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PRELIMINARY RESULTS OF THE USE OF EUREF-IP PILOT PROJECT IN WARSAW METROPOLIS BASED ON TWO NTRIP SERVERS OF EPN STATIONS BOGI AND JOZ2

Abstract

The location of two EPN stations BOGI and JOZ2 that take part in the EUREF-IP pilot project is extremely suitable to provide the RTK corrections at any place of the capital of Poland with a sub-decimetre accuracy.

The results of test measurements are presented and discussed in the paper.

The test measurements were performed in three steps:

1. Precise positioning as the Ntrip client of different places of Warsaw in field conditions.
2. Discussion of the results of positioning using RTK corrections from both EUREF-IP stations BOGI and JOZ2 at the points of known position.
3. The experiments of the use of the RTK survey as the Ntrip client in urban area.

INTRODUCTION

The last few years brought many new applications of the internet such as radio, TV or telecommunication by internet. The wireless communication gives possibility of connecting to the internet almost everywhere. It is possible to send a package of data of any dimension by the Internet Protocol (IP) in a very short time. In particular it is possible to send packages of DGNSS corrections and RTK data that can be used for real time positioning using DGNSS or RTK technology. The dimension of such packages is very small as compared with packages of music or images.

This new technology of sending DGNSS corrections and RTK data simultaneously to multiple users via internet is called a Networked Transport of RTCM via Internet Protocol. (Ntrip)

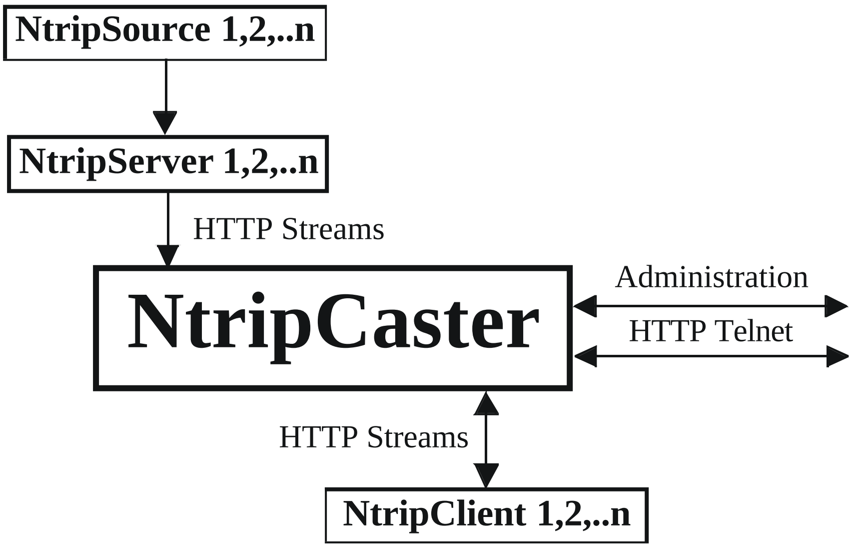


Fig. 1. The Ntrip components

The components of the Ntrip (Fig. 1) are as follows: NtripSources, NtripServers, NtripCaster, NtripClients (Lenz, 2004).

Taking into consideration the increased demand of using DGPS and RTK technology in positioning and navigation, and the possibility of sending necessary data via internet, the Symposium of IAG Reference Frame Sub Commission for Europe in Ponta Delgada in June 2002 has taken a **Resolution No. 3** about the possibility of providing reliable and standard-data by EPN (EUREF Permanent Network) in real time. Technical Working Group was asked to set up and maintain a differential GNSS infrastructure based on selected EPN stations through the internet. All member countries were asked to support that activity by making the necessary upgrade of the respective EPN stations.

The new project focuses on estimation potentiality of that new technology and stimulates its usage. German Federal Agency for Cartography and Geodesy (BKG - Bundesamt für Kartographie und Geodäsie) was appointed the co-ordinator of the project.

Presently, the system is composed of about 130 EPN and IGS stations on different continents as well as some stations of commercial providers. In Only 9 EUREF network stations are presently working in the project; participation of BOGI station is currently in the test mode.

Three Polish stations KRAW, JOZ2, BOGI take place in the project. Both JOZ2 and BOGI permanently acquire GPS as well as GLONASS data and transmit RTK and DGPS corrections in RTCM-104 format. The stations are located at opposite outskirts of Warsaw (Fig. 2). Their location is suitable to provide the RTK measurements at any place of Warsaw with sub-decimetre accuracy. The results of test measurements with use of those stations are discussed in the paper.

FIELD MEASUREMENTS

Figure 2 shows the location in the map of Warsaw of BOGI and JOZ2 stations that generate and transmit (NtripSources and NtripServers) the RTCM-104 corrections. For getting and using the corrections the NtripClient software was used (Fig. 3).

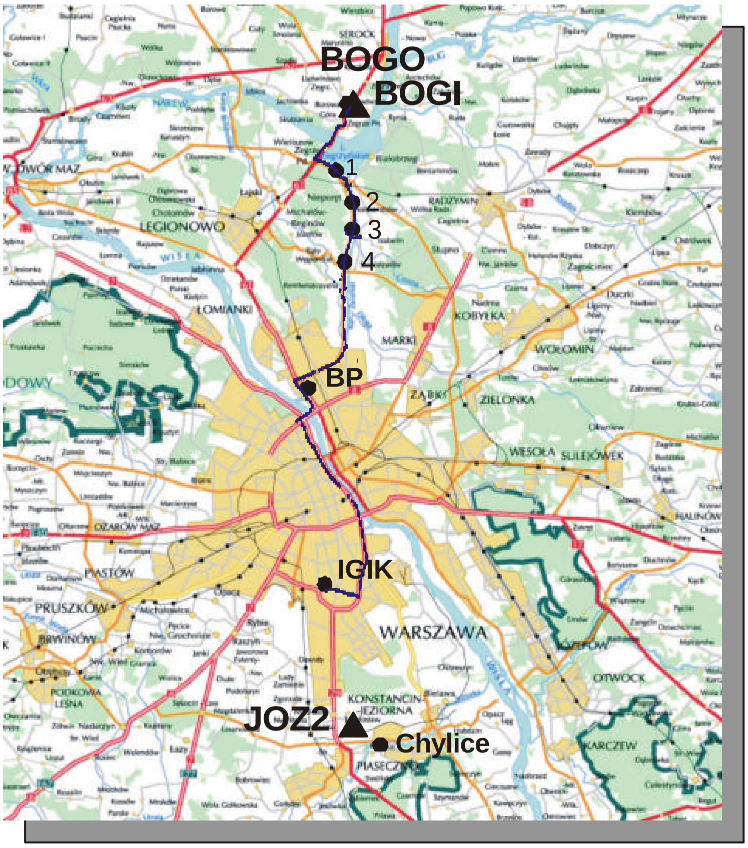


Fig. 2. The Map of Warsaw including suburbs with marked base stations (black triangles) as NtripSources & NtripServers that transmit the RTCM-104 corrections and with the measured RTK points (black circles)

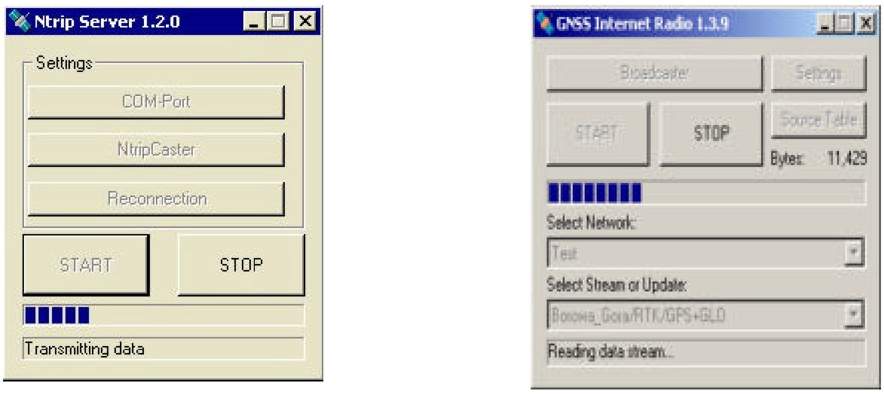


Fig. 3.
a) NtripServer software *b) NtripClient software*

A set of Javad Legacy receiver with Javad LegAnt antenna (Fig. 4) installed on a roof of a car was used in test measurements.

Fig. 4. Javad LegAnt antenna and Javad Legacy receiver

RTCM corrections were received by a Toshiba notebook equipped with a PCMCIA GSM card (Fig. 5).

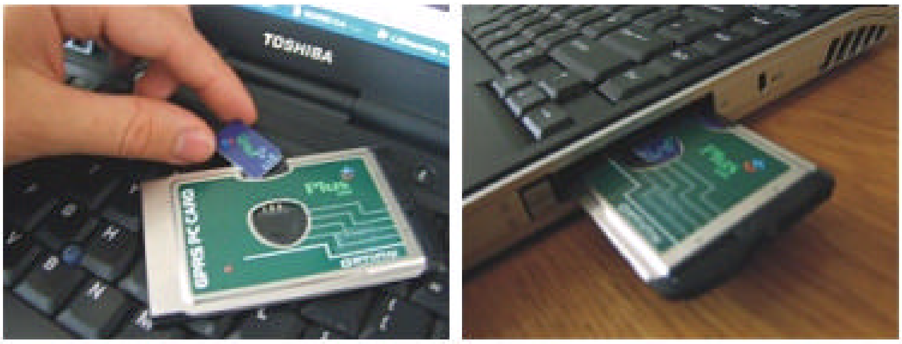


Fig. 5. Toshiba notebook with GPRS PCMCIA card

A computer was linked to a receiver by a serial port. The second port of the receiver was used to link it with a Husky fex-2 controller equipped with GART software operating under Windows CE. GART gives possibility of recording 3D position of points and checking quality of solution (Fig. 6).

Fig. 6. Husky fex-2.

The measurements started at the Geodetic-Geophysical Observatory in Borowa Gora about several hundred meters from BOGI station.

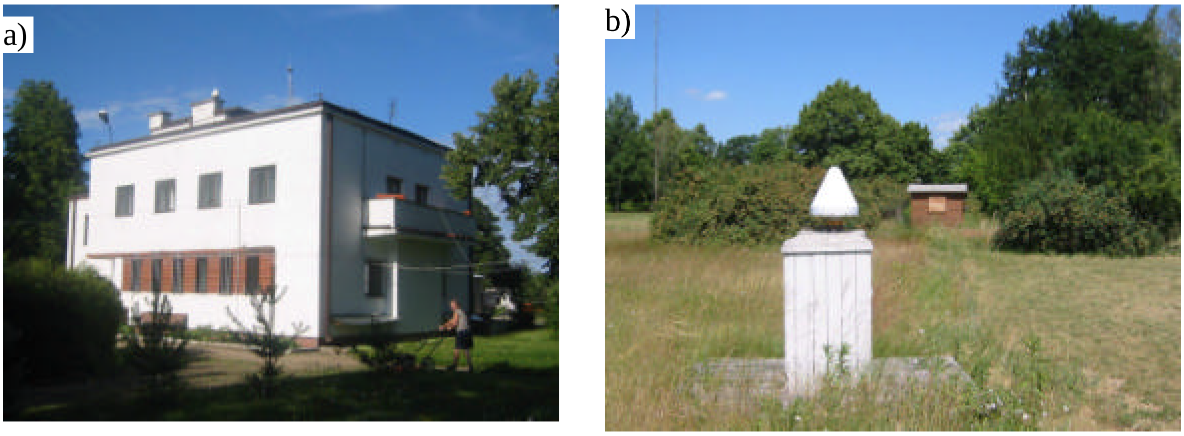


Fig.7. Base stations in Borowa Gora Geodetic-Geophysical Observatory

a) BOGO station   b) BOGI station

On the way to the Institute of Geodesy and Cartography (about 40 km), the car stopped several times and differential measurements were performed (Fig. 2). The GSM signal was unfortunately not strong enough throughout the measurements; it caused interruptions in receiving corrections. The RTK solution was also not possible to achieve at all points along the route because obstructions caused by numerous trees on the side of the road. The RTK solution was flagged as "fixed" and the solution was reliable (the blue line in Fig. 8) during first several kilometers only. 2.2 kilometers from the beginning of surveyed trajectory, initialization "on the fly" has been switched on at 50 km/h speed; no obstructions due to the trees were recorded.

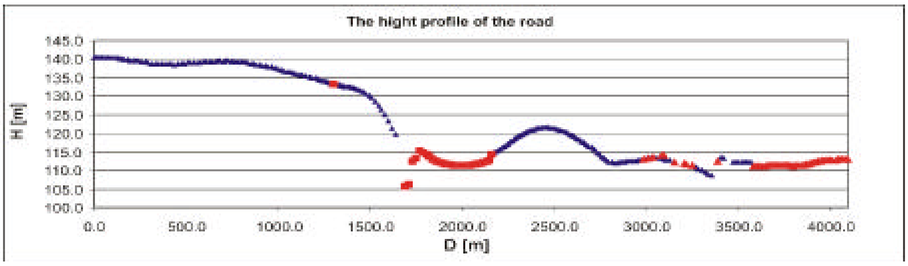
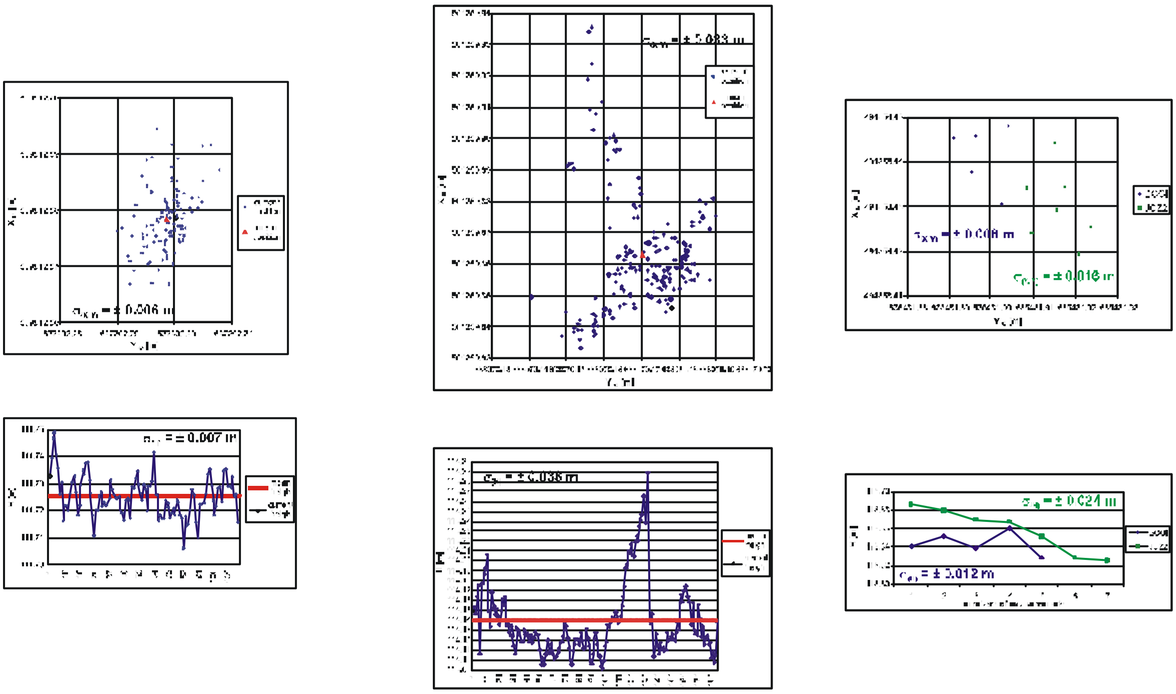


Fig. 8. Vertical profile of the trajectory derived from the DGNSS measurement as a function of distance from the base station BOGI. The line composed of blue triangles corresponds to „fixed" solutions. The line composed of red rectangles corresponds to "standalone" solutions

After completing measurements along first 5 km of the trajectory the following measurements were performed in stop and go-like mode, i.e. stopping on the points and waiting until "fixed" RTK position was reached. Time of initialization did not exceed 3 minutes.



Point No 1 (4.5 km from BG), corrections from BOGI station only

Point No 6 (13.5 km from BG) corrections, from BOGI station only

Point BP (19.5 km from BG and 23 km from JOZ2) corrections from both stations

Fig. 9. Examples of RTK measurements at three points of different distances from BOGI and JOZ2 stations

Figure 9 shows the discrepancies in horizontal (1 × 1 cm grid) and vertical positions (1 cm grid for points No 1-6, and 2 cm grid for BP point). The computed rms of all positions are smaller than 4 cm. At point No 6 the discrepancies in horizontal positions reached 10 cm but in vertical position it exceeded as much as 20 cm. At BP point that is almost equidistant from base stations BOGI and JOZ2, the measurement was made using corrections from both base stations. The differences between the solutions from both stations are systematic and do not exceed 3 cm.

At BOGO point (the receiver of the Ntrip client was connected by a splitter to the same antenna as BOGO EPN station) located 42 km from JOZ2 station and 0.1 km from BOGI station, the RTK corrections were acquired in a similar manner as at BP point. The position derived using RTK corrections from JOZ2 station exhibit much larger dispersion as the one obtained using corrections from BOGI station (Fig. 10).

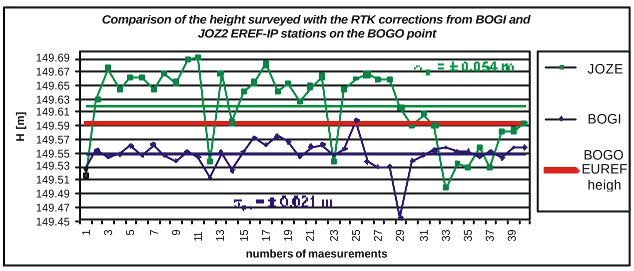


Fig. 10. Discrepancies in height of the BOGO point from RTK measurements using BOGI and JOZ2 reference stations

The next experiment was conducted in Chylice village about 3.5 km south of JOZ2 and 45.2 km from BOGI. The “true” position of the point was measured with static method. Results were compared with RTK measurements using corrections from both reference stations (Fig. 11 and Fig. 12).

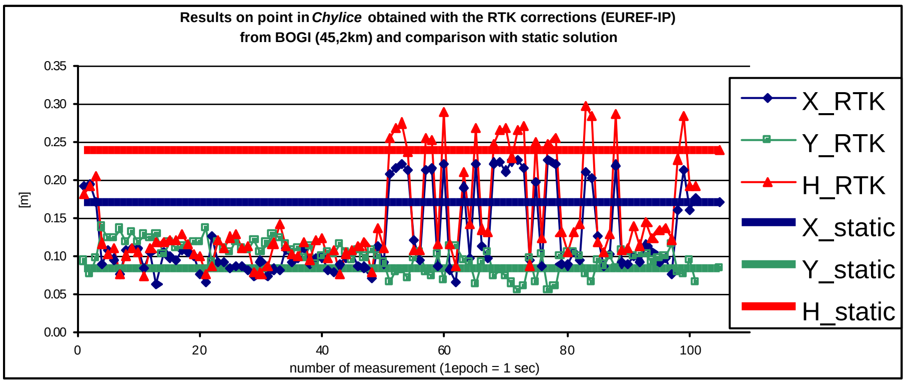


Fig. 11. The discrepancies in RTK solutions obtained using corrections from BOGI compared with static solution

The graph warns of danger of relying on results from one short series of measurement. The results from the first minute, in spite of “fixed” solution, differ of about 15 cm in height and about 8 cm in North component from static “true” solution. In the next minute only, the results of RTK approach to the “true” values. The observed jump in the solution corresponded to the rising of a new satellite over the horizon. It should also be noted that the distance from base station, transmitting the RTK corrections, was very long – 45.2 km.

At points with a short distance from JOZ2 the results were satisfactory; the discrepancies obtained did not exceed 3 cm. The graphical view of the results obtained with use of JOZ2 is shown in Fig. 12.

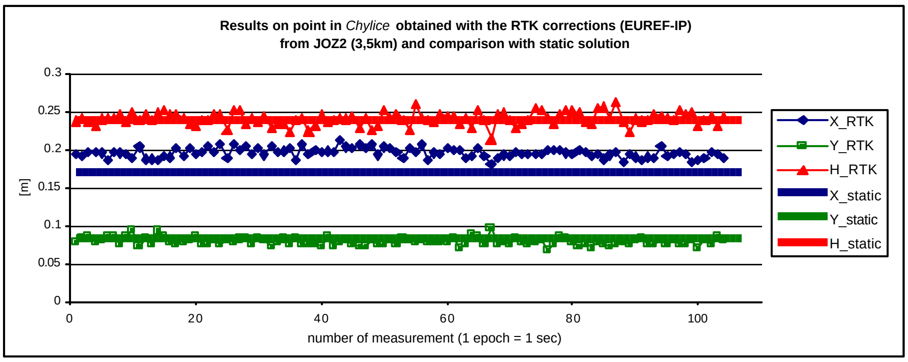


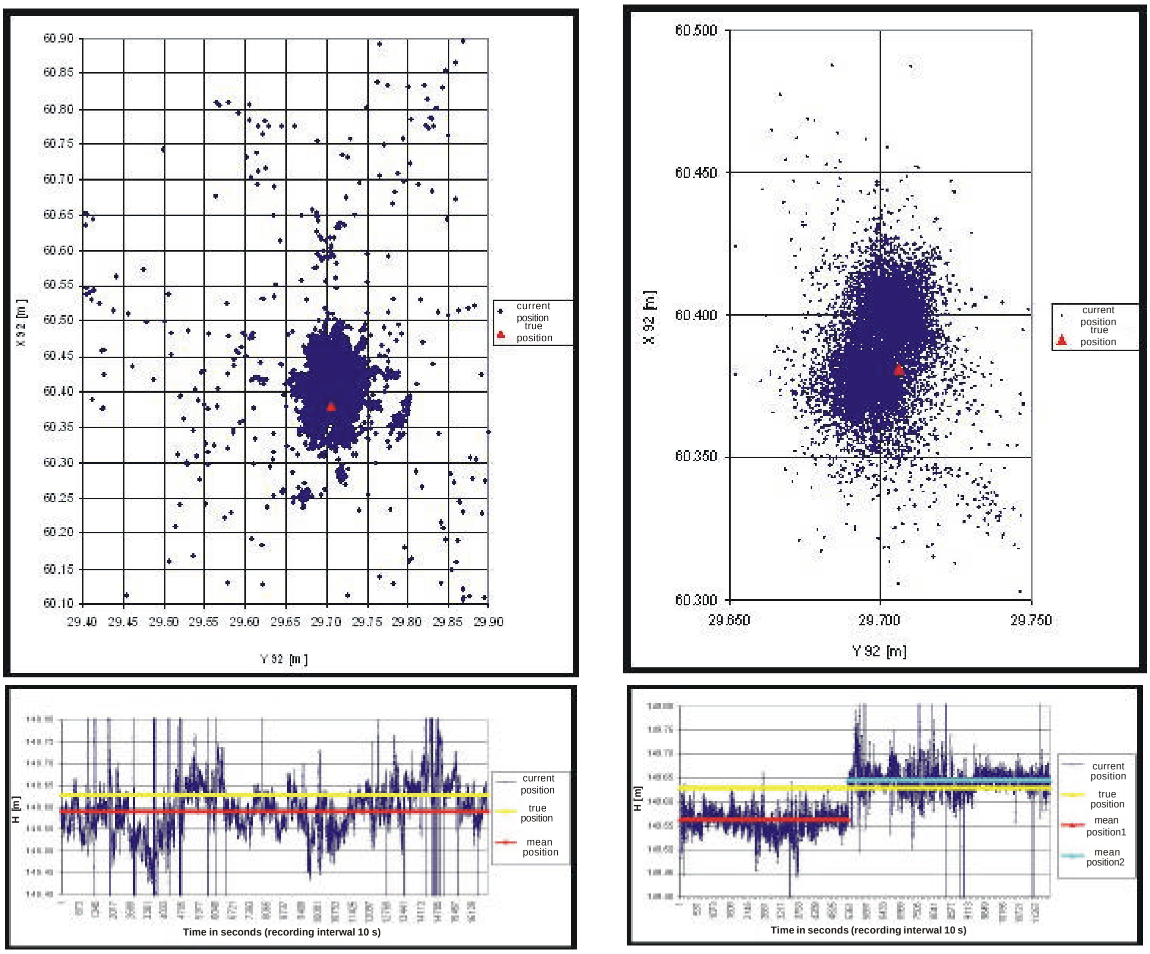
Fig. 12. The discrepancies of RTK solutions obtained using corrections from JOZ2 compared with static solution

Similar experiments were performed by the team from Warsaw University of Technology with use of their own Ntrip system and software.

LONG SERIES OF RTK STATIONARY MEASUREMENTS AT THE POINTS OF KNOWN CO-ORDINATES

Javad RegAnt – choke ring GPS/GLONASS antenna was placed on the roof of a building of the Institute. The position of the antenna was determined from a few days session of static measurements. For differential measurements Javad Legacy receiver connected to the antenna was used once more. RTCM corrections were received on PC by the NtripClient software and a local access to the internet. The on-line downloading the data in 1 s interval was performed on the same PC using PCCDU software.

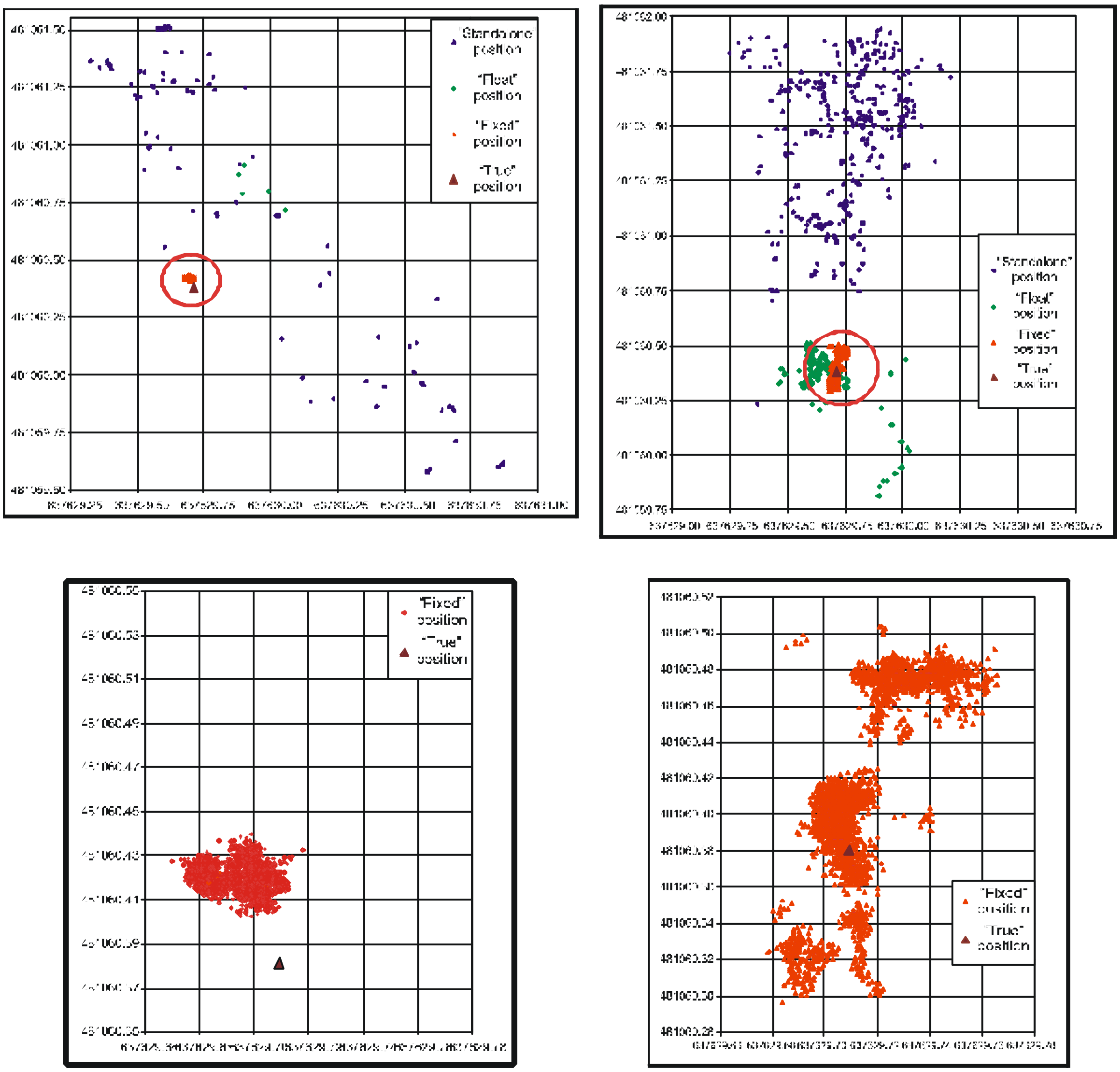
Distance from the IGiK to Jozefoslaw (JOZ2) is about 12.2 km and to Borowa Gora (BOGI) is about 33 km. The observations from a few days of recording were downloaded and stored during for each station separately. The results of two independent experiments are further discussed.



a) Use of corrections from BOGI station *b) Use of corrections from JOZ2 station*

Fig.13 Solutions of RTK measurements (Experiment 1) at IGiK point using Ntrip corrections from a) BOGI station and b) JOZ2 station („fixed" only)

The "fixed" solutions only are presented on the graphs in Fig. 13 using 5 × 5 cm grid. The solutions from BOGI as well as from JOZ2 are mainly grouped within the rectangle of 10 cm side. Larger discrepancies, exceeding even half a meter, are observed in case of solutions from BOGI due to larger distance from the measured point. It confirms the mentioned above conclusion that one short series of measurement is not sufficient when using RTK. It is rather necessary to perform at least three series of measurements and, if possible, to use two different reference Ntrip stations.



a) Use ofcorrections from BOGI station *b) Use of corrections from JOZ2 station*

Fig. 14. Solutions of RTK measurements (Experiment 2) at IGiK point using Ntrip corrections from a) BOGI station and b) JOZ2 station

The upper graphs in Fig. 14 show all terms of time-series from three types of solutions: "fixed", "float" and "standalone".

The discrepancies obtained are typical for each type of solution. It should be stressed, however, that there is a large number of „float" and „standalone" solutions; their occurrence cannot be easily explained. Changes in satellite configuration (number of satellites, PDOP, etc) might be one of the reasons.

The lower graphs in Fig. 14 show the zoomed part of "fixed" solutions only. It is obvious that the solutions obtained using the corrections from BOGI that in this case is substantially distant station are worse than those obtained from JOZ2 station that is closer. They do not exceed, however, 20 cm, that was a case of previous experiments. The solutions are grouped in a few separate and internally consistent blocks, each affected with a bias. Dispersion of those blocks grows with a distance from a base station. The mean value of the solutions obtained with the corrections from JOZ2 station differs from the one obtained using a static method. It is very likely that the co-ordinates of the base station in Jozefoslaw were erroneously entered.

Figure 15 shows the variations of co-ordinates of IGiK point and variations of number of satellites and PDOP for the period of test measurement.

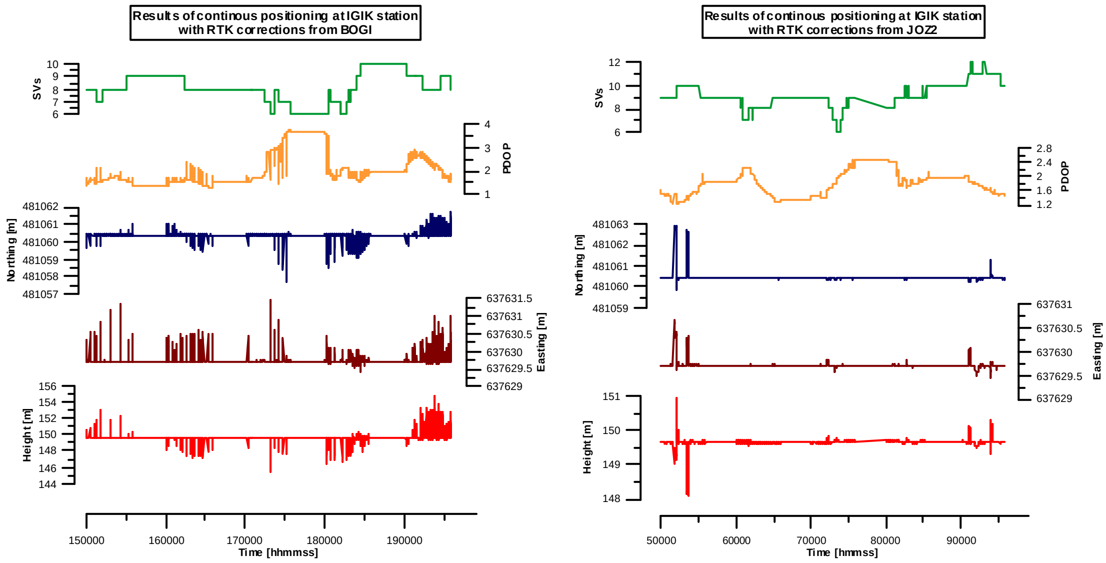


Fig. 15. Variations of co-ordinates of the IGiK point from DGPS measurements with the corrections from BOGI and JOZ2 stations and the variations of satellite configuration

Similar test measurement was performed using the Ntrip system elaborated by the team from Warsaw University of Technology (WUT). The JOZ3 station was used as the Ntrip Source and NtripServer as well as the server of WUT was used as the NtripCaster. The obtained results (Fig. 16) are comparable to the discussed above test results obtained within EUREF-IP pilot project.

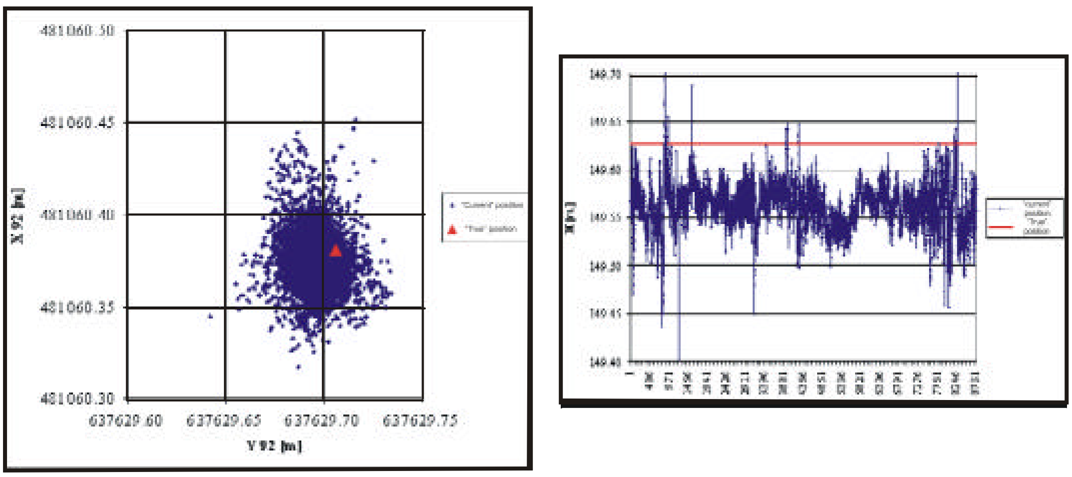


Fig.16. Results of the RTK survey using WUT Ntrip system

PRACTICAL EXAMPLES OF EUREF-IP RTK SURVEY IN URBAN AREA

The set consisting of Javad Legacy receiver, Javad LegAnt antenna, Toshiba notebook with PCMCIA GPRS card, and Husky fex-2 was used in the field experiments referred to surveying of typical municipal features. It should be noted that the RTK survey with Ntrip corrections does not differ from ordinary RTK with radio link. It means that at least 5 satellites should be tracked and in addition a low PDOP (not exceeding 3) is required. It obviously limits the use of RTK in urban area due to frequent obstructions (Cisak et al., 2001). Two typical municipal features – entry to the parking lot (Fig. 17a) and sewer's lid (Fig. 17b) have been surveyed in opened area with good conditions for RTK survey ensured. Positioning accuracy at the centimetre level obtained in both experiments is sufficient for many inventory purposes.

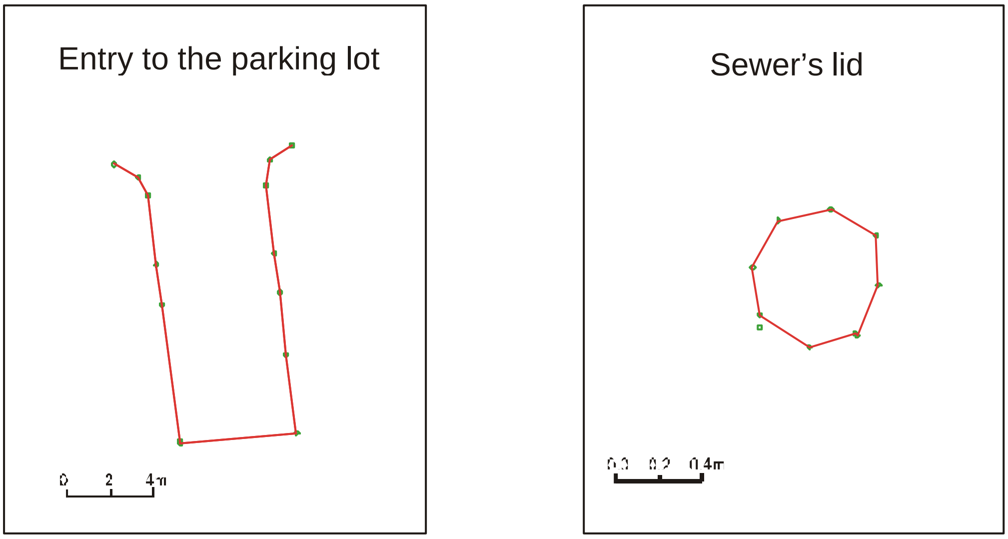


Fig. 17. RTK Ntrip survey of some municipal features

Such a type of measurements requires a surveying team consisting of at least two surveyors, for carrying the equipment, checking a type of solution, recording co-ordinates and drawing the sketch. In spite of acceptable accuracy of positioning achievable using Ntrip technology neither efficiency nor convenience make the technique attractive for practical use. Newest technical developments have been applied at the Institute of Geodesy and Cartography to develop more user-friendly implementation of that technology. In a new surveying set the Javad Legacy receiver accompanied with Husky fex-2 was replaced by the Javad PREGO receiver with build in battery and palmtop equipped with GART operating software running under Windows CE (Fig. 18a). Moreover, a cumbersome and inconvenient in field work notebook was replaced by a small Motorola mobile phone with "mobile Ntrip" application (Fig. 18b) (*http://www.nadowski.geo.pl/detale/ntrip_eng.htm*). The new surveying set requires a single operator only (Fig. 19). In addition the operating procedure is substantially simplified.

a.)

b.)

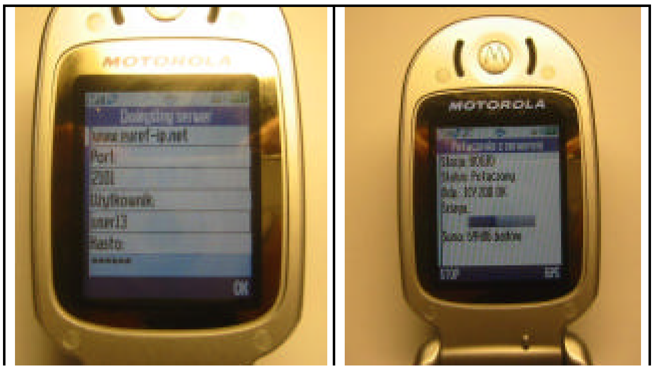


Fig. 18. a) GPS&GLONASS Javad PREGO receiver, b) Motorola mobile phone with the application "mobile Ntrip" http://www.nadowski.geo.pl/detale/ntrip_eng.htm

Fig. 19. A set of surveying instruments implemented for EUREF-IP RTK survey

CONCLUSIONS

The use of the internet for data transmission from GNSS base station substantially improves efficiency of the RTK survey as compared to the technology based on radio transmission. It becomes particularly advantageous in urban areas where radio signal is attenuated by tall constructions. Moreover it allows for extension of the RTK range.

Positioning accuracy achievable with Ntrip technology as well as reliability and repeatability requirements correspond to respective once of ordinary RTK survey. The results of test surveys conducted in the framework of the project confirmed the usefulness of the technique for surveying practice. The developed system can become attractive for surveyors due to its efficiency, portability and simplicity in operation. Experience gained within the project could be used for designing the modern multifunctional regional networks of GNSS base stations.

ACKNOWLEDGMENTS

The project was conducted in the framework of the statutory research on „Problems of geodesy and geodynamics" at the Institute of Geodesy and Cartography, Warsaw. The authors express their gratitude to Dr. G. Weber from BKG for his helpful suggestions during establishing the NtripSource and NtripServer at BOGI station. Fruitful discussions and some technical support of Prof. J.B. Rogowski and his collaborators from WUT and help of Mr. M. Stelmaszuk in conducting field experiments are kindly appreciated.

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