Noise Characterization of Highly Sensitive SQUID Magnetometer Systems in Unshielded Environments

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Per our invitation, this Highlight was submitted by the authors of the highlighted paper which appeared in SuST 26 (2013) 035017 [1]. We believe the paper deserves special interest (Editors comment).

April 11, 2013 (HP57). Characterising the noise performance of a highly sensitive SQUID magnetometer system is challenging, as the intrinsic noise is superimposed by many other (mostly external) noise source. While it is possible to measure the noise in a magnetically shielded environment this is sometimes not the method of choice as

- it may not reflect the effective noise of the sensor in the presence of signal and/or the Earth's magnetic field and
- it is difficult and expensive to construct an environment whose level of magnetic shielding is commensurate with the exceptionally low noise characteristics of SQUID based sensors.

Even in rural environment the Earth's magnetic field noise (eg. Sferics noise, cavity resonances and so forth) is much larger than the intrinsic noise of any sensitive SQUID (cf. Fig1).

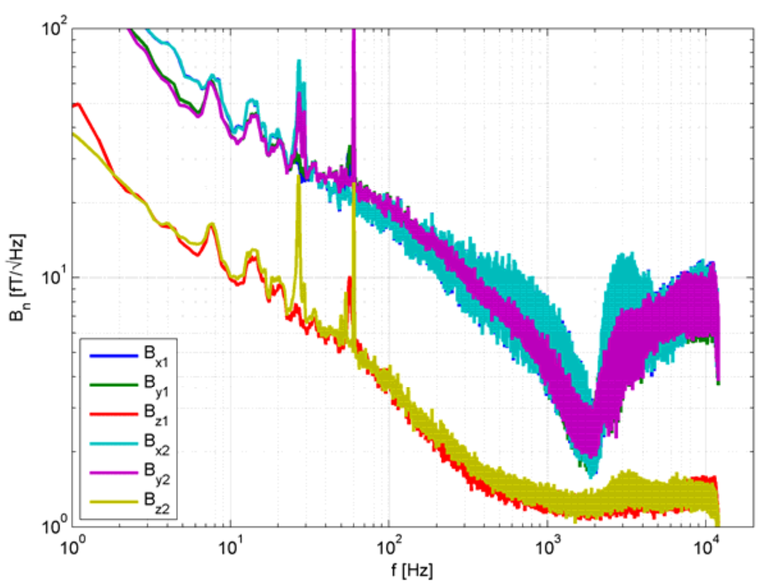

Figure 1: Unshielded noise of 2 high sensitive SQUID triples, acquired simultaneously NW of Delta, Utah, USA. Note the good correlation between the channels in parallel, obviously we mostly see external signal.

Therefore, we have developed a method in order to investigate the intrinsic noise by calculating the correlated signals (time domain) or spectra (coherence based in the frequency domain) of 2 identical systems.

If the signal from a reference system is subtracted from the original signal one can assume that the remainder is a representation of the intrinsic noise. The paper describes how the weights for the reference channels are calculated and how the intrinsic noise can be derived from the time series.

The coherence based approach calculates an estimate for the intrinsic noise power by

$$S_i = \sqrt{S_{aa} S_{bb}} - |S_{ab}| ,$$

where S_{aa} and S_{bb} are the auto-power-spectra and S_{ab} is the averaged cross-spectral power between the two sensors.

Both methods result in very similar noise spectra, Fig. 2 shows the results from the coherence based approach:

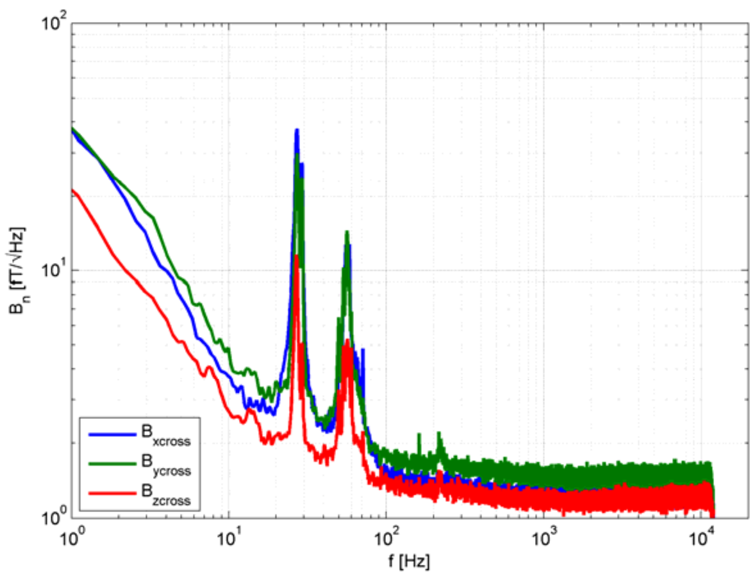

Figure 2: Estimated intrinsic noise by cross-correlation in the frequency domain.

The intrinsic white noise of the SQUID sensors used amounts to 0.6 fT/√Hz, while we achieve 1.5 fT/√Hz in magnetic shielding (measured inside the BMSR-1 at the PTB Berlin) and down to 1.2 fT/√Hz by estimation via cross-correlation as well as by referencing in the time domain.

It is yet to be understood what causes the unexpected high excess noise at low frequencies. We presume, this might be caused my minimal tilt changes in the Earth's magnetic field. Already 10^{-9} rad relative angular motion between the 2 systems buried several meters apart might be enough to cause this kind of spectra.

[1] http://iopscience.iop.org/0953-2048/26/3/035017; http://dx.doi.org/10.1088/0953-2048/26/3/035017