ESTIMATING SPECTRAL MAGNITUDE
(in Matlab)
Frequency Representation of a Signal

- There are several key ways to see the frequency domain representation of a signal in matlab
  - abs(fft())
  - psd()
  - spectrum() is now obsolete and will be removed in the future. Matlab suggests using pwelch(), tfestimate(), or mscohere() instead.
Example Checking Signal Magnitude

- Input waveform made up of two complex sinusoids. Red=real, blue=imag
- The higher frequency is half the magnitude of the lower-freq tone
Magnitude of $\text{abs(fft())}$

- magnitude of $\text{fft()}$ of the signal plotted on a linear scale
Magnitude of $\text{abs}(\text{fft}())$

Frequencies: 5.1 and 50.1

- magnitude of $\text{fft}()$ of the signal plotted on a linear scale
Magnitude of $\text{abs}(\text{fft}())$

Frequencies: 5.5 and 50.5

- magnitude of $\text{fft}()$ of the signal plotted on a linear scale
Magnitude of \text{abs}(\text{fft}())

- magnitude of FFT of signal on magnitude-log scale
- Note double precision floating point has 52-bit mantissa (52 bits x 6 dB = 312 dB)
Magnitude of \( \text{abs}(\text{fft}()) \)

- magnitude of \( \text{fft} \) of signal on magnitude-log scale
- Higher tone is \(-6\)dB down from lower tone
Magnitude of \( \text{abs}(\text{fft}()) \)
Frequencies: 5.1 and 50.1

- magnitude of \( \text{fft} \) of signal on magnitude-log scale
Magnitude of \( \text{abs}(\text{fft}()) \)
Frequencies: 5.5 and 50.5

- magnitude of fft of signal on magnitude-log scale
Magnitude of \texttt{psd()} 

- \texttt{psd()} of the same signal

\begin{verbatim}
Error using psd (line 3)
PSD has been deprecated. Use PERIODOGRAM or PWELCH instead.
\end{verbatim}
Magnitude of \text{psd}() 

• \text{psd}() zoomed in to the spectral peaks
• Higher tone is \(-6\text{dB} \) down from lower tone

\begin{verbatim}
Error using psd (line 3)
PSD has been deprecated. Use PERIODOGRAM or PWELCH instead.
\end{verbatim}
Magnitude of \texttt{pwelch()}

- \texttt{pwelch()} estimates the spectrum using Welch's averaged, modified periodogram method using a Hamming window.
Matlab for the Previous Plots

```
% estim_spect_mag.m
% 2003/05/19 Written
% 2019/03/05 Fixed 0 - N-1 offsets, improved axes placements, etc.
% 2021/02/09 Added pwelch()
% 2022/02/10 Commented psd() because matlab now quits when it sees it

PrintOn = 0;
Length  = 1024;
Freq1   = 5;
Freq2   = 50;
in      = 0:Length-1;

wave = cos(Freq1*2*pi*in/Length) ...
     + sqrt(-1) * sin(Freq1*2*pi*in/Length);
wave = wave + 0.5*(cos(Freq2*2*pi*in/Length) ...
     + sqrt(-1) * sin(Freq2*2*pi*in/Length));

figure(1); clf;
plot_complex(wave, 1, 0);
title('Input waveform composed of two complex sinusoids. Freq = 5, 50');
axis tight;
if PrintOn print -dtiff filter1.tiff; end

figure(2); clf;
plot(in, abs(fft(wave)), 'linewidth', 2);
title('abs(fft()); linear scale');
axis ([0 Length-1 -1 Length*1.05]);
grid on;
if PrintOn print -dtiff filter2.tiff; end

figure(3); clf;
plot(in, 20*log10(abs(fft(wave))), 'linewidth', 2);
title('abs(fft()); 20*log scale');
axis ([0 Length-1 -300 75]);
grid on;
if PrintOn print -dtiff filter3.tiff; end

figure(4); clf;
plot(in, 20*log10(abs(fft(wave))), 'linewidth', 3);
title('abs(fft()); 20*log scale');
axis([-1 1.1*Freq2 52 62]);
grid on;
if PrintOn print -dtiff filter4.tiff; end

figure(5); clf;
pwelch(wave);
title('pwelch(): Welch Power Spectral Density Estimate');
axis ([0 pi/2 -60 20]);
if PrintOn print -dtiff filter7.tiff; end
```