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The Study of Position Accuracy Using Precise Point Positioning (PPP) In Perspective of Indonesian National Standard of Horizontal Reference Network

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Abstract. Precise point positioning is a GNSS based positioning method that is known to regaining more precise information about major systematical errors in its functional model. This method is seen as an advanced version of the conventional absolute positioning method that is able to offer higher accuracy of the estimate parameter. Contrarily, the relative positioning method is able to achieve high precise of the estimated parameters by using two or more receiver. Consequently, it utilizes more resources in performing observation. Hence, this contribution attempts to explore some considerable aspects that can make the PPP method has a comparable precision of the National Standard of Horizontal Reference Network (SNI JKH). Based on the experiments, with data rate of 0.03 Hz for GPS and GLONASS observation shown that result of the PPP method is comparable to the relative method, whenever the observation is performed in minimum duration of six hours. Moreover, the 3th order of accuracy can be achieved after a demanding observation period, depends on processing strategy.
Index Terms – GNSS, Precise point positioning (PPP), Relative Positioning, SNI JKH

1. Introduction

Precise point positioning (PPP) is an advanced version of the conventional GNSS-based absolute positioning. The method regains more precise information about systematical errors in its functional model, so that it can offer higher accuracy of the estimate parameter more than the absolute positioning. The quality of PPP method depends on its ability to eliminate the observation related errors. This contribution focuses on the minimum observational duration that is required to fulfill a certain level of accuracy standard. Consequently, the accuracy standard demands particular information about specific orbit products.

Relative positioning method requires more effort by using two or more receivers with one of receiver acting as a reference station. This method eliminates the observation errors with double difference technique. Relative positioning method quality depends on the distance between receivers. In case of PPP, direct usage of reference station is no longer needed, so that the spatial operating range limit is no longer exist, hence the coverage is global [6].

The experiments expect to fulfill the 3th order of the Indonesia National Standard of horizontal reference network (SNI JKH). Furthermore, this contribution attempts to investigate some considerable aspects that can make accuracy of the PPP method is comparable to the accuracy of relative positioning method.

2. Precise Point Positioning versus relative positioning

PPP method uses only one receiver without respecting to reference station. It makes common mode errors do not cancel in PPP [3], such as orbital error, tropospheric delay, ionospheric delay, multipath, satellite clock error and receiver clock error. The absolute observation model using pseudorange and phase range data, expressed by the following equations: [2, 3, and 4]

$$P^s_{r,f}(t) = \rho^s_{r,f}(t) + d\rho^s_{,f}(t) + dT^s_r(t) + dI^s_{r,f}(t) + dm^s_{r,f}(t) + c\left[\delta t_{r,f}(t) - \delta t^s_{,f}(t)\right] + e^s_{r,f}(t) \quad (1)$$

$$\varphi^s_{r,f}(t) = \rho^s_{r,f}(t) + d\rho^s_{,f}(t) + dT^s_r(t) - dI^s_{r,f}(t) + dm^s_{r,f}(t) + c\left[\delta t_{r,f}(t) - \delta t^s_{,f}(t)\right] + \lambda_f\left[\phi_{r,f}(t_0) + \phi^s_{,f}(t_0)\right] + \lambda_f N^s_{r,f} + \varepsilon^s_{r,f}(t) \quad (2)$$

Where $*^s$ is the superscript identifying satellite s, $*_r$ is the subscript identifying receiver r, $*_{,f}$ is the *subscript* identifying the L1 or L2 frequency, $d\rho^s_{,f}(t)$ is the orbital error (m), $dT^s_r(t)$ is the tropospheric delay (m), $dI^s_{r,f}(t)$ is the ionospheric delay (m), $dm^s_{r,f}(t)$ is the *multipath* (m), $\phi_{r,f}(t_0)$ is the receiver initial phase at t_0 (*cycle*), $\phi^s_{,f}(t_0)$ is the satellite initial phase at t_0 (*cycle*), $e^s_{r,f}(t)$ is the Pseudorange noise (cycle), and $\varepsilon^s_{r,f}(t)$ is the Phase noise (cycle)

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In PPP method, utilizing precise product from IGS can eliminate the observational error. Moreover, the duration of observation can affect the result. In this contribution we assume that the observations are multipath free. Ionospheric delay can be eliminated by utilizing the ionospheric-free linear, while tropospheric delay can be eliminated by using troposphere model like saastamoinen. Utilizing precise clock product from IGS can eliminate of satellite and receiver clock errors, and using precise orbit from IGS can reduce the orbital error.

On the other side, the relative positioning method uses two or more receivers. This method requires simultaneous observations at both receivers to determine the coordinates of an unknown point with respect to a known point [2]. Assuming such simultaneous observation at the two points A and B to satellites j and k, linear combination can be formed leading to single difference, double difference, and triple difference. For example, the double difference model can be expressed with [2]:

$$P^{jk}_{AB,f}(t) = \rho^{jk}_{AB,f}(t) + dm^{jk}_{AB,f}(t) + e^{jk}_{AB,f}(t) \quad (3)$$

$$\varphi^{jk}_{AB,f}(t) = \rho^{jk}_{AB,f}(t) + dm^{jk}_{AB,f}(t) + \lambda_f M^{jk}_{AB,f} + \varepsilon^{jk}_{AB,f}(t) \quad (4)$$

By using the double difference technique, common errors can be eliminated. However, quality of the result of relative method depends on the distance between receivers. Based on SNI JKH, relative method can be performed with a maximum distance of 20 km length (short baseline) between receivers, with the absence of the tropospheric and ionospheric influences.

3. The experiment of PPP

The observation was using two points with the approximately distance of 8.5 kilometers length; which is short baseline. The reason to use short baseline is for good quality result of the relative method. Therefore, this study attempts to investigate some aspects that can make accuracy of the PPP method is comparable to the relative method.

One station is acting as reference station, CLBG, which is located at Lembang. Another station is acting as rover, ITN1, which is located at Itenas. The CLBG station is a CORS maintained by *Badan Informasi Geospasial*. Observation was held for 48 hours duration. Station position was obtained using goGPS and RTKLIB. Accuracy of position of each method is based on the standard deviation and the error ellipse parameters. The order of position is defined by horizontal error ellipse parameters. To define the PPP method order, it has to do some procedure.

The order of relative method must be defined by defining the 3rd order position based on SNI JKH from the relative error ellipse perspective, and its corresponding absolute error ellipse. The PPP method order can be achieved by comparing the absolute error ellipse of PPP method and relative method. This procedure purposes to define the quality of position accuracy from PPP process by referring to the absolute error ellipse, which corresponds to the SNI standard.

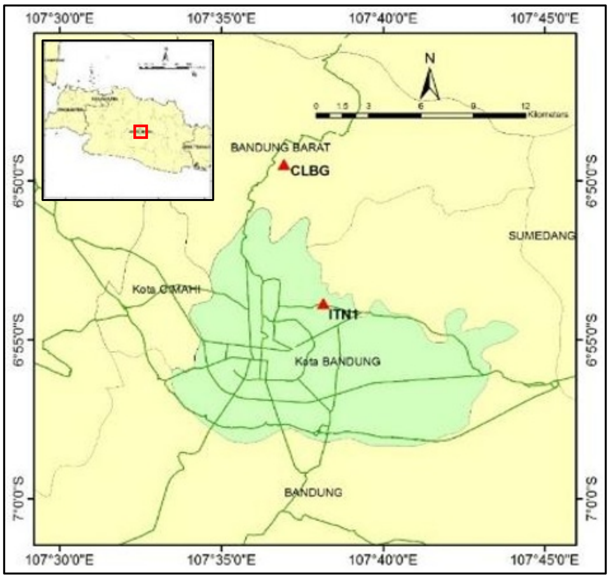

Fig 1. Location of two CORS used in the experiment

The observation was held in two days with phase and pseudorange data. Technical specification of each station is shown in Table 1.

Table 1. Technical Specification

Station	CLBG	ITN1
Location	Bosch-Lembang, Bandung	Gedung 18 Itenas, Bandung
Latitude	6° 49' 27.98" S	6° 53' 51.06" S
Latitude	107° 36' 56.16" E	107° 38' 9.32" E
Height above ellipsoid	1329.737 m	742.212 m
Receiver	Leica GRX1200GGPRO	Hi Target VNet6
Antenna	LEIAT504GG	HITAT35101CR
Antenna height	0.008 m	1.428 m
Mask Angle	10°	10°
Observation Interval	30 s	30 s
GPS Week	19750 dan 19751	19750 dan 19751

From the observation with 10 degree of mask angle and 0.03Hz of data rate, obtained the number of satellite, PDOP, and GDOP that is shown in Fig. 2. From Nsat graphic in Fig. 2 shown that station of ITN1 receive more satellite signal than CLBG station. It makes each of stations have different value of PDOP and GDOP, where the lowest value of GDOP is 1.1 and the highest value is 2.2 at ITN1, while the CLBG has the lowest value of GDOP is 1.2 and the highest value is 4.0. Each stations are on acceptable condition as the average of GDOP value is smaller than 5 [5].

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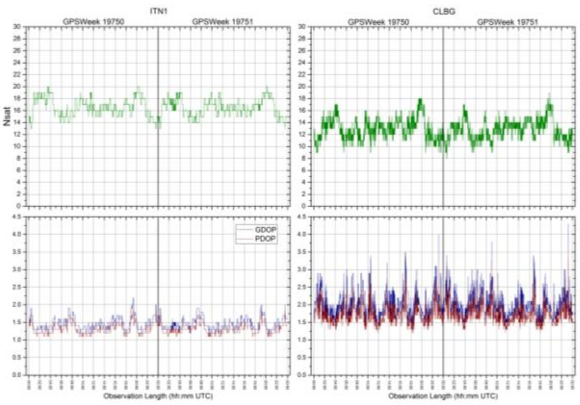

Fig 2. Nsat, PDOP, and GDOP Graphics

3.1. Residuals

Based on one-day observation and data rate of 0.03Hz for GPS and GLONASS observations, the residual value of carrier phase and pseudorange observations, respectively, can be seen at Fig. 3 (ITN1) and Fig. 4 (CLBG).

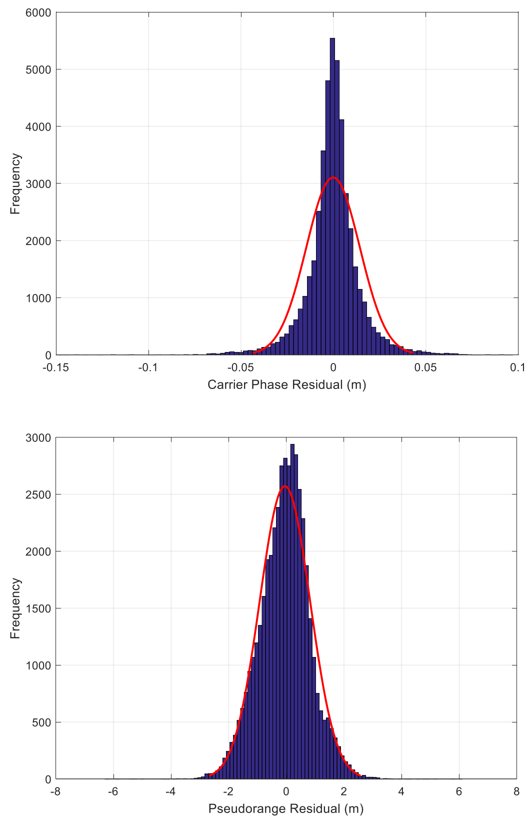

Fig. 3 ITN1 Observation Residual

Fig. 3 shown that the observation at ITN1 station is normally distributed. The observation with carrier phase is more accurate than pseudorange, it can be seen from the class interval of carrier phase is every 5 cm and pseudorange is 2 m.

The observation at CLBG station is also normally distributed. It is similar with ITN1 station that carrier phase observation is more accurate than pseudorange. The class interval of carrier phase observation is 5 cm while at pseudorange observation is 5 m. This also shows that the observation on ITN1 is better than CLBG.

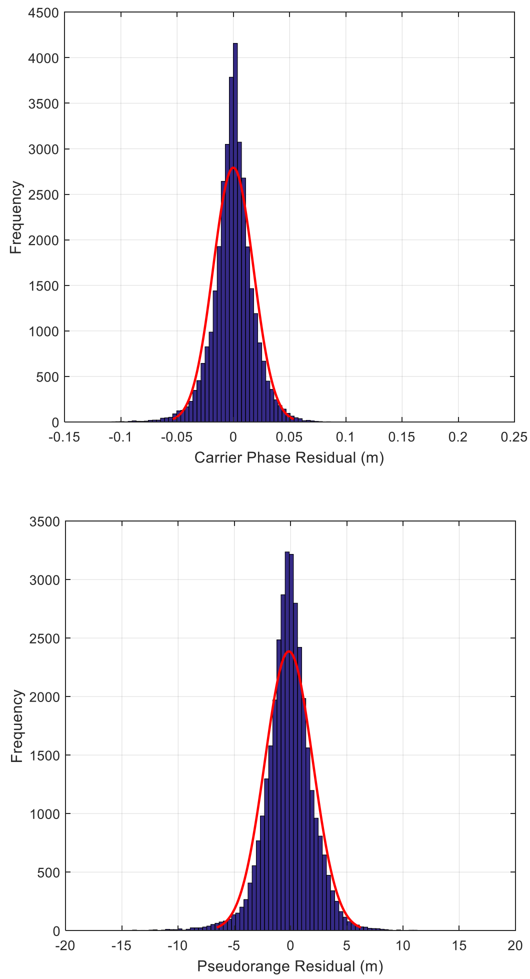

Fig. 4 CLBG Observation Residual

3.2. Coordinates difference

Fig. 5 shows the result of PPP method by utilizing IGS Final orbit. CLBG is used as the reference station of relative positioning to determine the coordinate of ITN1. The coordinates on Fig. 5 are expressed in local ENU coordinates system.

Fig. 5 Shows the result of PPP method by 48 hours duration of observation. The results are settled in 3-4 cm to the known point by using IGS final or IGS rapid product for both softwares. The difference between RTKLIB and goGPS result is only at the level of 1.1 cm, where the result from RTKLIB processing is 3.4 cm deviated to the known point, and the result from goGPS processing is 4.3 cm deviated to the known point. On the other side, the use of IGS Ultra product for both softwares is deviated by 6 up to 9 cm to the known point.

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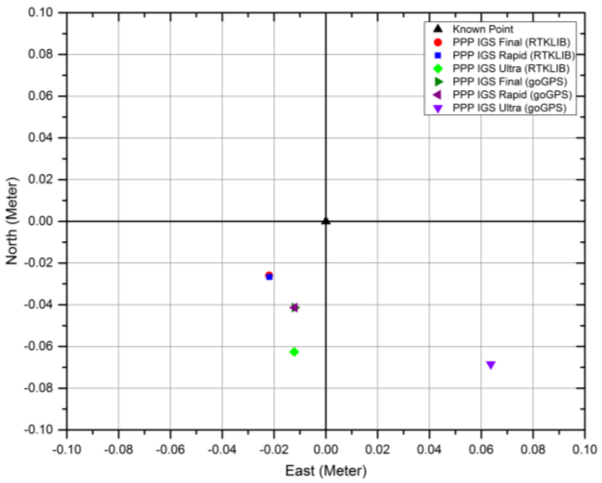

Fig. 5 Horizontal position of CLBG station

Similar to the CLBG station, the observation at ITN1 station use data rate of 0.033 Hz and IGS final orbit. In this point, the method that used to processed observation data are both of PPP method and relative positioning method. The coordinates variation is illustrated by Fig.6.

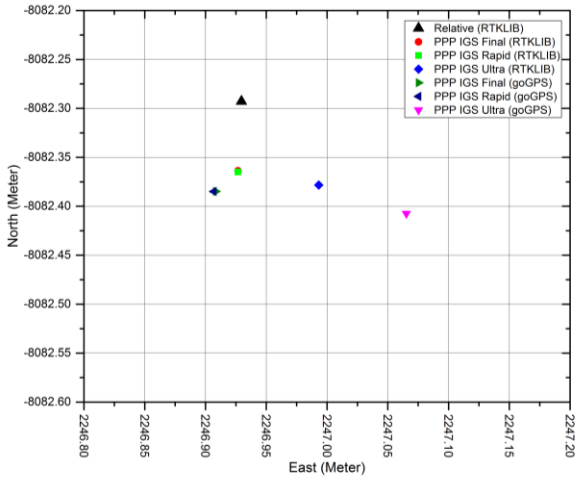

Fig. 6 Variations of ITN1 Station

Fig.7 shows the result from 48 hours duration of observation. The difference between RTKLIB and goGPS result are 2 cm, where RTKLIB and goGPS result are deviated 7.1 and 9.4 cm to the known point, respectively. Further, the using of IGS Ultra product gives bigger deviations for both processing, which is around 10 cm and 17 cm to the known point, respectively.

The coordinates differences between the product from PPP processing method and the known point can be seen at CLBG station. The known point of CLBG station refers to report from BIG. In this case, PPP method has three different results by utilizing three precise orbit products (IGS final, IGS rapid, and IGS ultra-rapid). Fig.7 shows the coordinates difference between PPP product and known point that using RTKLIB software. It shows that the using of IGS final and IGS rapid product gives more convergence than the IGS ultra products by 6 hours duration of observation.

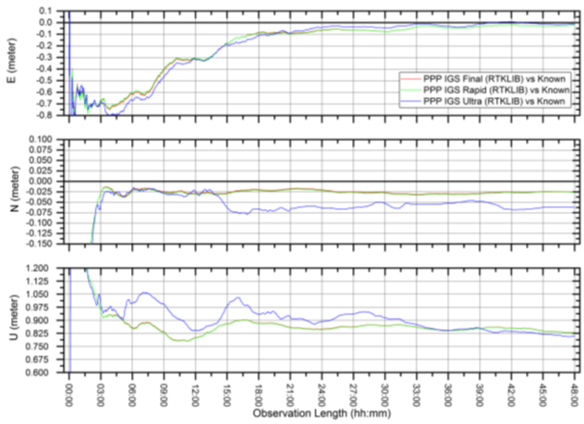

Fig.7 Coordinates difference between PPP (RTKLIB) and known point

In this case, the difference of North component is convergent after 3 hours observation, on the other side the difference of East and Up components is convergent after 15 hours duration of observation. Coordinates difference between PPP and the known point using goGPS is shown in Fig.8.

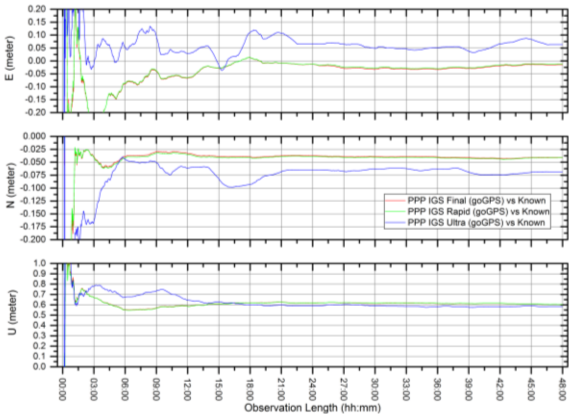

Fig.8 Coordinates difference between PPP (goGPS) and known point

By using goGPS software, the average coordinates difference between PPP and known point is convergent after 6 hours duration of observation. The utilization of the IGS final and IGS rapid product is more accurate than the IGS ultra product. The difference of North component is convergence after 6 hours duration of observation in 2-5 cm scale. On the other side, the East component is convergent after 15 hours of observation in 5 cm scale, and the Up component is convergent after 15 hours of observation in 7 dm scale. The coordinates difference figure shows that the vertical position difference is less convergent than horizontal [2].

Coordinates difference between PPP and relative positioning method can be seen at ITN1 station. The result of relative positioning on ITN1 station is referring to CLBG station.

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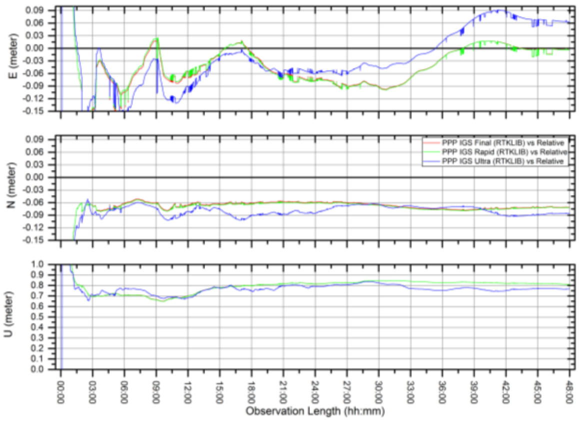

Fig.9 Coordinates Difference Between PPP (RTKLIB) and Relative Method

Fig.9 shows that coordinate difference between the PPP against the relative method is going to be convergent after 2 hours duration of observation for North component. Coordinates difference for East and Up components is not good as North component.

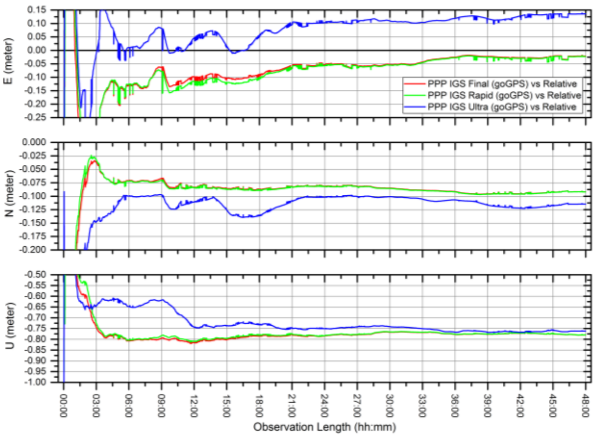

Fig.10 Coordinate Difference Between PPP (goGPS) and Relative method

Fig.10 is the coordinates difference between PPP and relative positioning using goGPS software. The coordinates difference for North component is convergent after 3 hours observation for IGS final and IGS rapid product. On the other side, coordinate difference for East component is convergent after 6 hours of observation, and Up component is convergent after 12 hours of observation. The average of absolute coordinates difference for East, North, and Up components are 18 cm, 15 cm, and 85 cm, respectively.

3.3 Standard deviations

Standard deviations of precise products are also can be seen in this station. Standard deviation comparisons between IGS Final, IGS Rapid, and IGS Ultra-rapid products are shown in Fig.10.

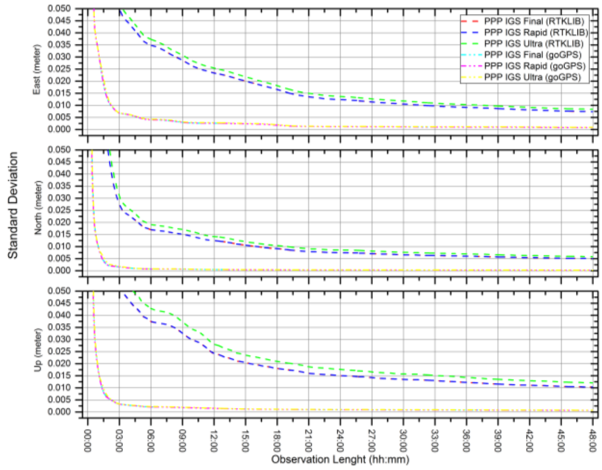

Fig.11 Standard deviation of precise product on CLBG station

Fig.10 shows that the using of goGPS is more accurate than RTKLIB. Standard deviation from goGPS software is in millimeter level after 3 hours duration of observation, yet the standard deviation from RTKLIB is still in centimeter level. The Standard deviation of RTKLIB is in millimeter level after 36 hours duration of observation. The difference between goGPS and RTKLIB standard deviation after convergence is 7 mm for East and North components, and 10 mm for Up component. The using of precise product IGS final and IGS rapid gives a very small difference of standard deviation for both softwares.

Comparison of standard deviation between PPP and relative positioning method can be seen on ITN1 station. The relative positioning method is computed for ITN1 by taking CLBG as the master station.

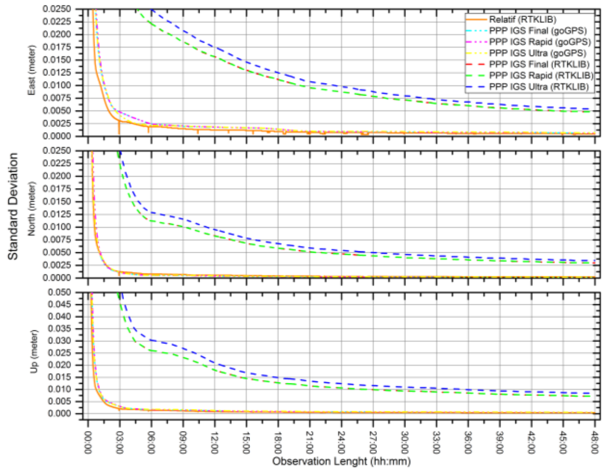

Fig.12 Standard deviation between PPP and Relative positioning method

Fig.12 shows that the standard deviation of the relative positioning method and the PPP using goGPS is convergent faster than the PPP from RTKLIB. Standard deviation of relative positioning reaches decimeter scale by minimum 0.5 hours duration of observation, and it reaches millimeter level after 1.5 hours observation. On the other side, PPP method using goGPS reaches millimeter scale after 2 hours duration of observation, and PPP method using RTKLIB reaches millimeter scale after 22 hours duration of observation. The smallest standard deviation value of PPP method can be reached by using goGPS for 48 hours duration of observation with 0.6 mm for East component, 0.2 mm for North component, and 0.6 mm for Up component. Standard deviation of relative method by 48 hours of observation is 0.5 mm for East component, 0.2 mm for North component, and 0.4 mm for Up component. The result of PPP method on ITN1 station is more accurate than CLBG station because of field condition in ITN1 is widely open than CLBG.

4. Classification of horizontal reference point network

The classification depends on the relative error ellipse. Relative error ellipse can be obtained only in relative positioning method. Hence, the horizontal position order of PPP method is assumed by regarding absolute error ellipse from relative positioning that has been accepted in 3rd order of horizontal position.

Based on SNI JKH, the 3rd order of horizontal position can be achieve by regarding on empiric value of 30 ppm. By the distance between CLBG and ITN1 station of 8.41 km length and 30 ppm of empiric value, the maximum semi-major axis (r) can be achieved by

$$r = c\,(d + 0.2)$$
$$r = 30\,(8.41 + 0.2) \qquad (5)$$
$$r = 258.291 \text{ mm} = 25.83 \text{ cm}$$

Calculating of equation 5, maximum value of semi-major axis is 25.83 cm, then the 3rd order of horizontal position can be achieved after value of semi major-axis of relative error ellipse is less than 25.83 cm. The semi-major axis value of relative error ellipse is shown at Table.2

Table.2 Relative error ellipse parameter between CLBG and ITN1

Duration of Observation (hours)	Relative error ellipse parameter			r (cm)
	a (cm)	b (cm)	θ	
0.5	1.95668	1.27017	34.49512˚	
0.75	1.16718	0.66352	35.31097˚	
1	0.98798	0.46677	35.36272˚	
2	0.46668	0.23134	35.23794˚	25.38
4	0.31005	0.20154	35.20035˚	
6	0.26550	0.19512	35.21533˚	
12	0.23503	0.19242	35.22364˚	

By referring to SNI JKH and technical specification, the 3rd order can be reached after 1 hours duration of observation. The absolute error ellipse parameters of relative positioning method after 1 hours duration of observation are a = 0.0116 m, b = 0.0043 m, and θ = 17˚ 40' 55.55". If the absolute error ellipse of PPP method is lower than the value above, it means that the PPP method reaches the 3rd order of horizontal position.

The semi major axis value of absolute error ellipse for PPP method with 1 hour observation of relative positioning method is shown by Fig.13.

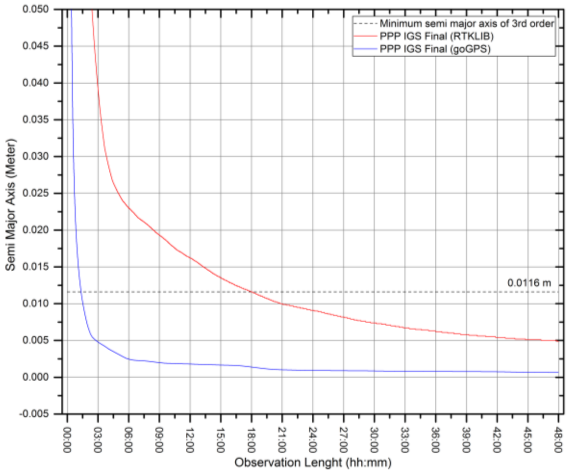

Fig.13 Semi major axis of absolute error ellipse

Fig.13 implies that longer observation period causes the absolute error ellipse is getting smaller. By assuming the position of absolute error ellipses is at the same position, the comparison of both methods can be seen (Fig.14).

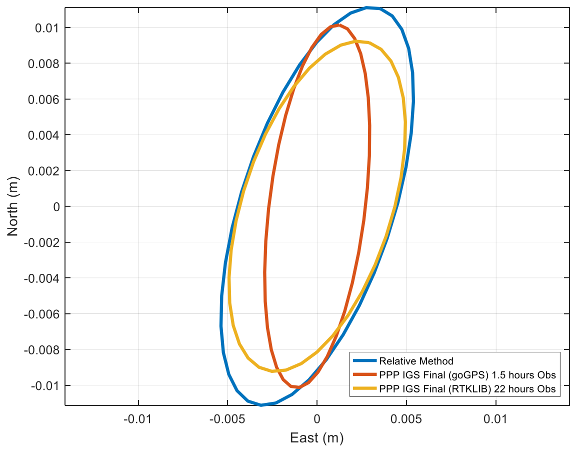

Fig.14 Comparison of PPP and relative method error ellipse

Based on the experiments, the 3rd order of horizontal position accuracy for PPP method can be achieved by using goGPS within 1.5 hours duration of observation, or by using RTKLIB within 22 hours duration of observation. In the case of time efficiency, the usage of goGPS gives more effective time than RTKLIB. It is possible to have different result for using other softwares. The value of absolute error ellipse parameters by using goGPS is 0.0102 m for semi-major axis, 0.0026 m for semi-minor axis, and 13˚54'58.86" for azimuth angle. The value of absolute error ellipse parameters by using RTKLIB is 0.0102 m for semi-major axis, 0.0026 m for semi-minor axis, and 13˚54'58.86" for azimuth angle.

8. Summary

Based on the result of the experiment, PPP method can reach the 3rd order classification by utilizing the IGS final product after 1.5 hours duration of observation, which is performed by using goGPS software. The RTKLIB software needs more time to reach 3rd order classification.

The difference of standard deviations of the PPP and the relative method is around 0.1 - 0.3 mm for each of East, North, and Up components, respectively. GoGPS software gives more excellent result than RTKLIB by looking at the standard deviation and error ellipse parameter.

The result on ITN1 station is more accurate than CLBG station because of field condition at ITN1 station widely open than CLBG station. Therefore, in this experiment shows that the PPP can be applied to some positioning to fulfill the 3rd order of Indonesian National Standard of Horizontal Reference Network (SNI JKH).

Reference

1. Badan Standarisasi Nasional, *Indonesian National Standar of Horizontal Reference Network (SNI JKH)*, SNI 19-6724-2002 (2002).
2. B. Hofmann-Wellenhof, H. Lichtenegger, and E. Wasle, *GNSS – Global Navigation Satellite System GPS, GLONASS, Galileo & more,* SpringerWienNewYork, Austria, (2008).
3. B. Witchayangkoon, *Elements of GPS Precise Point Positioning,* PhD dissertation, University of Maine, Orono, Maine. (2000).
4. H. F. Suhandri, *Instantaneous Estimation of Attitude from GNSS,* Institute of Navigation, University of Stuttgart, Germany. (2017).
5. H. Z. Abidin, J. Andrew, and J. Kahar, *Survei dengan GPS*, Institut of Technology Bandung, Indonesia, ISBN 978-602-905-01-3, (2011).
6. J. Kalita, Z. Rzepecka, and I. Szuman-Kalita, *The Application of Precise Point Positioning in Geosciences*, eISSN 2029-7092 / eISBN 978-609-457-640-9 (2014).