Overview of Initial Observation Data of Technical Data Acquisition Equipments on the First Quasi-Zenith Satellite

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Technical Data Acquisition equipments (TEDA) on the first Quasi-Zenith Satellite (QZS-1) "MICHIBIKI" was launched by the H-IIA Launch Vehicle No.18 on September 11, 2010 from the Tanegashima Space Center. The TEDA consists of sensors of three types; Light Particle Telescope [LPT, including Alpha particle and Proton Sensor-B (APS-B) and Electron Sensor-A (ELS-A)], Magnetometer (MAM), and Potential Monitor (POM). The TEDA on the QZS-1 has collected these data of space environment from September 21, 2010, these data will help us to identify the cause of the satellite anomaly. This paper describes some results from these data analysis on the QZS-1 orbit.

Key Words: TEDA, QZS-1, Space Environment

1. Introduction

As electronic devices for space use have decreased in size and power, with increased complexity, they have become sensitive to space radiation environment increasingly. To meet the high level of system performance, it is necessary to use commercial electronic devices that are not expected to be used in radiation hardened systems. Also, by using commercial electronic devices, it is possible to reduce the cost of satellite development and to promote the development of space technology. Therefore, a detailed observation of the space environment is an important issue in the development of space technology, and it is necessary to quantify the space environment accurately than ever before.

Technical Data Acquisition equipments (TEDA) on the first Quasi-Zenith Satellite (QZS-1) "MICHIBIKI" was launched by the H-IIA Launch Vehicle No.18 on September 11, 2010. The QZS-1 orbit is unique, and draws a figure 8 orbit projected onto the ground surface. The QZS-1 altitude is almost the same as the altitude of geosynchronous satellites (GEO), inclination is not 0 degree (GEO) but about 45 degrees and eccentricity is not 0 degree (GEO) but about 0.1 degrees. QZS-1 TEDA is expected that valuable data is observed, because this is the first observation on this unique orbit. QZS-1 TEDA consists of sensors of three types; Light Particle Telescope [LPT, including Alpha particle and Proton Sensor-B (APS-B) and Electron Sensor-A (ELS-A)], Magnetometer (MAM), and Potential Monitor (POM). A picture of QZS-1 showing the physical layout of TEDA instruments is presented in Fig. 1.

This paper describes some results from these data analysis on the QZS-1 orbit.

2. Instrument Description

2.1 Light Particle Telescope (LPT)

LPT includes sensors of two types, Alpha particle and Proton Sensor-B (APS-B) and Electron Sensor-A (ELS-A). They are designed to detect, discriminate, and analyze energy...
of charged particles including electrons, protons, and alpha particles. They cover a much wider energy range than conventional telescopes through their complementary functions. APS-B can observe down to 1.5 MeV for protons and ELS-A can observe down to 0.03 MeV for electrons as their lower limit. Observations in these measurement ranges are important for investigating the surface charging effect. They can also provide measurements up to 250 MeV for protons and 1.4 MeV for electrons in the upper limit. Observations in these measurement ranges are important for investigating the internal charging effect and the single event effect on electronics devices.

Table 1 shows the performance of APS-B, and Table 2 shows the performance of ELS-A.

### Table 1. Performance of APS-B.

<table>
<thead>
<tr>
<th>Observable particle</th>
<th>Measurement range</th>
<th>Counting ability</th>
<th>Geometric factor</th>
<th>Field of view</th>
<th>Time resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>proton, deuteron, tritium, helium</td>
<td>proton: 1.5 MeV - 250 MeV, deuteron: 8 MeV/n - 26 MeV/n, tritium: 9.2 MeV/n - 21 MeV/n, helium-3: 21 MeV/n - 84 MeV/n, helium-4: 10 MeV/n - 400 MeV/n</td>
<td>5×10⁴ event/s</td>
<td>0.05749 cm²·sr</td>
<td>±21.8°</td>
<td>1 s</td>
</tr>
</tbody>
</table>

### Table 2. Performance of ELS-A.

<table>
<thead>
<tr>
<th>Observable particle</th>
<th>Measurement range</th>
<th>Counting ability</th>
<th>Geometric factor</th>
<th>Field of view</th>
<th>Time resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>electron</td>
<td>electron: 0.03 MeV - 1.4 MeV</td>
<td>5×10⁴ event/s</td>
<td>0.00301 cm²·sr</td>
<td>±10.0°</td>
<td>1 s</td>
</tr>
</tbody>
</table>

The sensor of APS-B uses four semiconductor detectors. To consider the electron contamination, the first sensor (S1) has adopted in the thickness of the semiconductor sensor 250 μm. To observe the proton for energy range from S1 to S3, S4 are only used for anti-signal detection. The side wall shield which is made of tantalum excludes penetrating protons at normal incident on the sensor holder.

Similarly, the sensor of ELS-A uses four semiconductor detectors. To eliminate a mixture of protons and to consider the energy resolution of the sensor, the first sensor (S1) has adopted in the thickness of the semiconductor sensor 80 μm.

To measure with unprecedented low-energy electrons, this detector has deposited light-shielding film of aluminum (1 μm) on S1. To observe the electron for energy range from S1 to S3, S4 are only used for anti-signal detection.

Fig. 2 shows the sensor conceptual diagram of APS-B and ELS-A.

### 2.2. Magnetometer (MAM)

MAM objective is to measure magnetic field strength on the QZS-1 orbit to obtain the technical data given to a factor of the satellite space environment. MAM consist of two sensor assembly, MAM sensor-1 (MAM-S1) is mounted on top of the antenna tower away from the satellite assembly and MAM sensor-2 (MAM-S2) is mounted on the antenna tower base. Two MAM sensors measure the magnetic field between the tip of the antenna tower and the base, identify and distinguish the magnetic field gradient from the satellite, improve measurement accuracy, and constitute a redundant system.

Table 3 shows the performance of MAM.

### Table 3. Performance of MAM.

<table>
<thead>
<tr>
<th>Measurement range</th>
<th>Time resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>±65536 nT</td>
<td>±4096 nT</td>
</tr>
<tr>
<td>±10 s</td>
<td></td>
</tr>
</tbody>
</table>

MAM is used fluxgate magnetometer method, it observes magnetic flux density by using symmetry of the core saturation flux density. Fig. 3 shows the functional block diagram of MAM. The ring-core type was adopted in QZS-1 MAM, it consists of the excitation coil to energize the core made of soft magnetic material formed in the shape of a ring and the detection coil to detect changes in magnetic flux density induced in the excitation core.
Then, it is excited by the alternating magnetic field to the saturation region excitation coil energized by applying the voltage to the excitation coil from excitation circuit, the detection coil detected from the change in magnetic flux density induced in the excitation core.

It is symmetric induced magnetic flux density when magnetic field except the excitation magnetic field is not applied to the excitation core, and only odd-order harmonics of the excitation wave occur in the detection coil. When an external magnetic field is applied to the excitation core, because the excitation magnetic field is added from the external magnetic field, changes in magnetic flux density becomes asymmetric bias in the magnetic field applied to the excitation core, even-order harmonics occur in the detection coil. Fluxgate magnetometer measures the magnetic fields to detect this even-order harmonics.

2.3. Potential Monitor (POM)

POM objective is to measure relative to the surface potential of the satellite assembly for which the three samples measured assessment of the potential charge. The measurement results output to TEDA in format of serial telemetry. POM is supplied the primary power from the bus powered satellite, and started by the command to enable from satellite system.

Table 4. shows the performance of POM.

Table 4. Performance of POM.

<table>
<thead>
<tr>
<th>Measurement range</th>
<th>-10 kV - +5 kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>12 bit</td>
</tr>
<tr>
<td>Measurement accuracy</td>
<td>±5% (Full Scale)</td>
</tr>
<tr>
<td>Time resolution</td>
<td>1 s</td>
</tr>
</tbody>
</table>

POM is used tuning-fork modulation method, and has three charging test samples. POM measures the charge potential of the test samples relative to the satellite body structure.

Fig. 4. shows the sensor conceptual diagram of POM. Although the sensor unit of POM is insulated from the surrounding by the thermal control materials (MLI), the test samples are exposed to space.

3. Overview of Initial Observation Data

3.1. Initial data of LPT

Fig. 5. shows the differential proton flux in each channel of APS-B around February 15, 2011 when the X-class solar flare occurred. The horizontal axis shows the time from February 14, 0:00(UT) to February 17, 0:00(UT) and the vertical axis shows the differential flux. This graph shows growing low-energy protons about 6 hours after the flare, particles of less than 10 MeV two digits increase, less than 30 MeV particles one digit increase. Compared with solar wind data of ACE and X-ray data of GOES, in spite of the solar wind is calm before and after the flare, increase of the proton was observed after the flare, particles from the sun flow directly.

Fig. 6. shows the differential electron flux in each channel of ELS-A around February 15, 2011. Axis definition and time range are same as Fig. 5. This graph shows growing low-energy electrons about 12 hours after the flare occurrence, particles of less than 200 keV increase.

3.2. Initial data of MAM

Fig. 7. shows magnetic field intensity data of X, Y, Z and the synthesis of 3-axis around February 15, 2011. The horizontal axis shows the time from February 14, 0:00(UT) to February 20, 0:00(UT). These data were corrected for residual magnetic field in each axis. This graph shows magnetic field disturbance caused by solar wind from about 3 days after the flare occurrence.

3.3. Initial data of POM

Fig. 8. shows charge potential data of POM around February 15, 2011. These data were collected from three types of test samples of POM, and show a daily periodic variation.

4. Conclusions

We have developed the space environment monitor system (TEDA) onboard QZS-1, which is capable to provide measurements of radiation particles, magnetic field and charge potential on the quasi-zenith orbit. The initial data from QZS-1 TEDA shows reasonable results compared with the data of examination on the ground. QZS-1 TEDA is expected to continue to obtain the high accuracy data required for modeling the space environment for quasi-zenith orbit, and to help analysis of variation mechanisms of the space environment.
Acknowledgments

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References


Fig. 7. Magnetic field intensity data of MAM.

Fig. 8. Charge potential data of POM.