

2009 International Symposium on GPS/GNSS

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

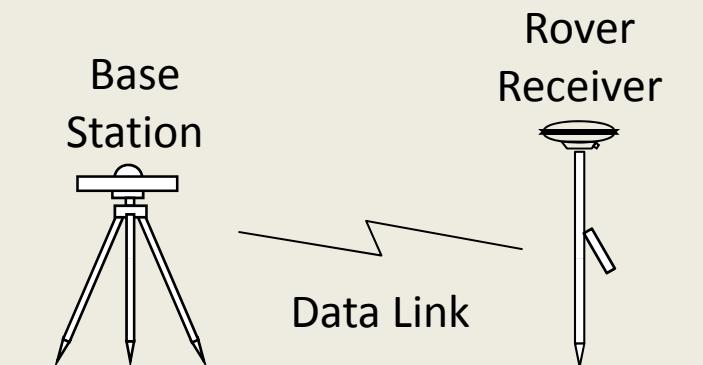


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Background (1)

- **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



\$10,000-\$30,000

- **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



\$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...

The screenshot shows a web browser displaying the RTKLIB download page. The URL in the address bar is <http://gpspp.sakura.ne.jp/rtklib/rtklib.htm>. The page title is "RTKLIB: An Open Source Program Package for RTK-GPS". The main content area is titled "Download" and contains a table showing binary packages for Windows and a full package with source programs. The table includes columns for Version, Date, Binary AP Package for Windows, and Full Package with Source Programs.

| Version | Date | Binary AP Package for Windows | Full Package with Source Programs |
|---------|------------|---|---|
| 2.2.0 | 2009/01/31 | rtklib_2.2.0_bin.zip (10.7MB) | rtklib_2.2.0.zip (23.4MB) |
| 2.2.1 | 2009/05/17 | rtklib_2.2.1_bin.zip (15.3MB) | rtklib_2.2.1.zip (30.6MB) |
| 2.2.2 | 2009/09/07 | rtklib_2.2.2_bin.zip (21.4MB) | rtklib_2.2.2.zip (33.8MB) |

A note at the bottom of the table says: "Please refer the [support information](#) to get the latest patches."

The "Overview" section describes RTKLIB as an open source program package for RTK-GPS, mentioning its components and capabilities. It lists 17 matrix and vector functions, various positioning models, SBAS DGPS correction, single point positioning, carrier-based and code-based relative positioning, integer ambiguity resolution, raw binary data input, positioning solution/NMEA input/output, RINEX observation data/navigation message input/output, precise ephemeris input, stream data communication library, NTRIP (Networked Transport of RTCM via Internet Protocol) library, RTK-GPS positioning server, and RTCM 2.3 and 3.0/3.1 message handling.

The "License" section states that RTKLIB is distributed under GPLv3 license (<http://gplv3.fsf.org/>).

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

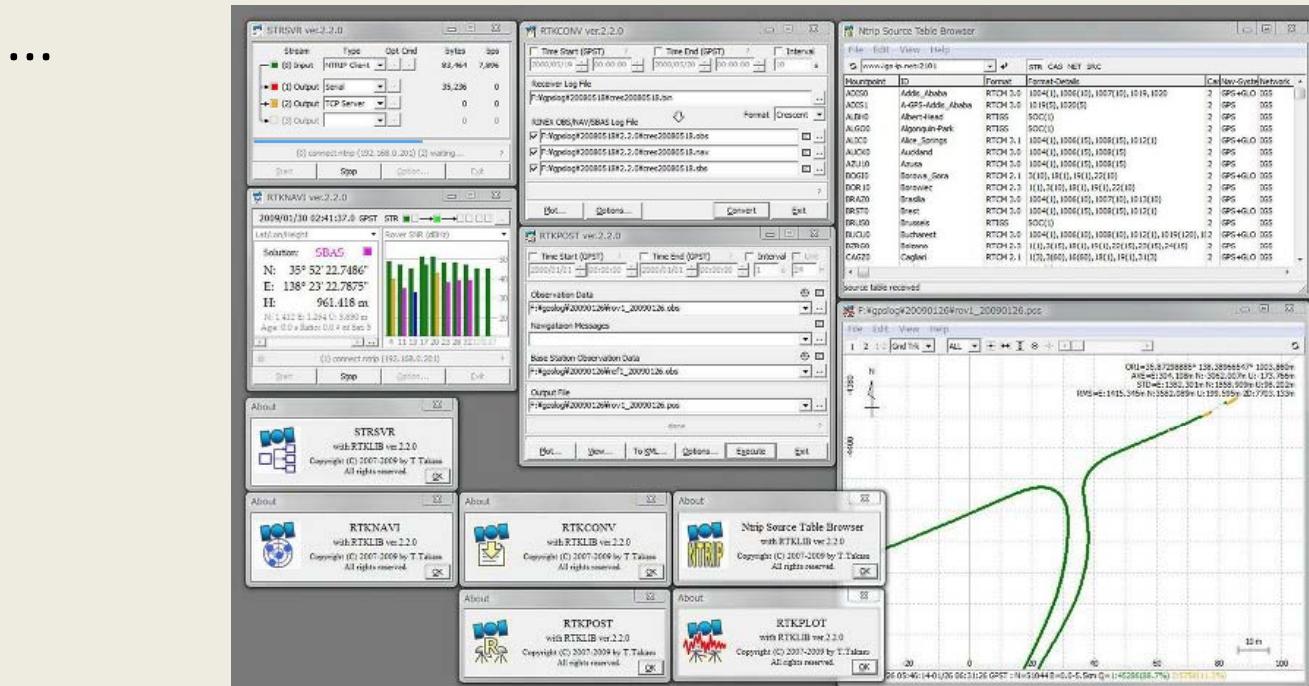
RTKLIB APs on Windows

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

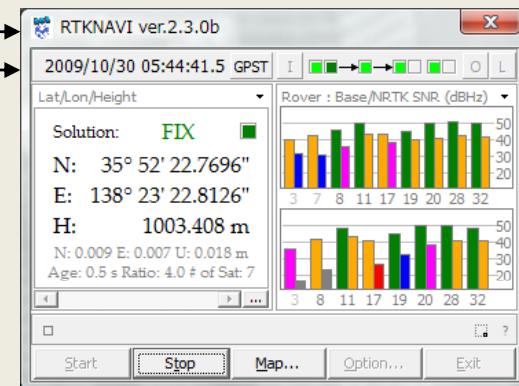


Input Formats

- 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

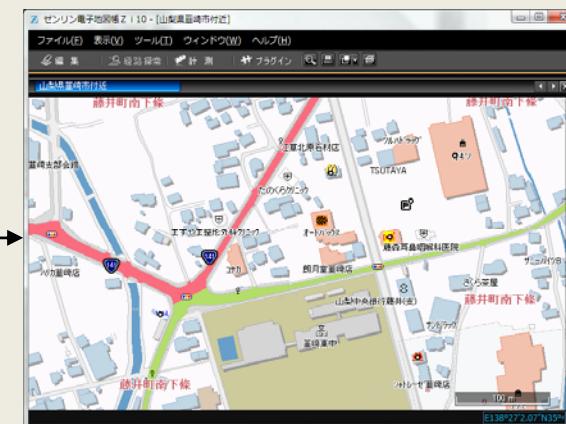
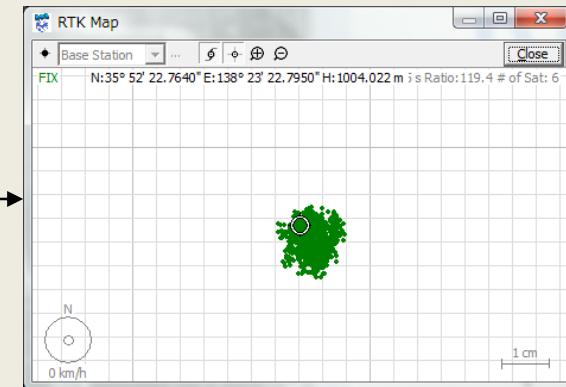
I/O Stream Types

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



Output Formats

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



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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

The screenshot shows a web browser displaying the official BeagleBoard.org website. The page features a large orange header with the BeagleBoard logo and the text "beagleboard.org". Below the header, there's a main banner with a hand holding a Beagle Board and a price tag of "Only \$149". The banner text highlights that the USB-powered Beagle Board delivers laptop-like performance and expansion, listing several key features based on the OMAP3530 processor. To the right of the banner, there are links to "Support", "About Us", "Videos/Pictures", a "Google Custom Search" bar, and search and discuss buttons. The main content area includes sections for "Upcoming Events" (listing Symbian Exchange & Expo, The beagle board port for SF^2, ARM Techcon3, and ESC Boston 2009), "Latest News" (mentioning Symbian now open source and a new Symbian smartphone operating system), and "Top Resources" (linking to System Reference Manual, eLinux Wiki, and various support forums). There are also sections for "Third Party Resources" featuring the KBOC System Module and KwikByte.

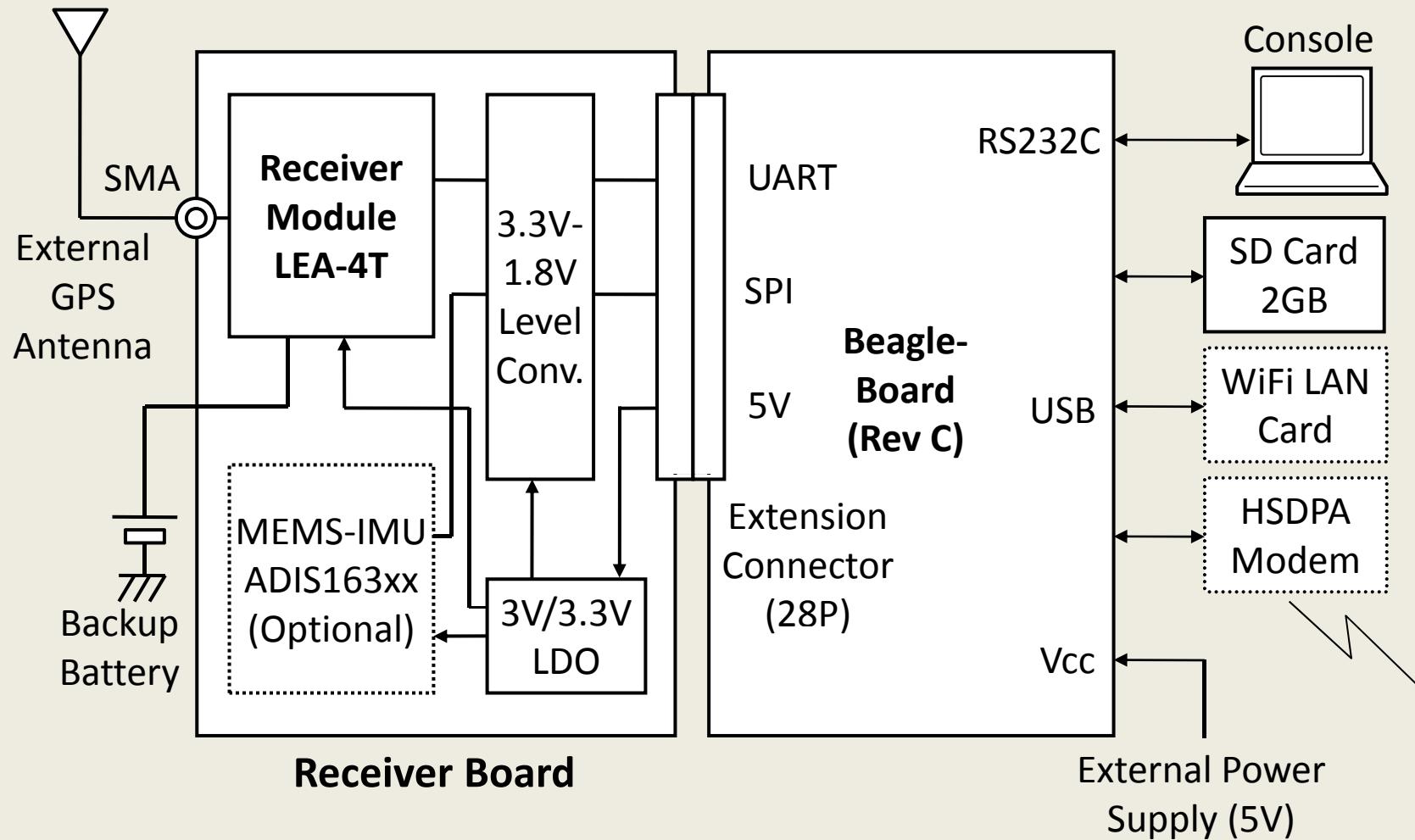
<http://beagleboard.org>

Selection of Receiver Module

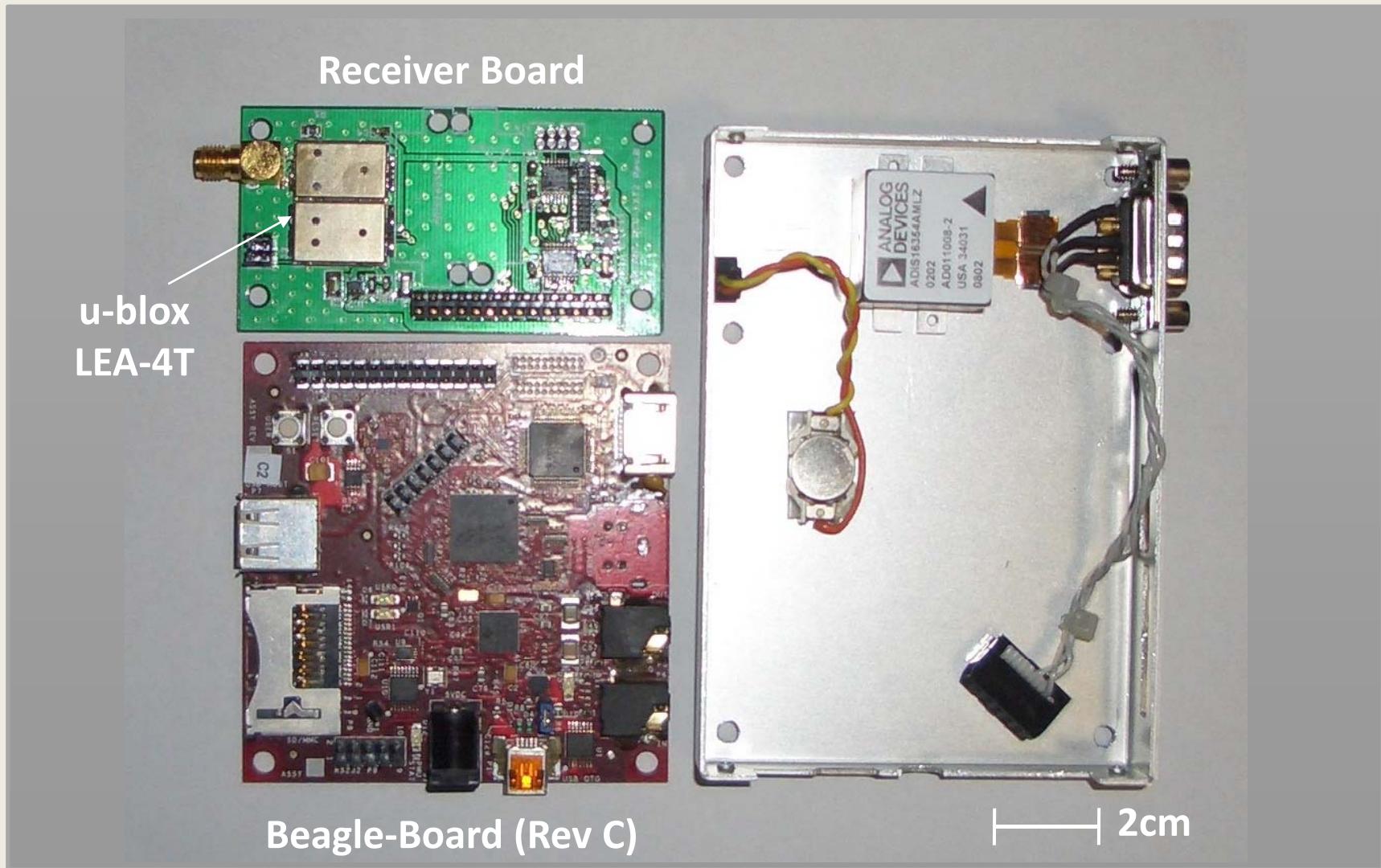
| Vendor | Receiver Board/Module | B/M *1 | # of CH | Max Raw Rate | Sample Price |
|------------|-----------------------|--------|---------|--------------|--------------|
| NovAtel | SuperStar II | B | 12ch | 1Hz | \$165 |
| NovAtel | OEMStar *2 | B | 14ch | 10Hz | 2009/4Q |
| Magellan | AC12 | M | 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 |

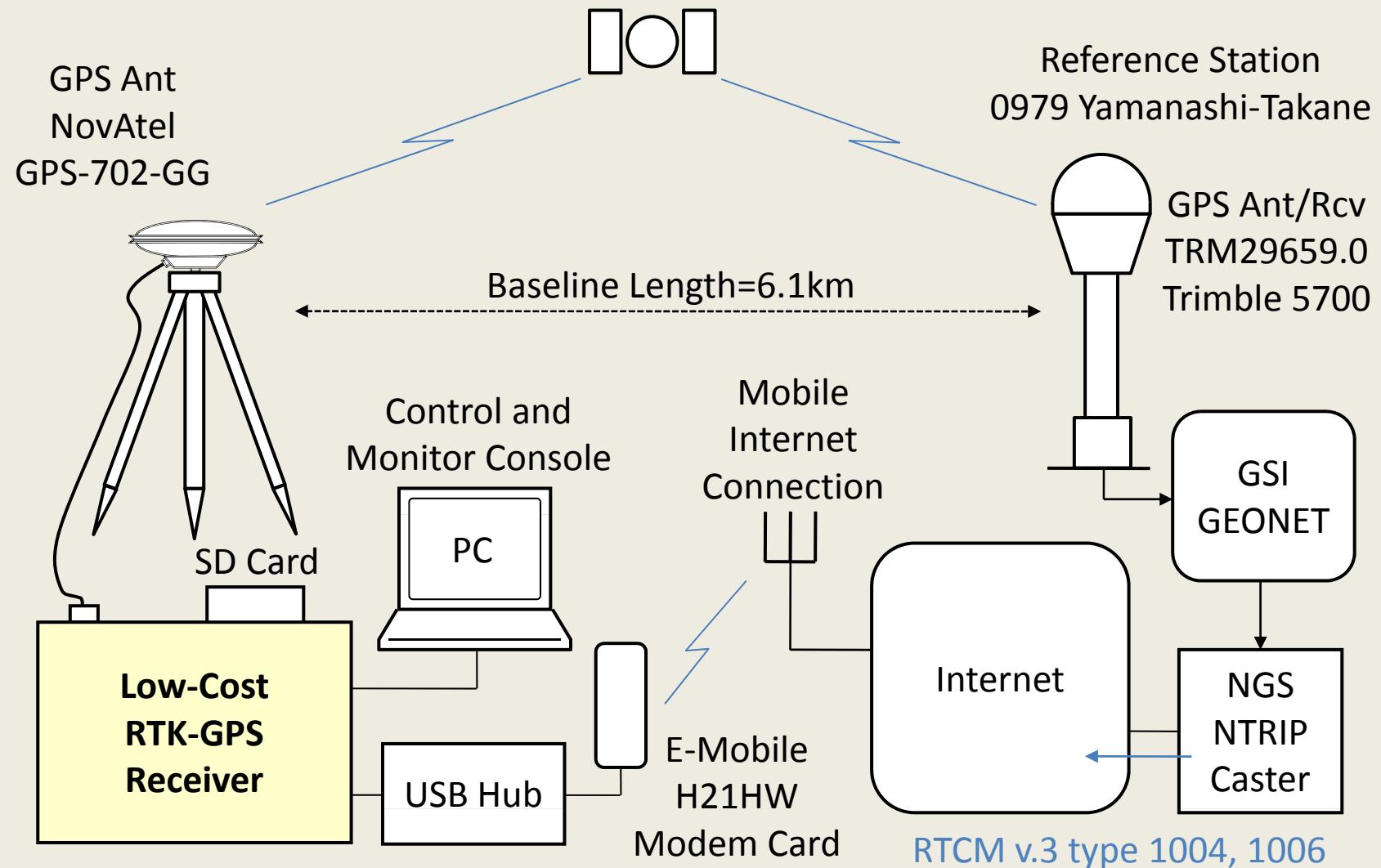
Software Configuration

- **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

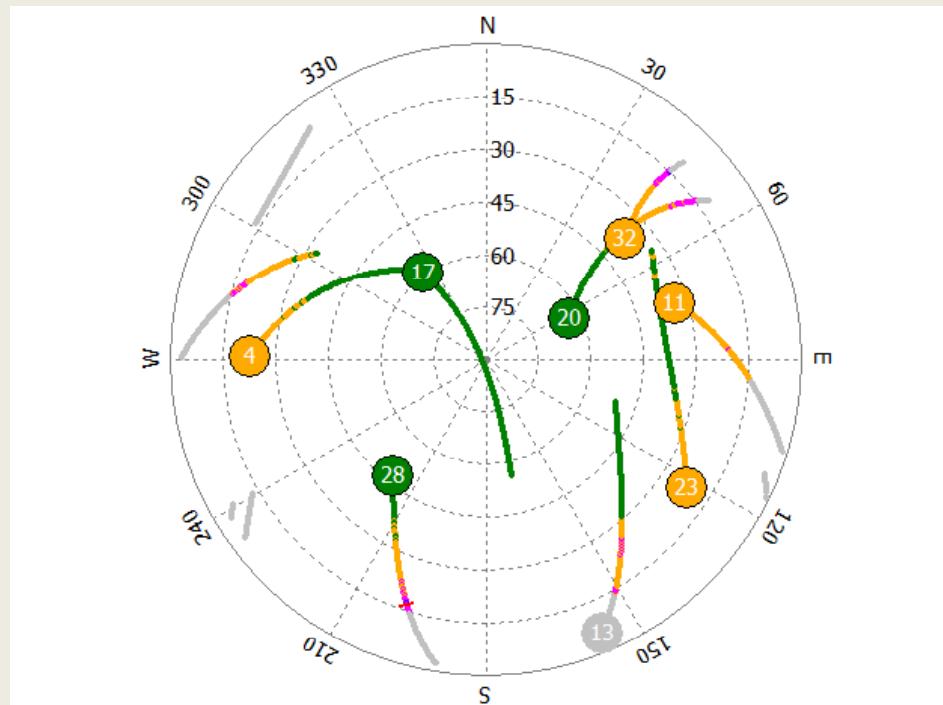
- **Console AP for real-time positioning**
 - Newly implemented for Beagle-Board-based RTK receiver
 - Portable to many targets like Windows, Linux, Mac OS X
 - Will be incorporated into RTKLIB ver.2.3.0
- **Features**
 - Various receivers, input/output formats, stream types, positioning options are 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

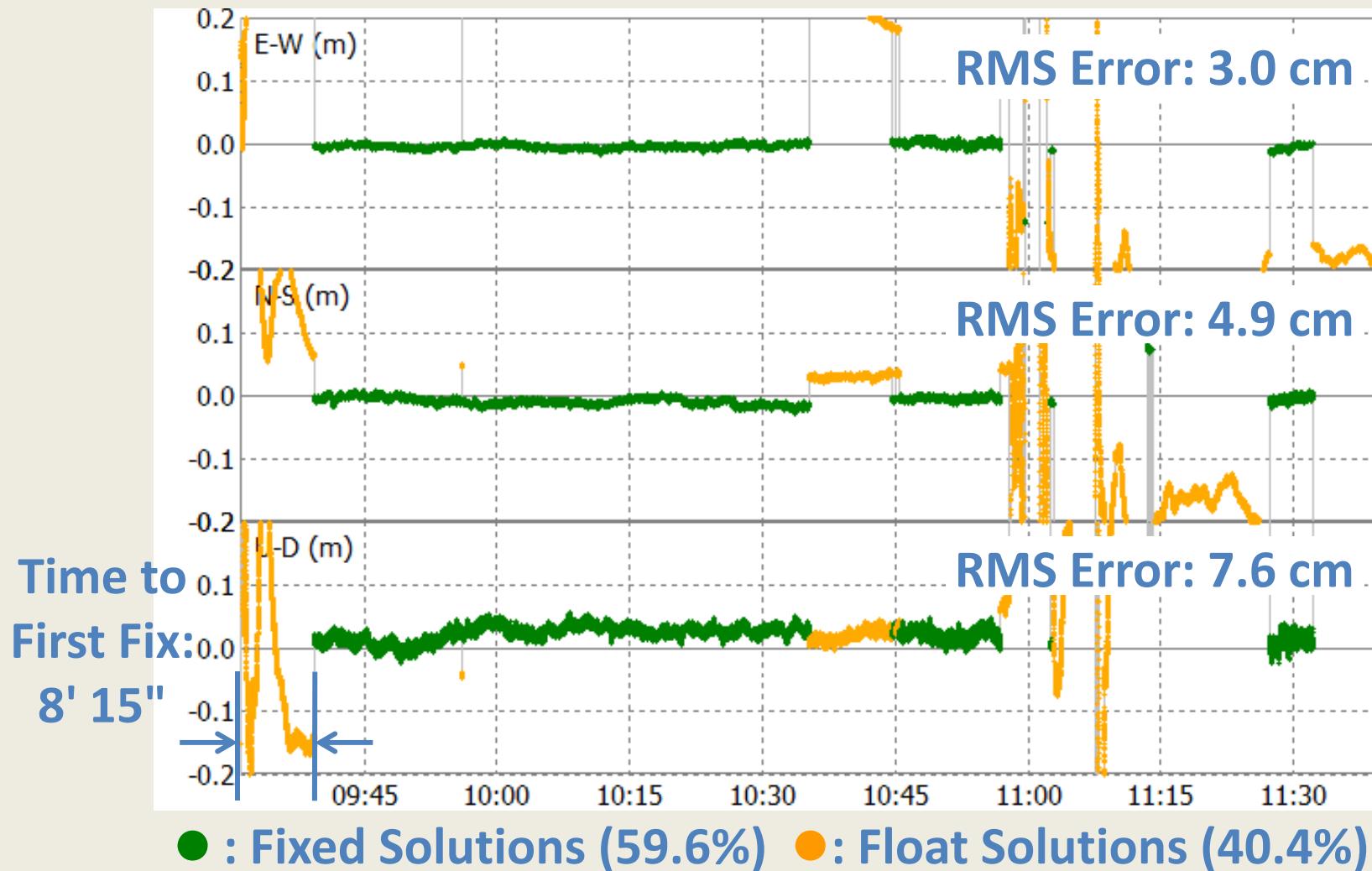
- 10 Hz update of RTK-GPS solutions
- Receiving RTCM v.3 via NTRIP with E-Mobile HSDPA modem
- Logging all raw measurement data and solutions to SD card

```
$ 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



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