EXPERIENCES OF RTK POSITIONING IN HARD OBSERVATIONAL CONDITIONS DURING NYSA KŁODZKA RIVER PROJECT

M. Bakuła, S. Oszczak

University of Warmia and Mazury
Chair of Satellite Geodesy and Navigation
5 Heweliusza St., 10-724 Olsztyn, Poland
Tel.: +48-89-523-4746; Fax.: +48-89-523-4723.

ABSTRACT

The paper presents the application of RTK technology for measuring the horizontal and vertical cross-sections of the Nysa Kłodzka River located in the southern part of Poland. GPS measurements were performed by the staff of Chair of Satellite Geodesy and Navigation of University of Warmia and Mazury in Olsztyn in cooperation with the team of the OPeGieKa Wroclaw company. The measurements had been done for 30 days during August and September 2004. Three GPS receivers were used such as two Ashtech Z-Xtreme and one Ashtech Z-Surveyor. The radiomodems Satelline of SATEL company were used for transmitting RTK corrections from a reference station to rovers. RTK measurements were being performed in very difficult observational conditions like in heavy shrubbery or under trees. It was excellent occasion to test reliability and accuracy of RTK positioning in practice. In general, the use of RTK technology in woodlands and rural terrain extremely improved efficiency of works, but gross errors were being occurred from time to time in very severe conditions of GPS observations due to the lack of good satellite geometry and availability.

1. INTRODUCTION

Nowadays it is well known that RTK (real-time kinematic) mode of GPS positioning can provide a user with centimeter precision and accuracy in open area. It involves a reference station transmitting its raw measurements or observation corrections to a rover receiver via a telemetry link. RTK uses the carrier signal in addition to the code signal. The remote receivers use transmitted RTK data to compute a corrected position. A communication link must exist between the base and remote receivers such as VHF or UHF radio, cellular telephone, communications satellite link or any other medium that can transfer digital data. The data processing at the rover site includes ambiguity resolution of the differenced carrier phase data and coordinate estimation of the rover position. That goal is achieved by phase observation of L1 and L2 frequencies.
In the case where there are no obstacles between satellites and a GPS antenna, the RTK positioning is extremely efficient for surveying applications (e.g. Bakuła et al. 1998) and navigation (e.g. Grzegorzewski at al., 2001: Dąbrowski and Rogowski, 2002), but there are some situations where visibility to the satellites is limited due to buildings, trees and

the like (e.g. Sigrist et. al., 1999; Kryński et al., 2000; Naesset and Jonmeister, 2002; Oszczak and Bakuła, 2002; Yoshimura and Hasegawa, 2003). In that situation a GPS operator might have some problems with ambiguity resolution and its validation.

2. HARDWARE CONFIGURATION

The GPS FieldMate is a real-time GPS system positioning for surveying applications. The system operates in geodetic or local coordinate systems and allows the user perform layout or pickup surveys (Ashtech, 1998). Data can be stored in the handheld and the receiver depending on the operational mode of GPS positioning. The system can operate in RTCM or CPD differential modes. In the real-time modes, the system displays a constant accuracy value and ambiguity resolution results i.e. fixed or float.
The handheld software provides the user with several point logging and offset options and offers several different modes of navigation:
The GPS FieldMate system consists of two main components: the Base and the Rover. The Base system is composed of a GPS base receiver, a radiomodem and a radio antenna; but the Rover system is also composed of a GPS receiver and a radio antenna and additionally a handheld controller e.g. Husky computer (Fig. 1).

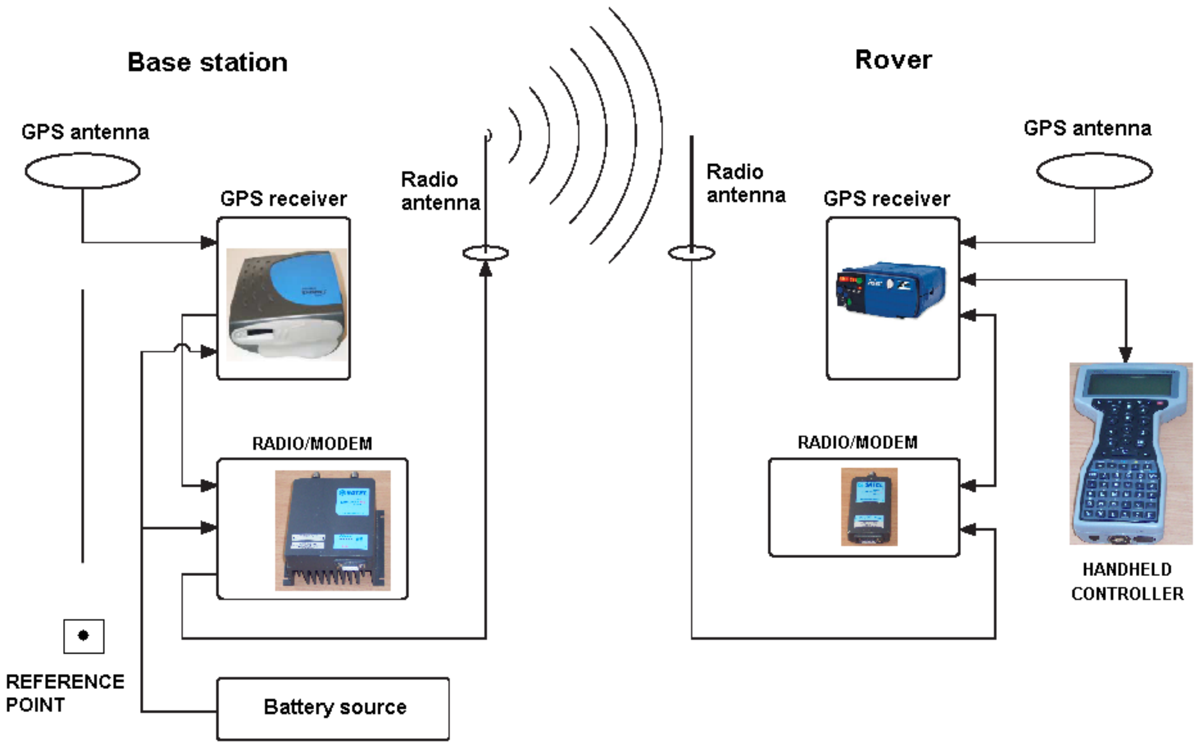

Fig. 1. Base and Rover configuration

The Base GPS antenna is located over a reference point that the coordinates are known and entered into the base receiver. Having calculated correction data, based on reference point coordinates and GPS measurements, the Base GPS receiver sends its to the Base radio via a serial cable. Next the Base radio broadcasts the corrections to Rover receivers. In real-time the Rover radio receives the correction information through the Remote radio antenna and sends the data to the Rover GPS receiver vie a serial cable. The Rover GPS receiver uses measurements from the Base and applies them to derive a corrected position for the Rover GPS antenna.

The position information is transferred to the Husky controller though a serial cable where the GPS FieldMate software converts the position data into local coordinates using transformation parameters. Local coordinates are displayed along with the current positional accuracy. The user can then log points to handheld memory or use the uploaded earlier points to navigate to a specific location.

3. PRACTICAL RTK SURVEYING

At the beginning of the GPS project two GPS receivers of Ashtech Z-Surveyor and one Ashtech Z-Extreme were used. One receiver Ashtech Z-Surveyor was used as a reference station but for remote RTK positioning the Z-Surveyor and Z-Extreme were used. After first day of the project it was clear that the Z-Extreme is much more efficient than the Z-Surveyor. Discrepancies were getting higher in terms of time to fix ambiguity resolution, especially in difficult conditions like under trees or in high bushes located near the river, so we decided to exchange the rover Ashtech Z-Surveyor into another Ashtech Z-Extreme receiver. It was possible due to the fact that two Ashtech Z-Extreme receivers were already purchased by the Chair of satellite Geodesy and Navigation. So then two Ashtech Z-Extreme were used as rover receivers. The Ashtech Z-Xtreme receiver is featured in the Ashtech Instant-RTK technology (Abousalem et al, 2001). The receiver is designed to provide surveyors centimeter-accurate positions in a variety of system configurations based on the superior satellite electronics using patented Z-Tracking™ technology. The base and rover hardware is presented in Figs 2 and 3.

Fig. 2. Temporary RTK base station

Fig. 3. RTK rover equipment

Fig. 4. RTK rover positioning

Fig. 5. RTK rover positioning near the river bank in open area

The Nysa Kłodzka river is located in the southern part of Poland and from time to time makes large damages because of flood. The flood, happening from time to time in the spring, makes heavy damages around the rover changing even lines of river bed and riverside. After that accident a quick surveying is necessary to detect horizontal and vertical changes made by the flood. The surveying around the rover is not easy taking classical methods of surveying into consideration. Around the river there are tall bushes making surveying difficult and time consuming (Fig. 4). To expedite progress of work the OpeGieKa company asked the Chair of Satellite Geodesy and Navigation for cooperation. The Chair of Satellite Geodesy and Navigation have used RTK technology since 1996, in many practical applications also abroad e.g. in the big project in the United Arab of Emirates (Bakula et al., 1998). But this project was a real challenge for the heavy terrain and obstructions like trees hindering surveying, but gave a good occasion to test the newest Ashtech Z-Extreme receiver.

During RTK positioning, experienced surveyors from OpeGieKa company were surprised how efficient RTK technology can be in that conditions comparing to classical methods of surveying. On every day of our job, about 1-3 kilometers progress was made along the river (Fig. 7). The varied terrain, in terms of obstruction and distances between the line of water and the river bank, caused those discrepancies in scope of work.

In open area (Fig. 5), time to fix ambiguity took seconds for the distance 1-2 kilometers from a reference station to the rover. However, in difficult conditions it was varying on the number of good satellites and their configuration, and took minutes. In very hard condition (Fig. 6) the redundant re-initializations were made because the results seemed unreliable. There were also many places where ambiguity resolution failed and no position was determined by RTK technology. The figures 8 and 9 present an example of two-day work.

Fig. 6. RTK rover positioning near the river bank in hard observational conditions

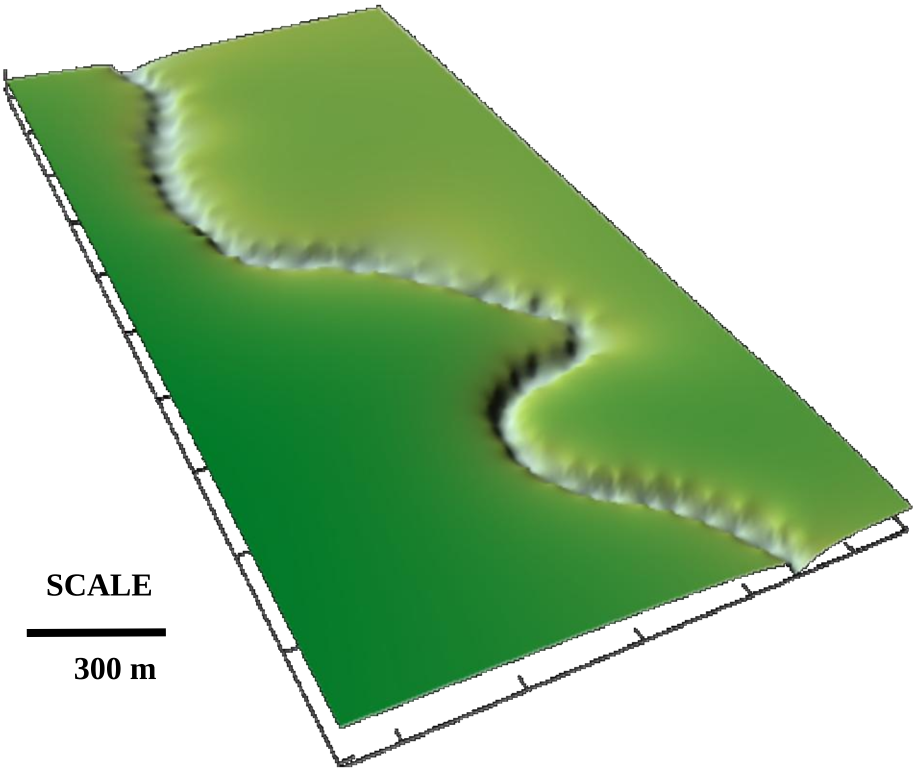

Fig. 7. The result of RTK positioning during two days of work

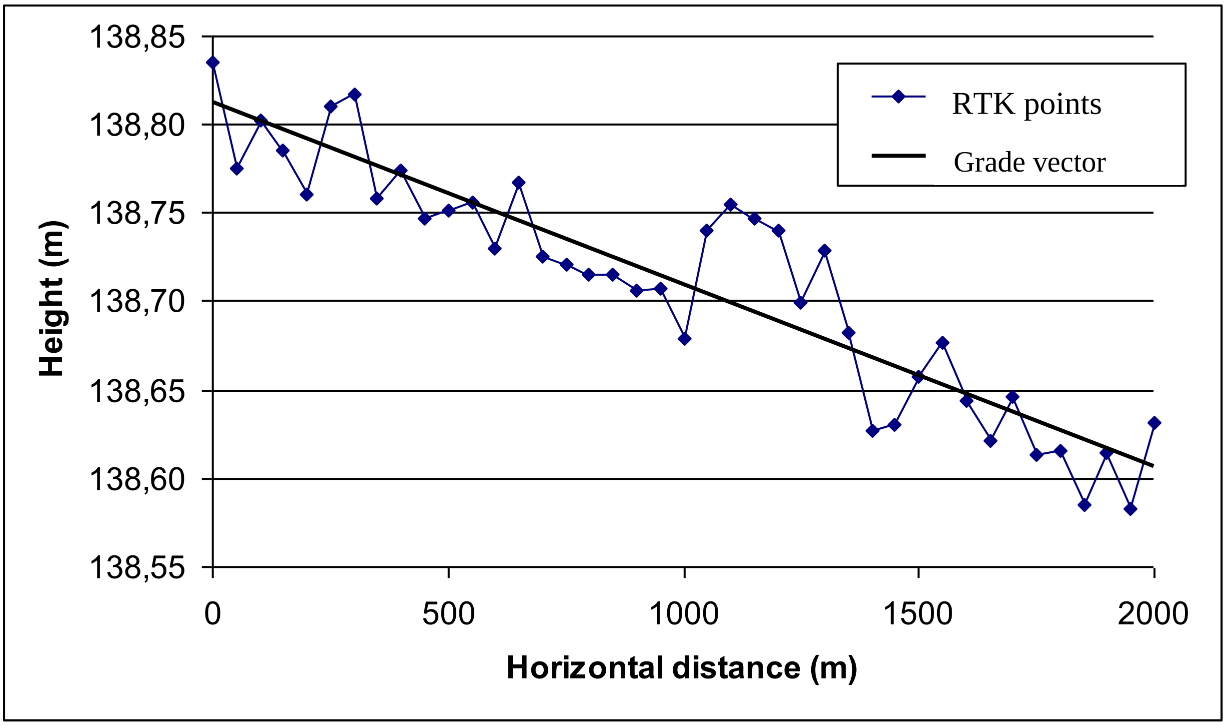

Fig. 8. Slope of water of the river on the distance of 2 km

Analyzing Fig. 8 one can see that RTK positioning is appropriate technology to measure level of water. The grade vector, obtain as a linear trend of heights, shows slope of water. It is clear that setting a pole with GPS antenna over surface is within a few centimeters due to waves. Therefore, heights of RTK points cannot be precisely located in the grade vector of the river. The level of water had one advantage, allowed permanent monitoring validation of RTK positioning by monitoring values of height. If there were differences in heights it was a sign that something was wrong and re-initialization of ambiguity was required. Turning the rover GPS antenna upside down and back, the re-initialization process was carried out. Some internal and external accuracy of those re-initializations is presented in Table 1. The values marked by *dx, dy, dh* presents gross errors of RTK positioning which happened during the surveying, but *mx* and *my* present internal accuracy obtained from the handheld controller.

Table 1. Values of gross errors in RTK positioning happened in hard observational conditions under canopies of trees

Point	North (x)	East (y)	Height (h)	*mx*	*my*		*dx*	*dy*	*dh*
1137	5523096.54	3766008.02	146.81	0.03	0.05		**-3.51**	**-0.01**	**-3.11**
1137	5523093.03	3766008.01	143.70	0.02	0.02		**Correct position**		
2139	5523093.03	3766008.22	143.27	0.03	0.05		**5.31**	**-1.18**	**1.72**
2139	5523098.33	3766007.04	144.98	0.03	0.05		**Correct position**		
2141	5523111.94	3766055.28	147.84	0.03	0.04		**2.28**	**0.59**	**-2.45**
2141	5523109.60	3766055.35	151.45	0.03	0.04		**4.62**	**0.51**	**-6.06**
2141	5523111.25	3766054.43	153.26	0.04	0.04		**2.97**	**1.44**	**-7.87**
2141	5523114.22	3766055.86	145.39	0.04	0.04		**Correct position**		
2133	5523084.89	3765905.09	150.32	0.03	0.07		**-1.43**	**0.30**	**-3.72**
2133	5523083.46	3765905.38	146.60	0.02	0.06		**Correct position**		
2123	5523140.13	3765614.00	149.29	0.03	0.06		**0.55**	**-0.95**	**-2.49**
2123	5523140.68	3765613.05	146.80	0.03	0.06		**Correct position**		
4177	5523509.02	3766844.13	143.05	0.01	0.01		**0.50**	**-1.17**	**3.20**
4177	5523509.52	3766842.97	146.25	0.01	0.01		**Correct position**		
4119	5523162.89	3765528.07	141.34	0.01	0.01		**-1.93**	**1.17**	**5.48**
4119	5523164.49	3765527.38	148.65	0.02	0.02		**-3.53**	**1.87**	**-1.84**
4119	5523160.96	3765529.24	146.81	0.05	0.07		**Correct position**		
4077	5522944.38	3764678.02	-75.27	0.03	0.05		**110.16**	**21.98**	**222.51**
4077	5523054.55	3764700.00	147.24	0.01	0.03		**Correct position**		
4291	5532200.36	3772563.71	139.40	0.05	0.04		**1.61**	**1.42**	**-0.84**
4291	5532200.80	3772566.35	142.79	0.04	0.03		**1.17**	**-1.23**	**-4.23**
4291	5532201.97	3772565.13	138.56	0.05	0.04		**Correct position**		

4. SUMMARY

The use of RTK technology allowed performing surveying much more efficiently. In the situation where about 2-3 meters long bushes occurred, classical methods of surveying were not possible for lack of visibility between a tachymeter station and a prism. Additional works like cutting bushes out should be done in order to conduct classical surveying.

The influence of trees located near the GPS antenna had strong influence on ambiguity resolution taking time to fix ambiguity resolution and its reliability into consideration. This problem is known and has been investigated by many researchers and still more research is required in terms of ambiguity validation procedures. From a practical point of view, an operator of RTK positioning should be very careful during RTK positioning near the trees and additional re-initialization of ambiguity should be carried out as

redundant observables. In the surveying project, re-initializations were carried on in the case where the rover GPS receiver had problems with ambiguity resolution, especially under big trees with broad canopy of large leaves.

REFERENCES

Abousalem M., Han S., Qin X., Martin W., Lemoine R. (2001): *Ashtech Instant-RTK: A Revolutionary Solution for Surveying Professionals,* Presented at The 3th International Symposium on Mobile Mapping Technology, Cairo, Egipt, January 3-5, http://products.thalesnavigation.com/assets/techpapers/19_AshtechInstant-RTK.pdf

Ashtech (1998): *GPS Fieldmate,* Operation and Reference Manual, USA.

Ashtech (1998): *Ashtech Z-Surveyor & Z-FX,* Operation and Reference Manual, Magellan Corporation, USA.

Ashtech (1998): *Ashtech Z-family, Technical Reference Manual,* Magellan Corporation, USA.

Bakuła M., Kapcia J., Oszczak S. (1998): *Tyczenie tras ropociągów metodą RTK na polach naftowych pustyni Asab w Zjednoczonych Emiratach Arabskich,* Konferencja techniczna "Wiosna w geodezji", Poznań.

Dąbrowski T., Rogowski J. B. (2002): *Application of RTK System to Investigate Ship's Maneuverability,* REPORTS ON GEODESY, No. 3 (63), pp 45-52.

Grzegorzewski M., Oszczak S., Ciećko A., Bakuła M., Walawski M., Popielarczyk D. (2001): *Accuracy of Aircraft Trajectory determination During En-route, Approaching and Landing Phase with GPS Technique,* Proceedings of The V GNSS International Symposium (GNSS'2001) Satellite Navigation Objectives and Strategies, 8-11 May Seville – Spain.

Hasegawa H., Yoshimura T. (2003): *Application of dual-frequecy GPS receiver for static surveying undet tree canopy.* Journal of Forest Research, Springer-Verlag, Tokyo Inc, t. 8, pp. 103-110.

Kryński J., Cisiak J., Mańk M. (2001): *RTK w terenie zurbanizowanym. Przykład Warszawy,* Konferencja nt.: Satelitarne metody wyznaczania pozycji we współczesnej geodezji i nawigacji, Dęblin 22-23.05.2001, Zeszyty Naukowe WSOSP w Dęblinie, Dodatek: do nr 2/2001, s 63-78.

Naesset E., (2001): *Effects of differential single- and dual-frequency GPS and GLONASS observatons on point accuracy under forest canopies.* Photogrammetryic Enginieering And Remote Sensing t. 67, pp. 1021-1026

Oszczak S., Bakuła M. (2002): *Pomiar osnów leśnych za pomocą techniki GPS*. Systemy Informacji Przestrzennej XII Konferencja Naukowo-Techniczna, Warszawa.

Sigrist P., Coopin P., Hermy M. (1999): *Impact of forest canopy on quality and accuracy of GPS.* International Journal of Remote Sensing, Taylor and Francis Ltd, t. 20(18), pp. 3595-3610.