TECHNICAL SCIENCES
Abbrev.: Techn. Sc., No 11, Y 2008

DOI 10.2478/v10022-008-0026-8

INITIAL RESULTS OF RTK/OTF POSITIONING USING THE NTRIP DATA TELETRANSMISSION TECHNOLOGY

Mieczysław Bakuła, Renata Pelc-Mieczkowska, Barbara Chodnicka, Małgorzata Rogala, Arkadiusz Tyszko

Chair of Satellite Geodesy and Navigation
University of Warmia and Mazury in Olsztyn

K e y w o r d s: NTRIP, GPS, RTK, OTF, GPRS.

A b s t r a c t

The paper presents the initial results of RTK/OTF satellite measurements made using NTRIP Internet data transmission. Two permanent reference stations belonging to the University of Warmia and Mazury in Olsztyn were used for test measurements. As a result of measurements taken at three measurement points situated 1,5 to 20 kilometers from the reference stations the accuracies of up to a few centimeters were obtained for points situated in the open terrain. The accuracies obtained at the point with numerous covers in the form of tree branches ranged from several centimeters to almost 3 meters, which is characteristic for GPS measurements taken under conditions of limited availability of satellites.

WSTĘPNE WYNIKI POZYCJONOWANIA RTK/OTF Z WYKORZYSTANIEM TECHNOLOGII TELETRANSMISJI DANYCH NTRIP

Mieczysław Bakuła, Renata Pelc-Mieczkowska, Barbara Chodnicka, Małgorzata Rogala, Arkadiusz Tyszko

Katedra Geodezji Satelitarnej i Nawigacji
Uniwersytet Warmińsko-Mazurski w Olsztynie

S ł o w a k l u c z o w e: NTRIP, GPS, RTK, OTF, GPRS.

A b s t r a k t

W artykule przedstawiono wstępne wyniki pomiarów satelitarnych RTK/OTF wykonanych z wykorzystaniem internetowego przesyłania danych NTRIP. Do pomiarów testowych wykorzystano dwie permanentne stacje referencyjne należące do Uniwersytetu Warmińsko-Mazurskiego w Olsztynie. W wyniku pomiarów przeprowadzonych na trzech punktach pomiarowych, oddalonych od 1,5 do 20 kilometrów od stacji referencyjnych, uzyskano kilkucentymetrowe dokładności dla punktów zlokalizowanych na otwartym terenie. Dokładności uzyskane na punkcie, nad którym znajdowały się liczne zasłony w postaci gałęzi drzew, wahały się od kilkunastu centymetrów do prawie 3 metrów, co jest charakterystyczne dla pomiarów GPS wykonywanych w warunkach ograniczonej dostępności satelitów.

Introduction

Currently the satellite positioning method RTK/OTF (Real Time Kinematic/ On The Fly) is the technologically most advanced kinematic method for determining coordinates of points in real time. That method allows obtaining precise coordinates in real time thanks to which it finds wide application in numerous areas, including: land, water and air navigation, hydrography, road safety and first of all land survey measurements (e.g. BAKUŁA et al. 1998, CIEĆKO et al. 2006, GRZEGORZEWSKI et al. 2001, POPIELARCZYK et al. 2006).

GPS RTK measurement method is based on determining the coordinates of a mobile receiver (or a number of mobile receivers) in relation to the reference station transmitting continuously corrections/satellite observations. The set for GPS RTK measurements consists of a reference station and mobile receiver. The reference station is a land survey GPS receiver with the antenna centered on a point with known coordinates and a device for transmission of corrections. The mobile station on the other hand consists of land survey receiver with a GPS antenna, device for reception of data from the reference station and handheld computer in which the results of GPS/RTK measurement are recorded (*Ashtech Z-family...* 1998, *GPS Fieldmate...* 1998). Traditionally in RTK/OTF measurements local reference stations fixed for the time of measurement on the reference point and using radio-modem for GPS data transmission are used. That model requires the use of at least two satellite receivers and the distance between the mobile receiver and the reference station is limited by the radio-modem range, which is important particularly in case of dense buildings or measurements taken in forest conditions (BAKUŁA et al. 2006).

Currently, the network of permanent reference stations assuring continuous access to observations from reference stations with high accuracy is developing dynamically worldwide thanks to which performance of GPS RTK measurements using only one GPS receiver is becoming possible.

In Poland, the Main Office of Geodesy and Cartography is implementing a multifunction system of precise satellite positioning ASG-EUPOS that will encompass GNSS reference stations evenly spread (at the distance of ca. 70 km) over Poland and the neighboring countries (PODLASEK 2007). Corrections from the reference stations will be transmitted using the INTERNET/GPRS technology (OSZCZAK et al. 2004), which currently is the most advanced method of GPS data teletransmission. The NTRIP system is one of the solutions allowing long distance transmission of the corrections. Under the name of NTRIP (Networked Transport of RTCM via Internet Protocol) the protocol of making available and transmitting the DGNSS (Differential GNSS) corrections allowing increasing of positioning accuracy in real time has been made available (PETERZON, 2004, LENZ, *Networked Transport of RTCM*...). Scientists from the Federal Agency for Cartography and Geodesy (BKG) and, as partners, employees from the University of Dortmund and specialists of Trimble Terrasat GmbH worked on creating and development of that new technique. NTRIP is based on stateless protocol of documents transmission HTTP 1.1 (Hypertext Transfer Protocol). NTRIP consists of the following components (Fig. 1):

– NTRIP Source, station or stations generating streams of GNSS data. Sources have their allocated (by administrator) unique names (mountpoint)

– NTRIP Server, software based in a PC, transmitting data from the NTRIP Source do NTRIP Caster. The password and the above mentioned name are allocated by the administrator

– NTRIP Caster, HTTP server – the main system component. Its task is to receive, copy and split the data (HTTP Splitter Server), allowing simultaneous access to data from one source to multiple users

– NTRIP Client, the user who may select a NTRIP Source/mountpoint from the list of currently available ones. The Client may transmit the data received to a GNSS receiver, record the data on the hard drive or transmit data to another IP address.

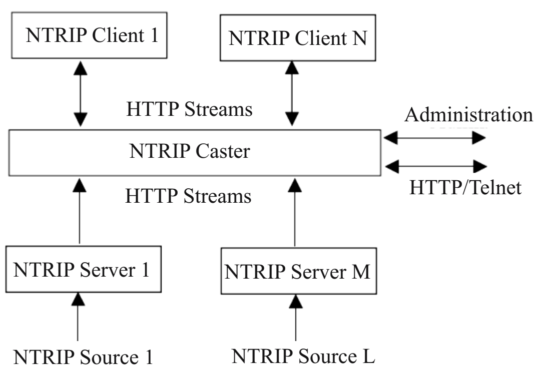

Fig. 1. Diagram of data distribution system operation using the NTRIP protocol (source BKG – Bundesamt fur Kartographie und Geodasie)

NTRIP protocol offers the possibility of making GNSS data available in two ways. The first way is transfer of data from a single reference station while the second one allows transmission of a stream of information from the reference stations (Fig. 2).

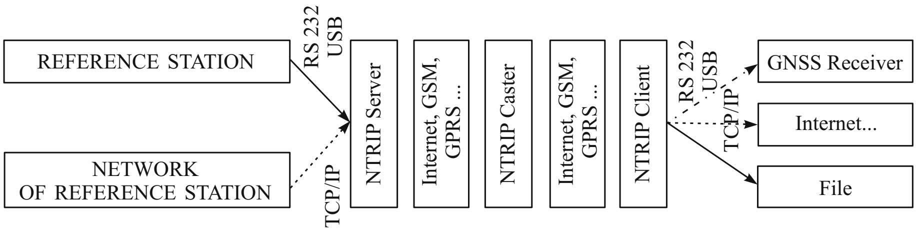

Fig. 2. Diagram of GNSS data presentation and transfer in NTRIP system

The paper presents the initial results of RTK measurements during which RTK corrections from reference stations were transmitted using the NTRIP technology.

Methodology of studies

Positioning of measurement points and reference stations

Three triangulation points (0474, 0409, 0016) situated in Olsztyn and vicinity and two reference stations: LAM6 belonging to the ASG-PL network, situated in Lamkówko at the geodesic satellite observatory of the University

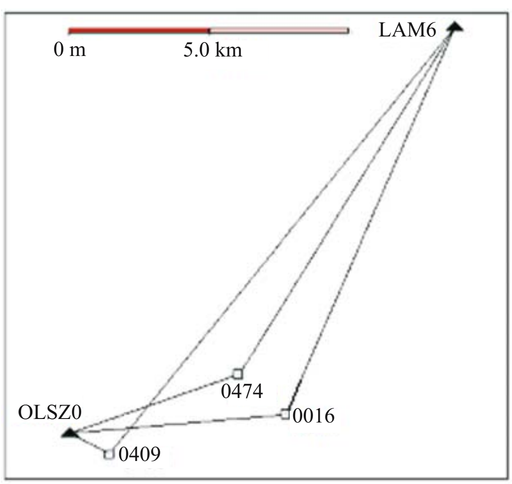

Fig. 3. Diagram of measurement points and reference station positions

of Warmia and Mazury in Olsztyn and OLSZ0, situated in the building of the Faculty of Geodesy and Land Management of the University of Warmia and Mazury in Olsztyn were selected for test measurements (Fig. 3).

Reference station OLSZ0 was included in the NTRIP system in September 2009. As of that moment satellite observations are both transmitted by NTRIP Server (Fig. 4) to NTRIP Caster and recorded on PC hard drive. Synchronized data with one-second interval are made available on current bases on a specially configured FTP server. In that reference station an Ashtech Z-XII receiver is working (Fig. 5). The GPS antenna is fixed on the roof

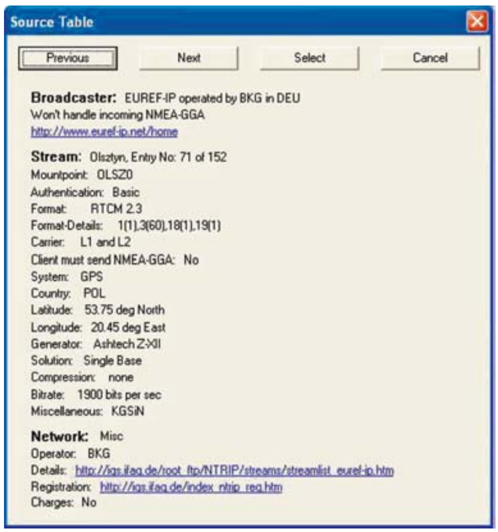

Fig. 4. NTRIP Server – information on OLSZ0 station

Fig. 5. Reference station OLSZ0

of a three-stores building. Differential adjustment data is transmitted using the RTCM-104 standard. The receiver was configured to transmit three types of messages. The first one is DGPS differential corrections broadcast at one-second interval. The second type of messages containing reference station coordinates is transmitted at one-minute interval. Carrier phase measurements and pseudorange measurements are broadcast once per second. The minimum topocentric height is set at 5 degrees.

LAM6 station is equipped with a ROGUE SNR-8000 receiver with an AOAD/M-T antenna. Adjustments from both stations can be transmitted via a radio-modem in GPRS technology and in NTRIP protocol while raw data is made available for post-processing.

Measurement points 0474 and 0016 were located in open terrain while point 0409 was overhang by terrain obstacles in the form of branches of deciduous trees (Fig. 6), which caused significant deterioration of measurement results in that point Measurement of the covered point allowed analysis of the cover influence on RTK measurements accuracy. All measurement points were permanently fixed with concrete blocks with a cross clearly marked at their upper face.

Fig. 6. Test points 0474, 0409, 0016

Distances of individual measurement points to the reference station OLSZ0 were a few kilometers (1,5 km, 6,4 km and 7,8 km respectively for points 0409, 0474 and 0016), while the distance to the LAM6 station several kilometers (19,6 km, 14,6 km and 15,1 km respectively for points 0409, 0474 and 0016).

Hardware and software

The mobile set used during the studies consisted of a land survey receiver Ashtech Z-Surveyor, GPS antenna by Ashtech mounted on two-meter pole, HUSKY controller and mobile telephone Motorola V547 with mobileNTRIP v 1.0 software allowing reception of RTK corrections in NTRIP protocol (Fig. 7). The controller was configured so that the measurement results were recorded in the flat national system of coordinates “2000”, and height of points in the system of ellipsoid heights. Position recording interval was set at the level of 5 seconds but the actual interval ranged from 5 seconds to around 1 minute. That situation was caused by momentary loss of connection with the reference station and loss of ambiguity determination.

Fig. 7. Measurement set

RTK terrain measurements vs. post-processing

Test measurements were taken on 14-15 May 2007. The division into measurement sessions is presented in Table 1. Measurement time for individual points a panned so that the number of available satellites and their geometric distribution should guaranty achievement of high measurement accuracy and similar during all measurement sessions. The following GPS parameters were assumed for all measurement sessions: minimum height of satellites above the horizon 15^{o}, measurement interval 1 s, and the assumed recording interval for RTK position was 5 s, the minimum number of satellites 5 and the value of PDOP < 6.

As a result of measurements in consecutive sessions 26, 8, 29, 52, 52, 51, 52 positions were obtained respectively for which the ambiguity was solved. The results of measurements were recorded in a HUSKY controller in the text file containing such information as: consecutive position number, flat coordinates x,y for consecutive points in “2000” system, ellipsoid height and accuracy analysis.

Table 1

Schedule of division into measurement sessions

Session number	Measurement point number	Reference station	Date	Measurement performance time in UTC
1	409	OLSZ0	14.05.2007	11:08 – 11:23
2		LAM6		12:00 – 12:02
3		OLSZ0		12:46 – 13:02
4	474	LAM6	15.05.2007	8:20 – 9:00
5		OLSZ0		9:03 – 9:44
6	16	OLSZ0	15.05.2007	10:27 – 10:40
7		LAM6		10:48 – 11:28

On the basis of raw data from mobile receiver and data obtained from reference stations the coordinates of points 0409, 0474, 0016 were computed in post-processing. Data from station OLSZ0 had one-second interval while the interval of data from station LAM6 was 5 seconds. Ashtech Office Suit for Survey v 2.0. (*Ashtech Office Suit*... 1998) was used for computations. Coordinates of measurement points were computed by means of RTK/OTF kinematic post-processing method.

As a result of post-processing the total of 5958 positions were obtained including 4725 positions for which ambiguity was solved. During sessions 1-7 84, 0, 344, 475, 2500, 842, and 480 fixed type positions were obtained respectively. During the second measurement session no solution was obtained and because of that and because of a very low number of RTK positions computed the second session was excluded from further works.

Next, the coordinates computed were transformed into the flat system x,y "2000" using TRANSPOL software (Technical guidelines G-1.10... 2001). In that software the distance of geoid from the ellipsoid needed for reduction of ellipsoid heights to normal heights was also computed.

Analysis of results

Flat coordinates of measurement points obtained as a result of RTK/OTF measurements and post-processing were compared with the known coordinates of those points (in the system "2000"), that were considered the true ones (Fig. 8). On the basis of that comparison the accuracy of determination of coordinates for individual points during individual measurement sessions was made.

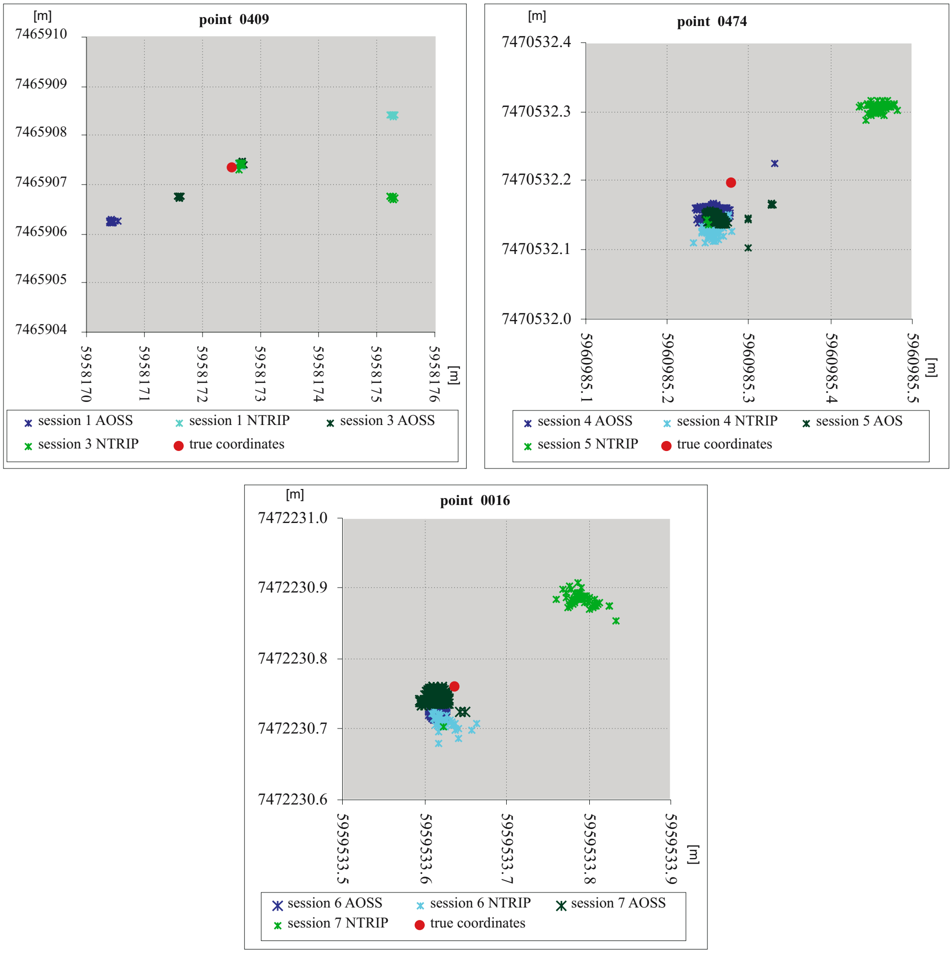

Fig. 8. Flat distribution of obtained coordinates in “2000” system

Accuracy of determination of point 0409 flat coordinates over which there were numerous obstrucles in form of branches of deciduous trees ranged for RTK/OTF method from a few centimeters to almost 3 meters. In post-processing accuracy of from fifteen centimeters to almost 2,5 m was obtained (Fig. 9). Analyzing individual measurement sessions for point 0409 for both RTK method and post-processing groups of consecutive determinations of the position can be identified characterized by a relatively high precision. For RTK measurements in session 1 (reference station OLSZ0) from the beginning of the session up to determination number twenty the determination accuracy was several centimeters and next it deteriorated rapidly to 3 meters and stayed

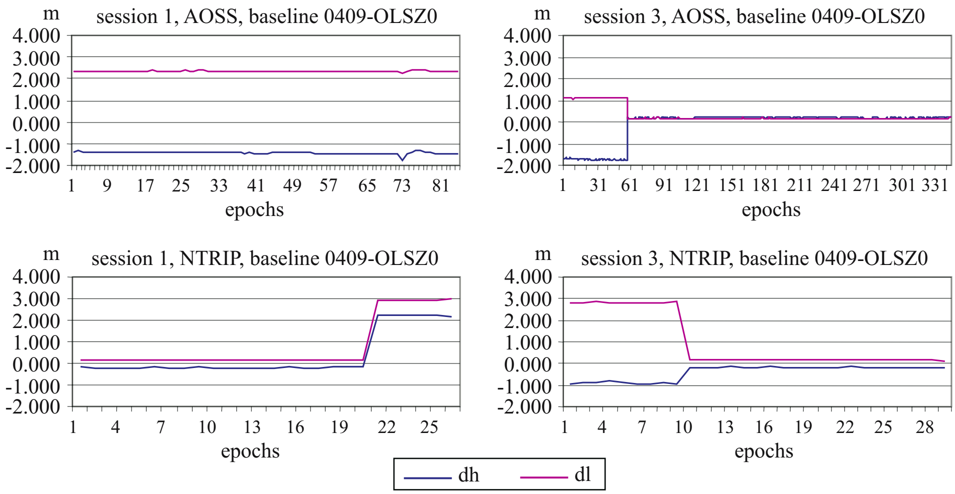

Fig. 9. Accuracies obtained for sessions 1 and 3

at that level until the end of the session. In post-processing on the other hand, during the entire first session the accuracy ranged from 2,26 m to 2,38 m. Obtaining the accuracy of almost 2,5 m in the first group of session one in post-processing while in direct RTK measurements accuracies of several centimeters were obtained for the same group may indicate that the computation algorithms of the receiver may allow obtaining better results under difficult observation conditions than the algorithms applied in computation software. During session 3 (reference station OLSZ0), from the session beginning up to a certain moment the accuracy was around 2,7 m for RTK method and over 1 m for post-processing and next it rapidly increased to 10-18 cm for RTK measurements and 15-25 cm for post-processing. It should be noticed that during session 3 increase in accuracy of coordinates determination is tightly linked with the increase of visible satellites and improved geometry of their distribution (Fig. 10.), while for session 1 the relation between accuracy and PDOP coefficient is not so obvious, which is characteristic for GPS measurements performed under conditions of limited access to the celestial sphere, particularly in case of covers in form of tree branches.

Flat coordinates of point 0474 were determined with accuracy better than 10 centimeters for both RTK method and post-processing in case of both OLSZ0 and LAM6 station with the exception of RTK/NTRIP results from session 5 (Fig. 11). Accuracy of determination of point 0474 coordinates by RTK method using corrections from OLSZ0 station was around 20 cm during the entire session and for LAM6 station it was several times better at 6

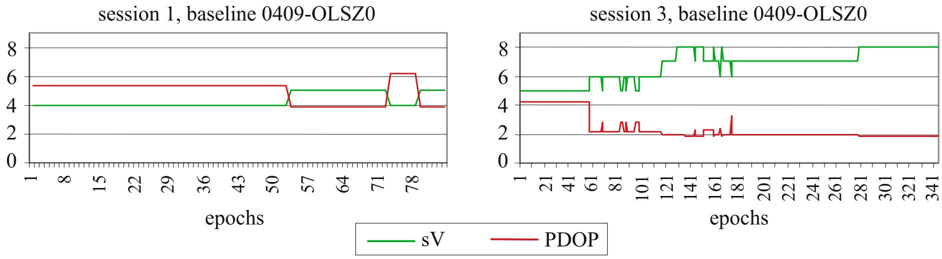

Fig. 10. PDOP coefficient value and number of satellites available during sessions 1 and 3

to 10 cm, which is surprising considering the fact that the distance of measurement point from LAM6 station was twice larger than the distance from OLSZ0 station and exceeded 14 km. Results obtained in post-processing were characterized by accuracy at the level of 3-7 cm for both reference stations, and the results obtained for OLSZ0 station were characterized by a slightly higher precision, which could be caused by changes in the PDOP coefficient value during the fourth measurement session (Fig. 12).

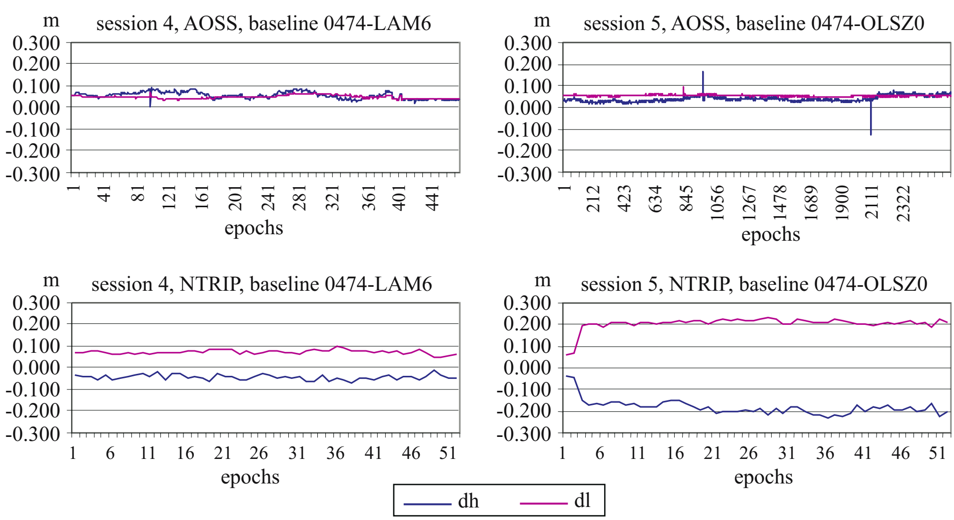

Fig. 11. Accuracy of measurement results for point 0474

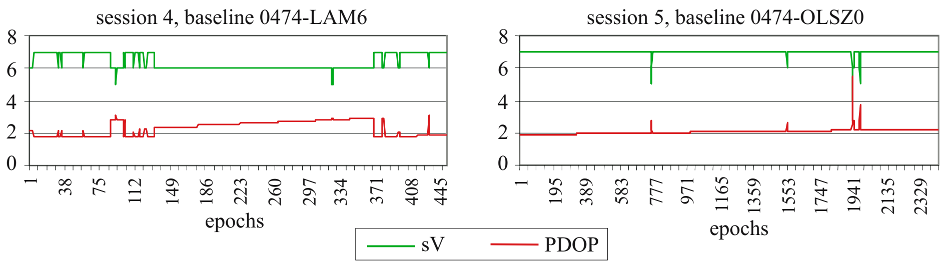

Fig. 12. PDOP coefficient value and number of satellites available during measurements at point 0474

During sessions 6 and 7, when coordinates of point 0016 were determined in RTK measurements accuracies of 4-8 cm and 6-22 cm respectively were obtained for flat coordinates, (Fig. 13), that is the opposite than in case of point 0474, better results were obtained using corrections from station OLSZ0 than from station LAM6, and the distance from points 0016 and 0474 to stations OLSZ0 and LAM6 were similar and they were for point 0016 7,8 km and 15,1 km respectively. In post-processing the accuracies of under 5 cm were obtained for both sessions and, similar to the case of point 0474 precision of the results obtained in post-processing was slightly higher for vector 0016-OLSZ0 than the vector 0016-LAM6. During the entire measurement from 6 to 9 satellites were available and the PDOP coefficient was 2-3, with the exception of rapid, short increase in its value during session 7 (Fig. 14).

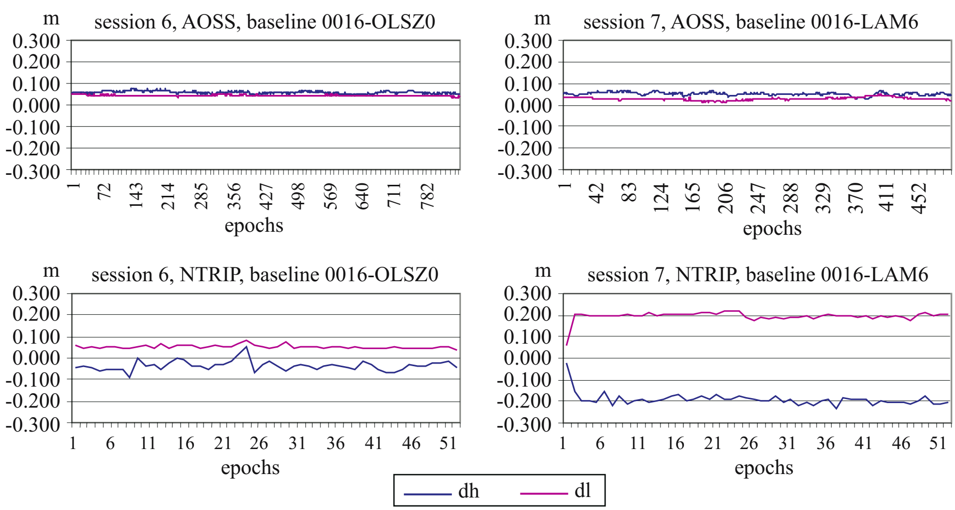

Fig. 13. Accuracy of measurement results for point 0016

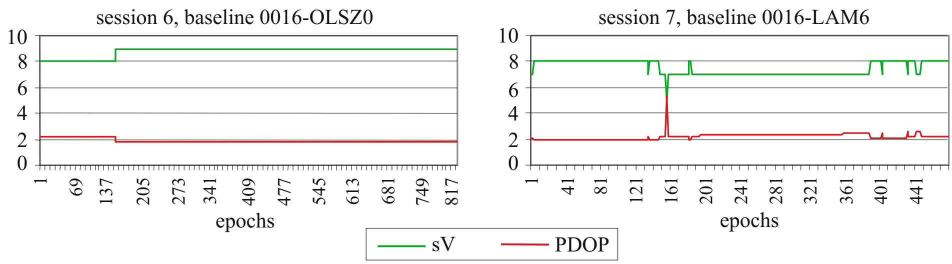

Fig. 14. PDOP coefficient value and number of satellites available during measurements at point 0016

Ellipsoid heights of measurement pints obtained directly from RTK measurements results and computed in post-processing were reduced to normal heights (distance of geoid to ellipsoid was determined in TRANSPOL software) and next the results were compared to heights of those points considered true.

Accuracy of height determination for point 0409 ranged from several centimeters to over 1,7 m in post-processing and from 15 cm to over 2 m in RTK measurements. The heights determined, similar to flat coordinates for that point, were characterized by relatively high precision in individual groups. Height of points 0474 and 0016 were determined with the accuracy of below 10 cm with the exception of RTK measurements from sessions 5 and 7 for which the height determination accuracy was around 20 cm. Height determinations from sessions 4, 5, 6 and 7 were distributed in the same way as accuracies of flat coordinates although they were characterized by a slightly lower precision.

Summary and conclusions

Accuracy of results from measurements by RTK/OTF method using the NTRIP protocol for transmission of corrections, as indicated by the initial experiments, can be a few centimeters. Results of RTK measurements conducted under conditions of unlimited access to the celestial sphere actually match the results obtained in post-processing, although the results obtained directly from RTK/OTF measurements show a slightly lower precision than the results from post-processing.

On the other hand results of measurements conducted under conditions of access to the celestial sphere limited by numerous tree branches deserve attention. In this case characteristic decreases in accuracy of RTK/OTF measurements with the increase of PDOP coefficient occur although that dependence is not tight and as a consequence PDOP coefficient cannot be in this case the reliable indicator of measurements accuracy. Inconsistency of RTK measurements results with the results obtained in post-processing is highly characteristic for GPS measurements conducted under forest conditions. On the basis of session 1 and referring to the experiments described in earlier literature it can be concluded that in certain situations it is possible to obtain much better accuracy in direct RTK measurements than in post-processing. This situation suggests that computation algorithms applied in the receivers are better and allow more accurate determination of coordinates under more difficult observation conditions than the algorithms of software applied.

RTK/OTF measurements with application of NTRIP technology may be applied with success in land survey measurements that require lesser than higher than one centimeter accuracy however particular care and limited confidence in measurement results should be applied under conditions of limited access to the celestial sphere. Measurements in difficult conditions should be made by experienced measurement teams and subjected to control (e.g. by multiple re-initialization on the point). It is also necessary to conduct comprehensive studies allowing assessment of accuracy as well as credibility and availability of RTK/NTRIP measurements under conditions of limited access to the celestial sphere.

References

Ashtech Office Suite for Survey, User's Manual. 1998. Ashtech and Spectra Precision Terrasat GmbH Germany, USA.

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

BAKUŁA M., KAPCIA J., OSZCZAK S. 1998. *Technika RTK GPS w pracach realizacyjnych na polach naftowych w Zjednoczonych Emiratach Arabskich*. Materiały konferencyjne z Seminarium Komisji Geodezji Satelitarnej PAN nt. „Zastosowanie technik kosmicznych w geodezji i geodynamice", Wrocław.

BAKUŁA M., OSZCZAK S. 2006. *Experiences of RTK Positioning in Hard Observational Conditions During Nysa Kłodzka River Project*. Reports on Geodesy, 1(76): 71-79, Vienna, Austria.

CIECKO A., OSZCZAK B., OSZCZAK S. 2006. *Driver-By DTM – GPS and GSM Power Cost-Effective Terrain Modeling*. GPS Word, 17(4): 44-49.

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

GRZEGORZEWSKI M., OSZCZAK S., BAKUŁA M. 2001. *Badania nad precyzyjnym wyznaczeniem trasy lotu samolotu TS 11 ISKRA*. Zeszyty Naukowe WSOSP w Dęblinie, 2: 35-43.

LENZ E., *Networked Transport of RTCM via Internet Protocol (NTRIP) – Application and Benefit in Modern Surveying Systems*. http://www.fig.net

Networked Transport of RTCM via Internet Protocol (NTRIP) ver. 1.0, http://igs.bkg.bund.de/

OSZCZAK S., OSZCZAK B., GRYGORCZUK P. 2004. *Teletransmisja DGPS/RTK za pomocą GSM/GPRS z wykorzystaniem n-stacji referencyjnych i dedykowanych APN*. Seminarium nt. Satelitarne metody wyznaczania pozycji we współczesnej geodezji i nawigacji, Kraków.

PETERZON M. 2004. *Distribution of GPS-data via Internet*. Information Technology Engineering at Uppsala University.

PODLASEK S. 2007. *Trzy poziomy ASG-EUPOS*. Geodeta, 5(144): 24-26.

POPIELARCZYK D., OSZCZAK S. 2006. *Application of Integrated Satellite DGPS/GPRS Navigation and Hydrographic Systems for Safe Sailing on Great Mazurian Lakes in Poland.* ION NTM 2006, Conference proceedings, pp. 188-194, Monterey, CA, USA.

Wytyczne Techniczne G-1.10. Formuły odwzorowawcze i parametry układów współrzędnych. 2001. Główny Urząd Geodezji i Kartografii, Warszawa.

Accepted for print 6.10.2008 r.