# *Evaluation of Multi-path and Accuracy Improvement method in a stand-alone Positioning*

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# *Outline of our study*

- Understanding of multi-path
- Data analysis
- Accuracy improvement
- Result and conclusion

# *Object of our study*

Use “code - carrier” measurement technique

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Detect SVs contaminated with multi-path

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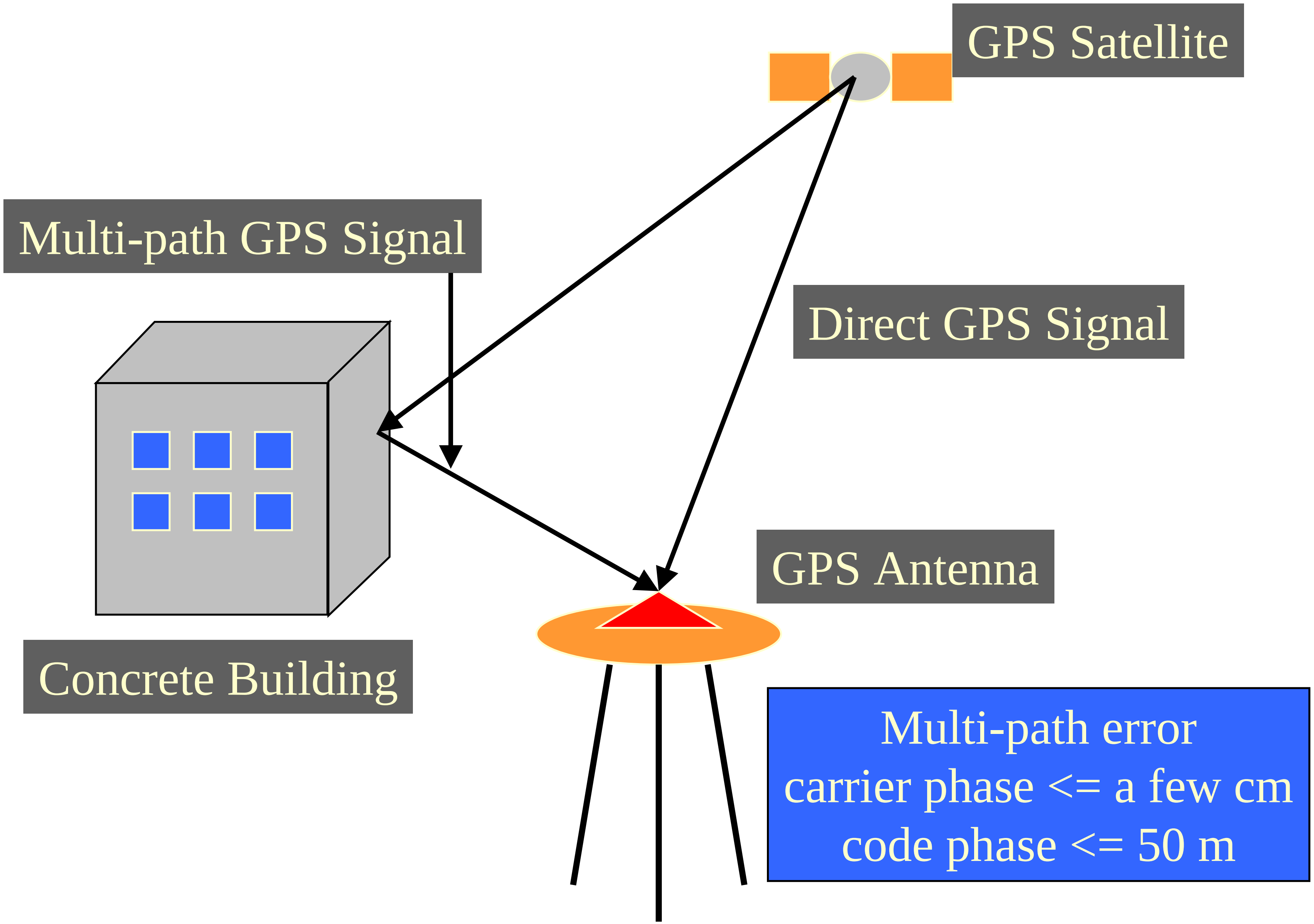
Remove SVs from positioning

↓

***Improve accuracy in positioning***




Picture 1  Direct and multi-path GPS signal

# *Reduction in pseudorange error by DGPS technique*

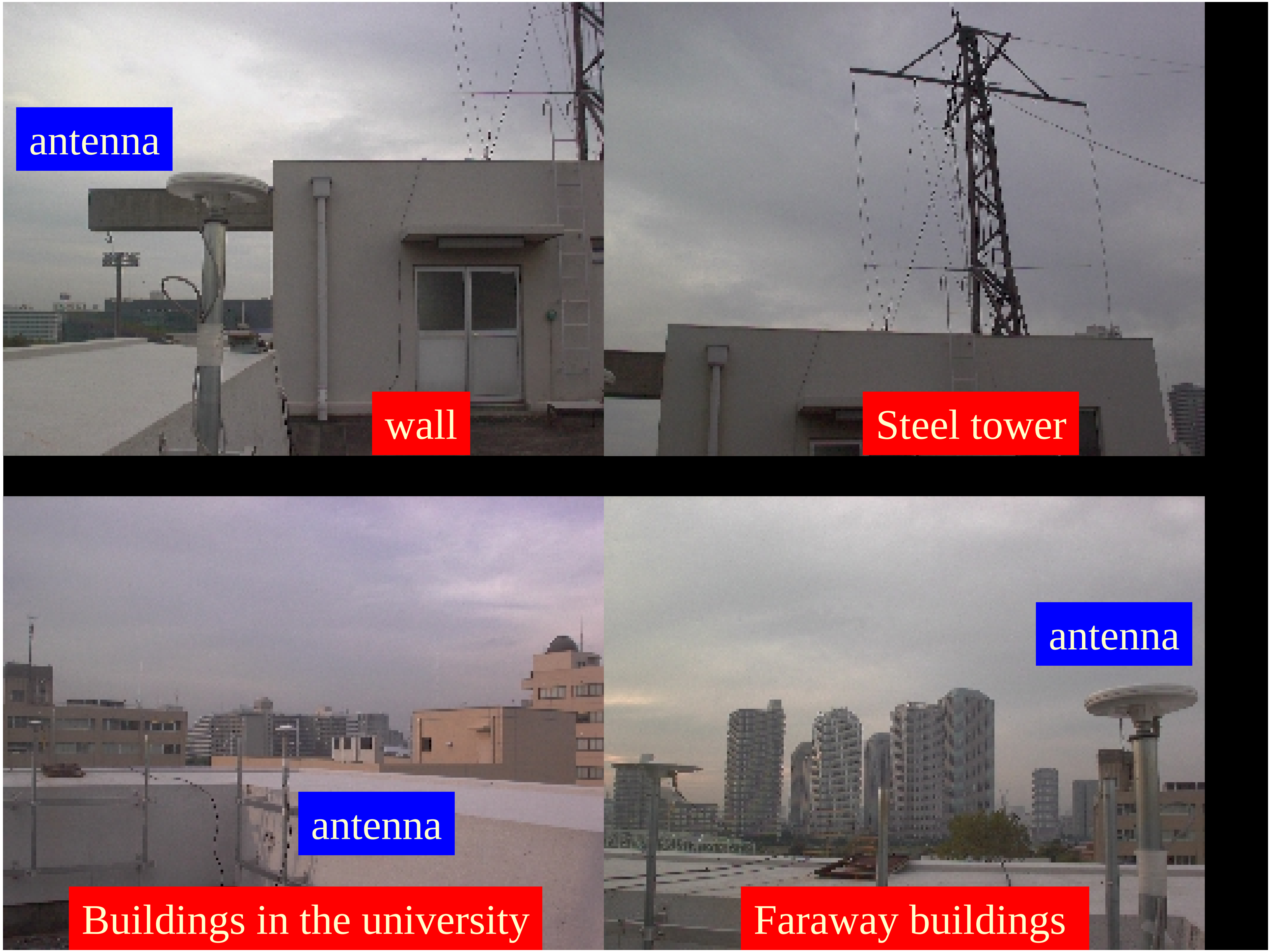
- Satellite clock stability
- Satellite perturbations
- Ephemeris prediction error
- Ionospheric delay
- Tropospheric delay

Most of error sources in GPS positining

Multi-path and Receiver noise are not reduced.

# *Data collection*

- Period : 2000/12/2～12/3 (48hours)
- Place : On the roof of labolatory
  //there is a wall and high steel tower
- Antenna : Aero Antenna Technology AT2775
- Receiver : NovAtel RT-2
  //Mask 5 degrees
  //Csmooth 20 seconds (L1,L2)


antenna
wall
Steel tower
antenna
Buildings in the university
antenna
Faraway buildings

# *Investigation of multi-path*

Investigation consists of 2 points

1. Relationships between code multi-path and accuracy
2. Accuracy improvement by removing SV (Satellite Vehicle) contaminated with multi-path

# *Caribration of code multi-path*

Standard "code-carrier" technique

Code multi-path + bias = L1_code - 4.0915 × L1_carrier

+ 3.0915 × L2_carrier

**Errors concerned with carrier phase are negligible.**

**Ionospheric term can be removed**

Code multi-path error traces tend not to be zero-mean. In this study, we consider them zero-mean. Because we don't use absolute multi-path error but we use only variation of multi-path error.

# *Fig.1 Code multi-path error for 30min.*

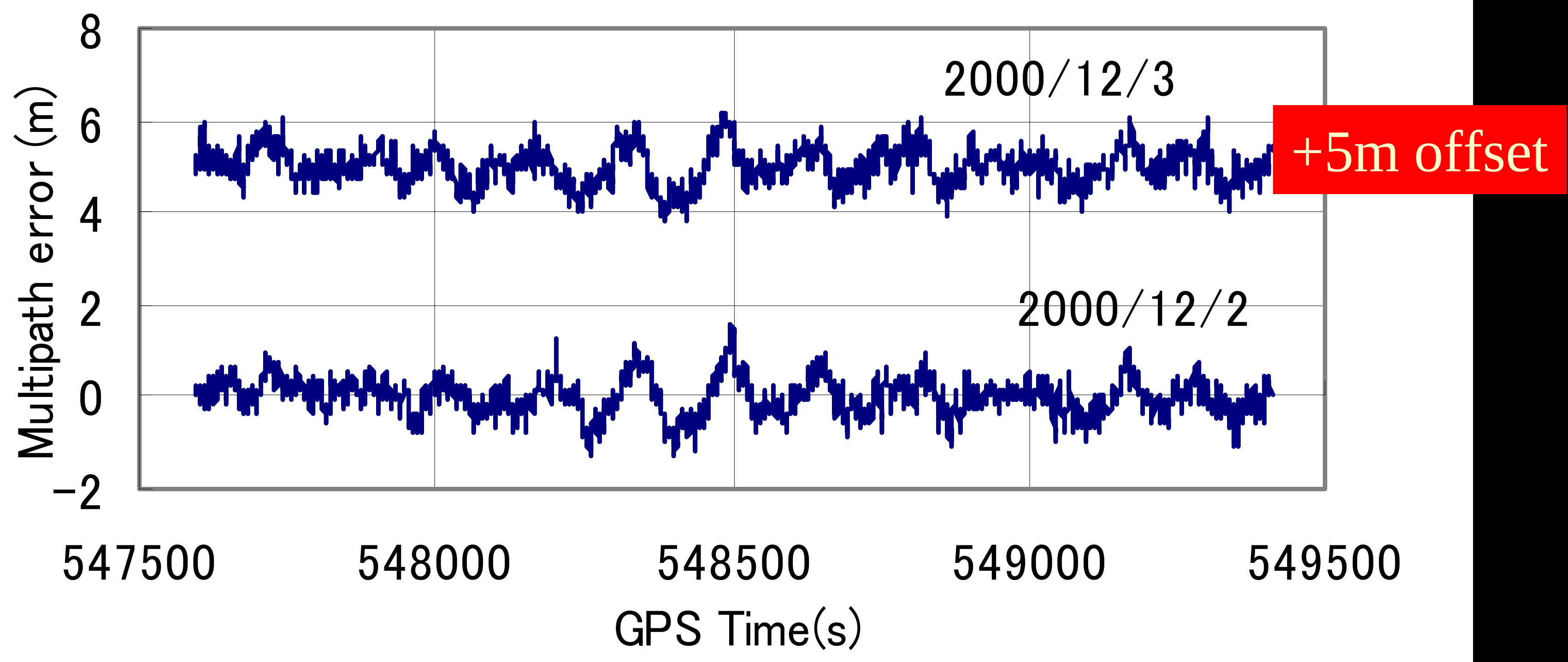



Fig.1 Day-to-day repeatability of multipath

# *Fig.2 Relationships between code multi-path error and elevation*

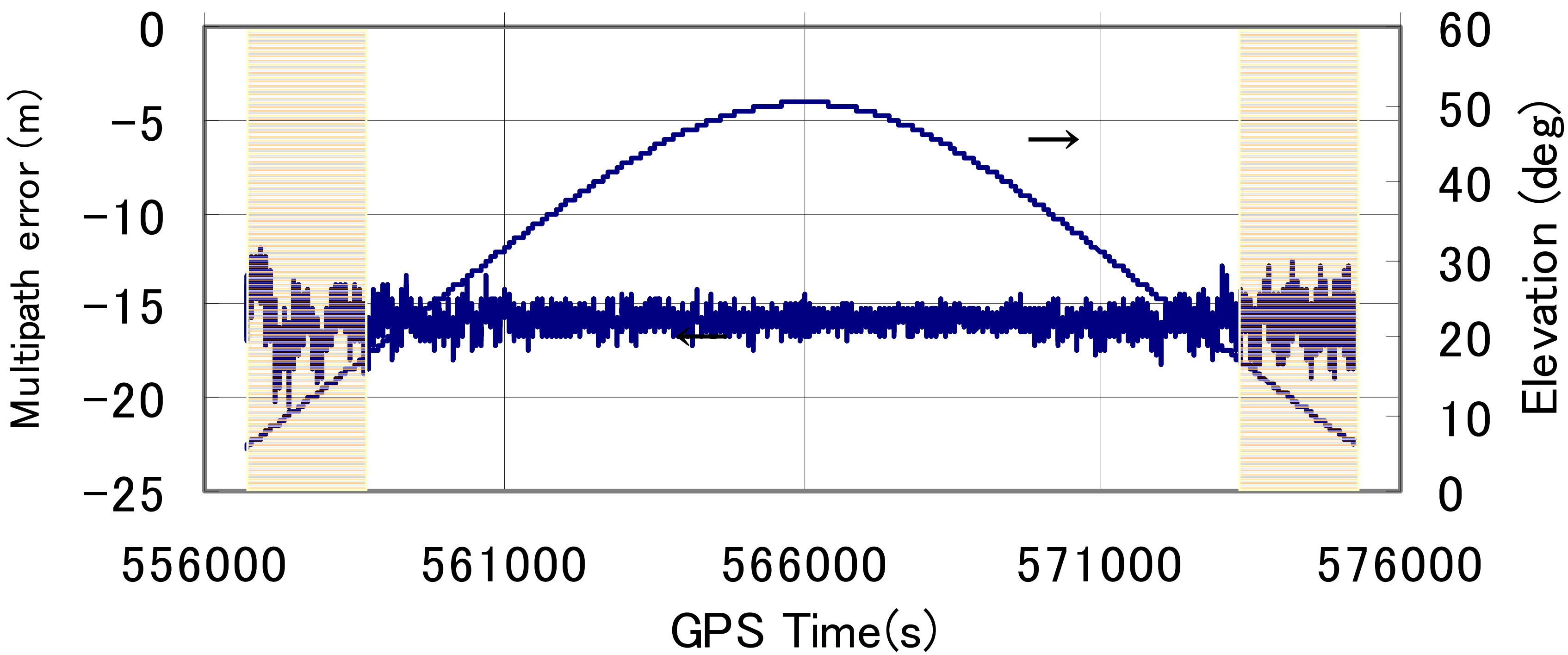



Fig.2 Relationship between multipath error and elevation

# *Fig.3 12hours Stand-alone positioning*

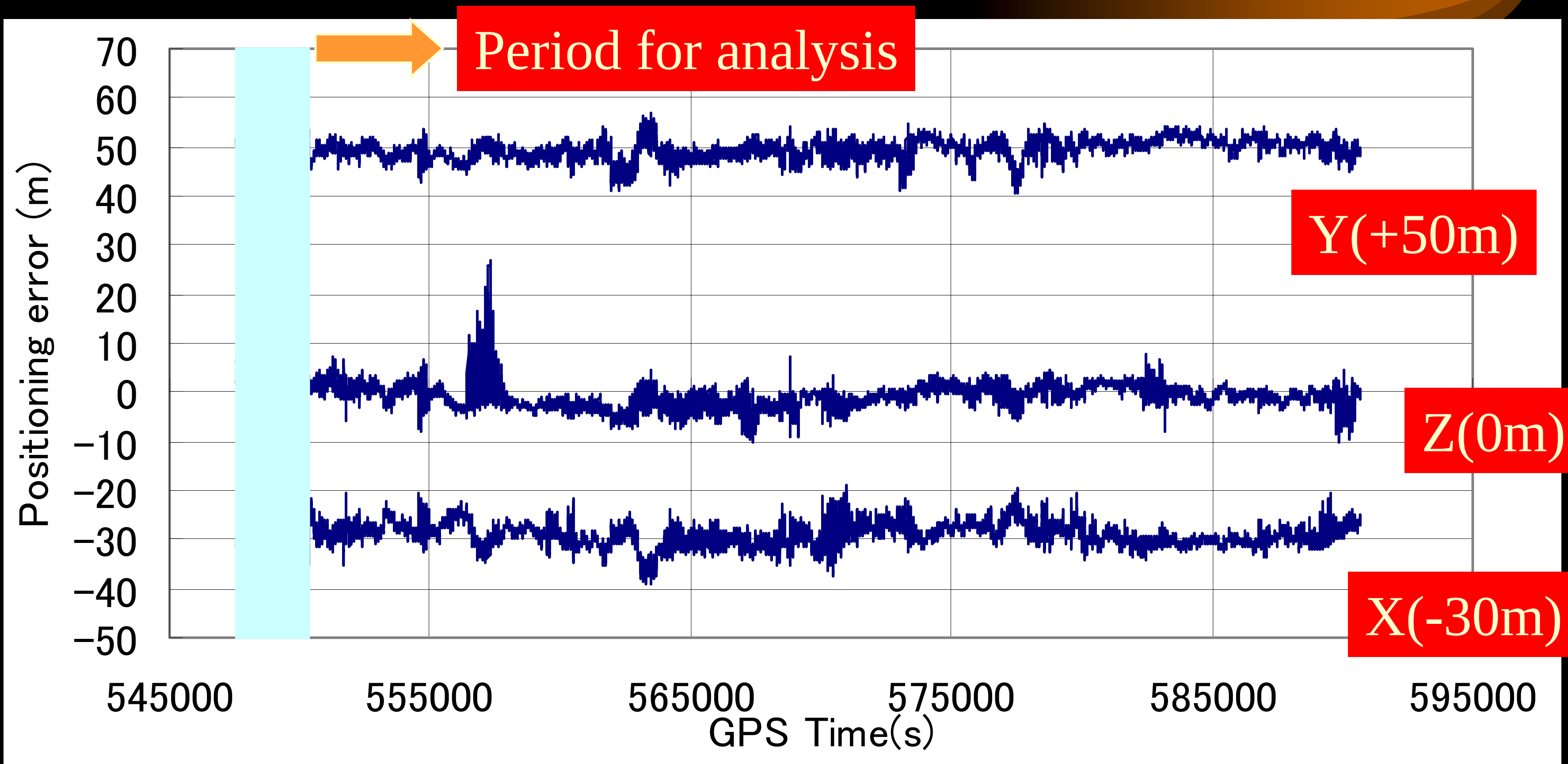


Fig.3 12hours Stand-alone positioning error

# *Fig.4 Code multi-path and rate of carrier phase SV49*

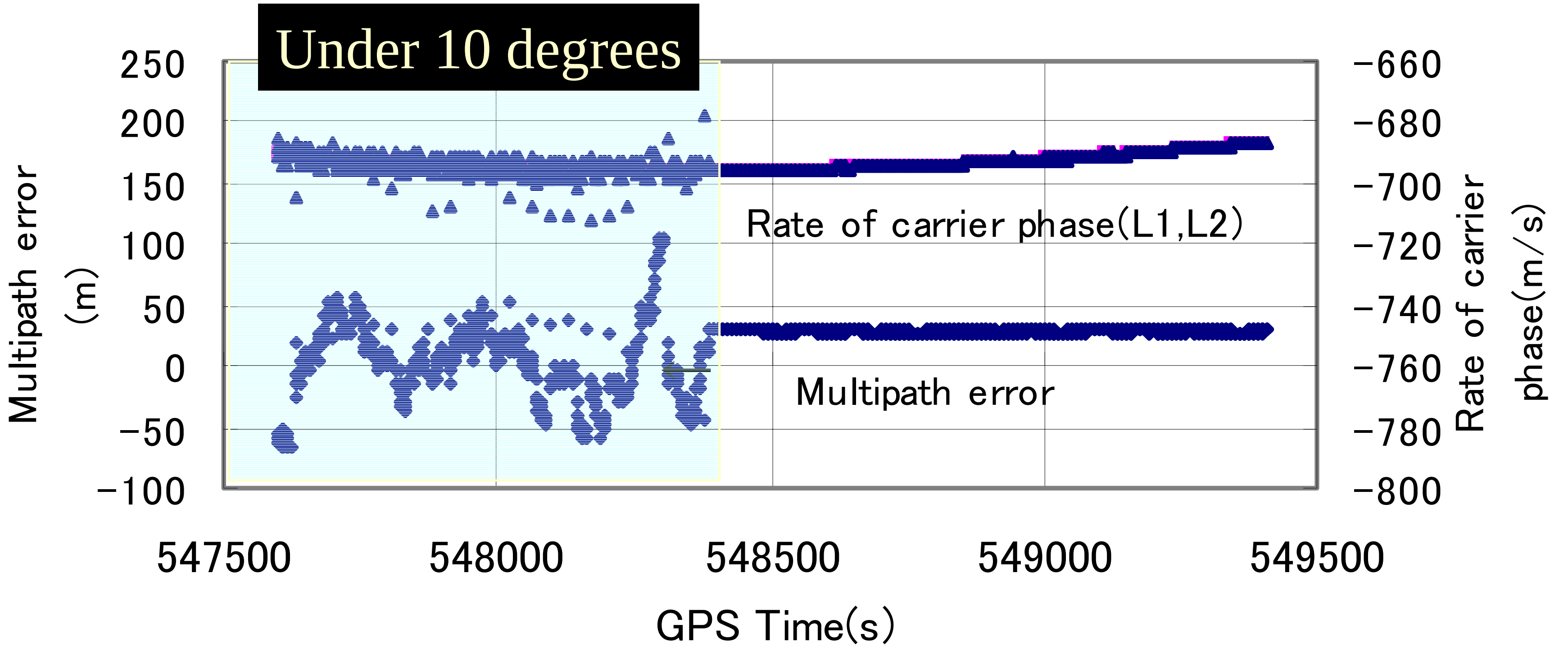



Fig.4 Temporal variation of multipath error and the rate of carrier phase(SV49)

# *Fig.5 Code multi-path and rate of carrier phase SV17*

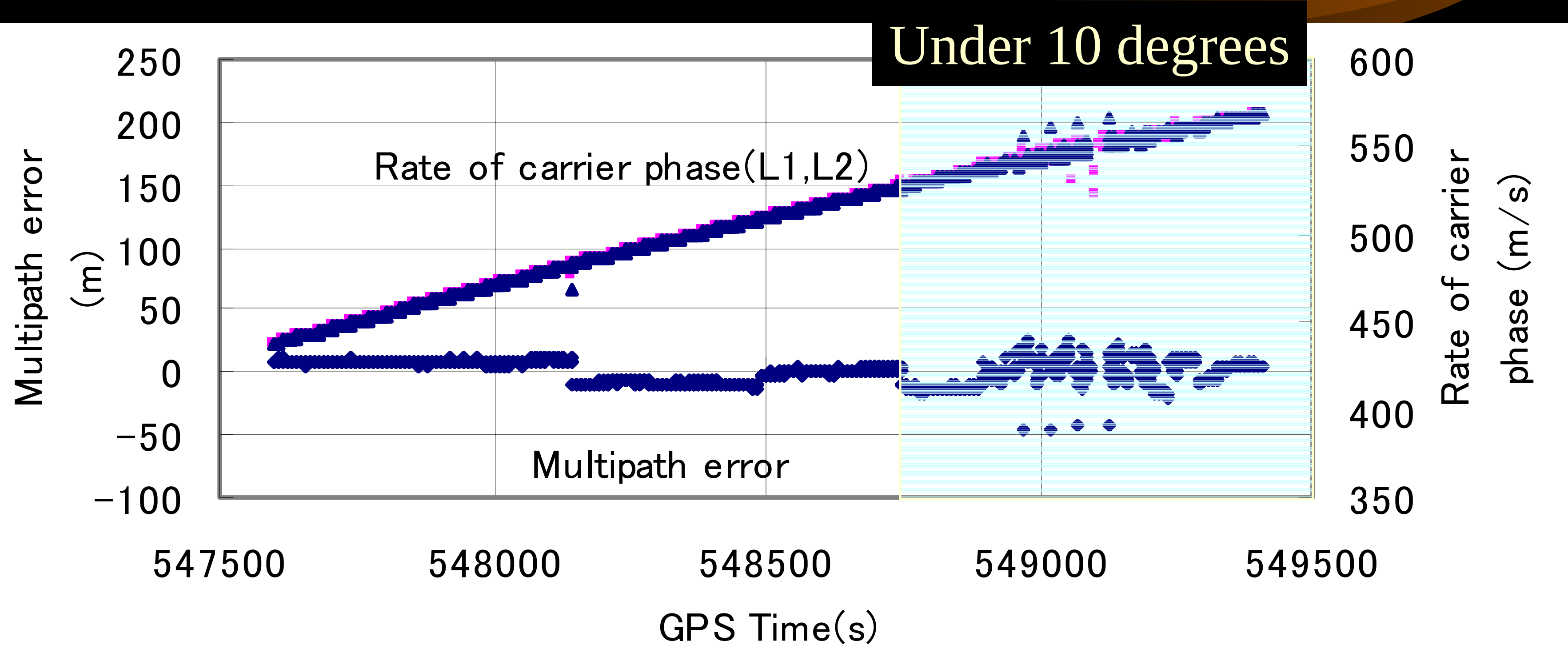



Fig.5 Temporal variation of multipath error and the rate of carrier phase(SV17)

# *Fig.6 Code multi-path and rate of carrier phase SV25*

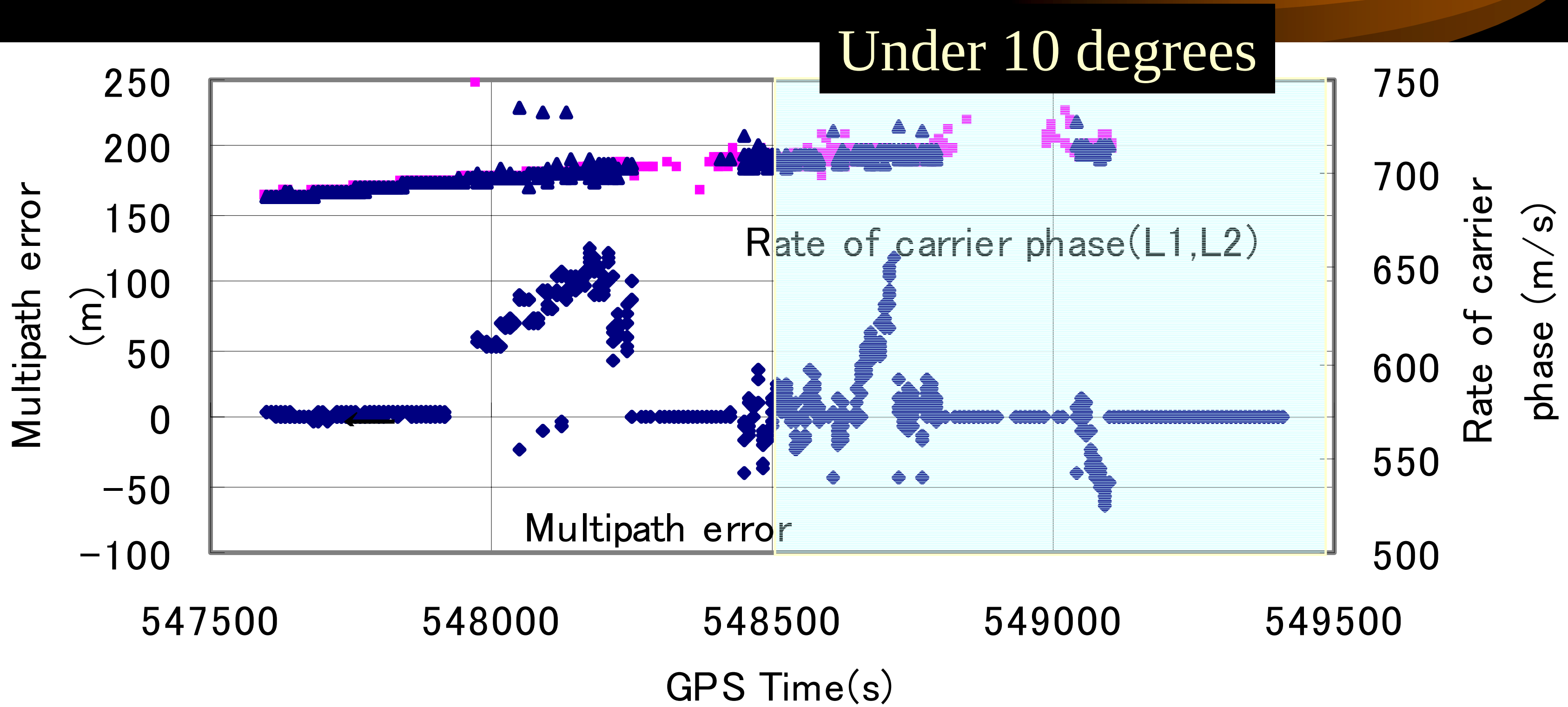



Fig.6 Temporal variation of multipath error and the rate of carrier phase(SV25)

# Fig.7 Transition of elevation

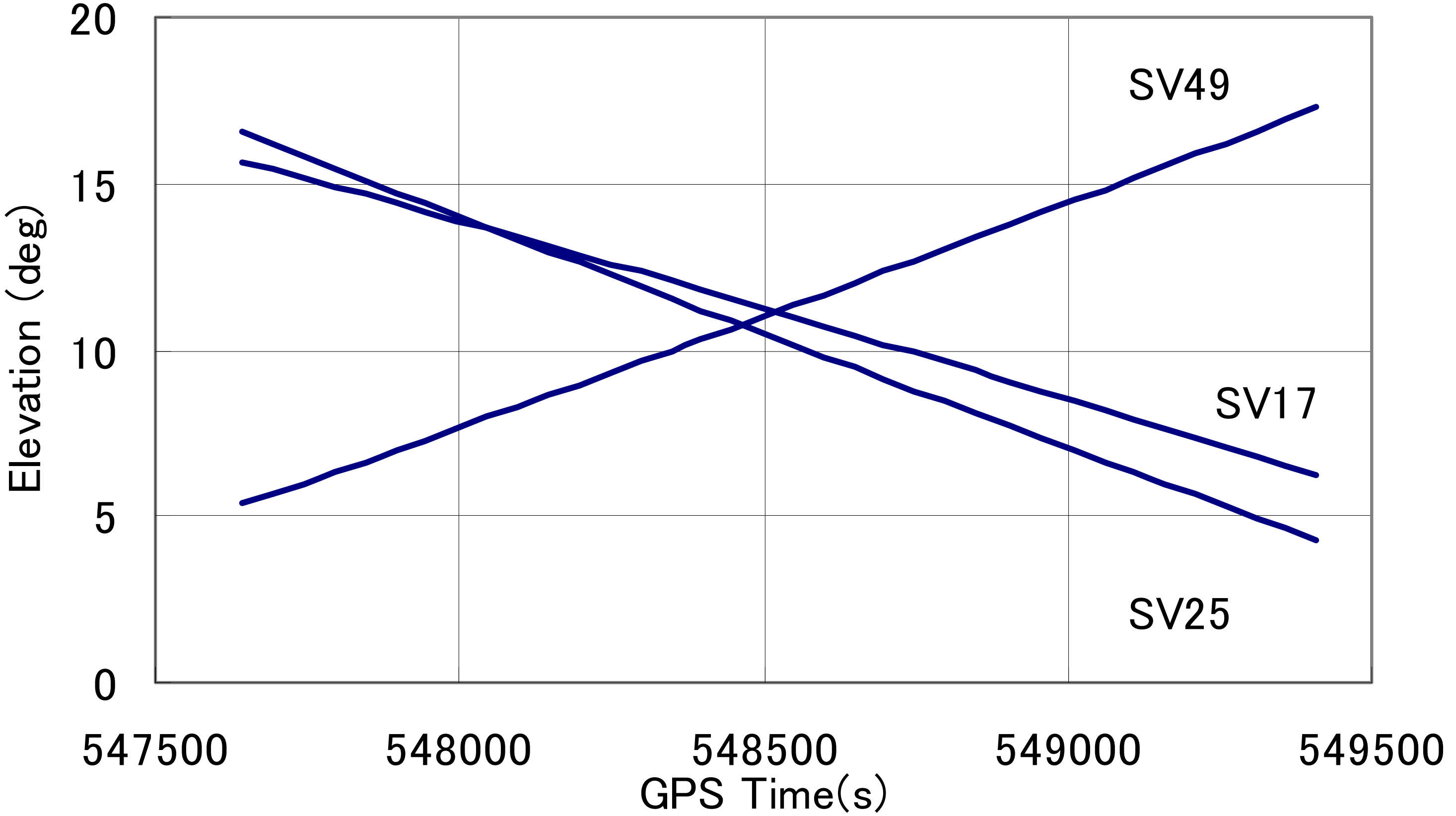
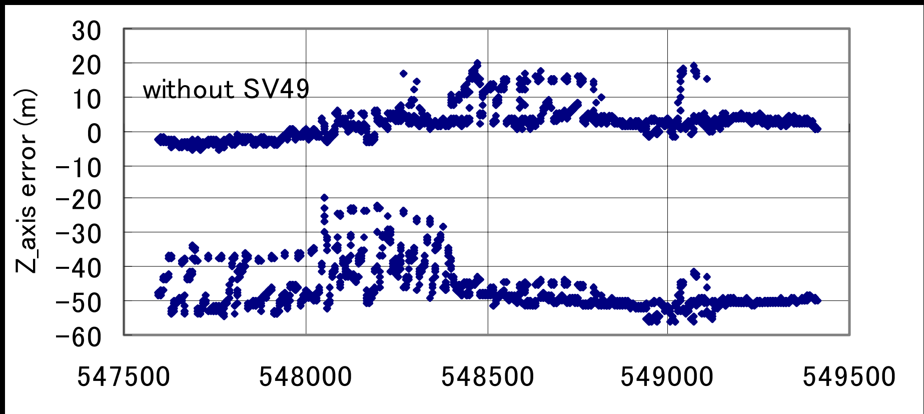
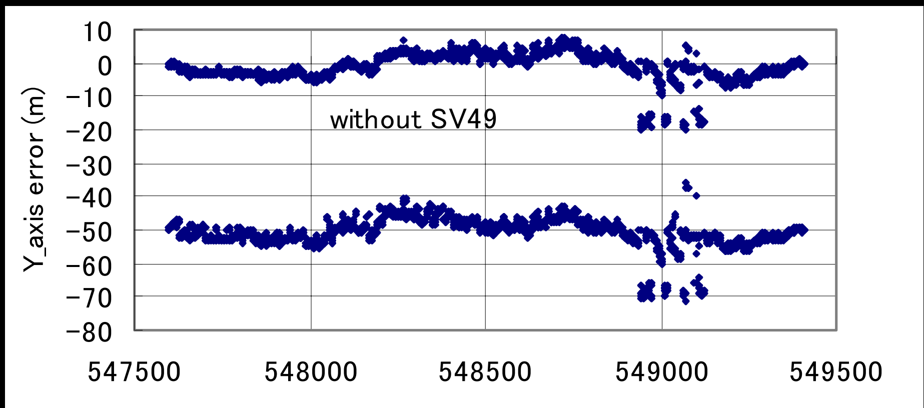



Fig.7 Elevation for SV49, SV17, SV25

# *Fig.8 Stand-alone positioning with and without SV49*

upper: without SV49
lower: all visible SVs



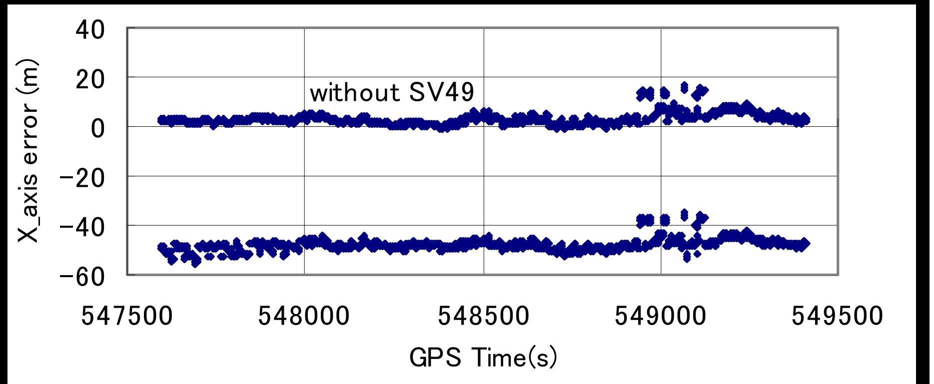
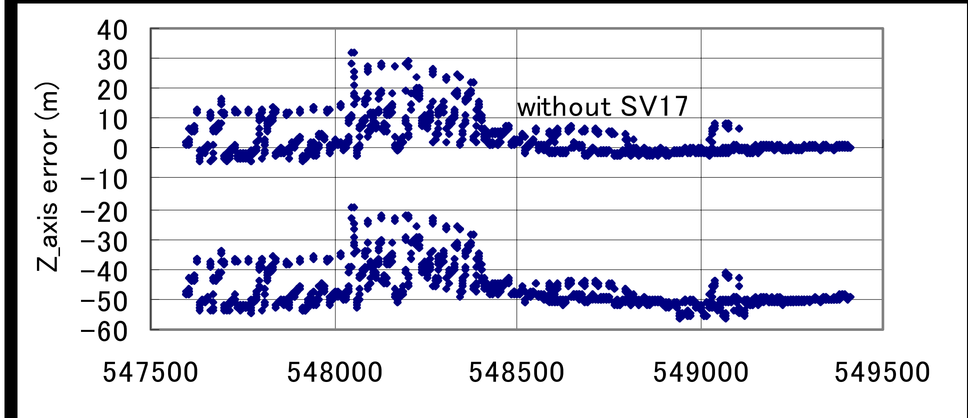




Fig.8 Stand-alone positioning error with and without SV49

# *Fig.9 Stand-alone positioning with and without SV17*

upper: without SV17
lower: all visible SVs



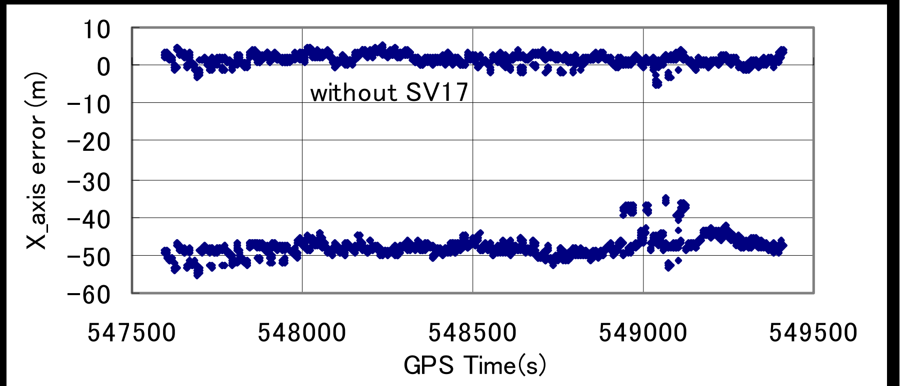
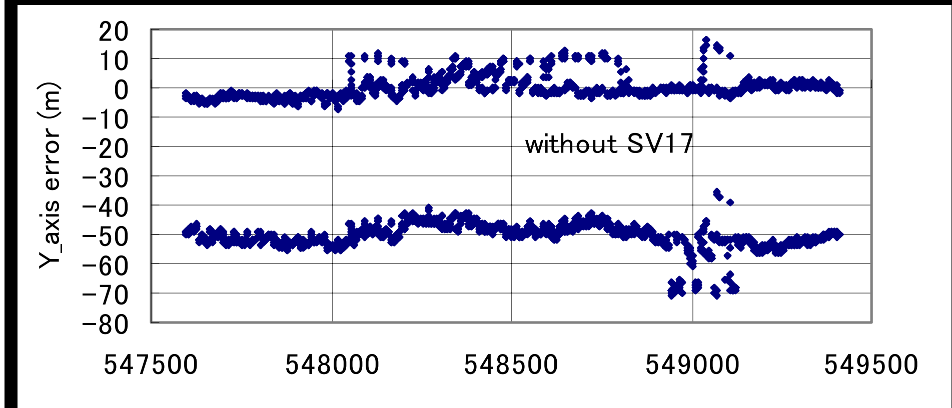
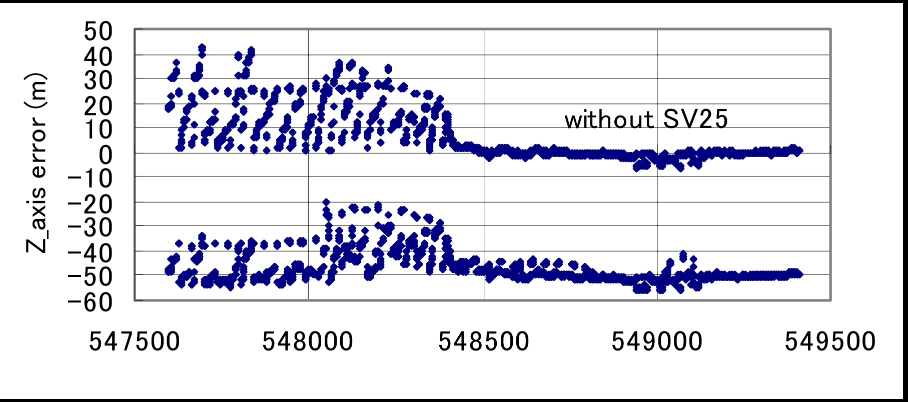



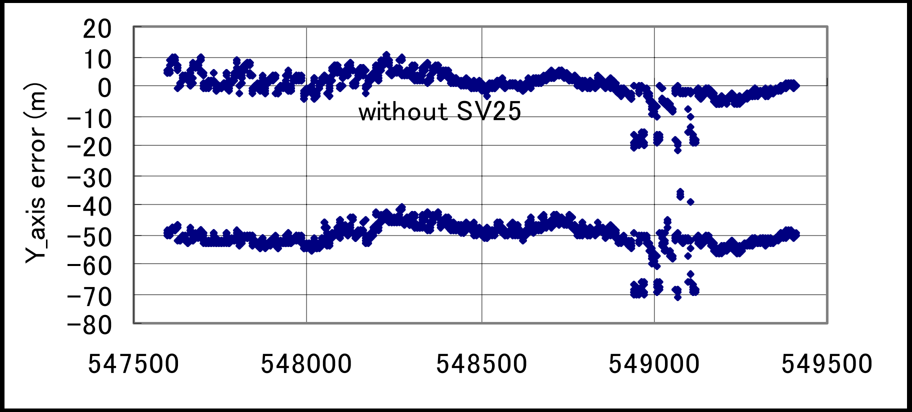

Fig.9 Stand-alone positioning error with and without SV17



# *Fig.10 Stand-alone positioning with and without SV25*

upper: without SV25
lower: all visible SVs



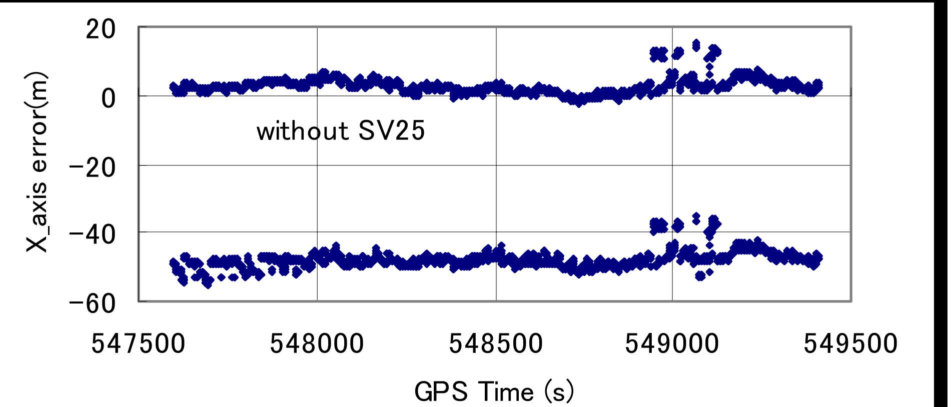




Fig.10 Satnd-alone positioning error with and without SV25

# *Fig.11 Algorithm to remove SV contaminated with multi-path*

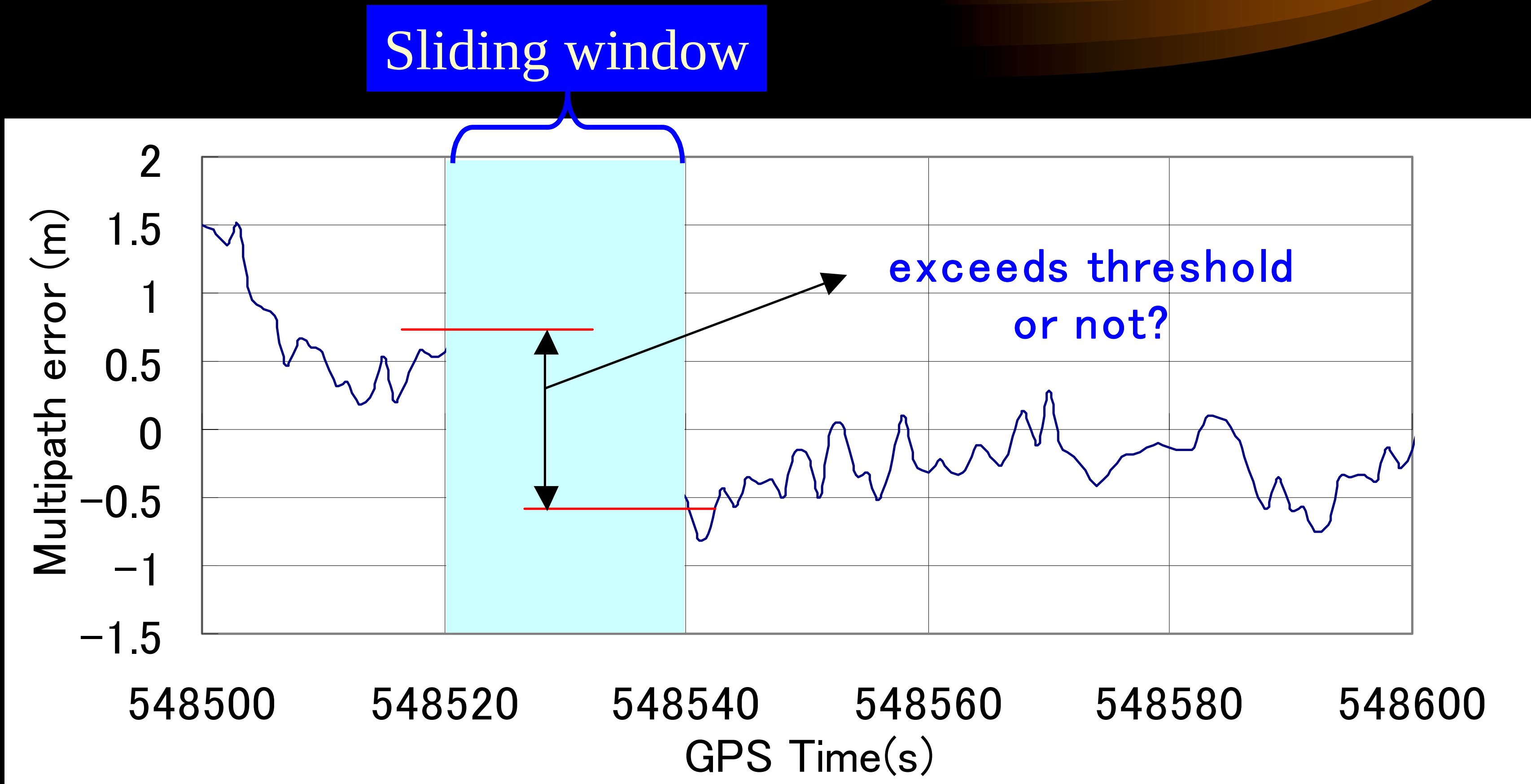
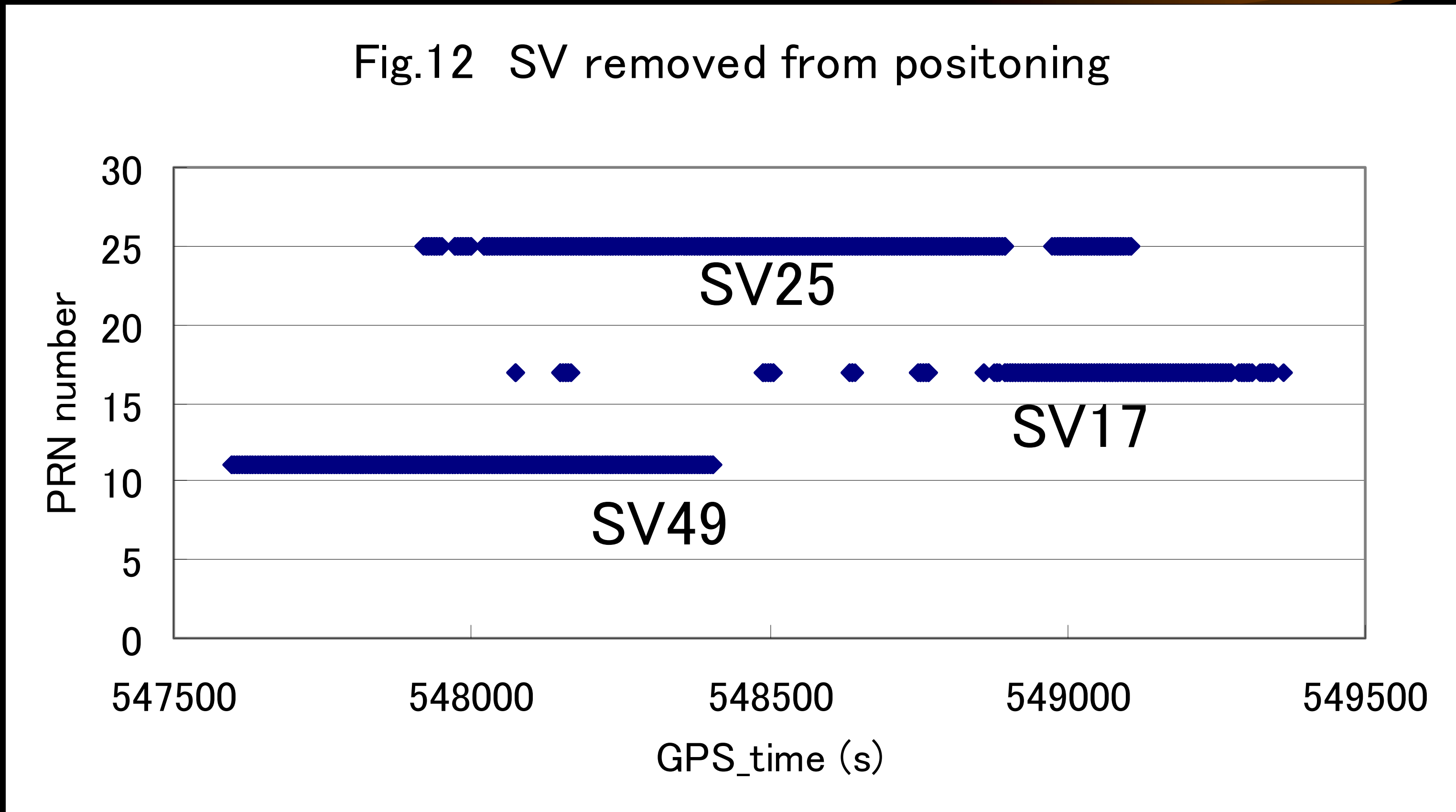
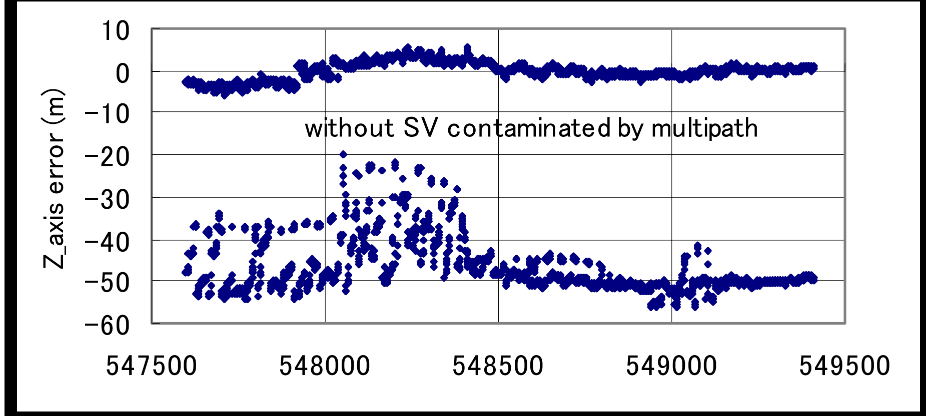



Fig.11 Algorithm to remove SV contaminated with multi-path

# *Fig.12 The interval removing SV contaminated with multi-path*



# Fig.13 Stand-alone Positioning without SV contaminated with multi-path




upper: without SV contaminated with multi-path
lower: all visible SVs

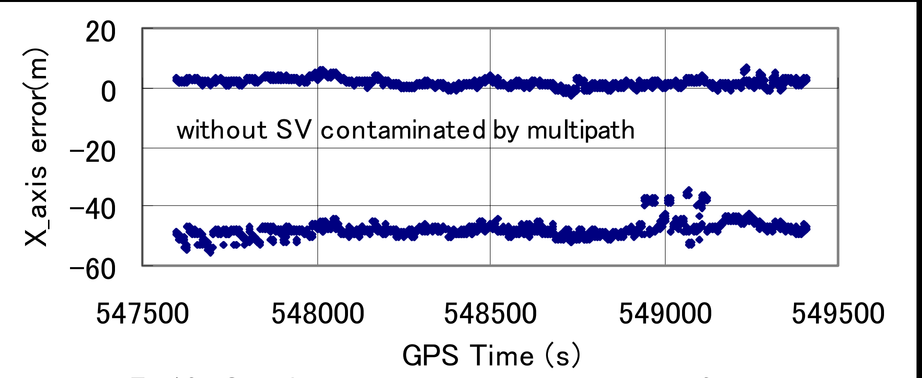
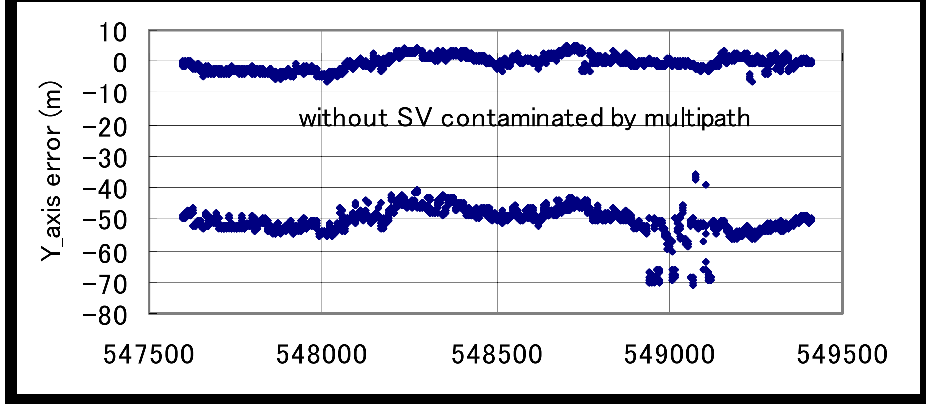



Fig.13 Stand-alone positioning error in case of removing SV contaminated by multipath



# *Standard deviation in positioning*

| Threshold(m) | average | X_std(m) | Y_std(m) | Z_std(m) |
|---|---|---|---|---|
| 2 | 8 | 0.64 | 0.92 | 2.27 |
| 4 | 9.5 | 0.83 | 1.2 | 2.01 |
| 6 | 9.7 | 0.85 | 1.22 | 1.99 |
| 8 | 9.7 | 0.85 | 1.22 | 1.99 |
| 10 | 9.7 | 0.85 | 1.22 | 1.99 |

Table1 Relationships between Std, average SVs and threshold by proposed algorithm

| average | X_std(m) | Y_std(m) | Z_std(m) |
|---|---|---|---|
| 10.8 | 2.01 | 3.29 | 4.17 |

Table2 Output of RT-2 receiver

# *Summary*

Significant accuracy improvement in a stand-alone positioning by proposed algorithm

In urban environment, more over the number of SVs decrease due to surrounding obstacles (causing multi-path)

We need SVs as many as we can in positioning (at least 4SVs).

We would like to develop the positioning algorithm, which use different weight cofficients for SVs contaminated with multi-path not remove SVs.