<div style="border:1px solid black; text-align:center;">

Lab 4

Medical Imaging

IST 2021-2022

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Consider the study of a sample with T_1/T_2 = 1400 ms /90 ms by ^{1}H-NMR in a 3T static magnetic field, using the rotating reference frame and assuming on-resonance spins. Consider the equilibrium magnetization vector M_0 = [0; 0; 1] and simulate the evolution of the magnetization vector (displaying the time course of each of its components) using a time step of 0.05 ms in the following conditions:

1. Excitation (ignoring relaxation) by a 90° flip angle B_1 pulse along $-y$ with duration 5 ms.

2. Relaxation following the 90° excitation simulated in 1., for an observation period of 790 ms. Try also an observation period of 3000 ms.

3. Repeat 1. 2. for the flip angles 45º and 180º.

4. Now repeat 3. for a flip angle of 45º, over 10 consecutive cycles of excitation and relaxation (repetition time (TR) = 790 ms).

Bloch equations for excitation by B_1 along $-y$ in matrix form:

$$\begin{bmatrix} M_x(t_{n+1}) \\ M_y(t_{n+1}) \\ M_z(t_{n+1}) \end{bmatrix} = \begin{bmatrix} \cos(\gamma B_1 \Delta t) & 0 & \sin(\gamma B_1 \Delta t) \\ 0 & 1 & 0 \\ -\sin(\gamma B_1 \Delta t) & 0 & \cos(\gamma B_1 \Delta t) \end{bmatrix} \begin{bmatrix} M_x(t_n) \\ M_y(t_n) \\ M_z(t_n) \end{bmatrix}$$

Bloch equations for magnetisation relaxation in matrix form:

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