Characteristics of Multi-GNSS Involving Chinese Global Navigation Satellite System, Beidou-Compass

Kwangsoob Ko* , Chang-Mook Choi**
*Mokpo Maritime University
**Korea Naval Academy
E-mail :kwangsoob@hanmail.net

ABSTRACT

Recently, China officially declared to operate its satellite positioning system, Beidou so called Compass. The system is currently having 10 orbiting satellites which regionally cover from Australia to Russia in the north. Moreover, the system will be planed not only to launch 6 navigation satellites in its orbit in 2012 but also to complete the system with 35 satellites in 2020. The China satellite navigation system can affect to the current circumstance of global satellite navigation world in terms of navigation parameters. In this paper, we investigate characteristics of multi-integrated GNSS involving Beidu-Compass system and discuss general issues involving visibility and GDOP.

Key word
GNSS, Compass, GDOP, visibility

I. Introduction

Most recently, China officially announced that China's satellite navigation system, Beidou-2(called as Compass), has been offered navigation data, position, and timing in December 2011. Currently, 10 satellites of the system are transmitting signals and covering from Australia in the south to Russian in the north. Additional six satellites would be launched in orbit by end of 2012, and then its coverage also seems to extend to most part of Asia. Futhermore, it is known that the total of 35 satellites, which include 5 geostationary orbit satellites and 30 medium Earth orbit satellites, will offer global coverage by 2020[1],[2],[3].

In reality, there has been security and military concern in view of US since China started to develop its own global navigation system in early 2000. By contrast, it has considered that the new developing system is able to contribute to not only extend the user's choice of satellite navigation system but also enhance navigation quality parameters.

While China and EU are developing their GNSS, Beidou-Compass and Galileo, respectively, the modernization policy for Global Navigation Satellite System has been performed by US and Russia to upgrade their own systems. It seems that multi-integrated GNSS constellations, which involve GPS (current 31 operating), GLONASS(current 23 operating), Compass(current 12 operating) and QZSS(3 satellites), will be additionally installed in few years, at least by 2015[4],[5].

The future multi-integrated GNSS systems consist of more than 100 GNSS satellites and transmit their signals in various frequency spectrums compared to current GPS signal. The advantages given by integrated GNSS satellites can be expected to improve the user performance in coming years, but there have not been proper investigations available under operating Compass. In this paper, we investigate characteristics such as visibility, GDOP and accuracy around the Korean Peninsula based on multi-integrated GNSS involving Beidou-Compass system and discuss general issues.

II. Current issues of GNSSS

1) GPS

The US government has maintained policy for dealing GPS, which meets growing demands by improving the performance and the competitive international satellite navigation system as well. The first step of GPS modernization followed by turning off the GPS Selective Availability (SA) feature by the Department of Defense in May 2000. The program has been processed in order to upgrade the GPS space and control segments to enhance performance for both civilian military applications[6]. There are currently 31 healthy satellites in constellation, which are 10 Block IIA satellites, 12 Block IIR satellites, 7 Block IIR-M satellites and 2 Block IIF satellites. GPS is broadcasting a civil signal at L1, second civil signal "L2C" designed to meet commercials needs from 7 Block IIR-M satellites(full capability/24 satellites by 2016) and third civil signal "L5" designed to meet demanding requirements for transportation safety by 2 Block IIF satellites(full capability/24 satellites by 2018. In addition, the fourth civil signal "L1C" designed with international partners for interoperability will begin to transmit signal with GPS III in 2014 and will be expected with 24 satellites by 2021[7].

2) GLONASS

Russia's GLONASS system designed with 24-satellite constellation in 1996 was not sufficient to give full service due to the financial turmoil of the mid 90's. However the rebuilding of the GLONASS system has progressed since 2000, and then GLONASS modernization program has almost completed. There has been outstanding improvement of GLONASS in increasing satellites and transmitting a new navigation signal as well.

In constellation status, currently GLONASS is fully deployed with 23 healthy satellites for service, and the signal-in-space range error is equal to1.37 meter[8]. Moreover, since the first launch of GLONASS-K2 satellite in February 2011, the satellite has been transmitting CDMA navigation signal in L3. This must be the first step in a new navigation signal development strategy, and it may lead new era for interoperability between different GNSS systems. In future steps, GLONASS CDMA navigation signal will focus on L1 and L2 bands. The system is scheduled to have 24 satellites transmitting both the new CDMA and legacy FDMA signals through 2020[4],[5]. It is sure that the recent GLONASS modernization will improve the various navigation parameters such as accuracy, compatibility and interoperability with other GNSS.

3) Galileo

The European Union and the European Space Agency has been building the Galileo satellite navigation system since 2000. It has rapidly advanced to reach the final constellation which consists of 30 satellites(27 operational and 3 spares satellites)[9]. The Galileo program has already contracted for development and manufacturing of 26 operational satellites, including the two in-orbit validation spacecraft launched last October and two more expected to go up this coming September. The program expects to declare an initial operational capability in 2014[9],[10].

III. Consideration on visibility and DOP for multi-GNSS

1) Effect of Satellites Geometry to Accuracy

The effect of geometry of satellites on position error is called geometric dilution of precision (GDOP) and it is also interpreted as ratio of position error to the range error. In case of three-dimensional satellite positioning, the GDOP value is deeply related to the volume of a tetrahedron formed using four unit-vectors point toward the GNSS satellites. As it is the r.s.s(square root of sum of the squares) of the area of the 4 faces of the tetrahedron, divided by its volume[11].

The larger the volume, the smaller the GDOP values. And then the low DOP value gives a better positioning precision because of the wider angular separation between the satellites used to calculate the receiver's position.

If the visible satellites increases, accuracy ,availability, availability, integrity and continuity will be improved[12,13]. As mentioned previously, the multi-GNSS involving Chinese Global Navigation Satellite System, Beidou-Compass will bring more satellites in sky, more than 100 satellites in few years, and then the number of visible satellites also would be increased[4]. Consequently, the DOP values decrease and the position will be enhanced while observing increased visible satellites by a receiver. Eventually, the more satellites and signal there are, the better the positioning performance is in terms of accuracy. The typical way to determine how accurate position solution will be given to multiply the range error value by Dilution of Precision (DOP)[4]. For instance, if there are DOP of 2.0 and a UERE of 2.5 meters, a position bound error is given to 5.0 meters.

2) Visibility and DOP in Multi-integrated GNSS System

In recent years, there have been few studies on visibility and DOP investigations focusing on Asia region in terms of simulation based on future multi-GNSS including Compass [14]. In this section, the visibility and GDOP of multi-integrated GNSS System are compared with the experimental work performed using a hybrid GNSS receiver. More effectively, it seems to lead to recognize how fast the multi-integrated GNSS systems will be changed in near future. The experimental result for counting DOP values and visibility around Korea Peninsula has been performed by author using hybrid GNSS receiver[15]. Table 1 shows the summarized the experimental values by author and simulation ones referred to[14].

According to the referred Table 1, the visible satellites, 8-11 of GPS, increase to 10-15 of GPS + GLONASS. As increasing the number of visible satellite, the availability is increased, and then GDOP decreases from 1.51-2.56 to 1.35-2.21, which can improve the position accuracy with pseudorange error parameter, UERE(user equivalent range error) mentioned previously.

Table 1. Visibility & GDOP of GNSS

Type	Visible Satellites	GDOP	Remarks
GPS	8-11	1.51-2.56	experimental values
GPS+ Glonass	10-15	1.35-2.21	
Compass	11-17	1.47-3.24	simulation values
GPS+ Compass	20-27	1.24-1.48	
GPS+ Galileo + Glonass	23-26	1.13-1.29	

As shown in the table, the several combinations of GNSS produce the different results of the visible number and GDOP due to their own different constellations and almanacs as well. The hybrid system(GPS+Glonass) approximately can improve the value in range of 11%-24% compared to GPS only.

Similarly, the improvement ratios of GPS to multi-GNSS such as GPS+Compass and GPS +Galileo+GLONASS are approximately expected to 18%-42%, 25%-50%, respectively.

IV. Discussion & Conclusion

As mentioned previously, there has been rapidly changed in Global Navigation Satellite System. The main progress might be the Chinese Global Navigation Satellite System, Beidou-Compass announced the official transmitting signal by the Chinese Government in December 2011. With emerging Beidou-Compass recently, in near future, multi-integrated GNSS system having more than 100 navigation satellites seems to be available to civil users. The advantages given by integrated GNSS satellites can be expected to improve the user performance in coming years. Through the investigations, it is realized that multi-integrated GNSS greatly enhance visibility and DOP values. As an example, in case of GPS+Galileo+Glonass, the improvement of multi-integrated GNSS compared to GPS only can reach to approximately 50% in terms of GDOP. It also would be getting better with proper combination using various GNSS systems. This study is the first step, therefore, the more details for characteristics of multi-integrated must be done in near future.

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