Attitude estimation of nano-satellite HIT-SAT by received power fluctuation

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1. Introduction

In recent years, many universities have already launched small satellite on-orbit. Attitude information is important for satellite operation. However, many nano-satellite communication systems used amateur radio by narrow bandwidth frequency segment. Therefore, down-link of attitude information is expected to require substantial time. In this paper, we propose establishment of the attitude estimation method by means of the received radio power. And, satellite attitude information being estimated from the fluctuation of the received power. Then, comparison of satellite data obtained from on-board sensors with ground experiment. One major problem in this approach is the effect of Earth's ionosphere. As the radio signal passes through the ionosphere, the polarization angle is rotated by the Faraday Effect [1]. The detection of attitude by the radiation pattern has been assumed that inaccurate. However, we are get data the spin satellite of liner polarization antenna. As a result, we can estimate 0.4[rad/s] accuracy of angular velocity measurement. This method can be applied to the attitude detection of many small satellites.

2. Overview of HIT-SAT

The measurement target HIT-SAT was launched as a sub-payload of JAXA M-V-7 on September 23 2006. HIT-SAT is 2.7 kg and 12cm cubed [2]. Table 1 shows specification of HIT-SAT. Fig. 1 shows flight model HIT-SAT. The HIT-SAT main mission is orbital demonstration of bus system by commercial-off-the-shelf components [3]. The satellite is spin-stabilized one, and controlled by three magnetic torquers. Attitude control bus system consists of a magnetometer (Fig. 2), a gyro sensor (Fig. 3), a sun sensor, magnetic torqures (Fig. 4) and CPU. Attitude control result is record by smart media (128MB). Communication bus system consists of a dipole antenna, a monopole antenna, CW and FSK transmitter and receiver. The dipole antenna was used for down-link of 430MHz band. The monopole antenna was used for up-link of 145MHz band. Table2 shows the specification of communication system. Ground station is built in Hokkaido Institute of Technology. On September 24 2006, attitude control experiment started. However, the attitude control halfway stopped by internal communication error. Then on October 30 2006, spin-up experiment was conducted of 90 minute. Since down-link of attitude control and housekeeping data history was acquired. The HIT-SAT was decay orbit on June 19 2008.

Table 1: Specification of HIT-SAT

Weight	Satellite	2.7 [kg]
	Separation system	4.3[kg]
Size	Satellite	12×12×12 [cm]
	Antenna	Monopole:25 [cm]
		Dipole:16 [cm]
Power consumption		0.5 [W]

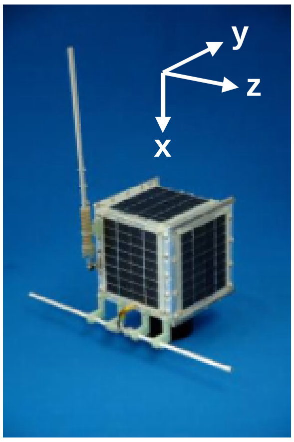

Figure 1: Flight model of HIT-SAT

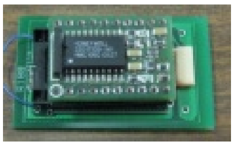

Figure 2: Magnetometer

Figure 3: Gyro sensor

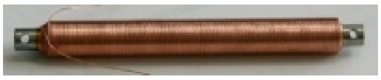

Figure 4: Magnetic torqure

Table 2: Specification of communication system

Antenna gain	2.15[dbi]
Transmission power	CW:0.1[W] FM:0.8[W]
Transmit frequency	CW:437.275[MHz] FM:437.275[MHz]

3. Measurement system

Received power measurement was ground station built in Sapporo-city Hokkaido Japan. Table3 shows specification of ground station. Cross yagi antenna and two stack horizontally polarized wave antenna are set up in ground station as shown in Fig. 5. The signal of this receiver is A-D converted with the H8 microcomputer board, it transmits to PC, the voltage value is taken out, and it is preserved as well as time information. Time information makes an internal clock of the personal computer the origin. The sampling rate is 11.36 milliseconds. Accuracy is 10 bit because it used the microcomputer board. The pursuit of the antenna and the correction of the doppler shift were done with software for the satellite tracking that I had made. The orbit calculation with this software was done by using the orbital element open to the public in the TLE form on the homepage of SPACE TRACK based on SPG4. SGP4 is a theory to calculate an arbitrary satellite position of time and the speed of the satellite from orbit information on the TLE form. This system can be measured only by the reception. Therefore, there is no obstacle to the satellite operation even if this system measures.

Table 3: Specification of ground station

Lat/Lon	43.131N,141.2537E
Sea level altitude	69[m]
Cross yagi antenna gain	16.15[dB]
Horizontal yagi antenna gain	18.55[dB]

Figure 5: Antennas of ground station

4. Measurement result and discussion

4.1 Ground experiment

This method we need to understand about radiation pattern. Therefore, it is measured radiation pattern of radio dark room. Radiation pattern of dipole antenna e-plane of rotation around x-axis is shown in Fig. 6. Null point level and peak point level mismatching was by antenna asymmetrical of dipole antenna.

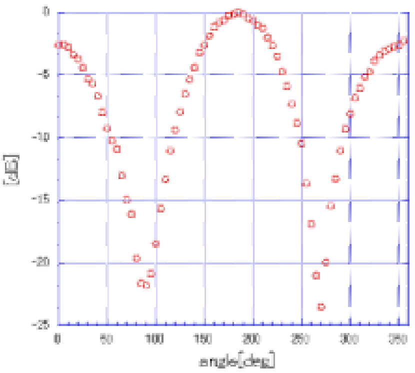

Figure 6: X-axis radiation pattern

4.2 Measurement result

We were measured period between October 28 2006 and January 30. As a result, the received signal power data fluctuated periodically. Fig. 7 shows data of November 1 2006. The change of this received power is guessed to be a radiation pattern of the antenna by rotation.

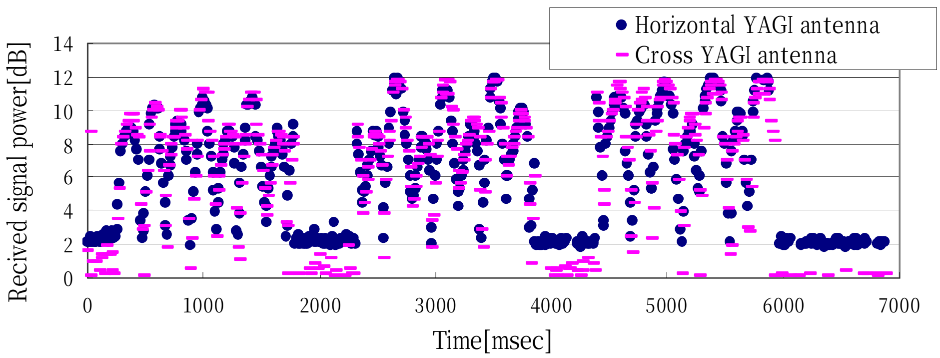

Figure 7: Date of 2006/11/1

4.3 Angular velocity estimation

Angular velocity was estimated from the received signal of HIT-SAT. Angular velocity was directly measured by on-board gyro sensors and magnetometer. Angular velocity estimation was conducted by using the received radio data from October 28 2006 to January 15 2007. Fig. 8 shows estimation result of angular velocity. This graph is angular velocity slowly from day to day. We will change was by residual field of magnetic torqures. Moreover, Fig. 9 shows estimated angular velocity by on-board attitude sensors. The data of estimation attitude was by magnetometer and gyro sensor. We have a margin of error 0.4[rad/s] by compare received power angular velocity data with sensor data.

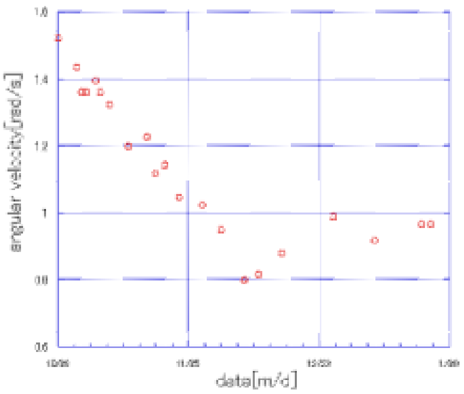

Figure 8: Estimation result of angular velocity

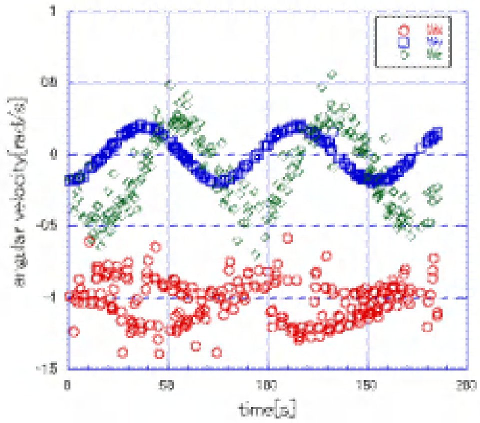

Figure 9: Angular velocity data at Oct 31 2006

5. Conclusion

In this paper, it is verified that the angular velocity of the small satellite can be estimated from the cycle of the received signal intensity. Estimated angular velocity from received signal coincides with that valuated from on-board sensor of gyro and magnetometer. It will be possible that high sampling rate and multi position measurement as demonstrated in this experiment gives us more information about satellite attitude.

Acknowledgments

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