CURRENT AVAILABILITY OF GLOBAL NAVIGATION SATELLITE SYSTEMS AND THEIR WIDE AREA AUGMENTATION SEGMENTS ON THE TERRITORY OF THE SR

Marián Staňa – Stanislav Ďurčo

The importance of the Global Navigation Satellite Systems ha s been constantly growing since their invention not only in the common civil life, but mainly in the aviation. Usage of this systems in the applications of civil aviation is the subject of long-term development aimed on increase of system parameters, so to meet the requirements of the specific regulations in the field of civil aviation. The information about current status of the GNSS, comparison of their accuracy in the Slovak Republic and their availability to be used on the approach segment is described in this report.

K e y w o r d s: cosmic segment, ground segment, accuracy, integrity

1 INTRODUCTION

Driving force of the GNSS development in the field of civil aviation is not only to provide the reliable navigation systems but it is the effort to achieve the system's parameters in accordance to high safety requirements. Introduction of the specialized services called SoL (Safety of Life) is one of the most important contributions to the enhanced usability of the Global Navigation Satellite Systems nowadays. In the territory of the Europe, the Safety of Life service can be used thanks to the EGNOS system, which is wide area augmentation system, officially made for augmentation of the GPS system. EGNOS stands for European Geostationary Navigation Overlay Service and it is the joint program of the European Space Agency (ESA), European Commission (EC) and the Eurocontrol.

2 CURRENT STATUS OF THE GNSS SYSTEMS

2.1 GPS

The GPS (Global Positioning System) is a well known global satellite navigation system created by the U.S. military which achieved the full operational capability in the 1995 after more than twenty years of research, development and implementation activities. The GPS includes cosmic, control and user segments.

The cosmic segment of the system currently consists of 31 satellites (Blocks IIA, IIF, IIR, IIR(M)) placed on the six orbits with altitude of 20 200 km and inclination of 55º. These orbits are rotated by 60º against each other.

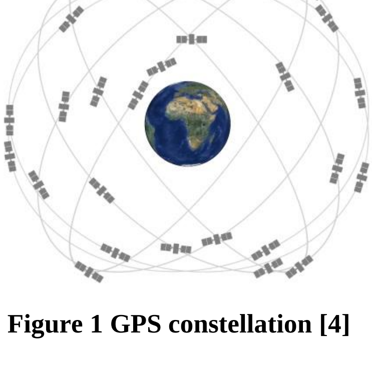

Figure 1 GPS constellation [4]

Control segment of the GPS is created by the site of ground facilities used for monitoring of the satellites, analysis of their signal and transmission of commands and data to the satellites. Master Control Station (MCS) of the system is located at Schriever AFB in Colorado USA. Main task of the MCS is to ensure the operational capability of the GPS. To fulfil this task, MCS receives the monitoring information from the Monitoring Stations, analysis this information and uses it for proper system corrections. The third part of the segment are Communication Stations used for transmission of command and control information to the satellites.

The GPS uses the L – band frequencies (L1-L5) to transmit the navigation signal. Two basic signals are transmitted – precision (P), which is transmitted on L1, L2 frequency and the civil signal (C) available to users without any limitations but offers worse accuracy, using the L1. Band L3 is used for signals containing the information about nuclear explosions or other high-energy sources of emissions in the infrared spectre. Band L4 transmits ionosphere corrections. SoL signal uses L5 but it will be available on 24 satellites in the 2021 according to the latest system information. Two more signals are planned to be used on L1 and L2 specifically L1C (will ensure interoperability of GNSS) andL2C (for commercial use).[4]

2.2 GLONASS

GLONASS is global navigation satellite system of Russian Federation and it is the Russian counterpart to U.S. GPS. Maybe the main difference is, that GLONASS uses frequency multiplexing instead of code multiplexing used by GPS, which means the GLONASS satellites are transmitting on different frequencies while GPS satellites are transmitting on one frequency, but with different code (PRN).Russian system also uses different referential ellipsoid – PZ-90 instead of WGS-84.

Cosmic segment currently consists of 29 satellites (23 operational capable, 3 in maintenance status, 2 spare, 1 in test phase). These satellites are placed at three orbits with altitude of 19 100 km. Orbits have inclination of 64,8º and they are rotated by 120º against each other. Constellation consists of GLONASS M satellite type but the future of the system will be presented by GLONASS K satellites.

Figure 2 GLONASS constellation

Control segment is presented by:
System Control Centre (SCC), which receives the data from monitoring stations, analysis it and use it for corrections then transmitted to the satellites by the site of Communication stations. It's task is similar to GPS MCS.. Control segment consists also from other specialized facilities and devices such as Laser Ranging Stations and Central Synchronizer.

Such as GPS, the GLONASS uses the L – band frequencies to operate, but as mentioned above, GLONASS uses frequency multiplexing. L1 and L2 frequencies are used to transmission of standard (C) and precision (P) signals. L3 and L5 frequencies are also available and similar to the GPS.[5]

2.3 EGNOS

It is the system of wide area augmentation officially designed to augment the GPS. EGNOS signal is available in the territory of Europe and the transmission of the signal is ensured by three geostationary satellites (ARTEMIS, INMARSAT AOR-E, INMARSAT IOR-W) placed on geostationary orbit at an altitude of 36 000 km.

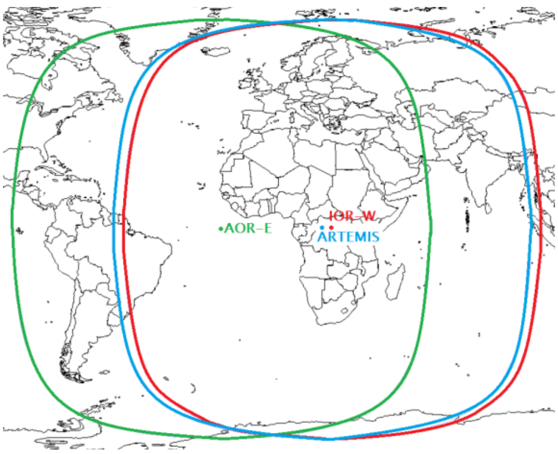

Figure 3 EGNOS satellites position

Control segment of the EGNOS system consists of:

- Mission Control Centres (MCC),
- Ranging and Integrity Monitoring Stations (RIMS),
- Navigation Land Earth Stations (NLES),
- Performance Assessment and Checkout Facility (PACF),
- Application Specific Qualification Facility (ASQF).

EGNOS system operation principle can be described in three steps:

1. Collection of GPS satellites data,
2. Differential corrections calculations and creation of EGNOS messages,
3. Transmission of messages via EGNOS system satellites.[2]

Data are collected via network of RIMS and then processed by Central Processing Facilities, which are parts of the Mission Control Centres. Central processing Facilities generates the system messages, which are transmitted to users via EGNOS satellites.

System provides three basic services:

- Open Service (OS),
- Safety of Life (SoL),
- Commercial Data Distribution Service (CDDS).

The system can support aviation navigation down to the Approach with Vertical Guidance (APV I). Requirements for such an operations are described in Annex 10 Vol. I and are presented in the following figure

	Accuracy		Integrity				Availability	Continuity
	Lateral 95%	Vertical 95%	Alert Limit Lateral	Alert Limit Vertical	Integrity [1]	Time to Alert		
En route	2.0 NM / 3704 m	N/A	4 NM / 7.4 km	N/A	$1-10^{-7}$/h	5 min	0.99 to 0.99999	$1-10^{-4}$/h to $1-10^{-8}$/h
En route, Continental	0.4 NM / 740 m	N/A	2 NM / 3.7 km	N/A	$1-10^{-7}$/h	15 s	0.99 to 0.99999	$1-10^{-4}$/h to $1-10^{-8}$/h
Terminal Area	0.4 NM / 740 m	N/A	1 NM / 1.85 km	N/A	$1-10^{-7}$/h	15 s	0.999 to 0.99999	$1-10^{-4}$/h to $1-10^{-8}$/h
Initial Approach, Departure	220 m	N/A	0.3 NM / 0.6 km	N/A	$1-10^{-7}$/h	10 s	0.99 to 0.99999	$1-10^{-4}$/h to $1-10^{-8}$/h
Non Precision Approach	220 m	N/A	1 NM / 1.85 km	NA	$1-10^{-7}$/h	10 s	0.99 to 0.99999	$1-10^{-4}$/h to $1-10^{-8}$/h
Approach Vertical Guidance APV I	16 m	20 m	40 m	50 m [2]	$2-10^{-7}$ per approach [3]	10 s	0.99 to 0.99999	$1-8x10^{-6}$ in any 15 s
Approach Vertical Guidance APV II	16 m	8 m	40 m	20 m	$2-10^{-7}$ per approach [3]	6 s	0.99 to 0.99999	$1-8x10^{-6}$ in any 15 s
Precision Approach CAT I	16 m	6 m to 4 m	40 m	12-10 m	$2-10^{-7}$ per approach [3]	6 s	0.99 to 0.99999	$1-8x10^{-6}$ in any 15 s

Figure 4 Signal performance requirements[3]

3 COMPARISON OF GNSS ACCURACY IN THE TERRITORY OF THE SLOVAKREPUBLIC

Comparison of GNSS is based on the on available DOP values for GPS and GLONASS systems. Selected methods of mathematical statistic used:

- Median, which is the method used for calculation of the points stored in a series. It is the middle value of the sample, so the half of the values are greater in size and second half of the values is lesser in size.
- Mean squared error, which is a measure of statistical dispersion, which allows to determine the distribution of values in the set. It is characterized as the positive square root of the variance.

Comparison consists of DOP values for 29 Slovak airports. On the basis of determined values, it can be said, that the GPS is more accurate then the GLONASS in the territory of the Slovak Republic. GLONASS system is less accurate for about 18,5 %.

Bratislava / M. R. Štefánik N 48° 10' 12" E 017° 12' 45"		**Median**			
		GDOP	PDOP	VDOP	HDOP
	GPS	1.68985	1.51026	1.22804	0.87117
	GLONASS	2.00626	1.99346	1.52699	0.99931
		Mean squared error			
		GDOP	PDOP	VDOP	HDOP
	GPS	0.07741	0.04584	0.04604	0.00554
	GLONASS	0.15740	0.11098	0.10834	0.03131
Košice N 48° 39' 46" E 021° 14' 28"		**Median**			
		GDOP	PDOP	VDOP	HDOP
	GPS	1.70627	1.51742	1.19751	0.87733
	GLONASS	1.98566	1.78756	1.48499	0.99883
		Mean squared error			
		GDOP	PDOP	VDOP	HDOP
	GPS	0.05331	0.03548	0.04041	0.00583
	GLONASS	0.08546	0.05977	0.07500	0.01678
Piešťany N 48° 37' 30" E 017° 49' 42"		**Median**			
		GDOP	PDOP	VDOP	HDOP
	GPS	1.67507	1.50830	1.25262	0.87349
	GLONASS	1.98289	1.78623	1.51453	1.00514
		Mean squared error			
		GDOP	PDOP	VDOP	HDOP
	GPS	0.07644	0.04424	0.04352	0.00809
	GLONASS	0.08616	0.04593	0.07383	0.01934

Figure 5 Comparison of choosen airports

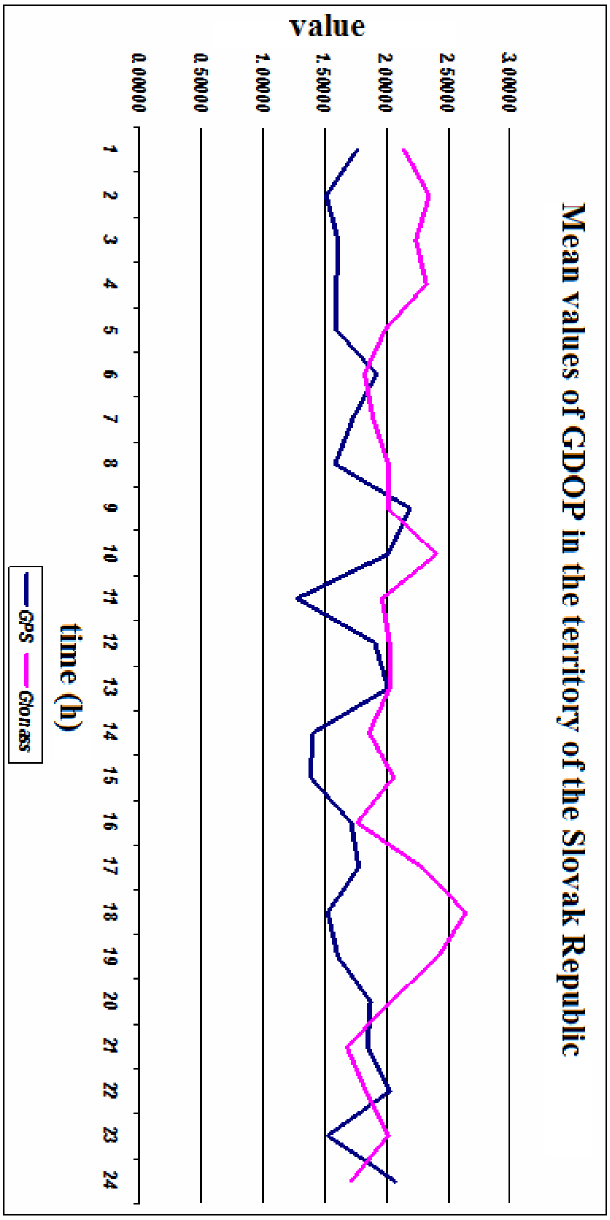

Figure 6 Example of the GDOP comparison for the territory of the Slovak Republic

4 OPTIONS OF USE OF THE GNSS IN THE APPROACH PHASE

The GPS system has been chosen to predict integrity for, because of better accuracy in the territory of the Slovak Republic. RAIM method (Receiver Autonomous Integrity Monitoring) has been chosen to predict the integrity of GPS in the areas of specified Slovak airports. Two algorithms were used:

- FD (Fault Detection),
- FDE (Fault Detection with Exclusion)

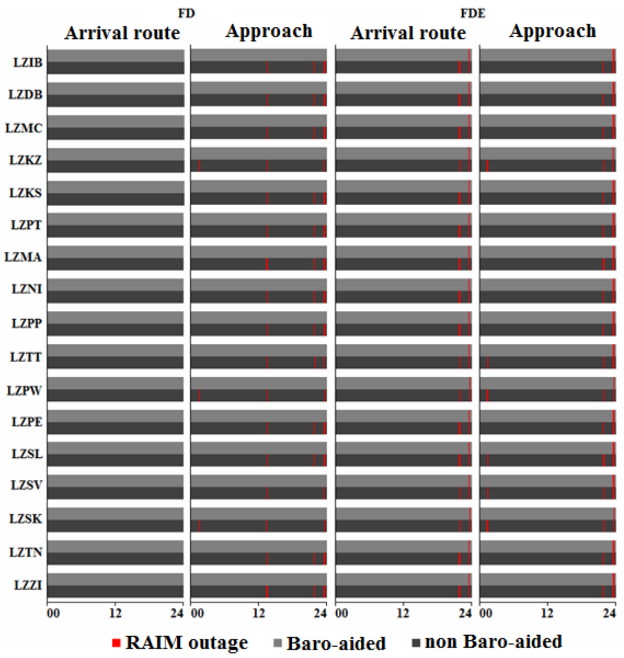

Figure 7 Integrity prediction for specified airports [5]

As a result, it can be said, GPS can be used for navigation in the areas of presented airports, but there is a necessity to plan the flight so to avoid RAIM outages, although these outages are negligible.

5 CONCLUSION

GNSS gain on importance nowadays, when amount of air traffic is rising and surface navigation facilities have their capacity limitations. Long-term efforts of GNSS development are to improve these systems and to allow their use in all phases of flight, however this efforts have to meet the specified requirements on accuracy, integrity, availability and continuity of the navigation signal. In Europe, the EGNOS system can be used in applications that are so called safety critical. EGNOS officially augments the GPS, and it is capable to be operated in accordance of requirements for Approach with Vertical guidance (APV I), but EGNOS is planned to be used for CAT I approaches in the future.

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AUTHOR(S)´ ADDRESS(ES)

Marián Staňa, Bc.
Technická univerzita v Košiciach
Letecká fakulta, Rampova 7

Stanislav Ďurčo, Ing. , PhD.
Technická univerzita v Košiciach
Letecká fakulta, Rampova 7
stanislav.durco@tuke.sk