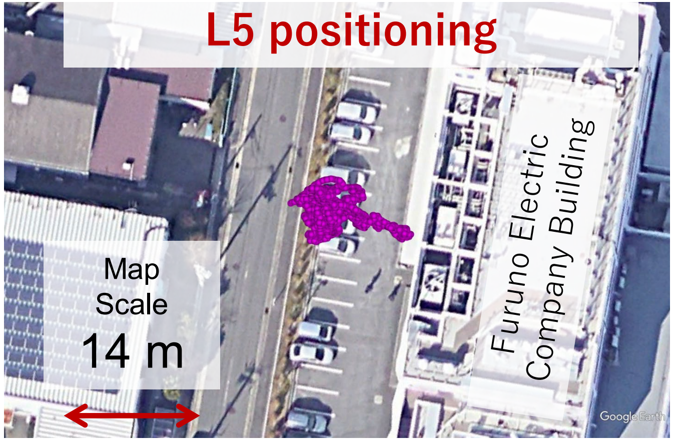
Use of L5 signals significantly reduces drift in positioning results

When converted to time error …
L1 C/A: about 150ns
L5: about 15ns









The benefit of multi-constellation GNSS

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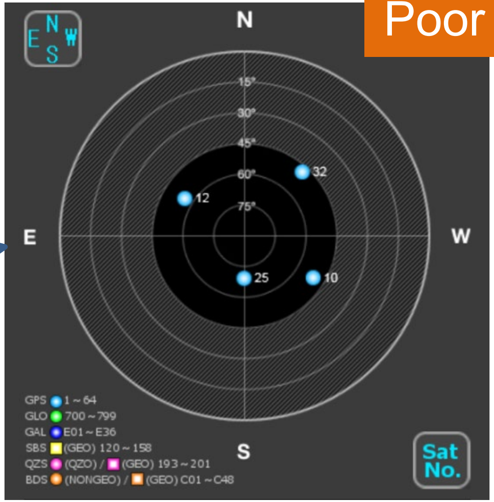
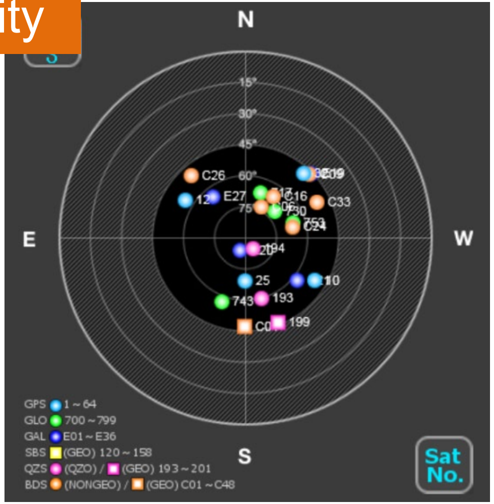
Many satellites available

Comparison when masking an elevation angle of 45 degrees or less

Poor visibility



GPS only
→ Small number of satellites(4) can be used.



Multi constellation
→ Large number of satellites(22) can be used.

Antenna installation locations are not always open skies.
If visibility is limited, a multi-GNSS receiver can utilize more satellites than a single-GNSS receiver.
It could be used to check the integrity of the GNSS used, if for political reasons it is not possible to use the GNSS of another country for time calculations.

The benefit of multi-constellation GNSS

Reduced risk of relying on a single GNSS

GNSS System error

There have been some anomalies on GNSS.

- ✓ July, 2001 GPS SVN22 experienced a clock failure.
- ✓ April,2014 GLONASS satellite broadcast erroneous ephemeris data.
- ✓ Jan. 2016 GPS, multiple GPS satellites broadcast erroneous information regarding the offset between GPS time and UTC.
- ✓ June, 2018 QZSS stop to service due to technical problem.
- ✓ July, 2019 Galileo stop to send new ephemeris during 1week.

GNSS is not error free.
Relying on just one GNSS runs the risk of being subject to errors.
It is desirable to compare the GNSS of each country and confirm the soundness of the GNSS being used.

Conclusion

◆ Multi-band and multi-constellation GNSS receivers are useful for applications requiring high accuracy and robustness

◆ In particular, the L1 and L5 dual bands are the frequency bands used by GNSS around the world, making them ideal for applications that require the use of many satellites

◆ The modernized L5 signal has a faster bit rate, higher ranging accuracy, and can reduce the effects of LOS multipath