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Phase-dependent CMRR enhancement method for optically pumped magnetic gradiometers

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Optically pumped magnetometers (OPMs) offer significant advantages for biomagnetic measurements such as magnetoencephalography (MEG), owing to their high sensitivity, room-temperature operation, and potential for wearable configurations. In these applications, gradiometric measurement serves as an effective method to suppress common-mode environmental noise. However, it is difficult to make the two channels in a gradiometer perform identically, and precisely adjusting system parameters remains a challenge, which limits the common-mode rejection ratio (CMRR).

To overcome this limitation, we propose a method to improve the CMRR of OPM gradiometers, based on analyzing and controlling the phase-frequency response differences between the two channels. The phase differences between the two channels would degrade the CMRR, as they reduce the consistency of the responses. We model the relationship between the phase-frequency response of the gradiometer and the relaxation rate of the cell and the remanence along the pump axis. This model reveals a phase intersection point at which phase responses between two channels are aligned, leading to the enhanced CMRR. By precisely adjusting the magnetic field along the pump axis, this intersection point can be controlled, thereby enabling optimization of the frequency band in which maximum CMRR is achieved. As a result, the average CMRR within 1-50 Hz frequency band is improved by more than one order of magnitude, exceeding 2000. This method enables efficient performance enhancement without additional components and offers flexibility for various application scenarios.

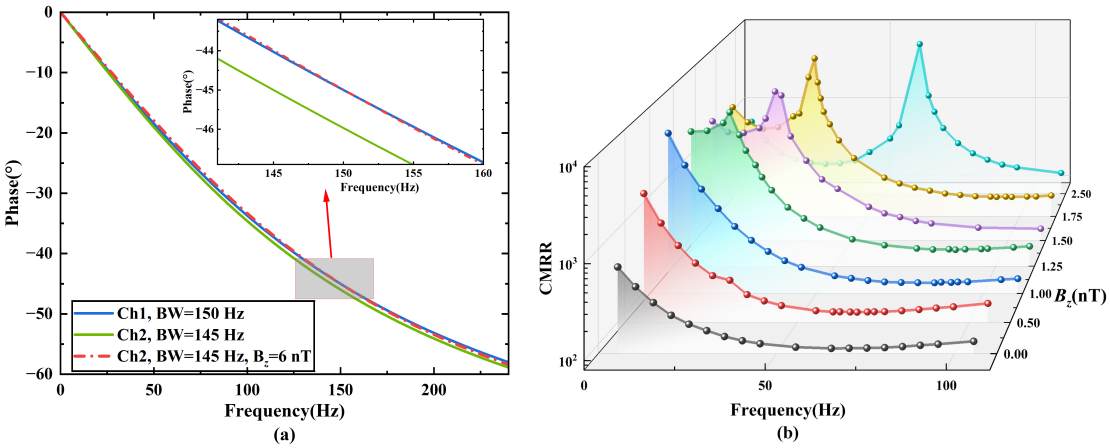

Figure 1: (a) Simulated phase-frequency response of OPMs with different bandwidths. (b) Variation of CMRR with signal frequency under different Bz.

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