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PERFORMANCE EVALUATION OF LOW-COST GNSS RECEIVER USING MADOCA CORRECTIONS WITH THE PRECISE POINT POSITIONING (PPP) MODE IN THAILAND.

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Outline

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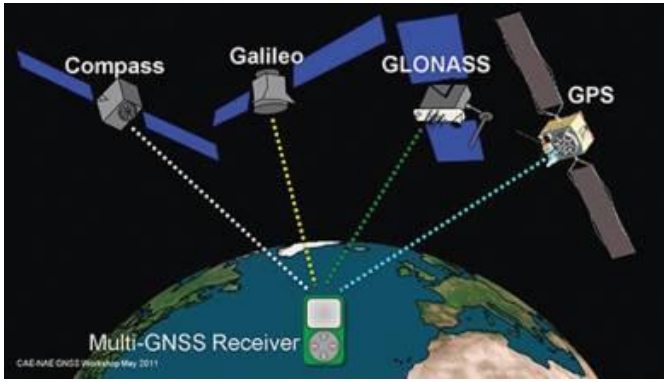
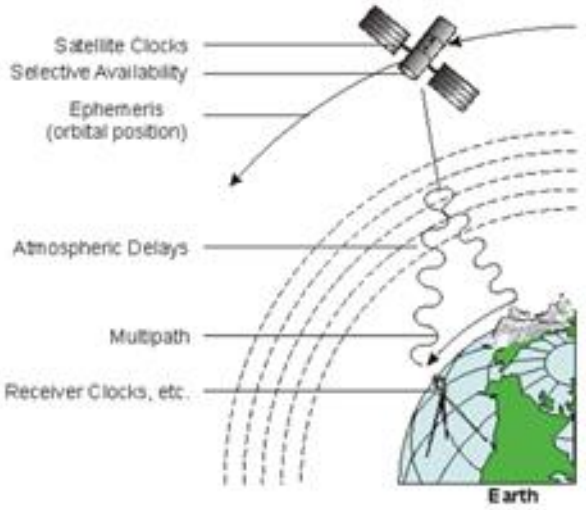
- BACKGROUND AND SIGNIFICANCE
-  MADOCA
- OBJECTIVES
- EXPERIMENTS
- RESULT AND CONCLUSION

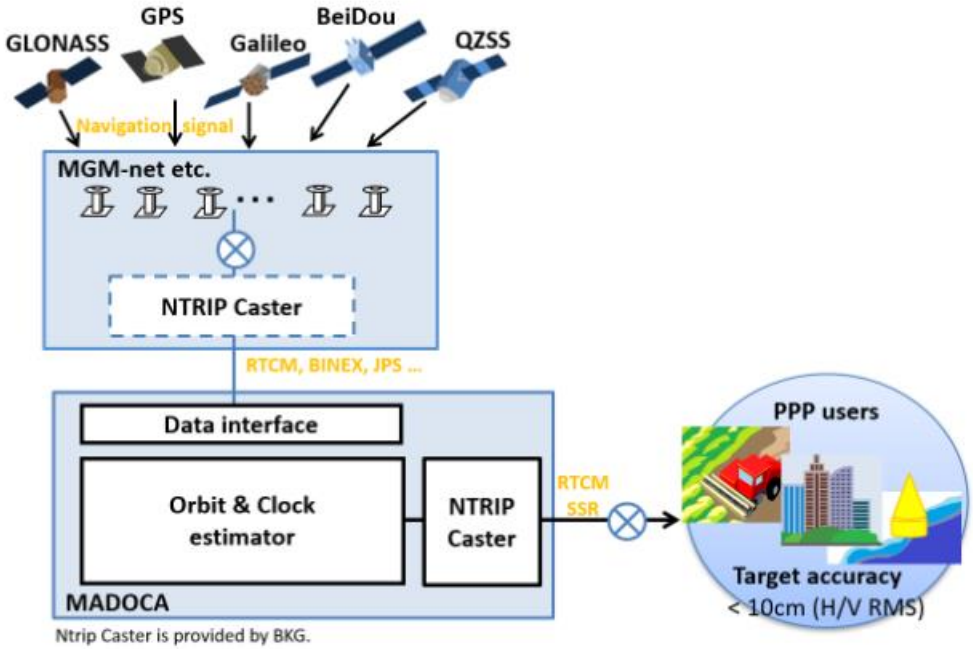
Background and Significance

- Increasing prevalence of Global Navigation Satellite Systems (GNSS) services for location determination especially in Precise Point Positioning (PPP).
- PPP is independently processing high-precision GNSS coordinates (Using the receiver only 1).
- The current PPP trend involves
  - GNSS data post-processing through software package or online service.
  - Real time PPP.
- Both of this 2 methods need the correcting some GNSS errors.





- In this study, we undertake PPP with high accuracy by using **MADOCA (Multi-GNSS Advanced Demonstration tool for Orbit and Clock Analysis)** corrections.



https://ssl.tksc.jaxa.jp/madoca/public/public_index_en.html

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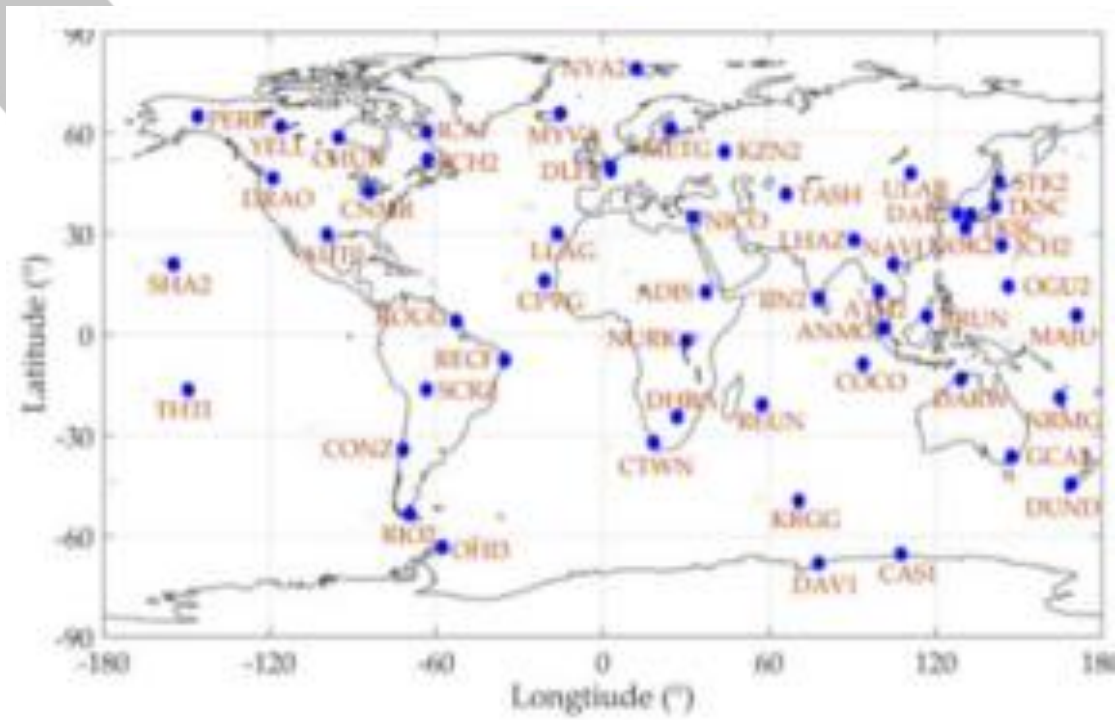
Multi-GNSS Advanced Demonstration tool for Orbit and Clock Analysis (MADOCA)

Manila, Philippines, 22 – 26 April 2024

MADOCA



- Satellite orbit
- Satellite clock

53 CORS world-wide

MADOCA products

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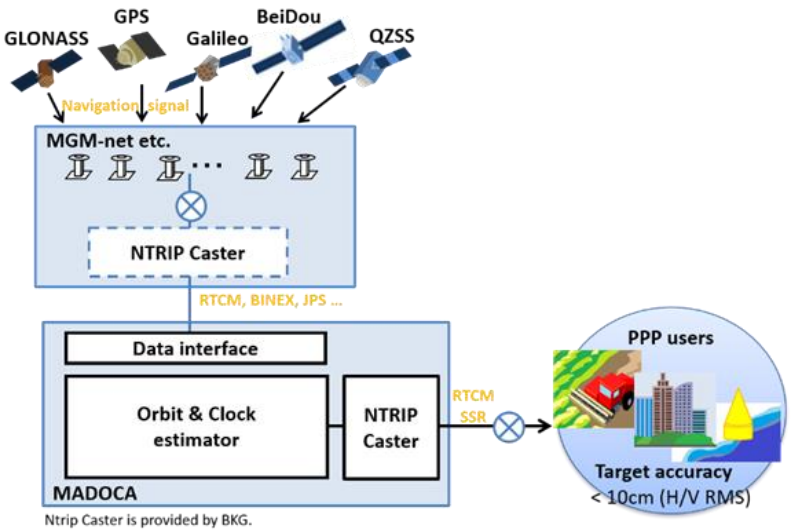
- Real-time message from QZSS L6E signal (signal decoding, only areas where QZSS is visible)
- Real-time message from Ntrip (User account required, global, internet required)
- Offline RTCM3 SSR file (For post-processing)



MADOCA products accuracy

Product	Offline			Real-Time		
	GPS	GLO	QZS	GPS	GLO	QZS
OBT	3cm	7cm		6cm	9cm	
CLK	0.1ns	0.25ns		0.1ns	0.25ns	

Objectives

To study the accuracy positioning and performance evaluation of low-cost GNSS receiver using MADOCA corrections with the precise point positioning (PPP) mode in Thailand.

Experiments

Receiver System Architecture

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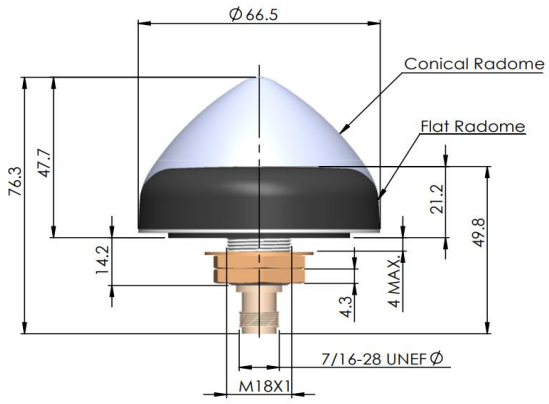
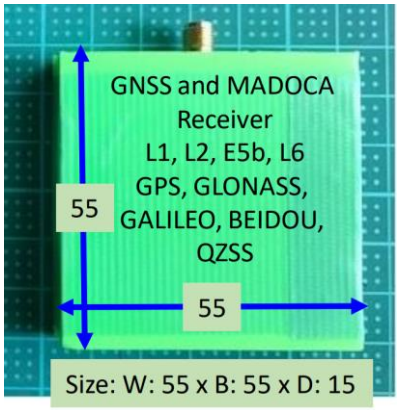
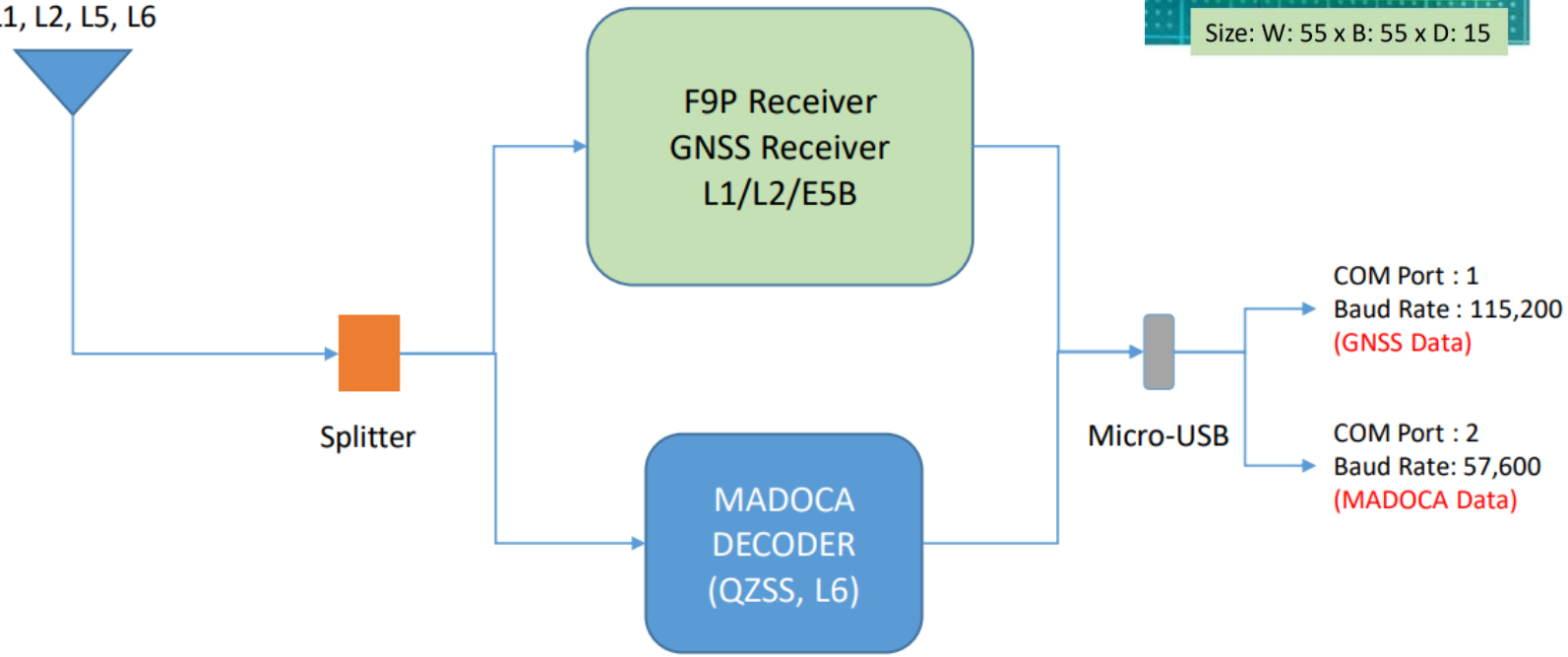


GNSS Antenna
L1, L2, L5, L6

Tallysman Antenna

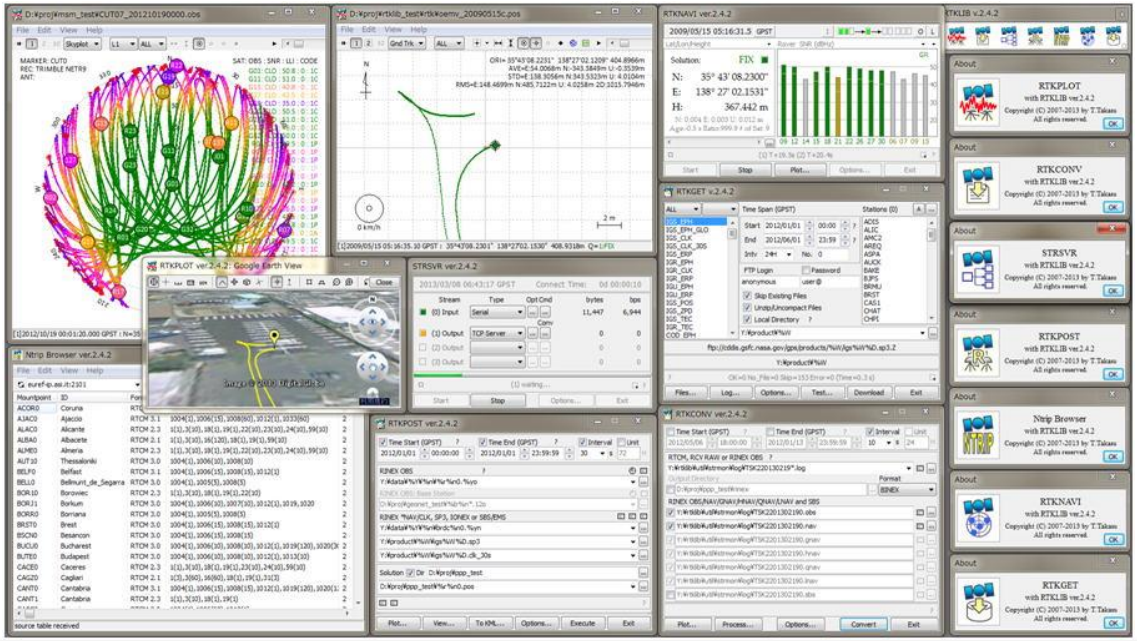




Software used

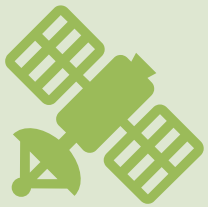
- GipsyX

- RTKLIB 2.4.3



https://www.rtklib.com/

EXPERIMENTS



Fixed-Point Positioning Test

- Open Area
- Multipath Area

OPEN AREA

Google Map

Multipath Area

Fixed-Point Positioning Test

PPP Static test (7 DAY)

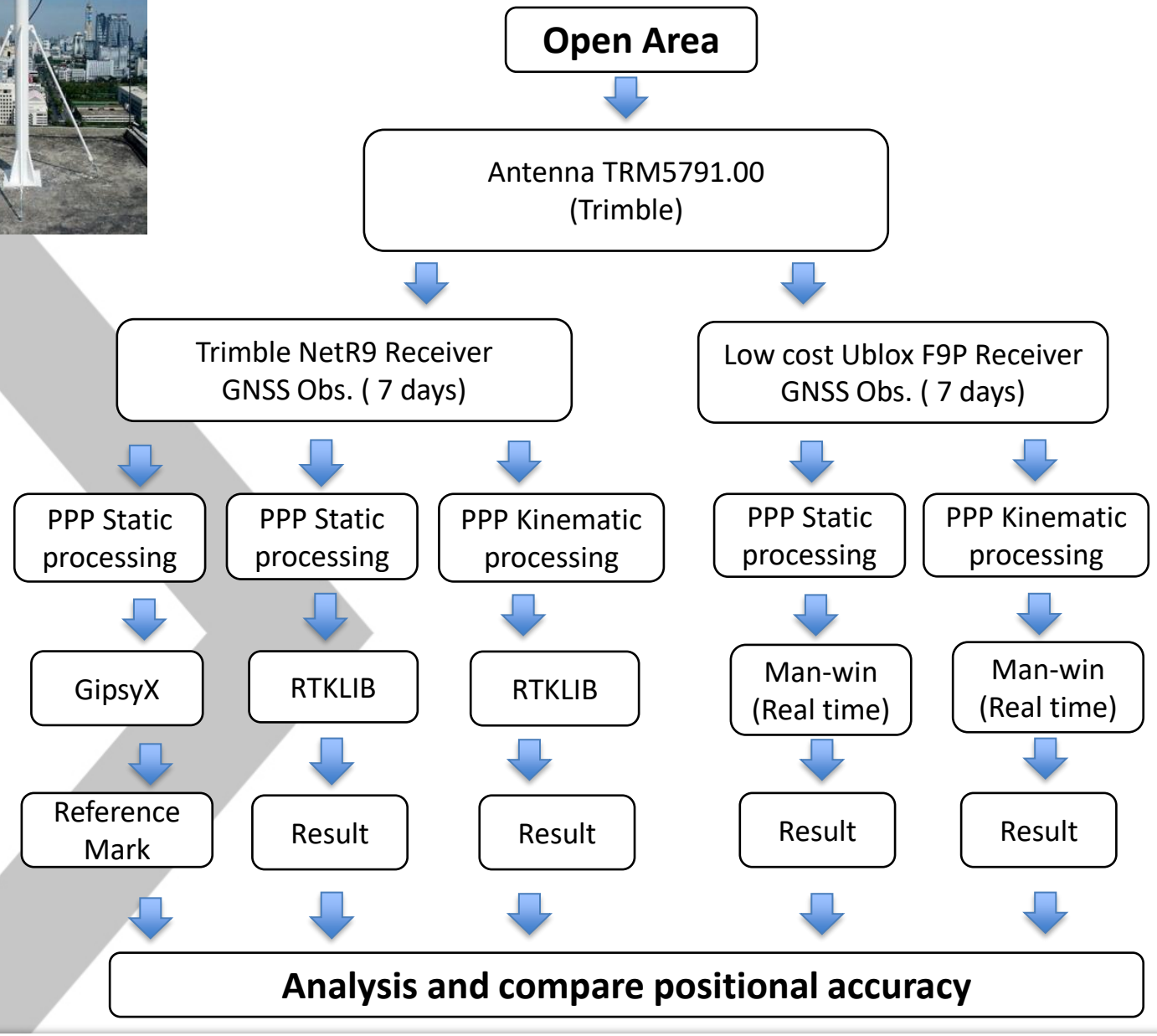
Low-Cost Receivers (UBLOX F9P and MADOCA Receivers)

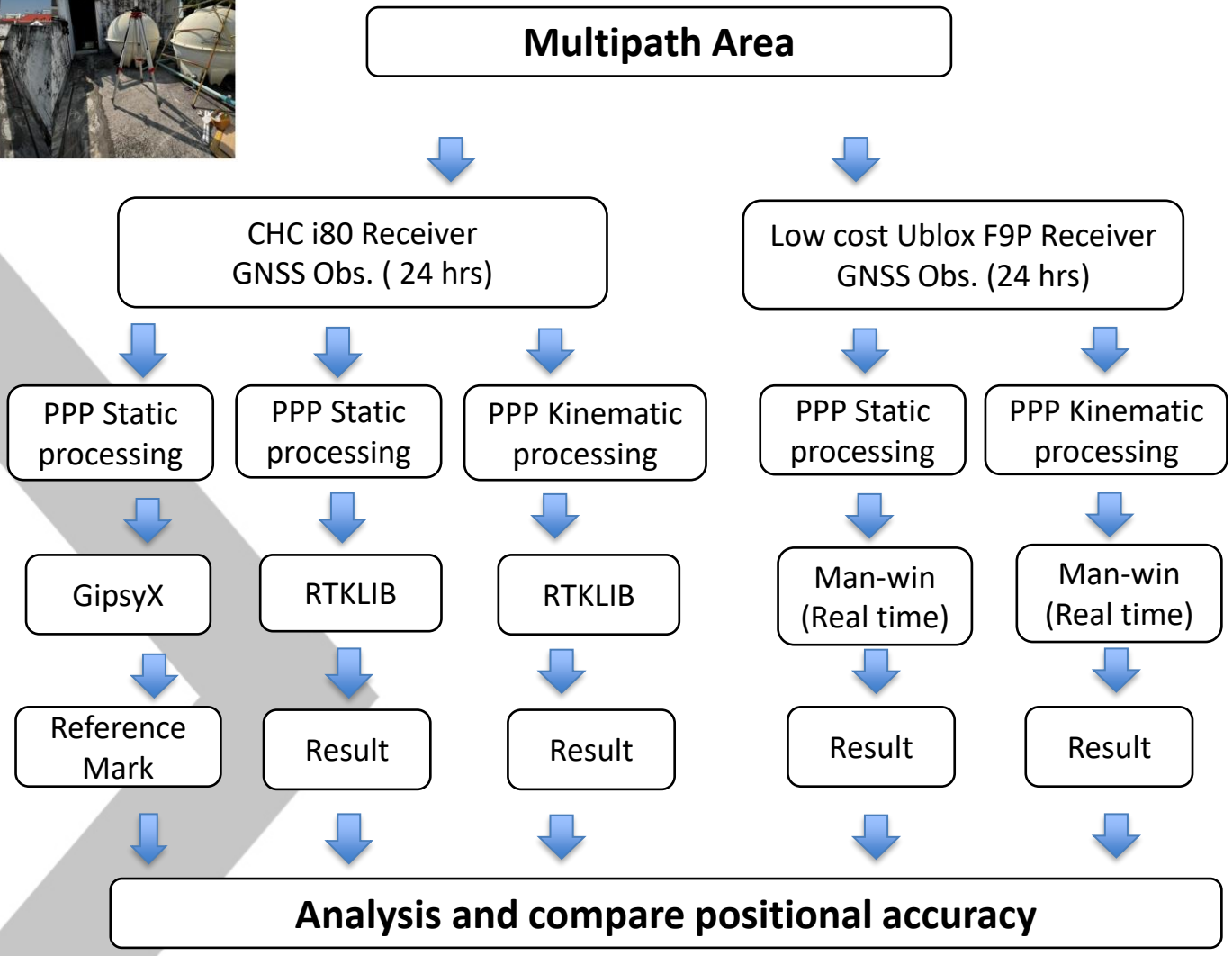
Survey Grade (Trimble NETR9)

PPP Kinematic test (7 DAY)

Low-Cost Receivers (UBLOX F9P and MADOCA Receivers)

Survey Grade (Trimble NETR9)


Open Area
Antenna TRM5791.00 (Trimble)
Trimble NetR9 Receiver GNSS Obs. (7 days)
Low cost Ublox F9P Receiver GNSS Obs. (7 days)
PPP Static processing
PPP Static processing
PPP Kinematic processing
PPP Static processing
PPP Kinematic processing
GipsyX
RTKLIB
RTKLIB
Man-win (Real time)
Man-win (Real time)
Reference Mark
Result
Result
Result
Result
Analysis and compare positional accuracy


Multipath Area
CHC i80 Receiver
GNSS Obs. (24 hrs)
Low cost Ublox F9P Receiver
GNSS Obs. (24 hrs)
PPP Static processing
PPP Static processing
PPP Kinematic processing
PPP Static processing
PPP Kinematic processing
GipsyX
RTKLIB
RTKLIB
Man-win (Real time)
Man-win (Real time)
Reference Mark
Result
Result
Result
Result
Analysis and compare positional accuracy

EXPERIMENTS

Vehicle Positioning Test

- Urban Area
- Rural Area

Rural Area

Google Earth

Urban Area

Vehicle Positioning Test

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PPP Kinematic test

1. Low-Cost Receivers (UBLOX-F9P Receivers + MADOCA Receivers)
2. Survey Grade (CHC-i80)

Vehicle Positioning Test

CHC i80 Receiver GNSS Obs.

Network-based RTK

Reference Mark

Low cost Ublox F9P Receiver GNSS Obs.

PPP Kinematic processing

Man-win (Real time)

Result

Analysis and compare positional accuracy

Vehicle Positioning Test

EXPERIMENTS	Speed
1	< 20 km/hr.
2	21-50 km/hr.
3	51-80 km/hr.

Result

Accuracy assessment

- Reference marks and PPP-MADOCA difference
- Compute Horizontal and Vertical RMSEs

Standard Deviation (SD)

$$SD_{hol} = \sqrt{\frac{\sum_{i=1}^{n}\left(\left(E_i - \overline{E}\right)^2 + \left(N_i - \overline{N}\right)^2\right)}{n}}$$

$$SD_{Ver} = \sqrt{\frac{\sum_{i=1}^{n}\left(H_i - \overline{H}\right)^2}{n}}$$

Root Mean Square Error (RMSE)

$$RMSE_{hol} = \sqrt{\frac{\sum_{i=1}^{n}\left(\left(E_{obs} - E_{true}\right)^2 + \left(N_{obs} - N_{true}\right)^2\right)}{n}}$$

$$RMSE_{Ver} = \sqrt{\frac{\sum_{i=1}^{n}\left(\left(H_{obs} - H_{true}\right)^2\right)}{n}}$$

*Geospatial Positioning Accuracy Standards
Part 3: National Standard for Spatial Data Accuracy
Appendix 3-A (normative): Accuracy Statistics

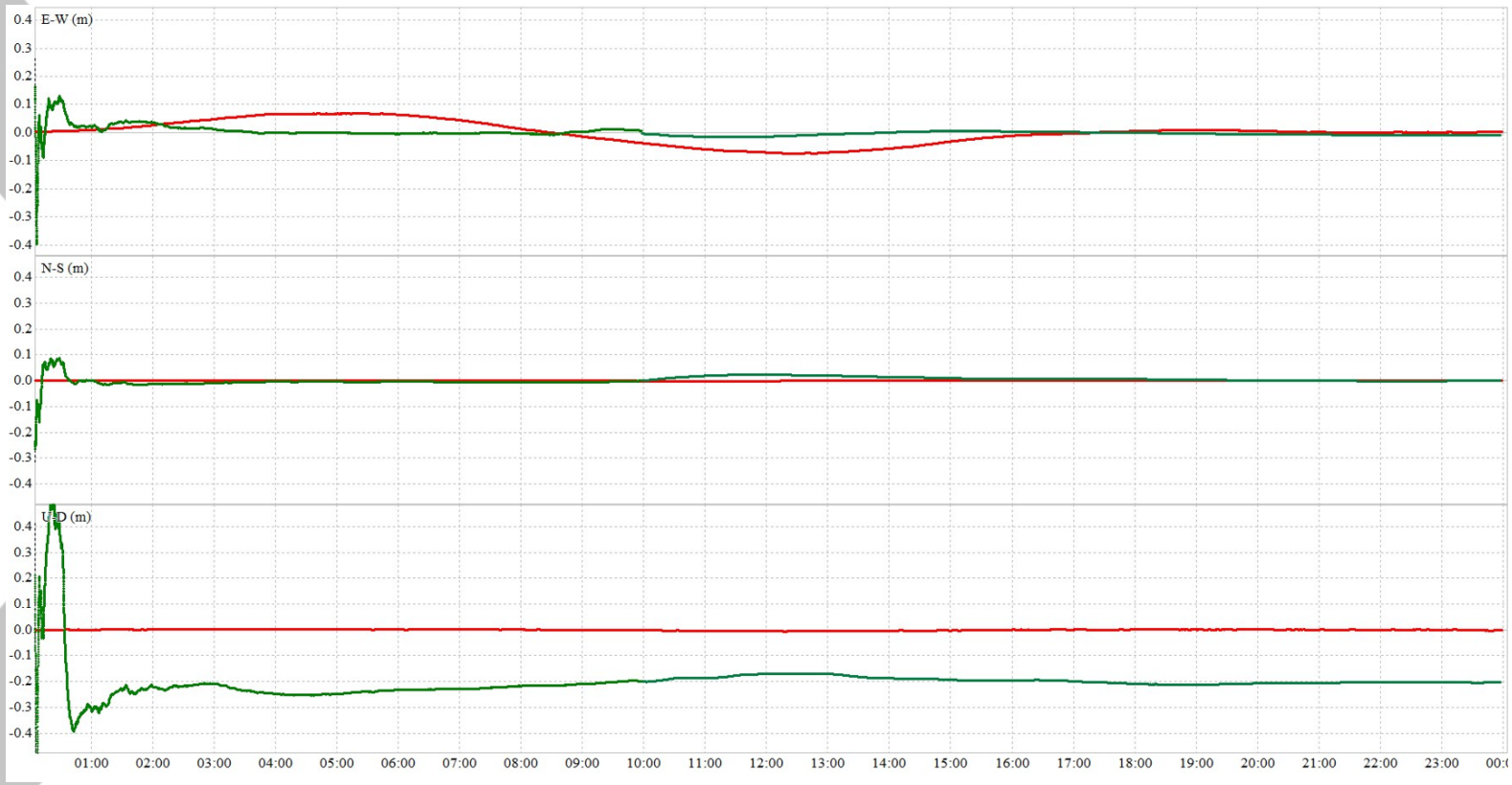
Fixed Point Test

- Open Area

		RMSE (m.)		SD (m.)	
		Hor.	Ver.	Hor.	Ver.
PPP-static	Low-cost	0.099	0.133	0.078	0.091
	Trimble	0.012	0.085	0.007	0.001
PPP-Kinematic	Low-cost	0.158	0.260	0.132	0.245
	Trimble	0.069	0.136	0.067	0.085
	MJS	0.086	0.187	0.061	0.111

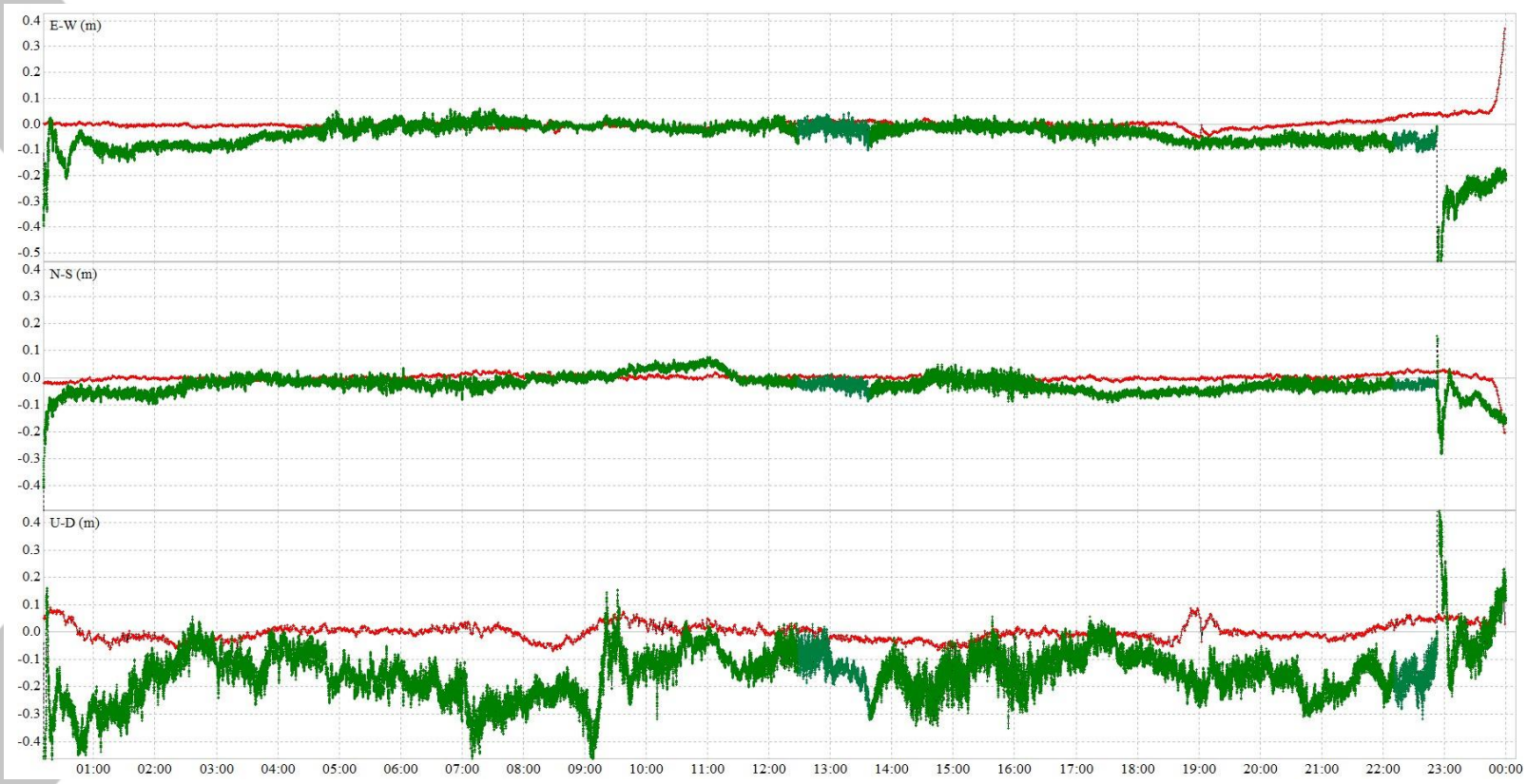
Fixed Point Test

- Open Area (PPP-Static)



Fixed Point Test

- Open Area (PPP-kinematic)

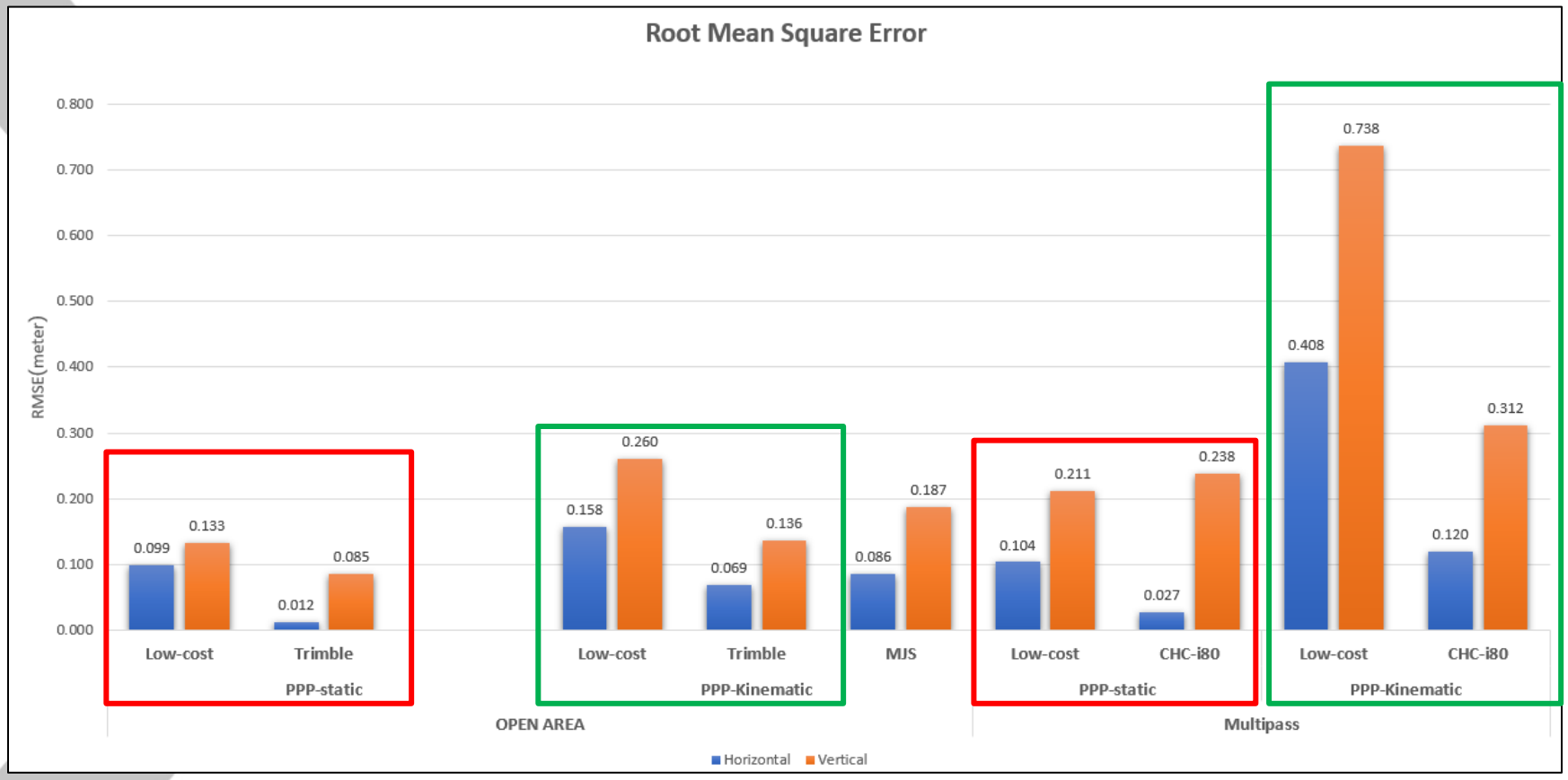


Fixed Point Test

- **Multipath Area**

Process	SD (m.)				RMSE (m.)			
	Low-cost		CHC-i80		Low-cost		CHC-i80	
	Hor.	Ver.	Hor.	Ver.	Hor.	Ver.	Hor.	Ver.
PPP-static	0.104	0.081	0.012	0.003	0.104	0.211	0.027	0.238
PPP-Kinematic	0.406	0.734	0.117	0.216	0.408	0.738	0.120	0.312

Bar chart


Root Mean Square Error
RMSE(meter)
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
0.099
0.133
0.012
0.085
0.158
0.260
0.069
0.136
0.086
0.187
0.104
0.211
0.027
0.238
0.408
0.738
0.120
0.312
Low-cost
Trimble
PPP-static
Low-cost
Trimble
MJS
PPP-Kinematic
OPEN AREA
Low-cost
CHC-i80
PPP-static
Low-cost
CHC-i80
PPP-Kinematic
Multipass
Horizontal
Vertical

Vehicle Test

- Urban Area

Vehicle Test

- Urban Area

Speed Interval (KM/HR)	Order	Urban AREA			
		MEAN diff Hor.(m)	RMSE diff Hor.(m)	MEAN diff ver.(m)	RMSE diff ver.(m)
0-20	1	2.370	2.609	2.892	2.960
	2	0.699	1.013	1.121	1.772
	3	1.539	1.906	2.456	2.600
	Average	1.536	1.843	2.157	2.444
21-50	1	0.453	0.691	2.841	2.882
	2	2.450	2.548	0.973	1.179
	3	1.531	1.536	1.142	1.161
	Average	1.478	1.592	1.652	1.740
51-80	1	0.456	0.468	5.323	5.326
	2	0.249	0.256	4.330	4.333
	3	0.426	0.615	4.212	4.227
	Average	0.377	0.446	4.622	4.629
Average Total		1.130	1.294	2.810	2.938

Vehicle Test

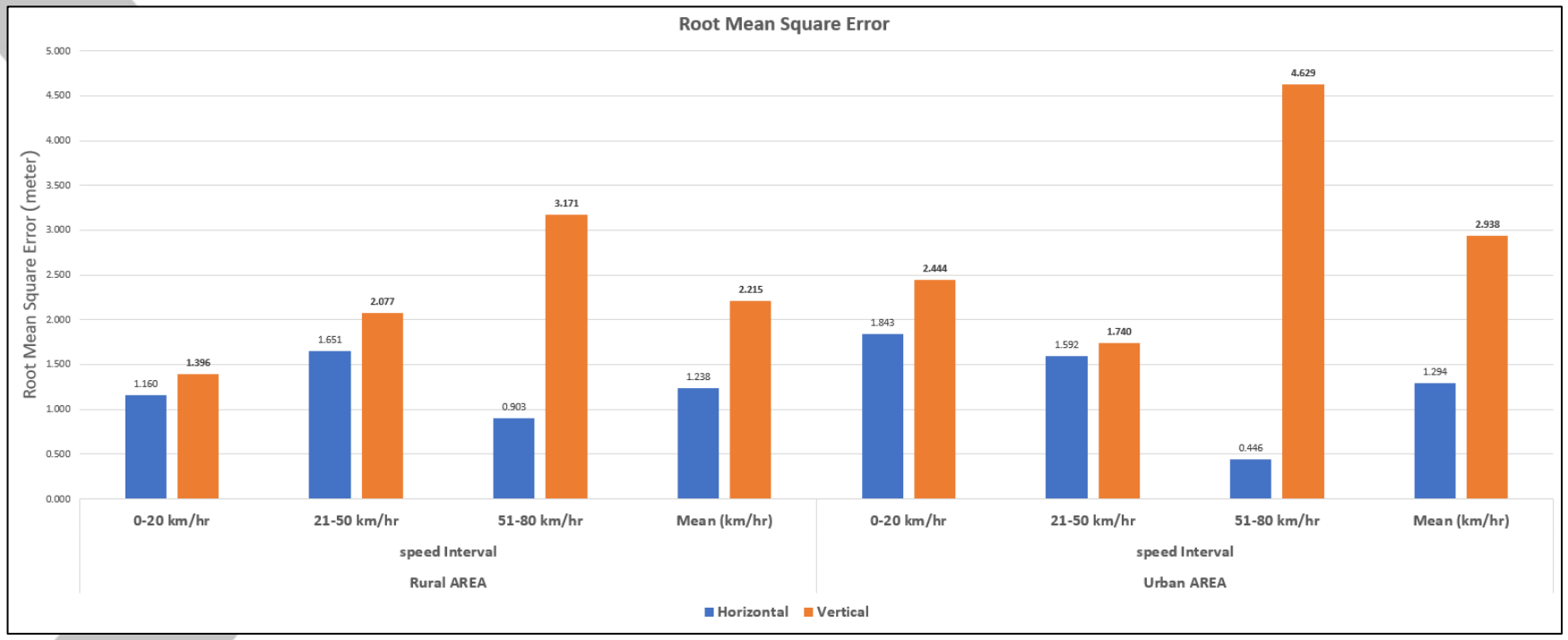
- Rural Area

Vehicle Test

- Rural Area

Speed Interval (KM/HR)	Order	Rural AREA			
		MEAN diff Hor.(m)	RMSE diff Hor.(m)	MEAN diff ver.(m)	RMSE diff ver.(m)
0-20	1	1.362	1.185	1.764	1.860
	2	1.140	0.955	1.051	1.213
	3	1.531	1.339	0.616	1.115
	Average	1.344	1.160	1.144	1.396
21-50	1	1.096	1.170	2.172	2.320
	2	0.897	1.463	1.177	1.572
	3	1.745	2.320	1.194	2.340
	Average	1.246	1.651	1.514	2.077
51-80	1	0.849	0.856	3.538	3.547
	2	1.363	1.386	2.990	2.998
	3	0.414	0.466	2.935	2.967
	Average	0.875	0.903	3.154	3.171
Average Total		1.155	1.238	1.938	2.215

Bar chart


Root Mean Square Error
Root Mean Square Error (meter)
5.000
4.500
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
1.160
1.396
1.651
2.077
0.903
3.171
1.238
2.215
1.843
2.444
1.592
1.740
0.446
4.629
1.294
2.938
0-20 km/hr
21-50 km/hr
51-80 km/hr
Mean (km/hr)
speed Interval
Rural AREA
0-20 km/hr
21-50 km/hr
51-80 km/hr
Mean (km/hr)
speed Interval
Urban AREA
Horizontal
Vertical

Conclusion

Fixed-Point Positioning Test

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- **Open Area**

PPP-static

Horizontal accuracy = 0.09 meter

Vertical accuracy = 0.13 meter

PPP-Kinematic

Horizontal accuracy = 0.16 meter

Vertical accuracy = 0.26 meter

- **Multipath Area**

PPP-static

Horizontal accuracy = 0.10 meter

Vertical accuracy = 0.21 meter

PPP-Kinematic

Horizontal accuracy = 0.41 meter

Vertical accuracy = 0.74 meter

Vehicle Test

- **Urban Area**

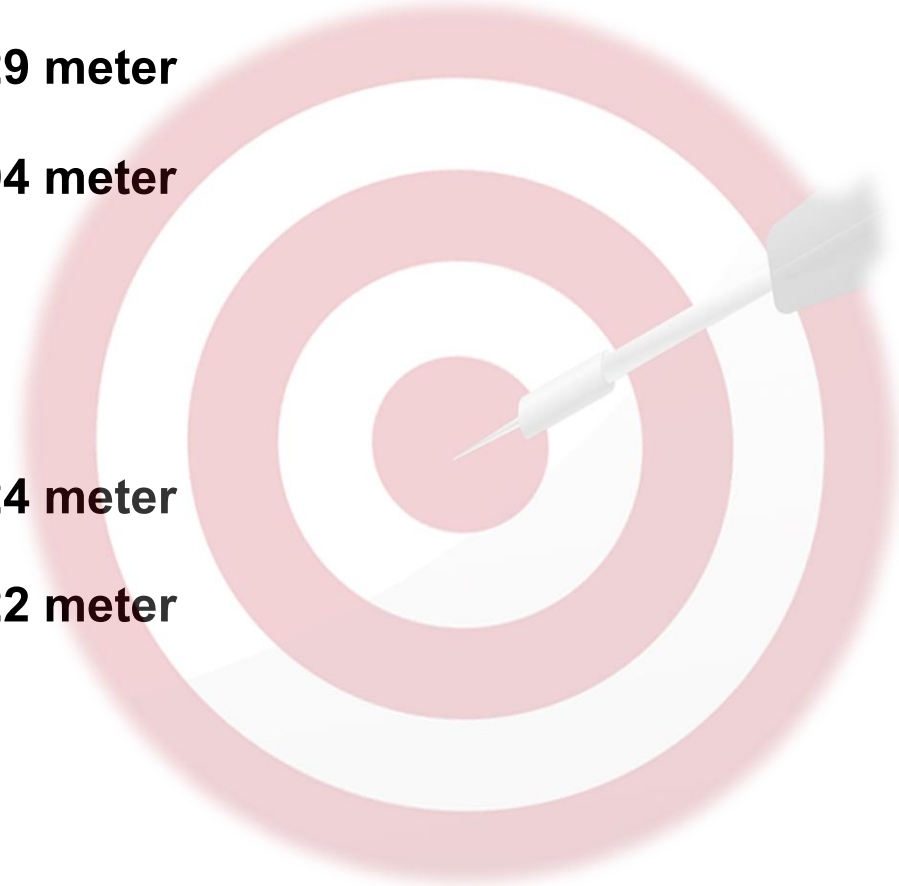
  Horizontal accuracy = 1.29 meter

  Vertical accuracy = 2.94 meter

- **Rural Area**

  Horizontal accuracy = 1.24 meter

  Vertical accuracy = 2.22 meter



BENEFITS

POSITIONING ACCURACY

PERFORMANCE EVALUATION OF LOW-COST GNSS RECEIVER

APPLICATION ABILITY LOW-COST GNSS RECEIVER

THANK YOU

Questions and Answers