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Development of the low-cost RTK-GPS receiver with the open source program package RTKLIB

Tomoji Takasu, Akio Yasuda

Tokyo University of Marine Science and Technology

RTK-GPS (real-time kinematic GPS) is one of the most precise techniques, with which users can determine the real-time position in cm-level accuracy by using GPS/GNSS signals especially carrier-phase observables. RTK-GPS has already been utilized for several positioning applications like land survey, precise agriculture or machine control for construction. The RTK-GPS receivers, however, have been still much expensive compared to general purpose GPS receivers for code-based positioning. This is one of the reasons why RTK-GPS is still not popular and used only for limited applications. If more inexpensive RTK-GPS receivers were available, larger number of users, who need more precise positions, would intend to use the technique. More applications of RTK-GPS, currently not applicable due to cost issues, would become practical.

RTKLIB is a program package for RTK-GPS developed by the authors [1]. The objective RTKLIB is to provide a standard platform for RTK-GPS applications. RTKLIB consists of a simple and portable program library for RTK-GPS written in standard ANSI C (89), and several useful APs (application programs) utilizing the library. From the version 2.2.0, RTKLIB has been distributed under GPLv3 license as an open source program package. Any user can freely download the package via Internet and use it (http://gpspp.sakura.ne.jp/rtklib_e.htm). All source codes of the library and APs are included in the package and able to be modified or customized by the users. The users also can add the user-specific program codes according to the environment or application. The library of RTKLIB includes the fundamental functions for RTK-GPS positioning algorithms, such as matrix/vector computation, coordinates transformation, geoid model, ephemeris processing, troposphere/ionosphere models, antenna phase center corrections, SBAS DGPS corrections, single point positioning and carrier-based relative positioning with OTF integer ambiguity resolution. The library implements the RTK-GPS server function by using the standard POSIX pthreads library. The RTK-GPS server inputs data streams of rover and base-station observation, computes the rover receiver position by applying real-time sequential estimation filter, resolves integer ambiguity by a popular efficient integer vector search strategy LAMBDA, and outputs the solution in various formats typically NMEA-0183. The library supports several single- or dual-frequency GPS receivers, which can output raw observation data and satellite ephemerides. In the next version of RTKLIB, we are planning to incorporate the handling of RTCM 2.3 and 3.0 messages in the library for many other receivers and NRTK (network RTK) service. For the communication between the rover and the base-station, RTKLIB implements a general binary stream I/O library, which supports serial devices for direct, USB or Bluetooth connection to the receiver, standard TCP/IP client/server

sockets and NTRIP. By using mobile Internet connection like HSDP (high speed data access), users can obtain precise RTK-GPS solutions on the moving vehicle with RTKLIB. In addition to the real-time capability, the package also includes a post-mission baseline analysis AP called RTKPOST. RTKPOST inputs standard RINEX 2.10 observation data and navigation messages and computes the precise baseline solution in the static, kinematic or moving-baseline mode. For medium or long baseline analysis, RTKPOST also has the capability for SP3 precise ephemerides as well as ionospheric and tropospheric parameter estimation.

RTKLIB was originally implemented on Windows PC. In this study, to construct a low-cost RTK-GPS receiver, we ported RTKLIB to a very compact (3” x 3”) single-board computer Beagle Board (http://beagleboard.org/). Beagle Board has 600MHz ARM Cortex-A8 based CPU-core, which provides sufficient performance for 10 Hz update of the RTK-GPS solution with integer ambiguity resolution. Beagle Board supports the embedded Linux environment, which provides the pthreads library, TCP/IP stack, file system on a SD card and device drivers for many useful peripherals like USB WiFi network card. In order to acquire and track GPS signals, we also employed a single-frequency GPS receiver module LEA-4T provided by u-blox, which can output 10 Hz raw observation data. The receiver module is connected to Beagle Board via the internal serial port with the bit rate of 115200 bps. The RTK-GPS server running on Beagle Board inputs the rover receiver raw binary data as RXM-RAW and RXM-SFRM messages according to u-blox protocol. The server also inputs the base-station observation data via the USB network device and computes RTK-GPS solution in real-time. The total cost of the developed RTK-GPS receiver was about $600 for the single-board computer, the receiver board with a GPS receiver module and the case and internal cables. Note that it does not include the cost for the external GPS antenna and equipment for the base-station.

To demonstrate and verify the performance of the low-cost RTK-GPS receiver with RTKLIB, we conducted some field tests in the stationary and dynamic environment. In the experiments, the accuracy of solutions, TTFF (time to first fix) with integer ambiguity resolution were evaluated. The paper will contain the performance evaluation results of the low-cost RTK-GPS receiver.