HL2011: Exercise Set 5
Image Contrast and Chemical Shift

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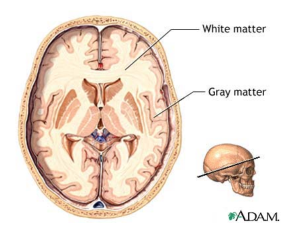
1 Image Contrast

Reuse your gradient echo imaging sequence from the previous exercise. For this exercise, you can assume perfectly homogeneous field, i.e. $T_2 = T_2^*$. Image one of the brain phantoms (`brain_4mm_pixel_fuzzy`, `brain_2mm_pixel_fuzzy` or `brain_halfmm_pixel`) and try echo times T_E of 5 ms, 50 ms and 100 ms and study how the contrast changes. Let $T_R = 5$ s and $\tau = 2$ ms. **Q1: What contrast weighting do we get with long T_E's?**

Also, image using different T_R values: 2 s, 1 s and 0.5 s. Let $T_E = 5$ ms and $\tau = 2$ ms. **Q2: How does the contrast change? What is the contrast weighting called with shorter T_R?**

Include the images in your report.

1.1 Design of sequence parameters



The gray and white matter in this brain phantom have the following tissue parameters: $T_{1,GM} = 833$ ms, $T_{2,GM} = 83$ ms, $\rho_{GM} = 0.86$ and $T_{1,WM} = 500$ ms, $T_{2,WM} = 70$ ms, $\rho_{WM} = 0.77$ respectively. Contrast is defined as intensity difference (between white and gray matter) in this exercise.
Now create three combinations of sequence parameters (echo and repetition time) for different contrast weightings. Let *short echo time* be defined as the echo time that gives exactly 5% signal dephasing for the shortest T_2 and *long repetition time* repetition that results in 95% signal recovery for the longest T_1.

T_1 *weighting:* Use the *short echo time* and compute the repetition time that maximizes the contrast. Compute the contrast.

T_2 *weighting:* Use the *long repetition time* and compute the echo time that maximizes the contrast. Compute the contrast.

Proton density weighting: Use the *short echo time* and the *long repetition time* to generate proton density contrast. Compute the contrast.

Q3: Which contrast weighting maximizes the contrast between gray and white matter? Give both analytical expressions and their corresponding numerical values for all three contrasts.

Compare with the contrast in the images from the previous task and see if it is better.

2 Chemical Shift

Try the water and fat phantom (see `help wanterandfat`) and see if you can see the chemical shift artifact. Try imaging with different values of τ, for example 2 ms, 4 ms and 10 ms. Also, make sure your echo time T_E is greater than $2\tau + t_p$, so that there is room in the sequence diagram.

Q4: How does τ influence the gradient amplitude and the receiver bandwidth, and how does this affect chemical shift?

Q5: What is the value of τ that results in a chemical shift of one pixel?

2.1 Echo-planar Imaging (EPI)

Design and simulate an EPI-planar gradient echo sequence. Use the same type of trajectory as in Fig. 9.12/9.13 in the book, but using gradient echo instead of spin echo. In this exercise, let $\tau = 0.5$ ms

```
tau = 0.5e-3; % ms
```

It is easier to debug the trajectory while working on a disk.

```
iv = disc(3,1);

kmax = 1/2;
dk = 1/8;
dk = kmax/ceil(kmax/dk);

B0 = 1.5; % T
tp = 1e-3; % ms

B1 = pi/(2*gamma*tp);
f_rf = gammabar*B0;
rf = RectPulse(B1, f_rf, 0, tp);
```

Gradient strength and timing can be defined as vectors with pairwise values of the gradient strength at any given time. If you want the gradient to begin right after the RF-pulse and have the duration tau you write:

```
% Phase prewinder
Gpex1 = [-kmax/(gammabar*tau) 0];
Tpex1 = [tp tp+tau];
```

Calculate correct gradient strengths and timing for the readout prewinder, the first readout in the EPI-train as well as dt for the readout. Let the duration of the prewinder be tau, and the duration of the readout 2*tau.

```
% Frequency prewinder
Gfey1 = [...  0];
Tfey1 = [... ...];

% First readout
Gfey2 = [...  0];
Tfey2 = [... ...];

dt = ...
```

An EPI-train consists of multiple readout gradients following a single RF-pulse. Between each readout gradient a small gradient called a *blip* is used to jump to the next k-space line. The blips and the subsequent readout gradients can be calculated in a for loop. Here the command cat is used to concatenate vectors. The keyword end is used to get the last element in a vector, so that the blip begins at the same time as the previous readout ended (and vice versa). **Calculate the gradient strength of the readout gradients and the blip gradients**. Let the duration of the blips be dt and the duration of the readout 2*tau. Remember that every other readout gradient should have inverted sign.

```
Gblip = []; % Leave this empty
Tblip = []; % Leave this empty


for ll = 2:2*kmax/dk
    Gblip = cat(2,Gblip,[... ...]);
    Tblip = cat(2,Tblip, [Tfey2(end) Tfey2(end)+dt]);
    Gfey2 = cat(2,Gfey2,[... ...]);
    Tfey2 = cat(2,Tfey2, [Tblip(end) Tblip(end)+2*tau]);
end

gx = Gradient([Tpex1 Tblip], [Gpex1 Gblip]);
gy = Gradient([Tfey1 Tfey2], [Gfey1 Gfey2]);
```

In this task, we let the ADC be on at all time, even during the blips. We can use the fact that we have defined the time of the readout gradients when we define the duration of the ADC. Note: To get the correct amount of sample points, we sample one last imaginary blip, even though it is never played out.

```
adc = ADC(Tfey2(1), Tfey2(end)+dt, dt);
[S, ts] = seemri(iv, B0, rf, gx, gy, adc, Tfey2(end), 1,'PlotKspace',true);
```

Now every other line in k-space is flipped, and we have sampled during the blips. Therefore, we need to clean our k-space up a little before calling mrireconstruct

```
S = reshape(S,[2*kmax/dk+1 2*kmax/dk]);
S(:,2:2:end) = flip(S(:,2:2:end)); % Flip every second k-space line
S(end,:) = []; % Cut away the blip samples
mrireconstruct(S, kmax, 'Plot', true);
```

When you see that your trajectory works, try it on the brain_4mm_pixel. **Include both the disc image and the brain image in your report, and a plot of the k-space trajectory for the disc.**

Q6: Effective TE is defined as the time from the middle of the RF-pulse to the time when we sample the center of k-space. What is effective TE in this case?

Q7: How would shorten the TE of the EPI-readout? How does this affect the receiver bandwidth? What happens to the SNR?

3 Report

Submit an individual report and source code (as separate PDF and .m files) on Canvas by May 7 23:59, or before 10:15 to count as attendance for the session.