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EVALUATION OF THE MEASUREMENT NOISE AND THE SYSTEMATIC ERRORS FOR THE KOMPSAT-1 GPS NAVIGATION SOLUTIONS

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ABSTRACT

GPS Navigation Solutions are used for operational orbit determination for the KOMPSAT-1 spacecraft. GPS point position data are definitely affected by systematic errors as well as noise. Indeed, the systematic error effects tend to be longer term since the GPS spacecrafts have periods of 12 hours. And then, the overlap method of determining orbit accuracy is always optimistic because of the presence of systematic errors with longer term effects. In this paper, we investigated the measurement noise and the system error for the KOMPSAT-1 GPS Navigation Solutions. To assess orbit accuracy with this type of data, we use longer data arcs such as 5-7 days instead of 30 hour data arc. For this assessment, we should require much more attention to drag and solar radiation drag parameters or even general acceleration parameters in order to assess orbit accuracy with longer data arcs. Thus, the effects of the consideration of the drag, solar radiation drag, and general acceleration parameters were also investigated.

Keywords: GPS navigation solutions, KOMPSAT-1, overlap method, orbit determination

1. INTRODUCTION

The KOMPSAT-1 spacecraft, launched into a circular sun synchronous orbit on Dec. 21, 1999, entered its 5th year of successful operation this year (Choi et al. 2004). The purpose of the mission are to collect earth images, multi-spectral images of the ocean, and to collect information about particle environment of the low earth orbit. However, for the operational orbit determination, we usually use about 1 day data arc. But, GPS point position data are definitely affected by systematic errors as well as noise. Indeed, the systematic error effects tend to be longer term since the GPS spacecrafts have periods of 12 hours. Thus, we investigate the measurement noise and the systematic error for the KOMPSAT-1 GPS Navigation Solutions using longer data arcs such as 5-6 days instead of 30 hour data arc. However, at the start of the life of KOMPSAT-1, the 11-year solar activity cycle was at a maximum until 2002 and the solar flux has reduced to a moderate level in 2004. Thus, we divided into 2 cases according to the solar activity (solar maximum and solar minimum). The period spanning Dec. 15, through Dec. 26, 2001 was selected as a solar maximum and the period spanning Apr. 15 through Apr. 26 2004 was selected as a solar minimum (relatively, during the operation).

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Table 1. RCA rms Difference using 7 days data arcs with 1 day overlap according to the solar activity.

CASE	Cd, Cr Fixed				Cd, Cr Adjusted				Cd, Cr, and Ga Adjusted			
	R	C	A	3D(m)	R	C	A	3D(m)	R	C	A	3D(m)
1(high)	16.6	3.1	849.1	849.3	4.0	3.3	194.3	194.4	6.7	3.3	110.2	110.4
2(low)	8.3	9.8	181.4	181.6	1.1	4.2	8.3	9.4	0.9	4.9	5.7	7.6

Table 2. rms of fit to the observations according to solar activity.

CASE	rms of fit to the observations (m)	X (m)	rms Y (m)	Z (m)
1(high)	29.54	49.4	73.2	60.4
2(low)	11.37	77.9	56.9	208.4

2. ORBIT DETERMINATION AND ASSESSMENT

In this paper, we used the MicroCosm$^{(R)}$ software for the orbit determination. This software, which is derivative of and based upon a full implementation of the GEODYN II version 8609 precision orbit and geodetic parameter determination software system, employed as a part of the flight dynamics system at KGS (Kompsat Ground Station). Bayesian least squares estimation is used by this software for parameter determination and the batch mode of estimation is used. As for measurement, we use only GPS position data since the velocity data tend to contain significant systematic errors.

The dynamic models used in this study included gravity, point masses, solar radiation pressure, and atmospheric drag. The Joint Gravity Model field 3 (JGM-3) of degree and order 70 was used. Solar and lunar point mass perturbations (JPL DE405 ephemerides) were also included in the model. The Jacchia-71 atmospheric density model with 3-hourly geomagnetic indices was used. To investigate the effect of the type of solve-for parameters, the drag coefficient (Cd), solar radiation coefficient (Cr), and the general accelerations (Ga) are options according to the cases. In this study, we use the orbit overlap method that will still be the best method for assessing the orbit accuracy since we have no independent orbits of comparable accuracy for the KOMPSAT-1 spacecraft.

3. RESULTS

First of all, each arc was seven days long, and 24-hour overlaps were used to assess performance and the systematic errors. The results are shown in Table 1. These results clearly show that the rms of fit is better than the results obtained using data at low solar activity. The 3D rms of position for the overlaps shown in Table 1 are on the order of 850 m in case that Cd and Cr were fixed at high solar activity, while that of position are on the order of 181 m at low solar activity. However, the rms of fit can be improved using solve-for parameters. The 3D rms differences were dramatically reduced from 850 m to 110 m at high solar activity and from 181 m to 7.6 m at low solar activity in case that Cd, Cr, and Ga were adjusted in orbit determination process. However, these results are worse than that of 30 hour data arc. We can get an overall accuracy on the order of 1.6 m using 30 hour data arc in case that Cd, Cr, and Ga were adjusted at low solar activity (Kim, Kim, & Choi 2004). The fact that the 30 hour data arc are more consistent than the seven-days arcs is attributed to deficiencies in the dynamical model, mostly gravity and drag, that is, these errors have less impact on the shorter arcs. Table 2 shows the rms of fit to the observations. The difference between the solar maximum and minimum is up to 3 times. Additionally, we investigated the orbit repeatability

Table 3. RCA rms Difference for orbit repeatability according to the solar activity.

CASE	Cd, Cr Fixed				Cd, Cr Adjusted				Cd, Cr, and Ga Adjusted			
	R	C	A	3D(m)	R	C	A	3D(m)	R	C	A	3D(m)
1(high)	3.8	1.9	128.7	128.8.	0.9	7.4	146.2	146.4	1.7	6.0	97.3	97.5
2(low)	2.2	1.7	113.1	113.1	0.1	0.4	7.1	7.1	0.3	0.6	7.0	7.0

using orbits determined independently without any command measurements. Orbit repeatability for December 2001 and April 2004 uses data from Dec. (Apr.) 15, 17, 20 for one solution and Dec. (Apr.) 16, 18, 21 for the other. The rms difference between the two solutions is computed over Dec. (Apr.) 19 during which no data was taken. Table 3 shows that overall rms differences of two cases are slightly smaller than that of overlaps using 7 days arcs as shown in Table 1.

4. CONCLUSIONS

The measurement noise and the systematic errors were evaluated using longer data arcs in this paper. The effect of solve-for parameters on the orbit accuracy was also presented. As a result, the systematic errors are significantly observed in case that longer data arcs were used in orbit determination compared to that of shorter data arcs. The measurement noise was varied with the solar activity significantly. However, the rms residuals can be dramatically reduced when the solve-for parameters such as Cd, Cr, and Ga were used at low and high solar activity.

REFERENCES

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