Quick Evaluation of Spacecraft Orbit Maneuver Using Small Sets of Real-time GPS Navigation Solutions

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Abstract

Quick evaluations of two in-plane orbit maneuvers using small sets of real-time GPS navigation solutions were performed for the KOMPSAT-1 spacecraft operation. Real-time GPS navigation solutions of the KOMPSAT-1 were collected during the Korean Ground Station(KGS) pass. Only a few sets of position and velocity data after completion of the thruster firing were used for the quick maneuver evaluations. The results were used for antenna pointing data predictions for the next station contact. Normal orbit maneuver evaluations using large sets of playback GPS navigation solutions were also performed and the result were compared with the quick evaluation results.

1. Introduction

The Korea Multi-Purpose Satellite-1(KOMPSAT-1) was successfully launched by the Taurus at 07:13:00 UT, December 21, 1999, from Vandenberg Airforce Base, California, U.S.A. Although the injection orbit of the KOMPSAT-1 was within the allowable tolerances of the Taurus launch vehicle, the size of the orbit was somewhat larger than that of the nominal size and the inclination of the orbit is greater than that of the nominal inclination[1,2]. So, both in-plane and out-of-plane maneuvers were required to achieve the nominal orbit of the KOMPSAT-1. Totals of four orbit maneuvers were performed for the KOMPSAT-1 spacecraft in Launch and Early Orbit Phase(LEOP) operation. Two In-Plane Maneuvers(IPM) and two Out-of-Plane Maneuvers(OPM) were performed for reducing the orbit size and decreasing the orbital inclination, respectively.

The first KOMPSAT-1 IPM for decreasing the semi-major axis was performed on Jan. 1, 2000. The first OPM for decreasing the inclination was performed on Feb. 2, 2000 and the second OPM for achieving the final target inclination was performed on Feb. 9, 2000. The second IPM for decreasing the semi-major axis to the operational KOMPSAT-1 orbit was performed on Feb. 16, 2000.

Thruster firing should be executed for orbit maneuver and performance of the thruster firing affects the maneuver results. So, orbit maneuver should be evaluated for precision maneuver planning and execution. Normally, evaluation of the orbit maneuver starts from the Orbit Determination(OD) using post-burn tracking data. The OD result shows the realized orbit maneuver. Then, thruster calibration factor is derived from the comparison between the planned orbit and the realized orbit. Maneuver evaluation is very important because satellite ground station could not contact with the spacecraft after the maneuver execution with the wrong thruster calibration factor.

In this paper, the evaluation of the first and second IPM for the KOMPSAT-1 is described. Only a few sets of real-time GPS navigation solution data after the completion of the thruster firing are used for the quick maneuver evaluations. The results are used for antenna pointing data predictions for the next station contact. Normal orbit maneuver evaluations using large sets of playback GPS navigation solutions are also performed and the result are compared with the quick evaluation results.

2. The first in-plane orbit maneuver

The first IPM was performed at near perigee point by thrusting backward to the orbit direction. The maneuver planning was performed using KOMPSAT MAPS[3,4,5]. Table 1 shows the maneuver parameters. The first IPM was performed as a calibration burn. So, no calibration was applied to the thruster and specific impulse from database values in maneuver planning. The used fuel was expected to 1.229 kg for the 180 seconds burn. The applied pitch attitude is - 90 degrees for reducing the orbital velocity. The planned delta velocity was worth of decreasing the semi-major axis of 10.708 km.

Table 1. The 1st IPM planning parameters

Burn Start Time	2000/01/01 23:37:22.000
Burn Duration(sec)	180.0
Maneuver target(km)	-10.708 km of semi-major axis
Thruster Calibration Factor	1.0
Effective Thrust(Newton)	14.669
Effective Isp(sec)	214.414
Expected Fuel Used(kg)	1.229
Delta Velocity Magnitude	- 5.615 m/sec

The maneuver was executed during the German Space Operations Center(GSOC) contact time. The thruster firing and the attitude were monitored in Korean Ground Station(KGS) via communication link. Also, Earth-Centered-Earth-Fixed(ECEF) position and velocity of the KOMPSAT-1 from on-board GPS receiver were gathered every 32-seconds interval. Totals of 20 GPS navigation solutions were collected from GSOC.

Figure 1 shows the variation of the osculating semi-major axis with and without maneuver. The osculating semi-major axis values from GPS navigation solutions are used as thrust values. Orbit propagation without maneuver is used as no thrust values. The thruster firing was executed in between the two vertical lines of 416 seconds and 576 seconds in Figure 1. There is discrepancy between the propagation and GPS navigation solutions during pre-burn time. It is because GPS navigation solutions include many error factors. The semi-major axis of the orbit for thrust is decreased from the maneuver start point.

Figure 2 shows the variation of the osculating eccentricity. The eccentricity of the orbit for thrust is also decreased from the maneuver start point. Two data points before the maneuver are noisy GPS data.

There was KGS contact after the orbit maneuver execution in GSOC contact. Twelve sets of the real-time GPS navigation solution data during the KGS pass time were collected. And 275 sets of post-burn playback telemetry data were gathered in the next KGS pass. Table 2 shows the Maneuver Planning