**Supplement to Chapter 4 of *The Science of Digital Media* – Digital Audio Representation**

## Worksheet – Digital Audio > Spectral Leakage and Windowing Functions[1]

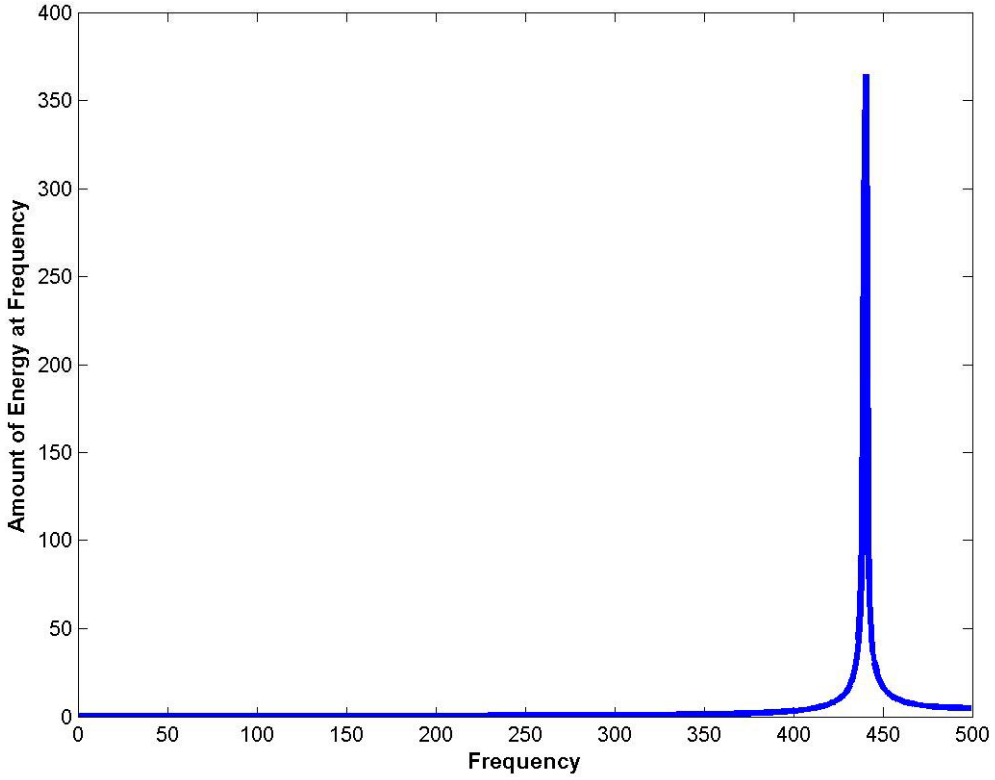
Before completing this worksheet, you should view the on-line interactive tutorial "Windowing Functions for the Fourier Transform." This tutorial can be accessed at the website for *The Science of Digital Media*.

1. Explain two reasons why windowing functions are necessary in implementations of the Fourier transform (especially the fast Fourier transform). Think about how the Fourier transform calculates the frequency components in general and how the fast Fourier transform is implemented.

2. Spectral leakage is caused by discontinuities in neighboring windows of samples used in the calculation of the Fourier transform. In the following diagram, circle the discontinuity that would cause spectral leakage. Then describe exactly what causes this discontinuity to appear and how it will affect the frequency spectrum generated by the Fourier transform.

[1]This material is based on work supported by the National Science Foundation under Grant No. DUE-0340969. This worksheet was written by Todd Martin and Jennifer Burg.

3. The following graph shows the frequency spectrum for a 440 Hz wave sampled at 1000 Hz with a window size of 1024 samples. Draw an arrow that points to the spectral leakage. Then calculate exactly how many cycles of the 440 Hz wave are contained in the 1024-sample window. Explain why this number indicates leads to spectral leakage.




Number of cycles in window =

4. Given below is the formula for another of the windowing functions that was not used in the tutorial – the Blackmann windowing function. In the space provided, explain how this function is used to reduce spectral leakage in the frequency spectrum of a windowed signal.

$$u(t) = 0.42 - 0.5\cos\left(\frac{2\pi t}{T}\right) + 0.08\cos\left(\frac{4\pi t}{T}\right) \; for \; 0 \le t \le T$$

5. Assume that the following graph depicts a 1024-sample window of a signal. Draw on the graph the shape that the waveform would take on after a windowing function like Hanning or Blackmann is applied.