SENSORS AND ACTUATORS OF THE ALSAT-1 FIRST ALGERIAN LOW EARTH ORBIT OBSERVATION MICROSATELLITE IN ORBIT

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ملخص:

في نطاق هذا البحث تم التعرض إلى نظام التحكم و التقدير لـــ ألسات-1 أول قمر إصطناعي جزائري لملاحظة الأرض و الموجود حاليا في مداره.
تجدر الإشارة إلى أن أجهزة الإستشعار في نظام التقدير هو جهاز قياس شدة الحقل المغناطيسي الأرضي و إلى جانب ذلك جهاز إلتقاط الأنظمة الشمسية. أما فيما يخص أجهزة التحكم تم الإستعانة بعجلات الإستقرار و جهاز العزم المغناطيسي.
و إلى جانب ذلك البيانات المدارية الجد قيمة المحصل عليها من المحطة الأرضية مقارنة لمتطلبات القمر الإصطناعي ألسات-1.

Résume:

Cet article présente le sous système de contrôle d'attitude et d'orbite du premier microsatellite algérien d'observation de la terre en orbite Alsat-1. Les senseurs d'attitude utilisés sont le magnétomètre, le capteur solaire, les actionneurs qui sont les roues de stabilisation et un magnéto-coupleur. Par ailleurs les résultats obtenus à partir des données de la télémétrie de la station sol sont des résultats pertinents par rapport aux exigences de la mission d'Alsat-1.

Abstract:

This paper describes the attitude determination control system for earth observation (imaging mode) on Alsat-1 first Algerian microsatellite in orbit. The attitude determination sensor required is a magnetometer and sun sensor and the actuator required is a Y/Z wheels and magnetorquer coil. In addition the in orbit results obtained by telemetry from the ground station are much better than the Alsat-1 mission requirements.

I. Introduction

On the 28th of November 2002 and from Plesetsk in north of Russia, Cosmos-3M rocket put into a 700 km sun synchronous orbit the first Algerian microsatellite Alsat-1. Alsat-1 is 90 kg enhanced microsatellite, stabilised 3 axis for imaging mode and was designed and built by a join team of Surrey Technology Limited – UK and Centre National des Techniques Spatiales – Algeria under a know how transfer and training program. Alsat-1 is one of five microsatellites of the first earth observation constellation specifically designed for disaster monitoring (DMC). Since Alsat-1 launch, the imager has taken more than 700 images.

The imaging system allows windowing and it is supported by a total storage capacity of two 0.5 Gbytes of data which could be downloaded to a ground station at 8 Mbps. The downlink and the uplink, both operate in S band at 8 Mbps in normal operation and 38.4/9.6 Kbps during commissioning for the downlink and uplink respectively.

Most of the Alsat-1 subsystems were designed with no single point failure to be highly resilient to non nominal situation. Alsat-1 as part of the constellation is equiped with a propulsion system of 50 mN thrust and two tanks with a capacity of 2.5 litres each for orbital maintenance.

II. Attitude Sensors

II.1 Magnetometer

Three 3-axis flux gate magnetometers are used to measure the geomagnetic field vector in the satellite's body co-ordinates. These measurements are used to determine the torque vector generated when switching the magnetorquer coils. When used with a magnetic field model (e.g. IGRF), magnetic measurement and model vectors can be fed to an extended Kalman filter to estimate the full attitude and angular rates of the satellite. For a calibrated magnetometer, during periods of low solar activity, the attitude angles can be estimated to an accuracy of less than 1° per axis. The magnetometer can also be used when the satellite is still tumbling after the launch, to estimate the orbit referenced angular rates of the satellite body by using a rate Kalman filter

II.2 Sun Sensors

Four 2-axis (azimuth and elevation) analogue sun sensors are used to determine the position of the sun relative to the satellite body. Each axis has a ± 60° range and can measure the sun vector to a 1σ accuracy of 0.3°. The four sensors therefore cover the full 360° azimuth range (with an overlap of 30° between sensors) and a 120° elevation range. The attitude accuracy will be better than 0.1° per axis if enough filtering is applied.

III. Attitude Actuators

III.1 Magnetorquers

The magnetorquers are coils through which a constant current can be switched. Both the polarity (direction) of these current can be controlled to generate on average a magnetic moment vector of any specific magnitude and direction within a defined time interval. The magnetic torquers on Alsat-1 are three magnetorquer rods let say X/Y/Z.
The magnetorquer will be used for the following control function on Alsat-1

- Detumbling of the body angular rates after ejection from the launch vehicle;
- Control body spin around orbit normal;
- Libration damping when the gravity gradient boom is deployed;
- Yaw phase or yaw angular rate control when the gravity gradient boom is deployed;
- Momentum management of the reaction/momentum wheels.

Magnetorquers can be designed to provide momentum management on a low Earth orbiting spacecraft. Dipole moments generated by the magnetorquer interact with the Earth's magnetic field to generate small torques on the spacecraft. Since the magnetic torque is always orthogonal to the local magnetic field vector, it is not possible to generate instantaneously a required torque direction as demanded by a full 3-axis control system. However, in the course of an orbit the direction of the vector may change and it may be possible to generate the required torque on average during the course of an orbit. A consistent and reasonable strength vector is available only in LEO orbits.

III.2 Reaction/Momentum Wheels

One momentum wheel is installed in Y axis-axis and two reaction wheels are installed in Z axis (x2 for redundancy). Reaction wheels are essentially torque motors with high-inertia rotors. They can spin in either direction. Roughly speaking one wheel provides for the control of one axis. Momentum wheels are wheels with a nominal spin rate above zero. Their aim is to provide a nearly constant angular momentum.
The wheels are used for the following control functions on Alsat-1

- Z-axis wheel (x2 redundancy);
- Yaw control for push broom;
- Quick transfer between BBQ mode and yaw steering;
- Z disturbance cancellation during X thruster firings;
- Pitch momentum wheel for 3 axis stabilization with and without boom;
- Y disturbance cancellation during X thruster firings.

IV. In Orbit Imaging Mode Results

This section describes the in orbit results of Alsat-1 attitude determination and control system which has been demonstrated during the begening of junuary 2005.
The sensors measurement and actuators profiles on 7th junuary 2005 are shown in figure 1 to 4.

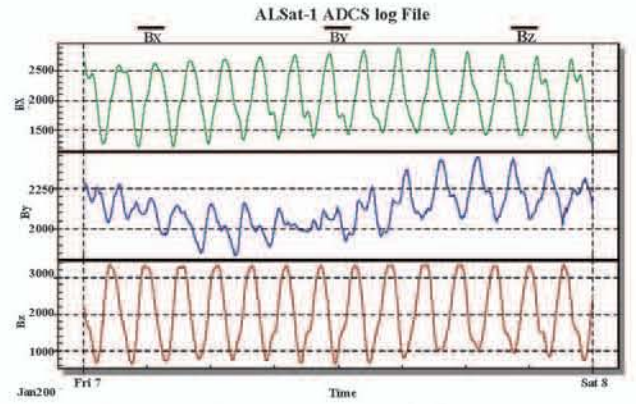

Figure.1 Magnetometre measurement during imaging mode

Figure. 2 Sun sensor measurement during imaging mode

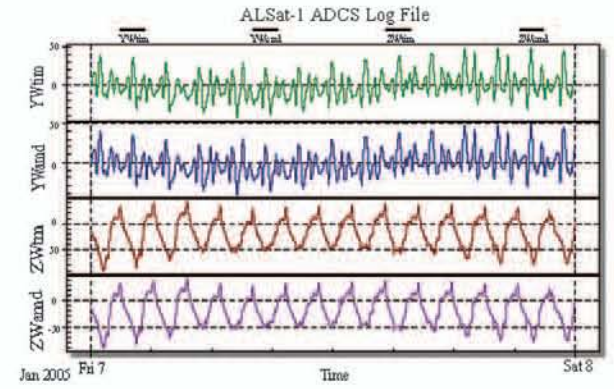

Figure. 3 (Y/Z) Wheels profile during imaging mode

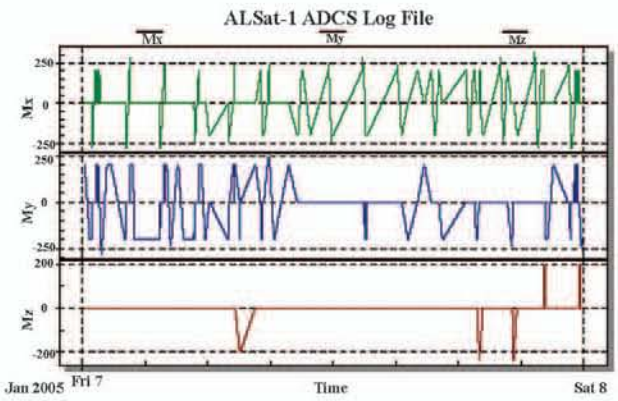

Figure. 4 Magnetorquer activity during imaging mode

Conclusion

The Alsat-1 attitude determination and control system has been fully operated and the results show good performance from the sensors (magnetometer and the sun sensor) and actuators (Y/Z wheels and magnetorquer).
The results we have obtained indicate, the roll and pitch pointing are much better than the requirements.
The extension to the use of GPS, as a receiver is in orbit on the Alsat-1 platform, for attitude determination is an important future step.

Acknowledgements

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