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Precise GNSS Kinematic Observation Using Absolute Positioning Method at Bandar Universiti Residential Area

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Abstract: Absolute Positioning (AP) mode, related to pseudo-range measurements, limits the level of accuracy to several meters in open sky and to several dozens of meters in urban canyons. This study explores the effect of using a large number of Absolute Positioning(AP) observations from Leica Viva GS10/GS15 receivers. Data segmentation and bootstrapping statistical methods were used to obtain the deviation, which can describe the accuracy of the large sample. The final goal was to obtain the single positioning and associated deviations from single GNSS receivers positioned on a network. The process was tested in two geodetic network examples. The results indicated that the enhanced Absolute Positioning mode was able to improve its accuracy. Errors of several meters were reduced to values close to 50 cm in 25–37 min periods. For all observations from multiple GNSS systems, a closely coupled observational model assumes a single difference satellite. Investigation on the influence of different frequencies on Absolute Positioning (AP) and the development of precise accuracy can be improved with both code and carrier phase can be use together with Precise Point Positioning that allows certain errors to be eliminated.

Keywords: Absolute Positioning, Single Difference Satellite, Single Positioning

1. Introduction

Absolute positioning can be defined as determination of station position using only the measurements made in that station. It is opposite to the relative positioning for which the station position is determined using both its measurements and those made in another station of which the position is known. This section explains how Absolute Positioning (AP) is computed using code data only. This approach provides a precision on the position of a few meters to tens of centimeters, depending on the satellite orbits and clocks used (broadcasted or more precise products computed in a post-processing). For a more precise position, both code and carrier phase can be used together, with the Precise Point Positioning (PPP) approach. For this study, the main focus is only on Absolute Positioning method.

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2. Literature Review

Being precise on observing the positioning of the GNSS receiver is the key to obtain accurate results. Thus, kinematic observation must be held. Kinematic surveying is specifically defined as surveying using interferometric carrier phase observations in a kinematic mode. The survey begins with two receivers 'I' and 'J' positioned over two starting points A and B respectively. After an initial period, with both receiver static over these two points, the antenna of receiver 'J' is lifted and moved on to a new point whose coordinates are unknown. [4]

The transmission rate is determined on the basis of specific parameters. Parameters that may be used to determine the data transmission rate include rover demand, required rover accuracy, satellite positioning system (SATPS) events, the required data for ambiguities, and the type and content of the data transmitted. [4]

Comparing network Kinematic Observation and PPP, Kinematic Observation gives many advantages over conventional differential GNSS (DGNSS), however, PPP only requires single receiver and automatically removes the need of reference station or data [1].

An Absolute Positioning can be said to be a between-satellite single positioning of a between-receiver difference. The improved positions from the between-receiver single difference step are not further enhanced by the combination with the between-satellite single positioning. The Absolute Positioning, for all practical purposes, has eliminated the receiver clock errors and the satellite clock errors. [5]

Multi-system Absolute Positioning combination methods gives much easier and economic process compared to other Differencing method. These include loose combination in which case each of the systems uses its own pivot satellite and Kinematic observation being formed across systems [2], and tight combination in which case single GNSS receiver link to multiple of GNSS satellite constellation, thus permitting Absolute Positioning interlink with different GNSS systems [2]

RTKLib is an open source GNSS data processing software developed by Tomoji Takasu of Tokyo University of Marine Science and Technology. It is developed in C and includes numerous application programs such as RTKPOST, RTKNAVI, STRSVR, RTKPLOT, and others [6]. or from real-time to post-processing. It is simple, portable, and performs well. It can process data from GPS, GLONASS, Galileo, QZSS, BeiDou, and SBAS [7]. RTKPOST has nine different positioning modes: Single, DGPS, Kinematic, Static, MovingBase, Fixed, PPPKinematic, PPP-Static, and PPPFixed SBAS [7].

3. Methodology

3.1 Installation

For the installation of this set-up there are 4 main equipment that are needed to be use such as GNSS Receiver Leica Viva GS10/GS15, GNSS Controller Leica Viva CS15, tripod and rover pole. First of all, the tripod with a GNSS receiver need to be set on a position with a point precise longitude and latitude for calibration purposes. Then, the GNSS receiver need to be attach on the rover pole and mounted on motorcycle with a speed that not exceed 10 km/h. The rover will move along the designated roads that were proposed and sets of data will be obtained throughout the survey expedition. Before starting the survey, a call need to be made connecting to Jabatan Ukur dan Pemetaan Malaysia (JUPeM) to gain the coordinate of the current satellite that passing near UTHM's area 1 hour before starting the survey.

3.2 Equipment

Figure 3.2: Leica Viva GNSS Receiver GS10/GS15

Figure 3.3: GNSS Controller CS15/with Bluetooth

Figure 3.4: Rover Pole

Figure 3.5: Rover Pole

3.3 On- Site Survey

3.3.1 Location

- Bandar Universiti Residential Area

As for the location of the survey, routes have been selected and divided into two parts which are main road and artery road for our research purposes which contains only the residential area's road and surroundings of the area will be covered by this research. Figure 3.6 shows the plan view captured from Google Earth with designated road lines which consist main roads and alternative roads. The road lines were used to record the kinematic observation on site as shown in Figure 3.7.

Figure 3.6: Satellite of Bandar Universiti residential area (source from Google Earth)

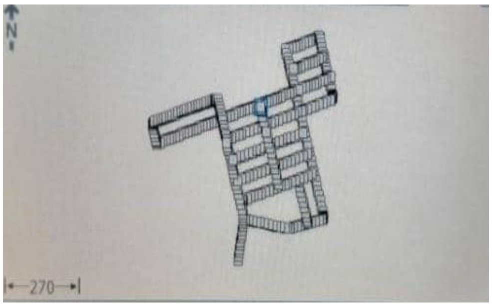


Figure 3.7: Kinematic Observation of Bandar Universiti residential area's road from Leica VIVA GS10/GS15.

3.3.2 Data Collection

For this research, a Leica GS15 GNSS receivers will be used to collect the data. Various kinds of GNSS receivers can also be used, according to Bhatta [3]. But nowadays, a basic GNSS receiver is usually simple and consists of an internal or an external receiver, external antenna, portion of radio frequency, microprocessor, unit of control and display, and a storage with a power unit. The antenna acted as a collector of electromagnetic signals emitted by satellites to transform them to electrical signals that can be used by electronics. The receiver's antenna may be external or internal, but most are built-in. It needs a connecting coaxial cable or other forms of cable to pass the external antenna to signal from GNSS. But the longer the length of the wire, the more GNSS signal errors can occur.

Figure 3.8: Interface of the Leica VIVA CS15's Controller.

In order to obtain data through Absolute Positioning method, multiple satellites needed to be use as a reference. Thus, it needed to obtain more than one data for each points which are obtained from two different satellite in order to eliminates any clock errors from the GNSS receiver and satellites. Other than that, a few precautions also needed to be taken during the data collection process such as hazardous area and weather conditions. The survey need to be stop if the surrounding area were affected by bad weathers and hazardous environment. This is due to signal disturbance between GNSS receiver and satellite. The display of the Leica Smartworx software was shown in Figure 3.8.

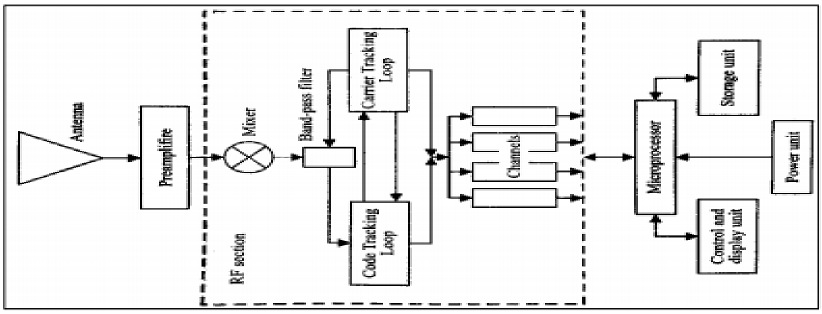
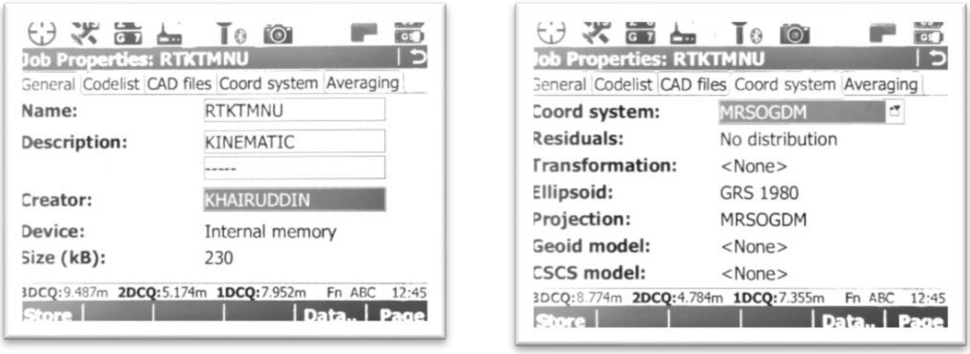


Figure 3.9: Typical GNSS receiver block diagram [3]

The Radio Frequency (RF) section is the first section to perform signal operations in the receiver as shown on Figure 3.9. The code will be synchronized from the satellite broadcast using the replica code created by the receiver or best known as the pseudo-range measurement. The method takes place in the RF segment code monitoring loop. Then, the signal chosen from two intermediate or beat-frequencies produced when the satellite signal is combined with the replica signal is sent to the carrier-tracking loop. At the carrier tracking loop, the voltage-controlled oscillator is constantly balanced to obey the exact beat frequency. The microprocessor serves as the controller of the entire receiver, controlling the processing of data. The power of the microprocessor can influence several things, such as the processing capacity, the power parameters, the speed of signal acquisition and measurement, and the size of the receiver. In order to obtain a wide receiver, the processor must be efficient.



Name: RTKTMNU
Description: KINEMATIC

Creator: KHAIRUDDIN
Device: Internal memory
Size (kB): 230
3DCQ:9.487m 2DCQ:5.174m 1DCQ:7.952m Fn ABC 12:45

Coord system: MRSOGDM
Residuals: No distribution
Transformation: <None>
Ellipsoid: GRS 1980
Projection: MRSOGDM
Geoid model: <None>
CSCS model: <None>
3DCQ:8.774m 2DCQ:4.784m 1DCQ:7.355m Fn ABC 12:45

Figure 3.10 & Figure 3.11: Starting new work interface on Leica Viva CS15 Controller.

The control and monitor unit functioned as an interface between the user and the receiver's microprocessor. All data will be shown in this section as shown in Figure 3.10. Next, the storage unit is a location where all the data gathered can be processed for further processing as Shown in Figure 3.11. Nowadays, flash cards are used as storage, making it convenient for the data to be moved to the device. Finally, most receivers use the battery to work and a rechargeable battery is usually used in surveying. The battery will last a long time, as the GPS receiver does not need high voltage to work, it requires just around 3 to 36 volts of direct current (DC).

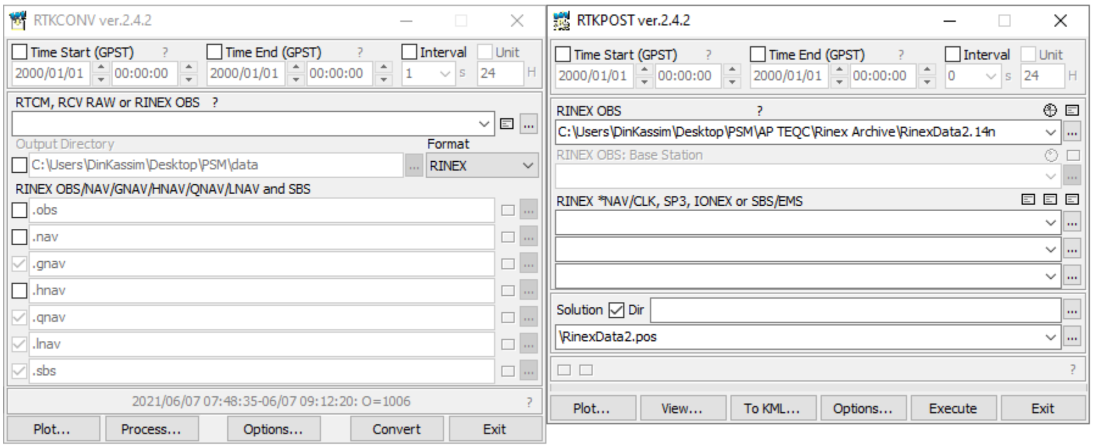
3.3.3 Data Processing

The raw data would first be transferred to the RINEX file format in order to process the data received from the GNSS receiver. It can transfer everything online or offline, such as using Leica Geosystem to the RINEX utility. The utility receives different types of measurement files, which are DAT, T00, T01, T02, T04, RT17, RT27, or .cap format, to convert it to RINEX version 2.10, 2.11, 3.02, 3.03, For this research, the data obtained must be converted in RINEX format. The data received were recorded in 24 hours-time. Hence, the data need to be split manually using Notepad application according to the time needed, which is for an hour until 24 hours-time period.

In order to convert the raw data from Leica GS10/GS15 into RINEX data. The usage of command prompt TEQC will be used to convert raw data into RINEX data. The command will give the RINEX numbers and also Observation and Navigation data. Then, the data that were extracted will be process by the usage of RTKlib Open Source GNSS Processor. From the RTKlib files, two (2) software will be use in order to gain the process output. Thus, resulting graphical representation of the processed data.

3.4 Data Analysing

For analyzing purposes, all the graphs that were obtained from RTKCONV and RTKPOST were organized side by side according to its attributes and the change in terms of patterns. This part of process is the most crucial part in this research. This is because through this process each patterns of graph will be interpreted to its tendency on getting better accuracy in Absolute Position method. Thus resulting sets of graphs that can be analyzed and discussed later on in Chapter 4. Figure 3.12 shows the interface of RTKCONV and RTKPOST that will be use during the data post processing for the research.



RTKCONV: Time Start (GPST) 2000/01/01 00:00:00; Time End (GPST) 2000/01/01 00:00:00; Interval 1 s; Unit 24 H

Output Directory: C:\Users\DinKassim\Desktop\PSM\data; Format: RINEX

2021/06/07 07:48:35-06/07 09:12:20: O=1006

RTKPOST: Time Start (GPST) 2000/01/01 00:00:00; Time End (GPST) 2000/01/01 00:00:00; Interval 0 s; Unit 24 H

RINEX OBS: C:\Users\DinKassim\Desktop\PSM\AP TEQC\Rinex Archive\RinexData2.14n

Solution: \RinexData2.pos

Figure 3.12: The interface of RTKCONV and RTKPOST for data processing

4. Results and Data Analysis

4.1 Data Analysis

This topic will cover on the analysis of the coordinate quality value from single Leica VIVA GNSS GS10/GS15 receiver impacts the kinematic observation's points and the single positioning accuracy. The analysis of northing and easting coordinates was also included based on the data received by both receivers from current multiple satellites that were orbiting above us. Then, analysis of graph outcomes from RTKPOST and RTKCONV were then made. The list of calculations result of standard deviation will be shown in Appendix C. The average accuracy of the Absolute Positioning that were gained during the research is 0.593m (59 cm) which is less than 0.6m(60cm) (targeted accuracy) and successfully decreasing the PDOP value from 10.675(initial) to 5.215(finish). This shows that the objectives of this research were achieved as expected. Figure 4.1, Figure 4.4 and Figure 4.7 are corresponding towards each other in the same set of day. So does Figure 4.2 with Figure 4.5 and Figure 4.8 and Figure 4.3 with Figure 4.6 and Figure 4.9.

It is very important to consider PDOP values, therefore, GNSS post-processing software is not only used in the computation of coordinates results but also in the selection of observation project. In the view of consideration of PDOP values, the observation was set to form the consistency of the PDOP value. The sampling rate consist of 3 sets of data which consist of certain amount of data in each set. The PDOP values are targeted to be less than 2.5, the average observation time interval of each measurement is 25 minutes and the computation of statistics for each data are based on 350 points recorded during the research process. The PDOP values drop down to 50% from the initial PDOP, the initial PDOP is 10.675. It drops drastically during the survey process to a finish PDOP of 5.215.

4.2 Data Interpretation

By considering all the systematic and random errors on the observation, math model written by using observable difference for code and carrier phase measurements, respectively, as below:

$$R_A^1(t_0) = \rho_A^1(t_0) + \Delta\rho_A^1(t_0) + c\delta^1(t_0) - c\delta_A(t_0) + I_A + T_A + \varepsilon$$

$$\lambda\phi_A^1(t_0) = \rho_A^1(t_0) + \Delta\rho_A^1(t_0) + \lambda N_A^1 + c\delta^1(t_0) - c\delta_A(t_0) - I_A + T_A + \varepsilon \quad \text{(Equation. ii)}$$

Where S Δρ R is the orbital error, 'I' is the ionosphere error, 'T' is the troposphere error and ε is the other types of noise and errors such as the ones due to multipath. Using single receiver and involving more than 3 different satellites, we can perform single point positioning. In Absolute Positioning(AP) the orbital error and satellite clock error are cancelled. Absolute Positioning(AP) can be form in order to reduce the clock error.

$$DD = \phi_{AB}^{12}(t) = \frac{1}{\lambda}\rho_{AB}^{12}(t) + N_{AB}^{12} \quad \text{(Equation. iii)}$$

With the usage of RTKLib, four (4) sets of data were obtained which consist of Kinematic Observation points, the Positioning variation, Velocity Solution of GNSS and Satellite status which also includes the Dilution of Precision (DOP) readings throughout the survey process. Any irregularity in the data usually are caused by non- avoidable errors that are normal to the Absolute Positioning(AP) method.

4.3 Kinematic Observation Points

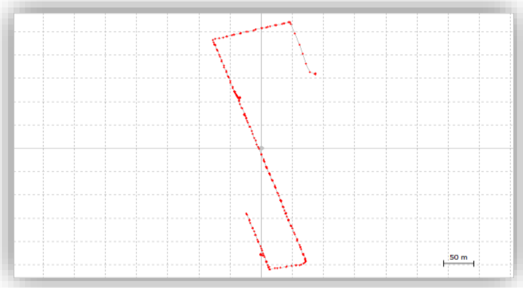


Figure 4.1: Kinematic Observation Point Set 1

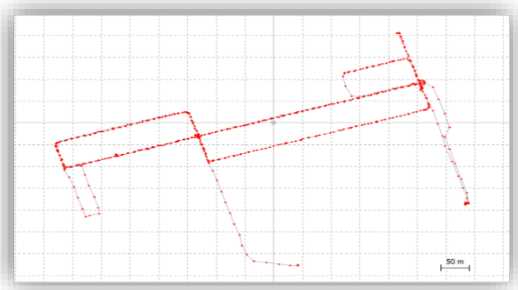


Figure 4.2: Kinematic Observation Point Set 2

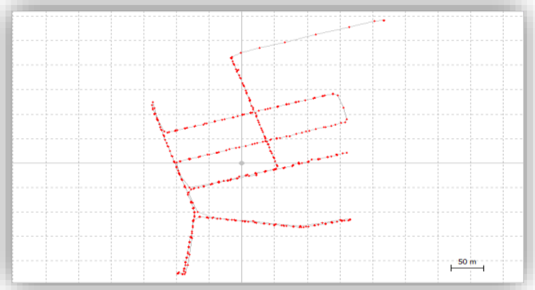
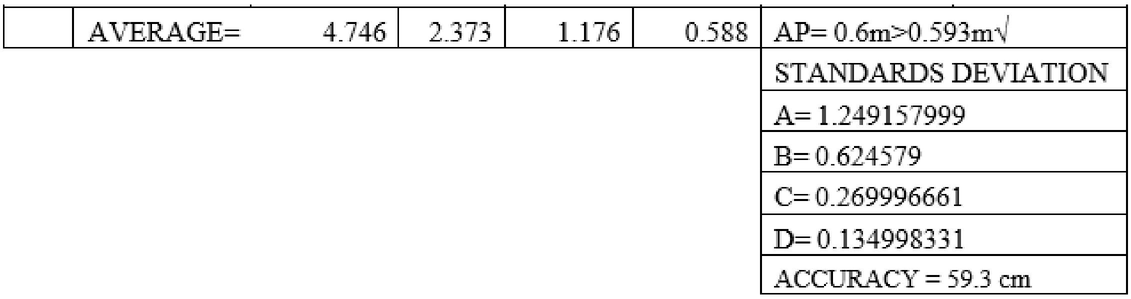


Figure 4.3: Kinematic Observation Point Set 3

Based on Figure 4.1, Figure 4.2 and Figure 4.3, these are segments that were divided during the surveying process. Hence it produced three sets of data that were needed to be converted due to the requirement of the RTKLib for certain specific file type in order to make an input for generating the output results. Specific files such as DAT, T00, T01, T02, T04, RT17, RT27, or .cap format are needed to be comply in order to complete the data processing. Each lines of the routes were identified clearly by RTKLib software. Thus, producing an astounding accuracy for better research outcome. The quality of the coordinate gained from kinematic observation survey is very important to make sure that each points of coordinate must be obtained through suitable amount of acceleration on rover. Thus, resulting a precise accuracy during post-processing data. Set 1 and Set 2 consist of 100 points each while Set 3 contains 150 points. Hence Set 3 have the most covered area for survey.



	AVERAGE=	4.746	2.373	1.176	0.588	AP= 0.6m>0.593m√
						STANDARDS DEVIATION
						A= 1.249157999
						B= 0.624579
						C= 0.269996661
						D= 0.134998331
						ACCURACY = 59.3 cm

Table 4.1: Calculations results for accuracy and Standard Deviations for each set of Output data.

Table 4.1 shows the calculations results that have been done using the provided formula and the whole sets of the standard deviation's calculation can be found in Appendix D. Every obtained sets of data were then analyzed and the criteria were determined based on the wanted criteria to ensure the precision of accuracy of Kinematic Observation by using Absolute Positioning method.

4.4 Positioning Variation

Graph of Positioning Variation

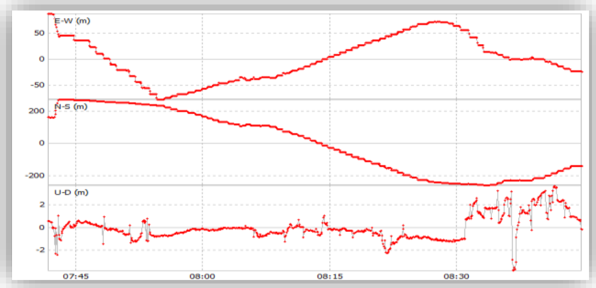


Figure 4.4: Positioning Variation Set 1

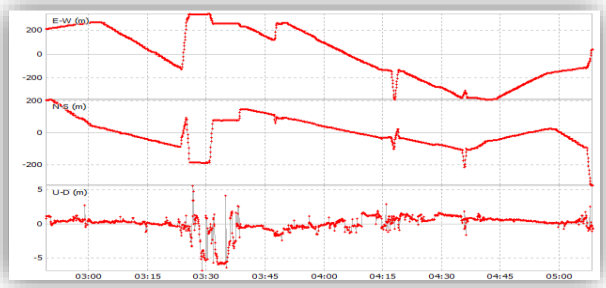


Figure 4.5: Positioning Variation Set 2

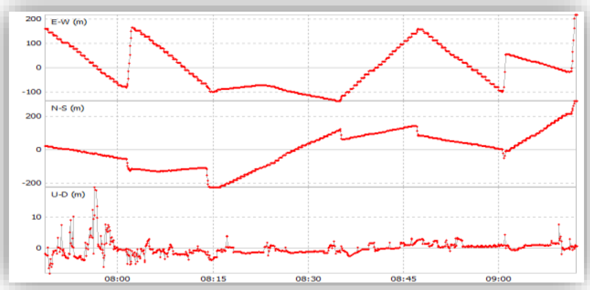


Figure 4.6: Positioning Variation Set 3

The position spikes that occur on E-W and N-S Sections Figure 4.4, Figure 4.5 and Figure 4.6 were produced due to signals orientation between receiver and the satellite. This phenomenon occurs always and its normal during data collection process. Usually it was due to certain rotation of bearing during survey. GNSS Coordinate Quality Indicators based on Satellite Geometry and Measurement RMS errors for Short Term and Long Tern Positioning Repeatability with Independent Site Re-Occupations have been examined as ways to assess GNSS Positioning Reliability. Looking towards the pattern obtained in U-D Section, it can be analyzed that the single positioning observation have a disrupted output reading as shown on each graphs, this was due to accidental signal lost causes by the receiver during site-survey process. Corresponding to the error that were obtained, it can be said that the error was caused by temporary signal lost. Hence, the impact still resulting Absolute Positioning(AP) and achieved near centimeter-level of accuracy. The standards deviation for each graph were combined and calculated using Microsoft Excel with a result of, ***1.250*** which can be considered as acceptable in terms of accuracy.

4.5 Velocity Solution of GNSS System

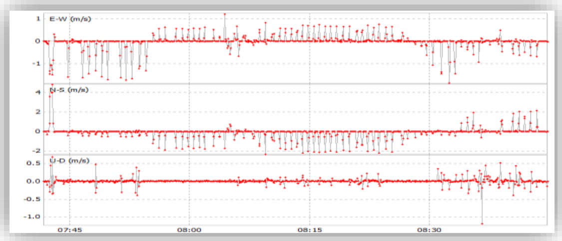


Figure 4.7: The velocity solution by the GNSS system Set 1

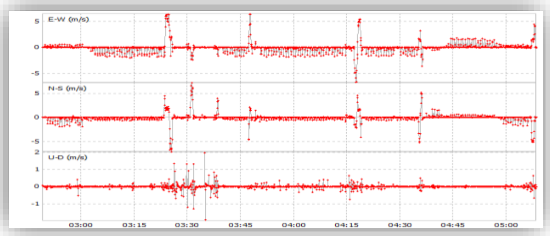


Figure 4.8: The velocity solution by the GNSS system Set 2

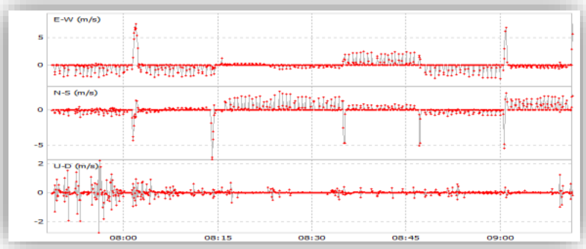


Figure 4.9: The velocity solution by the GNSS system Set 3

Based on Figure 4.7, it is shown that the velocity solution of GNSS is considerably stable with a slightly balanced set of graph reading. The velocity ascends increased slightly following with a slight descends all way back to initial velocity. Hence, the data obtained is permissible. With a few spikes on the end phase of U-D Section. Based on Figure 4.8, it was shown that the graph distributed well balanced although an acceptable amount of spike occurs in middle phase of U-D Section of the velocity solution. As on Figure 4.9, the graph data obtained have a few sudden spikes occur during the early phase of U-D Section and the velocity solution was on constants reading afterwards. These shown that the data graph patterns obtained were acceptable. Those three data were combined side by side and was analysed thoroughly. The spikes occur on the U-D sections are mostly due to signal disturbance during kinematic observation process. As a results, the velocity solution of the Kinematic Observation are consistent and the combined data patterns standard deviation calculated was within the absolute limit that is ***0.625***. Hence, the velocity solution of satellites is in good condition.

4.6 Satellite Status and Availability

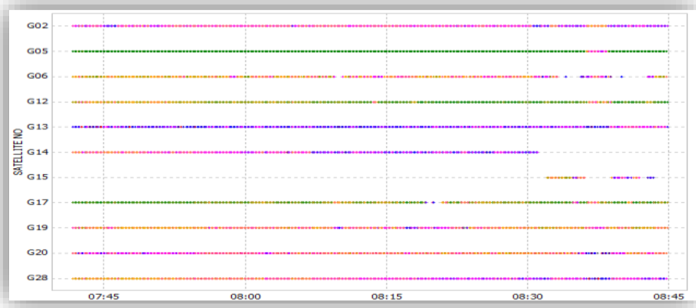


Figure 4.10: Multi-Satellites visuals that were connected to GNSS receiver

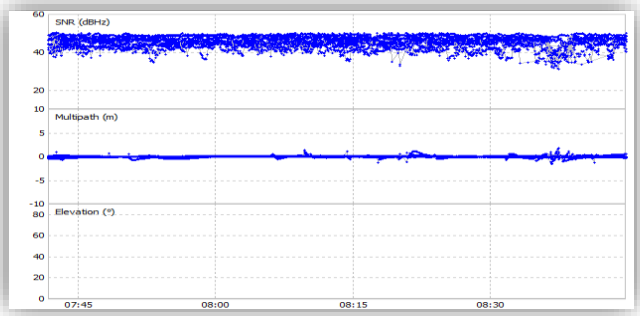


Figure 4.11: Satellite Signal Noise to Ratio and Multipath Errors

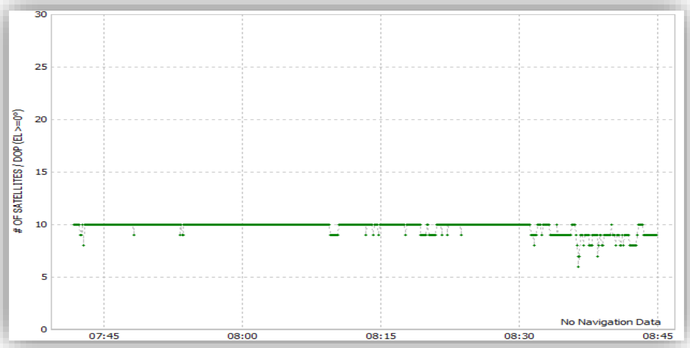


Figure 4.12: Satellites Dilution of Precision DOP

Based on Figure 4.10, it was shown that multiple of GNSS satellites showing different attribute and different colour outcomes which indicates its status on receiving signals from receiver. Figure 4.11 shows the satellite's Signal Noise Ratio in decibels during the kinematic process. The desired signal is essential data with a strict or narrow tolerance for errors and there are also other signals disrupting the desired signal. The data shows that the tolerance of SNR with a standard deviation of ***0.269***, the data pattern is within the requirement limit. Thus, the multipath error also has been minimized with a standard deviation of. ***0.135***. For Figure 4.12, it shown that the Dilution of Precision(DOP) of the satellite reading started as constant and eventually reduced by almost 50%. This occurrence can improve the accuracy of Absolute Positioning method. Each data for each set were analysed side by side to ensure the continuity of signals between receiver and satellites were always consistent. Thus, resulting an accuracy of ***0.593 m*** accuracy and achieved within 1-meter limit. All of the graphs results obtained were compared side by side to analysed the data's attribute.

5. Conclusion

GNSS Positioning is very versatile and sophisticated. A lot of background knowledge and various skills are required to fully exploit GNSS Positioning capabilities. We should be all very grateful to the people that have developed the fundamentals of Satellite Positioning. One shall be very grateful to the people that have developed the fundamentals of Satellite Positioning and Navigation during the past few centuries up to the organizations that have designed, developed and are more recent maintaining these systems in operation with the participation of emerging computer and communication technologies. As we can see, most of systematic errors are cancelled or reduced with multi-constellation GNSS by using Absolute Positioning(AP). The GNSS-based absolute positioning technologies can provide reliable kinematic position services anywhere and anytime using a single receiver. With single-frequency code measurements and broadcast satellite ephemeris, the Absolute Positioning(AP) can provide near centimeter-level positioning accuracy. In recent years, the satellite systems have been booming. In view that both Absolute Positioning(AP) and Precise Point Positioning(PPP) belong to the satellite-based kinematic absolute positioning technologies, the multi-constellation combination provides new prospects for their performance improvement, due to more visible satellites, increased measurement redundancy, and enhanced satellite sky distribution. The multi-constellation GNSS integrated Absolute Positioning models with GPS, and GLONASS measurements can be developed, respectively. The results indicate significantly improved positioning performance of the multi-GNSS integration, which will further promote the applications of Absolute Positioning(AP) and Precise Point Positioning(PPP) technologies. Hence ease the works for surveying the residential area roads for improvement and extension of routes.

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