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Accuracy Analysis of Influences by Satellite Ephemeris

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Abstract

In the positioning using GPS, the satellite ephemeris can greatly affect the precise positioning. So, final ephemeris has used in precise positioning. However, to calculate final ephemeris to take 12~18 days have been urgent it's impossible to apply precision positioning. This study analyzed the influence of ephemeris on GNSS positioning, and influence of the ephemeris were investigated by executing the precise point positioning and the relative positioning with CORS data in South Korea. Even though the precise point positioning was shown to have the smallest difference but there was an insignificant difference from of the application of rapid ephemeris, and in case of the relative positioning, results of applications of ultra-rapid ephemeris, rapid ephemeris and precise ephemeris were shown to be differ from the standard data for less than 1.4cm. Through this study, it was possible to evaluate the influences of ephemeris on the precise point positioning and the relative positioning and also, the study suggests of the possibility of the applicability of ultra-rapid and rapid ephemeris on the precise point positioning.

Keywords: GPS, Ephemeris, Precise point positioning, Relative positioning

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1 Introduction

As for GNSS positioning, there could be various error factors including errors in orbits of satellites and visibility errors of a receptor and/or a satellite as well as errors caused by an ionosphere and convection zone. Especially, the distance between a GNSS satellite and a receptor is calculated with a position data of a satellite, which is the ephemeris of a satellite), so as ephemeris is inaccurate, positioning accuracy and preciseness on the ground would be lowered as well [1]. GNSS ephemeris transmits ephemeris, which is a anticipated by the master control station, Florida, U.S., which is also known as broad cast, in a form of a navigation message to users. At the time of writing in 2013, this broadcast is deemed to have an error of about 1m [2]. Therefore, it would be challenging to obtain the precise baseline vector if it is measured with the broad cast.

To cope with such issues, there has been an international joint study on the calculation of precise ephemeris of GPA satellites, and as one of such efforts, the IGS(International GNSS Service, which is participated by about 360 observatories throughout the world, was established in January 1994 and has calculated and supplied of the precise ephemeris of GNSS satellites ever since [3][4][5]. Table 1 shows a list of ephemeris provided by the IGS.

Even though the application of the broadcast onto the GNSS positioning has the lower preciseness than of precise ephemeris, still it could be faster and simpler [6]. For the application of precise ephemeris, you may have to wait up to 18 days. Therefore, users have been in charge of determining the type of ephemeris to be used for the process of GNSS data and these decisions are usually made based on the required level of preciseness, urgency, and the length of the baseline to be measured. Despite of such circumstances, ultra-rapid and rapid ephemeris provided by the IGS can be applied in real-time or within up to 2 days, much shorter than of precise ephemeris. Moreover, their accuracy level is outstanding [7].

Therefore, in this study, the results of positioning were evaluated per ephemeris with data of the CORS(Continuously

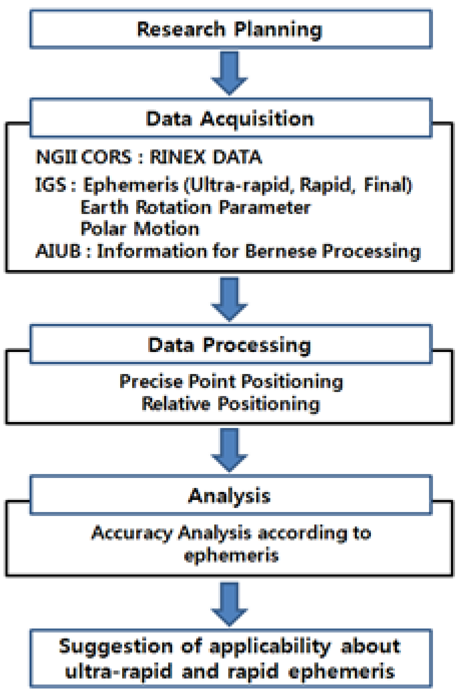

Fig. 1. Study flow diagram

Operating Reference Station) and the influence of GNSS positioning over ephemeris was analyzed to support of a possibility and properness of ultra-rapid and rapid ephemeris on the precise point positioning. Fig. 1 shows the study flow diagram.

2 Data Acquisition and Processing

In this study, data from the national geographic information institute and the DGPS satellite center of the ministry of land, transport and maritime affairs was used for analyzing the influence of GNSS positioning over satellite ephemeris. RINEX files form 51 observatories were collected and then, processed with the Bernese S/W.

Data observed from the 18th to 20th of August, 2013 was collected and then, processed by the precise point positioning and the relative positioning. Table 1 shows present condition of CORS.

Table 1. CORS

No.	ID	No.	ID	No.	ID	No.	ID	Date
1	ANHN	14	EOCH	27	KANR	40	SOUL	8.18~20
2	ANSG	15	GOCH	28	KIMC	41	SUWN	
3	BOEN	16	GSAN	29	KUNW	42	TABK	
4	CHCN	17	HADG	30	KWNJ	43	TEGN	
5	CHEN	18	HONC	31	MARA	44	ULLE	
6	CHJU	19	INCH	32	MUJU	45	WNJU	
7	CHLW	20	INJE	33	NAMW	46	WOLS	
8	CHNG	21	JAHG	34	NONS	47	WULJ	
9	CHSG	22	JEJU	35	PAJU	48	YANP	
10	CHWN	23	JEOJ	36	PUSN	49	YECH	
11	CHYG	24	JINJ	37	SEOS	50	YONK	
12	CNJU	25	JUNG	38	SNJU	51	YOWL	
13	DOND	26	JUNJ	39	SONC	-	-	

Observed data was processed by the precise point positioning and the relative positioning with Bernese BPE. The relative positioning was employed with SUWN as its standard point and data was processed by classifying into the ultra-rapid, the rapid and the precise ephemeris to evaluate the influence of ephemeris onto positioning. To correct a deviation generated by physical motion of the earth, information on the earth rotation and the polar motion was employed, and as for a delay in the troposphere, Saastamoinen model and Niell Mapping

Function were used. Also, only observed data with altitude of 10° or above was produced to minimize the influence of multi-pass. For the antenna satellite-oriented offset compensation, the complete compensation model was used.

3 Results and analysis of data

3.1 Precise point positioning

Precise point positioning was developed to overcome the limitations of the relative positioning which has been commonly adopted for the precise position determination, including a decrease in accuracy as the baseline distance increases and the requirement of a number of receptors. There have been a number of studies for the development of a technique which can execute the position determination with only one receptor in a highly accurate manner. Data observed from the 18th to 20th of August, 2013 was collected. Table 2 ~ Table 4 show a part of results of the precise point positioning per ephemeris.

Table 2. PPP results – Ultra Rapid ephemeris

No.	CORS	8.18			No.	CORS	8.18		
		X(m)	Y(m)	Z(m)			X(m)	Y(m)	Z(m)
1	ANHN	-3020237.098	4136468.347	3788431.798	6	CHJU	-3168622.637	4277489.420	3501649.916
2	ANSG	-3087667.750	4058167.257	3818526.404	7	CHLW	-3050945.394	3988270.740	3920005.462
3	BOEN	-3141805.246	4060585.403	3772023.021	8	CHNG	-3233224.634	4067916.258	3686212.065
4	CHCN	-3083732.040	3988333.089	3894101.855	9	CHSG	-3237146.106	3989513.575	3767338.513
5	CHEN	-3085225.640	4071232.584	3806614.106	10	CHWN	-3260411.615	4070678.293	3659345.227
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Table 3. PPP results - Rapid ephemeris

No.	CORS	8.18			No.	CORS	8.18		
		X(m)	Y(m)	Z(m)			X(m)	Y(m)	Z(m)
1	ANHN	-3020237.098	4136468.347	3788431.798	6	CHJU	-3168622.637	4277489.420	3501649.916
2	ANSG	-3087667.750	4058167.257	3818526.404	7	CHLW	-3050945.394	3988270.74	3920005.462
3	BOEN	-3141805.246	4060585.403	3772023.021	8	CHNG	-3233224.634	4067916.258	3686212.065
4	CHCN	-3083732.040	3988333.089	3894101.855	9	CHSG	-3237146.106	3989513.575	3767338.513
5	CHEN	-3085225.640	4071232.584	3806614.106	10	CHWN	-3260411.615	4070678.293	3659345.227
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Table 4. PPP results - Final ephemeris

No.	CORS	8.18			No.	CORS	8.18		
		X(m)	Y(m)	Z(m)			X(m)	Y(m)	Z(m)
1	ANHN	−3020237.095	4136468.341	3788431.796	6	CHJU	−3168622.635	4277489.414	3501649.916
2	ANSG	−3087667.748	4058167.252	3818526.403	7	CHLW	−3050945.391	3988270.732	3920005.459
3	BOEN	−3141805.243	4060585.397	3772023.02	8	CHNG	−3233224.633	4067916.252	3686212.063
4	CHCN	−3083732.037	3988333.081	3894101.853	9	CHSG	−3237146.105	3989513.57	3767338.514
5	CHEN	−3085225.638	4071232.579	3806614.106	10	CHWN	−3260411.612	4070678.286	3659345.225
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

To understand the influence of ephemeris on the positioning, a deviation per component was calculated based on the average of results of the precise point positioning for three days. In Table 5 ~ Table 7, a part of deviations per component are listed and Fig. 2 ~ Fig. 10 show a graph of deviations.

Table 5. PPP results deviation – Ultra Rapid ephemeris

No.	CORS	8.18			No.	CORS	8.18		
		dX(m)	dY(m)	dZ(m)			dX(m)	dY(m)	dZ(m)
1	ANHN	0.014	−0.006	−0.006	6	CHJU	0.002	−0.012	−0.007
2	ANSG	0.002	−0.001	−0.008	7	CHLW	−0.004	−0.010	−0.007
3	BOEN	0.001	−0.005	−0.004	8	CHNG	0.007	−0.016	−0.012
4	CHCN	0.011	−0.013	−0.014	9	CHSG	−0.009	−0.004	−0.001
5	CHEN	0.009	0.001	−0.003	10	CHWN	−0.003	−0.003	−0.002
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Table 6. PPP results deviation – Rapid ephemeris

No.	CORS	8.18			No.	CORS	8.18		
		dX(m)	dY(m)	dZ(m)			dX(m)	dY(m)	dZ(m)
1	ANHN	−0.005	−0.008	0.000	6	CHJU	0.000	−0.006	0.002
2	ANSG	0.000	−0.009	0.003	7	CHLW	0.003	−0.007	0.002
3	BOEN	0.001	−0.009	0.001	8	CHNG	−0.003	−0.004	0.005
4	CHCN	−0.004	−0.006	0.004	9	CHSG	0.005	−0.008	0.000
5	CHEN	−0.003	−0.010	0.001	10	CHWN	0.003	−0.012	−0.002
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Table 7. PPP results deviation – Final ephemeris

No.	CORS	8.18			No.	CORS	8.18		
		dX(m)	dY(m)	dZ(m)			dX(m)	dY(m)	dZ(m)
1	ANHN	0.012	0.000	−0.003	6	CHJU	0.000	−0.007	−0.007
2	ANSG	0.000	0.004	−0.007	7	CHLW	−0.007	−0.002	−0.005
3	BOEN	−0.003	0.001	−0.003	8	CHNG	0.005	−0.009	−0.011
4	CHCN	0.008	−0.006	−0.012	9	CHSG	−0.010	0.001	−0.002
5	CHEN	0.007	0.006	−0.002	10	CHWN	−0.006	0.005	0.001
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

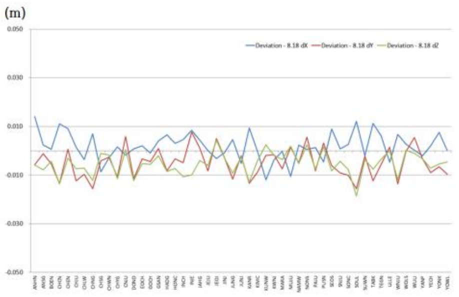

Fig. 2. PPP Deviation – Ultra Rapid (8/18)

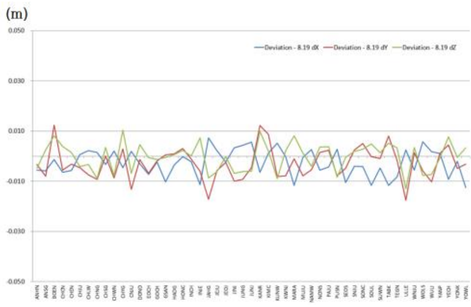

Fig. 3. PPP Deviation – Ultra Rapid (8/19)

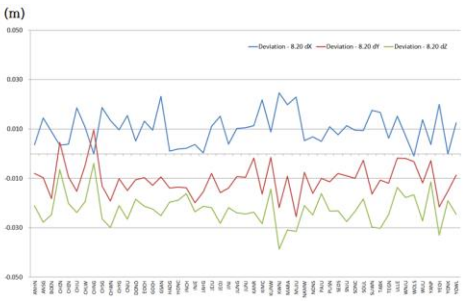

Fig. 4. PPP Deviation – Ultra Rapid (8/20)

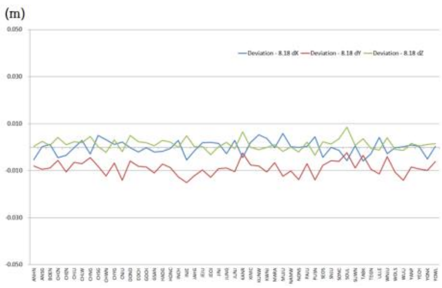

Fig. 5. PPP Deviation – Rapid (8/18)

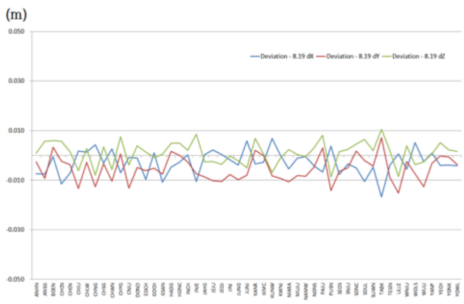

Fig. 6. PPP Deviation – Rapid (8/19)

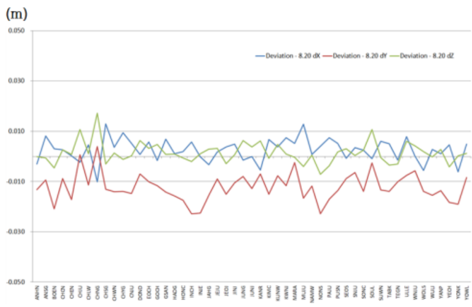

Fig. 7. PPP Deviation – Rapid (8/20)

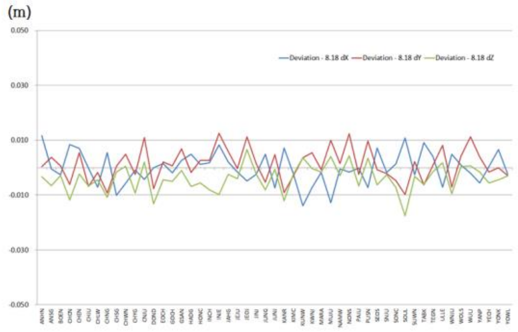

Fig. 8. PPP Deviation – Final (8/18)

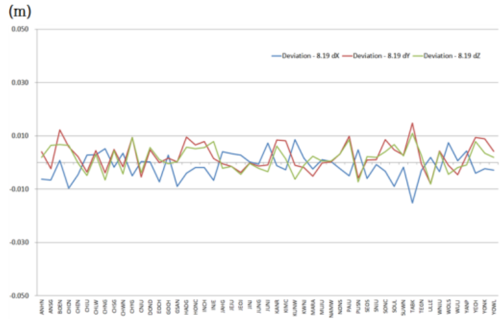

Fig. 9. PPP Deviation – Final (8/19)

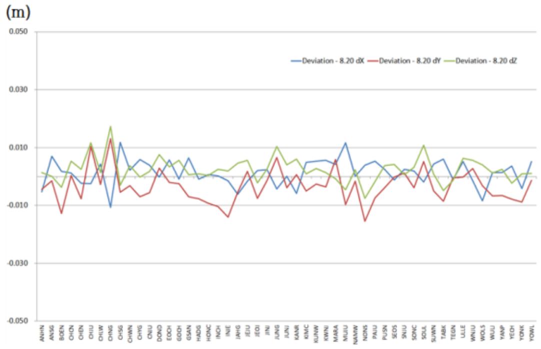

Fig. 10. PPP Deviation – Final (8/20)

3.2 Relative positioning

The relative positioning showed that there was a deviation of 0.8cm ~ 1.5cm from the standard. Table 8 shows a deviation of the relative positioning per ephemeris and Table 9 is the RMSE of the relative positioning results.

Table 8. Deviation of the relative positioning per ephemeris

Items	Ultra Rapid(m)	Rapid(m)	Final(m)
Minimum deviation	−0.012m	−0.014m	−0.008
Maximum deviation	0.014m	0.015m	0.014

Table 9. RMSE of the relative positioning results

Items		Ultra Rapid (m)	Rapid (m)	Final (m)
8/18	X	±0.003	±0.004	±0.004
	Y	±0.004	±0.004	±0.004
	Z	±0.003	±0.003	±0.003
8/19	X	±0.004	±0.004	±0.003
	Y	±0.004	±0.004	±0.004
	Z	±0.003	±0.003	±0.003
8/20	X	±0.002	±0.004	±0.002
	Y	±0.002	±0.005	±0.003
	Z	±0.001	±0.003	±0.002

The relative positioning with the ultra-rapid ephemeris shows a deviation of –1.2cm ~ 1.4cm from the standard, and –1.4cm ~ 1.5cm and -0.8cm ~ 1.4cm for rapid ephemeris and precise ephemeris, respectively. RMSE has the distribution of ±0.001m ~ ±0.004m, and there was no distinctive tendencies upon ephemeris.

In case of the relative positioning, there was up to 1.4cm deviation from the standard, and RMSE was found to be less than ±0.004m in all cases. Since the relative positioning uses a standard point of which a coordinate is known to generate the compensation and apply it to an unknown point, its deviation caused by ephemeris might have been less than the precise point positioning. In other words, it is possible to determine the accurate position with the ultra-rapid ephemeris.

4. Conclusion

This study was aimed to analyze influences of ephemeris on GNSS positioning. With CORS data observed in South Korea, the precise point positioning and the relative positioning were conducted and influences of the ultra-rapid, the rapid and the precise ephemeris on GNSS positioning were evaluated. In the precise point positioning, the ultra-rapid ephemeris had a deviation of up to 3.9cm from the standard, which was the largest deviation, but the rapid and the precise ephemeris had a deviation of less than 1cm. Also, RMSE had the high precise of ±0.005m ~ ±0.007m. For the relative positioning, there was a deviation of up to 1.4 cm from the standard data, and RMSE was shown to be ±0.004m or less in all cases. It was possible to evaluate the influence of ephemeris on the precise point positioning and the relative positioning, and this study suggests that it would be available to employ the ultra-rapid and the rapid ephemeris on the precise position determination.

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