Spectral Analysis: Everything You Always Wanted to Know (but were afraid to ask)

CPE 381 Fundamentals of Signals and Systems for Computer Engineers

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FFT in Matlab

- FFT procedures in Matlab

FFT Discrete Fourier transform.
FFT(X) is the discrete Fourier transform (DFT) of vector X. For matrices, the FFT operation is applied to each column. For N-D arrays, the FFT operation operates on the first non-singleton dimension.

FFT(X,N) is the N-point FFT, padded with zeros if X has less than N points and truncated if it has more.

FFT(X,[],DIM) or FFT(X,N,DIM) applies the FFT operation across the dimension DIM.

For length N input vector x, the DFT is a length N vector X, with elements

$$X(k) = \sum_{n=1}^{N} x(n)*\exp(-j*2*pi*(k-1)*(n-1)/N),\ 1 <= k <= N.$$

The inverse DFT (computed by IFFT) is given by

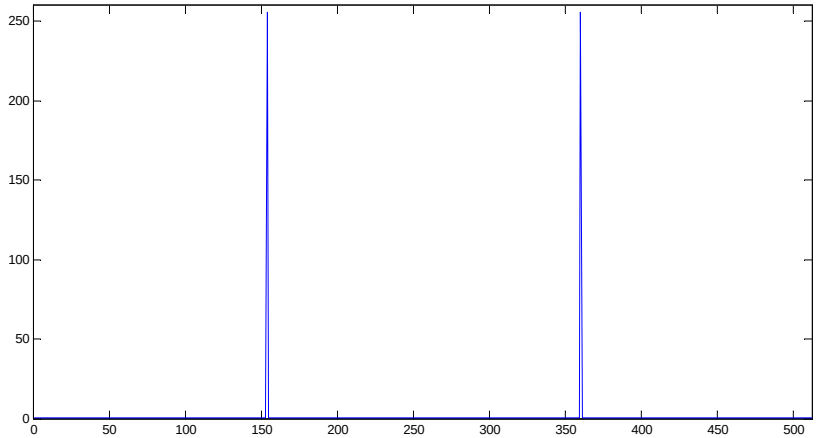
$$x(n) = (1/N) \sum_{k=1}^{N} X(k)*\exp(j*2*pi*(k-1)*(n-1)/N),\ 1 <= n <= N.$$

Custom Procedures

- [X,theta,f]=spectral_plot(x,Fs,N)
  - Calculates and plots spectrum of the signal x

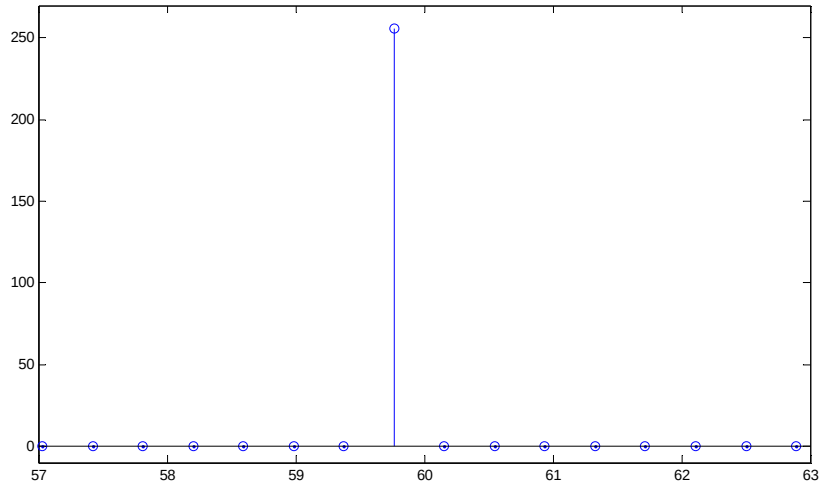
FFT notes

- N point FFT generates N point DFT
- x=sin(2*pi*59.7656.*t); % f=153*df=59.7656 Hz
- Component X(1) represents DC offset (amplitude at 0 Hz)



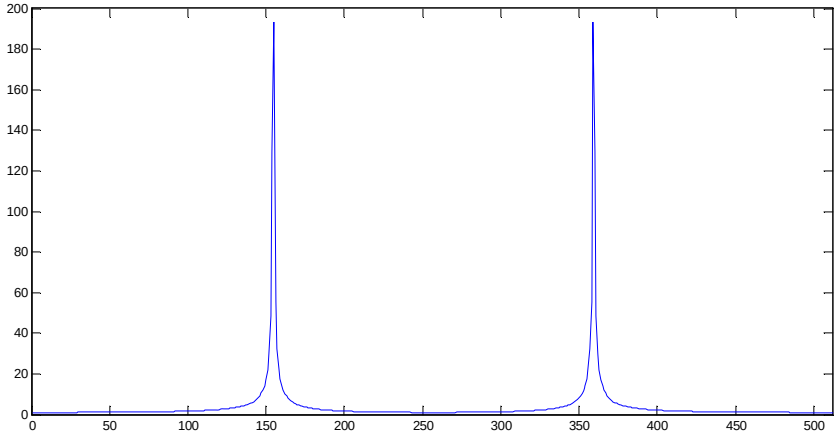
FFT notes #2

- Periodic vs. unperiodic signals



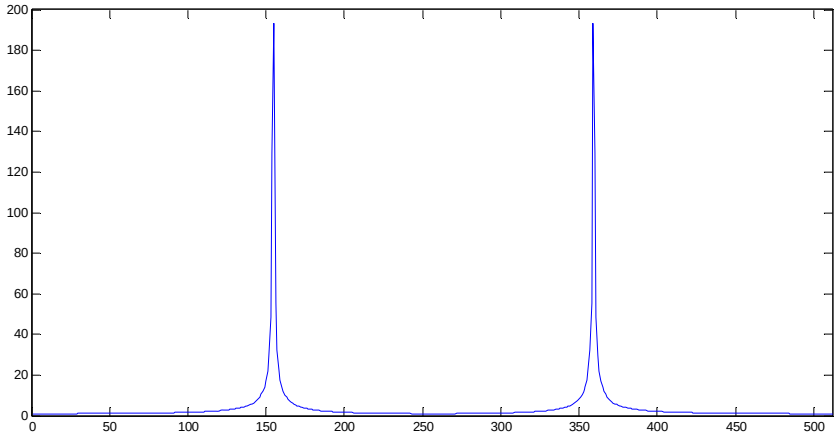
FFT notes #3

- Periodic vs. aperiodic signals
  - f=60 Hz
  - Spectrum leakage



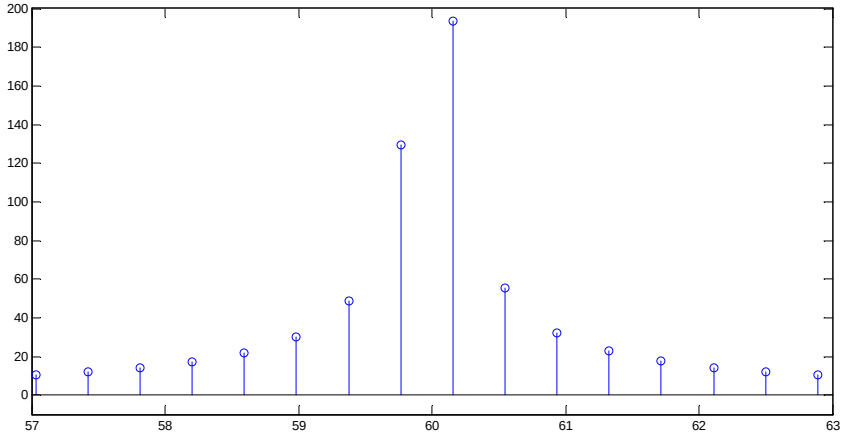
FFT notes #4

- N point FFT generates N point DFT
- x=sin(2*pi*60.*t);
- Component X(1) represents DC offset (amplitude at 0 Hz)



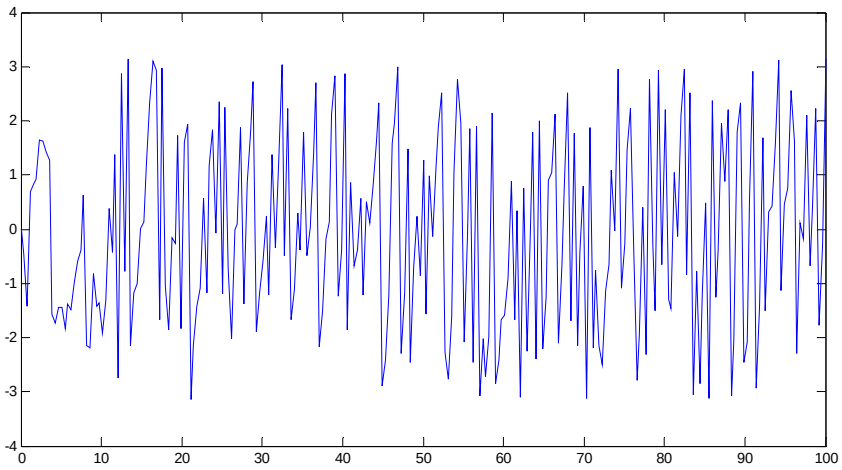
FFT notes #5

- Spectrum leakage



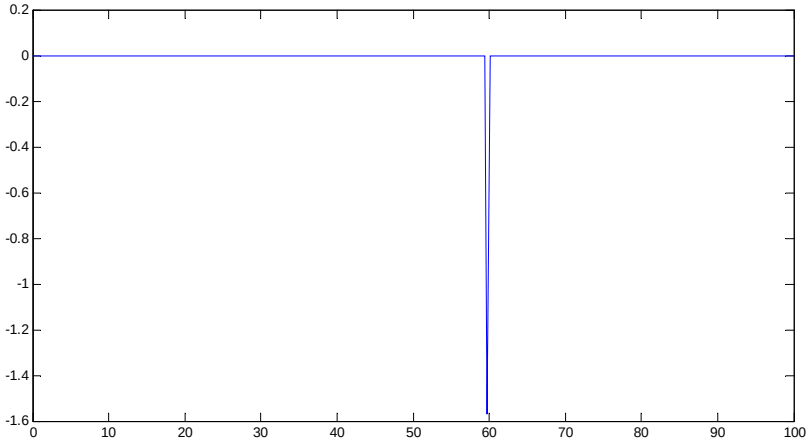
FFT notes #6

- Phase unwrapping

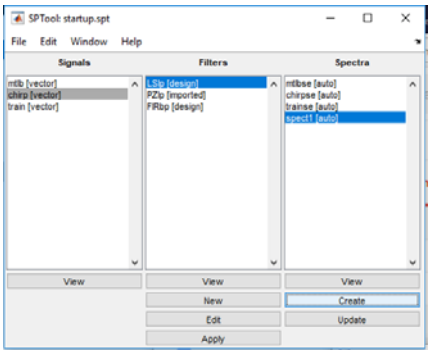


FFT notes #6

- Phase unwrapping
  - theta_orig=angle(F);
  - theta=theta_orig.*X/max(X);



Spectral Analysis in Matlab: sptool#1

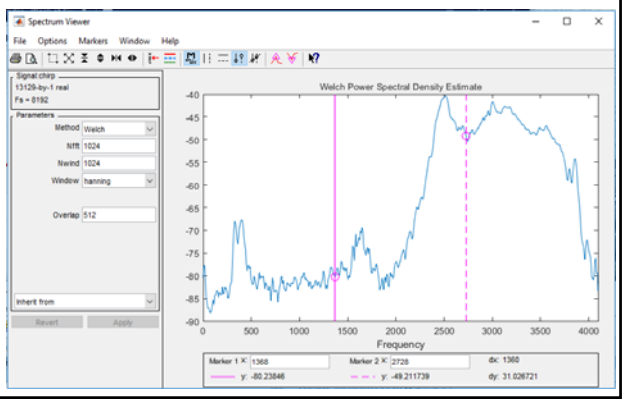


- Integrated signal processing tool in Matlab
  - sptool
- Import signal
  - Import signal in Matlab from your WAV file
  - Import signal to sptool
    - File/Import
    - Define sampling frequency
    - Don't forget to import a single array! For stereo signals select only one channel: for example, if your signal is stereo y(535231,2) select only one channel in Matlab as

      y1=y(:,1);
- Create spectrum of the imported signal

sptool #2

- Spectral analysis
  - Click on your signal on the list of signals in sptool
  - Click on "Create" new spectrum (see figure below)
  - Use default method and window, or try alternative settings
  - Use larger length of FFT/Nwind and use Nwind/2 overlap
  - Click on "Apply"
  - Copy figure and paste it in your report
- Repeat process for
  - Original signal
  - Modified signal with sine waves
  - Filtered signal
- Discuss the results



Conclusion

- Spectral analysis is very convenient
- Be aware of the limitations of the FFT