POLISH ASSOCIATION FOR SPATIAL INFORMATION
ANNALS OF GEOMATICS 2009 ❍ VOLUME VII ❍ NUMBER 2(32)

ANALYSIS OF GNSS RECEIVER ACCURACY IN THE FOREST ENVIRONMENT

DOKŁADNOŚĆ WYZNACZANIA WSPÓŁRZĘDNYCH GEOGRAFICZNYCH W ŚRODOWISKU LEŚNYM ZA POMOCĄ ODBIORNIKA GNSS

Natalia Grala, Michał Brach

Faculty of Forestry, Warsaw University of Life Sciences, Poland

Keywords: GNSS, forestry, surveying
Słowa kluczowe: GNSS, leśnictwo, geodezja

Introduction

The phrase Global Navigation Satellite System (GNSS) is the standard generic term for satellite navigation systems that provide autonomous geo-spatial positioning with global coverage. A GNSS allows small electronic receivers to determine their location (longitude, latitude, and altitude) to within a few centimeters using by measuring the distance to satellites. Receivers on the ground with a fixed position can also be used to calculate the precise time as a reference for scientific experiments. The United States NAVSTAR Global Positioning System (GPS) is the only fully operational GNSS but there is a big chance that other systems will be fully operational soon.

Signals from the GNSS satellites must travel a long distance until they reach the earth's surface. Many factors, such as delays caused by the ionosphere and the troposphere, can cause errors in position calculation. Objects near a receiver antenna, such as trees or buildings, can reflect GNSS signals and result in one or more secondary propagation paths (D'Eon, 1996; Sigrist, 1999). These secondary path signals can interfere with the signal that reaches the receiver directly from the satellite, distorting its amplitude and phase significantly (Zheng et al., 2002).

It is known that forest canopy adversely affects the accuracy of GNSS positioning. Multipath propagation of GNSS signals is one of the main sources of errors in the forest. There have been many attempts to enhance the GNSS positioning accuracy under forest canopy but they still have not fully met requirements of surveyors or researchers who need to obtain accurate coordinates inside a forests (Yoshimura, Hasegawa, 2006). There is some evidence that if we put the receiver antenna higher we can improve measurements quality (Yoshimura, Nose, Sakai, 2005).

The main goal of this experiment was to check at which height the precision of data collection is best in our stand-case. In order to obtain the highest quality the DGPS method was used. A net of reference stations (ASG-EUPOS) gives opportunities to test if the GNSS system is an appropriate tool to obtain accurate positioning in forested area. Such an experiment was conducted for the first time in Poland, in order to attempt to determine the usefulness and accuracy of GNSS receivers in forest environments.

Study area

The research was conducted in April 2009 in the forest district of Głuchów, in Poland. Głuchów is in the centre of the country, close to the city of Łódź. The area belongs to the Forest Experimental Station, managed by Warsaw University of Life Science (WULS). This area has 900 hectares of forests. The research was conducted in coniferous, broadleaved and mixed forests of different ages and height.

Measurements

There were three reference lines located in the forest. The coordinates of each reference line was set by a geodetic survey with line deviation around ±0.20 meter. For each of reference line there were 12 additional points measured, so the total number of points with well known coordinates was 36. The coordinates of these 36 points were taken for this project as a reference for further calculations. The precision of these coordinates may influence to the experimental calculations.

The same points were measured second time, but in different way. During the field work a GNSS (Topcon HiperPro, dual frequency) receiver used, a recorder (FC-200 with TopSurv software) and an aluminium pole (18 meters height). GNSS measurements were carried out for each sample point at heights of 5, 10 and 15 meters using an antenna placed on the leveled aluminum pole (Fig. 2).

Observations were collected a minimum of five times for every height. Measurements were registered in 10 epochs (number of observations) on the L1 and L2 frequency channels. Where the equipment permitted, coordinates were collected in both Fixed and Floating stations. The Fixed station technique uses a network of fixed ground reference (”base”) stations to broadcast the difference between the positions indicated by the satellite systems and the known fixed positions. These stations broadcast the difference between the measured satellite pseudoranges and actual (internally computed) pseudoranges, and receiver stations may correct their pseudoranges by the same amount. The Floating station method is very similar to the fixed RTK method of calculating location, but is not as precise, yielding typically around a 0.20 to 1 meter accuracy range. This decreased accuracy is offset by increased speed, since the time consuming initialization phase is skipped (Leick, 1995). Measurements were corrected in real-time with using the National System of Reference Stations (Polish abbreviation: ASG-EUPOS) that consist of permanent GPS Navstar & GLONASS station data to generate corrections. This network of ground reference stations covers the whole country (Fig. 1).

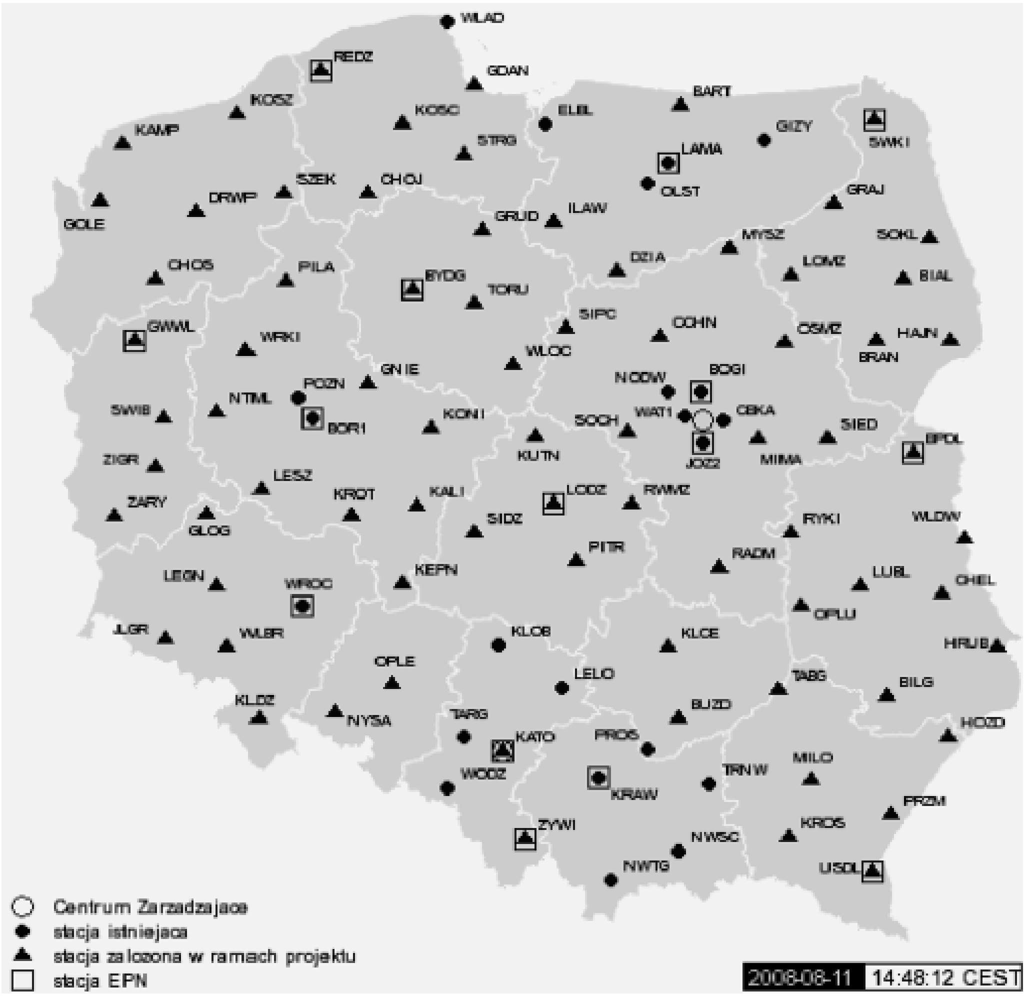

Figure 1. National net of reference stations ASG-EUPOS. Source: www.asgeupos.pl

Results

523 observations were captured using 15 m, 10 m, 5 m antenna heights (Fig. 3). 258 were registered using the Fixed station solution and 265 with the Floating stations (Table 1). Comparisons were made between traditional geodetic measurements and coordinates gathered by a GNSS receiver, the difference between them is termed the D value [m].

Linear misclosures (differences between reference and GNSS coordinates) were calculated based on reference coordinates and GNSS coordinates using the following formula:

$$D = \sqrt{{f_{\Delta X}}^2 + {f_{\Delta Y}}^2}$$

where:
D – linear misclosure
$f_{\Delta x}$; $f_{\Delta y}$ – increment of coordinates misclosures

The results were used as input to further analysis.

The mean differences for all observations were 0.20 m for the Fixed stations and 0.67 m for the Floating stations (Table 2). Mean D values were calculated by summarizing for all Fixed or Floating solutions and dividing by the number of observations. The smallest difference between the coordinates it is the minimum, and the largest is the maximum. There is no significant difference hodbetween the two minimum values by met. For the maximum value the change is greater, a 1.77 meter difference. The Floating method is much more unstable and variable.

When considering the height of the antenna pole and the differences between the coordinates,we found that the smallest mean was occurred at 5 meters height (0.12) and the largest mean deviation was at 15 meters height (0.29) (Fig. 4), where the difference between these two means is 0.17 meter (Table 3).

Using the Fixed method for capturing data gives results that are more precise and stable even if we change the height of the GNSS receiver.

The data are displayed three boxplots (Fig. 5), according to height, which shows the range of the D values. Herr the mean value has the biggest extent for the data recorded at 15 meters height. Boxplots show the trend of the observations. There is a tendency that the values are rather overestimated. The deviation from the mean increases as the antenna height increases, which could be caused by deflection in the mast.

These results confirm the theory that Floating stations cannot yield the same coordinate precision as can Fixed stations; the mean difference values were in excess of 0,5 meter (Table 4.).

In the same way calculations for the different height for the Floating stations were prepared (Fig. 6). The smallest D value was observed at 10 meters receiver height.

The results for the Floating stations are given in boxplots. The big range of D values at 5 meters antenna height could be caused by a multipath effect. However, data collected at 10, 15 meters have a similar range of D values, which are much smaller then at 5 meter height (Fig. 7). Raising the antenna height reduces the variability of the D value.

Conclusions

The ASG-EUPOS network of reference stations allows the capture of data with a precision around ±0.03 meter. This is possible in many conditions, including receiver type, satellite visibility, absence of multipath effect etc. We have shown that Fixed station solutions allow very accurate data capture: the error of 0.29 meter with the antenna placed at 15 meters above ground is caused mainly by mast movement. Stabilization of a mast 15 meters long is a significant problem, especially in forest environment. The experiments proved, however, that precise data capture in the forest is more efficient when using an aluminum mast. By increasing antenna height it was possible to capture more observation in the Fixed station method, which is the best for accurate measurements. Higher antenna location improves coordinates accuracy using Floating stations, which may be explained by easier satellite signal acquisition higher above ground level. There is need to check the kind of factors that have significant impact on the collected data coordinates according to tree height, age and measurement method, which will be carried out in further research.

References

D'Eon S.P., 1996: Forest canopy interference with GPS signals at two antenna heights. *Northern Journal of Applied Forestry* Vol 13 No 2: 89-91.

Leick A., 1995: GPS satellite surveying 2nd edn. New York.

Nć sset E., 1999: Point accuracy of combined pseudorange and carrier phase differential GPS under forest canopy. *Canadian Journal of Forest Research* Vol 29: 547-553.

Sigrist P., 1999: Impact of forest canopy on quality and accuracy of GPS measurements, *International Journal of Remote Sensing*; pp. 3595-3610.

Yoshimura T., Nose M., Sakai T., 2005: High-end GPS vs. low-end GPS: comparing GPS positional accuracy in the forest environment. Kyoto University, Japan.

Yoshimura T., Hasegawa H., 2006: Does a consumer GPS receiver achieve submeter accuracy under forest canopy? Kyoto University, Japan.

Zheng J., Wang Y., Nihan N., 2002: Quantitative Evaluation of GPS Performance under Forest Canopies. Department of Civil and Environmental Engineering, University of Washington.U.S.A.

Streszczenie

Technologia nawigacji satelitarnej podlega procesowi ciągłego rozwoju sprawiając, że uzyskiwane dokładności wyznaczania współrzędnych są coraz większe, przy jednoczesnym zmniejszeniu nakładu pracy ze strony użytkownika. Jest to możliwe dzięki jednoczesnemu wykorzystaniu systemów nawigacyjnych GPS i GLONASS oraz korekcji danych z sieci stacji referencyjnych o zasięgu krajowym (ASG-EUPOS). Mając ponadto na względzie stale malejące ceny odbiorników do nawigacji satelitarnej, prawdziwym staje się stwierdzenie, że wkraczamy w nową erę pomiarów geodezyjnych opartych o technologię GNSS – Global Navigation Satellite System.

Istotnym mankamentem tej technologii jest znaczące obniżenie dokładności pomiarowej uzyskiwanej przez odbiorniki do nawigacji satelitarnej w środowisku terenów leśnych i zadrzewionych. Zjawisko odbicia i wielotorowości sygnału jest problemem, który próbuje się rozwiązać stosując różnego rodzaju metody. W eksperymencie zaproponowano zastosowanie lekkiego aluminiowego masztu do wyniesienia anteny odbiornika na trzy różne wysokości – 5, 10 i 15 metrów, aby poprawić odbiór sygnałów radiowych z satelitów nawigacyjnych. Metoda ta nie była dotąd stosowana w Polsce. Wykonanie w ten sposób wielu pomiarów i porównanie wyników z danymi referencyjnymi posłużyło do przeprowadzenia analizy wpływu wysokości na dokładność pomiaru współrzędnych. Ważnym zagadnieniem stanowiącym przedmiot badań w ramach niniejszego projektu jest sprawdzenie dokładności określania współrzędnych wspomaganych ogólnopolską siecią stacji referencyjnych ASG-EUPOS. Deklarowane przez wykonawcę systemu wartości błędu określania pozycji na poziomie ±0,03 m nie zostały bowiem potwierdzone w środowisku leśnym. Badania wykazały, że sieć referencyjna ASG-EUPOS pozwala na osiągnięcie 0.5 metra dokładności przy wyznaczaniu współrzędnych w środowisku leśnym. Tryb pomiarów jest głównym elementem przyczyniającym się do stopnia dokładności określania współrzędnych. Zwiększenie wysokości anteny odbiornika pozwala na zmniejszenie błędu pomiaru w trybie Float.

dr inż. Michał Brach
michal.brach@wl.sggw.pl
+48 22 593 82 13

inż. Natalia Grala
nataliagrala@o2.pl

Table 1. Summary of collected observations

	Antenna height [m]		
	5	10	15
Fixed solution	61	90	107
Float solution	114	91	60
Total number of observations	175	181	167

Table 2. Mean differences (D) [m] depend on type of solution

	Fixed solution [m]	Float solution [m]
Mean	0.20	0.67
Minimum	0.05	0.04
Maximum	0.55	2.32

Figure 2. Aluminum pole with GNSS receiver

Figure 3. GNSS receiver gather data on 15 meters height

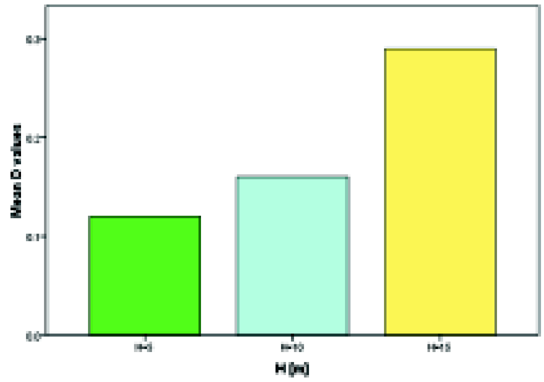

Figure 4. Mean D [m] value depends on height, Fixed solution

Table 3. Mean differences (D) [m] depend on height, in Fixed solution

	Antenna height [m]		
	5	10	15
Mean D	0.12	0.16	0.29
Minimum D	0.05	0.06	0.06
Maximum D	0.22	0.35	0.55

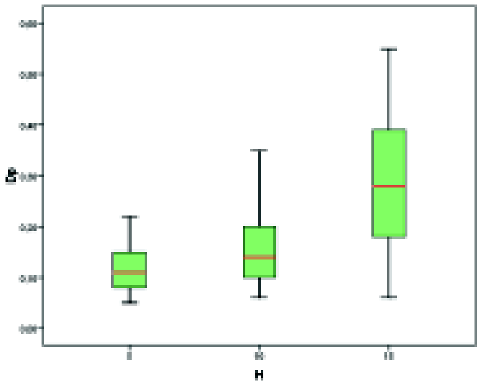

Figure 5. Boxplots. Mean difference between coordinates [m] on 5, 10 and 15 meters with Fixed phase

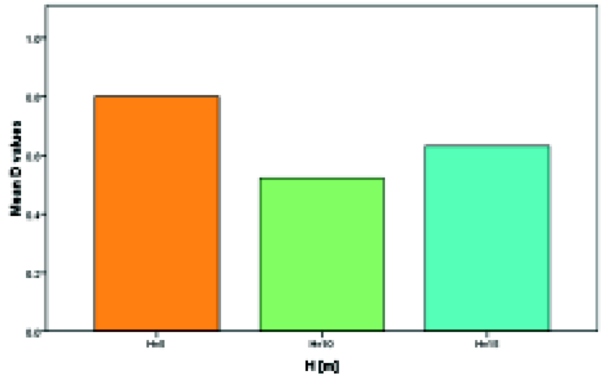

Figure 6. Mean D [m] value depends on height, Float solution

Table 4. Mean differences (D) [m] depend on height, in Float solution

	Antenna height [m]		
	5	10	15
Mean D	0.80	0.52	0.63
Minimum D	0.04	0.07	0.11
Maximum D	2.32	1.25	1.30

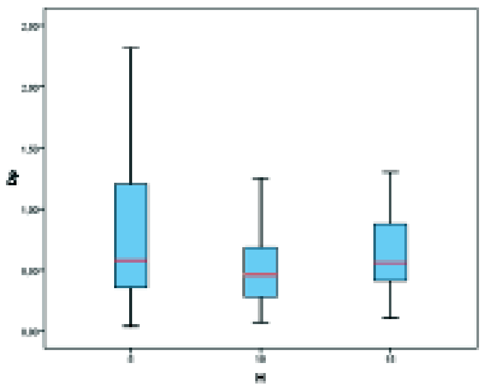

Figure 7. Boxplots. Mean difference between coordinates [m] on 5, 10 and 15 meters with Float phase