

Maciej Antosiewicz: All-Poland Precise Positioning System for the Małopolskie Province • Geomatics and Environmental Engineering 2007, Vol. 1, No. 1/1

In September 2006, the Małopolski Precise Positioning System (Małopolski System Pozycjonowania Precyzyjnego – MSPP) for universal economic purposes was initiated. The activities related to developing the system aimed at:

- ensuring an opportunity to set the position of any point with 3 cm accuracy using the NAVSTAR GPS satellite system and the RTK/DGPS surface corrections generated based on the network of evenly distributed reference stations;
- providing an instrument to support regional development in using the GPS system for universal economic purposes, including ICT systems for coordination, management and monitoring.

Working on MSPP included: constructing 3 additional reference stations in the Małopolskie Province (Tarnów, Nowy Targ, Proszowice), creating a computing system to generate RTK/DGPS surface corrections, and delivering 8 GPS receivers for precise RTK measurements. MSPP uses a solution developed by Trimble/Terrast company, using the Virtual Reference Stations technology (VRS). Main functional features of the MSPP:

- openness of the system, which means that the system can be expanded, more stations can be added, new format of available data introduced,
- high accuracy of positioning (up to 3 cm horizontally), keeping 99% level of confidence,
- making data available 24h/365 days (24 hours a day, 365 days a year),
- rapid and easy operation with automatic restarting option in case of emergency,
- possibility to distribute RTK/DGPS corrections through GSM/GPRS transmission, the Internet or FM within separate transmission packages: for all the network and every station.

Signing a cooperation agreement between the Chief National Geodesist, the Śląskie Province and the Małopolskie Province, allowed to include in the scope of the MSPP operation (RTK/DGPS corrections) the area of the two provinces. Using the station of the Space Research Centre in Warsaw makes data from this station available for the Warsaw area, and precise DGPS corrections will be available for the area between Warsaw, Katowice and Krakow. The MSPP construction has been completed by the Małopolskie Province Marshal Office with the resources of the Integrated Operational Program for Regional Development measure 1.5

– Information Society Infrastructure, constituting a part of the European Regional Development Fund.

Keywords: Precise Positioning System, GPS, RTK, DGPS, Virtual Reference Station (VRS)

Mieczysław Bakuła, Stanisław Oszczak, Radosław Baryła, Dariusz Popielarczyk, Wojciech Jarmołowski, Arkadiusz Tyszko, Bartłomiej Oszczak, Eliza Sitnik, Rafał Gregorczyk, Paweł Wielgosz, Jacek Rapiński, Grzegorz Jesiotr: **Determination of Coordinates of Control Points in the Wieruszów District Area** • Geomatics and Environmental Engineering 2007, Vol. 1, No. 1/1

The paper presents the methodology of GPS measurements and data elaboration for control points in the Wieruszów District area. GPS measurements of 988 points were executed with the use of static method during ten days of measurements and twelve GPS receivers of Ashtech company i.e. Z-XII, Z-Surveyor, Z-Xtreme. The results and analyses of adjustment and transformation from ETRF-89 to the national coordinate systems: „1965” and „2000” were also presented. Due to bad observational conditions of GPS measurements there were about thirty points on which GPS measurements were repeated in order to achieve reliable and accurate results. Additionally, loop closures of baselines and geometric conditions of ambiguity network solutions were successfully useful before final adjustment.

Keywords: ambiguity resolution, ETRF-89, GPS

Piotr Banasik: **The Determination of Normal Height and Characteristic of Gravity Field for KRAW Permanent Station** • Geomatics and Environmental Engineering 2007, Vol. 1, No. 1/1

The results of leveling measurements carried for the determination of normal height of the KRAW point – permanent station, located on C4 AGH apartment are presented. The results of gravity measurements and its vertical gradient carried outside and inside the building are presented as well. The values of gravimetric anomalies and distance between quasi-geoid and ellipsoid on that area were calculated. Determined values complete existing geodetic characteristic of the KRAW point.

Keywords: GPS permanent station, levelling, gravimetric measurements

Radosław Baryła, Mieczysław Bakuła, Stanisław Oszczak: **Utilization of GPS Positioning Methods for Modernization of Geodetic Control Network and Cadastre** • Geomatics and Environmental Engineering 2007, Vol. 1, No. 1/1

In his paper, a new technology for land and buildings registration modernization supported by GPS (Global Positioning System) technique is

presented. The modernization is based on archival materials and new coordinates of the reference network. The new coordinates are provided through strengthening an existing reference network with new points derived from GPS survey. As the result of the modernization, a numeric map of parcel and building cadastre together with the list of parcel areas calculated from numeric map data is provided. The authors provide also insight into RTK (Real-Time Kinematic) GPS technique that allows for centimeter-level point surveying in any user-defined reference frame. The feasibility of using RTK GPS technique for works related to cadastre modernization is also discussed.

Keywords: GPS, RTK, geodetic control network, cadastre, digital map

Józef Beluch, Mariusz Frukacz, Józef Mróz, Andrzej Pokrzywa, Tadeusz Szczutko: **The studies of precise levelling equipment in Geodetic Metrological Laboratory of AGH** • Geomatics and Environmental Engineering 2007, Vol. 1, No. 1/1

In order to examine precise levelling equipment one should check geometric conditions of the levelling instrument, the appropriacy of functioning of its single elements as well as the calibration of rods used in the set with the instrument. The set for studying the levelling equipment contains: optical collimators, a thermal chamber to calculate the coefficient of thermal expansion of the invar band rods and interferential measurement set Hewlett-Pacard HP 5529A. The set is used to check levelling instruments on horizontal base and the calibration of rods on the vertical comparator. The technology of invar rods developed in Geodetic Metrological Laboratory enables one to determine the values of the average horizontal metre of the rod with an average error of about 1.4-2.0 $\mu\text{m}/\text{m}$. Both the technology of the calibration of rods with the automatic elimination of systematic errors that are made by the mechanical system of the comparator column and substitution of the optical observation with the analysis of the picture of the rod graduation from the camera are still tested.

Keywords: laser interferometer, calibration, code staff, precise levelling

Józef Beluch, Mariusz Frukacz, Józef Mróz, Andrzej Pokrzywa, Tadeusz Szczutko: **The Results of the Research Concerning the Coefficient of the Linear Thermal Expansion of Invar Levelling Rods After the Modernization of the Chamber in Metrologic Geodetic Laboratory of AGH in Cracow** • Geomatics and Environmental Engineering 2007, Vol. 1, No. 1/1

Construction solutions of a thermal chamber developed within the framework of the research grant of SRC (Scientific Research Committee) have been presented. These solutions enable to determine the coefficient of the linear thermal expansion (CLTE) of the invar band of rods for pre-

cise levelling. The determination technology and the calculation procedure of CLTE which are applied in Geodetic Metrologic Laboratory of AGH (Academy of Mining and Metallurgy) in Cracow have been shown. Main research problems connected with the determination of CLTE of the invar band of rods including the anomalies of length changes of the invar exposed to thermal changes, a thermal hysteresis of the invar, as well as the phenomenon of non linear length changes of the invar under the influence of a temperature have been characterised. Characteristic results of determination of CLTE of the invar band together with their analysis have been presented. The values of coefficients of the linear thermal expansion and their unreliability determined in Geodetic Metrologic Laboratory of AGH (Academy of Mining and Metallurgy) in Cracow and in Finnish Geodetic Institute have been compared for two coding rods Topcon-Nedo.

Keywords: the coefficient of the linear thermal expansion, an invar, precise levelling, levelling rods/staff

Jarosław Bosy: **Precise Processing of GPS Observations in Local Networks Connected to the EPN/IGS Permanent Stations** • Geomatics and Environmental Engineering 2007, Vol. 1, No. 1/1

The local GPS networks are processed in connection to permanent GNSS stations of EUREF Permanent Network (EPN) or/and International GNSS Service (IGS). The permanent GNSS stations are used for realization of Terrestrial Reference Frame (e.g. International Terrestrial Reference Frame), precise orbits determination and ionosphere and troposphere models. The products of above networks solutions give the possibility of reference frame realization and higher accuracy of estimated parameters in local GPS networks. In the paper the processing methodology of a local GPS network connected to IGS/EPN permanent stations and same examples has been presented

Keywords: local GPS networks, GPS data processing

Jacek Rapiński, Sławomir Cellmer: **Influence of pseudolite observations on GPS network adjustment** • Geomatics and Environmental Engineering 2007, Vol. 1, No. 1/1

This paper presents results of GPS network adjustment in difficult survey environment. Network was adjusted twice – with and without pseudolite observation. Calculations were made with authors own software for GPS and pseudolite data processing. The influence of pseudolite observation on GPS network adjustment was evaluated from differences between GPS only survey with no obstructions and Survey with obstructions with and without pseudolite.

Keywords: GPS, pseudosatellite, network

Mariusz Figurski, Marcin Gałuszkiewicz, Paweł Kamiński: **Monitoring of the Polish GPS Reference Stations Network** • Geomatics and Environmental Engineering 2007, Vol. 1, No. 1/1

Dynamic development of permanent GNSS stations in Poland restores the problem of supervising the stations' performance and ETRS'89 system realization. Although the permanent GNSS stations' coordinates have been used for a few years now, their source is unknown. Permanent stations monitoring according to the EPN standards is one of the possibilities to solve the problem. The paper presents a concept of such a solution and the computation results obtained in 2006. The results analysis presents also a comparison of the coordinates with the results from the ASG-PL system.

Keywords: GPS, permanent station, GNSS station monitoring.

Idzi Gajderowicz: **Proposal of New Polish Vertical Reference Frame** • Geomatics and Environmental Engineering 2007, Vol. 1, No. 1/1

Polish first class leveling network has been measured in the period of 1999-2002. The paper presents main parameters of the network and definition of new Polish vertical reference frame. The frame should fulfil the following conditions:

- Heights of bench marks determined by new measurements, in new reference frame, should be as close as possible to the heights given in Kronsztad 1986 frame which was created for elaboration of the measurements carried out in the period 1974-1982.
- Results of new measurements should not be distorted by adjustment of the network based on old heights of reference bench marks (taken for example from the Unified Precise Leveling Network created for East European countries).

The following procedure was applied for determination of new vertical reference frame:

- The network was adjusted as a network connected to one reference bench mark (Warsaw-Wola nodal point). Height of the reference bench mark was known in Kronsztad 1986 frame.
- For each of 15 permanent bench marks (monumented deeply in stable places) there was computed the difference $R = H_{WW} - H_{1986}$ between the height H_{WW} determined by the adjustment and the old height H_{1986} known in Kronsztad 1986.
- Height of the reference bench mark was increased by the average value of $-R$, equal to 6.1 mm, and the network was adjusted again. The differences $C = H_{2006} - H_{1986}$ computed for the 15 permanent bench marks are in the range from -19 mm to $+21$ mm.

The average value of C for the 15 permanent bench marks is equal to 0.

Keywords: precise leveling, vertical reference frame, Kronsztad 1986, Kronsztad 2006.

Władysław Góral, Jacek Kudryś: **Computation of the Antenna Phase Center Offsets Corrections in GPS Phase Measurements** • Geomatics and Environmental Engineering 2007, Vol. 1, No. 1/1

The phase variations of GPS receiving antennas are a significant error component in precise GPS applications, especially with introduction of permanent reference station and the use at the same time of different antenna types. Than in order to further improvements in accuracy and reliability of GPS solutions in geodetic applications the introduction of corrections for offsets and phase center variations (PCVs) to GPS receiving antennas are needed. In this paper results obtained with using relative GPS antenna calibrations, only elevation-dependent variations, are presented. Two numerical examples where L1 and L2 phase measurements were processed are given.

Keywords: GPS phase measurements, antenna phase center offset.

Bernard Kontny, Sławomir Szwed, Marcin Zajac: **The Time Series of GPS Observation from Period of 9 Years Existence of Permanent Station "Wrocław" Was Analyzed** • Geomatics and Environmental Engineering 2007, Vol. 1, No. 1/1

Studied time series was formed from EPN Network weekly solutions. The identification of the movement character and movement velocity estimation were the aims of the analysis. Three models of the point's movement were assumed: linear model with invariable velocity monotonous movement (using robust estimation for linear model coefficients determination); model in which point location periodically changes and model with episodic displacement, or with coordinate jump. Results were analyzed and interpreted resulting following conclusions:

1. Linear model parameters consist of mainly Euro-Asiatic continental plate velocity. Residual (intraplate) velocity remains up to 1.5 mm/y NW after removing plate movement.
2. Periodic changes of "OC" point location were confirmed by results of spectral analysis. Periodical components for all coordinates have a character of long period oscillations. 9 and 4.5 year component dominates with amplitude 1.2 mm/y and 2.2 mm/y for horizontal coordinates, N and E respectively and 3.8 mm/y for vertical one.
3. Coordinate jumps (episodic displacements) were not detected for „WROC" station. The usefulness of this station for geodynamic studies was confirmed.

Keywords: permanent GPS station, time series, movement parameters, linear model, periodic components

Kamil Kowalczyk: **Vertical Movements of Theearth's Crust in Poland** • Geomatics and Environmental Engineering 2007, Vol. 1, No. 1/1

Work is in progress at present in Europe on the realization of the second stage of unifying the levelling networks in Europe, i.e. the kinematic adjustment of the UELN-95 network (resolution 5 of the EUREF symposium, Prague 1999). To perform such an adjustment, a model is necessary for vertical crustal movements for the area of Europe. For the area of Poland such movements calculated twice Tadeusz Wyrzykowski from the Institute of Geodesy and Cartography in Warsaw (1961, 1986). Ending the fourth levelling campaign and recording databases tide gauge, undertake repeated the test of calculation the vertical movements earth crust an area of Poland and made a model of these movements.

The paper uses the data of the third and fourth precision levelling campaigns in Poland and the data from tide gauge stations in Władysławowo, Ustka, Kołobrzeg and Świnoujście. On the basis of those data a model of vertical movements in the area of Poland was developed. During the first stage of the study, the relative vertical crustal movements referenced to the tide gauge in Władysławowo were computed. Next the vertical movements of tide gauge in Władysławowo in respect to the mean sea level of the Baltic Sea were determined. Elements of statistical analysis: moving average and linear regression methods were used for identification of tide gauge motions. Finally, the vertical movements of network bench marks relative to the mean sea level were determined. The model of vertical crustal movements in the area of Poland was developed by applying interpolation method. The model developed in that way should provide surveyors, geophysicists and geologists with precious information on the behavior of earth crust in the area of Poland. The model should also allow development of a kinematical levelling network in Poland.

Keywords: Vertical movements, levelling, tide gauges, GPS

Krzysztof Kroszczyński, Mariusz Figurski: **Tropospheric Refraction in the Light of Mesoscale Meteorological Forecasting Models** • Geomatics and Environmental Engineering 2007, Vol. 1, No. 1/1

The paper presents a method of determining the GPS slant delay on the basis of diagnostic and forecasted data from the COAMPS (Coupled Ocean/Atmosphere Mesoscale Prediction System) non-hydrostatic model of the atmosphere which is run in operational mode on a IA64 computer cluster in the Applied Geomatics Section, Faculty of Civil Engineering and Geodesy, Military University of Technology. The slant delay value was obtained by integrating the spatial function of the tropospheric refraction along the GPS wave propagation path. The path was determined from the solution of the differential equations system of the path ray that results from the eikonal equation. The atmospheric refraction field was determined using the atmospheric parameters obtained from the COAMPS model.

Keywords: meteorological model, tropospheric refraction, slant delay

Zofia Rzepecka, Alojzy Wasilewski: **Influence of Adding Pseudolite Observations on GPS Determinations Under Conditions of Reduced Sky Visibility** • Geomatics and Environmental Engineering 2007, Vol. 1, No. 1/1

Processing method of GPS integrated with pseudolite (PL) observations is shown in this report. Own software was created and applied for dealing with PL observations. The software takes advantage of the least squares sequential adjustment. An evidence of positive influence of augmentation GPS observations with additional observations to a PL, under assumption of various, simulated obstructions of the sky, is given.

Keywords: GPS, pseudosatellite

Zbigniew Szczerbowski, Piotr Banasik, Jacek Kudryś: **The Example of GPS Technique Application for Height Measurements on Mining Areas** • Geomatics And Environmental Engineering 2007, Vol. 1, No. 1/1

The popularization of GPS technique and global positioning system has led to increase practical importance of satellite and classic survey combination. Thanks to adequately accurate geoid model advantages of satellite techniques proves execution of height measurements with accuracy that equals classic spirit leveling. The most discussions about GPS techniques concern reference system or geoid models. The small number of papers dealing with the problem of practical uses resulting from application of GPS technique to engineering practice (in the range of height measurements) does not allow to their dissemination (what implies economical effect as well). Presented paper discusses results of height measurements on Inowrocław region (reference measurements for mines' networks) and it is an example proving utility of GPS measurements in such works.

Keywords: GPS survey, Levelling, geoid, mining deformations

Tadeusz Szczutko: **The study of the occurrence of cyclic errors in precise electromagnetic distance measuring instruments** • Geomatics and Environmental Engineering 2007, Vol. 1, No. 1/1

In order to acquire the appropriate scale of geodetic special network, distance measuring instruments, which are used for measurement, should be calibrated in such a way as to eliminate systematic measurement errors of linear and cyclic character from the observation. Distance measuring instruments such as TC 2002, TCA 2003 made by Leica firm as well as Geodimeter GDM 640 ATS have been included in the study of the occurrence of cyclic errors. Hewlett-Packard HP 5529A interferential measurement set has been used as a length etalon to provide an ap-

propriate accuracy of the measurement. The set is installed in Geodetic Metrological Laboratory of AGH. The applied measurement technology enables one to determine the values of cyclic errors of distance measuring instruments of an average error $\pm 0,2$ mm. The results of the study can be used in industrial and laboratory measurements while special networks are placed.

Keywords: laser interferometer, cyclic error, electronic distance meter (EDM)

Bogdan Skorupa: **Double difference integer ambiguity resolution in GPS phase measurements collected on points of permanent stations network** • Geomatics and Environmental Engineering 2007, Vol. 1, No. 1/1

Geodetic coordinates of GPS permanent stations are calculated with high precision, in given homogeneous reference frame. There is an requirement for elaborating the measurements collected on points of permanent stations, for integer phase ambiguity resolution. Next, this ambiguities are used in estimation process of local differential refraction models. The paper presents a method for determining double difference integer phase ambiguity, with assumption of constant GPS vector coordinates. The efficiency of ambiguity resolution was analysed at use of Integer Search Ratio. Quoted numerical examples were realized at use of the computer programs made in Department of Geodesy and Cartography at the AGH University of Science and Technology and AOS v. 1.6 software. In computational experiments phase measurements were performed on points of active geodetic network ASG-PL.

Keywords: GPS permanent stations, ambiguity resolution