2009 International Symposium on GPS/GNSS

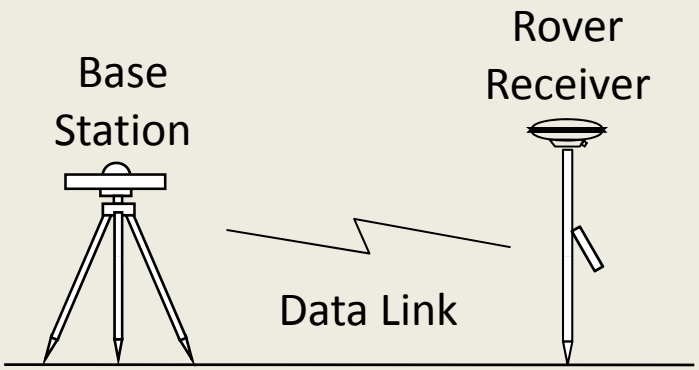
Development of the Low-Cost RTK-GPS Receiver with an Open Source Program Package RTKLIB

Tokyo University of Marine Science and Technology

T. Takasu and A. Yasuda

Background (1)

- **RTK-GPS (Real-time kinematic GPS)**
  - Most precise positioning technique with cm-level accuracy
  - Determine relative position wrt base-station position
  - Needs communication link between rover and base-station
- **Applications of RTK-GPS**
  - Geodetic survey
  - Construction machine control
  - Precision agriculture
  - Mobile mapping system
  - ITS (Intelligent Transportation System)
  - ....



Background (2)

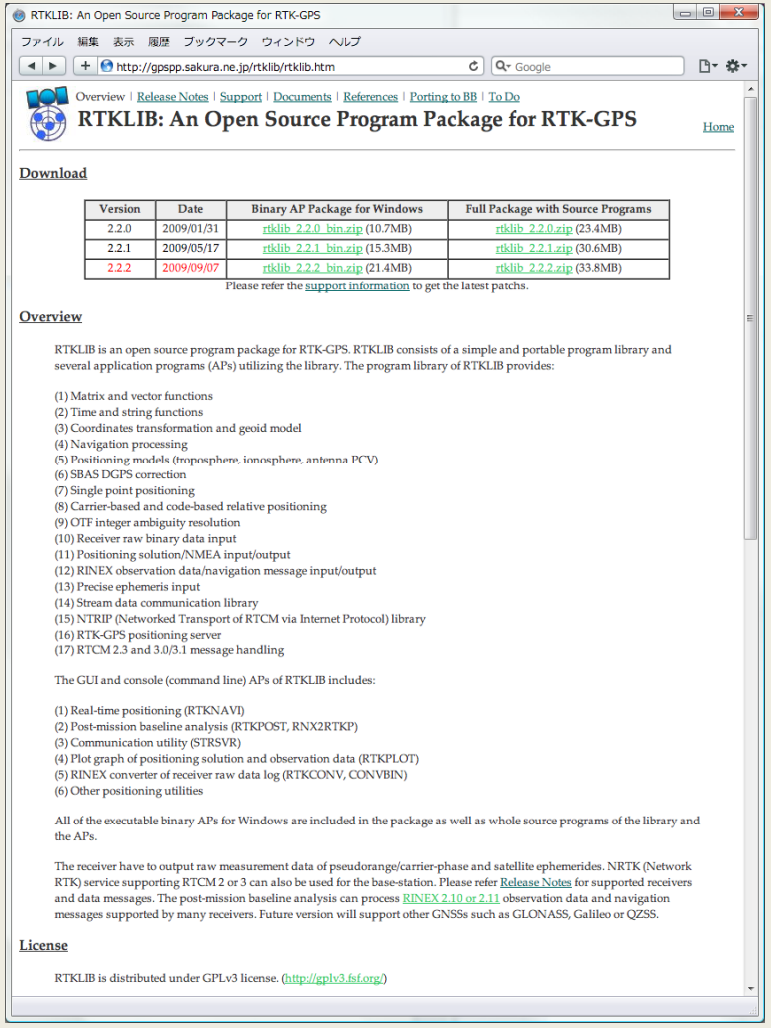
- **High operational cost for RTK-GPS**
  - Expensive geodetic-grade receivers
  - Expensive RTK F/W Options
  - Limited applications by cost issue
- **RTK-GPS with low-cost receiver**
  - Feasible and practical
  - Little performance degradation with high performance antenna
  - Needs raw measurement data output and external RTK-GPS processing

$10,000-$30,000

$30-$300

RTKLIB

- **Open source program package for RTK-GPS**
  - Distributed under GPLv3
  - Has been developed by the authors since 2006
  - Latest version: 2.2.2 (stable), 2.3.0 (devel.)
- **Portable C library + useful positioning APs**
  - GUI APs on Windows
  - Console APs on Linux etc...



http://gpspp.sakura.ne.jp/rtklib/rtklib.htm

RTKLIB APs on Windows

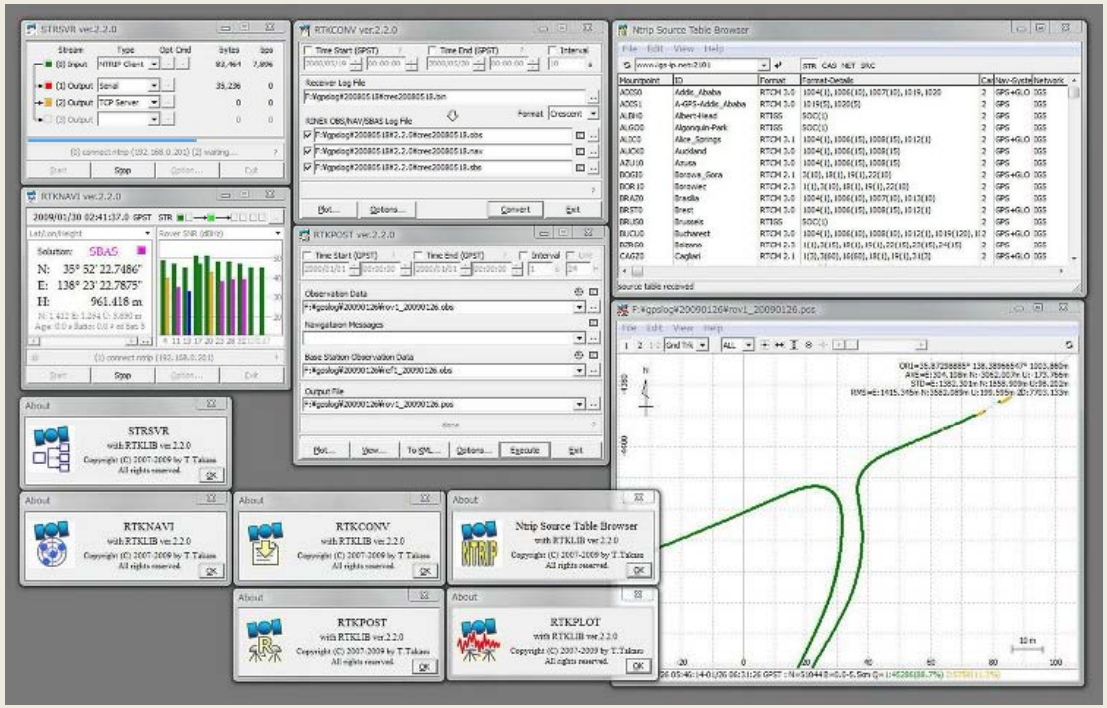
RTKNAVI : Real-time positioning

RTKPOST : Post-processing baseline analysis

RTKPLOT : Plot raw observation data and solutions

RTKCONV : RINEX converter for raw receiver log

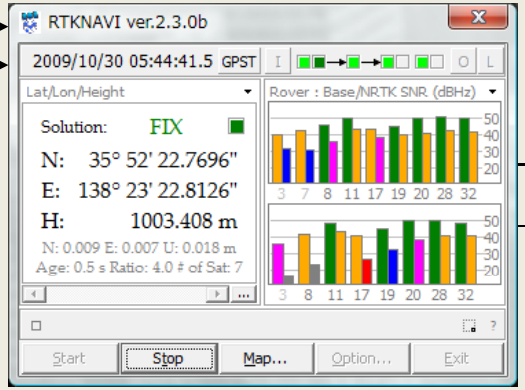
...

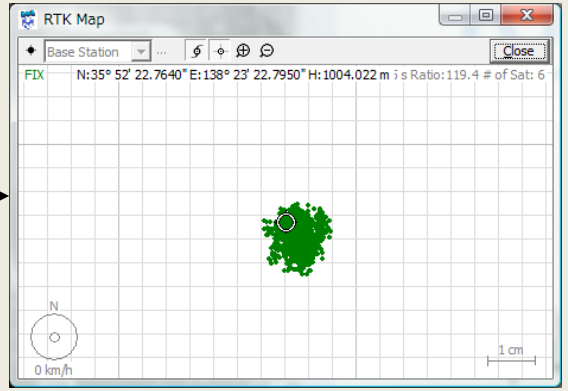


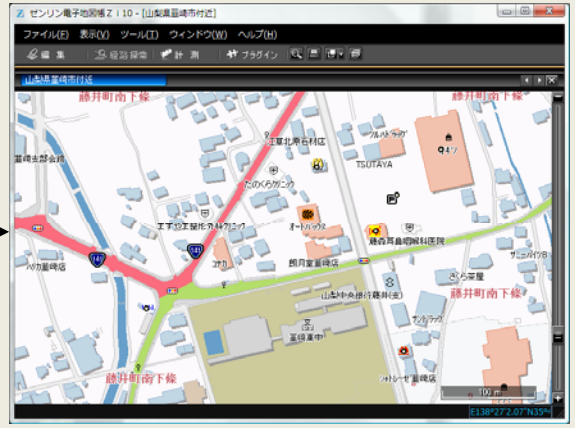
RTKNAVI: Real-Time AP

I/O Stream Types

- Serial (RS232C/USB)
- TCP Server/Client
- NTRIP Server/Client
- Local File







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Input Formats

- RTCM v.2.3
- RTCM v.3.1
- NovAtel OEM4/V
- NovAtel OEM3
- NovAtel Super Star II
- Hemisphere Eclipse
- Hemisphere Crescent
- u-blox LEA-4T/5T
- SkyTraq S1315F

Output Formats

- NMEA-0183
- Lat/Lon/Height
- X/Y/Z-ECEF
- E/N/U-baseline

Low-Cost Receiver with RTKLIB

- **Objectives**
  - To demonstrate and verify the low-cost RTK-GPS receiver without PC
  - To evaluate production cost, CPU load, memory usage, power consumption, RTK performance, etc.
  - To provide a platform for various RTK applications
- **Porting RTKLIB to Embedded CPU**
  - Needs powerful CPU for many floating point operations
  - Needs various peripherals for rover-base station communications like WiFi LAN, Bluetooth, modem devices

Beagle Board

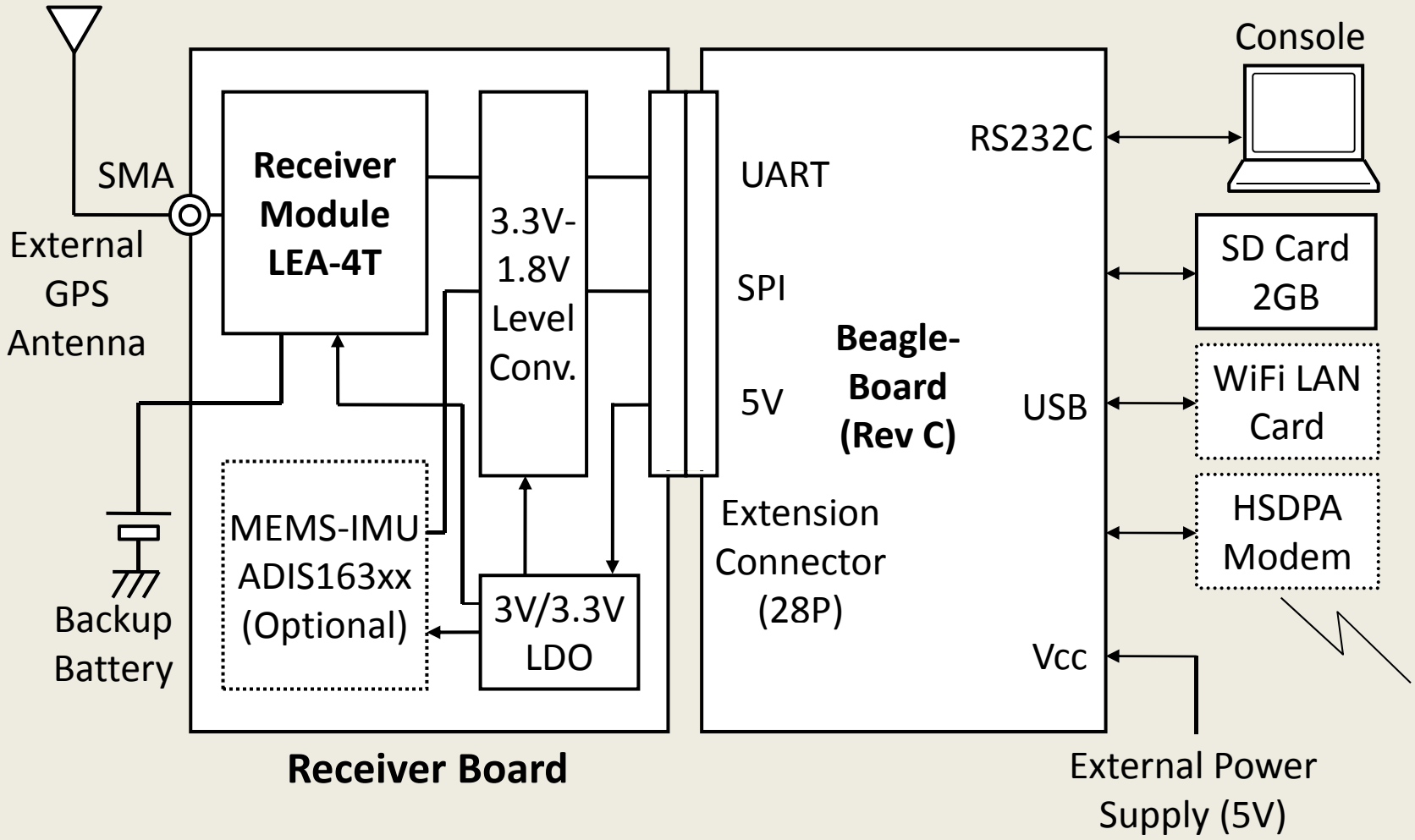
http://beagleboard.org

Selection of Receiver Module

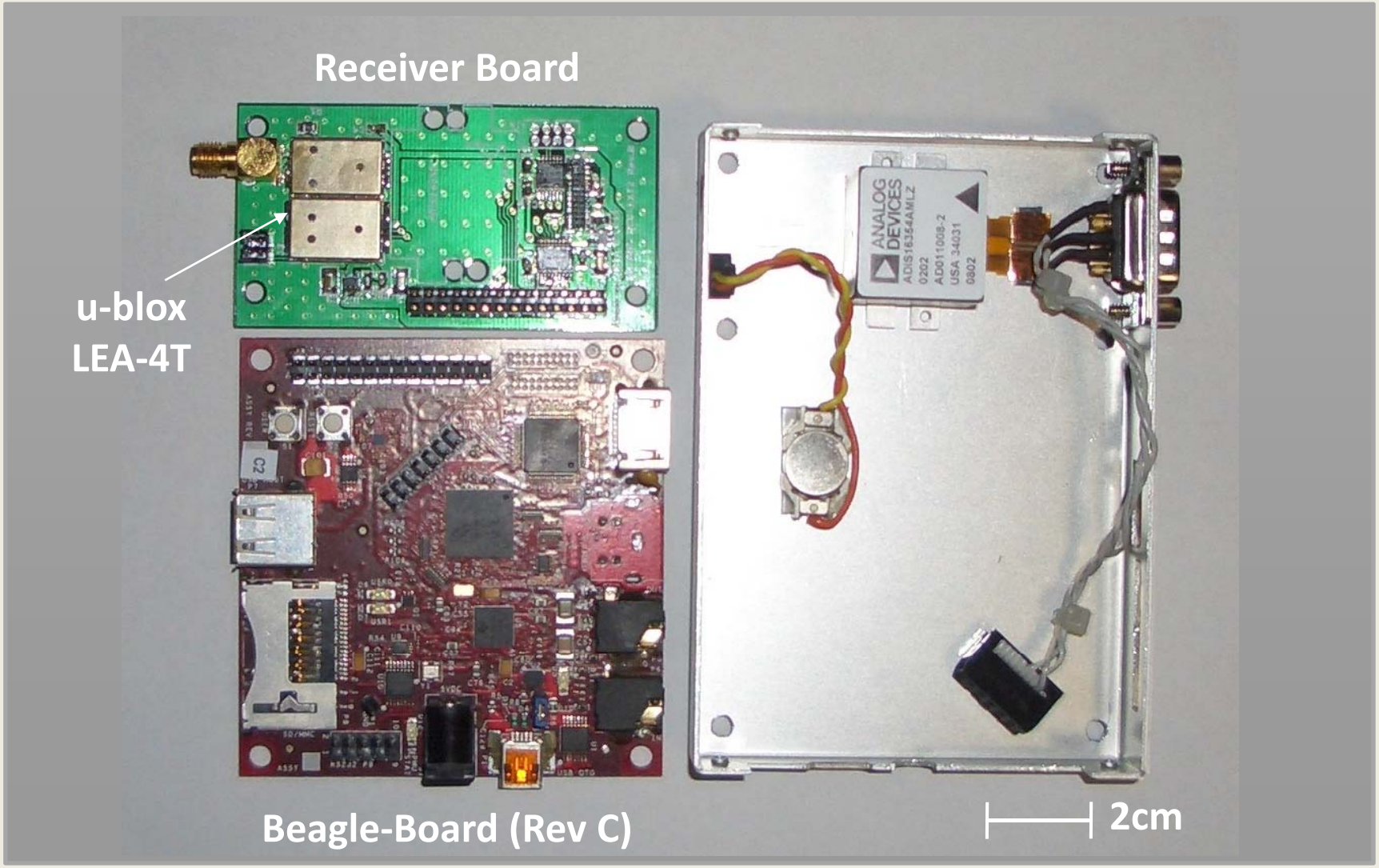
Vendor	Receiver Board/Module	B/M *1	# of CH	Max Raw Rate	Sample Price
NovAtel	SuperStar II	B	12ch	1Hz	$165
NovAtel	OEMStar *2	B	14ch	10Hz	2009/4Q
Magellan	AC12	M	12ch	1Hz	$106
SiRF	SiRF star II	C	12ch	1Hz	$57
GARMIN	GPS 15L/15H	M	12ch	1Hz	$60
u-blox	LEA-4T	M	16ch	10Hz	$179
u-blox	LEA-5T	M	50ch	2Hz	$179
u-blox	LEA-6T	M	50ch	?	2010/1Q
Hemisphere	Crescent	B	12ch	10Hz	$285
SkyTraq	S1315F	M	12ch	20Hz	$25

*1 B: OEM Board, M: Module, C: Chip, *2 Supports GLONASS

Hardware Configuration



Hardware Configuration



Parts List and Price

No	Parts	Specs	Provider	#	Price
1	Beagle-Board	OMAP3530, 256+256MB RAM/Flash	Digi-key	1	$149
2	LEA-4T	16ch, Single-Freq Receiver Module	u-blox	1	$179
3	Extension Board	3" x 1.2", double-side	Silver Circuit	1	$18
4	TPS79933DDCR	IC LDO Reg 200mA 3.3V TSOT-23-5	TI	1	$1
5	TPS79930DDCT	IC LDO Reg 200mA 3.0V TSOT-23-5	TI	1	$1
6	TXS0108E	IC 8bit Non-Inv Transtr 20TSSOP	TI	1	$2
7	TXS0104E	IC 4bit Non-Inv Transtr 14TSSOP	TI	1	$2
8	Connectors	SMA, D-Sub-9P, Header-28P-M/F	-	1s	$20
9	Chip Cap, Reg.	-	-	1s	$2
10	Case YM-115	115 x 80 x 20 mm	Takachi	1	$6
11	Screws, Spacers	-	-	1s	$3
12	SD Card	2GB	-	1	$20
	Total	-	-	-	**$403**
OP1	ADIS16354	6-Axis MEMS-IMU, 1.7g, 300deg/s	ADI	1	$720
OP2	CLM-112-02	24P 1mm-pitch sockets	Samtech	1	$7

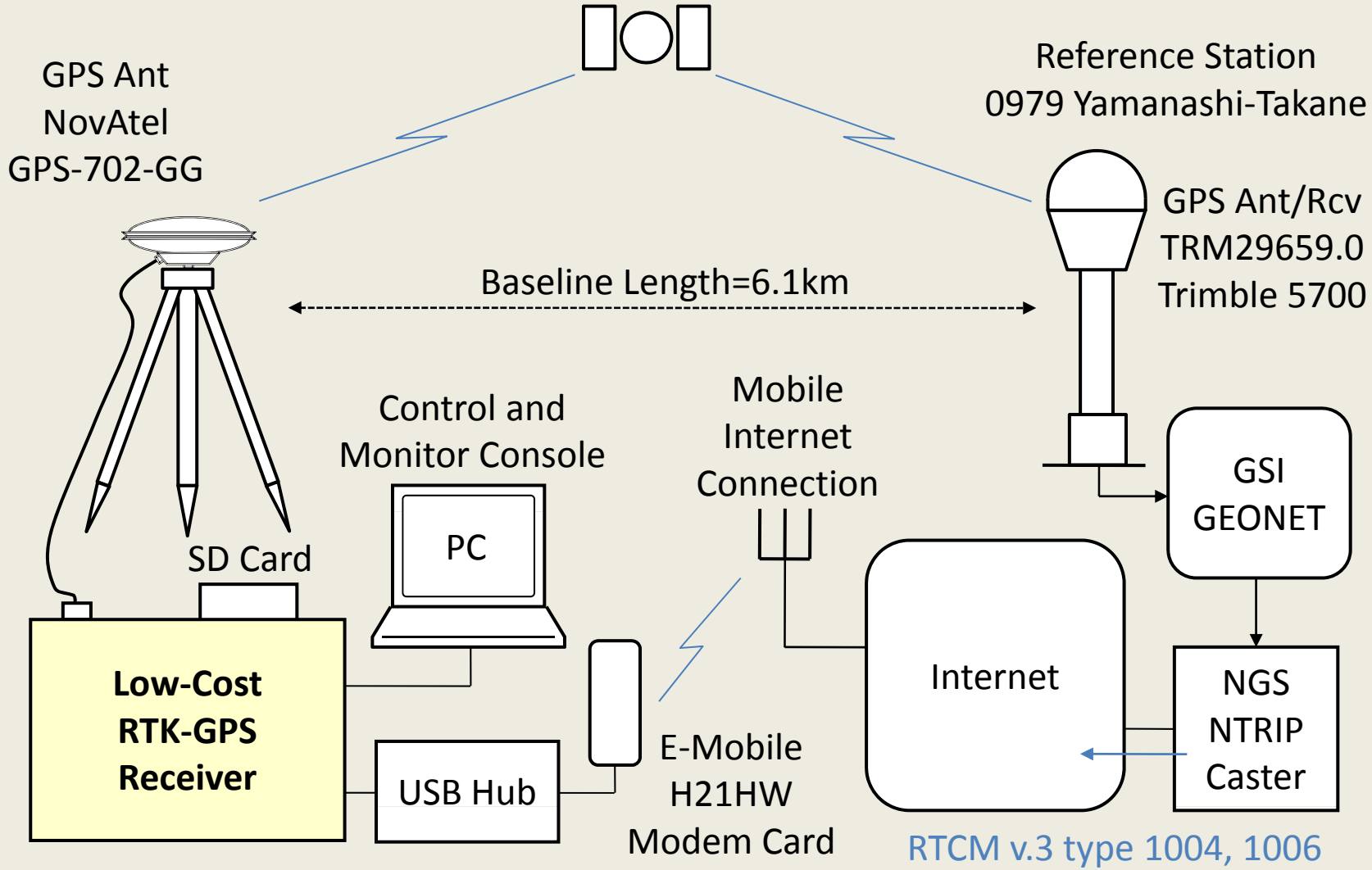
Software Configuration

- **Operating System**
  - Kernel: Linux 2.6.29-OMAP1+Patchs
  - Root FS: Ubuntu 9.04 for ARM on SD-Card
  - Peripherals: USB LAN, USB WiFi, USB Modem,...
- **Cross-compiler**
  - ARM-gcc 4.2.1
  - Compiler options
    -O3 -mfpu=neon -mfloat-abi=softfp -ffast-math
- **LIBC: glibc 2.9, libc6-vfp**
  - Optimized floating-point library for ARM co-processor

RTKRCV

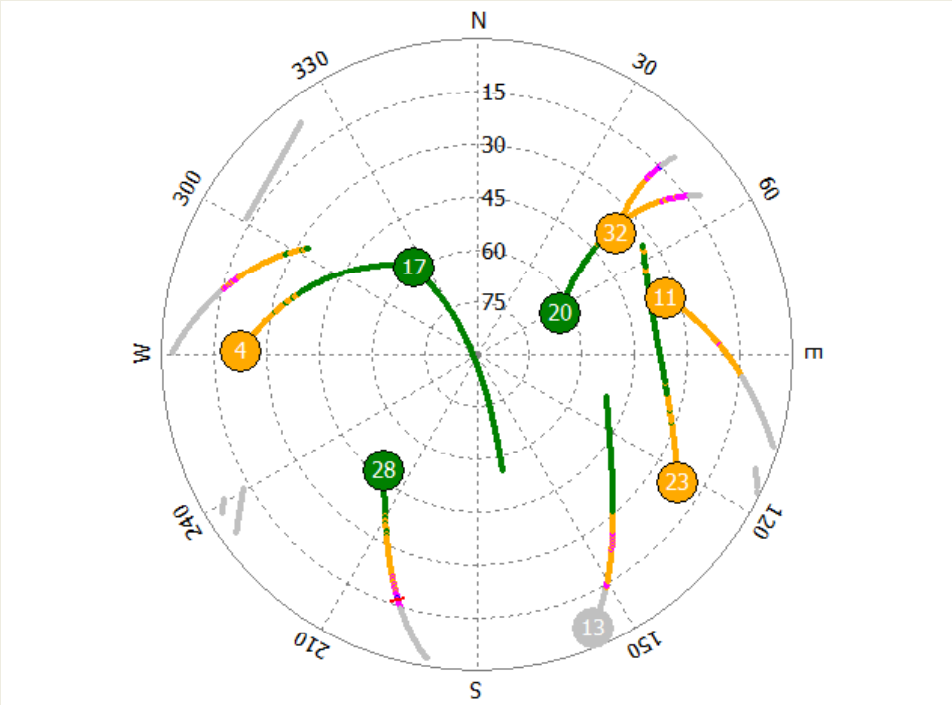
- **Console AP for real-time positioning**
  - Newly implemented for Beagle-Board-based RTK receiver
  - Portable to many targets like Windows, Linux, Mac OS X
  - Will be incorporated into RTKLIB ver.2.3.0
- **Features**
  - Various receivers, input/output formats, stream types, positioning options are supported same as RTKNAVI
  - No GUI but support TELNET login from remote console to set options, control and monitor the receiver
  - TCP/IP stack and device drivers are provided by OS

Test Configuration



Test Conditions

- 2009/9/30 9:31 - 11:39 GPST (2 hr 8')
- 10 Hz raw measurement data (total 76971 epochs)
- Baseline length: 6.1 km
- Number of visible satellites: 7 - 9 (elevation>15°)



CPU Load and Memory Usage

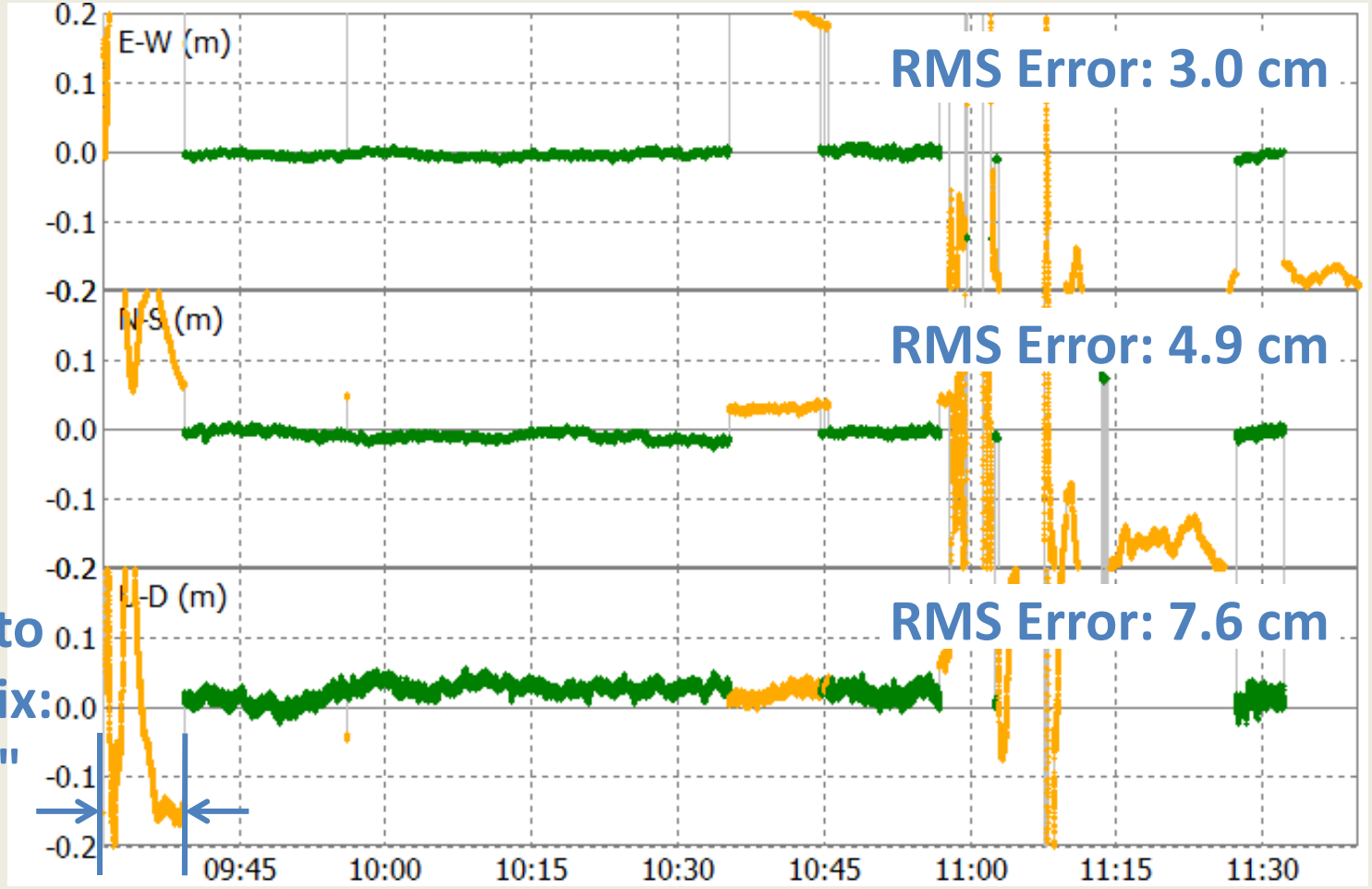
- 10 Hz update of RTK-GPS solutions
- Receiving RTCM v.3 via NTRIP with E-Mobile HSDPA modem
- Logging all raw measurement data and solutions to SD card

```
$ top

top - 00:08:24 up 24 min,  1 user,  load average: 0.16, 0.24, 0.18
Tasks:  46 total, 1 running, 45 sleeping,  0 stopped,  0 zombie
Cpu(s): 24.3%us, 1.3%sy, 0.0%ni,73.4%id, 0.7%wa, 0.3%hi, 0.0%si, 0.0%st
Mem:   239616k total,   30476k used,  209140k free,     3540k buffers
Swap:       0k total,       0k used,       0k free,    12492k cached

 1876 ubuntu    20   0 11896 2344 1256 S 25.1  1.0   4:13.09 rtkrcv
 1894 ubuntu    20   0  2492 1160  936 R  0.7  0.5   0:00.16 top
    1 root      20   0  2860 1896  572 S  0.0  0.8   0:01.49 init
    2 root      15  -5     0    0    0 S  0.0  0.0   0:00.00 kthreadd
    3 root      15  -5     0    0    0 S  0.0  0.0   0:00.07 ksoftirqd/0
    4 root      RT  -5     0    0    0 S  0.0  0.0   0:00.00 watchdog/0
    5 root      15  -5     0    0    0 S  0.0  0.0   0:00.04 events/0
    6 root      15  -5     0    0    0 S  0.0  0.0   0:00.05 khelper
...
```

Positioning Error and Fixing Ratio



Time to First Fix: 8' 15"

● : Fixed Solutions (59.6%) ● : Float Solutions (40.4%)

Summary

- **RTKLIB**
  - Open source program package for RTK-GPS
- **Implementation of low-cost RTK receiver**
  - Beagle Board + u-blox LEA-4T + Ubuntu Linux
  - Total cost: about $400 (w/o options)
- **Evaluation of performance**
  - CPU load and memory usage: no problem for 10 Hz RTK
  - Accuracy: <5cm H-RMS, <8cm V-RMS
  - Fixing ratio: 50-60% range
  - Need to tune parameters and improve AR performance