About Excitation of a Quadrupole Spin Echo

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For the first time the excitation of a quadrupole spin echo by a sequence of radio frequency pulses with the filling frequencies ω₀ and ω₀ ± Δω₀ is theoretically and experimentally considered, where ω₀ is the resonance frequency of the raised transition and Δω₀ the offset within the half-width of the NQR line. It is shown that in this case the amplitude of the observable signals does not depend on the offset size, and the echoes appear at times which depend on the intervals between pulses, on the ratio Δω₀/ΔQ, and on the offset sign.

The experimental observation [1] and the theory [2] of a quadrupole spin echo assume a periodic influence of radiofrequency (r. f.) pulses on a sample containing quadrupole nuclei, where the filling frequency is equal to the resonance frequency ω₀ of the raised transition and where the echo registration occurs at this frequency.

In [3] a nuclear spin-system was experimentally studied under the influence of r. f. pulses with the filling frequency ω₀ ± Δω₀, where Δω₀ is the offset within the limits of the NQR line half-width, and the registration of the response is performed for this frequency too.

In the present work the r. f. pulse sequences with filling frequencies equal to ω₀ and ω₀ ± Δω₀ are considered. The registration of the echo signals is conducted on the resonance frequency.

Let us consider two (from many possible) variants of three-pulse excitation of the stimulated echo.

In the first variant the first radio frequency pulse is applied with the filling frequency ω₀ and at the time τ₁ and τ₂ the second and third radio frequency pulses follow with the filling frequency ω₀ ± Δω₀.

In the second variant the first radio frequency pulse is applied with the filling frequency ω₀, at the time τ₁ the second pulse follows with the filling ω₀ ± Δω₀, and at the time τ₂ the third radio frequency pulse follows with the filling frequency ω₀ ± Δω₀. The size of Δω₀ is always the same. In both variants the echo signal registration is carried out on the resonance frequency ω₀.

In case of the first variant the echo signals are observed with the amplitudes

\[
E^{(1)}_{m,m-1} = 2 (I_2')_{m,m-1} c_1 (x_i) \omega_{m,m-1} \cdot \sin[\omega_{m,m-1} (t - t_1)],
\]

where \( t_1 = (2 + \Delta\omega_{m,m-1}/\omega_{m,m-1}) \tau_1; \)

\[
E^{(2)}_{m,m-1} = 2 (I_2')_{m,m-1} c_2 (x_i) \omega_{m,m-1} \cdot \sin[\omega_{m,m-1} (t - t_2)],
\]

where \( t_2 = (2 + \Delta\omega_{m,m-1}/\omega_{m,m-1}) \tau_1 + (1 + \Delta\omega_{m,m-1}/\omega_{m,m-1}) \tau_2; \)

\[
E^{(3)}_{m,m-1} = 2 (I_2')_{m,m-1} c_3 (x_i) \omega_{m,m-1} \cdot \sin[\omega_{m,m-1} (t - t_3)],
\]

where \( t_3 = \Delta\omega_{m,m-1}/\omega_{m,m-1} \tau_1 + 2 (1 + \Delta\omega_{m,m-1}/\omega_{m,m-1}) \tau_2; \)

\[
E^{(4)}_{m,m-1} = 2 (I_2')_{m,m-1} c_4 (x_i) \omega_{m,m-1} \cdot \sin[\omega_{m,m-1} (t - t_4)],
\]

where \( t_4 = \Delta\omega_{m,m-1}/\omega_{m,m-1} \tau_1 + (1 + \Delta\omega_{m,m-1}/\omega_{m,m-1}) \tau_2. \)
where \( t_4 = (1 + \frac{\Delta \omega_{m,m-1}}{\omega_{m,m-1}}) \tau_1 + 2 (1 + \frac{\Delta \omega_{m,m-1}}{\omega_{m,m-1}}) \tau_2; \)

\[
E_{m,m-1}^{(5)} = 2(t_5') \omega_{m,m-1} \sin[\omega_{m,m-1}(t - t_5)],
\]

where \( t_5 = (2 + \frac{\Delta \omega_{m,m-1}}{\omega_{m,m-1}}) \tau_1 + 2 (1 + \frac{\Delta \omega_{m,m-1}}{\omega_{m,m-1}}) \tau_2. \)

In case of the second variant the echo signals are observed with the amplitudes

\[
E_{m,m-1}^{(1)} = 2(t_1') \omega_{m,m-1} \sin[\omega_{m,m-1}(t - t_1)],
\]

where \( t_1 = (2 - \frac{\Delta \omega_{m,m-1}}{\omega_{m,m-1}}) \tau_1 + 2 (1 - \frac{\Delta \omega_{m,m-1}}{\omega_{m,m-1}}) \tau_2; \)

\[
E_{m,m-1}^{(2)} = 2(t_2') \omega_{m,m-1} \sin[\omega_{m,m-1}(t - t_2)],
\]

where \( t_2 = (2 - \frac{\Delta \omega_{m,m-1}}{\omega_{m,m-1}}) \tau_1 + (1 - \frac{\Delta \omega_{m,m-1}}{\omega_{m,m-1}}) \tau_2; \)

\[
E_{m,m-1}^{(3)} = 2(t_3') \omega_{m,m-1} \sin[\omega_{m,m-1}(t - t_3)],
\]

where \( t_3 = -\frac{\Delta \omega_{m,m-1}}{\omega_{m,m-1}} + 2 \tau_2; \)

\[
E_{m,m-1}^{(4)} = 2(t_4') \omega_{m,m-1} \sin[\omega_{m,m-1}(t - t_4)],
\]

where \( t_4 = (1 - \frac{\Delta \omega_{m,m-1}}{\omega_{m,m-1}}) \tau_1 + 2 \tau_2; \)

\[
E_{m,m-1}^{(5)} = 2(t_5') \omega_{m,m-1} \sin[\omega_{m,m-1}(t - t_5)],
\]