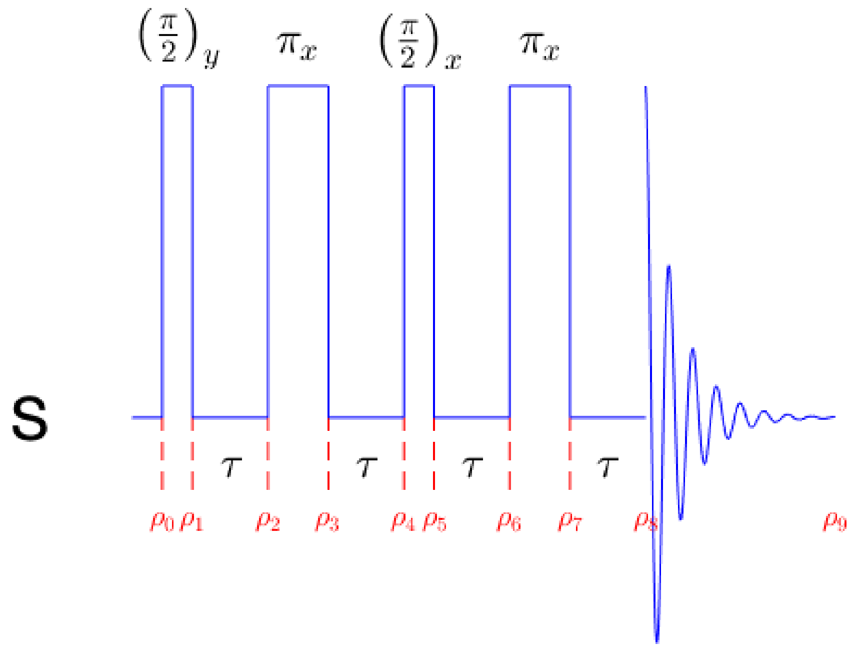
August 2022 NMR Topic of the Month: The Perfect Echo Pulse Sequence



Why is this called a perfect echo?

In a Hahn echo J-coupled magnetization is only fully refocused and in-phase when $\tau = 1/|2J|$. In other words, if there is more than a single J-coupling involved the signal will have mixed-phase peaks. The perfect echo requires that $\tau \ll 1/|J|$ which may be met for all the J-couplings simultaneously to produce a fully refocused and completely in-phase signal.

Where does one find a perfect echo?

The perfect echo was first described in 1989, but was only sparingly used until 2010. Often the mixed-phase of the Hahn echo is not a severe limitation and/or the additional signal lost to relaxation during the perfect echo is even less desirable.

How does the perfect echo work?

The π/2-pulse in the center of the pulse sequence (at ρ_4) changes the sign of the anti-phase terms. Then, during the following Hahn echo, those anti-phase terms evolve in the opposite direction. You can think of the first Hahn echo winding up the anti-phase terms and the second Hahn echo unwinding those same terms. Specifically, where $c_S = \frac{1}{4}\left(\gamma_S B_0 / k_B T\right)$:

$$\rho_0 = c_S S_{1z} + c_S S_{2z} \rightarrow \rho_1 = c_S S_{1x} + c_S S_{2x} \rightarrow$$

$$\rho_4 = c_S S_{1x} cos(2\pi J\tau) + c_S 2S_{1y} S_{2z} sin(2\pi J\tau) + c_S S_{2x} cos(2\pi J\tau) + c_S 2S_{1z} S_{2y} sin(2\pi J\tau) \rightarrow$$

$$\rho_5 = c_S S_{1x} cos(2\pi J\tau) - c_S 2S_{1z} S_{2y} sin(2\pi J\tau) + c_S S_{2x} cos(2\pi J\tau) - c_S 2S_{1y} S_{2z} sin(2\pi J\tau) \rightarrow \rho_8 = c_S S_{1x} + c_S S_{2x} = \rho_1$$

References

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