Analysis on Euler Angles Rotation of a Rigid Body in Three-Axis Attitude Based on RazakSAT Data

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Abstract—Satellite attitude estimation uses different attitude representation such as Euler angles, direction cosine matrix, Gibbs vector or quaternion parameters as a kinematic model. This three-axis attitude parameter using quaternion parameter is mostly used to represent the attitude of satellites. As well as in RazakSAT satellite mission, the attitude data is represented by quaternions parameters. However, the quaternions parameters do not have a physical interpretation on the attitude of the satellite. Therefore, quaternion parameters of the satellite are converted to Euler angles rotation for the physical interpretation of its orientation. This paper present and analyse the satellite three-axis Euler angles rotation for its attitude using average rotation, maximum/minimum error and standard deviation. The result shows that the quaternions parameters are successfully represented in Euler angles. The error measurement or noise exists on roll, pitch and yaw of Euler angles. For verification of the Euler angles error, the angular velocity from satellite gyroscopes is used as references. Residual analysis at low frequency is 0.00515 [degree/second] which considered as Euler angles measurement error or noise.

Index Terms—Attitude Determination System; Euler Angles Rotation; Quaternion Parameters; RazakSAT Satellite.

I. INTRODUCTION

The Malaysian own satellite name RazakSAT which is the world first remote sensing satellite launched into Near Equatorial Orbit (NEqO). It is a mini-satellite with 180 kg mass, orbiting in Low Earth Orbit (LEO) of altitude 680 km with an inclination of 9 degrees from the equatorial plane. The imaging satellite will provide a high-resolution image of Malaysia which will be used for various applications [1-6]. The satellite attitude location is crucial in determining the quality of image acquired as shown in Figure 1.

The satellite attitude is an orientation in space relative to the inertial frames such as Earth, Moon, Sun or any other celestial object. The attitude analysis is an important characteristic in satellite operations such as for Earth observation, communication and military. The determination technique uses different attitude representation such as Euler angles, direction cosine matrix, Gibbs vector or quaternion parameters as their kinematic model. The three-axis attitude parameter using Euler angles is the most suitable technique due to its straightforward physical interpretation [7-9].

Figure 1: The RazakSAT satellite.

The accuracy of RazakSAT satellite attitude is influenced by errors such as sensor noise, bias, and misalignment. The prediction of attitude using Attitude Determination System (ADS) sensor would involve errors. The space phenomena such as eclipse, dazzling and earth albedo would cause misalignment in estimation and ADS sensor measurement [10-13]. The accuracy of attitude estimation will be improved by applying the ADS sensor measurement. The satellite is using the gyroscope, sun sensor and magnetometer as the inertial sensor and references sensor as shown in Figure 2, 3 and 4.

Figure 2: The RazakSAT magnetometer

Figure 3: The RazakSAT gyroscopese