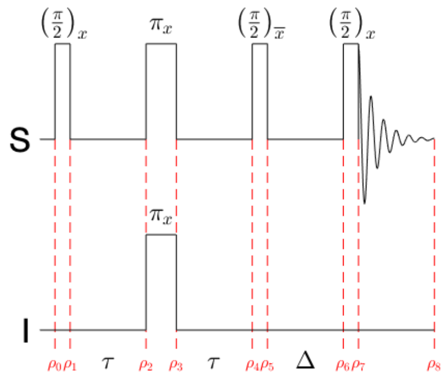
November 2022 NMR Topic of the Month: The BIRD is the word.



For what does the acronym BIRD stand?

BIRD = BIlinear Rotation Decoupling.

What is the role of the BIRD sequence?

The BIRD sequence is a filter, it removes uncoupled magnetization during the Δ period through T_1 relaxation.

How does the BIRD work?

Product-operators can help explain, but the solution at ρ_7 does a poor job. Instead, a better explanation is found at ρ_5. As usual, $c_X = \frac{1}{4}\left(\gamma_X B_0 / k_B T\right)$:

$$\rho_0 = c_I I_z + c_S S_z \rightarrow \rho_1 = c_I I_z - c_S S_y \rightarrow$$

$$\rho_2 = c_I I_z - c_S S_y cos\left(\omega_S \tau\right) cos(\pi J \tau) + c_S S_x sin\left(\omega_S \tau\right) cos(\pi J \tau) + c_S 2 I_z S_x cos\left(\omega_S \tau\right) sin(\pi J \tau) + c_S 2 I_z S_y sin\left(\omega_S \tau\right) sin(\pi J \tau) \rightarrow$$

$$\rho_3 = -\ c_I I_z + c_S S_y cos\left(\omega_S \tau\right) cos(\pi J \tau) + c_S S_x sin\left(\omega_S \tau\right) cos(\pi J \tau) - c_S 2 I_z S_x cos\left(\omega_S \tau\right) sin(\pi J \tau) + c_S 2 I_z S_y sin\left(\omega_S \tau\right) sin(\pi J \tau) \rightarrow$$

$$\rho_4 = -\ c_I I_z + c_S S_y cos\left(\omega_S \tau\right) cos(\pi J \tau) + c_S S_x sin\left(\omega_S \tau\right) cos(\pi J \tau) - c_S 2 I_z S_x cos\left(\omega_S \tau\right) sin(\pi J \tau) + c_S 2 I_z S_y sin\left(\omega_S \tau\right) sin(\pi J \tau) \rightarrow$$

$$\rho_5 = -\ c_I I_z - c_S S_z cos(2\pi J \tau) - c_S 2 I_z S_x sin(2\pi J \tau) \rightsquigarrow \rho_6 = -\ c_I I_z - c_S S_z cos(2\pi J \tau) \rightarrow \rho_7 = -\ c_I I_z + c_S S_y cos(2\pi J \tau)$$

Consider two cases at ρ_5: $J = 0$ and $J \neq 0$ but $\tau = \frac{1}{|2J|}$. For the uncoupled case ($J = 0$), $\rho_5 = -\ c_I I_z - c_S S_z$ so the S-spin magnetization is along $-\hat{z}$ and will diminish under the spin-lattice relaxation during Δ. In the latter case, $\rho_5 = -\ c_I I_z + c_S S_z$ so the S-spin magnetization is along $+\hat{z}$ and will happily sit there until the final pulse. During Δ the anti-phase term will also diffuse and be lost, this is often further ensured by the application of a gradient pulse. In the version of the BIRD shown above the Δ time is varied to find the minimum in the uncoupled signal. If you don't wait long enough the uncoupled signal survives the Δ period, but the magnetization that has relaxed back to $+\hat{z}$ during Δ also will be detected - so there's a trade-off. Keep in mind that a ^1H-^{13}C $^1J \approx 140$Hz so $\tau \approx 3.6$ms, but Δ may be many seconds.

References

1. J.R. Garbow, D.P. Weitekamp, A. Pines, *Chem. Phys. Lett.* **93**(5), 504-508 (1982).
2. D. Uhrin, T. Liptaj, K.E. Kövér, *J. Magn. Reson. Ser. A* **101**(1), 41-46 (1993).
3. R.T. Williamson, J.R. Carney, W.H. Gerwick, *J. Nat. Prod.* **63**(6), 876-878 (2000).
4. S. Berger and S. Braun, *200 and More NMR Experiments. A Practical Course*, Wiley-VCH, Weinheim (2004).