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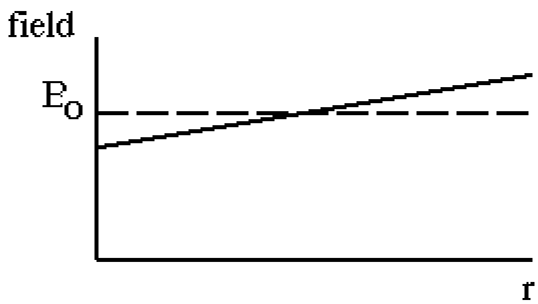
Magnetization Gradients, k-space and Molecular Diffusion

Magnetic field gradients, magnetization gratings and k-space

In order to record an image of a sample (or obtain other spatial information) there must be a measurable difference introduced between two locations in the sample. The most straightforward approach to this is to apply a magnetic field gradient,

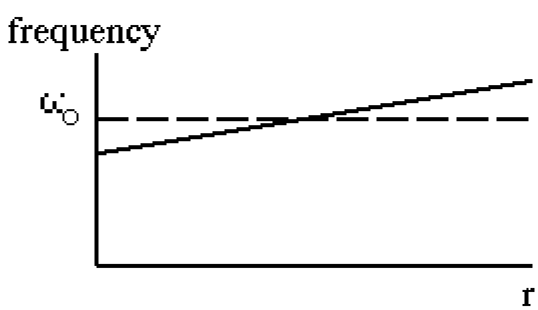
$$B = B_0 + \frac{\partial B_z}{\partial u} u, \quad \text{where } u \text{ is } x, y, \text{ or } z,$$

so that the resonance frequency varies across the sample.



Only the three partial derivatives of the z-component of the magnetic field are of interest, since the others correspond to static fields in the transverse direction of the laboratory frame, and thus rotating fields in the rotating frame. Rotating fields (with respect to the spin) do not influence the long time spin dynamics.

The presence of a magnetic field gradient introduces a spatial heterogeneity into the experiment so that the resonance frequency varies over the sample.



Recall that the observed signal is the integrated bulk magnetization from the entire sample. If a z-gradient (_Bz/_z) is applied to a sample whose spin density is described by ρ(x,y,z) then the FID, is,

$$M_{x,y}(t) = M_0 e^{-i\Delta\omega t} e^{-t/T_2} \int \rho(x,y,z) e^{-i\gamma \frac{\partial B_z}{\partial z} z t} \, dx\,dy\,dz.$$

This is put in a more recognizable form by introducing the reciprocal space vector,