Multipath Mitigation Technique under Strong Multipath Environment using Multiple Antennas

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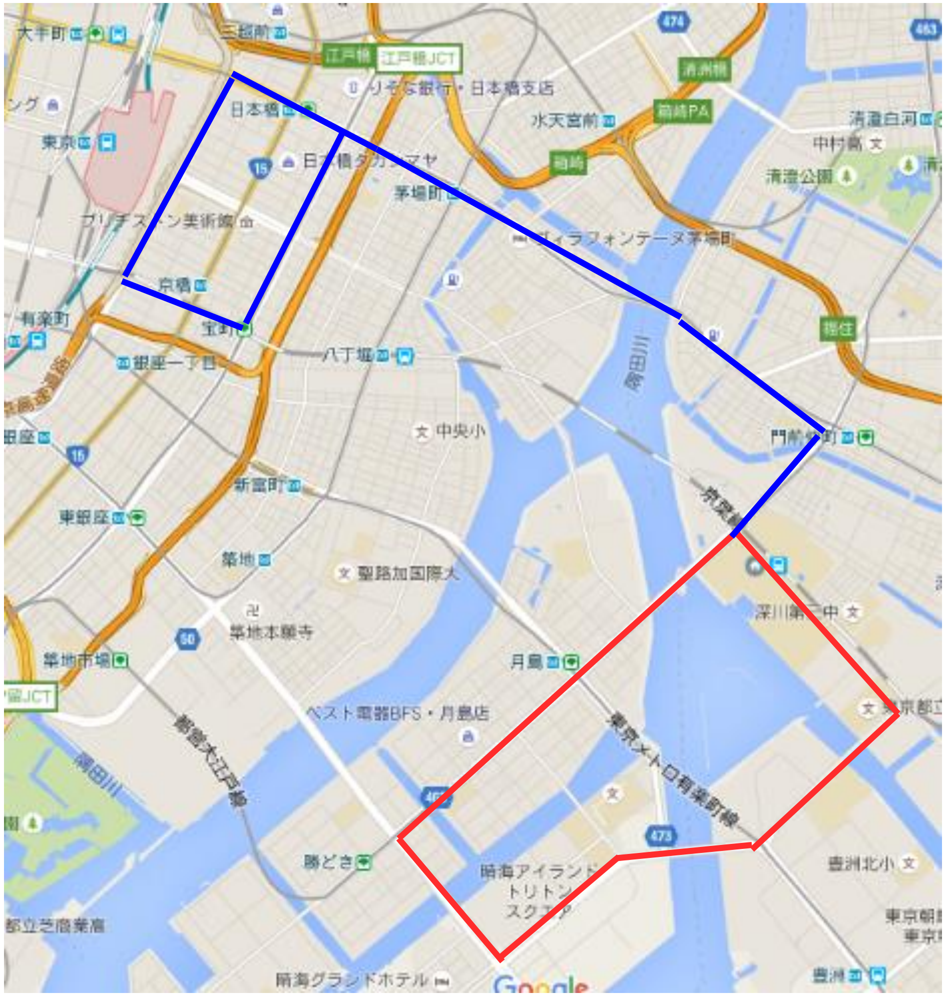
Outline

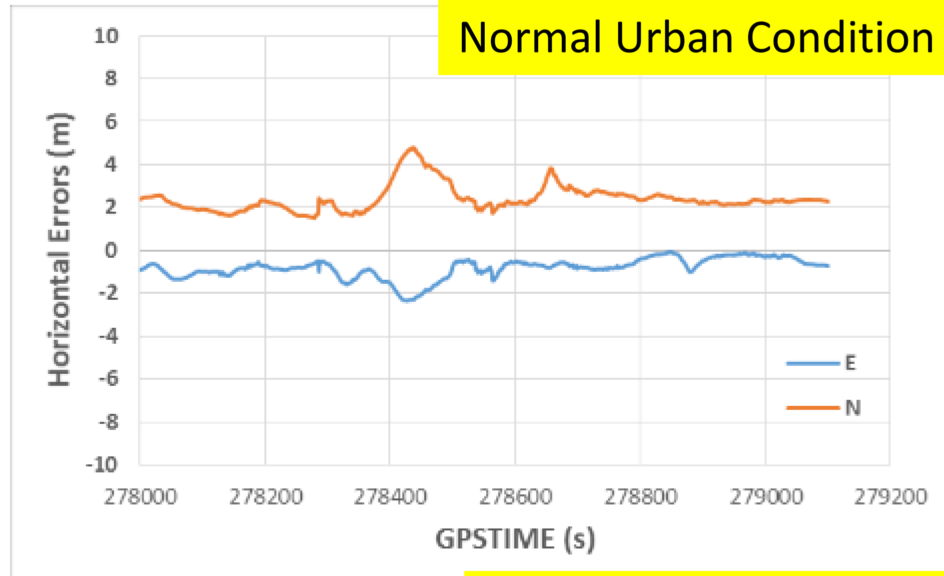
- Background and objective
- Multipath errors and speed
- Antenna motion test (static and kinematic)
- Newly proposed method
- Multiple antenna test (static)
- Conclusion

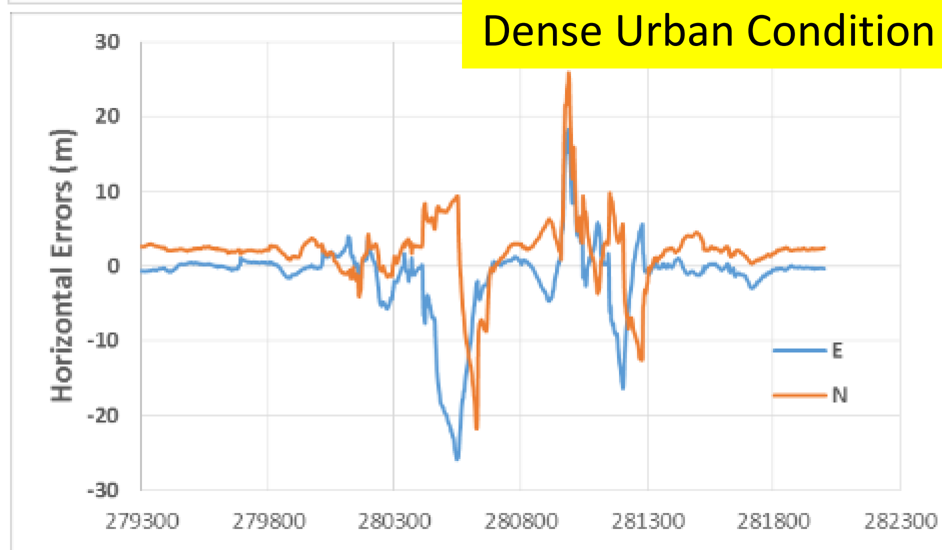
Background

- Future ITS services will focus on technologies for vehicles safety driving. The number of death while walking is significantly high in Japan (1444/4013 , 35%).
- GNSS is one of the candidates for these ITS services.
- Except for tunnel and long underpass, multipath is a major source of error in high precision GNSS.
- There are many important works related to multipath mitigation techniques.
- Even using these techniques, we still need to reduce multipath errors more.

Present performance of low-cost commercial receiver in urban areas (car)







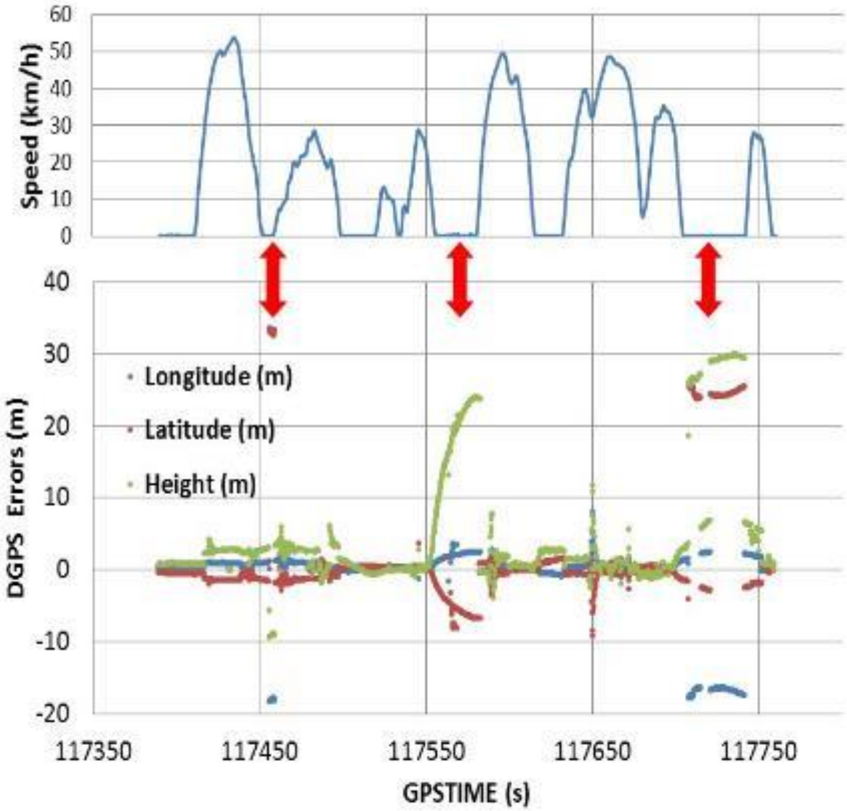
Single frequency multi-GNSS
Reference positions : POS/LV

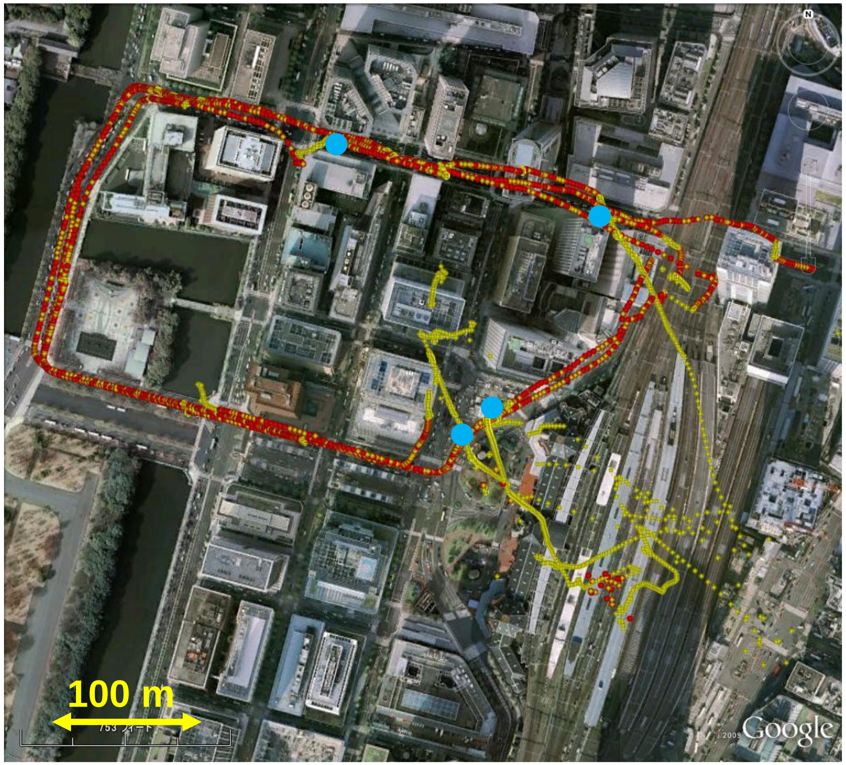
Objective

Our target : Maximum horizontal error within 1.5m of the car using <u>only low-cost single frequency GNSS receiver</u> under normal urban areas

- Consumer GNSS receiver
  - ✓Can provide several meters level horizontal positions with high availability
  - ✓Can provide raw measurements (Pr, Dp, Cp)
  - × Affected by strong multipath including NLOS
- Approach
  - ✓Mitigating strong multipath using a unique method

Multipath and Speed (only GPS)



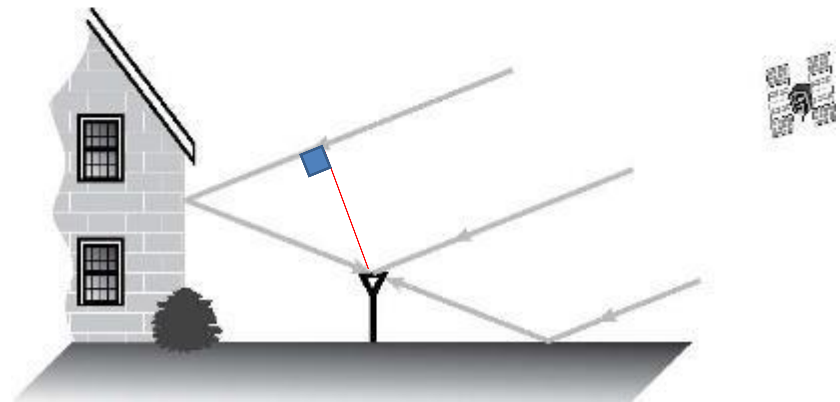


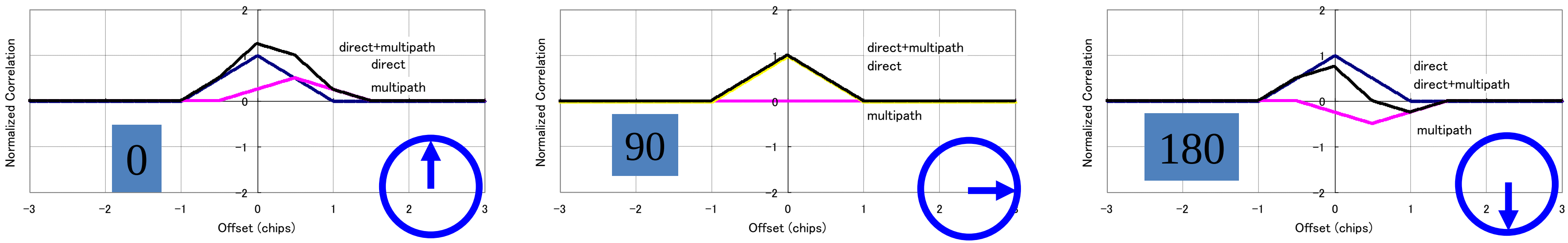
DGPS of Survey grade receiver in normal urban areas

Standalone positioning of low-cost receiver in dense urban areas

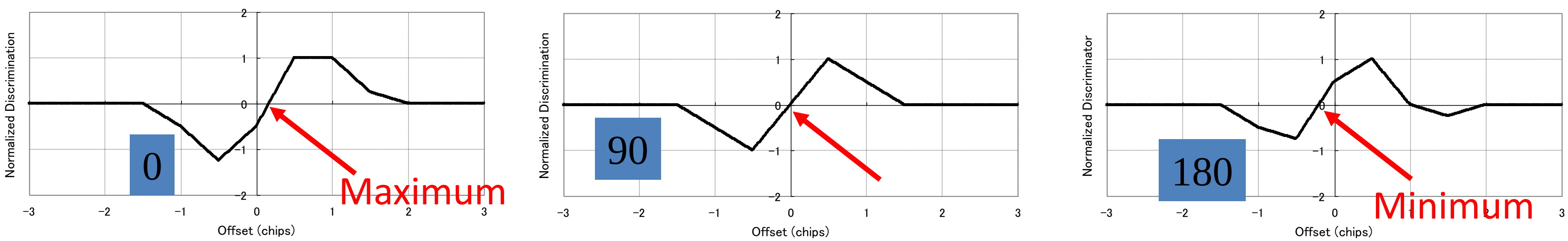
Why do we receive strong multipath ?

- The range measurement error due to multipath depends on the strength of the reflected signal and the delay (relevant to phase) between direct and reflected signals.

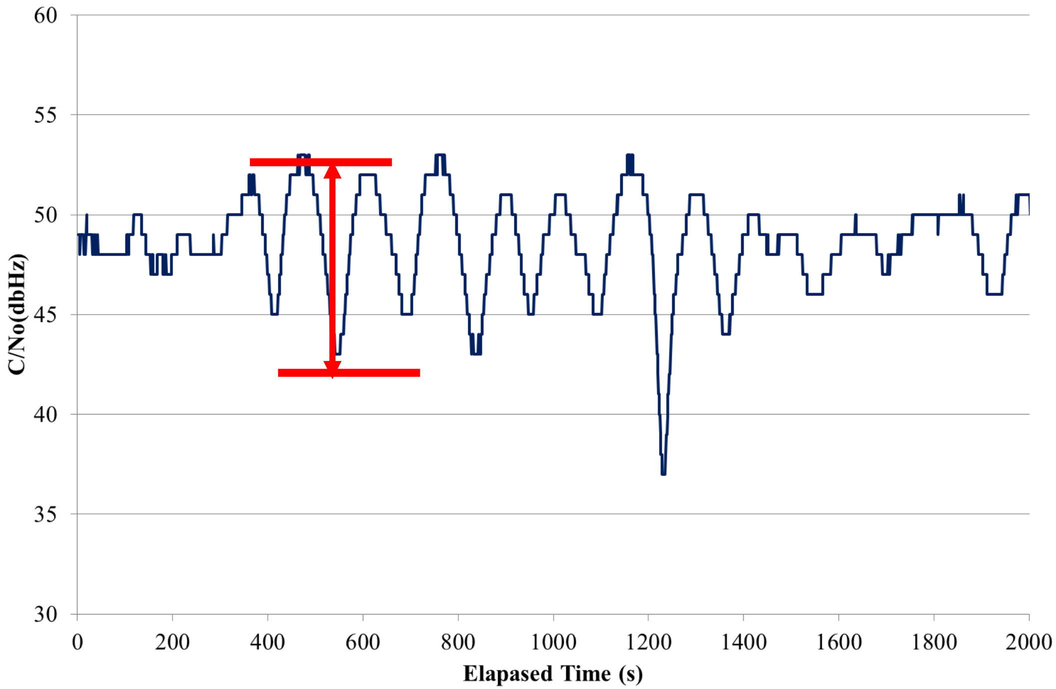




Delay = N*wavelength



Multipath errors at Zero Speed near building

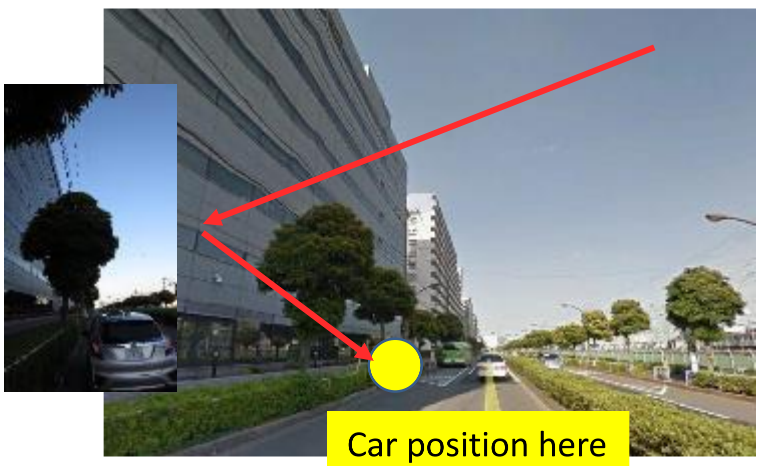


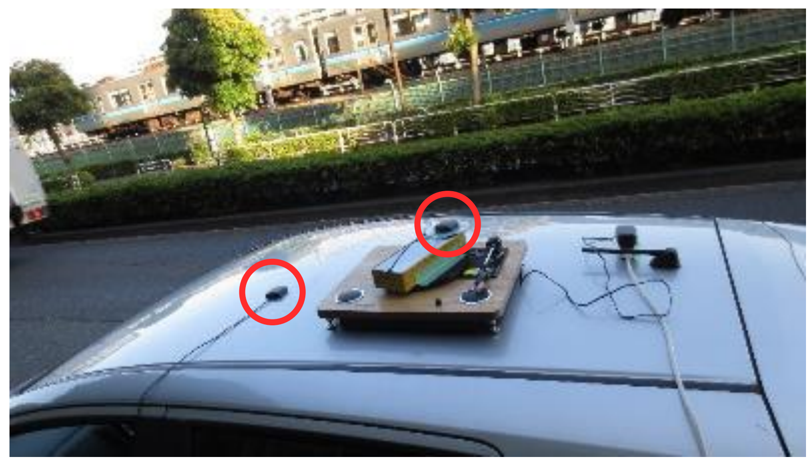
The satellite elevation and azimuth changes little by little.
→ the delay of the multipath changes **slowly**.
→ the phase of the multipath changes **slowly.**
→ we have the maximum errors due to multipath

It is easy for us to imagine that this kind of strong multipath can’t be received often when the car is moving (→ the phase of the multipath changes **quickly**).

Antenna motion test (static)

- We demonstrated the characteristic that standard GNSS receivers are vulnerable to multipath interference when the rover antenna is static. Then, **we attempt to use this characteristic to mitigate strong multipath errors**.



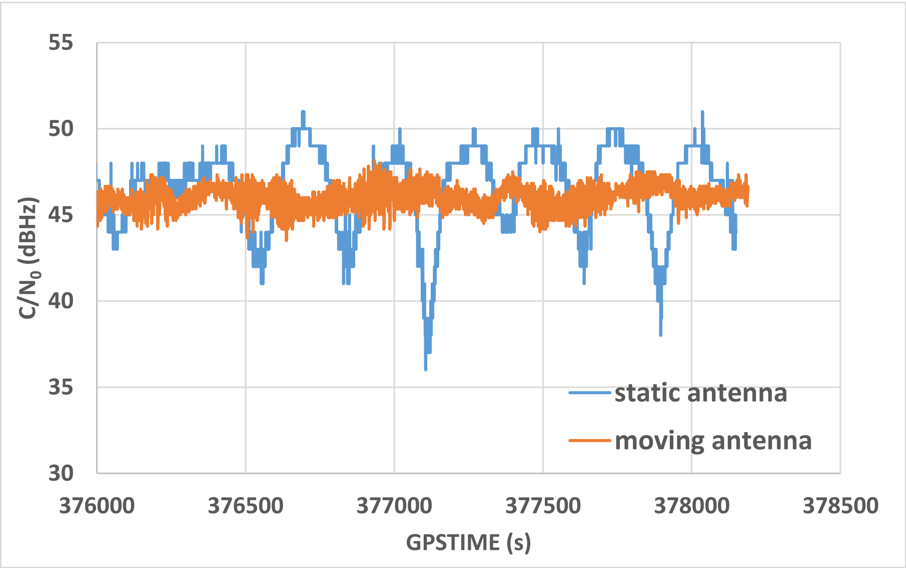


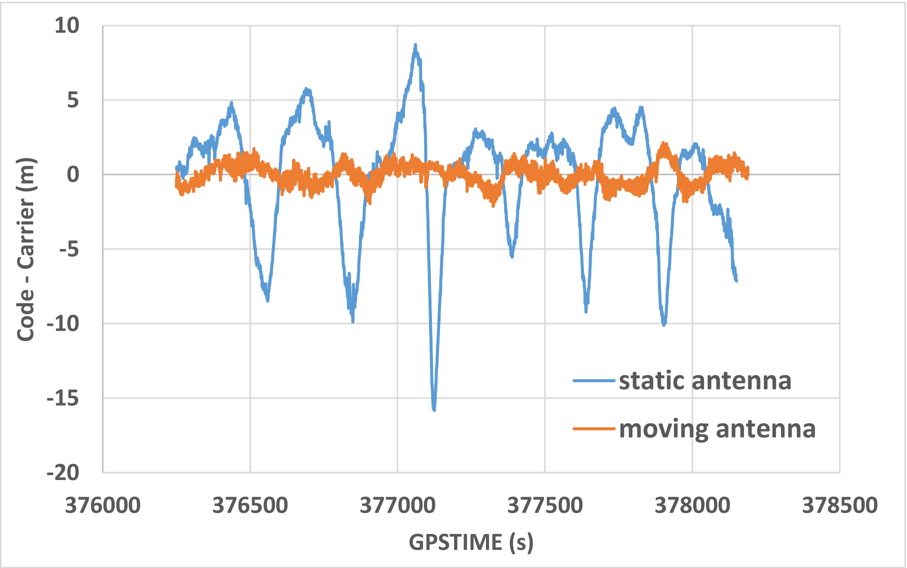
Record player
33.3/min.

Clear strong reflected signal (QZS) was received in this environment.

We investigated the difference between <u>static antenna and turning antenna</u> in terms of C/N_0 and code multipath.

C/N_0 and Code multipath



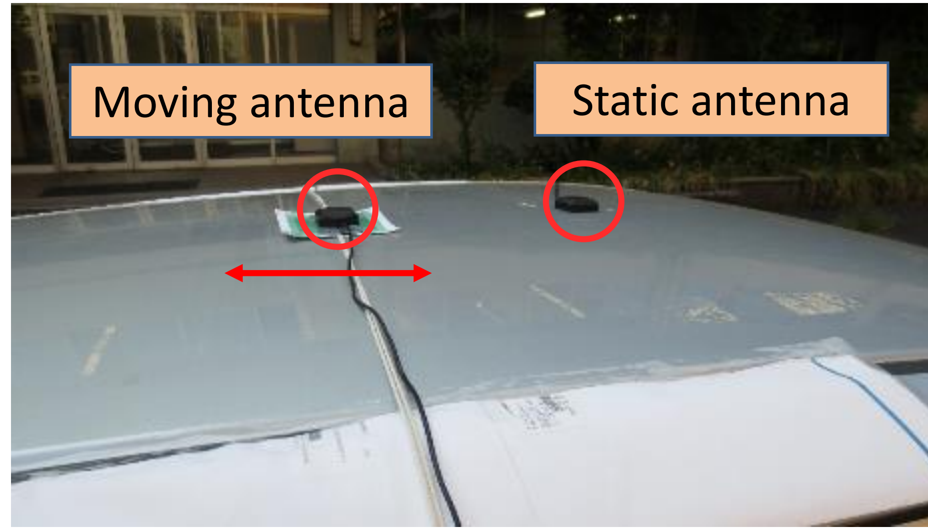


Both results show the distinct difference between static antenna and moving antenna.

The multipath error was mitigated heavily owing to the antenna motion.

Antenna motion test (kinematic)

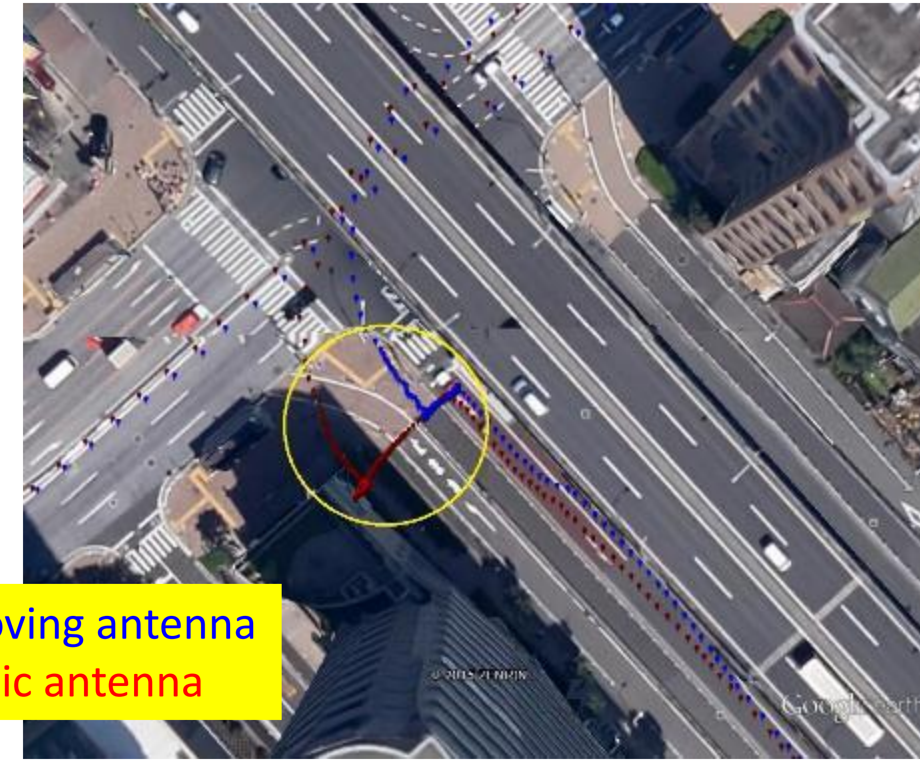
Test route (normal urban area)



While I was driving the car, my student shook the second antenna manually when the vehicle speed was less than approximately 5 km/h.

- Two low-cost same receivers (same configurations)
- GPS/BEIDOU/QZS
- 20 minutes test with 5Hz raw-data
- Reference positions : RTK-GNSS (Correct Fix rate over 90%) + FOG + Speed

Comparison of horizontal plots between moving antenna and static antenna (the car stopped at an intersection)



Blue plots : moving antenna
Red plots : static antenna

* Maximum deviation was approx. 6 m in red.
* The horizontal results of the moving antenna did not deviate in blue.

* Maximum deviation was approx. 15 m in red.
* Maximum deviation was approx. 5 m in blue.

Maintaining antenna motion can attenuate the effect of a strong multipath signal.
Velocity accumulation in the static antenna during this stop was approx. within 50 cm.

Newly proposed method

We have demonstrated that antenna motion is effective to mitigate multipath errors.

However….

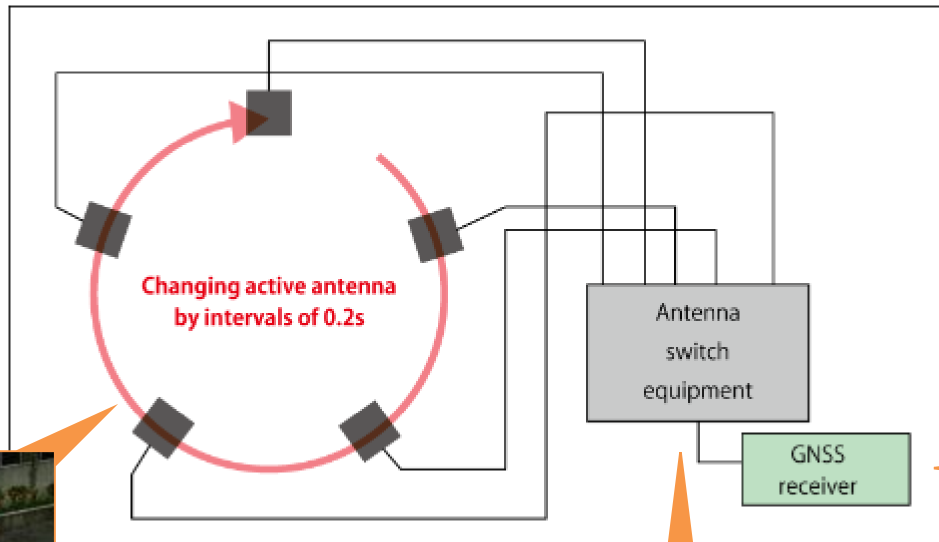
- Rotating record player
- Shake by hand → Not practical!

We propose a new method using multiple antenna.

- Changing active antenna and reproduce antenna moving virtually.

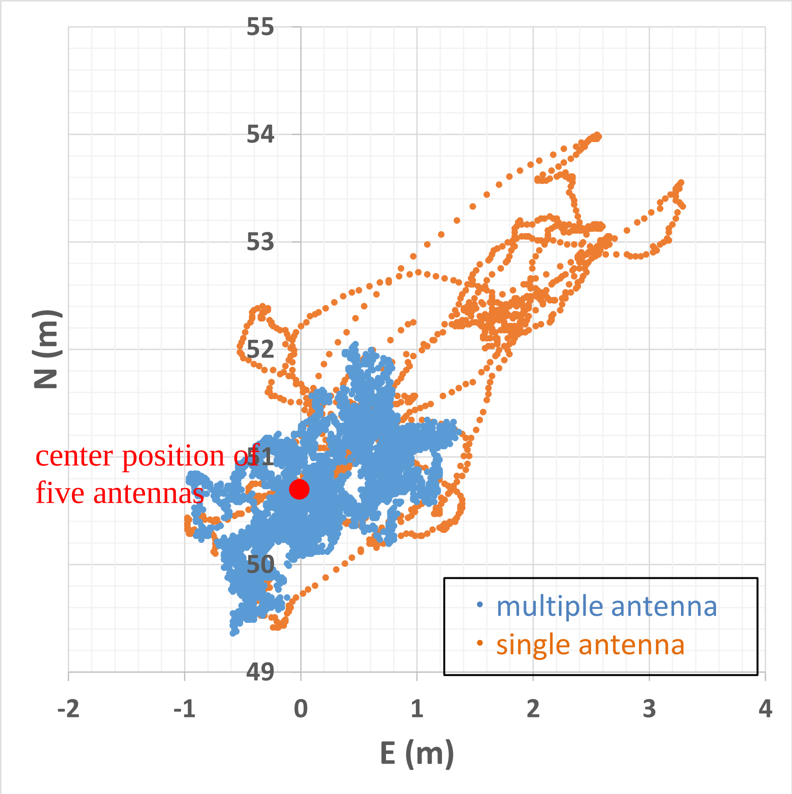
Multiple antenna system

We set 5 patch antennas and connect these antennas to rover receiver through the antenna switching devise. This enables the antenna looks moving.



Multiple antenna test (static)

We set 5 patch antennas on top of the car. Car is parking close to the concrete wall of the building.



Comparison of horizontal position by single positioning.

The maximum horizontal errors was reduced about 70 %.
This indicates that our proposed method can mitigate the large multipath errors when receiving direct signals as well as strong reflected signals.

Conclusion

We introduced several approach to mitigate strong multipath error.

- ✓GNSS receivers were vulnerable to multipath interference when the speed of the car was slow or zero.
- ✓By maintaining antenna motion, multipath errors were mitigated from over 15m to 1-2m.
- ✓we proposed a new approach to mitigate strong multipath errors in a practical way using multiple antennas with the antenna switching devise.
- ✓Even using popular low-cost receiver, our proposed method was effective to reduce large multipath errors.

Issues and Future work

Issues

- Multiple antenna can’t track carrier-phase .

  ➡ It might be hard to use on a car.

- This method is effective when receiving direct signals as well as strong reflected signals.

  ➡ The effective for NLOS reception is unknown.

Future work

- Investigate the relationship between an NLOS signal and the speed of a moving platform.
- Devise new technique to mitigate multipath error caused by NLOS.