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Cluster Techniques to Study Spin Decoherence in a Spin Bath[1]

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Noisy nuclear spin environments in many solid state materials pose a serious threat to the feasibility of solid-state spin quantum computation where localized electron spins, as qubits, may interact with millions of lattice nuclei [1, 2, 3, 4]. Such nuclear induced decoherence may be partially reduced through the application of a strong magnetic field that suppresses electro-nuclear flip-flops (due to a large mismatch of their gyromagnetic ratios). However, even in the limit where electro-nuclear flip-flops are completely suppressed, dephasing decoherence, known as spectral diffusion, occurs as a result of fluctuations of the nuclear field that is caused by dipolar (or other) interactions among the nuclear bath spins. While a direct approach to this problem is impossible due to the intractable Hilbert space of many interacting spins, we have devised a cluster method to formally solve this problem. Direct application of perturbation theories are futile due to the large size of the bath. Perturbation methods become effective, however, in the cluster expansion framework. These techniques will be discussed and qubit decoherence calculation results will be shown, including effects of dynamical decoupling pulse sequences [5, 6] that prolong qubit coherence. [1] W. M. Witzel, Rogerio de Sousa, S. Das Sarma, Phys. Rev. B 72, 161306(R) (2005). [2] W. M. Witzel, S. Das Sarma, Phys. Rev. B 74, 035322 (2006). [3] W. M. Witzel, S. Das Sarma, Phys. Rev. Lett. 98, 077601 (2007). [4] W. M. Witzel, Xuedong Hu, S. Das Sarma, Phys. Rev. B 76, 035212 (2007). [5] W. M. Witzel, S. Das Sarma, arXiv:0707.1037. [6] B. Lee, W. M. Witzel, S. Das Sarma, arXiv:0710.1416.

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