Geosci. Instrum. Method. Data Syst. Discuss.,
https://doi.org/10.5194/gi-2017-53-RC1, 2017

Geoscientific Instrumentation Methods and Data Systems Discussions

Interactive comment on "Investigation of a low-cost magneto-inductive magnetometer for space science applications" *by* Leonardo H. Regoli et al.

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Received and published: 22 December 2017

General Comments:

This paper investigates the suitability of a commercial magneto-inductive sensor for use in geo and space physics applications particularly on small and low-cost platforms such as CubeSats. The tests results presented suggest that the sensor compares well to other types of magnetometers in the literature in terms of magnetic range, frequency range, noise, mass, power, volume and cost. The paper aligns well with the scope of GI and is timely given recent trend towards small and low-cost platforms. The results of the paper are, in general, sound and backed by the data. However, to more fully evaluate

the suitability of the sensor for geophysical applications some additional details and analysis would be appropriate.

In Section 2, the description of how the external magnetic field manifests in the output of the oscillator is sparse and would benefit from being shown explicitly by, for example, oscilloscope captures under different applied fields. The authors note that, in this manuscript, their optimization of the sensor was software only. Could the authors suggest avenues to further improve the sensor performance via hardware modification – for example by increasing the oscillator frequency or the base clock against which the output of the sensor is compared?

In Section 3.3, the description of "Linearity" matches what I would describe as the Gain Error/Sensitivity of the sensor (i.e., nT_measured / nT_applied). This is a useful metric to calibrate the sensor but does capture the deviation of the instruments performance from linear. To do this, the authors should fit and subtract a linear trend to the results of each axis and plot the residual to show any non-linear trend. Quantitatively, the authors should also present the RMS deviation of the measured data from the fit linear trend.

Could the authors estimate the offset/zeros of the sensor using a simple technique such as 180 degree sensor rotations? The offsets shown in Figure 9 suggest that the zeros could be large, on the order of 1000 nT, but they would need to be separated from the residual external magnetic field in the test chamber.

Specific Comments:

Page 2, Lines 1-4. Reference specific current and planned missions

Page 2, Table 1. Add approximate amplitude range for each wave category to motivate the required magnetometer performance.

Page 5, Line 1. Add a reference describing the magneto-inductive principle.

Page 5, Figure 1. Note what the red boxes represent in the figure caption and label the X, Y, and Z axes.

Page 6, Figure 2. Expand the figure to show explicitly how the output of the oscillator is measured and how that corresponds to the H_E

Page 6, Figure 3. Provide a more detailed description of what is being presented and define all terms used in the figure.

Page 9, Figure 6. The power spectrum appears essentially flat with frequency rather than exhibiting the 1/f dependence referenced in the text. Recreating the plot from a longer period of data, applying some averaging, and using log-log axes would make it easier to understand shape of the noise density. Also, if the sensor is sampling at 40 Hz why does the frequency range stop at 10 Hz rather than the 20 Hz Nyquist?

Page 10, Section 3.2. It would be interesting to see a raw and low-pass filtered time series of the 100 hour data set to see if there are any significant trends.

Page 11, Figure 8. The distribution shows some large discrepancies in adjacent bins which is somewhat surprising given the large number of data points (∼10ˆ5). Could the authors comment on the potential cause? Is this statistical or suggestive of a digitization artifact similar to missing codes.

Page 12, Section 3.4. It would be interesting to see the signal amplitude as well as the calculated SNR.

Page 12/13, Figures 10/11. The large error bars in the SNR calculation might be reduced by the application of an appropriate window function to better separate the test signal from the background. e.g., Heinzel et al., 2002.

Page 12, Figure 10. Is this the correct caption for the figure?

Page 16, Lines 12-14. The difference in sensitivity at Pc1 frequencies between the presented instrument and a typical search coil magnetometer is not insignificant – e.g., Figure 5 in Hospodarsky, (2016)

Technical Corrections:

Page 5, Line 11. Define RL

Page 5, Line 11, Define A/D

Page 5, Line 15. Define ‘H’

Page 6, Line 3. Here the sampling rate is ‘approximately 40 Hz’ elsewhere it is just referred to as ’40 Hz’. Please clarify.

Page 8, Table 2. Add units to the ‘STD’ column.

Page 8, Figure 5. Add the Configuration # from Table 2 to the legend.

Page 15, Table 3. It seems unlikely that the MMS DFG consumes 450 W.

Page 15, Table 3. The miniature fluxgate from Miles et al. 2016 produces 100 Hz data.

References:

Heinzel, G., Rüdiger, A., & Schilling, R. (2002). Spectrum and spectral density estimation by the Discrete Fourier transform (DFT), including a comprehensive list of window functions and some new at-top windows.

Hospodarsky, G. B. (2016). SpacedâĂŘbased search coil magnetometers. Journal of Geophysical Research: Space Physics, 121(12).

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