METROLOGICAL INVESTIGATIONS OF GNSS RECEIVERS ON THE BASIS OF DATA FROM IGS/EPN AND EUPOS STATIONS OR LOCAL PERMANENT GNNS NETWORK IN POLAND AND UKRAINE

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Abstract

Geodetic GNSS receivers, forming a complex, along with the calibrated antenna and software, must be, like other surveying instruments, periodically monitored metrologically. Such metrological control should be conducted in conditions close to practical surveying. At the same time, the accuracy of such measurements should be much better than the one required in ordinary practice. The authors checked whether the data from permanent GNSS stations forming the Central and Eastern Europe EUPOS network or local permanent network, togetrher with IGS/EPN stations may serve as a reference base for metrological control of GNSS receivers. In Poland, the ASG-EUPOS stations in the vicinity of Warsaw and EPN stations in Borowa Gora and Jozefoslaw were used in the investigations. To conduct research in the Geodetic and Geophysical Observatory Borowa Gora, two concrete pillars of the EDM calibration baseline were used. The co-ordinates of the pillars were obtained from four days observations with Javad Eurocard receiver and choke ring antenna. Postprocessing was performed with Pinnacle, Topcon Tools and Bernese softwares.The statistics of results obtained was calculated and the accuracy was estimated. Four different receivers (Javad Legacy, Ashtech Z12, Javad Triumph and Javad Prego) with their respective antennas have been tested in relation to the reference ASG-EUPOS stations located at different distances from the Observatory. The results were analysed. Similar studies were carried out by the Ukrainian team using the data from IGS/EPN station in Kharkiv and local network of permanent stations NGCNET at different distances from the station in Kharkiv as well as with different session's duration. The analyses of the results obtained are presented.

Fig. 1. Polish control network formed from ASG-EUPOS permanent stations

Introduction

Positions for surveying can be determined either by the static GNSS method in post-processing or in real-time. Metrological control of the receiver and antenna kit used for each of these methods of measurement must be performed in a different way. Tests presented are related only to the static method. The aim of the research was to develop the method of metrological verification of GNSS receivers used in surveying practice. The use of local network of permanent GNSS stations for metrological control of GNSS receivers offers similar conditions to those in practical GNSS surveying. The length of measured vectors usually does not exceed 150 km. In Poland, 10 stations of the ASG-EUPOS network and two concrete pillars in the Geodetic-Geophysical Borowa Gora Observatory, were selected for the tests. The lengths of the vectors between pillars and reference stations vary from 100 m to 150 km. The GNSS receiver investigated is placed on a single benchmark with known coordinates. The baselines are measured simultaneously. The duration of the session depends on the length of the longest baseline and there is no need to move the receiver from one benchmark to another.

In Ukraine, there are recently implemented new permanent GNSS stations distributed country-wide as well as a couple of local private networks. The data can be downloaded and used for processing user's measurements. The European Permanent GNSS Network (EPN) stations are the core of those networks. In the presented experiment five stations of NGCNET and two other permanent stations participated with KHAR station used as a testing site. The lengths of the vectors from KHAR to those stations are in the range from 1.3 km to 59 km.

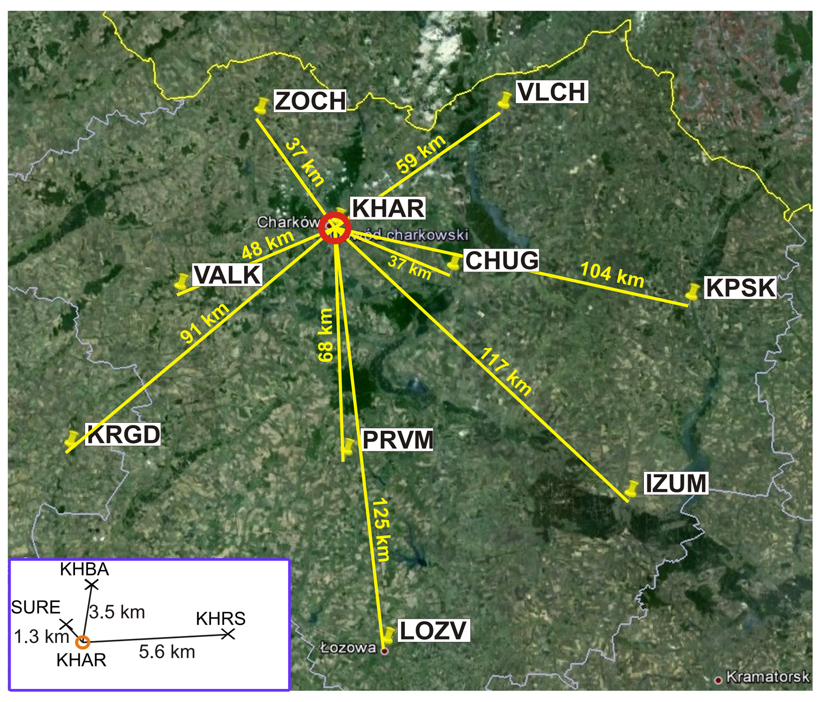

Fig. 2. Ukrainian control network formed from permanent GNSS station and NGCNET

Research performed at the Geodetic-Geophysical Observatory "Borowa Gora" of the Institute of Geodesy and Cartography, Warsaw, Poland

The coordinates of the point at which metrological control of GNSS receivers is carried out, should be determined much more accurate than in the ordinary GNSS survey. Data from several 24-hour observing sessions acquired with the use of different receivers, processing using various software, were thus applied to determine the coordinates of two points - JAN2 (Fig. 3) and JANM (Fig. 4). In the first stage, GNSS data from a few 3 days observing sessions at the point JAN2, with JAVAD TRIUMPH receiver and EGGDT-3 receiver and with choke ring antenna were used. The observations were processed with Pinnacle software using data from ten permanent ASG-EUPOS stations (Fig. 1). In the second stage, data collected on JANM, as well as on JAN2, will be processed with the Bernese software. In this presentation the results of that stage are not included. The plane coordinates of Gauss-Krüger projection obtained from the first stage, with some statistical estimates are presented in Table 1. The mean values of co-ordinates derived from EGGDT-3 receiver are treated as "true values" in next presented investigations.

Fig. 3. Ashtech choke ring antenna on JAN2 point

Fig. 4. Javad Trumph receiver on JANM point

Table 1. Coordinates of JAN2 point with statistical analysis

Receiver software	Statistical analysis	X_{G-K}	Y_{G-K}	H_{el}
		m	m	m
TRIUMPH-1 PINNCLE	**mean**	**514122.877**	**638164.707**	**140.495**
	max-min [mm]	11.4	10.9	38.6
	Std. Dev. [mm]	***4.7***	***4.9***	***16.4***
EGGDT_3 PINNACLE	**mean**	**514122.874**	**638164.716**	**140.521**
	max-min [mm]	4.6	4.4	70.7
	Std. Dev. [mm]	***2.0***	***1.3***	***27.4***

The coordinates of the JAN2 point determined with Pinnacle software from the observations with the JAVAD TRIUMPH-1 receiver, in one-hour sessions, in relation to the "true values" together with the accuracy discussion are presented in Table 2 as well as in Figures 7, 8 and 9.

Table 2. Coordinates of JAN2 point from single stations

Data collected by TRIUMPH-1 from 1 days 18/19.03.2012 elaborated by PINNACLE from each single station.									
„True" co-ordinates	**514122.874**	**638164.716**	**140.521**	The „sigmas" given by *Pinnacle* software			Differences between co-ordinates from single station and "true values"		
	X G-K	**Y G-K**	**H el**	**σ x**	**σ y**	**σ h**	**Δ X G-K**	**Δ Y G-K**	**Δ H el**
	m	m	m	mm	mm	mm	mm	mm	mm
JAN2__BOGI	514122.875	638164.709	140.590	0.7	0.6	1.6	**0.4**	**-6.9**	**68.6**
JAN2__CCHN	514122.870	638164.717	140.567	14	10.7	30.2	**-4.8**	**1.2**	**46.1**
JAN2__DZIA	514122.873	638164.721	140.566	19.4	14.8	41.3	**-1.1**	**4.7**	**45.0**
JAN2__LOMZ	514122.867	638164.715	140.575	19.4	14.8	42	**-7.4**	**-1.0**	**54.4**
JAN2__MIMA	514122.861	638164.709	140.506	12.8	10.8	27.9	**-13.0**	**-6.6**	**-15.1**
JAN2__OSMZ	514122.869	638164.716	140.580	16	12.2	33.7	**-5.0**	**-0.1**	**58.7**
JAN2__PITR	514122.883	638164.709	140.547	23.1	17.7	50.5	**8.1**	**-7.3**	**25.9**
JAN2__RWMZ	514122.875	638164.709	140.548	18.7	14.4	40	**0.5**	**-7.3**	**26.7**
JAN2__WAT1	514122.875	638164.717	140.600	6.7	9.4	13.9	**0.6**	**0.7**	**78.6**
Mean	**514122.872**	**638164.713**	**140.564**	**14.5**	**11.7**	**31.2**			
Std. Dev	0.006	0.005	0.028				**6.5**	**5.3**	**53.7**
max-min	0.021	0.012	0.094	22.4	17.1	48.9	21.1	12.0	93.7

JAN2 point height and its distances from reference stations of the test network determined using Pinnacle software

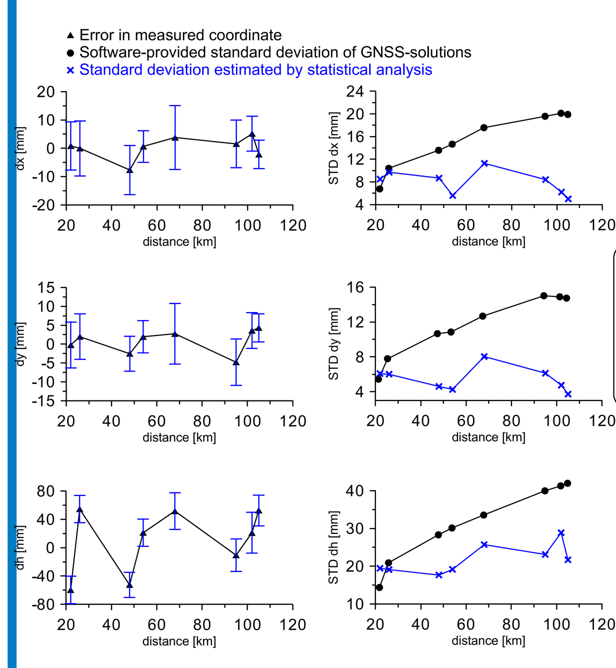

Fig .7. Differences of coordinates from the "true" values and their errors obtained from all stations of the test network in all sessions

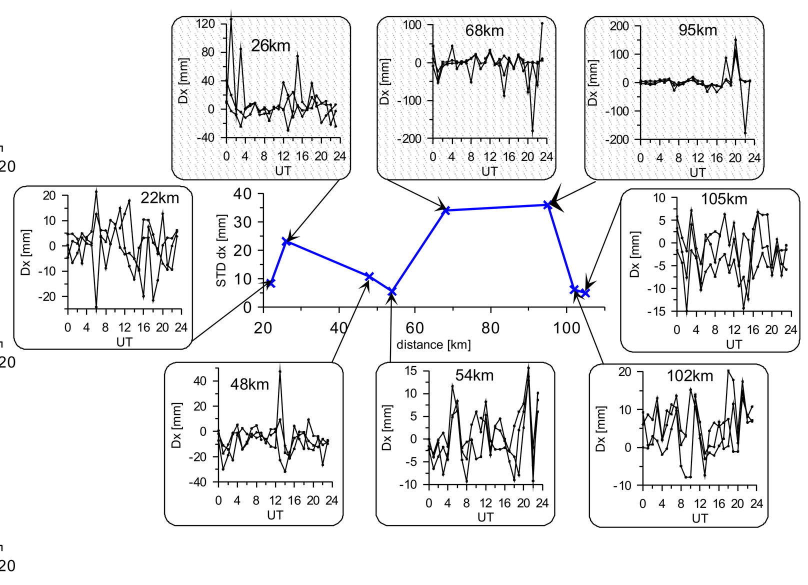

Fig. 8. Differences of *X* coordinate of JAN2 point determined from the reference stations applied, and their standard deviations

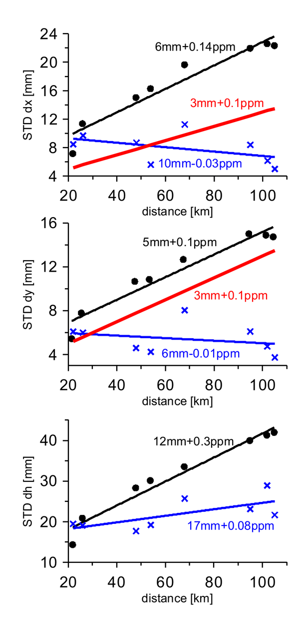

Fig. 9. Standard deviations of differences of coordinates for all stations after rejecting outlying sessions

Research performed at the National Scientific Centre "Institute of Metrology", Kharkiv, Ukraine

NSC "Institute of Metrology" conducts scientific fundamental and applied investigations, performs verification, calibration and certification of measuring devices, and renders metrological services (preparation of examination procedures, etc.).

GNSS receivers in Ukraine are the subject of state verification by the Gospotrebstandart bodies. In order to determine the measurement error of the specific set of GNSS receivers, linear bases are recently used (Fig. 5). While verifying the receivers one of them is fixed (base) and the other (rover) is placed on the benchmarks of linear bases.

To develop the modern procedure of state verification of GNSS receiver and antenna kits the local network of base stations, around the Kharkiv was tested. Data from KHAR EPN station was used and treated as the data from the point beiing checked. Coordinates and distances were calculated with Pinnacle software.

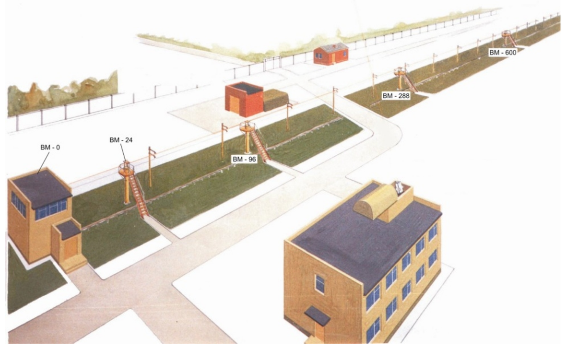

Fig. 5. Linear basis "Lipcy" of NSC "Institute of Metrology" near Kharkiv

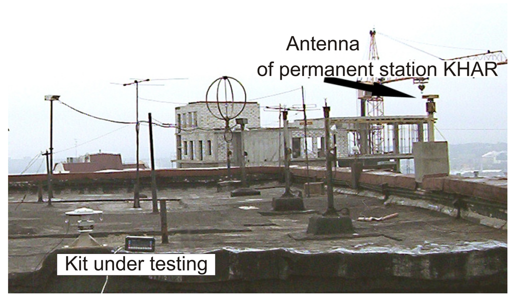

Fig. 6. Roof of main building of NSC "Institute of Metrology" as the testing field in adverse environment

The coordinates of vectors between KHAR (Fig. 6) and several base stations (Fig. 2) were calculated from 24-hour observing sessions with various softwares. In the first stage GNSS data from 3 days observations in January and March 2012 was processed by LEICA Geo Office. Later, to obtain the comparable results, vectors where reprocessed with Pinnacle software using seven base stations mainly of NGCNET (Table 3).

Table 3. Vectors formed by KHAR and local network stations

No.	Vector	Length, km	Owner of base
1.	KHAR-SURE	1.3	KhNURE
2.	KHAR-KHBA	3.5	NGC
3.	KHAR-KHRS	5.6	SKNOU (NIIRI)
4.	KHAR-ZOCH	36.6	NGC
5.	KHAR-CHUG	37.2	NGC
6.	KHAR-VALK	47.9	NGC
7.	KHAR-VLCH	59.1	NGC

The Cartesian coordinates of KHAR point determined with Pinnacle software from one-day session data are shown in Table 4.

Table 4. Coordinates of KHAR station from 1 day of observations

Data collected from 1 day 04.02.2012 elaborated by PINNACLE from each single station.									
„True" co-ordinates	**3312984,222**	**2428203,548**	**4863307,93**	The „sigmas" given by *Pinnacle* software			Differences between co-ordinates from single station and "true values"		
	X	**Y**	**Z**	**σ X**	**σ Y**	**σ Z**	**Δ X**	**Δ Y**	**Δ Z**
	m	m	m	mm	mm	mm	mm	mm	mm
SURE-KHAR	3312984.238	2428203.56	4863307.96	0.8	0.6	1	15.5	12	29.7
KHBA-KHAR	3312984.222	2428203.549	4863307.938	1.4	1.1	1.8	-0.5	1	7.7
KHRS-KHAR	3312984.245	2428203.565	4863307.97	2.1	1.8	2.8	22.5	17	39.7
ZOCH-KHAR	3312984.222	2428203.548	4863307.924	13.3	10.2	18	-0.5	0	-6.3
CHUG-KHAR	3312984.213	2428203.544	4863307.913	13.7	11.2	17.7	-9.5	-4	-17.3
VALK-KHAR	3312984.199	2428203.523	4863307.886	17.7	13.3	23.3	-23.5	-25	-44.3
VLCH-KHAR	3312984.218	2428203.547	4863307.92	20.1	15.7	26.1	-4.5	-1	-10.3
Mean	**3312984,222**	**2428203,548**	**4863307,93**	**9.9**	**7.7**	**13**			
Std. Dev	0,015	0,013	0,029				**15.3**	**13.4**	**28.6**
max-min	0,046	0,042	0,084	19.3	15.1	25.1	46	42	84

KHAR point height and its distances from reference stations of the test network determined using Pinnacle software

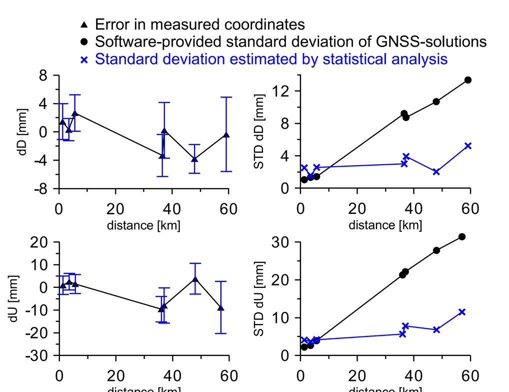

Fig. 10. Differences of coordinates from the "true" values and their errors obtained from all stations of the test network in all sessions

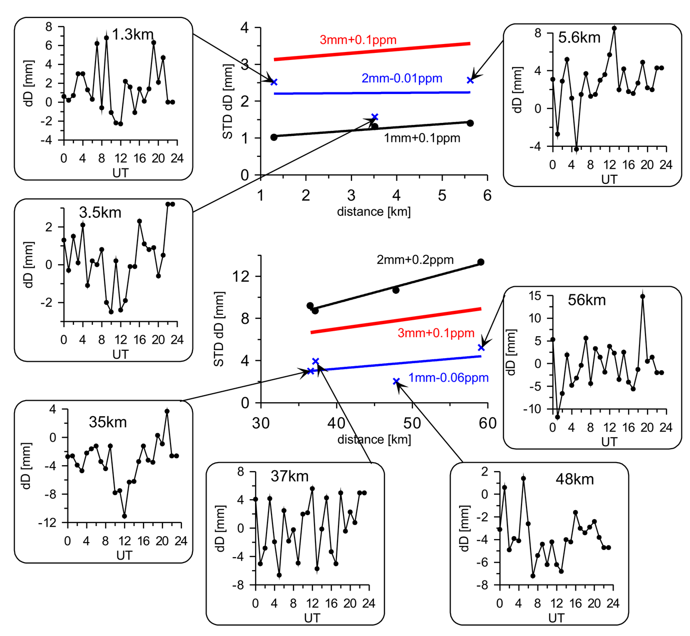

Fig. 11. Differences of distances of KHAR point from the reference stations applied, and their standard deviations

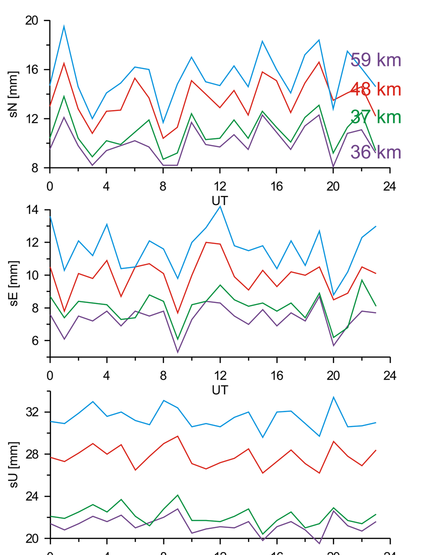

Fig. 12. Software-provided standard deviations of coordinates of vectors between KHAR and base stations. Visible similarity is the consequence of predominance of specific GNSS errors and the absence of environmental disturbances

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Conclusions

It has been shown that the network of permanent GNSS stations supplemented with a special metrological benchmark, is suitable for validation of GNSS receivers. To be reliable, validation should be based on observation sessions longer than those commonly used in the surveying practice and the results should be carefully analyzed.

It is evident, that it is necessary to check the results and to reject large deviations, which significantly improves the consistency of results, even when using data from the worst stations. This procedure can be easily implemented with attestation of GNSS receiver kit, provided that the observing session on the point will exceed 1 hour (preferably 1 day).

The problem of estimation of measurement errors and the rejection of jumps cannot be resolved during the normal field work of surveyors, who will not occupy the point longer than it is recommended for a single measurement session.

May arise the question whether international organizations should establish a policy of metrological control of GNSS receivers. The purpose of the corresponding documents is to contribute to increased conformity and improved quality of surveying and mapping products. It will also contribute to the development of methods and norms for the quality marking of measuring systems and their reliability, in order to help users to have control over their measuring processes.