Seasonal Analysis of Attitude Estimation Accuracy for the Brazilian Satellite Amazonia-1 under Normal and Faulty Conditions

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ABSTRACT

The Brazilian mission Amaziona-1 has as its primary objective the monitoring of the Amazonia rainforest. The satellite uses the Brazilian Multi-Mission Platform (MMP) and will be launch on a sun-synchronous orbit with semi-major axis of 7131.00 km, inclination of 98.405°, eccentricity of 0.001111, and a RAAN such that the apparent local time at the illuminated part of the orbit is 10:30 AM.

The MMP uses two SED-26 star trackers and a four axis fiber optic gyro Astrix-120 to estimate the attitude at the routine satellite operation mode (ROU). In this mode, the attitude determination process first evaluate a static estimate by combining the output quaternion from both star trackers and then the static estimate is filtered with the aid of the gyro measurements. The star trackers were positioned with their field of view orthogonal from each other in order to minimize the total error under the constraint that neither of them can point closer than a given excluding angle to the Sun nor to the Earth. In a previous study, the satellite attitude estimation accuracy was evaluated considering the star trackers with constant accuracy equivalent to their 3-sigma level over the whole celestial vault. However, since the satellite will be placed on a sun-synchronous orbit and will point towards Earth, then the star trackers will see different sets of stars throughout the orbit and consequently the measurement error statistics will vary.

The star tracker manufacturer, as can be seen in fig. 1, provided data to obtain the low frequency error (LFE) and noise equivalent error (NEA) as a function of the ascension and declination of the star tracker optical axis related to the J2000 reference frame. In this paper the aforementioned previous study is extended by using this novel information to compute more realistically the seasonal variation of the Amazonia-1 attitude estimation accuracy throughout the year.

The attitude estimation accuracy for this study has been obtained by simulating the satellite orbit and attitude to compute the vectors represented in the J2000 reference frame that are aligned with the star tracker optical axes. Then, using the information from the manufacturer in fig. 1, it has been possible to compute the LFE and NEA for each sensor. These errors have been evaluated for each satellite position at each orbital plane during one year and the attitude estimation accuracy has been obtained for several scenarios regarding the considered set of attitude sensors. First the analysis has considered the routine operation mode, when all the sensors are fully available. Then the analysis is repeated for different sensor failure scenarios as indicated in Table 1.

In scenarios 01 to 06, the star tracker measurements were fused by means of a recursive filter in which the model was constructed with the FOG measurements. Notice that the attitude estimation filter embedded in the AOCS on-board computer has a constant gain, which is the steady-state Kalman filter gain based on the constant model of the star trackers accuracy (scenarios 02, 04, and 06). In scenarios 07 and 08, the measurements of both star trackers were represented in a common reference frame and then were fused using a static algorithm to minimize the fused measurement noise covariance. The scenario 07 used the true covariance (NEA) as provided by the manufacturer whereas the scenario 08 used the average over the whole celestial vault, as embedded in the AOCS on-board computer. The simulations were written in MATLAB and C++ and were executed in a desktop PC with an Intel Core i7-3770 processor and 8 GB of RAM using openSUSE Linux.

Concluding, this novel analysis extends the previous study by adding a more realistic error model of the star tracker measurements that takes into account the satellite orbit and attitude. Moreover, it provides additional information about the mission performance under a set of possible sensor failures. In the routine operation mode, the effect of taking into account the star tracker accuracy variation on the filter gain evaluation was not benefic comparing to the constant accuracy model due to the presence of low frequency errors (LFE). Also, effect of locally poor accuracy areas over the celestial vault were mitigated by the combination of two star trackers and remarkably smoothed by the filtering process with the gyro. The same does not happen under some sensor failure conditions, when the current analysis becomes a more realistic accuracy prediction tool.

Table 1: Scenarios.

Scenario	**Available Sensors**			**Fusion algorithm**
	Star Tracker A	**Star Tracker B**	**FOG**	
01	**X**	**X**	**X**	Kalman filter
02	**X**	**X**	**X**	Constant gain filter
03	**X**		**X**	Kalman filter
04	**X**		**X**	Constant gain filter
05		**X**	**X**	Kalman filter
06		**X**	**X**	Constant gain filter
07	**X**	**X**		Inverse covariance (true)
08	**X**	**X**		Inverse covariance (mean value)
09	**X**			None
10		**X**		None

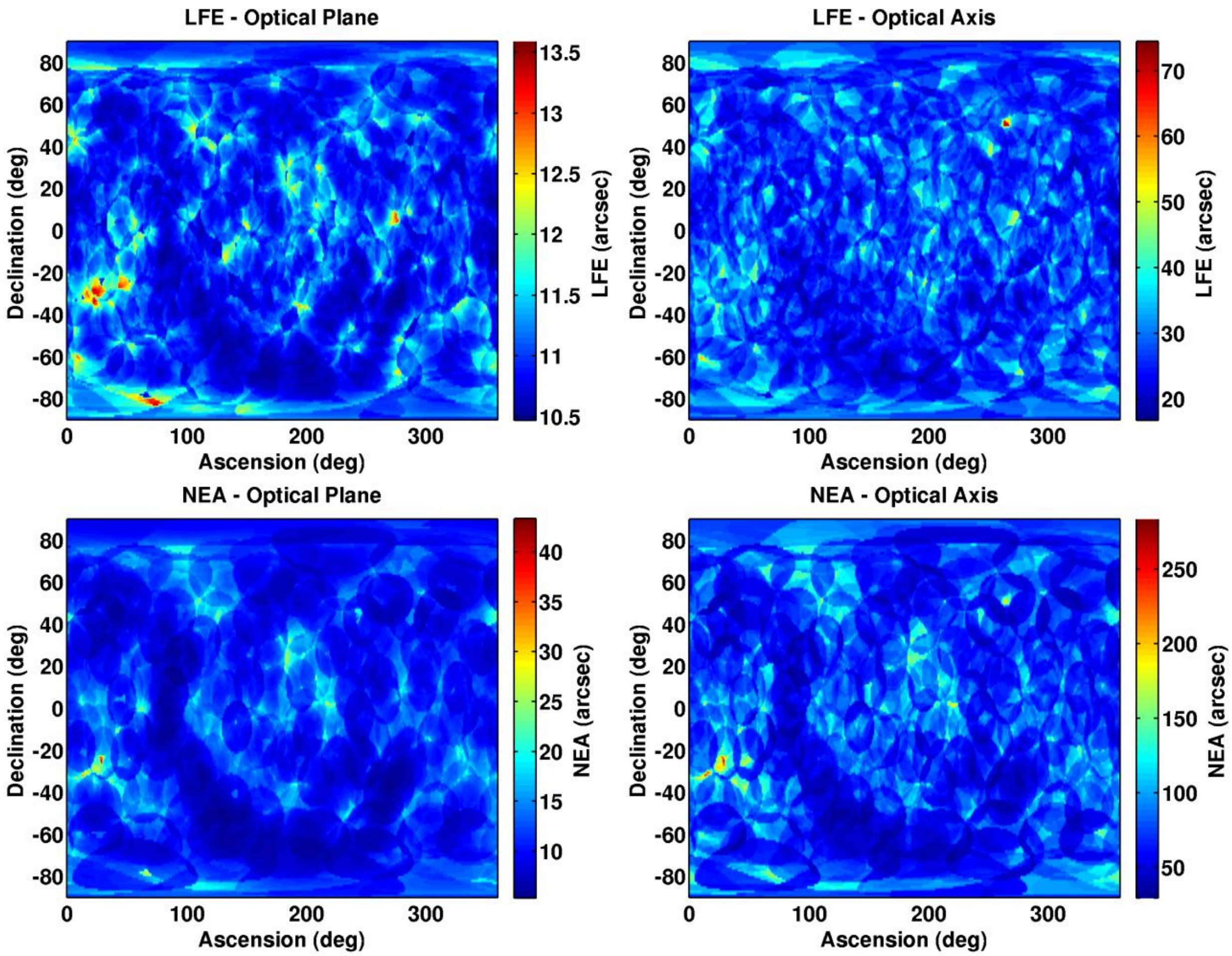

Figure 1: Low frequency error (LFE) and noise equivalent error (NEA) as a function of the ascension and declination of the star tracker optical axis in the J2000 reference frame. The left column contains the errors in the star tracker optical plane and the right column contains the errors in the star tracker optical axis.