Lab 5

Medical Imaging

IST 2022-2023

Consider the study of a homogenous sample with T_1/T_2 = 400/40 ms, using a spin-echo NMR sequence, with *TE/TR* = 10/100 ms, and 90° excitation along +x. In the simulations, use the rotating reference frame and a time step of 0.5 ms, and assume instantaneous excitations.

First consider on-resonance spins ($\Delta\omega$ = 0 Hz):

1. Simulate the evolution of the magnetization during one *TR* and plot each magnetization component as a function of time.

2. Compute the complex transverse magnetization, and plot its amplitude and phase as a function of time.

Now consider an ensemble of off-resonance spins with $\Delta\omega$ between -60 and +60 Hz, in steps of 1 Hz:

3. Repeat 1. and 2.; for the plots, consider the average magnetization of all spins.

4. Repeat 3. for a multiple spin-echo experiment with 8 echoes and determine the T_2 of the sample using the data measured in this experiment.

Matrices for the clockwise rotation by angle ϕ about x, y and z:

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\phi) & \sin(\phi) \\ 0 & -\sin(\phi) & \cos(\phi) \end{bmatrix} \quad \begin{bmatrix} \cos(\phi) & 0 & -\sin(\phi) \\ 0 & 1 & 0 \\ \sin(\phi) & 0 & \cos(\phi) \end{bmatrix} \quad \begin{bmatrix} \cos(\phi) & \sin(\phi) & 0 \\ -\sin(\phi) & \cos(\phi) & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Bloch equations for relaxation in matrix form:

$$\begin{bmatrix} M_x(t_{n+1}) \\ M_y(t_{n+1}) \\ M_z(t_{n+1}) \end{bmatrix} = \begin{bmatrix} \exp\left\{-\frac{\Delta t}{T_2}\right\} & 0 & 0 \\ 0 & \exp\left\{-\frac{\Delta t}{T_2}\right\} & 0 \\ 0 & 0 & \exp\left\{-\frac{\Delta t}{T_1}\right\} \end{bmatrix} \begin{bmatrix} M_x(t_n) \\ M_y(t_n) \\ M_z(t_n) \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ M_0\left(1-\exp\left\{-\frac{\Delta t}{T_1}\right\}\right) \end{bmatrix}$$