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Geoscientific Instrumentation Methods and Data Systems Discussions

Interactive comment on "Error estimate for fluxgate magnetometer in-flight calibration on a spinning spacecraft" *by* Yasuhito Narita et al.

Anonymous Referee #1

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1 General remarks

The submitted manuscript provides an analysis of the errors of the FGM magnetic field data related to the uncertainties of the calibration parameters determined for spinning spacecraft through the procedure described by Plaschke et al. 2019. The errors are computed in the first order by introducing small perturbations of the calibration parameters and taking into account typical values of the uncertainties as determined for a number of spacecraft (Cluster, THEMIS, MMS, and BepiColombo).

The manuscript can be a useful resource both for planning future spacecraft missions and for estimating the accuracy of the magnetic field data delivered by current missions. There are however a number of issues which should be addressed before publication.

2 Specific comments

• page 2, line 29-30: Please explain what do you mean through "Fourier series of spacecraft spin frequency".

• page 2, line 45-49: Is ϕ_a the angle between the projection of the spin axis on the (P_x, P_y)-plane of the sensor package coordinate system? If so, please mention this in the description of the step 3.

• page 2, line 48: "... σ_{P_x} and σ_{P_y} (with respect to the P_z axis) ..." This definition of σ_{P_x} and σ_{P_y} is nor clear enough. From Fig. 1 it appears that σ_{P_y} is the angle between the P_z axis and the projection of the spin axis on the (P_z, P_y)-plane. σ_{P_x} appears to be the angle between the spin axis and the (P_z, P_y)-plane. If this is correct, please clarify this in the description of step 3.

• page 5, line 55-59: The description of step 5 is misleading. A clear distinction should be made between the ideal exact transformations and the transformations derived through the calibration procedure. The "above transformations" as described in steps 1-4 are the exact transformations (not derived through calibration, thus not affected by calibration errors). If they are inverted then the true field is obtained. In lines 56-59 the Authors refer to the transformations estimated through the calibration procedure. To eliminate the potential confusion I suggest that at each step the corresponding transformation is explicitly stated. E.g. step 2: coord 1 $\mathbf{\Omega}^{-1}$ coord 2; step 3: coord 2 $\mathbf{\Sigma}^{-1}\mathbf{\Phi}^{-1}$ coord 3; step 4: coord 3 $\mathbf{G}^{-1}\mathbf{\Gamma}^{-1} + O_s$ coord 4; step 5: coord 4 $\mathbf{\Omega}'\mathbf{\Phi}'\mathbf{\Sigma}'\mathbf{\Gamma}'\mathbf{G}' - O_s'$ coord 5; direct transform: coord 4 $\mathbf{\Omega}\mathbf{\Phi}\mathbf{\Sigma}\mathbf{\Gamma}\mathbf{G} - O_s$ coord 1; The prime symbol denotes the quantities derived using the calibration procedure. Alternatively, the transformations could be added to Fig. 1.

• page 3, line 55,60-61: While correct, the formulations in lines 55 "... transformations are inverted to estimate the magnetic field ..." taken together with the lines 60-61, "... the forward transform is defined for the conversion ..." can be confusing for the reader. Adding the transforms to the steps as suggested above and reformulating line 55 could help clarifying this.

• page 4, line 82: "(angle between the coord 2 system and the coord 3 system)" formulation is ambiguous. Please reformulate.

• page 4, line 84-86: The descriptions of $\delta\theta_1$, $\delta\theta_2$ and $\delta\Phi_{12}$ are unclear. Perhaps instead of "with a relation to the deviation from $90°$", simply writing "the deviation from $90°$ of the elevation/azimuth" angles would be better.

• page 5, line 115-118: The formulation is difficult to understand. Please reformulate to make clear that the coord 5 system is obtained using the transformation matrices resulted from the calibration procedure.

• page 12, section 4: It might be useful to rewrite the estimated errors (Eqs. 27,30,33) using the expected values given in Table 1.

$|\Delta B_{x'}| \leq 0.1nT + (B_p + B_a) \times 10^{-2}$
$|\Delta B_{y'}| \leq 0.1nT + (10B_p + B_a) \times 10^{-3}$
$|\Delta B_{z'}| \leq 0.21nT + (B_p + B_a) \times 10^{-3}$

or similar.

• page 13,14, Fig 2,3: Many spacecraft measure magnetic fields much higher than 300 nT. Please extend the ambient magnetic field domain (x-axis) to 10 000 nT.

• page 14, lines 303-304: "... when the ambient field is aligned with the spin axis ...". From Eq.(30) Φ_a multiplies B_p, therefore the largest error due to Φ_a is for the ambient magnetic field orthogonal to the spin axis.

3 Minor points

• page 1, line 5 and elsewhere in the manuscript: "... perturbing the calibration procedure ..." – not the procedure, but the calibration parameters are perturbed.

• page 1, line 7-8: "The final error ... are important factors." this sentence is difficult to understand. Please reformulate.

• page 2, line 31: "sensor output", "not ourput"

• page 2, line 32: "sensor-axes" (if plural)

• page 4, line 72: "The", not "There"

• page 4, line 82: remove "to the angles"

• page 13,14, Fig 2,3: The gray lines cannot be distinguished from the black lines. Please use colors or solid/dashed lines.

• page 14, line 307: remove one "how"