STA exercise

Design RF pulses using the spatial domain framework and evaluate the effect of k-space trajectory. This code can be used to compute RF pulse waveforms required to produce 2D selective exultation pulses. The code is completely generic so please feel free to adapt it to any purpose you wish.

Script STA_exercise.m contains the exercise to run. Function lsqrSOL is a least squares solver function that can be saved anywhere on the path. Note that lsqrSOL was downloaded from the Stanford University Optimization Lab website http://www.stanford.edu/group/SOL/software/lsqr/

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Exercise 1:

Run the code in its original form; it will calculate the necessary RF pulse to produce a localised rectangular excitation using a 2D spiral k-space trajectory:

You should get the following resulting excitation pattern:

Apart from some errors at the edges, this is quite a faithful reproduction of the intended target.

The acquired RF pulse is stored in variable b. We can plot this as a function of time (shown on the right).
Remember that in the picture introduced for the small-tip approximation, the RF pulse is laying down energy as we go through k-space, defined by the gradients. A more intuitive way of viewing the RF pulse is to plot the pulse amplitude along the k-space trajectory as shown on the right.

You see that the higher amplitudes of the RF pulse correspond to areas of k-space that are horizontally or vertically displaced from the centre - this is because the target excitation was a rectangle.

Exercise: modify the target excitation \( P \) to be circular instead of rectangular. Thus the distribution of RF amplitude as a function of k-space change as expected?

Exercise 2:

Although the excitation shown above is good it is not a perfect reproduction of the target. This might be because the k-space coverage is not sufficient.

Experiment with variables \( K_{\text{max}} \), \( N_{\text{cycles}} \) and \( \text{dur} \) in order to try to improve the result.

**Hint: the original values were \( \text{dur}=6\text{ms}, \ N_{\text{cycles}}=12, \ K_{\text{max}}=350 \text{ rad/m} \)**

Remember that the resolution in real space is a function of the maximum k-space value, and in general \( dx=\pi/K_{\text{max}} \). So \( K_{\text{max}}=350 \text{ rad/m} \) corresponds to a resolution of 9mm, whereas the spatial domain has been defined with a resolution of 5 mm. Increasing \( K_{\text{max}} \) to 630 rad/m would achieve this objective, but doing this alone would then result in a larger gap between turns of the spiral. Recall also that the gaps in k-space sampling have an effect on the field of view of the Fourier transform, so just increasing \( K_{\text{max}} \) but keeping \( N_{\text{cycles}} \) the same results in too small a radial field of view. You’ll find the optimal solution is to increase both of these, and also to increase \( \text{dur} \). Increasing the duration is necessary to make sure that k-space is covered with sufficient resolution in the axial direction. If you want an example try \( \text{dur}=16\text{ms}, \ N_{\text{cycles}}=24, \ K_{\text{max}}=630 \text{ rad/m} \)

Exercise 3:

The variable lambda penalises solutions in which the RF power \( (|b|^2) \) is large. Compute solutions for a selection of different values of lambda and then plot error (called nRMSE in the code) against power.