SATELLITE NAVIGATION AND ITS IMPORTANCE IN TRANSPORTATION

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Summary: Satellite navigation systems have become nowadays very common and people can see them everywhere. Their use in transport is currently indispensable. Just the fact that navigation systems are very useful and necessary leads to the expansion of available systems. In the past, product selection for the user was easy and clear, because GPS was only one option. Currently, there are several satellite systems, but their number is constantly increasing.

Key words: GPS, GLONASS, Galileo, satellite navigation

INTRODUCTION

Nowadays, we know many departments, where people need and use satellite navigational systems. In old history, they did not use these achievements of modern times, but nowadays people cannot imagine work and live without them. They are used for working, pleasure activities and also for everyday activities. Here are some departments, in which is using navigation systems common.

Automobiles

Today´s higher class automobiles include automatically satellite navigation system, mostly GPS. Also other automobiles and motorcycles, which do not have GPS from factory may have additional GPS. The main advantages of using GPS instead of map are comfortable, speed and accuracy.

Air navigation

Navigation systems in planes are usually connected with auto pilot for en-route navigation. Cockpit-mounted GNSS receivers are included in general aviation aircraft of all sizes and they are using systems as a LAAS or WAAS to improve accuracy. LAAS (Local Area Augmentation System) is an all-weather aircraft landing system based on real-time differential correction of the GPS signal. WAAS (Wide Area Augmentation System) is an air navigation aid developed by the Federal Aviation Administration to augment the Global Positioning System, with the goal of improving its accuracy, integrity, and availability.

Boats and ships

All boats and ships in the world can use the GNSS, no matter in which area they sail. Maritime GNSS units include one very important and useful function such as "man

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overboard" (MOB). This function knows how to immediately mark the place on GPS, where sailor has fallen overboard and they can easier find him.

Pleasure activities

Latterly is very modern use navigational systems for a lot of kind of pleasure activities. Fishermen uses usually these systems for marking place, where they found many fish or where the fish has hiding place. Cyclist, runners and use satellite navigation systems for easier and more accurate navigation in unfamiliar surroundings. Especially for hikers in mountains happen few times, that one of modern navigation system helped them safe their life in hostile conditions.

1. GPS (GLOBAL POSITIONING SYSTEM)

GPS is network of integrate orbiting satellites, which send precise details about their exact position in space, back to earth. Signals are obtained from GPS receivers, for example navigation devices, and they are used to calculate the exact position, time and speed at the object location.

First real mention about GPS was in 1960s during Cold War. Actually, GPS was designed for military purposes and operations. In that time, just five satellites orbiting the earth allowed ships to fix their position on the seas once every hour. Between years 1978 and 1985 GPS progressed and in the orbit were already 11 satellites. From the summer of 1993 started modern history of GPS. During this period was launched their 24th satellite into orbit and modern Global Positioning System was put into operation in 1995.

How does GPS work?

In general, GPS is consist of three main parts, which are necessary for easily operation. First part is constellation of between 24 and 32 solar power satellites orbiting the earth in orbits at an altitude of approximately 20,000 kilometres. Second part is main control station and the last part are control and monitoring stations (on Hawaii, Ascension Islands, Diego Garcia and Kawajale) and GPS receiver by the user.

Each of satellite is on orbit, which allows the receiver to detect at least four of all satellites. The satellites transmit microwave signals to the receiver, in which is built-in computer. Built-in computer these signals process and evaluate. Based on the distance, between each satellite and receiver, it can determine exact location of object.

In fact, for exact position are sufficient signals from just three satellites, to carry out this trilateration process, the calculation of receiver position based on distance from receiver to three satellites. Signal from the fourth satellite is redundant and it is used for confirmation the results of computer calculation. If the receiver position from satellites A, B, C does not match the computer calculation of the satellites A, B, D, other combinations are tested until a correct result.

2. GLONASS

GLONASS is a Russian navigation satellite system. In Russian it is called Globalnaya Navigazionnaya Sputnikovaya Sistema, or Global Navigation Satellite System in English language. The main and the most important part of this navigation system are 24 satellites orbiting above the Earth´s surface. They are located in altitude of approximately 19,100 kilometres and they are moving with inclination 64,8°. Full availability of this navigation system in all parts of Earth is with 21 active satellites. Other three serve as a service satellites in case that something happen. GLONASS is the most expensive program of the Russian Federal Space Agency.

Development of GLONASS started Soviet Union in 1976. First GLONASS satellites was launched at the orbital speed of the earth in the USSR in 1982. By 1995, all 24 navigation satellites were in orbit, completing the constellation.

How does GLONASS work?

Satellite navigation system GLONASS is consist from three components. The first of them is space infrastructure, which consists of satellite constellation. This group of satellites is working together in the system and they are usually set up in orbital planes or paths. Because these satellites are connected with ground, speed and accuracy of satellites is higher. Actually, the second component of GLONASS are ground location networks. They should be ideally spread all over the world, however GLONASS ground location networks are located mostly in Russia, Brazil, Antarctica and Cuba. Russia also wrote agreement with China for open new ground location networks on the territory of China. After this act could GLONASS become a full competitor against American GPS. The third and last part of system GLONASS is receiver. This can be any modern device that is compatible with GLONASS.

3. GALILEO

Galileo is new global navigation satellite system, which was created by European Union and European Space Agency with headquartered in Toulouse and London with two operation centres near Munich and Fucino in Italy. All project is named after Italian astronomer Galileo Galilei and it costs around 5 billion euro. The use of basic Galileo service will be absolutely free and open to everyone. The high-precision capabilities will be available for paying commercial users. Galileo is designed to measure horizontal and vertical position measurements within one meter precision and with better positioning services at high latitude, than other positioning systems.

Navigation system Galileo is constellation of 30 satellites. Twenty seven of them are operational satellites and other three are substitutes. First Galileo satellite was launched to the orbit in 2005. In the end of year 2015 system had 12 from 30 satellites in orbit. Galileo is offering Early Operational Capability (EOC) during year 2016. In next two years they wish to offer for customers Initial Operational Capability (IOC) and Full Operational Capability should be in order in 2019. Complete 30 satellites Galileo system is expected by 2020.

How does Galileo work?

Every 30 Galileo satellites will be divided over three spheres surrounding the Earth at a distance of more than 23,000km. Fact, that Galileo will have 30 satellites means, that it will be very accurate and system also can tell users how accurate signal is. Each of the Galileo satellite will have carries multiple atomic clocks on board, which are perfectly accurate. So system is working based on sending signals. Sensor station on the ground extract measurements and information from satellites and send them to operation centres in Munich or Fucino. Here, in operational centre processing takes place to derive very accurate satellite orbits and clock synchronisation. Any repairs are sent to the updated navigation message, which is then transmitted to the satellites through a series of five uplink stations. Finally, to the users are sent correct and exact information about location.

4. COMPARISON OF GPS, GLONASS AND GALILEO

4.1 Constellation characteristics

Satellites are for electronical navigation systems the most important parts. At least 4 satellites need to be visible for a receiver to be able to calculate its exact position. It is quite clear, that ideal is to have an infinite number of satellites to ensure visibility from all receivers in the world at all times. Because of the high price of one satellite approximately 40 million € (not included cost for the implementation, maintenance and operation), number of satellites is limited. Compromise between number and availability of satellites must be found.

Tab. 1 – Basic comparison of satellite systems

	GPS	GLONASS	Galileo
Number of satellites in complete constellation	32	24	27+3 spheres
Orbital planes	6	3	3
Orbital planes inclination	55°	64,8°	56°
Orbital radius	26650km	14100km	23222km
Satellite period	12h	11h 15m	-

Source: http://www.positim.com

American GPS has 6 orbitals, while Russian GLONASS and European Galileo has just 3. System GLONASS provides better accuracy of the northern skies, while GPS covers rest parts of the world. Galileo is very young navigation system, which is not finished yet and that´s why it is hard to say, how it will work, when it will be completed.

4.2 Transmitted data characteristics

We know already, that at least 4 satellites are necessary for positioning. And what is happening then? Only satellites are not enough for determining position. Receiver has to be able decode information and then it can determine location.

Tab. 2 – Transmitted data characteristics

	GPS	GLONASS	Galileo
Encoding	CDMA	FDMA, CDMA	CDMA
Modulation	BOC	BPSK	BOC, BPSK
Civil data rate	50bps, up to 100 sps	50bps	50bps, up to 1000 sps
Error, raw mode, civilian band	5 – 20m	50 – 70m	Claimed 1m

Source: http://www.positim.com

GPS is using for channel access method CDMA (Code Division Multiple Access), which was firstly utilized exclusively only in GPS navigation. CDMA is an example of multiple access, where several transmitters can send information simultaneously over a single communication channel. This allows several users to share a band of frequencies. GLONASS started with channel access method FDMA (Frequency Division Multiple Access). FDMA gives users an individual allocation of one or several frequency bands, or channels. It is particularly commonplace in satellite communication. FDMA, like other multiple access systems, coordinates access between multiple users. Scientists, whose are working for GLONASS found, that FDMA was not such a great idea as the spectrum overlapped with other uses. The latest version of GLONASS (GLONASS-K) is using CDMA and it has also allowed compatibility with GPS receivers.

Binary Offset Carrier (BOC), which is using GPS is in order to allow interoperability of satellite navigation systems. Not only in GPS, BOC modulation is used in Galileo navigation systems and Indian system IRNSS as well. BOC modulation has big advantage against BPSK modulation, because GPS with BOC is able to transmit more signals per second than GLONASS with BPSK modulation.

4.3 Provided services

GPS as a first protocol designed for military action later got declassified for public purposes. Civil signal is worldwide open and it is free for every private user. GLONASS is constructed the same is in this way and for private users is signal for free. Galileo was firstly designed for to purposes – military action and public user. As such, it will provide Open, Commercial, Safety of life, Public regulated navigation, search and rescue signals. Some of this signals (Commercial and Public regulated signal) will be encoded for fee. Galileo, as only one navigation system, will provide special rescue signals, which are intended for rescue

operations. For the first time in history of navigation systems, receiver of Galileo signals will be able to broadcast a distress signal back to the satellite.

4.4 Orbit repeat periods

One of the aim of satellites is to maintain their relative position. It means, that orbital planes have to keep the same separations (distances) as well as that all the satellites in an orbital plane have to keep the same separation (distance). In GPS it resolved by giving the constellation a repeat cycle of one day. It splits, that each sidereal day, satellite passes the same location on the Earth. This causes, that satellites are in condition, which is called ,,deep resonance" with Earth´s gravity field. Because of this ,, deep resonance" some satellites in the GPS constellation experience significant orbit perturbations. These satellites have to regularly manoeuvre to keep them close to their nominal orbit position.

In the system GLONASS satellites repeat by taking over each other position. The satellites are separated by 15 minutes in rotary position. Together with orbital period of 11 hours and 15 minutes this means, that after one day satellite in orbital plane passes the same orbital plane like a day before. This fact ensures, that constellation remains fixed and avoids the effect of resonance. Every repeat cycle of GLONASS satellites is 8 days.

One of the main idea of constructing system Galileo, that each satellite should need only one turnover during whole lifetime, for keeping it in near its nominal position in the orbital plane. This is a way to avoid ,,deep resonance", as GPS satellites have. Orbit constellation for system Galileo is 10 days repeat cycle. After 10 days, the orbit of each Galileo satellite repeats.

CONCLUSION

Russian GLONASS system is last few years in the centre of fraudulent scandals. Of the total budget was stolen more than 100 million dollars. It is the biggest reason, why is completing of GLONASS system very slowly and for this operation they need couple of more years. Galileo satellite launches, on the other side, they have gone break a couple of times. With only few prototype satellites in orbit, it is very hard to expect, that it will be difficult to truly consider them with a full-weight contender to GPS. These are the reasons, why is Global Position System still on the top between every available navigation systems and it making sense for users all over the world.

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