M229 Advanced Topics in MRI, Spring 2018
Homework 2: Pulse Sequence Simulations
Assigned: 2018.04.19; Due: 5 pm, Fri, 2018.05.04 by email
Questions? Email HoldenWu@mednet.ucla.edu

Turn in (1) a PDF with your simulation results and discussions, and (2) your MATLAB code. Include comments in your code to improve readability.

1. Bloch Equation Simulations

In the first part, we will take a closer look at the transient and steady states of rapid gradient echo (GRE) sequences using Bloch equation simulations. Follow Brian Hargreaves's web tutorial (http://www-mrsrl.stanford.edu/~brian/bloch/). The MATLAB scripts xrot.m, yrot.m, zrot.m, throt.m, and freeprecess.m will be especially helpful.

1A. *Steady state signal comparison*. Simulate the steady state signal levels for bSSFP (center of pass band), SSFP-FID, and SSFP-Echo. Assume the parameters: bSSFP TE/TR = 2.5/5 ms, SSFP-FID TE/TR = 2/10 ms, and SSFP-Echo TE/TR = 8/10 ms. Plot and compare the steady state signal levels over a range of flip angles (0-180°) and different tissue T_1 and T_2: (a) T_1 = 1000 ms and T_2 = [100, 200, 500, 1000] ms, (b) T_2 = 40 ms and T_1 = [100, 200, 500, 1000] ms. (cf. slides 47-48 in Lecture 3)

Hints: For bSSFP, you can use sssignal.m. For SSFP-FID/Echo, start with gresignal.m and gssignal.m, and then add an option for the position of gradient spoiling in TR.

1B. *Catalyzation for bSSFP*. Simulate the approach to steady state for a bSSFP sequence. Assume the parameters: RF θ = 70° and $\Delta\phi = \pi$, TR = 5 ms, 200 TRs, tissue T_1/T_2 = 600/100 ms. Compare no preparation, $\theta/2$-TR/2 preparation, and linear ramp catalyzation with number of ramp pulses = [5, 10, 20]. RF phase cycling (e.g., $\Delta\phi = \pi$) should be consistently applied throughout the catalyzation and regular TRs. For each preparation scheme, plot the transition to steady state for a range of off-resonance frequencies (±400 Hz) as an image (magnitude) and specifically for spins in the center of the pass band and stop band (magnitude and phase). (cf. slides 50-51 in Lecture 3)

Hints: Modify Sim_SatRecovery.m to simulate bSSFP and then make it into a function.

Bonus: Come up with another scheme for catalyzation and compare with linear ramp.

2. Extended Phase Graph Simulations

In the second part, we will use the extended phase graph (EPG) formalism to simulate rapid gradient echo sequences. You can use the scripts from Box (link sent to class mailing list) as a starting point.

2A. *Gradient-spoiled GRE*. Simulate the evolution of phase states for a gradient-spoiled GRE (SSFP-FID) sequence. Assume the parameters: RF θ = 30°, TR = 10 ms, 200 TRs, tissue T_1/T_2 = 1000/100 ms. Plot the evolution of all F and Z states as an image (magnitude), as well as the specific evolution of F_0 (magnitude and phase). (cf. slides in Lecture 4)

Hint: Instead of the crusher pairs used for FSE, use one spoiler at the end of TR.

Bonus: Compare the EPG simulations of gradient-spoiled GRE with Bloch simulations.

2B. *RF-spoiled GRE*. Based on your work in 2A, add quadratic RF phase spoiling to simulate an RF-spoiled GRE sequence. Remember to demodulate the received signal by the same phase as the RF pulse. Assume the parameters: RF θ = 60° and quadratic $\Delta\phi$ based on [2, 5, 117°], TR = 20 ms, 400 TRs, tissue T_1 = 1000 ms and T_2 = [100, 500, 1000] ms. Plot the evolution of all F and Z states as an image (magnitude), as well as the evolution of F_0 (magnitude and phase). Compare with Fig. 11 in Scheffler's paper (Concepts in MR, 1999).

Hint: Compress the dynamic range of your images (e.g., |Img|^p, p<1.0) for better visualization.

Bonus: Compare the EPG simulations of RF-spoiled GRE with Bloch simulations.