

Status and prospects of differential navigation and high precision positioning GNSS-technologies in Ukraine

Alexey Zhalilo, Vladimir Shokalo

Abstract – The results of the analysis of status and prospects of differential navigation and high precision positioning using GNSS and their functional augmentations in the world and in Ukraine are stated. The ways of implementation in Ukraine of up-to-date technologies and EGNOS, EUPOS systems, prospects and tasks of development of domestic satellite navigation service are analyzed.

Keywords - GNSS (GPS, ГЛОНАСС, Galileo, EGNOS/WAAS), functional augmentation, differential subsystem.

INTRODUCTION

At present satellite technologies of navigation and precision positioning (geoinformation and other applications) have got great progress connected with presenting by countries-owners of global navigation satellite systems (GNSS) GPS, GLONASS to the international community, in the nearest prospect - Galileo, Beidou-Compass and their functional augmentations EGNOS/WAAS/MSAS, GAGAN, GBAS/LAAS and others. Satellite radio navigation systems are in continuous evolution, there is integration and complexification with other systems, more update methods of GNSS observation performance and processing are developed. This is also confirmed by sustainable development of the world market of information services for support of high precision and reliable navigation and numerous geoinformation applications.

Now in Ukraine the abilities of satellite navigation are called-for practically in all the spheres of economy – from transport, power engineering and communication up to building and agriculture. In order to solve the problem there is need to search solutions that considerably decrease the cost of positioning and increase their effectiveness and economic return.

The objective of this paper is presentation of the current condition and tendencies of development of state-of-the-art technologies of differential navigation and high precision positioning by GNSS signals in the world and in Ukraine, working out of proposals concerning choice and development of technologies and systems that are more prospective and optimal for economic conditions and users of Ukraine.

STATUS OF DEVELOPMENT OF UP-TO-DATE TECHNOLOGIES AND SYSTEMS OF DIFFERENTIAL NAVIGATION AND HIGH PRECISION POSITIONING IN THE WORLD AND IN UKRAINE

1. Today it is impossible to imagine the vehicle navigation, carrying out researches, geodetic surveys and other kinds of activity without GNSS use. GLONASS updating is in high rate, there are being developed satellite systems and their functional ground and space augmentations in China, India, Japan and other countries. In Europe the efforts are directed to the creation of Galileo system. Below are given the typical

examples and main tendencies of development in the world of technologies and systems of satellite navigation and precision positioning at the modern stage. A short characteristic of the condition of development of the given branch in Ukraine is presented.

2. In the world there are several different approaches to differential corrections formation. We can mark out two main groups. The first group of systems (Multi-Reference Differential –MRD) forms corrections in measurement space, the second one – in state space of separate model-based observation errors components. During the realization of the second approach (Wide Area Differential - WAD) user receivers transform separate error components in the vector of observation corrections of the current position of users. WAD-method is correlated by accuracy with MRD-method, however it has a very important advantage – in ensuring the monitoring reliability of the quality of navigation determinations directly at user's. It is very important for critical navigation transport applications. Putting into operation of (in addition to traditional ground correcting DGNSS stations) of space (SBAS) wide area WADGNSS (WAAS (USA), EGNOS (EU), MSAS (Japan) and other functional GNSS augmentations) changed greatly the approaches to providing "Safety-Of-Life" navigation. Such international organizations as ICAO, IMO and others noted in their documents that satellite navigation systems and their augmentations are today the most priority means.

3. It is also important to mention about up-to-date commercial network global real time differential systems OmniSTAR/FUGRO and StarFire NavCom Tech. of sub-meter and decimeter accuracy that use combined WAD/MRD approaches. Another interesting example of building the regional multifunctional differential system of a modern level is the alternative European multifunctional commercial system EUPOS, based on the principles of SAPOS system (Germany) which assumes the deployment in the countries of Central and Eastern Europe (including Ukraine) of the ground infrastructure similar to SAPOS. EUPOS includes the subsystems of meter/decimeter and centimeter accuracy and also the post processing subsystem of centimeter/sub-centimeter accuracy. Here it is supposed to deploy in the served territory the network of stations of high concentration with baselines of 50-70 km.

4. Today in Ukraine is outlined certain progress in need and use of GNSS information by different users. At the modern stage of development of Ukraine one of the main tasks is creation and implementation of new up-to-date satellite technologies of navigation and coordinate service, in particular, expansion of EGNOS system and its zone of responsibility in the territory of Ukraine – deployment of the Ukrainian part of the ground segment and its integration to EGNOS, participation in the deployment of GALILEO

Alexey Zhalilo, Vladimir Shokalo – Kharkiv National University of Radio Electronics, Lenin Ave., 14, Kharkiv, 61166, UKRAINE, E-mail: gpsgroup@kture.kharkov.ua

system. The further stages of development of navigation service in Ukraine presuppose the deployment of local systems including high precision geoinformation applications.

Unfortunately, in Ukraine there is still a lack of available for mass users national satellite navigation service of modern quality level. But the area of high precision positioning, geodetic branch have undergone lately considerable positive changes. This also concerns the creation of national system of coordinates USK-2000, deployment in Carpath and Lviv regions of modern foreign local RTK/VRS systems, development of domestic technologies of precision positioning.

A serious legislative instrument of development and implementation of modern GNSS technologies is National Special Purpose Science-Technical Space Program of Ukraine for 2008-2012. Within the framework of the Program it is prepared the project of the agreement between Ukraine and Russia on the performance of the project of the creation of the united navigation-time area on the base of GLONASS system and other GNSS. The interaction between Ukraine and EU on EGNOS-Galileo program is planned to be carried out by use within the framework of the ground infrastructure of EGNOS system of Ukrainian GNSS stations. Such joint activity can serve as a base for the development of transboundary cooperation between Ukraine and EU countries including the activity during the performance of the European Football Championship EURO-2012.

DOMESTIC DEVELOPMENTS AND IMPLEMENTATION IN UKRAINE OF UP-TO-DATE DIFFERENTIAL GNSS-TECHNOLOGIES AND SYSTEMS WITH THE PURPOSE OF EFFECTIVENESS INCREASE OF TRANSPORT, GEOINFORMATION AND OTHER APPLICATIONS

Below is given a short description of the examples of some domestic developments having scientific practical value for Ukraine, allowing, in the opinion of the authors, to approach to the European and world standards in the examined sphere. Here it is also necessary to make special mention to considerable contribution in the development of domestic GNSS-technologies of many enterprises and universities of Ukraine. We will mark out the following important projects and developments.

1. Now the foundation of the base coordinate service of Ukraine is the created under the direction of Academician Yaroslav Yatskiv the Ukrainian network of permanent GNSS stations [1] (Fig. 1). This network, as well as the majority of the national networks of other countries, is created by common efforts of several organizations and institutes. As to 2009 in the territory the network consists of 14 permanent stations which data are open (see Web-site <http://www.mao.kiev.ua/EOP/>).

2. Under the aegis of NSAU (the National Space Agency of Ukraine) it is being realized the project of creation of SNSSU – Space Navigation Service System of Ukraine [2] (developer – JSC NIIRI, Kharkiv). The system is created as multifunctional National ground functional differential GNSS augmentation of MRD-type. Initially SNSSU was planned to

be created similar to the European system EGNOS as differential WAD augmentation to GPS and GLONASS systems. However, in the course of the subsequent events due to the changed circumstances it was accepted the decision to assume as a basis of SNSSU the principles of the European project EUPOS. The differential corrections that are formed at the existing stage of SNSSU development allow, by estimate, to carry out user positioning with accuracy of ~1 m in the plan and ~2 m by height in all the territory of Ukraine. The SNSSU main functions are formation of differential corrections and integrity signals (serviceability) of GNSS satellites in real time scale and providing SNSSU primary measuring information to users for carrying out geodetic works. In contrast to EGNOS/WAAS SNSSU due to the principles of its building does not provide for support the mechanism of granting in real time high reliability of user navigation service in critical applications.

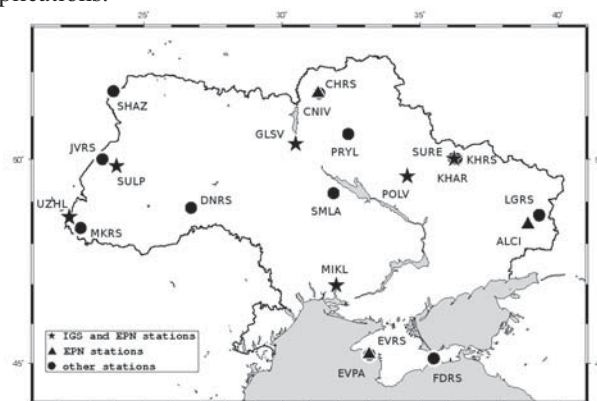


Fig.1 Ukrainian permanent GNSS station network

3. In 2007-2008 the Main Astronomic Observatory (MAO) of NASU of Ukraine under the leadership of Academician Yaroslav Yatskiv performed the innovation pilot-project [3] of creation of the prototype of the information-measuring GNSS system (IMS) for the purpose of providing high precision positioning which for the conditions of Ukraine is an effective alternative to the west RTK-technologies VRS/FKP и MAX/i-MAX.

The base of the performance of the project were the results of the researches that had been obtained in the course of the previous developments of MAO NASU and partner organizations (KhNURE, Kharkov, NAU, Kiev, ChSIEC, Chernigov). State Enterprise «Orizon-Navigation» (Smela, Cherkassy region) also took part in the performance of the project.

The system gives the opportunity to provide centralized informational support of user geodetic surveying works, has the opportunity of granting information and other services. The core of the system's software is OCTAVA complex which had been jointly developed by the specialists of KhNURE and MAO NASU. In the area of GNSS station network's activity (Kiev, Chernigov and Cherkassy regions) with baselines of ~150-170 km it is achieved centimeter/decimeter accuracy of positioning in post-processing mode. During the realization of real time kinematic RTK positioning the users can do geodetic survey (accuracy 2-5 cm) in the radius 20-25 km relative to

the nearest base station. At the present time are being done works on putting the system into experimental operation. Here it is supposed to expand the network of reference permanent GNSS-stations by way of adding the stations in Poltava (POLV) and in Kharkov (KHAR, SURE), and also to deploy new stations in Sumy and Novgorod-Seversky (Sumy region), that gives the opportunity to cover ~20% of the territory of Ukraine (see Fig. 2).



Fig.2 Expansion of IMS station network

4. In compliance with the National Space Program the important direction of GNSS-developments is creation of means of independent monitoring (supervision) of real characteristics of satellite navigation service (accuracy, integrity, availability and service continuity).

5. The contribution in GNSS-technologies development is also done by KhNURE. The basic achievements of the University in this sphere consist in the following:

1) Recently after the appropriate certification in the structure of the network has been implemented SURE station (KhNURE, Kharkiv). SURE station. The station (Fig.3) has been continuously operating since 2007. The station's observation quality control is performed by use of OCTAVA_PPA software (the joint development of KhNURE and MAO NASU). The antenna's phase center periodic coordinate tying is performed with millimeter accuracy in ITRF-2005 coordinate system.

2) Firstly in Ukraine at SURE station was realized the mode of formation and transmitting in real time of DGPS/RTK differential corrections [4]. Here it is organized simultaneous transmitting of any two types of DGPS/RTK messages or primary measuring information through NTRIP-caster.

3) In the course of researches it is proposed an effective and simple technique of quality verification of geodetic class GPS antennas phase calibrations [5]. The technique allows to carry out phase calibrations accuracy estimation for specified conditions of GNSS antenna operation.

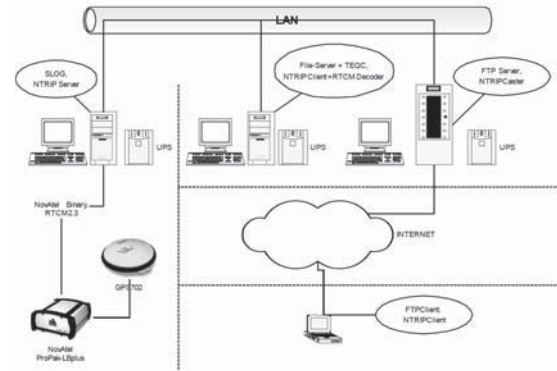


Fig.3 Architecture of SURE station

4) In the period of 2005-2007 were developed and realized new methods and algorithms of positioning by use of smoothed code-phase observations. It is realized the network method of formation and use of DGNSS/MRD differential corrections. The method permits to achieve decimeter accuracy level at base distances up to 300-500 km.

5) At present it is carried out the development of the alternative, principle new approach to solving the tasks of centimeter accuracy network positioning based on centralized «cooperative» optimized estimation and precision modeling of slowly varying errors by use of the network reference stations GNSS observations and user observations. The given approach allows to overcome informational restrictions of the existing foreign VRS/FKP и MAX/i-MAX technologies when a user himself carries out differential positioning using the corrections formed only by the network of base stations.

PROSPECTS AND TASKS OF SATELLITE NAVIGATION SERVICE AND HIGH PRECISION POSITIONING DEVELOPMENT IN UKRAINE

With the purpose of speed-up of creation and implementation of the most effective for users of Ukraine modern satellite navigation technologies in Ukraine and participation in EGNOS and Galileo programs there may be recommended the following perspective directions of developments and researches.

1. Performance of the planned project of researches with the aim of extension of EGNOS functioning to the territory of the Eastern Europe - «EGNOS Extension to Eastern Europe» (FP7-GALILEO-2008-GSA-1, GALILEO.2008.4.3.4 EEGS) with participation of MAO NASU, JSC NIIRI and KhNURE. Within the framework of the project in 2010 it is planned to estimate the quality of EGNOS navigation service in the territory of Ukraine by realization of GMV magicSBAS technology. This will allow later to solve reasonably the problem of deployment in Ukraine of the elements of EGNOS system.

2. The completion of the development and performance of SNSSU certification by use of domestic instrumentation of independent monitoring (supervision) of real characteristics

(accuracy, integrity, availability, continuity) of satellite navigation service.

3. Within the framework of prolongation of MAO NASU innovation pilot-project the completion of creation and putting in operation of the information-measuring multifunctional system of high precision positioning by use of the infrastructure of the network of permanent reference GNSS-stations of Ukraine.

4. It is necessary to use and implement new, the alternative more effective for the Ukraine methods of solving the tasks of high precision network positioning of centimeter accuracy based on centralized «cooperative» optimized estimation and precision modeling of slowly varying errors by use of the network reference stations GNSS observations and user observations.

CONCLUSION

The analysis of the current state and tendencies of the development of the latest technologies of differential navigation and precise positioning by GNSS signals in the world and in Ukraine is stated in the paper.

The examples of significant domestic developments having the important scientific and practical value, allowing, in the opinion of the authors, to approach to European and world standards in the examined sphere are shortly described.

The proposals on the development of technologies and systems of satellite navigation service and precision positioning that are more perspective and optimal for economic conditions and users of Ukraine are presented.

It is shown that modern information service in all the territory of Ukraine is possible on the assumption of deployment and development of different up-to-date supplementing each other differential GNSS-subsystems of precision and reliable coordinate determination and navigation.

Of great importance is integration and compatibility of GNSS infrastructure of Ukraine with the European navigation systems.

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