Satellite Selection Technique of RTK-GNSS in the Challenging Environments

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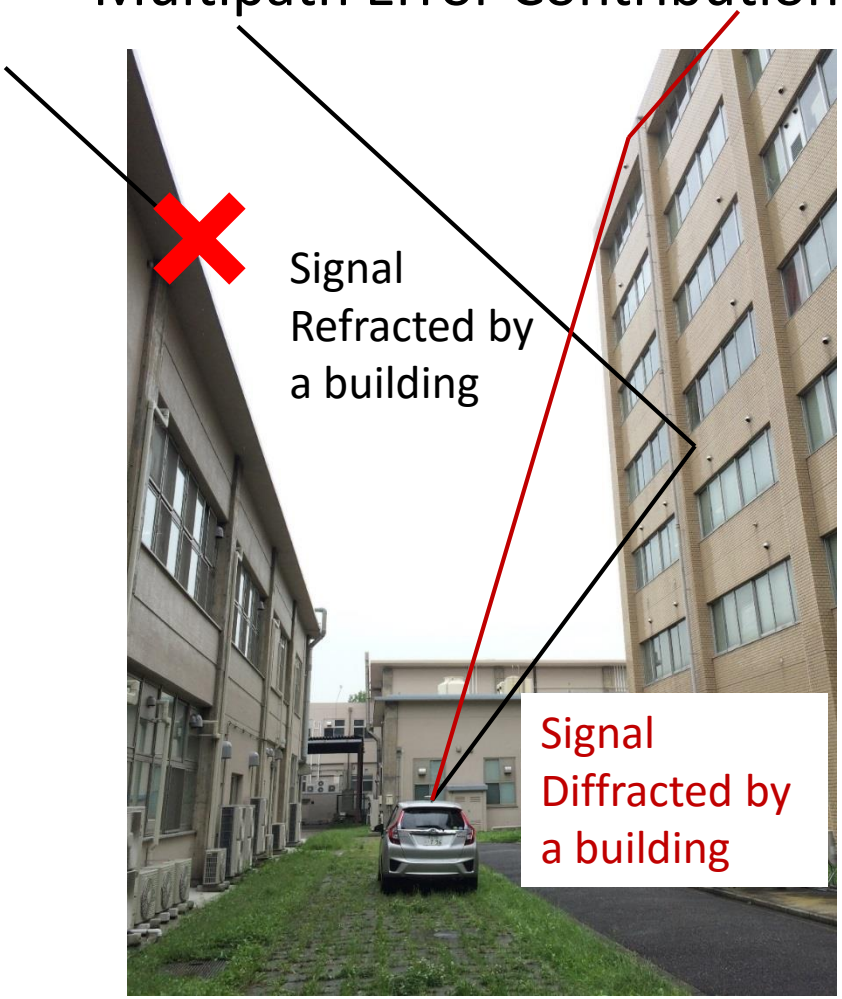
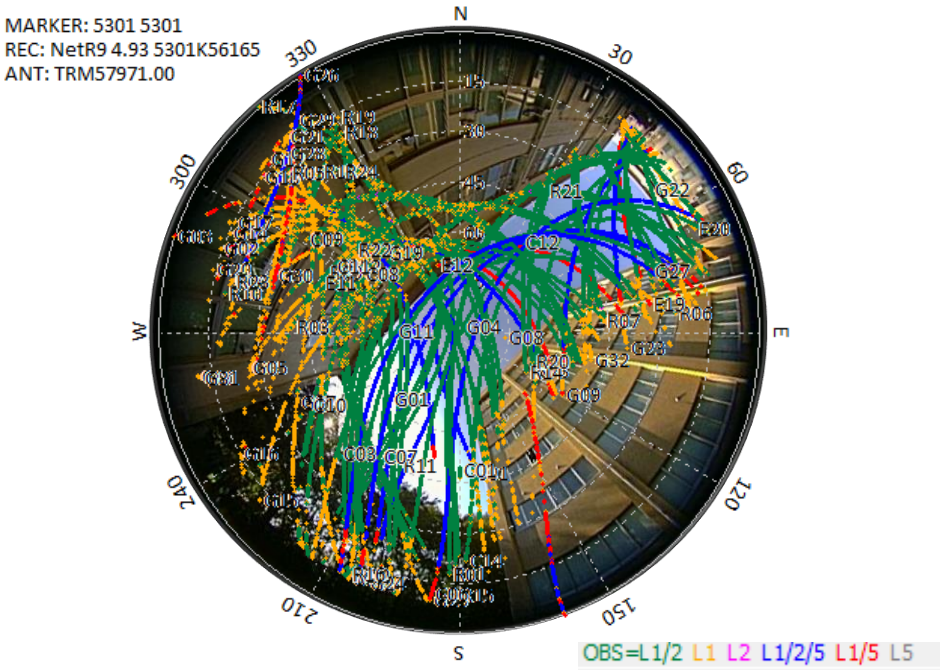
Outline

- Background and Objective
- Conventional Method
  - Based on C/N_0 Measurements quality check
- Proposed Methods
  - Based on Ratio value in the RAMBDA method
  - Based on Doppler measurements
- Conclusions

Background

Multipath Error Contribution



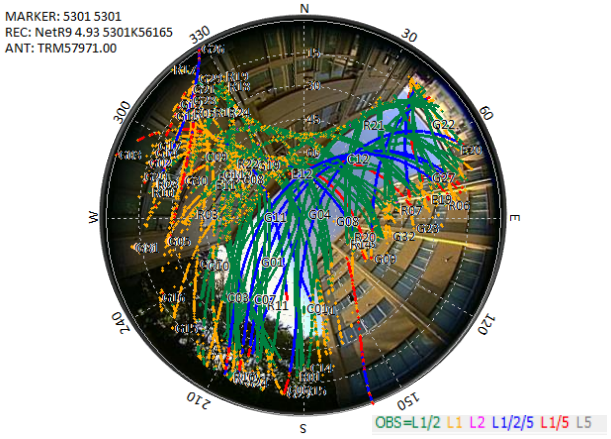


Multipath signal effect in RTK

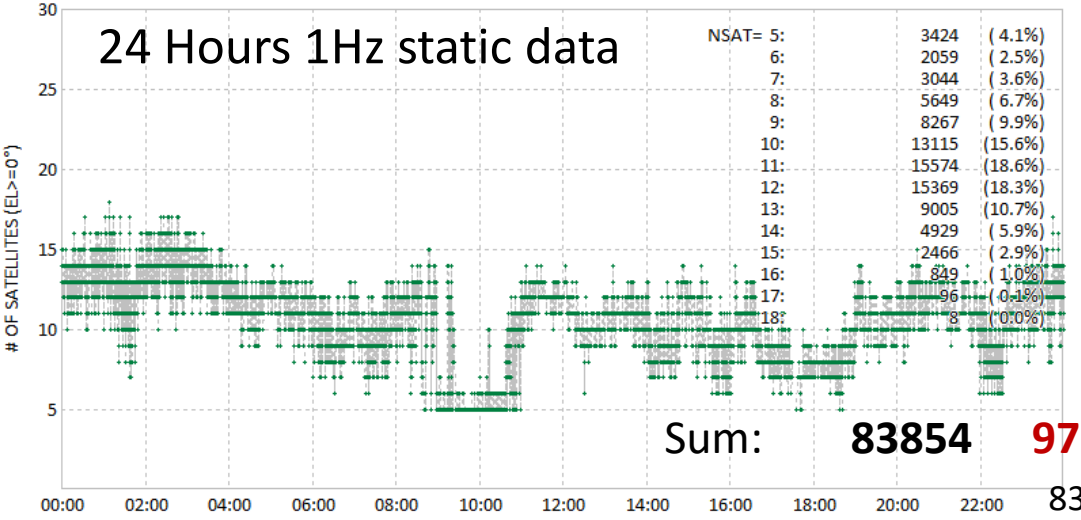
× Wrong Fix Solution

× Decrease Availability

Background



Time series of Number of satellites
(GPS, QZSS, BeiDou, GLONASS)



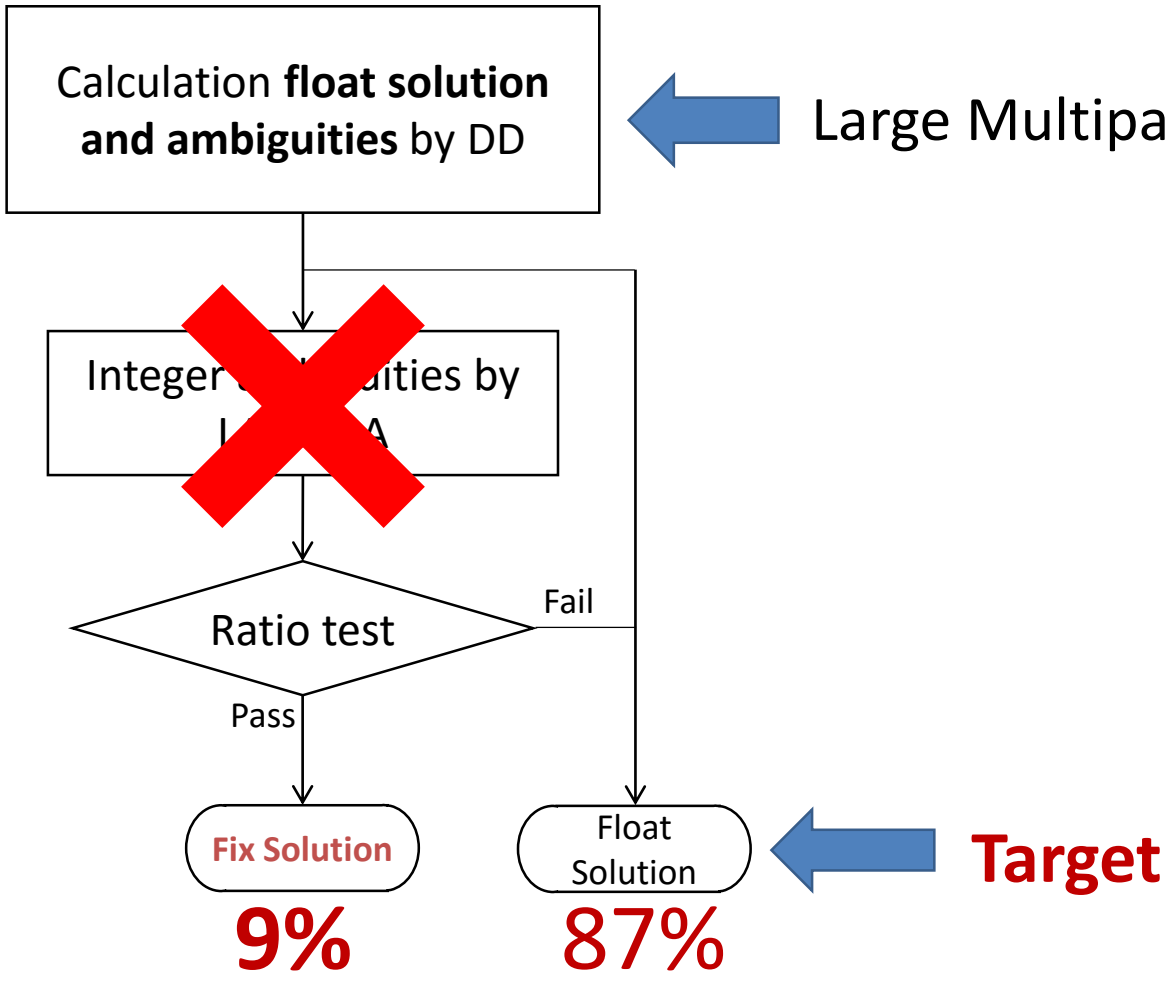
*Conditions : HDOP < 10, Elevation mask < 15

Fix Rate	Reliability (<0.1m)
8076 / 86400 **9.3 %**	7582 / 8076 93.9%

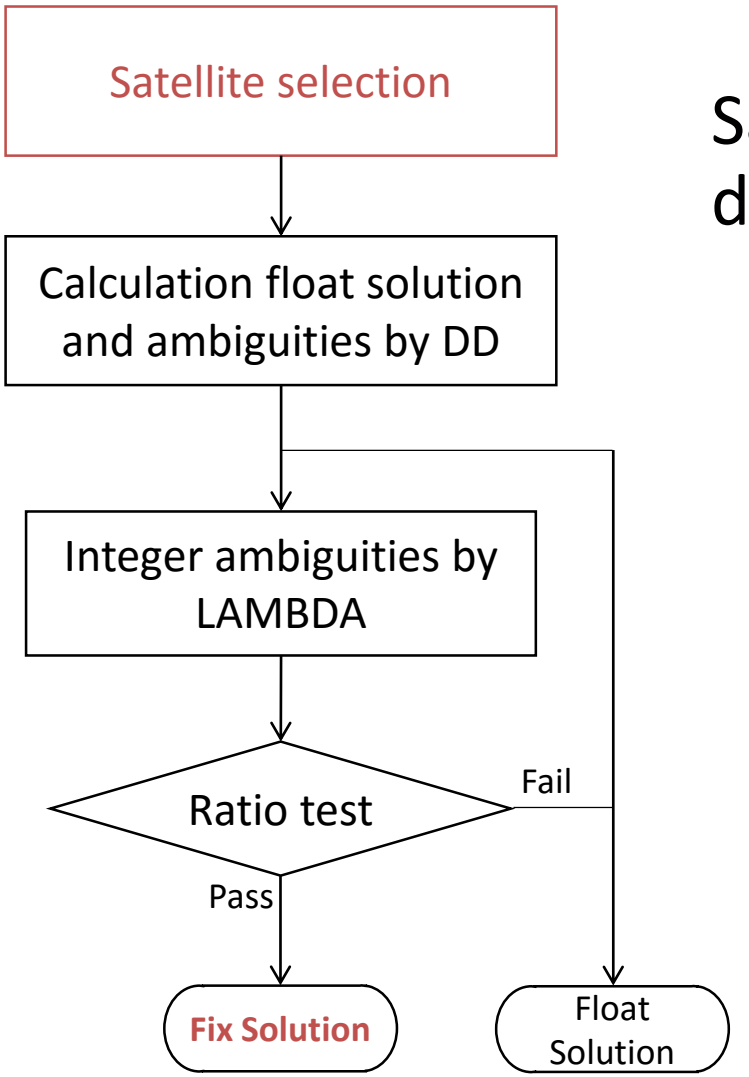
$$Reliability = \frac{Number\ of\ soluions\ within\ 10cm}{Number\ of\ Fix\ soluions}$$

Over 87% solutions are not able to obtain Fix Solution

Fix Rate (Ambiguity Resolution and Ratio test)



Objective

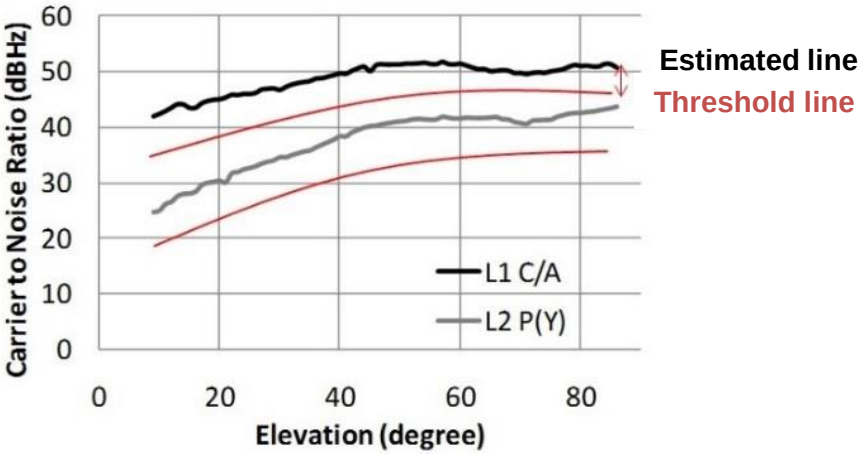


Satellites selection methods for detecting multipath signal

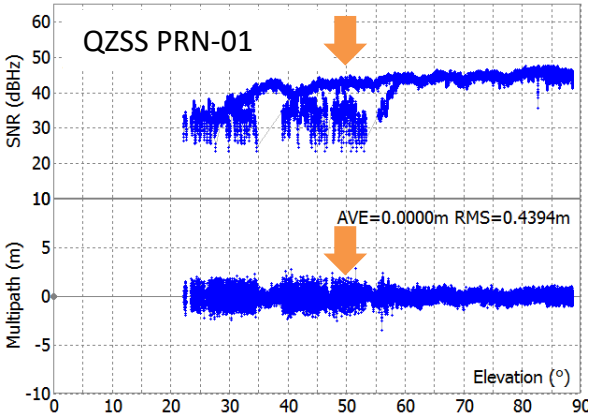
- Conventional Method
  - Based on C/N_0 Measurements quality check
- Proposed Methods
  - Based on Ratio value in the RAMBDA method
  - Based on Doppler information (for increasing availability)

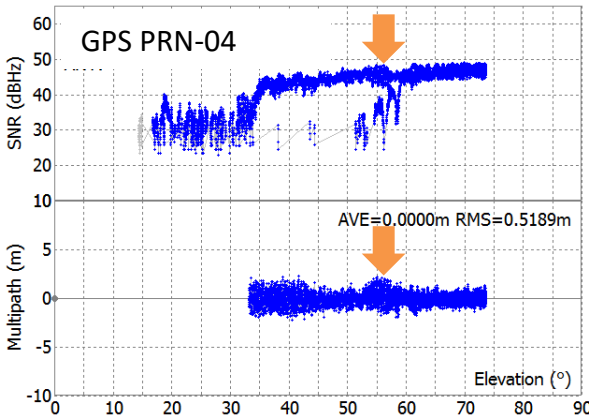
Conventional Methods
Based on C/N_0 Measurements quality check

Elevation-C/N_0 estimated line and Threshold line



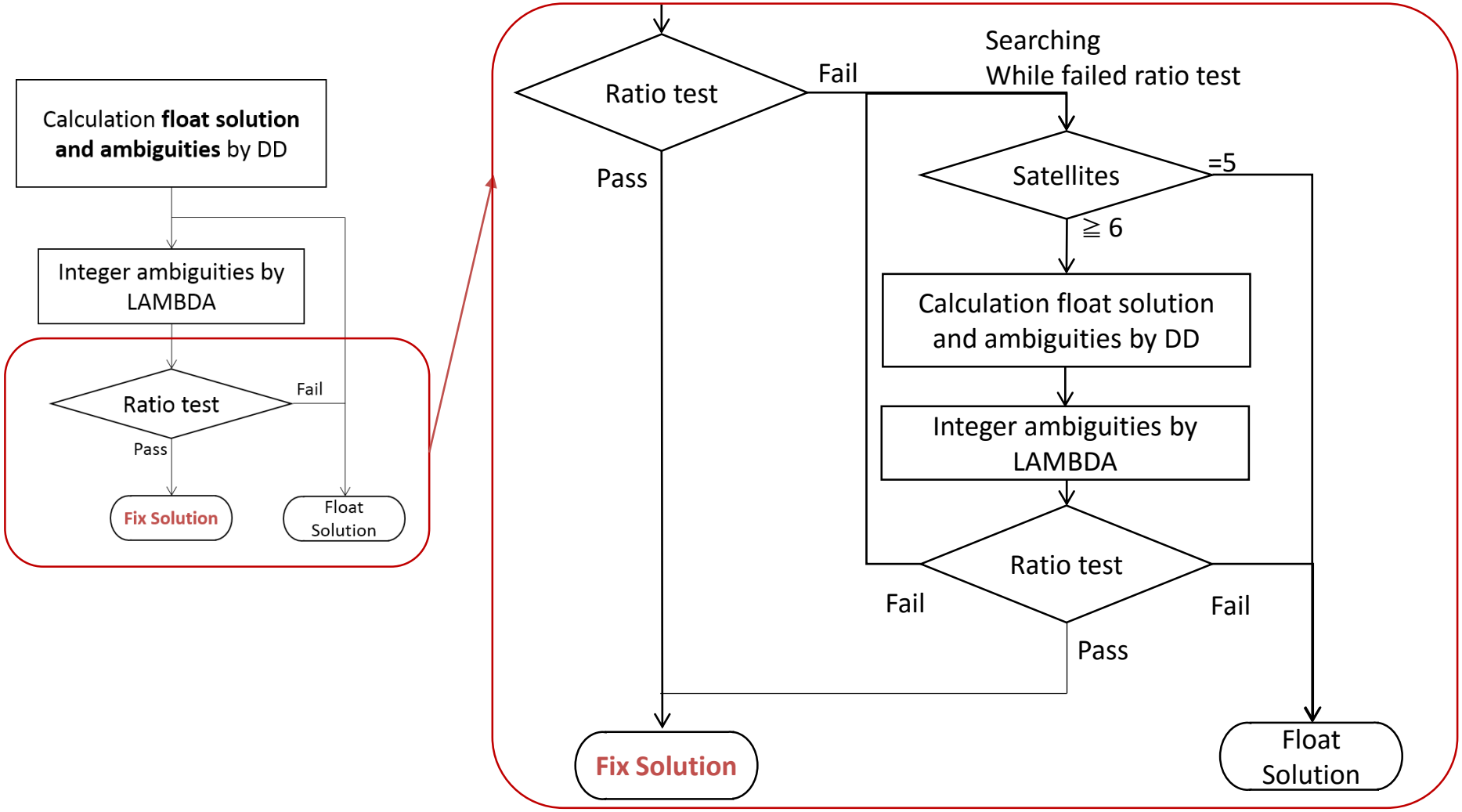
Examples of multipath effect in C/N_0





Checking C/N_0 Quality for detecting multipath signal

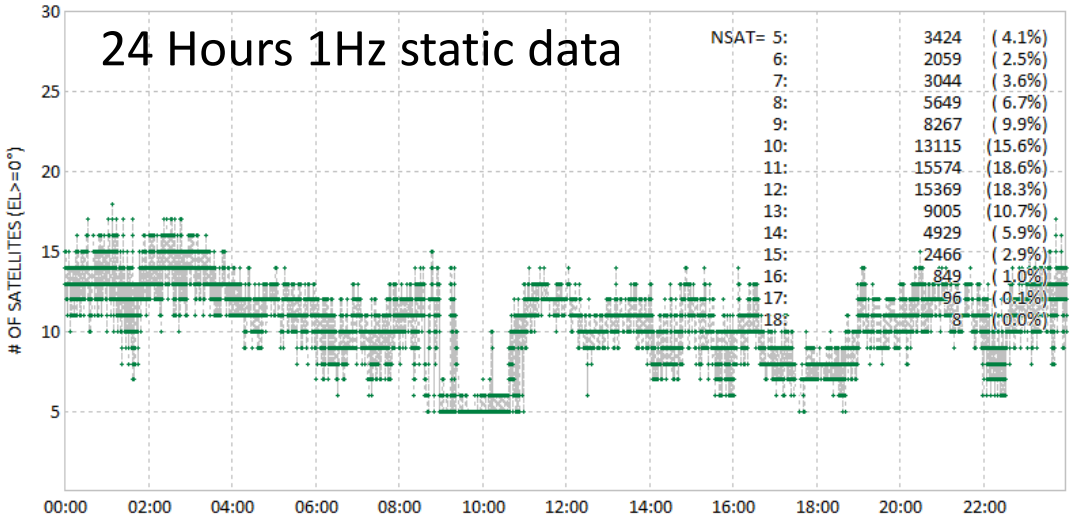
Proposed method
Based on Ratio value



Searching best satellites combination based on Ratio Value

Proposed method
Based on Ratio value

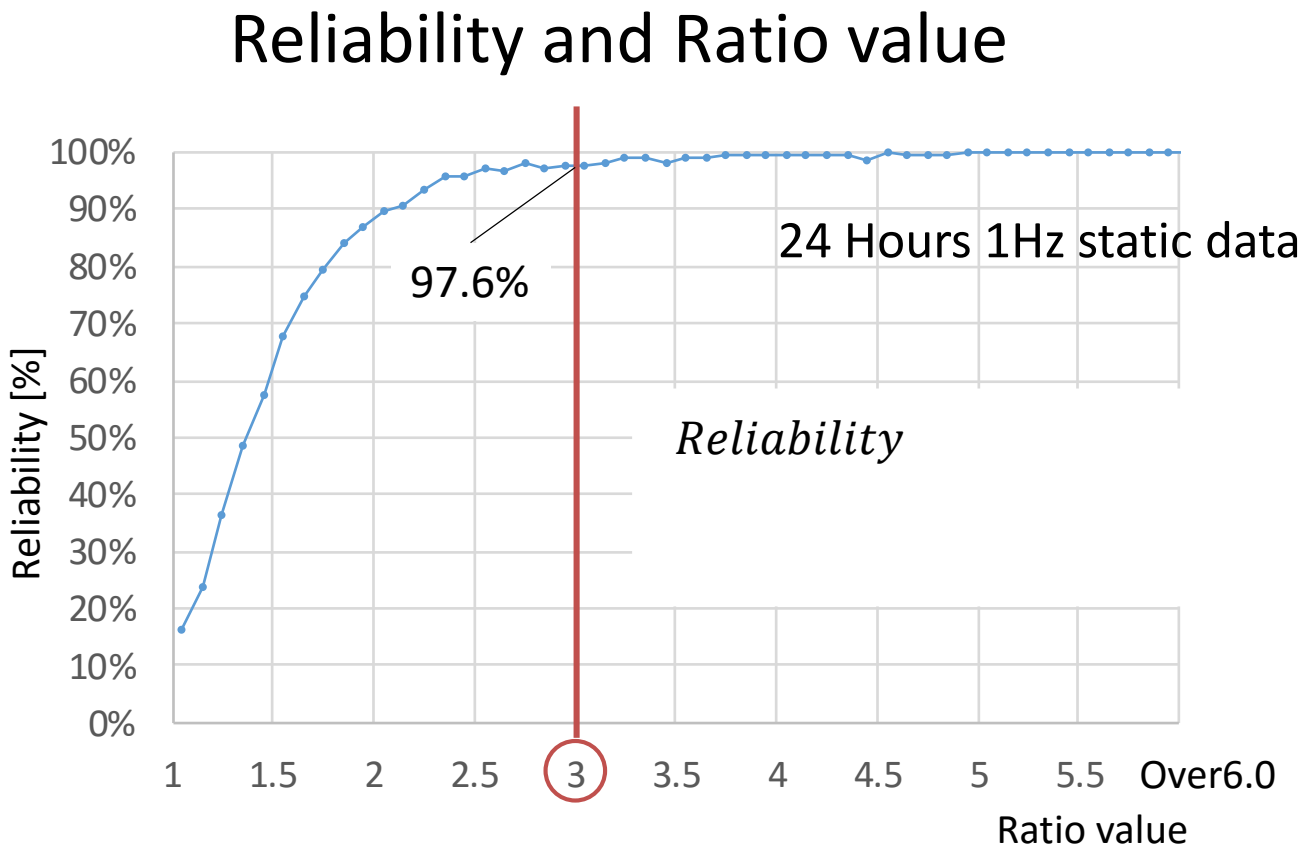
- Takes time to calculate



*Conditions : HDOP < 10, Elevation mask < 15

- Maximum number of satellites = 18
  ${}_{18}C_5$=8568
- Combination with conventional method

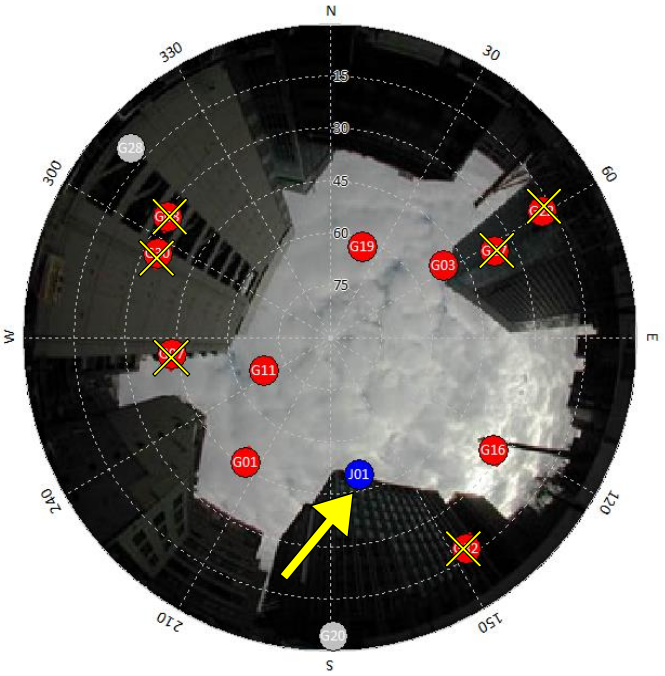
Proposed method
Based on Ratio value



High relationship between Reliability and Ratio value

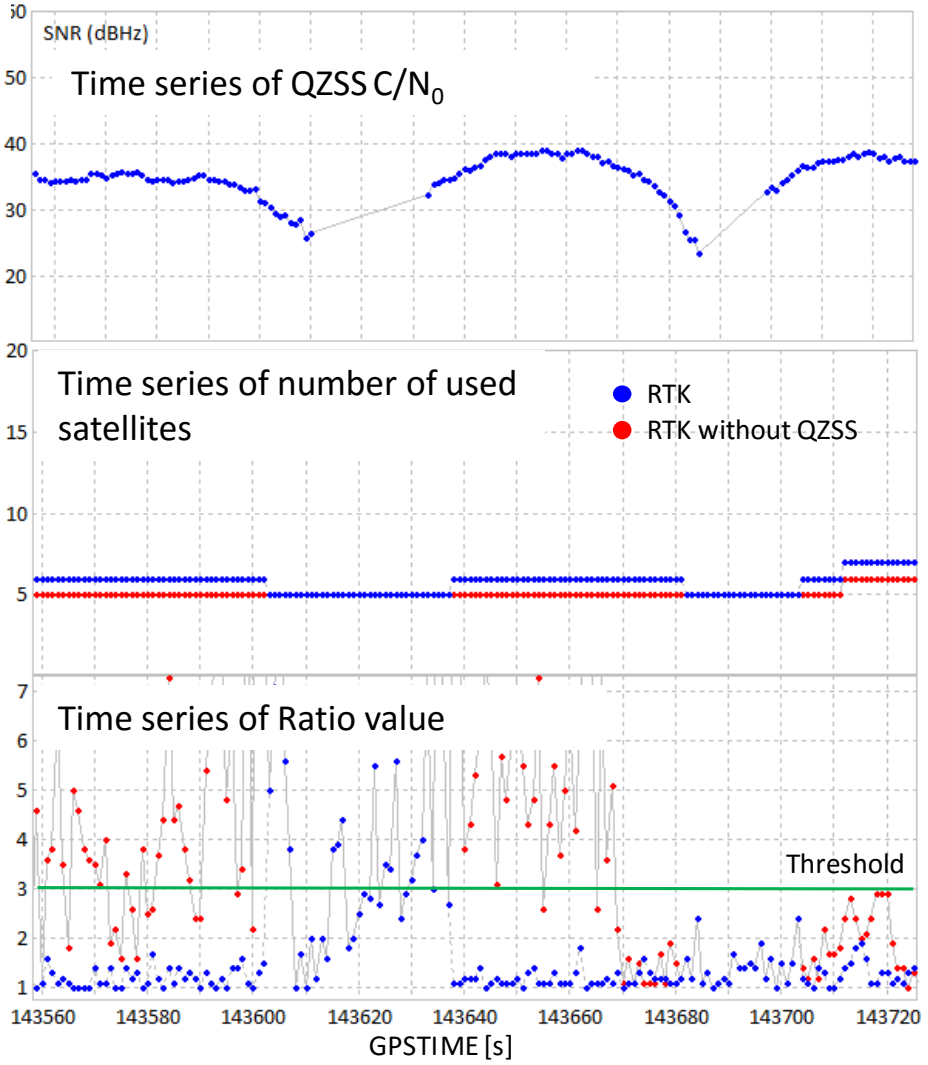
Proposed method
Examples of RTK affected by the diffracted signal

Satellite plot on Skyview



QZSS
(Dominant Multipath satellite)

Exclude Dominant Multipath satellite cause improving Ratio value



Proposed method
Based on Doppler measurements

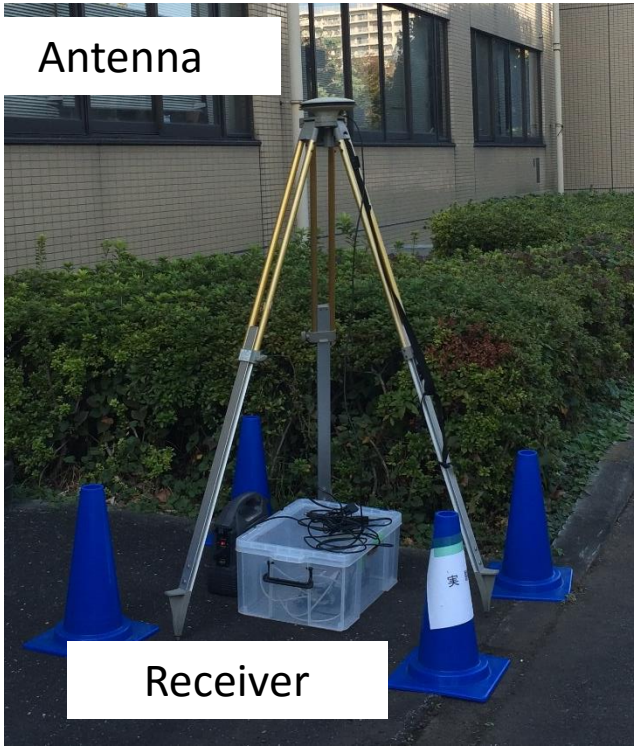
- To compare the Pseudo-range, Doppler measurements less contaminated by multipath
- Position integrated by Doppler measurements

- Once fix solution are obtained, use Fix solution and position integrated by Doppler measurements to Float solution for next epoch

Proposed Float solution= calculate by **previous Fix solution** and **Doppler measurements**

Doppler measurements were used for increasing availability

Testing and results
3 static trials condition



Point 1

1 High and 1 Middle high buildings

Point 2

1 High building

Point 3

2 Middle high buildings

Point1		Point2		Point3	
24h-1Hz Total 86400 Epoch		24h-1Hz Total 86400 Epoch		2h-5Hz Total 36000 Epoch	
Fix	Reliability (<0.1m)	Fix	Reliability (<0.1m)	Fix	Reliability (<0.1m)
8076 / 86400 9.3 %	7582 / 8076 93.9%	11680 / 86400 13.5 %	11322 / 11680 96.9 %	26778 / 36000 74.4 %	26734 / 26778 99.8%

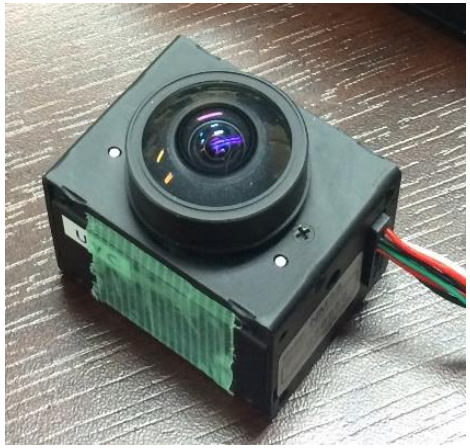
- ✓ Multi-GNSS antenna and Receiver
  - ✓ Surveying grade receiver
  - ✓ Double frequency
  - ✓ GPS/QZSS/BaiDou/GLONASS
- ✓ Reference position was calculated by Post process RTK-GNSS

Dual-Frequency RTK
AR：LAMBDA methods
Ratio test :3

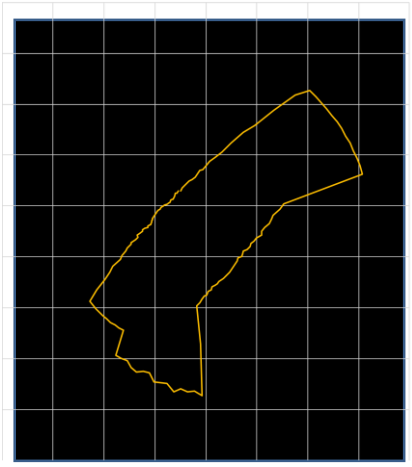
$$Reliability = \frac{Number\ of\ soluions\ within\ 10cm}{Number\ of\ FIX\ soluions}$$

Satellite Selection Based on Fisheye view

- To complete proposed methods, Fisheye view were used for exclude satellites



Fisheye view camera



Azimuth-Elevation Mask

Summery of results

	Point1		Point2		Point3	
	Fix	Reliability (<0.1m)	Fix	Reliability (<0.1m)	Fix	Reliability (<0.1m)
GPS/QZSS/GLONASS/BeiDou	8076 / 86400 9.3 %	7582 / 8076 93.9%	11680 / 86400 13.5 %	11322 / 11680 96.9 %	26778 / 36000 74.4 %	26734 / 26778 99.8%
C/N_0 Quality check	19508 / 86400 22.6 %	19125 / 19508 98.0 %	10890 / 86400 12.6 %	10593 / 10890 97.3 %	34949 / 36000 97.1 %	34949 / 34949 100.0 %
Ratio						
Cn8+Doppler	26990 / 86400 31.2 %	26309 / 26990 97.5 %	18311 / 86400 21.2 %	17080 / 18311 93.3z %		
Fisheye	13620 / 86400 15.8 %	13207 / 13620 97.0 %			35454 / 36000 98.5 %	35452 / 35454 100.0 %

Conclusion

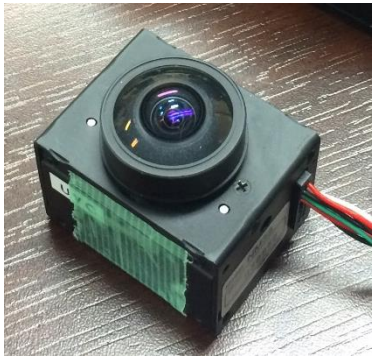
Thank you for kind attention!

Summery of results

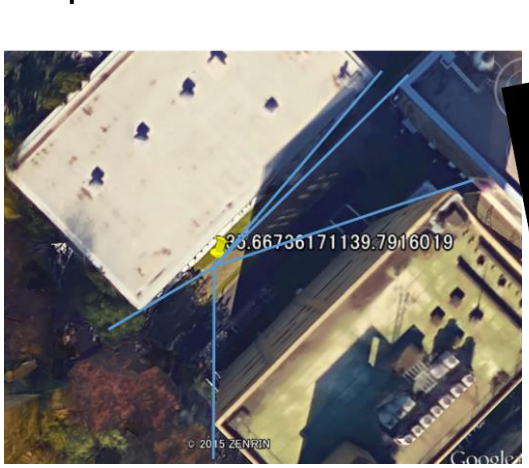
	Point1		Point2		Point3	
	Fix	Reliability (<0.1m)	Fix	Reliability (<0.1m)	Fix	Reliability (<0.1m)
GPS/QZSS/GLONASS/BeiDou	8076 / 86400 9.3 %	7582 / 8076 93.9%	11680 / 86400 13.5 %	11322 / 11680 96.9 %	26778 / 36000 74.4 %	26734 / 26778 99.8%
cn8	19508 / 86400 22.6 %	19125 / 19508 98.0 %	10890 / 86400 12.6 %	10593 / 10890 97.3 %	34949 / 36000 97.1 %	34949 / 34949 100.0 %
Ratio						
Cn8+Doppler	26990 / 86400 31.2 %	26309 / 26990 97.5 %	18311 / 86400 21.2 %	17080 / 18311 93.3z %		
Fisheye	13620 / 86400 15.8 %	13207 / 13620 97.0 %			35454 / 36000 98.5 %	35452 / 35454 100.0 %
Fisheye + Doppler	19895 / 86400 23.0 %	19109 / 19895 96.0 %			35652 / 36000 99.0 %	35650 /35652 100.0 %

Satellite Selection Based on Fisheye view

- To comprete proposed methods, Fisheye view were used for Exclude satellites.

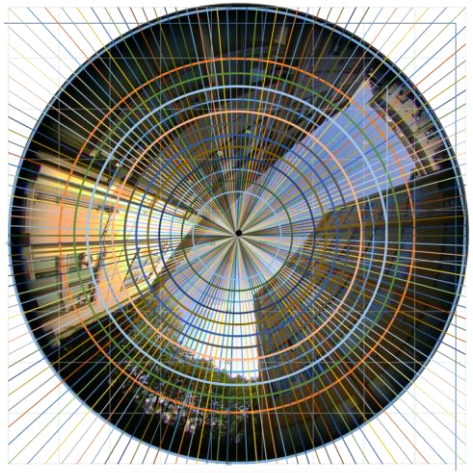


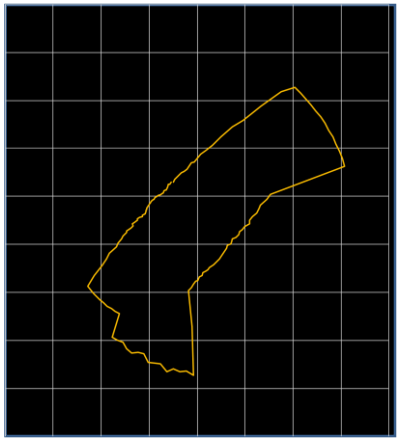
Step 1



Azimuth correction

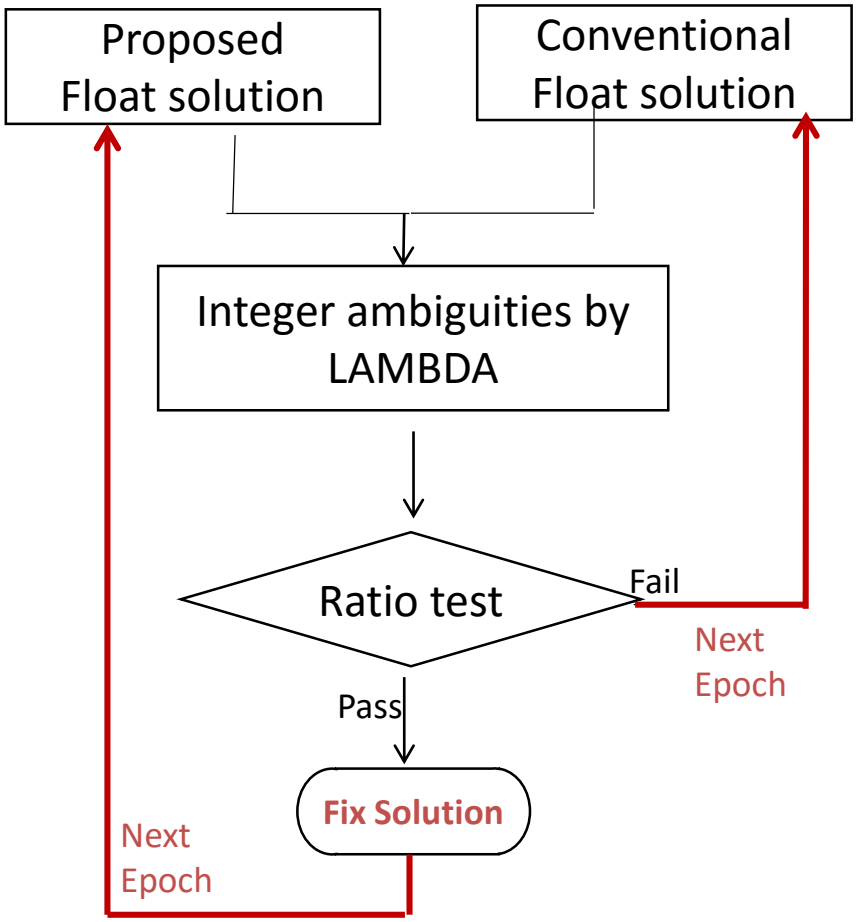
Step 2





Azimuth-Elevation Mask

Proposed method
Based on Doppler measurements



- To compare the Pseudo-range, Doppler measurements less contaminated by multipath
- Position integrated by Doppler measurements

- Once fix solution are obtained, use Fix solution and position integrated by Doppler measurements to Float solution for next epoch

Proposed Float solution= calculate by **previous Fix solution** and **Doppler measurements**

RTK-GNSS by Multi constellation