Accuracy Assessment of Atlas L-band GNSS Global Correction Service and Autonomous Positioning at Perlis, Malaysia

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ABSTRACT

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Differential Global Navigation Satellite System (DGNSS) is the most common positioning method used for navigation in the hydrography field. During the loss of the correction signal, the differential solution becomes an autonomous solution that may affect the accuracy of the position during that time. However, the availability of the Atlas L-band global correction service that adapts the Real-

Time Precise Point Positioning (RT-PPP) technique has broadened the choice of solutions that can be used for navigation in the maritime industry and may solve the problem of signal loss. This research compares the positioning between autonomous solution GNSS and Atlas L-band correction solution using the static method to assess the accuracy of positioning between both methods. Data acquisition of the autonomous positioning and Atlas L-band service was conducted by using Hemisphere receiver VS330 and antenna A43. The statistical T-test reveals that the accuracy of analysis Atlas-L band and autonomous solution GNSS using static positioning was significant, as the p < 0.05 with 95% confidence interval. Besides, the result also shows that the position given by the Atlas L-band is more accurate and precise than Autonomous Solution GNSS, with an average position of 0.479 meters and 2.281 meters, respectively. Ultimately, the continuity of positioning data given by the Atlas L-band in the northern part of Malaysia is good, and positioning using Atlas L-band can be classified as Special Order based on the classification table by the International Hydrographic Organisation (IHO).

Keywords: Atlas L-Band, GNSS, RT-PPP, Autonomous Positioning

INTRODUCTION

With the rapid development of the multi-constellation Global Navigation Satellite System (GNSS), the world of satellite navigation has undergone a dramatic transformation. There are already more than 70 satellites available for positioning. Approximately 120 satellites will be available in the coming years when all four systems of BeiDou, Galileo, Global Navigation Satellite System (GLONASS) and Global Positioning System (GPS) become available(Xingxing Li et al., 2015). Precise Point Positioning (PPP) is a GPS-based technique used widely for scientific and industrial research. Multi constellation GNSS PPP can improve the positioning accuracy considerably and reduce the convergence of position times by high redundancy(Cai et al., 2015). In addition to GPS, GLONASS observations confirm the increase in precision and convergence speed (Xin Li et al., 2017; Xingxing Li et al., 2015)

Differential Global Navigation Satellite System (DGNSS) is the most common solution used for navigation in the maritime industry. DGNSS consists of two types which are the local area and wide area. The components in local area DGNSS are autonomous solution GNSS, conventional DGNSS, and NTRIP. Local area corrections are intended for use only near the reference station because errors due to the satellite clock, satellite orbit, ionosphere and troposphere are assumed to be correlated between the users and reference station (McKessock G. 2007). Meanwhile, the vast area measures current signal perturbations on many ground controls stations worldwide, then builds an error propagation model and broadcasts corrections through satellites or radio (Xingxing Li et al., 2015). Many commercial receivers can use these signals for submeter positioning accuracy. Once the differential signal is lost, it converts the positioning concepts into autonomous GNSS positioning.

A recent study shows the importance of using the carrier phase-based double differencing method during GPS positioning(Duraisamy et al., 2019). The carrier phase double differencing technique can improve the positioning method by providing higher accuracy in real-time with differential, provided by reference station and rover station (Duraisamy et al., 2019). Atlas L-Band is a service provider that offers this solution with a robust performance to correct the signals with accuracies from the meter to sub-decimeter level. Therefore, carrier phase double differencing can expand the positioning accuracy significantly and lessen the convergence of position times by high redundancy.

Accuracy assessment is a method to determine the accuracy of the procedure, which helps to ensure proper collection and use of the data and resulting products(Wilson & Richards, 2006). Furthermore, GNSS errors can be distinguished by the computation of residual errors and root means square errors(Rao, 2016). Based on the analysis provided, proper judgement can be made by referring to the International Hydrographic Organization (IHO) standards.

This paper compares the positioning between the autonomous solution GNSS and Atlas-L band using the static method. To achieve the aim, three objectives have been outlined: i) to determine the continuity of given data by Atlas-L band, ii) to analyse the accuracy of positioning data using differential correction of Atlas-L band and autonomous solution GNSS using static positioning, and iii) to determine the classification of differential correction data referring to the IHO minimum standards table.

STUDY AREA AND DATASETS

Study Area

This study was conducted in Universiti Teknologi MARA (UiTM) Perlis Branch, located in Arau, Perlis, Malaysia. The observation was carried out on top of a building at Block A, located at $6^{\circ} 26'$ 44.40" N and $100^{\circ} 16' 29.82$ ". This campus is the largest branch campus with an estimated 150-hectare area which consist of 61.6 are the built-up area, and others are of the farming activities (Zainuddin et al., 2011).



Figure 1: Location of the study area. a) Peninsular Malaysia b.) Perlis State. (Sources: Google, 2020)

Atlas L-Band

Atlas is a flexible and scalable service that accurately delivers its L-band correction signals from the meter to the sub-decimeter (Hemisphere GNSS, 2015). The entire world is virtually covered with approximately 200 benchmarks worldwide, with L-band satellites distributing Atlas corrections. Atlas GNSS provides correction data for the GPS, GLONASS, Galileo and BeiDou constellations (Hemisphere GNSS, 2015).

Correction services is a GNSS positioning model where consumers are typically able to operate their receivers effectively anywhere globally and obtain accuracy at centimetre levels, depending on the hardware platform and application, by receiving information from a control centre. One of the correction services features is that corrected positioning data is produced and transmitted in real-time to end-users.

The network data is combined with other auxiliary data at the processing centres and processed, where accurate satellite information is generated. This data involves satellite orbits, clock errors and different amounts important for worldwide positioning with high accuracy. The correction was sent to the user using L-band satellites transmission.

Implementing multi-frequency hardware Atlas provides higher accuracy than satellites, generating faster convergence times in canopy or feathered areas and robust and reliable.

Atlas Basic

Atlas Basic offers the ability to achieve SBAS equivalent performance in any part of the world where the correction service is available to users of single-and multiple-frequency products. Atlas Basic has proven its accuracy at 30 to 50 cm (95%) as a new feature. Atlas Basic offers immediate sub-meter accuracy, enabling DGPS-level precision in Atlas-supported global regions (Hemisphere GNSS, 2015).

DATA PROCESSING

GNSS Review

The overall workflow for this study is shown in Figure 2. It includes a review on positioning using the GNSS phase, data collection phase, data processing phase, and result and analysis phase. This study focuses on the RT-PPP correction services, specifically Atlas L-band.

Data Collection

Data collection is the most crucial part of this study. Before the data collection began, all the equipment used must be tested and installed (mobilisation). Integrity check was done at an established control point. This is to ensure that the instruments are calibrated and provide data needed for positioning works.

Two control points were established before the data collection process using the static method, which took about a two-hour observation for each station. The location of control points was established at the top of the Al-Farabi 3 building, as shown in Figure 3. The location was selected to ensure the sky view was clear and free from multipath error. Both control points were then used for the Atlas L-band and autonomous solution GNSS station, respectively.



Figure 2: Methodological Workflow

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Figure 3: Location of Control Points during data collection.

After the control points were established, data acquisition was conducted using the Hemisphere receiver VS330 and antenna A43 from 20th to 22nd January 2019. The Atlas L-band service, which uses the Carrier phase solution, was done from the 20th until 21st January 2019. Meanwhile, for autonomous positioning, which adapting the code phase solution, the observation commenced on the 21st until 22nd January 2019, where the total observation time was 48 continuous hours.

Data Processing

The observed positioning data was then processed to analyse the continuity of data at the northern part of Malaysia given by the Atlas L-band. Besides, the data was also used to compare the accuracy between each of the differential corrections provided by the Atlas L-band and autonomous solution GNSS. Also, the observed was data processed to check the distribution of data around the control points.

Result and Analysis

All the observation results were analysed to verify whether they achieve the objectives of this research. The first analysis was to evaluate the reliability of the Atlas L-band data. Then, the second objective was to differentiate the accuracy of the Atlas L-band and autonomous positioning data. The final analysis classifies and identifies the accuracy that fits the IHO minimum standards. Recommendations were made based on the findings of the study. The T-test was used to determine a significant difference between the means of difference of Atlas L band and autonomous data.

RESULTS AND DISCUSSION

Continuity of Atlas L-Band Data

This analysis answered the first objective: to determine the coverage and continuity of data provided by the Atlas-L band. Continuity of data is essential because it represents the availability of the Atlas Lband data during the observation. A continuous feed of data will give the best positioning result for the observed point. All the data was collected using the Hemisphere A43 antenna and VS330 receiver.



Figure 4: 48 Hours Observation Data.

Figure 4 shows the result of the Atlas L-band data that was observed for 48 hours continuously. The result showed normal fluctuations rates during the 48 hours of observation. A total reading of 176,519 data was recorded, as listed in Table 1, where the lowest data was 0.005 meters, while the highest data was 1.066 meters. The most constant reading recorded during daytime was from 08:39:32 until 19:52:16, with the reading recorded continuously at 0.800 meters to 0.200 meters. Total data recorded during the period was 80,729 readings which were about 45.73% from 48 hours of observation.

	Table 1: Descriptive Test Result for 48 Hours Observation Data						
	Ν	Minimum	Maximum	Mean	Std Deviation		
V17	176519	.005	1.066	.479	.170		
Valid N	176519						
(Listwise)							

The lowest data observed was 0.005 meters at 07:42:01 on 21st January 2019. The highest vector distance recorded during this 48-hour observation was 1.066 meters at 03:08:41 on 20th January 2019. Vector distance observed for 48 hours observation below 0.5 meters amounted to 99,947 readings, which was about 56.6% from the total of the observed data. In comparison, the vector distance observed over the 0.5-meter reading during this 48-hour observation was counted to 76,573 or 43.4% from the total observed data.

Accuracy of Positioning Data

Accuracy of positioning data is essential to determine whether the correction given by the Atlas Lband is much better than the autonomous solution GNSS. A t-test statistical analysis was executed to verify this issue. Atlas L-band and autonomous solution GNSS data were analysed based on known coordinates of a point.

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Figure 5: Horizontal Error of Atlas L-band

Figure 5 shows the horizontal errors of the Atlas L-band results, which were located at a known point observed. It was easily confirmed that the horizontal result of the Atlas L-band was slightly biased on the right side of the control point. However, this bias is still acceptable since the error value was under two meters, as stated in the Special Order based on the IHO specification table. The different range for northing was 1.321 meters from the known point coordinate with the minimum difference at 0.776 meters and the maximum different at 0.545 meters. The diverse easting range was 1.168 meters, where the minimum difference was -0.211 meters, and the maximum difference was 0.957 meters. Table 2 below shows the known point coordinate values of the observation point.

Table 2: Coordinate of Known Control Point at Atlas L-Band Receiver

Point	Northing (m)	Easting (m)
1	713913.685	255120.625

Figure 6 below shows the horizontal error of Autonomous Solution GNSS positioning data observed for 48 hours continuously from 20th until 22nd January 2019 compared with the known coordinate point.



Figure 6: Horizontal Error of Autonomous Solution GNSS

The horizontal result of the Autonomous Solution GNSS was biased on the right side of the control point. This bias is unacceptable for the Special Order classification based on the IHO classification table since the error value was under two meters. Error for northing was 1.765 meter from the known point coordinate with the minimum difference at -2.130 meter, and the maximum difference at -0.365 meter. The different range for easting was 1.649 meters, where the minimum difference was 0.609 meters, and the maximum difference was 2.258 meters. Table 3 below shows the known point coordinate value of the observation point.

Table 3: Coor	dinate of	Known Control	Point at Autonom	nous Receiver
	Point	Northing (m)	Easting (m)	
-	2	713913.643	255122.456	

Table 4 below shows the t-test result of the Atlas L-band data obtained from the IBM SPSS software. The result was then used to indicate the accuracy of positioning data using differential correction of Atlas-L band and autonomous solution GNSS using static positioning. The result shows that the Atlas L-band accuracy is acceptable because the significance of the two-tailed test is less than 0.005 meters based on the test value of 0.015-meter test value with a 95% confidence interval. The lower value of the difference is 0.464 meters, and the upper value is 0.465 meters.

Table 4: Atlas L-band t-test Analysis Result						
Test Value = 0.015033296						
					95% Confide of the D	ence Interval ifference
	t	df	Sig. (2- tailed)	Mean Difference	Lower	Upper
V17	1144.802	176518	.000	.4644	.4636	.4652

Figure 7 below shows the distribution of Atlas L-band data for 48 hours of observation. The graph contains the frequency of data recorded. The mean of the data was 0.479 meters from 176,519 readings with a standard deviation of 0.170 meters. Based on the Gaussian histogram, it can be concluded that the observation was normal and well distributed.



Figure 7: Distribution Graph of Atlas L-band

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Table 5 below shows the t-test result of autonomous solution GNSS data to analyse the accuracy of positioning data using differential correction of the Atlas-L band and autonomous solution GNSS using static positioning. The result shows that the autonomous solution GNSS accuracy is acceptable because the significance of the two-tailed test is lower than 0.005 meters based on a test value of 0.010-meter test value with a 95% confidence interval. The lower value of the difference is 2.270 meters, and the upper value is 2.273 meters.

Test Value = 0.015033296						
					95% Confider the Dif	nce Interval of ference
	t	df	Sig. (2-tailed)	Mean	Lower	Upper
				Difference		
V17	1144.802	176518	.000	.4644	.4636	.4652

Table 5: Autonomous Solution GNSS T-Test

Figure 8 below shows the distribution of the Autonomous Solution GNSS data for 48 hours of observation. The graph contains the frequency of data recorded and distance error. The mean of the data is 2.281 meters from a total of 173,699 readings. The observations were recorded as being dispersed out from the mean of the graph, where the data pattern is unusual and unexpected. The standard deviation of this data was 0.329 meters. Based on the result, it can be concluded that the observation was not normal and not well distributed.



Figure 8: Distribution graph of Autonomous Solution GNSS

Classification of Positioning Data

A statistical method combining all uncertainty sources for determining positioning uncertainty should be adopted. The position uncertainty at the 95% confidence level was recorded together with the survey data and the capability of the survey system demonstrated by the total horizontal uncertainty (THU) calculation. Table 6 below shows the classification of the minimum standard for hydrographic survey. By referring to Table 6, it can be concluded that the Atlas L-band could be classified in the Special Order because the minimum position reading produced by this solution was 0.005 meters and the highest reading made was 1.066 meters which are within the tolerance of Special Order standards. The average of data recorded is 0.479 meters. Special Order tolerance should not exceed 2 meters.

Surveys)						
Ref	Order	Special	1a	1b	2	
Positioning	Maximum allowable THU	num allowable THU 2 m		5 m + 5%	20 m + 10%	
	95% Confidence level	2 111	of depth	of depth	of depth	

Table 6: Classification IHO table (source: IHC	OMinimum Standards for Hydrographic
Surveys	3)

For Autonomous Solution GNSS, it can be concluded that the position given by this solution can be classified in 1a and 1b order as the lowest reading recorded is 1.145 meters and the highest data recorded is 3.009 meters. The average of data recorded by the Autonomous Solution GNSS is 2.281 meters. 1a and 1b order tolerance are 5 meters.

CONCLUSION

In conclusion, the continuity of positioning data given by the Atlas L-band in the northern part of Malaysia was within the acceptable tolerance and continuous feeding based on results produced. The positioning comparison between Atlas L-band and Autonomous Solution GNSS showed that the position given by Atlas L-band was more accurate and precise, as the average position was 0.479 meters and 2.281 meters, respectively. Ultimately, the position given by the Atlas L-band can be classified as Special Order. At the same time, the autonomous solution by GNSS was classified to be in the order of 1a and 1b based on the classification table by the International Hydrographic Organisation (IHO) standard (IHO, 2010).

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