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Frequency Shift Caused by Nonuniform Field and Boundary Relaxation in Magnetic Resonance and Comagnetometers

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In magnetic resonance experiments, it is widely recognized that a nonuniform magnetic field can lead to an increase in the resonance line width, as well as a reduction in sensitivity and spectral resolution. However, a nonuniform magnetic field can also cause shifts in resonance frequency, which has received far less attention. In this work, we investigate the frequency shift caused by boundary relaxation and nonuniform magnetic field with arbitrary spatial distribution. We find that this frequency shift is spin-species dependent, implying a systematic error in NMR gyroscope and comagnetometers. The first order correction to this systematic error is proportional to the difference of boundary relaxation rate, and dominates for small cells. In contrast, the third and higher order corrections arise from the difference of gyromagnetic ratios of spin species, and dominates for large cells. This insight helps understanding the unexplained isotope shifts in recent NMR gyroscope and new physics searching experiments that utilize comagnetometers. Finally, we propose a tool for wall interaction research based on the frequency shift's dependency on boundary relaxation.

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