FIGHT FOR THE THIRD PLACE OF THE STAND – THAT IS TO SAY GALILEO AND COMPASS

István Havasi

Introduction

Today it can be stated undoubtedly that ***satellite navigation*** has become an integral part of everyday life. It is known that the basis of this is provided by satellite fundamental systems. The two most developed representatives of these are the American ***NAVSTAR GPS*** and the Soviet-Russian ***GLONASS***. In the fight for market positions of satellite navigation – in addition to the afore-mentioned determinant systems – further competitors joined in, and they also appeared with their plans for implementing fundamental systems. One of these was the European ***Galileo***, the development of which has slowed down recently; the other one was the Chinese ***Compass*** (***Beidou-2, B-2***), the investigation of which means another purpose of my study. We can say that the implementation of the Chinese satellite fundamental system has been dynamic recently. We can often read newer and newer launches of navigation satellites; it was one reason of our topic selection aiming at Compass. The other reason was that Hungarian literature pays relatively little attention to Compass, so this part of my article is intended for completion.

Characteristics of Galileo satellite fundamental system

Galileo is the first global satellite positioning and navigation system to be developed by the ***E***uropean ***U***nion (***EU***) and the ***E***uropean ***S***pace ***A***gency (***ESA***) for ***special civil purposes*** in the form of a joint venture. A modern, future, second generation system will be reviewed now where the process of implementation has not been fulfilled yet.

The space segment of Galileo is planned to consist of 30 satellites deployed in three Mean Earth Orbits. The inclination of orbital planes to the Equator is 56º, and there will be 9 satellites and a spare one in each plane (Figure 1). This satellite constellation will provide better coverage on locations of higher geographical latitude – such as in the northern part of Europe – than it is realized with American GPS satellites today. The mean rotation altitude of satellites is 23,616 km; the orbital periodic time is 14 hours; their weight is 650 kg and their life expectancy will reach 12 years. On board of each satellite two atomic clocks will provide the required frequency etalon. One of them will be a rubidium clock, while the other one will be a hydrogen maser clock. These clocks are produced in Europe and are being tested on board of the first pilot satellites. The Galileo system time will be adjusted to the International Atomic Time. Galileo satellites will transmit ten different signals on the following four L-band frequencies: 1176.45 MHz, 1207.14 MHz, 1278.75 MHz and 1572.42 MHz. As it can be seen, the frequencies of two Galileo signals are equal to the L1 and L5 frequencies in American GPS system (the L5 signal is connected to only new F type satellites). The service provided by Galileo signals can be divided into two levels: basic level and selective availability. The basic level is intended to be free here as well, similarly to the American GPS, but the system operators promise more reliable service for general

ISTVÁN HAVASI
Associate Professor, Department Head, Department of Geodesy and Mine Surveying, University of Miskolc, 3532 Miskolc-Egyetemváros, gbmhi@gold.uni-miskolc.hu

user applications. To use the other value-added commercial and professional level, naturally, it will be fee-paying, and available only to authorized users.

The ground service infrastructure of Galileo system and its sub-system of monitor stations (30-40) will be widened with an integrity-monitoring infrastructure separated from the afore-mentioned sub-system. The main tasks of the subsystem of monitor stations will be to observe the satellite constellation continuously – that is, to determine each satellite's orbit – to provide time synchronization and to produce navigation messages. All of these are provided by establishing and operating 15 automatic monitor stations, a control centre and 4 telemetric stations. An independent monitoring system consisting of a European integrity centre and 3 radio stations will be responsible for system integrity. Integrity capability of the system is a key issue for navigation applications.

The most important element of the user system is the receiver itself. Galileo will be compatible with the American GPS system. When designing Galileo receivers, combined receivers came into consideration to enable all the three fundamental systems to receive the transmitted signals. It also means that new processing programmes will be needed as well. Because of competition it is also not difficult to predict that the modernization process of each operating fundamental system will lead to increasing demand for receivers, including combined receivers – a trend which has been confirmed by the market in recent years.

In addition to the applications that are well known among users, a number of value-added services will be offered by Galileo. As it was mentioned earlier, application fields will cover, among others, traffic (road, rail, aviation, maritime) and the transport of goods; energetics; telecommunications; agriculture; fishing; environmental protection; the construction industry; recreation activities; national defence; civil defence; tasks related to safety and private defence and finally, such kind of special fields as mining.

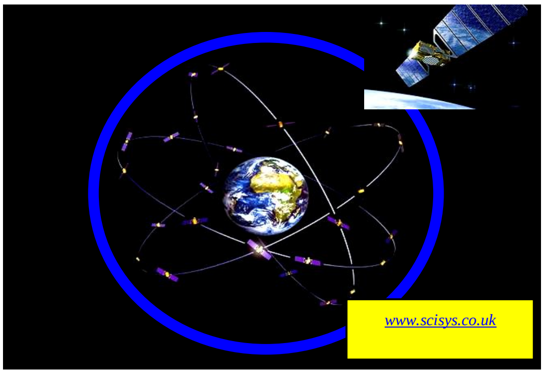

Figure 1. Galileo satellite configuration

As far as the present situation connected to the development of Galileo is concerned, let us mention some matters. With reference to this system, it is well known that it is in ***Initial Test Operation Phase***. The tasks in this phase are to model the designed orbit; to form navigation message and to test the on-board clocks. The two test satellites launched until now to perform these tasks are ***GIOVE-A*** and ***GIOVE-B***. A brief life story and the mission of the test satellites are as follows:

- In the morning of ***December 28, 2005*** the first test satellite, ***GIOVE-A*** was launched successfully according to schedule with a Soyuz-Fregat booster, and put into its final orbit. Thus GIOVE-A started its planned mission. The mission of this satellite is to test Galileo navigation signals and both on-board rubidium atomic clocks. A further task of this satellite is to examine the radiation along its space orbit, the height of which is 23,258 km and whose inclination is 56º to the Equator.
- On ***April 27, 2008*** – with a significant delay compared to the scheduled time – the Russians put ***GIOVE-B*** in orbit. The primary task of this satellite is to test frequency etalons, the passive hydrogen maser clock which can provide more precise positioning and is designed for installation in the final satellites.

/Both test satellites have been withdrawn from service this summer. According to officials their missions were performed. /

Launches of further satellites giving already real service were delayed significantly due to recent economic problems. Then, on April 21, 2011 the first two "true" Galileo satellites were put in orbit with a Soyuz booster from Kourou Launch Centre, French Guiana. Launch of the next two satellites is expected in September this year. The satellite sub-system of Galileo includes 4 satellites; two test and functional ones. By 2018 the officials would like to operate 18 satellites. The configuration of 30 satellites they would like to realize by 2019. By the end of 2011 about 3 billion Euros were spent on Galileo system, from which 560 million was used for developing and 2.4 billion for establishing costs. Between 2014 and 2020 further 7.5 billion Euros are intended for the European satellite global positioning system. The separate cost items cover the implementation of Galileo; its operation and EGNOS as well. The Fucino Control Centre near Rome received the first navigation signals at the beginning of 2012.

It was considered as a significant step forward, however, that the Septentrio Company developed the first Galileo receiver card. The Belgian Septentrio is an active participant in the Galileo program, and this company runs several research and development projects continuously at Galileo Joint Undertaking (GJU) and European Satellite Agency (ESA). According to this Septentrio will be able to offer the best Galileo receivers in commercial circulation very soon.

The Galileo concession company, led by Alcatel Espace, agreed with the EU about the most important ground locations of this system. As a result of this agreement the Centre of Concession Owner will be planned in Toulouse (France), however the Operation Centre will be established in London (United Kingdom). The ***C***onstellation ***C***ontrol ***C***entre (***CCC***) and one of the ***P***erformance ***E***valuation ***C***entres (***PEC***) will be built in ***Germany***. The other PEC and the ***M***ission ***C***ontrol ***C***entre (***MCC***) will be established in Italy. In Spain, an essential establishment, a Second Control Centre will be developed for critical applications being important from the aspect of life and property safety such as commercial shipping and public aviation). When ***primary control centres*** (CCC, MCC) are operated in perfect order this station will be the venue for further education of the staffs of MCC and CCC and for testing new hardware, software and processes.

Compass global navigational satellite fundamental system

In the middle of the first decade of the 21st century China started to develop a new second-generation satellite positioning system that is designed to be realized first in regional form (China and its region), then in global form (extended for the Earth). The name of this system is COMPASS, which is the name used here from now on, although an accepted practice is to term COMPASS Beidou-2 (B-2). COMPASS is a system under development which cannot be considered an extension of the available B-1 at all.

According to the plans the future fundamental system would consist of ***35*** satellites, from which ***5*** rotate in geostationary orbit (hereafter GEO); ***3*** in inclined geostationary orbit (IGSO) and ***27*** (***3x9***) in a so-called Middle-Earth Orbit /hereafter MEO/ (Figure 2). Each launch was executed from ***X***ichang ***S***atellite ***L***aunch ***C***entre (***XSLC***), (Figure 3). The MEO satellites move in orbits having an altitude of about 21,000 km and an inclination of 55 degrees. Their rotation time is 12 hours. The ***first herald*** of COMPASS system was a MEO satellite. The task of this satellite was to validate and test the frequencies of Compass signals. This launch was symbolic at the same time because it became unambiguous that since that time the Asian country has been working for implementing an own global system which is independent from its rivals.

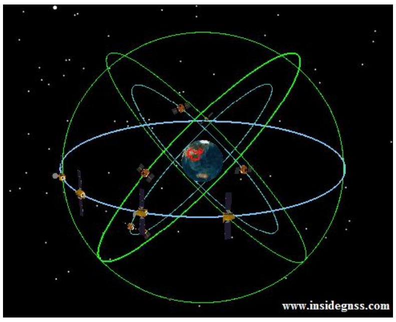

Figure 2. Compass configuration

Figure 3. Launch of a Compass satellite

The new Compass satellites – in contrast to Beidou-1 satellites (S-band) – send L-band signals. Beidou-2 – following the American GPS, European Galileo and Russian GLONASS - introduced such kind of signal structure which applies frequencies near to the afore-listed navigation fundamental systems or are identical with them completely in case of the implementing ***regional system***.

The Chinese Compass global navigation system will offer its users 10 services (on the basis of common signal structure of phases 2 and 3); among them 5 will be free (open), and 5 will be restricted (official). Each service is based on 8 carrier phases, and ***two-kinds of modulation techniques*** are used. One of them is the so-called ***Q***uad ***P***hase ***S***kip ***K***eying (***QPSK***, phase 2, end of 2012); the other one will be the ***B***inary ***O***ffset ***C***arrier (***BOC***). By 2020 (phase 3), when, the full global system is expected to be implemented, Beidou signals – applying mainly the ***BOC modulation technique*** – will approach further to the American GPS and European Galileo.

The first two satellites of Beidou-2 were followed by two additional GEO ones (B2-G1 and B2-G3), and on July 31, 2010 the Chinese also successfully launched the fifth, and at the same time the first IGSO satellite (B2-IG1). In 2010 a further GEO (B2-G4) and an IGSO satellite joined the satellite constellation of this system.

According to Chinese officials the ***basic function*** of Compass navigation system was realized with the launch of the eighth satellite (B2-IG3) on April 04, 2011. Together with the previous five satellites (3 GEO and 3 IGSO), the ***basic configuration*** of this system was implemented, which (after finishing tests) will enable the system to meet navigation demands in the greatest part of China.

The tenth Chinese navigation satellite (B2-IG5) was put in orbit on December 1, 2011 with an HM-3A booster from Xichang. Even at the end of December Chinese officials announced the official test run of B-2, and a document (protocol) introducing the navigation signals of this system accurately came to light (***BNSS ICD***). It describes the ***regional service system*** (implementation by 2012), which will be developed as a global one by 2020. The nominal satellite sub-system of BNSS regional system covers 5 GEO and 9 non-GEO satellites, the latter group of which includes 5 IGSO and 4 MEO satellites.

This year (on February 24, 2012) the Chinese first put in orbit the fifth GEO satellite in geostationary orbit, then on April 29, 2012 two MEO satellites were launched with a single LM-3B booster. So the present satellite configuration is as follows: ***4 GEO***; ***5 IGSO*** and ***3 MEO***. This year three further spacecraft launches are expected.

After all this information, let us survey in Table I what the actual Compass satellite constellation is like.

Table I. Satellites of Beidou-2 system (08. 2012)

BEIDOU-2 (COMPASS)	***1.***	B2-M1	13. 04. 2007.	MEO	test
	2.	B2-G2	14. 04. 2009.	GEO	drifting
	3.	**B2-G1**	16. 01. 2010.	GEO	usable
	4.	B2-G3	01. 06. 2010.	GEO	usable
	5.	**B2-IG1**	31. 07. 2010.	IGSO	usable
	6.	B2-G4	31. 10. 2010.	GEO	usable
	7.	B2-IG2	17. 12. 2010.	IGSO	usable
	8.	B2-IG3	09. 04. 2011.	IGSO	usable
	9.	B2-IG4	26. 07. 2011.	IGSO	usable
	10.	B2-IG5	01. 12. 2011.	IGSO	usable
	11.	B2-G5	24. 02. ***2012***.	GEO	usable
	12.	**B2-M3**	29. 04. ***2012***.	MEO	usable
	13.	**B2-M4**	29. 04. ***2012***.	MEO	usable

As for Beidou-2 satellites they are more robust than their predecessors were. Their designed life is about 8 years.

The ***first phase of COMPASS*** (the ***Chinese regional system***), which would consist of 14 satellites, is planned to be finished by 2012, and with it they intend to service the potential users of the Pacific Ocean region. Afterwards, according to the plans, they would develop the afore-mentioned global CNSS (Chinese Navigation Satellite System) system. It will mean total operation capacity. The cost of this system can be estimated at 62 billion US dollars. Hundreds of Chinese companies already deal with producing satellite receivers and specialize in GNSS services. At present the ***contribution of China to satellite-based services*** amounts about ***25%***.

By the autumn of 2012 B-2 tests are expected to be finished. The accuracy of the regional development phase carried out this way will improve for 5-10 m. With B1+GPS L1 signals an accuracy of 5 m might be obtained (about 12,000 receivers till now); moreover by means of combined application of B1/B2 and GPS L1/L2 signals an absolute positional accuracy of about 2 m can also be guaranteed.

The CNSS system (***5 GEO***, ***3 IGSO*** and ***27 MEO*** satellites) will be fully similar to the afore-mentioned other fundamental system in a sense that the so-called one-way range measurement is used for determining the position of a ground receiver. The expected accuracy of autonomous surveying is about 10 m; the accuracy of time measurement is $\mathbf{10^{-8}}$ seconds with synchronized clocks. It is free. Applying surveys of a ground-based augmentation system positioning accuracy with real time corrections might improve for 1 m. The second level (licensed) will cover the military and authority demands where, considering the previous data, much higher accuracy, communication facilities and system-status are provided.

Conclusions

The purpose of our study was to introduce the features of Galileo and Compass and their actual status. As for ***Galileo*** it turned out that its predicted development – because of mainly financial reasons – slowed down significantly. The ***plans referring to the near future are promising,*** from which we hope for accelerated implementation of the satellite sub-system.

We know that realization of ***Compass*** is one of the main objectives of Chinese national strategy. Considering its state of development it is ***in the third place*** among the fundamental systems, surpassing the European Galileo system discussed here previously. I think that the ***future of Compass*** seems to be ***bright*** now.

Acknowledgement

"The described work was carried out as part of the ***TÁMOP - 4.2.1.B - 10/2/KONV – 2010-0001 project*** in the framework of the New Hungarian Development Plan. The realization of this project is supported by the European Union, co-financed by the European Social Fund."

References

Frey, S.: Short articles on the astrological news portal called 'Space World, e.g. Expanding Beidou (2012.); Chinese satellites, navigation and mapping (2011.),

Havasi, I. - Mezei L.: Compass (Beidou-2) Chinese global navigation satellite fundamental system – development, state of affairs and future, Hungarian Journal of Mining and Metallurgy, 2012/1 (p. 12-17).

Havasi, I.: GLONASS and Galileo, state of affairs and future. 43rd Conference on Mine surveying, Proceeding, Dobogókő, Hungary, 2004.

http://www.beidou.gov.cn; http://www.sinodefence.com

http://www.globalsecurity.org; http://www.nasaspacefight.com

http://wwwen.wikipedia.org; http://www.gpsworld.com

***http://www.insidegnss.com*; **http://europa.eu.int/comm/energy_transport/en/gal_en.html