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Comment on egusphere-2022-220

Anonymous Referee #3

Referee comment on "Tesseract – a high-stability, low-noise fluxgate sensor designed for constellation applications" by Kenton Greene et al., EGUsphere, https://doi.org/10.5194/egusphere-2022-220-RC3, 2022

"General comments"

The paper “Tesseract - A High-Stability, Low-Noise Fluxgate Sensor Designed for Constellation Applications” by Green et al. is a useful contribution to ÐµÑ□Ñ□ design of the fluxgate magnetometers for space applications, particularly those for multi-point magnetic field measurements. The scientific and technical questions addressed in the paper are within the scope of GI.

The paper proposes further development of some ideas intended to improve the accuracy of fluxgate magnetometers including but not limited to such approaches: a) selection of the sensor components with similar coefficients of linear thermal expansion; b) the use of a three-axial system of magnetic feedback coils for creating near-zero field inside ferromagnetic cores of the sensor; c) using a solid homogeneous base as a support for windings and sensors for minimizing mechanical deformations, that is expected to provide excellent stability of the sensor magnetic axes; d) selection a compact configuration of two cores per axis for further reducing cross-talk between orthogonal components.

The last method - the pairing of identical cores on each axis – is also useful, in my opinion, for reducing noise levels. Besides, such a configuration of the cores makes it possible to measure the three components of the magnetic field at the same point. See, for example, patents “EP0275767A1. Triaxial homo-centered magnetometer” (https://patents.google.com/patent/EP0275767A1/en) and “FR2740556A1. Single symmetry center magnetic core for multi-axial magnetometer” (https://patents.google.com/patent/FR2740556A1/en?oq=FR2740556A1). As far as I know, the idea of the triaxial homo-centered magnetometer was implemented in the variometer VM391 developed for geomagnetic observatories (http://www.ipgp.jussieu.fr/~chulliat/papers/Chulliat_etal_2009b.pdf).

The paper describes the new construction of the sensor in detail with excellent graphical materials. The computer simulation and experimental results mainly concern characteristics of the three axial feedback windings without magnetic cores inside. The temperature and long-term stability of the complete flight-ready magnetometer are going to be characterized in the next stages of work.

The results obtained at the current stage of research are very promising.

However, some details of the exploited procedure for sensor calibration during temperature tests are not completely clear, in my opinion. This would cause some difficulties in reproducing similar experiments by other researchers.

The authors based their research on an analysis of a large number of related studies and this is reflected in the appropriate list of references.

The title and abstract clearly and completely represent the contents of the paper. The overall presentation of the research results is well structured and clear. Abbreviations, symbols, and units are correctly defined and used.

The equations (2), (3), and (4) for estimating sensor orthogonality have to be explained in detail or appropriate reference should be added.

"Specific comments"

In my opinion, more details about the method used for measuring sensitivity and orthogonality of the feedback coils (subsection 3.2) have to be provided.

The references (Brauer et al., 1999; Miles et al., 2017) exploit some other approaches in comparison with that described in the manuscript. Brauer et al. (1999) used so-called “thin shell” calibration - the calibrating signals “were randomly distributed over shells of fixed field magnitudes”. The data processing was also different – the overdetermined system of linear equations was solved for a parameters matrix by singular value decomposition.

Miles et al. (2017) did not estimate orthogonality. In both references, a fluxgate magnetometer as a whole unit was calibrated, whereas the manuscript estimates the temperature characteristics of the feedback coils only, without magnetic cores inside.

page 12, lines 347-349

“To characterize the thermal stability of the Tesseract sensor’s design, we temporarily configured it as an air-core search coil magnetometer to directly access the attributes of the sensor base and feedback windings without any dependence on cores or electronics.”

Were the feedback coils used in the air-core search coil magnetometer to form feedback signals or to serve as sense windings? What was a sense winding in the first case?

In the second case (the feedback winding is used as a sense one) the temperature dependence of the sensitivity or gain of such air-core search coil magnetometer was actually tested. The temperature stability of the fluxgate magnetometer’s scale factor depends on the stability of the coil constant of the feedback winding. Is it assumed that the gain of the air-core search coil magnetometer based on the feedback winding depends on the temperature in a similar way as the coil constant of the feedback winding does?

pages 12-13, lines 350-351:

“The polystyrene box is then placed within the two-meter Merritt coil system and fixed to the table so that Tesseract’s axes are aligned with the coil systems axes as shown in Figure 9a”

The mutual orientation of the axes of the calibrating system and the device under test is not clear in Figure 9a.

How accurately were aligned the magnetometer feedback coil axes with that of the Merritt coil system and what method was used to achieve this?

pages 13-14, lines 370-378.

The way Equations (2), (3), and (4) for estimating orthogonality angles were derived is not clear. Why are these equations different for the XY pair and the XZ, and YZ pairs? How was the total magnitude (A) of the applied field calculated or measured?

"Technical corrections"

Which component of the magnetic field generated by the feedback coil is presented in the color map in Figure 4a? Bx? It would be useful to clarify.

The length of the racetrack sensor is equal to 31.45 mm (Subsection 2.1, p. 5, line 132), but the Racetrack boundaries are equal to +/-14.5 mm in Figures 6, 7, and +/-15 mm in Figure 8.

page 9, Figure 6

The last part of the caption of Figure 6: "...Configuration (b) was optimized for best homogeneity while sensor while (c) was chosen for good homogeneity with very low power consumption."

Should it be "...Configuration (b) was optimized for best homogeneity within the sensor while (c) was chosen for good homogeneity with very low power consumption." or "...Configuration (b) was optimized for best homogeneity while sensor (c) was chosen for good homogeneity with very low power consumption."?