Proceedings of International Conference on Astronomy and Space Science Celebrating 20th Anniversary of Korea Space Science Society, Jeju, 2004

DEVELOPMENT OF PRECISION ATTITUDE DETERMINATION SYSTEM FOR KOMPSAT-2

Jae-Cheol Yoon[1]†, Dongseok Shin[2], Hungu Lee[2], Young-Ran Lee[2], Hyunjae Lee[3], Hyo-Choong Bang[3], Yee-Jin Cheon[1], Jae-Min Shin[1], Hong-Youl Moon[1], Sang-Ryool Lee[1], and Gab-Ho Jeun[1]

[1]KOMPSAT Systems Engineering and Integration Department, KARI, Daejeon 305-333, Korea
[2]Satrec Initiative Co. Ltd., Daejeon 305-811, Korea
[3]Korea Advanced Institute of Science and Technology, Daejeon 305-701, Korea
email: yjch@kari.re.kr

(Received September 25, 2004; Accepted October 1, 2004)

ABSTRACT

KARI precision attitude determination system has been developed for high accurate geo-coding of KOMPSAT-2 image. Sensor data from two star trackers and a IRU are used as measurement and dynamic data. Sensor data from star tracker are composed of QUEST and unit vector filter. Filter algorithms consists of extended Kalman filter, unscented Kalman filter, and least square batch filter. The type of sensor data and filter algorithm can be chosen by user options. Estimated parameters are Euler angle from J2000 frame to optical bench frame, gyro drift rate bias, gyro scale factor, misalignment angle of star tracker coordinate frame with respect to optical bench frame, and misalignment angle of gyro coordinate frame with respect to optical bench frame. In particular, ground control point data can be applied for estimating misalignment angle of star tracker coordinate frame. Through the simulation, KPADS is able to satisfy the KOMPSAT-2 mission requirement in which geo-location accuracy of image is 80 m (CE90) without ground control point.

Keywords: precision attitude determination, estimation, IRU, star tracker, QUEST, unit vector filter, geo-location, ICESAT, KOMPSAT-2

1. INTRODUCTION

The mission requirement for geo-location of KOMPSAT-2 image with panchromatic 1-m resolution is 80 m (CE90) without ground control point (GCP). Precision orbit determination (POD) and precision attitude determination (PAD) process in the ground station are required to satisfy image geo-location requirement. KOMPSAT-2 will implement a TOPSTAR-3000 global positioning system (GPS) receiver of Alcatel Space Industries for POD process, and also payload a SIRU with four gyros of Litton guidance and control system and two SED-16 star trackers of EADS Sodern company for PAD process. A POD system using the differential GPS (DGPS) method had been already developed (Yoon et al. 2002). In this research, Korea aerospace research institute precision attitude

†corresponding author

determination system (KPADS) using gyro and star tracker data has been developed. GCP is used as optional measurement in KPADS. Since KOMPSAT-2 is sun-synchronous orbit of which geometric angle between Sun and orbit plane is always constant, it can be assumed that misalignment of star tracker coordinate frame (SCF) due to thermal distortion has the same variation characteristics in the orbit pass over Korean peninsula during two or three months. Thus, a priori misalignment angles estimated by KPADS with GCP can be applied for post estimation process without GCP. The precision attitude determination using the simulated gyro, star tracker, and GCP data was conducted to verify the accuracy of KPADS in the cases of ICESAT and KOMPSAT-2.

2. KARI PRECISION ATTITUDE DETERMINATION SYSTEM

KPADS has been developed successfully by cooperative research between KARI and SatTrac-i company during about 1.5 year from 2003. Sensor data from star tracker are composed of QUEST and unit vector filter (UVF). Filtering algorithms consists of extended Kalman filter (EKF), unscented Kalman filter (UKF), and least square batch filter. Estimated states are Euler angle from J2000 frame to optical bench frame (OBF), gyro drift rate bias, gyro scale factor, misalignment angle of SCF with respect to OBF, and misalignment angle of gyro coordinate frame (GCF) with respect to OBF. In particular, GCP data can be applied as additional measurement for estimating misalignment angles of SCF and GCF. In addition, KPADS has a sensor data simulator which generates data of gyros, star trackers, and GCP using realistic noise models and simulates reference truth states (Lee et al. 2004).

3. RESULTS

The precision attitude determination was implemented for ICESAT and KOMPSAT-2 using simulated sensor data. ICESAT mounted a hemispherical resonator gyro (HRG) and a HD-1003 star tracker which were aligned to optical bench of laser payload (Bae & Schutz 2001). KOMPSAT-2 will mount a SIRU and two SED-16 star trackers without optical bench. QUEST measurements of star tracker were used and sensor noises were simulated statistically on the base of satellite system specification. Since both HRG and HD-1003 of ICESAT were mounted on optical bench, it was assumed there is no misalignment of SCF due to thermal distortion. In the case of KOMPSAT-2 without optical bench, the misalignment of SCF was added in the simulated sensor data and it was estimated using GCP for PAD process. Total 20 numbers of GCP were used, which consist of 10 points for Daejeon and 10 points for Seoul. EKF was applied for PAD process of two satellites.

Fig. 1 and Fig. 2 show the result of the precision attitude determination of ICESAT. After EKF converges, Earth pointing errors in local-vertical-local-horizontal (LVLH) frame are about 0.3, 1.0, and 3.5 arcseconds (RMS) in roll, pitch, and yaw axis, respectively. Geo-location error is under 3-m (RMS) in longitude and latitude direction. Since the results of ICESAT is comparable to those of Bae et al. (2004) using real ICESAT sensor data, it can be considered that the KPADS developed in this research have good performance.

Fig. 3 and Fig. 4 describe the KPADS results of KOMPSAT-2. 10 numbers of GCP in Daejeon were applied from the time of 90 seconds after initial epoch. EKF rapidly converged as soon as GCP data were used, That means that misalignment of SCF was estimated correctly by GCP data. After EKF converges, Earth pointing errors in LVLH frame are about 5, 4, and 4 arcseconds (RMS) in roll, pitch, and yaw axis, respectively. Geo-location error is under 25 m (RMS) in longitude and latitude direction.

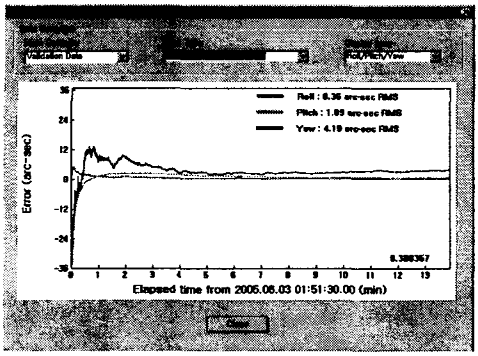

Figure 1. Estimated Earth pointing angle error (ICE SAT satellite).

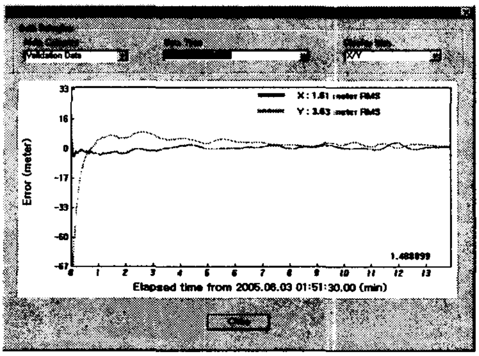

Figure 2. Estimated geo-location error (ICESAT satellite).

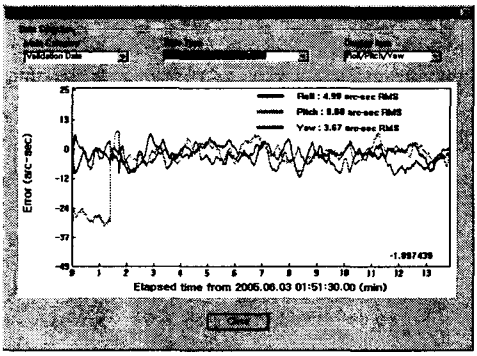

Figure 3. Estimated Earth pointing angle error (KOMPSAT-2 satellite).

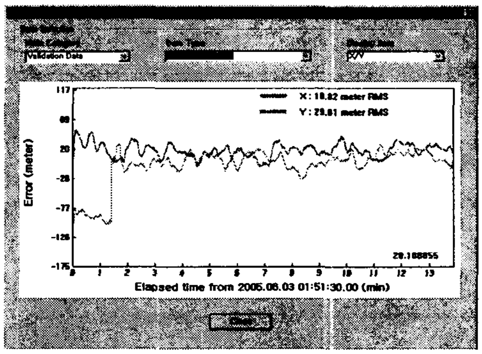

Figure 4. Estimated geo-location error (KOMP SAT-2 satellite).

4. CONCLUSIONS

KPADS has been developed successfully. The performance of KPADS was verified using the simulated sensor data of ICESAT and KOMPSAT-2. Since KOMPSAT-2 will mount no optical bench, it is important to reduce the misalignment effect of SCF due to thermal distortion. Since KOMPSAT-2 is sun-synchronous orbit of which geometric angle between Sun and orbit plane is always constant, it can be assumed that misalignment of SCF has the same variation characteristics in the orbit pass over Korean peninsula during 2 or 3 months. Thus, a priori misalignment angles estimated by KPADS with GCP can be applied for post estimation process without GCP. The estimation results using GCP show that KPADS is able to satisfy the mission requirement of geo-location error, 80 m (CE90) without GCP under the limited GCP distribution circumstance of Republic of Korea.

REFERENCES

Bae, S., & Schutz, B. E. 2001, GLAS Algorithm Theoretical Basis Document Ver.2.1 (Texas: The

University of Texas at Austin)

Bae, S., Magruder, L., Ricklefs, R., Webb, C., Yoon, S., & Schutz, B. E. 2004, ICESAT/GLAS Precision Attitude Determination for Early Laser Operation, 14th AAS/AIAA Space Flight Mechanics Conference (Hawaii: AAS/AIAA), AAS-04-118

Lee, H., Yoon, J.-C., Cheon, Y.-J., Shin, D., Lee, H., Lee, Y.-R., Bang, H.-C., & Lee, S.-R. 2004, Simulation of Spacecraft Attitude Measurement Data by Modeling Physical Characteristics of Dynamics and Sensors, International Conference on Control, Automation and Systems (Bangkok: ICCAS), FE03-05

Yoon, J.-C., Roh, K.-M., Park, E.-S., Moon, B.-Y., Choi, K.-H., Lee, J.-S., Lee, B.-S., Kim, J., & Chang, Y.-K. 2002, J. of Spacecraft and Rockets, 39, 5