Clustering into three groups on a quantum processor of five spins S = 1, controlled by pulses of resonant RF fields

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Currently, quantum artificial neural networks are attracting more and more interest, due to their advantages over classical ones. In our previous works, we proposed to replace qubits to qutrits represented by spins S = 1, showed the advantages of such a replacement, and obtained a time-dependent effective Hamiltonian for clustering by means of quantum annealing [1, 2]. In this paper, we consider the control of a system of five spins using selective rectangular radio frequency (RF) pulses to solve the problem of clustering six points into three groups. The Hamiltonian of the pulse action in a coordinate system rotating with the pulse frequency $W_{\rm rf}$ takes the form:

$$H = \sum_{i=1}^{n=5}(W_i - W_{\rm rf})S_i^z + \sum_{i=1}^{n=5}Q_1\left(3(S_i^z)^2 - 2I\right) + H_y + H_{\rm dd} \ ,$$

where W_i is the Larmor frequency of spin i, Q_i is quadrupole interaction (or zero-field splitting), S_i^α is spin projection operator on the corresponding axis $\alpha \in (x, y, z)$, I is identity matrix, $H_y = h_y\sum_{i=1}^{5}S_i^y$ is Hamiltonian of the interaction with the transverse magnetic field of the RF pulse, h_y is the amplitude of the RF pulse, which must be small to reduce crosstalk, $H_{\rm dd}$ is dipole-dipole interaction Hamiltonian (DDI). The selectivity of the RF pulse is tuned using its frequency: $W_{\rm rf} = -3Q_i + W_i$ for the transition between levels 1 and 2 of the qutrit i, and $W_{\rm rf} = 3Q_i + W_i$ for the transition between levels 2 and 3. For selective rotation by an angle θ, we take the pulse duration $t_i = \theta/\sqrt{2}h_y$ and pulse amplitude $h_y = (W_i\theta)/(2\sqrt{2}\pi n)$ (n is an integer) such that the phase shifts of the energy levels are a multiple of 2π. We have found the parameters of RF pulses of all selective rotation required for the implementation of the above algorithm in the processor on five qutrits.

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1. Zobov V.E., Pichkovskiy I.S.: Quantum Inf. Process **21**, 144 (2022)
2. Zobov V.E., Pichkovskiy I.S.: Proc. SPIE **12157**, 121571Z (2022)