

Frequency Properties of Filters in MATLAB

The main goal of this lab is to learn how to examine the frequency selective properties of a filter in Matlab and to examine those properties for a few filters.

0) `freqz()`

- a) As we saw last week, the Matlab function `freqz()` is used to calculate the frequency response of a filter. Its simplest use is the form `[H,w]=freqz(h,1,N)`, where `h` is the impulse response of the filter, (e.g. `[0.5; 0.5]` for the two point moving average), `N` is the number of frequency points to be calculated, for which 256 is a reasonable number (frequency is continuous, but to plot it we have to choose a finite number of points to plot), `H` is the transfer function (Fourier transform of the impulse response) and `w` (called ω = omega, in class) is 2π times the frequency (i.e. $\omega = 2\pi f$). To get `f`, divide `w` by 2π : `f = w/(2*pi)`;
- b) Once you have calculated `H` and `w`, you can plot the magnitude as a function of frequency, $|H(f)|$, by opening up a figure and using the `plot()` command (use `plot()` when something is intrinsically continuous; use `stem()` or `bar()` when something is intrinsically discrete): `plot(f,abs(H))`
- c) Once you have calculated `H` and `w`, you can also plot the phase of `H` as a function of frequency, $\angle H(f)$, by opening up a figure and using the `plot()` command. For this lab, please plot phase in **cycles**, not **radians** (or degrees): `plot(f,angle(H)/(2*pi))`
You may, or may not, wish to `unwrap()` the phase before converting to cycles.

1) Consider the system $y[n] = \frac{1}{2}x[n] + \frac{1}{2}x[n-1]$.

- a) Determine the half-max width of the filter (the frequency width for which the magnitude is greater than or equal to 1/2 of the maximum). You may find the zoom tool (magnifying-glass-with-a-plus icon) or data cursor (tool-tip-along-a-data-curve icon) useful. This estimate will be for comparison with later filters. Note: It is possible to automate this calculation (instead of using visual inspection of the plot), and you may wish to try, since it will be repeated many times below.
- b) Measure the steepness (slope) of the magnitude of the filter at the half-max point(s). Again, you may find the zoom tool or data cursor useful, and again, this is for comparison with later filters. It is also possible to automate this calculation.
- c) What is the negative of the slope, in **cycles/frequency**, of the phase? This is the effective (or “group”) delay and characterizes the effective delay/shift (in time steps) caused by the filter. Note: by measuring the phase in **cycles** instead of **radians**, the necessary division by 2π has already been performed. You should definitely try to automate this calculation, since it is not hard (and it will be repeated many times below).

- 2) Consider the system $y[n] = \frac{1}{2}x[n] - \frac{1}{2}x[n-1]$.
- Measure the half-max width of the filter.
 - Measure the steepness (slope) of the magnitude of the filter at the half-max point(s).
 - What is the negative of the slope, in **cycles/frequency**, of the phase, i.e. the group delay?
 - How do the values compare to the values measured above?
- 3) Consider the system $y[n] = \frac{1}{4}x[n] - \frac{1}{2}x[n-1] + \frac{1}{4}x[n-2]$.
- Measure the half-max width of the filter.
 - Measure the steepness (slope) of the magnitude of the filter at the half-max point(s).
 - What is the negative of the slope, in **cycles/frequency**, of the phase, i.e. the group delay?
 - How do the values compare to the values measured above?
- 4) Consider the system $y[n] = \frac{1}{4}x[n] + \frac{1}{2}x[n-1] + \frac{1}{4}x[n-2]$.
- Measure the half-max width of the filter.
 - Measure the steepness (slope) of the magnitude of the filter at the half-max point(s).
 - What is the negative of the slope, in **cycles/frequency**, of the phase, i.e. the group delay?
 - How do the values compare to the values for (1)?
- 5) Consider the system with an impulse response given by the Matlab function `h=kaiser(30,3)/20`.
- Measure the half-max width of the filter.
 - Measure the steepness (slope) of the magnitude of the filter at the half-max point(s).
 - What is the negative of the slope, in **cycles/frequency**, of the phase, i.e. the group delay?
 - How do the values compare to the values measured above?
- 6) Consider the system $y[n] = x[n] - x[n-2]$.
- Measure the half-max width of the filter.
 - What is the negative of the slope, in **cycles/frequency**, of the phase, i.e. the group delay?