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Lab 3
Fourier Transform

Week of February 6, 2012
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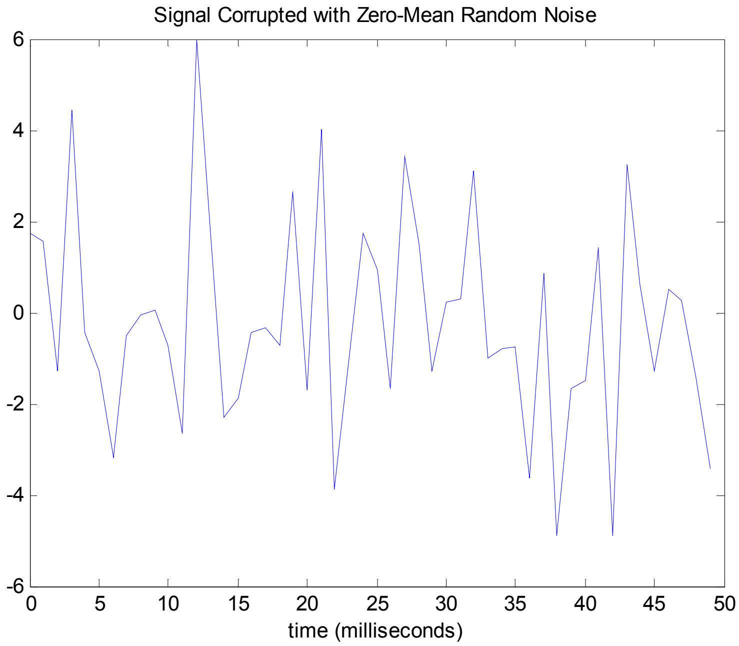
Objectives: Get familiar with Fourier series and Fourier transform.

1. [Fourier series] Display the frequency spectrum of the following signals:
   a. $s(t) = 1 + (4/\pi)[\sin(2\pi ft)+(1/3)\sin(2\pi(3f)t)]$
   b. $s(t) = (4/\pi)[\sin(2\pi ft)+(1/3)\sin(2\pi(3f)t)+(1/5)\sin(2\pi(5f)t)]$
   c. $s(t) = (4/\pi)[\sin(2\pi ft)+(1/3)\sin(2\pi(3f)t)+(1/5)\sin(2\pi(5f)t)+(1/7)\sin(2\pi(7f)t)]$
2. [Fourier transform] A common use of Fourier transforms is to find the frequency components of a signal buried in a noisy time domain signal. Consider data sampled at 1000 Hz. Form a signal containing a 50 Hz sinusoid of amplitude 0.7 and 120 Hz sinusoid of amplitude 1 and corrupt it with some zero-mean random noise:

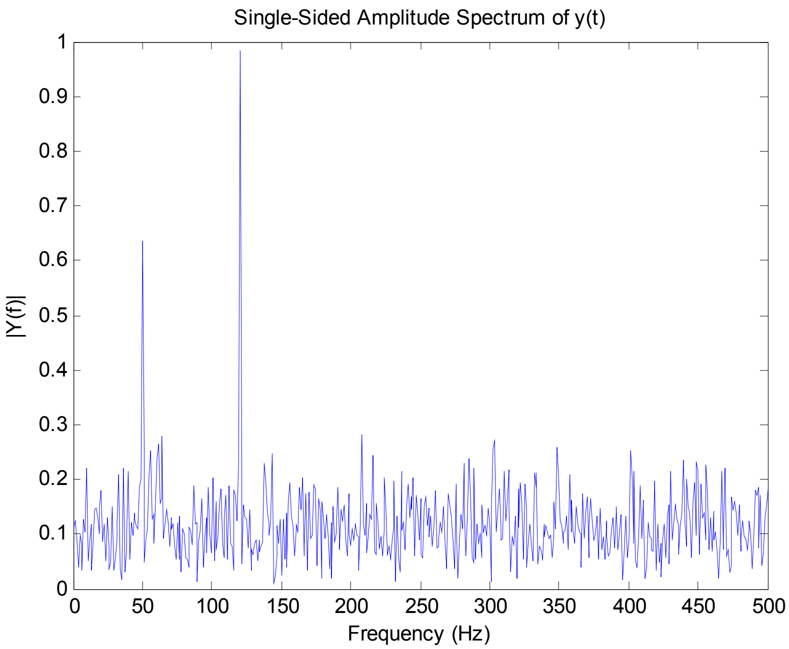
```
% from Matlab help file
Fs = 1000;                    % Sampling frequency
T = 1/Fs;                     % Sample time
L = 1000;                     % Length of signal
t = (0:L-1)*T;                % Time vector
% Sum of a 50 Hz sinusoid and a 120 Hz sinusoid
x = 0.7*sin(2*pi*50*t) + sin(2*pi*120*t);
y = x + 2*randn(size(t));     % Sinusoids plus noise
plot(Fs*t(1:50),y(1:50))
title('Signal Corrupted with Zero-Mean Random Noise')
xlabel('time (milliseconds)')
```



It is difficult to identify the frequency components by looking at the original signal. Converting to the frequency domain, the discrete Fourier transform of the noisy signal y is found by taking the fast Fourier transform (FFT):

```
% from Matlab help file
NFFT = 2^nextpow2(L); % Next power of 2 from length of y
Y = fft(y,NFFT)/L;
f = Fs/2*linspace(0,1,NFFT/2+1);

% Plot single-sided amplitude spectrum.
plot(f,2*abs(Y(1:NFFT/2+1)))
title('Single-Sided Amplitude Spectrum of y(t)')
xlabel('Frequency (Hz)')
ylabel('|Y(f)|')
```



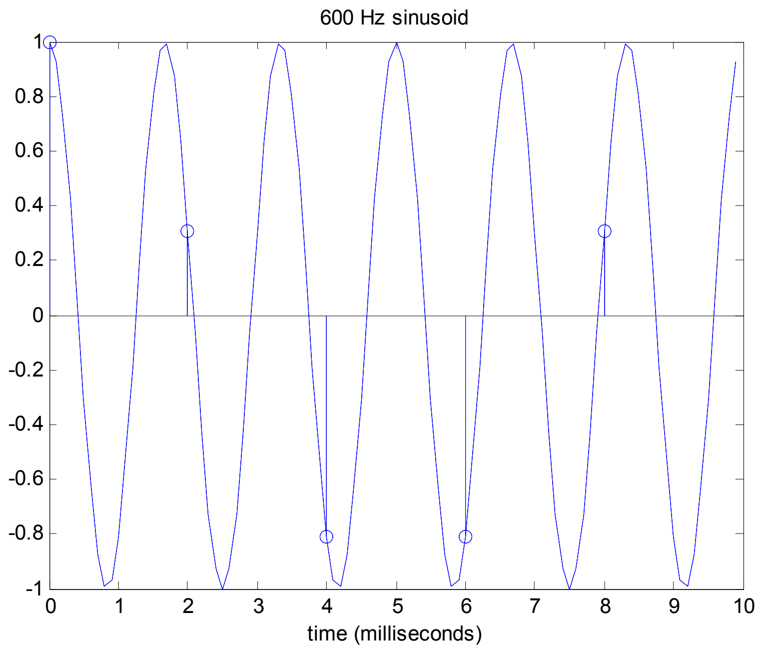
Circularly shift the 1024 (NFFT) sample points 100 samples to the right. Then draw the single-sided amplitude spectrum. Compare the resulting spectrum with the spectrum above.

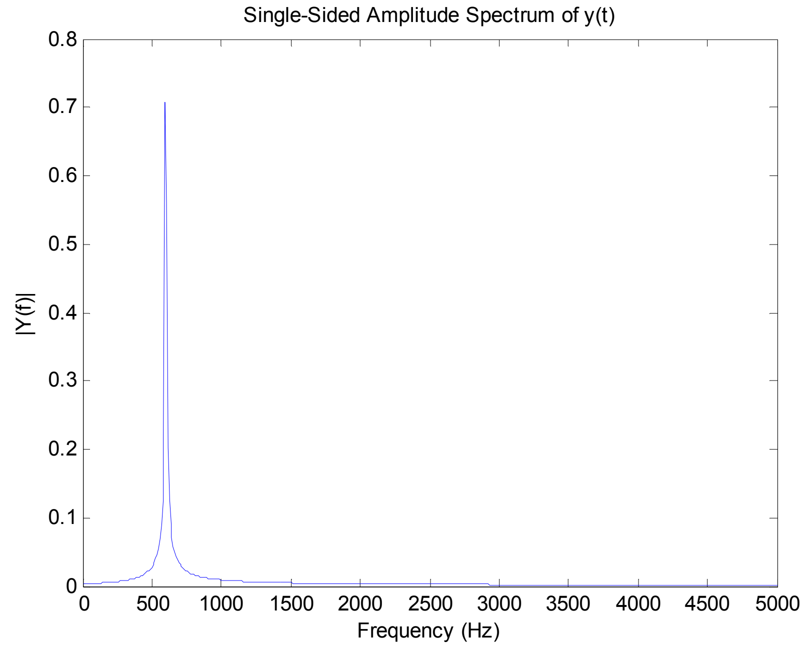
3. [Aliasing] A 600 Hz sinusoid is sampled at a sampling rate of 10000Hz. (fs=10000 sample/second) resulting in the sequence of samples x[n]=cos(2.4*pi*n). The following Matlab scripts display the sinusoid and its single-sided amplitude spectrum.

```
% see page 75 of signal processing first
% suppose
Fs = 10000;                    % Sampling frequency
T = 1/Fs;                      % Sample time
L = 1024;                      % Length of signal
t = (0:L-1)*T;                 % Time vector
% Sum of a 50 Hz sinusoid and a 120 Hz sinusoid
x = cos(2*pi*600*t);
figure(1);
plot(Fs/10*t(1:1:100),x(1:100));
hold on;
stem(Fs/10*t(1:20:100),x(1:20:100));
title('600 Hz sinusoid');
xlabel('time (milliseconds)');

figure(2);
y=x;
NFFT = 2^nextpow2(L); % Next power of 2 from length of y
Y = fft(y,NFFT)/L;
f = Fs/2*linspace(0,1,NFFT/2+1);

% Plot single-sided amplitude spectrum.
plot(f,2*abs(Y(1:NFFT/2+1)));
title('Single-Sided Amplitude Spectrum of y(t)');
xlabel('Frequency (Hz)');
ylabel('|Y(f)|');
```





Modify the Matlab scripts to sample the 600 Hz sinusoid with a sample rate of 500 Hz, then draw the corresponding single-sided amplitude spectrum.