EXPERIMENT OF THE HIGH ACCURACY POSITIONING BY QUASI-ZENITH SATELLITE MICHIBIKI OF JAPAN

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ABSTRACT

In 2010, the Japanese government launched Quasi-Zenith Satellite, and the main roles of Quasi-Zenith Satellite are augmentation and complementation of GPS. Augmentation of GPS is a reinforcement signal which improves positioning using compensation information, and Quasi-Zenith Satellite broadcasts LEX signal and L-1SAIF signal which are reinforcement (augmentative) signals. Especially, the LEX signal is expected noting that it will be able to perform positioning of the centimeter class. This paper describes the research of an experiment which used the LEX signal.

INTRODUCTION

GNSS positioning technology already has important role in our life-style. People must obtain positional information by GNSS including GPS. It has been well known that the satellite positioning must receive a signal from four or more satellites, however, most of Japanese land is covered with mountain and there are lots of tall buildings. This is one of the reasons why we cannot obtain the exact position information by multipath and cycle slip etc. Moreover, foreign countries, such as GLONASS of Russia and GALILEO of EU and GPS of USA are advancing maintenance of the global positioning. By the background of worldwide positioning system, the Japanese government launched Quasi-Zenith Satellite (QZS). Aiming at the practical application of Quasi-Zenith Satellite, the experiment has been performing all over Japan. At the present time, we have only one zenith satellite which was named "MITIBIKI", however, Japanese government has already decided to launch seven satellites in until 2018. [1] After seven satellites are arranged, at least one satellite is in the zenith in Japan. Figure 1 shows Quasi-Zenith Satellite orbit. At the end of 2010s, a satellite will always be in the zenith, and accurate position information is acquired for 24 hours. This paper describes the comparison of the positioning using QZSS and VRS-GPS.

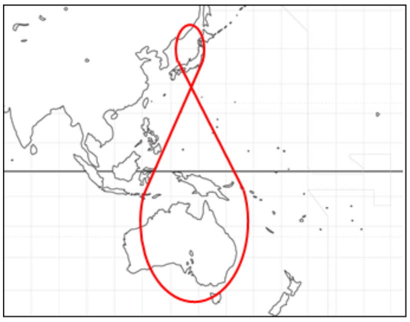

Figure1 Quasi-Zenith Satellite orbit

QZSS (Quasi-Zenith Satellites System)

QZSS is the satellite system which combined plural satellites with the special orbit in Japan which passes along the zenith. In order that the orbit of QZS might stay at the zenith in Japan for a long time, the orbit of the asymmetrical character of 8 was adopted. QZSS transmits six kinds of QZS signals using four kinds of frequency. [2] Table 1 shows positioning signal of QZS. QZS has some functions, which are GPS augmentation, GPS complementary and message service. First of all, QZSS extends the time which can use a satellite. Signals sent from high elevation will increase the receivable number of satellites, and improve a satellite constellation. The second is the augmentation of GPS which is transmitting a high accuracy correction date signal from QZS, and it can progress high accuracy positioning. Message service has two types of safety check service using a "safety check services by satellite" and "the disaster and risk management report service". If especially safety check service is used, it will become a clue of a search by transmitting automatically the mail which added position information to catastrophic disaster developmental time from a cellular phone, a smart phone, etc. to the close relatives who registered beforehand.

Table 1 Positioning signal of QZS

signal	Center frequency	channel		
L1C/A signal	1575.42MHz	IPM	I	-
L1C signal				Date
			Q	Pilot
L1-SAIF signal		BPSK		
LEX signal	1278.75MHz	BPSK		
L2C signal	1227.60MHz	I-channel		
L5 signal	1176.45MHz	Q-channel		

IPM: Inter plex Moducation

*Compatible with GPS

LEX SIGNAL

QZS augmentation has LEX signal and L1-SAIF signal. Especially, the positioning by LEX signal is expected that it can allow getting positioning of the centimeter level. Moreover it is expected that the positioning using a LEX signal is utilized for computerized construction, automated driving, IT agriculture and survey. The revised signal is created using the electronic reference point, and corrects the error by troposphere delay and an ionosphere delay, etc. This is a way to create precise centimeter-scale positioning that does not use relative distances from ground-based reference points as the conventional way uses, but directly measures using a carrier phase between the satellite and a user by employing precise satellite orbit and clock information was sent by MICHIBIKI's LEX signals. At present, the LEX signal is broadcast only in still limited time. Therefore, the experiment using a LEX signal can be conducted only in the limited place and time.

OUTLINE OF EXPERIMENT

Experiments were performed at Kanazawa Institute of technology which is located in Hokuriku District from 6th to 7th in March 2013. The zenith angle of QZS from 9:00 a.m. to 3:00 p.m. was 45 degrees from 90 degrees. The purpose of experiment is to demonstrate the relationship between number of satellite and positioning accuracy, and researching the influence of positioning accuracy by a building. On the experimental plan, although the LEX signal must have been broadcast from 9:00 a.m. to 3:00 p.m., however, it ended when the signal was stopped. When elevation of QZS became to 40 degrees, it was impossible to receive a LEX signal. Figure 2 shows experiment area and view of the sky took by fish eye lens. The used receivers are a LEX receiver and a VRS-GPS receiver.

Figure 2 Experiment point and image in the sky by fish eye lens

From figure 2, sky of experiment area is opening to the north direction and there was building to the south direction. The LEX signal is interrupted by the building in such a condition. The positioning by LEX became impossible according to this condition.

RESULT OF EXPERIMENT

By analysis of LEX's log and QZ-radar, change of LEX solution was influenced from number of GPS satellite. Elevation of QZS was computed from QZ-radar. Figure 3 and Figure 4 shows the elevation of QZS, number of satellite and positioning of each experiments days. FIX solution has high accuracy and FLOAT solution has slightly low.

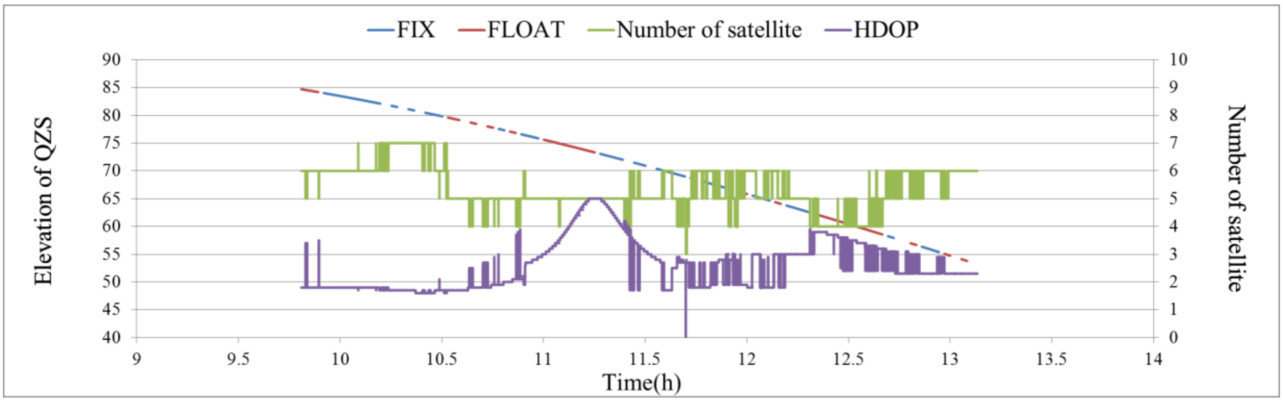

Figure 3 The elevation of QZS, number of satellite and positioning solution

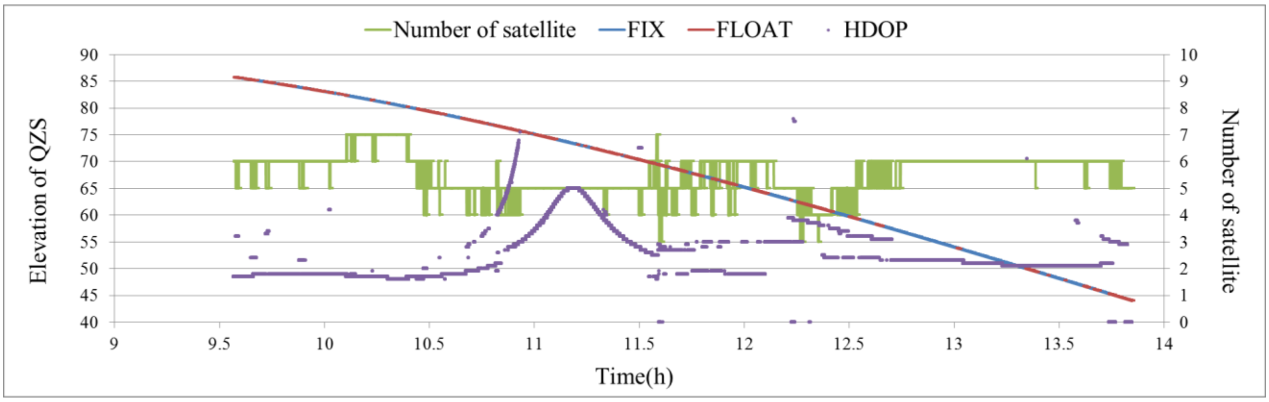

Figure 4 The elevation of QZS and number of satellite and positioning solution

From Figure 3 and Figure 4, it becomes a FLOAT solution when the number of satellites decreased. The elevation of QZS was 53.19 degrees and 43.96 degrees when it becomes impossible to receive a signal. At the 6th and 7th experiments, FIX rate was 54.2% and 51.4% respectively. Although both the experiments performed same condition, non-signal time had about 1 hour time lag. This problem is unsolved.

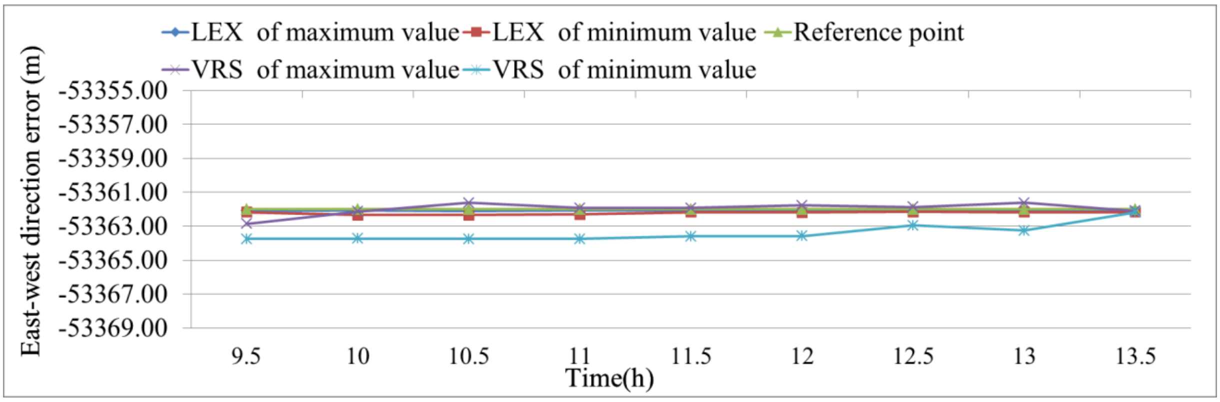

Figure 5 The comparison to VRS-GPS result of east-west direction error (m)

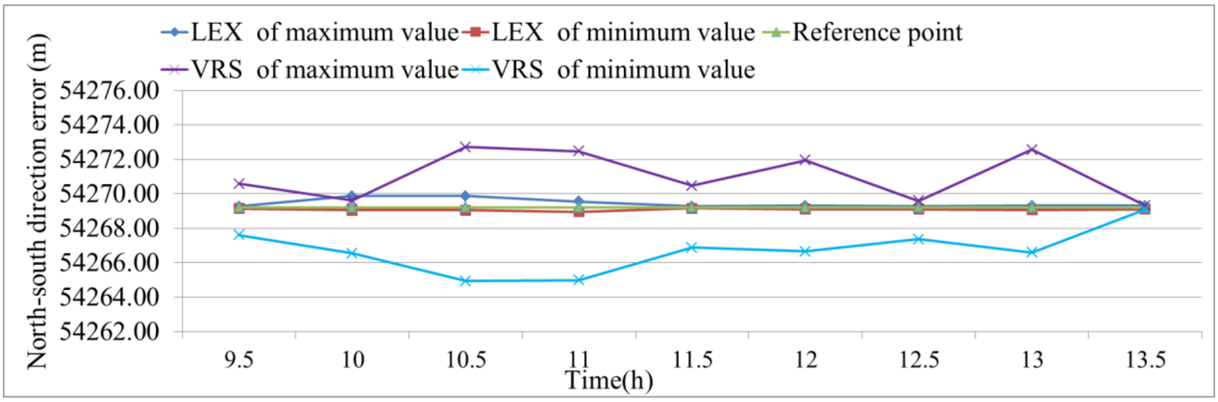

Figure 6 The comparison to VRS-GPS result of north-south direction error (m)

Figure 5 and Figure 6 portrays positioning result. These Figure's error of north-south and east-west direction error was compared by using LEX receiver and VRS-GPS receiver. The reference point was surveyed by the static positioning on other days. These figures used only FIX solutions and it adopted Japan Geodetic Datum 2000. First, the positioning using LEX receiver was the accuracy of less than 1 m, and the positioning using VRS-GPS receiver was the accuracy of less than 5 m. North-south direction error is larger than east-west direction error. Figure 7 shows standard deviation. From Figure 7, the value of LEX standard deviation is smaller and LEX signal is stable. The result of LEX is stable compared with the result of VRS.

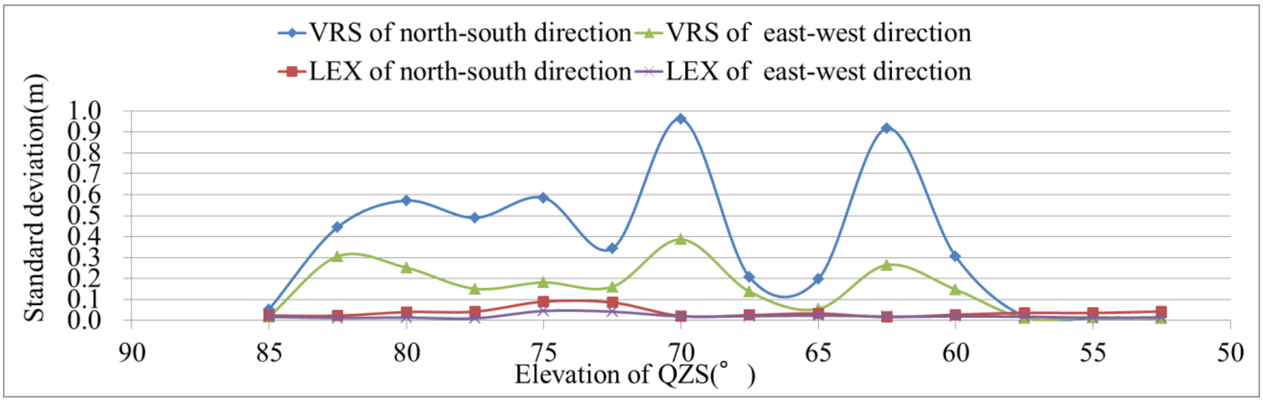

Figure 7 standard deviation

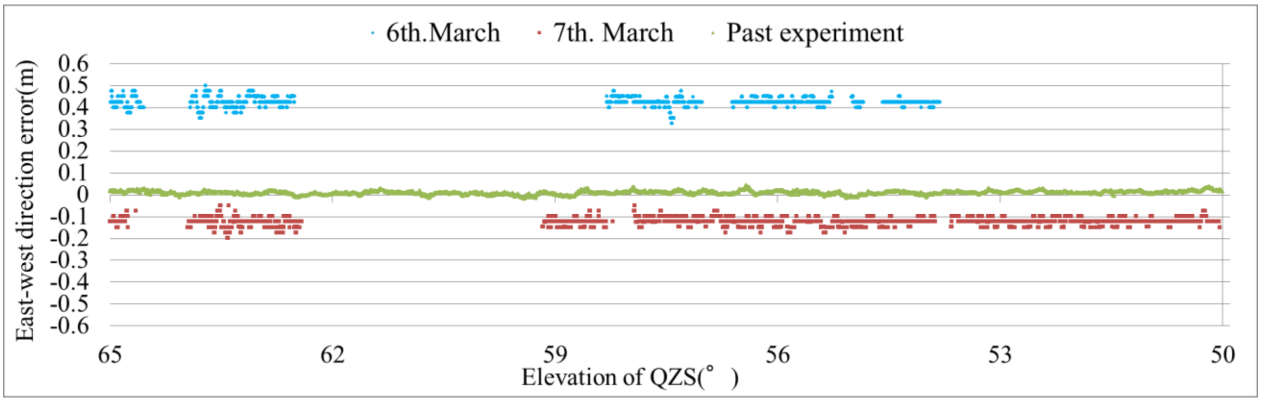

Figure 8 The east-west direction error

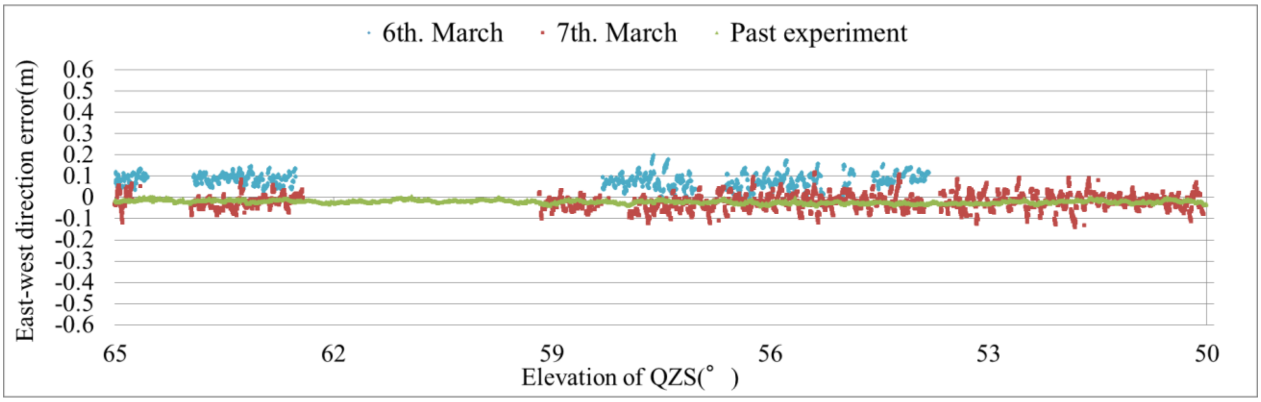

Figure 9 The north-south direction error

Figure 8 and Figure 9 show the past experiment results performed in 2012. The past experimental area is as same as Kanazawa Institute of Technology. The observed area is a point which has 10m distance from the nearest building. As can be seen from the figure, the positioning using a LEX signal can get correct data of the centimeter class in the past experiment. The points where data is discontinuous are more than 0.6 m error in Figure 8 and Figure 9.

CONCLUSIONS

At the present, the experiment using LEX signal can be performed only in the limited time zone. Therefore, since we do not have a lot of data, we described consideration only about this experimental result. The main results of our experiment are as follows, the experiment by LEX signal was not able to position accuracy of the centimeter class. The cause of this is decrease in number of satellite, and deterioration of geometric arrangement by the building. The positioning by LEX signal was not able to give full situation to the performance by the condition that one side is covered with buildings. The LEX solution of standard deviation was smaller than the VRS solution. The elevation of QZS was not related to positioning accuracy. The experiment was able to be conducted during the long term rather than our plan. From the results of an investigation, the LEX signal may be able to diffract a building. The special factor which influenced the accuracy of a LEX signal was not able to be specified in this research. We must find the important factor influences the accuracy of QZSS including QZS in the future. [4]It is much difficult to make a fair judgment on LEX signal of QZS in only this experiment. Further experiment will be needed to find the characteristics of LEX signal.

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