EE469B: Assignment 6

Due Thursday Nov. 7

This problem set requires several m-files that are available on the course web site. These are:

`dinf.m, fmp.m, dzpm.m, dzls.m, dzmp.m`

These are located in the directory

`http://www.stanford.edu/class/ee469b/mfiles/`

as usual.

1. SLR Pulse Design The mfiles `dzls` and `dzmp` provide an interface to the matlab `firpm` and `firls` routines using the relationships we discussed in class.
    These should be invoked by

```
>> bls = dzls(N, tb, delta1, delta2)
>> bpm = dzpm(N, tb, delta1, delta2)
```

where `N` is the filter length, `tb` is the time bandwidth, and `delta1` and `delta2` are the pass-band and stopband ripple amplitudes. These use the m-file `dinf.m` that computes the $D_\infty(\delta_1, \delta_2)$ function, provided on the class web site.
    Once you have $B_N(z)$, you can design an RF pulse by computing the corresponding minimum phase $A_N(z)$, and then doing the back recursion. There are m-files `b2a.m` and `ab2rf.m` that perform these functions. The `b2a.m` routine requires `mag2mp.m` which is also available on the web site. To design an RF pulse for a flip angle `theta`,

```
>> b = dzls(N,tb,delta1,delta2);
>> bs = b*sin(theta/2);
>> a = b2a(bs);
>> rf = ab2rf(a,bs);
```

Note that the passband and stopband ripples should be chosen according to they type of RF pulse you are designing, and the amount of ripple you can allow in the magnetization profile.

a) Short Spin-Echo Pulse Design a spin-echo pulse with $\delta_1 = \delta_2 = 0.001$, and a time-bandwidth $TBW = 3.4$. Use a least-squares design. How long is the pulse, if the RF is limited to 0.2 G? Plot the RF waveform, and the spin-echo slice profile. What is the gradient amplitude for a 5 mm slice? This is a very typical spin-echo pulse.

b) Long Spin-Echo Pulse Redesign the pulse for a time bandwidth $TBW = 7$. How long is the pulse, if the RF is limited to 0.2 G? Plot the RF waveform, and the spin-echo slice profile. What is the gradient amplitude for a 5 mm slice?

2. Power in Accurate 180 Pulses   Design a "perfect" $B_N(z)$ for a time-bandwidth $TBW = 8$, and passband and stopband ripples of $\delta_1 = 1e - 6$, and $\delta_2 = 1e - 3$.

```
>> b = dzls(256,8,1e-6,1e-3);
>> b = b/(1+1e-6);
```

where we have scaled `b` to be exactly one at the ripple peaks. Design a sequence of RF pulses by scaling `b` by 0.99, 0.999, 0.9999, and 0.99999.

a)   What flip angles do these correspond to?

b)   Plot the RF pulses on a common axis. Describe how they differ.

c)   Plot the peak power as a function of flip angle.

This example shows that it is very expensive to produce a true 180 degree pulse. Very small gains in the spin-echo profile require very large increases in peak and average power. This is very important to keep in mind.

3) Minimum Phase Inversion Pulses   This problem compares linear phase and minimum phase inversion pulses. In each case, use a time-bandwidth of 8, passband ripple of 0.001, and stopband ripple of 0.0001.

To design minimum phase filters, there is a matlab routine `dzmp.m` on the web site. This requires `fmp.m` and `mag2mp.m`, which are also available on the web site. The inputs to `dzmp.m` are the same as for the routines `dzls.m` and `dzpm.m` described on problem 1.

a)   Design a linear phase equal-ripple inversion pulse, and a minimum phase inversion pulse. What are fractional transition widths? Assume the pulses are 8 ms, and plot both scaled to Gauss, on the same axis.

b)   Simulate the slice profiles, and plot them. In one plot show the entire slice profile, and in a second plot, show the difference in transition width.

4) Project Topics   Start thinking about a project topic. You can pick something from your research work, as long as there is an RF pulse design component. Otherwise, pick an article about RF pulse design, and see if you can get it to work. Often it isn't as easy as the authors make it out to be!

For your project, you can choose to do a 12-15 minute presentation or submit a report describing the basic concept for your project, how you went about it, and how well it worked. Aim for something like two homework assignments in effort. These will be due during the last class of dead week. Simulations are fine. You don't need to get things working on the scanner. If the schedule is a problem, let me know.