RECOMMENDED METHODOLOGY OF DETERMINING COORDINATES OF A PERMANENT REFERENCE STATION IN THE ASG-EUPOS SYSTEM

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Keywords: GNSS, reference stations, postprocessing

Introduction

Basic geodetic control networks of national coverage ensure the use of uniform national systems of spatial references. They are applied for scientific purposes, tying and aligning detailed control networks and also carrying out tasks related to the national defence. Therefore, they guarantee uniformity and high qualitative standard of geodetic and cartographic works, in engineering terms, according to the general top-down approach principle adopted in geodesy. The procedures of establishing and maintaining basic geodetic control networks are organised differently in different countries. In Poland, the basic geodetic control network is divided into:

– fundamental basic geodetic control network
– reference basic geodetic control network

Following the latest Ordinance of the Minister of Administration and Digitisation "on geodetic, gravimetric and magnetic control networks", the fundamental basic geodetic control networks have been classified into the highest first accuracy class. The average concentration of the fundamental horizontal geodetic control network points is 1 point per 20000 km^2 whereas the average concentration rate of the reference basic geodetic control network classified into class 2 is 1 point per 50 km^2. The basic geodetic control networks in Poland are presented on a synthetic qualitative and quantitative basis in tables 1 and 2 [3].

Table 1.
Basic horizontal geodetic control network

Class	Number of points	Type of network
1	15	ASG-EUPOS (EPN)
2	7062	ASG-EUPOS, EUREF, POLREF, EUVN, I klasa
Total	7077	1 pkt / 44,1 km^2

Table 2.
Basic vertical geodetic control network

Class	Number of points	Type of network
1	10	EUVN (main points 10 fundamental points EUVN in the Polish area serving of references)
2	41867	EUVN, ASG-EUPOS, I and II class
Total	41877	1 pkt / 7,4 km^2

National System of Spatial References in Poland

The national system of spatial references is used in geodetic and cartographic works and to develop spatial data bases and it is formed by:

1) Geodetic reference systems designated by symbols PL-ETRF2000 and PL-ETRF89 which constitute the mathematical and physical rendition of the European ETRS89 global reference system;
2) Vertical systems designated by symbols PL-KRON86-NH and PL-EVRF2007-NH which constitute the mathematical and physical rendition of the European EVRS global vertical system;
3) Cartesian geocentric coordinate systems designated by the symbol XYZ, geocentric geodetic ones designated by the symbol GRS80h and geodetic ones designated by the symbol GRS80H;
4) Flat rectangular coordinate systems designated with symbols: PL-LAEA, PL-LCC, PL-UTM, PL-1992, PL-2000 [4].

ASG-EUPOS Reference Station Points

Points of the ASG-EUPOS system reference stations constitute the European EPN network which pursues the ETRS89 system of coordinates and at the same time a national Polish uniform system of spatial references. In the territory of our country, 15 stations are included into the EPN (European Permanent Network) network and constitute the fundamental control network. These points transpose the ETRS89 system, the rendition of which is presently the PL-ETRF2000 reference system for the epoch 2011, onto the territory of Poland; these points are approximately evenly distributed all over the whole country (Fig. 1).

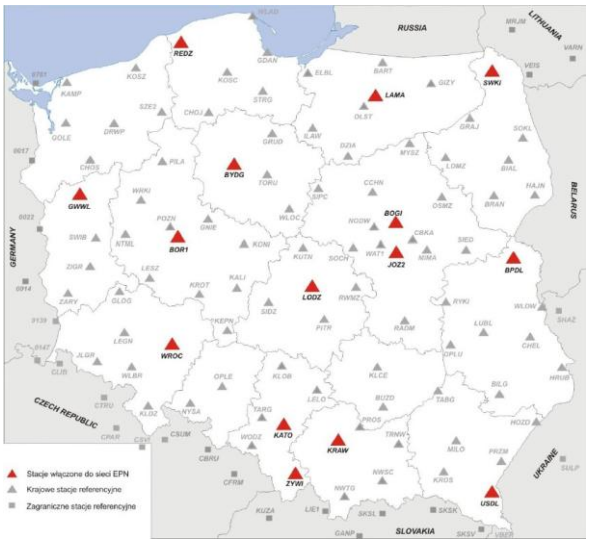

Fig. 1. Distribution of the ASG-EUPOS system stations in Poland [www.asgeupos.pl]

Establishing New Points of the Horizontal Reference Geodetic Control Network

New points of the horizontal reference geodetic control network are established by means of the GNSS technique in relation to the fundamental horizontal reference geodetic control network points.

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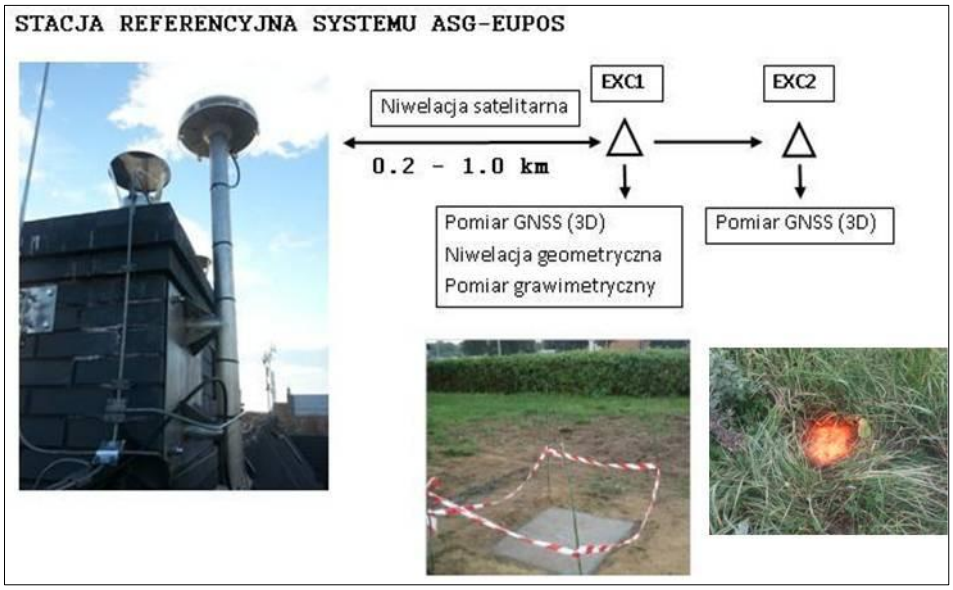

Fig. 2. New reference station of the ASG-EUPOS system in Nowy Targ: NWT1

For each point of the basic reference horizontal geodetic control network (Fig. 2), one or two eccentric points are established which are located at 0.2 – 1.0 km from the main point. The stabilisation of the points is performed with the use of geodetic signs which enable surveying and gravimetric measurements.

While planning a measurement campaign comprising the basic horizontal geodetic control network points, it is required to:

– ensure that the points and their eccentric points are tied to the points of the basic vertical geodetic control network and provide the possibility to carry out gravimetric measurements [2],
– plan the inclusion of the observations performed on selected EPN stations located abroad into the post-processing.

Measurements of the basic horizontal geodetic control network should be carried out at least with a dual system, dual frequency GNSS satellite receivers. The observations on the basic horizontal geodetic control network must be performed uninterruptedly in the course of at least two independent observation sessions and their total duration should not be shorter than two days.

While processing the GNSS observation results, it is required to ensure the possibility to:

– use precise elements of orbits with the satellite clock adjustments,
– model the troposphere and the ionosphere by applying the current models and the models recommended by EPN/IGS or by determining them,
– control the closure of figures made of independent vectors,
– compare the obtained results to the values determined independently in the course of other observation campaigns or with the use of other measurement techniques.

Establishment of NWT1 Reference Station in Nowy Targ

The NWT1 reference station in Nowy Targ was established as a class **B** station according to the criteria defined in "Guidelines for EUREF densifications" [1]. According to the official classification of geodetic control networks in Poland, the NWT1 station became a class 2 reference basic geodetic control network point and a class 2 detailed reference vertical geodetic control network point. The station was assigned code **NWT1** and number: **408935100** as a class 2 reference basic horizontal geodetic control network point. The point number was assigned centrally by the Main Centre of Geodetic and Cartographic Documentation in Warsaw.

The location of the station has met the following requirements:

– good visibility of satellites for the entire horizon above the height of 5^{o},
– the station antenna mounting has been stabilised by being installed on a special mast fixed to the chimney (Fig. 1),
– no electromagnetic interferences or bounces of signals have been found in the place of installation,
– the distance between the antenna and the nearest fixed elements (surface of the chimney) was 0.6 m.

Station Eccentric Points

The NWT1 station was secured by two ground eccentric points in such a way as to enable carrying vertical and gravimetric measurements on EXC1 and carrying out unequivocal GNSS 3D measurements on EXC2. The situational distribution of the eccentric points in relation to the NWT1 parent point is presented on Fig. 3

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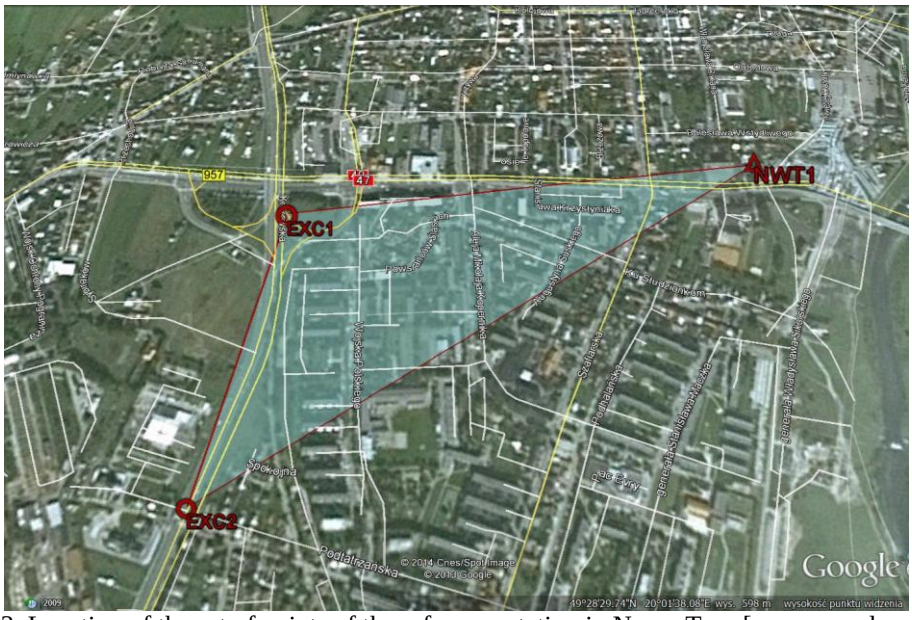

Fig. 3. Location of the set of points of the reference station in Nowy Targ [www.google.earth]

Tying the NWT1 Station

The coordinates of the **NWT1** station **no. 408935100** and the eccentric points (**EXC1 no. 408935101** and **EXC2 no. 408935102**) have been measured as designed in relation to 10 points of the basic, fundamental geodetic control network (reference stations working in the **EPN** network), including six domestic stations:

- **JOZ2** - a reference station located in Józefosław,
- **KATO** - a reference station located in Katowice,
- **KRA1** - a reference station located in Krakow,
- **USDL** - a reference station located in Ustrzyki Dolne,
- **WROC** - a reference station located in Wroclaw,
- **ZYWI** - a reference station located in Żywiec;

and four foreign stations:

- **GANP** (Ganovce – Slovakia),
- **GRAZ** (Graz – Austria),
- **SULP** (Lviv - Ukraine),
- **WTZR** (Bad Koetzting - Germany).

The measurements on the main point (of the **NWT1** reference station) and on the eccentric points **EXC1 and EXC2** were carried out in the course of one measurement campaign from **20.11.2013, 7:00:00** till **22.11.2013, 8:38:38**. The observations were carried out at an interval of **1s**, with an elevation of **5°** and the minimum number of the satellites observed equal to **5**.

On the **NWT1** reference station, the **Trimble** NetR9 P/N 97503-10 S/N 5103K73204 receiver has been installed with the Zephyr Geodetic antenna, model 2 P/N 58295-00 S/N 1441043012, equipped with the P/N 46291-00 anti-snow shield.

At the point **EXC1** numbered **408935101**, the **Trimble R8 GNSS** receiver**, Model 3, serial no.: 5108461861**, integrated with the antenna was used for measurement, whereas at the point **EXC2** numbered **408935102**, the **Trimble SPS882, serial no.: 5152479582**, integrated with the antenna was used.

The observations for the foreign connecting points were downloaded from the EUREF Permanent Network service while the observations for the Polish stations - from the ASG-EUPOS system through the POZGEO-D service. Before starting the final processing, all observations were inspected for potential errors by means of the TEQC Editor application designed to inspect the quality of the GNSS observations and to remove potential errors. The post-processing of the results of the GNSS observations employed:

- precise elements of orbits with the satellite clock adjustments: "IGS Final Orbits",
- ionosphere and troposphere models recommended by EPN/IGS,
- the closure of figures (triangles) made of independent vectors was inspected.

Calculations and Analysis of Results

In the first stage of post-processing, the observations from the measurement campaign were divided into **8** sessions so as to ensure that the maximum duration of a session for a vector being processed was **7h**. The **GNSS** vectors were post-processed by means of the **Trimble Business Center v3.10** programme. The precise IGS Final Orbits were used in the post-processing. Finally, the closure of figures was inspected to check the quality of the spatial vectors obtained.

In the second stage, the pseudo-observations (vectors) obtained were aligned on a free basis for each session independently by means of the Trimble

Business Center v3.10 programme. The average values of coordinates and the empirical values of average errors determined from deviations were accepted as the final result.

In the third stage of post-processing, a 3D conformal transformation (defined by 7 parameters) into the ITRF2008 system onto the epoch t_0 001/2005 was carried out. As the adaptation points, the following **5** EPN stations were used: **GRAZ, JOZ2, SULP, WROC, WTZR**.

In the fourth stage of post-processing, a 3D conformal transformation (defined by 7 parameters) with Hausbrandt corrections onto **6** EPN domestic stations: **JOZ2, KATO, KRA1, USDL, WROC, ZYWI** was carried out. This produced coordinates of the points determined in the PL-ETRF2000 system on the epoch t_0 001/2011.

The final results of post-processing (the coordinates and their determination errors) for the set of points of the NWT1 station are summarised in Table 3.

Table 3.
Summary of Results of Cartesian Coordinates

Nazwa	**X**	**Y**	**Z**	**mX**	**mY**	**mZ**
	[m]	[m]	[m]	[m]	[m]	[m]
408935100	3901293.4201	1422610.7502	4825778.7345	0.0017	0.0006	0.0011
408935101	3901716.7674	1421854.1279	4825639.9173	0.0017	0.0006	0.0011
408935102	3902151.0580	1421914.8727	4825276.9251	0.0017	0.0006	0.0011

Conclusions

The employed solution allowed for achieving results of coordinate solutions (errors of mX, mY, mZ coordinates) which are more than twice better than the standard approach where the final result of the alignment is obtained through strict alignment in relation to reference stations as fixed points. In fact, the approach adopted in the present study enables the elimination of potential regular errors and residual scale errors in relation to the EPN station system. Therefore, the author of the study recommends the presented solution as a better alternative for this type of geodetic projects.

Work revealed except that the reference station SULP working in Lviv is not fully compatible with the system, EUPOS, because in three computing sessions on eight completed, showed too much mistakes and had to be excluded from the final calculations.

References

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Recommended methodology of determining coordinates of a permanent reference station in the ASG-EUPOS system

Siejka Z.

The article presents the methodology of the coordinate designation of a permanent reference station. The work was carried out on an empirical example of the designation of the reference station coordinates NWT1 (Nowy Targ, Poland). This station is a reference station type B, (according to Guidelines for EUREF Densifications) and this station also is the point of the basic horizontal national geodetic network class 2 and the vertical minor geodetic network class 3. Stations type B provide access to the European geodetic reference system on Polish territory.