Rapid Single-Shot Measurement of a Singlet-Triplet Qubit

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Accessibility
In one of the experiments described in the accompanying Letter, “Rapid Single-Shot Measurement of a Singlet-Triplet Qubit”, two electrons in a double quantum dot are initialized in the singlet state, then brought to the anticrossing of the lower branch of the hybridized singlet, $S$, and the $m=+1$ triplet, $T_+ = \{ || \}$, and the $S-T_+$ resonance, the difference in transverse components of the Overhauser fields in the left (L) and right (R) dots, $\Delta B_{x(y)} = |B_{x(y)}^L - B_{x(y)}^R|/2$ mix singlet and triplet state, while the average longitudinal Overhauser field, $B_z = |B_z^L + B_z^R|/2$, acts as a random energy detuning. An external magnetic field, $B$, defines the quantization axis $z$. The analysis assumes classical Overhauser fields that are static on the time scale of electron spin evolution but fluctuate randomly on longer time scales, where ensemble statistics are measured.

The nuclear Overhauser field $z$-component, $B_z$, and the gradient fields, $\Delta B_x$ and $\Delta B_y$, are not known and constant, but distributed $[1, 2]$ according to the distribution function $\rho(B) = (2\pi B_{\text{nuc}})^{-3/2}e^{-(B/(B_{\text{nuc}}))^2}/2$, with $B = (\Delta B_x, \Delta B_y, B_z)$. The evolution of the nuclear fields is slower than the evolution of the electron spin, hence the return probability, $P_T$, of $T$, because of imperfect preparation or miscounting of singlets as triplets and a smaller than one visibility, $V$, yields the equation in the paper:

$$P_T = P_T^0 + V \int d^3B \rho(B) \frac{(\Delta B_x^2 + \Delta B_y^2)}{2(\hbar/|g^*\mu_B|)^2} \sin^2(\omega \tau),$$

where $\omega = \frac{1}{2\hbar}\sqrt{\delta \omega^2 + 2 \cos^2 \theta (g^*\mu_B)^2 (\Delta B_x^2 + \Delta B_y^2)} = \frac{|g^*\mu_B|}{2\hbar} \sqrt{\Delta B_x^2 + \Delta B_y^2 + 2 \cos^2 \theta (\Delta B_x^2 + \Delta B_y^2)}.$

This supplementary note presents a derivation of an equation that appears in the main text of the Letter “Rapid Single-Shot Measurement of a Singlet-Triplet Qubit” for the ensemble-averaged triplet $T_+$ return probability, $P_T$. The equation is used to fit experimental data in Fig. 4(b) of that Letter. The analysis assumes classical Overhauser fields that are static on the time scale of electron spin evolution but fluctuate randomly on longer time scales, where ensemble statistics are measured.

$$H = g^*\mu_B \left( -\frac{\hbar}{2} \sin(\omega \tau) \right) \frac{\cos \theta B_z}{\sqrt{2}},$$

with the precession frequency, $\omega$:

$$\omega = \frac{1}{\hbar} \sqrt{\delta \omega^2 + 2 \cos^2 \theta (g^*\mu_B)^2 (\Delta B_x^2 + \Delta B_y^2)}.$$
which describes the measured triplet probability, averaged over many singleshot measurements.