FIG 2018 ISTANBUL

XXVI FIG CONGRESS

6–11 May 2018, İstanbul

Improvement of GNSS positioning accuracy under urban environment by multipath mitigation methods

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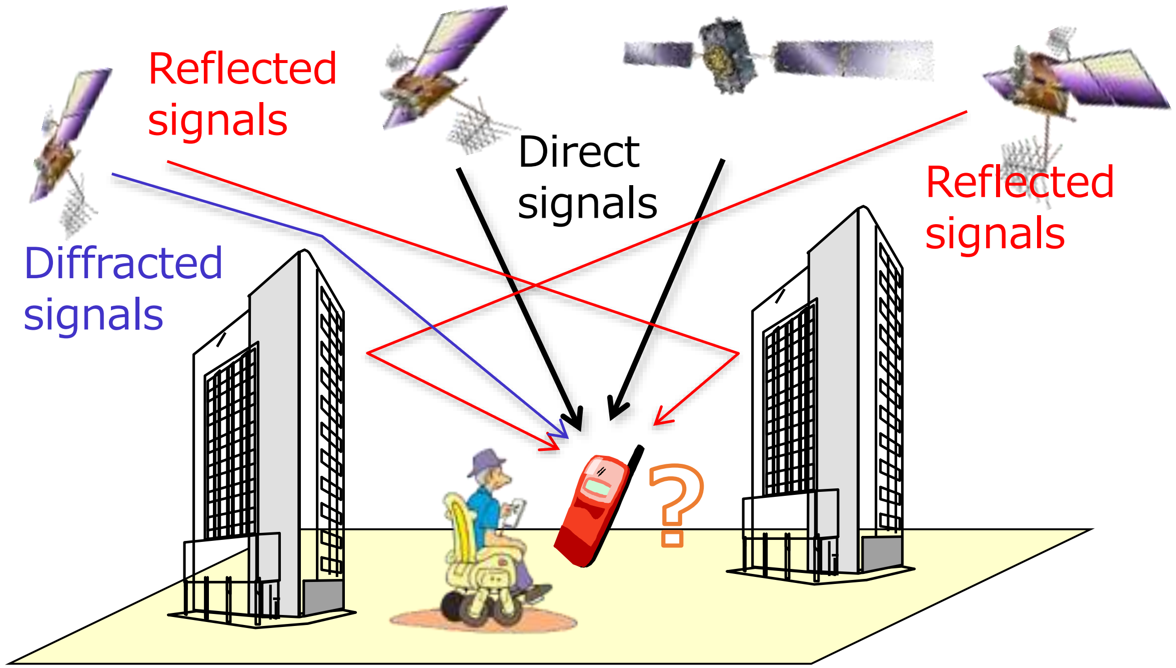
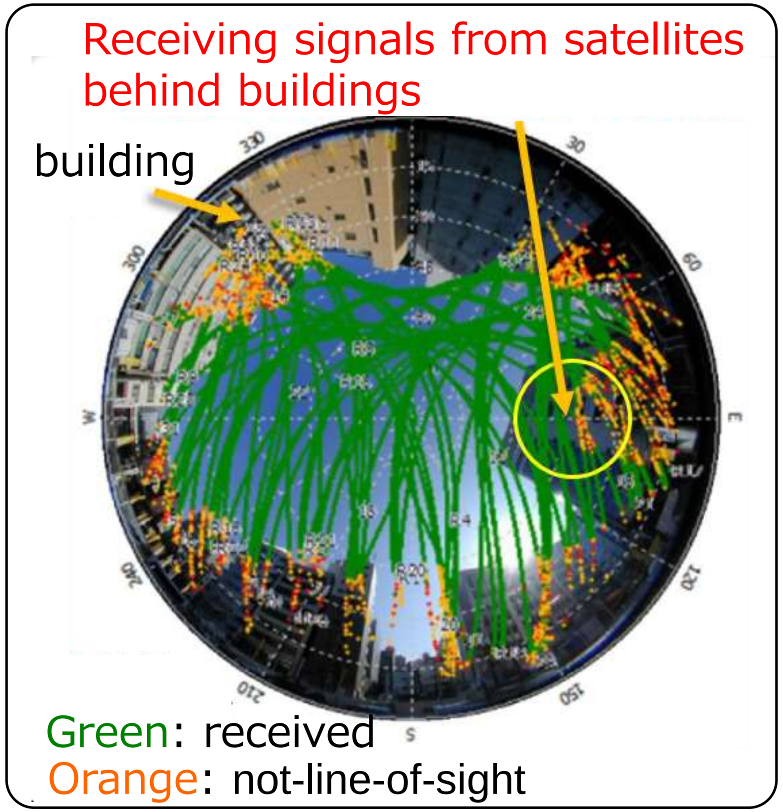
EMBRACING OUR SMART WORLD WHERE THE CONTINENTS CONNECT:
ENHANCING THE GEOSPATIAL MATURITY OF SOCIETIES

GNSS observation condition in urban area





Sky view and received signals

Multipath caused by buildings reduces positioning accuracy

Goal & Schedule

Development of multipath mitigation method for GNSS precise positioning

Geospatial Information Authority of Japan (GSI) has been developing three software-based techniques mitigating multipath effects in order to expand availability of GNSS precise positioning in urban environment.

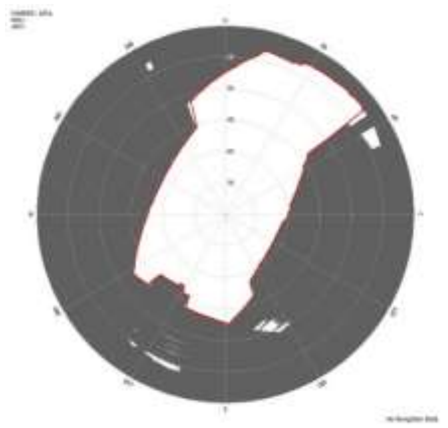
~2017: Development of multipath mitigation methods
~2018: Improvement and evaluation of the methods

Development of multipath mitigation methods (~2017)

Method 1

Selecting line-of-sight satellites with cutoff masks generated from fish-eye lens photos taken at observation sites. (T. Suzuki (2011))

Sky photo at a site



Cutoff mask

% Elevation Mask
% AZ(deg.) EL(deg.)
0.0 22.4
1.0 21.6
2.0 20.9
. .
. .

Development of multipath mitigation methods (~2017)

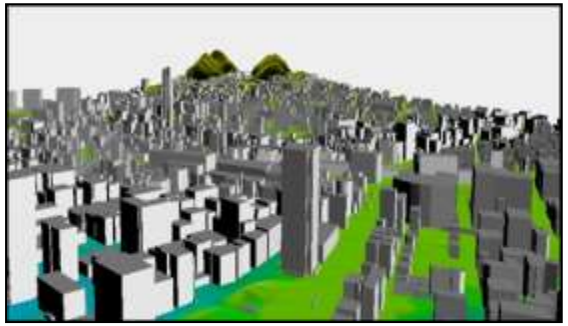
Method 2

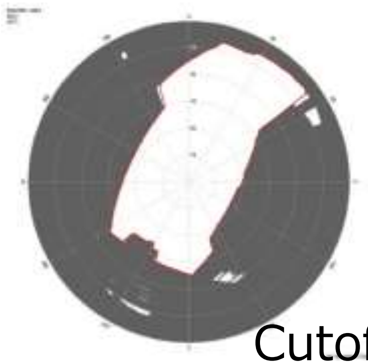
Quality check of observation data based on phase differences of Doppler observables. (T. Ikeda (2013))

Method 3

Selecting line-of-sight satellites with cutoff masks generated from 3D maps. (S. Miura (2014))

3D map of buildings





Cutoff mask

```
% Elevation Mask
% AZ(deg.) EL(deg.)
     0.0   22.4
     1.0   21.6
     2.0   20.9
      .      .
      .      .
```

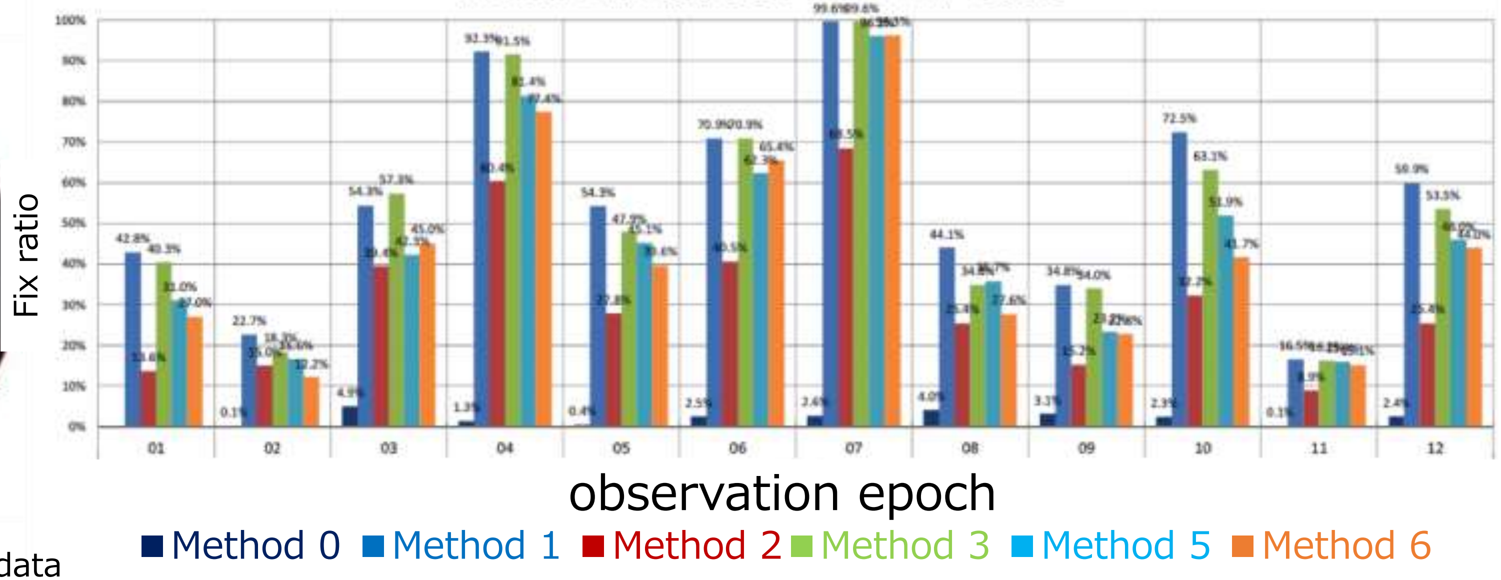
Result (~2017)

Method 0 : Raw observation with no method
Method 5 : Method 1 + 2 Method 6 : Method 2 + 3

Sky % : 50.8%

Dual frequency RTK with 1hz data

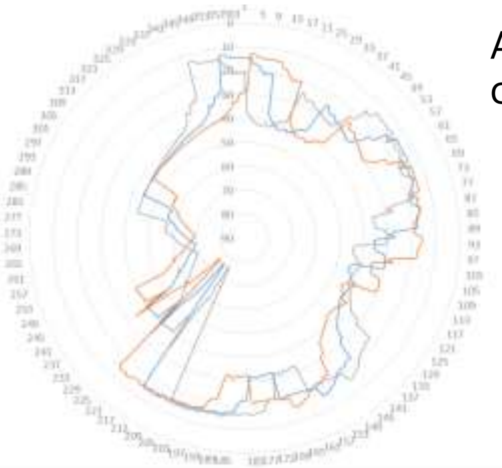
Fix ratio on each observation epoch



- Fix ratios are improved by all methods. Method 1 is the most effective.
- Degree of improvement depends on time (maybe mainly depends on constellation).

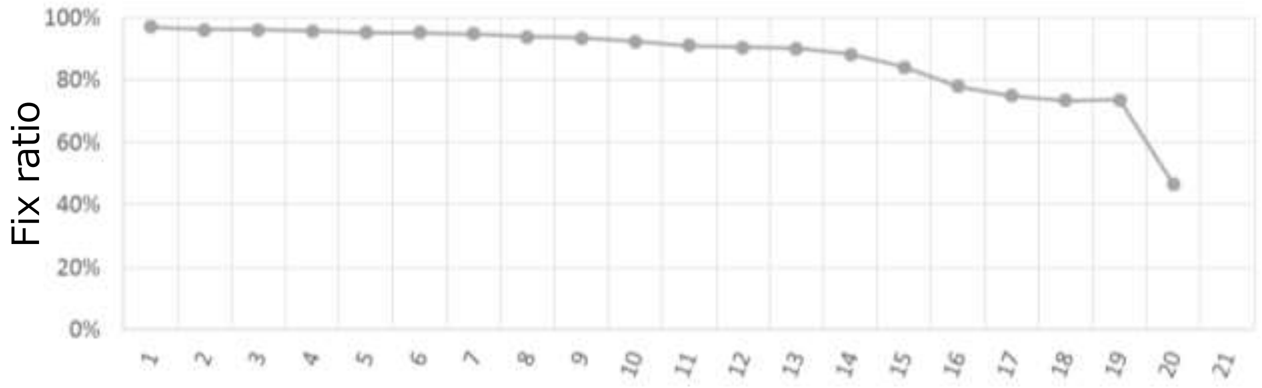
Improvement of method 1 (cutoff mask from sky photo)

Issue: misalignment of azimuth angle of the mask
-> Evaluation of the misalignment



Azimuth rotation of cutoff mask

Blue: True position
Orange: Bias +10 degree
Gray: Bias -10 degree



Influence of the misalignment on fix ratio is small even if the bias reaches 10 degree.

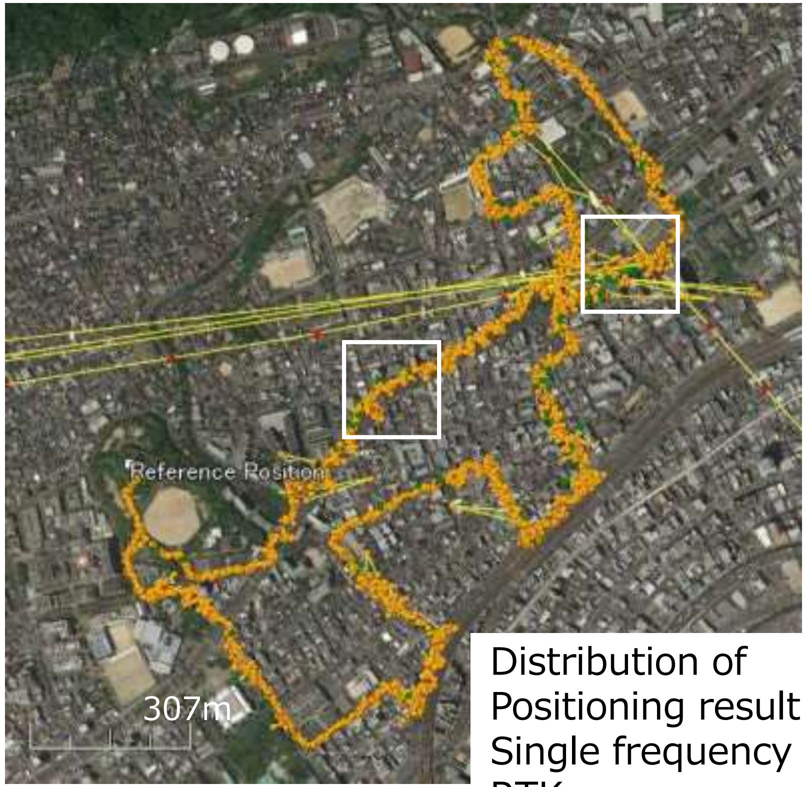
Evaluation of performance of methods (~2018)

- Field moving GNSS observation (method 2 or 3)
- 5 minutes continuous observations at each red circles
- Processing applying three methods
  1: cutoff mask (sky photo)
  2: Quality check using Doppler observables
  3: cutoff mask (3D maps)

Data: 2016/26-27
Satellite: GPS, QZSS, GLONASS, Galileo
Equipment: JAVAD Delta-G3T GrAntG3T
Sampling ratio: 1hz
Software: GSILIB ver2.0.1

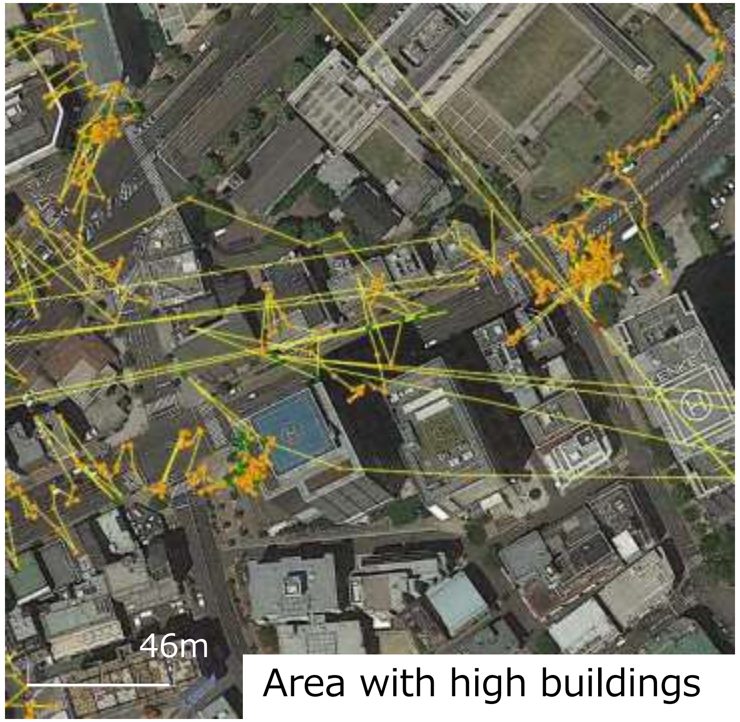
Trace of moving observation
(● : 5min. continuous obs.)

Result (Moving observation with method 3: Mask (3Dmap))



Distribution of Positioning result
Single frequency RTK

Area without high buildings



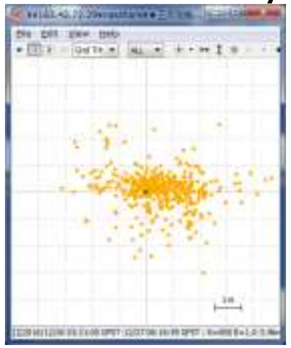
Area with high buildings

Method 3 is not effective in area with high buildings.

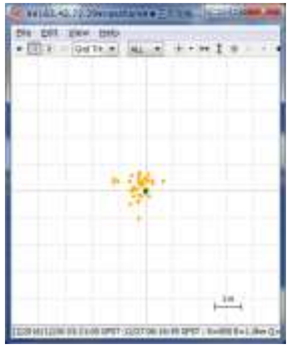
Result

High visibility
Dual frequency
RTK

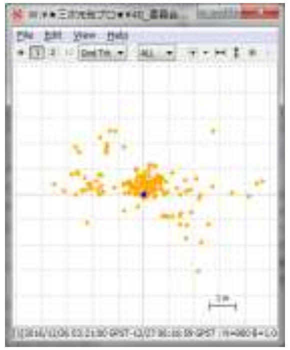
Site 514 (Satellite visibility : 55.9%)



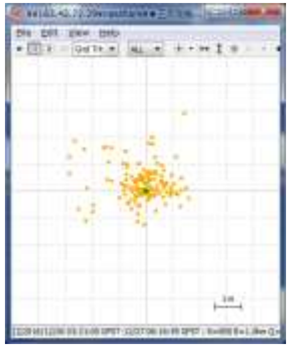
No method
(FIX ratio : 48%)



Method 1
(FIX ratio : 96%)



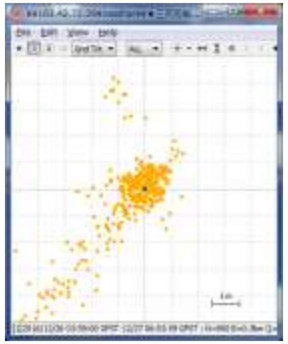
Method 3
(FIX ratio : 81%)



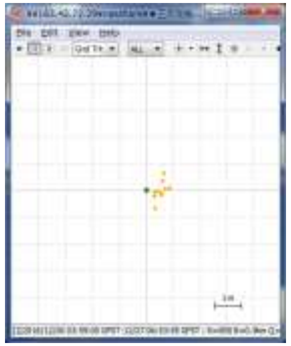
Method 2
(FIX ratio : 85%)

● : FIX
● : FLOAT

Site 518 (Satellite visibility : 57.7%)

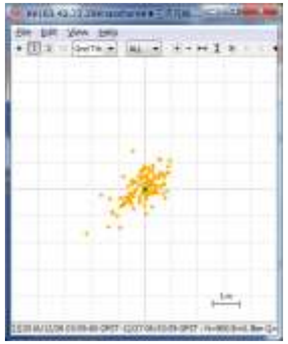


No method
(FIX ratio : 59%)



Method 1
(FIX ratio : 99%)

Method 3
(FIX ratio : 97%)



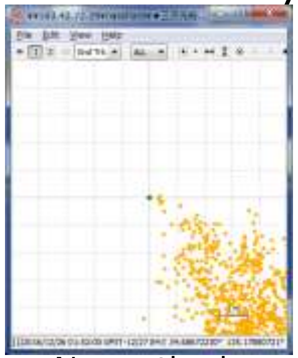
Method 2
(FIX ratio : 87%)

1: cutoff mask (sky photo)
2: Quality check (Doppler)
3: cutoff mask (3D maps)

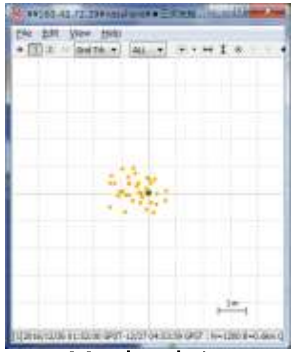
Result

Low visibility
Dual frequency
RTK

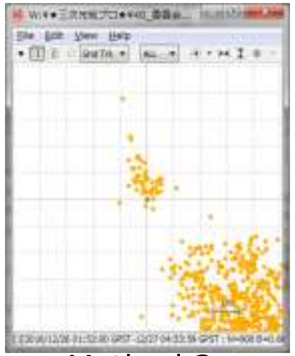
Site 505（Satellite visibility : 41.2%）



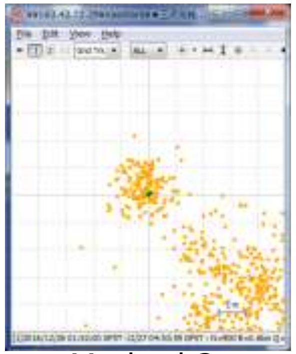
No method
(FIX ratio : 1%)



Method 1
(FIX ratio : 96%)



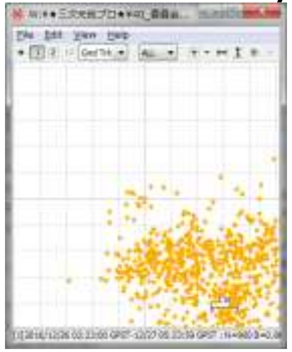
Method 3
(FIX ratio : 7%)



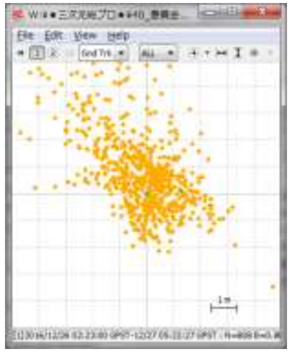
Method 2
(FIX ratio : 33%)

● : FIX
● : FLOAT

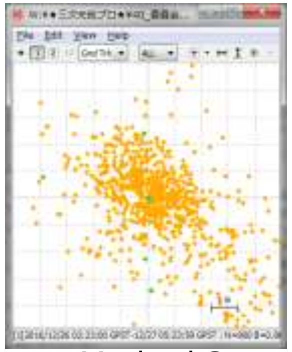
Site 508（Satellite visibility : 37.9%）



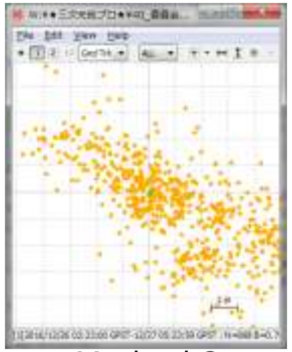
No method
(FIX ratio : 2%)



Method 1
(FIX ratio : 5%)



Method 3
(FIX ratio : 4%)



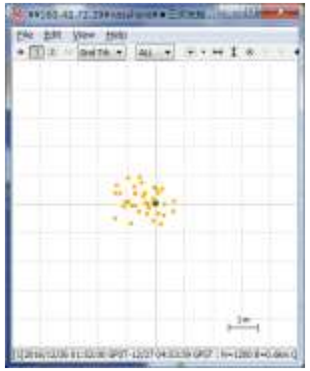
Method 2
(FIX ratio : 9%)

1: cutoff mask (sky photo)
2: Quality check (Doppler)
3: cutoff mask (3D maps)

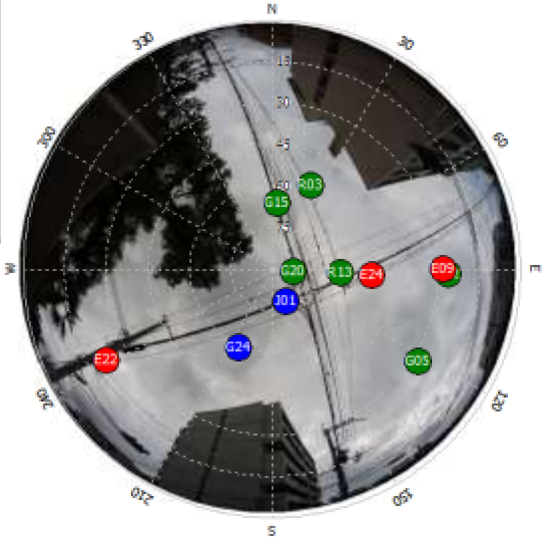
Result

Difference in Low visibility Conditions

Site 505（Satellite visibility : 41.2%）

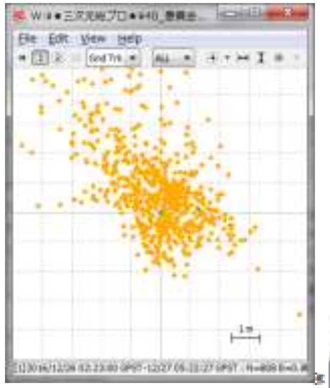


Method 1
(FIX ratio : 96%)

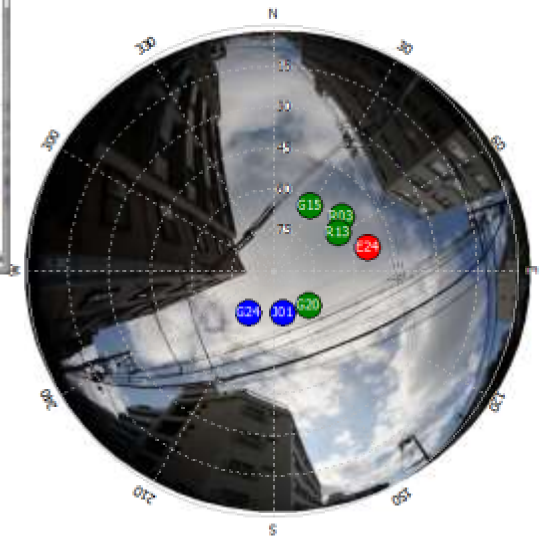


Satellite constellation (2016/12/27 4:49UTC)

Site 508（Satellite visibility : 37.9%）



Method 1
(FIX ratio : 5%)

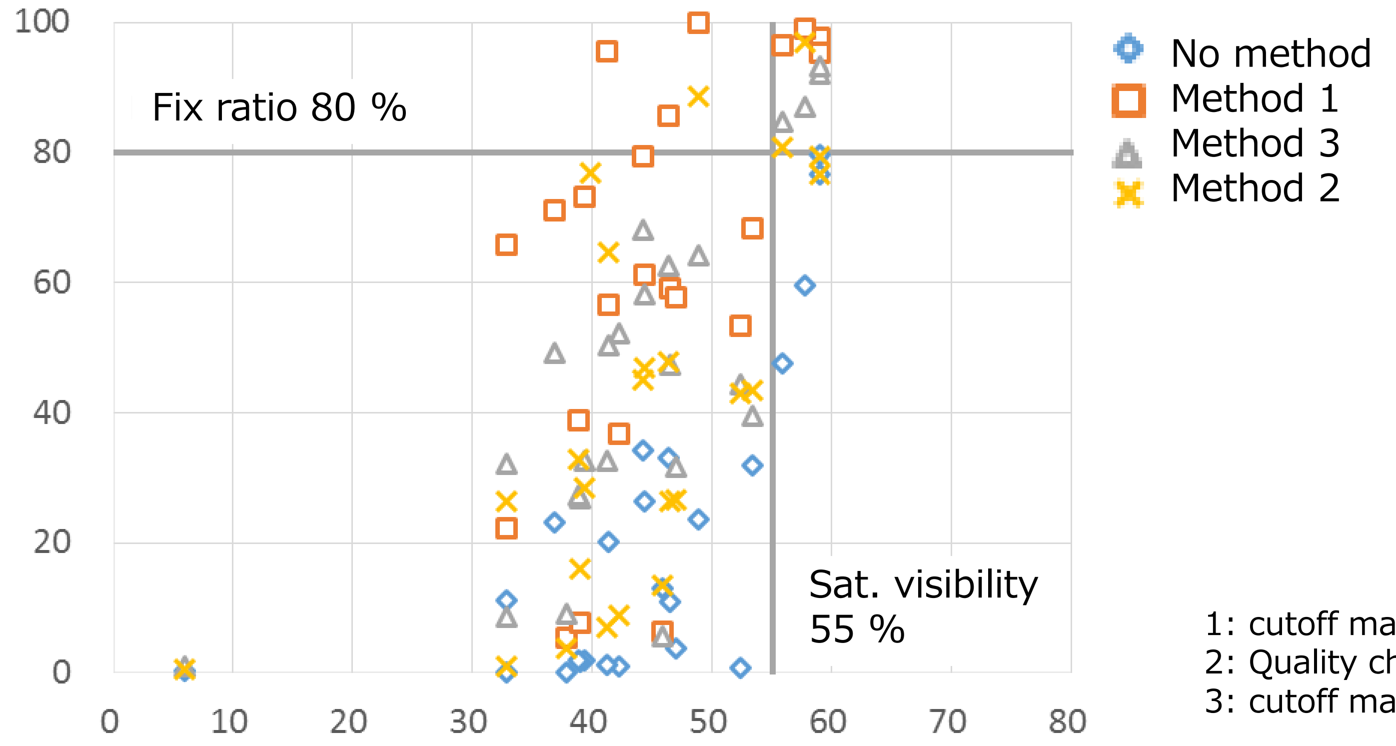


Satellite constellation (2016/12/27 5:19UTC)

Satellite constellation at 505 is better than 508.

Result

Dual frequency
RTK
(Total)



1: cutoff mask (sky photo)
2: Quality check (Doppler)
3: cutoff mask (3D maps)

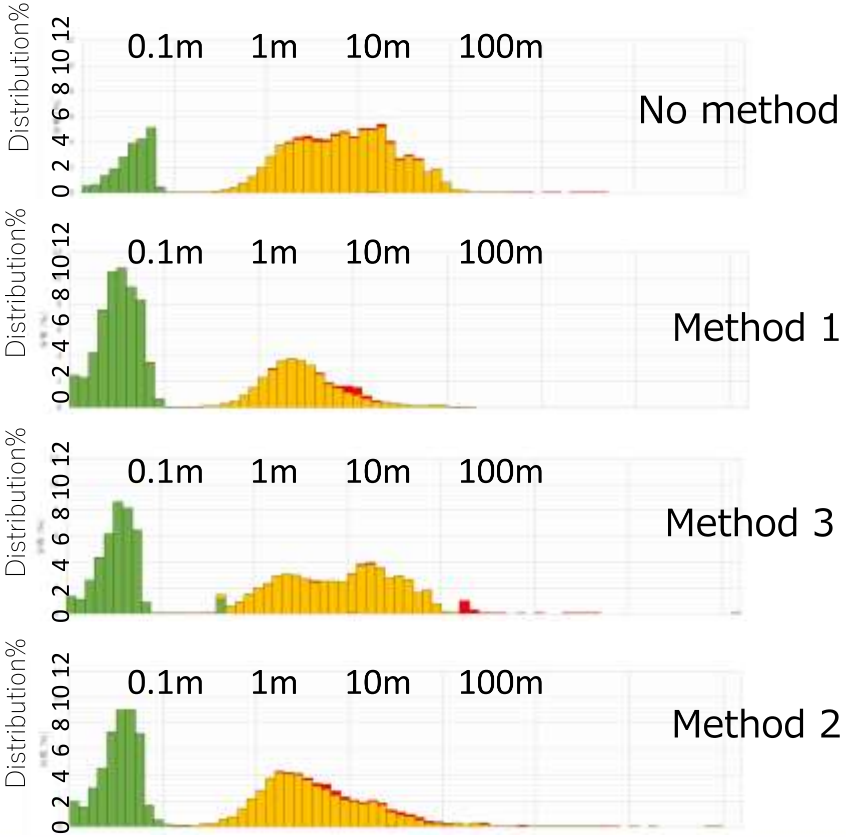
All methods achieve fix ratio 80% in case satellite visibility exceeds 55%.

Result (RTK)

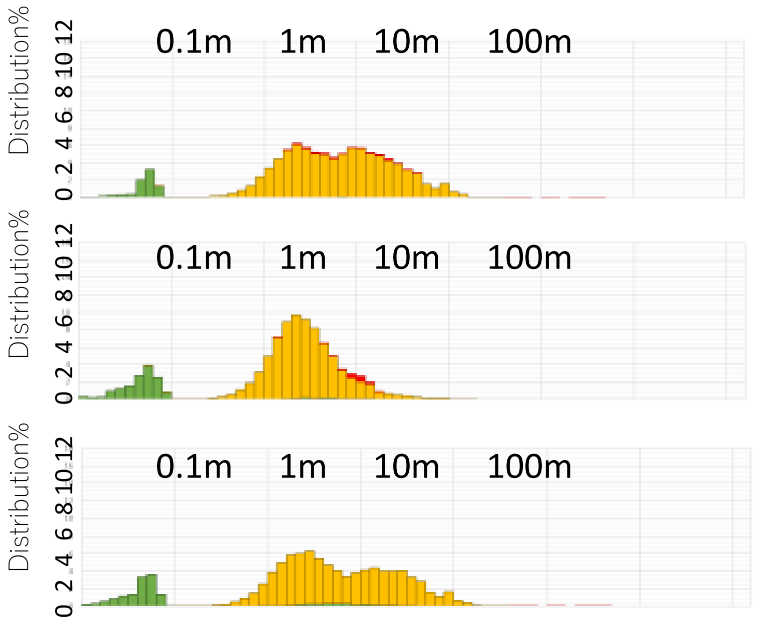
- All results show improvement in dual frequency RTK.
- Almost all fixed solutions show consistency with observed value of total station within 10cm.
- Results of Single frequency RTK also show improvement but smaller than dual frequency.

FIX
FLOAT
Point positioning

Dual frequency RTK



Single frequency RTK



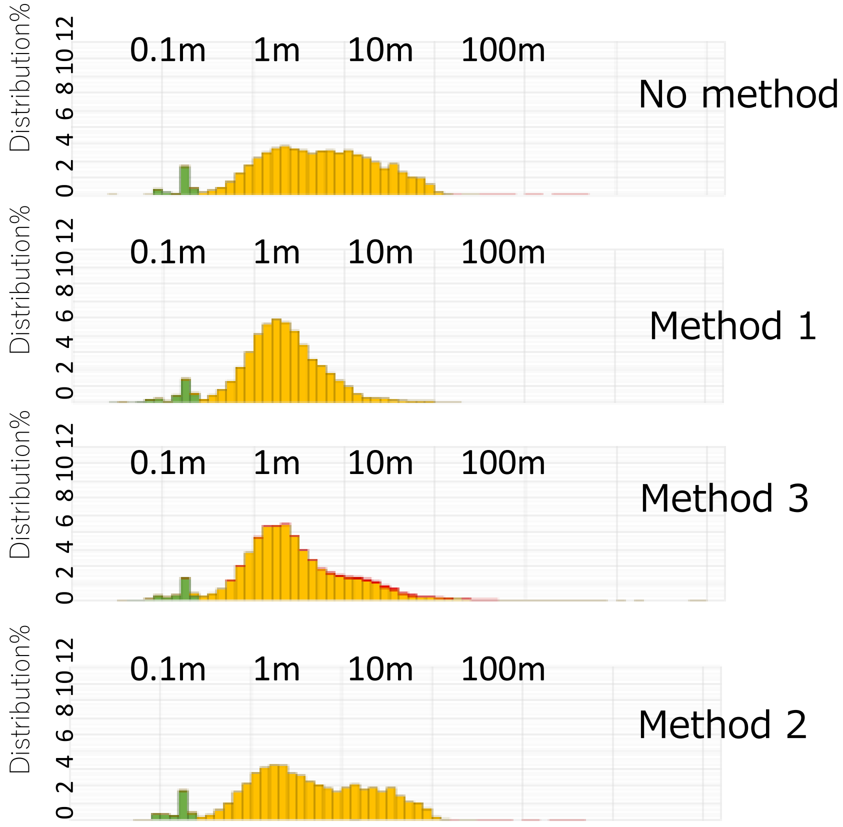
Applicable only for dual frequency

Result (VRS)

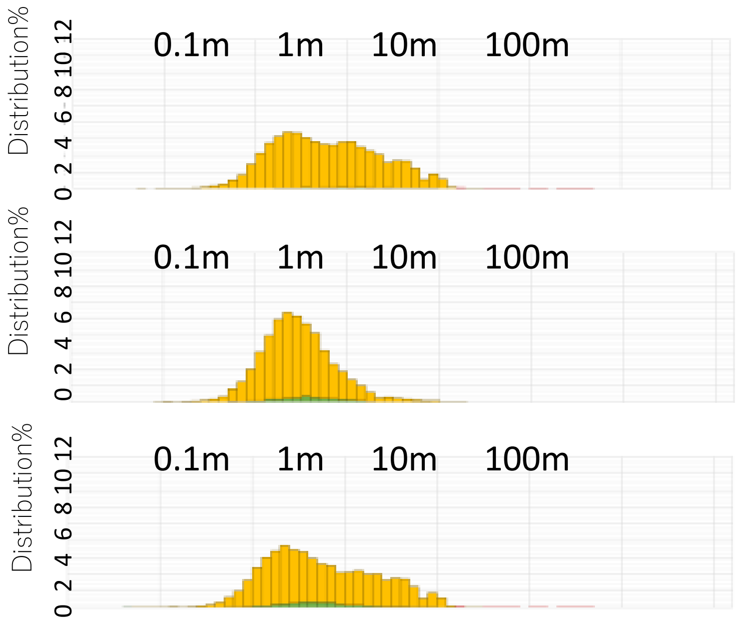
- Float solutions show improvement but no obvious improvement in fixed solutions.

FIX
FLOAT
Point Positioning

Dual frequency VRS



Single frequency VRS



Applicable only for dual frequency

Summary

- GSI developed three software-based techniques to mitigate multipath on GNSS signals.
- They are 1) cutoff mask generated from sky photo, 2) quality check using Doppler observables and 3) cutoff mask generated from 3D map of buildings.
- Three techniques are all effective to improve accuracy of GNSS positioning under urban environment.
- Cutoff mask generated from sky photo is the most effective. Cutoff mask from 3D map is the second.
- All methods achieve fix ratio 80% if satellite visibility exceeds 55%.
- The methods are effective when applying to dual frequency RTK. They are also effective for single frequency RTK, but the effect is smaller.
- The effect is limited when applying to VRS.
- The final report will be open to public users (in Japanese).