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Evaluation of RTKLIB's Positioning Accuracy Using low-cost GNSS Receiver and ASG-EUPOS

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ABSTRACT: The paper focuses on a comparison of different positioning methods provided by free and open source software (FOSS) package called RTKLIB. The RTKLIB supports real-time and post-processed positioning. The most important modes of operation tested by the authors are Kinematic, Static, Fixed and Precise Point Positioning (PPP). The data for evaluation were obtained from low-cost Global Navigation Satellite System (GNSS) receiver. The tested receiver was based on the u-blox's LEA-6T GNSS module. This receiver provides different types of information including raw carrier phase measurements. It gives the possibility for centimeter-level precision of positioning. As the supporting source of data ASG-EUPOS system was used. ASG-EUPOS is a Polish network of GNSS reference stations providing the real-time corrections and post processing services for the entire territory of Poland.

1 INTRODUCTION

The goal of performed research was to familiarize with functionality of RTKLIB (Takasu 2007) and its possibility to use in precise positioning. This tool is a free open-source package containing applications designed for real-time navigation and post-process positioning. RTKLIB uses several modes such as Single, PPP and carrier-phase based. Those modes are described in detail in next chapter.

In process of gathering data LEA-6T module (Fig. 1) and antenna (Fig. 2) from u-blox were used. LEA-6T is a low-cost precision-timing GNSS module. It allows to gather lots of type of data including raw measurements, which were used. Data gathered using the module are listed in chapter 3.

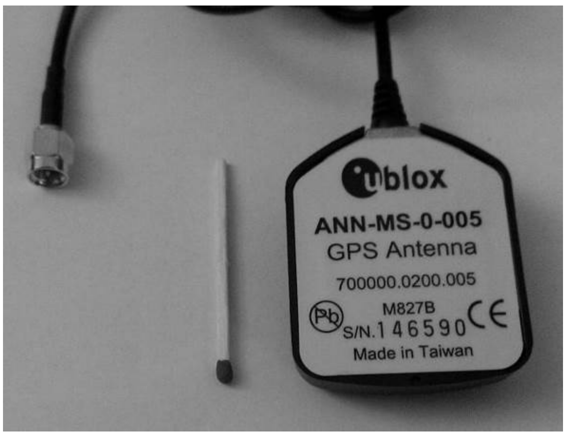

Figure 2. u-blox GPS Antenna with magnetic base.

Figure 1. u-blox LEA-6T mounted on the printed circuit board.

ASG-EUPOS (Bosy et al. 2007) was used as supporting source of data. This Polish network of reference stations provides different type of positioning services. Available services deliver supporting data for real-time navigation (NAWGEO, KODGIS, NAWGIS) and for post-processing (POZGEO, POZGEO D). In the research POZGEO and POZGEO D were used. First one allows to post-process given data file in order to calculate position. The second one provides data about base-stations (position, raw observation data), which are used in post-process tool that is part of RTKLIB package.

2 POSITIONING METHODS AND ACCURACY

Nowadays, satellite navigation is a non-negligible technology when developing an inexpensive, location-based system accessible for many people. For example, surveys conducted by the authors with the visually impaired in the "Voice Maps" project (Kamiński & Bruniecki 2012) showed the desired accuracy should be at a level of few meters or better – depending on the actual application.

In order to improve the accuracy of positioning by a smartphone-based GPS receiver in the "Voice Maps" project, the authors developed and implemented the Differential GPS (DGPS)-based module. A DGPS approach reduces some sources of errors occurring during the GPS-based positioning (Prasad & Ruggieri 2005). Among these errors one can distinguish the impact of ionosphere and troposphere effects, which could result in inaccuracies reaching tens of meters (Prasad & Ruggieri 2005). The implemented system uses additional information from Polish ground-based augmentation networks i.e. ASG-EUPOS.

The Figure 3 shows the hardware for a DGPS solution. It consists of a GARMIN eTREX H GPS receiver (capable of interpreting DGPS corrections sent via the RTCM protocol) and a Bluetooth adapter responsible for communication between the mobile device and the GPS receiver.

Figure 3. DGPS measurement unit.

The adapter provides a wireless connection to the smartphone and the RS232-based connection to the GPS receiver. A mechanism implemented in the smartphone application is responsible for communication with the ASG-EUPOS network, and for sending corrections to the receiver via the adapter. In response, the receiver uses the adapter to provide a more accurate position for the smartphone application.

However the results obtained with DGPS were not sufficiently good. Measurements of the DGPS accuracy showed that the KODGIS-based positioning gives better results than the NAWGIS service. A comprehensive comparison of the KODGIS and the NAWGIS approaches is given in Figures 4 and 5. Those Figures shows percentages of measurements of three GNSS approaches within selected ranges of positioning error and the cumulative distribution of positioning error for all the measurements (Kamiński & Bruniecki 2012) respectively:

$$F(x) = \frac{|\{d \in D : \mathrm{error}(d) \le x\}|}{|D|} \cdot 100\% \quad (1)$$

where D is the set of all measurements.

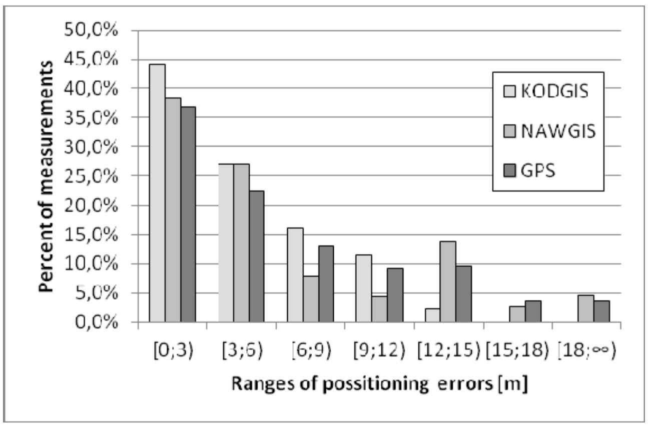

Figure 4. Comparison of DGPS based KODGIS, NAWGIS and embedded GPS receiver positioning accuracy.

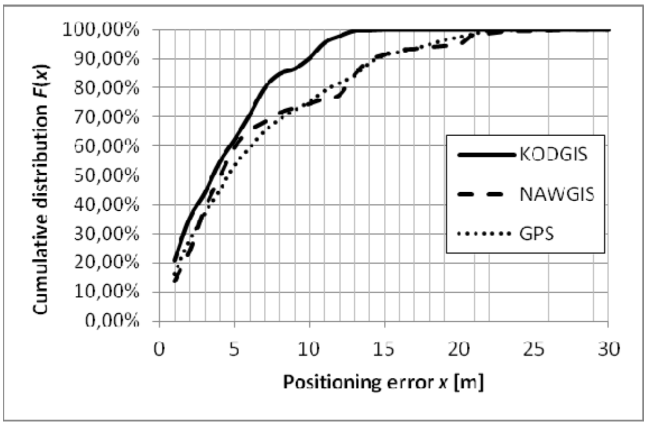

Figure 5. Comparison of DGPS based KODGIS, NAWGIS and embedded GPS receiver positioning accuracy.

That was the reason for this research on inexpensive carrier phase measurement based positioning algorithms.

2.1 *Single Point Positioning*

In RTKLIB this mode is used to calculate position using Single Point Positioning (SPP) or Space Based Augmentation System Differential GPS (SBAS DGPS) when usage of SBAS data is enabled. Configuration of this tool allow to use many sources of data, although only rover data is required in process of positioning. Additional sources of data are ephemeris corrections, ionosphere corrections, and precise satellite clock (all three can also be used in other modes).

In SPP the position is calculated using only given satellites positions. Using at least four satellites is necessary to find solution of navigation equations with four unknowns representing receiver position and errors (NRC 1995).

SBAS is a solution that use one or more geostationary satellites to transmit corrections obtained using observations from several to tens of measurement stations. Few SBAS exists at the time. Territory of Europe is covered by European Geostationary Navigation Overlay Service (EGNOS).

Accuracy of results obtained using Single mode in RTKLIB are at level of meter to dozen of meters for SPP and level of meter for SBAS DGPS. Single mode test results are shown in chapter 4.

2.2 *Reference dependant carrier-phase methods*

RTKLIB provides variety of modes using carrier-phase based positioning. Modes which were used in this evaluation are Kinematic, Static and Fixed. All three are described below. Required sources of data are raw observations from receiver and base station.

Kinematic carrier-based method is usually applied when positioning of moving object is required. This technique allow to achieve decimeter level of accuracy (NRC 1995). For proper work base station position is required to be set in configuration. This position can be obtained from observations file, obtained from RTCM message or by other manners. In performed research base station position was available in RINEX observation file provided by ASG-EUPOS.

In static carrier-phase measurement solution, there is need for long observations and data collection. This requirement is related to geometry change in satellite track, which assist in ambiguity resolution (NRC 1995). Like in all carrier-phase based methods two sources of data are necessary which of one have well known coordinates to serve as base station.

Fixed is special mode provided by RTKLIB. It's similar to previously mentioned carrier-phase modes, with the difference that rover's initial position is known. The rover position can be configured in exact manner as base station position.

2.3 *Precise Point Positioning (PPP)*

PPP is a positioning technique in which only single receiver is required, without need for reference from base stations. To calculate position input code, phase observations, precise satellite orbits and precise satellite clock is used. Best results are achieved for at least dual frequency (L1+L2) receiver. It is known that good quality results can be acquired for single frequency (L1) receiver, but these measurements are based mostly on pseudo-range. High dependence on pseudo-range causes also bigger influence of ionosphere behavior and increased need for its corrections (Witchayangkoon 2000).

The main drawback of PPP algorithms is long time of convergence. To reach good quality of positioning measurements have to be taken for over dozen minutes. When using single frequency this time can extend to tens of minutes or few hours. It happens that convergence won't be achieved at all (Witchayangkoon 2000).

To use PPP mode in RTKLIB single source of data is required - raw observations from rover. The tool will automatically detect how many frequencies were used in measurement. RTKLIB implements three methods of Precise Point Positioning. These methods are Kinematic, Static and Fixed.

3 MEASUREMENTS SETTING AND GATHERED DATA

In order to evaluate RTKLIB's positioning accuracy two measurements were taken. First at "Pachołek Gdański" (54º24'41"N; 18º33'02"E, Fig. 6) second one at parking lot near "Real" Shopping Center (54º24'11"N; 18º35'24"E, Fig. 7).

First measurement was failure due to poor weather condition and suboptimal location of antenna. Results showed that algorithms were not able to hold stable fix for a longer period. Furthermore when tool has been reaching another fixed solutions, the positions of point clusters were scattered.

Figure 6. First measurement site.

While performing second measurement optimal location of antenna was assured, which provided better sky view. Antenna was attached directly to center of car roof so it prevented from gathering signals reflected from ground. Results of second measurement analysis are described in detail in the next chapter.

In order to gather necessary data proper configuration of LEA-6T module has been performed.

Figure 7. Second measurement site.

Configuration took the following steps:

1 Connection between computer and receiver has been established with baud rate set at 115,000, which was enough value for maximum frequency of incoming samples,

2 In View -> Configuration View -> RATE (Rates) -> Measurement Period value was set to 200 ms, which gave 5 Hz Measurement Frequency.

3 In View -> Configuration View -> MSG (Messages) -> Messages of type 02-10 RXM - RAW and 02-11 RXM - SFRB were enabled at UART1 and USB ports.

4 Recording was turned ON. This was achieved by selecting Record Button on Player Bar and creating new log file.

This setup allowed to collect five samples of raw data and SFRB measurements per second for further analysis. File was saved in UBX format.

4 RESULTS OF POSITIONING WITH THE RTKLIB AND ASG-EUPOS

As the experiment at the first site was unsuccessful only the results from the second experiment will be described here.

The raw data from the receiver was acquired in the UBX format. The essential part were carrier phase measurements inside the UBX\RXM\RAW frames. The Figure 8 presents the sample UBX\RXM\RAW frame. Such a frame contains Carrier Phase, Pseudo Range, Doppler Signal, Noise Ratio, Satellite designation and the interior receiver Lock Signal status.

Beside the UBX\RXM\RAW frames the essential for further processing with RTKLIB are UBX\RXM\SFRB data. These frames gives the information on actual navigational massages from each satellite.

In order to test the navigational algorithms the acquired UBX stream was decomposed into the RINEX 2.10 format parts. The decomposition gave the observation file (OBS), GPS satellites navigation message file (NAV), Geostationary satellites navigation message file (HNAV) and the satellite based augmentation file (SBS). For further processing only the OBS file is needed in every mode. Rest of the files are optional depending on the algorithm selected.

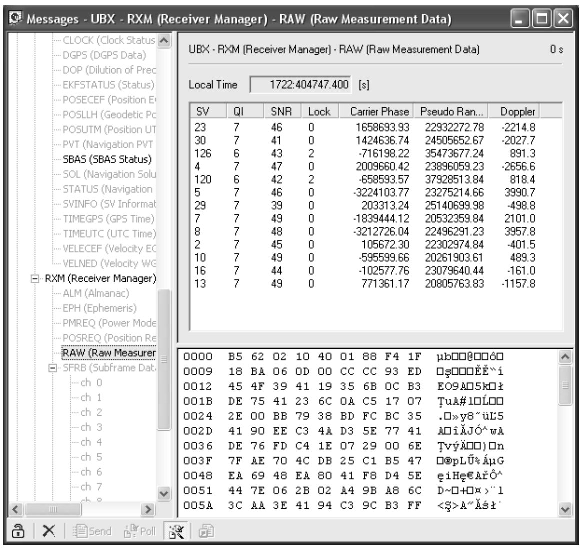

Figure 8. Sample UBX\RXM\RAW frame from the u-center.

The simplest configuration of RTKLIB is for the Single solution. It needs only the OBS file. The results of Single solution algorithm is presented on the Figures 9 and 10.

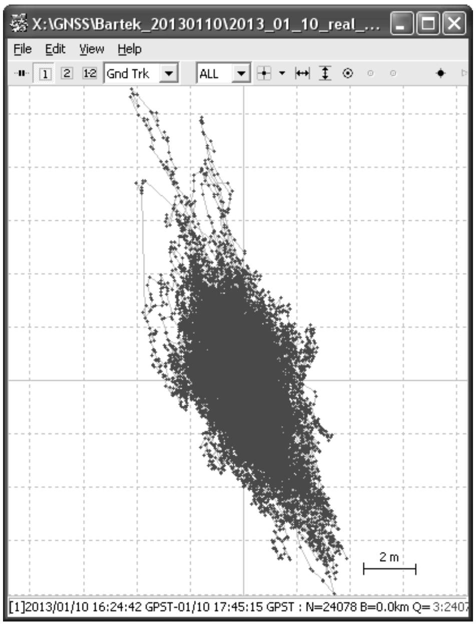

Figure 9. The result of single solution positioning.

Much better results were achieved when computing the Static solution. Its computation demands availability of reference data. Performed evaluation included the use of reference data from single ASG-EUPOS station (GDAN1) as well as from virtual reference station (VRS) prepared for the nearby location (54º24’11”N; 18º35’24”E; h_el=40m). The Figures 11 and 12 presents the configuration of RTKLIB for static positioning with the reference data from the GDAN1 reference station. The computation is based only on the L1 frequency and only the forward analysis is selected.

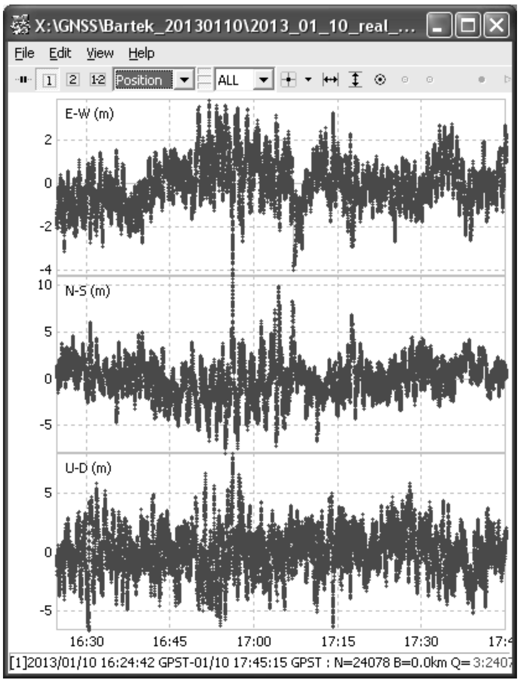

Figure 10. Single solution positioning fluctuations.

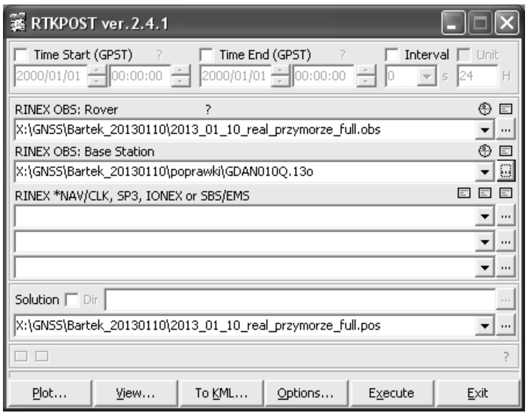

Figure 11. Configuration of the RTKLIB input files.

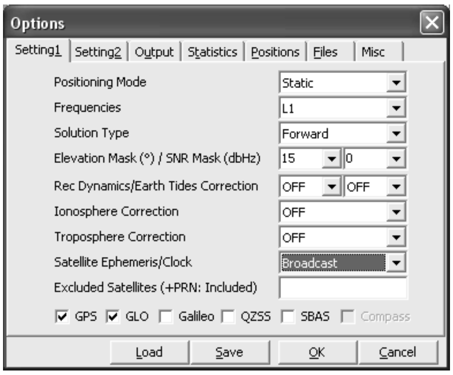

Figure 12. RTKLIB algorithm configuration - the major part.

The time of computation lasts about 50 seconds. The time of whole observation is about 1 hour 20 minutes and the observation rate is 5Hz, which gives about 24,000 epochs. The general solution of static computation is presented in the Figures 13 and 14.

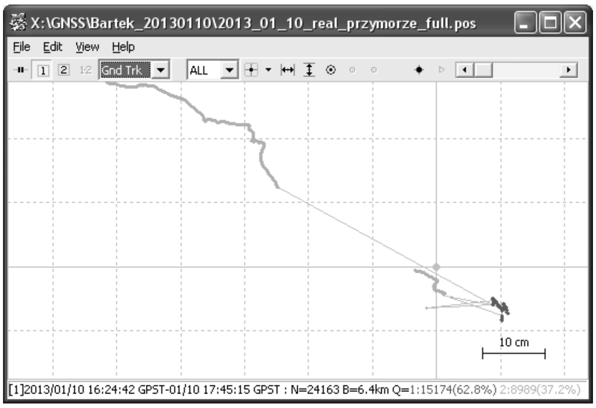

Figure 13. The results of static positioning on the Cartesian plane.

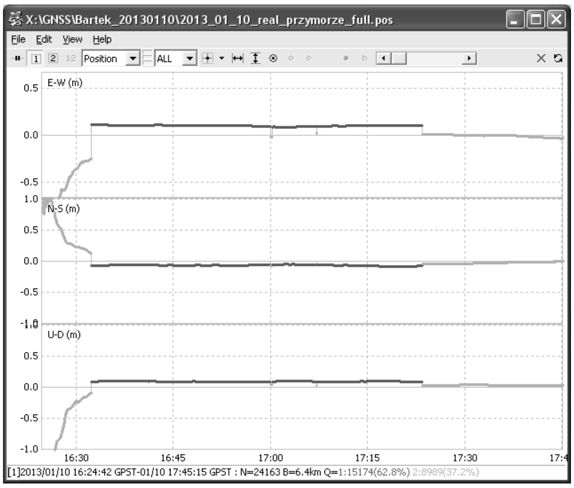

Figure 14. Static positioning fluctuations.

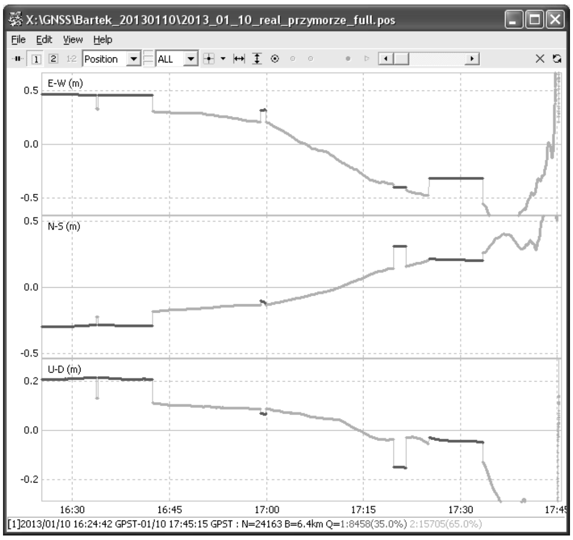

Figure 15. Static positioning in backward positioning mode.

The statistics gave approximately 62 % successful fix rate. The first fix is obtained after about 8 minutes. The second half of observation gave much worse results. Such effect made much less promising the results from the backward computation results on the same data. The results obtained in the backward and combined computation mode are presented in the Figures 15 and 16. The successfully fix rate in the backward mode is on the level of 35 %.

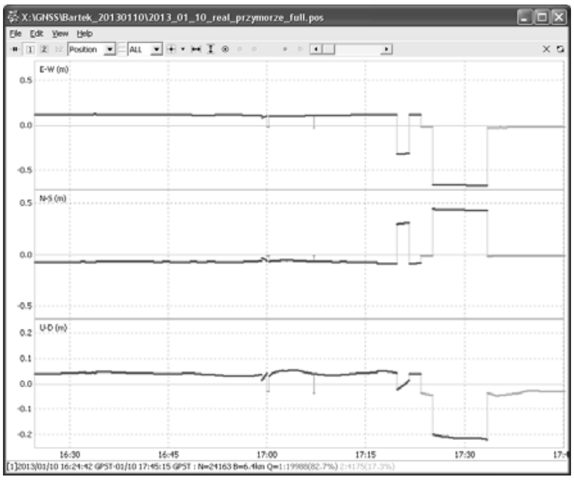

Figure 16. Static positioning in combined positioning mode.

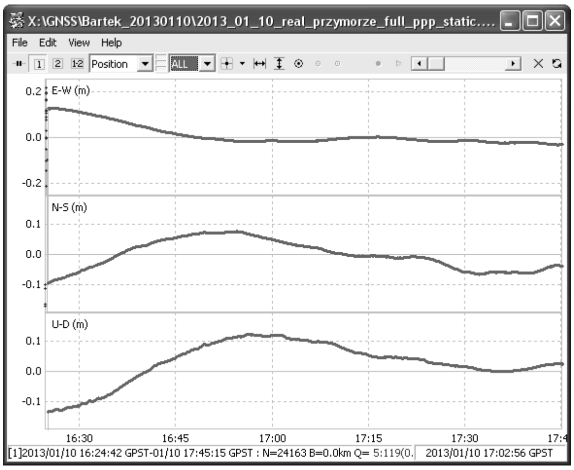

Figure 17. The results of PPP-static positioning in combined mode.

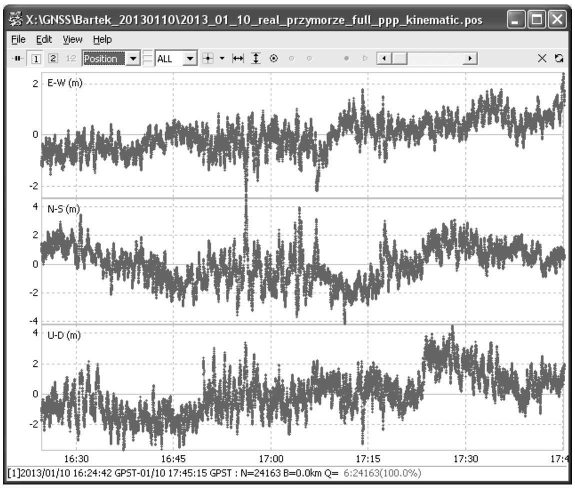

Figure 18. The results of PPP-kinematic positioning in combined mode.

The figure shows also the false fixes obtained near the end of observation. Processing in the combined mode gave much better results. Unfortunately even in the combined mode near the end of observation period is unsuccessful. The fixes obtained near the end are probably false fixes. Fortunately in the combined mode observations from the beginning are being fixed. This give the biggest success rate for combined mode although near the end there are some false fixes.

The PPP-static processing without the reference data was also tested. The Figures 17 and 18 shows the results of combined mode of computation for PPP-static and PPP-kinematic algorithms.

The RTKLIB in PPP-static mode fixes the location with relatively high stability. Analysis of the accuracy of this fix results in the 2 m horizontal error when the vertical inaccuracy is at a level of 3 meters. In the PPP-kinematic mode dynamic fluctuations can be seen. However comparing PPP-kinematic positioning accuracy to the Single solution with SBAS as show in the Figure 19 may be seen that PPP-kinematic positioning is more cohesive.

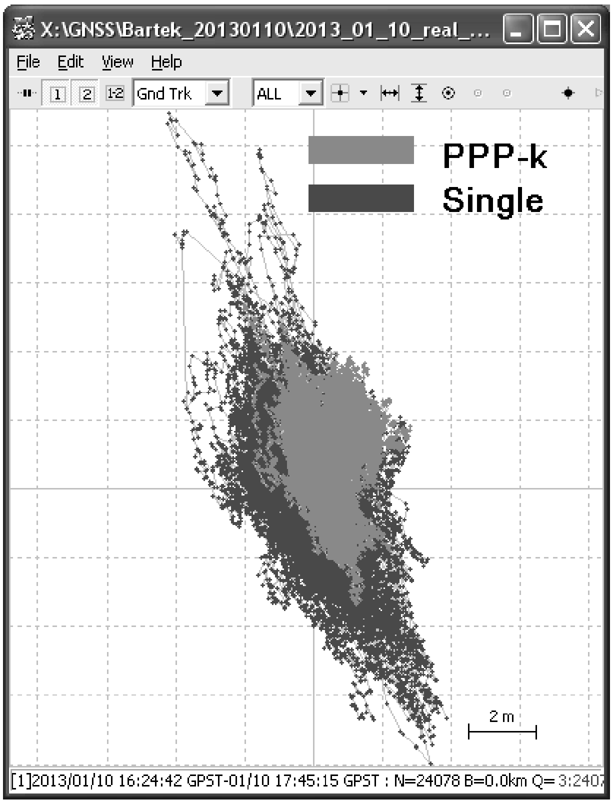

Figure 19. The comparison of Single and PPP-Kinematic positioning results.

5 CONCLUSIONS

RTKLIB found to be a tool that allow to perform broad variety of post-analysis of gathered data. Furthermore it's a tool that allows real-time navigation (subject for further research).

Most important modes were checked in order to evaluate tool's positioning accuracy. Though all of tests gave worse outcomes near the end of measurement, obtained results were very promising and satisfactory – for Static mode tool achieved centimeter level of precision (Fig. 13) when fix was reached. The reason of calculated results deterioration was probably signal reflections from nearby buildings (the measurement site wasn't perfectly open environment). The effect of probable reflections is best seen in Figures 9 and 19.

6 SUMMARY AND FUTURE WORK

The general results are promising specially when look at the inexpensiveness of the receiver and the results of static positioning. As the usage of ASG-EUPOS in the real-time is also possible so taking into consideration the time of computation (50 seconds in the combined mode) porting the RTKLIB to the mobile device and doing the computation in the field is even more attractive for the future experiments.

The next step is to perform research of the tool accuracy in real-time kinematic navigation. Future work could include development of precise kinematic navigation for vehicle/pedestrian, most preferably integration with the "VoiceMaps" project.

REFERENCES

Bosy, J. & Graszka, W. & Leończyk, M. 2007. ASG-EUPOS. a multifunctional precise satellite positioning system in Poland. *European Journal of Navigation 5* (4): 2-6.

Google 2013. GoogleMaps. *http://maps.google.com/*

GUGiK 2009. ASG-EUPOS. *http://www.asgeupos.pl/*

Kamiński, Ł. & Bruniecki, K. 2012. Mobile Navigation System For Visually Impaired Users In The Urban Environment. *Metrology and Measurement Systems* vol. XIX: 245-256.

Natural Resources Canada 1995. *GPS Positioning Guide*. Ottawa: Natural Resources Canada.

Prasad, R. & Ruggieri, M. 2005. *Applied Satellite Navigation Using GPS, GALILEO, and Augmentation Systems*. Artech House.

Takasu, T. 2007. RTKLIB: An Open Source Program Package for GNSS Positioning. *http://www.rtklib.com/*

Takasu, T. 2011. RTKLIB ver. 2.4.1 Manual. *http://www.rtklib.com/prog/manual_2.4.1.pdf*

u-blox. LEA-6T module with Precision Timing. *http://www.u-blox.com/en/gps-modules/u-blox-6-timing-module/lea-6t.html*

Witchayangkoon, B. 2000. Elements of GPS Precise Point Positioning. Maine: University of Maine.