Multipath Error Detection Using Different GPS Receiver's Antenna

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SUMMARY

The use of satellite based Global Positioning System (GPS) is normal in engineering and surveying for a wide range of applications as the accuracy capability increases. The GPS satellites transmit signals that are received by the receivers on the earth's surface to determine the position. As long as each satellite's signal travels along a direct path straight to the receiver's antenna, the unit can determine the satellite range quite accurately. However the ground and other objects easily reflect GPS signals, often resulting in one or more secondary paths, which are superimposed on the direct-path signals at the antenna and caused longer propagation time and can significantly distort the signals waveform's amplitude and phase. This paper will discuss the detection of the multipath errors from test carried out using two different types and design of GPS antenna. The existence of the multipath is analyzed.

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1. INTRODUCTION

Global Positioning System (GPS) is a satellite-based navigation system that revolutionizes tasks in navigation and surveying. GPS offers several advantages such as it allows high accuracy in relative positioning, each signal will pass through the clouds, rains and it can be used day and night regardless weather condition and also it can be operate 24 hours daily. GPS also gives coordinate information's in a three dimensional (3D) position at any point.

Every GPS satellite transmits unique navigation signals base on dual-frequency electromagnetic band: L1 is at 1575.42 MHz and L2 is at 1227.60 MHz. The frequency of the signal will reflect to the direction when it hit objects called multipath. Somehow, it still can penetrate the clouds but the signal will hinder when it pass through heavy fog and thick wet leaves. Basically, GPS satellite signals consists (Hoffman-Wellenhof et.al., 1997, Leick, 1995 and Wells et. al., 1987):

- Dual band frequency – L (L1 and L2)
- Modulated frequencies carrier of distance measurement code
- Navigation message

All signal components is produced from atomic clock output in high stabilization. Every satellite is equipped with two cesium atomic clock and two atomic rubidium clock. These clocks will generate the sinus wave at f_o = 10.23 MHz frequency. This frequency is known as basic frequency.

Although GPS has been a great assistant in navigation and surveying, but there is situation where the GPS solution is unreliable and unreachable. The first case happened for bad satellite's geometry and GPS multipath error that introduced multiple signals. The second case happened when the antenna could not receive GPS signals since it affected from high buildings and other objects in urban areas. This paper will describe the GPS multipath error and several GPS observations that have been conducted using two different antennas; one antenna used to overcome the GPS multipath (ground plane antenna) problem and another usual antenna supplied by the manufacturer. Data analysis has been carried out on GPS carrier phase residual (especially L1 double difference residuals) by calculating the statistic value and graphically data comparison.

2. GPS MULTIPATH ERROR

Multipath error happens when part of the transmitted signals from satellite is reflected by the earth surface or any surface that have high power of reflection before the signals reach to the receiver. This scenario also happen when the receiver received more secondary path signal from various directions, which is neither coded translated nor understandable by GPS receiver and resulted from reflection from earth surface or any high objects for instance buildings around the observation station.

Magnitude from the multipaths depends on few factors:

- Position and types of reflected surface that located near the antenna
- The height of antenna from earth surface
- GPS wave distance signals

Base on these factors, it clearly shows that received signals from low altitude satellite have more tendencies to cause multipath error rather than signals from higher altitude satellite. Apart from that, range code is more influenced by this consequences compare to carrier phase. For single reading epoch this error affected up to 10-20m for pseudo range code (Evans, 1986 and Wells et. al, 1987). While for carrier phase, this error affected for shorter base line is around 1 cm (for good satellite's geometry and longer observation period).

Various methods have been conducted to reduce the errors for example by choosing the antenna having signals polarization or by filtering signals and applying ground plane antenna or choke ring. However, the effective method to overcome these errors is by avoiding the areas or surrounding that cause multipath such as buildings and other reflecting surface.

3. DATA COLLECTION

The data collection for this study involving the comparison of the observation results at two different areas; one is located in an open area and the other in an area that has obvious tendencies in causing the multipath errors.

The GPS observation has been conducted at station G11 (an open area) and station G12 (area with obvious multipath) as shown in Figure 1. Station G01 was chosen as reference station since the position is known. For two consecutive days (25th January 2003 and 26th January 2003) the observation has been carried out for 2 hours at about the same period of time in order to obtain the same satellite geometry. Using the same stations, the second phase observation was continued but an additional station (G13) was observed using a normal antenna to evaluate the significant change of the multipath error in two days.

The data have been collected using the receiver of Trimble GPS 4700 with ground plane antenna and Trimble GPS 4800 with normal antenna. There are four GPS receivers used in collecting data simultaneously. The observations are conducted when GDOP (Geometric Dilution of Precision) value is less than 3.0 and 15 minutes time interval for 2 hours observation. The GDOP value indicates the satellite's geometry with the reference of observation location.

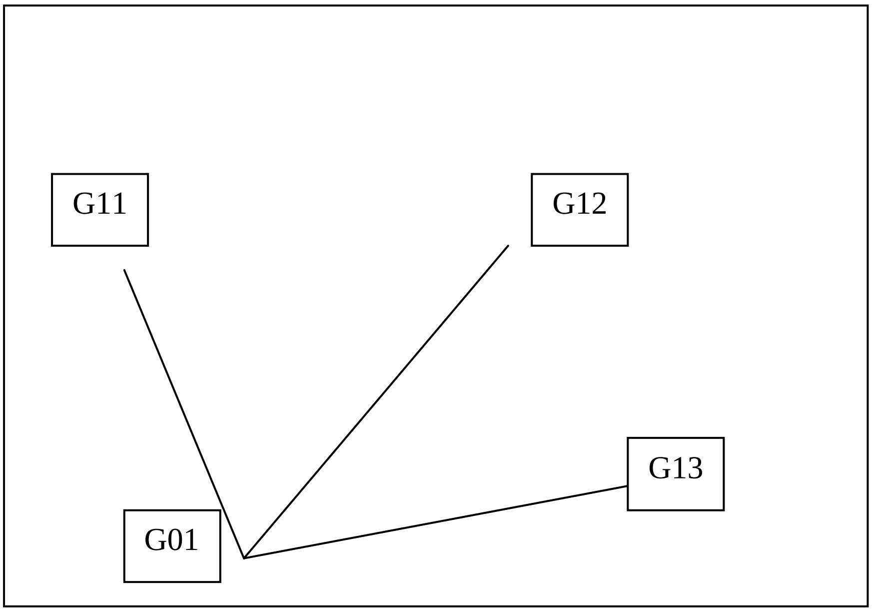

Figure 1. GPS stations position.

Table 1 shows observation session, station location and types of antennas used for phase 1 and 2. Figure 2 shows the two types of antenna used in data collection for this study.

Observation day	**Station Location**	**Antenna**
25 Jan. 2003	G01 (Reference Station)	Ground Plane
	G11	*Ground Plane*
	G12	*Ground Plane*
	G13	Normal
26 Jan. 2003	G01 (Reference station)	Normal
	G11	Normal
	G12	Normal
	G13	Normal

Table 1: Observation session, station location and two types of antenna

a) Ground Plane antenna b) Normal antenna

FIGURE 2: Two types of antenna used.

4. DATA ANALYSIS

All observation have been processed with Trimble Geomatic Office (TGO) software. This software can be used to process baseline and other additional modules such as for network adjustment and coordinate transformation. In this study, the data processing involved computation of observation accuracy and residual.

The data analysis are carried out in three stages:

- To compare the quality of the observation due to different between stations environment

- To identify the residual of every satellite with reference to other existing antenna in ideal area (zero multipath errors) and area with suspected multipath errors.

- Day to day residual analysis for two consecutive days of observation.

4.1 Data Quality Comparison

The analysis is based on the quality of observation from two different receivers. The parameters involved are ratio value, variance reference and root mean square (RMS) error for every observation. The ratio is a relationship between two variances that was generated from the integer in the processing and high ratio shows high difference between two choices. Base line processing is more reliable with high accuracy integer value. Other factors are relevant with ratio such as:

- Higher ratio value is more reliable to every observation.
- Ratio value shows quality point for every quality GPS observation.
- Fixed integer solution produces ratio value.

The baseline processing will only solve for ratio value that is more than 1.5. However, this ratio can possibly vary to higher value or lower value. Reference variance shows how collected data could fulfill the base line requirement. Base line processing will predict the error before continue data processing and comparing the predicted error and actual error obtained during the processing data. The reading from reference variance should be at 1.000 if the error is equivalent.

The quality for base line solution mostly depends on noise measurement and satellite's geometry. RMS uses noise measurement for observation distance satellite to show solution quality. It also depends on satellite's geometry and smaller RMS value.

Table 2 shows the comparison between ratio value, reference variance and RMS obtained from processed data in two days observation. From the table, it clearly shows that by using ground plane antenna (25th January 2003) more reliable results were achieved compared to normal antenna (26th January 2003). For instance, the baseline from G01 to G11 contained ratio value up to 23.335, while on second day observation (26th January 2003) is only at 22.034. For base line processing from G01 to G12, it gives smaller ratio value of 3.656 for the first day and 3.629 on the second day, which resulted from multipath error factor as the G12 station was located near buildings while G11 station located in an open and clear area.

Date	Baseline	Ratio	Reference variance	RMS	Antenna
25/ 01/ 03	G01 to G11	23.335	5.252	0.006	*Ground Plane*
	G01 to G12	3.656	15.552	0.015	*Ground Plane*
26/ 01/ 03	G01 to G11	22.034	5.838	0.008	normal
	G01 to G12	3.629	21.287	0.016	normal

Table 2: Observations quality for phase 1 and phase 2

4.2 Residual Analysis

Apart from ratio factor, reference variance and RMS, the observation quality can be distinguished through residual observation for every involved satellite during data collection. Residual is a difference value between observation quantity and calculated value for the quantity, which is in this case the carrier phase value. Residual values have been analyzed to determine the consequences of multipath error occurred to carrier phase measurement. In this study carrier phase residual have been used. The residual had been plotted verses time for two different areas.

Figure 3 shows observation residual value between the first and second day for SV4 and SV7 satellites at station G11 (no interference). On the other hand, Figure 4 shows comparison between two days observation and at station G12 that is considered to be prone to multipath. As described in Section 2, station surrounding plays an important role to every GPS observation. The figure also shows L1 phase value for observation residual for satellites SV4 and SV24. Standard deviation value for Figure 3 is 0.451 cm, while in Figure 4 the value is 0.933 cm.

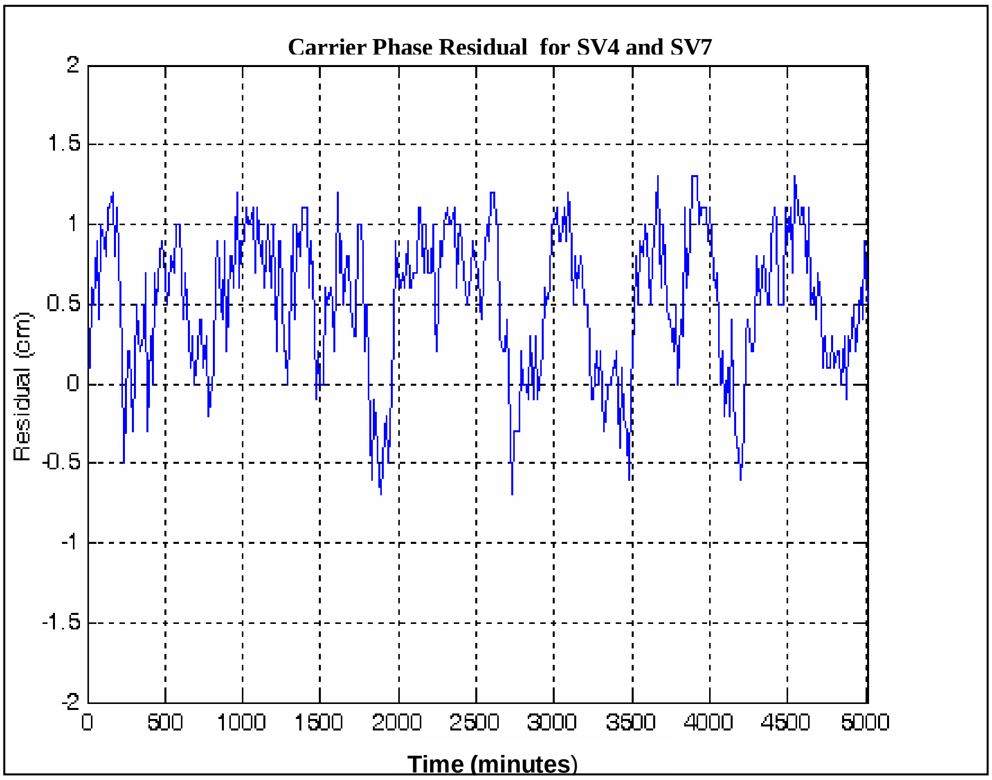

FIGURE 3: Residual for Station G11

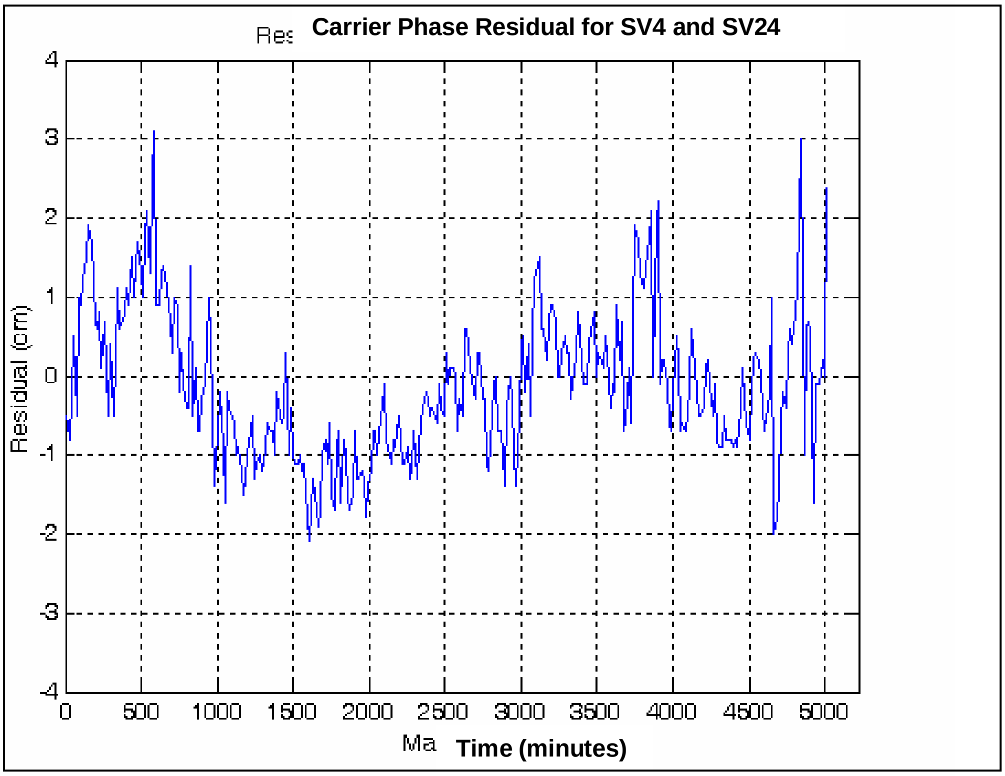

FIGURE 4: Residual for Station G12

Beside these two figures, analysis on observation residual for two days observation at station G13 has been carried out. Figure 5 shows residual for satellite difference of SV4 and SV7. Both observations was conducted on the same day, time and using the same tools. It can be seen that multipath errors occured on the same time for those two days (yellow and black lines coincide each other). Correlation value for both observation set is 0.548. It can be concluded from this graph that day-to-day correlation can be used to remove the multipath errors. Accordingly, multipath characteristic of day-to-day repeatability can be used for applications such as continuous monitoring. By substracting these two conservative days of observation, one can determine for example the true movement of object as the multipath error has been eliminated or reduced.

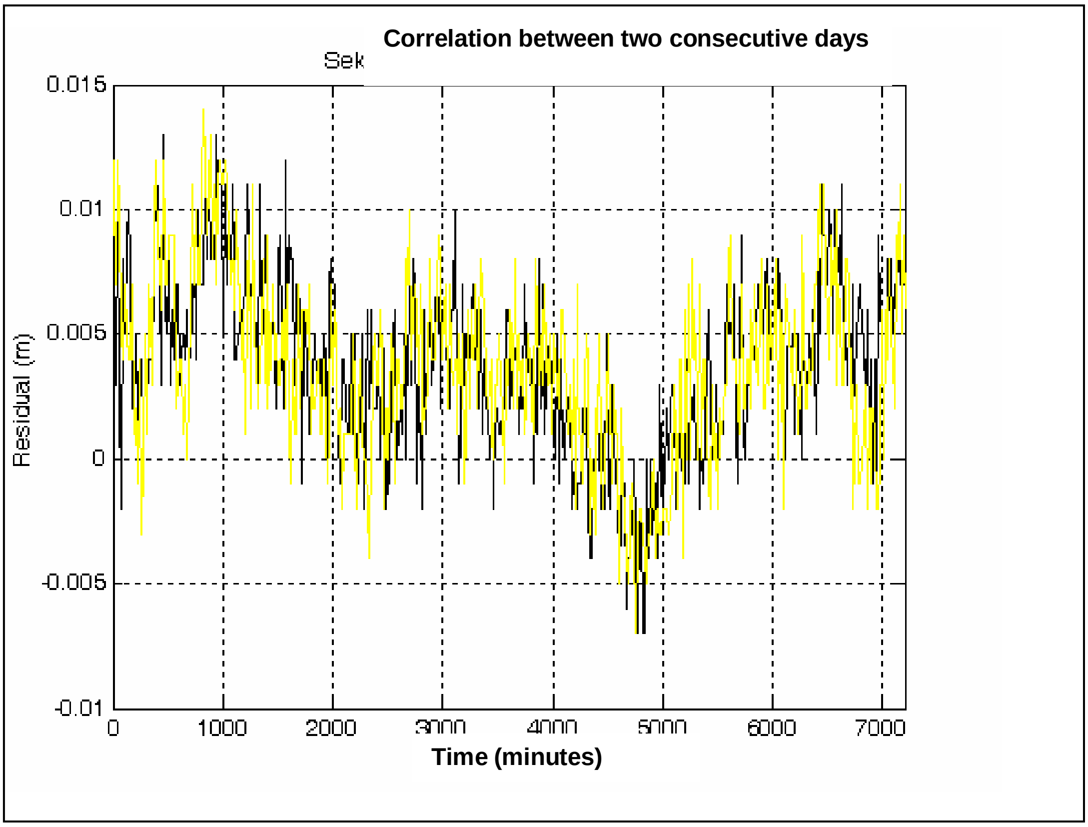

Figure 5: Correlation between two days observation based SV4 and SV7 at Station G13.

5. CONCLUSION

This paper described the multipath error detection using two different GPS receiver's antennas such as the ground plane and normal antenna. From the analysis of the GPS observations, it shows that multipath error exist in the observation. Multipath error can be detected in areas with reflected GPS signals at station G12. Referring to a graphic Figure 4, we can see an error component of 2 cm compared to a graph for station G11. For an open and clear area such as at station G11, the residual value being influenced by other errors such as high noisy frequency. It also shows the ground plane antenna is capable to reduce the multipath errors as shown in Table 2.

As conclusion, a reliable technique for reducing the multipath errors was successfully been done by differencing observation for two days consecutively. Day-to-day correlation is useful for application of GPS in continuous monitoring such as structural monitoring. From GPS continuous observation such as Real Time Kinematics (RTK), the observation output for those two days has to be differentiated between them in order to obtain the actual object position in observed area.

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