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Geoscientific Instrumentation Methods and Data Systems
Discussions

Interactive comment on "A radiation hardened digital fluxgate magnetometer for space applications" *by* D. M. Miles et al.

Anonymous Referee #2

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General Comments:

The authors present a novel concept of a fluxgate magnetometer (i.e. direct digitisation combined with a new feedback system based on two cascaded PWM stages) for space application. However, the new concept is not compared with already existing similar fluxgate magnetometer designs and a potential weakness (non-linearity) as well as the dependence of the transfer function on the new feedback design are not discussed.

Two topics which are not so relevant for the application are discussed with too much detail (text and figures). The output voltage at large applied magnetic fields is not so important in a loop configuration (Fig. 5) and the scientific need for a very large bandwidth of 100Hz and more with the (limited) sensitivity of a fluxgate sensor is not made clear (Fig. 7).

Relevant papers for comparison are:

Auster, H. U. et al. The THEMIS Fluxgate Magnetometer. Space Sci Rev 141, 235–264 (2008).

Forslund, Å. et al. Miniaturized digital fluxgate magnetometer for small spacecraft applications. Measurement Science and Technology 19, 015202 (2008).

Magnes, W. et al. Highly integrated front-end electronics for spaceborne fluxgate sensors. Measurement Science and Technology 19, 115801 (2008).

O'Brien, H. et al. A radiation tolerant digital fluxgate magnetometer. Measurement Science and Technology 18, 3645–3650 (2007).

Pedersen, E. B. et al. Digital fluxgate magnetometer for the Astrid-2 satellite. Measurement Science and Technology 10, N124–N129 (1999).

Specific Comments:

Abstract, 16-19: The novelties of the new design should be compared with already published fluxgate magnetometers instead of with a precursor model.

Ch. 1, p. 3, 20-21: The science objectives only require a 10 Hz bandwidth. There seems to be no need for an instrument with a bandwidth of 450 Hz (and more)?

Ch. 2, p. 4, 20-22: Reference to an earlier publication of a two ring-core sensor design should be included.

Ch. 2, p. 5, 5-8: This paragraph somehow briefly describes the core of the instrument design. The measured magnetic field is obviously the sum of the two PWM stages and the remnant field digitised by the ADC. How is this realised in the FPGA? What elements are limiting the linearity and determining the overall transfer function? The inclusion of an additional block diagram of the required logic in the FPGA should be considered.

Ch. 2.1, p. 6, 22 and p. 7, 14: In principle, only odd harmonics should couple from the drive to the sense windings. Coupling of even harmonics would result in large offsets.

Ch. 2.1, p. 7, 18: Is an 'out-of-range polarity inversion' in the analog domain a realistic scenario?

Ch. 2.2, p. 8, 6-7: There is a low-pass filter in the feedback of the OBrien et al. design!

Ch. 2.2, p. 9, 15-16: It is not understood why 2 bits are lost due to the drive residuals?

Ch. 2.2, p. 10, 6: The design should in principle lead to a (10 - 2) +10 = 18 bit design. But it obviously is not having the linearity performance of an 18 bit DAC. What happens at the transition from the low range to the high range PWM DAC at multiples of about 256nT? Is there a significant differential non-linearity error at the 0 nT transition?

Ch. 3: As pointed out above, the scientific relevance should be made clear.

Ch. 4.1, p. 12, 8-10: Noise, offset and linearity (with applied sine signal) are ideally tested in a magnetic shielding can. It is not understood why the described facility is too noisy.

Ch. 4.2, p. 12, 16-17: One shouldn't speak of an error measurement. The remnant field is a consequence of the overall design. Furthermore, are the 57.6 ksps just decimated or digitally filtered and then decimated. A simple decimation would lead to a serious aliasing problem.

Ch. 4.2, Fig. 8 and 9: This is not a representative discussion of the magnetic resolution. When the time series is long enough, even much smaller periodic signals can be resolved with an FFT.

Ch. 4.3, Fig. 10: The 10, 7 and 5 pT/rt(Hz) lines are misleading since the values are just valid at 1 Hz.

Ch. 4.4: What exactly is meant with RMS error? Is it the overall non-linearity of the instrument? Is it dominated by either integral or differential non-linearity? Residual plots should demonstrated what is meant here exactly. Is the presented number compliant with the performance required for the scientific missions?

Ch. 5: Offset stability tests with sensor and electronics temperature should be important tasks in the future.

Technical corrections:

Ch. 4.1, p. 11, 22-23: ... National Resources Canada (NRC) ...

Ch. 4.1, p. 12, 8: ... than the NRC facility ...

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