Research Journal of Environmental and Earth Sciences 3(1): 32-37, 2011
ISSN: 2041-0492

Received: September 10, 2010 Accepted: October 09, 2010 Published: January 05, 2011

Control Position Fix Using Single Frequency Global Positioning System Receiver Technique - A Case Study

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Abstract: Controls are useful in all survey works and how they are established must be treated with great caution. Recent increase in the use of Global Positioning System (GPS) as a way of fixing positions of survey beacons as compared to the traditional methods brings to mind how certain precautions about GPS must be adhered to so that GPS technique in position fix is used with the least problem. The commonly used GPS receivers in Ghana for most cadastral surveys are the single frequency GPS receiver. This paper investigate the use of Single frequency GPS for position fix by differential GPS technique. Ten controls on the University of Mines and Technology campus were coordinated by Precise Traversing and GPS techniques. Single frequency GPS receivers were employed to obtain the coordinates of the selected beacon at different epochs and orientations of the GPS receivers. The results shows average standard deviations for morning observations for the planimetric coordinates to be 0.007 and 0.0112 m for receivers oriented to the north and not to the north respectively. Afternoon and evening obtained coordinates gave 0.0132 and 0.012 m; and 0.0098 and 0.01136 m average standard deviations for orientations of the receivers to the north and not to the north direction respectively. From the analysis of the results obtained, the morning and evening observations with GPS receiver oriented to the north direction produced better accuracy.

Key words: Controls, cadastral, Global Positioning System (GPS), single frequency

INTRODUCTION

The use of controls for survey works such as Topographic surveys, Land, boundary and cadastral surveys, Hydrographic surveys, Engineering surveys, Mine surveys and other surveys employs all forms of techniques in position fixing which includes Astronomy, Precise Traversing and GPS (Boye and Yakubu, 2010). In recent times, GPS is becoming the order of the day among other techniques in position fixing. The interest in the use of GPS as an efficient and effective way of position fixing has also increased in many professions especially among professionals in the surveying field. Andrew and Alan (2004), at the proceedings of the Institute of Navigation (ION) GNSS Meeting, Long Beach, California. Presented a paper on ‘Evaluation of Precise, Kinematic GPS Point Positioning’ the results indicated a precision at the level of a few centimeters, for static solutions, and below one decimeter, in kinematic mode. These results go to confirm the increasing use of GPS for position fix.

The general acceptance of GPS in position fix is a good idea but is it possible that certain time of observation in a day and orientation of GPS receivers to the approximate north can affect the position fixed by GPS especially the single frequency GPS receivers? Differential GPS surveying is a relative technique with baseline being “observed” and computed from the reference to rover stations. As many baselines will often be measured from the same reference station, the choice and reliability of reference station are of particular importance. Thus, the absolute coordinates of at least one position have to be known accurately. This research therefore, seeks to use GPS for position fix in three dimensions (X, Y, Z) of selected survey beacons taking into account the time of observation and orientation of the receivers.

MATERIALS AND METHODS

Study area: The area of study is the University of Mines and Technology (UMaT) Campus in Tarkwa. Tarkwa is the capital of the Tarkwa Nsuaem Municipal Assembly, a mining community in the Western Region of Ghana. The town is about 85 km from Takoradi, which is the regional capital, 233 km from Kumasi and about 317 km from Accra (Kesse, 1985). The University campus covers an area of approximately 1.39 km^2 of undulating land and pleasant surroundings, about 2 km south of Tarkwa. Established survey controls stations used in the study are shown in Fig. 1. This study was conducted in March, 2010.

Materials: Primary data was collected by field visit using handheld GPS receivers for the reconnaissance surveys

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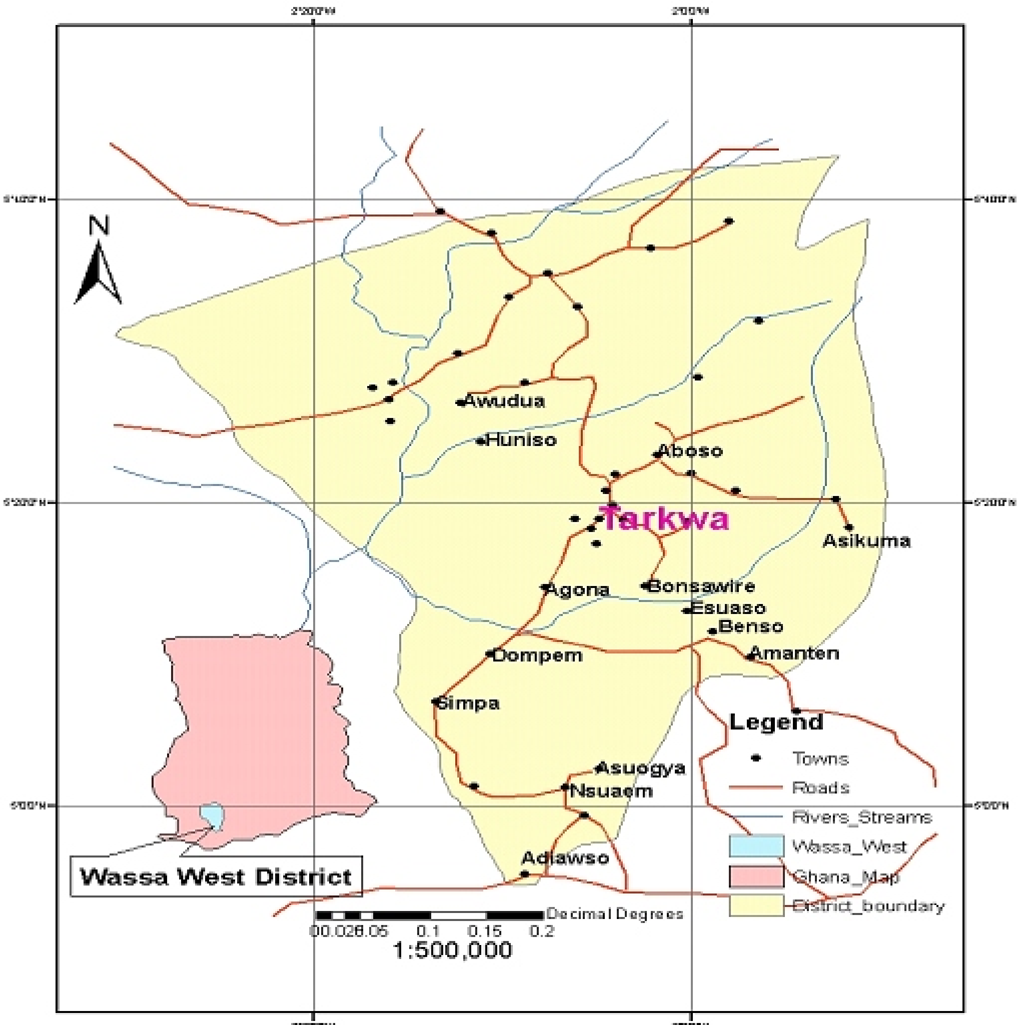

Fig. 1: Map of Wassa West District showing location of Tarkwa (Yakubu *et al*., 2010)

and single frequency GPS receiver for the main surveys. Sokkia Spectrum survey 4.12 software was used for downloading, editing and post processing of the GPS data. Data structures, descriptive and summary statistics for the various stations selected were produced with Microsoft Excel.

Methods: The methods adopted for this research are elaborated as follows:

Planning of GPS surveys: To ensure that results from GPS receivers are reliable and accurate, the need for proper planning cannot be over emphasised. Large projects involving GPS surveys and which require higher accuracies need project planning but for small projects, planning is not much different from what is done in the other surveys. The work undertaken in this research in the preliminary stage was based on the following factors:

- Check selected observation sites
- Overhead obstructions
- Reflecting surfaces that can cause multipath
- Nearby electrical installations that can interfere with the satellite signal
- The expected accuracy of the survey work
- The principles and techniques to be employed
- Satellite configuration and the number and type of receivers to be used
- Observation period
- Determination of the approximate north direction (Anonymous, 2010)

Reconnaissance and building of survey pillars: The most important aspect of any survey work is reconnaissance. It involves procedure that brings to bear the general overview of the working area. Reconnaissance takes into consideration the availability of existing

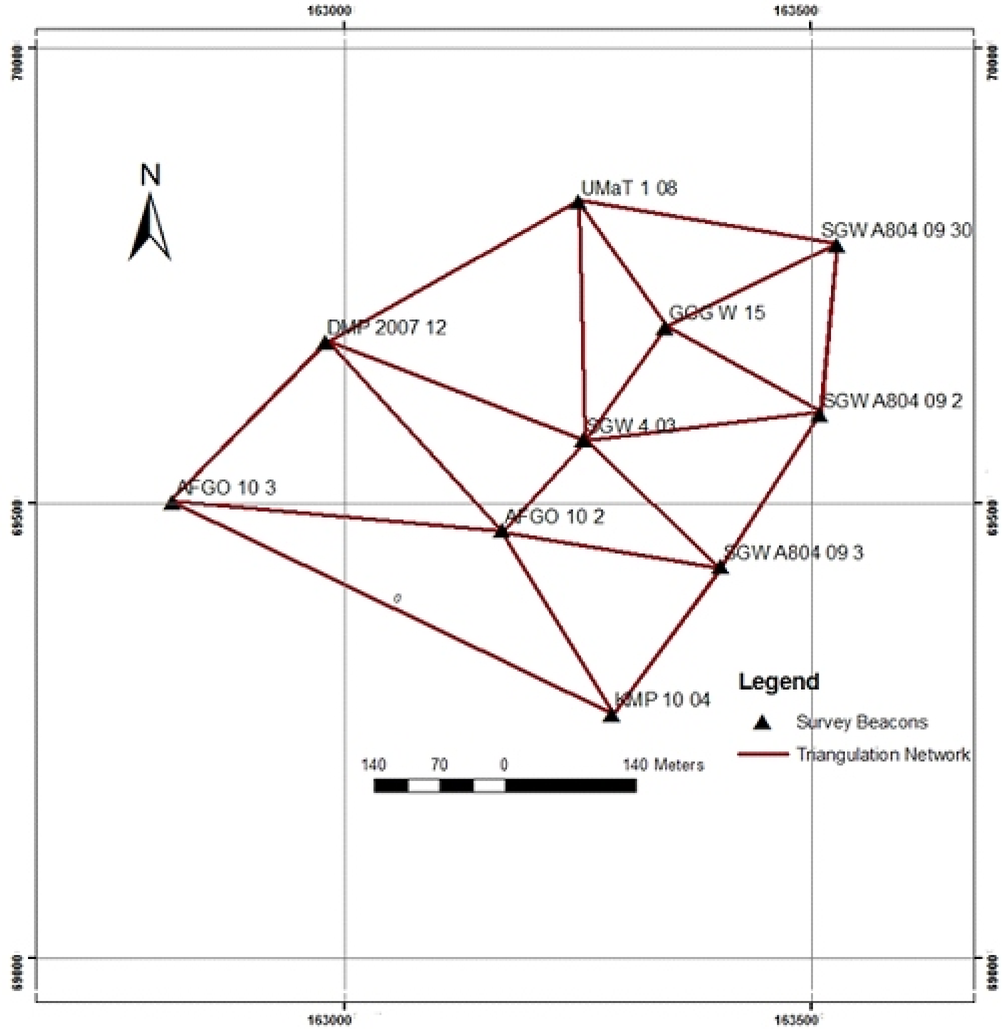

Fig. 2: Triangulation network of survey beacons

controls and also let it be known were to build pillars for the commencement of the surveys. A handheld GPS receiver was used to find the absolute positions of the selected points so that further planning could be done in the office. In this research, type C pillars with dimensions 6×6×18 inches were built in addition to the existing ones. Through this exercise, a network of triangles was formed from the area that the survey is to be carried out. All potential problems to GPS survey work were taken note of Fig. 2 shows network of triangles from reconnaissance survey.

Method of surveying: The Differential GPS technique was adopted. In differential GPS, one or more receiver(s) occupies a base station and the other receivers also known as rovers are set up at stations whose positions are unknown and are to be determined. The method works by carefully centring a receiver on a station of known position for its pseudorange corrections to be determined. Usually, the base station and the rovers are not so farther apart but are considerably close to each other. This makes pseudorange errors at both the base station and at the rovers have approximately the same magnitudes (Anderson and Mikhail, 1998). When corrections for each visible satellite have been computed at the base station, they are applied to the roving receivers which reduce or eliminate many of the errors that come from clock biases, atmospheric refraction and other sources such as ionospheric refraction.

Data collection: Acquisition of data for the research was carried out with great caution. It involved the proper centring of the receivers and accurate measuring of the height of the receivers. This process was done at every station with the appropriate occupational time for observation adhered to for data from satellites to be

Fig. 3: GPS receiver mounted on a pillar for observation

uploaded properly. Figure 3 shows how GPS receiver was used to collect data. During the field observation and for the purpose of this research, observations were made in the morning, afternoon and in the evening. In all these periods of observation, the receivers were oriented to the north and not to the north directions. Observations were done for a period of six days. Data uploaded in the field by the receivers were sent to the office for post-processing.

Office procedure: The procedure that was gone through at the office is called post-processing and it involved:

- Downloading the data from the receivers that were used at the field using the Spectrum Survey Software 4.12 version.
- The base whose position has been previously coordinated was used to process the data.
- Appropriate corrections are done to bring about refinement to the coordinates obtained from the various positions.

Data analysis: The data collected was reduced and statistically analysed using hypothesis test.

Correlation analysis: Correlation is the attempt to measure the strength of such relationships between two variables by means of a single number called sample correlation coefficient(r) (Anonymous, 2005). In probability theory and statistics, correlation coefficient indicates the strength and direction of linear relationship between two random variables (Webster, 1998). In this research, observations for the different epochs and orientations of receivers were the basis upon which relationship was obtained:

$$r = \frac{\sum (x-\bar{x})*(y-\bar{y})}{\sqrt{\sum (x-\bar{x})^2 + (y-\bar{y})^2}}$$

r = Coefficient of correlation

Values of r lie between -1 and +1. When r is equal to +1, it implies a perfect linear relationship with a positive slope while r = -1 implies a perfect linear relationship with a negative slope. Values of r near zero indicate little or no correlation (Al-Hassan, 2008). The calculated r by using data for morning and evening observations gave a value of 0.983683.

Testing of hypothesis: All morning coordinates do not have any correlation with the evening coordinates.
Null hypothesis $H_0: \rho = 0$
Alternative hypothesis $H_1: \rho \neq 0$
From the table, r = 0.983683.
$\alpha = 0.05$ (level of significance)

A t-test for significance of r is given by: $t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}}$

where, n indicates the number of observations:

$$t = \frac{0.983683\sqrt{30-2}}{\sqrt{1-0.983683^2}}$$

$$t = \frac{5.205161174}{0.179910409} = 28.93196232$$

From tables:

$$t_{\alpha/2}(n-2)$$

$$t_{0.05/2}(30-2) = 2.048$$

Decision: Since calculated t is greater than $t_{0.025}$ (28), the hypothesis of no correlation is rejected.

RESULTS AND DISCUSSION

The results obtained were from the precise traversing data which served as the baseline data and the series of data produced by the GPS observations for the different epoch and orientation of the GPS receivers. Differences were obtained from GPS coordinates and coordinates

Table 1: Baseline data collected using precise traversing

ID	N (m)	E (m)	Z (m)
KMP/10/04	69269.180	163286.900	67.674
SGWA408/09 2	69598.371	163508.101	71.541
SGWA408/09 3	69431.390	163403.106	69.114
SGWA408/09 30	69785.581	163527.110	69.472
UMaT 1 08	69832.712	163251.504	74.118
DMP 2007 12	69678.771	162979.402	98.928
AFGO 03	69503.112	162816.902	82.751
AFGO 02	69471.562	163168.602	72.999
SGW0403/303B1	69570.431	163255.802	68.086
GCG W 15	69694.192	163343.901	73.027
DMP 2007 11	69571.50	163346.80	74.788

Table 2: Correlation among the various epoch and orientations of gps data collection

Correlation coefficient (r)	Correlation of morning and afternoon observations. Receiver oriented to north direction			Correlation of morning and afternoon observations. Receiver not oriented to north direction		
	E (m)	N (m)	Z (m)	E (m)	N (m)	Z (m)
r	-0.0749	0.02026	0.32908	-0.2245	0.25842	0.18113
	Correlation of morning and evening observations. Receiver oriented to north direction			Correlation of morning and evening observations. Receiver not oriented to north direction		
r	0.70311	0.73798	0.9983	0.50999	0.54213	0.7516
	Correlation of afternoon and evening observations. Receiver oriented to north direction			Correlation of afternoon and evening observations. Receiver not oriented to north direction		
r	-0.4109	0.37329	0.61534	0.15683	0.35554	0.55964

Table 3 Average standard deviations for the various observations

	Average SD for MORN			Average SD for MONRN			Average SD for AORN		
ID	N (m)	E (m)	Z (m)	N (m)	E (m)	Z (m)	N (m)	E (m)	Z (m)
KMP/10/04	0.00124	0.01242	0.00022	0.00224	0.01988	0.0004	0.00224	0.02485	0.00040
SGWA408/09 2	0.00124	0.01988	0.00025	0.00248	0.02981	0.0003	0.00298	0.03727	0.000450
SGWA408/09 3	0.00199	0.01988	0.000199	0.00224	0.02236	0.000199	0.00298	0.02485	0.000248
SGWA408/09 30	0.00199	0.01491	0.00025	0.00224	0.02236	0.0003	0.00298	0.03478	0.000300
UMaT 1 08	0.00149	0.01988	0.0002	0.00224	0.01988	0.0003	0.00248	0.02485	0.000370
DMP 2007 12	0.00124	0.01988	0.00119	0.00224	0.02236	0.0003	0.00398	0.03478	0.000370
AFGO 03	0.00124	0.01988	0.00199	0.00248	0.02981	0.00373	0.00348	0.03727	0.003530
AFGO 02	0.00149	0.01988	0.0002	0.00199	0.01988	0.00022	0.00248	0.02236	0.000250
SGW0403/303B1	0.00149	0.01988	0.0002	0.00248	0.02981	0.0003	0.00298	0.03478	0.000520
GCG W 15	0.00199	0.012423	0.0003	0.00447	0.037268	0.00035	0.00373	0.037268	0.000370
	Average SD for AONRN			Average SD for EORN			Average SD for EONRN		
ID	N (m)	E (m)	Z (m)	N (m)	E (m)	Z (m)	N (m)	E (m)	Z (m)
KMP/10/04	0.00298	0.02981	0.0005	0.00149	0.01988	0.0003	0.00199	0.02236	0.000400
SGWA408/09 2	0.00373	0.03975	0.00052	0.00199	0.01988	0.0002	0.00248	0.02981	0.000300
SGWA408/09 3	0.00348	0.02981	0.000248	0.00199	0.01988	0.000248	0.01988	0.02485	0.000199
SGWA408/09 30	0.00398	0.03727	0.00037	0.00199	0.01491	0.00025	0.00298	0.02485	0.000300
UMaT 1 08	0.00298	0.03478	0.00037	0.00199	0.01988	0.00022	0.00248	0.02236	0.000220
DMP 2007 12	0.00447	0.03975	0.00045	0.00124	0.01988	0.00306	0.00298	0.02485	0.000250
AFGO 03	0.00373	0.04472	0.00368	0.00199	0.01988	0.00298	0.00298	0.02485	0.00373
AFGO 02	0.00348	0.03727	0.00045	0.00199	0.01988	0.00012	0.00224	0.01988	0.00022
SGW 04/03	0.00298	0.03727	0.0005	0.00199	0.01988	0.0002	0.00348	0.03727	0.00089
GCG W 15	0.00398	0.04472	0.00045	0.00124	0.01242	0.00149	0.00373	0.02485	0.0003

MORN = Morning observations oriented to north direction
MONRN= Morning observations not oriented to north direction
AORN = Afternoon observations oriented to north direction
AONRN = Afternoon observations not oriented to north direction
EORN = Evening observations oriented to north direction
EONRN = Evening observations not oriented to north direction

from precise traversing data which served as the baseline data. These differences were made to observations obtained at particular periods and orientation of the GPS receiver. Table 1 shows the baseline data for the beacons used in this research. Statistical analysis of the data gave standard deviations (Table 3); correlation analysis of observations for the different epochs and orientations of receivers resulted in correlation coefficient (r) to be 0.983683. To further confirm the correlation of both morning and evening observations, a test of hypothesis was conducted on the correlation coefficient. The results established strong correlation between the morning and evening observations (Table 2).

From the results obtained comparison was made with respect to the correlation coefficient value obtained (Table 2). The correlation coefficient values of the morning against the evening observations where the receivers were approximately oriented to the north direction show strong positive relationship, indicating no significant difference between the morning and evening observations using GPS. Critical observations of Table 2 and 3 revealed that there is significant difference of the afternoon from the morning and evening observations. The values obtained therefore buttresses the point that indeed, morning and evening observations are good times for data collection.

CONCLUSION

The application areas using GPS has proven it to be a useful tool for control position fix if the needed precautions are adhered to. The techniques employed in the determination of three dimension coordinates of the beacons yielded acceptable results.

From the analysis carried out, the following results were obtained; the average standard deviations for morning coordinates were 0.007 and 0.0112 m for receiver oriented at north and not north directions respectively. Afternoon and evening coordinates gave 0.0132 and 0.012 m and 0.0098 and 0.01136 m, respectively for the same orientation of receiver. From the results and analysis, it was realised that Morning and Evening observations with GPS receiver oriented to the north direction produced the best result. It can therefore be concluded that for efficient use of the single frequency GPS in position fix, observations has to be made in the morning or evening's with the GPS receiver oriented to the north direction. This will be very important when the receiver has not got inherent automatic orientation to the north direction capabilities.

ACKNOWLEDGMENT

The authors are grateful to Prof. Adetunde, I.A. Dean of Faculty of Engineering, University of Mines and Technology, Tarkwa, for his valuable suggestions and seeing through the publication of the article.

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