Unambiguous measurement of DC field in a cold atom magnetometer with sensitivity below 1 pT/rHz

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Optical magnetometers sense magnetic field magnitude by optical measurement of the Larmor frequency during free induction decay (FID). Extracting the Larmor frequency by Hilbert transform is common in NMR applications [1], but relatively new to coherent atomic magnetometry [2]. We describe a measurement and reconstruction method which uses a dispersive Faraday optical probe to perform weak continuous measurement of a cold atomic vapour. Coherent phase reconstruction using the Hilbert transform allows us to determine the DC magnetic field unambiguously, with no risk of fringe-hopping, as well as measure the low-frequency modulation of the field. This measurement of modulation allows us to neutralise line-synchronous magnetic interference and significantly improve sensitivity in DC sensing. Using an unshielded ultracold cloud of 1.8×10^6 ^{87}Rb atoms in a volume of $(100\,\mu\text{m})^3$, we infer a sensitivity of 160 fT/rHz, approaching the atom shot-noise limit sensitivity of 35 fT/rHz.

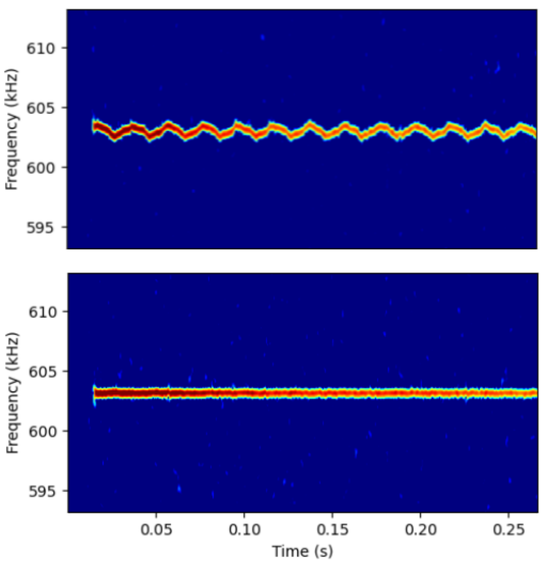

Figure 1: Spectrogram of optical Faraday measurement of ^{87}Rb cloud undergoing free induction decay in unshielded environment (top), and in the same environment with feed-forward interference cancellation (bottom).

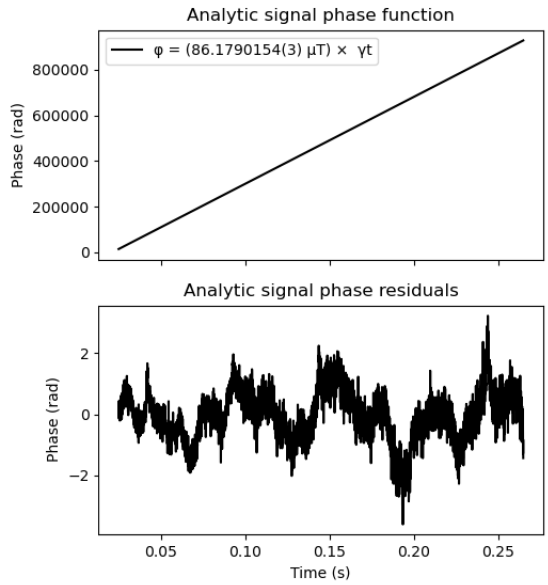

Figure 2: Phase extracted from analytic signal generated by Hilbert transform (top) and linear fit residuals (bottom). With feed-forward interference cancellation, phase residuals are kept to less than 2π radians.

[1] R. Hong et al., *Systematic and Statistical Uncertainties of the Hilbert-Transform Based High-precision FID Frequency Extraction Method*, Journal of Magnetic Resonance **329(2)** (2021)

[2] N. Wilson et al., *Wide-bandwidth atomic magnetometry via instantaneous-phase retrieval*, Phys. Rev. Research **2** (2020)