A Study on Attitude Detection System with Lunar Direction for CubeSat of Observing Jupiter's Dynamic spectrum

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Abstract In this paper, attitude detection system for ultra-small satellite(called as cubesat) to observe the decametric radio emission from Jupiter is conducted. Then in order to achieve the mission, it is necessary for the cubesat to be implemented with a dipole antenna of the length of 7.2m. However, an attitude fluctuation for the cubesat is caused by gravity gradient torque with antenna deployment then an attitude control system for the cubesat is needed. In this paper, the attitude fluctuation for the cubesat is introduced and the authors propose an attitude detection system such as relatively direction between the cubesat on orbit and the moon is analyzed by the image captured with omnidirectional camera. To verify the effectiveness of the proposed attitude detection system for the cubesat, an experiment and analysis for the attitude detection system are executed and obtained results are evaluated.

Keywords : Cubesat, Attitude detection system, Gravity gradient torque, Antenna deployment mechanism

1. Introduction

Nowadays, some business markets and some observation missions for small satellite has been developing significantly by organizations such as universities, technical colleges and private companies because the developing cost and term, launching cost and coordination for the cubesat are so lower comparing with normal large satellites launching.

Then the authors conduct a cubesat to observe for Jupiter's decametric radio emission [1]. It is considered that the elucidation of the Jupiter's emission is applied to the Earth's electric energy problem. In this paper, a preliminary study of attitude detection system for the cubesat is conducted. Then to observe the Jupiter's emission with a frequency of 20MHz corresponding, a dipole antenna with length being 7.2m is required [1]. Fig.1 shows image of antenna deployment of the cubesat in outer space. However the cubesat is received an attitude disturbance due to gravity gradient torque with the dipole antenna deployment. Then active attitude control system for the cubesat is needed, however it is impossible that the cubesat implement normal attitude control device such as a star-tracker and a sun-sensor to detect the body attitude of the such satellite because of the cubesat having few electric power and few space to equip of many functional devices. Hence, the authors conduct the attitude detection system with analyzing relatively direction between moon and the satellite. Then to find the relatively direction, the image captured with an omnidirectional camera implemented on the cubesat is applied. And experiment for the attitude detection is introduced and obtained result are evaluated.

Fig.1 Image of Cubesat with antenna deployment

2. Attitude Fluctuation with Antenna Deployment

2.1 Attitude Fluctuation Next, the attitude fluctuation caused by gravity gradient torque for the cubesat is described. Fig.2 shows the gravity gradient torque received for the satellite with the dipole antenna deployment. The gravity gradient torque is occurred by displacement between the center of gravity of the body and tip of the body. Then the gravity gradient torque is formulated as following,

$$T = \frac{GMLm_a \cos\theta}{2}\left(\frac{1}{2}\left(\frac{1}{r_b^2} - \frac{1}{r_a^2}\right) - \frac{3\sin\theta}{r_0^3}\right) = 0 \qquad (1)$$

Where G is represented as the gravitational constant, M is represented as the mass of the Earth, L is represented as the length of the dipole antenna, θ is given as the body angle and r is given as distance between the body and the center of the Earth.

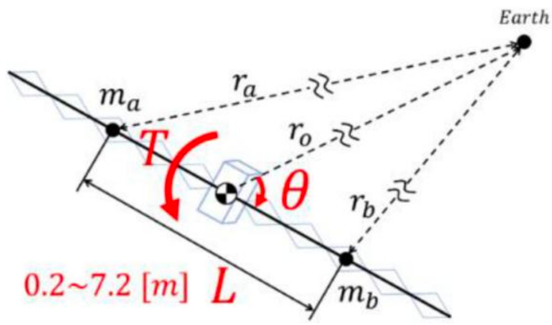

Fig.2 Construction of the satellite model

2.2 Numerical Simulation Next, the body angle rotated by such gravity gradient torque while antenna deploying is described. It is shown that distribution of the body angle for each antenna condition is calculated by Eq.(1).Then Fig.3shows the contour map of torque caused by the gravity gradient torque. The horizontal axis gives the length of antenna and the vertical gives the angle of satellite.From Fig.3, angle of satellite cannot be determined passively. Then active attitude control system is required.

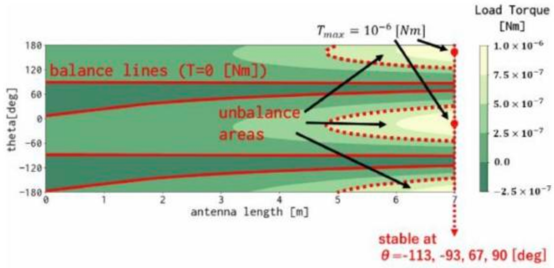

Fig.3 Contour map of the gravity gradient torque

3. Attitude Detection System

3.1 Attitude detection approach Next, the attitude detection system for the cubesat is described. The authors conduct the attitude detection system by using relatively direction information for lunar direction view from the cubesat. The relatively direction vector from cubesat to the moon is decided uniquely when the orbit for the cubesat is known.

3.2 Analyzing procedure In this section, procedure for the attitude detection is described. Fig.4 shows the aspect of analyzing procedure and captured image by an omnidirectional camera with the satellite. The capturing point is shown as the elevation angle α[deg] and the azimuth angle β[deg] as follow equations using percentage of pixels.Then the gap between nominal point and capturing point for elevation and azimuth are corresponding to attitude angle for the cubesat.

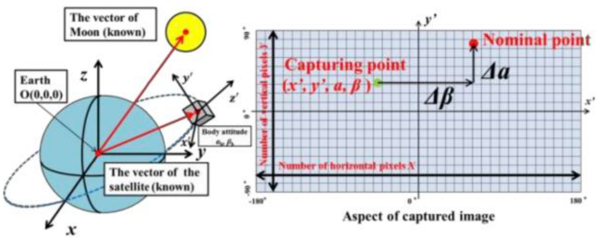

Fig.4 Aspect of analyzing procedure

$$\begin{cases} \alpha = \frac{y'}{Y} \times 180 + \alpha_b \\ \beta = \frac{x'}{X} \times 360 + \beta_b \end{cases} \tag{2}$$

4. Attitude Detection Experiment

4.1 Experimental Condition Next, experiment of attitude detection system is described. To verify the effectiveness of the proposing attitude detection system, attitude detection experiment for two conditions are executed. Fig.5 shows experimental setup and Table.1 shows components product of the experimental device. Then experimental condition is shown in Table 2.

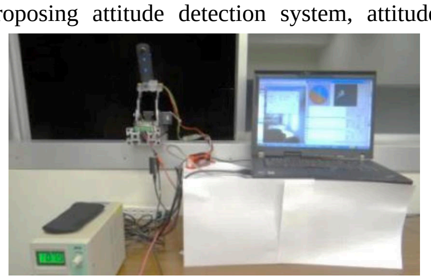

Fig.5 Experimental setup

Table.1 Components used as experimental setup

Component	Manufacturer	Model number
Servo motor	Futaba	RS405CB
Camera	RICOH	THETA S
Attitude angle detector	Silicon Sensing System Japan	AMU-3002BLite

Table.2 Experimental condition

Number	Time	Camera angle		Observation point	
		Elevation angle α_b[deg]	Azimuth angle β_b[deg]	Latitude[deg]	Longitude[deg]
Case1	2017/12/28 18:46	0	167.31	36.38	139.02
Case2	2017/12/28 18:59	29.85	167.31		

4.2 Experimental Result In this section, experimental results are described. Fig.6 shows capturing image by omnidirectional camera in the two cases as experimental results.Then Table 3 shows analyzing result as detected attitude angle for elevation and azimuth. It is found that experimental result for detected attitude angle is almost consistent measurement value as nominal. Hence, the authors consider that the proposing attitude detection system is available.

Fig.6 Capturing image

Table.3 Experimental result

Number	Nominal point		Measurement analysis point		Angular error	
	Elevation angle [deg]	Azimuth angle [deg]	Elevation angle α [deg]	Azimuth angle β [deg]	Elevation angle [deg]	Azimuth angle [deg]
Case1	59.4	162.1	59.9	165.0	0.5	2.9
Case2	60.1	168.2	59.9	168.5	-0.2	0.3

5. Conclusion

The authors have been developing the cubesat to observe Jupiter's decametric radio emission. Then it is clearly that the attitude of cubesat is received a fluctuation by effectiveness of the gravity gradient torque of the antenna deployment and active attitude control system is needed. Thus the authors conducted attitude detection system utilized the relatively lunar direction vector which the image is captured by omnidirectional camera from the view of cubesat. And the experiment was executed and it is shown that the proposing attitude detection system for the cubesat is available.

References

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