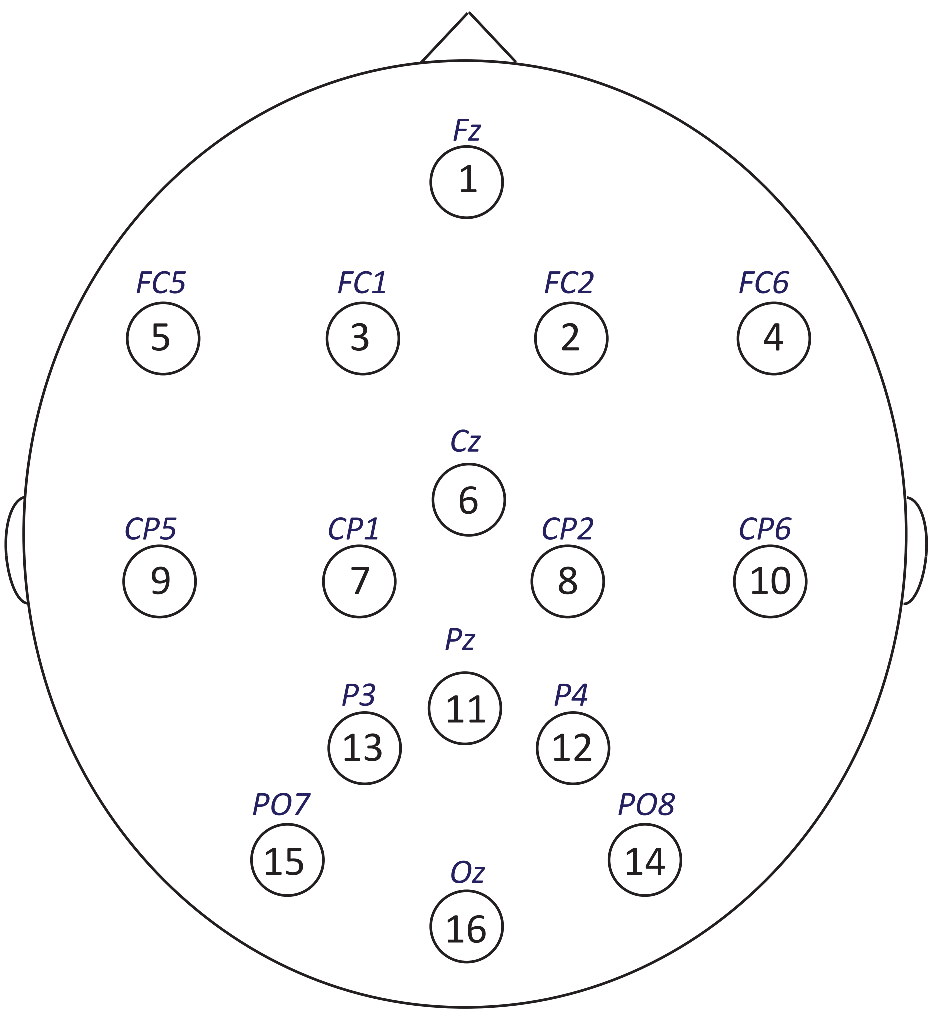
COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

Lab Instruction 3
Neurofeedback

Brain Computer Interface Lab
ECBM 4090



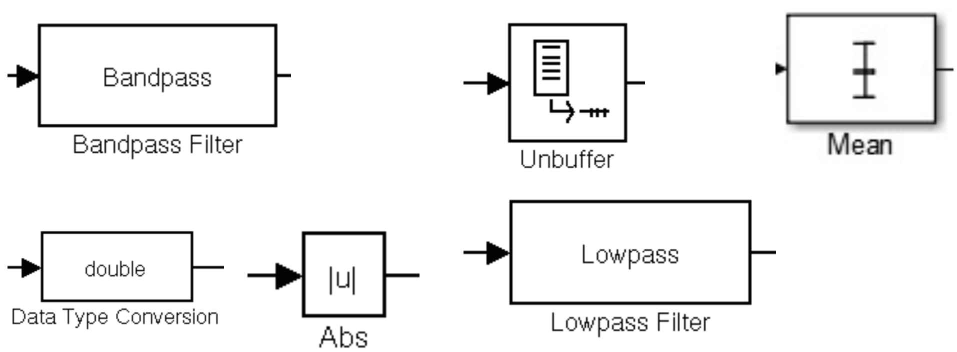
Can you learn to regulate the alpha activity in your brain?

In this session, we will learn how to process and display neural signals in real time using a neurofeedback paradigm in Simulink. Neurofeedback is a type of biofeedback that uses real-time displays of brain activity, most commonly electroencephalography (EEG), to teach subjects to self-regulate brain function. Sensors are placed on the scalp to measure neural activity which is then displayed using video or sound.

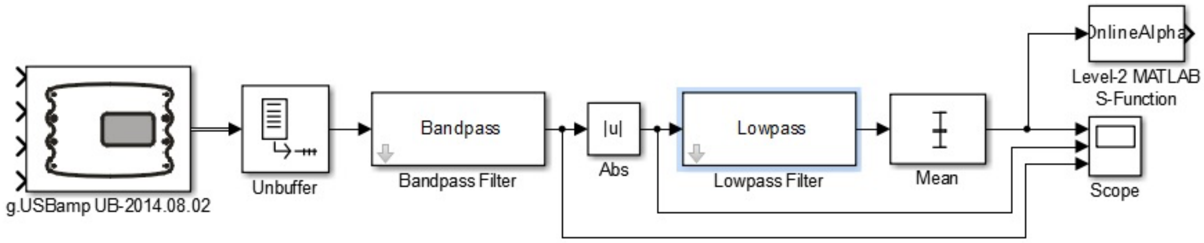
The goal of this project is to measure neural activity in various frequency bands and provide a real-time display to the subject. We will begin by extracting the power in the alpha band and displaying average alpha to the subject in real time.

1. Cap your subject. We will use these electrodes: **Cz, P3, Pz, P4, Oz.**

2. Create a Simulink model to detect alpha power using the following modules.

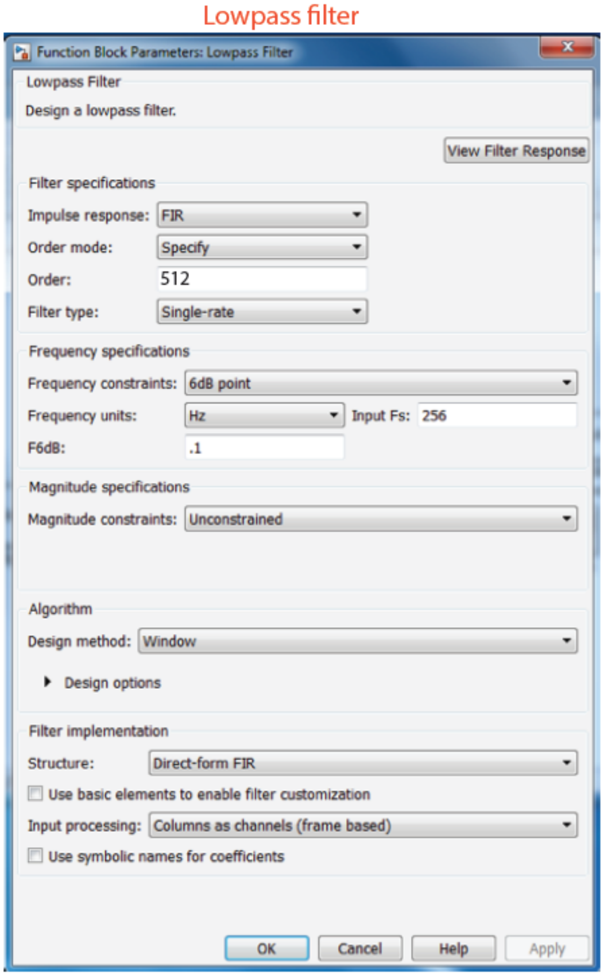


   a. Set up the first portion of the Simulink module.
      i. Record from g.USBamp.
      ii. Un-buffer the signal
      iii. Bandpass filter the data to a particular band (begin with Alpha 8-12Hz):
         i. Theta = 4-7Hz
         ii. **Alpha** = 8-12Hz
         iii. Beta = 16-31Hz
      iv. Then detect the envelope of the signal by taking the absolute value and then applying a lowpass filter.

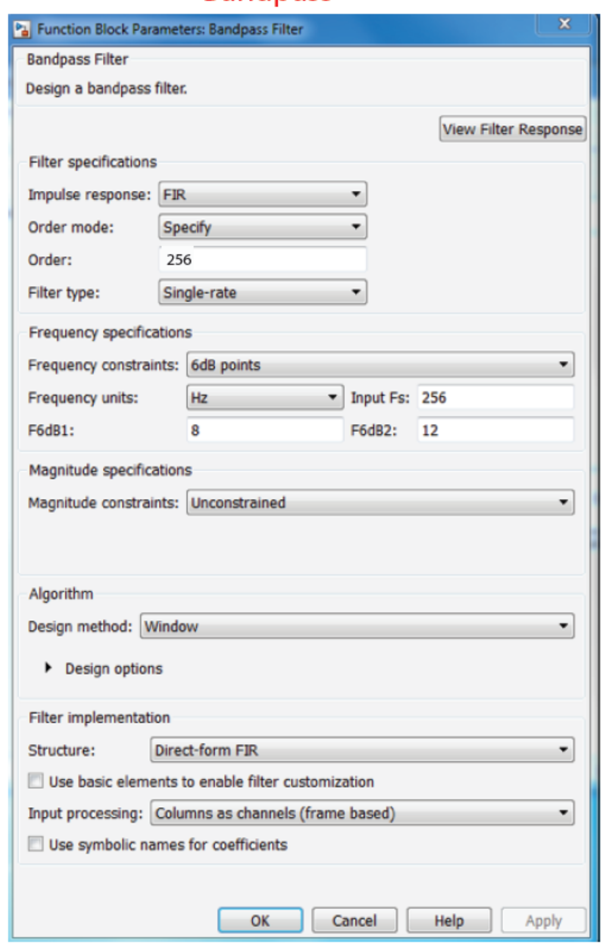


b. Add a scope that simultaneously displays the output of the bandpass, absolute value, and lowpass modules so you can visualize the signal transformation at each stage.
c. Use Mean block to compute the average alpha power of all the channels. Start with the following parameters for the bandpass and lowpass filters, then adjust as necessary.
    i. Lowering the cut-off frequency of the low-pass filter makes the output change more slowly.

Lowpass filter



Bandpass



d. Save the EEG data before and after processing.
   i. Add "Data Type Conversion" blocks (convert to double) before the Bandpass and after the Mean module.
   ii. Add a "To File" module connected to both Conversion blocks.
   iii. Change the File names so that you generate two separate, labeled files.

3. Test and expand your module.
   a. Close your eyes. You should see a strong increase in the alpha amplitude.
   b. Add a second bandpass filter.
      i. This bandpass should have a wider frequency range, e.g. 4-20Hz.
      ii. Repeat the blocks required for envelope detection for the second bandpass.
   c. Use the output of this filter to normalize the alpha band.
      i. Divide the envelope of the first bandpass by the of envelope of the second. This ratio measures the relative power in alpha, rather than absolute power.
      ii. Make sure the division occurs after the Mean.

4. Once you are confident about your module, generate the neurofeedback.
   a. Feed the output to an s-function (a template has been provided).
      i. The s-function receives the alpha amplitude at each time step.
      ii. In the "Output" sub-function of the s-function, you have access to the input in block.InputPort(1).Data.
   b. Display the alpha amplitude on your screen using MATLAB's "bar" function.
      i. Use the commands "axis ([0 2 0 10]); draw now;" to fix the axis
      ii. Ensure that the refresh rate for the "bar" is more than 0.5 seconds, otherwise data may be lost. Your s-function should not take longer to execute than the time it takes for the arrival of the EEG samples.

Report: Show the effect of subject behavior on alpha power: 1) Close your eyes. 2) Try alpha blocking (e.g. ask the subject to solve math problems). 3) Try relaxation. (3 pts)

5. Try at least three different values of the lowpass filter's cutoff frequency

Report: Examine the effect of the lowpass filter's cut-off frequency on 1) the convergence speed and 2) smoothness of the output. (2 pts)

6. Change the bandpass filter to select the theta band (4-7 Hz)

Report: Show the theta band effect you observe when trying the 3 subject behaviors as before (eyes closed, alpha blocking, relaxation). (3 pts)

7. Implement a different way to visualize or display the output. For example, use sound to play a tone (sinusoid) whose loudness or frequency change with alpha power.

```
function Output(block)
    block.OutputPort(1).Data = 2*block.InputPort(1).Data;
    dt = block.InputPort(1).Data;
    ct = get(block,'CurrentTime');
    if ceil(ct*2)==floor(ct*2)
        disp(ct);
        t = (1:3000)/8000;
        w = sin(2*pi*100*dt*t);
        w = w.*hanning(length(w))';
        soundsc(w);
    end
```

Report: Does the auditory (or other) feedback help your subject control their alpha power? (1 pt)

8. A popular neurofeedback paradigm is alpha-theta training. In this paradigm, subjects try to control alpha power (8-12Hz) compared to theta power (4-7Hz). To try this yourself, modify your Simulink module to display 3 measures: theta envelope, alpha envelope, and their ratio. Is this new measure easier to control?

Report: Is the alpha-theta ratio easier to control than alpha or theta alone? (1 pt)

Homework:

1. Plot the raw EEG signal and inspect the signal quality over time. Zoom in on the signal, find the artifacts, and learn to distinguish noisy signals from good quality data. You don't need to submit this part, but it is very important to be able to recognize artifacts if you wish to work with EEG signals going forward.

2. Generate an envelope detection function in MATLAB. The function should use the following format: (4 pts)

   ```
   function [envelope]= envelope_detection(raw_EEG_signal, band_low_cut_off,
   band_high_cut_off, low_cut_off)
   ```

   in which, `band_low_cut_off` and `band_high_cut_off` are *low cut off* and *high cut off* frequencies of *bandpass* filter respectively and, `low_cut_off` is *cut off* frequency of the *lowpass* filter in the model.

   You are free to use any toolbox or function you want, or you may replicate the functions you used in Simulink.

3. Plot the output of your function and the output of the Simulink model (recorded in the lab) on the same figure using different colors. Choose a time window that ensures that the signal is clearly observable. Include two figures: (6 pts)
    1. One figure illustrating a stretch of time where the two outputs are very similar
    2. One figure for a period where the outputs are different