THE ARCHIVES OF TRANSPORT

VOL. XXIII NO 3 2011

10.2478/v10174-011-0021-x

# Selected Problems of Determining the Course of Railway Routes by Use of GPS Network Solution

Władysław Koc*
Cezary Specht*

Received November 2010

**Abstract**

The main problem related to railroad surveying design and its maintenance is the necessity to operate in local geodetic reference systems caused by the long rail sections with straight lines and curvatures of the running edge. Due to that reason the geodetic railroad classical surveying methods requires to divide all track for a short measurement section and that caused additional errors. Development of the Global Navigational Satellite Systems (GNSS) positioning methods operating in the standardized World Geodetic System (WGS-84) allowed verification of capability of utilization GPS measurements for railroad surveying. It can be stated that implemented satellite measurement techniques opens a whole new perspective on applied research and enables very precise determination of data for railway line determining, modernization and design.

The research works focused on implementation GNSS multi-receivers measurement positioning platform for projecting and stock-taking working based on polish active geodesic network ASG-EUPOS, as a reference frame. In order to eliminate the influence of random measurement errors and to obtain the coordinates representing the actual shape of the track few campaigns were realized in 2009 and 2010. Leica GPS Total station system 1200 SmartRover (with ATX1230 GG antennas) receivers were located in the diameter of the measurement platform. Polish Active Geodetic Network ASG-EUPOS was used as a reference network transmitted Real Time Kinematic Positioning Service according to RTCM 3.1 standard. Optimum time period were selected for GNSS campaign and testing area was chosen without large obstructions.

The article presents some surveying results of the measurement campaigns and also discusses the accuracy of the course determination. Analyzes and implementation of results in railroad design process are also discussed.

* Gdansk University of Technology, Gabriela Narutowicza 11/12, 80-233 Gdańsk, e-mail: wladyslaw.koc@pg.gda.pl

**Keywords:** rail track, satellite surveying GPS, course of railway route

# 1. Introduction

Line sections and curves on a railway area are very often so large that visual evaluation of their shape is impossible. Conventional geodesy requires division of the railway route into smaller parts examined separately. It becomes an additional errors source and a total appraisal of particular geometrical system is difficult. Development of geodesic satellite techniques combined with improving precision of GPS (Global Positioning System) measurements induces geodesists to make an attempt to apply GNSS technique for the purpose of making inventory of railway tracks. Accessible to researchers at the beginning of the 21 century measurement techniques and development of the RTK (Real Time Kinematics) methods have allowed researchers to obtain measuring accuracy of one centimetre at 1÷5 Hz frequencies with necessity of additional altitude measurement reduction between ellipsoidal and geoidal heights [8].

Meaningful change of quality has appeared with emission GPS/GPRS (General Packet Radio Service) at transmission of active geodetic network service. In 2004 year RTCM (Radio Technical Commission for Maritime Services) introduced NTRIP (Networked Transport of RTCM via Internet Protocol) which determined usage of wireless radio links in relation base receiver (or active geodetic network) – rover receiver [14].

In 2008 project of a GNSS reference station system (Active Geodetic Network) designed for Poland, was carried out by the polish authority for geodesy – Head Office of Geodesy and Cartography. The precise GNSS satellite positioning network ASG-EUPOS was also a part of the European Position Determination System (EUPOS), which has prepared the standards for reference systems for countries in Central and Eastern Europe, in order to establish a unified infrastructure for positioning services.

Research works consisted in taking a few dozen kilometre railway detour by a motor truck WM 15 with GNSS positioning receivers installed on platform and used ASG-EUPOS network. The initiator of experimental research was Gdansk University of Technology – Department of Railway Engineering and Chair of Geodesy; Polish Naval Academy in Gdynia – Faculty of Navigation and Naval Weapons. Technical support was given by Railway Lines Works of PKP PLK S.A. in Gdynia and measuring apparatuses were given by Leica Geosystems GA.

# 2. Development of Global Positioning System

Permanent GNSS observations were implemented by large-area GPS reference stations networks and now are transformed into complex data communication system. They have offered not only post processing GPS services but also the provision of real time corrections transmission. The first stage of GNSS permanent observations implementation was national passive GNSS reference systems created at the beginning of the 1990s, also in our country [1]. They have evolved from single reference stations located at technical universities to national complex systems.

The first idea of creation permanent station network GNSS was prepared in 1995 on the initiative of Satellite Geodesy Board of PAN (Polish Academy of Sciences) Cosmic and Satellite Research Committee and Geodesy Networks Section of PAN Geodesy Committee [2]. It was assumed that the network should be multifunctional and adapted not only to geodesy. In consequence of different centres' activity, the local stations were forming. They were created in Warszawa, Łódź, Gdańsk, and at intensive mining industry area of Upper Silesia as well as Lubin-Głogów Copper Area [3]. Then a six-point network at Silesia and a three-point network at the Three-City area were created [5].

The dominant world trend at the beginning of the 21 century was starting active national network activity, for example CORS, SAPOS, SWEPOS, OS-AGN (Fig. 1).


Fig. 1. Architecture of chosen active geodetic networks: a/ SWEPOS – Sweden, b/ OS-AGN – Great Britain, c/ CORS – USA

The networks generally offered to users payable or unpaid services as well as always payable real time services [6, 12]. Modernity of network techniques, compared to classical coordinates determination with exploitation of single reference station and movable receiver in RTK method, lies among other things in implementation of correction using virtual reference station VRS [8]. It enables working out of pseudo-distance correction dedicated to receiver coordinates [11].

## 3. Polish ASG-EUPOS Network

The concrete initiative to establish compatible GNSS reference station systems in Europe started by the more than 50 participants from 16 countries on the workshop on ”Multifunctional GNSS Reference Station Systems for Europe”, 4-5 March 2002, Berlin, Germany. In Berlin, in 2002 was taken a decision about European Position Determination System (EUPOS) development in the direction of the East. The EUPOS is an initiative to establish a uniform DGNSS basis infrastructure in Central and Eastern Europe (CEE). Uniform multifunctional DGNSS reference station systems and services are going to be build up in 18 participating CEE countries. EUPOS will in the end cover 25% of the European Union territory and more than 60% of the area of whole Europe.

Polish part ASG-EUPOS – multifunctional precise positioning system project was finished in 2008 utilizing the resources of the European Regional Development Fund within the Operational Programme “Improvement of the Competitiveness of Enterprises”. The goal of building of ASG-EUPOS system is to provide web-enable corrections for GNSS observations performed with satellite receivers and enabling the precise positioning and navigation in Poland.

The Polish part of the system ASG-EUPOS has consisted of 98 reference stations evenly located over the country (Fig. 2). Except for the new starting up stations, the system has adapted also existing stations managed by universities, research and development centres, state administration and private firms. At the present moment ASG – EUPOS is composed of the following reference station groups: 84 stations with GPS module, 14 stations with GPS/GLONASS module. Additionally the system has cooperated with nearly 30 foreign stations.

National Management Centres, called also Counting Centres are the second segment of ASG-EUPOS system. Central Office is located in Warszawa with spare station in Katowice. They have a task of controlling, managing stations network and pseudoange correction calculation.

Using mobile Internet, the user’s rover receiver has to send its position in a GGA string (NMEA 0183 version 3.01 formatted) to the provider’s Internet NTRIP caster to select the favorable ASG-EUPOS reference station automatically. But also the user’s direct selection of the ASG-EUPOS reference station is supported. If broadcast is used, the selection of the favorable GNSS reference station has to be carried out by selection of the corresponding station.

Satellite GNSS network surveying usage, in contradistinction to the classical geodetic GPS measurement allows removing different types of signal pseudorange errors like: satellite clock error, ionosphere and troposphere refraction and some instrumental receiver errors. The networking accuracy is strongly correlated with the distance between the user receiver and reference stations. The lower figure presents the accuracy of position coordinates determining within the GNSS network (different distances between user receiver and reference stations) [11].

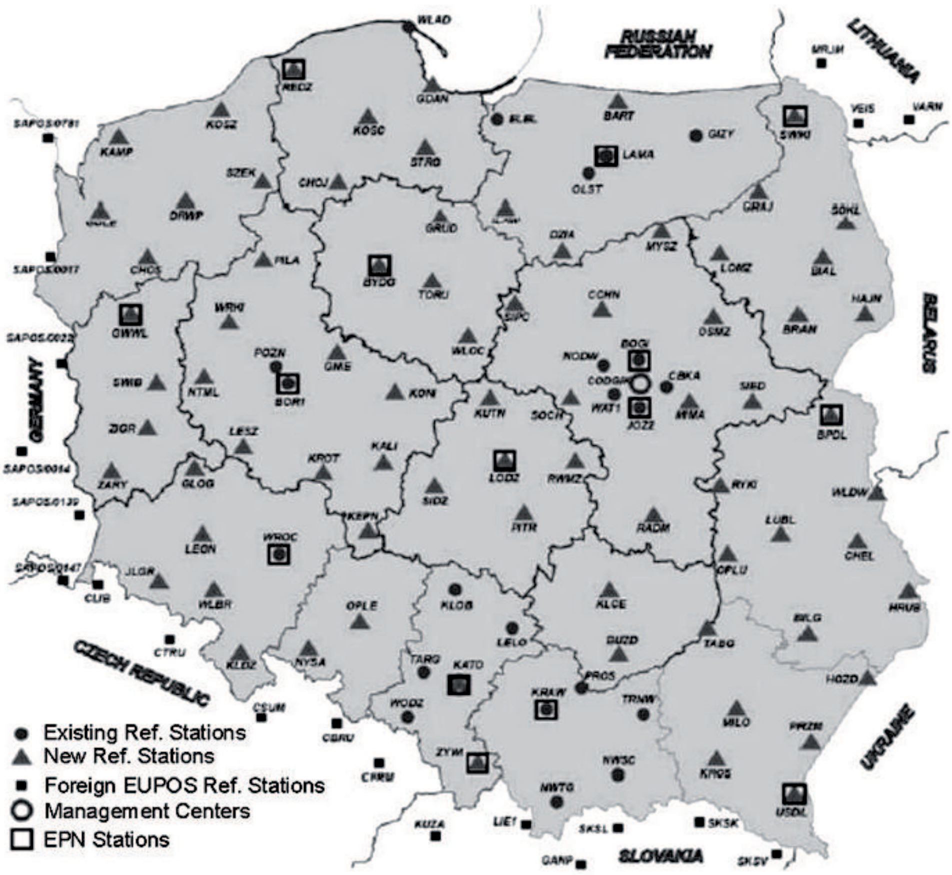


Fig. 2. Location of the reference station in ASG-EUPOS system

GPS pseudorange correction implementation – with modeling – reduces significantly influence of most environmental factors. It is worth using ASG-EUPOS service characteristics. Configuration connected with medium distances between GNSS reference stations has meaningful influence on the determining active geodetic network accuracy. Particularly interesting research at that range of activity was carried out in 2003 year [11]. Precision of coordinates determining for network with diversified distance 30, 50, 70, 100 kilometres between stations was verified. Results were related to real-time measurements.

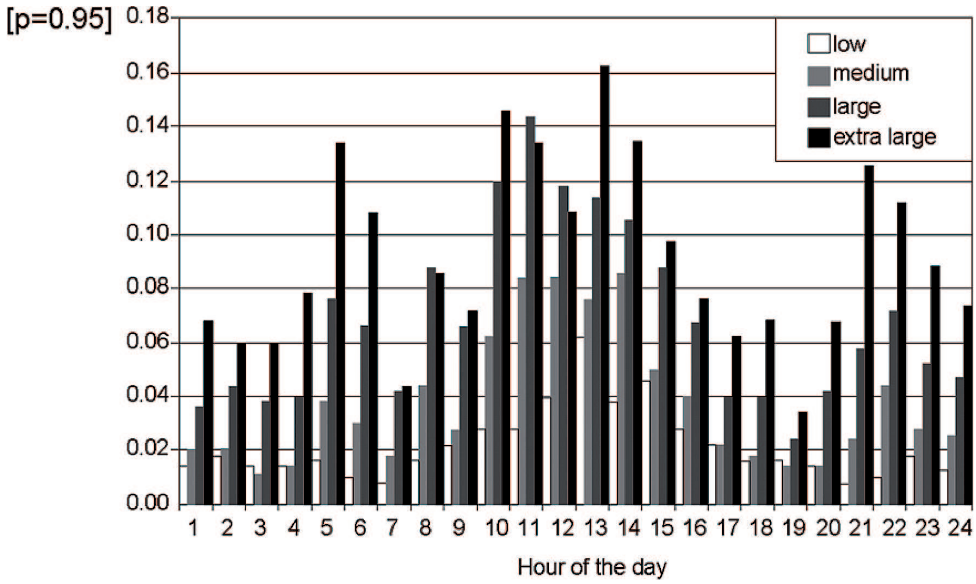


Fig. 3. Accuracy of the position coordinates determining within the GNSS network (the colours represent different distances between user receiver and reference stations) [11]

Results conclusions (Fig. 3) indicate meaningful connection between station distances and determining coordinates error. The error is mainly a consequence of ionosphere and troposphere GPS signals refraction. Analysis of presented results was made and it is possible to obtain 1÷2 cm accuracy.

The Polish ASG-EUPOS network has been working since 2008 year [15]. The complex measure tests of all real-time and post-process services and obtained results analysis were made. Additional tests of compatibility correction were also carrying out. Test territories are numbered as in Fig. 4.

In every test territory at least 5 points were measured, among them 1 EUVN point (European Unified Vertical Network), minimum 2 POLREF points (Polish Reference Frame) and 1 altitude matrix point of I or II class. Within test territories (1, 2, 3) six points were measured; in the rest territories 5 points were measured. Essentially measurements were made in 48 points over the country and 58 independent complex measure tests were made together. Gdańsk University of Technology, University of Warmia and Mazury in Olsztyn and Polish Naval Academy in Gdynia carried out accuracy assessment of NAVGEO service during all 58 independent and comprehensive test measurements. They were carried out with usage of all kind of correction in the following: RTCM 2.3 from single station, RTCM 3.1 from single station, RTCM 3.1 (surface correction) (Net, Max), RTCM 2.3+FKP (surface correction), RTCM 3.1+VRS (surface correction), RTCM 2.3+VRS (surface correction).

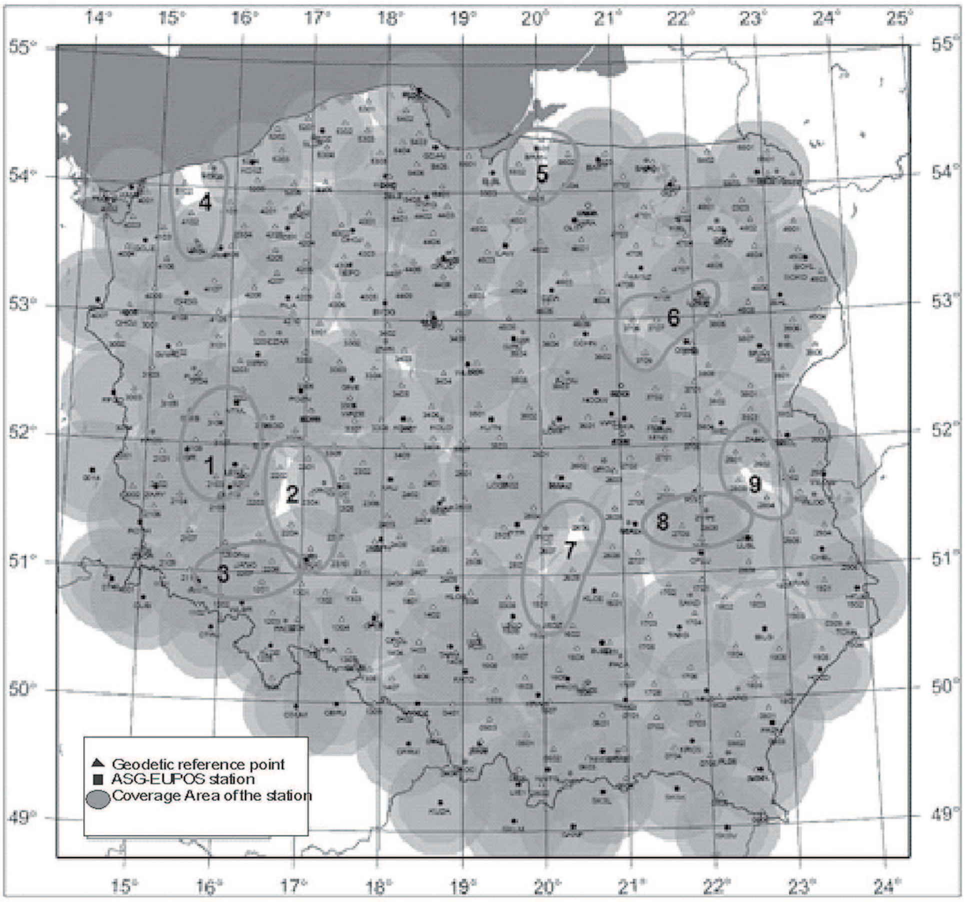


Fig. 4. Test area with working numeration implemented for particular territories in the project

RTK measurements were carried out with raw observation recordings which were converted into RINEX format (Receiver Independent Exchange Format). Measurements were recorded in World Geodetic System WGS-84. They were made at the real-time with GPRS correction transmission, NTRIP protocol, Plus GSM, Era GSM and Orange mobile communications. At each point 6 types of real time geodetic services were carried out and for each service 5 sessions with 10 measuring points were made. Altogether at test points 17.400 five-second independent RTK measurements were made. The position errors between point catalogue coordinates and results of the campaign measurements, for 39 chosen measuring points, are shown in Figure 5.

It is possible to obtain two-dimensional coordinates with 1÷2 cm accuracy at 1÷2 cm level with ASG-EUPOS; it means that it is possible to obtain analogous accuracy at railway route inventory.

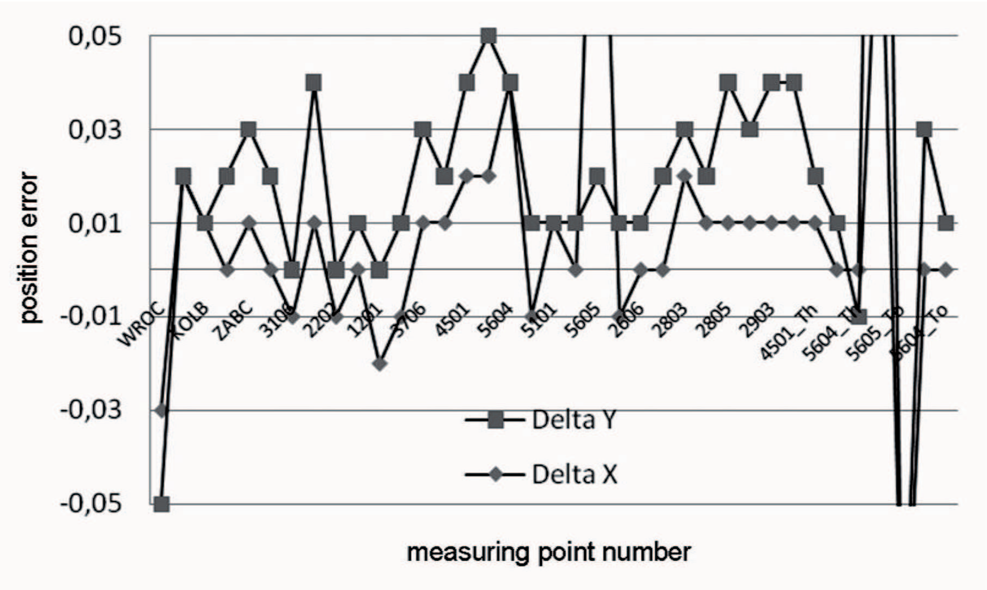


Fig. 5. Position accuracy for 39 chosen measuring points calculated in the testing campaign [15]

## 4. GNSS Active Geodetic Network Measurements of Railway Track

In 2009, at the Gdańsk University of Technology started continuous satellite surveying of railway track by the use of the relative phase method based on geodesic active network ASG-EUPOS and NAVGEO service. Still continuing research works focused on the GNSS multi-receivers platform evaluation for projecting and stock-taking. Next year the same team repeated similar measurements (07.04.2010) on the railroad. Four (in 2009) and next three (in 2010) Leica GPS Total station system 1200 SmartRover (with ATX1230 GG antennas) receivers were located on the platform (Fig. 6 and Fig. 7). Polish Active Geodetic Network ASG-EUPOS was used as a reference network transmitted Real Time Kinematic Positioning Service according to RTCM 3.1 standard.


Fig. 6. GPS Total station receivers location on the platform (trials in 2009)

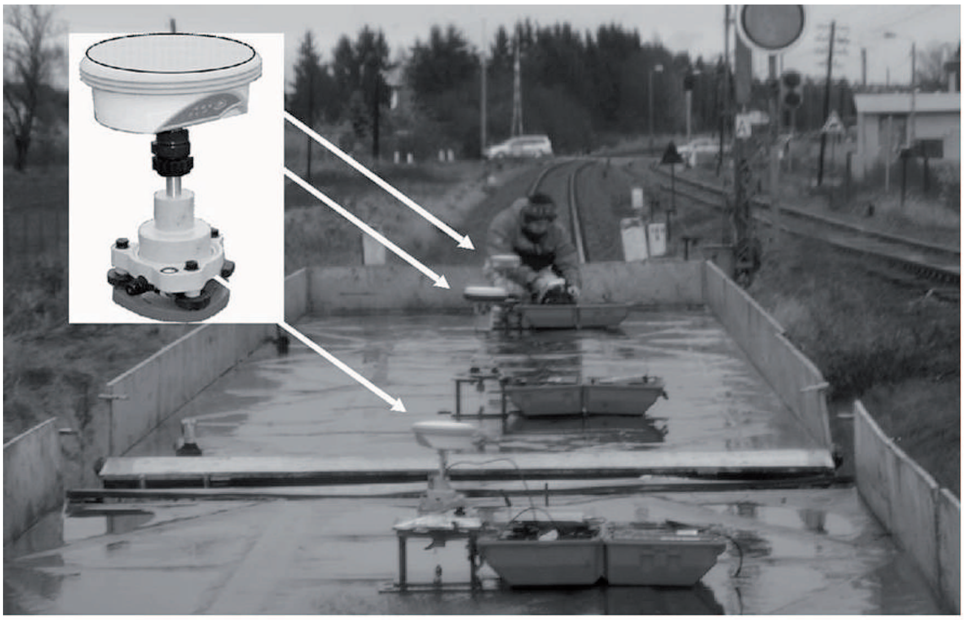

Fig. 7. GPS Total station receivers location on the platform (trials in 2010)

For the best determination of the measurement time period software Leica Survey Design was used. It shoved the best constellation for GPS satellites were between 10.40–11.40 LMT and 12.40–14.40 LMT. The GPS system guaranteed 8÷9 satellites with low values of PDOP (Position Dilution of Precision) and GDOP (Geometric Dilution of Precision) coefficients (Fig. 8).

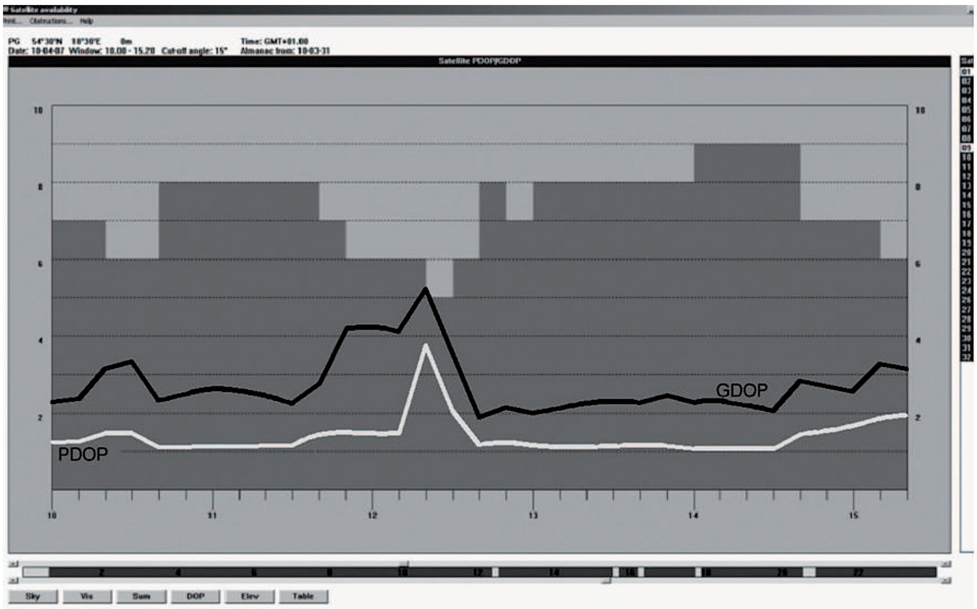


Fig. 8. Satellite availability and PDOP values during the measurements

In order to evaluate accuracy characteristics of different GNSS methods received positions were recorded. Data files were containing position time series in the format of NMEA 0183 standard, GGA referenced to WGS-84 datum ($a$= 6378137,00m, $b$= 6356752,314m). The World Geodetic System 1984 (WGS84) datum is the nominal datum used by GPS. It is based on the WGS84 ellipsoid which only exhibits a small difference in the flattening parameter compared to the GRS80 and therefore both ellipsoids can be assumed identical for most practical purposes.

Measured ellipsoidal coordinates were transformed to Gauss-Kruger ($X$,$Y$) conformal coordinates, based on relations:

$$y = R \cdot \left[ dL\cos(B) + \frac{dL^3}{6}\cos(B)^3\left(1 - t^2 + \eta^2\right) + \right.$$
$$\left. + \frac{dL^5}{120}\cos(B)^5\left(5 - 18t^2 + t^4 + 14\eta^2 - 58\eta^2 t^2\right)\right] \tag{1}$$

$$y = k \cdot R\left[\frac{S(B)}{R} + \frac{dL^2}{2}\sin(B)\cos(B) + \frac{dL^4}{24}\sin(B)\cos(B)^3\left(5 - t^2 + 9\eta^2 + 4\eta^4\right) + \right.$$
$$\left. + \frac{dL^6}{720}\left(\sin(B)\cos(B)^5\right)\cdot\left(61 - 58t^2 + t^4 + 270\eta^2 - 330\eta^2 t^2\right)\right] \quad (2)$$

where: $B$, $L$ – measured ellipsoidal coordinates, $R$ – radius of curvature in the prime vertical, $S(B)$ – distance from the equator to defined coordinate $B$, $dL$ – difference in longitude between $L$ and prime meridian, $k$ – scale factor ($k$ = 0,999923).

Other parameters could be calculated as:

$$t = \tan(B) \quad (3)$$

$$\eta = \frac{e^2\cos(B)^2}{1 - e^2} \quad (4)$$

where: $e$ – eccentricity of ellipsoid, $\eta$ – orientation angle of distortion ellipses.

# 5. Practical Applications of the Results

On the basis of the obtained results it was possible to define the main direction of the whole railway route and its segments. These are basic data to design a geometric system of railway route. For that purpose, a particular run of the route was examined on railway segments. The final measurement was conducted in ellipsoidal GPS coordinates and transformed into Gauss-Kruger ($X$,$Y$) conformal coordinates. This procedure allows confronting two main issues: possibility to establish the railway route and turning angle determination for the design purpose and also determination of the railway route (arcs and transition curves) for the modernization purpose. The analysis is presented on the example of geometric system (Fig. 9) where two, relatively long, straight lines utilize the position obtained from GPS.

Let us define the straight line in the parametrical form as time functions: $X(t)$ and $Y(t)$, where measured errors impact on dependent values: $X$ and $Y$. The method of least squares is applied to calculate the equations. Then for straight line 1 (Fig. 9), we can write parametric equations for coordinates measured by receiver A:

$$X = 5997482,803 + 2,87311t, \quad (5)$$

$$Y = 6498829,206 - 0,03388t, \quad (6)$$

where $t$ = 2151,00 ÷ 2493,20 s.

The equations (5), (6), can be written in a Cartesian coordinate system ($Y$, $X$) as:

$$X = 557114695,89386 - 84,80253837Y \quad (7)$$

The directional coefficient of the line $b = \tan\phi$ were calculated for other three GPS receivers; the final form is presented below:

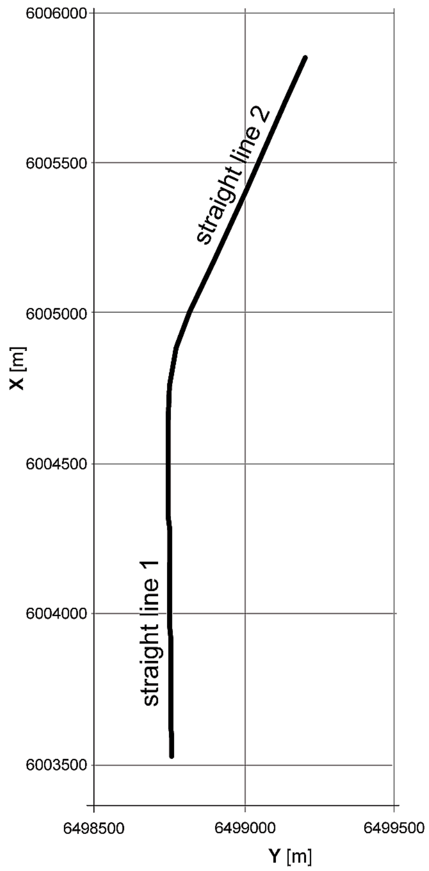


Fig. 9. Geometric system under consideration

- for receiver *B* $X = 557268029{,}52202 - 84{,}82609979\ Y$ (8)
- for receiver *C* $X = 556946536{,}77392 - 84{,}77663027\ Y$ (9)
- for receiver *D* $X = 557114696{,}09606 - 84{,}80135773\ Y$ (10)

In our case, the particular segment of the route was calculated on the basis of 1713 measurements obtained from GPS receivers. Presented results proved small differences between directional coefficient $b$ estimated for GPS receivers and confirmed the high usefulness of the proposed method. The next step was to calculate the turning angle. For GPS receiver $A$ directional coefficient was equal –84,80253837 and means $\varphi_1 = 90{,}6756^0$. Let us define the equation $X = f(Y)$ for straight line 2 as (receiver A):

$$X = -8405165,30199 + 2,21735165Y \tag{11}$$

For straight line 2, tan $\varphi_2 = 2{,}217352$, then $\varphi_2 = 65{,}7252^0$. The module of the turning angle can be presented as $|\alpha\ | = |\varphi_2 - \varphi_1| = 24{,}950^0$.

The area where the route changes direction can be determined in relatively a simple way when the coordinates of the route are transformed into the symmetrical position as presented in Figure 10. The new transformed coordinates can be calculated as the following equations:

$$x = (Y - Y_0)\cos\beta + (X - X_0)\sin\beta \tag{12}$$

$$y = -(Y - Y_0)\sin\beta + (X - X_0)\cos\beta \tag{13}$$

where rotation angle $\beta$ has a form:

$$\beta = \varphi_1 + \frac{\alpha}{2} = \frac{1}{2}(\varphi_1 + \varphi_2) \tag{14}$$

For GPS receiver $A$, calculated angle rotation $\beta$ was established as 1,36485432 rad. The conformal coordinates of the turning point were calculated as: $Y_0$ =6498745,04911 m, $X_0$ = 6004519,50986 m. Final equations of the straight railway route lines were as follows (15,16). Figure 10 presents the area of direction change of the railway route in the local coordinate system ($X_{loc}$, $Y_{loc}$):

$$y(1) = 0,221241x \tag{15}$$

$$y(2) = 91,89349 - 0,221241x \tag{16}$$

Performed measurements enabled very precise definition of main direction position and turning angle of existing railway route [9]. These are basic data for design of railway lines geometric system. For that purpose a particular run of the route on railway line segments was examined. The obtained results from specified antennas were examined independently. The results were taken on chosen line segment with $B$ antenna (located nearby the motor truck cabin) and $C$ antenna (located far away from the motor truck cabin). Taking into consideration preceding procedure described in work [9] and data of 1507 measuring points, the authors have obtained the following straight line equation (in National Coordinate System called “2000”):

- receiver $B$ $X = -\ 8411684,83136 + 2,2183539\ Y$ (17)
- receiver $C$ $X = -\ 8409472,52597 + 2,21801348\ Y$ (18)

In order to obtain information on quality of coordinates estimation, the coordination system transformation must be done (Fig. 11). Dependency diagrams $X_1(Y_1)$ for both examples (receiver B and receiver C) are show in Figures 12 and 13.

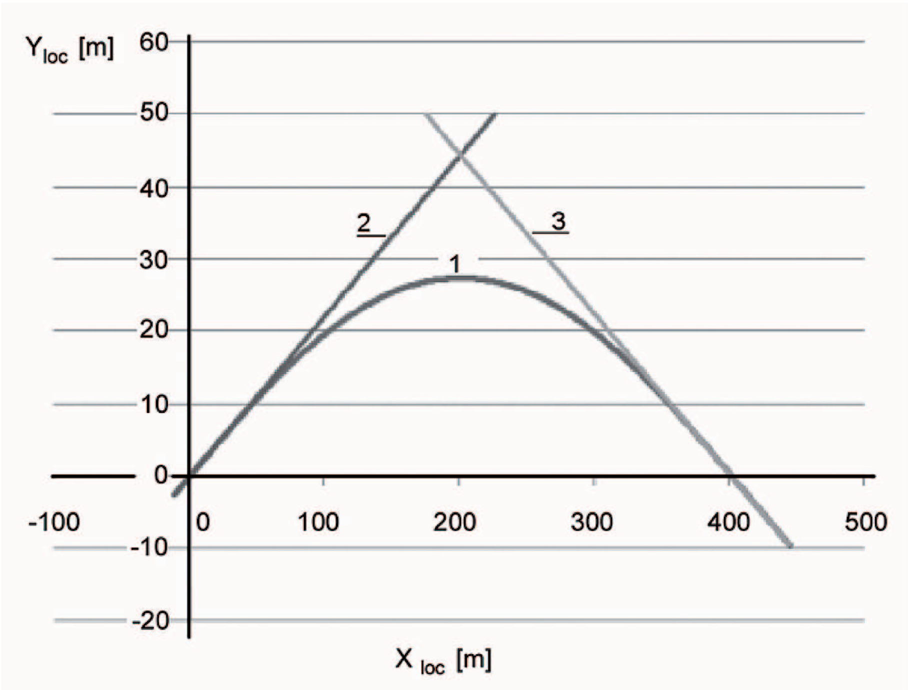


Fig. 10. Treated part of the railway route in the local coordinate system; 1 – route course in the arc, 2, 3 – directions of adjacent straight lines

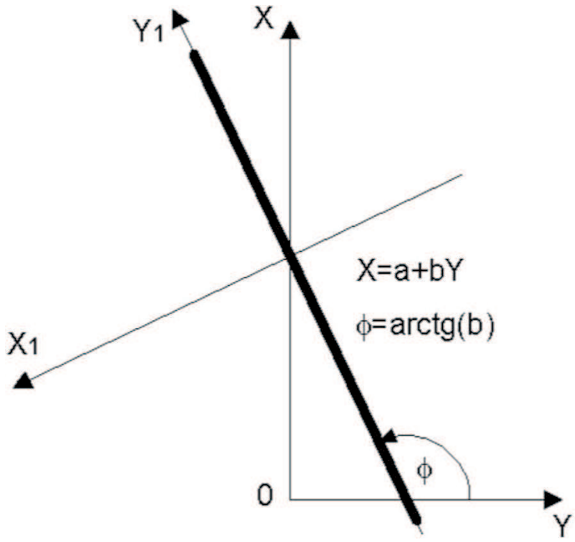


Fig. 11. Idea of coordinate system transformation

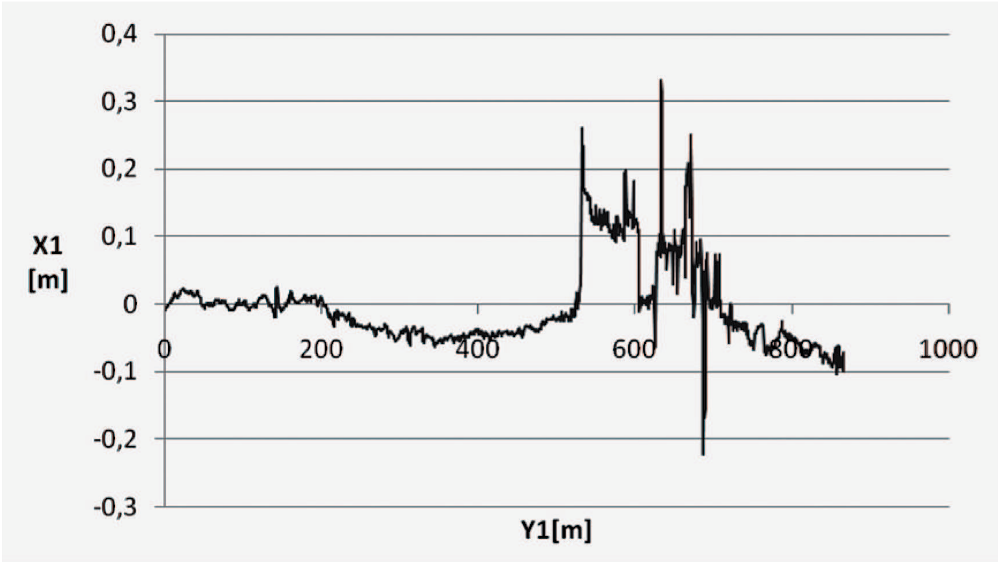


Fig. 12. Dependency diagram $X_1(Y_1)$ for considered straight line on the basis of $B$ receiver results

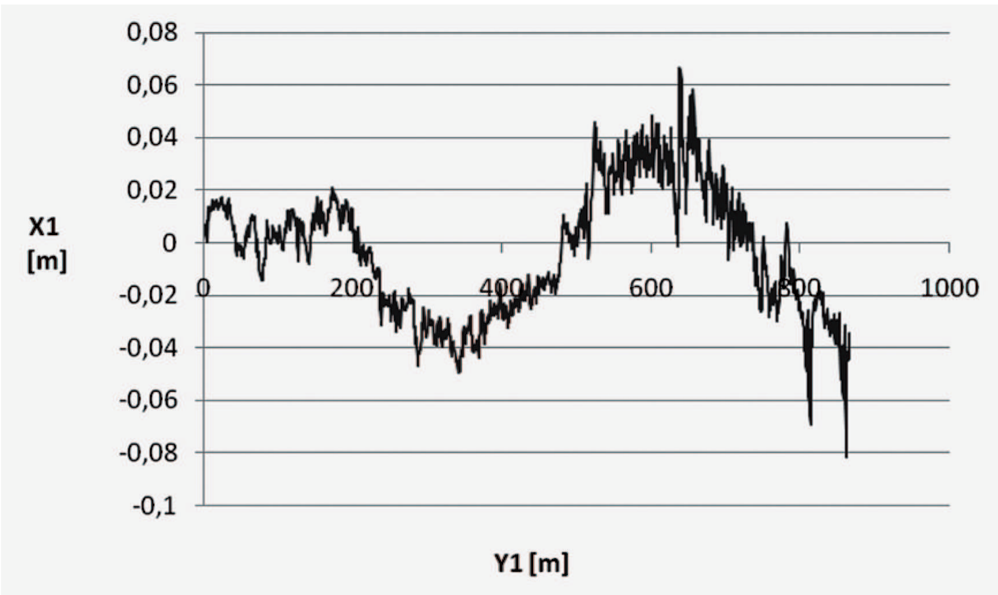


Fig. 13. Dependency diagram $X_1(Y_1)$ for considered straight line on the basis of $C$ receiver results

Standard deviation for B receiver data (Fig.12) was calculated as 0,0607 m and for C receiver (Fig. 13) it was 0,0242 m. Results from receiver A (similar location to receiver B) archived standard deviation as – 0,0711 and confirmed strong impact of the cabin as a satellite view obstracle. Accuracy of the receiver D measurements (far from the cabin) with standard deviation 0,0256 were similar to receiver C.

In 2010 the same trials on the railway route were done. Archived receiver position accuracy were almost the same. Additionally, the measurements showed that precision of the railway course determination depends also on the line regression errors which are strongly correlated with the technical status of the railroad. The trials were done in the Gdańsk Główny Station before and after modernisation. Figure 14 presents cross track error-XTE for GNSS receivers positions archived before railway track modernisation (approximately 200 m straight line). The Six GNSS receivers tracks (3 receivers track into two ways) are presented and their $Y$, $X$ regression line. The standard deviation of XTE position receivers were calculated as a 13÷15 mm. Used in the figure the abbreviations mean: VRS1, VRS2, VR3 results related to the first trail and Vertical Reference Station ASG-EUPOS Solutions. Others like: 2FPF, 2VRS, 2MAC relate to the opposite site measurements based on Flächen-Korrektur-Parameter FKP (in German) and The Master-Auxiliary Concept ASG-EUPOS Solution.

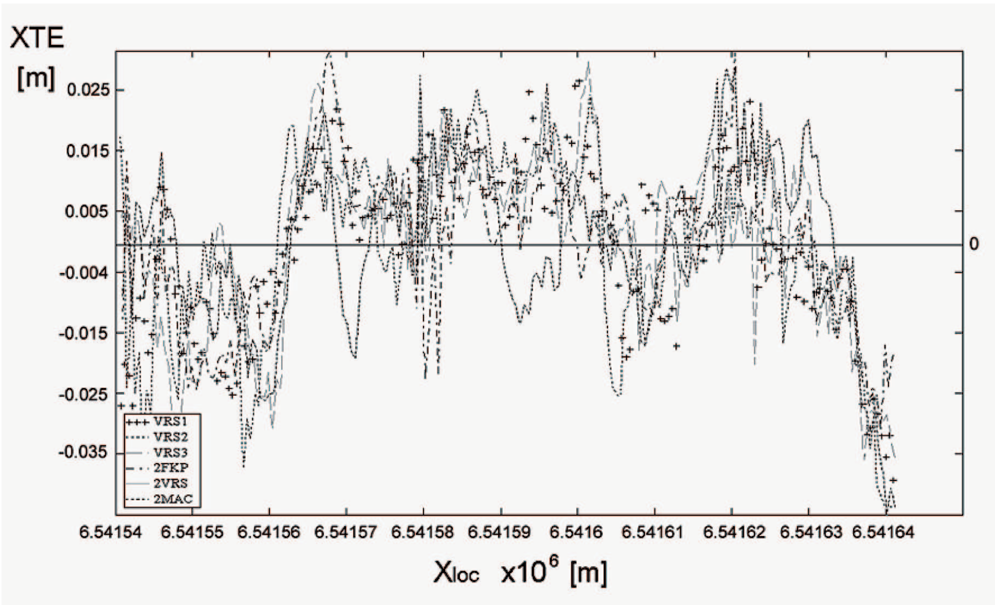


Fig. 14. GNSS receivers cross track error in [m] of the regression line archived on the railroad before modernisation – 2009

Figure 15 presents similar results for 3 GNSS receivers after modernisation, where the same errors were archived between 8÷10 mm.

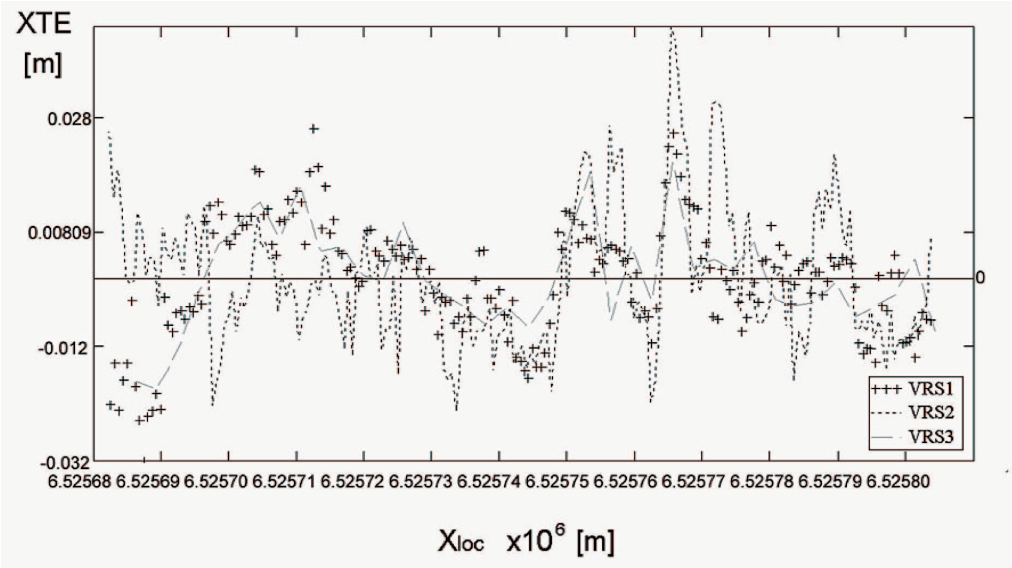


Fig. 15. GNSS receivers cross track error in [m] of the regression line archived on the railroad after modernisation – 2010

# 6. Conclusions

The research works focused on implementation GNSS multi-receivers measurement positioning platform for projecting and stock-taking working based on polish active geodesic network ASG-EUPOS, as a reference frame. In order to eliminate the influence of random measurement errors and to obtain the coordinates representing the actual shape of the track few campaigns were realized in 2009 and 2010.

Measurement carried out with ASG – EUPOS network demonstrated the accuracy differences between stationary measurements presented in work [15] and direct testing results of the platform.

Presented research is a result of a general report obtained from measurement campaign and focuses on establishing GPS active geodetic network capabilities in railway route determination. The future analyses and trials will enable to explore the estimation methods further, especially in the aspect of the railway route regulation.

The main reason of the receivers position accuracy were conditions of geometric observation represented by geometric coefficient DOP (local diaphragms). The analysis indicated strong connection between location of GNSS receiver and accuracy of position determination.

At the present stage, it can be stated that implemented measuring technique opens a new perspective on polish active geodetic network - ASG-EUPOS application for determination of the course of railway routes. As proved, it enables very precise determination of basic data definition for railway line modernization design.

## References


1. Baran W.: New National System of Geodetic Coordinates in Poland, Geodezja i Kartografia 1994, vol. XLIII, no. 1 (in Polish).
2. Baran L.W., Zieliński J.B.: Active GPS Stations as a New Generation of the Geodetic Network, Geodezja i Kartografia 1998, vol. XLVII, no. 1-2 (in Polish).
3. Baran L.W., Oszczak S., Zieliński J.B.: The use of cosmic techniques in geodesy and navigation in Poland, Nauka 2008, no. 4 (in Polish).
4. Bosy J., Graszka W., Leonczyk M.: ASG-EUPOS The Polish Contribution to the EUPOS Project, Symposium on Global Navigation Satellite Systems, Berlin, November 2008.
5. Ciećko A., Oszczak B., Oszczak S.: Determination of Accuracy and Coverage of Permanent Reference Stadion DGPS/RTK in Gdynia, Proceedings of the 7th Bilateral Geodetic Meeting Italy – Poland, May 2003, Bressanone, Italy, Reports on Geodesy, no. 2 (65), 2003.
6. Cord-Hinrich J.: SAPOS-Part of a Geosensors Network, Symposium on Global Navigation Satellite Systems, Berlin, November 2008.
7. Dziewicki M., Felski A., Specht C.: Availability of DGPS Reference Station Signals on South Baltic, Proceedings of the $2^{nd}$ European Symposium on Global Navigation Satellite Systems – GNSS'98, Toulouse, France, 1998.
8. Gocał J., Strach M.: RTK in engineering applications – GPS receivers in the tracks, Geodeta – Magazyn Geoinformacyjny 2004, no. 5 (in Polish).
9. Koc W., Specht C.: Results of railway track's satellite measurements, Technika Transportu Szynowego 2009, no. 7-8 (in Polish).
10. Koc W., Specht C., Jurkowska A., Chrostowski P., Nowak A., Lewiński L., Bornowski M.: Determining of railway route course on the basis of satellite measurements, II Sci.-Tech. Conference "Designing, Building and Maintenance of Infrastructure in Rail Transportation INFRASZYN 2009", Zakopane, 2009 (in Polish).
11. Landau H., Vollath U., Xiaoming Chen: Virtual Reference Stations versus Broadcast Solutions in Network RTK – Advantages and Limitations, GNSS Conference 2003, Graz, Austria, April 2003.
12. Rizos C., Yan T., Omar S., Musa T., Kinlyside D.: Implementing network – RTK: the SydNET CORS infrastructure, The 6th International Symposium on Satellite Navigation Technology Including, Mobile Positioning & Location Services, Melbourne SatNav 2003, Australia, July 2003.
13. RTCM Recommended Standards for Differential GNSS (Global Navigation Satellite Systems) Service, Version 3.0, RTCM Paper 30-2004/SC104-STD, 2004.
14. RTCM Recommended Standards for Network Transport of RTCM via Internet Protocol (NTRIP), Version 1.0, RTCM Paper 200-2004/SC104-STD, 2004.
15. Specht C. (project manager) et al.: Realization of infrastructure tests and services of precise satellite positioning system ASG-EUPOS, Research project "Realization of infrastructure tests of ASG-EUPOS system and realization of services tests of ASG-EUPOS system" on commision of the Main Office of Geodesy and Cartography, Science Consortium: Gdańsk University of Technology / University of Warmia and Mazury in Olsztyn / Polish Naval Academy in Gdynia, May – June 2008.