INITIAL EVALUATION OF USEFULNESS OF GEODETIC COORDINATES OBTAINED WITH THE USE OF RTK-GPS CORRECTIONS GENERATED BY MAŁOPOLSKI SATELLITE POSITIONING SYSTEM

Dr inż. Zbigniew Siejka
Akademia Rolnicza im. Hugona Kołłątaja w Krakowie

SUMMARY

The paper presents attempt to find the answer to the question, if the experimentally functioning in Małopolska and Silesia system of reference stations is useful to determine geodetic coordinates, using real time technology when the final result of the measurement is known immediately. To obtain the aim multiple measurements were performed using the RTK-GPS technology on selected points of the POLFER network using corrections generated by the System. On a basis of empirical results of measurements, the evaluation of the usefulness of the system for geodetic applications was performed.
Reference stations network of the system ASG-PL which was tested, is one of the so called terrestrial differential systems aiding measurements GPS-RTK (real time kinematic).
Networks of the type are very often build in different countries and have national or even continental character.

1. INTRODUCTION

Established for the regions of Małopolska and Silesia (Fig. 1) System of Precise Satellite Positioning, consists now of 11 reference stations. The System is the part of the broader reference-navigating project EUPOS (European Position Determination System), which of the range including 15 countries of Eastern and Middle Europe. It is planned within the project, that individual countries will build according to uniform standard about 430 reference stations connected through national managing centers in one unified navigating system. Finally EUPOS system is going to create stabile spatial reference system, which will replace existing classical geodetic networks, in the future. To accomplish these aims the following technical assumptions were made:

- **set of reference stations form multifunctional system, which will fulfill needs as well of precise geodetic measurements as of the navigation airspace, marine and terrestrial,**
- **fundamental data will be determined in EUREF-89 reference system, uniform for the whole Europe, and then they will be transformed to national reference systems [Czarnecki, 1996],**

- all countries taking part in the project will use uniform technical standard,
- distances between reference stations will not exceed 70 – 80 km,
- all countries will reciprocally make accessible data from adjoining the borders reference stations .

Fig. 1. Distribution of reference stations of Małopolski Satellite Positioning System [www.gps.malopolska.pl]

2. MAŁOPOLSKI PRECISE POSITIONING SYSTEM

Małopolski Precise Positioning System runs basing on the VRS – Virtual Reference Stations technology and covers now the area of Małopolskie and Silesia Voivodeships, fulfills 3 bsic aims:

1. **It generates corrections RTK/DGPS available through Internet, which enable to determine in real time using satellite system NAVSTAR GPS coordinates by the RTK method with accuracy not worse than:**

± 0.03 m – horizontally,

± 0.05 m – vertically.

2. **Makes available observational data from the reference stations included into system.**
3. **Creates virtual observational data for any chosen point situated inside the reference stations area, or situated in their proximity.**

Additionally it delivers current information about conditions connected with satellites tracking for every reference station and also information about possible influence of ionosphere, troposphere and satellites orbits on performed measurements.
Data from the System are accessible for the users in Internet using the WebServer program, which enables the selection, review and receiving of data. The home page of internet service is : http://62.233.151.28.
On the other hand integrated program GPSNet archives data from base stations for the needs of postprocessing and creates correcting bulletins RTCM/CMR for the users in the field. Furthermore it enables the full supervision and control of the base stations GPS network.

Real time measurements (RTK) may be used by surveyor equipped only with mobile GPS receiver and mobile phone with GPRS technology and Internet. The phone is used to receive corrections RTK/DGPS from the network of permanent reference stations. The corrections are calculated on the base of differential measurements, that assume, that errors of satellite signal propagation are similar to each other in the same geographic area of the Earth. If the corrections are properly determined on the specified area by comparison of satellite observations performed for reference station with known coordinates, the corrections can then be used as the corrections for other measurements performed in the same time for other points determined on the specified area [Śledziński, 2005].
Additionally reference stations network in comparison to corrections from single station enables reduction of errors, which are dependent from the distance to reference station. Actually there are in the world some known and applied methods of creation of differential corrections from the area reference stations systems: FKP – Das Flachenkorrekturparameter, VRS – Virtual Reference Stations, MAC – Master Auxiliary Concept.

3. THE METHOD OF RESEARCH OF EMPIRICAL EXPERIMENTS

To accomplish the work one of the optional ways of determining corrections of real time definitely firm solution Trimble/Terrasat using technology of virtual reference stations (VRS). The technology is based on the reference stations network connected with calculating center which performs permanent supervision over the network and processes collected observational data and determines regional differential corrections. The Center of Management of Małopolski System of Precise Positioning is situated in Kraków in the Marshal Office.
The user of the system begining the measurement GPS-RTK (Fig. 2) in the range of the network, at first determines his average position using navigating solution, next he sends it to calculating center. Center equipped with the GPSNet program records position of the receiver and sends back to the user DGPS correction of very high accuracy. The user basing on received precise DGPS correction determines its new position and sends it again to the calculating center. Center generates virtual reference station in close neighbourhood of the user and determines corrections for it, and next, makes the corrections available for the user performing RTK GPS measurements.

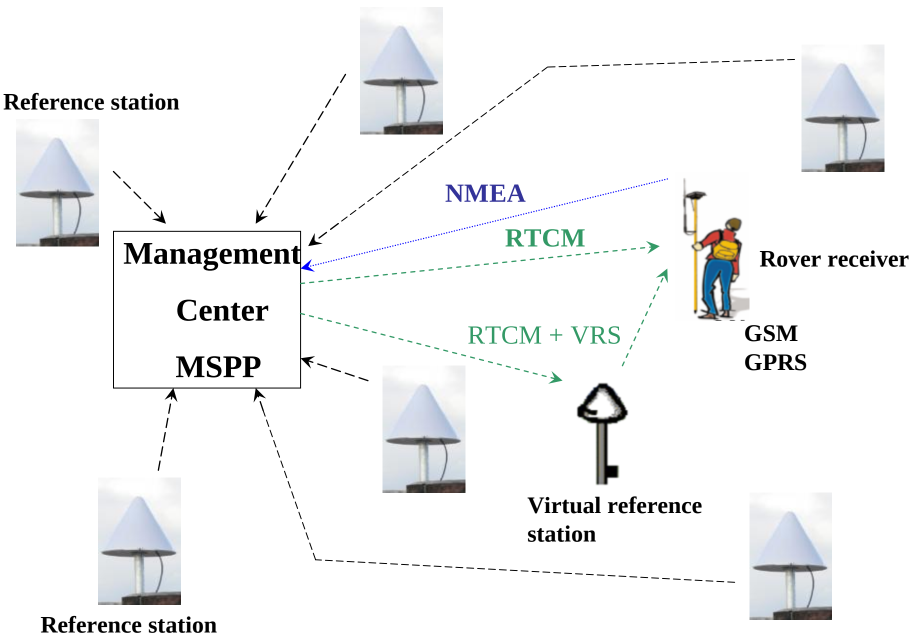

Fig. 2. Principle of functioning of virtual reference stations system.

For field measurements GPS receiver Trimble R8 GNSS with TSC@ controler was applied and to transmission of RTK corrections mobile phone working in the Era network was used.

Trimble R8 GNSS is a multichanell receiver of satellite signals GPS, GLONASS, WASS/EGNOS integrated in one casing with the aerial, internal radiomodem receiving-transmitting or GSM/GPRS modem, equipped with wireless communication and internal memory. R8 GNSS may work as a mobile receiver (rover or rover VRS) or as a basis station. The receiver is equipped with 72 channels for measurements, having abbility to receive LC2 and L5 signals, which are the element of GPS system modernization. Additionally patent firm solution of four point connection of GPS aerial applied in the receiver, gives submilimeter stability of the faze centrum of the aerial, what results in higher accuracy of measurements.

Accuracy of kinematic measurements in the system of single or multiple basis station is as follows:

- **horizontally ± 10 mm + 1 ppm (RMS)**
- **verically ± 20 mm + 1 ppm (RMS).**

During measurement corrections RTK generated by calculating system in data format RTCM SC 104 v.2.3 VRS were applied., they were received with the use of protocol NTRIP (Networked Transport of RTCM via Internet Protocol).

Verifying measurements were performed on fourteen points of POLREF network, during the measurements coordinates were recorded in following systems: Cartesian, geocentric, and geographic on WGS84 ellipsoid and national coordinates in 2000 system. Normal heights of the points were determined on the basis of leveling geoid model 2000, elaborated by professor Kadaj. To minimize errors of GPS aerial position over the point, the receiver with the aerial were positioned together above the point for the whole time of measurement on a geodetic tripod. Leveling and centring of the antenna was every time performed using optical plummet produced by FREIBERGER PARZISIONMECHANIK FG-OZL with accuracy of centring ±0.25 mm/1.5m. On

every point 75 measurements RTK-GPS were performed and their results were recorded in the memory of TSC2 controller in appropriate observation files. Measurements were conducted using more then 6 satellites and PDOP of 4 or below.

4. ANALYSIS OF OBTAINED RESULTS

Detailed analysis was performed for all national coordinates in 2000 system obtained from the measurements. The errors of coordinates were calculated as differences between catalogue coordinates which were assumed as accurate and the results obtained from measurements. Table 1 presents the results of the measurements listed in two ranges of errors for each investigated variable. From the analysis two points: 1508 ŁOSIEŃ and 501 KOSKOWA were excluded, because on these points some significant disturbances of GPRS transmission during measurements were discovered.

Table 1. Differences between catalogued coordinates and obtained from measurements.

POINT NUMBER	VARIABLE	OBTAINED DIFFERENCES OF COORDINATES	
		0.05 m – 0.03m	< 0.03m
1606 JAKSICE	dx	1 %	99 %
	dy	0 %	100 %
	dh	0 %	100 %
1605 ŁĘTKOWICE	dx	0 %	100 %
	dy	0 %	100 %
	dh	0 %	100 %
603 OLSZANA	dx	0 %	100 %
	dy	0 %	100 %
	dh	3 %	97 %
310 GRYBÓW	dx	0 %	100 %
	dy	0 %	100 %
	dh	6 %	94 %
1505 ZAGÓRZE II	dx	0 %	100 %
	dy	0 %	100 %
	dh	0 %	100 %
1509 ZAGÓRZE	dx	12 %	88 %
	dy	0 %	100 %
	dh	4 %	96 %
1405 RADZIONKÓW	dx	0 %	100 %
	dy	0 %	100 %
	dh	57 %	43 %
503 WIEPRZ	dx	1 %	99 %
	dy	0 %	100 %
	dh	28 %	72 %
404 WAWRZACZÓW	dx	0 %	100 %
	dy	0 %	100 %
	dh	94 %	6 %
403 GUMNA	dx	0 %	100 %
	dy	0 %	100 %
	dh	26 %	74 %
401 RADOSTOWICE	dx	67 %	33 %
	dy	0 %	100 %
	dh	44 %	56 %
308 ROGACZEW	dx	0 %	100 %
	dy	0 %	100 %
	dh	0 %	100 %

Analysis of the standard deviation as a measure of mean standard error showed the high internal accuracy of determined coordinates. Average standard deviation for plane coordinates was in the interval between: $\sigma = 2mm$ and $\sigma = 9mm$. However determined standard deviation for vertical coordinate was in the interval between $\sigma = 4mm$ and $\sigma = 12mm$.

Furthermore results obtained from the measurements was elaborated statistically to verify hypothesis about the normal distribution of measurement errors of measurements obtained on control measuring points. To obtain the aim two normality tests were performed:

Kołmogorow-Lilliefors test and W Shapiro-Wilk test. Both tests were performed on the significance level of α=0.05. The results of tests are put together in Table 2 in binary system.

Table 2. Results of statistical tests.

POINT NUMBER	VARIABLE	RESULTS OF THE TESTS	
		KOŁMOGOROWA – LILLIEFORSA	SHAPIRO - WILKA
1606 JAKSICE	dx	0	0
	dy	1	1
	dh	1	1
1605 ŁĘTKOWICE	dx	0	0
	dy	1	1
	dh	1	1
603 OLSZANA	dx	1	1
	dy	1	1
	dh	1	0
310 GRYBÓW	dx	1	1
	dy	1	0
	dh	1	1
1505 ZAGÓRZE II	dx	1	0
	dy	0	0
	dh	1	1
1509 ZAGÓRZE	dx	0	0
	dy	1	0
	dh	1	1
1405 RADZIONKÓW	dx	1	1
	dy	1	1
	dh	1	1
503 WIEPRZ	dx	1	1
	dy	1	0
	dh	1	1
404 WAWRZACZÓW	dx	1	1
	dy	1	1
	dh	1	0
403 GUMNA	dx	1	1
	dy	1	1
	dh	1	1
401 RADOSTOWICE	dx	1	1
	dy	1	0
	dh	1	1
308 ROGACZEW	dx	1	1
	dy	1	1
	dh	1	1

1 – There is not enough evidence to reject the hypothesis about the normal distribution on the significance level α = 0,05.
0 – null hypothesis about the normality of distribution has been rejected on the significance level α = 0,05

5. CONCLUSIONS

Detailed analysis of obtained results shows that in the case of Kołmogorowa-Lillieforsa consistency test the null hyupothesis was rejected for 11% investigated variables. However in the case of more demanding W Shapiro-Wilk test the null hypothesis was rejected for about 27% of investigated variables.

It is well known, that when the hypothesis was not rejected, it does not mean that it was accepted. Therefore in further analysis additionally the coefficient of skewness was calculated as a measure of asymmetry of distribution for each analysed variable. Values of the coefficient were:
negative , for distributions of leftside asymmetry – 13 cases,
positive, for distributions of rightside asymmetry – 17 cases,
close to zero for symmetric distributions – 6 cases.

On the basis of presented above analyses it is possible to come to a conclusion generally about usefullness of the method for the geodetic measurements. The essential advantage of applied method is the increase of accuracy of mobile station coordinates determination, increase of the range of measurements and reduction of performance costs. However on the basis of the coefficient of skewness for particular variables it is possible to come to a conclusion that there exist some systematic errors, which appear in the applied method of coordinates determination. But evaluation of these errors is possible on investigation of more numerous statistical sample. Significant limitation of the described method is limited range of GPRS transmission, what caused the rejection of measurement results on two analysed points.

6. REFERENCES

Czarnecki K., 1996. Geodezja współczesna w zarysie. Wydawnictwo Wiedza i Życie.
Śledziński J., 2005. Technologie pomiarów GPS. Geodeta. Nr 3.