International Journal of Engineering & Technology, 7 (4.29) (2018) 178-181

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

The Influence of RTK GNSS Antenna Heights on Multipath Error

Sarah Isnan[1*], A.Hardy[1], Wan Baderul Hisan [1], Mohamad Abu Ubaidah Amir [1], Mohd Norsyarizad Razali[1], M.N. Azzeri[1], Mohd Arif Ahmad[1], Zulkifly M.R.[1], Afiqah Rosly[1], Ainul Rahman[1], Adenen Aziz[1], Siti Nur Muhamad[1]

[1] Faculty of Defence Science and Technology, Universiti Pertahanan Nasional MALAYSIA
**Corresponding author E-mail: sitisarah@upnm.edu.my*

Abstract

Hydrographic surveying is critical to provide safe navigation and route selection to the vessels. Since GNSS has evolved throughout the decade, it became a fundamental equipment for survey. Real Time Kinematic (RTK) GNSS is one of the GNSS technology, which capable in computing position in real time and produce centimetre accuracy. However, this GNSS equipment is susceptible to multipath error causing error in positioning computation. This project attempts to investigate how different antenna heights will effect the positioning accuracy and size of multipath error on RTK GNSS. Various types of analysis have been done in order to determine whether different antenna heights will affect the positional accuracy and size of multipath error. The result shows that different antenna heights effect the positional accuracy and size of the multipath error and this will provide basic guides in order to carry out hydrographic survey. Conclusion and future research also has been made in order to guide researchers in conducting future projects.

Keywords: *Antenna Heights; Global Navigation Satellite System; Hydrography; Multipath Error; Real Time Kinematic (RTK)*

1. Introduction

Global Navigation Satellite System (GNSS) has been widely used in hydrographic surveying. RTK GNSS is one of the common survey equipment used in this area as it used dual frequency, which involves pseudorange code and phase carrier. RTK GNSS makes dynamic measurement more robust in real time. RTK GNSS computes position by transmitting correction from known position (base station) to unknown position. However, precision and accuracy of RTK GNSS will be affected by multipath error. This paper aims to discuss about how different antenna heights affect the coordinates accuracy and size of the multipath error. The observation data is processed in the RTKLIB using static and kinematic mode. The static mode will be used as 'true' value. The positional error and root mean square error are computed in order to quantify the level of accuracy and precision. Multipath error of L1 and L2 of each set ups are computed to quantify which antenna heights produce the most error..

2. Multipath Error

Multipath error occurs when the satellite signals are reflected to another surfaces making the satellite signals delayed and taking longer time to reach the antenna receiver. Usually, when the satellite signals took a longer time to reach the GNSS receiver, the receiver is able to solve the multipath. However, reflections from nearby objects will arrive at very short delays. This delay actually distorts the computation of pseudorange and carrier phase making the measurement of the velocity, time and position to be inaccurate. The amount of multipath error that will be produced will also depends on the power and carrier phase of the direct path. The smaller the received power compared to the direct path, the smaller the error. The carrier phase also will influence the distortion characterization and its degree [1].

3. Multipath Error Mitigation

Mitigation of multipath has been widely studied by carrying out environment test [2,3,4]. Most of the mitigation focused on the antenna enhancement by designing a better antenna which is able to detect and eliminate the multipath error [2]. Most of the methods have focused to cover the antenna from contaminated signals and detect the contaminated signals [2].

Mitigation method such as using choke ring antenna is only suitable to detect multipath signals coming from below antenna [3]. Most of current GNSS used right hand circular polarized antenna compared to choke ring antenna as it is cheaper in price [3]. However, this antenna is unable to mitigate multipath error thus, this type of antenna is attached with ground planes to make it able to detect multipath error coming from low satellite elevation [3].

Apart of antenna, enhancement for the GNSS receiver also has been made [2]. A paper [4] has studied the effect of various parameters such as receiver bandwidth towards the GNSS multipath effect. This paper has indicated that errors will started to appear below 1 to 2-meter level [4]. The GNSS receiver with Strobe Correlator Technology technology is able to compute calculations to estimate multipath error especially in RTK GNSS [5]. However, despite of these studies and researches, the multipath error still exists and appear in GNSS equipment [2].

Apart of mitigating the multipath error by protecting and enhancing the antenna and receiver, the basic method to reduce the error is to position the GNSS antenna far away from multipath error sources [6]. High buildings and trees will contribute to multipath errors as the satellite signals will be reflected to these surfaces before the signals arrive to the receiver. However, not all the survey locations are free from buildings and trees thus, other methods of mitigating the multipath error must be determined.

Most of the research work discussed on the antenna height and distance from the reflectors to mitigate the multipath error as these are the basis methods to avoid the contaminated satellite signals from the receiver.

4. Multipath Geometries

There are three types of multipath geometries which are Forward Scatter (F-mode), Backscatter Geometry A (BA-mode) and Backscatter Geometry B which is also known as BB-mode [2]. Forward Scatter Geometry (F-mode) occurs when the reflector is located under the antenna which usually happens when the satellites elevation is low [2]. In order to reduce the multipath signals coming from low elevation, the GNSS is usually set to a minimum of satellite elevation angle at 10 degrees [2]. However, this method does not remove all the multipath errors. This geometry occurs when the satellite signals are reflected to the horizontal ground and travels to the receiver antenna. Backscattering geometry (BA-mode) occurs when the satellite signals hit the vertical reflector and reflected back to the antenna receiver causing error in position [2]. Backscatter geometry (BB-mode) occurs when both F-mode and BA-mode are combined together [2].

5. MP1 and MP2

In order to quantify the multipath error, MP1 and MP2 can be computed because the GNSS receiver is able to provide pseudorange data in L1 and L2 frequencies [3]. This is done by applying phase linear combination observation equations in the computation [3]. This computation will be able to remove the effect of satellite clocks, tropospheric delay, ionospheric delay and station clocks [3]. Below are the equations to compute the pseudorange multipath [7].

$$MP1 = P1 - 4.0915C1 + 3.0915C2 + [\,4.0915(\lambda 1K1 + MPC1) - 3.0915\,(\lambda 2K2 + MPC2)]$$

$$MP2 = P2 - 5.0915C1 + 4.0915C2 + [5.0915\,(\lambda 1K1 + MPC1) - 4.0915\,(\lambda 2K2 + MPC2)]$$

Where,
P1 and P2 = Pseudorange data on L1 and L2
C1 and C2 = Carrier phase data on L1 and L2

MPC1 and MPC2 = Multipath carrier phase on L1 and L2

N1 and N2 = Unknown integer ambiguities
$\lambda 1$ and $\lambda 2$ = Carrier phase wavelength on L1 and L2

All units are in meters except the integer ambiguities [3].

6. Project Background

This research focuses on the multipath error by conducting test environment of RTK GNSS at Glasgow University Observatory. This observatory is actually the fourth observatory and was introduced by one of the Scotland astronomer in 1969 [8]. This location is chosen as it is made specially for making observation and there is no disruption from surroundings. The location of the experiment is situated to the north west from the Observatory building. RTK GNSS is used in this research as it is able acquire data in real time and able to attain centimetre accuracy. RTK GNSS needs one base station (known position) with one or more rovers (unknown position). The data will be observed for 24 hours for 3 days in each set up. However, the data is only processed for 4 hours each day as there is limitation on the memory card storage. The data is processed in kinematic mode as it is suitable for hydrographic surveying. This is because when the hydrographic surveying is carried out, the rover is always moving due to pitching, rolling and yawing in the ocean or river.

GPS day will start 4 minutes earlier than the day before, the observation will be carried out within the GPS day in order to acquire same satellite configuration and same number of satellites as all satellites will complete their rotation in 11 hours and 58 minutes [2]. All of the observation settings during the experiment is set to zero-degree satellite elevation and 60 seconds time interval. All the data is then processed in RTKLIB in order to acquire the coordinates for every 60 seconds and multipath error for L1 and L2 is computed in BNC. TEQC is used to compute the MP1 and MP2 for different time interval and satellite elevation. The graph of positional error, root mean square error and coordinates for both X-ECEF and Y-ECEF are plotted using Excel.

There are three antenna heights which act as a setting in this experiment which are 1.0 m, 0.75 m and 0.5 m. These three different antenna heights are actually made of scaffolding metal pole. The pole is cut into three heights and is attached to the metal peg which has been set up on the ground. Tripod is not use in this project as it can cause position error during changing of the antenna height. These antenna heights are chosen as it is about similar to the antenna height which is being practiced in hydrographic survey. These three heights are observed for three consecutive days so that the multipath geometry for each day can be compared. The first height of 1.0 m was observed for three consecutive days started from GPS day 179 until 181, after that 0.75 m antenna height was observed from GPS Day 182 until 184 and lastly 0.5 m antenna height was observed from GPS Day 185 until 187.

Kinematic mode is a high precision dynamic GNSS mode which is suitable for moving rover as this research focussed on the hydrographic survey. The rover in the boat is always moving thus kinematic mode is suitable to be applied. The precise ephemeris of each product are obtained from IGS website. The RINEX base station of Glasgow is downloaded from the Ordnance Survey website. After that, the observation data and the navigation data is uploaded in the RTKPLOT. The time interval for each day is set based on the GPS Start time and will end after 4 hours on each day. The interval is set for 60 seconds and the elevation mask is set to zero degree except for the satellite elevation setting. All types of satellites are included and WGS84 is set as the datum. The base station coordinates (Glasgow) is also input in the setting. Solution mode is set to X/Y/Z-ECEF and the integer ambiguity is set to "Continuous" which means integer ambiguities are continuously estimated and resolved. This kinematic mode is able to attain position at millimetre accuracy and use both pseudorange code and carrier phase in the processing.

7. Project Result & Analysis

The data are processed in RTKLIB using kinematic processing mode and static mode. Graph of each coordinates are plotted. Figure 1, 3 and 4 show how the coordinates (X-ECEF and Y-ECEF) of the data changed and spread over three days for 240 minutes starting on each GPS Day. It can be seen that from the graph, each set up has different patterns of data spreading. GNSS antenna will connects the satellite signals to the receiver [9] and the point where the GNSS measurement is taken is called antenna phase centre [10]. The antenna phase centre actually varies with the signals of radio frequencies, satellite elevation and azimuth [9].

Changing the antenna height will change the point of antenna phase centre thus causing a slight different in coordinates obtained.

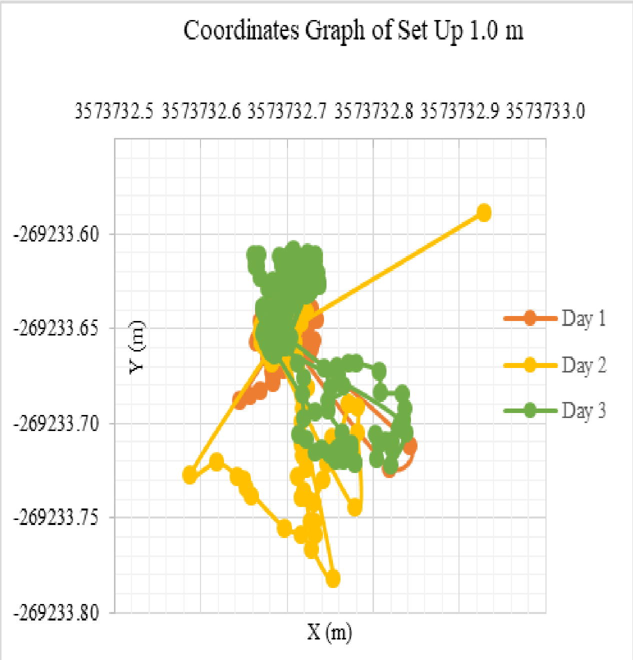

Fig. 1: Coordinates of X-ECEF and Y-ECEF for Set Up 1.0 m (x-axis and y-axis represent coordinate)

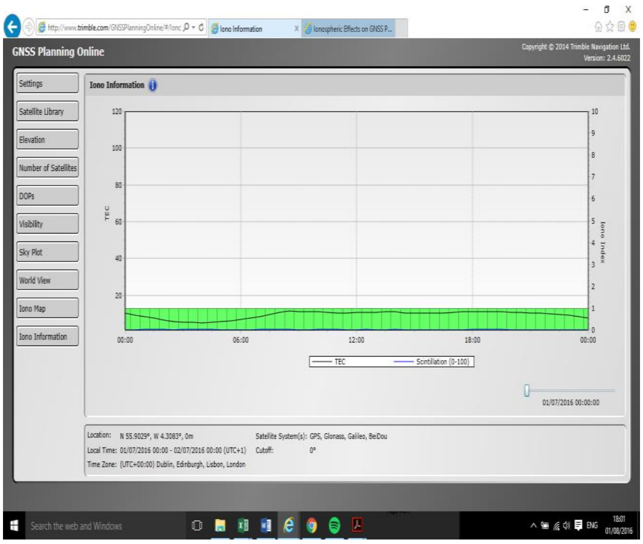

Fig. 2: Example of Ionosphere Information on 01 July 2016 from Trimble GNSS Planning Online

(Trimble Navigation Limited, 2016)

Each set up has different observation data on different days which is from Day 1 to Day 3. This is mainly due to signal wave propagation from the satellite to the antenna receiver [1]. Radio frequency waves can be interfered with different layers of the Earth's atmosphere such as ionosphere and troposphere atmosphere [1]. The free electrons in the atmosphere may cause delay on the wave propagation from the satellite to the receiver and lead to constructive and destructive interference of the signals [1]. From the Trimble GNSS Planning Online on 1st July 2016 (Figure 2), it could be seen that the most active time for high electrons is during the day time until late evening at location of latitude N 55.9029°, longitude W 4.3083° and height 0 m. The local time and time zone are Coordinated Universal Time (UTC) + 1 and UTC 00:00 in London.

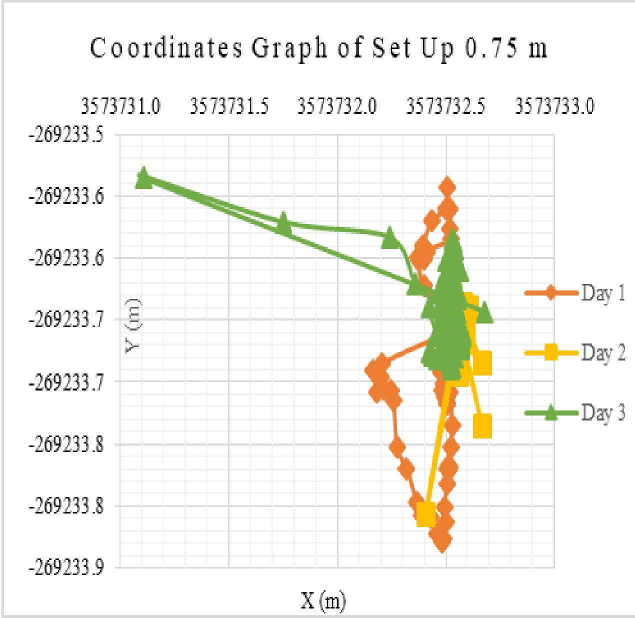

Fig. 3: Coordinates of X-ECEF and Y-ECEF for Set Up 0.75 m (x-axis and y-axis represent coordinate)

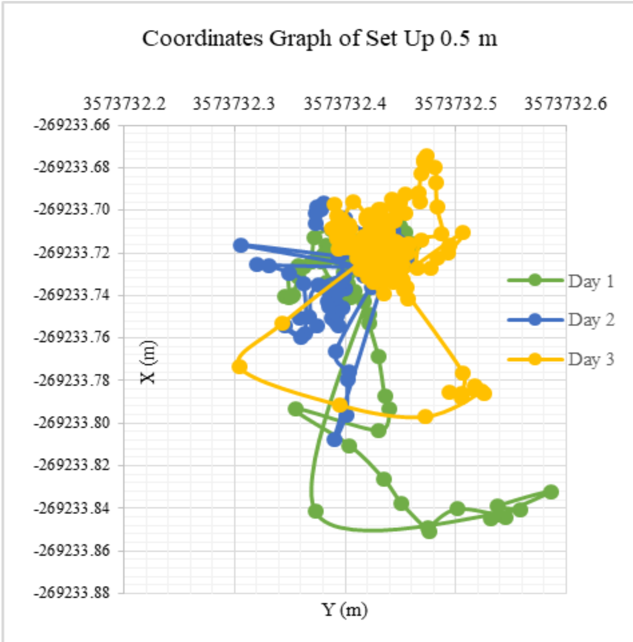

Fig. 4: Coordinates of X-ECEF and Y-ECEF for Set Up 0.75 m (x-axis and y-axis represent coordinate)

Based on the standard deviation in Table 1, the observation data from the 0.75 m antenna height has the highest data spreading. Meaning the frequency of the observation data has spread a lot from the 'true' value. So, the precision of this 0.75 m set up is very low. The root mean square error of 0.75 m also shows that it is very high. This shows that the accuracy or the closeness of the observation data from the true value is very low. 0.5 m set up has the lowest standard deviation (0.0480 m) and root mean square error (0.1051 m).

Table 1: Standard Deviation and Root Mean Square Error on Different Antenna Height Set Ups

Antenna Height Set Up (m)	Standard Deviation (m)	Root Mean Square Error (m)
1.00	0.0552	0.1163
0.75	0.1077	0.2288
0.50	0.0480	0.1051

Table 2: Mean Multipath on L1 and L2 on Different Antenna Height Set Ups

Antenna Height (m)	Mean Multipath on L1 Frequency (m)	Mean Multipath on L2 Frequency (m)	Total Mean Multipath (m)
1.00	0.21	0.42	0.63
0.75	0.28	0.31	0.59
0.50	0.34	0.58	0.92

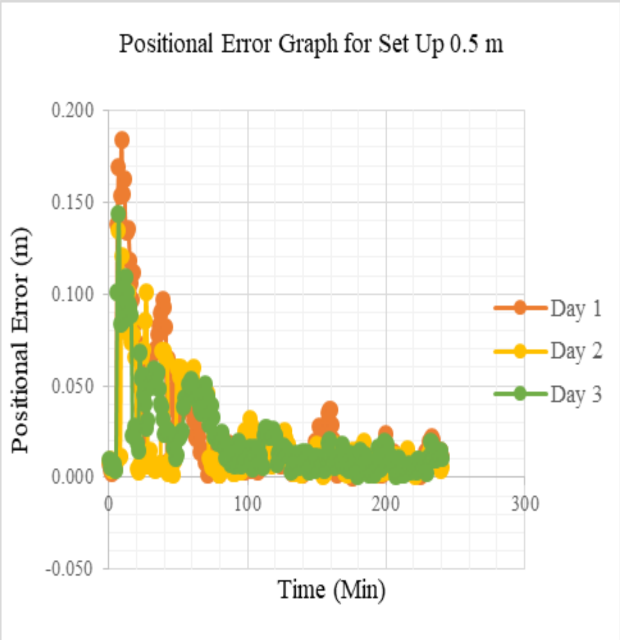

Fig. 5: Positional Error Graph for Set Up 0.50 m

From Figure 5, it can be seen that most of the positional error occurs at the early minutes of the observation. This happened for almost the same time (first 70 minutes) on the three days of the observation. The operational mode or how the data is being processed will actually affect the accuracy of the position. During the data processing, some of the data is processed in fixed solution and some is processed in float solution in RTKLIB. From the post processed data, all the data is mostly being processed in fixed solution for the first 10 minutes, however the number of satellites being used to compute the position is less than 10 satellites. After 10 minutes, the data is being processed in float solution using more than 10 satellites. In RTKLIB software, fixed solution means all the integer ambiguity is properly resolved whereas the float solution means all the integer ambiguity is not resolved [11]. During the initial stage of measurements, [12] have stated that fixed solution shall be applied in the computation. In this study, there are two possibilities in which that float solution is preferred to be used in RTKLIB or this software is not managed to solve the integer ambiguity.

7. Conclusions and Future Work

Based on the investigation in this research, antenna height of 0.5 m produced the lowest root mean square error (0.1051 m) and standard deviation (0.0480 m) thus, produced the lowest positional error (15.9519 m) compared to other antenna heights. However, the multipath error produced by this set up is the highest which is 0.92 m. 1.0 m antenna height produced second lowest root mean square error of 0.1163 m and standard deviation of 0.0552 m. The positional error produced by this antenna height is 19.0724 m and the multipath error produced is 0.63 m. Antenna height of 0.75 m produced the highest standard deviation of 0.1077 m and 0.2288 m. Therefore, this set up produced the highest positional error which is 23.4841 m however, it produced the lowest multipath error which is 0.59 m.

Future work that is being suggested is to investigate how different positions of reflectors effect the multipath error based on the multipath geometries. The reflectors must be positioned on the direction which most of the signal of the satellites coming the most. Different elevation angles also can effect the size of the multipath error. This can be done using the RTKLIB or TEQC or any other reliable software.

Acknowledgement

This work is not supported by any grant from any Institution but authors would like to thank University of Glasgow for allowing the experiment to be conducted at university and providing all the necessary equipment.

References

[1] Kaplan, E. and Hegarty, C. (2006). Understanding GPS. 2nd ed. Boston: Artech House, pp.279-295.

[2] Mekik, C. and Can, O. (2010). An investigation on multipath errors in real time kinematic GPS method. Scientific Research and Essays, 5(16), pp.2186-2200.

[3] Even-Tzur, G. and Shaked, D. (2008). GPS Antenna Height and Its Influence on Pseudorange Multipath. In: International Federation of Surveyors (FIG) Working Week. Stockholm: International Federation of Surveyors, p.112.

[4] Coz, D., Shallberg, K. and Manz, A. (1999). Definition and Analysis of WAAS Receiver Multipath Error Envelopes. Navigation, 46(4), pp.271-282.

[5] Pirti, A. (2015). Multipath and multipath reduction in the obstructed areas by using enhanced strobe correlator (ESC) technique. Tehnicki vjesnik , 22(2), pp.509-519.

[6] Noor Suryati, M.A. & Musa, T.A. (2008). Site-specific Multipath Characteristic of GPS ISKANDAR Network. , pp.1–13. Available at: http://www.utm.my/gng/files/2014/09/12.pdf.

[7] Ge, L., Han, S. and Rizos, C. (2002). GPS Multipath Change Detection In Permanent GPS Stations. Survey Review, 36(283), pp.306-322.

[8] Roy, A. (1993). Glasgow and the heavens. Vistas in Astronomy, 36, pp.389-407.

[9] EL-Hattab, A. (2013). Influence of GPS antenna phase center variation on precise positioning. National Research Institute of Astronomy and Geophysics : Journal of Astronomy and Geophysics, 2(2), pp.272-277.

[10] Sanz Subirana, J., Juan Zornoza, J., and Hernández-Pajares, M. (2011). Antenna Phase Centre - Navipedia. [online] European Space Agency Navipedia. Available at: http://www.navipedia.net/index.php/Antenna_Phase_Centre [Accessed 2 Aug. 2016].

[11] Takasu, T. (2013). RTKLIB ver. 2.4.2 Manual. [online] RTKLIB. Available at: http://www.rtklib.com/prog/manual_2.4.2.pdf [Accessed 2 Aug. 2016].

[12] Tusat, E. and Turgut, B. (2004). Investigation Ambiguity Resolution in GPS and the Effects of Ionospheric Modeling on Base Vector Components. In: Fédération Internationale des Géomètres. Turkey: Fédération Internationale des Géomètres, pp.1-1