Emulating Majorana fermions and their braiding by Ising spin chains

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We analyse the control of Majorana zero-energy states by mapping the fermionic system to a chain of Ising spins. Although the topological protection is lost for the Ising chain, the properties of this system provide insight into the nature of the quantum states. By controlling the local magnetic field the Ising chain can be separated into topological and non-topological parts. Specifically we propose – for a strictly one-dimensional geometry – a (topologically non-protected) scheme, which allows performing the braiding operation. It also allows for more general rotations. The proposed setup relies on an extra spin-1/2 coupler included as part of the chain, such that it controls one of the Ising links. Depending on the quantum state of the coupler this link can be either ferromagnetic or antiferromagnetic. The coupler can be manipulated once the topological parts of the chain hosting the Majorana fermions are moved far away. Our scheme overcomes limitations which are a consequence of the 1D character of the Jordan-Wigner transformation. We also propose an experimental implementation of our scheme using a chain of ux qubits with a design providing the needed control fields.