How multipath error influences on ambiguity resolution

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Background of presentation

- Current RTK application is not always perfect everywhere and every time due to mainly insufficient satellites (urban area).
- The increase of satellites will be expected by the advent of Galileo and QZSS in the future.
- Detection and elimination of satellite contaminated by multipath and cycle slips are significant in the case of short baseline application.

Introduction of presentation

- Purpose
- Ambiguity resolution technique
- Simulation for ambiguity resolution under multipath condition
- Static field test
  - under many visible satellites (6,7,8,…)
  - under few visible satellites (4,5,6)
- Kinematic field test (2 places)
- Summary

Purpose and Outline

- Investigating the impact of multipath on ambiguity resolution and introducing the simple solution for the difficulties
- To specify the effects of multipath, the case of very short baseline RTK is only considered.
- To emphasize on the difficulties of RTK with insufficient satellites, we picked up two conditions (under relatively many or few satellites) in each test (static or kinematic) to compare the results.

Ambiguity resolution technique

- Least Squares Ambiguity Search Technique
- A single epoch approach
- Divide the satellites in view into two groups

  (At least 5 satellites are needed)
- Measurement and positioning domain test

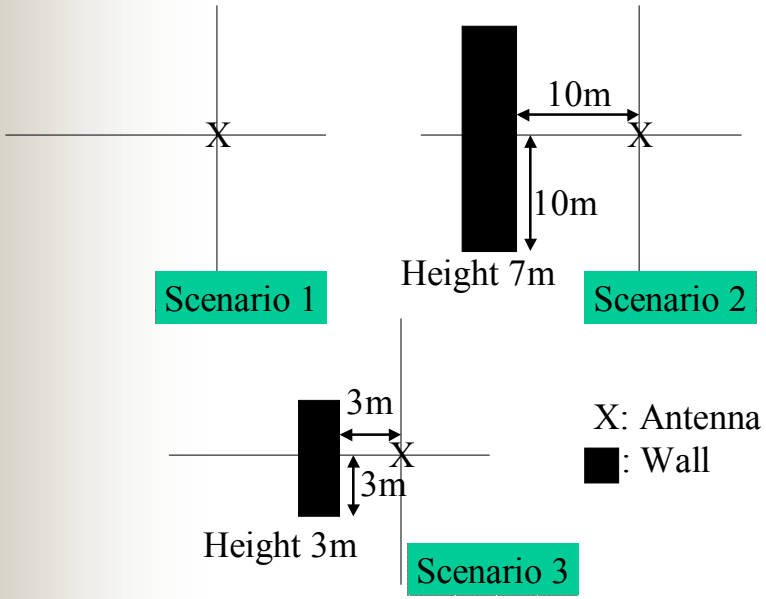
  (with a confidence level of 99%)

There are some ambiguity resolution techniques that have good performance (success rate) besides our standard technique. Therefore, the performance in this ambiguity resolution technique will not better than the best ambiguity resolution technique.

Simulation and Assumptions

- Residual atmospheric biases and orbital errors are assumed zero.
- Code and carrier phase std is computed according to the equations. Single specular reflection is assumed. 100sec carrier smoothing
- Reference station is only affected by ground reflection multipath.
- Cycle slip is not considered.
- Correlator spacing 0.1chip
- GPS YUMA 205　86400epochs (1Hz) July 27 2003
- 3 scenarios (3 configurations)

Configurations and Results

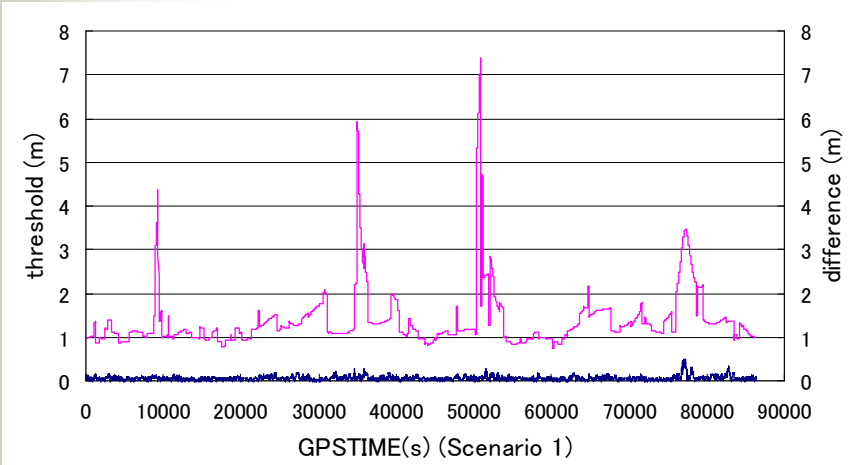


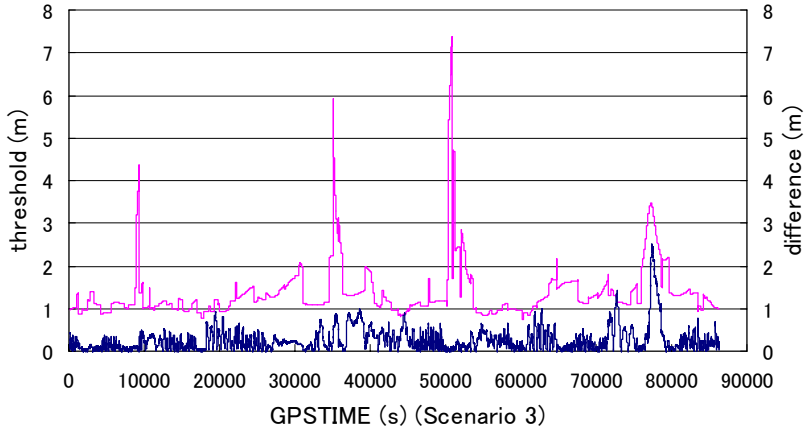
Obstacle: Concrete wall
Ground: Medium dry ground

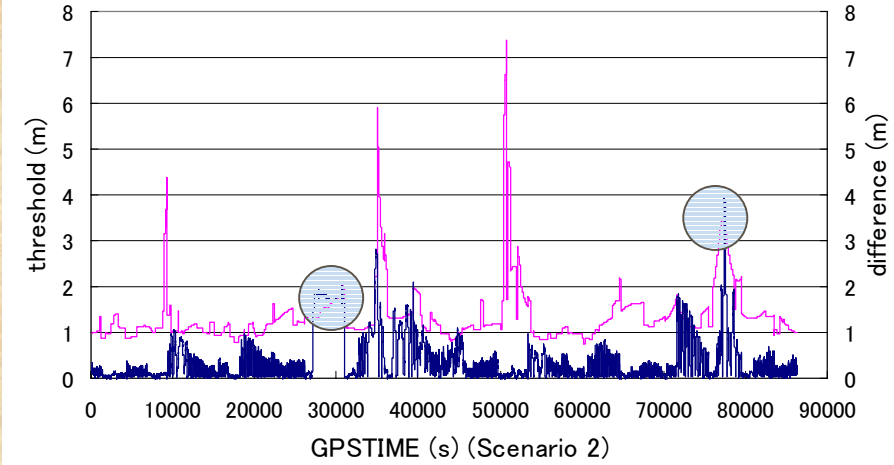
Scenario	1	2	3
Cases	50	60	58
Fix	50	52	56
Fix (over 300 sec)	2	7	9
Wrong Fix	0	8	2
Average	7.3	6.5	6.5

Ambiguity fix statistics

Relationship between difference and threshold for positioning test



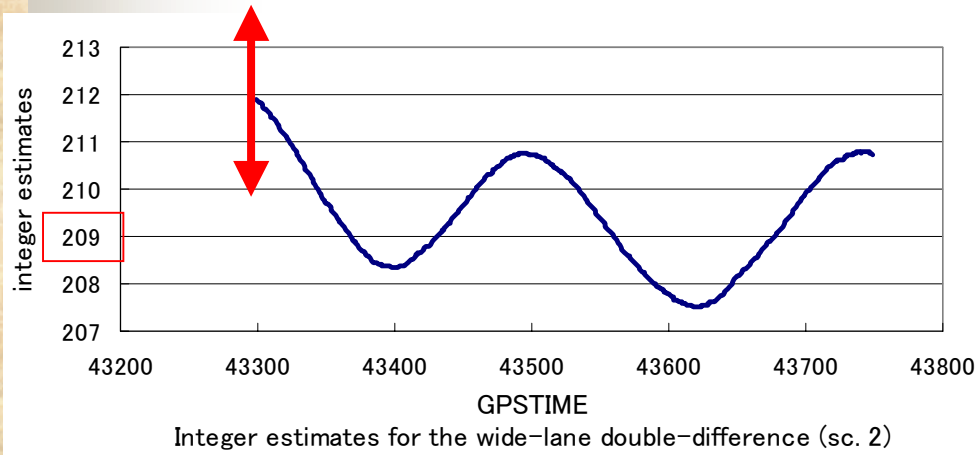




red line : threshold
blue line : difference

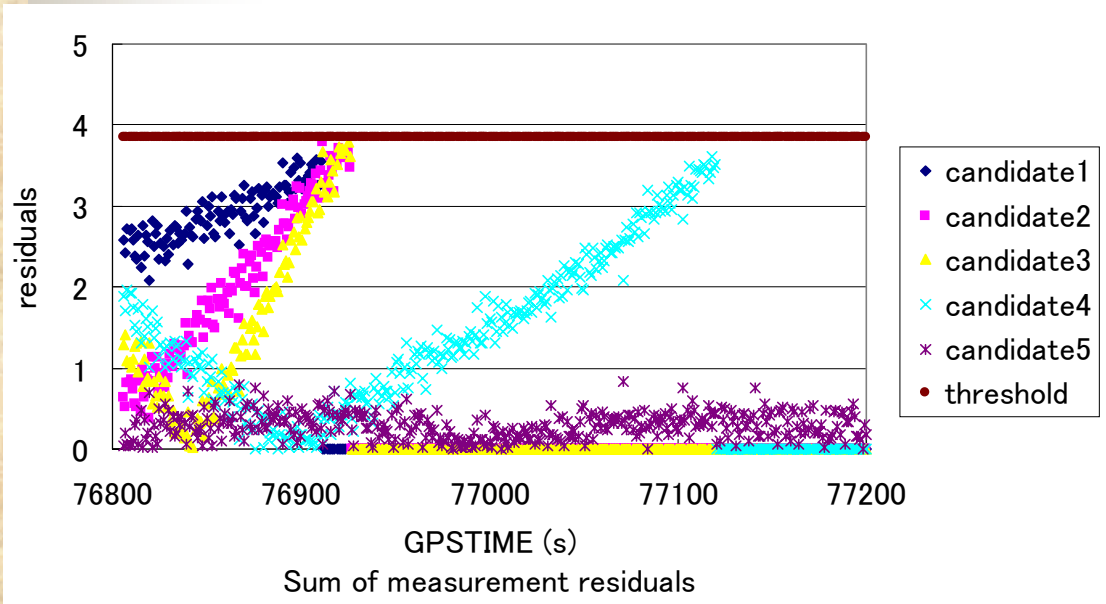
Difference (Blue Line) is between horizontal DGPS positioning and Horizontal wide-lane positioning

Cases of Wrong Fix



Large fluctuation due to code multipath

Ambiguity range determination fails



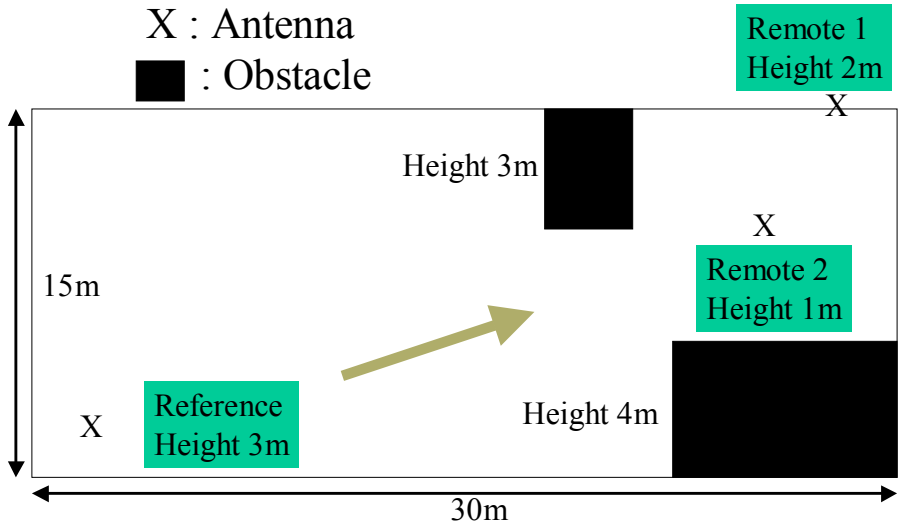
It takes a lot of time to fix due to insufficient satellites

Ambiguity resolution will fail due to carrier phase multipath if the residuals of correct ambiguity candidate exceeds the threshold

Static field test

1. Test under relatively many visible satellites (2/8/2003 12:00-15:00 JST)
   remote station 1 and 2 (Receiver:NovAtel RT-2　Antenna:GPS600)
2. Test under relatively few visible satellites (18/8/2003 0:30-3:30 JST)
   remote station 1 and 2 (Receiver:NovAtel RT-2　Antenna:GPS600)

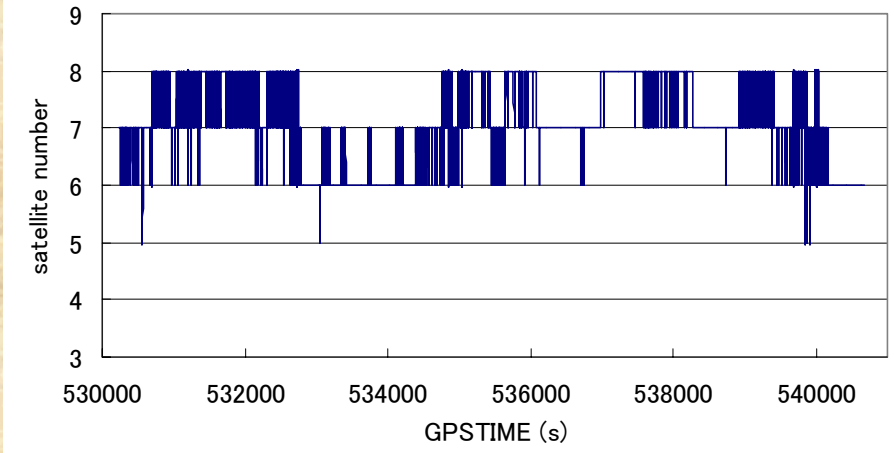
View from the reference



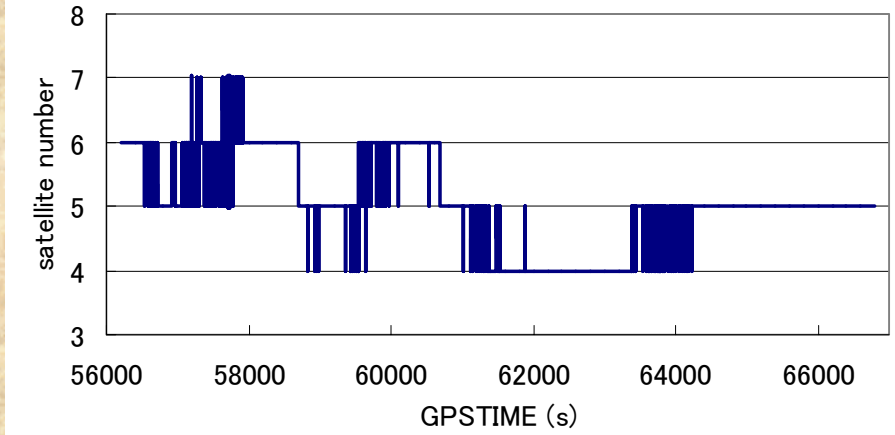
The outline of the rooftop

Configuration

Comparison of satellite number in two periods (Mask: 15degrees)



Under many satellites case
Almost: 6,7,8
Occasionally: 5



Under few satellites case
Almost: 4,5,6
Occasionally: 7

Ambiguity fix statistics

Station	1	2
Cases	6	37
Fix	6	27
over 300 sec	0	0
Wrong Fix	0	4
Unfix	0	6
Average	7.7	7.1
Under 5	0	0
Fix percentage	99.8	80.2

Station	1	2
Cases	4	108
Fix	4	18
over 300 sec	0	0
Wrong Fix	0	26
Unfix	0	64
Average	5.8	5.1
Under 5	0	2196
Fix percentage	97.2	60.3

Total 10800 epochs

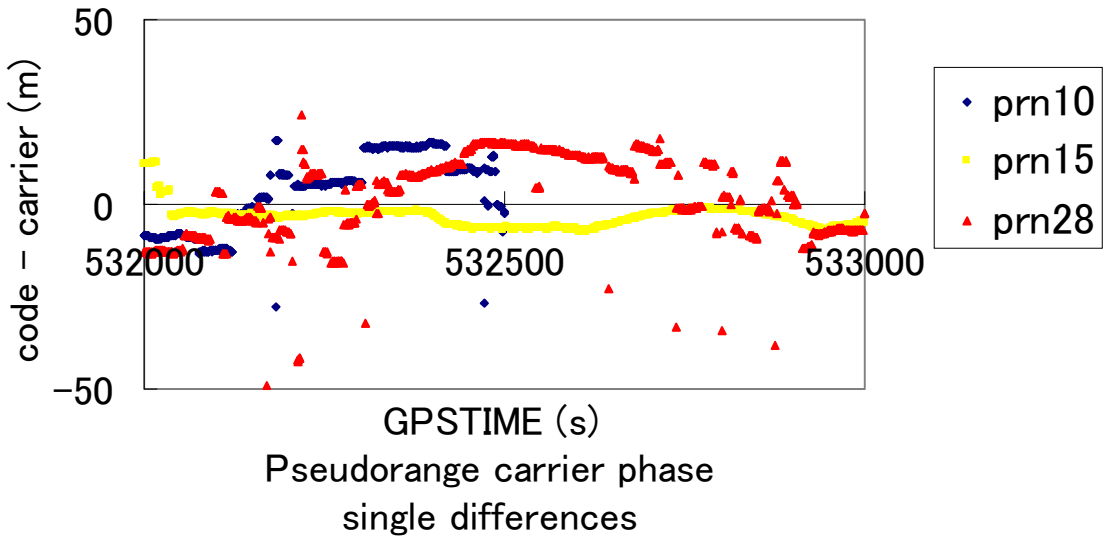
Under relatively many satellites

Under relatively few satellites

Detection and elimination of satellite contaminated by multipath (Under many satellites, remote station 2)

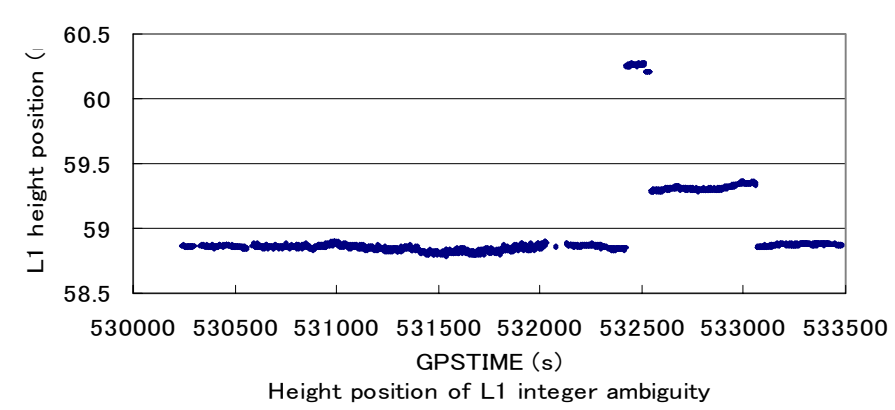
GPSTIME (532000-532500)

PRN	9,17,18,21,26	10	15	28
Cycle slips	0	49	8	89

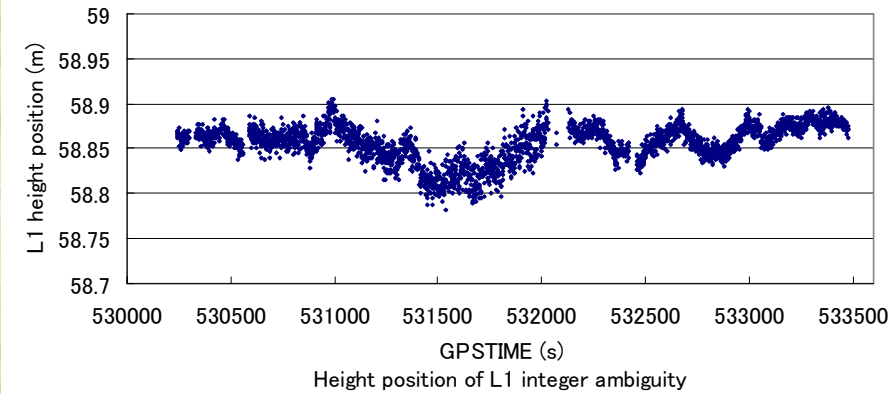


From two results, clearly PRN 28 is contaminated by multipath and this satellite should be removed primarily

Accuracy improvement (Under many satellites, remote station 2)



Without step of detection and elimination



With step of detection and elimination

After removing satellite contaminated by multipath using these criteria

1. Frequency of cycle slips
2. Value of Code-carrier

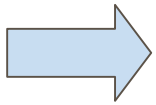
Correct fix percentage
80% → 89%

Correct fix percentage improvement (Under few satellites, remote station 2)

A lot of cycle slips caused low fix percentage and many wrong fixes

We change the criteria to choose 4 primary satellites.

1. Minimum RDOP



Priority of criteria

1. Frequency of cycle slips
2. Fluctuation of SNR
3. Minimum RDOP

It is possible to maintain primary satellite, but the validation has a chance of failure due to contaminated secondary satellite

We make much of maintaining of primary satellite because we can't move the step of the validation if the primary satellites aren't set.

Correct Fix percentage 60% ⇒ 79%

Kinematic field test

1. Test under multipath free condition (Rover1)
2. Test under multipath condition (Rover2)

Configuration

Rover2
Pond in our university
(multipath condition)
1/8/2003 10minutes

Rover1
Ground in our university
(multipath free condition)
29/7/2003 30minutes

Test Field Picture

Pond in our university
(multipath condition)

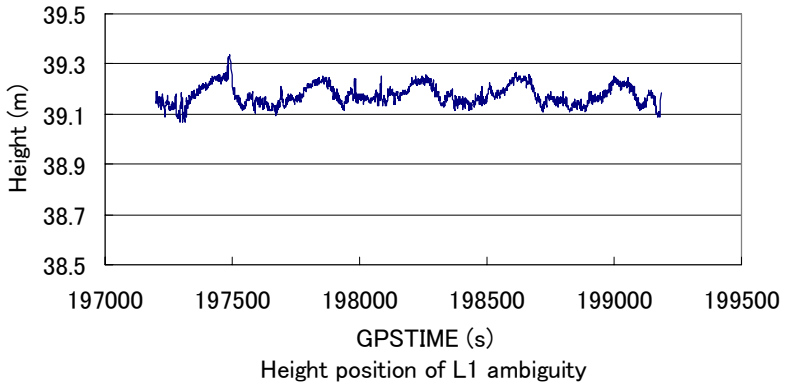
Ground in our university
(multipath free condition)

We walk around the pond or ground track pushing the vehicle

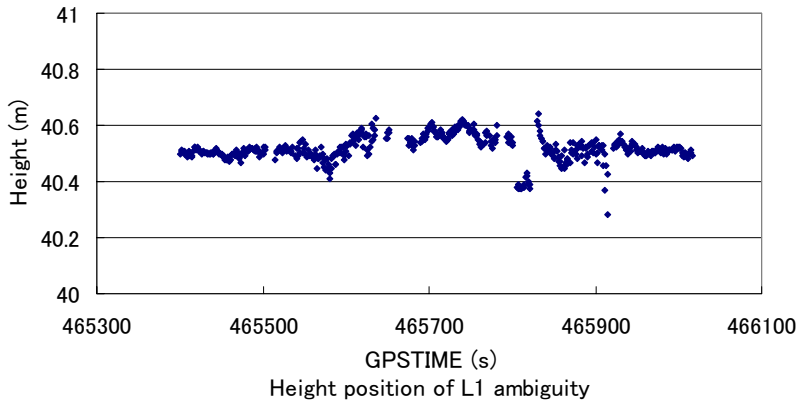
Height and ambiguity fix statistics

Ambiguity fix statistics
Rover1: 2000epochs
Rover2: 620epochs

Rover station	1	2
Cases	2	23
Fix	2	11
Fix (over 300sec)	0	0
Wrong Fix	0	3
Unfix	0	9
Average Satellite	6.0	6.7
Under 5 satellite (epochs)	0	13
Fix percentage (%)	97.7	88.7

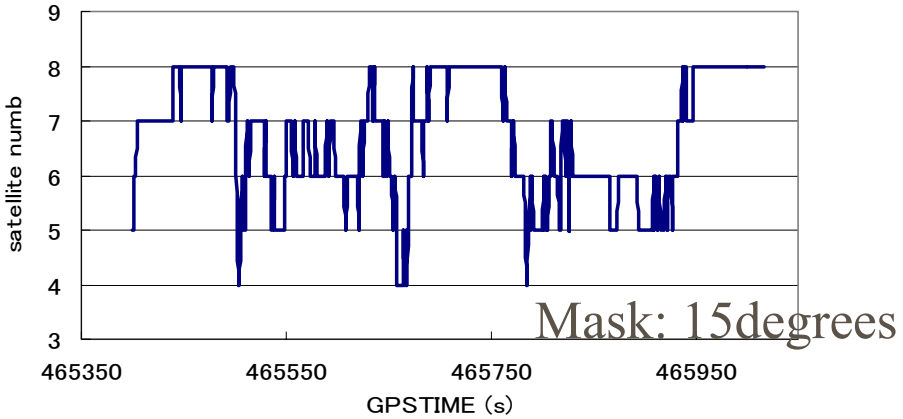


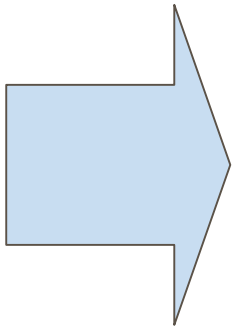
Height (Rover1:Ground)

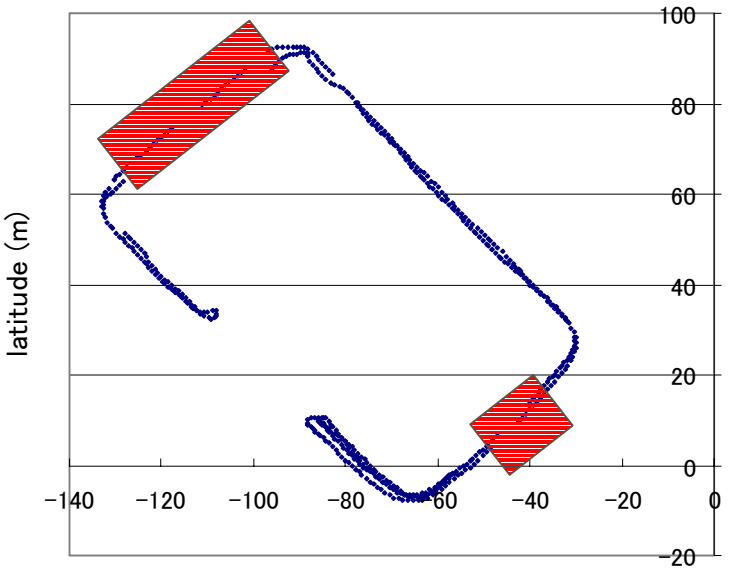


Height (Rover2:Pond)

Multipath conditions in the pond







Horizontal position of L1 ambiguity

Summary

- The effects of the multipath fails integer ambiguity resolution
- More satellites are available, detection and elimination of satellite contaminated by multipath is very effective for ambiguity resolution. There is a room for development the method
- Under many visible satellites without frequent change of satellite, current RTK can provide practical service
- Under few visible satellites, it is important for ambiguity resolution to choose the primary satellites properly in this kind of our technique. It is still difficult for current RTK to provide practical service.
- In the case of moving rover under multipath condition, further research is necessary and alternative technique will also be required.

Thank you!