REDUCTION OF TEMPORAL MAGNETIC FIELD VARIATIONS IN RESISTIVE MAGNETS USING DIGITAL FEEDBACK CONTROL

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The high field achieved in resistive and hybrid magnets holds great potential for solid state NMR applied to materials research [1]. However, temporal variations in the magnetic field rule out virtually all multiple pulse experiments. Presently, a research effort is underway to reduce these variations using feedback control. The most recent developments are based on the design and testing of filters implemented on a digital signal processor (DSP) to improve the gain and bandwidth of the feedback system. The work is being conducted on the enhanced homogeneity Keck magnet.

A useful metric for gauging temporal magnetic field variations is the standard deviation of the nmr signal phase at the center of a spin echo generated by a 90°-τ-180°- τ -acquire pulse sequence. Here, the delay between the first pulse and the echo peak, the "time to echo," is ~2 τ . For a time to echo value of 1 ms, the phase deviation is about 2° for a persistent superconducting magnet, and about 50° for the Keck resistive magnet. For the Keck magnet, Fig. 1 shows the standard deviation, σ, of the echo phase as a function of the time to echo. The open green circles show that, without any form of compensation, σ is substantially larger than the 2° obtained with a superconducting magnet. The red squares show the largest reductions achieved using proportional feedback control. Greater reductions, specifically for larger values of τ, require the ability to shape the magnitude and phase response of the compensator. In particular, it is necessary to increase the low frequency gain of the compensator to improve the reduction of magnetic field variations, and reduce the high frequency gain to prevent oscillations. This compensator, known as a phase lag controller, was recently implemented using a digital feedback control system, and the results are shown by blue triangles in Fig. 1. At a time to echo of 5 ms the phase-lag system has a factor 4 improvement in comparison the proportional control system. Further improvements in the control design are expected to yield greater reductions in σ.

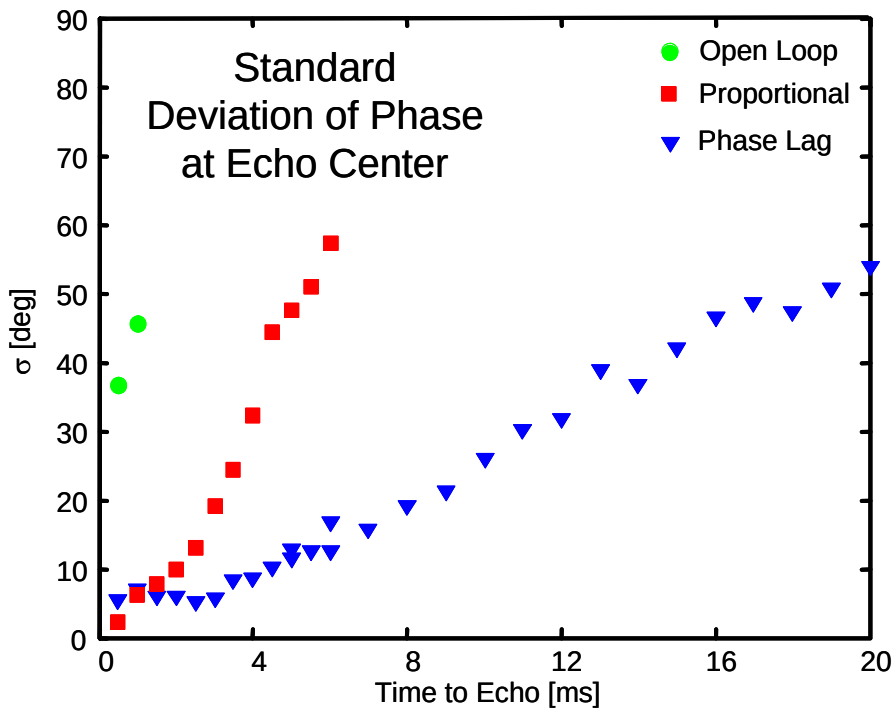

Figure 1. Standard deviation of spin echo phase in a 90°-τ-180°-acquire Hahn spin echo sequence as a function of the time to echo.

[1] Gan, Z.; *et al*., J. Am. Chem. Soc., **124** (20), 5634-5935 (2002).