EVALUATION OF THE ACCURACY AND PERFORMANCE OF GPS ANTENNAS (ESPECIALLY FOR HEIGHT POSITIONING)

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Key words: GPS antenna performance; height determination, vertical replacement; accuracy

SUMMARY

The antenna type and characteristics are important factors for precise height positioning in GPS. This feature is very important because the antenna has the ability to receive GPS signals. There are various antennas designed for different geodetic applications. This article covers several aspects of the GPS antenna design and performance to consider when using them on the field. Today, GPS heightening is considered as an alternative to conventional terrestrial height surveying methods. The purpose of this study is to evaluate the effects of the GPS antenna to determine the accuracy of the height component in different scenarios designed to perform survey performance. It is also included in this study to investigate GPS heightening accuracy using different antennas by replacing the antenna height.

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1 INTRODUCTION

GPS offers enormous potential for a wide variety of applications in the fields of measurement, mapping, engineering and geographic information. Although many such applications require only a two-dimensional position, the three-dimensional capability of the GPS has created an important opportunity for efficient, high-accuracy height detection, particularly when traditional leveling methods are very time consuming, inefficient and expensive. GPS provides three dimensional positions at no extra cost. However, when compared to horizontal locations only, GPS does not provide the same geometric weakness, but the same height accuracy due to a few observational error sources that primarily affect the height component. However, high accuracy of height measurements can be obtained provided that appropriate calculation strategies are adopted. There are a number of faults that need to be taken into account when using GPS for any purpose, but special attention is given to determining the height with GPS. This is because when the GPS signal starts to pass from a satellite antenna to a receiving antenna, there are several layers (ionosphere, stratosphere and troposphere) with significant signal quality between entering the Earth's atmospheric layers. The nature, magnitude and variability of the troposphere effect and the methods of reducing the effectiveness of GPS location determinations. (Arribas 2013), (Brunner 1993), (Hartinger 2001), (Hoffmann 2000), (Misra 2001), (Van Diggelen 2014), (Schnmitz 2007), (Wolf 2008). This paper investigates the accuracy of GPS heightening by using the different antennas and the main error sources affecting heights in particular.

2 EXPERIMENT AND DATA PROCESS

The experiments were designed to evaluate the achievable accuracy of the GPS heightening. Three special apparatus were prepared for this purpose. The three devices are 20 cm long and marked with every millimeter piece. All GPS measurements was held at a site in Istanbul,Turkey. Figure 1 shows the placement of three exposures at the Samandira site (Project area) in Istanbul. GPS measurements lasted two days (2-3 May 2012). For the static measurements, 1 Thales (Ashtech) Z Max, 2 Ashtech Z Surveyor measuring instruments, 1 Ashtech 701008-01B geodetic antenna, 1 Ashtech Marine 700700-C antenna and 1 Thales (Ashtech) Mac-Trac antenna were used. On May 2, 2012, all of the antennas were centered on three points and the heights of the antennas were measured three times after the 0 cm was set for the three points of the special device, see Figures 2 (a), 3 (a) and 4 (a). On May 3, 2012, all of the antennas were centered on three points, and the heights of the antennas were measured three times after the special device for all three devices was set to 10 cm, see Figures 2 (b), 3 (b) and 4 (b). Coordinates of the three points were determined with 10 s sampling interval in three sessions over 6 hours on different days. The cutting angle of GPS observations was selected at 10 degrees. The RINEX data were processed with Canadian Spatial Reference System-Precise Point Positioning (CSRS-PPP) web-bsed online PPP service (CSRS-PPP 2013).

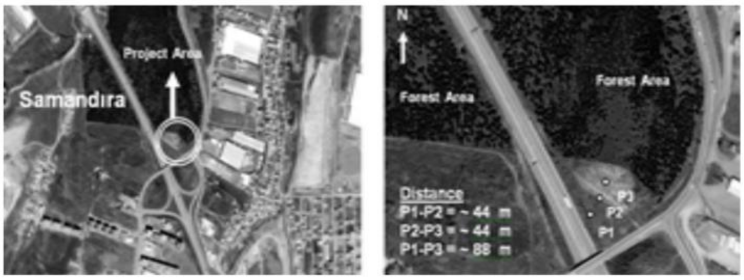
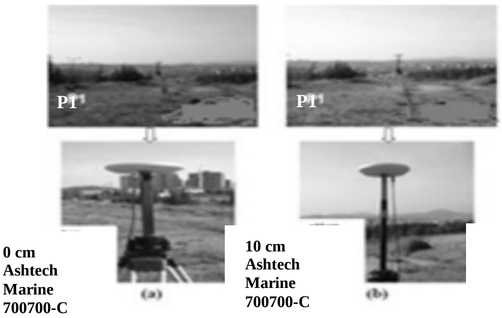


Figure 1. Project area and GPS network



(a) (b)

Figure 2. Point I (P1) and three special apparatuses were set to 0, 10 cm on 2, 3 May 2012

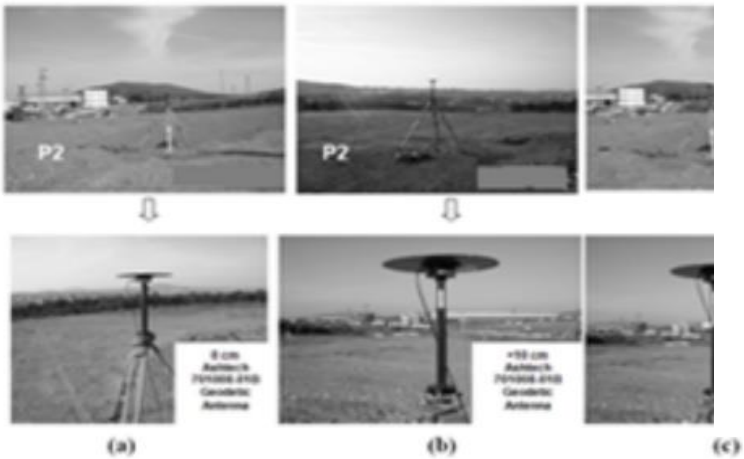


Figure 3. Point II (P2) and the three special apparatus were set 0, 10 cm in 2, 3 May 2012

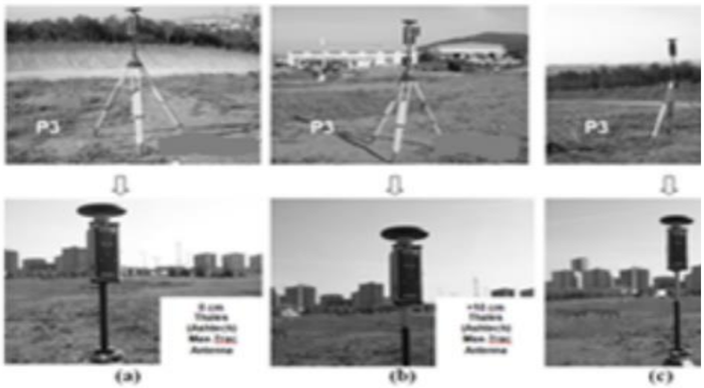


Figure 4. Point III (P3) and the three special apparatus were set 0, 10 cm in 2, 3 May 2012

In addition all geometrical leveling tasks (with Topcon's DL-102 digital leveling) can be performed automatically, accuracy for electronic digital-level reading (standard deviation for 1 km of double grading, 10 mm with Fiberglass staff) to assess the accuracy of the GPS height results. To determine the precise location of a point on the ground, the GPS receiver antenna must be exactly centered on the spot. The height of the GPS antenna must also be measured by the spot. The vertical position of the center is determined by removing the measured height of the antenna from above. When the antenna is perfectly centered on the point and the height of the antenna is measured. Each GPS receiver in the system will have a GPS receiver antenna. For the Ashtech Z-Max system (Max-Trac antenna) used in these experiments, the antenna contains highly sensitive antenna. The Z-Max antenna module, see Figure 4, uses a unique design that allows the signal path to pass directly to the receiver's top. The Max-Trac Antenna Module shown in Figure 4 includes a GPS antenna that enables the Z-Max receiver to monitor signals from GPS satellites. This geodetic quality antenna allows accurate and robust viewing of the horizon satellites and provides a multi-path rejection for the signal reflected from interfaces such as the ground (Thales 2002).

3 RESULTS AND ANALYSES

Coordinates are calculated entirely using the CSRS-PPP web-based online PPP service. The three-point ITRF 2000 coordinates were determined using data from 2-3 May 2012, see Tables 1, 2. Using the CSRS-PPP service to obtain ITRF 2000, the coordinates of the three points have been set in 2-3 May 2012.

Table 1. The coordinates of all three points in 2 May 2012

2 MAY 2012 (0 cm)				
	Antenna Type	**φ_{ITRF} (dms)**	**λ_{ITRF} (dms)**	**h (m)**
P1	Ashtech Marine 700700-C	40° 58' 09''.9930	29° 13' 4''.0112	204.847
P2	Ashtech 701008-01B	40° 58' 11''.2235	29° 13' 4''.9892	204.352
P3	Ashtech Max-Trac	40° 58' 12''.4562	29° 13' 5''.9426	202.980

Table 2. The coordinates of all three points in 3 May 2012

3 MAY 2012 (+10 cm)				
	Antenna Type	**φ_{ITRF} (dms)**	**λ_{ITRF} (dms)**	**h (m)**
P1	Ashtech Marine 700700-C	40° 58' 09''.9924	29° 13' 4''.0112	204.902
P2	Ashtech 701008-01B	40° 58' 11''.2240	29° 13' 4''.9912	204.459
P3	Ashtech Max-Trac	40° 58' 12''.4563	29° 13' 5''.9421	203.088

Table 3. Differences in three-point GPS results in Samandıra region on two different days and results from the levelling questionnaire

2 May 2012 (0 cm)				
Point	**h_{GPS} (m)**	**Δh_{GPS} (m)**	**$\Delta h_{Leveling}$ (m)**	**Difference (cm)**
P1	204.847	Δh_{12} = 0.495	Δh_{12} = 0.551	± 5.6
P2	204.352	Δh_{23}= 1.372	Δh_{23}= 1.361	± 1.1
P3	202.980	Δh_{13}= 1.867	Δh_{13}= 1.882	± 1.5
3 May 2012 (+10 cm)				
Point	**h_{GPS} (m)**	**Δh_{GPS} (m)**	**$\Delta h_{Leveling}$ (m)**	**Difference (cm)**
P1	204.902	Δh_{12} = 0.443	Δh_{12} = 0.551	± 10.8
P2	204.459	Δh_{23}= 1.371	Δh_{23}= 1.361	± 1.0

P3	203.088	Δh_{13}= 1.814	Δh_{13}= 1.882	± 6.8

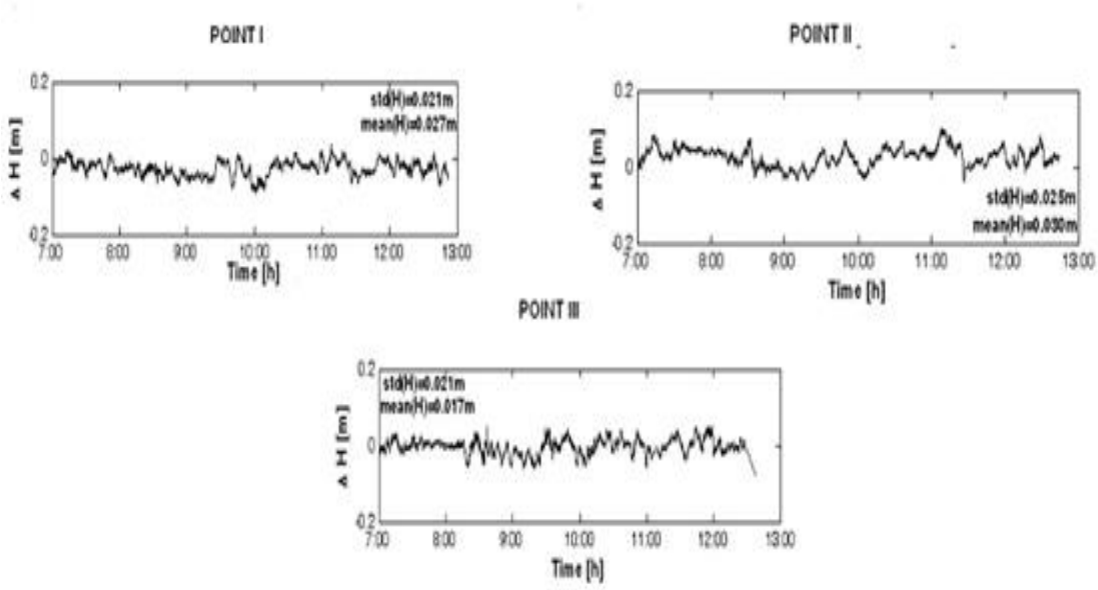


Figure 5. Time series of epoch-to-epoch Height (h) components in 2 May 2012

The digital leveling was used to partially control the height differences to obtain static GPS height results. Height differences were calculated based on the point heights measured using three GPS instruments. Table 3 presents comparison of GPS height measurement results with digital leveling results in Samandıra region, Istanbul.

The horizontal coordinates (North, East) of the test points were determined separately when comparing the GPS results of the three tests. These are very consistent with the tests and the changes range from a few millimeters to 4 cm. This is illustrated in Figures 5 and 6, which gives mean differences for all three points between the coordinates determined from the first and second GPS tests. However, the height component was less consistent and sometimes varied about 5 cm between the three GPS sessions for P1. For the other points (P2 and P3), the height differences were only a few millimeters. This is predominantly attributed to the methodology of the GPS system, which provides more information on the nature and the altitude of the orbits and tropospheric faults.

Figures 5, 6 show the standard deviations of the three tests in the height components. As expected, height accuracy sees Figures 5, 6 when the standard deviation reaches 6 cm for P1 on 3 May 2005.

The three-point ITRF 2000 coordinates obtained on 2-3 May 2012 are very close to each other, except for the height component for P1 on 3 May 2012, see Table 3. The tropospheric peak delay is insignificant for these experiments (because of the short distances between the points) because the baseline between all the points P1P2 = ~ 44 m and P2P3 = ~ 44 m, P1P3 = ~ 88 m. Perhaps the best way to explain these terms is to use different GPS receivers. These receivers are set to collect points over a period of time. After you have collected a lot of positions, if you draw these points, the points will resemble a randomly scattered plot. The variance of these positions may vary widely from receiver to receiver or from antenna to antenna. The plot consisting of the obtained points can be analyzed from many directions using such terms, accuracy and precision. While accuracy refers to the distance measured from a known point to an unknown point, tenderness refers to the reproducibility of a location. It is possible that a GPS receiver or antenna is correct, but the sensitivity is very low. Conversely, if a receiver or an antenna is correct, it may have a very weak sensitivity. Excellent GPS receiver (Z Max) and antennas (Max Trac and Ashtech 701008-01B geodetic antenna) both show good accuracy and precision. That is, the observations taken to calculate a final position are slightly different from each other, and the resulting corrected position is very close to the actual coordinate (Thales 2002).

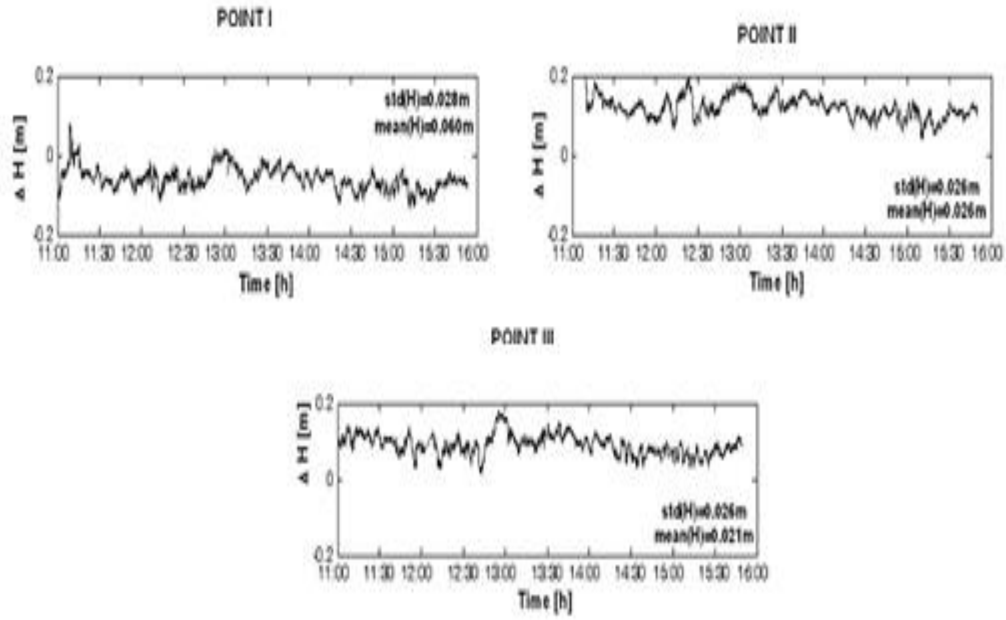


Figure 6 Time series of epoch-to-epoch North, East and Height components in 3 May 2012

4 CONCLUSIONS

Numerous external errors can affect GPS accuracy. Fault sources include excessive multipath, carrier phase shifts, spatial decay over long baselines, insufficient signal strength, and poor field techniques. These factors are part of the GPS positioning. Fortunately, excellent GPS receivers (Ashtech Z Max) and appropriate field training can be removed from most of the mistakes associated with these types of events. It has been shown that the accuracy of determining the accuracy of GPS accuracy is significantly influenced especially in the Ashtech Marine 700700-C antenna when satellite signals are distorted and reflected. Faults can be ± 6 cm in the vertical position average value. These effects were shown to be completely dependent on the performance of the receivers used in GPS antennas and GPS surveys.

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