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Evaluation of Positioning Functionality in ASG EUPOS for Hydrography and Off-Shore Navigation

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ABSTRACT: The paper discusses the ASG EUPOS services. It assesses the possibility of using this system selected sites in hydrography and off-shore navigation tasks. The experiments presented and analyzed in the paper were carried out in the port of Gdynia and on the Gulf of Gdańsk. The results confirm that the ASG EUPOS services guarantee positioning accuracy. The obtained accuracy greatly exceeds the needs and requirements of coastal navigation and underwater mining and sea bottom exploration.

1 INTRODUCTION

Navigation positioning systems are an important element in ensuring the safety of land, marine and air transportation. For each transport application protected by such systems, the requirements for the object position accuracy , the availability, reliability, continuity and coverage of the positioning systems should be specified globally and nationally. A legislative solution can be national plans for radio navigation systems, such as European Radio Navigation Plan (ERNP) 2004; General Lighthouse Authorities Radio Navigation Plan (GLAs) 2007; Swedish Radio Navigation Plan (SMA) 2009; US Federal Radionavigation Plan (FRP) 2012 [19]. These acts not only define the strict minimum requirements in terms of navigational positioning systems imposed on different forms of transport activity, but also recommend them for specific systems.

In the 1990s, the first Differential GPS stations were launched. Within a few years, it became the main positional system used in coastal navigation, hydrography and coastal works. The signals of DGPS reference stations cover coastal waters approx. 100 nautical miles from the shore. Over the years, its positioning accuracy was improving steadily – from 10 to 1-2 meters (2drms). Despite such high accuracy, DGPS still does not meet the requirements for hydrography, coastal works, natural resources exploitation, or marine construction in the coastal zone.

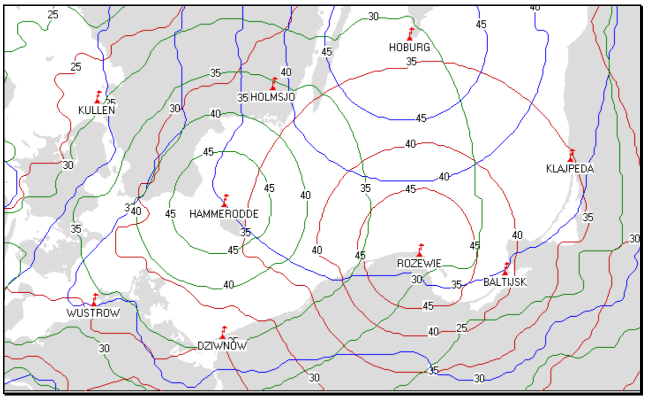

Figure 1. Coverage areas of DGPS reference stations in the Gulf of Gdańsk

Due to insufficient accuracy in determining the position of the aforementioned, marine applications must apply geodetic measurement methods used in surveying.

The dominant world trend at the beginning of the 21st century in geodesy was starting active national network activity, such as CORS, SAPOS, SWEPOS, OS-AGN. The networks offered users paid or free post-processing services as well as real time signals.

In 2007, the Head Office of Geodesy and Cartography launched the ASG-EUPOS Active Geodetic Network, which is the national permanent GNSS stations network offering services for geodesy and navigation. That investment ended in July 2008 with service and data communications tests.

The ASG-EUPOS Polish national GNSS network uses mobile communication modems for the transmission of RTCM messages – i.a. pseudorange corrections. For this reason, the operating zone is limited by coverage of cellular mobile networks. Thus, it seems reasonable to undertake a research on the potential use of the ASG-EUPOS for precision navigation, marine construction, hydrography and other applications requiring high location accuracy.

2 POSITIONING REQUIREMENTS FOR HYDROGRPHY AND OFF-SHORE NAVIGATION

The International Hydrographic Organization (IHO) has been issuing Standards for hydrographic surveys (S-44) since 1957.

The 1st Edition of IHO S-44 entitled "Accuracy Standards Recommended for Hydrographic Surveys" was published in January 1968 with the foreword which stated that "(…) hydrographic surveys were classed as those conducted for the purpose of compiling nautical charts generally used by ships" and "The study confined itself to determining the density and precision of measurements necessary to portray the sea bottom and other features sufficiently accurately for navigational purposes."

Over the years, technologies and procedures changed, and the IHO established further WGS to update S-44 with the 2nd Edition published in 1982, the 3rd in 1987, and the 4th in 1998. Throughout these revisions, primary objectives of the publication have remained substantially unchanged, the 5th Edition included.

Below are the standards used by most producers of hydrographic data. IHO S-44 5th Edition classifies surveys into four different types (four 'intended uses') [10]:

Special Order – for specific critical areas with minimum under-keel clearance and where bottom characteristics are potentially hazardous to vessels (generally less than 40 metres), such as harbours, berthing areas, and associated critical channels with minimum under-keel clearances.

Order 1a – for those areas where the sea is sufficiently shallow to allow natural or man-made features on the seabed to be a concern to the type of surface shipping expected to transit the area but where the under-keel clearance is less critical than for Special Order above. Because man-made or natural features may exist that are of concern to surface shipping, a full sea floor search is required, however the size of the feature to be detected is larger than for Special Order. Under-keel clearance becomes less critical as depth increases so the size of the feature to be detected by the full sea floor search is increased in areas where the water depth is greater than 40 metres. Order 1a surveys may be limited to water shallower than 100 metres.

Order 1b - for areas shallower than 100 metres where a general depiction of the seabed is considered adequate for the type of surface shipping expected to transit the area. A full sea floor search is not required which means some features may be missed although the maximum permissible line spacing will limit the size of the features that are likely to remain undetected. This order of survey is only recommended where under-keel clearance is not considered to be an issue. An example would be an area where the seabed characteristics are such that the likelihood of there being a man-made or natural feature on the sea floor that will endanger the type of surface vessel expected to navigate the area is low.

Order 2 – the least stringent order and its is intended for those areas where the depth of water is such that a general depiction of the seabed is considered adequate. A full sea floor search is not required. It is recommended that Order 2 surveys are limited to areas deeper than 100 metres as once the water depth exceeds 100 metres the existence of man-made or natural features that are large enough to impact on surface navigation and yet still remain undetected by an Order 2 survey is considered to be unlikely.

The summary of minimum standards for positioning in hydrographic surveys, according to [10], is presented in Tab. 1.

Table 1. Standards for positioning in hydrographic surveys [10]

Parameter	Special	1a	1b	2
Maximum allowable THU (95%)	2 m	5 m +5% of depth	5 m +5% of depth	20 m +10% of depth
Maximum allowable THU (95%)	a=0.25 m b=0.0075	a=0.5 m b=0.0075	a=0.5 m b=0.013	a=1.0 m b=0.023
Positioning of fixed aids to navigation and topography significant to navigation	2 m	2 m	2 m	5 m
Positioning of the coastline and topography less significant to navigation	10 m	20 m	20 m	20 m
Mean position of floating aids to navigation	10 m	10 m	10 m	20 m

Total Horizontal Uncertainty (THU) – represents horizontal accuracy, with 95% confidence level and Total Vertical Uncertainty (TVU) is depth accuracy measurement calculated in the vertical dimension.

The GNSS permanent observations implemented by large-area satellite network have been transformed into complex data communication system. They have offered not only post processing of GPS services but also the correction of real-time data. The first stages of their development were national passive systems created at the beginning of the 1990s, also in Poland [1]. They have evolved from single reference stations located at technical universities to national systems. They were characteristic of autonomous station, and lacked standardization within the range of unified report data replacement exploitation and local character of use [8]. As time passed by, passive systems gained differential function (GPS) in real time, becoming active structures – making DGNSS services possible. A significant broadening of action zone, similar to nautical DGPS system, was connected with new RTCM-type telegram (updated from version 2.0 to 3.0) and mathematical simulation of GPS surface correction [14].

3 DEVELOPMENT OF POLISH GNSS SATELLITE NETWORKS

The idea to create the GNSS permanent station network was initiated in 1995 by the Commission on Satellite Geodesy of the Space and Satellite Research Committee of the Polish Academy of Sciences [2]. The network was assumed to be multifunctional and used not only for geodesy purposes. As a result of different centres' activity, the local stations were created in Warszawa, Łódź, Gdańsk and the intensive mining industry areas: Upper Silesia (Górny Śląsk) and Lubin-Głogów Copper District (Lubińsko-Głogowski Okręg Miedziowy) [3]. Then a six-point network in Śląsk and a three-point network in the Tri-City area were created [6].

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. 2). The networks offered users payable or unpaid services as well as payable real time services [13]. Modernity of network techniques, compared to classical coordinates determination with exploitation single reference station and movable receiver in RTK method, lies among other things in implementation of correction using virtual reference station VRS [9]. It enables working out of pseudo-distance correction dedicated to receiver coordinates [12].

In 2007 the Head Office of Geodesy and Cartography realised Active Geodetic Network ASG-EUPOS which is the national permanent GNSS stations network offering services for geodesy and navigation [4]. That investment ended in April, 2008 with service and data communications tests [5].

Accessible to researchers at the beginning of the 21st 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 [9]. Meaningful change of quality has appeared with emission GPS/GPRS (General Packet Radio Service) at transmission 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 VHF radio commonly implemented in RTK systems. NTRIP also determined usage of the other applications using wireless radio links in relation base receiver – rover receiver; their a few metres range made GNSS realisation and surface correction transfer (VRS, Max, FKP methods) impossible [15].

Figure 2. Architecture of selected active geodetic networks:
a) SWEPOS – Sweden,
b) OS-AGN – Great Britain, and
c) CORS – USA

The standard RTCM 3.0 version has been recommended since 2004 [14]. Setting up in 2008 of the active geodetic network service and a significant quality change within the range of precise GPS (multi system receivers, frequency increasing up to 20 Hz, leveling geodetic model implementation) have induced interdisciplinary team of researchers to undertake a study on GPS usability for geodetic railway services [11]. Satellite surveying will enable in the future to perform the actual state inventory as well as a regularly updated rough route marking. Action towards the implementation base of a new measurement technique for railway should be undertaken.

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4 ASG-EUPOS NETWORK

In the 1990s, Central and East European countries started setting up DGNSS stations. They were not compatible with the West European stations. In Berlin in 2002, a decision was taken about European Position Determination System development in the direction of the East. Polish part of the ASG-EUPOS system has consisted of 98 reference stations evenly covering the country area (Fig. 3). Except for the new starting-up stations, the system also adapted existing stations managed by universities, research and development centres, state administration and private companies. At present, 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.

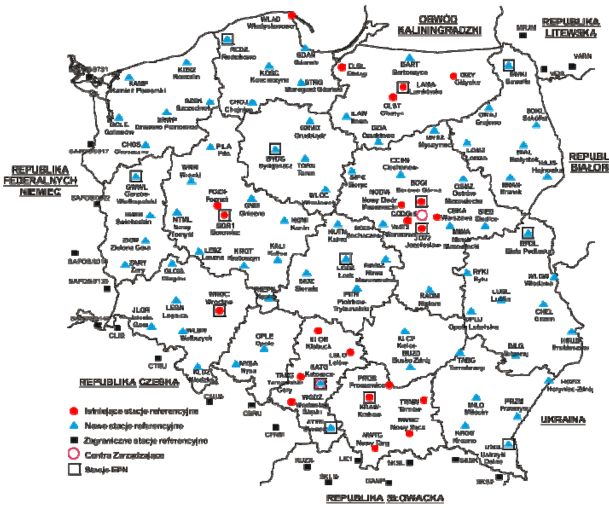

Figure 3. Location of ASG-EUPOS reference station system

National Management Centres, called also Counting Centres, are the second segment of ASG-EUPOS system. The Central Office is in Warsaw and its branches are in Katowice. They are responsible for: controlling and managing the network of stations, corrections generating of conducted observations, and making satellite surveying available to the recipients. All interferences are signalled and analysed; if necessary, countermeasures are undertaken. Both Counting Centres are redundant in the range of done services. Beside position surveying services, Counting Centre has maintained a reference system. A weekly control makes it possible to supervise the invariability of points defined by the system. The highest number of users served by Counting Centre is 1,200. Users, who use the centre services of real-time data provision and correction, exploit mainly Internet and GSM. Corrective information is sent to users via Internet using specially elaborated NTRIP protocol. GSM has used GPRS package data transfer. Working far from the cities can pose a problem of being out of range of one or even all mobile communication operators. For that reason, users who want to take the advantage of being delivered the correction data should have SIM cards of a few mobile operators.

5 EVALUATION OF THE USE OF SELECTED SERVICES IN COASTAL AND INLAND NAVIGATION

The main products (services) of ASG-EUPOS are presented in Table 2.

Real-time services are based on the principle of differential observations using DGNSS (Differential GNSS) or RTK (Real-Time Kinematics) utilizing a reference stations network [20]. The whole process of data exchange is in real time with the use of GPRS transmission via Internet, therefore the users receive their precise position in the field, in real time. Depending on the surveying method and hardware capabilities the precision of real-time services in ASG-EUPOS vary between 3 metres and 3 centimeters. KODGIS and NAWGIS DGPS services are generally used in GIS applications. The NAWGEO service is most commonly used in geodetic applications of all kinds. In NAWGEO service the user has the possibility to choose from various types of RTK/RTN corrections, such as traditional corrections from a single base station (RTK), although mainly network corrections (RTN) like MAC (Master and Auxiliary Concept), VRS (Virtual Reference Station), FKP (Ger. Flächenkorrektur-parameter) are used.

Table 2. ASG-EUPOS Products (Services)

Type	Name	Survey method	Data transmission	Estimated precision	Minimal hardware requirements
Real-time services	NAWGEO	kinematic (RTK/RTN)	Internet, GSM (GPRS)	up to 0,03 m (hor.) do 0,05 m (vert.)	L1/L2 RTK receiver, communication module
	KODGIS	kinematic (DGPS)		up to 0,25 m	L1 DGPS receiver, communication module
		NAWGIS		up to 3 m	
Post-processing services	POZGEO	static, rapid static	Internet	Depends on survey conditions (0,01 - 0,10 m)	L1 GPS receiver
	POZGEO D	static, kinematic			

The post-processing services are provided mostly for users that conduct static surveys in the field and demand most precise results. POZGEO service enables the user to send one's observation file in RINEX format in order to receive automatically calculated coordinates of the measured point along with estimated precision of the assessment. The result is generated in the form of a report available for downloading via ASG-EUPOS website. The POZGEO D service is meant for more advanced users that utilize their own software to process GNSS observations and adjust GNSS networks. Here users download observation files from ASG-EUPOS reference stations for their own processing.

But there are also a lot of special dedicated services. There is huge potential to use selected services in inland, coastal and off-shore navigation: positioning of drilling rigs, floating production storage and offloading (FPSO) vessels, location of natural gas and oil platforms, compliant towers, condeep plat-forms, offshore wind farms, installation of cables and gas pipelines, operation with conductor support systems (satellite platforms), etc.

This capabilities and expertise can include:

- float-over detailed design,
- conventional jacket and deck loadout, transportation, launch, floatation, lowering and lifting,
- large deck float-over concept development,
- marine analysis, structural analysis and design, offshore operation support,
- compliant tower installation,
- floating platform installation,
- flexible riser and umbilical installation.

At least two simultaneously operating receivers are required for differential global navigation satellite system (GNSS) positioning. In this mode, the systematic errors between stations can be es-timated or reduced in order to achieve much high-er accuracy. Precise point positioning (PPP) is a combination of the original absolute positioning concept and differential positioning techniques [7]. In PPP we use observation data of a single re-ceiver and additional information on individual GNSS errors derived from a GNSS network, usu-ally from ground based augmentation systems (GBAS). GBAS systems can be divided by the area of operation into global, continental, national or regional ground support systems (e.g. ASG-EUPOS, CORS, SAPOS, SWEPOS). GBAS sys-tems allow users with a single receiver to position in differential mode based on observations from the reference stations. For differential processing mode, the ASG-EUPOS service can be selected. Accuracy clearly decreases for points measured under conditions of limited satellite availability. Analogous ASG-EUPOS service accuracies are much better.

6 EXPERIMENTAL MEASUREMENTS

The experimental measurements for usability evaluation of ASG EUPOS network was conducted on February 18th, 2015. Measurements were made by Trimble 5700 receiver using RTK/VRS technology (NAVGEO). Data for the RTK correction was obtained via the Internet from the Orange mobile phone network. Measurements were made at points of Gdynia (near the AMG Faculty of Navigation), Hel (main square), and Cetniewo (in COS). The ASG EUPOS reference stations in the area of the Baltic Sea coast are shown in Figure 4.

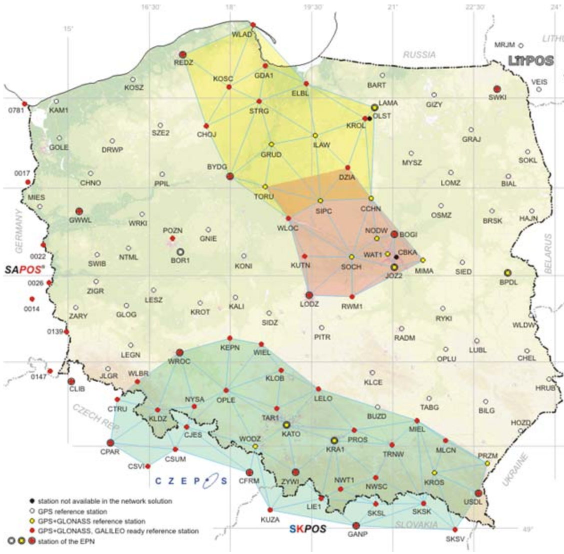

Figure 4. Network of ASG EUPOS reference stations [21]

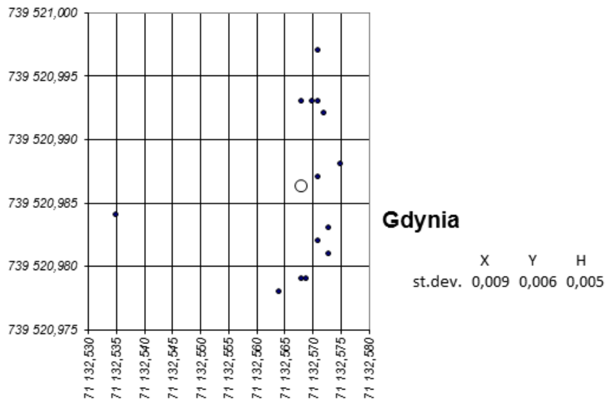

Figure 5. The results of measurements at Gdynia point in the GUGiK '92' coordinate system (coordinates in meters)

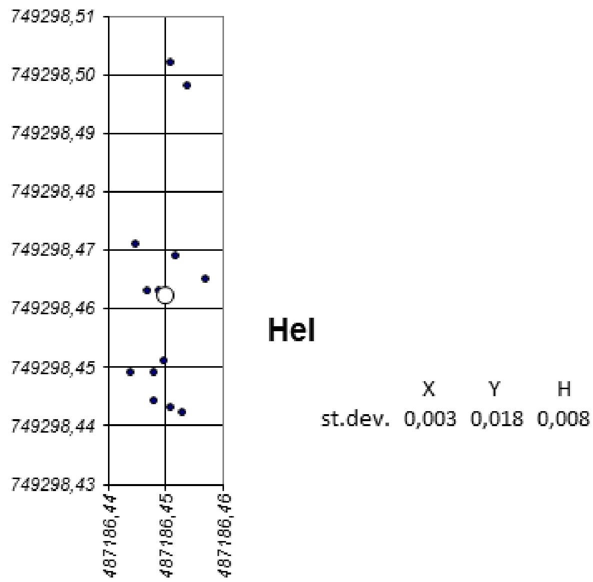

Figure 6. The results of measurements at Hel point in the GUGiK '92' coordinate system (coordinates in meters)

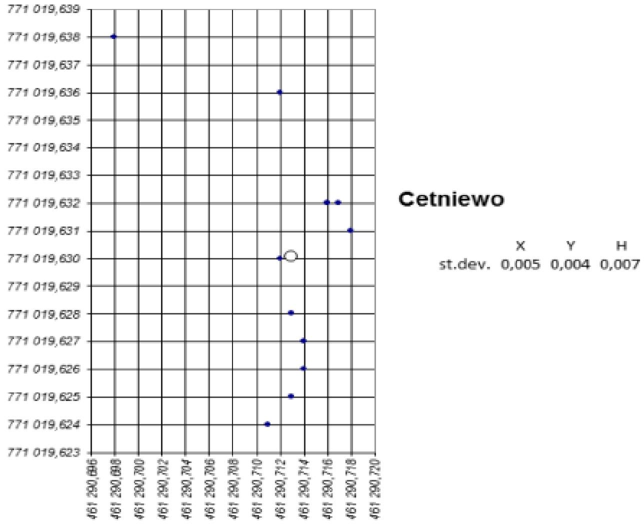

Figure 7. The results of measurements at Cetniewo point in the GUGiK '92' coordinate system (coordinates in meters)

Gdynia point is located inside the triangle of the ASG EUPOS reference stations: WLAD (Władysławowo), Gdańsk (GDA1) and Elbląg (ELB). Hel point lies outside the aforementioned triangle net-work of reference points and therefore uses extrapo-lated differential correction. Cetniewo point lies near WLAD reference point. In the aforementioned points triplicate measurement results after 10 ses-sions are shown in figures 5, 6 and 7.

The analysis of the results presented in Figures 5, 6 and 7 indicates that the results obtained at Cetniewo point are much better than those from Gdynia point, because Cetniewo point is located very close to WLAD reference station. At Hel station , there is much greater divergence in the northern component (up to 4 centimetre) because the corrections of the RTK/VRS are extrapolated.

An important problem to occur as measured by RTK with ASG EUPOS network is internet coverage provided by mobile telephony. The ORANGE mobile phone coverage map is shown in Figure 8.

Figure 8. Coverage Map Orange mobile in Poland [22].

The analysis of the map brings the conclusion that mobile phone range covers almost the entire Gulf of Gdansk and in the coastal zone of less than 10 nautical miles (Nm). These information are estimates, because network administrators, unfortunately, do not provide accurate data.

7 SUMMARY AND CONCLUSIONS

The ASG-EUPOS system is a convenient tool to precisely specify the location of stationary or moving object. The NAVGEO services will enable to identify the object position at sea. Depending on the expected accuracy, it will be possible to take advantage of the NAWGEO, KODGIS and NAWGIS services. The applications of all these services require Internet connection to work with the ASG-EUPOS network. In practice, the coverage of the Internet range outside the mainland limits to a distance of about 10 nautical miles from shore. Another limitation is the distance from the reference station at which it is possible to use the method of RTK. In practice, this distance is about 20 kilometres, which is about 10 nautical miles. In conclusion, the distance of 10 nautical miles from shore limits the application of the RTK method using data via the Internet. This disadvantage is mitigated by the use of the VRS method. It should be noted, however, that the VRS data at sea will be extrapolated which will reflect on the measurement results. The results of our measurements can be seen at HEL station, which lies outside the reference station network. However, even for this station, they were well within the limits provided by the ASG network administrators. That means for the NAWGEO service – 3 centimetres in horizontal position and 5 centimetres in a vertical one.

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