Range Analysis of RTK Base Station in Urban Environment

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SUMMARY

Substantive scope of paper covers issues related to RTK measurements in urban environment. This technique using traditional radio-modem for streaming RTK/DGPS corrections allows mobile users to achieve high-accuracy positioning. Unfortunately, the radio link, playing the communication task, has a few drawbacks. The most important one is the typical short transmission range of low-powered systems caused by obstacles located in the path between a base station and a mobile receiver. Another drawback is signal interference, which can reduce transmission range and cause poor signal quality. Noting all these drawbacks, the author was interested in checking of actual state of problems in geodetic RTK measurements.
Our approach of testing the performance of this service is based on field experiments and the analysis of both the accuracy and availability of RTK data using radio-modem transmissions. Investigation of advantages and disadvantages of this technology is also given. Experiment was conducted on the test marks which were determined by static occupation (below centimeter level of accuracy) under different conditions (opened areas and covered by trees and buildings or close to water). All the tests were performed using the latest Topcon HyperPro GPS/GLONASS receivers.

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1. INTRODUCTION

GNSS surveying techniques are still being developed, therefore there are many ways of their classification. One should take into account the time of obtained results, accuracy and the number of receivers. Commercial products offer user–friendly equipment and software which can definitely increase accuracy and achieve maximum service capacity. Especially Real–Time Kinematic (RTK) technique became another tool for professional surveying. It became effective and ubiquitous tool to facilitate work in cadastral surveys and other investments (Roberts, 2005). Noting great potential of this technique (enabling positioning to centimeter accuracy), author decided to put it into test as a potential tool for map and geographical databases updating. The approach of testing the performance of this technique is based on field experiments and the analysis of the radio-modem transmission range, playing the communication task. Low-powered RTK system usually has short transmission range which is caused by obstacles located in the path between a base station and a mobile receiver. This happens especially in urban environment. Author investigates the advantages and disadvantages of this transmission link. All the field experiments were conducted on the test marks which were determined by static occupation (below centimeter level of accuracy) under different conditions and in various periods of time using the latest Topcon HyperPro GPS/GLONASS receivers.

2. THE RTK POSITIONING METHODS

There are a few methods of position determination in GNSS/RTK technique:

– Single-Reference Station
Rover receiver determines the position using signals transmitted by radio-modem or cellular phone from single reference station.

– Multi-Reference Stations
At least to BASE receivers are used, which are set over the points with known position, and ROVER receiver, which determines position from each BASE station. The main goal of Multi-Reference stations is repeated independent vector measurement of consecutive station and receiving averaged coordinates.

– Network RTK
Network RTK is based on at least three GNSS receivers. This method takes into consideration two techniques of downloading data from reference stations and uses them for precise positioning. The first techique is FKP (area correction parameters), and the other one is VRS (Virtual Reference Station). Both cases belong to RTK/DGPS surface correction distribution system (Uradzinski et al., 2008; McKessock, 2007)

As one can see from above, setting up the GNSS permanent reference station is necessary for RTK technique. This station sends corrections/observations in RTCM or CMR standards to the rover receiver. Radio-modems are common used devices for this transmission link. Unfortunately, this radio link, has a few drawbacks. As mentioned before, the most important one is the typical short transmission range of low-powered systems caused by obstacles located in the path between a base station and a mobile receiver. Another drawback is signal interference, which can reduce transmission range (up to few kilometers) and cause poor signal quality (Kim and Langley, 2003). Noting all these drawbacks, the author was interested in checking of actual state of problems in classical geodetic RTK method. This method requires one local base station. Measurement errors increase over a distance between base receiver and rover receiver what decreases reliability and efficiency of measurements.

3. METHODOLOGY OF STUDIES

Standard test approach is based on field experiments and the analysis of both the accuracy and availability of RTK data using radio-modem transmissions. Investigation of advantages and disadvantages of this technology is also given. Experiment was conducted at the test marks which were determined by static occupation (below centimeter level of accuracy) under different conditions (opened areas and covered by trees and buildings or close to water).

3.1 Equipment and system configuration

The GNSS equipment used for all experiments consisted of two dual-frequency GPS/GLONASS TOPCON HyperPro receivers and Topcon FC-200 compact field controller.

Figure 1. RTK Topcon HyperPro receiver over one of the test marks

Wireless communication (Bluetooth) between the receivers and the controller has a significant advantage. Complete GNSS Topcon HiperPro system can by used for various applications. It contains GSM/GPRS option, what can easily provide RTK corrections from Polish ASG-EUPOS service. However, the most important thing is using one of the receivers as local BASE station.

3.2 GNSS Software

After the field surveys, the raw measurements recorded in static sessions were processed in the office using TopconTools v.7.3 software. Precise coordinates from post-processing were used to compare with receiver RTK results. For experiment purposes field controller was equipped with Windows CE and Topcon TopSURV application installed.

4. FIELD EXPERIMENTS

Field test was conducted to check the range of local base station and to analyze both the accuracy and availability of RTK data using radio-modem transmissions in urban environment. All the experiments took place in the area of University of Warmia and Mazury in Olsztyn and its surroundings.

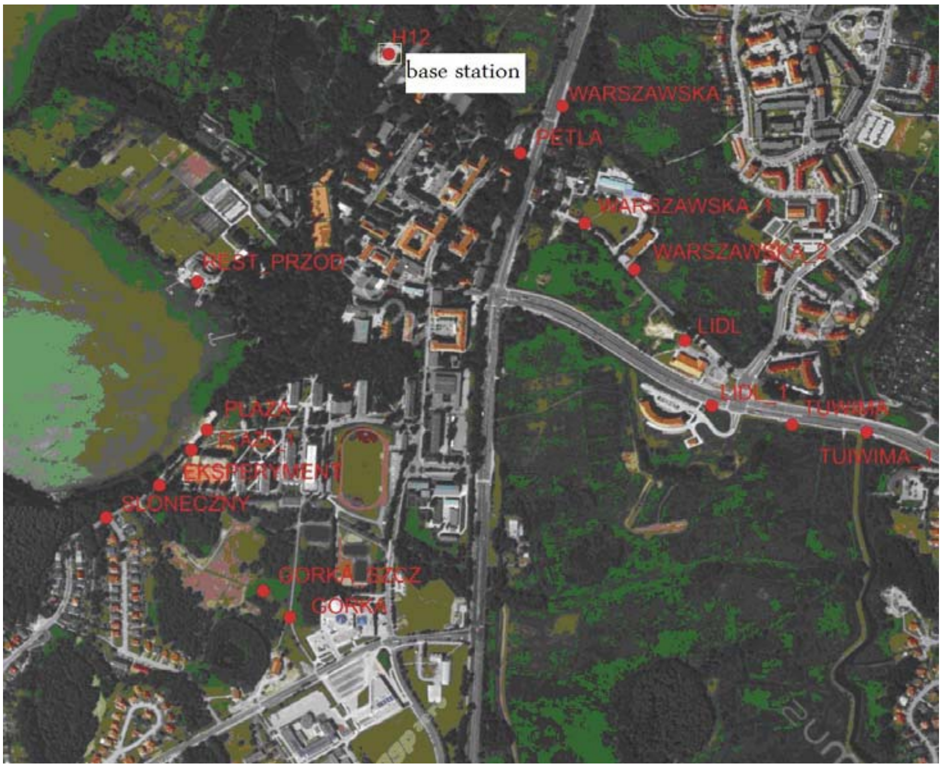

Figure 2. Localization of test points (background: www.zumi.pl)

Range analysis covered the area from eastern “Kortowka” river to “Lyna” river and the region starting from south side of “Gorka Kortowska” to military area, where the base station was located nearby.
All the measured points were located both in the opened areas and covered by trees and buildings or close to water for checking the performance of the system under different conditions. Proper measurements were conducted on 30th June 2010.

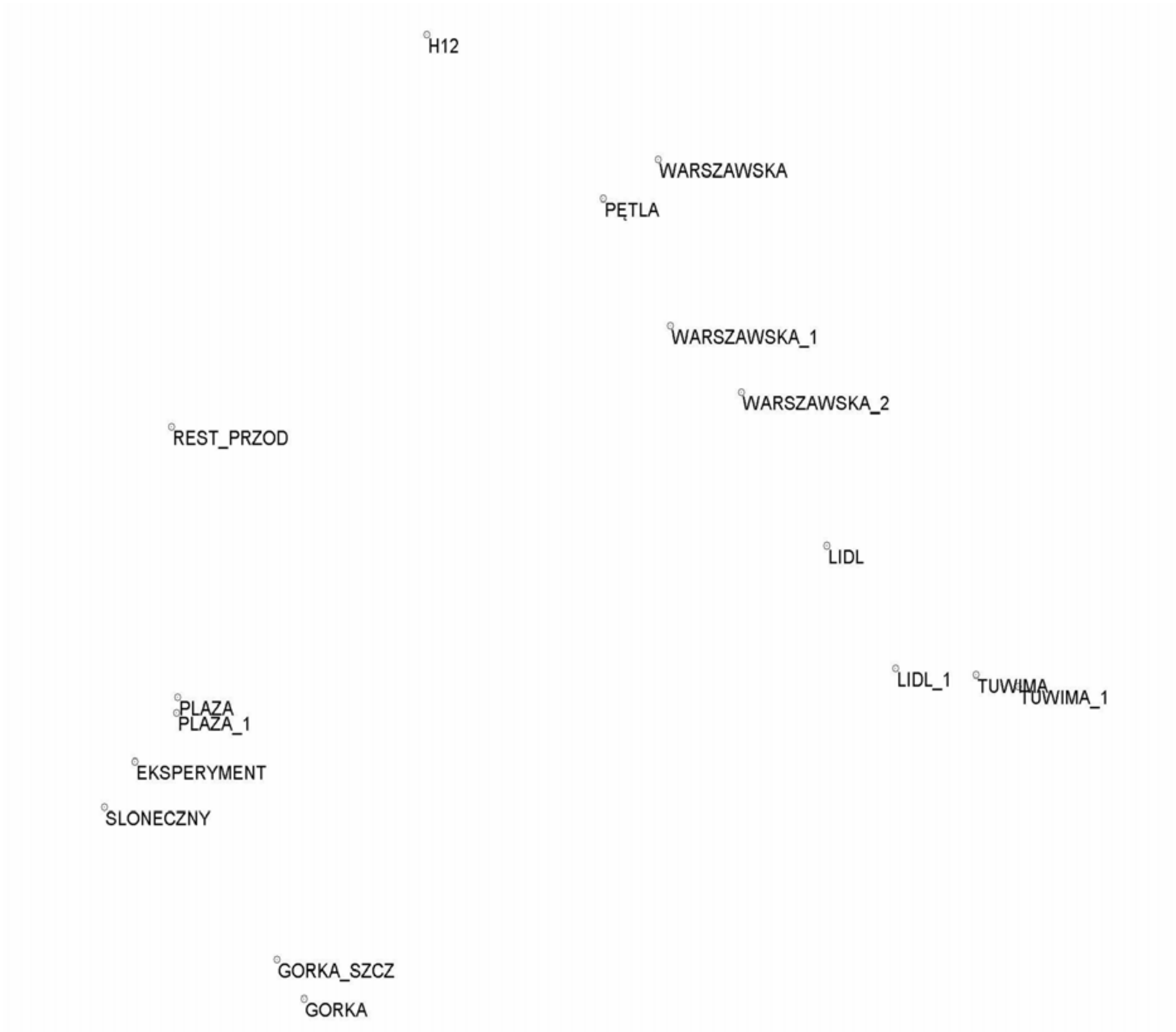

Figure 3. Visual sketch overview of test points

For RTK experiment purposes, local base station (H12) was set up over the point with known position (adjusted coordinates in coordinate system “2000”). Next all the test points were measured with RTK system. The results of radio-modem signal power are presented in Table1(RTK fixed solution obtained).

	name of the point	type of the point	radiomodem signal power in % (fixed RTK solution)
1	EKSPERYMENT	test mark	97%
2	GORKA	test mark	99%
3	GORKA_SZCZ	test mark	80%
4	LIDL	test mark	97%
5	LIDL_1	test mark	92%
6	PETLA	test mark	100%
7	PLAZA	test mark	90%
8	PLAZA_1	test mark	94%
9	REST_PRZOD	test mark	84%
10	SLONECZNY	test mark	92%
11	TUWIMA	test mark	81%
12	TUWIMA_1	test mark	80%
13	WARSZAWSKA	test mark	100%
14	WARSZAWSKA_1	test mark	97%
15	WARSZAWSKA_2	test mark	96%
16	H12	local base station	

Table 1. The results of radio-modem signal power

5. ANALYSIS OF THE RESULTS

All RTK results, conducted at 15 test points, were compared to static session results (Table 2). Firstly, it was planned to settle more test points, but they were rejected due to a lack of ambiguity resolution in forested areas (long transmission range from base station). Therefore, they were not taken into account. Probably the main reason of this problem was signal interference, which reduced transmission range and caused poor signal quality. There are a lot of electronic devices in the surrounding buildings and there are also many radio transmitters placed on roofs of academic buildings.

Name	Grid Northing (m)	Grid Easting (m)	Elevation (m)	Std Dev n (m)	Std Dev e (m)	Std Dev Hz (m)	Std Dev u (m)
EKSPERYMENT	5958307,052	7463877,069	104,028	0,013	0,010	0,016	0,018
GORKA	5958025,432	7464109,685	125,429	0,011	0,006	0,012	0,017
GORKA_SZCZ	5958072,342	7464071,961	130,584	0,009	0,008	0,012	0,014
LIDL	5958562,857	7464827,295	106,100	0,012	0,008	0,014	0,018
LIDL_1	5958417,426	7464921,753	105,728	0,013	0,010	0,016	0,016
PĘTLA	5958974,260	7464520,262	109,888	0,015	0,015	0,021	0,022
PLAZA	5958383,128	7463935,995	102,871	0,010	0,016	0,019	0,024
PLAZA_1	5958364,536	7463934,300	104,757	0,014	0,011	0,018	0,015
REST_PRZOD	5958703,547	7463927,605	103,730	0,013	0,012	0,018	0,020
SLONECZNY	5958253,020	7463835,005	106,718	0,015	0,010	0,018	0,016
TUWIMA	5958409,501	7465032,386	104,260	0,015	0,011	0,019	0,017
TUWIMA_1	5958396,229	7465090,040	104,512	0,008	0,008	0,011	0,014
WARSZAWSKA	5959020,524	7464595,519	106,351	0,007	0,006	0,010	0,011
WARSZAWSKA_1	5958823,678	7464612,086	106,861	0,010	0,008	0,013	0,016
WARSZAWSKA_2	5958745,014	7464709,780	106,420	0,010	0,009	0,014	0,013
H12 (base stadion)	5959168,342	7464278,086	109,083				

Table 2. Test point coordinates with accuracy analysis

A distance between rover receiver and local base station had a significant impact on point position accuracy. It was dependent on a radio signal power which was generated by the BASE radio-modem. Internal radio, which was used in the experiment, had a power of 0.5W. Usefulness of radio-modems with higher power would definitely increase a range of RTK measurements. Unfortunately, it is not allowed to use such radio-modems in Poland.

Distances of ten points from base station (H12) were within one kilometer (Table 3). Five of test points were over 1000m away from the base station and GORKA point was even away of 1155,25 meters. Considering the hard environment, where the points were located, the results were very satisfactory.

Name	Grid Northing (m)	Grid Easting (m)	Elevation (m)	Distance form base station
EKSPERYMENT	5958307,052	7463877,069	104,028	950,07
GORKA	5958025,432	7464109,685	125,429	1155,25
GORKA_SZCZ	5958072,342	7464071,961	130,584	1115,21
LIDL	5958562,857	7464827,295	106,100	817,46
LIDL_1	5958417,426	7464921,753	105,728	989,03
PĘ TLA	5958974,260	7464520,262	109,888	310,35
PLAZA	5958383,128	7463935,995	102,871	856,50
PLAZA_1	5958364,536	7463934,300	104,757	874,24
REST_PRZOD	5958703,547	7463927,605	103,730	582,13
SLONECZNY	5958253,020	7463835,005	106,718	1016,92
TUWIMA	5958409,501	7465032,386	104,260	1069,96
TUWIMA_1	5958396,229	7465090,040	104,512	1120,46
WARSZAWSKA	5959020,524	7464595,519	106,351	350,16
WARSZAWSKA_1	5958823,678	7464612,086	106,861	479,95
WARSZAWSKA_2	5958745,014	7464709,780	106,420	604,62

Table 3. Test point coordinates with distances from base station

6. SUMMARY AND CONCLUSIONS

The latest GNSS/RTK technology (OTF) provides accurate centimeter-level positions in real time without the need of using post-processing. Traditional local base stations are still commonly used for distributing raw GPS data and real-time corrections of GNSS observations via RTCM protocols. This method provides many advantages for GNSS users, especially for geodesists, because of survey speed and obtained accuracy. It has also become popular in other public and private sectors. In the near future, dual-frequency GNSS receivers will be available at a moderate price, and therefore RTK activities will be focused on dissemination of GNSS corrections for applications requiring greater accuracy like intelligent vehicle navigation systems and automatic machine guidance and control systems.

Unfortunately, the classical RTK system, has a few drawbacks. The most important one is the typical short transmission range of low-powered systems caused by obstacles located in the path between a base station and a mobile receiver. Another drawback is signal interference, which can reduce transmission range and cause poor signal quality.

The field experiments proved that the performance of the system is suitable for putting it to practical use for land survey measurements that require centimeter level of accuracy.

One should also mention that in experimental situations, combination of GPS and GLONASS constellations definitely sped up all the measurements.
Field experiments showed that Topcon HyperPro receiver with integrated internal radio-modem fulfills the expectations of base station range and required accuracy in difficult urban scenario. However, there where some places (tree canopies or multipath effect close to buildings) where obtaining RTK fixed solution was difficult or impossible.

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BIOGRAPHICAL NOTES

Dr. Marcin Uradziński is an assistant professor in the Department of Geodesy and Land Management, University of Warmia and Mazury in Poland since 2006. He has been involved in GPS research since 2000. His main research topics are: integrated navigation systems and digital mapping. In 2007-2008 he was a postdoctoral fellow at the University of New Brunswick, where he carried out research related to Internet-based RTK positioning for precise navigation. In 2009-2010 he was a postdoctoral fellow at the Wuhan University where his research topic was the usefulness of moving base station for vehicle tracking systems.

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