Lab P-12: Frequency Response: Bandpass and Nulling Filters

Pre-Lab and Warm-Up: You should read at least the Pre-Lab and Warm-up sections of this lab assignment and go over all exercises in the Pre-Lab section before going to your assigned lab session.

Verification: The Warm-up section of each lab must be completed **during your assigned Lab time** and the steps marked *Instructor Verification* must also be signed off **during the lab time.** One of the laboratory instructors must verify the appropriate steps by signing on the **Instructor Verification** line. When you have completed a step that requires verification, simply demonstrate the step to the instructor. Turn in the completed verification sheet to your instructor when you leave the lab.

Lab Report: Write a lab report on Sections 5 and 6 with graphs and explanations. Please **label** the axes of your plots and include a title for every plot. In order to keep track of plots, include your plot *labsed* within your report. If you are unsure about what is expected, ask the instructor who will grade your report.

1 Pre-Lab

The goal of this lab is to study the response of FIR filters to inputs such as complex exponentials and sinusoids. In the experiments of this lab, you will use `firfilt()`, or `conv()`, to implement filters and `freqz()` to obtain the filter's frequency response.[1] As a result, you should learn how to characterize a filter by knowing how it reacts to different frequency components in the input.

This lab also introduces two practical filters: bandpass filters and nulling filters. Bandpass filters can be used to detect and extract information from sinusoidal signals, e.g., tones in a touch-tone telephone dialer. Nulling filters can be used to remove sinusoidal interference, e.g., jamming signals in a radar.

1.1 Frequency Response of FIR Filters

The output or *response* of a filter for a complex sinusoid input, $e^{j\hat{\omega}n}$, depends on the frequency, $\hat{\omega}$. Often a filter is described solely by how it affects different input frequencies—this is called the *frequency response*.

For example, the frequency response of the two-point averaging filter

$$y[n] = \tfrac{1}{2}x[n] + \tfrac{1}{2}x[n-1]$$

can be found by using a general complex exponential as an input and observing the output or response.

$$\begin{aligned} x[n] &= Ae^{j(\hat{\omega}n+\phi)} && (1)\\ y[n] &= \tfrac{1}{2}Ae^{j(\hat{\omega}n+\phi)} + \tfrac{1}{2}Ae^{j(\hat{\omega}(n-1)+\phi)} && (2)\\ &= Ae^{j(\hat{\omega}n+\phi)}\tfrac{1}{2}\left\{1+e^{-j\hat{\omega}}\right\} = Ae^{j(\hat{\omega}n+\phi)}\cdot H(e^{j\hat{\omega}}) && (3)\end{aligned}$$

In (3) there are two terms, the original input, and a term that is a function of $\hat{\omega}$. This second term is the frequency response and it is commonly denoted by $H(e^{j\hat{\omega}})$, which in this case is

$$H(e^{j\hat{\omega}}) = \tfrac{1}{2}\left\{1+e^{-j\hat{\omega}}\right\} \quad (4)$$

[1] For the MATLAB function `freqz.m`, there is a substitute available called `freeks.m` in the *DSP First* toolbox.

Signal Processing First Lab 5 Solutions

Richard A. McPherson

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