International Symposium on GPS/GNSS 2008, 11-14 November 2008

Evaluation of RTK-GPS Performance with Low-cost Single-frequency GPS Receiver

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Background

- cm-level accuracy of position with RTK-GPS
- Expensive (>$9,000) geodetic-grade dual-frequency antennas/receivers are necessary
- Still not popular because of its cost issue

Simple Questions

- What is the difference between low-cost (<$300) (single-frequency) antenna/receivers and geodetic-grade dual-frequency antennas/receivers?
- With low-cost antennas/receivers, RTK-GPS can not provide practical performance?

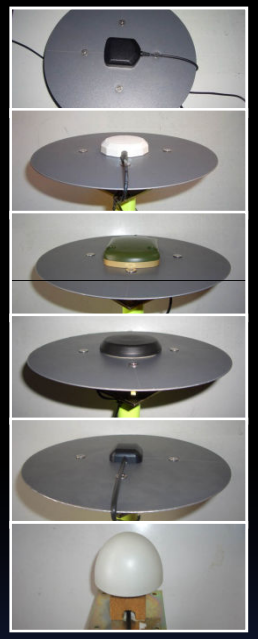
Evaluated Performance

- Raw antenna/receiver performance
  - Antenna phase center stability
  - Carrier-phase multipath
  - Code multipath
- RTK-GPS performance
  - Positioning accuracy (RMS errors)
  - Ratio of correct AR (ambiguity resolution)
  - TTFF (time to first fix) with AR
- Various antenna/receiver combinations

Antennas

Low-cost

u-blox	ANN-MS	$31
AeroAntenna	AT575	$200
AntCom	AG15A2-XS-3	$194
MicroPlus	2335TB	$47
Pioneer	GPS-M1ZZ Ant	?
Trimble	Bullet III	$125



Geodetic-grade (for reference)

NovAtel	GPS-702-GG	$995

Receivers

Low-cost

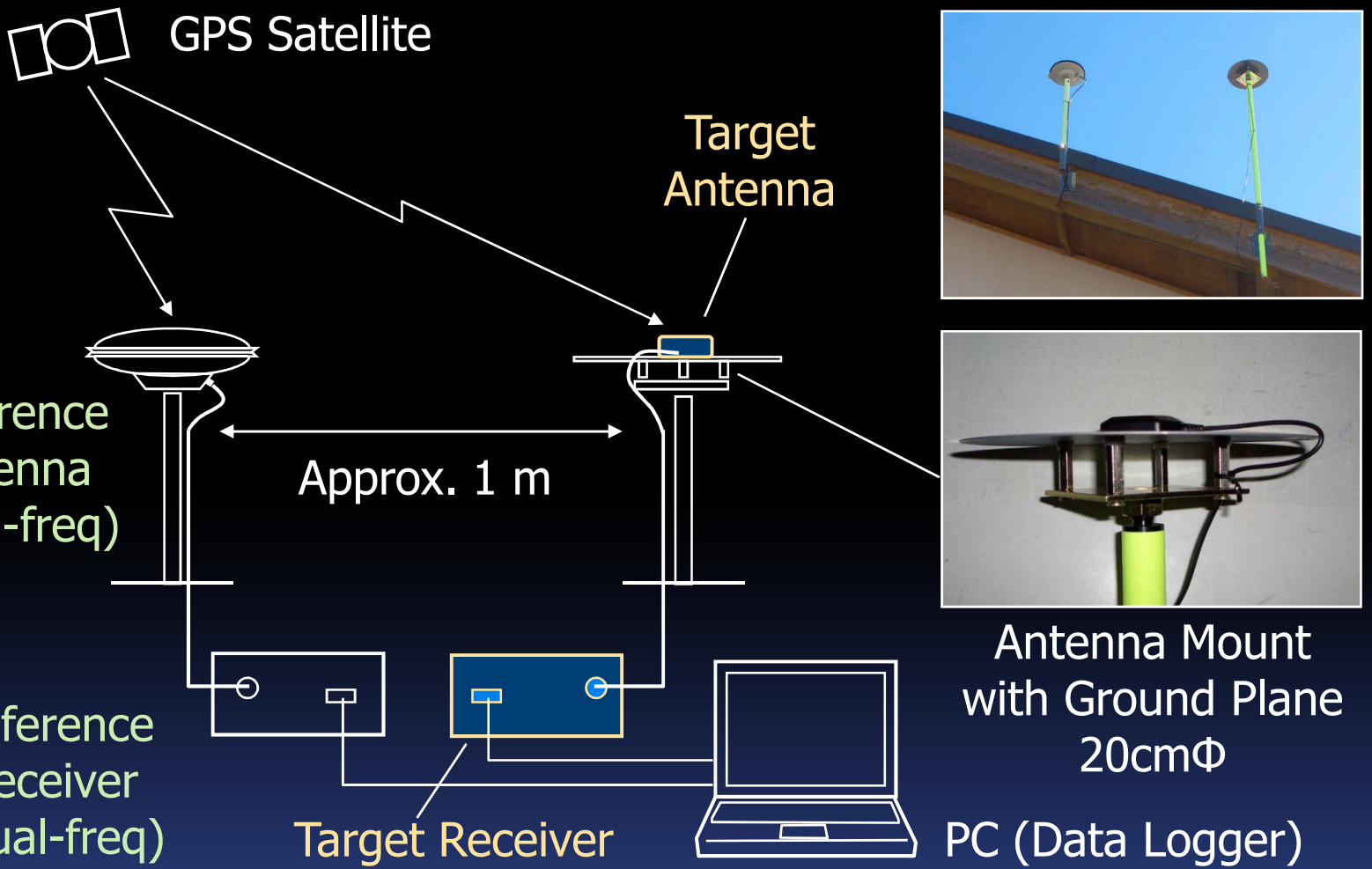
u-blox	AEK-4T	$179*1
u-blox	EVK-5H*2	$99 *1
NovAtel	Superstar II	$165
Hemisphere	Crescent	$285

Geodetic-grade (for reference)

NovAtel	OEMV-3	$7,995

*1 module only, *2 F/W version 3.00

Configuration of Experiment



Evaluation Method

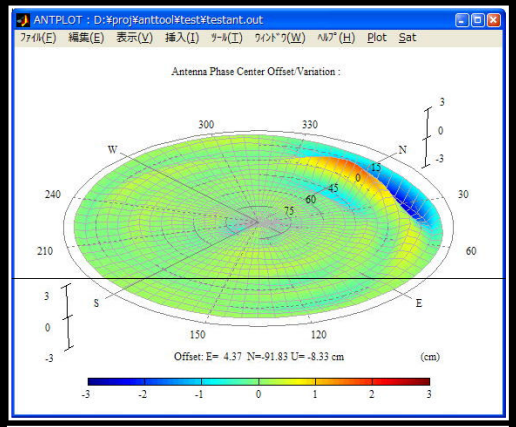
- Raw antenna/receiver performance
  - Continuously captures raw observation data at the target and reference (24hr)
  - Field-calibration analysis by ANTTOOL v.1.1
- RTK-GPS performance
  - Processes raw observation data with RTK-GPS algorithms by RTKLIB v.2.1.0
  - Integer ambiguity is resolved by LAMBDA and validated by ratio-test (threshold=3)
  - Evaluates TTFF with AR by sliding start time

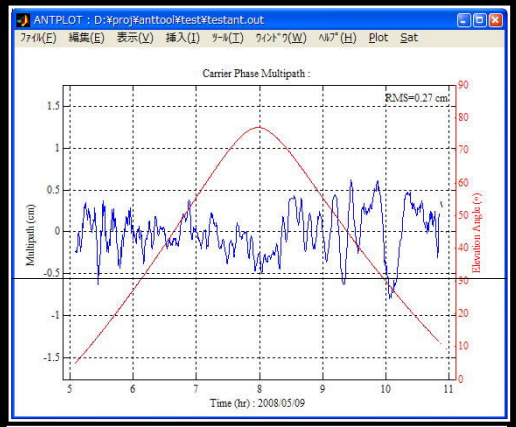
ANTTOOL v.1.1 (1)

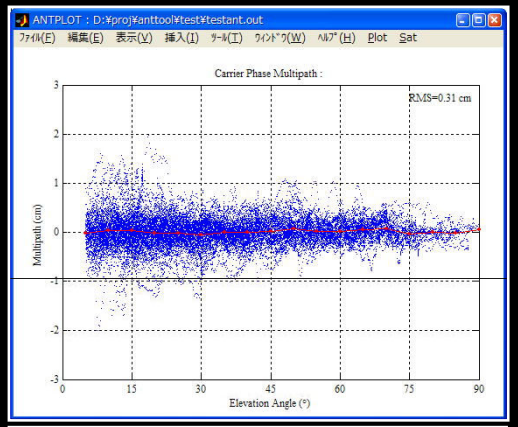
- Analysis tool written as MATLAB m-files
- Functions:
  - Inputs RINEX OBS/NAV of target/reference
  - Determines antenna phase center position and variation by field calibration method
  - Estimates code and carrier-phase multipath
  - Analyzes receiver SNR (C/N0)
  - Generates plots of analysis results
- Freely available under GPLv3 license

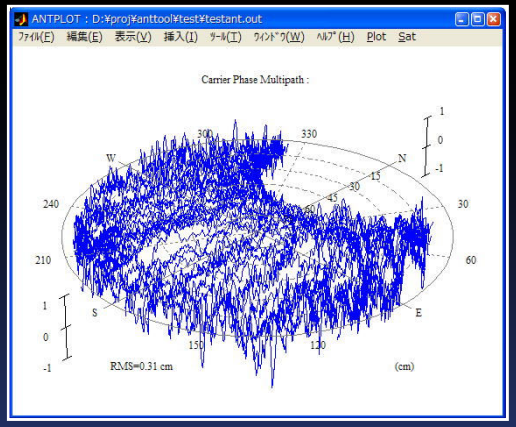
ANTTOOL v.1.1 (2)

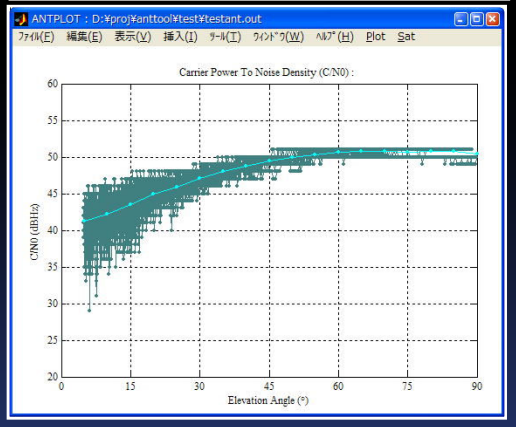
Examples of Analysis Results

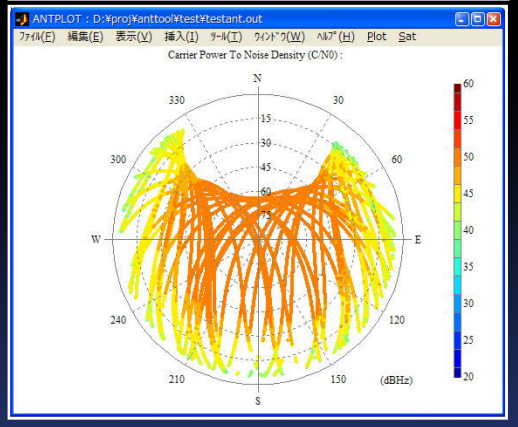










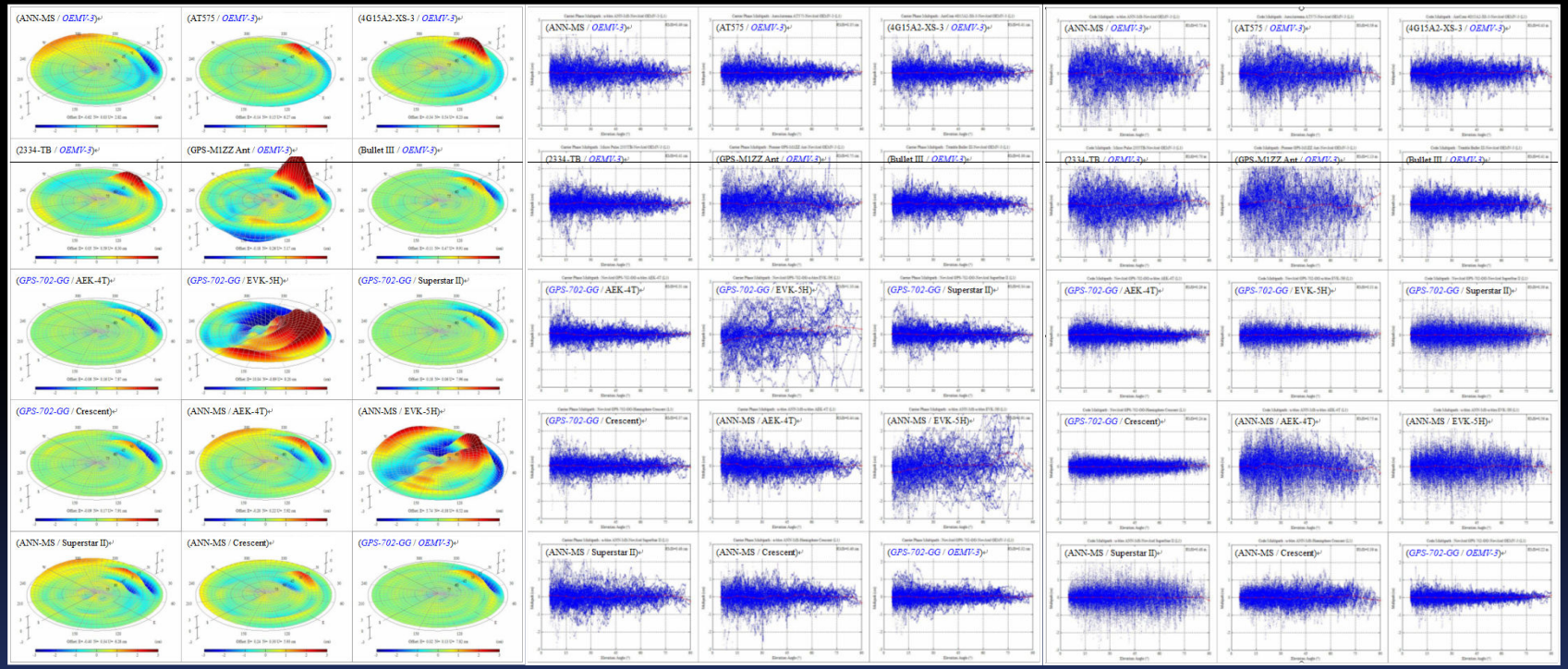


Results of Experiment (1)

Antenna PCV

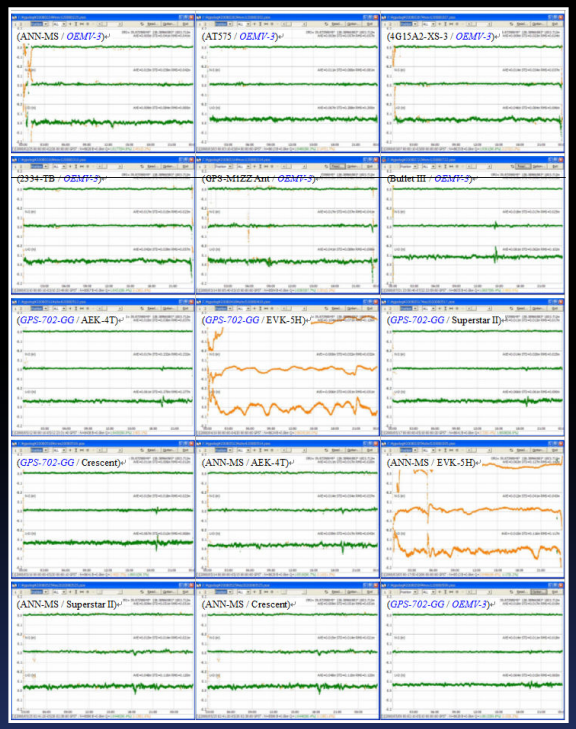
Carrier-phase Multipath

Code Multipath

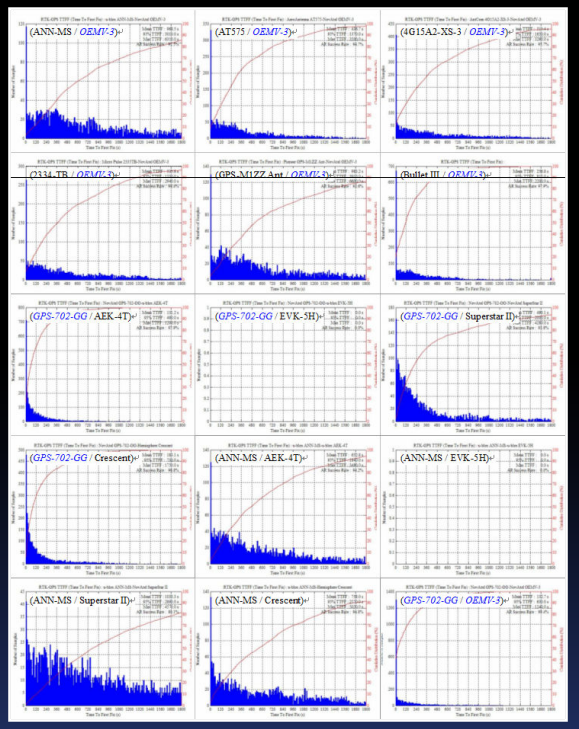


Results of Experiment (2)

RTK-GPS
Positioning Accuracy

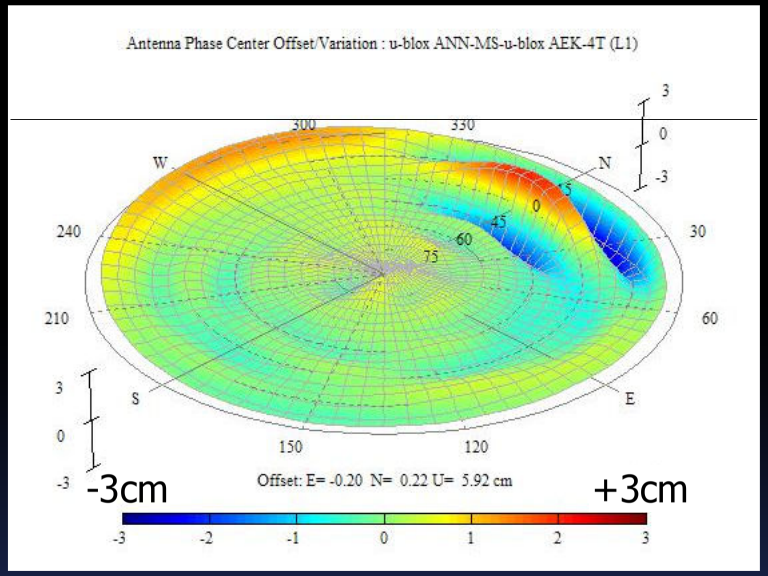


RTK-GPS
TTFF with AR

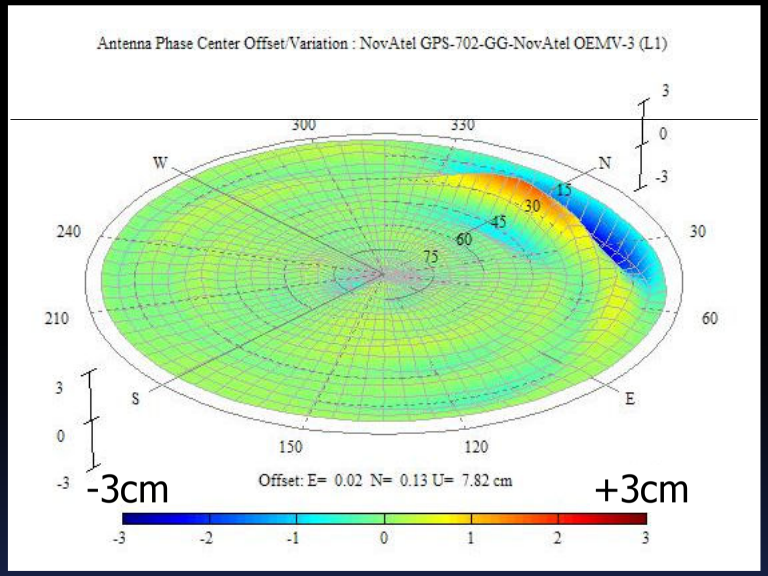


Antenna Phase Center Stability

Low-cost Antenna/Receiver (ANN-MS/AEK-4T)

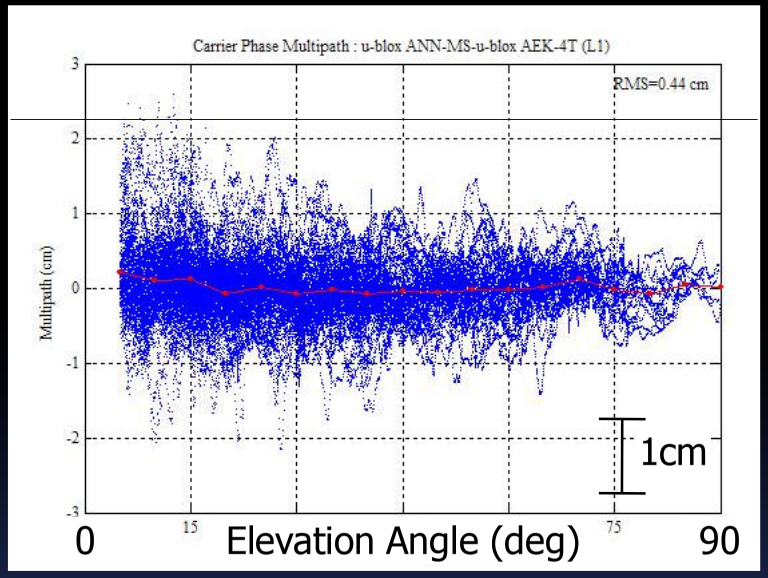


Geodetic-grade Antenna/Receiver (GPS-702-GG/OEMV-3)



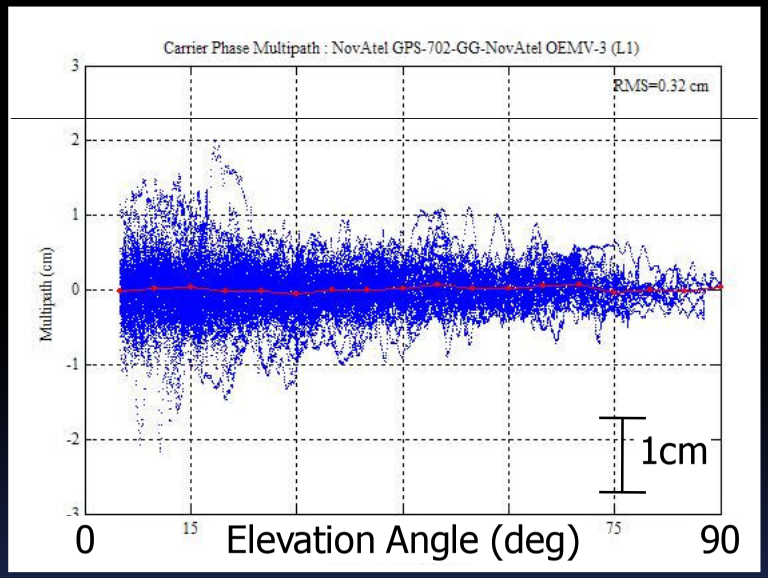
Carrier-phase Multipath

Low-cost Antenna/Receiver (ANN-MS/AEK-4T)



RMS=0.44cm

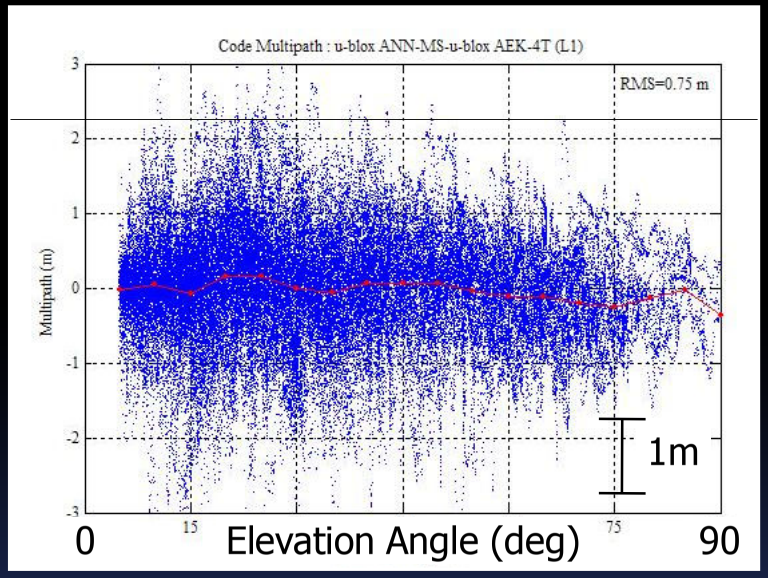
Geodetic-grade Antenna/Receiver (GPS-702-GG/OEMV-3)



RMS=0.32cm

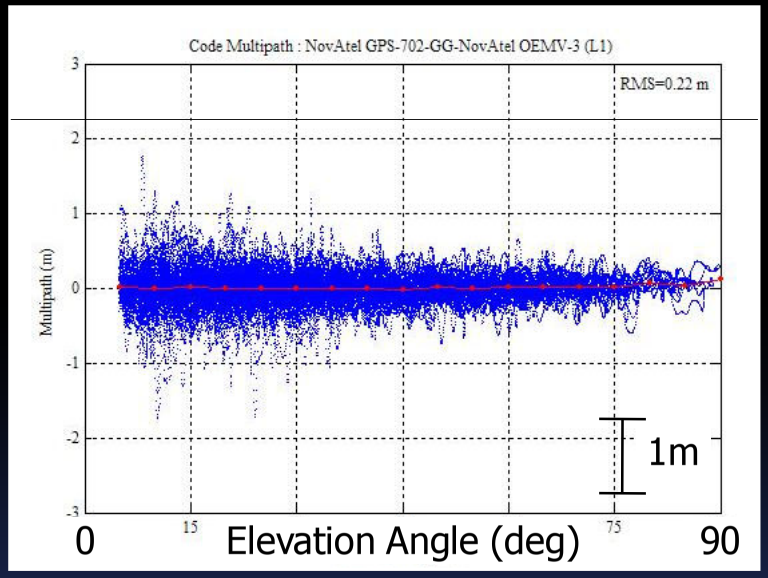
Code Multipath

Low-cost Antenna/Receiver (ANN-MS/AEK-4T)



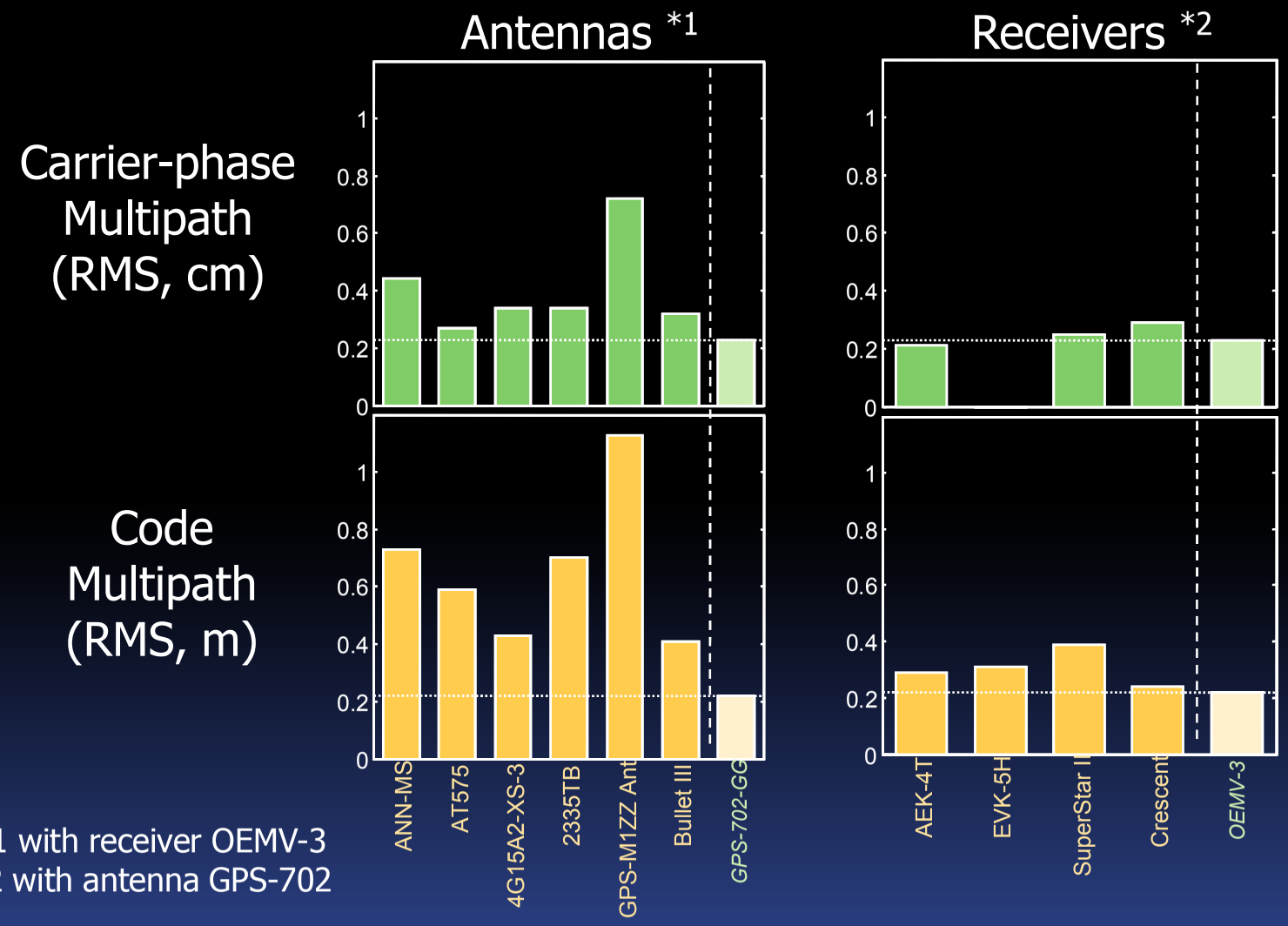
RMS=0.75m

Geodetic-grade Antenna/Receiver (GPS-702-GG/OEMV-3)



RMS=0.22m

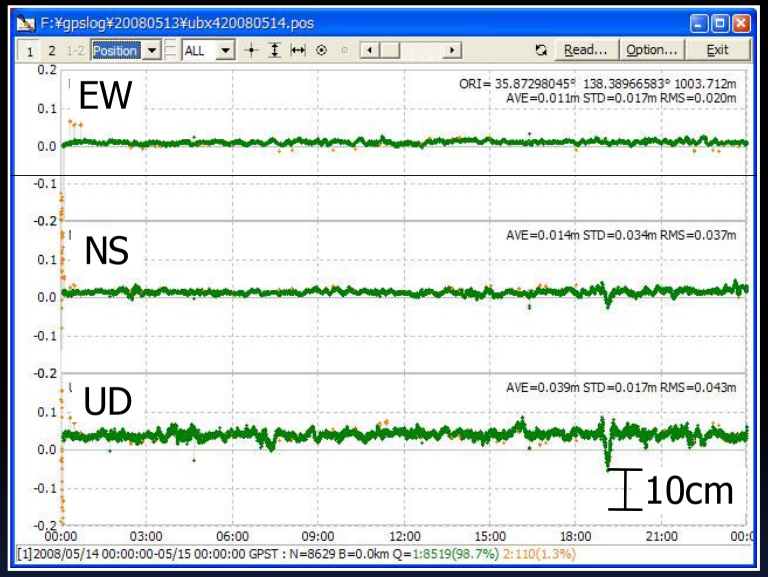
Comparison of Antennas/Receivers



*1 with receiver OEMV-3
*2 with antenna GPS-702

RTK-GPS Positioning Accuracy

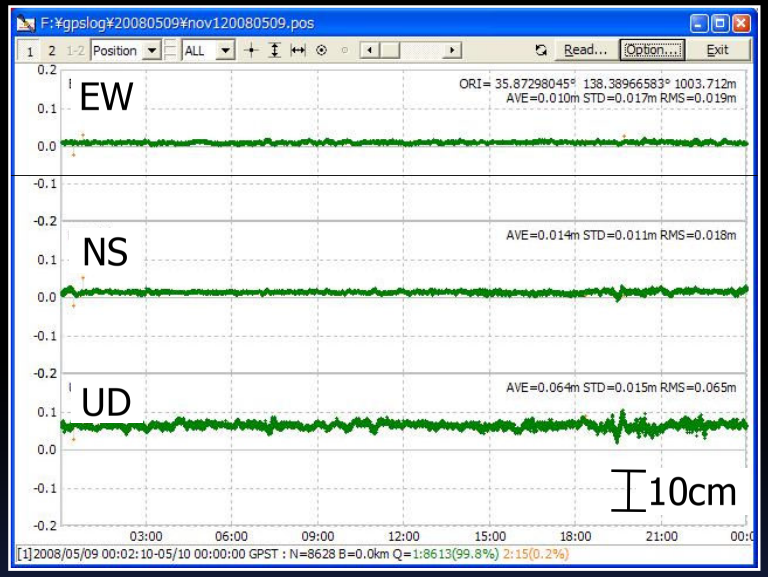
Low-cost
Antenna/Receiver
(ANN-MS/AEK-4T)



RMS Error (cm):
E 0.39, N 0.59, U 1.08
Fixing-ratio: 98.7%

Fix
Float

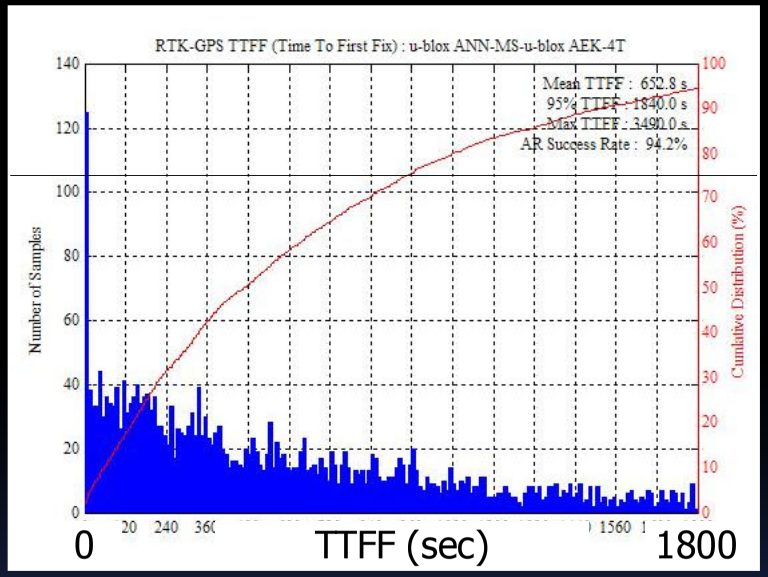
Geodetic-grade
Antenna/Receiver
(GPS-702-GG/OEMV-3)



RMS Error (cm):
E 0.26, N 0.36, U 0.77
Fixing-ratio: 99.8%

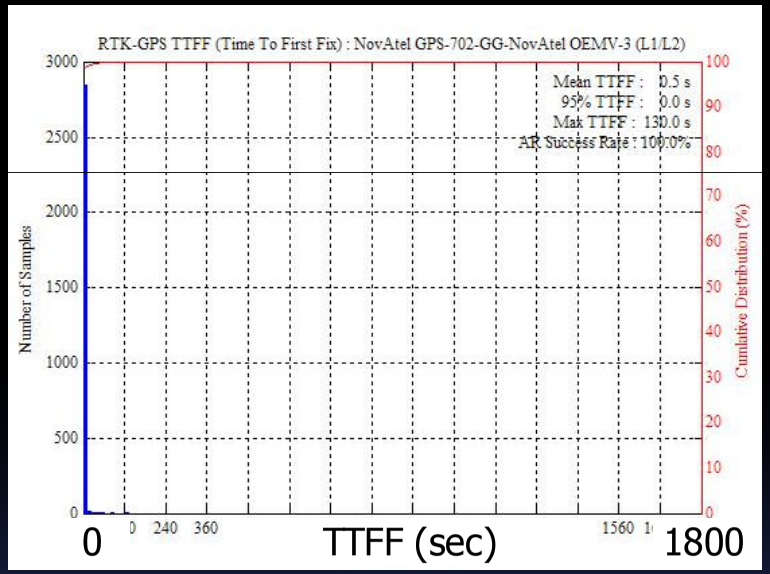
TTFF with AR

Low-cost Antenna/Receiver (ANN-MS/AEK-4T)



Mean: 652.8 s
95%: 1840.0 s
Max: 3490.0 s

Geodetic-grade Antenna/Receiver (L1/L2) (GPS-702-GG/OEMV-3)



Mean: 0.5 s
95%: 0.0 s
Max: 130.0 s

Conclusions

- Low-cost antenna/receiver
  - Antenna has poorer characteristics especially on code multipath than geodetic-grade. The selection is important.
  - Receiver has no large degradation concerning signal tracking.
- RTK-GPS with low-cost antenna/receiver is feasible in good condition.
- TTFF has large difference between single and dual-frequency. We need more satellites.