Assessment of the Single Frequency Low Cost GPS RTK Positioning

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Abstract. The Global Navigation Satellite System (GNSS), nowadays, is to be an important tool for determining positions and times on the real-time and post-processing applications. This study aims to assess the performance of the single frequency L1-GPS using low cost receivers. The performance will be evaluated by comparing with the geodetic L1+L2 GPS receiver to positioning performance. The low cost receivers used were Ublox NEO-M8T and Allystar HD9100. While, the dual frequency GPS TOPCON was used as reference receiver. The results show, RTK mode can improve the accuracy compare with single positioning up to centimetres. In this experiment, the Allystar HD9100 gives a better result than Ublox Neo M8T. However, the result discrepancies may be caused by the simple antenna splitter.

1. Introduction

In present, the Global Navigation Satellite System (GNSS) involves several satellites which fly around the Earth continuously. By using the code signal / pseudorange signal, the GNSS users can determine their position, example: latitude, longitude and height on the earth by measuring distance from satellite at least 4 satellites at the time. Many applications can be obtained using GNSS with the accuracy spectrum from coarse accuracy in meters up to precise accuracy in millimeters [1,2].

The grade receiver for geodetic surveying which has dual frequency and advantage of shorter for calculating the ambiguity resolution, will give the precise accuracy up to mm. However, this equipment is an expensive receiver; it can be more than $2000 of price.

Currently, the majority of GNSS users have sensors available at low coast. The low cost GPS/GNSS receiver has a low price, small size, easy handling and embedding [3, 4]. The receiver is also equipped for real time kinematic (RTK) application. The one of precise positioning method is the Real Time Kinematic (RTK) which can obtain up to centimeter level accuracy of position in real-time using phase data measurement. However, most low cost receiver has only single frequency (L1). The open source program package for RTK application using low cost receiver is namely RTKLIB which is developed by [5]. The program supports the receivers able to get raw measurement of GPS data. Using RTK mode, the low cost GPS can be improve to obtain a good accuracy.

In this article, we will assess the performance of single frequency using low cost receivers: Allystar HD9100 and Ublox Neo M8T. Thus, we compare their performance with the survey-grade receiver: Topcon GB-1000.
2. Instrument setting

In this study, we use three GPS receivers: TPS-GB1000, Allystar HD9100 and Ublox Neo M8T. All of them will be described by following sub-section.

2.1. TPS-GB1000

The TPS-GB1000 is a Topcon GPS product which can receive and process both L1 and L2 signals for improving the position accuracy. This GPS is equipped a feature of Real Time Kinematic (RTK) for short and long baseline [Ref]. The GB-1000 can be built with internal memory for recording survey data, and recorded data can be downloaded using the USB, Ethernet, or RS232C port. A compact flash card slot allows data to be easily copied from the built-in memory and read on a computer [REF].

The accuracy of GB1000 can be up to 3 mm + 5 ppm x distance in kilometer and 5 mm + 5 ppm x distance in kilometer for horizontal and vertical static measurements, respectively. For RTK/Kinematic modes, the accuracy is about 10 mm for horizontal and 15 mm for vertical measurement. The unit price is still expensive up to $2,300 [6].

2.2. Allystar HD9100

![Figure 1. Experimental Design](image-url)
The allystar is the one of low cost GNSS receiver with single frequency from China. The HD9100 series adopts Real Time Kinematics (RTK) technology with the correction data from CORS network. Support RTCM 2.3 / RTCM 3.2 protocols. It also supports both rover and base solutions for which don’t have public CORS network. HD9100 is the chip-level compact solution and the best-in-class low power solution for precise positioning application. GNSS engine 72 channels and DSP hardware acceleration, satellite reception GPS/QZSS, Beidou, GLONASS and Galileo. Position accuracy for GNSS is about 2.5 m in autonomous; RTK accuracy is 2 cm + 1 ppm (baseline) and 5 cm + 1 ppm for elevation. Environment data for operation temperature -40 to + 85° C, for storage temperature -40 to + 125° C. The price of Allystar HD9100 is less than $100.

2.3. Ublox Neo-M8T
The Ublox receiver is manufactured by U-blox Company in Switzerland. Ublox NEO-M8T is a single frequency of GNSS series which is able to receive various signals such as GPS, GLONASS, Beidou QZSS and SBAS. Horizontal position accuracy for autonomous is about 3 m and SBAS ± 2 m. Antenna support active and passive, package NEO-M8T 24 pin LCC (leadless Chip Carrier) with dimension 12.2 x 16.0 x 2.4 mm. The price is about $ 75 – $ 100 [7].

2.4. Antenna
The PGA-1 antenna, as shown in figure 2, is a geodetic antenna dual frequency GPS and GLONASS. PGA-1 is designed by Topcon GNSS manufacture to complement of Topcon GNSS product. Using the precision micro center antenna and integrated ground plane, PGA-1 is able to obtain the high accuracies in horizontal and vertical, and eliminate the multipath errors.

![Figure 2. PGA-1 antenna diagram](image)

3. Experiments and Results
3.1. Experiment set up
The configuration of instrument test is shown in Figure 1. The receivers were connected with dual frequency GPS antenna Topcon PGA-1 which was mounted on the roof-top for getting good sky view. The geodetic antenna was used to suppress multipath [8]. GPS signals from antenna were split for three receivers: TPS-GB1000, Allystar-HD9100 and Ublox NEO-M8T, through the simple antenna splitter. Using the internet service, receivers linked to the CORS station via 1Hz NTRIP data. CSBY station which is one of CORS GPS station that located in central of Surabaya region and maintained by Badan Informasi Geospasial (BIG) is used as a reference station where the baseline length was near 10 km from the ITSS as rover station.

GPS data were recorded every one second by RTKLIB setting on Personal Computer (PC). RTKLIB is a software library for RTK GPS that can be able to extract raw data measurement of GNSS signals [5]. ITSS positions were derived by static relative positioning (dual frequency L1+L2) using TPS-GB1000 for 14 hours. The result coordinates can be seen at Table 1.
Table 1. The coordinates of CSBY and ITSS

| Station Name | Latitude            | Longitude            | Ellipsoid height |
|--------------|---------------------|----------------------|------------------|
| CSBY         | 7° 20’ 03.60420” S  | 112° 43’ 27.71424” E| 51.253 m         |
| ITSS         | 7° 16’ 47.95034” S  | 112° 47’ 40.64932” E| 48.312 m         |

In order to assess the single frequency of low cost GNSS by comparing with the survey-grade receiver, the two data sets of each mode were performed. Due to the availability of satellite among three receivers are different, example Allystar HD9100 receives GPS (L1) and Beidou, and Ublox Neo M8T receives GPS (L1), Glonass, QZAA, therefore, the single frequency GPS L1 was used in order to make the comparison. The modes are single point positioning and real time kinematic (RTK). The results of two measurement modes would be presented as following sub-sections.

3.2. Single Point Positioning and Real Time Kinematic

In this section, the investigation of single positioning for Allystar and Ublox was performed. The single point positioning (SPP) uses only one GPS receiver to collect data from multiple satellites for determining the receiver position. In this study, Allystar and Ublox employ the SPP method to determine the 3 dimension positions using only single GPS frequency L1.

![Figure 2](image2.png)

Figure 2 illustrates the number of GPS satellites tracked over a 14 hours period with a 1 s measurement interval in October 16th, 2018 for Allystar and Ublox receivers. Figure 2 shows that the number of GPS satellites tracked by the Allystar is smaller than Ublox, where the total numbers of satellites range between 6 and 10, whereas the Ublox receives satellites of range between 6 and 12.

GPS data from Allystar and Ublox were collected every second for 14 hours. Afterwards, single positioning data were compare with the fixed coordinates of ITSS. The discrepancy of coordinates between the fixed ITSS and the coordinates-derived from Allystar and Ublox are shown at Figure 3 – (a) and Table 3.

The investigation of the RTK positioning is performed by the comparison between RTK coordinates and fixed coordinates. The RTK coordinates were derived by the single frequency GPS L1 which is corrected using NTRIP method from CORS GPS station. The results are shown at Figure 3 and Table 3.

![Figure 3](image3.png)
Figure 4. (a) Single point positioning errors of single frequency GPS (L1) and (b) RTK positioning errors of single frequency GPS (L1)

Table 2. Mean and standard deviation of single positioning and RTK Measurements for Allystar HD9100 and Ublox Neo M8T, respectively. Units are in meter

| Receiver          | Single Positioning | Real Time Kinematic (RTK) |
|-------------------|--------------------|---------------------------|
|                   | Mean               | Std. Deviation            | Mean               | Std. Deviation |
| Allystar HD9100   |                    |                           |                    |
| Northing          | 9194905.398        | 0.753                     | 9194906.149        | 0.008          |
| Easting           | 698129.184         | 0.040                     | 698129.221         | 0.002          |
| Height            | 47.086             | 1.226                     | 48.188             | 0.065          |
| Ublox Neo M8T     |                    |                           |                    |
| Northing          | 9194905.340        | 0.881                     | 9194906.179        | 0.014          |
| Easting           | 698129.115         | 0.109                     | 698128.465         | 0.416          |
| Height            | 46.542             | 1.771                     | 48.108             | 0.116          |

Table 3 shows that the accuracy of the low cost single frequency is up to 1 m for horizontal and less than 2 m for vertical positions relative to fix coordinates. Meanwhile, the improvement of positions was obtained by applying RTK mode. At Table 3, the Allystar HD9100 gives the results better than Ublox Neo M8T.

In this experiment, the simple splitter antenna was used. However, this splitter is not ideal due to there is not availability of the DC block. It may a getting incorrectly sense an antenna fault. Regarding the results, the big standard deviation of Ublox can be obtained due to improper of antenna splitter.

4. Conclusion and future work

The assessment of the single frequency low cost GNSS using some analysis was presented. It shown that in general, the low cost GPS receiver gives the good results when comparing with the survey-grade receiver. Using RTK method, the accuracy can be reduced from meters to centimeters.

In this study, the results are deduced only using single frequency GPS L1. Due to a lot of satellite cross to the Indonesian region, the next study will use not only GPS L1, but also it will use the Beidou, Glonass, and QZSS satellites for getting better accuracy. Moreover, the splitter antenna is also important thing for getting a good accuracy when we use a sharing antenna.

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